dominates at the site from 2400-0 cm. These results suggest greatly enhanced marine productivity prior to 100 ka off Baja California than at any time in the past 100 kyrs. One potential way to explain this result is to invoke stronger La Nina-like conditions in response to the enhanced northern hemisphere solar forcing at that time.

### OS22C-05 1440h

### A 35,000 years record of the Oceanic Primary production variability in the Santa Barbara basin

Luc Beaufort[1] (33 442 97 15 71; beaufort@cerege.fr)

Stephanie Cuven[1] (phanie.cuven@infonie.fr)

Noelle Buchet[1] (nbuchet@cerege.fr)

[1]CNRS CEREGE, Europole de l'Arbois BP 80, Aix-en-Provence 13545 C04, France

The high sedimentation rate of the Santa Barbara Basin has attracted many paleoclimatic studies since drilling of ODP Site 893. In particular the occurrence of laminated sediments during each Dansgaard-Oeschger (D/O) event is particularly intriguing. The reason of these anoxic events can be related either to higher primary production or to change in the chemistry of the intermediate water that fill the deep part of the basin. Here we present a record of primary production (PP) estimations based on coccolith assemblages. It is based on the relative abundance of deep photic zone flora (Florisphaera profunda) versus the upper photic zone flora. This record has been established on Core MD02-2103 in the vicinity of ODP Site 893 during the IMAGES-VIII cruise (2003). The PP record shows higher PP during the Holocene and Boelling Allerod (250 g C/m2/year) than during the Youger Dryas, MIS 2 and MIS 3 (150 g C/m2/year). This record therefore confirms the importance of Glacial/Interglacial influence on strength and path of the California current. During the D/O events no significant increase of primary production is observed, implying that the preservation of laminations during these events is controlled more by the chemistry of the intermediate water rather than by primary production. In order to check the variability of El Nino Southern Oscillation through time and how ENSO influence PP in that contest, we sampled lamina in some intervals (Holocene, Boelling Allerod and D/0 5). Preliminary analysis of a 20 years record from the upper Holocene indicates that the ratio between two Emiliania huxleyi morphotypes show small but significant seasonal variability and a 5-6 year period which may correspond to ENSO cycle.

### OS22C-06 1455h

### Climate-Related Changes in Particle Flux and Export Production During the Last 40 ka from the Pacific Margin of Baja, Mexico

Robert F. Anderson[1] (845-365-8508; boba@ldeo.columbia.edu)

Martin Q. Fleisher[1] (martyq@ldeo.columbia.edu)

Joseph Ortiz[2] (jortiz@kent.edu)

Yan Zheng[1,3] (yan_zheng@qc.edu)

Alexander van Geen[1] (avangeen@ldeo.columbia.edu)

[1]Lamont-Doherty Earth Observatory, P. O. Box 1000, Palisades, NY 10964, United States

[2]Geology Dept. Kent State University, 336 McGilvrey Hall P.O. Box 5190, Kent, OH 44242, United States

[3]Queens College, City University of New York, Flushing, NY 11367, United States

Millenial-scale changes in the organic carbon content of sediments deposited within the oxygen minimum zone (OMZ) along the Pacific Coast of North America have been correlated with the global pattern of climate variability as manifest, for example, in ice cores recovered from Greenland. These and related features have been attributed by various investigators either 1) to changes in the supply of oxygen associated with the ventilation of intermediate water mass, or 2) to local changes in productivity, as a result of ocean-atmosphere reorganizations, such as is seen during El Nino events today. Whereas evidence for changes in the intensity of the OMZ is unequivocal, most sedimentary proxies cannot discriminate between the two proposed causes, because the impact of low bottom-water oxygen concentrations on the composition of marine sediments (organic carbon concentration; trace metal enrichment; etc.) is generally indistinguishable from that of high biological productivity and related organic rain rates. Th-230, Pa-231 and Be-10 were measured in samples from a core collected off the Pacific coast of Baja, Mexico, at a water depth of 700-m. Th-230 profiling was used to evaluate changes in bulk particle fluxes, as well as the fluxes of opal, C-org, and CaCO3. Pa/Th and Be/Th ratios are sensitive to changes in the flux of biogenic particles, but not to the concentration of dissolved oxygen. Hence, these ratios provide unambiguous evidence for changes in productivity. Th-normalized mass fluxes are systematically greater during warm periods (corresponding to high C-org content) than during cold periods, both throughout the last deglaciation and across Interstadials 5 through 8. Pa/Th ratios are also systematically greater during times of warmer climate (Be-10 results are not yet available). While these results do not rule out changes in the ventilation of intermediate waters, they do provide clear evidence for changes in biological productivity and the export flux of biogenic particles. Enhanced productivity during warm events reflect either a shoaling of the nutricline, or an increase in upwelling-favorable winds, or some combination thereof.

### OS22C-07 1510h

### Stagnation of the Eastern Tropical Pacific During Deglaciation?: Porewater Oxygen Concentration Shifts in the Gulf of Tehuantepec

Ingrid L Hendy[1] (734 615 6892; ihendy@umich.edu)

Robert C Thunell[2] (Thunell@geol.sc.edu)

Thomas F Pedersen[3] (tfp@uvic.ca)

[1]University of Michigan, 2534 C.C. Little Building, 425 E. University Ave,.University of Michigan, Ann Arbor, MI 48109-1063

[2]University of South Carolina, Department of Geological Sciences, 700 Sumter Street,University of South Carolina, Columbia, SC 29208

[3]University of Victoria, School of Earth and Ocean Sciences, P.O. Box 3055 STN CSC, University of Victoria, Victoria, BC V8W 3P6

The oxygen minimum zone (OMZ; 400 m water depth) is a significant oceanographic feature along the North American Margin. However, during the last glacial, large changes in porewater oxygen concentrations have been documented suggesting the waxing and waning of the OMZ in close concert with rapid climate change events. It has been suggested that changes in California Undercurrent flow along the North American Margin and/or increased ventilation of intermediate waters played a role in OMZ ventilation off California. However little is known about ventilation at the source of the California Undercurrent (intermediate water in the Eastern Tropical Pacific). A depth transect of cores (15.7$^{o}$N; 95.3$^{o}$ E; 570 to 750 m water depth) through the OMZ collected in the Gulf of Tehuantepec has provided a unique opportunity to examine regional intermediate water mass ventilation and local productivity from the present to the last glacial maximum (24 ka). The resolution of the cores (sedimentation rates of 40 to 100 cmkyr$^{-1}$) is such that evidence of OMZ responses to rapid climate timescales should have been recorded through the transition from glacial to interglacial. The cores show surprisingly similar sedimentation rates, trace metal (Mo, Re, U, Cd and Ag) and organic carbon concentrations and $\delta^{15}$N values suggesting that the water column between 570 and 750 m was relatively homogenous. A significant increase in trace metal concentration occurs during the deglacial interval coincident with increases in % organic carbon and $\delta^{15}$N, decreases in bulk sediment Si and Al contents and distinct sediment laminations. Most significantly this time interval contains the lowest sedimentation rate in the cores and yields an organic carbon flux that was constant through the deglaciation. The invariant organic carbon flux implies that the increase in trace metal concentrations seen during deglaciation cannot be the result of an increase in productivity. Further, an increase in organic carbon flux during the Holocene is not matched by an enrichment in trace metal concentration. These observations together show that porewater oxygen concentrations are not primarily controlled by productivity in this area. The low deglacial sedimentation rate suggests that less detrital clay was delivered to the site during deglaciation. Disappearance of detrital clay may be due to a number of factors including flooding of the shelf during sea level rise, winnowing of bottom sediments by contour hugging bottom currents and reduced rainfall in the region. What, then, produced the observed trace-element enrichments? The most probable explanation is that very low oxygen contents in regional bottom waters coupled with ample time for downward diffusion of trace metals allowed the elements to accumulate in the deposits, most likely as authigenic sulphides. These results imply an intensification of the oxygen minimum in the Gulf of Tehuantepec region during the deglaciation. This cannot be attributed to increased export production (and thus subsurface oxidant demand) but instead requires a primary physical control.

### OS22C-08 1525h

### Late Quaternary History of the Tropical Pacific: THe Gulf of Tehuantepec Foraminiferal Record

Maria Luisa Machain-Castillo[1] (525 622 5832; machain@mar.icmyl.unam.mx); Elsa Arellano-Torres[1] (525 622 5832; arellano@mar.icmyl.unam.mx); Robert Thunell[2] (Thunell@geol.sc.edu); Mitchell Lyle[3] (mlyle@cgiss.boisestate.edu); Alan C Mix[4] (mix@coas.oregonstate.edu); Nicklas G Pisias[4] (pisias@coas.oregonstate.esu)

[1]Instituto de Ciencias del Mar y Limnología, Universidad Nacional Autónoma de México, Ciudad Universitaria, A. P. 70-305, Mexico City 04510, Mexico

[2]Department of Geological Sciences, University of South Carolina, 700 Sumter Street, Columbia, SC 29208, United States

[3]Center for Geophysical Investigation of the Shallow Subsurface, Boise State University, Center for Geophysical Investigation of the Shallow Subsurface, Boise, ID 83725, United States

[4]College of Oceanic and Atmospheric Science, Oregon State University, 104 Ocean Admin Bldg, Corvalis, OR 97331-5503, United States

The geographic location of the Gulf of Tehuantepec makes it sensitive to climatic changes. It is influenced by latitudinal shifts of the Trade Wind System and the Intertropical Convergence Zone which make for a complex oceanographic pattern. Today, two prominent features in the region are: 1) wind induced upwelling during the winter, and 2) a well developed oxygen minimum zone (OMZ) resulting from low oxygen Pacific Intermediate Water and high biological productivity in surface waters. We present the variation of these two features during the Late Quaternary as indicated by planktic and benthic foraminiferal records in a core from the OMZ (740m water depth). The benthic foraminiferal record indicates bottom waters were more oxygenated during the last glacial and a progresive strengthening of the OMZ during the interglacial. Planktic foraminiferal records show the presence of warm stratified waters during late Pleistocene, and increased influence of upwelling during Holocene, probably due to a latitudinal shift of the Trade Wind System. The coupling of these records could suggest that during times of upwelling, increased productivity strenghtened the OMZ. In contrast, in the absence of upwelling, bottom waters would be more oxygenated. However, high biological productivity in the area today is due to both, fertilization induced by upwelling during winter, and the presence of high-nutrient surface water carried out by the Costa Rica Coastal Current (CRCC) during summer and fall. Planktic foraminifera suggests a stronger presence of tropical water (CRCC) in the Gulf of Tehunatepec during Pleistocene, but not necessarily a significant drop in biological productivity. This scenario would require the supply of higher oxygenated bottom waters to the Gulf during glacial times. Ongoing research with other cores and paleoceanographic proxys will aid to elucidate these questions.

## OS22D MCC: 3000 Tuesday 1600h

**General Ocean Sciences: Ocean Carbon** *(joint with A, B)*

***Presiding:*** **W Cai,** University of Georgia**; N M Levine,** Princeton University

### OS22D-01 1600h

### Dcadal Variation of the Surface Water pCO2 in the Western and Central Equatorial Pacific Ocean

Taro Takahashi[1] (1-845-365-8537; taka@ldeo.columbia.edu)

Stewart C. Sutherland[1] (1-845-365-8688; suth@ldeo.columbia.edu)

Richard A. Feely[2] (1-206-526-6214; feely@pmel.noaa.gov)

Catherine E. Cosca[2] (1-206-526-6183; cosca@pmel.noaa.gov)

[1]Lamont-Doherty Earth Observatory of Columbia University, 61 Route 9W, Palisades, NY 10964, United States

[2]Pacific Marine Environmental Laboratory, NOAA, 7600 Sand Point Way, NE,, Seattle, WA 98115, United States

The equatorial Pacific Ocean is known to undergo significant changes on interannual (e. g. El Nino/La

Nina ) and decadal time scales. This area is a major source of CO2 to the atmosphere during non-El Nino periods, but near neutral during strong El Nino periods. Over decadal time scales, the North Pacific Ocean has undergone major physical and biological changes commonly called the Pacific Decadal Oscillation (PDO). Most recent and well-documented major shifts occurred in 1977 and 1989. While causes and effects of PDO have been investigated extensively in recent years, its effects on CO2 chemistry have not yet been identified. The partial pressure of CO2 (pCO2) measured in surface waters over the past two decades are used to examine the effect of the 1989 Pacific Decadal Oscillation (PDO) phase shift on the CO2 chemistry of the equatorial Pacific waters. During 1980-1989, the surface water pCO2 (corrected for temperature changes and atmospheric CO2 uptake) in the central and western equatorial Pacific decreased at a mean rate of about -20 matm per decade, whereas it increased at about +20 matm per decade during 1990-2001. These changes alter the CO2 sink/source flux of the equatorial Pacific significantly in a decadal time scale: in the central equatorial Pacific, the net sea-to-air CO2 flux would be affected by as much as 30 to 40 percent in a decadal time scale, while the western warm pool area would change from a CO2 sink to source.

### OS22D-02 1615h

## Argon concentration in the deep sea as an indicator of atmosphere/ocean $CO_2$ coupling and thermocline mixing

David E Archer (773-702-0823; d-archer@uchicago.edu)

Department of the Geophysical Sciences, University of Chicago, 5734 S. Ellis, Chicago, IL 60637, United States

Box model atmospheric $pCO_2$ values are systematically more sensitive to changes in the biological pump than are $pCO_2$ levels predicted by GCMs. Toggweiler et al. [2003] showed that the difference lies in the degree of equilibration between the high latitude surface ocean and the atmosphere, i.e. how much "traction" the surface ocean has on the atmosphere. $pCO_2$ measurements in the real ocean are unable to tell us which of these models best represents the real ocean, because high nutrient levels counterbalance low temperatures in high latitude surface waters. This is the reason why box models and GCMs both get the right atmospheric $pCO_2$ over the present-day ocean. Dissolved argon concentrations in the deep ocean may be usable to diagnose the high latitude disequilibrium of the real ocean. Hamme and Emerson [2002] measured 0-3% undersaturation of argon, and 2% supersaturation of neon, in the Atlantic and Pacific deep ocean. High heat fluxes before subduction generate undersaturation, because gas exchange is unable to keep up with changing SST, while bubble injection tends to generate supersaturation. Atmospheric pressure is typically 1% lower over the Southern Ocean where deep water is formed. Neon is more sensitive to bubbles and less sensitive to heat fluxes than argon, while pressure offsets affect both gases equally. Using the pair of gases we can estimate that disequilibrium alone would generate a deep ocean 1-2.5% undersaturated in argon. Traditional box model deep argons are within 0.1% of equilibrium, while GCMs generate 1-2% undersaturation. More data would be useful, but the data we have seem to be telling us that the real ocean is more like a GCM than a box model, supporting a lowered atmospheric $pCO_2$ sensitivity to the biological pump and other high-latitude forcings. Argon saturation is exponential in temperature, while mixing generates linear covariation of properties. Saturated waters of different temperatures, mixed together, therefore generate a supersaturated argon solution. This mechanism generates a thermocline maximum of about 3% supersaturation in GCMs and box models where waters of dissimilar temperatures mix. In the GCM, this feature is most pronounced in the equatorial Pacific, where there is unfortunately no recent data to compare to. The closest Hamme and Emerson profile is near Hawaii, where the GCM doesn't show supersaturation either. Argon supersaturation may serve as an indicator of diapycnal mixing, integrated over the lifetime of the water mass, balanced against direct isopycnal ventilation. New measurements of the regional distributions of inert gas concentrations, and measurements of heavier inert gases, would be useful. Hamme, R.C., and S.R. Emerson, Mechanisms controlling the global oceanic distribution of the inert gases argon, nitrogen, and neon, *Geophys. Res. Lett., 29 (23)*, doi:10.1029/2002GL015273, 2002. Toggweiler, J.R., A. Gnanadesikan, S. Carson, R. Murnane, and J.L. Sarmiento, Representation of the carobn cycle in box models and GCMs: 1. Solubility pump, *Global Biogeochemical Cycles, 17 (1)*, doi:10.1029/2001GB001401, 2003.

### OS22D-03 1630h

## Do Continental Shelves Act as an Atmospheric CO2 Sink?

Wei-Jun Cai (7065421285; wcai@uga.edu)

The University of Georgia, Department of Marine Sciences, Athens, GA 30602, United States

Recent air-to-sea CO2 flux measurements at several major continental shelves (European Atlantic Shelves, East China Sea and U.S. Middle Atlantic Bight) suggest that shelves may act as a one-way pump and absorb atmospheric CO2 into the ocean. These observations also favor the argument that continental shelves are autotrophic (i.e., net production of organic carbon, OC). The U.S. South Atlantic Bight (SAB) contrasts these findings in that it acts as a strong source of CO2 to the atmosphere while simultaneously exporting dissolved inorganic carbon (DIC) to the open ocean. We report pCO2, DIC, and alkalinity data from the SAB collected in 8 cruises along a transect from the shore to the shelf break in the central SAB. The shelf-wide net heterotrophy and carbon exports in the SAB are subsidized by the export of OC from the abundant intertidal marshes, which are a sink for atmospheric CO2. It is proposed here that the SAB represents a marsh-dominated heterotrophic ocean margin as opposed to river-dominated autotrophic margins. To further investigate why margins may behave differently in term of CO2 sink/source, the physical and biological conditions of several western boundary current margins are compared. Based on this and other studies, DIC export flux from margins to the open ocean must be significant in the overall global ocean carbon budget.

### OS22D-04 1645h

## A better particulate organic carbon (POC) distribution below 1000 meters in the ocean: mineral ballasting in the HAMOCC5 ocean general circulation model.

Matthew T Howard[1] (608-265-9201; mthoward2@wisc.edu)

Arne M E Winguth[1] (608-265-8477; amwinguth@facstaff.wisc.edu)

[1]University of Wisconsin-Madison, 1225 W. Dayton, Madison, WI 53706

Work by Armstrong et al. (Deep-Sea Research II 49 (2002) 219) and Klaas and Archer (Global Biogeochem. Cycles 16 (2002) 63) has established that organic carbon rain to depths of greater than 1000 meters in the ocean is closely correlated with the rain of the ballast minerals $CaCO_3$, opal, and lithogenic material. Their work supplants the Martin curve, until now widely used in OGCMs. The HAMOCC5 three-dimensional ocean carbon cycle model used in this study has substantial improvements to the model used by Klaas. The improvements include an increased vertical resolution to twenty-two layers, the ten layer sediment model with pore-water chemistry of Heinze and Maier-Reimer, and the detailed ecosystem model of Six and Maier-Reimer with a three day time step for the marine biota. The higher temporal resolution and ecosystem model allows the effects of the seasonal cycle of plankton blooms on POC fluxes to be evaluated. In addition, regional tracer distributions are evaluated and compared with earlier model runs and observational data.

### OS22D-05 1700h

## In Situ Measurements of Persistent Organic Pollutants in Coastal Waters of the Southern California Bight with a Solid Phase Microextraction (SPME)-Based Method

Eddy Y Zeng[1] (714-372-9214; EDDYZ@SCCWRP.ORG)

David Tsukada[1] (DAVIDT@SCCWRP.ORG)

DARIO DIEHL[1] (DARIOD@SCCWRP.ORG)

James A Noblet[1] (JIMN@SCCWRP.ORG)

[1]SOUTHERN CALIFORNIA COASTAL WATER RESEARCH PROJECT, 7171 FENWICK LANE, WESTMINSTER, CA 92683

Global distribution and fate of persistent organic pollutants (POPs) have become an increasingly significant topic in environmental research, as POPs are potential agents of carcinogenicity and mutagenicity to both humans and non-human species. One of the important transport mechanisms for POPs is advection and dispersion from point sources via oceanic currents. Therefore, measurements of POPs in open coastal waters can provide key information about the global geochemical cycling of POPs. However, because concentrations of POPs in ocean waters are typically in sub-ppt (ng/L) levels or lower, accurate measurement of ambient concentrations is challenging. To obtain sufficient mass that can be detected by current analytical instrumentation, extremely large water volumes (e.g., thousands of liters) have to be processed. Such large sample volumes represent a practical impediment for regional-scale sampling efforts. In an attempt to improve our ability to study the fate of POPs in oceanic environments, we have developed an in-situ sampling approach based on the technique of solid-phase microextraction (SPME) and tested it at several coastal locations within the Southern California Bight. A custom-made SPME sampler consists of a polydimethylsioxane-coated (100-m thickness) fiber supported on a stainless steel needle and a copper cage shielding the SPME assembly (to slow bacterial growth). We were able to deploy a large number of the samplers simultaneously at different locations and water depths known to contain varying concentrations of DDTs. The SPME samplers were retrieved after about 15 to 30 days of deployment, and the organics partitioned on the SPME fibers were analyzed with GC/MS under optimized chromatographic conditions suitable for SPME analysis. The concentrations of p,p'-DDE (the most dominant component of all DDTs) measured by the in situ SPME approach were very similar as a function of water depth and spatial location as concentrations previously measured by analyzing more than 2000 L of water using an in situ water pumping system. This paper will further present details of sampling logistics, calibration procedures, detection limits, and cost factors, etc., in association with the SPME-based sampling technique.

### OS22D-06 1715h

## Physico Chemical Control of the Oceanic Iron Cycle in the Crozet Basin (Indian Sector of the Southern Ocean)

Eva Bucciarelli[1] (Eva.Bucciarelli@univ-brest.fr)

Peter Sedwick[2] (psedwick@bbsr.edu)

Stephane Blain[1] (Stephane.Blain@univ-brest.fr)

Paul Treguer[1] (Paul.Treguer@univ-brest.fr)

[1]LEMAR, UMR CNRS 6539, IUEM, Place Nicolas Copernic, Plouzane 29280, France

[2]Bermuda Biological Station for Research, 17 Biological Lane, Ferry Reach, St George's GE01, Bermuda

The Subantarctic Southern Ocean between the Polar and Subtropical water masses is among the largest oceanic sinks for atmospheric $CO_2$, partly because of biological uptake by phytoplankton. As iron was demonstrated by numerous studies to exert a prevailing role on the oceanic primary production, the study of its biogeochemical cycle is of the greatest importance. As part of the Antares 4 JGOFS cruise, ultra clean samplings were performed in the water column of the Southern Ocean (open ocean: Crozet Basin) in order to better understand the oceanic biogeochemistry of iron. Three watermasses were sampled (subantarctic, subtropical, and at the confluence between subantarctic and subtropical watermasses), at depth varying from 0 m to 300 m. We measured two fractions of Fe: dissolved iron (acidified 0.4 $\mu$m filtered samples) and total dissolvable iron (acidified unfiltered samples). The vertical distributions of dissolved iron in the water column were characteristics of open ocean profiles, with an enrichment in the sub-surface, a depletion in the photic zone, and an increase with depth. These profiles are generally assimilated to nutrient-type profiles, although the dissolved iron concentrations in the photic zone vary with depth. We also applied a crustal ratio of 0.33 to concentrations of particulate aluminium (Cattaldo and Cardinal, pers. com.) to estimate the concentrations of refractory particulate iron. We established a linear relationship between the three fractions of iron, whatever the watermass and depth sampled. This indicated a distribution controlled by physical and chemical processes (e.g. scavenging) and excluded a control by biological uptake. This hypothesis could explain why vertical distributions of dissolved iron are not homogeneous in the photic zone, but decrease when particles, both lithogenic and biogenic, scavenge this micro nutrient.

### OS22D-07 1730h

## Stability and Resilience as Organizing Constructs for Aquatic Food Webs

Edward A Laws (808-956-2912; elaws@hawaii.edu)

University of Hawaii, Department of Oceanography, Honolulu, HI 96822, United States

The idea that physical, chemical, and biological systems tend to persist in stable configurations underlies much theoretical understanding of systems behavior. Systems analysis indicates that locally (as opposed to globally) stable configurations of systems may persist indefinitely. The existence of such locally stable configurations may to some extent explain the phenomenon of regime shifts and the irreversibility of some anthropogenic impacts on ecosystems. In a stochastic environment merely being stable is not good enough. Resilience becomes important. Given a multitude of stable system configurations, a stochastic environment will tend to select for those configurations that are most resilient. The greater the variance associated with environmental noise, the greater the selection pressure.

OS

Application of the concept of maximum resilience to pelagic and mesopelagic food webs leads to predictions about system behavior that are in remarkable agreement with observations. The predictions underscore the role of temperature as a regulator of community behavior.

**OS22D-08 1745h**

### Clues to Coral Reef Ecosystem Health: Spectral Analysis Coupled with Radiative Transfer Modeling

Liane Guild[1] (650-604-3915; lguild@mail.arc.nasa.gov); Barry Ganapol[2] (520-621-4728; GANAPOL@cowboy.ame.arizona.edu); Philip Kramer[3] (305-361-4768; pkramer@rsmas.miami.edu); Roy Armstrong[4] (787-899-6875; neptune@caribe.net); Art Gleason[3] (305-361-4801; art.gleason@miami.edu); Juan Torres[4] (jtorres@caribe.net); Lee Johnson[5] (650-604-3331; ljohnson@mail.arc.nasa.gov); Newell Garfield[6] (831-375-4670; garfield@sfsu.edu)

[1]NASA Ames Research Center, MS 242-4 Ecosystem Science and Technology Branch, Moffett Field, CA 94035-1000, United States

[2]University of Arizona, Departments of Aerospace and Mechanical Engineering and Hydrology and Water Resources, Tucson, AZ 85721-0020, United States

[3]University of Miami, Rosentiel School of Marine and Atmospheric Sciences 4600 Rickenbacker Cswy, Miami, FL 33149

[4]University of Puerto Rico, Department of Marine Sciences Isla Magueyes Field Statio La Parguera, Lajas, PR 00667, United States

[5]CSU Monterey Bay, MS 242-4 NASA Ames Research Center, Moffett Field, CA 94035-1000, United States

[6]San Francisco State University, Romberg Tiburon Center 3152 Paradise Dr., Tiburon, CA 94920, United States

Coral reefs are among the world's most productive and biologically rich ecosystems and are some of the oldest ecosystems on Earth. Coralline structures protect coastlines from storms, maintain high diversity of marine life, and provide nurseries for marine species. Coral reefs play a role in carbon cycling through high rates of organic carbon metabolism and calcification. Coral reefs provide fisheries habitat that are the sole protein source for humans on remote islands. Reefs respond immediately to environmental change and therefore are considered "canaries" of the oceans. However, the world's reefs are in peril: they have shrunk 10-50% from their historical extent due to climate change and anthropogenic activity. An important contribution to coral reef research is improved spectral distinction of reef species' health where anthropogenic activity and climate change impacts are high. Relatively little is known concerning the spectral properties of coral or how coral structures reflect and transmit light. New insights into optical processes of corals under stressed conditions can lead to improved interpretation of airborne and satellite data and forecasting of immediate or long-term impacts of events such as bleaching and disease in coral. We are investigating the spatial and spectral resolution required to detect remotely changes in reef health by coupling spectral analysis of in situ spectra and airborne spectral data with a new radiative transfer model called CorMOD2. Challenges include light attenuation by the water column, atmospheric scattering, and scattering caused by the coral themselves that confound the spectral signal. In CorMOD2, input coral reflectance measurements produce modeled absorption through an inversion at each visible wavelength. The first model development phase of CorMOD2 imposes a scattering baseline that is constant regardless of coral condition, and further specifies that coral is optically thick. Evolution of CorMOD2 is towards a coral-specific radiative transfer model that includes coral biochemical concentrations, specific absorptivities of coral components, and transmission measurements from coral surfaces.

URL: http://geo.arc.nasa.gov/sge/coral-health/

## OS31A MCC: 3000 Wednesday 0800h

### Identifying Submarine Landslide Time of Failure II *(joint with T)*

***Presiding:*** **D R Tappin,** British Geological Survey**; P Watts,** Applied Fluids Engineering, Inc.

**OS31A-01 0800h INVITED**

### Dating of Submarine Landslides and Their Tsunami Deposits Using Hawaii as an Example

Gary M McMurtry[1] (808-956-6858; garym@soest.hawaii.edu)

Emilio Herrero-Bervera[1] (808-956-6192; herrero@soest.hawaii.edu)

[1]School of Ocean and Earth Science and Technology, University of Hawaii, 1000 Pope Road, Honolulu, HI 96822, United States

There have been several approaches to dating the initiation of submarine landslides and the tsunamis they inevitably produce. In Hawaii, the timing of flank failures of major volcanoes has been estimated by radiometric and paleomagnetic dating of the youngest shield-building flows and dikes, the apex ages of the volcanoes, which can also be constrained by the oldest flows of post-collapse volcanism. More precise age estimates can be obtained by direct dating of the landslide. These approaches include paleomagnetic and U-series stratigraphic dating of the overlying pelagic sediment cover upon and in front of the landslide, the latter method producing minimum ages of last landslide turbidite emplacement, e.g., the ca. 120 ka Alika phase 2 event. Elevated, detached landslide blocks make the best targets for such dating because it is assumed that smaller post-emplacement turbidites will not reach their summits. Catastrophic events such as the 1.0 Ma Wailau giant landslide have, however, been dated by turbidite deposition upon large, elevated blocks of the nearby 1.8 Ma Nuuanu giant landslide. Other direct methods for older events include use of thickness of ferromanganese crusts collected from steep, exposed rock scarps and cosmogenic Be-10 or U-series radiometric determination of the few mm/Ma rate of accumulation. In subtropical areas such as Hawaii, coral clast-bearing, elevated marine deposits on the southeastern islands have been identified as deposits from giant tsunamis. Among the key evidence are the great age and paleo-elevations of the coral clasts found in situ. Since modern coral clasts are relatively young, a few thousand years old or less, older analogs swept from the presently submerged reefs offshore can reliably date tsunamigenic depositional events within the late Quaternary using U-series methods. The age of the tsunami will date within these limits (and the analytical precisions) to the youngest in situ coral clast that was entrained by the waves. U-series dates approximately coeval with the Alika 2 giant landslide suggest a youngest 100 ka tsunami emplacement age from 100-137 ka corals collected on Lanai and Hawaii; likewise, older deposits on Molokai and Lanai suggest a 200 ka tsunami emplacement age from corals that range 200-258 ka in age, but interpretative care must be taken as open-system behavior upon weathering may produce apparently younger dates. Other promising methods for dating these deposits include cosmogenic Cl-36 exposure ages of cements and Cl-36 and He-3 exposure ages of the entrained volcanic rocks. Younger events can be dated by the above methods using C-14 or unsupported Pb-210.

**OS31A-02 0815h**

### Ages of Potentially Tsunamigenic Landslides in Southern California

Homa J. Lee[1] (650-329-5485; hjlee@usgs.gov); William R. Normark[1] (650-329-5200; wnormark@usgs.gov); Michael A. Fisher[1] (650-329-5158; mfisher@usgs.gov); H. Gary Greene[2] (831-632-4438; greene@mlml.calstate.edu); Brian D. Edwards[1] (650-329-5488; bedwards@usgs.gov); Jacques Locat[3] (418-656-2179; jlocat@ggl.ulaval.ca)

[1]U.S. Geological Survey, 345 Middlefield Road, Menlo Park, CA 94025, United States

[2]Moss Landing Marine Laboratories, 8272 Moss Landing Road, Moss Landing, CA 95039, United States

[3]Laval University, Medicene Street, Quebec, Que G1K 7P4, Canada

The innermost basin slopes of the Southern California Borderland contain numerous large-scale submarine landslides. Many of these are of sufficient size to have generated tsunamis when they occurred, assuming that the imaged deposits represent a single failure and that their motion was rapid. We have obtained high resolution subbottom profiles of five well-defined slope failures. These failures are located off the Palos Verdes Peninsula, within Santa Monica Bay, and within the Santa Barbara Channel. A landslide motion and tsunami generation model for one of the landslides shows that it likely generated a tsunami with a source height of at least 8 m. For four of the failures, ages were determined by identifying acoustic reflectors in the vicinity of the failed masses that either clearly postdate or predate the landslide events. The ages of the reflectors are determined by using seismic-reflection profiles to correlate with dated sections at ODP sites or by directly dating the slide masses with piston cores. In the case of the most recent failure in the Santa Barbara Channel, post-failure sediment deposited on the scar of the landslide was sampled completely with a gravity corer, and the age was estimated based on a representative sedimentation rate. Our assessment shows that three of the four older landslides are approximately 10,000 years old and that the Palos Verdes event was about 7,500 years ago. However, the most recent failure may be as young as 200 years. Such a landslide might have generated a tsunami such as was observed by early Spanish settlers during the 1812 earthquake.

**OS31A-03 0830h INVITED**

### Dating one Slide Event of the Complex Compound Goleta Submarine Landslide, Santa Barbara Basin, California, USA

H. Gary Greene[1] (831-771-4140; greene@mbari.org)

Michael A. Fisher[2] (650-329-5158; mfisher@usgs.gov)

William Normark[2] (650-329-5158)

Norman Maher[3] (831-633-7400; nmaher@aoageophysics.com)

[1]Monterey Bay Aquarium Research Institute, 7700 Sandholdt Road, Moss Landing, Ca 95039, United States

[2]US Geological Survey, 345 Middlefield Road, Menlo Park, CA 94025, United States

[3]AOA Geophysics Inc., 7532 Sandholdt Road, Moss Landing, CA 95039, United States

Dating of submarine sediment slumps and slides is fraught with problems, especially those taking place during the past several thousand years. However, we need to develop accurate dating techniques so as to improve our ability to assess the periodicity of, and the actual risk from, these events. The large (130 km2) Goleta landslide located off Coal Oil Point near the town of Goleta, California measures 14.6-km long, extends from 90 m to nearly 574 m below sea level, and is 10.5 km wide. The slide is complex, and includes both buried slump blocks and mudflows, with a surface expression of three distinct segments of failures. Each segment is composed of a distinct head scarp, downdropped head block, and a slide debris lobe. We estimate that at least 1.75 km3 of surface material represents the most recent displaced events of this slide. Dating of the more recent failures of this slide has been speculative and based on modeling and estimated sediment cover on one of the head scars. The most recent event is thought to be the cause of the reported tsunamis of 1812. However, sophisticated dating of the slide has yet to be done. Recent interpretation of newly acquired seismic reflection profiles indicates that the head slump block of the eastern segment of the slide dammed sediment behind it after it came to rest at the base of the head scarp. We calculated that about 64 m of sediment was dammed behind the block, based on a measured two-way travel time through the sediment pond of 0.075 sec. and an assumed velocity of 1680 m/sec. Using a sedimentation rate of 1.73 m/Ka to 2.5 m/Ka, the range of sedimentation rates determined by other investigators for the mid- to lower shelf areas of the western Santa Barbara Basin, the time required for deposition would be 37-25.6 Ka. Therefore, if the sedimentation rates are correct and that the ponded sediment represent nothing but normal sedimentation devoid of sloughing or debris flows down the slope, the maximum age of when the block came to rest in its present position would be 37-25.6 Ka. However, given the tectonic dynamics of the area and the instability of the slope in this part of the Santa Barbara Basin, the likelihood of deposits derived from mass movement filling the depression behind the slump block is high, thus suggesting a possible younger age for the failure.