

In this study we develop an algorithm that allows us to derive global gas transfer velocities ( $k$ ) from SeaWinds normalized radar backscatter ( $\sigma_w$ ) with a 25 km, one day resolution. We achieve this objective through a combination of theoretical physics of scatterometer backscatter and calibration with another algorithm developed for TOPEX's dual frequency altimeter. The altimeter-based algorithm is calibrated with field data collected as part of the NSF CoOP Coastal Air-Sea Chemical Fluxes Program. At the heart of both algorithms is the relationship between normalized radar backscatter and the "partial" mean square slope ( $(s^2)$ ) of the gravity-capillary surface waves. Using the dual frequency capabilities of TOPEX we are able to probe only that portion of the gravity-capillary wave field most directly involved in active gas transfer, hence the partial mean square slope. The altimetry algorithm is valid only for incidence angles close to nadir, whereas the scatterometry algorithm is applicable to much higher incidence angles. Higher incidence angles allow greater spatial (and temporal) coverage at the price of complicating the signal with an azimuthally dependent modulation, which must be removed before the calibration with altimetry can be done. The results from the TOPEX algorithm are used to constrain the output of the SeaWinds algorithm, which we present as normalized to the Schmidt number for  $\text{CO}_2$  in sea water at 20°C (i.e. 660). Derivation, sensitivity and application of the SeaWinds algorithm will be discussed and initial results shown.

## OS62D-09 1550h

Air-Sea Fluxes in the Southern Ocean:  
Dual Deliberate Tracer Results from  
the SoFex ExperimentRik Wanninkhof<sup>1</sup> (rik.wanninkhof@noaa.gov)Kevin Sullivan<sup>1</sup> (kevin.sullivan@noaa.gov)Joaquin Trinanes<sup>1</sup> (trinanes@aoiml.noaa.gov)Zafer Top<sup>2</sup> (ztop@rsmas.miami.edu)<sup>1</sup>NOAA/AOML, 4301 Rickenbacker Causeway, Miami, FL 33149, United States<sup>2</sup>RSMAS/MAC, 4600 Rickenbacker Causeway, Miami, FL 33149, United States

During the Southern Ocean Iron Fertilization Study, (SoFex) the iron-fertilized patches were tagged with the deliberate tracer Sulfur Hexafluoride ( $\text{SF}_6$ ) to be able to follow the iron enriched water mass. In conjunction with the  $\text{SF}_6$  injection of the Southern patch a trace amount of the isotope  $^3\text{He}$  was added as well to determine the gas exchange rate from the change of  $^3\text{He}$  and  $\text{SF}_6$  ratio over time. The resulting air-sea gas exchange estimates from the dual deliberate tracer method were related to wind speed. The trend of decrease in ratio of  $^3\text{He}$  and  $\text{SF}_6$  with time could be well modeled with either a quadratic or cubic dependence with wind speed ( $U$ ) with relationships of gas transfer velocity,  $k = 0.34U^2$  and  $k = 0.0277 U^3$ , close to those proposed previously by Wanninkhof (1992) and Wanninkhof and McGillis (1999) which yielded coefficients of 0.31 and 0.0283, respectively.

The relationship of gas exchange with wind speed determined from the SoFex study along with winds for 2001/2002 obtained from the QuikScat satellite were combined with the climatology of air-sea partial pressure difference of Takahashi et al., 2002 to estimate the air-sea  $\text{CO}_2$  gas flux for the Southern Ocean (defined as latitudes greater than 34 S). The estimate of -1.4 to -1.5  $\text{Pg}$  per year is significantly lower than the values proposed by Takahashi et al. of 1.7 to 2.5  $\text{Pg}$  C per year primarily because the wind speed variability is taken into account in our estimate.

## OS62D-10 1605h

Trends in the Zonal Winds over the  
Southern Ocean from the  
NCEP/NCAR Reanalysis and  
ScatterometersJames G Richman (541 737 3328;  
jr@coas.oregonstate.edu)

Oregon State University, COAS 104 Ocean Admin Bldg, Corvallis, OR 973315503, United States

The winds over the Southern Ocean for the entire 54-year (1948-2001) period of the NCEP/NCAR Reanalysis have been decomposed into Principal Components (Empirical Orthogonal Functions). The first EOF describes 83 percent of the variance in the zonal wind. The loading of the EOF shows the predominately westerly surface flow with strongest winds in the Indian sector of the Southern Ocean. The structure of this EOF is similar to the Southern Annular Mode (SAM) identified by Thompson, et al 2000. The amplitude of this EOF reveals a large trend of 4.42  $\text{cm/s/yr}$  in the strength of the zonal wind corresponding to a nearly 50 percent increase in the wind stress over the Southern Ocean. Such a trend, if real, would be important in the dynamics of the Antarctic Circumpolar Current (ACC). Recent

studies by Gille, et al. (2001), Olbers and Ivchenko (2001) and Gent et al. (2001) have shown that the transport of the ACC is correlated to the variability in the zonal wind with a monotonic increase in the transport with increasing zonal wind strength. However, errors in the data assimilation scheme for surface pressure observations on the Antarctic continent appears to have caused a spurious trend in the sea level pressure south of 40S of -0.2 hPa/yr (Hines, et al. 2000 and Marshall, 2002). The sea level pressure difference between 40S and 60S has risen by 8 hPa over the same period. This sea level pressure difference is used as a proxy for the strength of the zonal winds. Thus, the trend in the zonal wind EOF amplitude may be an artifact of model errors in the NCEP Reanalysis. To check this trend, we analyzed scatterometer winds over the Southern Ocean from the SEASAT, ERS (1 and 2), NSCAT and QuikScat satellites. The scatterometer data is not used in the NCEP Reanalysis and, thus, is an independent estimate of the winds. The SEASAT Scatterometer (SASS) operated for 90 days in July-September, 1978, while the ERS, NSCAT and QuikScat scatterometers provide a continuous dataset from September 1992 through the present. The zonal winds for the combined ERS/NSCAT dataset were decomposed into Principal Components, similar to the NCEP winds. The first EOF describes 78 percent of the variance in the zonal wind. The loading of the EOF is nearly identical in structure to the loading of the NCEP EOF, and the correlation between the amplitudes is 0.93 for the co-incident period. The trend in the scatterometer winds is 3.9  $\text{cm/s/yr}$  for the eight years, which is not significantly different from the 4.4  $\text{cm/s/yr}$  trend of the NCEP winds. The three months of SASS data were projected onto the scatterometer EOF and the amplitudes compared to the long-term NCEP amplitudes. The agreement between the scatterometer amplitudes and the NCEP is remarkable. The comparison between the scatterometer winds and NCEP Reanalysis winds suggests that the trend towards increasing zonal winds is real. The increasing zonal winds over the Southern Ocean may lead to a substantial increase in the transport of the ACC over the past 50 years.

## OS62D-11 1620h

Ekman heat flux variability from four  
wind sourcesOlga T Sato<sup>1</sup> (55-12-3945-6484; olga@ltdid.inpe.br)Paulo S Polito<sup>1</sup> (55-12-3945-6484;  
polito@ltdid.inpe.br)<sup>1</sup>Instituto Nacional de Pesquisas Espaciais (INPE) Divisao de Sensoriamento Remoto, Ave. dos Astronautas, 1758, Sao Jose dos Campos, SP 12227-010, Brazil

The variability in the Ekman heat flux estimated from four different sources of wind is examined. The wind vectors are obtained from the European Remote Sensing (ERS), Quikscat, the Special Sensor Microwave Imager (SSM/I-Atlas) satellites, and from the National Centers for Environmental Prediction (NCEP) model. The temperature in the Ekman layer is estimated by combining the Reynolds sea surface temperature and climatological sub-surface profiles. Except for the Quikscat which span the period between 1999 and 2002, the data sets range a period over 10 years. The annual mean of the meridional Ekman heat flux (EHF) is consistently smaller when estimated with the ERS data. The NCEP tends to get larger values for the North Atlantic while the Quikscat is the largest for the North Pacific. The EHF has a better agreement at subtropical latitudes while the largest differences are found near the equator.

To investigate the spatial variability of EHF we use a series of 2D finite impulse response filters. We quantify the role of several regions of the frequency-zonal wave number spectrum of the wind in establishing the observed Ekman heat flux. The mean component of the EHF, which keeps all the variability from the temperature field, is much higher in the low latitudes in the Atlantic. The relative variance of the mean component to the total EHF reaches up to 60% in the Atlantic while in the Pacific it explains only 30% of variance. The contribution to the variability of several bands of planetary westward propagating waves is larger in the Pacific and Indian Oceans while in the Atlantic it can explain at most 20% of the total variance. All wind sources show a change in the variability regime around 15° of latitude with lower frequencies prevailing over meso and small-scale variability within the tropics.

## OS62D-12 1635h

Impact of Scatterometer Winds on the  
Tropical Pacific Heat BudgetLuAnne Thompson<sup>1</sup> (206 543 9965;  
luanne@ocean.washington.edu)Kathryn A Kelly<sup>2</sup> (2065439810;  
kkelly@apl.washington.edu)<sup>1</sup>University of Washington, School of Oceanography Box 355351, Seattle, WA 98195, United States<sup>2</sup>University of Washington, Applied Physics Laboratory Box 355640, Seattle, WA 98195, United States

Scatterometer winds not only can be used to improve the predictions of ocean currents in ocean models, but also can impact the upper ocean heat budget through the latent and sensible heat fluxes and through ocean heat flux divergence associated with changes in the current structure. Comparisons against NCEP (National Center for Environmental Prediction) wind stress and NCEP-derived fluxes show substantial differences with the scatterometer derived fluxes, particularly in the equatorial Pacific near the ITCZ (inter-tropical convergence zone). To test what impact the scatterometer winds have on a modeled tropical Pacific Ocean, we run a three-dimensional isopycnal general circulation model with a tropical Pacific domain from 30S to 30N at 0.5 degree resolution. The model has 16 layers in the vertical and includes an active mixed layer. The model is forced with NCEP stress for spinup, and then parallel runs are done using the NCEP and QuikSCAT stress fields. The surface thermal boundary condition is calculated from the COARE bulk formulae, using the model SST with NCEP atmospheric variables and either NCEP stress or QuikSCAT stress. There are significant differences between the two model runs, with QuikSCAT winds generally giving better performance relative to observations. Along the equator, the QuikSCAT runs show a smaller SST gradient and a lower maximum SST, both of which match the observations better. Comparisons are also made of the model and observational heat content anomaly derived from the TAO and altimetric data. The differences between the two model runs come about not only from changes in the dynamics, but also from changes in the heat flux fields associated with changes in wind speed. Estimates of the latent heat flux differences are particularly sensitive to the wind product in the tropics, with the eastern Pacific and the ITCZ giving the largest differences.

## OS62D-13 1650h

Modeling Study of Cross-Shore  
Exchange Processes in the Southern  
California Bight Using QuikSCAT  
WindsY. Tony Song<sup>1</sup> (818-393-4876;  
song@pacific.jpl.nasa.gov)W. Timothy Liu<sup>1</sup>Wendy Tang<sup>1</sup><sup>1</sup>Jet Propulsion Laboratory, California Institute of Technology, 4800 Oak Grove Dr., Pasadena, CA 91109, United States

The South California Bight (SCB) forms a complex bathymetric region (islands, shallow banks, basin, and channels) extending from the coast to about 200 km offshore and from Point Conception to the tip of Baja California. Geographically the region is sheltered from the strong upwelling-favorable winds characteristic of the region north of Point Conception. However, recent QuikSCAT winds, for the first time, clearly reveal a persistent cyclonic eddy centered at Catalina Island within the Bight (Liu et al. 2001). Using a costal circulation model, we have investigated the oceanic response to the newly observed sea-surface winds. Two experiments are carried out to explore the individual roles of wind forcing and topography. The first experiment uses the COADS winds to determine the general circulation of the Bight. The second experiment uses the QuikSCAT winds to examine how the space-time variability of atmospheric forcing affects the frontal structure, circulation pattern, and cross-shore exchange of water masses. Comparisons of these two experiments allow us to identify the combined effect of winds and topography on the cross-shore exchange processes between the Bight and its adjacent waters.

OS62E MCC: 274 Saturday 1330h  
Nearshore Processes III (joint with T)Presiding: N Plant, Naval Research  
Laboratory; A Reniers, Naval  
Postgraduate School

## OS62E-01 1330h INVITED

## The Nearshore Canyon Experiment

Steve Elgar (elgar@whoi.edu)

Woods Hole Oceanographic Institution, WHOI MS11,  
Woods Hole, MA 02543, United States

Observations collected in Fall 2003 during the Nearshore Canyon Experiment (NCEX) will be used to test hypotheses about the effect of complex continental-shelf bathymetry on surface gravity waves and on wave-driven circulation. Refraction, diffraction, reflection, scattering, and trapping by abrupt shelf

bathymetry can result in dramatic alongshore variations in wave height and direction. Onshore of the irregular bathymetry, alongcoast changes in breaking waves can force complicated circulation, including alongshore flows that reverse direction across the surf zone and along the shoreline, and strong offshore-directed rip currents that may be an important mechanism for transport of water, sediment, and pollution between the surf zone and inner shelf.

Observations for NCEX will be obtained along the southern California coast near two steep submarine canyons (separated alongshore by a few km) that cross the shelf from about 300-m water depth to just seaward of the surfzone near Black's Beach (famous for large waves) and La Jolla Shores (well known as a calm area with small waves). Frequency-directional spectra of incident waves estimated from observations offshore of the canyons will be used to initialize models that predict the effect of the canyons on infragravity waves, swell, sea, and wave-driven circulation. Model predictions will be tested with observations from alongshore arrays deployed near, between, and onshore (including the surf and swash zones) of the canyons. Arrays also will be deployed to investigate wave reflection and scattering from the steep canyon walls, and cross-shore changes in surf and swash zone circulation. Additional instrumentation will be used to study alongcoast changes in wave breaking and set-up, details of surface currents in the surf and swash, and breaking-induced turbulence and dissipation.

The NCEX instrument arrays will be designed in collaboration with modelers, and near-real time data will be used to initialize and test model predictions. In addition, model forecasts will be used to guide placement of movable sensors, allowing predictions of nearshore waves and currents to be tested during the observational period.

NCEX team members are listed on <http://science.whoi.edu/PVLAB/NCEX/ncex.html>.

Funding for NCEX is provided by the US Office of Naval Research and the National Science Foundation.

#### OS62E-02 1350h

##### A Preliminary Look at the NCEX Field Site Using Argus

Rob Holman<sup>1</sup> (1-541-737-2914; holman@coas.oregonstate.edu)

John Stanley<sup>1</sup> (1-541-737-3251; stanley@coas.oregonstate.edu)

Cindy Paden<sup>1</sup> (1-541-737-3251; paden@coas.oregonstate.edu)

<sup>1</sup>Oregon State University, COAS-OSU 104 Ocean Admin Bldg., Corvallis, OR 97331-5503, United States

The Nearshore Canyon EXperiment (NCEX) is scheduled to take place at Black's Beach in the fall of 2003. The primary objectives of this field experiment are to test models for wave propagation across the abrupt topography of the Scripps Submarine Canyon and for the resulting circulation and sediment transport driven by the associated longshore gradients. One component of the sampling scheme is optical measurements of fluid and beach properties, to be made (among others) using a range of Argus techniques. Thus, on October 15, 2001, an Argus Station was installed at the site to begin collection of background data.

This talk will summarize the Argus data that has been collected during the initial 1.1 years of collection. The focus will be on describing variations in a set of general site characteristics that will affect NCEX investigators. Most notable will be a morphological description of the site, including statistics of the substantial variability of topographic rips that are commonly observed (and will be a modeling challenge) as well as the scales and genesis of sand bars that have been observed to form on occasion. Other characteristics such as typical surf zone width and width of the dry beach are useful for experimental planning and will be described.

URL: <http://cil-www.oce.orst.edu:8080/ncex/ncex.html>

#### OS62E-03 1405h

##### A Test of the Curvilinear SWAN Model Under Unsteady Conditions

Qin Jim Chen<sup>1</sup> ((251)460-6174; qchen@jaguar1.usouthal.edu)

Kelin Hu<sup>1</sup> ((251)460-6258)

Scott L Douglass<sup>1</sup> ((251)460-6174)

<sup>1</sup>University of South Alabama, Department of Civil Engineering, EGCB 280, Mobile, AL 36688, United States

An accurate prediction of wind waves in shallow estuaries, such as Mobile Bay in Alabama, is of interest for shore protection, environmental conservation, and estuarine resource management. In comparison to wave modeling on an open coast, the complex geometry and bathymetry of estuaries, the unsteady conditions associated with estuarine circulation generated by tides and

winds, and the relatively inadequate field data present a unique challenge to wave modelers. Fortunately, the curvilinear version of SWAN provides us with the flexibility to resolve large geometric and bathymetric gradients, and the unsteady mode of the model allows for consideration of unsteady forcing and media. The objective of this study is to test the curvilinear SWAN model under unsteady conditions using laboratory data and field observation in a shallow estuary.

First, a laboratory data set collected by Chawla and Kirby (1996) on wave transformation over a circular shoal is chosen to test the curvilinear model. A curvilinear grid with high resolution over the shoal is generated for the SWAN model. Excellent agreement is found between the numerical results and the laboratory measurements with a directional wave input. In comparison to the model prediction with a uniform, rectangular grid, the curvilinear grid improves the accuracy of the modeled maximum wave height on top of the shoal. Second, the field measurements of wind waves in Mobile Bay (Pendygraft and Gelfenbaum, 1994) are utilized to test the curvilinear SWAN model with unsteady forcing and ambient currents. A curvilinear grid is designed to resolve abrupt changes in water depth near the ship channel and close to the shoreline. The Princeton Ocean Model provides SWAN with a varying current field and water levels. The wind forcing is taken from the C-MAN station located at the entrance of the bay. Fairly good agreement between the model results and field data has been obtained. The study has been supported by the USEPA.

#### OS62E-04 1420h

##### A Fourier-Boussinesq method for short wave coastal problems

Harry B. Bingham (hbb@mek.dtu.dk)

Technical University of Denmark Mech. Eng., Bldg. 101E, Lyngby, DK 2800, Denmark

Predicting the nonlinear propagation of dispersive waves over a bathymetry is desirable in many coastal and offshore applications. Realistic problems require analysis over a complicated geometry on the order of a hundred by a hundred significant wavelengths, and in relative water depths all the way from practically infinite to zero. Such problems pose a formidable challenge and are generally treated using potential flow methods. Typically the velocity potential is expanded in a set of basis functions which individually satisfy the Laplace equation; and the expansion coefficients are determined to satisfy the remaining conditions on the fluid boundary. The number of degrees of freedom (usually a set of values of the potential or its derivatives on the boundary) is hence significantly smaller than would result from discretizing the entire fluid volume. The most commonly used basis functions are polynomials, singular Green's functions, and Fourier functions; each of which has advantages and disadvantages depending on the phenomena of primary interest. Polynomial based methods, such as the Boussinesq method, are perhaps the most widely used for coastal applications.

This abstract describes a new Boussinesq method which is fully dispersive in the sense that the errors of the approximation are small for all  $kh$  ( $k = |k|$  the magnitude of the wavenumber and  $h$  the water depth). We call the new method a Fourier-Boussinesq method as it includes a Fourier transform. In contrast to other polynomial based methods, the Fourier-Boussinesq method approximates the dispersion operator  $\tanh(kh)/(kh)$  by a rational function of  $kh$  rather than  $k^2h^2$ , and can thus be made asymptotically correct in both limits of  $kh$ . The odd powers of  $kh$  are evaluated in physical-space by introducing the generalized Hilbert operator, which is efficiently implemented using the Fast Fourier Transform (FFT). This leads to approximations with small errors in dispersion over the entire domain  $0 \leq kh < \infty$ . Variable bottom terms are derived both in mid-slope form, and in augmented mid-slope form including all terms that are linear in derivatives of  $h$ . Calculations will be presented which demonstrate the performance of the method using a number of nonlinear wave propagation problems on both flat and variable bottoms.

#### OS62E-05 1435h INVITED

##### Evaluation of Boussinesq Model Predictions of Nearshore Hydrodynamics.

James T Kirby<sup>1</sup> (302-831-2438; kirby@udel.edu)

Qin Chen<sup>2</sup> (qchen@jaguar1.usouthal.edu)

James Noyes<sup>3</sup> (jnoyes@coast.ucsd.edu)

Steve Elgar<sup>4</sup> (elgar@whoi.edu)

Robert T Guza<sup>3</sup> (rtg@coast.ucsd.edu)

<sup>1</sup>University of Delaware, Center for Applied Coastal Research, Newark, DE 19716, United States

<sup>2</sup>University of South Alabama, Dept. of Civil Engineering, Mobile, AL 36688, United States

<sup>3</sup>Scripps Institution of Oceanography Integrative Oceanography Division CCS 0209 SIO La Jolla, CA 92093-0209 Center for Coastal Studies, CCS 0209, La Jolla, CA 92093-0209, United States

<sup>4</sup>Woods Hole Oceanographic Institution, Applied Ocean Physics and Engineering, MS11, Woods Hole, MA 02543, United States

Recent studies show that Boussinesq models mimic nearshore hydrodynamic processes ranging from the propagation, shoaling, breaking, and runup of incident wind waves and swell, to the generation and instabilities of mean alongshore flows and rip currents. In particular, the numerical model predicts that mean alongshore currents on beaches with shore-parallel sandbars are unstable. Here, Boussinesq model predictions of mean alongshore currents and the temporal and spatial structures of their shear instabilities are compared with observations from a two-dimensional array of current meters and pressure gages deployed between the shoreline and 5-m water depth on a barred beach near Duck, NC. The model is initialized 800 m offshore (8-m water depth) with observed incident wave frequency-directional spectra, and uses the measured bathymetry. In the model predictions, shear instabilities (that have non-zero vorticity) are separated from irrotational gravity waves by calculating the instantaneous vorticity, as well as with Fourier techniques that use the spatially dense and extensive (1.5 km alongshore domain) model predictions of the flow field. These techniques cannot be applied to the spatially sparse and 200-m long instrument arrays, and standard array processing techniques are used to provide exact correspondence between the analysis of the model and the field data.

Funded by ONR and NOPP

#### OS62E-06 1450h

##### On Nonlinear Properties of Waves Predicted by a Boussinesq Model

Fengyan Shi<sup>1</sup> (302 831 4173; fyshi@coastal.udel.edu)

James T. Kirby<sup>1</sup> (302 831 2438; kirby@coastal.udel.edu)

Robert A. Dalrymple<sup>2</sup> (410 516 7923; rad@jhu.edu)

Qin Chen<sup>3</sup> (251 460 7507; qchen@jaguar1.usouthal.edu)

<sup>1</sup>Center for Applied Coastal Research, University of Delaware, Newark, DE 19716, United States

<sup>2</sup>Department of Civil Engineering, Johns Hopkins University, Baltimore, MD 21218, United States

<sup>3</sup>Department of Civil Engineering, University of South Alabama, Mobile, AL 36688, United States

In this study, a fully nonlinear Boussinesq model (Wei, et al., 1995) is used to investigate nonlinear wave features observed in a physical model study of Ponce de Leon Inlet, Florida. The experiment was conducted and the laboratory data were provided by the U.S. Army Engineer Research and Development Center. We employ a curvilinear version of the fully nonlinear Boussinesq model and use a curvilinear grid which is able to resolve a broad spectrum of waves in the computational domain. Eighteen cases with monochromatic input waves and TMA spectral waves are carried out. To show the superiority of the Boussinesq model to other conventional wave models, we focus on examinations of wave nonlinearity in the study. Secondary wave crest features are presented by snapshots of the computed wave field and time series of surface elevations in both the physical model and the numerical model. Spectral analyses of spectral wave cases also show the wave energy transfer from the original peak frequencies to the corresponding harmonic frequencies. As another indicator of wave nonlinearity, the probability distributions of wave surface elevations are computed from both the measured data and numerical results and show similar deviations from their Gaussian distributions. Other measures of wave nonlinearity, such as wave skewness and asymmetry, are also examined in the study. The fairly good agreement between modeled and measured indicators of wave nonlinearity demonstrates the capability of the Boussinesq model for predicting nonlinear wave transformation in the nearshore region.

#### OS62E-07 1525h

##### A CFD Model for Wave Transformation and Breaking in the Surf Zone

Sreenivas C Chopakatl<sup>1</sup> (614-247-6051; chopakatl.1@osu.edu)

Thomas C Lippmann<sup>1</sup> (614-688-0080; Lippmann.2@osu.edu)

John E Richardson<sup>2</sup> (508-829-6000 ext. 492; jr Richardson@aldenlab.com)

Edward B Thornton<sup>3</sup> (thornton@oc.nps.navy.mil)

Robert A Holman<sup>4</sup> (holman@oce.orst.edu)

<sup>1</sup>The Ohio State University, Department of Civil and Environmental Engineering, Byrd Polar Research Center, 1090 Carmack Rd., Columbus, OH 43210-1002, United States

<sup>2</sup>Alden Research Laboratory, Inc., 30 Shrewsbury st., Holden, MA 01520, United States

<sup>3</sup>Naval Postgraduate School, Oceanography Department, Monterey, CA 93943, United States

<sup>4</sup>Oregon State University, College of Ocean and Atmospheric Sciences, Corvallis, OR 97331, United States

Wind-generated surface gravity waves are the major driving force for nearshore circulation and sediment transport. As waves shoal in shallow coastal waters, spectra evolve strongly owing to refraction, nonlinear energy transfers, and dissipation caused by wave breaking and bottom friction. Although considerable progress has been made in modeling wave propagation over complex bottom topography, the dissipation mechanisms are still poorly understood. As a consequence, wave transformation models for the surf zone use crude descriptions of the wave breaking process based on simple saturation criteria or empirical probability distributions that do not always work well for the range of bathymetric and wave conditions commonly observed in nature. In this report, we will discuss the results of studies made with the commercially available Computational Fluid Dynamics (CFD) software system known as FLOW-3D (Flow Science, Inc., Sante Fe, NM). FLOW-3D is designed to solve transient, free surface flow problems based on the solution of the Navier-Stokes equations in three-dimensions. As part of FLOW-3D's formulation, the dissipation of energy is determined by use of coupled turbulence closure schemes (e.g., closure schemes based on the solution of turbulent kinetic energy transport equations). In this study, fine scale pressures and velocities are computed over a two-dimensional beach profile measured during the 1990 Delilah experiment. The model is driven by observed wave spectra obtained in 8 meter water depths, and results compared with a cross-shore array of pressure sensors and current meters spanning the width of the surf zone. In the calculations, wave breaking is a natural consequence of the fluid dynamics and does not require the use of empirical formulations, or breaking criteria. The spatial and temporal variability in the wave breaking locations will be compared with video observations obtained during the experiment. Good comparison between modeled and observed wave breaking variability suggest that the model can be used as a numerical laboratory to study the wave breaking and dissipation process in detail, and perhaps lead to improved parameterizations for more computationally efficient numerical models.

This work was supported by Sea Grant.

OS62E-08 1540h

**Surfzone Currents Over Irregular Bathymetry: Drifter Observations and Numerical Model Results**

Wilford E Schmidt<sup>1</sup> (858-534-9596; wschmidt@coast.ucsd.edu)

Donald N Slinn<sup>2</sup> (352-392-1436 x1431; slinn@coastal.ufl.edu)

Robert T Guza<sup>1</sup> (858-534-0585; rtg@coast.ucsd.edu)

<sup>1</sup>Scripps Institution of Oceanography, 9500 Gilman Drive, La Jolla, CA 92093-0209, United States

<sup>2</sup>Department of Civil and Coastal Engineering, University of Florida, PO Box 116590, Gainesville, FL 32511-6590, United States

Surfzone currents on alongshore variable bathymetry were observed with recently developed GPS-tracked drifters and numerically modeled with the time-dependent, nonlinear shallow water equations. These currents, forced by alongshore inhomogeneous pressure and radiation stress gradients, contain flow features difficult to resolve with fixed instrument arrays, such as rips, eddies, and meanders.

Drifters were repeatedly released and recovered near Scripps Beach, La Jolla, California, in July 2000, 2001, and 2002. The most recent deployment of 10 drifters yielded about 32 hours of drifter data for each 5 hour deployment day. Offshore wave heights were moderate, between 0.3-1.0 m. The bathymetry, measured over a 600-700 m alongshore span with a GPS- and sonar-equipped jetski (2001 and 2002 deployments), was alongshore inhomogeneous primarily where an irregularly shaped bar-trough feature spanned the surf zone. The model simulations suggest that the alongshore inhomogeneous bathymetry strongly influences the location and strength of the observed flow features.

Research supported by the California Sea Grant College Program and the Office of Naval Research.

OS62E-09 1555h

**RIPEX: Characteristics of Very Low Frequency Motions**

Jamie MacMahan<sup>1</sup> (macmahan@coastal.ufl.edu)

Ad JHM Reniers<sup>2</sup> (areniers@nps.navy.mil)

Ed Thornton<sup>2</sup> (thornton@nps.navy.mil)

Tim Stanton<sup>2</sup> (stanton@nps.navy.mil)

<sup>1</sup>University of Florida, Civil Coastal Eng. Dept., Gainesville, FL 32601, United States

<sup>2</sup>Naval Postgraduate School, Oceanography Dept., Monterey, CA 93943, United States

Highly energetic motions for topographically controlled rip currents have been documented within a laboratory setting (Haller et al., 1997) and during a few field experiments of rip currents (Aagaard et al., 1997; Brander, 2001). These motions are defined as very low frequency motions (VLF) and occur at frequencies less than infragravity motions (0.004-0.04 Hz). Due to the limited number of field observations on complex beaches, the forcing mechanism and characteristics of VLFs is, at present, unknown. Highly energetic VLFs were consistently observed during the RIP current EXperiment (RIPEX) in the Spring 2001 at Sand City, Monterey Bay, CA (MacMahan et al, 2002; Reniers et al, 2002). The wave climate consisted of predominantly shore-normal waves, and though the existence of longshore currents was minimal, rip currents were copious. Frequency-wave number analysis indicates that the VLF energy is located outside the theoretical range for gravity waves and are concentrated at a spatial scale related to the spacing of rip channels (125 m). The VLF energy was fairly constant within the surf zone and strongly correlated to tidal elevation and sea-swell wave energy. Detailed analysis of VLF characteristics and potential forcing mechanisms will be presented at the meeting.

OS62E-10 1610h

**The linear instability characteristics of the coupled wave-current system in the nearshore**

Haiying Jiao<sup>1</sup> ((541) 737-9505; jiao@coas.oregonstate.edu)

H. Tuba Özkan-Haller<sup>1</sup> ((541) 737-9170; ozkan@coas.oregonstate.edu)

<sup>1</sup>College of Oceanic and Atmospheric Sciences, Oregon State University 104 Ocean Admin. Bldg., Corvallis, OR 97331-5503, United States

Recent numerical studies of longshore and rip currents in the nearshore zone suggest that the interactions between the incident waves and the time-varying wave-induced circulation field can be an important process in determining the nature of rip current circulation systems (Haas et al, 2002) and longshore currents (Özkan-Haller and Li, 2002). Simulations also suggest that the initial growth rate, offshore extent and energetics of instabilities associated with longshore currents are affected by the consideration of wave-current interaction. Therefore, it is hypothesized that the linear instability characteristics of the combined wave-current system are distinct from those of the current system alone.

However, the above-mentioned numerical studies have not been ground-truthed with a linear instability analysis of the combined system, and this study aims to fill this gap in our existing knowledge by analyzing the linear instability of a system of equations describing the coupled behavior of incident waves and the wave-induced circulation. We utilize the mass conservation and momentum equations for the circulation. Free surface effects are included and the circulation is induced due to radiation stress gradients associated with the incident waves. The wave energy equation and the conservation of waves principle describe evolution of the incident waves in the presence of variable bathymetry and time-varying currents. It is this modification of the incident wave field due to the circulation that is often neglected in circulation studies. The resulting system of six equations provides information about the length scales, propagation speeds, growth rates of any unstable modes along with the cross-shore profiles of the low frequency motions expected in the presence of wave-current interaction. In addition, the solution also provides similar information about any stable or neutrally stable solutions (such as edge waves). Results from this study should serve as a useful benchmark for full nonlinear circulation models.

It is noted that the analysis of the coupled wave-current system is a necessary step towards analyzing the fully coupled wave-current-morphology system. The instability of such a system has been hypothesized to lead to the formation of longshore variable features in the bathymetry, although all analyses of this mechanism to date have simplified the feedback between the incident waves and the circulation or morphology. Therefore, an extension of the present study can address these shortcomings and provide information about morphological features that may result as a result of an instability to the combined wave-current-morphology system.

OS62E-11 1625h

**Wave Reflection on a Steep Beach**

Edward B Thornton<sup>1</sup> (831-656-2847; thornton@nps.navy.mil)

Timothy P Stanton<sup>1</sup> (831-656-3144; stanton@nps.navy.mil)

Ad R Reniers<sup>1</sup> (831-656-2379; reniers@nps.navy.mil)

<sup>1</sup>Naval Postgraduate School, Oceanography Department Naval Postgraduate School, Monterey, CA 93943, United States

Wave reflection was measured during the RIPEX/SteepBeach experiment conducted at the Sand City Beach in Monterey Bay, California during April/May 2001. The morphology is a barred shoreline, cut by rip channels spaced 100-200 m apart. The beach slope is steep at 1:5, and the slope offshore of the bar is 1:20. Measuring wave reflection in the dissipative surf zone is complicated because the wave field is not spatially homogeneous and the nodes of the reflected waves pose difficulties in analysis. The inverse approach by Dickson et al. (1995) is extended to the case of local pressure/velocity (puv) measurements, to avoid having to assume spatial homogeneity. In this inverse approach, the various expected puv cross-spectra and energy density spectra are modeled for a reflective wave field and compared with actual measurements. The unknown coefficients as a function of frequency are reflection coefficient, phase difference, mean incident wave direction, and incident wave energy of the model, and are determined iteratively in a least square sense. The estimated reflection coefficients increase towards the shoreline inside the surf zone, decrease with increasing frequency and vary with the tidal stage.

Dickson, W.S., T.H.C. Herbers, and E.B. Thornton, 1995, Wave Reflection from Breakwater, J. Waterway, Port, Coastal and Ocean Engineering, Vol. 121 (5), 262-268.

OS62E-12 1640h

**Directional Properties of Infragravity Waves**

Alexandru Sheremet<sup>1</sup> (225-578-2951; asherel@lsu.edu)

R. T. Guza<sup>2</sup> (858-534-0585; rtg@coast.ucsd.edu)

Steve Elgar<sup>3</sup> (508-289-3614; elgar@whoi.edu)

Thomas H. Herbers<sup>4</sup> (831-656-2917; thherber@nps.navy.mil)

<sup>1</sup>Coastal Studies Institute, 324A Howe-Russell Geoscience Complex, Louisiana State University, Baton Rouge, LA 70803

<sup>2</sup>Integrative Oceanography Division, Scripps Institution of Oceanography, University of California at San Diego, La Jolla, CA 92093-0209

<sup>3</sup>Woods Hole Oceanographic Institution, MS #11, Woods Hole, MA 02543

<sup>4</sup>Department of Oceanography, Naval Postgraduate School, Monterey, CA 93943

The directional properties of infragravity waves are studied using field observations obtained across the shoaling and surf zones of a gently sloping sandy beach. Five alongshore arrays, each containing collocated *p*, *u* and *v* sensors (pressure, cross-shore and alongshore velocity respectively), were deployed in between 1- and 6-m water depth for four months. A new estimator technique is described that uses observed cross- and auto-spectra between *p*, *u* and *v* sensors in each alongshore array to estimate infragravity energy fluxes in alongshore wavenumber - frequency (*f* - *k<sub>y</sub>*) space. The analysis sometimes shows significant shoreward energy flux at the *f* - *k<sub>y</sub>* corresponding to (theoretically) refractively trapped modes, suggesting that a significant fraction of this energy can be dissipated in the surf zone.

This research was supported by the Office of Naval Research and the National Ocean Partnership Program.