OS31B-0212 0830h POSTER

Climatic and Environmental Controls of Organic Carbon Accumulation on the California Continental Margin: a Comparison of Deep and Shallow Sites in the Late Quaternary Santa Barbara Basin

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The Quaternary sedimentary sequence of the Santa Barbara Basin presents a unique opportunity for testing the relative importance of different environmental criteria for the preservation of organic carbon. New piston cores obtained during the IMAGES MONA Cruise (2002) from a central/ deep (569 m) and marginal/ shallow (481 m) location in the Santa Barbara Basin lie within and above the intermediate water mass and have been deposited within more consistently dysoxic (deep core) and consistently oxygenated (shallow core) settings. This study correlates total organic carbon (TOC) with C/N ratios, carbonate and grain size. Our results will help evaluate the relative significance of local environmental versus regional oceanographic/climatic variation in the preservation of organic matter. Initial sample spacing analyses were acquired at 40 cm (∼275 y). TOC ranges from 3.4 to 1.0 wt.% (shallow) and 4.1 to 1.3 wt.%(deep). C/N ratios vary from 10.5 to 8.4 (shallow) and from 13.3 to 8.7 (deep). Gross trends in TOC and C/N are well correlated between core MD 2503 (deep) and core MD 2504 (shallow). The TOC profile in both has a typical "burned-down" pattern decreasing downcore from 4.1 and 3.4 wt.% respectively to ∼1.5 wt.% at 12 - 14 mbsf at the base of the Holocene. The C/N ratios show an inverse relationship to TOC suggesting a downcore decrease in the preservation of marine organic matter. Below the most dramatic effects of burial diagenesis C/N ratios in both cores are highly correlated with TOC, suggesting that the relative contribution of organic matter is controlling TOC. In cores MD 2503 and MD 2504, mean $CaCO_3$ sharply drops from higher values during the glacial (3.7 and 6.3 wt.%, respectively) to lower values during the Younger Dryas and Bolling Allerod (2.0 and 4.5 wt.%). After initially increasing at the base of the Holocene, both locations record a gradual decrease in $CaCO_3$ to the present. Higher (20 cm, 130 y) resolution TOC and C/N data is being produced to strengthen correlations with other proxy data. Grain size analysis for both cores is being completed to determine the role of fine-grained material. From data provided by co-workers stable isotopes of planktonic and benthic foraminifera, Mg/Ca ratios, faunal and floral (nannoplankton and pollen) assemblages, and clay mineralogy are also being correlated with TOC to determine the relative significance of provenance productivity, ventilation and substrate composition in the accumulated preservation of organic matter.

OS31B-0213 0830h POSTER

Late Quaternary intermediate water oxygenation history in Santa Barbara Basin from benthic foraminiferal assemblages

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The Southern California margin adjacent to Santa Barbara Basin (SBB) experienced dramatic changes in bottom water oxygenation and related strength of the oxygen minimum zone (OMZ) on millennial through orbital scales during the late Quaternary. These are clearly recorded by quantitative changes in benthic foraminiferal assemblages and/or strength of sediment laminations in SBB. The basin was well oxygenated during cool episodes and poorly oxygenated during warm episodes, in response to changes in intermediate water ventilation and surface ocean productivity. Previous work has shown that benthic foraminiferal assemblages exhibit high sensitivity to changing oxygenation state and groups of taxa can be ranked accordingly. The history of basin oxygenation change during the late Quaternary (last 25 to 33 ka) is now extended over greater depth range through studies of two new IMAGES cores in SBB (569 m at deep basin and 440 m at sill depth). During cool episodes (LGM; Younger Dryas) the assemblages indicate that the water column was well mixed and oxygenated. No evidence exists of significant water mass stratification or presence of the OMZ. Faunal changes are remarkably similar and correlated between the two water depths. In contrast, the assemblages during warm episodes (Bolling/Allerod; and Holocene) indicate strong vertical water mass stratification in oxygenation. The deep basin is much more poorly oxygenated than that at sill depth. Yet, changes in assemblages at sill depth, although often taxonomically different, clearly record oscillations in strength of the OMZ. One benthic foraminiferal species (Bolivina tumida) appears, from earlier works, to be indicative of high concentration of dissolved methane and/or maximum deficiency of oxygen concentration in the basin floor. If so, changing pattern in this species would suggested broad methane expulsions during the early Holocene and during the three episodes in the B/A. The early Holocene was poorly oxygenated compared with the late Holocene.

OS31C MCC: Level 1 Wednesday 0830h

General Ocean Sciences: Geochemistry and Ocean Circulation Posters *(joint with A, B)*

Presiding: **W Cai,** University of Georgia**; E A Laws,** University of Hawaii**; E Y ZENG,** Southern California Coastal Water Research Project

OS31C-0214 0830h POSTER

Seasonal and Interannual Variability of the Carbon Exchange Coefficient Between the Ocean and the Atmosphere

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We use wind speed data from the Special Sensing Microwave Imager (SSM/I), sea-surface temperature (SST) and salinity, to compute the carbon exchange coefficient (K) between the ocean and the atmosphere. The computation is performed on the finest spatial and temporal available grid, i.e., weekly on a 1/4 degree grid, between 1992 and 2002 and over the entire ocean. On average, the Pacific basin is the area with the least seasonal variability, whereas the Indian basin shows the highest variability, with peaks at 0.095 (in moles CO2 kg-1 microatm-1 cm hour-1) around week 30-31 (end of July).The Atlantic basin shows the lowest value (about 0.058) around week 32 (mid-august). The interannual variability shows a slight increase in the exchange coefficient, probably related to an increase in wind speed. The carbon flux is also computed using K and the air-sea CO2 pressure difference and shows that the uptake by the ocean is mostly concentrated in the south eastern part of South America, in the south western part of the Indian Ocean and south of Greenland, whereas the Equatorial region, especially in the west part of the Pacific, releases up to 10 Gt C per year (for an area of 4x5 degrees). This release is also observed in the north western part of the Indian Ocean (around the Oman Sea).

OS31C-0215 0830h POSTER

An Idealized Model of Organic Carbon Dynamics on the Continental Margin of the Eastern United States

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Continental margins play a significant role in the production and burial of organic carbon in the ocean, bur these areas are poorly resolved global circulation models. In this study, a high-resolution three-dimensional, nonhydrostatic model of an idealized eastern coastal United States after Mahadevan and Archer, 1998, was modified to simulate organic carbon production and export off the shelf. The model assumes a periodic north and south boundary, and an offshore boundary at the shelf-break density front determined by bathymetry. The model uses a free surface and a sigma grid in the vertical. The model is initialized with a vertical nutrient profile taken from the open Atlantic Ocean. As the winds are given time to influence the region, upwelling conditions can result in the vertical movement of water. Vertical diffusion also carries nutrients into the euphotic zone. Excess nutrients in the euphotic zone are converted to particles that advect with the flow while sinking with a velocity of 10^{-5} m/s. Remineralization is treated as a first-order decay. We will vary the alongshore wind stress, shelf width, and vertical diffusivity to determine their respective impacts on organic carbon export. Eventually, we hope to parameterize the impact of coastal circulation on the carbon cycle with global circulation and carbon models. Mahadevan, A., Archer, D., Modeling a Limited Region of the Ocean, Journal of Computational Physics 145, 555-574, 1998.

OS31C-0216 0830h POSTER

Hydrothermal Reduction of Carbon Dioxide at 250°C and 500 bar

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Fischer-Tropsch type catalysis reactions are believed to play important roles in abiotic synthesis of organic compounds in mid-ocean ridge vent fluids. However, little is known about the mechanisms of these processes, especially the reaction intermediates in the formation of abiotic hydrocarbons from reduction of CO_2. To better understand abiotic synthesis of hydrocarbons, an experiment involving CO_2 reduction was carried out in a flexible-Au/Ti-cell hydrothermal solution apparatus at 250°C, 500 bar. To limit sources of contamination and simplify the pathway of this reduction process, this experiment was conducted by injecting CO_2 and then H_2 into the reaction cell, instead of using organic acids as surrogate sources. Magnetite was used as a catalyst for organic synthesis. To exclude organic contaminants on the catalyst and their potential effects on this reduction process, however, the magnetite was reacted with hydrogen peroxide prior to the experiment. Subsequently, H_2 was injected into the reaction cell to restore the magnetite structure. Dissolved CO_2 (aq) (35 mmol/kg) was then injected into the reaction cell. This was followed by systematic addition of dissolved H_2. With the addition of H_2 into the system, trace amounts of dissolved CO and CH_4 were produced. 7 μmol/kg formate ($HCOO^-$) and 8 μmol/kg acetate (CH_3COO^-) were also detected by ion chromatography. More formate was produced with adding more H_2. When injecting H_2 to a final concentration of 11 mmol/kg, the concentration of formate increased to 0.16 mmol/kg, CO and CH_4 remain constant, while CO_2 decreased to 4 mmol/kg, and no acetate was observed. Surface compositional analysis of magnetite was conducted using X-ray Photoelectron Spectroscopy (XPS). The concentration of carbon increased following reaction. The prominent C_{1s} peak from the reacted magnetite occurred at 284.5 eV, which corresponds to graphite. The subsidiary peak was consistent with that expected for trace carbon on metal surfaces, which also can be seen in the unreacted magnetite. Results suggest that at 250°C, 500 bar, graphite and formate exist as two primary reduced carbon phases in the system, while the amount of CH_4 and CO were much less than predicted from theoretical data. We speculate that the coating of graphite on the magnetite surface and concomitant loss of magnetite catalytic activity prevent the formation of methane. A similar experiment with temperature stepping scheme (from 250 to 400°C) is in progress. It will allow us to assess the potential contribution of reduced carbon phase formation to the abiotic synthesis of organic compounds under seafloor hydrothermal conditions.

OS31C-0217 0830h POSTER

Helium isotopes and heavier noble gas abundances of water in adjacent sea of Japan

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We have measured helium isotopic ratios of water samples collected with various depths in adjacent sea of Japan. The $^3He/^4He$ ratios vary significantly from

0.989 Ratm to 1.242 Ratm where Ratm is the atmospheric ratio of $1.39x10^{-6}$. It is confirmed that all deep sea water (2000 - 2500 m) of western North Pacific is affected by the mantle helium with a high $^3He/^4He$ ratio. More precisely mid-depth (750 - 1500 m) profiles of $^3He/^4He$ ratios of northwestern Philippine Sea (Nansei Trench) and east of East China Sea (northeast and southwest of Okinawa Trough) are higher than those of western North Pacific (Off Joban) and comparable to those of northern Philippine Sea (Nankai Trough). Excess ^3He of the mid-depth samples may be attributable to the subduction-type mantle helium originated from high-temperature hydrothermal sites in the Okinawa Trough. Noble gas abundances (neon, argon, krypton and xenon) were measured in water samples collected in western North Pacific and northwestern Philippine Sea. Neon abundances show slight excess relative to air saturated sea water at ambient temperature and salinity. This may be due to either air bubble effect or contamination during the sampling. When these effects are corrected using the neon anomaly, heavier noble gas abundances (argon, krypton and xenon) of samples with the temperature higher than 5°C (shallower than 500m) agree well with those of calculated air saturated seawater, while the lower temperature samples (deeper than 500 m) indicate anomaly of -7% to +10%.

OS31C-0218 0830h POSTER

Temporal and Spatial Variations in the Oxygen Isotopic Compositions of Surface Waters from the Northern Caribbean

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Surface water samples collected over a nine-month period from a range of stations in the northern Caribbean and the Bahamas have been analyzed for their salinity vs. oxygen isotopic relationships. These samples were collected at approximate two week intervals during cruises made by the Royal Caribbean Explorer of the Seas. This vessel is equipped with a continuous flowing seawater system which can be used to sample water at predetermined locations. On alternate weeks the ship traced a track which during the first week included the Bahamas, Puerto Rico, and Virgin Islands, and the second week the Dominican Republic, Jamaica, the Cayman Islands, Cozomel, and Key West. As expected analyses show a positive correlation between salinity and the oxygen isotopic composition (m= 0.23), although the r value of only 0.55 suggest a variety of factors other than dilution with freshwater from a single source control the oxygen isotopic composition. These controls include evaporation as well as input of freshwaters with a range of oxygen isotopic compositions from different rivers and precipitation. Spatially the most positive oxygen isotopic values are found in the Bahamas, in the eastern portion of the cruise tract. These are enriched in oxygen-18 by 0.4 per mille compared to samples taken in the western portion at the same time. Temporally the isotopic composition are the most positive during the early portion of the year and trend towards more depleted values in the summer. Spatial differences tend to diminish in the summer months suggesting that the winter differences are related to variations in evaporation and summer values are more negative as a result of higher amounts of precipitation. The difference between winter and summer values is approximately 0.2 per mille. Further evaluation of the temporal and spatial relationship in this dataset will oxygen isotopic ratios in proxy indicators such as corals to be used in combination with temperature proxies as indicators of salinity.

URL: http://www.rsmas.miami.edu/rccl/

OS31C-0219 0830h POSTER

The $\delta^{18}O$ of Dissolved O_2: Implications for Ocean Respiration and Circulation

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The $\delta^{18}O$ of dissolved O_2 of aphotic waters has been shown to be a tracer of both ocean circulation and oxygen consumption by respiration. Here we present $\delta^{18}O$ of O_2 data for samples from the South Atlantic Ventilation Experiment(SAVE) in a zonal section along ~15°S. Our samples are concentrated in the main thermocline including the strong oxygen minimum off the coast of Africa. The data significantly extend the existing dataset of deep ocean $\delta^{18}O$ of O_2. We interpret the data with two models of varying complexity. Because of isotope fractionation during respiration, $\delta^{18}O$ rises as $[O_2]/[O_2]_{sat}$ falls. As elsewhere, the $\delta^{18}O$ increase in the SAVE samples is far less than predicted for Rayleigh (closed system) fractionation. A one-dimensional isopycnal diffusion-reaction model successfully simulates the SAVE $\delta^{18}O$ data using reasonable values for the ratio of O_2 consumption to horizontal eddy diffusion, and for the respiratory isotope fractionation. This model provides a good fit to the South Atlantic data using an isotope fractionation factor between 0.980 and 0.985 and a range of $-2x10^{-5}$ to $-2x10^{-6}$ $mmol/m^3/km^2$ for the ratio of consumption to isopycnal diffusion. These results agree with the conclusions of previous studies. The Geophysical Fluid Dynamics Laboratory general circulation model MOM3 was modified to include the tracer $^{18}O^{16}O$. The model successfully simulated the observed relationship between $\delta^{18}O$ and oxygen saturation for the SAVE samples. The model thus adequately represents the interaction between respiration rates and mixing as expressed by $\delta^{18}O$ of O_2 in our study region.

OS31C-0220 0830h POSTER

Vertical Fluxes of Particulate Trace Metals From the Upper Ocean Using $^{234}Th/^{238}U$ Disequilibrium

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An empirical technique to quantify the vertical flux of particulate trace metals from the upper ocean using simultaneous measurement of $^{234}Th/^{238}U$ disequilibrium and metal/^{234}Th ratios on large, rapidly sinking particles is presented. ^{234}Th-derived particulate metal fluxes represent a bulk metal flux, which includes both scavenged and refractory metal fractions, and metals derived from external input (e.g. atmospheric input). Study sites were selected to include shelf-slope (Gulf of Maine-Scotian Shelf) and open ocean waters (Labrador Sea). In shelf waters, particulate Al/^{234}Th, Fe/^{234}Th, and Pb/^{234}Th ratios in >53-μm particulate matter increase with depth toward the sediment interface. Sinking fluxes of particulate Al (8.91-197 $\mu mol\ m^{-2}\ d^{-1}$), Fe (25.5-151 $\mu mol\ m^{-2}\ d^{-1}$), and Pb (13.4-79.0 $nmol\ m^{-2}\ d^{-1}$) in shelf waters were calculated at 50 m, a depth chosen to limit the influence of sediment resuspension on the calculated particulate metal flux. For slope waters, fluxes of particulate Al (5.92-96.1 $\mu mol\ m^{-2}\ d^{-1}$), Fe (2.20-59.3 $\mu mol\ m^{-2}\ d^{-1}$), and Pb (2.77-89.7 $nmol\ m^{-2}\ d^{-1}$) were calculated at 50 m (mixed layer) and 100 m (total ^{234}Th deficit). In the Labrador Sea, particle size-fractionated (0.4-10-μm, 10-53-μm, and >53-μm) Al/^{234}Th, Fe/^{234}Th, Ba/^{234}Th, and Pb/^{234}Th ratios in the upper 250 m exhibit an increase with depth and are essentially invariant with particle size. Sinking fluxes of particulate Al (2.47-95.9 $\mu mol\ m^{-2}\ d^{-1}$), Fe (2.69-60.8 $\mu mol\ m^{-2}\ d^{-1}$), Ba (0.13-2.91 $\mu mol\ m^{-2}\ d^{-1}$), and Pb (2.85-59.5 $nmol\ m^{-2}\ d^{-1}$) at this open ocean site were calculated at 50 m (euphotic zone) and 100 m (mixed layer). The ^{234}Th-derived trace metal fluxes are within the range or approximately two to four times greater than available published sediment trap results compiled for the world ocean.

OS31C-0221 0830h POSTER

The Potential Importance of Metal-Sulfide Complexes in the Ancient Ocean on Cyanobacterial Metal Requirements

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Recent evidence from the sulfur isotopic record indicates a transition 2.5 billion years ago from an ocean chemistry first dominated by iron and then by sulfide. It has been hypothesized that the selection of metal centers in metalloenzymes has been influenced by the availability of metals through geological time, in particular as a result of large differences in the solubility of metals-sulfides. In this study, we examine the trace metal requirements and sensitivities of marine cyanobacteria and use recent stability constants to model the abundance and chemical speciation of metals across this chemical transition 2.5 billion years ago. Two major results are reported here: 1) the marine cyanobacterial species studied thus far show trace metal preferences and sensitivities that are consistent with their evolution in a sulfidic marine environment; 2) in an ancient ocean dominated by high fluxes and concentrations of iron, the relative availability of trace metals would have been similar to that of a sulfidic system (Fe>Mn,Ni,Co>>Cd,Zn,Cu) as a result of the formation of dissolved sulfide complexes. Thus the formation of strong aqueous metal-sulfide complexes was likely as important as the precipitation of minerals in influencing the selection of metals in biology. These results suggest that marine biogeochemical cycles and marine bioinorganic chemistry have co-evolved, and that the evidence for this co-evolution has been preserved in the physiology and genomes of modern descendants of the early cyanobacteria.

OS31C-0222 0830h POSTER

Photochemical Formation of Fe(II) and Peroxides in Coastal Seawater Collected around Okinawa Island, Japan - Impact of Red Soil Pollution

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In a study to elucidate the impacts of red soil pollution on the oxidizing power of seawater, photochemical formation of Fe(II) and peroxides was studied in seawaters collected around Okinawa Island, Japan. The northern part of Okinawa Island suffers from red soil pollution which is caused mainly by land development such as pineapple farming and the construction of recreational facilities. We studied photochemical formation of peroxides and Fe(II) in the same seawater samples because the reaction between HOOH and Fe(II) forms hydroxyl radical (OH radical), the most potent environmental oxidant. Photochemical formation of Fe(II) was fast and reached steady-state in 30 minutes of simulated sunlight illumination and the steady-state Fe(II) concentrations were about 80% of total iron concentrations. Photochemical formation of peroxides was relatively slow and formation kinetics varied, depending on the initial peroxide concentrations. Because photochemical formation of peroxides was faster and total iron concentrations in the red soil polluted seawater were higher, red soil polluted seawater is expected to have greater oxidizing power than seawater that is not polluted with red soil.

OS31C-0223 0830h POSTER

Silica cycling in mobile mud deposits of coastal French Guiana

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Coastal French Guiana lies within the Amazon - Guianas mobile mud belt and is characterized by intensely reworked migrating mud waves. Diatoms are the primary source of autochthonous organic matter in these deposits and are rapidly remineralized under suboxic diagenetic conditions. The siliceous diatom frustules are subject to dissolution and recycling, burial, or diagenetic alteration. Pore water profiles demonstrate that mudwave deposits are undersaturated with respect to biogenic silica, reaching values ranging from 200-600 μM at depth. Overall, dissolved Al varies inversely with dissolved Si between sampling sites but inverse relations are not discernable within individual cores. Dissolved K is often depleted with depth. Analyses indicate that frustules may be stored as whole or partially dissolved diatoms, metal-oxide coated frustules, authigenic clay-coated frustules, or completely altered particles. Operational leaches of sediment indicate that the commonly used (1% Na_2CO_3) alkaline procedure underestimates biogenic silica content in these sediments, presumably by failing to react with metal-oxide coated frustules and alteration products. A combined mild acid (0.1 N HCl) / mild alkaline (1% Na_2CO_3) leach procedure, used previously in the Amazon delta, was presumed to more accurately quantify reactive Si. Total reactive Si and K extracted from mudwave sediments lies on the regional trend for the Amazon delta (K/Si = 0.19 mol/mol), implying similar authigenic minerals. SEM observations of experimentally incubated diatoms demonstrated the potential for rapid alteration of diatoms into authigenic clays in the mudwave deposits.

OS31D MCC: 3000 Wednesday 1020h

General Ocean Sciences: Tropical Oceanography and the Impacts of El Niño I *(joint with A)*

Presiding: **D Yuan,** NASA Goddard Space Flight Center**; P Rhines,** University of Washington

OS31D-01 1020h

MODIS Ocean Primary Productivity and the Thermocline Circulation During the 2002-2003 El Niño

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Global ocean primary production anomalies, estimated using data acquired by the Moderate Resolution Imaging Spectroradiometer (MODIS) instrument on board of Terra satellite, and results from an ocean general circulation model during the 2002-2003 El Niño are analyzed to study the influence of ocean circulation on the interannual variations of ocean productivity. As the El Niño progresses from 2002 into 2003, the interannual anomalies of the primary production show marked decrease in the eastern equatorial Pacific, whereas the northern off-equatorial Atlantic and the western Indian Ocean reveal a strong increase. The model results show that the thermocline was anomalously depressed in the eastern equatorial Pacific whereas it is significantly lifted in the northern off-equatorial Atlantic and in the western Indian Ocean during the 2002-2003 El Niño. It is, therefore, suggested that the enhanced productivity may be induced significantly by the ocean upwelling anomalies. We also make a preliminary assessment of the possible impact of atmospheric aerosols (retrieved by MODIS) on the ocean primary productivity.

OS31D-02 1035h

Simulated Sea Surface Salinity Variability in the Tropical Pacific

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Sea Surface Salinity (SSS) variability simulated by an oceanic general circulation model forced by daily NCEP-NCAR reanalysis from 1990 to 2001 is analyzed in the research. With daily forcing, the model can reproduce SSS change of the tropical Pacific on different time scales. The model-simulated SSS compares well with the Tropical Atmosphere Ocean (TAO) mooring observation. Correlation coefficients between the model output and observation are around 0.6 and significant at a level of 99% for selected sites that have relatively long observations. The western tropical Pacific is a large variability center on different time scales. On the interannual time scale, the standard deviation of SSS in the region could reach 0.4 practical salinity unit (psu). The 1997-1998 ENSO event is associated with a freshening of the whole equatorial Pacific with an amplitude as large as 0.6 psu. However, the eastern equatorial Pacific shows relatively weak SSS variability (0.1 psu), implying that the western tropical Pacific and the eastern tropical Pacific have quite different mechanisms of SSS changes. On the seasonal time scale, the western tropical Pacific has variability around 0.3 psu. On the intraseasonal time scale (time scale shorter than 50 days), SSS variability in the equatorial Pacific has an amplitude of 0.1 psu. There is pronounced SSS variability associated with the Tropical Instability Waves (TIWs) in the eastern equatorial Pacific on intraseasonal time scale. The activity of TIWs has seasonal and interannual modulation. TIWs tend to be weak during boreal spring and early summer and strong during fall and winter. During the 1997-1998 ENSO event the westward propagating TIWs disappear completely. Relevance to the upcoming *Aquarius* satellite mission to measure SSS from space is discussed.

OS31D-03 1050h

The Influence of Multiplicative Stochastic Forcing on a Coupled Ocean-Atmosphere Model of the El Niño-Southern Oscillation

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The El Niño-Southern Oscillation (ENSO), while exhibiting variability on interannual to decadal timescales, interacts with atmospheric phenomena which have lifetimes of weeks to months. Many observational studies have suggested that the intraseasonal Madden-Julian Oscillation (MJO) may play an important role in regulating the development of El Niño events. It is known that the MJO couples intermittently to the ocean through the deep convection which accompanies it over the western to central Pacific which leads to the possibility that ENSO may be responding to multiplicative stochastic forcing by the MJO. "Multiplicative" means that the stochastic forcing depends on a function of the current state of the model (e.g. Niño 3 index) whereas an "additive" forcing does not and is thereby is uncorrelated with the deterministic part of the model. Diverse model studies already support the idea that the tropical Pacific is an inherently stable system and ENSO variability is maintained by additive stochastic atmospheric forcing. We derive stochastic forcing from observations of surface wind and SST which we apply to an intermediate coupled model of ENSO in both multiplicative and additive scenarios. Our experiments show that the ENSO model's underlying probability distribution function (PDF) changes significantly depending on the nature of forcing in conjunction with the stability of the model. We compare time series of the model Niño 3 index for various forcing experiments to the observed 51-year record of the monthly Niño 3 index and find that it is a strong possibility that multiplicative stochastic forcing, and by extension the MJO, plays an important role in creating the observed ENSO variability.

OS31D-04 1105h

Impact of Atmospheric Intraseasonal Variability in the Equatorial Indian Ocean: Low-Frequency Rectification in Equatorial Surface Currents

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An ocean general circulation model (OGCM) is used to investigate the low-frequency rectification of atmospheric intraseasonal variability (10–90 day periods) in surface currents of the equatorial Indian Ocean. A hierarchy of OGCM solutions are found in an actual tropical Indian Ocean basin for the period of 1988–2001. To isolate the contribution from various nonlinear processes, a $4\frac{1}{2}$-layer intermediate ocean model is also used. Results from the OGCM solutions suggest that the intraseasonal atmospheric forcing causes episodical, swift eastward surface currents during spring and fall. These eastward currents are commonly referred to as the Wyrtki Jets (WJs). Of particular interest is that except for this intraseasonal behavior there are low frequency rectification in zonal surface currents. Amplitudes of the spring and fall WJs and westward surface flow during January–March are weakened by as much as 15-25 cm s^{-1} with intraseasonal forcing. These rectified currents exhibit significant interannual variabilities and they result primarily from intraseasonal wind forcing. Processes that determine the rectification are: asymmetric response of mixed layer depth to easterly and westerly winds, entrainment and advection of subsurface water into the surface mixed layer, and horizontal advection. During an intraseasonal event, westerly wind deepens whereas easterly wind shoals the surface mixed layer. A net, westward current is produced over an event mean because easterly wind acts onto a thinner surface mixed layer whereas westerly wind acts onto a thicker one. This effect is especially strong and dominates other processes during spring and fall, when the seasonal westerly winds are strong, the WJs are intense, and mixed layers are relatively thick. Meanwhile, the strong, episodical westerly winds enhance the entrainment of the slower subsurface water into the surface mixed layer, also tend to weaken the WJs. Zonal and meridional advections contribute somewhat to the WJs weakening near the WJs maxima. In contrast, during January–March when the seasonal winds are equatorial easterlies, surface currents are westward, equatorial undercurrents (EUC) develop, and mixed layers are thin. The rectified surface currents are eastward, which act to reduce the westward surface flow. This eastward rectification results largely from the vertical advection and entrainment of the EUC. During the Indian Ocean Zonal Mode events, surface winds are weak easterlies and EUC reappear during summer and fall. The rectified currents are westward in the OGCM solutions, because effects of the asymmetric response dominate the entrainment and vertical advection of the EUC.

OS31D-05 1120h

Surface Water Processes in the Indonesian Throughflow as Documented by a 115-Year High-Resolution Coral $\Delta^{14}C$ Record

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Radiocarbon has been used as a tracer to study global ocean circulation through the distribution of natural and bomb-derived ^{14}C. In order to get a complete picture of the temporal variation of ^{14}C, proxy records, such as those provided by corals are needed. Corals can provide time series of seasonal and interannual ^{14}C variations of the surface ocean over time scales of hundreds of years. Bi-monthly radiocarbon values from a 115-year time series have been recovered from a coral in the Indonesian Seaway in order to better understand seasonal, interannual and decadal variability in the surface water masses that contribute to the Indonesian Throughflow. The radiocarbon time series occasionally displays a small seasonal signal (10-15 per mil) from 1890 to 1954, with the time period 1875-1880 displaying higher radiocarbon possibly due to a strong El Nino. After 1954 the radiocarbon record

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