URL: http://www.physics.utoronto.ca/~edwards/

OS31A CC: 524 C Wednesday 0830h

Coastal Region Dynamics III

Presiding: **W Alex,** Naval Research Laboratory, Stennis Space Center**; K Lamb,** University of Waterloo

OS31A-01 0830h INVITED

The evolution of nonlinear internal waves in Massachusetts Bay: observations and model results.

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Nonlinear internal waves are a common feature in many coastal areas. In Massachusetts Bay, trains of high-frequency and short-wavelength internal waves are generated by the semidiurnal barotropic tide flowing over Stellwagen Bank, and propagate shoreward. In this talk, we present observational and modeling results that have been accumulated over the past 6 years. We will consider in particular the strongly nonlinear interaction with the bottom that occurs when the waves propagate along the incline leading to the shallow (25 m) area just off the coast south of Boston. Contrary to what was previously thought, only part of the baroclinic energy is dissipated locally. The remaining energy propagates in the shallow area to the west of the incline, creating highly nonlinear and very steep waves of elevation that we were able to observe in great detail. The evidence accumulated so far suggest that these waves depart strongly from the hydrostatic equilibrium. The consequences for modeling will be discussed.

OS31A-02 0850h

On the resonant generation of breaking, mode-2 solitary-like waves

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The weakly nonlinear theory of the resonant generation of internal solitary waves by temporally varying background currents over small amplitude topography (i.e as recently discussed by Wang and Redekopp, Dyn. Atm. Oceans, vol. 33, pg. 263) shows no preference for mode-1 waves over higher mode waves. In this talk we discuss numerical modeling efforts we have undertaken to resonantly generate mode-2 solitary-like waves. After briefly reviewing the reasons why mode-2 waves cannot, in general, be truly solitary we show examples of mode-2 wave generation for a stratification typical of the coastal ocean. We demonstrate that for certain physically reasonable situations the energy lost to a mode-1 tail is of secondary importance, when compared to the changes in the wave shape due to the existence of a highly active core. We discuss diagnostics based on weakly nonlinear theory that can be employed to diagnose whether a given situation (stratification and background current) can reasonably be expected to yield resonantly generated mode-2 solitary-like waves.

OS31A-03 0905h

Circulation Variability on the Newfoundland and Scotian Slopes

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Moored measurements and hydrographic surveys are used to describe the structure and recent variability of currents and hydrographic properties along the Newfoundland and Scotian Slopes. Measurements from June 2002 to July 2003 at two sites in Flemish Pass show a seasonal variation in the upper-slope branch of the Labrador Current, with greatest transport in winter. Measurements from June 2000 to May 2003 at three sites across the Scotian Slope on the Halifax line show seasonal and interannual variations, including a disruption of the equatorward Labrador Current Extension by an intrusion of Warm Slope Water associated with a Gulf Stream meander. The current structure and transports are compared with historical observations and numerical model estimates.

OS31A-04 0920h

Ageostrophic Fluctuations in the Cozumel Channel.

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The Caribbean Current flows easterly and turns mostly north as it impinges the Yucatan coast, producing a persistent northerly flow along the coast that passes between the Yucatan Peninsula and the Cozumel Island; through the Cozumel Channel. The near surface subinertial flow of the Cozumel Channel, which is 18 km wide, 50 km long and 400 m deep, and its relationship with pressure measurements at both sides of the channel, was recently examined by Chávez *et. al.* (2003) showing the existence of periods lasting over one month with large ageostrophic fluctuations. Five years latter, the flow velocity was measured again for a year, but at four locations around Cozumel Island, two of them 8.6 km apart in the middle of the channel, thus allowing estimations of the along the channel velocity gradients. The new measurements reveal that, as suggested by Chávez *et. al.* (2003), the advective nonlinearity or curvature of the current explains most of the lack in geostrophy for subinertial motions. The curvature is, at times, large enough that the geostrophic flow is in the opposite direction than the actual flow; i.e. a larger than unity Rossby number. Intensity indexes, in pressure difference as well as in velocity, that favor suprainertial variations show consistently that the periods of ageostrophic fluctuations are much richer in high frequency fluctuations than the periods of nearly geostrophic behavior. The intensity index is smaller on the eastern side of Cozumel Island remaining correlated with the other. The speculation is that small eddies or meanders ride, at times, on the Caribbean Current and produce: the ageostrophic fluctuations observed within the channel, and the intensification of high frequency fluctuations all around the island.

OS31A-05 0935h

A Laterally-Averaged Nonhydrostatic Ocean Model

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Laterally-averaged dynamical equations are often used in numerical models of narrow coastal regions such as fjords and estuaries. Such models are preferable to 2D formulations, because they can handle variable-width effects such as flow acceleration at coastal constrictions. They also have a considerable speed advantage over 3D models. However, most laterally-averaged models share a significant weakness – they rely on the hydrostatic approximation. This is problematic for application in coastal areas where nonhydrostatic effects, such as mixing by sill-generated internal waves, are important. To fill this gap in applicability, we developed a nonhydrostatic laterally-averaged model. Its iterative scheme for the nonhydrostatic terms makes it comparable in speed to conventional hydrostatic models for flows that are approximately hydrostatic. This gives the model a wide range of applicability. We illustrate the model strengths and weaknesses in the context of laboratory experiments and field measurements of the tidal flow over Knight Inlet sill.

URL: http://www.physics.mun.ca/∼danielb

OS31A-06 0950h

Modeling Of The Langmuir Circulation And Breaking Waves Effects On The Oil Spreading and Dispersion In Surface Layer

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The problem of the modeling of the oil slick and surfactant spreading in the field of the unsteady and inhomogeneous currents and breaking waves is discussed. Some analytical solutions of the advective-diffusion equation for slick are obtained. Results show that the variation of the concentration field is the nonlinear function of the current velocity. To simulate oil spreading, transport by currents and wind, entrainment, breakup and dispersion the new 3D Lagrangian model was developed. It describes oil spreading and advection, entrainment of oil in the water by breaking waves and resurfacing entrained droplets. The turbulent diffusion processes are modeled by use Lagrangian stochastic simulation technique based on the random walk method for Gaussian "spillets". The statistical model of the breakup was proposed to reproduce observed log normal distribution of oil droplet sizes. The model was linked with 3D hydrodynamics model that includes Stokes drift. The used turbulence model Kantha and Clayson (2003) describes turbulent kinetic energy injected near the surface by breaking waves and the kinetic energy input from Langmuir circulations. The detailed results of simulations of turbulence, droplet spectra and concentration in the wave enhanced layer for stormy conditions by linked models are presented.

OS32A CC: 524 C Wednesday 1030h

General Ocean Sciences I

Presiding: **K Lamb,** University of Waterloo**; T Qu,** IPRC/SOEST, University of Hawaii

OS32A-01 1030h

On the reliability of ENSO

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In this study, ensemble predictions were constructed using two realistic ENSO prediction models and using stochastic optimals. By applying a recently developed theoretical framework, we have explored several important issues relating to ENSO predictability including the reliability measures of ENSO dynamical predictions; and the dominant precursor that control reliability. It was found that prediction utility (R), defined by relative entropy, is a useful measure for the reliability of ENSO dynamical predictions, such that the larger the value of R, the more reliable a prediction. The prediction utility R consists of two components, a dispersion component (DC) associated with the ensemble spread, and a signal component (SC) determined by the predictive mean signals. Our results show that the prediction utility R is dominated by SC. Using a linear stochastic dynamical system, we further examined SC and found it to be intrinsically related to the leading eigenmode amplitude of the initial conditions. This finding was validated by actual model prediction results, and is also consistent with other recent work. The relationship between R and SC has particular practical significance for ENSO predictability studies, since it provides an inexpensive and robust method for exploring forecast uncertainties without the need for costly ensemble runs.

OS32A-02 1045h

Can Luzon Strait Transport play a role in conveying the impact of ENSO into the South China Sea?

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Water exchange between the SCS and the Pacific through the Luzon Strait is examined using results from a high-resolution ocean general circulation model. Its transport (called the Luzon Strait Transport or LST below) from the model has a mean value of 2.4 Sv, and reaches its seasonal maximum (6.1 Sv, westward) in winter and minimum (0.9 Sv, eastward) in summer. Both the annual mean value and seasonal variation are in good agreement with observations. On interannual time scale, LST tends to be higher during El Nino years and lower during La Nina years, with its maximum (minimum) leading the mature phase of El Nino (La Nina) by about 1 month. Since water leaving the SCS in the south is of higher temperature than that with LST, horizontal advection is equivalent to a surface heat flux of -19 W m-2 in the mean. Most of this cooling advection is balanced by atmospheric heating (17 W m-2). From late spring to early fall, surface heat flux is the primary heating process; only a small part of the heat content change can be explained by heat advection. But, in winter, heat advection is the only important process responsible for the cooling in the upper-layer of the SCS. The upper-layer heat content of the SCS has a strong signature of ENSO, and LST seems to be a key process conveying the impact of ENSO into the SCS.

OS32A-03 1100h

Assessing the Impact of Stochastic Forcing on ENSO Events

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Previous work suggests that ENSO is influenced by a highly chaotic, essentially stochastic, component of atmospheric variability. To assess the impact of this "noise" on ENSO evolution and forecasts, we perform a suite of ENSO hindcasts spanning the past two decades. The hindcast model consists of an ocean general circulation model (GFDL MOM4), coupled to a statistical atmosphere derived by regressing historical air-sea fluxes onto historical sea surface temperature anomalies (SSTAs). The residual fluxes not captured by the statistical atmosphere are linearly independent of large-scale SSTAs, providing a rough estimate of the historical stochastic forcing. An ocean data assimilation provides initial conditions for a suite of year-long stochastic ensemble hindcasts. In a given hindcast, ensemble members begin from identical initial states but are forced by residual fluxes taken from different years. One particular member, a "cheatcast," is forced by the actual residual observed during that year, and an additional "noise-free" hindcast is performed with the residual fluxes turned off. The results show that both the initial conditions and the noise forcing affect the subsequent evolution of ENSO. The initial state preconditions the tropical Pacific toward the development of ensemble-mean SSTAs, while the noise forcing induces a rapid dispersion of the hindcasts about their ensemble mean. The noise-free hindcast in all cases closely tracks the stochastic ensemble mean, suggesting that the system is reasonably linear. To some extent, the residual fluxes induce similar effects regardless of the ocean preconditioning; in particular, the ensemble member forced by the 1997 residual is always among the warmest hindcasts, while that forced by the 1988 residual is always among the coldest. However, initializing from different years does alter the dispersion of the ensemble, indicating that some weak nonlinearity is present. The season of initialization also affects the ensemble dispersion. Implications of the results and limitations of the method are discussed.

URL: http://www.gfdl.noaa.gov/~atw/research/conf/agu_spring_2004

OS32A-04 1115h

Modulation of Interannual SST by the Seasonal Cycle in the Tropical Indian Ocean: A Study of Physical Processes

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Modulation of sea surface temperature (SST) patterns by interactions between seasonal and interannual variabilities in the Indian Ocean (IO) region are studied via a hierarchy of experiments utilizing both a 4-1/2 layer ocean model in a realistic tropical Indian Ocean basin, and a version of this same ocean model coupled to a model of the atmospheric mixed layer (AML). Results demonstrate that seasonal atmospheric forcing enhances positive (negative) SSTa in the western (eastern) IO basin associated with both the 1994 and 1997 Indian Ocean Zonal Mode (IOZM) events, $\sim 1^{\circ}C$ respective to a control run. Additionally, when seasonal forcing is removed from the system, the 1994 cool event in the eastern basin is prolonged by about 2 months. This indicates the seasonal cycle of atmospheric forcing is at least partly responsible for the timely termination of IOZM events at the end of an event year. To determine the specific physical processes leading to interannual IO SSTa modulation by seasonal variability, the coupled ocean-AML model is used to examine the effects on SSTa of each of the following in isolation: (1) thermocline variability and horizontal advection forced by seasonal wind stress variability; (2) vertical mixing due to seasonal wind speed; (3) changes in surface heat flux due to seasonal wind speed; and (4) variation in radiative forcing via seasonal cloud variability. Of these processes, those driven by seasonal wind stress variability prove most significant to IOZM amplification by the seasonal cycle, and to the timing of event termination. An analysis of the thermodynamics associated with seasonal wind stress forcing is presented, in which the relative contributions of each process represented in the model mixed layer temperature equation are compared, for both a control run and a run in which seasonal variability is removed from the wind stress forcing.

OS32A-05 1130h

Contradictions to Darwin's Evolution of Reef Types in Barrier Reef Relationships

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The Darwinian progressive subsidence model for the evolution of fringing reefs, barrier reefs and atolls has been generally accepted following the indisputable proof of subsidence provided by drilling results in the Pacific. Nonetheless, there are data that do not fit the expectations of the model, such as the similar lagoon depths of barrier reefs and atolls as opposed to the subsidence theory's implicit prediction that atolls should have significantly greater depths. In contrast, much evidence supports the influence of meteoric-water solution on barrier reef morphology. For example, the maximum lagoon depth of the 56 modern barrier reefs is statistically correlated with the lagoon catchment area for modern annual rainfall. These modern rainfall patterns are a reasonable proxy for relative geographic differences in glacial lowstand rainfall, even though the absolute amounts of such rainfall are unknown. The correlation therefore stongly suggests the importance of Pleistocene subaerial solution in contributing to barrier reef morphology. Further support for antecedent influence occurs in the form of barrier reef passes in which the depth of the reef pass is correlated with onshore drainage volumes. On a larger scale, the Cook Island of Mangaia provides evidence that solution can produce barrier reef morphology independent of reef development. In contrast, there are no examples of the Darwinian subsidence-predicted lagoon transition of fringing reefs to barrier reefs to atolls. Moreover, the common occurrence of fringing reefs within barrier reefs negates subsidence as a causal factor in their presumed progressive evolutionary development. Consequently, the evidence points to a solution morphology template which has been accentuated by reef construction to produce the diagnostic barrier reef morphology we see today. Rapid subsidence of seamounts by flexural loading during their early history, combined with Pleistocene sealevel fluctuations results in permanent drowning of older barrier reef. The importance of slower, thermal subsidence is in accounting for the overall thickness of the resulting carbonate caps.

OS32A-06 1145h

Dynamics of Chlorophyll Concentration over the Oceans using MODIS Data

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Chlorophyll concentration data derived from satellite borne ocean color sensors provide information of the distribution of phytoplankton and help us to understand their spatial and temporal dynamics. The changes in the patterns of distribution and abundance of the plankton have significant impact on the entire ecosystem and play a key role in the global carbon cycle. In this paper, we have analyzed annual and seasonal chlorophyll concentrations retrieved from MODIS data for the periods March 2000- October 2003, which reveal the spatial and seasonal distribution of chlorophyll concentrations across the global oceans. Chlorophyll concentration anomalies indicate that chlorophyll concentrations in almost all the ocean regions examined have responded similarly, maybe with different magnitudes to non-seasonal factors.

OS33A CC: 220 C-E Wednesday 1330h

Coastal Region Dynamics IV Posters

Presiding: **W Alex,** Naval Research Laboratory, Stennis Space Center**; K Lamb,** University of Waterloo

OS33A-01 1330h POSTER

Numerical Modeling of Thermal-Mechanical Niche Formation and Block Failure on Herschel Island, Yukon Territory, Canada.

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Wave action is the critical variable influencing coastal erosion rates in Arctic environments. Melting of interstitial ice and/or massive ice results in the addition of fine-grained sediment to the swash zone. This sediment is then held in suspension and transported along the coast by longshore currents. Removal of the insulating layer of unfrozen material exposes frozen cliff sediments directly to wave action, increasing the rate of thaw. Development of a thermoerosional niche proceeds until either (a) the storm abates and direct heat conduction to the coastal sediment stops, or (b) the overburden pressure exceeds the shear stress of the material, in which case a cohesive block of frozen sediment will fall directly onto the beach. In the case of (b), mechanical erosion of the cliff sediments will cease until the block material has been fully eroded and transported away, allowing the waves to again interact directly with the cliff sediments. A numerical model originally proposed by Kobayashi et al. (1999) was further developed to simulate the horizontal retreat associated with thermoerosional niche formation and block failure on Herschel Island during the annual 3-4 month ice-free period extending from mid-June to late September. The model was parameterized using data obtained from oblique aerial photographs, video footage and existing geomorphological data. Herschel Island was classified into three distinct categories based on cliff height, cliff angle, and ice content. Low frequency, high-magnitude storm events generate several metres of coastal backwasting in a very short time. Values for storm frequency and storm surge were modified from the existing model to reflect the 30-year mean. Results were compared with measured rates of coastal retreat in each distinct category for the previous 30 years. A high level of correlation is demonstrated between model results and existing data. A climate change factor was then introduced, predicting an increase in storm frequency and storm surge height.

URL: http://www.geog.mcgill.ca/grad/turner

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