

initial wave with different assumptions of source mechanisms for 1939 event are used in simulation. The arrival times of the tsunami waves, the initial sign of the wave form, the wave period and the nearshore tsunami amplitudes are computed at selected coastal stations. The computed tsunami records at the coastal locations are compared with the available data. The comparison of the observational, instrumental and numerical data at the shore locations are used for analysis and comparison of the assumed source mechanisms. The probable source mechanism of 1939 Black sea Tsunami is also discussed. Altýnok, Y. and P. Ersoy (2000), Tsunamis observed on and near the Turkish coast. *Natural Hazards*, 21, 185-20. Nikonov, A. A. (1997), Tsunami occurrence on the coasts of the Black Sea and the Sea of Azov. *Izvestiya, Physics of Solid Earth*, 33, 72 - 87. Papadopoulos, G.A. and F. Imamura (2001), A proposal for a new tsunami intensity scale, *Proceedings of International Tsunami Symposium 2001*, Seattle, Washington, Aug. 7 -10, 2001, 569- 577. Richter C. F. (1958), *Elementary Seismology*, W. H. Freeman and Co., San Francisco, California, 1958

OS14A CC: 520 F Monday 1530h Tsunami and Rogue Waves

Presiding: E Pelinovsky, Institute of Applied Physics, Russian Academy of Sciences; E A OKAL, Northwestern University

OS14A-01 1530h INVITED

M-TSU : From tsunameters to earthquake source

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We use tsunami records obtained by ocean-bottom "tsunameters" of the DART project to relate tsunami amplitudes on the high seas to the source of major earthquakes around the Pacific rim. Our approach is derived from the concept of mantle magnitude $M_{sub m}$, developed by Okal and Talandier [1989], and exploits the possibility of working directly with tsunami signals on the high seas, unaffected by the later interaction of the wave with coastlines. Through a modification of the $M_{sub m}$ algorithm, we develop a tsunami magnitude $M_{sub TSU}$, whose calculation is supported theoretically using normal mode theory. We analyze records of tsunamis from several major earthquakes including the 1994 Shikotan (Kuriles) and 2003 Rat Island events. We find that acceptable estimates of their seismic moments can be derived from tsunami spectral amplitudes at periods > 700 seconds. We are presently expanding this analysis to an enlarged database of records covering the past 10 years.

OS14A-02 1550h INVITED

Tsunamis and Tsunami Prone Mechanisms in Eastern Mediterranean

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There are numerous earthquakes and tsunamis that occurred in eastern Mediterranean and are documented in historical records. The fault zones around eastern Mediterranean basin are Hellenic Arc, North Anatolian Fault Zone (NAF), East Anatolian Fault Zone (EAF), Cyprus Arc, and Dead sea Fault. Hellenic Arc is a subduction zone of about 1000 km in length. It is the most active seismic region in Europe containing active volcanoes in historic times. The Hellenic Arc starts from the Peloponnese passes from the south of Crete Island, goes at east side of Rhodes Island end enters mainland Anatolia around Dalaman. It has a roughly circular shape. The deepest region of the Mediterranean Sea is between Rhodes and Dalaman near Hellenic Arc. The deepest region lies as a trench with the depth more than 4000 m depth, at the coordinates 28.7 oE, 35.7 oN, and with the size of 80 km in E-W direction and 60 km in S-N direction. At the centre of the Aegean sea there is a series of volcanic systems almost parallel to the trench and forming the internal arc (Milos, Antimilos, Antiparos, Santorini, Christiana, Colombus, Kos, Yali, Nisiros, etc). The North Anatolian fault is more than 1000 km-long, strike-slip fault. It starts near Erzincan Karliova, is roughly parallel to the Black

Sea coasts towards W, enters the sea of Marmara at Izmit Bay and splits two branches. South branch lies at south of the sea of Marmara, North branch passes along the sea of Marmara towards Aegean sea. The East Anatolian Fault Zone starts near Karliova and goes to South and splits two Branches as Amonos Fault and Misis Fault. The Cyprus Arc starts in the Antalia Gulf and develops towards Cyprus. The link between the Cyprus Arc and the Hellenic Arc and the link between the Cyprus Arc and EAF is still not described. The Dead Sea fault is a strike slip fault running in a N-S direction from the termination of the East Anatolian fault to the Red Sea. There are numerous earthquakes along the Dead Sea fault, but they recently do not exceed magnitude 4. The stronger earthquakes are more rare and always have magnitude lower than 6 and are mainly concentrated in the most internal zone of the Aqaba Gulf. In this study, the data about historical earthquakes, the distribution of their epicenters, the historical tsunamis in the eastern Mediterranean are presented. The fault zones, volcanic activities, probable submarine landslides, and their relation to the earthquakes and tsunamis are examined. The source areas and source mechanisms of historical tsunamis are analyzed. The probable source areas, expected source characteristics and tsunami prone mechanisms in eastern Mediterranean are discussed.

OS14A-03 1605h

Ocean-Scale Tsunami Propagation: Boussinesq Approximations.

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Tsunamis propagating over trans-oceanic distances can be significantly modified by effects of frequency dispersion, leading to (among other effects) alteration of wave fronts and wave packets, and changes in spatial distribution of wave energy due to alteration of ray patterns over complex bathymetry. In this presentation, we describe the theory and implementation of an ocean-scale tsunami propagation model in the Boussinesq approximation. The work focuses on the usual weakly dispersive, weakly nonlinear formulation of the classical theory. Working in spherical polar coordinates, we introduce a parameter which characterizes a horizontal wave packet length scale, leading to an aspect ratio which characterizes dispersion effects. Boussinesq equations are then obtained from the Euler equations with rotation included. Although the spherical coordinate model is aimed mainly at basin scale propagation problems, we describe an extension retaining several aspects of the formulation which would be more appropriate to local wave evolution either near the source or in the final runup stage, in order to obtain a more unified model. These effects include a representation of bottom motion, and a fully nonlinear treatment of surface conditions in order to represent large runup amplitudes during inundation. Numerical implementation of the code is described, and we discuss several examples of idealized and real-world applications.

OS14A-04 1620h

Freak Waves as a Result of Modulational Instability

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We have studied numerically the development of modulational instability for stationary propagating Stokes waves of a moderate magnitude, ($k_a = 0.15$), on a deep water. The spectral code method was applied to exact one-dimensional hydrodynamic equations, which describe the potential flow of an ideal fluid with free surface; this surface was conformally mapped to the half plane. The equations were solved in a box with periodic boundary conditions containing as much as ten lengths of the leading wave. The total amount of spectral modes were varied between $3 \cdot 10^4$ to $1 \cdot 10^6$. In the initial moment of time, the exact Stokes wave was

modulated by a small long scale perturbation. As a result, we observed an exponential growth of modulation, which was leading to the formation of a single freak wave. The freak wave grew up to the limiting amplitude of ($k_a \sim 0.45$); then, it demonstrated a tendency to an explosive formation of singularity.

OS14A-05 1635h

Model Simulations of Waves in Hurricane Juan

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Hurricane Juan made landfall at 0300 UTC near Halifax Nova Scotia. This was a category 2 hurricane with winds of 44 m/s, the largest storm to pass over these coastal areas in several decades. Associated high ocean waves were experienced in coastal waters, from Peggy's Cove to Sheet Harbour, growing to epic proportions on the Scotian Shelf, and exceeding the 100-year return wave based on the present climatology. As part of the GoMOOS program (Gulf of Maine Ocean Observing System, www.gomooos.org), winds from the USA Navy COAMPS (Coupled Ocean Atmosphere Model Prediction System) were used to evaluate and compare three widely-used third generation numerical wave models, SWAN, WAM and WaveWatch-III (hereafter WW3) for accuracy, with in situ measurements. Model comparisons consist of a set of composite model systems, respectively nesting WAM, WW3 and SWAN in WAM and WW3. We report results from the intermediate-resolution grid for Hurricane Juan. Wave measurements were made using four operational deep-water buoys (C44258, C44142, C44137, 44005), by a conventional directional wave rider (DWR) moored offshore from Lunenburg Bay, and also by two acoustic Doppler current profiler (ADCP) located (1) near an oil rig on Sable Island Bank, in relatively shallow water, and (2) near the outer boundary of Lunenburg Bay. We discuss the reliability of DWR wave data compared to ADCP wave data. We show that all models provide reliable hindcasts for significant wave height (Hs) and for peak period (Tp) for Juan, although a clear underestimation of Hs at the peak of the storm is evident, compared to observations. A feature in the COAMPS storm simulation is that the storm track appears to be slightly to the east of that of Quikscat scatterometer data. Comparisons between models and 2-dimensional wave spectra are presented. Preliminary results suggest that the recently released upgrade to the WW3 model shows slightly enhanced skill compared to the other models.

OS14A-06 1650h

Freak Waves: Physical Mechanisms And Experimental Data

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A review of physical mechanisms of the rogue wave phenomenon is given. The data of marine observations as well as laboratory experiments are briefly discussed. They demonstrate that freak waves may appear in deep and shallow waters. Simple statistical analysis of the rogue wave probability based on the assumption of a Gaussian wave field is reproduced. In the context of water wave theories the probabilistic approach shows that numerical simulations of freak waves should be made for very long times on large spatial domains and large number of realizations. As linear models of freak

waves the following mechanisms are considered: dispersion enhancement of transient wave groups, geometrical focusing in basins of variable depth, and vorticity interaction. Taking into account nonlinearity of the water waves, these mechanisms remain valid but should be modified. Also, the influence of the nonlinear modulational instability (Benjamin-Feir instability) on the rogue wave occurrence is discussed. Specific numerical simulations were performed in the framework of classical nonlinear evolution equations: the nonlinear Schrödinger equation, the Davey - Stewartson system, the Korteweg - de Vries equation, the Kadomtsev - Petviashvili equation, the Zakharov equation, and the fully nonlinear potential equations. In particular, the experimental data recorded in the North and Black Seas are simulated to determine the lifetime of the freak waves.

**OS23A CC: 524 C Tuesday 1330h
Coastal Region Dynamics I**

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

OS23A-01 1330h INVITED

Propagation of Ocean Acoustic Fields Through Shallow-Water Internal Waves

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Under certain conditions when an ocean acoustic wave propagates through and interacts with shallow water internal waves, the acoustic wave can suffer an abrupt reduction in intensity that extends over a narrow band of acoustic frequencies. This "anomalous loss" in signal was measured by Zhou, et al. (1991), and attributed to a "resonance" effect caused by acoustic mode conversions that occurred when the acoustic fields interacted with the internal wave fields. Numerous subsequent field experiments and computer model simulations have verified this intensity loss, and the acoustic mode conversions hypothesis. We review the physical mechanisms and environmental conditions that are necessary for this loss in acoustic signal to occur, and present computer simulations with analysis that illustrate the "resonance" effect. The simulations indicate that for the anomalous signal loss to occur, a complex set of environmental conditions must first occur that involves a lengthy portion of the ocean volume and ocean bottom (rather than just a short range "snap shot" of the ocean volume). Since the solitary internal wave fields are slowly evolving, and the acoustic signals are near-instantaneous and often broad band in frequency, the opportunity for fulfilling the conditions needed to produce anomalous signal losses is quite prevalent. [Work supported by ONR/NRL.]

OS23A-02 1350h

Winter Primer4 Ocean-Acoustic Dynamics and Energy Structures.

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Solitary wave generation and propagation simulations are conducted with the Lamb(1994) nonhydrostatic model in conjunction with winter Primer4 data. The model simulation parameters are adjusted until the structures of the simulated wave packets compare favorably with the measured data, in period and amplitude. Acoustical field calculations are performed with a parabolic equation acoustical model along the path of solitary wave train propagation. Comparisons of time series spectra are undertaken between the thermistor chain data and the corresponding observation mooring post in the model. The variance spectra of the data and model moorings show the presence of semidiurnal tidal and internal solitary wave energies. In addition two other moorings are placed in the model domain, one 10km to the right and another 10km to the left. The mooring locations are in the vicinity of bores of depression, first appearance of solitary waves, and well developed solitary waves of elevation. The analysis of model variance spectra, at the three moorings, exhibits a conversion of energy from the semidiurnal tidal band to the internal solitary waves band as one moves up onto the shelf through the three moorings. The internal solitary wave energy increases and the semidiurnal tidal energy decreases. This indicates energy conversion from the barotropic tide to the baroclinic tide and into internal solitary waves. Calculation of acoustical intensity in conjunction with model predicted internal bore and solitary wave train structures on the shelf indicate significant fluctuations of acoustical intensity in the spatial and temporal bands. In some cases these fluctuations in acoustic intensity are similar to that observed by Zhou, et al., resulting in anomalous losses; however, in other cases these fluctuations can produce significant gains in acoustic intensity. Although such gains were not reported by Zhou, et al., we have observed them in our coupled ocean-acoustic model studies of winter Primer4 solitary waves. [Work supported by ONR/NRL.]

OS23A-03 1405h

Shoaling Internal Solitary Waves

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Shoaling large amplitude internal solitary waves (ISWs) are common in the coastal ocean environment. In this talk the properties of exact, fully nonlinear ISWs will be discussed and compared with the predictions of weakly nonlinear theory. Numerical simulations of their shoaling behaviour will be presented using a variety of stratifications which exhibit different shoaling behaviours

OS23A-04 1420h INVITED

Life-Time Of Internal Solitary Waves On Oceanic Shelves Based On Numerical Simulations

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Due to the horizontal variability of oceanic hydrology (density and current stratification) and the variable depth over the continental shelf, internal solitary waves transform as they propagate shorewards into the coastal zone. If the background variability is smooth enough, a solitary wave possesses a soliton-like form with varying amplitude and phase. This stage is studied in detail in the framework of the variable-coefficient extended Korteweg-de Vries equation where the variation of the solitary wave parameters can be described analytically through an asymptotic description of a slowly-varying solitary wave. Direct numerical simulation of the variable-coefficient extended Korteweg-de Vries equation is performed for several oceanic shelves (North-west Shelf of Australia, Malin Shelf Edge, Arctic Shelf) to demonstrate the applicability of the asymptotic theory. It is shown that the solitary wave may maintain its soliton-like form for large distances (up to 100 km), and this confirms why internal solitons are observed widely in the world's oceans. In some cases the background stratification contains critical points (when the coefficients of the nonlinear terms in the extended Korteweg-de Vries equation change sign), or does not vary sufficiently smoothly; in such cases the solitary wave deforms a group of secondary waves. This stage is studied numerically. These

results are used to estimate the life-time of the internal solitons on oceanic shelves.

OS23A-05 1435h

Physical Oceanographic Conditions in Barkley and Clayoquot Sounds, British Columbia Canada - Late Summer 2000-2003

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The physical oceanographic conditions in the inlets and fjords of Barkley and Clayoquot Sounds along the outer coast of Vancouver Island have been explored for the past four years as part of a five-year interdisciplinary project that involves faculty and undergraduates from three institutions. Temperature, salinity, density, oxygen and chlorophyll sections from 2000 through 2003 will be presented and compared. Many of these fjords contain anoxic bottom waters with renewal times on the order of months to years. During 2000, the visited inlets were all anoxic, yet during the summer of 2001 many of the inlets turned over, resulting in large fish kills. A number of inlets were again anoxic in 2002 and 2003. Understanding the local and regional physical oceanographic conditions and mechanisms that lead to these fish kill events is an important factor in determining the future health and function of these estuaries.

OS23A-06 1450h

The New York Harbor Observation System (NYHOS): Preliminary Results on Real-Time Quality Control of Hourly Reported Data

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The New York Harbor Observation System is a regional integrated system dedicated to monitoring the New York Harbor area through model-directed observations and model forecast for security and surveillance purposes. Observations encompass a unique combination of sensors, both at fixed stations and upon dynamic platforms. Measurements include surface and bottom CTD (YSI) from numerous shore-side and buoy stations, moored ADCP (RDI) and bottom CTD (SeaBird) from a cross river transect, High Frequency radars (CODAR) as well as surface CTD (Seabird) from a series of ferries. The combined data allow an optimal fine coverage of the studied area of the order of 50km², within a time window of 60 min. Transmission is performed hourly via wireless transmission (both UHF conventional radio and cellular), cable or regular telephone lines. In order to insure the quality of the newly collected data, we proceed in two steps. First, we test our data for quality control using the NDBC man-machine mix data control protocols. These protocols concern in particular data associated with physical processes, such as sea level, water temperature, conductivity and salinity. They focus on transmission errors, gross range and time-continuity checks and wind gust to wind speed checks, following D.B. Gilhousen (1998) specifications. We then test our data for quality control using protocols based on static as well as dynamic checks as proposed by Miller et al. (2003). We address in particular spatial and temporal data disparity resulting from the operational mode of the instrumented ferries using wavelets following Mallat, (1998). Assuming the physical data is temporally constant within a one hour time frame, the fine model grid, used by the system's nowcast and forecast model, is filled using simple data interpolation. The modified data persistence analysis can then be used as background for horizontal consistency checks. Results of the two approaches are compared in terms of detection percentage and false alarm percentage. Shore-based and moored CTD are used as reference values to test the ferry data when possible. Then, results on salinity and temperature disparities in the New York harbor are