same data set were examined. The purpose is to determine the cause of the increasing trend in the GSSTF2 latent flux data over the period of 1988-2000. An increase of domain average wind speed (6%) was found over the same period, along with an increase of sea-air humidity difference (11%). These results are consistent with the trends in latent heat flux, which is approximately proportional to the product of the two. Sea-air humidity difference is computed as sea surface humidity minus sea surface air humidity, therefore these two parameters were examined as well. A 1% increase and a 2.4% decrease were found in sea surface humidity and sea surface air humidity respectively, which explains the increase of sea-air humidity difference. The boundary layer (lowest 500 meters) precipitable water was also examined and a 3% decrease was found. Because it is the basis for deriving sea surface air humidity its decrease is consistent with the decrease of the sea surface air humidity. An EOF analysis will be performed for each parameter to evaluate the contribution to variances associated with the trends and interannual variations. An Empirical Mode Decomposition will be applied to the principal EOF time series to examining the intrinsic modes of the time series. Combined EOF analysis will also be applied to selected parameters to examine the coupling between the different parameters.

OS12C-06 1720h INVITED

The Aquarius/SAC-D salinity mapping satellite mission: Science and measurement objectives for studying the ocean freshwater budget

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The scientific motivation for measuring sea surface salinity (SSS) from satellites is to study the interactions between the Earth's water cycle, ocean circulation and climate on intra-seasonal to interannual time scales. The key science objectives are 1) to improve closure of the mean and seasonal global ocean-atmosphere freshwater balance, 2) to study the influence of SSS variability on tropical dynamics and ENSO, and 3) to monitor large scale SSS changes in high latitudes that influence ocean convective overturning circulation and long term climate variability. Aquarius/SAC-D is a dedicated salinity mapping mission being developed by the United States and Argentina for launch in 2008 and a three-year baseline mission life. Aquarius/SAC-D is designed to optimize the salinity retrieval accuracy for global climate studies. The satellite will provide global maps every 8-9 days at 100 km resolution with a three-beam push-broom configuration of 60-90 km single-beam resolution. The measurement requirements prescribe an rms uncertainty <0.2 psu globally on monthly time scales. The satellite data will be validated and jointly analyzed with the growing array of in situ salinity observations from Argo, surface drifters, moored buoys and ships of opportunity. Perhaps the most significant scientific advances to come from Aquarius/SAC-D will be understanding the atmosphere-ocean fresh water budget. In many regions, today's uncertainties are on the same order as the net fresh water flux. Simulations show that the Aquarius/SAC-D measurement accuracy will resolve the range of SSS responses in an ocean model forced with various different commonly used precipitation fields. Aquarius/SAC-D will be launched in the same time frame as the Global Precipitation Measurement (GPM) and the European Soil Moisture Ocean Salinity (SMOS) missions, providing an unprecedented opportunity to address simultaneously the atmosphere-ocean-land components of the global water cycle.

URL: http://aquarius.gsfc.nasa.gov/

OS12C-07 1740h

On the Construction of Reanalysis Argo Dataset Using a 4DVAR Data Assimilation System

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The Argo program is known as a major component of the ocean observing system. It will measure the upper layer profiles of temperature and salinity by a global array of 3,000 profiling floats. When the Argo float network is completed, 100,000 profiles of temperature and salinity will be reported every 10 days. The Argo data will provide a quantitative description of the evolving state of the upper ocean and patterns of ocean climate variability. The in-situ Argo data, however, can only give us discontinuous information on the ocean state, since the Argo float is a floating buoy and the sampling time and position vary continuously. Therefore, it is necessary to create a 3-dimensional grid dataset from the sparsely measured Argo data for the effective use of the observational data. To make such a physically integrated Argo dataset, we developed a 4DVAR data assimilation system, which is constituted on the basis of MOM3 and its adjoint by using 4-dimensional variation method, and tried to apply it to the Argo data. An experiment was carried out, in which the assimilation duration was set as 2 year from 2001 to 2002, and a global ocean model with the resolution of 1x1 deg. in horizontal and 36 levels in vertical was used. The 22 years of simulation beginning from 1980 was firstly conducted by using the sea surface heat flux, fresh water flux, and wind stress of the NCEP reanalysis data. Then, we started the assimilation by using the profiles of temperature and salinity obtained with the Argo float during 2001 to 2002. Comparisons of the results with and without the Argo data revealed that both fields of temperature and salinity are significantly improved by the Argo data. Meanwhile, results of the volume transport and heat transport are also reasonable. Further study is still needed for the operational use of this assimilation system.

OS21A MCC: 3000 Tuesday 0800h

Progress in Tsunami Research and Mitigation I *(joint with T)*

Presiding: **E N Bernard,** NOAA Pacific Marine Environmental Laboratory**; C Synolakis,** University of Southern California

OS21A-01 0800h INVITED

The National Tsunami Hazard Mitigation Program

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The National Tsunami Hazard Mitigation Program (NTHMP) is a state/Federal partnership that was created to reduce the impacts of tsunamis to U. S. Coastal areas. It is a coordinated effort between the states of Alaska, California, Hawaii, Oregon, and Washington and four Federal agencies: the National Oceanic and Atmospheric Administration(NOAA), the Federal Emergency Management Agency (FEMA), the U. S. Geological Survey (USGS), and the National Science Foundation(NSF). NOAA has led the effort to forge a solid partnership between the states and the Federal agencies because of it's responsibility to provide tsunami warning services to the nation. This successful partnership has established a mitigation program in each state that is preparing coastal communities for the next tsunami. Inundation maps are now available for many of the coastal communities of Alaska, California, Hawaii, Oregon, and Washington. These maps are used to develop evacuation plans and, in the case of Oregon, for land use management. The partnership has successfully upgraded the warning capability in NOAA so that earthquakes can be detected within 5 minutes and tsunamis can be detected in the open ocean in real time, paving the way for improved tsunami forecasts. NSF's new Network for Earthquake Engineering (NEES) program has agreed to work with the NTHMP to focus tsunami research on national needs. An overview of the NTHMP will be given including a discussion of accomplishments and the new collaboration with NEES.

URL: http://www.pmel.noaa.gov/tsunami-hazard/

OS21A-02 0815h INVITED

NTHMP Product Example: Tsunami Forecasting

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Long- and short-term tsunami forecast products for Hazard Assessment and Warning Guidance advance the goals of Mitigation, the third NTHMP component. Thus, an inundation map for Hazard Assessment can be considered a long-term forecast on a time scale appropriate to the history of tsunami attacks in the area, typically on the order of years to decades. Inundation maps are used by State and local officials to develop Mitigation tools that include evacuation maps, public workshops, educational brochures, and other outreach programs. Short-term tsunami forecasts provide Warning Guidance on time scales appropriate to tsunami travel time from the source region to coastal communities, typically on the order of minutes to hours. Such tsunami forecasts help improve the accuracy and reliability of warnings issued by NOAA's Tsunami Warning Centers. Observational technology and numerical modeling technology are both critical to development of these products – inundation maps are produced by numerical models that must be tested and improved through case studies that include field measurements; short-term tsunami forecast systems must integrate real-time data with numerical simulations. This presentation will provide an overview of the methodologies used in these products, the progress and accomplishments thus far, and future plans.

OS21A-03 0830h INVITED

NEES Tsunami "Product" Example : Standards and Guidelines for Construction of Coastal Structures.

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In the past decade, considerable progress has been achieved in improving tsunami inundation models. In addition to the availability of high qualify field survey data, comparisons with small and larger scale laboratory data as in NSF's Friday Harbor workshop (Yeh et al., 1996) have allowed validation of inundation predictions. By contrast, there has been far less progress in predicting forces or in translating inundation predictions to standards and guidelines. One example of addressing this issue is in a companion FEMA study undertaken jointly by the Marine Faciltiies Division of the State Lands Commission (CSLC) with USC to develop standards and guidelines for marine terminals in Los Angeles, Ventura and Orange Counties in Southern California, referred to as MOTEMS. Poorly or inadequately designed oil terminals can pose significant risks to public safety; SLC regulates the operation of marine facilities in California waters and and has the mandate to adopt performance standards for the construction and maintenance of these terminals. Prior to this study, no standards existed for seismic or tsunami hazards. The consortium comprised of USC, SLC and LLNL first completed a probabilistic hazard assessment to suggest combined probabilities for ground accelerations from different events that might affect marine terminals in the Southland. Then both tsunamigenic faults and offshore landslide-prone areas were identified and the associated runup modeled (Borrero, 2002). SLC then integrated the seismic and tsunami results and developed engineering standards for marine oil terminals, now in the final stages to state adoption as regulations (Eskijian et al, 2003). While the tsunami-specific standards allow for safer design of marine facilities, they are currently stated in terms of expected tsunami wave heights and return periods. Consulting engineers and the CSLC have to make their own assessments as to the adequacy of resulting force predictions for the design tsunami heights, as well as impact loads from ships and floating debris. While small scale data on forces on piles and walls have been obtained in collaborative NSF-funded studies (Harry Yeh, pers. comm.), predictions from these data sets at prototype scales have yet to be validated. Also, no predictions for tsunami forces from numerical models have

yet been compared with lab data. Large scale laboratory experiments planned under NEES will allow for the validation of numerical predictions for wave velocities and forces, the extrapolation from small scale lab experiments, and the translation of force predictions to construction standards. It is anticipated that the latter will include performance guidelines for the design of seawalls, wharfs, piers, and structures to mitigate both direct and indirect tsunamigenic losses. References Borrero, J.C., 2002, *Analysis of Tsunami Hazards in Southern California*, PhD thesis, USC, 262p. Eskijian, M.S. Heffron, R.E., Dahlgren, T., 2003.. *Engineering Standards for Marine Oil Terminals*, in Submarine Landslides and Tsunamis, Yacliner, A. et al (eds), NATO Science Series, Kluwer Academic Publishers. Yeh, H. Liu, P.L-F., Synolakis, *Long Wave Runup Models*, World Scientific. *Marine Oil Terminal Engineering and Maintenance Standards*, (MOTEMS), July 2003, published by the California State Lands Commission.

OS21A-04 0900h

Tsunami Inundation Mapping for the State of California

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Since the International Tsunami Symposium held in Seattle, Washington in August 2001, significant progress has been made in tsunami inundation mapping for the state of California. While the mapping effort continues to focus on creating a "worst case scenario" for use by emergency management in evacuation planning and guidance, the modeling technologies being developed will be instrumental in creating a future generation of tsunami hazard prediction that include probabilities of occurrence. Significant progress over the last two years has been achieved with the completion of a uniform, 3 arcsec combined bathymetry and topography data set that extends from San Diego County to north of San Francisco Bay. This data set also includes a 1 sec resolution grid over the San Francisco Bay region. Over the last two years, the inundation mapping program has continued to focus on near–shore tsunamis sources. These include submarine mass movements, offshore thrust faulting and complex ruptures on near–shore strike slip faults. Sources recently modeled include the Palos Verdes debirs avalanche, the Catalina Island restraining bend, the Lasuen Knoll uplift structure and the San Mateo Thrust Fault. These sources in particular that showed a significant time lag for a variety of near–shore sources for first wave arrival in to the Ports of Los Angeles and Long Beach. Numerical modeling has confirmed that this lag can be more than 20 minutes, leaving room for the possibility of a local tsunami warning system - something previously assumed to be of little use due to the proximity of the tsunami generation sources to the Ports. Thus far the inundation mapping program has completed inundation maps for Los Angeles, Santa Barbara, and San Diego Counties. As well as the Pacific side of San Francisco and the Monterey Bay area. Final maps for Ventura, Orange and San Luis Obispo county will be completed by year's end with the remainder of the state to be mapped in the coming year. Other projects being undertaken in this effort include examining sources within San Francisco Bay to investigate the tsunami hazard for marine oil transfer terminals located inside the Bay.

URL: http://www.usc.edu/dept/tsunamis

OS21A-05 0915h

M-TSU: Direct evaluation of an earthquake "mantle" magnitude from ocean-bottom pressure records of tsunami waves

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We apply the concept of the mantle magnitude M sub m, developed by Okal and Talandier [1989], to tsunami records obtained by ocean-bottom pressure sensors of the DART project. Our goal is to devise an algorithm to use these tsunami waveforms on the high seas, unaffected by the later interaction of the wave with coastlines, to infer the characteristics of the parent earthquake in the ultra-low frequency band, which may be improperly rendered by seismic mantle waves. Because tsunamis constitute a branch of the spheroidal oscillations of a self-gravitating Earth, it is straightforward to apply normal mode theory in order to derive a simple variant of the M sub m algorithm, to be used with tsunamis. The source correction is predicted from the theoretical expression of normal mode excitation coefficients in the range 300-6000 seconds. The distance correction is simplified from the case of seismic waves by the elimination of the effect of anelasticity (finite Q) which becomes irrelevant in the case of tsunami waves. The locking constant, still predicted theoretically, is simply adapted to the measurement of a different physical quantity – pressure rather than displacement, and to the choice of units. We will present examples of computation of M sub TSU from actual records at DART stations.

OS21A-06 0930h

1992-2002: Perspective on a decade of tsunami field surveys

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The past decade has seen the systematic deployment of international field survey teams (ITST), following damaging regional tsunamis. Fourteen such surveys have been carried out: Nicaragua (1992), Okushiri (1993), Mindoro (1994), Java (1994), Flores (1994), Kuriles (1994), Mexico (1995), Biak (1996), Chimbote (1996), PNG (1998), Izmit (1999), Fatu Hiva (1999), Vanuatu (1999), Peru (2001) and PNG (2002). In addition, similar techniques have been applied to the survey of important historical tsunamis such as Aleutian (1946) and Amorgos (1956). The primary goal of the field surveys is to obtain a reliable, quantitative dataset of run-up and inundation measurements, which can be used in simulation experiments based on hydrodynamic modeling, in order to unravel the mechanism of generation of the tsunami. One of the most important results obtained from the compilation of such datasets has been the emergence of the aspect ratio of the distribution of run-up in the near field as a most promising discriminant between generation by the seismic dislocation (e.g., Nicaragua; Peru, 2001; PNG 2002) and by an underwater slump (e.g., Aleutian 1946, PNG 1998). Surveying also reveals localized enhancement of run-up, controlled on a smaller scale by occasional underwater landslides (Flores, 1992), splashes against cliffs (Mexico, 1995; Peru, 2001) or interaction with steep coastal valleys (Okushiri, 1993). Field surveys have also provided insight into engineering and societal factors controlling the extent of human and property losses, such as coastal land use, building codes and materials, and public education and awareness. To foster the latter, the teams constantly repeat simple messages on tsunami mitigation during one-on-one interviews with local residents, as well as town meetings. In this respect, the successful self-evacuation at Bay Mairtele, Vanuatu in 1999 is a gratifying example of the value of education.

OS21A-07 0945h

Field Survey of the 30 December 2002 Stromboli Tsunami

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On December 30, 2002 a series of slumps occurred in Stromboli, an active volcanic island in the Tyrrhenian sea, north of Sicily, Italy. The slumps triggered a moderate tsunami, that struck the village of San Vincenzo in the island with very destructive waves. The mass movements originated from magma intrusion, opening of new vents and lava accumulation in Sciara del Fuoco in the NW side of the island, and lava flows to the sea were continuing at least up to late June. The tsunami was reportedly noticed as far as the Straits of Messina. We present observations from one of four field surveys of the Stromboli 2002 event from Stromboli and Panarea and we report inundation measurements. Earlier surveys by al. (2003), Maramai et al. (2003) have allowed for the modelling of Tinti et (2003), while Fumihiko Imamura (pers. comm.) also surveyed the site and provided measurement. We attempt to approximately model the source of the tsunami and find that it refracted around the island, Fatu Hiva like (Okal et al, 2002). Maramai, A., Tinti, S., Graziani, L., Armigliato, A., Pagnoni, G., Manucci, A., Zaniboni, F., 2003, *Quantitative observations of the physical effects of the Stromboli tsunami occurred on December 30, 2002*, paper EAE03-A-09880, Geophysical Research Abstracts, Vol.5, EGS (abstract). Okal, E.O., Fryer, G.J., Borrero, J.C., Ruscher, C., 2002, *The landslide and local tsunami of the 13 September 1999 on Fatu Hiva* , Bull. Soc. Geol. Franc., 359-367. Tinti, S., Pagnoni, G., Zaniboni, F., Armigliato, A., 2003, *Simulations of the 30 December 2002 Stromboli tsunami, Italy*, paper EAE03-A-10994, Geophysical Research Abstracts, Vol.5, EGS (abstract).

OS21B MCC: Level 2 Tuesday 0830h

The Arctic and North Atlantic Oscillations: Past, Present, and Future II Posters *(joint with A, H, PP, C)*

Presiding: **D A Darby,** Old Dominion University**; L Mysak,** McGill University

OS21B-1120 0830h POSTER

The not so ice-free Norwegian sea, and its Connection to the Arctic Ocean

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The Norwegian Sea is usually considered ice-free year round. It thus came as a surprise that Holocene pelagic sediments more than 700 km south of the maximum ice margin and 400 km from the nearest land contained in part large quantities of coarse, ice rafted rock and mineral fragments. The quantities of these grains drop from an early Holocene maximum to a mid-Holocene minimum, corresponding to a powerful Norwegian Current, and then rise again to the present. The composition of these grains is incompatible with a derivation from Norway or Iceland, and is also profoundly different from debris deposited by the East Greenland Current. The presence and type of coal places its origin to either the East Siberian Islands or to NW Alaska. In either case, the grains document a strong, periodic southward extension of the Transpolar Drift. Cores from the western Arctic Ocean replicate this pattern in an opposite sense, from an early Holocene low to a mid-Holocene high and back. Superimposed on this long-term dynamic are shorter directional changes at ca. 1000 year spacing, documented by highs and lows in the abundance of chert. The Arctic ice intrusions into the Norwegian Sea most likely occur on much shorter time scales, perhaps on the order of only a few decades.

OS

OS21B-1121 0830h POSTER

High Latitude Climate Variability During the Last Glacial Maximum

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The annular modes are instrinsic patterns of variability in the extratropical atmospheric circulation observed in both the Northern and Southern Hemispheres.