contrasts, as well as longitudinal variation in SSS, are less important than latitudinal thermal gradients and inter-basin salinity contrasts. Details of SSS also decrease in importance as soon as its inter-basin contrasts are retained. This is especially important for paleoclimate and future climate simulations, as only the large-scale inter-basin contrasts of the sea surface conditions really matter.

URL: http://www.personal.psu.edu/dxs60

OS21C-1141 0830h POSTER

Progress in Modeling the Gulf Stream in a Duo Grid North Atlantic Ocean/Caribbean Sea/Gulf of Mexico model

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The DieCAST ocean model is applied to the combined North Atlantic Ocean, Caribbean Sea and Gulf of Mexico, using two two-way coupled grids between 10 deg N and 75 deg N. Open boundary conditions derived from a one degree resolution global adaptation of DieCAST are applied at 10 deg N. Climatology based open conditions are applied at 75 deg N and combined with a northern sponge layer. The two grid resolutions are: 1/2 deg east of 60 deg W; and 1/6 deg west of 60 deg W. Vertical resolution is 30 levels. Annual cycle wind stress climatology and surface heat and freshwater fluxes are applied at the surface. The fluxes are derived from surface temperature and salinity climatology, using no unphysical transient damping (restoring toward climatology). The derived fluxes are such that the model multi-year *ensemble mean annual cycle* matches the observed surface annual cycle climatology. An idealized shelfbreak near the open northern lateral boundaries avoids unphysical vortex stretching effects caused by conventional vertical walls. Using annual cycle Hellerman wind stress climatology, the model results give: correct Gulf Stream (GS) separation and path; vigorous transients including cold- and warm-core GS rings; and a steep front in the Denmark Strait between a northward flowing fragment of North Atlantic Gyre water near Iceland and southward flowing East Greenland Current that feeds into the Deep Western Boundary Current (DWBC). The model DWBC strongly affects the GS separation and path. Labrador-Sea-modified dense DWBC water arrives in the Grand Banks shelfbreak area after $\sim$ 10 model years, leading to: GS separation and path much closer to observations; offshore thermocline outcropping along an intense GS front; and relatively flat time mean isopycnals between the strongly sloping GS and DWBC isopycnals. Such flattening is clearly seen in Yashayaev's non-diffused climatology, and indicates eddy dynamics characteristic of baroclinic instability rather than diffusive lateral mixing between the GS and DWBC.

OS21C-1142 0830h POSTER

Interannual Variability of Sea-ice over the Eurasian Shelf Seas and its Interaction with Large-scale Atmospheric Circulation

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It has been documented that the sea-ice over the Eurasian shelf seas has large variance on interannual time scale. Not only does the sea-ice in this area serve as a freshwater source in solid form but also its variability considerably affect oceanic freshwater distribution. In this study, we detected dominant spatiotemporal modes of the interannual variability of sea-ice over the Eurasian shelf seas (from the Barents Sea to the East Siberian Sea) by a frequency domain singular value decomposition of monthly sea-ice concentration data from HadISST1.1 from 1979-2002. Three significant oscillatory modes, with periods of quasi-biennial, 4.5 year and 5-6 year, are isolated. These modes explain about 60-70% of the total variance at their respective local frequency. The reconstructed time evolution of spatial patterns show that the 5-6 year mode has stationary characteristics with large fluctuations over the Barents and Kara Seas, the 4.5 year mode has two centers of action in the Barents-Kara Sea and the western Laptev Sea, respectively, with the larger fluctuations in the Barents-Kara Sea, and the quasi-biennial mode has two centers of action located over the Barents-Kara Sea and the western Laptev-East Siberian Sea, respectively. Apparent feature of eastward propagation of sea-ice anomaly appears in the quasi-biennial mode. This analysis extends to sea level pressure and surface air temperature to examine coherence of sea-ice and atmospheric variability and to investigate their interactions.

OS21C-1143 0830h POSTER

Variations of Oceanic Evaporation Derived from SSM/I

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Variations of the oceanic evaporation of recent years were examined using latent heat flux derived from Special Sensor Microwave Imager (SSM/I) on board the Defense Meteorological Satellite Program (DMSP) satellites. Analysis of the version 2 of the Goddard Sea Surface Turbulent Flux (GSSSTF2) data set shows an increase of global oceanic evaporation of 17 percent over the period July 1988-December 2000. Data gaps exist in the major rain belts due mostly to non-retrieval in heavy rain, but there are no trends in temporal coverage. The first Emprical Orthogonal Function (EOF) of the non-seasonal data, which explains 9.2 percent of the variance, is characterized by changes of the same sign in most regions, dominated by changes in the subtropics oceanic dry regions. The time series shows an increasing trend that starts around 1990 of 1.5 percent per year. An Empirical Mode Decomposition (EMD) shows a long-term mode that shows similar pattern as the global trend. The first EOF pattern is interpreted as an enhanced Hadley type circulation. The second EOF, explaining 5.7 percent of the variance, is characterized by an equatorial east-west and a mid ocean north-south dipole in the Pacific, and its ssociated time series is correlated to a Southern Oscillation Index at 0.74, significant at the 95 percent confidence level.

OS21C-1144 0830h POSTER

Circulation and Fluxes in the Nordic Seas and Exchanges with the Arctic and Atlantic Oceans

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The Nordic Seas provide the main oceanic connection between the Arctic and the deep global oceans via dense overflows between Greenland and Scotland, into the North Atlantic. The inflow of warm, salty Atlantic waters and the outflow of ice and cold, fresh Arctic waters form two major components of the Nordic Sea circulation, and influence both the long-term variability of the overflows into the North Atlantic, and the formation mechanisms of Denmark Strait Overflow Water. We have a unique data set, collected under the auspices of the UK Natural Environment Research Council's thematic programme ARCICE (Arctic Sea Ice and Environmental Variability), of near synoptic hydrographic and LADCP (lowered acoustic doppler current profiler) measurements across the entire region during summer 1999. The box inverse method has been applied to the hydrographic data, using computed geostrophic velocities referenced to detided LADCP measurements. Our work aims to quantify the full Nordic Sea flux field (volume, heat and freshwater), studying the exchanges between the Nordic Seas and the Arctic Ocean to the north, the Barents Sea to the east, and North Atlantic to the south, via North Atlantic Current inflow and the Denmark Strait and Iceland-Scotland overflows. An understanding of the circulation and exchanges of this region is vital for any consideration of the implications of high latitude climate change to variability in the Atlantic thermohaline circulation and consequences for regional (European) climate.

URL: http://www.soc.soton.ac.uk/JRD/HYDRO/shb/arcice/arcice.php3

OS21C-1145 0830h POSTER

The Viability of COADS Data Assimilation in Coupled Ocean Atmosphere Models

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COADS data from 1950 through 1997 are tested using the coherence squared method to determinine their suitability for data assimilation into coupled ocean / atmosphere models. The results of these tests are then compared to the least squared method to ascertain any benefits of coherence testing for data assimilation.

OS21D MCC: 3000 Tuesday 1020h

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

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

OS21D-01 1020h

Vulnerability Assessment and Prevention Measures for Tsunami Flooding of Coastal Areas in Mexico

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The Middle-America Trench subduction zone adjacent to the southwestern coast of Mexico accounts for a consistent and regular history of locally destructive tsunamis generated by large earthquakes. 3 and 5 meters are the maximum wave heights representative of low and middle risk for the most frequent of these tsunamis. This coast is the site of industrial ports, tourist resorts and urban communities. The main industrial port, located on the sand shoals of a river delta, has two steel mill plants, a fertilizer factory, container, metal and mineral docks, grain storage silos, and a fuel oil terminal. An important element for the vulnerability assessment is the determination of probable tsunami wave elevations and expected inundation limits. The two cases mentioned above were computer simulated. An ocean water disturbance produced by a sea-floor earthquake was assumed. Linear wave theory for the deep ocean, and non-linear one for the near shore and interaction with the coast, were used. Non-fixed boundaries were considered. The equations were solved by a finite-difference algorithm for interconnected grids of different sizes. The model was validated comparing the results with sea level data, run-up and flooding extensions measured from past tsunamis. Results of the numerical simulations show maximum water levels and boundaries of the inundation areas under threat. Inundation maps were produced. Vulnerability assessments for two cases, an urban settlement and the main industrial port, are described. A low risk event will produce slight damage, railroad tracks destroyed, access bridges washed out, and ledges of sand removed or deposited on the beaches; and a middle risk event will produce major and extensive damage to the installations and danger to life. Recommendations include the relocation of urban settlements, installations and services, and the establishment of evacuation routes and emergency shelters.

OS

OS21D-02 1035h

Puerto Rico Tsunami Warning and Mitigation Program

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The circum-Caribbean region has a documented history of large damaging tsunamis that have affected coastal areas, including the events of the Virgin Islands in 1867 and Mona Passage in 1918. These tsunamis have been triggered by large tsunamigenic earthquakes that deformed the ocean floor. The seismic water waves originating in the prominent fault system around PR are considered to be a near-field hazard for Puerto Rico and the Virgin islands (PR/VI) because they can reach coastal areas within a few minutes after the earthquake. Sources for regional and tele tsunamis have also been identified. To help mitigate the risk of potential tsunamis on the coastal communities of Puerto Rico, with initial funding from the Federal Emergency Management Administration (FEMA) and the University of Puerto Rico (UPR), the Puerto Rico Tsunami Warning and Mitigation Program (PRTWMP) was established in 2000. Three of the main tasks are to evaluate the possibility of establishing a Tsunami Warning System (TWS), prepare tsunami flood maps and education. The need to establish a system of rapid notification for tsunami alerting in the Caribbean region has been recognized by the emergency management and scientific community. Presently, the Puerto Rico Seismic Network (PRSN) of the University of Puerto Rico at Mayagüez is establishing a Tsunami Warning System (TWS) for PR/VI. Part of the TWS is the EarlyBird system, developed by the West Coast/Alaska Tsunami Warning Center, which has been running in the PRSN since January, 2003. This program automatically locates and disseminates information on potentially tsunamigenic earthquakes. Also, the existing protocol for exchanging data and information on potentially tsunamigenic events in the PR/VI is currently being reviewed by the concerned institutions. Tsunami flood maps were prepared for all of Puerto Rico, including the island municipalities of Vieques and Culebra. These flood maps were generated in three phases. First, hypothetical tsunami scenarios on the basis of the parameters of potential underwater earthquakes were developed. Secondly, each of these earthquakes source scenarios was simulated. The third step was to determine the worst case scenario for a tectonically generated tsunami throughout Puerto Rico. The runups were drawn on GIS referenced topographic maps and aerial photographs. These products are being used by the local, state and federal emergency managers to educate the public and develop mitigation strategies. Based on these maps tsunami warning signs are being installed throughout the potentially affected zones and are a very important component of the TWS.

OS21D-03 1050h

THE PRELIMINARY ESTIMATES OF TSUNAMI RISK ZONES FOR THE COAST OF MARMARA SEA

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The sea of Marmara is located at Northwestern part of Turkey, south of Istanbul. The western end of North Anatolian Fault zone passes the sea of Marmara and terminates at north Aegean. More than 30 tsunami events have impacted the coasts of the sea of Marmara in the past two millennium and clustered in Ýzmit Bay, Ýstanbul shores, Gemlik Bay, Tekirdag shores of Kapýda and Gelibolu peninsulas. The historical earthquakes and associated tsunamis near Southwestern Anatolia are selected from the catalogues (till 1900) and seismic data (since 1900. The occurrence probability of large magnitude earthquakes and tsunamis are determined. The sources of tsunamis might be either submarine landslides or fault breaks in the region. Numerous different synthetic tsunamis related to either landslides or fault breaks are determined and simulated by using two mathematical models TUNAMI-N2' and TWO-LAYER' which are developed in Tohoku University and METU for different types of tsunami generation mechanisms. The maximum water level near the shore for each simulation at 50 different specified shore locations are stored and analyzed together for all different scenarios. The distribution functions of the positive tsunami amplitudes for each shore station are obtained. The relation between the maximum tsunami amplitude and the expected mean tsunami amplitude for the region is determined from the analysis. The expected range of tsunami arrival times and the relation between the expected and maximum tsunami amplitudes for the North and South coasts of the sea are derermined. The computed statistical distribution function is compared with the theoretical model of log-normal distribution. The distribution functions for randomly selected cases are presented. The probabilistic results are discussed for the determination of the tsunami danger at selected coastal locations in order to support the mitigation studies against not only the seismic but marine hazards.

OS21D-04 1105h

New Approach to Sea Level Monitoring Tested at Shemya, Alaska

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Due to the prohibitive installation cost to replace a storm damaged stilling well type tide gauge at Earickson Air Force Station on Shemya Island, Alaska, an alternative sea-level gauge was sought by the West Coast and Alaska Tsunami Warning Center (WCATWC). An Omart-Vega radar system was chosen as the alternative, since it had low power needs, did not require a stilling well and its design included observation of rough surface liquids. The Omart-Vega radar system works by emitting a 5 gHz radar wave which reflects off the water surface and then back to the unit at a specified rate. This information is then telemetered directly to a computer which records the sample. Although the cost of the Vega system (3500USD) was similar to that of the stilling well unit (2500USD), the comparison of the installation costs of the two different units was an issue. To install the stilling well system, two certified under-water welding divers were required at a cost of 40K-USD or more. In comparison, the installation of the Vega system simply required an arm constructed so as to hang and support the Vega unit off the pier at Shemya. This arm assembly would also house the unit to protect it from surf and weather. The arm was designed in-house and built by a local metal contractor for less than 500USD. This portable unit was sent to Shemya via C-130 aircraft. The arm assembly and housed radar tide gauge was installed by one person. The circuitry to run the Vega was developed and tested at the WCATWC. Software was designed and tested there as well, although the software was written by Omart at no cost to the Warning Center. The circuitry allows for direct remote reconfiguration from Palmer to the radar system. The Vega is accessed by software directly from the WCATWC computer to sample the water level at numerous settable sample rates, which include one second, five second, fifteen second, and thirty second. After nearly one year of operation at Earickson, which included many major storms, the radar unit is proving to be a reliable substitute for the previous stilling well type gauge.

OS21D-05 1120h

Hydrodynamic modeling of the 1946 Aleutian tsunami in the far field using a dislocation source

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We present the results of simulations of the amplitude of 1946 Aleutian tsunami at about 25 transpacific locations, principally in Polynesia, and compare them to the database obtained during the field surveys taken in 1999-2001 by Okal et al. The source used is an elastic dislocation with a seismic moment of 9*10**28 dyn-cm as suggested by the recent analyses of Lopez and Okal [2002]. The simulation is carried out on a series of grids of increasingly fine scale, up to a final 50 m. We consider only overland locations, and do not model run-up in narrow river beds. Absolute values are found to vary from 2.5 m to 7 m on the shorelines of the Marquesas and Juan Fernandez Islands. A dataset of 22 comparisons with values surveyed in the field shows an average ratio (computed/observed) of 0.84 (-0.07 decimal logarithmic units) with a standard deviation of 0.17 d.l.u. (*/ by a factor of 1.48). In particular, the values computed overland in the principal bays of the Marquesas are generally well reproduced. Most importantly, we compute a small amplitude at Juan Fernandez Island (2.5 m; measured: 2.7 m). We are thus able to reproduce the sharp directivity of the wave in the far field, a consequence of the longitudinal extent of the source region along the trench. When combined with previous successful modeling of run-up in Hilo from a dislocation source by Titov [2001], we conclude that the far field of the 1946 tsunami can be adequately modeled by an acceptable seismic dislocation, rather than by a landslide source. The latter, which is necessary to model the near field [Okal et al., 2003] most probably took place, but did not contribute substantially to the far field.

OS21D-06 1135h

Tsunami Hazards From Strike-Slip Earthquakes

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Strike-slip faulting is often considered unfavorable for tsunami generation during large earthquakes. Although large strike-slip earthquakes triggering landslides and then generating substantial tsunamis are now recognized hazards, many continue to ignore the threat from submarine tectonic displacement during strike-slip earthquakes. Historical data record the occurrence of tsunamis from strike-slip earthquakes, for example, 1906 San Francisco, California, 1994 Mindoro, Philippines, and 1999 Izmit, Turkey. Recognizing that strike-slip fault zones are often curved and comprise numerous en echelon step-overs, we model tsunami generation from realistic strike-slip faulting scenarios. We find that tectonic seafloor uplift, at a restraining bend or"pop-up" structure, provides an efficient mechanism to generate destructive local tsunamis; likewise for subsidence at divergent pull-apart basin structures. Large earthquakes on complex strike-slip fault systems may involve both types of structures. The California Continental Borderland is a high-relief submarine part of the active Pacific-North America transform plate boundary. Natural harbors and bays created by long term vertical motion associated with strike-slip structural irregularities are now sites of burgeoning population and major coastal infrastructure. Significant local tsunamis generated by large strike-slip earthquakes pose a serious, and previously unrecognized threat. We model several restraining bend pop-up structures offshore southern California to quantify the local tsunami hazard. Maximum runup derived in our scenarios ranges from one to several meters, similar to runup observed from the 1994 Mindoro, Philippines, (M=7.1) earthquake. The runup pattern is highly variable, with local extremes along the coast. We only model the static displacement field for the strike-slip earthquake source; dynamic effects of moving large island or submerged banks laterally during strike-slip events remains to be examined. Depending on the size, recurrence of Southern California tsunamis from submarine strike-slip faults is estimated at a few hundred to few thousand years, similar to return periods estimated for large earthquakes on other active faults within the urban area. The combined probability from onshore and offshore hazards may be higher.

OS21D-07 1150h

Progress in Tsunami Deposit Research- What Should Mega-tsunami deposits look like?

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Large landslide scars and debris flows surround ocean islands. It has been proposed that these landslides could trigger "Giant Waves." However, the basic tenets of the Giant Wave Hypothesis have proven problematic. What characteristics should mega-tsunami deposits display? Tsunamis are depositional and erosional

in desultory fashion. Numerous studies, show that tsunami derived deposits share many characteristics, e.g. sand sheets, marine shells deposited in subaerial settings, boulder deposits, etc. Sediments fine inland and upland (a distribution pattern not unique to tsunami). Tsunami deposits could be restricted to a single event, or alternately the backwash could erode and mix materials from multiple events (e.g. material in wave cut notches). It is difficult to differentiate between tsunami and storm deposits. Modern cementation of coral and basalt clasts on rocky shores today resemble proposed paleo-tsunami deposits. Tsunami deposits reflect their local source. Although tsunami deposits should reflect the carrying power of the waves, they can only do so if material of the appropriate size and density is present to reflect that carrying power. Complicating the situation, uplift can expose conglomerates above sea level. Although subsidence is characteristic of many oceanic islands, it should not be assumed to dominate in all cases.Tsunami deposits are ephemeral (easily eroded by normal beach processes, mixed with soils, and remobilised by anthropogenic activity) and many of their most diagnostic features can disappear within years after an event.

OS21D-08 1205h

Numerical Modeling of Generation of Surface Water Waves by Motion of the Drowned Soil

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Recent scientific publications contain enough evidences that the key source mechanisms of formation of abnormal tsunami waves in near-shore areas of the World Ocean are the large-scale underwater landslides. The mathematical modeling of generation of waves of such nature is reduced to the description of dynamics of the motion of the drowned mass of a soil and to the solution of a hydrodynamic problem for the arising surface waves. The scales of temporal and (or) spatial characteristics of lithodynamic processes are different, therefore several approaches to simulation of the motion of a landslide were proposed. In a number of publications the landslide is treated as a non-deformable solid body. The attempts to consider a landslide as elastoplastic medium moving and interacting with the surrounding flow are made. For some underwater slides the simulation of a phenomenon is represented within the framework of a two-layer fluids of different density and viscosity. To construct the numerical model of a phenomenon it is necessary to match the mathematical models of the slide motion and surface water waves propagation. The aim of this work is to construct and to investigate the hydrodynamic component of such a complex model. It is supposed, that the phenomenon has the long-wave nature, and the simulation of surface waves in ideal incompressible fluid is conducted in a usual way - within the framework of a hierarchy of shallow water models of different order of hydrodynamic approximation (linear, non-linear and non-linear-dispersion equations). The numerical algorithms are based on finite-difference methods. For hyperbolic equations the Mac-Cormack type schemes with special adjustment of the right hand side is used. For non-linear-dispersion equations the schemes of the second order of approximation keeping a number of control parameters, permitting to allow for or to leave out the non-linear effects, and also selectively to apply a procedure of smoothing are constructed. A one dimensional numerical model of waves generated by a body moving over the bottom was constructed as a first step. The relation of parameters of a generated wave to the shape and size of a mooving body, and also from the law of is studied. We consider the cases of a horizontal and an inclined bottom. The problem was further investigated, when the landslide is modelled within the framework of elastoplastic medium. Our numerical experiments have proved that the specific features of the wave generation process can be robustly reproduced within the framework of approximated hydrodynamic models: the fore-runners by the way of denivellation waves, rearrangement of wave process are described at the moment when the landslides slows down and other effects. The features of the processes, related to the non-linear and dispersive characteristics of the medium are determined. The work is executed under financial support of the Russian Foundation for Basic Researches, grant 03-05-64108, and also the Program of Integration Researches SB RAS, grant 2003-5.

OS22A MCC: Level 2 Tuesday 1330h

Identifying Submarine Landslide Time of Failure I Posters *(joint with T)*

Presiding: **D R Tappin,** British Geological Survey**; P Watts,** Applied Fluids Engineering, Inc.

OS22A-1146 1330h POSTER

The Matakaoa Margin Multiple Mudflows, North-East New Zealand

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The 45 km-long, 30 km-wide Matakaoa re-entrant near the collisional Australian-Pacific plate boundary off New Zealand, has incised the at least 1000 m-thick, seaward dipping sedimentary section of the East Cape margin. Swath bathymetry and seismic reflection data provide clear insights into the margin's evolution, and in particular the mechanisms associated with submarine debris avalanches and flows. The re-entrant morphology suggests active erosion at its head, as shown by pervasive gully formation, large slump blocks in the process of collapse, and an active, fan/channel system. Blocks up to 2.8 km across scatter the area north of the re-entrant, and indicate the large Matakaoa debris avalanche. North of the re-entrant, three major debris flows are identified within the first kilometres beneath seafloor. (1) The oldest flow is 60 km wide and extends 70 km north from a large basement anticline at the re-entrant mouth. At the base of the flow, coherent reflections indicate numerous imbricated thrusts and faults over a distance of at least 50 km. This may indicate viscous behaviour possibly due to dewatering during flow emplacement. (2) The second flow overlies the first over its entire 70 km-length. Its western flank is eroded into a conspicuous 200 m-high NNE-trending scarp, outlined by numerous kilometre-scale angular blocks detached from the main body of the debris flow. The scarp forms the eastern limit of the major channel that guides turbidity currents descending from the re-rentrant. (3) The youngest flow, the Matakaoa debris flow, fills the major channel, and extends 200 km north. It appears contemporaneous with the Matakaoa avalanche. First estimates give debris flow volumes ranging 500-1000 km3. The eastern re-entrant is filled by an estimated 15 km3 of material slumped from the margin either contemporaneous with or post-dating the Matakaoa debris flow. Rapid sediment accumulation, from high discharge rivers draining the rapidly uplifting East Cape region, may provide enough material to generate 20 km3 debris flows every 500-2000 yrs. Deposition of thick sediment piles about the faulted headward scarp of the re-entrant, coupled with the region's high seismicity, are prime factors controlling the multiple margin failures.

OS22A-1147 1330h POSTER

Investigation of gravitational mass transport processes using numerical simulations

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High-production regions, i.e. the NW African continental margin, are characterized by high sedimentation rates at upper slope. These materials are episodically transported down-slope in form of slides, debris flows, or turbidities. The main aim of our studies is to quantify the influence of different key parameters, i.e. material properties and geometrical settings, for deformation and kinematic behavior of gravitational mass transport processes. We use a numerical particle-based method - the Distinct Element Method (DEM) which has been proved to be an efficient tool to simulate geodynamical processes. This technique provides detailed information about mechanics and kinematics of downslope processes, their mass transfer patterns, as well as internal and morphological structures. Furthermore, it enables a wide range of material parameters and model configurations to be tested. We develop a 3D DEM model which consists of a plane shelf, continental slope, and abyssal plain. Sediment layer is built up by spherical, elastic frictional particles which settle down under gravity on upper slope. We change iteratively the basal friction of slope surface as well as internal friction of sediments. Further model configurations are fixed. A decrease of basal and internal friction of sediments causes always an increase of run out length of the flow while thickness of depositions and lateral extension decrease. In addition, surface structures of lower slope change remarkable. Thus, we identified basal friction as important key parameter for spatial dimension and morphology of mass flow events. Nevertheless, we have to investigate the influence of model configurations in the face of transferability of model results into a natural system. Therefore, we developed a high-resolution 2D DEM model where (a) all spheres settle down under gravity in a triangular shaped box on upper slope. Removing box boundaries releases a gravitational mass flow. In experiment (b) all particles are settled under gravity on top of a shelf surface and they are transported progressively by a bulldozer to the upper slope. In both experiments, we observe a similar relationship between friction distribution and mass flow behavior. However, experiment settings (b) produce more natural process behavior.

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Landslide Deposits, Cookie Bites, and Crescentic Fracturing Along the Northern Puerto Rico-Virgin Islands Margin: Implications for Potential Tsunamigenesis

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The seismogenic North America-Caribbean oblique-slip plate boundary forms the 8-km-deep Puerto Rico trench north of the densely populated islands of Puerto Rico and Virgin Islands (combined population of just over 4 million people). The southern slope of the Puerto Rico trench adjacent to the Puerto Rico-Virgin Islands (PRVI) carbonate platform is characterized by frequent seismicity, rapid trenchward tilting, over-steepened slopes, and mass wasting. We present high-resolution bathymetry, HMR1 sidescan imagery, and single-channel seismic data to document extensive landslide deposits that we infer to have been the result of multiple slide events capable of producing prehistoric tsunamis along the coasts of Puerto Rico and the Virgin Islands. Landslide deposits can be traced upslope to two, 45-55 km-wide arcuate-shaped embayments or "cookie bites" carved out of the PRVI platform. Three-dimensional visualization of the debris field and the slope of the largest of the arcuate-shaped embayments centered at 66° 40' constrain volume removal to 1.1 km^3 of the PRVI carbonate platform and underlying volcanic and volcaniclastic basement. Sidescan sonar and single-channel seismic data reveal crescentic cracks in the seafloor of the PRVI platform 35-45 km in length located 35 km offshore the northwestern tip of Puerto Rico. These cracks, interpreted to represent the sites of future breakaway scarps and landslides, are similar in shape and length to the head wall scarps of the amphitheaters to the east. An $\sim$500 km^2 section of the PRVI platform (750 m thick) has begun to detach and slump trenchward along the larger of these cracks. Investigation of the existing arcuate-shaped embayments is essential because massive (tens to hundreds of km^3) and instantaneous slope failure has the potential to be tsunamigenic. Puerto Rico and the Virgin Islands were inundated by tsunamis in 1867 (mainly affecting St. Thomas and St. Croix, 7 m of runup, casualties in the hundreds) and 1918 (mainly affecting western and northwestern Puerto Rico; 6 m of runup, 120 casualties). Calculation of the potential volume, runout extent, and triggering mechanisms of past submarine landslides will better constrain the tsunamigenic potential of the newly discovered crescentic faults.

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Dating Submarine Landslides: the July 17th 1998 Papua New Guinea Event

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