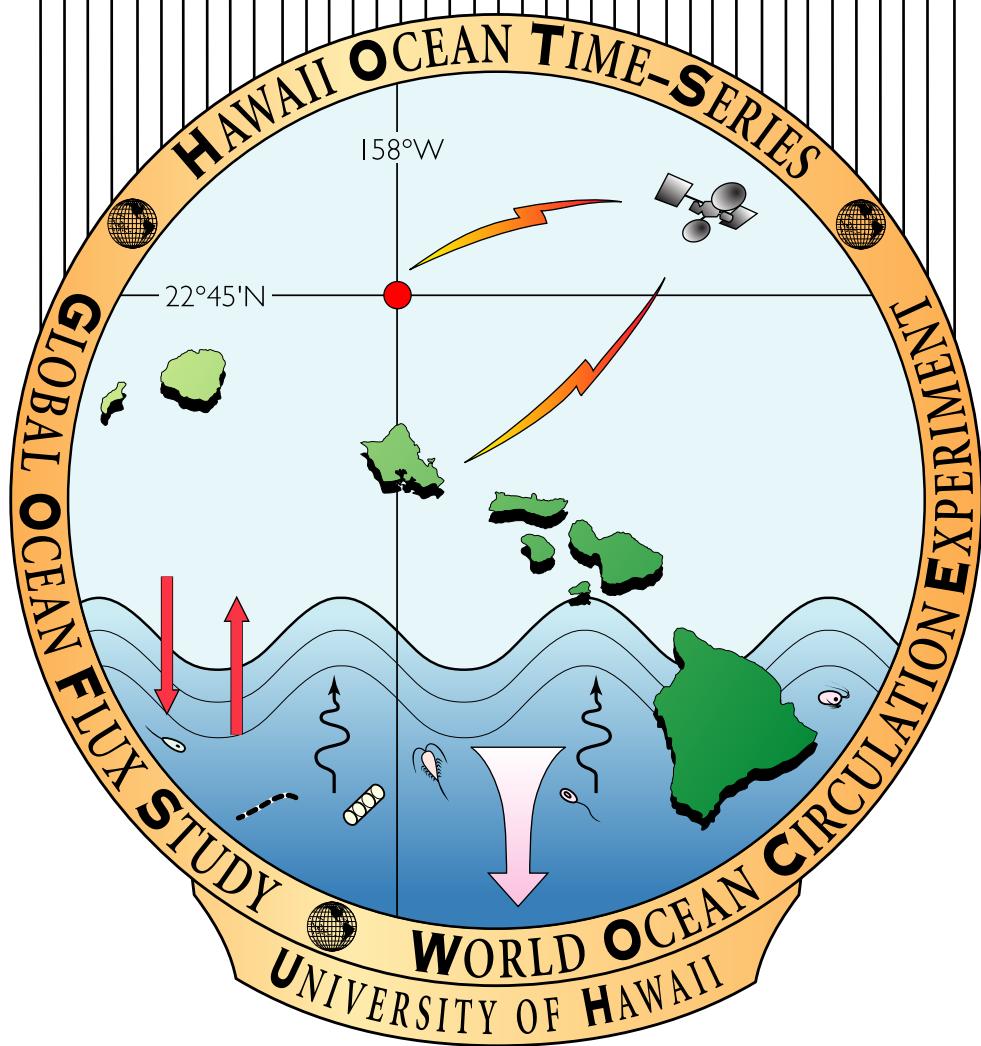


Hawaii Ocean Time-series Program

DATA REPORT 32

2020

February 2023



Hawaii Ocean Time-series Data Report 32: 2020

February 2023

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PREFACE

Scientists working on the Hawaii Ocean Time-series (HOT) program have been making repeated observations of the hydrography, chemistry and biology of the water column at a station north of Oahu, Hawaii since October 1988. The objective of this research is to provide a comprehensive description of the ocean at a site representative of the North Pacific subtropical gyre. Cruises are made approximately once per month to the deep-water [Station ALOHA](#) (A Long-term Oligotrophic Habitat Assessment; $22^{\circ} 45' \text{N}$, $158^{\circ} 00' \text{W}$) located 100 km north of Oahu, Hawaii. Measurements of the thermohaline structure, water column chemistry, currents, optical properties, primary production, plankton community structure, and rates of particle export are made on each cruise.

A surface mooring, in collaboration with the Woods Hole Oceanographic Institution (WHOI), has also been maintained at Station ALOHA since August 2004. The objective of the WHOI HOT Site (WHOTS) surface mooring is to provide long-term, high-quality air-sea fluxes as a coordinated part of the HOT program and contribute to the goals of observing heat, fresh water, and chemical fluxes.

This document reports the data collected in 2020. However, we have included some data from 1988-2019 to place the 2020 measurements in the context of ongoing time-series observations. The data reported here are a subset of the complete data set. Summary plots are given for CTD, biogeochemical, optical, shipboard meteorological, navigational, thermosalinograph and ADCP observations, as well as meteorological, temperature, salinity and current observations from the WHOTS mooring. The complete data set resides on a File Server at the University of Hawaii. These data are in ASCII format, and can easily be accessed using either anonymous file transfer protocol ([HOT_ftp](#), [WHOTS_ftp](#)), the World Wide Web ([HOT_html](#), [WHOTS_html](#)) or the Hawaii Ocean Time-series Data Organization and Graphical System ([HOT-DOGS](#)).

CTD & bottle data and metadata from each individual CTD cast from HOT cruises are converted to NetCDF (Network Common Data Form) files following OceanSITES ([www.oceansites.org](#)) format conventions, and submitted to the OceanSITES data repository. Data files are retrieved from this repository by the NOAA National Centers for Environmental Information (NCEI) and archived in their database. These files are also available in our public ftp site (<ftp://ftp.soest.hawaii.edu/hot/netcdf>).

HOT data are also available on BCO-DMO (<https://www.bco-dmo.org/project/2101>). The [CTD](#), [bottle](#), [particle flux](#) & [primary production](#) data sets can be downloaded via their Website.

ACKNOWLEDGMENTS

Many people participated in the 2020 cruises sponsored by the HOT program. Special thanks are due to Karin Björkman, Brandon Brenes, Tim Burrell, Mathieu Caffin, Dan Fitzgerald, Carolina Funkey, Lucie Knor, Tully Rohrer, Dan Sadler, Ryan Tabata, and Blake Watkins for the tremendous amount of time and effort they have put into the program. Special thanks are given to Jennifer Kondo for her excellent administrative support of the program and Julia Hummon for providing training and advice during the ADCP data processing. Brandon Brenes and Eric Grabowski performed many of the core chemical analyses. Karin Björkman, Carolina Funkey, and Ryan Tabata performed the nutrient analyses. Dan Sadler performed the carbon analyses. Lucie Knor and Daniel Fitzgerald performed the salinity measurements. Kelsey Maloney provided additional technical support. We gratefully acknowledge the support from Sea-Bird for helping us to maintain the quality of the CTD data throughout the HOT program. We also would like to thank the captains and crew of the R/V *Kilo Moana* and the UH Marine Center staff for their efforts. Without the assistance of these and the many technicians, students and ancillary investigators, the data presented in this report could not have been collected, processed, analyzed, and reported. Shipboard ADCP data were collected and processed using Eric Firing's ADCP data collection/processing suite.

This data set was acquired with funding from the National Science Foundation (NSF) and State of Hawaii general funds. The specific grant which supported our 2020 work is NSF grant [OCE-1756517](#) (White, Karl, and Potemra). Additional support for HOT Research was provided by the Simons Foundation. The WHOTS mooring work was funded in part by the Ocean Observing and Monitoring Division, Climate Program Office (FundRef number 100007298), National Oceanic and Atmospheric Administration, U.S. Department of Commerce, and under grant NA14OAR4320158 to the Woods Hole Oceanographic Institution.

1.0 INTRODUCTION

1.1 Origins

1.1.1 JGOFS & WOCE : 1988 – 2003

In response to the growing awareness of the ocean's role in climate and global environmental change, and the need for additional and more comprehensive oceanic time-series measurements, the Board on Ocean Science and Policy (BOSP) of the National Research Council (NRC) sponsored a workshop on “Global Observations and Understanding of the General Circulation of the Oceans” in August 1983. The proceedings of this workshop (National Research Council 1984a) served as a prospectus for the development of the U.S. component of the World Ocean Circulation Experiment (WOCE). US-WOCE had the following objectives:

- To understand the general circulation of the global ocean, to model with confidence its present state and predict its evolution in relation to long-term changes in the atmosphere.
- To provide the scientific background for designing an observation system for long-term measurement of the large-scale circulation of the ocean.

In a parallel effort, a separate research program termed Global Ocean Flux Study (GOFS) focused on the ocean's carbon cycle and associated air-sea fluxes of carbon dioxide. In September 1984, NRC-BOSP sponsored a workshop on “Global Ocean Flux Study” which served as an eventual blueprint for the GOFS program (National Research Council 1984b). In 1986, the International Council of Scientific Unions (ICSU) established the International Geosphere-Biosphere Program: A Study of Global Change (IGBP), and the following year JGOFS (Joint GOFS) was designed as a Core Project of IGBP. US-JGOFS research efforts focused on the oceanic carbon cycle, its sensitivity to change and the regulation of the atmosphere-ocean CO₂ balance (Brewer *et al.*, 1986). The broad objectives of US-JGOFS were:

- To determine and understand on a global scale the time-varying fluxes of carbon and associated biogenic elements in the ocean.
- To evaluate the related exchanges of these elements with the atmosphere, the sea floor and the continental boundaries (Scientific Committee on Oceanic Research 1990).

In order to achieve these goals, four separate program elements were defined: (1) process studies to capture key regular events, (2) long-term time-series observations at strategic sites, (3) a global survey of relevant oceanic properties (e.g., CO₂), and (4) a vigorous data interpretation and modeling effort to disseminate knowledge and to generate testable hypotheses.

In 1987, two separate proposals were submitted to the US-WOCE and US-JGOFS program committees, respectively, by scientists at the University of Hawaii at Manoa, to establish a multi-disciplinary, deep water hydrostation in proximity to the Hawaiian islands. In July 1988, these proposals were funded by the National Science Foundation and [Station ALOHA](#), the benchmark study site for the Hawaii Ocean Time-series program, was officially on the map (Karl and Lukas 1996). A sister station in the western North Atlantic Ocean, near the historical Panulirus Station, was likewise funded by the US-JGOFS program and is operated by scientists at the Bermuda Biological Station for Research, Inc. (Michaels and Knap 1996).

The primary research objectives of these ocean measurement programs were to establish and maintain deep-water hydrostations for observing and interpreting physical and biogeochemical variability. The program designs called for repeat measurements of a suite of core parameters at approximately monthly intervals, compilation of the data and rapid distribution to the scientific community.

1.1.2 Ocean Carbon & Biogeochemistry (OCB) : 2004 - present

By the end of the JGOFS and WOCE programs in the early 2000s, HOT and BATS found themselves lacking a unified programmatic base that could facilitate community input into science priorities conducted by these programs. The initiation of the OCB program in 2007 provided a scientific support network whose research interests aligned well with these on-going time series efforts. Under the OCB program umbrella, HOT and BATS remain focused on studying processes that control the distributions and cycling of elements in the sea, with specific focus on carbon, in sufficient detail to provide predictive understanding on how global scale perturbations to ocean-climate influence biogeochemical transformations. To achieve this broad objective, the programs seek understanding of the following:

- The linkages between seasonal, interannual, and long-term (multi-decadal) variability and trends in ocean physics, chemistry, and biology.
- Processes underlying physical and biogeochemical temporal variability.
- The role of physical forcing on carbon fluxes, including rates of biologically-mediated carbon transformations, air-sea CO₂ exchange, and carbon export.
- The response of ocean biogeochemistry to ocean change.

Beginning in 2009, under guidance from the National Science Foundation, the two core elements of HOT (biogeochemistry & ecology and physical oceanography) were centralized into a single program. This unification retains the strong interdisciplinary, collaborative structure that has characterized the program since its inception, including a core suite of measurements of biogeochemistry, physics, and ecology. The program remains based at the University of Hawaii where Angelique White and David Karl contributes expertise in biogeochemistry & ecology and satellite remote sensing and James Potemra provides physical oceanographic expertise. In addition, the program retains long-time HOT collaborators: A) John Dore (Montana State University) overseeing inorganic carbon measurements and quality control of core biogeochemical analyses; B) Michael Landry overseeing zooplankton and plankton community structure measurements; and C) Ricardo Letelier overseeing analysis of HPLC pigments. In addition, the program contributes to a NOAA-led, full ocean depth mooring at Station ALOHA (termed the WHOTS mooring), overseen by Robert Weller and Al Pluedmann (Woods Hole Oceanographic Institution).

1.2 Hawaii Ocean Time-series Program

The Hawaii Ocean Time-series (HOT) Program consists of several research components led by scientists at the University of Hawaii at Manoa ([Table 1.1](#)). The hydrographic (P.O.) and biogeochemistry & ecology components are fully integrated operationally and are both involved in all aspects of planning and execution of HOT Program objectives.

Table 1.1: HOT Research Components in 2020

Scientists	Project role
Angelicque E. White (lead-PI)	Biogeochemistry and optics
David M. Karl (co-PI)	Biogeochemistry and ecology
James T. Potemra (co-PI)	Physical oceanography
John E. Dore (collaborator)	Inorganic carbon
Michael Landry (collaborator)	Zooplankton community structure
Craig Carlson (collaborator)	DOC/TN
Ricardo M. Letelier (collaborator)	HPLC Pigments
Robert A. Weller & Albert J. Pluedmann (collaborators)	WHOTS (full ocean depth) mooring

1.3 Scientific objectives for HOT

The primary objective of HOT is to obtain a long time-series of physical and biogeochemical observations in the North Pacific subtropical gyre that will address the goals of the US Global Change Research Program. The program objectives are:

- Document and understand seasonal and interannual variability of water masses.
- Relate water mass variations to gyre fluctuations.
- Develop a climatology of short-term physical variability.
- Document and understand seasonal and interannual variability in the rates of primary production, new production and particle export from the surface ocean.
- Determine the mechanisms and rates of nutrient input and recycling, especially for nitrogen (N) and phosphorus (P) in the upper 200 m of the water column.
- Measure the time-varying concentrations of dissolved inorganic carbon (DIC) in the upper water column and estimate the annual air-to-sea CO₂ flux.

In addition to these primary objectives, the HOT Program provides logistical support for numerous complementary research programs ([Table 1.2](#)). A complete listing of these projects can be obtained from the HOT web page (hahana.soest.hawaii.edu/hot/ancillary.html).

Table 1.2: Ancillary Projects Supported by HOT in 2020

Principal Investigator(s)	Institution	Agency	Project Title
Matthew Church	UM/FLBS	SF	Diversity and activities of nitrogen-fixing microorganisms
Ralph Keeling & Andrew Dickson	UCSD SIO	NSF #0120527	$^{13}\text{C}/^{12}\text{C}$ ratio of atmospheric carbon dioxide and oceanic carbon in relation to the global carbon cycle
Karl, Armbrust & others	Various	SF	Simons Collaboration on Ocean Processes and Ecology
Nicholas Hawco & Eleanor Bates	UH	NSF #2022969	Quantifying Iron Turnover in the Upper Ocean via Time-series Measurements at Station ALOHA
David Karl & Sara Ferrón-Smith	UH	SF	Determination of gross primary production from the euphotic zone in situ, using the drifting primary production array
David Karl & Sam Wilson	UH	NSF	Reduced gases in the upper ocean: The cycling of methane, sulfide and nitrous oxide
Tracy Villareal & Robert Letscher	UNH	NSF #1923667	Transparent exopolymer and phytoplankton vertical migration as sources for preformed nitrate anomalies in the subtropical N. Pacific Ocean
Paul Quay	UW	NOAA	$^{13}\text{C}/^{12}\text{C}$ of dissolved inorganic carbon in the ocean

1.4 HOT Study Site

There are both scientific and logistical considerations involved with the establishment of any long-term, time-series program. Foremost among these are site selection, choice of variables and general sampling design and sampling frequency. Equally important are choices of analytical methods for a given candidate variable, an assessment of the desired accuracy and precision of each measurement, availability of suitable reference materials, the hierarchy of sampling replication and mesoscale horizontal variability.

We evaluated several major criteria prior to selection of the site for the HOT oligotrophic ocean benchmark hydrostation. First, the station must be located in deep water (>4000 m), upwind (north-northeast) of the main Hawaiian Islands and of sufficient distance from land to be free from coastal ocean dynamics and biogeochemical influences. On the other hand, the station

should be close enough to the port of Honolulu to make relatively short duration (<5 d) monthly cruises logically and financially feasible. A desirable, but less stringent criterion would locate the station at, or near, previously studied regions of the central North Pacific Ocean, in particular Station GOLLUM ($22^{\circ} 10'N$, $158^{\circ} 00'W$). Documentation of oceanic time-series measurements in the North Pacific Ocean can be found in Karl and Winn (1991), Karl *et al.* (1996b), Karl and Lukas (1996) and in the HOT web page (hahana.soest.hawaii.edu/hot).

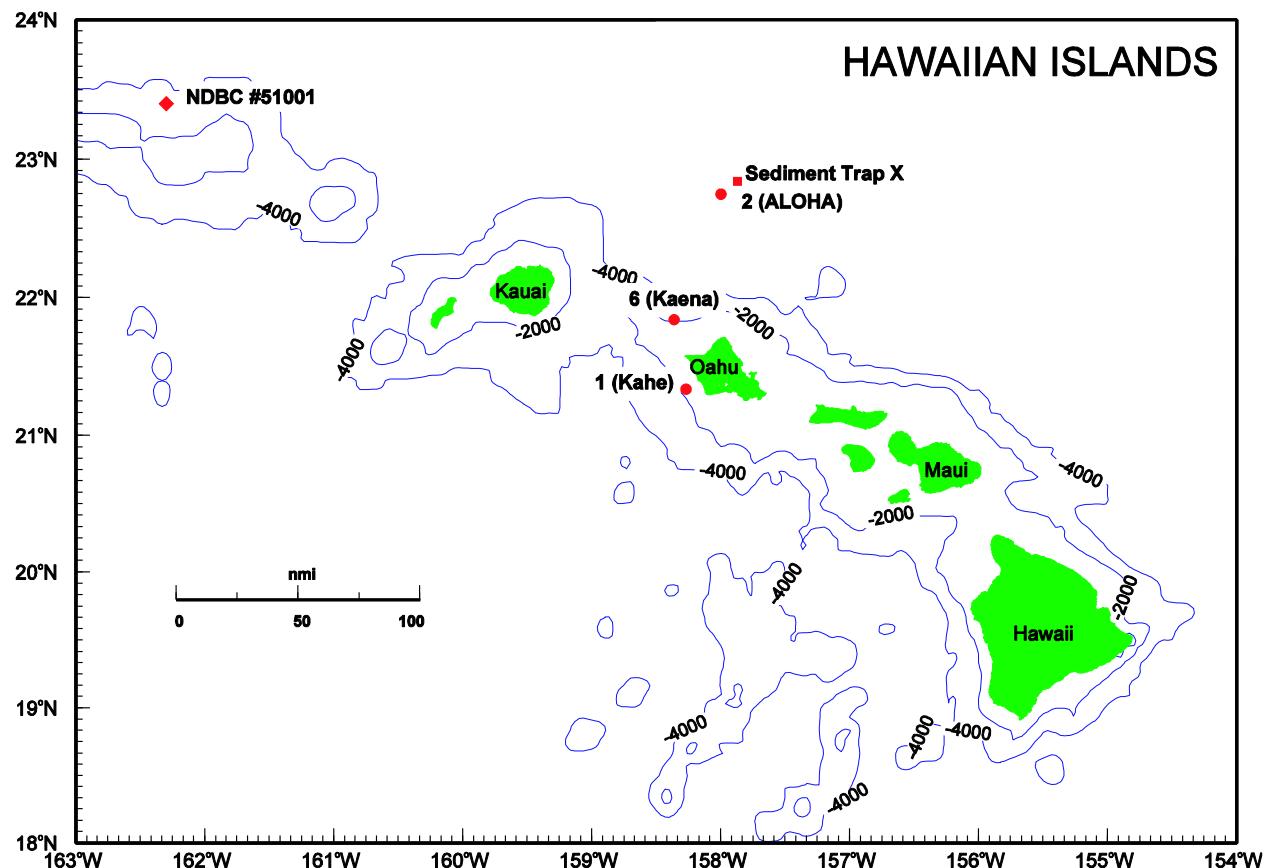


Figure 1.1: Map of the Hawaiian Islands showing the locations of the HOT stations occupied in 2020 and the NOAA-NDBC weather buoy #51001. Depth contours are in meters.

After consideration of these criteria, we established our primary sampling site at $22^{\circ} 45'N$, $158^{\circ} W$ at a location approximately 100 km north of the island of Oahu (Figure 1.1), and generally restrict our monthly sampling activities to a circle with a 6 nautical mile radius around this nominal site (Figure 1.2). Station ALOHA is in deep water (4750 m) and is more than one Rossby radius (50 km) away from steep topography associated with the Hawaiian Ridge. We also established a coastal station WSW of the island of Oahu approximately 10 km off Kahe Point ($21^{\circ} 20.6'N$, $158^{\circ} 16.4'W$) in 1500 m of water, as well as a mid-water station Kaena ($21^{\circ} 50.8'N$, $158^{\circ} 21.8'W$) WNW of Oahu in 2500m of water.

Station Kahe serves as a coastal analogue to our deep-water site and the data collected there provide a near-shore time-series for comparison to our primary open ocean site. Station

Kahe is also used to test our equipment each month before departing for Station ALOHA, and to orient new personnel at the beginning of each cruise.

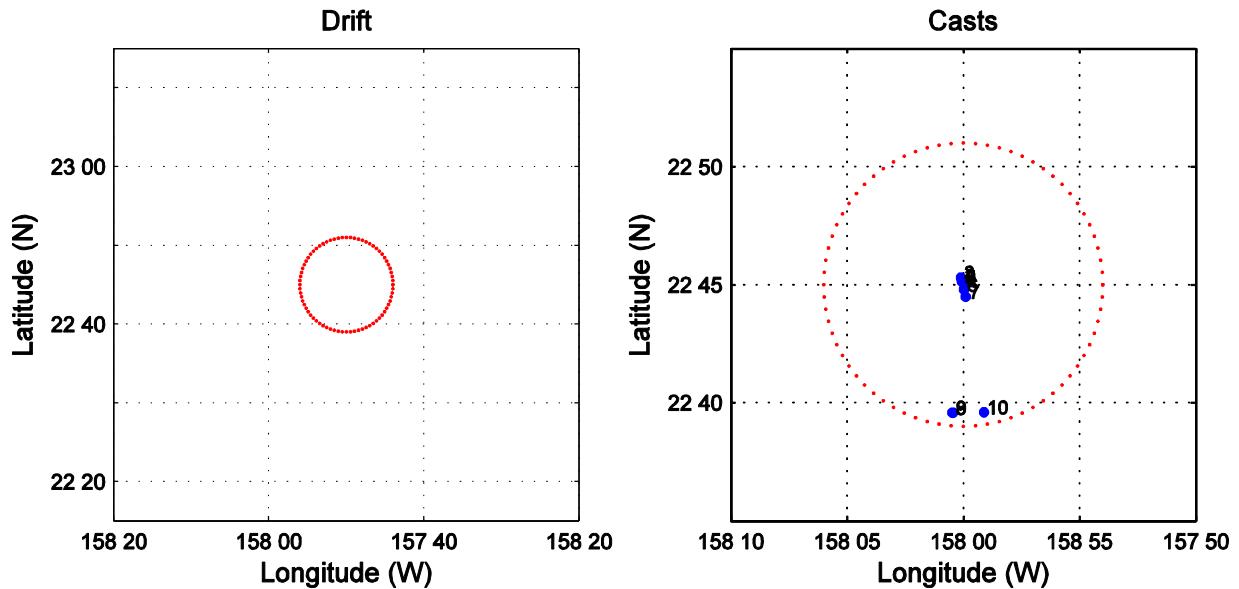
The sub-sea ridge between Oahu and Kauai (where the Station Kaena is located) is an area of high internal tide energy (<http://www.soest.hawaii.edu/PubServices/1999pdfs/Luther.pdf>). It was the focus of the Hawaii Ocean Mixing Experiment (HOME) and the data from HOT cruises at this site have been used for diapycnal mixing studies (Finnigan et al., 2002)

From January 1997 to October 2000, a physical-biogeochemical mooring was deployed to obtain continuous measurements of various atmospheric and oceanographic parameters. The mooring was located at 22° 28' N, 158° 8' W and was designated as Station HALE-ALOHA. From August 2004 to July 2007, HALE-ALOHA was redeployed at a site 6 nautical miles west of Station ALOHA (22° 46' N, 158° 5.5' W) as part of the Multi-disciplinary Ocean Sensors for Environmental Analyses and Networks (MOSEAN) project. MOSEAN was directed toward new technologies that would lead to increased observations that are essential for solving a variety of interdisciplinary oceanographic problems. These include: biogeochemical cycling, climate change effects, ocean pollution, harmful algal blooms (HABs), ocean ecology and underwater visibility. This site, also called Station 51, was a collaboration with the University of California Santa Barbara and WET Labs.

Also in August 2004, a surface mooring outfitted for meteorological and oceanographic measurements was deployed 6 nautical miles east of Station ALOHA (22° 46' N, 157° 54' W). This site, named WHOTS (Woods Hole Oceanographic Institution [WHOI] Hawaii Ocean Time-series [HOT] Site) is a collaboration with the Woods Hole Oceanographic Institution. It has also been called Station 50. The mooring has been turned around once a year since 2004, alternating its location between Station 50 and Station 52, 6 nautical miles south of Station ALOHA (22° 40'N, 157° 57'W). It is intended to provide long-term, high-quality air-sea fluxes as a coordinated part of the HOT program and contribute to the goals of observing heat, fresh water, and chemical fluxes (<http://www.soest.hawaii.edu/whots>).

Locations and dates of occupancy of HOT water column and bottom recording stations are available on the HOT web page (hahana.soest.hawaii.edu/hot/locations.html).

HOT-318



HOT-319

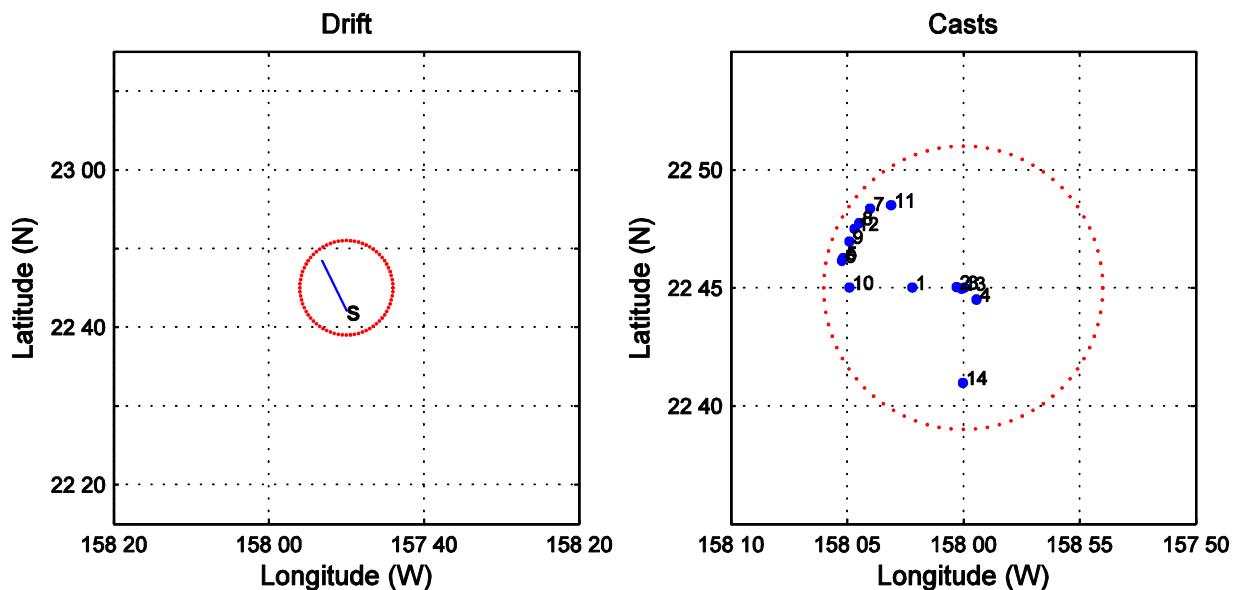
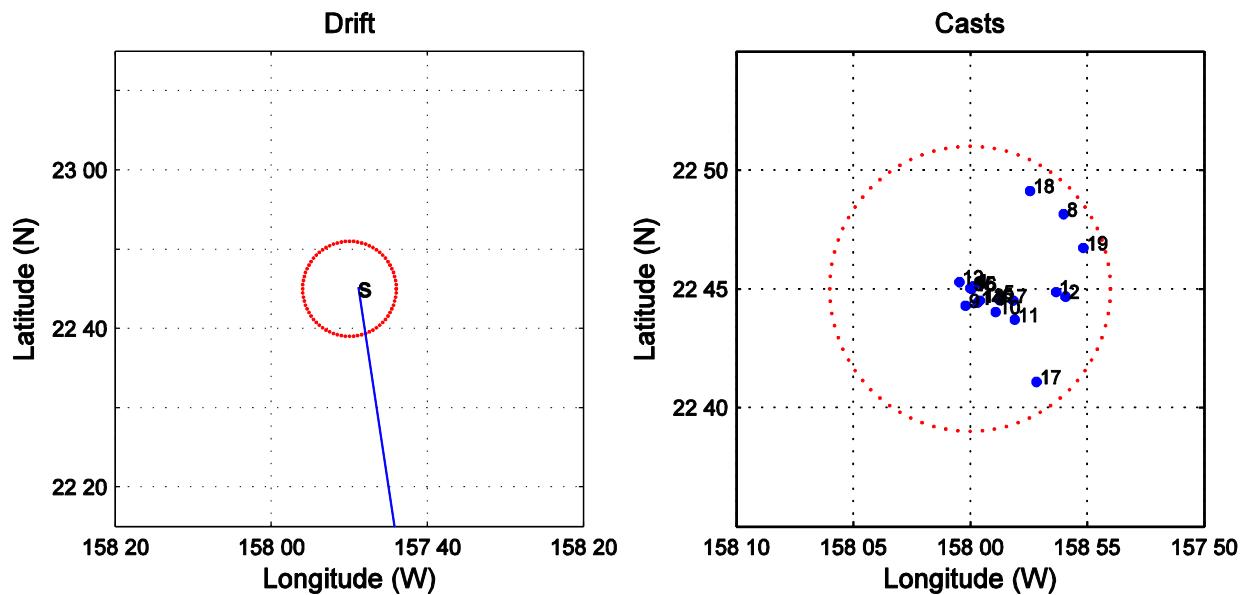


Figure 1.2: [Left panels] Drift tracks of the sediment trap array during each HOT cruise in 2020. Starting point of deployment indicated by “S”. [Right panels] CTD cast locations during each HOT cruise in 2020. Location numbers correspond to cast numbers. Dashed line indicates the 10 km radius circle defining the station. Due to rough seas and high winds during HOT-318, the sediment trap array was not deployed.

HOT-320



HOT-321

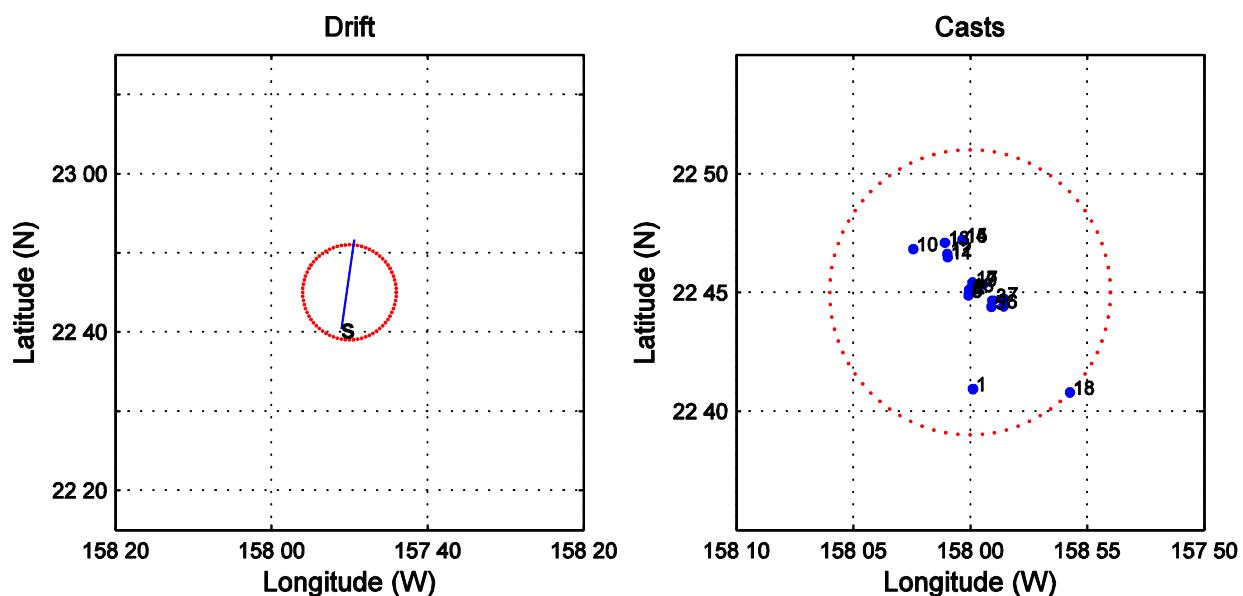
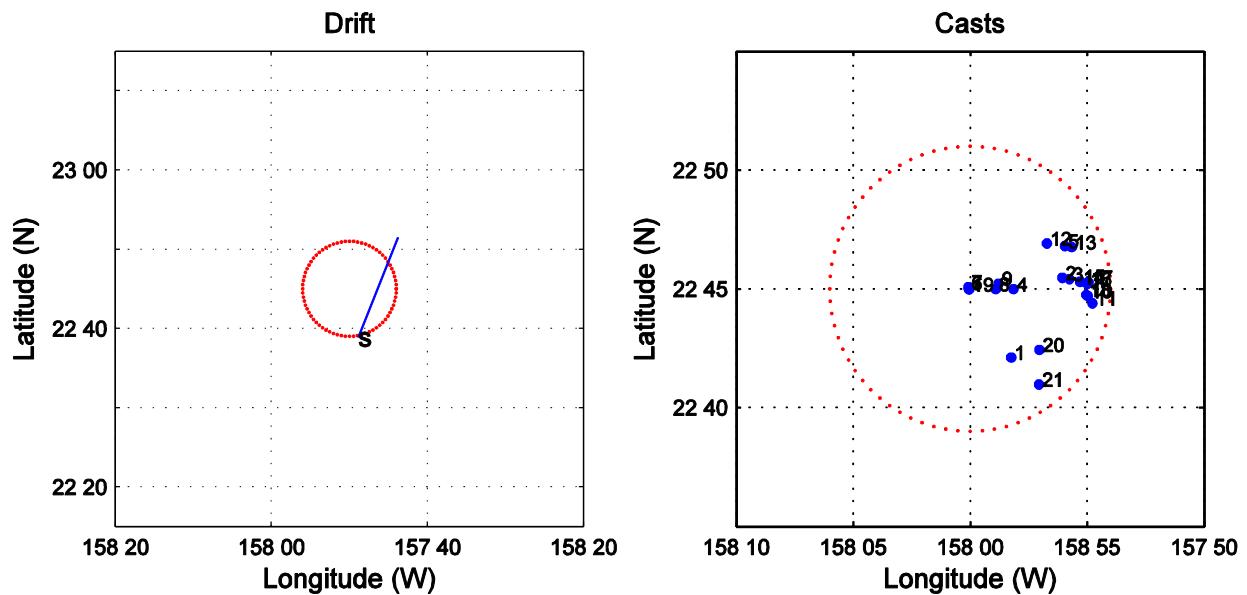


Figure 1.2: continued

HOT-322



HOT-323

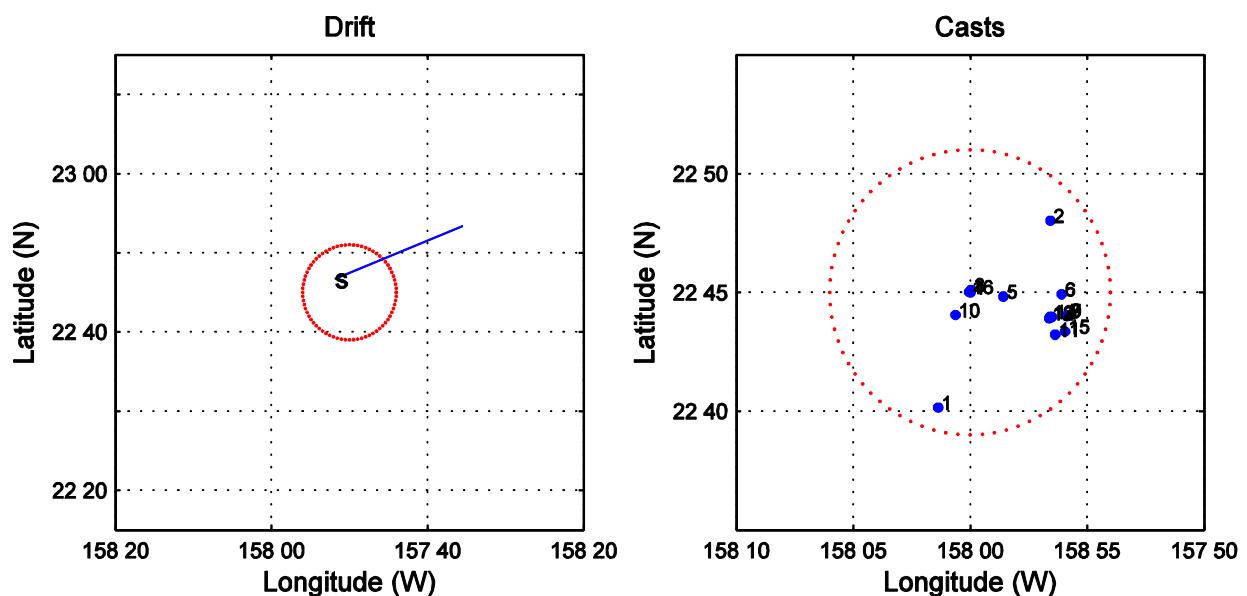
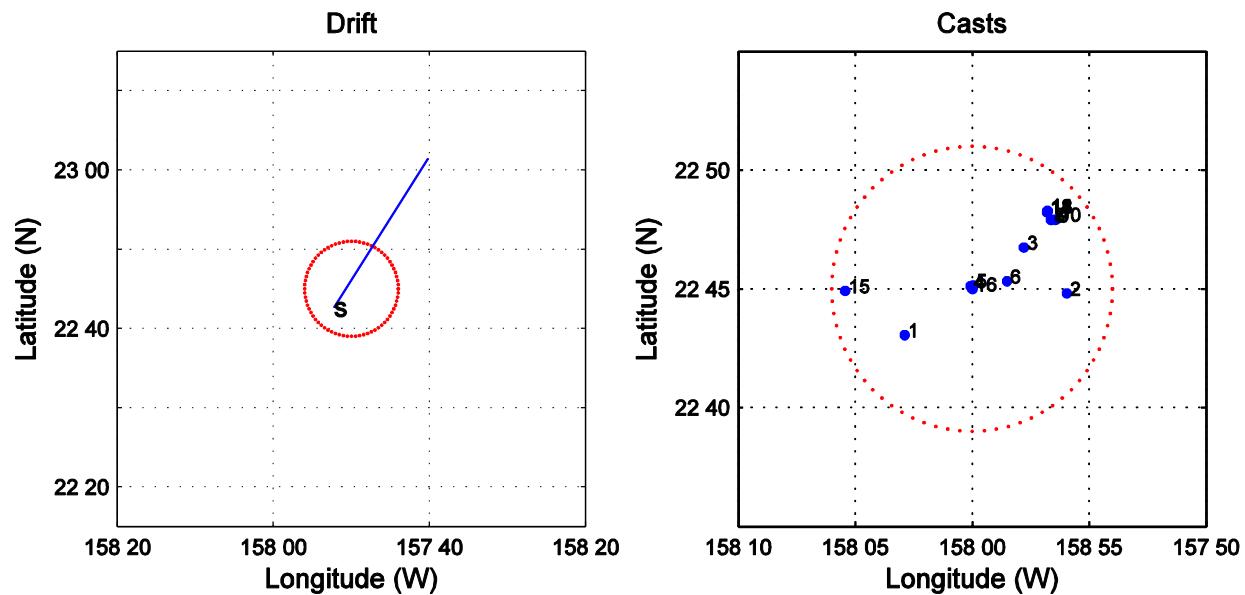


Figure 1.2: continued

HOT-324



HOT-325

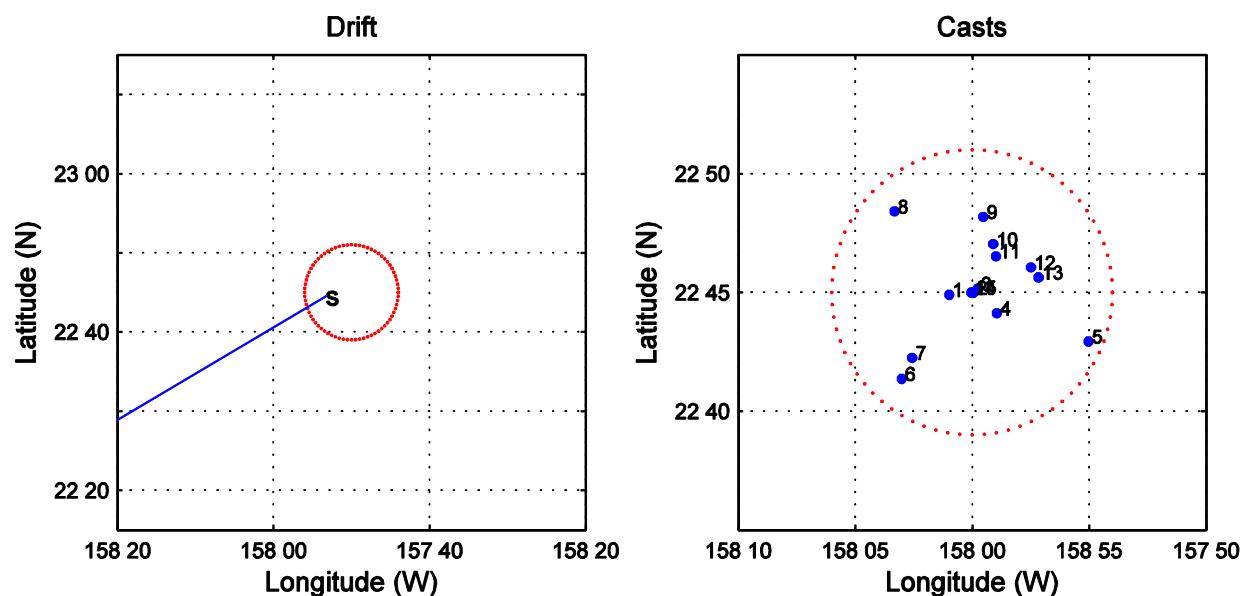


Figure 1.2: continued

1.5 Field Sampling Strategy

HOT program cruises are conducted at approximately monthly intervals; the exact timing is dictated by the availability of research vessels. From HOT-1 (October 1988) to HOT-65 (August 1995), with the exception of HOT-42 and HOT-43 (November and December 1992), each cruise was 5 d in duration (port to port). Beginning with HOT-66 (September 1995) the standard HOT cruise was reduced to 4 d in order to accommodate the additional mooring-based HOT field programs within a fixed per annum allocation of ship days.

From HOT-1 (October 1988) to HOT-32 (December 1991), underway expendable bathythermograph (XBT; Sippican T-7 probes) surveys were conducted at 13 km spacing on the outbound transect from Station Kahe to Station ALOHA. These surveys were later discontinued because the space-time correlation of the energetic, internal semi-diurnal tides made it difficult to interpret these data. From February 1995 until December 1997 we added an instrumented, 1.5 m Endeco towfish package (Sea-Bird CTD, optical plankton counter and fluorometer) to our sampling program (Tupas *et al.*, 1997). Upper water column currents are measured both underway and on station using a hull-mounted Acoustic Doppler Current Profiler (ADCP), when available (Firing, 1996).

Underway near-surface measurement of a variety of physical, chemical, and biological properties were made possible by sampling seawater through a pumped intake system positioned in the hull of the R/V *Moana Wave*. In May 1995, a thermosalinograph was installed in line to the ship's seawater intake system. In July 1996, the existing system was replaced with a non-contaminating PVC/stainless steel system. A flow-through fluorometer was installed in 1996. The R/V *Ka'imikai-O-Kanaloa* was outfitted with a similar seawater intake system to which the existing instruments were installed when R/V *Moana Wave* was retired. The R/V *Kilo Moana* also has a similar system which was sampled from during 2020.

The majority of our sampling effort, approximately 60-72 h per standard HOT cruise, is spent at Station ALOHA. High vertical resolution environmental data are collected with a Sea-Bird CTD having external temperature (T), conductivity (C), dissolved oxygen (DO), and fluorescence (F) sensors and an internal pressure (P) sensor. A Sea-Bird 24-place carousel and an aluminum rosette that is capable of supporting 24 12-L PVC bottles are used to obtain water samples from desired depths. The CTD and rosette are deployed on a 3-conductor cable allowing for real-time display of data and for tripping the bottles at specific depths of interest. The CTD system takes 24 samples s⁻¹ and the raw data are stored both on the computer and, for redundancy, on VHS-format video tapes (prior to HOT-322) and as an audio signal on a laptop PC (HOT-322 - present).

In February 2006, before cruise 178, we replaced our 24 aging 12-L PVC rosette bottles with new 12-L bottles fabricated at the University of Hawaii Engineering Support Facility, using plans and specifications from John Bullister (PMEL).

Up until HOT-96 (August 1998), we routinely conducted a dedicated hydrocast to collect “clean” water samples for biological rate measurements, using General Oceanics Go-Flo bottles, Kevlar line, a metal-free sheave, Teflon messengers, and a stainless steel bottom weight. During HOT-97 through HOT-118, due to the frequency of mis-trips & the inability to know the exact depth from which samples were collected, replicate samples were taken from the CTD rosette

and the Go-Flo bottles. Comparisons with the Go-Flo collected samples showed there was no statistical difference in rates of ^{14}C -primary production derived from samples collected using the Go-Flo bottles or the CTD rosette. As a result, beginning with HOT-119 (October 2000), we have collected samples for biological rate measurements only from the rosette.

A free-drifting sediment trap array, identical in design to the VERTEX particle interceptor trap (PIT) array (Knauer *et al.*, 1979), is deployed at Station ALOHA for an approximately 60 h period to collect sinking particles for chemical and microbiological analyses.

Sampling at Station ALOHA typically begins with sediment trap deployment followed by a deep (> 4700 m) CTD cast and a “burst series” of at least 13 consecutive 1000 m casts, on 3-h intervals, to span the local inertial period (~ 31 h) and three semidiurnal tidal cycles. The drift tracks of the sediment trap arrays and the location of the CTD casts for each cruise are shown in [Figure 1.2](#). The repeated CTD casts enable us to calculate an average density profile from which variability on tidal and near-inertial time scales has been removed. These average density profiles are useful for the comparison of dynamic height and for the comparison of the depth distribution of chemical parameters from different casts and at monthly intervals. This sampling strategy is designed to assess variability on time scales of a few hours to a few years. Very high frequency variability (< 6 h) and variability on time scales of between 3-60 d are not adequately sampled with our ship-based operations.

Water samples for a variety of chemical and biological measurements are routinely collected from the surface to within 10 m of the seafloor. To the extent possible, we collect samples for complementary biogeochemical measurements from the same or from contiguous casts to minimize aliasing caused by time-dependent changes in the density field. This approach is especially important for samples collected in the upper 350 m of the water column. Furthermore, we attempt to sample from common depths and specific density horizons each month to facilitate comparisons between cruises. Water samples for salinity determinations are collected from every water bottle to identify sampling errors. Approximately 20% of the water samples are collected and analyzed in duplicate or triplicate to assess and track our precision in sample analyses.

The HOT program relies on a selected set of core suite environmental variables that are expected to display detectable change on time scales of several days to one decade. Except for the availability of existing satellite and ocean buoy sea surface data, the initial phase of the HOT program (Oct 1988 - Feb 1991) was entirely supported by research vessels. In February 1991, an array of five inverted echo sounders (IES) was deployed in an approximately 150 km^2 network around Station ALOHA (Chiswell 1996) and in June 1992, a sequencing sediment trap mooring was deployed a few km north of Station ALOHA (Karl *et al.*, 1996a). In 1993, the IES network was replaced with two strategically-positioned instruments: one at Station ALOHA and the other at Station Kaena. The IES at Station Kaena was retired in October 1995. Between 1994 and 1999, a single IES was positioned and annually replaced at Station ALOHA.

1.6 WHOTS Mooring

In 2003, Robert Weller (Woods Hole Oceanographic Institution [WHOI]), Albert Plueddemann (WHOI), and Roger Lukas (University of Hawaii [UH]) proposed to establish a long-term surface mooring at Station ALOHA to monitor sustained, high-quality air-sea fluxes and the associated upper ocean response as a coordinated part of the HOT program, and as an element of the array of global ocean reference stations supported by the National Oceanic and Atmospheric Administration's (NOAA) Office of Climate Observation.

With support from the NOAA and the National Science Foundation (NSF), the WHOI HOT Site (WHOTS) surface mooring has been maintained at Station ALOHA since August 2004. This project aims to record long-term, high-quality air-sea fluxes as a coordinated part of the HOT program and contribute to the goals of observing heat, freshwater, and chemical fluxes at a site representative of the oligotrophic North Pacific Ocean. The approach is to maintain a surface mooring outfitted for meteorological and oceanographic measurements at a site near Station ALOHA by successive mooring turnarounds. These observations will be used to investigate air-sea interaction processes related to climate variability.

The mooring system is described in the mooring deployment and recovery cruise reports (Plueddemann et al., 2006; Whelan et al., 2007, 2008, 2010; Santiago-Mandujano et al., 2009, 2018; Hasbrouck et al., 2019, Santiago-Mandujano, et al., 2018, 2021, 2022). Briefly, a Surlyn foam surface buoy is equipped with meteorological instrumentation, including two complete Air-Sea Interaction Meteorological (ASIMET) systems, measuring air and sea surface temperatures, relative humidity, barometric pressure, wind speed and direction, incoming shortwave and longwave radiation, and precipitation (Colbo and Weller, 2009). Complete surface meteorological measurements are recorded every minute, as required to compute air-sea fluxes of heat, freshwater, and momentum. Each ASIMET system also transmits hourly averages of the surface meteorological variables via the Argos satellite system. The mooring line is instrumented to collect time series of upper ocean temperatures, velocities, and salinities coincident with the surface forcing record. This includes vector measuring current meters, conductivity, salinity and temperature recorders, and Acoustic Doppler Current Profiler (ADCP) instrumentation.

The subsurface instrumentation is located to resolve the temporal variations of shear and stratification in the upper pycnocline to support the study of mixed layer entrainment. Experience with moored profiler measurements near Hawaii suggests that Richardson number estimates over 10 m scales are adequate. Salinity is essential to the stratification, as salt-stratified barrier layers are observed at HOT and in the region. Hence, we use Sea-Bird SeaCATs and MicroCATs with vertical separation ranging from 5 to 20 m to measure temperature and salinity. We use two ADCPs made by Teledyne RD Instruments to obtain current profiles across the entrainment zone and in the mixed layer zone. Both ADCPs are in an upward-looking configuration, one is at 125 m, using 4 m bins, and the other is at 47.5 m using 2 m bins. To provide near-surface velocity (where ADCP estimates are less reliable), we deploy two Vector Measuring Current Meters (VMCMs). The nominal mooring design is a balance between resolving extremes versus the typical annual cycling of the mixed layer. A pair of Sea-Bird SeaCATs (SBE-16) or MicroCATs (SBE-37) have been included since the WHOTS-9 deployment (June 2012) to measure near-bottom temperature and salinity.

The WHOTS-16 mooring, deployed in October 2019, could not be recovered in 2020 due to ship availability and restrictions due to the COVID-19 pandemic. The mooring was recovered in August 2021.

1.7 Core Measurements, Experiments and Protocols

The suite of core measurements provides a database to validate and improve existing biogeochemical models. Our list of core measurements has evolved since the inception of the HOT program in 1988, and now includes both continuous and discrete physical, biological and chemical ship-based measurements, optical, *in situ* biological rate experiments, and observations and sample collections from bottom-moored instruments and buoys ([Table 1.3](#)). Continuity in the measurement parameters and their quality, rather than continuity in the methods employed, is of greatest interest. Detailed analytical methods are expected to change over time through technical improvements. In addition to the core data, specialized measurements and process-oriented experiments have also been conducted at Station ALOHA ([Table 1.3](#)).

Table 1.3: Parameters Measured at Station ALOHA during 2020

Parameter	Depth Range (m)	Analytical Procedure
I. Continuous Measurements		
Depth (Pressure)	0-4750	Pressure transducer on Sea-Bird CTD package
Temperature	0-4750	Thermistor on Sea-Bird CTD package
Conductivity (Salinity)	0-4750	Conductivity sensor on Sea-Bird CTD package, with discrete salinity samples calibration
Dissolved Oxygen	0-4750	Sea-Bird sensor on Sea-Bird CTD package, with discrete oxygen samples calibration
Fluorescence (Chloropigment)	0-4750	Sea-Point chlorophyll fluorometer on Sea-Bird CTD package with discrete chlorophyll calibration

II. Water Column Chemical Measurements

Salinity	0-4750	Guildline AutoSal using Wormley seawater standard
Oxygen	0-4750	Winkler titration
Dissolved Inorganic Carbon	0-4750	Coulometry standardized using CRMs provided by A. Dickson (SIO)
Total Alkalinity	0-4750	Automated Gran titration
pH	0-4750	Spectrophotometric
Nitrate Plus Nitrite	0-4750	Autoanalyzer standardized using KANSO CRMs

Soluble Reactive Phosphorus (SRP)	0-4750	Autoanalyzer standardized using KANSO CRMs
Silicate	0-4750	Autoanalyzer standardized using KANSO CRMs
Low Level [Nitrate + Nitrite]	0-200	Chemiluminescence
Low Level SRP	0-200	Magnesium-induced coprecipitation
Total Organic Carbon	0-4750	High temperature catalytic oxidation
Particulate Carbon	0-350	High temperature combustion
Particulate Nitrogen	0-350	High temperature combustion
Particulate Phosphorus	0-350	High temperature combustion
Particulate Biogenic Silica	0-175	Base Hydrolysis

III. Biomass Measurements

Chlorophyll <i>a</i> and Pheopigments	0-175	Fluorometric analysis using the acid-method
Pigments	0-175	High Performance Liquid Chromatography (HPLC)
Adenosine 5'-triphosphate	0-350	Firefly bioluminescence
Bacteria and Cyanobacteria	0-175	Flow cytometry
Mesozooplankton	0-175	Net tows, elemental analysis

IV. Carbon Assimilation and Particle Flux

Primary Production	0-125	¹⁴ C-bicarbonate <i>in situ</i> incubations
Carbon, Nitrogen, Phosphorus, Silica	150	Free-floating particle interceptor traps

V. Currents

Acoustic Doppler Current Profiler	10-1200	Hull mounted, RDI #OS-38
Acoustic Doppler Current Profiler	10-100	Hull mounted, RDI #WH-300

VI. Optical Measurements

Incident Irradiance	Surface	LI-COR LI-1500 & Satlantic HyperOCR Hyperspectral Radiometer
Upwelling Radiance and Downwelling Irradiance	0-200	Satlantic Profiler II with HyperOCR Hyperspectral Radiometers & WET Labs ECO-BB2F Triplet
Particle Size Analysis	0-200	Sequoia Laser In-Situ Scattering & Transmissometry (LISST-100X)

VII. Bow Intake System

Temperature	3	Sea-Bird remote temperature sensor
Conductivity (Salinity)	3	Sea-Bird temperature and conductivity sensors inside the thermosalinograph package, with discrete salinity samples calibration
Fluorometry (Chloropigment)	3	In vivo fluorometry

VIII. Moored Instruments

Sequencing Sediment Traps (Ancillary)	2800, 4000	Parflux MK7-21
Physical Oceanographic Mooring	0-155	WHOTS

These selected measurements are part of a much larger HOT program data set on physical and biogeochemical variability at Station ALOHA that has been collected since October 1988. The complete data set is available to the community by several methods that are described in [Section 8.0](#) of this report.

This report presents selected core data collected during the 32nd full year of the HOT Program (January-December 2020). During this period, eight HOT cruises were conducted using the University of Hawaii research vessel *Kilo Moana* ([Table 1.4](#)). In addition, selected data collected with the WHOTS-16 mooring instruments (October 2019 through August 2021), and during the mooring recovery cruise (WHOTS-17) on board the NOAA ship *Oscar Sette* are presented here (see Pacheco et al. 2021).

University of Hawaii shipboard technical assistance personnel assisted a total field scientific crew of 34 HOT staff, students and visiting scientists ([Table 1.5](#)) in our 2020 field work. Due to the COVID-19 pandemic, extra precautions were set in place before and during the cruise to prevent the spread of COVID-19 onboard. UNOLS had provided guidelines which were followed during the cruise including sailing with a minimum science party of one scientist per stateroom if possible.

Table 1.4: Chronology of 2020 HOT Cruises

Cruise	Ship	Depart	Return
318	R/V <i>Kilo Moana</i>	6 January 2020	9 January 2020
319	R/V <i>Kilo Moana</i>	29 January 2020	2 February 2020
320	R/V <i>Kilo Moana</i>	13 July 2020	19 July 2020
321	R/V <i>Kilo Moana</i>	6 August 2020	11 August 2020
322	R/V <i>Kilo Moana</i>	28 August 2020	6 September 2020
323	R/V <i>Kilo Moana</i>	25 September 2020	30 September 2020
324	R/V <i>Kilo Moana</i>	17 November 2020	22 November 2020
325	R/V <i>Kilo Moana</i>	17 December 2020	21 December 2020

Table 1.5: 2020 Cruise Personnel (shaded area = cruise participant)

Cruise Participants	325	324	323	322	321	320	319	318
Bates, Eleanor								
Björkman, Karin								
Boza, Ximena								
Brenes, Brandon								
Burgos, Macarena								
Burrell, Tim								
Caffin, Mathieu								
Chan, Eric								
Chasin, Haley								
Clemente, Tara								
Curran, Kieran								
Dugenne, Mathilde								
Fitzgerald, Dan								
Funkey, Carolina								
Grabowski, Eric								
Granzow, Benjamin								
Hawko, Nicholas								
Indebetouw, Sophia								
Knor, Lucie								
Letscher, Robert								
Maloney, Kelsey								
Morgan Courtney								
Pacheco, Fernando								
Quiroz, Alexa								
Rohrer, Tully								
Sadler, Dan								
Salazar, Andrés								
Santiago-Mandujano, Fernando								
Shimabukuro, Eric								
Spooren, Paul								
Tabata, Ryan								
Tritsch, Jessica								
Walkins, Blake								
White, Angelique								

2.0 SAMPLING PROCEDURES AND ANALYTICAL METHODS

A comprehensive summary of all sampling and analytical methods currently used in the HOT program along with information on measurement accuracy and precision can be found in the "[Hawaii Ocean Time-series Program Field and Laboratory Protocols](#)" manual. Brief summaries of methods as well as calibration specifications and quality control / quality assurance information for 2020 are presented in this report. Hydrographic sampling methods are included in "[WOCE Hydrographic Sampling Procedure. A primer for ship-board operations at the Hawaii Ocean Time-series Station](#)" .

2.1 CTD profiling

Continuous measurements of temperature, salinity, oxygen, and fluorescence are made with a Sea-Bird SBE-9/11Plus CTD package with dual temperature, salinity, oxygen sensors, and fluorometer described in Tupas *et al.* (1995). In 2020, the CTD underwater unit #91361 was used during cruises HOT-318 through HOT-325.

CTD casts were made at Stations Kahe and ALOHA during each cruise in 2020. At Station ALOHA, a burst of consecutive CTD casts to 1000 m was made over 36 hours to span the local inertial period and three semi-diurnal tidal cycles. The full 36-hour burst sampling period was completed during all HOT cruises in 2020, except for HOT-318, when operations were canceled early due to rough weather. Two near-bottom CTD casts within about 10 m of the bottom were made during each 2020 cruise, except for HOT-318, which only had one near-bottom cast. Additional CTD casts were conducted during HOT-322 while tracking a trichodesmium bloom at stations 20 through 24.

CTD casts to depths ranging between 2400 and 2500 m were conducted at Station Kaena (Station 6) during HOT-320, -321, -322, -323, and -325.

CTD casts have been conducted during cruises near the WHOTS mooring since August 2004 to calibrate the moorings' sensors. Five yo-yo cycles to 200 m depth were performed near the WHOTS-16 mooring (Station 52: 22° 40.10'N, 157° 56.961'W) near the southeastern edge of the ALOHA circle during cruises HOT-319 through -325.

2.1.1 Data Acquisition and Processing

CTD data were acquired at a rate of 24 samples per second. Digital data were stored on a laptop personal computer, and for redundancy, the CTD signal was recorded using a USB sound card and Audacity® software on a separate laptop. Backups of CTD data were made onto USB storage cards and compact disks. The raw CTD data were quality controlled and screened for spikes described in Winn *et al.* (1993). Data alignment, averaging, correction, and reporting were done as described in Tupas *et al.* (1993). Salinity spike rejection parameters were modified for some cruises in 2020 because of rough sea conditions. Spikes occur when the CTD samples the disturbed water of its wake; therefore, samples from the downcast are rejected when the CTD moves upward or when its acceleration exceeds 0.5 m s^{-2} in magnitude.

Some cruises were conducted under relatively rough conditions. The CTD acceleration cutoff value had to be increased to between 0.55 and 0.70 m s⁻² for some casts to relax the data rejection criteria and avoid eliminating excessive points. The World Meteorological Organization (WMO) Sea State codes are as follows:

WMO Code	Wave height	Characteristics
0	0 metres (0 ft)	Calm (glassy)
1	0 to 0.1 metres (0.00 to 0.33 ft)	Calm (rippled)
2	0.1 to 0.5 metres (3.9 in to 1 ft 7.7 in)	Smooth (wavelets)
3	0.5 to 1.25 metres (1 ft 8 in to 4 ft 1 in)	Slight
4	1.25 to 2.5 metres (4 ft 1 in to 8 ft 2 in)	Moderate
5	2.5 to 4 metres (8 ft 2 in to 13 ft 1 in)	Rough
6	4 to 6 metres (13 to 20 ft)	Very rough
7	6 to 9 metres (20 to 30 ft)	High

The data were additionally screened by comparing the temperature and conductivity sensor pairs. These differences permitted the identification of problems in the sensors. Only the data from one set of T-C sensors and one oxygen sensor, whichever was deemed most reliable, are reported here.

Temperature is reported on the ITS-90 scale. Salinity and all derived units were calculated using the UNESCO (1981) routines; salinity is reported in the practical salinity scale (PSS-78). Oxygen is reported in µmol kg⁻¹. Chloropigment (Fluorescence) is reported in µg L⁻¹.

2.1.2 Sensor Corrections and Calibrations

2.1.2.1 Pressure

The pressure calibration strategy employed a high-quality quartz pressure transducer as a transfer standard. Periodic recalibrations of this laboratory standard were performed with a primary pressure standard. The transfer standard was used to check the CTD pressure transducers. The corrections applied to the CTD pressures included a constant offset determined when the CTD first enters the water on each cast, and a pressure-dependent offset, obtained from semi-annual bench tests between the CTD sensor and the transfer standard.

2.1.2.1.1 Transfer Standard Calibration

The transfer standard is a Digiquartz portable standard Paroscientific SN 136923 pressure gauge equipped with a 10,000-PSI transducer. This instrument was purchased in May 2016 and was originally calibrated against a primary standard. Subsequent recalibration was performed in May 2020 at Fluke. Calibrations before 2016 were conducted with a Paroscientific Model 760 pressure gauge which was in service between 1988 and 2014 (Fujieki *et al.*, 2020).

2.1.2.1.2 CTD Pressure Transducer Bench Tests

CTD pressure transducer bench tests were done using an Ametek T-100 pump and a manifold to apply pressure simultaneously to the CTD pressure transducer and the transfer

standard. All these tests had points at six pressure levels between 0 and 4500 dbar, increasing and decreasing pressures. The results of bench tests for sensor #75434 (CTD #91361) are shown in [Table 2.1](#). This pressure sensor failed and displayed bad data during one of the bench tests, and the sensor's card was replaced at Sea-Bird in April 2016, modifying the sensor's characteristic slope and offset. Therefore, only bench tests after this date are included in [Table 2.1](#). There were no bench tests conducted between August 2020 and September 2021 because the CTD was being serviced at SeaBird due to damages when the winch wire parted, and the CTD fell down and hit the ship's deck during the HOT-328 cruise. The September 2021 test showed that the sensor's characteristics changed after this incident ([Table 2.1](#)).

A correction of 0.861 dbar was applied to the pressure offset at 0 dbar during data collection for casts conducted with sensor #75434. However, a more accurate offset was later determined when the CTD first enters the water on each cast. On-deck CTD pressures are regularly recorded during cruises at the beginning, and at the end of each CTD cast, the mean of these pressures throughout each cruise is plotted in [Figure 2.1](#) (0.861 dbar offset correction applied to casts has been removed in this plot to make it comparable with the data in [Table 2.1](#)).

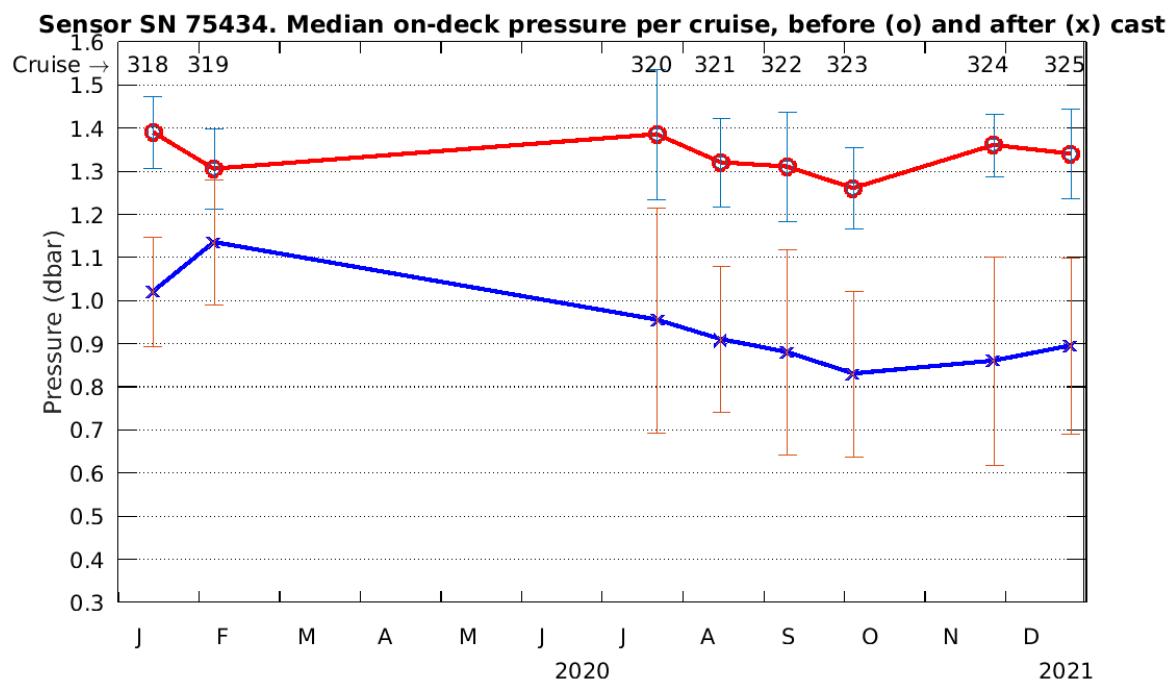


Figure 2.1: Median value of on-deck pressure measured with the CTD pressure sensors #75434 before (circles) and after (crosses) each cast for HOT cruises 318 through 325. Error bars are one standard deviation from the mean. Cruise numbers are shown in the upper X-axis.

[Table 2.1](#) indicates that the 0-dbar pressure for sensor #75434 was near constant during 2020 and increased slightly between the February and August 2020 calibrations. These pressures are smaller than the before-cast on-deck pressure ([Figure 2.1](#)) because during bench tests the CTD is powered on at least 12 hours before testing to allow the pressure sensor to stabilize, while during cruises, the CTD is powered on only about 15 minutes before each cast. The bench tests show that a slow sensor stabilization accounts for the observed differences.

The 0-4500 dbar pressure offset and hysteresis from the bench tests have been near-constant and within expected values. A linear pressure-dependent offset was applied during data collection for sensor #75434 to correct the 0-4500 dbar span offset of about 0.27 dbar from the September 2017 bench test ([Table 2.1](#)).

Table 2.1: CTD Pressure Calibrations against transfer standard. Units are in decibars.

Sea-Bird SBE-911 Plus #91361 / Pressure Transducer #75434			
<i>The sensor's card was replaced in April 2016, and recalibrated in April 2016 and June 2021</i>			
Calibration Date	Offset @ 0 dbar	0-4500 dbar offset	Hysteresis
28-Sep-21	0.44	0.12	0.04
20-Aug-20	1.20	0.40	0.05
27-Feb-20	0.92	0.20	0.05
28-Aug-19	0.75	0.18	0.05
24-Jan-19	1.14	0.35	0.09
17-Jul-18	1.04	0.21	0.09
7-Feb-18	1.06	0.14	0.03
7-Sep-17	1.05	0.27	0.10
18-Jan-17	1.02	0.13	0.05
3-Aug-16	0.52	0.25	0.05

2.1.2.2 Temperature

Five Sea-Bird SBE-3-Plus temperature transducers #1416, #2454, #2907, #4448, #5519 were used during 2020. These were calibrated at Sea-Bird on the dates indicated in [Table 2.2](#).

The history of the sensors, as well as the procedures, followed to obtain the sensor drift from the Sea-Bird calibrations, are well-documented in previous HOT data reports (Fujieki *et al.*, 2021, 2020, 2019, 2018, 2017, 2016, 2015, 2014, 2013, 2012, 2011, 2010, 2008, 2007, 2006, 2005, 2004, 2002, Santiago-Mandujano *et al.*, 2000, Tupas *et al.*, 1993, 1994, 1995, 1997, 1998, 1999, Karl *et al.* 1996). Calibration coefficients obtained at Sea-Bird for these sensors after 2019 and used in the drift estimates are presented in [Table 2.2](#). These coefficients were used in the following formula that gives the temperature (in °C) as a function of the frequency signal (f):

$$\text{temperature} = 1/\{a+b[\ln(f_0/f)]+c[\ln^2(f_0/f)]+d[\ln^3(f_0/f)]\}-273.15 \quad (1)$$

Table 2.2: Calibration coefficients for Sea-Bird temperature sensors. RMS residuals from calibration indicate the quality of the calibration.

<i>SN</i>	<i>Date</i> <i>yymmdd</i>	<i>f0</i>	<i>a</i>	<i>b</i>	<i>c</i>	<i>d</i>	<i>RMS</i> ($m^{\circ}C$)
1416	210417	6233.46	3.68120886e-03	6.01676696e-04	1.44727658e-05	1.69200157e-06	0.37
1416	210310	6233.74	3.68120917e-03	6.01694672e-04	1.45561602e-05	1.75442786e-06	0.33
1416	201013	6233.91	3.68120864e-03	6.01664202e-04	1.44653307e-05	1.69254547e-06	0.36
1416	200228	6233.97	3.68121040e-03	6.01711470e-04	1.46598400e-05	1.85988124e-06	0.31
1416	191122	6234.00	3.68120925e-03	6.01682603e-04	1.45581538e-05	1.76478711e-06	0.32
2454	210310	2884.90	3.68121202e-03	6.02184845e-04	1.67086722e-05	2.32530488e-06	0.04
2454	201013	2884.93	3.68121183e-03	6.02192919e-04	1.67505780e-05	2.36850830e-06	0.05
2454	200313	2884.99	3.68121197e-03	6.02198167e-04	1.67551911e-05	2.36488515e-06	0.03
2454	191031	2884.96	3.68121197e-03	6.02187811e-04	1.67603785e-05	2.38083311e-06	0.04
2907	210930	3035.52	3.68121233e-03	5.99762810e-04	1.58113610e-05	2.02441601e-06	0.03
2907	201013	3035.41	3.68121289e-03	5.99786963e-04	1.59578785e-05	2.16365838e-06	0.12
2907	200228	3035.50	3.68121357e-03	5.99762835e-04	1.58194167e-05	2.01842199e-06	0.04
2907	191031	3035.44	3.68121226e-03	5.99774184e-04	1.59052766e-05	2.10926077e-06	0.08
4448	210417	3075.39	3.68121375e-03	5.92755579e-04	1.50888065e-05	1.24316914e-06	0.09
4448	201013	3075.38	3.68121358e-03	5.92735067e-04	1.50403974e-05	1.20725700e-06	0.08
4448	200228	3075.38	3.68121495e-03	5.92735006e-04	1.50419277e-05	1.21071622e-06	0.09
4448	191031	3075.39	3.68121371e-03	5.92739420e-04	1.50586829e-05	1.21904221e-06	0.09
5519	210401	3004.18	3.68121300e-03	5.90828532e-04	1.48928779e-05	1.53832091e-06	0.05
5519	200228	3004.19	3.68121431e-03	5.90835866e-04	1.49196036e-05	1.56132372e-06	0.06
5519	191031	3004.19	3.68121302e-03	5.90847833e-04	1.49593259e-05	1.59336604e-06	0.05

For each sensor, the final calibration consists of two parts: first, a single "baseline" calibration is chosen from among the ensemble of calibrations during the year; second, for each cruise, a temperature-independent offset is applied to remove the temporal trend due to sensor drift ([Table 2.3](#)). The offset, a linear function of time, is calculated by a least-squares fit to the 0–30 °C average of each calibration during the year. The maximum drift correction in 2020 was less than 2.4×10^{-3} °C for the data collected with these sensors. The baseline calibration is selected as the one for which the trend-corrected average from 0–5 °C is nearest to the ensemble mean of these averages.

A small residual pressure effect on the temperature sensors documented in Tupas *et al.* (1997) has been removed from measurements obtained with our sensors. Another correction to our temperature measurements was for the viscous heating of the sensor tip due to the water flow. This correction is thoroughly documented in Tupas *et al.* (1997).

Dual sensors were used during each of the 2020 cruises. The temperature differences between sensor pairs were calculated for each cast to evaluate the quality of the data, and to identify possible problems with the sensors. Means and standard deviations of the differences in 2-dbar bins were calculated from the ensemble of all casts at Station ALOHA for each cruise. Both sensors performed correctly during the 2020 cruises, showing temperature differences within expected values. The mean temperature difference as a function of pressure was typically less than 1×10^{-3} °C, with a standard deviation of less than 0.5×10^{-3} °C below 500 dbar. The largest variability was observed in the thermocline, with standard deviation values of up to 5×10^{-3} °C.

Sensor #1416

This sensor was used during all the 2020 cruises. The instrument showed a large offset after the January 2018 calibration. The calibrations from March 2018 through March 2021 yielded a sensor drift of 5.59×10^{-6} °C day⁻¹, with an intercept of 3.0×10^{-4} °C and a RMS residual of 4.2×10^{-4} °C, which was used to obtain the drift correction for cruises HOT-318 through HOT-325. When corrected for linear drift to 30 July 2020 (the mid-date when the sensor was used), the 10 March 2021 calibration gave the smallest deviation in the 0-5 °C temperature range from the set of all calibrations (also corrected for linear drift to 30 July 2020). Drift corrections were obtained using this calibration as a baseline. The resulting drift corrections for each cruise were less than 2.4 m°C, and were applied to the data ([Table 2.3](#)).

Sensor #5519

This sensor was used during the HOT-318 and -319 cruises. The calibrations after June 2018 showed a change in the sensor drift. Calibrations between November 2018 through April 2021 yielded a sensor drift of 1.04×10^{-6} °C day⁻¹, with an intercept of -8.9×10^{-5} °C and a RMS residual of 1.2×10^{-4} °C, which was used to obtain the drift correction for cruises HOT-318 and HOT-319. When corrected for linear drift to 15 January 2020 (the mid-date when the sensor was used), the October 2020 calibration gave the smallest deviation in the 0-5 °C temperature range from the set of all calibrations (also corrected for linear drift to 15 January 2020). Drift corrections were obtained using this calibration as a baseline. The resulting drift corrections for each cruise were less than 0.3 m°C, and were applied to the data ([Table 2.3](#)).

Sensor #2454

This sensor was used during cruises HOT-320 through -325. The Sea-Bird calibrations showed a change in the sensor's drift after October 2019. Calibrations from March 2020 through March 2021 yielded a sensor drift of 4.1×10^{-6} °C day⁻¹, with an intercept of 4.8×10^{-5} °C and a RMS residual of 8.3×10^{-5} °C, which was used to obtain the drift correction for cruises HOT-320 through -325. When corrected for linear drift to 30 September 2020 (the mid-date when the sensor was used), the March 2020 calibration gave the smallest deviation in the 0-5 °C temperature range from the set of all calibrations (also corrected for linear drift to 30 September 2020). A drift correction was obtained using this calibration as a baseline. The resulting drift corrections for the cruise were less than 1.2 m°C as shown in [Table 2.3](#).

Sensor #4448

This sensor was not used during the 2020 cruises. The calibrations from February 2012 through October 2020 yielded a sensor drift of $9.9 \times 10^{-7} \text{ }^{\circ}\text{C day}^{-1}$, with an intercept of $1.0 \times 10^{-4} \text{ }^{\circ}\text{C}$ and a RMS residual of $2.3 \times 10^{-4} \text{ }^{\circ}\text{C}$.

Sensor #2907

This sensor was not used during the 2020 cruises. The calibrations from January 2015 through October 2020 yielded a sensor drift of $1.7 \times 10^{-7} \text{ }^{\circ}\text{C day}^{-1}$, with an intercept of $2.4 \times 10^{-4} \text{ }^{\circ}\text{C}$ and a RMS residual of $5.3 \times 10^{-4} \text{ }^{\circ}\text{C}$.

Table 2.3: Temperature (T) and Conductivity (C) sensor corrections, including the thermal inertia parameter (α). Dual temperature and conductivity sensors were used on all cruises. The last column indicates which T-C sensor pair's data is reported.

Cruise	T sensor #	T Correction ($^{\circ}\text{C}$)	C sensor #	α	Data reported
HOT-318	1416	-0.002391	3984	0.028	All Casts
HOT-318	5519	-0.000290	2959	0.028	
HOT-319	1416	-0.002252	3984	0.028	All Casts
HOT-319	2454	-0.000167	3162	0.028	
HOT-320	1416	-0.001330	3162	0.020	
HOT-320	2454	0.000505	4687	0.028	All Casts
HOT-321	1416	-0.001196	4687	0.020	All Casts
HOT-321	2454	0.000603	3162	0.020	
HOT-322	1416	-0.001050	4687	0.020	All Casts
HOT-322	2454	0.000709	3984	0.012	
HOT-323	1416	-0.000916	4687	0.020	All Casts
HOT-323	2454	0.000806	2959	0.020	
HOT-324	1416	-0.000620	3984	0.020	All Casts
HOT-324	2454	0.001022	4939	0.012	
HOT-325	1416	-0.000453	3984	0.020	All Casts
HOT-325	2454	0.001144	4938	0.012	

2.1.2.3 Conductivity

Six conductivity sensors were used during the 2020 cruises, #3162, #2959, #3984, #4687, and two new sensors #4938 and #4939 acquired in September 2020. Sensor's #3984 conductivity cell was found to be cracked at SeaBird during a routine calibration, and its cell was replaced in June 2020. The history of the sensors is well documented in previous HOT data reports (Fujieki *et al.*, 2021, 2020, 2019, 2018, 2017, 2016, 2015, 2014, 2013, 2012, 2011, 2010, 2008, 2007, 2006, 2005, 2004, 2002, Santiago-Mandujano *et al.*, 2000, Tupas *et al.*, 1993, 1994, 1995, 1997, 1998, 1999, Karl *et al.* 1996). The dual sensor configurations are shown in [Table 2.3](#).

For each sensor, the nominal calibrations were used for data acquisition, and a final calibration was determined empirically from salinities of discrete water samples acquired during each cast. Before empirical calibration, conductivity was corrected for thermal inertia of the glass conductivity cell, as described in Chiswell *et al.* (1990). [Table 2.3](#) lists the value of the α parameter used for each cruise.

Procedures for preliminary screening of bottle samples and empirical calibration of the conductivity cell are described in Tupas *et al.* (1993, 1994a). For cruises HOT-318 through -325, the standard deviation cutoff values for screening of bottle salinity samples were: 0.0034 (0-150 dbar), 0.0049 (151-500 dbar), 0.0019 (501- 1050 dbar), and 0.0009 (1051-5000 dbar).

The conductivity calibration coefficients ($b0, b1, b2$) derived from the least-squares fit ($\Delta C = b0 + b1C + b2C^2$) to the CTD-bottle conductivity differences (ΔC) as a function of conductivity (C) are given in [Table 2.4](#). None of the cruises required a quadratic calibration. The quality of the CTD calibration is illustrated in [Figure 2.2](#), which shows the differences between the corrected CTD salinities and the bottle salinities used for calibration as a function of pressure for each cruise. The calibrations are best below 500 dbar because the weaker vertical salinity gradients at depth lead to less error when the bottle and CTD pressures are slightly mismatched.

The final step of conductivity calibration was a cast-dependent bias correction described in Tupas *et al.* (1993) to allow for drift during each cruise or sudden offsets due to fouling ([Table 2.5](#)). Note that a change of 1×10^{-4} Siemens m⁻¹ in conductivity is approximately equivalent to 0.001 in salinity. [Table 2.6](#) gives the mean and standard deviations for the final calibrated CTD minus bottle samples shown in [Figure 2.2](#).

Conductivity differences between sensor pairs were calculated the same way for temperature sensors ([Section 2.1.2.2](#)). The range of variability as a function of pressure was about $\pm 1 \times 10^{-4}$ Siemens m⁻¹, with a standard deviation of less than 0.5×10^{-4} Siemens m⁻¹ below 500 dbar, from the ensemble of all the cruise casts. The largest variability was in the halocline, with standard deviations reaching 5×10^{-4} Siemens m⁻¹ between 50 and 300 dbar.

Table 2.4: Conductivity calibration coefficients

<i>Cruise</i>	<i>Sensor #</i>	<i>b0</i>	<i>b1</i>	<i>b2</i>
HOT-318	3984	0.000567	-0.000259	0
HOT-318	2959	0.000380	-0.000089	0
HOT-319	3984	0.000465	-0.000217	0
HOT-319	3162	0.000128	0.000022	0
HOT-320	3162	0.000287	0.000002	0
HOT-320	4687	0.000115	0.000102	0
HOT-321	4687	0.000499	-0.000041	0
HOT-321	3162	0.000414	-0.000020	0
HOT-322	4687	0.000531	-0.000104	0
HOT-322	3984	-0.000281	0.000121	0
HOT-323	4687	-0.000132	0.000054	0
HOT-323	2959	0.000078	0.000115	0
HOT-324	3984	0.000069	-0.000002	0
HOT-324	4939	0.000148	-0.000055	0
HOT-325	3984	-0.000023	-0.000001	0
HOT-325	4938	0.000081	0.000053	0

 Table 2.5: Individual cast conductivity corrections (units are Siemens m⁻¹)

<i>Cruise</i>	<i>Station</i>	<i>Cast</i>	<i>C Correction</i>
318	2	1	0.000032
319	2	2	-0.000029
319	2	13	0.000120
320	2	3	-0.000012
320	2	16	0.000112
321	2	4	0.000010
321	2	17	0.000043
322	2	6	-0.000018
322	2	19	-0.000001
323	1	1	-0.000147
323	2	3	0.000046
323	2	16	0.000091
324	2	4	0.000011
324	2	16	0.000074
325	2	2	0.000012
325	2	15	0.000139

Table 2.6: CTD-Bottle salinity comparison for each cruise

Cruise	Sensor #	0-4700 dbar		500-4700 dbar	
		Mean	St. dev	Mean	St. dev
HOT-318	3984	-0.0000	0.0012	0.0000	0.0008
HOT-318	2959	-0.0001	0.0015	0.0003	0.0011
HOT-319	3984	-0.0000	0.0019	0.0005	0.0011
HOT-319	3162	-0.0002	0.0017	0.0001	0.0009
HOT-320	3162	-0.0001	0.0025	-0.0004	0.0013
HOT-320	4687	-0.0000	0.0021	-0.0003	0.0012
HOT-321	4687	-0.0000	0.0019	-0.0003	0.0009
HOT-321	3162	-0.0001	0.0019	-0.0004	0.0010
HOT-322	4687	0.0000	0.0021	-0.0004	0.0010
HOT-322	3984	-0.0000	0.0019	-0.0003	0.0012
HOT-323	4687	-0.0001	0.0018	-0.0007	0.0009
HOT-323	2959	-0.0004	0.0030	-0.0004	0.0021
HOT-324	3984	-0.0000	0.0021	-0.0003	0.0014
HOT-324	4939	-0.0001	0.0018	-0.0001	0.0011
HOT-325	3984	-0.0001	0.0016	-0.0004	0.0011
HOT-325	4938	-0.0001	0.0018	-0.0003	0.0012

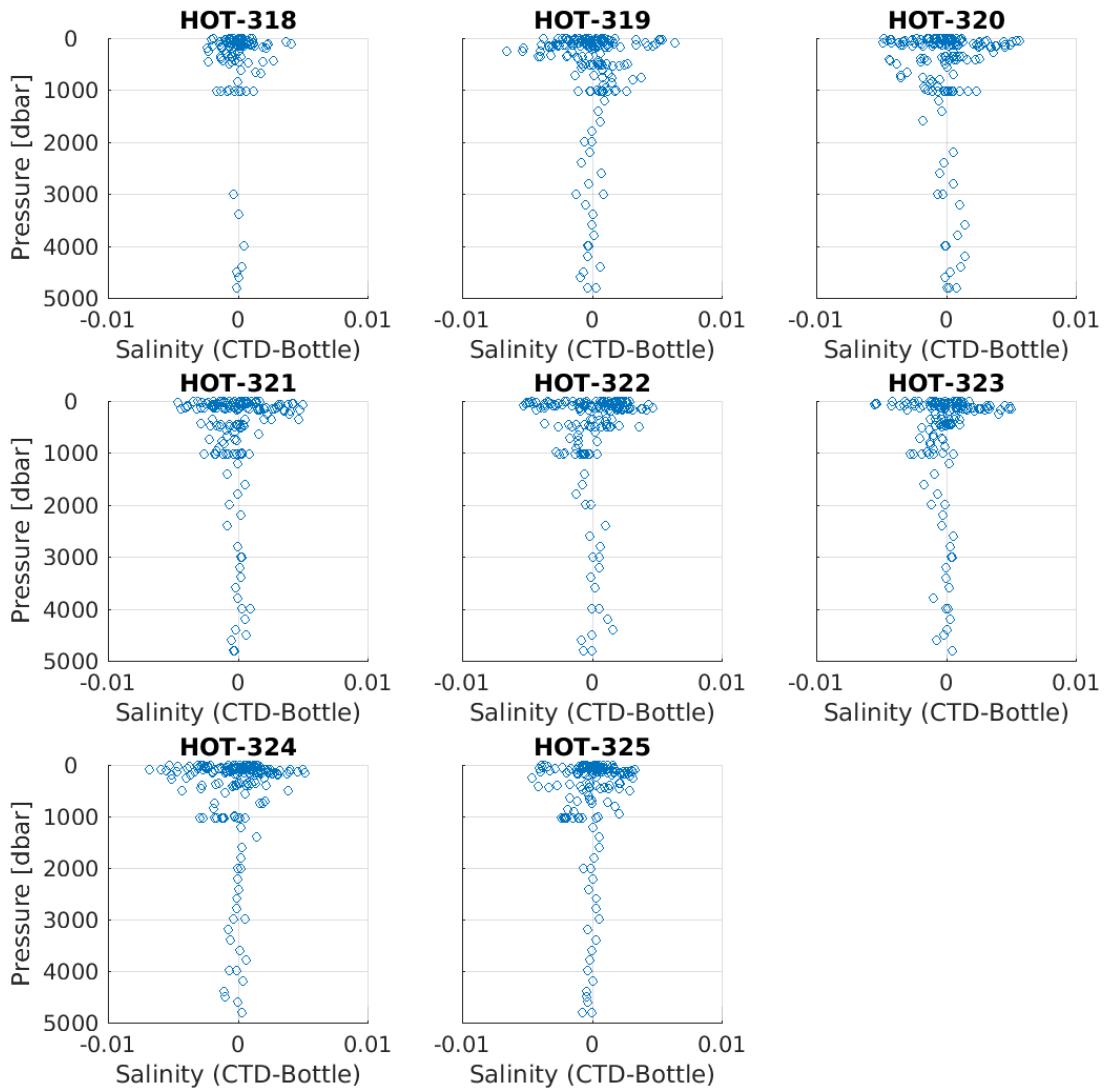


Figure 2.2: Difference between calibrated CTD salinities and bottle salinities for each cruise and all casts at Station ALOHA in 2020.

2.1.2.4 Oxygen

During the 2020 cruises, four of our five Sea-Bird SBE-43 oxygen sensors were used: #43262, #431601, #433761, and #43982, sensor #43918 was not used. Sensor #431601 membrane was found dirty during a SeaBird inspection and it was replaced in July 2020. Sensor #43262 membrane was found damaged at SeaBird and its lid and membrane assembly were replaced in November 2020; the sensor showed glitches during a deep cast, and an offset with respect to its paired sensor during HOT-324 and it was repaired again in May 2021 (replaced pressure compensation bag, lid and membrane assembly, and anode sub-assembly). The history of these sensors is documented in previous HOT data reports (Fujieki *et al.*, 2021, 2020, 2019,

2018, 2017, 2016, 2015, 2014, 2013, 2012, 2011, 2010, 2008, 2007, 2006, 2005, 2004, 2002, Santiago-Mandujano *et al.*, 2000, Tupas *et al.*, 1993, 1994, 1995, 1997, 1998, 1999, Karl *et al.* 1996). All these sensors have been calibrated annually at Sea-Bird.

Water bottle oxygen data were screened, and the oxygen sensors were empirically calibrated following procedures described previously (Winn *et al.* 1991; Tupas *et al.*, 1993). The analysis of water bottle samples is described in [Section 2.5.1](#). The calibration procedure follows Owens and Millard (1985) and fits a non-linear equation to the CTD oxygen current and oxygen temperature. The bottle values of dissolved oxygen and the downcast CTD observations at the potential density of each bottle trip were grouped for each cruise to find the best set of parameters with a non-linear least squares algorithm. Two sets of parameters were usually obtained per HOT cruise, corresponding to the casts at Stations 1 and 2 (calibrations coefficients from cast 2 are also used to calibrate the casts at stations 6 and 52). The calibration procedure for the Sea-Bird SBE-43 sensors is documented in Santiago-Mandujano *et al.* (2001).

[Table 2.7](#) shows the mean and standard deviation for each cruise's calibrated CTD oxygen minus water sample residuals. Dual sensors were used during cruises, but only the sensor whose data were deemed more reliable is reported.

Table 2.7a: CTD-Bottle dissolved oxygen per cruise at Station Kahe ($\mu\text{mol kg}^{-1}$).

Cruise	Sensor	0 to 1500 dbar	
		Mean	SD
HOT-318	43982	0.00	0.85
HOT-319	43982	0.01	0.82
HOT-320	43262	0.00	1.15
HOT-321	43982	0.00	0.45
HOT-322	43982	0.00	0.96
HOT-323	43982	0.00	1.06
HOT-324	43982	0.00	0.32
HOT-325	3761	-0.01	1.36

Table 2.7b: CTD-Bottle dissolved oxygen per cruise at Station ALOHA ($\mu\text{mol kg}^{-1}$).

Cruise	Sensor	0 to 4700 dbar		500 to 4700 dbar	
		Mean	SD	Mean	SD
HOT-318	43982	0.05	0.57	0.02	0.46
HOT-319	43982	0.00	0.73	0.03	0.52
HOT-320	43262	0.01	0.82	-0.04	0.69
HOT-321	43982	0.00	1.02	0.00	0.83
HOT-322	43982	0.01	0.71	0.00	0.71
HOT-323	43982	0.01	0.72	0.00	0.62
HOT-324	43982	0.00	0.76	-0.01	0.58
HOT-325	3761	0.01	1.16	-0.02	0.58

2.1.2.5 Fluorescence (Chloropigment)

Fluorescence was measured with a Sea-Point chlorophyll fluorometer (#2440 and #2441). The data was collected using the Sea-Bird CTD system. Fluorescence traces were collected on as many casts as possible. Because an absolute radiometric standard is not available for fluorometers, instrument drift was corrected via calibration with bottle fluorometric chlorophyll a plus accessory pheopigments analyzed using a Turner Designs Model 10-AU fluorometer as described in [Section 2.5.7.1](#). A linear relationship of the form, $V_{chl} = b \cdot V_{fluor} + a$, was used to convert all fluorescence data (V_{fluor}) to chloropigment (V_{chl}).

The R/V *Kilo Moana*'s IMET Lab also contained a TD 10-AU used to collect continuous, underway Fluorescence. Although available, this data has never been calibrated and thus is not accurate.

2.1.3 Discrete salinity

Salinity samples were collected, stored, and analyzed, as Tupas *et al.* (1993) described. IAPSO samples were measured to standardize the salinometer, and samples from a large batch of “secondary standard” (substandard) seawater were measured after every 24 to 48 bottle samples of each cruise to detect drift in the salinometer. Standard deviations of the secondary standard measurements were less than ± 0.001 psu for all the cruises ([Table 2.8](#)).

The secondary standard seawater batches are made from 60 liters of seawater taken from a depth of 1020 m from Station ALOHA. Three batches of secondary standard seawater were used during 2020. Batch #67 collected on August 18, 2019, from S2C11 during HOT-314 and prepared on August 29, 2019. Batch #68 had water collected during HOT-320 at S2C10 on July 16, 2020. This batch was prepared on July 28, 2020, and was first used after HOT-320. The last secondary standard seawater, Batch #69, was collected on December 20, 2020, from S2C13 during HOT-325 and prepared on December 24, 2020.

Before making each substandard batch, all substandard making materials and supplies were cleaned thoroughly. The plastic and glass carboys used to collect the substandard seawater on the cruise were washed with a non-hazardous buffered alkaline brewery cleaner (Powdered Brewery Wash), an acid-based sanitizer (StarSan), and then rinsed with 99% alcohol before drying.

The glass carboy and glass rod were rinsed with the substandard seawater before being filled and capped with a layer of white oil to prevent oxygenation and evaporation. The filled carboy was then wrapped in black bags to prevent light from reaching the stored substandard seawater.

Table 2.8: Precision of salinity measurements using secondary lab standards

<i>Cruise</i>	<i>Mean Salinity ± SD</i>	<i># Samples</i>	<i>Substandard Batch #</i>	<i>IAPSO Batch #</i>
HOT-318	34.4935±0.0007	14	67	163
HOT-319	34.4934±0.0006	19	67	163
HOT-320	34.4924±0.0007	17	67	163
HOT-321	34.4441±0.0004	20	68	163
HOT-322	34.4437±0.0009	22	68	163
HOT-323	34.4433±0.0009	22	68	163
HOT-324	34.4425±0.0004	22	68	163
HOT-325	34.4872±0.0005	20	69	163

2.2 Thermosalinograph

2.2.1 Data Acquisition

Continuous near-surface salinity and temperature data were collected during every 2020 HOT cruise (HOT-318 through HOT-325) using Sea-Bird thermosalinograph and temperature sensors aboard R/V *Kilo Moana* (KM). The system consisted of a remote temperature sensor measuring near-surface temperature close to the intake of the ship's uncontaminated seawater supply in conjunction with a thermosalinograph sensor that measured both conductivity and temperature further down the seawater supply line. The salinity of seawater was then calculated using the internal temperature and conductivity and the internal pressure of the pump. The 2020 HOT cruises are listed below in [Table 2.9](#), along with the serial numbers of the Sea-bird sensors used to collect the thermosalinograph data.

Thermosalinograph conductivities were calibrated using bottled salinity samples taken periodically (approximately every 4 hours) from the continuous seawater line outtake near the thermosalinograph. The data from each cruise were also compared with the CTD temperature and conductivity data collected simultaneously and from near the same depth as the seawater supply intake for a final data quality control.

Table 2.9: 2020 HOT Cruise Thermosalinograph Sensors

Cruise	Ship	Sensor S/N	
		SBE-38 External T	SBE-45 Internal T and C
HOT-318	KM	0150	0218
HOT-319	KM	0150	0218
HOT-320	KM	0150	0218
HOT-321	KM	0150	0218
HOT-322	KM	0150	0218
HOT-323	KM	0150	0218
HOT-324	KM	0150	0218
HOT-325	KM	0150	0218

The thermosalinograph system aboard the R/V *Kilo Moana* consisted of the SBE-38 external temperature sensor (SN 0150) in the bow-thruster chamber in the starboard bow close to the seawater intake. The intake depth was 8 meters below the surface, and the pump's internal pressure was approximately 6 dbar. An SBE-45 Seacat thermosalinograph (SN 0218) measuring internal conductivity and temperature was in the IMET lab at the ship's port bow. Data were acquired every second.

These data were processed and calibrated against bottled salinity samples. Final data for 2020 from cruises aboard R/V *Kilo Moana* are derived from the SBE-45 thermosalinograph at 1-second intervals.

2.2.2 Data processing and sensor calibration

2.2.2.1 Nominal Calibration

2.2.2.1.1 Temperature

The Sea-Bird internal and external temperature sensors ([Table 2.9](#)) have been calibrated at Sea-Bird ([Table 2.10](#)). These sensors use the following equation and coefficients from [Table 2.10](#) to convert the instrument output (n) to temperature (in °C).

$$\text{Temperature ITS-90} = 1/\{a0+a1[\ln(n)]+a2[\ln^2(n)]+a3[\ln^3(n)]\}-273.15$$

Internal SBE-45 sensor #218 was used onboard the R/V *Kilo Moana* during all the 2020 cruises. The instrument was repaired at SeaBird on 7 October 2016, which changed its calibration level, therefore only the calibrations after this date ([Table 2.10](#)) were used to calculate a sensor drift of -2.73×10^{-7} °C day⁻¹. Temperatures were calculated with the 18th March 2019

baseline calibration. Drift correction was not applied to the data for this sensor, as it was less than $2 \times 10^{-4} \text{ }^{\circ}\text{C}$ and inconsequential.

External SBE-38 sensor #150 was used onboard the R/V *Kilo Moana* during all the 2020 cruises. The calibrations in [Table 2.10](#) were used to calculate a sensor drift of $1.28 \times 10^{-7} \text{ }^{\circ}\text{C day}^{-1}$. Temperatures were calculated with the 3rd February 2018 baseline calibration. Drift correction was not applied to the data for this sensor, as it was less than $2 \times 10^{-4} \text{ }^{\circ}\text{C}$ and inconsequential.

Table 2.10: Calibration coefficients for Sea-Bird temperature sensors SBE-45 and SBE-38. RMS residuals from calibration indicate the quality of the calibration.

<i>SN</i>	<i>Date</i> <i>yymmdd</i>	<i>a0</i>	<i>a1</i>	<i>a2</i>	<i>a3</i>	<i>RMS</i> (m°C)
150	180203	-1.77616800E-04	3.07900600E-04	-4.60708300E-06	2.06391300E-07	0.04
150	170104	-1.88606400E-04	3.10492500E-04	-4.81083900E-06	2.11735100E-07	0.03
150	150113	-1.82930400E-04	3.09166900E-04	-4.70791200E-06	2.09073200E-07	0.01
150	130912	-1.72247600E-04	3.06668200E-04	-4.51299500E-06	2.04003700E-07	0.04
150	121025	-1.79407100E-04	3.08346000E-04	-4.64410600E-06	2.07418100E-07	0.04
150	120212	-1.72715300E-04	3.06779000E-04	-4.52199400E-06	2.04252000E-07	0.05
150	90916	-1.79443400E-04	3.08337300E-04	-4.64184200E-06	2.07313300E-07	0.06
218	210502	-7.08450100e-05	2.90278300e-04	-3.58308500e-06	1.82999500e-07	0.07
218	190318	-1.40960200e-05	2.77194900e-04	-2.57831800e-06	1.57297300e-07	0.07
218	161029	-3.27201400e-05	2.81425100e-04	-2.89869100e-06	1.65384000e-07	0.04

2.2.2.1.2 Conductivity

Two different conductivity sensors were used to collect thermosalinograph data for the 2020 HOT cruises ([Table 2.9](#)). All the conductivity data were nominally calibrated with coefficients obtained at Sea-Bird. However, all the final salinity data were calibrated against bottle data, as explained below ([Section 2.2.2.3](#)).

2.2.2.2 Processing

The thermosalinograph data were screened for gross errors with upper and lower bounds of 35 and 18 °C for temperature and 6 and 3 Sm⁻¹ for conductivity. There were 5 gross errors detected in temperature during HOT-319, -322; 3 gross errors detected in temperature during HOT-318,-323; 2 gross errors were detected in temperature during HOT-321, -324 ; 1 gross error was detected in temperature during HOT-320. No other gross errors were detected in temperature or conductivity during the other 2020 HOT cruises. All cruises during 2020 contained around 350,000 to 850,000 1-sec interval data points each. The remaining data were subsequently screened for bad or suspicious points and were ascribed to factors such as air bubbles entering the thermosalinograph system, low flow rate, electrical surges from the power supply, biological fouling of the thermosalinograph, the ship being in port, etc. A quality control system has been established so that each temperature and salinity point is given a flag to determine whether the data are good, suspect, or bad. A 21-point running median filter was used to detect one or two-point temperature and conduct glitches in the thermosalinograph data. Glitches in temperature and conductivity detected by the 21-point median filter were immediately replaced by the median. Threshold values of 0.3 °C for temperature and 0.1 Sm⁻¹ for conductivity were used for the median filter. Typically, no more than a few points per cruise are replaced after running the median filter. A 3-point triangular mean filter was used to smooth the temperature and conductivity data from all the cruises after they had gone through glitch detection. The temperature and conductivity record were manually inspected to further flag suspect or bad data.

After the temperature and conductivity data are processed through the gross error check, median filter, and mean filter, all the temperature (internal and external), conductivity, salinity, speed, and navigation data streams are merged into one set of plots for visual assessment. The merged data are visually inspected for spikes in the data that may have passed through the previous filters. After visually inspecting the remaining data, the number of thermosalinograph data points flagged as suspicious or bad during each of the 2020 cruises was about 20,000. The only exception was for HOT-322, a longer cruise that displayed about 130,000 suspicious or bad data.

Spikes are usually caused by bubbles entering the thermosalinograph system. Strong winds and rough seas (particularly around Ka’ena Point) during transit to ALOHA Station can introduce bubbles resulting in suspect data. The deep seawater intake of R/V *Kilo Moana* limits these intrusions. Other flagged data resulted from insufficient time allowed for flushing of the uncontaminated seawater line before logging was commenced or because the dataset included data when the ship was in port.

Significant changes were made to the *Kilo Moana*’s IMET lab before HOT-320, including the installation of a panel of flow meters and control knobs. Unfortunately, these

control knobs were prone to clogging, reducing the flow and causing subtle drift in the salinity and internal temperature values. Adjusting the flow cleared the clog and resulted in an abrupt correction to the true value. As a result of the random nature of the clogs, it was not possible to correct the data for these issues from HOT-320 to HOT-322. Before HOT-323, OTG plumbed an intake line for the thermosalinograph that avoids the trouble of low flow control panel that clogs on occasion. This resolved the intermittent drift issues present on past cruises, and dramatically reduced conductivity spikes. For more detailed information on specific problems encountered during 2020 cruises, please refer to https://hahana.soest.hawaii.edu/hot/proc_reports/proc_reports.html.

An estimate of the noise in thermosalinograph data was performed to evaluate quality. A 101-point running mean (17 minutes at a 10-second sampling rate) was applied to the thermosalinograph salinities and external temperatures, and the standard deviations of the residuals from the original data were used as an estimate of the data noise. Only data taken during periods of near-constant salinity or temperature were included in the estimates to avoid large residuals resulting in sections of great variability. Noise estimates were obtained for all cruises HOT-318 through 325 ([Table 2.11](#)).

Table 2.11: Thermosalinograph Data Noise Estimates

<i>Cruise</i>	<i>Salinity Noise (psu)</i>	<i>Temperature Noise (°C)</i>
HOT-318	0.00062	0.0039
HOT-319	0.00069	0.0049
HOT-320	0.00062	0.0046
HOT-321	0.00044	0.0059
HOT-322	0.00053	0.0075
HOT-323	0.00046	0.0072
HOT-324	0.00070	0.0086
HOT-325	0.00053	0.0096

2.2.2.3 Conductivity Calibration

The thermosalinograph salinity was calibrated by comparing it to bottle salinity samples drawn from the plumbing near the thermosalinograph. Bottle salinity samples were analyzed, as described in [Section 2.1.3](#).

The bottle sampling area aboard the research vessel is located within 1 m of the thermosalinograph used to calculate salinity. Therefore, thermosalinograph data were extracted within ± 15 seconds around the bottle sample time.

As in previously reported cruises (Tupas et al., 1997), a cubic spline was fit to the time-series of the differences between the bottle conductivity and the thermosalinograph conductivity separately for all the 2020 HOT cruises. The correction of the thermosalinograph conductivities was obtained from this fit. Salinity was calculated using these corrected conductivities, thermosalinograph temperatures, and the pressure of the pump. The mean values for the salinity bottle minus the final calibrated thermosalinograph were less than $\pm 0.5 \times 10^{-5}$ for all cruises. The mean differences and standard errors for all cruises in 2020 are shown in [Table 2.12](#).

Table 2.12: Bottle-Thermosalinograph Salinity Comparison

<i>Cruise</i>	<i>Sensor #</i>	<i>Mean Difference</i>	<i>Standard Error</i>
HOT-318	0218	0.000004	0.000815
HOT-319	0218	0.000003	0.000480
HOT-320	0218	0.000004	0.001188
HOT-321	0218	0.000000	0.000301
HOT-322	0218	0.000004	0.000240
HOT-323	0218	0.000000	0.000130
HOT-324	0218	0.000000	0.000140
HOT-325	0218	0.000000	0.000113

2.2.2.4 Comparison with the CTD Data

The external temperature and the calibrated thermosalinograph salinity data collected during CTD casts were compared with the downcast CTD salinity from 6 dbar (R/V *Kilo Moana* cruises) as additional quality control. This procedure was conducted in the same manner as in previously reported HOT cruises. The thermosalinograph data were averaged using data sampled one minute after the acquisition time of the CTD sample.

The mean thermosalinograph salinity difference with the CTD salinity was smaller than ± 6 mpsu. Mean temperature differences between the CTD and the external temperature sensor were smaller than ± 0.035 °C for all cruises.

Table 2.13: CTD – External Temperature and CTD – Thermosalinograph Salinity

<i>Cruise</i>	<i>SBE-38 Ext T Sensor #</i>	<i>CTD-External Temperature (°C)</i>	<i>SBE-45 Int T + C Sensor #</i>	<i>CTD- Thermosal Salinity (psu)</i>
HOT-318	0150	-0.02126	0218	-0.004965
HOT-319	0150	-0.01238	0218	-0.000431
HOT-320	0150	-0.02065	0218	-0.006000
HOT-321	0150	-0.02827	0218	0.000812
HOT-322	0150	-0.02699	0218	0.002317
HOT-323	0150	-0.03492	0218	0.002051
HOT-324	0150	-0.03355	0218	0.000628
HOT-325	0150	-0.03377	0218	-0.002300

2.3 Meteorology

Wind speed and direction, atmospheric pressure, wet- and dry-bulb air temperature, sea surface temperature (SST), cloud cover, and weather code were recorded at four-hour intervals while at Station ALOHA by the science personnel. Continuous wind velocity measurements were recorded at 5-min intervals from the anemometers on the R/V *Kilo Moana* (21 m height).

Also available were hourly atmospheric pressure, air temperature, SST, wind velocities, and relative humidity measurements from the WHOTS buoy (see [Section 2.10](#)). The anemometers in the buoy were 2.7 m above the sea surface.

The time series of shipboard observations obtained by the science group was plotted, and obvious outliers were identified and flagged. The SST-dry air temperature and wet-dry air temperature plots also helped to identify outliers. Outliers in the shipboard pressure, air temperature, SST, and wind observations were detected by comparison with the WHOTS buoy data.

In addition to wind speed and direction (RM Young port and starboard side anemometers), instruments on the R/V *Kilo Moana* provided measurements of air temperature (RM Young Resistive Temperature Device), relative humidity (Rotronic Instrument Corp. humidity probe), barometric pressure (Vaisala digital barometer), incoming shortwave (Eppley Precision Spectral Pyranometer) and longwave radiation (Eppley Precision Infrared Radiometer), and precipitation (OSI Optical Rain Gauge (ORG) and RM Young), these data were compared against the measurements taken by the WHOTS buoy (see [Section 4.10](#)).

2.4 ADCP Measurements

Currents in the upper ocean (0-1200 m) during 2020 were measured using shipboard Acoustic Doppler Current Profilers (ADCP) onboard R/V *Kilo Moana*.

Onboard ADCP data are collected and preliminarily processed in real-time using the University of Hawaii's CODAS processing system (<http://currents.soest.hawaii.edu>). This system allows for automatic quality control of the data and real-time graphic display of current profiles and other data products while at sea. Should any ancillary data stream be disrupted at sea or found to be in error, raw data are saved, and a complete re-processing of the data is possible later.

The R/V *Kilo Moana* is equipped with two ADCP systems. A Teledyne RD Instruments Ocean Surveyor 38 is located on the ship's starboard side, and an RD Instruments WorkHorse 300 is located on the port side; both feature a transducer depth of 7 m. The Ocean Surveyor operates at 38 kHz and can profile to 1200 m in broadband mode (OS38BB) with a bin size of 12 m averaging ensembles every 5 minutes. In narrowband mode (OS38NB) with 24 m bins, profiles can reach as deep as 1500 m. The WorkHorse (WH300) operates at 300 kHz, typically profiling to a maximum of 100 m with a bin size of 2 m and averaging ensembles every 2 minutes. Heading information is taken from the gyrocompass and corrected using a TSS POS/MV 320 (an integrated inertial and GPS). An Ashtech ADU5 is used as a heading-

correction device should there be a problem with the POS/MV. Position data are provided by the POS/MV system with an Ashtech ADU5 and a Trimble GPS as backups.

Final processing of shipboard ADCP data involves applying small heading corrections to the velocity data based on water track calibrations, trimming unnecessary data from the beginning and ends of the cruise, followed by visual inspection of the final dataset with manual data flagging of suspicious points.

ADCP data were collected using OS38BB, OS38NB, and WH300 during HOT-318, -319, and -324. During cruises HOT-320, -321, -322, -323, and -325 only data from the WH300 are available, the Ocean Surveyor had problems and was not used.

2.5 Biogeochemical Measurements

At Stations Kahe, ALOHA and Kaena , water samples for chemical analyses were collected from discrete depths using 12 liter PVC bottles with nylon coated internal springs as closing mechanisms. Sampling strategies and procedures are well documented in the previous [Data Reports](#) and in the [HOT Program Field and Laboratory Protocols manual](#). This report contains only a subset of the total database, which can be extracted electronically over the Internet (hahana.soest.hawaii.edu/hot/dataaccess.html). To assist in the interpretation of these data and to save users the time to estimate the precision of individual chemical analysis, we have summarized precision estimates from replicate determinations for selected constituents on each HOT cruise in 2020.

2.5.1 Dissolved Oxygen

Dissolved oxygen samples were collected and analyzed using a computer-controlled potentiometric end-point titration procedure as described in Tupas *et al.* (1997). As in previous years we measured, using a calibrated digital thermistor, the temperature of the seawater sample at the time the iodine flask was filled. This was done to evaluate the magnitude of sample temperature error that affects the calculation of oxygen concentrations in units of $\mu\text{mol kg}^{-1}$. [Figure 2.3](#) (upper panel) shows a plot of the difference between sample temperature and potential temperature computed from the *in situ* temperature measured at the time of bottle trip, versus pressure. [Figure 2.3](#) (lower panel) shows a plot of the difference between oxygen concentrations calculated using the sample temperature and potential temperature versus pressure. The depth dependent variability in Δ oxygen is a result of: 1) bottle warming as the rosette is brought up through the water column 2) warm air entering the niskin bottle as samples are being taken and 3) evaporative cooling that occurs while on-deck as bottles are waiting to be sampled.

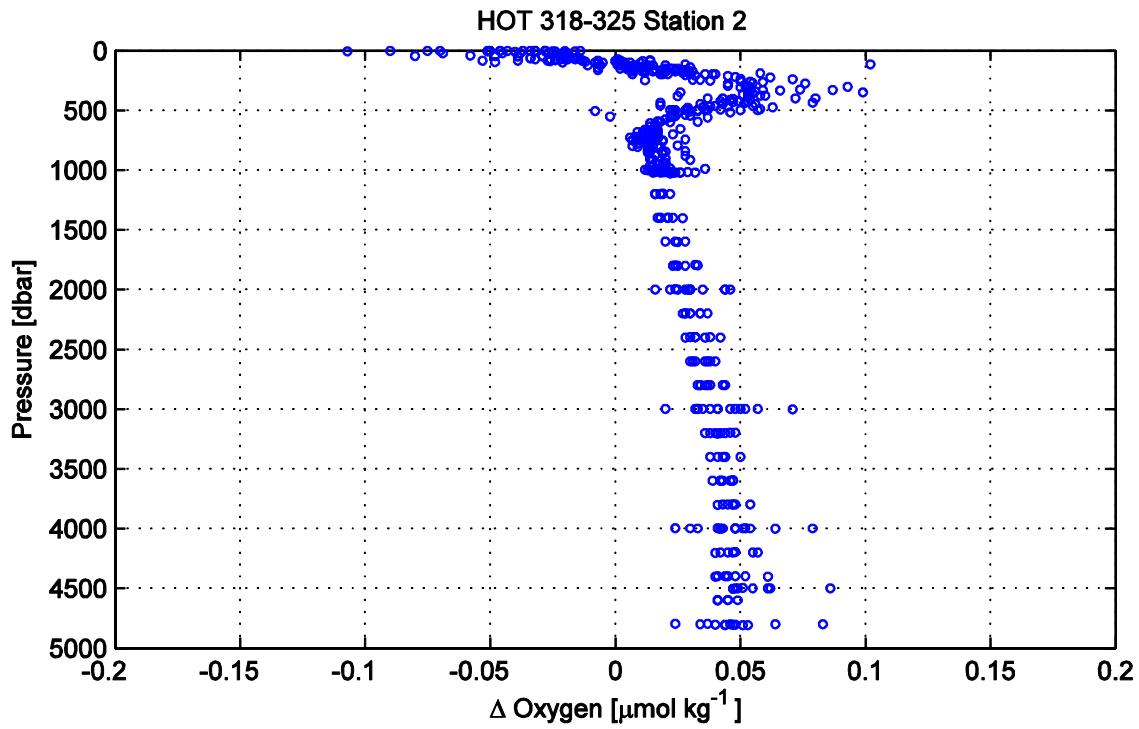
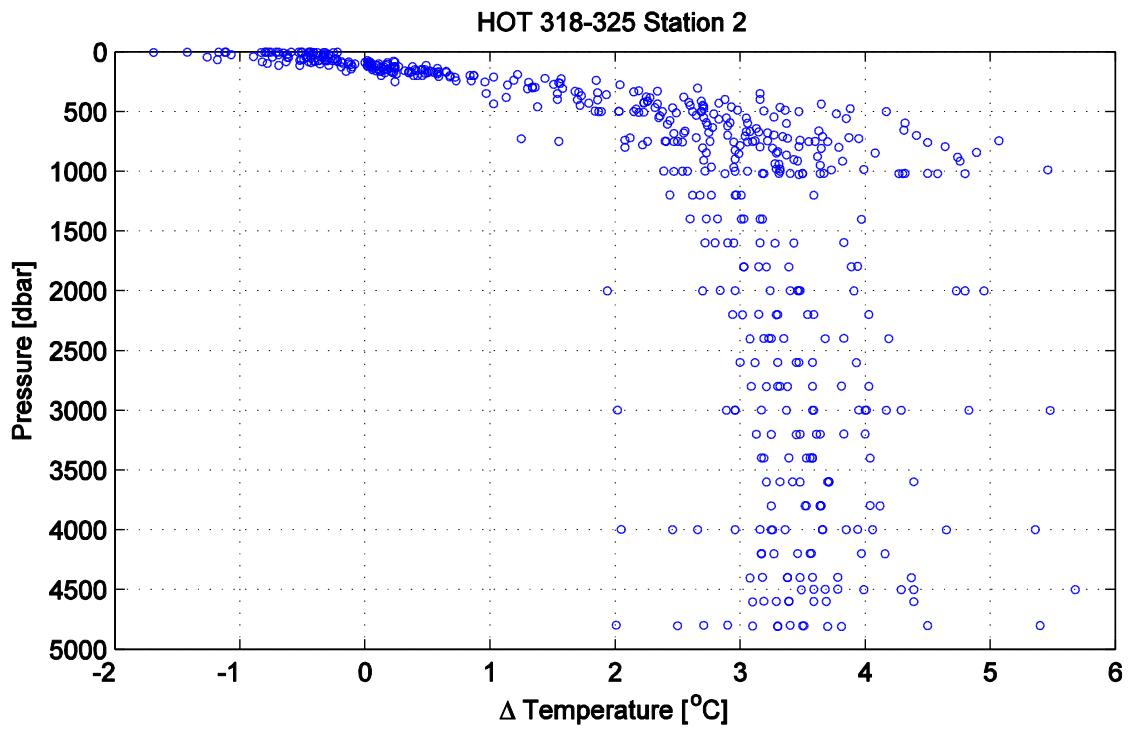


Figure 2.3: [Upper panel] Difference between sample temperature at the time of sample collection and potential temperature calculated from *in situ* temperature at the time of bottle trip. [Lower panel] Difference in oxygen concentration corrected for temperatures measured at the time of sample collection and potential temperature calculated from *in situ* temperature.

Precision of the Winkler titration method is presented in [Table 2.14](#). The pooled annual mean CV of our oxygen analyses in 2020 was 0.23 %, which was calculated by averaging the mean CV of N-triplicate samples on each cruise. Oxygen concentrations measured over the 32 years of the program are plotted at three constant potential density horizons in the deep ocean along with their mean and 95 % confidence intervals ([Figure 2.7](#) [upper panel]). These results indicate that analytical consistency has been maintained over the past 32 years of the HOT program.

Table 2.14: Precision of Winkler titration method during 2020

HOT	Dissolved O ₂		
	Mean CV (%)	Mean SD (μmol/l)	N
318	0.19	0.333	8
319	0.61	0.951	8
320	0.24	0.447	7
321	0.25	0.446	8
322	0.13	0.218	8
323	0.17	0.285	8
324	0.15	0.270	7
325	0.12	0.195	8
Mean	0.23	0.393	8

2.5.2 Dissolved Inorganic Carbon and Total Alkalinity

Samples for dissolved inorganic carbon (DIC) were measured using a Single Operator Multi-parameter Metabolic Analyzer (SOMMA) which was manufactured at the University of Rhode Island and standardized at the Brookhaven National Laboratory. The pooled annual CV of the DIC analyses during 2020 was 0.02 % ([Table 2.15](#)). It was calculated by averaging the mean CV of N-duplicate samples on each cruise. Total alkalinity (TALK) was determined using the modified Gran titration method as described in Tupas *et al.* (1997). The pooled annual CV of the TALK analyses during 2020 was 0.08 % ([Table 2.15](#)).

Table 2.15: Precision of DIC and Total Alkalinity analyses during 2020

HOT	DIC			TALK		
	Mean CV (%)	Mean SD ($\mu\text{mol kg}^{-1}$)	N	Mean CV (%)	Mean SD ($\mu\text{eq kg}^{-1}$)	N
318	0.00	0.033	3	0.10	2.286	3
319	0.02	0.351	3	0.06	1.414	3
320	0.03	0.632	3	0.06	1.367	3
321	0.01	0.279	2	0.08	1.862	3
322	0.02	0.405	3	0.15	3.347	3
323	0.02	0.469	3	0.07	1.591	2
324	0.04	0.926	3	0.04	0.966	3
325	0.02	0.521	3	0.05	1.226	3
Mean	0.02	0.452	8	0.08	1.757	8

The accuracy of DIC and total alkalinity measurements was established with certified reference materials (CRMs) obtained from Andrew Dickson at Scripps Institution of Oceanography. The time-series of measured differences from the CRM are shown in [Figure 2.4](#) and [Figure 2.5](#).

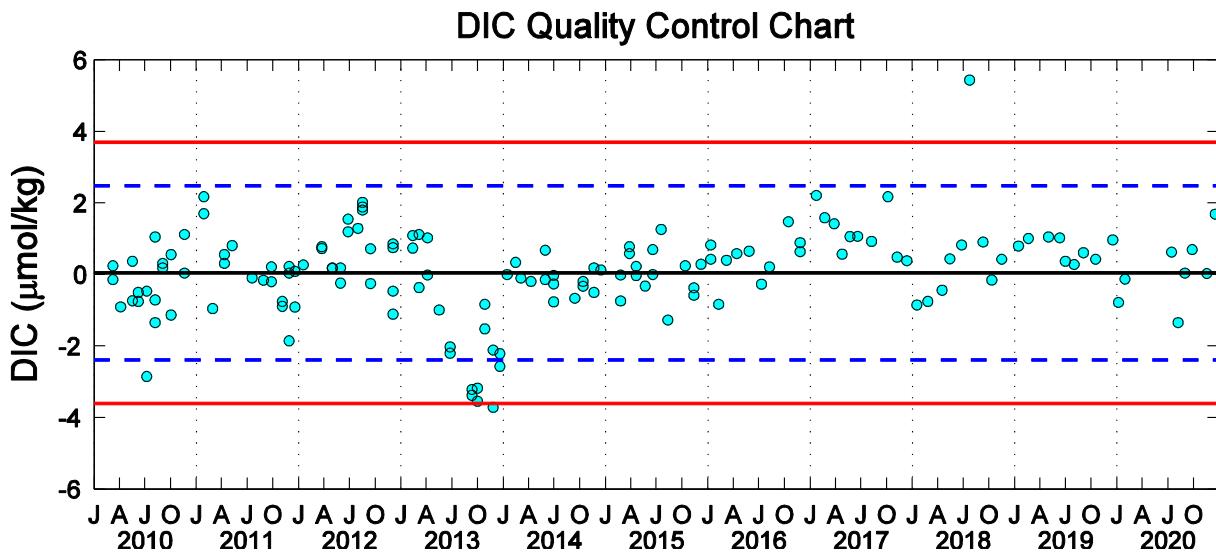


Figure 2.4 : DIC measured difference from certified reference materials (CRMs). The mean (\pm stdev, n=150) was $0.05 \pm 1.22 \mu\text{mol kg}^{-1}$.

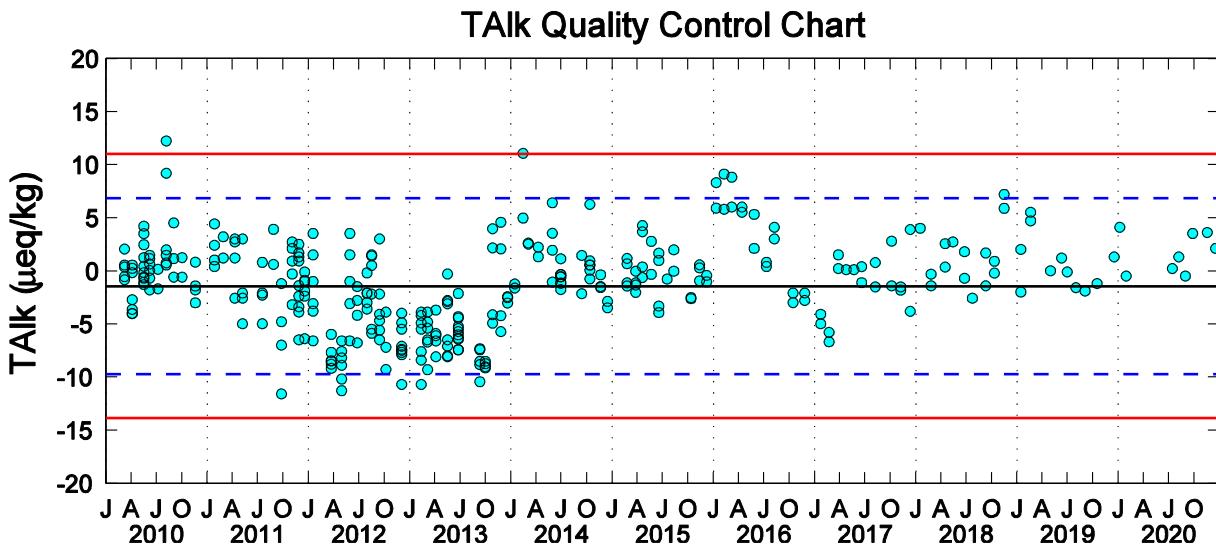


Figure 2.5 : Total alkalinity (TALK) measured difference from certified reference materials (CRMs). The mean (\pm stdev, n=337) was $-1.45 \pm 4.15 \mu\text{eq kg}^{-1}$.

2.5.3 pH

All pH data presently being made available were collected using the spectrophotometric method of Clayton and Byrne (1993) and are reported at a constant temperature of 25°C. The +0.0047 unit correction suggested by DelValls and Dickson (1998) has NOT been applied to any HOT data. The 1992-1993 HOT pH data were originally reported on the Seawater Scale, while later data have all been reported on the Total Scale. For the sake of consistency, the 1992-1993 pH data have as of today been converted to the Total Scale according to Lewis and Wallace (1998). The Total Scale values are approximately 0.01 pH units higher than the Seawater Scale

values they replace. The cruises affected are HOT 36-47 and HOT 49-50. Prior to 1992, on HOT 23-32, pH measurements were made using a pH electrode calibrated with NBS buffers and were reported on the NBS Scale. Potentiometric measurements of pH are inherently less precise than spectrophotometric measurements. Moreover, the relationship between the NBS Scale and the Total Scale is not exact and depends on characteristics of the electrode employed. Given these difficulties, we have not attempted to correct the pre-1992 data to the Total Scale.

The pooled annual CV of the pH analysis during 2020 was 0.026% ([Table 2.16](#)). It was calculated by averaging the mean CV of N-duplicate samples on each cruise. The time-series of measured values at 4500 decibars at Station ALOHA are shown in [Figure 2.6](#).

Table 2.16: Precision of pH analyses during 2020

HOT	pH		
	Mean CV (%)	Mean SD (Total@25°C)	N
318	0.009	0.0007	4
319	0.021	0.0016	4
320	0.028	0.0022	4
321	0.049	0.0039	4
322	0.030	0.0024	3
323	0.024	0.0019	4
324	0.028	0.0022	4
325	0.020	0.0015	4
Mean	0.026	0.0021	8

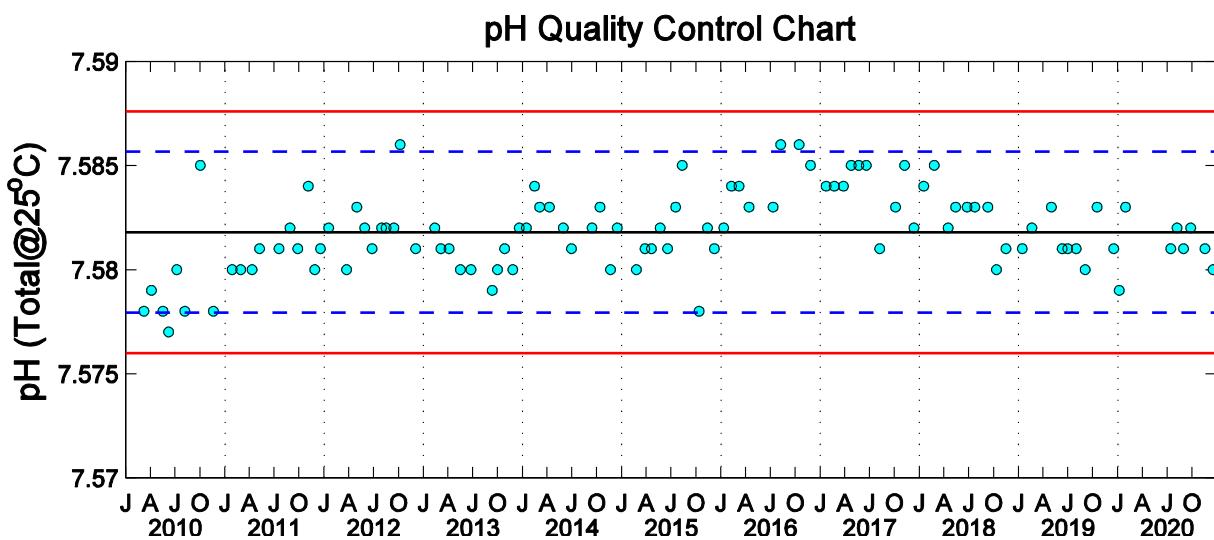


Figure 2.6 : pH measured at 4500 decibars at Station ALOHA. The mean (\pm stdev, n=102) was 7.582 ± 0.002 .

2.5.4 Inorganic Nutrients

2.5.4.1 Standard Autoanalyzer Method

Samples for the determination of dissolved inorganic nutrient concentrations (soluble reactive phosphorus, [nitrate+nitrite] and silicate) were collected as described in Tupas *et al.* (1993). Up until February 2000, analyses were conducted on a four-channel Technicon Autoanalyzer II continuous flow system at the University of Hawaii Analytical Services Facility. Starting March 2000, samples have been run using a six-channel Bran Luebbe Autoanalyzer III. The average precisions during 2020 from duplicate analyses are given in [Table 2.17](#). [Figures 2.7-2.8](#) show the mean and 95% confidence limits of nutrient concentrations measured at three potential density horizons for the 32 years of the program. In addition to standard automated nutrient analyses, specialized methods (described below) are used to determine concentrations of nutrients that are normally below the detection limits of autoanalyzer methods.

Table 2.17: Precision of Dissolved inorganic nutrient analyses during 2020

HOT	Phosphorus			[Nitrate + Nitrite]			Silicate		
	Mean CV (%)	Mean SD (μ M)	N	Mean CV (%)	Mean SD (μ M)	N	Mean CV (%)	Mean SD (μ M)	N
318	0.16	0.004	6	0.41	0.053	7	0.54	0.586	4
319	0.13	0.003	6	0.32	0.040	7	2.17	0.729	7
320	0.12	0.002	7	1.39	0.140	6	0.90	1.062	7
321	0.17	0.005	6	0.50	0.168	7	0.47	0.283	7
322	0.11	0.003	6	0.37	0.060	7	1.23	0.280	7
323	0.09	0.002	6	0.15	0.051	6	0.96	1.011	6
324	0.09	0.003	5	0.33	0.040	7	0.80	0.950	3
325	0.16	0.004	6	0.12	0.040	7	0.51	0.392	5
Mean	0.13	0.003	8	0.45	0.074	8	0.95	0.662	8

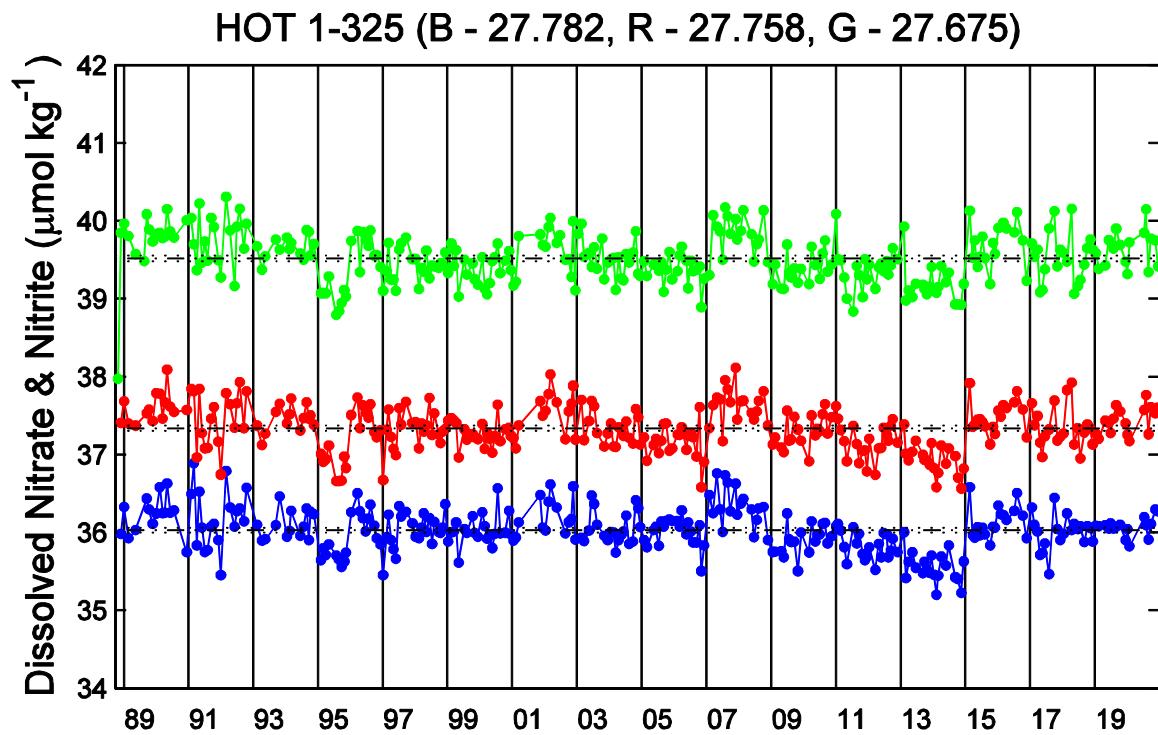
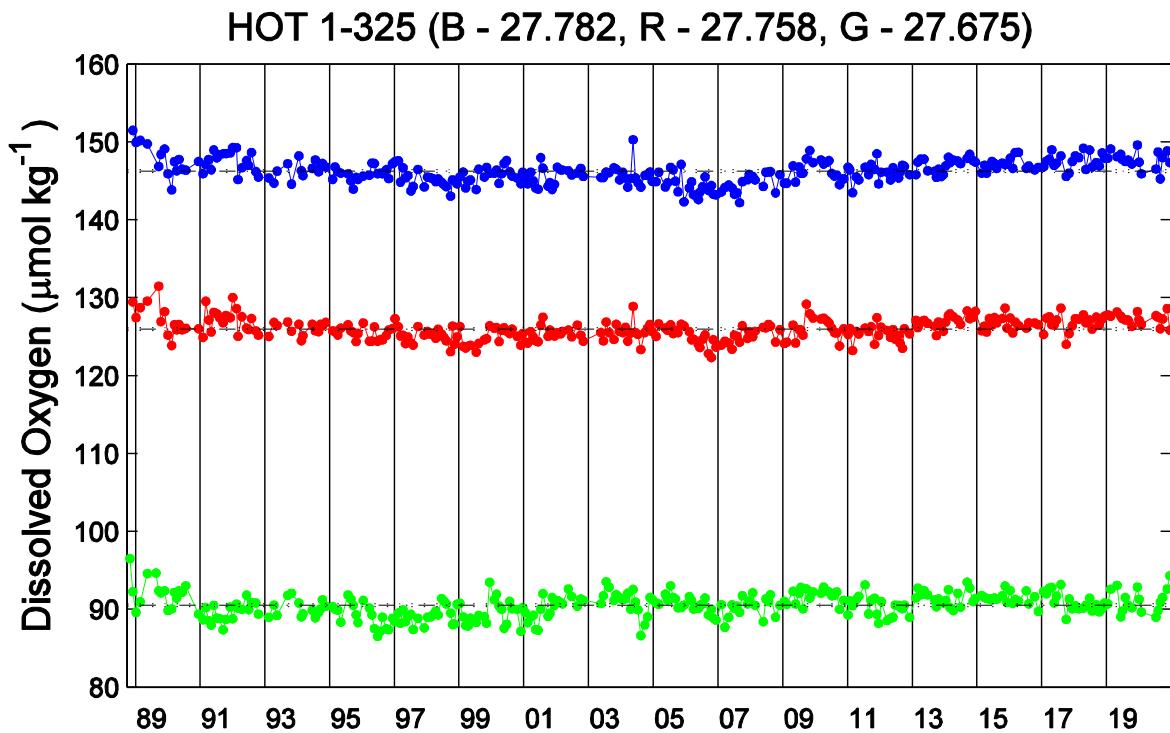


Figure 2.7: Concentrations at potential density horizons of 27.782, 27.758 and 27.675 (approx. 4000m, 3000m and 2000m) at Station ALOHA. The dashed lines indicate the mean while the dotted lines show the upper and lower confidence limits. [Upper panel] Dissolved oxygen. [Lower panel] nitrate + nitrite.

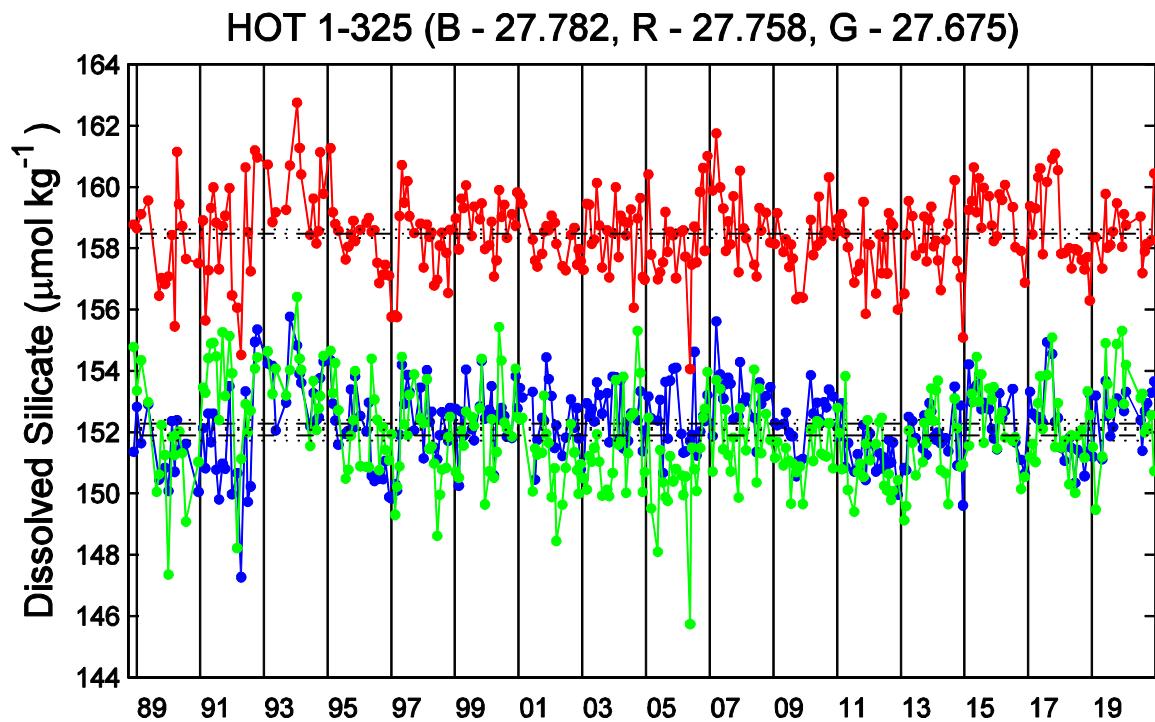
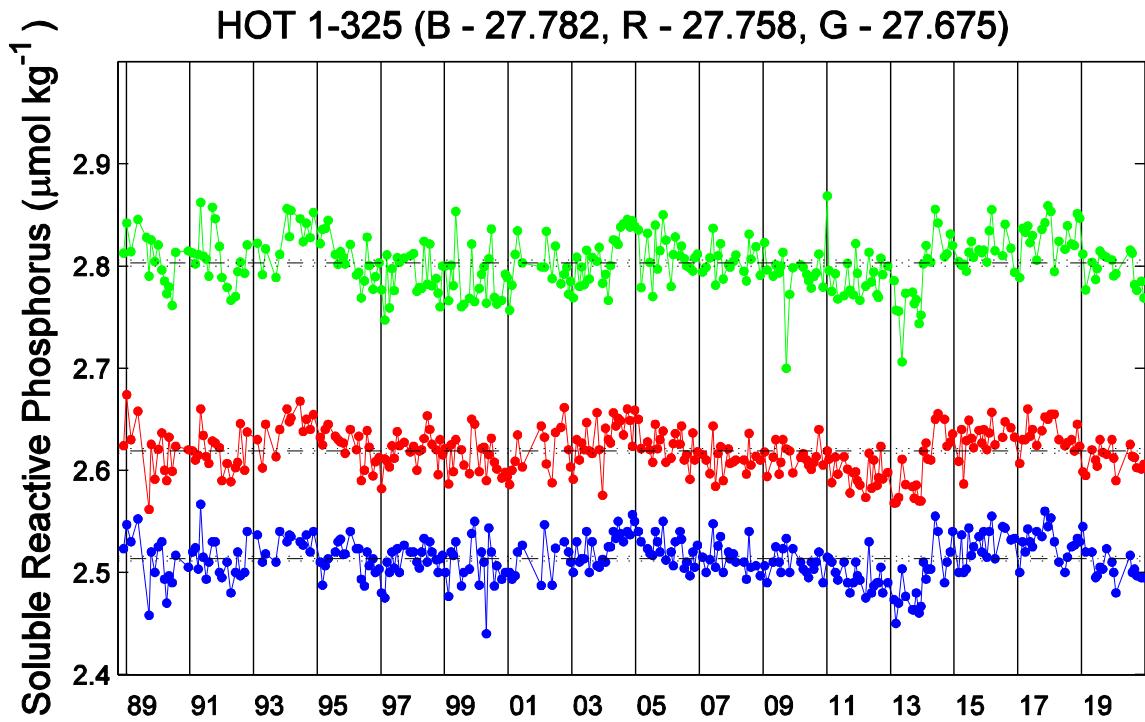


Figure 2.8: Concentrations at potential density horizons of 27.782, 27.758 and 27.675 (approx. 4000m, 3000m and 2000m) at Station ALOHA. [Upper panel] Soluble reactive phosphorus. [Lower panel] Dissolved Silicate.

Calibration, Data Reduction and Calculations

The calibration of dissolved inorganic nutrient determinations in the auto-analysis of seawater samples is performed using standard solutions containing dissolved N, P and Si salts. A nutrient stock solution is prepared by dissolving dried (50°C, 48 hr) analytical grade reagent chemicals with DIW in 1 L glass volumetric flasks containing 1 ml of chloroform. Once dissolved, this stock solution is immediately transferred into 1 L HDPE bottles and stored at room temperature in the dark. The reagent chemicals and concentrations are: KH₂PO₄ (1 mM), KNO₃ (1 mM) and Na₂SiF₆ (1 mM).

Working standards are prepared daily in PMP volumetric flasks using gravimetric dilutions of the nutrient stocks in LNSW. The PMP flasks are thoroughly rinsed with DIW after use. The LNSW is 0.2 µm filtered open ocean surface seawater from Station ALOHA that is kept in the dark at room temperature for at least six months prior to use. This technique provides a mixed standard solution of N, P and Si that is matrix-matched with the seawater samples and any cross-nutrient interference effect should also be accounted for.

Blank corrections

All seawater standard absorbance peaks are corrected for the absorbance of the seawater diluent (LNSW). All seawater sample peaks are corrected for the refractive index absorbance for each unique nutrient detection system. The refractive index corrections represent the increase in absorbance that is due strictly to the presence of dissolved salts in seawater when compared to the DIW baseline. These corrections are determined by running alternating seawater (LNSW) and DIW cups through the auto-analyzer with only non-color producing reagents online. DIW is run through the color producing reagent lines.

Quality Control

Wako CSK's and OSIL Nutrient Standards are measured in each channel as reference materials to validate sample measurements. The Wako CSK's are manufactured in 30.5 ‰ NaCl and are measured directly. The OSIL nutrient standards are manufactured in DIW and diluted using LNSW to the same concentration as the Wako CSK for direct comparison (40 µM for NO₃, 2 µM for PO₄, and 100 µM for Si). Due to the high price of the Wako CSK's, they are run only once per sample run. The OSIL check standards are run twice, once at the beginning and again at the end of each sample run.

Both the Wako and OSIL standards are used as checks of not only the sample analysis, but as checks of each other. Measured reference material values that are more than 2% from the expected concentration of the reference solutions are scrutinized and cross checked with the other reference material to determine if the analysis is correct. In most cases, both reference materials are within the accepted limits.

WAKO/KANSO SRP Quality Control Chart

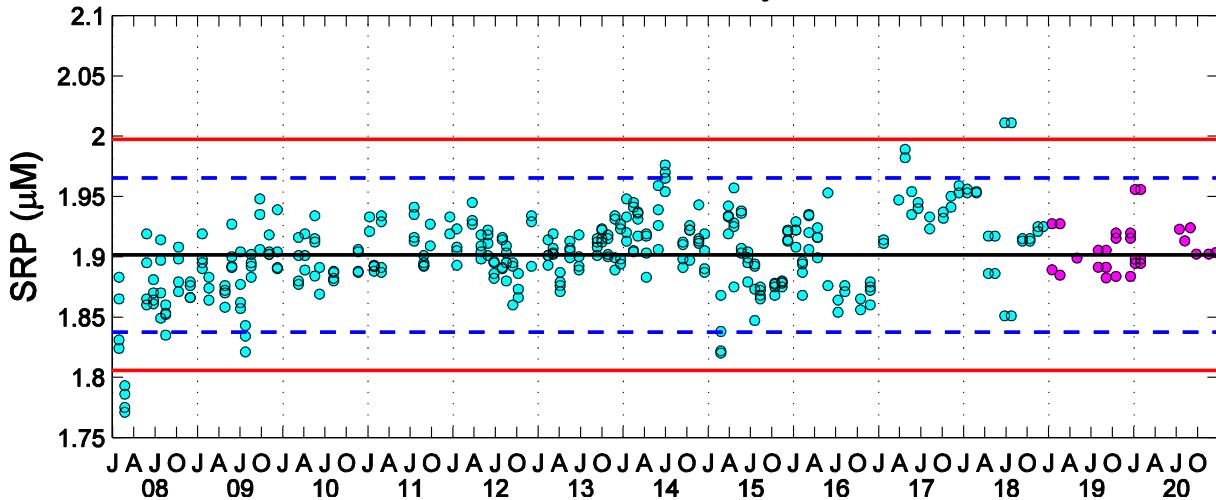


Figure 2.9 : Wako - 2.0 μM in NaCl, measured directly. Literature shows value of CSK can be up to ~7% low return, so concentration ~1.9 is acceptable. Starting 2019, we switched to using KANSO CRMs (plotted in magenta). The KANSO CRMs have a different concentration from the WAKO CRMs. So we normalized it using the formula: $\text{SRP}_{\text{WAKO}} = \text{SRP}_{\text{KANSO}} * (1.90/1.74)$ in order to plot them both on the same graph. The mean (\pm stdev, n=367) was $1.902 \pm 0.032 \mu\text{M}$.

OSIL SRP Quality Control Chart

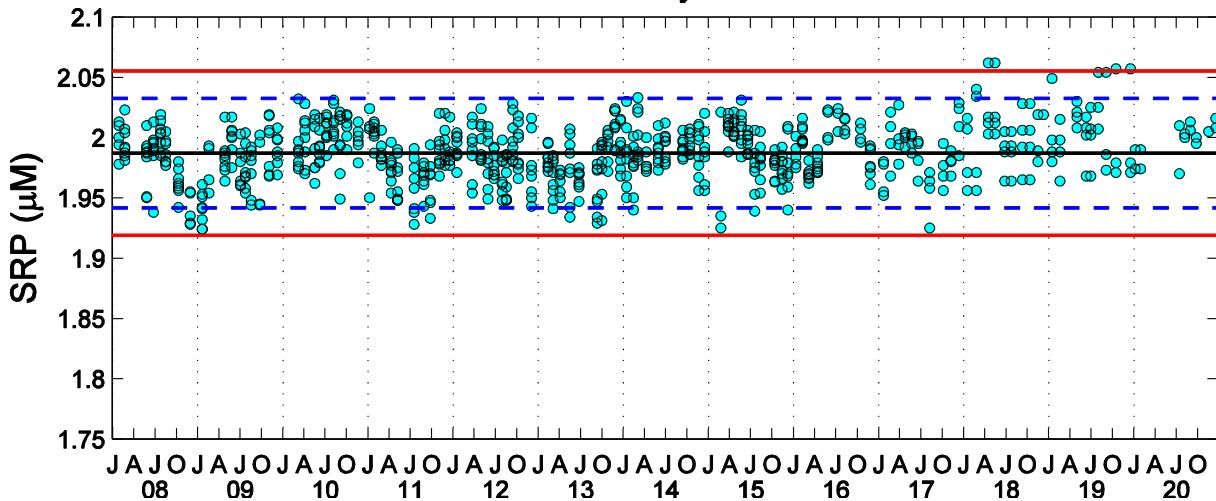


Figure 2.10 : OSIL - 100 μM stock in DIW, diluted in LNSW to be 2 μM . The mean (\pm stdev, n=773) was $1.987 \pm 0.023 \mu\text{M}$.

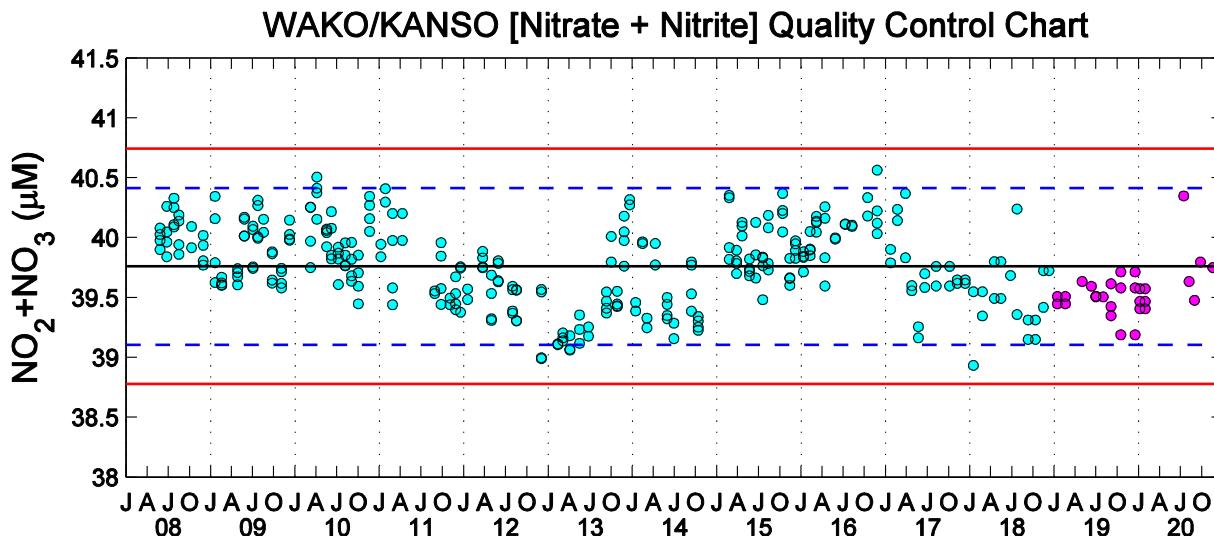


Figure 2.11 : Wako - 40.0 μM in NaCl, measured directly. Starting 2019, we switched to using KANSO CRMs (plotted in magenta). The KANSO CRMs have a different concentration from the WAKO CRMs. So we normalized it using the formula: $[\text{N+N}]_{\text{WAKO}} = [\text{N+N}]_{\text{KANSO}} * (39.78/24.33)$ in order to plot them both on the same graph. The mean ($\pm \text{stdev}$, $n=336$) was $39.760 \pm 0.328 \text{ } \mu\text{M}$.

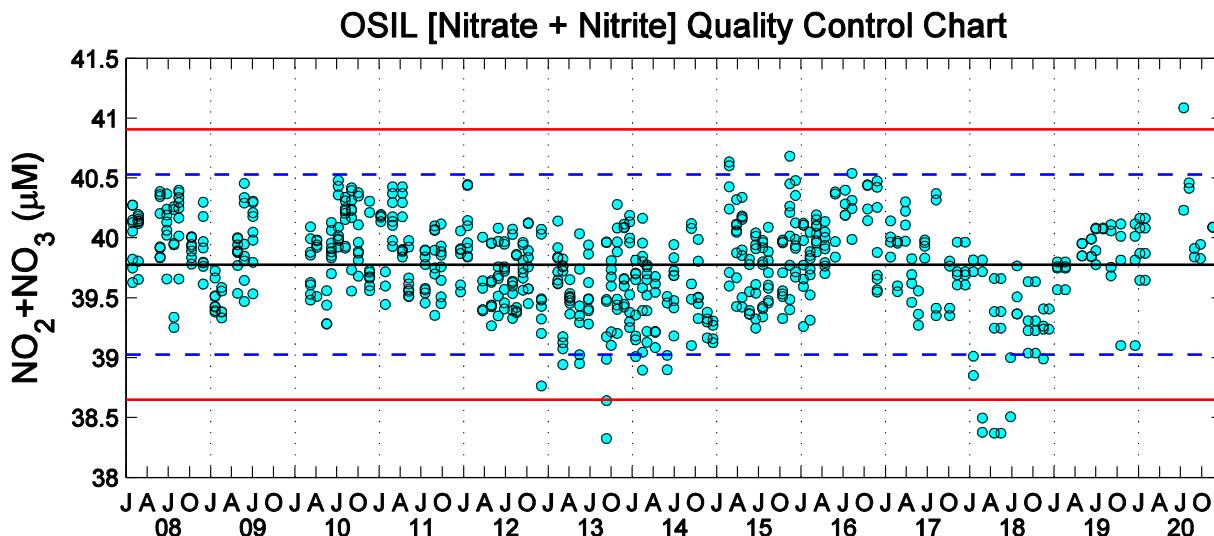


Figure 2.12 : OSIL - 1000 μM stock in DIW, diluted in LNSW to be 40 μM . The mean ($\pm \text{stdev}$, $n=697$) was $39.776 \pm 0.376 \text{ } \mu\text{M}$.

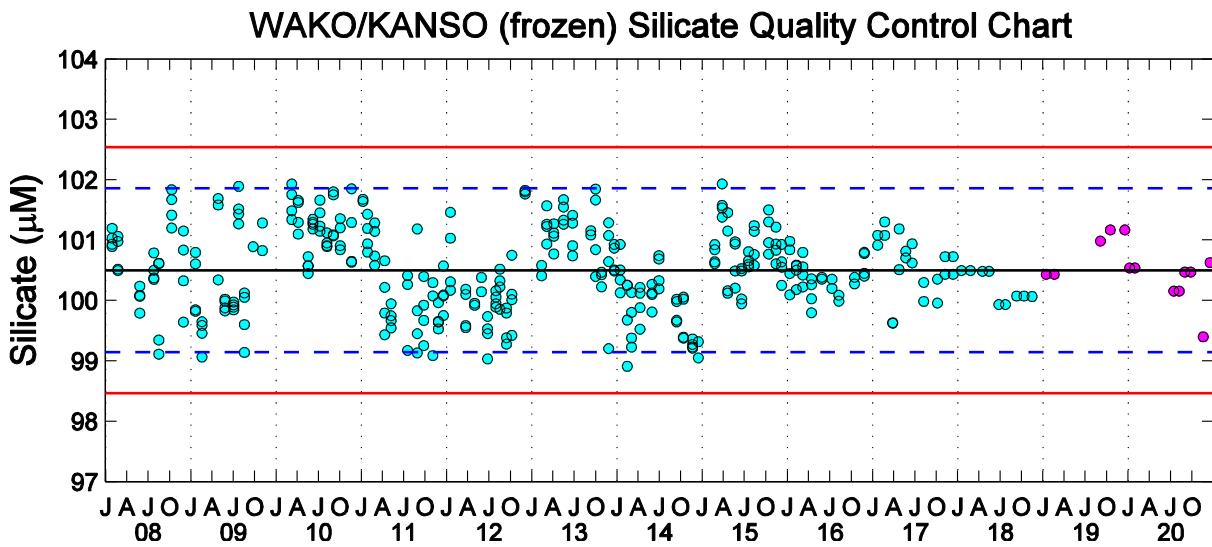


Figure 2.13 : Wako - 100.0 μM in NaCl, measured directly. Starting 2019, we switched to using KANSO CRMs (plotted in magenta). The KANSO CRMs have a different concentration from the WAKO CRMs. So we normalized it using the formula: $\text{Sil}_{\text{WAKO}} = \text{Sil}_{\text{KANSO}} * (100.50/57.75)$ in order to plot them both on the same graph. The mean (\pm stdev, n=353) was $100.497 \pm 0.679 \mu\text{M}$.

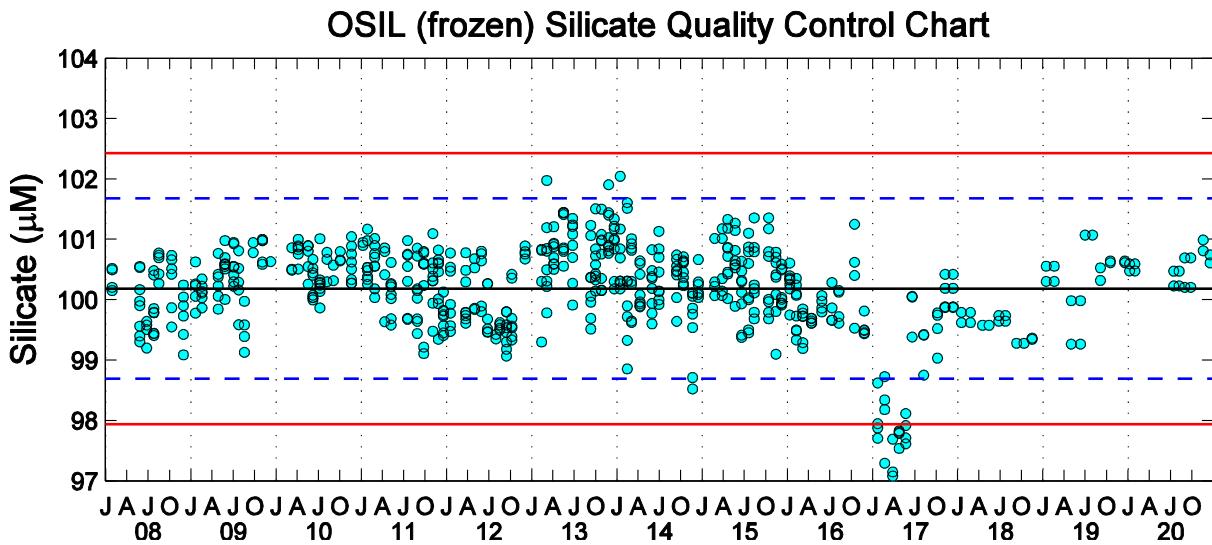


Figure 2.14 : OSIL - 1000 μM stock in DIW, diluted in LNSW to be 100 μM . The mean (\pm stdev, n=636) was $100.182 \pm 0.747 \mu\text{M}$.

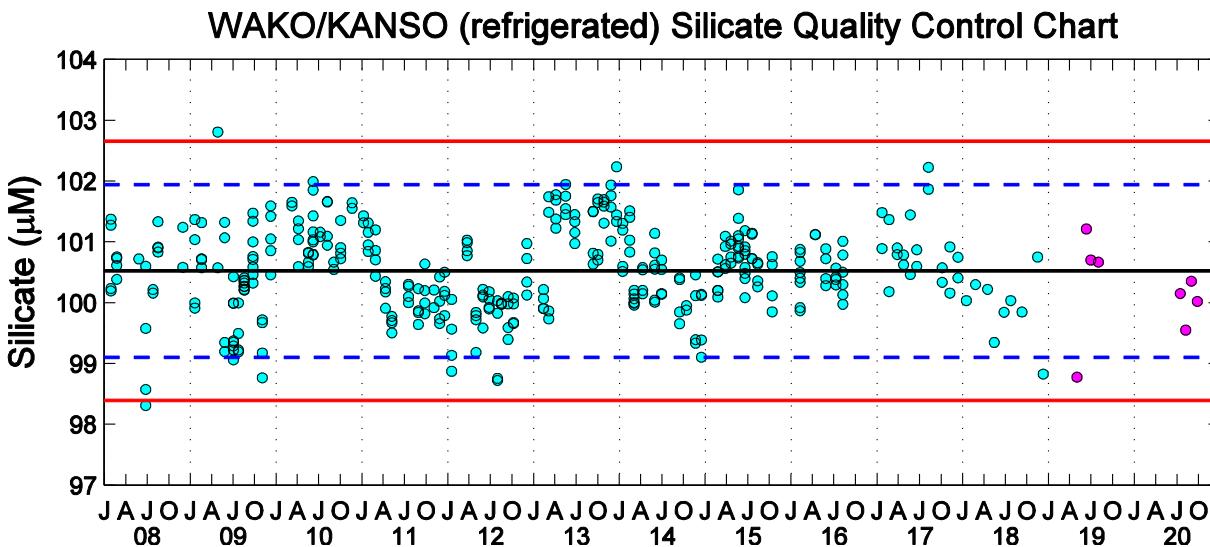


Figure 2.15 : Wako - 100.0 μM in NaCl, measured directly. Starting 2019, we switched to using KANSO CRMs (plotted in magenta). The KANSO CRMs have a different concentration from the WAKO CRMs. So we normalized it using the formula: $\text{Sil}_{\text{WAKO}} = \text{Sil}_{\text{KANSO}} * (100.53/57.75)$ in order to plot them both on the same graph. The mean (\pm stdev, n=370) was $100.524 \pm 0.711 \mu\text{M}$.

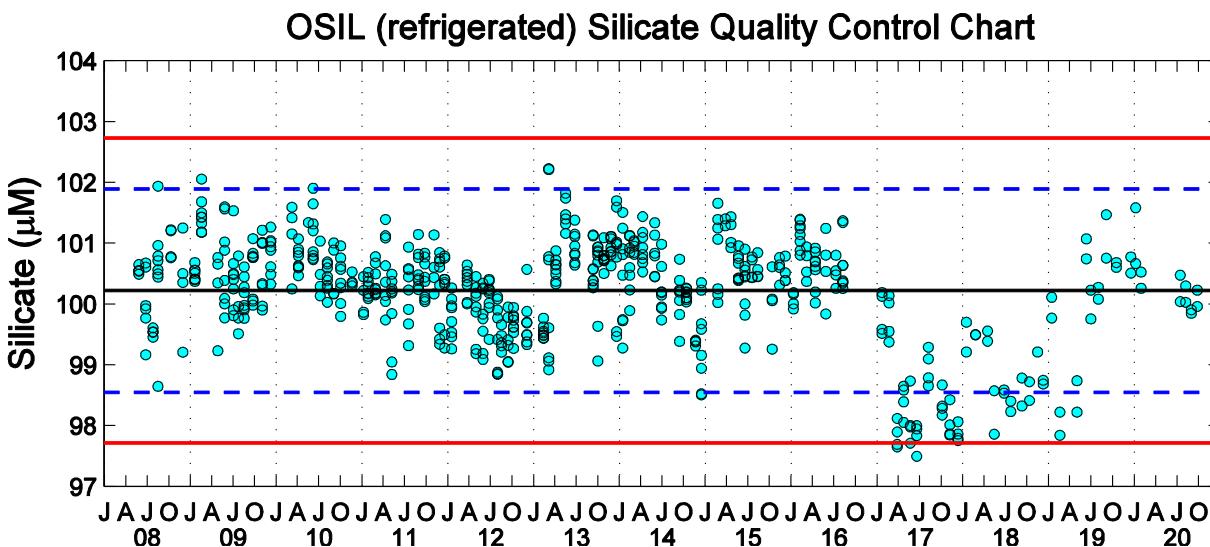


Figure 2.16 : OSIL - 1000 μM stock in DIW, diluted in LNSW to be 100 μM . The mean (\pm stdev, n=634) was $100.223 \pm 0.836 \mu\text{M}$.

Special Cases

In the case of SRP, literature shows that the Wako CSK returns lower than the expected concentration (~7%), therefore a measured value of 1.9 μM for a 2 μM CSK is considered acceptable, and a higher than 2% difference from the expected 2 μM concentration is accepted. The use of a PO₄ OSIL reference was introduced to have a reference material that produced a more reliable 2 μM concentration result.

In the case of NO₃, the addition of a check standard containing only NO₂ is also analyzed to check the cadmium column efficiency. If the CV of the NO₂ check standard is more than 2% from the expected 40 μM value, the run is aborted and the cadmium column chips are regenerated.

2.5.4.2 Low-Level [Nitrate+Nitrite]

The chemiluminescent method of Cox (1980) as modified for seawater by Garside (1982) was used to determine the [nitrate+nitrite] content of near surface (0-200 m interval) water samples. The limit of detection for [nitrate+nitrite] was approximately 2 nM with a precision and accuracy of ± 1 nM (Dore *et al.*, 1996).

Time-series of our LLN check standards are shown in [Figures 2.17-2.19](#). If check standards fall outside their respective control limits the standard curve will be remade until check standards are within their limits.

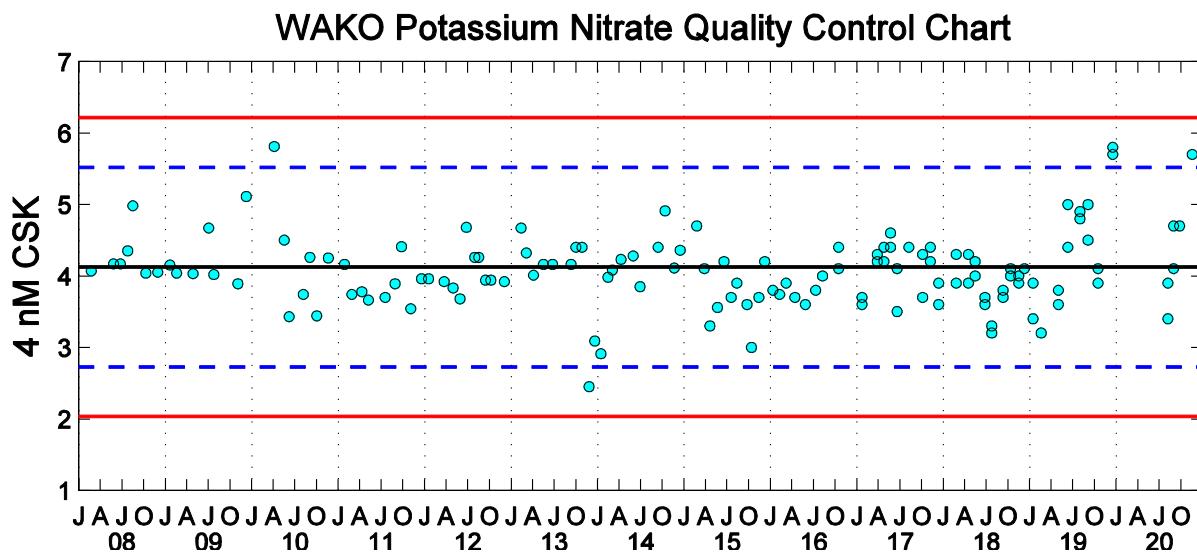


Figure 2.17 : The mean (\pm stdev, n=140) was $4.13 \pm 0.70 \text{ nmol L}^{-1}$.

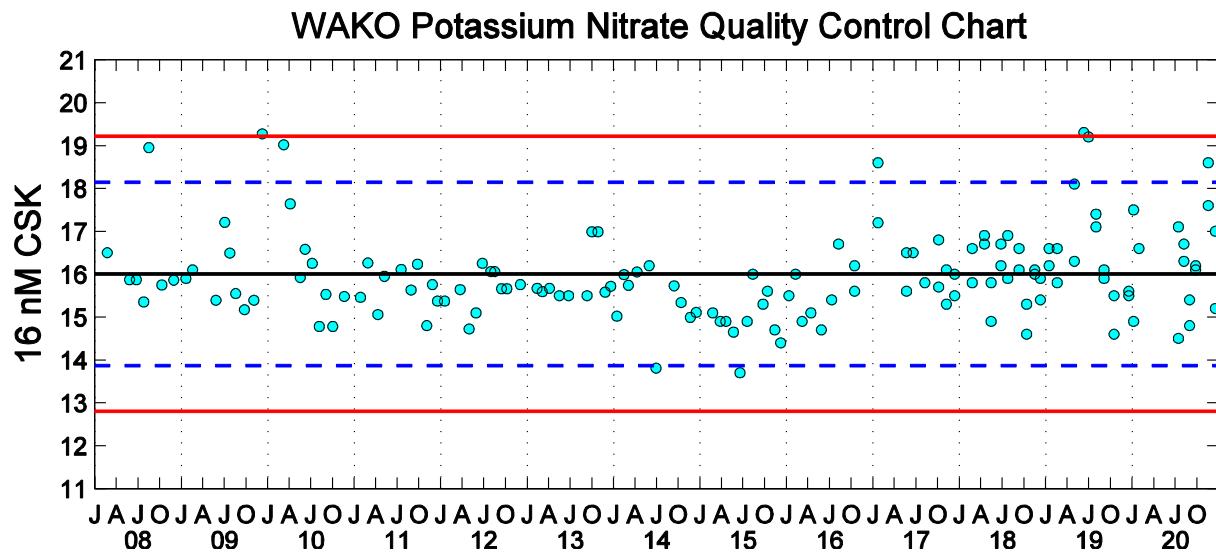


Figure 2.18 : The mean (\pm stdev, $n=151$) was $16.01 \pm 1.07 \text{ nmol L}^{-1}$.

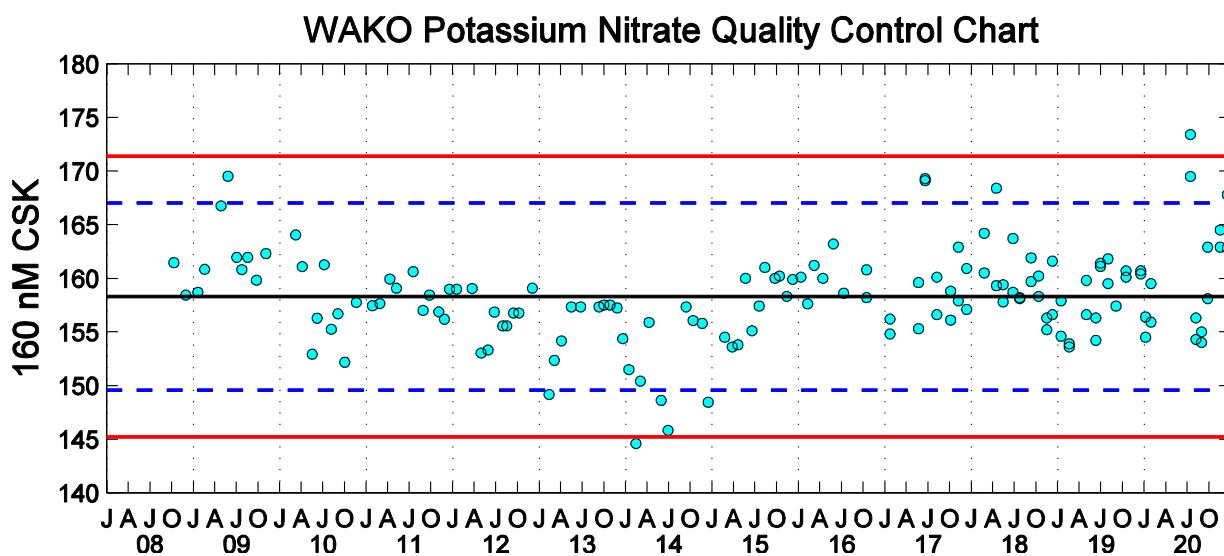


Figure 2.19 : The mean (\pm stdev, $n=144$) was $158.33 \pm 4.36 \text{ nmol L}^{-1}$.

2.5.4.3 Low-Level Soluble Reactive Phosphorus

Low level soluble reactive phosphorus (SRP) concentrations in the euphotic zone were determined according to the magnesium induced coprecipitation (MAGIC) method of Karl and Tien (1992). Typical precision estimates for triplicate determinations of SRP are from 1-3 % with a detection limit of 2 nM. The MAGIC SRP measurement is also corrected for arsenate interference of the molybdenum blue colorimetric procedure (Johnson 1971), unlike the standard autoanalytical method.

Check standards are made by diluting a CSK std (OSIL at 100 μ M-PO₄) to target concentrations of 50 nM and 100 nM PO₄ respectively in SSW. The dilutions are made gravimetrically on a Mettler 0-160 g balance by pipetting the OSIL (~ 25 μ l and 50 μ l), record the weight and adding 50 ml of SSW. These are then treated as regular MAGIC samples. [Figure 2.20](#) shows the difference from the expected concentration and that calculated from the absorbance at 880 nm and the standard curve created for each run. Samples to create the standard curve are also made gravimetrically in SSW, but by using an in-house made stock at 100 μ M-PO₄.

Potential sources of error are: 1) balance stability 2) variable volume of SSW that contains some PO₄ and 3) spectrophotometer stability.

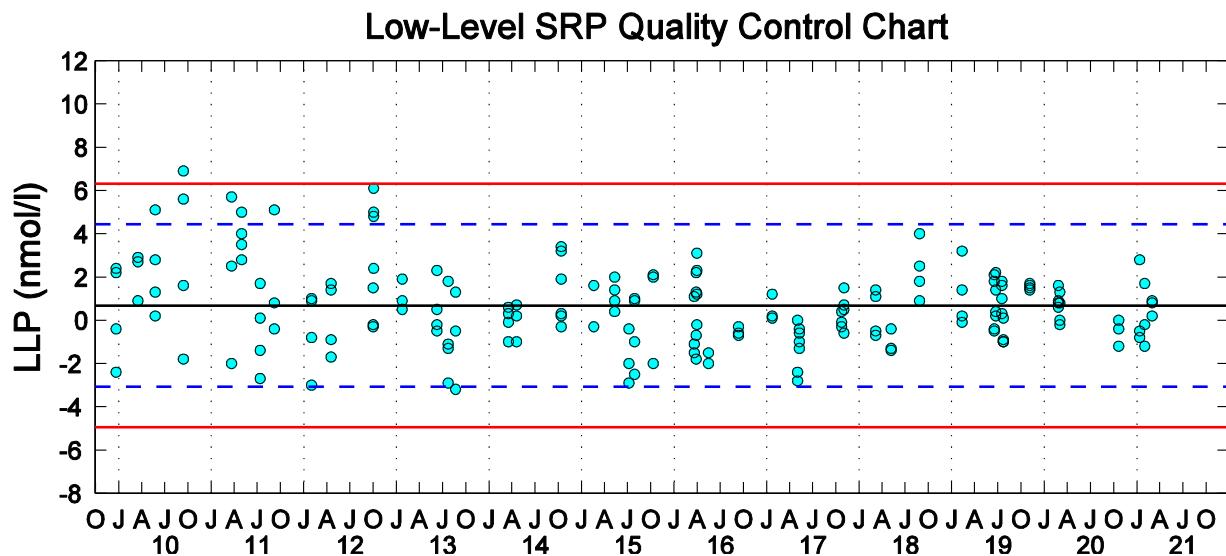


Figure 2.20 : Difference from expected concentration and that calculated from the absorbance at 880 nm. The mean (\pm stdev, n=180) was $0.68 \pm 1.88 \text{ nmol L}^{-1}$.

2.5.5 Total Organic Carbon

Total organic carbon (TOC) was determined by the high temperature catalytic oxidation method using a Shimadzu TOC-V CSH Total Organic Carbon Analyzer. Prior to HOT-125 (March 2001) TOC concentrations had been measured on a commercially available MQ model 1001 TOC analyzer equipped with a LICOR infrared detector. The average precisions during 2017 from duplicate TOC analyses are given in [Table 2.18](#).

Table 2.18: Precision of Total Organic Carbon analyses of replicate samples during 2017

HOT	TOC		
	Mean CV (%)	Mean SD (μM)	N
289	0.9	0.316	4
290	2.4	0.876	4
291	1.5	0.569	4
292	1.8	0.684	4
293	1.9	0.729	4
294	1.9	0.683	3
295	1.9	0.775	5
Mean	1.8	0.662	7

Beginning in 1997, certified TOC reference materials were obtained from J. Sharp (University of Delaware) and D. Hansell (RSMAS, University of Miami) and run each time TOC concentrations were analyzed. UV-oxidized distilled water was used to determine the instrument blank. [Figure 2.21](#) shows the time-series of deep seawater reference material (DSRM) obtained from RSMAS used to validate sample measurements. If a value is outside control limits, the run is deemed questionable, and the samples are rerun.

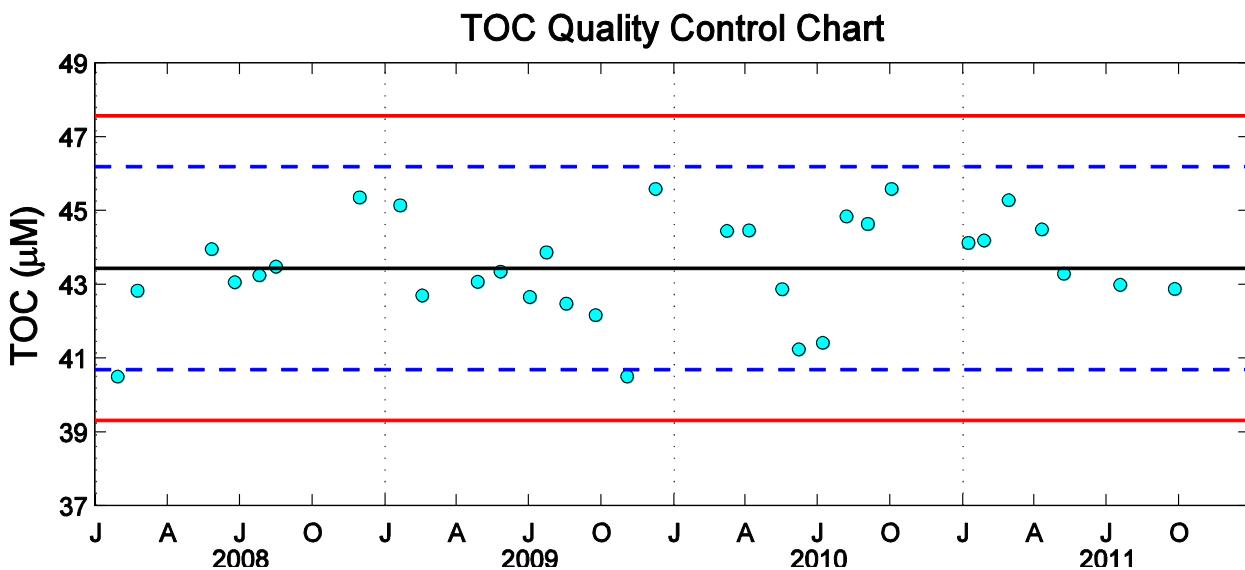


Figure 2.21 : Values were obtained from DSRM from the RSMAS Consensus Reference Materials (CRM) Project. The accepted range of the DSRM is 41-44 μM . The DSRM is used to verify the standard dilution curve used to calibrate each sample run. The mean (\pm stdev, n=32) was $43.45 \pm 1.38 \mu\text{M}$.

2.5.6 Particulate Bioelements

2.5.6.1 Particulate Carbon and Nitrogen

Samples for elemental analyses of Particulate carbon (PC) and nitrogen (PN) were prefiltered through 202 μm Nitex mesh to remove large zooplankton and collected onto combusted glass fiber filters (Whatman GF/F, 25 mm diameter). They were analyzed using an Exeter Analytical CE-440 CHN elemental analyzer. This instrument combines the classical Pregal and Dumas methods for the determination of PC and PN, respectively. The samples are combusted in pure O₂ under static conditions and the by-products are measured by a series of high precision thermal conductivity detectors each containing a pair of thermal conductivity cells (P.E.Hemming, Exeter Analytical (UK) Ltd). During the course of the analytical run a maximum of 8 samples are analyzed followed by a blank, check standard (acetanilide) and secondary standard (plankton).

The average field variability between duplicate analyses during 2020 are presented in [Table 2.19](#). [Figure 2.22a](#) shows the time-series of the acetanilide check standard and [Figure 2.22b](#) shows the time-series of our in-house plankton secondary standard. Two batches of plankton standards have been used during the course of the time-series. The old batch was used from HOT 166-264 (Sep 2005 - Aug 2014). While the new batch was used starting from HOT-249 (Mar 2014). The old plankton standard is shown in cyan, while the new standard is plotted in magenta. Should the PC/PN ratio of the plankton fall outside the control limits the analytical run is terminated.

Table 2.19: Field variability of Particulate carbon and nitrogen analyses during 2020

HOT	PC			PN		
	Mean CV (%)	Mean SD ($\mu\text{g l}^{-1}$)	N	Mean CV (%)	Mean SD ($\mu\text{g l}^{-1}$)	N
319	3.8	0.470	2	3.2	0.105	2
320	3.8	0.785	2	2.7	0.105	2
321	2.4	0.743	2	2.5	0.104	2
322	4.1	0.930	2	3.5	0.154	2
323	4.8	1.047	2	3.9	0.151	2
324	8.2	1.160	2	4.1	0.094	2
325	3.9	0.460	2	2.3	0.070	2
Mean	4.4	0.799	7	3.2	0.112	7

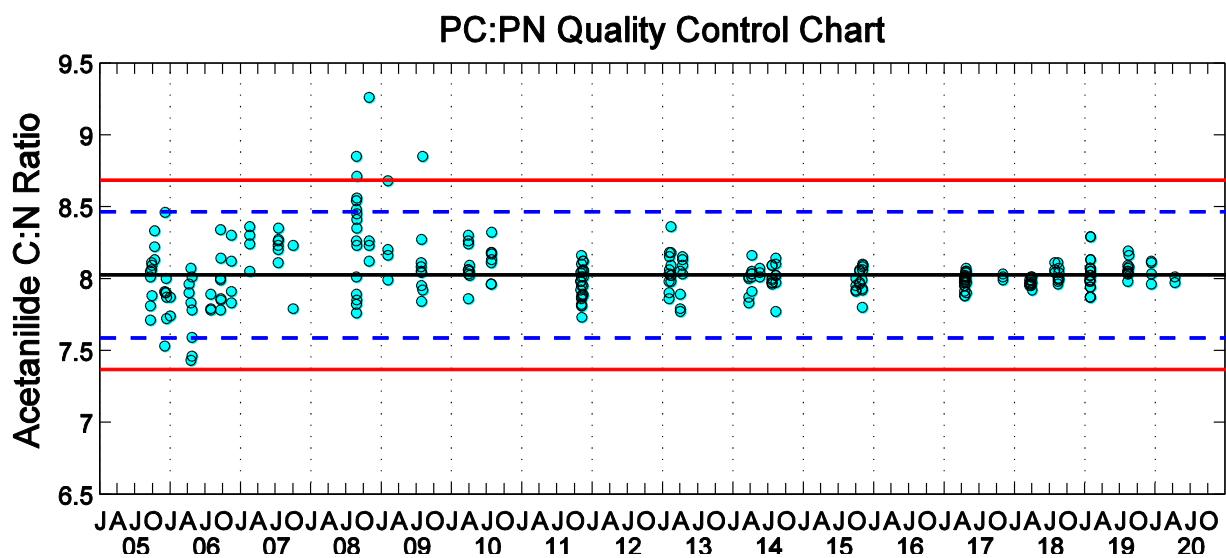


Figure 2.22a : PC/PN ratios obtained using acetanilide check standard. The mean (\pm stdev, n=289) was 8.03 ± 0.22 .

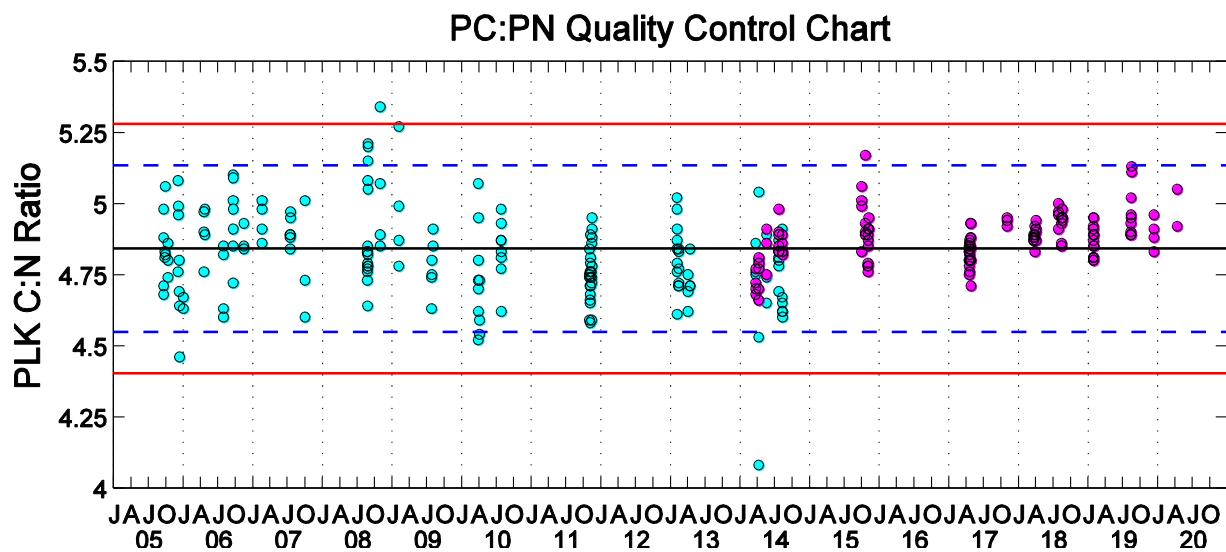


Figure 2.22b : PC/PN ratios obtained using an in-house plankton secondary standard. The secondary standard is used to verify the independently made standard curve used in each analytical run. The mean (\pm stdev, $n=298$) was 4.84 ± 0.15 . Two batches of plankton standards have been used during the course of the time-series. The 1st batch is shown in cyan. While the 2nd is plotted in magenta.

2.5.6.2 Particulate Phosphorus

Samples for elemental analyses of Particulate phosphorus (PPO_4) were prefiltered through 202 μm Nitex mesh to remove large zooplankton and collected onto combusted, acid washed glass fiber filters (Whatman GF/F, 25 mm diameter). Samples were analyzed using high temperature ashing followed by acid hydrolysis and subsequent determination of the liberated orthophosphate by colorimetry. These procedures are detailed in Karl *et al.* (1991). The average field variability between duplicate analyses during 2020 are presented in [Table 2.20](#).

Table 2.20: Field variability of Particulate phosphorus analyses during 2020

HOT	PPO ₄		
	Mean CV (%)	Mean SD ($\mu\text{g l}^{-1}$)	N
318	11.0	0.025	2
319	4.4	0.018	2
321	7.3	0.035	2
322	19.3	0.081	2
323	7.2	0.035	2
324	4.4	0.014	2
325	11.2	0.039	2
Mean	9.3	0.035	7

Apple leaves (0.159% P by weight; NIST 1515) were used as a check standard for the recovery of particulate organic phosphorus (PPO₄). A known amount of the std material was placed on a GF/F filter and treated as a sample. [Figure 2.23](#) shows the recovery of PPO₄ as reported as the percent of the expected amount of phosphorus in the sample. It is known that 5-10% of the DOP is not recovered from apple leaves during acid hydrolysis which could account for the difference in recovery.

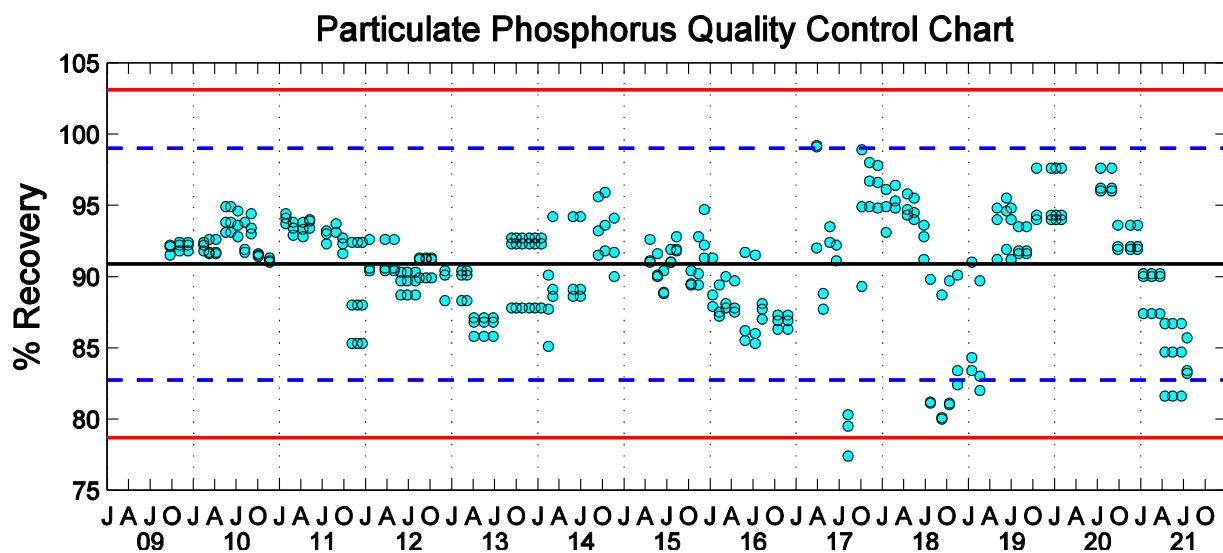


Figure 2.23 : Recovery of PPO₄ as a percentage of the expected amount. The mean (\pm stdev, n=252) was 90.90 ± 4.07 .

Analysis Comparison and Protocol Modification

The routine HOT protocol, in use for at least the past decade, involves combustion of particulate material collected on a GF/F filter placed inside an acid cleaned, combusted glass test tube (4 hours at 500°C). Following combustion, 10 ml of 0.15 N HCl is added and the sample centrifuged for 30 min at 1000 xg. A 5 ml aliquot, sampled from the bottom of the tube, is removed and placed into a clean polyethylene tube. The color forming reagent mixture is added (500 µl reagent mix to 5 ml sample) and the sample mixed by vortex and allowed to develop for 1 hour at RT. The sample absorbance is then read at 880 nm in a 1 cm cuvette cell on a Beckman DU-640 spectrophotometer.

In 2011, it was found that the remaining 5 ml volume in the glass tube yielded 2-3x higher concentrations than the first aliquot. A series of tests were conducted, including; increasing the leaching time of the filters in acid from 30 to 60 min, leaching at +60°C for 60 min, and vortex mixing the tube containing the filter and 10 ml 0.15N HCl prior to leaching for 60 min.

The conclusion was that the routine HOT protocol was underestimating the PPO₄ concentration of the sample, and that this most likely was due to either insufficient time to leach P off the filter matrix, or the sample heterogeneous. Heating the sample did not result in additional PPO₄ measured compared to a longer leach time and mixing ([Figure 2.24a](#)).

In order to assess leach time alone (treatment 1) versus vortex mixing + leach time (treatment 2), a time course sub-sampling was conducted. Samples consisted of PPO₄ collected on GF/F filters from 25 m at Station ALOHA, apple leaves (NIST 1515), and blank filters. The apple leaves were expected to return 51 nM-P.

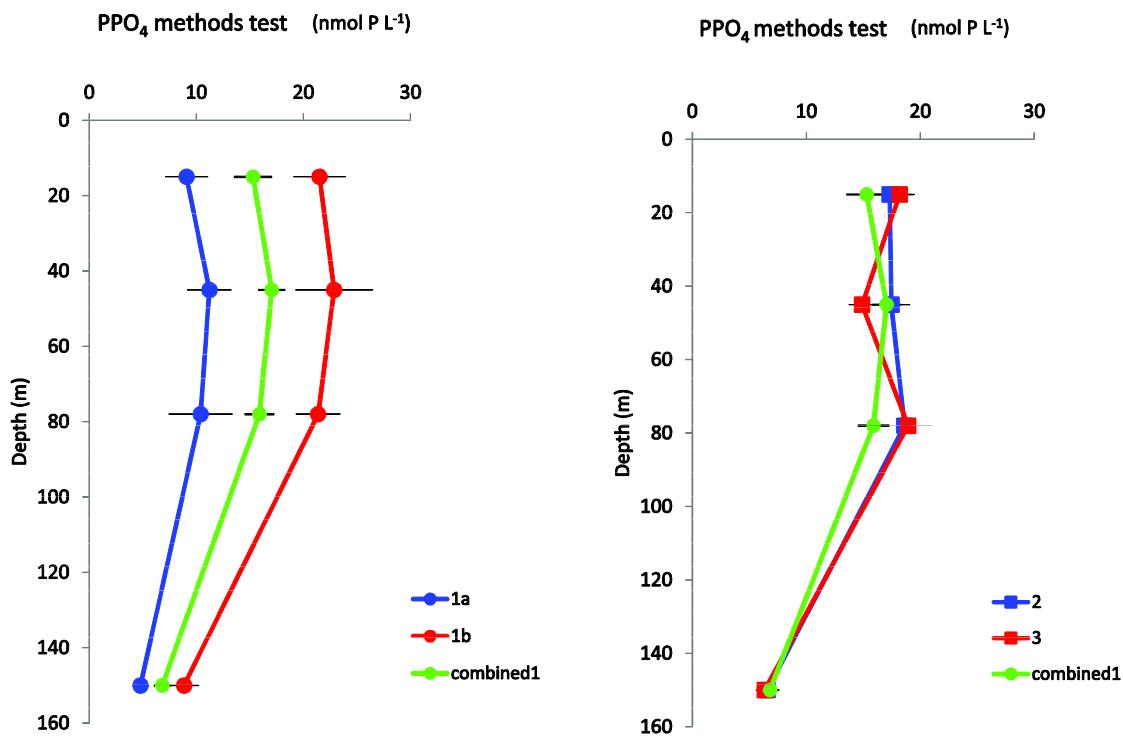


Figure 2.24a : Comparing treatments for PPO_4 determinations. 1 - current HOT protocol, 1a, the first aliquot out of 10 ml, 1b is the second aliquot from treatment 1. The ‘combined1’ is the concentration derived from the two aliquots 1a and 1b. Treatment 2 – leaching at 60°C, 60 min and treatment 3 – leaching at RT, 60 min and vortex mixing.

All concentrations were corrected for changes in the filter blanks for each time point and treatment as well as differences in subsample concentration.

For both the water column and apple leaves treatment 2 reached a stable concentration within 30 min whereas treatment 1, with the passive leaching, was more variable with relatively low concentrations after 30 minutes ([Figure 2.24b](#)). For the known concentrations of the apple leaves, both treatments reached the same final and expected concentration. Blank filters also showed increased absorbance with leach time, but remained low relative to the samples.

It was concluded that both mixing and leach time influences the extraction of the filters and that vortex mixing reduces the time necessary to fully extract the filters.

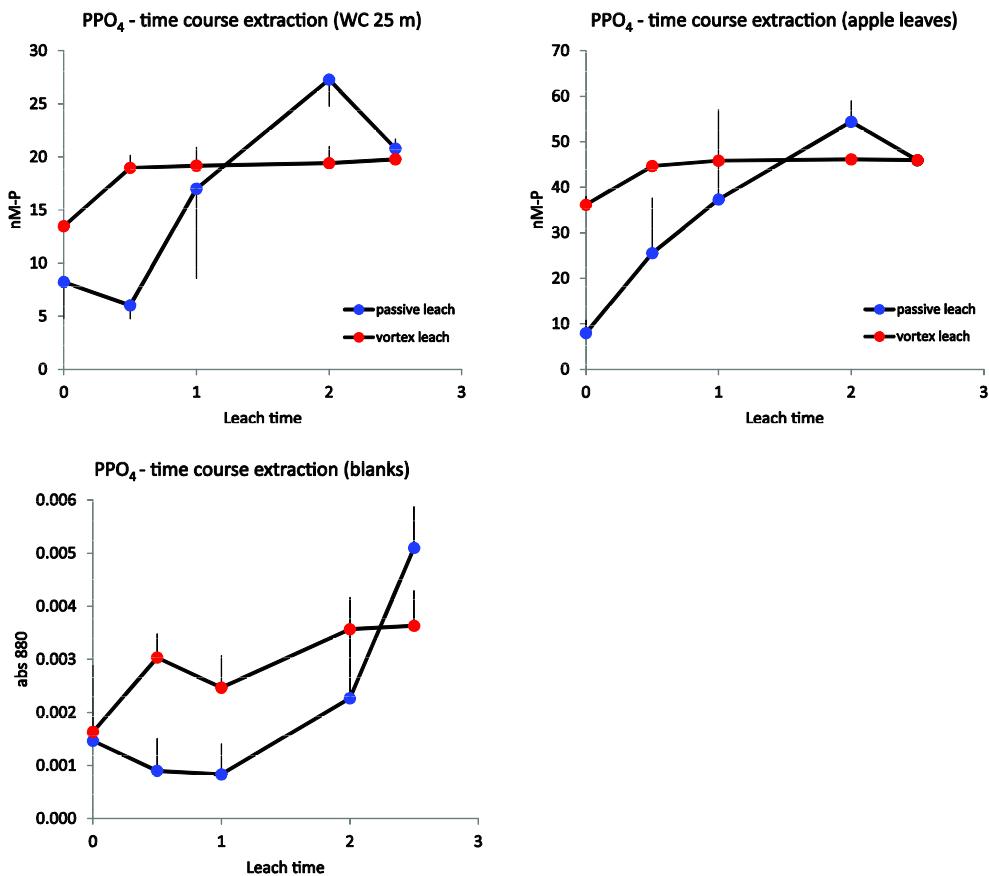


Figure 2.24b : Final concentrations for A) seawater (25 m) samples and B) apple leaf samples for treatments 1 (passive leach) and treatment 2 (vortexed and leached.) C) shows the absorbance values for blank filters over time, uncorrected for any dilutions. Leach time is in hours.

It was determined that HOT samples should be run using the modified protocol based on leaching in 0.15N HCl for 60 min, mixing by vortex and centrifuged 30 min to remove any filter debris before subsampling into new tubes for the colorimetric reaction. It was further decided that one year's worth of HOT samples (water column profiles and sediment trap samples: [Figure 2.24c](#), [Figure 2.24d](#)) should be run using the routine HOT protocol and that the second aliquot also should be analyzed to obtain the total P on the filters (i.e. the “combined” concentrations) in order to have overlapping data of the two protocols before transitioning to the modified protocol.

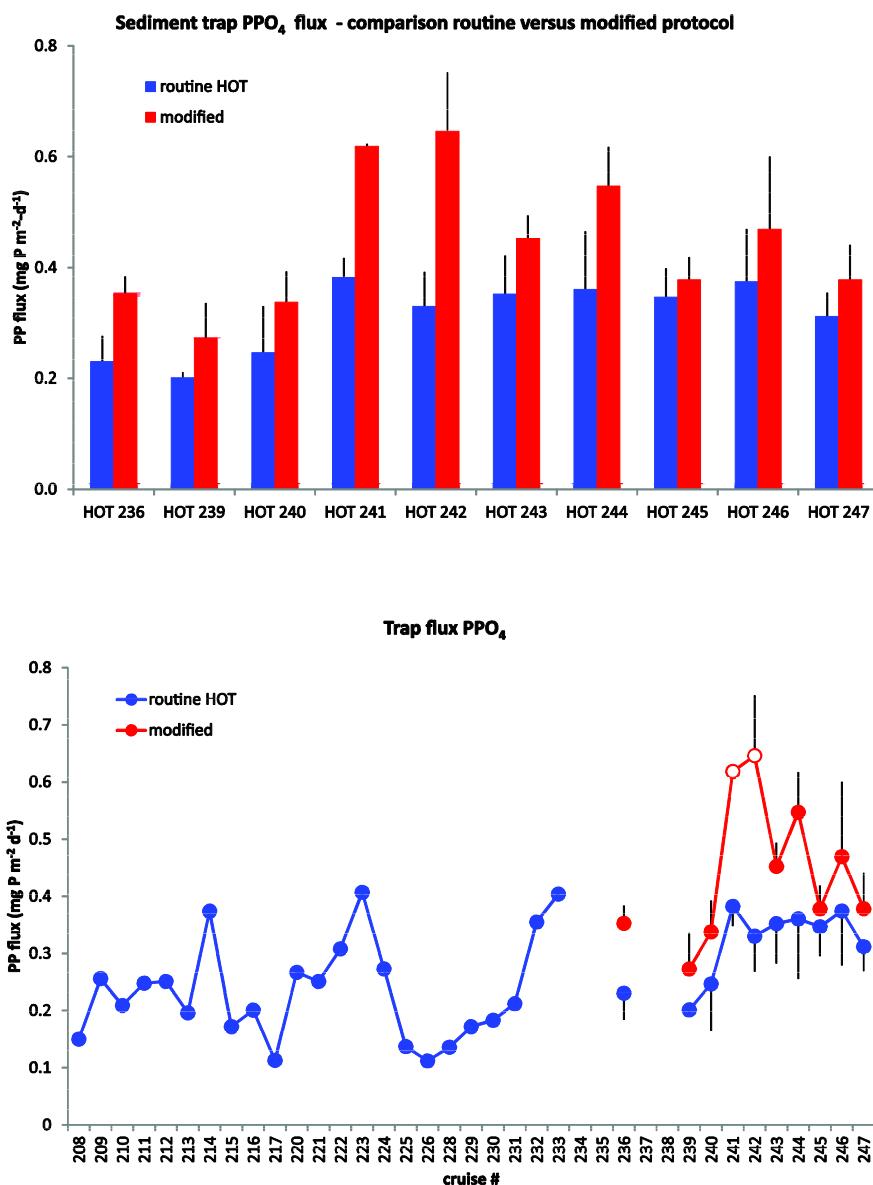


Figure 2.24c : Comparison of the “routine” versus “modified” HOT PPO₄ protocol on sediment trap samples (150 m). Note the grey circles in the lower panel for the new protocol are uncertain as the absorbance for the second aliquot subsample was out of range for the std curve.

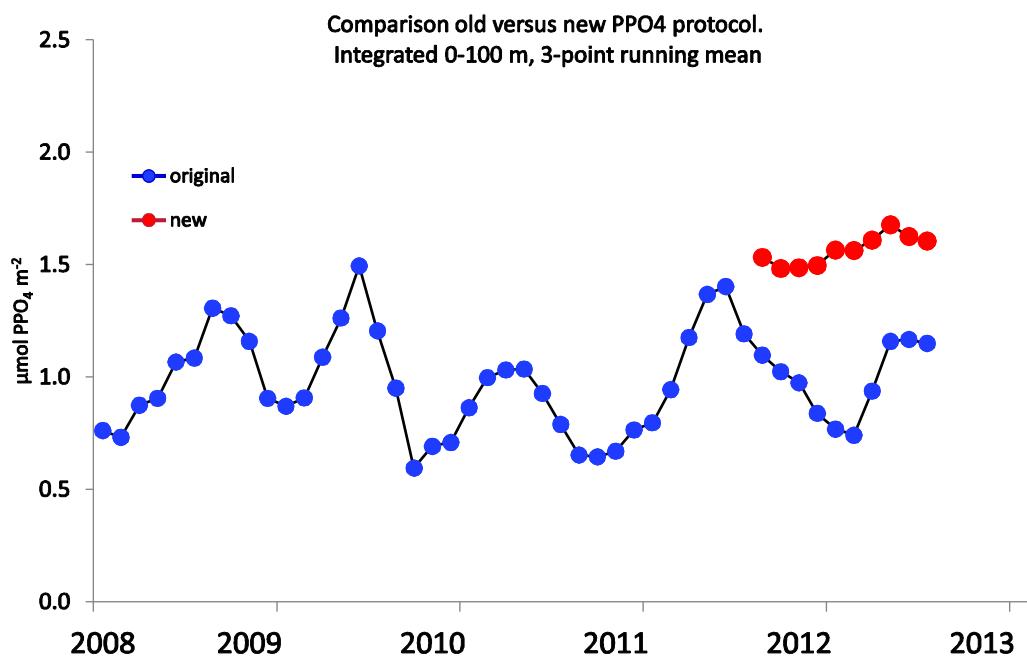
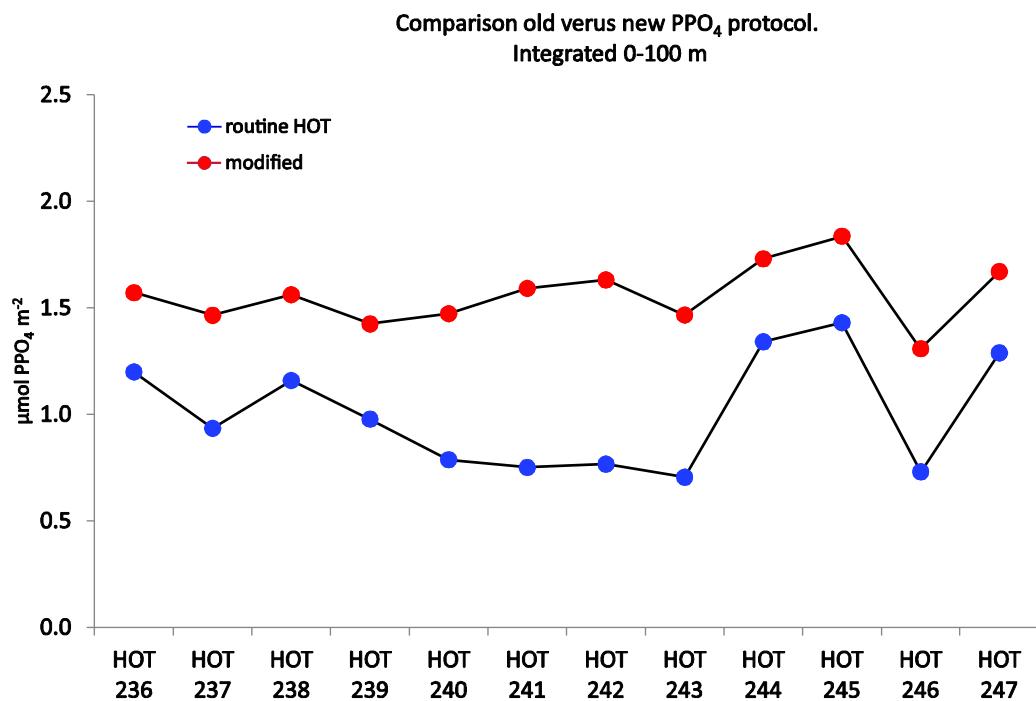


Figure 2.24d : Comparison of the “routine” versus “modified” HOT PPO₄ protocol on water column samples (integrated 0-100 m).

2.5.6.3 Particulate Biogenic Silica

Samples for elemental analyses of Particulate biogenic silica (PSi) were collected into 4L polyethylene carboys; filtered through 47 mm polycarbonate filter holders; onto 47 mm polycarbonate, membrane filters; and placed into 50 ml polypropylene centrifuge tubes. Time course subsamples (1.5, 3, 4.5, 6.5 and 24 hours) were measured colorimetrically to distinguish Lithogenic-Si from Biogenic-Si (Brzezinski and Nelson 1989 DSR 1 36: 1009 and 1995 DSR 1 42: 1215). The average field variability between duplicate analyses during 2020 are presented in [Table 2.21](#).

Table 2.21: Field variabilty of Particulate biogenic silica analyses during 2020

HOT	PSi		
	Mean CV (%)	Mean SD (nmol l ⁻¹)	N
318	20.2	2.744	2
319	0.5	0.067	2
320	24.4	5.445	2
321	4.4	6.859	2
322	2.8	0.481	2
323	6.9	1.672	2
324	21.5	2.217	2
325	7.7	0.849	2
Mean	11.1	2.542	8

2.5.7 Pigments

2.5.7.1 Standard Fluorometric Method

Samples for chlorophyll a (chl *a*) and pheopigments were collected onto uncombusted glass fiber filters (Whatman GF/F, 25 mm diameter) and measured fluorometrically on a Turner Designs Model 10-AU fluorometer with 100% acetone as the solvent using standard techniques (Strickland and Parsons 1972). It is known that this method will underestimate chlorophyll *a* in the presence of chlorophyll *b* (Welschmeyer 1994). The average precisions during 2020 determined from triplicate analyses are presented in [Table 2.22](#).

Table 2.22: Precision of Fluorometric Chlorophyll *a* and Pheopigment analyses during 2020

HOT	Chlorophyll <i>a</i>			Pheopigments		
	Mean CV (%)	Mean SD ($\mu\text{g l}^{-1}$)	N	Mean CV (%)	Mean SD ($\mu\text{g l}^{-1}$)	N
318	4.8	0.004	4	2.3	0.004	4
319	2.8	0.003	6	6.5	0.010	6
320	3.5	0.006	4	8.2	0.015	4
321	8.5	0.024	4	13.2	0.044	4
322	5.8	0.006	4	5.7	0.010	4
323	3.5	0.004	4	3.1	0.008	4
324	6.7	0.010	4	6.2	0.008	4
325	4.2	0.004	4	5.1	0.010	4
Mean	5.0	0.008	8	6.3	0.014	8

2.5.7.2 High Performance Liquid Chromatography

Chlorophyll *a* and photosynthetic accessory pigments were also measured by high performance liquid chromatography (HPLC) according to Wright *et al.* (1991). The response factors yielded by this method during 2020 are presented in [Table 2.23](#). [Figure 2.25](#) shows the relationship between chlorophyll *a* measured by fluorometry and chlorophyll *a* measured by HPLC during 2019-2020.

Table 2.23: 2020 HPLC Pigment analysis Response factors

Pigment	RF
Chlorophyll c & Mg 3,8D*	1.5526
Peridinin	2.1153
19'-Butanoyloxyfucoxanthin	1.4563
Fucoxanthin	1.4715
19'-Hexanoyloxyfucoxanthin	1.4206
Prasinoxanthin	1.4811
Violaxanthin	1.1734
Diadinoxanthin	1.5756
Alloxanthin	1.331
Lutein	1.8568
Zeaxanthin	1.3575
Chlorophyll b	3.4985
Chlorophyll a	2.5758
α -Carotene	1.1449
β -Carotene	1.5184

*Chlorophyll c = ($c_1 + c_2 + c_3$), Mg 3,8D = Mg 3,8 divinyl pheophorphyrin a_5 monomethyl ester.

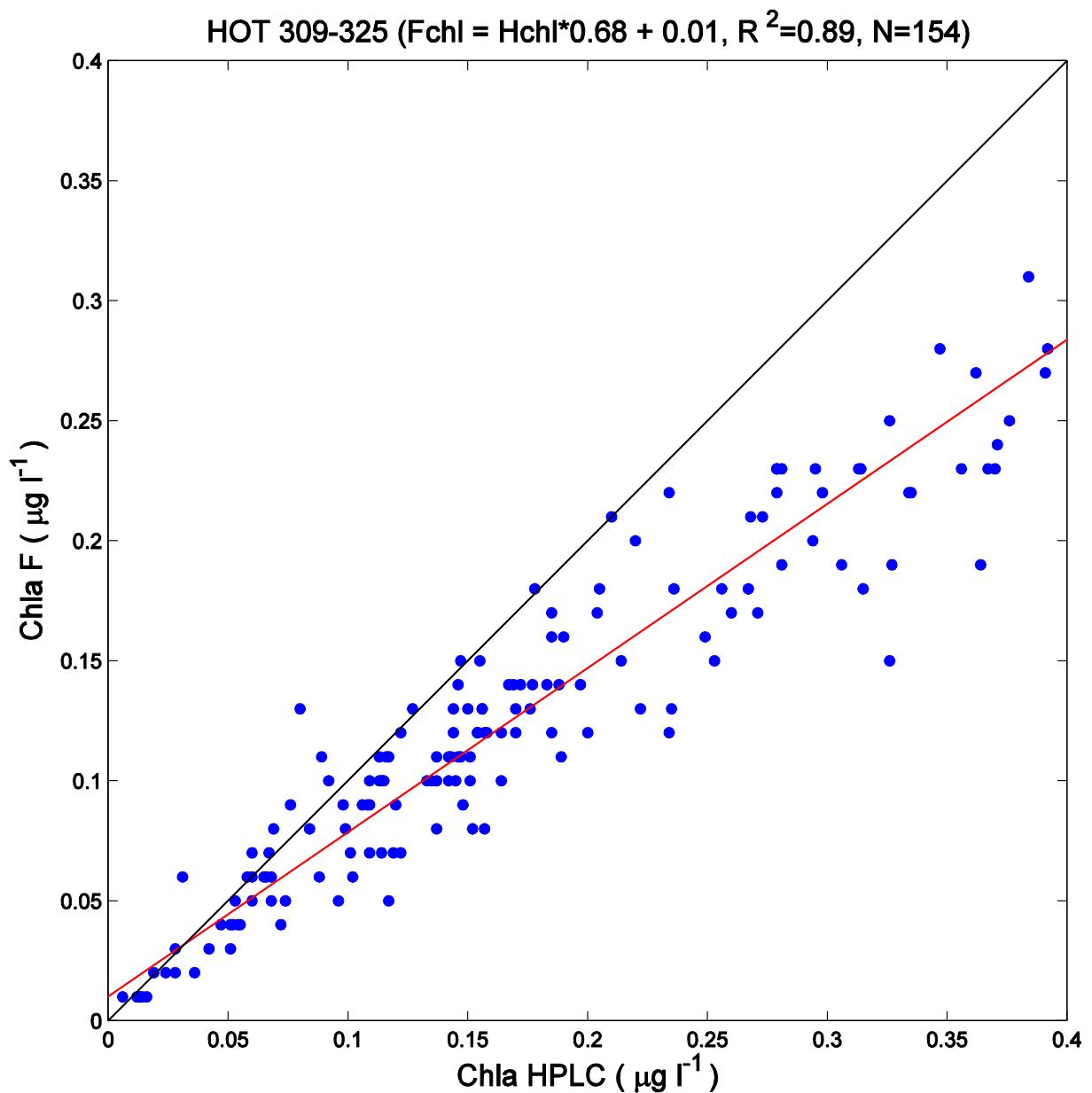


Figure 2.25: Chlorophyll a measured by fluorometry (Chla F) versus chlorophyll a measured by HPLC (Chla HPLC) for all data collected in 2019-2020. The black line shows the 1:1 x-y relationship while the red line is a model II linear regression analysis of the data set. The regression equation is at the top of the figure.

2.5.8 Adenosine 5'-triphosphate

The amount of living microbial biomass in the water column was determined by the measurement of adenosine 5'-triphosphate (ATP) concentrations. Seawater samples were filtered through glass fiber filters (Whatman GF/F, 47 mm diameter) to collect particulate material and the filters placed in boiling Tris-buffer for ATP extraction. ATP concentrations were measured on a Turner Luminometer using the firefly bioluminescence technique described by Karl and Holm-Hansen (1978).

The average field precision of Particulate ATP determinations during 2020 derived from triplicate analyses are presented in [Table 2.24](#). [Figure 2.26](#) shows the time-series of our in-house check standard. Should the mean result of the calculated check standard value fall outside the control limits, a new dilution curve will be made and the check standard remeasured against the new curve.

Table 2.24: Precision of Particulate ATP analyses during 2020

HOT	Particulate ATP		
	Mean CV (%)	Mean SD (ng l ⁻¹)	N
318	22.6	3.691	9
319	20.3	4.022	9
320	17.5	3.630	9
321	14.4	3.558	8
322	10.9	2.803	8
323	18.8	5.686	6
324	16.1	2.621	8
325	16.3	2.738	8
Mean	17.1	3.594	8

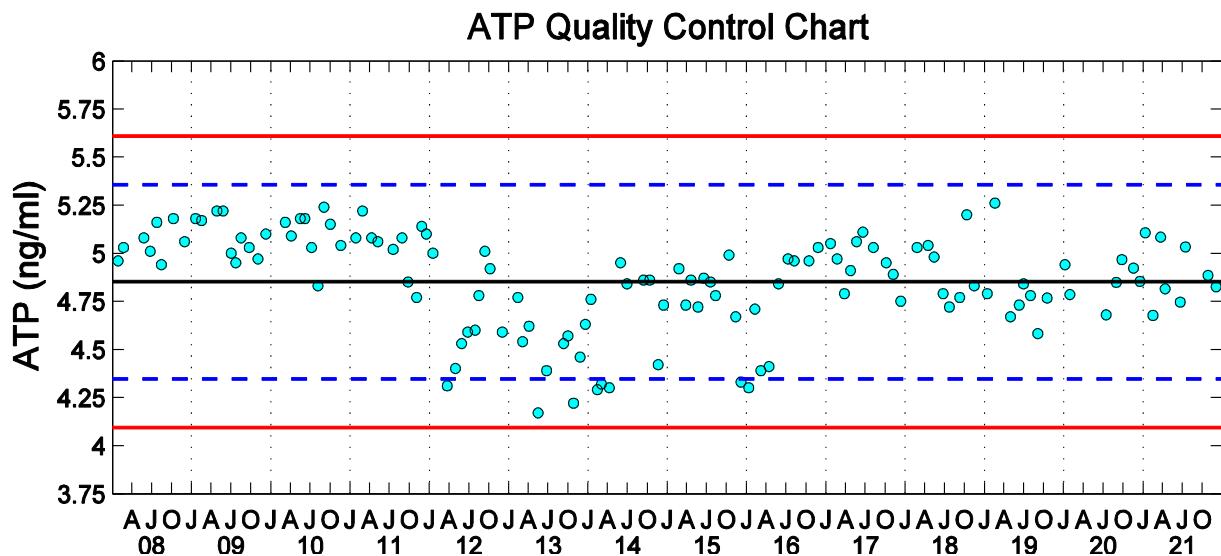


Figure 2.26: Values obtained using an in-house check standard at 5 ng ATP/ml. The check standard is used to verify the independently made standard curve dilution series used in each analytical run. The mean (\pm std dev, $n=127$) was $4.853 \pm 0.252 \text{ ng ml}^{-1}$.

2.6 Biogeochemical Rate Measurements

2.6.1 Primary Production

Photosynthetic production of organic matter was measured by the ^{14}C tracer method. All incubations from 1990 through mid-2000 were conducted *in situ* at eight depths (5, 25, 45, 75, 100, 125, 150 & 175m) over one daylight period using a free-drifting array as described by Winn *et al.* (1991). Starting HOT-119 (October 2000), we collected samples from only the upper six depths & modeled the lower two depths based on the monthly climatology. During 2020, all incubations were conducted *in situ* on a free floating, surface tethered array. Integrated carbon assimilation rates were calculated using the trapezoid rule with the shallowest value extended to 0 m and the deepest extrapolated to a value of zero at 200 m.

2.6.2 Particle Flux

Particle flux was measured at a standard reference depth of 150 m using multiple cylindrical particle interceptor traps deployed on a free-floating array for approximately 60 h during each cruise. Sediment trap design and collection methods are described in Winn *et al.* (1991). Samples were analyzed for particulate C, N, PO_4 and Si as described in [Section 2.5.6](#) above. Typically six traps are analyzed for PC and PN, three for PPO_4 , and another three traps for PSi.

2.7 Optical Measurements

2.7.1 Solar Irradiance

Incident irradiance (400-700 nm wavelength band) at the sea surface was measured on each HOT cruise with a LI-COR LI-1500 data logger and cosine collector. The instrument recorded data from the time the ship departed the University of Hawaii Marine Center until its return.

2.7.2 Downwelling Irradiance and Upwelling Radiance (HyperPro)

The Satlantic HyperPro is an in-situ free-fall profiling unit designed to measure the apparent optical properties of the ocean with concurrent measurements of temperature, salinity, chlorophyll and dissolved matter fluorescence, and optical backscattering (a proxy for total particle load). The unit is equipped with one up-looking and one down-looking hyperspectral (350-800nm) radiometer with 10 ± 0.3 nm resolution, a WET Labs ECO-Puck Triplet, and temperature, pressure, and conductivity sensors. It also incorporates a ship-mounted surface (air) hyperspectral radiometer. The applications for this sensor include bio-optical algorithm development, satellite calibration and validation, and environmental monitoring. The data products include water leaving radiance, remote sensing reflectance, energy fluxes, and PAR.

2.7.3 Laser In-Situ Scattering and Transmissometry (LISST-100X)

Forward light scattering can be used for rapid determination of *in situ* particle size distribution and particle concentration based on an inversion of the volume scattering function at small forward angles. One advantage of this technique is that it can capture continuous (1-Hz) *in situ* data. The LISST-100X measures the near-forward angular scattering distribution between 0.0017 to 0.34 radians (0.097-19.48°; Type-B), at 670 nm, which is a region where scattering is strongly influenced by particle size. Using Mie scattering theory, the LISST estimates a volumetric particle size distribution ($V(D_i)$ in units of mL L^{-1}) for 32 logarithmically spaced size classes with geometric mean diameters (D_i) ranging from 1.36 - 230.14 mm (for spherical particles). The shape of the PSD is based on an inversion of the angular pattern of forward scattering, and the concentration of particles is derived by the magnitude of scattering that reaches the detector.

Before the measured light scattering distribution is inverted to obtain the particulate volume distribution, the signal must be corrected for background scattering due to pure water. After the inversion the data are corrected for the difference in laser power between the factory calibration and the *in situ* data, and an instrument-specific correction factor is applied to obtain the calibrated particle volume concentration, in volume particles per volume of water. The areal size distribution ($A(D_i)$) is then calculated from the volume size distribution ($\mu\text{L L}^{-1}$) by assuming spherical geometry: $A(D_i) = \frac{3}{2} V(D_i) D_i^{-1}$. The mean particle size (D_{AVG}), the slope of the particle size distribution, and the total particle number (Σ 1.36mm - 230.14mm size classes) can then be calculated.

2.8 Microbial Community Structure

From December 1990 through September 2005 (HOT 22 - 173), analysis of microbial numbers was made using an EPICS 753 flow cytometer (Coulter Electronics Corporation, Hialeah, FL, USA) upgraded with a Cicero Data Acquisition System (Cytomation Inc., Boulder, Colorado). Prior to analysis by flow cytometry, samples were prepared using standard protocols (Monger & Landry 1993; Campbell *et al.*, 1994). Enumeration efficiency was tracked using fluorescent beads.

Picoplankton enumeration data collected after HOT 174 were analyzed using a B/D Influx flow cytometer. Three separate chlorophyll containing populations were enumerated by autofluorescence: *Prochlorococcus*, *Synechococcus* and the pico-Eukaryotes. Heterotrophic bacteria were enumerated using the DNA stain SYBR Green I and subtracting the previously obtained *Prochlorococcus* concentration from the DNA positive cells.

No adequate marine reference materials exist for flow cytometry. Samples for estimating inter-analysis variations were collected during HOT-281 at Station ALOHA and preserved from both the Deep Chlorophyll Maximum (DCM) and the surface (5 decibars). Several samples from each batch were analyzed each day of analysis. Precision percentages were calculated for both depths for each cell-type (Figures 2.27 - 2.30). *Prochlorococcus* in shallow samples are normally difficult to resolve and the precision associated with the counts of these cells represents this methodic limitation. Samples from the DCM and beyond are easily resolved and the precision values on these counts more closely indicate instrument variability.

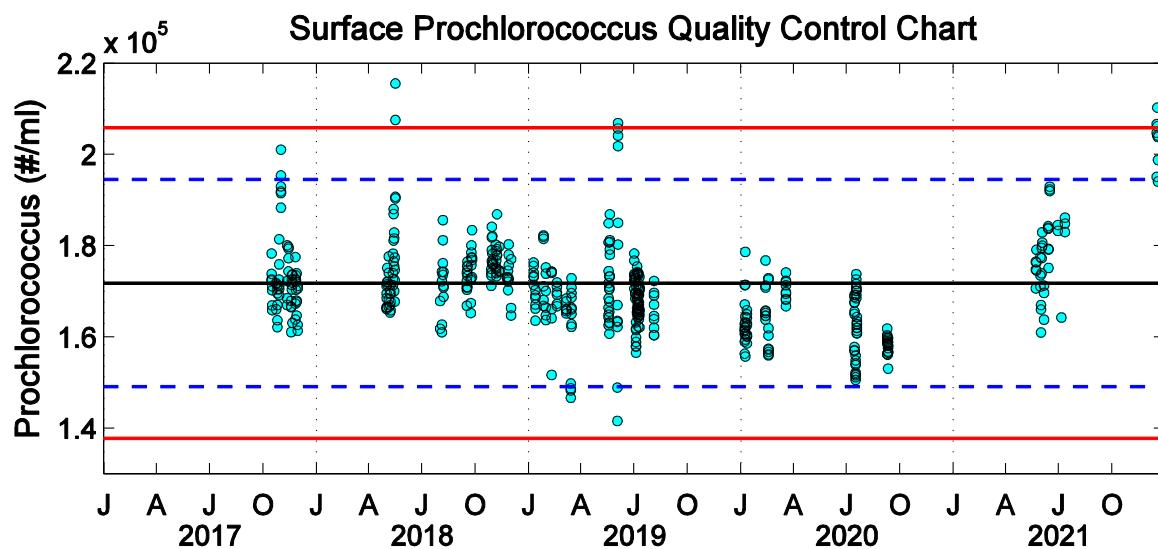


Figure 2.27: *Prochlorococcus* measured at 5 decibars at Station ALOHA. The mean (\pm stdev, n=534) was $1.718 \times 10^5 \pm 0.114 \times 10^5 \text{ # ml}^{-1}$.

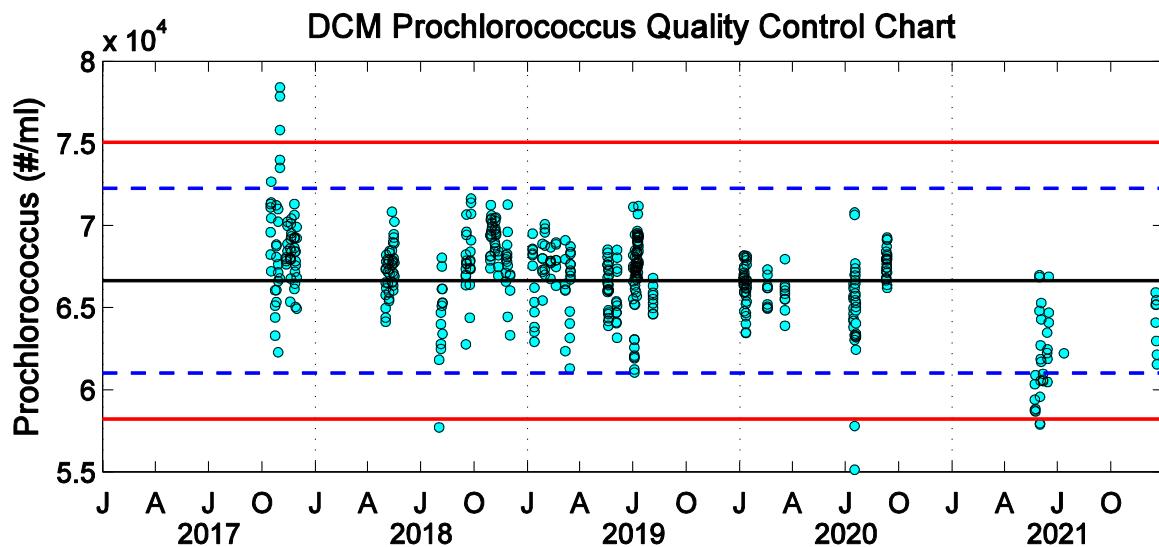


Figure 2.28: *Prochlorococcus* measured at the DCM at Station ALOHA. The mean (\pm stdev, $n=534$) was $6.666 \times 10^4 \pm 0.281 \times 10^4$ # ml⁻¹.

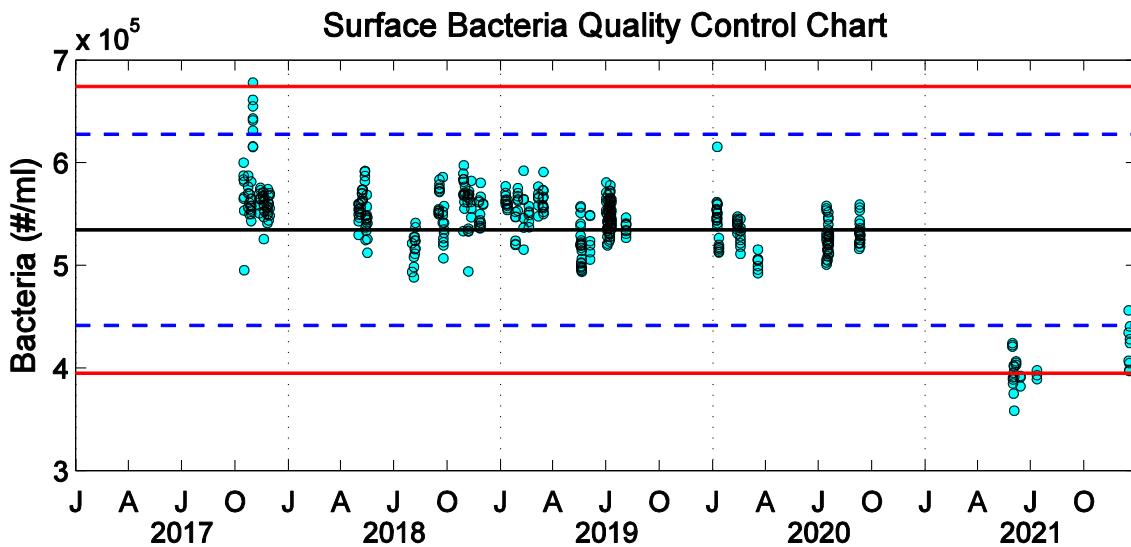


Figure 2.29: Heterotrophic Bacteria measured at 5 decibars at Station ALOHA. The mean (\pm stdev, $n=511$) was $5.347 \times 10^5 \pm 0.466 \times 10^5$ # ml⁻¹.

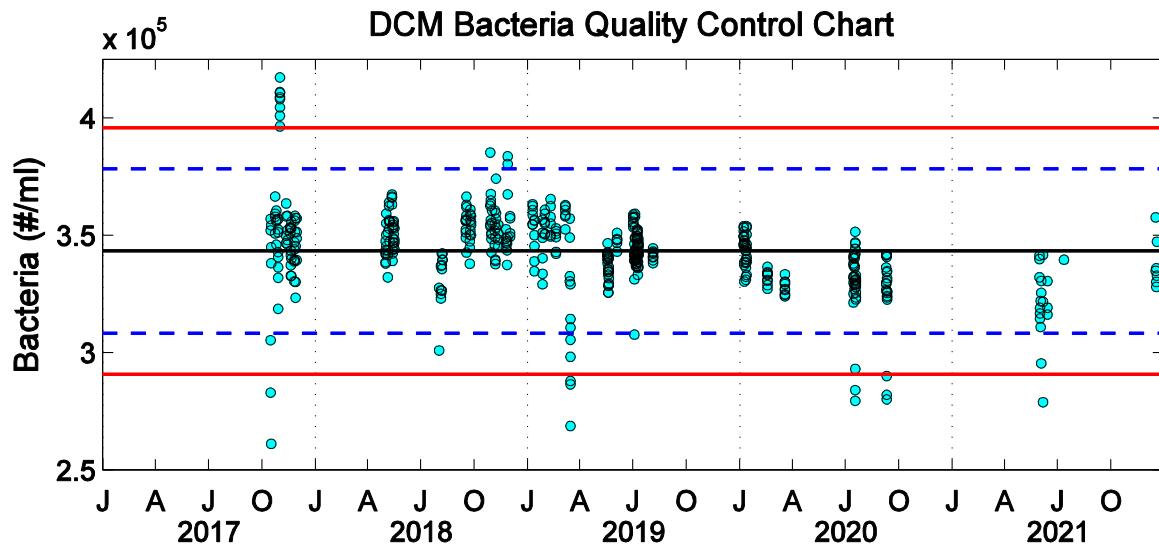


Figure 2.30: Heterotrophic Bacteria measured at the DCM at Station ALOHA. The mean (\pm stdev, $n=511$) was $3.434 \times 10^5 \pm 0.175 \times 10^5 \text{ # ml}^{-1}$.

2.9 Zooplankton Community Structure

2.9.1 Mesozooplankton Collection

Two net systems have been used for routine time-series collections of zooplankton at Station ALOHA. From 1994 to 2005 (Cruises 50-175), we used a 1-m² single-net frame with wire attachments and weighting similar to a MOCNESS (Landry *et al.*, 2001; Sheridan & Landry, 2004). A flow meter with a low-speed rotor (Model 2030R, General Oceanics, Miami, FL) was attached across the net opening to measure distance towed, and a temperature-pressure data logger (Model XL-200, Richard Brancker Research, Ottawa, Canada) was fastened to the net frame to measure depth of tow. From cruise 175 to present, the collection procedure was simplified by switching to a 1-m² diameter ring net, with GO 2030R flow meter and Vemco minilog Time-Depth Recorder. Both frames are fitted with 202-μm filter mesh nets with similar aspect ratios, and they have roughly comparable mouth areas under tow. They are lowered to depth and returned to the surface similarly (by capstan). The main difference is a preceding bridle on the ring net, which may be easier to avoid by larger animals with fast escape responses compared to the side bridles of the original rectangular net. As reported by Valencia *et al.* (2018), the two net systems were compared in a series of tows on the same cruise, revealing no significant differences in areal estimates of mesozooplankton biomass for either day or night tows (Mann-Whitney test, $p > 0.05$). They are therefore assumed to be equally efficient samplers in the time series. Since even very large, fast-towed nets (7.3 m² Isaacs-Kidd mid-water trawl and 96 m² Cobb nets; 2-4 kts) are unlikely to sample micronekton quantitatively (Kuba, 1970), neither of the small HOT nets is assumed to capture this fraction well.

2.9.2 Sample Processing

At the end of the tow, the outer side of the net is sprayed down with surface seawater to concentrate the animals in the collecting bucket. As soon as possible after collection, the sample is split using a Folsom plankton splitter. Subsamples are taken for preservation and size-fractionated biomass. Half of the tow is preserved in borate-buffered formaldehyde (0.5% final concentration), with strontium chloride (0.27 mM final concentration) added to aid in preservation of acantharians. The samples are stored in borosilicate-glass jars. Generally 1/4 of the tow is size-fractionated through nested filters of the following mesh sizes: 5-mm, 2-mm, 1-mm, 500- μ m, and 200- μ m. Each fraction is concentrated onto a 47-mm 200- μ m pre-weighed Nitex filter, rinsed with isotonic ammonium formate, placed in a labeled cryotube, and then frozen (liquid nitrogen or -80°C freezer).

Frozen samples are stored at -85°C until processed. Then, they are defrosted at room temperature in the dark on a paper towel to blot excess moisture. Each sample (which represents a single size-fraction of the tow) is weighed wet on an analytical balance before (total fraction wet weight) and after subsamples of the zooplankton mass are set aside for gut pigment analysis and carbon/nitrogen biomass. The remaining sample is dried at 60°C, and then reweighed for determination of the fraction's mass (total sample mass is the sum of all fraction masses). The mass of the sample is normalized to the ocean surface area using the volume of seawater filtered through the net as recorded by the flow meter (= volume filtered) and the depth to which the net fished as recorded by the data logger (= depth).

Carbon and nitrogen biomass are determined using a CHN Elemental Analyzer (Perkin Elmer Model 2400) on subsamples which have been dried at 60 °C in pre-weighed combusted aluminum foil boats and then weighed on an analytical balance (to 5-places). The dry weight of the sample is the difference between the final balance weight (sample + boat weight) and the pre-weighed boat weight.

2.10 WHOTS Mooring

The WHOTS-16 mooring was deployed on October 6, 2019 at 22° 40.01' N, 157° 56.96' W, during an eight-day cruise (WHOTS-16 cruise) and was recovered on August 28, 2021, during an eight-day cruise (WHOTS-17 cruise). The cruises were aboard the NOAA Oscar Sette. This mooring was scheduled to be recovered in 2020, but due to problems with the ship's availability the recovery was delayed, consequently most of the underwater instruments programmed to record data for one year stopped functioning before being recovered due to battery drain. Details of the instrumentation ([Figure 2.31](#)) and deployment are on the project's website (<https://www.soest.hawaii.edu/whots>). Briefly, a Surlyn foam surface buoy is equipped with meteorological instrumentation including two complete Air-Sea Interaction Meteorological (ASIMET) systems on the buoy and underneath subsurface instruments from 7 to 155 m depth and near the bottom. The buoy tower also contains a radar reflector, two marine lanterns, and Iridium satellite transmission systems that provide continuous buoy position monitoring. A Xeos Melo Global Positioning System (GPS) receiver, an SBE-39 temperature sensor adapted to measure air temperature, and a Vaisala WXT-520 multi-variable (temperature, humidity, pressure, wind, and precipitation) were also mounted on the tower. A fourth positioning system (Xeos Kilo transmitter) was mounted beneath the hull. Several other instruments were mounted

on the buoy. A Battelle pCO₂ system, a pumped SBE-16 CTD, and a SAMI-2 pH sensor were mounted to the buoy's underside. A Sea-Bird SBE-63 hosted a dissolved oxygen sensor. Three down-looking radiometers were mounted on the buoy. One hyperspectral sensor is mounted facing upward near the radiometers as a reference for the incoming spectral irradiance. A Wetlabs ECOFLNTUS chlorophyll fluorometer was also mounted on the buoy hull.

Four internally logging Sea-Bird SBE-56 temperature sensors were bolted to the buoy hull's underside, measuring sea surface temperature (SST) and salinity. The SBE-56s measured SST once every 60 sec between 80-95 cm below the surface. Two SBE-37 MicroCATs were at 1.50m measuring at every 300s.

Underwater instrumentation included 20 MicroCATs (SeaBird SBE-37) deployed to record temperature and conductivity (C-T) at 7, 15, 25, 35, 40, 45, 50, 55, 65, 75, 85, 95, 105, 120, 135, 155, 1875(2x), and two at about 40 m off the bottom. The MicroCATs at 45, 95, 105, 120, 135, 155, and 1875(2x) m and the two near the bottom included a pressure sensor. Two upward-looking RDI ADCPs were deployed at 47.5 m (600 kHz), and 125 m (300 kHz), respectively, and two Next Generation Vector Measurement Current Meters (VMCMs) were deployed at 10 and 30 m, respectively, to measure current speed and direction.

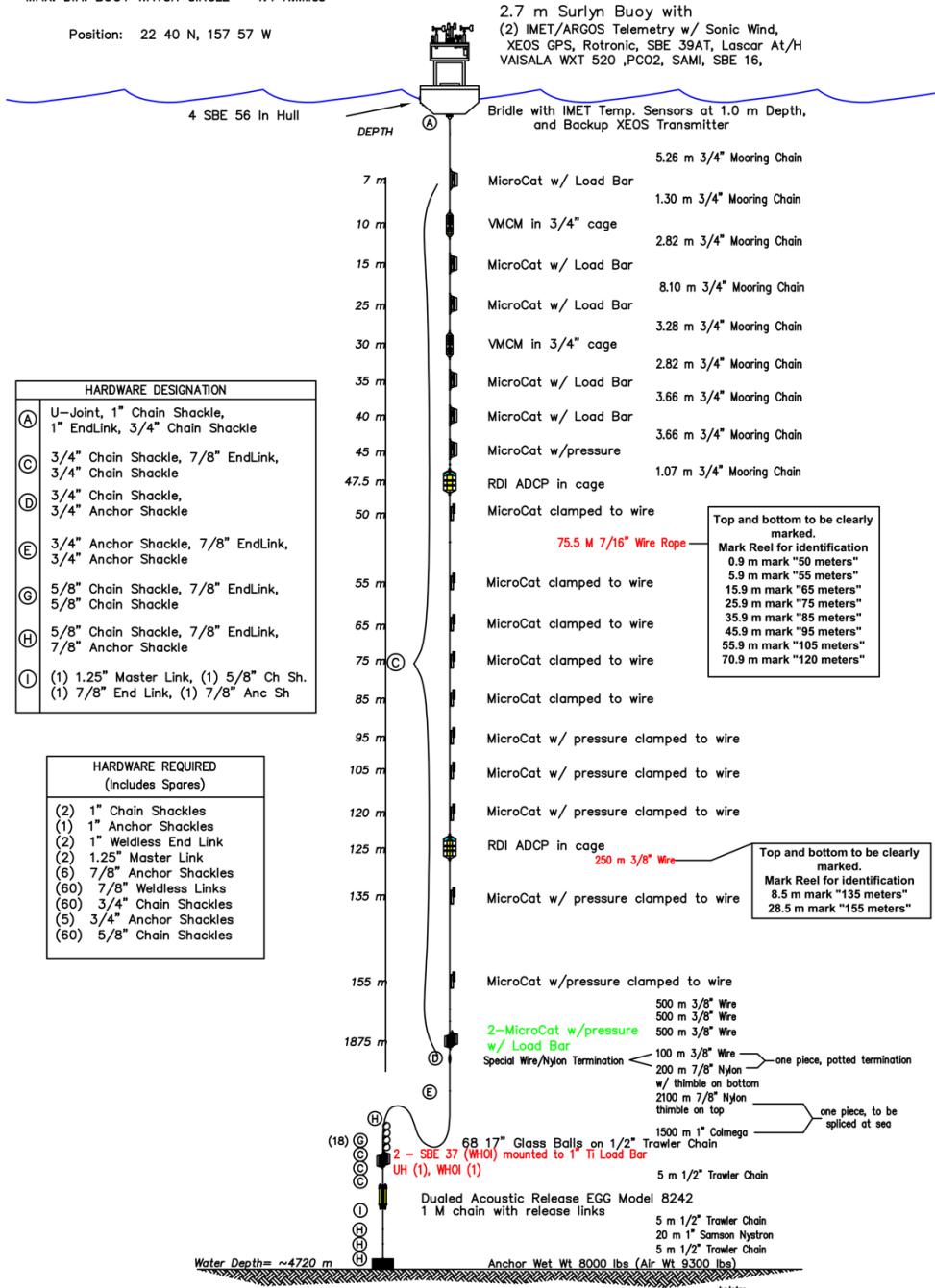
Details about instruments deployed in the WHOTS-16 mooring and data processing are available in the mooring data report (<https://whots-annual-report.readthedocs.io/projects/whots16-data-report/en/latest/>), and a description of the mooring deployment/recovery cruises can be found in the cruise reports (Santiago-Mandujano et al., 2021, 2022). The conductivity/temperature instruments (C-T) are factory calibrated before each deployment, and inter-comparisons with CTD data from HOT and WHOTS deployment/recovery cruises as well as inter-comparisons with the other mooring's C-Ts are used to correct for sensor's drift and data quality control. The ADCPs compasses are calibrated before and after each deployment, and the data are inter-compared and quality controlled using shipboard ADCP cruise data. The temperature sensor of the C-T instruments is put in contact with a bag of ice before deployment and after recovery to generate a spike in the data to be used for synchronization of their internal clocks; similarly, the ADCPs are rubbed gently to generate a spike in the data. VMCM data are processed using the WHOI UOP software package (Prada, 1992).

All underwater instruments, except the MicroCATs on the buoy and those below 155 m stopped recording data early because of battery drain due to the long deployment. The 47.5m ADCP failed on January 21, 2020. Details on the meteorological measurements are available at: <https://uop.whoi.edu/currentprojects/WHOTS/whots.html>.

PO # ---- (Add later)
May 5, 2019

MAX. DIA. BUOY WATCH CIRCLE = 4.4 N.Miles

Position: 22 40 N, 157 57 W



WHOTS MOORING

16 th Deployment - v3

Figure 2.31: WHOTS-16 mooring diagram

3.0 CRUISE SUMMARIES

The cruise summaries presented here give an overview of the activities conducted during the 2020 HOT cruises. The official Chief Scientist's reports can be found on the HOT web page (hahana.soest.hawaii.edu/hot/cruises.html) .

3.1 HOT-318

Chief Scientist: C. Funkey

R/V *Kilo Moana*

January 6-9, 2020

All operations were completed at Station Kahe. Upon arrival to Station ALOHA the winds were already at 27 knots with gust to 30 knots. We decided to cancel the deployment of the WireWalker and the sediment trap. Due to the slight tangle with the 322-wire winch which happened during the previous cruise (HOT-317), and the strong winds we decided to abort all operation until day light. During the night, despite the strong winds, the bridge was able to hold position; we deemed it safe to deploy the deep cast in the morning.

One 1000 m CTD cast was completed at Station Kahe. One near bottom CTD casts and nine 1000 m CTD casts were conducted at Station ALOHA.

Due to the strong winds during the duration of the cruise, all net tows, the primary production array and the gas array were canceled.

Hyperpro casts were completed at Station Kahe. Casts with a newly calibrated Hyperpro system were performed directly after the new Hyperpro unit to compare the two systems. One yo-yo and one profile was done on each. Due to the strong winds during the duration of the cruise at Station ALOHA the Hyperpro was canceled.

The underway fluorometer, thermosalinograph, transmissometer and the ship's meteorological suite ran without interruption during the cruise.

The lowered-ADCP gave problems during data downloading on the Kahe cast. We discovered that the dummy plug was not the problem but that it was the low voltage on the battery. A new battery was put in and the ADCP worked on all the other casts.

On the previous cruise, HOT-317, bad wrapping developed on the drum of the 322-winches at about 4000 meters during the deep cast. During the deep cast deployed on HOT-318 the crew was able to fix the tangle on the drum and properly wrap up the rest of the line onto the drum. Due to the high winds and the potential of having more level-wind problems with the 322-line we switched over to the 681-wire after the deep cast on January 7th. The rest of the CTD casts were done with the 681-wire.

The winds at Station ALOHA during that duration of the cruise were fairly consistent ranging from 23-31 knots coming from the NE. The swells had an average height of 10 ft.

The CTD yo-yo at the WHOTS mooring and Kaena station was canceled due to the high spiking wire tension seen on the last CTD cast (S2C10). We transited back to Pier 35 after Station 2 Cast 10 and arrived one day early, on January 9th.

3.2 HOT-319

Chief Scientist: D. Sadler
R/V *Kilo Moana*
January 29-February 2, 2020

All operations were completed at Station Kahe. Operations at Station ALOHA were impacted by large ground swells and a weather front to the north. The large swells kept the ship heaving and rocking, generating large tension spikes during CTD casts. Winch speeds were reduced to compensate, resulting in longer cast times. The motion also produced several kinks in the 0.322 CTD cable. CTD operations were switched to the 0.681 wire after S2C11. The 0.681 wire provided a larger safety margin and resisted further kinks.

Anticipating degenerating conditions from the approaching weather front, Seaglider-512 was recovered on Thursday along with the primary production array. The Wirewalker and sediment traps were recovered a day early on Friday afternoon and the gas array Friday after dark in 25 to 30 knot winds. The gas array samples were moved to a deck incubator overnight to complete the 24-hour experiment.

One 1000 m CTD cast and one 75m trace metal free cast were completed at Station Kahe. Two near bottom CTD casts, twelve 1000 m CTD casts, and one 500m trace metal free cast were conducted at Station ALOHA.

Two nighttime and three daytime net tows were completed.

Hyperpro casts were completed at Station Kahe and Station ALOHA. One yo-yo and two profiles at each station. A second cast at Station ALOHA was cancelled due to high winds and seas.

The underway fluorometer, thermosalinograph, transmissometer and the ship's meteorological suite ran without interruption during the cruise.

The secondary conductivity sensor kept showing greater-than-ideal differences from the primary sensor. Several replacement sensors were swapped in during the cruise but the problem persisted. It's looking like it might be a cabling issue. Sensors are being sent back to Sea-bird for analysis and recalibration, and new cables, and probably a newer CTD, will be used for the next HOT cruise.

Initially, the winds at Station ALOHA were from the south at 5-10 knots. They increased to 25-30 knots from the north on Friday, January 31st and backed off late Saturday afternoon to 10 to 15 knots. Several ground swells were present ranging from 6 -12 ft.

Kaena station was cancelled in order to remain at Station ALOHA for the trace metal free CTD cast. The trace metal line was used on the SeaMac winch for the 500m cast because the trace metal winch struggled to lift the rosette upon recovery at Station Kahe.

3.3 HOT-320

Chief Scientist: C. Funkey

R/V *Kilo Moana*

July 13-19, 2020

Due to the COVID-19 pandemic, extra precautions were set in place before and during the cruise to prevent the spread of COVID-19 onboard. UNOLS had provided guidelines which were followed on this cruise. A few of the guidelines included:

- Sailing with a minimum science party, one scientist per stateroom if possible.
- All cruise participants sheltered in place for 16 days (June 26th - July 12th) before the cruise.
- All cruise participants were tested for COVID-19 before and during the shelter in place (June 26th and July 10th).

During the cruise, all participants:

- wore face masks
- maintained a distance of 6 ft. when possible
- properly disinfected of all workspaces often
- remain in their staterooms as much as possible during non-work hours

All operations were completed at Station Kahe. Upon arrival at Station ALOHA, the WireWalker and sediment traps were deployed and drifted Northeast and were recovered on the last day. The primary production array was deployed at dawn and recovered at dusk on the 15th.

One 1000 m CTD cast was completed at Station Kahe. At Station ALOHA, two near bottom CTD casts, nineteen 1000 m CTD casts, and three Trace Metal CTD casts were done at 350 meters. One 5 cycle yoyo CTD cast to 200 m was completed near the WHOTS mooring (Station 52). A near bottom CTD cast was completed at Station Kaena.

Six net tows for the core HOT zooplankton collection were completed successfully; three during the day and three during the night. An additional six handheld net tows were completed three at noon and three at midnight.

The gas array was deployed and drifted Northeast and recovered successfully.

HyperPro casts were completed at Station Kahe and Station ALOHA.

The ADCP, transmissometer and the ship's meteorological suite ran without interruption during the cruise.

The Seafloor did not run on this cruise because it need maintenance.

Winds at the beginning of the cruise were from the Northeast at 15-18 kts and which shifted to the East strengthening to 12-15 kts near the end of the cruise. The Seas were 3-6 ft.

3.4 HOT-321

Chief Scientist: C. Funkey

R/V *Kilo Moana*

August 6-11, 2020

COVID-19 Protocols were the same as before with exceptions:

- All cruise participants self-isolated before the cruise (July 22nd - August 4th).
- All cruise participants were tested for COVID-19 3-days before the cruise (August 3rd).

All operations were completed at Station Kahe. Upon arrival at Station ALOHA, the WireWalker and sediment traps were deployed and drifted North and were recovered on the last day. The primary production array was deployed at dawn, drifted North and recovered at dusk on the 7th. Unfortunately, the bottles were put in reverse order and therefore the data was unusable.

One 1000 m CTD cast was completed at Station Kahe. At Station ALOHA, two near bottom CTD casts, fourteen 1000 m CTD casts, and two shallower casts varying from 25 -400-meter depths CTD casts. One 5 cycle yoyo CTD cast to 200 m was completed near the WHOTS mooring (Station 52). A near bottom CTD cast was completed at Station Kaena.

Six net tows for the core HOT zooplankton collection were completed successfully; three during the day and three during the night. An additional six handheld net tows were completed three at noon and three at midnight.

The gas array was deployed and drifted North and recovered successfully.

HyperPro casts were completed at Station Kahe and Station ALOHA.

The ADCP, underway fluorometer, transmissometer and the ship's meteorological suite ran without interruption during the cruise. The data from the thermosalinograph still had a few issues due to the pressure flow system causing the data to be segmented.

For the majority of the cruise the winds were from the East at 15-23 kts. The seas were 6-9ft.

3.5 HOT-322

Chief Scientist: D. Sadler
R/V *Kilo Moana*
August 28-September 6, 2020

COVID-19 Protocols were the same as before with exception:

- All cruise participants were tested for COVID-19 2-days before the cruise (August 26th).

HOT-322 differed from previous HOT cruises in that extra time was allotted to investigate a high chlorophyll region northwest of Kauai. The cruise was loaded and departed on the same day and proceeded to Station Kahe where the LARS system was weight tested and a 1000 m CTD cast completed.

The ship proceeded due west from Station Kahe and began the underway CTD survey approximately halfway between Oahu and Kauai ($21^{\circ} 20.96' N$, $159^{\circ} 08.69' W$). The underway CTD was deployed approximately every 4 nm along the route. At $21^{\circ} 20.66' N$, $159^{\circ} 42.02' W$, course was altered to the NW to sail between Kauai and Niihau towards a high chlorophyl area. This leg extended to $22^{\circ} 15.48' N$, $160^{\circ} 01.37' W$. At this point the cruise plan was revised to avoid military training exercises. Based on satellite imagery, a new route to the east of Kauai was selected for the underway survey along with 5 stations for CTD casts, water sampling and a primary production experiment.

Stations occupied were:

- Station 20: $21^{\circ} 20.66' N$, $159^{\circ} 42.02' W$ - 1000 m CTD cast
- Station 21: $21^{\circ} 34' 12'' N$, $159^{\circ} 26' 60'' W$ – 1000 m CTD cast
- Station 22: $22^{\circ} 14' 24'' N$, $158^{\circ} 35' 24'' W$ – 1000 m CTD cast
- Station 23: $22^{\circ} 59' 24'' N$, $158^{\circ} 29' 24'' W$ – Optics cast, 2 x1000 m CTD cast, Primary Production Array deployed and recovered, Hyperpro cast, Hand Net Tow.
- Station 24: $23^{\circ} 26' 24'' N$, $158^{\circ} 11' 24'' W$ – 1000 m CTD cast

After departing Station 24, the underway CTD survey was extended to Station ALOHA.

Upon arrival at Station ALOHA, the WireWalker, floating sediment traps, and IRS sediment traps were deployed just south of the station circle. They drifted northward and were recovered on the last day of the cruise just northeast of Station ALOHA. A primary production array and a gas array experiment were also completed at Station ALOHA.

At Station ALOHA, two near bottom CTD casts, eighteen 1000 m CTD casts, and one cast to 100 m were completed. One 5 cycle yoyo CTD cast to 200 m was completed near the WHOTS mooring (Station 52).

Six net tows for the core HOT zooplankton collection were completed successfully; three during the day and three during the night. An additional six handheld net tows were completed three at noon and three at midnight.

Hyperpro operations were conducted twice at Station ALOHA. Once during the primary production experiment and once near the WHOTS mooring. Each operation consisted of 2 deep casts and a 5 cycle Yo-Yo cast to 20m.

The ADCP, underway fluorometer, transmissometer and the ship's meteorological suite ran without interruption during the cruise. The data from the thermosalinograph still had a few issues due to the pressure flow system causing the data to be segmented.

Weather during the cruise was generally fair with some overcast skies and rain near the end. The cruise started with winds from the west at 10-15 knots then swinging to the northeast, becoming 25-30 knots before backing off to 10-15 knots. The last day saw an increase back to 20-25 knots.

3.6 HOT-323

Chief Scientist: F. Santiago-Mandujano
R/V *Kilo Moana*
September 25-30, 2020

COVID-19 Protocols were the same as before with exception:

- All cruise participants were tested for COVID-19 4-days before the cruise (September 21st).

The cruise was delayed two days from its original September 23rd departure date, waiting for the USCG clearance to repairs made to the ship's starboard propulsion drive.

Equipment loading was conducted on September 24th, and the cruise started on September 25th at 13:00 (HST). After conducting operations at Station Kahe the ship proceeded to Station ALOHA.

Upon arrival at Station ALOHA, a CTD cast was conducted to collect water for the primary productivity array. The primary productivity array, floating sediment traps, and WireWalker were deployed just northwest of the station center. They drifted northeastward. The sediment traps and WireWalker were recovered on the last day of the cruise nearly 17 nm northeast of Station ALOHA. A gas array experiment were also completed at Station ALOHA.

At Station ALOHA, two near bottom CTD casts, thirteen 1000 m CTD casts, and one cast to 100 m were completed. One 5 cycle yoyo CTD cast to 200 m was completed near the WHOTS mooring (Station 52), and one near bottom CTD cast was conducted at Station Kaena (Station 6).

Six net tows for the core HOT zooplankton collection were completed successfully; three during the day and three during the night. Additionally, six handheld net tows were completed.

Hyperpro operations were conducted twice at Station ALOHA. Once during the primary production experiment and once near the WHOTS mooring. Each operation consisted of 2 deep casts to 185 m, and a 5 cycle Yo-Yo cast to 20 m.

The 300 kHz ADCP, underway fluorometer, transmissometer and the ship's meteorological suite ran without interruption during the cruise. The data from the thermosalinograph had a few issues during the previous HOT-322 cruise due to the pressure flow system causing the data to be segmented. Before HOT-323, the flow to the thermosalinograph was separated from the other instruments in the IMET lab, and the instrument performed much better.

Weather during the cruise was fair. Winds were easterlies between 6 and 18 knots, with clear skies. A northeastward current of about 0.5 knots in the upper 80 m was present in during the cruise.

3.7 HOT-324

Chief Scientist: F. Santiago-Mandujano

R/V *Kilo Moana*

November 17-21, 2020

COVID-19 Protocols were the same as before with exception:

- All cruise participants were tested for COVID-19 twice before the cruise (October 27th and November 10th).

Equipment loading was conducted on November 16th, and the cruise started on November 17th at 09:00 (HST). After conducting operations at Station Kahe the ship proceeded to Station ALOHA.

Upon arrival at Station ALOHA, a CTD cast was conducted to collect water for the primary productivity array. The primary productivity array, floating sediment traps, IRSC sediment traps, and WireWalker were deployed just south of the station center, as there was a strong 0.5 knot northward current in the upper 80 m. Given the strong winds forecasted on the day scheduled for the arrays recoveries (November 21st), we decided to recover them earlier on November 20th. All arrays drifted NNEward nearly 33 nm from Station ALOHA, they were in the water for at least 48 hours. The IRSC traps malfunctioned and did not collect any samples. The gas array experiment scheduled to be deployed on November 20th was rescheduled for November 19th and recovered on November 20th.

At Station ALOHA, two near bottom CTD casts, and fourteen 1000 m CTD casts were completed. The 36-hour CTD burst period was interrupted for the recovery of the drifting arrays on November 20th, two of the CTD casts scheduled during this period were not conducted. One 5-cycle yoyo CTD cast to 200 m was completed near the WHOTS mooring (Station 52). The near-bottom CTD cast scheduled at Station Kaena (Station 6) for November 21st was not conducted because the CTD wire got caught in one of the ship's fittings during cast preparations and it was badly bent when the winch pulled the cable.

An anomalous feature was observed in all the CTD casts at Station ALOHA, consisting of a salinity increase (~0.1 g/kg) and an oxygen decrease (~0.3 ml/l) in the salinity minimum between 400 and 500 dbar.

Six net tows for the core HOT zooplankton collection were completed successfully; three during the day and three during the night.

Four casts were conducted with the Trace Metals CTD. The winch used for the first cast (the “HOT winch”) failed and could not bring the package onboard. The recovery and continued operations with this CTD were transferred to the SeaMac winch. One cast scheduled for November 21st was cancelled due to the rough weather.

Hyperpro operations were conducted once at Station Kahe and once at Station ALOHA, during the primary production experiment. The cast scheduled for November 21st near the WHOTS mooring was cancelled due to rough weather conditions. Each operation consisted of 2 deep casts to 185 m, and a 5 cycle Yo-Yo cast to 20 m.

The 300 kHz ADCP, underway fluorometer, transmissometer, thermosalinograph and the ship’s meteorological suite ran without interruption during the cruise. The 38 kHz ADCP is still not working. T. Young did some repairs to the system before the cruise, but it still did not function properly.

Seaglider-148 was successfully recovered in the morning of November 18th at Station ALOHA, and an APEX Argo float was deployed before leaving Station ALOHA on November 21st.

The weather was moderate at the beginning of the cruise with 15-20 knot easterly winds, turning rough starting on November 21st due to the winds increasing to 25-30 knot. A NNEward current of about 0.5 knots was present in the upper 80 m during the cruise.

3.8 HOT-325

Chief Scientist: T. Rohrer
R/V *Kilo Moana*
December 17-21, 2020

COVID-19 Protocols were the same as before.

Equipment loading was conducted on December 16th, and the cruise departed on December 17th at 07:35 (HST). After conducting operations at Station Kahe the ship proceeded to Station ALOHA.

Upon arrival at Station ALOHA, the IRSC sediment traps, the sediment traps, and WireWalker were deployed east of center station, as the currents were expected to move to the south. A CTD cast was conducted to collect water for the primary productivity array, and the array was deployed 1 nm east of center station. Despite strong winds, the primary productivity array recovery went smoothly just after sunset on December 18th. The gas array experiment was

deployed north of center station on December 19th and recovered on schedule on December 20th. The remaining arrays drifted south and then to the southwest nearly 40 nm from Station ALOHA, so recovery was postponed until after operations concluded at Station 52. They were recovered on the way to Station Kaena and were in the water for approximately 64 hours.

At Station ALOHA, two near bottom CTD casts and thirteen 1000 m CTD casts were completed. The 36-hour CTD burst period was uninterrupted except for a 50 minute delay before S2C12 due to unspooling of slack wire on the winch. The anomalous feature present at Station ALOHA during HOT-324 (a salinity increase (~0.1 g/kg) and oxygen decrease (~0.3 ml/l) in the salinity minimum between 400 and 500 dbar) was present for some of the casts during HOT-325, most notably S2C7, S2C8, and S2C15. One 5-cycle yoyo CTD cast to 200 m was completed near the WHOTS mooring (Station 52), as well as the near-bottom CTD cast at Station Kaena (Station 6).

Six net tows for the core HOT zooplankton collection were completed successfully; three during the day and three during the night.

Three casts were conducted with the Trace Metals CTD using the SeaMac winch. The experiments were completed using these casts, so the 4th cast scheduled for December 20th was cancelled.

Four casts were completed with the Scripps Plankton Camera package, also using the SeaMac winch. Two casts were conducted in the daytime, and two at night.

Hyperpro operations were conducted once at Station Kahe, and twice at Station ALOHA during the primary production experiment and near the WHOTS mooring. Each operation consisted of 2 deep casts to 185 m, and a 5 cycle Yo-Yo cast to 20 m.

The 300 kHz ADCP, underway fluorometer, transmissometer, thermosalinograph and the ship's meteorological suite ran without interruption during the cruise. The 38 kHz ADCP is still not working correctly due a failed cable, but data were collected using three transducers and may still be useful.

The weather was moderate at the beginning of the cruise with 15 knot easterly winds, turning rough starting on December 18th due to the winds increasing to 20-25 knots. Conditions improved overnight on December 19th – 20th, allowing for reasonable array recoveries. A SSWward current of greater than 0.7 knots was present in the upper 80 m during the cruise.

4.0 RESULTS

4.1 Hydrography

4.1.1 2020 CTD Profiling Data

Profiles of temperature, salinity, oxygen, and potential density (σ_0) were obtained from data collected at Stations Kahe, ALOHA, WHOTS, and Kaena. The downcast CTD profiles from Station ALOHA during 2020 are presented in [Figures 6.1.1a](#) to h, together with the results of bottle determinations of oxygen and salinity. Stack plots of CTD temperature and salinity profiles for all 1000 m casts conducted at Station ALOHA are also presented ([Figures 6.1.2a](#) to h). The offset between bottle salinities and CTD profiles apparent in some of the cruise's salinity vs. pressure plots is due to the mismatch between the downcast CTD profile and the bottle salinities taken during the upcast. This salinity mismatch is caused mostly by vertical displacements of the density structure and disappears when plotted against potential temperature (lower right panel in [Figures 6.1.1a](#) to h). In some instances, mismatches are caused by the freshening of the surface water due to rain during the cast.

Profiles of chloropigment (in vivo fluorescence) are shown in [Figures 6.1.3a](#) to h. Chloropigment profiles show the chlorophyll maximum at the base of the euphotic zone, characteristic of the central North Pacific Ocean. Chloropigment profiles show the influence of internal waves when plotted against pressure, but remain relatively constant within a cruise when plotted against potential density ($\sigma\theta$). However, there is substantial cruise-to-cruise variability in both the position and magnitude of the chlorophyll maximum.

Profiles of the data collected for Stations Kahe and Kaena during 2020 are presented in [Figures 6.1.4a](#) to h.

The potential temperature, salinity, and oxygen profiles obtained from the deep casts at Station ALOHA during 2020 are presented in [Figures 6.1.5](#) through 7.

4.1.2 Time-series Hydrography, 1988-2020

The hydrographic data collected during the first thirty-two years of HOT are presented in a series of contour plots ([Figures 6.1.8](#) through 23). These figures show the data collected in 2020 within the context of the longer time series. The CTD data used in these plots are obtained by averaging the data collected during the 36-hour period of burst sampling. Therefore, much of the variability, which would otherwise be introduced by internal tides, has been removed.

[Figures 6.1.8](#) and [6.1.9](#) show the contoured time-series for potential temperature and density (σ_0) in the upper 1000 dbar for all HOT cruises through 2020. Seasonal variation in temperature for the upper ocean is apparent in the maximum of the near-surface temperature of about 26 °C and a minimum of approximately 23 °C. Oscillations in the depth of the 5 °C isotherm below 500 dbar appear to be relatively large with displacements up to 100 dbar. The main pycnocline is observed between 100 and 600 dbar, with a seasonal pycnocline developing between June and December in the 50-100 dbar range ([Figure 6.1.9](#)). The cruise-to-cruise changes between February and July 1989 in the upper pycnocline illustrate that our quasi-monthly sampling does not always resolve variability in density.

[Figures 6.1.10](#) through 13 show the contoured time-series record for salinity in the upper 1000 dbar for all HOT cruises through 2020. The plots show both the CTD and bottle results plotted against pressure and potential density. Most of the differences between the contoured sections of bottle salinity and CTD salinity are due to the coarse distribution of bottle data in the vertical as compared to the CTD observations. Some of the bottles in [Figure 6.1.13](#) are plotted at density values lower than the indicated sea surface density. This is due to surface density changing from cast to cast within each cruise and even between the downcast and the upcast during a single cast.

Surface salinity is variable from cruise to cruise, with no apparent seasonal cycle and some substantial interannual variability. Relatively low surface salinities occurred during 1989, the early part of 1995, during 1996, 2004, during the late part of 2018 and during 2019-2020. A relative increase in surface salinity that started in the late months of 1997 continued throughout 2003, intensifying in the first half of 1999 and remaining with high values during the major part of 2000, 2001, and early 2002, showing a decrease in mid-2002, mid-2003, during the second half of 2004, in early 2005, during 2007, and mid-2008; and increasing again by the end of 2002, early 2003, late 2003, early 2004, early 2009, early to mid-2010, and early and late 2011, 2012, 2013, 2014 and 2015. This increase is also present in deeper layers reaching 200 dbar ([Figure 6.1.10](#)).

The salinity maximum is generally found between 50 and 150 dbar and within 24-25 σ_0 . A salinity maximum region extends to the sea surface in the later part of 1990, 1993 and during 1998 throughout the early months of 2002, during late 2002 and early 2003, and again in the late part of 2003, early 2004, late 2004, early 2006, late 2008, early and late 2009, early to mid-2010, and early 2011, 2012, 2013, 2014 and 2015, as indicated by the 35.2 contour reaching the surface. The maximum shows salinities lower than usual in early 1995 and 1996, and throughout these two years, the values are below 35.2. During 1997 the salinities decreased even further, with values below 35.1, to recover rapidly after February 1998 to values prior to 1995. The increase continued throughout 2004, reaching record values of up to 35.45 in the first half of 1999. During 2005 and 2006, the salinities decreased to values comparable to those during 1998, and even further during 2007, to increase again in 2008, and to continue increasing to values above 35.3 throughout 2015. In 2016 the salinities started decreasing, reaching values below 35.2 during 2017, 2018 and decreasing even further during 2019, and below 35 during 2020. These salinity anomalies seem to be related to rainfall anomalies in the central North Pacific dominated by the El Niño/Southern Oscillation phenomenon and by the Pacific Decadal Oscillation (Lukas, 2001). During 1998 through 2004 period of high salinities in the salinity maximum, brief periods of relatively lower salinity were observed during the second half of 1998, 1999, and 2003.

The maximum value of salinity in the salinity maximum region is subject to short-term variations of about 0.1, which is probably due to the proximity of Station ALOHA to the region where this water is formed at the sea surface (Tsuchiya, 1968). The variability of this feature is itself variable. Throughout 1989 there were extreme variations of a couple of months duration with 0.2 amplitude. The variability was much smaller and slower thereafter, except for a few months of rapid variation in earlier 1992.

In the thermocline region below the salinity maximum (between 150 and 300 dbar), the salinities present a decreasing trend starting around 1995 until mid-2008, when it started increasing until mid-2010 and decreasing again until 2012.

The salinity minimum is found between 400 and 600 dbar (26.35-26.85 σ_0). There is no apparent seasonal variation in this feature, but there are distinct periods of higher-than-normal minimum salinity in early 1989, in the fall of 1990, in early 1992 in the summer of 1996, in the fall of 2006, late in 2007, fall 2008 and 2009, the second half of 2010, in the summer of 2011 and 2012 and during 2013. These variations are related to the episodic appearance at Station ALOHA of energetic fine structure and submesoscale water mass anomalies (Lukas and Chiswell, 1991; Kennan and Lukas, 1995). The anomalous high salinity centered at 400 dbar in early 2001 was apparently caused by the passing of an eddy during HOT-122 (Lukas and Santiago-Mandujano, 2001). This caused anomalous values in all the hydrographic variables observed at the ALOHA station. A similar feature centered at 350 dbar was observed in mid-2012 during HOT-241, however its anomalous values were not as extreme as during HOT-122.

[Figures 6.1.14](#) and [6.1.15](#) show contoured time-series data for oxygen in the upper 1000 dbar at Station ALOHA. The oxygen data show a strong oxycline between 400 and 625 dbar (26.25-27.0 σ_0), and an oxygen minimum centered near 800 dbar (27.2 σ_0). Recurrent drops in the oxygen concentration can be seen throughout the time series between 25 and 26.25 σ_0 . These features are accompanied by a decrease in salinity and an increase in the nutrient concentration (see discussion below). The anomalous low oxygen centered at 400 dbar in early 2001 is due to the previously mentioned eddy feature observed during HOT-122. A similar low oxygen feature mentioned earlier is centered at 350 dbar in May 2012 (HOT-241).

The oxygen minimum exhibits some interannual variability, with values less than 30 $\mu\text{mol kg}^{-1}$ frequently appearing during the time series. This variability can be seen in a plot of the mean oxygen in the intermediate waters spanning the oxygen minimum (27-27.8 σ_0 , [Figure 6.1.24](#)). Superimposed on this variability is a general trend towards lower oxygen values from 1989 through 1996, with an increase between 1997 and 2000, followed by a sharp decrease during 2001, and reaching record low values during the second half of 2002, and increasing sharply during 2003 and 2004 to reach high values in mid-2004, decreasing again to values close to those in 2002 by the end of 2005 and in the Fall of 2007. An increase that started in late 2005 reached high values in mid-2010, followed by a decrease throughout late 2012 and then by a sharp increase in 2014 and a decrease from 2015 through 2018, followed by an increase to record values in 2020.

The surface layer shows seasonality in oxygen concentrations, with the highest values in the winter. This pattern corresponds roughly to the minimum in surface layer temperature ([Figure 6.1.8](#)).

[Figures 6.1.16-23](#) show [nitrate + nitrite], phosphorus, and silica at Station ALOHA plotted against both pressure and potential density. The nitricline is located between about 200 and 600 dbar (25.75-27 σ_0 ; [Figures 6.1.16-17](#)). Most of the variations seen in these data are associated with vertical displacements of the density structure, and when [nitrate + nitrite] is plotted versus potential density, most of the contours are level. Recurrent events with increasing [nitrate + nitrite] can be seen throughout the series between 25-26.25 σ_0 ([Figure 6.1.17](#)). These events are accompanied by a decrease in the oxygen concentration mentioned above ([Figure](#)

[6.1.15](#)). The most obvious events occurred in March-April 1990, January 1992, May 1992, February-March 1995, early 1996, mid-to late 1997, July-September 1999, mid-2002, late-2003, late-2007, mid-2008, late-2012, mid-2013, late 2014 to early 2015, and mid to late 2017, and significantly during 2020. These events can likely be attributed to mesoscale features such as eddies. It is possible for eddies to transport water with different biogeochemical characteristics from distant sources into the region of Station ALOHA (Nolan, 2008). The phosphorus variability is similar to the [nitrate + nitrite] in the upper water column ([Figure 6.1.20-21](#)).

During 1996, the intermediate waters between 27.0-27.8 σ_0 recovered from anomalously low [nitrate + nitrite] observed during 1995 ([Figure 6.1.18](#)). This anomaly is apparent in a time series of mean [nitrate + nitrite] between 27.0-27.8 σ_0 ([Figure 6.1.24](#)). A decrease in [nitrate + nitrite] began in late 1994, with a comparable increase from mid-1995 through early 1996. The maximum decrease appears to be about $1 \mu\text{mol kg}^{-1}$ below 27.5 σ_0 where nitrate concentrations are about $40 \mu\text{mol kg}^{-1}$. This decrease appears to be authentic as it does have coherence over time. A precision estimate of 0.3% has been made for [nitrate + nitrite] measurements involving the high concentration samples associated with intermediate water (Dore et al., 1995). This translates to a precision of roughly $0.12 \mu\text{mol kg}^{-1}$ for samples with a concentration of $40 \mu\text{mol kg}^{-1}$. Hence, the $1 \mu\text{mol kg}^{-1}$ decrease seen during 1995 is well within the precision level for the concentrations observed. However, the amount of the decrease could be approaching the accuracy limits of [nitrate + nitrite] measurements. This low [nitrate + nitrite] episode is accompanied by an increase in oxygen concentration ([Figure 6.1.24](#)). A [nitrate + nitrite] decrease of similar magnitude was observed in 2013-2014, reaching record low levels by the end of 2014, with a corresponding increase in oxygen concentration, and followed by a sharp [nitrate + nitrite] increase and oxygen decrease from early 2015 through 2018.

Intermediate water phosphorus (between 27.0-27.8 σ_0) reached low values in early 1997, after a decreasing trend established in early 1994 ([Figure 6.1.19](#)). A time series of mean phosphorus in this layer shows this trend clearly ([Figure 6.1.24](#)). The phosphorus maintained relatively low values throughout early 2001 when it increased sharply and maintained an increasing trend until 2005, starting a decreasing trend ending in 2010 to values similar to those observed during 1997-2001. A sharp decrease was seen in 2013, corresponding to the [nitrate + nitrite] decrease mentioned above, but increased to 2012 values during 2014 and continued increasing through 2018, to decrease again to near-record values by the end of 2020. Decreases in phosphorus in the deeper waters could persist for long periods as the oceanic ecosystem associated with Station ALOHA has been hypothesized to be phosphorus limited in recent years (Karl, 1995). Oxygen concentrations between 27.0-27.8 σ_0 vary during phosphorus decrease from early 1994 through 1997 ([Figure 6.1.24](#)) without any apparent correlation.

4.2 Thermosalinograph

Thermosalinograph measurements of near-surface temperature (NST) and near-surface salinity (NSS), as well as navigation for the 2020 HOT cruises, are presented in [Figures 6.2.1a](#) to h and [Figures 6.2.2a](#) to h. Thermosalinograph data recorded while on Station can be compromised by ship effects such as temperature changes in the water due to the ship's hull and engine temperatures. Salinity can also be influenced by the ship when on the station as the ship provides a potential source of contamination and disturbs the water being sampled. Additional problems with the thermosalinograph system during cruises were indicated in [Section 2.2.2](#).

In general, cooler near-surface temperatures and, in most cases, saltier near-surface salinities were observed at Station ALOHA compared to the data recorded near Oahu.

4.3 Meteorology

The meteorological data collected at 4-hour intervals by HOT program scientists include atmospheric pressure, sea-surface temperature, and wet and dry bulb air temperature. These data are presented in [Figures 6.3.1](#) to [6.3.3](#). As described by Winn et al. (1991), parameters show evidence of annual cycles, although the daily and weekly ranges are nearly as high as the annual range for some variables. Wind speed and direction are also collected on HOT cruises. These data are presented in [Figures 6.3.4a](#) to h.

Hourly atmospheric pressure, air temperature, sea surface temperature, and relative humidity measurements were also available from the WHOTS buoy. These data are also plotted in [Figures 6.3.1](#) through [6.3.3](#).

The thermosalinograph temperatures obtained at Station ALOHA during cruises are also plotted with the sea-surface meteorological observations in [Figure 6.3.1](#) (lower panel) and show good agreement with these measurements.

The wind vectors from the WHOTS buoy are plotted together with the ship wind observations in [Figures 6.3.4a](#) to h.

Meteorological observations taken at 5-minute intervals on board the R/V *Kilo Moana* are included in [Section 4.10](#) ([Figures 6.10.4a](#) to h).

4.4 ADCP Measurements

An overview of the shipboard ADCP data is given by the plots of velocity as a function of time and depth while on station ([Figures 6.4.1](#)) and velocity as a function of latitude and depth during transit to and from Station ALOHA and Station Kaena, combined ([Figures 6.4.2](#)). As in previous years, currents were highly variable from cruise to cruise and within each cruise.

4.5 Biogeochemistry

4.5.1 Dissolved Oxygen

A contour plot of dissolved oxygen concentration in the upper 200 dbar of the water column from 1988-2020 based on analyses of water samples collected at discrete depths is shown in [Figure 6.5.1](#). Dissolved oxygen shows a seasonal maximum between 60 and 110 m depth that develops during the summer-fall. This maximum, presumably of biological origin, is typically eroded during the winter.

4.5.2 Dissolved Inorganic Carbon and Total Alkalinity

Time-series of mixed-layer total alkalinity and DIC from 1988-2020 are presented in [Figure 6.5.2](#). A contour plot of dissolved inorganic carbon is shown in [Figure 6.5.3](#) and a contour plot of total alkalinity is shown in [Figure 6.5.4](#).

Mixed layer total alkalinity normalized to 35 ppt salinity averages approximately 2304 $\mu\text{eq kg}^{-1}$. No obvious seasonal or interannual pattern is evident. This observation is consistent with the results of Weiss *et al.* (1982) who concluded that total alkalinity normalized to salinity remains constant in both the North and South Pacific subtropical gyres. In contrast to total alkalinity, the concentration of DIC varies seasonally and interannually. DIC in the mixed layer is highest in March and April and lowest in September and October. This oscillation results from winter mixing of DIC rich waters from below and biological drawdown of CO_2 in the shallow summer mixed layers (Ishii, M. *et al.*, 2001). Using this data, Dore *et al.* (2003) found a significant decrease in the strength of the CO_2 sink between 1989 and 2001 due to changes in regional precipitation and evaporation patterns brought on by climate variability.

4.5.3 pH

The structure of pH in the upper water column closely resembles that of dissolved inorganic carbon ([Figure 6.5.3](#)). There appears to be a slight increase in pH during the winter months and gradually decreases after that. This is directly related to the drawdown of inorganic carbon in the water column during the spring and summer periods.

4.5.4 Inorganic Nutrients

Mixed layer nutrient concentrations at Station ALOHA are at or well below the detection limits of the autoanalyzer methods. Alternative high-sensitivity analytical techniques were used to measure the nanomolar levels of [nitrate + nitrite] and SRP in the upper water column.

The chemiluminescent method of Cox (1980) as modified for seawater by Garside (1982) was used to determine the [nitrate+nitrite] content of near surface (0-200 m interval) water samples. [Figure 6.5.5](#) shows the profiles obtained from our low level [nitrate + nitrite] analyses at Station ALOHA during 2020. The upper 100 m is generally depleted in [nitrate + nitrite]

(LLN) with values usually not exceeding 30 nmol kg^{-1} . A contour plot of LLN from 0-100 dbar during the 1989-2020 time period is shown in [Figure 6.5.6](#).

Dissolved inorganic P (DIP) was analyzed using the MAGnesium Induced Co-precipitation (MAGIC) method (Karl and Tien 1992). MAGIC improves both the sensitivity (detection limit $\sim 2 \text{ nM}$) and the precision of the low level SRP (LLP) determination in oligotrophic seawaters. [Figure 6.5.7](#) presents LLP data from 2020. At depths shallower than 100 m, LLP is typically less than 150 nmol kg^{-1} . A contour plot of LLP from 0-100 dbar during the period 1989-2020 is shown in [Figure 6.5.8](#). Several trends are evident, including a general reduction in DIP concentrations from $>90 \text{ nmol kg}^{-1}$ in 1989-1990 to $<30 \text{ nmol kg}^{-1}$ in 2001. The 0-100 m DIP depth integrated inventory was reduced from a high of $>10 \text{ mmol P m}^{-2}$ to a low of $<2.5 \text{ mmol P m}^{-2}$; more recently, DIP inventories appear to have stabilized and increased from these historic lows. There appear to be aperiodic injections of DIP (for example in early 1995 & 2012 and less dramatic increases in 1998, 2000, 2001, 2003, 2004, 2007, 2009, 2014, 2016, 2018 & 2019). The mechanism(s) controlling these inventory enhancements are not well understood.

4.5.5 Total Organic Carbon

A contour plot of total organic carbon (TOC) from 0 to 1000 dbar over the 2002-2017 time period is presented in [Figure 6.5.9](#). TOC concentrations are typically about $65\text{-}75 \mu\text{mol kg}^{-1}$ at the surface and decrease to about $45 \mu\text{mol kg}^{-1}$ at 800 m.

4.5.6 Particulate Bioelements

4.5.6.1 Particulate Carbon, Nitrogen and Phosphorus

Particulate carbon (PC), nitrogen (PN) and phosphorus (PPO_4) concentrations in the surface ocean over the 32 years of the program are shown in [Figures 6.5.10-6.5.15](#). PC ranges from about $1\text{-}3 \mu\text{mol kg}^{-1}$, PN from $0.1\text{-}0.6 \mu\text{mol kg}^{-1}$ and PPO_4 from $5\text{-}25 \text{ nmol kg}^{-1}$ in the upper 100 m of the water column. An annual cycle is suggested with the greatest particulate bioelement concentrations in summer/fall and the lowest in winter. Substantial interannual variability is also noted, especially for PPO_4 .

4.5.6.2 Particulate Biogenic Silica

Particulate biogenic silica (PSi) concentrations in the surface ocean over the last 24 years of the program are shown in [Figure 6.5.16](#) and [Figure 6.5.17](#). PSi typically ranges from <5 to about 30 nmol kg^{-1} in the upper 100 m of the water column. During the summer months in 1998, 2000 and 2005, PSi increased dramatically in the upper 50 m of the water. This feature appears associated with a large bloom of diatoms, as evidenced from the sharp increases in fucoxanthin ([Figure 6.5.20](#)).

4.5.7 Pigments

4.5.7.1 Standard Fluorometric Method

A contour plot of chlorophyll *a* concentrations measured using standard fluorometric techniques from 0 to 200 dbar during 1988-2020 is shown in [Figure 6.5.18](#). A chlorophyll maximum with concentrations up to about 0.3 mg m^{-3} is observed at approximately 110 m depth. The magnitude of this feature exhibits significant interannual variability, with a pronounced period of low chlorophyll concentration lasting from 1992-1998. Chlorophyll *a* concentrations at depths shallower than 50 m display an annual cycle with winter maxima and summer minima.

4.5.7.2 High Performance Liquid Chromatography

Contour plots of HPLC-determined pigment concentrations from 0 to 200 dbar during 1988-2020 are shown in Figures 6.5.19-6.5.21. The pigments have been segregated into three chromophore classes: chlorophylls (chlorophyll *a*, chlorophyll *b*, and chlorophyll *c*; [Figure 6.5.19](#)), photosynthetic carotenoids (19'-butanoyloxyfucoxanthin, fucoxanthin, and 19'-hexanoyloxyfucoxanthin; [Figure 6.5.20](#)) and photo-protective carotenoids (diadinoxanthin, zeaxanthin, and α/β -carotene; [Figure 6.5.21](#)).

Chlorophyll *a* includes contributions by monovinyl and divinyl chlorophyll *a* and serves as a proxy for phytoplankton community biomass. Chlorophyll *b* includes contributions by monovinyl and divinyl chlorophyll *b* and is primarily derived from *Prochlorococcus* spp. since chlorophyll *b*-containing eukaryotes (e.g., chlorophytes and prasinophytes) are relatively rare at Station ALOHA as evidenced by the low and variable concentrations of lutein (chlorophyte marker) and prasinoxanthin (prasinoxanthin marker) (data not shown). Chlorophyll *c* includes contributions by chlorophylls $c_1+c_2+c_3$ and serves as a proxy for chromophyte microalgal biomass (e.g., haptophytes, pelagophytes and diatoms). Photosynthetic carotenoids are typically useful for distinguishing phytoplankton at the “Class” level and the dominant species found at Station ALOHA include 19'-butanoyloxyfucoxanthin (pelagophyte marker), fucoxanthin (diatom marker), and 19'-hexanoyloxyfucoxanthin (haptophyte marker). The photo-protective carotenoids, diadinoxanthin, zeaxanthin, and α/β -carotene are respectively associated with chromophyte microalgae, cyanobacteria (e.g., *Prochlorococcus*, *Synechococcus* and *Trichodesmium* spp.), and all members of the phytoplankton community.

Pigment distributions display distinct temporal patterns at Station ALOHA, with highest pelagophyte abundances during the periods 1989-1991 and 1996-2002. For other key groups, such as the haptophytes and cyanobacteria, there appears to be a recent post-1996 enhancement in their biomass relative to the previous 7-year period of observation. Diatoms, on the other hand, display sharp increases during the summer months of certain years (e.g., 1998 and 2000). These interannual variations in phytoplankton populations are likely linked to climate forcing (e.g., ENSO and PDO) and are currently under investigation.

4.5.8 Adenosine 5'-triphosphate

The concentration of particulate ATP resembles those of the particulate bioelements, showing maximum concentrations near the surface and a decreasing profile with depth ([Figure 6.5.22](#)). Surface ocean ATP varies between years more than three-fold, with conspicuously high levels noted in 1994-1995.

4.6 Biogeochemical Rate Measurements

4.6.1 Primary Production

The depth-integrated (0-200 m) results of the ^{14}C incubations and pigment determinations for samples collected from CTD casts in 2020 are presented in [Table 4.1](#). Also included for each cruise is the incubation duration and the total incident irradiance (400-700 nm) measured on the deck of the ship during the incubation period. Integrated primary production rates measured over all 32 years of the program are shown in [Figure 6.6.1](#). A contour plot is shown in [Figure 6.6.2](#). Depth-integrated rates of primary production vary seasonally, with summer maxima and winter minima. Overall, primary production varies by approximately a factor of five, ranging from ~ 200 to $1000 \text{ mg C m}^{-2} \text{ d}^{-1}$. The mean ($\pm \text{sd}$) depth integrated primary production for the entire 32 year data set is $534 \pm 136 \text{ mg C m}^{-2} \text{ d}^{-1}$. Although this value is higher than historical measurements for the oceanic central gyres (Ryther 1969), it is consistent with more recent measurements (Martin *et al.*, 1987; Laws *et al.*, 1989; Knauer *et al.*, 1990).

Table 4.1: Primary production and pigment summary integrated values (0-200 m)

HOT	Incident Irradiance ($\text{E m}^{-2} \text{ d}^{-1}$)	Pigments (mg m^{-2})		Incubation Duration (hrs)	Light Assimilation Rates ($\text{mg C m}^{-2} \text{ d}^{-1}$)
		Chl a	Pheo		
319	35.36	19.2	43.9	14.50	609
320	51.72	20.3	48.9	14.50	725
321	46.87	18.0	35.9	14.75	NA
322	43.50	20.8	47.1	14.00	612
323	43.20	19.5	36.4	13.50	NA
324	20.1	22.4	41.6	13.75	592
325	25.82	19.3	30.0	14.75	495

4.6.2 Particle Flux

Particulate carbon (PC), nitrogen (PN), phosphorus (PPO_4) and silica (PSi) fluxes at 150 m are presented in [Table 4.2](#) and [Figure 6.6.3](#) for the 1988-2020 time period. All four fluxes show large month-to-month and interannual variations. The magnitudes of PC and PN fluxes vary by about a factor of five, while PPO_4 and PSi fluxes varies by about a factor of 20. These particle flux measurements are consistent in magnitude with those measured in the central North Pacific Ocean during the VERTEX program (Martin *et al.*, 1987; Knauer *et al.*, 1990). However, the HOT data set reveals interannual changes not documented by earlier studies

Table 4.2: Station ALOHA 2020 sediment trap flux data

HOT	PC Flux ($\text{mg m}^{-2} \text{d}^{-1}$)		PN Flux ($\text{mg m}^{-2} \text{d}^{-1}$)		PPO_4 Flux ($\text{mg m}^{-2} \text{d}^{-1}$)		PSi Flux ($\text{mg m}^{-2} \text{d}^{-1}$)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
319	20.2	5.0	2.81	0.85	0.390	0.147	3.125	0.629
320	29.6	3.6	4.89	0.79	0.193	0.005	5.227	0.433
321	32.2	2.7	4.19	0.40	0.364	0.011	4.734	0.579
322	21.3	2.7	3.22	0.43	0.213	0.016	4.641	0.574
323	25.5	5.2	3.62	0.86	0.367	0.039	3.677	0.324
324	26.6	1.5	3.64	0.14	0.479	0.233	2.366	0.474
325	16.7	1.6	2.42	0.27	0.289	0.039	1.575	0.404

4.7 Optical Measurements

4.7.1 Solar Irradiance

Incident irradiance (400-700 nm wavelength band) measured using a LICOR LI-1500 during the cruise is shown in [Figures 6.7.1a-h](#) (upper panel). Incident irradiance is dependent on cloud cover, so it can potentially vary greatly from cruise-to-cruise or even day-to-day. But in general, as would be expected, higher values are measured during the summer months (HOT-320) and lower values in the winter months (HOT-325). To help interpret the results, integrated incident irradiance measured during the Primary Production incubation period is included in [Table 4.1](#).

4.7.2 Downwelling Irradiance and Upwelling Radiance

Photosynthetically available radiation (PAR) was measured using a Satlantic HyperPro. [Figure 6.7.2](#) shows the time-series of the 1 % light level and K_{PAR} during the 23 years we've been collecting in-situ PAR data. Both vary seasonally. The average 1 % light-level at Station ALOHA is 105.4 m while the average K_{PAR} between 100 & 150m is 0.0440 m^{-1} .

4.7.3 Laser In-Situ Scattering and Transmissometry (LISST-100X)

On July 24th 2020, the manufacturer of the LISST-100X (Sequoia Scientific) announced that the LISST-100X would be discontinued and no longer serviceable. The replacement instrument (the LISST-200X) has a shorter pathlength and requires evaluation for limit of detection in the relatively clear waters of Station ALOHA. For this reason, we are reprocessing the full LISST-100X dataset for final release and conducting comparisons between LISST 100-X and LISST 200-X detection limits for 2020-2021. No additional LISST data will be released prior to this final re-processing.

4.8 Microbial Community Structure

Depth profiles of heterotrophic bacterial (actually non-pigmented picoplankton and archaea) and *Prochlorococcus* abundances for each cruise are presented in [Figure 6.8.1](#). A contour plot is shown in [Figure 6.8.2](#). At the surface, heterotrophic bacterial numbers (shown in blue) range from 4 to 7×10^5 cells ml⁻¹. In most cases bacterial numbers decrease with depth although there are some profiles where the numbers remain fairly constant with depth throughout the euphotic zone. *Prochlorococcus* cells (shown in red) are found at concentrations ranging from around 2 to 3×10^5 ml⁻¹ at the surface and usually decrease with depth but with a subsurface maximum between 50 and 125 m.

Depth profiles of *Synechococcus* and pigmented eukaryotes are presented in [Figure 6.8.3](#). A contour plot is shown in [Figure 6.8.4](#). At the surface, *Synechococcus* numbers (shown in blue) range from 1 to 5×10^3 ml⁻¹, and decrease with depth with a subsurface maxima between 50 and 100 m. The abundances of picoeukaryotes (shown in red) typically ranges from 1 to 3×10^3 ml⁻¹, and similar to *Synechococcus*, the eukaryote populations generally decline with depth, occasionally exhibiting a subsurface maximum.

4.9 Zooplankton Community Structure

Temporal variation in mesozooplankton biomass during 1994-2020 is presented in [Figure 6.9.1](#). Both zooplankton dry weight biomass (upper panel) and wet weight biomass (lower panel) are plotted. On average, zooplankton dry weight biomass was 12% of zooplankton wet weight biomass during the day (shown in red) and 13% during the night (shown in blue). The difference in biomass between zooplankton collected during the night and zooplankton collected during the day at Station ALOHA was significant for both dry and wet weights, and was caused by the upward migration of deep-living zooplankton and micronekton after sunset.

4.10 WHOTS Mooring

An overview of the data obtained with the Microcats in the WHOTS-16 mooring is given by the hourly averaged plots of temperature, salinity, and calculated potential density (σ_0) as a function of time for each of the instruments ([Figures 6.10.1a](#) to s), as well as contour plots of these variables as a function of time and depth ([Figure 6.10.1t](#)).

An overview of the mooring's ADCP data is given by the contour plots of zonal and meridional current velocity as a function of time and depth ([Figure 6.10.2](#)).

Data from the 10 and 30 m VMCMs are also shown in the plots of zonal and meridional current velocity as a function of time ([Figure 6.10.3](#)).

Data obtained with the WHOTS buoy meteorological instruments during HOT cruises conducted on the R/V *Kilo Moana* are shown together with the ship's meteorological observations taken at 5-minute intervals ([Figures 6.10.4a](#) to h). Figures (1) include the ship's port and starboard anemometers wind speed and direction relative to the ship, and the absolute wind speed and direction (true) after correcting for ship's speed and heading (Sperry Marine Digital Gyroscope), together with the buoy's measurements from the two data loggers. Figures (2) include the ship and buoy's measurements of short and longwave radiation ([Section 2.3](#)), the ship's measurements of Photosynthetically Active Radiation (PAR, Biospherical Quantum Scalar Reference), air temperature, and humidity. Figures (3) include ship's and buoy's measurements of barometric pressure and rain rate and accumulation.

During cruise HOT-319 on the R/V *Kilo Moana* the port anemometer exhibited few glitches in the relative wind direction. This problem was corrected and both anemometers functioned correctly during the rest of 2020 cruises. The RM Young precipitation gauge did not work properly during all 2020 cruises. The ORG precipitation gauges exhibited many glitches during all 2020 cruises. The shortwave, longwave radiation and PAR sensors worked very well for all cruises. The humidity temperature sensor had temperatures about 2°C higher than the RM Young RTD air temperature during all 2020 cruises, and the humidity sensor did not function properly during HOT-320 through -325.

The WHOTS-16 buoy logged data during cruises HOT-318 through -325 in data loggers #7 and #8. The data logger #8 only recorded wind data during HOT-318 and -319 (with some offset). The data logger #7 did not record humidity and air temperature data during HOT-318 and -319; and the humidity showed glitches during HOT-321, and didn't work during the first half of HOT-322, and during HOT-323 through -325.

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6.0 FIGURES

6.1 Hydrography

[Figure 6.1.1a-h](#): [Upper left panel] Temperature, salinity, oxygen and potential density (σ_0) as a function of pressure for the WOCE deep cast at Station ALOHA for each HOT cruise. [Upper right panel] Plot of [nitrate + nitrite], soluble reactive phosphorus, silicate, and bottle dissolved oxygen as a function of potential temperature for all water samples. [Lower left panel] CTD temperature and salinity plotted as a function of pressure to 1000 dbar for all casts at ALOHA. [Lower right panel] Salinity and oxygen from CTD and water samples plotted as a function of potential temperature. Only the CTD oxygen traces in which bottle oxygen samples were taken are included.

[Figure 6.1.2a-h](#): [1st panel] Stack plots of temperature versus pressure to 1000 dbar at Station ALOHA. Offset is 2 °C. [2nd panel] Stack plots of salinity versus pressure to 1000 dbar at Station ALOHA. The offset is 0.1.

[Figure 6.1.3a-h](#): Stack plots of CTD chloropigment (fluorescence) and bottle fluorometric chlorophylls+pheopigments versus pressure to 200 dbar [1st panel] and versus to 25.5 kg/m³ [2nd panel] at Station ALOHA. Chloropigment values have been offset by 0.2 µg/l for both plots.

[Figure 6.1.4a-h](#): [Upper left panel] Temperature, salinity, oxygen and potential density (σ_0) as a function of pressure for the cast at Station Kahe for each HOT cruise in which the station was occupied. [Upper right panel] Plot of CTD and bottle dissolved oxygen and salinity as a function of potential temperature for water samples at Station Kahe. [Lower left panel] Plot of temperature, salinity, oxygen, and σ_0 as a function of pressure at Station Kaena for each HOT cruise in which the station was occupied. [Lower right panel] Plot of CTD and bottle salinity and oxygen as a function of potential temperature at Station Kaena.

[Figure 6.1.5](#): [Upper panel] Potential temperature versus pressure for all deep casts in 2020. [Lower panel]: Potential temperature versus pressure deeper than 2500 dbar for all deep casts in 2020.

[Figure 6.1.6](#): [Upper panel] Salinity versus potential temperature for all deep casts in 2020. [Lower panel]: Salinity versus potential temperature for all deep casts in 2020 in the 1-5 °C range.

[Figure 6.1.7](#): [Upper panel] Oxygen concentrations from calibrated oxygen sensor data versus potential temperature for all deep casts in 2020. [Lower panel] Oxygen versus potential temperature for all deep casts in 2020 in the 1-5 °C range.

[Figure 6.1.8](#): Contour plot of CTD potential temperature versus pressure for HOT cruises 1-325.

[Figure 6.1.9](#): Contour plot of σ_0 , calculated from CTD pressure, temperature and salinity, versus pressure for HOT cruises 1-325.

[Figure 6.1.10](#): Contour plot of CTD salinity versus pressure for HOT cruises 1-325.

[Figure 6.1.11](#): Contour plot of CTD salinity versus σ_0 to 27.5 σ_0 for HOT cruises 1-325. A heavy line connects the average σ_0 at the sea surface.

[Figure 6.1.12](#): Contour plot of bottle salinity versus pressure for HOT cruises 1-325. The solid circles indicate location of samples in the water column.

[Figure 6.1.13](#): Contour plot of bottle salinity versus σ_0 to 27.5 σ_0 for HOT cruises 1-325. A heavy line connects the average σ_0 at the sea surface.

[Figure 6.1.14](#): Contour plot of bottle oxygen versus pressure for HOT cruises 1-325. The solid circles indicate location of samples in the water column.

[Figure 6.1.15](#): Contour plot of bottle oxygen versus σ_0 to 27.5 σ_0 for HOT cruises 1-325. A heavy line connects the average σ_0 at the sea surface.

[Figure 6.1.16](#): Contour plot of [nitrate + nitrite] versus pressure for HOT cruises 1-325. The solid circles indicate location of samples in the water column.

[Figure 6.1.17](#): Contour plot of [nitrate + nitrite] versus σ_0 to 27.5 σ_0 for HOT cruises 1-325. A heavy line connects the average σ_0 at the sea surface.

[Figure 6.1.18](#): Contour plot of [nitrate + nitrite] versus σ_0 from 27.0 to 27.8 σ_0 for HOT cruises 1-325.

[Figure 6.1.19](#): Contour plot of soluble reactive phosphorus versus σ_0 from 27.0 to 27.8 σ_0 for HOT cruises 1-325.

[Figure 6.1.20](#): Contour plot of soluble reactive phosphorus versus pressure for HOT cruises 1-325. The solid circles indicate location of samples in the water column.

[Figure 6.1.21](#): Contour plot of soluble reactive phosphorus versus σ_0 to 27.5 σ_0 for HOT cruises 1-325. A heavy line connects the average σ_0 at the sea surface.

[Figure 6.1.22](#): Contour plot of silicate versus pressure for HOT cruises 1-325. The solid circles indicate location of samples in the water column.

[Figure 6.1.23](#): Contour plot of silicate versus σ_0 to 27.5 σ_0 for HOT cruises 1-325. A heavy line connects the average σ_0 at the sea surface.

[Figure 6.1.24](#): Time series of mean bottle dissolved oxygen for HOT cruises 1-325 (upper panel), [nitrate + nitrite] (middle panel) and soluble reactive phosphorus (lower panel) between 27.0 and 27.8 σ_0 isopycnals. The smooth line is the spline fit to the data. The asterisks indicate the annual mean.

6.2 Thermosalinograph

[Figure 6.2.1a-h](#): Thermosalinograph data for HOT-318 through-325 cruises in 2020. Continuous near-surface temperature, salinity and σ_0 (continuous lines), CTD data at a depth of the thermosalinograph water intake (circles), and salinity bottle data (crosses). The section between the vertical dashed lines indicates the period when Station ALOHA was occupied.

[Figure 6.2.2a-h](#): Navigation data during HOT-318 through -325 cruises in 2020: latitude, longitude, and ship speed. The section between the vertical dashed lines indicates the period when Station ALOHA was occupied.

6.3 Meteorology

[Figure 6.3.1](#): [Upper panel] Atmospheric pressure while at Station ALOHA for 2020 HOT cruises (open circles), and WHOTS buoy hourly measurements throughout the year (continuous line). [Lower panel] Sea surface temperature measured from a bucket sample while at Station ALOHA for 2020 HOT cruises (open circles), WHOTS buoy hourly measurements throughout the year (continuous thin line), and near-surface temperatures from the thermosalinograph while at Station ALOHA during HOT cruises (thick line).

[Figure 6.3.2](#): [Upper panel] Dry bulb air temperature while at Station ALOHA for 2020 HOT cruises (open circles), and WHOTS buoy hourly measurements throughout the year (continuous line). [Lower panel] Wet bulb air temperature while at Station ALOHA for 2020 HOT cruises.

[Figure 6.3.3](#): [Upper panel] Sea surface temperature minus dry air temperature while at Station ALOHA for 2020 HOT cruises (open circles), and WHOTS buoy hourly measurements throughout the year (continuous line). [Lower panel] Relative humidity at Station ALOHA for 2020 HOT cruises and WHOTS buoy hourly measurements throughout the year (continuous line).

[Figures 6.3.4a](#) to h: [Upper panel] True winds measured at Station ALOHA for 2020 HOT cruises. [Middle panel] Continuous true wind record from the ship's anemometer during HOT cruises. [Lower panel] True winds measured by WHOTS buoy (no WHOTS wind data available for HOT-318 to -325). The orientation of the arrows indicates the wind direction; up is northward, right is eastward.

6.4 ADCP Measurements

[Figures 6.4.1a-h](#): Velocity fields at Station ALOHA were obtained during 2020 cruises conducted on the R/V *Kilo Moana* ([Section 2.4](#)). Top panels show hourly averages while the ship was on station. The orientation of each stick gives the direction of the current: up is northward, and to the right is eastward. Bottom panels show the results of a least-squares fit of hourly averages to a mean, trend, semi-diurnal and diurnal tides; the on-station time-series were not long enough to fit an inertial cycle. In the first column, the arrow shows the mean current and the headless stick shows the sum of the mean plus the trend at the end of the

station. For each harmonic, the current ellipse is shown in the first column. The orientation of the stick in the second column shows the direction of the harmonic component of the current at the beginning of the station and the arrowhead at the end of the stick shows the direction of rotation of the current vector around the ellipse. Some of the station data gaps are due to excursions to retrieve the primary productivity array and floating sediment traps.

[Figures 6.4.2a-h](#): Velocity fields on the transits to and from Station ALOHA and Station Kaena.

The orientation of each stick gives the direction of the current: up is northward, and to the right is eastward. Velocity is shown as a function of latitude averaged in 10-minute intervals.

6.5 Biogeochemistry

[Figure 6.5.1](#): Contour plot of bottle dissolved oxygen versus pressure for HOT cruises 1-325 from 0-200 dbar. Solid dots indicate water column sample locations.

[Figure 6.5.2](#): [Upper panel] Time series of mean mixed layer total alkalinity (normalized to 35 ppt salinity) for HOT cruises 1-325. [Lower panel] Mixed layer dissolved inorganic carbon (normalized to 35 ppt salinity) for HOT cruises 1-325. Error bars represent standard deviation of pooled samples collected between 0 and 45 dbar.

[Figure 6.5.3](#): [Upper panel] Contour plot of dissolved inorganic carbon versus pressure for HOT cruises 1-325 from 0-200 dbar. Solid dots indicate water column sample locations. [Lower panel] Contour plot of dissolved inorganic carbon normalized to 35 ppt salinity.

[Figure 6.5.4](#): [Upper panel] Contour plot of total alkalinity versus pressure for HOT cruises 1-325 from 0-200 dbar. Solid dots indicate water column sample locations. [Lower panel] Contour plot of total alkalinity normalized to 35 ppt salinity.

[Figure 6.5.5](#): Depth profiles from 0-150 dbar of low-level [nitrate + nitrite] at Station ALOHA for 2020 HOT cruises by the high-sensitivity chemiluminescence method.

[Figure 6.5.6](#): [Upper panel] Contour plot from 0-100 dbar of low-level [nitrate + nitrite] at Station ALOHA for HOT cruises 1-325. [Lower panel] 0-100 dbar integral of LLN at Station ALOHA for HOT cruises 1-325.

[Figure 6.5.7](#): Depth profile from 0-250 dbar of low-level soluble reactive phosphorus at Station ALOHA for 2020 HOT cruises by the high-sensitivity magnesium induced coprecipitation (MAGIC) method.

[Figure 6.5.8](#): [Upper panel] Contour plot from 0-100 dbar of low-level soluble reactive phosphorus at Station ALOHA for HOT cruises 1-325. [Lower panel] 0-100 dbar integral of LLP at Station ALOHA for HOT cruises 1-325.

[Figure 6.5.9](#): Contour plot from 0-1000 dbar of total organic carbon at Station ALOHA for HOT cruises 134-295. Solid dots indicate water column sample locations.

[**Figure 6.5.10**](#): [Upper panel] Mean concentrations of particulate carbon at Station ALOHA for HOT cruises 1-325 from 0-50 dbar. [Lower panel] Mean concentrations of particulate carbon at Station ALOHA for HOT cruises 1-325 from 50-100 dbar. Error bars represent standard deviation of pooled samples within specified depth ranges.

[**Figure 6.5.11**](#): Contour plot from 0-350 dbar of particulate carbon at Station ALOHA for HOT cruises 1-325. Solid dots indicate water column sample locations.

[**Figure 6.5.12**](#): [Upper panel] Mean concentrations of particulate nitrogen at Station ALOHA for HOT cruises 1-325 from 0-50 dbar. [Lower panel] Mean concentrations of particulate nitrogen at Station ALOHA for HOT cruises 1-325 from 50-100 dbar. Error bars represent standard deviation of pooled samples within specified depth ranges.

[**Figure 6.5.13**](#): Contour plot from 0-350 dbar of particulate nitrogen at Station ALOHA for HOT cruises 1-325. Solid dots indicate water column sample locations.

[**Figure 6.5.14**](#): [Upper panel] Mean concentrations of particulate phosphorus at Station ALOHA for HOT cruises 1-325 from 0-50 dbar. [Lower panel] Mean concentrations of particulate phosphorus at Station ALOHA for HOT cruises 1-325 from 50-100 dbar. Error bars represent standard deviation of pooled samples within specified depth ranges.

[**Figure 6.5.15**](#): Contour plot from 0-350 dbar of particulate phosphorus at Station ALOHA for HOT cruises 1-325. Solid dots indicate water column sample locations.

[**Figure 6.5.16**](#): [Upper panel] Mean concentrations of particulate silica at Station ALOHA for HOT cruises 79-325 from 0-50 dbar. [Lower panel] Mean concentrations of particulate silica at Station ALOHA for HOT cruises 79-325 from 50-100 dbar. Error bars represent standard deviation of pooled samples within specified depth ranges.

[**Figure 6.5.17**](#): Contour plot from 0-200 dbar of particulate biogenic silica at Station ALOHA for HOT cruises 79-325. Solid dots indicate water column sample locations.

[**Figure 6.5.18**](#): Contour plot from 0-200 dbar of fluorometric chlorophyll *a* concentrations at Station ALOHA for HOT cruises 2-325. Solid dots indicate water column sample locations.

[**Figure 6.5.19**](#): Contour plots from 0-200 dbar of HPLC chlorophyll (chlorophyll *a*, chlorophyll *b* & chlorophyll *c*) concentrations at Station ALOHA for HOT cruises 1-325.

[**Figure 6.5.20**](#): Contour plots from 0-200 dbar of HPLC photosynthetic carotenoid (19'-butanoyloxyfucoxanthin, fucoxanthin & 19'-hexanoyloxyfucoxanthin) concentrations at Station ALOHA for HOT cruises 1-325.

[**Figure 6.5.21**](#): Contour plots from 0-200 dbar of HPLC photo-protective carotenoid (diadinoxanthin, zeaxanthin & α - plus β -carotene) concentrations at Station ALOHA for HOT cruises 1-325.

[**Figure 6.5.22**](#): Contour plot from 0-350 dbar of particulate adenosine 5'-triphosphate concentrations at Station ALOHA for HOT cruises 1-325. Solid dots indicate water column sample locations.

6.6 Biogeochemical Rate Measurements

[**Figure 6.6.1**](#): [Upper panel] Integrated (0-200 m) primary production rates from 1988-2020. Filled circles and crosses indicate *in situ* and on deck incubations, respectively. Solid line represents the average production ($534 \text{ mg C m}^{-2} \text{ d}^{-1}$), dashed lines are \pm one standard deviation ($136 \text{ mg C m}^{-2} \text{ d}^{-1}$). [Lower panel] 3-point running mean of integrated primary production rates. Symbols same as in upper panel.

[**Figure 6.6.2**](#): Contour plot from 0-100 m of primary production rates at Station ALOHA for HOT cruises 1-325. Solid dots indicate water column sample locations.

[**Figure 6.6.3**](#): Particulate carbon flux [Top panel], Particulate nitrogen flux [2^{nd} panel], Particulate phosphorus flux [3^{rd} panel] and Particulate silica flux [Bottom panel] at 150 m measured on all HOT cruises from 1988-2020. Error bars represent the standard deviation of determinations from triplicate particle interceptor traps.

6.7 Optical Measurements

[**Figure 6.7.1a–h**](#): [Upper panel] Incident irradiance (400-700 nm wavelength band) measured using a Li-COR LI-1500 data logger during each cruise. The red, blue & green lines represent the minimum, average & maximum light value respectively of 10-minute intervals. The total incident irradiance measured when the primary production array was out (represented by the light-blue shaded area) is also calculated and included at the top of each figure. [Lower left panel] Photosynthetically available radiation (PAR_z : derived from K_{PAR} using the average downcast surface light) versus depth for every profile at Station ALOHA. [Lower right panel] PAR attenuation coefficient (K_{PAR}) versus depth for every profile at Station ALOHA.

[**Figure 6.7.2**](#): [Upper panel] Depth of the 1% surface PAR light level for HOT cruises 90-325. The solid red line represents the average 1% surface PAR light depth (105.4 m) at Station ALOHA. [Lower panel] Mean PAR attenuation coefficient (K_{PAR}) for HOT cruises 90-325 from 100-150m. The solid red line represents the average K_{PAR} (0.0440 m^{-1}) at Station ALOHA.

6.8 Microbial Community Structure

[Figure 6.8.1](#): Depth profiles (0-200 m) of Heterotrophic bacteria (blue) and *Prochlorococcus* numbers (red) measured by flow cytometry at Station ALOHA for 2019.

[Figure 6.8.2](#): Contour plots from 0-200 dbar of Heterotrophic bacteria [Upper panel] and *Prochlorococcus* numbers [Lower panel] at Station ALOHA for HOT cruises 177-317. Solid dots indicate water column sample locations.

[Figure 6.8.3](#): Depth profiles (0-200 m) of *Synechococcus* (blue) and Eukaryote numbers (red) measured by flow cytometry at Station ALOHA for 2019.

[Figure 6.8.4](#): Contour plots from 0-200 dbar of *Synechococcus* [Upper panel] and Eukaryote numbers [Lower panel] at Station ALOHA for HOT cruises 23-317. Solid dots indicate water column sample locations.

6.9 Zooplankton Community Structure

[Figure 6.9.1](#): Dry weight biomass [Upper panel] and wet weight biomass [Lower panel] of mesozooplankton collected at Station ALOHA for HOT cruises 51-325. Both nighttime (blue) and daytime (red) biomass are plotted.

6.10 WHOTS Mooring

[Figure 6.10.1.a](#): Temperature, salinity, and potential density (σ_0) from Microcat SBE-37 deployed at 1 m on the WHOTS-16 mooring.

[Figure 6.10.1.b](#): Temperature, salinity, and potential density (σ_0) from Microcat SBE-37 deployed at 7 m on the WHOTS-16 mooring.

[Figure 6.10.1.c](#): Temperature, salinity, and potential density (σ_0) from Microcat SBE-37 deployed at 15 m on the WHOTS-16 mooring.

[Figure 6.10.1.d](#): Temperature, salinity, and potential density (σ_0) from Microcat SBE-37 deployed at 25 m on the WHOTS-16 mooring.

[Figure 6.10.1.e](#): Temperature, salinity, and potential density (σ_0) from Microcat SBE-37 deployed at 35 m on the WHOTS-16 mooring.

[Figure 6.10.1.f](#): Temperature, salinity, and potential density (σ_0) from Microcat SBE-37 deployed at 40 m on the WHOTS-16 mooring.

[Figure 6.10.1.g](#): Pressure, temperature, salinity, and potential density (σ_0) from Microcat SBE-37 deployed at 45 m on the WHOTS-16 mooring.

[Figure 6.10.1.h](#): Temperature, salinity, and potential density (σ_0) from Microcat SBE-37 deployed at 50 m on the WHOTS-16 mooring.

[Figure 6.10.1.i](#): Temperature, salinity, and potential density (σ_0) from Microcat SBE-37 deployed at 55 m on the WHOTS-16 mooring.

[Figure 6.10.1.j](#): Temperature, salinity, and potential density (σ_0) from Microcat SBE-37 deployed at 65 m on the WHOTS-16 mooring.

[Figure 6.10.1.k](#): Temperature, salinity, and potential density (σ_0) from Microcat SBE-37 deployed at 75 m on the WHOTS-16 mooring.

[Figure 6.10.1.l](#): Temperature, salinity, and potential density (σ_0) from Microcat SBE-37 deployed at 85 m on the WHOTS-16 mooring.

[Figure 6.10.1.m](#): Pressure, temperature, salinity, and potential density (σ_0) from Microcat SBE-37 deployed at 95 m on the WHOTS-16 mooring.

[Figure 6.10.1.n](#): Pressure, temperature, salinity, and potential density (σ_0) from Microcat SBE-37 deployed at 105 m on the WHOTS-16 mooring.

[Figure 6.10.1.o](#): Pressure, temperature, salinity, and potential density (σ_0) from Microcat SBE-37 deployed at 120 m on the WHOTS-16 mooring.

[Figure 6.10.1.p](#): Pressure, temperature, salinity, and potential density (σ_0) from Microcat SBE-37 deployed at 135 m on the WHOTS-16 mooring.

[Figure 6.10.1.q](#): Pressure, temperature, salinity, and potential density (σ_0) from Microcat SBE-37 deployed at 155 m on the WHOTS-16 mooring.

[Figure 6.10.1.r](#): Pressure, temperature, salinity, and potential density (σ_0) from Seacat SBE-16 deployed at 4714 m on the WHOTS-16 mooring.

[Figure 6.10.1.s](#): Pressure, temperature, salinity, and potential density (σ_0) from Seacat SBE-16 deployed at 4714 m on the WHOTS-16 mooring.

[Figure 6.10.1.t](#): Temperature, salinity and potential density (σ_0) contours as a function of depth and time from Microcat instruments in the WHOTS-16 mooring

[Figure 6.10.2.a](#): Zonal and meridional current velocity contours as a function of depth and time for the upward-looking ADCP deployed at 47.5 m in the WHOTS-16 mooring.

[Figure 6.10.2.b](#): Zonal and meridional current velocity contours as a function of depth and time for the upward-looking ADCP deployed at 125 m in the WHOTS-16 mooring.

[Figure 6.10.3](#): Zonal and meridional current velocity as a function of time for the VMCMs deployed at 10 and 30 m on the WHOTS-16 mooring.

[Figure 6.10.4.a.1](#): Time-series of wind speed [top panel] and direction [second panel] relative to the ship; ship speed and heading [third panel]; “true” wind speed [fourth panel] and direction [fifth panel] in Earth coordinates for the port (red) and starboard (blue) anemometers on the R/V *Kilo Moana* during the HOT-318 cruise. The fourth and fifth panels also include data from the WHOTS anemometers (circles). The vertical solid lines indicate the initial and final time when the station ALOHA was occupied.

[Figure 6.10.4.a.2](#): Time-series of short wave radiation [top panel]; longwave radiation [second panel]; Photosynthetically Active Radiation [third panel]; air temperature from the Young RTD (red) and the Rotronic (blue) [fourth panel]; and humidity from instruments on the R/V *Kilo Moana* during the HOT-318 cruise. The top, second, fourth, and fifth panels also include data from the WHOTS buoy instruments (circles). The vertical solid lines indicate the initial and final time when the station ALOHA was occupied.

[Figure 6.10.4.a.3](#): Time-series of barometric pressure [top panel]; rain rate [second panel] and rain accumulation [third panel] from the OSI Optical Rain Gauge; and precipitation rate from the RM Young [fourth panel] on the R/V *Kilo Moana* during the HOT-318 cruise. The plots also include data from the WHOTS buoy instruments (circles). The vertical solid lines indicate the initial and final time when the station ALOHA was occupied.

[Figure 6.10.4.b.1](#): Same as in Figure 6.10.4.a.1, but for the HOT-319 cruise.

[Figure 6.10.4.b.2](#): Same as in Figure 6.10.4.a.2, but for the HOT-319 cruise.

[Figure 6.10.4.b.3](#): Same as in Figure 6.10.4.a.3, but for the HOT-319 cruise.

[Figure 6.10.4.c.1](#): Same as in Figure 6.10.4.a.1, but for the HOT-320 cruise.

[Figure 6.10.4.c.2](#): Same as in Figure 6.10.4.a.2, but for the HOT-320 cruise.

[Figure 6.10.4.c.3](#): Same as in Figure 6.10.4.a.3, but for the HOT-320 cruise.

[Figure 6.10.4.d.1](#): Same as in Figure 6.10.4.a.1, but for the HOT-321 cruise.

[Figure 6.10.4.d.2](#): Same as in Figure 6.10.4.a.2, but for the HOT-321 cruise.

[Figure 6.10.4.d.3](#): Same as in Figure 6.10.4.a.3, but for the HOT-321 cruise.

[Figure 6.10.4.e.1](#): Same as in Figure 6.10.4.a.1, but for the HOT-322 cruise.

[Figure 6.10.4.e.2](#): Same as in Figure 6.10.4.a.2, but for the HOT-322 cruise.

[Figure 6.10.4.e.3](#): Same as in Figure 6.10.4.a.3, but for the HOT-322 cruise.

[Figure 6.10.4.f.1](#): Same as in Figure 6.10.4.a.1, but for the HOT-323 cruise.

[Figure 6.10.4.f.2](#): Same as in Figure 6.10.4.a.2, but for the HOT-323 cruise.

[Figure 6.10.4.f.3](#): Same as in Figure 6.10.4.a.3, but for the HOT-323 cruise.

[Figure 6.10.4.g.1](#): Same as in Figure 6.10.4.a.1, but for the HOT-324 cruise.

[Figure 6.10.4.g.2](#): Same as in Figure 6.10.4.a.2, but for the HOT-324 cruise.

[Figure 6.10.4.g.3](#): Same as in Figure 6.10.4.a.3, but for the HOT-324 cruise.

[Figure 6.10.4.h.1](#): Same as in Figure 6.10.4.a.1, but for the HOT-325 cruise.

[Figure 6.10.4.h.2](#): Same as in Figure 6.10.4.a.2, but for the HOT-325 cruise.

[Figure 6.10.4.h.3](#): Same as in Figure 6.10.4.a.3, but for the HOT-325 cruise.

7.0 HOT PROGRAM PRESENTATIONS AND PUBLICATIONS

The following is a listing of Presentations & Publications as of July 2022. For an up-to-date listing please refer to our Web site (hahana.soest.hawaii.edu/hot/hotpub.html).

7.1 Invited Presentations and Published Abstracts

1. 1988 Karl, D. NSF-sponsored symposium on Dissertations in Chemical Oceanography, "Research opportunities in Hawaiian waters", Honolulu, Hawaii, November 1988.
2. 1988 Karl, D. NSF/GOFS-sponsored workshop on sediment traps, "Determination of total C, N, P flux" and "Screens: A potential solution to the problem of swimmers", Gulf Coast Research Laboratory, Mississippi, November 1988.
3. 1989 Winn, C. D., S. Chiswell, D. M. Karl and R. Lukas. Long time-series research in the Central Pacific Ocean. The Oceanography Society 1st Annual Meeting, Monterey, California.
4. 1990 Karl, D., R. Letelier, D. Bird, D. Hebel, C. Sabine and C. Winn. An Oscillatoria bloom in the oligotrophic North Pacific Ocean near the GOFS station ALOHA. EOS, Transactions of the American Geophysical Union 71, 177-178.
5. 1990 Winn, C. D., D. Hebel, R. Letelier, D. Bird and D. Karl. Variability in biogeochemical fluxes in the oligotrophic central Pacific: Results of the Hawaii Ocean Time- Series Program. EOS, Transactions of the American Geophysical Union 71, 190.
6. 1990 Chiswell, S. M. and R. Lukas. The Hawaii Ocean Time-series (HOT). EOS, Transactions of the American Geophysical Union 71, 1397.
7. 1990 Karl, D. "JGOFS time-series programs," San Francisco, California, December 1990.
8. 1991 Winn, C., C. Sabine, D. Hebel, F. Mackenzie and D. M. Karl. Inorganic carbon system dynamics in the central Pacific Ocean: Results of the Hawaii Ocean Time-series program. EOS, Transactions of the American Geophysical Union 72, 70.
9. 1991 Lukas, R. Water mass variability observed in the Hawaii Ocean Time Series. EOS, Transactions of the American Geophysical Union 72, 70.
10. 1991 Letelier, R., D. Karl, R. Bidigare, J. Christian, J. Dore, D. Hebel and C. Winn. Temporal variability of phytoplankton pigments at the U.S.-JGOFS station ALOHA (22 45'N, 158 W). EOS, Transactions of the American Geophysical Union 72, 74.
11. 1991 Karl, D. "The Hawaii Ocean Time-series program: Carbon production and particle flux", The Oceanography Society 2nd Annual Meeting, St. Petersburg, Florida, March 1991.
12. 1991 Karl, D. NATO symposium on Biology and Ecology of Diazotrophic Marine Organisms, "Trichodesmium blooms and new nitrogen in the North Pacific gyre", Bamberg, Germany, May 1991.
13. 1992 Anbar, A. D. Rhenium in seawater: Confirmation of generally conservative behavior. EOS, Transactions of the American Geophysical Union 73, 278.

14. 1992 Schudlich, R. and S. R. Emerson. Modelling dissolved gases in the subtropical upper ocean: JGOFS/WOCE Hawaiian Ocean Time-series. EOS, Transactions of the American Geophysical Union 73, 287.
15. 1992 Tupas, L. M., B. N. Popp and D. M. Karl. Dissolved organic carbon in oligotrophic waters: experiments on sample preservation, storage and analysis. EOS, Transactions of the American Geophysical Union 73, 287.
16. 1992 Karl, D., C. Winn, D. Hebel, R. Letelier, J. Dore and J. Christian. The U.S.- JGOFS Hawaii Ocean Time-Series (HOT) program. American Society for Limnology and Oceanography Aquatic Sciences Meeting, Santa Fe, NM, February 1992.
17. 1992 Campbell, L., R. R. Bidigare, R. Letelier, M. Ondrusek, S. Hall, B. Tsai and C. Winn. Phytoplankton population structure at the Hawaii Ocean Time-series station. American Society for Limnology and Oceanography Aquatic Sciences Meeting, Santa Fe, NM, February 1992.
18. 1992 Karl, D. NSF-sponsored GLOBEC scientific steering committee meeting, "Hawaii Ocean Time-series (HOT) program: A GLOBEC 'Blue Water' initiative", Honolulu, Hawaii, March 1992.
19. 1992 Karl, D. IGBP International Symposium on Global Change, "Oceanic ecosystem variability: Initial results from the JGOFS Hawaii Ocean Time-series (HOT) experiment", Tokyo, Japan, March 1992.
20. 1992 Karl, D. Conoco HOT Topics Seminar Series, "The U.S.-JGOFS Hawaii Ocean Time- Series (HOT) Program: Biogeochemical Vignettes from the Oligotrophic North Pacific Ocean" and "Temporal Variability in Bioelement Flux at Station ALOHA (22 45'N, 158 W)", Woods Hole, Massachusetts, May 1992
21. 1992 Bidigare, R. R., L. Campbell, M. Ondrusek, R. Letelier and D. Vault. Characterization of picophytoplankton at Station ALOHA (22 45'N, 158 W) using HPLC, flow cytometry and immunofluorescence techniques. PACON 1992 Meeting, June 1992.
22. 1992 Winn, C. D., D. Hebel, R. Letelier, J. Christian, J. Dore, R. Lukas and D. M. Karl. Long time-series measurements in the central North Pacific: Results of the Hawaii Ocean Time-series program. PACON conference, Kona, Hawaii, June 1992.
23. 1993 Atkinson, M. J. A potentiometric solid state sensor for oceanic CTDs, Abstract of The Oceanography Society Annual Meeting, Seattle, Washington, April 1993.
24. 1993 Campbell, L., H. A. Nolla and D. Vault. Microbial biomass in the subtropical central North Pacific Ocean (Station ALOHA): The importance of Prochlorococcus, Abstract of The Oceanography Society Annual Meeting, Seattle, Washington, April 1993.
25. 1993 Emerson, S., P. Quay, C. Stump, D. Wilbur and R. Schudlich. Oxygen cycles and productivity in the oligotrophic subtropical Pacific Ocean. Abstract of the Oceanography Society Annual Meeting, Seattle, Washington, April 1993.
26. 1993 Sharp, J. H., R. Benner, L. Bennett, C. A. Carlson, S. E. Fitzwater, E. T. Peltzer, and L. Tupas. Dissolved organic carbon: Intercalibration of analyses with equatorial Pacific samples. Abstract of The Oceanography Society Annual Meeting, Seattle, Washington, April 1993.

27. 1993 Winn, C. D., C. J. Carrillo, F. T. Mackenzie and D. M. Karl. Variability in the inorganic carbon system parameters in the North Pacific subtropical gyre. Abstract of The Oceanography Society Annual Meeting, Seattle, Washington, April 1993.
28. 1993 Yanagi, K. and D. M. Karl. Note on the fractional determination of TDP in seawater by an UV-irradiation method combined with the MAGIC procedure. Abstract of the Oceanography Society of Japan annual meeting, Tokyo, Japan, April 1993.
29. 1993 Campbell, L., H. Liu, R. R. Bidigare and D. Vault. Immunochemical characterization of Prochlorococcus. Abstract of the American Society of Limnology and Oceanography 1993 Annual Meeting, Edmonton, Alberta, Canada, May 1993.
30. 1993 Christian, J. R. and D. M. Karl. Bacterial exoenzymes in marine waters: Implications for global biogeochemical cycles. Abstract of the American Society of Limnology and Oceanography 1993 Annual Meeting, Edmonton, Alberta, Canada, May 1993.
31. 1993 Moyer, C. L., L. Campbell, D. M. Karl and J. Wilcox. Restriction fragment length polymorphism (RFLP) and DNA sequence analysis of PCR-generated clones to assess diversity of picoeukaryotic algae in the subtropical central North Pacific Ocean (Station ALOHA). Abstract of the American Society of Limnology and Oceanography 1993 Annual Meeting, Edmonton, Alberta, Canada, May 1993.
32. 1993 Sharp, J. H., R. Benner, L. Bennett, C. A. Carlson, S. E. Fitzwater and L. Tupas. The equatorial Pacific intercalibration analyses of dissolved organic carbon in seawater. Abstract of the American Society of Limnology and Oceanography 1993 Annual Meeting, Edmonton, Alberta, Canada, May 1993.
33. 1994 Yuan, J., C. I. Measures and J. A. Resing. Rapid determination of iron in seawater: In-line preconcentration flow injection analysis with spectrophotometric detection. EOS, Transactions of the American Geophysical Union 75, 25.
34. 1994 Smith, C. R., S. Garner, D. Hoover and R. Pope. Macrobenthos, mechanisms of bioturbation and carbon flux proxies at the abyssal seafloor along the JGOFS Equatorial Pacific Transect. EOS, Transactions of the American Geophysical Union 75, 70.
35. 1994 Farrenkopf, A. M., G. W. Luther, III and C. H. Van Der Weijden. Vertical distribution of dissolved iodine species in the northwest Indian Ocean. EOS, Transactions of the American Geophysical Union 75, 78.
36. 1994 Campbell, L., C. D. Winn, R. Letelier, D. Hebel and D. M. Karl. Temporal variability in phytoplankton fluorescence at Station ALOHA. EOS, Transactions of the American Geophysical Union 75, 100.
37. 1994 Winn, C., F. T. Mackenzie, C. Carrillo, T. Westby and D. M. Karl. Air-sea carbon dioxide exchange at Station ALOHA. EOS, Transactions of the American Geophysical Union 75, 112.
38. 1994 Lukas, R., F. Bingham and A. Mantyla. An anomalous cold event in the bottom water observed north of Oahu. EOS, Transactions of the American Geophysical Union 75, 205.
39. 1994 Tupas, L. M., B. N. Popp and D. M. Karl. Dissolved organic carbon in oligotrophic waters; experiments on sample preservation, storage and analysis. EOS, Transactions of the American Geophysical Union 75, 287.

40. 1994 Bingham, F.M. Drifter observations of the North Hawaiian Ridge Current. EOS, Transactions of the American Geophysical Union 75, 307.
41. 1994 HOT Program P.I.s, staff and students. [The Hawaii Ocean Time-series \(HOT\) program: The first five years](#), p. 59. Abstract of The Oceanography Society Pacific Basin Meeting, Honolulu, Hawaii, July 1994.
42. 1994 HOT Program P.I.s, staff and students. [HOT: a time-series study of carbon cycling in the oligotrophic North Pacific](#), p. 24. Abstract of The Oceanography Society Pacific Basin Meeting, Honolulu, Hawaii, July 1994.
43. 1994 Bidigare, R. R., L. Campbell, M. E. Ondrusek, R. Letelier, D. Vaulot and D. M. Karl. [Phytoplankton community structure at station ALOHA \(22 45'N, 158 W\) during fall 1991](#), p. 58. Abstract of The Oceanography Society Pacific Basin Meeting, Honolulu, Hawaii, July 1994.
44. 1994 Bingham, F. M. and B. Qiu. Interannual variability of surface and mixed layer properties observed in the Hawaii Ocean Time-series, p. 89. Abstract of The Oceanography Society Pacific Basin Meeting, Honolulu, Hawaii, July 1994.
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163. 2007 Church, M. J. Time Series Observations at Station ALOHA: Ecosystem Dynamics in the Oligotrophic North Pacific Ocean. Japan Agency for Marine Science and Technology. Tokyo, Japan.
164. 2007 Goebel, N. L., C. A. Edwards, M. J. Church, K. M. Achilles, J. P. Zehr. Relative contributions of three cyanobacteria phylotypes to total nitrogen (N_2) fixation at Station ALOHA. ASLO Aquatic Sciences Meeting, Santa Fe, New Mexico.
165. 2008 Beversdorf, L., J., K. Björkman, M. J. Church, E. F. DeLong and D. M. Karl. Aerobic production of methane in the sea. Ocean Sciences Meeting, Orlando, FL, March 2008.
166. 2008 Church, M. J., R. R. Bidigare, J. E. Dore, D. M. Karl, M. R. Landry, R. M. Letelier and R. Lukas. The Hawaii Ocean Time-series (HOT) program: Sensing ecosystem variability in the Subtropical North Pacific Ocean. Ocean Sciences Meeting, Orlando, FL, March 2008.
167. 2008 Karl, D. M. and HOT/C-MORE Team. Nutrient dynamics at Station ALOHA. Ocean Sciences Meeting, Orlando, FL, March 2008.
168. 2008 Mahaffey, C., K. Björkman and D. M. Karl. Physiological and community response of autotrophs to simulated upwelling of nutrient rich deep water at Station ALOHA in the North Pacific Subtropical Gyre. Ocean Sciences Meeting, Orlando, FL, March 2008.
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170. 2008 Quay, P. D., C. Peacock, K. Björkman and D. Karl. Rates of primary production in the ocean: A comparison of traditional in-vitro and newer in-situ methods. Ocean Sciences Meeting, Orlando, FL, March 2008.
171. 2008 White, A. E., Y. H. Spitz, J. P. Zehr, D. M. Karl and K. Björkman. Physical and chemical forcing of diazotrophic biomass along a transect from 23 S to 24.75 N. Ocean Sciences Meeting, Orlando, FL, March 2008.
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173. 2008 Church, M. J. The Hawaii Ocean Time-series (HOT): Temporal dynamics in ecosystem processes in the subtropical North Pacific Ocean. Changing Times: An International Ocean Biogeochemical Time-Series Workshop. Scripps Institution of Oceanography, La Jolla, CA.

174. 2008 Church, M. J., J. E. Dore, D. M. Karl, R. M. Letelier, R. Lukas. Implementation of quality assurance and control practices for ocean time series programs. OceanSITES Annual Meeting, Vienna, Austria.
175. 2008 Church, M. J. Microbes and Climate: Stories from the Sea. Hanauma Bay Evening Lecture Series. Honolulu, HI.
176. 2008 Church, M. J., R. R. Bidigare, J. E. Dore, D. M. Karl, M. Landry, R. Letelier, R. Lukas. The Hawaii Ocean Time-series (HOT) program: 20 years of sustained ocean observations in the North Pacific Subtropical Gyre. European Geosciences Union, Vienna, Austria.
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178. 2009 Church, M. J. Investigating the responses of ocean diazotrophs to variations in seawater $p\text{CO}_2$ in the North Pacific Subtropical Gyre. Rising CO_2 , Ocean Acidification, and Their Impacts on Marine Microbes. University of Hawaii, Honolulu, Hawaii.
179. 2010 Santiago-Mandujano, F. E., R. Lukas, S. DeCarlo, P. J. Lethaby, J. Snyder, E. Firing, R. Bidigare, M. J. Church, J. E. Dore, D. M. Karl, M. R. Landry and R. M. Letelier. Physical trends at Station ALOHA in the North Pacific subtropical gyre. Ocean Sciences Meeting, Portland, OR, February 2010.
180. 2010 Nahorniak, J., A. L. Whitmire, R. M. Letelier, S. Poulos, L. Fujieki and D. M. Karl. High temporal resolution observations of chlorophyll and particle concentration dynamics at Station ALOHA derived from Seaglider optical records. Ocean Sciences Meeting, Portland, OR, February 2010.
181. 2010 Björkman, K. M., M. J. Church, K. Doggett and D. M. Karl. The effect of light on phosphorus and amino acid uptake in *Prochlorococcus* spp. In the North Pacific subtropical gyre using cell-sorting flow cytometry. Ocean Sciences Meeting, Portland, OR, February 2010.
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183. 2010 Church, M. J., R. Bidigare, J. E. Dore, M. R. Landry, R. M. Letelier, R. Lukas and D. M. Karl. The annual flow of carbon through an open ocean plankton food web.: Synthesis of 20 years of measurements at Station ALOHA. Ocean Sciences Meeting, Portland, OR, February 2010.
184. 2010 Calil, P. H., L. Guidi, K. J. Richards, D. M. Karl and Z. S. Kolber. Modulation of carbon export at the submesoscale by Lagrangian coherent structures. Ocean Sciences Meeting, Portland, OR, February 2010.
185. 2010 Karl, D., A. White, K. M. Björkman, L. J. Beversdorf and R. M. Letelier. Elemental stoichiometry of organic matter production by *Trichodesmium* IMS 101 as a function of phosphorus source with emphasis on phosphonate utilization and the production of greenhouse gases. Ocean Sciences Meeting, Portland, OR, February 2010.

186. 2010 Duhamel, S., K. M. Björkman and D. M. Karl. Alkaline phosphatase activity and regulation in the North Pacific subtropical gyre. Ocean Sciences Meeting, Portland, OR, February 2010.
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188. 2010 Brzezinski, M. A., J. W. Krause, B. Li, M. J. Church, D. M. Karl and J. L. Jones. HOT and BATS: A comparative analysis of the silicon cycle. Ocean Sciences Meeting, Portland, OR, February 2010.
189. 2010 Quay, P., C. Peacock, K. M. Björkman and D. M. Karl. Measuring primary production rates in the ocean: Differences between incubation, non-incubation and satellite methods at Stn ALOHA. Ocean Sciences Meeting, Portland, OR, February 2010.
190. 2010 Li, B., M. A. Brzezinski, D. M. Karl and M. J. Church. Investigations into the temporal and spatial dynamics of diatoms in the North Pacific Subtropical Gyre (NPSG). Ocean Sciences Meeting, Portland, OR, February 2010.
191. 2010 Guidi, L., J. Uitz, L. Legendre, H. Claustre, D. M. Karl and D. Stramski. Estimating carbon export and sequestration in ocean at regional and global scales. Ocean Sciences Meeting, Portland, OR, February 2010.
192. 2010 Letelier, R. M., A. White and D. M. Karl. Wave-driven upwelling as a tool for the enhancement of biological sequestration of carbon in open oceans. Ocean Sciences Meeting, Portland, OR, February 2010.
193. 2010 Buesseler, K., R. S. Lampitt, H. J. De Baar, S. Blain, F. Chai, K. H. Coale, M. Dai, D. M. Karl, M. Leinen, M. C. Lohan, L. Rothstein, T. W. Trull, D. Whaley and M. Zhou. Understanding and assessing the feasibility of ocean iron fertilization to reduce atmospheric carbon dioxide. Ocean Sciences Meeting, Portland, OR, February 2010.
194. 2010 Campbell, T. L., D. Hayakawa, D. Karl, M. J. Church and M. S. Rappé. Spatial distribution of bacterioplankton lineages along a meridional transect of the Pacific Ocean. 13th International Symposium on Microbial Ecology. Seattle, WA, August 2010.
195. 2011 Böttjer, D., M. J. Church, R. M. Letelier, D. Sadler, D. Viviani, K. S. Watkins-Brandt. [Diazotroph activity and population structure in an increased CO₂ world](#). Aquatic Sciences Meeting (S58), San Juan, Puerto Rico, February 2011.
196. 2011 Brzezinski, M. A., J. W. Krause, B. Li, M. J. Church. [Interannual variability and drivers of the silicon cycle at the Hawaii Ocean Time-series Station ALOHA](#). Aquatic Sciences Meeting (S02), San Juan, Puerto Rico, February 2011.
197. 2011 Church, M. J., D. Böttjer, D. M. Karl, R. M. Letelier, D. A. Viviani and J. P. Zehr. [Nitrogen fixation in the North Pacific Subtropical Gyre](#). Aquatic Sciences Meeting (S58), San Juan, Puerto Rico, February 2011.
198. 2011 Del Valle, D. A., R. P. Kiene and D. M. Karl. [Light dependence of dissolved DMSP-sulfur assimilation and DMS production in the oligotrophic North Pacific subtropical gyre](#). Aquatic Sciences Meeting (S86), San Juan, Puerto Rico, February 2011.
199. 2011 Johnson, K. S., S. C. Riser, D. Swift, L. J. Coletti, H. W. Jannasch, J. N. Plant, C. M. Sakamoto, M. J. Church, M. W. Lomas. [HOT and BATS: An in situ comparison using](#)

- [profiling floats with chemical sensors](#). Aquatic Sciences Meeting (S02), San Juan, Puerto Rico, February 2011.
200. 2011 Lomas, M. W., M. J. Church. [BATS and HOT: Comparative analysis of similar yet different marine ecosystems](#). Aquatic Sciences Meeting (S02), San Juan, Puerto Rico, February 2011.
 201. 2011 Nicholson, D. P., R. H. Stanley, E. Barkan, D. M. Karl, B. Luz, P. D. Quay and S. C. Doney. [Evaluating triple oxygen isotope estimates of gross primary production at the Hawaii Ocean Time-series and Bermuda Atlantic Time-series Study sites](#). Aquatic Sciences Meeting (S02), San Juan, Puerto Rico, February 2011.
 202. 2011 Pasulka, A. L., D. A. Taniguchi, A. G. Taylor, M. R. Landry. [Temporal variations in the microplankton community in the oligotrophic subtropical open ocean and potential environmental factors influencing these variations](#). Aquatic Sciences Meeting (S02), San Juan, Puerto Rico, February 2011.
 203. 2012 Alford, M. H., R. Lukas, B. M. Howe, A. Pickering and F. Santiago-Mandujano. [Moored observations of episodic abyssal flow and mixing at Station ALOHA](#). Ocean Sciences Meeting (090), Salt Lake City, UT, February 2012.
 204. 2012 Della Ripa, L. A., M. R. Landry, M. Decima, C. J. Bradley, B. N. Popp. [Predator:prey size relationships in pelagic ecosystems: testing the 10:1 hypothesis with mesozooplankton from three regions](#). Ocean Sciences Meeting (123), Salt Lake City, UT, February 2012.
 205. 2012 Dore, J. E., R. Lukas, M. J. Church, D. W. Sadler and D. M. Karl. [Consistent trends and patterns of interannual variability in surface ocean CO₂ at contrasting sites windward and leeward of the Hawaiian islands](#). Ocean Sciences Meeting (039), Salt Lake City, UT, February 2012.
 206. 2012 Gradoville, M. R., A. E. White, M. J. Zirbel, D. Böttjer, M. J. Church, R. M. Letelier. [Metabolic response of *Trichodesmium* and *crocospaera* to pCO₂ perturbations on multiple time scales](#). Ocean Sciences Meeting (046), Salt Lake City, UT, February 2012.
 207. 2012 Howe, B. M., R. Lukas, F. Deunnebier. [ALOHA Cabled Observatory: Early results including acoustics](#). Ocean Sciences Meeting (047), Salt Lake City, UT, February 2012.
 208. 2012 Kavanaugh, M. T., B. Hales, M. Saraceno, Y. H. Spitz, A. E. White, M. J. Church, R. M. Letelier. [Satellite-derived dynamic seascapes: Spatiotemporal context for oceanographic observations of North Pacific ecosystems](#). Ocean Sciences Meeting (141), Salt Lake City, UT, February 2012.
 209. 2012 Lukas, R., F. Santiago-Mandujano, C. Nosse, E. Firing, D. Luther, M. Alford, B. Howe and F. Duennbier. [Surprising abyssal tidal signals at Station ALOHA](#). Ocean Sciences Meeting (021), Salt Lake City, UT, February 2012.
 210. 2012 Nosse, C. T., F. Santiago-Mandujano, R. B. Lukas, J. E. Dore, R. A. Weller and A. J. Plueddemann. [Recent strong interannual variation disrupted pycnocline and abyssal salinity trends at Station ALOHA](#). Ocean Sciences Meeting (039), Salt Lake City, UT, February 2012.
 211. 2012 Pasulka, A. P., M. R. Landry, D. A. Taniguchi, A. G. Taylor, M. J. Church. [Temporal dynamics of phytoplankton and heterotrophic protists at Station ALOHA](#). Ocean Sciences Meeting (039), Salt Lake City, UT, February 2012.

212. 2012 Santiago-Mandujano, F., C. T. Nosse, R. A. Weller, A. J. Plueddemann and R. B. Lukas. [Observations and modeling of the mixed layer at Station ALOHA](#). Ocean Sciences Meeting (048), Salt Lake City, UT, February 2012.
213. 2012 White, A. E., A. L. Whitmire, R. M. Letelier, M. T. Kavanaugh, M. J. Church. [Time-series analyses of primary productivity as a function of absorption, pigment based phytoplankton diversity and particle size distribution](#). Ocean Sciences Meeting (039), Salt Lake City, UT, February 2012.
214. 2013 Heal K. R., S. R. Smith, C. Amano-Sato, T. Coale, J. Dinasquet, A. Fischer, R. Golda, W. Johnson, A. Lopes, M. R. Rodriguez, J. Saunders, K. Shoemaker, T. Silovic, W. Smythe, O. Sosa, T. Vick-Majors, D. Karl and M. J. Church. [Photosynthetic parameters over hourly and daily timescales shed light on population stability at Station ALOHA](#). ASLO 2013 Aquatic Sciences Meeting (SS73), New Orleans, LA, February 2013.
215. 2013 Kavanaugh, M. T., B. R. Hales, R. M. Letelier, S. Doney, C. O. Davis, Y. Spitz, A. E. White, M. J. Church, M. Saraceno. [Dynamic seascapes: An objective and hierarchical framework for understanding pelagic spatiotemporal variability](#). ASLO 2013 Aquatic Sciences Meeting (SS64), New Orleans, LA, February 2013.
216. 2013 Robidart, J. C., M. J. Church, J. P. Ryan, S. T. Wilson, F. Ascani, R. Marin III, K. Richards, D. M. Karl, C. A. Scholin, J. P. Zehr. [Application of high resolution autonomous time series to detect patterns of nitrogen fixing cyanobacteria in the North Pacific Ocean](#). ASLO 2013 Aquatic Sciences Meeting (SS33), New Orleans, LA, February 2013.
217. 2013 Smith, S. R., K. R. Heal, C. Amano-Sato, T. Coale, J. Dinasquet, A. Fischer, R. Golda, W. Johnson, A. Lopes, M. R. Rodriguez, J. Saunders, K. Shoemaker, T. Silovic, W. Smythe, O. Sosa, T. Vick-Majors, D. Karl and M. J. Church. [High resolution sampling reveals light-driven fluctuations in microbial biomass and activities at Station ALOHA](#). ASLO 2013 Aquatic Sciences Meeting (SS73), New Orleans, LA, February 2013.
218. 2013 Viviani, D. A., M. J. Church, D. Böttjer. [Variability in dissolved primary production and microbial growth in the North Pacific Subtropical Gyre](#). ASLO 2013 Aquatic Sciences Meeting (SS14), New Orleans, LA, February 2013.
219. 2014 Barone, B., M. J. Church, D. M. Karl, R. M. Letelier and A. E. White. [Size structure and particle maxima in different layers of the water column of a subtropical gyre: Influences of algal ecology and density stratification](#). Ocean Sciences Meeting (049), Honolulu, HI, February 2014.
220. 2014 Bidigare, R. R., F. R. Buttler, S. J. Christensen, B. Barone, S. T. Wilson. [Evaluation of the utility of xanthophyll cycle pigment dynamics for assessing upper ocean mixing processes at Station ALOHA](#). Ocean Sciences Meeting (049), Honolulu, HI, February 2014.
221. 2014 Björkman, K. M., J. K. Doggett, M. J. Church, D. M. Karl. [Differential response to light intensity in \$^{14}\text{C}\$ -bicarbonate versus \$^3\text{H}\$ -leucine incorporation by *Prochlorococcus* at Station ALOHA](#). Ocean Sciences Meeting (069), Honolulu, HI, February 2014.
222. 2014 Böttjer, D., D. Viviani, D. M. Karl, R. M. Letelier and M. J. Church. [No evidence for enhanced carbon or dinitrogen fixation under elevated seawater \$\text{pCO}_2\$ in the North Pacific Subtropical Gyre](#). Ocean Sciences Meeting (125), Honolulu, HI, February 2014.

223. 2014 Bryant, J. B., J. M. Eppley, D. M. Karl, M. J. Church and E. F. DeLong. [Wind and season drive microbial community diversity in the North Pacific Subtropical Gyre at Station ALOHA](#). Ocean Sciences Meeting (049), Honolulu, HI, February 2014.
224. 2014 Church, M. J. and the HOT Team. [The Hawaii Ocean Time-series \(HOT\) program turns 25: Highlights of a quarter century of sustained observations in the sea](#). Ocean Sciences Meeting (049), Honolulu, HI, February 2014.
225. 2014 Curless, S. E., K. M. Björkman, B. Updyke, C. Mahaffey, J. E. Dore. [Analyses of inorganic nutrient pools by the Hawaii Ocean Time-series \(HOT\) program: Methods, procedures, and standardization](#). Ocean Sciences Meeting (049), Honolulu, HI, February 2014.
226. 2014 Del Valle, D., S. Martinez-Garcia, C. Suffridge, L. Cutter, S. Sanudo-Wilhelmy and D. Karl. [The role of B₁ and other B-vitamins at the oligotrophic Station ALOHA during natural and induced bloom conditions](#). Ocean Sciences Meeting (151), Honolulu, HI, February 2014.
227. 2014 Doggett, J. K., G. Van Den Engh, M. A. Doblin and D. M. Karl. [High resolution flow cytometry profiles of Prochlorococcus at Station ALOHA](#). Ocean Sciences Meeting (049), Honolulu, HI, February 2014.
228. 2014 Dore, J. E., D. W. Sadler and the HOT CO₂ team. [The HOT program presents: A Carbon carol: ghosts of CO₂ past, CO₂ present and CO₂ yet to come](#). Ocean Sciences Meeting (049), Honolulu, HI, February 2014.
229. 2014 Duhamel, S., K. M. Björkman, J. K. Doggett and D. M. Karl. [Microbial group specific uptake of inorganic phosphate and ATP at Station ALOHA: Kinetics, effect of light and response to rapid changes in N:P availability](#). Ocean Sciences Meeting (049), Honolulu, HI, February 2014.
230. 2014 Ferrón, S., S. T. Wilson, D. A. Del Valle and D. M. Karl. [Methane sources in the upper ocean at Station ALOHA](#). Ocean Sciences Meeting (043), Honolulu, HI, February 2014.
231. 2014 Fitzsimmons, J. N., R. Zhang, E. A. Boyle. [Short- and long-term temporal variability of iron at Station ALOHA](#). Ocean Sciences Meeting (049), Honolulu, HI, February 2014.
232. 2014 Foley, J. M. [Taking time-series to the streets: educational programs that communicate Station ALOHA research](#). Ocean Sciences Meeting (049), Honolulu, HI, February 2014.
233. 2014 Fontanez, K. M., E. F. DeLong. [Microbial community structure and function on sinking particles at Station ALOHA](#). Ocean Sciences Meeting (049), Honolulu, HI, February 2014.
234. 2014 Gradoville, M. R., A. E. White, D. Böttjer, M. J. Church, R. M. Letelier. [Diversity trumps acidification: No CO₂ enhancement of N₂ fixation by the *trichodesmium* community at Station ALOHA](#). Ocean Sciences Meeting (125), Honolulu, HI, February 2014.
235. 2014 Hayes, C. T., E. A. Boyle, D. McGee, J. N. Fitzsimmons, R. F. Anderson. [²³²TH/²³⁰TH at the Hawaii Ocean Time-series Station ALOHA: A Tool for iron cycling](#). Ocean Sciences Meeting (049), Honolulu, HI, February 2014.
236. 2014 Howe, B. M., R. Lukas. [ALOHA Cabled Observatory: On-going results and new instruments](#). Ocean Sciences Meeting (049), Honolulu, HI, February 2014.

237. 2014 Karl, D. M., T. Clemente, E. Grabowski, S. T. Wilson and M. J. Church. [Variability in particle export at Station ALOHA](#). Ocean Sciences Meeting (049), Honolulu, HI, February 2014.
238. 2014 Letelier, R. M., A. E. White, M. J. Church, D. M. Karl and R. R. Bidigare. [Local to basin scale modulation of primary productivity in the North Pacific Subtropical Gyre: Lessons learned from the Hawaii Ocean Time-series program](#). Ocean Sciences Meeting (049), Honolulu, HI, February 2014.
239. 2014 Lukas, R., F. E. Santiago-Mandujano, A. J. Plueddemann, R. A. Weller, F. K. Duennebier. [Quantifying the surface freshwater flux at Station ALOHA](#). Ocean Sciences Meeting (049), Honolulu, HI, February 2014.
240. 2014 Luo, Y. W., D. P. Nicholson, S. C. Doney. [High-frequency biogeochemical modeling based on HOE-DYLAN experiment at Station ALOHA](#). Ocean Sciences Meeting (049), Honolulu, HI, February 2014.
241. 2014 Martinez-Garcia, S. and D. M. Karl. [Euphotic and mesopelagic zone microbial respiration at Station ALOHA](#). Ocean Sciences Meeting (049), Honolulu, HI, February 2014.
242. 2014 McCoy, D., F. E. Santiago-Mandujano, R. A. Weller, A. J. Plueddemann, R. Lukas. [The WHOI-Hawaii Ocean Time-series site \(WHOTS\) mooring: Highly-resolved upper ocean trends, variability, and forcing](#). Ocean Sciences Meeting (049), Honolulu, HI, February 2014.
243. 2014 Poulos, S., L. Fujieki, B. Watkins, S. Searson, D. M. Karl. [The ALOHA SeaGlider fleet](#). Ocean Sciences Meeting (049), Honolulu, HI, February 2014.
244. 2014 Sadler, D. W., J. E. Dore, M. J. Church, L. A. Fujieki and D. M. Karl. [Assessing the internal consistency of CO₂ measurements at Station ALOHA](#). Ocean Sciences Meeting (049), Honolulu, HI, February 2014.
245. 2014 Segura-Noguera, M., S. E. Curless, M. J. Church and D. M. Karl. [Ammonium distribution at Station ALOHA in the North Pacific Subtropical Gyre](#). Ocean Sciences Meeting (049), Honolulu, HI, February 2014.
246. 2014 Thomas, S. E., M. J. Church. [Diversity and activity of chemoautotrophic bacteria in the aphotic waters of the subtropical North Pacific Ocean](#). Ocean Sciences Meeting (051), Honolulu, HI, February 2014.
247. 2014 Viviani, D. A., M. J. Church. [Dissolved organic matter production and microbial growth at Station ALOHA](#). Ocean Sciences Meeting (049), Honolulu, HI, February 2014.
248. 2014 Wai, B. R., M. J. Church, D. M. Karl and E. F. DeLong. [Temporal variability of ammonia-oxidizing Archaea at Station ALOHA](#). Ocean Sciences Meeting (049), Honolulu, HI, February 2014.
249. 2014 Wilson, S. T., D. A. Del Valle, M. Segura-Noguera and D. M. Karl. [Nitrifier denitrification as a source of nitrous oxide in the lower euphotic zone of the oligotrophic North Pacific Subtropical Gyre at Station ALOHA](#). Ocean Sciences Meeting (043), Honolulu, HI, February 2014.

250. 2014 Zehr, J. P., B. J. Carter, R. A. Foster, A. W. Thompson, H. J. Tripp. [Same stage but different actors: 20 Years of change in nitrogen fixation at Station ALOHA](#). Ocean Sciences Meeting (049), Honolulu, HI, February 2014.
251. 2015 Martinez-Garcia, S.; Karl, D. M. [Microbial respiration in the euphotic zone at Station ALOHA](#). ASLO Aquatic Sciences Meeting (063), Granada, Spain, February 2015.
252. 2016 Böttjer, D., J. E. Dore, D. M. Karl, R. M. Letelier, C. Mahaffey, S. T. Wilson, J. P. Zehr, M. J. Church. [Temporal Variability in Nitrogen Fixation and Particulate Nitrogen Export at Station ALOHA](#). Ocean Sciences Meeting (B34B), New Orleans, LA, February 2016.
253. 2016 Deppe, R. W., R. Lukas, F. Santiago-Mandujano. [Characterization of bathymetric constraints on deep ocean circulation in the Kauai Deep region around Station ALOHA](#). Ocean Sciences Meeting (PO14C-2807), New Orleans, LA, February 2016.
254. 2016 Howe, B., J. T. Potemra, R. Butler, F. Santiago-Mandujano, R. Lukas, F. K. Duennebier, D. M. Karl, J. Aucan. [Continuing and New Measurements at the Abyssal ALOHA Cabled Observatory](#). Ocean Sciences Meeting (OD11A-04), New Orleans, LA, February 2016.
255. 2016 Lukas, R., F. Santiago-Mandujano, B. M. Howe, A. J. Plueddemann, R. A. Weller, R. W. Deppe, N. G. Larson, D. J. Murphy, R. Guenther. [Spatial Analysis of Abyssal Temperature Variations Observed From the ALOHA Cabled Observatory and WHOTS Moorings](#). Ocean Sciences Meeting (PO12C-01), New Orleans, LA, February 2016.
256. 2016 McCoy, D., F. Santiago-Mandujano, A. J. Plueddemann, R. A. Weller, R. Lukas. [Accelerating Salinity Trends at Station ALOHA in the North Pacific Subtropical Gyre](#). Ocean Sciences Meeting (PO41C-04), New Orleans, LA, February 2016.
257. 2016 Nicholson, D. P., B. Barone, D. M. Karl. [Biogeochemistry from Gliders at the Hawaii Ocean Times-Series](#). Ocean Sciences Meeting (OD21A), New Orleans, LA, February 2016.
258. 2016 Rii, Y. M., R. Bidigare, M. J. Church. [Responses of photosynthetic assemblage structure and physiology to variations in nitrogen substrates](#). Ocean Sciences Meeting (B34B-0358), New Orleans, LA, February 2016.
259. 2016 Santiago-Mandujano, F., R. Lukas, D. J. Murphy, N. G. Larson. [MicroCAT/SeaCAT Sensor Calibration and Data Quality Control: Lessons Learned from 10 Years of WHOI-Hawaii Ocean Time-Series Site \(WHOTS\) Mooring Deployments](#). Ocean Sciences Meeting (OD14C), New Orleans, LA, February 2016.
260. 2016 Viviani, D. A., M. J. Church. [The effects of light, primary production, and temperature on bacterial production at Station ALOHA](#). Ocean Sciences Meeting (B34A-0343), New Orleans, LA, February 2016.
261. 2016 White, A. E., R. M. Letelier. [Primary productivity \(PP\) in the North Pacific Subtropical Gyre: Understanding drivers of variability via ¹⁴C-tracer incubations and PP diagnosed via the diurnal cycle of particulate carbon](#). Ocean Sciences Meeting (PP12A-08), New Orleans, LA, February 2016.
262. 2017 Barone, B.; Nicholson, D. P.; Karl, D. M. [Mesoscale eddy structure and horizontal biogeochemical variability from autonomous observations in the North Pacific Subtropical Gyre](#). ASLO Aquatic Sciences Meeting (040), Honolulu, HI, February-March 2017.

263. 2017 Björkman, K. M.; Duhamel, S.; Church, M. J.; Karl, D. M. [Spatial and temporal variability in phosphorus inventories and turnover of inorganic P and adenosine-triphosphate in the North Pacific](#). ASLO Aquatic Sciences Meeting (040), Honolulu, HI, February-March 2017.
264. 2017 Bryant, J. A.; Mende, D. R.; Aylward, F. O.; Eppley, J. M.; Nielsen, T. N.; DeLong, E. F. [A Genomic inflection point in the twilight zone of the ocean's interior](#). ASLO Aquatic Sciences Meeting (040), Honolulu, HI, February-March 2017.
265. 2017 Church, M. J.; Björkman, K. M.; Karl, D. M.; Rii, Y. M.; Viviani, D. A. [Emerging views on picoplankton dynamics at Station ALOHA](#). ASLO Aquatic Sciences Meeting (040), Honolulu, HI, February-March 2017.
266. 2017 Curless, S. E.; Church, M. J.; Segura-Noguera, M.; Karl, D. K. [Ammonium concentrations at Station ALOHA - Improved methodology allows for full ocean depth analysis](#). ASLO Aquatic Sciences Meeting (040), Honolulu, HI, February-March 2017.
267. 2017 Edwards, B. R.; Romano, A. E.; Eppley, J. M.; Clemente, T. M.; Karl, D. M.; DeLong, E. F. [Particle-associated microbial community structure and metabolism at abyssal depths in the North Pacific Subtropical Gyre](#). ASLO Aquatic Sciences Meeting (040), Honolulu, HI, February-March 2017.
268. 2017 Eichner, M.; Klawonn, I.; Wilson, S. T.; Littmann, S.; Whitehouse, M.; Church, M.; Kuypers, M. M.; Karl, D. M.; Ploug, H. [Distinct microenvironments and high single-cell variability in *Trichodesmium* colonies collected at Station ALOHA](#). ASLO Aquatic Sciences Meeting (040), Honolulu, HI, February-March 2017.
269. 2017 Ferrón, S.; Barone, B.; Church, M. J.; Karl, D. M. [Biological oxygen production in the North Pacific Subtropical Gyre](#). ASLO Aquatic Sciences Meeting (040), Honolulu, HI, February-March 2017.
270. 2017 Follett, C. L.; White, A. E.; Follows, M. J. [Nitrogen fixation measured by stoichiometric fluctuations](#). ASLO Aquatic Sciences Meeting (040), Honolulu, HI, February-March 2017.
271. 2017 Foreman, R. K.; Karl, D. M. [Advancing a new method for the direct determination of dissolved organic nitrogen \(DON\) in seawater](#). ASLO Aquatic Sciences Meeting (012), Honolulu, HI, February-March 2017.
272. 2017 Grabowski, E. M.; Karl, D. M. [Caloric content of Sinking particulate matter in the North Pacific Subtropical Gyre](#). ASLO Aquatic Sciences Meeting (040), Honolulu, HI, February-March 2017.
273. 2017 Gradoville, M. R.; Crump, B. C.; Letelier, R. M.; Church, M. J.; White, A. E. [The Diversity and functional potential of microbial communities associated with the colonial, N₂-fixing cyanobacterium *Trichodesmium*](#). ASLO Aquatic Sciences Meeting (017), Honolulu, HI, February-March 2017.
274. 2017 Hayes, C. T.; Fitzsimmons, J. N.; Morton, P. L.; McGee, D.; Boyle, E. A. [Diel trace metal variations in the North Pacific Subtropical Gyre](#). ASLO Aquatic Sciences Meeting (040), Honolulu, HI, February-March 2017.
275. 2017 Karl, D. M. [Station ALOHA: A gathering place for discovery, education and scientific collaboration](#). ASLO Aquatic Sciences Meeting plenary presentation. Honolulu, HI, February-March 2017.

276. 2017 Lindh, M. V.; Church, M. J. [There and back again - Unraveling mechanisms of microbial biogeography in the North Pacific Subtropical Gyre to and from Station ALOHA](#). ASLO Aquatic Sciences Meeting (040), Honolulu, HI, February-March 2017.
277. 2017 Liu, X.; Levine, N. M. [Impact of fine-scale physics on marine ecosystem and carbon dynamics in the North Pacific Subtropical Gyre: Perspectives from a new modeling approach](#). ASLO Aquatic Sciences Meeting (040), Honolulu, HI, February-March 2017.
278. 2017 Luo, E.; Eppley, J. M.; Aylward, F. O.; Romano, A. R.; DeLong, E. F. [Vertical variability in viral and host assemblages at Station ALOHA](#). ASLO Aquatic Sciences Meeting (040), Honolulu, HI, February-March 2017.
279. 2017 Mende, D. R.; Aylward, F. O.; Bryant, J. A.; Eppley, J. M.; Nielsen, T.; DeLong, E. F. [High resolution profiling of marine microbial communities reveals population distributions across the water column at Station ALOHA](#). ASLO Aquatic Sciences Meeting (016), Honolulu, HI, February-March 2017.
280. 2017 Nelson, A. J.; Church, M. J.; Dornan, N.; Kyi, E.; Van Mooy, B.; Ossolinski, J.; Viviani, D. [Rates of microbial activities associated with sinking particles at Station ALOHA in the North Pacific Subtropical Gyre](#). ASLO Aquatic Sciences Meeting (040), Honolulu, HI, February-March 2017.
281. 2017 Olson, D. K.; Mende, D. R.; Aylward, F. O.; DeLong, E. F. [Metagenomics reveals phylogenetic diversity and depth stratification of unique proteorhodopsin genes in shallow versus deep ocean waters at Station ALOHA](#). ASLO Aquatic Sciences Meeting (040), Honolulu, HI, February-March 2017.
282. 2017 Rosburg, K. C.; Potemra, J. T.; Santiago-Mandujano, F.; Lukas, R.; Weller, R. A.; Plueddemann, A. J. [Comparison of observed and independently-derived upper ocean currents at Station ALOHA](#). ASLO Aquatic Sciences Meeting (040), Honolulu, HI, February-March 2017.
283. 2017 Royer, S. J.; Ferrón, S.; Wilson, S. T.; del Valle, D. A.; Sosa, O.; Karl, D. M. [Methane production from sinking particulate matter at Station ALOHA](#). ASLO Aquatic Sciences Meeting (040), Honolulu, HI, February-March 2017.
284. 2017 Rii, Y. M.; Lindh, M. V.; Church, M. J. [Diversity and dynamics of eukaryotic picoplankton in the North Pacific Subtropical Gyre](#). ASLO Aquatic Sciences Meeting (054), Honolulu, HI, February-March 2017.
285. 2017 Sadler, D. W.; Barone, B.; Burkitt, J. W.; Dore, J. E.; Church, M. J.; Karl, D. M. [High-resolution in-situ pH measurements at Station ALOHA using an ion-sensitive field effect transistor](#). ASLO Aquatic Sciences Meeting (040), Honolulu, HI, February-March 2017.
286. 2017 Sosa, O. A.; Ferrón, S.; DeLong, E. F.; Repeta, D. J.; Karl, D. M. [Degradation of dissolved organic phosphorus by heterotrophic bacteria in the oligotrophic ocean](#). ASLO Aquatic Sciences Meeting (003), Honolulu, HI, February-March 2017.
287. 2017 Turk-Kubo, K. A.; Hogan, M. E.; Zehr, J. P.; Munoz-Marin, M. [In-situ diazotroph net growth rates under different resource ratios at Station ALOHA](#). ASLO Aquatic Sciences Meeting (040), Honolulu, HI, February-March 2017.

288. 2017 Valencia, B.; Landry, M. R.; Decima, M.; Hannides, C. C. [Environmental drivers of mesozooplankton biomass variability at Station ALOHA, North Pacific Subtropical Gyre](#). ASLO Aquatic Sciences Meeting (040), Honolulu, HI, February-March 2017.
289. 2017 Vislova, A.; Aylward, F. O.; Romano, A.; Sosa, O. A.; Den Uyl II, P. A.; DeLong, E. F. [A Depth profile of diel periodicity in marine picoplankton yields insight into ecosystem structure and function](#). ASLO Aquatic Sciences Meeting (028), Honolulu, HI, February-March 2017.
290. 2017 Viviani, D. A.; Böttjer, D.; Letelier, R. M.; Church, M. J. [The Influence of abrupt increases in seawater pCO₂ on rates of microbial production in the subtropical North Pacific Ocean](#). ASLO Aquatic Sciences Meeting (040), Honolulu, HI, February-March 2017.
291. 2017 White, A. E.; Watkins-Brandt, K. S. [Annual variability in the abundance and diversity of large diazotrophs at Station ALOHA](#). ASLO Aquatic Sciences Meeting (040), Honolulu, HI, February-March 2017.
292. 2017 Wilson, S. T.; Ferrón, S.; Karl, D. M. [Seasonal and interannual concentrations of methane and nitrous oxide in the surface waters of the oligotrophic North Pacific Subtropical Gyre from 2008-2016](#). ASLO Aquatic Sciences Meeting (036), Honolulu, HI, February-March 2017.
293. 2018 Barone, B., M. J. Follows, J. S. Weitz and D. M. Karl. [The Impact of Sea Surface Height Variability on Biogeochemical Dynamics at Station ALOHA](#). Ocean Sciences Meeting (EP24D-0819), Portland, OR, February 2018.
294. 2018 Björkman, K. M. and D. M. Karl. [Diel Variability in the Incorporation of Leucine in the Light and Dark by Prochlorococcus at Station ALOHA](#). Ocean Sciences Meeting (MM14A-1411), Portland, OR, February 2018.
295. 2018 Granzow, B. N., O. Sosa, M. Gonnelli, C. Santinelli, D. M. Karl and D. Repeta. [Fast Fluorescent Bioassay for C-P Lyase Activity in Marine Microbes](#). Ocean Sciences Meeting (BN24D-1109), Portland, OR, February 2018.
296. 2018 Lee, K., Y. H. Ko, T. Takahashi and D. M. Karl. [Carbon-based estimate of nitrogen fixation-derived net community production in N-depleted ocean gyres](#). Ocean Sciences Meeting (BN33B-01), Portland, OR, February 2018.
297. 2018 Letelier, R. M., D. M. Karl, K. M. Björkman, A. E. White, J. J. Wettstein and M. J. Church. [Climate Driven Oscillations in the Proximate Elemental Control of Ecosystem Productivity Observed in the North Pacific Subtropical Gyre](#). Ocean Sciences Meeting (BN53B-06), Portland, OR, February 2018.
298. 2018 Potemra, J. T., B. M. Howe, Rosburg, K., F. Santiago-Mandujano, and K. Terada. [Real-time Data, Delivered in Real-time, from the Sea Floor](#). Ocean Sciences Meeting (OD34B-2763), Portland, OR, February 2018.
299. 2018 Potemra, J. T., R. Lukas, R. A. Weller, A. J. Plueddemann, S. Decarlo, and F. Santiago-Mandujano. [Tropical Biases in Model and Reanalysis Products](#). Ocean Sciences Meeting (IS14B-2559) , Portland, OR, February 2018.
300. 2018 Repeta, D., C. Santinelli, O. Sosa, B. N. Granzow, M. Acker, L. Valentin-Alvarado, C. Johnson and D. M. Karl. [Organic Phosphorus Composition and Cycling of Particulate](#)

[and High Molecular Weight Dissolved Organic Matter](#). Ocean Sciences Meeting (BN23B-04) , Portland, OR, February 2018.

301. 2018 Santiago-Mandujano, F., and R. Lukas, Station ALOHA: Update and Science Highlights. OceanSITES Meeting, Kiel, Germany, July, 2018.
302. 2018 Santiago-Mandujano, F., R. Lukas, R. A. Weller, A. J. Plueddemann, K. Rosburg, and J. T. Potemra. [Non-local forcing of the mixed layer at Station ALOHA](#). Ocean Sciences Meeting (AI34E-1684) , Portland, OR, February 2018.
303. 2018 Wilson, S. T. and G. J. Rehder. [A Global Intercomparison of Oceanic Methane and Nitrous Oxide Measurements](#). Ocean Sciences Meeting (BN14D-1047) , Portland, OR, February 2018.
304. 2019 Santiago-Mandujano, F, J. T. Potemra, R. Lukas, A. J. Plueddemann, R. A. Weller and B. M. Howe. [Spatial Analysis of Abyssal Temperature Variations Observed from the ALOHA Cabled Observatory and WHOTS Moorings](#). OceanObs19, Honolulu, HI, September 2019.
305. 2020 Beckett, S., D. J. R. Demory, A. Coenen, J. Casey, C. L. Follett, M. Dugenne, P. E. Connell, M. Carlson, S. K. Hu, S. T. Wilson, D. Muratore, A. Boysen, M. Harke, E. Luo, R. Rodriguez, S. Peng, K. Becker, S. Coesel, D. R. Mende, A. E. Ingalls, B. AS Van Mooy, S. Dyhrman, J. P. Zehr, E. V. Armbrust, E. DeLong, D. M. Karl, D. A. Caron, D. Lindell, M. J. Follows, A. E. White, F. Ribalet and J. S. Weitz. [A day in the life of Prochlorococcus: Diel ecological oscillations of cyanobacteria, viruses and grazers in the North Pacific Subtropical Gyre](#). Ocean Sciences Meeting (OB14F-0430) , San Diego, CA, February 2020.
306. 2020 Caffin M., S. T. Wilson, A. E. White and D. M. Karl. [Hydrogen production by diazotrophs: a novel approach for high frequency measurements of nitrogen fixation](#). Ocean Sciences Meeting (OB14D-0397) , San Diego, CA, February 2020.
307. 2020 Dore, J. E., D. W. Sadler, A. E. White and D. M. Karl. [Temporal Variations of Inorganic Carbon Pools and Air-Sea CO₂ Fluxes in the North Pacific Subtropical Gyre Evaluated from 30 Years of Sustained Field Observations](#). Ocean Sciences Meeting (IS4C-3377) , San Diego, CA, February 2020.
308. 2020 Juranek, L. W., A. E. White, M. Dugenne, S. Ferrón, S. Dutkiewicz and D. M. Karl. [High-resolution dissolved O₂/Ar and optical scattering observations from the North Pacific subtropical/subpolar transition zone reveal contributions of small phytoplankton to oceanic net community production](#). Ocean Sciences Meeting (CT14A-0837) , San Diego, CA, February 2020.
309. 2020 Linney, M., A. E. Romano, E. DeLong and D. M. Karl. [Characterization of Dissolved DNA in the North Pacific Subtropical Gyre](#). Ocean Sciences Meeting (MM11A-06) , San Diego, CA, February 2020.
310. 2020 Weller, R., J. T. Farrar, S. Bigorre, J. Smith, J. Potemra and F. Santiago-Mandujano. [Best practices for surface radiation observations from long-term moored buoys](#). European Geosciences Union General Assembly, May 2020.
311. 2020 Wilson S. T., M. Caffin, A. E. White and D. M. Karl. [Introducing the Argon-Hydrogen Method to Measure Biological Nitrogen Fixation](#). Ocean Sciences Meeting (OB13C-01) , San Diego, CA, February 2020.

312. 2020 Zhou, M., J. Granger, A. E. White, B. Barone, and D. M. Karl. [Effects of Mesoscale Eddies on the Contribution of N₂ Fixation to Export Production in the North Pacific Subtropical Gyre](#). Ocean Sciences Meeting (OB14D-0396) , San Diego, CA, February 2020.

7.2 Invited/Contributed Book Chapters and Refereed Publications

1. 1990 Firing, E. and R. L. Gordon. Deep ocean acoustic Doppler current profiling. In: G. F. Appell and T. B. Curtin (eds.), Proceedings of the Fourth IEEE Fourth Working Conference on Current Measurements, pp. 192-201. IEEE, New York.
2. 1990 Giovannoni, S. J., E. F. DeLong, T. M. Schmidt and N. R. Pace. Tangential flow filtration and preliminary phylogenetic analysis of marine picoplankton. Applied and Environmental Microbiology, 56(8), 2572-2575.
3. 1991 Chiswell, S. M. Dynamic response of CTD pressure sensors to temperature. Journal of Atmospheric and Oceanic Technology 8(5), 659-668.
4. 1991 Karl, D. M., J. E. Dore, D. V. Hebel and C. Winn. Procedures for particulate carbon, nitrogen, phosphorus and total mass analyses used in the US-JGOFS Hawaii Ocean Time-series Program. In: D.C. Hurd and D. Spencer (eds.), Marine Particles: Analysis and Characterization, pp. 71-77. American Geophysical Union, Geophysical Monograph 63.
5. 1991 Karl, D. M., W. G. Harrison, J. Dore et al. Chapter 3. Major bioelements workshop report. In: D. C. Hurd and D. W. Spencer (eds.), Marine Particles: Analysis and Characterization, pp. 33-42. American Geophysical Union, Geophysical Monograph 63.
6. 1991 Karl, D. M. and C. D. Winn. A sea of change: Monitoring the oceans' carbon cycle. Environmental Science & Technology 25(12), 1976-1981.
7. 1991 Laws, E. A. Photosynthetic quotients, new production and net community production in the open ocean. Deep-Sea Research I 38(1), 143-167.
8. 1991 Lukas, R. and S. Chiswell. HOT Results: Submesoscale Water Mass Variations in the Salinity Maximum of the North Pacific. WOCE Notes, 3(1), 1,6-8.
9. 1991 Sabine, C. L. and F. T. Mackenzie. Oceanic sinks for anthropogenic CO₂. International Journal of Energy, Environment, Economics 1, 119-127.
10. 1991 Schmidt, T. M., E. F. DeLong and N. R. Pace. Analysis of a marine picoplankton community by 16S ribosomal-RNA gene cloning and sequencing. Journal of Bacteriology 173(14), 4371-4378.
11. 1992 Anbar, A. D., R. A. Creaser, D. A. Papanastassiou and G. J. Wasserburg. Rhenium in seawater: Confirmation of generally conservative behavior. Geochimica et Cosmochimica Acta 56(11), 4099-4103.
12. 1992 Benner, R., J. D. Pakulski, M. McCarthy, J. I. Hedges and P. G. Hatcher. Bulk chemical characteristics of dissolved organic matter in the ocean. Science 255(5051), 1561-1564.
13. 1992 Chen, R. F. and J. L. Bada. The fluorescence of dissolved organic matter in seawater. Marine Chemistry 37(3-4), 191-221.

14. 1992 Karl, D. M. The oceanic carbon cycle: Primary production and carbon flux in the oligotrophic North Pacific Ocean. In: Y. Oshima (ed.), Proceedings of the IGBP Symposium on Global Change, pp. 203-219. Japan National Committee for the IGBP, Waseda University, Tokyo, Japan.
15. 1992 Karl, D. M., R. Letelier, D. V. Hebel, D. F. Bird and C. D. Winn. *Trichodesmium* blooms and new nitrogen in the North Pacific Gyre. In: E. J. Carpenter et al. (eds.), Marine Pelagic Cyanobacteria: Trichodesmium and Other Diazotrophs, pp. 219-237. Kluwer Academic Publishers, Netherlands.
16. 1992 Karl, D. M. and G. Tien. MAGIC: A sensitive and precise method for measuring dissolved phosphorus in aquatic environments. *Limnology and Oceanography* 37(1), 105-116.
17. 1992 Quay, P. D., B. Tilbrook and C. S. Wong. Oceanic uptake of fossil fuel CO₂: Carbon-13 evidence. *Science* 256(5053), 74-79.
18. 1992 Williams, P. M. Measurement of dissolved organic carbon and nitrogen in natural waters. *Oceanography* 5:107-116.
19. 1993 Campbell, L. and D. Vault. Photosynthetic picoplankton community structure in the subtropical North Pacific Ocean near Hawaii (station ALOHA). *Deep-Sea Research I* 40(10), 2043-2060.
20. 1993 Coble, P. G., C. A. Schultz and K. Mopper. Fluorescence contouring analysis of DOC intercalibration experiment samples: a comparison of techniques. *Marine Chemistry* 41(1-3), 173-178.
21. 1993 Emerson, S., P. Quay, C. Stump, D. Wilbur and R. Schudlich. Determining primary production from the mesoscale oxygen field. *Measurement of Primary Production from the Molecular to the Global Scale. ICES Marine Science Symposium* 197, 196-206.
22. 1993 Hedges, J. I., B. A. Bergamaschi and R. Benner. Comparative analyses of DOC and DON in natural waters. *Marine Chemistry* 41(1-3), 121-134.
23. 1993 Karl, D. M. Total microbial biomass estimation derived from the measurement of particulate adenosine-5'-triphosphate. In: P. F. Kemp, B. F. Sherr, E. B. Sherr and J. J. Cole (eds.), *Handbook of Methods in Aquatic Microbial Ecology*, pp. 359-368. Lewis Publishers, Boca Raton, FL.
24. 1993 Karl, D. M., G. Tien, J. Dore and C. D. Winn. Total dissolved nitrogen and phosphorus concentrations at US-JGOFS Station ALOHA: Redfield reconciliation. *Marine Chemistry* 41, 203-208.
25. 1993 Keeling, C. D. Lecture 2: Surface ocean CO₂. The Global Carbon Cycle. *NATO ASI Series I*(15), 413-429. Heimann M, Springer-Verlag, Heidelberg, Germany.
26. 1993 Letelier, R. M., R. R. Bidigare, D. V. Hebel, M. Ondrusek, C. D. Winn and D. M. Karl. Temporal variability of the phytoplankton community structure based on pigment analyses. *Limnology and Oceanography* 38(7), 1420-1437.
27. 1993 Mopper, K. and C. A. Schultz. Fluorescence as a possible tool for studying the nature and water column distribution of DOC components. *Marine Chemistry* 41(1-3), 229-238.
28. 1993 Selph, K. E., D. M. Karl and M. R. Landry. Quantification of chemiluminescent DNA probes using liquid scintillation counting. *Analytical Biochemistry* 210(2), 394-401.

29. 1993 Sharp, J. H., E. T. Peltzer, M. J. Alperin, G. Cauwet, J. W. Farrington, B. Fry, D. M. Karl, J. H. Martin, A. Spitz, S. Tugrul and C. A. Carlson. Procedures subgroup report. *Marine Chemistry* 41, 37-49.
30. 1993 Winn, C. D., R. Lukas, D. Hebel, C. Carrillo, R. Letelier and D. M. Karl. The Hawaii Ocean Time-series program: Resolving variability in the North Pacific. In: N. Saxena (ed.), *Recent Advances in Marine Science and Technology*, pp. 139-150. Proceedings of the Fifth Pacific Ocean Congress on Marine Science and Technology (PACON 1992).
31. 1994 Baines, S. B., M. L. Pace and D. M. Karl. Why does the relationship between sinking flux and planktonic primary production differ between lakes and oceans? *Limnology and Oceanography* 39(2), 213-226.
32. 1994 Bingham, F. M. and R. Lukas. [Water Mass Variations in the Subtropical North Pacific](#). "U.S. WOCE Report 1994", U.S. WOCE Implementation Report #6, U.S. WOCE Office, 48 pp.
33. 1994 Björkman, K. and D. M. Karl. Bioavailability of inorganic and organic phosphorus compounds to natural assemblages of microorganisms in Hawaiian coastal waters. *Marine Ecology Progress Series* 111, 265-273.
34. 1994 Campbell, L., H. A. Nolla and D. Vault. The importance of *Prochlorococcus* to community structure in the central North Pacific Ocean (Station ALOHA). *Limnology and Oceanography* 39(4), 954-961.
35. 1994 Campbell, L., L. P. Shapiro and E. Haugen. Immunochemical characterization of the eukaryotic ultraplankton from the Atlantic and Pacific Oceans. *Journal of Plankton Research* 16(1), 35-51.
36. 1994 Chiswell, S. M. Using an array of inverted echo sounders to measure dynamic height and geostrophic current in the North Pacific Subtropical Gyre. *Journal of Atmospheric and Oceanic Technology* 11(5), 1420-1424.
37. 1994 Chiswell, S. M. Vertical structure of the baroclinic tides in the central North Pacific Subtropical Gyre. *Journal of Physical Oceanography* 24(9), 2032-2039.
38. 1994 Christian, J. R. and D. M. Karl. Microbial community structure at the U.S.-Joint Global Ocean Flux Study Station ALOHA: Inverse methods for estimating biochemical indicator ratios. *Journal of Geophysical Research* 99(C7), 14,269-14,276.
39. 1994 Karl, D. M. Accurate estimation of microbial loop processes and rates. *Microbial Ecology* 28, 147-150.
40. 1994 Karl, D. M. and B. D. Tilbrook. Production and transport of methane in oceanic particulate organic matter. *Nature* 368, 732-734.
41. 1994 Lukas, R. Interannual Variability of Pacific Deep and Bottom Waters Observed in the Hawaii Ocean Time-series. *WOCE Notes*, 6(2) 1, 3, 14-15.
42. 1994 Price, J. M., M. L. Van Woert, and M. Vitousek. On the possibility of a ridge current along the Hawaiian Islands. *J. Geophys. Res.*, 99(C7), 14101-14111, [doi: 10.1029/94JC00838](https://doi.org/10.1029/94JC00838).
43. 1994 Tupas, L. M., B. N. Popp and D. M. Karl. Dissolved organic carbon in oligotrophic waters: experiments on sample preservation, storage and analysis. *Marine Chemistry* 45, 207- 216.

44. 1994 Winn, C. D., F. T. Mackenzie, C. J. Carrillo, C. L. Sabine and D. M. Karl. Air- sea carbon dioxide exchange in the North Pacific Subtropical Gyre: Implications for the global carbon budget. *Global Biogeochemical Cycles* 8(2), 157-163.
45. 1995 Atkinson, M. A., F. I. M. Thomas, N. Larson, E. Terrill, K. Morita and C. Liu. A micro-hole potentiostatic oxygen sensor for oceanic CTDs. *Deep-Sea Research* 42, 761-771.
46. 1995 Chavez, F. P., K. R. Buck, R. R. Bidigare, D. M. Karl, D. Hebel, M. Latasa, L. Campbell and J. Newton. On the chlorophyll *a* retention properties of glass-fiber GF/F filters. *Limnology and Oceanography* 40(2), 428-433.
47. 1995 Christian, J. R. and D. M. Karl. Bacterial ectoenzymes in marine waters: Activity ratios and temperature responses in three oceanographic provinces. *Limnology and Oceanography* 40(6), 1042-1049.
48. 1995 Christian, J. R. and D. M. Karl. Measuring bacterial ectoenzyme activities in marine waters using mercuric chloride as a preservative and a control. *Marine Ecology Progress Series* 123(1-3), 217-224.
49. 1995 Emerson, S., P. D. Quay, C. Stump, D. Wilbur and R. Schudlich. Chemical tracers of productivity and respiration in the Subtropical Pacific Ocean. *Journal of Geophysical Research* 100(C8), 15,873-15,887.
50. 1995 Jones, D. R., D. M. Karl and E. A. Laws. DNA:ATP ratios in marine microalgae and bacteria: Implications for growth rate estimates based on rates of DNA synthesis. *Journal of Phycology* 31, 215-223.
51. 1995 Karl, D. M. A reply to a comment by J. A. McGowan "HOT and the North Pacific gyre." *Nature* 378(6552), 21-22.
52. 1995 Karl, D. M., R. Letelier, D. Hebel, L. Tupas, J. Dore, J. Christian and C. Winn. Ecosystem changes in the North Pacific subtropical gyre attributed to the 1991-92 El Niño. *Nature* 373, 230-234.
53. 1995 Liu, H., L. Campbell and M. R. Landry. Growth and mortality rates of *Prochlorococcus* and *Synechococcus* measured with a selective inhibitor technique. *Marine Ecology Progress Series* 116(1-3), 277-287.
54. 1995 Maranger, R. and D. F. Bird. Viral abundance in aquatic systems: a comparison between marine and fresh waters. *Marine Ecology Progress Series* 121(1-3), 217-226.
55. 1995 McGowan, J. HOT and the North Pacific Gyre. *Nature* 378(6552), 21-22.
56. 1995 Mullins, T. D., T. B. Britschgi, R. L. Krest and S. J. Giovannoni. Genetic Comparisons Reveal the Same Unknown Bacterial Lineages in Atlantic and Pacific Bacterioplankton Communities. *Limnology and Oceanography* 40(1), 148-158.
57. 1995 Sabine, C. L. and F. T. Mackenzie. Bank-derived carbonate sediment transport and dissolution in the Hawaiian Archipelago. *Aquatic Geochemistry* 1, 189-230.
58. 1995 Sabine, C. L., F. T. Mackenzie, C. Winn and D. M. Karl. Geochemistry of carbon dioxide in seawater at the Hawaii Ocean Time-series Station ALOHA. *Global Biogeochemical Cycles* 9(4), 637-651.

59. 1995 Sharp, J. H., R. Benner, L. Bennett, C. A. Carlson, S. E. Fitzwater, E. T. Peltzer and L. M. Tupas. Analyses of dissolved organic carbon in seawater: the JGOFS EqPac methods comparison. *Marine Chemistry* 48(2), 91-108.
60. 1995 Thomas, F. I. M. and M. J. Atkinson. Field calibration of a microhole potentiostatic oxygen sensor for oceanic CTDs. *Journal of Atmospheric and Oceanic Technology* 12(2), 390-394.
61. 1995 Thomas, F. I. M., S. A. McCarthy, J. Bower, S. Krothapalli, M. J. Atkinson and P. Flament. Response characteristics of two oxygen sensors for oceanic CTDs. *Journal of Atmospheric and Oceanic Technology* 12, 687-690.
62. 1995 Tilbrook, B. D. and D. M. Karl. Methane sources, distributions and sinks from California coastal waters to the oligotrophic North Pacific gyre. *Marine Chemistry* 49(1), 51-64.
63. 1995 Winn, C. D., L. Campbell, J. Christian, R. M. Letelier, D. V. Hebel, J. E. Dore, L. Fujieki and D. M. Karl. Seasonal variability in the phytoplankton community of the North Pacific subtropical gyre. *Global Biogeochemical Cycles* 9(4), 605-620.
64. 1996 Anbar, A.D., G.J. Wasserburg, D.A. Papanastassiou and P. S. Andersson. Iridium in natural waters. *Science* 273(5281), 1524-1528.
65. 1996 Andersen, R. A., R. R. Bidigare, M. D. Keller and M. Latasa. A comparison of HPLC pigment signatures and electron microscopic observations for oligotrophic waters of the North Atlantic and Pacific Oceans. *Deep-Sea Research II* 43, 517-537.
66. 1996 Atkinson, M. J., F. I. M. Thomas and N. Larson. Effects of pressure on oxygen sensors. *Journal of Atmospheric and Oceanic Technology* 13(6), 1267-1274.
67. 1996 Bingham, F. M. and R. Lukas Seasonal cycles of temperature, salinity and dissolved oxygen observed in the Hawaii Ocean Time-series. *Deep-Sea Research II* 43, 199-213.
68. 1996 Campos, M. L. A. M., A. M. Farrenkopf, T. D. Jickells and G. W. Luther III. A comparison of dissolved iodine cycling at the Bermuda Atlantic Time-series station and Hawaii Ocean Time-series station. *Deep-Sea Research II* 43, 455-466.
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7.3 Submitted Papers

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7.4 Thesis and Dissertations

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7.5 Data Reports and Manuals

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7.6 Newsletters

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14. 1994 Karl, D. M. HOT Stuff: Surprises emerging from five years' worth of data. U.S. JGOFS Newsletter 5(4), 9-10.
15. 1994 Tupas, L. M. Euphotic zone nitrate variability in the central North Pacific gyre at the Hawaii Ocean Time-series Station ALOHA. International WOCE Newsletter 17, 21-23.
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7.7 Symposia

- 1) Presentations from the "HOT Program: Progress and Prospectus" symposium, 3-4 June 1992, East-West Center, Honolulu, HI
 - a) Campbell, L. Bacterial numbers by flow cytometry: A new approach
 - b) Chiswell, S. Results from the inverted echo sounder network
 - c) Christian, J. Biomass closure in the epipelagic zone
 - d) Christian, J. Exoenzymatic hydrolysis of high molecular weight organic matter
 - e) Dore, J. Annual and short-term variability in the distribution of nitrite at the US-JGOFS time-series station ALOHA
 - f) Dore, J. and D. Hebel. Low-level nitrate and nitrite above the nutricline at Station ALOHA
 - g) Firing, E. Ocean currents near ALOHA
 - h) Hebel, D., R. Letelier and J. Dore. Evaluation of the depth dependence and temporal variability of primary production at Station ALOHA
 - i) Hebel, D., R. Letelier and J. Dore. Past and present dissolved oxygen trends, methodology, and quality control during the Hawaii Ocean Time series
 - j) Hebel, D. and U. Magaard. Structure and temporal variability in biomass estimates at Station ALOHA
 - k) Houlihan, T. and D. Hebel. Organic and inorganic nutrients: Water column structure and usefulness in time-series analysis
 - l) Karl, D. Carbon utilization in the mesopelagic zone: AOU-DOC relationships
 - m) Karl, D. HOT/JGOFS program objectives: A brief overview
 - n) Karl, D. P-control of N2 fixation: An ecosystem model
 - o) Karl, D. Primary production and particle flux
 - p) Karl, D. *et al.* Review and re-assessment of core measurements: Suggestions for refinement and improvement
 - q) Karl, D. and G. Tien. Low-level SRP above the nutricline at Station ALOHA
 - r) Karl, D., L. Tupas, G. Tien and B. Popp. "High-temperature" DOC: Pools and implications
 - s) Karl, D., K. Yanagi and K. Bjorkman. Composition and turnover of oceanic DOP
 - t) Letelier, R. Temporal variability of algal accessory pigments at Station ALOHA: What does it tell about the phytoplankton community structure at the DCML?
 - u) Letelier, R. and D. Hebel. Evaluation of fluorometric and HPLC chlorophyll a measurements at Station ALOHA
 - v) Letelier, R. and F. Santiago-Mandujano. Wind, sea surface temperature and significant wave height records from NDBC buoy #51001 compared to ship observations at Station ALOHA

- w) Lukas, R. Water mass variability observed in the Hawaii Ocean Time-series
 - x) Sadler, D., C. Winn and C. Carrillo. Time-series measurements of pH: A new approach for HOT
 - y) Schudlich, R. Upper ocean gas modelling at Station ALOHA
 - z) Winn, C. DIC variability
 - aa) Winn, C. and C. Carrillo. DIC and alkalinity profiles and elemental ratios
- 2) Presentations from the "HOT Golden Anniversary Science Symposium," 16 November 1993, East-West Center, Honolulu, HI
- a) Bingham, F. M. The oceanographic context of HOT
 - b) Campbell, L., H. Nolla, H. Liu and D. Vaulot. [Phytoplankton population dynamics at the Hawaii Ocean Time series Station ALOHA](#)
 - c) Campbell, L., H. Nolla and D. Vaulot. [The importance of Prochlorococcus to community structure in the central North Pacific Ocean](#)
 - d) Christian, J. [Vertical fluxes of carbon and nitrogen at Station ALOHA](#)
 - e) Dore, J. [Nitrate diffusive flux cannot support new production during quiescent periods at Station ALOHA](#)
 - f) Dore, J. [Nitrification in lower euphotic zone at Station ALOHA: Patterns and significance](#)
 - g) Firing, E. The north Hawaiian ridge current and other flows near ALOHA
 - h) Hebel, D. [Temporal distribution, abundance and variability of suspended particulate matter \(particulate carbon, nitrogen and phosphorus\) at Station ALOHA -- Observations of a seasonal cycle](#)
 - i) Karl, D., D. Hebel, L. Tupas, J. Dore and C. Winn. [Station ALOHA particle fluxes and estimates of export production](#)
 - j) Karl, D. M., R. Letelier, L. Tupas, J. Dore, D. Hebel and C. Winn. [N₂ fixation as a contributor to new production at Station ALOHA](#)
 - k) Karl, D. M., G. Tien and K. Yanagi. [Phosphorus dynamics at Station ALOHA](#)
 - l) Kennan, S. C. Possibilities for stirring along the Hawaiian ridge
 - m) Krothapalli, S., Y. H. Li and F. T. Mackenzie. [What controls the temporal variability of carbon flux at Station ALOHA?](#)
 - n) Letelier, R. M. [Inorganic carbon assimilation at Station ALOHA: Possible evidence of a change in carbon fluxes](#)
 - o) Letelier, R. M. [Spatial and temporal distribution of Trichodesmium sp. at Station ALOHA: How important are they?](#)
 - p) Liu, H. and L. Campbell. [Measurement of growth and mortality rates of *Prochlorococcus* and *Synechococcus* at Station ALOHA using a new selective inhibitor technique](#)
 - q) Lukas, R. and F. Bingham. Annual and interannual variations of hydrographic properties observed in the Hawaii Ocean Time-series (HOT)

- r) Lukas, R., F. M. Bingham and A. Mantyla An anomalous cold event in the bottom water observed at Station ALOHA
 - s) Moyer, C. L., L. Campbell, D. M. Karl and J. Wilcox. [Restriction fragment length polymorphism \(RFLP\) and DNA sequence analysis of PCR-generated clones to assess diversity of picoeukaryotic algae in the subtropical central North Pacific Ocean \(Station ALOHA\)](#)
 - t) Polovina, J. J. and D. R. Kobayashi. [HOT and Hawaii's fisheries landings: Complementary or independent time-series?](#)
 - u) Sadler, D. [Time series measurement of pH at Station ALOHA](#)
 - v) Smith, C. R., D. J. DeMaster, R. H. Pope, S. P. Garner, D. J. Hoover and S. E. Doan. [Seabed radionuclides, bioturbation and benthic community structure at the Hawaii Ocean Time-series Station ALOHA](#)
 - w) Tupas, L. M., B. N. Popp and D. M. Karl. [Dissolved organic carbon in oligotrophic waters: Experiments on sample preservation, storage and analysis](#)
 - x) Winn, C. D. [Air-sea carbon dioxide exchange at Station ALOHA](#)
 - y) Yuan, J. and C. I. Measures. [Sampling and analysis of dissolved iron](#)
- 3) Presentations from the "HOT-75 Commemorative Science Symposium," 9 September 1996, East-West Center, Honolulu, HI
- a) Atkinson, M. [A Potentiostatic, Solid-state Oxygen Sensor for Oceanic CTDs](#)
 - b) Bidigare, R., M. Latasa, R. Andersen and M. Keller. [A Comparison of HPLC Pigment Signatures and Electron Microscopic Observations for Oligotrophic Waters of the North Atlantic and North Pacific Oceans](#)
 - c) Campbell, L., H. Liu, H. Nolla and D. Vaulot. [Annual Variability of Phytoplankton and Bacteria in the Subtropical North Pacific Ocean at Station ALOHA during the 1991-1994 ENSO Event](#)
 - d) Christian, J., M. Lewis and D. Karl. [Vertical Fluxes of Carbon, Nitrogen and Phosphorus at the US-JGOFS Time-Series Station ALOHA](#)
 - e) Dore, J. and D. Karl. [Nitrification, New Production and Nitrous Oxide at Station ALOHA](#)
 - f) Ducklow, H. [Joint Global Ocean Flux Study -- Vision and Progress](#)
 - g) Emerson, S., C. Stump and D. Wilber. [Inert Gases as Tracers of Diapycnal Mixing in the Upper Ocean](#)
 - h) Firing, E. [Currents in the Vicinity of Station ALOHA: An Update](#)
 - i) Fujieki, L. [HOT-DOGS: A New Tool for HOT Program Data Base Analysis and Presentation](#)
 - j) Hebel, D., L. Tupas and D. Karl. [The Importance of Organic Exudates in the Measurement of Oligotrophic Ocean Primary Productivity](#)
 - k) Karl, D., D. Hebel and L. Tupas. [Regionalization of Station ALOHA](#)
 - l) Karl, D., G. Tien, K. Björkman, K. Yanagi, R. Letelier, A. Colman and A. Thomson. [The "Forgotten" Open Ocean P-Cycle](#)

- m) Karl, D., L. Tupas, D. Hebel, R. Letelier, J. Christian and J. Dore. [Station ALOHA N-Cycle: The Case for N₂ Fixation](#)
- n) Landry, M., K. Selph and H. Al-Mutairi. [Seasonal and Diurnal Variability of the Mesozooplankton Community at Ocean Station ALOHA](#)
- o) Letelier, R. and M. Abbott. [Effects of a Subsurface *Trichodesmium* spp. Bloom on the Optical Reflectance Measured in the Upper 150 m of the Water Column in the North Pacific Subtropical Gyre](#)
- p) Liu, H., L. Campbell and H. Nolla. [Prochlorococcus Growth Rate and Daily Variability at Station ALOHA](#)
- q) Lopez, M. and M. Huntley. [Particle Concentrations at the Hawaii Ocean Time-series Station \(Station ALOHA\) Measured with an Optical Plankton Counter](#)
- r) Michaels, A. and A. Knap. [The Bermuda Atlantic Time-Series Study \(BATS\): A View from the "Other" Ocean](#)
- s) Nolla, H., J. Kirshtein, M. Landry, D. Karl, L. Campbell and D. Pence. [Flow Cytometry Correction Factors for Enumeration of Heterotrophic Bacteria and Phytoplankton](#)
- t) Quay, P. and H. Anderson. [A Dissolved Inorganic Carbon Budget at Station ALOHA](#)
- u) Santiago-Mandujano, F. and R. Lukas. [Cold Bottom Water Events Observed in the Hawaii Ocean Time-Series: Modelling and Implications for Vertical Mixing](#)
- v) Scharek, R., M. Latasa, D. Karl and R. Bidigare. [Vertical Flux of Diatoms at the JGOFS/WOCE Station ALOHA](#)
- w) Smith, C., R. Miller, R. Pope and D. DeMaster. [Seafloor Inventories of Pb-210, Th-234 and Benthic Biomass as Proxies for Deep POC Flux: Placing Export Production at the HOT Station in a General Oceanic Context](#)
- x) Tien, G., D. Pence and D. Karl. [Hydrogen Peroxide Measurements at Station ALOHA](#)
- y) Tupas, L., G. Tien, D. Hebel and D. Karl. [Dissolved Organic Carbon Dynamics in the Upper Water Column at Station ALOHA](#)
- z) Vink, S., K. Falkner, V. Tersol, J. Yuan and C. Measures. [Variations in Iron, Aluminum, Beryllium and Barium Concentrations in Surface Waters at Station ALOHA](#)
- aa) Winn, C. [Secular Changes in Inorganic Carbon Parameters at HOT and BATS](#)

- 4) Ocean Carbon & Biogeochemistry - Sea Change: Charting the Course for Ecological and Biogeochemical Ocean Time Series Research, 21-23 September 2010, Honolulu, HI
 - a) Welcome/Introduction/Workshop objectives (Matthew Church, UH)
 - b) The Bermuda Atlantic Time-series Study (Michael Lomas, BIOS)
 - c) The Hawaii Ocean Time-series (Matthew Church, UH)
 - d) The CARIACO Oceanographic Time-Series Program (Frank Muller-Karger, USF)
 - e) Plenary 1: Cross ecosystem perspectives on aquatic biogeochemistry and plankton community structure (Robert Sterner, University of Minnesota)

- f) Ocean Biogeochemistry Research Opportunities Using the Ocean Observatories Initiative Infrastructure (Kendra Daly)
 - g) An update on the European network of marine observatories (Richard Lampitt)
 - h) The Ocean Time Series Advisory Committee (OTSAC): An introduction (Ken Johnson)
 - i) Evening plenary: "The Joy of ocean Time-Series" (David Karl, University of Hawaii)
 - j) Plenary 2: Biogeochemical and ecological coupling or decoupling of the epiplagic and deep sea: regional to global implications (Richard Lampitt, NOC, Southampton)
 - k) Plenary 3: Autonomous platform time series (Ken Johnson, MBARI)
 - l) Plenary 4: Ocean-time series as windows into scales of variability in the sea (Francisco Chavez, MBARI)
 - m) Concluding remarks (Matthew Church, UH)
- 5) Station ALOHA: Celebrating 25 years of sustained ocean observations, Ocean Sciences Meeting - Session 049, 23-28 February 2014, Honolulu, HI

Oral Presentations

- a. Bidigare, R. R.; Buttler, F. R.; Christensen, S. J.; Barone, B.; Wilson, S. T.; [Evaluation of the utility of Xanthophyll cycle pigment dynamics for assessing upper ocean mixing processes at Station ALOHA](#)
- b. Lukas, R.; Santiago-Mandujano, F. E.; Plueddemann, A. J.; Weller, R. A.; Duennebier, F. K.; [Quantifying the surface freshwater flux at Station ALOHA](#)
- c. Dore, J. E.; Sadler, D. W.; HOT CO₂ team, T.; [The HOT program presents: A Carbon carol: ghosts of CO₂ past, CO₂ present and CO₂ yet to come](#)
- d. Fitzsimmons, J. N.; Zhang, R.; Boyle, E. A.; [Short- and long-term temporal variability of iron at Station ALOHA](#)
- e. Zehr, J. P.; Carter, B. J.; Foster, R. A.; Thompson, A. W.; Tripp, H. J.; [Same stage but different actors: 20 Years of change in Nitrogen fixation at Station ALOHA](#)
- f. Bryant, J. B.; Eppley, J. M.; Karl, D. M.; Church, M. J.; DeLong, E. F.; [Wind and season drive microbial community diversity in the North Pacific Subtropical Gyre at Station ALOHA](#)
- g. Barone, B.; Church, M. J.; Karl, D. M.; Letelier, R. M.; White, A. E.; [Size structure and particle maxima in different layers of the water column of a Subtropical Gyre: Influences of algal ecology and density stratification](#)
- h. Karl, D. M.; Clemente, T.; Grabowski, E.; Wilson, S. T.; Church, M. J.; [Variability in particle export at Station ALOHA](#)

Poster Presentations

- i. Foley, J. M.; [Taking Time-series to the streets: Educational programs that communicate Station ALOHA research](#)

- j. Luo, Y. W.; Nicholson, D. P.; Doney, S. C.; [High-Frequency biogeochemical modeling based on HOE-DYLAN experiment at Station ALOHA](#)
- k. Duhamel, S.; Björkman, K. M.; Doggett, J. K.; Karl, D. M.; [Microbial group specific uptake of Inorganic phosphate and ATP at Station ALOHA: Kinetics, effect of light and response to rapid changes in N:P availability](#)
- l. Hayes, C. T.; Boyle, E. A.; McGee, D.; Fitzsimmons, J. N.; Anderson, R. F.; [\$^{232}\text{TH}/^{230}\text{TH}\$ at the Hawaii Ocean Time-series Station ALOHA: A Tool for iron cycling](#)
- m. Fontanez, K. M.; DeLong, E. F.; [Microbial community structure and function on sinking particles at Station ALOHA](#)
- n. Martinez-Garcia, S.; Karl, D. M.; [Euphotic and mesopelagic zone microbial respiration at Station ALOHA](#)
- o. Poulos, S.; Fujieki, L.; Watkins, B.; Searson, S.; Karl, D. M.; [The ALOHA Seaglider fleet](#)
- p. Church, M. J.; HOT Team, T.; [The Hawaii Ocean Time-series \(HOT\) program turns 25: Highlights of a quarter century of sustained observations in the sea](#)
- q. Segura-Noguera, M.; Curless, S. E.; Church, M. J.; Karl, D. M.; [Ammonium distribution at Station ALOHA in the North Pacific Subtropical Gyre](#)
- r. Letelier, R. M.; White, A. E.; Church, M. J.; Karl, D. M.; Bidigare, R. R.; [Local to basin scale modulation of primary productivity in the North Pacific Subtropical Gyre: Lessons learned from the Hawaii Ocean Time-series program](#)
- s. Wai, B. R.; Church, M. J.; Karl, D. M.; DeLong, E. F.; [Temporal variability of ammonia-oxidizing archaea at Station ALOHA](#)
- t. Doggett, J. K.; van den Engh, G.; Doblin, M. A.; Karl, D. M.; [High-resolution flow cytometry profiles of *Prochlorococcus* at Station ALOHA](#)
- u. Sadler, D. W.; Dore, J. E.; Church, M. J.; Fujieki, L. A.; Karl, D. M.; [Assessing the internal consistency of CO₂ measurements at Station ALOHA](#)
- v. Viviani, D. A.; Church, M. J.; [Dissolved organic matter production and microbial growth at Station ALOHA](#)
- w. Curless, S. E.; Björkman, K. M.; Updyke, B.; Mahaffey, C.; Dore, J. E.; [Analyses of inorganic nutrient pools by the Hawaii Ocean Time-series \(HOT\) program: methods, procedures, and standardization](#)
- x. Howe, B. M.; Lukas, R.; [ALOHA Cabled Observatory: On-going results and new instruments](#)
- y. McCoy, D.; Santiago-Mandujano, F. E.; Weller, R. A.; Plueddemann, A. J.; Lukas, R.; [The WHOI-Hawaii Ocean Time-series Site \(WHOTS\) mooring: highly-resolved upper ocean trends, variability, and forcing](#)

- 6) Station ALOHA: A Sentinel of open ocean change, ASLO Aquatic Sciences Meeting - Session 040, 26 February - 3 March 2017, Honolulu, HI

Oral Presentations

- a. Hayes, C. T.; Fitzsimmons, J. N.; Morton, P. L.; McGee, D.; Boyle, E. A.; [Diel trace metal variations in the North Pacific Subtropical Gyre](#)
- b. Liu, X.; Levine, N. M.; [Impact of fine-scale physics on marine ecosystem and carbon dynamics in the North Pacific Subtropical Gyre: Perspectives from a new modeling approach](#)
- c. Barone, B.; Nicholson, D. P.; Karl, D. M.; [Mesoscale eddy structure and horizontal biogeochemical variability from autonomous observations in the North Pacific Subtropical Gyre](#)
- d. Ferron, S.; Barone, B.; Church, M. J.; Karl, D. M.; [Biological oxygen production in the North Pacific Subtropical Gyre](#)
- e. White, A. E.; Watkins-Brandt, K. S.; [Annual variability in the abundance and diversity of large diazotrophs at Station ALOHA](#)
- f. Eichner, M.; Klawonn, I.; Wilson, S. T.; Littmann, S.; Whitehouse, M.; Church, M. J.; Kuypers, M. M.; Karl, D. M.; Ploug, H.; [Distinct microenvironments and high single-cell variability in *Trichodesmium* colonies collected at Station ALOHA](#)
- g. Follett, C. L.; White, A. E.; Follows, M. J.; [Nitrogen fixation measured by stoichiometric fluctuations](#)
- h. Church, M. J.; Björkman, K. M.; Karl, D. M.; Rii, Y. M.; Viviani, D. A.; [Emerging views on picoplankton dynamics at Station ALOHA](#)
- i. Edwards, B. R.; Romano, A. E.; Eppley, J. M.; Clemente, T. M.; Karl, D. M.; DeLong, E. F.; [Particle-associated microbial community structure and metabolism at abyssal depths in the North Pacific Subtropical Gyre](#)
- j. Bryant, J. A.; Mende, D. R.; Aylward, F. O.; Eppley, J. M.; Nielsen, T. N.; DeLong, E. F.; [A Genomic inflection point in the twilight zone of the ocean's interior](#)
- k. Valencia, B.; Landry, M. R.; Decima, M.; Hannides, C. C.; [Environmental drivers of mesozooplankton biomass variability at Station ALOHA, North Pacific Subtropical Gyre](#)
- l. Olson, D. K.; Mende, D. R.; Aylward, F. O.; DeLong, E. F.; [Metagenomics reveals phylogenetic diversity and depth stratification of unique proteorhodopsin genes in shallow versus deep ocean waters at Station ALOHA](#)

Poster Presentations

- m. Grabowski, E. M.; Karl, D. M.; [Caloric content of Sinking particulate matter in the North Pacific Subtropical Gyre](#)
- n. Rosburg, K. C.; Potemra, J. T.; Santiago-Mandujano, F.; Lukas, R.; Weller, R. A.; Plueddemann, A. J.; [Comparison of observed and independently-derived upper ocean currents at Station ALOHA](#)

- o. Lindh, M. V.; Church, M. J.; [There and back again - Unraveling mechanisms of microbial biogeography in the North Pacific Subtropical Gyre to and from Station ALOHA](#)
- p. Nelson, A. J.; Church, M. J.; Dornan, N.; Kyi, E.; Van Mooy, B.; Ossolinski, J.; Viviani, D.; [Rates of microbial activities associated with sinking particles at Station ALOHA in the North Pacific Subtropical Gyre](#)
- q. Björkman, K. M.; Duhamel, S.; Church, M. J.; Karl, D. M.; [Spatial and temporal variability in phosphorus inventories and turnover of inorganic P and adenosine-triphosphate in the North Pacific](#)
- r. Curless, S. E.; Church, M. J.; Segura-Noguera, M.; Karl, D. K.; [Ammonium concentrations at Station ALOHA - Improved methodology allows for full ocean depth analysis](#)
- s. Sadler, D. W.; Barone, B.; Burkitt, J. W.; Dore, J. E.; Church, M. J.; Karl, D. M.; [High-resolution in-situ pH measurements at Station ALOHA using an ion-sensitive field effect transistor](#)
- t. Luo, E.; Eppley, J. M.; Aylward, F. O.; Romano, A. R.; DeLong, E. F.; [Vertical variability in viral and host assemblages at Station ALOHA](#)
- u. Viviani, D. A.; Böttjer, D.; Letelier, R. M.; Church, M. J.; [The Influence of abrupt increases in seawater pCO₂ on rates of microbial production in the subtropical North Pacific Ocean](#)
- v. Royer, S. J.; Ferron, S.; Wilson, S. T.; del Valle, D. A.; Sosa, O.; Karl, D. M.; [Methane production from sinking particulate matter at Station ALOHA](#)
- w. Turk-Kubo, K. A.; Hogan, M. E.; Zehr, J. P.; Munoz-Marin, M.; [In-situ diazotroph net growth rates under different resource ratios at Station ALOHA](#)

8.0 DATA AVAILABILITY AND DISTRIBUTION

Data collected by HOT program scientists are made available to the oceanographic community in various ways as soon after processing as possible. The complete data set, containing data collected since year 1 of the HOT program (1988-89), as well as 2 dbar averaged CTD data, may be accessed using anonymous File Transfer Protocol (FTP) or the World Wide Web (WWW).

8.1 File Transfer Protocol

In order to maximize ease of access, the data are in ASCII files.

The workstation's Internet address is *ftp://ftp.soest.hawaii.edu*. The data are in a subdirectory called */hot*. More information about the data base is given in several files called *Readme.** at this level. The file *[Readme.first](#)* gives general information on the data base; we encourage users to read it first.

The following is an example of how to use FTP to obtain HOT data.

1. FTP into *ftp.soest.hawaii.edu*.
2. Enter *anonymous* as the user name.
3. Enter your e-mail address as the password.
4. The HOT database is in */hot*.
- 5a. To obtain information about the database, view *[Readme.first](#)*.
- 5b. To obtain 2-decibar averaged CTD data, change directories to *ctd/hot-#*, where # is the HOT cruise of interest.
- 5c. To obtain water column data, change directories to *water*. For each cruise, 2 files are provided. The *hot#.gof* files contain all of the physical and biogeochemical data, while the *hot#.sea* files only contain the physical and inorganic nutrient data.

Please contact us (<https://hahana.soest.hawaii.edu/hot/contact/contact.php>) to access hydrographic data from recent cruises (data preliminarily calibrated and quality controlled).

8.2 World Wide Web

The Hawaii Ocean Time-series Program maintains a site on the World Wide Web where data and information about the program and its activities can easily be accessed over the Internet. The address is <https://hahana.soest.hawaii.edu/hot/hot.html>. The first half of the most recent year's hydrographic data is usually available by July and the second half by January of the

following year with certain quality control caveats. All available data are quality controlled by around July of the following year. Downloading of data is through FTP but the web pages provide a more detailed means of access.

8.3 HOT-DOGS[©]

HOT-DOGS is the acronym for the Hawaii Ocean Time-series Data Organization and Graphical System. Its address is <https://hahana.soest.hawaii.edu/hot/hot-dogs/interface.html>. HOT-DOGS is a Matlab™ based program that displays HOT data in a graphical format as depth profiles, time-series or contour plots. In addition to its graphical capabilities, HOT-DOGS provides a means of downloading selected data parameters during specific years of the program. The user may perform the following:

- **Data Extraction**

- [Bottle](#) (discrete)
- [CTD](#) (continuous)
- [Macrozooplankton](#) (Nets)
- [Particle Flux](#)
- [Primary Production](#)

- **Display**

- [Bottle](#) (discrete)
- [CTD](#) (continuous)
- [HPLC Pigments](#)
- [Particle Flux](#)
- [Primary Production](#)
- [Solar Irradiance](#)
- [PRR \(Ir\)radiance](#)
- [Hyperspectral \(Ir\)radiance](#)
- [TSRB \(Ir\)radiance](#)
- [Fast Repetition Rate Fluorometry](#)
- [Laser In-Situ Scattering & Transmissometry](#)
- [Absorption Spectra \(PUR\)](#)
- [Chlorofluorocarbon & Sulfur Haxafluoride](#)
- [Underway Measurements](#)
- [User Defined](#)

- **Standard Intervals** (vertical Water-Column)

- [Bottle](#) (discrete)
- [HPLC Pigments](#)
- [Primary Production](#)
- [User Defined](#)

- **Time-series**

- [Bottle](#) (discrete)
- [HPLC Pigments](#)
- [Macrozooplankton](#) (Nets)
- [Particle Flux](#)
- [Primary Production](#)
- [\(Ir\)radiance](#)
- [User Defined](#)

- **Contour**

- [Bottle](#) (discrete)
- [CTD](#) (continuous)
- [HPLC Pigments](#)
- [Primary Production](#)
- [User Defined](#)

- **Miscellaneous**

- [Mixed-layer Depth](#)
- [Cruise Summary](#)

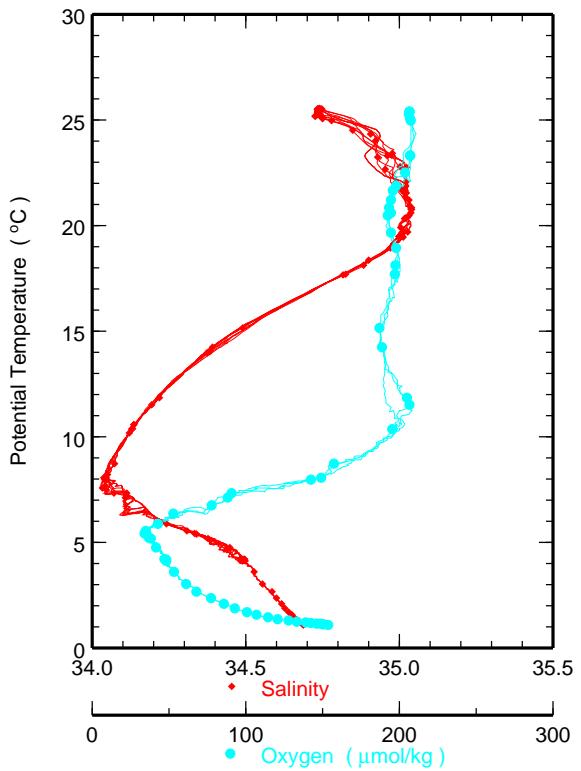
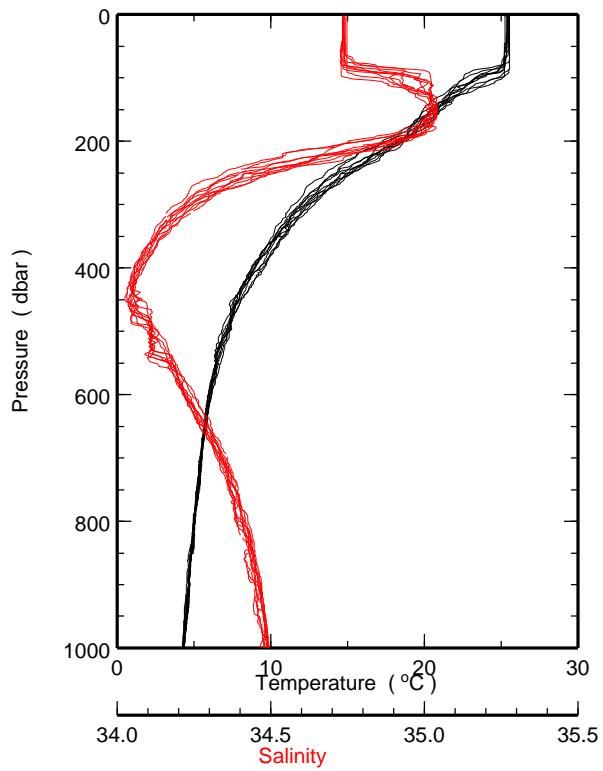
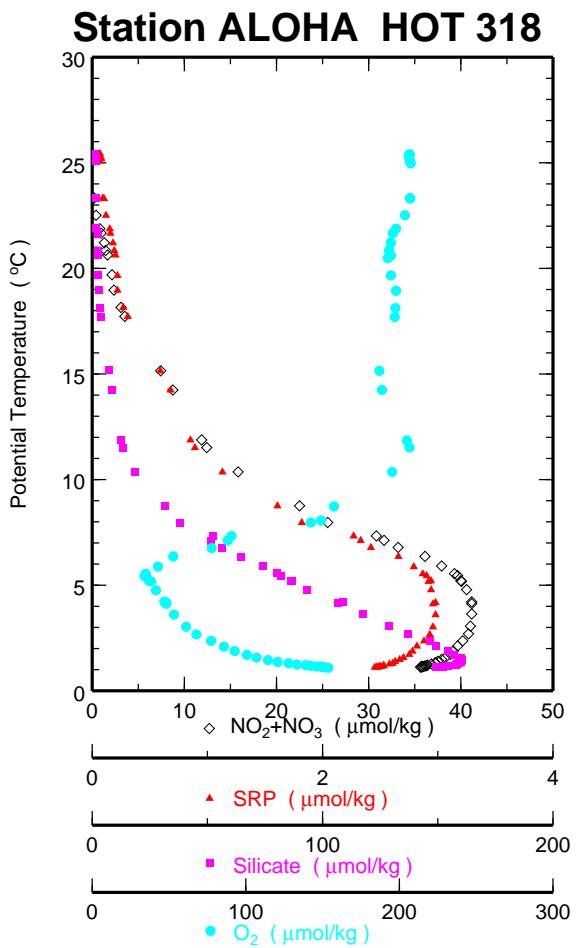
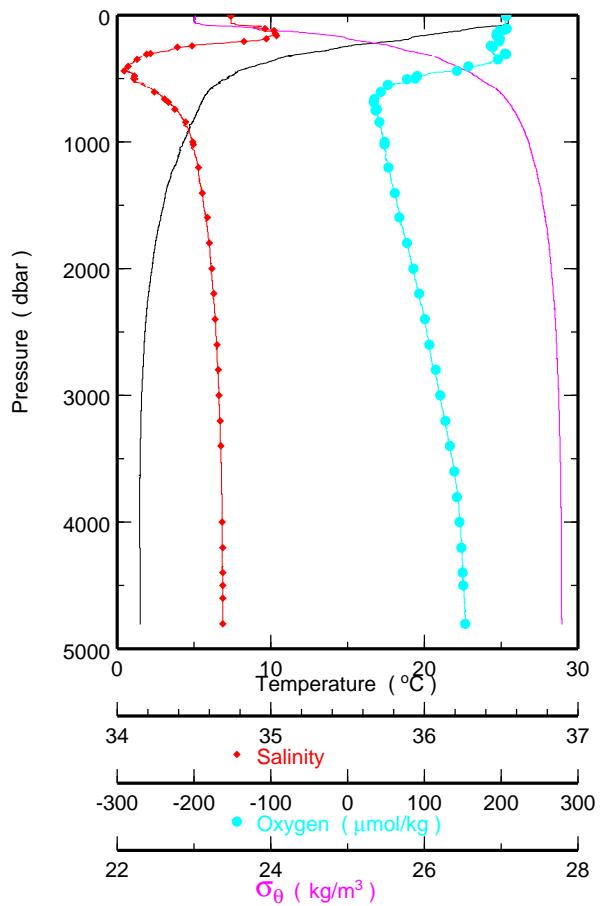


Figure 6.1.1a

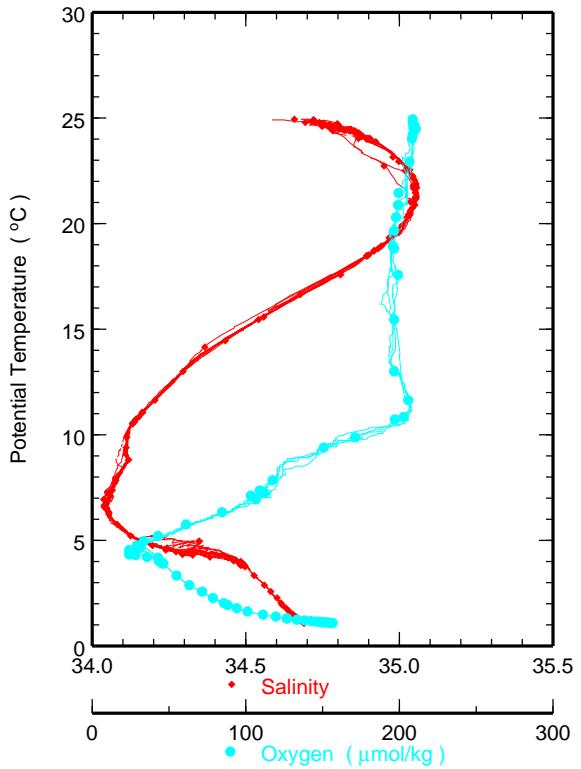
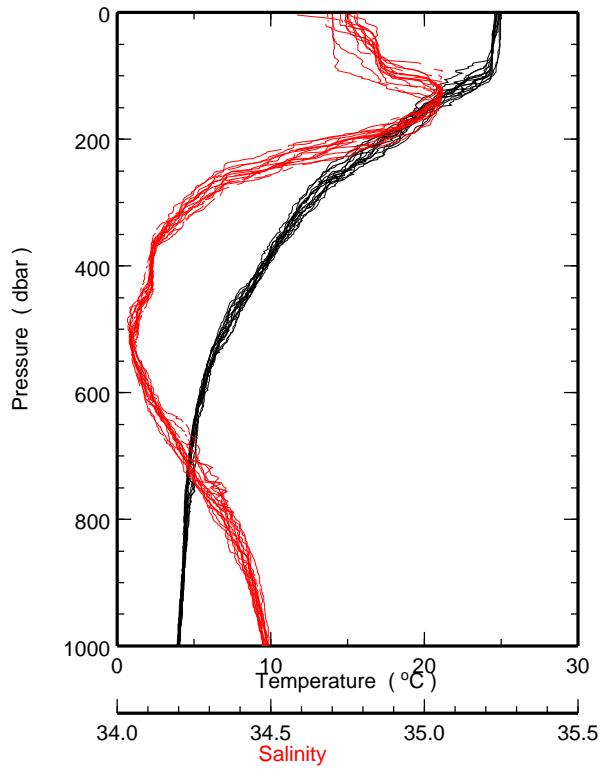
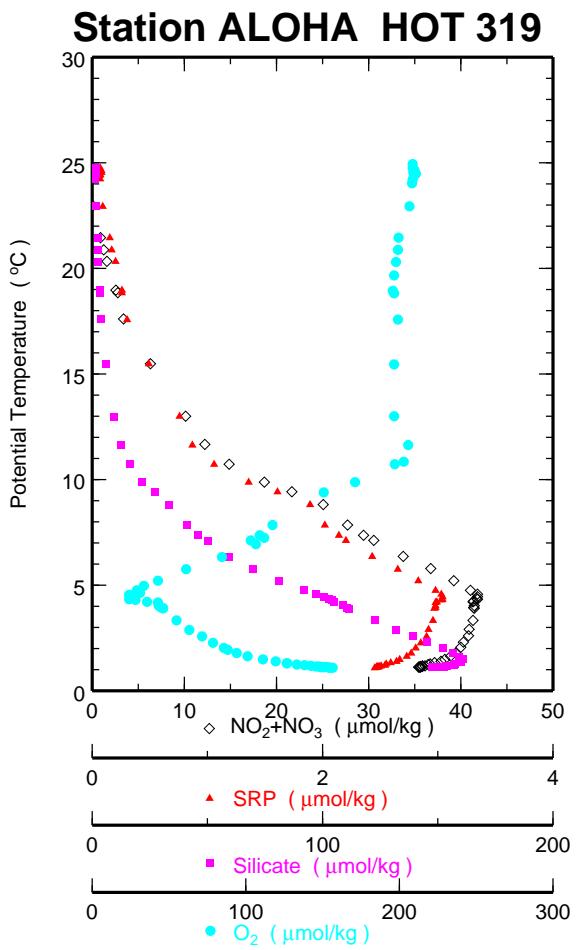
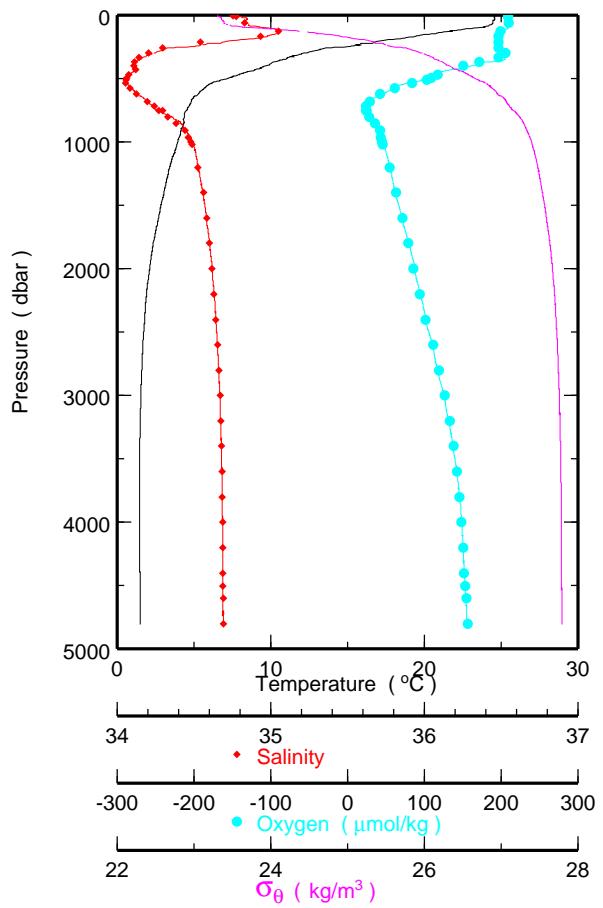


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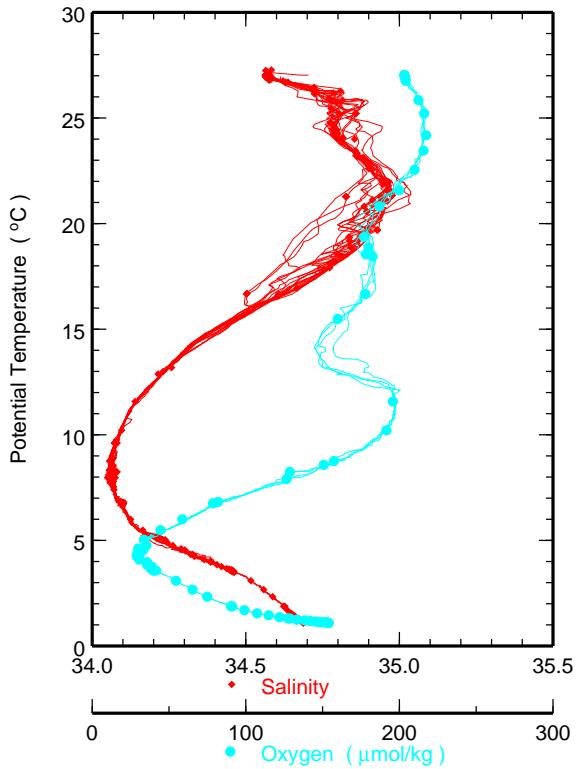
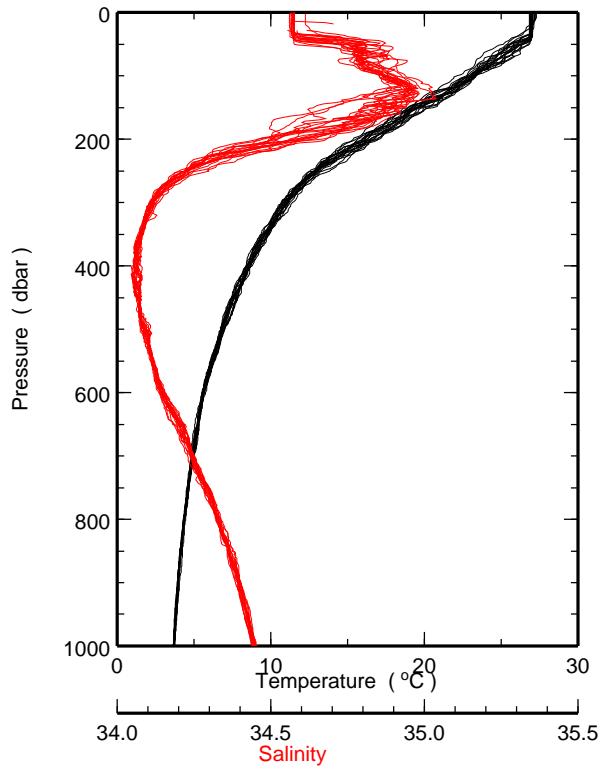
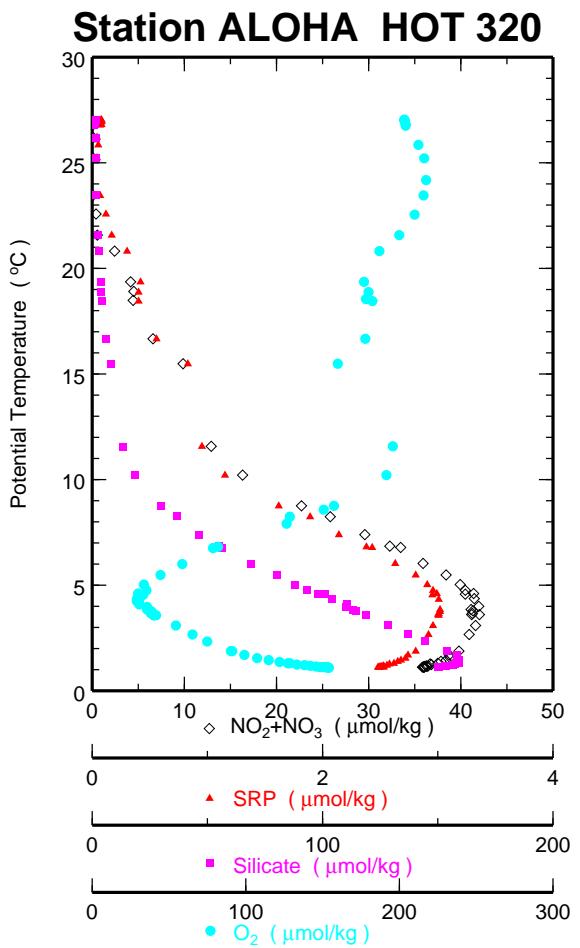
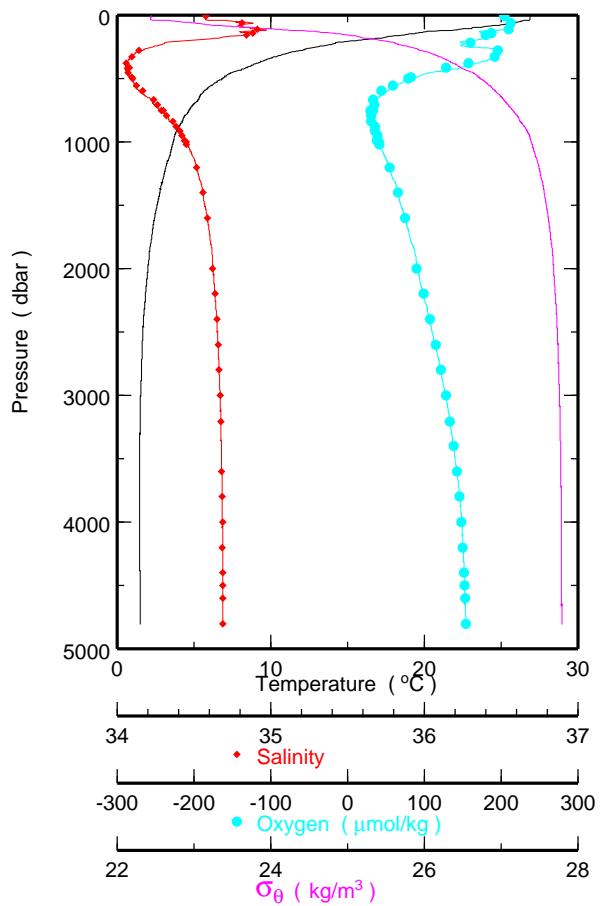


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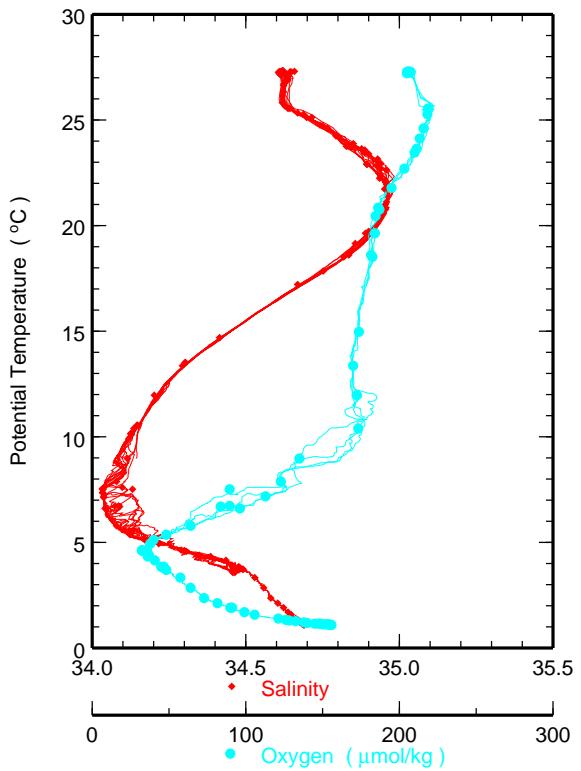
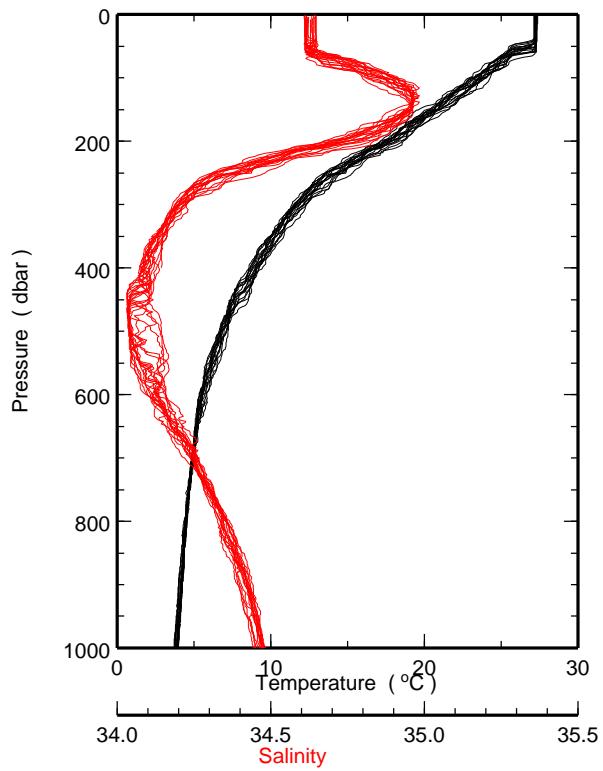
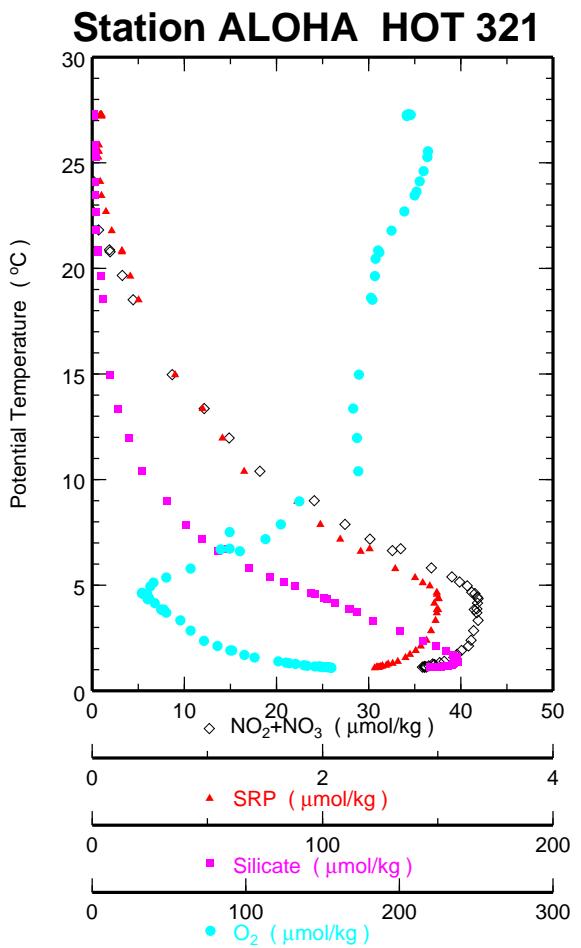
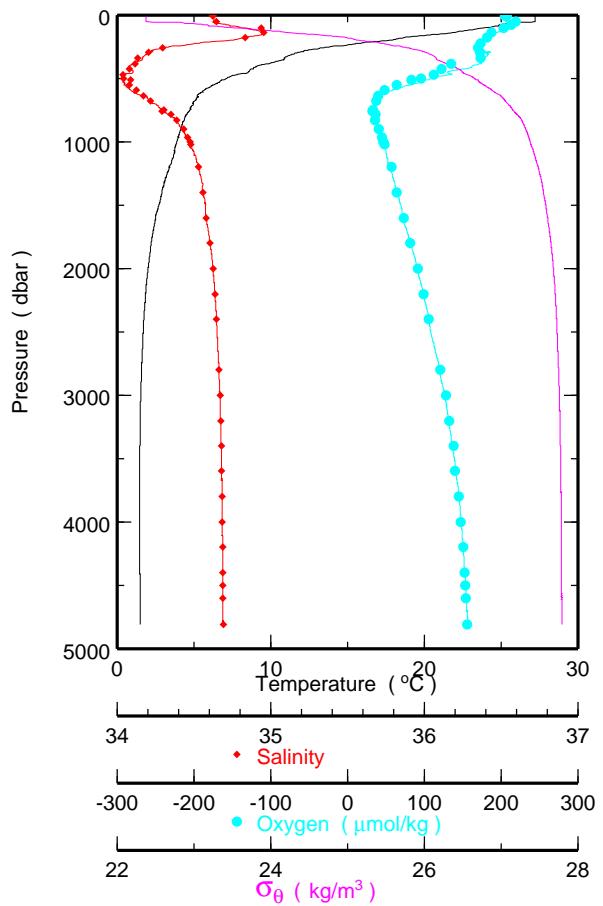


Figure 6.1.1d

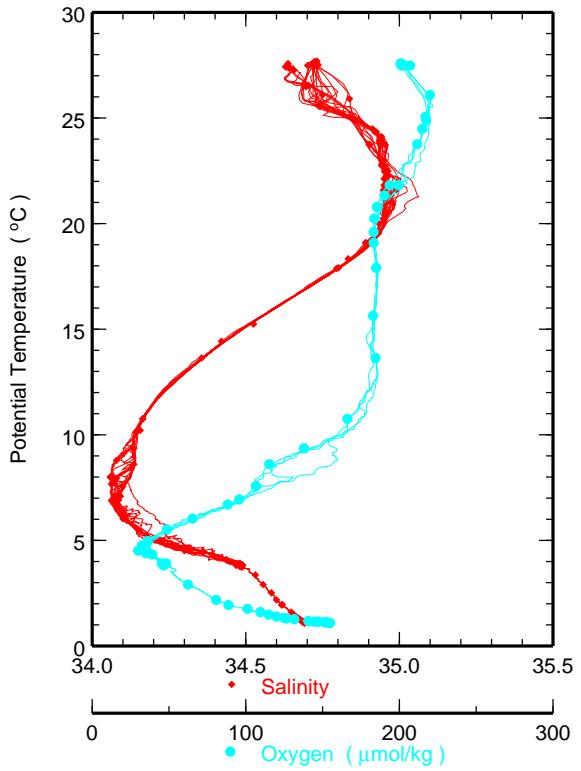
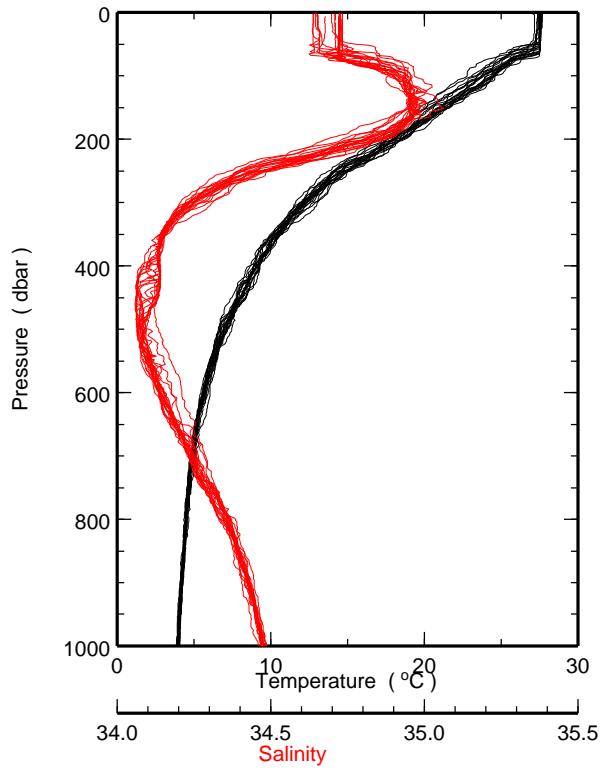
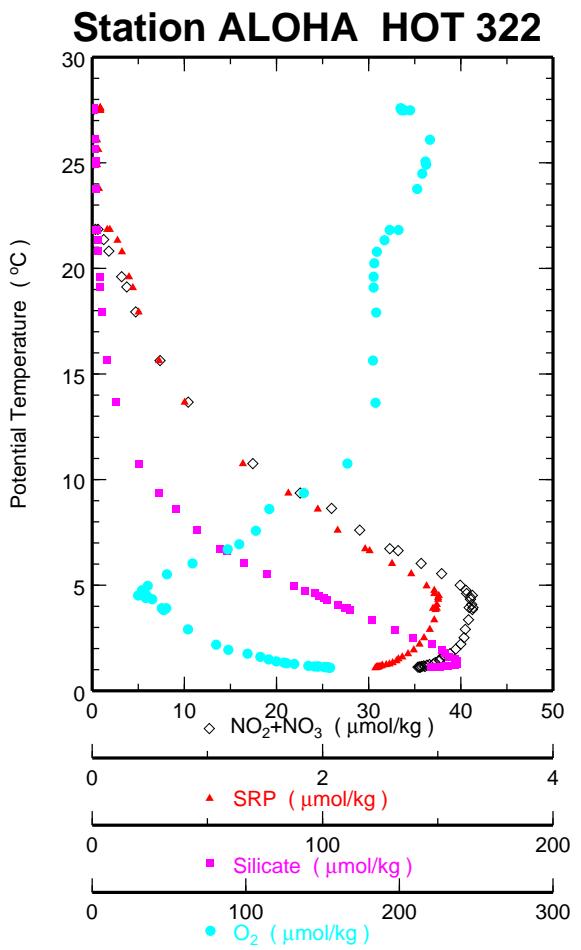
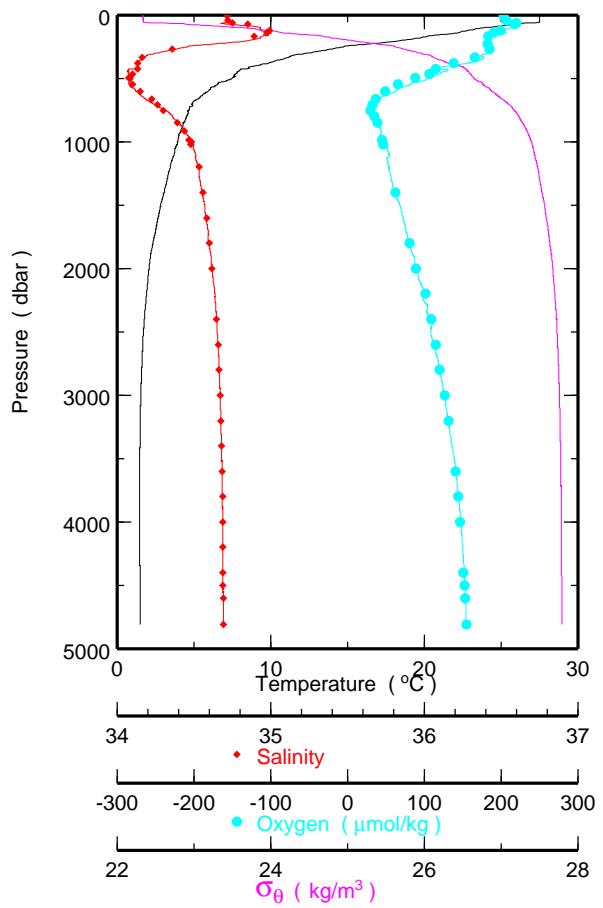


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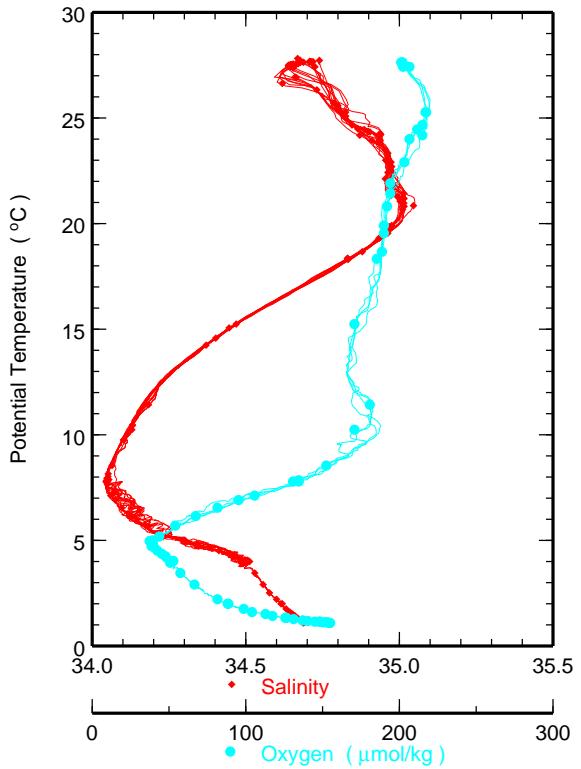
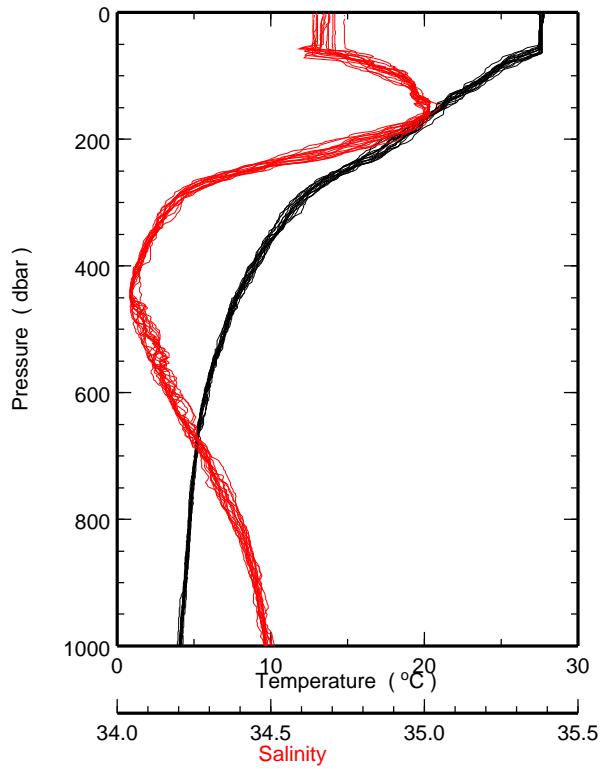
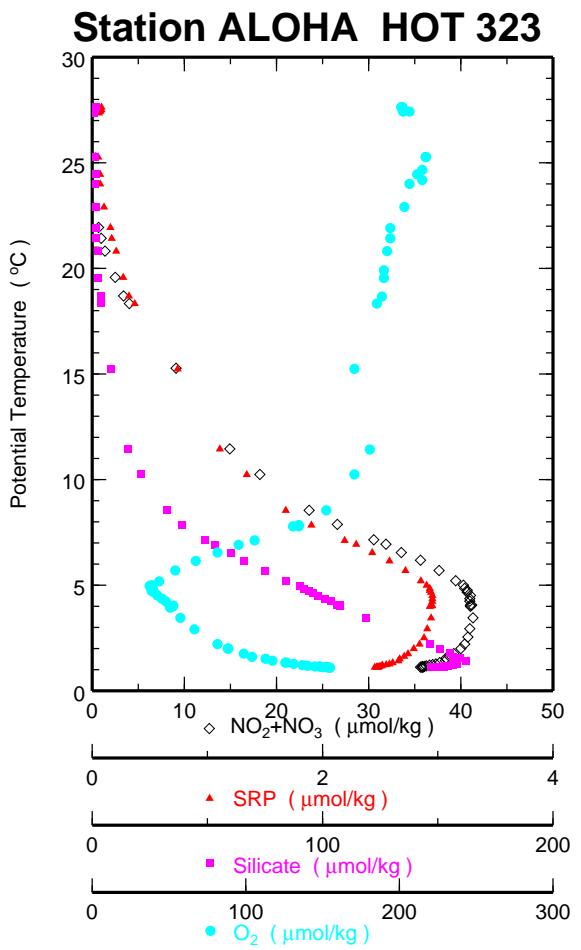
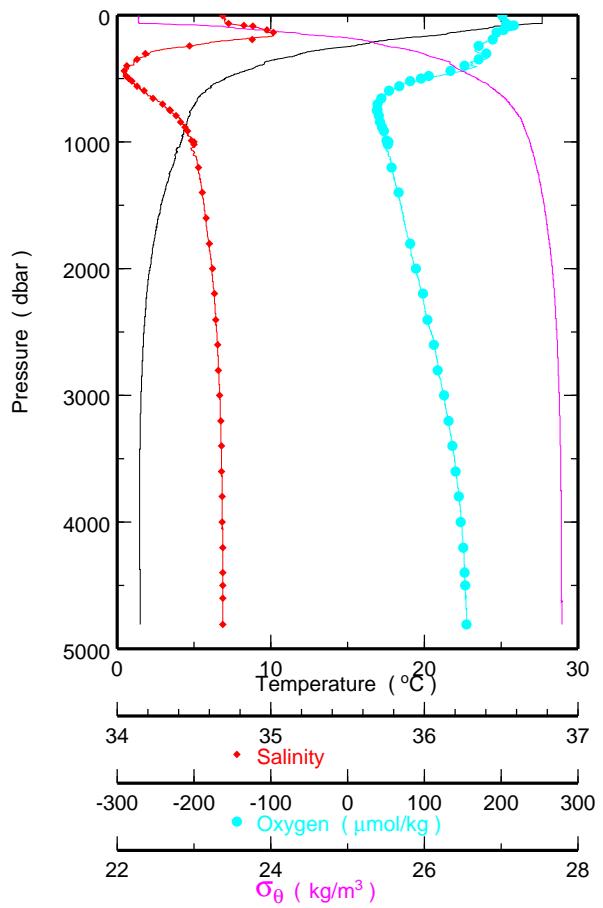


Figure 6.1.1f

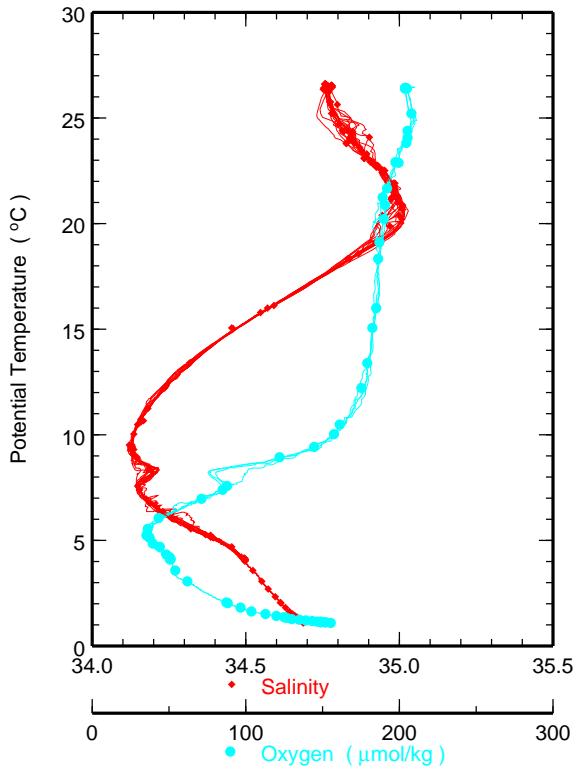
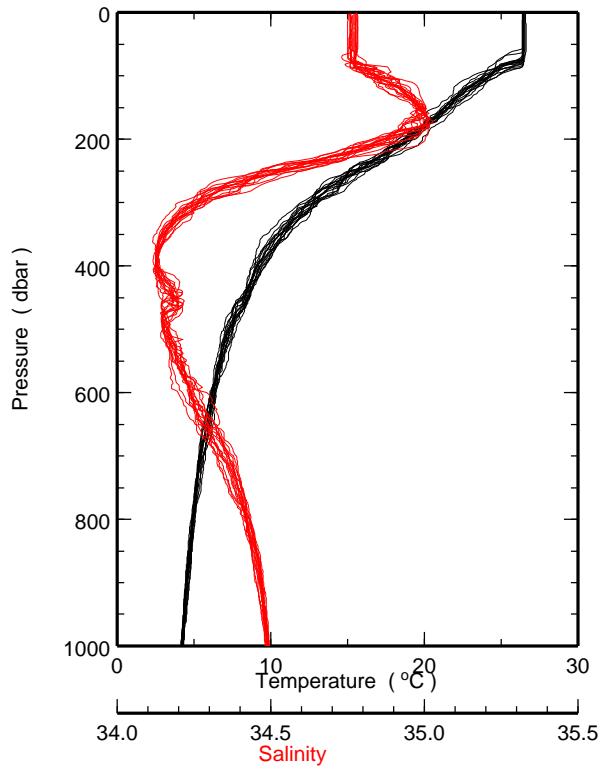
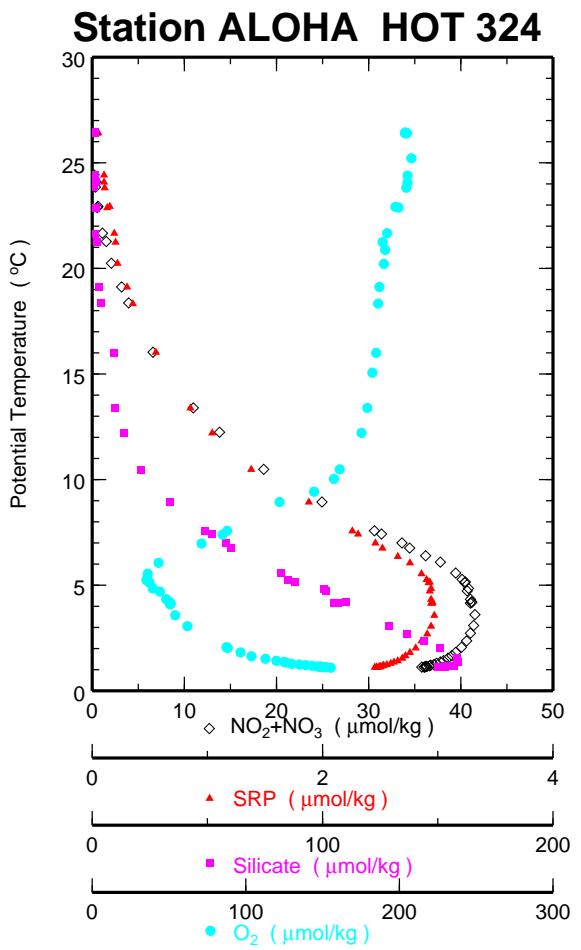
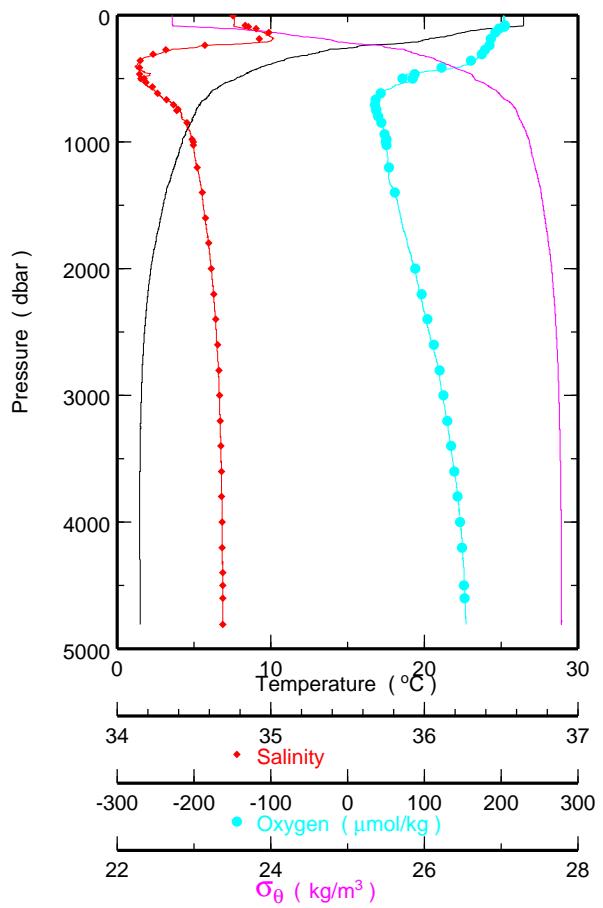


Figure 6.1.1g

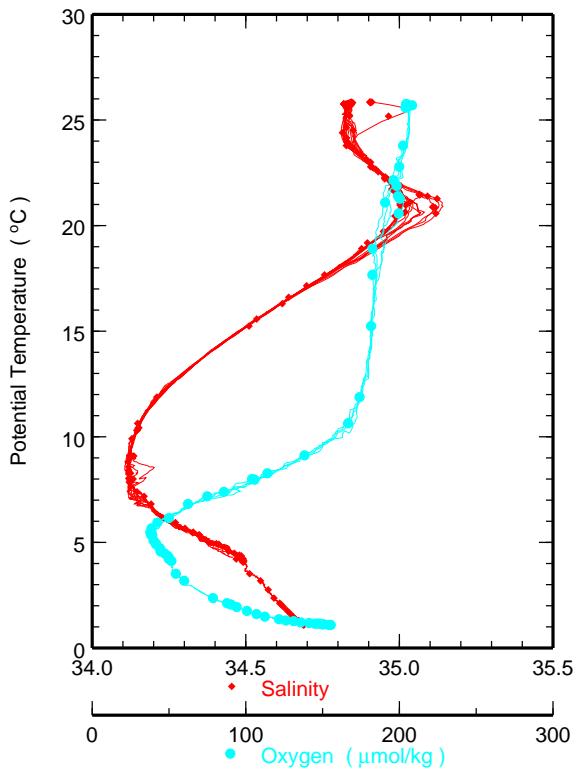
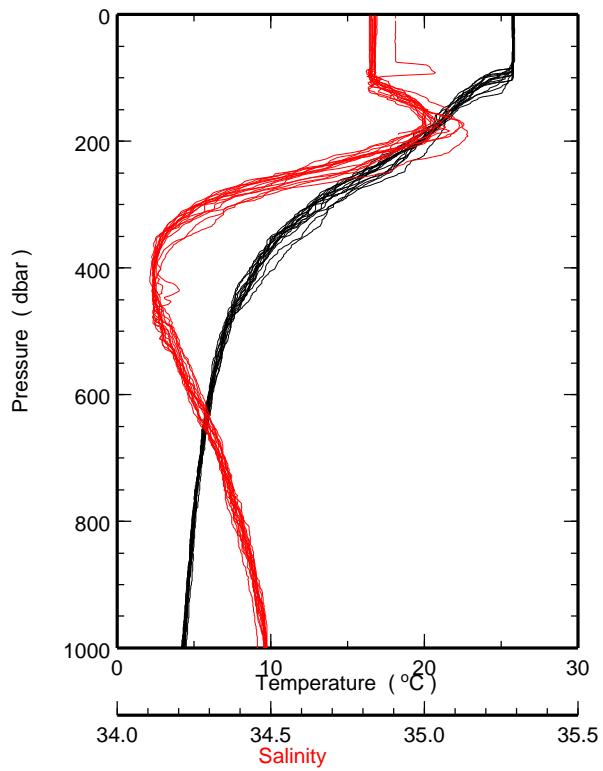
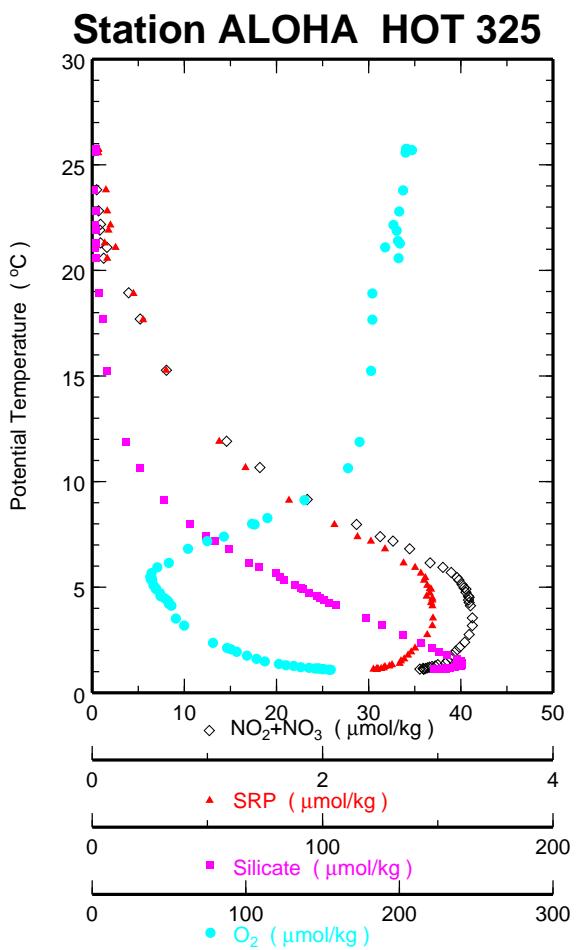
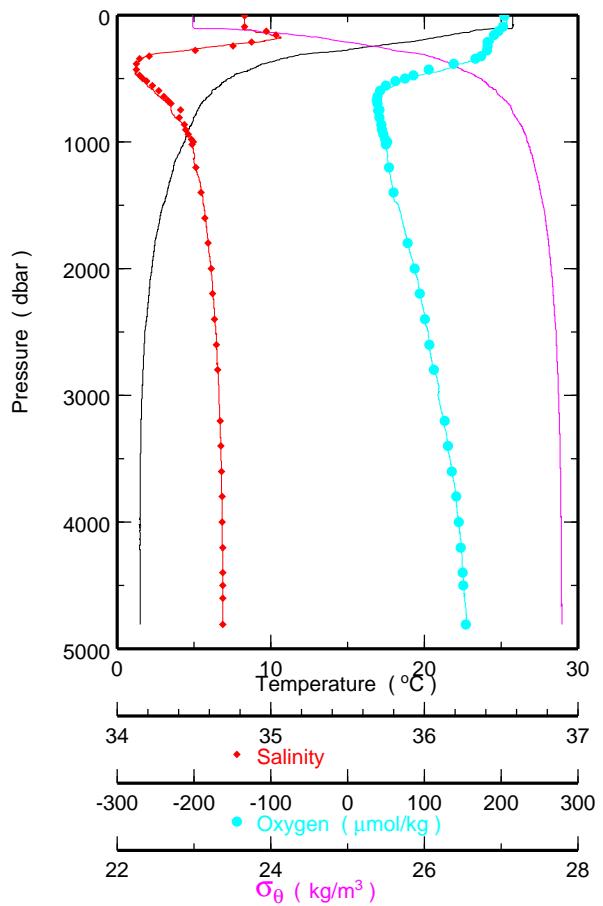


Figure 6.1.1h

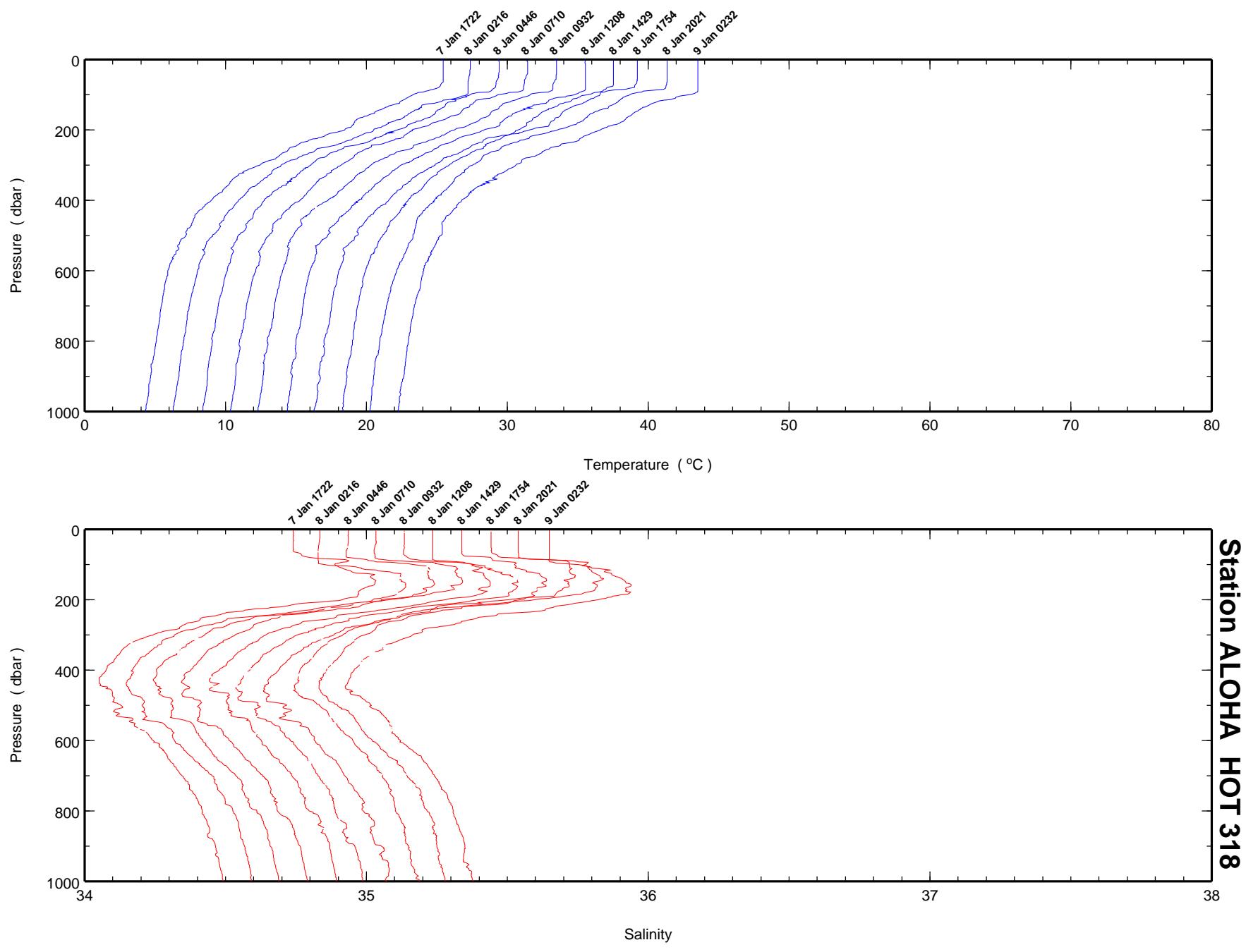


Figure 6.1.2a

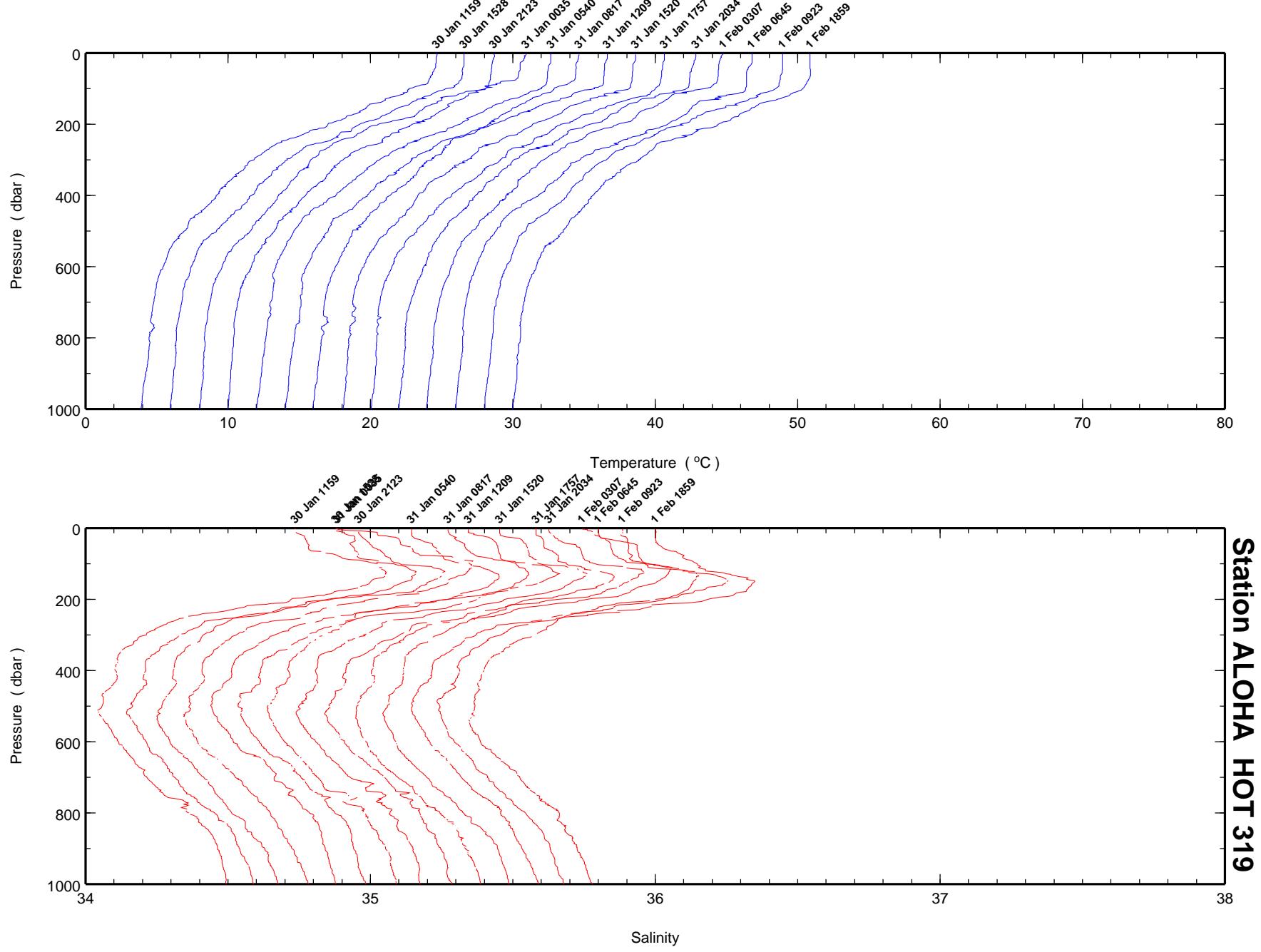


Figure 6.1.2b

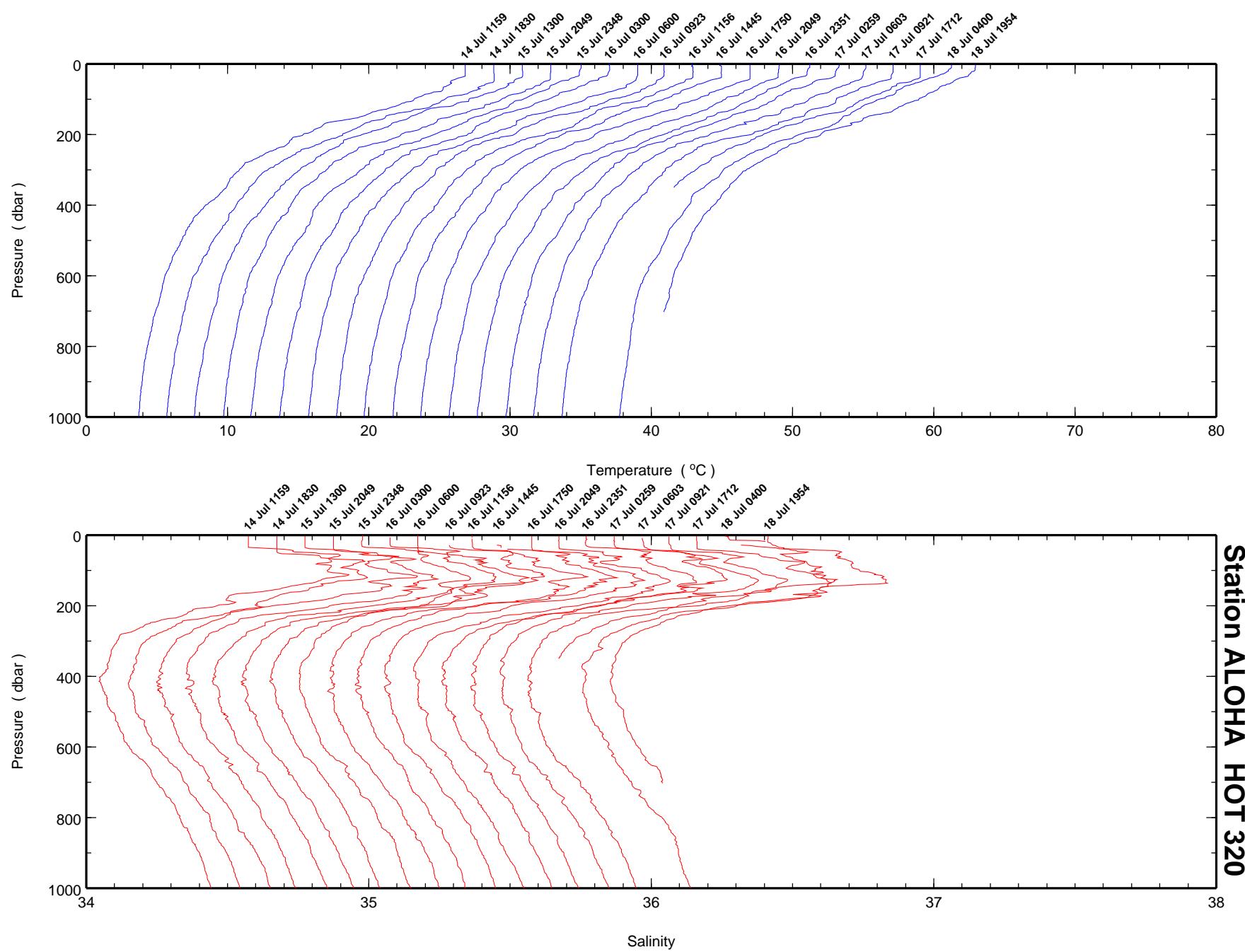


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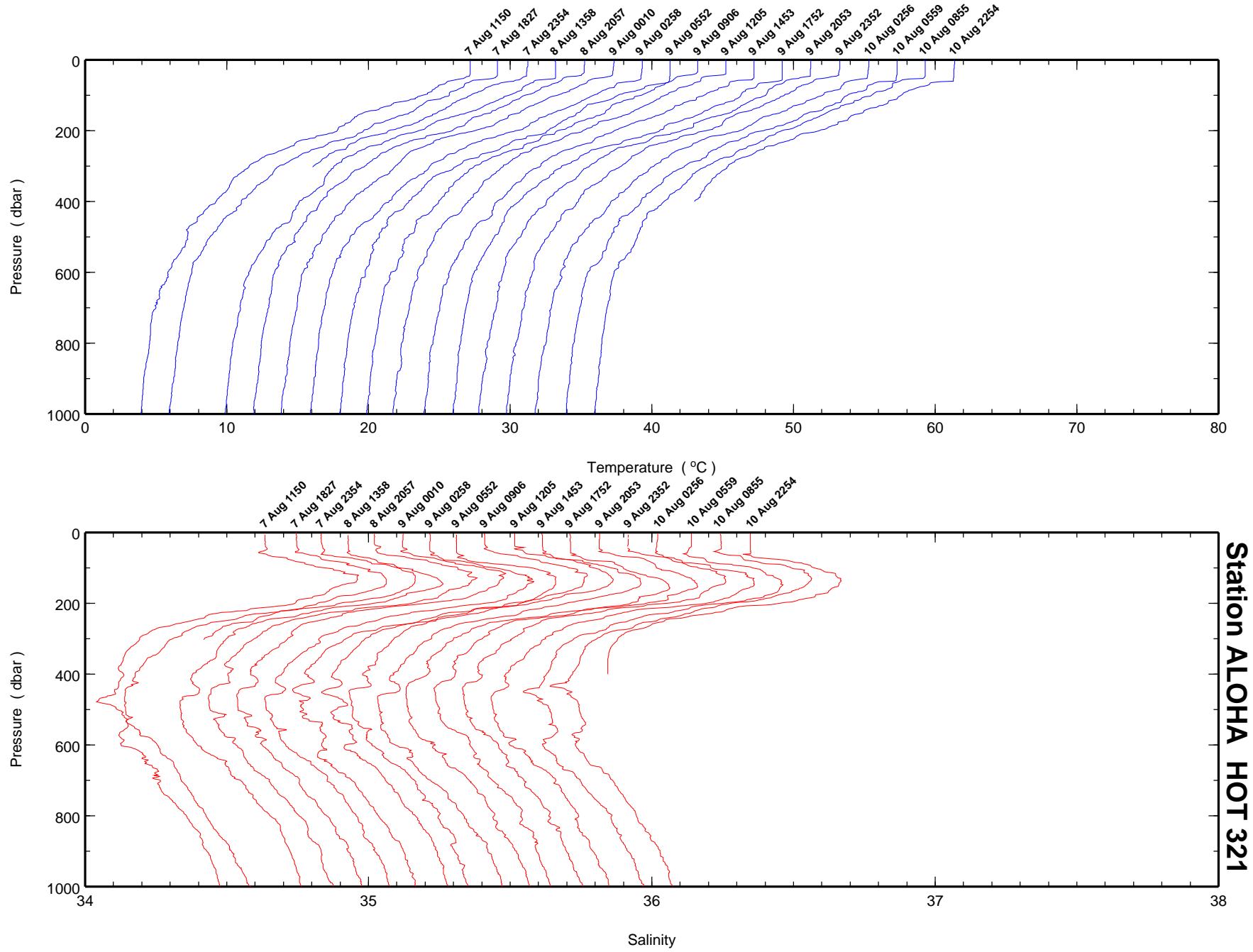


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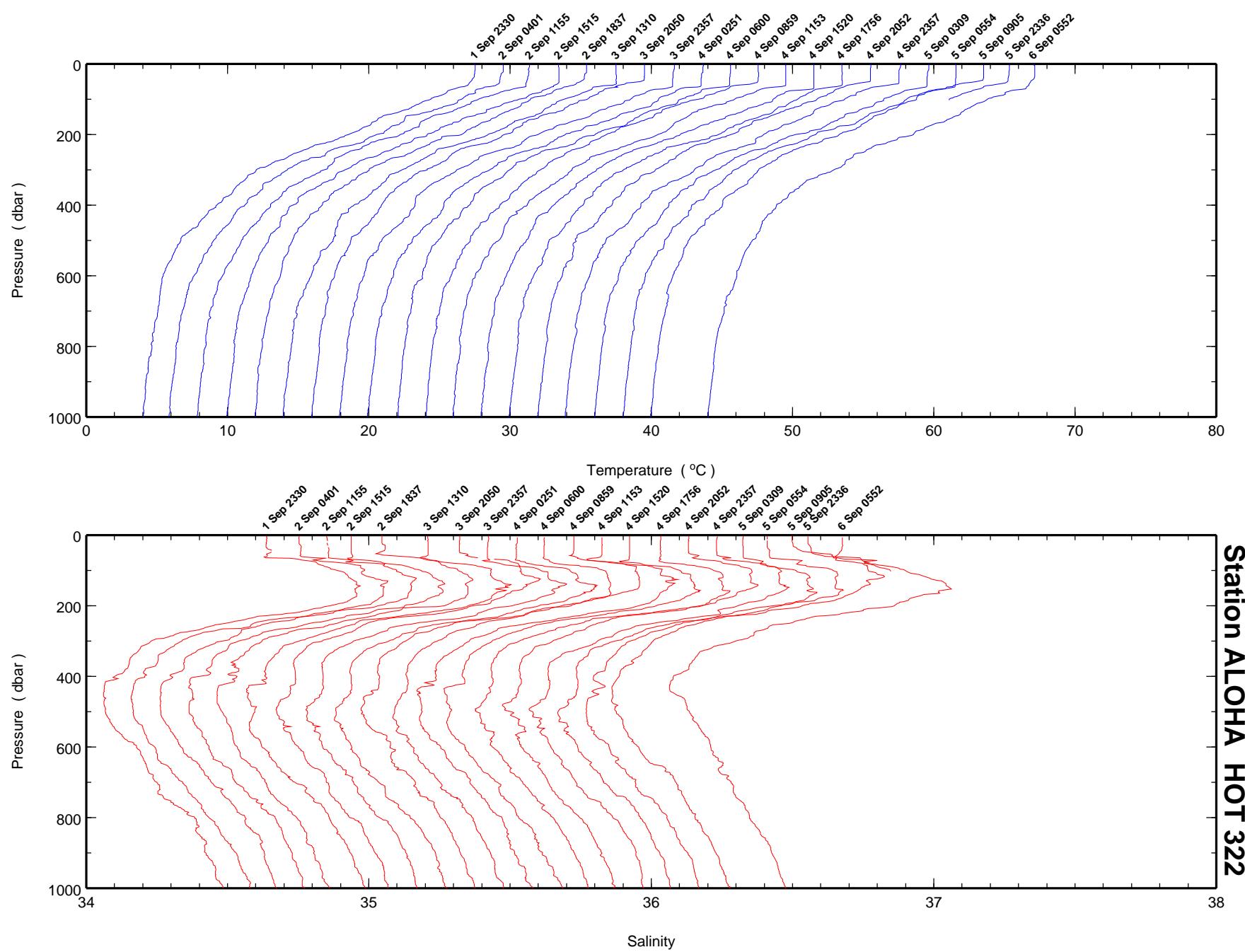


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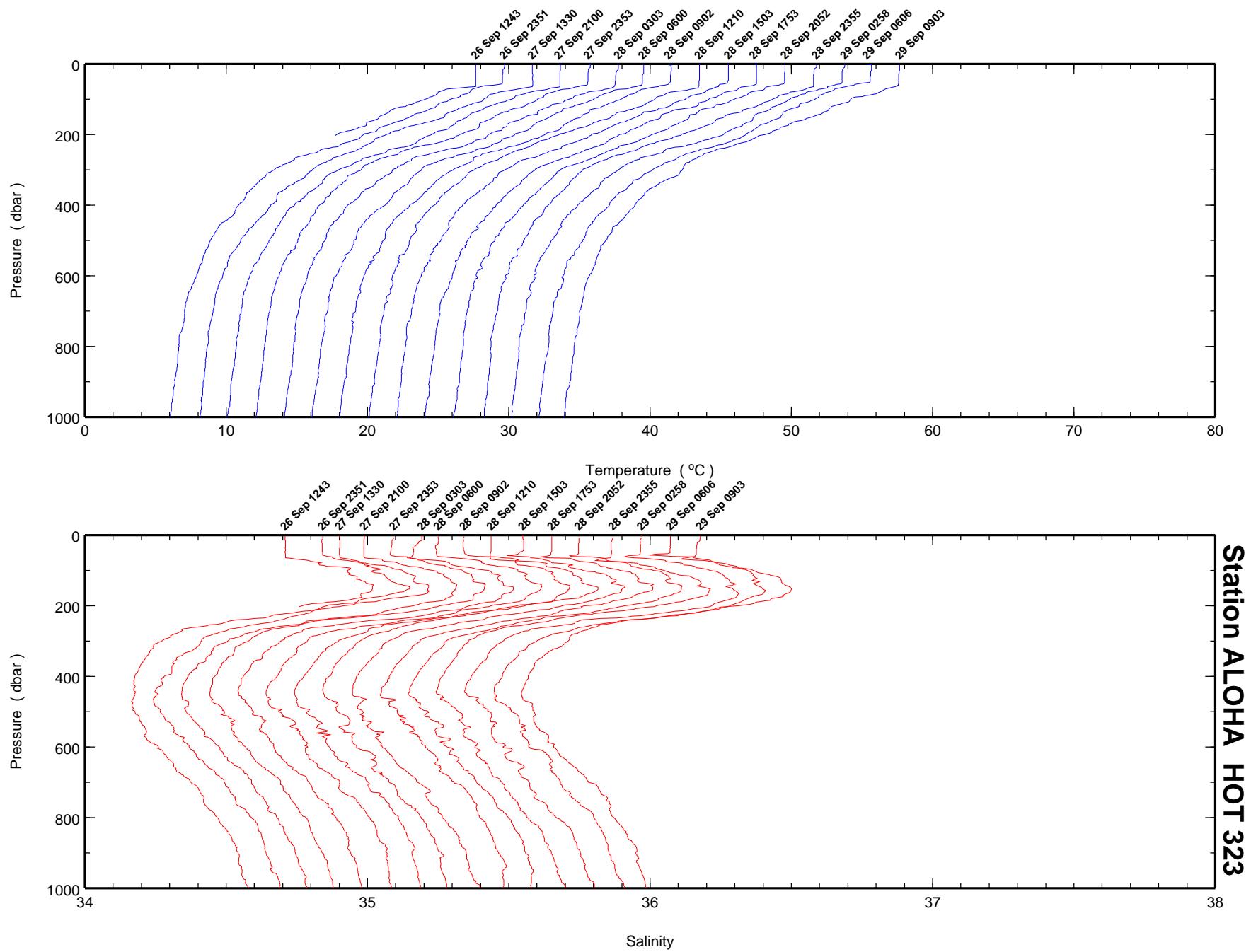


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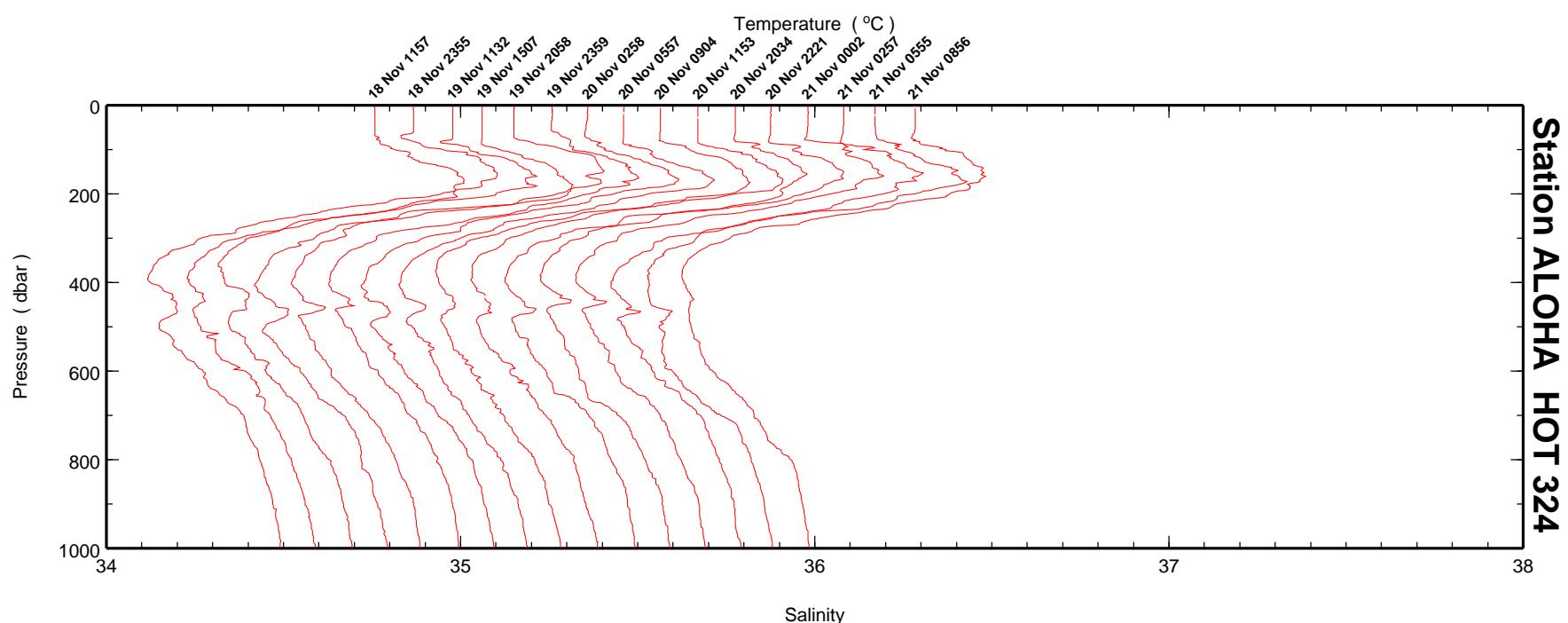
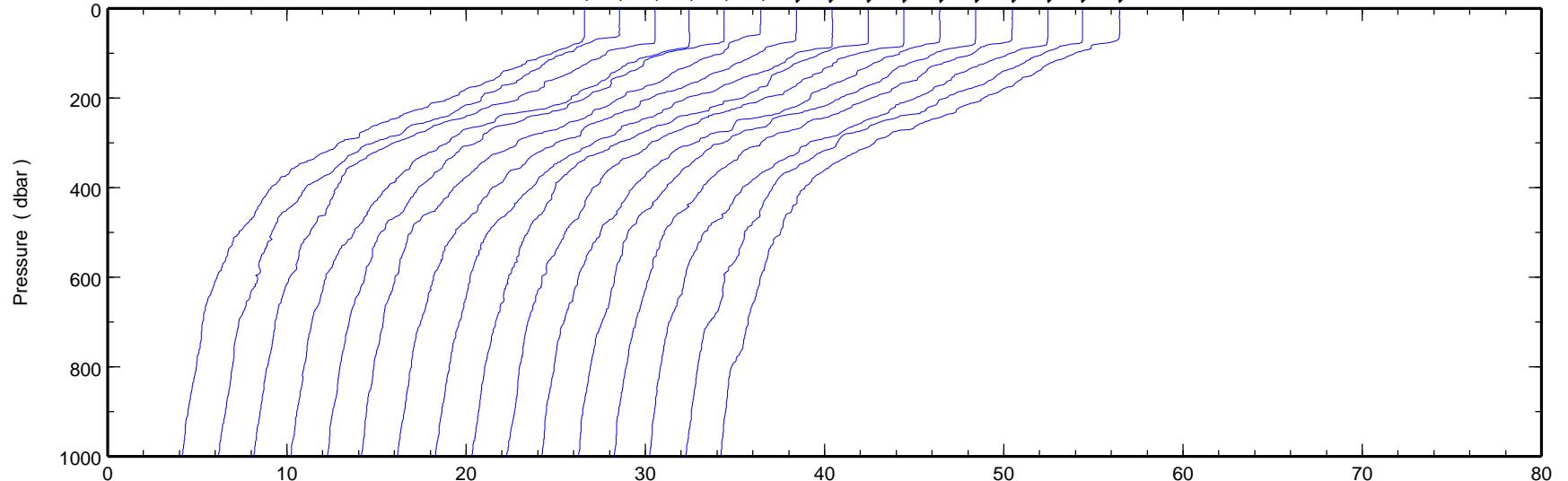


Figure 6.1.2g

Station ALOHA HOT 324

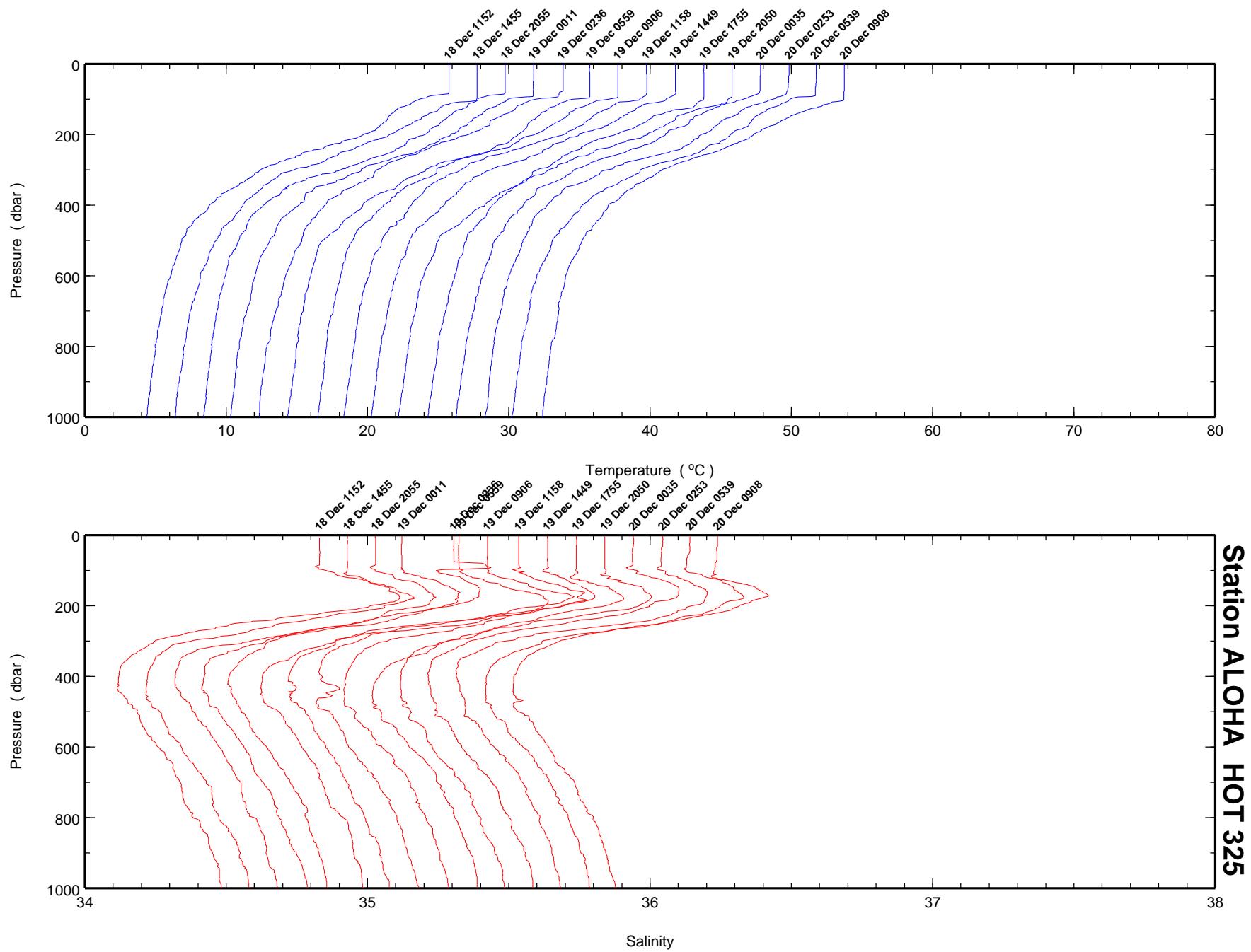


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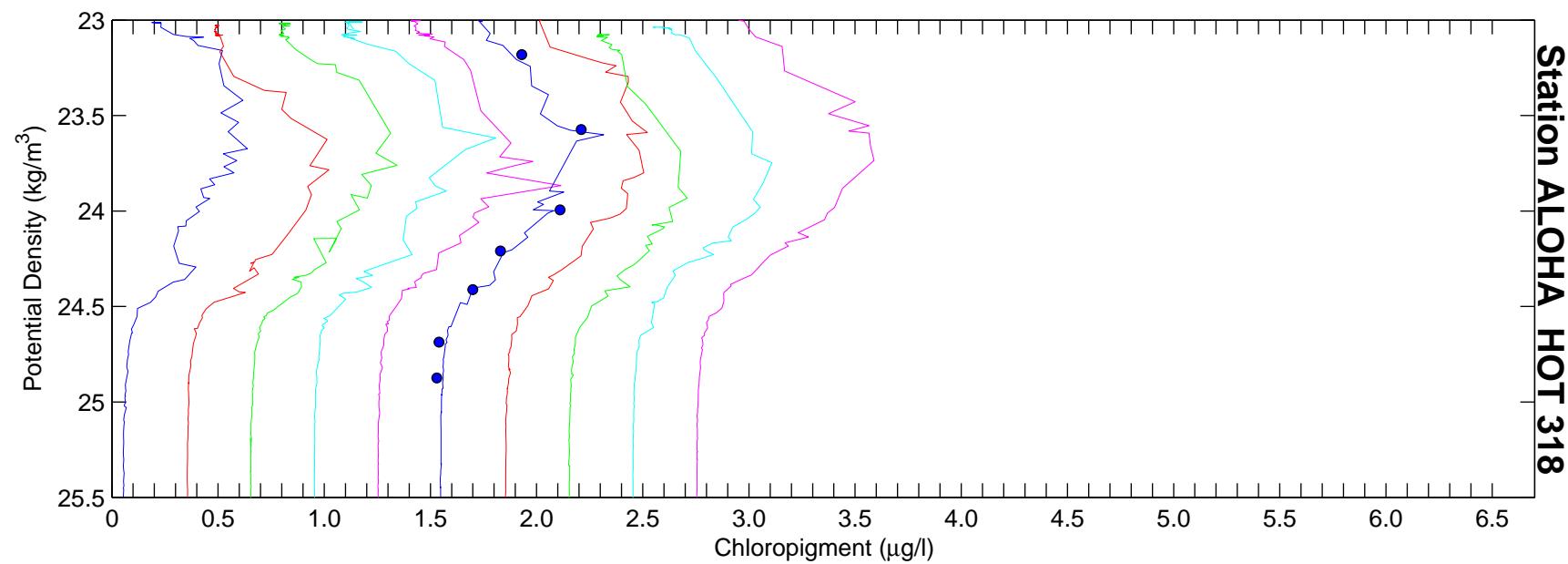
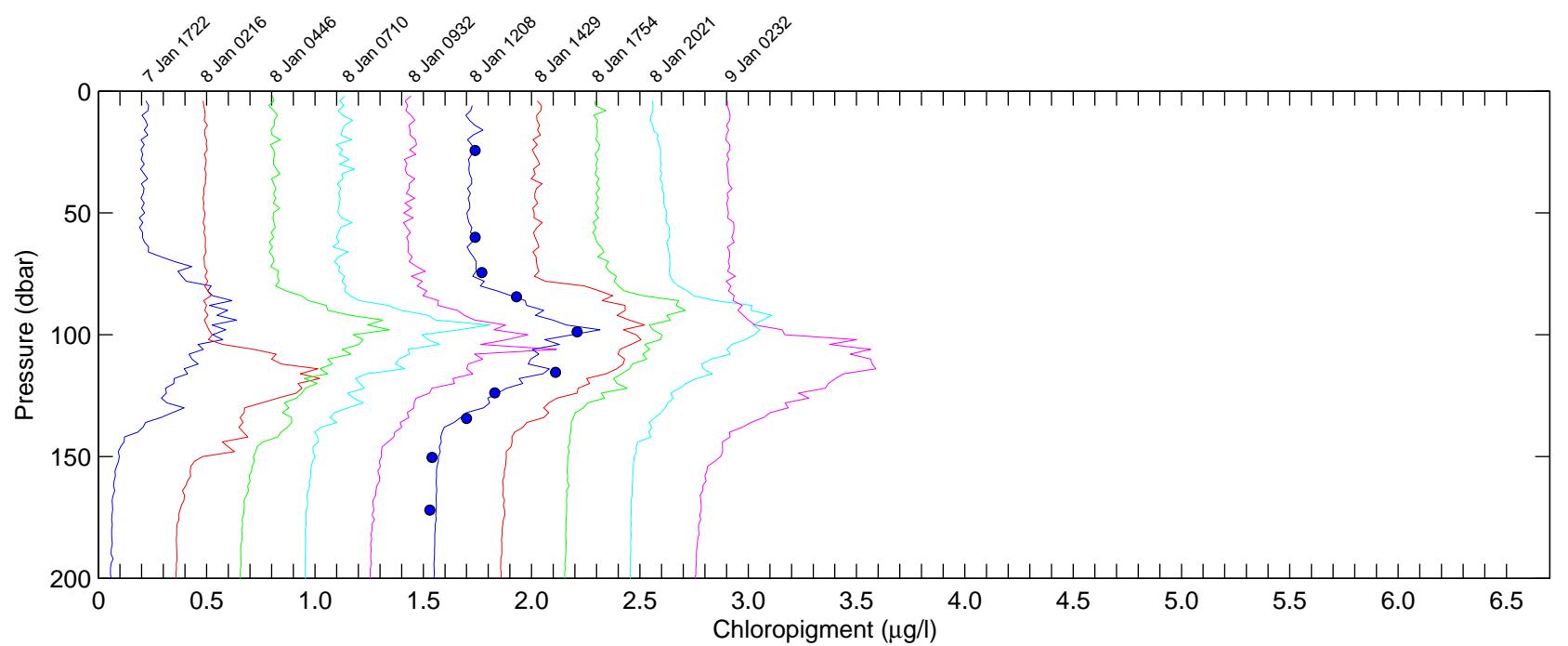


Figure 6.1.3a

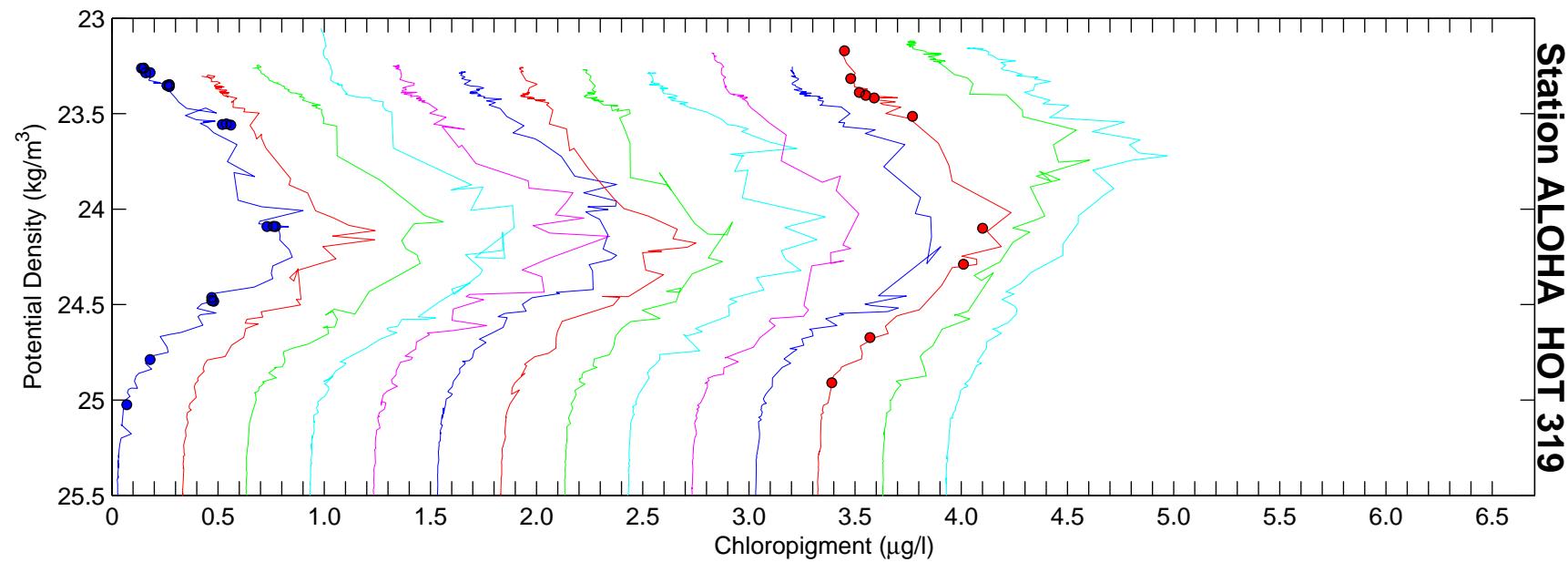
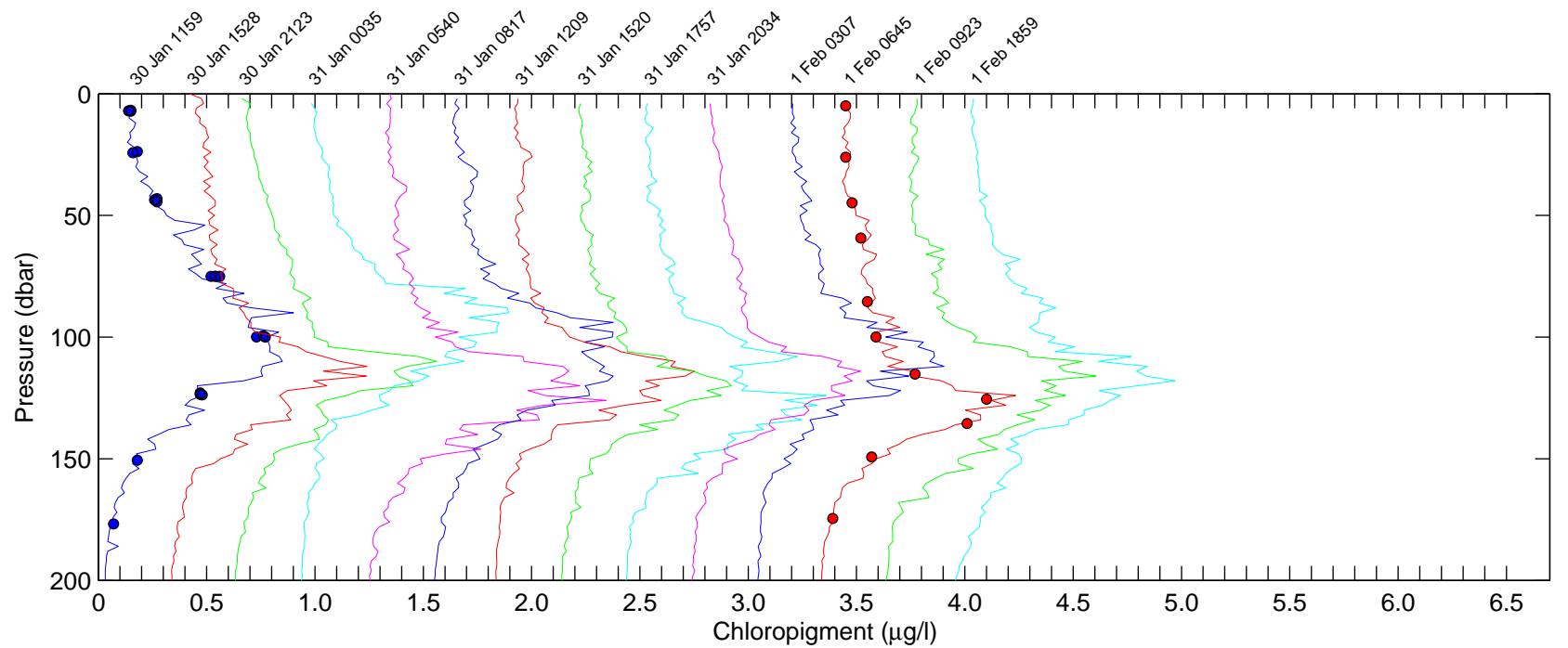


Figure 6.1.3b

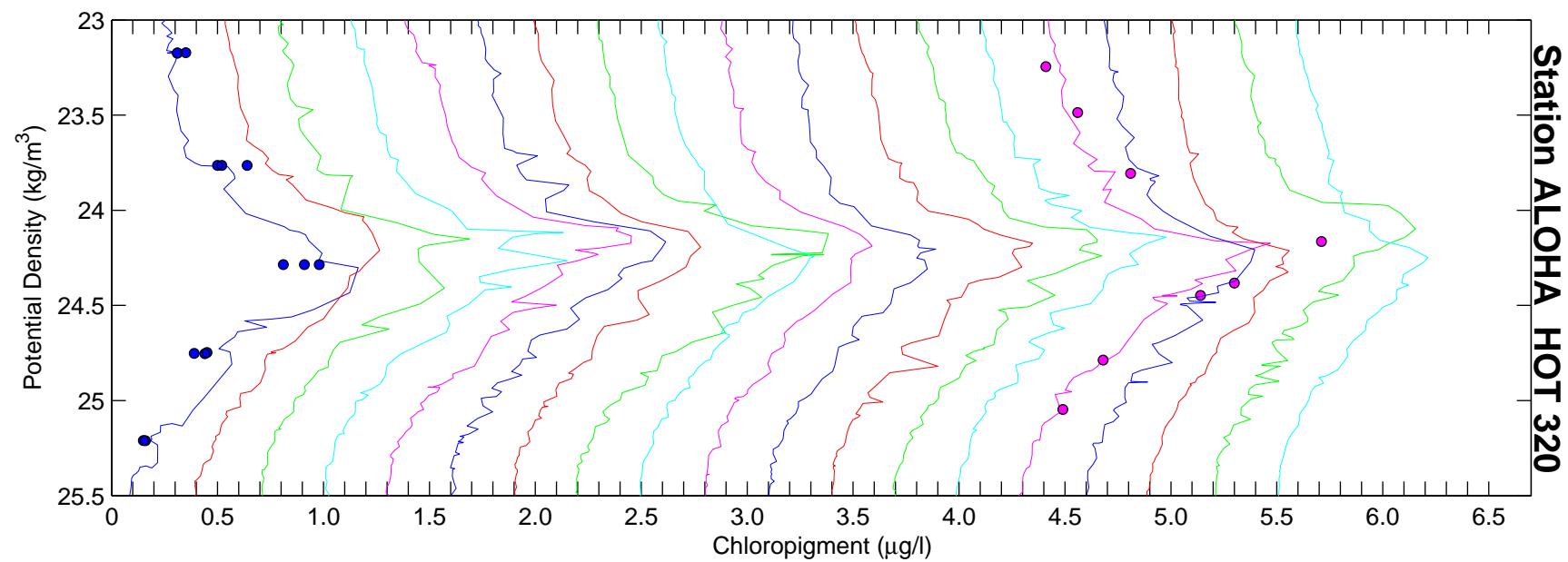
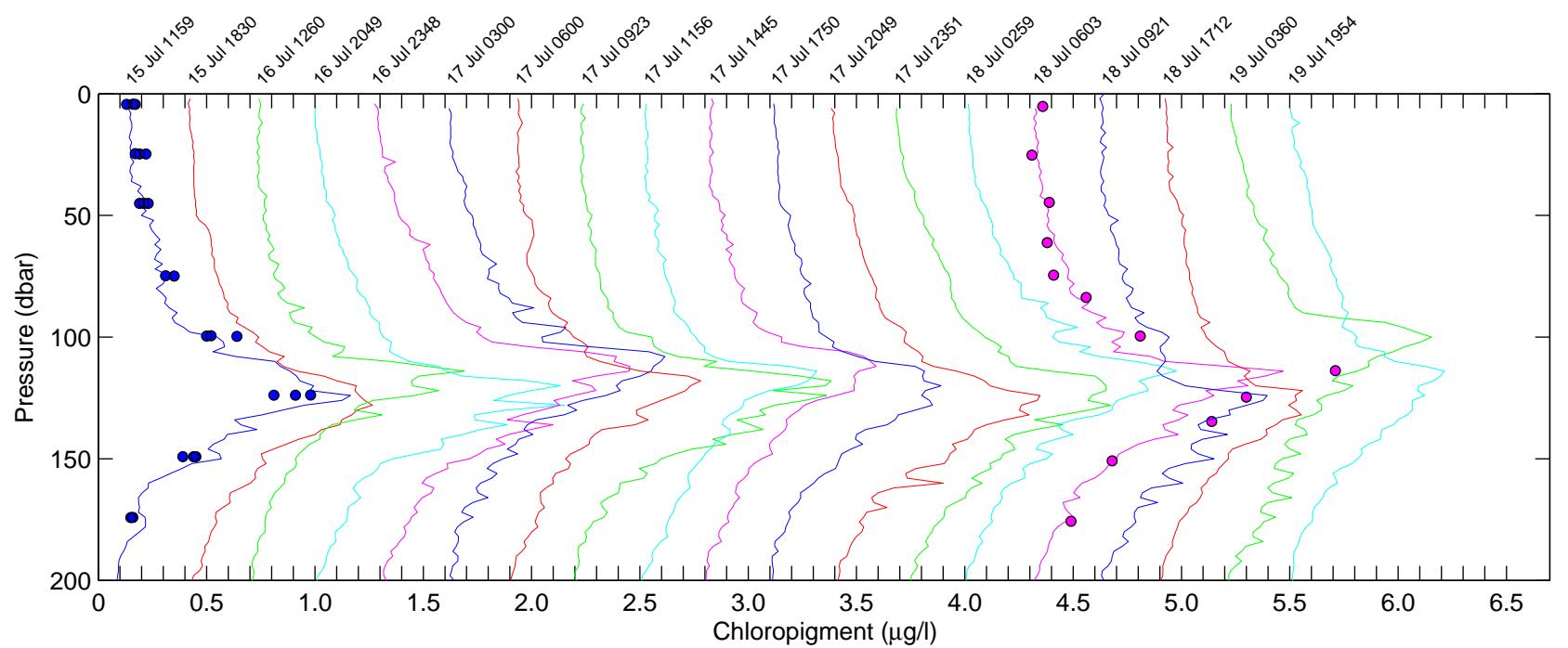


Figure 6.1.3c

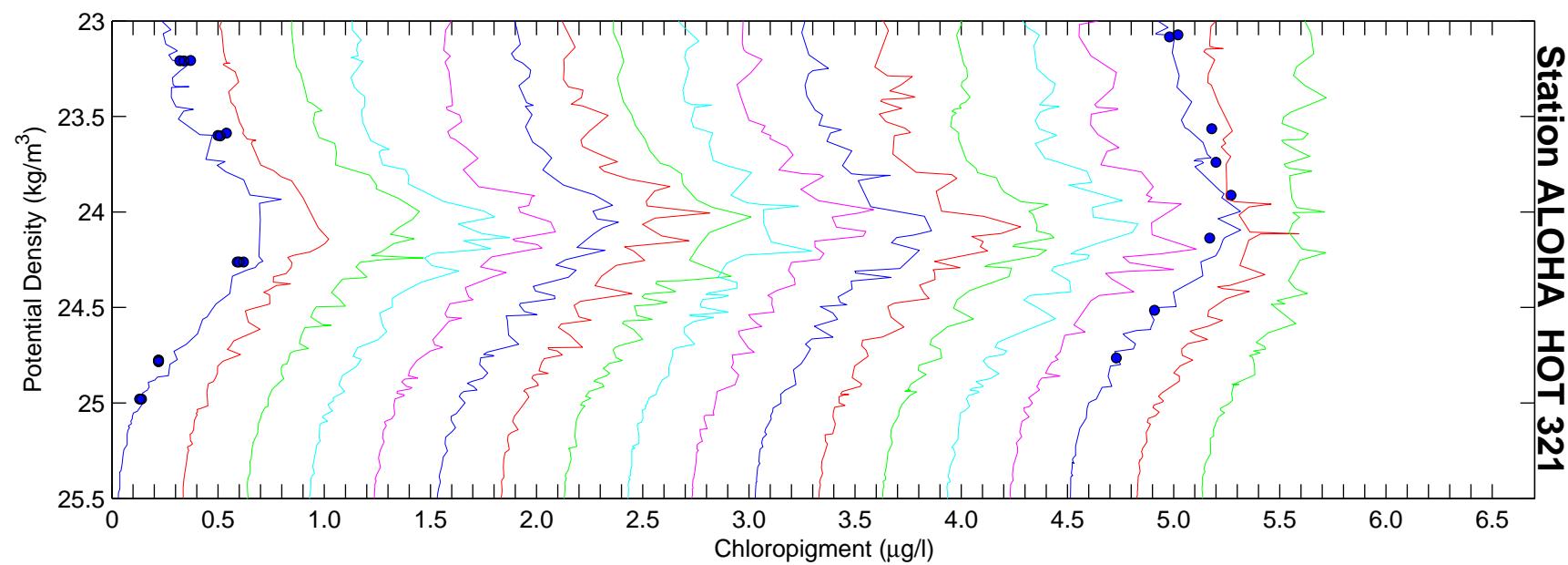
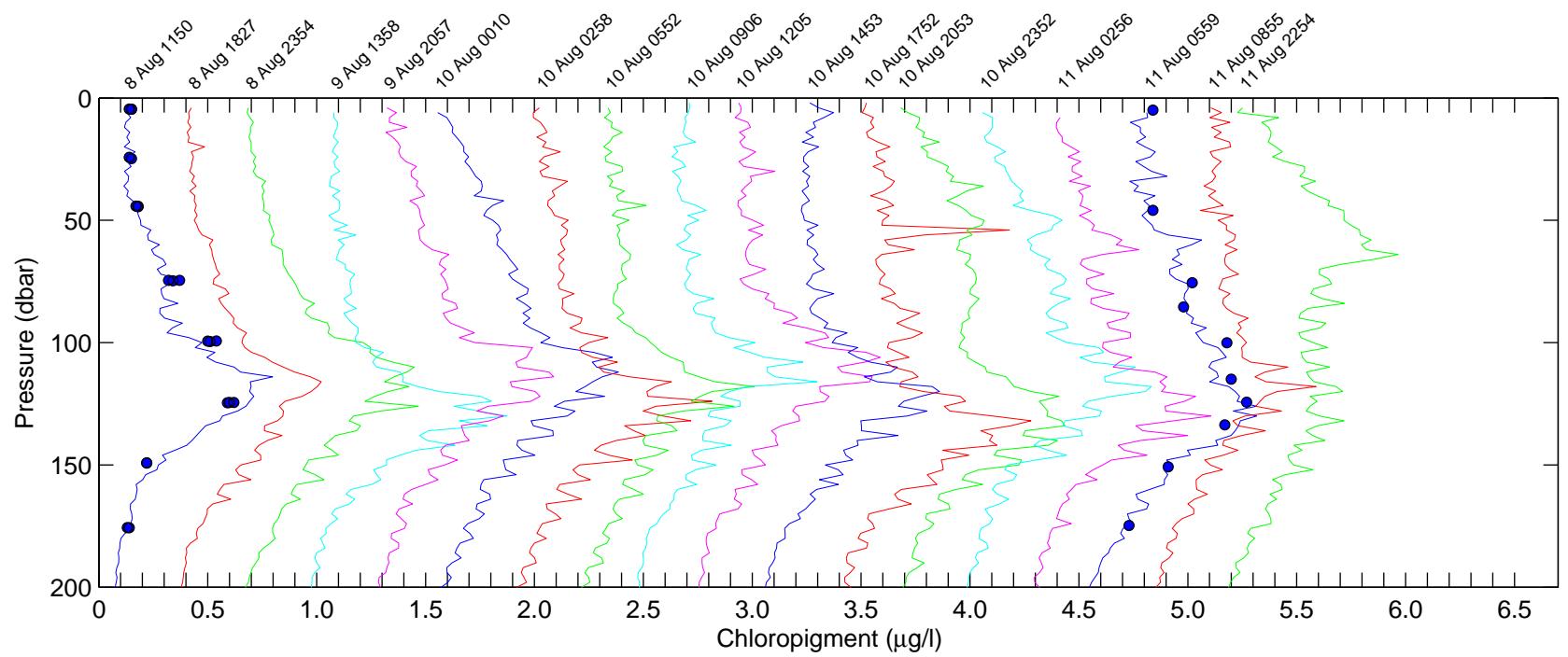


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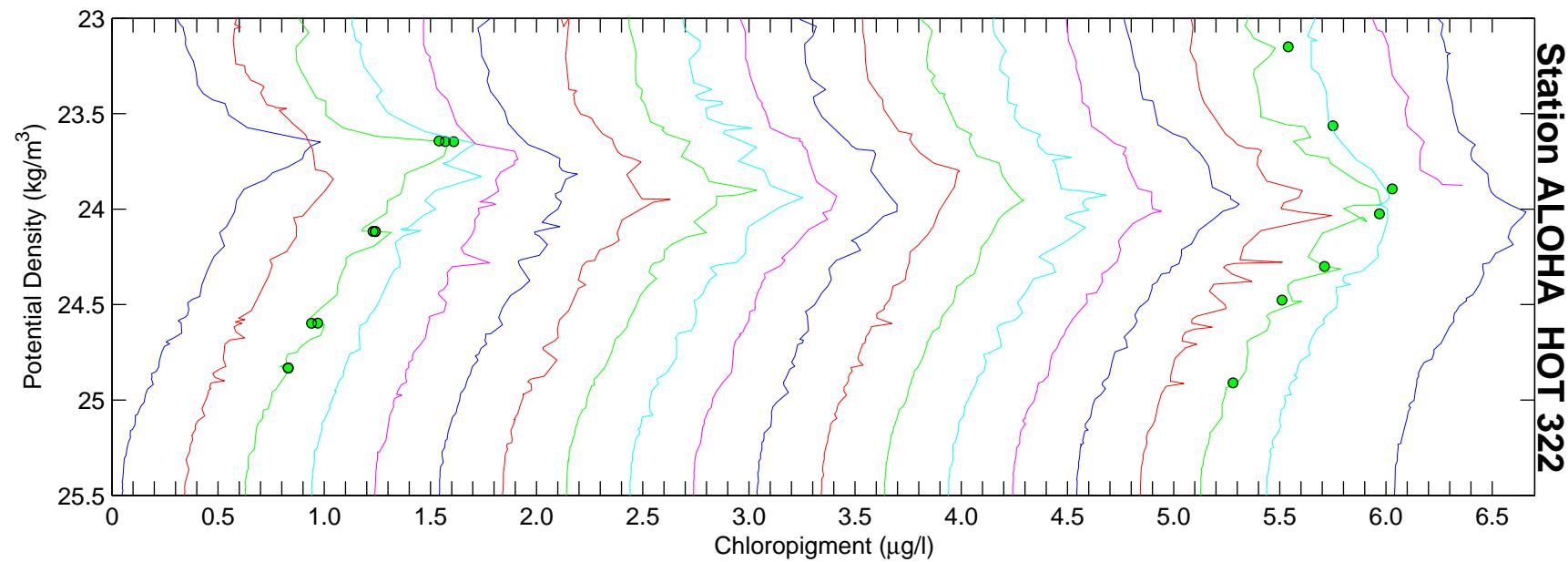
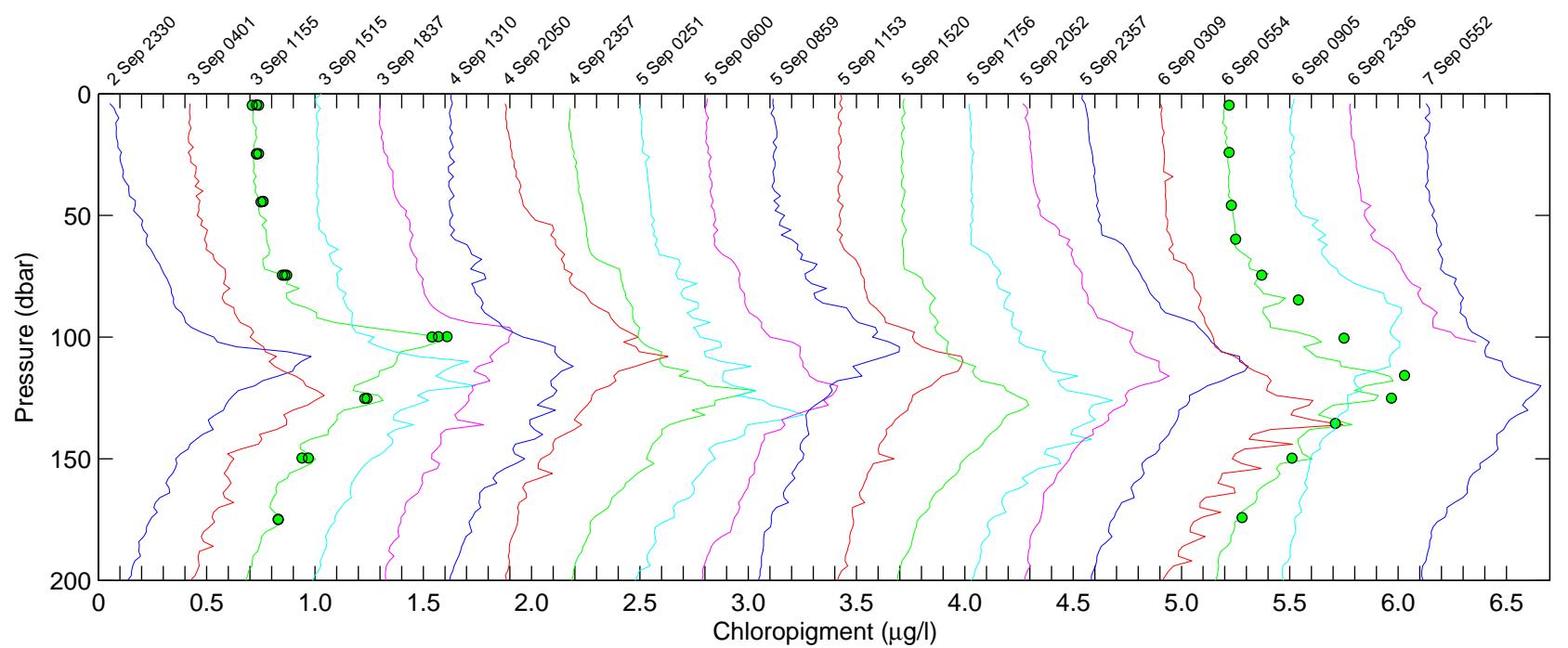


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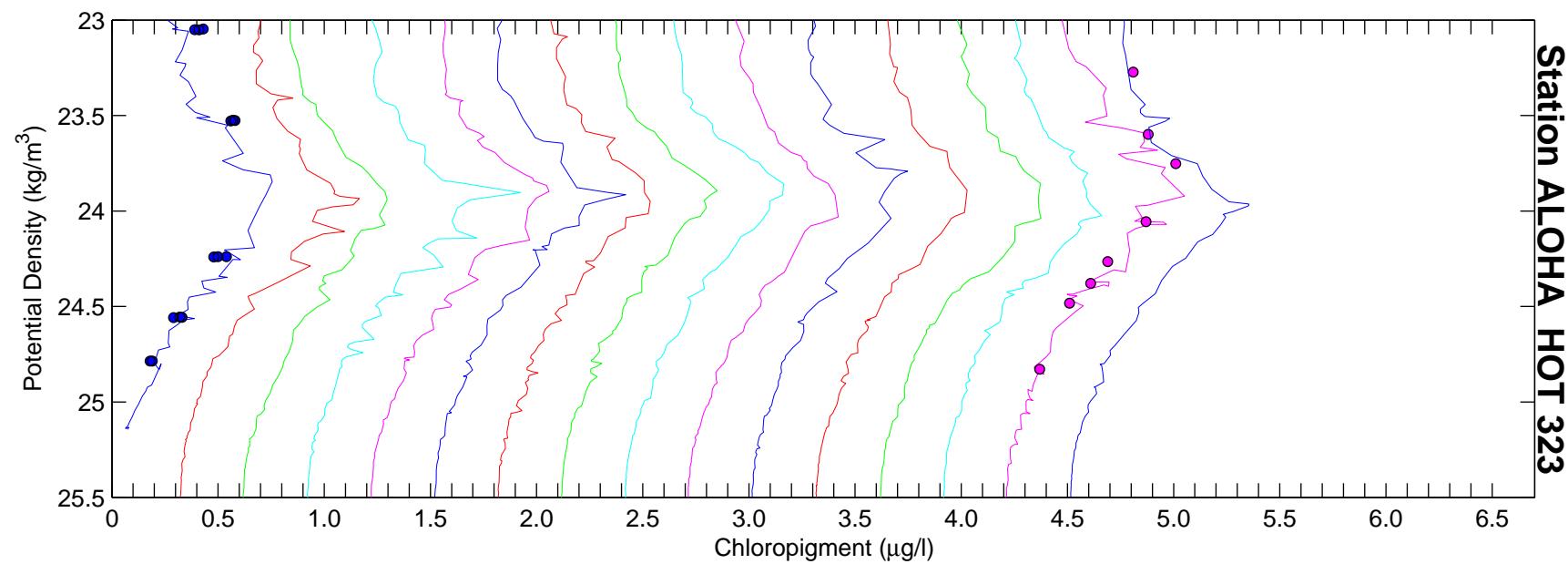
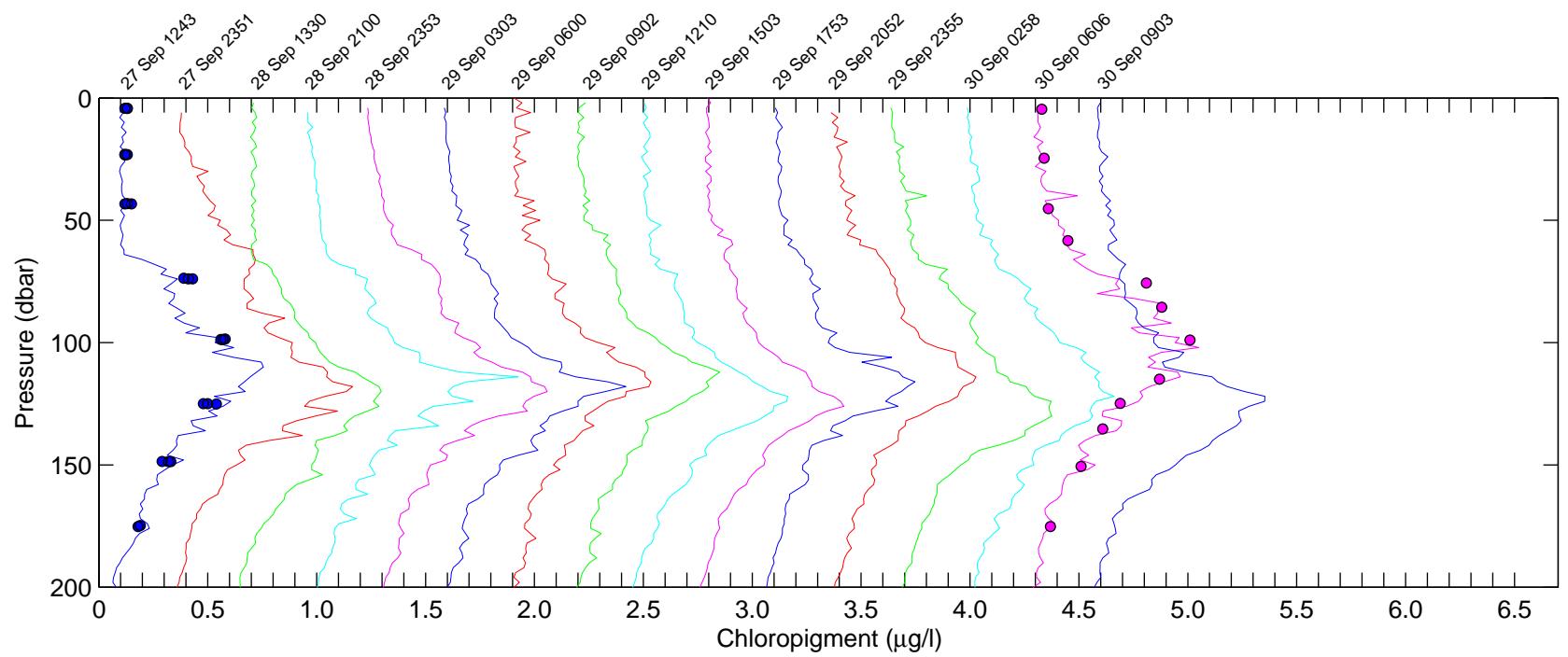


Figure 6.1.3f

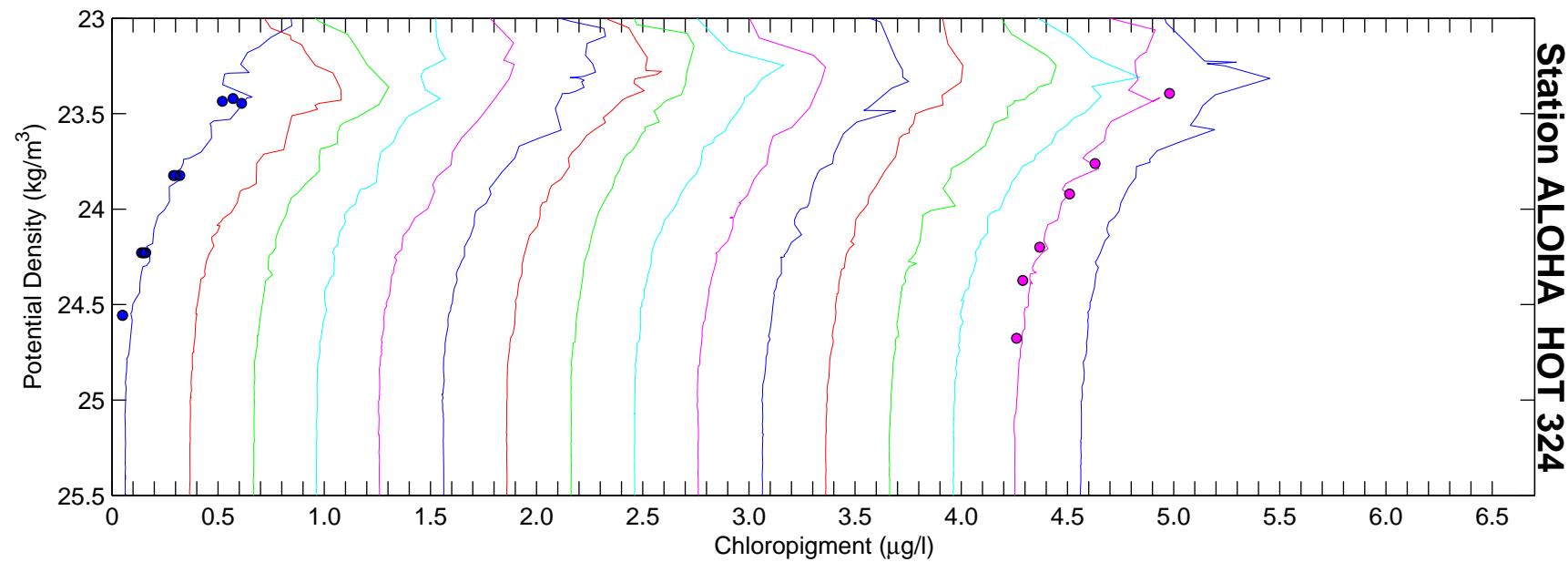
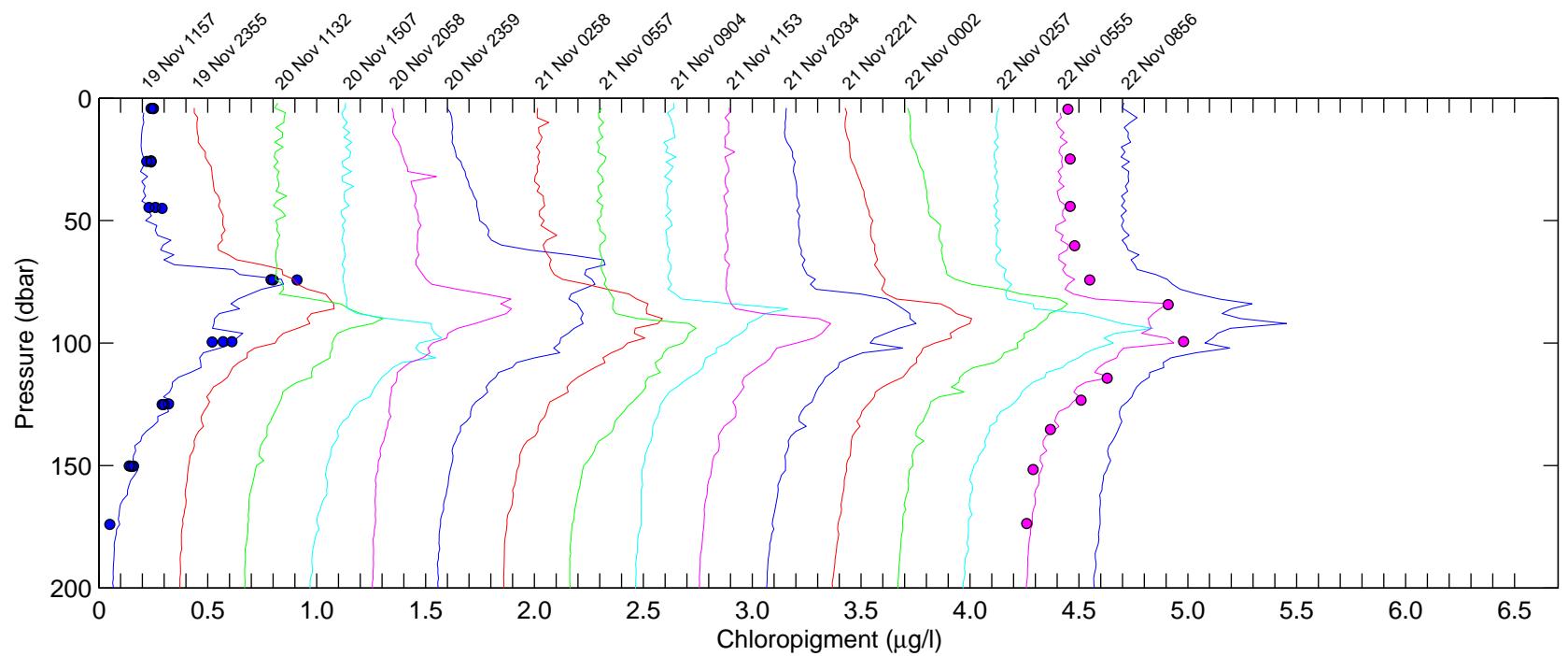


Figure 6.1.3g

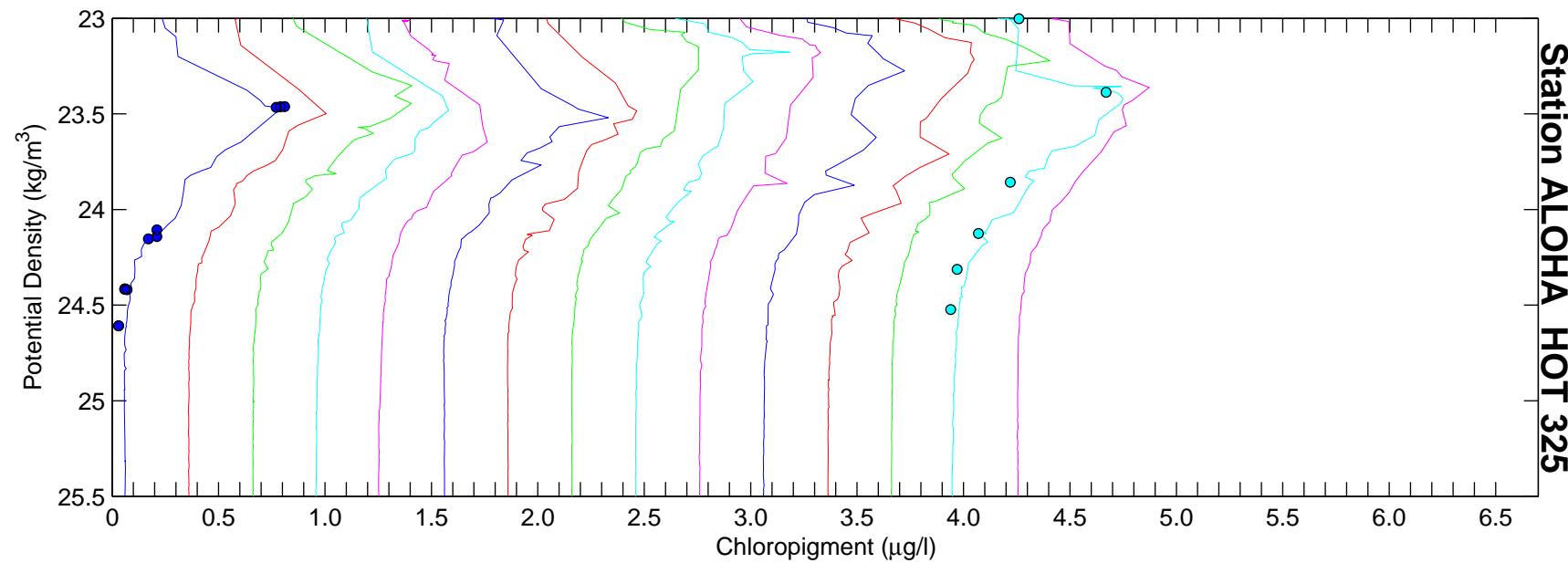
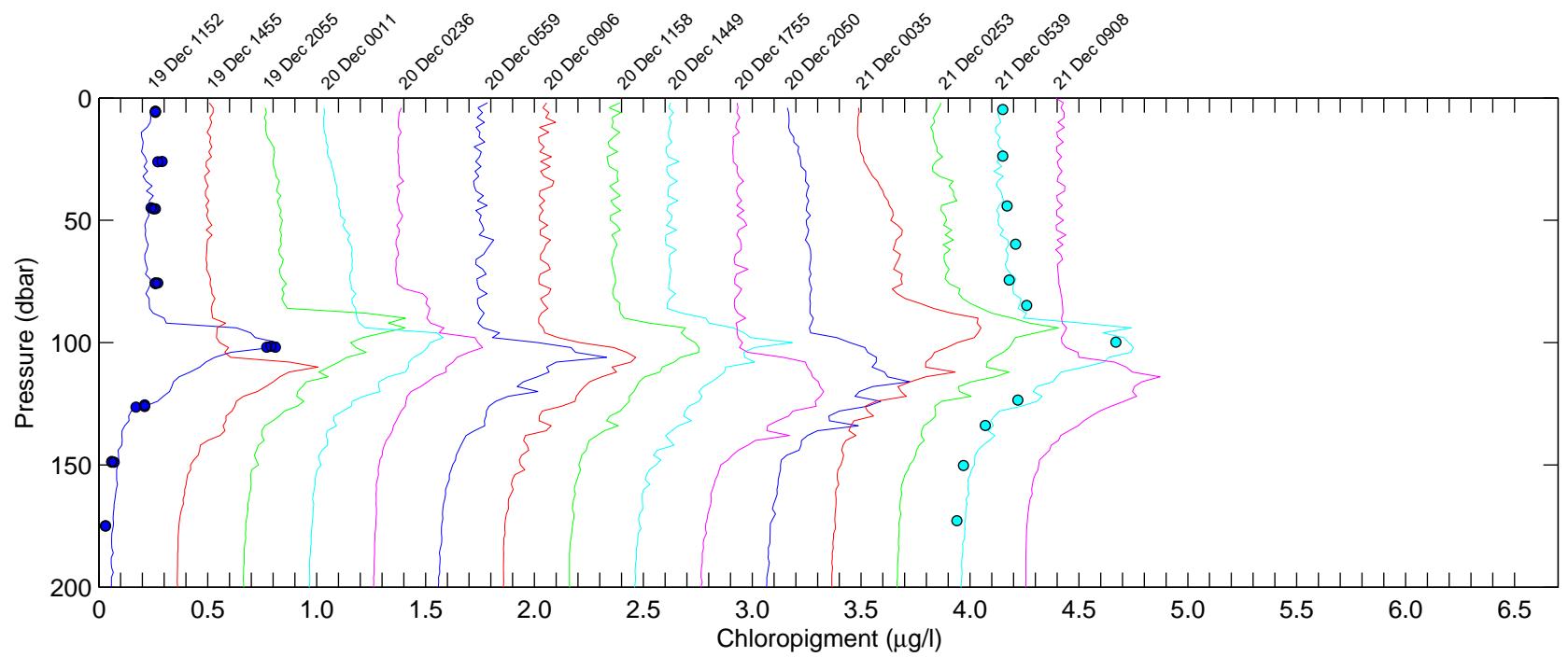


Figure 6.1.3h

Kahe Pt. HOT 318

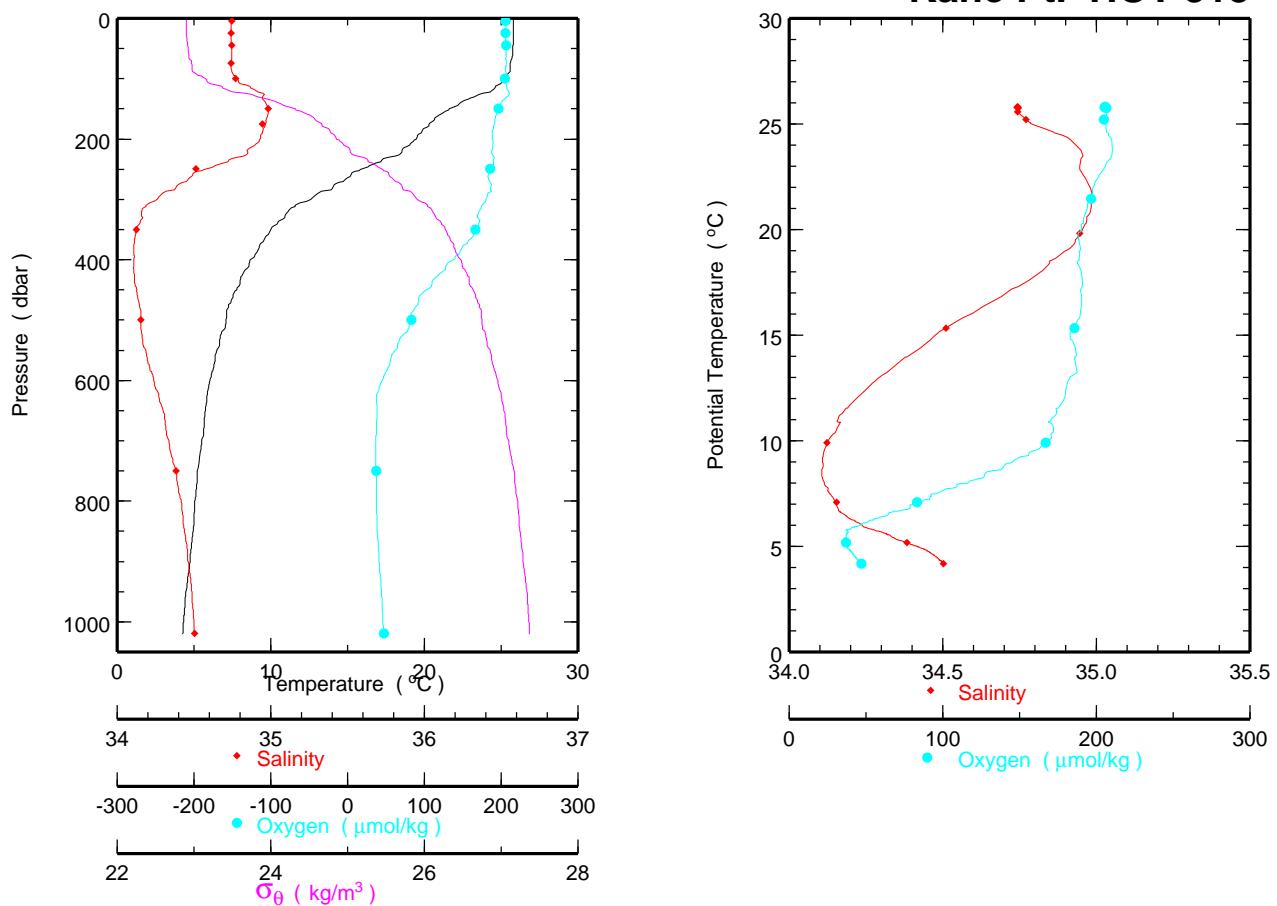


Figure 6.1.4a

Kahe Pt. HOT 319

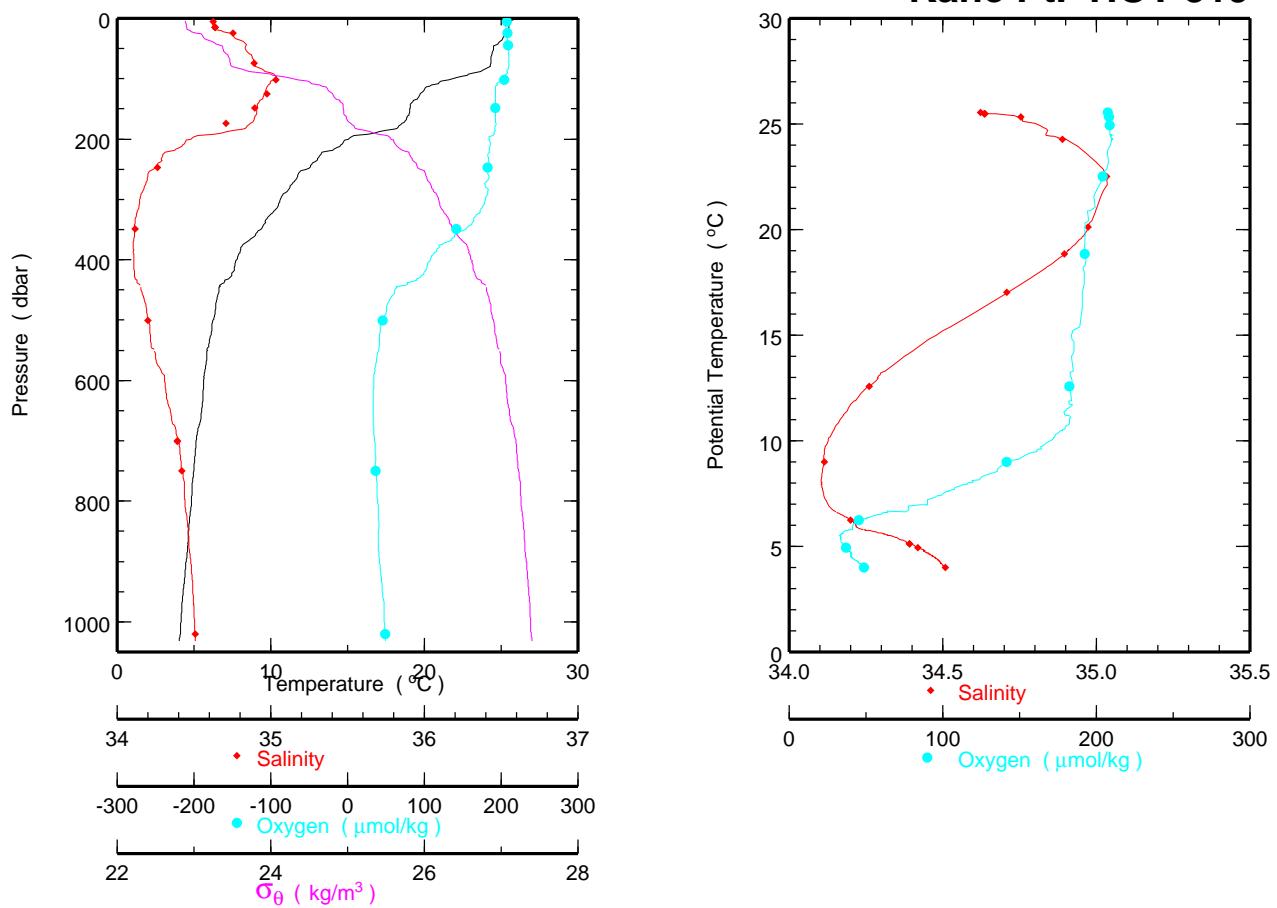
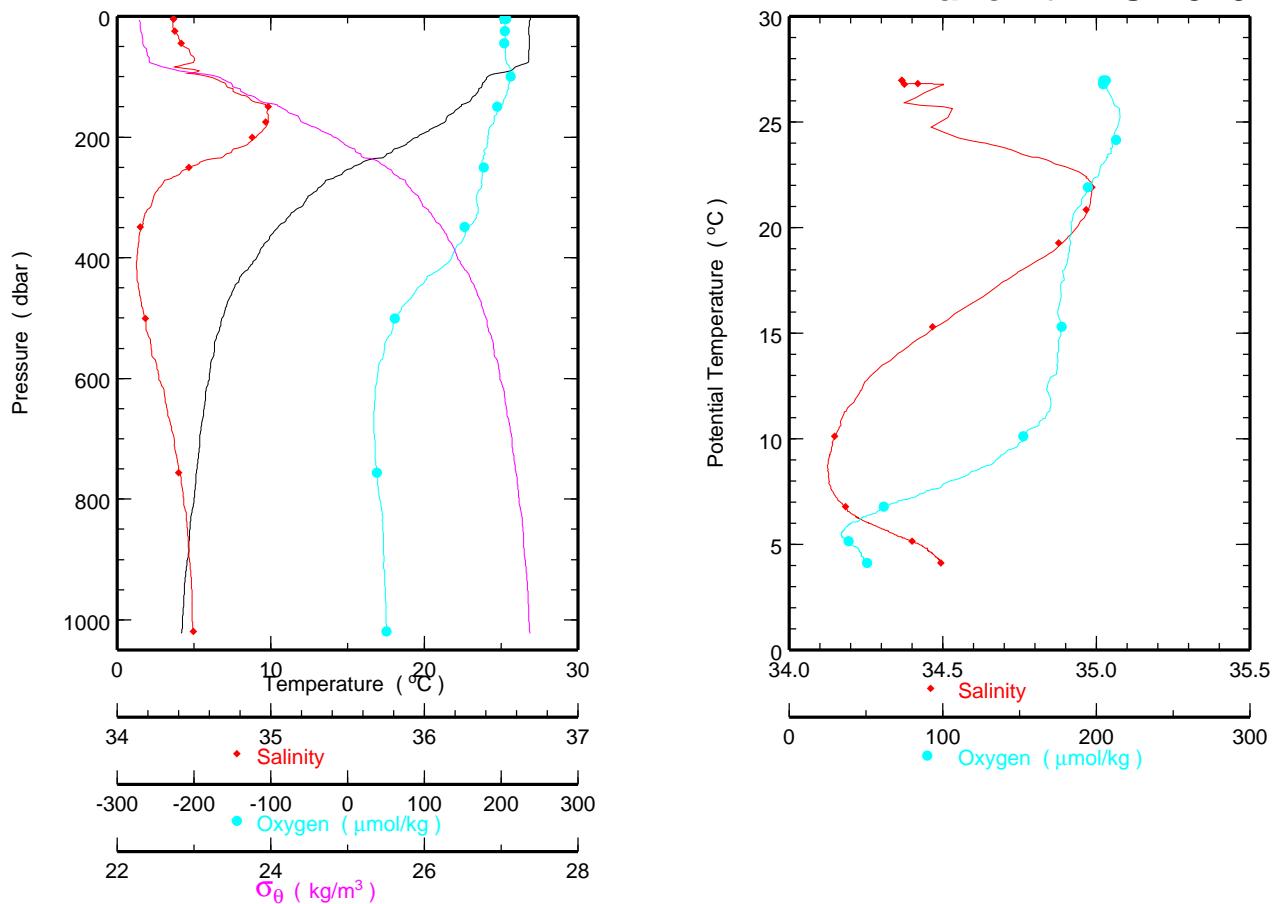


Figure 6.1.4b

Kahe Pt. HOT 320



Kaena Pt.

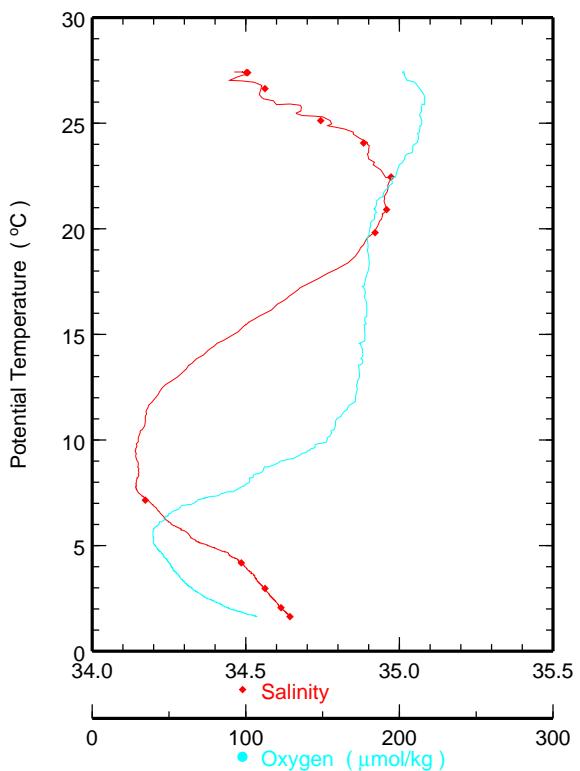
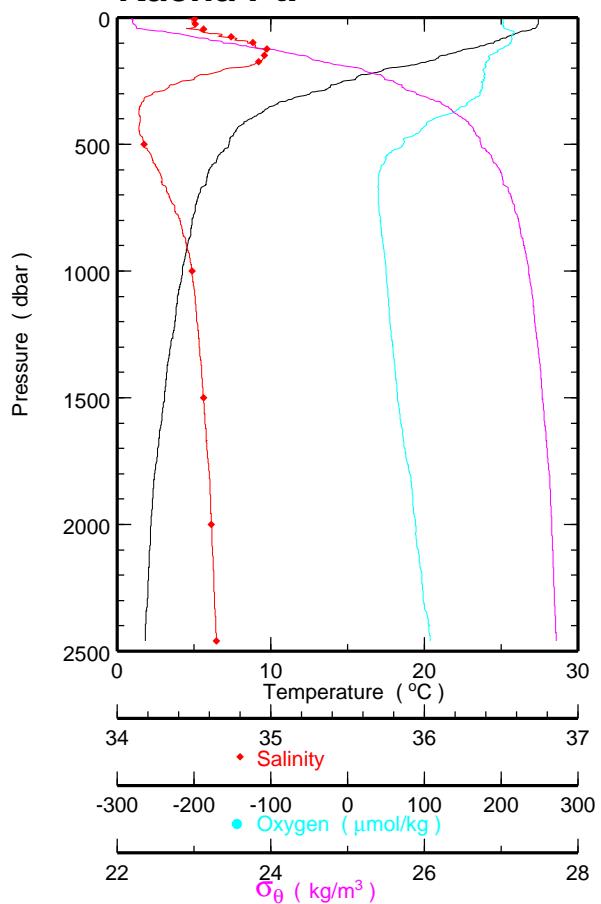
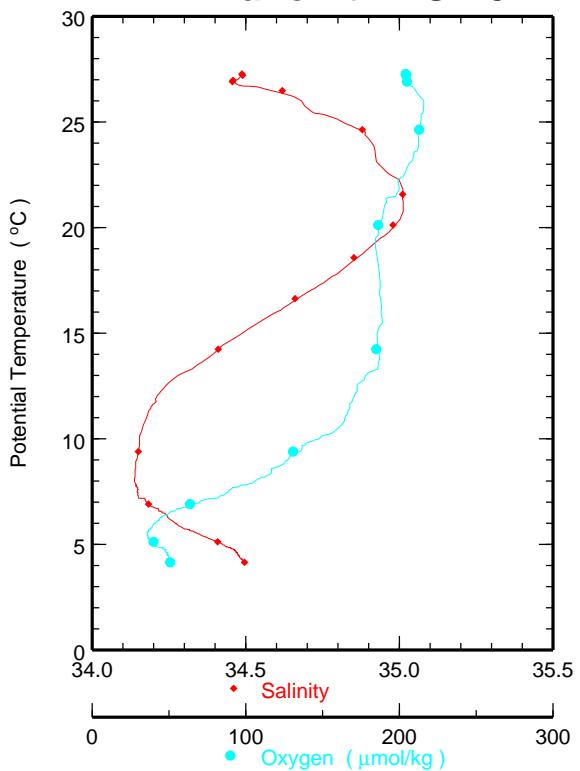
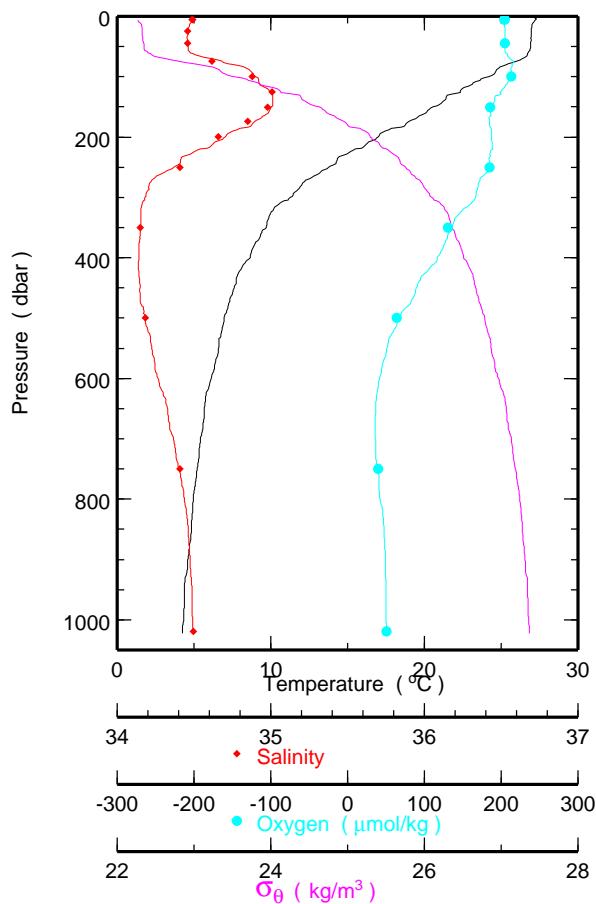


Figure 6.1.4c

Kahe Pt. HOT 321



Kaena Pt.

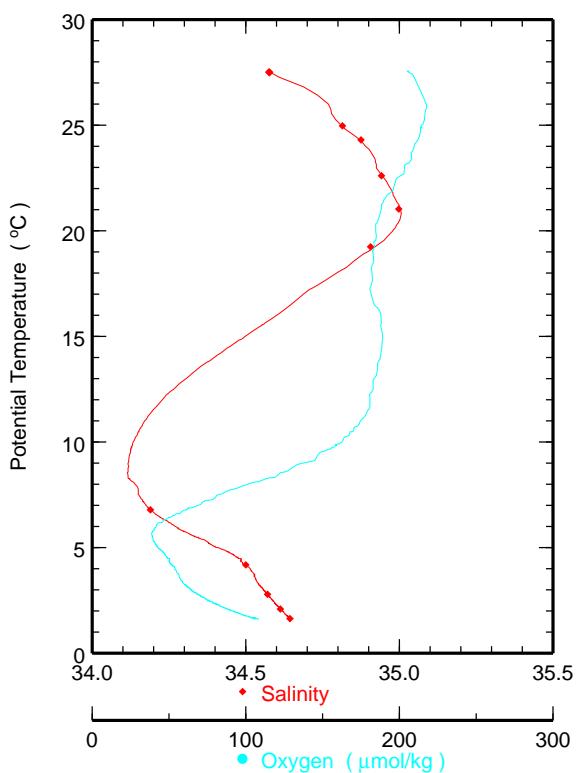
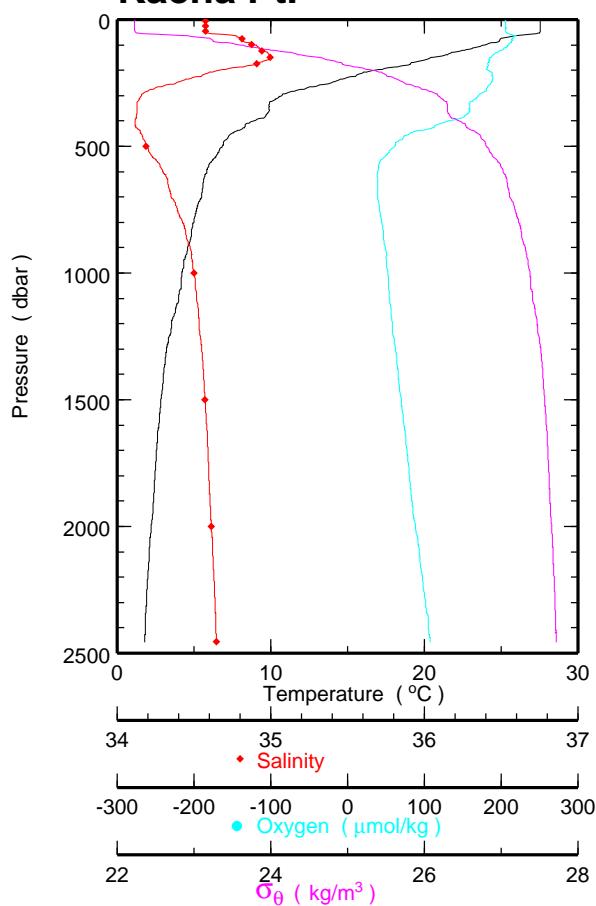


Figure 6.1.4d

Kahe Pt. HOT 322

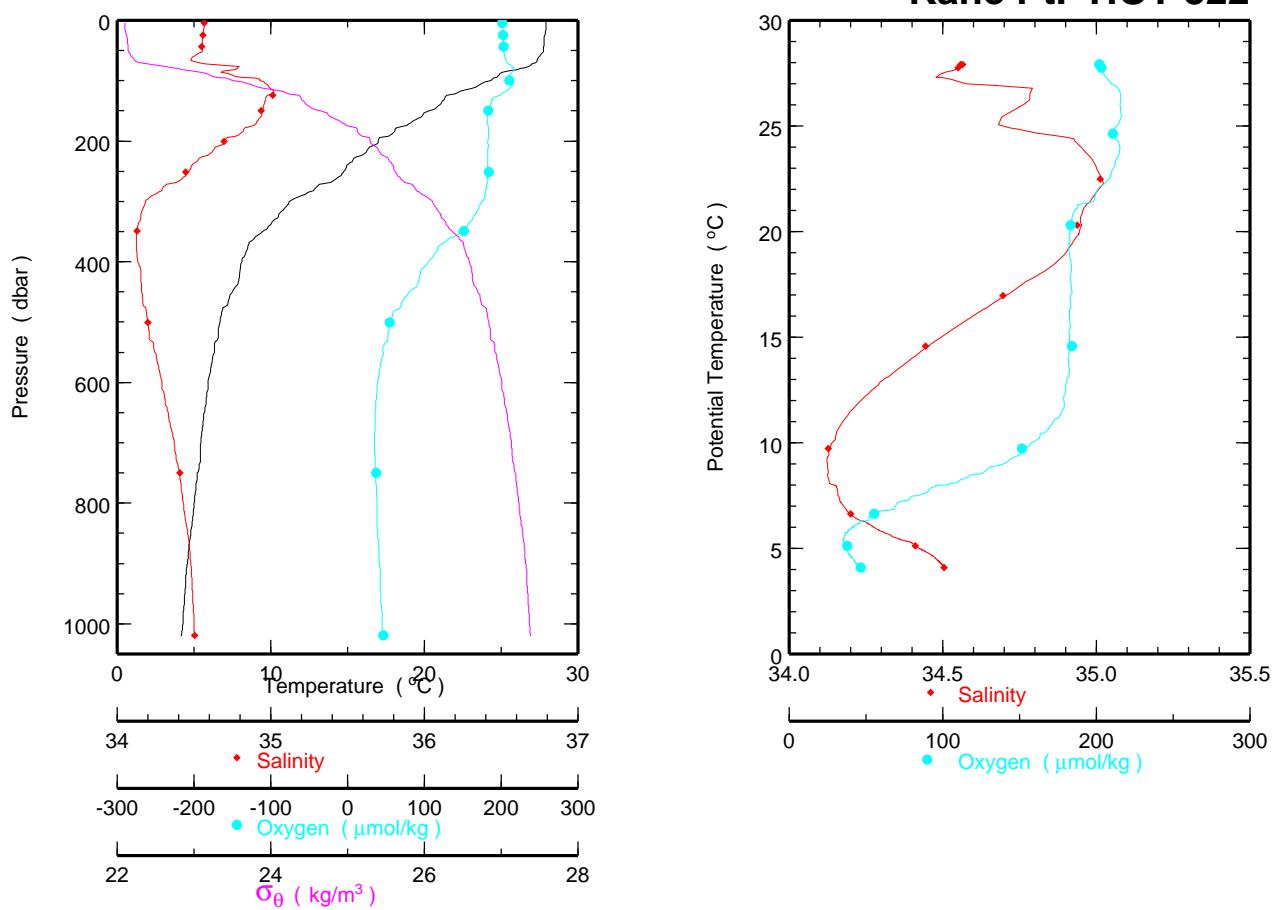
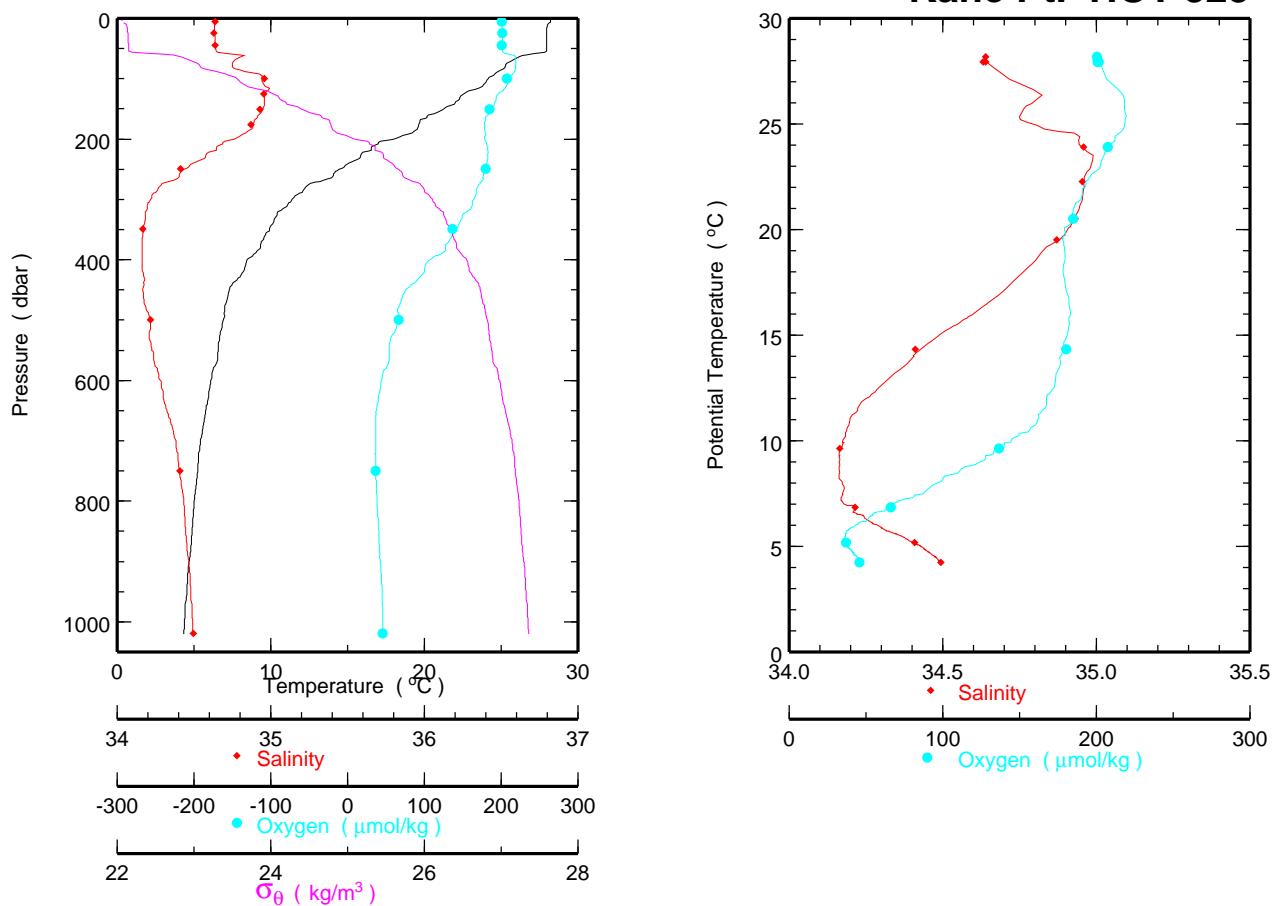


Figure 6.1.4e

Kahe Pt. HOT 323



Kaena Pt.

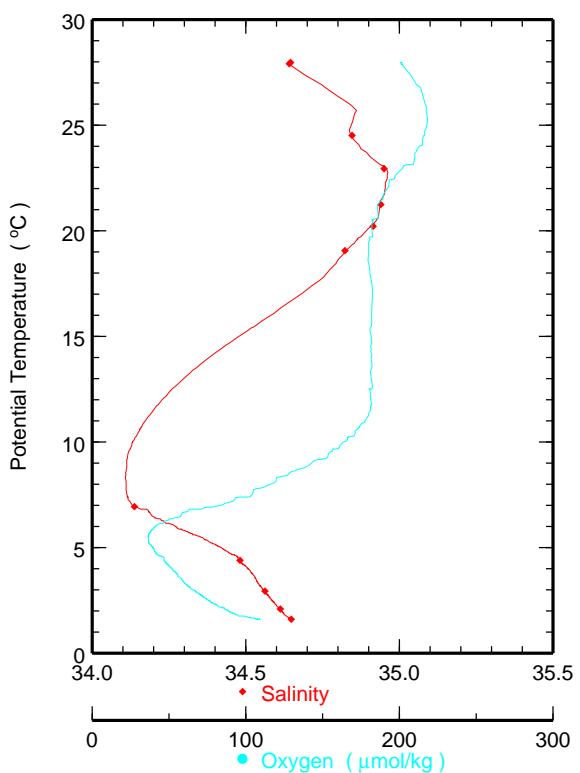
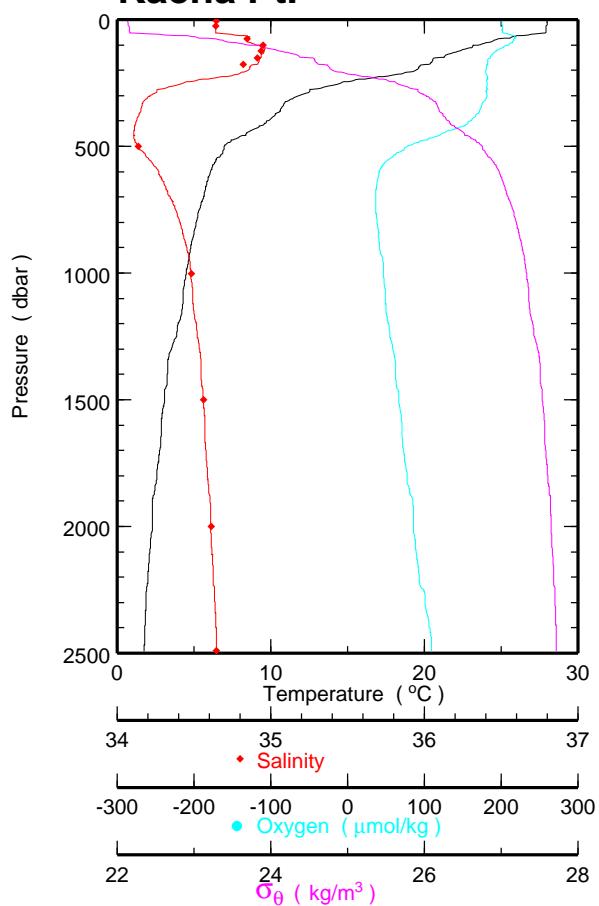


Figure 6.1.4f

Kahe Pt. HOT 324

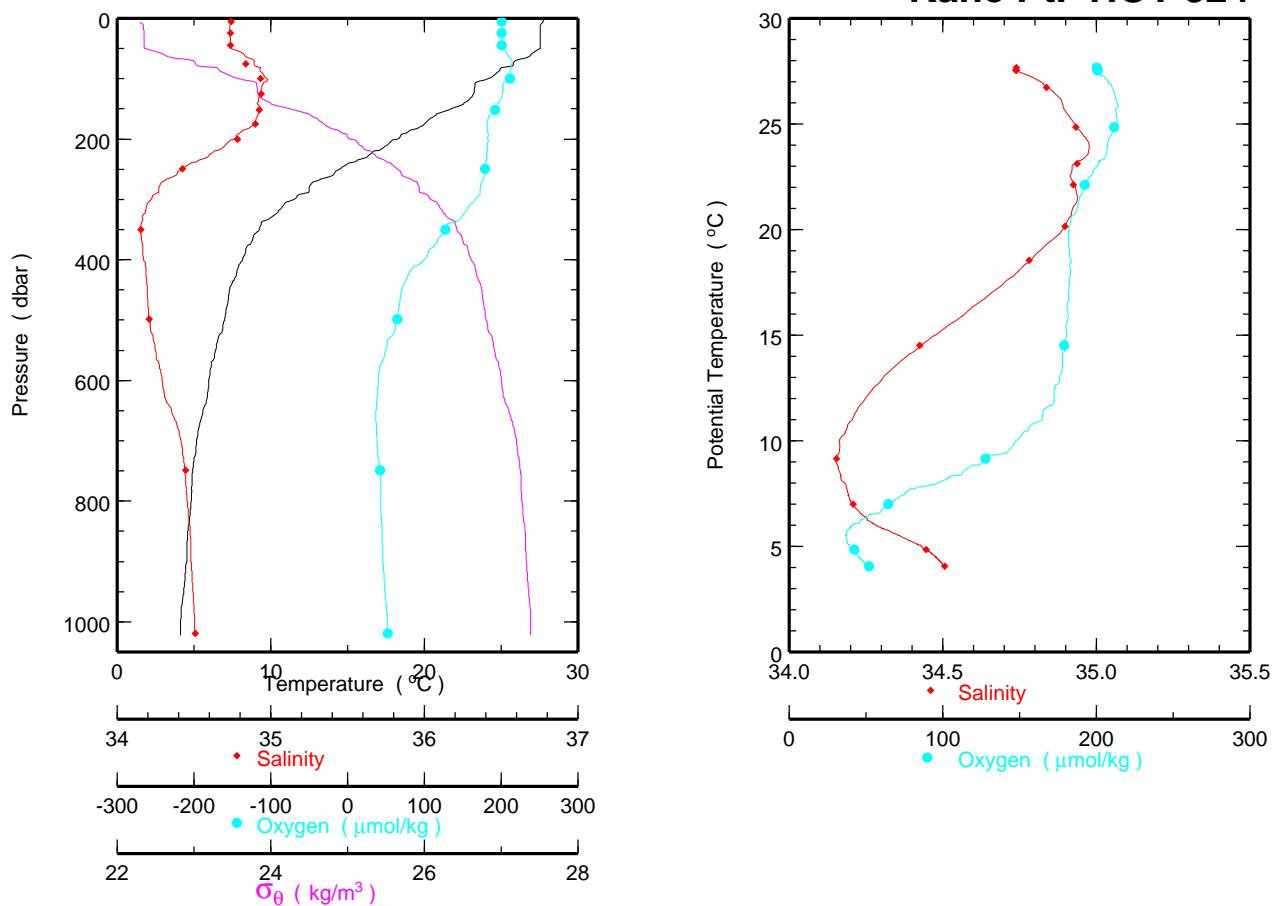
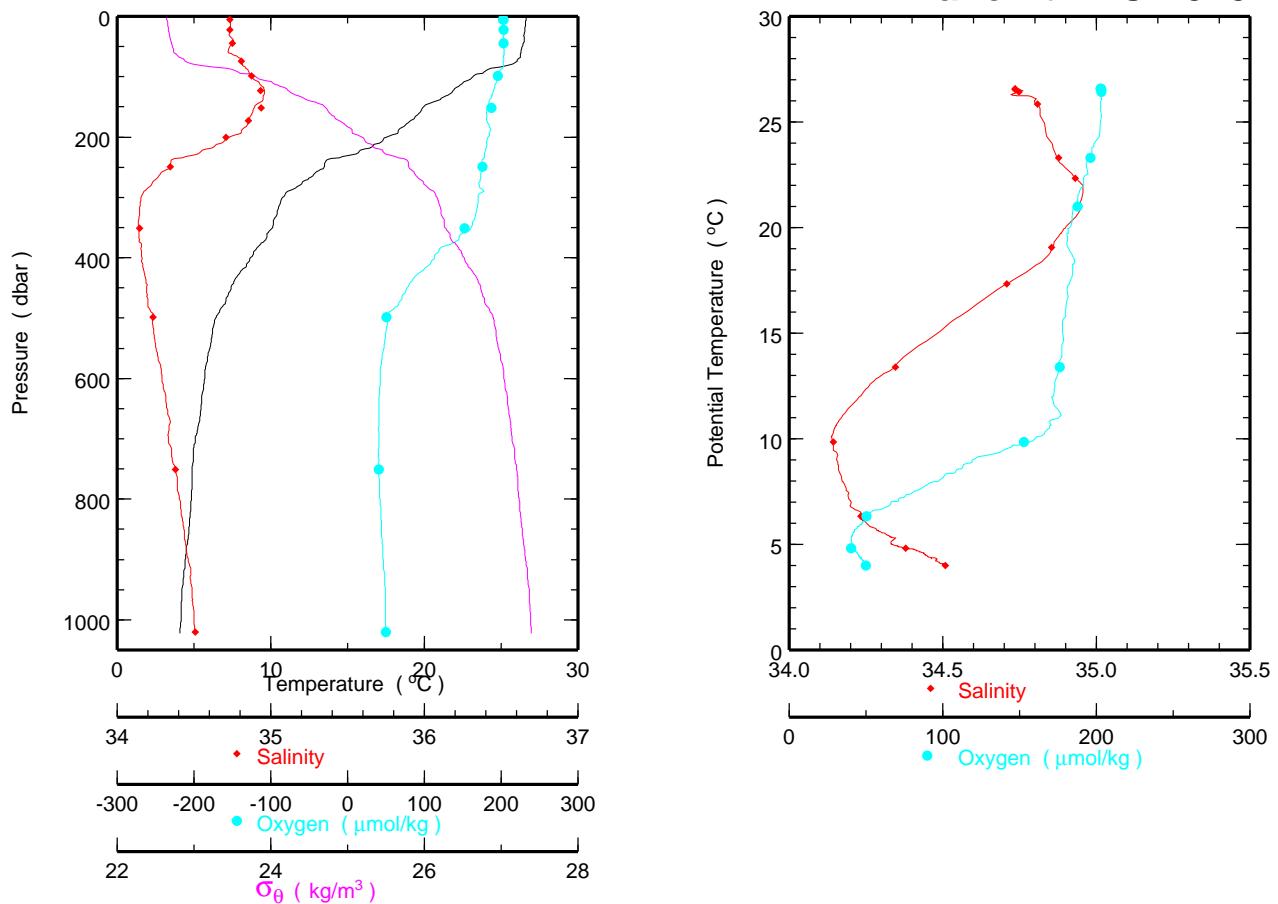


Figure 6.1.4g

Kahe Pt. HOT 325



Kaena Pt.

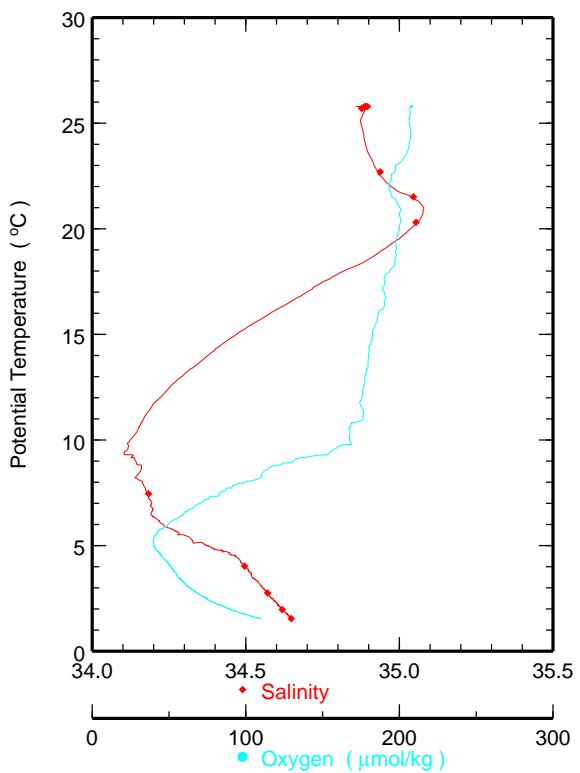
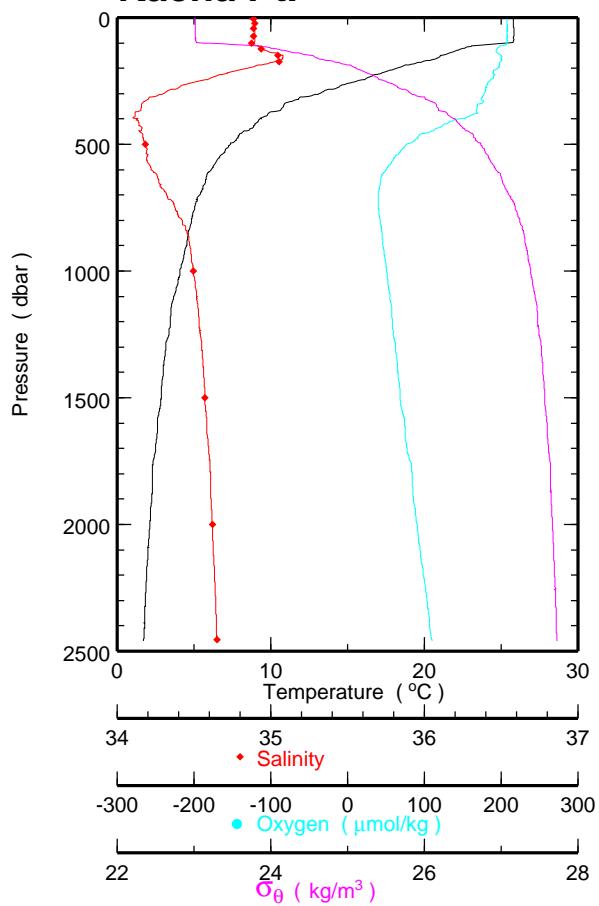


Figure 6.1.4h

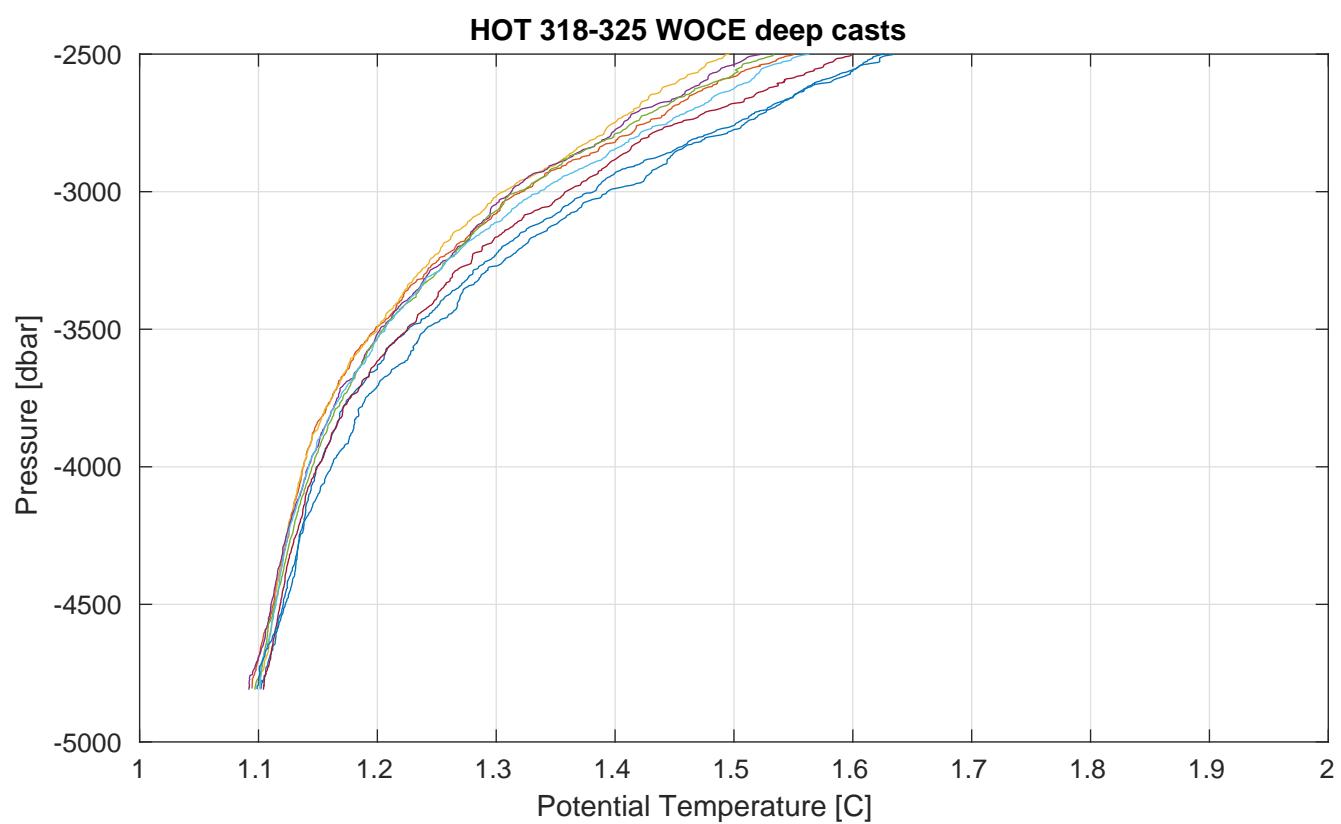
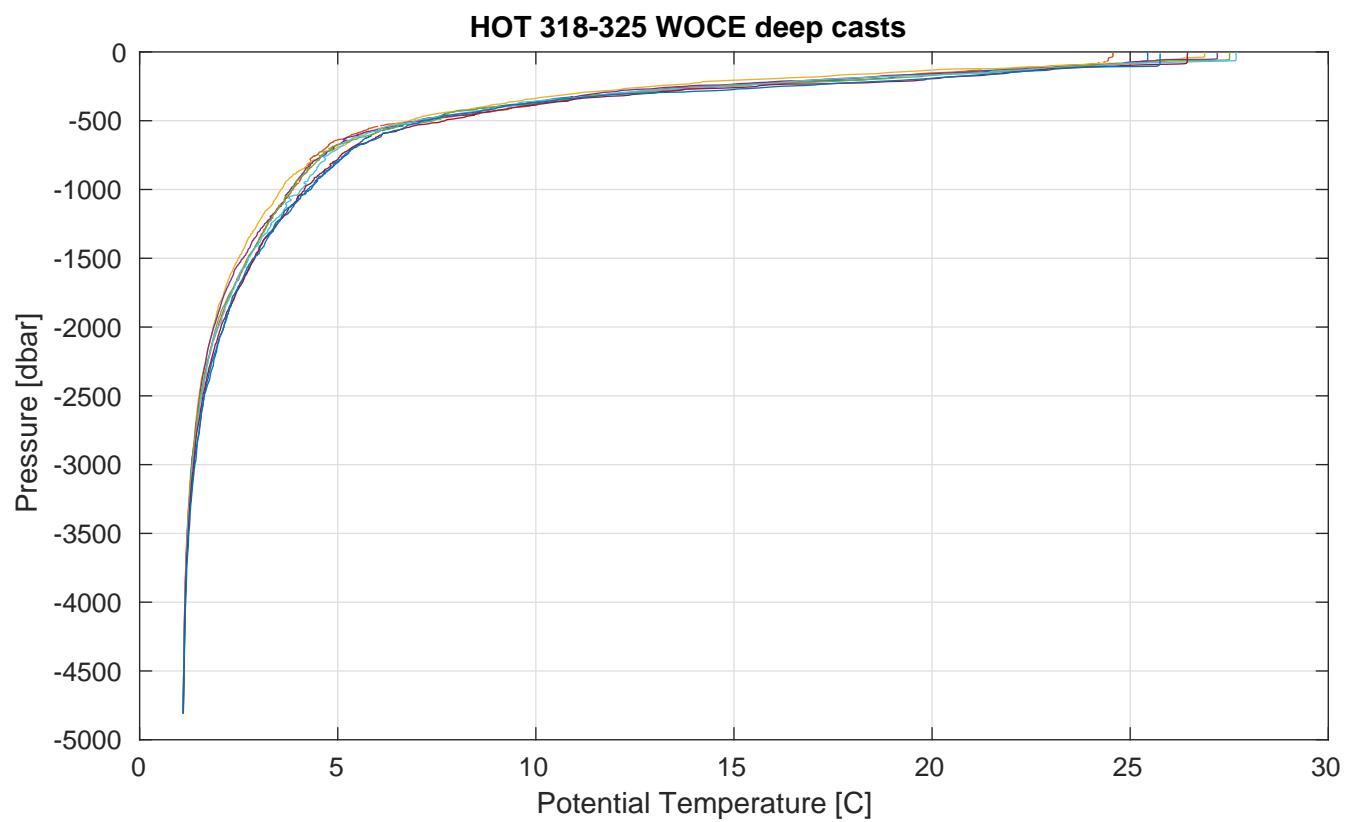


Figure 6.1.5

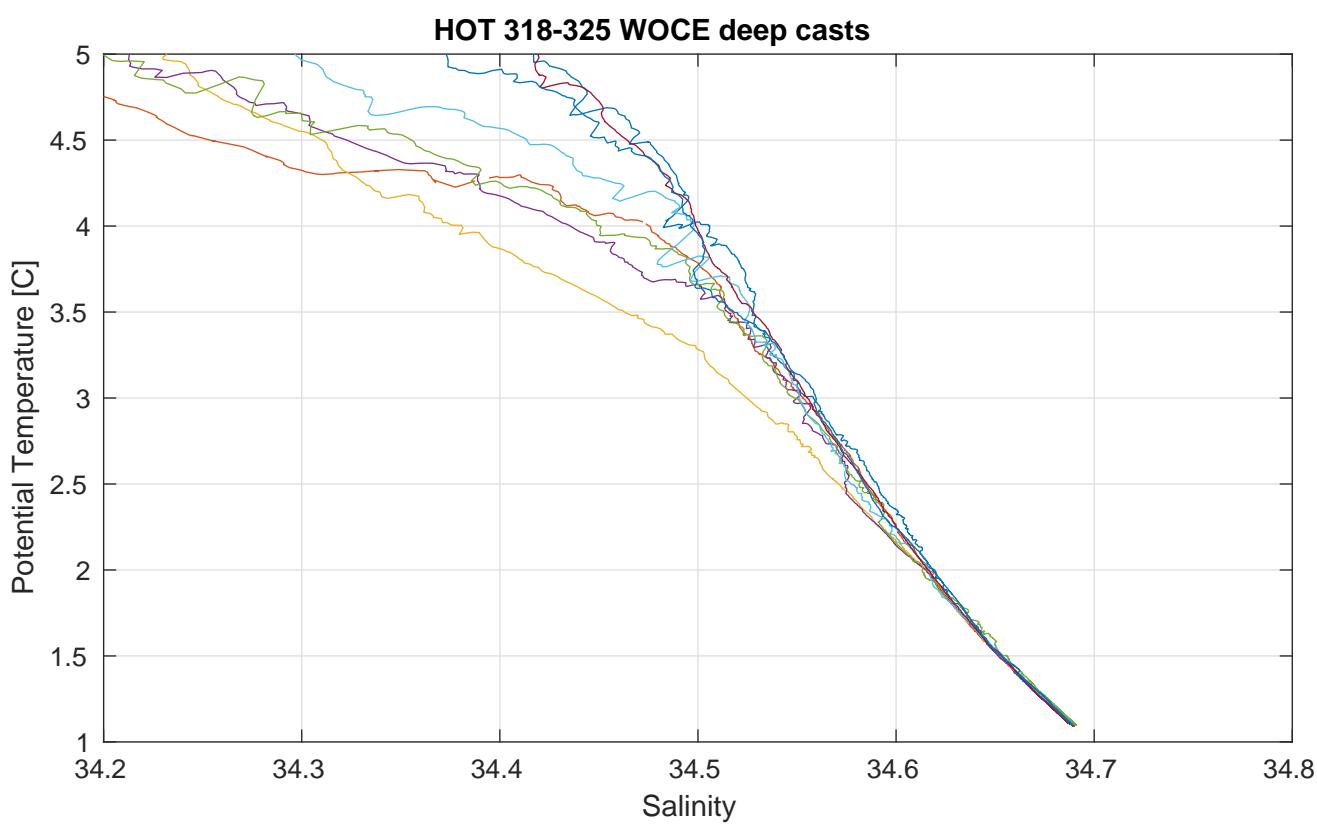
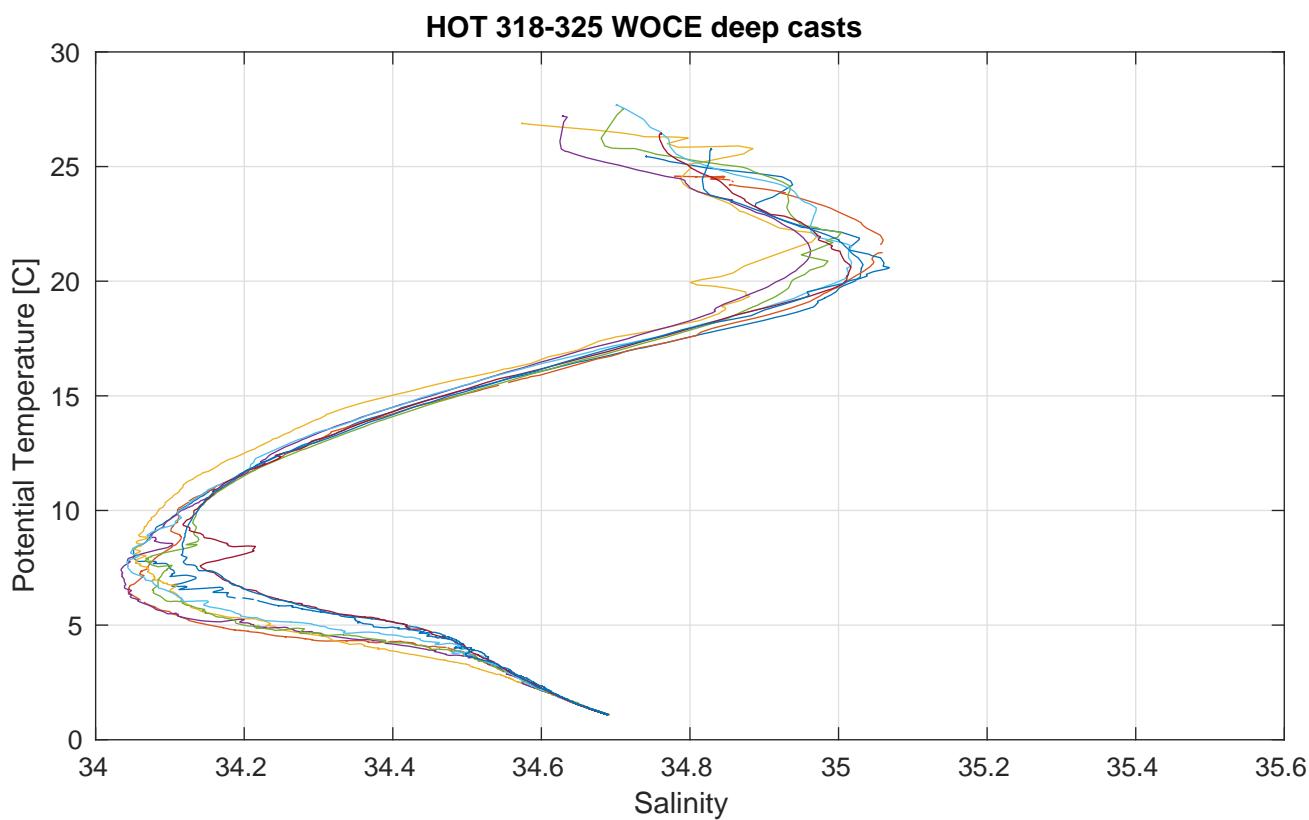


Figure 6.1.6

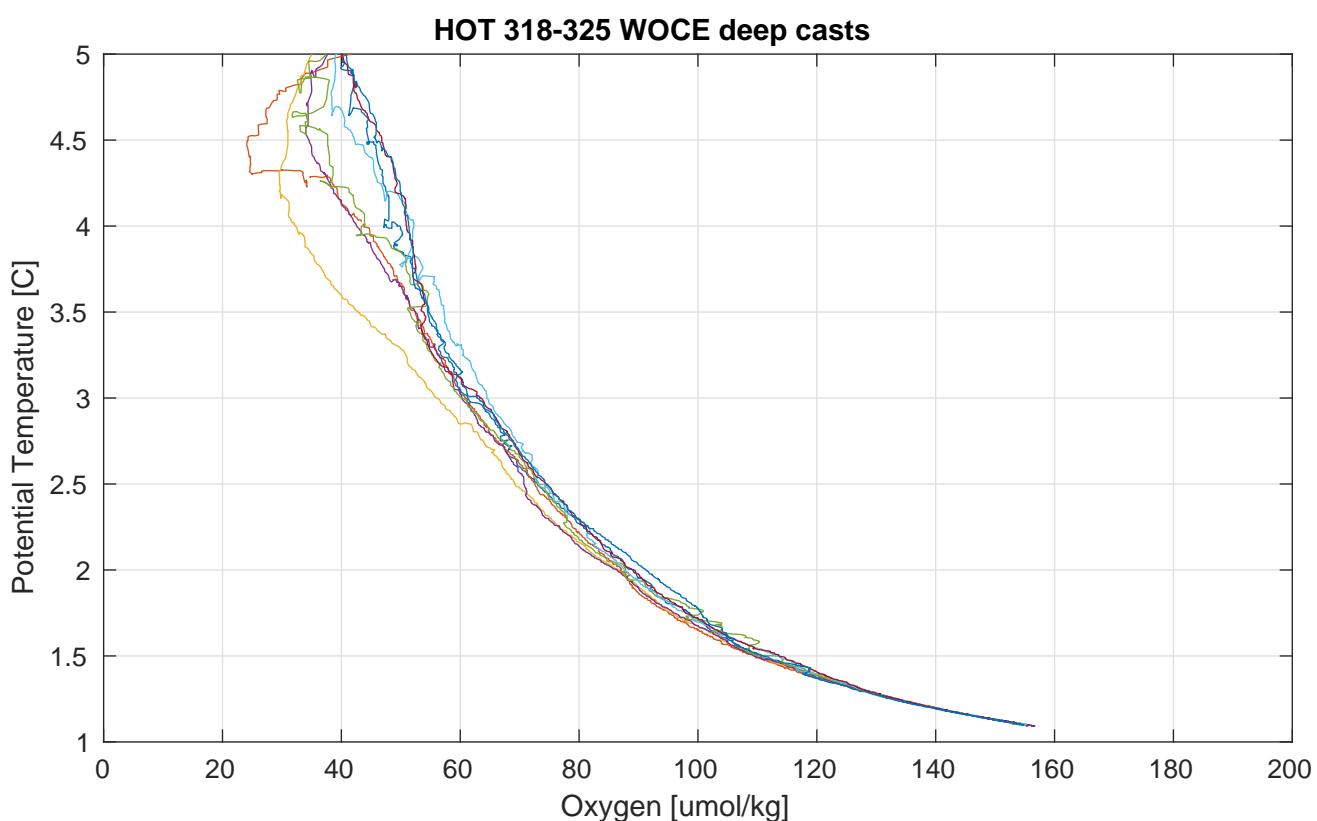
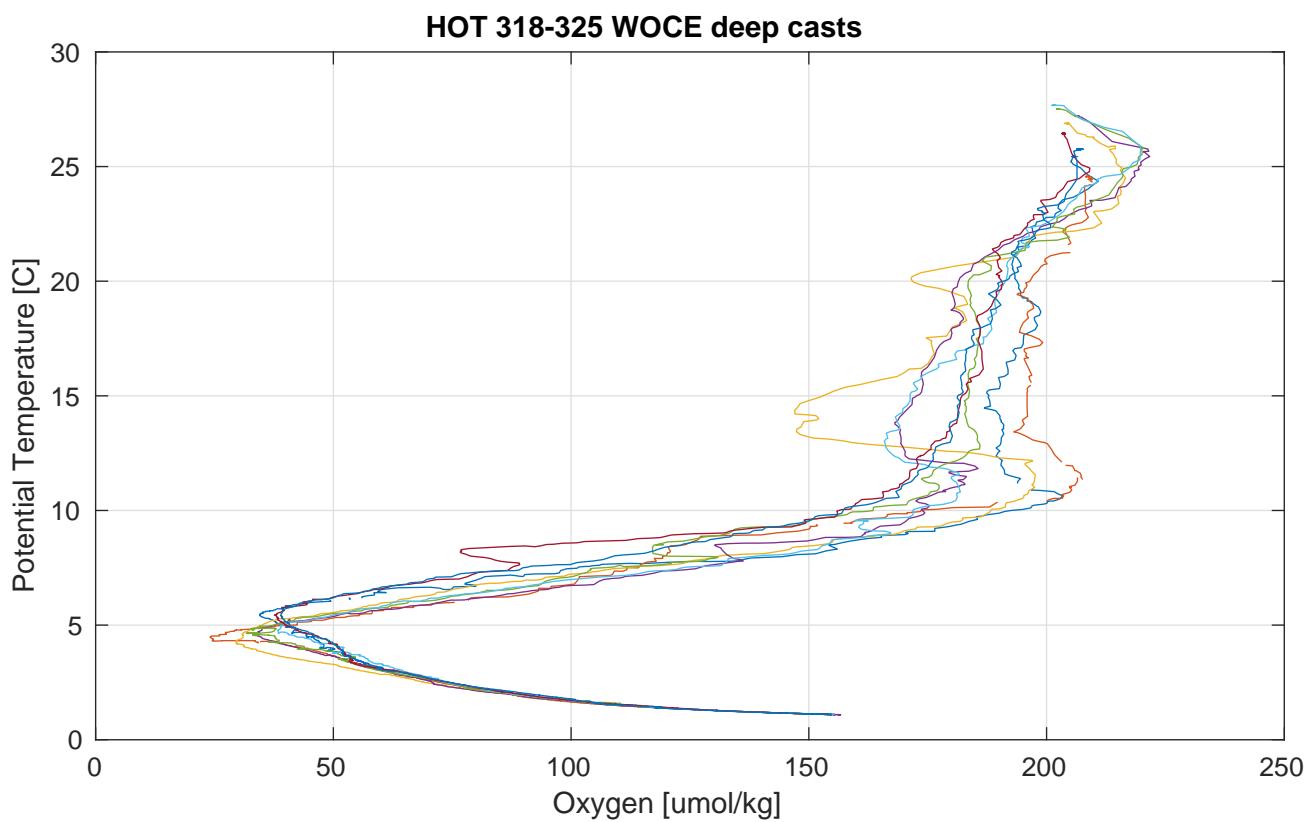


Figure 6.1.7

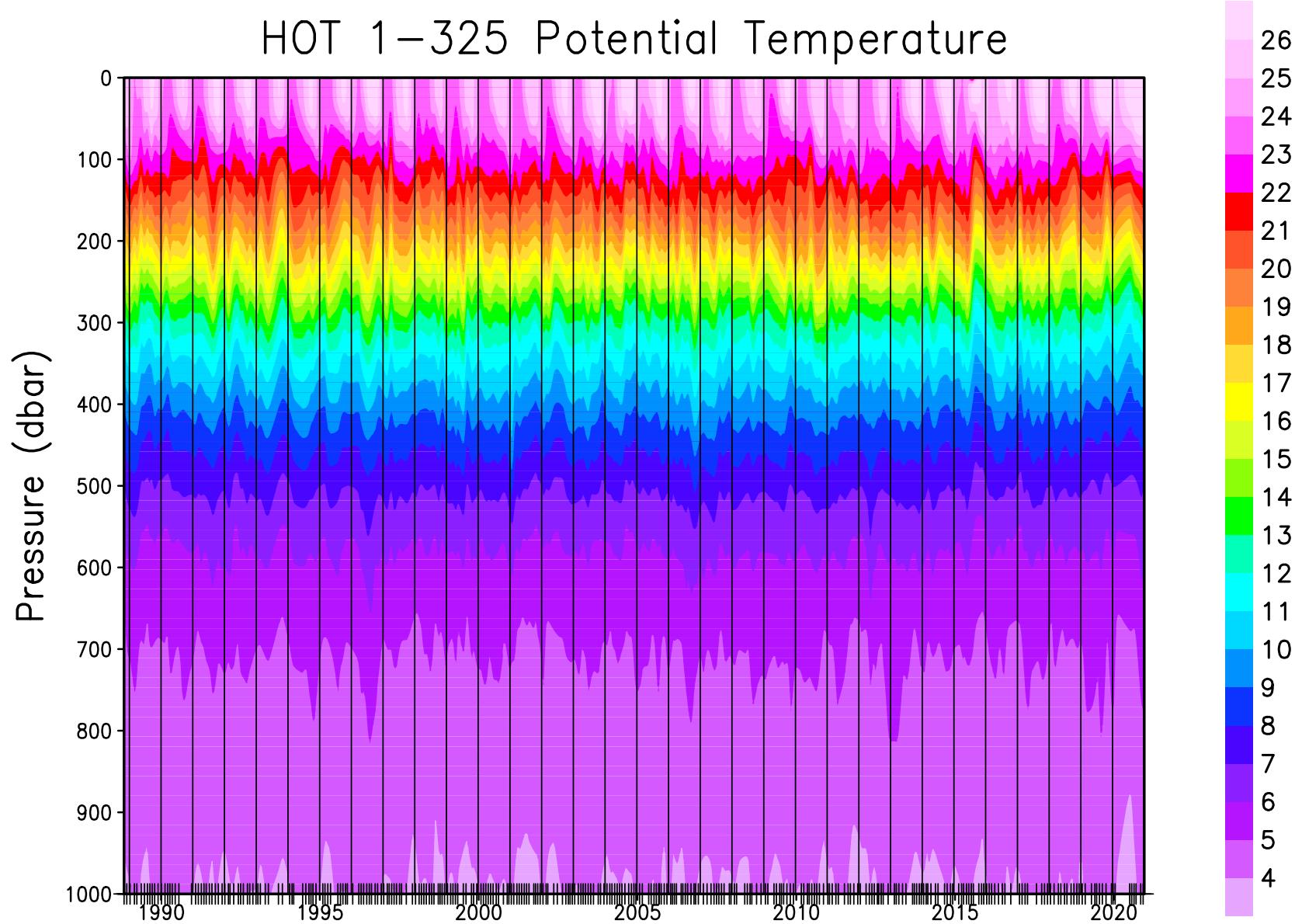


Figure 6.1.8

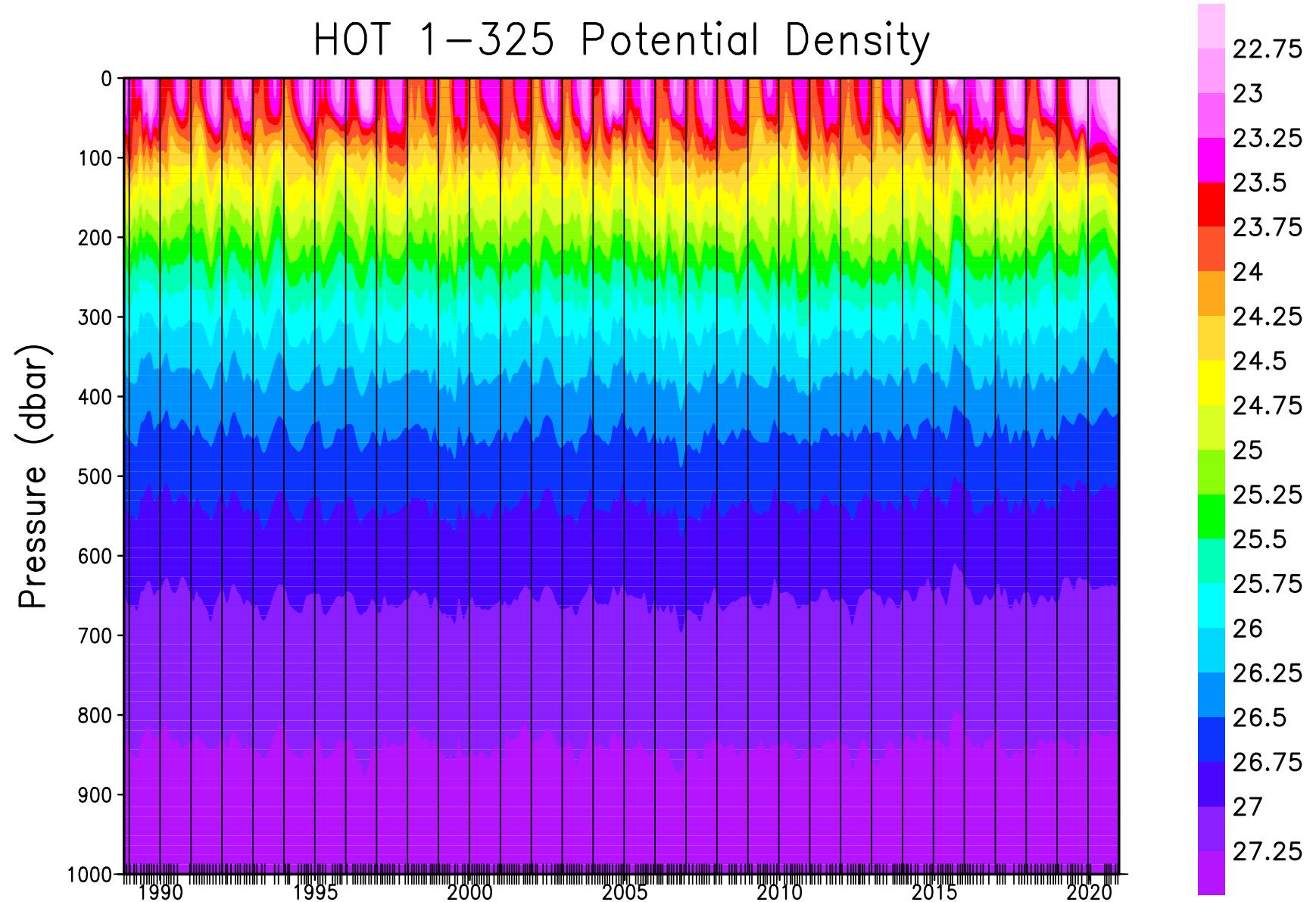


Figure 6.1.9

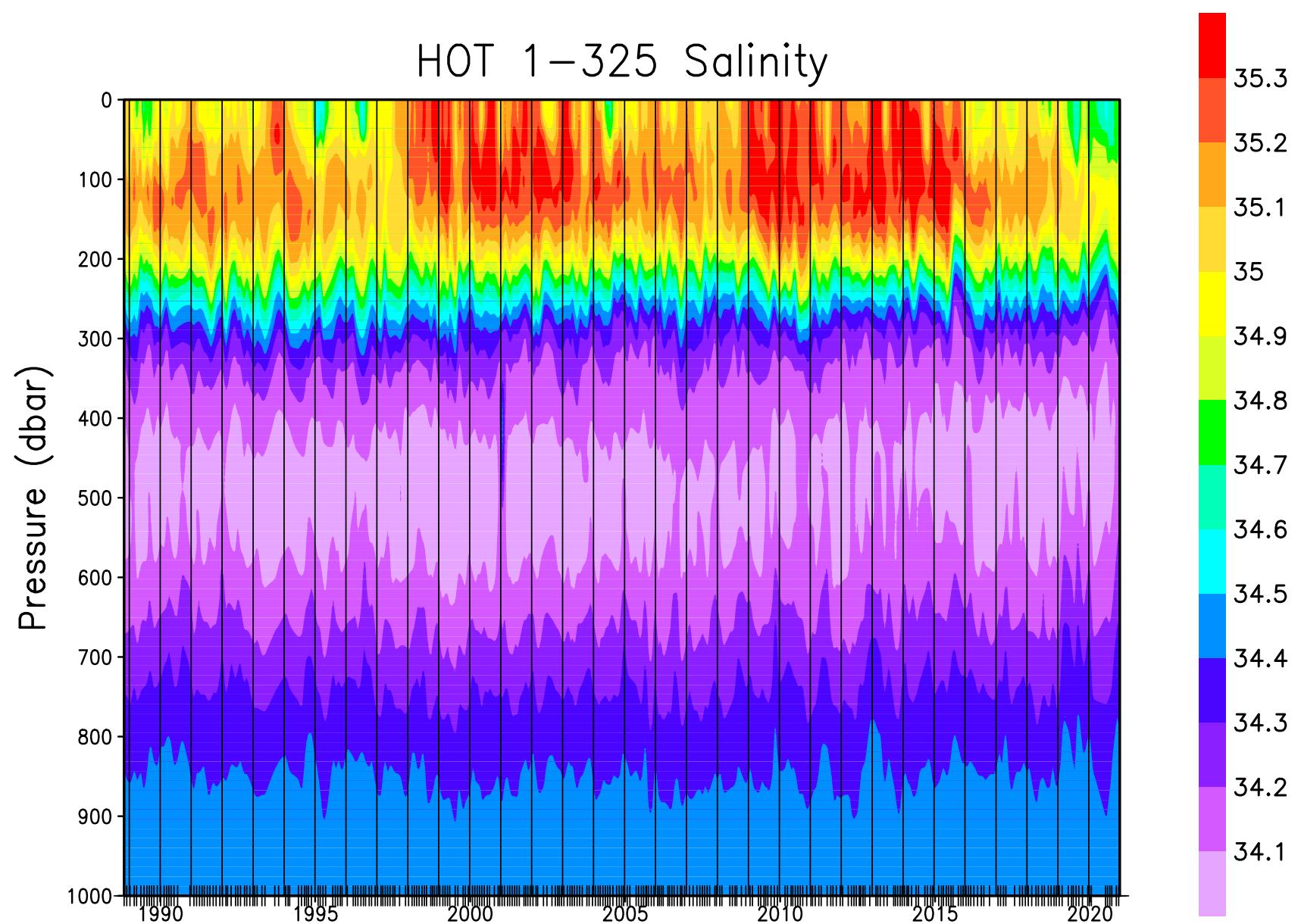


Figure 6.1.10

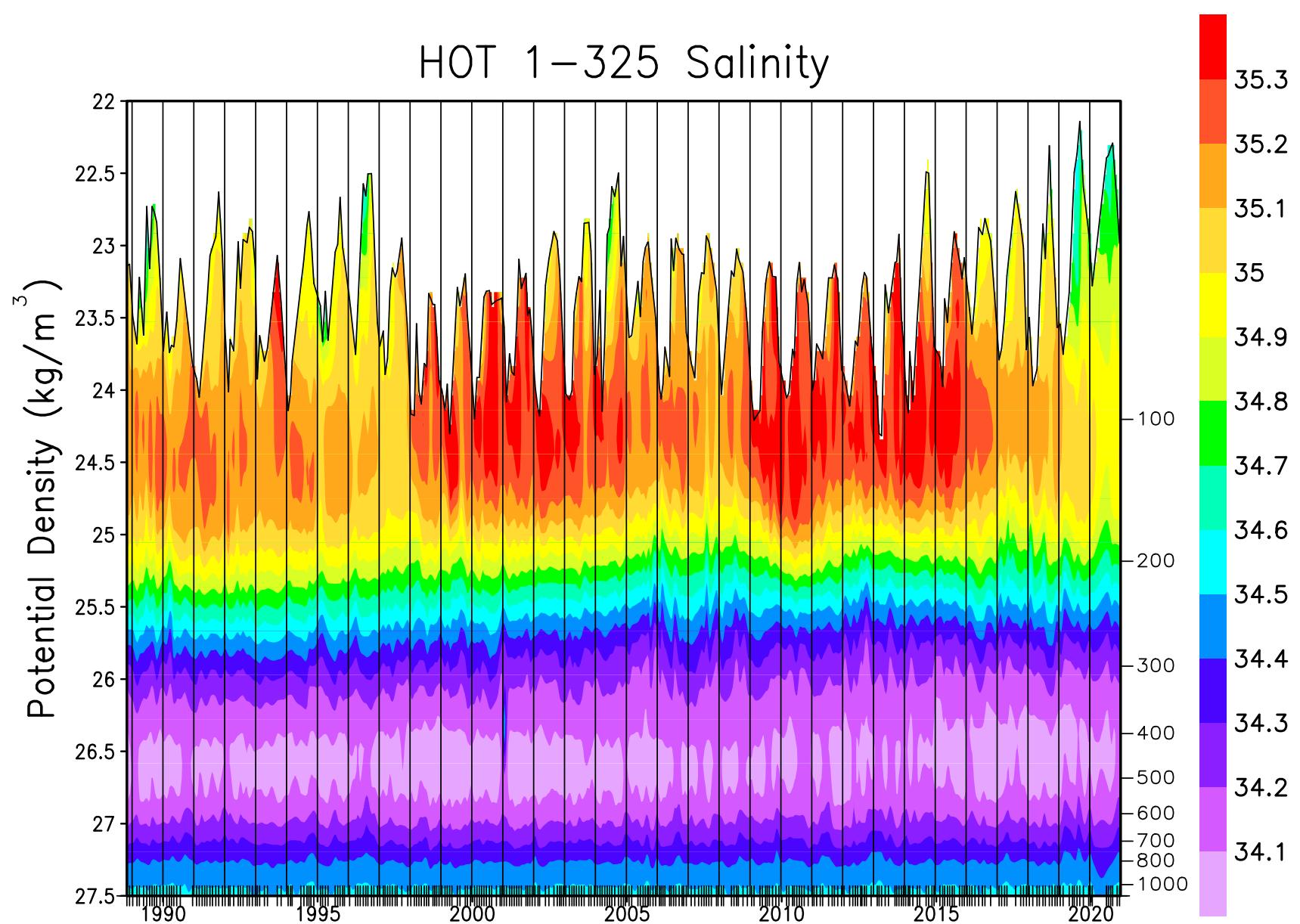


Figure 6.1.11

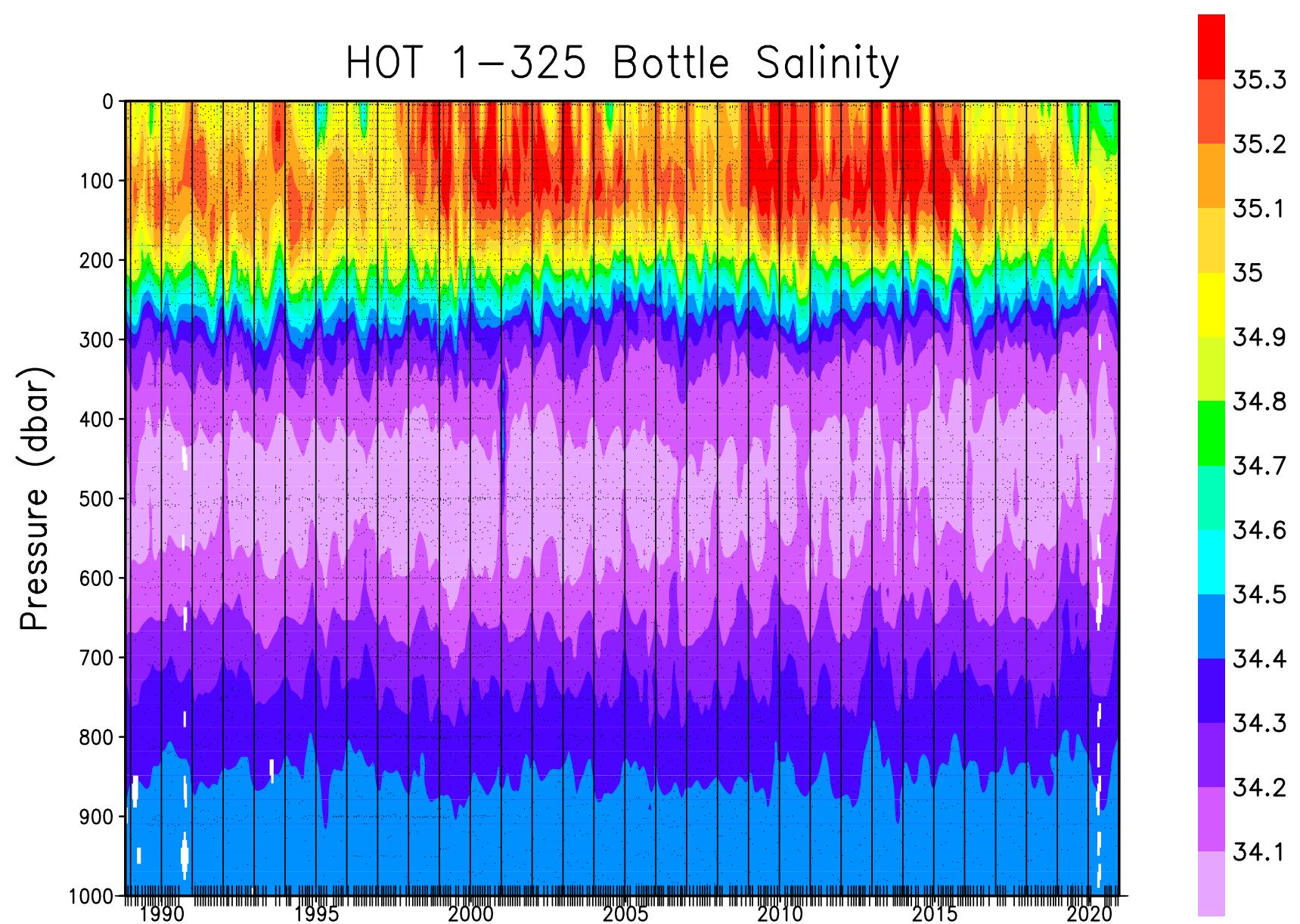


Figure 6.1.12

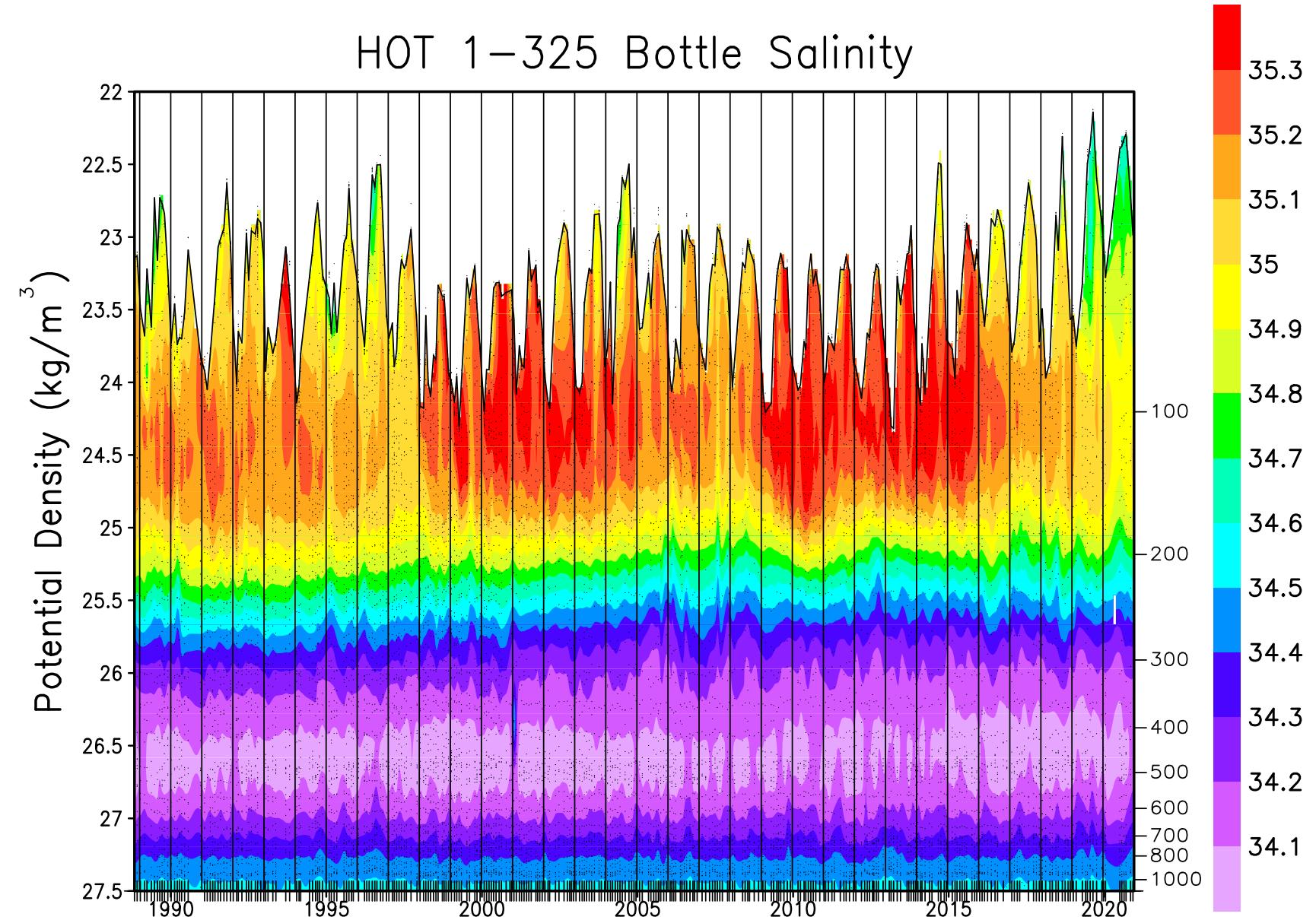


Figure 6.1.13

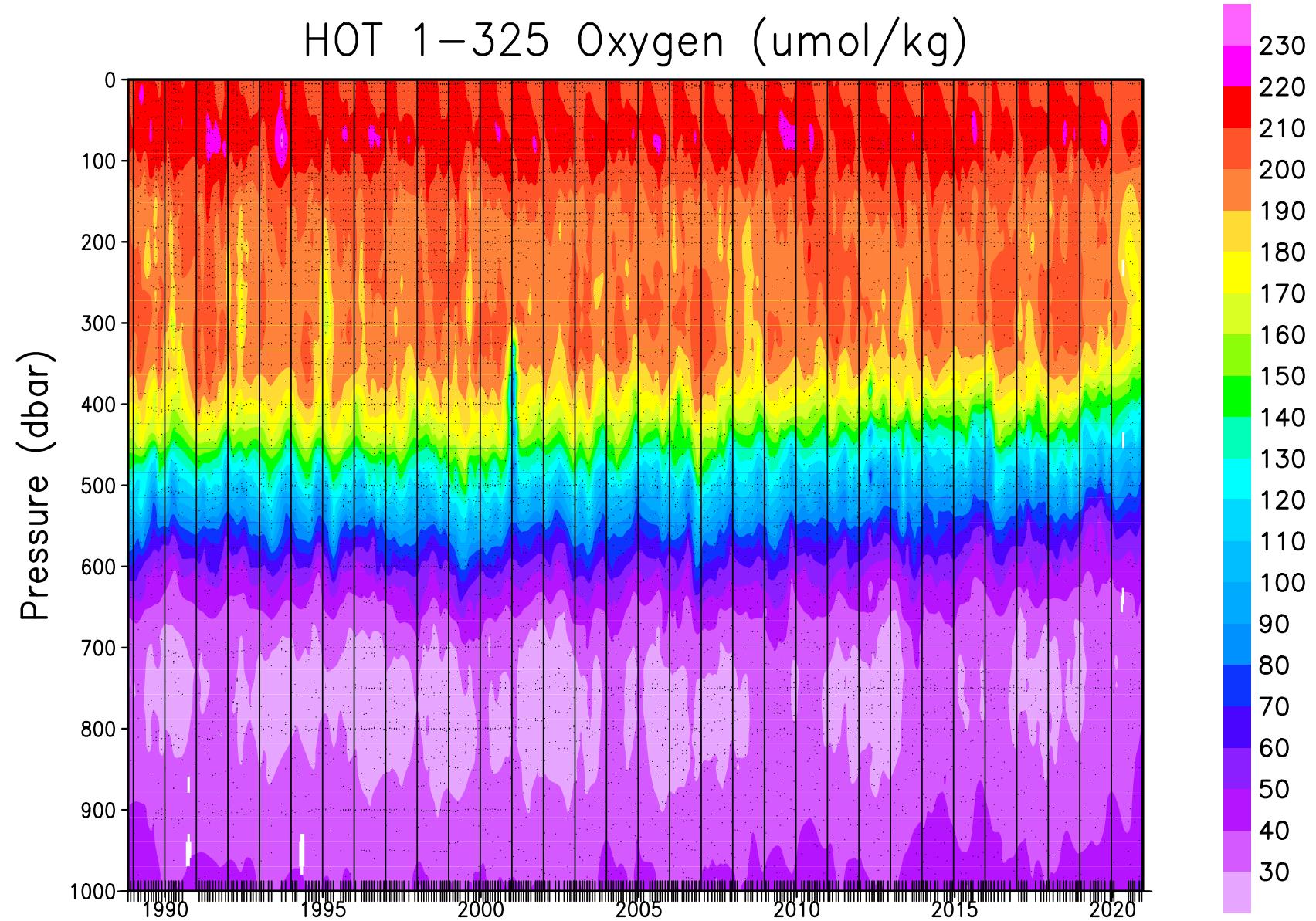


Figure 6.1.14

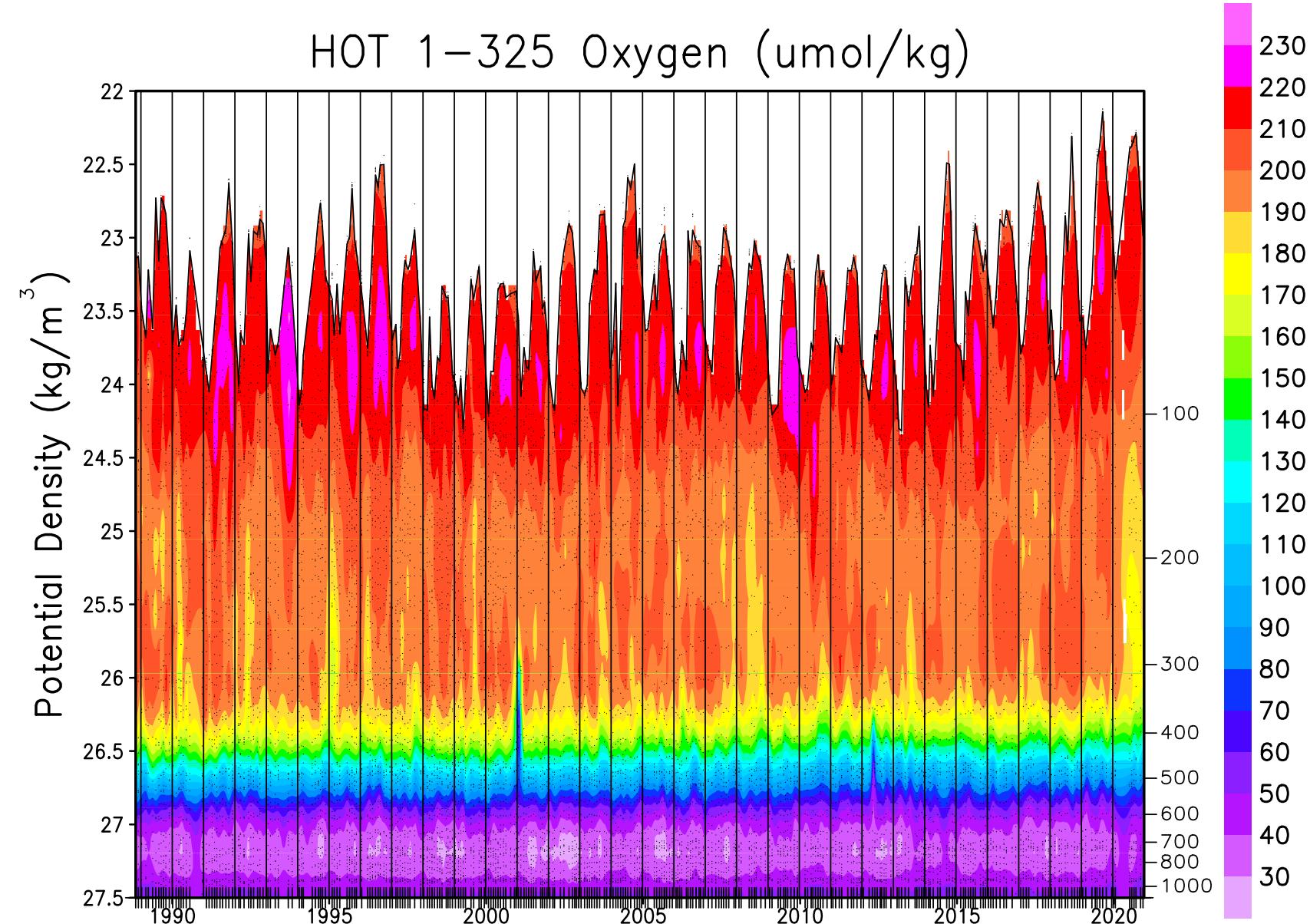


Figure 6.1.15

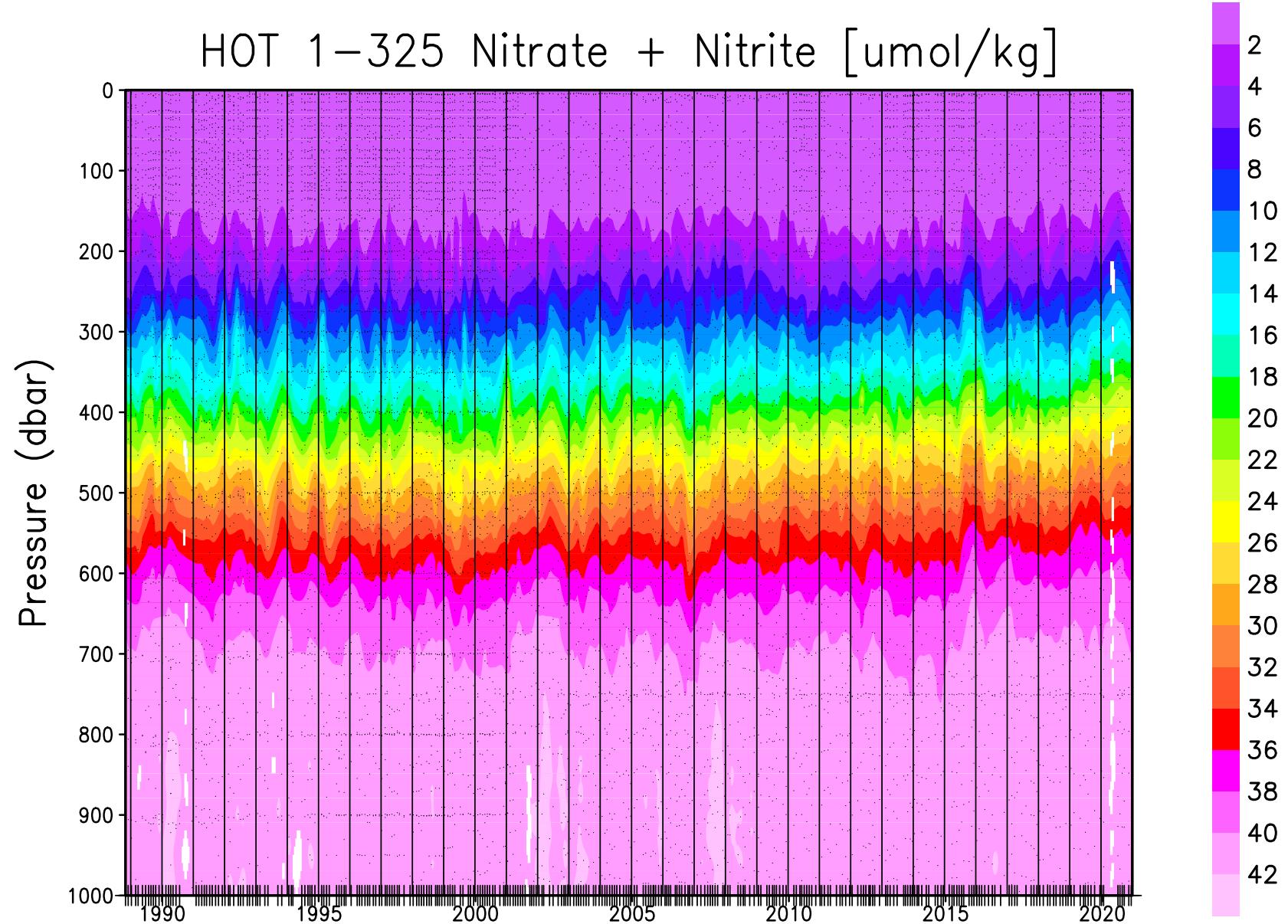


Figure 6.1.16

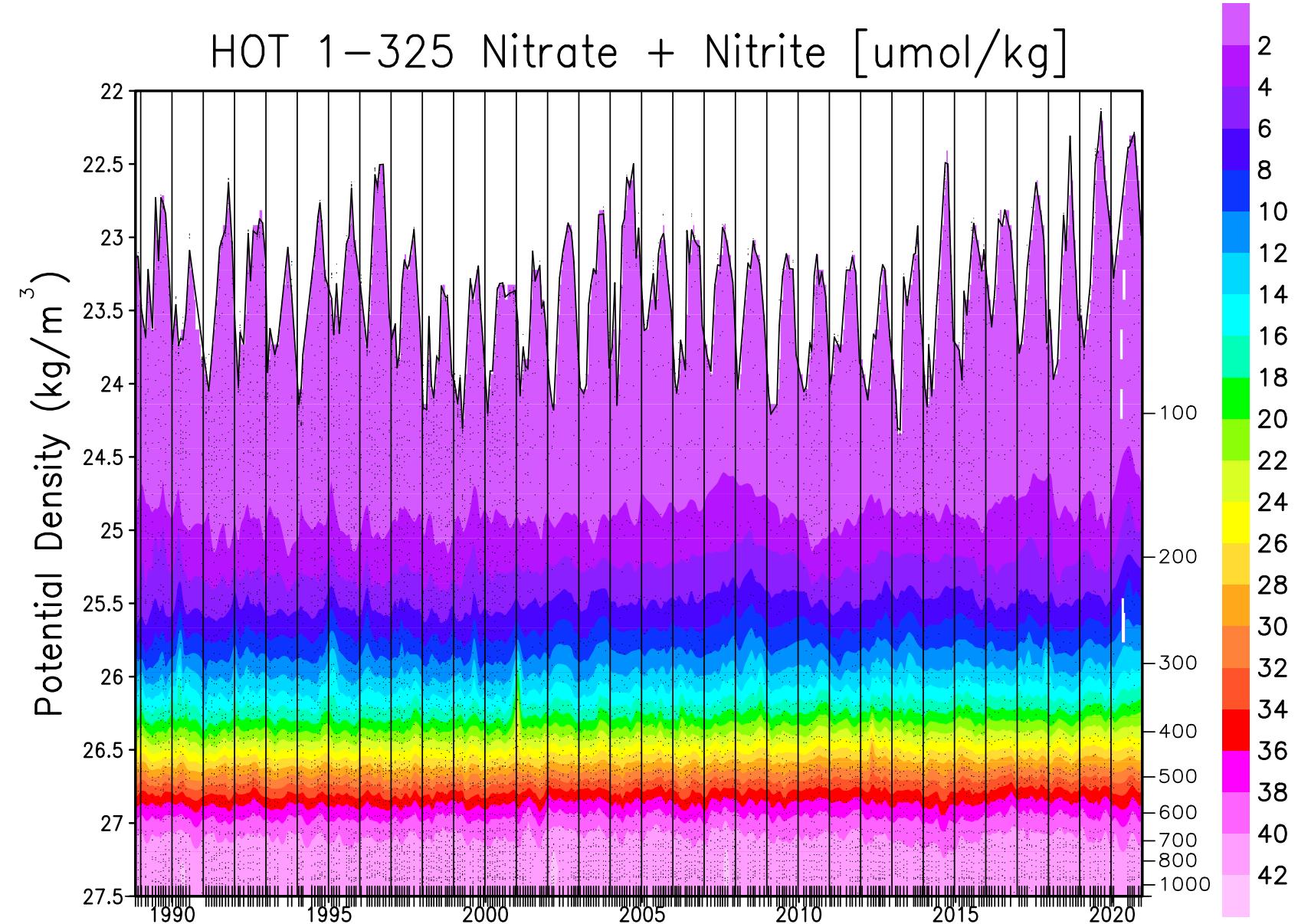


Figure 6.1.17

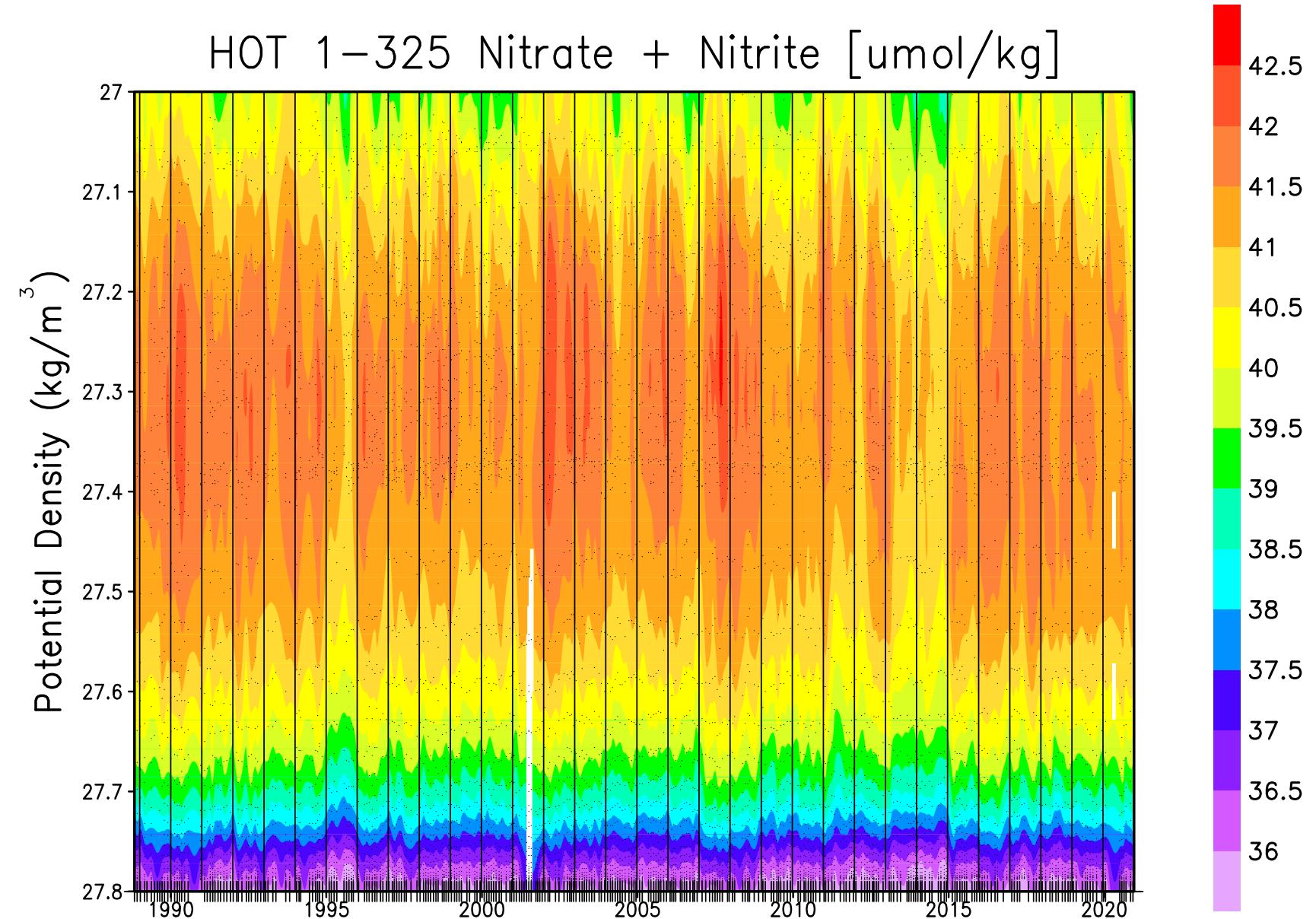


Figure 6.1.18

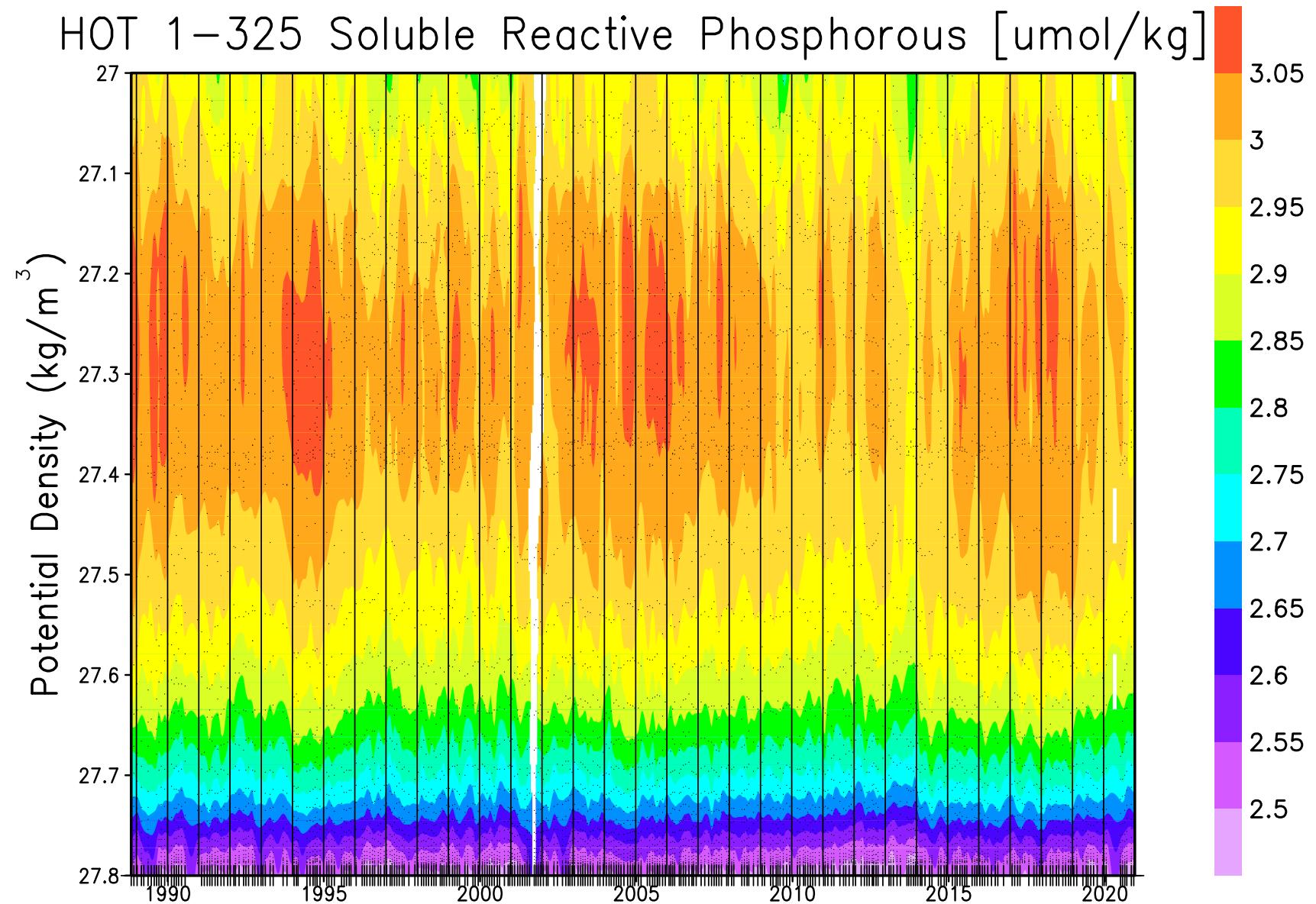


Figure 6.1.19

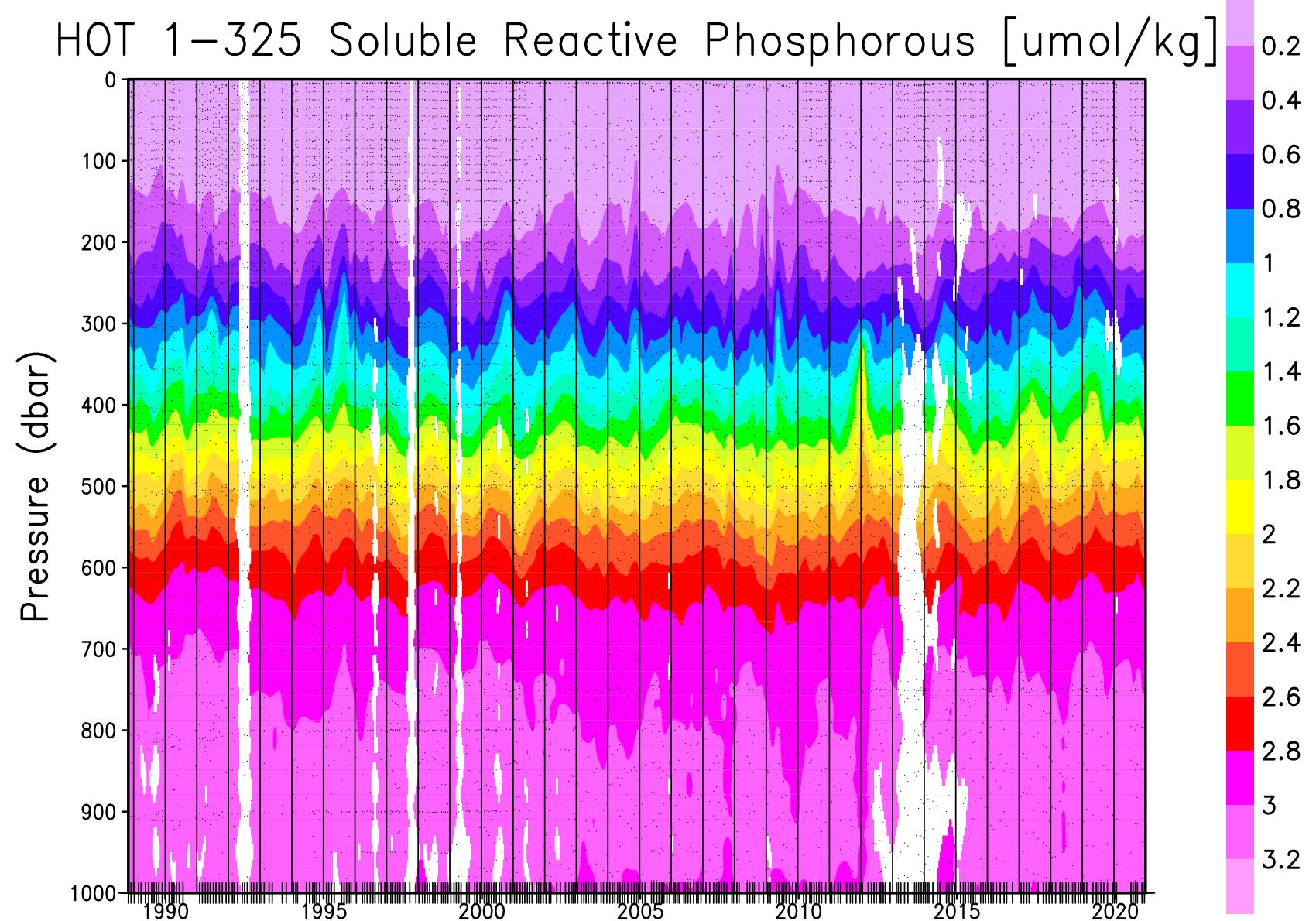


Figure 6.1.20

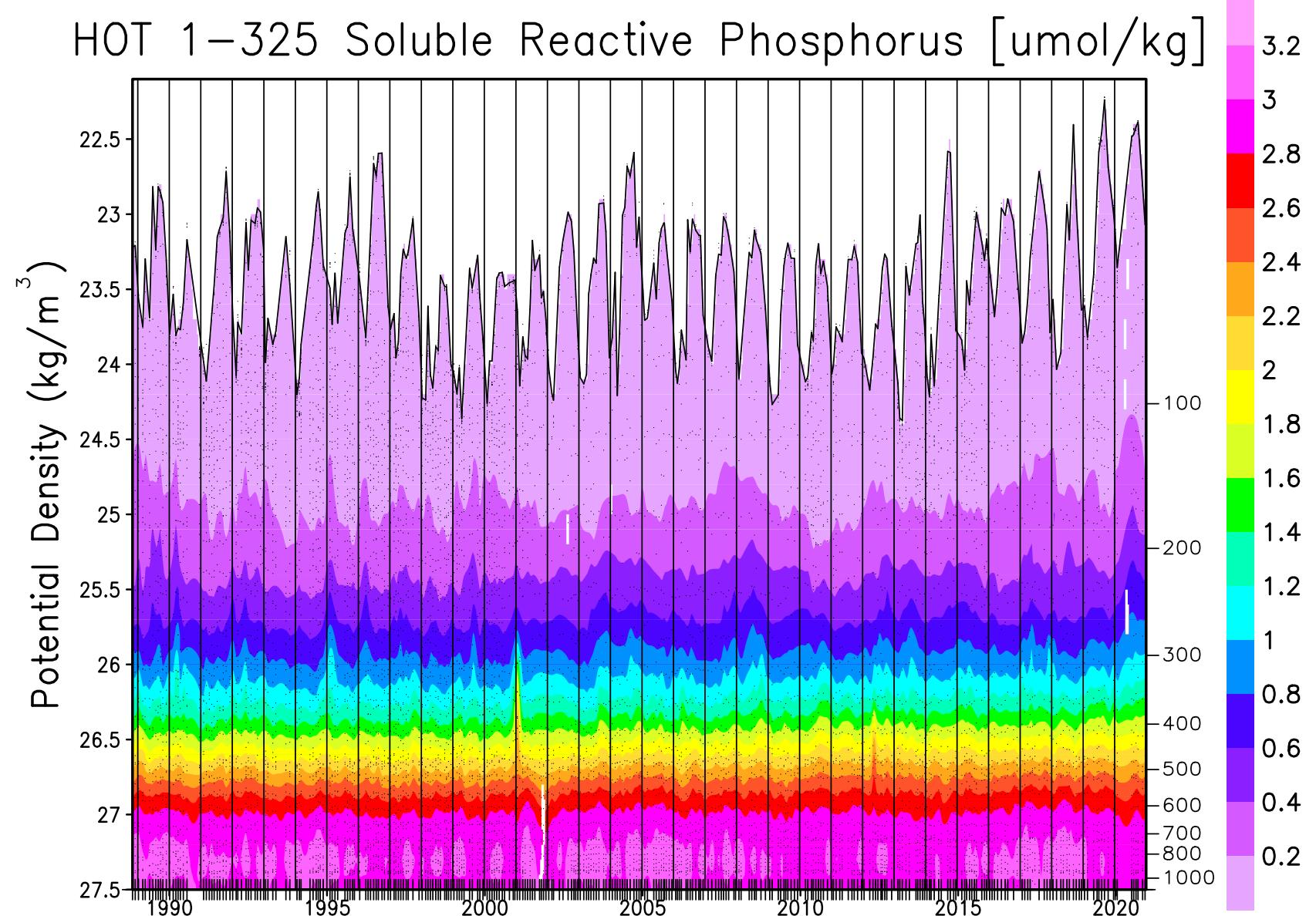


Figure 6.1.21

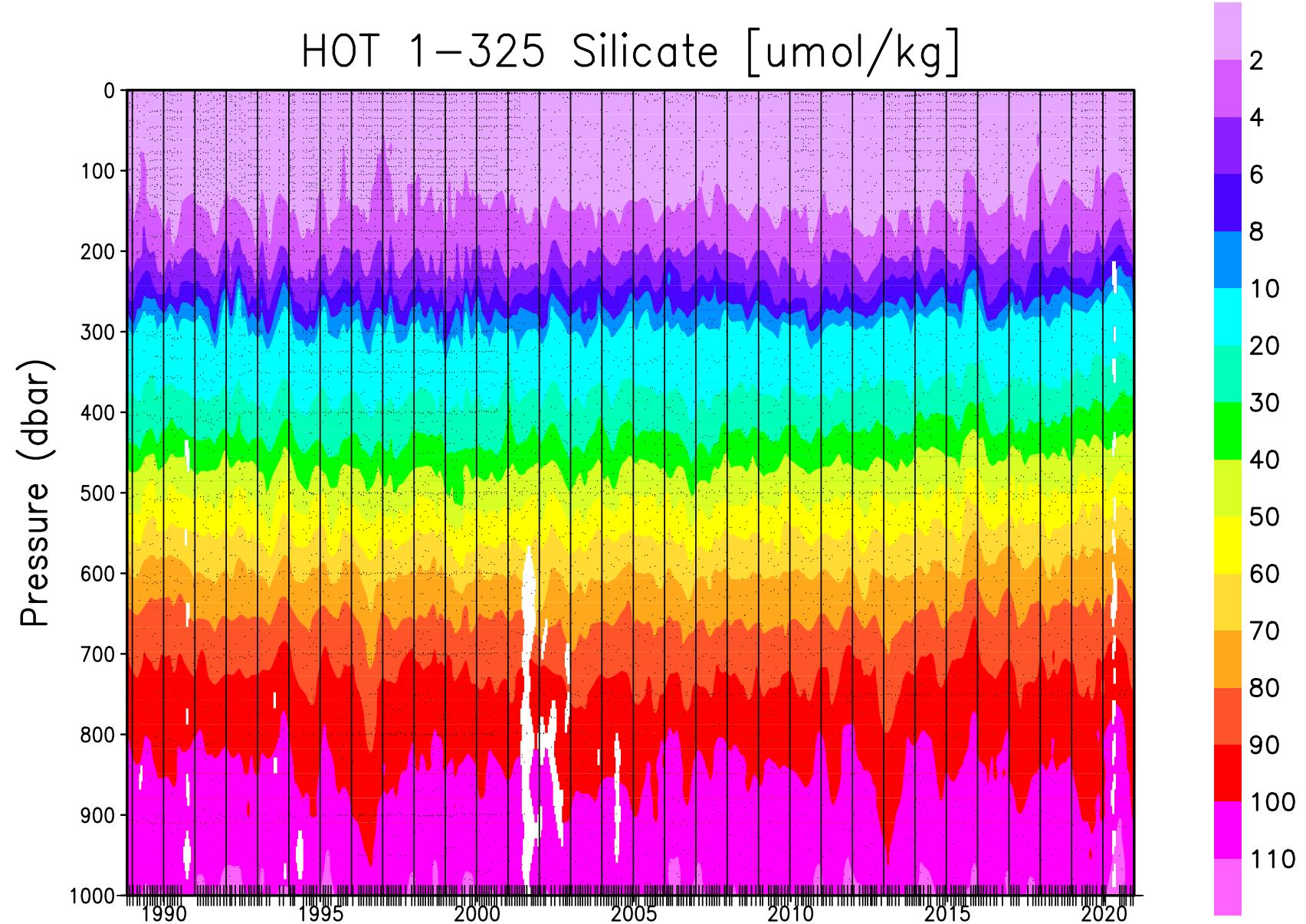


Figure 6.1.22

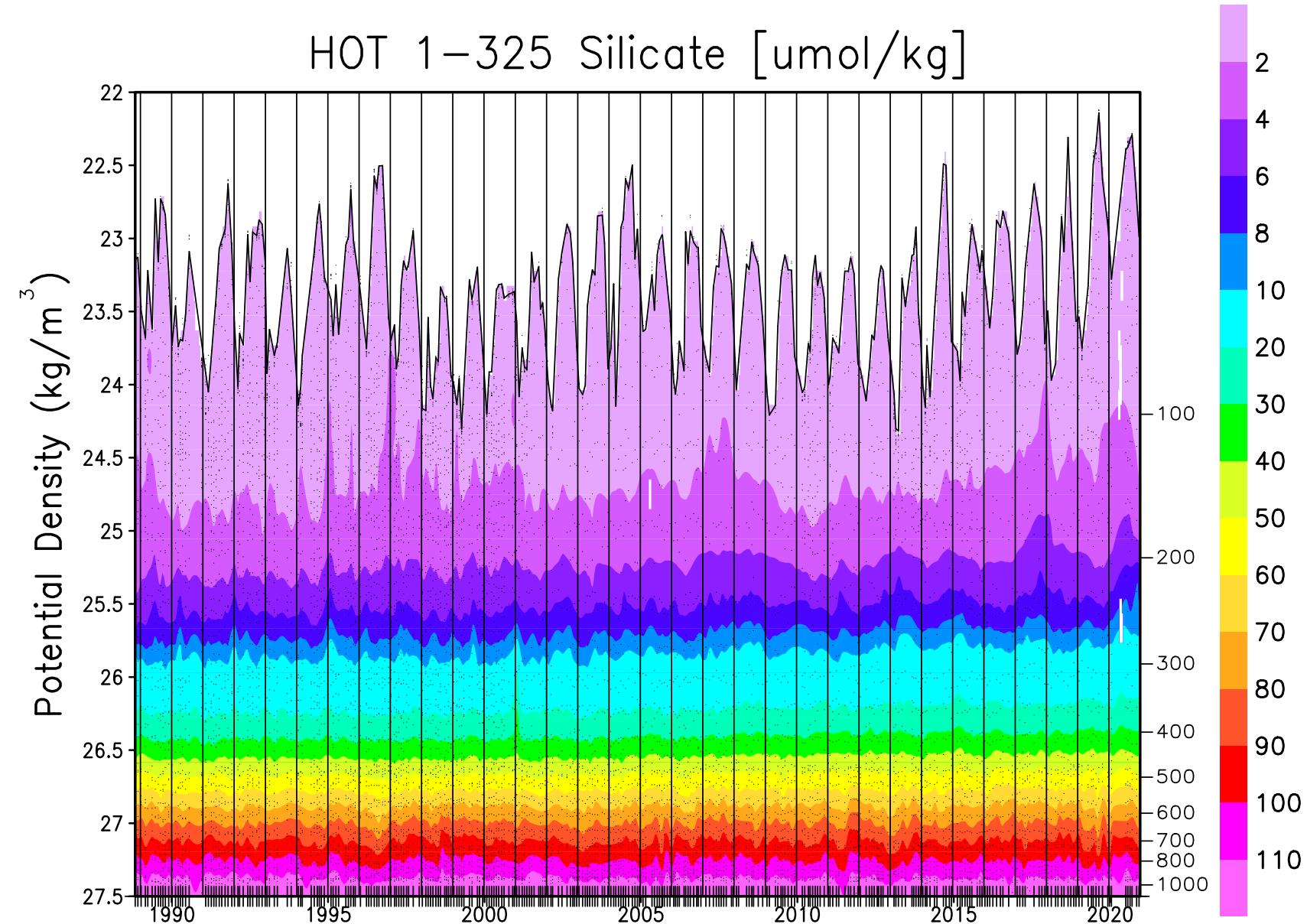


Figure 6.1.23

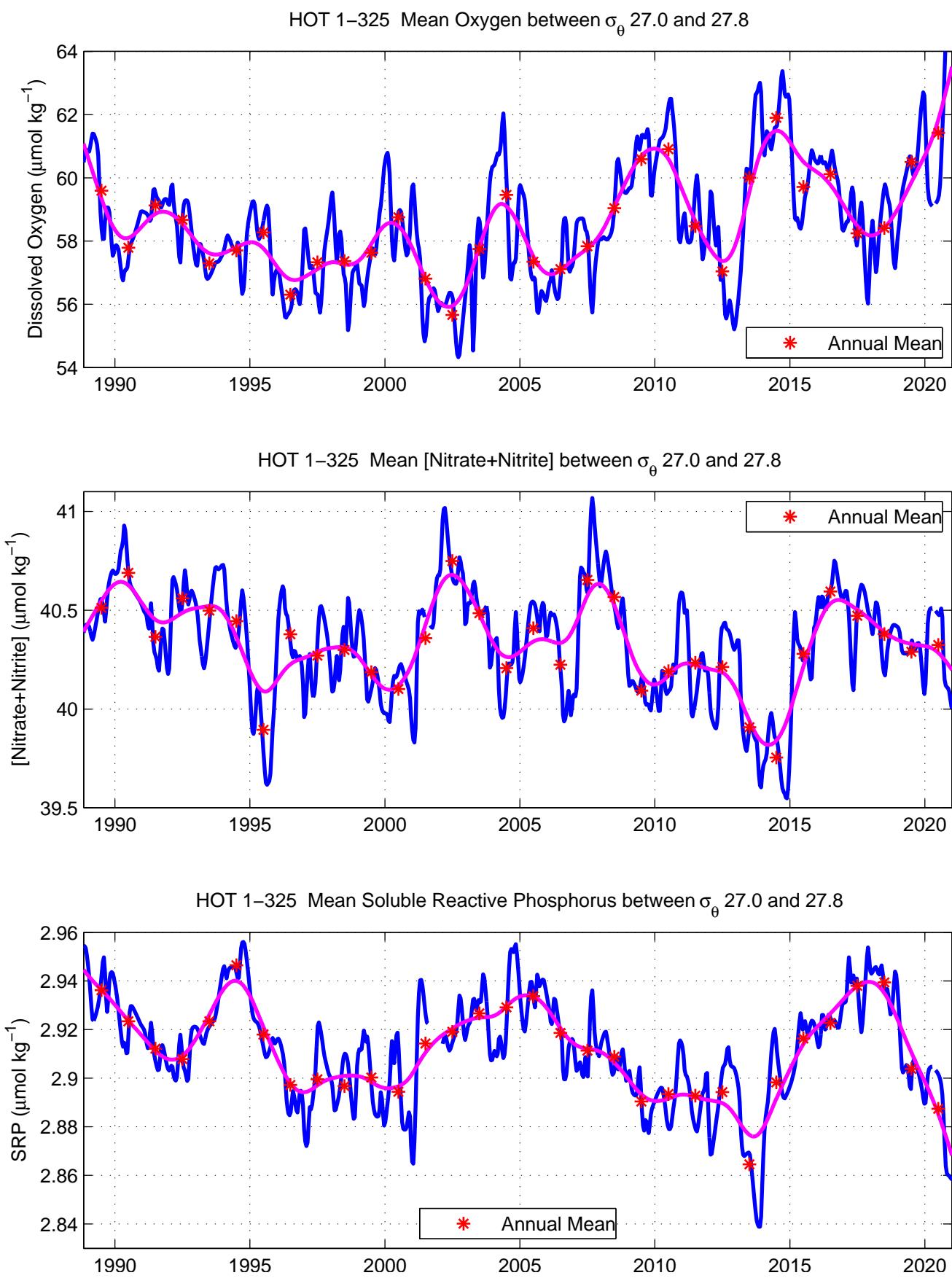


Figure 6.1.24

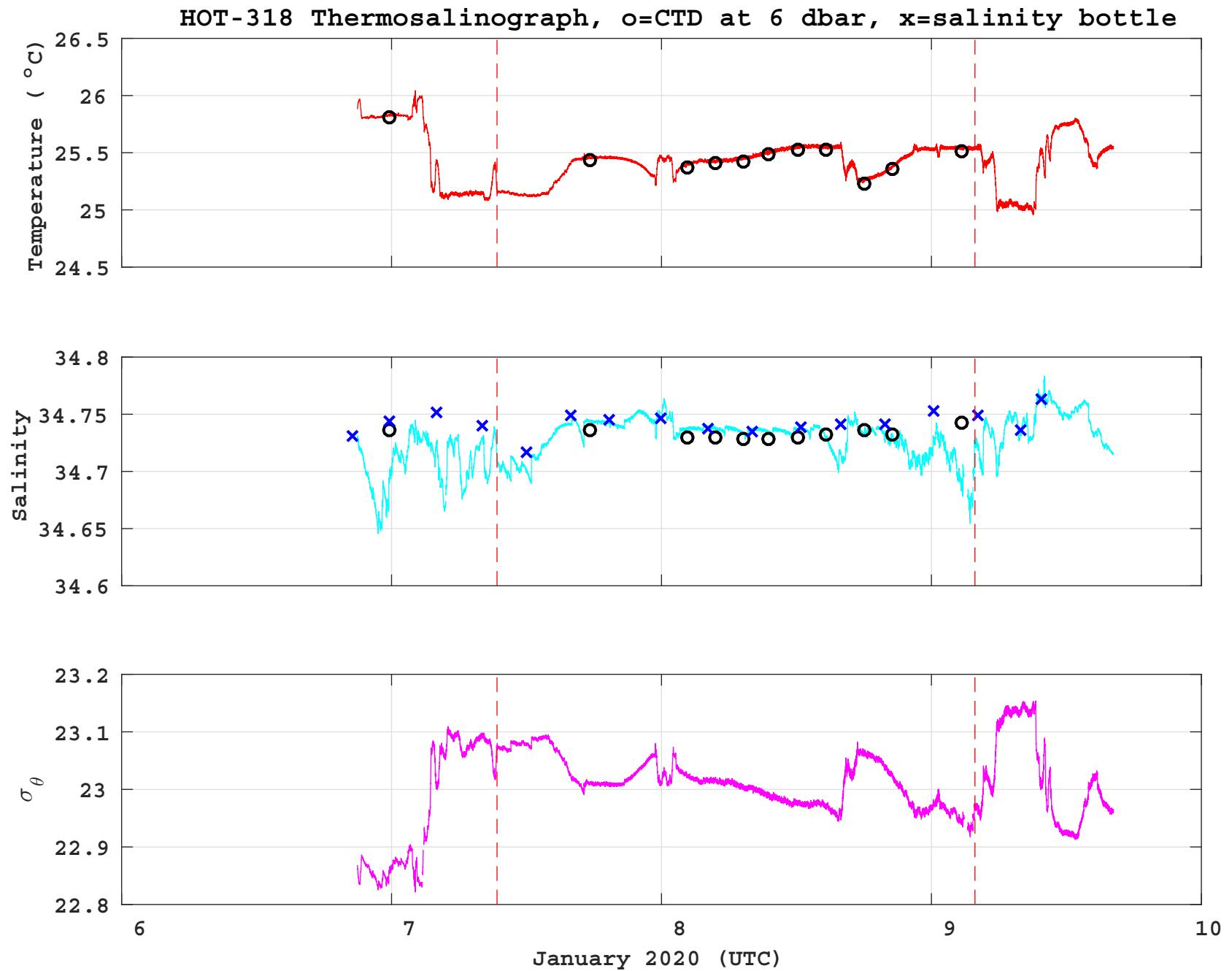


Figure 6.2.1a

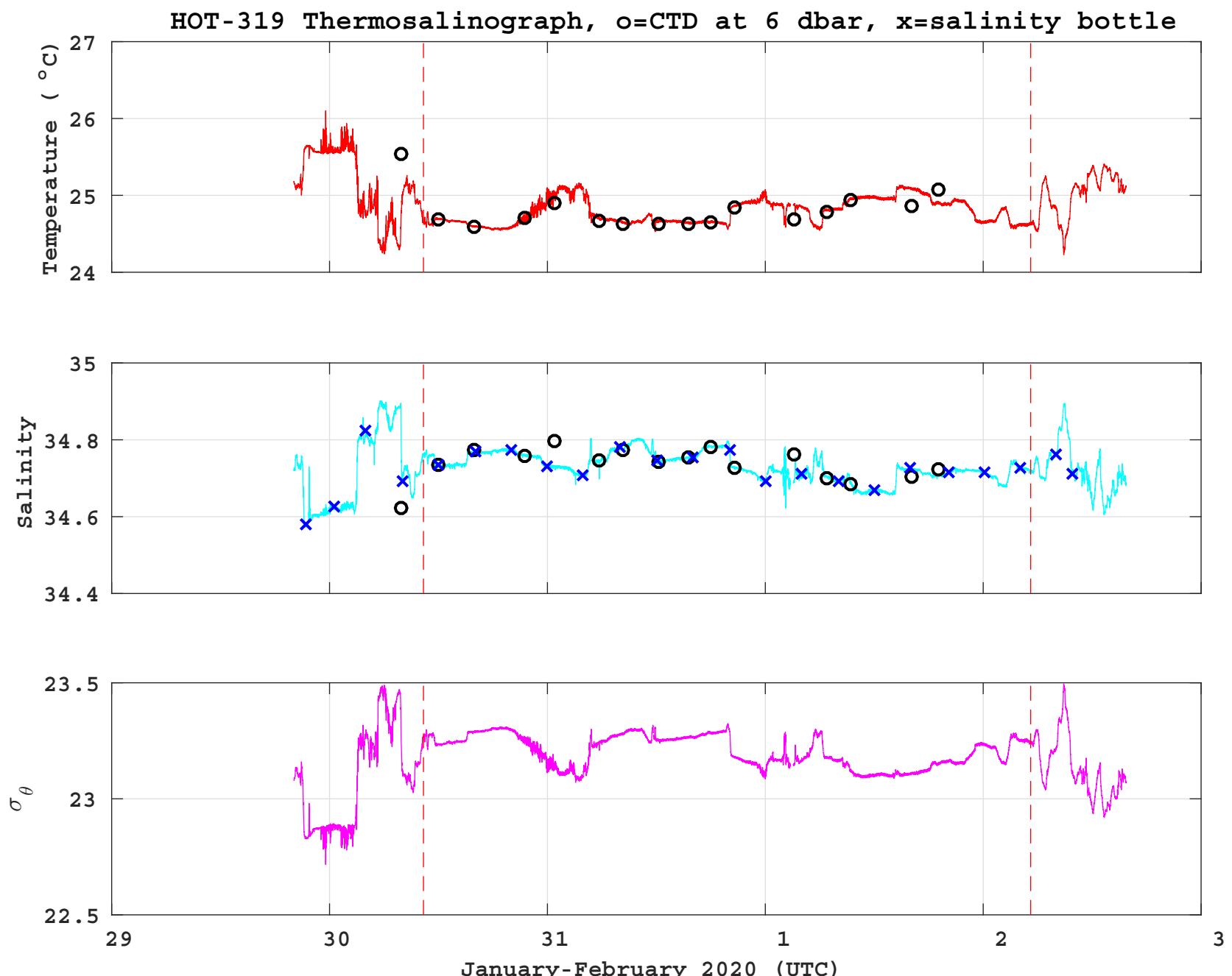


Figure 6.2.1b

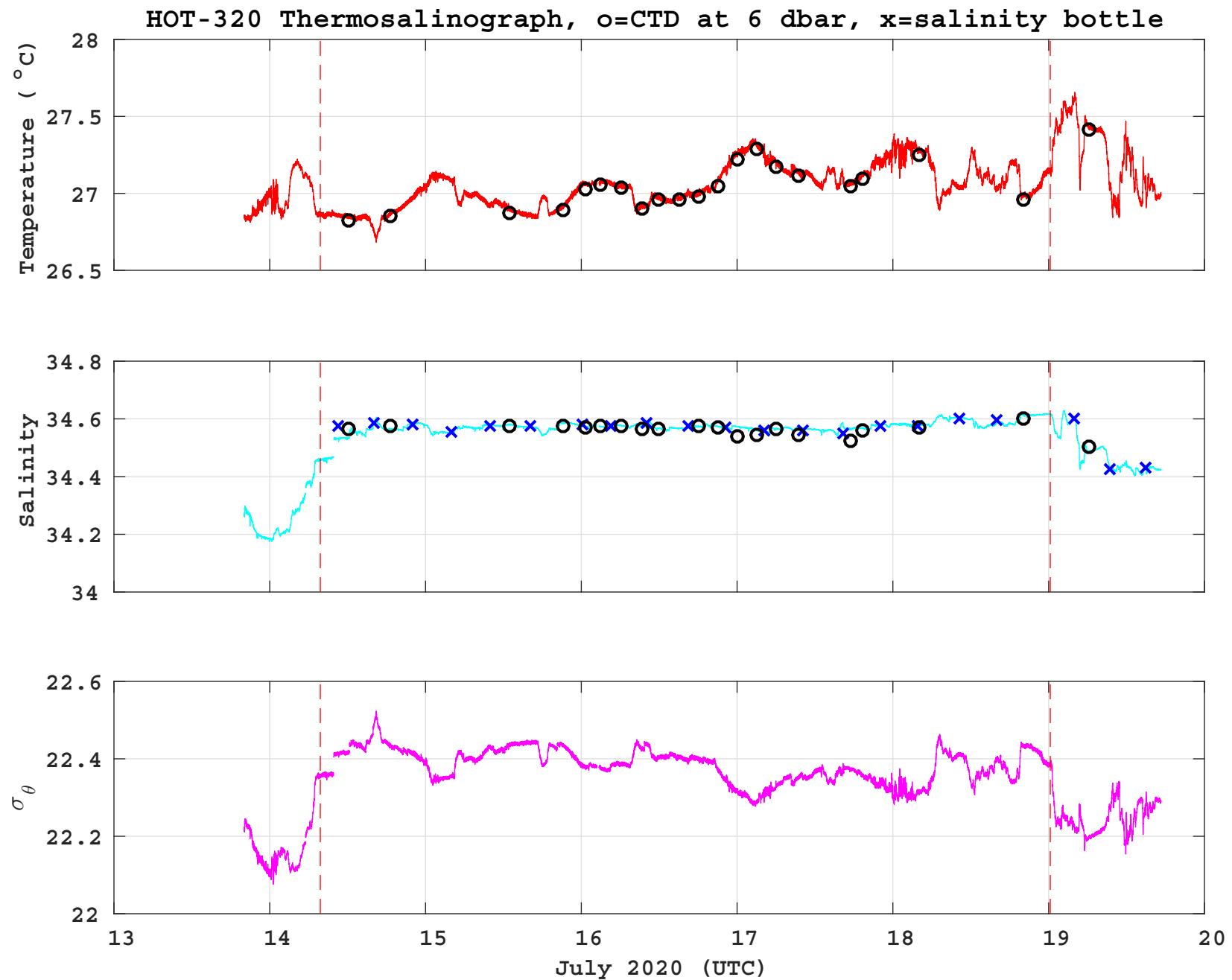


Figure 6.2.1c

HOT-321 Thermosalinograph, o=CTD at 6 dbar, x=salinity bottle

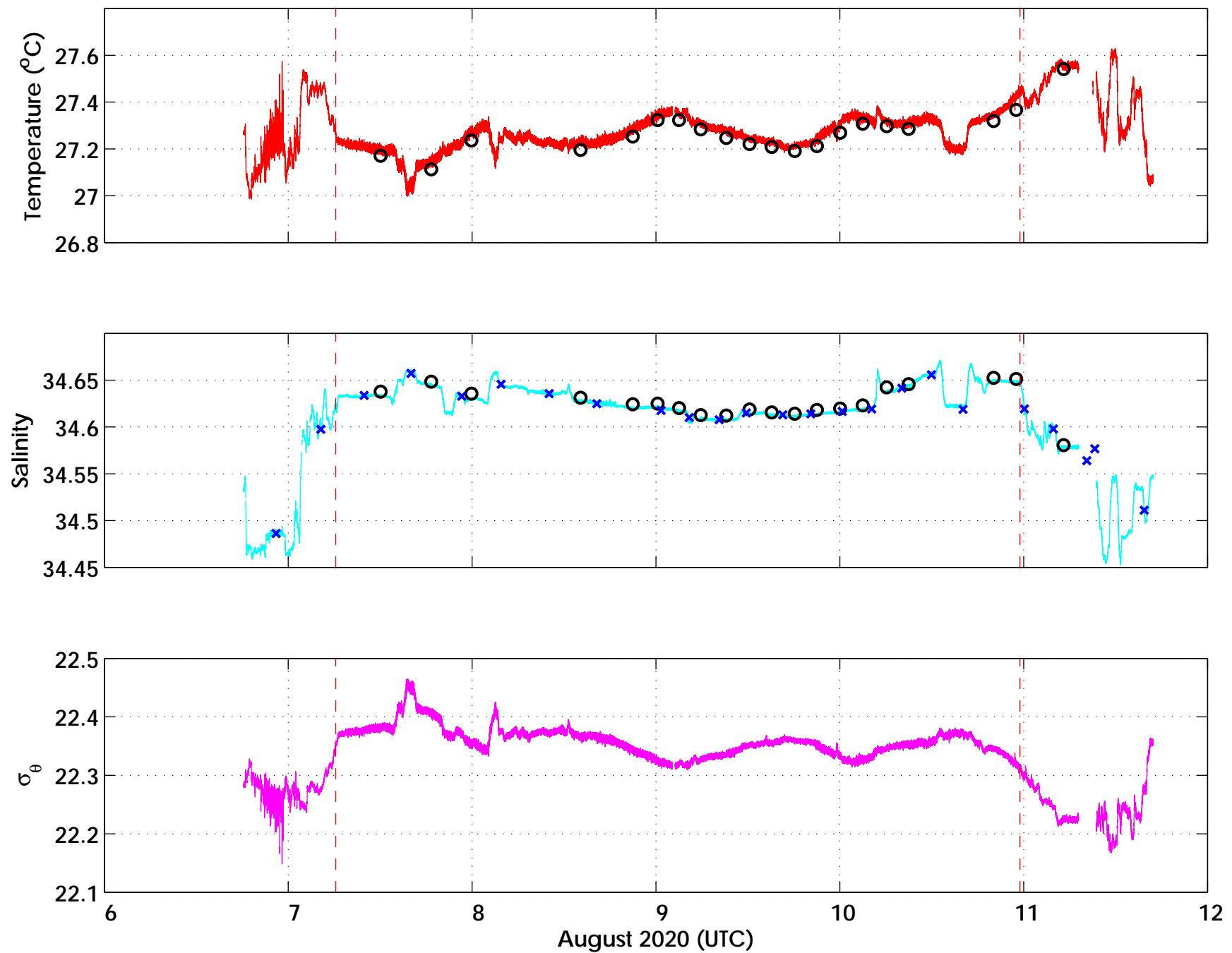


Figure 6.2.1d

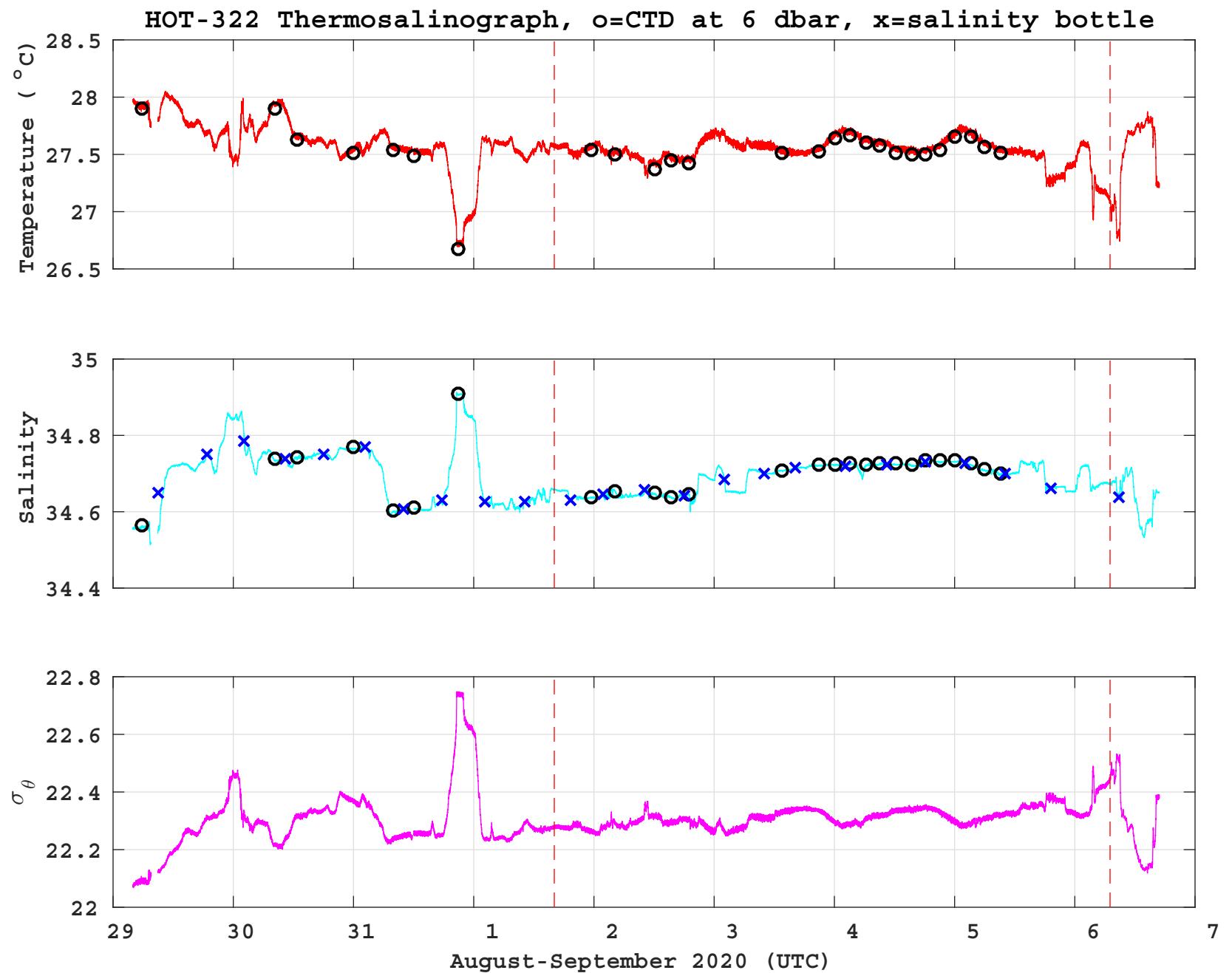


Figure 6.2.1e

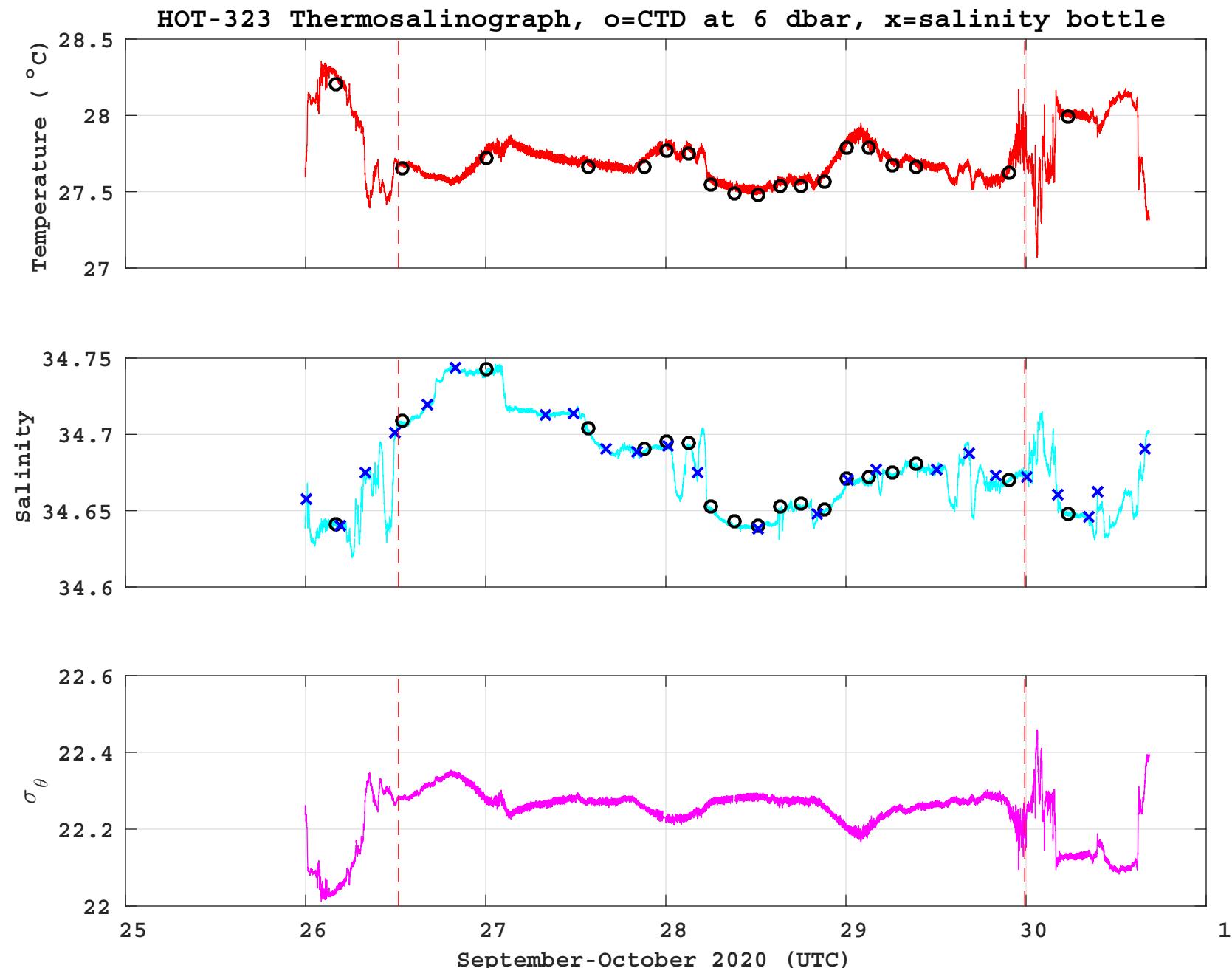


Figure 6.2.1f

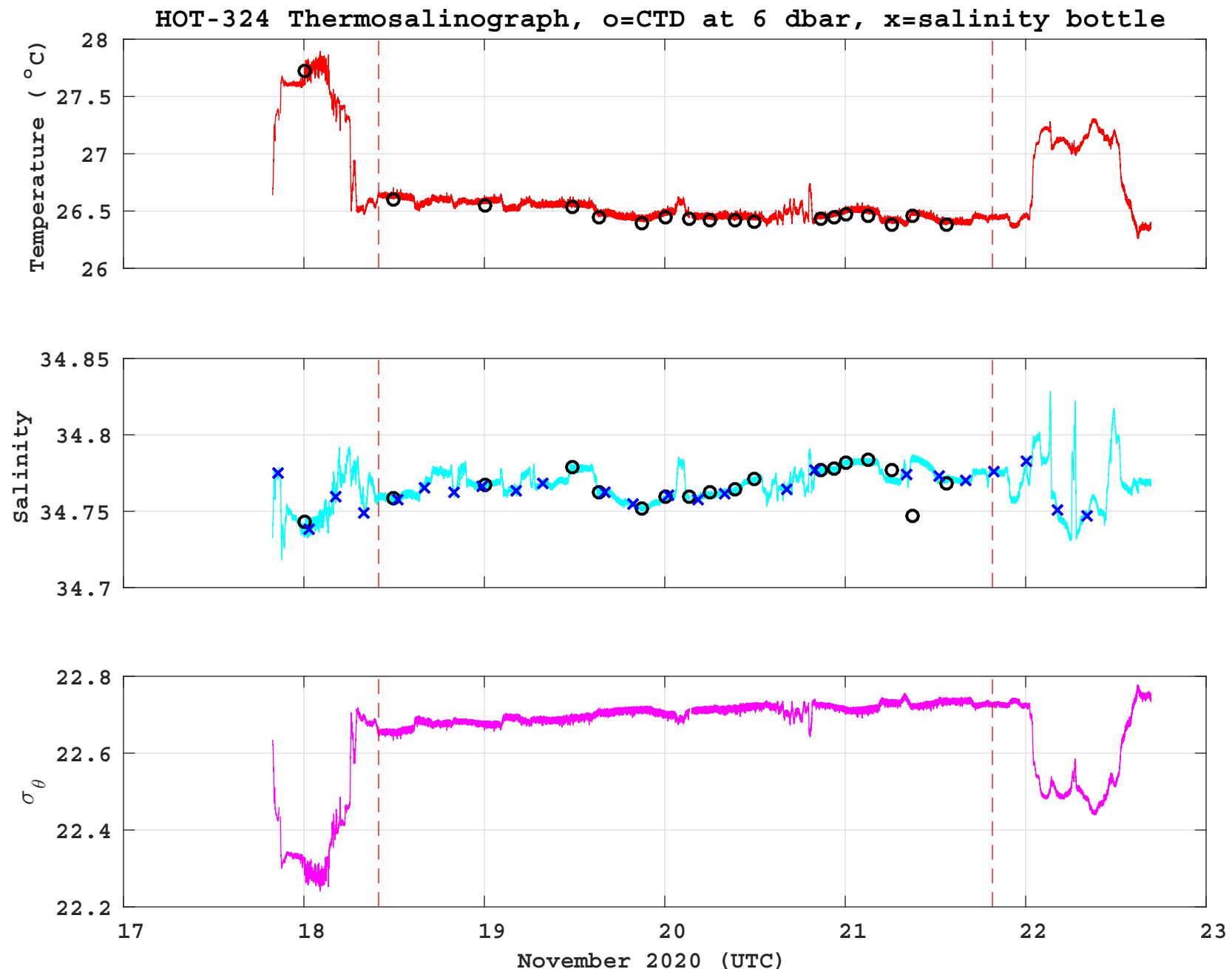


Figure 6.2.1g

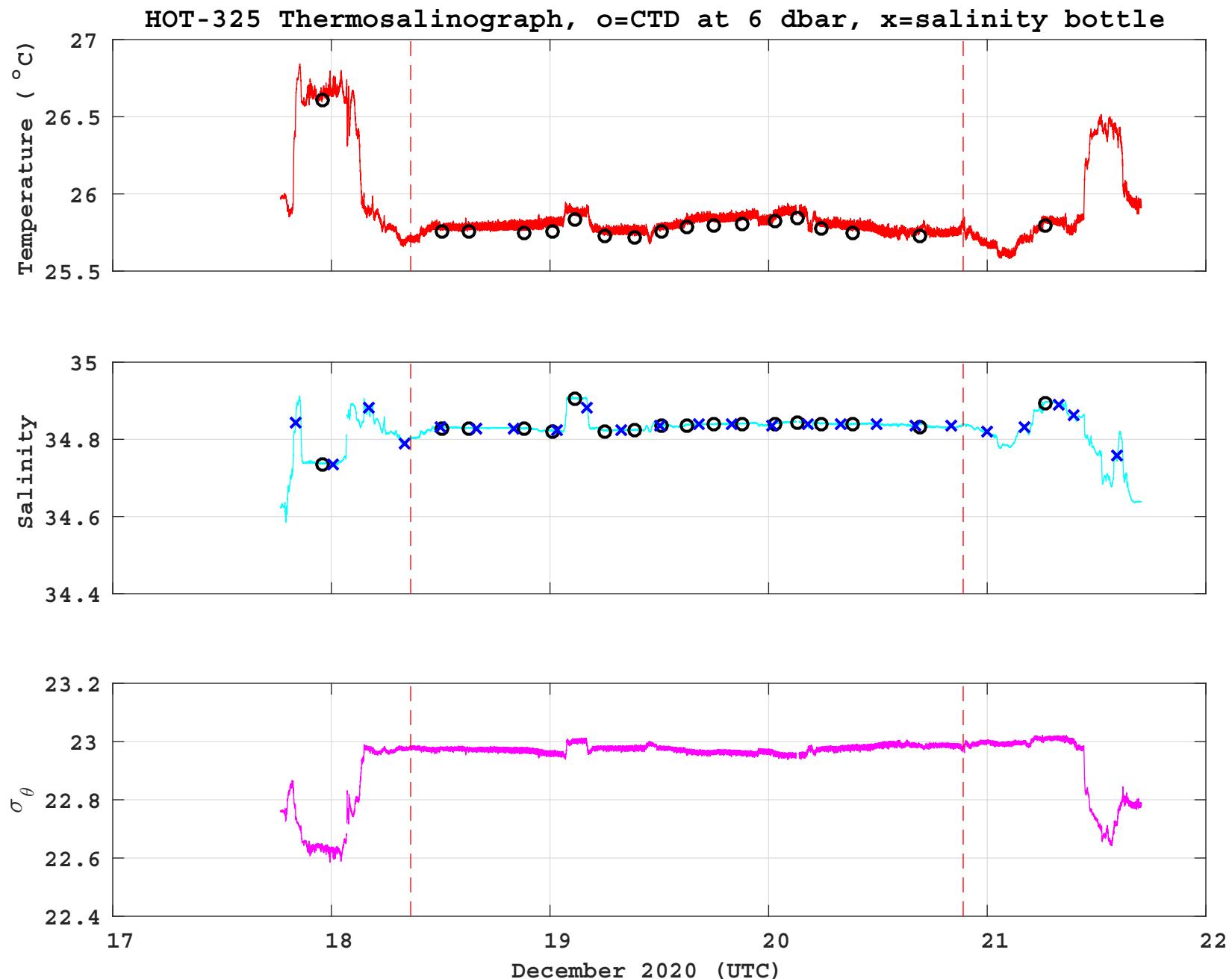


Figure 6.2.1h

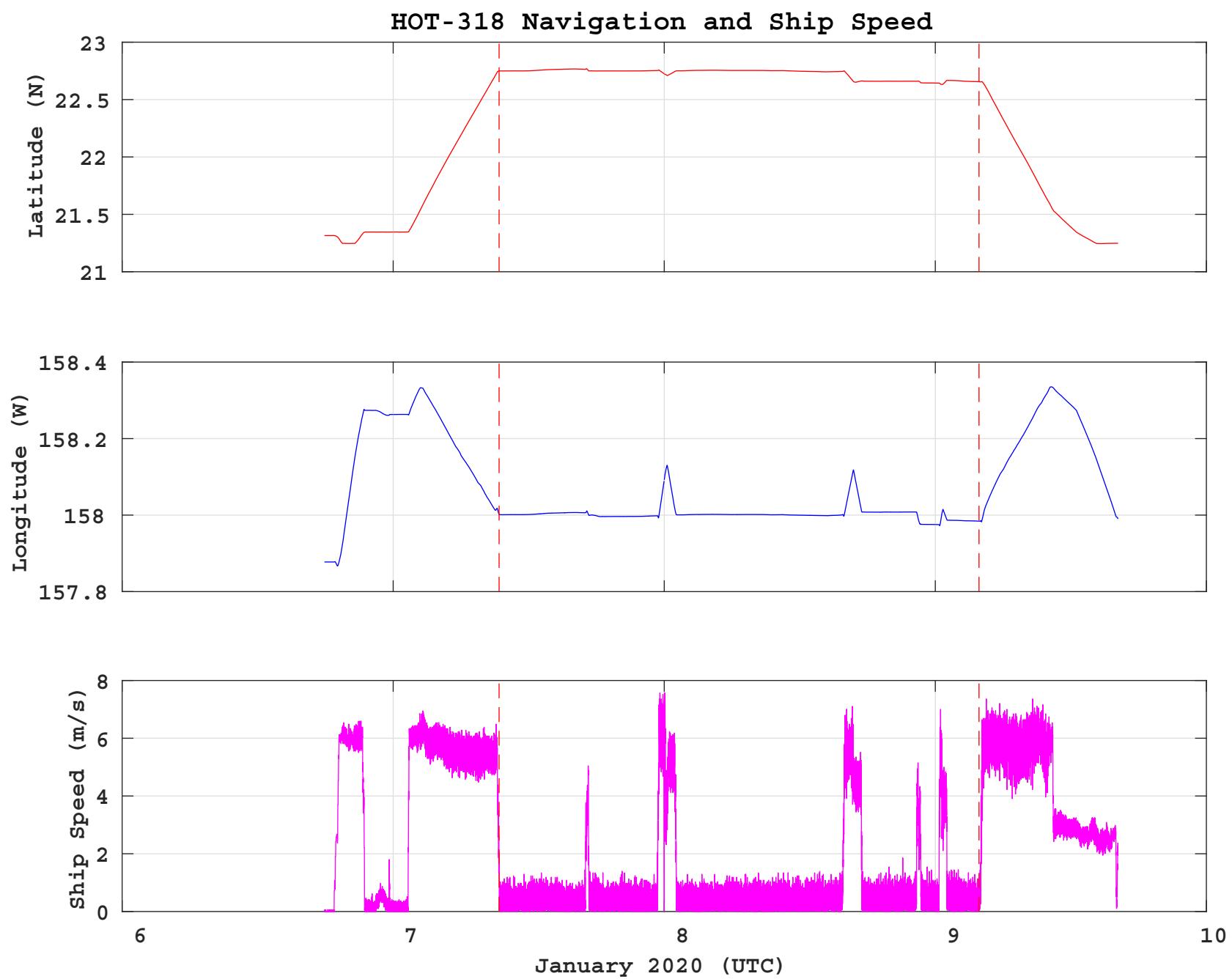


Figure 6.2.2a

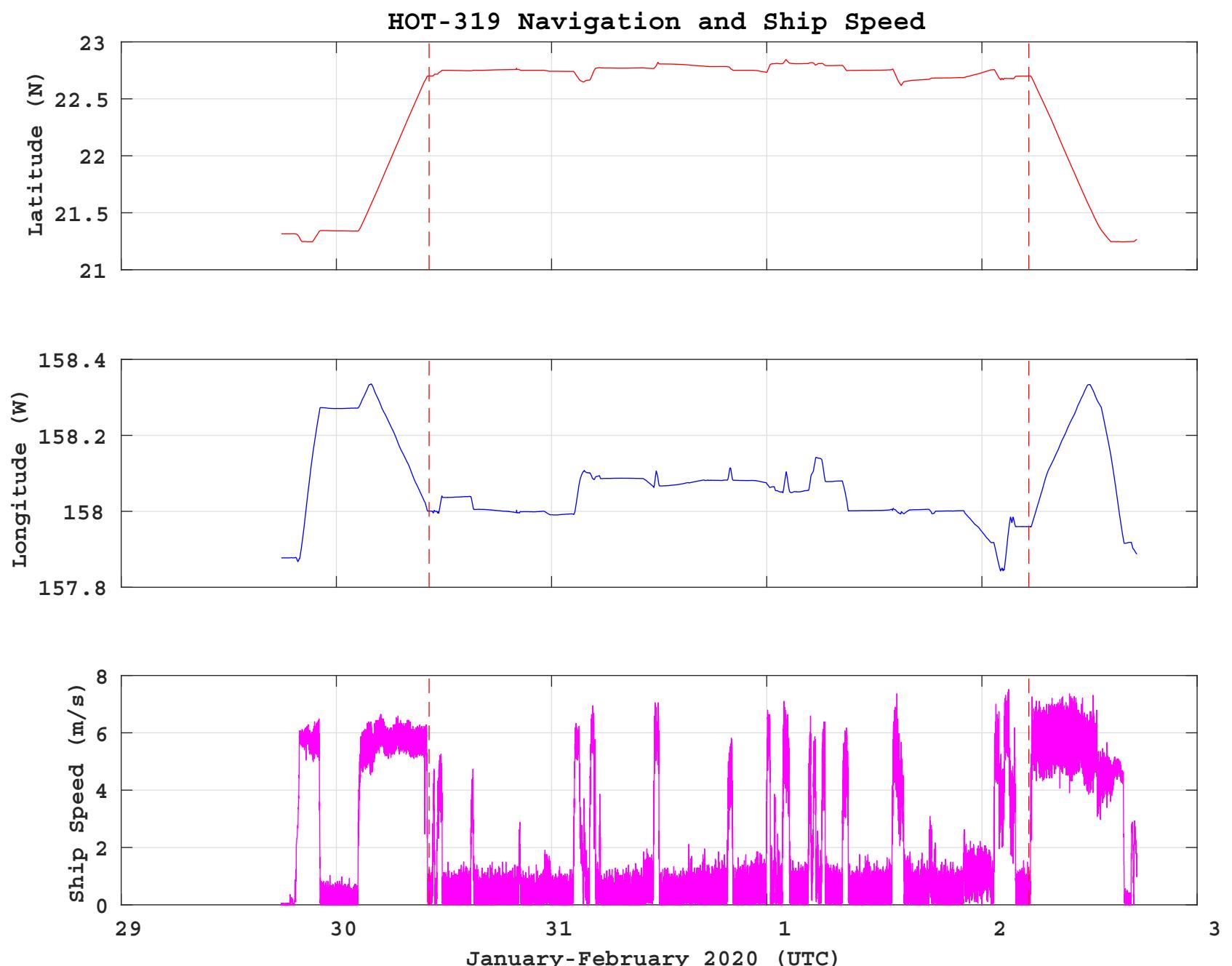


Figure 6.2.2b

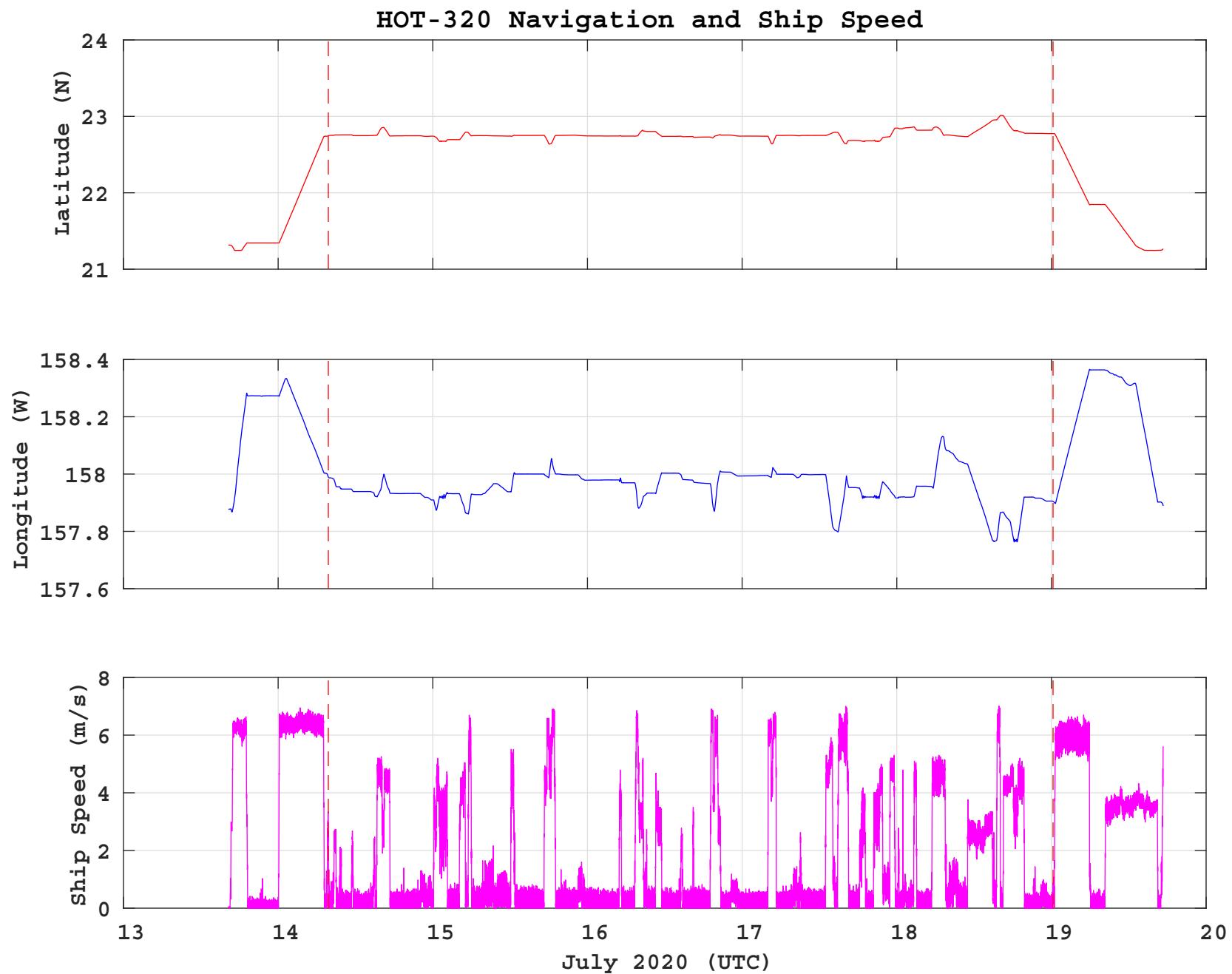


Figure 6.2.2c

HOT-321 Navigation and Ship Speed

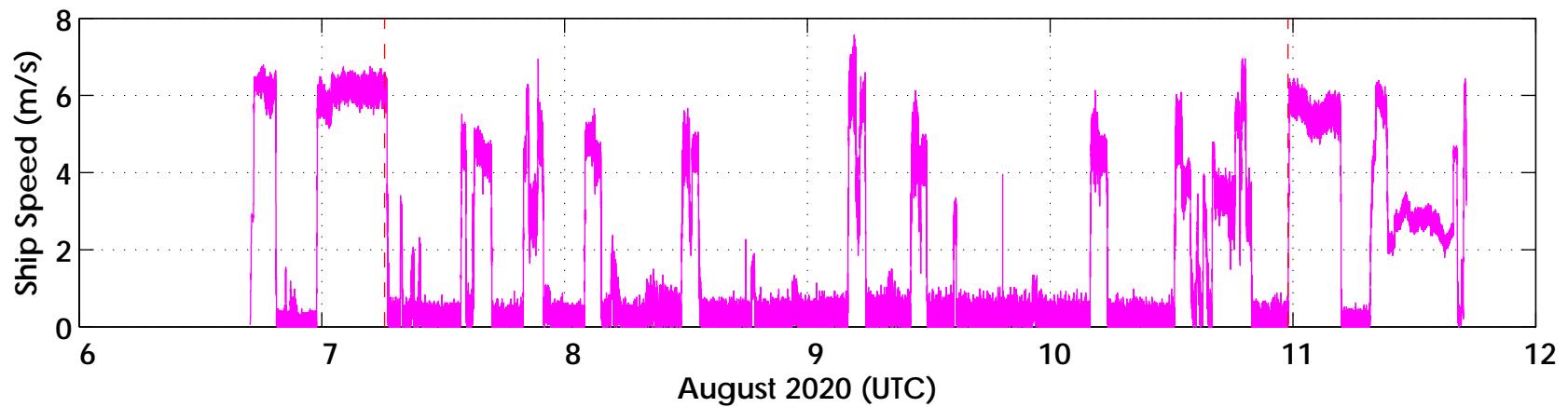
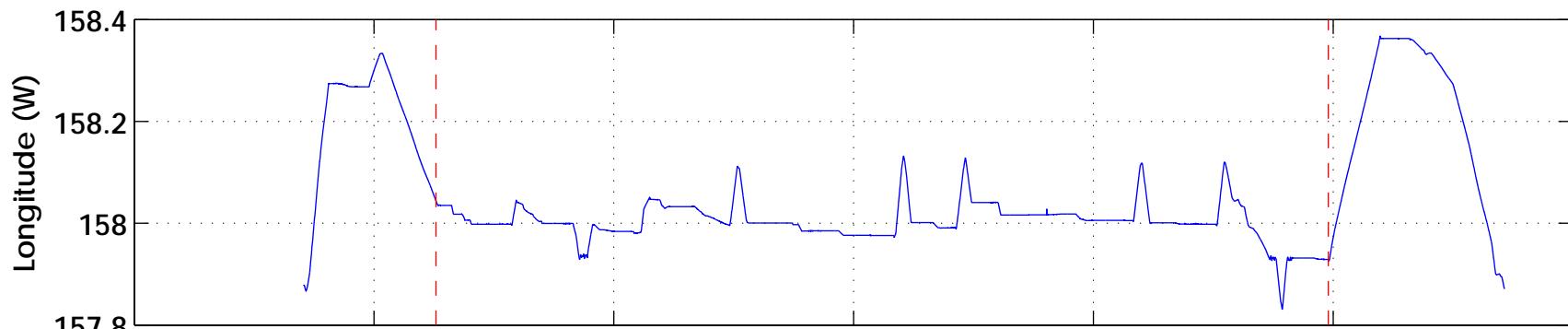
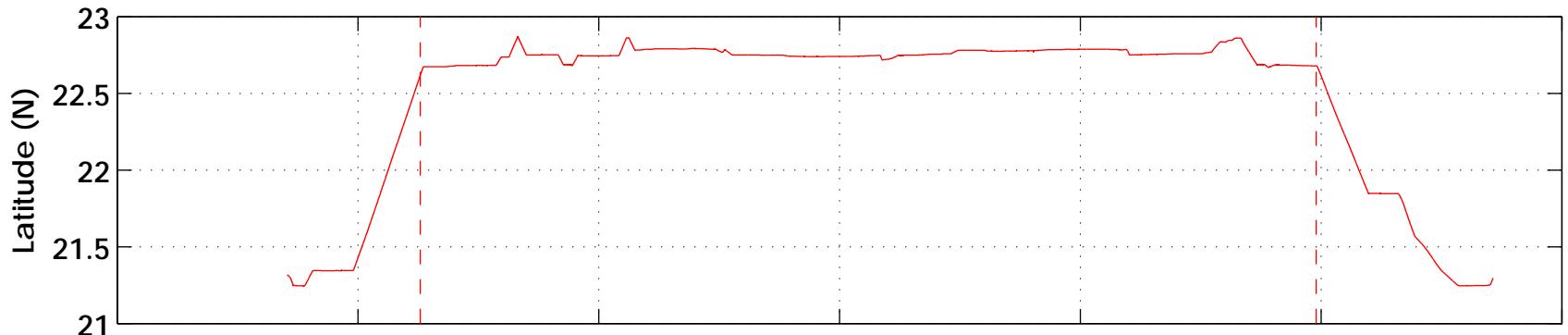


Figure 6.2.2d

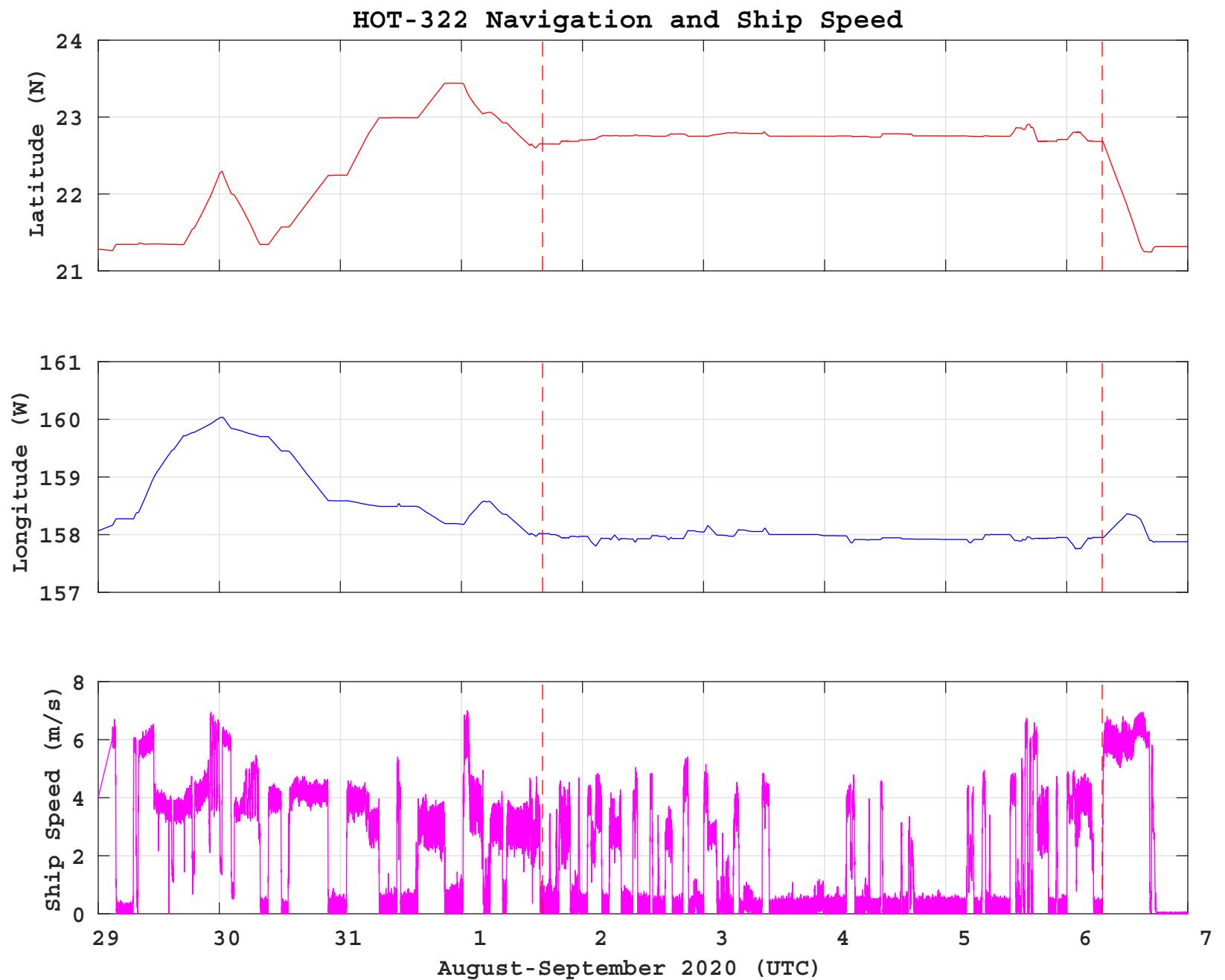


Figure 6.2.2e

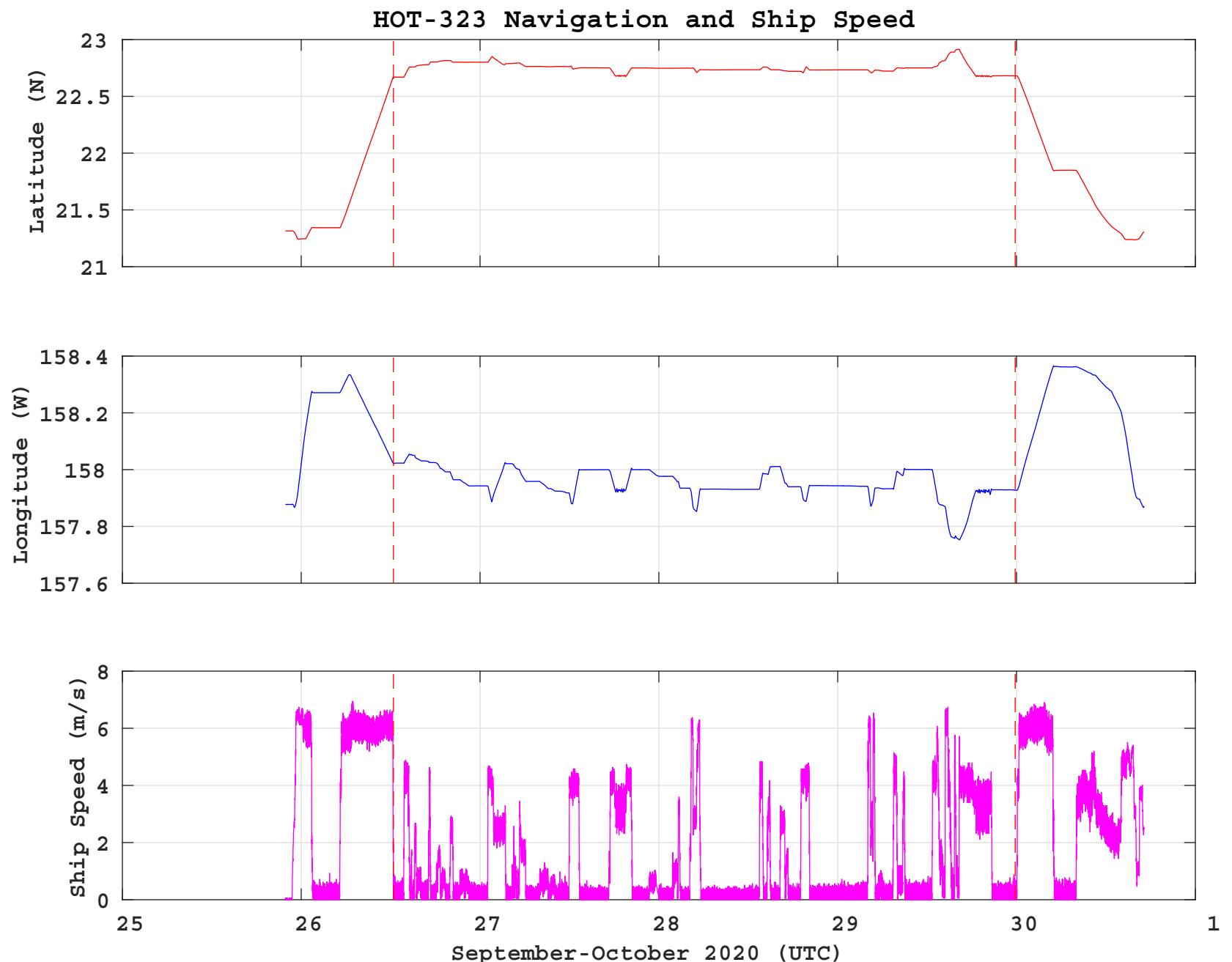


Figure 6.2.2f



Figure 6.2.2g

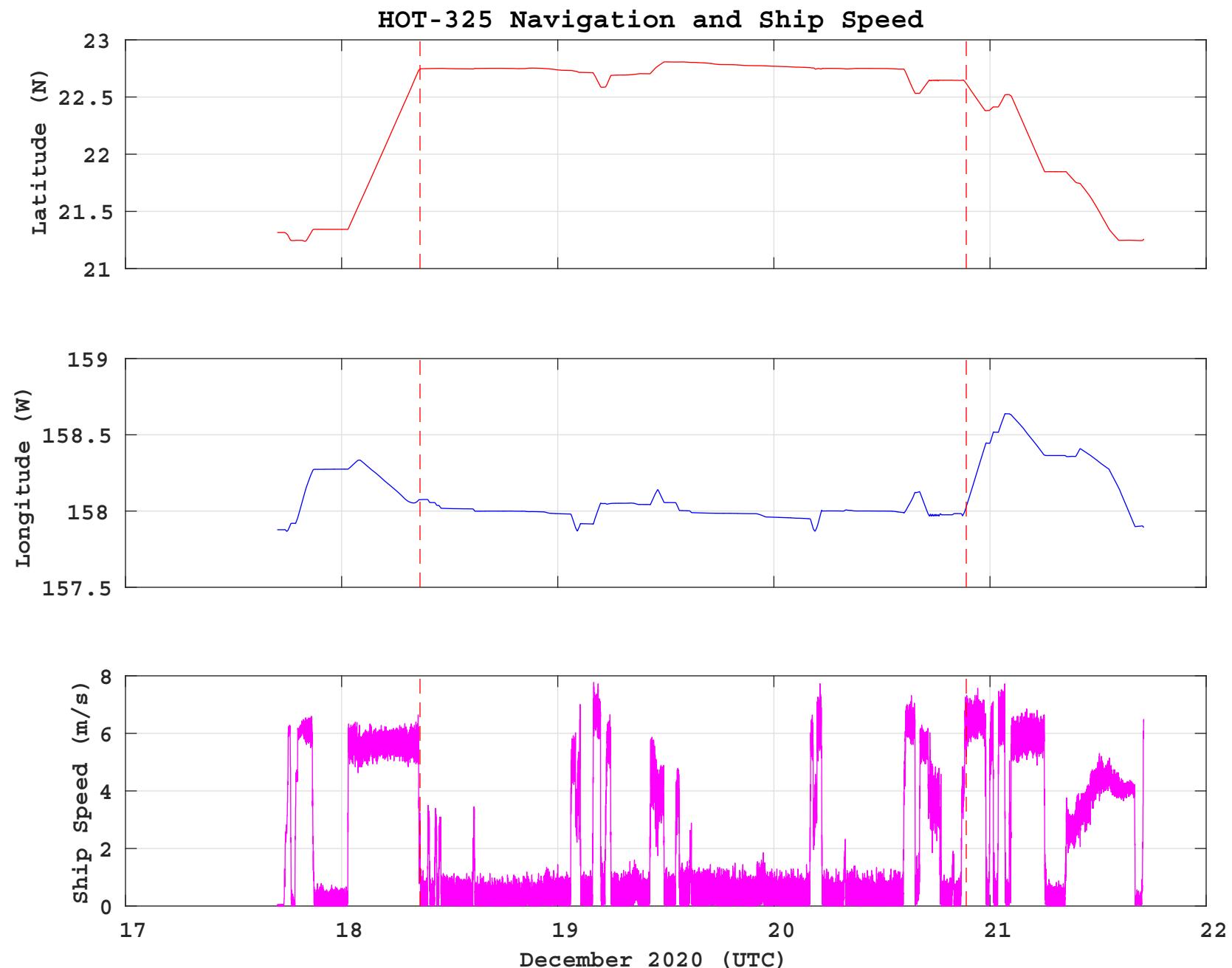


Figure 6.2.2h

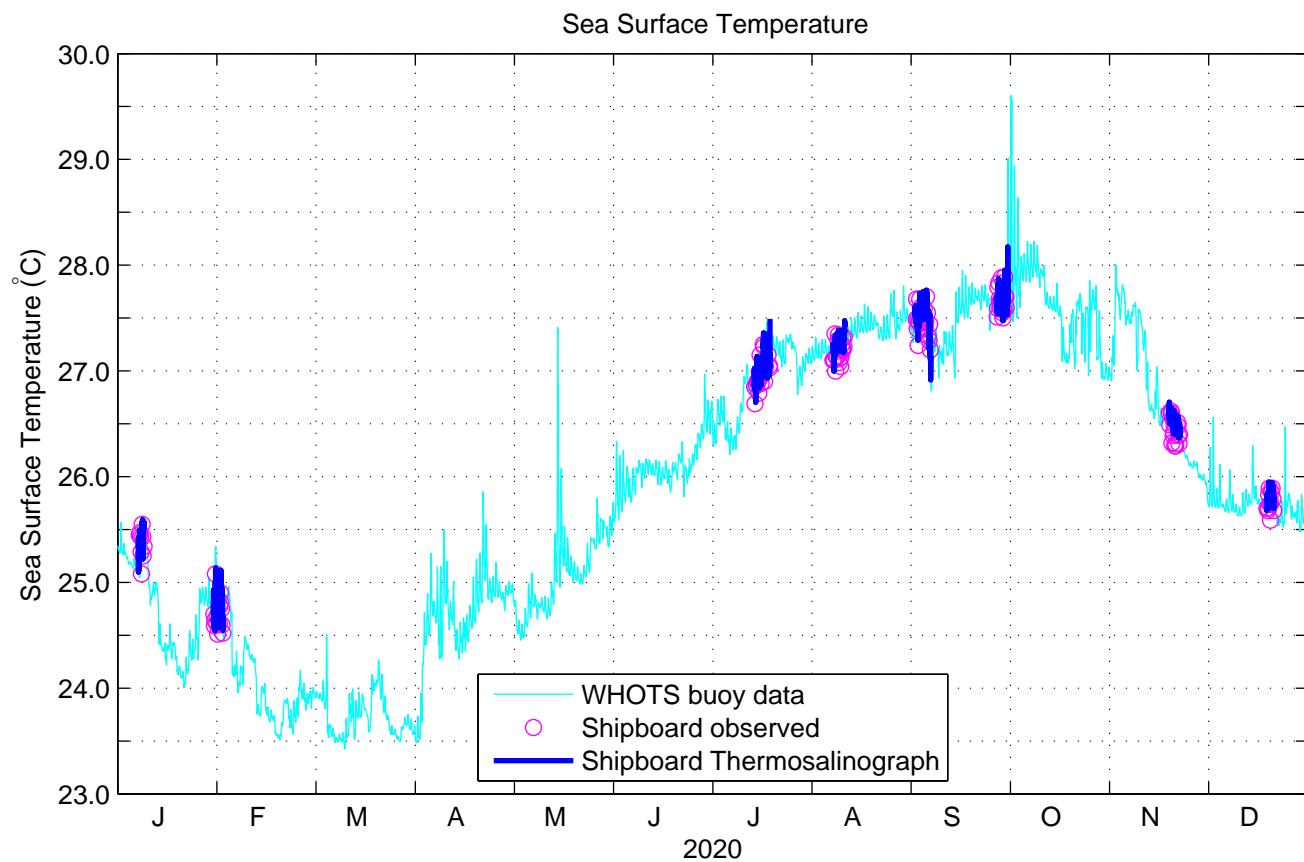
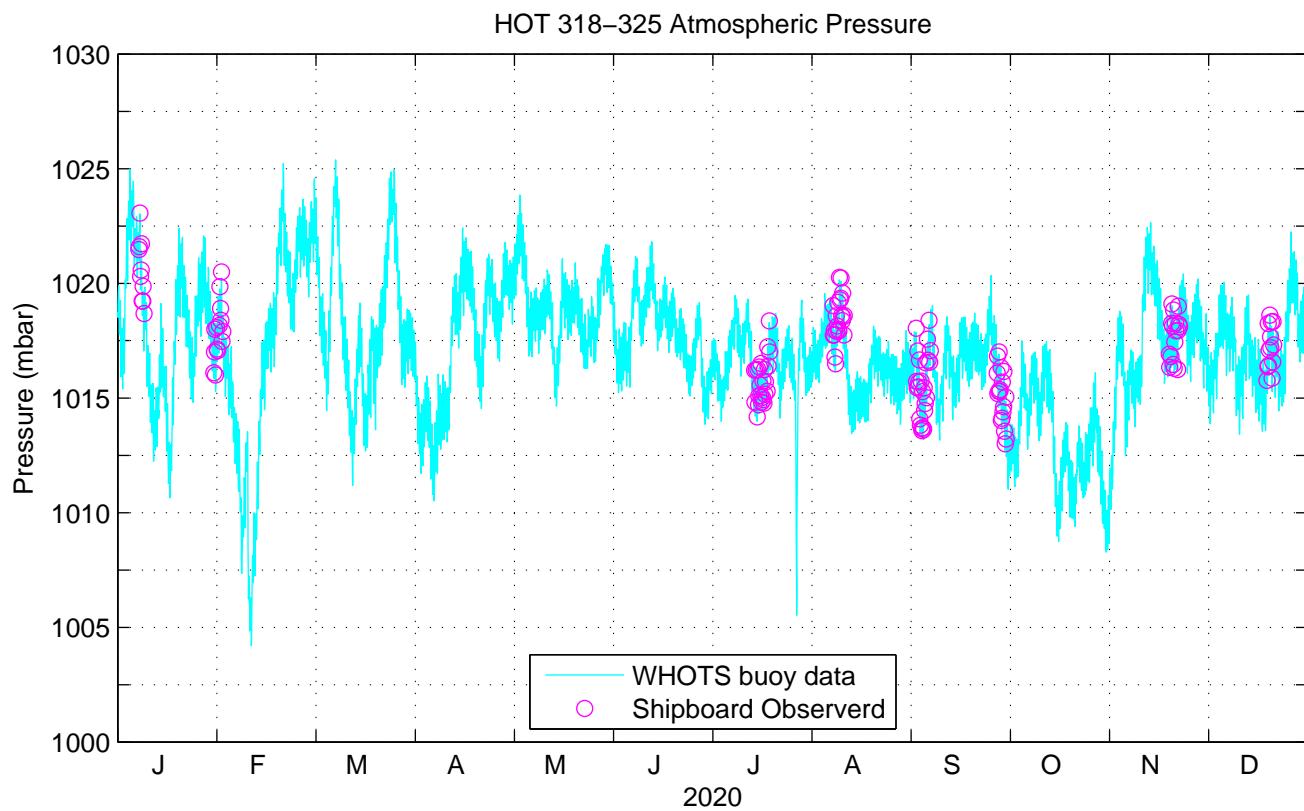


Figure 6.3.1

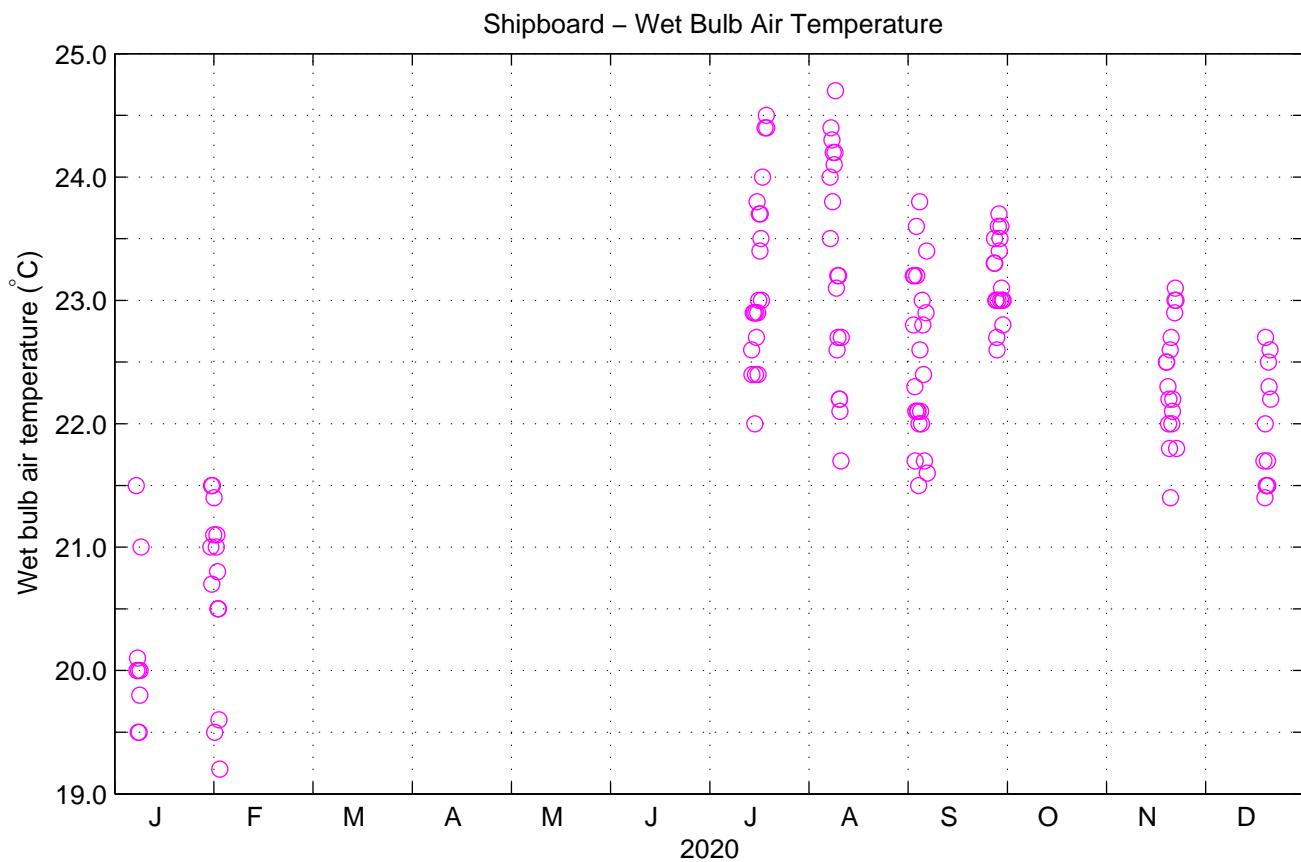
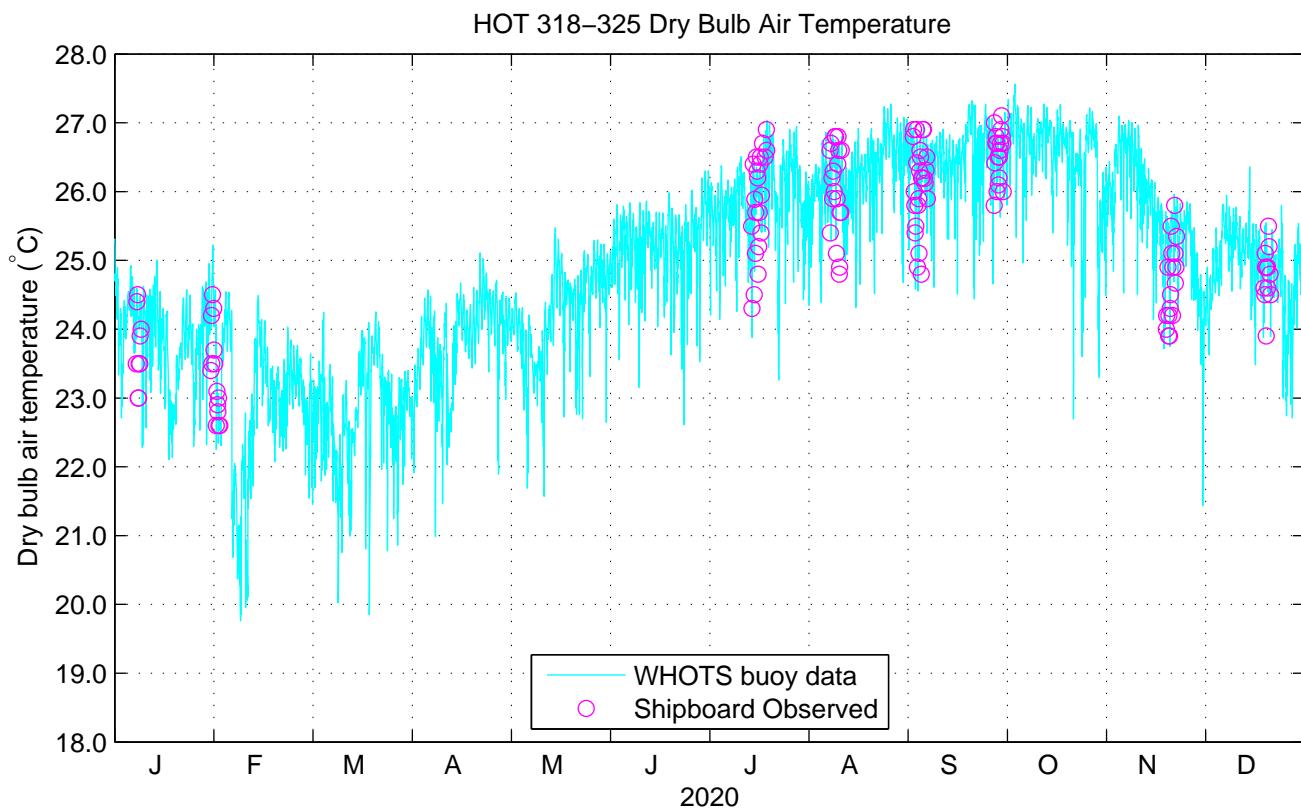


Figure 6.3.2

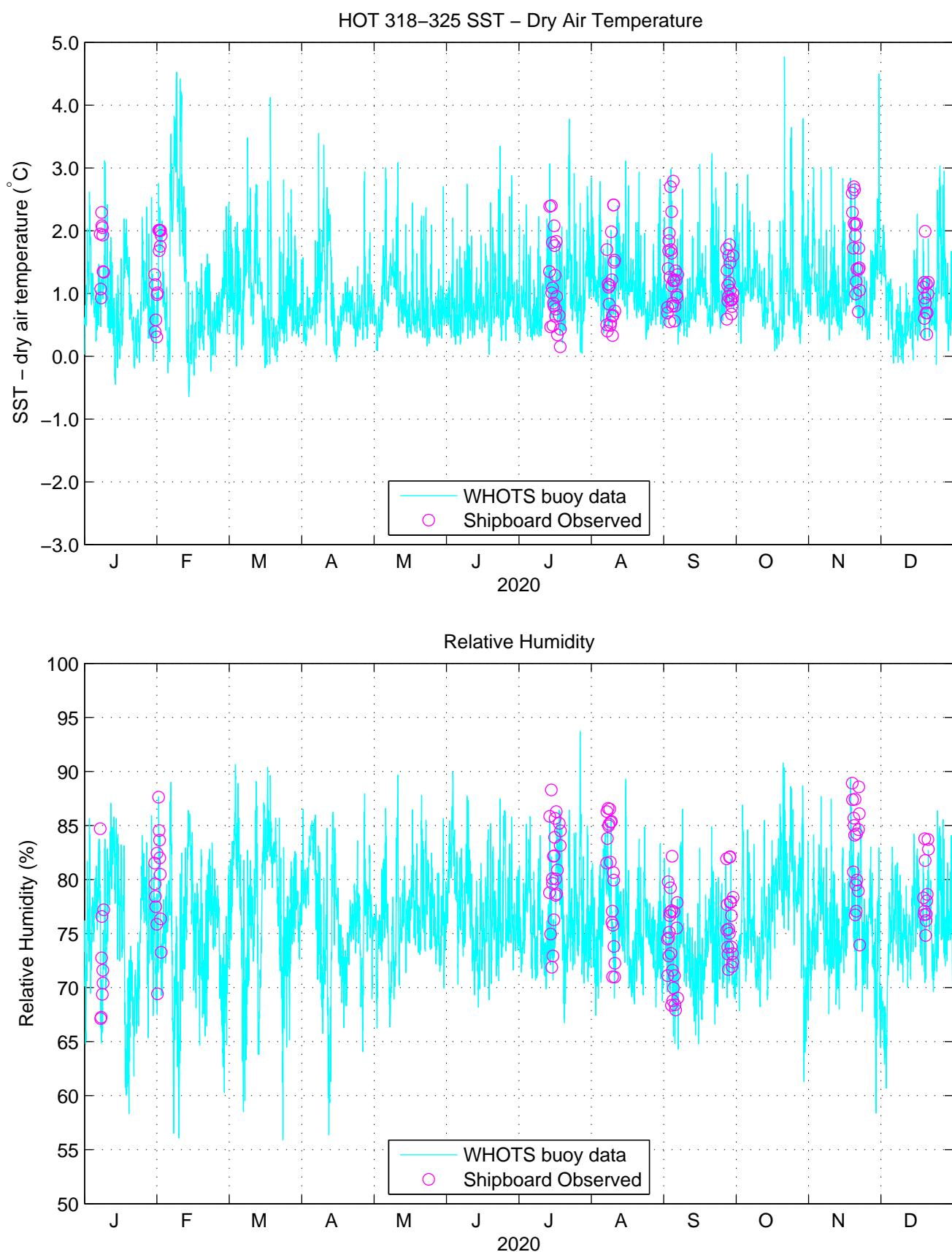


Figure 6.3.3

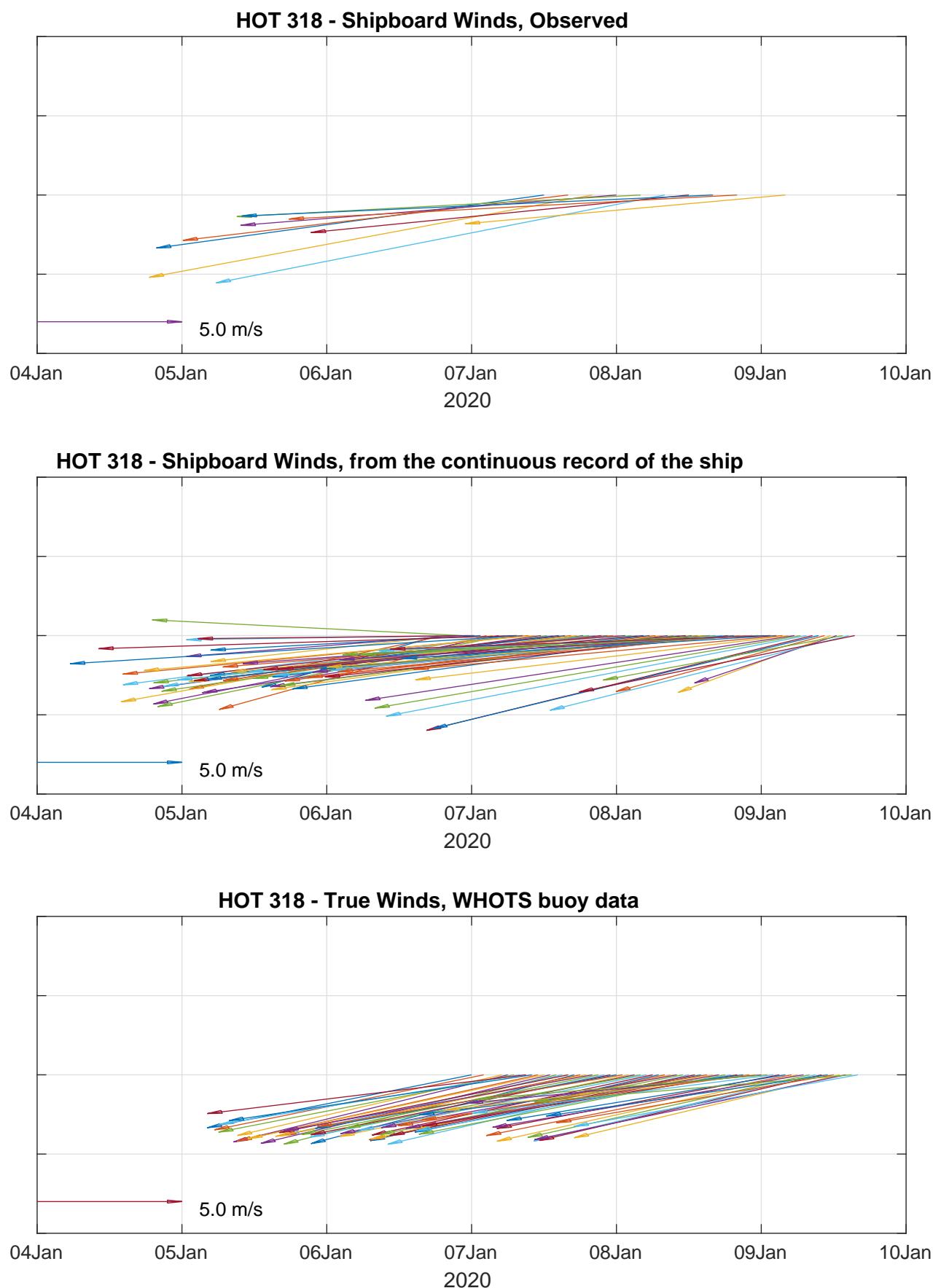
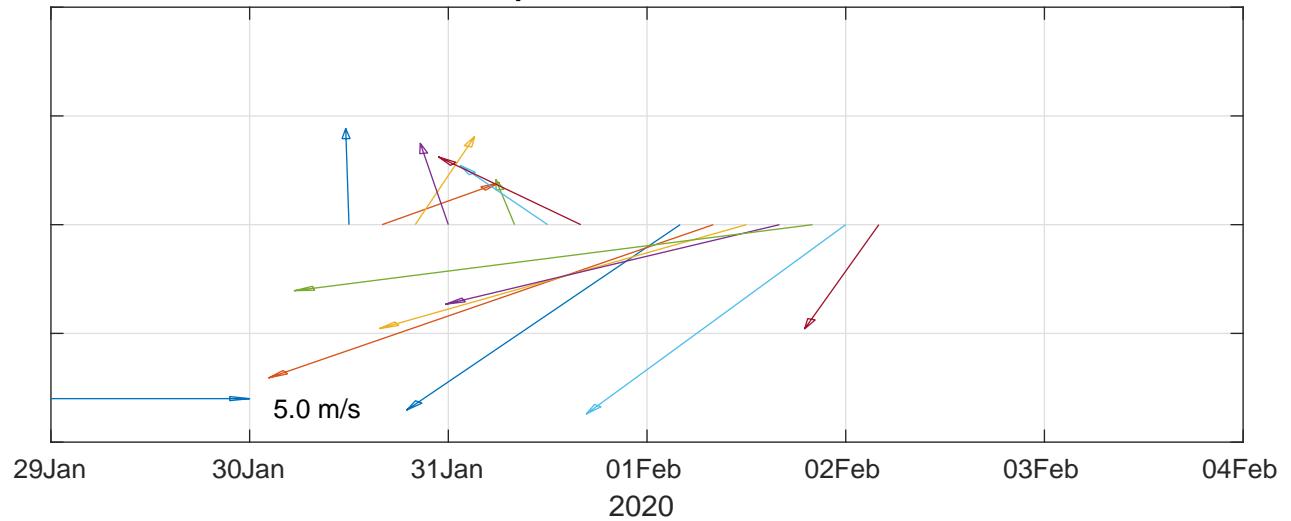
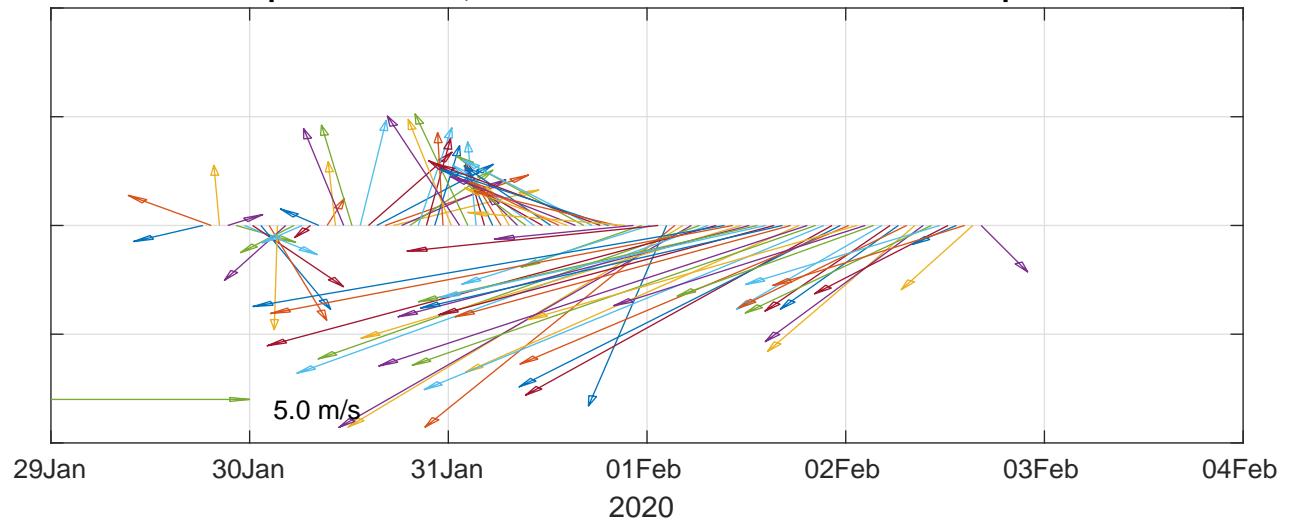


Figure 6.3.4a

HOT 319 - Shipboard Winds, Observed



HOT 319 - Shipboard Winds, from the continuous record of the ship



HOT 319 - True Winds, WHOTS buoy data

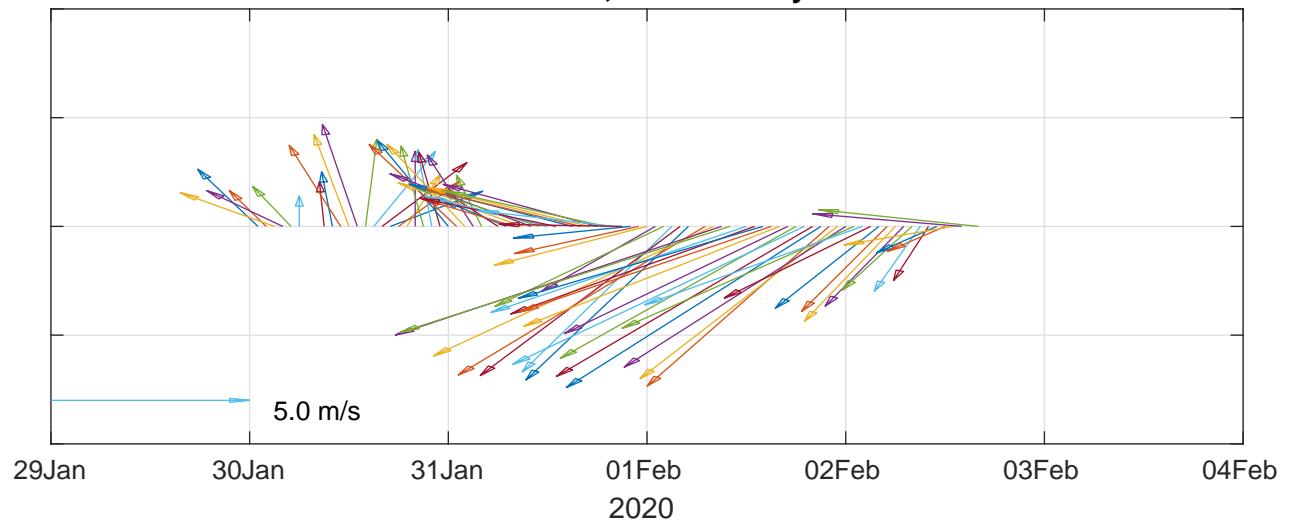
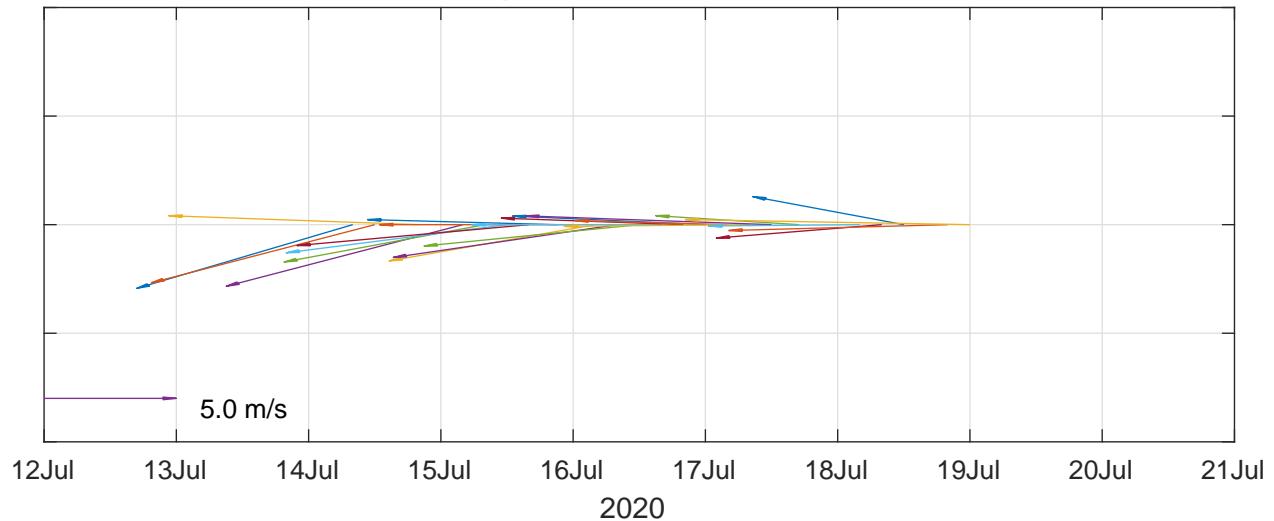
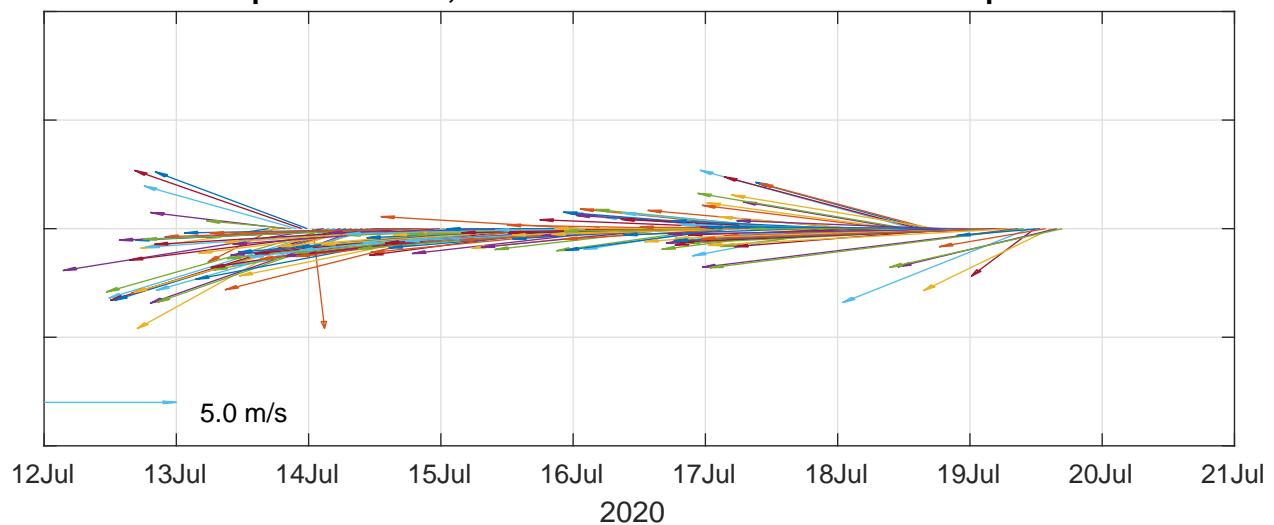


Figure 6.3.4b

HOT 320 - Shipboard Winds, Observed



HOT 320 - Shipboard Winds, from the continuous record of the ship



HOT 320 - True Winds, WHOTS buoy data

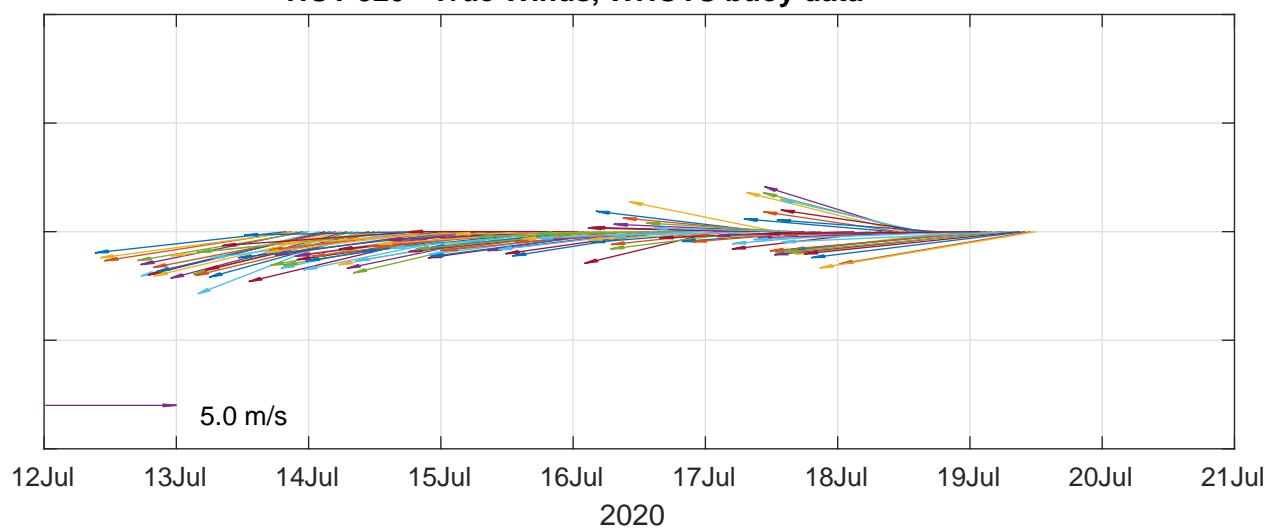


Figure 6.3.4c

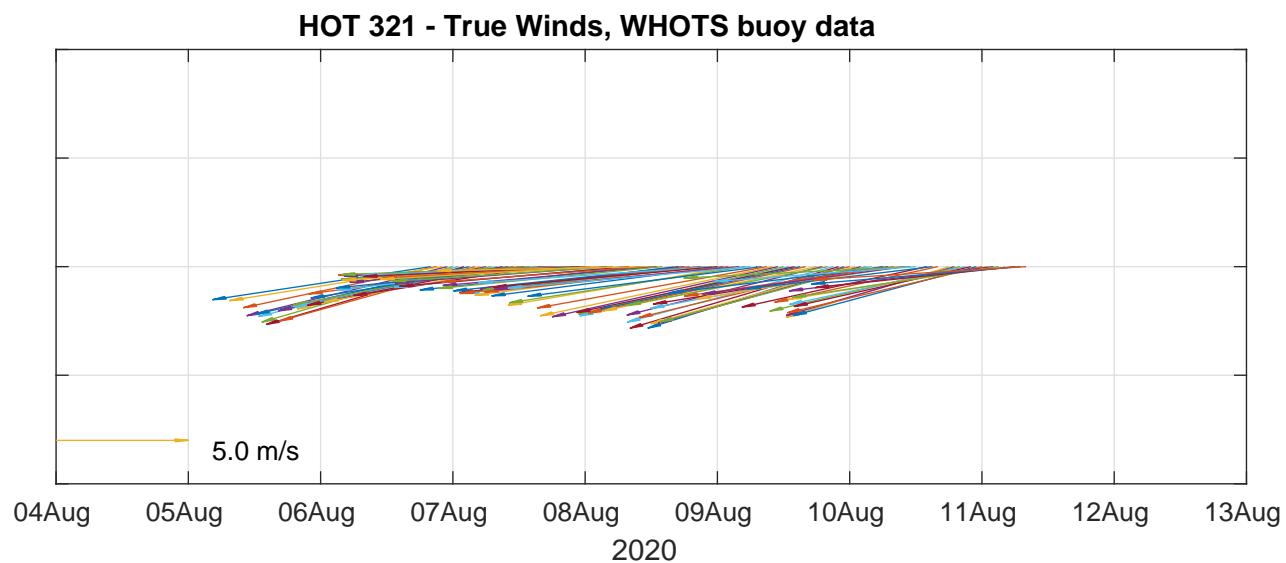
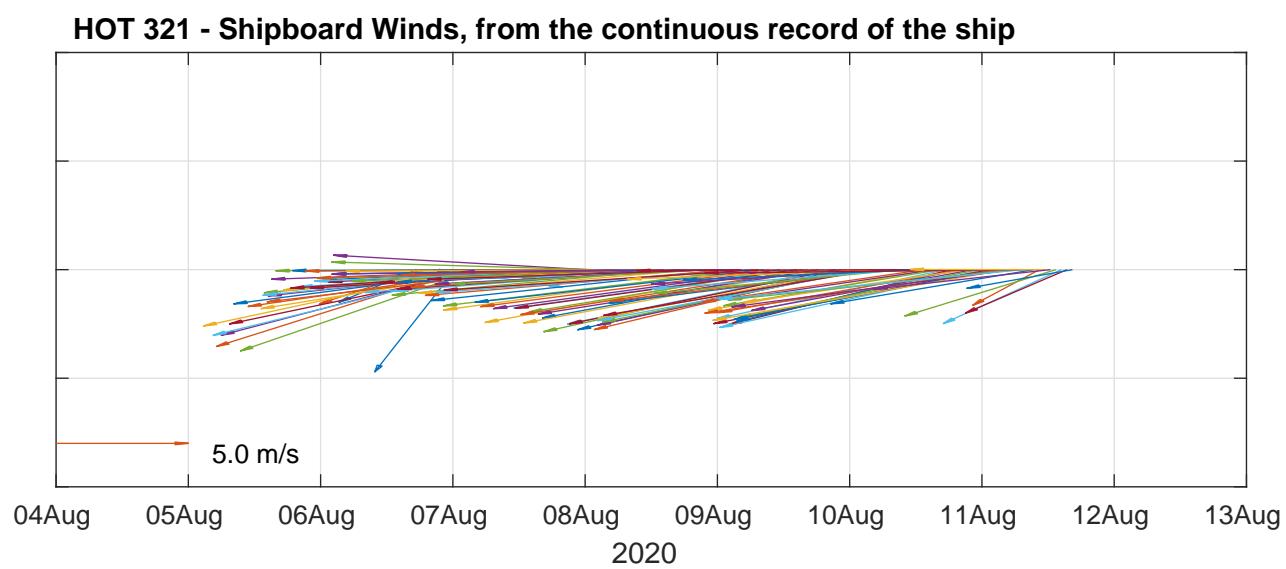
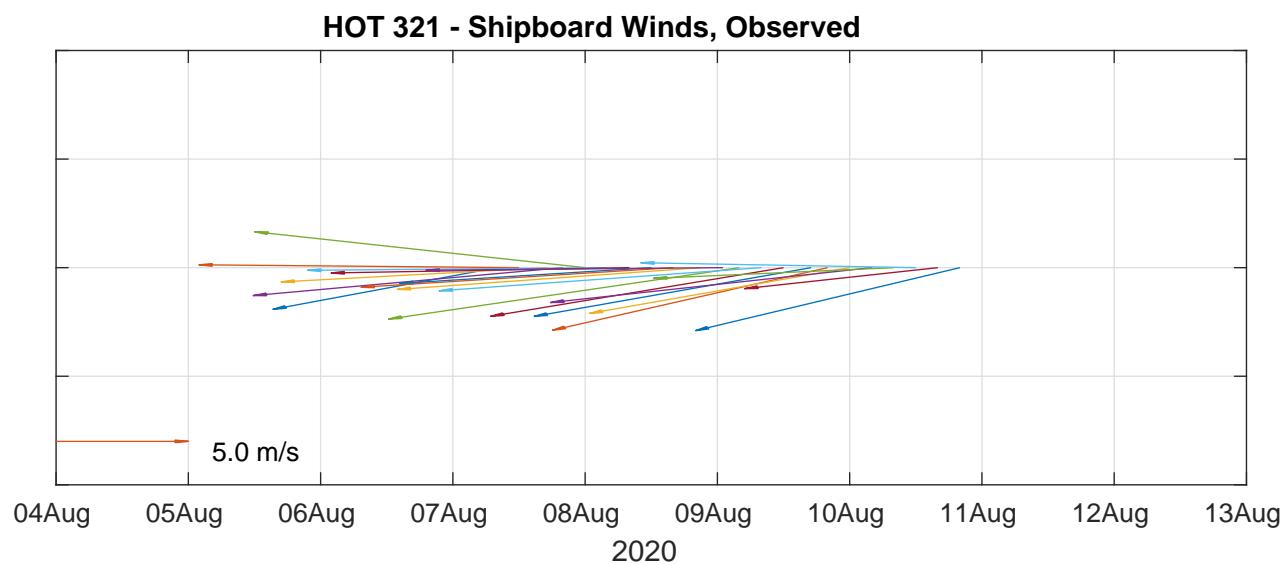
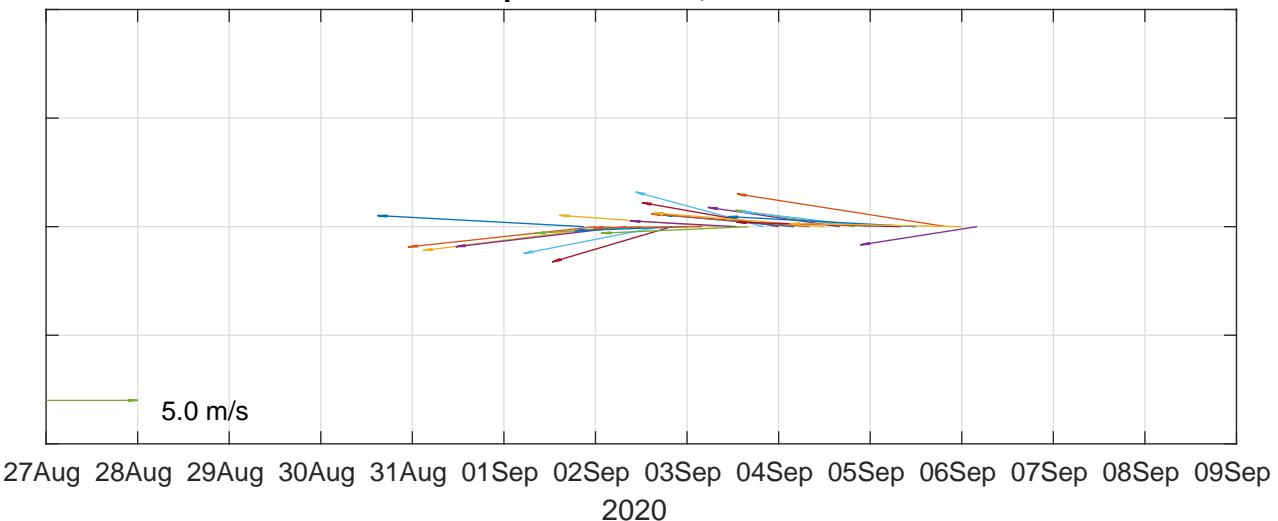
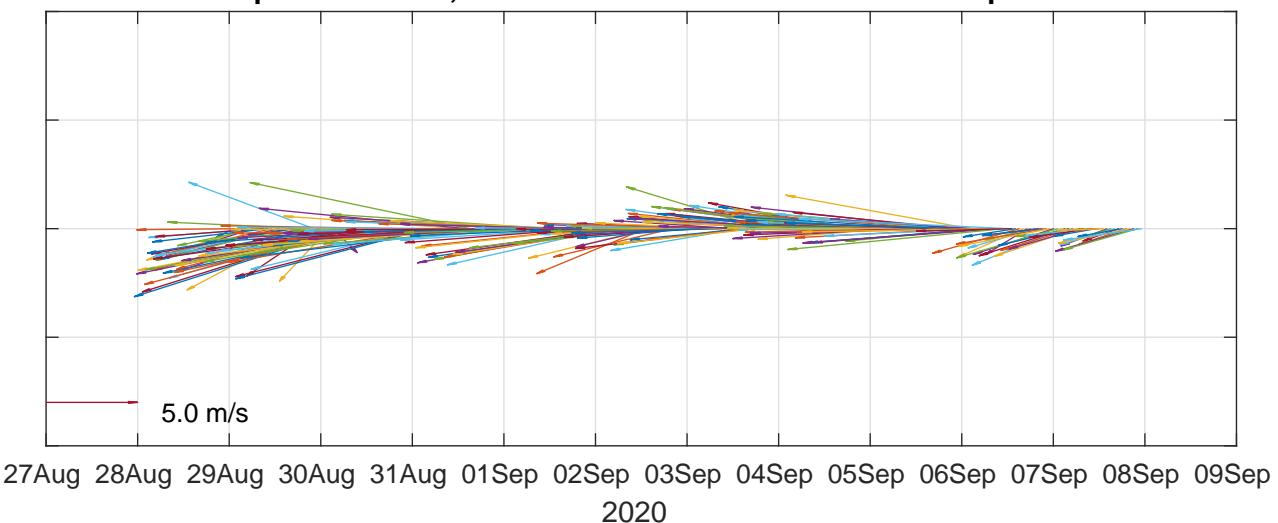


Figure 6.3.4d

HOT 322 - Shipboard Winds, Observed



HOT 322 - Shipboard Winds, from the continuous record of the ship



HOT 322 - True Winds, WHOTS buoy data

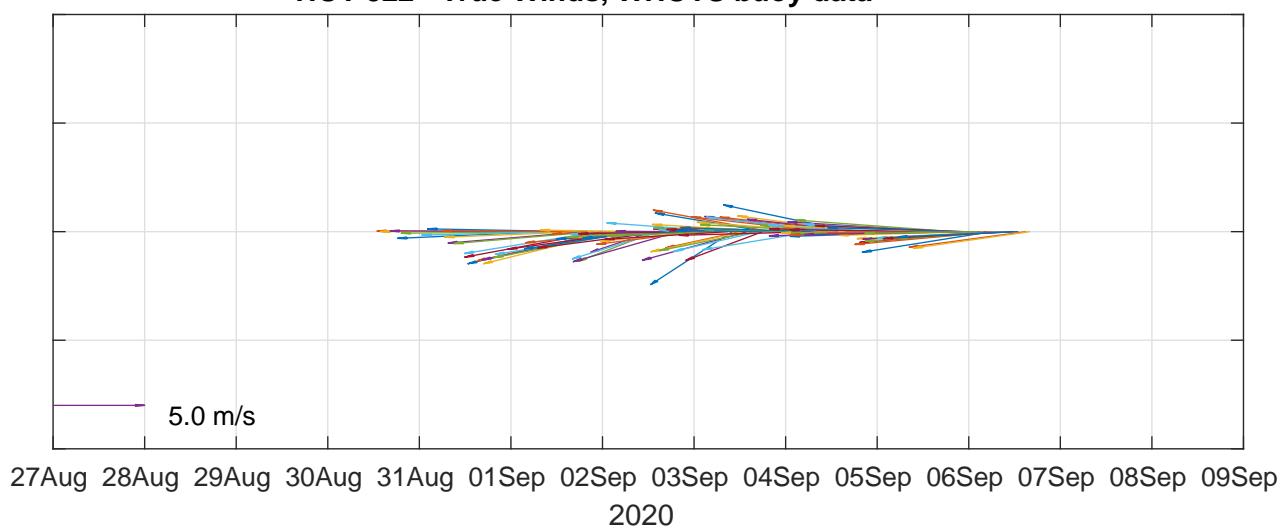
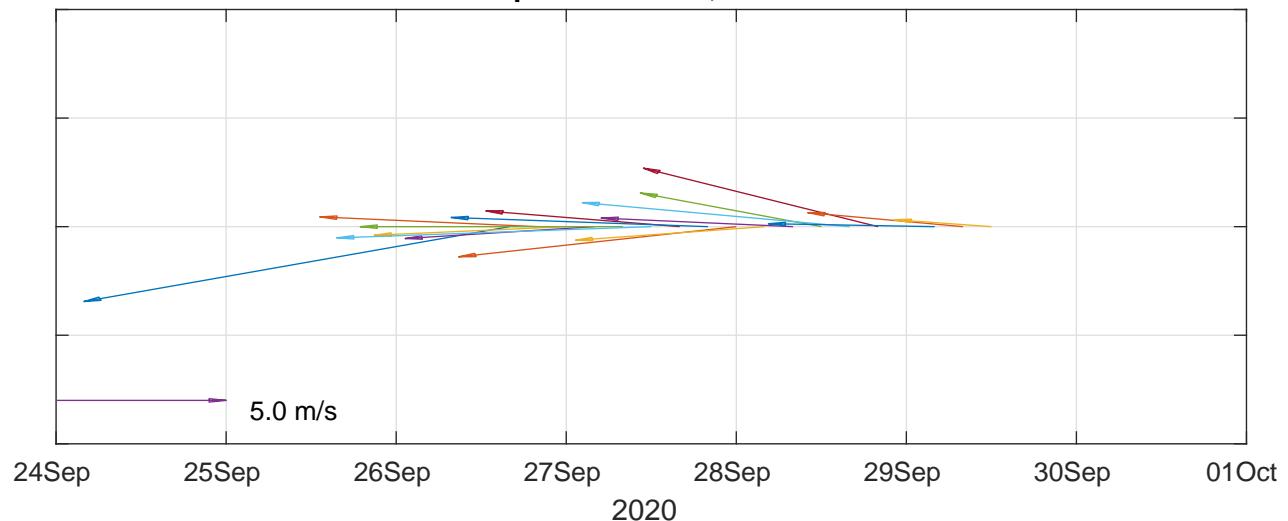
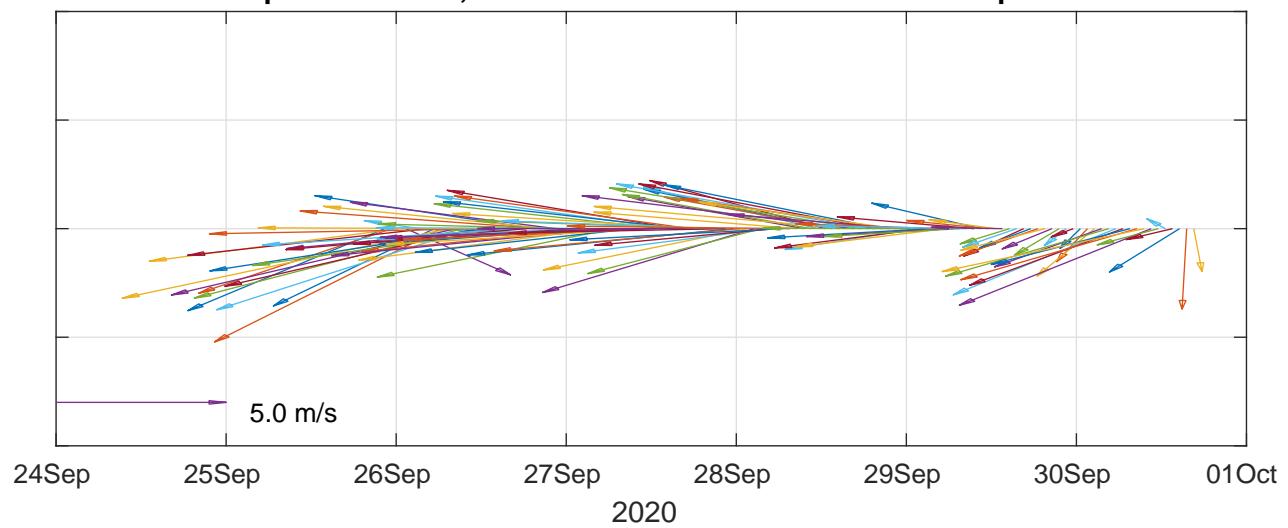


Figure 6.3.4e

HOT 323 - Shipboard Winds, Observed



HOT 323 - Shipboard Winds, from the continuous record of the ship



HOT 323 - True Winds, WHOTS buoy data

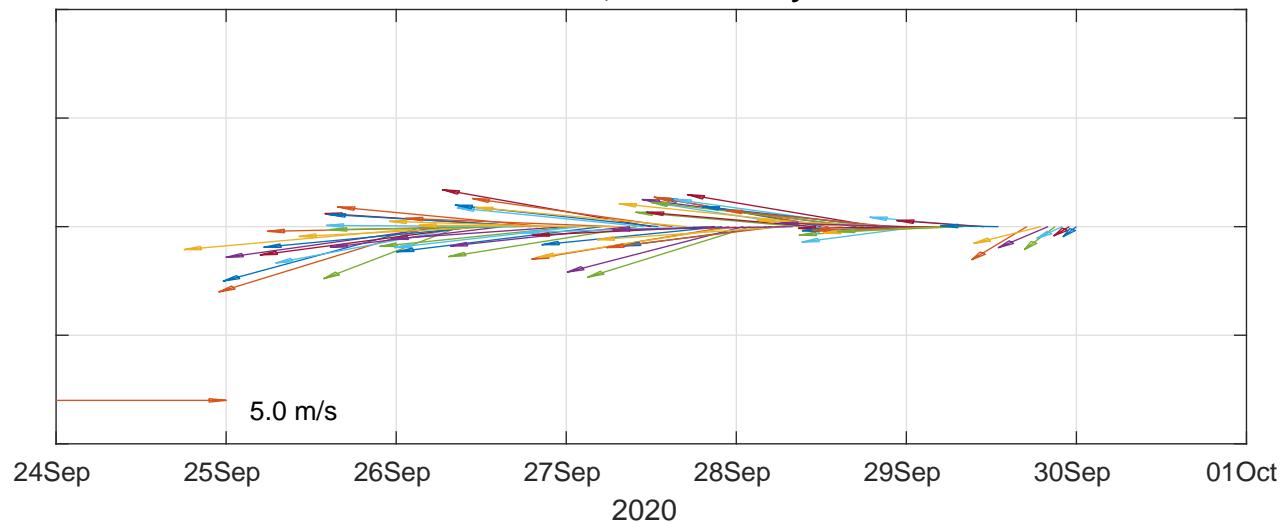
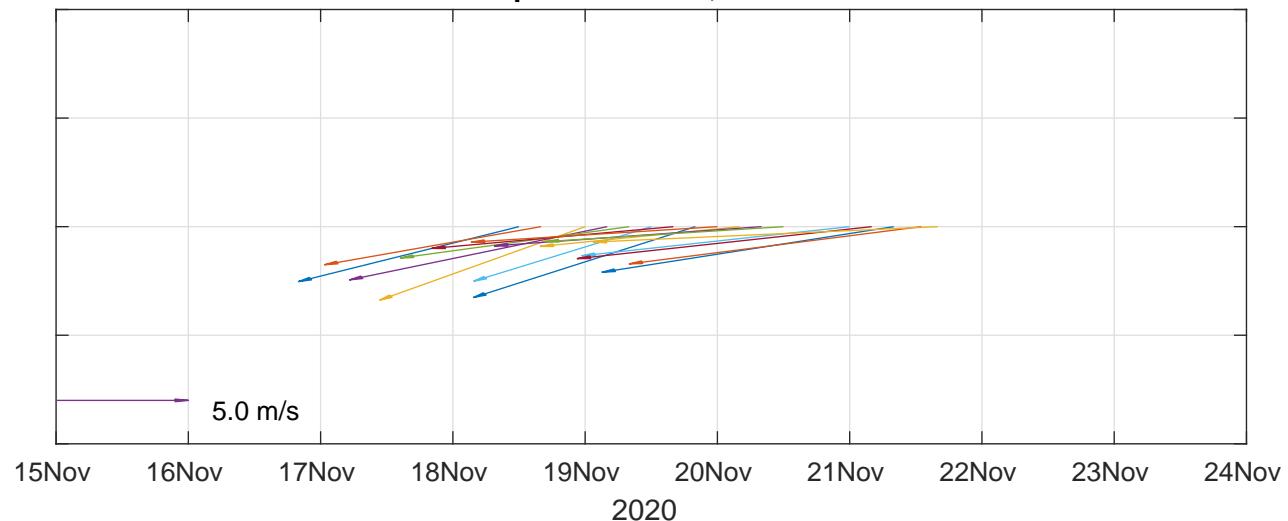
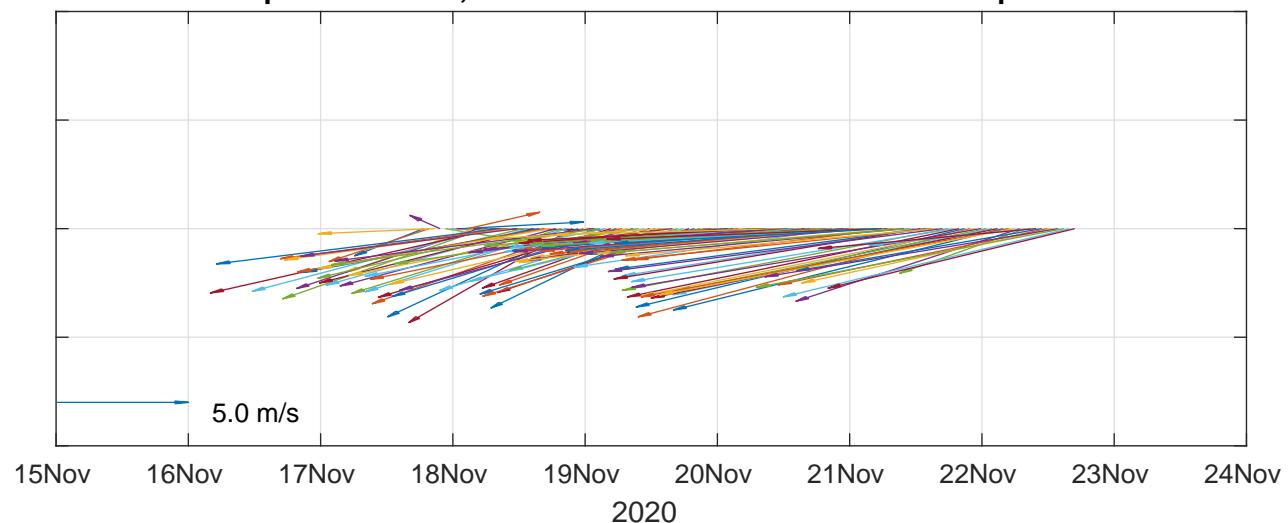


Figure 6.3.4f

HOT 324 - Shipboard Winds, Observed



HOT 324 - Shipboard Winds, from the continuous record of the ship



HOT 324 - True Winds, WHOTS buoy data

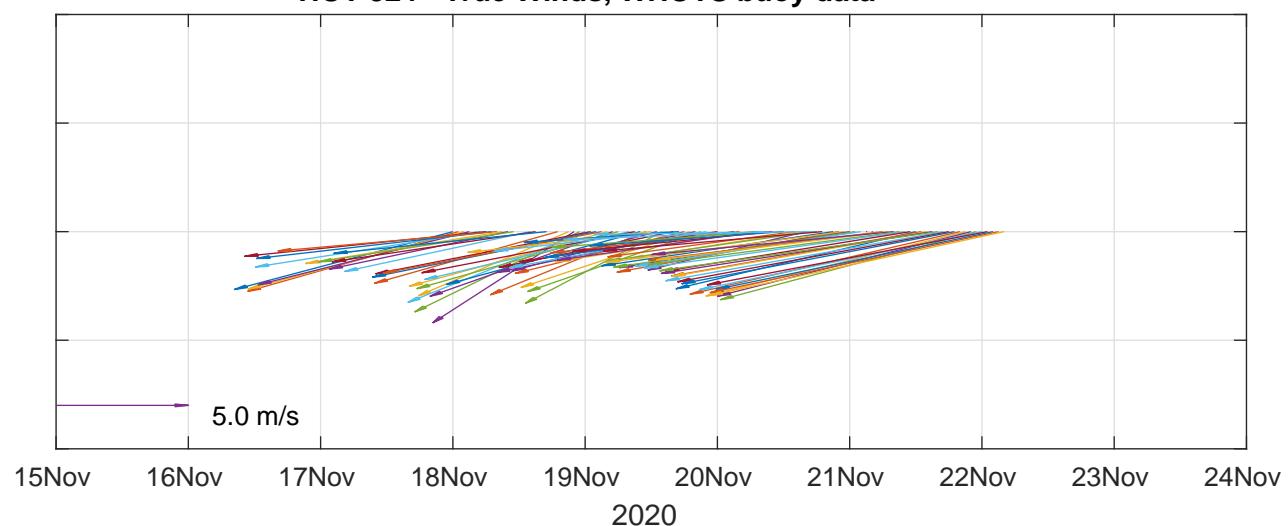
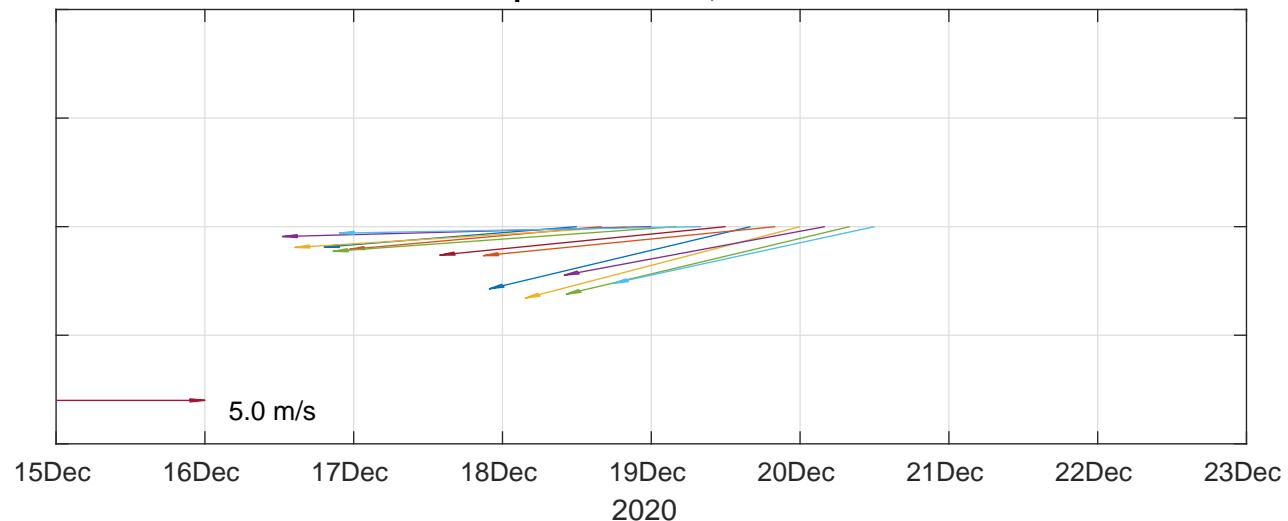
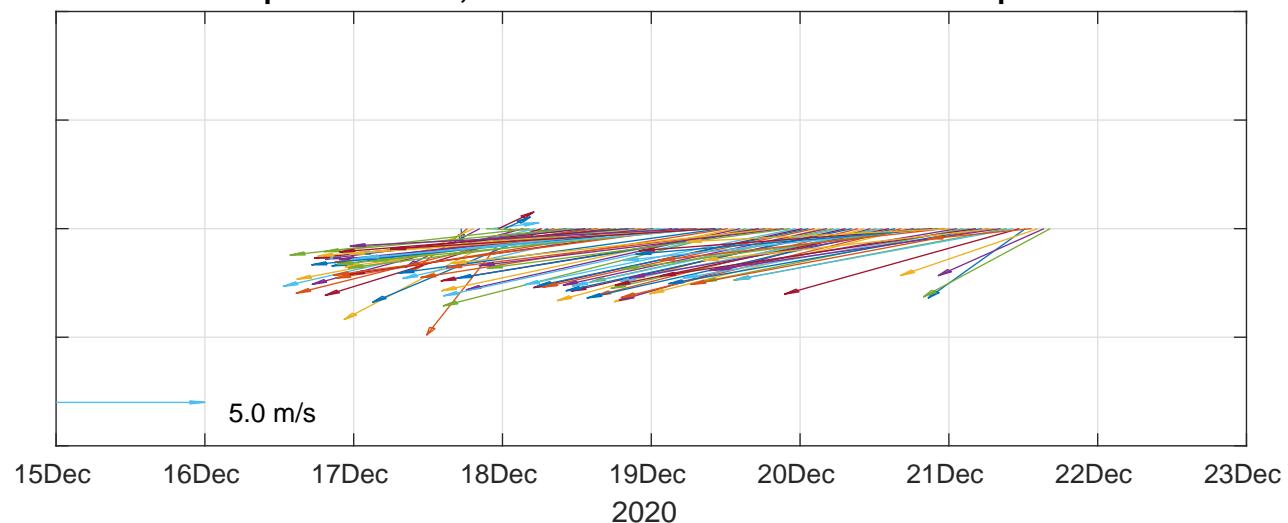


Figure 6.3.4g

HOT 325 - Shipboard Winds, Observed



HOT 325 - Shipboard Winds, from the continuous record of the ship



HOT 325 - True Winds, WHOTS buoy data

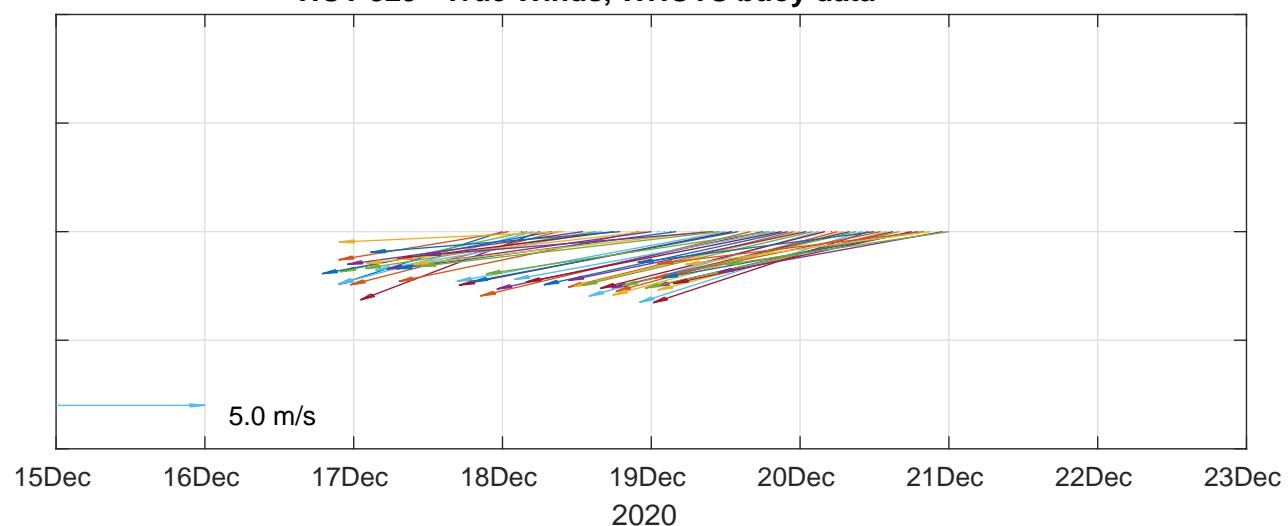


Figure 6.3.4h

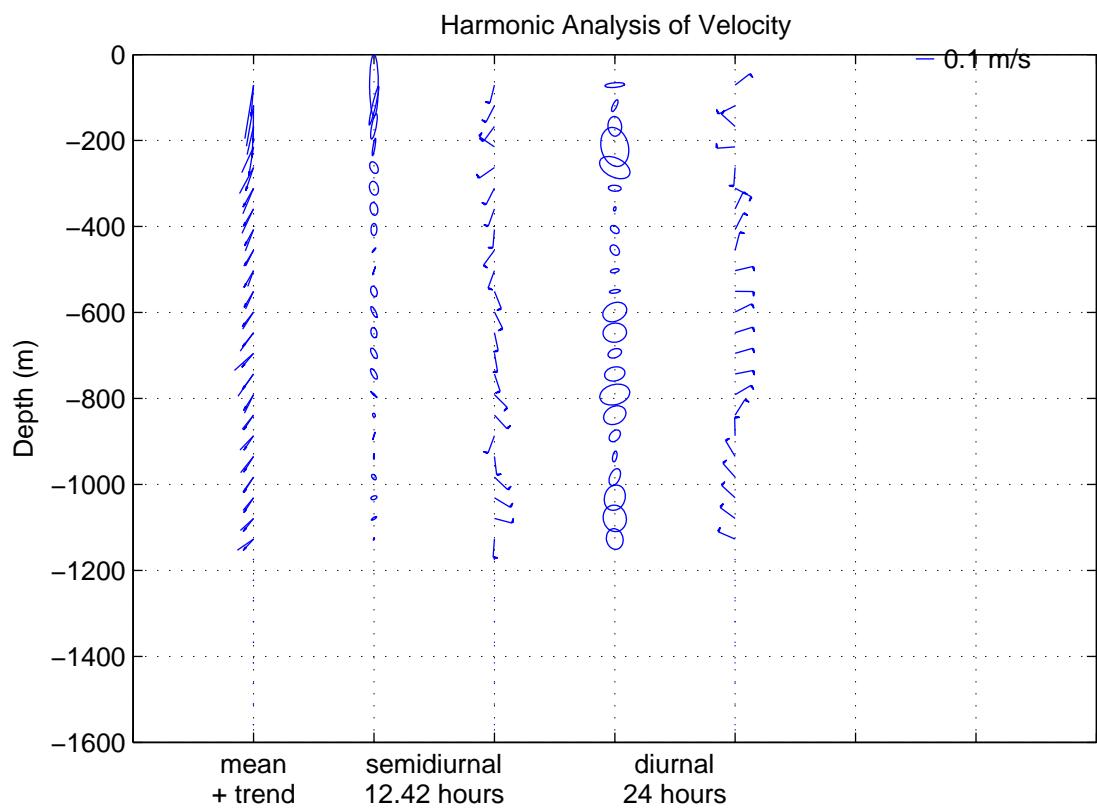
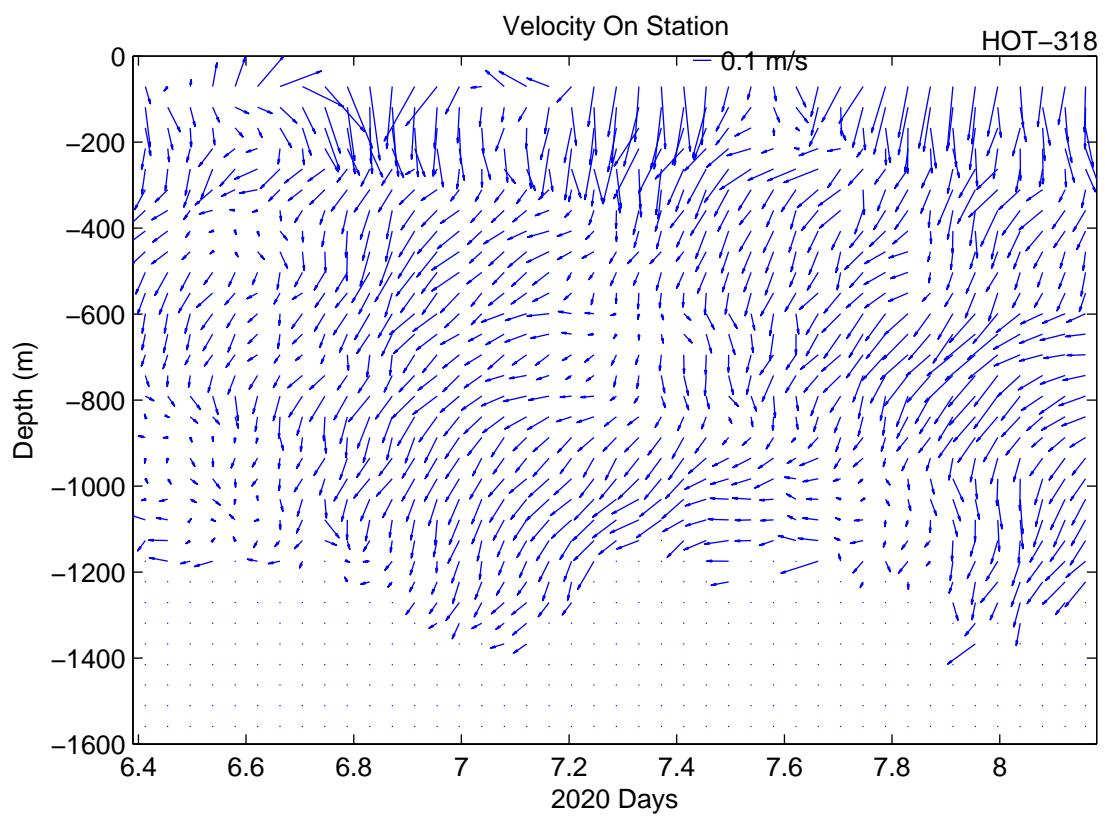


Figure 6.4.1a

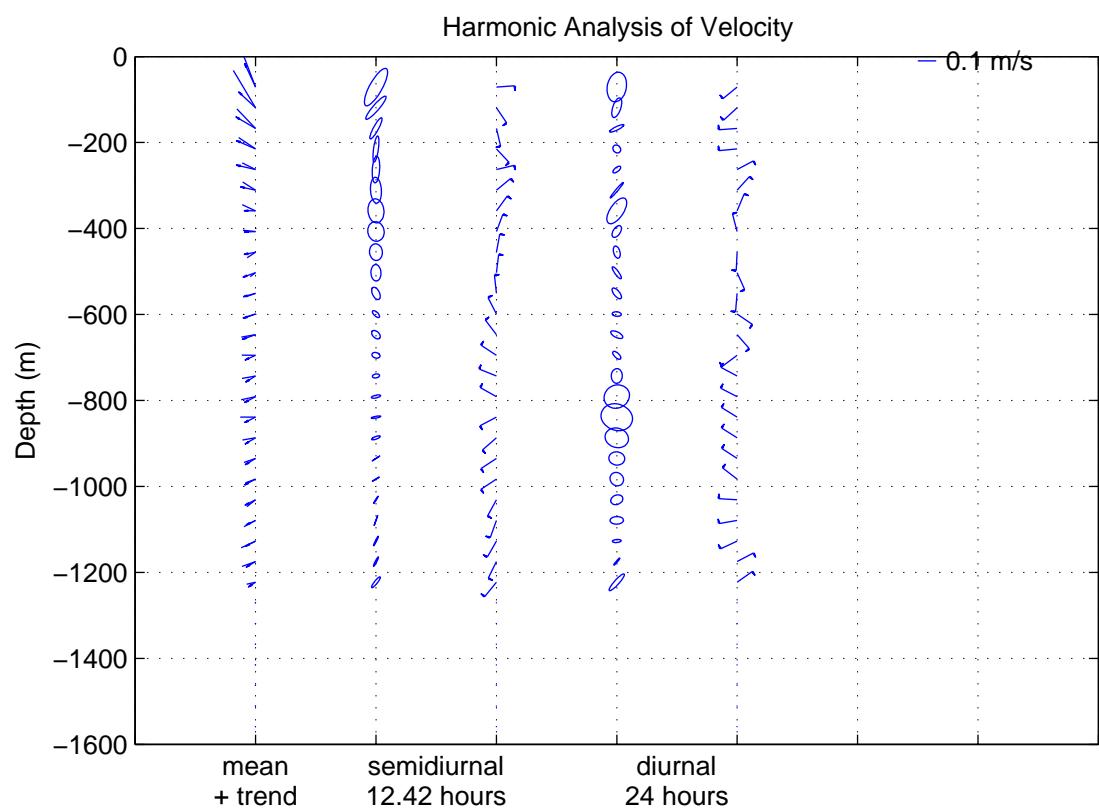
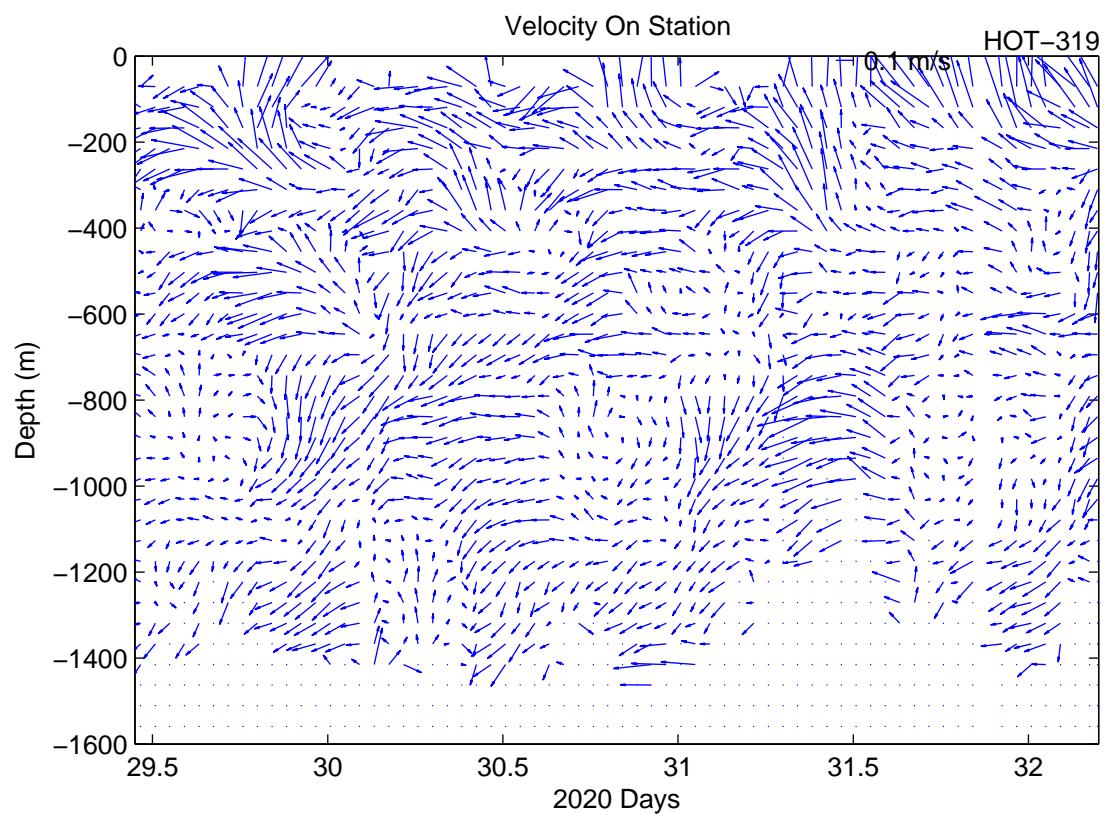


Figure 6.4.1b

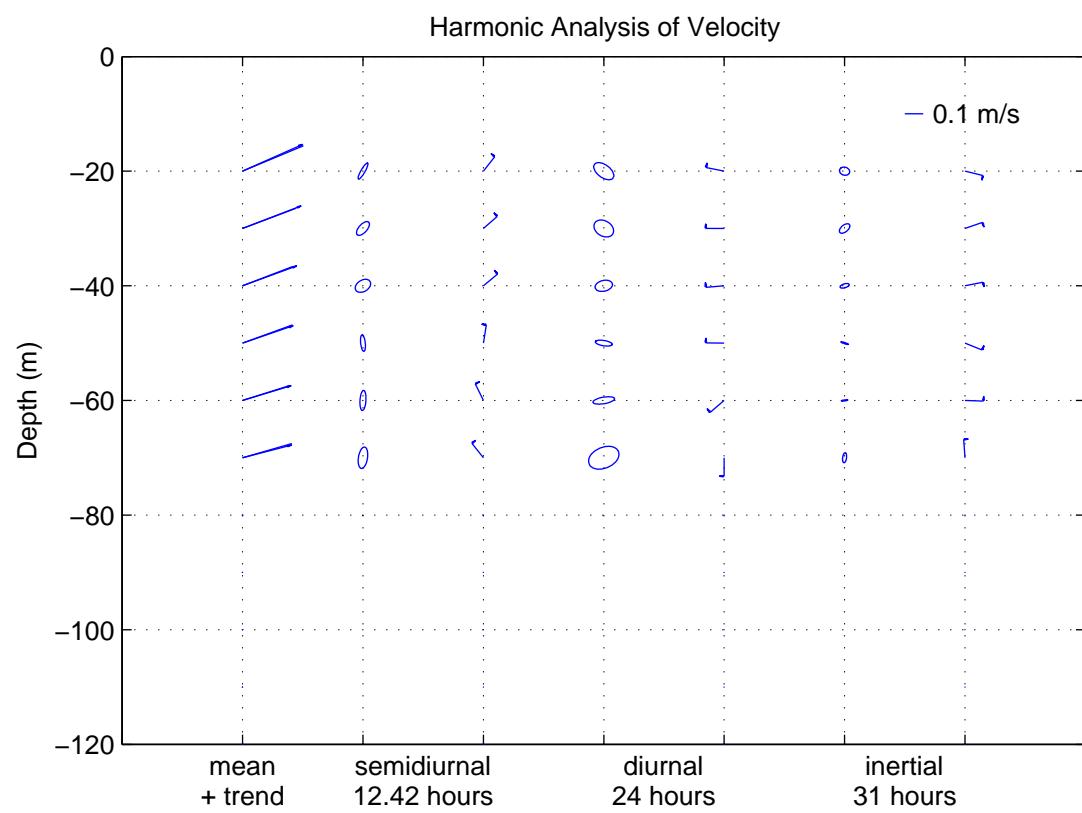
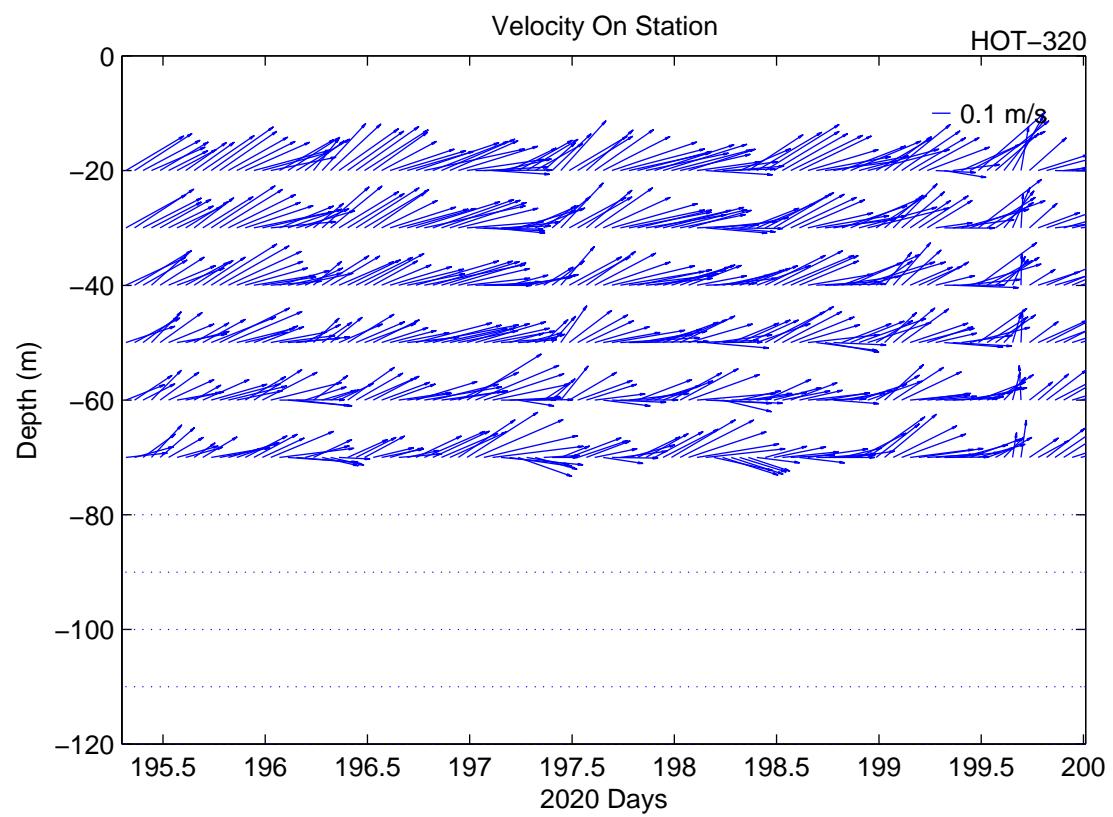


Figure 6.4.1c

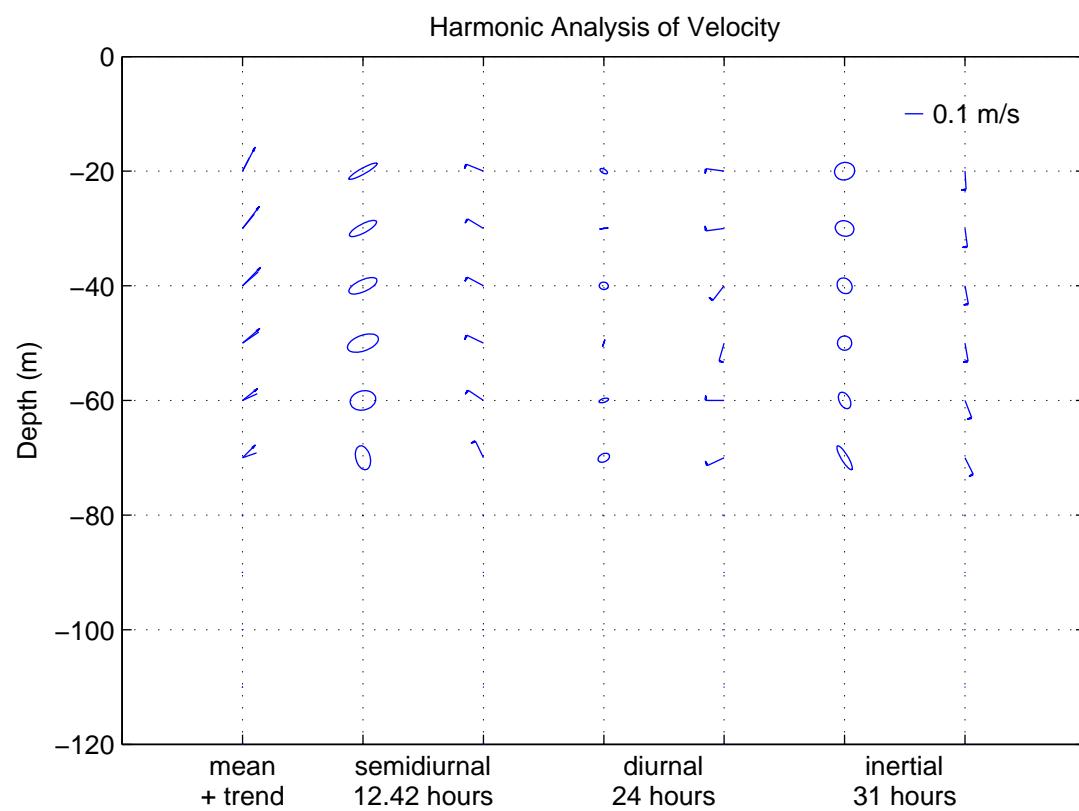
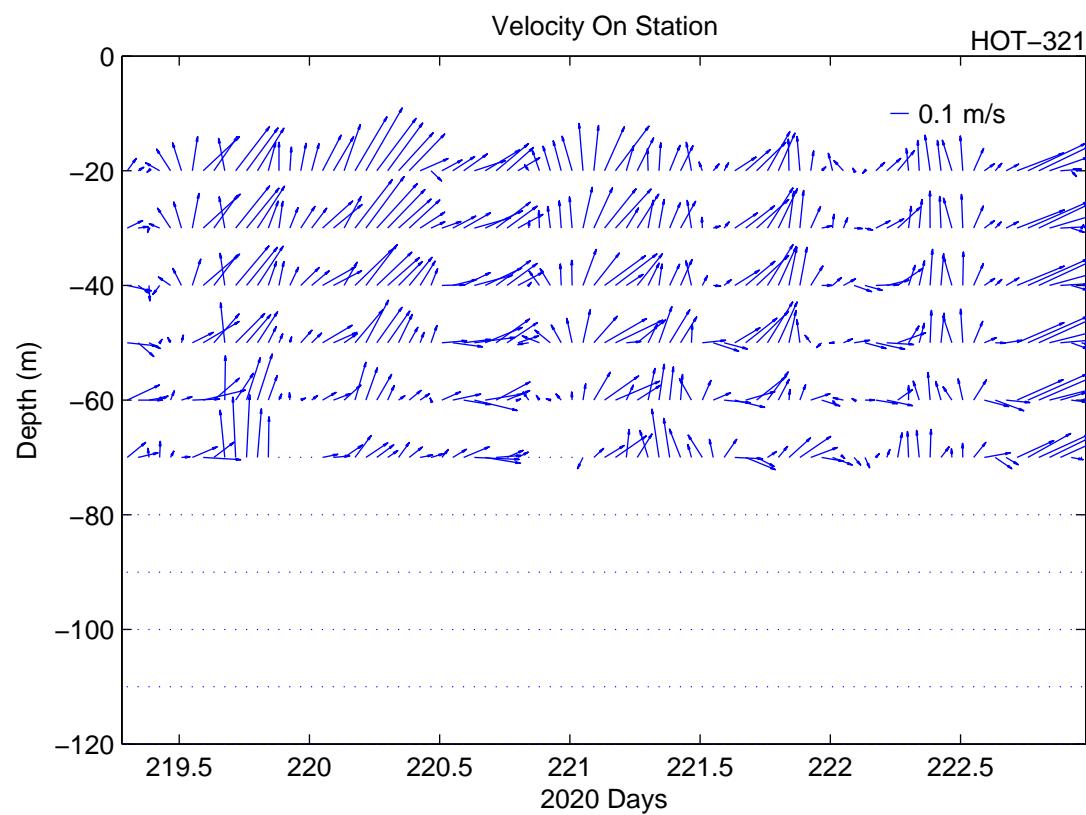


Figure 6.4.1d

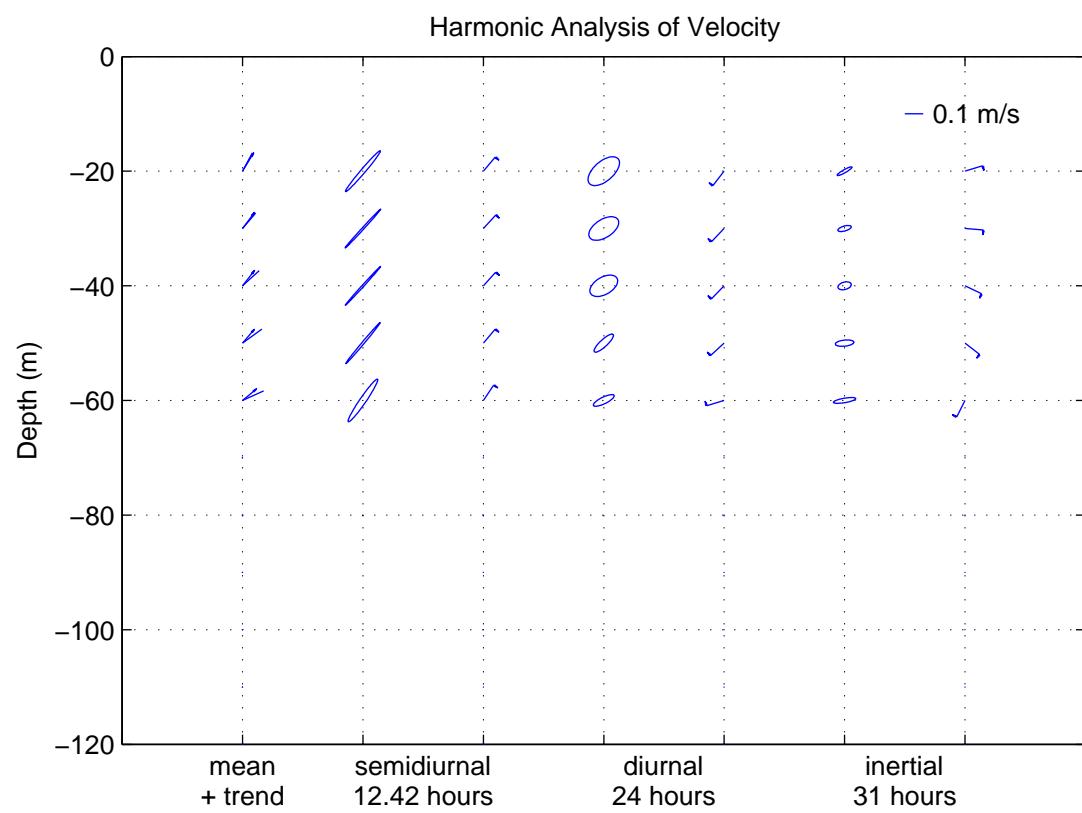
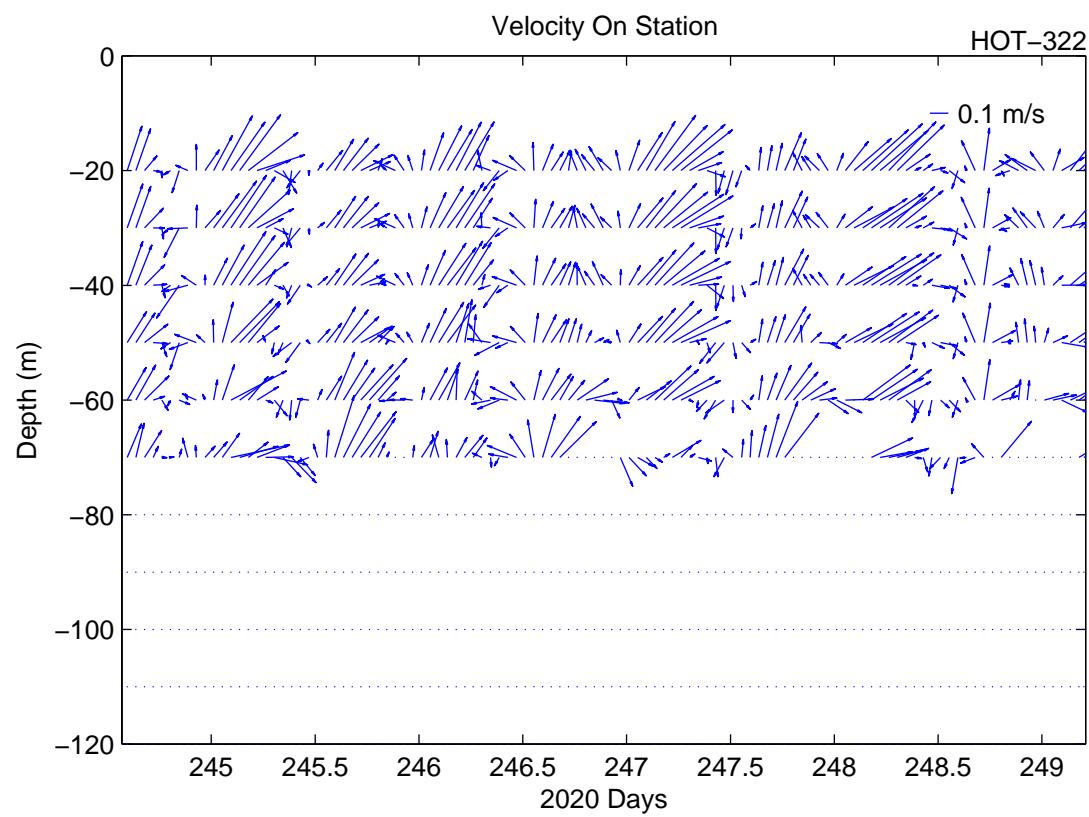


Figure 6.4.1e

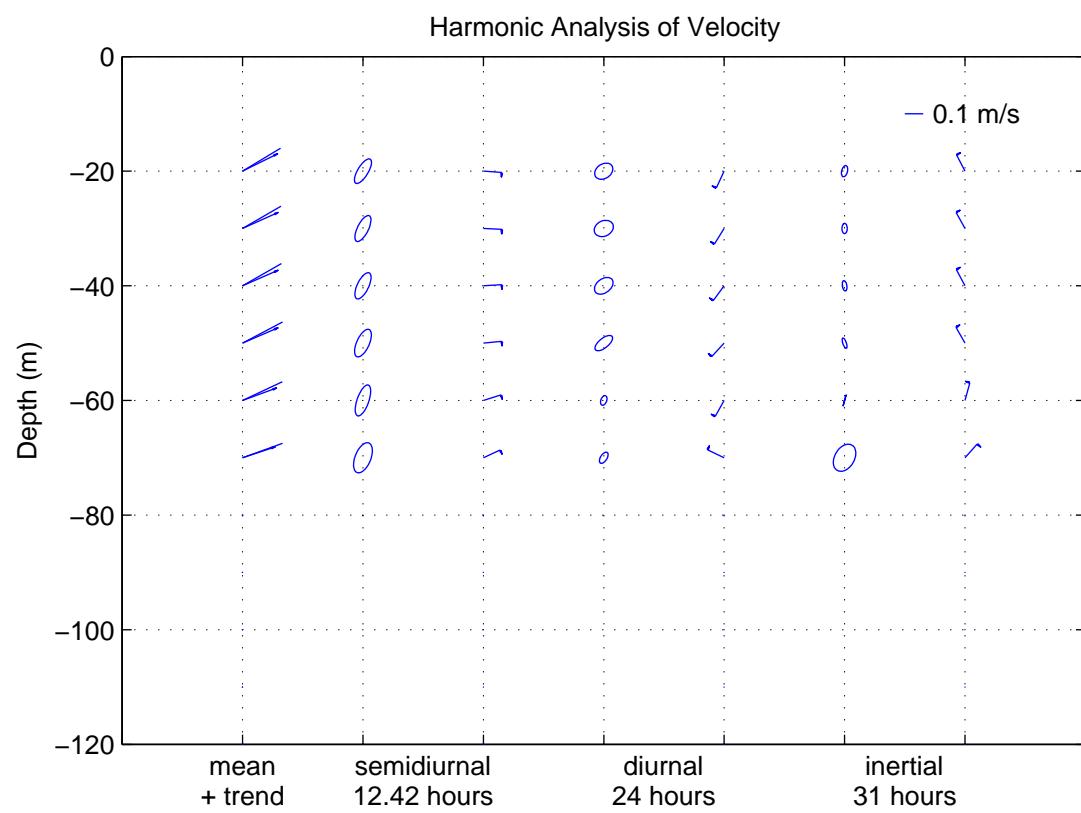
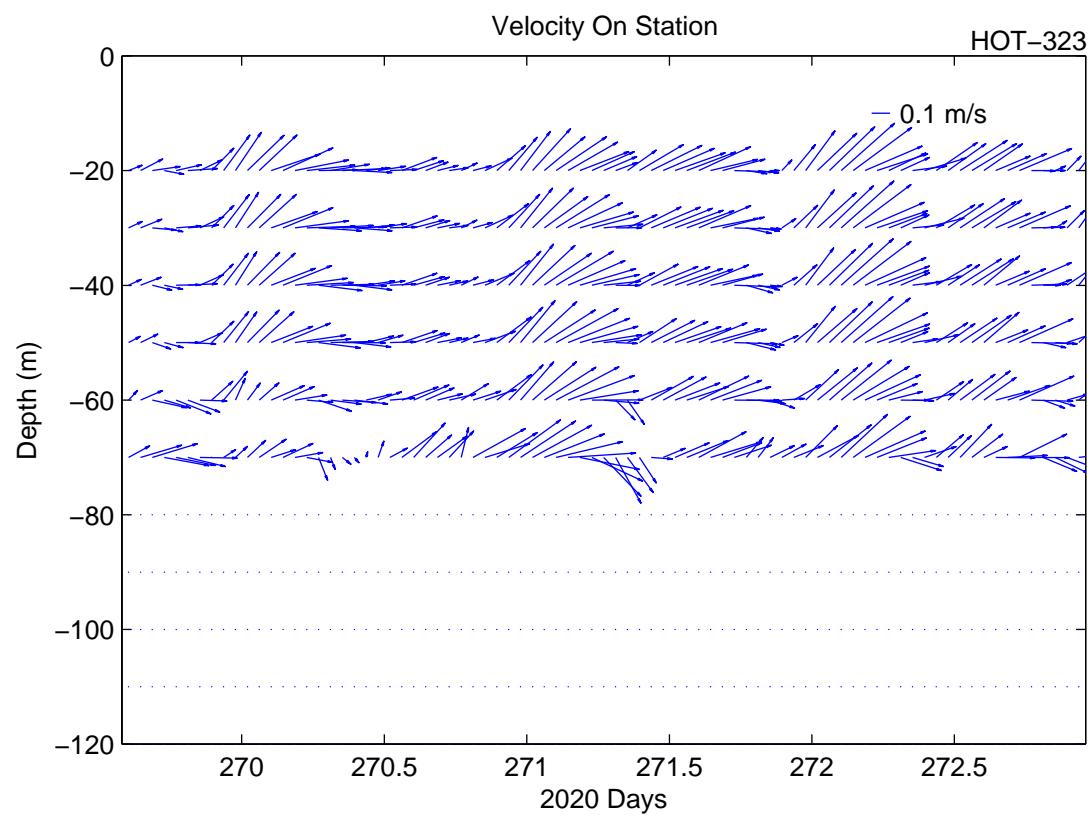


Figure 6.4.1f

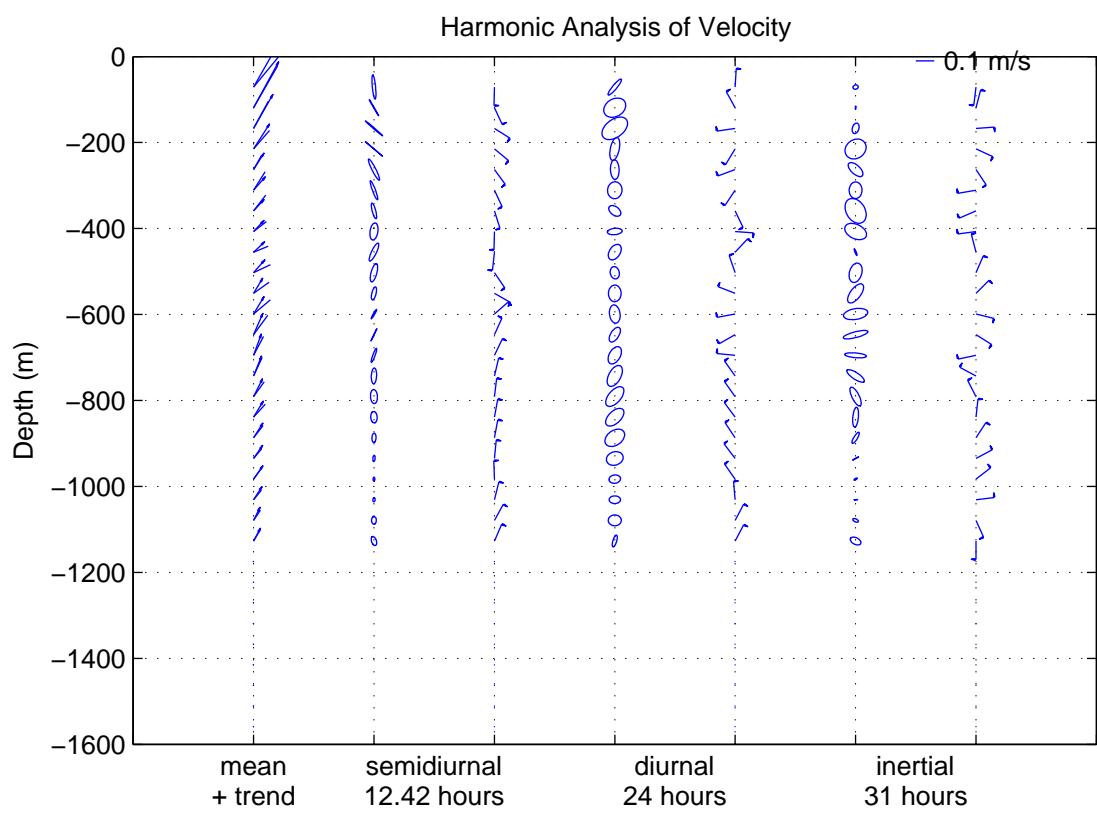
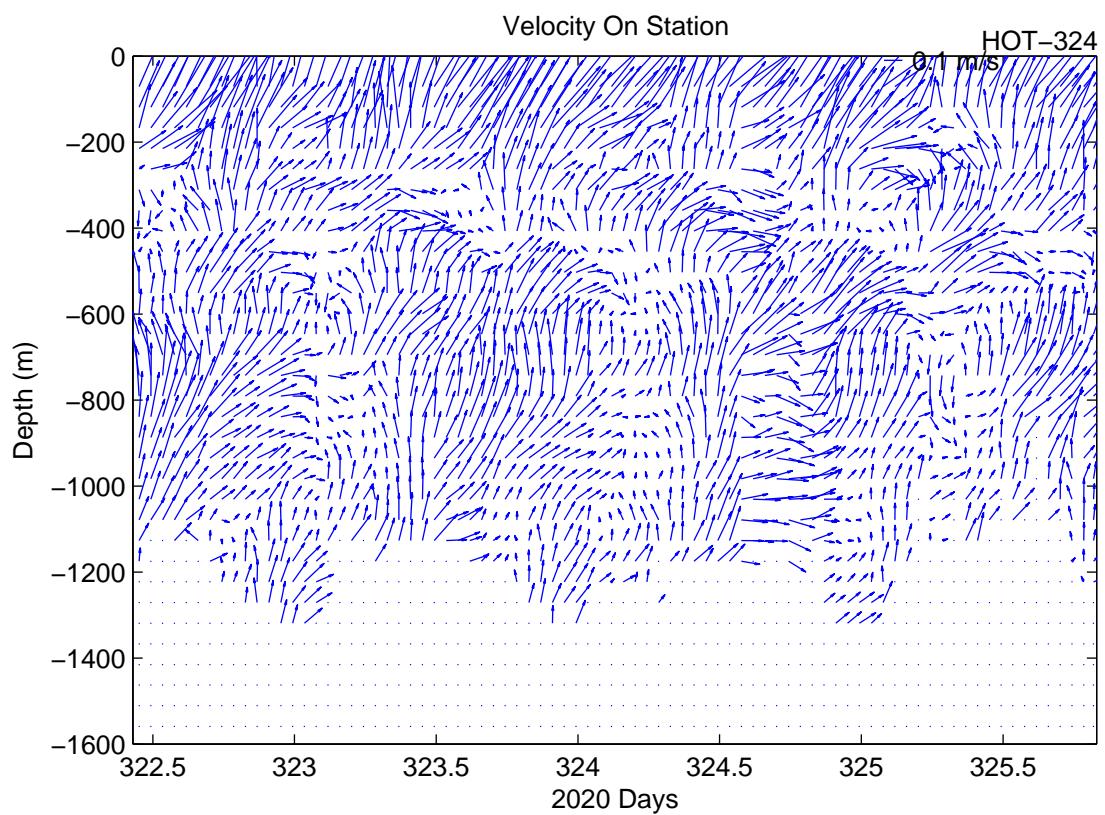


Figure 6.4.1g

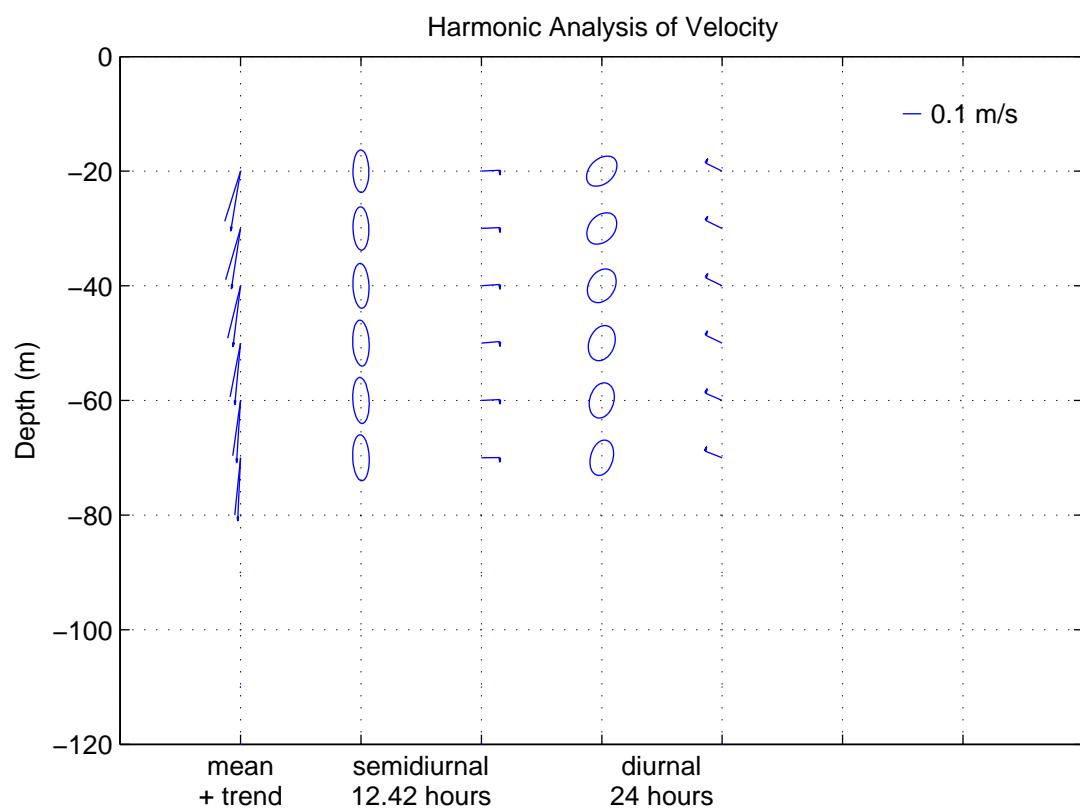
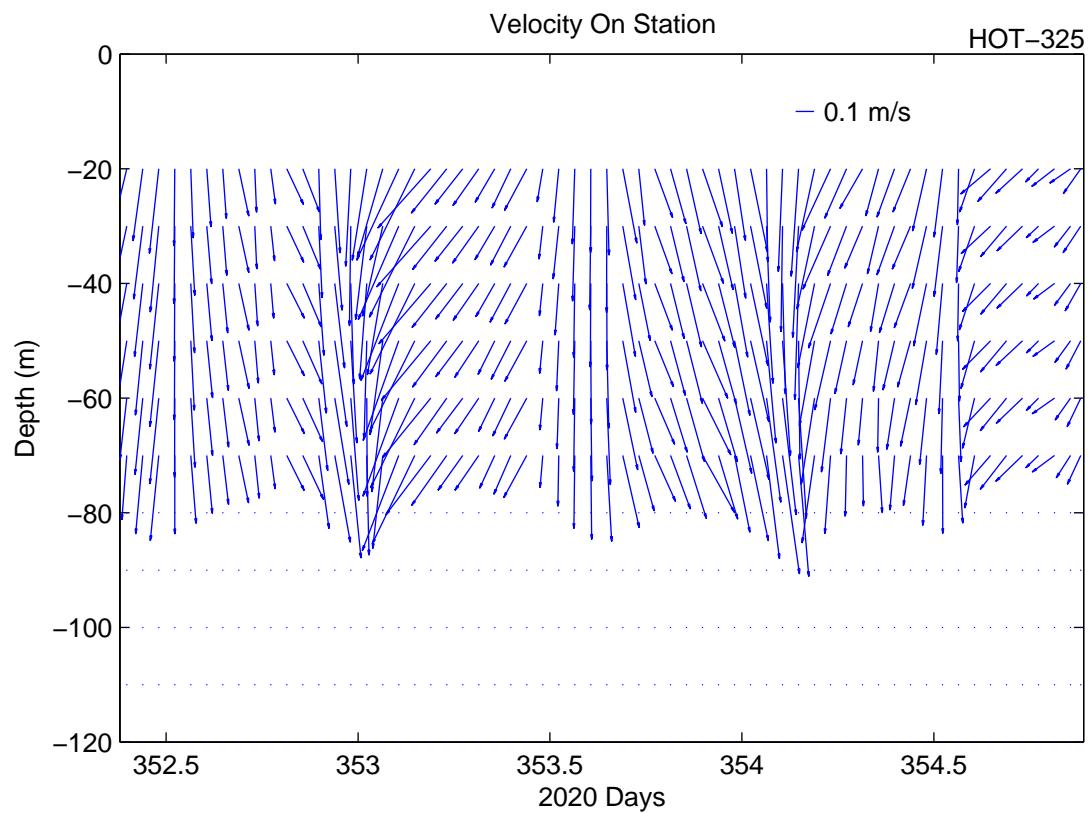


Figure 6.4.1h

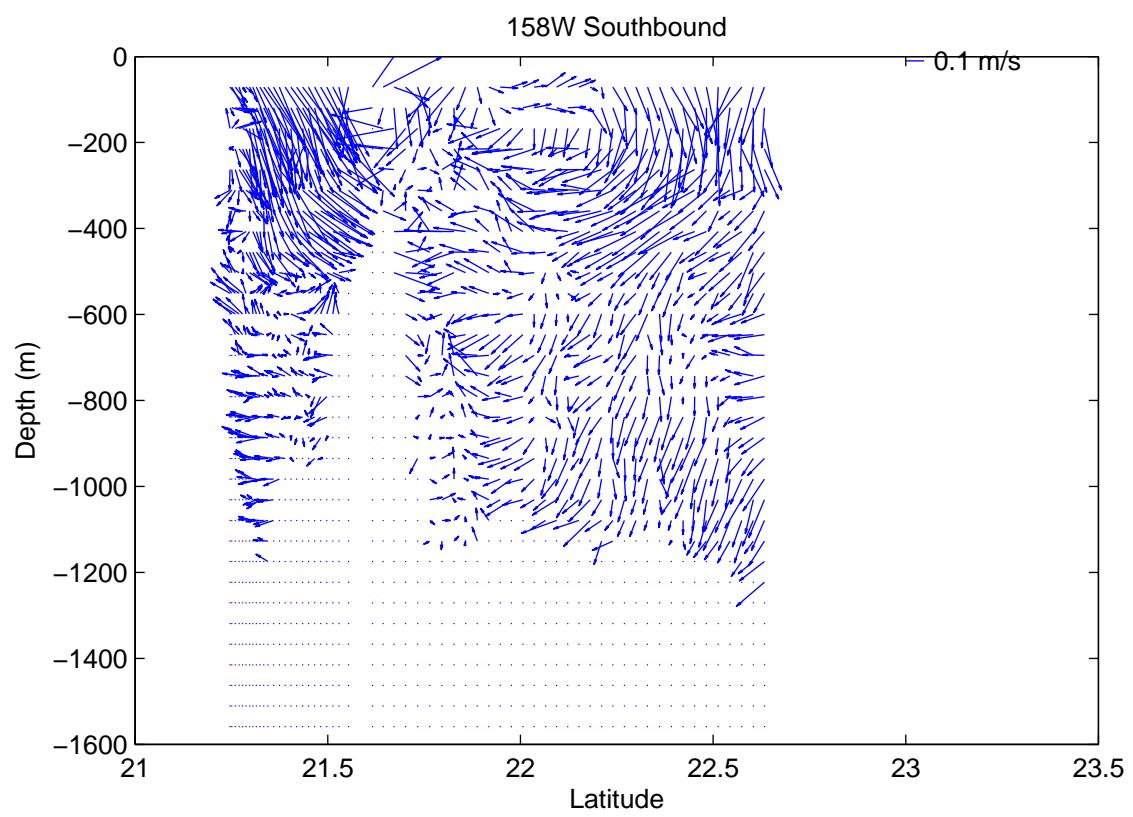
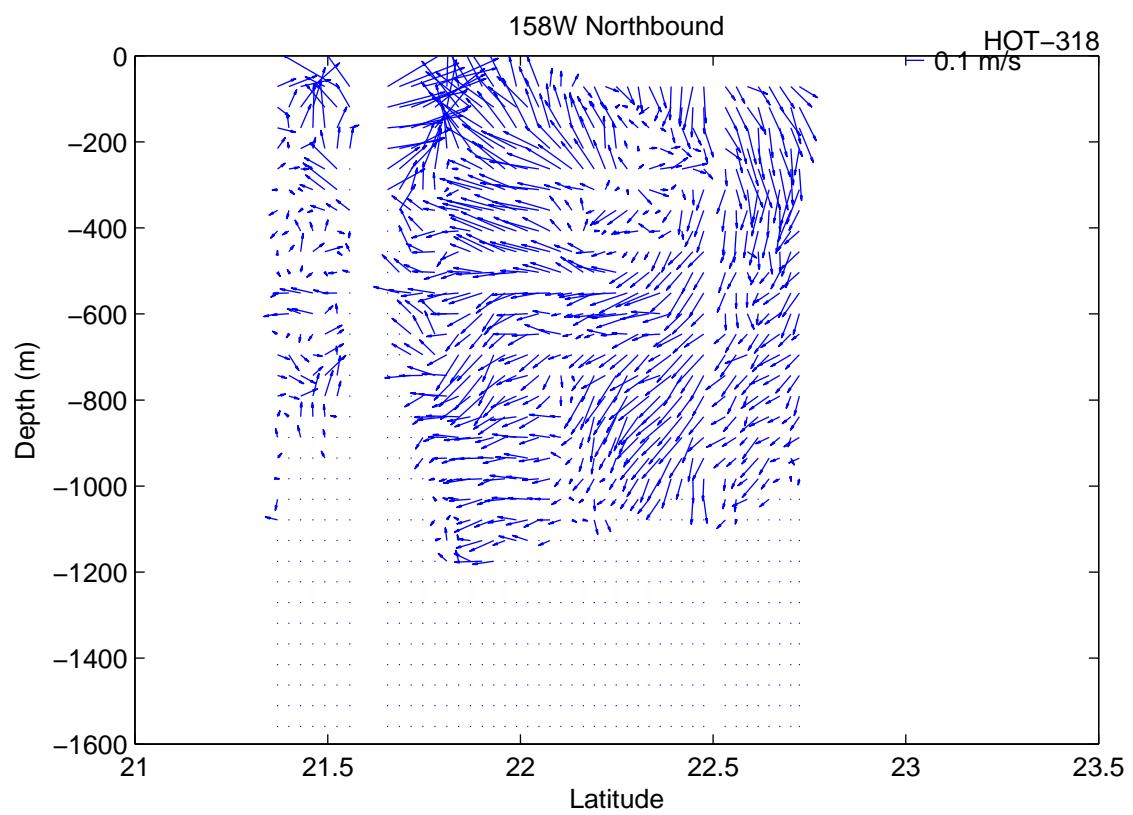


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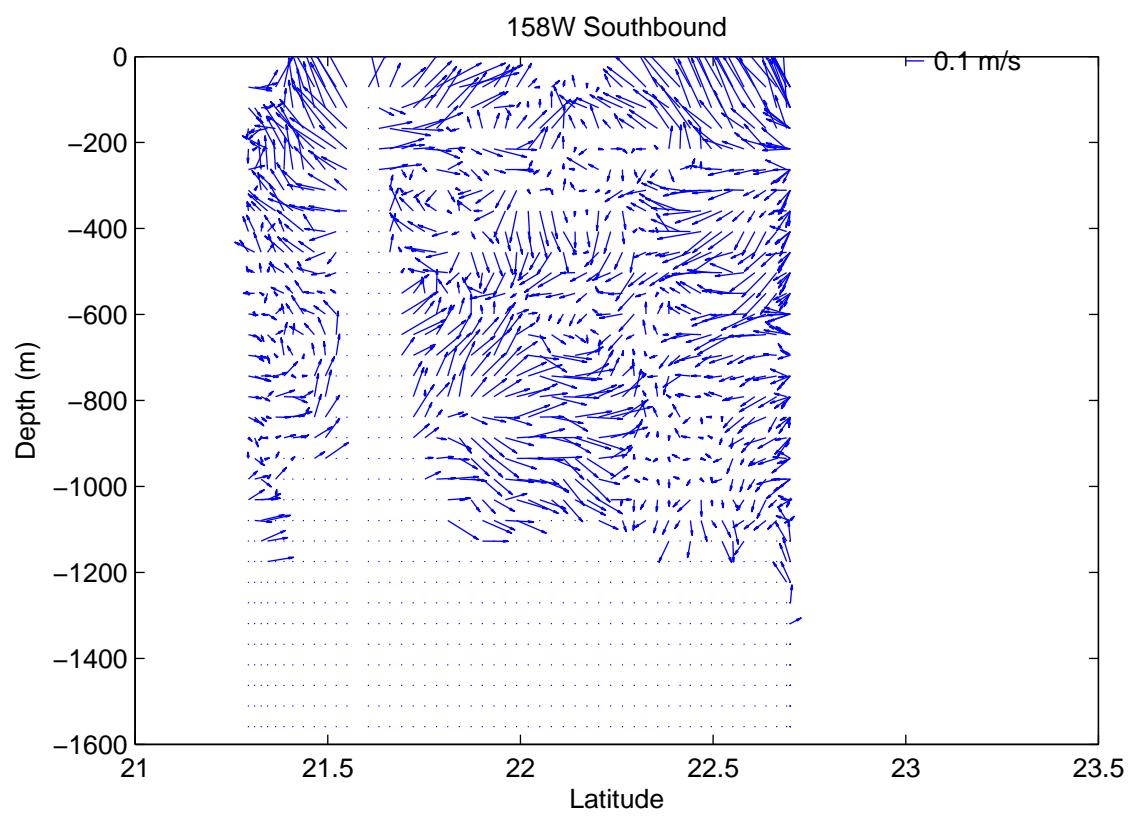
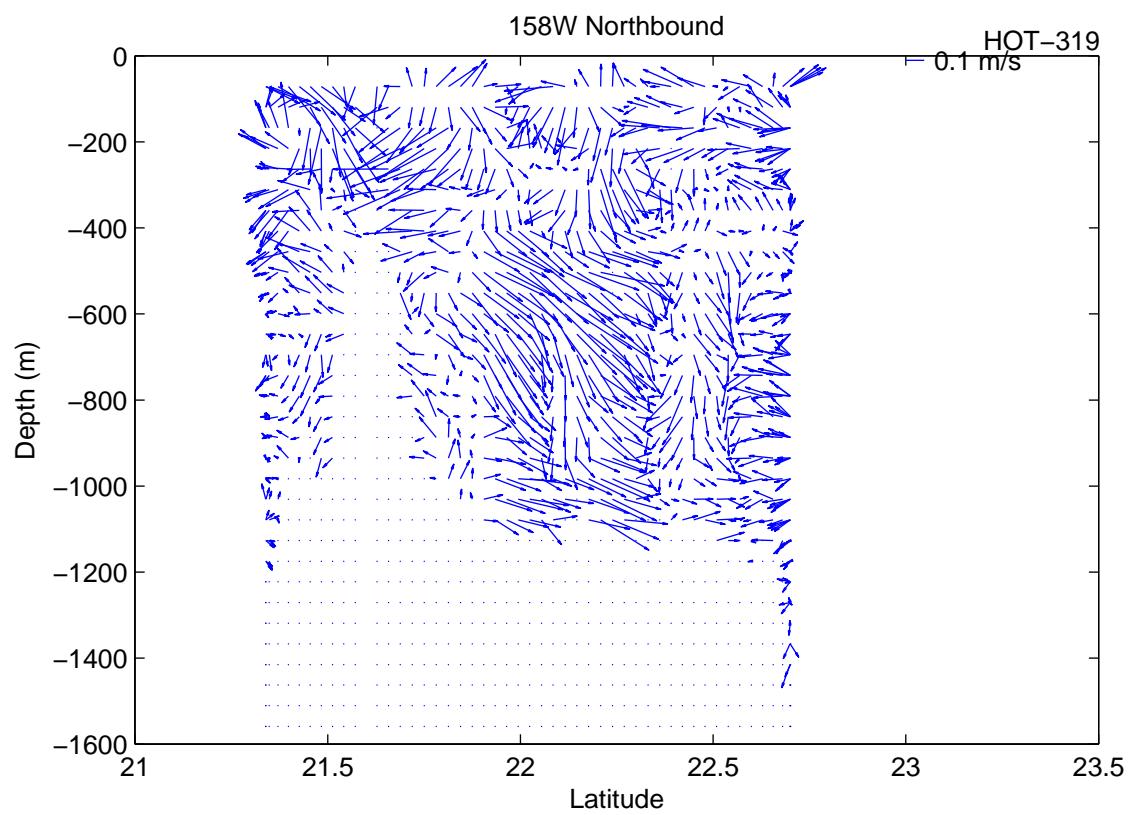


Figure 6.4.2b

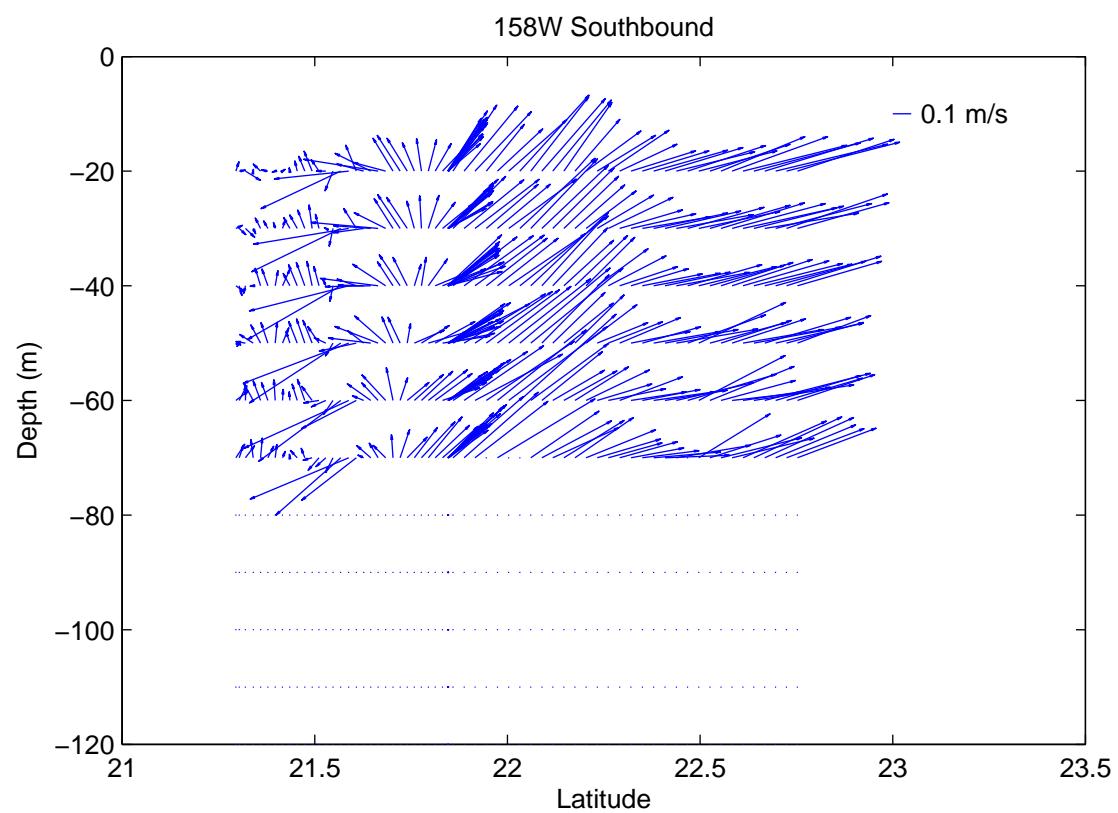
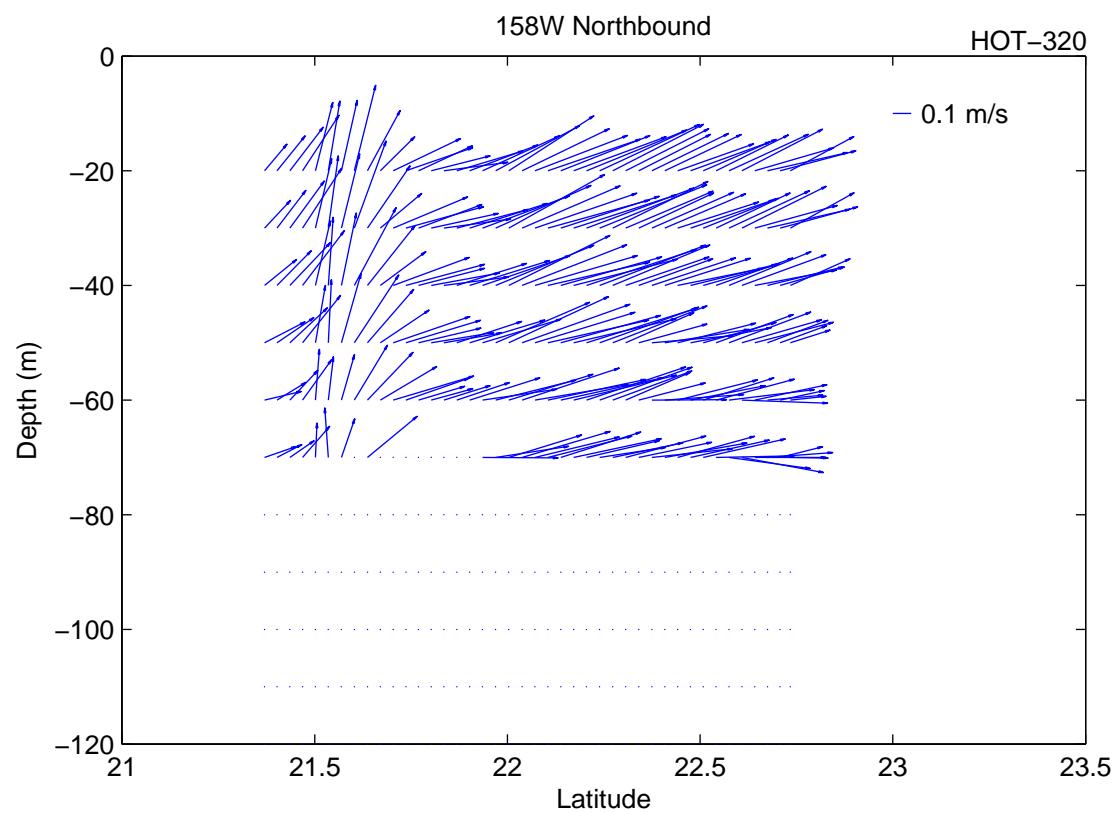


Figure 6.4.2c

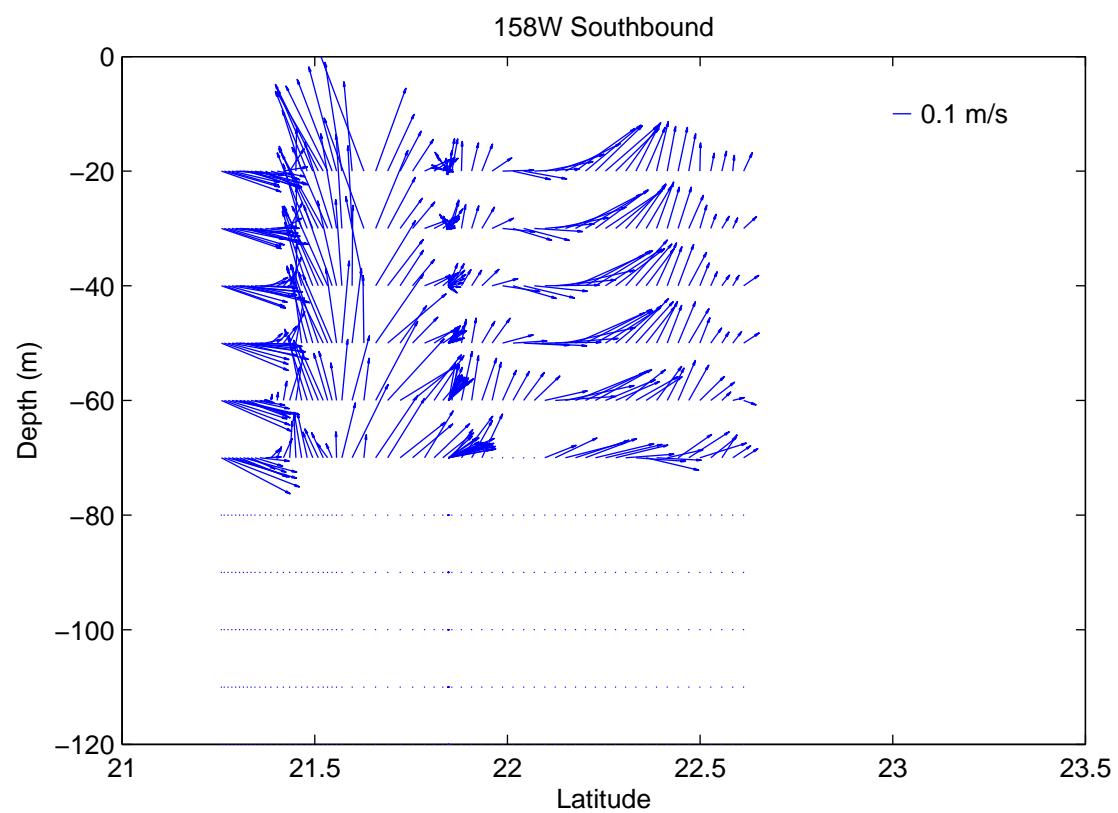
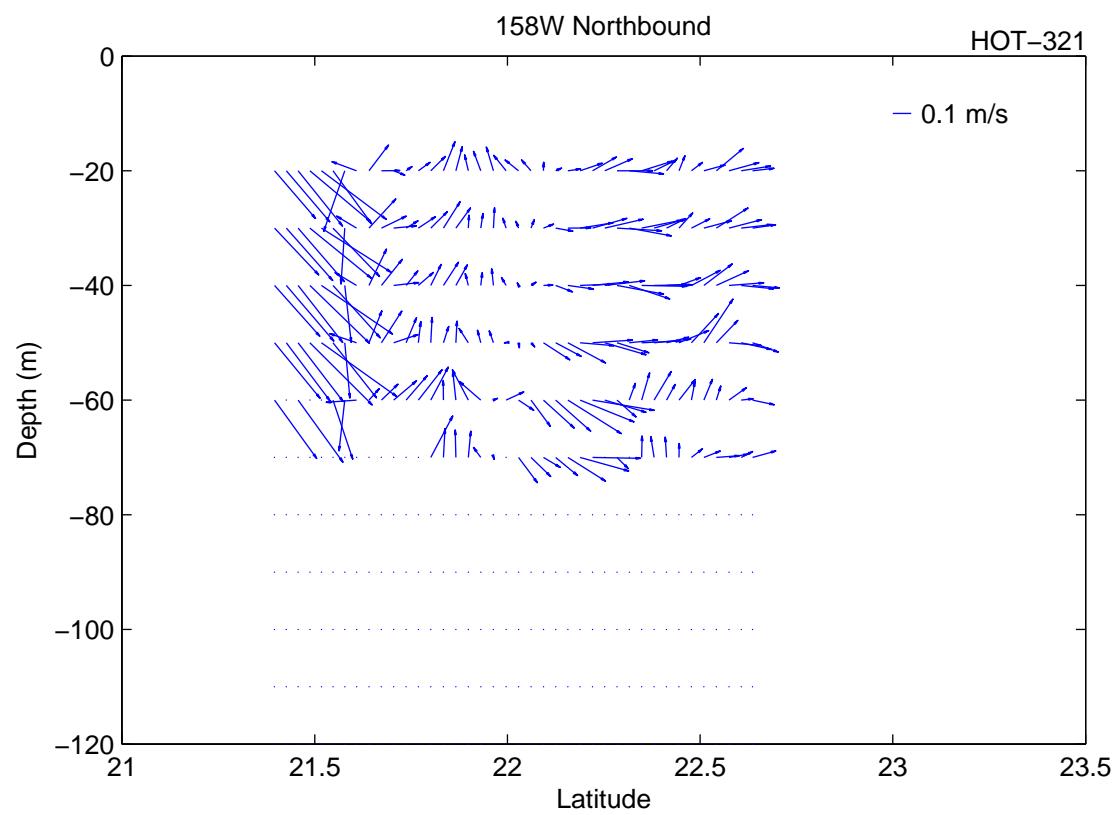


Figure 6.4.2d

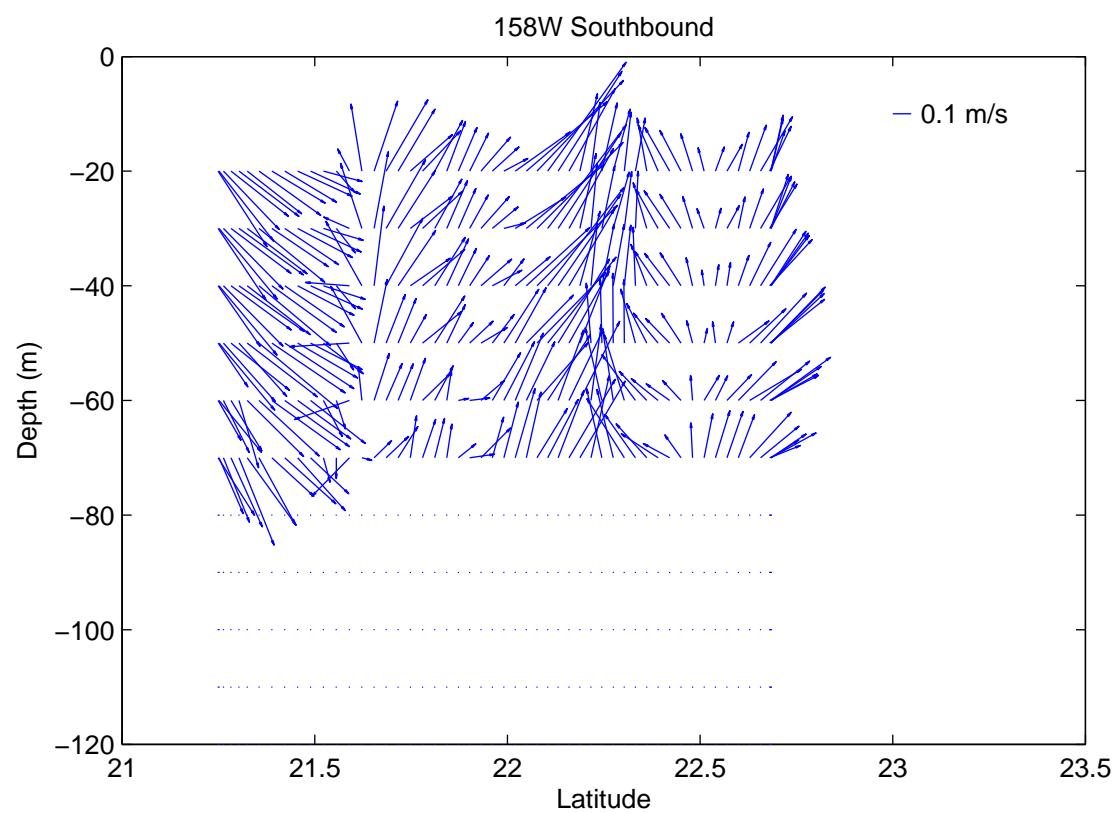
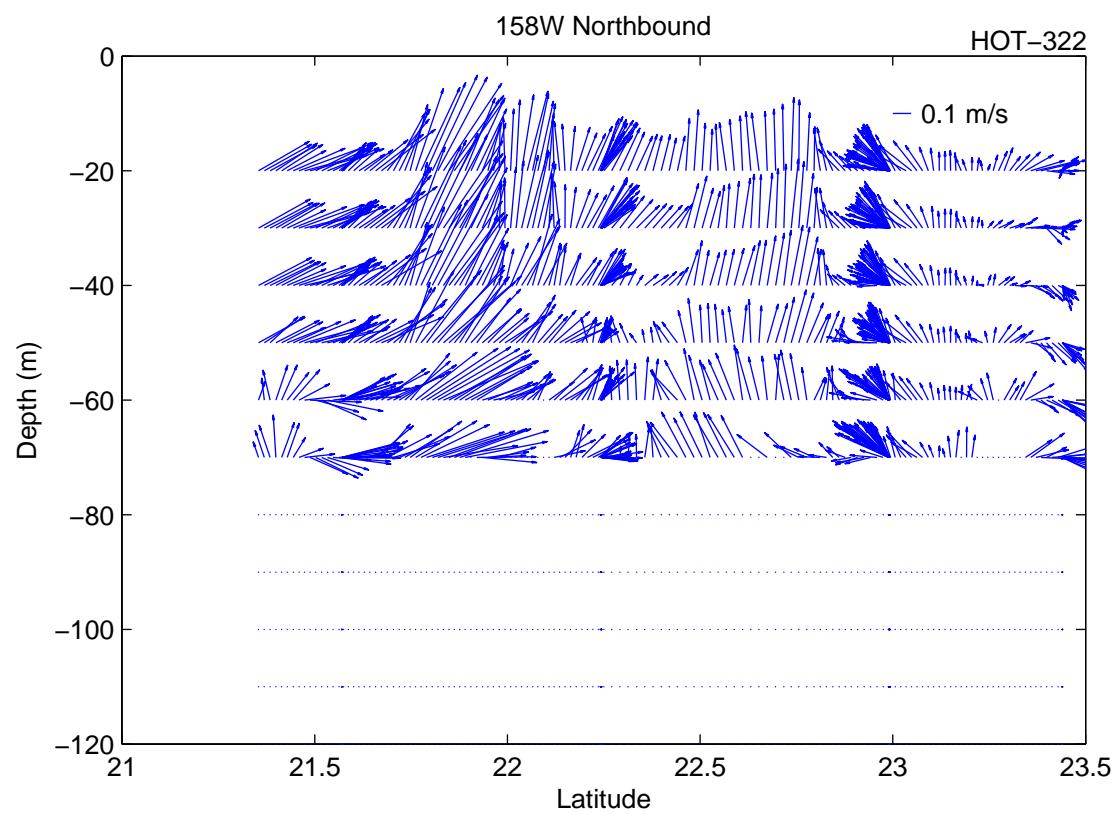


Figure 6.4.2e

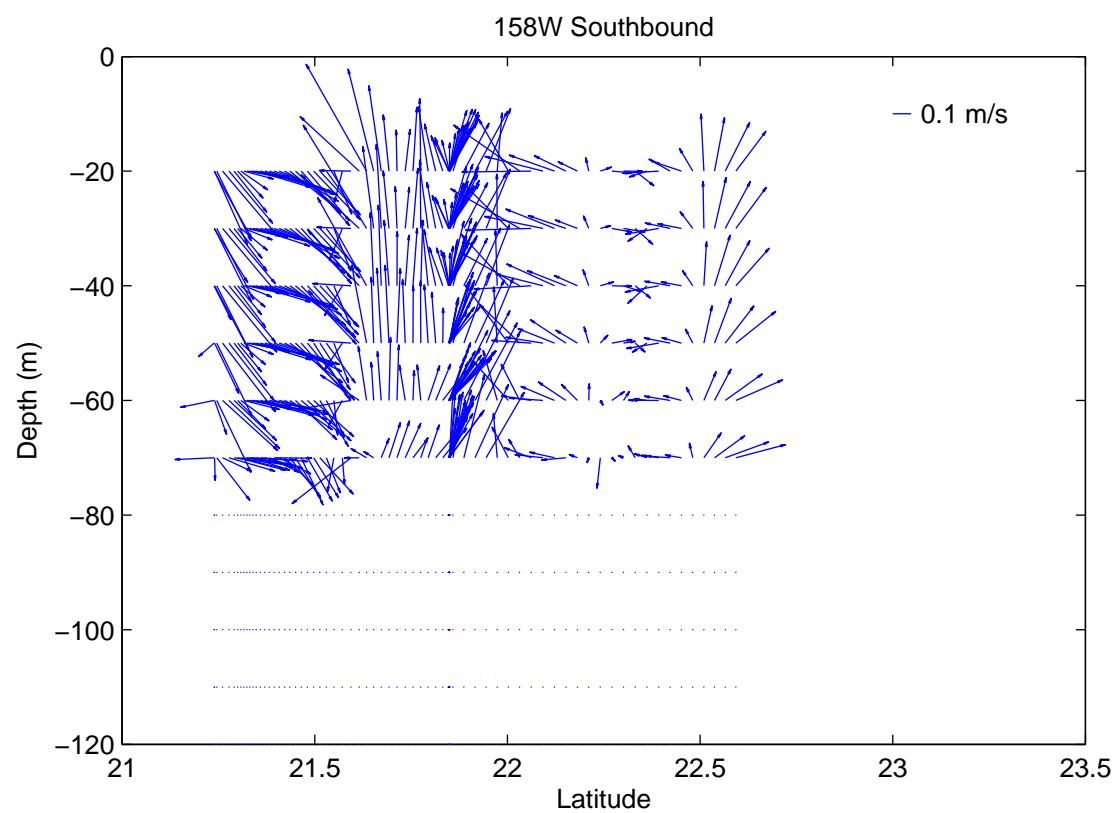
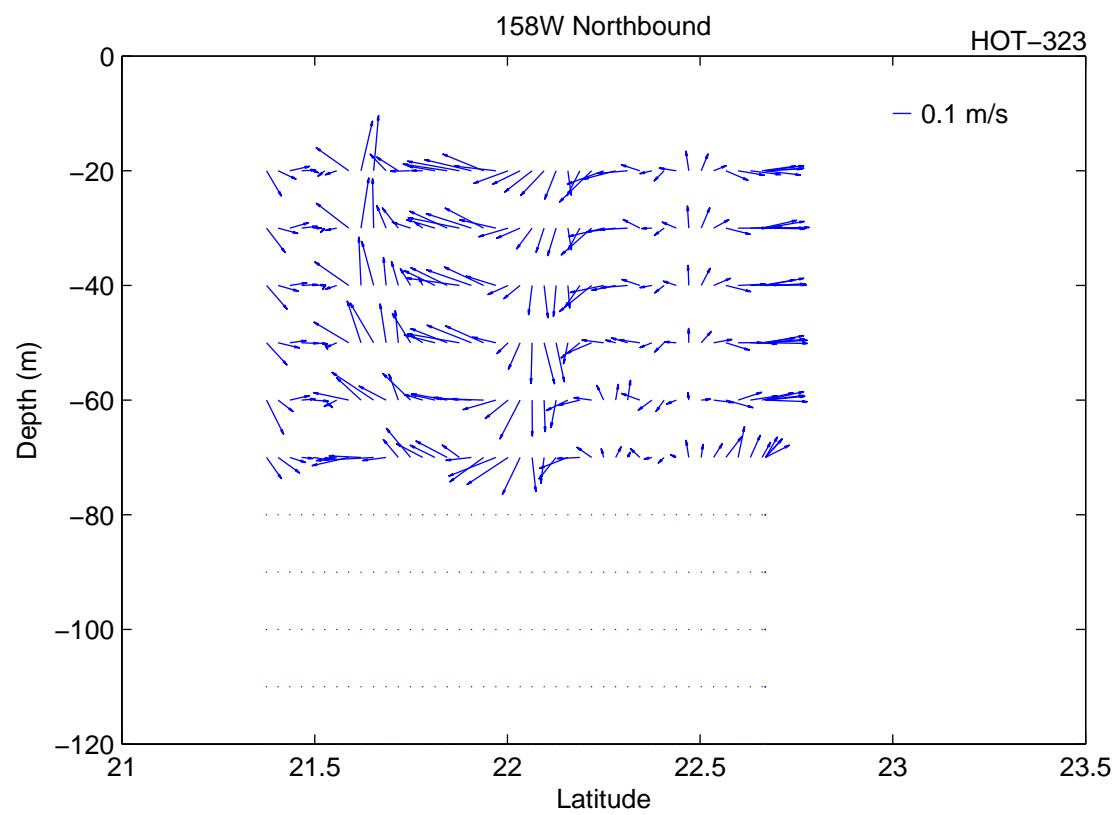


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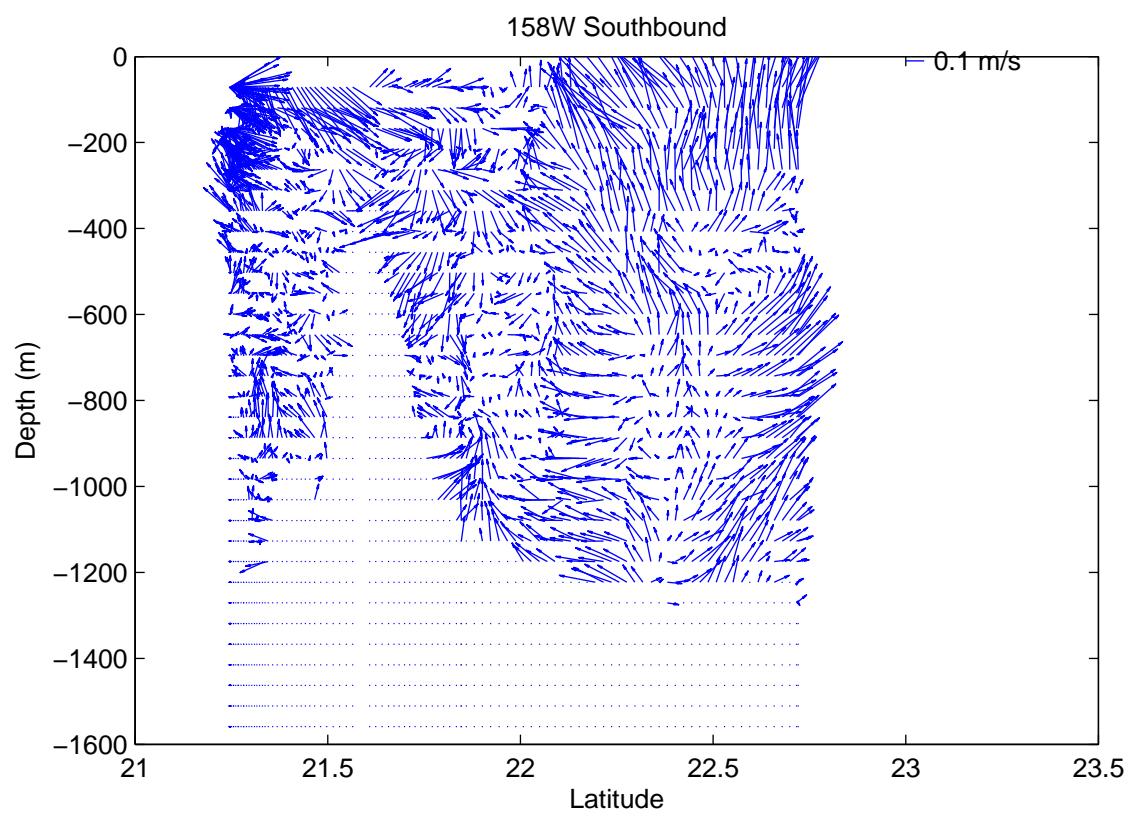
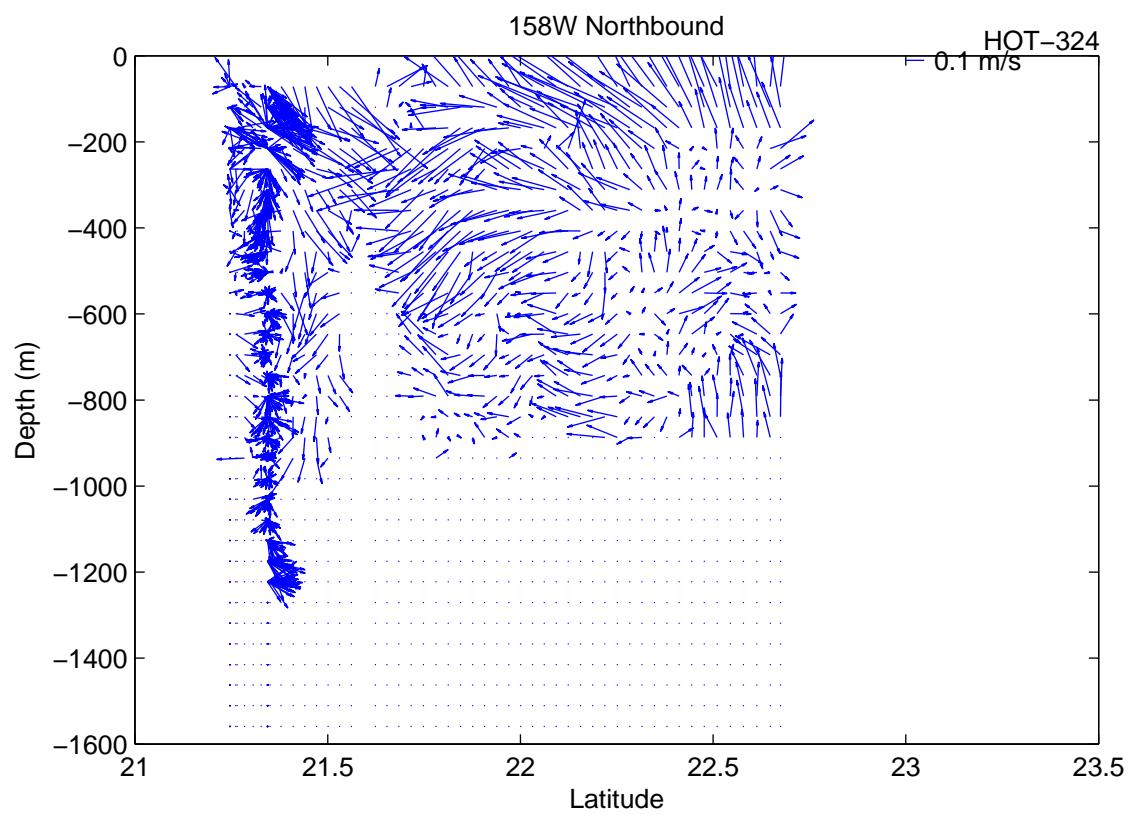


Figure 6.4.2g

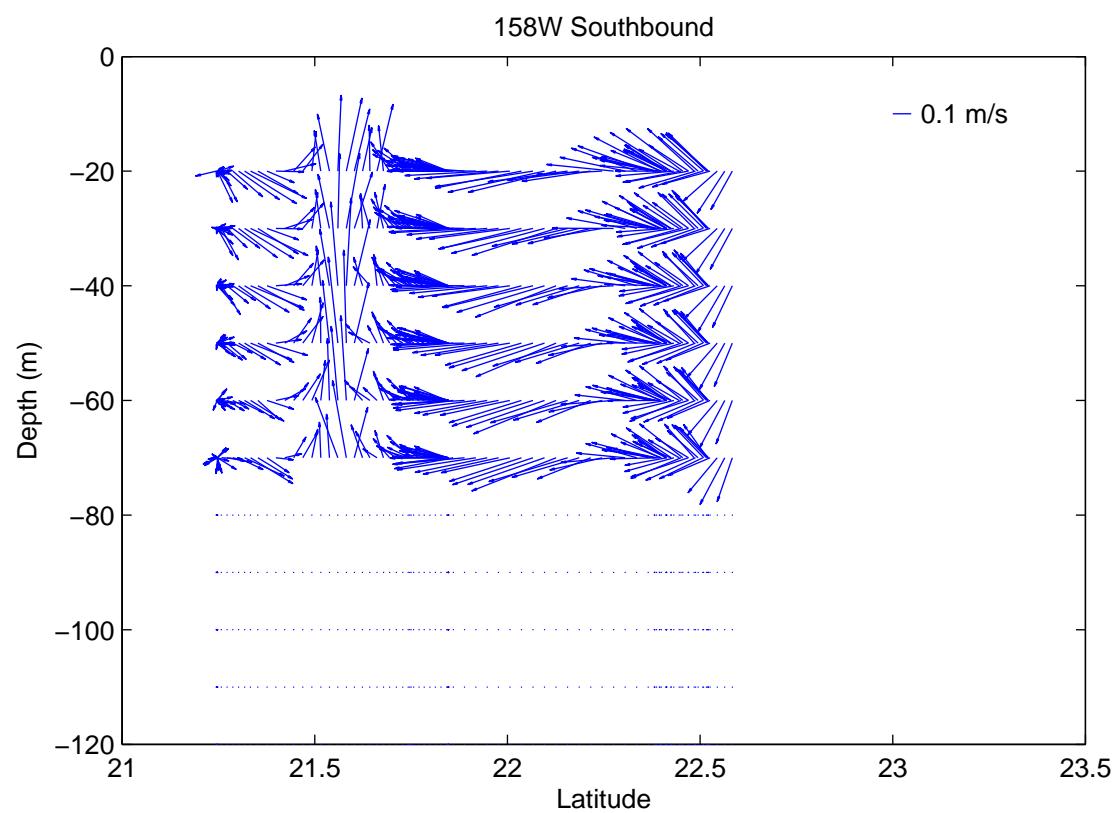
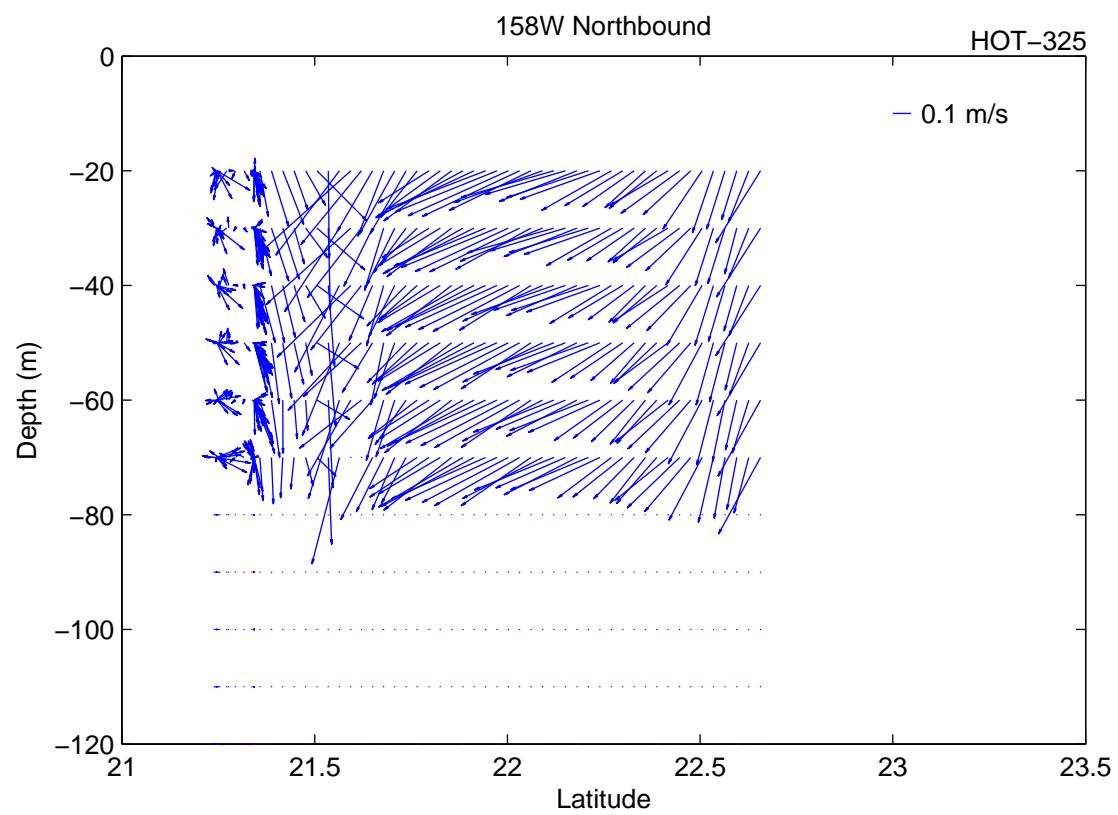


Figure 6.4.2h

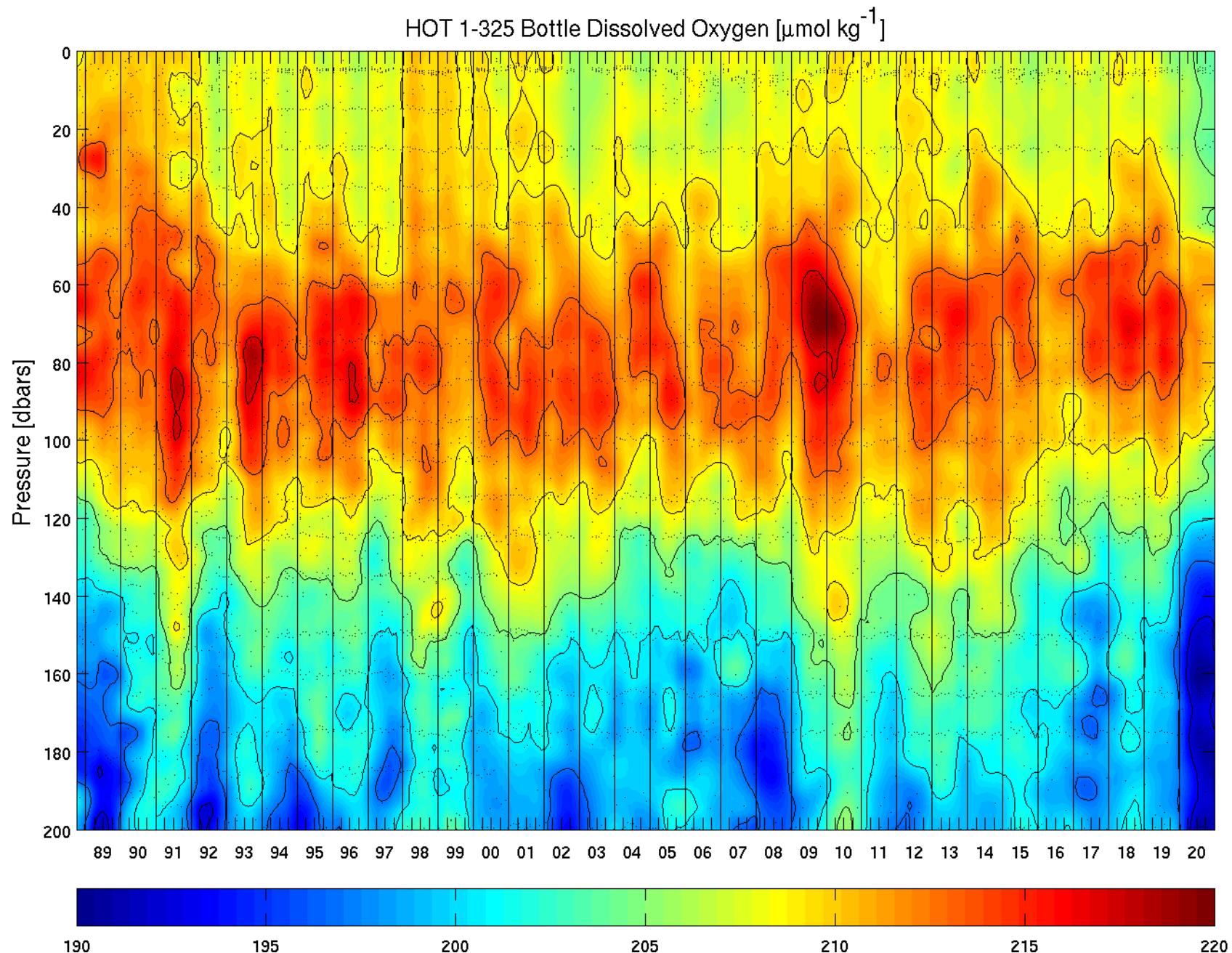


Figure 6.5.1

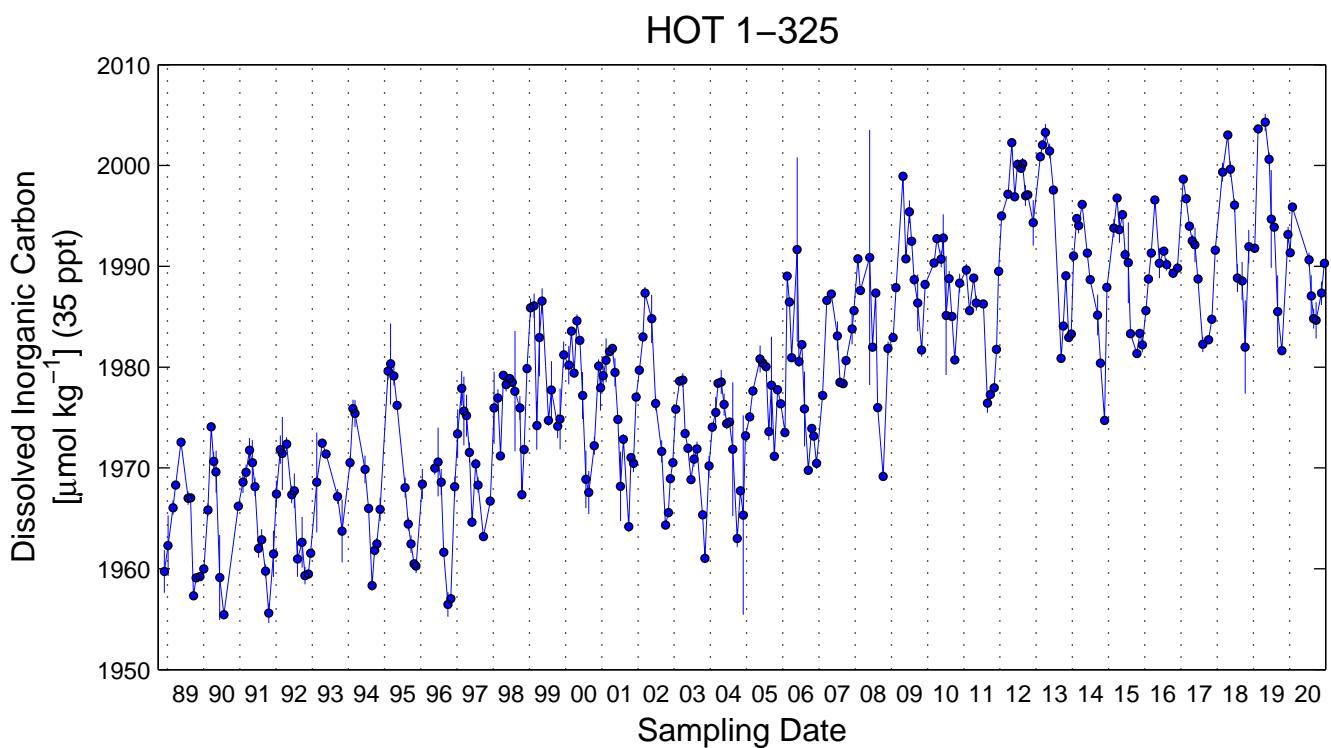
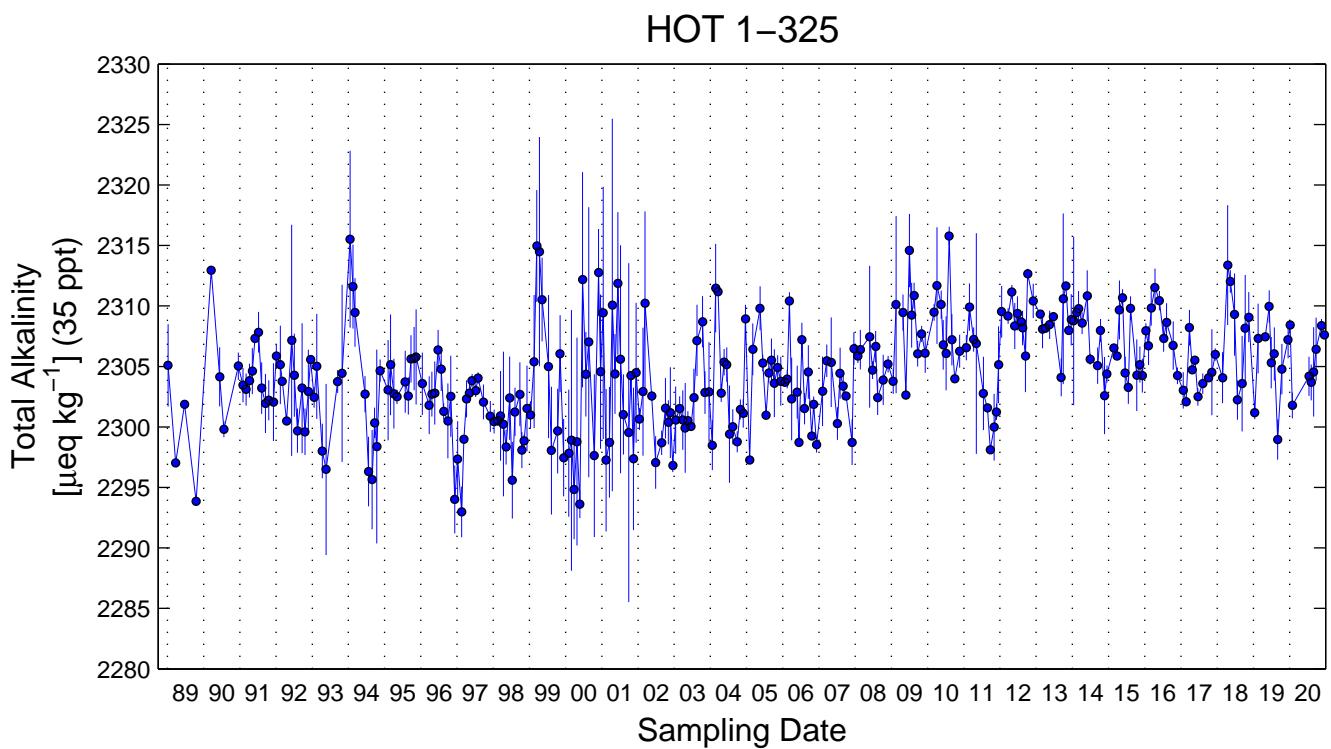


Figure 6.5.2

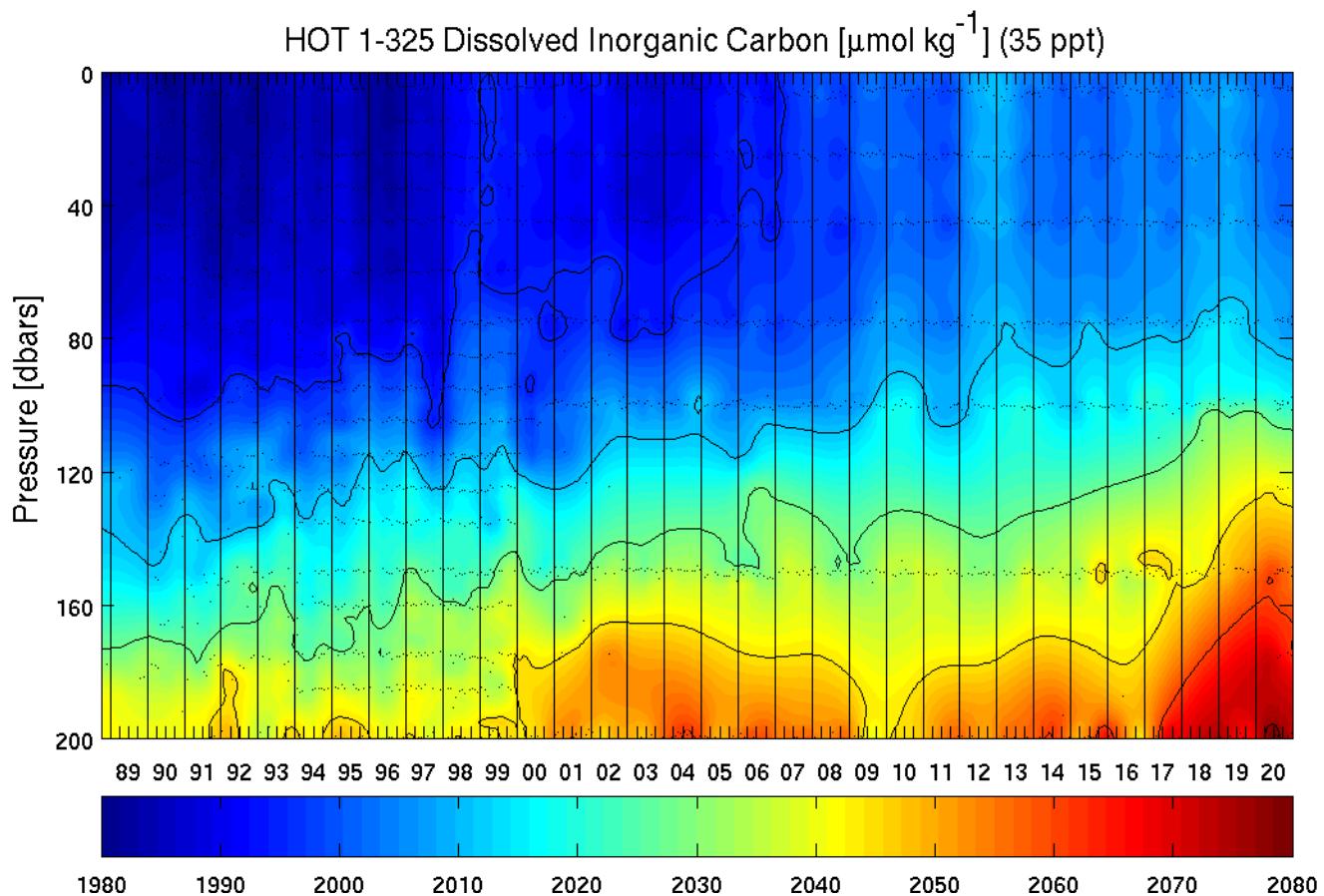
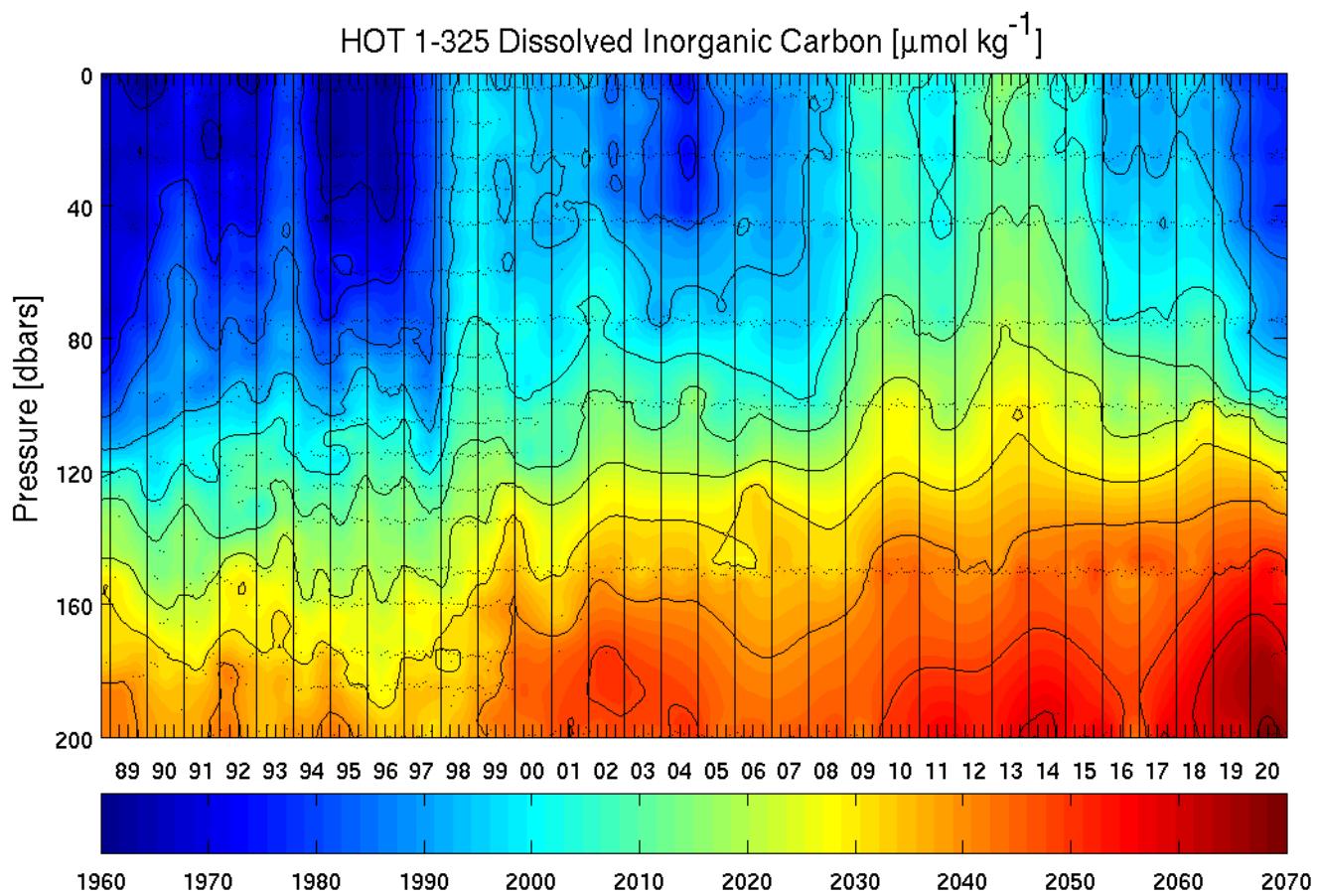


Figure 6.5.3

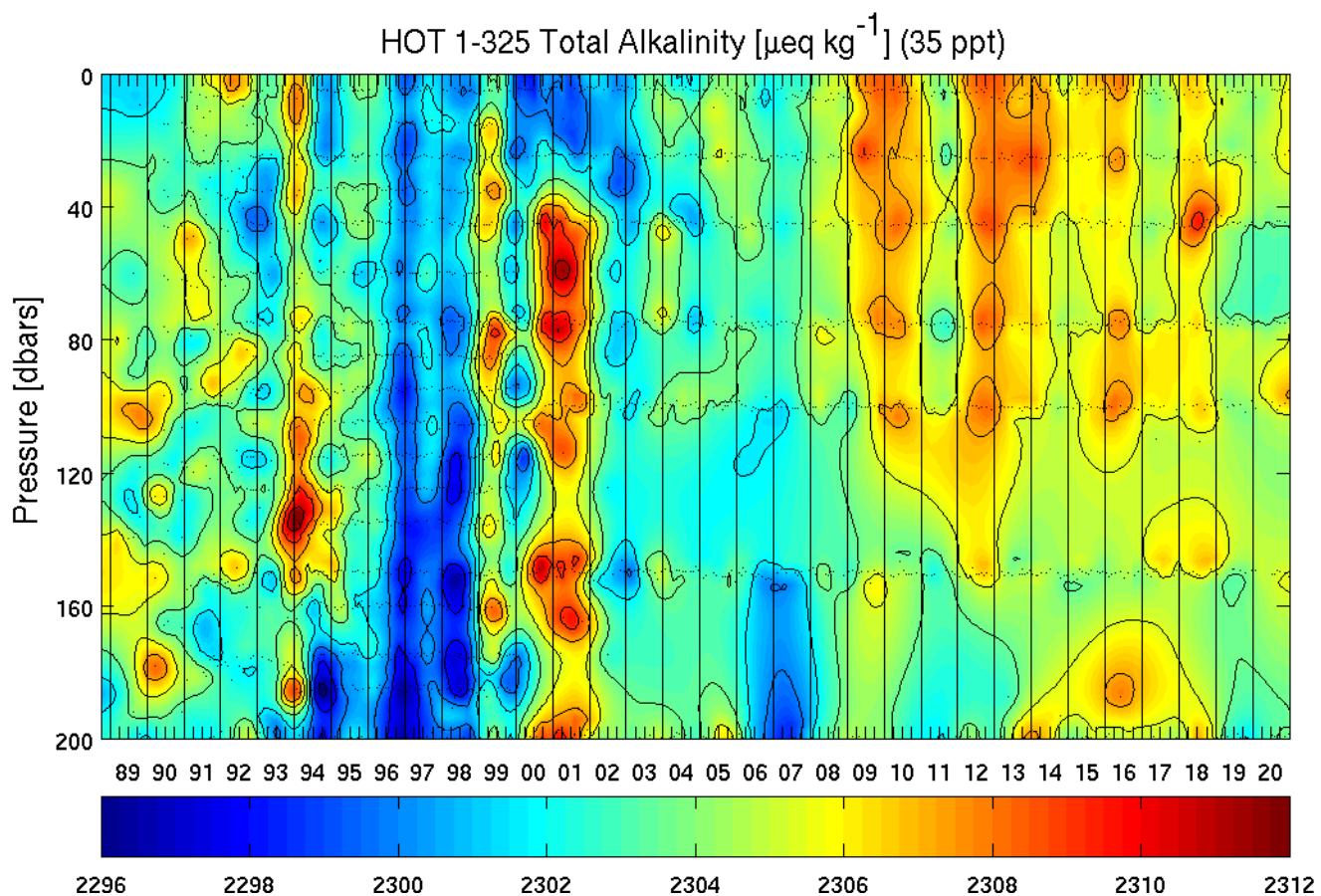
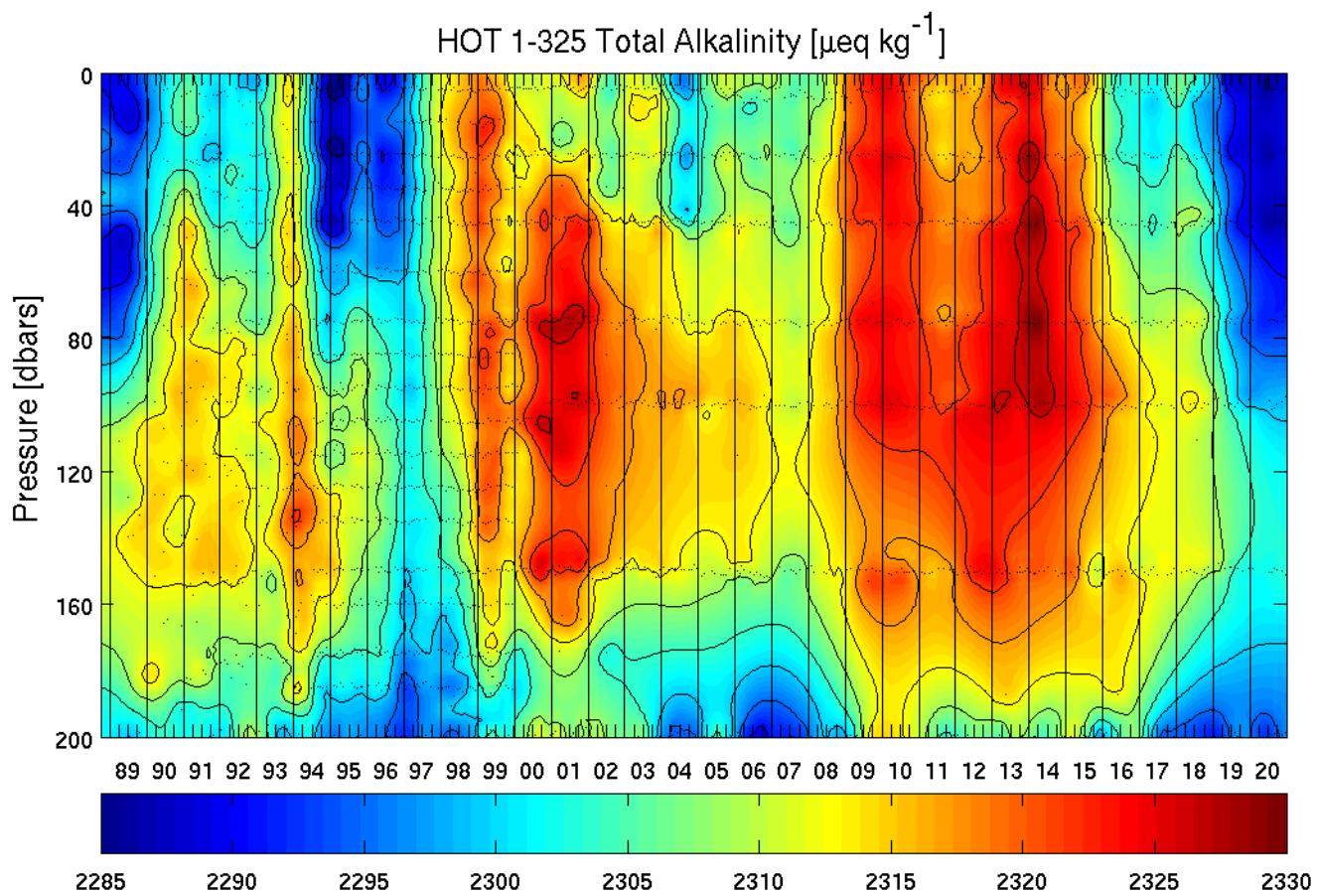


Figure 6.5.4

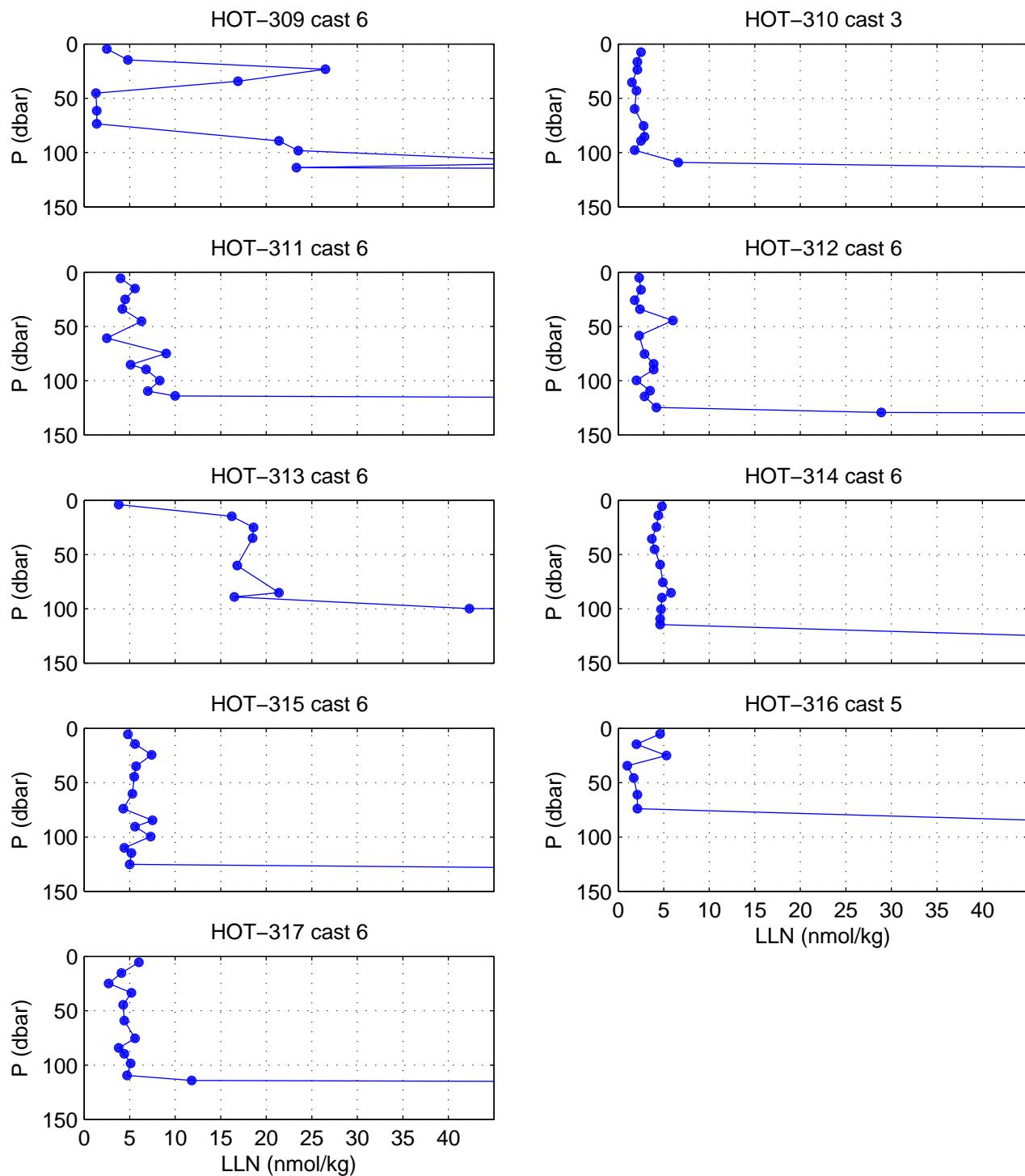


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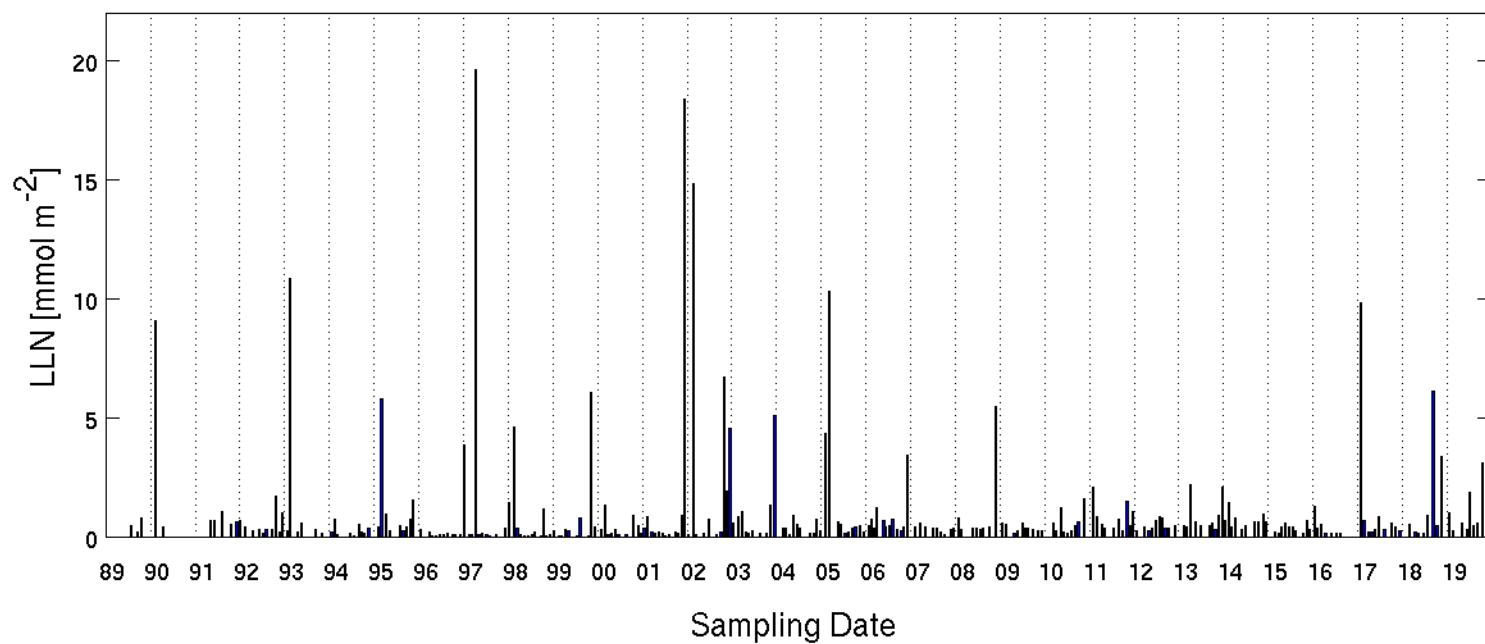
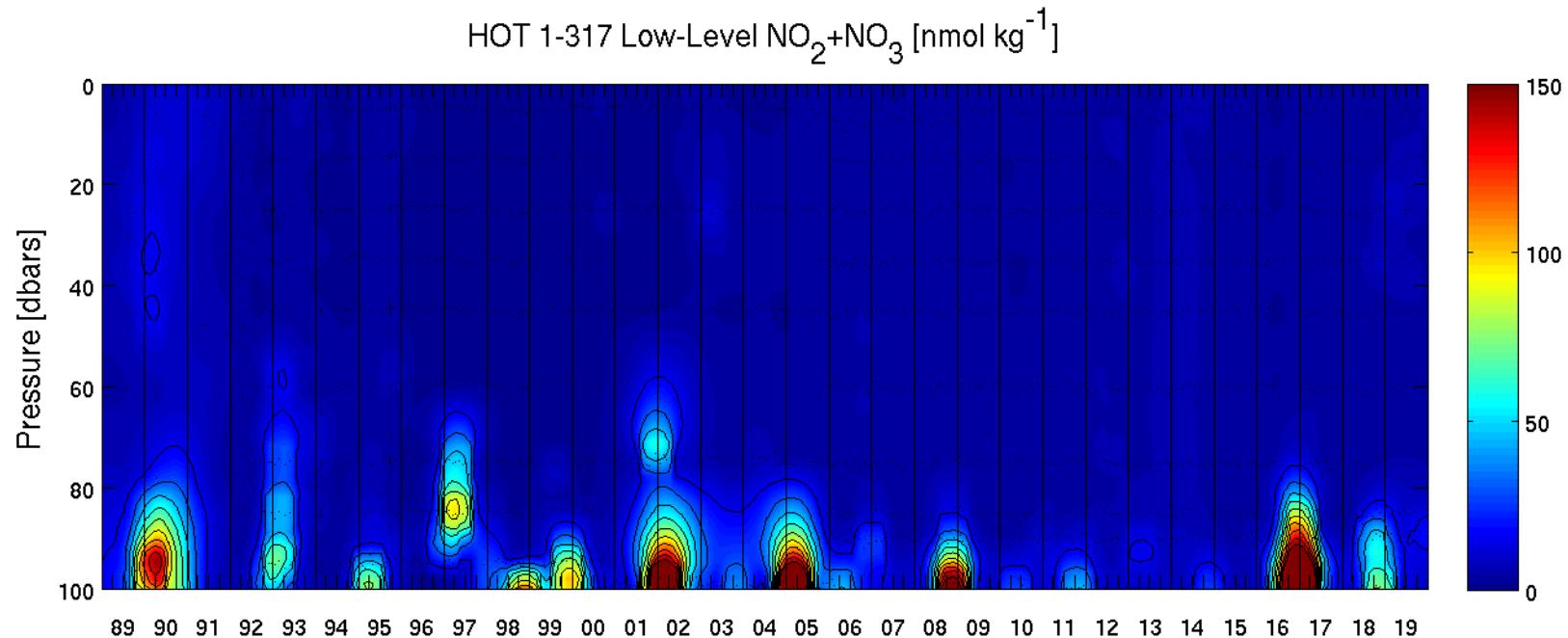


Figure 6.5.6

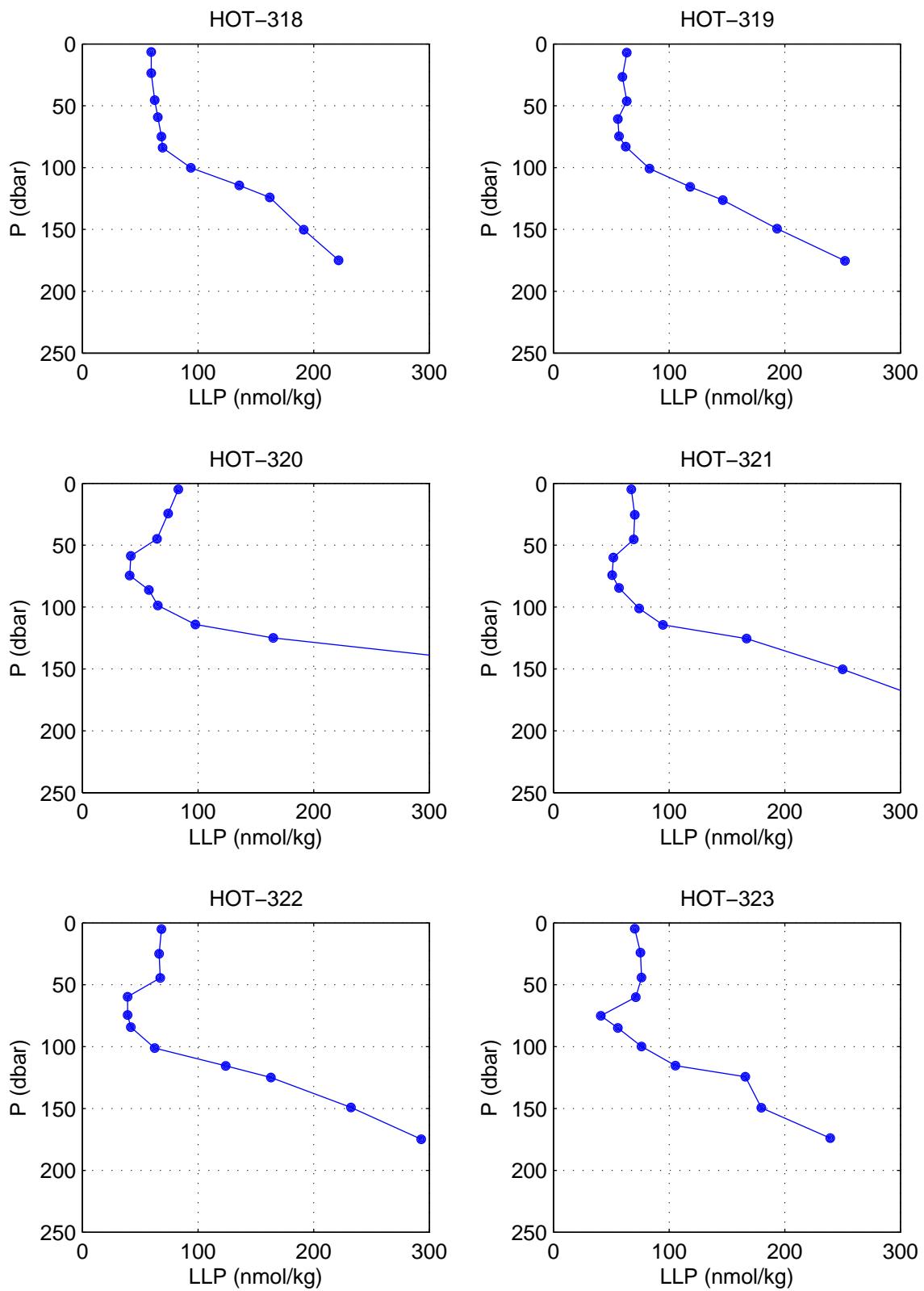


Figure 6.5.7

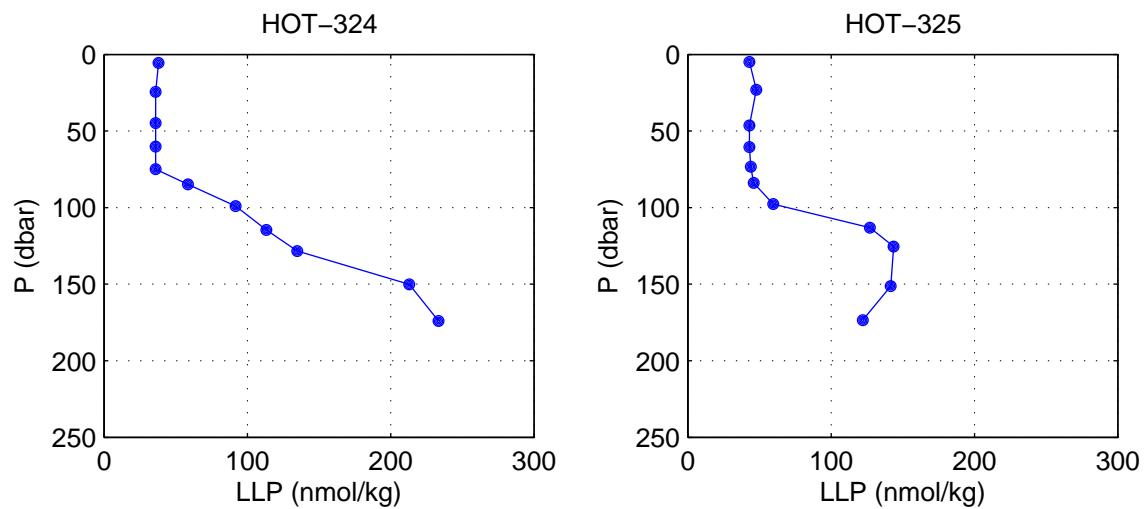


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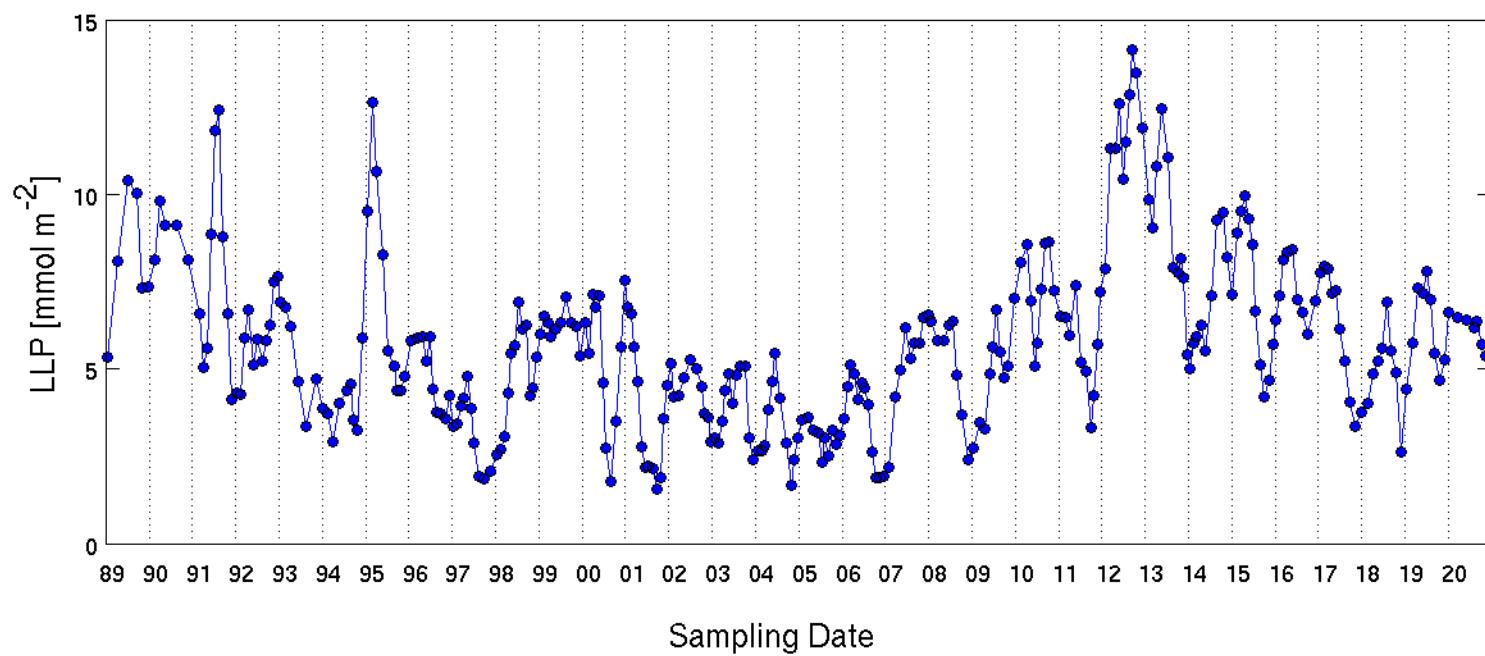
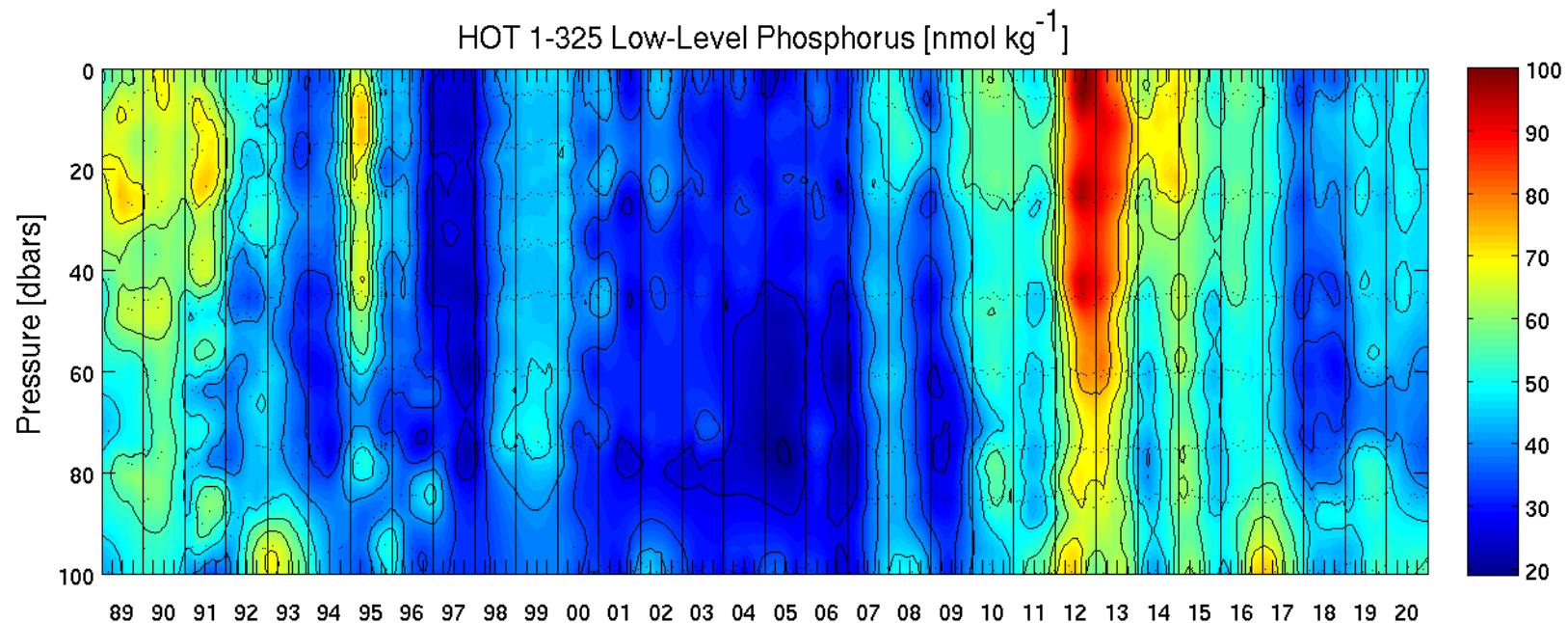


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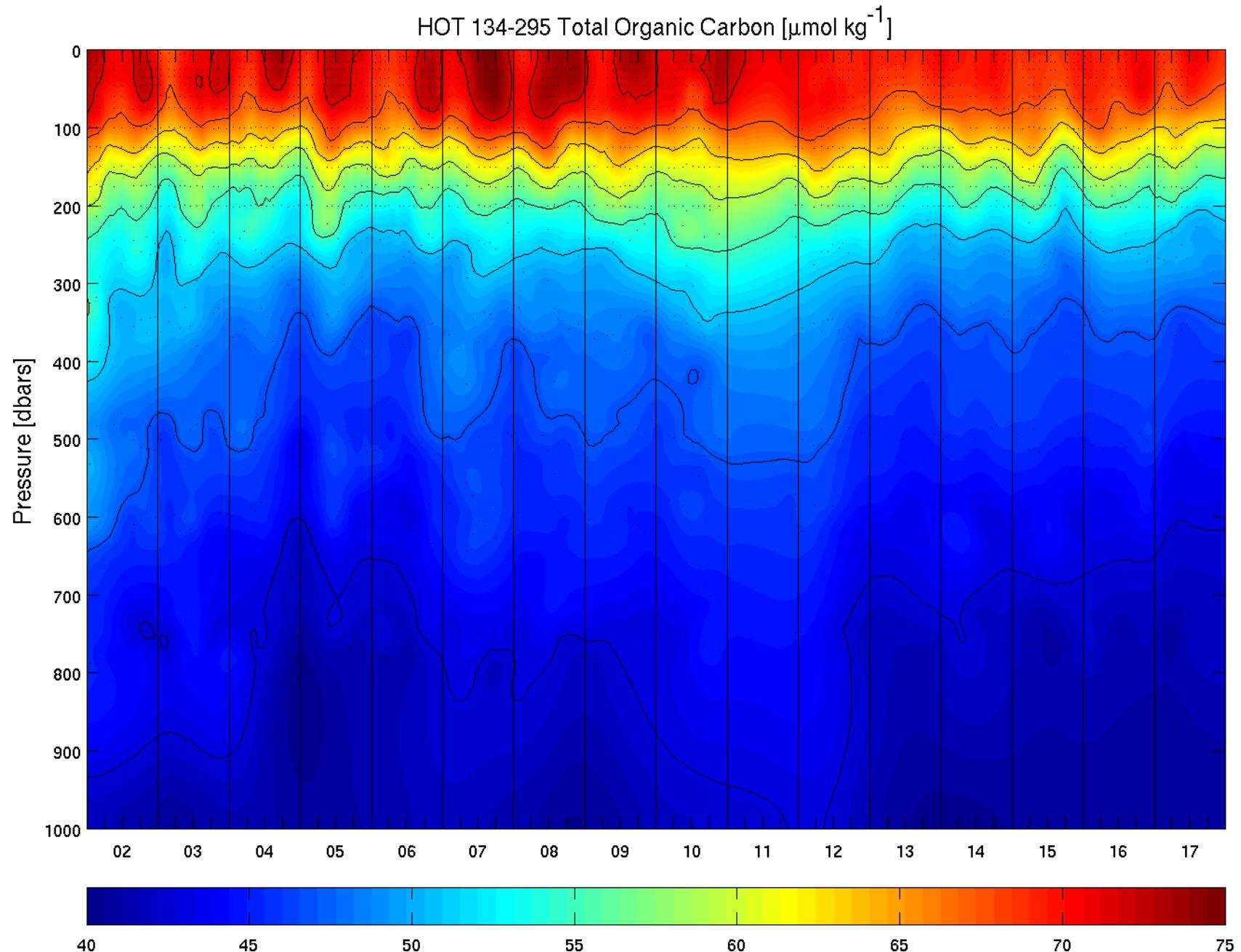


Figure 6.5.9

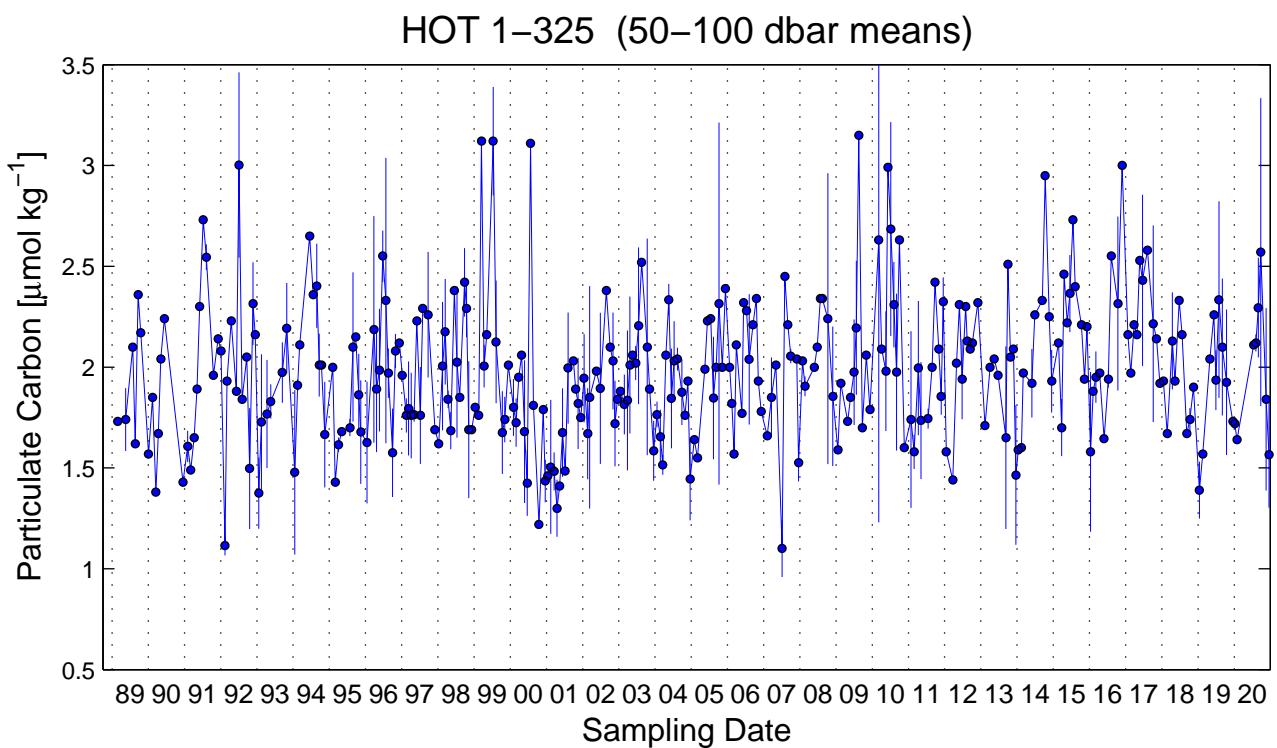
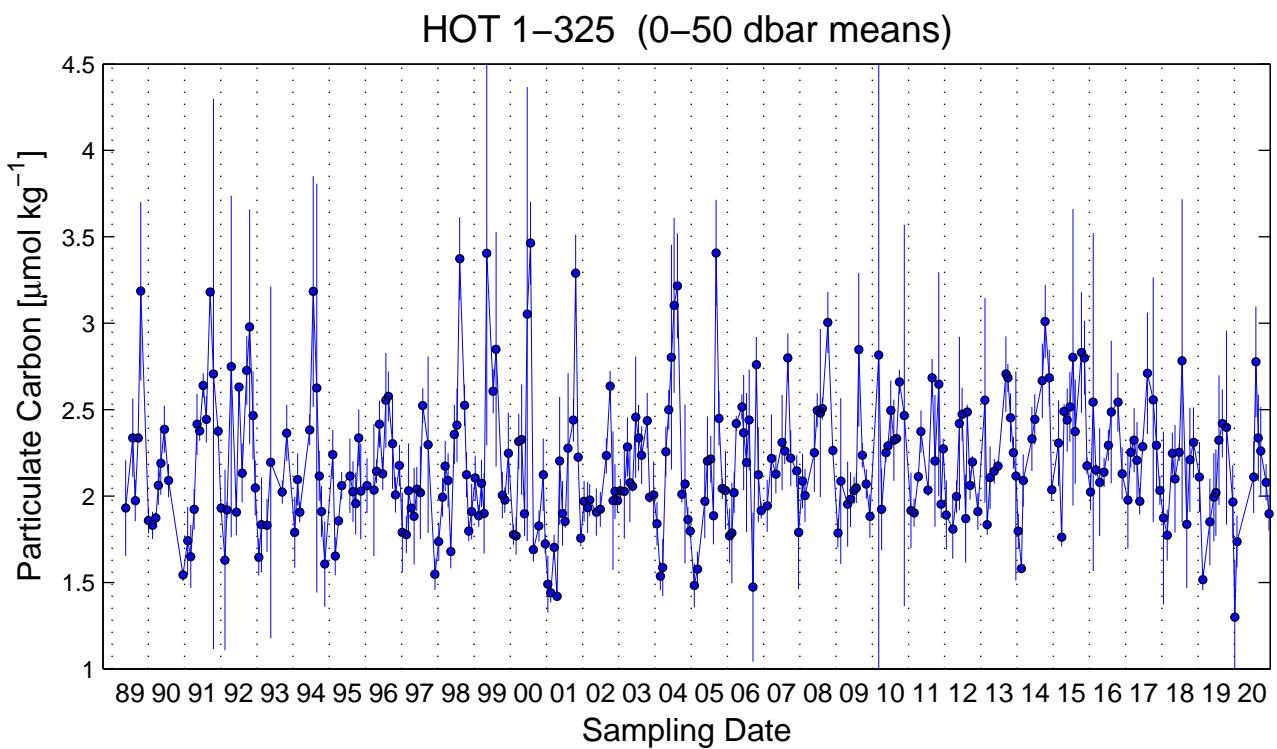


Figure 6.5.10

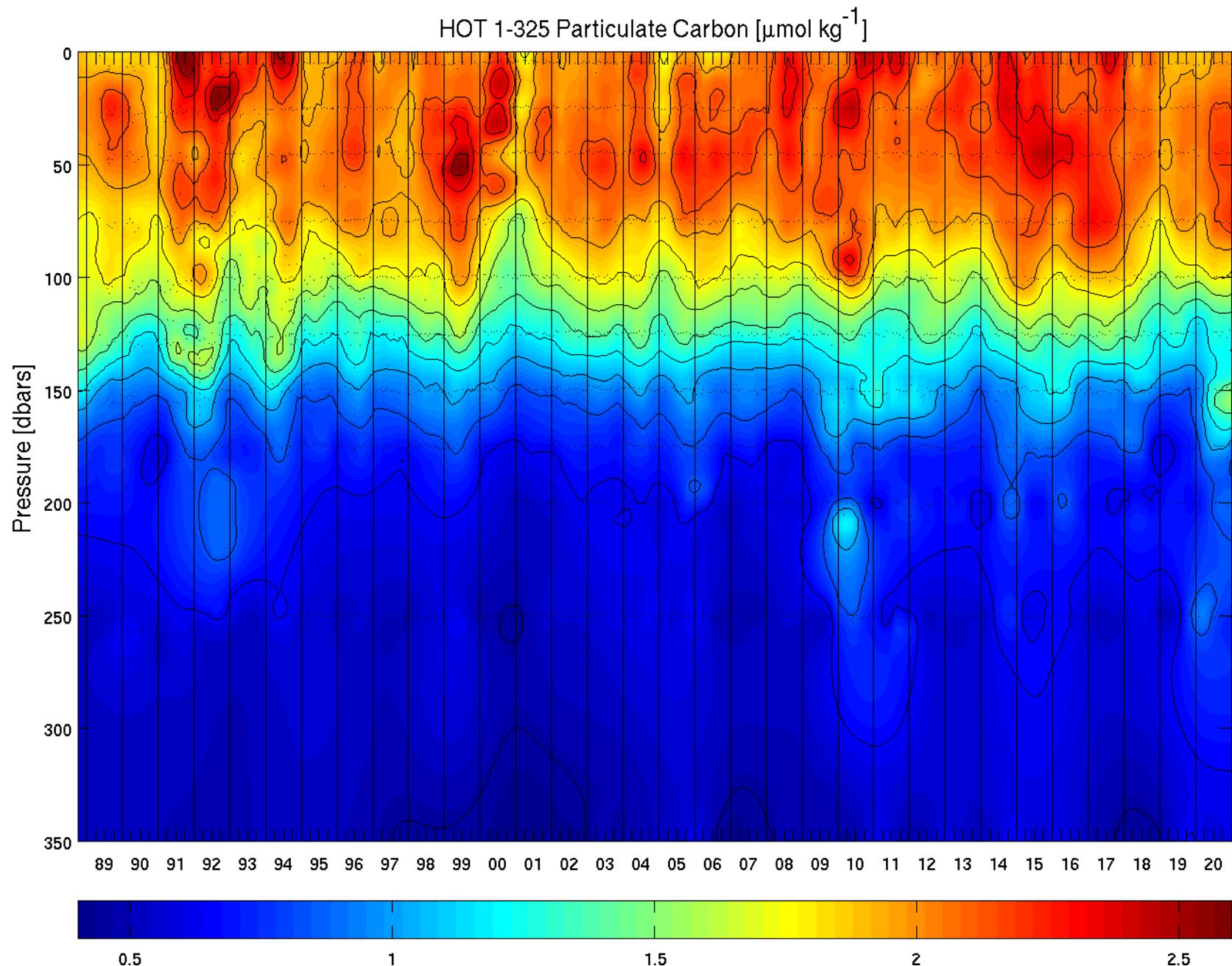
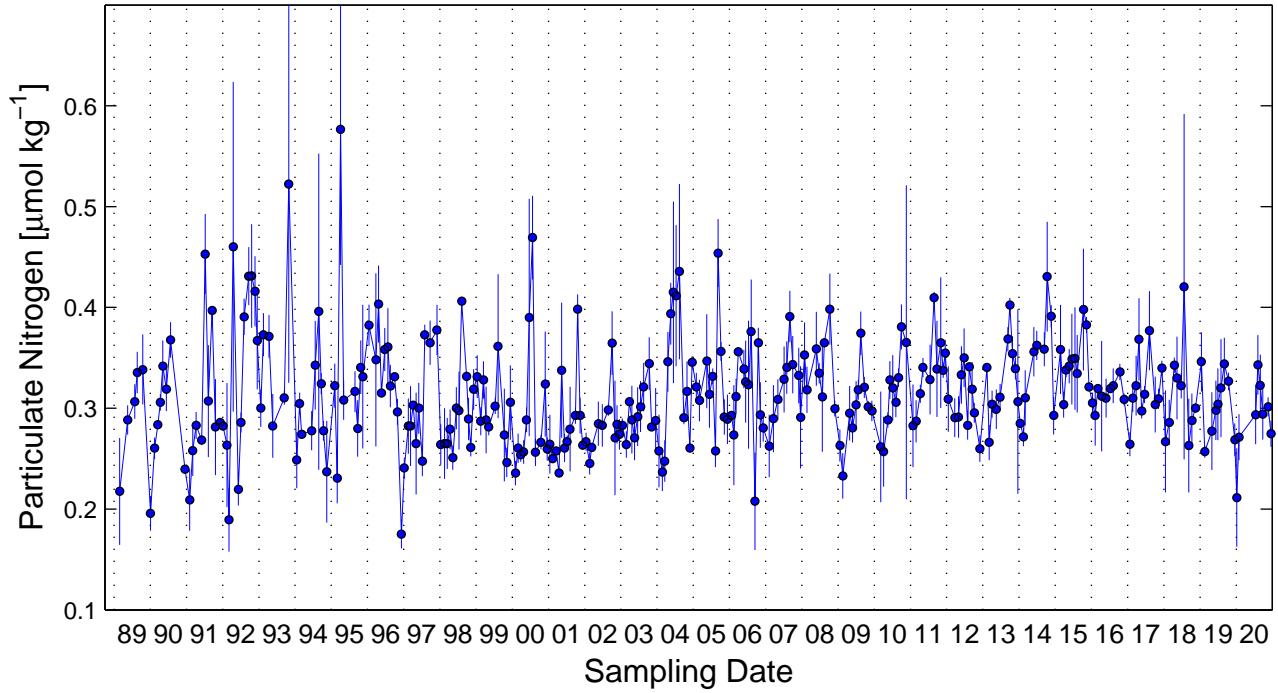


Figure 6.5.11

HOT 1–325 (0–50 dbar means)



HOT 1–325 (50–100 dbar means)

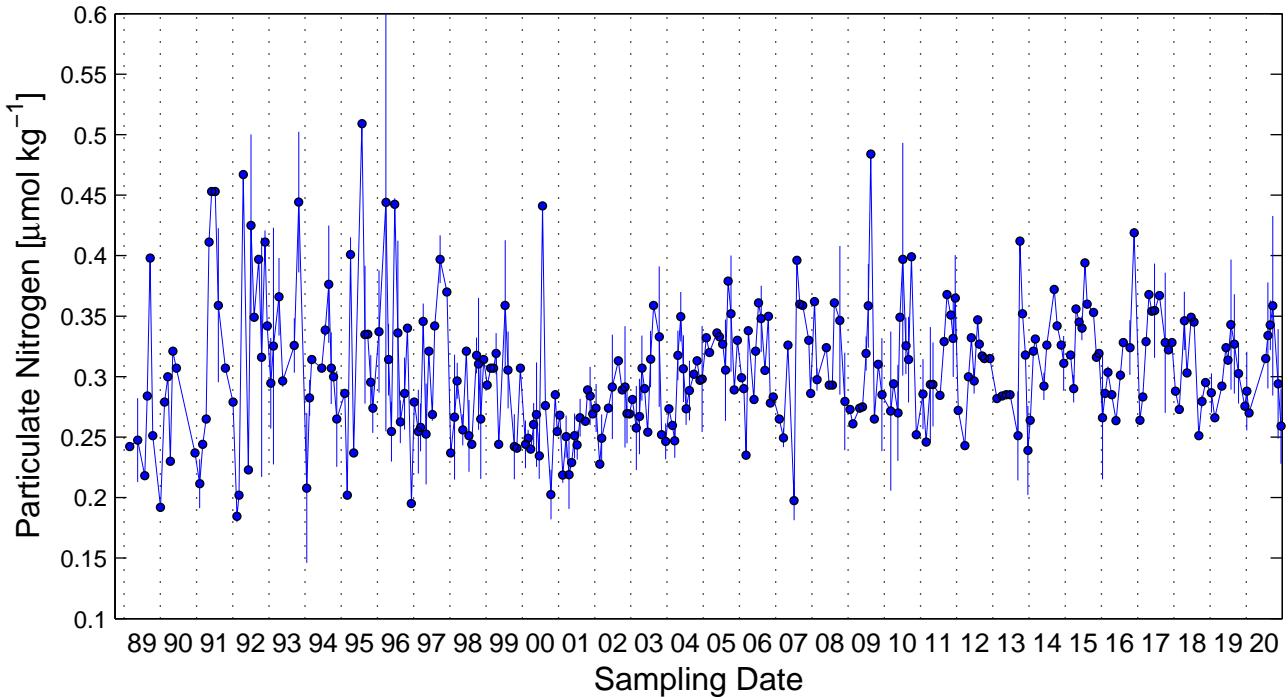


Figure 6.5.12

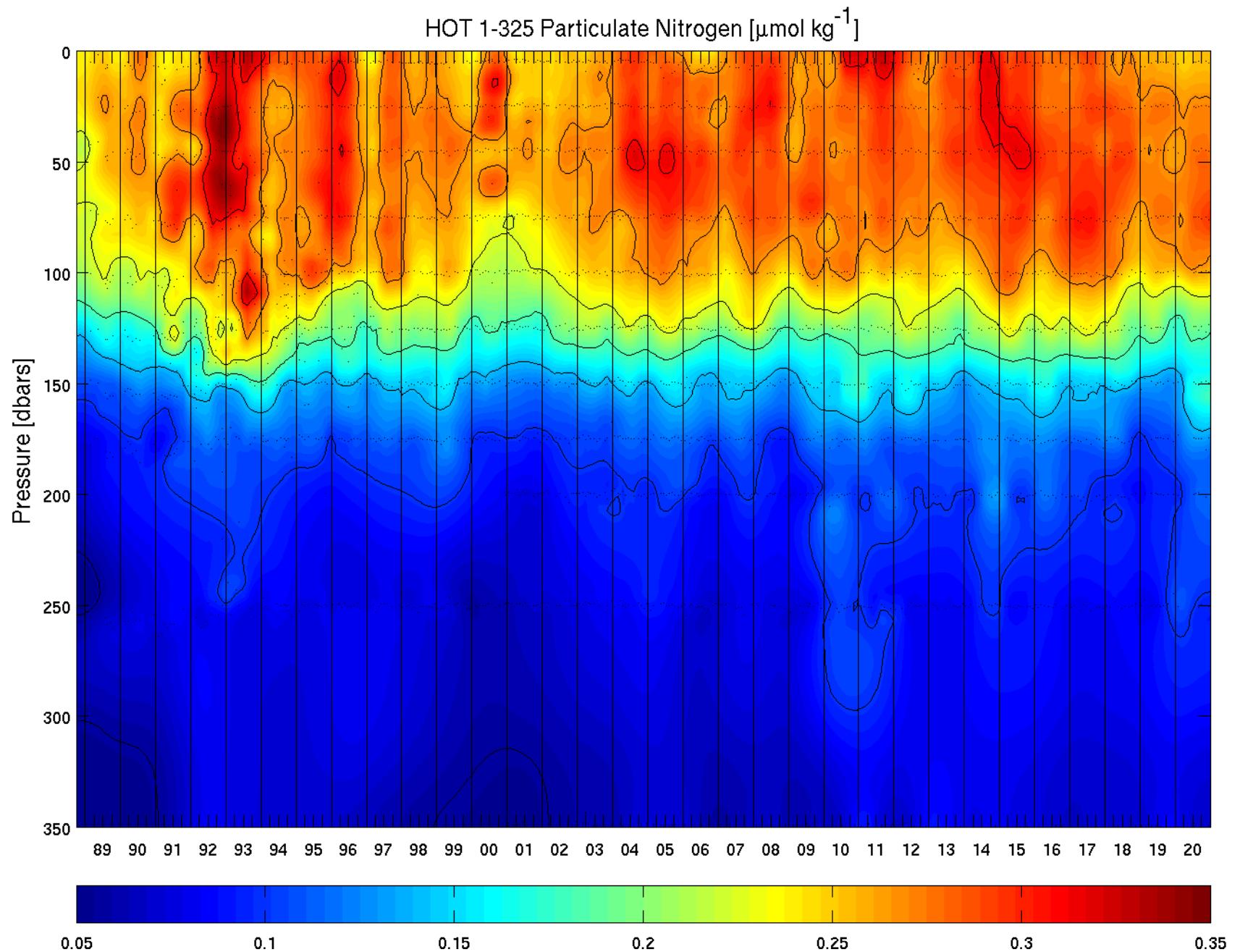


Figure 6.5.13

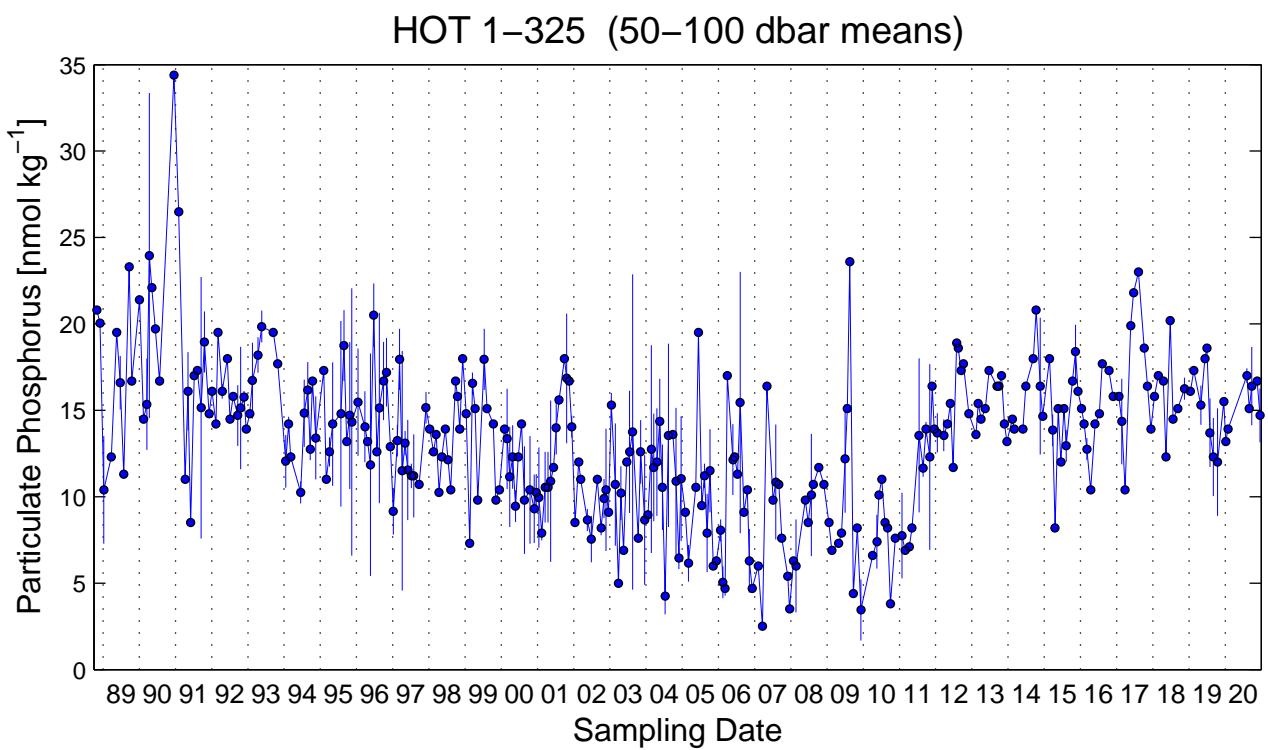
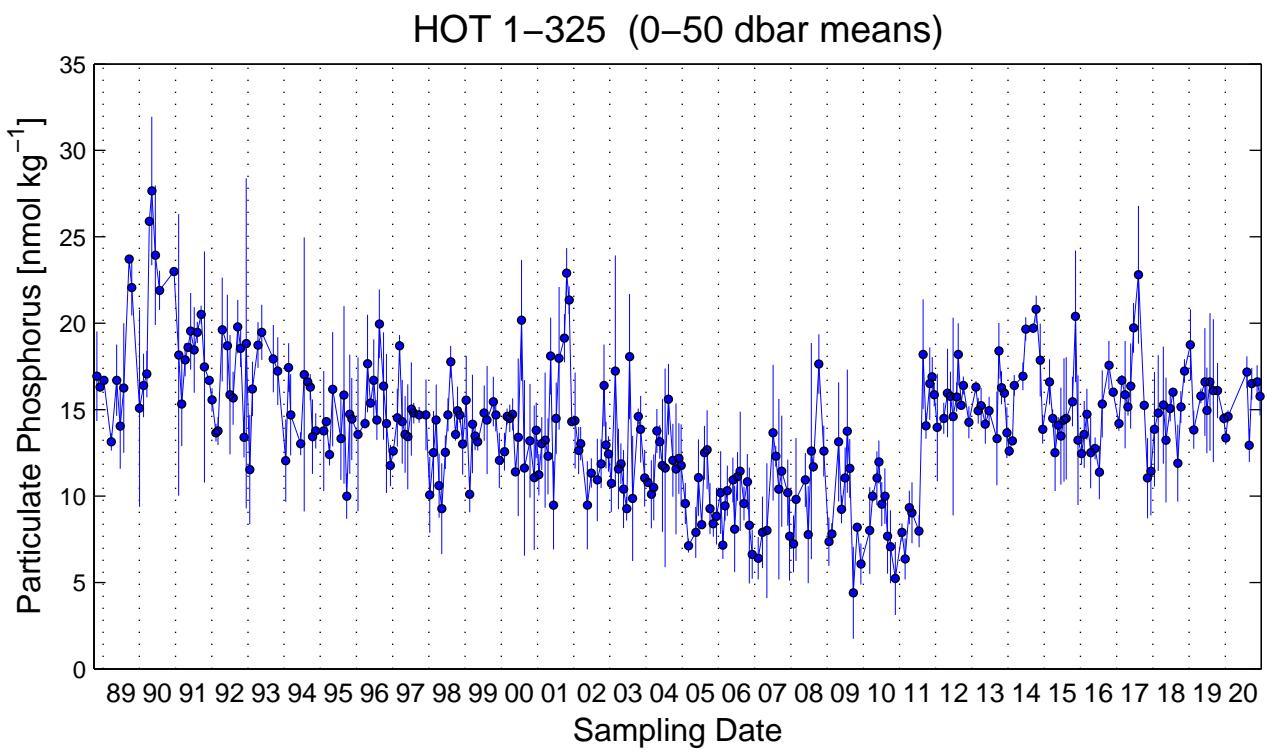


Figure 6.5.14

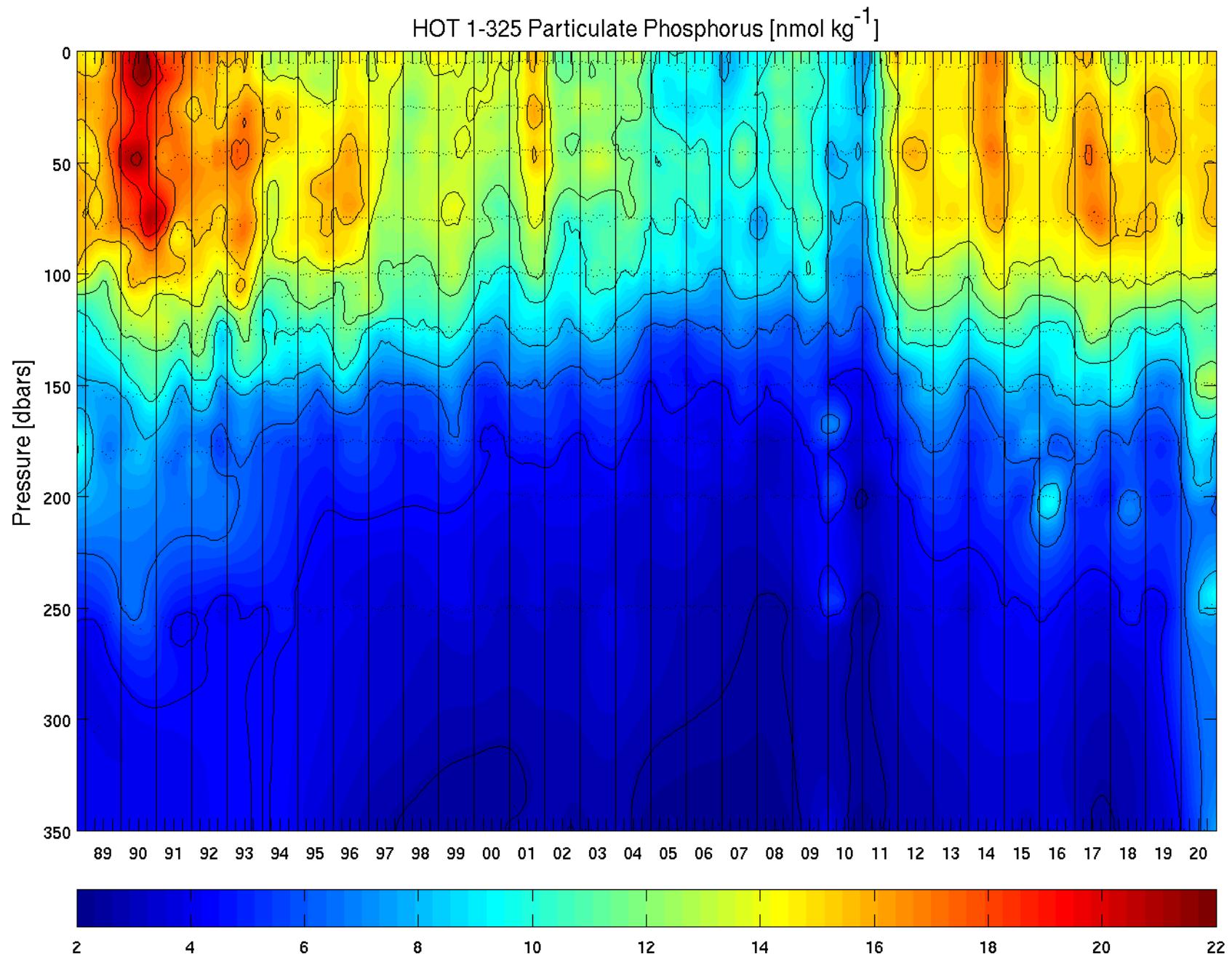
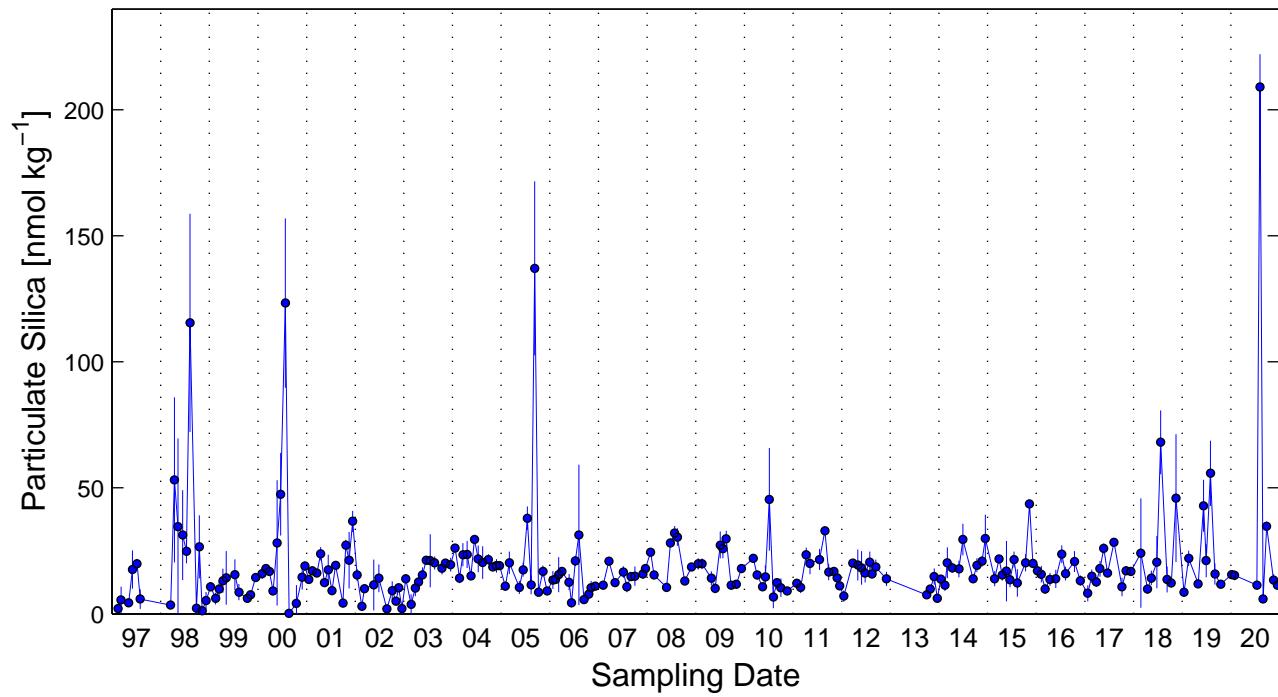


Figure 6.5.15

HOT 79–325 (0–50 dbar means)



HOT 79–325 (50–100 dbar means)

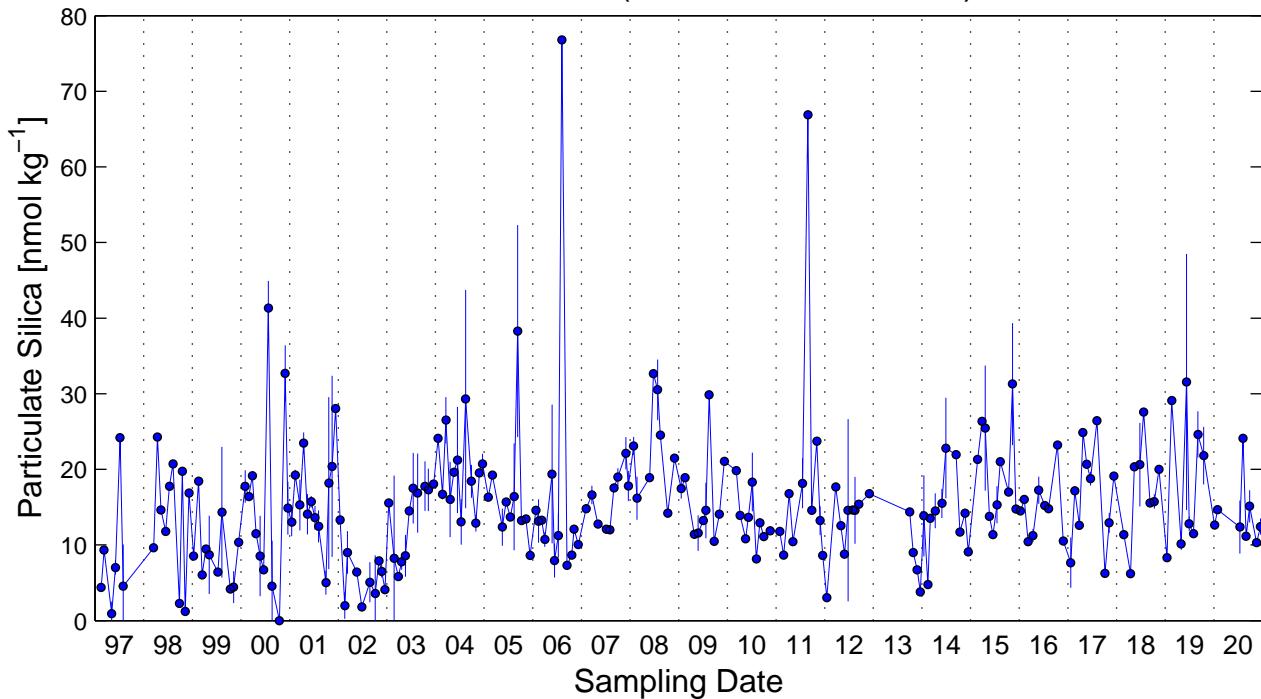


Figure 6.5.16

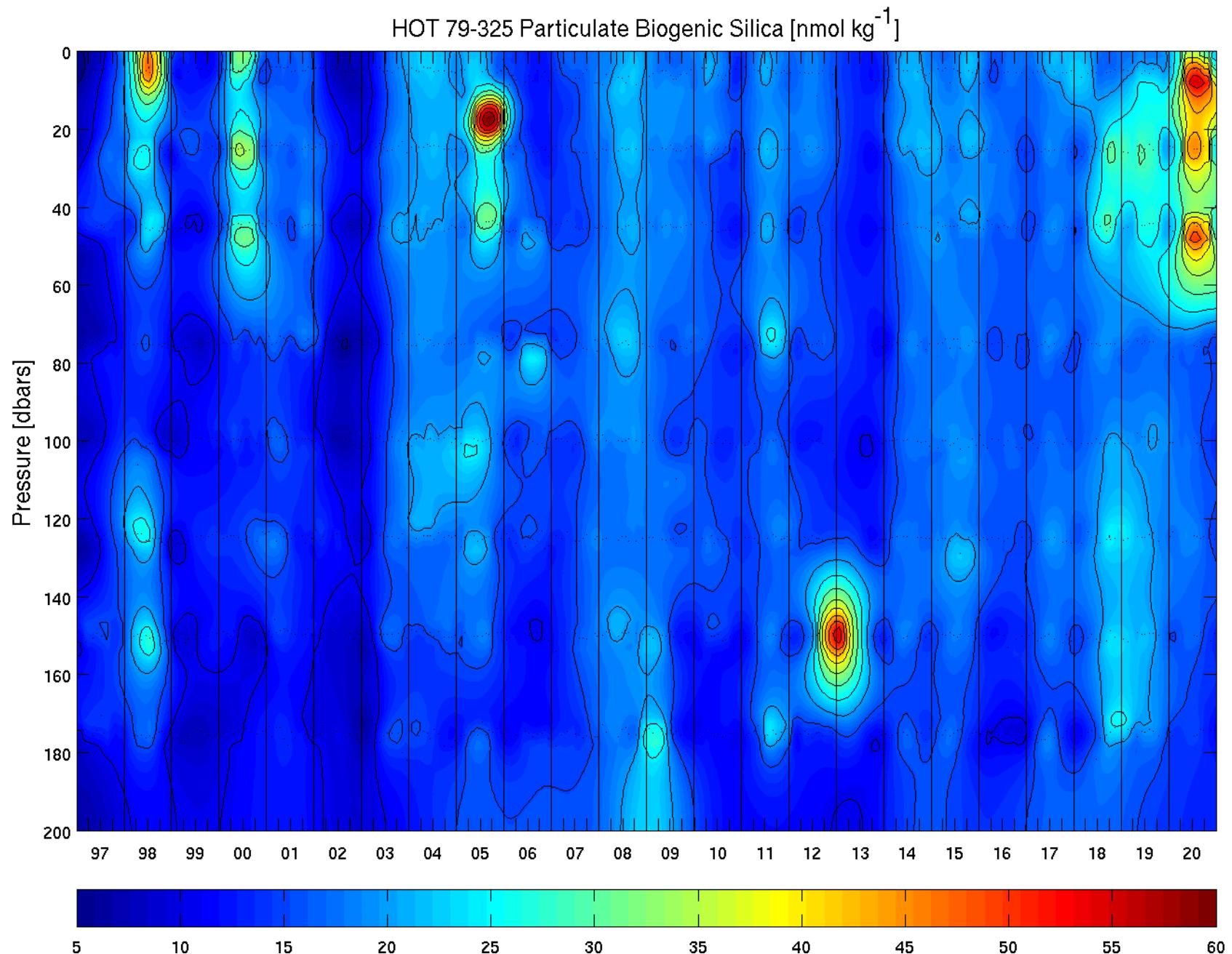


Figure 6.5.17

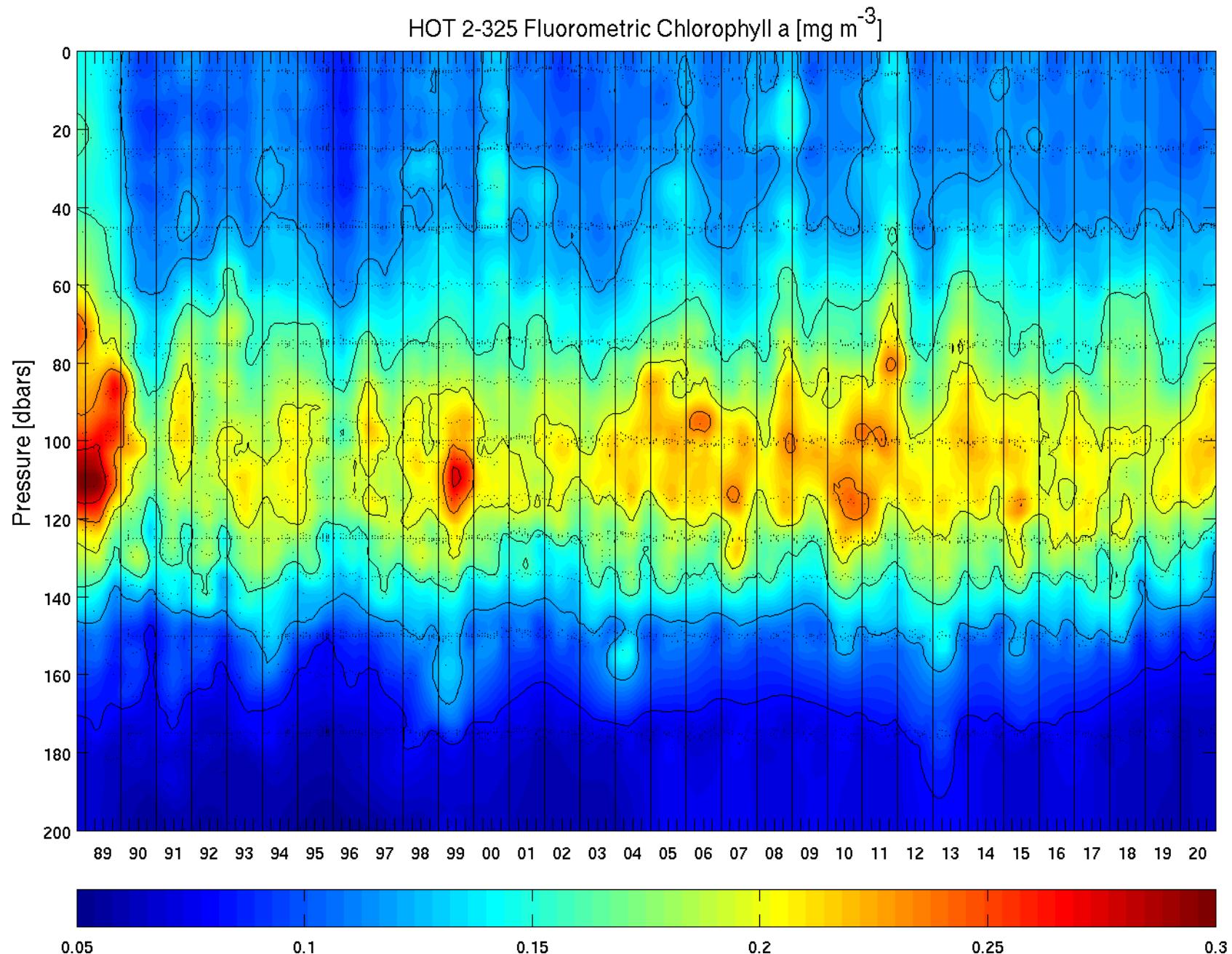


Figure 6.5.18

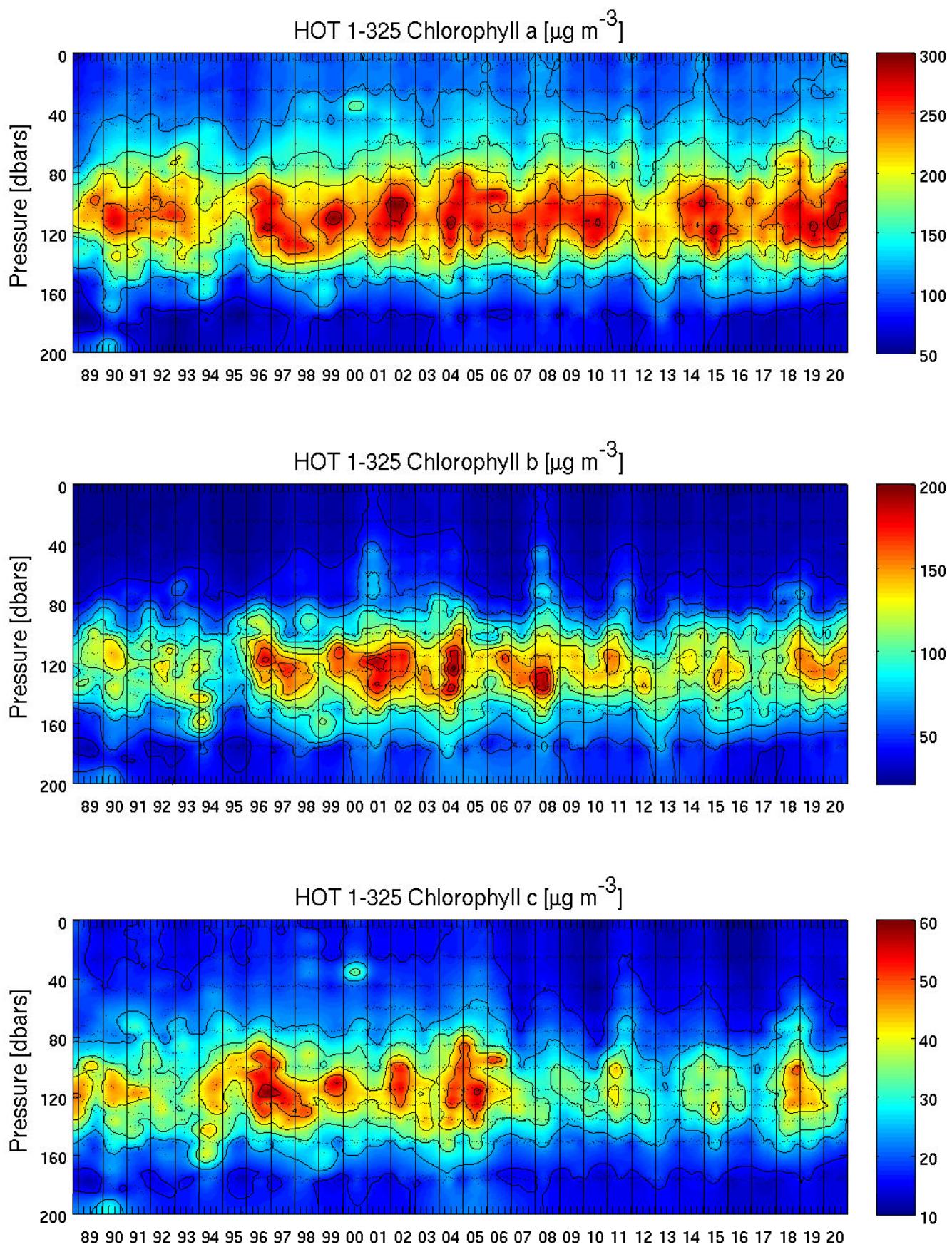


Figure 6.5.19

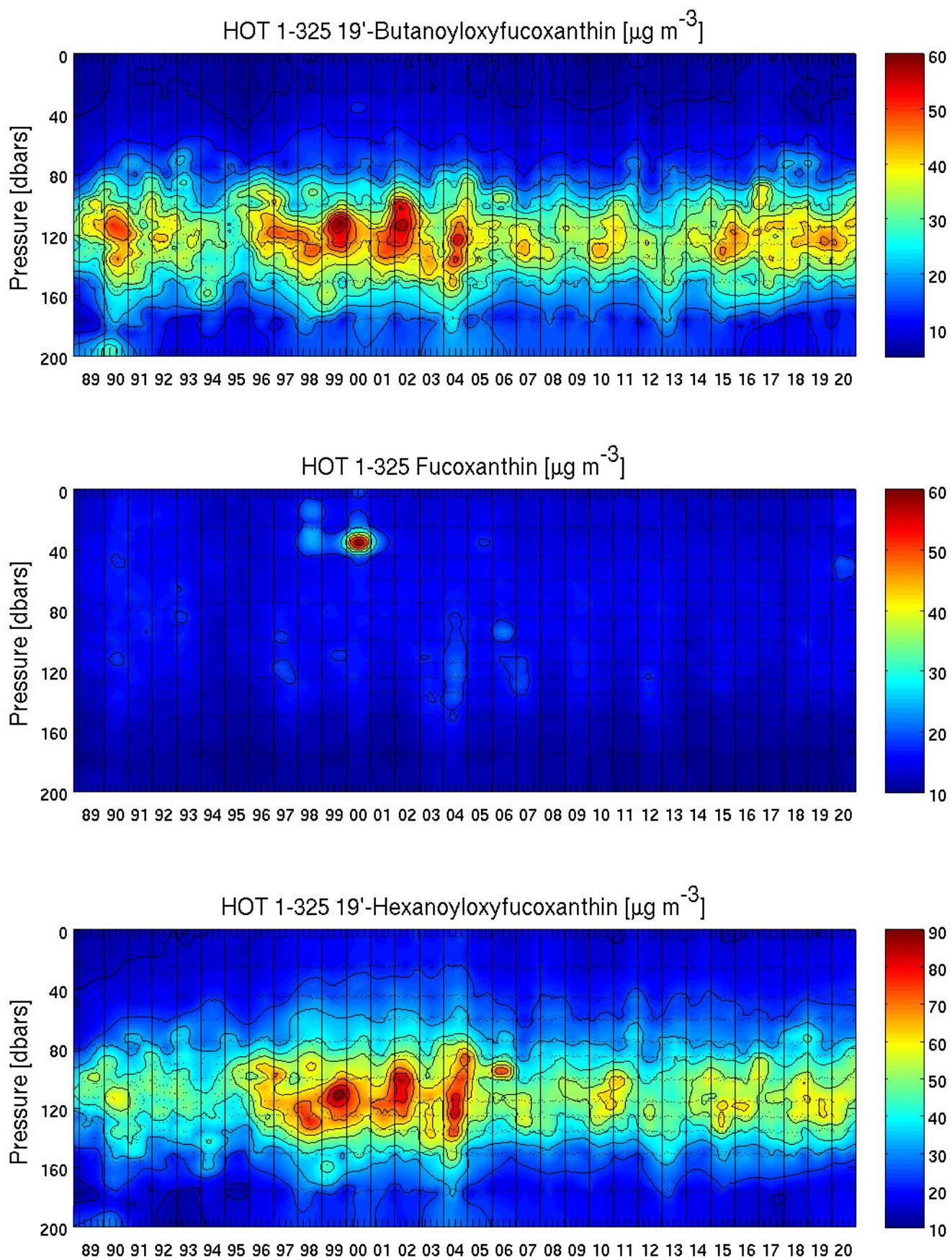


Figure 6.5.20

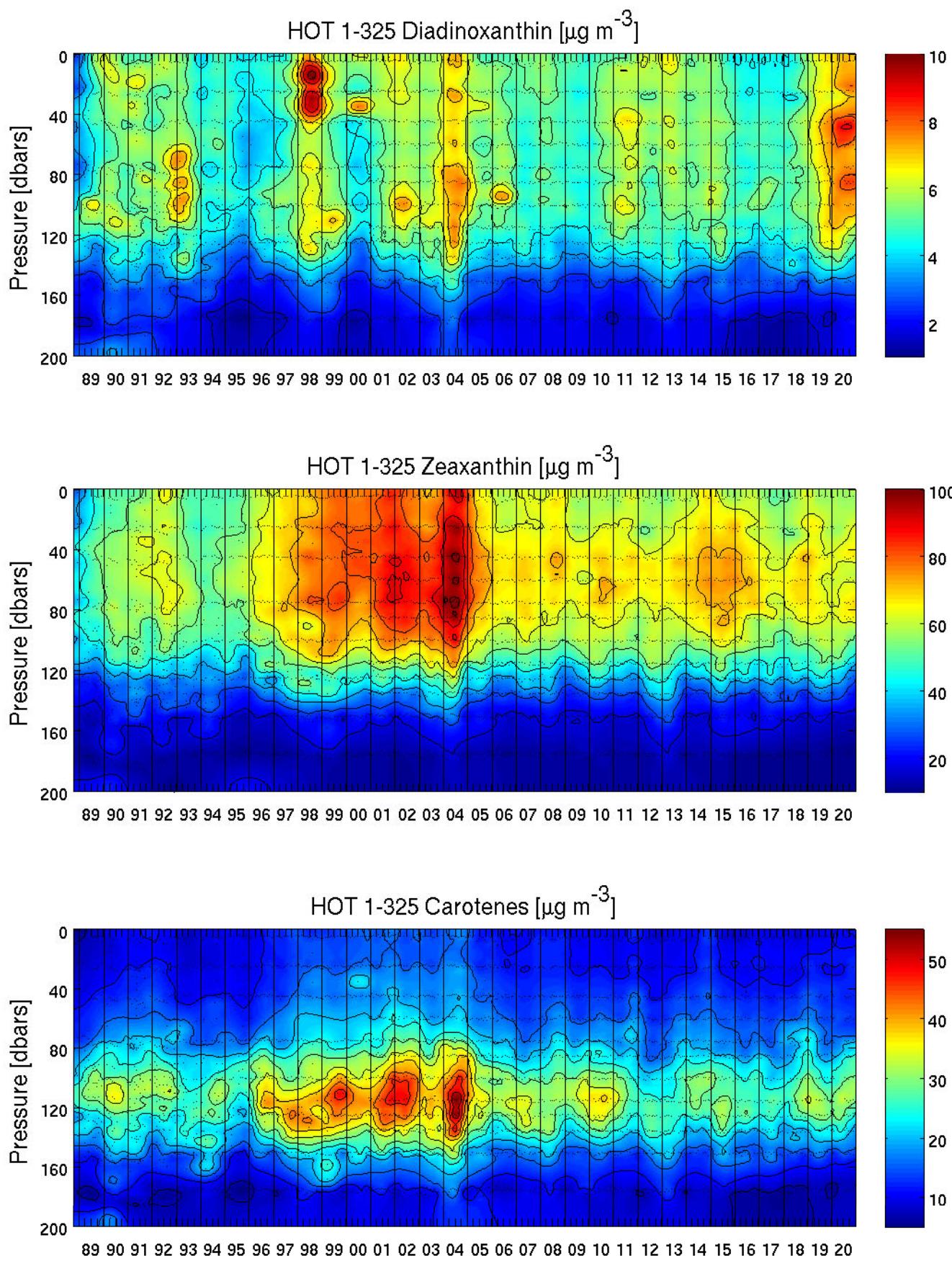


Figure 6.5.21

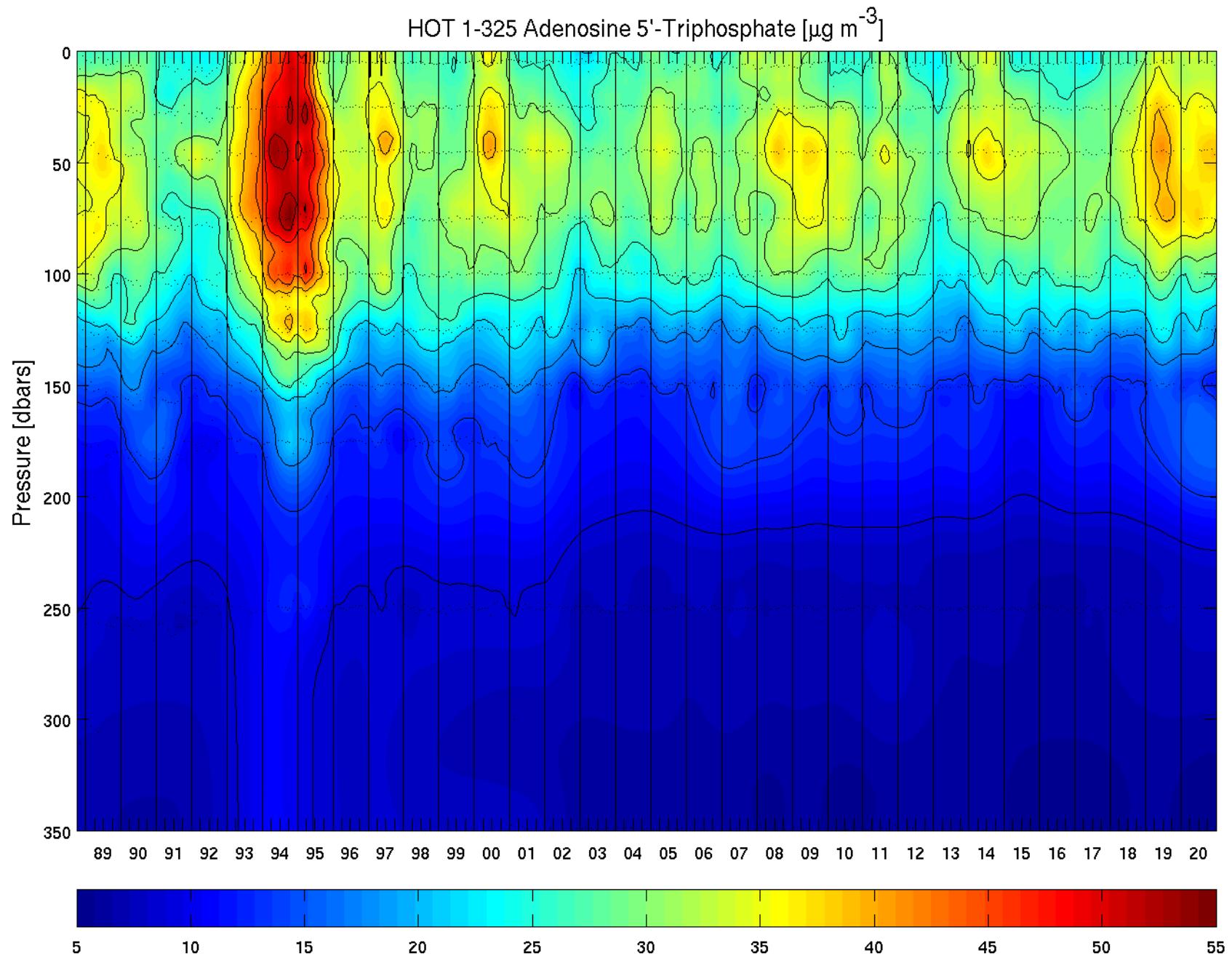


Figure 6.5.22

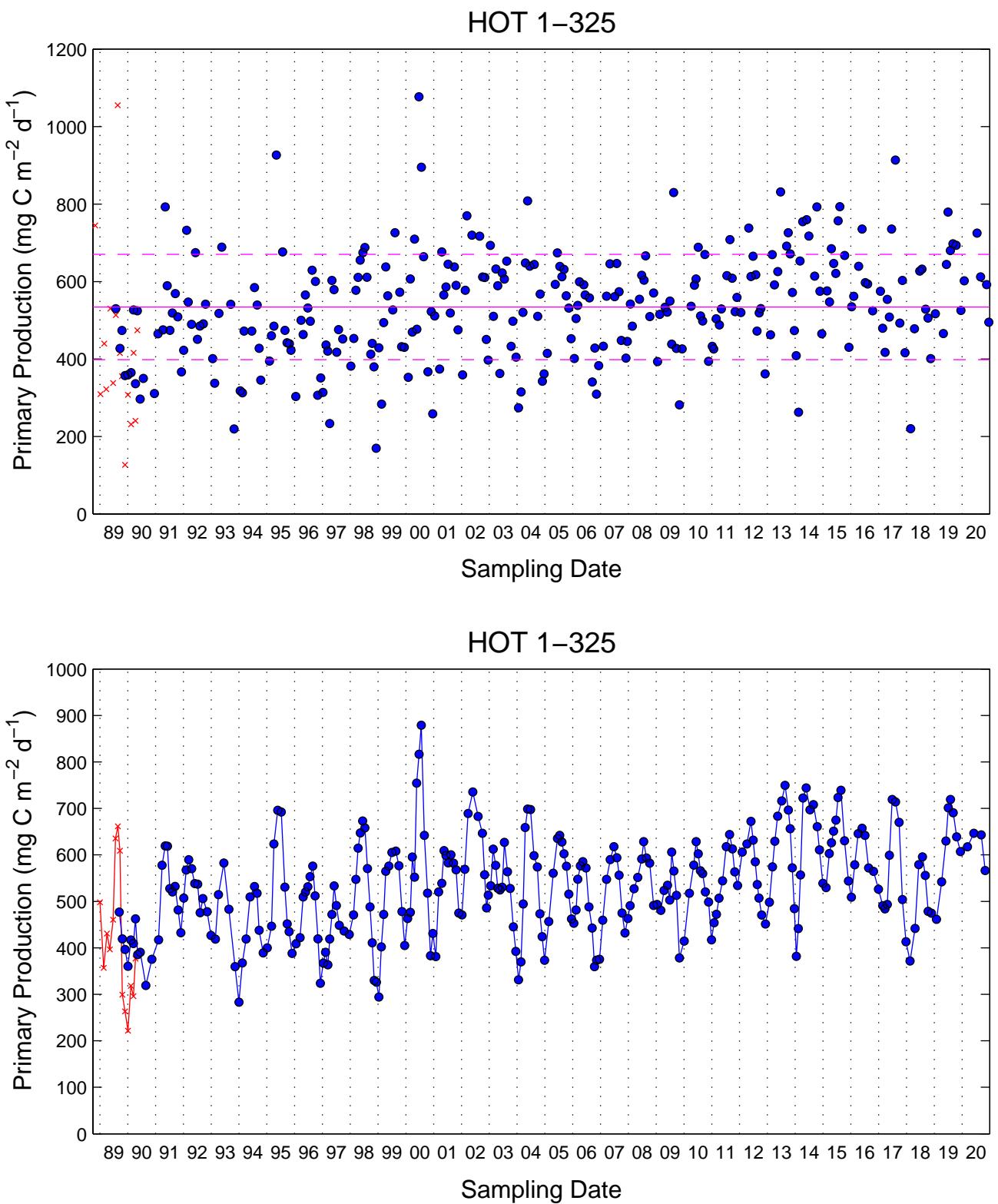


Figure 6.6.1

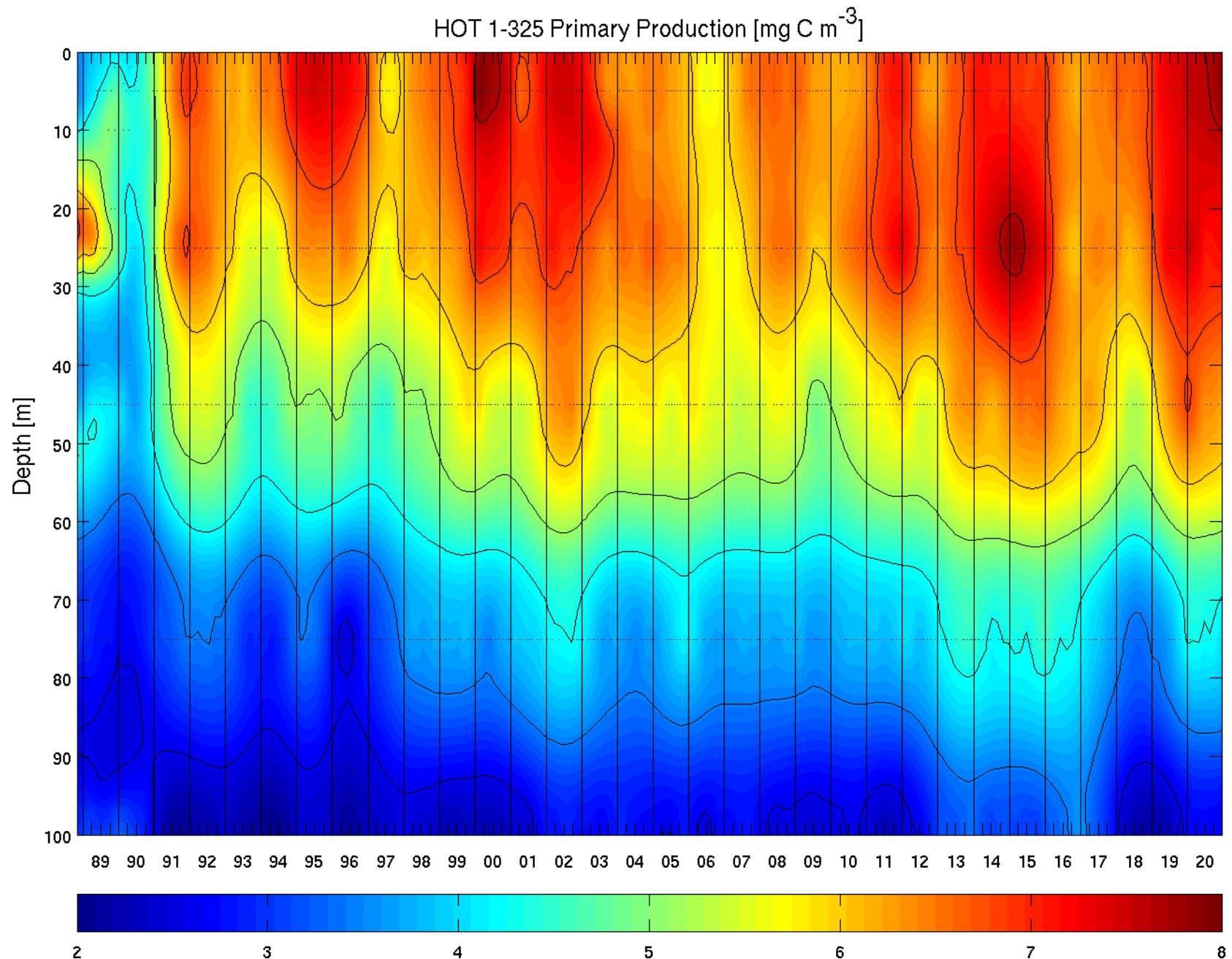


Figure 6.6.2

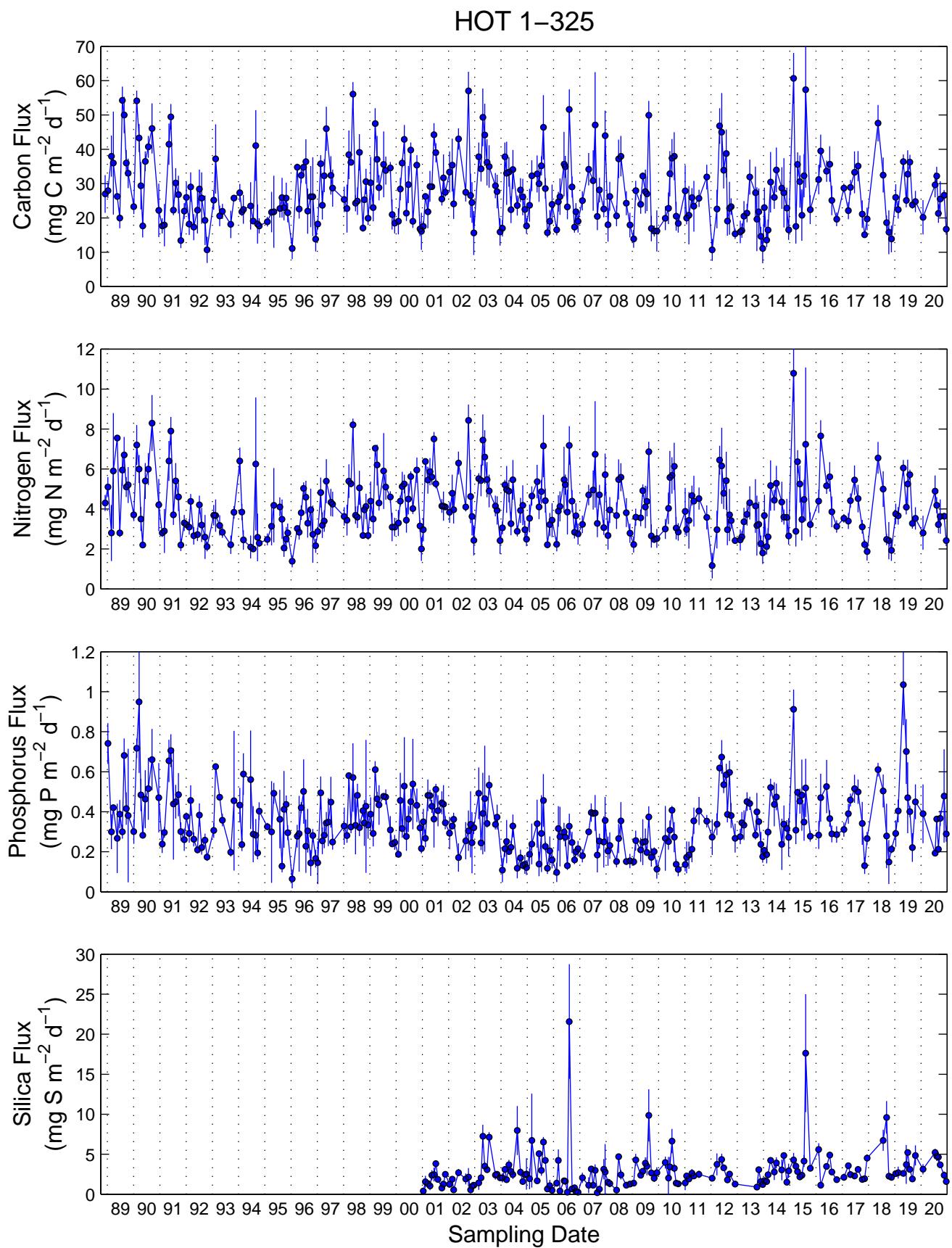


Figure 6.6.3

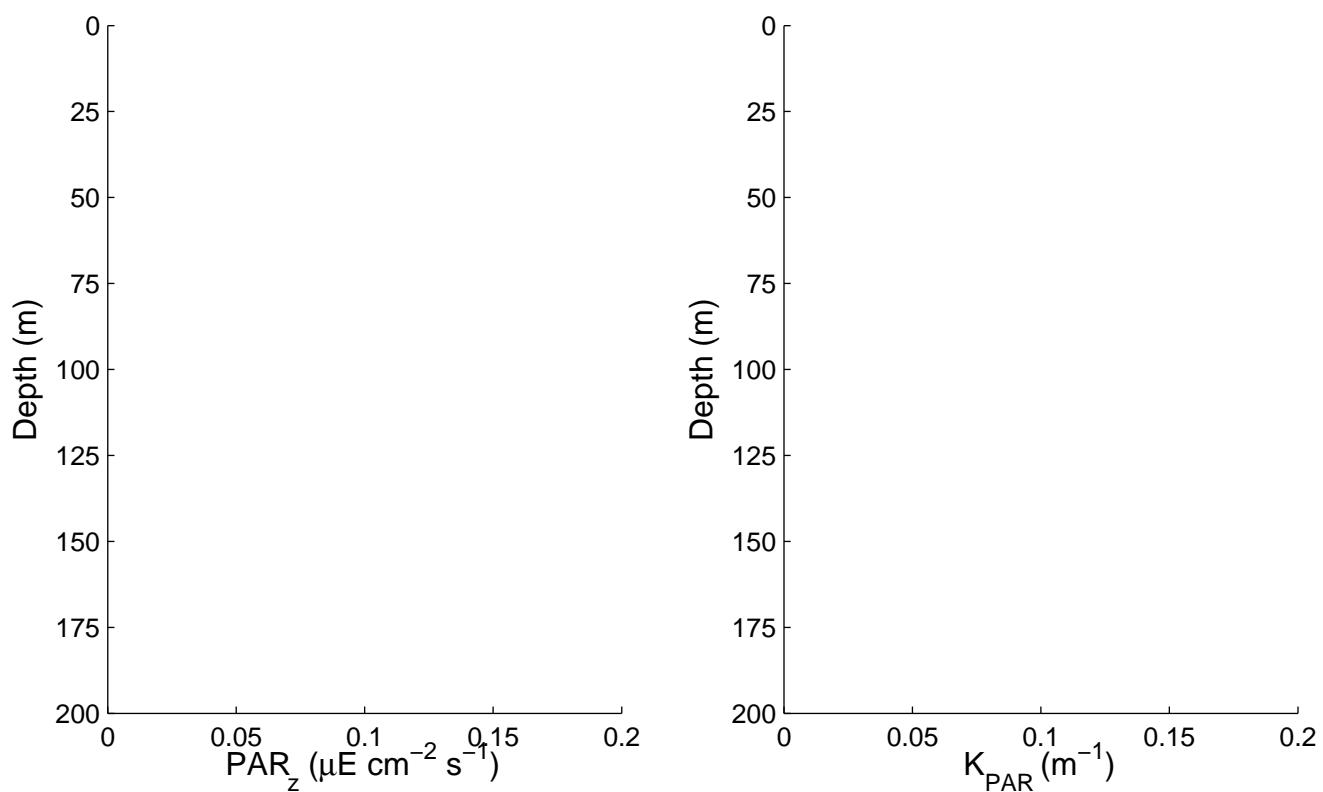
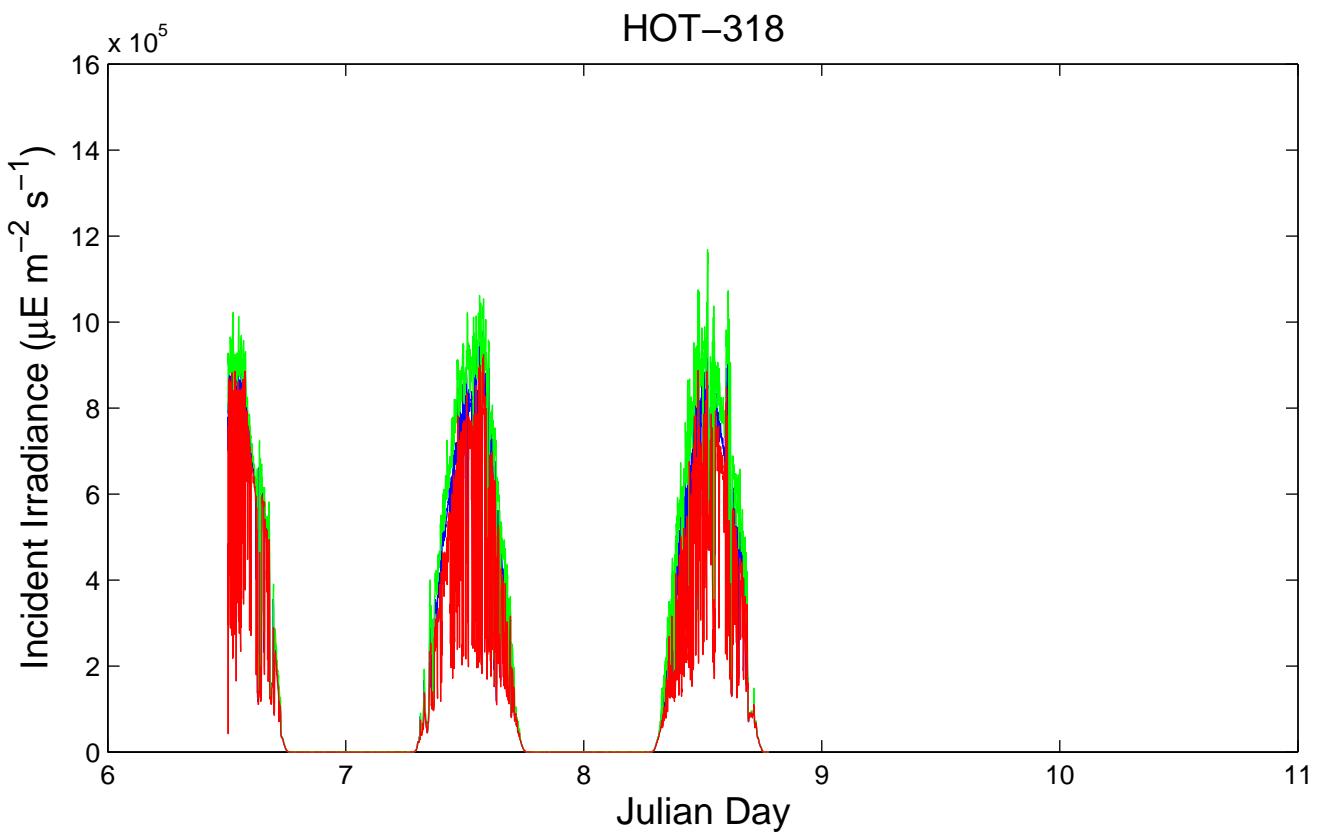


Figure 6.7.1a

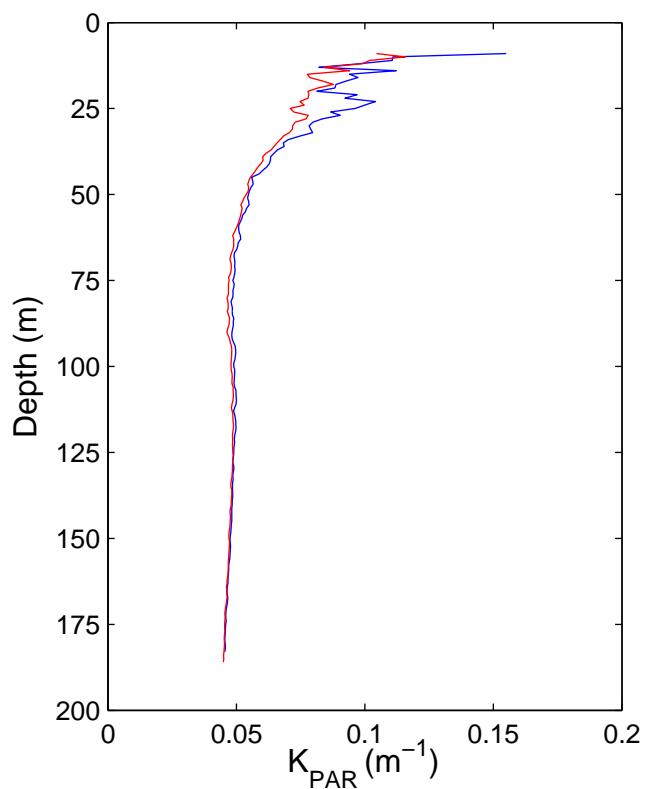
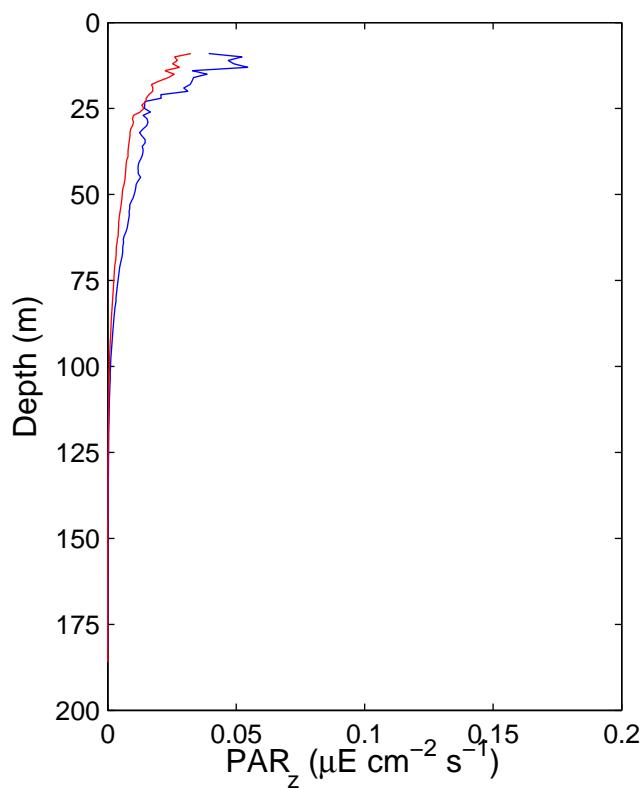
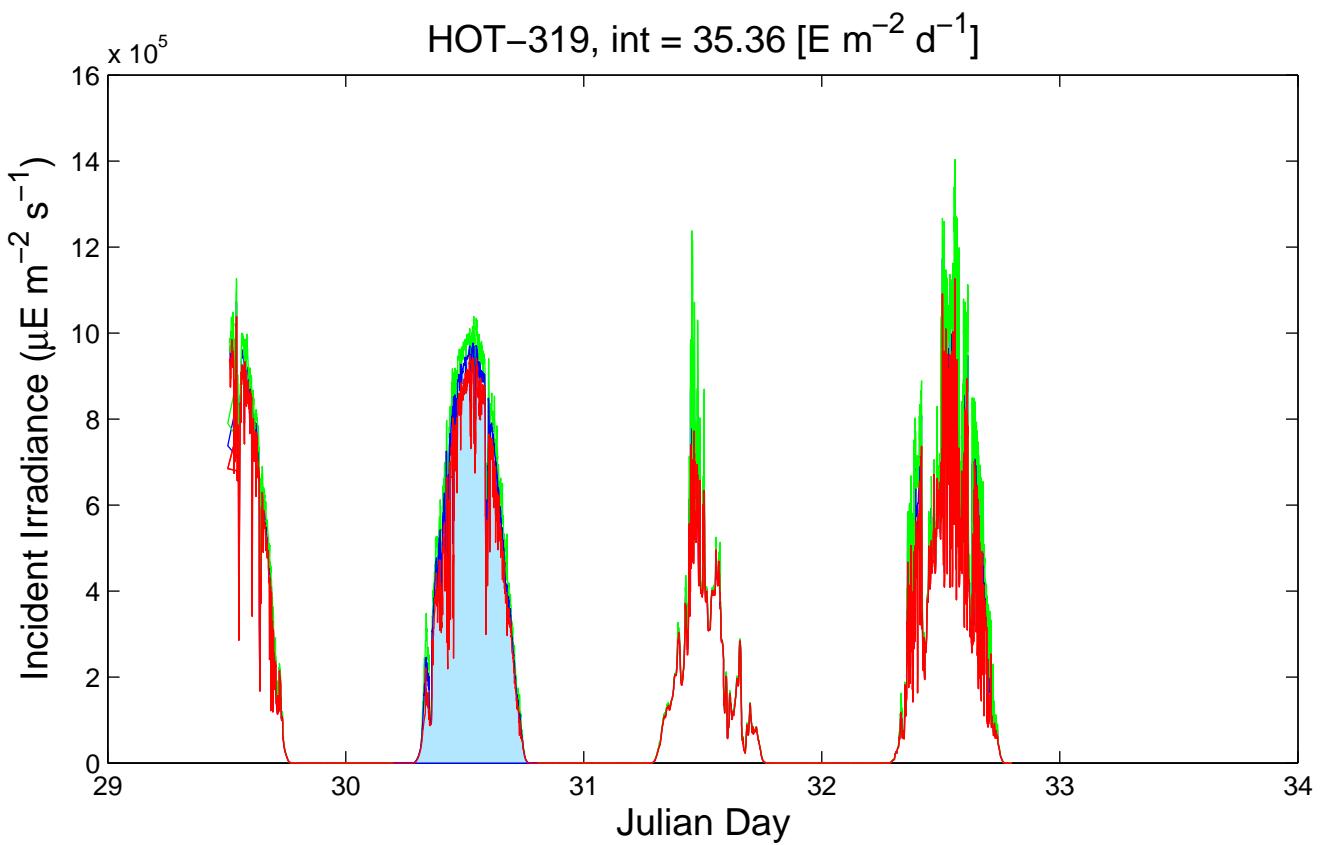


Figure 6.7.1b

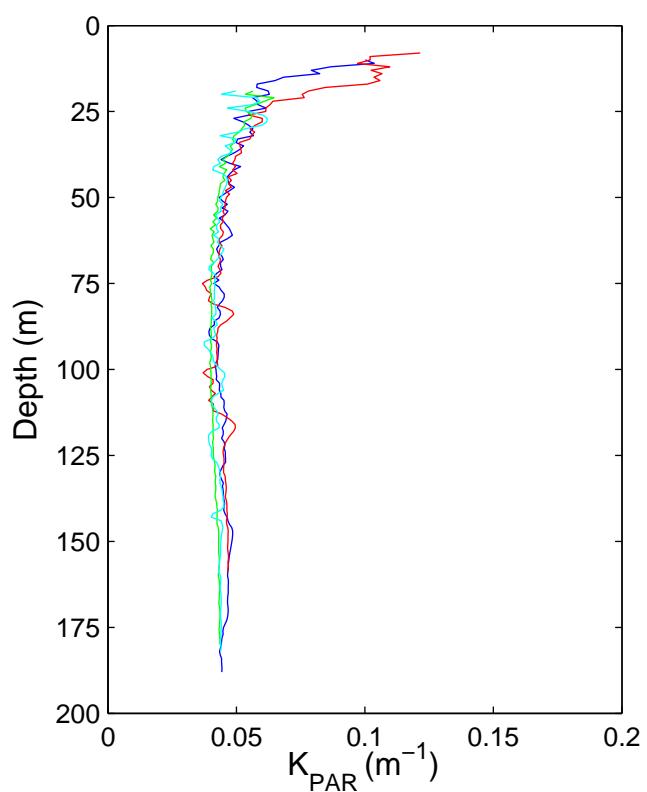
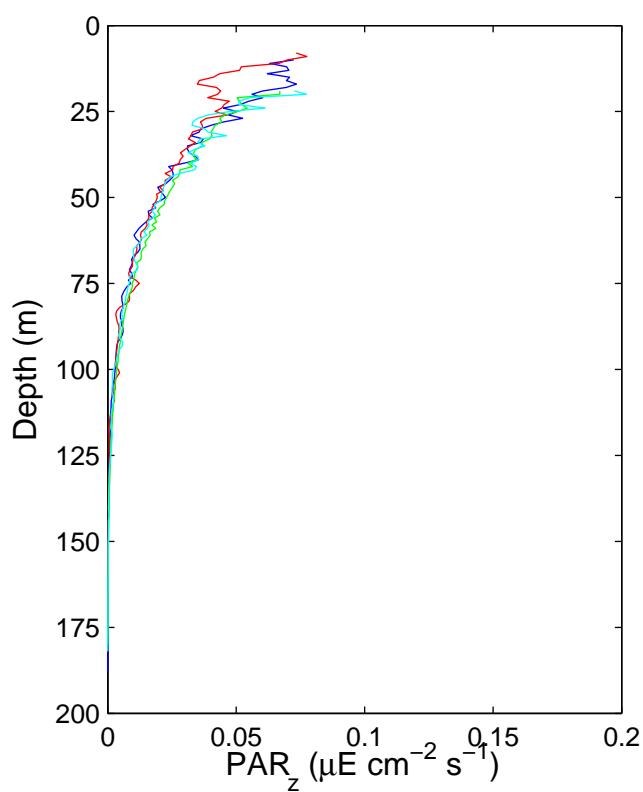
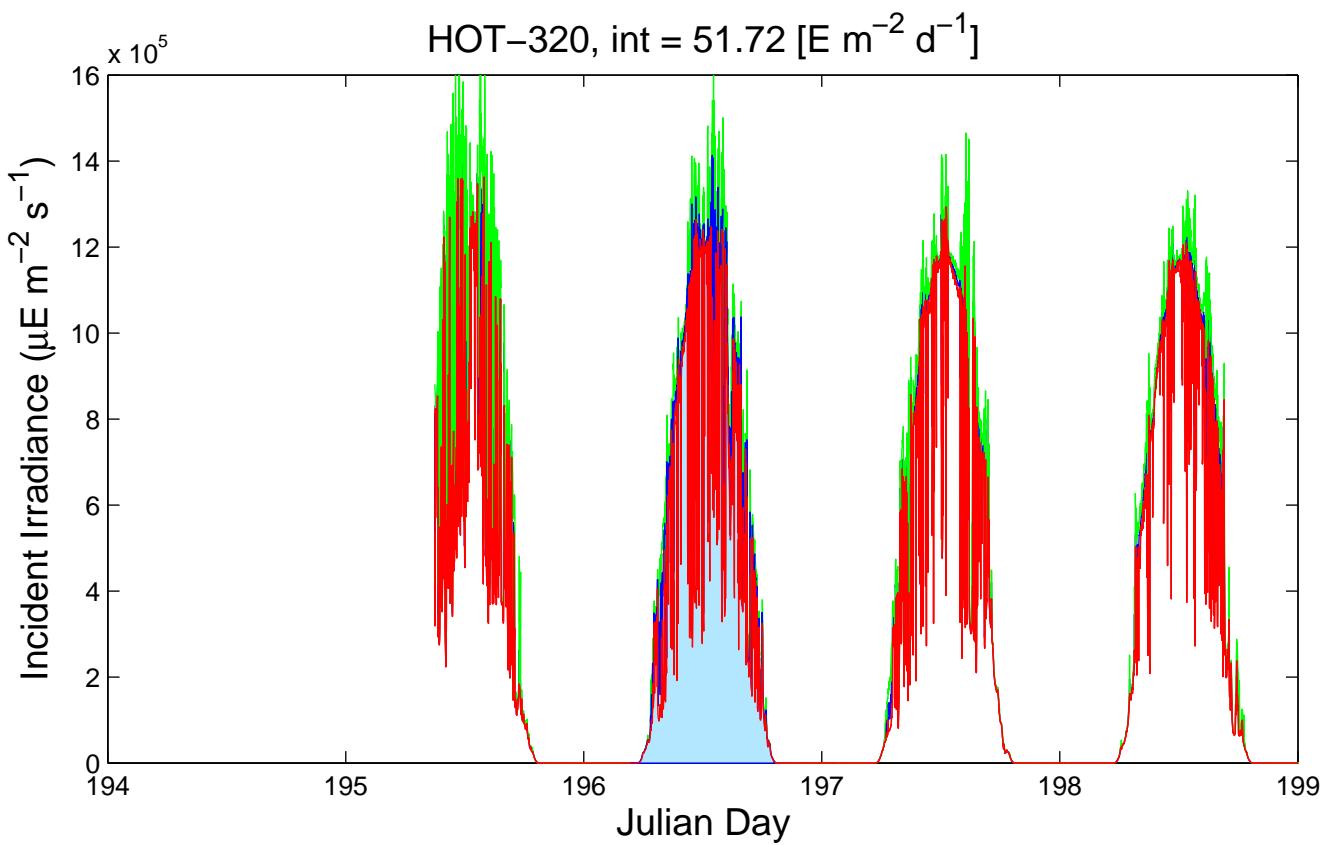


Figure 6.7.1c

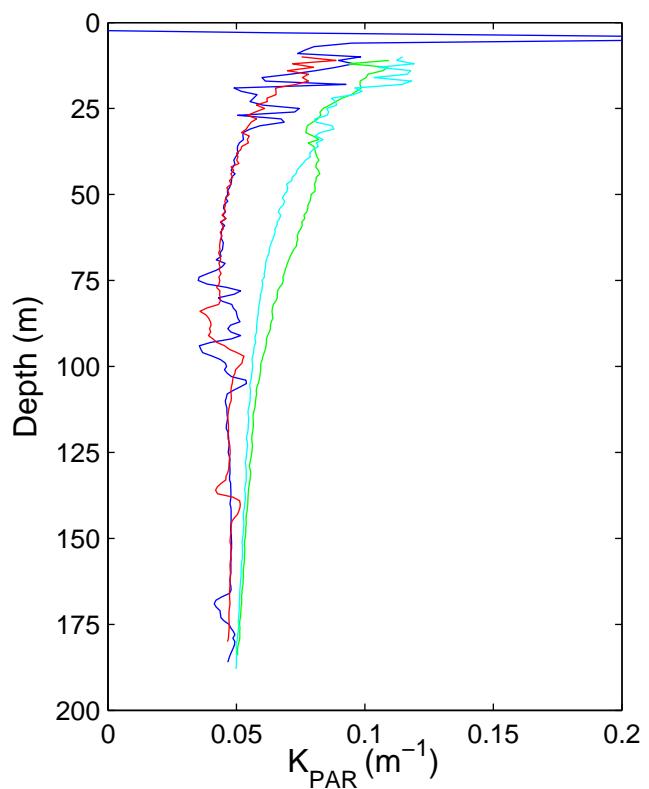
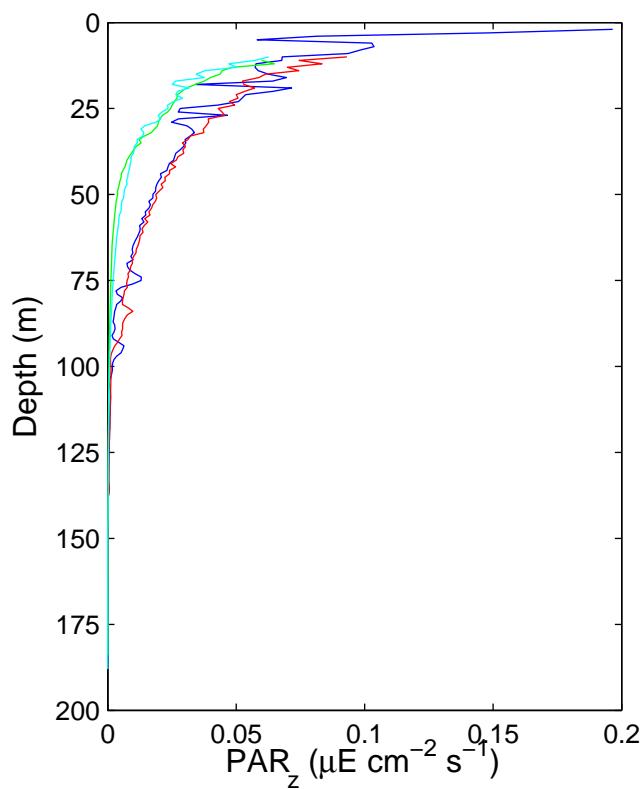
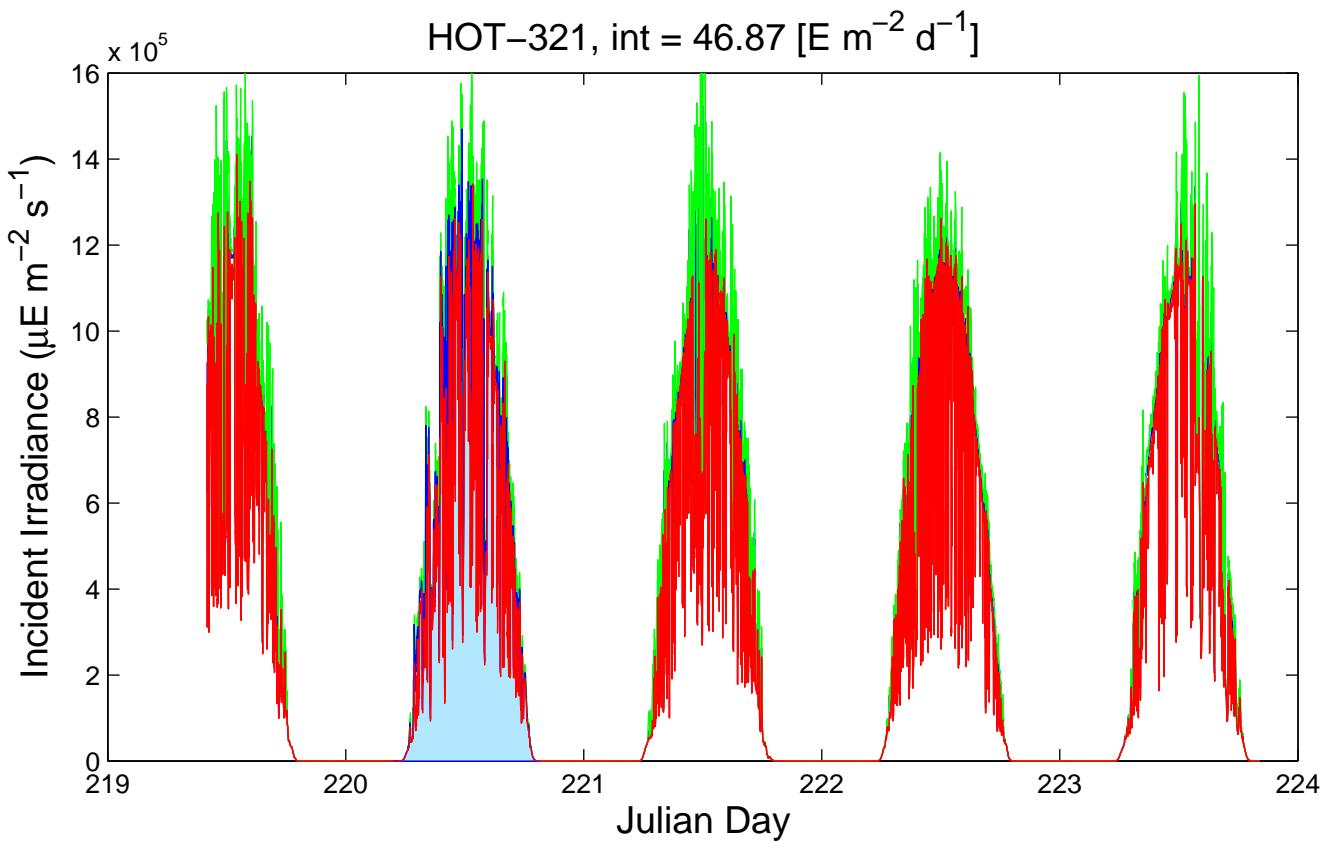


Figure 6.7.1d

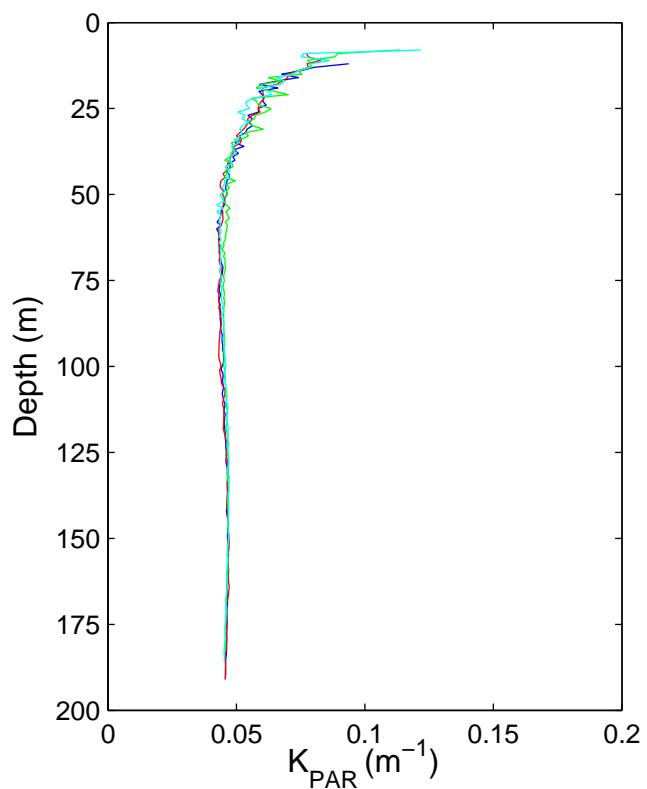
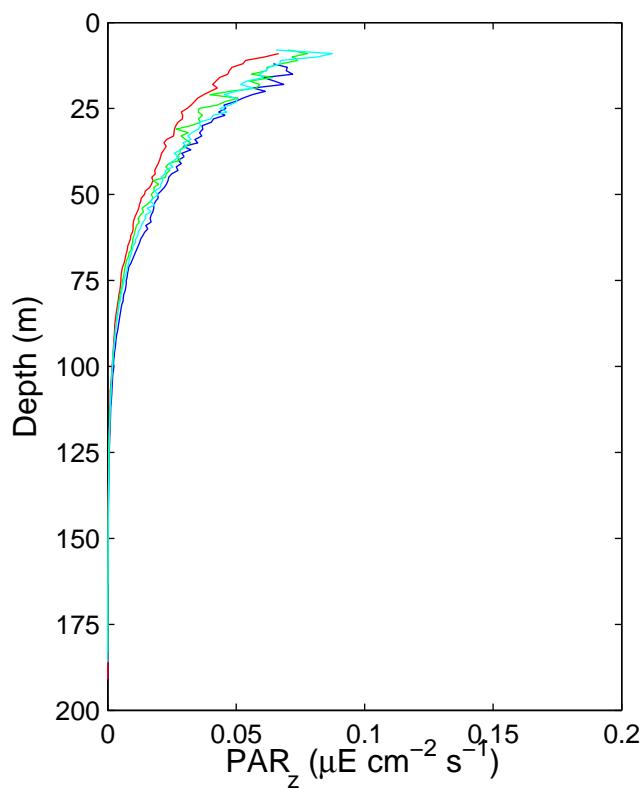
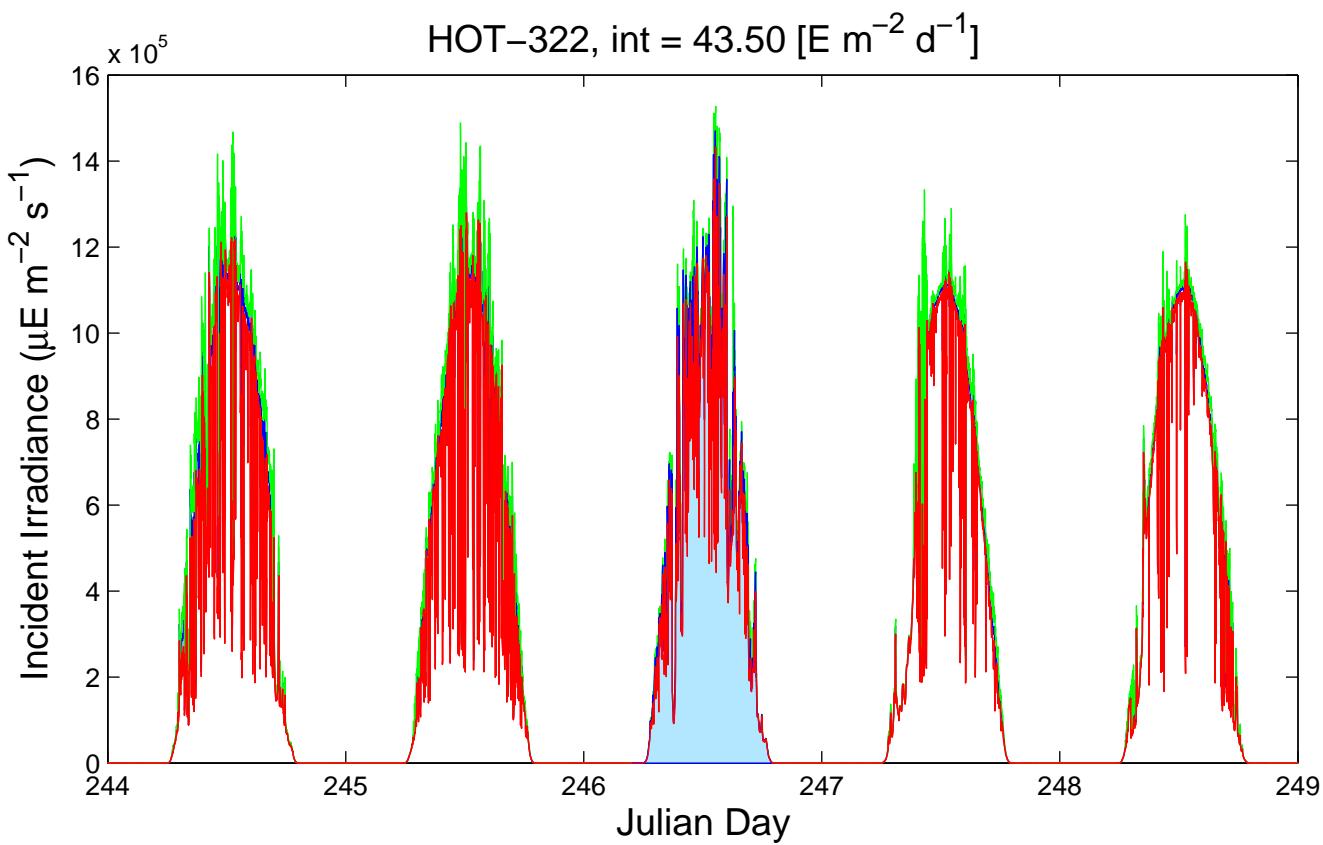


Figure 6.7.1e

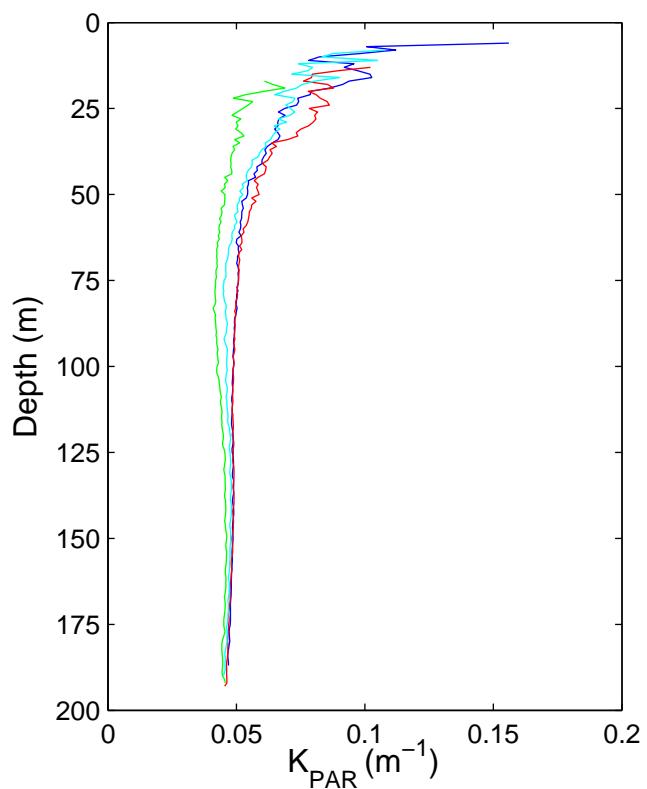
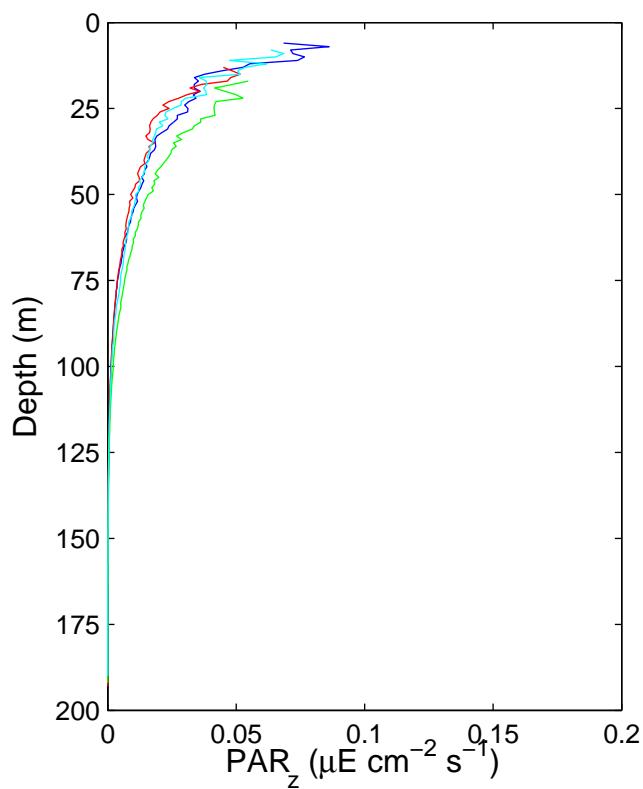
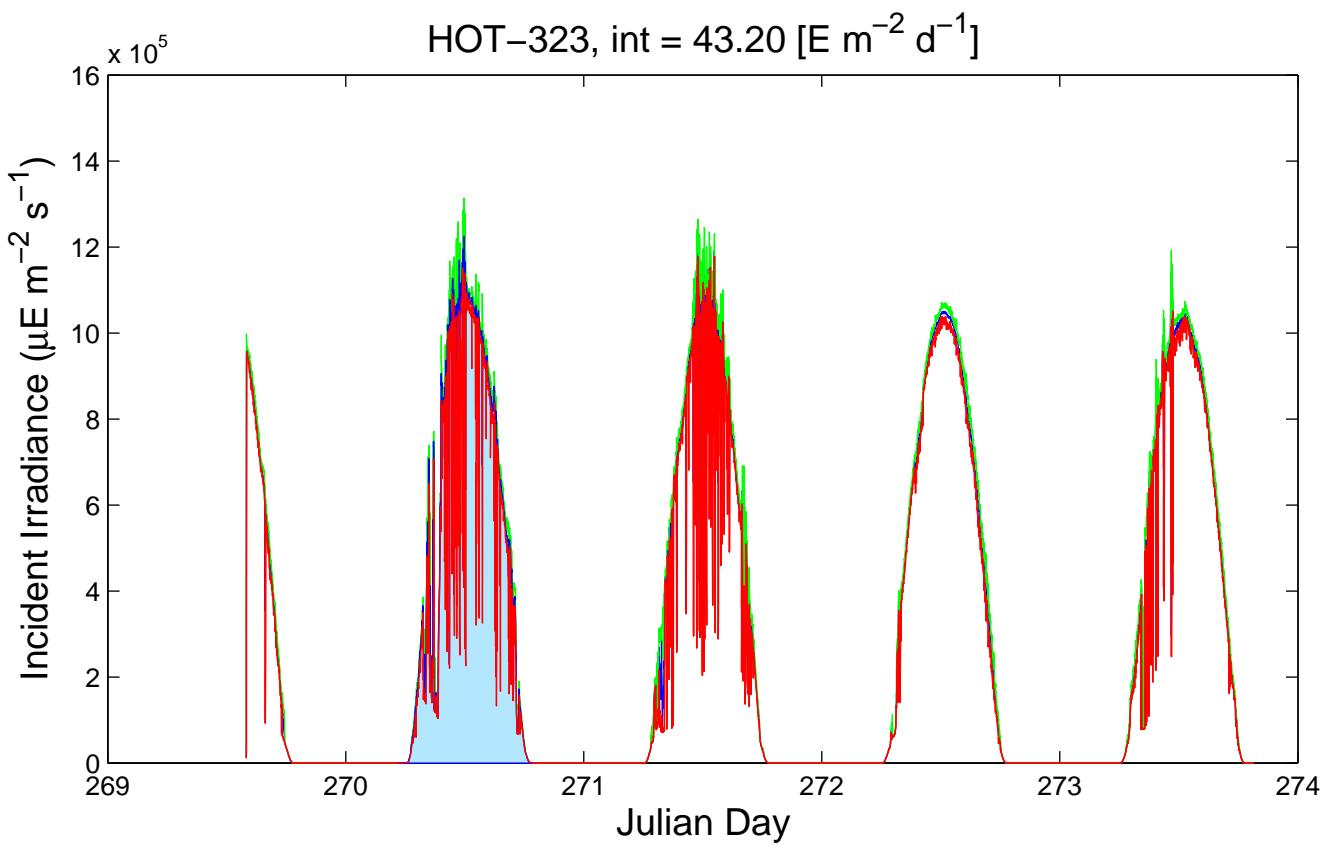


Figure 6.7.1f

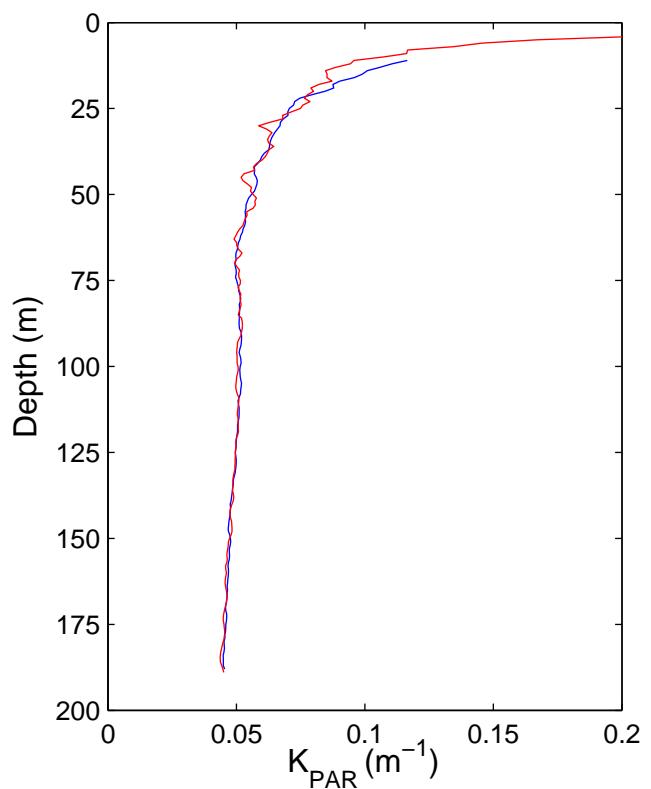
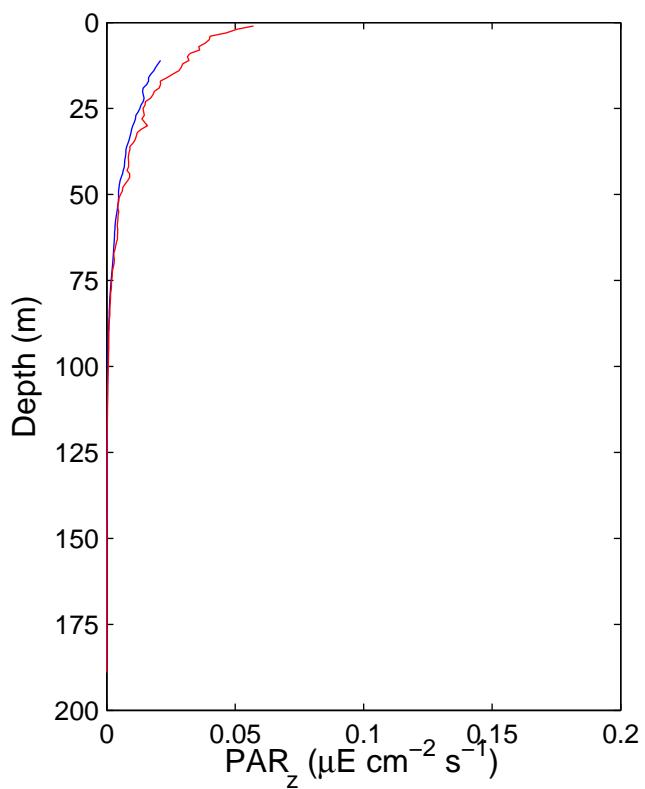
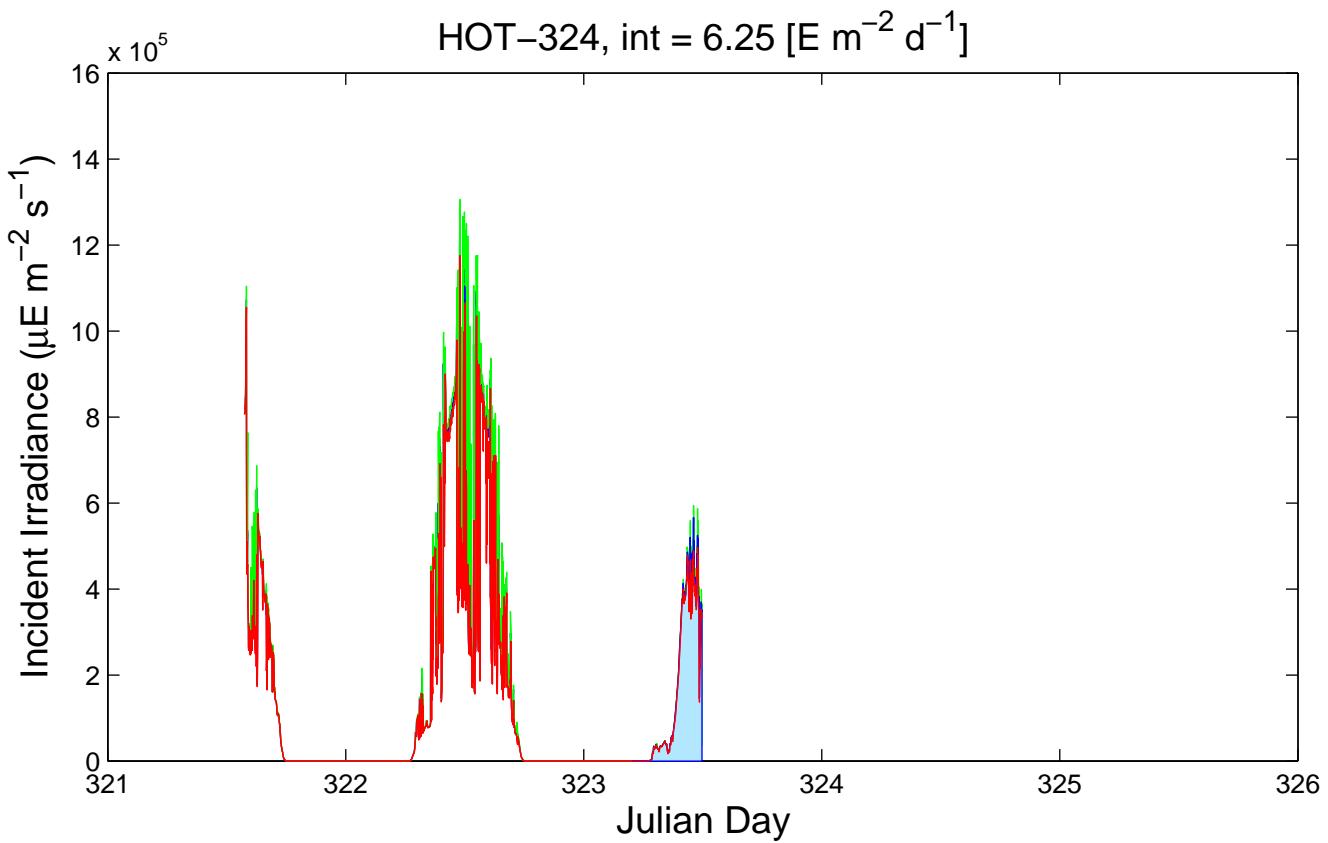


Figure 6.7.1g

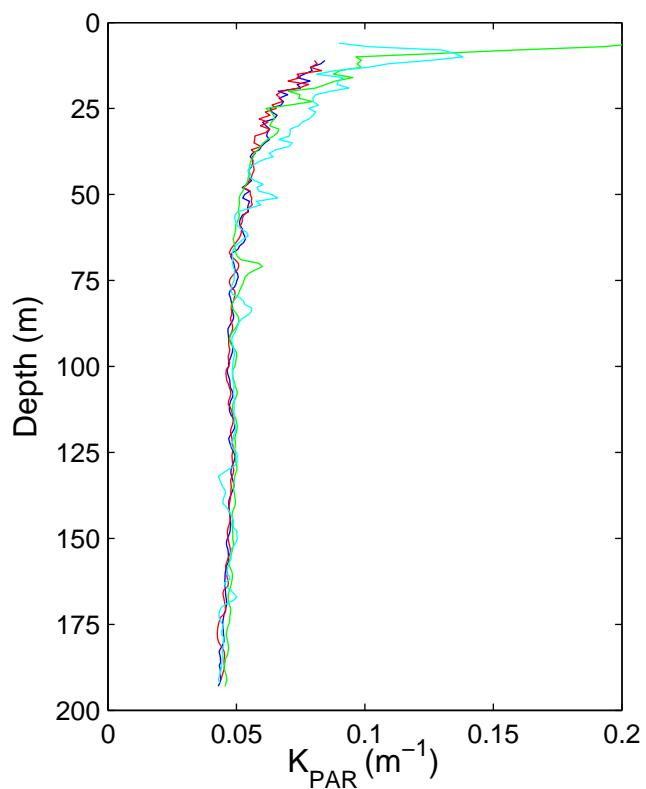
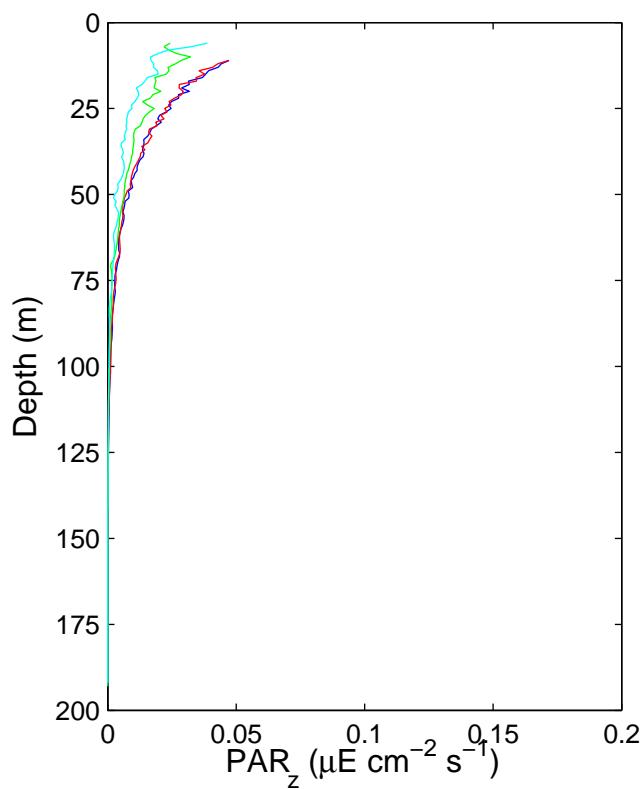
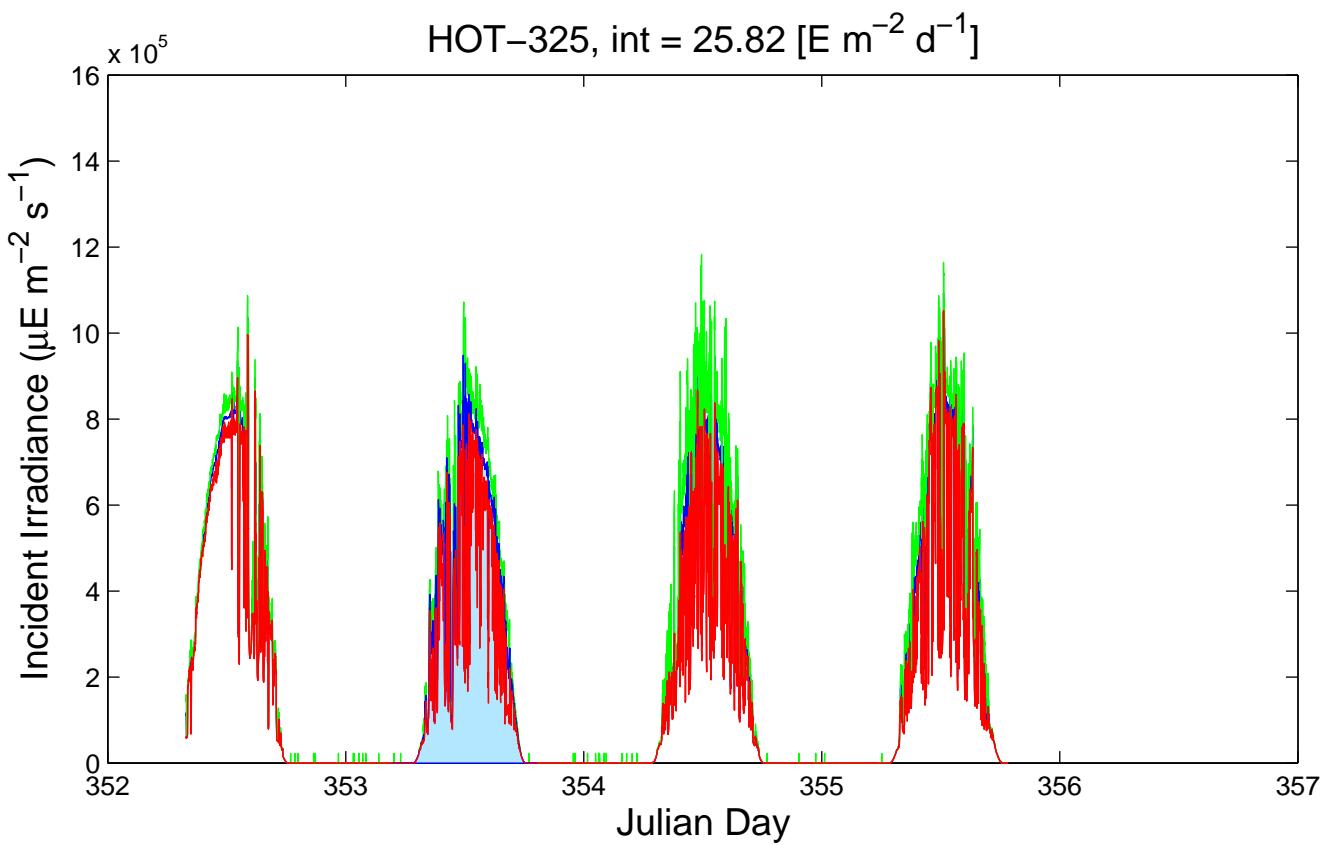


Figure 6.7.1h

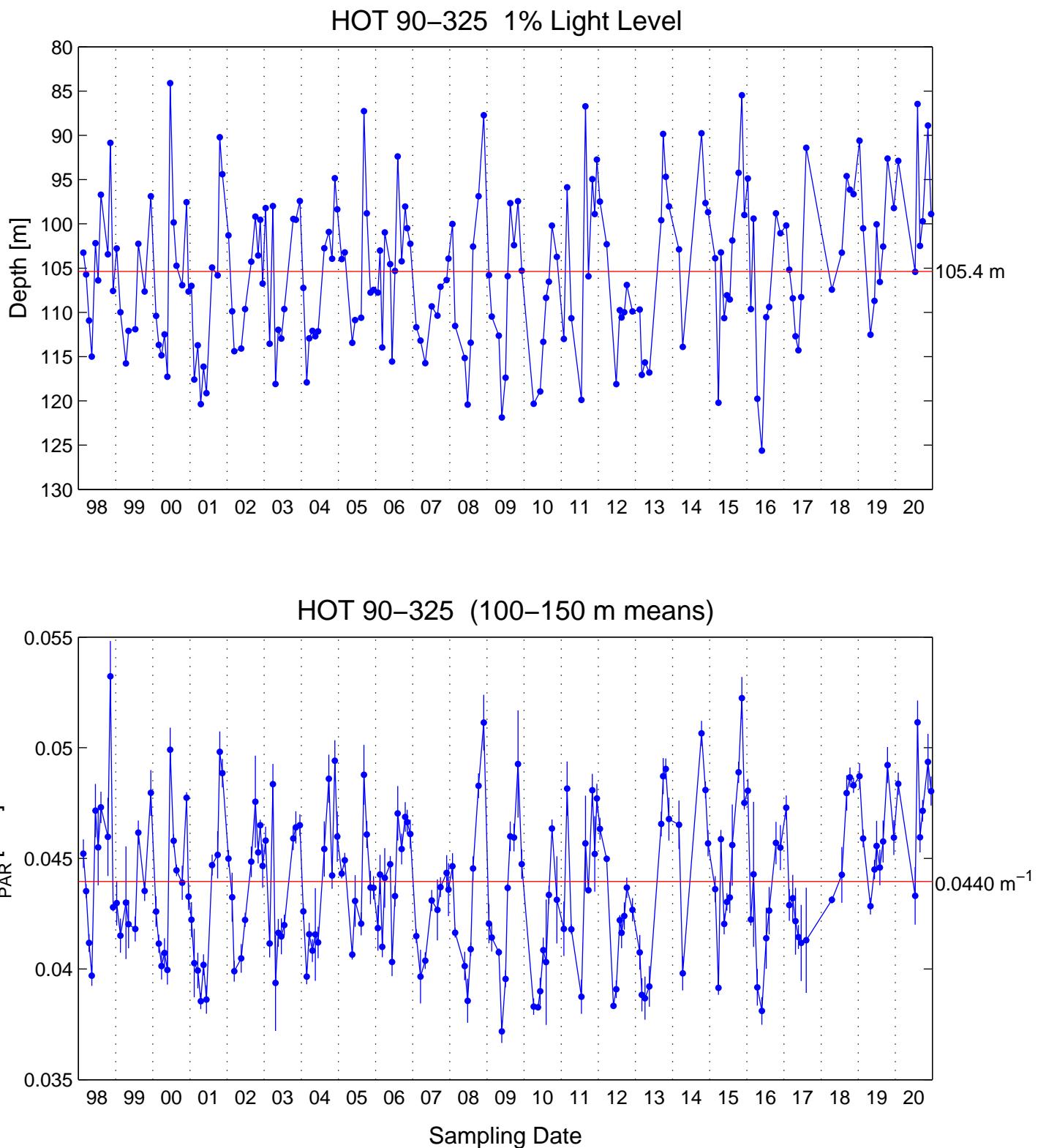


Figure 6.7.2

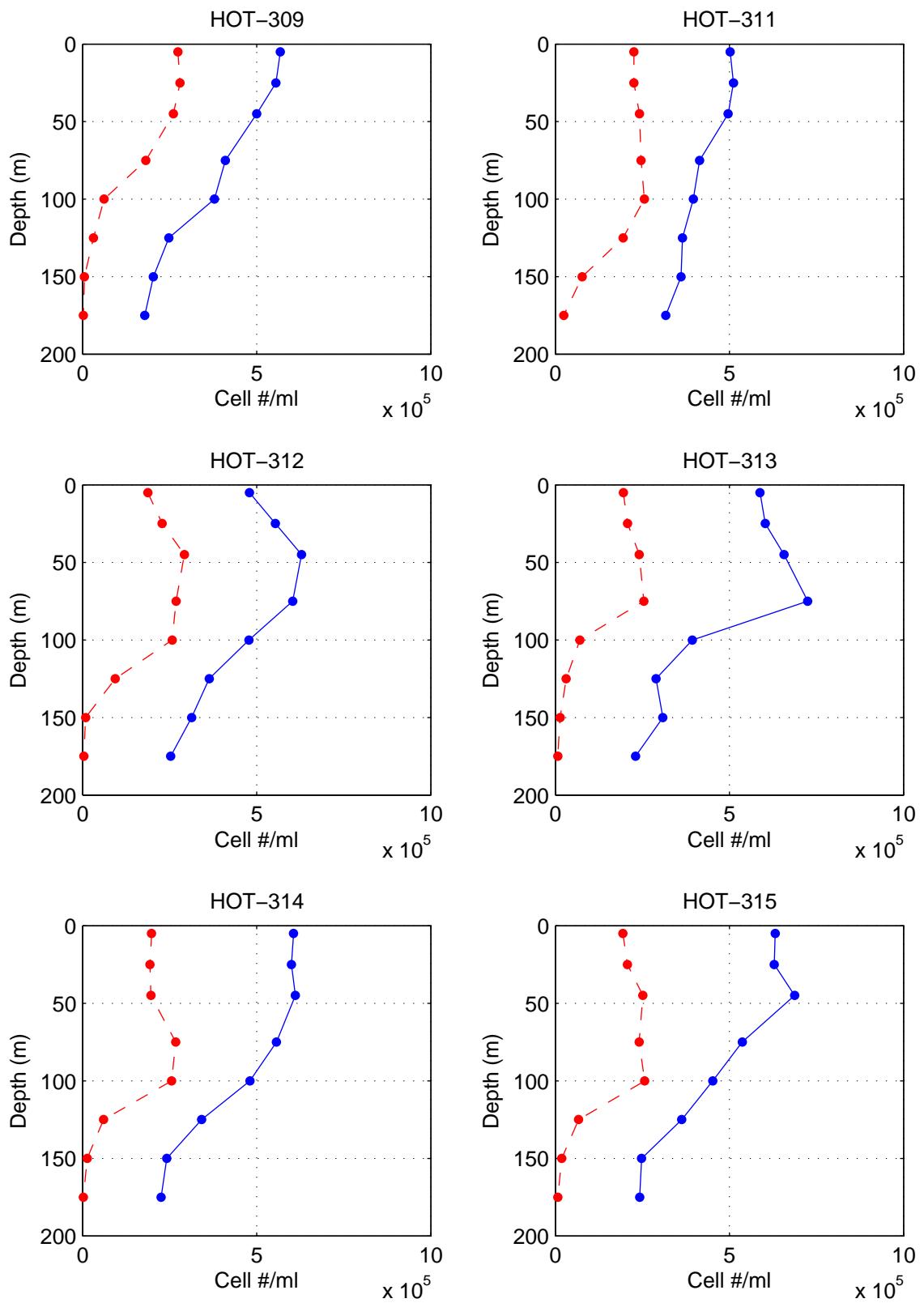


Figure 6.8.1

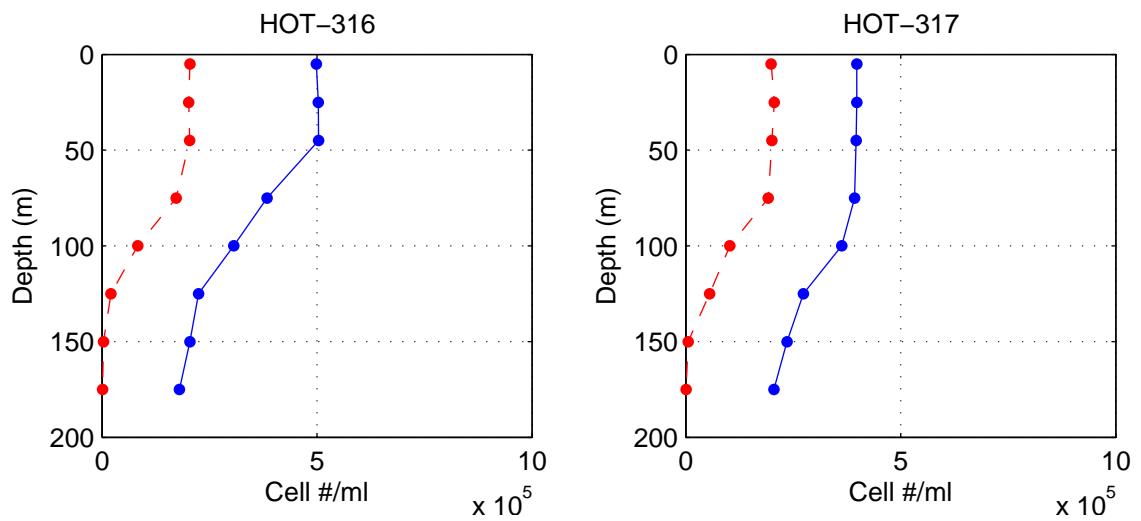


Figure 6.8.1 continued

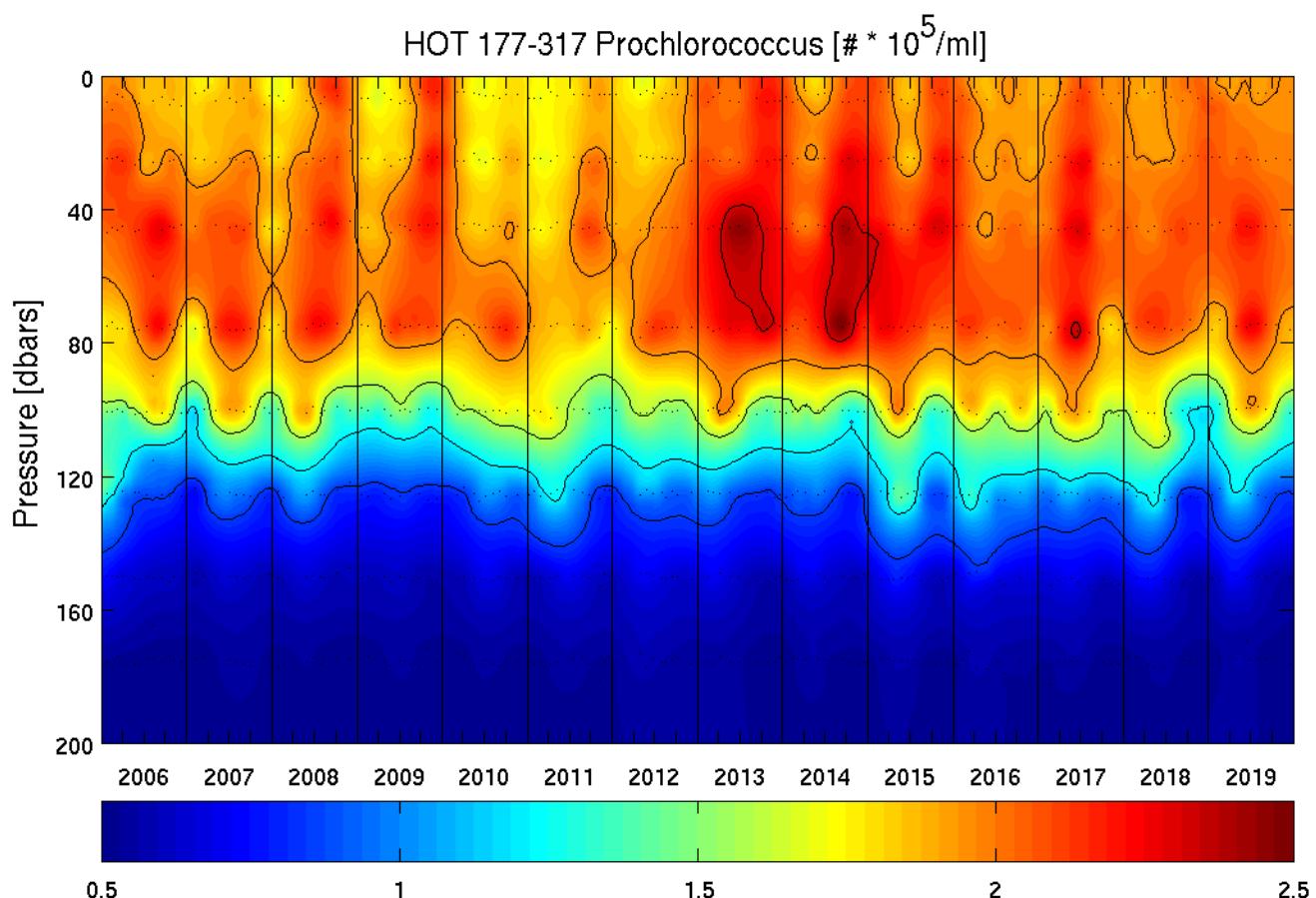
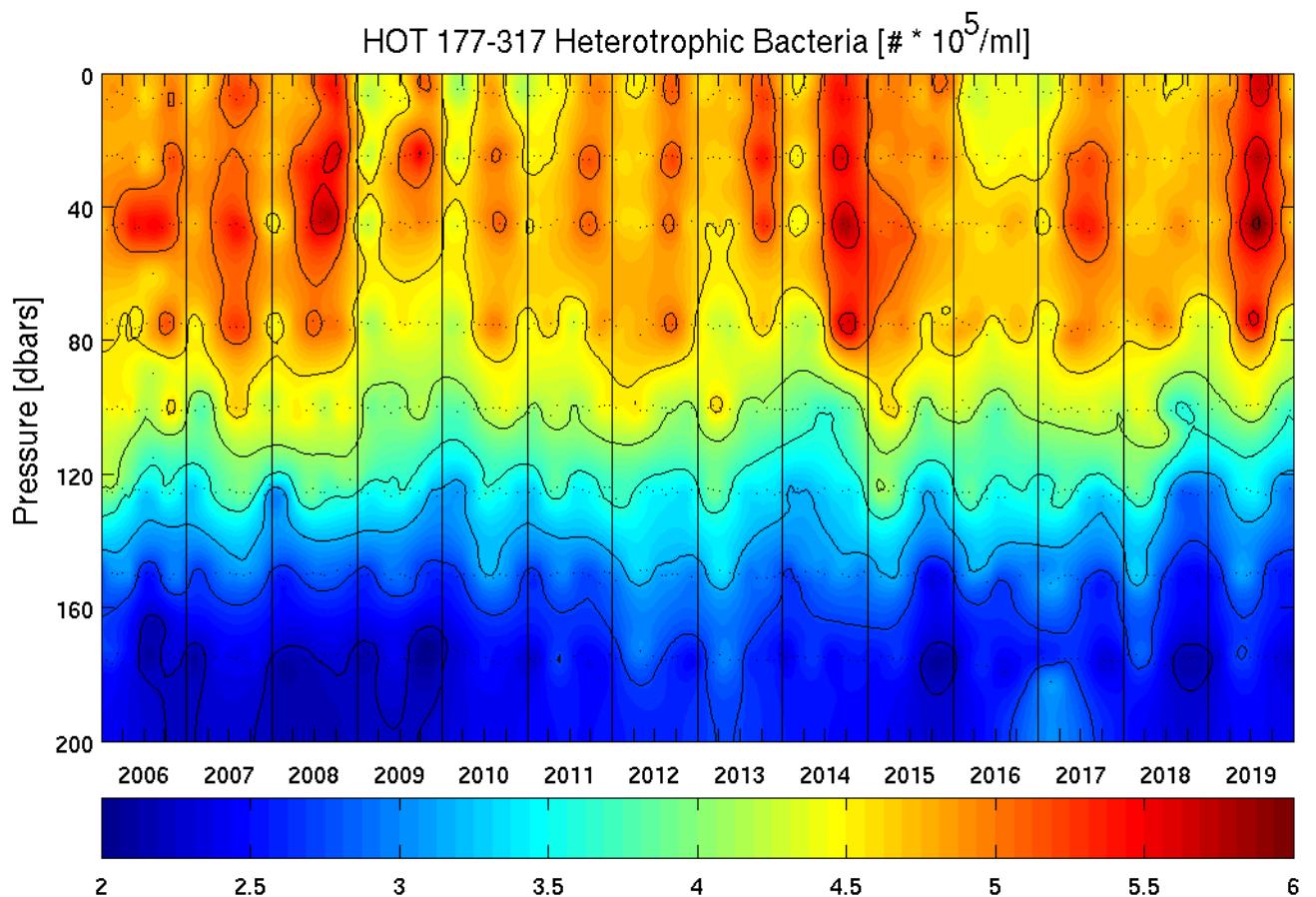


Figure 6.8.2

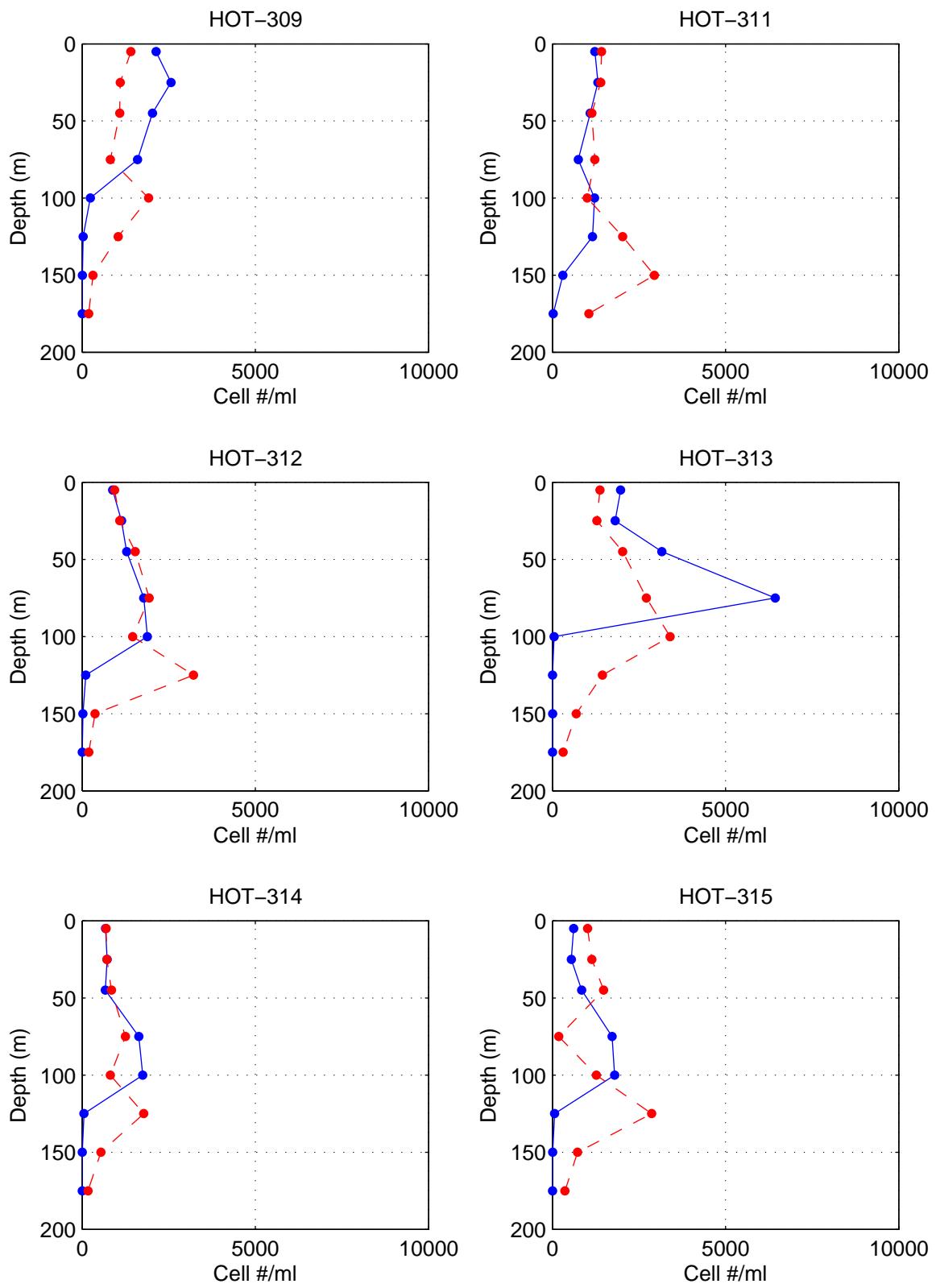


Figure 6.8.3

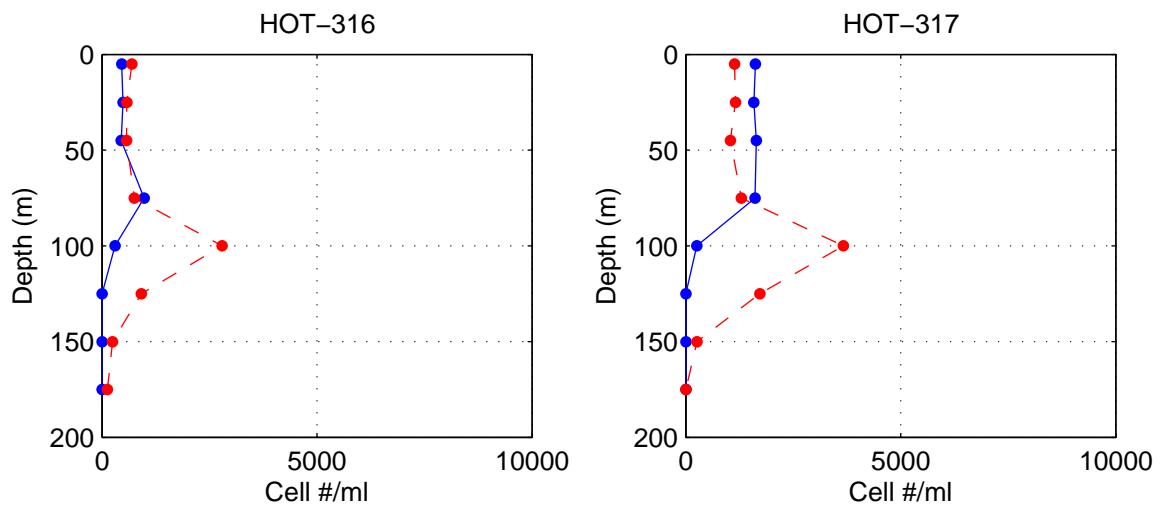


Figure 6.8.3 continued

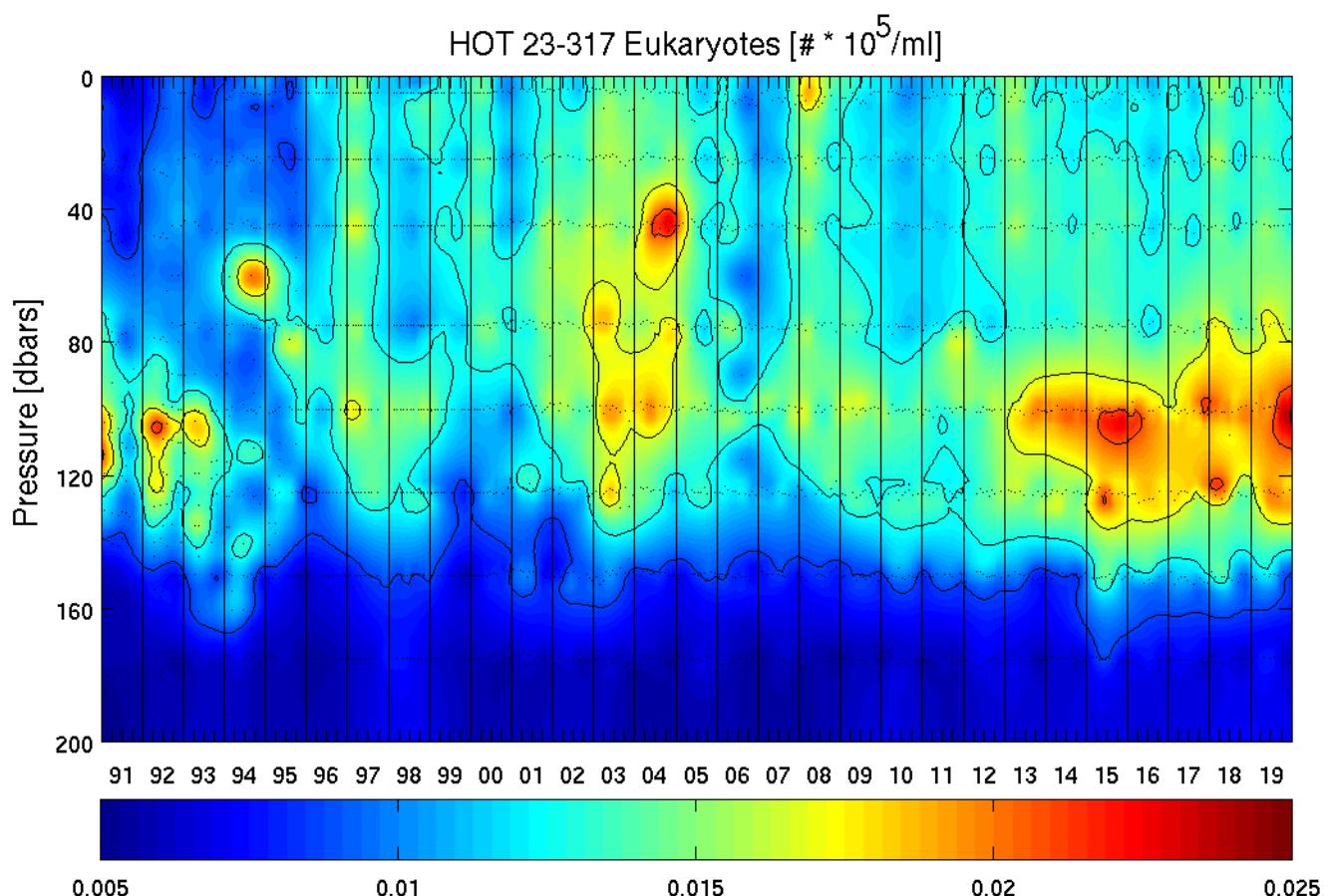
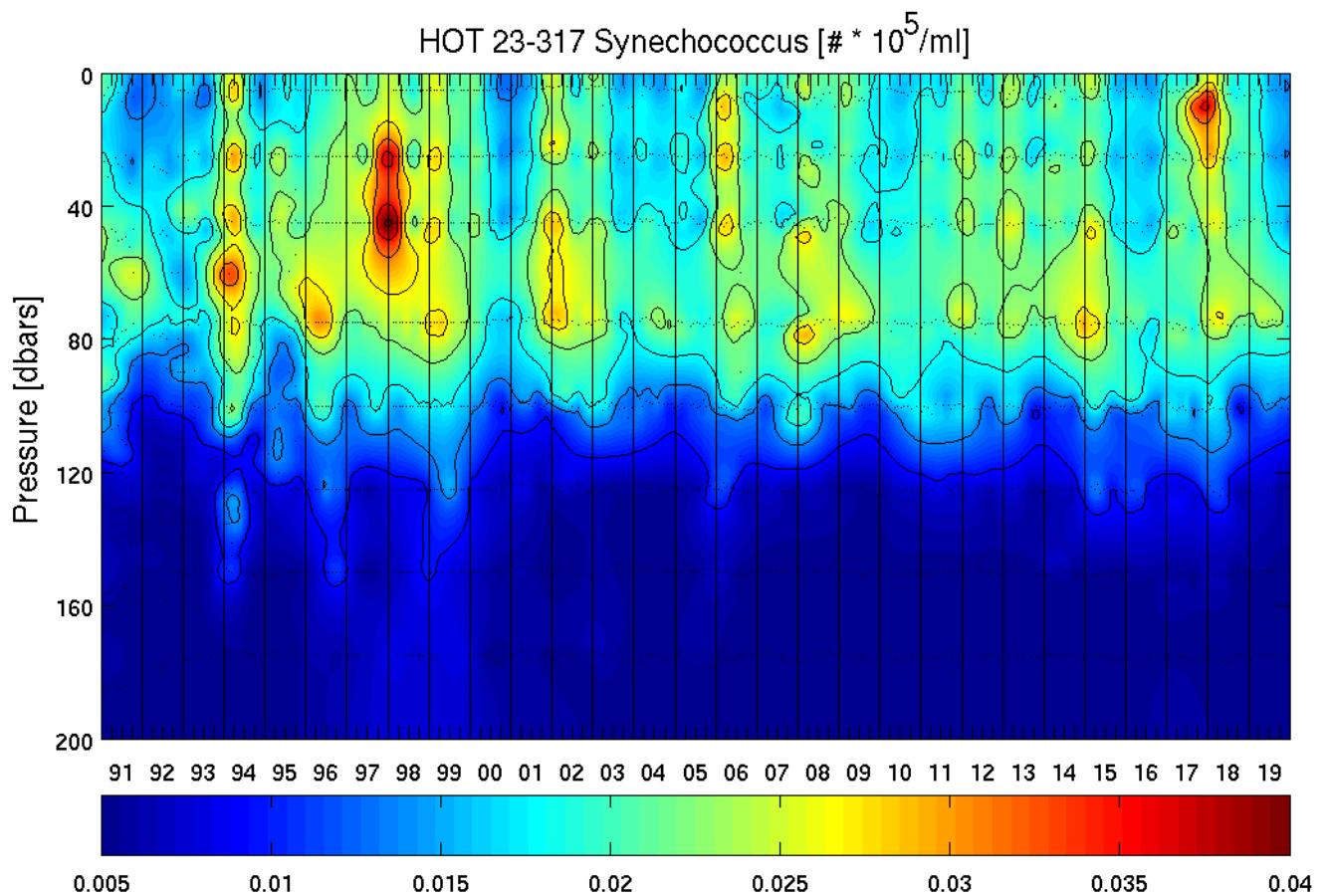
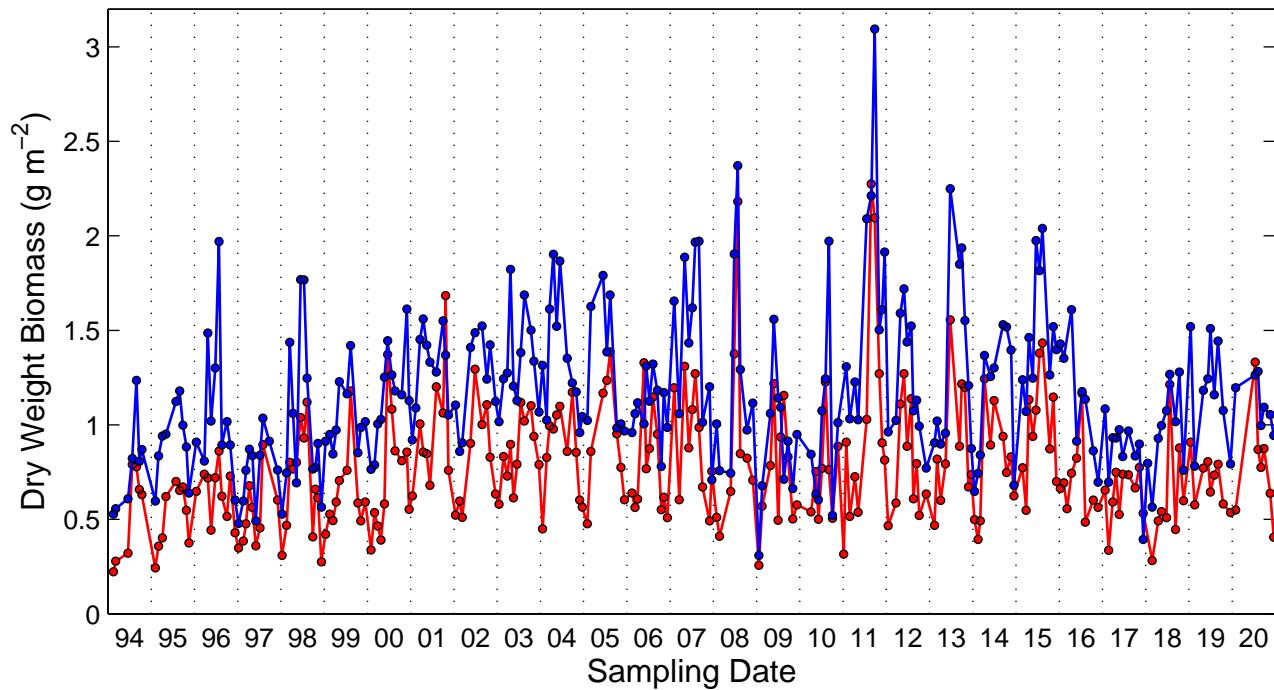


Figure 6.8.4

HOT 51–325



HOT 51–325

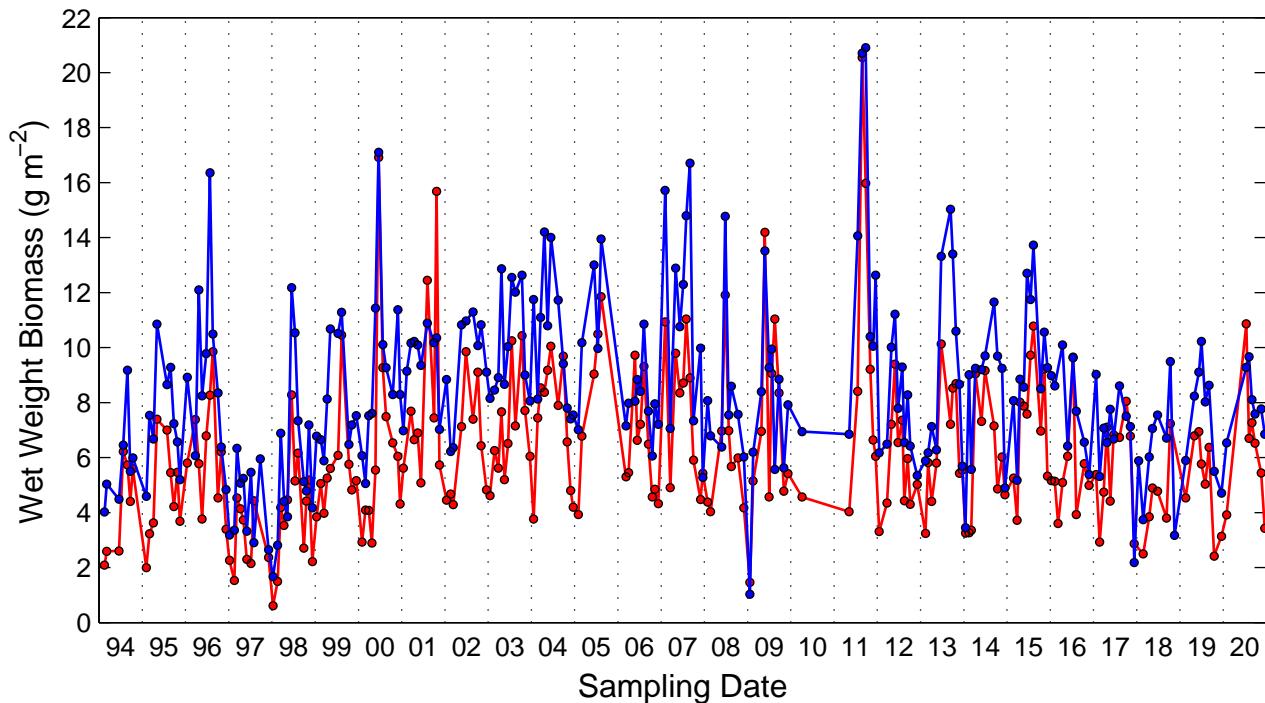


Figure 6.9.1

WHOTS-16, 1 m. SN 1841

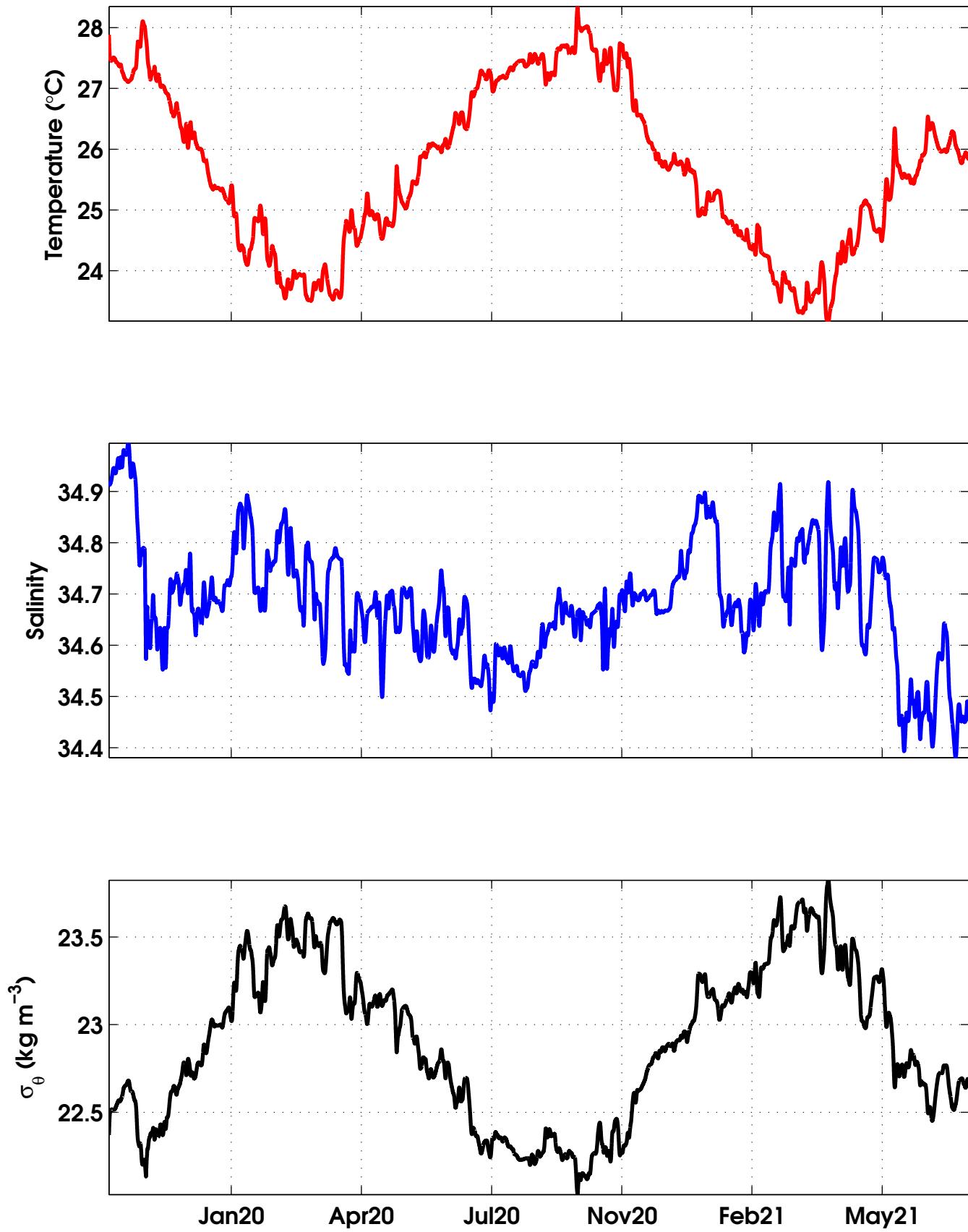


Figure 6.10.1.a

WHOTS-16 7 m. SN 3617

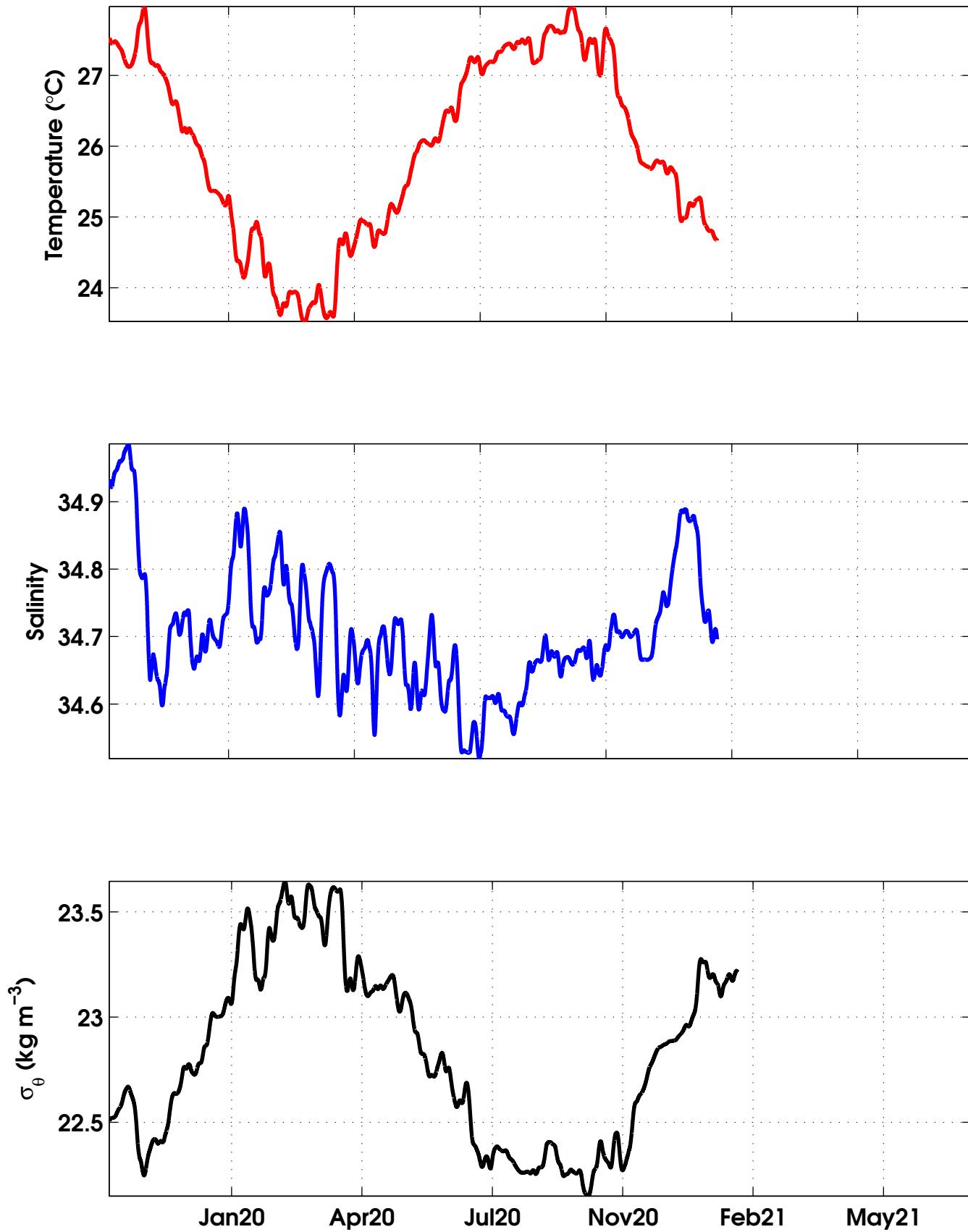


Figure 6.10.1.b

WHOTS-16, 15 m. SN 6893

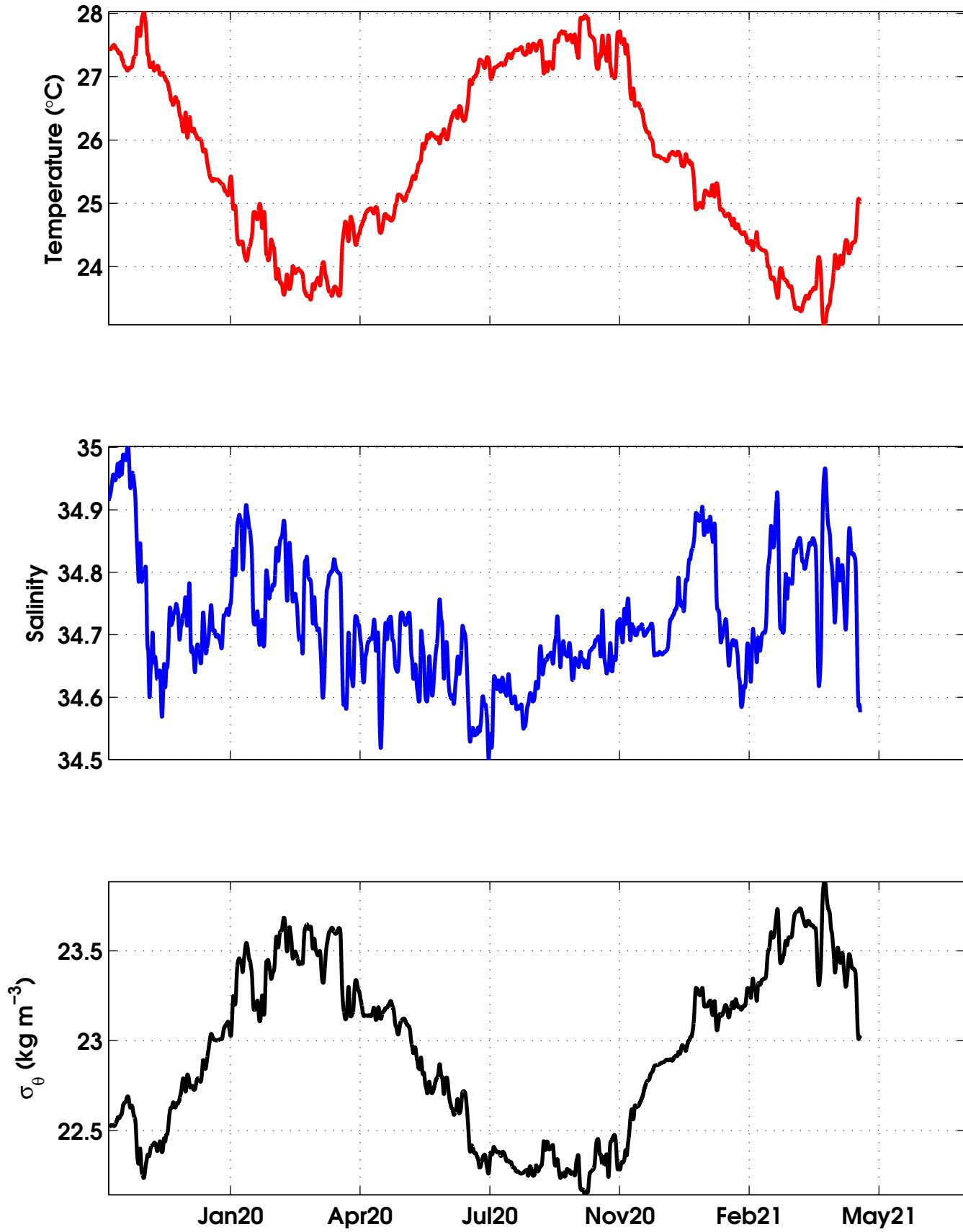


Figure 6.10.1.c

WHOTS-16, 25 m. SN 6894

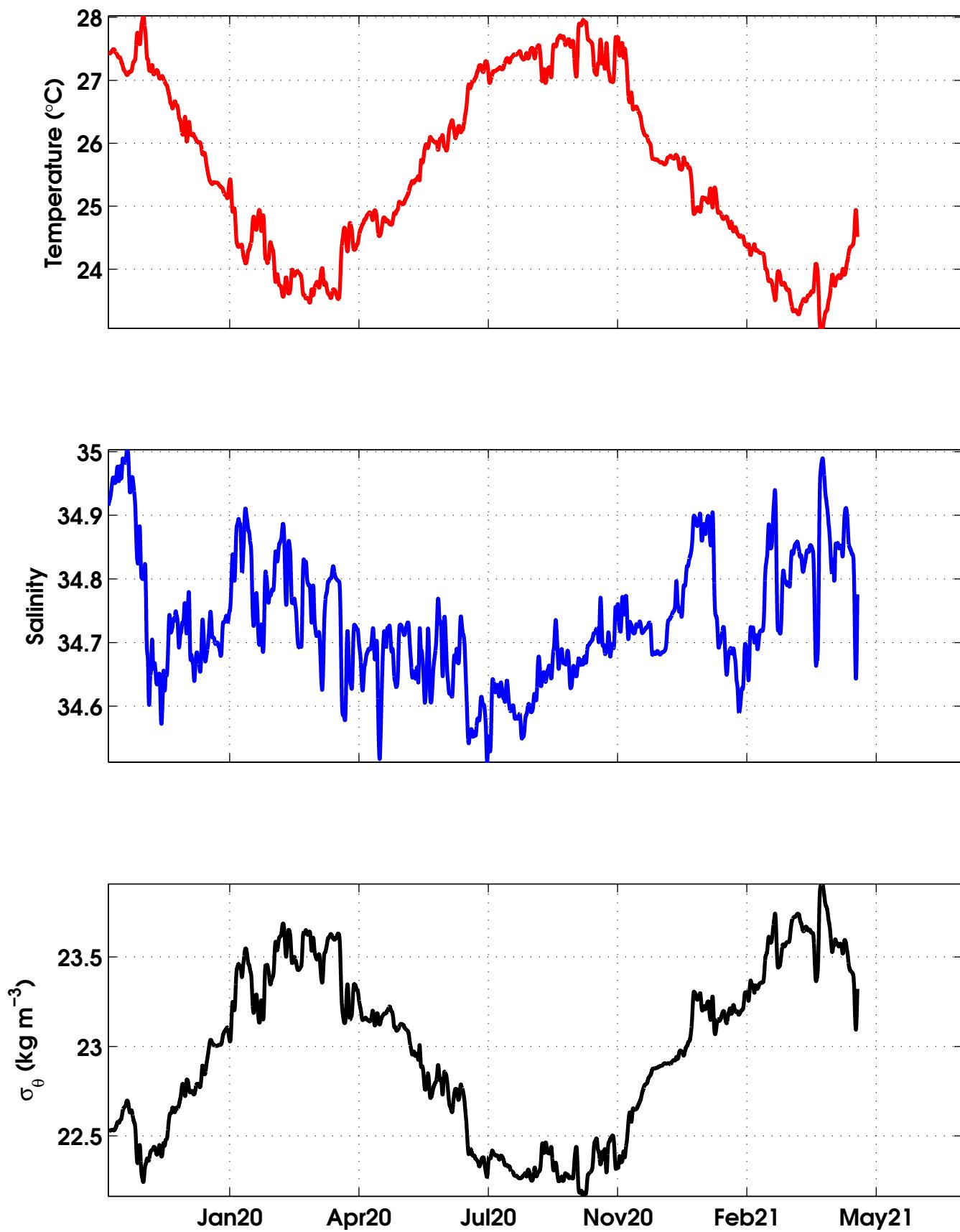


Figure 6.10.1.d

WHOTS-16,35 m. SN 6895

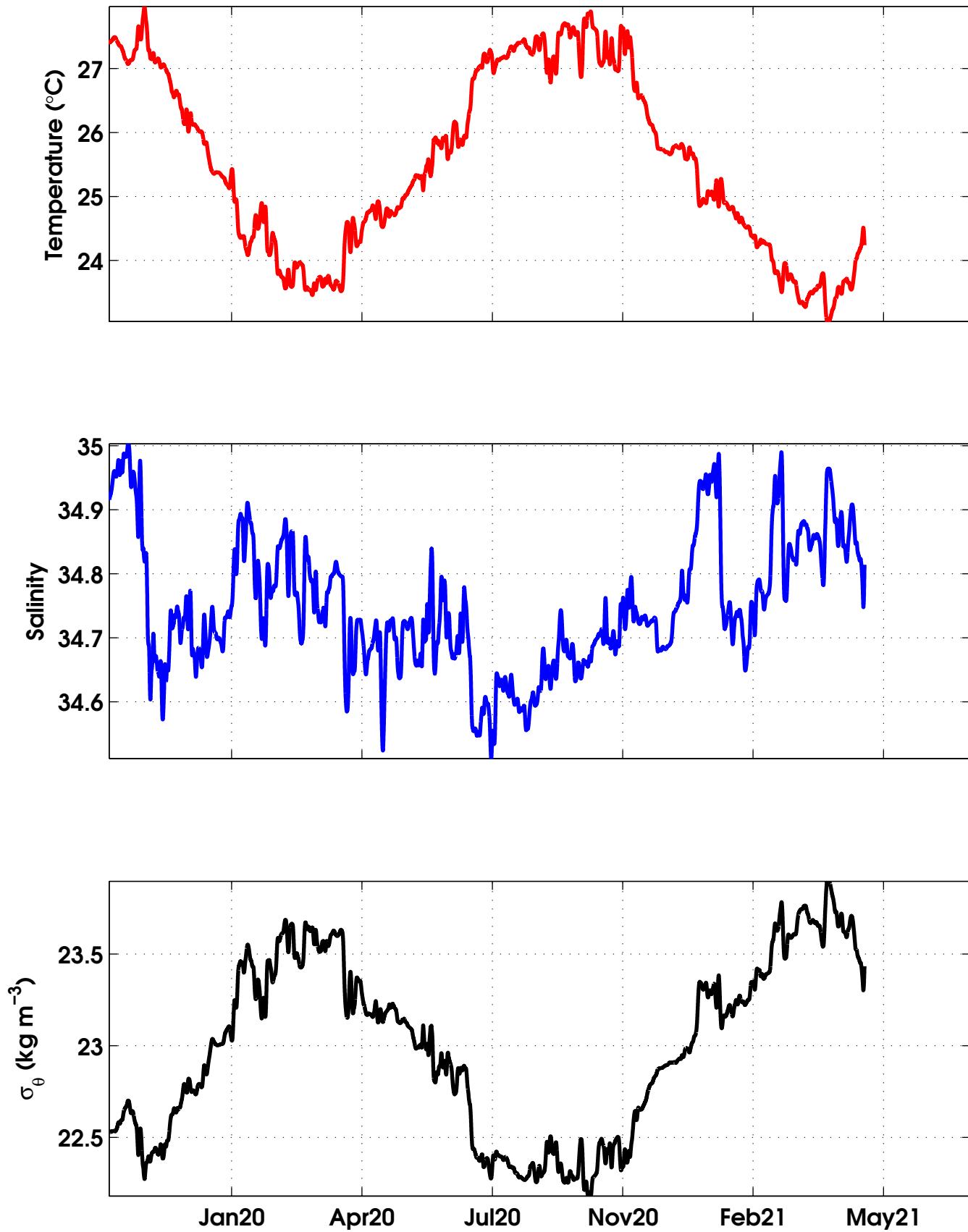


Figure 6.10.1.e

WHOTS-16,40 m. SN 6896

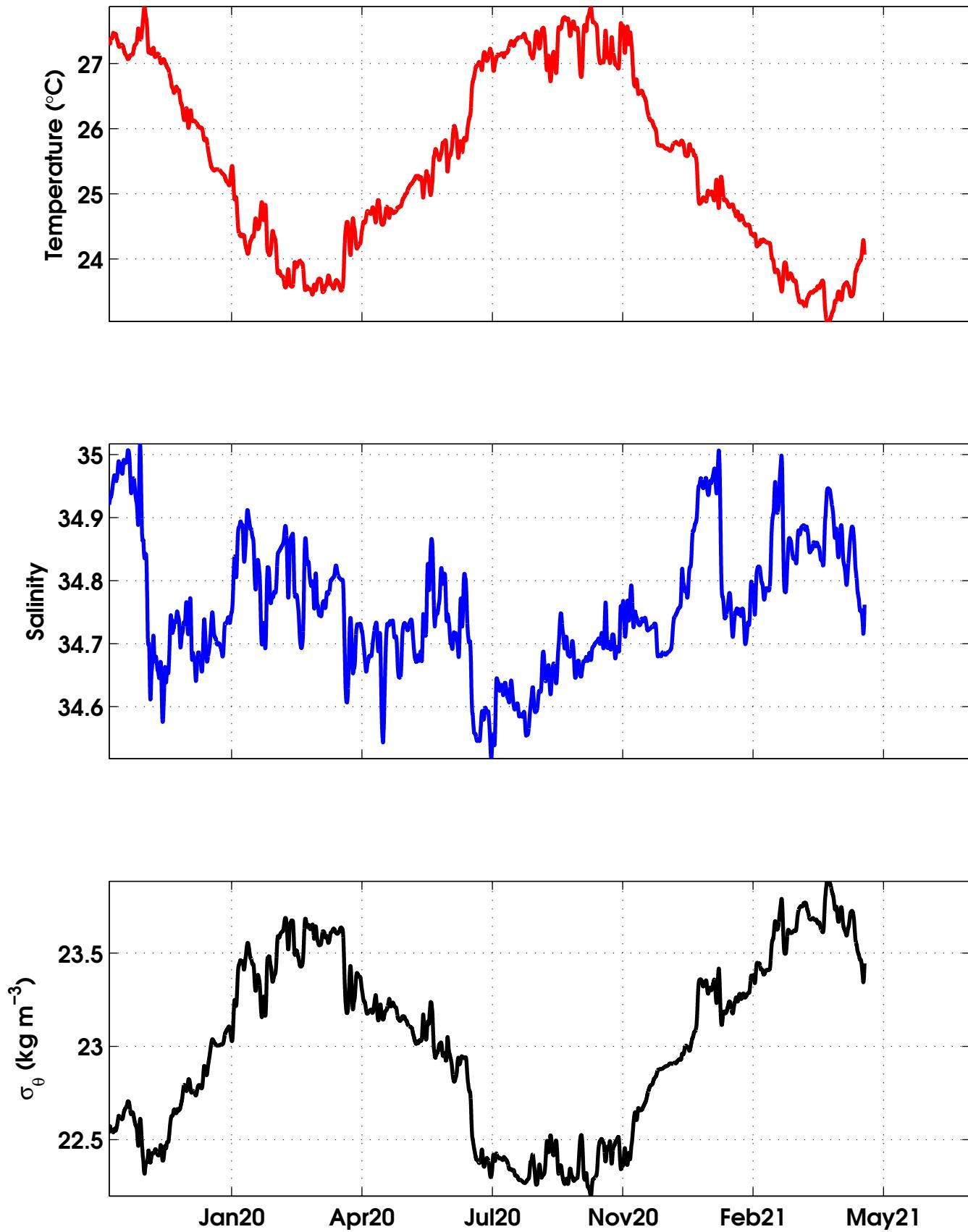


Figure 6.10.1.f

WHOTS-16,45 m. SN 6887

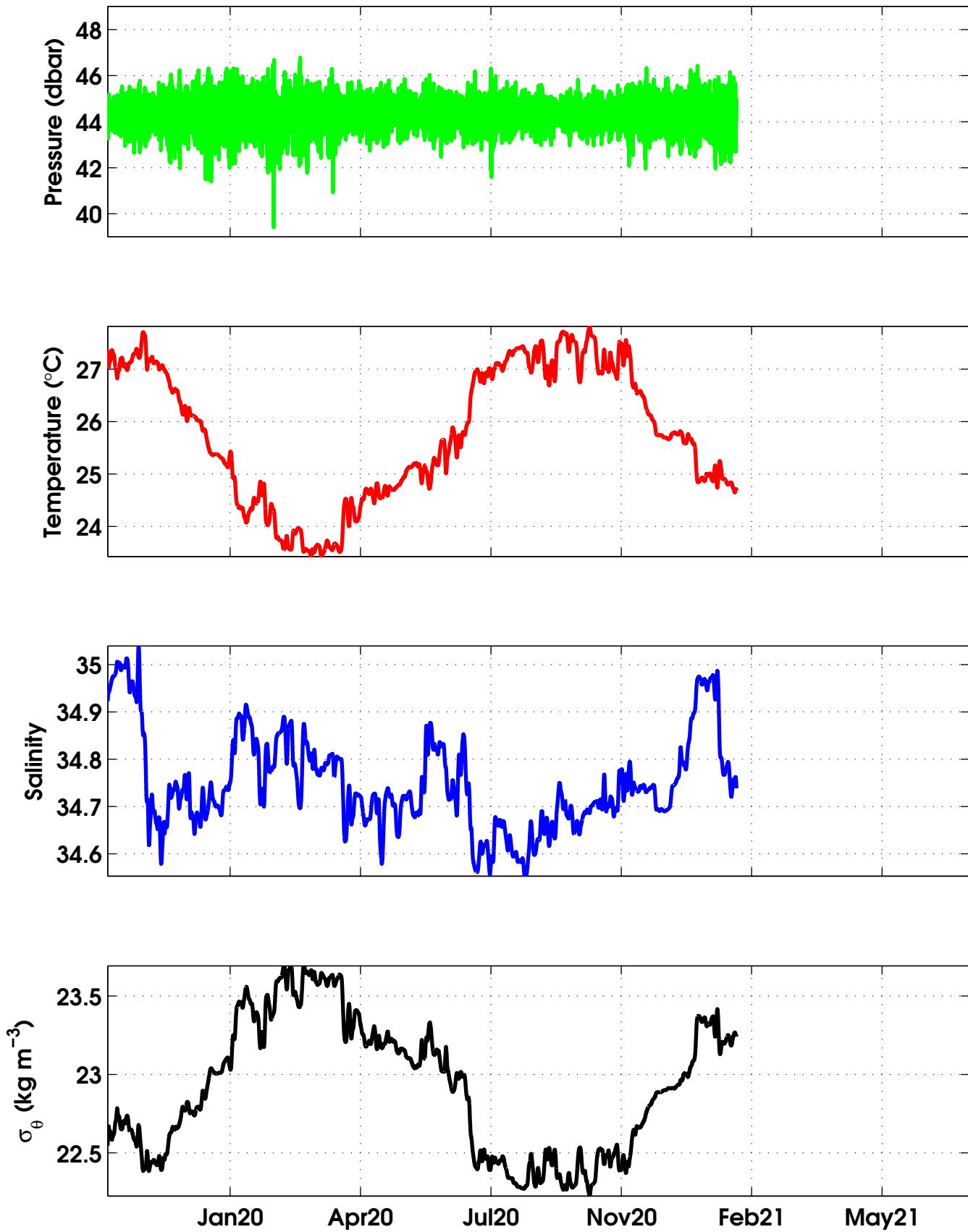


Figure 6.10.1.g

WHOTS-16,50 m. SN 6897

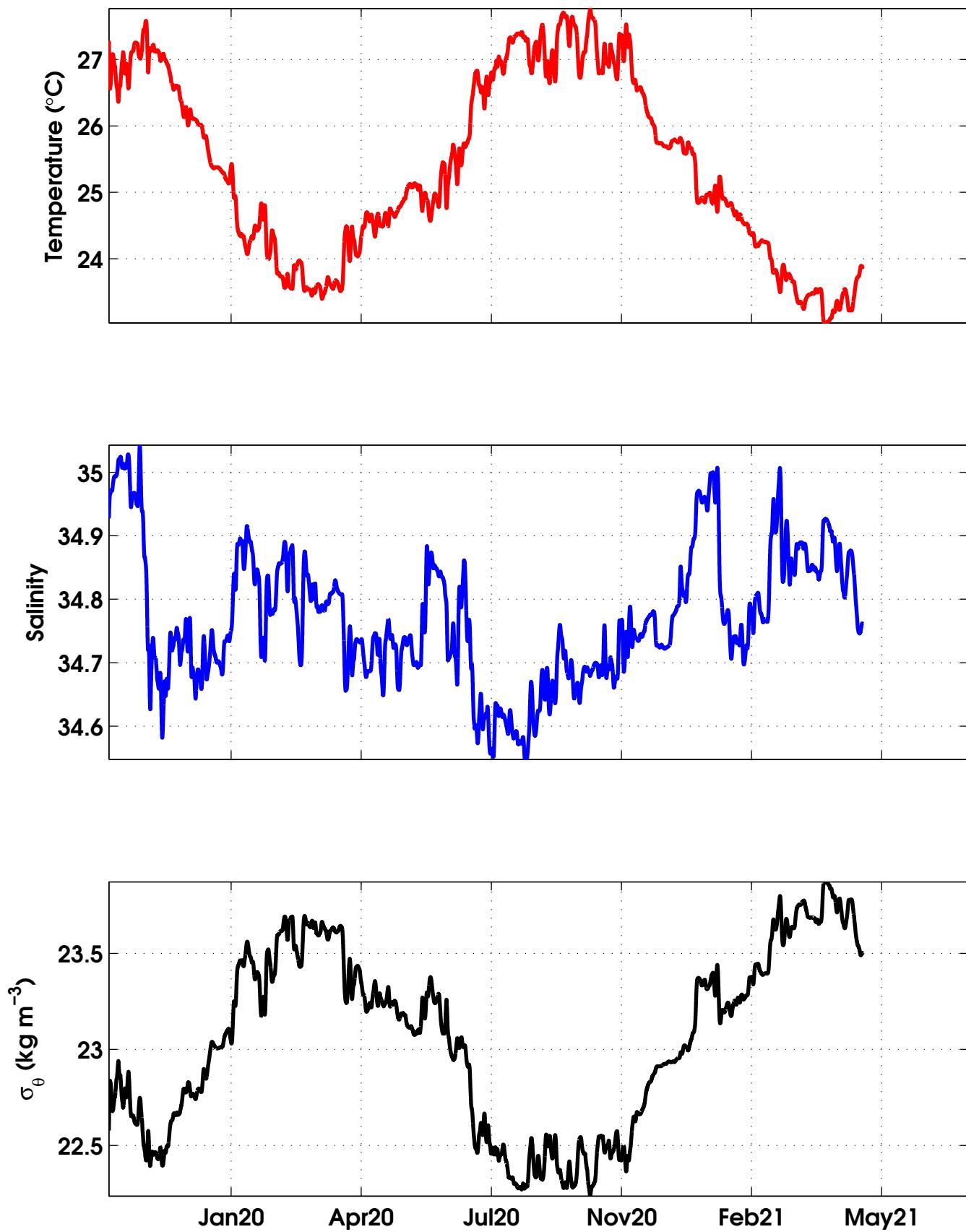


Figure 6.10.1.h

WHOTS-16,55 m. SN 6898

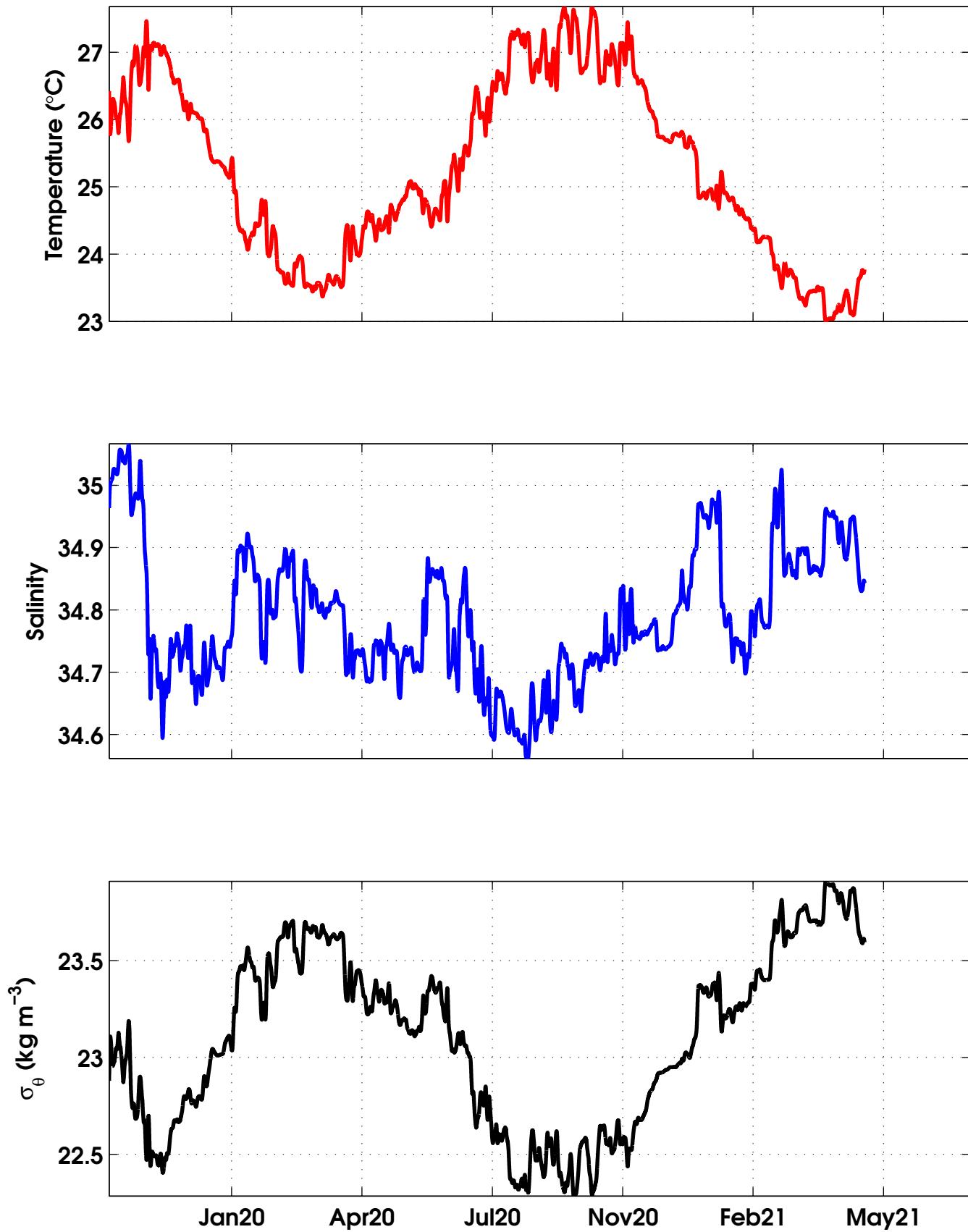


Figure 6.10.1.i

WHOTS-16,65 m. SN 6899

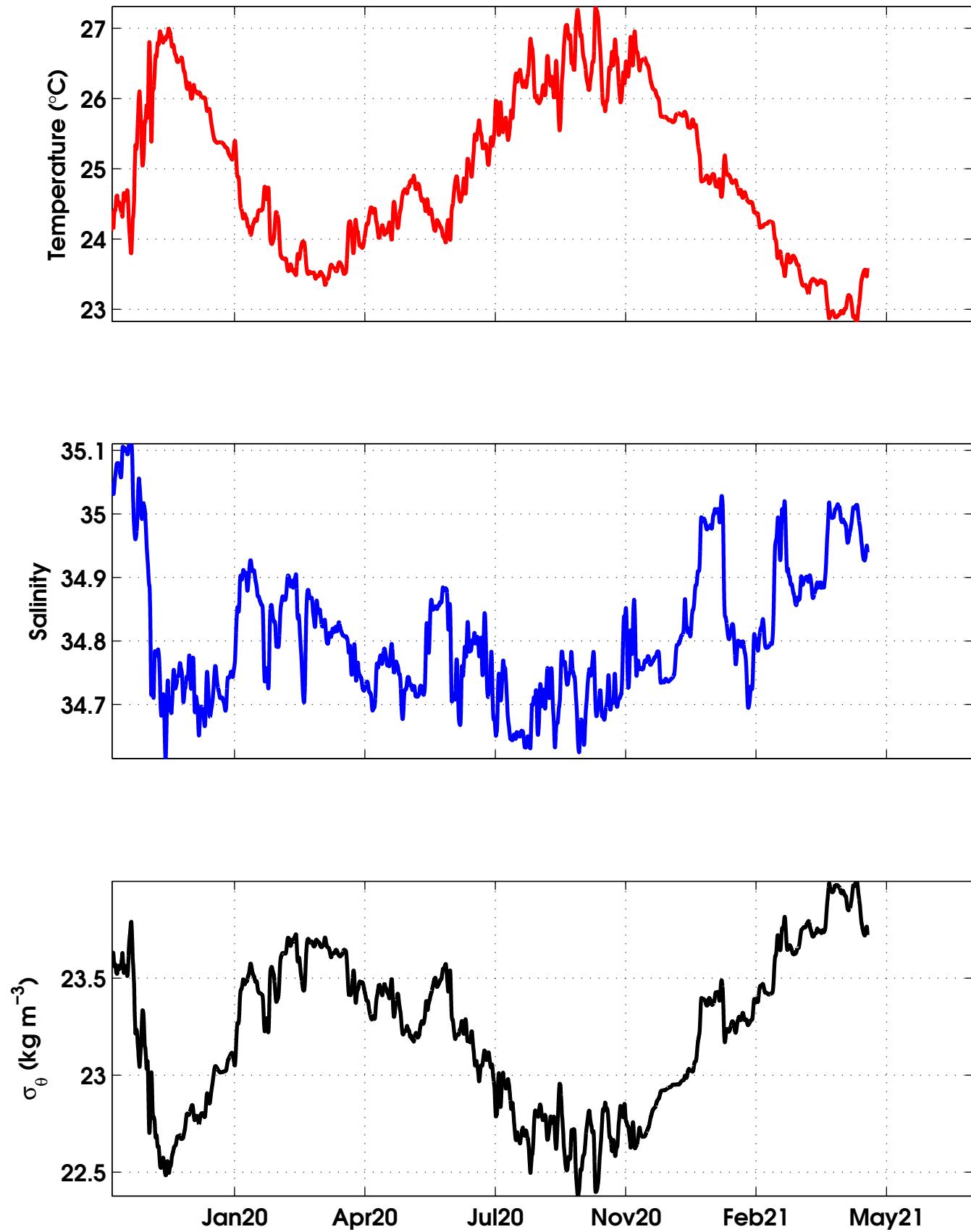


Figure 6.10.1.j

WHOTS-16,75 m. SN 3618

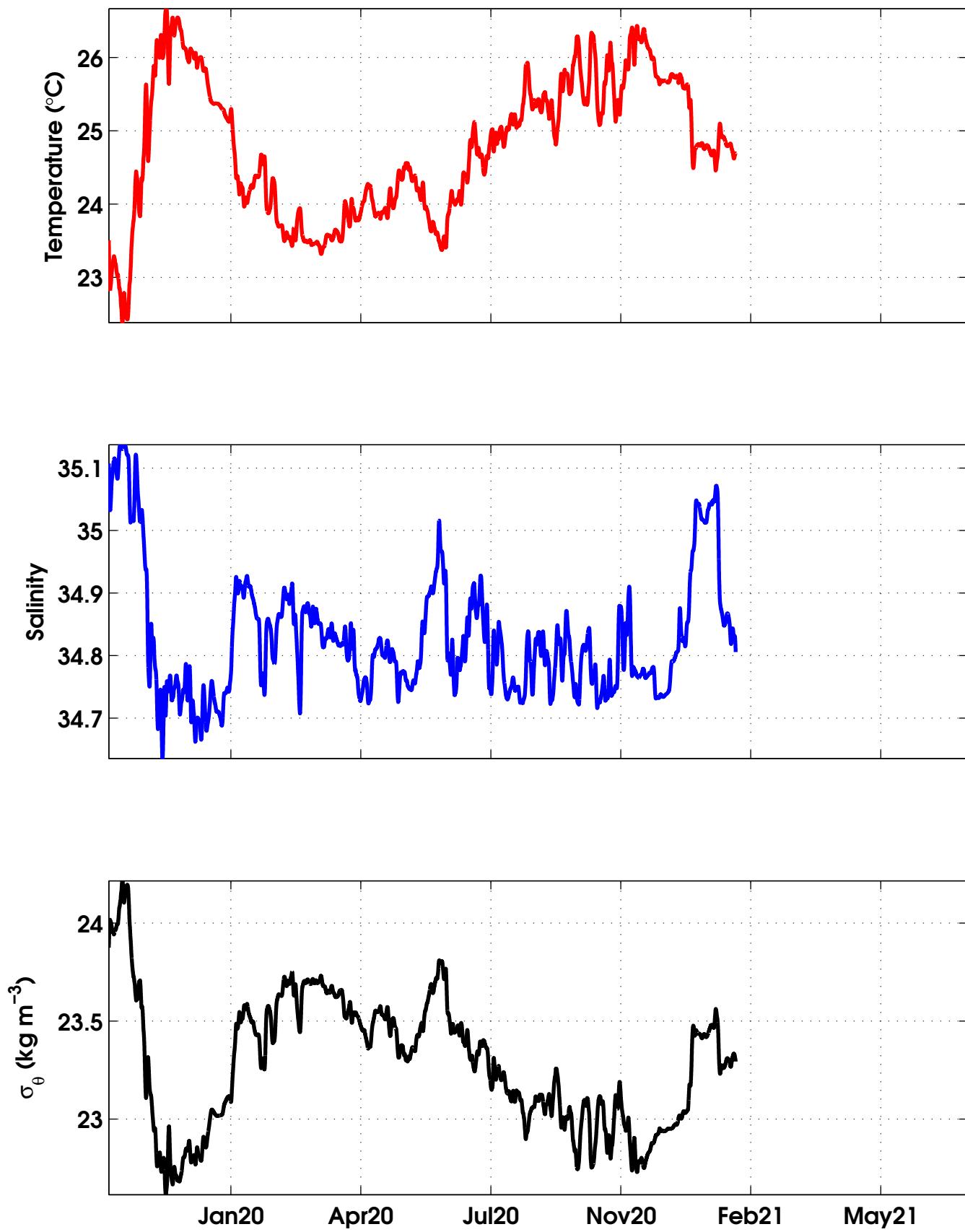


Figure 6.10.1.k

WHOTS-16,85 m. SN 3634

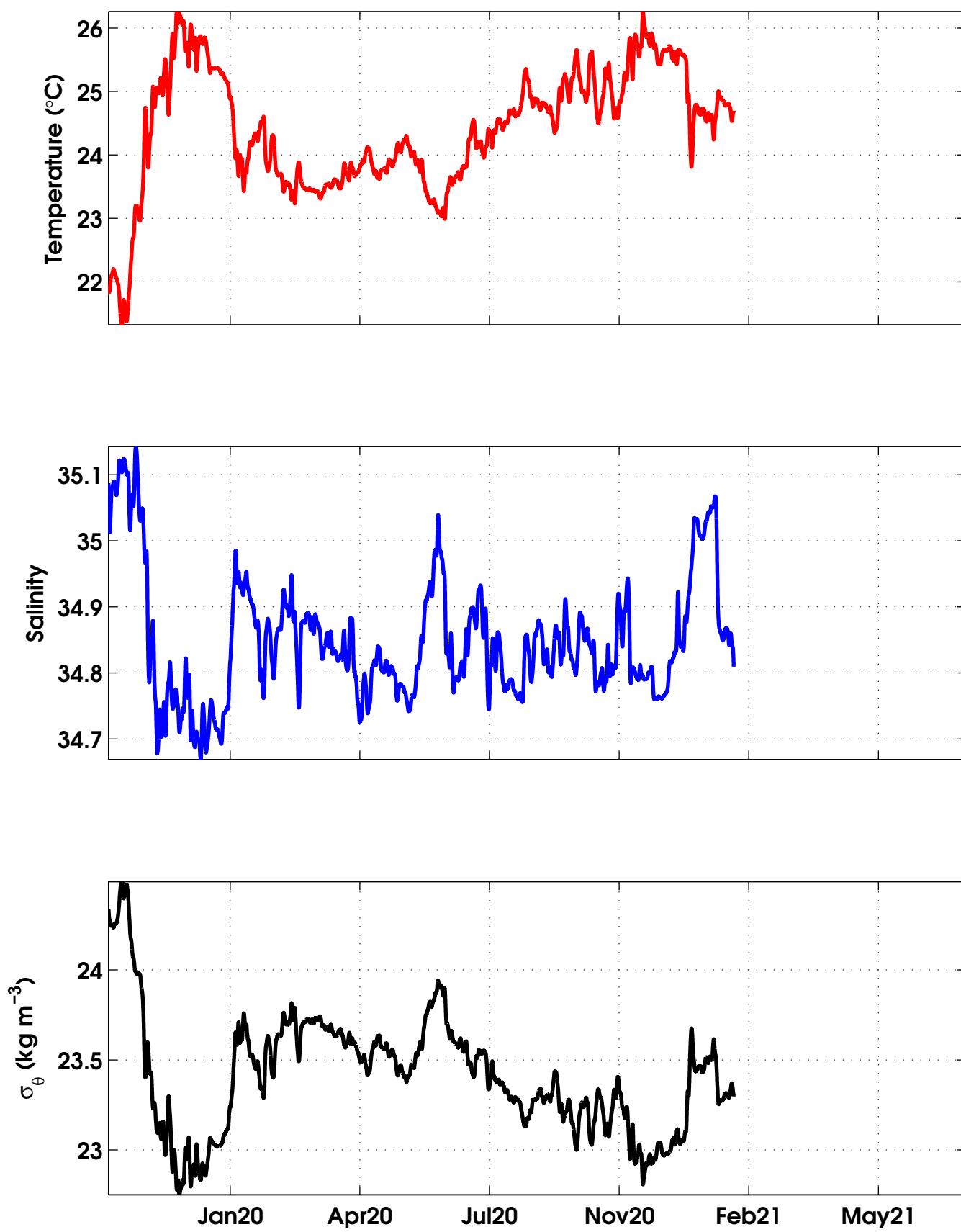


Figure 6.10.1.I

WHOTS-16,95 m. SN 3670

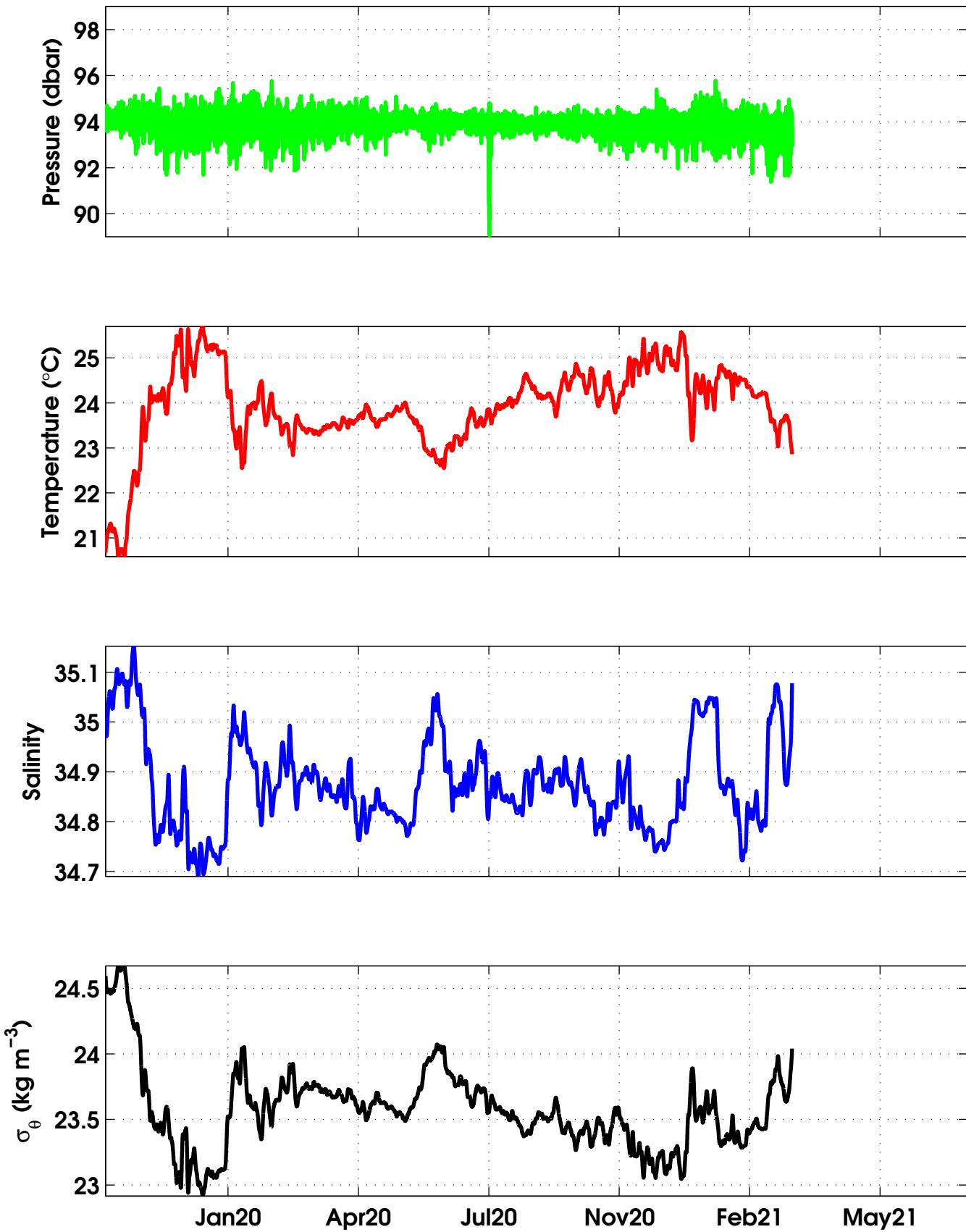


Figure 6.10.1.m

WHOTS-16, 105 m. SN 6889

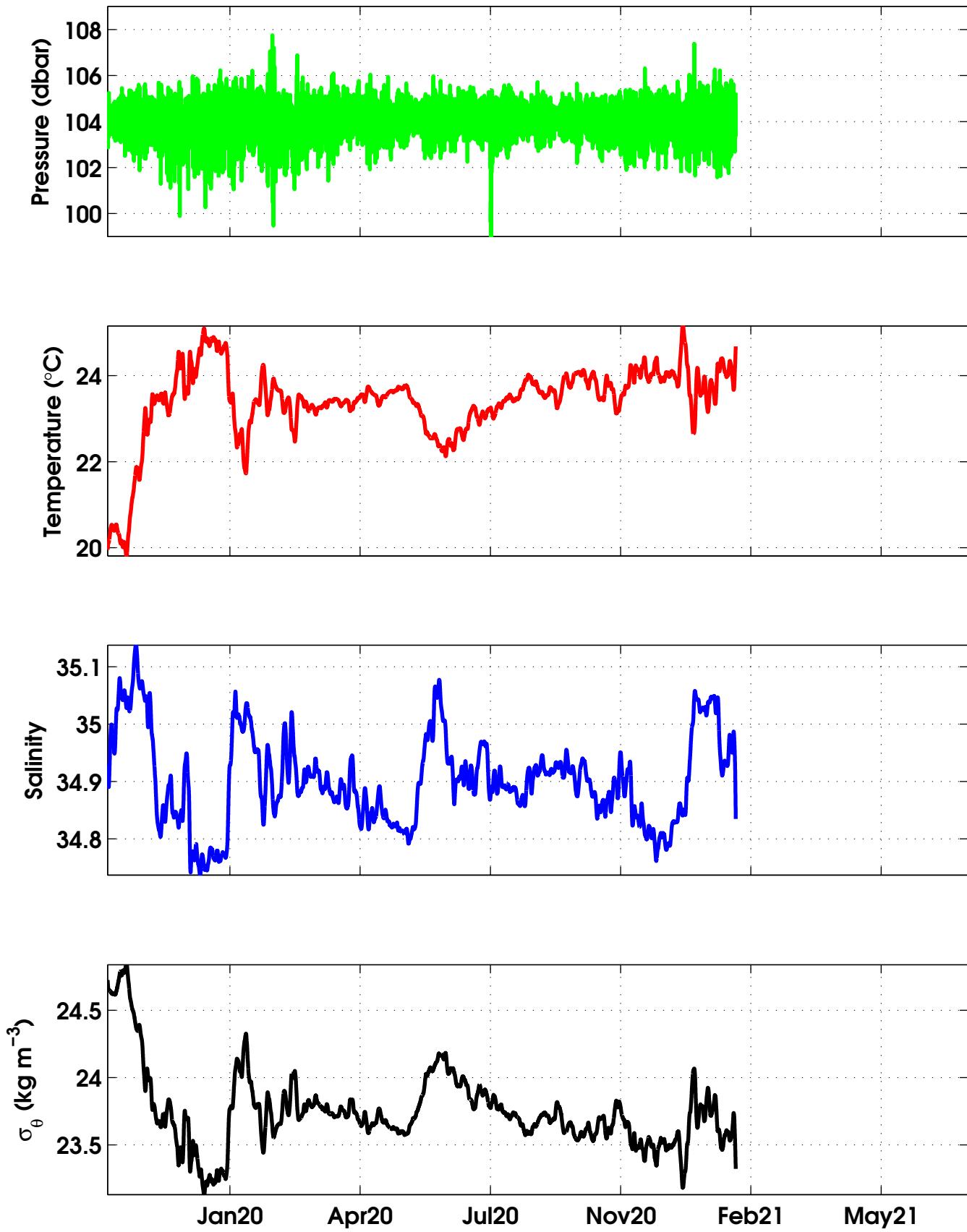


Figure 6.10.1.n

WHOTS-16, 120 m. SN 6890

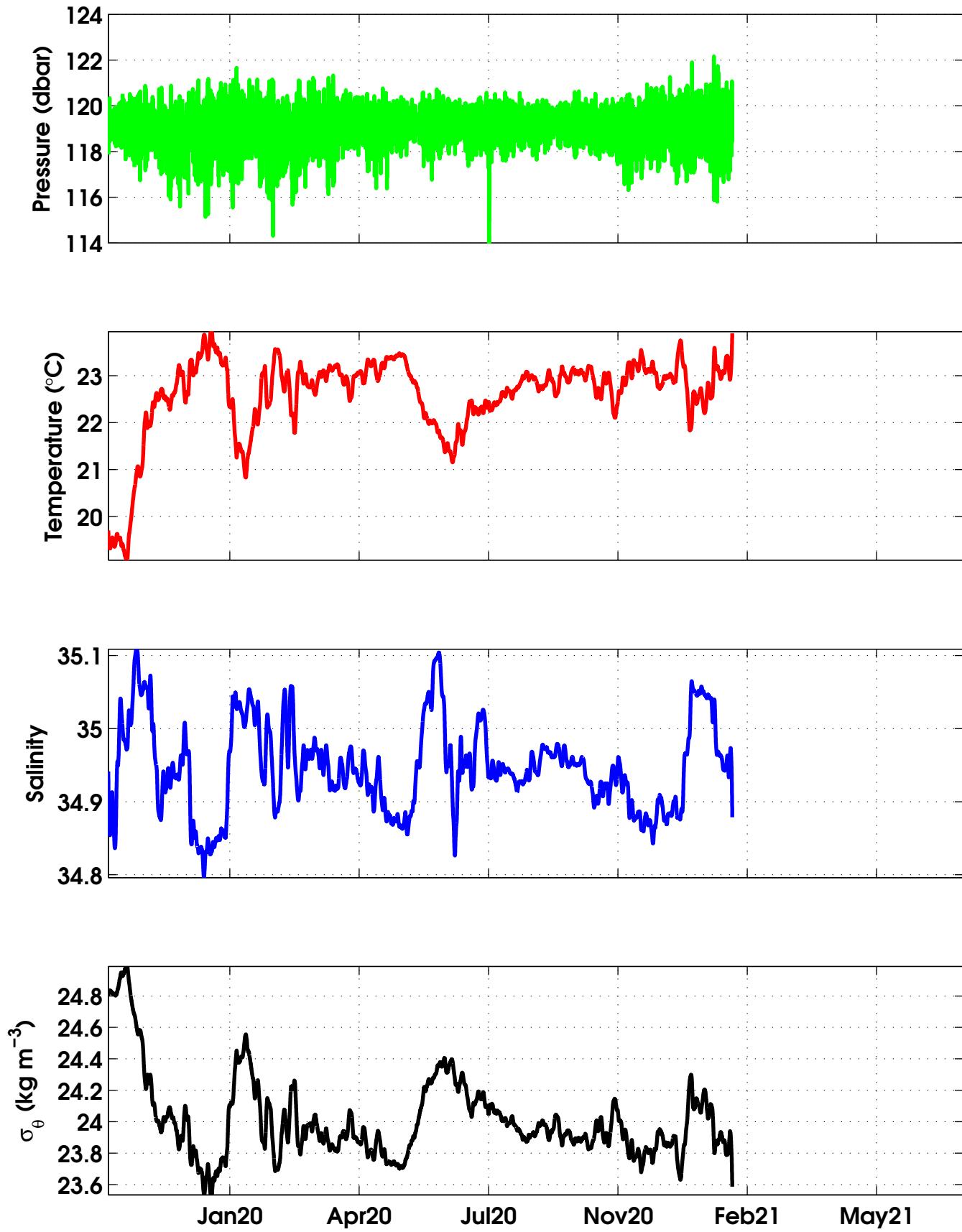


Figure 6.10.1.o

WHOTS-16, 135 m. SN 6888

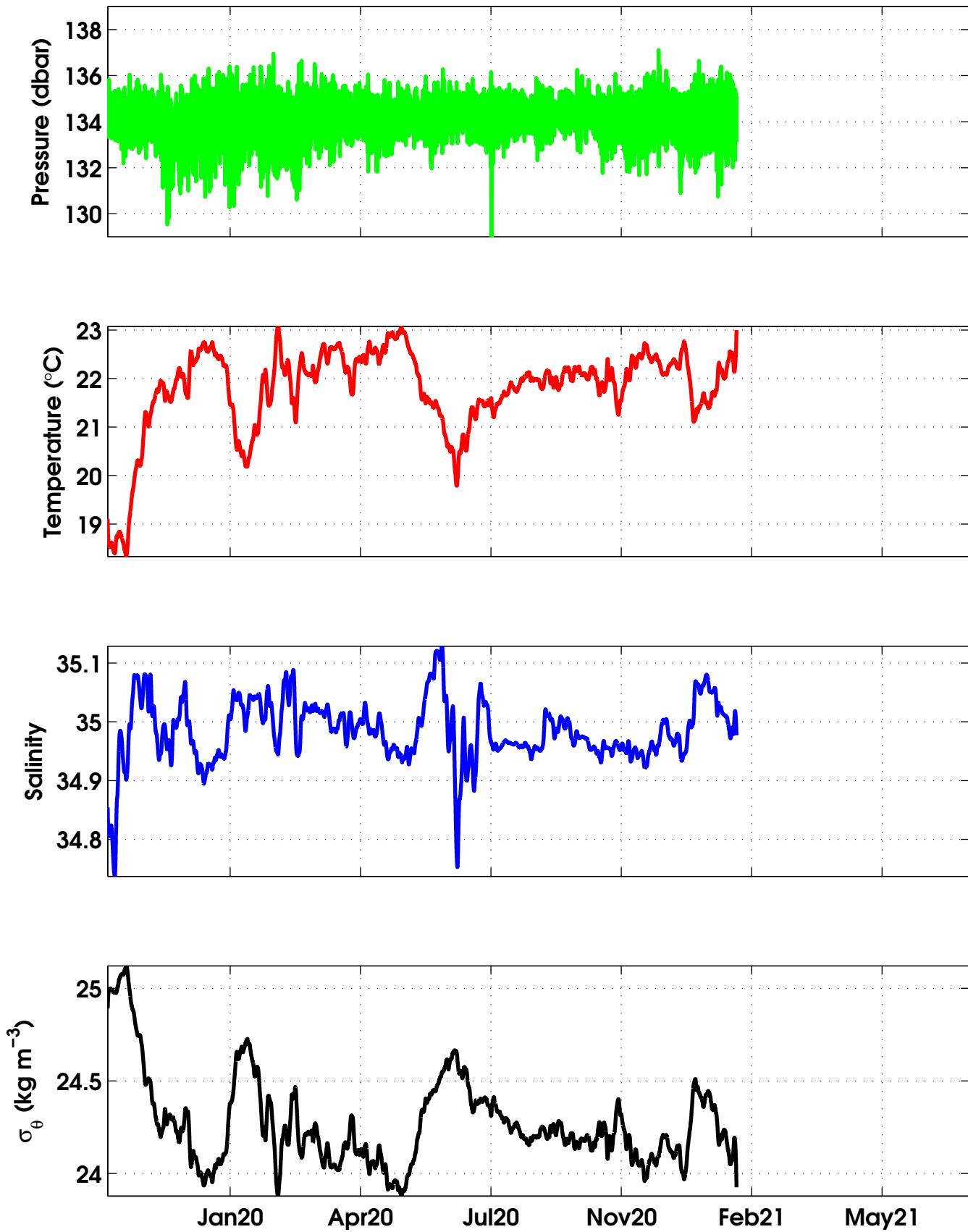


Figure 6.10.1.p

WHOTS-16, 155 m. SN 6891

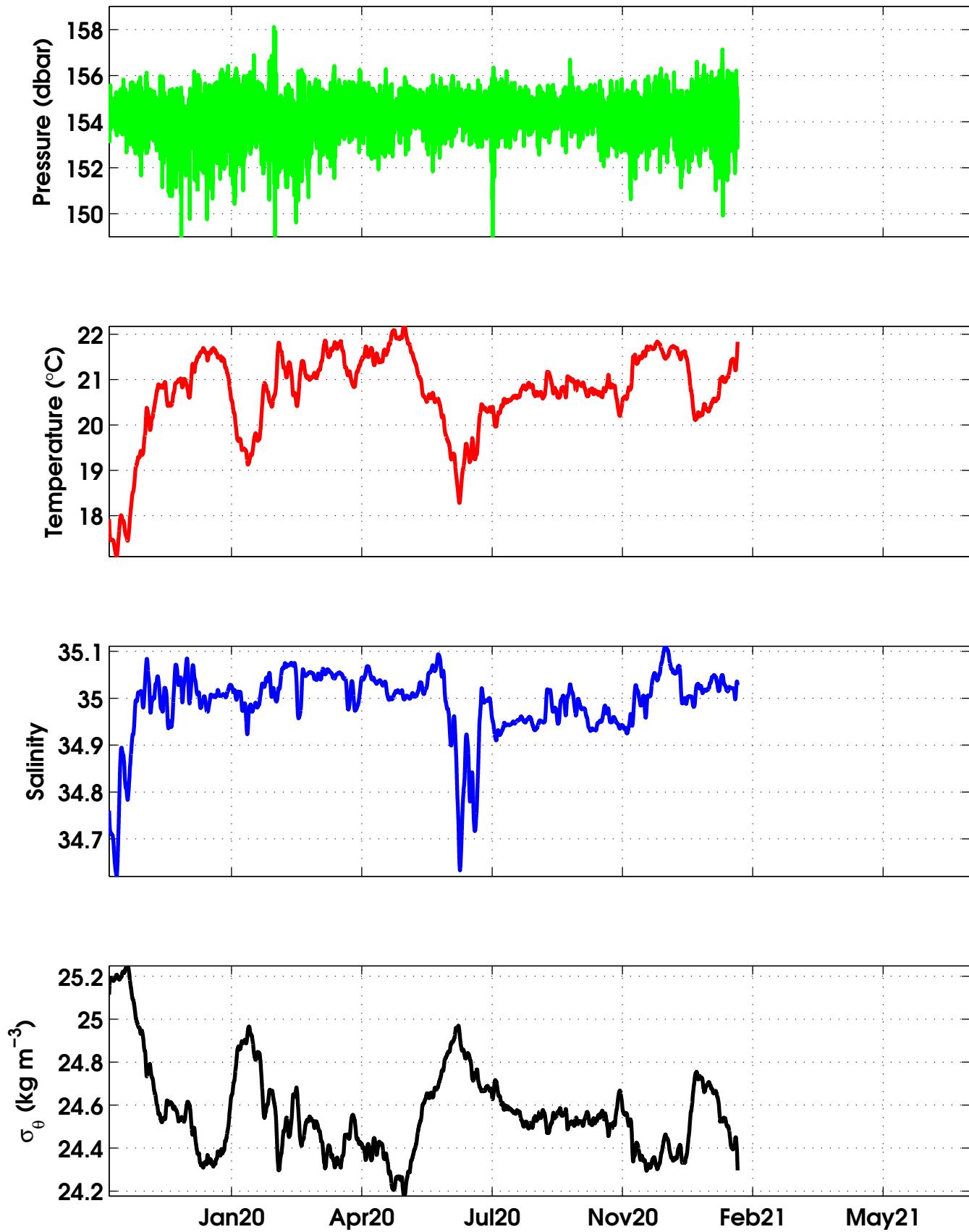


Figure 6.10.1.q

WHOTS-16 4714 m. SN11391

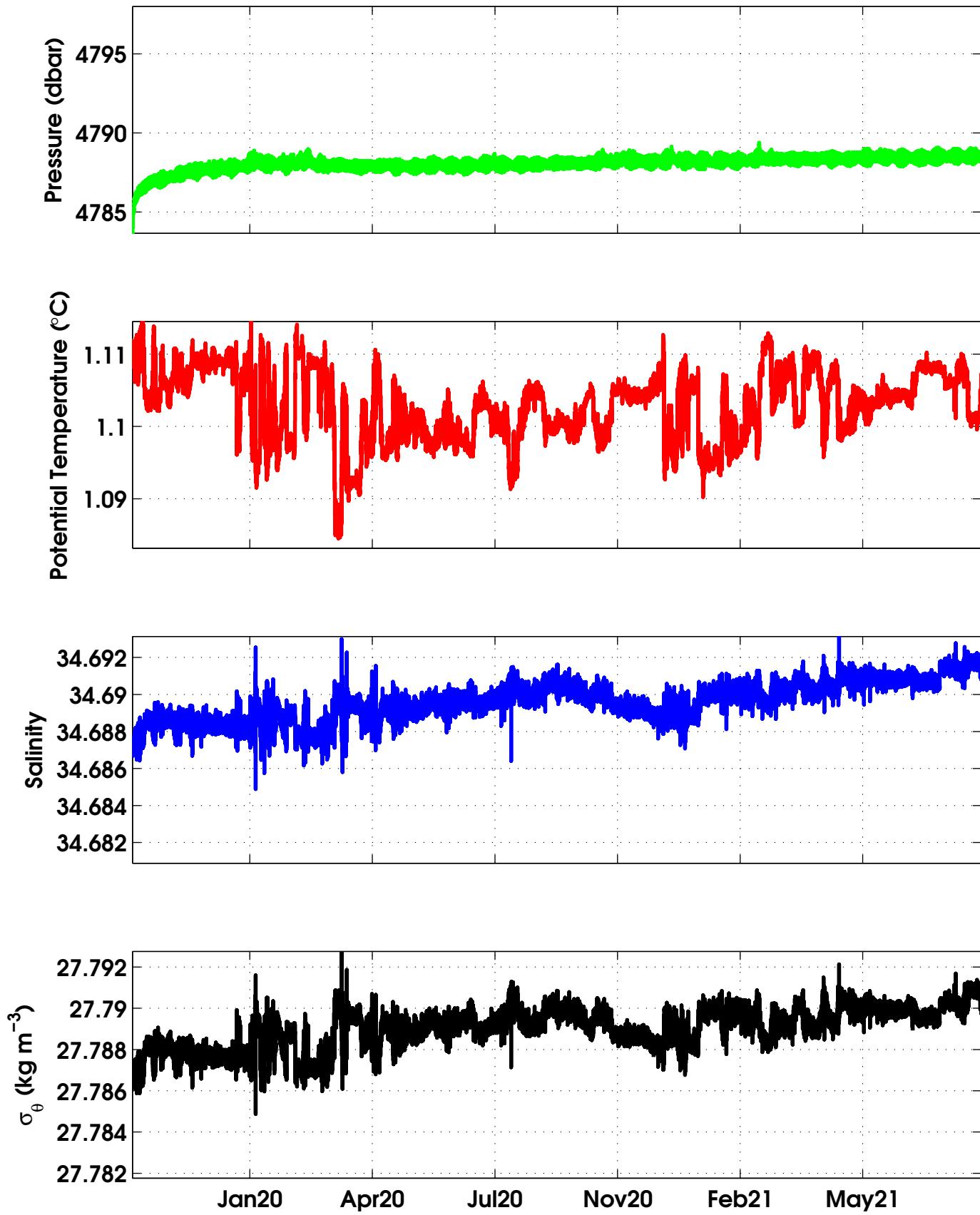


Figure 6.10.1.r

WHOTS-16 4714 m. SN12241

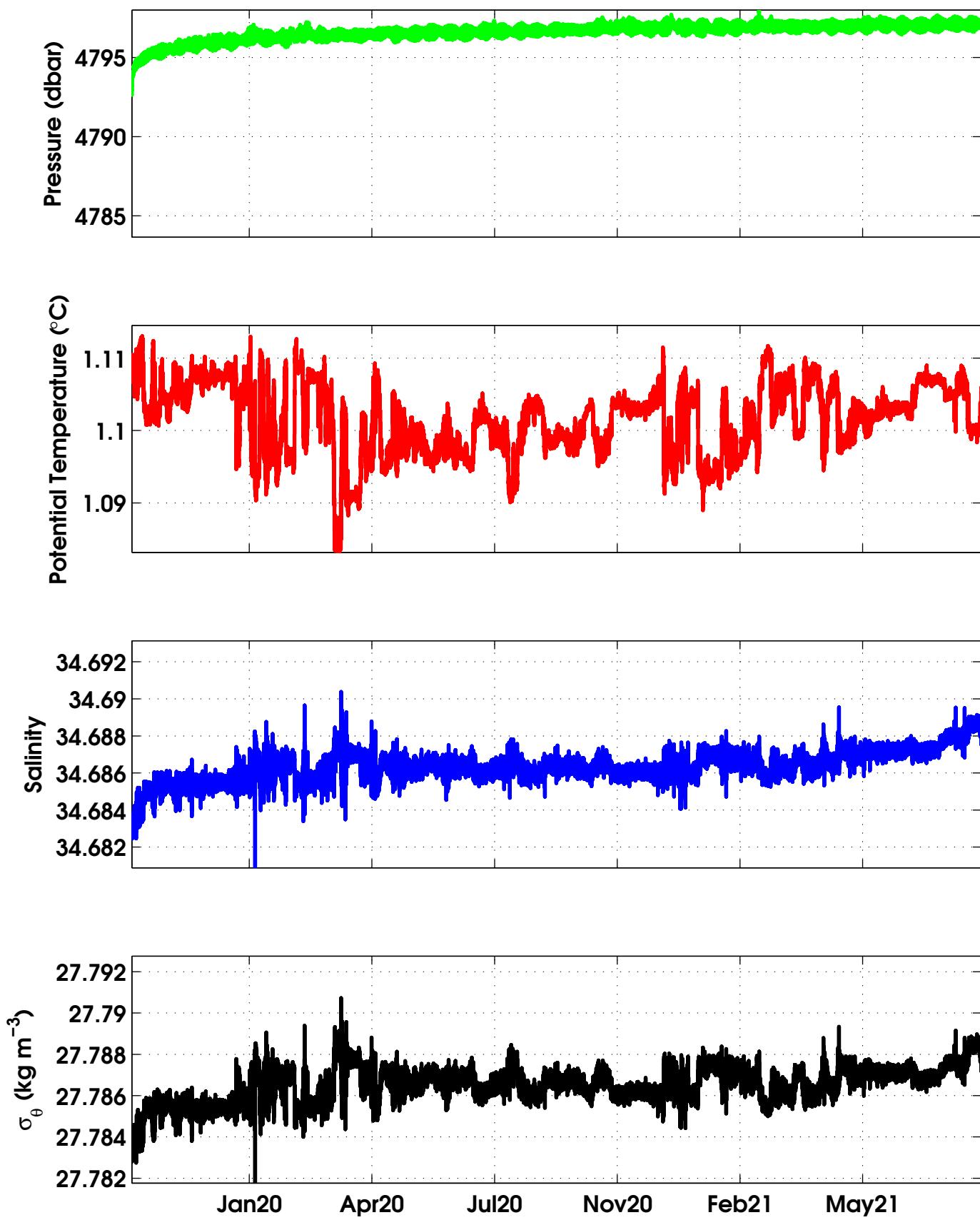


Figure 6.10.1.s

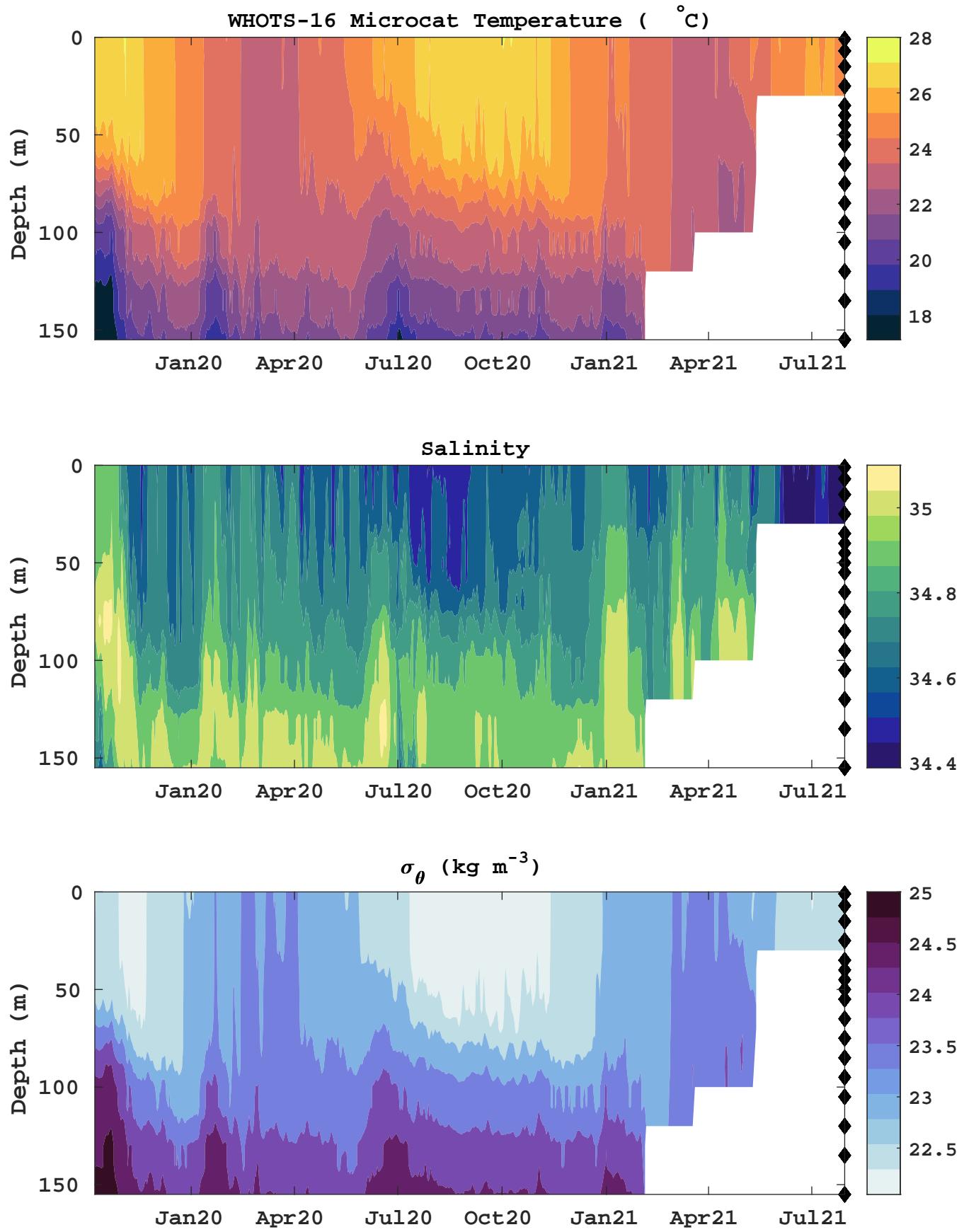


Figure 6.10.1.t

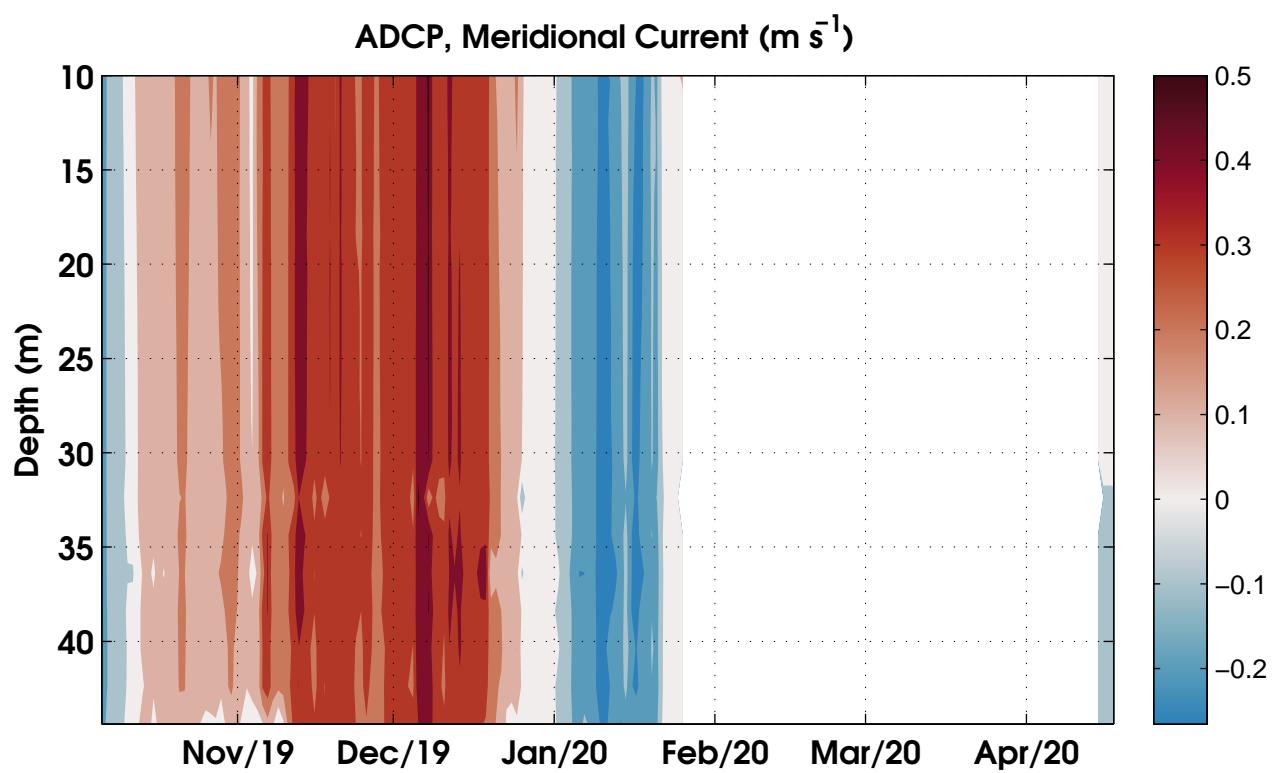
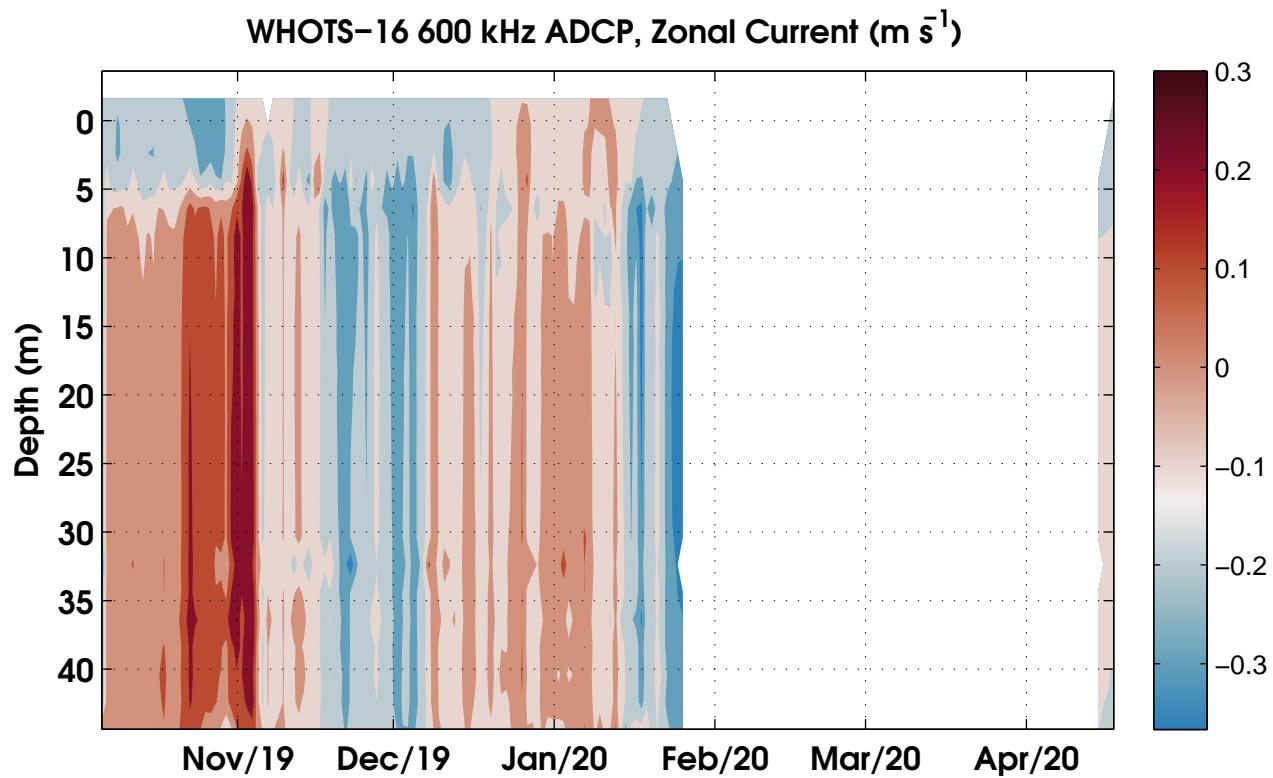


Figure 6.10.2.a

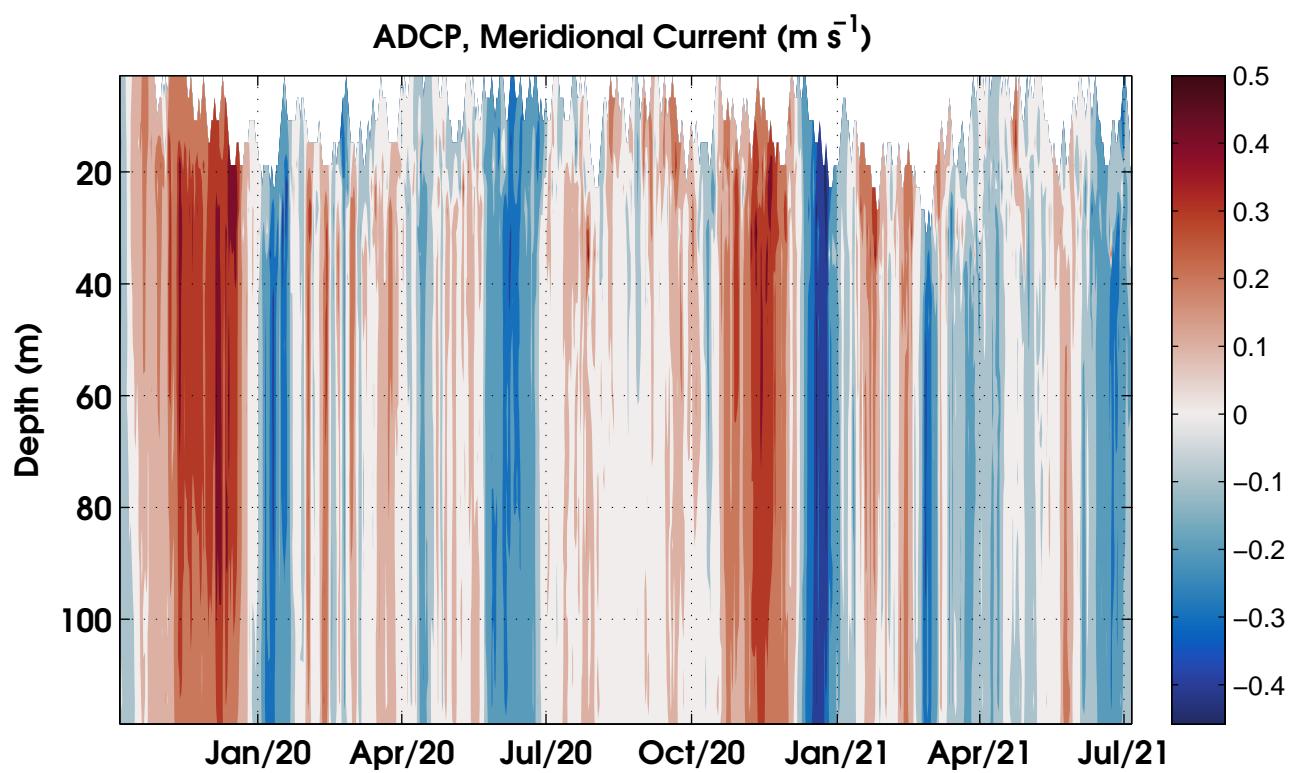
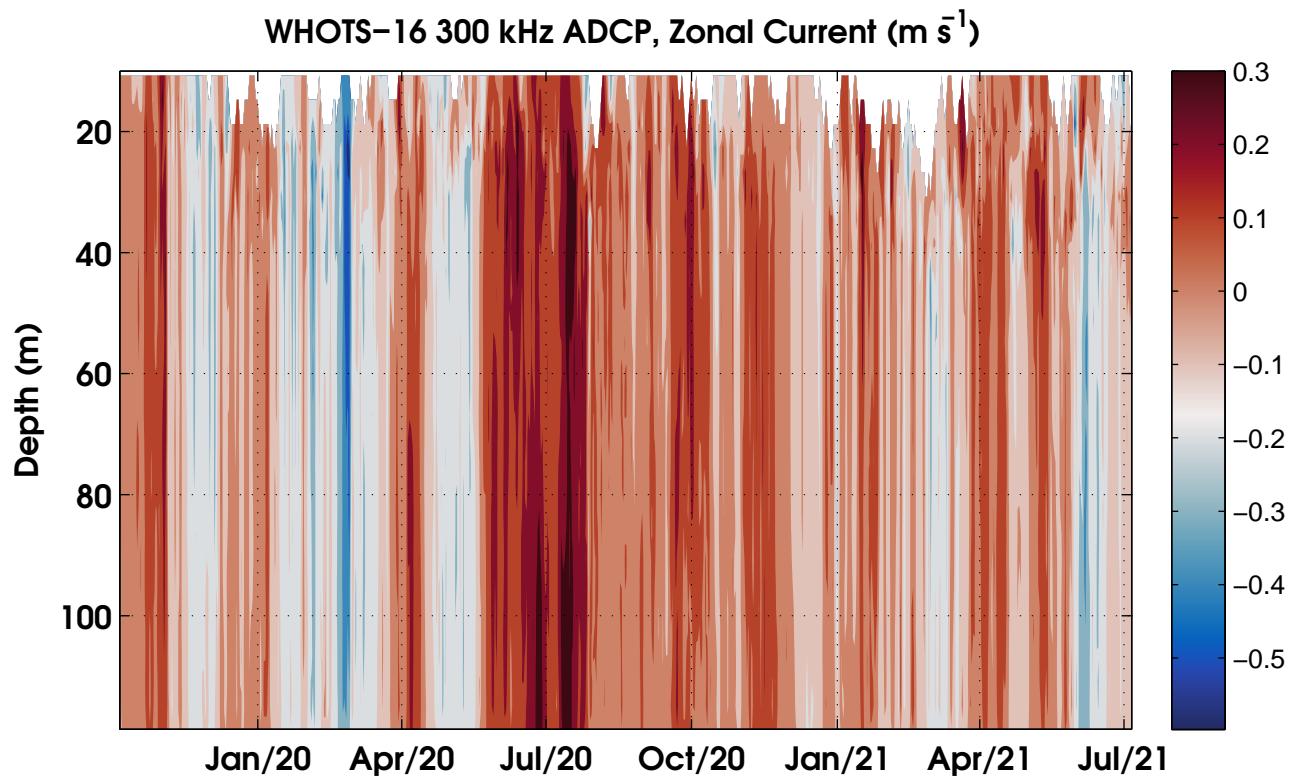


Figure 6.10.2.b

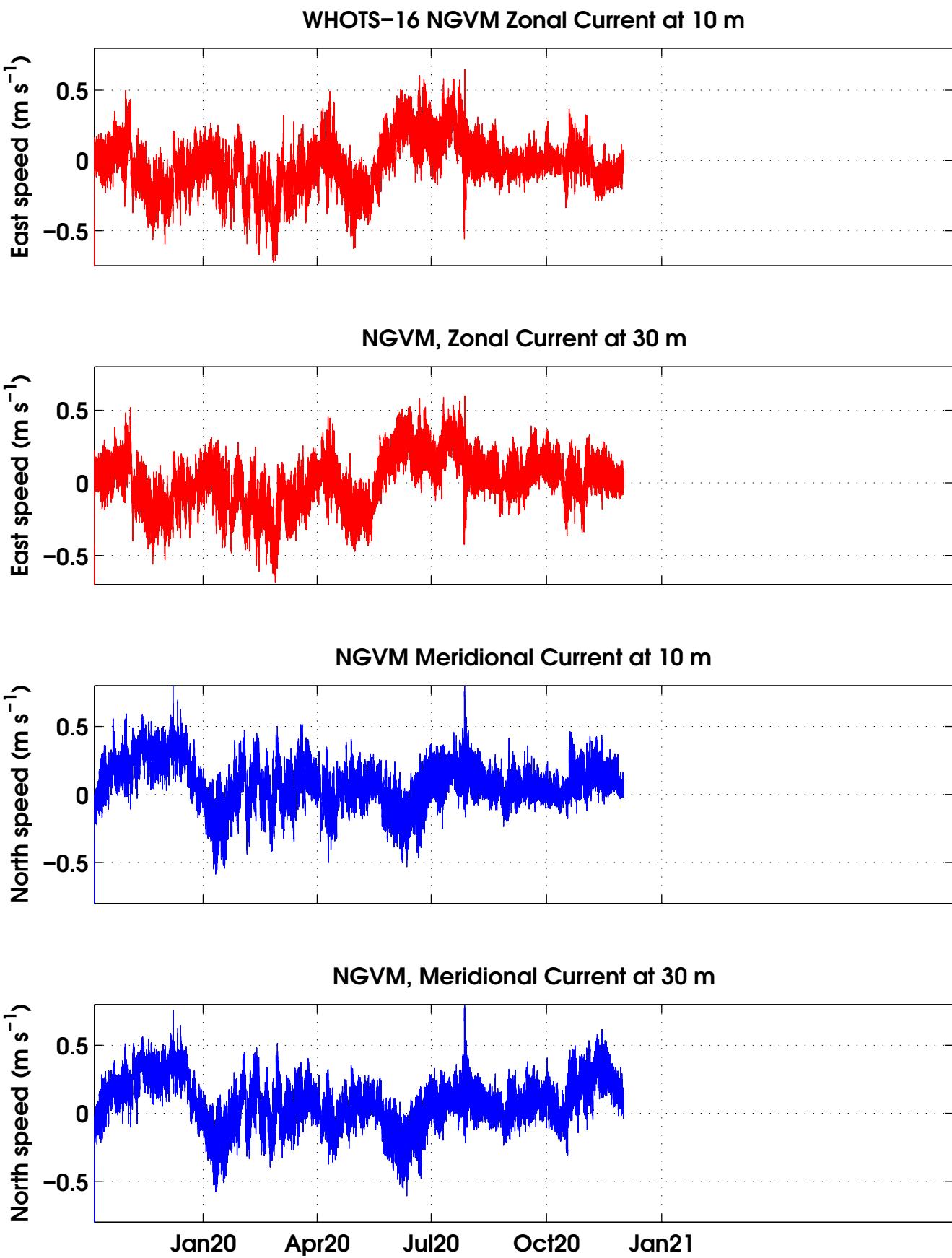


Figure 6.10.3

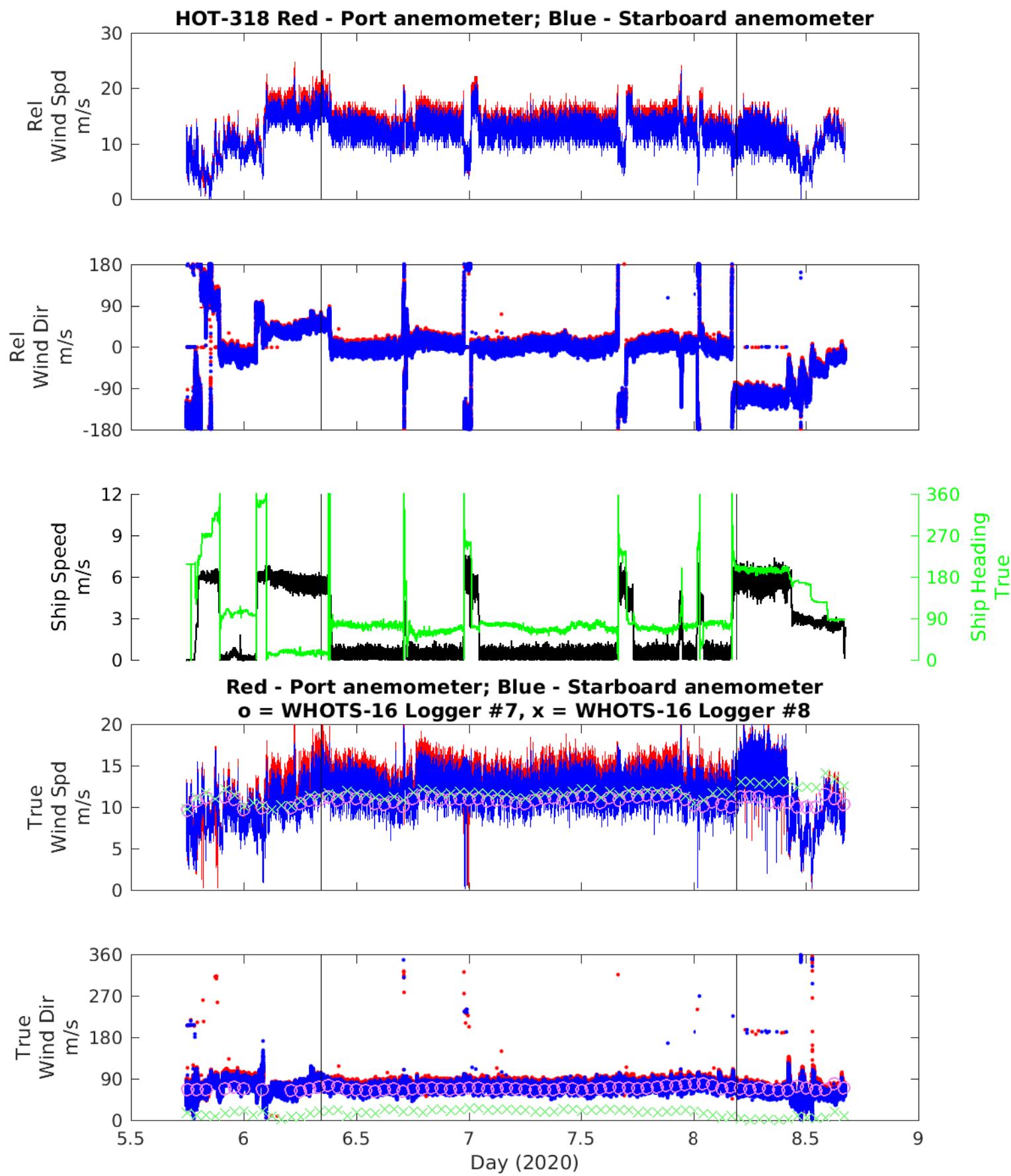
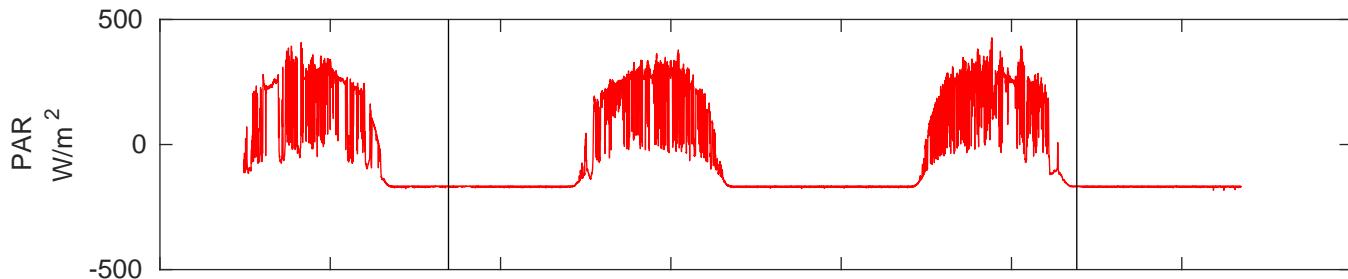
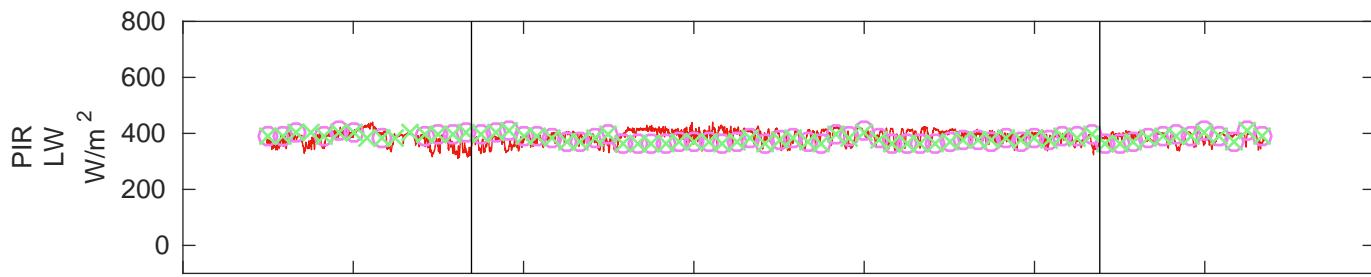
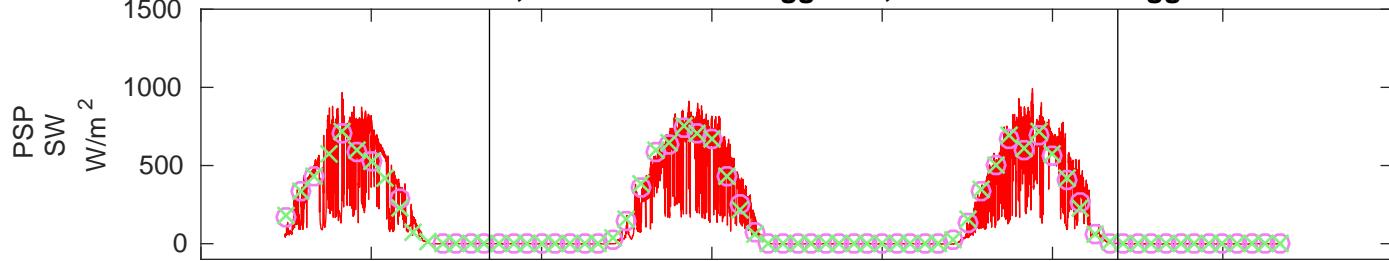


Figure 6.10.4.a.1

HOT-318 Red line = Kilo Moana, o = WHOTS-16 Logger #7, x = WHOTS-16 Logger #8



Red line = RM Young RTD, Blue line = Humidity Temp,
o = WHOTS-16 Logger #7, x = WHOTS-16 Logger #8

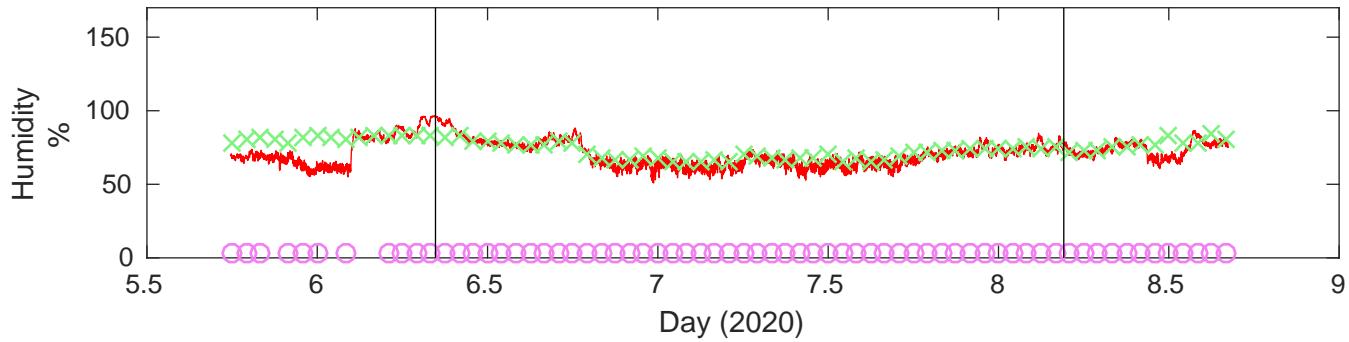
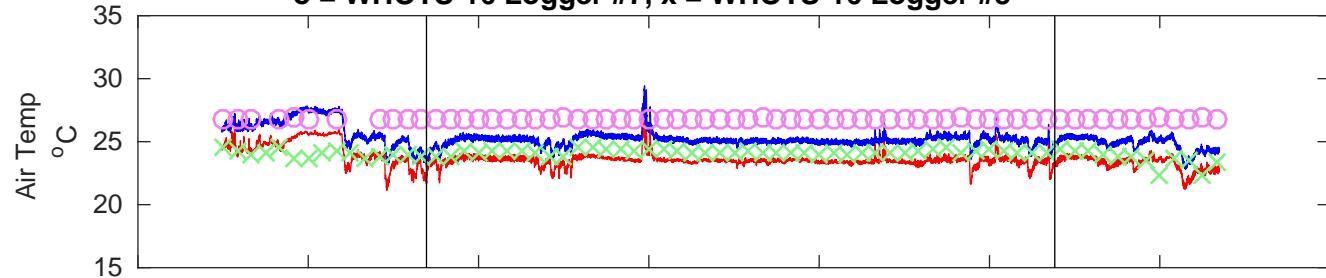


Figure 6.10.4.a.2

HOT-318 Red line = Kilo Moana, o = WHOTS-16 Logger #7, x = WHOTS-16 Logger #8

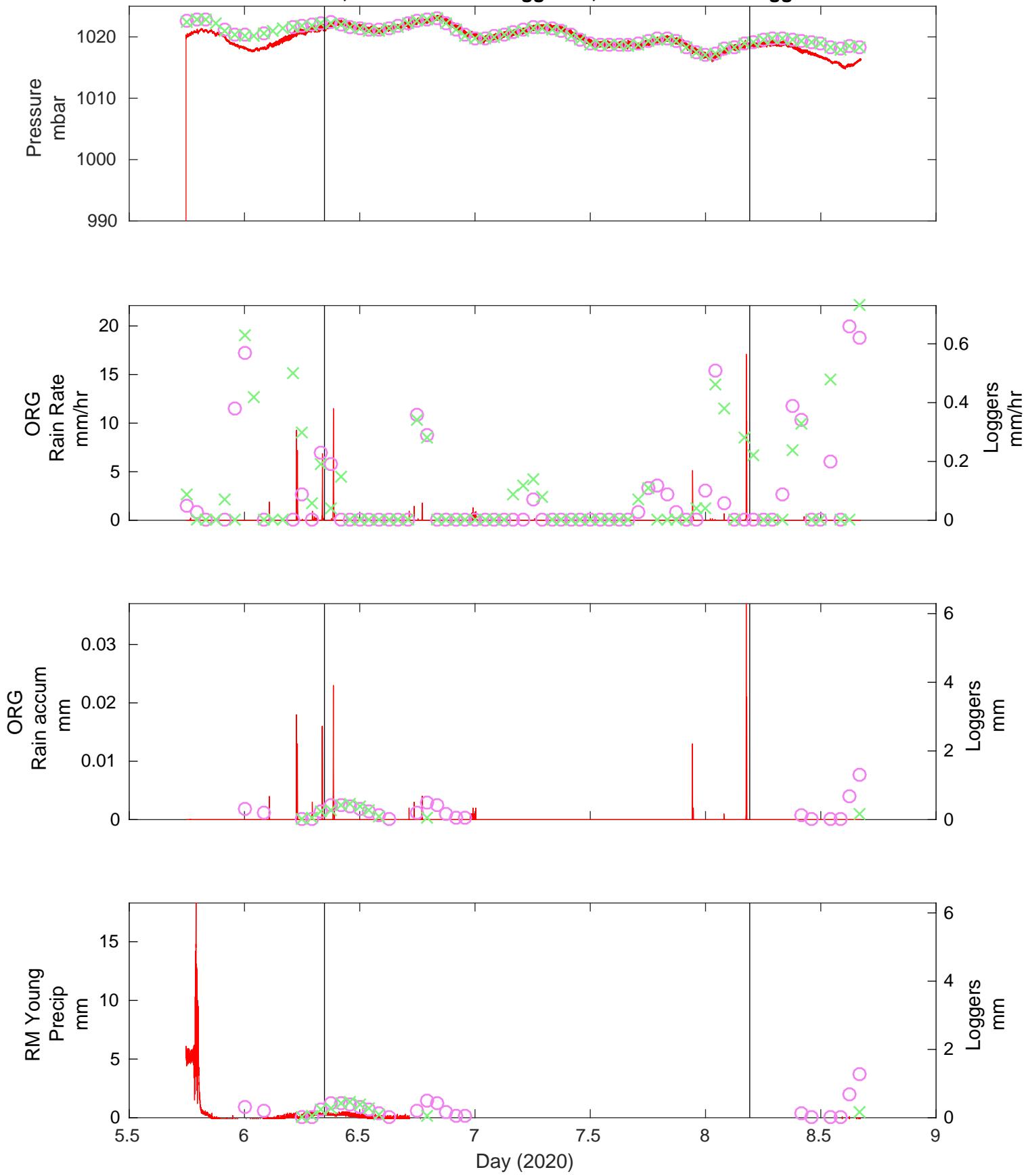


Figure 6.10.4.a.3

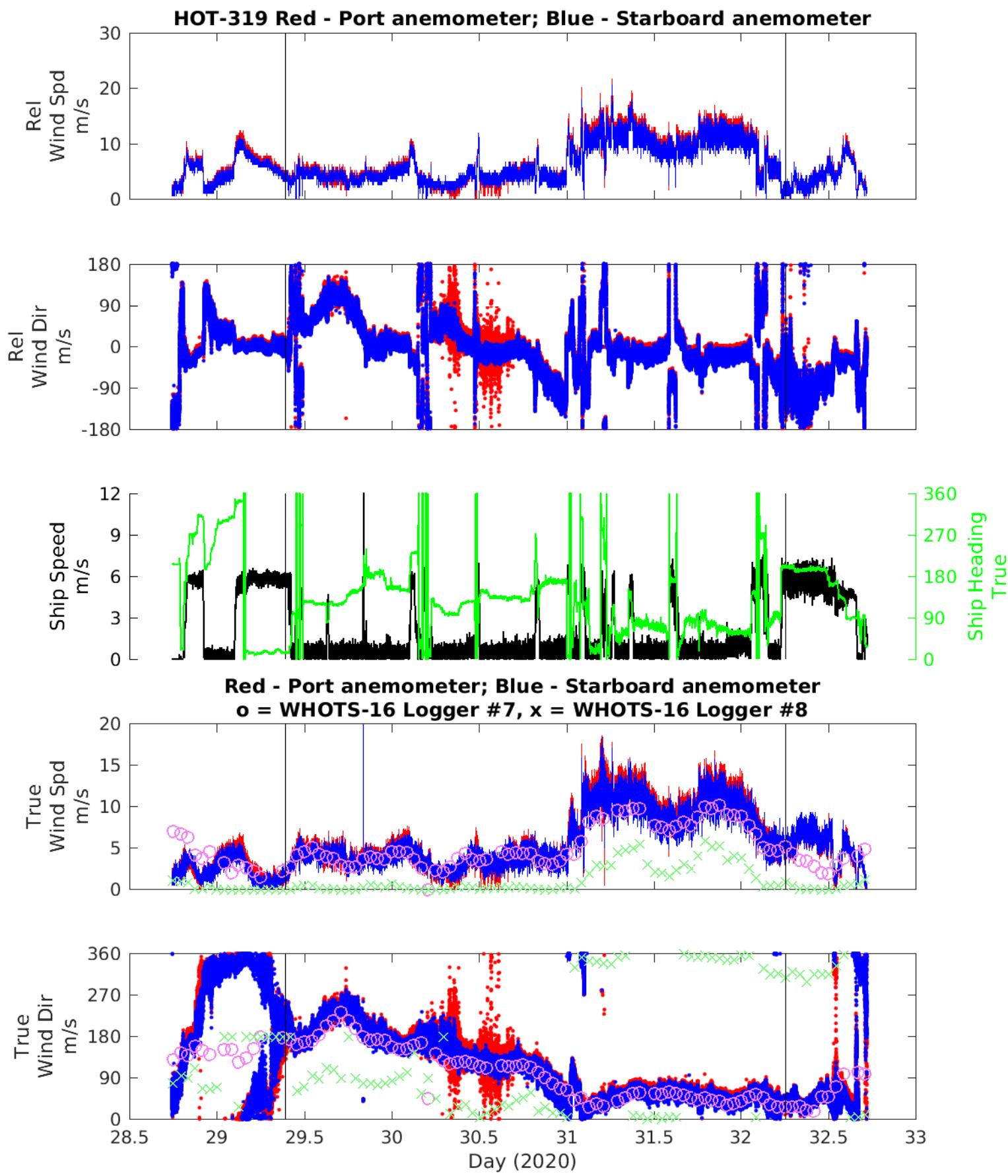
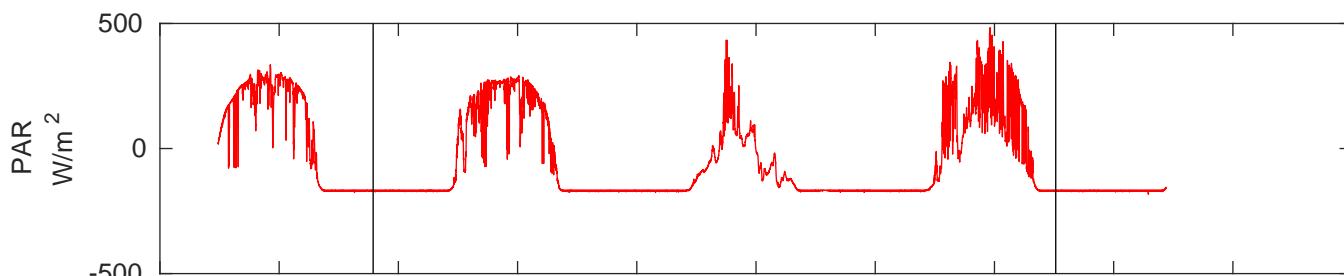
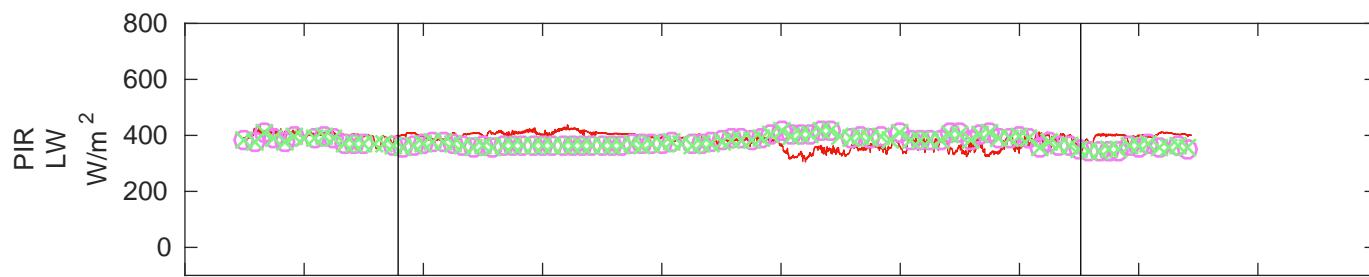
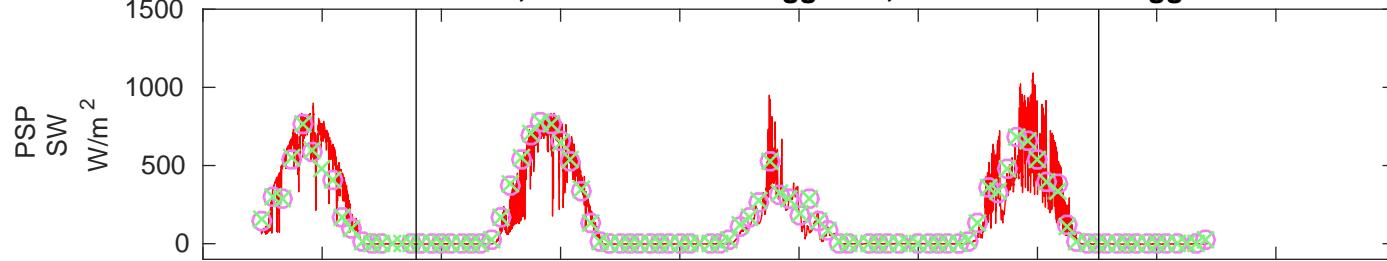


Figure 6.10.4.b.1

HOT-319 Red line = Kilo Moana, o = WHOTS-16 Logger #7, x = WHOTS-16 Logger #8



Red line = RM Young RTD, Blue line = Humidity Temp,
o = WHOTS-16 Logger #7, x = WHOTS-16 Logger #8

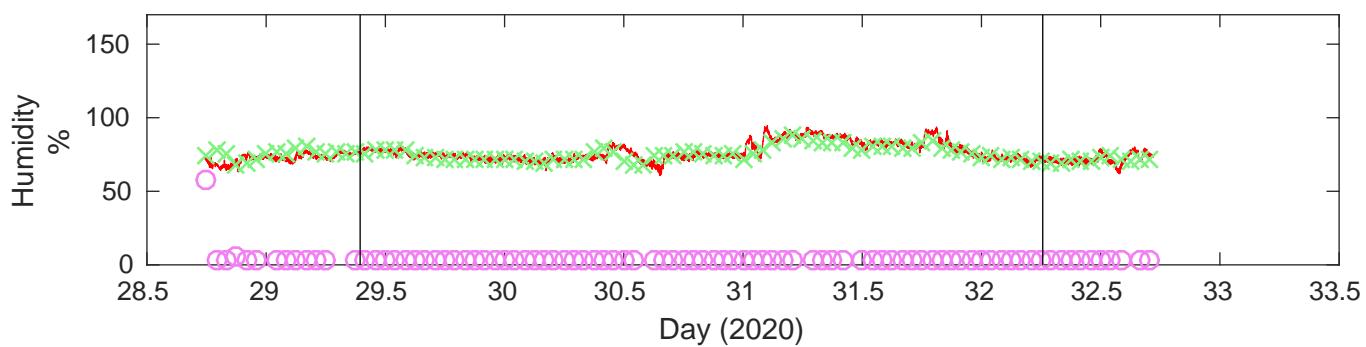
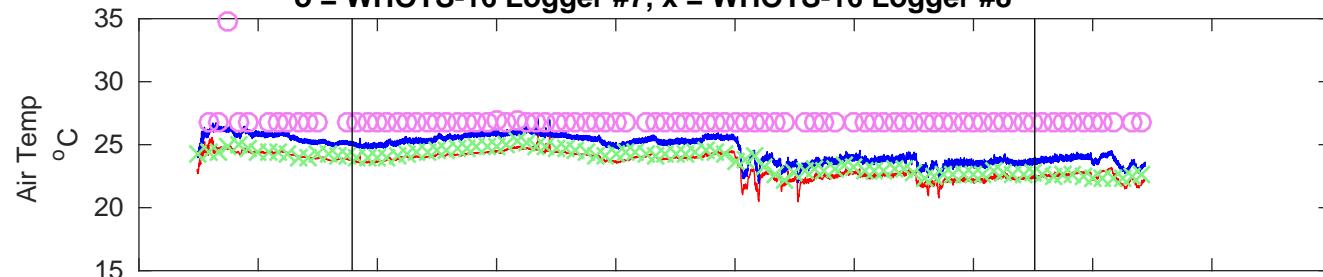


Figure 6.10.4.b.2

HOT-319 Red line = Kilo Moana, o = WHOTS-16 Logger #7, x = WHOTS-16 Logger #8

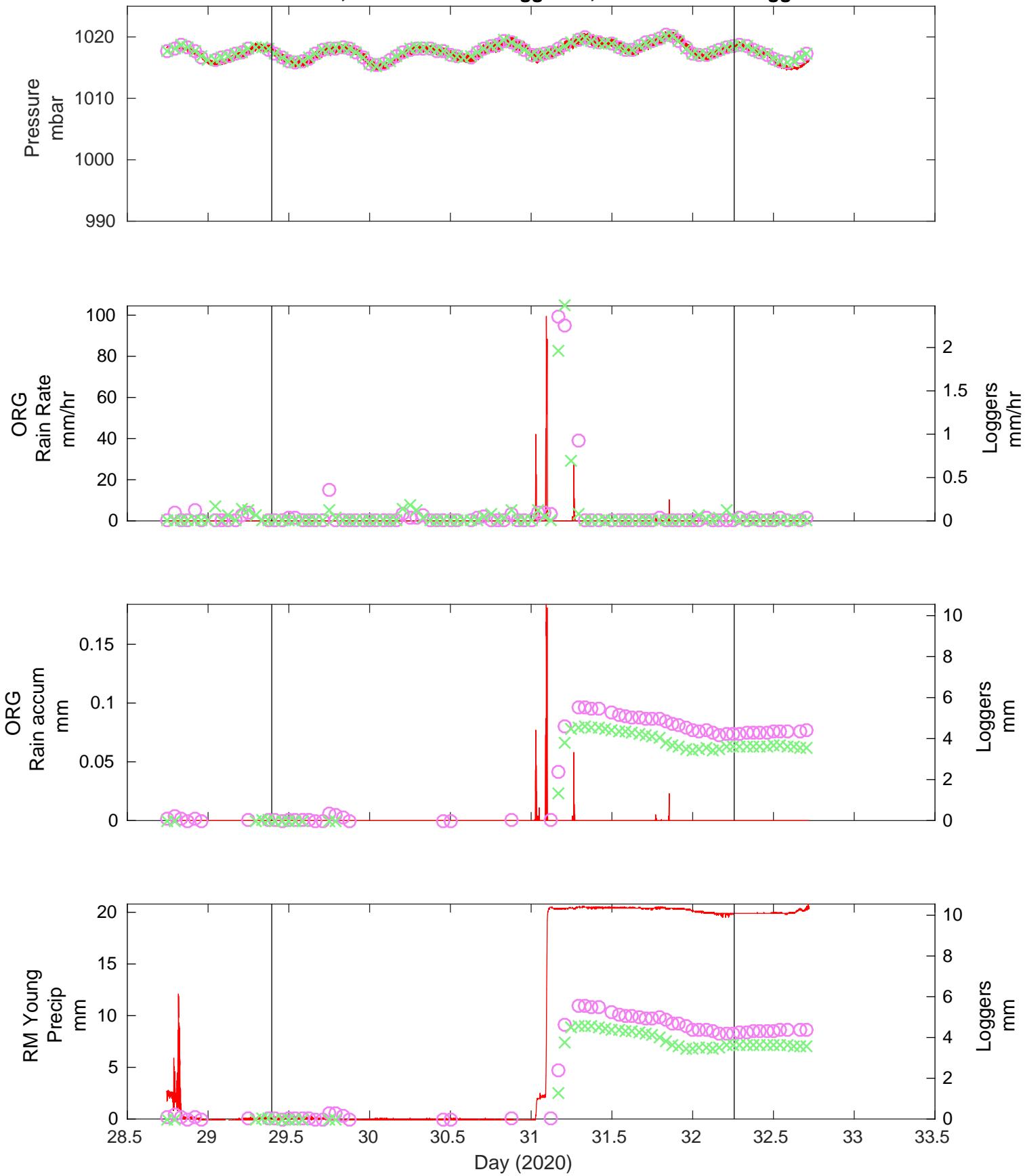


Figure 6.10.4.b.3

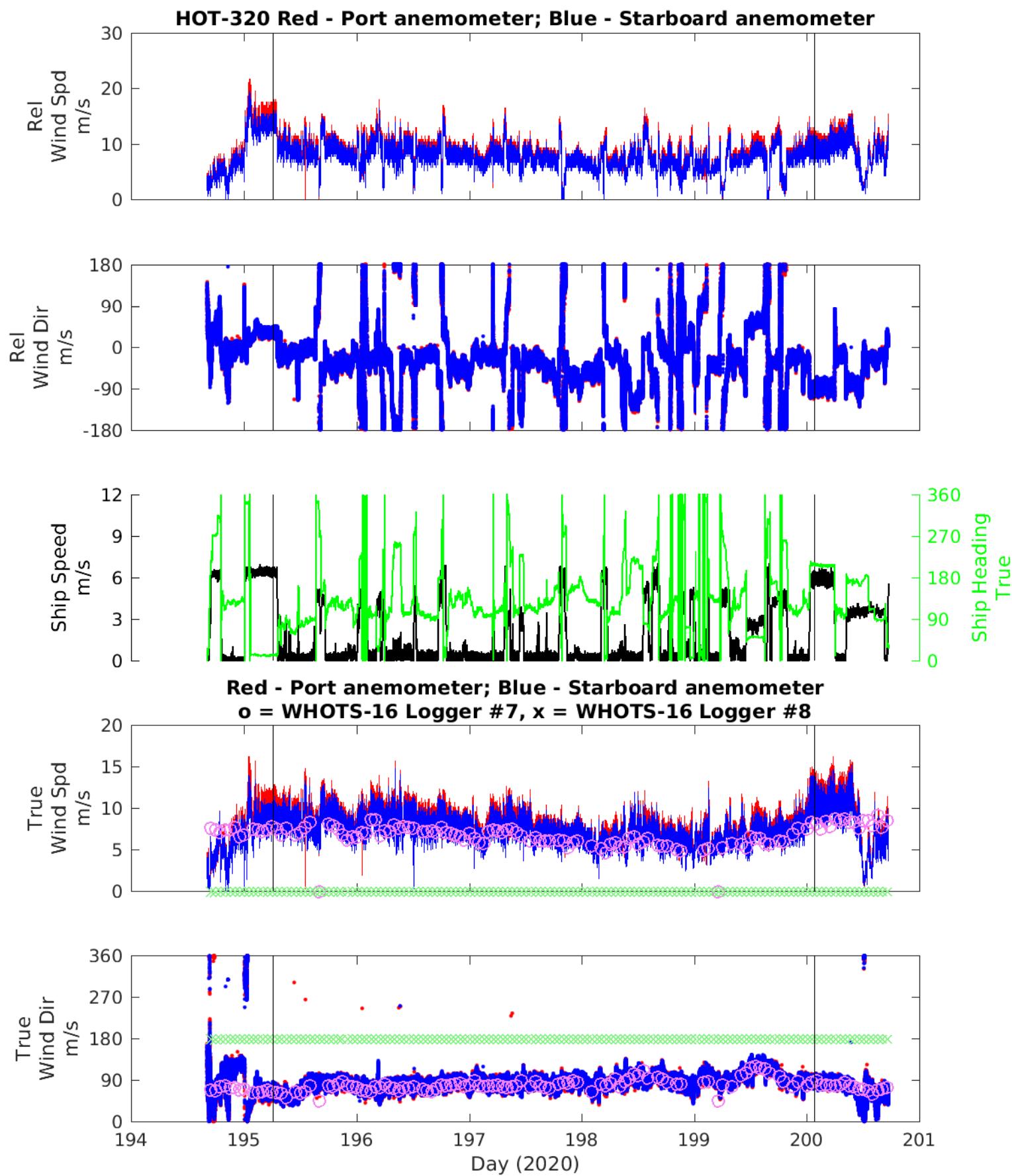
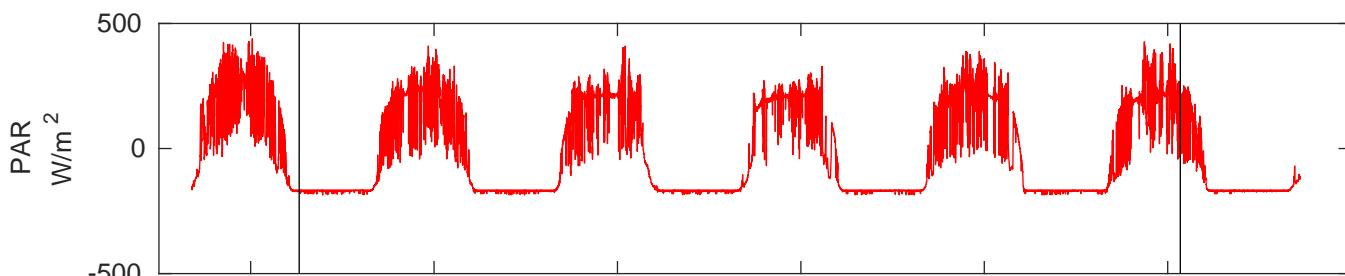
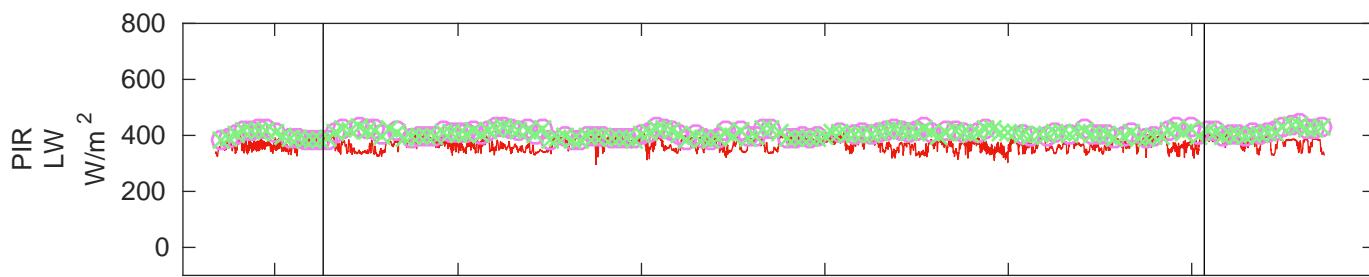
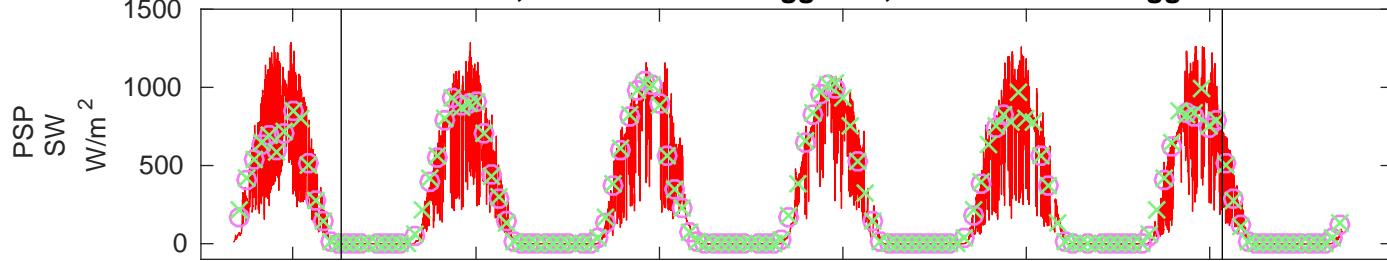


Figure 6.10.4.c.1

HOT-320 Red line = Kilo Moana, o = WHOTS-16 Logger #7, x = WHOTS-16 Logger #8



Red line = RM Young RTD, Blue line = Humidity Temp,
o = WHOTS-16 Logger #7, x = WHOTS-16 Logger #8

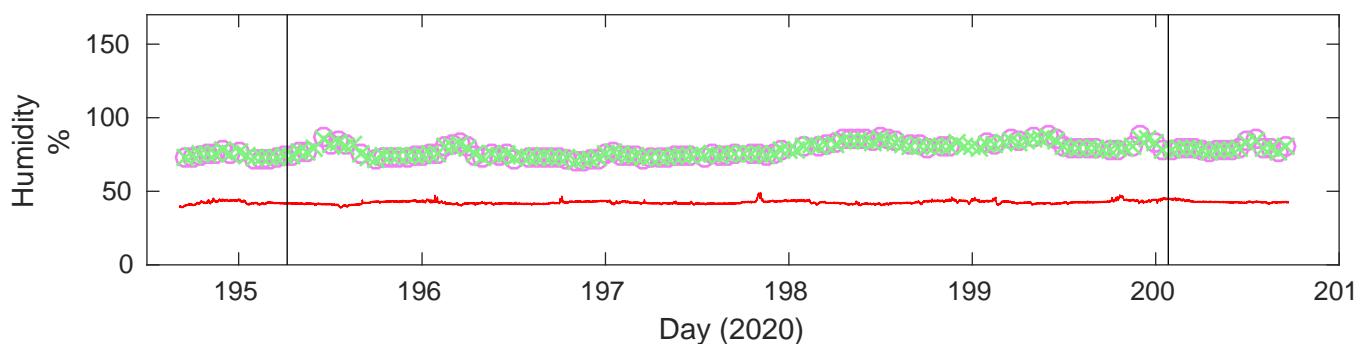
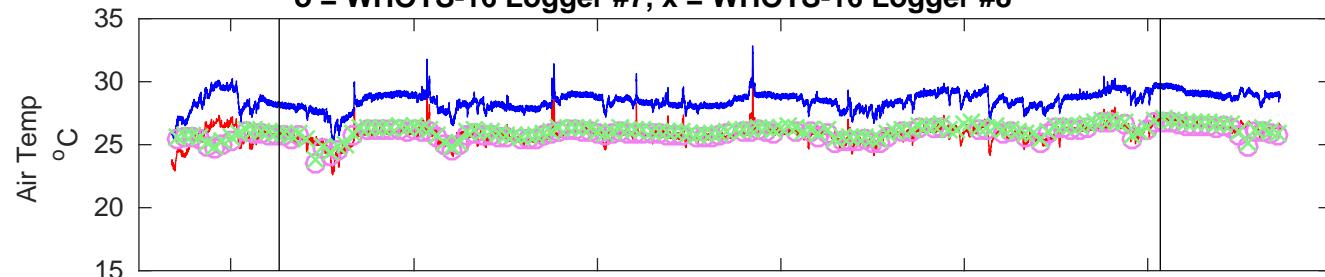


Figure 6.10.4.c.2

HOT-320 Red line = Kilo Moana, o = WHOTS-16 Logger #7, x = WHOTS-16 Logger #8

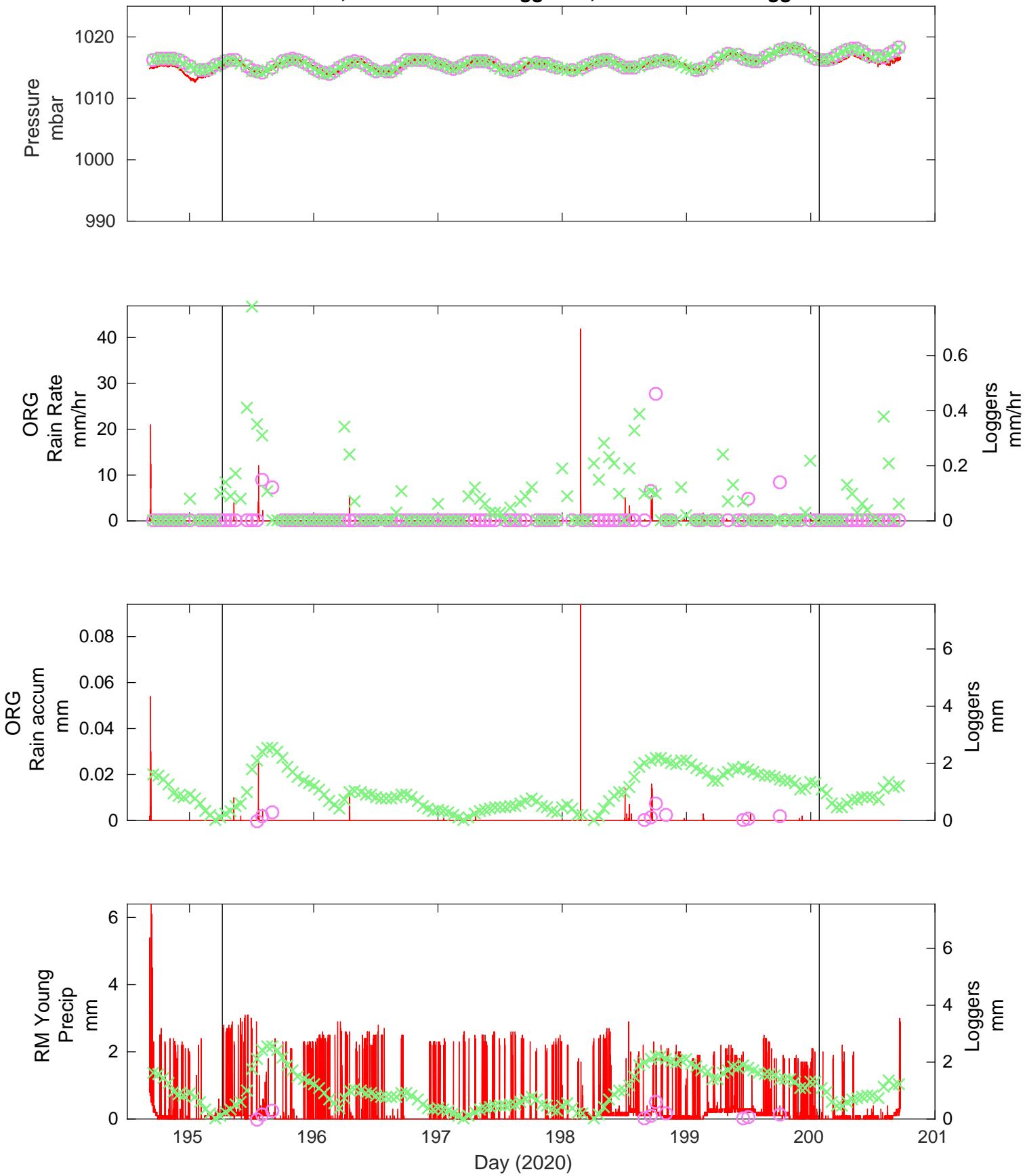


Figure 6.10.4.c.3

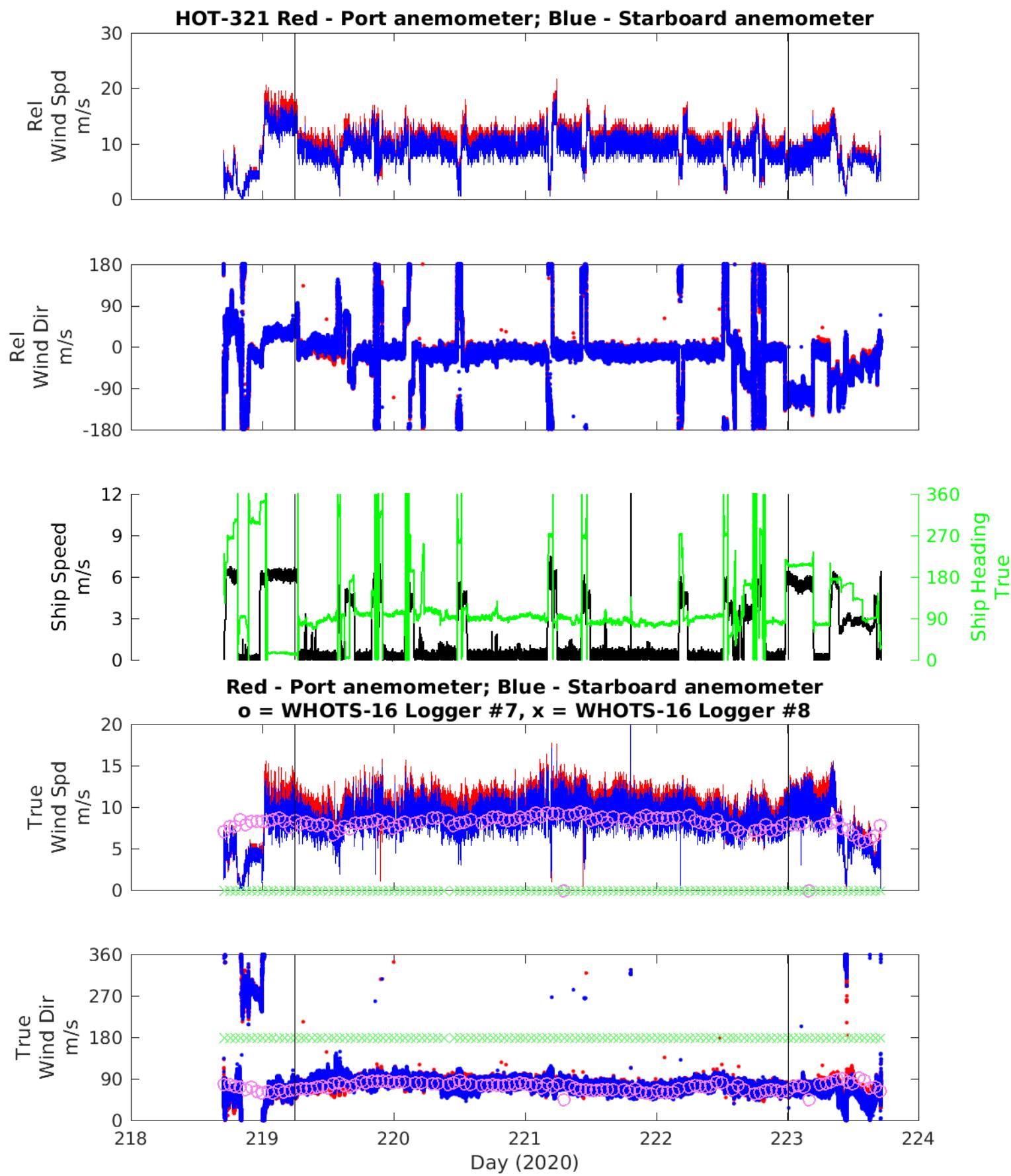
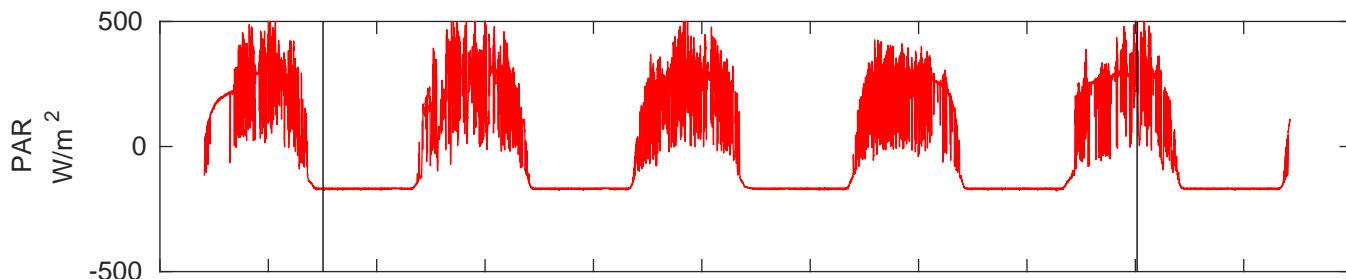
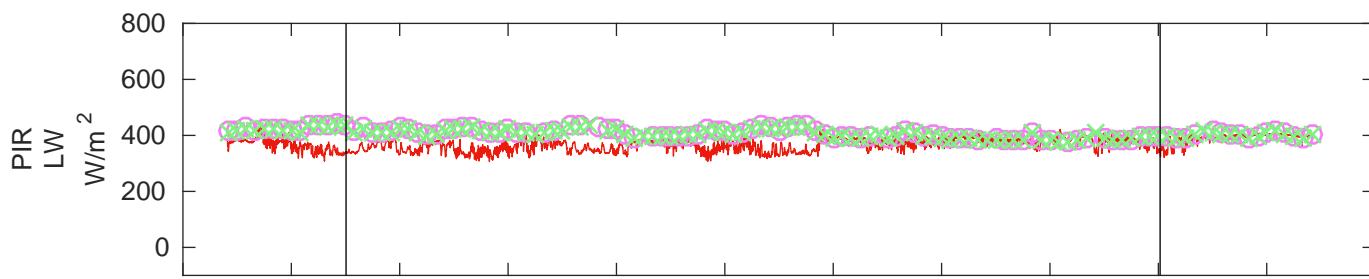
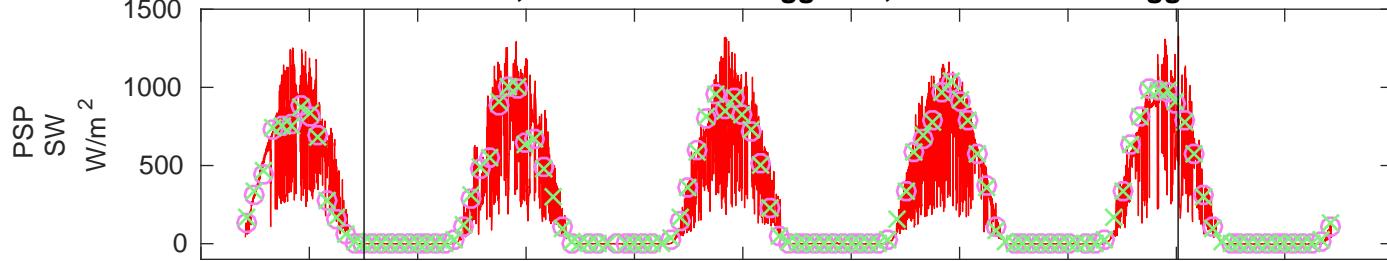


Figure 6.10.4.d.1

HOT-321 Red line = Kilo Moana, o = WHOTS-16 Logger #7, x = WHOTS-16 Logger #8



Red line = RM Young RTD, Blue line = Humidity Temp,
o = WHOTS-16 Logger #7, x = WHOTS-16 Logger #8

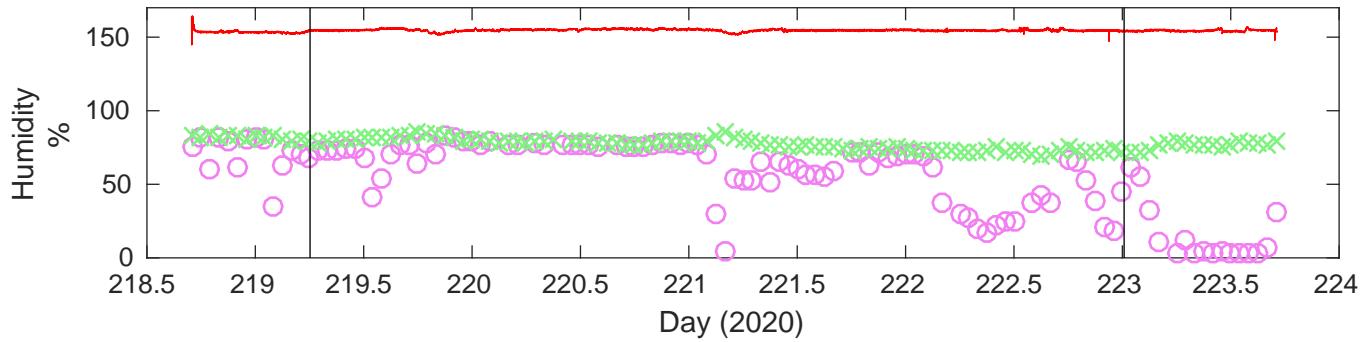
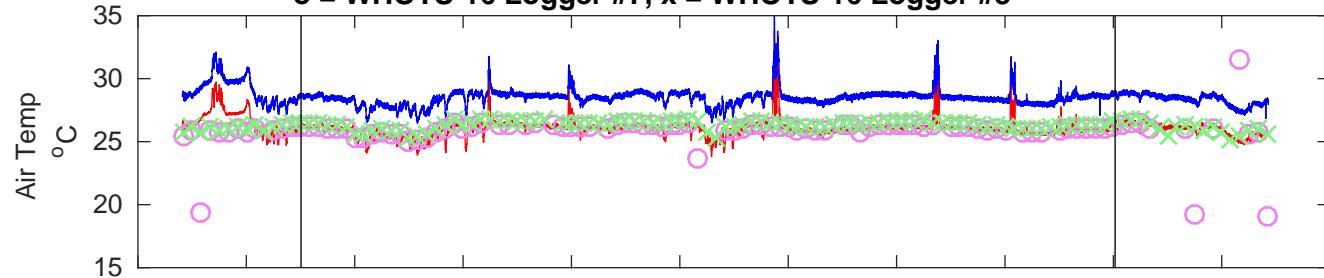


Figure 6.10.4.d.2

HOT-321 Red line = Kilo Moana, o = WHOTS-16 Logger #7, x = WHOTS-16 Logger #8

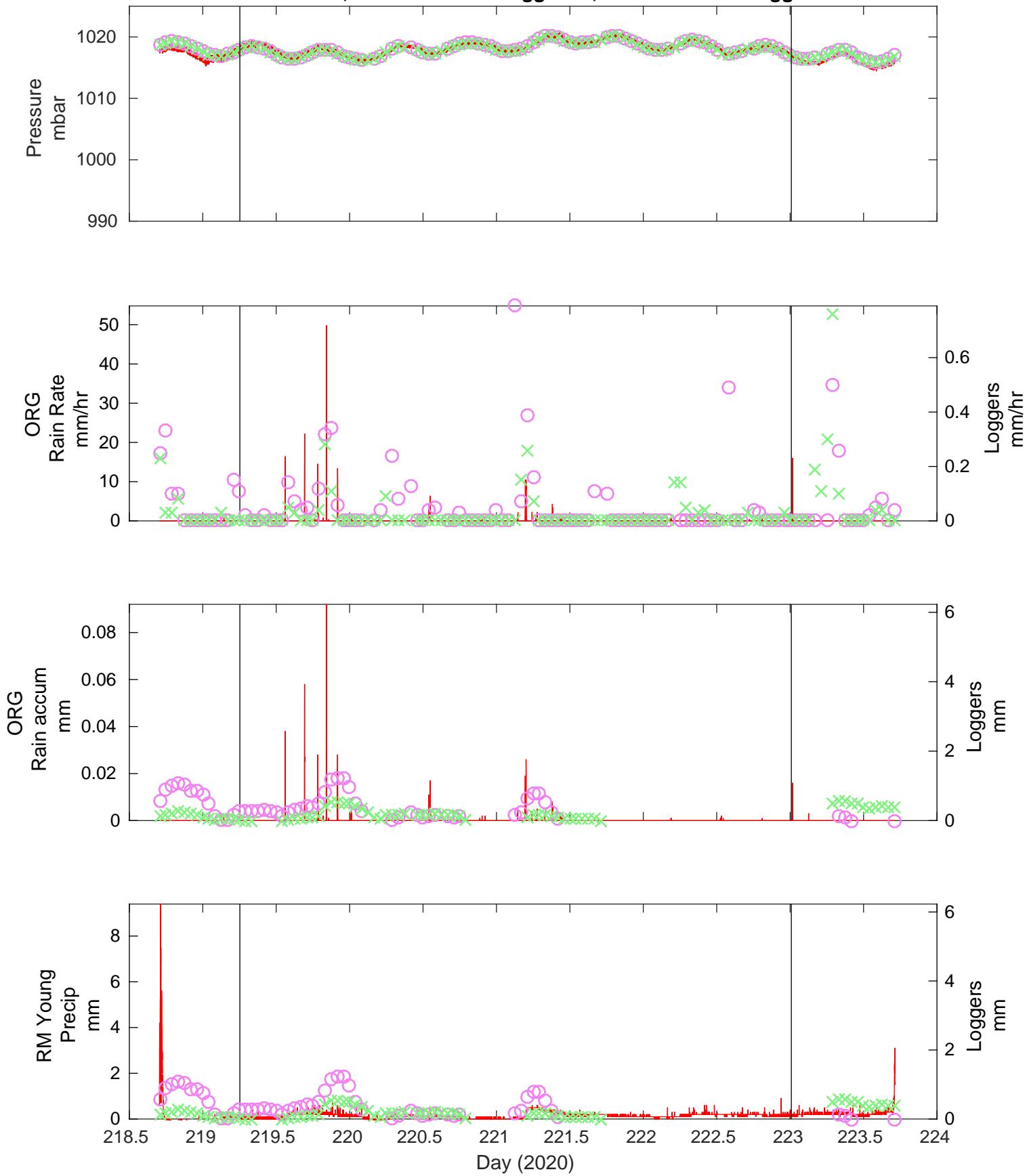


Figure 6.10.4.d.3

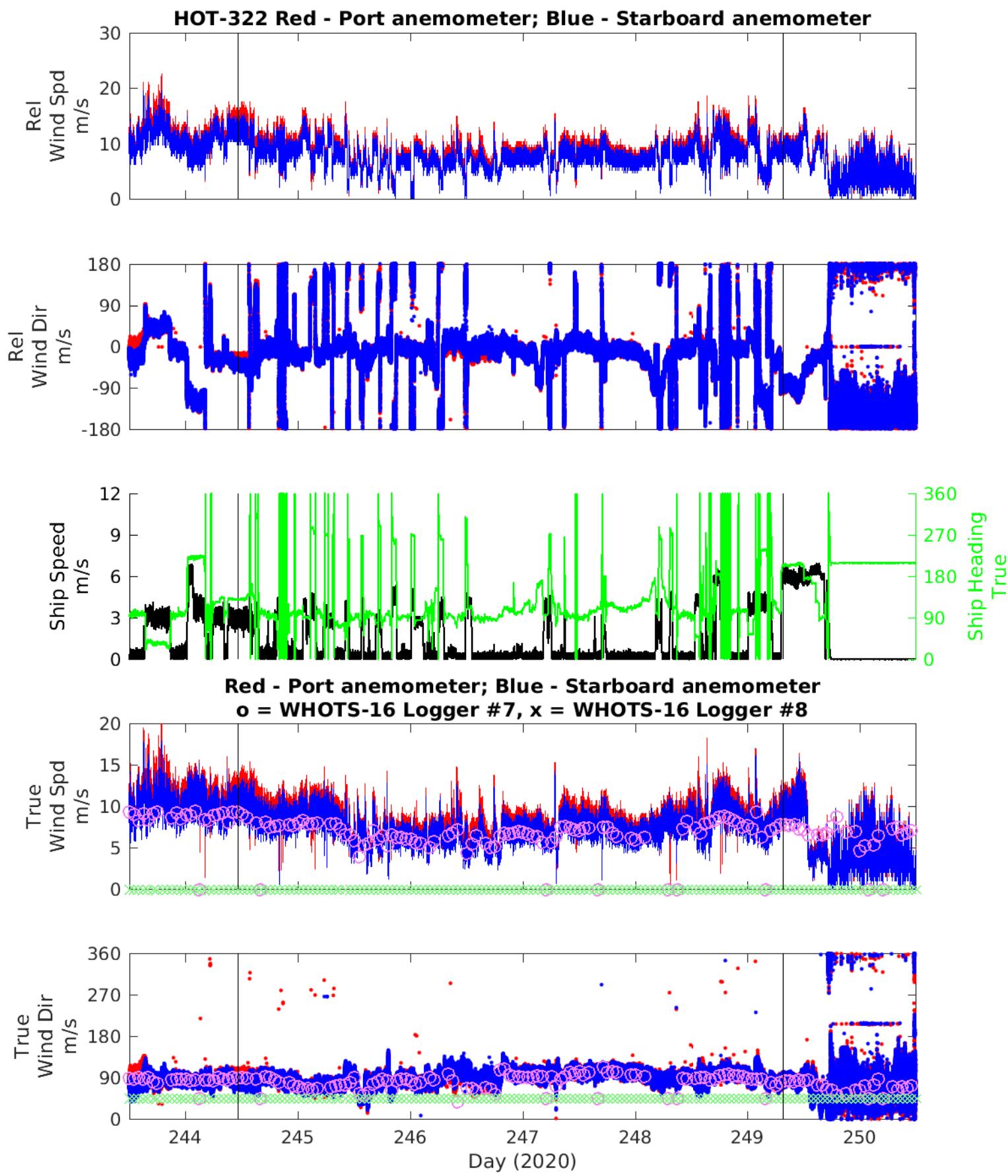


Figure 6.10.4.e.1

HOT-322 Red line = Kilo Moana, o = WHOTS-16 Logger #7, x = WHOTS-16 Logger #8

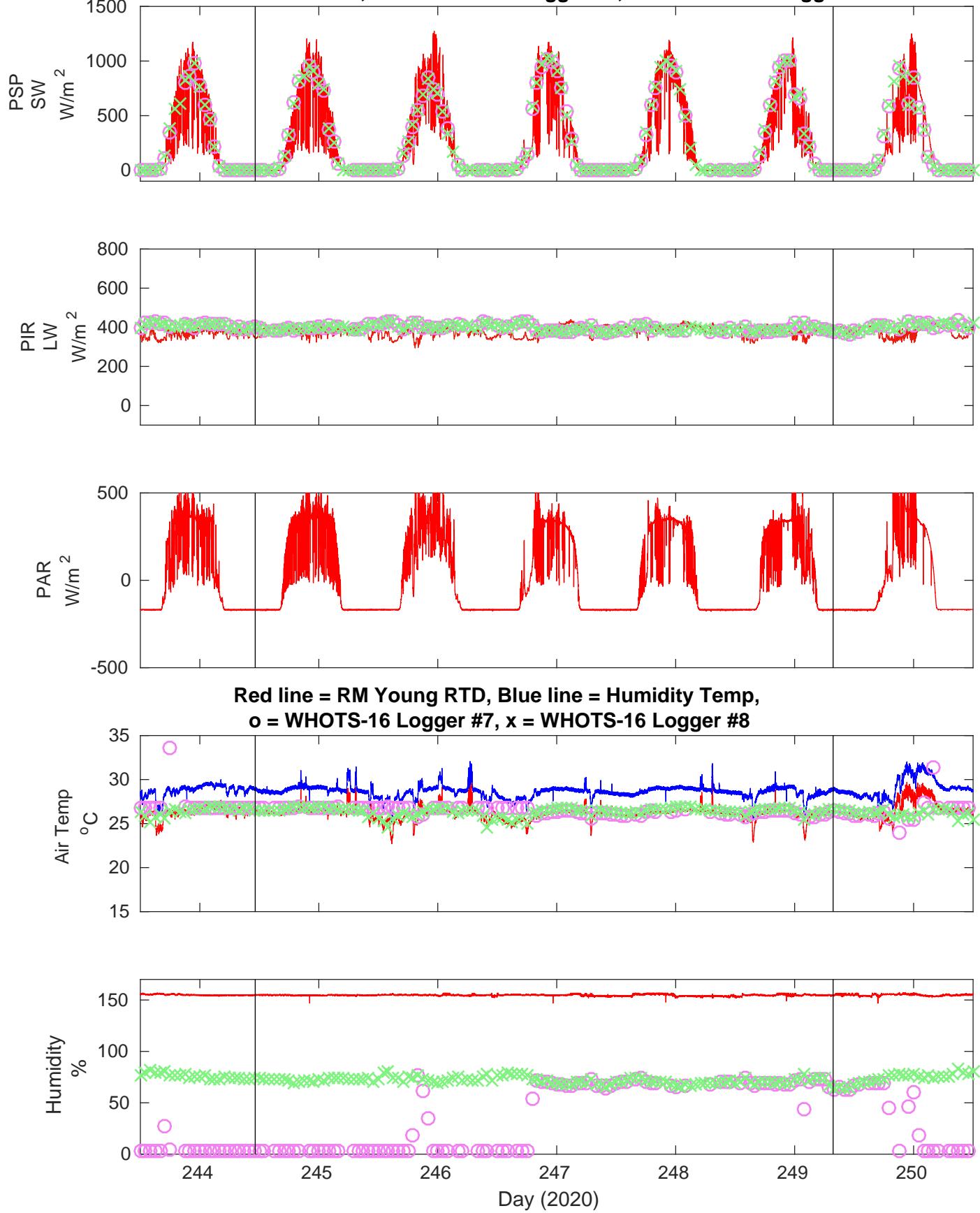


Figure 6.10.4.e.2

HOT-322 Red line = Kilo Moana, o = WHOTS-16 Logger #7, x = WHOTS-16 Logger #8

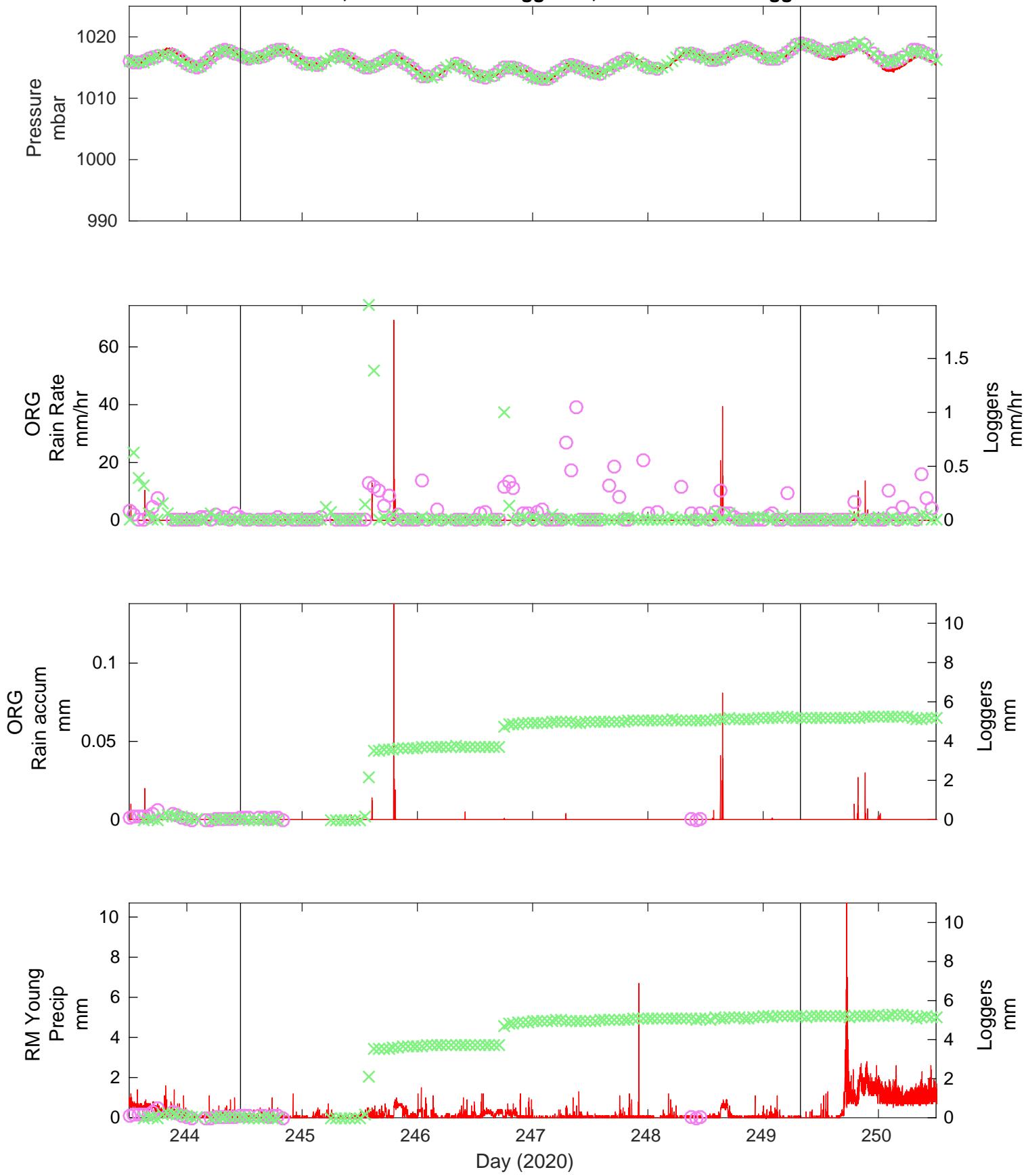


Figure 6.10.4.e.3

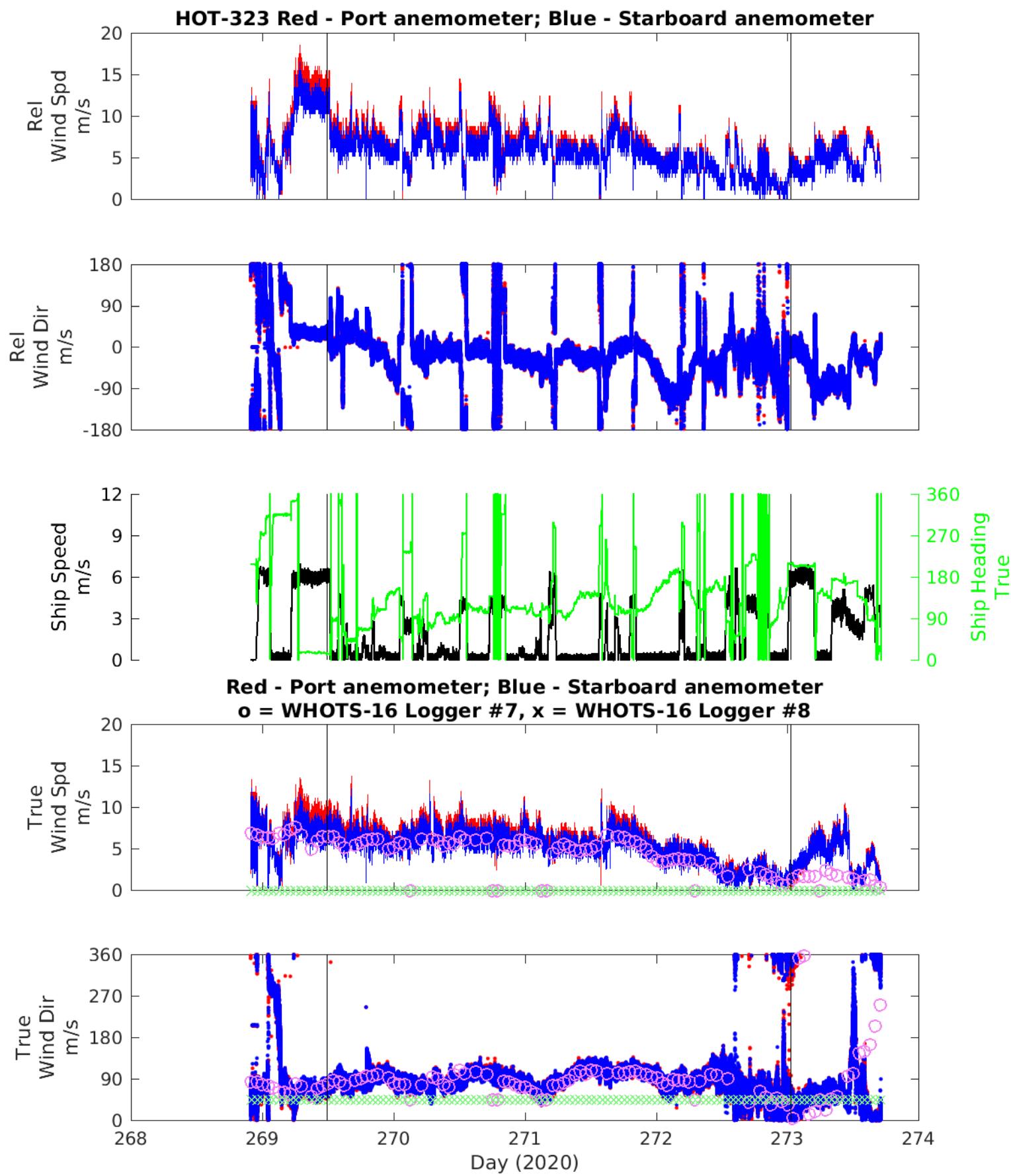
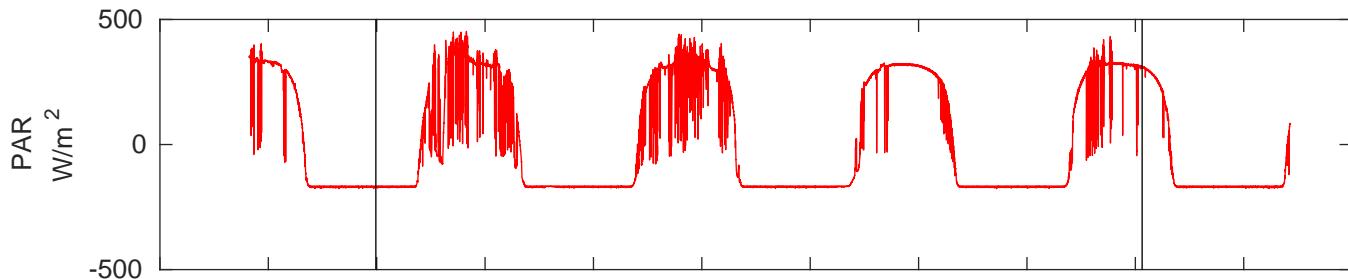
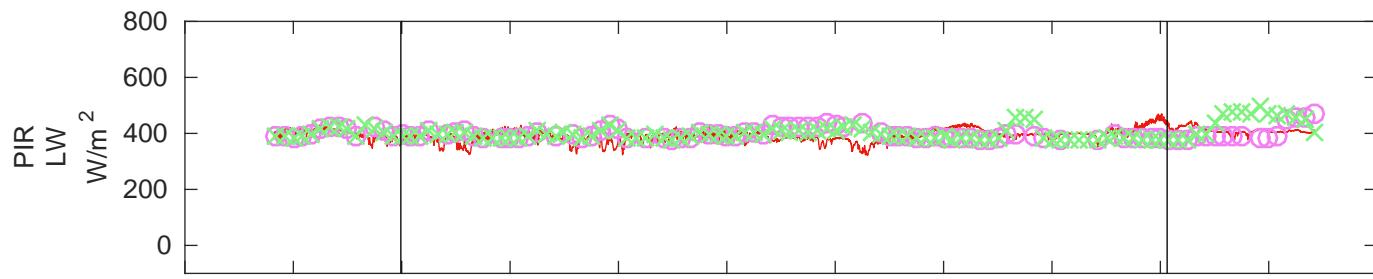
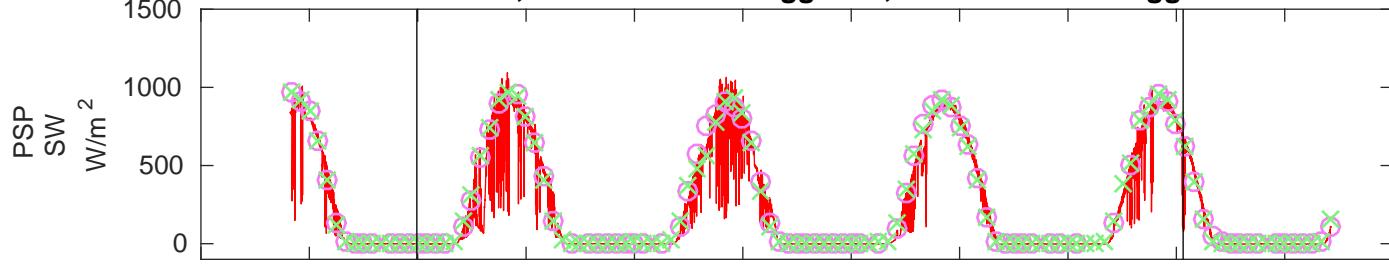


Figure 6.10.4.f.1

HOT-323 Red line = Kilo Moana, o = WHOTS-16 Logger #7, x = WHOTS-16 Logger #8



Red line = RM Young RTD, Blue line = Humidity Temp,
o = WHOTS-16 Logger #7, x = WHOTS-16 Logger #8

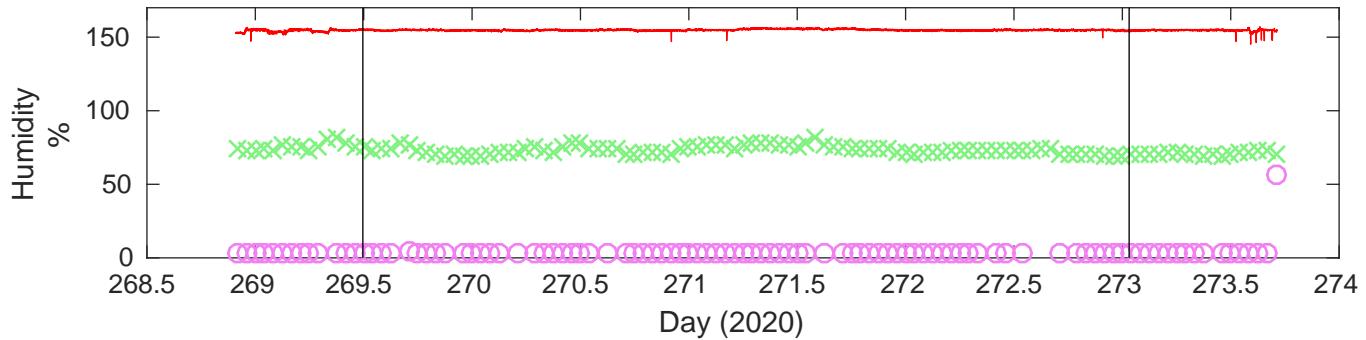
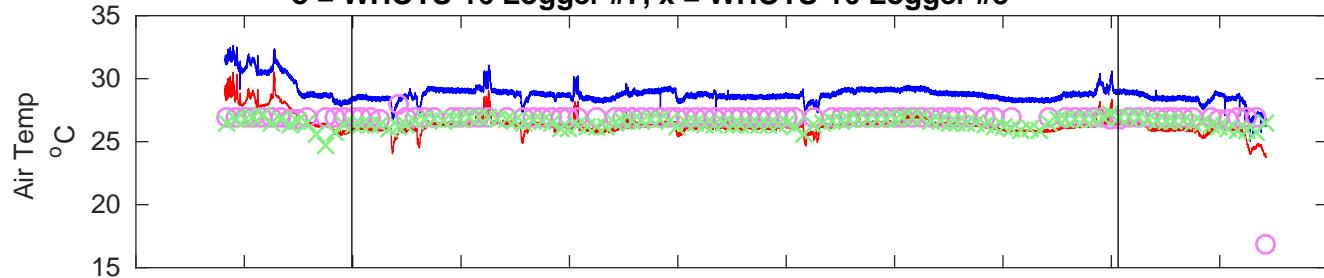


Figure 6.10.4.f.2

HOT-323 Red line = Kilo Moana, o = WHOTS-16 Logger #7, x = WHOTS-16 Logger #8

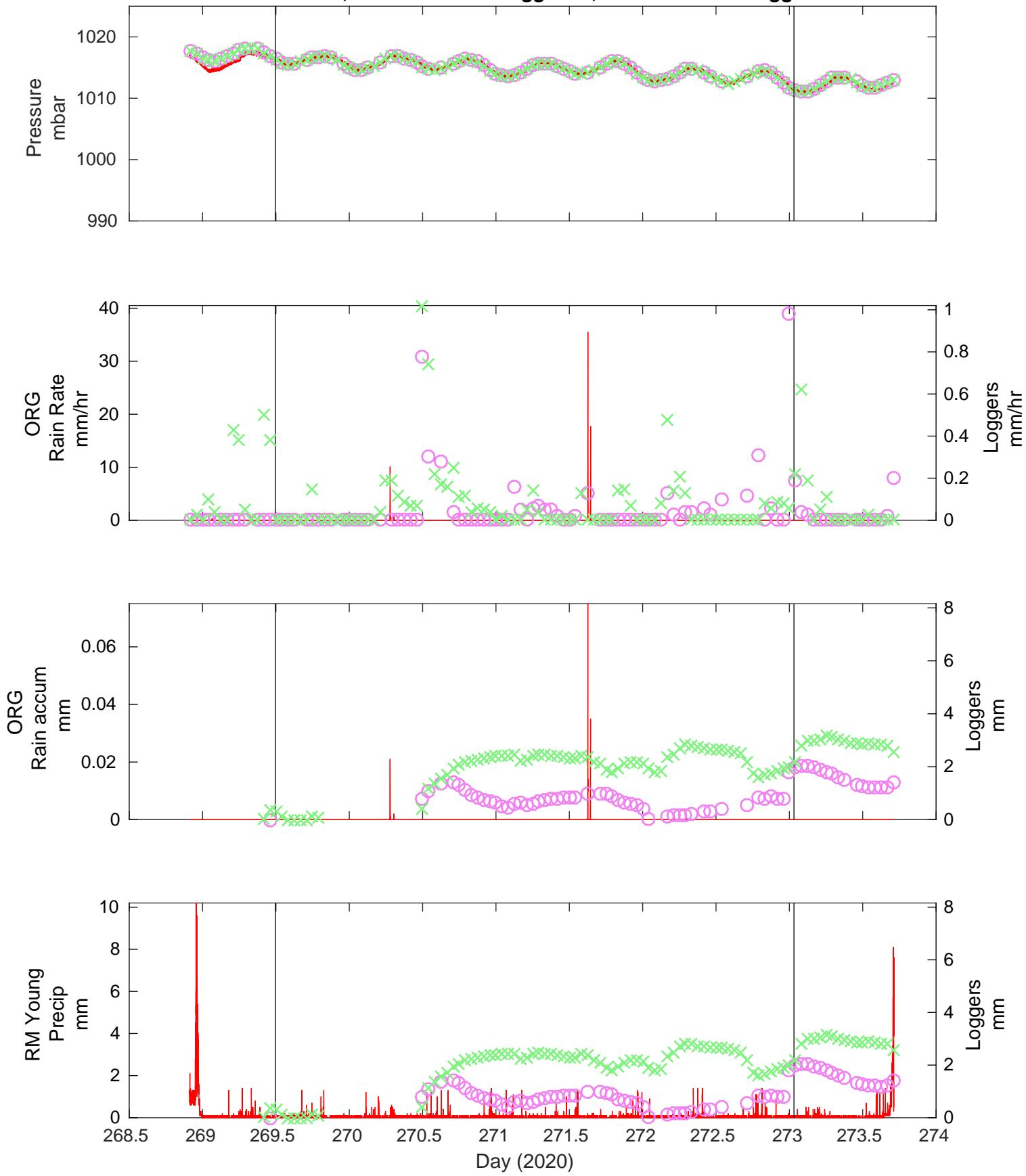


Figure 6.10.4.f.3

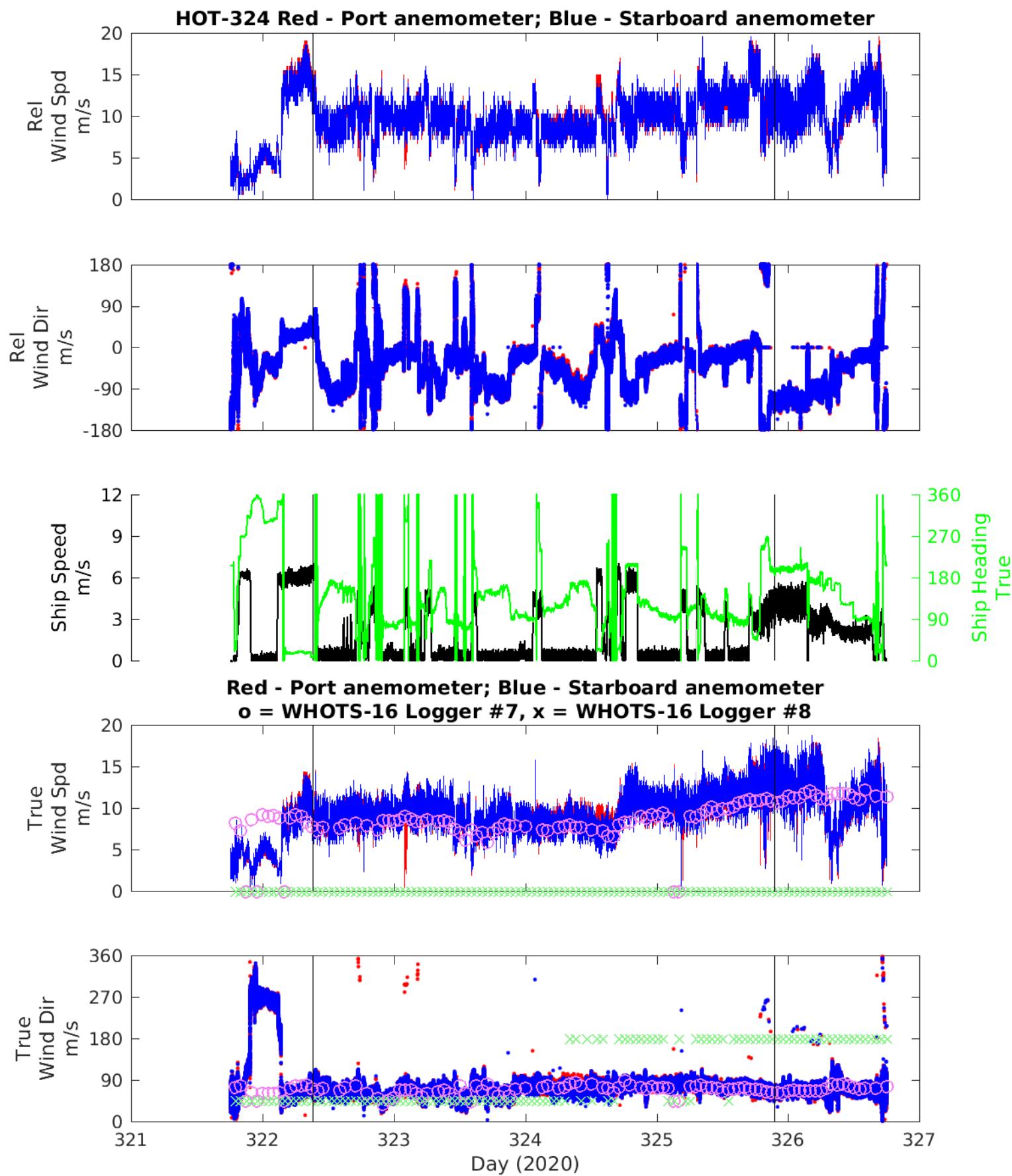


Figure 6.10.4.g.1

HOT-324 Red line = Kilo Moana, o = WHOTS-16 Logger #7, x = WHOTS-16 Logger #8

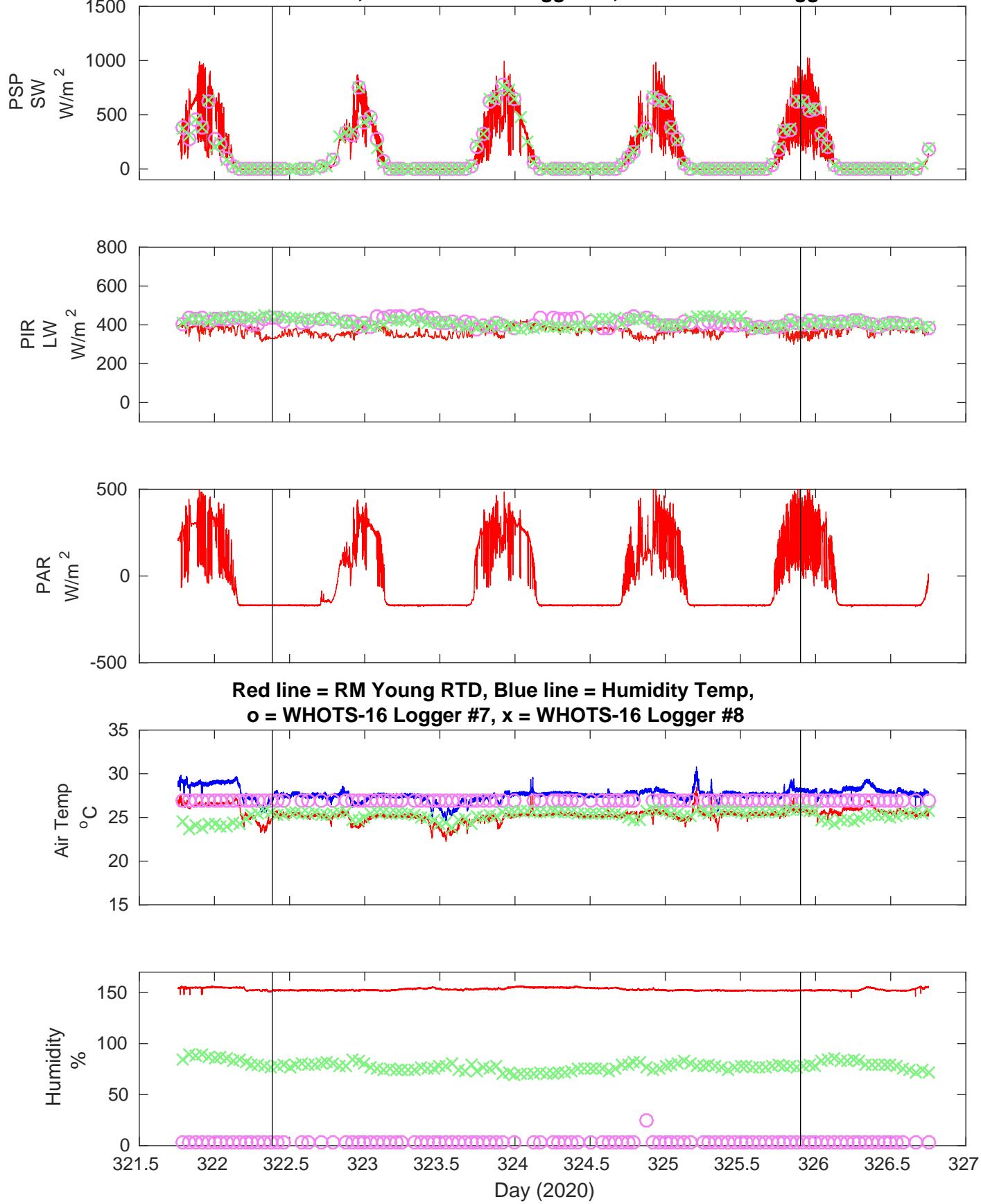


Figure 6.10.4.g.2

HOT-324 Red line = Kilo Moana, o = WHOTS-16 Logger #7, x = WHOTS-16 Logger #8

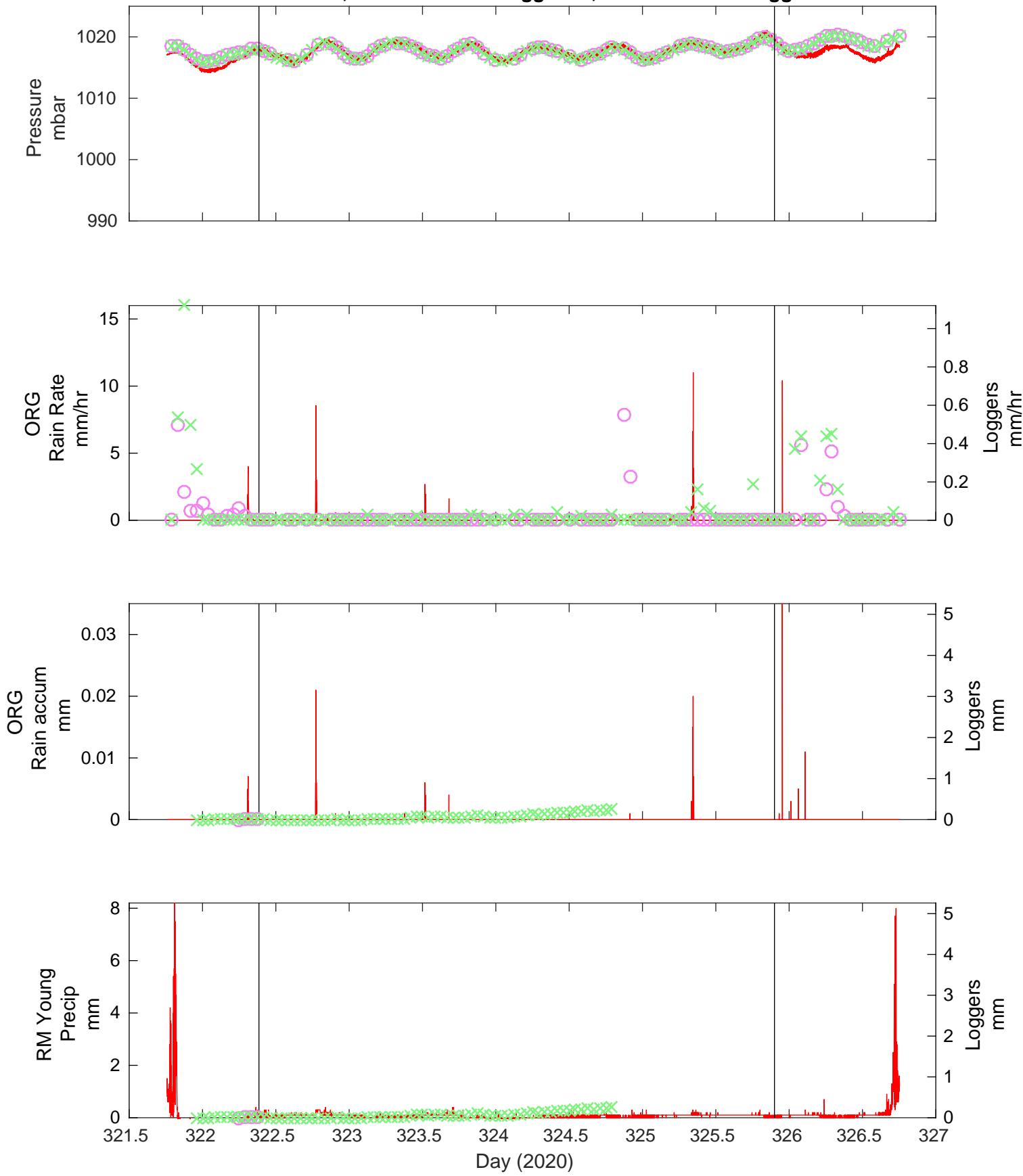


Figure 6.10.4.g.3

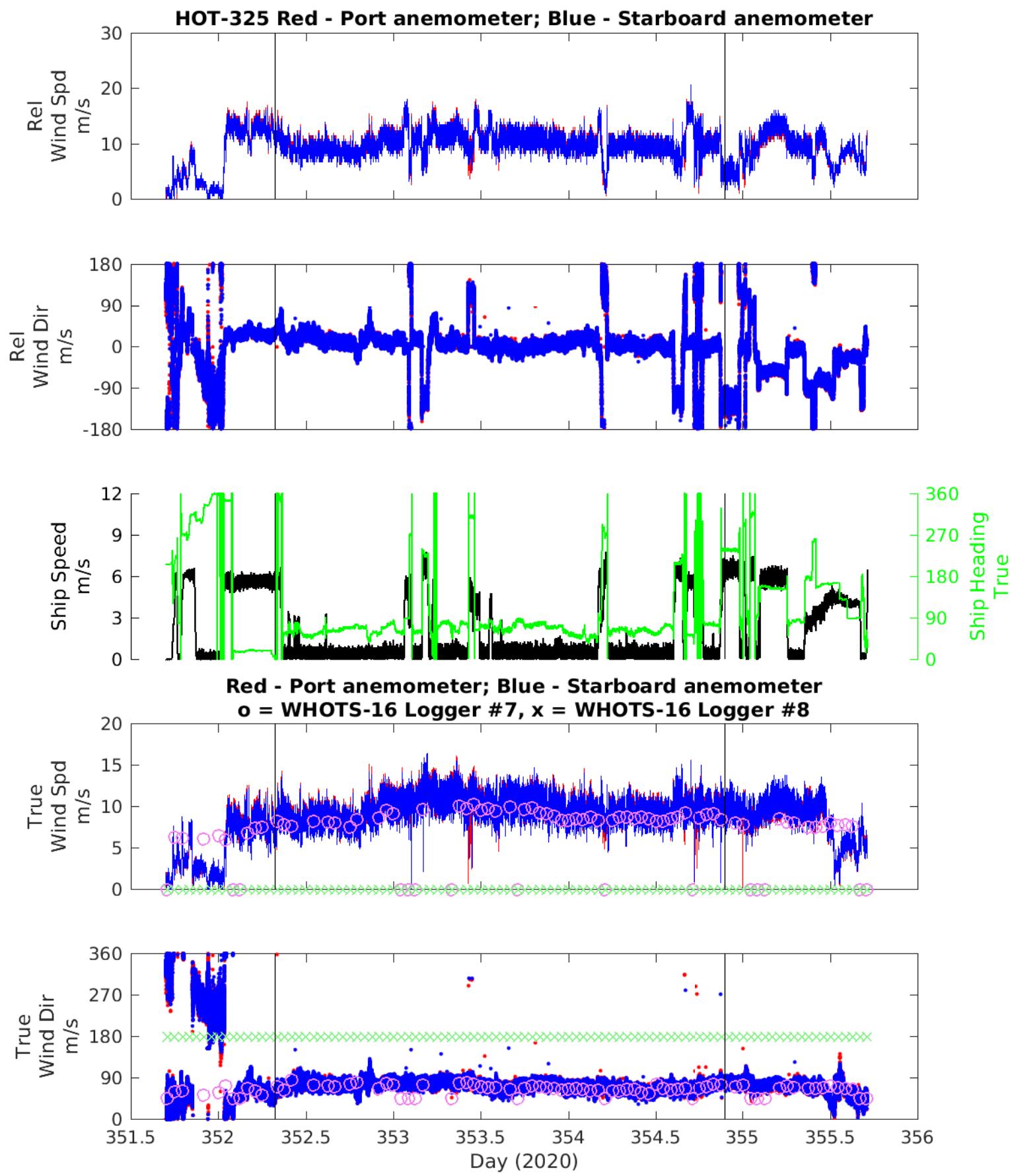


Figure 6.10.4.h.1

HOT-325 Red line = Kilo Moana, o = WHOTS-16 Logger #7, x = WHOTS-16 Logger #8

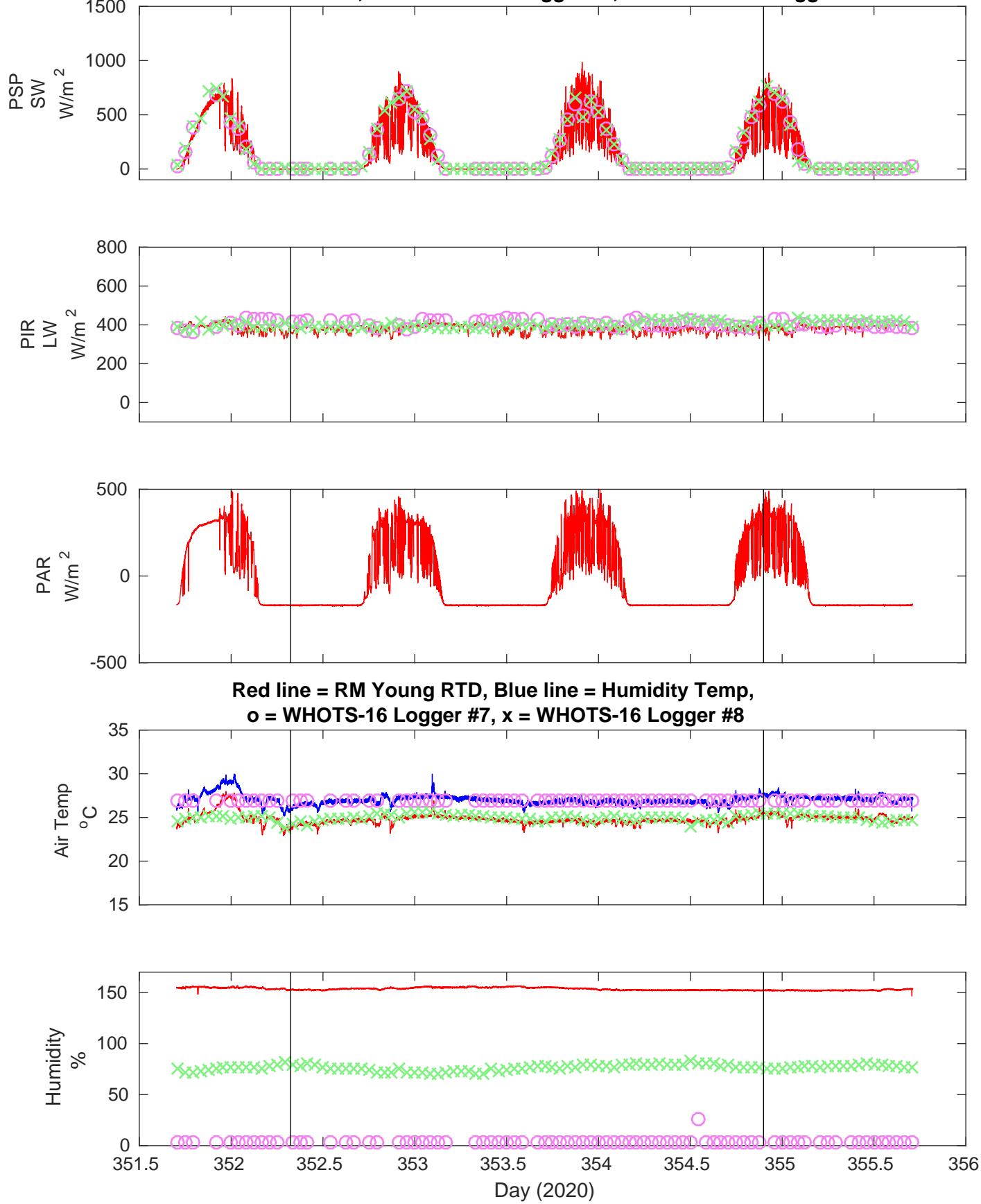


Figure 6.10.4.h.2

HOT-325 Red line = Kilo Moana, o = WHOTS-16 Logger #7, x = WHOTS-16 Logger #8

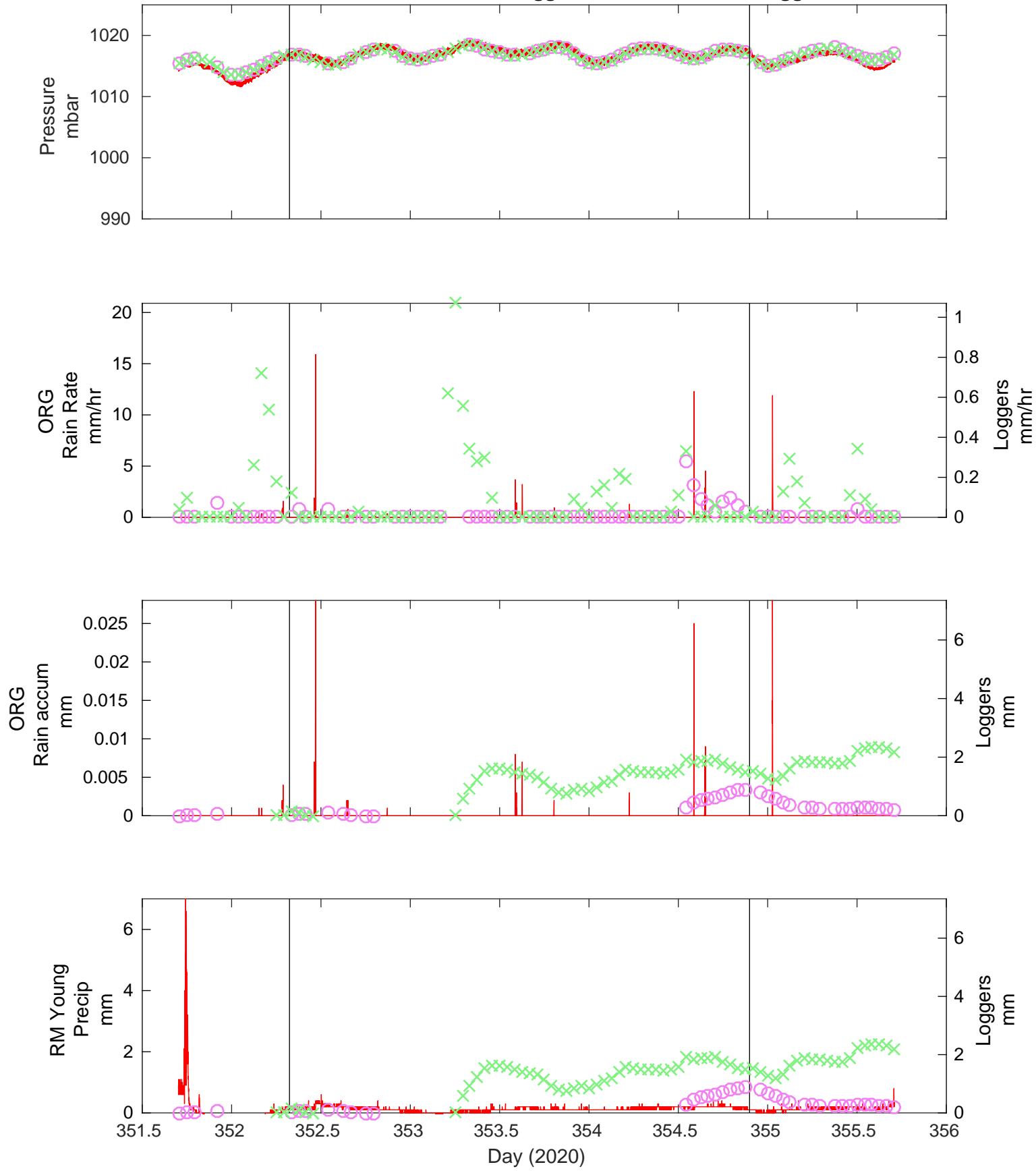


Figure 6.10.4.h.3