Appendix A: Workshop Participants
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Appendix B: Science Questions Submitted Prior to Meeting

The following is a verbatim list of processes/science questions submitted by participants prior to the workshop. For convenience, the list has been sorted by general category. However, many contributions belong in more than one category, and no editorial assumptions are implied by the category designations.

integrative models

How can coastal observations be used to develop better boundary conditions for open ocean models?

Can we use the observation systems to force small scale (50km or so) physical models of the coastal ocean? Many important processes in the coastal ocean occur on the 10-50km scale of banks and points. The small domain models capable of resolving these features will be largely forced by the flux of momentum and advection of buoyancy through their open boundaries, and not by the local fluxes. Can the observation systems provide the boundary conditions for these analytic and numerical models? And is this better or cheaper than embedding the high resolution model inside larger model domains?

Biological - Chemical - Physical Coupling at the Event Scale - Events such as the intrusion of eddies; brief upwelling; episodic discharges from rivers - can all stimulate primary and secondary production, carbon transformations and export. During traditional sampling - we often face the “smoking gun” and do not have the data to piece together the cause and effect of physically-driven biological reactions. Theory and scant observations of these phenomena suggest that these event scale forcings are important in coastal waters. We now are near the stage of our science where coastal time series using physical/chemical/biological sensors can shed new insights into these event scale events.

Coastal observatories provide seasonal data from the synoptic to the interannual and thus permit the resolution of issues not previously available. Measurements in the vertical, combined with local meteorological measurements, will permit development and testing of mixing models that include winter convection (at least at higher latitudes where it happens). Of course, one-dimension is only an approximation and resolving the turbulent kinetic energy sources that are the source of mixing will still be an issue.

Surface fluxes of properties (gases, light, buoyancy) which are likely event driven require observatories that integrate physical, biological and chemical measurements. The role of wave breaking, bubble injection, and other turbulent mixed-layer dynamics will need to be resolved to integrate from the events out to the low frequencies.

Integrating from the synoptic to the seasonal and interannual will require observatories, and not just a single observatory. The question of how to ‘interpolate’ observatory measurements is key to integrating the short-time scales out to the longer and will require substantially local studies to determine how the point and line measurements provided by observatories scale up.

Integrating biological, physical and chemical dynamics, e.g. spring bloom shelf dynamics and the depletion of nutrients related to mixing and convection events. We have through shipborne studies only seen a few realizations of such events and undoubtedly have not seen all the possible ‘types’ of such events that can occur.

Wind fields and related data for assimilation into hurricane surge models

Can we parameterize mixing processes from the data collected in coastal observatories and use these parameterizations in numerical models?

How much of the wind stress goes to advective processes and how much goes into mixing processes?

Mean Flows - In the Middle Atlantic Bight the mean flow tends to be southward alongshore at about 10 cm/s. On the west coast there is a northward mean flow of similar magnitude (in the absence of wind forcing). The question in both cases is what drives these mean flows and what are the dynamics. We lack long-term measurements that would document interannual variations in these “mean” flows and allow us to test hypotheses regarding the forcing and dynamics. For example, one hypothesis for the mean flow in the Middle Atlantic Bight is that it is driven by freshwater buoyancy forcing from farther north. This raises the question of tion of whether the mean flow would change and how if there was a change in the buoyancy forcing, such as a substantial increase in freshwater flux out of the Arctic.

Shelf-slope exchange in the Middle Atlantic Bight. There is considerable interest in the magnitude and the processes that drive exchange between the shelf and slope water within the Middle Atlantic Bight. This question is relevant to understanding the salinity of the shelf water, carbon fluxes (SEEP studies), and sources of nutrients. However, it is not even known which are the dominant processes driving exchange. Possible candidates include: wind forcing, warm-core rings, frontal instabilities, and intrusions. Systematic long-term measurements would provide the opportunity to test various hypotheses. For example, is there more exchange during years with strong winds or more warm-core rings?

How can we use coupled circulation/biogeochemical models to optimize coastal observatory developments?

optics/acoustics/remote sensing

Can satellite data products be used with local observations to derive additional satellite data products for coastal ocean science?

What level of coastal ocean observations are required to carry out an adequate Cal/Val program for coastal ocean color sensors?

Of naval interest - ocean optical (and acoustical) variability - How can we predict fundamental optical (acoustical) variables needed for predictions of underwater visibility (sound propagation)?

bloom/population dynamics

Harmful algal blooms: What causes them and what are their effects on ocean ecology and human health? What can be done to mitigate them or should they be mitigated?

Harmful algal blooms - early detection/prediction

Integrating biological, physical and chemical dynamics, e.g. spring bloom shelf dynamics and the depletion of nutrients related to mixing and convection events. We have through shipborne studies only seen a few realizations of such events and undoubtedly have not seen all the possible 'types' of such events that can occur.

episodic events (e.g., harmful algal blooms, El Niño)

Blooms in general and harmful algal blooms in particular. Once the observatory has detected a bloom there is the possibility of a rapid response to obtain more detailed measurements, particularly of spatial variability and how this varies with time. Accurate prediction of blooms will be an excellent test of models.

What is the small scale co-distribution of organisms?

How does environmental change (climate or anthropogenically- induced) influence marine zooplankton and fish population variability? Or, how does temporal and spatial variability of physical and biological factors govern reproduction, growth, recruitment, and survivorship throughout the year?

What role do marine zooplankton play in coastal elemental (C,N,Si,S,Fe) dynamics and flux? Coastal observatories will be able to provide a year-round environmental context (weather stations, TS, current and tidal properties, nutrient concentrations, PAR, fluorescence, phytoplankton productivity, active and passive acoustics, imaging systems, profiling net systems) for focused biological studies of shorter duration.

Are zooplankton a vector for disease in coastal regions and how may this be affected by climate and/or anthropogenic changes? Molecular probes are being developed to detect harmful algal blooms and disease vectors, such as those that infect commercially important shellfish or farm-raised salmon. Passive acoustics on observatories may be used to detect the movement of marine mammals. Downward-looking and side-looking acoustics on closely spaced moorings or on AUVs with cameras will be able to track the movement of organisms through areas and diel vertical changes. Mass spectrophotometers on moorings may provide information on anthropogenic contaminants and pollution influencing marine organisms. All of these approaches require studies to validate procedures and interpretation.

process/observatory/model scaling

Can we use the observation systems to force small scale (50km or so) physical models of the coastal ocean? Many important processes in the coastal ocean occur on the 10-50km scale of banks and points. The small domain models capable of resolving these features will be largely forced by the flux of momentum and advection of buoyancy through their open boundaries, and not by the local fluxes. Can the observation systems provide the boundary conditions for these analytic and numerical models? And is this better or cheaper than embedding the high resolution model inside larger model domains?

Biological - Chemical - Physical Coupling at the Event Scale - Events such as the intrusion of eddies; brief upwelling; episodic discharges from rivers - can all stimulate primary and secondary production, carbon transformations and export. During traditional sampling - we often face the "smoking gun" and do not have the data to piece together the cause and effect of physically-driven biological reactions. Theory and scant observations of these phenomena suggest that these event scale forcings are important in coastal waters. We now are near the stage of our science where coastal time series using physical/chemical/biological sensors can shed new insights into these event scale events.

Long time series of measurements from coastal observatories will enable a better understanding of the statistics of processes including seasonality, the impact of variations in river discharge and inter-annual variability .

Understanding the effects of transient events on coastal physical processes:

> Short term events (such as storms, hurricanes, spring freshet, seismic waves) can have a significant effect on the short term and seasonal patterns
>
> Duration of short term events: duration/recovery time to earlier state; triggering longer term changes?
>
> Effects on land and interactions with open ocean areas?
>
> Scales of processes affected?

Criteria for scalability and applicability of observatory data to other coastal environments

Effects of changes in physical processes due to short term events on acoustic noise, scattering, and propagation

Effects of changes in physical processes due to short term events on biological activity - local transient changes and long term modifications

Observing, understanding, and predicting the propagation and coastal influence of low frequency, interannual signals like El Niño and La Niña.

Determining how mesoscale features like eddies influence water mass properties (nutrients) and productivity.

Assessing the relative importance of local versus remote wind and buoyancy forcing in driving circulation and upwelling.

I would stress a coastal observing system rather than observatories, since observatories imply to me a few discrete locations. I feel that in order to make progress in understanding the coastal ocean we need to sample on space and time scales that will resolve the ocean mesoscale (in space) and the seasonal cycle (in time), and for that we need an observing system.

biogeochemical processes

Biogeochemical cycling - What role do the coastal oceans play? Questions raised during SEEP and other early programs remain unanswered.

Shelf-slope exchange in the Middle Atlantic Bight. There is considerable interest in the magnitude and the processes that drive exchange between the shelf and slope water within the Middle Atlantic Bight. This question is relevant to understanding the salinity of the shelf water, carbon fluxes (SEEP studies), and sources of nutrients. However, it is not even known which are the dominant processes driving exchange. Possible candidates include: wind forcing, warm-core rings, frontal instabilities, and intrusions. Systematic long-term measurements would provide the opportunity to test various hypotheses. For example, is there more exchange during years with strong winds or more warm-core rings?

Inshore/nearshore/estuarine processes - nutrient loading/eutrophication; habitat change; flooding; sediment loads

Seasonal anoxic or suboxic events in the water column - e.g. Gulf of Mexico, Chesapeake Bay

What is the state of the carbon and nutrient budget for the U. S. coastal zone today, and how do human and natural perturbations influence this budget?

How does fluid advection through coastal sediments affect the biogeochemistry of the coastal ocean? What drives this advection? What fraction of the discharge occurs as relatively steady flow and how much as episodic discharge?

Integrating biological, physical and chemical dynamics, e.g. spring bloom shelf dynamics and the depletion of nutrients related to mixing and convection events. We have through shipborne studies only seen a few realizations of such events and undoubtedly have not seen all the possible 'types' of such events that can occur.

what is the evolution of marine snow formation and how is it related to physical and biological properties of the water?

carbon cycle (e.g., inputs, exports)

What is the fate of water, solutes and particulate load originating from major rivers? i.e. sinking depth, lateral dispersion. How are dissolved and particulate nutrients that originate from large rivers modified by biogeochemical processes in the water column and sediments of the coastal zone?

Coastal pollution: How can we predict and mitigate major coastal pollution events such as river and groundwater runoff and oil spills leading to input of chemically and biologically harmful materials?

pollution hazards (e.g., runoff, wastewater discharge)

Sediment and bottom material resuspension and transport: How can we predict and intervene for bottom resuspension events and transports of harmful materials as well as naturally occurring materials (implications for ocean ecology and human health [e.g., 200 tons of DDT in bottom sediments off Palos Verdes, CA - what next, where will it go, what harm will be caused?]

Carbon and nutrient cycles - budgets and their evolution over time.

sediment transport/riverine input/buoyancy

Can we come up with a relationship between river discharge and water column stratification, and between river discharge and gravitational convection? What are the response times for these processes?

Buoyant discharges. River and estuarine discharges are an important component of the dynamics on many shelves. Dispersal of this discharge and its various constituents remains poorly understood. Strategically located observatories would allow us to develop a better understanding of the processes that contribute to dispersal and the character of the dispersal. One obvious application is the issue of hypoxia off the Mississippi River. Rabelais and coworkers have clearly shown the importance of the nutrient load to this problem, but they have also shown that interannual variations depend on discharge and, I think, on the meteorological conditions. In general, while we know buoyant discharges are very responsive to wind forcing, we don't understand the dynamics or the implications.

Inshore/nearshore/estuarine processes - nutrient loading/eutrophication; habitat change; flooding; sediment loads

What is the state of the carbon and nutrient budget for the U. S. coastal zone today and how do human and natural perturbations influence this budget?

What is the fate of water, solutes and particulate load originating from major rivers? i.e. sinking depth, lateral dispersion. How are dissolved and particulate nutrients that originate from large rivers modified by biogeochemical processes in the water column and sediments of the coastal zone?

Impacts of storms, including coastal flooding; wave-current interaction; erosion, movement and deposition of sediment and the consequent release of contaminants. Measurements during storms, apart from coastal tide gauges, are scarce. There is the additional possibility of rapid response to deploy equipment prior to a storm and for the observatory to provide context measurements for surf zone studies.

Long time series of measurements from coastal observatories will enable a better understanding of the statistics of processes including seasonality, the impact of variations in river discharge and inter-annual variability.

Sediment and bottom material resuspension and transport: How can we predict and intervene for bottom resuspension events and transports of harmful materials as well as naturally occurring materials (implications for ocean ecology and human health [e.g., 200 tons of DDT in bottom sediments off Palos Verdes, CA - what next, where will it go, what harm will be caused?]

Roles of sediment supply vs accumulation

Ground and sea level subsidence. Seasonal Influence on coastal evolution

Appendix C: Agenda

Coastal ocean processes and observatories:
Advancing coastal research
7-9 May 2002
Savannah, Georgia

Tuesday 7 May 2002

0815 - 0830 - Trolley transit from hotels to Coastal Georgia Center (CGC)

0830 - 0840 - Welcome - J. Sanders, Director SkIO

0840 - 0900 - Introductions, logistics, goal of meeting, general background and CoOP overview and connection to observatories - R. Jahnke

0900 - 0915 - NSF Background, Major Research Equipment Initiative - A. Isern

0915 - 0945 - What are ocean observatories, observing systems and what is the status of the Ocean.US Integrated Ocean Observing System - Airlie House Workshop Report - L. Atkinson

0945 - 1015 - Review of existing operational and experimental coastal ocean observing systems - F. Chavez and O. Schofield

1015 - 1020 - Charge to working groups - Jahnke/Atkinson

1020 - 1045 - Break

1045 - 1200 - Four parallel working groups

Identify coastal ocean processes (critical research questions) that can best be investigated with coastal observatories. A listing of topics supplied prior to the workshop will be distributed to assist the discussion. Aspects of coastal observatories that uniquely contribute to the identified studies should also be indicated.

1200 - 1300 - Catered Lunch (deli buffet)

1300 - 1500 - Four parallel working groups (continue)

1500 - 1530 - Break

1530 - 1700 - Plenary, working group reports

1700 - 1715 - Trolley transit from CGC to hotels

1745 - 1815 - Bus transit to reception and low country boil at Skidaway Institute of Oceanography

1815 - 1845 - Reception on board the R/V Savannah

1845 - 2030 - Low country boil dinner

2030 - 2100 - Bus transit back to downtown hotels

[Overnight the research questions identified by the working groups are compiled into a master list for distribution back to the working groups]

Wednesday 8 May 2002

0815 - 0830 - Trolley transit to Coastal Georgia Center

0830 - 0900 - Review of compiled master list and charge to working groups.

0900 - 1000 - Parallel working groups

> *Groups discuss list of research topics to clarify entries, delete duplication, add omissions, etc. then vote to provide a preliminary prioritization. If each individual votes for the top 1/3 of the list, a rough sense of prioritization can be quickly achieved*.

1000 - 1030 - Break

1030 - 1130 - Plenary, Reports by working groups.

1130 - 1200 - Plenary, Charge to afternoon working groups

> *Identify which existing observatory capabilities are most appropriate for addressing the critical research questions determined yesterday.*

> *Identify and prioritize observatory development areas which would provide the greatest benefit to future coastal oceanographic research.*

1200 - 1300 - Lunch

1300 - 1530 - Four parallel working groups

1530 - 1600 - Break

1600 - 1700 - Plenary, report by working group chairs

1700 - Dinner on your own

Thursday 9 May 2002

[Overnight, the existing capabilities and most promising R&D topics from the groups will be compiled for distribution]

0815 - 0830 - Trolley transit to CGC

0830 - 0945 - Working groups meet, discuss compiled list and vote to prioritize

0945 - 1015 - Break

1015 - 1200 - Plenary, Report by working group chairs. Final wrap-up discussion of workshop report

1200 Adjourn - trolley back to hotels

Appendix D. Glossary of Acronyms

ADCP	Acoustic Doppler Current Profiler
AOP	Apparent Optical Properties
AUV	Autonomous Underwater Vehicle
Cal-COOS	California Coastal Ocean Observatory System
Caro-COOPS	Carolina Coastal Ocean Observation and Prediction System
CODAR	trade name for high frequency radar
CBOS	Chesapeake Bay Observing System
C-IOOS	Coastal Integrated Ocean Observing System
COMPS	West Florida Coastal Ocean Monitoring and Prediction System
COS	Coastal Observing System: refers to observing assets in the coastal zone whether they are part of OOI or IOOS
CMAN	Coastal Marine Automated Network
CPR	Continuous Plankton Recorder
CTD	Continuous Temperature Depth profiler
CUFES	Continuous Underway Fish Egg Counter
DOM	Dissolved Organic Matter
ENSO	El Niño Southern Oscillation
FRONT	Front-Resolving Ocean Network with Telemetry
FRRF	Fast Repetition Rate Fluorometer
GoMOOS	Gulf of Maine Ocean Observing System
HF	High Frequency (radar)
HPLC	High Performance Liquid Chromatography
IOOS	Integrated Ocean Observing System
IOP	Inherent Optical Properties
LEO	Long-term Ecosystem Observatories
LIDAR	Light Detection and Ranging
MOOS	MBARI Ocean Observing System
MREFC	Major Research Equipment and Facilities Construction
MVCO	Martha’s Vineyard Coastal Observatory
NADP	National Atmospheric Deposition Program
NDBC	National Data Buoy Center
NWLON	National Water Level Observation Network
NWS	National Weather Service
OOI	Ocean Observatory Initiative
OPC	Optical Plankton Counter
OSSE	Ocean System Simulation Experiment
SABSOON	South Atlantic Bight Synoptic Offshore Observational Network
SAR	Synthetic Aperture Radar
SAR-ATI	Synthetic Aperture Radar Along-Track Interferometry
SeaWIFS	Sea-viewing Wide Field of View Sensor
SIPPER	Shadowed Image Particle Profiling and Evaluation Recorder
TABS	Texas Automated Buoy System
TOGA COARE	Tropical Ocean Global Atmospheres/Coupled Ocean Atmosphere Response Experiment
VPR	Video Plankton Recorder

Appendix E. Working Group Reports

Working Group 1 - *Clark Alexander, Claudia Benitez-Nelson, James Boyd, Mario Cosmo, Mike Dagg (CC1), Hans Dam (CC1), Jim Edson (OC), Peter Franks (OC), John Howarth, Andy Lane, Marvin Moss, Jim Nelson, Heidi Sosik (CC2), Arnoldo Valle-Levinson (CC2), Shelby Walker, Paul Work*

Question: What is the role of episodic events on the fate of organic matter and nutrients in coastal systems? What are the relative roles of consumption, sinking and lateral export?

Example: In many coastal environments (e.g., the northern Gulf of Mexico) large phytoplankton blooms are associated with river inputs (e.g., the Mississippi River). However, there is no clear correlation between production, consumption and sinking. Moreover, consumption is variable and sinking losses are highly episodic. Yet, we do not understand the factors controlling variability in these episodic losses.

Necessary Components & Characteristics of Coastal Observing System:

Parameters: Growth (phytoplankton and bacteria); consumption (zooplankton; bacteria); downward and lateral fluxes; stocks (composition of particles [e.g., phytoplankton, bacteria, fecal pellets, marine snow, etc], nutrients, and DOM)

Platforms: Moorings and ships (adaptive sampling in the short run)

Configurations: 3-D array network (for lateral export measurements) and ships for process studies

Tools: (already available)

> *Rates:* Growth/physiology: In situ: fast repetition fluorometer; shipboard (incubations); losses (incubations for consumption; traps et al. for downward fluxes; current meters for horizontal advection)
>
> *Stocks:* (nutrient and DOM analyzers, fluorometers, particle counters/sizers and characterizers; e.g., acoustics, images, spectral, flow cytometers, etc.)

What needs to be developed? Continuous in-situ measurements of stocks and rates (growth, consumption, sinking and lateral loss)

What will be ready soon? This is entirely up to the community. More in situ measurements of stocks; some measurements of growth

What will take years to decades? In situ rates in general

Question: What is the impact of ocean-atmosphere interactions on storm movement and development?

Examples: Rapid cyclogenesis (bombs, Nor'easters) on the eastern seaboard, mid-latitude cyclone and hurricane evolution and track in all regions.

Rationale: Ongoing modeling efforts will benefit from the integrated, near real-time components of a coastal observing system (COS). A logical first step is to focus on the scale of (loosely) coupled coastal atmosphere-ocean models that cover the east, west, and gulf coasts. The continuous measurements from a coastal observing system will provide opportunities for:

> a) Processes study of the oceanic response to atmospheric forcing (and vice versa) over an unprecedented range of conditions.
>
> b) Investigations of severe storm response with the deployment of 'ruggedized' fast response sensors.
>
> c) Development of finer resolution (nested) models run in support of many of the smaller scale process studies.

Requirements: Ideally, a COS with synoptic scale (100 km?) spacing. The existing NDBC/CMAN stations, although certainly not optimal with regards to spatial scale, provide a starting point. Therefore, the first steps in this process involve:

> a) Upgrading the existing NDBC/CMAN network to include radiation and precipitation measurements with the met packages with temperature, salinity and current profiles beneath for vertical structure.
>
> b) Integrating the existing research observatories into these networks. The research ob-

servatories will provide additional measurements that take advantage of their enhanced infrastructure for process studies.

c) The above efforts should/must be under-taken by federal agencies with help and advice from coastal scientists.

d) Next, additional platforms will have to be deployed during a research phase to optimize the coastal observing system. This phase will include deployment and testing of the next gen-eration of platforms that are likely to include additional cabled observatories; research moorings and towers; gliders, drifters, and AUVs; and a coastal network of HF radars.

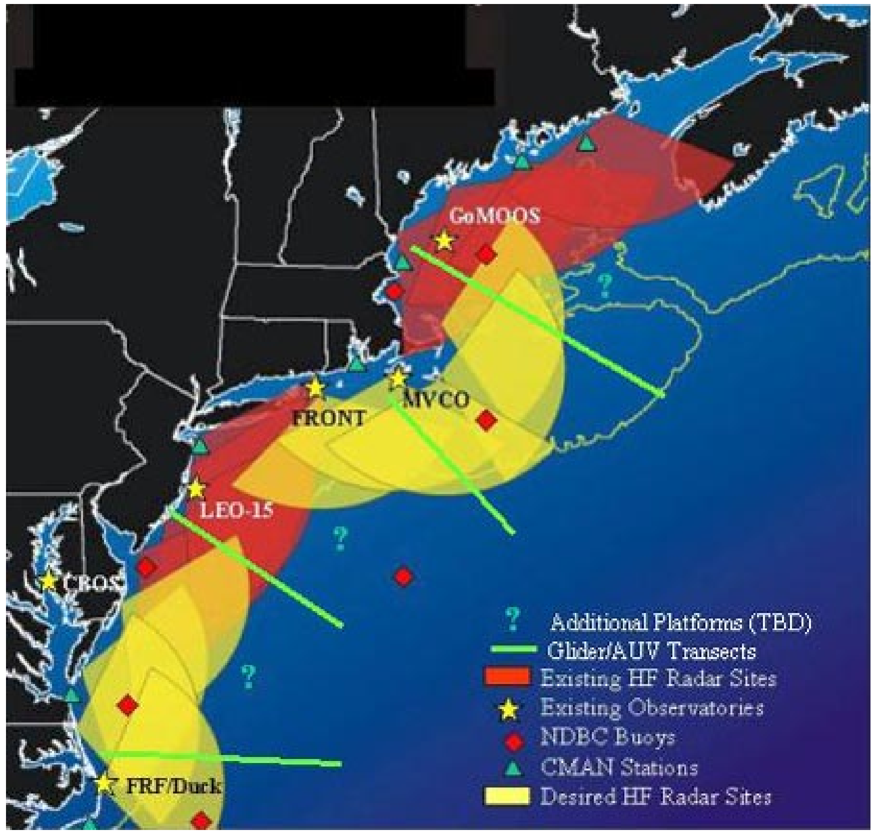


Figure 1. A Northeast US-centric view of an observatory

Tools:

Platforms: Buoys, bottom mounted, HF radars (surface currents & waves), fixed towers, satellites (winds, SST), gliders, drifters, planes, ships

Configuration: See Figure 1.

Instruments: fast response anemometers, hygrometers, thermometers, mean met (wind speed, wind dir, Tair, RH, P, IR, Solar, Precip, vertical profiles of T, RH, and U), oceanography (tide gauge, pressure, sensors, directional waves, vertical profiles of T,S,currents).

What exists? NDBC buoy and CMAN network, individual research observatories (some have been integrated), NWLON, upper air network (Rawinsonde & aircraft), some drifters.

What will be ready soon?*:* Vertical profiles at NDCB buoys, radiative flux measurements at NDBC/CMAN, integration of existing observatories, glider transects.

What will take a few years?*:* Coastal HF radar network. Integration of measurements into forecast models. Evaluation and testing of coupled ocean-atmosphere modeling.

What will take a decade?*:* Probably all of the above. An operational coupled ocean-atmosphere model.

Question: What are the inputs of nutrients and anthropogenic species into the coastal ocean?

Example 1: Harmful algal blooms (red tides) are increasing in occurrence along the coasts of the US (Gulf of Maine, Chesapeake, Florida Bay) potentially as a result of anthropogenic increases in nutrient loads and/or atmospheric delivery (i.e. Fe/*Trichodesmium* link in Southeast US).

Example 2: Increases in nutrient load result in increased primary production and hence, coastal bottom water anoxia (a fisheries and human health hazard).

Example 3: Finally primary production and carbon export (or sequestration) within coastal regions play an important role in global C storage.

Example 4: Recent evidence from the southeastern United States suggests that groundwater (Carolinas) and atmospheric delivery may be an important *additional* source of nutrients to the coastal ocean.

Example 5: Anthropogenic activities (automotives, chicken farms, smelters, etc.) have greatly impacted organic and trace metal levels within groundwater and riverine ecosystems resulting in general fisheries and human health impacts.

Rationale: Coastal nutrient inputs are highly dynamic varying on timescales ranging from hours and days (tides) to seasonal and interannual (wet vs. dry years). Sources range from local (fertilizer, smelter) to remote (inland drainage to cross ocean basin). Small changes in water flow resulting from both natural and anthropogenic (dams, etc.) processes greatly influence chemical and sediment inputs into the region.

Necessary **components** and **characteristics** of coastal observing system:

Platforms*:* stable platforms (with towers), telemetered moorings, cabled profiling mooring, satellites (dust), ship

Configuration*:* distributed moorings (vertical and horizontal e.g. ~5 km) with basic instruments, adaptive ship sampling, shore-based station (HF radar, MET)

Tools*:* a) Basic mooring suite; b) Full mooring suite: Basic suite plus tower (a la National atmospheric deposition program (NADP), includes wet/dry deposition collector, MET package), organic nutrients, contaminants, trace metal collector, in situ gamma detector, adaptive water sampler; c) Remote sensing algorithms (dust); d) Models: 3-D physical, atmospheric transport

What exists? Basic mooring suite

Which will be ready soon? a) Trace metal sampler; b) NADP; c) In situ phosphate, silicate sensors (not necessarily included in current nutrient packages)

Which will take a few years? a) Models; b) Organic nutrient (total) sampler; c) In situ gamma detector

Which will take a decade? In situ trace metal and organic contaminant sensors

Question: How can we improve understanding of vertical mixing processes in the coastal ocean (including effects on suspended and dissolved matter)? Is vertical mixing similar from estuaries to the shelf (and beyond)?

Example*:* The mixing parameterizations embedded in hydrodynamic models are unreliable under different conditions of stratification, winds, tides. We need better mixing parameterizations to understand, for example, the physical mechanisms responsible for hypoxia and anoxia in the Gulf of Mexico and in Chesapeake Bay.

Rationale: A better understanding of mixing processes is needed to understand transport processes in general and to increase reliability of any hydrodynamic or ecological model in the coastal ocean.

A process-oriented study is insufficient because it is restricted to certain forcing conditions and to a specific location.

Necessary components and characteristics:

Components: a) bottom-mounted ADCPs with high sampling rate (12 Hz) - already available; b) autonomous CTDs (ready/will be ready soon); c) meteorological sensors; d) data telemetry; e) pressure recorders

Characteristics: Fixed/moored platforms distributed along the shelf and in estuaries where advection of turbulence is weak .

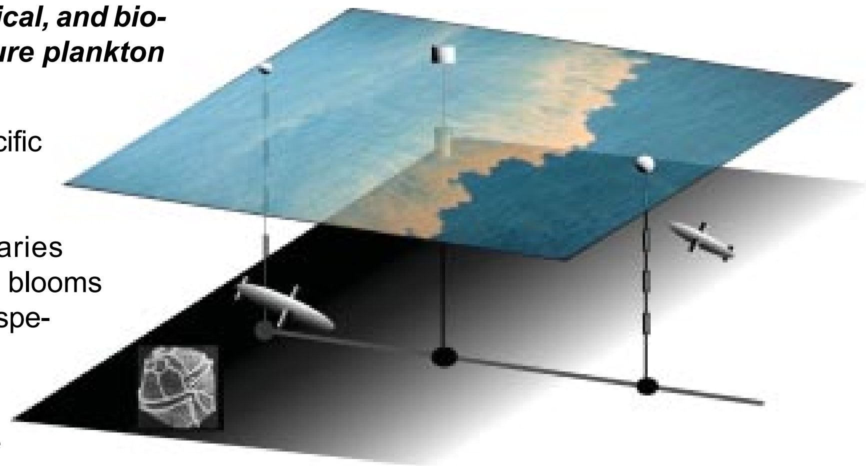
What components and characteristics already exist? Existing platforms should be used (C-Man and NDBC stations). Pressure sensors, meteorological sensors and data telemetry already exist there. Additional platforms in estuaries and coastal ocean should be added to represent various stratification, wind and tide conditions.

What components and characteristics must be developed? The technique of measuring Reynolds stresses (turbulence production) with ADCPs needs to be tested further (a few applications have proven successful, e.g., studies by Stacey, Simpson, Seim). Could use redundant measurements with fixed ADVs.

What components and characteristics will be ready soon? Autonomous CTDs.

What components and characteristics will take a few years? Measurements of turbulence production will continue to evolve but essentially we are ready to begin.

Question: How do physical, chemical, and biological factors combine to structure plankton communities?



Example: There are near mono-specific phytoplankton blooms (red tides) that occur irregularly off Southern California, and the dominant species varies among bloom events. Why do these blooms occur and what factors control which species dominates?

Rationale: The basic moorings, satellites, and AUV sampling will provide temporal and spatial resolution of hydrographic, chemical (nutrients) and meteorological variables that describe environmental forcing. In addition, they will help to define the extent of bloom phenomena. The sampling possible at the full mooring and from the ship surveys will provide the details necessary to completely characterize species level biological responses. Models will be used to quantify advective fluxes and test hypotheses of physical-biological couplings and dynamics.

Necessary **components** and **characteristics** of coastal observing system:

Platforms: telemetered moorings, cabled profiling mooring, satellites (SST, ocean color), AUV, ship

Configuration: cross-shelf transect of moorings (~5 from 30 to 300 m water depth, spaced ~5 km) with basic instruments, one profiling mooring with full suite of instruments, AUV for 3D surveying, adaptive ship sampling, shore-based station (HF radar, MET)

Tools: a) Basic mooring suite: vertically-resolved T, S, upwelling and downwelling spectral radiation, bulk fluorometer, spectral absorption meter, nutrient analyzer; bottom-mounted ADCP, MET (incident visible radiation, wind speed and direction, precipitation, T, relative humidity, IR radiation); b) Full mooring suite: Basic suite plus submersible flow cytometer, imaging system for phytoplankton and microzooplankton, fast repetition rate fluorometer, in situ molecular analysis systems; c) AUV suite: T, S, fluorometer; d) Shore station: HF radar (for surface currents); MET (solar radiation, wind speed and direction, precipitation, T, relative humidity, IR radiation), coastal runoff; e) Models: 3-D physical, targeted biological

What exists? Basic mooring suite

Which will be ready soon? Submersible flow cytometry, in situ molecular assays for a target species, and phytoplankton imaging systems have been proven in prototype.

Which will take a few years? Models

Which will take a decade? Advanced molecular techniques (e.g., microchips, etc.) for analyzing species composition and metabolic activity

Question: What are the effects of storms on material resuspension and mobilization (e.g., contaminants, nutrients)?

Example: Nutrient or contaminant release during extreme events may significantly influence primary productivity and community structure.

Rationale: Natural and anthropogenic materials are sequestered for varying lengths of time in estuarine and shelf sediments. These materials can be redistributed by physical processes or become remineralized by biotic and abiotic processes within the sediment column. In either case, they become available for assimilation into coastal food webs. The magnitude and frequency of this remobilization is unknown but has significant implications for bioavailability and the cycling of nutrients and contaminants. An observatory is required to allow sampling before, during and immediately after events.

Wave-current interaction: the coastal observing system measurements will provide the context for measurements during storms. Measurements are required referenced relative to the seabed of the stresses, of the seabed shape, suspended sediment distribution and the chemical consequences of the resuspension of sediments.

Platforms: Fixed towers or bottom mounted platforms at multiple locations, AUV.

Tools: Generalized observations from the regional coastal observing system, including currents, T, S, meteorology.

- Required measurements for this specific question: bedforms, particle size, concentration and composition, directional waves, vertical array of chemical sensors (DOM, inorg P,N, contaminants). Rugged fast response anemometers. Detailed current structure and stress in benthic boundary layer and throughout the water column. ADVs. Water samples.

The parameterisations in predictive models of sediment resuspension and the biogeochemical consequences will be improved and tested against the measurements.

What exists? Basic hydrographic and MET sensors, nutrient analyzers, water samplers, ADV

Which will be ready soon? Real time measurement of sediment, size distributions.

Which will take a few years? Development of rugged anemometers, hygrometers and thermometers. AUV missions in severe conditions. Measurements of Reynolds stress throughout the water column.

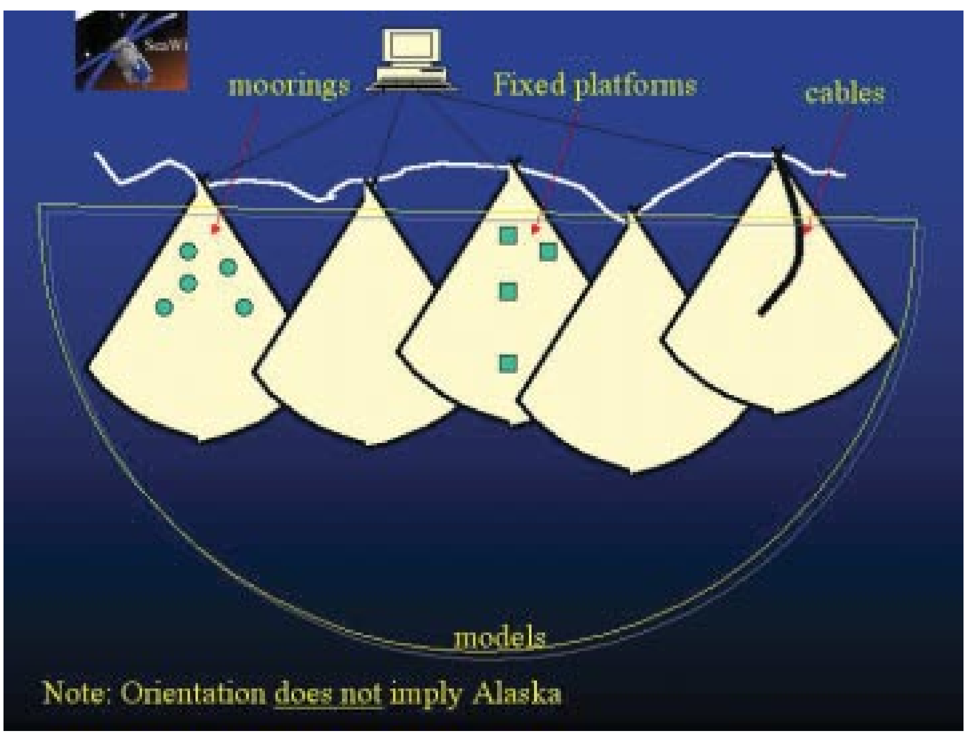
Which will take a decade? Real-time, in-situ contaminant and DOM concentrations

Working Group 2 - *John Allen, Tom Bianchi (CC2), Alan Brandt, Brad De Young, Scott Glenn (CC2), Ellery Ingall, Philip John Knight, Steve Lentz (CC1), John Moisan, Jim O'Donnell (OC), Dan Rudnick, Oscar Schofield (OC), David Stooksbury, Libe Washburn (CC1)*

Science Justification for Coastal Observatories

We need to collect data over decadal scales and over large spatial (10-1000 km) scales so we can define the mean behavior variability and the trends occurring due to natural and anthropogenic changes. Superimposed on these changes are episodic events, which impact the physics, chemistry, and biology. Quantifying the relative importance of these fluctuating properties requires an adaptive sampling capacity which the observatories can provide. To collect statistics on the importance of the episodic events, data will need to be collected for over a decade to assure that several episodic events are encountered.

So what does the observatory look like…….



UP FRONT, WE NEED PERSONNEL TO RUN THE SYSTEMS (MS LEVEL), REQUIRING AN EXPANDED TEACHING ROLE. DATA HANDLING NEEDS TO BE DESIGNED FROM THE OUTSET

What is the temporal and spatial variability in the long term & large-scale coastal circulation?

Examples: How would changes in annual and decadal time scales in the freshwater flux of the Arctic influence the Mid-Atlantic Bight? How does ENSO propagate through the California Current system? What forces the poleward undercurrent? How does the inter-annual variability in the Mississippi river discharge and the inter-annual variability in the Loop Current influence the circulation in the Gulf? What are the Lagrangian pathways (upwelling, recruitment, particulates, dissolved matter) on different time scales in the coastal ocean?

The observatory provides an array of broad scale measurements with nested local regional enhancements. The linked sites need to collect data over decadal time-scales over broad spatial scales. The fixed mooring can be unified via radars, AUVs, and models.

COMPONENTS: Radars, Moorings and fixed platforms (vel, T, S, P, AOPs(I)), AUVs flying standard lines, Satellites, Data Assimilation Models, Bottom Stress Measurements, Directional Wave Spectra, Subsurface Floats

What must be developed?

i) The trained personnel to run the systems, ie. MS levels ii) MET flux sensors

ii) OSSE's for optimized grid and what is the appropriate scale

iii) Need a data handling structure that works

In the Next Few Years

i) Gliders with increased payloads (ADCPs)

ii) Affordable moorings

iii) Improve Salinity Mapping Sensitivity (aircraft)

iv) MET flux measurements

v) Improve Data Assimilation Systems

Decade

i) Delayed Doppler Altimeter (make recommendation now)

How does the temporal and spatial variability in coastal circulation influence primary, secondary, and higher trophic level productivity of coastal ecosystems?

Examples: What is the connection between the eddy variability and sardine recruitment? Are red-tides in the Gulf driven by Loop current intrusions or river discharge? What is the impact of inter-annual variation in river discharge on the production of commercially important species (like shrimp, crab and oyster populations)? How is fish larval recruitment driven by Gulf Stream frontal eddies?

The observatory provides an array of broad scale physical, chemical and biological measurements with nested local regional enhancements. The linked sites need to collect data over decadal time-scales over broad spatial shelf scales. The fixed moorings can be unified via radars, AUVs, and models.

COMPONENTS: Radars, Moorings and/or Fixed Platforms (vel, T, S, P, Fl, AOPs(I), IOPs(I), Nutrients), AUVs flying standard lines, Satellites, Data Assimilation Models, Bottom Stress Measurements

What must be developed?

i) Chemical Sensors (Chemiluminescence probes, Dissolved Gases)

ii) Trace nutrient sensors

iii) In situ Imaging for Phytoplankton & Zooplankton Species

In a Few Years

i) Gliders with bigger payloads (optics)

ii) light-weight inexpensive instruments and moorings (NOPP O-SCOPE)

iii) In situ Imaging

iv) Robust trace gas measurements

v) Real-time local calibrated ocean satellite sensors using the observatory

vi) Transducer arrays and individual fish tags

vii) Improve coupled physical and biological models

viii) Develop regional earth modeling system (hydrological cycles)

ix) develop turn-key instrument package for platforms of opportunity (ferries, lobster traps, aircraft, tug & tows, fishing boats)

Decade

i) Biological data assimilation models coupled to nowcast/forecast models

ii) Outfit platforms of opportunity

What is the importance of episodic events in the coastal ocean and atmosphere?

Examples: Is the cross-shelf sediment transport dominated by storms? How are phytoplankton blooms initiated? What is the impact of hurricanes and subsequent recovery on ecosystems? How do extreme weather events (droughts, hard freezes, floods) on phytoplankton community composition?

The observatory allows for continuous data, which allows the episodic events (storms, physical, phytoplankton bloom initiation) to be studied. Capturing the events and allow for detailed sampling from ships and other platforms of opportunity. The events will require a decade of effort to allow an understanding the relative importance of mean and fluctuating quantities.

A) Radars, REAL-TIME Moorings & Fixed Platforms (vel, T, S, P, Fl, AOPs(I), IOP(I), Nutrients), AUVs flying standard lines with the capability of adjusting the flight missions, Satellites (Special Event Imagers), Data Assimilation ocean Nowcast/Forecast Models, Sensor web Technology (Trigger for Adaptive samplings), MET sensors (fixed platform & buoys), Bottom Stress Measurements

What must be developed?
i) Real-time data streams
ii) Sensor web technology software
iii) Adaptive sampling with satellites and in situ sensors
iv) Fast Action Response Capabilities

Few Years
i) Coupled Ocean/Atmospheric forecast/nowcast models
ii) Particle Imaging and Improved Acoustics
iii) Airborne Sensors and the UAVs
iv) Hyperspectral Optics
v) Access the international suite of satellites
vi) Turbulence Measurements for improved parameterization
vii) Improved surge and wave models

Decade
i) Air deployed autonomous vehicles
ii) Nowcast/Forecast Ecosystem Models
iii) Operational Hyperspectral Satellites

What is the fate (sequestration versus transport versus air-sea flux) of carbon/nutrients in the coastal ocean over inter-annual scales?

Example: Is the coastal ocean a net source or sink for atmospheric carbon? Are there anthropogenic impacts (human pathogens, eutrophication, climate change, hypoxia/anoxia and land use) on coastal biogeochemical cycles? What is the role of the benthic boundary layer on coastal ocean biogeochemistry?

COMPONENTS: Radars, REAL-TIME Moorings & Fixed Platforms (vel, T, S, P, Fl, AOPs(I), IOP(I), Nutrients, wet-dry deposition), AUVs flying standard lines with the capability of adjusting the flight missions, Satellites, Data Assimilation Ocean Models, Sensor web Technology (Trigger for Adaptive samplings), MET sensors (fixed platform & buoys), Bottom Stress Measurements, Benthic Flux Measurements

What must be developed?
i) chemical sensors
ii) remotely sensed salinity for coastal waters
iv) Benthic probes and chambers
v) Servicing Boats should Occupy Standard Lines and Deploy Benthic Chambers

Few Years
i) Ocean forecast/nowcast
ii) Particle Imaging
iii) Improved Acoustics
iv) Airborne Sensors and the UAVs
v) Long-lived Dissolved Gas Probes for Gliders & AUVs
vi) Benthic probes

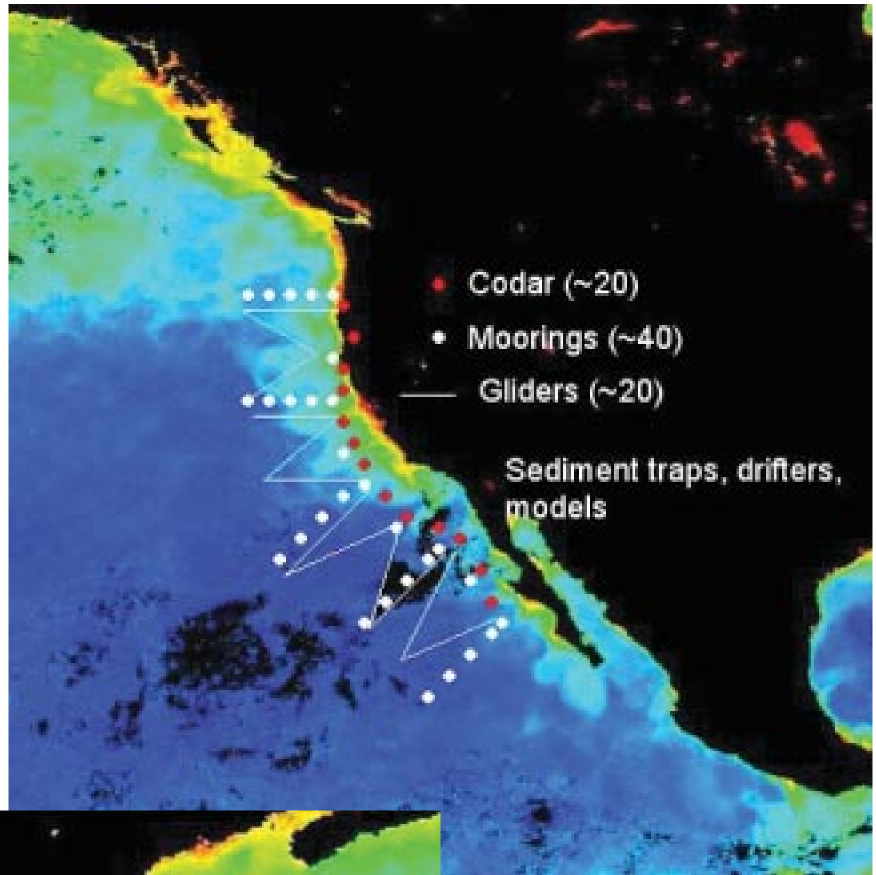
Decade
i) Coupled Biogeochemical Models
ii) Flux measurement technology for benthos

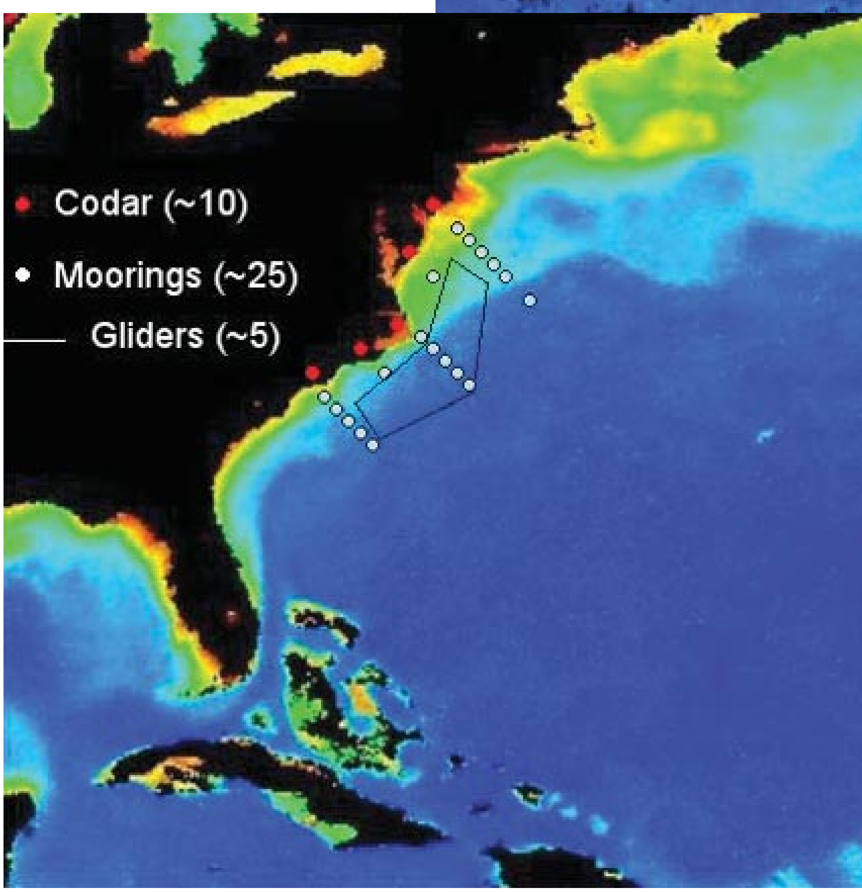
Working Group 3 - *Larry Atkinson (OC), Harvey Bootsma, Francisco Chavez (OC), John Cullen (CC1), Tommy Dickey (CC2), Charlie Eriksen, Miguel Goni, George Jackson (CC1), Björn Kjerve, Mike Kosro (CC2), Willard Moore, Mike Roman, Doug Williams*

Theme: Local vs. Large-Scale Forcing

Generic Hypothesis : The structure and productivity of coastal ocean ecosystems is driven by transport/mixing/ sedimentation) of mass, organisms, sediments and nutrients. The transports/mixing/ sedimentation are regulated by local as well as remote forcing and these forcing functions vary over time (days to decades) and space (1 to 1000 km) scales.

Example 1: What is the relationship between large-scale forcing & HABs (Windows of opportunity)





Processes:

ENSO circulation effects

propagating signals vs. local forcing (coastal trapped waves vs. local wind)

example - pseudonitzia: generated off Pt Conception; transported by PUC to north)?

other shifts in populations farther north

modulation of mesoscale & submesoscale? (squirts/jets)

changes in nitrate/depth relationship: shifts in stratification, light penetration (to useful depths)

spatial/temp effects on nutrients & organism distributions

Processes, cont.:

propagation of conditions vs. propagation/transport of individuals

physical (strat/transport), chemical structure (nuts)

trophic dynamics

runoff, groundwater

limiting nutrients (iron, silica, nitrate)

Variables

mets

physical: T, S, u,v,w?

nuts (N, Si DON[?])

spectral light (AOP, IOP)

Chl (fluorometers)

zooplankton by size, species

aggregation problems for moorings

variables	now	3-5 years	5-10 years
mets: wind	O		
T, S, p	O		
u, v w	O R	R	?
nutrients, nitrate, silicate, phosphate	P	O	
spectral optics AOP IOP	O P	O	
Chl fl	O		

Unique observations (before/during/after)

species level

demoic acids

sediment traps (w/ optical sensors):

optics – species flow thru spectrophotometer

profiling capability plus instrumentation (e.g. to detect thin layers)

sediment resuspension

runoff

iron, silica, nitrates

Variables	now	3-5 years	5-10 years
key species microscopy DNA on a chip	O R	O	
demoic acid HPLC automated	O R	-	-
sediment traps w/optics/settling rate	O P	O	
water samplers w/ preservation for spp., chemistry	P	O	O
ocean color drifters			
telemetry (adaptive sampling)	O, P, R		
spectral flowthrough photometer	R	P	O
multiwavelength optics	O	O	O
profiling (thin layers)	P	O	O
tripods/sediments and Fe	P	O	O
underwater mass spectrometry	R		
FRRF active fluorescence	R	O	O
flow cytometry, flow cam, capillary spectrum			

THEME: Ecosystem Dynamics

Topics considered:

recruitment

HABs

interannual variability

episodic events (hurricanes e.g.)

forcing

nutrients

species variability

structure of system

mixing, transport, settling & transformations (advection)

benthic processes

Example 2: What controls recruitment success of menhaden on east coast of U.S.?

Hypotheses: anthropogenic vs. climate driven variability

Processes:
food availability (feed on zooplankton (early,offshore) then on phytoplankton (later, inshore/estuaries)). Factors affecting include

nutrient supply/upwelling; bottom. runoff

transport; mixing

buoyancy/stratification

meteorological forcing/episodic storms (frequency/ intensity)

spawning biomass

match/mismatch hypothesis for timing of spawning (optimal conditions)

spatial variations in productivity and zooplankton do/don't match distribution of spawning

Sampling considerations:

Variables required for problem

Distributions in time and space

Why are observatories needed?

To span the important time and space scales

Tools:

moorings (10-100)

altimetry/extrapolation to depth with models

Codar/extrapolation to depth with models

offshore platforms

gliders (~5): 250m resolution at 40m depth; 0.5km at 55m depth): 1 month at 0.25 m/s

AUV? With advances, 150km range.

adaptive sampling

stream gauges

tide gauges

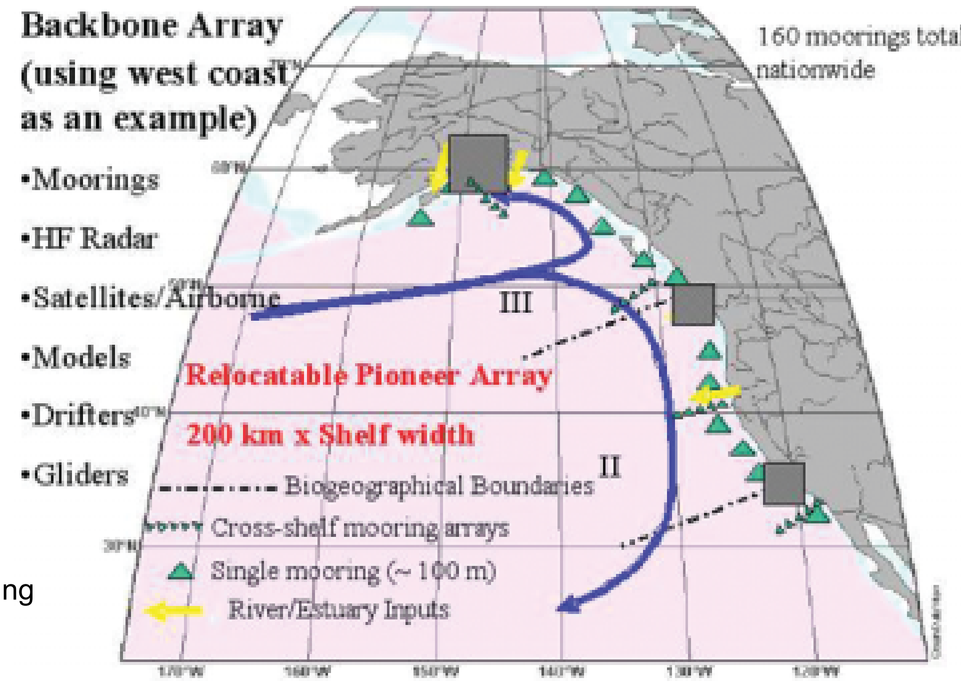
remote sensing (surface)

models/data assimilation/observational sampling system experiments

variables	now	3-5 years	5-10 years
mets: wind	O		
T, S, p	O		
u, v w	O R	 R	 ?
nutrients, nitrate, silicate, phosphate	P	O	
spectral optics AOP IOP	 O P	 O	
Chl fl	O		
zooplankton (acoustics) multifrequency, TAPS ADCP, imaging laser holography OPC	P O R/P R O/P	 O P/O	 O
fish (surveys?) eggs/acoustics adults/sidescan ROV/AUV?	 O P/O R		

Working Group 4 - *Jack Barth (OC), Emmanuel Boss, Teresa Chereskin (CC2), Paul DiGiacomo, Madilyn Fletcher, Ross Heath, Rick Jahnke (OC), Raphael Kudela, George Luther (CC1), Joseph Montoya, Dave Musgrave (CC2), Jamie Pringle, Andy Shepard, George Voulgaris, Clinton Winant (CC1)*

Designing One OOS
The Pioneer Array: Intensive Regional Studies
Sediment Transport



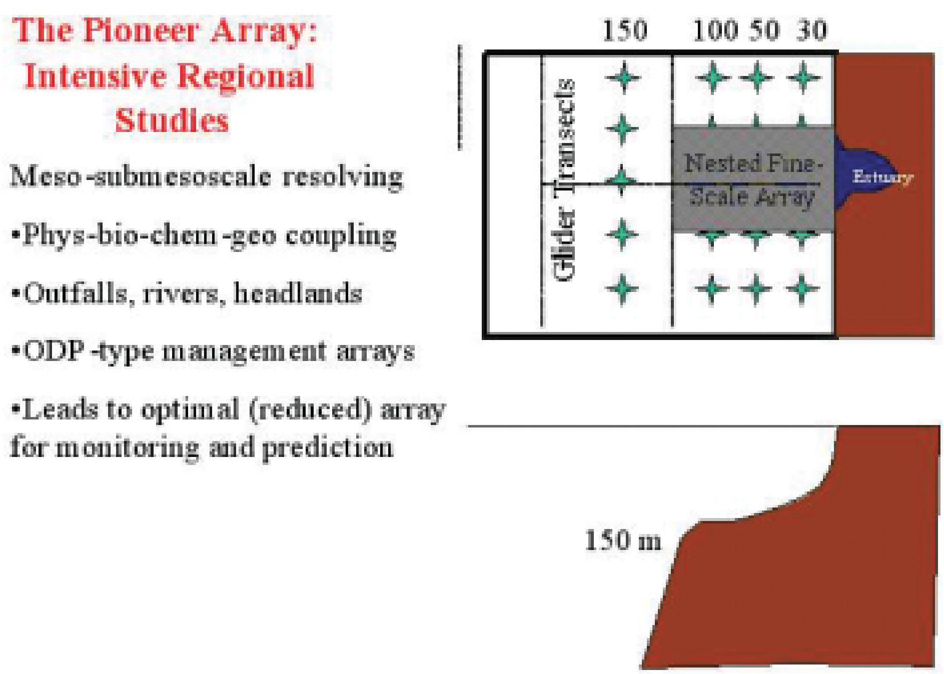
What are impacts of strong episodic storms on: sediment transport, resuspension, blooms, biogeochemistry, stratification, benthic mixing?

Examples

a) Estuaries as source of sediments: pulses during floods and hurricanes
b) Storm events
c) Turbidity flows

Parameters:

"Wind (stress)" (met obs), T, S, Velocity (3-D), light transmission, particle size, nitrate, phosphate, oxygen, sulfide



Platforms:

a) Application of parameters, sensors and platforms are regionally dependent
b) Remotely-based AUV for adaptive sampling of spatial variability
c) Profiling Moorings: Triggering
  1)Optical sensors
  2) Met package
d) sensor webs (arrays of moorings, AUVs, etc.)
e) Existing Platforms (derelict oil rigs)

Develop:

a) Platform technology for adaptive sampling
  1)New AUV technology
b) Power and data transmission capabilities
c) Discrete sampling capability for chemistry
d) New chemistry for real-time measurements

Beach Erosion

Hypothesis: Beach erosion responds to the surface wave field acting on beach morphology: episodic as well as gradual

Examples:
a) Barrier Islands, spits
b) Catastrophic cliff failure
c) Sea-level rise will affect above

Parameters:
a) Wave Climate (height, direction, met. obs.)
b) Length scales
c) SAR, ocean color, LIDAR, scatterometer

Required Issues (address with models)
a) Interaction with inlets and channels
b) Wave-current interaction

Platforms:
a) Shore stations: tide gauges/sea level, met obs
b) Drifters
c) Models
d) Satellites or airborne
e) DUCK crabwalker

Develop:
a) SAR (high res winds)
b) Scatterometer (improve near coast)
c) LIDAR-based for remote mapping

Population Dynamics

Hypothesis: Circulation, habitat and behavior determine biogeographical boundaries

Examples:
a) Life cycle of Dungeness crab in CA
b) Blueclaw crab on East coast
c) Salmon covariability between Alaska and West Coast

Parameters:
T, S, V, species abundance and distribution, met obs, nutrients, primary production, secondary production, IOP, AOP, sound, habitat

Tools:
a) Acoustic measurements of zooplankton (operational)
b) Passive acoustics (operational)
c) Acoustic sensing of fish (eg, salmon: beta)
d) LIDAR (beta-operational)
e) Egg counter (CUFES, operational)
f) OPC operational
g) VPR (operational)
h) CPR (operational)
i) Molecular fingerprinting (beta)
j) Discrete Samplers (operational)
k) Flow cytometry (beta)
l) Imaging cytometry (beta)
m) Seabeam (operational)
n) Hyperspectral ocean color (beta-operational)
o) Models (coupled physical-ecosystem models: all over)
p) CTD
q) HF Radar

Platforms:
a) VOS
b) Moorings
c) Research vessels
d) Satellites/Airborne (including geostationary)
e) HF Radar
f) Gliders/AUVs
g) GPS towers

Develop:
a) Gliders/AUVs
b) Molecular-based identification
c) General: Counting techniques
d) Automated measurements of productivity
e) Low-light video
f) Appropriate anti-fouling

Transport Pathways

Hypothesis: Sub-mesoscale (fronts, internal waves, eddies) determine the fate and transport of natural and anthropogenic substances.

Examples:
a) Sewage plumes
b) HAB

c) Blooms at fronts
d) Non-point source runoff
e) Pathogen distribution

Parameters:
V (Lagrangian & Eulerian), organic contaminants, bacteria, viruses, nutrients, T,S, trace elements, pollutants (generic), tracers, bioactive compounds, CDOM, ocean color, winds, met obs.

Tools:
a) Moored mass spectrometers (incipient)
b) Raman spectrometers (incipient)
c) Voltametry (beta)
d) In situ HPLC (5-years)
e) Diode Array UV (beta)
f) Nutrient sensors (beta)
g) CTD
h) DNA micro-arrays (beta)
i) Flow cyctometry (beta)
j) Salinity mappers

Platforms:
a) Drifters
b) AUV/Gliders
c) Moorings
d) Towed UV
e) Ships
f) Satellite/Airborne

Develop:
a) High bandwidth data transfer & power
b) HPLC
c) Low-cost constant constant density floats
d) SAR along-track interferometry
e) Appropriate anti-fouling agents

Appendix F: The Proudman Oceanographic Laboratory Coastal Observatory

John Howarth, Philip John Knight and Andy Lane

The Proudman Oceanographic Laboratory is starting to implement a Coastal Observatory in Liverpool Bay to integrate (near) real-time measurements with coupled models into a pre-operational coastal prediction system whose results will be displayed on the web. The concept is founded on obtaining data in (near) real-time, using telemetry, from underwater to the sea surface to land to POL to a web site, and applying developments already used to telemeter tide gauge data from the South Atlantic. The Observatory will grow and evolve as resources and technology allow, all the while building up long time series. The aim is to understand a coastal sea's response to natural forcing and to the consequences of human activity. The foci are the impacts of storms, variations in river discharge (especially the Mersey), seasonality, the effect of nutrients discharged into Liverpool Bay and blooms.

Figure 1 (above). CEFAS SMART Buoy recovery. http://www.cefas.co.uk/monitoring

Instrument/sensor	Measurement	Derived Variable
CTD	conductivity, temperature, pressure	salinity, density (kg m^{-3}), depth (m)
Fluorometer (blue LED)	chlorophyll fluorescence	phytoplankton biomass (mg chl m^{-3})
Optical backscatter	turbidity	suspended particle load (mg l^{-1})
Quantum irradiance (at 1 and 2 m depth)	downwelling photosynthetically active radiation k, vertical extinction (400 - 700 nm) coefficient	E_d (light available for phytoplankton growth at depth d)
Dissolved oxygen	oxygen concentration	oxygen concentration (mg l^{-3})
In situ NO_3 analyzer (NAS2-E)	NO_3 conc. (μM)	nutrient uptake rate
Aqua Monitor (automated water sampler collecting up to 500 x 200 cc samples)	samples preserved and stored for subsequent laboratory analyses	phytoplankton numbers and species composition, nitrate and silicate concentrations
Eco-System Monitor (ESM-2)	multichannel programmable logger incorporating CTD controls satellite (ORBCOMM) telemetry	

Although POL will be providing its backbone, both for measurements and modelling, partners are essential if the Observatory is to meet its full potential both in terms of its capability and of applications. Already the Environment Agency, the Met Office and CEFAS are involved (plans are being finalised to deploy the CEFAS SMART Buoy in 2002 to measure surface properties including nutrients and chlorophyll).

Other measurements will include: In situ time series of current, temperature and salinity profiles and of waves and weather: pilot in 2002, operational 2003; with a second site and measurements of turbidity and chlorophyll eventually planned; shore-based HF radar measuring waves and surface currents out to a range of 50 km, starting in 2003; instrumented ferries for near surface temperature, salinity, turbidity, chlorophyll and later nutrients. The first route will be Liverpool to Douglas, with pilot measurements in 2002.

Tide gauges, with sensors for met, waves, temperature and salinity, where appropriate;

drifters, measuring surface currents and properties such as temperature and salinity, will start in 2004. satellite data - infra-red (for sea surface temperature) and visible (for chlorophyll and suspended sediment) are also planned.

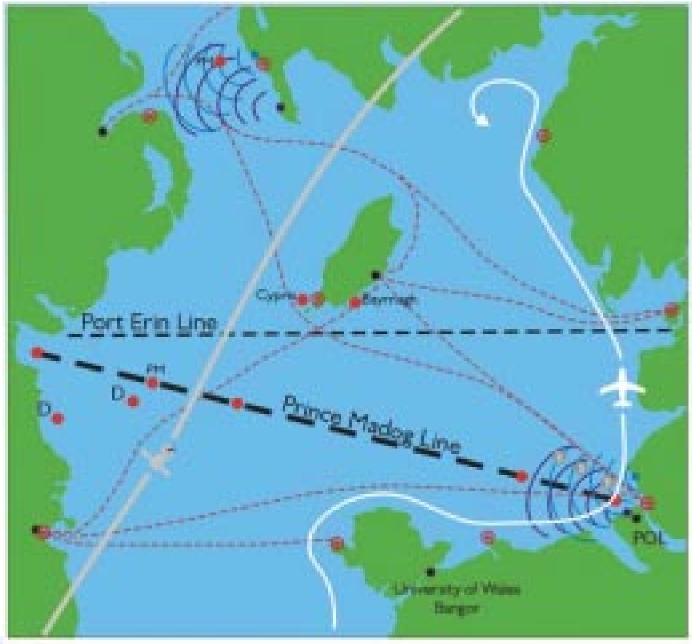


Fig. 2 (left) Coastal Observatory from the Eastern Irish Sea to Liverpool Bay.

The Coastal Observatory will use POLCOMS (the Proudman Oceanographic Laboratory Coastal Ocean Modelling System, shown below). Nested 3-dimensional models covering the ocean/shelf of northwest Europe (12km resolution), Irish Sea (1km) will focus on Liverpool Bay (100-30m resolution). The Met Office implementation of POLCOMS on the ocean/shelf domain, forced with NWP mesoscale model meteorology and FOAM (Forecast Ocean Atmosphere Model) data along the ocean boundaries, provides the boundary conditions for the Irish Sea model, which in turn provides boundary conditions for the Liverpool Bay model. Local river discharges will be included through a link-up to the Environment Agency river-flow network. The suite of models is planned to run daily in near-real time. All results (e.g. daily mean sea surface and sea bed temperature, currents, waves and sea surface height) will be displayed on the Coastal Observatory web-site: http://www.pol.ac.uk.

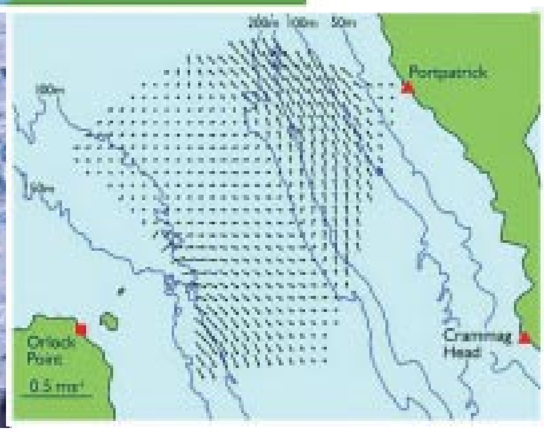
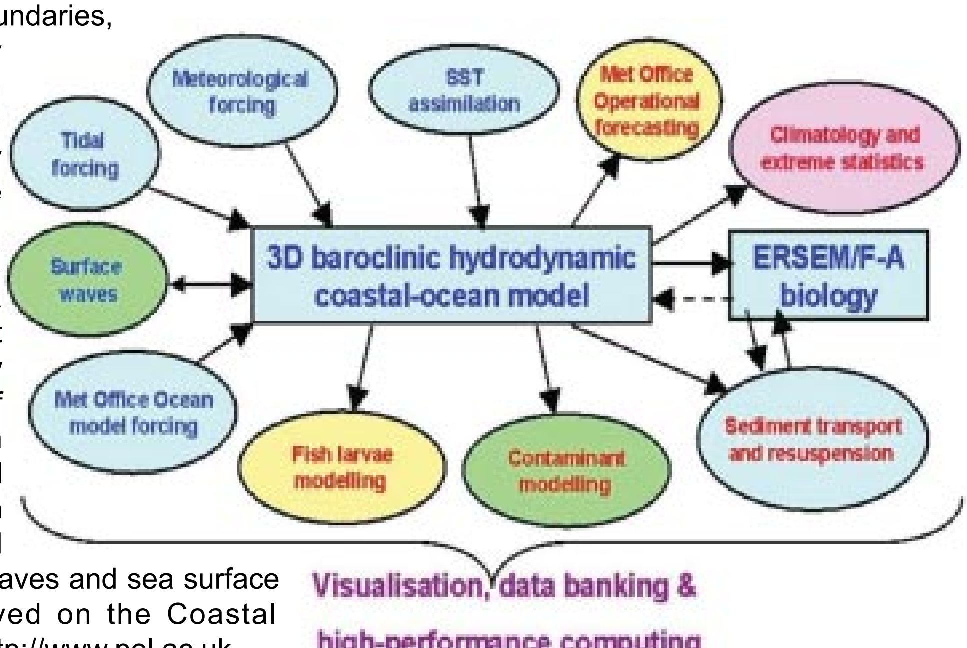


Fig. 3a (above left) ADCP recovery. Fig. 3b (above right) mean current in North Channel measured by HF radar.



Appendix G: A Status Report on Seagliders

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1. Introduction

Small glider vehicles for oceanographic research are currently under development and have recently started to operate experimentally. We are aware of three groups developing such vehicles, all in the U.S. The vehicles they have produced share many features but differ in detail in how they operate (see Davis et al. 2002). They are all small enough to be handled manually without mechanical assistance, use buoyancy to power themselves, communicate data and commands at the sea surface, and have ranges and mission durations that far exceed those of conventional propellor-driven autonomous underwater vehicles.

Pictures of Spray (Scripps Institution of Oceanography and Woods Hole Oceanographic Institution), Slocum (Webb Research Corporation), and Seaglider (University of Washington) are given in Figure 1. Because the request to give a talk at this workshop was made at dinner the night before it was presented, attention was restricted to Seaglider, especially because it was in the midst of its first offshore operation.

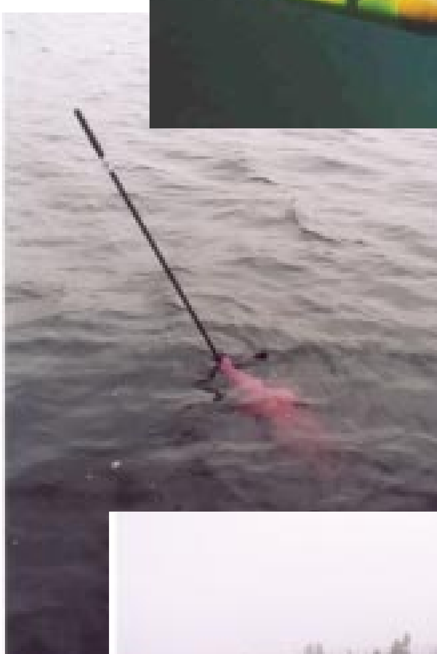

Figure 1. Photographs of Spray (top) being loaded aboard a small boat; Slocum (middle), battery and thermal powered versions; and Seaglider (lower two) being prepared for launch from a rigid inflatable boat and at the sea surface with Iridium/GPS antenna positioned for communication and navigation.

2. Seaglider Description

Seagliders are small, reusable autonomous underwater vehicles (AUVs) designed to glide from the ocean surface to as deep as 1000 m and back while collecting profiles of temperature and salinity (Eriksen et al. 2001). They use a low drag hydrodynamic design to allow them to profile over 2000 km vertically while travelling as much as 6000 km horizontally over many months. Typical horizontal speed is ~0.25 m s^{-1}. Seagliders are commanded remotely and report their measurements in near real time via Iridium satellite telephone. They use GPS navigation at the sea surface to dead reckon toward commanded targets by assimilation with a Kalman filter. Navigation and knowledge of vehicle buoyancy and pitch angle allow estimation of depth-averaged current and suitably energetic vertical velocity fluctuation.

A Seaglider consists of a pressure hull enclosed by a fiberglass fairing to which wings, rudders, and a trailing antenna are attached. Energy use, cost, reliability, and ease of operation guided the design. A low drag shape provided by the fairing combined with a pressure hull that is nearly neutrally compressible in seawater allows predicted ranges comparable to ocean basin dimensions. Propulsion is by buoyancy control in combination with hydrodynamic lift and drag. In contrast to aerodynamic gliders, Seagliders glide both as they dive and as they climb by adjusting their volume to be either slightly smaller or larger than what would make them neutrally buoyant. Attitude control is accomplished by moving mass within the vehicle, obviating the need for active external control surfaces and their inherent complexity.

To keep the cost modest and allow it to be launched and recovered from small boats, the vehicle size was chosen to be just big enough to carry the constituent parts, namely a buoyancy control system centered on a small high pressure pump and the batteries and electronics to run the vehicle. The Seaglider fairing is 1.8m long, its wings span 1 m, and the antenna mast is 1.4 m long. The vehicles weigh 52 kg so they are easily carried by two people. Seagliders use a Seabird CTD to measure temperature and salinity. They also carry a Seabird dissolved oxygen sensor and a Wetlabs chlorophyll fluorometer and optical backscatter sensor. Seagliders use the difference between dead-reckoned and actual displacements to estimate depth-averaged current. By taking two GPS fixes bracketing communications activity when on the sea surface, an estimate of surface current is also obtained.

Glider range depends principally on how fast it is operated, the stratification of the water through which it glides, the depth of dive cycles and the slope of its sawtooth path. In the tropics or in regions of buoyant plumes, about half the buoyancy range is devoted simply to transiting stratification and the rest to thrust. Since the Seaglider buoyancy engine requires less than twice as much power to operate at 1000 m depth as at the surface, dives to shallow depths (e.g. over the continental shelf) are several times less efficient than dives to 1 km depth, thus limiting missions to perhaps several weeks instead of many months.

3. Seaglider Offshore Experience

Field experience with Seagliders includes several missions of several hundred of dive cycles each, including multi-vehicle operations. Until March 2002, these have been in coastal or fjord environments because of reliance on cellular telephone data telemetry. Recently, Iridium satellite telemetry has been incorporated into Seagliders, making possible open ocean operation. The Iridium network survived bankruptcy to win a US government long-term contract paying nearly half their operating costs, hence likely economic survival. Data transmission costs are about 200 times less than those for ARGOS, while speed is about 100,000 times faster and bidirectional.

The first offshore Seaglider operations took place April 18 - May 16, 2002 off the Washington coast. Seaglider #005 was deployed from a 14-ft RIB vessel 2 nautical miles off Neah Bay, WA, in the Strait of Juan de Fuca and recovered four weeks later from a chartered fishing vessel ~65 miles from Grays Harbor, WA, 9 days after a problem with the glider buoyancy engine was detected

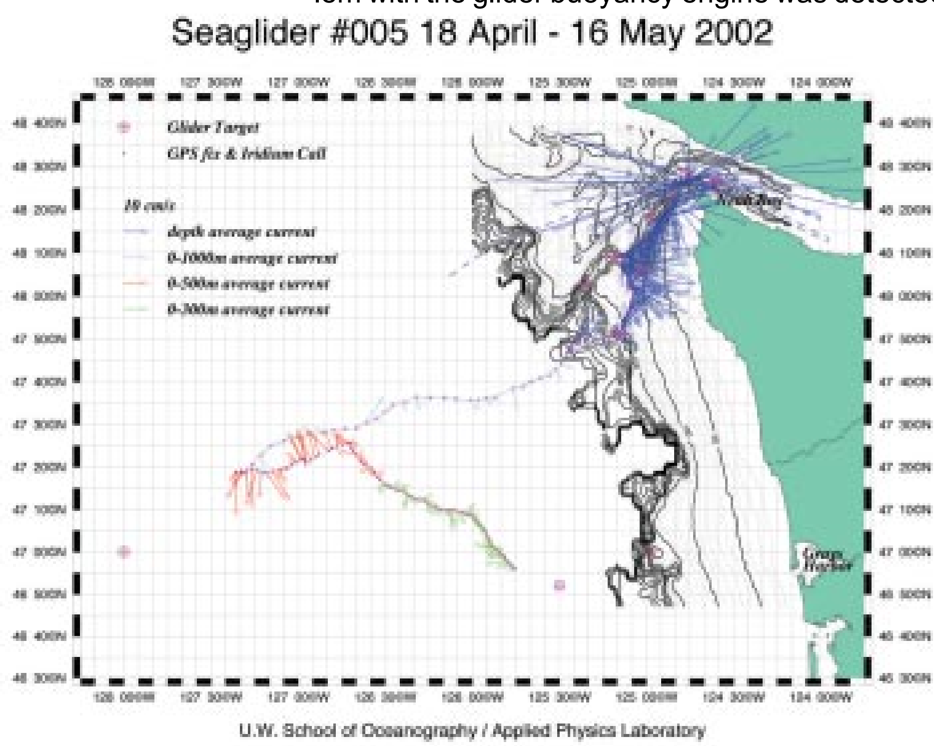

Figure 2. Seaglider track from Neah Bay, near the mouth of the Strait of Juan de Fuca, off the Washington coast 120 nautical miles. Arrows indicate currents inferred from glider navigation. The bathymetry map shown is carried by the glider to determine dive depth.

while it was 120 miles offshore diving to 1000 m depth (Fig. 2). (The author detected the problem while attending this workshop by analyzing glider data downloaded via the hotel room telephone).

Typical horizontal glider speeds were 0.25 m s^{-1} so that depth averaged currents of comparable magnitude limited its ability to follow arbitrary courses. Currents associated with a persistent eddy on the continental shelf near 48°10'N, 125°10'W, for example, prevented the glider from following a course down the Juan de Fuca canyon. Instead, the glider was sent south to the edge of the continental shelf where it was then directed down the continental slope and offshore toward 47°N, 128°W. The dramatic offshore decrease in tidal velocities demonstrates that the main impediment to glider navigation on the outer continental shelf is flow associated with mean and eddy currents.

After about 30 dives to 1000 m depth, a slow pressure-dependent internal leak in the hydraulic system controlling buoyancy developed, causing the glider to appear ever less buoyant on successive dives. The glider was commanded to head toward Grays Harbor for recovery and to dive only to 500 m depth in an attempt to slow the loss of buoyancy. This strategy worked for about 6 days until more buoyancy loss was detected, after which dives were shortened to 300 m depth. Despite the stronger average currents over these shallower depth ranges, the glider was able to transit close enough to the coast to arrange for recovery during reasonable weather and sea conditions in a day trip aboard a chartered fishing vessel. Post mission examination revealed a slow leak in a fitting in the high pressure portion of the hydraulic system.

Roughly a quarter of the glider's battery pack was expended in the 230 dives in the first 10 days of the mission crossing the continental shelf with dives as shallow as 40 m. Energy expenditure in the deep dives confirmed that 6 month missions at 0.25 m s^{-1} speed should be attainable with 1000 m deep dives. Instead of launching very close to shore, several month glider missions will require launch and recovery near the continental shelf break. Fortunately, such operations can be carried out by small vessels on day trips from port. Glider recovery on this mission required 11 minutes after searching visually for a comparable time, aided by frequently updated GPS glider positions relayed from shore by satellite telephone.

Glider data telemetry rates over Iridium were typically ~180 bytes s^{-1} with from 5-40 kilobytes transferred on each dive cycle at energy and monetary costs of ~30J and ~$0.12 per kilobyte, respectively.

Seaglider #005 collected profiles of temperature, salinity, dissolved oxygen, chlorophyll fluorescence, and optical backscatter at two wavelengths as it flew along a roughly 1:2.5 glide slope in this mission (Fig. 3). The glide slope resulted in horizontal resolution of roughly 5 km in dives to 1 km depth taking roughly 6 hr to complete and proportionately finer resolution for shallower dives. Sections of temperature, salinity, and dissolved oxygen show the expected gentle downward offshore tilt associated with equatorward geostrophic shear for all but the shallowest layers. Very close to the surface, the sense of geostrophic shear was poleward, a result of the fresher water over the shelf. Salinity and particularly temperature and oxygen show much more variability than density, indicating intrusive structure throughout the upper ocean. The nearly anoxic oxygen minimum is seen at ~850 m depth. The fluorescence signal is confined to the upper 50 m, but optical backscatter signals are evident to at least 500 m depth over the continental slope. Depth average flow over the continental slope reveals a ~12 km wide poleward current of 0.10-0.15 m s^{-1}, yet the density field shows little indication of geostrophic shear in its vicinity (roughly over bottom depths 500-800 m), indicating a largely barotropic transport of ~1 Sverdrup.

References

Eriksen, C. C., T. J. Osse, R. D. Light, T. Wen, T. W. Lehman, P. L. Sabin, J. W. Ballard, and A. M. Chiodi (2001) Seaglider: a long range autonomous underwater vehicle for oceanographic research. I.E.E.E. Journal of Oceanic Engineering, 26, 424-436.

Davis, R. E., C. C. Eriksen, and C. P. Jones (2002) Autonomous buoyancy-driven underwater gliders. In: The Technology and Applications of Autonomous Underwater Vehicles, G. Griffiths, ed., Taylor and Francis, London, in press.

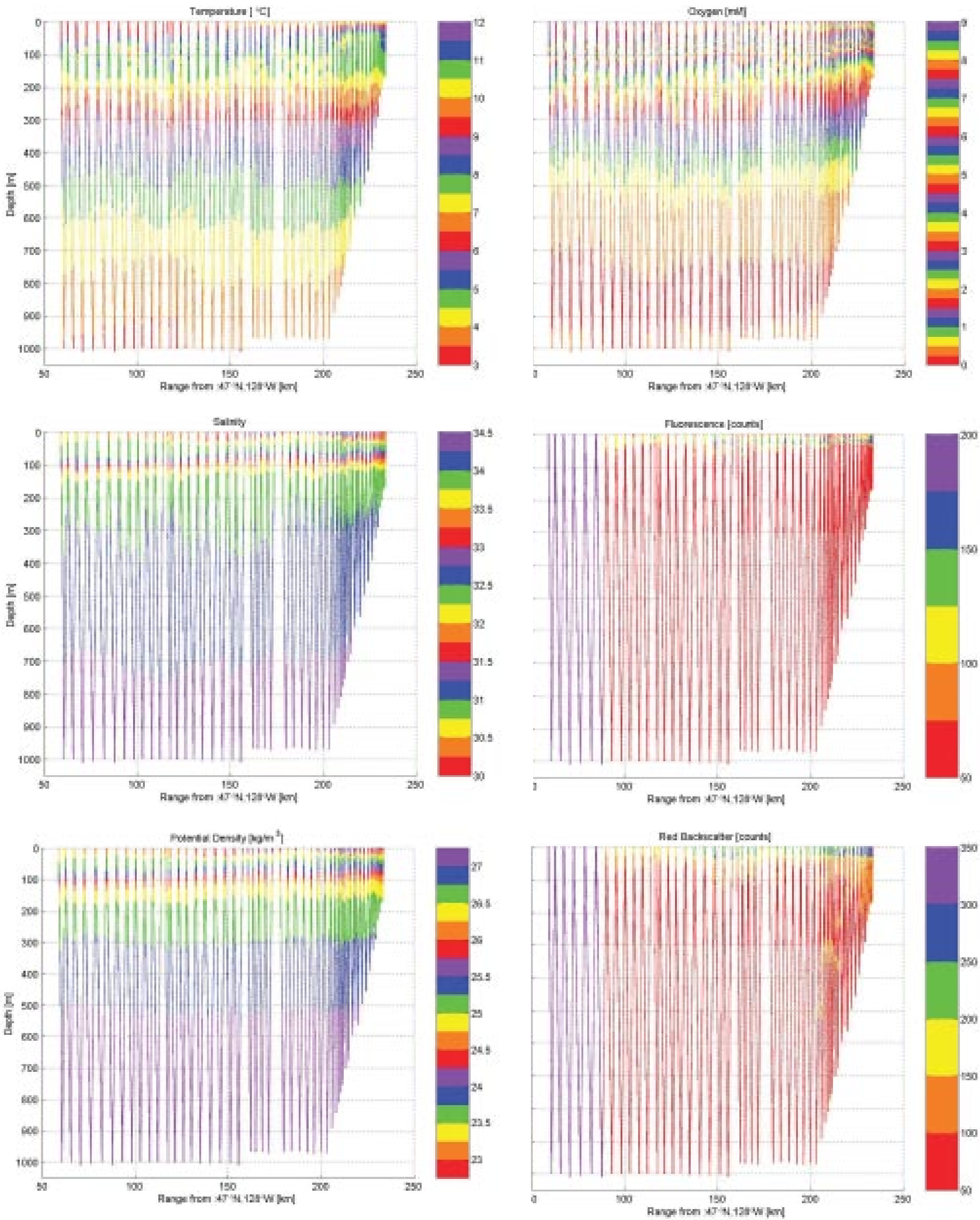

Figure 3. Seaglider depth - offshore distance tracks made 27 April - 7 May 2002 colored by (upper left) temperature [℃]; (middle left) salinity; (lower left) potential density [kg m^{-3}]; (upper right) dissolved oxygen [ml l^{-1}]; (middle right) chlorophyll fluorescence [counts]; and (lower right) red optical backscatter [counts]. Data are raw, uncalibrated, and uncorrected for glider speed, as sent via Iridium. Vertical resolution is ~0.75 m for depths < 50 m, ~1.5 m for depths 50-300 m, and ~3 m for depths > 300 m. The optical sensor cable flooded 6 dives from the end of the section.