A C-MORE PROSPECTUS:

Biogeochemistry and Genomes (BAG – 1) Mesocosm Experiment (Leg 1)
1 – 15 Dec 2011

Introduction:

Long term ocean ecology characterization is predicated on a variety of *in situ* shorter term experiments and field exercises. These shorter term experiments can be generally classed in one of two ways. The first way of approach is to observe or capture physical or biogeochemical ocean events that do not have a clear initial starting time (T_0). The time line of observation is typically a segment of time, where T_0 is generally calculated at the point the instrument is deployed in the water. The time line of observation is short in terms of duration or in location. We would consider the use of the research vessel or autonomous vehicle, or sediment trap part of this first approach. The second type of experiment is also an in situ approach, where at some starting point (T_0) one perturbs a "subset" of the natural ecosystem by manipulating or isolating various features (and/or processes) to test a hypothesis. This is illustrated with the use of instruments such as the wave pump (transport mechanism) or with our current effort to utilize a system of larger 'bags' called mesocosms (larger volume subset) to induce a phytoplankton response. Part of this experiment is to correlate the timeline of the mesocosm phytoplankton response utilizing artificial deep sea nutrients to what has been traditionally seen in the smaller scale volumes. Similar or large volume experiments on land have been accomplished via the use of lakes or ponds to test the growth response (negative or positive) of an ecosystem when artificially exposed (at some T_0) to a variety of chemical substances. Both pond (or lake) and open ocean mesocosms enclose a larger mass of water but the difference is that the ratio of the vertical depth to the horizontal affords the open ocean mesocosm user unique opportunities to simulate depth or measure stratified characteristics of plankton communities. In this particular cruise experiment IFM-GEOMAR and C-MORE are partnering together to utilize large mesocsoms in the open ocean to study the biogeochemical effects to Deep Sea Water (DSW) nutrient additions.

Background: ***CMORE COLLABORATION WITH IFM-GEOMAR***

A network of mesocosm facilities (6 European partner institutions) has been established in Europe that aims to combine experience and excellence in mesocosm work with the scientific need for access to contrasting environments (http://mesoaqua.eu/). IFM-GEOMAR is one of the 6 institutions involved in MESOAQUA that designed the first mesocosm prototype in 2005. IFM-GEOMAR carried out the first full-scale field application in the summer of 2007 and 2008 in the Gotland Sea, Proper Baltic which was worldwide the first operated mesocosm in off shore waters. After this, IFM-GEOMAR upgraded the mesocosms with new extremely strong bottom-plates that were deployed in 2010 in the Kongsfjord in Svalbard/Spitsbergen and in 2011 in Bergen/Norway. Therefore the next step is to utilize these mesocosms in more potentially hostile open ocean conditions. Since C-MORE has had a long history of open ocean field and experimental work, ***this collaboration provides a unique opportunity to not only test the engineering feasibility of utilizing the mesocosms in the open ocean, but the opportunity to compare many aspects of smaller volume experiments done aboard the research vessel, in-situ, or in the lab with a significantly larger volume (60 cu meters) of water.***

Two Overall Objectives:

This exercise has both engineering and scientific components. The first part is to test the feasibility and logistics of utilizing three large-scale mesocosms in the open ocean. The second part is to measure the surface response of the phytoplankton communities when deep-water macro and micronutrients are added.

Scientific Objectives:
Between December 1st – 15th CMORE and IFM-GEOMAR will deploy three 60cu meter mesocosms south (~ 10-15 nautical miles) or west (Kahe Point) of the island of Oahu. The aim is to study the biogeochemical effect of the addition of deep-sea water nutrients on surface ocean plankton communities and processes. The treatments of the mesocosm bags will be the following:
<u>BAG-1A</u> will contain surface seawater only, serving as the negative control for the experiment.
<u>BAG-1B</u> will contain surface seawater plus nitrate/silicate/trace metals and vitamins. BAG-1B is predicted to drive phosphate to subnanomolar levels and will also use the bioavailable DOP over time. This treatment would match one possible treatment of deep seawater effluent in SWAC or OTEC facilities wherein phosphate is first scrubbed from the wastewater product prior to ocean disposal.
<u>BAG-1C</u> will contain surface seawater plus nitrate/phosphate/trace metals and vitamins. BAG-IC will stimulate a much more significant phytoplankton bloom that would last for a longer period of time, with estimates from similar carboy experiments predicting that in 5-6 days all the nutrients (within detectable limits) will be consumed.

In addition, BAG-1B and BAG-1C will be enriched with stable nitrogen isotopes (3-5umolar) that will be added as sodium nitrate. This addition and other core measurements (see table below) will assist in the calculations of the N mass balance, export, metabolic balance, and transformations.

GEOMAR		CMORE	
N_2O (air/sea exchange)	500mL	Primary production	2L
CHL a	200mL	Nutrients	1L
HPLC (pigments)	4L	FCM	5mL
Microscopy (Phyto+Zoo)	500ml	DIC/TA/pH	1L
PPO_4	4L	ATP	2L
PC/PN	4L	BP	20mL
Bsi	?	DOC, DON, DOP	300mL
Sediment traps		DMS, CH_4, N_2O	1L
		N_2-fixation	5L (less if AR)
? POP, POC/PON, TPC/TPN, BSi		DNA/RNA	5L
		Respiration (O_2 consumption/Winkler)	8L
		Multispectral FRRF	200mL
		Viral Abundance	15mL
		TFF(Tangential Flow Filtration)	2-4L
		Photosynthesis irradiance (Size Fractionated)	1-2L
		Membrane Inlet Massspectrometer (for Net Community Production)	~50mL
		Sediment trap material (for e.g. calorimetry, fluxes)	
		Discrete Depth Sampling	?

Onboard and potential *in situ* incubations will be carried out in various size containers (subscale) with the same and additional treatments (e.g. P only) as the deployed mesocosms (Microbial container: 1L, 10L, 20L). In preparation for these deck incubations and the bag nutrient loading, some preliminary experiments are planned to evaluate the response of the 'mix recipe' (N+P) to the natural deepwater when added to surface seawater (ssw). These experiments will be checks to verify the ssw response to the deep water is similar to the mix. Therefore, ~20L deep water (750-

1000m) from the November HOT leg (HOT 236) will be collected to be utilized in the evaluation of this recipe. At a 10% volume addition this provides enough water to run a variety of 5%, 10%, and 15% nutrient mix concentration comparisons.

Daily, the three mesocosms will be sampled from a small boat using the small hand deployed CTD, integrated sampler (volume ~ 5L) and a small optics package (OSU) – if one can be configured. If a small hand held optics package is not available samples could be collected for use in the on board Multispectral FRRF. Four sampling devices are available for sampling, either integrated samples or discreet samples. In addition, we will be sampling next to the mesocosms, with the hand held CTD, small optics package, Hyperpro, and the shipboard CTD/instrumentation. These external measurements will serve as additional controls to compare to the data of BAG-1A (potential BAG effect). Adding all core measurements, we will need to sample ~ 30-35L daily from each mesocosm bag plus from the ocean next to the bag. At the end of the experiment, pieces of the bag material will be cut out (inside and outside) and tested for types of microbes that are growing on the bag material.

Engineering Objectives:
Our aim is the successful deployment, maintenance, and recovery (~14days) of large mesocosms (frame ~3m dia x 9m H, 60cu meter bags) in the open ocean (Receive, unpack, and assemble the mesocosms approximately 2 weeks prior to the cruise)
The deployment location is tentatively scheduled for either the south side of Oahu (see the Ref) or off of Kahe point, but the final deployment location is predicated on the wind and sea state conditions at that time. (see Sec:Reference –HF radar http) The three completely assembled mesocosms will be loaded and secured on the aft deck of the *R/V* KOK at the dock. When the R/V KOK is on site, the small boat will be deployed first. The mesocosms will be then deployed one at a time (Aurora crane) with the small boat initially being used to pull the mesocosm clear of the ship. When all three mesocosms are floating in the water, they will be secured in series with the use of two 3cm x 20-meter lines. A drogue and/or sea anchor will be attached to keep the drift rate reduced – which one is selected will also be part of the engineering test and is TBD.
Divers (4 in the small boat) will then enter the water and drop the lower portion of the plastic bag to depth while the upper bag is left below the surface to allow for equilibrium to be established among the mesocosms.
After the equilibrium time has completed the divers will close off the bottom of the bag with the funnel or sediment trap cone and raise the upper bag. At this point the mesocosms are ready for the additives.
The additions to BAG-1B and BAG-1C will be via the IFM-GEOMAR 'spider' which will inject and distribute evenly the nutrients over the entire water column of the mesocosm. The Spider pumps 7l/min, so amounts of 25 to 300l are practical for manipulation. Mixing bottles typically are 25L size, so it may be advantageous to use 20-25L as a basis for the quantity pumped via the spider and on figuring the ratio for the final solution recipe. Daily engineering checks on each mesocosm will be conducted to evaluate potential ripping of the bags.

Specifications –

- Floating frame: 8.5m height, with ropes (bridles) ~ 10m
- Weight: 1.8 tons
- Assembling takes ~ 10 days to 2 weeks
- Disassembly approx 5-8 days, If possible, IFM-GEOMAR, for a few days, assists & instructs the UH team re-pack procedures prior to flying out.
- Assembling area needed: 50x50m, with a maximum height of ~10-12m. Assembling possible outside near dock, equipment: a) forklift b) shore crane (brief: to lift horiz assembly to vertical, min height 7m[21ft; but more like 30ft w/bridle) & c) man lift (up to 7.5m H reach)
- Typical mesocosm load time on the Vessel- 1.5hrs – 2hrs
- Volume of each bag: est ~60m^3 (pi * r^2 * H = pi * ***1m***^{2} * ***19m*** = ~59m^3)
- Bag Material: The bags are made from thermoplastic polyurethane (TPU Walopur 4201; data sheet attached) 500µm thick in the main part and 1000µm in the upper part (within the flotation frame) and at the funnel on the bottom

- The flotation bodies (black and orange) are made of glass fiber reinforced plastic tubes as used for chemical pipelines (and are not covered in tape).
- The folded bag is hanging inside the flotation frame attached by ropes before the deployment. It will be additionally secured by tension belts to prevent swinging.
- After recovery of the mesocosms, the bags with the bottom flange construction are separated from the flotation frame and will need additional space (about the space of one mesocosm). But the Bag material and the flanges can be also secured on top of one of the working vans.
- Depth of bags: ***17m*** (water surface to bottom of sediment trap) cylindrical part, with a funnel of ~ 2m makes it to a total length of 19m
- Diameter of bag: ***2m***. Diameter of frame probably adds 1m overall.
- Mesocosms can be left drifting with drogue anchor, are equipped with lights for locating during night. Radar reflectors/ ARGOS or VHF are to be installed.
- Mesocosms are connected by a 20m buoyant- floating rope, ~ 3cm in diameter;
- Drogue buoy Specs: (see reference drawing below)
  a) 1 hard buoy with buoyancy of ~150-250kg with underwater drifter as sail
  b) (consisting of 2 panels, 8-10m^2 each positioned crosswise)
  c) 50-200m rope to keep drifter panels well below surface currents
  d) 1 small weight (about 40kg)
- Assembly instructions attached

Science Personnel:

The *RV* KOK accommodates up to 21 scientists (typically 19 + 2 OTG). To date's list of participants is as followed:

#	Participant	Institution
1	Kuhio Vellalos	OTG
2	Ulf Riebesell	IFM GEMOAR
3	Andrea Ludwig	IFM GEMOAR
4	Jan Czerny	IFM GEMOAR
5	Jan Büdenbender	IFM GEMOAR
6	Klaus von Bröckel	IFM GEMOAR
7	Matthias Fischer	IFM GEMOAR
8	Steve Poulos	UH
9	Daniela Böttjer	UH
10	Karin Björkmann	UH
11	Tara Clemente	UH
12	Blake Watkins	UH
13	Shimi Rii	UH
14	Eric Grabowski	UH
15	Shasha Tozzi	UCSC
16	Chris Schvartz	UH
17	Sandra Martinez-Garcia/Ken Doggett?	UH
18	Angel White	OSU
19	Student Angel White (TBD)	OSU
20	David Pence	UH
21	UH Diver female/male (TBD)	UH

Time Line: 2011

July 6 Video teleconference:

IFM-GEOMAR Ulf Riebesell, Andrea Ludwig

C-MORE Dave Karl, Daniela Böttjer, Steve Poulos, Jonathan Zehr, Ed Delong Penny Chisholm

September 30 3-mesocosms(w/ consumables) shipped out of Bremerhaven in 40ft container

October 12 Video teleconference

UH: Dave Karl, Grieg Steward, Matthew Church, Karin Björkmann, Tara Clemente, Blake Watkins, Shimi Rii, Steve Poulos, Daniela Böttjer

OSU: Ricardo Letelier, Angel White

November 6 Arrival of 40ft container with mesocosms bags and consumables
November 13 Arrival of Jan Czerny and Detlef Hoffmann (Assembling team)
November 16 ~Start of mesocosm assembly
November 28 Arrival of remaining GEOMAR participants
December 1 Loading after HOT arrival and departure around Noon
December 15 Return to SNUG and full offload
December 16 Start de-assemble and container packing

REFERENCE MATERIAL

Weather: Upto Beaufort 4: [HF Radar Current: http://cordc.ucsd.edu/projects/mapping/maps/
(click on Hawaii/Oahu a few times to zoom in)

a) Max wind- 11-16kts (moderate breeze);

b) waves – small waves, some whitecaps; Hence it means most likely deployment will be planned within the lee of the Islands (Kahe Pt – West or South Oahu off Barbers) for the most part.

(Note: Typical Hawaiian Trade Winds – 10-15kts with gusts to 20kts)

c) after deployment , wave heights possible: 2-2.5m

Vessel: R/V Ka'imikai-O-Kanoloa http://www.soest.hawaii.edu/UMC/RVKOK.htm

a) Dates - Dec 1 – 15th , 2011
b) Aurora Crane : 45f (10,000lbs); 25ft (16,200lbs)
c) Main R/V KOK Working Boat – ~5.5m length, rigid hull, inflatable sides 90HP Honda motor
This is the main working boat for diving
d) Back Up OTG SAFEBoat - ~6m rigid hull, inflatable side, twin 90HP Yamaha outboard
upto 11 people, load 3200lbs; cruising spd 12kts, top 35kts, 6dive tank racks (see ref pic)

IFM – GEOMAR 'spider' Procedure for additions: (rate of dispersement)

The spider is composed of a membrane pump (12 v car battery a 25 m rubber hose ½ ' and a dispersing part. It will inject and distribute evenly the nutrients over the entire water column of the mesocsom. The Spider pumps 7l/min (dispersion rate) so amounts of 25 to 300l are practical for manipulation. Mixing bottles - 25L size, and GEOMAR will provide the bottles for mixing the nutrient solution. Planning should utilize this quantity to determine solutions that can be added volumetrically (to ~ 25 l of milliQ or sea water) prior to addition.

IFM – GEOMAR 'integrated sampler'

Integrated depth sampler will be used daily for routine measurements and a data logger probe, equipped with several sensors (temperature, salinity, turbidity, pH, fluorescence, oxygen etc.). The Instruments will be lowered by hand over a davit (manually) into the mesocosm.

Equipment (brief):

- OTG CTD; Dual SBE sensors; fluorescence; (see Std HOT config for OTG CTD/Rosette) deck boxes etc.
- OTG Rosette and 24 -12 liter water sampling bottles, all spare parts
- OTG small Retriever Winch – open end drum
- KOK/OTG standard underway sampling (THSL, fluoro), met, ADCP, and navigation information/ logging
- Hyperpro (hyperspectral radiometer, a WET Labs ECO-BB2F triplet: Chlorophyll-a fluorescence & backscattering: blue & red wavelengths, temp & conductivity sensors) and associated optical measuring instruments
- UCSC - FRRF –Benchtop Fast Rate Repetition Fluorometer
- AC9 - ?
- UH – Inverted Microscope (with Digital Camera)
- GEOMAR - 5L bottles
- HOT Van in Hangar, Flow Cyto Van up on top of Hangar
- Incubation systems on top of hangar (for subscale process studies)
- KOK - RDF
- KOK – Comms (VHF) , email, possible extended us of the F77 system
- KOK – Depth Indicators
- Pertinent MSDS

Reference Drawing for the Mesocosm Drogue