OS41D-62 0830h POSTER

Processes Underlying Seasonal Chlorophyll Variability in the Tropical Pacific

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Since it began operation in September 1997, the SeaWiFS ocean color sensor has observed great variability in surface chlorophyll concentrations in the tropical Pacific. Seasonal variation emerges as an important mode of variation in EOF decomposition of nearly 4 years of monthly mean SeaWiFS chlorophyll between 10°N and 10°S. The first EOF mode, describing El Niño, accounts for 41% of the variance. The second mode, accounting for 15% of the variance, describes the seasonal cycle that is out of phase between waters on and near the equator (approximately 5°S to 4°N) and adjacent waters poleward of this latitude range. Seasonal variability defined by this mode is greatest along and north of the equator. In near-equatorial waters, positive chlorophyll anomalies of the seasonal mode peak during July-September. Poleward of this region, the out-of-phase seasonal chlorophyll anomalies peak during February-April. EOF decomposition of TOPEX sea surface height (SSH) shows similar spatial and temporal variation in the third EOF mode (10% of the variance) that describes seasonal variability. The relationship between seasonal variation in chlorophyll and SSH defined by EOF decomposition is peak seasonal chlorophyll during minimum seasonal SSH in both regions, consistent with the importance of thermocline depth to nutrient supply to the euphotic zone. Using satellite sea surface height and temperature, scatterometer winds, moored observations from Tropical Atmosphere Ocean (TAO) array, and numerical model simulations of the tropical Pacific using the Regional Ocean Modeling System (ROMS), we examine seasonal and spatial variation in processes influencing euphotic zone nutrient supply from the nutricline.

OS41D-63 0830h POSTER

CLIVAR in the Pacific Ocean

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Coupled atmosphere/ocean processes across the Pacific Ocean region exhibit perhaps the most pronounced interannual to decadal variability on the earth, and have a profound influence on climate around the Pacific rim and over the entire globe. The processes responsible span a range of time and space scales including phenomena such as ENSO, Indo-Pacific Decadal Variability and the Asian-Australian Monsoon system. There has been significant progress in understanding Pacific ocean variability and its influence on climate but there are many problems still to be solved. Essential for a better understanding and prediction of Pacific basin phenomena are observation systems and state-of-the-art models which will enable timely availability of high quality oceanographic and atmospheric data for monitoring and forecasting. The key to success in this enterprise is the coordination of international plans through the exchange of information.

The CLIVAR international research programme brings together oceanic and atmospheric scientists from the Pacific nations. It provides an umbrella for the international implementation of Pacific sector observations and modelling efforts with the goal of advancing our knowledge of the role of the Pacific ocean in global climate change. Strong collaboration with other international programs such as IGBP provides important link to bio-geochemical climate applications and the social impacts of climate change. The poster will summarise the present status of climate-relevant Pacific observations and highlight the need for an internationally co-ordinated approach.

OS41D-64 0830h POSTER

A New FSU Winds and Flux Climatology

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An objective technique is used to create a new monthly climatology for surface fluxes and related fields. The wind (pseudostress) products are improvements over the subjectively analyzed FSU winds. Fields of turbulent surfaces fluxes and the variables needed to calculate these fluxes are also generated. The fields are created through minimization of a cost function, which maximizes information from the observational data and minimizes smoothing. This approach ensures internal consistency between the turbulent fluxes and the related fields. Comparisons are made between the new FSU fields (based on volunteer observing ships and buoy observations), the old subjective FSU fields, individual TAO buoys, the DaSilva climatology (the background for the objective technique), the NCEP reanalysis, and fields based solely on the SeaWinds scatterometer observations.

The new (objective) FSU wind fields have stronger convergence zones (the ITCZ and SPCZ) as well as better zonal resolution. An ocean model, forced with a preliminary release of the winds, produced much more realistic currents than when forced with the old FSU winds. The new wind and flux products will be discussed.

OS41D-65 0830h POSTER

On the Search of a Statistical Correlation Between Tropical Pacific SST and Southeast U.S. Precipitation

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Previous studies have examined correlations between Tropical Pacific SSTs and US precipitation amounts. Correlations have been found on monthly, seasonal, and inter-annual time scales. However, many studies consider only the Western and Central parts of the country, an area that is directly affected by ENSO teleconnections. This study focuses on Southeast US precipitation and its correlations with Tropical Pacific SST at various time scales. Correlations were derived statistically between mean SSTs and mean precipitation amounts on monthly, seasonal, and annual time scales. Linear regressions were fit to better examine these correlations. Lack of fit tests, hypothesis testing, and confidence intervals were done to analyze the regression models. In addition, residual analyses were performed and are displayed graphically. Furthermore, a CCM3 model run was performed to determine how well the model simualtes observed SST and precipitation amounts. Finally, it was used to investigate precipitation pre-cursors, such as humidity, latent heat flux, and cloudiness.

OS41E HC: Hall III Thursday 0830h

Oceanic Internal Tides II

Presiding: **D Luther,** University of Hawaii at Manoa**; M A Merrifield,** Department of Oceanography, University of Hawaii at Monoa

OS41E-66 0830h POSTER

Theoretical Expression for an Ocean Internal Soliton Synthetic Aperture Radar Image and Determination of the Soliton Characteristic Half Width

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This study deals with the development of techniques for satellite synthetic aperture radar (SAR) ocean image interpretation. We derived a theoretical model of a radar image for a Korteweg-de Vries type ocean internal soliton and validated the model using ocean internal wave signals taken from ESR-1 SAR and RADARSAT SAR images. The results indicate that the model perfectly simulates ocean internal soliton signatures with double-sign variations of radar backscatter. On the basis of the model, we developed the curve fitting method and the peak-to-peak method for determining the internal soliton characteristic half widths, which then were used to calculate the internal soliton amplitudes. The test results indicate that ocean internal soliton amplitudes derived by the two metnods agree with in situ data acquired on the Portuguese Continental Shelf and in the South China Sea with reasonable accuracy. The role that wind fields play in ocean radar remote sensing was also analyzed.

OS41E-67 0830h POSTER

The Role of Internal Tides in Mixing the Deep Ocean

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Internal wave theory is used to examine the generation, radiation, and energy dissipation of internal tides in the deep ocean. Estimates of vertical energy flux based on Bell's (1975) linear model are adjusted to account for the influence of finite depth, varying stratification, and lateral variations in topography and tidal currents. Finite amplitude corrections to the linear model are also examined. Estimates along the Mid Atlantic Ridge in the South Atlantic Ocean suggest that the vertical energy flux of the M_2 internal tides is 3-5 mW m^{-2}. A small fraction of the energy flux, 1-2 mW m^{-2}, is generated at spatial scales less than 10 km, and this may dissipate locally as turbulence. Most energy, however, is generated as low modes associated with spatial scales of 20 to 100 km. The Richardson number of the radiated internal tide typically exceeds unity for these motions, so direct shear instability of the generated waves is not the dominant energy transfer mechanism. Wave-wave interactions are also ineffective at transferring energy from the large wavelengths that dominate the energy flux. Radiated low modes are likely influenced by topographic scattering, though general topography scatters less than 10% of the low mode energy to higher wavenumbers during each reflection. Thus, it appears that most low mode energy is radiated over O(1000) km distances, possibly contributing to mixing at locations far away from generation sites.

OS41E-68 0830h POSTER

Laboratory and Numerical Experiments on Breaking Interfacial Waves

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Breaking internal waves are known to be responsible for much of the mass and energy redistribution in the world oceans. Using both numerical and laboratory experiments, we attempt to quantify the instabilities that govern the breaking of large amplitude internal waves and to obtain an understanding of the three-dimensional post-breaking dynamics and mixing. Our experiments focus on internal waves travelling on a thin density interface between two homogeneous layers.

For the numerical experiments, moderate to high-frequency interfacial waves in a periodic domain are generated in order to determine the breaking mechanisms that result from large amplitude effects. These waves are generated by imposing positive shear at the wave trough and negative shear at the wave crest. As a result of this forcing, an interfacial wave grows in amplitude until the forcing is removed. If the forcing is removed before the wave reaches a critical steepness, the result is a stable, progressive interfacial wave. The critical steepness is found to be limited by a shear instability at the interface. Continued forcing of the interface beyond the critical steepness causes wave breaking when the horizontal fluid velocity within the wave exceeds the wave speed. We find that moderate-frequency waves break due to a predominant shear instability, while high-frequency waves break as a result of a mixed shear-convective instability.

For the laboratory experiments, low to moderate-frequency monochromatic interfacial waves are forced to breaking through a lateral contraction. The critical wave steepness and the subsequent wave breakdown are determined visually, using planar laser-induced fluorescence (PLIF). The critical steepnesses for these lower-frequency waves are found, as in the numerical experiments, to be limited by a shear instability. Specifically, the breakdown of these waves takes the form of an organized row of Kelvin-Helmholtz billows that originate in the high-shear regions of the wave crests and troughs. These billows grow in amplitude, sometimes pairing, with collapse occurring either when the billow size becomes limited by the stratification, or when the background wave phase changes. The exact fate of these billows is determined by the billow growth rates relative to the wave frequency, the former of which can be compared to results from linear stability analysis for stratified parallel shear flows. The numerical and laboratory results for the critical wave steepnesses are in good agreement and do not follow the stability limit predicated by the standard $Ri = 1/4$ limit, where Ri is the minimum gradient Richardson number in the wave.

This work is supported by the Computational Science Graduate Fellowship Program, DOE; ONR Grant N0014-99-1-0413 (Scientific Officer: Dr. Stephen Murray, Phys. Ocean. Program); and NSF Physical Oceanography program grant NSF OCE-9871808.

OS41E-69 0830h POSTER

Tidal Dynamics and Mixing in the Ross Sea

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In certain areas of the Southern Ocean, tidal energy is believed to foster the mixing of different water masses, which contribute to the formation of deep and bottom waters. Since the Ross Sea is one of the major ventilation sites of the global ocean abyss, we investigated tidal dynamics and mixing there using a three-dimensional sigma coordinate model, the Regional Ocean Model Systems (ROMS). Internal tides were generated at the continental shelf/slope break and other areas of steep topography. Additionally, strong vertical shears in the horizontal velocities, indicative of mixing, occurred at the back and edges of the Ross Ice Shelf and along the continental shelf/slope break. Estimates of lead formation due to divergence of baroclinic velocities were much higher than those of barotropic velocities, reaching over 10% at the continental shelf/slope break.

For these simulations, realistic topography and hydrography were used from existing observational data together with four tidal constituents: two semi-diurnal, M2 and S2, and two diurnal, K1 and O1. The model fields showed reasonable agreement with 10 tidal elevation observations and over 35 tidal current measurements.

OS41E-70 0830h POSTER

Variability of Tidal Band Currents and Temperatures at the Boundary between Southern and Central California.

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Motivated by interest in the long term variability of the circulation and flow conditions in the area surrounding Point Conception, a number of moorings incorporating temperature, current and conductivity sensors have been installed throughout the Santa Barbara Channel since 1992. The multiple year time series generated by this instrumentation allow for examination of the temporal and geographical variability of physical parameters at periods of one day and shorter.

Sea level spectra from the region are characterized by sharp lines at the known tidal frequencies. Although these lines are also present in the current and temperature spectra, broad shoulders of energy are also present at the frequencies surrounding them. In order to explore the influence of the spectral line shoulders, we calculate the fraction of the total variance in the time series within the diurnal (18 to 33 hours) and semi diurnal (11 to 14.5 hours) frequency bands that can be accounted for by the tidal frequency lines. This fraction varies significantly within the Santa Barbara Channel but is typically higher in the channel than at mooring locations along the coast, north of the channel. An annual cycle is also apparent, the variance fraction reaching a maximum during the summer months.

Eigenmode analyses of the vertical temperature profile time series indicate that the diurnal temperature profiles have two dominant vertical modes, a surface enhanced mode and a mode with a subsurface maximum. The semi diurnal frequency band is dominated by a subsurface maximum mode only. Preliminary statistical analyses seem to indicate that the surface enhanced diurnal mode is correlated with meteorological forcing.

OS41E-71 0830h POSTER

On the Spring-Neap Variability of the Internal Tide at the Hawiian Ridge

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Observations and numerical modeling have shown that an energetic semi-diurnal internal tide is generated by tidal flow over the Hawaiian Ridge. In this talk we present numerical results that explore the variability of the internal tide over the spring-neap cycle resulting from the combination of M_2 and S_2 tidal constituents. The spring-neap cycle in the internal tide is computed in terms of baroclinic currents, vertical displacements and sea surface elevations. This can be achieved from model runs forced by a combination of M_2 and S_2 constituents over an approximately 15 day spring neap cycle, or from a re-combination of results from separate M_2 and S_2 model runs. In terms of the resulting energy fluxes, we find that results are very similar from the two methods, indicating that, at tidal frequencies and the 4 km model resolution, the system is approximately linear. Energy fluxes at spring tides are substantially stronger than the sum of M_2 and S_2 fluxes, due to the cross product of velocity and perturbation pressure in determining energy flux, although averaged over a spring neap cycle, the energy flux equals the sum of the M_2 and S_2 values. Computations of the age of the internal tide show substantial variability in the time of spring internal tides over the model regions. These variations are generally up to a few days, partly due to the time taken for the waves to propagate away from the generation sites, and partly due to small scale differences between the M_2 and S_2 internal tides.

OS41E-72 0830h POSTER

Boundary Layer Separation and its Effects on Internal Wave Generation in Knight Inlet

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Recent observations by Farmer and Armi in Knight Inlet show that boundary layer separation can have a major impact on internal waves generated by tidal flow over a sill. In this talk I will present results of numerical simulations of tidal flow over the sill in Knight Inlet. The results show that during the early stages of the flow, boundary layer separation significantly reduces the amplitude of the overturning wave downstream of the sill, restricting the initial overturning and mixing to regions above the sill. The final high drag state is similar in model runs with and without boundary layer separation, however boundary layer separation causes a delay in the transition to the high drag state.

OS41E-73 0830h POSTER

Estimating Barotropic Tidal Currents Using Very Long Records From HF Radar

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The intermittency of the internal (i.e., baroclinic) tide signal has been noted on many of the worlds continental shelves. It is also commonly found that the internal tide is not phase-locked to the surface (i.e., barotropic) tide. These properties of the internal tide may allow barotropic tidal currents to be estimated from very long records of currents at only one depth, even in areas where internal tides are known to be large. In Monterey Bay for example, previous work has shown the baroclinic tidal currents to be highly variable in both time and space. In that area, it is also observed that the amplitudes of the baroclinic tidal currents exceed those of the barotropic tidal currents as estimated from large-scale tide models. In this study, we estimate barotropic tidal currents around Monterey Bay using harmonic analyses of greater than two-year-long surface current records deriving from HF radar measurements. Results for both semi-diurnal and diurnal frequencies are compared with shorter-length analyses for which internal tides and sea breeze-driven currents, respectively, are known to be dominant.

This opportunity to map barotropic tidal currents for a particular coastal region is somewhat unique because long records from HF radar sites are not common. Accurate knowledge of the spatially variable barotropic current field could be used to validate the barotropic response of high resolution numerical models. Many such model studies are underway in which barotropic forcing from large-scale tide models is applied along the open boundaries. The resulting barotropic model currents lead to barotropic-to-baroclinic energy conversion. Validating the resulting barotropic currents will be important because the internal tide generation that takes place may be quite sensitive to these currents, depending on the local topography.

OS41E-74 0830h POSTER

Forward and Inverse Modeling of Internal Tides with Simplified Approximate Dynamics

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Analysis of barotropic (BT) tidal energetic based on TOPEX/Poseidon (T/P) altimeter data show that up to 1 Terawatt is dissipated over areas of rough topography in the deep ocean. The spatial pattern of dissipation is consistent with simple theories for the generation of internal tides, and many of the high dissipation areas are sources of radiating low baroclinic (BC)

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modes, which can themselves be mapped over much of the globe with the altimeter data. To make quantitative connections between empirical estimates of internal tides, BT tidal dissipation, and ocean physics, modeling and data assimilation at global scales will be required. Use of the full 3D primitive equations for internal tide modeling is computationally demanding,and has thus so far been restricted to relatively limited domains. Here we consider use of highly simplified models which can be more readily applied to global scale modeling and data assimilation, and can be used to shed light on some fundamental issues. Our approach is based on a local flat bottom approximation. In the simplest application, which we have used for global estimates of BT/BC conversion, we convolve the BC forcing (derived from bathymetry, stratification and high resolution BT currents) with a flat bottom Greens function(modified to account for spatial variations with a WKB-like approximation) to compute BC pressure, and thence work done by the BT tide. Results from initial computations (with a 1/12 degree grid)are spatially consistent with the T/P based estimates of open ocean BT dissipation, though amplitudes are low by a factor of roughly 2. A scheme for assimilation of the altimetric internal tide estimates has also been developed. For this we use a local flat bottom modal decomposition, and write the internal tide elevation data as a linear combination of a small number of local modes. Each mode approximately satisfies the reduced gravity linear shallow water equations, with spatially varying coefficients determined from local bathymetry and stratification. This approach allows use of existing BT tidal data assimilation software to map radiating internal tides and energy fluxes in the Open Ocean.

OS41E-75 0830h POSTER

M2 Internal Tide off Oregon: Inference From Data Assimilation

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A linearized, baroclinic, spectral in time, inverse model has been developed and applied to study the M2 internal tide during May-July 1998 in a limited area (40x60 km) near the Oregon coast, where measurements of surface currents are available from two coast-based HF radars. The surface current data are harmonicly analyzed in short time segments and the resulting harmonic constants are assimilated into the model with use of the generalized inverse method. ADCP mooring currents are analyzed in a similar way and are used for validation of data assimilation results. Data analysis reveals substantial intermittency of the internal tide, both in amplitude and phase. Representers obtained as a part of the generalized inverse solution show the zone of influence of surface data. In particular, since the M2 frequency is superinertial, the information from the surface data propagates along baroclinic beams throughout the water column. Most baroclinic signal in the area is generated outside our small domain and baroclinic fluxes at the OB are restored by means of data assimilation. Experiments with synthetic data demonstrate that the choice of error covariance for the OB fluxes affects wave radiation through the OB, and hence model performance. An OB condition covariance that allows radiation is obtained by nesting. Assimilation of surface velocity radial components measured by the HF radars captures the temporal variability of the internal tide both near the surface and at depth, and improves the rms difference between the solution and the ADCP measurements, thus demonstrating that surface velocity observations contain valuable information about the internal tide.

OS41E-76 0830h POSTER

Tidally generated undular bores and near-surface plankton distribution in Massachusetts Bay: a combined observational and theoretical approach

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We determined the effects of internal tidal bores on plankton distribution, and whether plankton distribution is dependent on plankton behavior. Our observational program included following internal bores in September 2000 as they propagated from Stellwagen bank to Scituate, in Massachusetts Bay. The bores were sampled with a shipboard ADCP and a towed video plankton recorder (VPR). We also observed the bores and plankton with moored instruments, including a moored video plankton observatory system ("AVPPO"), temperature moorings, and Doppler current meter profilers. We contrasted our observations and guided our sampling with an internal bore model. On occasions, zones of high backscatter were associated to the internal bore depressions, and these zones were present as the waves propagated. We sampled these zones of high backscatter with the Video Plankton Recorder (VPR). Preliminary observations of plankton distributions associated with internal waves indicated taxon-specific associations within specific regions of the internal waves (IWs), and at certain times of the day. A striking example of this was observed for Euphausiids. Between 19:00 and 00:00 EDT, Euphausiids were found localized in the leading edges of the IW where vertical velocity vectors were downward. Between 02:00 and 06:00 EDT, Euphausiids were found in very high abundance in the trailing edges of the IW where velocity vectors were upward. This suggests an interaction between vertical migration behavior and velocity structure in controlling location and patch dynamics of Euphausiids in IWs. We also observed the evolution of bores with trailing high frequency internal waves, in 80 m water, into bores with no trailing waves at 30-40 m water. The model shows that the sloping bottom to the west of Stellwagen Basin, under the majority of the environmental conditions observed, acts as a low-pass filter for the internal bore. The high frequency train of solitary waves trailing the initial depression does not propagate beyond the 30 m isobath, but dissipates due to instabilities. However, the leading edge of the bore is able to move upshelf towards shallow waters.

OS41E-77 0830h POSTER

Observations of Boundary Mixing in the Hawaiian Ridge System

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Observations made using our towed turbulence platform, Marlin, as part of the Hawaiian Ocean Mixing Experiment reveal systematic patterns of shear and mixing. Dissipation rates were elevated over Kaena Ridge and French Frigate Shoals at all depths by almost two orders of magnitude relative to that found in the deep open ocean. Long tows made transverse to the ridges indicate that this turbulence approaches background oceanic levels within 100 km of the ridge.

The strong turbulence near the ridge is localized in the along-ridge direction, and is stronger near gaps in the ridge where high wave flux has been predicted by numerical models and observed in other components of this experiment. The 8-m vertical shear measured from acoustic Doppler sonars aboard Marlin exhibits high values where values of dissipation are high. This suggests that variations in the continuum wave-field are the source of turbulent variability.

OS41E-78 0830h POSTER

Lagrangian Observations and Ship-Based Inferences of Upper-Ocean Mixing Along the Hawaiian Ridge

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There have been many reports of enhanced mixing close to regions of rough topography. Here, mixing is investigated along the Hawaiian Ridge using microstructure temperature observations from Lagrangian floats and finescale density and velocity data from SeaSoar and hydrographic Doppler sonar. Microstructure temperature measurements are made using the Lagrangian Microstructure Profiler (LAMP), which cycles from the surface to 400 m every 2 hours for 12 days while drifting with the ocean current. Five LAMPs were deployed along the 1000 m isobath between French Frigate Shoals and the Kauai Channel. LAMP observations reveal strong vertical diffusivities of greater than 10^{-4} m^2/s only very close to the ridge crest at certain locations along the ridge. One such location is the Kauai Channel, where a LAMP drifted off the ridge measuring the decay of diffusivity down to the typical open ocean value of 10^{-5} m^2/s. There is some suggestion of the modulation of mixing by the semidiurnal tide. Finescale SeaSoar/Doppler data and parameterizations allow diffusivity to be inferred over broad areas of the ridge. The diffusivity is found to be enhanced above ocean background levels within 50 km of the ridge at a few locations. Mixing is inferred to be asymmetric across the ridge, consistent with an observed asymmetry in internal wave displacement and shear. A particularly large mixing event is found during the peak of spring tide just west of Oahu along the 1000 m bathymetric contour. Observations at this same location near the neap tide reveal much weaker mixing. Put together, the observations suggest tidally modulated mixing, decaying rapidly off the ridge, large at only a few "hot spots" along the ridge.

OS41E-79 0830h POSTER

A Study on the Influence of Tropical Cyclones on the Generation of Internal Tides

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An investigation is made into modifications of the internal wave field at semi-diurnal tidal frequencies on the Western Australian Shelf by a passing tropical cyclone. Current mooring observations are presented taken during Tropical Cyclone Bobby (1995), which passed over the mooring locations. The observations reveal large vertical excursions at near inertial frequency of the isotherm during and following the cyclone's passage. This coincides with diminishing semidiurnal baroclinic tides.

To gain dynamical insight into the observations, a fully three-dimensional, free surface, non-linear, hydrostatic model (the Princeton Ocean Model) is applied to the Western Australian Shelf. The cyclone modifies stratification by turbulent mixing, upwelling/downwelling and density advection up or down the shelf slope. This results in significant changes to internal tide characteristic paths and hence the internal tide generation process on the continental slope. Mixing is enhanced over the shelf due to shallow topography with respect to the shelf slope region creating a strong density front at the shelf edge. The model reproduces the main features of the observed inertial oscillations concomitant with the dampening of M_2 internal tides after the passage of the cyclone.

OS41E-80 0830h POSTER

The Process of Breaking of Internal Solitons on Shelf: Transition of Internal Solitary Wave Through Turning Point

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Well known in common features process of internal wave propagation shoreward from shelf break has a peculiarity connected with passing of the waves trough so called "turning point", a location on a shelf where pycnocline is in the midpoint of water column. Passing through the point leads to transformation of initially internal depression waves into elevation waves. We study this process on the basis of observations of large-amplitude internal waves propagating on shelf of Pacific Coast of Kamchatka and by numerical modeling. Next main features of the process were revealed. Solitary internal depression wave with symmetrical profile transforms its profile into a steepened back face in the vicinity of turning point. Moreover, two depression waves of less amplitude in the wave train follow the leading solitary wave. During and after the passage of turning point, the leading depression wave gradually transforms into elevation wave. The case of large internal waves propagating above a horizontal bottom without any incline will be discussed. The research work described in this publication was made possible in part by a grant of Award No. RP2-2255 of the U.S. Civilian Research and Development Foundation (CRDF).

OS41E-81 0830h POSTER

Ten Years of Shipboard ADCP Data Along the Northwestern Hawaiian Islands

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Analyses of 10 years of shipboard acoustic Doppler current profiler data collected along the Northwestern Hawaiian Islands from October 1990 to November 2000 are presented. Over this period, 105 transects have been analyzed to provide spatial and temporal variability of the current structure in the depth range of 20-300 m. Most of the transects occur from February through November, with few in January and December. There are typically 10-11 transects per year. The analyses include spatial means and variances of velocities on a quarter degree latitude and longitude grid rotated along the ridge, and the mean RMS vertical shears at 16 m resolution over 20 km rotated longitude of the entire data set. Time series at selected banks, atolls, and channels along the ridge are presented to examine seasonal and interannual variability. This work was conducted as part of the National Science Foundation funded Hawaii Ocean Mixing Experiment to examine historical data to identify likely regions of enhanced tidal mixing associated with the Hawaiian Ridge. In addition, these analyses are being utilized to support studies of coral reef ecosystem dynamics, such as transport and recruitment of larval fishes, crustaceans, corals, and algae.

OS41E-82 0830h POSTER

An Internal Tide Climatology from the Hawaii Ocean Time-Series

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Thirteen years of CTD and ADCP profiles at the Hawaii Ocean Time-Series (HOT) Station ALOHA 100 km north of Oahu have been analyzed for tidal variations. During most of the approximately monthly cruises, CTD profiles were made to 1000 m every 3 hours for 36 hours. Hourly ADCP profiles extend to about 200 m. Least squares regression using either two or 8 tidal constituents was used for the analysis, depending on the length of the record.

The long-term record allows estimation of the internal tides that are coherent with the barotropic tides, and permits separation of neighboring diurnal and semidiurnal tidal constituents. For surface dynamic height relative to 1000 dbar, M2 dominates (2.5 dynamic cm) and S2 is the next most energetic (0.8 dynamic cm). K1, O1 and P1 are all in the range 0.2-0.4 dynamic cm. The dominance of the M2 tide is consistent with results of previous studies. Depth-dependent isopycnal displacement amplitudes show about the same ratio of constituent amplitudes, with M2 displacements peaking at 10 m near 250 m depth. Only M2 and N2 show nearly constant vertical phase expected of a standing mode, while K1, S2, O1, K2 and Q1 show upward phase propagation, but at different rates.

Tidal displacements of isopycnals during individual cruises are generally much more energetic than the long-term coherent signals, suggesting that stochastic processes strongly modulate the coupling of internal and barotropic tides in the generation regions and/or the propagation of internal tides from these regions to Station ALOHA. The vertical phase structure varies considerably, sometimes exhibiting downward phase propagation. During one cruise, a submesoscale vortex appeared to scatter internal tidal energy upward and downward. The robustness and the implications of these observations of non-stationary internal tides will be discussed.

OS41F HC: Hall III Thursday 0830h

Maintaining Deep Ocean Stratification III

Presiding: **D Luther,** University of Hawaii at Manoa

OS41F-83 0830h POSTER

Observations of Enhanced Diapycnal Mixing Near the Hawaiian Ridge and Its Relationship to Tidal Cycles

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As part of the Hawaii Ocean Mixing Experiment (HOME), evidence of enhanced diapycnal mixing near the Hawaiian Islands Ridge, and its relationship (if any) to tidal cycles, has been sought in CTD data obtained by the Hawaii Ocean Time-series (HOT) program. Profiles of potential density over the slope of the Ridge at 2500 m near Oahu and from 110 km north of Oahu in water deeper than 4500 m have been examined for evidence of diapycnal turbulent mixing as indicated by density inversions and internal wave vertical strain. Ensemble averages of the number of inversions and the Thorpe scale have been obtained as a function of depth. Both parameters are found to be higher at the Ridge site than at the deep ocean site. Over the slope of the Ridge, Thorpe-scale based estimates of the rate of dissipation of turbulent kinetic energy and turbulent vertical diffusivity are elevated by an order of magnitude above background levels. The vertical distributions are non-uniform and exhibit signs of localized (in depth) enhancement of dissipation, possibly due to tidal rays generated at the Ridge. At the deep station, turbulence is at well-known background levels from the surface down to 2000 m. Below 2000 m, a localized (less than 1000 m wide) zone of enhanced mixing was observed, perhaps due to an internal tide ray originating at the Ridge. And near the bottom, enhanced mixing is inferred, in agreement with previously reported enhanced eddy diffusivities near the bottom associated with episodic cold bottom water flows into the Kauai Deep.

The full-depth topographical enhancement of mixing near the Ridge also appears in the vertical strain field. Estimates of dissipation rate and turbulent diffusivity, based on internal wave-wave interaction theory, give results similar to direct Thorpe scale methods, except in weakly stratified environments where both methods are subject to uncertainty.

At the Ridge, the variation in mixing intensity observed between casts is sensitive to sporadic large mixing events which are triggered by internal wave displacements associated with the spring tide. The upper portion of the water column (stronger stratification) is more responsive to the tide than the deeper waters.

OS41F-84 0830h POSTER

Characteristics of Deep Currents in the Japan Trench

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In the deep sea area of the Japan Trench, located about 150 km east from northern Honshu, one observes southward flow on the landward slope and the northward flow on the oceanward slope. To confirm above currents system, current meters were deployed at the landward slope of the Japan Trench off Iwate in 1994 and 1995. One mooring deployed for 275 days at depth of about 5800m and another mooring deployed for 20 days at depth of about 4200m. Deep western-boundary current, such as SSW-ward flow along the trench axis above the landward slope, was measured through the observation. Inferences from benthic fauna observed using manned submersible and deep tow camera, oppositely directed flow along the oceanward slope of the trench, forming a trench countercurrent.

In 1998, two current meter moorings were deployed at the landward slope and the oceanward slope of the Japan Trench at depths of about 6000m off Miyagi to compare with deep currents above landward and oceanward slopes. Three months current data, which were measured at 30m above the each seafloor, indicated SSW-ward flow above the landward slope as a mean speed 4.2cm/sec and NNE-ward flow above the oceanward slope as a mean speed 7.9cm/sec.

The similar deep current systems are known in the Aleutian Trench and the Izu-Ogasawara Trench. Deep current system of the Japan Trench is one of the systems in North Pacific Trench Deep Current Chain, which is expected continuously existing along the trenches.

In addition, there is no difference carbon-14 age between the bottom waters on the each slope, which is measured in 2000. This result suggests that the time scale of deep current circulation in the trench is less than several decades that estimated from measurement error of carbon-14.

OS41F-85 0830h POSTER

Richardson Number and Ocean Turbulence; Towed Thermistor Chain Observations

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A 7.2 km tow in the upper seasonal thermocline of the Sargasso Sea with an 80-m aperture thermistor-conductivity chain and shipborne 150-kHz ADCP is examined to determine the relationship between patches of scalar activity and buoyancy frequency, vertical shear, and gradient Richardson number (Ri). The horizontal temperature gradient variance in the 0.5 - 3 m band normalized by the mean gradient squared is used as our measure of scalar activity to remove bias due to high gradient regions. Two-dimensional images show qualitative coincidence between patches of activity and low Ri computed over 10-m vertical scales. Hypothesis testing quantifies and supports these visual results. The null hypothesis, "scalar activity is independent of Ri number" fails at the 90% confidence interval for Ri$<$0.8 for a threshold representing $\sim$ 9% of the most active regions. The probability increases rapidly as Ri approaches 0.25. The results are quite robust for vertical smoothing from 4 - 20 m, although the details of the probabilities are dependent upon the scalar activity threshold and vertical smoothing. It is shown that the most intense scalar activity occurs for Ri $<$ 0.3 and that including less intense activity results in probabilities greater than the null hypothesis for Ri as high as 1.2 - 1.5.

These results are strong evidence for the Kelvin-Helmholz shear instability but no single critical Ri, either 0.25 (Miles and Howard) or 1 (Abarbanel et al.) is identified. Increased scalar activity for part of the tow with enhanced short wavelength ($\sim$ 125 m) internal waves and Ri near 1 is suggestive of the advective instability enhanced by low Ri.

OS41F-86 0830h POSTER

Relationships among Tracer Ages

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Measurements of chemical tracers whose spatial gradients are primarily due to the time dependence of sources and/or sinks ("transient tracers") can be used to estimate transport time scales in geophysical systems. However, a major problem with interpreting these "tracer ages" is that different tracers can yield different ages and, at present, it is not clear what aspects of the transport is measured by the different tracers. We use the concept of a distribution of transit times ("age spectra") to compare the timescales derived from different transient tracers (including CFCs, tritium-helium, and radioactive tracers). By performing a systematic study over a wide range of age spectra we examine under what conditions two tracers yield similar or different ages. It is shown that there can be

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