functions of space and time scales are shown. Adapted algorithms, derived from these results, are discussed in details.

OS24A CC: 524 C Tuesday 1530h

Coastal Region Dynamics II

Presiding: **K Lamb,** University of Waterloo**; A C Warn-Varnas,** Naval Research Laboratory, Stennis Space Center

OS24A-01 1530h INVITED

Seasonal Variability of Internal Tides and Associated Nonlinear Internal Waves on the New Jersey Continental Shelf

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Internal tides and associated internal wave packets generated by tidal flow over bathymetry variability have been observed on the New Jersey Shelf during the summer, fall and winter seasons. In mid summer the mixed layer was thin and the seasonal thermocline was near the ocean surface. The internal wave packets were mode 1 nonlinear waves of depression. In the early fall the mixed layer thickness was nearly half the water column depth. Depending on their location within the internal tide the internal wave packets were composed of either depression or elevation waves. In addition, interfacial mode 2 internal waves were observed. In the winter the mixed layer was often more than 3/4 of the water column depth in thickness. The mixed layer often lay on an intruding slope water front. Internal tides and internal waves of elevation, some of large amplitude, were observed during this time period. This work was supported by The Office of Naval Research.

OS24A-02 1550h INVITED

Internal Tides in the Northern South China Sea

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Internal tides have been observed by the PI's of the ASIAEX acoustics/physical oceanography experiment at the continental shelf break south of China. The bathymetry favors generation of diurnal internal tides at this site because of near-critical bathymetry. The bathymetric slope is subcritical for semidiurnal internal tides. The diurnal internal tidal waves are seen to propagate upward as they move shoreward (phase velocity downward). They also steepen to form bores with associated packets of nonlinear high-frequency internal waves as they move into shallow water. The tide may be interacting with a surface reflection of itself at this point. The steepening occurs in a fraction of a wave period. The ratio of particle velocity to phase velocity is of order 0.2 for these waves. The energy flux of the diurnal waves has an average value of about 1000 W/m, and a peak value at spring tide of over 2000 W/m. This energy flux happens to be close to that of large high-frequency internal waves moving into the area from the Luzon Strait area to the east. The detailed observations of waves present an opportunity to compare internal tide generation and nonlinear internal wave generation theories and simulations to detailed field data. The spatially broad internal tides have first-order effects on the acoustic wave guide and thus influence signal propagation, whereas the short nonlinear waves produce sound-speed perturbations that produce high-frequency signal fluctuations.

OS24A-03 1605h

On the Formation and Cirulation of the Intermediate Waters of the Gulf of St. Lawrence

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The Gulf of St. Lawrence is a seasonally ice covered northern shelf sea that exhibits strong interannual variability in its water mass characteristics and circulation. In summer, the vertical water column in the Gulf is comprised of three layers: a warm and fresh surface layer, a deep saline layer of Atlantic slope waters, and a cold intermediate layer (CIL) which was formed during the previous winter. It is unclear, however, where and how the CIL is formed, how it circulates through the GSL, and to what extent inflowing waters from the Labrador Sea through the Strait of Belle Isle contribute to its formation. The results of a winter observation campaign that shed new information on these processes will be presented. The renewal of the CIL found in summer in the St. Lawrence Estuary is due to its advection into the region at the end of winter, rather than in situ formation. Deep mixing in the Estuary is prevented by strong winter surface stability, which remains high throughout winter. The observations also suggest an intensified bottom layer circulation during winter, with the intrusion of warm Atlantic waters, usually found deeper than 150 m, at depths near 30 m. A hindcast simulation of the winter 2002/3 was performed using a three-dimensional numerical ice-ocean model. The model reproduces the observed strong spring renewal event of the CIL into the Estuary, and helps to explain the role of local dynamics, including the stability of the Gaspé Current and the coupled circulation in the northwestern GSL, in controlling the exchange processes at depth. The model results suggest the existence of a stable offshore Gaspé Current, that is maintained by the combined effects of downwelling along the Gaspé coast and upwelling along the south coast of Anticosti Island. The results demonstrate that lateral and vertical structures of the estuarine circulation in the GSL undergo a strong and well-defined seasonal cycle.

OS24A-04 1620h

Intercomparison of Third Generation Wave Models in Shallow Water

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For coastal engineering studies, as well as offshore oil platforms and related marine activities, wave information is required in shallow water areas where wind growth, bottom dissipation and wave-current interactions may be important. In this study the performances of three widely-used third generation numerical wave models, SWAN, WAM and WaveWatch-III (hereafter WW3) are evaluated through comparisons for accuracy, with *in situ* measurements, and with their computational efficiency. These models were adapted to the Northwest Atlantic in a set of four composite model systems: (a) the nesting of WAM in WAM, (b) WW3 in WW3, (c) SWAN in WAM and (d) SWAN in WW3. The models were driven with wind fields from two severe winter storms: the Superbomb of January 2000 and the Bomb of January 2002. On one hand, observations of peak waves from these storms are used to inter-compare the capabilities the wave models to simulate extreme waves. On the other hand, the capabilities of different instruments to measure those waves in shallow waters are discussed. Directional wave measurements were made using a conventional directional wave rider (DWR), and also by an acoustic Doppler current profiler (ADCP) co-located in shallow water. Additional deep-water measurements are available from non-directional wave riders (WR). Although all models provide skillful hindcasts for significant wave height (H_s) and for peak period (T_p), under-estimation of H_s at the peak of both storms, compared to observations, is evident. Moreover, we also present comparisons between models and 2-dimensional wave spectra. The recently released upgrade to the WW3 model shows some advantages over the other models, in these comparisons with measurements.

OS24A-05 1635h

Results of 3-D Travel Time Tomography Studies of the Gas Hydrate Bearing Sediments in Cascadia Region Offshore Vancouver Island

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The COAMS'99 experiment was one of a series of seismic and other surveys designed to study the gas hydrate field offshore Vancouver Island near the ODP 889/890 drill site. The presence of the gas hydrate was proven by the occurrence of the Bottom Simulating Reflector (BSR) on the seismic sections as well as by physical recovery of the gas hydrate samples. The experiment included multichannel COAMS streamer, single channel Teledyne streamer, and 5 Ocean Bottom Seismographs (OBS). The survey was targeted on a hydrocarbon vent site and the associated with it "blank zones" - zones of decreased seismic signal strength visible on seismic recordings. The nature of the blank zones at the site is quite speculative, since very little is yet known about the physical properties of the sediment environment. The paper reports results for a 3-D tomographic inversion that images the structure of the velocity field above the BSR around the most prominent blank zone. The seismic dataset used for picking of travel times consisted of 22 main grid parallel profiles and 3 cross lines recorded by the OBS's placed in proximity of the blank zone, and 15 lines of normal-incidence seismic data recorded by the Teledyne streamer. A 40 in. single airgun was used as controlled seismic source. The arrival time of seismic waves reflected from 4 interfaces (the deepest interface corresponds to the BSR) were inverted using a linearized travel time inversion code (JIVE3D by James Hobro). The resulting model with horizontal dimensions of 2.3 x 2.6 km and a volume cell size of 50(X)x50(Y)x20(Z) m reveals a positive velocity anomaly that spatially corresponds to the blank zone.

OS24A-06 1650h

A Controlled Source Electromagnetic Experiment for Gas Hydrate Assessment: First Results from the Chilean Margin

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Gas hydrates in seafloor sediments are recognized as an important future energy resource, a powerful greenhouse gas and the potential cause of submarine landslides. Gas hydrates are ice-like solids consisting of a mixture of water and gas molecules, mainly methane, and are stable at low temperatures and high pressures. They have been found worldwide on continental margins and in permafrost areas. In general, a gas hydrate deposit can be identified on a seismic section by a so-called Bottom Simulating Reflector (BSR) which is associated with trapped free gas below the base of the hydrate stability zone (BHSZ), or the depth where the geothermal gradient intersects the hydrate stability curve. However, the area above the BSR is often invisible on seismic sections, which therefore, generally provide no information about hydrate concentration that is essential to resource assessment and hazard evaluation. Measurements of the electrical conductivity of seafloor sediments can be the key to the estimation of gas hydrate concentrations. The relation between conductivity and porosity is given by Archie's law. In the hydrate layer, insulating hydrate forms in pore spaces and replaces conductive pore fluid and subsequently increases the bulk resistivity. Exact conductivity measurements therefore allow estimation of hydrate concentration. A controlled source electromagnetic (CSEM) method has been developed at the University of Toronto and has been tested on the Cascadia Margin. In March 2003 the group was invited to take part in a Chilean project to explore the gas hydrate deposits along the Chilean Margin. Data have been collected in 3 different areas. The data show little variation within the respective areas and are comparable to those obtained in the Cascadia Margin. At this stage of the data analysis, there is no observed correlation between conductivities and preliminary BSR locations from seismic data. Two scenarios could be the cause for this disagreement: a) Hydrate is everywhere, and therefore we see no anomalies, the conductivities are uniform. The BSRs are patchy since free gas is not throughout available. b) The hydrate concentration is not high enough to make any anomaly, even if there is a BSR.

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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.