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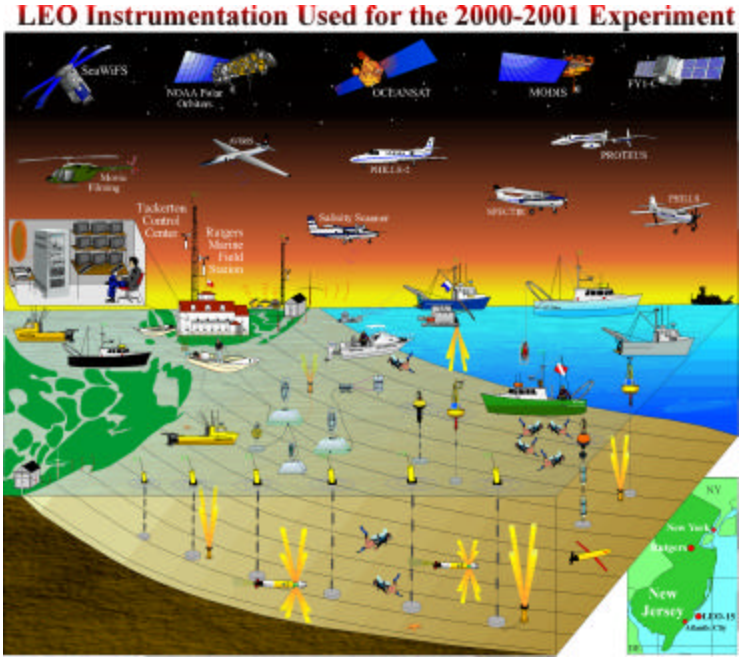

Presentations by COOL Researchers

From Rutgers, Cal-Poly, FERI, Lamont-Doherty, MOTE, NRL, Stevens, UCSB, U. Maine, U. South Carolina, USM and WHOI

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Sea Change for the Ocean Planet

J. Frederick Grassle, John Orcutt, Ken Johnson, Tom Malone
With Marcia McNutt, Larry Atkinson, Dave Martin, Worth Nowlin, John Delaney, Bob Weller

Through development of new platforms, observational technologies, and modeling capabilities, the ocean and earth sciences are on the threshold of a revolution in ability to address fundamentally new scientific questions and to support a much broader community of users of information about the ocean. Specifically, advance in knowledge of the oceans has been severely limited by lack of sustained observations over extended periods and large areas. There is an immediate need for a new approach that effectively links basic research and operational oceanography to provide the data, information, and understanding required for more timely detection, understanding and prediction of change in all aspects of marine and estuarine ecosystems and the resources they support. New approaches are being developed to continuously visualize and assess environmental data that describe physical, biological, chemical, and geological processes operating in the four dimensions of space and time. To achieve expected new scientific insights at previously poorly-explored scales of observation and simultaneously serve national needs for better awareness of ocean processes, the GOOS (Global Ocean Observing System)and DEOS (Dynamics of Earth and Ocean Systems) international initiatives need to develop synergistically and become operational via the National Ocean Partnership Program (NOPP) and Ocean.US as soon as possible. A key premise of this approach is that hypothesis-driven basic research programs and the development of operational oceanography are critically dependent on each other. Basic research to be conducted via the DEOS initiative will be required to develop the full capabilities of the GOOS initiative, and the scales of observation and visualization made possible by use of GOOS, will increase the value and importance of more specifically-scientific inquiries.

Evolution of LEO into a Shelf-Wide Ocean Observatory
Invited Talk for the Ocean Observatory Session

Oscar Schofield, Paul Bissett, Fred Grassle, Dale Haidvogel, Mark Moline, John Wilkins, Scott Glenn

The integrated Long-term Ecosystem Observatory (LEO) was developed in the coastal waters off the central coast of New Jersey (USA) and has been operated since 1997. A major goal for the Long-term Ecosystem Observatory (LEO) was to develop a real-time capability for rapid environmental assessment and physical/biological forecasting in coastal waters. To this end, observational data was collected by satellites, shore-based radars, aircrafts, ships, fixed/relocatable moorings, and autonomous underwater vehicles in a 30 x 30 km research space and the data was provided real-time to a data assimilative ocean forecast model. Results of 4 coastal predictive skill experiments demonstrated that in this observationally rich research environment model forecast errors were dominated by uncertainties in the model physics or future boundary conditions rather than initial conditions. Therefore, ensemble forecasts with differing model parameterizations provided a unique opportunity for model refinement and validation. Currently the LEO system is being expanded into the New Jersey Shelf Observation System (NJ SOS) in order to develop an integrated system allowing for regional questions (300 x 300 km) to be addressed. New enabling technologies make this regional expansion possible. These enabling technologies include: (1) strategically located, long-duration physical/bio-optical moorings or cabled observatories for subsurface time series at fixed locations, (2) long-range shore-based high-frequency Coastal Radars (CODAR) that generate real-time surface current maps over 200 km distances, (3) a growing international constellation of high-resolution (spatial and spectral) ocean color satellites that can be used to generate surface temperature, chemical and biological maps, and (4) an emerging class of mobile subsurface oceanographic sampling platforms, the long-duration remotely-controlled Glider-type Autonomous Underwater Vehicles (AUVs) that provide guidance to short-duration propeller AUVs that can be steered into regions of scientific interest to underwater weather forecasters. NJ SOS will form part of the NorthEast Observatory System (NEOS), which is an ocean observatory consortium spanning from North Carolina to Maine.

Validation of CODAR Wave Measurements: Comparison to Pressure Sensor, ADCP and NOAA Buoys

Kristie Andresen, Scott Glenn, Josh Kohut, Belinda Lipa

Two 25 MHz Coastal Ocean Dynamics Applications Radar (CODAR) systems have been operating since 1998 off the southern New Jersey coast as part of the Rutgers University Long-term Ecosystem Observatory (LEO 15). One system is located in Brant Beach NJ, the other is located about 26 km south in Brigantine. It has been demonstrated that first-order Bragg peaks of the returned signal are used to derive ocean surface currents. Additionally second-order sea echo can be used to derive information about the directional wave spectra. The shallow water environment of the New Jersey shelf requires inclusion of the full dispersion relationship in the CODAR wave spectral calculations.

Directional wave spectra derived from the two CODAR systems were evaluated by comparing to local measurements from an RD Instruments moored ADCP and a ParoScientific pressure sensor located at LEO-15. Additionally, CODAR estimates were compared to remote measurements from two data buoys maintained by the National Data Buoy Center (NDBC) located offshore of Long Island and Delaware Bay. Directional wave spectra are being compared for significant wave height, peak period, frequency spectral shape, and mean direction as a function of frequency. This was done during varying sea states: calm and storm seas, swell and wind seas, as well as mixed seas to evaluate system performance. Preliminary analysis indicates that the CODAR remote sensing estimates of wave parameters track the in situ data through a variety of events.

Coupled Physical/Bio-Optical Model Experiments at LEO-15

Hernan Arango, Paul Bissett, Scott Glenn, Oscar Schofield

A coupled Atmosphere-Ocean-Ecosystem high resolution model is used to study the inherent and apparent optical properties (IOPs and AOPs) associated with recurrent summer upwelling events off of the New Jersey Coast. The physical and bio-optical data gathered by the observational network at the Long-Term Ecosystem Observatory (LEO-15) is used to initialize, update, and validate the coupled system (COAMPS/ROMS/EcoSim). A series of real-time, atmosphere-ocean nowcasting and forecasting experiments were carried during July 2001 as part of the HyCODE adaptive sampling program. The forecasting schedule was tuned to the data sampling strategy which required a three-day forecast twice a week. The overall predictive skill of the atmosphere-ocean system was improved by increasing the horizontal resolution of the atmospheric model (COAMPS) to 5km, when compared to previous year resolution of 40km. The bio-optical simulations using EcoSim were done in hindcast mode.

A Comparison of the Operational and Experimental COAMPS Meteorological Forecasts at LEO During 2001 HYCODE Experiment

Louis Bowers, Scott Glenn, Rob Cermak, Jim Doyle, Shouping Wang

Real-time forecasts with the Operational (FNMOC) and high-resolution Experimental (NRL-MRY) versions of the Navy Coupled Ocean Atmosphere Prediction System (COAMPS) were generated during the July 2001 Hyperspectral Coupled Ocean Dynamics Experiment. The oceanographic experiment centered on the New Jersey coastline at the Rutgers University Long-term Ecological Observatory (LEO) located in Tuckerton, NJ. The ensemble of Navy forecasts and standard NOAA forecasts were used to plan aircraft and shipboard operations, and to drive the Regional Ocean Modeling System (ROMS). The higher spatial and temporal resolution of the Experimental COAMPS showed a substantial improvement in the accuracy of forecast wind speed and direction, temperature, and relative humidity during the eight cycle experiment. Both the Operational and Experimental versions of the COAMPS model showed approximately equal skill in resolving synoptic scale features such as low-pressure areas associated with frontal systems. The high-resolution Experimental COAMPS performed exceptionally well in forecasting the variations and movement of mesoscale phenomena such as the New Jersey coastal sea breeze. The substantial gains of the higher spatial and temporal resolution at the mesoscale level, combined with the negligible losses in the resolution of larger scale atmospheric phenomena, indicates the Experimental COAMPS was a valuable tool for guiding research activities during the HYCODE experiment.

A Model for a National Network of Regional Coastal Ocean Observatories

Scott Glenn, Oscar Schofield, Bob Chant, Fred Grassle

Regional-scale coastal ocean observatories are being operated and expanded along many U.S. coasts. Common observational elements include satellite remote sensing data, HF radar surface current maps, and time series of in situ observations at high-interest locations. In the Northeast U.S., regional-scale observatories such as the Gulf of Maine Ocean Observing System (GoMOOS) and the New Jersey Shelf Observing System (NJSOS) already distribute data products of proven interest to the scientific community and the general public. Plans to link GoMOOS, NJSOS, and other ongoing observation efforts into the NorthEast Observing System (NEOS) are underway. One driving force for the linkage is the desire to produce new regional or larger-scale composite products that can only be accomplished by combining datasets from multiple observatories. These include (a) level 2 satellite data products with multiple vicarious calibration points derived from the international constellation of high-resolution ocean color satellites; (b) surface current maps from nested grids of standard, long-range and bistatic HF Radar systems from multiple operators; and (c) subsurface datasets designed to fill in the gaps between the widely-separated time-series point measurements using fleets of long-duration autonomous underwater Gliders. As a first step, a collaborative plan to construct a HF-Radar backbone for NEOS has been proposed. It includes an oversight committee, coordinated sampling protocols, calibration methods, standard data formats and a method for data sharing, while leaving the final product preparation and distribution to the discretion of the individual institution.

NEOS serves as a prototype for a national federation of linked regional observatories. Using GoMOOS and NJSOS as regional models, it would require between 20-30 regional centers to cover the U.S. East, Gulf and West coasts, Hawaii, and the Gulf of Alaska. A typical regional center would operate an X-Band Satellite Data downlink, about 5 Long-range HF Radar systems, and about 10 Long-duration underwater Gliders. Personnel requirements would be about 15 people, including operators for the different sensors and a 24x7 forecast watch. This is similar in magnitude to the existing National Weather Service regional forecast offices that operate the Doppler weather Radar network, or the U.S. Coast Guard Air Stations responsible for launching aircraft search and rescue missions. The personnel requirements to establish this system while still fulfilling the growing needs of existing operational oceanography efforts in the Navy and NOAA could motivate some universities to begin training a new generation of students in the now rapidly evolving profession of operational oceanographer. Based on the meteorological paradigm and over 10 years experience at existing observatories, Masters level oceanography students with practical training in an operational environment are targeted.

Development and Validation of a Nested HF-Radar System for the New Jersey Shelf Observation System (NJSOS)

Josh Kohut, Scott Glenn, Kristie Andresen, Sage Lichtenwalner, Don Barrick, Pete Lilleboe

A nested grid of HF-Radar systems has been deployed in the New York Bight (NYB) off the New Jersey coast. This network of CODAR HF-Radars consists of standard, long-range, and bistatic systems. The standard system, operational since 1998, provides hourly vector maps extending 40 km offshore and 50 km alongshore with a grid resolution of 1.5 km. The standard system has been used in antenna pattern validation studies and multi-disciplinary research conducted within the LEO-15 observatory. An important aspect of this validation has been to test the role of antenna pattern distortions in both the accuracy and coverage of the measurements. Experiments have shown that the local environment plays a significant role in antenna pattern distortion. Calibrating the radar sites with the antenna patterns was shown to improve correlation statistics with a moored ADCP. In June 2000, the first long-range system was deployed in Loveladies, New Jersey. Since that deployment, three more systems have been added to the network to provide total surface current maps that extend as far offshore as 160 km along the entire New Jersey coast with a grid resolution of 6 km. The overlapping coverage of the standard and long-range systems near LEO-15 provides an excellent testbed for validating and understanding the nature of the two measurements. The long-range system measures the scattered signal off a longer ocean wave than the standard system. In addition the long-range data cannot resolve smaller scale spatial features captured in the higher resolution standard current fields. Using a moored ADCP array, the nature and magnitude of the differences between co-located long-range and standard datasets were examined. The third system currently being developed at NJSOS, the bistatic system, compliments both the long-range and standard systems. By moving a transmitter offshore, additional surface current information is available for total vector calculations. These additional vectors reduce the GDOP error seen in HF-Radar fields and extend the data footprint to the coastal boundary. During a weeklong cruise in the NYB, a buoy-mounted transmitter was coupled to a standard site and a vessel-mounted transmitter was coupled to a long-range site. This nested multi-radar system will provide longterm surface current measurements as an integral part of the New Jersey Shelf Observation System (NJSOS). NJSOS is one of a series of linked regional observatories envisioned to form the NorthEast Observing System (NEOS).

Validation of an Atmosphere-Ocean Forecast Model at the Longterm Ecosystem Observatory

C. Sage Lichtenwalner, Scott M. Glenn, Hernan Arango, Dale Haidvogel, John Wilkin

Results from the Rutgers Regional Ocean Modeling System (ROMS) were quantitatively compared with an independent cross-shelf mooring array to validate available model ensemble schemes. ROMS was run in real-time during the July, 2001 Coastal Predictive Skill Experiment (CSPE) with surface forcing supplied by a high-resolution regional implementation of the Navy's COAMPS model. Available options for surface mixed layer dynamics in summer 2001 included the K Profile Parameterization (KPP) and the Mellor-Yamada level 2.5 closures. Real-time satellite-derived sea surface temperatures, CODAR-derived surface currents, and subsurface CTD data from the Rutgers University Long-term Ecosystem Observatory were assimilated to generate an ensemble of 3-day ocean forecasts twice per week for adaptive physical/biological sampling by ships, autonomous underwater vehicles, and aircraft. Each forecast cycle was evaluated in real-time using a stationary continuous CTD profiler. Further validation of the quality of the ocean model forecasts and subsequent hindcasts are being assessed through comparisons with a cross-shelf array of ADCPs and thermistors not included in the assimilation data set.

The coastal ocean offshore New Jersey in July is characterized by a strong pycnocline located at a depth of 5-8 m. It responded as a two-layer system to several wind events during the month-long experiment, alternately causing upwelling of cold water or downwelling of warm water at the coast. The strongest wind event of the July 2001 CPSE was the formation of a low-pressure system that moved quickly offshore to the east. The downwelling favorable winds were observed to rapidly force the resulting bottom front through the cross-shelf validation array. Quantitative model metrics for a two-layer system were developed to evaluate model performance using the independent cross-shelf mooring array. The result is an extensive database for the evaluation of different closure schemes, data assimilation methodologies, and boundary conditions. Preliminary comparisons with the real-time ocean forecasts indicate that the KPP closure scheme reproduced the timing of the upwelling and downwelling events with sufficient accuracy to improve adaptive sampling during the experiment.

Coordinating a Fleet of Autonomous Underwater Glider Using a Decision Theoretic Approach in a Multi-agent System

Chhaya Mudgal, Scott Glenn, Oscar Schofield, Clayton Jones, Douglas Webb

Autonomous underwater Gliders have the ability to patrol the subsurface Ocean for long durations. They surface at regular intervals to transmit data and download new sets of instructions. A small fleet of Gliders can improve efficiency and help scientists study the subsurface features of coastal waters around-the-clock and at controllable locations. A Glider fleet could be coordinated with a preset instruction set, but events measured from other scientific systems or model forecasts can change the sampling priorities. To direct the Glider Fleet to desirable locations there will be need for a scientist who studies data from various sources and provides new instructions for the Glider fleet to be downloaded. The focus of this research is to automate the coordination of the Glider Fleet given the information from the components of regional observation network to minimize direct human involvement.

It is proposed in this research to develop a flexible, autonomous and a responsive software tool to coordinate a Glider Fleet. The coordinating software design is based on a Decision Theoretic Expert System. The field of Decision Analysis studies the application of Decision Theory to solve actual decision problems. The system will make optimal decisions based on available evidence. This software will be both adaptable and adaptive. The adaptable behavior will allow it to take instructions from the user and change the download instructions for the Gliders accordingly. The ability of the software to change the instruction set for the Gliders without human intervention provided some evidence is available demonstrates adaptivity. The advantage of using Decision Theory over other approaches is its ability to incorporate uncertainty in the environment and taking into account the value of information before making decision.

Comparisons of Satellite and In Situ Chlorophyll-a Measurements in Coastal Upwelled Waters

Michael Crowley, Alex Kahl, Kota Prasad, Cristina Orrico, Oscar Schofield, Scott Glenn

Off the southern coast of New Jersey, upwelled water evolves into an alongshore line of three recurrent upwelling centers that are co-located with historical regions of low Dissolved Oxygen (DO). The upwelling eddys have been clearly visible AVHRR over the last decade, and other the annual seasonal warming cycle, represent the second most significant factor influencing sea surface temperatures. Associated with the upwelling are high concentrations of phytoplankton which are visible in ocean color remote sensing. The optical features of the upwelled waters are dominated particulate organic carbon (POC) with C:N ratios of healthy phytoplankton. A robust relationship between POC and in-water optical parameters has allowed POC patterns to be defined in space and time. Using ocean color imagery, POC loads were estimated in response to the recurrent upwelling events. These maps are strongly dependent on the accuracy of the ocean color estimates of the inherent optical properties. Given this, the in situ database, collected during the HyCODE/COMOP research effort, was used to validate currently available ocean color products for these optically complex coastal waters and the estimated in water respiration from the POC export is estimated to deplete bottom water oxygen concentrations by at least 10%. One major advantage of the upwellings is that they provide strong optical gradients, which have allowed us to cross-calibrate the international constellation of satellites against each other and in situ data. During summer 2001 we cross-calibrated SeaWIFS, MODIS, Oceansat, and FY1-C ocean color satellites. For the Chinese FY1-C ocean color satellite, launched in 1999 has no post launch calibration coefficients, a local overpass time of ~9:00AM which dictates a low sun angle, and has bands which average a width of 0.6 microns in the visible spectrum. Through darkest pixel and sun angle corrections, we have been able to achieve estimates of surface chlorophyll-a values similar to SeaWIFS and Oceansat. By tapping the full constellation of international ocean color satellites, we were able to adaptively sample episodic features on the scales of hours, not days, which has never before been possible.

Comparisons of SeaWiFs derived Inherent Optical Properties to In Situ Coastal Measurements at LEO

Alex Kahl, Michael Crowley, Robert Arnone, Trish Bergmann, Cristina Orrico, Oscar Schofield

A large data base of in situ bio-optical measurements were collected at the LEO-15 (Long-term Ecosystem Observatory) off the southern coast of New Jersey (USA) as part of the HyCODE/COMOP experiment. The data was used to quantify the impact of coastal upwelling on nearshore bulk apparent and inherent optical properties. There was good qualitative agreement between the AOPs and IOPs in space and time. The measured IOPs were used as inputs to the Hydrolight radiative transfer model (RTE). Estimated spectral AOPs from the RTE were strongly correlated (generally R^2 > 0.80) to measured AOPs. The RTE was then used to construct the spectral remote sensing reflectance. Spectral signatures of Hydrolight-derived in situ and SeaWiFs derived Rrs values compared favorably pooling all data. Generally, the R^2 between the measured and modeled was above 0.7 using all available imagery; however just using the days with ideal satellite geometry and clear atmospheric conditions the R^2 was greater than 0.92. However, within each spectral band the R^2 Rrs values were compared directly, the results were far less encouraging. Direct comparison of SeaWiFs to modeled in situ Rrs as a function of wavelength was less encouraging. The R^2 between measured and modeled varied with wavelengths and between days. Generally the correlations were greatest in the red and green wavelengths with poor correlations in the blue wavelengths. The R^2 varied by on average by a factor of 4 across the spectral bands with values ranging from 0.9 in the red to 0.2 in the blue wavelengths on certain days. The relative impact of solar and satellite geometries and the corresponding impact on the correlation to the in situ data is discussed.

The Effects of a Spring Resuspension Event on In-situ Optical Parameters and Phytoplankton Light Utilization

Trisha Bergmann, Gary Fahnensteil, Steven Lohrenz, David Millie, Oscar Schofield

As part of the Coastal Ocean Processes-Episodic Events in the Great Lakes Experiment (CoOP-EEGLE) in-situ optical data was collected during an episodic turbidity plume in southern Lake Michigan during spring 1999 and 2000. This recurrent sediment plume is formed onshore before advecting offshore and is characterized by high surface reflectivity. The formation of this offshore optical gradient provides a wide range of optical conditions to help develop remote sensing algorithms and serves as a model testing ground for studying the effects of constrained light parameters on phytoplankton communities. Measured inherent optical properties (IOPs) were used to compute spectral radiance distributions using Hydrolight 4.1 in natural water columns based on collected in water AC-9 (Wetlabs) data. Calculated AOPs and remote sensing reflectances were compared to measured values; in-situ AOPs were measured using Satlantic OCR-200 and hyperspectral TSRB radiometers. Measured and modeled optical properties showed good agreement especially in clearer water offshore stations (R^2 = 0.91). Although absorption and scattering are both increased within the plume (up to 3X), total light attenuation was dominated by scattering and was highest in the blue wavelengths of light. The increased attenuation within the plume alters both the intensity and spectral quality of light available to phytoplankton leading to a decrease in total primary production and a shift in phytoplankton community composition. Diatoms tend to dominate onshore stations while cryptophytes, which are always present, become the dominant species (comprising up to 75\% of the population) in the offshore stations and at depth. The light field in these areas is sharply skewed to the green wavelengths of light thus favoring the cryptophytes who are better able to harvest the available light utilizing their accessory phycobilin pigments (max absorption = 545nm). The calculated integrated photon absorption for cryptophytes in this light environment is 2.5X that for diatoms at depth.

Forecasting the Colored Dissolved Organic Matter Dynamics on the West Florida Shelf

Paul Bissett, Jason Jolliff, John J. Walsh, Dwight A. Dieterle, Oscar Schofield, Gary Kirkpatrick, Paula Coble, Robert Arnone

The prediction of water-leaving radiance in coastal waters is strongly dependent on a quantitative prediction of the depth-dependent distribution of Colored Dissolved Organic Matter (CDOM) in the water column. In coastal waters, the CDOM distribution is a function of the supply of CDOM from allochthonous offshore and estuarine boundaries, and autochthonous production and removal processes. As part of a larger effort to forecast the Inherent and Apparent Optics Properties (IOPs and AOPs, respectively) of the coastal ocean, we have created a numerical solution of the sources and sinks of CDOM on the West Florida Shelf (WFS). This solution includes the autochthonous production via phytoplankton and bacterial grazing and lysis, as well as direct bacterial CDOM creation. The autochthonous sinks of CDOM are driven by photolysis of the colored matter to colorless organic and inorganic matter. These processes are embedded in a larger 2-dimensional ecological simulation (EcoSim 2.0) that resolves the time-dependent change of the phytoplankton and bacterial communities, as well as the in situ IOPs and AOPs.

An earlier numerical study of IOPs in the Sargasso Sea had difficulties resolving the seasonal cycles of CDOM. It was found in this study that contrary to the assumptions of the earlier work, the bacteria do not use CDOM as an energy or nutrient source. In addition, the rates of photolysis were far smaller than assume in the prior study. Lastly, the cross-shelf distribution of absorption on the West Florida Shelf is strongly dependent on the estuarine source of CDOM. Inclusions of these new estimates of autochthonous and allochthonous processes allowed us to simulate the depth-dependent distribution of CDOM during the fall of 1998 on the WFS.

Development of an AUV to Measure Bioluminescence in the Coastal Ocean

Shelley Blackwell, Chris Van Alt, Jim Case, Scott Glenn, Mark Moline, Mike Purcell, Oscar Schofield

During the summer of 2001 a modified REMUS (Remote Environmental Measuring UnitS, WHOI) AUV, measuring physical, optical and biological properties, was incorporated into a multiplatform adaptive sampling experiment at LEO-15 (Long-term Ecosystem Observatory) off the southern coast of New Jersey. The REMUS is the first of its kind in that it is the only hand deployable AUV capable of quantifying bioluminescence. Modifications to the AUV have greatly increased its applications in the field of oceanography. In addition to CTD and ADCP sensors, a new nosecone has been developed which incorporates an internal bathyphotometer (bioluminescence sensor), an external fluorometer and an external turbidity sensor. Vehicle performance, including comparisons of goal to realized velocity, heading and depth will be examined for deployments in the nearshore environment. The vehicle's high temporal and spatial resolution sampling capabilities enable it to measure biological, optical and physical parameters on scales relevant to complex coastal environments. An example of this was the characterization of a tidally-driven frontal feature and the associated effect on the biological and optical loads. In an attempt to optimize AUV flight paths in quantifying small-scale features in the coastal ocean, an assessment of different sampling strategies will also be demonstrated.

Taxonomic recognition of plankton using optics

Emmanuel Boss, Collin Roesler, Oscar Schofield, Mike Sieracki

In this contribution of the SCOR working group 118 (New Technologies for Observing Marine Life), we review the state-of-the-art optical methods for obtaining information on phytoplankton species composition and taxonomic distribution in the ocean. Single-cell imaging systems are presented as well as methods for analyzing bulk optical properties to obtain information on the dominant species. We present methods based on both in-situ and laboratory measurements of optical properties, as well as from satellite remote sensing. The application of these methods to the specific condition of red tides (i.e. extreme blooms) is presented as an example. Present imitations and future development are discussed.

Resource Limitation Alters Allometric Scaling of Metabolic Rates in Phytoplankton.

Zoe V. Finkel, Andrew J. Irwin and Oscar Schofield
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Allometric scaling of metabolic rates is a universal property of living organisms. Metabolic rate is often expressed as a power-law function of organism size with an exponent of ¾, referred to as the ¾ rule. Previous studies have found that metabolic rates often deviate from the ¾ rule. We show that resource limitation can cause these deviations. Under resource limiting conditions, energy is diverted from growth to enhanced resource acquisition, leading to changes in chemical composition, which result in size-dependent changes in metabolic rate. Using a bio-optic model we show that under light limitation, optimal intracellular chlorophyll concentration is inversely proportional to cell diameter. As a result, the size scaling exponent associated with light-limited photosynthesis is closer to ½ than ¾.

The Comparative Evolution of Plastid Genomes in Eukaryotic Algae

Daniel Grzebyk, Oscar Schofield, Costantino Vetriani and Paul Falkowski

Although all chloroplasts are derived from a common ancestor, a major schism occurred early in the evolution of eukaryotic algae that gave rise to red and green plastids. In Paleozoic and earlier times, the fossil record suggests that oceanic eukaryotic phytoplankton were dominated by the green lineage, however, following the end-Permian extinction, eukaryotic phytoplankton that evolved from secondary symbiotic associations in the red algal lineage rose to ecological prominence. To understand the intrinsic genetic factors that may have facilitated the radiation and ecological success of phytoplankton in the red line, we analysed whole plastid genomes. Our results suggest that whereas a core set of genes has been retained in all algal plastids, red plastids retain a secondary set of genes that potentially confer greater physiological independence from the host. We hypothesize that specific gene losses in the primary endosymbiotic green plastid, especially the transfer of the small subunit of ribulose 1,5-bis-phosphate carboxylase/oxygenase (RuBisCO) to the host nucleus, reduced the fitness of green plastids as a portable genetic entity for subsequent symbiotic associations.

Physical Dynamics and Optical Character of the Hudson River Outflow Plume

Donald R. Johnson, Oscar Schofield

Under pressure and density forcing, river outflow plumes turn in an anticyclonic path and become trapped by Coriolis and topographic constraints against adjacent coastlines. The resulting freshwater plumes can extend for along-coast distances of over 100 km from their sources, with an offshore scale of 5-15 km. Downwelling favorable winds confine the plumes and amplify the alongshore currents within them. When winds turn to an upwelling favorable state, the plumes are rapidly mixed into the interior of the continental shelf. The plumes are biologically and optically important contributors to interior shelf waters due to high loads of CDOM, chlorophyll particulates and sediments. In this study, we examine the results of a mooring array and shipboard survey along the coast of New Jersey during July, 2001. Using ac-9 (wetlabs) and other optical instruments, calibrated against filter pad measurements, we describe the distribution of optically important materials in the plume and adjacent waters, and relate the dynamics of the plume (adcp and temperature/salinity arrays) to the inherent optical property distribution, an important foundation for interpretation of color satellite images.

Vertical migration of a toxic Karena brevis red-tide and the impact on ocean color remote sensing reflectance

John Kerfoot, Kevin Mahoney, Gary Kirkpatrick, Steve Lohrenz, Oscar Schofield

Remotely sensed data primarily provides information on the surface layer of the ocean. In the optically deep ocean, however, there can be large vertical variability in particulate and colored dissolved organic matter (CDOM), which significantly affects the absorption, scattering and attenuation properties of the water column. Together, these facts raise the question of whether information on subsurface structure can be determined by surface satellite data. Blooms of the toxic red-tide dinoflagellate, Karena brevis, are positively phototactic, and their migration will impact ocean color remote sensing reflectance as they swim into an optical depth detectable by the satellite. As part of the EcoHAB and HyCODE programs, we measured the vertical migration of a natural population of K. brevis over a diel cycle making hourly measurements of the inherent optical properties (IOPs). The IOPs provided inputs into the Hydrolight radiative transfer model allowing us to assess the impact of the diel changes in the vertical distribution of K. brevis on remote sensing reflectance (Rrs). Initial surface water values of attenuation at 412 nm during predawn hours were approximately 0.64 m-1, but increased ca. 3 fold during the course of the light period to 2.00 m-1 by mid-afternoon. Surface slicks decreased in the afternoon as cells migrated away from the surface and toward the bottom. The impact was apparent on the magnitude and spectral shape of the IOP's, with late afternoon samples consistent with high phytoplankton absorption. Concentrations of CDOM increased with the migration of the K. brevis population to the surface waters; however the change in the reflectance was dominated by the increase in the phytoplankton absorption (73% decrease in a412/a676 and 60% increase in b4440/a440). Overall however, the net result was that remote sensing reflectance became increasingly green-shifted reflecting the position of the subsurface population. The greening of the surface reflectance, derived from the IOPs, over the diel migration cycle was used to assess the degree with which subsurface features could be distinguished. Secondarily, comparison of the overpass schedule of the international constellation of color satellites with this diel behavior will determine whether the red tide will be detected by the changes in surface reflectance.

Continuous, Real-Time Determination Of Hyperspectral Absorption Of Colored Dissolved Organic Material

Gary J. Kirkpatrick, Matthew Oliver, Barbara Berg, Cristina Orrico, Mark A. Moline, Steven E. Lohrenz and Oscar M. Schofield

Rapid characterization of CDOM over relevant time and space scales is important for characterization of coastal processes. Water just offshore in the 'coastal zone' can vary rapidly both in space and time between 'blue', clear water to dark, loaded water. Standard methods for determining the absorption of CDOM are laborious and susceptible to interference, and are therefore not conducive to providing the temporal and spatial resolution desired. To improve spatial and temporal resolution and to minimize variability due to sampling, storage and analysis techniques, a real-time, automated system was developed based on a liquid waveguide capillary cell and a fiber-optic spectrometer. New technologies in sample handling and optical characterization incorporated in the automated system reduced user involvement and greatly increased spatial and temporal coverage. The CDOM mapper was tested during two summer seasons at the Rutgers University LEO-15 study site and during the ECOHAB: Florida process cruise in October 2001. Concurrent discrete water samples were collected, filtered and stored at regular sampling stations for laboratory analysis of CDOM absorption. Additionally, vertical profiles of CDOM absorption were conducted using a commercial, hyperspectral absorption meter during the ECOHAB: Florida cruise. Contour maps of CDOM absorption spectra generally showed strong gradients along the depth gradient. The LEO-15 results contained small-scale features in the mapped absorption that indicated boundaries where terrestrially derived water met oceanic water. Similarly, in the ECOHAB: Florida results there were distinct boundaries between bloom and non-bloom waters. The results to be presented suggest that the CDOM mapper may be applicable to routine high- resolution (time, space and spectral) characterization of CDOM absorption.

Characterization and Calibration of a Hyperspectral Coastal Ocean Remote Sensing Instrument

David Kohler, Paul Bissett, Curtiss Davis, Jeffery Bowles, Daniel Dye, Jessica Britt, Jonathan Bailey, Robert Steward, Oscar Schofield, Mark Moline, Scott Glenn, Cristina Orrico

The non-linear responses of marine optical signals have made coastal ocean areas of Case 2-type waters a challenging environment for remote sensing. Hyperspectral remote sensing with its continuous, high-resolution spectral information has long promised to help in unraveling some of the difficulties by bringing to bear the mathematical tools of imaging spectroscopy onto the non-linear problem. However, these tools require a high confidence in the absolute radiometric calibration of the hyperspectral sensor. During the 2001 Hyperspectral Coastal Ocean Dynamics Experiment (HyCODE) at the Long-term Ecological Observatory-15 m (LEO-15) site off the coast of New Jersey we collected multiple days of high altitude imagery in support of the ONR objectives to develop in-situ optical hyperspectral algorithms and nowcast/forecast techniques. An explanation of the calibration techniques and data produced by the Portable Hyperspectral Imager for Low Light Spectroscopy II (PHILLS II) will be presented, as well as comparisons between the hyperspectral imagery and in-situ data.

Inferring Physical Processes Using Phytoplankton Structure and Bulk Optical Properties in Coastal Waters.

M. A. Moline, W. P. Bissett, R. Chant, S. M. Glenn, and O. M. Schofield

The nearshore waters off the central New Jersey coast are characterized by a two-layered system separated by a strong offshore pycnocline. The onshore expression of this density gradient fluctuates in response to the episodic upwelling and downwelling events, with a spreading of the isopycnals in intermediate conditions. Phytoplankton responses to this physical structure are varied, with the chlorophyll maximum located either on or within the pycnocline layer, suggesting differential mixing. During the summer of 2001, multiple transects of physical, optical and biological data were collected at the Long-term Ecological Observatory (LEO-15) to examine the biological response to pycnocline dynamics. While biological material is distributed cross-shore along the pycnocline, generally increasing inshore ($>$15ug/L), it is not known whether the origin of the material offshore is the same as that along the coast. A time series of satellite ocean color data suggests that the origin of biological material along the pycnocline may be dependent on the episodic events. Bulk optical properties along with discrete measurements of phytoplankton taxonomic structure will be used as tracers to examine and differentiate the physical processes in the study area.

Bio-Optical Estimates of Phytoplankton Productivity from an Autonomous In Situ Profiler in the Coastal Waters of the Mid-Atlantic Bight

Matt Oliver, Mark Moline, Oscar Schofield, Trish, Paul Bissett, Scott Glenn

As part of the Hyper Spectral Coupled Ocean Dynamics Experiment (HyCODE), a high resolution vertical 15 day time series of the inherent optical properties (IOPs) and bioluminescence were collected with an autonomous optical profiler. Significant variability was observed in the water column optical properties. Using multivariate cluster analysis, water masses were defined based on the inherent optical and physical parameters. The cluster results from the IOPs alone could differentiate both the major water masses and episodic mixing events as indicated by density. For the distinct water masses productivity parameters were assigned from photosynthesis- irradiance curves that were measured throughout the experiment. The resulting productivity database was combined with downward light fluxes derived from continuous above water measurements and the measured in situ inherent optical properties. The resulting productivity measurements were compared to productivity estimates derived phytoplankton absorption capabilities, derived by deonvoluting the total absorption measured with an ac-9, downward light fluxes, and a constant maximum quantum yield. Over the fifteen day experiment, both volume specific and integrated water column estimates of gross phytoplankton production compared favorably between the physiology-based and optically based model (WHAT ARE % here, put some numbers in the manuscript), indicating a good estimate of phytoplankton production can be derived from measured IOP's in dynamic, nutrient replete, coastal waters.

Deconvolution of Spectral Measurements to Derive Optically Active Constituents in Turbid Coastal Waters.

C. M. Orrico, T. Bergmann, P. Bissett, M. A. Moline, O. M. Schofield

Quantitative estimates of phytoplankton absorption are central to bio-optical productivity models and are a key component for field programs dependent on delineating specific algal classes. Estimating phytoplankton absorption from bulk {\it in situ} measurements is difficult given the absorption of Colored Dissolved Organic Matter (CDOM) and detritus, which becomes especially significant in optically-complex coastal waters. We have developed a method that deconvolves the bulk absorption, as measured with a Wetlabs ac-9, into the respective contributions of CDOM, detritus, and three spectral classes of algae (chlorophyll c-, chlorophyll b-, and phycobilin-containing). As part of NASA and ONR research at the Long term Ecosystem Observatory (LEO-15), we validated the approach with over 580 discrete filter pad absorption estimates for the 2000 and 2001 field seasons. The R^{2} between measured and ac-9 predicted absorption was 0.88 for the 2000 field season, with no major spectral bias except in the wavelengths associated with phycoerythrins. When particulate spectra were deconvoluted into the three major spectral classes of phytoplankton, with chlorophyll a-c containing groups being prevalent, the R^{2} was 0.62. This approach was found to be limited by the availability of wavelengths as measured by the ac-9. Application of the inversion model to deconvolute both discrete filter pad absorption spectra as well as {\it in situ} hyperspectral data will be examined and demonstrated.

Optical Estimation of Phytoplankton and Sediment Transport in Morro Bay Estuary

Jessica Pearson

Morro Bay National Estuary, California has experienced an increase in sediment deposition resulting from land use changes in the surrounding watershed. An increase in suspended particles in the water and the resultant loss of the estuary's aerial extent has had a detrimental effect on the survival of benthic filter feeders and other invertebrates. Two possible explanations for sedimentation events are increased erosion from fresh water sources into the bay, and the transport of sediment from adjacent coastal waters. To assess sediment loading and primary production over an extended period of time under a variety of environmental conditions, moored instruments (HydroScat-6, CTD) took physical and optical measurements at forty-five minute intervals between October 2000 and May 2001. Discrete measurements were taken during optical sampling intervals and correlated with instrument data. Through observation and statistical validation between the differences of incoming and outgoing tidal components, this data set provides evidence for Morro Bay estuary as a net source for sedimentation (t-test, $p=0.003$) and a net sink for phytoplankton production (t-test, $p=0.000$). Despite Morro Bay's national recognition, little work has been done to assess the loss of aerial extent of the estuary. Based on these results, assumptions can be made about possible terrestrial sources of sediment load and appropriate management practices.

The Evolution and Radiation of Eucaryotic Phytoplankton Taxa (EREUPT)

Oscar Schofield and Paul Falkowski

The EREUPT research team, representing a group of 21 scientists from numerous institutions, is focused on understanding the historical origins and environmental conditions that led to selection and radiation of the major eucaryotic phytoplankton taxa, and the ecological processes that contribute to their continued success in the contemporary ocean. The proposed research utilizes a combination of geological, molecular biological, ecological, and models. Our primary goal is to develop the first quantitative models of eucaryotic phytoplankton community structure in the contemporary oceans based on paleoecological and evolutionary inference. The proposed research seeks to test a set of three related hypotheses, from which we will develop a conceptual model for evolution and ecological success (dominance) of key phytoplankton taxa in the contemporary ocean. The central hypotheses are: 1) The three dominant phytoplankton taxa in the contemporary ocean evolved in shallow shelf-seas in the Mesozoic Era in response to changes in the ocean environment, such as anoxia, changes in sea level, or tectonic processes that excluded ecological advantages previously afforded to chlorophytes. 2) Once established, these groups radiated rapidly. The rapid tempo of evolution was a consequence of high mutation frequencies relative to reversion and sexual recombination, resulting in high genetic potential and DNA content relative to genetic expression in the three taxa. The rapid tempo of evolution in the three taxa has permitted rapid radiation and adaptation to changing oceanic conditions throughout the Mesozoic. This rapid tempo continues to the present time. 3) The ecological dominance of the three major eucaryotic phytoplankton taxa is a consequence of pan-division traits that permit individual species within each group to rapidly accommodate large variations in oceanic conditions. These traits include the evolution of cell walls and vacuoles that respectively provide protection from predation while simultaneously optimizing the exploitation of pulsed nutrient supplies. A corollary of this hypothesis is that the structure of marine food webs in the contemporary ocean is primarily a consequence of the tempo of evolution of the three major taxa of eucaryotic phytoplankton, which itself is a consequence of continuous changes in oceanic regimes.

Light Stress and TEP Production in Phytoplankton Communities in Turbid Coastal Waters

Jessie Sebbo, Trisha Bergmann, John Kerfoot, Sasha Tozzi, Oscar Schofield

The effect of light stress on the production of transparent exopolymer particles (TEP) was studied in natural phytoplankton populations off the New Jersey coast during the 2001HyCODE/COMOP Coastal Predictive Skill Experiments. Nearshore waters generally are optically turbid and the resident phytoplankton populations are often low-light adapted. TEP production is generally enhanced when cells are photoinhibited. Given this, we hypothesized that coastal communities should be particularly sensitive to high light stress and thus potentially produce a great deal of TEP when they are mixed to surface waters. Secondarily, we predicted that surface light stress should be greater for inshore communities compared to offshore communities who reside in clearer waters. Discrete samples were collected from offshore and inshore stations at 8 m depth, and were incubated for 24 hours outdoors under ambient light. Ambient light levels were comparable to light levels just below the surface at both offshore and inshore sampling sites. Nearshore populations were very low light adapted as indicated by significantly lower Ik values (factor of 2) and were heavily light stressed, compared to their offshore counterparts, by surface irradiance. The TEP abundance and TEP production rates were an order of magnitude greater than the offshore community. This confirmed that light stress is positively correlated with TEP production in natural populations. In this area, topographic variations associated with ancient river deltas cause upwelled water to evolve into an alongshore line of three recurrent upwelling centers that are co-located with historical regions of low Dissolved Oxygen (DO). Upwelling results in the Ekman transport of water offshore and the transport of mid- and bottom water phytoplankton communities to the surface. Satellite and ship data confirm that significant phytoplankton blooms are associated with these upwelling events. Furthermore, SCUBA divers often observe marine snow. Given our findings of the potentially large TEP production rates in the nearshore populations, we hypothesize that TEP formation, via light-stressed populations, may strongly influence the hypoxic/anoxic zones off the coast of New Jersey.

The spatial and temporal relationship between biomass and hydrography on New Jersey's inner shelf during the summer of 2001.

Robert J. Chant, Oscar Schofield and Scott M. Glenn

As part of the Hyperspectral Coupled Ocean Dynamics Experiment (HyCODE) remote and in situ observations of the ocean's color were made on New Jersey's inner shelf to characterize its relationship to coastal circulation processes. During the summer of 2001 a plankton bloom developed that was so intense that it drew the attention of the public and the local press. During this bloom we conducted ~40 20-km cross-shore shipboard surveys with an undulating CTD/fluorometery package. While each transect displayed a strong correlation between fluorescence, which we use as a proxy for biomass, and stratification the position of the biomass in temperature space varies in time. High biomass occurs either in the surface mixed layer or in a tight band in the thermocline and this positioning appears to be correlated with the physical forcing. During upwelling conditions high biomass was observed in the stratified upwelled waters inshore and tended to move offshore into the thermocline as upwelling conditions relaxed. After a storm biomass was intensified in the surface mixed layer, but moved back into the thermocline as stratification was reestablished. With these cross-shore sections a 30 day time series of the first and second moments of the biomass in temperature space is constructed for both the inshore half and offshore half of the transect. The variability of this time series is related to coastal circulation and wind and buoyancy forcing.

Particle Transport Observations in the New York – New Jersey Harbor.

Clinton Haldeman III, Richard Styles, Robert Chant, Scott Glenn, Kelly Rankine, Michael Bruno

A major goal of the New Jersey component of the Contaminant Assessment and Reduction Program in New York-New Jersey Harbor is the identification of the transport pathways for contaminated sediments within the estuary. Monitoring efforts have been established within three waterways (Newark Bay, the Arthur Kill and the Kill van Kull) to provide validation data for upcoming modeling studies. Between March 5th and April 2nd, 2001, moorings equipped with a small suite of monitoring elements were deployed within each of these three waterways. Sensors included a LISST (Laser In Situ Scattering and Transmissometer), an Optical Backscatter Sensor (OBS) and an Acoustic Doppler Profiler (ADP) to measure suspended particle concentrations, particle size distributions and current/backscatter profiles. Results from these moorings indicate that total suspended particle concentrations vary substantially, in both time and space, over the one-month deployment. The highest concentrations across all particle sizes occur during maximum flood tide with lower concentrations during the weaker ebb tide. This pattern is modulated by the spring-neap tidal cycle, where total concentrations during spring tide are increased an order of magnitude.

One potential advantage of the LISST is that it measures particle concentrations in 32 size classes. Acoustic backscatter from the bottom bin of the ADP was highly correlated with the largest LISST particles (400-500 microns), while correlations between the LISST and the OBS were much smaller for all size classes. At the northern end of Newark Bay, acoustic backscatter, optical backscatter, and the large LISST size class concentrations were approximately symmetric with respect to flood and ebb, leading to a net transport in the same direction as the residual flow. The smaller particle sizes observed by the LISST in the range 70-90 microns (um), however, where found to be significantly larger during the maximum flood tide, leading to a net transport of fines opposite the residual flow. In the southern reach of the Arthur Kill, flood tides produced the highest concentrations with larger sediments in the 200 – 300 um range. Particle concentrations in the Kill van Kull are much lower than in the other two systems, and are not well correlated with the tide at any particle size range.

Direct Observations of estuarine dispersion: Results from a recent dye study

W.R. Geyer, R.J. Chant, R.W. Houghton

A dye study conducted in the Hudson River estuary has revealed how secondary circulation and mixing influence stream-wise dispersion in a partially mixed estuary. The study was conducted in a reach of the channel characterized by relatively uniform cross section, with a 15m thalweg running along the eastern edge of the channel that gradually shoals to the west. The dye injection occurred at 10 m depth into the bottom mixed layer across thalweg during flood. During flood the dye remained in the bottom mixed layer but most of it was advected across the channel, towards the shoaling western flank, and was jammed into the region where the halocline intersects the bottom. Most of the diapycnal transport of dye occurred during the ebb, on the shallow side of the estuary, where the halocline extended right to the bottom. As the dye was transported vertically, it encountered higher velocities due to the strong shear, resulting in rapid seaward advection. The northern edge of the dye patch was not mixed vertically during the ebb, but rather was advected back into the deeper eastern channel, where currents were weakened during ebb due to the competing baroclinic forcing.

This combination of along-channel shear, secondary circulation and mixing resulted in a rapid straining of the dye patch, with an effective along-channel dispersion of O(1000 m2/s). The nature of the dispersive process fundamentally differs from the classic estuarine paradigm for dispersion, which involves only shear and vertical mixing. The observations are closer to the Ron Smith dispersion mechanism, although the presence of stratification and the tidal variations of secondary circulation lead to a more complex and energetic regime. These observations suggest that secondary circulation is an important element not just for dispersion but also for its contributions to the momentum and salt balances.

Circulation and mixing in a complex estuarine environment. Effects on the transport and fate of suspended matter.

Elias Hunter, Robert Chant, Rich Styles, Scott Glenn, Kelly Rankin, Mike Bruno

As part of the New Jersey Department of Environmental Protection's Toxics Reduction Program, we are conducting hydrographic surveys of the Newark Bay complex to characterize physical pro-cesses within this estuarine system. The observations include shipboard and moored current observations and salinity, temperature and turbidity measurements. A major objective of these surveys is to provide a dynamical framework that will aid in the interpretation of chemical data, as well as to provide insights into the transport and fate of dissolved and suspended material. This framework is particularly needed because of the complex nature of this estuarine system that is comprised of multiple sources of fresh water that feed several semi-enclosed bays that are inter-connected by a pair of tidal straights. This poster will focus on exchange processes in the two tidal straights. The Kill van Kull tidal straight runs east-west connecting New York Harbor to Newark Bay and the Arthur Kill tidal straight runs north-south connecting Newark Bay to Rari-tan Bay. Observations emphasize that while buoyancy effects, meteorological forcing and tidal processes drive exchange in these straights the relative importance of these processes varies in both space and time. In the Kill van Kull a classic estuarine two-layer buoyancy driven flow is evi-dent, with eastward flowing surface layer over a westward flowing bottom layer. This two layer circulation, however, vanishes during spring tide conditions and during times of low river dis-charge. Wind forced motions appear to dominate exchange through the Arthur Kill. Examples of these processes will be presented as will their effect on the transport of suspended matter.

An Evaluation of the Mass-balance Equation for Suspended Sediments Using an Eddy Diffusitivy Parameterization

Richard Styles, Scott Glenn

A statistical average of the continuity equation for suspended sediments leads to a simple balance between upward turbulent diffusion and gravitational settling. This result has formed the basis of sediment transport studies for nearly a century and, with an appropriate turbulent closure scheme, it is routinely used to model vertical distributions. Despite its widespread use, it is almost never evaluated, unlike the momentum equation, to determine the conditions for which the simple balance holds. The present study focuses on a depth-integrated form of the mass-balance equation in the context of predicting suspended sand concentrations over ripples in a wave-dominated continental shelf environment. The results indicate that for two widely used eddy diffusivity closures the depth-integrated sediment concentration is strongly correlated with the turbulent sediment flux. The results show further that the balance holds for heights above the predicted wave boundary layer thickness only when the closure scheme is formulated in terms of the combined stress. This has implications for modeling sediment transport in wave-dominated environments, in which the present state-of-the-art bottom boundary layer models may be significantly under predicting the spatially averaged wave boundary layer thickness.