Oceans, Climate and Biogeochemical Cycling

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Background

The working group in its first meeting reviewed the overview presented earlier on the first day of the workshop. It was clear that a number of additional ideas and issues had been explored and expressed in the newly available Report of the NEPTUNE Pacific Northwest Workshop held in Portland, OR 23-24 April 2003. These were reviewed by the members. On the second day the working group met after a brief plenary and decided to organize its report under the following headings:

- Priority Science themes
- Key Issues
- Science Questions
- Experiments and Data
- Location
- Sensors (Core, Community, PI)
- Additional Sites and Rationale
- Synergies
- Recommendations

Priority Science Themes

A regional cabled ocean observatory offers new opportunities to detect oceanic variability from subtidal to interdecadal time scales, and to observe both long term changes and establish a 'mean' picture of the regional role in the ocean carbon cycle. The northeast Pacific region provides several distinct bathymetry roughness environments for observation and determination of the role of ocean margins in vertical mixing and exchange of heat and other properties over ocean basins. A cabled observing system also offers great potential for realtime adaptive sampling, a currently emerging methodology.

To exploit these opportunities in a scientifically exciting and productive manner, the working group developed the following priority themes to guide detailing planning:

1. Observe the regional oceanic response to external forcing from subtidal to interdecadal time scales: Determine the regional climate change fingerprint.
2. Quantify the contribution of the region to the global carbon cycle: Are ocean continental boundary systems a source or sink of atmospheric carbon?
3. Determine the role of regional features and processes in physical transports and biogeochemical cycles.

Key Issues

Common with the other two 'water column' working group, we felt that:

- Mooring platforms extending basic power/communications capability into the water column must be part of the basic/core infrastructure from the start.

It also became clear that for a cabled regional observatory to realize its full potential, there must be a related coordinated activity for:

- Ongoing development of sensors.

Science Questions

Theme 1. Regional response to external forcing (climate, tectonics, terrestrial inputs)

- How does ENSO variability affect the physical and biogeochemical structure of the thermo- and nutricline?
- How does methane hydrate flux (stability?) respond to climate and seismic forcing? [our domain??]
- How does ocean productivity respond to variations in the hydrological (rivers, precip) cycle?
- How does the regional exchange of carbon (CO_2, CH_4) with the atmosphere and the seafloor change with these external forcings?
- What physical mechanisms determine the structure of the regional current system?
- How do these physical mechanisms change as a result of the external forcings?
- How do these physical processes affect the biogeochemical cycles?

Theme 2. Role of regional features and processes in physical transports and biogeochemical cycles

- How do specific topographical features (e.g., smooth slope, rough slope, ridges and slope features, canyons), affect diapycnal mixing along the ocean margins and the transport of mixed waters from the boundaries to the ocean interior? (ref PNW Report) The (bottom) boundary mixing of the ocean likely plays a key role in the maintenance of the Abyssal stratification, so this line of research is of global importance.
- What is the relative contributions of various mesoscale processes (e.g., upwelling filaments, instabilities in the boundary current) on nutrient flux and ecosystem dynamics?
- What is the spatial and temporal variability of remineralization? And what controls it?

Theme 3. Determine the contribution of the region to the global biogeochemical (e.g., carbon, iron, …) cycles

- How are nutrients and carbon exchanged between the coastal margin and the oceanic interior?
- What is the contribution of eastern boundary current regions to the global carbon cycle?

Figure 1 illustrates schematically most of the processes operating in the water column along the boundary between the continental shelf and the ocean interior. (missing: atmospheric deposition of nitrogen and iron; bottom resuspension of chemical constituents and chemical transformations)

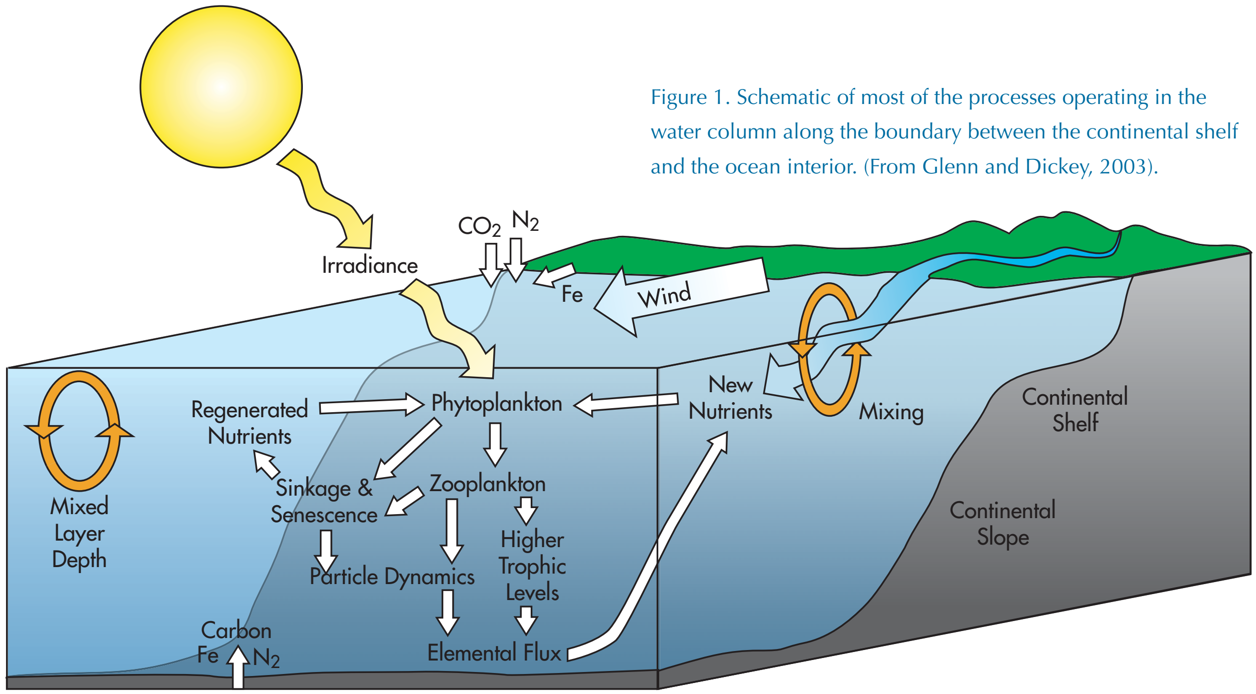


Figure 1. Schematic of most of the processes operating in the water column along the boundary between the continental shelf and the ocean interior. (From Glenn and Dickey, 2003).

Sampling Issues

A regional cabled ocean network provides a new opportunity to satisfy the following sampling requirements:

- Need to span 'event scales' to climatic trends, with spatial delineation of environmental forcing and biogeochemical signals. 'Events' include both episodes and regime shifts.
- Need to resolve mesoscale eddy spatial scale and episodic event scales in environmental forcing and biogeochemical signals.
- Need to capture time scales of climatic variation and change.
- Need to span shelf to deep-sea environments to determine synchronicity and exchange.

There is also the following requirement to realize the full potential of regional cabled networks:

- A need to measure exchange with upper and lower boundaries

The challenge of observing properties at the ocean surface (e.g. winds, waves, temperature, pCO_2, physical and chemical fluxes) has not been thoroughly explored in previous planning for regional cabled networks. It may be that initially separate surface moorings will be required, but a long term goal should be innovative development to obtain surface observations from a bottom-based cabled network.

Experiments & Data

The proposed experiments that could be conducted with a cabled regional ocean observatory fall into three main types:

- Regional scale sustained observations for climate
  - Determine the mean and varying budgets of heat, salt and biogeochemical variables in a 3D volume encompassing the continental shelf and extending to deep waters beyond the continental slope.
  - Provide a data set highly resolved in time and space over long enough time scales for constraining and evaluating coupled models.
- High resolution

- Topography/mixing experiments at five specific sites (red dots in Figure 2) – on a ridge crest, a transform fault, a steep continental slope, in a canyon and over severely rough topography on Gorda Plate – to estimate the contribution of each type of site to small scale mixing along oceanic margins.
- Carbon budget control volume
- Three East-West lines (red lines in Figure 2) of water column moorings (attached to the bottom nodes) from the shelf to the ridge, number of moorings (~5/line) TBD. The northern line follows the inner station positions along Line P. The middle line repeats the OSU Newport Line along 44° 39' N. The southern line is designed to cut through the flow separation south of Cape Blanco that carries shelf waters SW into deep water.

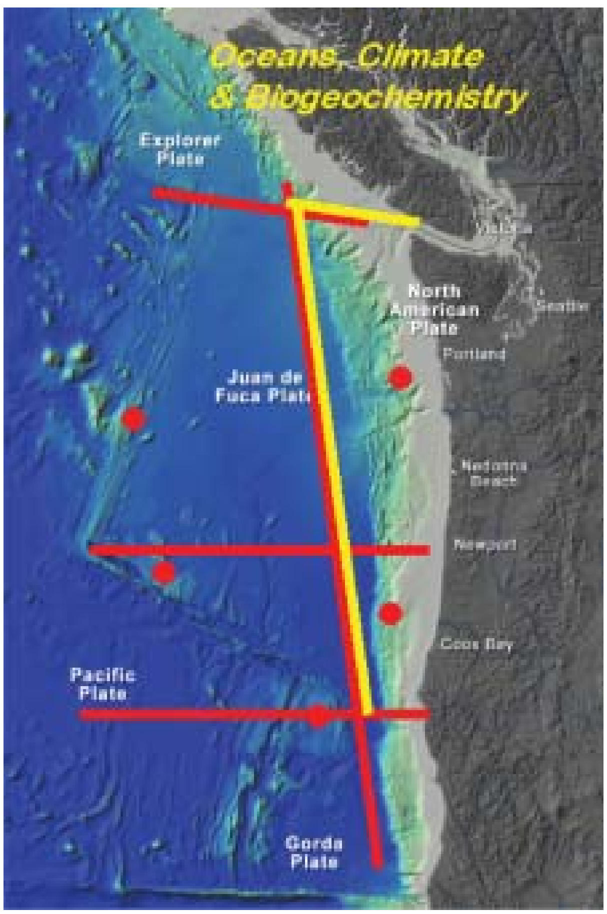


Figure 2. Map of Locations for Carbon budget and flow / topography.

- 1 North-South line of moorings offshore near the base of the continental slope, to close the control volume (yellow line in Figure 2).

Sensors – Core

The guiding philosophy used by the working group to identify sensors as 'Core' or part of the infrastructure is that they are:

- mature
- of broad interest across many users
- robust sensors (with long inherent life, low maintenance, stable/self calibration, minimal moving parts, resistance/insensitive to fouling)

The classes of sensors that the working group identified as 'core' include:

- broadband pressure
- temperature, salinity (conductivity),
- broadband acoustic hydrophones and transceivers (ambient sound, inverted echosounder, acoustic profiler/fish sonar, geodesy, navigation, and communications);
- electrometer (for barotropic velocity), acoustic Doppler current profiler,
- dissolved oxygen, nitrate
- pCO_2
- optical transmission and backscatter, fluorometer,
- Video imagery

Generally, we excluded high performance optical sensors from the 'core' group because of the fouling problems inherent in their use.

Sensors – Community

Sensors that the WG identified as 'Community' sensors include:

- Moored profilers with physical and biogeochemical sensors (velocity, T, C, pCO_2, DO, nitrate, spectral radiometers, etc..)
- Mobile platforms (auv, rovers, gliders, …) with above sensors
- Methane
- Optical and acoustic plankton counters/recorders
- Sediment traps
- Air-sea fluxes
- Sediment properties
- Physical *in situ* Sampling (sediment, water, biology, etc.) – remote control

Additional Sites and Rationale

Extensions

- NE Pacific

  There was broad interest in extending cables farther out into the N. Pacific to provide comparative and contrasting observations in the subtropical and subarctic domains. It may be that moored observatories are the most cost effective way to reach these sites, but there is an existing communications cable with a junction in the vicinity of Ocean Station P (50°N, 145°W). Certainly, the group felt that there was a great opportunity to link events and changes in the NE Pacific regional cabled observatory region with larger scale oceanic changes. Specifically, the group wants to monitor the physical gyres (sub-polar & sub-tropical) and their distinct biological domains, include PAPA and ALOHA (or UNCLE) to capture main environments affected by the Pacific Decadal Oscillation.

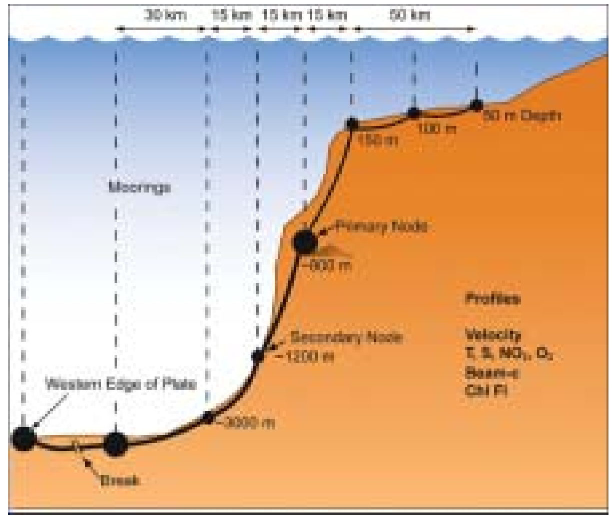


Figure 3. Sampling of the Eastern Boundary Current. (from Howe et al., 2003).

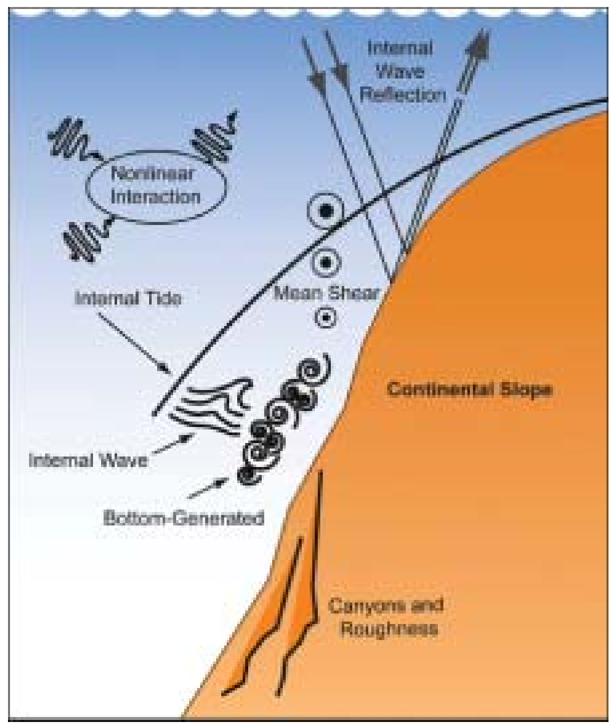
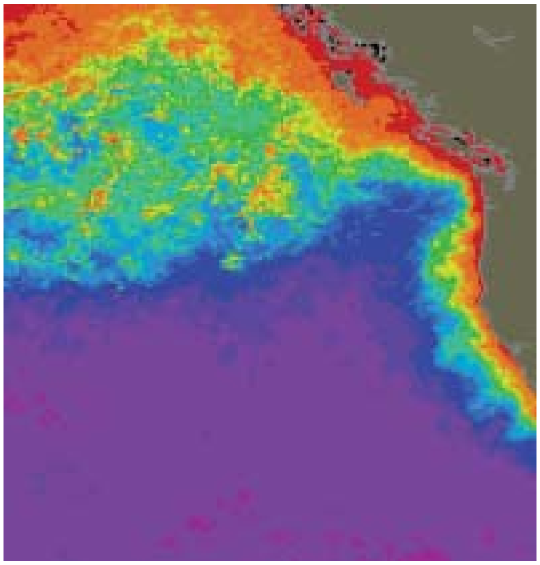


Figure 4. Sampling flow processes generated by rough bottom topography. (a) Flow over rough topography; (b) High resolution arrays to sample features generated by flow over rough topography. (from Howe et al, 2003).

July August September CZCS climatology



August 19, 2003 Observed SST from satellite

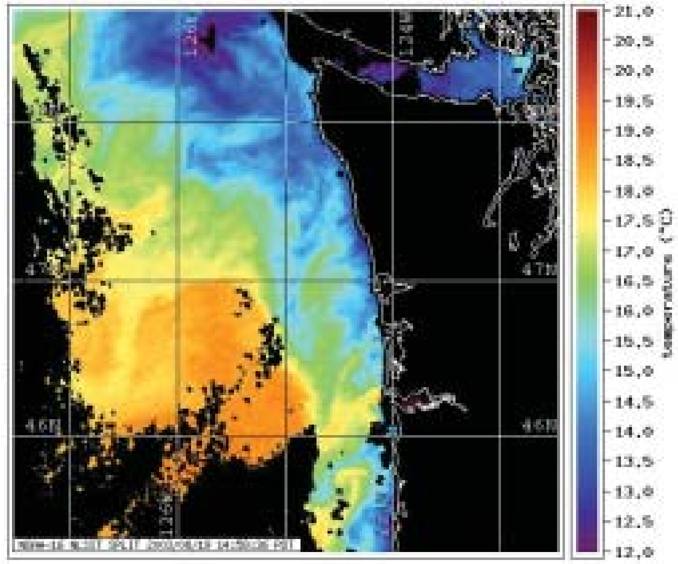


Figure 5. Satellite images showing the dynamic nature of the surface color (phytoplankton chlorophyll climatology) and temperature (instantaneous) in the Eastern Boundary Current upwelling regime in the NE Pacific.

New Sites

- Polar Regions
  The working group felt that climate change is expected to be felt first in polar regions. The working group felt that there are interesting challenges and opportunities in both the
  - Southern Ocean, and
  - Arctic—from pole to deep convection areas (e.g., Greenland Sea)

- Northwest Atlantic
  The northwest Atlantic offers opportunities to study several dynamic environments and also a strong contrast with the NE Pacific Eastern Boundary Current regime:
  - Compare and contrast Eastern Boundary Current region (northeast Pacific) with a Western Boundary Current region (Gulf Stream)
  - Narrow (northeast Pacific) versus broad shelves
  - Newfoundland basin a possibility – comparable geographic features—mixing/topography

Synergies

- Internal
  - Leading to predictive capabilities for fisheries
  - PACOS links (NOAA fisheries program to monitor the biophysics of the California Current for support of “ecosystem considerations” in fisheries management in the EEZ)
  - Ocean salinity (from space)
  - Carbon Cycle science
  - Real time forecasting for harmful algal blooms (HABs) and fisheries—‘in-season’ forecasts.

- External
  - “Global” buoys—North Pacific

Recommendations

- Mooring platforms extending basic power/communications capability into the water column must be part of the basic/core infrastructure from the start

- Must do trade-off studies prior to final array decisions – OSSEs (including high resolution regional ocean circulation models)
- Make sensors/instruments/platforms more robust and reliable
- Need meteorological forcing over the regional observatory on same time scales as the in water observations
- Need land runoff temporal information—for influence on stability and regional circulation patterns and for inputs of biogeochemical materials—dissolved and particulate forms of carbon and nutrients (N, P, Fe, etc.).

References

Glenn, S.M., and T.D. Dickey, eds., 2003, *SCOTS: Scientific Cabled Observatories for Time Series, NSF Ocean Observatories Initiative Workshop Report*, Portsmouth, VA., 80 pp. http://www.geoprose.com/projects/scots_rpt.html.

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