

OS11B-0229 0830h POSTER

Silver in the North Pacific

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Water data gathered in the North Pacific (May 2002) during the fourth International Oceanographic Commission cruise (IOC IV) are offering new insights into the biogeochemical cycling of Ag in the worlds oceans. Ag concentrations in surface waters and from nine vertical profiles will greatly supplement the limited data set of Ag measurements in the Pacific Ocean, which at present consist of one site in the South Pacific [1], two sites in the eastern North Pacific [2], and three sites near Japan [3]. Natural biogeochemical processes govern the distribution of Ag, as is clear from its nutrient-type distribution in oceanic vertical profiles, with depletion in surface waters and enrichment at depth. Ag has previously been shown to positively correlate with Si [2-6], and that trend will again be examined in these samples. Any deviations from this trend can be used as an indicator of anthropogenic Ag contamination.

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OS11B-0230 0830h POSTER

The Atmospheric Dust Concentration and the Fractional Solubility of Atmospheric Al in seawater

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In order to determine the atmospheric dust concentration and the fractional solubility of atmospheric aluminum (Al), aerosol samples were collected weekly on the windward side of Oahu, Hawaii between February and June 2002. Sampling was conducted using an automatic sector controlled aerosol sampling system to prevent pumping during times when winds would bring dust from nearby islands and local sources to the sampler. Aerosols were collected on 10 replicate acid cleaned Millipore 47 mm Polycarbonate filters with a pore size 0.4 μm at a mean pumping rate of 80 L/min. Microwave acid digestion of a complete set of filters and their aerosol load followed determination of Al by flow injection analysis (FIA) yielded a precision (1σ) of 11% for the entire sampling and analysis process. Partial dissolution of the aerosols was determined by suspending a replicate filter in 60 mL of 0.2 μm filtered surface seawater at pH 8.3. 10 mL of this solution was then filtered (0.2 μm) and the amount of dissolvable Al was determined. In order to see changes in Al solubility with respect to time, samples were analyzed for Al at 24 hour intervals for 4 successive days. Another replicate filter sample was analyzed for major ions including Na<sup>+</sup>, K<sup>+</sup>, Mg<sup>2+</sup>, Ca<sup>2+</sup>, Cl<sup>-</sup>, NO<sub>3</sub><sup>-</sup> and SO<sub>4</sub><sup>2-</sup>.

During the sampling period, the atmospheric Al concentrations and atmospheric mineral dust concentrations observed above Hawaii were 1.2-56.1 (ng/m<sup>3</sup>) and 15-700 (ng/m<sup>3</sup>), respectively, assuming mineral aerosols are 8% Al by mass. Atmospheric dust concentrations at Hawaii increased shortly after an intense dust outbreak was observed in Mongolia in late March. Al fractional solubility varied from 0.087-14.3% with a

mean value of 4.6%. Within the first 24 hours, Al in the aerosol samples appeared to dissolve relatively quickly (first mode). It then continued to dissolve slowly over the next three days (second mode). The total dissolvable Al (1st plus 2nd mode) as well as the total charge of dissolvable non sea salt (nss) K<sup>+</sup>, Mg<sup>2+</sup> and Ca<sup>2+</sup> was well correlated with the total charge of NO<sub>3</sub><sup>-</sup> and nss SO<sub>4</sub><sup>2-</sup> (R<sup>2</sup>=0.78, R<sup>2</sup>=0.84). These results indicate that the abundance of atmospheric (NO<sub>3</sub><sup>-</sup> + nss SO<sub>4</sub><sup>2-</sup>) acids is one of the major factors controlling the fractional solubility of atmospheric dust.

OS11B-0231 0830h POSTER

Halocarbon Production by Pelagic, Sea-Ice and Snow Communities of Micro-organisms - A Source for Halogens in the Arctic Troposphere

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Volatile halocarbons are trace constituents of the oceans and the atmosphere, and they contribute significantly to atmospheric chemistry and the biogeochemical cycling of the elements chlorine, bromine and iodine in the environment. The trace gases and their degradation products contribute to the atmospheric destruction of ozone. An inverse correlation between bromine and ozone in the troposphere has been reported from certain areas, such as the Arctic region.

Previous observations suggest that there is a major release of brominated substances into the troposphere during early spring in the Arctic Ocean. Therefore, we participated in an expedition during April and May 2002 to the Greenland Sea with I/B Oden to identify the origin of halocarbon production with emphasis on brominated compounds.

Incubation experiments were performed with micro-organisms from different habitats, seawater, brine and snow. The aim was to measure the magnitude of halocarbon production and relate this to the micro-organisms in the different habitats. It has been suggested that the formation of organo-bromine compounds in snow in spring conditions may be due to the formation of reactive bromine species such as HOBr. However, tests of the brominating activity in seawater, brine and melted snow suggested no significant production of HOBr. Instead our results indicate that snow and ice communities contribute to a larger extent to the total production of halocarbons (e.g. bromoform) than previously assumed. We also found that the production was higher with increasing salinity in the brine.

URL: <http://www.amc.chalmers.se>

OS11B-0232 0830h POSTER

Colloidal Iron, Aluminum, and DOC/DON in Surface Waters of the Northwest Pacific: Results from the 2002 NSF/IOC Cruise

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Over 70 surface seawater samples were collected on the 2002 NSF/IOC cruise between Japan and Hawaii using a towed fish peristaltic pump trace-metals clean sampling system. Samples for total dissolved Fe and Al were filtered using 0.2 μm cartridge filters. Colloidal Fe and Al were isolated using a Millipore Prep-Scale 1 kDa regenerated cellulose tangential flow ultrafiltration device. Concentration factors were 8-10. Aluminum concentrations were measured using the lumogallion fluorometric technique; Fe concentrations were measured by Fe-57 isotope dilution with a Finnegan Element high-resolution magnetic sector ICPMS.

Total dissolved Fe concentrations ranged from 0.2 to 0.6 nM and were weakly correlated with atmospheric Fe

deposition (calculated from aerosol Fe concentrations). Colloidal Fe ranged from 10-60 percent of the total dissolved Fe and appeared to be related to atmospheric input and biological activity. We will discuss the relationships between the concentrations of particulate, dissolved and colloidal Fe, Al, and DOC/DON and the intertwined effects of atmospheric input, complexation by natural ligands, and physical dilution into the mixed layer.

OS11B-0233 0830h POSTER

Atmospheric Deposition and Upper Ocean Cycling of Iron and Aluminum in the Gulf of Mexico: Results from the SWISS project

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Three cruises have been conducted in the Gulf of Mexico for the Surface Water Iron Speciation Study (SWISS). Our goal is to investigate the processes that lead from aerosol Fe solubilization to stabilization in the water column and eventually to uptake by phytoplankton. One cruise was conducted during the low dust, high river runoff period (spring 2001); two cruises occurred during the high dust, low runoff period (late summer 2001 and 2002). Surface seawater samples were collected using a clean towed batwing pump system and separated into particulate, total dissolved, colloidal, and truly dissolved fractions using cartridge filters and tangential flow ultrafiltration. Colloidal Fe concentrations ranged from 20-80 percent of the total soluble Fe, and were generally lower in the open Gulf waters. Aerosol samples were collected for 12-24 hour intervals onto 47 mm, 0.45 μm filters using a sector-controlled system to avoid stack exhaust. The solubilities of aerosol Fe and Al were assessed by rinsing the filters with surface seawater or ultrapure water. The leach solutions were analyzed for trace elements and major ions. The concentrations of total aerosol Fe ranged from 5-30 nmol/m<sup>3</sup> and correlated strongly with Al. The total soluble Fe ranged from 2-19 percent and averaged 9 percent. The soluble Fe(II) ranged from 1-60 percent of the total soluble Fe (average 17 percent). The data from the third cruise (Sep. 2002) will be discussed in context with what we have learned from the first two cruises.

OS11C MCC: Hall D Monday 0830h

Internal Waves and Seafloor Interactions Posters

Presiding: D A Cacchione, U.S.

Geological Survey; L Pratson, Duke University

OS11C-0234 0830h INVITED POSTER

Preliminary Estimates of Abyssal Mixing from WOCE Lowered ADCP/CTD Sections

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Internal-wave-generated turbulent mixing is inferred from O(1000) lowered ADCP velocity profiles collected during WOCE and ACCE hydrographic cruises in the Australian Southern, tropical Indian, eastern South Pacific and polar-gyre North Atlantic Oceans. Half-overlapping profile segments 16 points

(320 m) were first Fourier transformed. The resulting shear spectra are then corrected for attenuation of wavelengths 50-300 m due to smoothing inherent in the data collection and processing (Polzin et al. 2002 *J. Atmos. Oceanic Technol.* 19 205-224). Shear and strain spectral levels are then used in finescale parameterizations for turbulence (Gregg 1989 *J. Geophys. Res.* 94 9686-9698; Polzin et al. 1995 *J. Phys. Oceanogr.* 25 306-328). In the water column well above the bottom, inferred eddy diffusivities are about  $0.1 \times 10^{-4} \text{ m}^2 \text{ s}^{-1}$ , consistent with past estimates. Diffusivities intensify in the bottom 500-1500 m, approaching  $10 \cdot 1000 \times 10^{-4} \text{ m}^2 \text{ s}^{-1}$  over rougher topography, with average diffusivities in the bottom 1000 m of  $O(10^{-4} \text{ m}^2 \text{ s}^{-1})$ . High diffusivities extend to within 1000 m of the surface for 1000 km east of the Kerguelen Plateau. Preliminary results will be presented and compared to tide/topography interaction theory.

#### OS11C-0235 0830h INVITED POSTER

##### On the Role of Internal Tides in Sediment Resuspension

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In deep water over continental slopes, where the influence of surface waves is weak, near-seabed flows can often be dominated by semi-diurnal internal tides. This work investigates the potential for such flows to create sufficient seabed stress to resuspend fine sediment. Model results are presented from a first mode internal tide propagating over idealized topography, including slopes that are critical with respect to the internal tide characteristics. Results and observations show that, over sloping topography in the presence of stratification, there can be strong asymmetry between the periodic up- and down-slope flows. This asymmetry results in varying shear and vertical mixing between the up- and down-slope flows, and this impacts on the process of sediment resuspension. Numerical results from the Australian North West Shelf demonstrate the potential of internal tides to resuspend sediment. In addition, the interaction of barotropic tidal currents with the internal tidal flows can both enhance and reduce bottom stress, depending on the phase relationship between the flows.

#### OS11C-0236 0830h INVITED POSTER

##### Modeling Internal Tides and Mixing Over Ocean Ridges

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Moored observations from the Hawaiian Ocean Mixing Experiment (HOME) Survey component suggest an increase in diapycnal mixing events during spring tides in the region above the slope. To study possible mixing mechanisms, we utilize large eddy simulations of the benthic boundary layer, using a domain on the order of 200 m thick, with environmental parameters from the HOME.

When the barotropic tidal flow is upslope, the stratification near the boundary is greatly reduced as denser deep water is advected above the less dense water retained in the boundary layer. This leads to statically unstable situations and persistent strong mixing events that are several tens of meters thick and last for approximately one quarter of the tidal period. Conversely, during the down-slope tidal flow, denser fluid remains trapped in the boundary layer as less dense upslope fluid is advected downward, leading to very strong stratification near the boundary, which shuts down vertical mixing over the slope. The current structure and statistics of the overturning are compared with the field observations.

We demonstrate also from the simulations that the Coriolis force plays an important role in both increasing the levels of turbulence in the boundary layer and in producing an efficient mechanism for fluid exchange between the interior and the boundary. Comparisons with numerical experiments where the Coriolis force is

artificially turned off show decreased levels of turbulent mixing and less complex velocity shear structure in the boundary layer. Numerical dye release and Lagrangian drifter experiments indicate that horizontal exchange flows at the inertial period produce a pathway for the new intermediate density water formed in the mixing process to leave the boundary layer.

We generalize our results to consider combinations of oceanic parameter ranges of slope, inertial, buoyancy, and tidal frequencies and amplitudes that could combine to produce increased boundary mixing.

#### OS11C-0237 0830h INVITED POSTER

##### Large-amplitude cross-shore internal bores resuspend sediments near the shelf break, Santa Monica Bay, California

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Two sets of moorings were deployed near the shelf break and over the mid-shelf along a cross-shelf transect in central Santa Monica Bay for four months in the winter of 1998-99. Current and temperature profiles, surface waves, water clarity and suspended sediment were measured with bottom-mounted tripods and surface/sub-surface moorings at both sites. The subtidal currents in the region flowed parallel to the isobaths with fluctuating time scales around 10 days, a typical coastal-ocean pattern. However, during the falling phase of the barotropic spring tide, sets of large-amplitude, cross-shore internal bores with duration of 2-5 hours were observed at the shelf break site. Currents in these internal bores flowed exclusively offshore in a thin layer near the bed with amplitudes reaching 30-40 cm/s. Simultaneously, currents with amplitudes around 15-20 cm/s flowed exclusively onshore in the thicker upper layer. The net offshore transport was about half the onshore transport. Near-surface isotherms were depressed 30-40 m. The sediment-transport processes over the shelf break were dominated by these internal bores. Bed stresses associated with these events exceeded 2 dynes/cm<sup>2</sup>. These amplitudes were large enough to resuspend and transport not only fine-grained material, but also medium to coarse-grained sands from the shelf toward the slope. Consequently, the seafloor over the shelf break was swept clear of fine sediments. The data suggest that the internal bores dissipate and are reduced in amplitude as they propagate across this relatively narrow shelf. The bed stresses over the mid-shelf are weaker, more oriented alongshelf and associated with the usual surface-wave processes. Surficial sediments over the mid-shelf are much finer than at the shelf break.

#### OS11C-0238 0830h POSTER

##### A new Nonhydrostatic Parallel Coastal Ocean Model

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We introduce a new parallel model for the coastal ocean, SUNTANS, or Stanford Unstructured Terrain-following Adaptive Navier-Stokes Simulator, that is capable of simulating many of the physical processes, from the surface to the bed, using a large-eddy simulation for the resolved motions. The code is based on the unstructured algorithms described by V. Casulli in his 1999-2001 papers. The nonhydrostatic Boussinesq equations with a semi-implicit time discretization are solved on an unstructured horizontal grid with layers in the vertical. The momentum and scalar fields are advected using higher-order interpolation, and the nonhydrostatic pressure and free surface are computed with a preconditioned conjugate gradient algorithm using the PETSc (Parallel Extensible Toolkit for Scientific Computation) package. Load balancing and grid-partitioning are managed with the ParMetis (Parallel Graph partitioning and Sparse Matrix Ordering) package.

Using a Smagorinsky model for the unresolved motions in the large-eddy simulation, we demonstrate the efficiency and effectiveness of our model by computing the energy cascade of nonhydrostatic internal waves on an idealized oceanic ridge. Because the code can be made into a primitive-equation code by omitting the nonhydrostatic pressure, we compare the energy spectra for the nonhydrostatic case to the hydrostatic case and determine regions of elevated nonhydrostaticity. This sets the stage for the next step of development, which

will employ an adaptive solver to resolve more accurately the regions of nonhydrostatic activity.

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#### OS11C-0239 0830h POSTER

##### An Open-Ocean Wide Analysis of the Slope of the Continental Slope and Internal Tides

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Cacchione and others (Science 296, 724 (2002)) show that a correlation exists between the angles of energy propagation of semidiurnal tides and the average gradient of the continental slope in the US STRATIFORM study areas offshore New Jersey and California. Based on this correlation, they propose that internal tides may be a strong influence on the slope of the continental slope worldwide by affecting sedimentation patterns through the bottom shear stresses the tides generate.

For the internal tide and other internal waves, the angle of energy propagation,  $c$ , is given by

$$c = (\sigma^2 - \beta^2) / (N^2 - \sigma^2)$$

where  $\sigma$  is the internal wave frequency (0.081 cph for semi-diurnal tides),  $N$  is the Brunt Visl frequency, and  $f$  is the local inertial frequency, which is a function of latitude  $\phi$ , i.e.,  $f = (\sin\phi)/12$  cph. Assuming  $N$  is relatively constant with latitude,  $c$  will be greatest near the equator (where the angle is undefined) and decrease toward the poles. The gradient of the continental slope should behave similarly if the internal tide is the primary influence on the gradient.

We test these hypotheses by computing  $c$  and the mean gradient of the continental slope as a function of latitude in the western Pacific, the eastern and western Atlantic, and the Indian Oceans.  $c$  is computed from the mean annual temperature and salinity measurements contained in the NOAA 1998 World Ocean Database, while the mean slope gradients are computed from the Scripps/NOAA ETOPO2 2-minute gridded global topography and bathymetry.

As hypothesized,  $c$  systematically decreases with increasing latitude in all three ocean basins, gradually falling from a high of  $\sim 4^\circ$  near the equator to a low of  $< 2^\circ$  at  $60^\circ$  latitude, which is the poleward most extent of the ETOPO2 dataset. Over this latitudinal range,  $N$  in fact also decreases due to a deepening and smoothing of the main pycnocline, but it decreases slower than  $f$  thus causing the decrease in  $c$ .

By contrast, the mean slope of the continental slope shows a weaker dependence on latitude. Along convergent margins and carbonate portions of passive margins, the mean slope gradients (av.= $4-6^\circ$ ) tend to be  $\sim 2-4^\circ$  higher than  $c$ , but they fluctuate substantially, being steeper in some regions and more gradual in others. Along the clastic portions of passive margins the relationship changes. In these regions, the mean slope gradients (av.= $1-2.5^\circ$ ) are considerably more uniform and  $\sim 0.5-1^\circ$  lower than  $c$ . However, a general correlation is seen to exist between mean slope gradients and  $c$  over significant stretches of the continental slopes, i.e., as  $c$  decreases with latitude the mean slope gradient tends to decrease as well. This correlation is strongest along the western Atlantic continental slopes, and in particular along the eastern South American slope.

While still being analyzed, the results suggest that active tectonics and/or relatively hard substrates lessen the influence the internal tide may have on slope gradients. Along passive, clastic margins, however, bottom shear stresses caused by the internal tide may indeed be inhibiting slope steepening and fostering the slope gradients that fall significantly below those predicted for gravitationally stable slopes.

#### OS11C-0240 0830h INVITED POSTER

##### Internal Waves over Continental Slopes: Implications for the Suspension and Transport of Sediment

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Critical reflection of internal tides from continental margins and other topographic features transfers energy from low-wavenumber tidal frequencies directly to high wavenumbers, leading to increased shear and strain. This process has been linked to sediment erosion and the generation of intermediate nepheloid layers. Recent observations from the northern California margin show episodic pulses of baroclinic semidiurnal

energy, with bottom intensification of cross-isobath velocity and bore-like behavior suggestive of reflection of the semidiurnal internal tide. Observations of intermediate nepheloid layer generation and regions of relatively high erosion suggest a response of sediment associated with this process. The effect on sediment is twofold. Near-critical reflection amplifies wave velocities near the region of reflection. This can impart a bottom shear stress high enough to erode sediment from the seafloor. Secondly, sediment suspended within the water column can also be affected by internal wave interaction with topography. Elevated turbulence can prevent particles from settling. Relaxation or restratification following mixing events near or within the boundary layer can increase horizontal diffusivity, possibly resulting in the formation of intermediate nepheloid layers. Laboratory and numerical experiments on internal wave reflection have shown that the magnitude of turbulent dissipation, and associated along-isopycnal spreading or horizontal diffusivity, are proportional to the divergence of internal wave energy density flux at the boundary. Quantifying the energy flux divergence is necessary before we can predict sediment fluxes due to this process, either for ocean margins in general, or for a particular location. The geographic distribution of energy flux in internal tides is related to factors such as regional topographic roughness, latitude, and spatial distribution of stratification. Internal wave spectra near margins and rough topography such as canyons are often dominated by peaks at the semidiurnal and tidal harmonics. The description of energy transfer into turbulence in these conditions differs from parameterizations applied in the open ocean, and may require direct measurements in the field. In addition to critical reflection, other mechanisms which transfer internal wave energy to small scales near topography should also be considered.

## OS11C-0241 0830h POSTER

### A Note on the Resonant Interaction of a Surface Wave With two Interfacial Waves

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Recently Hill and Foda (1998) and Jamali (1998) have performed theoretical and experimental studies of the resonant interaction between a surface wave and two oblique interfacial waves. Despite many similarities between the findings of the two studies there is one seemingly major difference. The analysis of Hill and Foda (1998) indicated that there are only narrow bands of frequency, density ratio, and direction angle within which growth is possible. On the other hand Jamali (1998) predicted and observed wave growth over wide ranges of frequency and direction angle, and for all the density ratios that he investigated. We show that second order representation of the dynamic interfacial boundary condition of Hill and Foda (1998) is missing a term proportional to the velocity shear across the interface. When this missing term is included in the analysis the resulting predictions are consistent with the laboratory experiments.

## OS11C-0242 0830h POSTER

### Internal Waves and Turbulence at the Hawaiian Ridge

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The internal waves caused by the tide flowing over topography are a large source of energy, and ultimately mixing, to the abyssal ocean. We used our towed vehicle Marlin to investigate the structure of internal waves and mixing as part of the Hawaiian Ocean Mixing Experiment, a study designed to look at the energy cascade from the barotropic tide, through topographically induced internal waves, down to the micro-scale.

Marlin is towed at an almost constant depth of up to 3000 m behind a vessel at a rate of 90 km a day. It measures internal wave activity using ADCPs and temperature sensors mounted in the nose, and turbulence and mixing with a microstructure suite. We find that the internal wave field and turbulence is greatly enhanced

near the sea floor, both vertically and horizontally indicating a bottom source or focusing of internal waves. The enhancement drops rapidly with distance from the bottom, typically back to background values within the bottom 40% of the water column and 60 km away from topography. The rapid decay scales indicates the need for closure schemes that account for the rapid decay of bottom-generated internal waves.

The mixing observed near Hawaii was up to two orders of magnitude higher than in the background ocean, though in limited areas. Extrapolation of the turbulence along the ridge leads to energy dissipation estimates that are close, though less, than the difference between the energy lost from the barotropic tide and that observed in coherent low-mode waves by remote sensing.

URL: <http://mixing.oce.orst.edu/>

## OS11C-0243 0830h POSTER

### The Propagation Features of Tidally Generated Internal Waves in the Intermediate Regime of Unsteady Lee Waves and Internal Tides

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According to earlier investigations by Nakamura et al. [2000] and Nakamura and Awaji [2001] (NA01), internal waves excited by a tidal flow over a topographic feature are characterized by the nondimensional parameter  $kU_0/\sigma_f$  (where  $k$  is the curvature of topography,  $U$  is the flow speed, and  $\sigma_f$  is the frequency associated with the tidal flow). These internal waves can then be classified into three wave types; (1) unsteady lee waves ( $kU_0/\sigma_f \gg 1$ ), (2) mixed tidal lee waves ( $kU_0/\sigma_f \sim 1$ ), hereafter MTL, and (3) internal tides ( $kU_0/\sigma_f \ll 1$ ). As opposed to internal tides, unsteady lee waves propagate upstream alone relative to the fluid and effectively vorticity, because their phase speeds are equal to the tidal flow speed at their time of generation. MTL waves show an intermediate properties of internal tides and unsteady lee waves.

However, their approximation that the frequencies of individual waves generated at each instance are determined as  $-kU_0 \pm \sigma_f$  is, strictly speaking, beyond the limit of the WKB approximation when  $kU_0/\sigma_f$  is nearly equals to unity in the MTL wave regime. Here, we investigate to what extent the result of NA01 is appropriate in this range using a numerical model. The result shows that the propagation features are qualitatively consistent with those predicted by NA01 even when  $kU_0/\sigma_f = 1$ . For example, (1) fast MTL waves obtain higher energy and smaller vertical wavenumbers (i.e. higher frequencies and faster phase speeds) than those of slow MTL waves (the former propagate upstream since its internal-tide constituent is directed upstream as is the lee-wave constituent, and the latter vice versa), (2) and thus adding the fast and slow MTL waves yields an asymmetrical V-shape. For a quantitative measure, vertical wavenumbers of the fastest component of fast MTL waves are estimated from the numerical model results and compared with the approximation by NA01, which yield rough agreements (the difference is about 30% when  $kU_0/\sigma_f = 1$ ). These results suggest that the concept of unsteady lee wave and MTL wave is useful to understand the basic mechanism of an internal-wave response. Though the above discussion focused on energy conversion from barotropic to internal waves, similar processes will also occur during the reflection of internal waves on rough topography.

## OS11C-0244 0830h INVITED POSTER

### The Role of Internal Waves in the Generation of Intermediate and Bottom Nepheloid Layers Within and Around the Guadiaro Submarine Canyon

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Nepheloid layers distribution within and around the Guadiaro submarine canyon (northwestern

Alboran Sea) was identified using closely-spaced CTD/transmissometer profiles collected during two hydrographic surveys. A well defined pattern of particulate matter distribution consisting in surface, intermediate and near-bottom nepheloid layers was observed. Intermediate and bottom nepheloid layers were always observed within the canyon and in the adjacent continental slope, spanning mainly from 200 to 500 m depth. As part of this study, a currentmeter with a turbidimeter was deployed in the lower section of the Guadiaro Canyon at 600 m depth, 25 meters above the seafloor. Spectral analysis of time series indicated that the currents, temperature and turbidity within the canyon fluctuate principally at semi-diurnal tidal frequencies. Increases of water turbidity were associated with down-canyon current velocities and temperature increases. This behavior suggests the presence of semi-diurnal internal tides affecting the near-bottom suspended sediment concentration along the canyon axis. High-resolution bathymetry from the study area was used to evaluate the internal wave reflection conditions at semi-diurnal tidal frequency for the entire continental slope region. Critical slope conditions were reached at the upper continental slope and along the canyon axis, coinciding with the region where nepheloid layers were observed. This evidence indicates that the generation of intermediate and bottom nepheloid layers within and around the Guadiaro Canyon can result from the interaction of internal waves and the seafloor morphology.

## OS11C-0245 0830h POSTER

### Near-Inertial Internal Waves: a Mechanism to Maintain a Permanent Bottom Nepheloid Layer on the Ebro Shelf (Northwestern Mediterranean)

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In the Ebro delta continental shelf activity of near-inertial waves (17 h period) was recorded by a current meter with turbidimeter deployed 5 m above the bottom at 60 m depth. Between 60 m depth and the shelf break this shelf has very gentle slopes of  $0.1^\circ$  or less and coincides with the range of estimated angles of propagation of near-inertial internal waves energy of this region ( $\theta$ ; from  $0.05$  to  $0.15^\circ$ ). Data from a closely-spaced grid of CTD+T+F stations in the Ebro shelf show a permanent bottom nepheloid layer extending from about 50-60 m depth to the shelf break, coinciding with the zone where the shelf gradient fits with  $\theta$ . The development of this mid-to-outer shelf nepheloid layer maintains similar during the year independently from storms and river avenues events and can remain isolated within or underneath the thermocline. These facts suggest that the repetitive action of near-inertial internal waves maintain this mid-to-outer shelf nepheloid layer during the year. Internal waves could contribute to distribute and maintain suspended sediment near the bottom in the mid and outer part of the Ebro shelf. This mechanism could be affecting other Mediterranean continental shelves and could explain similar nepheloid layer distributions found in other Mediterranean prodeltaic systems.

## OS11C-0246 0830h POSTER

### Baroclinic tides at Fieberling Guyot: Evaluating the Ability to Simulate Velocities

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Terrain-following ocean models are being used to simulate the barotropic and baroclinic tides and to provide estimates of the tidal fields to circulation and mixing studies. These models have successfully reproduced elevations with most inaccuracies attributed to topographic errors. The reproduction of either the baroclinic or barotropic velocity fields has not been as robust, although including stratification has improved the agreement in some areas. Part of the problem is the insufficiency of the observational data set for comparison in the simulated regions. What is needed is a series of moorings with multiple current meters in the neighborhood of abrupt topography known to generate internal tides. Such a data set has been collected by K. M. Brink, J. M. Toole, and C. C. Eriksen near Fieberling Guyot. In order to evaluate the capability of the Regional Ocean Model System (ROMS) to simulate tidal velocities, the combined tides of four constituents, M2, S2, K1, and O1 for the Fieberling Guyot region were modeled. Several model parameters were varied in order to improve the agreement with observations, including 1) horizontal resolution, 2) vertical resolution

(number of layers and layer spacing), 3) forcing at the boundaries (by elevations or velocities), and 4) the parameterization of vertical mixing (Large-McWilliams-Doney, Mellor-Yamada-2.5, Pacanowski-Philander, and a Lamont scheme). The results of these simulations were used to evaluate the model performance with respect to these factors.

#### OS11C-0247 0830h POSTER

##### The Limitation of Internal Wave Propagation the Offshore Direction

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No reports of clearly formed solitons propagating offshore from the continental shelf break have been published yet. Why do the internal waves generated from the shelf break propagate onshore not offshore? The objective of this project is to investigate the limitation of internal wave propagation offshore (deep water) from the continental shelf break. The two-layer analytical model will be formulated to investigate the internal wave reflection and transmission when there is an abrupt change in the bottom slope. The numerical simulation of internal wave evolution and propagation with observed data in South China Sea will be able to provide reliable guideline for the test of limitation of internal wave propagation offshore.

#### OS11C-0248 0830h POSTER

##### Are Asymmetric Flow Fields Around Kilometer-Scale Topographic Seafloor Elevations Reflected in the Sediment?

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Kilometer-scale topographic seafloor elevations like abyssal hills, knolls and seamounts are ubiquitous and abundant features of the oceanic seafloor. Modeling and field studies in physical oceanography have indicated that there are asymmetric flow fields enfolding such seafloor elevations: On the northern hemisphere the lateral asymmetry in the flow exhibits an accelerated flow to the left of the elevation, looking downstream, and decelerated flow to the right. We expect this asymmetry to affect the near-bottom hydro- and particle dynamics and, thereby, the intensity of sediment deposition.

To address the proposed effect on intensity of sediment deposition we assessed the spatial distribution of sedimentary excess 210Pb (210Pb<sub>ex</sub>) inventories using samples taken from the four major slopes and the summit of an abyssal knoll (rising up to ca 850m above the surrounding abyssal plain) in the NE Atlantic. Reference samples were obtained from an upstream far-field station on the abyssal plain (i.e. located southward as viewed from the knoll) not being profoundly influenced by any topographic elevations. Sediment inventories of 210Pb<sub>ex</sub> were compared to the expected 210Pb input from the water column.

This comparison shows that on the summit and on the western slope 210Pb<sub>ex</sub> inventories are smaller than expected. There is also some evidence for 210Pb<sub>ex</sub> inventories on the northern and eastern slopes to be somewhat higher than expected. The spatial 210Pb<sub>ex</sub> pattern (low deposition on the summit and in the west, higher deposition in the northeast) coincides with the predicted pattern of flow intensity (high on the summit and in the west, lower in the northeast) around the topographic elevation.

Other data (e.g. organic carbon, carbonate, uranium contents, grain size distribution) suggest an additional effect of the hydrodynamic asymmetry on the composition of the sedimentary deposit. Given the ubiquity of kilometer-scale topographic seafloor elevations, possible consequences of the described asymmetries for general pattern formation in the deep ocean are discussed.

## OS11D MCC: Hall D Monday 0830h

### Progress in El Niño Forecasting Posters (joint with A)

**Presiding:** B Kirtman, Center for Ocean-Land-Atmosphere Studies; L Goddard, International Research Institute for Climate Prediction, Columbia University; P Schopf, George Mason University

#### OS11D-0249 0830h INVITED POSTER

##### Retrospective ENSO Forecasts from the ARCs Coupled Model Project

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Results are described from a series of 40 retrospective forecasts of tropical Pacific SST, starting January 1 and July 1, 1980-1999, performed with several coupled ocean-atmosphere general circulation models sharing the same ocean model, the MOM3 OGCM, and the same initial conditions. The atmospheric components of the coupled models were COLA, ECHAM, and CCM3 models at T42 horizontal resolution, and the coupling between the ocean and atmosphere did not use empirical corrections. Additionally, the forecasts using the COLA and ECHAM atmospheric models were carried out with two resolutions of the OGCM. The high resolution version of the OGCM had 1 deg. horizontal resolution (1/3 deg. meridional resolution near the equator) and 40 levels in the vertical, while the lower resolution version had 1.5 deg. horizontal resolution (1/2 deg. meridional resolution near the equator) and 25 levels. The initial states were taken from an ocean data assimilation performed by GFDL using the high resolution OGCM. Initial conditions for the lower resolution forecasts were obtained by interpolation from the GFDL ocean data assimilation.

The systematic errors of the coupled models depend strongly on the atmospheric model, with the COLA versions having a warming bias in tropical Pacific SST, the CCM3 version a cooling bias, and the ECHAM versions a slight cooling bias. Each of the models exhibits similar levels of skill, with better forecast performance from the July 1 initial conditions. A consensus forecast produced by taking the ensemble average of the forecasts from all of the models is markedly superior to any of the individual forecasts.

There are obvious problems with the forecasts that can be connected to the systematic errors of the coupled models, and which are ultimately due to physical errors in the parameterizations and numerical truncation errors in the models. These errors lead to initial shock and the development of unrealistic modes of behavior which degrade the forecasts.

#### OS11D-0250 0830h POSTER

##### Are scale interactions a limit to ENSO predictability ?

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Westerly wind bursts and Madden and Julian Oscillations have been suggested to play an important role in the onset of ENSO through a rectification of the low-frequency coupled variability. We assess that the scale interaction between high-frequency wind variability and ENSO does not reduce to these specific atmospheric events. Indeed, we demonstrate that, in order to explain the amplitude and phase of, at least, strong El Niño events such as the 1997-1998 one (largest on record), it is crucial to simulate the high-frequency wind variability prior to and during El Niño. The complex succession of high-frequency westerly and easterly wind anomalies define its phase (relative to the seasonal cycle) and amplitude, therefore the characteristics of its teleconnections and impacts. As a conclusion, ENSO cannot be viewed as a low-frequency coupled mode of the tropical Pacific, but as a multi-scale phenomenon where both high-frequency and low-frequency variability interplay leading to each unique observed

El Niño. This result has strong implications considering that even if the present ENSO prediction systems claim its predictability up to 12 months (not verified in 1997-1998, nor in 2002), they may actually always be limited by the unpredictability at such lead times of the high-frequency wind variability.

#### OS11D-0251 0830h POSTER

##### Assimilating SST data for ENSO predictions

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With a simple 3D Var assimilation scheme, a new strategy of assimilating sea surface temperature (SST) observations has been proposed in this paper. The strategy involves in assimilating two proxy data, SST and subsurface thermal data, into the ocean model. An ensemble of predictions for the Niño3 region SST anomalies (SSTA) is performed to validate the new strategy. The results show that the new strategy can effectively improve Niño3 SSTA predictions at all lead times, in particular for lead times over 6 months, and for the predictions of El Niño episodes. The prediction skills of the Niño3 SSTA attained by the new scheme can be as high as those attained by the assimilation of subsurface data and sea level height. Comparisons between two schemes of SST assimilations suggest that the impact of observations on the initializations of ENSO predictions could greatly depend on how the observations were assimilated.

#### OS11D-0252 0830h POSTER

##### Effect of salinity barrier layer in the preconditioning and onset of El Niño

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Specific salinity stratification of the western Pacific warm pool known as the barrier layer has been proposed to be important in the coupling between sea surface temperature (SST) and winds leading to El Niño-Southern Oscillation. Thick barrier layer maintains surface waters warmer than 28C (the threshold for organized atmospheric convection) by reducing the entrainment cooling from below the ocean mixed layer. This mechanism allows an accumulation of heat in the upper ocean layers prior to El Niño. It also confines the forcing of westerly wind burst (WWB), the most accepted process as a trigger of El Niño, in a shallow mixed layer thus increasing the eastward displacement of the eastern edge of the warm pool. The importance of salinity barrier layer in the preconditioning phase characterized by high ocean heat content and in the onset phase characterized by high WWB activity is investigated using a general circulation coupled model of the tropical Pacific, coupled to a general circulation model. The Meteo-France/ARPEGE global atmospheric model coupled to the LODYC/OPA ocean model is able to reproduce self-sustained El Niño events together with WWBs. The methodology consists of removing the stratification effect of salinity in the vertical mixing parameterization. This cutoff is restricted to the western side of the equatorial band (4N-4S) where SST is larger than 28C. By removing the barrier layer, the main effect is to reduce the ocean heat content in the preconditioning period and to modify the ocean dynamics in response to WWBs in the onset period. Considering three El Niño events of different intensities, hindcasts show that interactions between the ocean and the atmosphere over the warm pool do not amplify and each El Niño is weakened or even aborted. A detailed analysis confirms that the physics of the warm pool such as vertical diffusion and horizontal advection is essential to set up the favorable conditions for the development of El Niño. For each event, a 5 additional members ensemble confirms that salinity stratification play a crucial and significant role during these initial phases of El Niño and that it should be considered in coupled models in order to improve El Niño forecasts.