OS42A-0465 1330h POSTER

The Stacked Channel-Levee Systems at the Middle Bengal Fan Imaged by High Resolution Seismic Data

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The Bengal Fan is the largest submarine fan on Earth and covers the whole Bay of Bengal. The fan is built up by the sediment load of the Ganges and Brahmaputra rivers, which drain the Himalayan and react to tectonic and climatic changes on land. Therefore the Bengal Fan is well suited to study the linkage between processes on land and the marine sedimentary record. The sediment reaches the deep sea through a canyon deeply incised into the shelf, acting as a temporary trap. Turbidity currents transport the sediment episodically on the fan building successively several channel-levee systems, but only one channel is active at a time. In 1997 during R/V Sonne Cruise SO 125 to the Bay of Bengal, the morphology and structure of the Bengal Fan were studied at different distances from the shelf. In addition, the seismic data were used for an ODP drilling proposal "Drilling in the Bengal Fan" by France-Lanord, Spiess, Molnar & Curray. A main objective of the SO 125 Cruise was the investigation of the middle Bengal Fan at 16.5°N, especially of the architecture of the active channel-levee system. A closely spaced grid of Parasound sediment echosounder, Hydrosweep Swath Sounder and very high-resolution seismic data were collected in the vicinity of the active channel, completed by two long W-E Profiles to the west and the east of the active channel. As seismic sources a watergun with frequencies between 200 and 1600 Hz and a GI Gun with frequencies between 100 and 400 Hz were used in an alternating operation mode. At the middle Bengal Fan, the active channel is characterised by a high sinuosity and an exceptionally low gradient. By a combined Parasound and Hydrosweep survey more than 20 cut-off loops could be identified. The sedimentation on the levees varies strongly and depends on the relative position to the channel loops. The base of the active channel is characterised by high amplitude reflections in the seismic data, which are interpreted as coarse-grained sediments deposited after erosion of older sediments. Numerous abandoned and buried channel-levee systems could be identified in the seismic data. They strongly vary in lateral and vertical dimensions, suggesting different sediment inputs and lifetimes. High amplitude reflections were found at the base of most of the channels. The channel-levee systems are grouped in distinct complexes, which are separated by thick turbidite sequences. With increasing depth, the reflectors become flat and no levee structures are visible, leading to the conclusion that they were either destroyed or have never existed.

URL: http://www.mtu.uni-bremen.de

OS42A-0466 1330h POSTER

Controls on Submarine Canyon Development Along the Eastern Margin of the Rockall Trough

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Deep towed sidescan sonar data from the Rockall Trough, west of Ireland, provides an example of how shallow sedimentary facies architecture and slope morphology, related to major submarine canyons, evolve in a deep-water basin straddling the transition from a glaciated to a non-glaciated basin margin. In the north (54° to 56° N), glacial influences were overwhelming and a stacked sequence of flow slides is developed on the upper to mid-slope. In steeper regions of the slope, cauliform gully systems are likely to have been produced by gravitational collapse of Quaternary glaciomarine and older sediments close to the steeper headwall regions of incised pre- Quaternary canyons. The input of glacial sediment and the frequency of slope failure events was probably pulsed and forced by palaeoclimatic variations in the North Atlantic during the Pleistocene epoch. A difference in the morphology of the canyons south of 54° N (notably the absence of gully complexes) marks an important change in sedimentological processes and is related to a severe reduction in the supply of glaciomarine sediments southwards along the margin. Channels along this part of the basin margin are deeply incised into consolidated sediments or rock along the lower part of the slope. These channels may be part of geologically ancient system of canyons, which were active during a period of basin margin uplift and later drowned by rapid Tertiary subsidence. Subsequently, they acted as a transport pathway for late Tertiary and Quaternary sediments and for those remobilized by strong Holocene contour currents.

OS42A-0467 1330h POSTER

Reevaluation of the 1737 C.E. Earthquake Based on Paleoseismic Evidence Collected Along the Coast of Kamchatka, Russia

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Tephrochronological dating of deposits underlying the coastline from the Vestnik River delta to Karaginskiy Island, Kamchatka Peninsula, Russia was conducted in the search for tsunami deposits. This study revealed the presence of one sand sheet that may have been deposited by the November 4, 1952 A.D. tsunami. The sand sheet becomes thinner and finer-grained landward, and blankets pre-tsunami topography along with some evidence of erosion. It has been interpreted as tsunamigenic, mainly because its stratigraphic position and sedimentological characteristics are consistent with the 1952 event.

The rupture zone of the earthquake that triggered the tsunami of 1952 A.D. is located parallel to the subduction zone proximal to Vestnik Bay. Based on Russian and Japanese historical records it is accepted that another tsunami from the pre-instrumental seismology period was triggered by an earthquake in the same rupture zone in 1737 C.E. The 1737 tsunami is known among seismologists as the largest and earliest known historical seismic event for Kamchatka. Due to the lack of strong evidence for the 1737 deposits along the shoreline of Southern Kamchatka we had to reevaluate the rupture zone area for 1737 event.

OS42A-0468 1330h POSTER

A Peek at Fluid Flow in Monterey bay Cold Seeps Using Peepers

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The egress of pore water from the oceanic crust along plate boundaries includes pore water and bound volatiles from sediment as well as seawater that have interacted with basement rock. The chemical composition of these fluids is governed by complex water-rock interactions that are also a function of temperature and pressure. Several such sites of fluid seepage were located in Monterey Bay (USA), which has active strike-slip faulting and evidence for compression in the northern portion of the bay. Fluid and chemical fluxes were determined from these seeps to provide insights to the mechanisms for fluid release and the chemical conditions under which this fluid was altered.

Systematic variations in pore water chemical and thermal data provide a measure of the composition of the fluid at depth, an estimate of the speed of upwelling, and an assessment of chemical reactions that alter the fluid as it ascends to the seafloor. Pore water chemical data, which were collected from in-situ extractors ("peepers") that provide for a contamination-free sample, and thermal data indicate maximum upwelling speeds of 1-5 cm/yr at most seeps, with the exception of Extrovert Cliff where upwelling speeds are as high as hundreds of m/yr. These fluids are the most altered fluids in the bay (units mmol/kg: S 12; SO4 0; Ca 16.4; Mg 28.4; K 6.0; Sr 0.35; Li 0.038; Alk 15; Cl 560). Elucidating environmental conditions under which fluids from each of the sites formed may ultimately permit us to constrain some of the variables controlling tectonic phenomena in Monterey Bay and along plate margins in general.

OS42B MC: Hall D Thursday 1330h

High Latitude Oceanography

Presiding: **J Whitehead,** WHOI

OS42B-0469 1330h POSTER

Statistics of Ice Extent in the Barents Sea, 1850-1949

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In the early 1850s, Norway began an intensive program of sealing and hunting (typically March through September) in the Nordic seas. Comprehensive ice edge data were organized and charted by the Norwegian Meteorological Institute (DNMI). In addition to the ice edge position, there is limited information about ice type near the ice edge.

Our working hypothesis is that direct observations of sea ice extent are suitable for quantitative study; thus, we seek reasonable definitions of the mean and second moment statistics. For the initial study we focus on ice extent in the Barents Sea. Because of the large annual cycle of the ice edge position, the statistics are being grouped by month. The mean monthly ice edge position is parameterized as a function of distance, here measured from the west coast of Spitsbergen along the mean ice edge, to the Kola Peninsula. The annual anomaly of ice edge location is defined as the perpendicular distance from the mean to the observed ice edge.

Monthly ice edge anomaly is regarded as a random variable. We have formulated ice edge anomaly as a scalar function of distance along the mean monthly ice position. Our objective is to present conventional statistical results: mean monthly ice edge, variance of ice edge position and spatial autocovariance.

OS42B-0470 1330h POSTER

Thermocline Depth and Exchange Fluxes Across Circumpolar Fronts

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In the southern oceans meridional gradients in air-sea buoyancy flux act to create a strong polar front along which the Antarctic Circumpolar Current (ACC) flows in thermal wind balance with lateral density gradients. Westerly winds also drive the ACC eastward and, through associated Ekman currents, induce an Eulerian meridional circulation (the Deacon cell) which acts to overturn isopycnals enhancing the strong frontal region. The potential energy stored in the front is released through baroclinic instability and the ensuing eddies play a fundamental role in the dynamical and thermodynamical balance of the ACC.

We are investigating the possibility that the final stratification of the circumpolar front could be set by a balance between the rate at which potential energy is created by mechanical and buoyancy forcing and the rate at which it is released by eddies. A series of idealized laboratory experiments have been performed to examine the processes that govern such phenomena. In a rotating cylindrical tank, the combined action of mechanical and buoyancy sources using pumps acts to build stratification creating a large-scale front. At equilibrium, the depth of penetration and strength of the current is then determined by the balance between lateral/vertical eddy transport and sources and sinks associated with imposed patterns of Ekman pumping and buoyancy fluxes.

There are two governing dimensionless numbers. One is the non-dimensional deformation radius, $L_\rho = (g'H/2)^{0.5}/fR$, a measure of the strength of the buoyancy forcing. This parameter compares the rotation time scale, f^{-1}, to the time it takes a internal gravity wave of half tank depth, H/2, of speed $c = (g'H/2)^{0.5}$

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to travel the radius of the tank R. The second is the mechanical forcing parameter $\tau = w_e/Hf$, which compares the rotation time scale to the vertical advective time-scale H/w_e, where w_e is the vertical velocity from a pump. By varying these parameters we controlled the mix of mechanical and buoyancy forcing.

Hence, in a rotating tank we generated a dense current using both a buoyancy and mechanical source. A theoretical prediction for the equilibrium depth h_c is proportional to $R(w_e f/g')^{0.5}$ and for experiments within a certain parameter range the experimental equilibrium depth agrees with this prediction. Comparison between the theoretical prediction for the velocity scale and the experimental horizontal velocity will be also presented.

Finally we discuss the implications of our study for understanding those processes that contribute to setting the stratification and transport of the ACC itself.

OS42B-0471 1330h POSTER

Measurements of the sea ice Thickness Distribution and Icebergs Using the Autonomous Underwater Vehicle Autosub 2 in Antarctica

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In February 2001 the AUV Autosub 2 was used to investigate the marginal ice zone of the northern Weddell Sea. Targeted goals were to deploy the AUV from a research ship and derive the thickness of Antarctic sea ice on the scale of 10's of km, make measurements beneath different types of icebergs, determine whether a very important food resource - the Antarctic krill - was more abundant under sea ice or in open water and to measures downwelling irradiance beneath sea ice. Here we report on the first two of these goals. For these missions Autosub was comprehensively equipped with a scientific package including two CTD's, two ADCP's, a light sensor, oxygen and chlorophyll sensors, transmissiometer and a scientific echosounder operating at two frequencies. There were routinely two types of missions: relatively long transects from open water into the ice and back out again, and short missions under selected icebergs in various states of decay. There were 20 missions in total that collected over 480 km of data, 275 km being beneath sea ice. Whilst on the longer missions the research ship partially followed the same track as the AUV and collected digital images for photogrammetry in addition to measuring snow depths at selected locations. Here we present the sea ice thickness distribution for the missions and various associated parameters including lead spacing and mean ice keel depths. We also present hydrographic data from a particularly close approach to an iceberg showing a distinctive melt signature.

OS42B-0472 1330h POSTER

Viscous-plastic Behavior of Sea Ice as the Quasi-static Limit of Elastic-plastic Behavior

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In the past, viscous-plastic (VP) and elastic-plastic (EP) constitutive laws have been compared for stress states within the yield surface. Here we consider the relationship between these laws when plastic flow occurs and stress lays on the yield surface. An essential property is that steady state solutions to the EP law satisfy the VP law. This property suggests that the two different laws describe sea ice dynamics behavior at two different time scales. Inertia in the ice momentum balance also introduces a time scale on the order of a fraction of a day. As a result, we suggest that one of two different consistent models should be used. For short-term simulations that resolve synoptic time scales, the model should include inertia in the ice momentum balance and the upper ocean model (water drag law), tidal forcing should be included, and the EP law is preferred because it describes the stress path. For long-term simulations describing climate changes that resolve time to no less than a day, inertia should be neglected in the ice momentum balance the and upper ocean model, tidal forcing should be neglected, and the VP law is preferred. The latter model is quasi-steady, with time entering only through the hardening law.

OS42B-0473 1330h POSTER

A Study of the Momentum Balance of the Antarctic Circumpolar Current in a Global Ocean General Circulation Model

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The Antarctic Circumpolar Current (ACC) is the strongest current in the world. It connects all three major ocean basins and is therefore of greatest importance for the global ocean circulation. Ocean models need to include a realistic representation of the ACC in order to correctly simulate the transport of heat, freshwater, and geochemical tracers throughout the world ocean.

It is still a matter of heated debate what the balances of forces are that drive the ACC. To address this question, the thermohaline and wind driven components of the circulation as well as their interactions need to be identified and quantified. Studies with models of different complexities, using realistic or idealized topographies and applying various wind and thermohaline forcings have helped our understanding of the interactions between the ocean floor, the baroclinic and barotropic structure of the water column and the wind driven circulations. Yet, the relative importance of these components in establishing the momentum balance of the ACC is still unclear.

Here, we use the latest version of the GFDL modular global ocean model (MOM3) to investigate the momentum sources and sinks and the dynamical balance of the ACC. The path of the ACC is divided into several regions, namely the Drake Passage, the Weddell Sea, the Indian and Western Pacific Sectors of the Southern Ocean and the Bellinghausen Seas, in each of which the barotropic and baroclinic structures of the ACC are investigated.

The dynamics of the ACC are strongly influenced by the action of the eddy field that is parameterized in coarse resolution ocean models via horizontal-isopycnal and vertical diffusion terms. In our simulations we use the spatially non-uniform mesoscale eddy diffusivity formulation of Bryan 1999 and the topographically enhanced vertical mixing of Hasumi and Suginohara 1999.

The magnitude and distribution of these diffusivities is crucial for determining the strength of the ACC notably in the Drake Passage. The overall picture of the study is that the ACC is strengthened over areas of rapidly changing topography and weakened in areas of intense mesoscale eddy activity.

OS42B-0474 1330h POSTER

Multiple equilibrium laboratory devices

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Devices⋆ will be demonstrated and videotapes played of a number of laboratory studies that exhibit multiple equilibrium. All devices have two competing effects driving the flow. In two of them, temperature and salinity oppose each other. In another, air and water compete. In a fourth, wave propagation is opposed by inertia. Connection with hypothesized ocean behavior will be made.

⋆ Whitehead, J. A. 2000 Stratified Convection with Multiple States. Ocean Modelling, 2, 109-121. Whitehead, J. A. W. Gregory Lawson and John Salzig. 2001 Multistate flow devices for geophysical fluid dynamics and climate. American Journal of Physics, 69 546-553. Whitehead, J. A. and P. G. Baines. 2000. Hydraulic Jump Location as a Multiple Equilibrium feature. 2000 Ocean Sciences Meeting, American Geophysical Union, San Antonio Texas, January 25, 2000. Abstract: EOS 80 #46 (Supplement), OS125. Whitehead, J. A. , M. L. E. Timmermans, W. Gregory Lawson, S. N. Bulgakov, A. M. Zatarian, J. F. A. Medina, and John Salzig, Laboratory studies of thermally and/or Salinity-driven flows with partial mixing: Part 1 Stommel transitions and multiple flow states. In preparation

OS42B-0475 1330h POSTER

Spatial patterns in buoy-derived sea-ice motion and deformation in the Arctic Ocean over the last two decades.

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The Arctic sea ice is an important part of the northern polar climate system. Since the 1970s remote observations of sea-ice velocity are available from satellite-based instruments and *in situ* from drifting buoys. The spatial resolution of the remotely-sensed data is generally too coarse to resolve the typical floe size. Often the instrument repeat cycle was once per day or less. From 1979 onwards sea-ice buoys have systematically been deployed in the Arctic Ocean, and lagragian ice-drift data have been archived by the *International Arctic Buoy Program* (IABP). Over the years the horizontal accuracy obtained through the *Argos* positioning system improved from about 400 to 250 m and better, and is better than 50 m for GPS positioning. For buoys deployed in the region between $60^{\circ}N$ and the north pole temporal resolution ranges from 22 to 28 location fixes per day. Generally this allows the construction of equi-temporal data sets at resolutions as fine as 2 hourly. These high-resolution buoy-derived ice velocities are analyzed to yield spatial patterns of the two-dimensional variance. These are then compared to the variance pattern obtained from the analysis of atmospheric surface forcing. Similarly the variance of the two-particle motion of a pair of buoys or the variance ellipse of the deformation of a cluster of three or more buoys can be geographically mapped. In regions with persistent buoy coverage (e.g., the central basin) time-series of the variance patterns of ice motion and deformation are constructed. The persistence of the spatial variance patterns of sea-ice motion and deformation are then evaluated in the light of the variability in the atmospheric forcing.

OS42C MC: Hall D Thursday 1330h

Oceanography Along the Ocean Margins

Presiding: **C Flagg,** Brookhaven National Laboratory

OS42C-0476 1330h POSTER

Historical Changes in River Discharge in the Lower Columbia River: Impacts on River Stage, Tidal Range and Salmonid Habitat

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Juvenile salmonid access to favorable shallow water habitat in a tidal river and estuary is a function of river stage, tidal range, and the system's distribution of bed elevation. In this study, we investigate how historical changes in Columbia River discharge, due to climatic variability and flow regulation, affect river stage, tidal range, and salmonid access to shallow-water habitat in the lower Columbia River. Tidal height data collected (19802001) at gauging stations below Bonneville Dam (230 km from the ocean) are filtered to retrieve time-series of fluctuations in river stage, diurnal and semi-diurnal amplitude, overtides and tidal range. It is necessary to design a new filter bank, optimized with respect to time-frequency resolution, in order to capture the relevant physics of the non-stationary riverine-tidal processes. Tidal range and tidal amplitudes of the major tidal constituents are shown to have an approximately negative-exponential dependence on upriver distance and the square root of river flow. The river stage varies linearly with river flow to the first order. These results are consistent with solutions of the linearized St. Venant equations. Further, the results imply the division of the Lower Columbia River with respect to tidal damping and stage-flow dependency into fluvial and estuarine regimes. Stage and tidal range are more strongly related to river discharge in the fluvial than in the estuarine regime. The interface between the two regimes lies in the energy minimum region, roughly 50 km from the ocean, where dissipation is weak and about equally divided between tides and river flow. With these results and hypsometeric data, scenarios of historical flow variability and their impacts on shallow-water habitat access are reconstructed. We compare: a) tides during years with low-flow to those during years having strong freshets, and b) tides under highly regulated flows with those that would have prevailed without regulation. Because tides are strongly damped by high river flows, tides were historically much smaller during the downstream migration of juvenile salmonids than is the case at present. Overall, the historic decrease in spring river stages has not compensated by the increased tidal range. Modern flow regulation coupled with diking prevent overbank flow and access to previously available habitat.