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Listed alphabetically by first author.
Asterisk(*) indicates invited speaker.

ALLARD, Richard[1], John Christiansen[2], Steve Williams[3] and Larry Jendro[4]

The Distributed Integrated Ocean Prediction System (DIOPS)

The Distributed Integrated Ocean Prediction System (DIOPS) is a wave, tide and surf prediction system designed to provide U.S. Navy and U.S. Joint Forces a capability to predict wave and surf conditions at any given location, worldwide. DIOPS contains a suite of wave, tide and surf models (WAM, REFDIF, STWAVE, PCTIDES and SURF3.0) which can be run in a nested fashion. DIOPS is designed to operate under an object-oriented framework and provides access to environmental inputs via the Tactical Environmental Data Server (TEDS). DIOPS will be installed at the Naval Pacific Meteorology and Oceanography Center in San Diego in Spring 2001, where a Beta-test site with an onboard scientist will be established for training and enhancements. Planned upgrades to the system include the addition of the shallow-water wave model SWAN, which is a full plane model (offshore and onshore winds and waves) that can be run in both time dependant and steady state modes.

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***APEL**, John R.[1]

From Pictures to Measurements: Four Decades of Ocean Remote Sensing

With the arrival of more-or-less continuous satellite data streams and fully vetted measurement capabilities, ocean remote measurement has gone from being confined to the province of specialists to finding its way into the toolkit of working oceanographers. While it has taken well over three decades to come about, data from a variety of sensors can currently give information of much interest across the spectrum of disciplines in our science, even to those concerned with the sea floor if acoustics is included as a remote sensing method. A review is given of some sensor outputs, both historic and current, and examples are presented of remote sensing contributions to the understanding of various processes and phenomena taking place in the sea. The historical imagery, especially, is such that the reluctance of an earlier generation of marine scientists to have much faith in it is perfectly understandable. However, today's data are so splendid that, when blended together with in situ observations and used in quantitative models, much new will be learned about the breadth and depth of the sea. One cannot help but feel excitement about the prospects.

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Satellite Algorithm to Derive Skin-Sea Surface Temperatures in the Canary Islands

The estimation of sea surface temperature (SST) from satellite is performed by means of multichannel algorithms with infrared channels from sensors ATSR-ERS and AVHRR-NOAA. Commonly, these algorithms express the SST as a linear combination of the satellite brightness temperatures in those channels with constant coefficients obtained empirically by means of statistical regressions of *in situ* and satellite surface temperatures. However, the atmospheric dependence of the split-window coefficients prevents the use of global algorithms in local studies. As a consequence, it is necessary to derive algorithms limited to areas of certain atmospheric conditions. Due to our interest in the Canary Islands Sea, we have determined an optimized regional algorithm for SST with a statistical method from simulated measurements with a radiative transfer code and a set of radiosoundings. We have added the angular dependence and a term that contains the marine aerosols correction into the final split-window equation. Results of application of this method and its intercomparison with algorithms from other authors are analyzed. We concluded that the model suggested here seems very appropriate for the determination of SST in the portion of the Atlantic Ocean around the Canary Islands.

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Seasonal Cycle of Bio-optics and Temperature of the Japan/East Sea

The seasonal cycle of the bio-optical properties and the sea surface temperature are described in the Japan/East Sea using SeaWIFS and AVHRR satellite imagery for 1998 – 2000. We show how this cycle is linked to the seasonal circulation of the basin. The spring bloom begins in the southern basin in March and propagates into the northern basin in late May. The spring bloom closely follows the sea surface warming in the basin with increasing solar insulation. A strong bloom (>1mg/m^3) is well defined at the Subpolar front in May which is characterized by a complex series of anticyclonic eddies. By summer (June), the basin has low chlorophyll levels (<0.1 mg/l) with elevated SST. A fall chlorophyll bloom occurs in Nov, begins in the northern basin (>1.0 mg/m^3), and moved into the southern basin by January. We observed a 2-week difference in the timing of the spring bloom in 1998 and 1999. We show how the chlorophyll distribution is associated with SST front locations and that the locations of biological and SST fronts are not always the same and they change seasonally in the basin. We further characterize the bio-optical distribution in the JES using SeaWIFS to estimate the backscattering (b_b550) (particle concentration) and absorption from dissolved organic matter (a_{dg}) in addition to chlorophyll concentration. These properties are used to trace biological water mass evolution in the basin using a 3 axis ternary plot. We show how the distribution of these properties during the spring bloom is coupled to the physical processes associated with the anticyclic eddies at the Subpolar front.

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BARBER, R.T.[1], R.C. Dugdale[2], F.P. Wilkerson[2], F. Chai[3], M. Jiang[3] and T-H. Peng[4]

Modeling the Ecosystem Responses and CO^2 Drawdown of Transient *In Situ* Iron-enrichment Experiments in the Equatorial Pacific Ocean

In situ iron-enrichment experiments in the Southern Ocean and the equatorial Pacific Ocean have shown that transient addition of very low concentrations of iron to high-nitrate, low-chlorophyll (HNLC) waters sets in motion changes in the productivity and growth of picoplankton, larger phytoplankton and the grazers of both of these groups. The logistic constraints of single-ship experiments have prevented these otherwise successful efforts from resolving the full temporal pattern of responses. These experiments necessarily have been limited to 20 days or less. To overcome the temporal (and spatial) constraints we use an ocean ecosystem model developed for the equatorial Pacific Ocean. The model consists of ten compartments describing two size classes of phytoplankton and zooplankton, detrital nitrogen and detrital silicon, silicate, total CO_2 and two forms of dissolved inorganic nitrogen: nitrate (NO_3) and ammonium (NH_4), which are treated separately, thus enabling division of primary production into new production and regenerated production. This ten-component biological model is coupled with a three-dimensional ocean circulation model based on the Modular Ocean Model and forced with COADS monthly wind and heat flux. In the eastern equatorial Pacific, multiple iron-enrichment

experiments in an area of 4000 km^2 are simulated bychanging the photosynthetic efficiency and nutrient uptake kinetics. The model results of iron-enrichment experiments will be discussed.

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BARNES, J.[1], J. Grace[1], S. Veitch[1], P. Egli[2] and A. Hanson[2]

Integration of a Real-Time Trace Chemical Analyzer into an AUV

The study of chemical plumes in the ocean is made difficult by a lack of capable instrumentation. SubChem Systems has created a real-time, trace chemical analyzer that solves this problem. To increase its capabilities, in May of 2000 a student project to mount a next generation chemical analyzer on an AUV was initiated. The REMUS AUV built by Woods Hole Oceanographic Institution was chosen as a platform. This project included the automation of the next generation SubChem Analyzer by adding microprocessor control, a reconfiguration of the analyzer utilizing improved components, and the design of a hull segment to be incorporated in the REMUS. The design of the hull segment included many challenges put forth by the demands of both the SubChem Analyzer and the REMUS. The difficulties of working with a complex electro-fluidic system in a marine environment and incorporating an instrument in an established platform were addressed in the structural design of the hull segment. The project has continued beyond the scope of the student project and the design is currently in its final stages. Approval and construction will be achieved in the spring of 2001 with open-water testing coming later this year.

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BARRON, Charlie N.[1], Daniel N. Fox[1], Dong S. Ko[1], Paul J. Martin[1] and Alan J. Wallcraft[1]

Real-time Ocean Assimilation and Prediction with Global NCOM

Real-time assimilative global ocean models at resolutions sufficient to be useful for a wide range of Navy operations have recently become viable due to continuing improvements in computational capacity, model development and data acquisition and processing. A global implementation of the Navy Coastal Ocean Model (NCOM), developed by the Naval Research Laboratory (NRL) at Stennis Space Center for transition to the Naval Oceanographic Office (NAVOCEANO), is at the forefront of global ocean modeling. Global NCOM encompasses the open ocean to 5 m depth in a curvilinear global model grid with 1/8 degree grid spacing at 45°N, extending from 80°S to a complete arctic cap with grid singularities mapped into Canada and Russia. Vertically the model employs 41 sigma-z levels with sigma in the upper ocean and coastal regions and z in the deeper ocean. The Navy Operational Global Atmospheric Prediction System (NOGAPS) provides 6-hourly wind stresses and heat fluxes for forcing, while the Modular Ocean Data Assimilation System (MODAS) provides background climatology and tools for data preprocessing. Operationally available sea surface temperature (SST) and altimetry (SSH) data are incorporated into NAVOCEANO global MODAS and Navy Layered Ocean Model (NLOM) analyses and forecasts of SSH and SST. These in turn are combined with the MODAS synthetic database to yield three-dimensional fields of temperature and salinity for assimilation into global NCOM. Global NCOM nowcasts and forecasts provide a valuable resource for rapid response to the varied and often unpredictable operational requests for 3-dimensional fields of ocean temperature, salinity, and currents. In some cases, the resolution of the global product is sufficient for guidance. In cases requiring higher resolution, the global product offers a quick overview of local circulation and provides initial and boundary conditions for small-scale relocatable models that may be more specialized for a particular task or domain. Nowcast and forecast results are presented globally and in selected areas of interest. Model results are compared with historical and concurrent observations and analyses.

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BARTH, J.A.[1], T.J. Boyd[1], P.M. Kosro[1] and S. Pierce[1]

Studies of Continental Shelf and Slope Processes

Scientists at Oregon State University and their collaborators are involved in a number of multidisciplinary studies of continental shelf and slope processes in the Pacific Northwest. These include a NOPP-funded study of wind-driven coastal circulation, the GLOBEC

Northeast Pacific study of the California Current System and a CoOP study of cross-shelf transport. Each of these is a study of water column processes involving the interaction of atmospheric sciences, physics, biology and chemistry. Measurements are obtained via moorings, towed and stationary profiling from ships, and land-based coastal radar. A network of submarine cables on the Juan de Fuca plate and its boundaries could significantly advance our ability to study water column processes over the continental margin. Moorings and vertical profiling systems could be arrayed across the margin at several locations including the cable landings at Port Alberni and Nedonna Beach, the historic Newport hydrographic line and a section near Cape Blanco. Instrumenting the continental slope and shelf from a seafloor cable located offshore has distinct advantages over a cable routed from shore. These locations would provide real-time, long-term measurements of the equatorward California Current and the poleward undercurrent. Knowledge of the variability of these boundary currents will enhance our understanding of their role in local margin processes and their contribution to meridional heat transport. Combining moored subsurface measurements with surface current fields from land-based radar will yield a three-dimensional realization of flow.

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BARTON, E.D.[1], J.M. Rodríguez[2], L. Eve[1] and S. Hernandez-Leon[3]

Physical Controls on Plankton Distributions Around the Oceanic Island of Gran Canaria

Mesozooplankton biomass and ichthyoplankton were studied in the waters surrounding the island of Gran Canaria (Canary Islands). The horizontal distributions of the planktonic components appear strongly related to the mesoscale oceanographic structures in the area. These included an area of weak flow around the stagnation point upstream of the island, where higher concentrations of neritic ichthyoplankton occurred, a warm lee region downstream, where mesozooplankton biomass and neritic ichthyoplankton were increased particularly on the convergent anticyclonic boundary, and the offshore boundary of an upwelling filament from the NW African coast, which acted as a barrier. These concentrations suggest that the stagnation point and the lee are areas of retention for neritic fish eggs and larvae. Simple Lagrangian simulations of particle trajectories in the observed field of flow demonstrate the potential for retention of organisms, both passive and with limited swimming ability, in these areas. On the flanks of the island and in the filament, the simulation suggests even swimming organisms will be largely swept away. The various oceanographic structures, by increasing the planktonic production, are partially responsible for the relatively high values of abundance obtained for fish larvae.

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BASCHEK, Burkard[1] and David Farmer[1]

Air-Sea Gas Exchange in Tidal Fronts

The role of air-sea gas exchange in tidal convergence zones has been studied in the stratified waters of Haro Strait, BC, Canada. Strong tidal currents interact with the rugged topography creating pronounced tidal fronts which can have a significant influence on local air-sea gas exchange. At Boundary Pass, dense water is forced over a steep sill by strong tidal flows and encounters a layer of fresh surface water. Due to the density difference between the two water masses, the upwelling layer sinks rapidly beneath the fresh layer creating an energetic convergence zone in which bubble clouds are formed by small breaking surface waves. These are dragged downwards to depths of up to 180m by violent eddies and vertical currents exceeding 1 m/s. The observations provide clear evidence of a flow in which internal hydraulic control has been lost over the sill crest, leading to downstream displacement of the plunge point which coincides with the descending bubble clouds. Measurements were carried out with an Echo Sounder, ADCP, CTD, oxygen sensor, and an acoustical resonator for determining bubble size distributions. From these measurements we may estimate the importance of air-sea gas exchange in this and other similar tidal fronts. The observations will be interpreted in terms of stratified flow dynamics and bubble behavior, which provide a basis for estimating the importance of air-sea gas exchange.

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BATES, R.[1] and E.J. Whitehead[2]

ECHO*plus* Measurements in Hopavågen Bay, Norway

Rapid, remote, acoustic survey techniques are being increasingly used in the study of marine habitats. The techniques provide wide-area coverage of the seafloor

with discrimination of bottom type when carefully calibrated to ground truth biology and sedimentology. One of these techniques involves the analysis of first and second echoes from the vessel's echo sounder using the ECHO*plus* Seabed Discrimination System. In order to test this acoustic system a survey was conducted in Hopavågen, a confined bay 80 km west of Trondheim on the coast of Norway. The principal objective of the survey was to assess the use of a single-beam acoustic technique for habitat mapping. The bay provides an ideal location for acoustic surveying with sheltered conditions, discrete biotope and sediment bottom types covering large areas with small topographic variations. A description of the ECHO*plus* hardware, DSPs, and hardness & roughness algorithms are given here, along with the results of calibration and surveying using the single-beam echo sounder. An acoustic map of bottom reflectance (hardness and roughness) was generated and compared to biological and sedimentological ground truth data obtained from grab, diver and video surveying. The results show excellent correlation between acoustic bottom classed type and ground truth data.

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BAUMERT, H.[1] and H. Peters[2]

On the Collapse of Turbulence

We interpret this phenomenon as resonance absorption of turbulence by the stratified water column as resonator. To derive quantitative relations, for (locally) homogeneous water columns we describe turbulence by a two-equation model for the Ellison scale L_E and the time scale τ, and the resonator by an internal-wave (IW) equation including friction. As decaying turbulence means increasing τ, the IW mode which is excited first corresponds to the highest wave frequency, $\omega_{max} = (N^2-\nu^2 l^4/4)^{1/2}$, where ν = viscosity, N = buoyancy frequency and l = wave number vector. The criterion for the collapse into (long) waves thus reads $\tau N = \pi$ (Short perturbations with $l \geq l_c$ $(2N/\nu)^{1/2}$ belong to the aperiodic limit and remain as remnant movements). Under structural equilibrium τ is a unique function of both the Richardson number and the Ellison-Ozmidov scale ratio. Our above criterion thus results in limitations for these variables. The values predicted agree well with various laboratory and DNS results. The above theory explains the observed high variability of γ in the traditional collapse criterion $\varepsilon > \gamma\nu N^2$, as deviations from structural equilibrium, where ε =dissipation rate. The theory has also practical aspects; at the base of the pycnocline, turbulence is continuously collapsing and converted into IW energy, which is radiated downwards and reconverted there into turbulence by IW shear. Possibly this mechanism is responsible for the "missing sink" observed in water-column models.

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BEEGLE-KRAUSE, C.J.[1]

Merging Spill Response and Academic Circulation Modeling

Under OPA 90, NOAA/HAZMAT is tasked with providing scientific advice to the US Coast Guard during spill response. GNOME, the General NOAA Oil Modeling Environment, is an Eulerian/Lagrangian spill trajectory model. Oil is not a passive tracer, but moves along the surface of the water at 1-4% of the wind speed. Oil's buoyancy allows it to reform slicks in convergence zones days after being reduced to small, scattered amounts.GNOME is formulated to use fields from 3-D time dependent circulation models in either finite element or finite difference formulations. HAZMAT hopes to integrate Nowcast/Forecast and other outside circulation models into spill response through GNOME. However, spill response requires two type of forecasts: "Best Guess" and "Minimum Regret." The Best Guess forecast assumes that all model and weather forecast information is correct, and predicts the most likely trajectory of the spill. The Minimum Regret forecast requires sampling other possible trajectories based on the uncertainty of the input fields. A statistical sample of alternative trajectories is used to create an Uncertainty Bound on trajectory forecasts. This Uncertainty Bound aids responders in identifying resources that have a lower probability of being impacted by the spill, but may have such a high value (e.g. endangered species, tourist beaches) they should be protected. Understanding and quantifying uncertainty in model forecasts is a key factor in bridging the gap between research and operational modeling.

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BELKIN, Igor M.[1], Peter Cornillon[1] and Zhengqiang Shan[1]

Global Survey of Ocean Fronts from Pathfinder SST Data

The Pathfinder SST dataset was used for the first-ever comprehensive global survey of thermal fronts. The Cayula-Cornillon front detection and declouding algorithms were applied to 8364 twice daily 9 km resolution images obtained from JPL. Objectively derived fronts detected in these synoptic images were mapped for each month from January 1985 through December 1996 for each of 50 regions that together cover the entire world ocean. Long term (1985-1996) frontal frequencies (normalized on cloudiness) were computed for each 9 km pixel and mapped globally. These maps emphasize persistent fronts in the Atlantic Ocean (Labrador, Nordic, North, Baltic, Mediterranean, and Caribbean Seas; Gulf of Mexico, South and Mid-Atlantic Bights; upwellings off Western and South Africa; equatorial zone; Brazil and Falkland [Malvinas] Currents and Patagonian Shelf); Indian Ocean (Arabian Sea and Bay of Bengal; Somali, Agulhas and Leeuwin Currents, and NW Australian Shelf); and Pacific Ocean (Tasman Sea and east of New Zealand; Asian marginal seas; Kuroshio; Bering Sea; California Current and Eastern Tropical Pacific). Analysis of frontal maps allowed us to distinguish a number of new fronts and elucidate important features of some previously known fronts, especially with regard to their spatial structure and its seasonal and interannual variability. This study was funded by the NASA (Grant No. 535834), whose support is gratefully acknowledged.

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Comparison of NCEP/NCAR and ECMWF Latent Heat Fluxes with Remote Sensed Estimates

The use of global atmospheric analysis products in climate studies has become common practice. However, the overall quality of these products, particularly the air-sea fluxes, is not well known. The main reason is the lack of independent observations to validate the analysis fields over the oceans. In this study, we evaluate the quality of NCEP/NCAR and ECMWF latent heat flux products by comparison with weekly and monthly satellite estimates. Our satellite estimates are based on a bulk formulation using remotely sensed winds and humidities, and Reynolds sea surface temperatures. The winds come from the European Remote Sensing Satellite-2 (ERS-2) and the NASA (NSCAT) scatterometers and the humidity from Special Sensor Microwave/Imager (SSM/I). The SSM/I humidity estimates are based on an improved algorithm derived from buoy and ship observations. We present and describe the spatial and temporal structure of the latent heat flux differences. The source of the flux differences is investigated by looking at the wind and humidity satellite-analysis differences.

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***BERNHARD**, Joan M.[1]

Fauna of Severely Oxygen-Depleted and Anoxic Sediments: Paleoceanographic Implications

Although it is generally accepted that laminated marine sediments are not populated by organisms that affect sedimentary microstructure, a community of eukaryotes, including metazoans, inhabits the oxygen-depleted sulfidic sediments of the Santa Barbara Basin (SBB). The majority of the SBB benthos, which includes numerous species of protists (foraminifera, flagellates, ciliates) along with two nematode species, a polychaete and a gastrotrich that are both new to science, and an epifaunal gastropod, has associated prokaryotes considered to be symbionts. This eukaryotic community is particularly abundant. For example, in laminated sediments laden with the sulfide-oxidizing filamentous bacterium *Beggiatoa*, the dominant nematode attains densities of 105 cm^{-2} and the dominant foraminifer reaches densities of 235 cm^{-2}. These densities exceed, or are comparable to, single species densities of well-aerated marine sediments. Conventional sedimentological and biomedical approaches were refined and combined to investigate sub-mm spatial distributions. The nematodes and dominant foraminifera reside throughout and below the *Beggiatoa* mat; most other foraminifera veil the sediment surface. The vagile nematodes do not appear to destroy laminations, but there is evidence of disturbance and solute transport must be affected in these high-porosity sediments. Most benthic foraminifera in the laminated SBB sediments may record bottom-water conditions, even though many species occur infaunally in well-oxygenated sediments; the dominant foraminifera likely records sub-surface

pore-water signals. These observations suggest that laminated sediments may undergo substantial post-depositional modifications.

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Topographic Effects on Wind Driven Circulation

A multi-layer eddy-resolving quasi-geostrophic model is used to study the oceanic circulation in the vicinity of a local large-scale topographic anomaly. The prevalence of large scale topographic features like the one studied here (e.g., Azores Plateau, Zapiola Drift), their critical locations for climate issues and the large transports observed in these areas motivate the present study. Results show a mean anticyclonic circulation around the seamount in all layers and upslope eddy mass fluxes, in accord with downgradient potential vorticity diffusion as an eddy parameterization. Maps of EKE are consistent with an eddy kinetic energy minimum observed by TOPEX above the Zapiola Drift. Compared to the flat bottom case, the spectrum over the bump is redder, a multi-year (7 years) band is energized, and the mesoscale band is suppressed. The 7 year oscillation is associated with the slow building of a large potential vorticity anomaly above the seamount followed by a rapid ejection phase. The 7 year period depends on the spatial extent of the circulation and vertical gradients favoring baroclinic instability. In stable regimes, the anomaly can persist for longer periods. The eddy potential vorticity fluxes show that relative vorticity flux, caused by vortex tube stretching along the slope of the seamount is dominant.

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BLAIN, Cheryl Ann[1], Jayaram Veeramony[2] and Mark Cobb[3]

Modeled 2-D and 3-D Embayment Circulation

The 2-D and 3-D circulation in a coastal embayment is examined through a series of numerical simulation experiments. Modeled circulation for an idealized domain that consists of a shallow bay of regular geometry connected by a narrow inlet to a sloping shelf region is analyzed. Parallels are drawn between circulation features observed in the idealized case and simulated circulation patterns within Bay St. Louis, located in the northeastern Gulf of Mexico. Forcings from tides, river inflow, wind and surface waves are considered. The 3-D finite element model, ADCIRC, is applied to the simulation of coastal circulation dynamics in all experiments.The aim is to quantify important mechanisms for 2-D and 3-D embayment circulation under realistic field conditions. Additionally of interest are the affect of various nonlinearities on circulation and the sensitivity of computations to the eddy viscosity formulation. The role of wave-current interaction is investigated both by considering phases of the tidal cycle separately and by modeling fully coupled waves and currents. Ascertaining the influence of various forcings on bay/inlet circulation is further aided by the introduction of Lagrangian tracers. Such tracers are a reasonable indicator of how circulation patterns affect the motion of sediment particles or passive biological organisms such as fish larvae.

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Surfactants at the Air-Sea Interface: Influence of Chemical Impact on Physical Processes

Surfactants in the ocean come from anthropogenic and natural sources. While the composition and molecular structure of these surfactants are diverse, their influence on physical processes at the air-ocean interface appears to have impact in ways that can be generalized. The most striking impact of surfactants at the interface is the suppression of short surface waves, a phenomenon reported for millennia. Recent observations made from aircraft and satellites indicating the suppression of short waves are presented. Variability of the distribution of surfactants as evidenced by these remote-sensing techniques is compared to direct measurements obtained *in situ* from surface sampling. Other physical processes affected by the presence of surfactants include the suppression of near-surface turbulence, heat- and mass-transport across the air-water interface. Experimental observations from both laboratory and field measurements are presented. Reduction of the rate constant for gas transfer by an order of magnitude is demonstrated, and its dependence on wind-stress is explored. Comparison of this effect across a range of both anthropogenic and biological surfactants exhibits similar behavior, with the degree of rate constant reduction correlating to concentration of surfactant. Surface slope statistics are demonstrated to correlate well with the

reduction of transport. The utility of such a correlation is demonstrated, with the use of scattering models from radar roughness estimates used to parameterize global gas transfer rate estimates.

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BONTEMPI, Paula S.[1] and James A. Yoder[1]

Phytoplankton Seasonality in Bio-optically Variable Ocean Margin Waters

Monthly and seasonal phytoplankton spatial variability was examined within ocean margin waters off the southeastern continental United States (SEC) after different bio-optical water masses were delineated from remotely-sensed Sea-Viewing Wide Field-of-View Sensor (SeaWiFS) data. Five months (January, March, May, August, and November, 1998) of phytoplankton chlorophyll *a* data represent seasonal patterns. Monthly data from two transects of subregions within SEC waters revealed an onshore/offshore phytoplankton gradient and seasonal signal, which were also evident in monthly arithmetic mean chlorophyll *a* composites. Bio-optical water masses were delineated using frontal analyses of SeaWiFS water-leaving radiance and chlorophyll *a* data; high radiances at 555nm indicated high scattering waters. Such waters confound simple empirical algorithms used for routine processing of SeaWiFS imagery, possibly yielding incorrect (high or low) chlorophyll *a* concentrations. Once waters of questionable chlorophyll *a* concentrations were identified, valid chlorophyll *a* fronts were delineated using an edge detection algorithm. Cross-shelf seasonal motion of major frontal zones was defined. Phytoplankton distributions were associated with the inner, middle, or outer shelf based on biological response to monthly physical and atmospheric forcings associated with each region. Inner shelf chlorophyll *a* distributions are influenced by river flow and wind stress, while offshore distributions are controlled by circulation features such as Gulf Stream meanders. Chlorophyll *a* frontal variability was associated with the local oceanography of the Carolina Capes.

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***BOTSFORD**, Louis W.[1], Cathy Lawrence[1], John Largier[2] and Alan Hastings[1]

Biological Effects of Event-Scale Variability in Wind Forcing in an Upwelling Region, the California Current

While eastern boundary currents are known to have high biological productivity due to coastal upwelling, details of the underlying mechanisms, specifically the effects of daily to weekly scale variability in the winds, are not well understood. Important biological questions include: (1) How does annual primary production depend on this high frequency temporal variability, and how is that transferred to higher trophic levels, and (2) How are populations of fish and invertebrates sustained with planktonic larvae subject to offshore, equatorward flows during the upwelling season, and what is the consequent effect on larval dispersal patterns. The answers to these questions depend on the responses of coastal circulation to event scale changes in wind and on coastal topography. Most of the salient features are present in a 2-dimensional view. The effects of wind variability on cross-shelf flows, transport of nutrients, depth of the mixed layer, and consequent primary and secondary productivity can be represented and explored in either a simple conveyor belt model or a 2-dimensional, cross-shelf slice. Observation of larval settlement in areas of 2-dimensional upwelling show larval settlement pulses after winds weaken or reverse, suggesting onshore transport as the ocean adjusts to the change in wind forcing. However, a comprehensive understanding requires consideration of the third, alongshore direction. Alongshore variability in topography and wind fields produces spatial variability in alongshore and cross-shore flows, with retention zones for planktonic larvae and holoplankton when upwelling winds are strong. Alongshore variability in primary productivity and phytoplankton biomass is also observed, and this in turn has direct effects on intertidal organisms. During wind relaxation larvae in retention zones are transported alongshore and settle in specific patterns. Phytoplankton-rich waters are similarly transported alongshore with complex effects on primary and secondary productivity. These effects have important practical implications for the spatial design of marine reserves, and for variability in fish stocks from year to year.

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Scatterometry Data Sets: Surface Winds, Stresses and Pressures Over Water

User-friendly data sets of scatterometer wind vectors are currently available. SeaWinds scatterometer observations cover 90% of the global oceans in one day, with an average of two overpasses each day. The in-swath resolution is 25 km. SeaWinds was developed to measure surface winds over water. The upper limits on uncertainty (for correctly selected ambiguities) are 0.3 ms^{-1} and 3°, and ambiguity selection skill is excellent. Scatterometer data can also be used to find surface pressures and stresses. Several types of data sets, appropriate to different applications, are being made available. The swath winds (i.e., gridded relative to the satellite position) are available for those who need winds that are not further processed. For example, these winds could be used to quality control ship and buoy observations. However, these data sets are not regularly gridded in a latitude-longitude grid, and have gaps in daily coverage. Several six-hourly global gridded products are also available. Such products are useful in constructing surface forcing climatologies that include synoptic scale variations, as well as some mesoscale variations. The easy availability of various scatterometer data sets will be discussed. Animations will be used to demonstrate the content of several data sets.

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Return of the Cold Halocline Layer to the Eurasian Basin of the Arctic Ocean

In the early- to mid-1990s the Arctic Ocean cold halocline layer (CHL), which isolates sea ice from the warm water of the Atlantic layer, retreated from the Eurasian Basin (EB) in response to changes in the surface circulation associated with large scale changes in the atmospheric pressure field. Here we report on the return of the CHL to the EB based on a comparison of May 1999 submarine-based observations to nearly coincident May 1995 submarine-based observations and August 1991 ice breaker-based observations. The CHL observed in the EB in 1999 was weaker than observed in 1991, which in turn was weaker than observed in the entire 40-year record of the Environmental Working Group Atlas. We find that the continued warming of the Atlantic layer in the second half of the 1990s was accompanied by an increase in the fresh water content of the upper water column throughout the region from the Alpha Ridge to the Arctic Mid-Ocean Ridge. The disappearance of the CHL from the EB in 1995 has been attributed to an eastward shift (toward Bering Strait) of the injection point into the central basin of fresh water from the Russian shelves. We conclude from IABP ice velocities and sea level pressure fields that the reappearance of the CHL in 1999 was due to a westward shift in the injection point.

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Modeling Carbon Cycle in the Pacific Ocean

To improve our understanding of physical variability and the carbon cycle response in the Pacific Ocean, especially on seasonal to decadal time scales, we have developed a physical-biogeochemical model for the Pacific Ocean. The lower trophic level ecosystem processes are linked with upper ocean carbon chemistry and embedded into a three-dimensional circulation model that is forced with observed the air-sea fluxes between 1960 and 1993. The improved physical-biogeochemical model produces a 34-year (1960-1993) retrospective analysis for the Pacific Ocean. The physical-biogeochemical model is capable of reproducing many observed features and their variability in the Pacific Ocean. Analyses of the modeled results are focused on two regions, the equatorial Pacific, a strong natural CO_2 source region to the atmosphere, and the North Pacific, a sink region for both natural and anthropogenic carbon. The abrupt shift in the North Pacific climate system that occurred during the mid 1970s, the modeled air-sea flux of CO_2, and the response of the upper ocean carbon cycle to this climate shift are discussed. Using the physical-biogeochemical model, we estimate how much anthropogenic CO_2 has entered into the North Pacific Ocean during the past several decades.

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Observing and Modeling the Upper Ocean in Monterey Bay: A Testbed for NEPTUNE

Monterey Bay has been proposed as a test-bed for new instrumentation prior to deployment in the NEPTUNE region. Seafloor and water-column instruments will be integrated into new moorings and cabled systems currently being developed as part of the MBARI Ocean Observatory System (MOOS). The cables will form the basis for NEPTUNE testing, and the moorings will eventually supplant current moorings maintained by MBARI. Here we describe a testbed project for coupled three-dimensional physical-biological models. With support from NOPP we are developing a model for Simulations of Coastal Ocean Physics and Ecosystems (SCOPE). The objective is to build an upper ocean physical-biogeochemical model capable of assimilating real-time observations and simulating fields at high temporal and spatial resolution (on the order of day, km). The implementation of an observing and modeling system for the NEPTUNE upper water-column will be discussed.

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Air-Sea Interaction: The Ultimate Challenge for Hurricane Predictions

Over the last few decades hurricane track forecasts have improved significantly, whereas very little progress has been made in hurricane intensity forecasts. The lack of the skill in the intensity forecasts may be attributed to deficiencies in the current prediction models: insufficient horizontal resolution, inadequate surface and boundary layer formulations, and no full coupling to the ocean. The extreme high winds, intense rainfall, large ocean waves, and copious sea spray push the surface-exchange parameters for temperature, water vapor, and momentum into untested new regimes. To resolve the hurricane eyewall structure, which is crucial in intensity forecasting, the horizontal resolution needs to be approximately 1-2 kilometers. The air-sea interaction in the eyewall region is largely unknown with very few observations. While hurricanes draw energy from the ocean surface, they cool the ocean by wind-induced surface fluxes and vertical mixing. Hypotheses have been put forward to address the ocean feedback on hurricane intensity. However, the current results remain inconclusive. The enthalpy and momentum exchange coefficients under the high-wind conditions are difficult to determine. The stress is supported mainly by waves in the wavelength range of 0.1-10 meters, which are unresolved by wave models. Rapid increases in computer power and recent advance in technology in observations have made it possible for us to develop a strategy for the next generation of hurricane prediction models. We begin by examining key parameterizations, e.g. effects of the wave "spectral tail" on drag coefficient, the source term for sea spray, and subgrid-scale turbulence at 1-2 kilometers resolution. Model simulations are compared with observations of surface wave spectra, surface fluxes, and vertical profiles of the atmospheric boundary layer and the ocean mixed layer from recent hurricane field programs.

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Estuarine Plume Observations in the Middle Atlantic Bight Using Spaceborne Synthetic Aperture Radar

Local wind and buoyancy fluxes from estuaries are major forcing mechanisms on the Middle Atlantic Bight (MAB) shelf circulation. Outflow of lower salinity estuarine water into a shelf region tends to form a plume of buoyant water that spreads out of the estuary mouth influencing the coastal circulation. Salinity features associated with bay tidal excursions have been observed using passive airborne radiometers. The ability of synthetic aperture radar (SAR) to detect sea surface roughness patterns associated with such salinity features is demonstrated with a series of available observations from the European Space Agency (ESA) ERS-2 and the Canadian Space Agency (CSA) RADARSAT-1 satellites. Spaceborne SAR observations are found to be consistent with both airborne data and historical *in situ* salinity observations.Plume features from the Hudson Estuary, Delaware Bay, Chesapeake Bay, and from several inlets throughout the MAB coast are shown to be routinely captured by SAR. Fronts associated with the Hudson Estuary, Delaware Bay, and Chesapeake Bay coastal currents are also imaged. Of particular interest are SAR observations of the Delaware Bay plume that provide for the first time a direct synoptic view from space of the twin-front nature of this feature. In addition to tidal dynamics and local winds, spaceborne SAR observations reveal that the horizontal extent of bay plume features can be further

affected by the presence of active upwelling centers in the region.

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Project Oceanography: Enhancing K-12 Science Education Via Satellite-Televised Interactive Technologies

Since 1996, advanced communications and broadcast technologies have been used by Project Oceanography to bring the latest ocean science research results to millions of middle school science students around the world. Project Oceanography is designed to provide the required physics, chemistry, geology, biology, or mathematics needed by the student to fully comprehend the causes and implications of the real-world environmental problems. Presented by the actual research scientists, middle school science students and teachers are exposed to the wealth of knowledge, resources, and state-of-the art facilities of the ocean science research community. Broadcasts are now distributed to schools in 40 states and 8 foreign countries. Cost effectiveness of this program is achieved by: use of the university-owned distance learning studio; satellite distribution to public-owned instructional TV stations; web site publication of written resource materials and on-demand video archive; and the volunteer efforts of the more than 60 scientists who have participated as science hosts to produce more than 100 programs. Growth and success of this program has also been fostered by strong partnerships with academic, government, schools, and private foundations – a prerequisite of funding from the National Ocean Partnership Program. Demonstrated benefits of the program to users is the high usage by students in non-traditional programs (home schools and drop-out prevention programs) and in urban settings. Details available at: http://www.marine.-usf.edu/pjocean

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Advances in Ocean Science Education and Education Technology

The increased emphasis on improving the quality of K-12 science education has led to the creation of innovative new National Science Education Standards based initiatives for application of advanced computer and communications technologies to link the ocean science researcher with students and educators in school classrooms. Several programs have sent teachers to sea on research expeditions, with the teachers reporting back to their students and mentoring other teachers via email, web sites, or live video broadcasts. Other programs have used advanced 3-D visualization software to develop materials for use in classrooms. CD-ROMs and web-based learning modules, some of which incorporate the interpretation of real-time data, have proliferated. Many of these products are prepared by scientists at federal agencies (e.g., NASA, NOAA) and universities. Educational television broadcasts and live web casts from unique environments, such as the bottom of the ocean, are also now available for use in the science classroom. In conjunction with the finals of the National Ocean Sciences Bowl (NOSB), we have assembled representatives of several of these ocean science education programs who will present details of their activities via posters and demonstrations. Presentations will include use of emerging multimedia and communications technologies, such as interactive television, for educational purposes. It is anticipated that facilities will be available in the exhibit area for multimedia presentations throughout the conference.

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Outreach from Ocean Observatories

The NEPTUNE ocean observatories promise a coherent system of high-speed, submarine communication-control links and fiber-optic/power cables connecting undersea instruments in the northeastern Pacific Ocean to land. Planning the observatories was undertaken by Woods Hole Oceanographic Institution, Jet Propulsion Laboratory, Pacific Marine Environmental Laboratory, University of Washington, Canada's Institute for Pacific Ocean Science and Technology and the Monterey Bay Aquarium Research Institute (MBARI) with support

from the National Oceanographic Partnership Program. The observatories will allow long term observations and experiments with remote interactive control and real-time data access in research laboratories, classrooms and homes. A NEPTUNE-sponsored education workshop developed ideas for an institute for lifelong learning, with access to images and data; mentoring interactions between students and professionals; experiential learning environments; and the integration of science, art, and the humanities. Communication technology can extend the outreach capabilities, allowing scientists, policy makers, classes and the public to gain new understanding of biogeochemistry, ridge crest processes, biology and ecology, and human influences on ocean and climate systems. A NEPTUNE test site is planned for Monterey Bay to serve as a prototype for infrastructure design and testing of cabling, instrument interfaces, and shore stations. Similarly, MBARI will collaborate with the Monterey Bay Aquarium and California State University to develop a prototype Ocean Observatory web site and teacher program for scientific and educational use.

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Seasonal Variation of Physical and Biogeochemical Features in Eastern Caribbean Surface Water

We describe vertical and temporal variation of water mass structure, dissolved nutrients, phytoplankton Chlorophyll a (Chl a) and dissolved organic matter south of Puerto Rico at 67°W, 17°36'N with particular emphasis on variability of Caribbean Surface Water (CSW) features. CSW at the Caribbean Time Series Station (CaTS) experiences year-long continental riverine influence as evidenced by surface salinity consistently below that of Tropical Atlantic Surface Water and elevated silicate content. Salinity exhibits close correlation to average rainfall over the Orinoco River Basin with a 3 month offset and salinity and silicate are in turn closely correlated. Calculations using a simple mixing model and based on known end-members for salinity and silicate indicate that river water accounts for between 0.4 and 3.8% of CSW while rainwater accounts for 0.2 - 4.2% throughout the year at CaTS. No significant correlation was found between salinity and phytoplankton Chl a, but the depth of the Chl a maximum was statistically correlated to seasonal salinity fluctuations. Dissolved organic matter, as detected by fluorescence spectroscopy, exhibited seasonality similar to that of dissolved silicate and depth of the Chl a maximum. Computation of phytoplankton carbon content from Chl a profiles and known C:Chl a ratios indicates that phytoplankton biomass increases during the period of riverine influence.

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Bigelow Laboratory: Building Piers Between Ocean Research and Education

Bigelow Laboratory for Ocean Sciences is a private, non-profit organization committed to translating its research into innovative education programs. We enable inquiry-based learning about marine ecosystems for those who do not have oceanographic equipment or access to natural seawater. Bigelow's small size and remote location compel us to deliver much of our content via the Internet (www.bigelow.org). "Hatch to Catch" is an on-line challenge to guide a group of 1,000 larval lobsters through the icy waters of the Gulf of Maine to settle on the sea bottom. The goal is ensure that at least 25 lobsters reach harvest size. Background information helps users select favorable environmental conditions: their decisions determine the ultimate success of their lobsters. All outcome scenarios are based on research data from the Gulf of Maine. "Ship Mates: Explore the Gulf of Maine as Oceanographers do" provides the means for teachers and students to study one of the world's most biologically productive areas. At twelve stations and during three seasons, we have collected temperature, salinity and chlorophyll data throughout the water column. Data profiles are augmented by photomicrographs of plankton netted at the ocean surface. On-line exercises invite exploration of these data to understand variations in water column mixing, stratification and chlorophyll concentration, and the seasonal succession of phytoplankton species. Our newest web-based resource and wall poster–"From the Top of the World...to the Bottom of the Food Web"–highlight marine phytoplankton, NASA programs that study ocean color, and Harmful Algal Blooms. Our longest-standing web resource, "Virtual Vacationland," helps teachers and students find and use web-based earth science data and information. Content is arranged by topic: land topography, bathymetry, coastal tides, ocean buoy data, ocean temperature, weather and climate, and watersheds and rivers. There are links to over forty "hands on" activities, as well.

Each topic has background information, terminology, key questions, web links, and images & animations.

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Phosphorus in Ocean Margin Sediments: California and Benguela Current Regions

Phosphorus (P) is essential for oceanic primary productivity, and biogeochemical interactions link it to oceanic cycles of key elements like carbon, nitrogen, and silicon. Geochemical reactions transform reactive sedimentary P from labile forms delivered to the sediment-water interface (primarily organic P in marine organic matter) to more stable authigenic forms. Understanding the nature and controls of these transformations requires an integrative approach combining interstitial water geochemistry, reflecting sediment redox state as a consequence of organic matter diagenesis, with sediment geochemistry of organic carbon and the various P forms. Recent scientific ocean drilling has provided long sedimentary sequences in the eastern boundary current regions of the California Current and the Benguela Current (sites from Ocean Drilling Program legs 167 and 175, respectively). We will focus on six sites from the California Current region, with site water depths from ~1150-4200 m, sediment depths to 450 m, and ages to 14 Ma, and three sites from the Benguela Current region, with site water depths from ~1300-2000 m, sediment depths to 600 m, and ages to 16 Ma. Sediments in ocean margin settings are ideal for these investigations, given the influence of relatively high primary productivity, the wide range of sediment redox state, and the role of margin sediments in carbon budgets.

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2-D Mapping of Hypoxia and Nutrient Plume Events in Narragansett Bay, Rhode Island

Excessive nutrient loading to estuaries, such as that associated with sewage effluent discharge, can lead to phytoplankton blooms and hypoxic conditions detrimental to the biota. Intense rain events often cause a Providence River sewage treatment plant to become overburdened, and result in the periodic direct discharge of untreated sewage into upper Narragansett Bay. The resulting nutrient rich effluent plume often leads to eutrophication, temporary hypoxic to anoxic conditions, and the closing of local areas to fishing. A better understanding of the dynamics of these nutrient plumes would facilitate the environmental management of Bay waters. We are developing and testing a real-time *in situ*, 2-D survey system for mapping chemical plumes with high spatial and temporal resolution. The X-Z *profiler*, an undulating tow body, has an instrument payload that includes a CTD with O_2 and pH sensors, and a fast response submersible nutrient analyzer, the *SubChemPak Analyzer*. Using this platform, continuous real time 2-D mapping of chemical plumes may be conducted simultaneously with underway ship board ADCP measurements of current velocity, and allows us to more fully characterize the spatial extent and movement of chemical plumes in coastal waters. Application of this methodology in Narragansett Bay has provided interesting results on the spatial extent of hypoxia and eutrophication in the Providence River.

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Determination of SST Over the Adriatic Sea

The errors associated with the determination of SST over the Adriatic Sea using different Multichannel Sea Surface Temperature (MCSST) and Non Linear Sea Surface Temperature (NLSST) global algorithms based on NOAA/AVHRR are analyzed. The data used in this work are a subset of the AVHRR Pathfinder Matchups Database which contain co-temporal, co-located AVHRR and *in situ* observations from buoys. The behavior of the different algorithms has been compared studying the residuals (buoy SST – satellite-derived SST) as a function of satellite zenith angles, water vapor content, buoy SST and observation time. We have found that to avoid the presence of systematic bias in the determination of SST over the Adriatic Sea from global algorithms, it would be necessary to re-calculate the algorithms' coefficients in a regional basis.

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Threshold and Hysteresis Effects in Wind Wave Growth and Decay

Measurements made in a wind wave tank demonstrate that a wind-speed threshold exists below which the wind cannot produce waves. This threshold is different,

however, depending on whether the waves are initially growing or being maintained by the wind. The measurements were made in a closed, recirculating wind wave tank at the Canada Centre for Inland Waters. Hot film anemometers and pitot tubes were used to measure the wind stress and speed, respectively. A Ku band microwave system was used at a variety of incidence angles looking both upwind and downwind. A laser height/slope gauge was employed to measure the height and slope of the surface at a single point. The latter measurements were analyzed as if they came from four closely spaced wave height probes. Time series of wave amplitudes produced by these probes in various frequency bands were determined using wavelet techniques. In each frequency band and at each time, the phases between the probes allowed the determination of the wavenumber corresponding to that frequency band while the surface displacement at the probes yielded the spectral density corresponding to that wavenumber. Thus, two completely different tools were available to measure the wave height spectral density as a function of wavenumber band: the microwave system through Bragg scattering and the laser system through wavelet analysis. Unlike the microwave system, however, the laser system yielded time series of spectral densities in a large number of wavenumber bands. Both techniques yielded the same threshold and hysteresis effects at the Bragg wavenumber and the laser technique revealed that these effects are present in a wide variety of wavenumber bands. We believe that the hysteresis effects arise in the following manner. When waves first develop, an initial time lag exists while the wind builds up sufficiently to overcome viscosity and while the necessary initial roughness of the surface grows, probably through the laminar to turbulent transition of the near-surface shear flow. When waves are already present on the surface, their decay begins at the point at which viscous dissipation can overcome energy transfer from the wind unless transfer from longer waves is taking place. In either case the point of decay is at a somewhat lower wind speed than that of growth, accounting for the observed hysteresis effects. We will present evidence in this talk for these ideas and will discuss the rates of growth and decay that are observed. The importance of these results for microwave observations of the sea at low wind speeds will be discussed briefly.

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The Wind Product of the Ocean and Sea Ice Satellite Application Facility

The aim of the Ocean and Sea Ice Satellite Application Facility (O&SI SAF) is to become an integral part of the EUMETSAT satellite ground segment for Europe. An important component of the O&SI SAF efforts is the scatterometer wind product. In the O&SI SAF, preparations are underway for the wind product from the ASCAT scatterometer on EPS/METOP. During the life time of ERS-1 and ERS-2 the processing of scatterometer winds has been developed considerably, and many operational centers using scatterometer data followed these developments. A routine product based on the ERS-2 scatterometer is being further developed for demonstration purposes, which can be found at www.knmi.nl/scatterometer. Quality control and monitoring are essential parts of the development, as well as investigations on ice discrimination and ambiguity removal. The North-Atlantic/European seas and global products becoming available from the O&SI SAF will be presented at the meeting. The benefits of these products for meteorology will be addressed. Finally, plans will be presented on how to make the data more useful for oceanography and climate research, using data assimilation schemes to combine measurements from different wind sensors, while maintaining high spatial and temporal resolution at the ocean surface.

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Changes in North Pacific Radiocarbon Precede Climate Variability in the Equatorial Pacific

We report annual, high precision radiocarbon ($\Delta^{14}C$) records in a Hawaiian surface coral, that demonstrate most of their spectral density at the 6 year cycle. Cross spectral analyses revealed that the 6 year period was coherent between the ^{14}C record and the Southern Oscillation Index, and between ^{14}C and wind speed at Hawaii. The coherencies were highest when the SOI lagged the ^{14}C record by several years, and when ^{14}C lagged wind speed by 2 years. This sequence is compared to the delay observed between the cool to warm transitions in the central North Pacific and in the eastern equatorial region [Deser et al., 1996; Gu and

Philander, 1997; Lysne et al., 1997]. Our results suggest that the dynamics of El Niño are linked to similar time scale processes in the North Pacific. The actual mechanism that causes the ^{14}C change in the North Pacific requires further study.

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Dependence of Equatorial Pacific Export Production and pCO_2 on Silica Trapping in the Southern Ocean; Implications for Paleo-Oceanography and Paleo-Climatology

Atmospheric CO_2 concentration varies in step with glacial cycles with lower values (by 80 - 100 µatm) during glacial periods. Although these cycles are driven by orbital parameters, the changes in radiation are insufficient to drive the large amplitude of the CO_2 changes. The interaction between the eastern equatorial Pacific (EEP) export production and Southern Ocean (SO) silica trapping may provide a major biogeochemical feedback system capable of amplifying the orbital signals to glacial/interglacial values. The diatom population of the EEP upwelling system is limited by $Si(OH)_4$ supplied in a low $Si(OH)_4$:NO_3 ratio from the Equatorial UnderCurrent (EUC). Increased $Si(OH)_4$ results in increased diatom productivity, suppression of non-diatom populations and decreased surface pCO_2. The deficiency in EUC $Si(OH)_4$ results from low $Si(OH)_4$:NO_3 water originating in the vicinity of the Antarctic polar front, a consequence of the extraordinary trapping of silica by the SO. In glacial periods this trapping is reduced several fold and likely results in increased $Si(OH)_4$ transport to the north, increased biogenic silica production and deposition at the equatorial Pacific which can be expected to reduce surface pCO_2. Fe from dust during glacial periods may paradoxically enhance northward transport of $Si(OH)_4$ from the SO by reducing the Si:N ratio of SO diatoms.

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In Situ Measurements of Fine-Scale Nutrient Gradients in Narragansett Bay, Rhode Island

Dissolved nitrate (NO_3) and nitrite (NO_2) are biologically essential chemical species that may significantly enhance or limit marine phytoplankton growth. Biological productivity, along with physical mixing and transport processes, have the potential to influence the development, maintenance, and dissipation of micro- to fine-scale (cm - m) chemical structure in the coastal marine environment. High-resolution submersible chemical profiling instrumentation is required to investigate such small-scale nutrient dynamics. A fast-response nutrient analyzer, the *SubChemPak Analyzer*, was configured for the simultaneous, real-time determination of dissolved nitrite and nitrate and deployed on a oceanographic profiling package, consisting of modular sensors for the simultaneous measurement of conductivity, temperature, pressure, dissolved oxygen, pH, chlorophyll fluorescence, light transmission, and irradiance, in the waters of Narragansett Bay. The internal calibration feature, low detection limit (nanomolar), large range of quantification (3 orders of magnitude), and fast sampling rate (1 Hz) of the *SubChemPak Analyzer* allowed for the accurate determination of fine-scale spatial and temporal changes in water column nutrient composition. The high-resolution nitrite and nitrate vertical profiles revealed considerable fine-scale structure and steep concentration gradients that would have been missed by traditional water sampling techniques. The comparison of the nutrient profiles with calculated apparent oxygen utilization, pH, and other comparably resolved parameters, provided insight on the influence of physical and biological processes on the distribution and redox cycling of nitrogen species in Narragansett Bay.

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Summer Trophic Conditions in the Southern California Current (IMECOCAL)

During the August 1999 IMECOCAL cruise, particulate matter samples were obtained by filtration at 0, 20, 50 and 100 m. Protein, carbohydrates and total, inorganic and organic seston were studied and compared with zooplankton biomass obtained with oblique tows with a 500 µm bongo net at the same stations. Higher inorganic and organic seston vales were found around

Punta Eugenia, coinciding with higher zooplankton biomass. This relation is clearer in the southern part of Punta Eugenia, in transects 130 and 133. Between San Quintìn and Ensenada, in the 103 transect near the coast, the same coincidence was found. These higher values were found at all depths, showing much lower concentrations below 50 m. Particulate organic matter (proteins + carbohydrates, POM) showed the same trend. However, no significant correlations were found between POM and displaced zooplankton volume (R=0.352, N=56). A significant difference was found for POM among the 4 depths. These preliminary results have to be related to the region's hydrography to better understand the mechanism controlling them.

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Organic Carbon Remineralization and Calcium Dissolution in the North Pacific Ocean

As a part of the JGOFS synthesis and modeling project researchers have been working to synthesize the WOCE/JGOFS/DOE/NOAA global CO_2 survey data to better understand carbon cycling processes in the oceans. Working with international investigators we have compiled a Pacific Ocean data set with over 36,000 unique sample locations analyzed for at least two carbon species, oxygen, nutrient, CFC tracer, and hydrographic parameters. These data are being used determine the rates of in situ organic carbon remineralization and $CaCO_3$ dissolution in the water column of the North Pacific Ocean. Organic carbon remineralization rates, ranging from about 1 – 6 μmol $kg^{-1}yr^{-1}$, are observed in the shallow and intermediate depths of the North Pacific, whereas observable calcium carbonate dissolution rates (ranging from about 0.05 - 0.9 μmol $kg^{-1}yr^{-1}$) can only be observed in the intermediate depths at or below the aragonite saturation horizon. Within the North Pacific Intermediate Water (depth range: 400 - 800 m), organic carbon remineralization rates are approximately 8-12 times faster than $CaCO_3$ dissolution rates. However, $CaCO_3$ dissolution rates between 500 – 1100 m are approximately 9 times faster than observed in mid- and deep water depths (average = 0.05 μmol $kg^{-1}yr^{-1}$) of the North Pacific.

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A Rapidly Relocatable Ocean Analysis and Forecasting Capability

The Modular Ocean Data Assimilation System (MODAS) combines remote sensed data (altimetry and sea surface temperature) with *in situ* temperature and salinity measurements to produce an analysis of the ocean that can be considerably more accurate than conventional climatological estimates. MODAS expands on the traditional climatology approach by including relationships between surface and subsurface properties which have been derived from nearly 3 million historical profiles, almost one million of which include salinity. Using these "synthetic profile" algorithms, daily global analyses of height and temperature from satellites are used to provide a dynamic climatology that matches front and eddy features seen on that day. These 3-D estimates of temperature and salinity are assimilated into a global implementation of the Navy Coastal Ocean Model (NCOM, see Barron *et al.* this issue) to provide daily analyses and forecasts of the ocean at approximately 15 km resolution. MODAS includes a relocatable implementation of the Princeton Ocean Model (POM) which includes tidal forcing and which can obtain initial and boundary conditions from the MODAS dynamic climatology as well as the daily NCOM model. Using this combination of NCOM, MODAS, and POM allows high resolution nowcasts and forecasts of temperature, salinity, and currents (including tidal effects) to be produced anywhere in the world on short notice. Results from several widely varying areas are presented with comparisons to historical and concurrent observations.

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Spectral Attenuation Coefficients in Narragansett Bay, Rhode Island

The attenuation of light in natural waters is governed by the optical properties of water itself and by the

constituents within it. In estuarine waters, the primary absorbers and/or scatterers of light are phytoplankton, suspended minerals, organic detritus, and colored dissolved organic material (CDOM). The purpose of this study was to determine temporal and spatial variability of spectral attenuation coefficients for downwelling irradiance (K_d) in Narragansett Bay, RI and the in-water constituents responsible for the observed patterns. Profiles of downwelling spectral irradiance (E_d) at selected wavelengths (412, 443, 490, 510, 555, 665 nm, plus PAR) at four stations were made along the West Passage of Narragansett Bay every 1-3 weeks for thirteen months. We also measured CDOM absorption, chlorophyll *a* concentration, and total suspended solids concentrations. The CDOM and chlorophyll *a* measurements were then used as inputs for *Hydrolight* modeling of the in-water optical field, and we compared K_d calculated by *Hydrolight* and that calculated from E_d profiles. Results showed high spatial and seasonal variability with $K_{d(PAR)}$ values ranging from 0.25-0.46 m^{-1} in the lower bay and 0.50-1.1 m^{-1} in the upper bay. Differences in spectral K_d were even more pronounced with values in the lower bay ranging from 0.34-1.00 m^{-1} and 0.10-0.56 m^{-1} for 412 and 555 nm, respectively. In the very turbid waters of the upper bay, ranges for the same 2 wavelengths were 1.01-2.40 m^{-1} and 0.34-0.85 m^{-1}, respectively. Although the observed variability in the bay was high, comparisons between *Hydrolight* calculations and the observations show that the factors affecting the spatial and temporal patterns of spectral attenuation coefficients in Narragansett Bay are well understood.

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Time Series of pCO_2 from Automated Shipboard and Mooring Observing Systems

High carbon fluxes are associated with coastal upwelling ecosystems. The spatial and temporal heterogeneity found in these regions dictates a concerted sampling scheme. The MBARI time series cruises and moorings on the central California coast addresses some of the scales of variability that have to be resolved to properly estimate air-sea carbon fluxes in coastal waters. In 1993 test deployments of a mooring based system to measure the air-sea difference of pCO_2 (ΔpCO_2) were accompanied by the start of a ship based time series of sea surface pCO_2. A hydrographic line that extents from the coast at 36° 48′ N to 60 km offshore is sampled monthly. Less frequent sampling is accomplished along a 300 km extension of this line. Since 1993 there have been more than 100 cruises with pCO_2 measurements in this region. In recent years deployment of ΔpCO_2 measuring systems on moorings located 20 and 55 km offshore have become routine and several years of hourly ΔpCO_2 data are now available. These data have been examined for seasonal and interannual variability. During the upwelling seasons, sea surface pCO_2 ranges from <200 to >700 µatm and can not be easily predicted from physical parameters due to high biological uptake rates. Ocean to atmosphere carbon flux estimates for the 1997-1999 El Niño/La Niña cycle suggest values of -1.1 and 1.85 moles m^{-2} $year^{-1}$ respectively during these extreme years.

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Measured and Predicted Ultraviolet-Induced Inhibition of Photosynthesis of Antarctic Phytoplankton

The effect of ultraviolet radiation (UV) on photosynthesis was examined in phytoplankton in surface coastal and open ocean waters of the Antarctic peninsular region during the austral spring from 1997 to 1999. Time course experiments were conducted in UV-transmitting and UV-opaque tanks during 10-12 hour periods under natural irradiance. Biological weighting functions (BWF) for the inhibition of photosynthesis were also measured on seawater samples obtained at the same time. Here we compare the productivity of the phytoplankton in the tanks to the productivity predicted from the application of the BWF to exposure irradiance. Ratios of UV-transparent to UV-opaque tanks were similar for the measured and predicted production rates with reductions due to the presence of UV of up to 45%. In addition, subsampling was conducted every 2.5-3 hours during these incubations and temporal trends in the production rates for the measured and predicted methods coincided throughout the incubation period.

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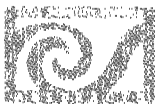

GARDNER, W.[1], M.J. Richardson[1] and A. Mishonov[1]

Assessment of Upper Ocean Beam Attenuation Data Collected During the South Atlantic Ventilation Experiment

Transmissometer data were collected during six South Atlantic Ventilation Experiment (SAVE) hydrographic expeditions conducted from November 1987 to March 1989 from R/V Knorr and Melville. A total of 361 beam attenuation profiles were made with a SeaTech transmissometer interfaced with a CTD/rosette. These data were processed and examined as vertical sections of the surface 500 m. Although the data are not synoptic, we also have mapped the data in plan view for presentation. Data were integrated for the upper 30 m for comparison with the distribution that might be obtained from satellite color data. No synchronous satellite data are available for those years, but we have compared our data with ocean color data from other years for comparable seasons. In general, values are high in the Argentine Basin and along the upwelling areas of the western coast of Africa. Values were low in the central gyre region between 5° and 35° S. This matches the chlorophyll distribution based on a 30-month compilation of CZCS data for the South Atlantic, reaffirming that most particulate matter in surface waters of the open ocean is of recent biological origin. Comparisons will also be made with the hydrology and currents to interpret the observed distributions.

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NEPTUNE and the Perfect Storm

At mid- to high-latitudes, most winter deepening of oceanic mixed layers occurs during one, or at most a very few, major storms. Such events are unpredictable and rarely coincide with scheduled scientific cruises. In the absence of observations of turbulent entrainment during the extreme events which accomplish major mixed layer deepening, models of the surface ocean assume that the effects of dominant storms resemble those of minor storms. The power and bandwidth available at a NEPTUNE node would enable establishment of upper ocean "observatories" which would allow critical examination of this assumption, determining the (nonlinear) combination of forcing characteristics which make a storm "perfect" for mixed layer deepening. Components of such an upper ocean observatory already exist. With sufficiently high sample rates, specialized ADCPs can provide estimates of mean velocity shear, turbulent stresses and kinetic energy dissipation rate, as well as the surface wave velocity field. Backscatter sonars track surface-generated bubble clouds transported by Langmuir cells, while ambient noise sensors provide estimates of wind speed and, potentially, of precipitation. Looking upwards from a mooring placed below the maximum winter mixed layer depth, such an acoustic observatory avoids two major problems associated with attempts to measure upper layer turbulent velocity fields during violent storms, namely equipment survival and sensor motion. Continuous high-frequency observations require the power and data transmission rates which are foreseen for NEPTUNE nodes. Alternate "on-demand" sampling requires real-time control, another feature of NEPTUNE technology.

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Data Management and Archiving for NEPTUNE

Project NEPTUNE plans to instrument the Juan de Fuca plate and its boundaries, in the Northeast Pacific, to allow reliable real-time observations and control of sea floor and water column experiments for several decades. A well-integrated data management and archiving system is important to the scientific and educational goals of the project given the nature of the data produced by NEPTUNE:

- the wide variety and number of instruments
- heterogeneous data
- the multi-disciplinary science goals
- the projected terabytes-per-day data volume
- long life span of the project

Data entering the data management and archive system must be properly and packaged. At the other end, the system must allow the research and public education communities to easily access relevant archive data. In between lies management of the data flow, catalog generation, data storage, data processing pipelines and numerous other components. This paper will present the goals of the NEPTUNE data management and archiving system, will outline a preliminary design, and will discuss the challenges facing the community.

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Particle Size, Concentration, and Optical Scattering Relationships Off Coastal New Jersey

During July, 2000, a large field campaign was directed off coastal New Jersey at the LEO-15 site, as part of the ONR-funded Hyperspectral Coastal Ocean Dynamics Experiment. A large group of scientists with diverse capabilities was assembled, to link observational and modeling results in a near-real time network and describe coastal oceanographic processes, such as wind-driven upwelling events. Our involvement focused on the optical and remote sensing components, and included measurements of particle size distribution and total suspended sediment concentration (TSS) from whole-water samples collected in river, bay, and nearshore coastal environments. Particle size is tightly linked to the backscatter intensity and remote sensing reflectance (R_{rs}). We also measured *in situ* optical backscattering, scattering, and beam attenuation coefficients using HydroScat and AC9 instruments in profiling and flow-through modes, and above-water R_{rs} with a field spectroradiometer. We examine relationships between R_{rs}, total particle cross-sectional area, TSS, beam attenuation, backscattering, and scattering coefficients, with the goal of developing new remote sensing algorithms for ocean color sensors. We also describe the spatial and temporal variability of the particle distributions in the study area, and relate the observed patterns to the local winds and currents.

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GREGG, Watson[1]

Clouds and Phytoplankton: Radiative Effects Simulated in a Global Coupled Ocean General Circulation/Biogeochemical/Radiative Model

Clouds affect the radiant energy available in the water column. As a result, they can affect ocean phytoplankton, which require light for photosynthesis. Clouds affect radiant energy in the water column in three distinct ways: 1) they reduce the total irradiance impinging on the ocean surface, 2) they change the spectral nature of the irradiance, and 3) they affect the pathways of irradiance in the water column. We investigated the net effects of clouds on phytoplankton distributions, abundances, and primary production in the global ocean using a coupled general circulation/biogeochemical/radiative model. The general ocean/atmosphere radiative model (GOARM) simulates the attenuative, spectral, and directional properties of irradiance resulting from clouds over the oceans, and the distribution of irradiance in the water column. Monthly mean surface irradiances computed from GOARM were compared to those provided by the International Satellite Cloud Climatology Project (ISCCP) for 1989-1991. Liquid water path and cloud cover were adjusted to observe resultant effects on global phytoplankton populations and primary production. The results suggested that changes in cloud properties did not affect phytoplankton significantly in areas where they were nutrient-limited, such as the central ocean gyres. In the high latitudes, 10-20% changes in phytoplankton biomasses were observed as a function of changes in cloud properties. These changes in abundance were associated with 50-100% changes in primary production. No substantial differences were observed in phytoplankton community structure as a result of clouds.

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Deep Sea Seasonality of Benthic Macrofauna in the Northern Gulf of Mexico

While it is generally accepted that seasonality has been observed in deep-sea environments, the effects of annual variations on the resident biota remain either obscure or controversial. It has been observed that the density of the polychaete and annelid macrofauna can vary between two time periods across a broad depth interval of the continental slope of the northern Gulf of Mexico (GOM). This temporal difference has been used to construct a numerical simulation that estimates variations in the amount of organic matter (POC) that is incorporated into the food chain over a typical seasonal cycle. The original macrofauna data suggest that the total POC flux and its variation in time both decline with increasing depth. This decline allows the growth rates in the model to be adjusted accordingly over the same depth interval to the predicted decline in POC delivery to the sea floor. An interdisciplinary investigation, the "Deepwater Program: Northern Gulf of Mexico Continental Slope Habitats and Benthic Ecology," has been initiated to validate the model.

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Enabling Technologies for Multi-Scale Ocean Circulation Modeling

Despite continuing improvements in computer size and speed, many contemporary problems in physical oceanographic modeling are not solvable using traditional models and methods. One such problem is the regional response of coastal ocean processes to global variability on seasonal, interannual and longer time scales. As an example, the U.S. GLOBEC program seeks to understand the impact of such climate variability on the coastal ecosystems and fisheries populations in the Northeast Pacific. The range of scales covered in this problem — from global (thousands of kilometers) to local (a kilometer or less for many important coastal transport processes) — is so enormous that brute-force approaches to their combined modeling are impractical for the near future. Nonetheless, such multi-scale ocean circulation problems may soon be amenable to "routine" treatment using a variety of newly emerging capabilities. These include ocean circulation models based upon unstructured, nested and/or adaptive grids and coordinate systems, as well as advanced methods of data assimilation. We give several examples of the research enabled utilizing these techniques, including: highly accurate process studies of upwelling and cross-shelf exchange in the presence of coastal geometry and topography; regional response of the Coastal Gulf of Alaska to interannual, basin-scale variability; and depiction of the ocean state at high resolution (~10 kilometer) using hybrid vertical coordinates and data assimilation.

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HALLIWELL, George[1], Rainer Bleck[2], Eric Chassignet[1] and Linda Smith[1]

Sensitivity of Atlantic Ocean Simulations by the HYbrid-Coordinate Ocean Model (HYCOM) to the Parameterization of Upper Ocean Mixing

A new hybrid-coordinate ocean model has been developed that employs an isopycnic vertical coordinate throughout the bulk of the ocean interior, but transitions smoothly to z-level coordinates near the ocean surface and to sigma (terrain-following) coordinates in shallow water regions. In particular, the nearsurface z-coordinate domain permits the inclusion of more sophisticated turbulence closure schemes than was possible in an isopycnic ocean model, but still preserves the advantages of isopycnic coordinates throughout the ocean interior where diapycnal mixing is relatively weak. The HYCOM has initially been equipped with the simple slab Kraus-Turner mixed layer model and with the non-slab K-Profile Parameterization (KPP) vertical mixing model to provide nearsurface boundary layer mixing. The mixing parameterizations have been tested in low-resolution Atlantic Ocean simulations driven by climatological forcing fields. The mixing schemes are evaluated by comparing HYCOM simulations to each other and to the Levitus climatology. The hybrid coordinate scheme is evaluated by comparing HYCOM simulations run with hybrid vertical coordinates to HYCOM simulations run with isopycnic coordinates. The comparisons indicate that HYCOM is performing very well. Improved realism is evident when hybrid coordinates are used instead of isopycnic coordinates, and also when KPP mixing is used instead of the Kraus-Turner slab model.

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Connection Btween Seawater Light Absorption Coefficient and Salinity in Chesapeake Bay

In many practically important cases it is necessary to estimate inherent optical properties of seawater using only available oceanographic data. Among many hydrographic parameters of seawater only salinity has significant correlation with such optical parameter as the absorption coefficient. This correlation is due to the coupling between salinity and concentration of dissolved organic matter. In order to derive dependencies between the absorption coefficient and salinity we used mooring data collected during the Cope 97 experiment in Chesapeake Bay. The derived correlation dependencies are based on hundreds of thousands of data points; these dependencies show significant correlation between salinity and optical absorption

coefficient for certain water types. The recovered absorption data were used to estimate other inherent optical properties such as scattering and backscattering coefficients and optical remote sensing reflectance. The applicability of derived relationships to remote sensing and optical modeling of seawater is discussed.

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Fresnel Light Reflection by Wavy Sea Surface

In studying light and image transfer in seawater the influence of Fresnel surface reflection is as significant as scattering and absorption phenomena. In these cases a knowledge of the reflective properties of the sea surface at different wind speeds is very important. At present, little is published about these properties. We present here results of numerical modeling of the angular reflection coefficient of sea water as a function of two directional angles, zenith angle of illumination, and wind speed. The ray-tracing computer model was developed and implemented as a FORTRAN code to generate wave slopes and elevations. In order to generate a realistic sea surface the model used the Pierson-Moskowitz and Paul Hwang wave height spectra. The values of Fresnel reflection coefficients were averaged over sea surface areas and time to produce angular distributions of reflection and transmission coefficients. The applicability of computed dependencies to radiative transfer modeling in seawater is discussed.

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Light Scattering Properties of Sand Particles Suspended in Seawater

Current models of seawater optical properties usually do not explicitly include sand (or quartz) particles. These models are good for open ocean waters and biologically stable coastal waters but fail to adequately predict optical properties of coastal waters with shallow sandy bottom. In this presentation we fill this gap by extending our previous optical model of quartz suspensions in seawater to sand particles with size parameter 20,000 and higher. In our model we consider sand as a non-absorbing scattering matter. Mie scattering calculations for quartz particles with the size parameters ranging from 48 to 20,000 were performed and published earlier. Here we extend the upper limit of sand particles size parameter from 20,000 to 100,000. To accomplish this task a special Mie scattering program was written. This program is capable of computing Mie scattering coefficients on particles with size parameters up to one billion and higher. By analyzing computed material we obtained analytical relationships that connect an efficiency factor and a backscattering probability with the size parameter for any monodisperse sand particle size distribution. These regression relationships were used to create an extremely fast algorithm to compute spectral light scattering and backscattering coefficients for any polydisperse system of sand particles.

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Impact of Photorespiration on Surface-Ocean DOC

Under normal light conditions, sinking diatomaceous aggregates act as a pump by facilitating the transfer of fixed carbon from the euphotic zone to deeper waters. In periods of high light and/or high O_2, photorespiration can short-circuit this pump by producing metabolites which can "leak" out of diatom cells and be remineralized by heterotrophs. Our research attempts to identify the correlation between leaking of dissolved organic carbon (DOC) and expression of a light-inducible gene for the T-protein of glycine decarboxylase, a key enzyme in the photorespiratory pathway. To induce photorespiration, we incubated 4 species of diatoms (*T. guillardii, L. danicus, T. weissflogii*, and *T. pseudonana*) at a normal ambient light level (140 $\mu E/m^2s$), followed by 24 hours of dark then 24 hours of intense light (~ 415 $\mu E/m^2s$). Subsamples for subsequent DOC analysis were collected from each incubation vessel at selected intervals throughout the experiment. We observed significant increases (as much as 50%) in the amount of DOC leaked by cells following exposure to high-intensity light for 3 diatom species (i.e. *T. guillardii* ΔDOC =100 μM, *L. danicus* ΔDOC=70 μM, and *T. weissflogii* ΔDOC= 60 μM). No significant changes in DOC concentration were observed for *T. pseudonana*. We observed variation between species with respect to timing of peak DOC leakage- beginning at 2 hours for *T. guillardii*, 4 hours for *L. danicus*, and 6 hours for *T. weissflogii*. Our results correlate well with those of Parker et al. which show a 2.5-fold increase in production of T-protein mRNA during the same exper-

iment. Our findings suggest photorespiration may play a significant role by affecting concentrations of DOC in the euphotic zone which may, in turn, affect current global carbon budget estimates.

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Ocean Prediction at the Naval Research Laboratory

The Oceanography Division of the Naval Research Laboratory conducts a coordinated program of research and development (R&D) supporting Navy operational ocean nowcast and prediction. This R&D covers domains from global scales down to local surf zone scales. It includes sophisticated primitive equation ocean circulation models on global, basin, and regional domains designed for the high performance computing platforms at the Naval Oceanographic Office (NAVO) and Fleet Numerical Meteorology and Oceanography Center (FNMOC). It also includes less sophisticated, but operationally relevant, models designed to run on workstations and personal computers at the Navy's regional Meteorology and Oceanography Centers (METOCCEN) as well as on-scene. These latter capabilities, while capable of stand-alone operations, are designed to also accept initial and boundary conditions available from the central site products. This paper presents first, an overview of current NRL R&D efforts in global and regional nowcast and prediction capabilities that provide these initial and boundary conditions. These efforts combine primitive equation models with optimal interpolation assimilation techniques using both in situ and satellite temperature and altimetry data. Assimilation of altimetry data via statistical models relating surface height to subsurface density structure is key to the nowcast and prediction system skill, especially for deeper water. Second, this paper presents an overview of the current, rapidly relocateable, local area nowcast and forecast capabilities for temperature, salinity, currents, and surface waves for the METOCCEN and on-scene applications.

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Dynamics of the Nearshore Branch of the Tsushima Warm Current Investigated Via HYCOM with High Horizontal Grid Resolution

A HYbrid Coordinate Ocean Model (HYCOM) has been used to simulate the circulation in the Japan/East Sea. HYCOM uses terrain-following (sigma) coordinates over the shelf region, z-levels in the mixed layer and unstratified regions, and an isopycnal coordinate system in the stratified deep water region, thereby retaining the advantages that each coordinate system has to offer. The model is forced with inflow/outflow through the straits via relaxation to monthly climatological temperature and salinity as well as a barotropic component with an annual mean of 2 Sv. ECMWF 10 m reanalysis 6 hourly wind and thermal forcing are used to force the model at the surface. Horizontal resolution ranges from 1/8 to 1/16 degree and 15 layers are used in the vertical. The simulations include a K-profile parameterization (KPP) style mixed layer which realistically reproduces the seasonal cycle of the mixed layer depth and sea surface temperature. Most of the major current systems are realistically reproduced at 1/8 degree, including separation of the East Korea Warm Current near 38°N. The Nearshore Branch (NB) of the Tsushima Warm Current appears as a robust eastern boundary current along the coast of Honshu. The primary benefit of increasing the grid resolution from 1/8 to 1/16 degree is the reversal of the flow offshore of North Korea (40-42°N) from northward (unrealistic) to southward (observed). The 1/16 degree simulations also show increased levels of eddy activity and energy. Furthermore, the shelf area near the coast of Honshu is better resolved in these simulations, and the evolved vertical structure indicates that isopycnal outcropping is the dominant mechanism for the formation of the NB during the summer when the flow is largely baroclinic. Conversely, during the winter the flow is largely barotropic and topographical influence is the dominant steering mechanism. Off the shelf, the flows are much stronger (total transport) and largely baroclinic. Simulations are planned using 1/32 degree to investigate the role of increased resolution over the shelf region and decreased frictional effects, especially the NB over the shelf.

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The Neptune Network: Potential Fisheries Applications

The proposed electric and fiber optic cabling of the Juan de Fuca plate provides fisheries scientists with unique research opportunities and challenges. Cabled monitoring networks exist at other local sites but they do not extend over the continental shelf on a defined tectonic plate. The potential of unlimited power and real time data transfer from an extensive grid of remote locations is unprecedented in fisheries research. Sensing technologies that could be connected to this network include acoustics (e.g. multibeam, multifrequency, broadband), optics, and the integration of acoustic and optic sensors on stationary or mobile platforms. A long term installation facilitates monitoring fish and macrozooplankton densities; changes in abundance including migrations through the grid; species 'habitat' preferences; stationary assessment of harvestable resources; and scale-dependent spatial and temporal distribution patterns of aquatic organisms. Primary challenges associated with deployment include the ability to locate sensors in areas of high contact rates with mobile nekton, identifying remotely sensed targets, and processing large, continuous data streams. Successful long-term monitoring of upper trophic level organisms and the surrounding environment is expected to provide insight to biological-physical interactions and the spatial and temporal scales at which they occur.

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Real-Time, Long-Term Ocean and Earth Studies at the Scale of a Tectonic Plate: NEPTUNE

For more than a century, the oceans have been studied by expeditions, supplemented in recent times by brief deployments of autonomous instruments and with satellite remote sensing. Recent developments in undersea fiber optic cables, data management tools, and sensors now make it possible to provide hard-wired observatory systems with substantial power (many kilowatts) and communication bandwidth (Gbits/s) to multiple nodes across an entire lithospheric plate. Project NEPTUNE is a plan to instrument the Juan de Fuca plate and its boundaries, in the Northeast Pacific, to allow reliable real-time observations and control of sea floor and water column experiments for several decades. The NEPTUNE capability will provide new ways of observing biological, chemical, and physical processes in the water column, on the seafloor, and in the sediments and rock beneath, and linking them together over a wide range of spatial and temporal scales (see www.neptune.washington.edu). This project will provide internet-accessible research and education opportunities in topics as diverse as ridge-crest hydrothermal systems, deep-sea biology, methane clathrate formation, seismology and plate geodynamics, sediment transport across the continental margin, carbon cycling, subseafloor geohydrology, fisheries dynamics, and marine mammal behavior.

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Wave-Coherent Structures and Turbulent Fluxes in the Marine Atmospheric Boundary Layer

Ocean waves profoundly affect the dynamics of the marine boundary layer by interacting with winds and currents. While the wave-induced Langmuir circulation in the ocean is basically described by Craik-Leibovich theory, the wave influence on the air side is regarded as much less comprehended. In particular, understanding the mechanism of coupling between the wind and the ocean waves is a remaining challenge in geophysical fluid dynamics. Phenomenological description of wind-wave interaction, if valid, would allow this interaction to be easily incorporated in coupled models of climate and weather and wave forecasting. One approach to obtain such phenomenological description is to treat the wind as a flow over a rough aerodynamic surface with all the physics of wind-wave interaction built into the drag coefficient. Large scatter of the measured drag coefficient both within and between the experiments has suggested that better insight in the underlying physics of wind-wave coupling is needed. Our analysis of data from the Marine Boundary Layers (MBL) Experiment revealed that (a) measurable wave-induced flow is responsible for the wind-waves coupling; and (b) clear critical layer effects are present in the wave-induced flow. In the light of these findings we consider an explanation for the observed drag coefficient scatter in terms of the critical layer theory.

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HWANG, Paul A.[1] and David Wang[1]

Recent Advances in Ocean Wave Measurements in Relation to Air-Sea Transfer Research

Ocean surface waves are the roughness element of the air-water interface. The directional distribution of ocean surface roughness is an important parameter in air-sea interaction and ocean remote sensing studies. The preferred representation of the ocean surface roughness properties is the directional wavenumber spectrum. Such data have become available recently thanks to advances in computer and optical measurement technologies. We present some recent developments in directional wave measurements using spatial measurement techniques. The presentation is divided into small-scale (several millimeters to several decimeters) and large-scale waves (decameter to several hundred meters). The former range represents primary contributors of surface roughness; the latter range represents the energy-containing portion of the wave spectrum. In most cases, wave measurements are associated with simultaneous acquisition of near surface air-sea parameters. For example, NRL recently developed a new scanning slope sensing and wave gauge array buoy. The system is designed to measure the directional spectrum of short surface waves of 0.004 to 1 m wavelengths. The free-drifting buoy also serves as a floating instrument platform and carries a suite of environmental sensors (above surface: 2 sonic anemometers, 1 thermometer, 1 humidity sensor; subsurface: 1 acoustic current meter, 1 thermometer, 2 pressure sensors, 2 accelerometers) and two video recorders (one above water and one subsurface). For the large-scale waves, airborne scanning lidar system provides 3D wave topography at 1.5m x 6m lateral resolution. These measurements have produced exciting new results on the bimodal directional properties of ocean waves.

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ISERN, A.R.[1], F. Anselmetti[2], P. Blum[3] and Shipboard Scientific Party

Sea Level Magnitudes and Variations Recorded by Continental Margin Sequences on the Marion Plateau, Northeast Australia: Initial Results from ODP Leg 194

Continental fragments in the western Coral Sea are relicts of Cretaceous rifting that were subsequently capped by Neogene and younger carbonates. The Marion Plateau carbonate platforms, which have grown on one of these fragments, provide an ideal location to address the magnitude, timing, and modulating effects of sea-level change and tectonics on mixed carbonate-siliciclastic continental margin sediments. A major objective of Ocean Drilling Program Leg 194 was to determine the absolute magnitude of the major middle Miocene sea level fall recorded in Marion Plateau sediments using the stratigraphic relationship between an early to middle Miocene second-order highstand carbonate platform complex and a late Miocene second-order lowstand platform. An important characteristic of this relationship is that the drillsites are essentially located in an area without intervening structural elements. Thus, subsidence of the platform affected all sites equally. In addition to sea level magnitudes, the platform and slope sediments of the Marion Plateau preserve an excellent record of sea level variations at both high and low frequencies. The correlation of high-resolution seismic images with drill core and logging data have provided a synoptic view of depositional and diagenetic processes in the Oligocene-Pleistocene mixed carbonate-siliciclastic carbonate platform setting. Preliminary results show the dominance of current-derived sedimentation on the formation of sequences in this region as well as the importance of fluids and diagenesis on the preservation of the recovered sediments.

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What Can Tritium and ^{3}He Tell Us About the Oceans?

Observations of transient tracers have provided us with many determinations of the rates of important ocean processes on large space and time scales. The incursion of bomb-produced tritium into the deep North Atlantic traces the leading edge of the global thermohaline conveyor. It provides a dramatic visualization of ocean ventilation. In combination with its stable, inert daughter ^{3}He, this tritium provides a direct measure of the propagation rate of material down the deep western boundary currents. The downward penetration of bomb tritium into the thermocline provides a direct measure of climatically important vertical motion and inter-gyre exchange. The coupling to ^{3}He can be exploited to compute the tritium-^{3}He age, a measure of the time elapsed since fluid was last at the ocean surface, which

is useful on timescales ranging from months to decades. The tritium^{3}He age can be used to study thermocline ventilation and water mass subduction, as well as subsurface circulation and mixing. In combination with geostrophic measurements, we have used tritium^{3}He dating in the North Atlantic to determine absolute velocities to 0.1 cm s^{-1}. This dating tool has also been applied to oxygen distributions to obtain oxygen utilization rates. The vertically integrated oxygen utilization curve thus determined provides us with a long-term, large space scale estimate of export primary production.

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Novel Chemical and Biological Sensors and Their Use for Interdisciplinary Ocean Science

Suites of autonomous chemical and biological sensors are rapidly becoming available for oceanographic studies. For example, sensor systems for nitrate have now been used in a variety of environments. Continuous observations of sea surface carbon dioxide have been made from TAO/TRITON buoys for nearly three years. A variety of trace metal sensors have been developed and a year-long deployment of an iron sensor has been achieved in a deep-sea hydrothermal vent. Development of species and functional group specific biological sensors is also progressing. DNA-based probes are available for a variety of phytoplankton taxa and systems for the deployment of these probes from oceanographic moorings are in development. Examples of interdiscplinary studies that have been enabled by these sensor systems will be reviewed. The issues that remain to be considered before these sensors can be utilized in global scale studies will be assessed.

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Gauging Littoral Optics for the Warfighter (GLOW): A Project for *In Situ* Validation of Navy Visibility Algorithms

Foreknowledge of underwater visibility is important to missions of U.S. Navy divers. Providing such environmental information is the responsibility of the Commander, Naval Meteorology and Oceanography Command (CNMOC). CNMOC, the Naval Research Laboratory, and Planning Systems Incorporated initiated the GLOW project to improve on CNMOC's existing capabilities by re-examining the Navy algorithms that relate optical data to visibility issues for divers. Currently this guidance is based on in-water optical measurements and applying a limiting case of contrast transmittance theory. To test and improve these methods, GLOW is conducting a series of experiments using actual in-water observations of Navy divers to validate predicted ranges. Concomitant measurements of optical properties are made as Navy divers approach targets at various depths and directions, noting the range at which the targets became visible. Results of recent GLOW experiments reveal that derived horizontal visibility predictions underestimate actual diver-observed ranges by as much as 50%. The operational importance of both swimmer depth and approach angle were also tested. Based on test results, GLOW has developed an enhanced visibility algorithm that allows for varying incident solar irradiance, optical properties, and target reflectance as well as software to aid in visualizing these effects. The new algorithm shows better agreement with diver data and is being adapted for use in Navy mission planning.

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Interannual Variability of Global Satellite Chlorophyll Patterns

Satellite remote sensing of ocean color, which began in 1978 with the launch of CZCS, provides basin scale measurements of chlorophyll concentration, an index of phytoplankton biomass. Although satellite ocean color measurements began over 20 years ago, global temporal and spatial coverage are limited. A ten year gap followed the CZCS mission and the OCTS/POLDER mission provided data for only eight months between 1996 and 1997. Currently in its fourth year of operation, SeaWiFS is adding substantially to the ocean color database. Our goal is to use data from the four ocean color sensors (CZCS, OCTS, POLDER and SeaWiFS) to assess interannual variability and determine its causes. To accomplish these objectives, imagery at 4-18 km spatial resolution is first mapped to a common global grid at 0.25 degree resolution and at monthly, and for some

years, weekly temporal resolution. Chlorophyll frequency distributions are compared to evaluate systematic algorithm biases. Chlorophyll imagery is then compared in absolute terms and using a relative index which tries to correct for bio-optical and other algorithm differences between sensor processing. In the North Atlantic, interannual variations are discussed in relation to climatic variations such as the North Atlantic Oscillation. Our tentative conclusions are that currently available data products from the four sensors cannot yet be used for quantitative comparisons in many areas of the ocean, but that the global patterns we observe by all the sensors are robust and interpretable.

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KHELIF, Djamal[1] and Carl A. Friehe[1]

Air-Sea Fluxes and Boundary-Layer Structure over the Japan/East Sea During Winter Cold-Air Outbreaks

Strong northwesterly wintertime winds resulting from the incursion of dry and cold air masses from the Eurasian continent into the Japan/East Sea (JES) known as "cold-air outbreaks" greatly enhance the air-sea interaction over the JES. In particular, an area about 150 km in diameter off Vladivostok referred to as the "Flux Center" experiences very large fluxes of momentum, sensible and latent heat. We present results of air-sea fluxes and boundary-layer aircraft measurements obtained under such conditions during the Winter 2000 JES experiment. The NPGS/CIRPAS Twin Otter aircraft was instrumented with fast-responding wind, temperature, humidity, IR sea temperature, aircraft motion, and navigation sensors. Thirteen research flights were flown from Misawa NAF, Japan, over the Japan/East Sea. Structure of the boundary layer was mapped by following an approximate streamline across the JES starting south of Vladivostok and ending on the west coast of Honshu. A dramatic growth of the internal boundary layer (IBL) and a subsequent jump or second IBL as the JES SST front was crossed were observed. The IBL warmed, moistened and lost momentum along the streamline. A grid pattern at 30 m with soundings to 1600 m was also flown to map the surface fluxes and their spatial variability and a vertical stack pattern was flown to determine the flux divergence profile in the boundary layer above the JES "Flux Center."

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A Remotely Forced Annual Signal Along the US West Coast

A high resolution model of the U.S. Pacific Coast is utilized to examine the remotely forced annual signal along the U.S. west coast. The model is a sigma coordinate formulation (the Princeton Ocean Model) with 30 levels in the vertical and 1/12 degree resolution in the horizontal. The model domain extends from 30°N to 49°N and from 115°W to 135°W and is embedded into the NRL 6-layer global layered model (NLOM) to obtain boundary information. The simulation is forced by the FNMOC Navy Operational Global Atmospheric Prediction System (NOGAPS) 12-hourly winds for 1999 and 2000. Model simulations using the NLOM fields for the period 1999-2000 as boundary conditions are compared to experiments using constant boundary information to examine the remotely forced signal. The study reveals a remotely forced annual signal of approximately 10 cm in amplitude that increases sea level along the Pacific coast during the summer period. The signal decreases in amplitude as it propagates northward, yielding only minimal effect along the Oregon coast. The effects of this remotely forced response on the California Current system are discussed.

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NPACNFS: An Experimental Real-Time North Pacific Ocean Nowcast/Forecast System

By integrating real time data, data analysis, an ocean model and data assimilation we have developed and have been running an experimental real time nowcast/forecast system for the North Pacific Ocean. Our objectives are to demonstrate the feasibility of making an ocean nowcast/forecast in real time for a basin scale ocean, to study various components of ocean nowcast/forecast system to improve the prediction capability and to provide an ocean nowcast/forecast for research and operations. The major components for the North Pacific Ocean Nowcast/Forecast System or NPACNFS are: 1. A fully 3D, data-assimilating 1/4 degree North Pacific ocean model (NPAC model) that is based on the Princeton Ocean Model (POM); 2. A statis-

tical ocean temperature/salinity analysis model MODAS or Modular Ocean Data Assimilation System (developed by M. Carnes at NRL); 3. A real-time data stream from the NRL/NAVO satellite data fusion center and from the Navy Operational Global Atmospheric Prediction System (NOGAPS) at Fleet Numerical Meteorology and Oceanography Center (FNMOC); 4. An Internet based nowcast/forecast data distribution system. For the real-time nowcast/forecast, the observational data, satellite altimeter (GFO, TOPEX/Poseidon and ERS-2) sea surface height and AVHRR sea surface temperature analyses are downloaded everyday from NAVO and processed. The 3D synthetic ocean temperature/salinity fields are then generated applying MODAS. Forcing data, the NOGAPS 12 hourly analyses and 3 hourly forecasts sea level air pressure, wind stresses, heat fluxes including solar radiation are downloaded from NOGAPS/-FNMOC and processed. The NPAC model is restarted from previous nowcast fields. Once the model is restarted, it continuously assimilates synthetic temperature/-salinity fields and is forced by the surface forcings to produce nowcast. Forecasts up to 72 hours are made with available NOGAPS forecasts. Once the nowcast/-forecast is done, various fields, plots and movies for many regions of North Pacific Ocean are distributed via an Internet website (http://www7320.nrlssc.navy.mil/-npacnfs_www/NPACNFS.html). The NPACNFS has been in experimental operation at NRL since July 1, 1999. The system is automated and has run everyday for over 1 year without major disruption. We will show the NPACNFS nowcast/forecast products and some evaluations of its capability compared to the observations. Various issues related to the real-time ocean nowcast/forecast will also be discussed.

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KONTAR, Alexei A.

Hydrodynamically Dominated Sedimentary Processes in the Black Sea

The bottom sediments of the Black Sea constitute the permanent repository for material retained by the basin that is derived from the surrounding land mass via the atmosphere, rivers, groundwater discharge and coastal erosion. We report here investigations of the energy and mass exchange sedimentary processes that determine propagation of pollution in the bottom boundary layer of the Black Sea. Special emphasis has been put on possible propagation of Chernobyl radioactive substances via physical mechanisms such as the global circulation, near-bottom gravity and turbidity currents, internal waves, large-scale eddies and chemical processes in near-bottom layer. One of the key problems in this program has been the modeling of mechanisms of the backward transport of radionuclides during bottom storms from deep water regions toward the beaches and surf zone of the Black Sea. We have investigated the near-bottom density and turbidity current diagnostics and calculation methods for the forecast of these flows on radionuclide transport. Such currents may be catastrophically powerful and may contaminate surrounding waters over tens of meters above the bottom level. The elaboration of current structure diagnostic methods based on the results of spectra analysis of suspended particle size and of current parameter distributions measurements have been performed both in depth and in time. The experimental base allowed development of diagnostic methods and mathematical models which were combined into a general model of the Chernobyl radionuclide fate in the Black Sea sediments.

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Global Salp Sightings

When present in high abundance, salp populations can produce significant fluxes out of the upper waters. The overall importance of salps in the global biological pump is impossible to assess however, because our information on their spatial and temporal distribution is so poor. It is obvious that if we must rely only on published accounts of salp swarms, we will make little or no progress towards a real understanding of the role salps play in oceanic biogeochemical processes. An objective of our investigation of salps is to enlist the assistance of the international community of oceanographers to report when they encounter salp swarms anywhere in the world. To help make reliable identification and reporting straightforward and easy for non-specialists, we have established a web site (www.salps.uconn.edu).

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Modeling of Coupling Wind and Baroclinic Currents in a Coastal Zone

A coastal area as a hydrodynamic object is a boundary zone. The neighborhood of the shore and the shallow waters result in generating processes with small time and spatial scales. Superimposed on the large-scale circulation, these processes determine the complexity of near-shore hydrodynamics. This paper studies the main mechanisms that are responsible for the formation of near-shore currents under a variety of hydrometeorological conditions. A simple parameterized mathematical model is developed for the calculations of near-shore currents. It is based on the assumptions of absence of horizontal density gradients in the boundary near-shore zone and neglect of horizontal turbulence beyond it. The model was verified by comparison with field data from Lake Ladoga. The results of calculations showed that the proposed model has most of the advantages of an analytical solution; under remarkable simplifications, it realistically describes the main mechanisms that affect the formation of near-shore currents. The calculations for two regions of Lake Ladoga were carried out reproducing vertical profiles of currents in vertically well-mixed areas as well as cases of stratification occurrence. One of the results achieved is the introduction of parameters that allow giving a quantitative definition of a near-shore zone that comes directly from a model solution as a distance on which shore impact becomes negligible. Consequently one need no longer deal with such very subjective criteria as "close/far" or "shallow/deep" to define the boundaries of near-shore zones.

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LADNER, S.D.[1], R.W. Gould, Jr.[2], R.A. Arnone[2], W.A. Goode[2], J.L. Miller[2] and W. Snyder[3]

Estimating Salinity from CDOM Absorption off Coastal New Jersey

In coastal areas, absorption by colored dissolved organic matter (CDOM) can act as a pseudo-conservative tracer of salinity, because CDOM concentration and salinity exhibit a tight, inverse correlation (both are functions of freshwater discharge). The river/bay discharge plumes are clearly visible in remote sensing ocean color imagery, which can be used to track the extent of the plume, examine temporal and spatial variability, and trace the mixing between low-salinity estuarine waters and high-salinity offshore waters. Using new coastal optical algorithms we can estimate CDOM absorption from satellite or airborne remote sensing ocean color imagery, and from these products we can subsequently estimate salinity. During July, 2000, we participated in a large field exercise at the LEO-15 site off coastal New Jersey. We collected *in situ* measurements of salinity, optical absorption, and beam attenuation coefficients using CTD and AC9 instruments in flow-through mode, and we developed relationships between CDOM absorption and salinity. We compare these results to similar analyses we performed in the Gulf of Mexico and to salinity estimates derived from an airborne microwave salinity mapper. We also present high-resolution, hyperspectral aircraft imagery from the PHILLS sensor to delineate spatial patterns in this coastal area.

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Use of the METS Methane Sensor in the Gulf of Mexico

A commercially produced solid state methane sensor (METS) from ASD Sensortechnik Gmgh (Germany) was used to obtain methane concentrations in sea water in the vicinity of methane hydrates. The use of semiconductor technology and membrane separation of methane (and other hydrocarbons) from the water column has been incorporated into the METS sensor. The response time is slow (minutes) and consequently complete equilibrium may never be reached depending upon the application of the sensor. The METS sensor was positioned on top of the forward platform of the Harbor Branch Oceanographic Institution's (HBOI) submersible, Johnson-Sea-Link I. This position enabled the sensor to be placed in the vicinity of methane hydrates. The Texas-Louisiana Shelf in the Gulf of Mexico was selected for investigation because of the existence of methane hydrates on the seafloor. The data reported here range from low µmol/l concentrations in no hydrate areas to mol/l concentrations in the vicinity of hydrates. Mussel beds and brine pools exhibited con-

centrations intermediate to these two extremes. Even though response and recovery time of the sensor can be slow when encountering high methane concentrations, interesting detail was obtained on several of the dives.

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Littoral Measurements of Bioluminescence in Temperate and Tropical Waters

Littoral bioluminescence is often found at greater intensities than encountered in the open ocean, however, few of these measurements have been published. Our studies have revealed that coastal bioluminescence (< 30 m of water depth) resembles the vertical spatial structures often encountered in deeper waters, yet, the biological-physical vertical structure is often compressed. Further, we observed that bioluminescence in San Diego Bay, Mina Salman-the Port of Sitrah (Bahrain), Pearl Harbor, Hawaii, and Mosquito Bay in Vieques Island, Puerto Rico often decreased with increasing distance from shore and with increasing depth. Large numbers of bioluminescent heterotrophic and photosynthetic dinoflagellates are the major source of coastal bioluminescence and may range from 100s to hundreds of thousand cells per liter of seawater. Within a 2-year period (1998-1999), we measured bioluminescence over a considerable range of intensities in Pearl Harbor, Hawaii (4-6e7 photons sec^{-1} ml^{-1} of seawater), Mina Salman, Bahrain, and Chinhae, S. Korea (4e9 photons sec^{-1} ml^{-1}), to approximately 4e11 photons sec^{-1} ml^{-1} seawater measured in Mosquito Bay (Bioluminescence Bay), Vieques Island. Each of these coastal and bay environments is unique physically, yet all possess similar dinoflagellate species. Other oceanographic correlations with bioluminescence in these areas will be presented.

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Bridge: Connecting Marine Science Education and Research

The Bridge <http://www.marine-ed.org/> is a unique online marine education clearinghouse that connects the K-12 education community with current marine-science information and research. Through the Bridge, K-12 teachers can access content-current and content-correct ocean science information and classroom activities. A major project emphasis is to help educators incorporate current oceanographic data into classroom instruction by linking to user-friendly oceanographic data sets. Two feature sections, "Data Tip of the Month" and "Spotlight on a Scientist," incorporate web-based data into student inquiry activities that reinforce the use of current research. Topics have included seafloor mapping, fisheries, global climate change, underwater technology and more. The Bridge also provides a forum for educators and researchers to discuss marine science education topics and questions through "Scuttlebutt," an e-mail discussion list. To assist researchers with their outreach efforts, the Bridge has posted a researchers' reference section with important information about education standards, links to sources of information useful in working with K-12 audiences and teachers, suggestions for developing web-based education materials and links to information about marine education projects with which researchers can become involved.

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LEE, Thomas N.[1], Elizabeth Johns[2], Ned Smith[3], Doug Wilson[2], Elizabeth Williams[1] and Ryan Smith[2]

Circulation and Exchange Processes Linking South Florida Coastal Waters

Recent hydrographic surveys, moored current measurements and drifter trajectories show a high degree of connectivity between the different subregions of south Florida coastal waters and with remote upstream areas of the Gulf of Mexico. The southwest Florida shelf and the Keys Atlantic coastal zone respond differently to wind forcing that is coherent over both areas due to different coastline configurations and topographic constraints. The connection between the two shelf regimes is provided by the transports through the Keys passages. Measurements show that subtidal transport variations of + 1000 to -2500 m^3/s (negative is toward the reef tract) are due to local wind forced cross-Key sea level slopes. In addition, a mean southeastward transport of about -700 m^3/s is estimated for the middle Keys that opposes the prevailing winds and appears to be related to the flow on the southwest Florida shelf, suggesting a Loop Current influence. Drifter trajectories show that there are three common pathways connecting the entire south Florida coastal system that follow the seasonal changes in wind patterns: southeastward through the passages of the middle Keys, (winter/spring); northwest with eventual entrainment

by the Loop Current, followed by transport to the Tortugas (summer/fall); and southwest to the Tortugas (fall). Advective time scales to reach the Keys coastal zone range from 1 to 6 months, that can be followed by 1 to 3 months retention in coastal eddies and counter-currents.

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Optical Variability Associated with a *Gymnodinium breve* Red Tide Event Off Northwestern Florida

Red tides of the toxic dinoflagellate *Gymnodinium breve* are commonly observed along the Florida coast. Our ability to detect and quantify these phenomena has the potential to be greatly enhanced by observations of in situ and remotely sensed optical properties. During October 2000, optical measurements were conducted in the area of a red tide bloom off the northwest Florida coast as part of the Florida ECOHAB program. Time-series sampling of the bloom was carried out over a 48 h period while tracking a surface drifter. Cells of *G. breve* accounted for the vast majority of particles visible by light microscopy. Repetitive profiles with a spectral absorption and attenuation meter (WETLabs, Inc. ac-9) revealed substantial vertical structure in attenuation and absorption that was largely attributable to *G. breve* distributions. Observed temporal variations in vertical structure were consistent with vertical migration and apparent wind-induced mixing. Our results illustrate the utility of optical measurements for characterizing red tide phenomena.

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The Nature of the Thermocline in the Coastal Zone of the Japanese Sea

Profiling and mooring measurements have been made in the coastal zone of the Peter the Great Bay of the Japanese Sea to study dynamics of internal waves. The deepening and splitting of the thermohalocline have been identified at several across-shelf sections. Deformations of the thermocline that can be associated with a hydraulic jump originated at the continental slope at distances 5-15 miles from the shelf break. A narrow horizontal seasonal thermocline that occupies a depth range between 20 and 40 m in the open sea dipped down by 20-30 m as the shelf break was approached. Sometimes a sharp thermocline thickened over the shelf break, followed by splitting into two new interfaces. Further splitting of the sub-layers between the two interfaces occurred several miles shoreward from the shelf break. Internal-wave-induced mixing within the thermocline appears to be a possible mechanism for the generation of a multi-layered thermocline in the coastal zone of the Peter the Great Bay.

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Influence of Rainfall on the Subtropical North Pacific Mixed Layer

Surface mixed layer properties were determined from more than 1200 high-resolution CTD temperature-salinity profiles, collected during 1989-1999 at the Hawaii Ocean Time-series station ALOHA (22°45'N, 158°W). A nearly-isothermal surface layer (MLD_T) was determined by the depth where potential temperature was 0.5°C less than the surface value. A nearly constant density layer (MLDρ) was defined by the depth where the anomaly of potential density was 0.14 kg m^{-3} less than the surface, equivalent to a 0.5°C change when salinity is constant. During some cruises, the MLDρ is more than 60 m shallower than MLD_T, usually during or shortly after winter storms, when MLD_T is deep. This result is likely sensitive to the phasing of heat flux, freshwater flux and wind work on the upper ocean during frontal passages associated with winter storms. The average MLD_T=65 m, while the average MLDρ=56 m, the difference being due to salinity stratification. Nearly a 20% error in the subtropical North Pacific Ocean mean mixed layer depth will be made in models which do not include salinity. Such models cannot properly distribute momentum and heat in the upper ocean on annual and longer times scales, let alone from month to month. The impact of related model errors is largest during the winter months, when strong air-sea exchanges of heat, freshwater and momentum occur, and when subduction may sequester anomalies. Models of North Pacific decadal variability will have to

accurately model the hydrological cycle, or properly parameterize its influence on ocean heat storage and circulation.

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LUKAS, Roger[1] and Fernando Santiago-Mandujano[1]

The Source Region for Eddies Influencing the Hawaii Ocean Timeseries

Mesoscale eddies are found north of the Hawaiian Islands, appearing in the Hawaii Ocean Time Series observations as anomalies in dynamic height, as well as salinity, potential vorticity, dissolved oxygen, nitrate, phosphate and silicate. The first principal component of these properties over a range of isopycnal surfaces in the pycnocline extracts a coherent signal in time, where mesoscale eddies are seen as distinct and extreme events. These characteristic water mass anomalies are used to identify possible source locations using the Levitus climatology assuming no mixing between the eddy and the environment. For each water mass property on each isopycnal surface, a particular isopleth is selected by this procedure, along with appropriate confidence intervals. A striking result is that the isopleths intersect within a relatively small region approximate 1500 km east of the Hawaiian Islands, and that the intersection region is consistent over a broad range of potential density. This suggests that there is relatively little vertical mixing within the eddies, and relatively little exchange with the environment as they propagate westward.

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LUTHER, M.E.[1], A.V. Soloviev[2] and R.H. Weisberg[1]

Internal Ttides Doppler-Shifted by Gulf Stream

As a part of the South Florida Ocean Measurement Center (SFOMC), a three-dimensional mooring array was deployed, with acoustic Doppler current profilers (ADCP) and a combination of recording temperature and temperature/ salinity sensors on each mooring, in coordination with an Ocean Surface Current Radar (OSCR). Exploratory measurements made during the first two years of SFOMC studies show a very energetic regime with variability occurring over relatively small spatial scales. In addition to what have been described as spin off eddies, modulated super-tidal oscillations with amplitudes exceeding 0.5 m/s are observed. The time scale of these oscillations is approximately 10 hours and they are modulated over time scales of a month or longer. These oscillations may be explained as internal tides generated by barotropic tidal interactions with the continental slope Doppler shifted by the mean flow of the Gulf Stream. The long period modulation of these oscillations is due to changes in stratification associated with local air-sea interaction and with lateral movements of the Gulf Stream. This superposition of very energetic, relatively high frequency/high wave number variability on the continental shelf attests to strong western boundary current-shelf interactions.

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MAFFIONE, Robert A.[1]

Remote Sensing of Optically Shallow Waters: New Challenges and Opportunities

During the past decade, remote sensing of ocean color has emerged as a powerful method for mapping surface chlorophyll distributions in the world's oceans. Much of the research emphasis in this area has been on optically deep waters, where the emerging ocean color signal consists of solar photons backscattered within the water column. In the simplest type of ocean-optical environment, so called Case 1 water, the incident shortwave solar radiation is modified chiefly by only the water itself and phytoplankton. The problem of interpreting the ocean color signal increases substantially when other "optically active" constituents are present, such as suspended sediments in coastal regions. Then there is the least studied, though increasingly important area known as optically shallow waters where the emerging spectral (i.e. color) signal includes reflected light by the bottom. Applications in remote sensing of optically shallow waters include mapping of coral reefs, seagrasses, and bathymetric surveying. But studying optically shallow environments requires new instruments and methods, high spectral and spatial resolution, and new modeling approaches. This talk will cover some of the exciting recent advances in this area and the research and technological challenges it presents.

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MAHONEY, Kevin L.[1], Steven E. Lohrenz[1], Gary J. Kirkpatrick[2] and Gary L. Fahnenstiel[3]

Mie Approximation of Light Scattering by *Gymnodinium breve* and Its Relationship to *In Situ* Scattering During A Red Tide Event

Scattering of light by particles in aquatic environments varies in relationship to particle properties including size distribution, shape and composition (refractive index). The backscattering of light strongly influences water-leaving radiance and, subsequently, remote sensing reflectance. Ideally, information about particle properties and concentrations can be derived from remotely sensed signatures. However, the contribution to backscatter by specific types of particles is difficult to measure in the field. Backscattering by particles of known characteristics can be modeled through Mie calculations for homogeneous spheres. During October 2000, a cruise was conducted during a red tide event off the northwest Florida coast as part of the Florida ECOHAB program. Measurements included spectral absorption and particle size distributions of samples dominated by the red tide organism, *Gymnodinium breve*. In addition, *in situ* total scattering and absorption were determined using a spectral absorption and attenuation meter (WETLabs, Inc. ac-9). The objective of this project was to compare Mie approximations of scattering to measurements of total in situ scattering, and to assess variability in the backscattering ratio attributable to *G. breve*. This information will be used to evaluate the potential for using remote sensing to detect red tide events.

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MARTIN, Paul J.[1]

Nesting with the NCOM Ocean Model

NCOM is a hydrostatic, free surface, baroclinic ocean model that has been developed for use in the Coupled Ocean/Atmosphere Mesoscale Prediction System (COAMPS). NCOM provides a nesting capability similar to that provided in the COAMPS atmospheric model wherein a main grid and an arbitrary number of nested grids can be calculated within the same Fortran program. This capability is enabled by passing variables into subroutines via argument lists rather than common blocks so that the same routines can be used to calculate the different ocean model grids. Boundary values for the nested grids are automatically interpolated from the coarser grids in which the nested grids are located and a number of boundary condition options are provided. Feedback is currently implemented by averaging the temperature and salinity fields from the nested grids back to the coarse grids. The application of the nesting scheme is illustrated by nesting some Mediterranean subregions within a larger simulation of the Mediterranean Sea.

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MASQUÉ, P.[1], J.K. Cochran[1], D.J. Hirschberg[1], A. Winkler[2] and D. Dethleff[2]

On the Radionuclide Transport by Sea Ice in the Arctic Ocean

Radionuclides can be incorporated into sea ice in the Arctic Ocean mainly by sediment suspension freezing in shallow waters and by atmospheric deposition during sea ice transport, and they ultimately may be released when ice melts in the Fram Strait and Barents Sea. Sea-ice sediment samples collected in the Fram Strait were analyzed for natural (^{7}Be, ^{210}Pb, ^{210}Po and ^{226}Ra) and artificial radionuclides (^{137}Cs and ^{239}Pu and ^{240}Pu). The main objective of the research was to determine the extent to which the radionuclide contents of sea ice were affected by sediment incorporated into the ice at formation or by interception of atmospheric fluxes during transport from coastal regions through the Arctic Ocean. Significant concentrations of ^{7}Be (half-life = 53 d) are present in most of the sea-ice sediment samples collected (mean = 69 Bq·kg^{-1}), which was likely added to sea ice by atmospheric deposition during transport. ^{137}Cs and 239,240Pu concentrations ranged from 2 to 18 Bq·kg^{-1} and 0.11 to 0.60 Bq·kg^{-1} respectively. ^{240}Pu/^{239}Pu atomic ratios ranged from 0.171 to 0.190 (mean = 0.183 ± 0.006), consistent with typical fallout values. Sediment grain size and mineralogical composition were examined in order to determine possible source areas for the ice-entrained sediment. Silt and clay accounted for about 80% of the sediment, with illite, chlorite and, to a lesser extent, smectite the major clay minerals. Bottom sediment cores collected from the same area were also studied in order to compare surface activities and inventories of selected radionuclides with the data obtained from the sea-ice sediments. In particular, we are evaluating whether the release of sea-ice sediment particles in ablation areas may have a significant impact on radionuclide inventories in bottom sediments.

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McFARLAND, Malcolm N.[1] and James A. Yoder[1]

Inherent Optical Properties of Narragansett Bay, Rhode Island During a Spring Bloom

The purpose of our study was to determine the spectral absorption and scattering characteristics by dissolved and particulate water constituents in Narragansett Bay, RI during a spring phytoplankton bloom. Cell densities, chlorophyll concentrations, salinity, and temperature were also measured. The profiling instrument package used to collect optical and hydrographic data contained 0.2 μm filtered and unfiltered WET Labs ac-9 absorption and attenuation meters and a Seabird SBE25 CTD. Optical and hydrographic data were collected from four stations along a north south transect on six dates between March 13 and June 21, 2000. Cell counts and chlorophyll analyses were performed weekly at one of the four stations. Results showed considerable variability in all measured parameters. Three different species of diatom were dominant at different times throughout the study period. Scattering by particles was responsible for most of the light attenuation. Absorption at 440 nm by dissolved substances was generally higher than absorption by particulate detritus and phytoplankton. Dissolved absorption at 412 nm was correlated with salinity and particulate absorption at 440 nm was correlated with chlorophyll a concentrations. The results will be discussed in relation to ocean color remote sensing.

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Future Oceanographers Should Know How to Teach

Students who are future oceanographers should learn how to teach other people their science. Scientific problems are increasingly too broad or too deep for solution by a single investigator, whether in academia, industry, or government. Scientists must work in teams to reach solutions and, therefore, must know how to "communicate," that is, "to make common," with other people. In other words, they must know how to "teach" people their science and how other people "learn" that science. For future faculty, learning how to teach is part of a growing national challenge to the traditionally narrow goals of doctoral education. A call by the National Academy of Sciences in 1995 to reshape graduate science education has been followed most recently by a call from a conference funded by The Pew Charitable Trusts to re-envision the Ph.D. Promising practices in graduate education, beyond a narrow research specialization, are proliferating. After two years of planning, the School of Oceanography, University of Washington, began a TA Preparation program in the fall of 2000. The first element is a required two-day orientation for new TAs, consisting of interactive workshops, several of which are led by graduate students who are experienced teachers. Workshops include how to relate to students, motivate students, use questions, and lead discussions. In a subsequent course, graduate students utilize microteaching. These methods are applicable in both formal and informal education.

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MEHRA, Avichal[1] and Joe McCaffrey[1]

A Distributed Marine-Environment Forecast system (DMEFS)

DMEFS is a research testbed for demonstrating the integration of various technologies and components prior to operational use as well as a framework in which to operate validated models. The focus of the DMEFS is to create an open framework for a distributed system for describing and predicting the marine environment that will accelerate the evolution of timely and accurate forecasting. The primary goals are to first focus the adaptation of distributed (scalable) computational technology into oceanic and meteorological predictions, and secondly, to shorten the model development time by expanding the collaboration among the model developers, the software engineering community and the operational end-users. The framework is extensible and is designed for rapid prototyping, validation, and deployment of legacy components (ocean models, atmospheric models, tools, etc.) as well as new models and tools. It provides an infrastructure in which numerical models of the open ocean, littoral ocean and atmosphere can be coupled to provide a nearly seamless, multi-dimensional view of a region for hindcasting, nowcasting, and forecasting. In the same infrastructure, the other simulation models can be run which use the oceanic and atmospheric parameters as input. The current status of this infrastructure along with the embedded applications will be discussed.

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MILLER, J.L.[1], D.R. Johnson[1], F.M. Pimenta[2] and E.J.D. Campos[2]

Effects of Varying Winds and River Discharge on a Large Coastal Buoyancy Jet

Salinity structure determines the density field and thus the resulting buoyancy-driven currents in regions influenced by outflow from rivers. River discharge varies relatively slowly and higher frequency atmospheric forcing can modify the associated low-frequency currents. The Naval Research Laboratory's Coastal Buoyancy Jets project has studied coastal systems with small and medium river discharge on the US east coast and has collaborated on analyses of a much larger system along the southeastern South American coast. During summer of 2000, the coastal jet driven by discharge from the Hudson River (mean fresh water discharge = 700 m^3/s) was observed to be not affected by the much smaller Mullica River discharge but was highly susceptible to upwelling winds, being essentially sheared out and destroyed by a 2-day wind event. While it re-established itself after cessation of the wind, significant offshore flux of its low salinity water and associated suspended constituents is implied. The medium sized Chesapeake jet (mean discharge = 2200 m^3/s), while obviously affected by winds, appears to be more robust. Historical observations and recent numerical results indicate that a relatively cold low-salinity coastal jet originates from the much larger Rio de la Plata (mean discharge = 20,000 m^3/s) and remains coherent for several hundred kilometers northward along the coasts of Uruguay and Brazil, even extending 2000 kilometers northward to Rio de Janeiro under favorable wind and discharge conditions.

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MOERSDORF, Paul F.[1]

National Weather Service's Marine Observation Network: Serving the Nation

The National Data Buoy Center (NDBC) of the National Weather Service (NWS) is the NOAA Center of Excellence for operational marine observations. In addition to its namesake buoys, the NDBC operates the Coastal Marine Automated Network (C-MAN), the NWS Voluntary Observing Ship (VOS) Program, and maintains the NOAA profiler network. The status (sensor suite, location, etc.) of the NDBC network will be presented as well the overall national requirements addressed at the various locations. NDBC has deployed and operates observational systems for a variety of government agencies whose missions include: (1) ensuring safe and efficient transportation of personnel and goods; (2) protecting natural resources by conducting environmental impact assessments; (3) collecting unique observations to strengthen national and international warning projects; (4) actively providing long term observation sites in accordance with climate research needs; and (5) monitoring the ocean and atmosphere in support of space launch and calibration activities. The discussion concludes with an up-to-date outlook on the future of existing observational platforms as well as the potential for new sites.

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MOOERS, Christopher N.K.[1], Inkweon Bang[1] and Shari L. Vaughan[2]

Estimation of the Circulation of Prince William Sound, Alaska

Prince William Sound (PWS) is a small (ca. 100 km square and ca. 500 m deep), semi-enclosed sea, and its circulation is under the influence of complex coastal topography and orography, tides, atmospheric forcing, runoff from snowmelt, seasonal stratification, and alongshelf flows. Numerical simulations of the PWS circulation (using the Princeton Ocean Model [POM] with 1 to 2 km resolution and 15 vertical [sigma] levels), and driven by synoptic forcing, indicate the three-dimensional complexity of the time-varying circulation, including strong seasonal changes in the vertical and horizontal structure of the circulation response to reversing alongshore winds. Observations from CTD/ADCP profiles acquired during seasonal quasi-synoptic surveys, a bottom-mounted ADCP, a moored thermistor string, WOCE drifters, NDBC buoys and C-MAN stations, and coastal tide gauges provide perspectives on the circulation and constraints on its interpretation.

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MORELL, Julio M.[1], and Jorge E. Corredor[1]

Longitudinal Distribution of Respiratory Electron Transport System Activity in Caribbean and Tropical/Subtropical Atlantic Waters

Planktonic Respiratory Electron Transport System activity (ETS) in Caribbean and Tropical/sub-tropical Atlantic surface waters exhibit marked longitudinal variations following a phytoplankton biomass gradient, largely driven by the Orinoco river plume. Integrated ETS in the upper water column (100m) presents secondary maxima downstream from the river plume as well as in the subtropical Atlantic (28°N) that result in high ETS/CHl *a* ratios. Possible explanations for the occurrence of such features and their relation to carbon sequestration rates will be presented.

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MOREY, Steven L.[1], Jorge Zavala-Hidalgo[1] and James J. O'Brien[1]

Alongshelf and Cross-Shelf Fronts in the Western Gulf of Mexico

Sharp thermal fronts oriented in both the alongshelf and the cross-shelf direction can be seen in high resolution images of sea surface temperature along the coast of Texas and Mexico. A newly developed numerical simulation of the Gulf of Mexico using the Navy Coastal Ocean Model captures these mesoscale structures remarkably well. The model is introduced and used to investigate the mechanisms responsible for the formation of the fronts and the associated cross-shelf mass exchange. The seasonal variability of the circulation in the northwest Gulf of Mexico is influential in the transport of water with contrasting temperature and salinity properties along the coast to the region where the fronts are observed. The role of decaying eddies along the shelf is examined in connection with fronts and other structures on the shelf.

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Context and Calibration: How the Long-Term Record Informs our Understanding of Modern Oceanographic Processes

Oceanographers working on short-term time scales (defined here as annual and shorter) and stratigraphers working on geologic times scales (millennial and longer) too rarely consider how each can inform the other. Short-term events affecting the supply, composition, transport, redistribution, or diagenesis of sediments potentially imprint the long-term record in significant ways, but are preserved only under a narrow range of conditions. Nonetheless, though it may be incomplete and sometimes difficult to read, the long-term record can enhance the understanding of modern processes by providing: (1) context in which the significance of modern events can be assessed, and (2) calibration of predictive models derived from short-term observations. For example, today's interglacial is an unusual time; we must go back roughly 120,000 years to find a similar balance of land-sea partition, ice budget, sea surface temperature, and other factors that we know significantly affect the earth system. Furthermore, models that incorporate processes such as precipitation, sea level, and slope failure in describing the modern system can be tested in the ancient world; there we find that the earth itself has performed countless experiments by varying these same fundamental processes in myriad ways. Significant progress in understanding how the earth works and how human activities may affect it depends on a vigorous and productive dialogue between various disciplines working across a wide range of time scales.

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Acoustic Thermometry of Ocean Climate (ATOC)

The development of acoustic tomography was a direct response to the discovery in the 1960s of the intense ocean variability at scales of 100 km and 100 days (the mesoscale); a few slowly moving platforms do not provide an adequate sampling strategy. Acoustic methods are attractive because the ocean is transparent to sound. In the 1970s the effort was directed towards mesoscale sampling, with ranges increasing from a few hundred km to 1000 km, and eventually to the antipodal distances of the Heard Island Experiment. Applications red by Spiesberger) yield average temperature profiles of the intervening waters to a precision of 5 millidegrees. The principal advantage is the suppression of the intense mesoscale "noise" which permits the detection of the climate-scale variability in the megameter averages. Concerns about the effects of the sonic transmissions on marine life have hindered the application of tomography.

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MUNK, Walter[1] and Larry Armi[1]

Spirals on the Sea

Spiral eddies were first seen in the sun glitter on the Apollo Mission 30 years ago; they have since been recorded on SAR images and in the infrared. The spirals are broadly distributed over the world oceans, 10-25 km in size and overwhelmingly cyclonic. We believe the spirals are associated with upper-ocean mixing. We present a small sample of images. To the best of our knowledge they have not been explained. We propose that frontal formations concentrate the ambient shear and surfactants into linear features. Horizontal shear instabilities ensue when the shear becomes comparable to the Coriolis frequency. The resulting vortices wind the linear features into cyclonic spirals.

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NELSON, James R.[1] and Harvey E. Seim[2]

First Year Observations from SABSOON

A variety of meteorological and oceanographic data are being collected on the continental shelf off Georgia by the South Atlantic Bight Synoptic Offshore Observational Network (SABSOON). Data are collected at offshore platforms and transmitted to shore in near-real time and made available on the project website (www.skio.peachnet.edu/ projects/sabsoon.html). Here we present examples of data collected during the first year of field deployment, some unexpected, that illustrate the range of processes being addressed using the network. Remarkably energetic downbursts have been observed in spring and summer, often associated with heavy rainfall, in which wind speed at 50 m height exceeded 40 m/s and air temperature dropped by 4°C in 6 minutes. Large variance of salinity in the winter of 2000 suggests enhanced cross-shelf exchange in the SABSOON region. This is also indicated by winter satellite imagery of SST and ocean color. ADCP current measurements show a polarization of tidal and subtidal frequency depth-averaged currents, with sub-tidal currents being correlated with wind stress. Strong cross-shelf tidal motion should efficiently generate internal waves. Continuous measurements of above-water and in-water irradiance (PAR) show the mid-shelf surface sediments are also in the euphotic zone. Chlorophyll fluorescence (stimulated) shows strong light-dependent diurnal variability in near-surface waters and evidence of resuspension of benthic diatoms during storm events, particularly in the early fall. Planned extension of the network to additional platforms that will support a NOPP-funded regional modeling effort will also be summarized.

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Cross-Margin Particulate Flux Studies Associated with NEPTUNE

The predominant path for 1010 tons/year of particulate material (sediment and associated chemical species) entering the global ocean is from continents toward the deep sea. The transport mechanisms, quantitative fluxes, and ultimate fate of this material are poorly constrained, because present observational techniques are not well suited to study the episodic and three-dimensional character of particulate transfer. However, enhanced knowledge is crucial for answering basic and applied questions about the ocean's impact on Earth processes, including the following examples. *How does cross-margin particulate flux control the architecture of continental margins? How does the transfer of sediment impact the morphologic and tectonic character of oceanic crust? How is the record of Earth processes preserved in deposits of the continental margin? How does the transfer of carbon on margins impact its burial and cycling to the atmosphere? What is the fate of anthropogenic pollutants adsorbed to sediment particles?* Cabled observatories can provide unique opportunities to address these and many other questions about cross-margin flux of particulates. Knowledge gained from such observatories would far surpass the limit of our capabilities with fixed-position (e.g. moorings, tripods) and shipboard instrumentation. The fundamental characteristics of a fiber-optic cable (power consumption, data transfer, long time series, and intervention capabilities) are especially well suited to the design of studies investigating sediment flux across margins, as demonstrated for the northern California margin near the Eel River.

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OVINOVA, N.V.[1]

CO_2 as an Indicator of Changing in Ocean Waters

Global climate changes in the atmosphere can lead to changes in the ocean circulation. As a result there may be unpredictable changes in the structure of chemical and biological fields in the world ocean with catastrophic consequences. CO_2 is involved in biochemical and hydrodynamic processes and at the same time presents the "absorption possibility" of the ocean. So it is very important to investigate scrupulously ocean CO_2 fields and their tendencies, because CO_2 is an indicator of changes and movements in water masses, and processes in the surface and deep ocean. This research requires a great database of the long period of time, at least 30-40 years. Data of Russian and US National Oceanographic Data Centers was gathered and adopted, including large masses of oceanographic data, including pH and Alk, for the Atlantic Ocean. The CDIAC (Carbon Dioxide Information and Analysis Center) data were used to compare calculated and directly measured pCO_2 for 5x5 degree boxes. The comparison of calculated and observed pCO_2 allows us to adjust historical values to the same scale and create sufficiently long series of carbon system elements. The corresponding data have been used to investigate their climatic variability in the Atlantic Ocean and to estimate CO_2 fluxes for the period 1960 -2000. Climatic maps for the North and Tropical Atlantic were constructed, long-term climatic trends, seasonal and inter-annual variations of pCO_2 were examined. Analysis of seasonal and interannual variations of pCO_2 and its relation with hydrometeorological processes was made.

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Atmospheric Forcing and Oceanic Response During Late Summer Upwelling and Relaxation Events in Monterey Bay

The air-sea interaction over the northwestern portion of Monterey Bay was studied during August 17-31, 2000 using real-time observations from an aircraft, HF radar installations, and moored acoustic Doppler current profilers (ADCPs). Ocean sea surface temperature, vector winds, air temperature, and dew point temperature were observed using a Navajo twin-engine aircraft flying at 400 ft elevation. The plane made 13 flights mostly once per day, but sometimes twice to allow comparison of the early morning and late afternoon sea-breeze conditions. Three moored ADCPs, two surface and one bottom mounted, were also deployed to examine the vertical structure of the observed features. The bottom instrument returned its data via an acoustic/RF link with no cables to the ADCP. All data were posted in real time on the web. During the first upwelling event, a cold filament tended south-south east across the mouth of the bay from the upwelling center near Point Ano Nuevo. A warm, dry, atmospheric jet of comparable scale, previously unobserved, was blowing off the Santa Cruz mountains directly above the filament. Such features may occur frequently along the California coast but have not been seen due to inadequate observing systems. During the subsequent relaxation, all the oceanic mesocale features moved shoreward, resulting in dramatic warming to over 20°C at the mouth of the bay.

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PARNAS, David Lorge[1] and Konstantin Kreyman[1]

Documenting Requirements for Software Models of Environmental Phenomena

Modern oceanographic engineering projects make use of simulation models to estimate or predict the behavior of sea systems. The models underlying the software can be complex and must take many details into consideration. It is important that the requirements for the software be precisely documented and subject to review before programming begins. The requirements for such software are usually described using a combination of natural language and mathematical equations. Such hybrid descriptions can be unclear and are sometimes misunderstood by some members of the development team. As a result of misunderstandings, the results obtained may not be correct and may cause the project to fail or incur cost overruns. The creation of a precise and complete mathematics-based requirements document, as an integral part of the model and software development process, is the only rational way to design trustworthy software for science and engineering. This paper introduces a new five-variable model for documenting requirements and illustrates it using a simple time-dependent contaminant diffusion problem. In the

example, tabular mathematical expressions (Parnas, 1992) are used to increase the readability of the software requirements document for a simple program that computes the penetration of radioactive contamination in deep water. The proposed approach decreases the likelihood that serious errors are introduced during the earliest phases of the software development process. It will also improve communication between the engineers, scientists, and programmers working on the project.

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PATTERSON, Karen W.[1], Rory K. Toon[1], Christopher L. Carroll[1] and Richard K. Myrick[1]

Characterization of the Underwater Optical Environment by the Naval Oceanographic Office: Comparisons Between the *a*-βeta Sensor, LSS6000 and ac-9

The Naval Oceanographic Office (NAVOCEANO) has added an *a*-βeta instrument from HOBI Labs, Inc. as its newest tool in characterizing inherent and apparent optical properties in the marine environment. The *a*-βeta is designed to measure *in situ* radiance diffuse attenuation (K_L) and the volume scattering function (β) at an angle of 140°, from which absorption (*a*) and optical backscatter (b_b) at 532 nm are derived. These measurements are important in determining diver visibility, LIDAR performance, and underwater obstacle detection and identification. In September and October 2000, NAVOCEANO deployed the *a*-βeta in the Gulf of Oman and Persian Gulf on an optics package with two WetLabs ac-9's and a Sea Tech LSS6000. All data were processed using procedures recommended by the respective manufacturer. The measured inherent optical properties from the *a*-βeta, ac-9 and LSS6000 were compared. Preliminary results show that the K_L values from the *a*-βeta correlate with ac-9 beam attenuation (c) at a wavelength of 532nm. Additionally, it is apparent that more research needs to be done in order to accurately interpret *a*-βeta measurements in turbid waters containing high inorganic sediment loads.

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Tides, Internal Waves and Ocean Mixing

The wind, sun and tides provide the energy to drive the general circulation of the ocean. The dissipation of this energy occurs at microscales. The pathways by which energy "cascades" from large to small scales remain unclear. The ocean internal wave field also draws energy from the tide and the winds as well as from the larger scale flows. Internal waves are responsible for the bulk of the shear observed in the sea and shear is thought to be associated with dissipation. Is the energy cascade within the wavefield an integral aspect of general circulation energetics, or is it a separate parallel track? Do internal wave shears catalyze energy loss from the larger scale flows, or visa versa? To track the cross-scale flow of energy, experiments and instruments which span a wide range of space-time scales are called for. One such experiment, HOME (the Hawaii Ocean Mixing Experiment), is now taking place. HOME is focused on the energy transfer from the barotropic to the baroclinic tide that occurs along the Hawaiian Ridge, and the subsequent propagation, interaction and dissipation of the internal tide. The goal is to understand the physics of these processes sufficiently that the results can be generalized to other mixing sites, globally. HOME is a cooperative effort involving over 20 investigators from 6 institutions. An initial survey of the Hawaiian Ridge, identifying regions of high wave energy and turbulence, has been completed. Coming experiments will document the large-scale energetics of the tide at the Ridge (Farfield-fall 2001) and the local details of generation and cascade processes (Nearfield-fall 2002).

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PIONTKOVSKI, S.[1], R. Williams[2], Yu Tokarev[3], A. Mishonov[4] and Z. Finenko[3]

Planktonic Fields of the Tropical Atlantic Ocean: Spatial Heterogeneity and Physical-Biological Coupling

International cooperation in the recent years, between oceanographic centers in Ukraine, USA, Russia, and United Kingdom, has enabled us to synthesize a large part of the biological data obtained from expeditions carried out by the Former Soviet Union Academy of Sciences in the tropical latitudes of the world's oceans between 1960 to 1989. In the case of the Atlantic Ocean, the database has over 1000 chlorophyll "a" vertical profiles, 500 primary production (by ^{14}C) onboard meas-

urements, 1000 mesozooplankton net hauls processed to the species level, and 4000 vertical profiles of bioluminescence intensity, collected within the upper 200 m layer. Biological sampling was accompanied by CTD casts, oxygen, nitrates, nitrites, and phosphate measurements. Macroscale and mesoscale patterns of chlorophyll "a", mesozooplankton abundance, copepod species diversity, and bioluminescence intensity are discussed and related to the dynamical topography (water mass dynamics), temperature and salinity fields.

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PIONTKOVSKI, S.[1] and R. Williams[2]

Zooplankton Aabundance, Species Diversity and Climate Change in the Tropical Atlantic Ocean in Comparison to Northern Latitudes

Compared to northern latitudes, where good sampling coverage has been achieved in the framework of recent national and international projects, trends of interannual variability of mesozooplankton in the tropical regions of the open ocean are still poorly sampled. An attempt was undertaken to amalgamate and analyze the data of 19 expeditions carried out by the Former Soviet Union Academy of Sciences to the tropical Atlantic Ocean in 1961 to 1989. Interannual changes of mesozooplankton abundance and species diversity indices were related to the spatial-temporal characteristics of the atmospheric pressure systems. Zooplankton patterns obtained for the tropical latitudes were compared to those from the Gulf of Maine (1961-1991), the northeastern Atlantic (1961-1994), the North Sea (1961-1994), and the Baltic Sea (1959-1997).

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Upper Thermal Structure of the Adriatic and Northern Ionian Seas as Measured by a Lagrangian Profiler in 1995 and 1996

A Profiling Autonomous Lagrangian Circulation Explorer (PALACE) was deployed twice in the Strait of Otranto (entrance of the Adriatic Sea) to measure intermediate currents and temperature profiles in the upper water column. The profiling float was programmed according to the following repetitive cycle: drift at 300 or 400 m nominal depth for about 51 hours followed by about 21 hours at surface in order to be located by, and relay data to, the Argos satellite system. Temperature data were collected during each ascent between 333 m and the surface with 3 m vertical resolution. The PALACE was first deployed on 18 May 1995 in the eastern Strait of Otranto. It was subsequently recovered in the northern Ionian Sea on 26 August 1996. After maintenance, the same float was redeployed at the same location in the Strait of Otranto in November 1995 and provided data in the Adriatic Sea until December 1996. Over 150 temperature profiles were acquired. The PALACE temperature data delineate clearly the seasonal development of the thermocline and upper mixed layer, with the former reaching a maximum depth near 50 m in late summer and fall. Superimposed on this seasonal trend, temperature variations at scales between 5 and 10 days can be seen. Their relation to the variable synoptic atmospheric forcing and to the local mesoscale oceanographic features is studied.

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PRELLER, Ruth H.[1], Pamela G. Posey[1] and Gretchen Dawson[1]

An Evaluation of the U.S. Navy's Globally Relocatable Tide Model on the United States Eastern Coast

The Naval Research Laboratory has developed a PC-based, globally relocatable tide prediction capability. This prediction system, called PCTides, consists of a barotropic ocean model that can be run in either a 2-dimensional or a 3-dimensional form. Surface winds and pressures and/or astronomical forcing drive the model. A global tide model, the Finite Element Solutions 95.1/2.1 (FES95.1/2.1) is used to provide tidal conditions at the open boundaries. All databases, except for the wind forcing, are internal to the PCTides system. These include: 1) the bathymetry, a 3-minute interpolated version of DBDBV, 2) the FES95.1/2.1 solutions and 3) tidal station data from the International Hydrographic Office (IHO) database. The IHO data is used for either model validation or for data assimila-

tion. PCTides was adapted to the eastern coast of the United States and run for a 30-day test period. PCTides generated a 48-hour forecast each day using wind and surface pressure forcing from the Navy Operational Global Atmospheric Prediction System. Tidal height forecasts were evaluated against observations at 12 select points along the eastern coast of the United States. The output of the PCTides system will be presented in two formats. Sample daily plots of the 48-hour forecast tidal height deviations at each evaluation point versus the NOAA observations are shown. Statistics of the model versus observations (mean error in both amplitude and phase, using the timing of the minimum/maximum of the tidal heights) are presented in tabular format.

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PRELLER, Ruth H.[1], Pamela G. Posey[1] and Gretchen Dawson[1]

An Evaluation of the U.S. Navy's Globally Relocatable Tide Model on the Western Coast of the United States

The Naval Research Laboratory has developed a PC-based, globally relocatable tide prediction capability. This prediction system, called PCTides, consists of a barotropic ocean model that can be run in either a 2-dimensional or a 3-dimensional form. Surface winds and pressures and/or astronomical forcing drive the model. A global tide model, the Finite Element Solutions 95.1/2.1 (FES95.1/2.1) is used to provide tidal conditions at the open boundaries. All databases, except for the wind forcing, are internal to the PCTides system. These include: 1) the bathymetry, a 3-minute interpolated version of DBDBV; 2) the FES95.1/2.1 solutions and; 3) tidal station data from the International Hydrographic Office (IHO) database. The IHO data are used for either model validation or for data assimilation. PCTides was adapted to the western coast of the United States and run for a 30-day test period. This is a complementary study to a previous exercise that was performed along the eastern coast of the United States. As in the east coast study, PCTides for the west coast also generated a 48-hour forecast each day using wind and surface pressure forcing from the Navy Operational Global Atmospheric Prediction System. Tidal height forecasts were evaluated against observations at 4 select points along the western coast of the United States. The output of the PCTides system will be presented in two formats. Sample daily plots of the 48-hour forecast tidal height deviations at each evaluation point versus the NOAA observations are shown. Statistics of the model versus observations (mean error in both amplitude and phase, using the timing of the minimum/maximum of the tidal heights) are presented in tabular format.

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Oceanographic LIDAR Analysis: Establishing Quantitative Relationships Between the KSS and *In Situ* Measurements of Bio-Optical Properties in Coastal and Open Ocean Waters

A LIDAR (Light Detection and Ranging) system has been developed to acquire mesoscale data sets of ocean water clarity. The K-meter Survey System (KSS) transmits linearly polarized light and receives both cross-polarized and unpolarized returns at 532 nm. The slope of the KSS backscatter signal defines the system attenuation coefficient (K_{sys}), an apparent optical property analogous to the vertical diffuse attenuation coefficient (K_d). The KSS has demonstrated a sensitivity to different water types. Changes in water column absorption, attenuation, and bulk chlorophyll *a* fluorescence are reflected in the decay rate, absolute amplitude, and polarization of the return signal. A primary program objective is to utilize the KSS apparent optical property data to deduce the inherent optical properties within surveyed regions, and ultimately, to establish predictive capabilities for characterizing dynamic underwater light fields. This work presents a quantitative analysis of the KSS LIDAR return signals relative to ambient biological and hydrographic features and defines the relationship between the Ksys parameter and independent, *in situ* measurements of K_d and the suite of inherent optical properties (volume scattering coefficient, β140°; back scattering coefficient, b_b; beam attenuation coefficient, *c*; absorption coefficient, a) made with instruments marketed by HOBI Labs (Watsonville, California) and WET Labs (Philomath, Oregon).

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Tropical Instability Wave Variability in the Central Tropical Pacific

Shipboard ADCP measurements of currents in the Central Tropical Pacific are being continuously accumulated by numerous oceanographic cruises, most notably those of the TOGA-TAO mooring maintenance program. The data set now amounts to nine years of high-quality data scattered in latitude, longitude, and time. Removal of the first-order zonal structure through a fitted zonal trend allows us to obtain a robust monthly composite estimate of the seasonal cycle as a function of latitude and depth. Removal of this seasonal cycle from the data leaves residuals that include the interannual variability and higher-frequency variability such as instability waves. Although the data are too sparse to track the interannual variability of currents with high fidelity, the intense contrast of the 1997/1998 ENSO warm/cold phases provides a higher signal/noise ratio. This allows us to compare the ocean in a low shear, low instability wave activity state with a high shear, high activity state. Composites of these two states are analyzed using the 2-D linear stability model of Proehl (1996) to elucidate the relationship between the structure and dynamics of the instability waves and the larger current structures which engender them.

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A Real-Time 1/16° Global Ocean Nowcast/Forecast System

An eddy-resolving global ocean nowcast/forecast system has been developed at the Naval Research Laboratory (NRL). The system uses a 7 layer Navy Layered Ocean Model (NLOM) with 1/16° resolution and is running in real time at the Naval Oceanographic Office (NAVO). The large size of the model (4096x2304x7) and operational requirements makes it necessary to use a computationally efficient assimilation scheme. Satellite altimeter data from Topex/Poseidon, ERS-2 and soon Geosat-Follow-on provided by NAVO's Altimeter Data Fusion Center (ADFC) are assimilated into the model. The method of assimilation is an incremental updating technique which includes: an OI deviation analysis, a statistical inference of lower layer corrections determined from the surface observations as well as a geostrophic correction to the velocities outside of the equatorial region. The sea surface temperature is relaxed to the daily Modular Ocean Data Assimilation System (MODAS) SST analysis. The results from the model are routinely used for ocean front and eddy analyses and prediction. The forecast skill of the model is being verified by comparing the forecast model to the analysis as soon as it becomes available. The results show that the model has predictive skill of the mesoscale variability for at least one month. Real-time results from the model can be viewed at the NRL web site http://www7320.nrlssc.navy.mil/global_nlom.

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REVEL Project – Research and Education: Volcanoes, Exploration and Life

The REVEL Project integrates science teachers into research to study the spectrum of processes associated with submarine volcanoes. Since 1996, 47 science teachers have explored the nature of mid-ocean ridge volcanism and the life it supports during cruises along the Juan de Fuca spreading center. Including educators into the scientific process through direct interaction with scientists on board research cruises is the focus of the program. Through seagoing and research experiences, educators inject into classrooms the issues and ideas associated with deep-sea research. They share the real approaches, successes, failures and tenacity that are the integral components of research into the unknown. Major by-products of the program are the overwhelming enthusiasm of teachers and scientists involved, and their lasting commitment for spreading the materials and insights gained in REVEL within their communities. Each educator teaches an average of 150 students per year, gives presentations at local, regional and national conferences and collaborates with colleagues to integrate their experience into teaching activities. The "ripple effect" of these personal experiences reaches far beyond the classrooms. It exposes thousands of students and hundreds of teachers to the scientific process and the excitement of interdisciplinary exploration of the deep crustal processes supporting extensive microbial activity within the volcanically

active portions of the earth. The REVEL project is gradually developing an extended community of students, teachers and researchers who work together to ensure the successful translation of scientific research to the public, http://www.ocean.washington.edu/-outreach/revel.

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Plankton Community Respiration During a Coccolithophore Bloom

In order to budget the oceanic carbon cycle, it is necessary to understand the ecological factors controlling the variability of photosynthesis and respiration. However, in contrast to photosynthesis, representative respiration data for all major plankton populations are lacking. The coccolithophore *Emiliania huxleyi* forms spatially extensive blooms which can significantly affect the air-sea exchange of CO_2 and production of dimethyl sulphide. Yet an insufficient amount is known about the causes of these blooms or of the activity of the microbial communities associated with them. The multidisciplinary Lagrangian study DISCO (**DI**methyl **S**ulphide Biogeochemistry within a **CO**ccolithophore bloom) aimed to progress understanding of the cycling of DMS during a naturally occurring *E. huxleyi* bloom. Our specific objective within this program was to investigate the variability of community respiration and relate this to bacterial, algal and microzooplankton activity. On 16 June 1999, a 40 km^2 bloom of *E. huxleyi* was tagged with sulphur hexafluoride at ~ 59 °N 2 °E and sampled for 10 days. Community respiration remained relatively constant with surface values ranging from 2 to 4 mmol O_2 m^{-3} d^{-1}. Bacterial growth efficiencies (~ 17%) were derived from incubations of 0.8 µm filtered seawater, and used to calculate the percentage of community respiration attributable to bacterial activity (~ 20%). This apportionment of community respiration to trophic group is discussed in comparison to previous studies in non- coccolithophorid waters.

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ROCHFORD, Peter A.[1], A. Birol Kara[2], Alan J. Wallcraft[1] and Robert A. Arnone[1]

Is Subsurface Solar Heating Important for an Ocean General Circulation Model?

The importance of subsurface heating on surface mixed layer properties in an ocean general circulation model (OGCM) is examined using attenuation of solar irradiance with depth below the ocean surface. The depth-dependent attenuation of subsurface heating is given by global monthly-mean fields for the attenuation of Photosynthetically Available irRadiance (PAR) [k(PAR)]. These global fields of k(PAR) are derived from Sea-viewing Wide Field-of-view Sensor (SeaWiFS) data on the spectral diffuse attenuation coefficient at 490nm [k(490)], and have been processed to have the smoothly-varying and continuous coverage necessary for use in OGCM applications. These monthly fields provide the first complete global datasets of subsurface optical fields that can be used in OGCM applications. Using the monthly-mean k(PAR) fields and a monthly PAR climatology, the effect of including subsurface heating in a global OGCM is examined in terms of the model's prediction of sea surface temperature (SST) and surface mixed layer depth (MLD). It is found that subsurface heating yields a marked increase in the SST predictive skill of the OGCM at low latitudes. Use of the monthly-mean k(PAR) reduces the annual mean SST by up to 0.8°C, and negligibly increases MLD on climatological time scales, with this primarily confined to the equatorial regions.

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Oceanographic Conditions in the Eastern Southeast Pacific Region During 1999 and 2000

Since 1999, the Chilean Navy Hydrographic and Oceanographic Service (SHOA) have performed eight cruises offshore the coast of Chile aboard the research vessel AGOR 60 Vidal Gormaz. The cruises analyzed are: one cruise spanning from 30° S to 33° S and from the coast to 73° W (Valparaiso-Coquimbo) where 52 CTD stations were performed in seven offshore sections, four ENOS cruises consisting each one of one offshore section of 13 CTD stations and three cruises spanning from 33° S to 36.2° S and from the coast to 74° W (Valparaiso-Talcahuano Norte y Sur) where an aver-

age of 40 CTD stations were performed in five to seven offshore sections from the coast. The cruises have been carried out to comply with a long-term goal of SHOA, i.e. to monitor, on an interannual and spatial scale, the thermohaline structure and variability of the Humboldt current as well as to monitor the low frequency variability of water masses and baroclinic structure of the flow, as an effort to keep track of the evolution of the oceanographic conditions related to El Niño (ENOS) or La Niña phenomena. In this study, sections and levels of temperature, salinity and oxygen data, geostrophic velocity sections as well as T-S curves for all the cruises, will be used to characterize the oceanographic conditions offshore the Chilean coast for the period considered.

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Differential mixing of salt and heat by breaking internal waves

In the ocean, it is generally assumed that the effective diffusivity of heat and salt due to turbulence produced by breaking internal waves is the same even though the molecular diffusivities of the two are different by a factor of 100. Gargett and Holloway (1992) found that unequal diffusivities can cause major changes in thermohaline circulation in an oceanic General Circulation Model. Laboratory studies of low-Reynolds-number grid-generated turbulence with interfacial entrainment have shown that the effective mixing rates of salt and heat are different. Is the effective mixing of salt and heat different for turbulence generated by breaking internal waves? We reproduced an elegant laboratory experiment from McEwan (1983) in which the gravest internal wave mode was forced at resonance by a paddle, and weak nonlinear triad interactions transferred this energy to higher modes. This created quasi-random overturns and turbulent mixing in the interior of the linearly stratified working fluid. The mixing was measured using two fluorescent tracers having different molecular diffusivities that were introduced together in a thin layer. Preliminary analysis of the results finds systematic differences between the effective turbulent diffusivities of each tracer. Assimilation techniques are currently being applied to obtain more accurate estimates, with error bars, of the turbulent diffusivities.

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Effects of Surface Microlayer and Sediment Water Interface Layer on the Nutrient Species in the Eastern Harbor of Alexandria

The Eastern Harbor (EH), a small shallow semicircular basin surrounded by Alexandria, has an area of 2.53 million m^2, with an average depth of 6.5 m and water volume of 16.44 million m^3. It is sheltered from the Mediterranean Sea by a water break leaving two openings through which the harbor water is connected to the open seawater. The EH is mainly influenced by sewage disposal from Alexandria. Water samples were collected seasonally at three selected stations from the surface microlayer (SML) to sediment water interface layer (SWIL) for studying the effects of SML and SWIL on the distribution of nutrient species in the rest of the water column, the middle water layer (MWL). Contrary to nitrate and particulate nitrogen, the annual means of the rest of the parameters (nitrite, ammonium, dissolved organic nitrogen, dissolved inorganic, organic and particulate phosphorus and silicate) in the SML were higher than the corresponding means in the SWIL, confirming that contribution of these nutrient species from the SML to the MWL was more than that from the SWIL to the MWL, which generally gave intermediate annual means. Accordingly, it could be concluded that most of the nutrient species in the EH originated mainly from an allochthonous source (untreated domestic wastes) floating over the surface harbor water rather than from the autochthonous sources:decomposition of organic remains and release from the harbor sediments.

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Anthropogenic Tracers in the Pacific Ocean

As a part of the JGOFS synthesis and modeling project researchers have been working to synthesize the WOCE/JGOFS/NOAA global carbon survey data to better understand carbon cycling in the oceans. Working with international investigators we have compiled a Pacific Ocean data set with over 36,000

unique sample locations analyzed for at least two carbon parameters. These data are being used to estimate the distribution of anthropogenic CO_2 in the Pacific using the ΔC^* technique. Parallel U.S. WOCE programs, conducted on the same cruises, have investigated the distributions of other anthropogenic tracers (e.g. chlorofluorocarbons and radiocarbon). This study will examine the distribution of anthropogenic CO_2 recently estimated for the Pacific Ocean. The observed trends will be compared and contrasted with observed CFC and bomb ^{14}C distributions in the Pacific. These three anthropogenic tracers have many similarities that are generally related to the large-scale circulation features in the Pacific. There are also several significant differences. Many of these differences can be attributed to the different atmospheric histories and equilibration times.

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Using the Long-term Ecosystem Observatory for Rapid Environmental Assessment in Coastal Waters

A multi-platform inter-disciplinary observation network has been operating at the Rutgers University Long-term Ecosystem Observatory (LEO) since 1996, with real-time capabilities beginning in July 1999. The network integrates numerous remote (satellites and shore- based), stationary (surface and subsurface), moveable (ships and AUVs) observation systems. The observation network provides spatially extensive updates of the physics, optics, chemistry and biology on time scales of an hour or better which are communicated in real-time to shipboard scientists and AUV operators. This rapid environmental assessment capability is changing current paradigms for ocean adaptive sampling strategies. For example, in the well-sampled ocean, where forecast errors are dominated by uncertainties in the model physics or future boundary conditions rather than initial conditions, ensemble forecasts with differing model parameterizations can be used to identify regions in which additional data can be used to keep a model on track. Furthermore these approaches are key for sampling episodic events that play a disproportionately large role in driving the biogeochemistry of the coastal ocean. Results from the 1999 and 2000 seasons demonstrate this utility of the LEO network to identify, track and sample small-scale (10 m) features that would go unnoticed with traditional sampling approaches. For example, during HyCODE 2000, aircraft were used to find small slicks of red-tide. These observations combined with the surface current CODAR measurements were used to adjust and successfully maneuver ships that were outfitted with bio-optical instrumentation. The red-tides were bioluminescent *Ceratium fusus* that were located in a surface convergence zone along a southward flowing alongshore jet of low saline water and tidally-dominated onshore flow. The feature was dramatically impacted by tidal forcing with convergence at high tide and dispersion at low tide. These findings illustrate the potential for ocean observatories to delineate processes poorly sampled using traditional techniques.

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A Climatological Comparison of Satellite and *In Situ* Chlorophyll Data in Continental Shelf and Slope Waters off the U.S. Northeast Coast

We compared monthly climatologies of Coastal Zone Color Scanner (CZCS) and SeaWiFS chlorophyll with more than 20,000 in situ observations in shelf and slope waters off the U.S. northeast coast to determine if all three data sets showed consistent spatial and temporal patterns. We also examined the corresponding sea-surface temperatures (SST) imagery to help determine if differences between CZCS and SeaWiFS chlorophyll patterns could be attributed to changes in physical forcing. We used the empirical orthogonal function (EOF) method to separate the data into spatial functions and time-varying amplitudes. In all 3 data sets, more than 98% of the variability is contained in the seasonal signal. The data were then reanalyzed after first removing the temporal and spatial means to emphasize smaller scale patterns and time scales other than seasonal. The results of the second analyses showed that the first four EOF modes contain more than 75% of the variability. All three data sets showed similar patterns in mode 1, but with CZCS the noisiest and diverging from the

other two at higher modes. By normalizing and calculating EOFs on the combined ocean color and temperature data sets, we were able to determine that satellite chlorophyll and SST have similar patterns implying similar forcing mechanisms.

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Can We Measure Things Accurately in Global Ocean Biogeochemical Studies?

Accurate analytical measurements are critical for large scale global biogeochemical research. In many previous large studies, analytical uniformity was achieved by having a single laboratory responsible for "core" measurements. When multiple laboratories carry out analyses for a parameter, there has been less success of the same "thing" being measured by all involved. There is a larger potential problem when programs extend over long periods of time with involvement from large numbers of institutions from many nations. With the JGOFS and WOCE programs, efforts were made to calibrate carbon measurements. A uniform method and certified reference materials were established for measurement of total carbon dioxide early in the field efforts of both programs. However, for dissolved organic carbon, efforts were made to better control and improve the measurement only part way through the field efforts and the time series stations. This presentation will address background in uniform chemical measurements in seawater in general and current efforts for carbon and nitrogen measurements specifically. The balance between developing community analytical comparability and urgency to get field programs underway will be discussed. Although we have had some success in the recent past, a determined commitment is necessary to achieve uniformity in biogeochemical measurements for global change assessment.

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Early Detection of Tropical Cyclones Using Seawinds-Derived Vorticity

A method of detecting tropical cyclones (TCs) in the Atlantic hurricane basin is developed using the SeaWinds scatterometer aboard the QuikSCAT satellite. The method is based on finding positive vorticity signals greater than a minimum size and magnitude within the swath of vector wind observations. The thresholds applied herein are subjectively derived from the TCs of the 1999 Atlantic hurricane season. The thresholds are applied to two sets of data for the 2000 season: research quality data and near real time (<3 hour delay) data (available from 18 August to 16 October 2000). For the 2000 research-quality data, 10 of 19 TCs are found an average of 23 hours before the National Hurricane Center classified them as TCs. For the near real time data 5 of 13 TCs were found an average of 32 hours before. The SeaWinds scatterometer is a powerful new tool that will improve early detection of TCs.

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Submesoscale Coastal Ocean Flows Detected by VHF Radar and AUV Technology

To understand the role of small-scale physical processes in the coastal ocean, the approach combines the Autonomous Underwater Vehicle (AUV) technology with the RSMAS Ocean Surface Current Radar (OSCR). The engineering part of the research seeks to develop, integrate and test instrumentation designed to measure subsurface current structure from a 1.2MHz workhorse ADCP on the AUV. The scientific focus of the research is to observe and understand the multi-dimensional flow structures in the coastal regime by relating subsurface to surface current structure. The OSCR radar system (Very High Frequency mode-49.9MHz) was deployed from late June to early August 1999 at the South Florida Ocean Measurement Center (SFOMC) to measure the surface current field. Subsurface current and density data were acquired on several AUV missions (6 to 24 hr) during July 1999 and on subsurface moorings in the SFOMC. During the AUV missions, repeated snapshots were observed over 1 to 2 hr intervals. At 20 min sample intervals, radar-derived surface currents (at 250 m resolution) revealed submesoscale vortices, frontal lobe-like structures, and Florida Current intrusions over the shelf break. Aerial-averaged AUV current profiler measurements at 3 to 4 m beneath the surface were correlated to the surface currents with RMS differences ranging from 5 to 20 cm s^{-1} from differing snapshots. Current direction differences suggest an anticyclonic veering of the current with depth that was more pro-

nounced during periods when the Florida Current was well offshore. The corresponding CTD measurements at 8 to 9 m beneath the surface indicated complicated water masses over the narrow shelf when more velocity structure (shear) was observed. By contrast, the current structure was more vertically uniform in the shallow water (<50 m) during intrusions of the Florida Current. In addition to providing new insights into the coastal ocean response over a narrow shelf subjected to strong western boundary current interactions, the aerial averaging of the subsurface current measurements were correlated to the radar-derived surface current field at this high resolution.

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Access Ocean Color Data from Goddard Earth Sciences DISC

The Goddard Earth Sciences Data and Information Services Center (GES DISC) archives and distributes ocean color data sets obtained from different satellite mission. Ocean color data have been used to study marine optical properties, biological productivity, and air-sea interaction, etc. One quality data set was obtained from the Sea-viewing Wide Field-of-view Sensor (SeaWiFS) on OrbView-2 satellite from September 1997 to present, available with two weeks delay from real time. Another data set was acquired by the Coastal Zone Color Scanner (CZCS) on Nimbus-7 for the time range October 1978 - June 1986. The GES DISC also archives ocean products from the Moderate Resolution Imaging Spectroradiometer (MODIS) on the TERRA. Ocean color data are widely used by researchers. Currently, there are more than 1,500 users at the GES DISC from 71 different countries. For SeaWiFS data only, the GES DISC has distributed more than 23 TB data by the end of December 2000. Ocean color data can be accessed through the GES DISC home page, URL: http://daac.gsfc.nasa.gov . For questions regarding the data, please contact our data support staff at ocean@daac.gsfc.nasa.gov or GES DISC help desk at 301-614-5224 or E-mail: daacuso@daac.gsfc.nasa.gov

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Real-Time, Long-Term Ecological Studies in the Deep Ocean

Establishment of an extensive network of fiber-optic cables with real-time connection to shore-based laboratories and covering a variety of diverse bio- and bathygeographic regions from the continental slope and abyssal plain to submarine canyons and seamounts (NEPTUNE) is very attractive for conducting long-term ecological studies in the deep ocean. Nodes in the cable network would serve as attachment points from which instrumentation can be operated to accommodate specific measurements. Given the unique capabilities of such a network, we identified six critical questions in deep-sea ecology that would be uniquely addressed through long-term monitoring: 1) What are the spatial and temporal dynamics of deep-sea community structure in terms of species composition, abundance, biomass, interactions, and diversity?; 2) What are the patterns of succession in deep-sea communities and how are they regulated by biotic and abiotic factors?; 3) What is the importance of vertical and lateral movements of deep-sea animals in the transport of nutrients through the water column and across the continental margin?; 4) What is the influence of a spatially and temporally variable food supply on deep-sea communities?; 5) What are the temporal and spatial influences of natural and anthropogenic perturbations on deep-sea communities, and; 6) How does the productivity of chemosynthetic systems influence surrounding deep-sea communities? We present currently available technology and new technology needed to address each of these questions. Realization of NEPTUNE will provide unprecedented opportunities to study the structure and dynamics of deep-sea populations and communities on broad spatial and temporal scales.

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Observations of Short, Stationary Waves Near a Beach

During July 2000 we collected time series of photographic images over a shoaling wave field near Duck, NC. The image field subtends an area of approximately 1 km square. The images are re-mapped onto the Army Field Research Facility coordinate system, a rectilinear system. The mapping results in an RMS registration error of 1-2 meters. Each photo sequence contains 12 images, spaced 2 seconds apart. Each sequence was averaged over the 12 images in order to remove gravity waves. These averages would then yield any time-independent effects such as lens vignetting that might affect the imagery. The averages, in fact, revealed a field of short (about 15 m wavelength) waves that were apparently stationary. The waves appeared shoreward and seaward of the principal sand bar, located in 4 m of water. The waves were imaged on 21 July, after the passage of a cold front. Significant wave height was about 90 cm. Averaged images obtained on the afternoon of 22 July, however, showed no stationary waves. The SWH had decreased to 60 cm by this date. The cause of such stationary waves is not known. One candidate mechanism would be an interaction between bottom bedforms and wave-induced current. Gallagher et al. (1998) report on measurements of bottom structures at Duck. They describe the bedforms as having wavelengths of "a few meters" and amplitudes of order 30 cm. In 3 meters of water such perturbations in the bottom represent 10% of the height of the water column and 30% of the significant height of the waves (on 21 July). While infinitesimal wave theory may not predict such waves under current conditions typically seen along the coast, a finite amplitude interaction theory may.

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Spatial Structure of Near-Surface Salinity in the Western Pacific Warm Pool on Scales of Atmospheric Convection

Freshwater input plays a key role in the air-sea interaction of the western Pacific warm pool (Lukas, 1990). During heavy rainfall, a low-salinity lens forms at the surface. Under low wind speed conditions, this lens is shallow. In such a lens the turbulent mixing is inhibited by stratification, which dramatically changes the response of the upper ocean to atmospheric forcing. This is a coupled system. A manifestation of this is that the dimensionless spectra of temperature, salinity, and rain rate calculated from a shipboard thermosalinograph tend to collapse on scales 3-20 km. These spatial scales are set by the convective complexes, which dominate the planetary boundary layer in the western, Pacific warm pool. Wavelet analysis of the density ratio, R, for the surface thermosalinograph data on these spatial scales (3-20 km) leads to the conclusion that R is ~0.5. The density ratio $R = 0.5$ can be derived from Stommel's box model with fixed salinity difference and stochastic, asymmetric thermal forcing like the diurnal cycle. Our work is aimed at parameterization of the spatial structure of the near-surface salinity field in the western Pacific warm pool on the spatial scales of atmospheric convection, which is important to model complex processes leading to onset of ENSO in the tropical Pacific. The theoretical considerations are validated using the field data obtained during the TOGA Coupled Ocean Atmosphere Experiment.

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Walter, Acoustics and Me

The author has had the wonderful experience of working with Walter Munk for more than two decades, a period in which Walter's interests became more acoustical, and the author's more oceanographical. Ocean acoustics was the catalyst that brought us together. In this talk we trace some of the early history and our personal involvement in how one thing led to another, how the U.S. Navy's interest in improving the acoustic performance of its weapons and defensive systems eventually revealed unknown ocean features and processes, how the fields of acoustics and oceanography eventually fused into what today is a new field called acoustical oceanography, and how that fusion has resulted in today's initiatives to employ acoustic methods for observing the ocean on regional to global scales.

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Characterization of Aerosols in the North Atlantic Using a SeaWiFS Time-Series Database

Aerosols have been identified as an important component of the earth-ocean-atmosphere system. In order to map their global distributions and determine if they are of anthropogenic or natural sources, synoptic and repeat coverage measurements are needed. These as well as a consistent methodology are available using satellite-derived estimates of the aerosol optical properties. Using SeaWiFS data, a time-series of concurrent aerosol optical thicknesses (AOT) and Ångström exponents at several stations in the north Atlantic Ocean has been assembled. The annual cycle at each of the stations is consistent with earlier, time-series measurements in addition to contemporaneous aerosol estimates from different satellite sensors. Stations with the highest Ångström exponents (i.e. smallest particle size) tended to have the lowest AOT levels. Characterization of seasonal cycles and inter-annual trends at each of the stations is presented.

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Observation of Tropical Instability Waves in the Pacific Ocean Using Multi Sensor Satellite Observations

This paper examines the characteristics of large-scale westward propagating waves, so-called Legeckis or Tropical Instability Waves (TIW) signature with multi-sensor satellite observations of sea surface temperature (SST) from TRMM Microwave Imager (TMI), ocean color data from SeaWiFS, and sea level anomaly (SLA) data from combined TOPEX/Poseidon and ERS altimeter data during 1998-1999. We find TIW have a much stronger signal in the SST data, while in the ocean color and the SLA data the signal is more complex. High resolution TRMM satellite SST allows the identification of the cold cusps associated with the wave crests. These TIW are found between equator and 6°N in latitude and 100°W and dateline in the longitude. The westward phase velocity of one cusp is about 36 cm/s, the distance between the individual cusps is about 900-2000 km, and period is 20 to 40 days. These kinematic properties are in general agreement with the theory of equatorial planetary waves.

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Subduction Zone Processes: Fluid Venting and Gas Hydrates at the Cascadia Convergent Margin

The tectonically induced release of fluids and gases, such as methane, has been observed in zones of plate convergence throughout the globe. Methane, which forms gas-hydrate deposits within the seafloor, is of interest because of its suspected link to past episodes of climate warming, its role in chemosynthetically based benthic ecosystems, and its resource potential. The NEPTUNE study area includes a study site off central Oregon. Associated with the hydrate exposures are: extensive vent fields from which methane-charged fluids are escaping; active bubble vents and fluid vents, which exhibit variable expulsion rates; benthic communities with distinct patterns related to the type andintensity of fluid and gas discharge; carbonate precipitate chimneys that retain the light 12°C signature of methane and the fabric of gas hydrate; methane plumes in the lower water column, which are advected by bottom currents, undergo in situ oxidation, and may be brought to the sea surface by upwelling; high and variable oxygen demand at the seafloor, which is stimulated by both the injection of chemically reduced species from the subsurface and the activity of benthic communities; fluxes of other chemical species that vary over time by several orders of magnitude and that show a tidal signal. The fluxes may also be responding to other processes, such as micro-earthquakes, changes in bottom-water temperature, and internal waves.

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Currents and Tides Observed in the Korea-Tsushima Strait

Current measurements over nearly a year are made in the Korea-Tsushima Strait for the first time. Twelve bottom-mounted acoustic Doppler current profilers returned high quality current profile measurements along lines located northeast and southwest of Tsushima Island at depths ranging from 59 to 142 m, for the time period between May 1999 and March 2000. The two sections show markedly different mean flow regimes. A high velocity current core was found to exist along the southwestern section along the western slope of the strait for the entire recording period. Tsushima Island disrupted the current flow towards the northeast to such an extent that a counter current commonly existed in the island shadow. The northeastern section is marked by strong spatial variability but in the mean consists of two streams, one on each side of the strait. Non-tidal currents exceeding 70 cm/s were found which were embedded in total currents exceeding 120 cm/s. Tidal currents are responsible for about 25% of the eddy kinetic energy in the near surface layer, they account for more than 50% of the eddy kinetic energy at mid depths and about 70% near the bottom. Current descriptions and statistics are presented to describe the three-dimensional current field.

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Coordinated Experiments at the RIDGE Endeavour Segment Seafloor Observatory in 2000

The Endeavour Segment Seafloor Observatory (Juan de Fuca Ridge) was established as part of the NSF-RIDGE Program's plan to enable investigation of relationships among different ridge crest processes, with continuous observations made throughout time intervals of days to years. In 2000, five related cruises carried out research at the well-characterized, diverse and vigorous Main Endeavour Field (MEF) hydrothermal system, and vent sites to the north and south. Instruments were deployed in the MEF from June to September to continuously monitor temperature, flow rate, and aspects of fluid chemistry, and time series samples of fluids were taken using newly developed samplers. In July, acoustic imaging of hydrothermal flow regimes was carried out to examine the behavior of hydrothermal plumes and diffuse flow. In August, the heat flux from MEF was determined from temperature, conductivity, pressure, electrochemical potential, and velocity data collected during repeated ABE surveys and time-series CTD casts at adjacent stations. In September/October, systematic arrays of acoustic current meters and thermistor strings were deployed for a year to measure vertical heat flux near the seafloor. Seafloor magnetometers and tilt meters, and a thermal blanket for conductive heat measurements, were also deployed. Data from this consortium of projects are being used to examine links among tidal effects, phase separation, heat and mass fluxes from the crust, and microbial output from Endeavour hydrothermal systems.

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NEPTUNE: Opportunities for Investigating Ridge Crest Processes

NEPTUNE could greatly improve our understanding of mid-ocean ridge processes by providing the power, control, bandwidth, and single clock for placement of highly interactive arrays of instruments both on and within the seafloor. By installing nodes at each segment high along the Juan de Fuca Ridge, and within the Blanco Trough, and by providing continuous, interactive access to drill holes within the plate and on the ridge crest, these arrays would be capable of observing patterns and linkages in heat and fluid output and the resultant biological responses within and between transform faults, ridge segments, and the plate. Water column observations from fixed moorings, AUVs, and Lagrangian floats launched from nodes into chronic or episodic hydrothermal plumes would enable study of ocean/crust interactions. Remotely operated vehicles could collect data and samples in response to events or for time series, and provide much needed information on seafloor structure, lava morphology, vent distribution, faunal distribution, and water column structure through detailed fine scale mapping. Rapid response on the order of hours instead of days is needed to better quantify heat and mass fluxes and the expulsion of sub-seafloor microbes associated

with tectonic, magmatic, or hydrothermal events. NEPTUNE would also stimulate new approaches toward carrying out research at high pressures, such as in situ manipulative experiments and analyses, and storage of frozen samples for later recovery.

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TOWNSEND, David W.[1] and Maura Thomas[1]

Springtime Nutrient and Phytoplankton Dynamics on Georges Bank

The dynamics of phytoplankton and nutrients before, during and after the winter-spring bloom on Georges Bank are described based on 6 monthly survey cruises from January to June 1999. We measured hydrography, phytoplankton cell counts, chlorophyll a, dissolved inorganic nutrients (NO_3+NO_2, NH_4, $Si(OH)_4$, PO_4), dissolved organic nitrogen (DON) and phosphorus (DOP), particulate organic carbon (POC) and nitrogen (PON) and total particulate phosphorus (TPP). Phytoplankton production may be significant year round and the winter-spring bloom may start in January. From January to April diatoms dominated, decreasing to <50 cells ml^{-1} in May, and increasing again in June. Dinoflagellates and other flagellates increased in May and June. Nitrate was already low (<3 μM) in January and decreased steadily each month. Silicate was similarly low January (<3 μM) and declined to < 1.5 μM in April. Silicate depletion, not DIN, contributed to the cessation of the diatom bloom. Silicate regeneration commenced in May and June. DON may have been utilized at the start of the winter-spring bloom. Overall micro-and nanoplankton biomass increased steadily each month, while C:N ratios decreased. Our observations indicate an increase in the heterotrophic component of the plankton in May and June which coincided with a second burst in diatom abundance.

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Geostrophic Turbulent Flux of Chlorophyll From Ocean Margins to the Interior

Maintenance of primary productivity in the upper ocean requires a supply of nutrients, which compensates for the loss through sinking particulate organic matter. This supply can be through upwelling and vertical mixing as well as through lateral fluxes. In regions of downwelling, such as the subtropical gyres, most of the nutrient input must occur laterally through Ekman drift or through geostrophic turbulence. The former has already been estimated from climatological data. The availability of concurrent altimetry and ocean color data for the first time allows the latter to be estimated. Since chlorophyll concentration is directly related to nutrient availability, chlorophyll flux is analogous to that of nutrients. We calculate the flux of chlorophyll from nutrient-rich margin waters to the ocean's interior as a Reynolds correlation between fluctuations of chlorophyll concentration and of geostrophic surface velocities over individual TOPEX ground tracks. These estimates of geostrophic turbulent fluxes are much smaller than the climatological Ekman drift fluxes.

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Acoustical Measurements of Bubbles in the Surf Zone

Over the last three years a series of experiments were conducted in the surf zone off Scripps Pier in southern California. A number of remote and *in situ* acoustical sensors were deployed for different periods during different tidal, wind, and wave conditions. Here we summarize measurements of the near shore bubble layer associated with breaking surf, the so called bubble wall, and offshore bubble transport in rip currents. The bubble size distributions and air fractions were measured at the injection point and tracked in time and as the bubbles were moving offshore. These results are interpreted using models that include bubble buoyancy and dissolution, rip-current-advection and the turbulent boundary layer.

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Large Subseasonal Air-Sea Variability in the Tropical Indian Ocean

The TRMM imaging microwave SST data set indicates that there is unexpectedly strong SST variability on subseasonal time scales over the tropical Indian ocean. Warm and cold anomalies of weekly SST in excess of 2.0°C are found over large regions of the basin. Strong variations in tropical convection, as indicated by changes in outgoing long wave radiation, surface and free-tropospheric wind are associated with the SST anomalies. There are also substantial local wind stress and wind stress curl anomalies before and during the SST anomalies. Simple scaling suggests that the SST anomalies are unlikely to have been forced solely by changes in the net air-sea heat flux. Only access to cold subsurface water can produce cooling of the observed rates, and horizontal advection can help explain the observed rapid warming. There appears to be significant ocean-atmosphere interaction here on these time scales, which deserves further investigation as a mechanism for understanding and forecasting monsoon breaks.

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Spatial and Temporal Variability of Hydrography in the Vicinity of the Main Endeavour Field, Juan de Fuca Ridge

During August 2000, we examined how hydrography is altered by hyrothermal plumes above the Endeavour Segment of the Juan de Fuca Ridge. Defining a background hydrography for proper calculation of thermal anomalies and associated heat fluxes from the Main Endeavour Field (MEF) was the goal. CTD, light transmission and redox potential were measured to characterize the water column. Forty navigated, small-scale surveys were conducted along with two time-series stations north and south of the MEF. The time-series show how tidally driven currents effect the hydrothermal plumes between 5 and 500 m above the seafloor through multiple tidal cycles. Potential density profiles show that a 50 m thick bottom mixed layer is common within the axial valley. The layer is typically about as defined by potential temperature and density. On a regional scale, we also observed a weakening of the Northeast Pacific deep ocean stratification within about 300 m of the bottom. We also conducted a 24-hr vertically oscillating tow around the perimeter of the MEF. The surveys indicate the neutrally buoyant plume above the MEF has a highly variable distribution. Generally, the effluent (defined as anomalously warm, occlusive, turbulent, and reactive) appears to be advected to the southwest as predicted by 1995 current meter time series. Current measurements were made throughout the hydrographic survey by a nearby mooring with meters at about 50, 100, 100, 200, and 250 m above the seafloor. We interpret our hydrographic results with attention to the current data and explore the calculation of heat fluxes with the combined data sets.

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Dynamics of the Burial of Cobbles/Mines in the Coastal Zone

The results of a laboratory experimental program designed to study the dynamics of cobble-sized objects (e.g. mines) in a coastal zone will be described. The measurements were performed in a wave tank, 32 x 0.9 x 1.8 m, equipped with a wave maker and a movable sloping beach (sandy slope). As waves arrive and break on the sandy beach, the initially flat bottom transforms to a series of sand ripples and a sand bar near the break, which reaches a quasi-steady state after a certain transition time. Although the incoming wave characteristics are fixed, the bottom topography never reaches an exactly steady state due to ripple drift and bar transformations. When wave characteristics are changed, a new quasi-steady bed shape is achieved. In a series of experiments, the dynamics of model cobbles/mines placed along the slope was studied. Four different possibilities were considered: (i) steady cobble oscillations with zero mean displacement and small scour; (ii) mean onshore motion of light cobbles; (iii) periodic burial of heavy cobbles, of which the size is comparable to that of sand ripples; and (iv) burial of relatively large cobbles under the sand bar when it migrates in response to a change of

break point. Data on the background flow, bed characteristics, ripple drift and displacement of cobbles were obtained. The experimental results could be explained using simple models. This research was supported by the ONR.

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Fisheries Habitat Studies at Heceta Bank on the Oregon Outer Continental Shelf

Heceta Bank is the largest of the heavily fished rocky banks on the outer continental shelf off Oregon. Since the late 1980s this bank has been a primary focus of groundfish habitat investigations. The first phase (1987-90) used submersible transects to establish relationships between seafloor habitats and the abundance of rockfish (genus *Sebastes*) and other benthic populations of fishes and invertebrates. A second phase of study was conducted after a comprehensive Simrad EM300 multibeam survey was completed in 1998. The habitat and biologic data from the 1980s submersible dives were retrofitted onto the multibeam grid using GIS techniques, and then extrapolated to broader areas of the bank using the new imagery. The third phase of the study began in 2000, focusing on the following questions: 1) At what scales are there quantifiable relationships between groundfish abundance and seafloor morphology/texture?; 2) What is the character of and what is the extent of likely natural refugia for groundfish?; and 3) What changes have occurred in the fish populations and habitat after a decade of intense fishing? This poster presents an overview of the Heceta Bank Project, and results from the June 2000 cruise where the remotely operated vehicle *ROPOS* and the two- person submersible *Delta* were used to explore five of the original sites surveyed during the first phase, and complete extensive transects over previously unsurveyed portions of the Bank.

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Understanding and Enhancing Interactions Between Academia and Industry: A Panel Discussion

Part I – General Issues

Part II – Focus on Observatories

It has been widely acknowledged that effective stewardship of marine resources and the development of sound environmental policy will require coordinated oceanographic efforts involving academia, industry, and government. Considerable effort has been devoted to enhancing interactions among these groups in the United States, Europe, and elsewhere. Although some tangible improvements can be cited in both academic-government cooperation and industry-government cooperation, industry-academic cooperation appears to be sporadic and limited. For example, with the establishment in the United States of the National Oceanographic Partnership Program, federal funds have been consciously directed at efforts involving partnerships between academic institutions, government agencies, and industry. Although this program is only five years old, the cooperation it has stimulated is well documented. Nevertheless, industry participation in the program is lower today than at any time in the program's short history. And yet, the advent of a new generation of national and international oceanographic research programs–programs requiring an expanded technology base–suggests a growing need for commercially available technology over the next ten years. By assembling a small panel consisting of leaders of major oceanographic institutions, international and national oceanographic research programs, and companies representing relevant industry sectors, this discussion will explore the underlying barriers to greater cooperation between industry and academic research efforts. Focus will be placed on identifying specific desired research capabilities and exploring how industry and academia could work together to provide those capabilities. The panel will attempt to identify specific steps that could be taken to address identified barriers and enhance the ocean science enterprise worldwide.

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Bridging Ocean Sciences Research and Education–A COSEE Update

A "Center for Ocean Sciences Education Excellence" (COSEE) Workshop-sponsored by the National Science Foundation, specifically the Divisions of Ocean Sciences and Undergraduate Education-was implemented May 23-26, 2000 by the Institute of Marine Sciences, administered by The University of Southern Mississippi. A group of approximately 80 researchers and educators met in Long Beach, MS and discussed the needs of the ocean sciences community. Specifically, the ultimate goal of the COSEE Workshop was to serve as a "needs assessment" of the ocean sciences research and education communities for the proactive facilitation and possible implementation of regional NSF-sponsored Centers for Ocean Science Education Excellence which can be used by this country's college professors, precollege teachers, scientists, informal educators, students, and the general public. This COSEE Workshop should result in these partnering institutions, organizations, and/or agencies becoming more proactive and focused in promoting an enhanced awareness and understanding of the ocean sciences through formal and informal efforts for these diverse audiences. An updated discussion of the status of the COSEE Workshop will be shared with attendees.

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Ocean-Atmosphere Interactions: ENSO Variability

The El Niño-Southern Oscillation (ENSO) is one of the most important climate phenomena on Earth since it affects weather around the world. It disrupts the normal patterns of life of countless species of plants and animals along with hundreds of millions of human beings. Better understanding and predictions of ENSO can help societies plan accordingly and then compensate for or alleviate economic and social loss. This presentation includes discussion of our present understanding of ENSO and data analysis of atmospheric circulation cells associated with ENSO. The previous ENSO mechanisms of the delayed oscillator, the western Pacific oscillator, the recharge discharge oscillator, and the advective-reflective oscillator are discussed. A new unified ENSO oscillator, which includes all of the previous ENSO mechanisms, is introduced. The recently available NCEP-NCAR reanalysis field shows that a weakening of the zonal equatorial Walker circulation cell is associated with the tropical eastern Pacific warming of ENSO, consistent with previous schematic of the Walker circulation. The anomalous meridional Hadley circulation cell in the eastern Pacific during the warm phase of ENSO shows the air rising in the tropics, flowing poleward in the upper troposphere, sinking in the subtropics, returning back to the tropics in the lower troposphere. The anomalous Hadley cell in the western Pacific behaves oppositely. The implications associated with these atmospheric circulation cells are also discussed.

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Meddy-Seamount Interaction

Observations suggest strong interactions between eddies of Mediterranean origin (i.e. Meddies) and seamounts are common. Here, the inviscid interactions between subsurface mesoscale eddies and seamounts are studied by point vortex methods. The Meddies are modeled by collections of point vortices embedded in the middle layer of a three layer quasi-geostrophic model, and seamounts are modeled using right circular cylinders extending through the fluid column. An iterative approach is used to obtain the Green's function for the point vortices subject to the presence of the seamounts. We find the dominant tendency is for vortices to survive collisions with seamounts for oceanically relevant parameter ranges. This is due to the tendencies for like-signed pools of vorticity anomalies to merge and for the topography to mediate the near field interaction of split vortex cores. In our experiments, on average, about 2/3 of the initial core of the Meddies survived collisions with seamounts as coherent eddies. This lessens the impact of seamount induced mixing in providing the salt anomaly maintaining the Mediterranean tongue.

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Towards Closure of the Backscattering Coefficient

The backscattering coefficient is a key optical property of the water that is critical to interpretation of remote sensing imagery. New commercial and research instru-

mentation now permits the estimation of the backscattering coefficient and the volume scattering phase function *in situ*. These instruments include the hydroscat (HOBILabs Inc.), the eco-vsf (WETLabs Inc.), and a research prototype phase function instrument. All of these instruments were deployed off the coast of New Jersey at the LEO-15 site during July 2000 as part of the ONR sponsored HYCODE program. The instruments differ in that the hydroscat measures six wavelengths at a single angular interval, the eco-vsf measures one wavelength at three different center angles, and the prototype measures the phase function from 0.6 to 177.3 degrees in 0.3 degree increments at a single wavelength. The water clarity conditions varied from those of a turbid estuarine plume to clean shelf ocean waters and included both high sediment and biological material. In addition, water samples were collected and the particle size distribution was determined. We examine the performance of each instrument and the ability to use both the angular and wavelength information to provide further details about the composition of the material in the water. Linkages between the optics and material composition are shown.

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Techniques For Comparing AXBT And MODAS Generated Dynamic Height Fields

AXBT surveys in the Gulf of Mexico (GOM) provide relatively rapid and large-scale characterization of the temperature structure of the water column. One product of these surveys is the dynamic height field. It is desirable to compute dynamic heights relative to a deep level of no motion (1500m) for the GOM. Thus, the AXBT profiles of temperature must be edited to eliminate noise and errors characteristic of the AXBT system, and then be extended in a reasonable way to 1500m depth. In addition, a suitable salinity profile must be developed as well, in order to calculate dynamic height for each AXBT profile. MODAS (Modular Ocean Data Assimilation System) is used by the US Navy to produce three-dimensional fields of temperature and salinity. We have used the MODAS climatology to extend AXBT temperature profiles and to develop salinity profiles for three AXBT surveys in the GOM (May, 1998; Jan. and May, 2000). We demonstrate the technique we have developed for this use and compare results from it to MODAS fields, in order to evaluate the quality of each system and determine future needs for remote and in-situ data acquisition.

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The Importance of Episodicity in the Formation and Preservation of Sedimentary Signals on Continental Shelves

Continental shelves are dynamic sedimentary environments that experience and, potentially, record a wide variety of oceanic and terrestrial signals. Although the accelerated rate of sediment accumulation on margins certainly plays a crucial role in the preservation of signals, the episodicity of sedimentation may be even more important. For example, the delivery of sediment to continental shelves due to river floods is an episodic phenomenon. So too is the redistribution of sediment due, for example, to wind-driven storms. The episodic nature of sediment supply and redistribution typically leads to the formation of event beds (one type of signal) that differ sedimentologically or geochemically from ambient sediments. Because these event beds are often several centimeters thick they have a higher probability of passing relatively unaltered through the pervasive benthic biological filter. In this talk, results from several recent programs (e.g. STRESS, STRATAFORM) will be provided that collectively underscore the importance of episodicity for the formation and preservation of sedimentary signals on time scales of hours to centuries.

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Bioluminescence: A Tool for Oceanography

Recent developments in methods designed to measure marine bioluminescence are shedding new light on plankton distribution patterns. Just as fluorescence measurements provide valuable data on fine-scale distribution patterns of primary producers, bioluminescence measurements can furnish similar data for significant secondary producers such as dinoflagellates, ostracods, copepods, euphausiids and gelatinous zoo-

plankton. By enabling continuous measurements at sampling frequencies that are compatible with other standard oceanographic instruments, bioluminescence measurements hold enormous potential for revealing factors that govern organism distribution patterns. A number of approaches have been used to derive an understanding of the relationship between distribution patterns of bioluminescence and plankton. Examples of different types of planktonic bioluminescence and different measurement technologies will be illustrated with a video presentation.

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Opportunities for Seismology in NEPTUNE

NEPTUNE is an opportunity to deploy a plate-scale ocean seismic network in a region that incorporates a remarkable array of plate tectonic features including all the major types of oceanic plate boundaries. Together with land arrays and seafloor geodetic measurements, the NEPTUNE seismic network will address many important problems. Great earthquakes occur along the Cascadia subduction zone and there is considerable interest in understanding of subduction zone seismogenesis and hazard. Seafloor observations will lead to improved constraints on the earthquake cycle, the width of the locked zone, deep intraslab earthquakes, and the relationships between earthquakes, fluid flow, and sediment transport events on the accretionary prism. On the Juan de Fuca ridge, the network will be part of multidisciplinary experiments to monitor seafloor volcanism and hydrothermal circulation. Observations on the Blanco transform fault will contribute to studies of the physics of earthquake rupture. At the plate-scale, the network will constrain the coupling of forces across plate boundaries, the variations in stress across the plate, and the characteristics of intra-plate earthquakes. It will contribute to studies of mantle melting, the coupling of the mantle to the lithosphere, the pattern of return flow from trench to ridge, the nature of mantle flow near plate boundaries, and the rheology of the mantle.

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North Pacific Intermediate Water Formation and Cross Frontal Mixing in the Northwestern Pacific

Data from 2873 historic hydrographic and CTD casts in the Northwestern Pacific (NWP) spanning 1946 to 1993 within 30° - 50° N, 140° - 160° E, were put into streamfunction coordinates, parameterized by dynamic height relative to 1000 dbar for fields of T, S, σ_θ(, and potential vorticity (PV). Fields were prepared for the total NWP region and five subregions. New North Pacific Intermediate Water (NPIW) is formed in the Mixed Water Region (MWR) between the Kuroshio and Polar Fronts, as a salinity minimum along the Polar Front with properties 2-4° C, 33.2-33.5 psu, and 26.5-26.8 kg/m^3. NPIW crosses the Kuroshio Front near 700 dbar and within the subtropical gyre has properties 4.5-6° C, 34.1-34.3 psu, and 26.8-27.1 kg/m^3. PV contours 1-2 x10^{-12}cm^{-1}s^{-1} parallel the axis of the salinity minimum within the NPIW. Fields of anomalies between the total NWP and each subregion provide evidence that water from the MWR exchanges across both the Kuroshio and Subarctic Fronts at NPIW density levels in the region east of 150° E. The anomaly fields also suggest that new NPIW is not formed in Kuroshio warm core rings, but the rings are important to the modification of NPIW in the MWR. Viewing properties in streamfunction coordinates enables the use of non-synoptic data to generate well resolved property fields, which resemble snapshot sections.

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Zooplankton in Tidal Fronts: Biological-Physical Interactions on Georges Bank

Zooplankton distributions relative to water column structure, frontal features, and the tidal cycle were studied during the 1999 US GLOBEC program at two fronts on Georges Bank. The sampling strategy consisted of two modes: an Eulerian mode during which CTD and MOCNESS samples were collected every 4 hours at a single station for 24 hrs (at 3 stations spanning the tidal front) and a tidally-coordinated mode during which transects of these 3 stations were made day and night at two different tidal phases (maximum on-Bank slack and maximum off-Bank slack tide). CTD and MOCNESS tows were done in quick succession at each station. At both fronts, well-mixed water extended farther off-Bank during the maximum off-Bank slack tide, while stratified water extended up onto the Bank during the opposite phase. Distributions of the copepod *Calanus finmarchicus* usually peaked in the surface layer when the water was stratified. Abundances were highest in strongly stratified situations and lowest in the on-Bank well-mixed water. *Calanus* did not vertically migrate, so day and night tows were similar for this species. However, at the Northern Front, a vertically migrating species *(Metridia lucens)* showed strong day - night differences in addition to tidal phase effects. Thus distributions, and presumably cross-frontal transport, of species with contrasting vertical migration behavior and water mass associations were affected differently depending on tidal phase, location relative to the front, and time of day.

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Association of a Low-Phycourobilin-Containing Phycoerythrin with Upwelling-Influenced Waters in the Gulf of California

Phycoerythrin (PE) is the predominant light harvesting pigment of *Synechococcus*, a ubiquitous picocyanobacterial group, as well as *Trichdesmium*. The pigment is highly fluorescent *in vivo*, λ_{EmMax}~560-570 nm and harvests green and blue-green wavelengths with varying efficiency depending on the chromophore composition of the form of phycoerythrin being synthesized. Most oceanic forms of *Synechococcus* are thought to produce a PE composed of higher concentrations of the blue-light absorbing chromophore, phycourobilin (PUB, λ_{AbsMax}~495nm), than the green-light absorbing chromophore, phycoerythrobilin (PEB, λ_{AbsMax}~550nm). Recent studies in the Arabian Sea have shown that spectral forms of PE characterized by a relatively low PUB:PEB ratio dominate the PE fluorescence signature in upwelling-influenced waters, even when these waters are transported far offshore. In this study we examine a range of water mass types in the Gulf of California to test the hypothesis that these low PUB PEs are typically associated with Case I waters, under conditions of increased productivity when the attenuation of blue light is greater than that of green light. We also evaluate the data for the degree of correlation between parameters of the PE fluorescence signature and other optical parameters of surface water that would influence the interpretation of remotely sensed data on ocean color.

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Wind-Driven Coastal Ocean Circulation Simulated by Using a Coupled Wave-Current Modeling System

The wind-driven coastal ocean currents and sea-level change are investigated by using a coupled wave-current modeling system. The ocean circulation model employed is the three-dimensional Princeton Ocean Model (POM) and the wave model invoked is an improved third generation wave model (WAM). The coupling procedure between the POM and the WAM, and the simulated wind-driven coastal ocean circulation are presented. The simulated results show that wind waves can significantly affect coastal ocean currents not only through an enhancement of wind stress but also through a modification of bottom stress. The results further indicate that at a fixed location, the relative importance of wave-induced surface and bottom shear stresses in coastal ocean circulation depends on the surface wind speed and direction. The net effect of wave-induced surface and bottom stresses enhances upper-ocean currents under high-wind conditions, but generally damps the near-bottom currents. The effect of wave-induced bottom stress is more significant in alongshore wind conditions than in cross-shore wind conditions.

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The Impact of Variable Inflow on the Dynamics of a Coastal Buoyant Plume

The impact of buoyant discharge variations on the dynamics of coastal buoyancy-driven currents is studied using the primitive equation numerical model (SPEM5). First, variable discharge is introduced as harmonic fluctuations of the inflow velocity at the tidal and subinertial frequencies. Tidal fluctuations produce minor effects on the buoyant plume while subinertial fluctuations substantially modify the anticyclonic bulge. A partly detached anticyclonic plume forms when discharge subsides after having reached its peak value. A secondary bulge forms during the low runoff interval. Second, an individual event of high discharge is considered, when both the net transport of the inflow and the absolute value of its density anomaly increase and then return to their initial values. This event also generates a partly detached plume. In this case, the lightest water occupies the downstream part of the bulge and is separated not only from the coast but from the mouth as well. The effect of variable discharge is more dramatic with a uniform downstream current of $0.1 ms^{-1}$. Under such conditions, constant buoyant discharge does not form a well pronounced anticyclonic bulge. In contrast, the variable discharge produces an almost circular anticyclone during the high runoff interval. Subsequently, this anticyclone separates from the source and propagates downstream. Observational evidence for both the partly detached bulge near the mouth and the anticyclone propagating downstream is also presented.

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Reef Watch: A Teacher Research Experience and Into The Classroom

Reef Watch - from the inside out - provides a collaborative learning model for K-12 teachers, students and scientists in the Florida Keys. Reef-building corals are plants inside animals that build rock! The focus of this study is the biodiversity of the reef ecosystem and how light and other factors impact the reefs. We explore the evidence to "know what we know" – and make measurements to advance what we are trying to find out. Parts of the initiative include intensive background information and the learning of advanced techniques as well as a field program to several of the reef areas – the most endangered to the most pristine. Educational expectations include forming teacher cohorts of four from school districts throughout the US; building an on-line learning community for daily journal entries on the Web; mentoring other teachers; and co-creating classroom activities. For the pilot two years, the program has been of mutual benefit to teachers, scientists and classrooms. The website is: www.reefwatch.org.

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ENSO and Eddies on the Southwest Coast of Mexico

TOPEX/Poseidon and ERS-2 (T/ERS) sea surface height altimeter observations and the Naval Research Laboratory Layered Ocean Model are used to study the circulation along the southwest coast of Mexico. The results of this research indicate that strong El Niño/Southern Oscillation (ENSO) warm phase Kelvin waves (KW) destabilize the upper ocean circulation. The effect of ENSO appears as three distinct stages. First, a coastal jet characterized by strong vertical shear flow develops. Second, the shear flow strengthens, increasing its horizontal dimension and the amplitude of its oscillations. Finally, the jet becomes unstable and breaks into anticyclonic eddies, which separate from the coast and drift southwestward. The genesis and strengthening of the jet is due to the simultaneous occurrence of the poleward-flowing currents along the southwest coast of Mexico and the poleward circulation associated with ENSO downwelling KW.

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Coccolithophore Abundance in the Bering Sea, 1997-1999

Field work in the Bering Sea during the period of 1997-1999 documented a new coccolithophore bloom, of unusually large proportions and unusual persistence. The abundance of the *Emiliana huxleyi* cells varied around the southeastern Bering Sea from a few cells/ml to well over 5000 cell/ml. Abundances were lowest near the Alaska Peninsula and increased northward. The percent composition also varied from almost none to over 90% of the phytoplankton community. A seasonal pattern was also observed which indicated lower numbers at the start of summer and increasing to maximal values near the end of summer. There is also evidence that the cells were able to overwinter as evidenced by samples taken in February at the edge of ice cover. Unusual atmospheric conditions allowed the initiation of this bloom, but other factors are maintaining it.

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Studying Ocean Mesoscale Features with the GPS Signal

The possibility of doing altimetry and scatterometry with the signal broadcast from the Global Positioning System (GPS) is currently being pursued as a possible augmentation of the existing ocean remote sensing capabilities. The main attractive features of the GPS signal for ocean remote sensing are dense spatial and rapid temporal coverage, combined with relatively inexpensive receiver technology, which could make the global monitoring of mesoscale features possible for the first time. The poster discusses the main features of the new type of measurement, starting with signal characteristics and how these relate to the quantities of oceanographic interest. Measurement sensitivity, expected resolution, accuracy and sources of error will be described. A summary of preliminary findings on altimetry accuracy stemming from our analysis of data from fixed receivers elevated above a body of water as well as moving receivers will be presented. Furthermore, the discussion will touch on enabling technologies and basic considerations for a system design. A specific mission design currently being investigated at NASA under the UnESS program will be addressed briefly.

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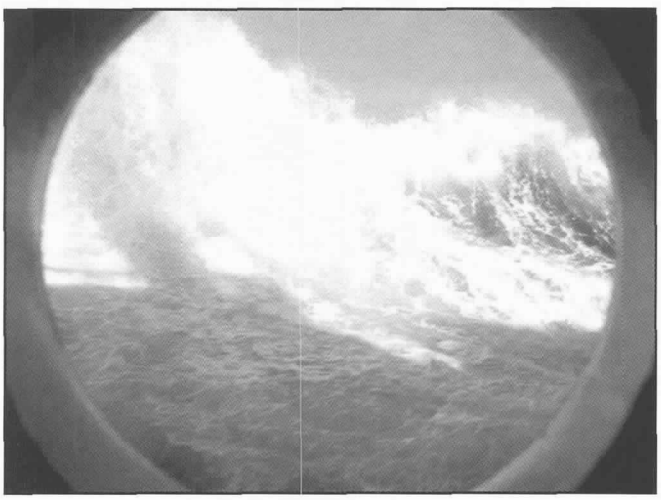

Waves breaking as seen from a porthole on the 0-1 Deck on the NATHANIEL B. PALMER, crossing the Southern Ocean, 1998. Courtesy NOAA.