OS42O-09 1550h

Internal Tide-Induced Variations in Primary Productivity and Optical Properties in the Mona Passage, Puerto Rico

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Internal tides of near-semidiurnal frequencies were observed in the euphotic zone. The maximum observed height (crest to trough) was 26 m. Maximum concentrations of chlorophyll-a (1.2 mg Chl-a m^{-3}) occurred near the crest during high upward velocities (> 40 m h^{-1}). Additionally, increases in vertical eddy diffusivity above 6 x 10^{-3} m^2 s^{-1} were observed one hour before the arrival of the internal tide trough. The development of K-H instabilities during the breaking of the internal tide can explain the formation of high diffusivity patches. Inside the patches (κ_d > 0.004 m^2 s^{-1}) increments in primary productivity of the order of 0.05 mg C m^{-3} h^{-1} were measured. The patches generated a NO3 flux equal to 1.058 x 10^{-4} mmol m^{-2} s^{-1} and can sustain a new production equal to 724 mg C m^{-2} d^{-1} or 264 g C m^{-2} yr^{-1}. These numbers are much higher than the estimates attributed to mesoscale eddies. Higher values of primary productivity were observed near the wave trough, than those observed during periods of maximum solar irradiance at noon. Significant changes in the attenuation coefficient (from 0.03 m^{-1} to 0.05 m^{-1}) for the following SeaWiFS bands: 412, 443, 490 and 512 nm corresponded to events of maximum upward velocities and higher diffusivity. These processes seem to be easy to detect in oceanic waters, out of the influence from high nutrient load waters due to river discharge.

OS42O-10 1605h

A view of internal tides courtesy the venerable tide gauge: Discrimination of barotropic and baroclinic contributions.

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Tide records provide one of the few multidecadal to century long timeseries measurements in oceanography. With renewed interest in internal tide phenomenon and with the launching of large field programs aimed at quantifying internal tide variability, tide gauge analysis of internal tides may provide an interesting long-term perspective, and coastal boundary condition. We have devised a method for separating the barotropic and baroclinic contributions to a standard tide elevation record. Our model is a phase and amplitude modulated internal tide from a few sources, which is superimposed on a steady tidal constituent. Phase modulation of the internal tide, presumably due to a variable thermocline, plays a dominant role, and leads to frequency smearing of tidal energy (a phenonemon that Munk and Cartwright in 1966 named tidal cusps). The connection of phase modulation to the variable thermocline suggests a tantalizing possibility for using baroclinic tide phase to measure the thermocline. Using demodulation and for a single internal tide source, we can solve the problem completely for the internal tide amplitude, and phase time history, as well as the barotropic tide amplitude and phase. We will present results from a toy model of barotropic and baroclinic tides, and we will apply the method to Hawaiian island tide records. A discussion of the application of the method to more complicated multiple source and/or baroclinic modes will be given.

OS42O-11 1620h

Spatially Broad Observations of Internal Waves in the Upper Ocean at the Hawaiian Ridge

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The internal wave field at the Hawaiian Ridge is studied using SeaSoar and hydrographic Doppler sonar data. Observations and models have demonstrated that the Hawaiian Ridge is an important generation site of lunar semidiurnal (M2) internal tides. Internal tides are the intermediate step in the energy cascade from the barotropic tides to turbulent mixing. Is internal wave activity at the Hawaiian Ridge enhanced above open-ocean background levels? At which topographic features along the ridge is internal wave activity largest? Over what distances do the internal tides propagate before being dissipated to mixing? These questions are investigated here through the use of underway finescale observations of the density and velocity structure of the upper 400 m made at a variety of topographic features and within 200 km of the ridge. Internal waves with a 60 m peak-to-peak maximum amplitude are found southwest of Oahu along a line normal to the ridge. The mean-square isopycnal displacement in the Kauai Channel region peaks at 10-20 times Garrett-Munk open-ocean values 60 km south of the ridge crest. This location of enhanced displacement is consistent with the upper ocean terminus of an internal tidal ray emanating from the base of the steepest part of the southern edge of the ridge. There is significantly more internal wave activity on the southern side of the ridge than on the northern side. This asymmetry is potentially related to the asymmetry in the slope of the across-ridge bathymetry west of Oahu which is steeper and clearly supercritical for the M2 internal tide on the southern side. Results of a spectral analysis of the internal wave field are reported. The density field, velocity field and vertically integrated baroclinic energy density of selected cruisetrack legs are compared to the results of a regional numerical model forced by the M2 tide.

OS42O-12 1635h

Along-slope Current Generation by Obliquely Incident Internal Waves

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A series of numerical experiments is performed to investigate the breaking of obliquely incident internal waves propagating towards a bottom slope. The case of critical reflection is considered, where the angle between the wave group velocity vector and the horizontal matches the bottom slope angle. The flow evolution is found to be principally different from the evolution observed previously in simulations of normally incident waves. The divergence of the Reynolds stress in the breaking zone causes a strong along-slope mean current, which changes the flow structure dramatically. The wave does not penetrate the current but breaks down at its upper surface as the result of a critical layer interaction. Continuously broadening mean along-slope current of an approximately constant velocity is produced. We propose a simple model of the process based on the momentum conservation law and the radiation stress concept. The model predictions are verified against the numerical results and are used to evaluate the possible strength of along-slope currents generated by this process in the ocean. The interaction of multiply incident waves shows that an unbalanced equilibrium can be established where incident waves from different directions interact with the boundary current in different nonlinear manners and produce a situation where the properties of the mean flow change in time. The net energetics show that approximately one third of the incident wave energy goes to irreversible mixing, one third goes to the mean current, and the remaining third is reflected away from the bottom slope as smaller scale internal waves.

OS42P HC: 323 C Thursday 1330h

Recent Advances in Understanding Submarine Biosystems and the Future in Submergence Research II

Presiding: **P Fryer,** University of Hawaii**; S Pomponi,** HBOI

OS42P-01 1330h

The Nested Survey Strategy for Deep Submergence Research: Examples From the use of National Deep Submergence Facility Vehicles

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The evolution of new paradigms in earth and ocean sciences over the past 40 years has been made possible largely through the development of enabling technologies. Key linkages between science and technology will be discussed as they relate to deep submergence vehicles and research, and a strategy termed - the nested survey approach - that can be applied to a wide range of investigations.

WHOI, over 30 years ago, understood the importance of developing deep submergence technology when it partnered with the US Navy to develop Alvin and its class of submersibles. Alvin allows the cognitive human eye and brain to reach into the abyss and observe relationships and processes that otherwise would not be possible. Similarly, over a decade ago, engineers and scientists at WHOI recognized that remotely operated and tethered vehicles, operated from a fiber optic cable that provides exceptional bandwidth, had the promise to revolutionize how we access the abyss and study the ocean and seafloor processes occurring there. ROVs and AUVs like ABE are critical to the nested survey approach to seafloor surveying because they provide enabling technology that allows intermediate and small scale features and processes to be resolved acoustically and optically.

Several applications of the nested survey strategy to the study of the geology, hydrothermal processes and biology at diverse seafloor sites will be discussed. The nested survey approach begins with broad area (100s to 1000s of square kilometers) multibeam sonar surveys with resolution of only 10-100 m (vertical and horizontal, respectively). Resolultion increases through use of high-frequency near-bottom sonar, like the DSL-120A, which can cover a swath of seafloor 1 km wide, but with resolution of features as small as 1-2m. Argo II and ROV Jason2 are then used in tandem to provide visual/optical imagery that permits the field relationships to be accurately placed and understood, and samples to be collected. Alvin dives are required for programs requiring in situ observations, delicate and complex manipulation, and heavy lift capacity.

The US National Deep Submergence Facility at WHOI has fostered this type of survey strategy by developing and operating the necessary vehicles for the oceanographic community, and by providing a research and engineering environment that continues to push the technological envelope that enables advances in scientific research.

URL: http://www.marine.whoi.edu/ships/ships_vehicles.htm

OS42P-02 1345h

Interstitial Water Chemistry of Sediments in the Eel River Basin: Implications for Carbonate Bioherm Formation

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We have undertaken a program of interstitial water studies in the Eel River Basin in conjunction with biological studies (c.f., contribution by Ziebis et al., this meeting). The principal aim of our program was to set a geochemical background to the methane seep activity in this area and to provide information on the formation of authigenic carbonate deposits. A total of four cruises have been carried out in this area. Studies of the depth distributions of Ca, Mg, SO4, HS, NH4, alkalinity, and the del13-C composition of dissolved HCO3, allow an evaluation of the geochemical processes affecting this area of seepage activity. Decreases in SO4 are accompanied by increases in alkalinity and sulfide. Ca and Mg decreases suggest carbonate precipitation reactions.

Especially the distribution with depth of del13-C is of importance in establishing the association with the del13-C of authigenic carbonates. Data on carbonates are presented for this area. In addition a comparison will be made with observations in the Monterey Bay, another area investigated by many workers for similar studies.

A generalized model of the seep activity will be presented. Differences in observations in methane seeps will be contrasted with observations in other areas both of Monterey Bay and Kodiak Trench.

THU

OS42P-03 1400h INVITED

Faunal Succession on Replicate Deep-Sea Whale Falls: Time Scales and Vent-Seep Relationships

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Faunal succession and and chemoautotrophic-community persistence times on deep-sea whale falls remain poorly known. To evaluate succession and persistence times on whale falls at 1000-2000 m depths on the California slope, we are conducting (1) time-series studies of three artificially implanted whale carcasses, and (2) radiometric dating of two natural whale skeletons harboring well-developed chemoautotrophic assemblages. Time-series studies of implanted carcasses ranging from 5000 to 35,000 kg indicate that whale-fall communities pass through three stages of faunal succession: (1) A **mobile scavenger stage**, lasting for at least 4 mo to more than 1.5 yr (depending on carcass size), during which typical deep-sea scavengers (hagfish, lysianassid amphipods, macrourid fish, sleeper sharks) remove most of the soft tissue. (2) An **enrichment opportunist stage**, during which surrounding seafloor sediments are colonized by extraordinary abundances of bizarre, undescribed chrysopetalid polychaetes, dorvilleid polychaetes, cumaceans, and in some cases, juvenile gastropods and bivalves (vesicomyids?). (3) A **sulfophilic (or chemoautotrophic) stage** characterized by >200 macrofaunal species, 10 of which also occur at hydrothermal vents, and 12 at cold seeps. Members of the sulfophilic stage also include diminutive mussels (Idas washingtonia) which appear to represent an early stage in the evolution of the vent-seep subfamily Bathymodiolinae. Preliminary measurements using ^{226}Ra-^{210}Pb disequilibrium suggest that the sulfophilic stage on a large whale skeletons may last for decades.

OS42P-04 1415h

Deep-sea hydrothermal vents of the Central Indian Ridge

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Science Party R/V Knorr Leg 162-12

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In April 2001, we conducted an interdisciplinary investigation of the hydrothermal systems along the southern edge of the Central Indian Ridge using the ROV Jason. We revisited the Kairei vent field (2519.23S, 7002.42E, about 2400m depth), first discovered by Japanese scientists in August 2000; and discovered a new vent field, the Edmond vent field at about 160 km NNW of Kairei (2352.68S, 6935.80E, about 3300m depth). The hydrothermal fluid chemistry suggested that the fluids were more similar to those observed from slow spreading ridge systems such as those typical of the Mid-Atlantic Ridge. However, the fluids from the Edmond field were some of the hottest brines ever sample from mid-ocean ridges. Based primarily on the molecular systematic analysis (of COI gene), most of the invertebrates showed evolutionary affiliations with western Pacific faunas, although the shrimp that dominated the CIR vents closely resembled the Mid-Atlantic Rimicaris exoculata. Numerous novel chemolithoautotrophic thermophiles were obtained from the two vent fields, and expanded our sampling of the hydrogen-oxidizing Persephonella spp. We also isolated a novel sulfate reducing bacterium, and the first deep-sea relative of Aquifex pyrophilus. Based on these and other data, it is clear that continued exploration of deep-sea vent environments with both ROV and DSV capabilities, will continue to provide insights into such processes as those controlling endemism, dispersal mechanisms of invertebrates and microbes, and microbial diversity at deep-sea vents.

OS42P-05 1430h

In Situ Solid State Voltammetry: a new Tool for Understanding the Ecology of Hydrothermal Vents

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An *in situ* submersible electrochemical analyzer was designed by Analytical Instrument Systems, Inc. for use from the deep sea submersible Alvin and used with up to four gold/amalgam solid state electrodes to study the diffuse flow chemistry of hydrothermal vents. The analyzer and electrodes will be described and compared to samples from discrete samplers. We present data from two cruises to hydrothermal vent sites (9 ^{o} north East Pacific rise and Guaymas basin). The electrodes measured the chemical species soluble Fe^{2+}, FeS, H_2S and polysulfides ($S_x{}^{2-}$) near and in the tubes of macrofaunal organisms. H_2S and traces of Fe^{2+} and $S_x{}^{2-}$ were detectable near *Riftia pachyptila*, the red tubeworm, whereas only soluble FeS was detectable in the tubes of the polychaete, *Alvinella pompejana*. *Riftia* require H_2S for chemosynthesis by symbiont bacteria and reside in cooler waters, < 30 ^{o}C. *Alvinella* do not require H_2S and reside in waters ranging from 40 to 90 ^{o}C. The higher temperatures allow for the formation of soluble FeS which is an intermediate in solid FeS formation and which reduces toxicity of H_2S for *Alvinella*. These data indicate that the electrodes can be used to prospect for life forms including micro-organisms.

OS42P-06 1445h INVITED

ROV-based Investigations of the Role of Appendicularian "Sinkers" in Vertical Carbon Flux

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The large, mucus feeding structures produced by giant appendicularians (e.g. Bathochordaeus) are prominent features of the midwater habitat off California. Because of the apparent abundance and broad depth range of discarded feeding structures (sinkers) we believed that they might play an important role in the vertical flux of organic matter from the upper layers of the ocean to the deep sea floor. Sinkers are very fragile and present serious challenges for in situ investigations. We used MBARI's two ROVs, VENTANA and TIBURON along with some new technical and methodological developments to conduct this research. Abundance, seasonality, patchiness, and vertical distribution were assessed from a time-series data base of quantitative video transects. Sinking rates were measured by tracking sinkers in real time with an ROV. Structure and configuration were analyzed with High-Definition video. Specimens were collected with specialized samplers and were returned to the laboratory ashore, intact, for chemical analysis. The results of the study show that individually and collectively, sinkers comprise a significant amount of organic carbon transfer to the benthos, from the shelf to full ocean depths.

OS42P-07 1520h INVITED

Using the Johnson-Sea-Links to Unravel the Biology of a Very Long Lived and Deeply Rooted Animal.

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Vestimentiferan tubeworms were first discovered associated with hydrothermal vents, and the species found on most mid-ocean ridges are adapted to the energy-rich but ephemeral vent environment. The tubeworms found around cold seeps in the Gulf of Mexico are similar to their vent relatives in that they have no mouth, gut or anus and also rely on their chemoautotrophic bacterial symbionts for nutrition. However, using a variety of custom equipment and the JSLs (such as bushmasters, banders, stainers, very small volume water samplers, and deep interstitial water samplers), we have found that the most abundant cold seep vestimentiferan species, Lamellibrachia cf luymesi, has a very different physiological ecology and life history than its vent relatives, and this is reflected in the communities of animals living among the tubeworms. Through banding and staining studies we have demonstrated that individuals of Lamellibrachia live in excess of 170 - 250 years and the co-occurring Seepiophila jonesi species lives at least as long. Using the unique water sampling capabilities of the JSL, coupled to special samplers and chemistry, we have found that sulfide is generally undetectable (<0.1μm) around the plumes (gill-like gas exchange organs) of the seep tubeworms while it is consistently present in substantial quantities in the interstitial water between 20 and 75 cm beneath the tubeworms. Using the bushmaster collection devices we have found extensive posterior extensions on the tubeworms we have nicknamed roots. The largest bushmaster (bushmaster senior) requires a custom basket and monopolizes the front end of a submersible. Because the JSL can dive up to three times in a day, we were able to use the largest collection device economically to collect several aggregations to study the structure of the communities associated with the tubeworms.

OS42P-08 1535h

Assets for Shallow Submergence Research: the Johnson-Sea-Link Submersibles

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Harbor Branch Oceanographic Institutions Johnson-Sea-Link submersibles have supported midwater and benthic submergence research for over thirty years. With a depth rating of 3000 fsw (914 m), the JSLs are versatile platforms with tool packages for photodocumentation, sample collection and storage, and a variety of in situ experiments. The latest upgrades to the vehicles as well as a brief review of research conducted using the JSLs will be presented, including bioluminescence of mid-water organisms, deep sea larval ecology, marine resources with pharmaceutical potential, exploration of gas seeps and associated fauna, and the discovery of new species of deep water invertebrates. Opportunities for access to these and other shallow submergence assets will be discussed in light of recommendations of the DESCEND workshop.

OS42P-09 1550h

National Deep Submergence Facility

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The Woods Hole Oceanographic Institution (WHOI) operates the National Deep Submergence Facility (NDSF), including the following components: R/V ATLANTIS, DSRV ALVIN and the tethered vehicles, JASON II, ARGO II and DSL-120A. The NSDF has provided safe, reliable, and science-effective manned submersible facilities to the U.S. oceanographic community for the past 25 years. The NDSF is jointly sponsored by three federal agencies: NSF, ONR and NOAA. Technical, scientific and operational services are provided to all NDSF users by personnel affiliated with the WHOI Marine Operations staff. These services include maintaining and assisting in the operation of shared-use research equipment provided in support of cruise specific scientific programs. A second level of scientific technical service is provided by the Shipboard Scientific Services Group (SSSG). Its members provide, maintain,

and may operate shared-use scientific instrumentation and equipment on a per-cruise basis. The newest addition to the WHOI fleet, R/V ATLANTIS, was built in 1997 and configured to serve as the tender for the submergence assets of the NDSF. The R/V ATLANTIS has a dynamic positioning system for precise navigation, abundant laboratory space for scientific needs and a fully equipped machine shop. The ALVIN submersible can operate at any depth from the surface to 4,500 meters at speeds of 0-3.4 km/h (0-2.0 knots), and can remain submerged for up to 10 hours during normal operations. The sub normally carries two observers and various internal and/or external instrumentation and tools. It is capable of maneuvering within areas of rugged bottom topography. It can hover at neutral buoyancy in mid-water and/or resting on the bottom to perform scientific and engineering tasks, including still and video photography. It uses its manipulators and storage basket to deploy various scientific tools and to collect samples. It can provide a limited amount of electric and hydraulic power plus data logging capabilities for instruments and equipment not normally part of the submersible. The ALVIN Group is dedicated to the productive execution of submersible scientific programs and is available to provide assistance to the user for program design and execution. The remotely operated vehicles (ROVs) operated by the NDSF include the JASON-MEDEA system, the ARGO II camera sled and the high-frequency deep-towed DSL-120A side-looking sonar. Over the past ten years, research using these vehicles has provided major contributions to the understanding of deep-sea geological, chemical and biological processes in the world oceans. They have contributed to successful deployment of ocean floor observatory monitors and various sensors which seek to understand the biological, geological and geotechnical properties of young crust and provide an ability to make routine time series measurements. These systems are currently undergoing upgrades and new capabilities will provide the scientific community with a 6500m capability and increased power, manipulation, control and sensors in each vehicle. Members of WHOI Marine Operations are available for pre-cruise planning and assistance in innovative uses of the assets at sea. The NDSF is sensitive to the requirements for multi-disciplinary submergence research and strives to provide continuing excellence in support of biological, chemical, geological, and physical oceanography.

OS42P-10 1605h

Scheduling and Planning Processes for the National Deep Submergence Facility

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The adaptability of the National Deep Submergence Facility (NDSF) to a wide variety of science needs is its strength, but this complexity can also confuse and intimidate new users. The NDSF maintains strong science liaison services and provides potential users with assistance throughout the process of cruise planning, proposal preparation, and execution of field programs. Procedures for gaining access to these vehicles are not difficult and potential users are assisted both directly by the NDSF personnel and also through a user group of scientists dedicated to providing the benefit of their experience. A successful mechanism for obtaining feedback between users and operator has been established through the Deep Submergence Science Committee (a UNOLS oversight committee) and the science community. Programs are selected for funding on a competitive basis through various federal funding agencies by standard agency review processes. Costs of the facility assets vary considerably depending on the assets chosen and advice regarding optimal use of the vehicles is discussed in detail with potential users. DSV ALVIN and its support ship R/V ATLANTIS are owned by the U.S. Navy. ATLANTIS is operated under charter agreement with the Office of Naval Research. Operation of the NDSF remotely operated vehicle (ROV) assets can be arranged in a fly-away mode on appropriate vessels within the UNOLS fleet or on commercial vessels or foreign research vessels provided they are suitably equipped. Scheduling of the R/V ATLANTIS is arranged through UNOLS, as is the use of the ROVs on UNOLS ships. Coordination between funding agencies and the UNOLS scheduling process strives to provide the users with the optimal scheduling of the assets in a given year.

OS42P-11 1620h

Deep-sea Biological Research: NOAA and NSF

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The presentation will outline NOAA and NSF programs available for the support of deep sea biological research. A wide diversity of projects are currently supported through programs such as NOAA's National Undersea Research Program and the new Ocean Exploration Program, as well as the NSFs Division of Ocean Sciences and its RIDGE2000 program. These routinely use deep submergence facilities available to the research community. A number of organizations and scientists have considerable experience with these programs and may be useful resources to the broader community in providing advice and perspectives on problems of particular importance in undersea research. The individual National Undersea Research Centers, DESSC the Deep Submergence Science Committee of UNOLS, and the operators of the National Deep Submergence Facility at Woods Hole, are well equipped to advise on issues such as scheduling, assessing the usefulness of manned vs. unmanned vehicles, the most appropriate and available technologies to undertake proposed research projects, and the need for patience.

OS42Q HC: 319 B Thursday 1330h

Stratified Coastal and Estuarine Circulation V

Presiding: **C N Flagg,** Environmental Sciences Department, Brookhaven National Laboratory**; G Pawlak,** Department of Ocean and Resources Engineering University of Hawaii

OS42Q-01 1330h

Laboratory Studies of T-S Driven Flows with Partial Mixing: Stommel Transitions, Multiple Equilibrium and Oscillations

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Laboratory experiments show behavior of a basin subjected to thermal and salinity buoyancy fluxes with limited mixing. Two distinct modes of flow have been observed in previous experiments*. The "S-mode" has significant salt stratification and relatively uniform temperatures. Using T as a measure of the temperature buoyancy flux, the "T-mode" develops for greater T. It possesses more rapid speeds and smaller salinity variation and even lower temperature than the S-mode. In box-model theory, hysteresis and discrete jumps (Stommel transitions) are found for the two flow modes as T' is gradually increased. Experiments show a much more limited range of hysteresis but the Stommel transitions are clearly visible. In recent experiments designed to investigate a new box-model theory**, the hysteresis and Stommel transitions are not detected. For small T' oscillations are found and for larger T' the T-mode is found. A simple new theory for oscillations is presented. Some results may apply to polar seas. The halocline present in Arctic and Antarctic regions clearly corresponds to the layers seen in the S-mode. Parameters needed for transition to either an oscillation or to a T-mode are discussed. *J. A. Whitehead, M. L. E. Timmermans, W. Gregory Lawson, S. N. Bulgakov, A. M. Zatarain, J. F. A. Medina & J. Salzig , Laboratory Studies of Thermally and/or Salinity-Driven Flows with Partial Mixing: Part 1 Stommel Transitions and Multiple Flow States, JGR, (In Press).

** Whitehead, 2000 Stratified Convection with Multiple States. Ocean Modelling, 2, 109-121 (2000).

OS42Q-02 1345h

Reversing Circulation Patterns in a Tropical Estuary

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Four shipboard surveys were carried out during the spring and neap tides of the dry and wet seasons in a tropical estuary of Central America in order to determine a) whether circulation patterns persisted with season, and b) whether the intraseasonal patterns changed from spring to neap tides. Water velocity profiles were measured along four transects in the Gulf of Fonseca, which communicates with the Pacific Ocean and fulfills the definition of an estuary. Water density profiles were obtained at the end of each transect repetition and also in the deepest part of each transect. During the dry season the Gulf of Fonseca showed a circulation pattern consistent with that of an inverse estuary. Net outflow of saltier gulf waters appeared near the bottom in the deepest part of the gulf and throughout the water column over the right (looking seaward), whereas net inflow from the adjacent Pacific Ocean developed near the surface and over the left. This circulation pattern was likely a consequence of large evaporation rates and coastal forcing. In contrast, during the wet season the gulf exhibited a typical estuarine circulation owing to increased precipitation and river discharge rates. The contrasting circulation patterns of both seasons were better developed during neap tides than during spring tides. The transverse dynamics of the system seemed to be more ageostrophic during spring tides than during neap tides as evidenced by more robust transverse flows. Therefore, advection and friction should have been more relevant to the transverse dynamics during spring tides than during neap tides.

URL: http://www.ccpo.odu.edu/~arnoldo/fonseca/fonseca.htm

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Buoyancy Forced Exchange Flow Over a Sill

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We consider the flow in a semi-enclosed basin, subjected to a destabilizing surface buoyancy flux and separated from a large adjoining reservoir by a sill. Convective mixing in the basin produces a lateral density gradient between the basin and reservoir, which drives an exchange flow over the sill.

A series of numerical experiments was conducted to quantify the energetics of the flow within the basin, that is, the amount of kinetic and potential energy stored within the basin and the rate at which these quantities are transported to and from the reservoir via the exchange flow over the sill. The numerical experiments were formulated to mimic and extend previous laboratory studies with the objective of developing scaling laws for the energy transfers in terms of the externally imposed flow parameters.

Volume and boundary integrated energetics were computed for both steady and time-varying regimes. In the steady-state limit, the rate of energy flux through the surface is balanced by dissipation within the basin and advection of potential energy over the sill and into the reservoir. The analyses focus primarily on this latter quantity because it is closely related to the outflow density and volume transport in two-layered exchange flows.

A second set of experiments was conducted to quantify the transient energetics in response to a sudden change in the surface forcing. These results, combined with a linear impulse-response analysis, were used to derive a general expression describing the advection of potential energy across the sill for periodically forced flows. The analytical predictions are shown to compare favorably with directly simulated flows and to be reasonably consistent with limited field observations of the seasonal variability through the Strait of Bab al Mandab.

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