



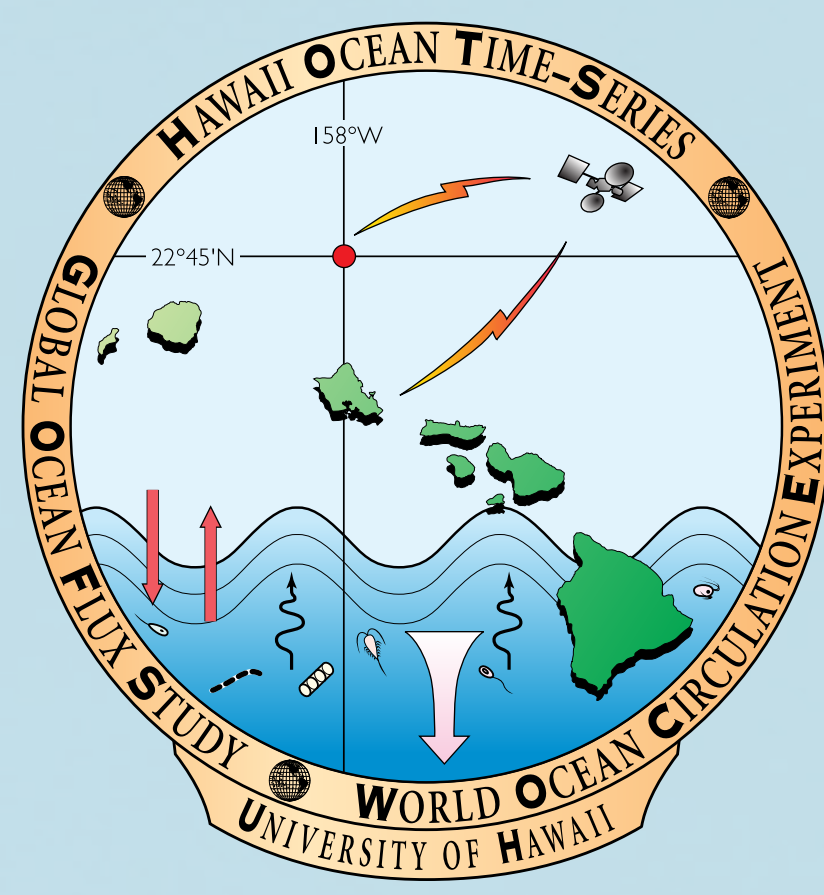
Initial planning committee for the Hawaii Ocean Time-series project. From left: Steve Chiswell, Chris Winn, David Karl, Roger Lukas and Eric Firing

Celebrating 17 Years of Observations at Station ALOHA

Thomas K. Gregory, Fernando Santiago-Mandujano and The HOT Team*

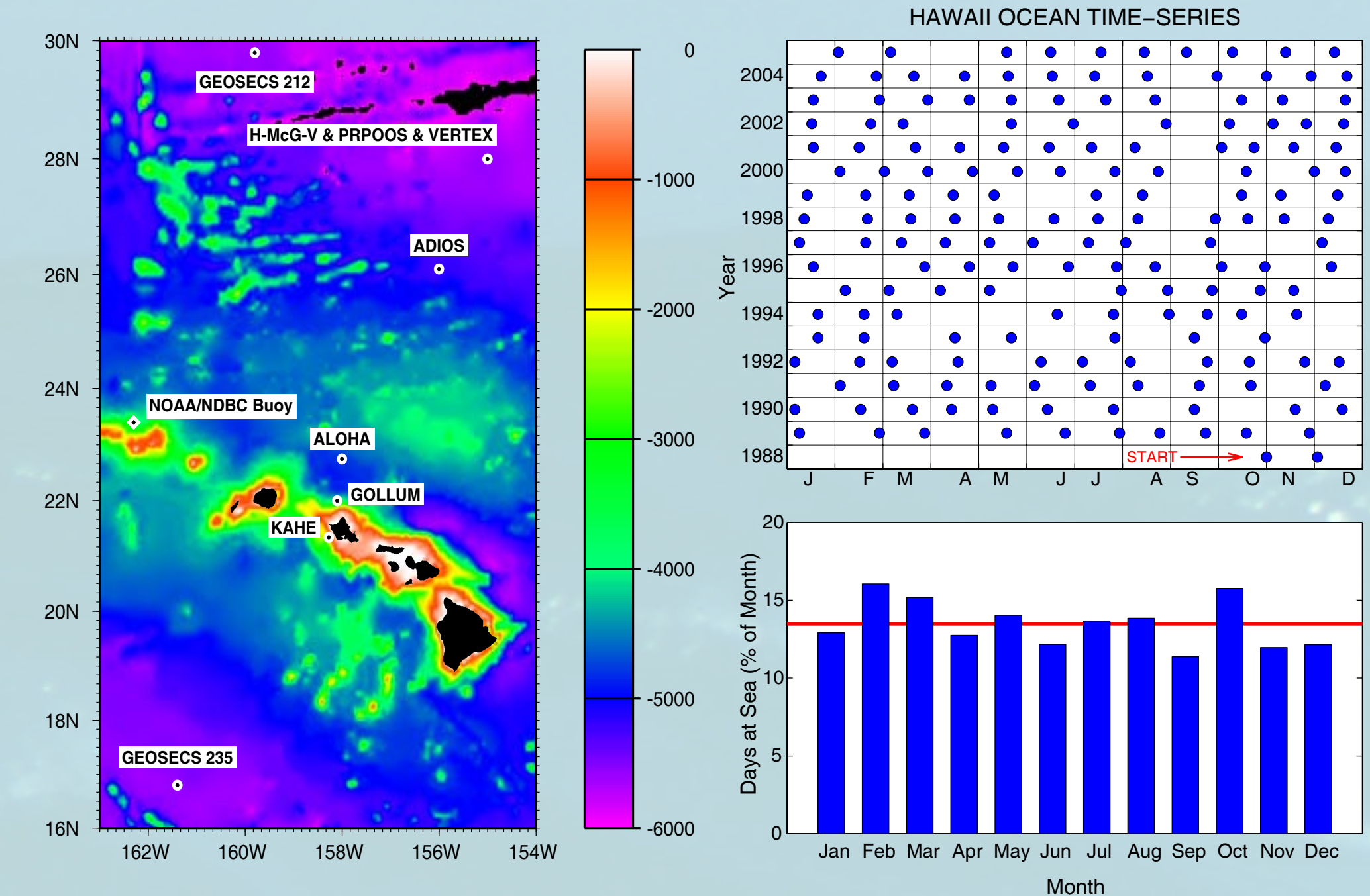
University of Hawaii, Department of Oceanography, Honolulu, HI 96822

<http://hahana.soest.hawaii.edu/hot/hot.html>



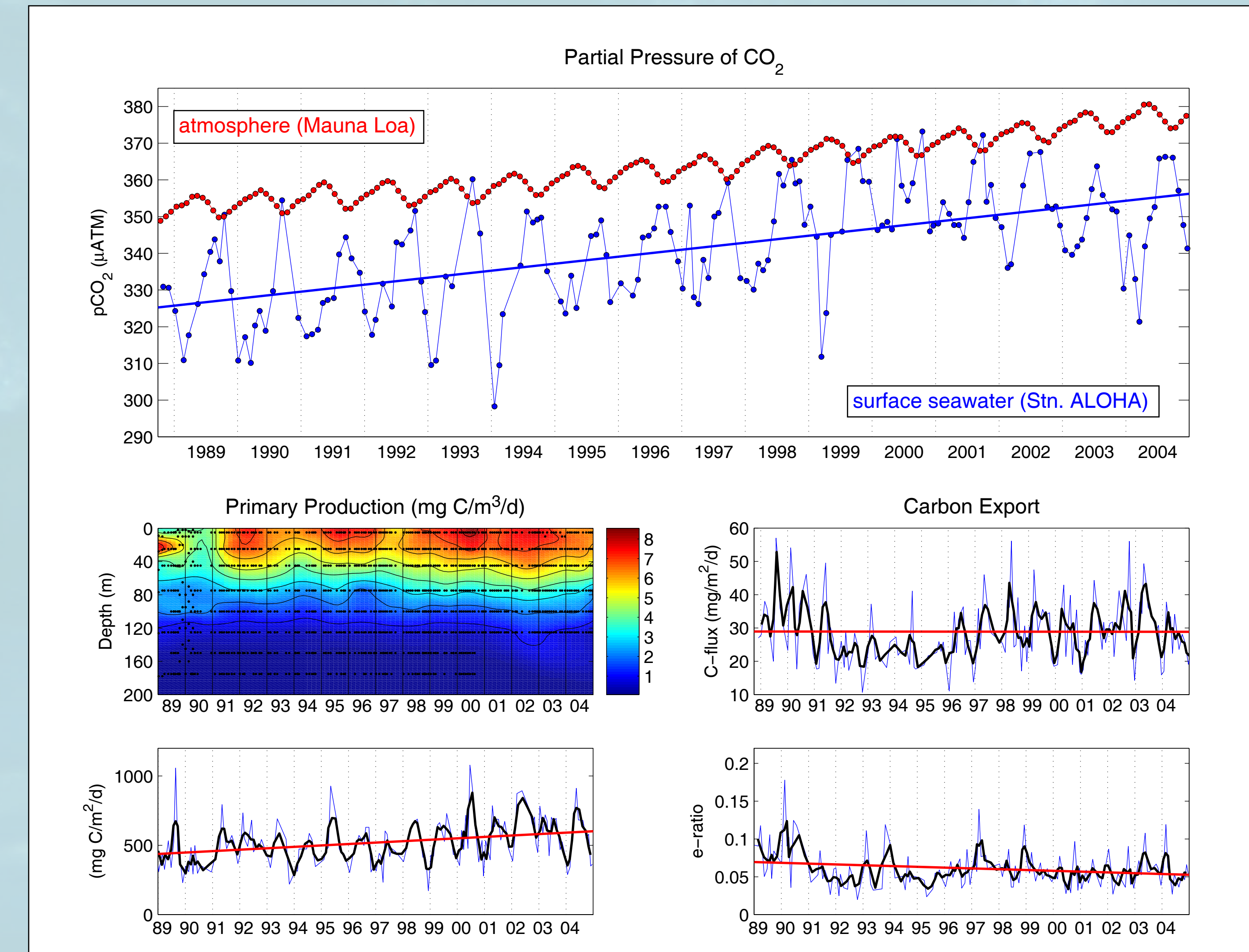
Abstract

The Hawaii Ocean Time-series was established in 1988 as part of the U.S.-JGOFS and WOCE programs in an effort to characterize the temporal dynamics of biology, chemistry and physics in the oligotrophic North Pacific subtropical gyre. As of February 2006, we have completed 178 cruises to Station ALOHA (A Long-term Oligotrophic Habitat Assessment). More than 17 years of monthly cruises to this open ocean location have revealed striking dynamics on time scales ranging from diurnal to inter-decadal. Important results stemming from observations at Station ALOHA include the non-steady state behavior in both organic and inorganic nutrient inventories; inter-decadal shifts in plankton community structure; the importance of ocean climate connections in regional and basin-scale physical forcing (rainfall, ENSO, PDO) on biogeochemical cycles and salinity changes; enhanced levels of turbulence near the seabed caused by intermittent water flow between abyssal basins; and the role of eddies on the mean distribution of properties and ocean biogeochemistry changes. Future integration of autonomous sampling platforms (moorings and satellite remote sensing) will strengthen existing shipboard observations and help resolve high frequency variability in physical and biogeochemical processes.



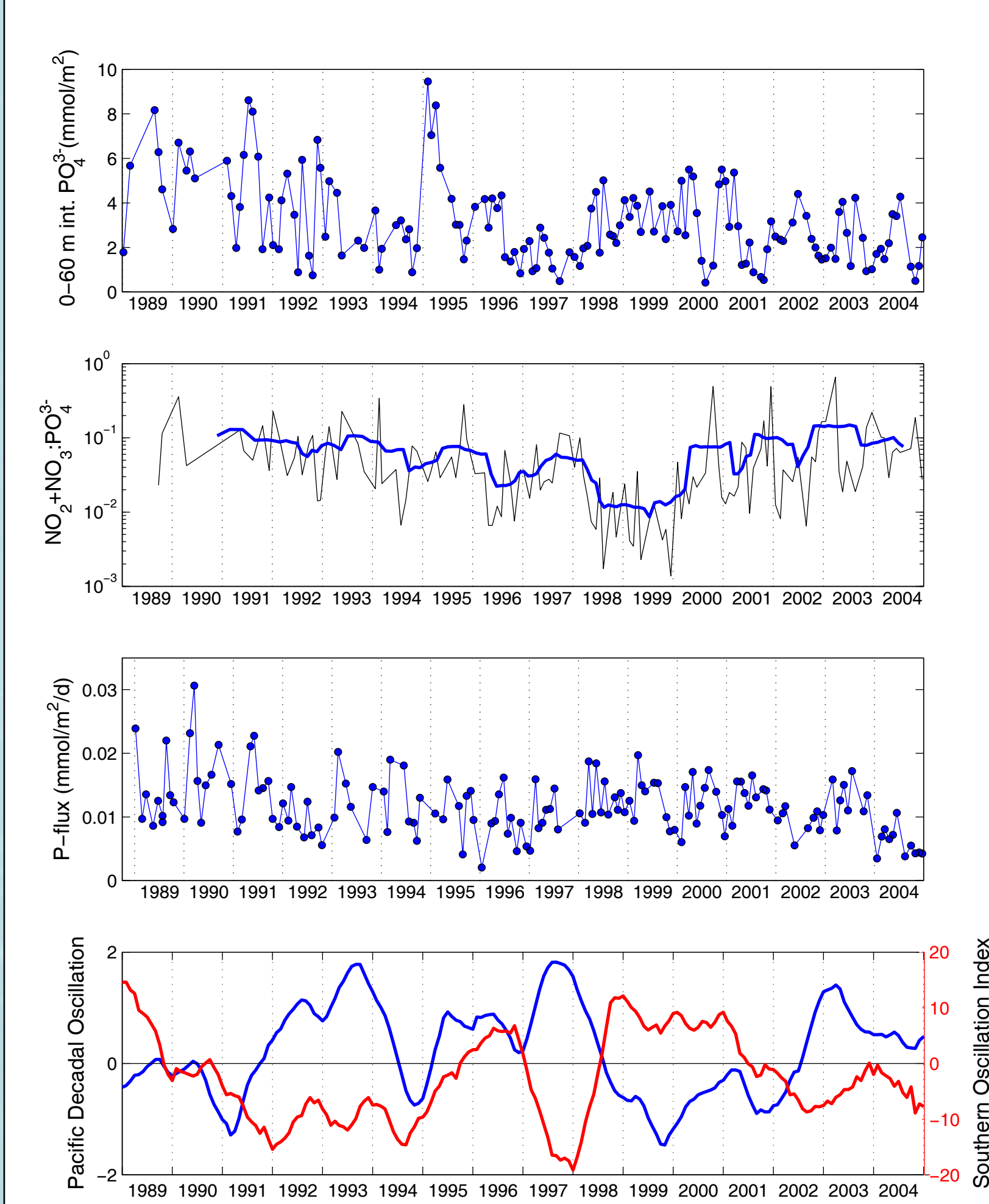
Map showing the location of Station ALOHA approximately 100 km north of Oahu, Hawaii in deep water. Also shown is the schedule of cruises since October 1988 and a graph showing the average percentage of each month during which observations were made over the 17 year period.

Station ALOHA: An outpost for assessing variability in oceanic carbon inventories

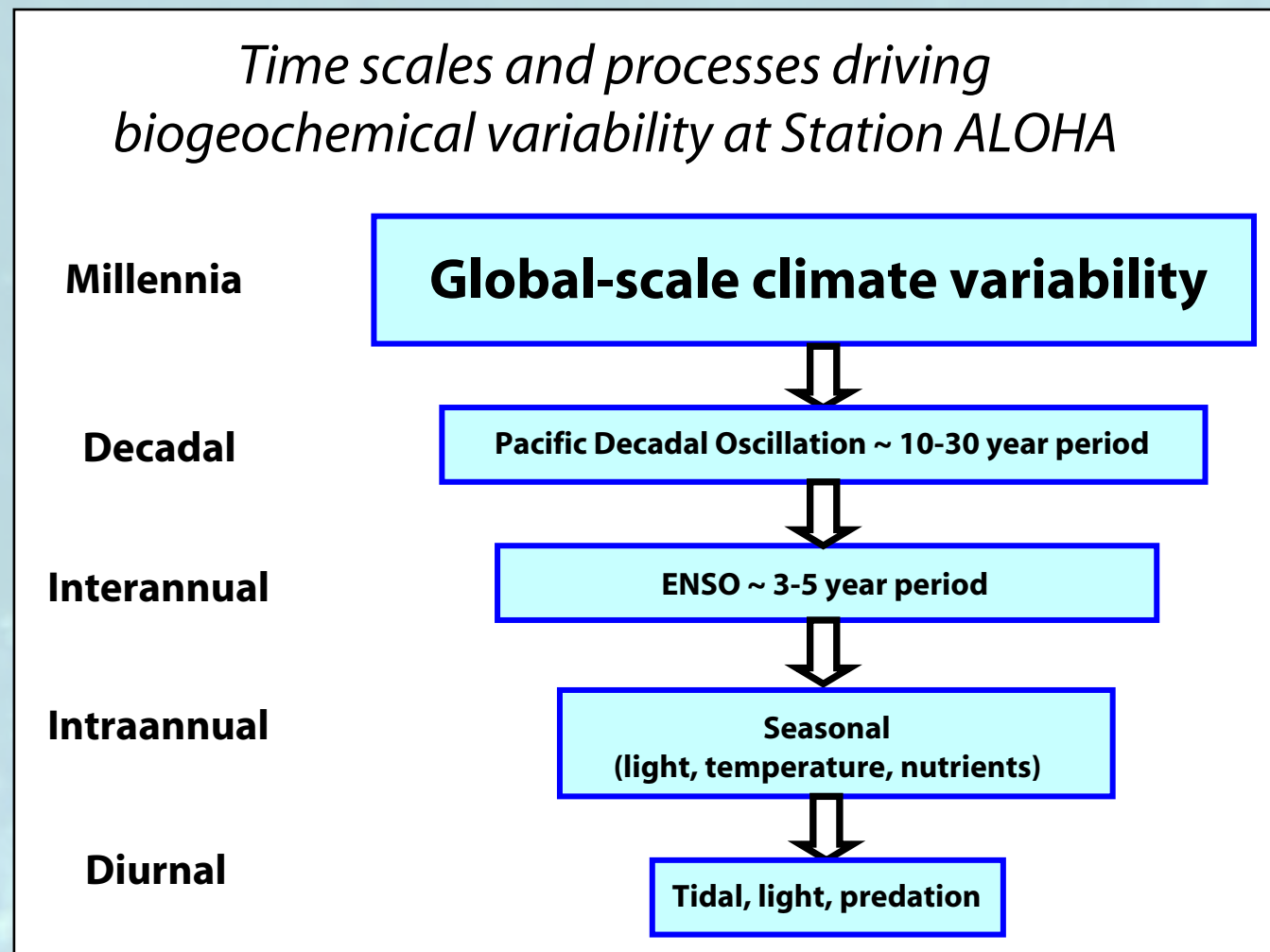


- The Hawaii Ocean Time-series (HOT) program has conducted monthly measurements of oceanic dissolved inorganic carbon, total alkalinity and pH since 1988, providing one of the longest records of time-dependent changes in oceanic inventories of CO₂.
- The upper ocean at Station ALOHA has been a net sink for atmospheric CO₂ throughout most of the time-series observations. However, the increase in pCO₂ in the upper ocean is greater than increasing atmospheric pCO₂, suggesting Station ALOHA may soon become a net source of CO₂ to the atmosphere.
- To identify the role of biology on ocean carbon cycling, the HOT program has conducted monthly measurements of primary production and carbon export.
- Despite a paucity of inorganic nutrients in the upper ocean, rates of primary production are consistently greatest in the well-lit portion of the euphotic zone.
- Depth-integrated rates of primary production at Station ALOHA average 522.5 ± 163.6 mg/m²/d while carbon fluxes out of the upper ocean average 28.9 ± 9.7 mg/m²/d, indicating efficient remineralization of carbon production in the upper ocean.
- Despite interdecadal variability in rates of primary production and carbon export, the e-ratio (export/primary production) appears largely unchanged, suggesting carbon production and export may be uncoupled in time.

Non-steady state behavior in nutrient inventories at Station ALOHA

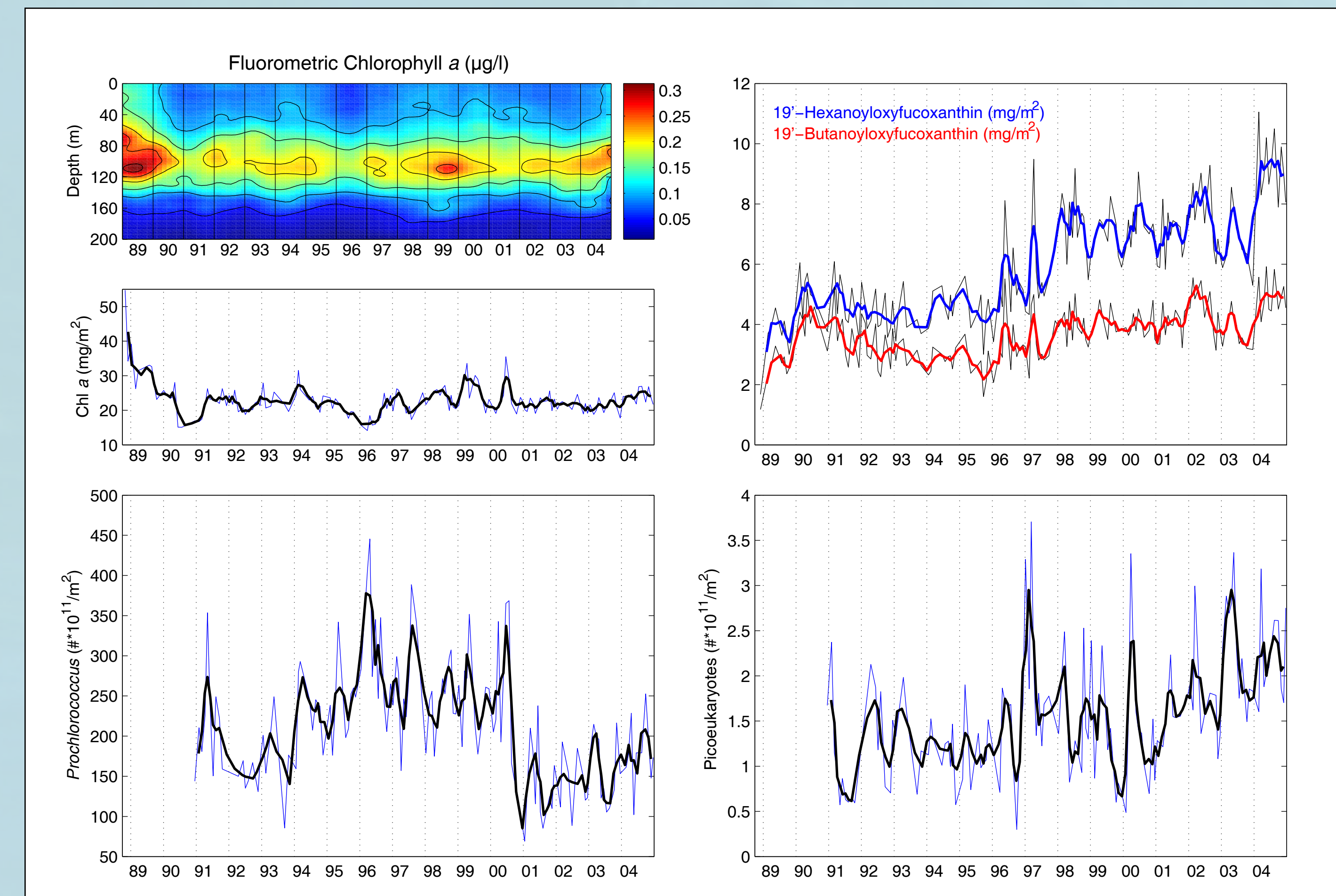


- Upper ocean inventories of PO₄³⁻ at Station ALOHA have undergone pronounced inter-decadal changes potentially linked to regional-scale climate variability (see Karl, this meeting, oral presentation OS33B-01 and Letelier et al., this meeting, oral presentation OS33B-03).
- The resulting N:P ratio of inorganic nutrient pools has also shown dramatic time-dependent variability.
- Coincident with declining availability of PO₄³⁻ inventories, particulate P fluxes have shown a systematic decline over the 17 years of time-series observations.
- Systematic variations in PO₄³⁻ availability may be linked to basin-scale climate forcing by processes such as the El Niño Southern Oscillation or phase changes in the Pacific Decadal Oscillation.



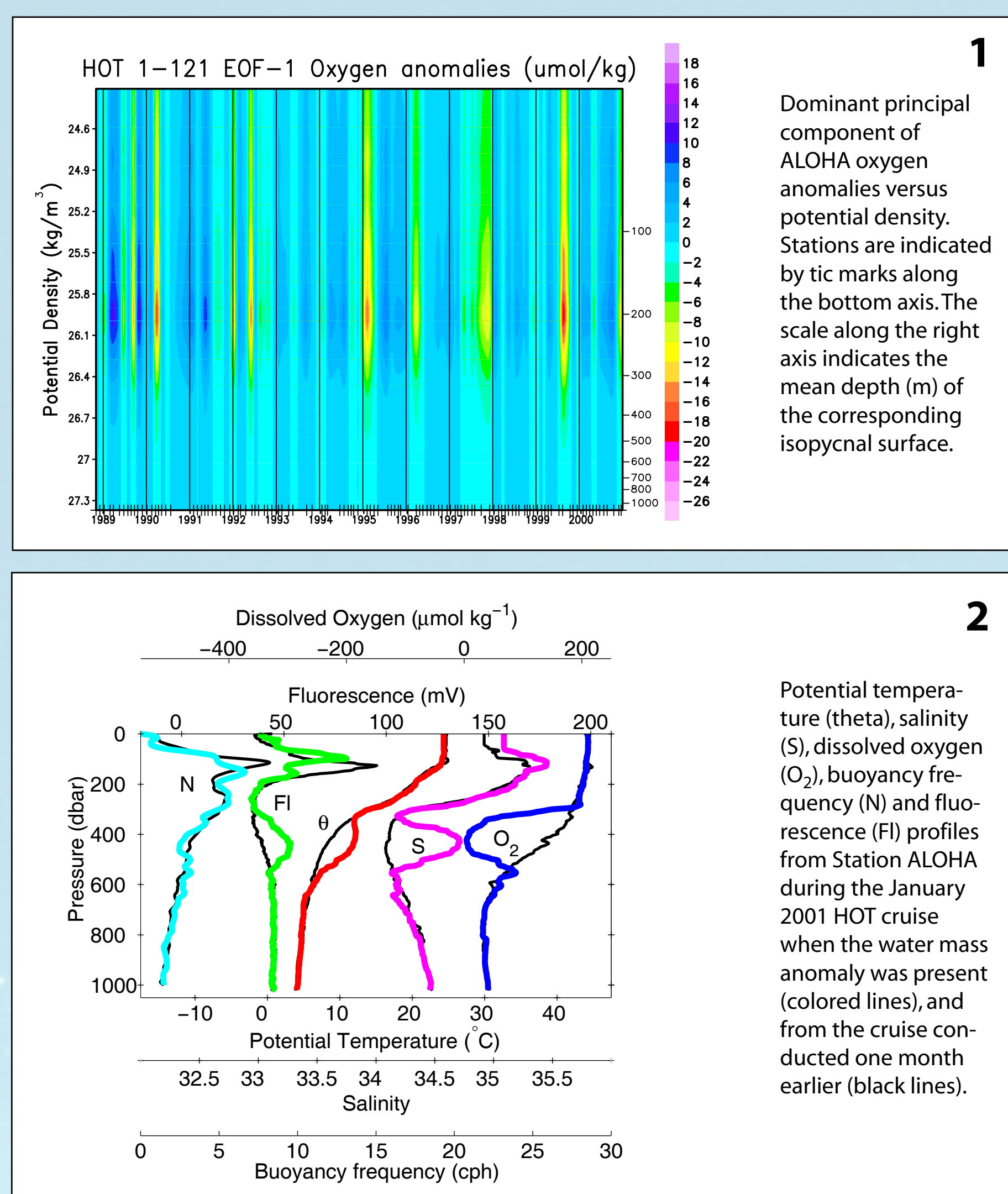
After more than 17 years of monthly observations, we are beginning to decipher regional and basin scale processes that control ocean biogeochemistry at Station ALOHA. These processes influence biogeochemical inventories and fluxes across time scales ranging from diurnal to decadal, and perhaps longer. Continuation of these observations will provide insight into the connections between climate variability and ocean biogeochemistry.

Temporal dynamics in plankton community structure



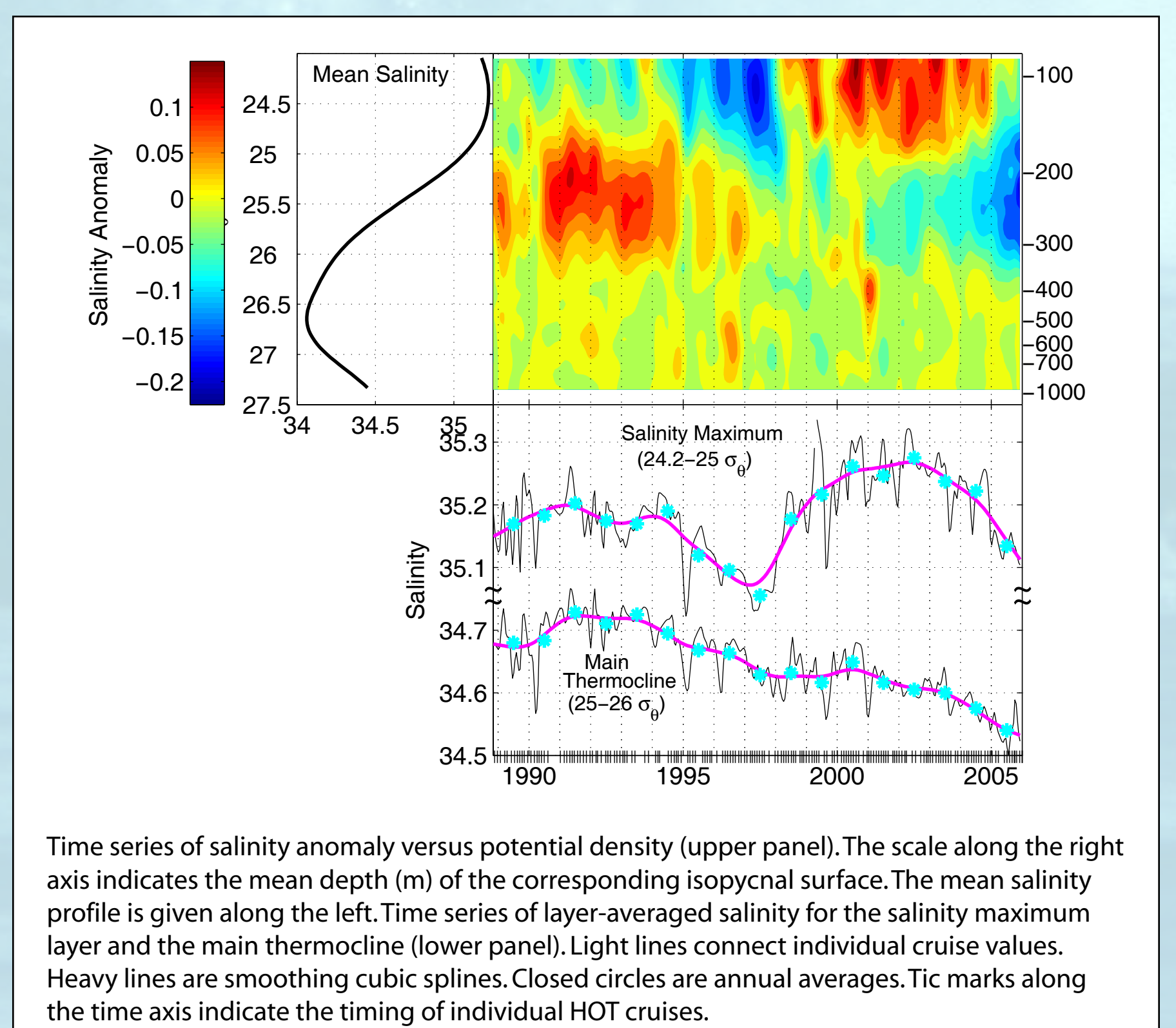
- Vertical concentrations of chlorophyll *a* are consistently greatest in the low light regions of the euphotic zone. Chlorophyll *a* inventories have varied ~2-fold over the time series program.
- In contrast to the relative stability of chlorophyll *a*, depth integrated concentrations of selected pigments demonstrate remarkable temporal variability.
- Similar to the apparent interdecadal changes in pigment concentrations and presumed time-dependent changes in selected groups of photoautotrophic plankton, picoplankton abundances have undergone large (~4-fold) changes. In particular, the abundances of *prochlorococcus* increased in the initial period of observation, then declined, while abundances of picocyanobacteria have gradually increased over the latter period of the time-series observations.

The role of eddies in the distribution of ocean properties and biogeochemical changes

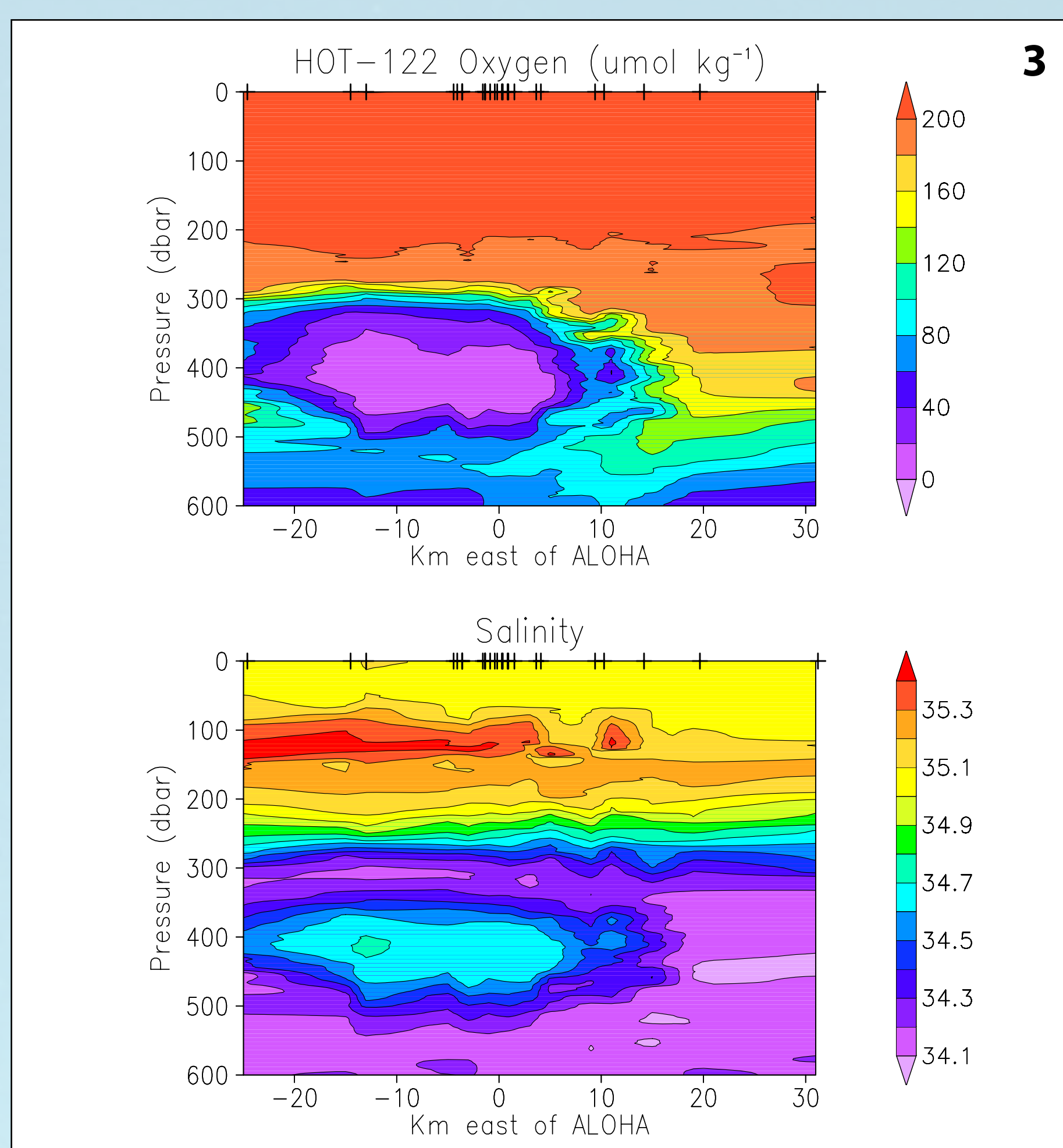


- Mesoscale eddies are found north of the Hawaiian Islands, appearing in the Hawaii Ocean Time-series observations as anomalies in salinity, potential vorticity, dissolved oxygen, nitrate, phosphate, silicate and fluorescence. Principal component analysis of these properties over a range of isopycnal surfaces in the pycnocline extracts a coherent signal in time, where mesoscale eddies are seen as distinct, extreme events (Figure 1). The most plausible source location of these anomalies determined from Levitus climatology (Levitus and Boyer, 1994) is a small region 1,500 km east of ALOHA (Santiago-Mandujano and Lukas, in preparation).

Long-term salinity variations associated with changes in rainfall

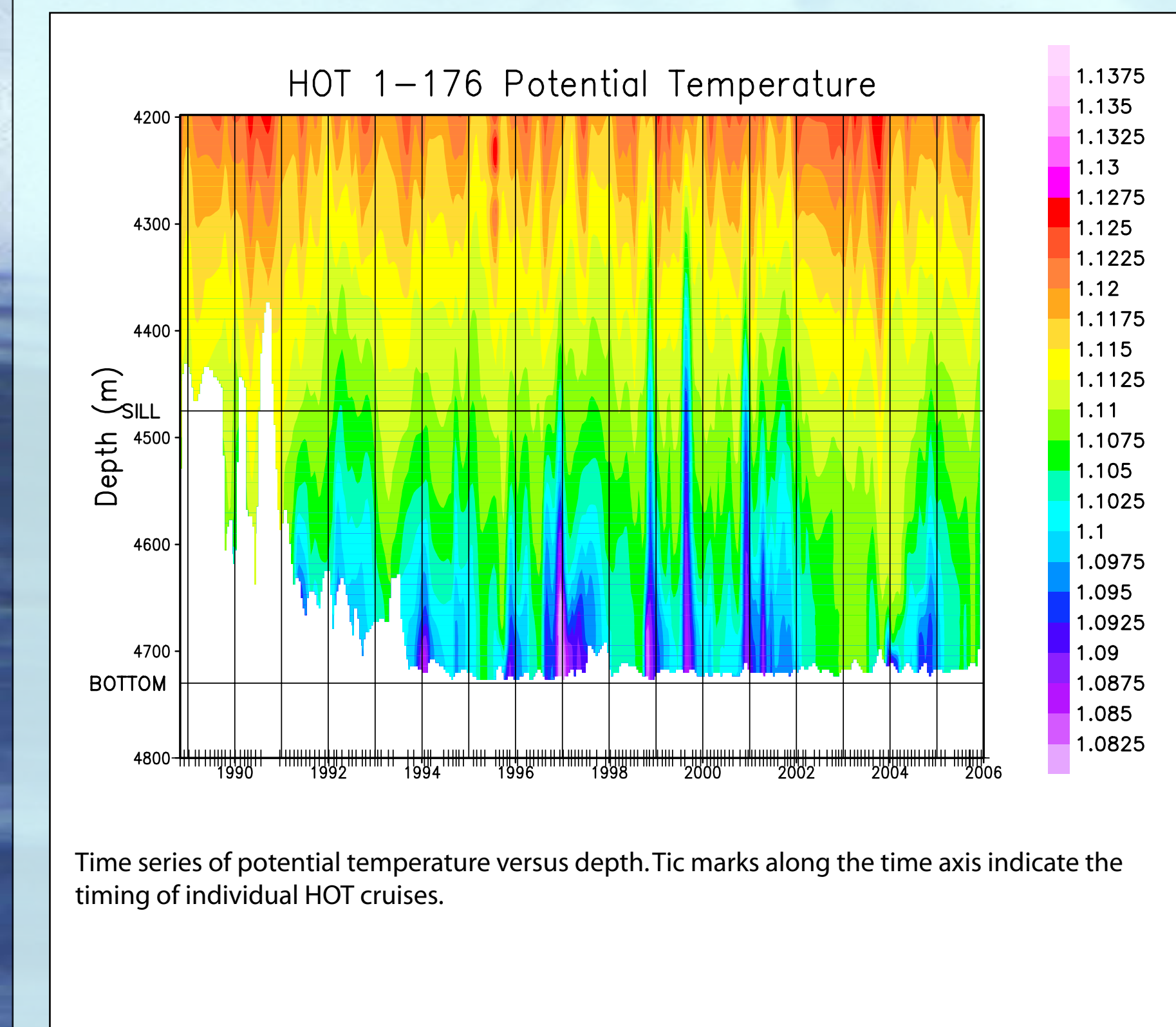


- The salinity maximum (S_{max}) at Station ALOHA is generally centered between 100-150 m (24.2 and 25.0 σ_θ). It is associated with the subduction of salty water in the north-central gyre and its advection southward to Station ALOHA. A pronounced salinity decrease is observed between 1991 and 1997. This corresponds to the downward penetration of decadal thermal anomalies in the Central North Pacific Ocean, suggested to be a manifestation of thermocline ventilation (Deser et al., 1996). The S_{max} nearly disappeared in early 1993 and during 1997. The rapid increase of salinity in 1998 coincided with the ENSO-related drought around Hawaii in the same year, and continued with the regional decadal rainfall deficiency of winter net freshwater flux over the North Pacific (Lukas, 2001).
- The main thermocline (25-26 σ_θ) shows a trend towards low salinities starting around 1992, and continuing until now. This trend is associated with large-scale rainfall variations in the North Pacific (Lukas et al., oral presentation OS44C-03).



- One particularly extreme water mass anomaly was observed in the thermocline during January 2001 (Figures 2 and 3). Climatological property distribution maps were used to trace the source of this anomalous water to off-shore of Mexico near Baja California (Lukas and Santiago-Mandujano, 2001).
- An eddy related surface plankton bloom was recently observed and sampled in July 2005 (Sadler et al., poster OS36F-03). This bloom, partly composed of diatoms and supported in part by nitrogen-fixing bacteria was associated with a southwestward traveling anticyclonic eddy.
- Eddy related anomalies have also been identified in a secondary station of the HOT program, about 40 km south of ALOHA (Letelier et al., 2000).

Enhanced levels of turbulence caused by abyssal water flows



- Cold events are produced when near-bottom, relatively cold and salty water from the Maui Basin "overflows" into the Kauai Deep, where Station ALOHA is located (Lukas et al., 2001). The figure indicates that these events became colder and more frequent after 1996.
- Enhanced levels of turbulence near the bottom are associated with the occurrence of the cold events. During the 1994, 1995-1996, 1998, and 1999 events, peak values of vertical diffusivity averaged 4 X 10⁻³ m²/s near the depth of the sill separating the Maui Basin from the Kauai Deep. Enhanced levels of turbulence near the bottom at the ALOHA station have also been inferred from Thorpe scale analysis of overturns (Finnigan et al., 2002), and are attributed to these overflow events.

*The HOT Team

Current HOT (co)PI.s

Robert Bidigare
John Dore
David Karl
Michael Landry
Ricardo Letelier
Roger Lukas

*Have been on at least 100 of the past 178 HOT cruises!

Current HOT Personnel

Karin Björkman
Matthew Church
Tara Clemente
Susan Curless
Suzanne Defelice
Ken Doggett
Allison Fong
Lance Fujieki*
Eric Grabowski
Tom Gregory

Adriana Harlan
Paul Lethaby
Lisa Lum
Claire Mahaffey
Nancy Paquin
Dan Sadler*
Fernando S.-Mandujano*
Blake Watkins
Mark Valenciano



Past and present Hawaii-based research vessels used during the time-series: Kaimaloa (top left), Ka'imikai-O-Kanaloa (top right), Moana Wave (center) and Kilo Moana (bottom)

Acknowledgements

We would like to acknowledge the dedicated efforts of the HOT program scientific and technical staff, the captains and crew of the various research vessels used during the time-series, as well as the logistic support from the UH Marine Center. Of particular note is the vision and continuing achievements of Principal Investigators Roger Lukas and David Karl. The help of Lance Fujieki and Matt Church in creating this poster is appreciated. The Hawaii Ocean Time-series is supported by NSF grants OCE-0327513 (Lukas) and OCE-0326616 (Karl).

Conclusions

Almost two decades of monthly, ship-based monitoring at Station ALOHA has provided a robust dataset which has proven useful in resolving dynamics on a wide range of time scales. Nevertheless, phenomena occurring on short timescales, including aperiodic events, are routinely undersampled by the current observational program. Autonomous sampling platforms are needed to continuously monitor and record biogeochemical and physical conditions at Station ALOHA. Two instrumented moorings with surface buoys are currently in place near Station ALOHA. Additionally, a cabled observatory connecting Station ALOHA to shore-based facilities with broadband data and power capabilities is currently being developed.