OS71F MCC: 274 Sunday 0830h

Scientific Results From Coastal Ocean Observing Systems I *(joint with B)*

Presiding: **C N Mooers,** University of Miami**; E P Dever,** Scripps Institution of Oceanography

OS71F-01 0830h

Oregon Coastal Observing System

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Since 1997, a growing system of sustained coastal measurements, together with a high-resolution, data-assimilating coastal modeling program, have been used off Oregon to study the response of the coastal ocean to forcing at a range of space and time scales. The measurements include a large array of HF radars, which permit time-series mapping of the surface circulation over most of the Oregon coast; both long-term and short-term moored components, which provide time-series sampling through the water column; and repeat hydrographic, ADCP and surface drifter sampling, including the Newport Hydrographic Line (which has been sampled since the 1960s). At interannual frequencies, these measurements show changes in the alongshore circulation over the continental slope accompanying ENSO. At seasonal and storm frequencies, the strength and persistence of spatial patterns in wind-driven currents and the importance of bathymetry in steering the circulation are seen. Discovery of episodic phenomena, such as the recent finding of a hypoxic pool and associated die-off of fish and crabs on the continental shelf off Heceta Head, are made possible by repeated sampling.

OS71F-02 0845h

Data Assimilative Studies of Coastal Circulation off Oregon

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A data assimilation system (DAS), which combines a dynamical model and available data to provide an estimate of the time-varying three-dimensional circulation, will be an essential component of an operational coastal observatory. Data collected in recent years off the Oregon coast provide an opportunity to build and validate a prototype DAS. The COAST data set for spring-summer 2001 includes time series of currents (from HF radars and moorings), temperature and salinity with substantial horizontal and vertical coverage. A data assimilative model of circulation on the Oregon shelf utilizing a sequential optimal interpolation algorithm incorporated into the Princeton Ocean Model (POM) is being applied to this data set. The assimilation method requires an estimate of a stationary forecast error covariance to allow correction of the forecast solution based on model-data differences. Our focus is presently on (a) understanding the sensitivity of the assimilation solution to the choice of the forecast error covariance and other constructs introduced by the DA scheme, (b) examining the effectiveness of constraining temperature and salinity fields by assimilating velocity from HF radars and/or moorings, and (c) optimal data sampling strategies.

OS71F-03 0900h

Ocean Observatory efforts in and around Monterey Bay, California, 1930 to the present

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Monterey Bay (MB) is a deep (>1000 m), non-estuarine embayment in central California broadly open to the coastal ocean. Its oceanography had received considerable study beginning in the early 1930s when MB was the center of a large sardine fishery, and continuing intermittently since the collapse of the fishery in the 1950s. Many studies had been conducted within and offshore of MB, primarily by the many marine science laboratories and academic departments ringing Monterey Bay, and the time series studies constituted an impressive, albeit discontinuous, record (at least 39 of 61 years between 1928-1989). The Monterey Bay Aquarium Research Institute (MBARI) initiated in 1989 a program of inter-disciplinary semi-monthly time series cruises to stations within and offshore of MB. In addition to the shipboard time series, MBARI has maintained two moorings since 1989 (M1 and M2). More recently, additional moorings have been deployed for shorter periods by MBARI (M3, S2, S3) and the Naval Postgraduate School (NPS) (M4). The M moorings are equipped with meteorological, physical, chemical, and bio-optical instrumentation. The S moorings have current meters and sediment traps. Since 1997, as part of a cooperative program between MBARI and NPS, quarterly cruises that occupy CalCOFI line 67 to 300 km from shore, have been carried out. High-frequency radar (CODAR) measurements of MB by NPS, Cal State University MB and UC Santa Cruz, collected since 1995, have recently been augmented with coverage south of Point Sur. Since 1997, UC Santa Cruz and MBARI have carried out cooperative studies of zooplankton abundance and composition. Finally in 1998 modeling studies have been initiated in an effort to integrate the available data and to direct future observational studies. Several new collaborative initiatives, funded by NSF (MARS), N OAA (CIMT) and, ONR (AOSN) geared at adding new and more sophisticated observing and modeling capabilities, are set to begin in the near future. In this paper we review some of the discoveries and scientific advances that have resulted from the sustained time series and show that we are beginning to understand the functioning and complexities of Monterey Bay pelagic ecosystems. As new technologies are deployed to explore the interconnected physical, geological, chemical and biological processes, the challenge will be to integrate these data into new conceptual and dynamical models of ocean dynamics. This will require a truly synergistic effort between organizations and disciplines.

OS71F-04 0915h

The Santa Barbara Channel - Santa Maria Basin Study: A model for Coastal Ocean Observing Systems

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The need to anticipate the potential impact of oil exploration and production activities on coastal resources, and the information needs of agencies charged with responding to coastal emergencies motivated the development of the oil-spill response system for the Santa Barbara Channel (SBC) and the Santa Maria Basin (SMB), along the California coast, between Ventura and Morro Bay.

In the Santa Barbara Channel (SBC), moorings and drifter trajectories document a persistent cyclonic circulation with a typical re-circulation period between three and five days. In the spring currents near the mainland are weaker than near the Channel Islands and the overall flow is toward the southeast. Trajectories document the possibility for water parcels to leave the channel through the inter-island passes. In the late fall and winter, a poleward flow with velocities often exceeding 0.5 m/s is confined within 20 km of the mainland. Between these two seasons, the cyclonic tendency is enhanced although most of the drifters eventually migrate westward. The trajectories of drifters released at the same time from sites only 20 km apart can be remarkably different.

In the Santa Maria Basin (SMB), the direction and amplitude of the flow is strongly depth dependent. Near the surface, moorings and drifters show the flow to be equatorward except during late fall and early winter when the surface flow is poleward. Beneath the surface layer the flow is poleward except in March and April, right after the spring transition.

The observations provide a basis on which several data assimilating model of the circulation are based. The models reproduce all the major observed features of the circulation, including individual drifter trajectories. With little effort these models could be used to maintain an operational predictive capability with real predictive skills over periods of a few days.

URL: http://www.ccs.ucsd.edu/oilspill

OS71F-05 0930h

The Santa Barbara Channel-Santa Maria Basin Circulation Study: A National Model for Applied Oceanographic Research and Monitoring

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In 1991 the Minerals Management System (MMS) and Scripps Institution of Oceanography (Scripps), through a Cooperative Agreement, devised a multi-year research program to ascertain the various surface circulation patterns characteristic of the Santa Barbara Channel (SBC) and the Santa Maria Basin (SMB). The resulting SBC-SMB Circulation Study serves as an excellent model for a balanced approach to physical oceanographic research and monitoring. The strategy of blending field observation efforts in these two adjacent, dynamically linked areas has produced a spatially and temporally coherent six-year time series of a suite of oceanographic and meteorological observations for the entire SBC-SMB area. Causal forcing and spatially coherent patterns of the surface circulation have been established from analysis of this carefully planned density and diversity of field measurements. The effects of interannual events, like the 1997 El Nino, on the physical oceanography of the area are being analyzed and reported. This extensive observational effort, combined with numerical modeling of surface current processes, has produced an unusually good understanding of the oceanic surface circulation in an oceanographically complex area.

The applied research effort includes the development of a six-year, four-per-day, time series of synoptic current maps of the entire SBC-SMB area based solely on the extensive observational data set. This state-of-the-art data set has tremendous impact on the accuracy of oil spill trajectory and ocean surface circulation models. A second applied research product is a six-year, four-per-day time series of synoptic current maps developed from the application of numerical modeling techniques to the previous observational data driven six-year time series. It will be available in late 2003. This blended observations-modeling product will add increased spatial density of surface current values to the present domain, and will spatially expand the domain from the SBC-SMB area to 100 miles offshore the California coastline from Point Sur to San Diego. The applications for such a powerful data set are many; one of which is that it will provide tremendous accuracy for environmental planning tools such as NOAAs Trajectory Analysis Planner.

The research conducted over the last ten years is also sufficient to support an effective physical oceanographic monitoring program made up of a sparse array of current meter and meteorological buoys presently deployed in the SBC-SMB area and reporting observations in real-time. An oceanographer, using criteria based on this extensive research and the real-time data provided on the MMS/Scripps website: www-ccs.ucsd.edu/oilspill/, can easily determine the particular characteristic flow regime that is occurring in the SBC-SMB area. The MMS/Scripps website, with links to the vast Scripps Data Zoo, receives 40,000 hits per day from scientists and the general public.

The combination of planning and support for long-term, spatially coherent field observations coupled with a strong numerical modeling effort has produced one of the most successful research efforts in the earth sciences. Further, the products that have been, and are being, developed from this study are unique in the applied science community. The Santa Barbara Channel-Santa Maria Basin Circulation Study, evolving from a time and spatially intensive field program to an efficient, sparse array monitoring program, serves as an excellent example of what the National Oceanographic Partnership Program is proposing for a national Integrated and Sustained Ocean Observing System (known as ISOOS).

OS71F-06 0945h

A Data-Assimilated Model of the Near-Surface Circulation of the Santa Barbara Channel: Comparison with Observations and Dynamical Interpretations

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The comprehensive observations of the near-surface circulation in the Santa Barbara Channel (SBC) in 1994 offers an opportunity to conduct model sensitivity studies and evaluation in a coastal region forced by complex combination of wind, windcurl and along-coast pressure forcing. In conjunction with data assimilation, the model study will also further our understanding of the circulation dynamics. We report here a model hindcast of the SBC near-surface currents with periods that range from days to months, forced by observed hourly winds, monthly climatological temperature and salinity along the open boundaries, and assimilated daily with moored temperature data. The hindcast currents are compared with those observed and a multitude of experiments are conducted to determine model sensitivity as a function of wind and assimilation parameters. It is shown that wind alone (high-resolution field incorporating ocean and coastal stations, but without assimilation) captures surprisingly well the spatial and seasonal patterns of the circulation. When the quality of the wind field deteriorates, as for example when we use only the ECMWF (European Center Medium-range Weather Forecast) wind, so does the quality of the hindcast. On the other hand, the wind-alone hindcast is not able to maintain the strong cyclone as observed in the western portion of the channel, and which is captured well by the hindcast with data assimilation. Momentum balance analysis shows that the strong cyclone is maintained by oppositely directed, time-dependent pressure-gradient (PG) forces that act along the northern and southern coasts of the channel. The PG is produced by warming episodes when, from late spring to fall, the temperatures rise in steps. The nature of these warming events is not known, though they appear to be related to heat advection caused by episodes of wind relaxations.

Both models (with or without assimilation) are able to reproduce the known seasonal variations in the channel, though with assimilation the strength as well as the phasing is better reproduced especially inside the channel where seven of the ten moorings are located. However, both hindcasts fail to reproduce the characteristically intense spring-time (April) equatorward current (-0.2 m/s) at the eastern entrance station ANMI, and the corresponding variance is also underestimated. We are only able to partially correct the discrepancy with a model forced locally by wind only and without assimilation. We tentatively conclude that the observed characteristics are remotely forced.

OS71F-07 1020h

Blending Model Results With Observations in the SBC/SMB Study

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The 1993-1999 Santa Barbara V Santa Maria Basin (SBC/SMB) circulation study, conducted by the Center for Coastal Study of the Scripps Institution of Oceanography, represents a major research effort towards designing a coastal ocean observing system (COOS). During the 6-year period, at any time there were always about a dozen current meter and temperature moorings maintained in the study area. The moored measurements have continuous spatial and temporal coverage and are most trustworthy (compared to, say, shipboard observation and remote sensing), and thus are ideally suited as the absolute reference in describing ocean states. On the other hand, the mooring observations are point measurements, and it is unlikely that the moored data alone will ever have adequate spatial resolution in a COOS. There is need for complementary data. Coastal circulation models could play a crucial role in filling this gap.

Examples of using coastal ocean models in the SBC/SMB study to obtain ocean state estimation will be presented. A coastal ocean model typically is driven by the atmospheric forcing (which must be specified over the entire model domain) and the mass and momentum exchange across open boundaries. In this study the atmospheric forcing is derived from a dozen met buoy observations plus numerous coastal weather stations collected during the SBC/SMB study. The need to specify open-ocean water mass exchange is circumvented by assimilating the moored temperature data. The possibility of impinging open-ocean eddy, however, is ruled out. Two research issues are addressed. First, an attempt is made to blend the model results with moored velocity observations. Second, the impact of data assimilation on model results is examined. These two issues, one dealing with the initialization in ocean forecasts and nowcasts and the other with the sampling design, are fundamental to any COOS. The comprehensive SBC/SMB study affords an excellent opportunity for a COOS feasibility study.

OS71F-08 1035h

Transient Deep Currents in the Santa Barbara Channel- Santa Maria Basin

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Transient Deep Currents observed in the Santa Barbara Channel (SBC) and the Santa Maria Basin (SMB) during the Minerals Management Service funded Santa Barbara Channel - Santa Maria Basin circulation study are surprisingly well correlated with local winds. Thus the correlation between the wind stress at ndbc54 in the western SBC and the east-west velocity component at ndbc62 in the SMB INCREASES with depth, at first rapidly from 24 m to about 40 m and then more gently but monotonically - and surprisingly - to the deepest bin (328 m). A qualitatively similar increase of current-windstress correlation is found at ndbc54. The very different vertical structure of the wind-flow and flow-flow correlations and the of the velocity field itself is examined separately in subtidal, diurnal, and semidiurnal tidal frequency bands, and related to previously proposed wave propagation models. These energetically important flow features are not predicted by existing models of the circulation; the point of this paper is that a Coastal Observing System must include synoptic observations at depth in order to capture them.

OS71F-09 1050h

Is There Decadal Scale Information Present in the Texas Coastal Current?

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Since 1995 Texas A&M University has operated a system of automated near real-time oceanographic buoys off the Texas coast (the Texas Automated Buoy System or TABS). This system supports the time-critical decision-support needs of the Texas General Land Office for oil spill prevention and response. The buoys are designed to measure the currents and water temperatures at 2-m below the surface and telemeter the data to shore. As of January 1, 2002 more than 550,000 half-hourly current meter and temperature records (representing 30 buoy-years of collective operation) have been collected, quality controlled, and made available on our DODS server. TABS buoys have occupied 18 different sites across the shelf, with two buoys, one near Galveston and one near Corpus Christi, operating almost continuously in the Texas Coastal Current. We examine data from those buoys for any evidence of decadal scale information. Sea surface temperature anomaly at the two sites shows a positive correlation to the North Atlantic Oscillation (NAO). The presence of a decadal signal in the current record is not clear; there is no long-term consistent correlation to either ENSO or NAO. We suspect the record may better correlate to a local index, possibly based on wind data.

OS71F-10 1105h

Material Property Distribution Insights From a Coordinated Observing and Modeling System for the West Florida Continental Shelf

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Material property distributions on continental shelves result through the commingling and modification of waters originating from land-drainage and deep-ocean sources. How this occurs depends on the relative influences of momentum and buoyancy input either locally on the shelf or from the deep-ocean at the shelf-break. We address this question of local versus deep-ocean forcing for the west Florida continental shelf (WFS) using in-situ data and a numerical circulation model. The data and model derive from an evolving WFS coastal ocean observing system complimented by other process-oriented studies. The spring and summer seasons of 1998 and 1999 show distinctively different water properties, both on the shelf and at the shelf-break. We account for these differences by a combination of local forcing, independent of the adjacent Gulf of Mexico Loop Current, and interactions of the Loop Current with the shelf. The primary role of the deep-ocean is to modulate the material isopleth distributions along the shelf-break. Local, shelf-wide wind and buoyancy forcing determines whether or not these material isopleths broach the shelf-break. The subsequent along and across-shelf material property transports are then determined by a combination of local and deep-ocean forcing effects with the bottom Ekman layer serving as the major conduit for across-shelf transport of ecologically important materials. These scientific findings required long-term observations at strategic locations and the direct coordination with numerical experiments. They also provide guidance for future coastal ocean observing systems.

OS71F-11 1120h

Initial Results From SABSOON: A Coastal Ocean Observatory on the South Atlantic Bight Continental Shelf

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The coastal ocean observing system for the South Atlantic Bight off the SE U.S. is in an early stage of development. However, the existing time series of meteorological and oceanographic observations illustrate the potential multidisciplinary applications of these data. Here, we will first review the existing observing system assets for the region in terms of spatial distributions and the parameters measured, then provide examples of results from the South Atlantic Bight Synoptic Offshore Observational Network (SABSOON), a dataset that strongly complements physical and biogeochemical studies in the region.

Among the physical studies has been an examination of a thirteen-month record of vertically resolved currents (35 m depth) for variations in tidal flow. A harmonic analysis was carried out on each month. Subsequent study focused on variability in the largest semi-diurnal constituent. Stratification is found to cause significant shifts in vertical shear, ellipticity, tidal phase and ellipse orientation. Estimates of bed stress and roughness length also vary in time and suggest that surface gravity waves are modulating the properties of the benthic boundary layer and impacting tidal current speed. A linearized, one-dimensional momentum balance was used to estimate the eddy viscosity necessary to explain the vertical current structure. Vertical structure of the eddy viscosity was also found to vary with stratification and maximum values range from 0.01 to 0.05 m2/s. Comparison of the observations during unstratified conditions with a one-dimensional model that includes a turbulence closure scheme confirms observational estimates of a roughness length of 2-10 cm, consistent with a strong influence of the surface gravity wave field on the benthic boundary layer. Such physical studies have important implications for studies of the continental shelf biogeochemistry. Along with physical data, bio-optical measurements from SABSOON and ocean color satellite imagery illustrate the applications of the observing system for studies of primary production on the shelf, cross-shelf exchange of materials, and exchange across the sediment-water interface. Observations relating to variability of benthic primary production and seasonal and episodic exchange are illustrated.

OS71F-12 1135h

Monthly Variation in the M_2 Tidal Characteristics in the South Atlantic Bight

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Barotropic tides in the South Atlantic Bight of the eastern United States coast are examined using a combination of recent observations of pressure and velocity from a permanent coastal ocean observing system and shorter term instrument deployments in the region. The data extent from near-shore to shelf-break and cover the region from Onslow Bay, North Carolina, to St. Augustine, Florida. The principal tidal elevation and depth-averaged velocity ellipse characteristics are described. Monthly variation in the tidal elevation and depth-averaged velocity is assessed from the longest available records.

Cross-shelf semi-diurnal water level amplification and phase lag associated with shelf width changes are observed. Maximum M_2 amplification and cross-shelf phase lag occurs at the widest part of the shelf and decrease to the north and south. Monthly variability of the M_2 tidal elevation and depth-averaged velocity ellipse phase appears significant. Monthly analysis indicates M_2 elevation phase variation of about 5 degrees. Diurnal constituent variability is generally below the error estimates. Comparison with a baroclinic numerical model is discussed.

URL: http://www.ncsc.org/nopp/sablam

OS72A MCC: Hall D Sunday 1330h

Remote Sensing of Ocean Surface Winds and Their Scientific Applications II Posters *(joint with A, GC)*

Presiding: **W T Liu,** Jet Propulsion Laboratory**; S Xie,** University of Hawaii

OS72A-0333 1330h POSTER

Ocean Observer Synthetic Aperture Radar User and Instrument Requirements and Configuration

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User and instrument requirements for a U.S. operational ocean and land observing synthetic aperture radar (SAR) has emerged out of the Ocean Observer Satellite Study sponsored by the U.S. Dept. of Commerce/Dept. of Defense/National Aeronautics and Space Administration Integrated Program Office. User requirements were identified for thirty parameters that are best measured with SAR instruments. These include coastal sea surface winds, wave characteristics, ocean currents, surf conditions, sea and lake ice type/motion/concentration/edge-location, flood mapping, land surface deformation, land surface topography, soil moisture, and land surface freeze/thaw state. The user requirements have been summarized in an Ocean Observer User Requirements Document including details of horizontal measurement spacing, measurement accuracy, refresh rate, geographic coverage, and long term stability. The SAR instrument requirements needed to measure these parameters were analyzed, drawing on the scientific literature, previous study reports and the experience of the User Requirements Team. The SAR instrument/satellite requirements and notional design that emerged from this process consists of a 15-year mission using three satellites, each with 7.5 year lifetime. During part of the mission, two satellites would fly in formation for cross track interferometry to allow precision land topography measurement. The satellites would be in sun-synchronous polar orbit with 1:00 pm ascending equator crossing time with a 8-day exact repeat orbit. The SAR would be a dual frequency (C-band and L-band), multi-polarization, multi-mode instrument. Orbit maintenance would allow repeat pass interferometry and antenna design would allow along-track interferometry for ocean current measurement.

OS72A-0334 1330h POSTER

Overview of the Ocean Observer Satellite Study

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A two-year study of ocean satellite remote sensing requirements and instrument/satellite options is nearing completion. This Ocean Observer Study was sponsored by the U.S. Dept. of Commerce/Dept. of Defense/National Aeronautics and Space Administration Integrated Program Office, whose mission is to develop the future U.S. National Polar-Orbiting Operational Environmental Satellite System (NPOESS). A comprehensive Ocean Observer User Requirements Document has been drafted by a team of over 150 government, academic, and private sector scientists, engineers, and administrators. Included are requirements for open and coastal ocean surface, cryospheric, hydrologic, and some land/hazard and atmospheric boundary layer parameters. This document was then used as input to the instrument and satellite study (conducted by the Jet Propulsion Laboratory) which produced five different instrument/satellite configuration options designed to address the maximum number of requirements which will not be met with the already-approved NPOESS instruments. Instruments studied include a synthetic aperture radar (SAR), an altimeter, and a hyperspectral coastal infrared/visible imager. After analyzing the alternatives, it appears that one of the best options is a two-satellite system consisting of (1) an altimeter mission in the Topex/Poseidon orbit carrying both wide-swath and delayed doppler altimeters, and (2) a multi-polarization, multi-frequency, multi-mode interferometric SAR mission including a coastal imager in a polar sun-synchronous orbit. This paper summarizes the user requirements process, briefly describes the notional satellite configuration, and presents some of the capabilities of the instruments.

OS72A-0335 1330h POSTER

Optical and Radar Observations of Surface Eddies in the North Atlantic Ocean Reveal Complex Physical and Biological Processes

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Numerous oceanographic studies have revealed the existence of near-circular oceanic disturbances along ocean boundaries, characterized by long-lasting ocean height anomalies and in some cases, abrupt sea surface temperature boundaries. These complex surface features, denominated marine eddies, represent unique atmospheric/marine manifestations that serve as primary factors that maintain the biological balance of the global marine ecosystem. This study utilized data from both active and passive sensors for the detection, mapping and 3-dimensional modelling of the physical and biological processes that occur at marine cyclonic and anticyclonic centers in the Atlantic Ocean off the coast of the United States. For this purpose, wave height data from the TOPEX/Poseidon radar sensor was obtained and merged with AVHRR sea-surface temperature maps in order to create 3-D scientific visualizations. Furthermore, the radar altimetry data was also compared to observations from other optical sensors, including SeaWiFS and MODIS. This study has demonstrated the numerous advantages of data fusion, including radar and spectral datasets, and allowed for the modeling of physical and biological processes that occur at these centers. In addition, the satellite data allowed for the identification and mapping of small-scale surface disturbances that coexisted with the mesoscale eddies. This technique proved to be particularly advantageous for topics related to the oceanographic remote sensing discipline.

OS72A-0336 1330h POSTER

Interpreting Satellite Views of Biophysical Coupling With Subsurface TAO/TRITON data in the Tropical Pacific

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The concurrent operation of the TOPEX altimeter (SSH) and the SeaWiFS ocean color sensor (chlorophyll) has allowed unprecedented views of biophysical coupling in the surface ocean. SSH largely reflects changes in the thermocline depth, which can directly impact the vertical flux of nutrients to the surface by moving the nutricline into or out of the surface mixed layer. As a result, surface chlorophyll and SSH are generally negatively correlated because higher SSH indicates a deeper thermocline and nutricline. There is however significant geographical variability in the relationships between SSH and thermocline variability and between the depths of the thermocline and nutricline. The strongest negative correlations between SSH and chlorophyll should occur in the tropics, as the relationship between both SSH and thermocline depth and thermocline depth and nutricline depth, are tightest in this region. However, significant positive correlations between SSH and chlorophyll are observed in the western tropical Atlantic and in the central tropical Pacific. To understand the underlying causes for this apparent decoupling of SSH and chlorophyll in the tropical Pacific we use subsurface temperature structure data from the TAO/TRITON moorings to investigate the validity of the primary assumption that satellite SSH reflects changes in the depth of the thermocline. The physical forcing of chlorophyll in this region is also examined using other satellite datasets.

OS72A-0337 1330h POSTER

Vertical Structure of the Zonal Currents Across the Luzon Strait

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The behavior of water exchange between the South China Sea (SCS) and the West Philippines Sea (WPS) is key issue for the formation of the SCS water. Hydrographic investigations so far conducted mostly focused on the intrusion of the WPS water into the SCS. Though some marine chemistry observations and inverse calculation suggested outflows from the SCS in the intermediate layer, the specific vertical distribution of the zonal currents is yet not clear, and the driving mechanisms remain unknown.

In the present paper, we show the basic vertical structure of the zonal currents across a meridional-vertical section in the Luzon Strait (LS) from a global ocean circulation model, and present a simple formulation to illustrate the mechanisms generating the model-produced vertical structure.

The ocean circulation model has a fine grid (1/6 by 1/6 deg) covering the Pacific-Asian marginal seas and a coarse grid (3 by 3 deg) covering the rest of the global ocean. The model results show that the zonal currents across the LS section basically possess a four-layer structure. The first layer is the surface Ekman layer, in which the currents are toward the west in winter and toward the east in summer with the annual mean velocities toward the west. The second layer covers the subsurface and intermediate layers, in which the prevailing currents are westward. The third layer is the deep layer, in which the prevailing currents point to the east. The fourth layer is the bottom layer in terms of the LS (or, lower deep layer in terms of the SCS or WPS), in which the prevailing currents are westward.

The structure of the second through fourth layers can be attributed to vertical mixing of water density. That is, due to the vertical mixing, the water in the upper layers in the SCS is denser than in the WPS, while the water in the lower layers in the SCS is less dense than in the WPS. Under the constraint of mass conservation, this horizontal gradient of the water density can cause a couple of pressure torques, which in turn result in westward flows in the second and fourth layers and eastward flow in the third layer. The annual mean flow in the first layer is a result of three mechanisms.

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