than that of the Pacific regions. SeaWiFS chlorophyll patterns are compared to coincident large-scale wind forcing and satellite-measured surface temperature to estimate linkages between physical forcing and biological response. Concentration differences during the El Nino period were not due to local differences in wind forcing.

OS11Q-10 1105h

Sverdrup's Critical Depth Hypothesis and the North Atlantic Spring Bloom

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The spring bloom of phytoplankton in the North Atlantic Ocean has long fascinated oceanographers. In 1953, Harald Sverdrup developed a simple, quantitative relationship for the necessary conditions leading to a spring bloom. Although this model has been applied extensively across a variety of aquatic ecosystems its application requires knowledge of the community compensation irradiance, the in situ light level where photosynthetic and community respiration processes balance. Here, we use satellite ocean color imagery from the SeaWiFS mission and available hydrological data to characterize the North Atlantic spring bloom and to estimate values of compensation irradiance. Ocean color imagery are used to determine the day of the onset of the spring bloom, as well as the fluxes of incident radiation and penetrating radiation at depth. Following Sverdrup's hypothesis, the value of the mixed layer depth when the spring bloom starts is equivalent to the critical depth which enables spatial distributions of the compensation irradiance to be made for an entire ecosystem. Average values of community compensation irradiance from 40°N to 75°N are 1.3 ± 0.3 Einstein m^{-2} d^{-1} and there are no consistent spatial variations. These estimates are roughly twice typical values found for phytoplankton populations alone and indicate that phytoplankton respiration accounts for roughly one-half of the total community respiration. This approach for estimating community compensation provides a powerful way of remotely quantifying heterotrophic processes in pelagic ecosystems.

OS11Q-11 1120h

Spatial Distribution of Optical Water Types in the Northwest Atlantic as Revealed by Feature-Based Classification of Satellite Ocean Colour Data

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We have undertaken an analysis of the spatial and geographic distribution of optical water types in the Northwest Atlantic based on remotely-sensed ocean colour data. Application of our novel optical water type classification approach to CZCS and SeaWiFS imagery of the Northwest Atlantic region has revealed that pixels from several different locations project into distinct clusters in water-leaving radiance feature space, suggesting that these waters can be distinguished using a few spectral bands of ocean colour data. We have constructed a classifier training set for the Northwest Atlantic, and developed two different feature-based classification techniques: the Euclidean Distance Classifier and the Eigenvector Classifier. These classifiers had very high success rates when applied to a test dataset with known class memberships; both classifiers averaged more than 290 correctly classified pixels of a possible 300. We applied these classifiers to ocean colour images of the Northwest Atlantic, and were able to map the geographical location and spatial extent of each water type. Our analysis exposed striking patterns of water type distribution throughout the region. The Northwest Atlantic appears to be dominated by six clearly distinguishable optical water types, and classifier application reveals that waters of the same optical type form well-defined, cohesive water masses that remain in the same general geographical regions over time. To interpret our classifier results, we applied our Classification Goodness of Fit measure, which indicates how closely a given pixel is associated with its assigned class. This measure confirmed that sharp boundaries generally exist between water masses of different optical types, with pixels on either side of the boundaries being strongly associated with their water type class. We anticipate that our classification techniques will facilitate long-term time series studies by tracking optical water types through seasonal and interannual changes, thereby furthering our understanding of the spatial and temporal dynamics of ecologically and biogeochemically important properties of the upper ocean.

OS11Q-12 1135h

Mesoscale and Submesoscale Ocean Color Variability About the Bermuda Atlantic Time-series Site (BATS)

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Study of mesoscale ocean color variability (20–200 km) is extended to the submesoscale (1–20 km) by applying geostatistical techniques to high resolution (∼1.1 km) SeaWiFS images from the Bermuda area. One goal of this study is to determine whether the patterns observed from an analysis of global, mesoscale resolution ocean color data are reflected also in higher resolution data that better resolves the submesoscale. In particular, the earlier global analysis of the standard mapped image (SMI) data showed that much of the high frequency space and time variability in oligotrophic regions is unresolved at ∼9 km resolution. This suggests either a significant submesoscale signal or a substantial contribution from instrument and algorithmic noise. To pursue this question an initial analysis of SeaWiFS data (∼1.1 km resolution) from an approximately 10° square around the BATS site is presented. The nugget (or unresolved variability) is larger in the high resolution data while the relative sill (or variability of the geophysical signal) is approximately the same. Additionally, the range (or the decorrelation scale length) for both the SMI and high resolution data are approximately the same with the high resolution values being slightly smaller. Statistical tests on the significance of these differences will be presented along with the results from the 12 month comparison between high resolution and SMI data at Bermuda. The ramifications for the application of mesoscale SMI ocean color variability at global scales and the relative contribution of submesoscale versus mesoscale processes will be explored.

OS11Q-13 1150h

Meso-Scale Oceanic Eddies On The Synthetic Aperture Radar Images: Eddy Classification And Image Interpretation

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Continuous observations since 1991 by using the (SAR) aboard the Almaz-1, ERS-1/2 and RADARSAT satellites have shown that oceanic eddies are worldwide distributed in the ocean. This paper presents the results of classification of typical vortex motion in the ocean visible in the optical, IR and SAR satellite imagery and evaluation of spaceborne technique potential for oceanic eddy detection and monitoring. Main typical elements of ocean vortex dynamics detected in the satellite imagery include the ocean rings, spin-off eddies, eddies of open ocean, island wakes, eddies due to current interaction, eddies behind islands (in bays) and mushroom-like structures. Space/time and kinematic characteristics of different vortical types are also presented and their generation mechanisms considered. Manifestations of the oceanic eddies allow to retrieve the eddy's parameters such as dimensions, rotation direction, spiraling order, lifetimes, temperature contrasts and chlorophyll/suspend matter concentration. Unknown aspects of oceanic eddy formation and evolution are also discussed. By analyzing the satellite imagery it's shown the common features for most observed eddies are a broad spectrum of spatial/temporal scales (ranged from 0.5-1 up to 300-400 km and from 0.5-1 days till 1 year), spiral shape and shear nature. Usage of satellite imagery, first of all, SAR images plus visual and IR images allows to extract the exhausting information on vortex motions in the ocean. It is concluded that the spaceborne sensors give valuable information about the ocean eddies. Examples of satellite images showing the different eddy types are also presented and discussed.

OS11R HC: 317 B Monday 0830h

Synthesis of the Arabian Sea Expeditions I

Presiding: **S L Smith,** University of Miami**; P Burkill,** Plymouth Marine Laboratory**; S W Naqvi,** National Institute of Oceanography

OS11R-01 0830h

A Feature oriented regional modeling system for the Arabian Sea, Persian Gulf and the Red Sea

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An eddy-resolving primitive equation dynamical modeling system has been set up for the Arabian Sea, Persian Gulf and the Red Sea regions using a feature-oriented approach. The model domain extends from 10N to 30N and from 45E to 75E with a horizontal resolution of 15 km. In the vertical, sixteen levels are selected in a double-sigma configuration to resolve both the shallow coastal/Gulf regions and the deep basins.

The water mass property distributions of the major circulation features in this region have been 'feature modeled' by analyzing historical synoptic data sets. Specific 'feature models' for the southwest summer monsoon regime have been developed for (1) the equatorward Western India Coastal Current, (2) the poleward undercurrent along the western coast of India, (3) northward currents along the coast of Arabia and associated upwelling regions, and (4) the high salinity waters in the Red Sea and the Persian Gulf. Synoptic realizations of these features in the climatology background provide the initialization fields for dynamical simulations. Example short-term (1-3 days) and medium-range (7-10 days) simulation case studies to calibrate the impact of monsoon winds, evaporation and precipitation will be the focus of this study.

OS11R-02 0850h

On the Generation of Coastal Filaments During the Spring Intermonsoon

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Among the discoveries of the JGOFS Indian Ocean Expedition was the realization of the importance of coastal jets and filaments along the Oman coast during the SW monsoon. It was shown that such filaments are capable of exporting nutrient rich upwelled water hundreds of kilometers offshore and appear to play important roles in the large-scale phytoplankton bloom in the Arabian Sea during the summer monsoon season. As to whether the generation of these filaments is governed more by the offshore deflection of a coastal current or from an interaction between the wind field and pre-existing meso-scale features in still in debate. But what about filaments generated during the weakly-forced Spring Intermonsoon season? What are the mechanisms by which these filaments are generated? What role(s) might they play in pre-conditioning the coastal environment to the ecosystem consequences of the strong SW monsoon forcing? Such questions are

addressed by using results from the operational, real-time, global Navy Ocean Layered Model(NLOM) running at the naval Oceanographic Office(NAVOCEANO) and SeaWIFS imagery for the Sping Intermonsoon of 2001. The NLOM model, which is run at 1/16th degree resolution, has an embedded mixed layer and assimilates altimeter and MCSST observations, is in excellent agreement with SeaWIFS ocean color imagery in revealing a filament along the Oman coast in mid-April of 2001. The model reveals that the filament was generated by the interaction of two counter-rotating eddies with the coastal circulation during an upwelling-favorable wind event. SeaWIFS imagery has been processed to uncouple the bio-optical properties within the filament infrastructure. We illustrate the distribution of chlorophyll, backscattering at 555 nm and absorption from colored dissolved organic matter (CDOM). Backscattering defines how coastal particles are located within the filament and how they are distributed offshore and settle below the satellite observations. CDOM absorption defines the degradation of organic matter and how is distributed and disbursed offshore. The implications of such intermonsoon filaments to the bio-physical response during the intense SW monsoon are discussed.

OS11R-03 0910h

Translocation of diapausing Calanoides carinatus in the Mesopelagic/Deep Layers in the Arabian Sea: Modeling Lagrangian Particle Drift in an Isopycnic Ocean Model.

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We use the Miami Isopycnic Coordinate Ocean Model (MICOM), configured for the Arabian Sea, to track particles as they drift in isopycnic layers corresponding to 500-1000m depths. The Lagrangian particles are assumed to represent populations of the copepod Calanoides carinatus, an indiginous species of the Arabian Sea that includes a diapausing stage as part of its life cycle, usually the last juvenile stage (fifth copepodite stage). It is hypothesized that the oligotrophic conditions, following the productive Southwest Monsoon season, may trigger the onset of diapause in this species that overwinters in the deep layers. The overwintering period is thought to begin in August-September and end in May, when the new generation takes advantage of increased diatom production associated with seasonal upwelling.

Model drifter trajectories are numerically solved at the same time step (15 min.) as MICOM (online simulations) using a forth-order Runga-Kutta algorithm. Particle trajectories consist of a deterministic component derived from the MICOM velocity fields and a random component that simulates turbulent flow. The particles themselves represent populations of C. carinatus that are in a state of nonfeeding diapause. Therefore only lipid catabolic expenditure (respiration) is modeled during the overwintering period. The particles are launched in isopycnic layers 6-10 at specified times in August and September off the coast of Somalia. Individuals have a lipid reserve of 50-65% of body dry weight and allowed to drift for an 8-9 month period. At the end of the simulation, the remaining lipid content is calculated and equated to potential egg production. Preliminary results indicate the layer at which particles drift is extremely important in determining the fate of these populations with respect to their emergence from diapause in favorable versus unfavorable conditions.

OS11R-04 0930h

A 4-Dimensional Validation of a Coupled Physical-Biological Model of the Arabian Sea

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The Arabian Sea was selected as one of the JGOFS Process Study sites because of its strong monsoonal forcing and large seasonal oscillations in physical and biogeochemical properties. Data from these studies provide a unique opportunity for testing the response of coupled models under a wide range of oceanic conditions. In this paper we compare horizontal sections and time-series generated by a 3-dimensional, coupled, biological-physical model with observations from the U.S. JGOFS Arabian Sea Process Study. These comparisons include modeled and observed mixed layer depth, chlorophyll concentration, inorganic nitrogen concentrations, zooplankton biomass, and particulate nitrogen export flux. With these comparisons we identify both strengths and weaknesses in the model and we attempt to use the model as a tool to help us understand the observed patterns. The model reproduces most of the large-scale variability in these physical and biogeochemcial quantities, which is driven by the monsoonal forcing cycle. Although chlorophyll concentrations are sometimes overestimated, dissolved inorganic nitrogen concentrations are reproduced quite accurately, and the modeled particulate nitrogen export fluxes are similar to the sediment trap measurements. The modeled and observed zooplankton concentrations compare favorably offshore, but they are significantly underestimated near the coast during the Southwest Monsoon. This may be linked to the model's tendency to overestimate chlorophyll concentrations there as well. Many of the discrepancies between the model and the observations are caused by the presence of mesoscale eddy-like features and chlorophyll-rich filaments which emanate from the coast of Oman. These features cannot be reproduced by the model due to its relatively low horizontal resolution. Our comparisons reveal a clear need for higher resolution simulations and they suggest that a more sophisticated representation of zooplankton grazing maybe required for modeling chlorophyll in the coastal zone.

OS11R-05 0950h

The Arabian Sea Model Testbed: an Intercomparison of Data Assimilative Ecosystem Models

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The central Arabian Sea is an ideal testbed for assessing the capabilities of oceanic ecosystem models, since the full range of pelagic environments occur in response to the annual monsoon cycle. The associated atmospheric forcing results in a biannual mixed layer deepening which triggers significant phytoplankton blooms during both the winter and summer monsoons, whereas during the intermonsoons the system shifts to an oligotrophic state. In this study, we carry out simulations using three distinct marine ecosystem models with varying levels of complexity, including a four-component model with diatom-like phytoplankton growth, a five-component model emphasizing the microbial loop, and an eight-component model containing multiple plankton size classes. The models are applied within a consistent one-dimensional framework at the site of the WHOI mooring (15.5N, 61.5E), using physical forcing extracted from a 3-D physical circulation model solution of the Arabian Sea. Chlorophyll a and nitrate data from Station S7 (16N, 62E) and sediment trap data from WHOI mooring MS-4 (15.33N, 61.5E) are assimilated using the adjoint method. In this technique model-data misfits are minimized by adjusting model parameters such as sinking velocities, growth rates, assimilation efficiencies and mortality rates. After objectively optimizing each model in this manner, we quantitatively compare the performance of the different models to determine which specific formulations are most appropriate. That is, we systematically ascertain which model formulations best represent the fundamental underlying biogeochemical processes and capture the magnitude and variability of observed biogeochemical quantities. We conclude with a discussion of the strengths and weaknesses of the various model formulations, recommendations for possible improvements, and suggestions for additional observations that would facilitate future development of pelagic ecosystem models of the Arabian Sea

OS11R-06 1010h

Simulation and Observation of Seasonal to Interannual Variability in the Arabian Sea Ecosystem

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A coupled bio-physical ocean general circulation model is employed to study the seasonal variability of the Indian Ocean ecosystem. The ecosystem portion of the model consists of a 9-component formulation that includes two size classes each of phytoplankton, zooplankton and detritus, as well as three nutrients (nitrate, ammonium and iron). The simulation's ecosystem component is validated against in-situ data obtained during the US JGOFS Arabian Sea Expedition, the NODC seasonal nitrate climatology and basin scale observations of surface chlorophyll a provided by SeaWiFS. A model/SeaWiFS comparison of basin scale chlorophyll a over the tropical Indian Ocean will be presented. A detailed examination of the seasonal cycle in the Arabian Sea will illustrate the model's performance in this region, which is a biogeochemical modeling challenge because of the wide-ranging spatio-temporal variability of its pelagic environment. We will also present some results of our recent research on the physical mechanisms that caused the interannual variation in the magnitude of wintertime phytoplankton blooms in the central Arabian Sea apparent in the SeaWiFS data. We present evidence that this interannual ecosystem variability observed in the Arabian Sea was the result of remote forcing that was affected by the 1997 manifestation of the Indian Ocean Zonal Mode.

OS11S HC: 316 A Monday 0830h

Coral Reef Habitats: New Insights From Integrated Coastal Science I

Presiding: **M Field,** University of California, Santa Cruz**; P Jokiel,** University of Hawaii at Manoa

OS11S-01 0835h

Monitoring Change in Coral Colonies by Changing Physical Environments

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To determine the effect of degrading or improving water quality on coral reefs, we have set up an experiment as part of a broader investigation of coral in which we are determining the effects of sediment and nutrient stress on living coral cover.

We selected sites on the shelf off Mayagez, Puerto Rico where four sites of coral reefs are impacted by terrigenous sediment and/or nutrient influx, and one clean water site. To measure recovery of individual coral removed from stress conditions and the effect of stress conditions on healthy corals, we transplanted corals from stressed environments into the clean water environment. These transplants were onto concrete slabs to avoid local bottom effects. Coral from the clean area were also transplanted as controls. We transplanted coral from the clean environment into stressed conditions at the other sites to observe the effects on these coral. Alizerin red was used to mark the coral at the time of transplant. Fourteen species of coral were transplanted.

Photographs are being taken bi-monthly to observe changes. At the end of the study, growth rates will be measured. The study is scheduled to run for two years, but we have already seen that: Coral are more resistant than expected when subjected to nutrient or sediment stress The colonies either died within the first month, or continued to survive. Stressed coral moved into the clean environment have shown little change except Montastraea cavernosa colonies that are actively budding between older polyps

URL: http://cima.uprm.edu/morelock/mayaguez.htm