OS32B-0245 1330h POSTER

Modeling wetting and drying process in San Francisco Bay using the Princeton Ocean Model

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Wetting and drying scheme (WDS) is developped to incorporate into the Princeton Ocean Model (POM, Blumberg and Mellor, 1987), which is based upon a sigma-coordinate system. Using a length scale D to characterize the bed topography or the roughness height, WDS scans each grid cell every 2DH external mode time step. If the depth at the center of each grid cell becomes less than D, the cell is considered potentially dry. This grid cell is effectively dry if the depths of all four adjacent cells are also less than D, and subsequently removed from the computational domain. The water elevation retained on the grid cell is set to the corresponding value at the end of the time step, and used for next flooding. If at least one water depth around the four sides of the grid cell is still greater than D, the cell is left in the computational domain to be scanned again by WDS at the next time step. Although WDS seems simplistic, it guarantees mass conservation and works well for an idealized estuarine intertidal basin with a uniform bed slope of about 1:4200. It is realistic that the onshore front of water body immediately runs up the slope during flood to inundate the dried cells in response to tide. This phase speed is relatively faster than that for ebb and accordingly it reproduces the tidal asymmetry. The model is next applied to South San Francisco Bay, California, which is often described as "a tidally oscillating lagoon with density-driven exchanges with the northern reach". The simulation does not include density effect, thus corresponds to summer condition when freshwater input is minimal. Sinusoidal semi-diurnal tide with amplitude of 1.2 m induces wetting and drying processes (WDP) effectively. The number of simultaneously dried-up grid cells varies with time, reaching up to 271 cells. The depth-integrated and 3D surface residual current velocities show that there exists intense horizontal mixing between shallower and deeper regions. Further examination such as detailed hydrodynamics according to WDP, results from a harmonic analysis and particle trackings, etc., will also be presented at the conference.

OS32B-0246 1330h POSTER

Calibration and Validation of a Hydrodynamic Model of the Tidal Hudson River

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A three dimensional model of the Hudson River Estuary has been constructed using the Estuarine, Coastal and Ocean Model (ECOM) framework. The model domain covers the entire tidal portion of the Hudson River from the Fedaral Dam in Troy, NY to the mouth at the Battery, New York City, nearly 250 km. The model grid is orthogonal and curvilinear with transverse and lateral resolution of approximately 200 and 500 m, respectively, for most of the river. Model inputs include water surface elevations, salinity, and temperature at the open boundary (Battery) and the freshwater inflows from the major upstream and tributary sources representing 80% of the watershed. Model calibration was performed over a two week period of average tide and flow in June 2001 and focuses on accurately reproducing water surface elevations at four stations and surface salinity at five stations along the river. Additional model calibration was performed using a survey of vertical salinity profiles measured at 28 locations along the river during this time. Model validation was performed over a six week period of average to low flow during the same summer and consist of comparisons of water elevations, surface salinity, and a deliberate SF_6 tracer release. Volatilization kinetics were included to simulate gas exchange across the air water interface due to the volatile nature of the tracer. The accuracy of the model in reproducing the hydrodynamics throughout the tidal Hudson River over these short time scales shows that the model can be used with confidence to simulate the short term transport of accidental or intentional releases of pollutants to the river and can assist as a tool for managing the impacts of such releases.

OS32B-0247 1330h POSTER

Unusually high lead-210 inventory in the sediment column of a tidal embayment

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San Diego Bay is a meso-tidal embayment located in southwestern California near US-Mexican border. Atmospheric fallout of Pb-210, which is the dominant source (>90%) of Pb-210 to the coastal sediments, was 0.17 +/- 0.03 dpm/cm^2/yr, by direct collection of atmospheric fallout as well as measurement of Pb-210 inventories in two soil cores collected from a nearby wetland. The inventory of Pb-210 in bay sediments was calculated from the Pb-210 profiles of sediment cores collected from 7 stations across San Diego Bay. The enrichment factors of Pb-210, defined as the ratios of sediment inventory of Pb-210 versus the rate of atmospheric fallout, were greater than 10.0 in two stations in the north San Diego Bay, which is connected to the Pacific Ocean. In comparison, the enrichment factors were significantly lower for stations located in the inner San Diego Bay (ranging 1.1-3.7). Enrichment factors of up to 3.5 have been reported in other coastal oceanic environments, and the unusually high inventory of Pb-210 in north San Diego Bay suggested dominant input of particle-reactive Pb-210 from outer sea as well as a highly efficient mechanism that retains Pb-210 in the bay sediments. By measuring Pb-210 in both dissolved and particulate phases in waters across San Diego Bay and nearby outer sea, we determined that tidal exchange between particle-laden bay water with outer sea water containing abundant dissolved Pb-210 (3-5 times higher than that in bay water) should be the cause of this unusually high Pb-210 inventory in north San Diego Bay. We define the process as "Pb-210 stripping", in which dissolved-phase Pb-210 supplied by outer sea through tidal exchange was continuously scavenged by settling particulate matter in bay water and retained in the north San Diego Bay. Heavy shipping traffic, tidal resuspension, as well as high productivity in San Diego Bay should have caused high concentration of particulate matter in bay water.

OS32B-0248 1330h POSTER

Airborne Sea-Surface Topography in an Absolute Reference Frame

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Highly dynamic coastal ocean processes occur at temporal and spatial scales that cannot be captured by the present generation of satellite altimeters. Spaceborne gravity missions such as GRACE also provide time-varying gravity and a geoidal msl reference surface at resolution that is too coarse for many coastal applications. The Naval Research Laboratory and the Naval Oceanographic Office have been testing the application of airborne measurement techniques, gravity and altimetry, to determine sea-surface height and height anomaly at the short scales required for littoral regions. We have developed a precise local gravimetric geoid over a test region in the northern Gulf of Mexico from historical gravity data and recent airborne gravity surveys. The local geoid provides a msl reference surface with a resolution of about 10-15 km and provides a means to connect airborne, satellite and tidegage observations in an absolute (WGS-84) framework. A series of altimetry reflights over the region with time scales of 1 day to 1 year reveal a highly dynamic environment with coherent and rapidly varying sea-surface height anomalies. AXBT data collected at the same time show apparent correlation with wave-like temperature anomalies propagating up the continental slope of the Desoto Canyon. We present animations of the temporal evolution of the surface topography and water column temperature structure down to the 800 m depth of the AXBT sensors.

OS32B-0249 1330h POSTER

Effect of tidal phase on solute flushing from a strait: SF_6 tracer study in the East River, New York

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Flow in the East River, a 25 km tidal strait connecting Long Island Sound with New York Harbor, is driven by a tidal phase lag between the two ends of the strait. The direction and rate of solutes transported in the strait, including natural materials as well as anthropogenic contaminants, has important implications for the environmental management of Long Island Sound and other fragile local ecosystems. Sulfur hexafluoride (SF_6) is a successful deliberate tracer for rivers, estuaries, and coastal areas. It is non-reactive, inexpensive, and offers an extremely low detection limit. High-resolution transport studies of complex coastal and estuarine areas up to 100 km^2, and lasting up to two weeks, have recently been achieved using a boat-mounted SF_6 measurement system with a sampling interval of 1 min and a detection limit of 1 x 10^{-14} mol L^{-1}. In June 2003, two injections of 6.2 mol sulfur hexafluoride (SF_6) were made 8 days apart in the East River to study residual circulation and rates of solute dissipation at different states of the tide. Both injections were made at the same location, but the first injection occurred at the slack before flood (northward flow), and the second injection occurred at the slack before ebb (southward flow). Tidally synchronized surveys of the SF_6 tracer patch were made by boat for 7 days following the flood injection and for 5 days following the ebb injection. For the flood and ebb injections, respectively, mean displacement of the center of tracer mass within the East River, a proxy for residual circulation, was northward at 0.31 $\pm$ 0.35 and 1.5 $\pm$ 1.0 km day^{-1}, mean fractional tracer loss due to tidal flushing was 0.32 $\pm$ 0.06 day^{-1} and 0.52 $\pm$ 0.10 day^{-1}, and mean residence time was 2.6 $\pm$ 0.4 days and 1.3 $\pm$ 0.6 days. These tracer loss rates include a small correction for air-water gas exchange, which was estimated by a combination of previously established relationships between gas transfer velocity and wind speeds, river flow velocities, and rain rates. Residual circulation appeared to have little impact on tracer fate, while the state of the tide at the time of injection had a large impact. Tracer injected on the ebb tide dissipated more rapidly, indicating a large differential between the mixing power at the two ends of the strait. (In the case of the East River, New York Harbor offered more rapid mixing than Long Island Sound). These results suggest that tidal phasing of contaminant discharges in a strait of this kind (where the tidal excursion is comparable to the length of the strait) has the potential to reduce ecological impacts, by increasing flushing rates and directing a greater fraction of solutes away from ecologically sensitive areas.

URL: http://www.columbia.edu/cu/tracer

OS32C MCC: 3000 Wednesday 1340h

General Ocean Sciences: Ocean Circulation

Presiding: **D E Dietrich,** AcuSea Inc.; **R G Curry,** Woods Hole Oceanographic Institution

OS32C-01 1340h

A Generic Approach to Dynamical Interpretation of Geophysical Fluid Flow Processes

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A real problem-oriented methodology, localized Multiscale Energy and Vorticity Analysis (MS-EVA), is developed to infer fundamental processes from oceanic data for complex dynamics. In general, geofluid flow processes are locally structured and windowed on scales (i.e., occurring on a range of scales). Many of the existing GFD theories, however, are based on classical analysis tools which are global in nature. A gap, therefore, exists between these theories and real oceanic/atmospheric problems. The development of

MS-EVA attempts to bridge this gap. It begins with the construction of a functional analysis tool, called the multiscale window transform (MWT), which is local, self-similar, and windowed on scales. Equations for multiscale energy and enstrophy are then derived and dynamical processes classified. The classification is made possible with the introduction of the concept of perfect energy transfer. These concepts allow to establish rigorously an avenue to stability studies. For example, it proves that barotropic and baroclinic instabilities are simply represented by the interaction analyses of a certain group of perfect transfer terms. The theory is validated with the Eady model and Kuo model, and the results are just as expected. The MS-EVA is then employed to study the Iceland-Faeroe Frontal (IFF) variability, with a real-time dataset gathered during the 1993 NRV Alliance cruise. The application starts with determining three scale windows, which characterize a double-peak structure in either the time wavelet spectrum or the space wavelet spectrum. The resulting energetics reveal that there is a clear baroclinic instability happening around the cold tongue intrusion observed in the middle of the study domain. Moreover, mesoscale features in the process are found to grow in distinctly different modes at different time stages, in the form of convective instability or absolute instability. An interaction analysis shows that the energy released through these instabilities goes to the sub-mesoscale window as well as the meso-scale window, but most of it stays in the meso-scale window, fueling the growth of the intrusion.

OS32C-02 1355h

Dynamically balanced global mean sea level

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The global decade-mean sea level at mesoscale resolution is obtained by integrating the horizontal momentum equation in its simplest form describing the balance in the upper ocean between acceleration, Coriolis force, pressure gradient and Ekman force. The components are estimated using drifter data, satellite altimetry and various wind products. The results are compared (and in a good agreement) with dynamic height calculated from historical hydrographic data, deep circulation observed with the floats and recent satellite (GRACE) products. Sources of the dynamical imbalance are considered including errors in the data and their preprocessing, accuracy of parameterizations and higher order terms in the momentum equation.

OS32C-03 1410h

Stochastic Forcing of the North Atlantic Wind-Driven Ocean Circulation

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The magnitude of stochastic wind stress forcing due to atmospheric weather has been observed to be comparable in size to that of the seasonal cycle at mid-latitudes. Stochastic forcing is therefore likely to have a significant influence on the ocean circulation and climate system. In this work, the goal is to determine the effect of the stochastic component of the wind forcing on the North Atlantic ocean circulation. To this end, a quasi-geostrophic model of the North Atlantic was forced with stochastic wind stress curl data obtained from NCAR's Community Climate Model 3. The enstrophy dynamics in model experiments suggests that much of the stochastically induced variability in the ocean circulation occurs via the western boundary current. This localized response occurs even though the stochastic forcing occurs over most of the ocean basin. Using the ideas of generalized stability theory, we are able to conclude that this localized response is due to Rossby waves interacting with the mean flow in the western boundary. We also find, by looking at the model pseudospectra, that the non-normal nature of the model enhances the transient growth of perturbation enstrophy and helps maintain the stochastically induced variance that is produced in the western boundary region.

OS32C-04 1425h

Investigation of the Mid-Atlantic coast sudden cold water

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In the midsummer of this year, it was reported that there was a tremendous change in ocean temperature along the Mid-Atlantic coast, dropping as much as 10 degrees overnight. This sudden sea surface temperature drop affected local tourism and fishing, keep the tourists out of water at this vacation time, caused local tuna fishing hasn't been as good this year, but the cold water lured chill-loving striped bass close to shore, and has two to three weeks of great rockfish, which fishermen could normally get till fall. This article investigates this event by using satellite observations, numerical model outputs, and surface weather analysis. It is found that the North Atlantic cold current, combined with the coastal upwelling driven by the weather influence might cause this sudden cold SST event.

OS32C-05 1440h

Sensitivity of the Carolina Coastal Ocean Circulation to Open Boundary and Atmospheric Forcing

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The ocean circulation on the continental shelf off the Carolina coast is characterized by a complex flow regime and temporal variability, which is influenced by atmospheric forcing, the Gulf Stream system, complex coastline and bathymetry, river discharge and tidal forcing. In this study, a triple-nested, HYbrid Coordinate Ocean Model (HYCOM) is used to simulate the coastal ocean circulation on the continental shelf off the Carolina coast and its interactions with the offshore large-scale ocean circulation system. The horizontal mesh size in the innermost domain was set to 1 km, whereas the outermost domain coincides with the near real-time 1/12 Atlantic HYCOM Nowcast/Forecast System operated at the Naval Research Laboratory. The intermediate domain uses a mesh size of 3 km. Atmospheric forcing fields for the Carolina coastal region are derived from the NOAA operational ETA model, the ECMWF reanalysis fields and NCEP/NCAR reanalysis fields. These forcing fields are derived at 0.8°, 1.125° and 1.875° resolutions, and at intervals of 6 hour, daily and monthly. The sensitivity of the model results to the spatial and temporal resolution of the atmospheric forcing fields is analyzed. To study the dependence of the model sensitivity on the model grid size, single-window simulations at resolutions of 1km, 3km and 9km are carried out using the same forcing fields that were applied to the nested system. Comparisons between the nested and the single domain simulation results will be presented.

OS32C-06 1455h

The Effect of Lateral Intrusions on Thermohaline Fronts - Diffusive or Frontogenetic?

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A density compensated thermohaline front with a finite width and specified total lateral salinity variation, superimposed on a finger favorable thermocline is studied by means of linear theory and non-linear numerical calculations using parameterized finger fluxes. By retaining the relatively small molecular heat diffusion and the dependence of the finger Nusselt number Nu on the density ratio, we show that marginal stability with critical frontal salinity variation is possible. The lateral eddy fluxes induce a mean vertical velocity which can sharpen the front, but when the frontal salinity variation exceeds a certain supercritical value the effect of the eddy fluxes exceeds that of the mean vertical velocity and the front diffuses. Non-linear 2D spectral calculations showed that the modification of the mean horizontal gradients is small and that the intrusions continue to grow exponentially even after they have produced overturns. By extrapolating our linear theory results beyond the overturning stage, the intrusion velocity was estimated to be proportional to the Brunt-Vaisala frequency multiplied by the intrusion thickness.

OS32C-07 1510h

Time-Lapse Seismic-Reflection Images Of Thermohaline Intrusions in an Oceanographic Front

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Recent results show that thermohaline intrusions can be acoustically imaged using conventional seismic reflection profiling methods. During acquisition of the data presented by Holbrook et al (2003) across the Labrador and North Atlantic currents, repeat profiles were also recorded. Here, we present pairs of images of thermohaline intrusions in an oceanographic front with a temporal separation in the order of days. Although distinct water masses and their internal structure are visible, they change dynamically such that the level to which similar structures can be recognised between the images varies substantially. The magnitudes of these changes both include and far exceed those expected for internal waves. Tentative estimates of the apparent rate at which these comparable structures have changed include vertical motions of 4.6×10^{-3} m/s and lateral motions of 69×10^{-3} m/s, while the oceanographic front is remarkably stable with little vertical or lateral movement. The apparent motion on 2-dimensional cross-sections may at least in part be due to lateral variations of 3-dimensional structures. Our results show that repeat seismic-reflection profiling is an effective means of studying the dynamic nature of fine-scale thermohaline structure in the ocean.

OS32C-08 1525h

Seismic Reflection Imaging of the Boundary between Norwegian Atlantic Current and Norwegian Sea Deep Water

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Water-column reflections acquired on a seismic survey in the Norwegian Sea and corroborated by an XBT survey suggest that traditional multi-channel seismic methods can distinguish boundaries between major water masses. The study area traverses the boundary between the Norwegian Atlantic Current (NwAC) and the adjacent, and underlying, Norwegian Sea Deep Water (NSDW). Stacked seismic reflection profiles clearly delineate an upper acoustically transparent surface layer separated from a lower transparent water mass by a highly reflective boundary layer. We interpret the upper water mass to be the NwAC and the lower water mass to be NSDW. Depth to the bottom of the upper layer and thickness of the boundary layer correspond to the published depth of the NwAC and thickness of a

layer of rapidly varying temperature separating it from the NSDW. Reflections seen in the seismic data result from abrupt, but subtle, changes in sound speed caused by change in temperature on the order of 0.1°C in the boundary layer. These results suggest that the boundaries between major water masses can be seismically imaged if they contain fine-scale thermohaline structure.

OS41A MCC: 3000 Thursday 0800h

General Ocean Sciences: Instruments, Techniques, and Programs I

Presiding: **R M Fitzgerald,** University of Texas at El Paso**; D Barrick,** CODAR Ocean Sensors, Ltd**; J Diebold,** Lamont-Doherty Earth Observatory

OS41A-01 0800h

Voyage into the Unknown: Ocean Exploration for the 21st Century

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Findings and recommendations from the new National Research Council (NRC) report will be presented. In 2001, at the request of Congress, the NRC organized a committee of 15 volunteers to assess the feasibility and value of implementing a major, coordinated, international program of ocean exploration and discovery. After examining existing ocean programs and strategies for national and international cooperation between governments, institutions, and ocean scientists and explorers the committee identified strengths, weaknesses, and gaps. Priority areas for ocean research and exploration were identified. The NRC report presents the rationale and outlines goals for initiating a new, international ocean exploration program, it's administration and organization both domestically and internationally, technical needs, and the financial support required to initiate such a program.

URL: http://www4.nas.edu/webcr.nsf/ProjectScopeDisplay/OSBX-U-01-04-A?OpenDocument

OS41A-02 0815h

NOAA Ocean Exploration 2003: A Scientific Overview

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A little over three years ago, a panel of leading ocean scientists, explorers, and educators developed a national strategy for ocean exploration. Their report, "Discovering Earth's Final Frontier: A U.S. Strategy for Ocean Exploration," opened the door to a new way of thinking about ocean exploration and inspired the National Oceanic and Atmospheric Administration (NOAA) to embark on a mission to expand knowledge and appreciation of the ocean. This year, in collaboration with over 100 partners including university, international, federal, state and tribal science agencies, private research and outreach organizations, civic groups, aquariums and museums, NOAA engaged in major multidisciplinary expeditions and multiple projects around the world aimed at mapping the ocean in new ways, understanding ocean interactions, developing sensors and tools, and reaching out in new ways to stakeholders to communicate findings. Expeditions and projects undertaken this year continued to build on inaugural work in 2001 and 2002 and continue to set a precedent for high quality discovery-based ocean research and exploration. This presentation will focus on expedition highlights and future program directions.

URL: http://oceanexplorer.noaa.gov

OS41A-03 0830h

R/V EWING seismic source array calibrations: 2003

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In the Northern Gulf of Mexico, May, 2003, an NSF-funded effort was carried out to obtain calibrated measurements of the various airgun arrays deployed by R/V EWING during its seismic surveys. The motivations for this were several: to ground-truth the modeling upon which safety radii for marine mammal mitigation are established; to obtain broadband digitized signals which will accurately define the full spectral content of airgun signatures; to investigate the effects of seafloor interactions and their contribution to the acoustic noise levels from seismic sources. For this purpose, a digital, remotely telemetering spar buoy was designed and assembled; affording interactive control over the choice of two hydrophone channels, four fixed gain settings and four digitizing rates [6,250 - 50,000 Hz.] Three deployments were planned: a deep-water site, suitable for comparison of actual signals with modeled results; a shallow-water [25 - 50m] site where the effects of bottom interaction would be strongest; and a continental-slope site, which represents the favored habitat of many cetacean species. Methodology was developed which enabled the sequential discharge of four subarrays of 6, 10, 12 and 20 airguns. A separate run was made with two "GI" airguns, the favored high resolution survey source. An Incidental Harassment Authorization and a Biological Opinion, including an Incidental Take Statement were issued for the project by National Marine Fisheries, and a suite of marine mammal observation and mitigation procedures was followed. The deep and shallow water sites were occupied, and some 440 airgun signals were recorded. The slope site work was cancelled due to weather too poor for accurate marine mammal observation, but calibration was subsequently carried out with an exploration industry source vessel in a similar environment. Preliminary results indicate that the mitigation modeling is accurate, though somewhat conservative; that the radiated energy from airgun arrays, known to be strongest at very low frequencies, continues to diminish as frequencies increase up to 25 kHz, and that interactions with the seafloor, while complex, are understandable.

OS41A-04 0845h

Application Of A Satellite Ocean Color Technique For Monitoring Coastal Waters: Great Barrier Reef Case Study

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Remote sensing is often considered as a means of addressing the limitations of ground-based monitoring networks by obtaining synoptic measurements of optical signals from the targeted water bodies. These optical signals, usually measured as water reflectance, must then be transformed, through appropriate methodologies, into estimates of water coloring substances and consequently, water quality parameters. In optically complex coastal waters, methods to accurately retrieve optical properties remotely are still evolving. Analytical and empirical relationships between apparent and inherent optical water properties are combined to develop a bio-optical model, using to Sea-viewing Wide Field-of-view Sensor (SeaWiFS) visible spectral bands. In this study the inverse bio-optical model was incorporated in the processing software SEADAS to allow for iterative atmospheric correction and subsequent retrieval of chlorophyll concentration, inorganic sediments load and dissolved organic matter absorption. The vicinity of Hinchinbrook channel, central Great Barrier Reef zone, Australia, was used as a case study, where presence of particulate matter and colored dissolved organic matter imply inadequateness of SeaWiFS standard chlorophyll algorithm. The new algorithm was validated using sea-truth measurements of water-coloring constituents acquired during various seasons throughout 2002-2003. In situ and corresponding remote observations agree within their uncertainty boundaries. The method was then applied to study fluxes of particulate and dissolved organic and inorganic matter following flood events of the adjacent Herbert River during austral summers of 1999 and 2002.

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A Global Ocean Model Based on Icosahedral-Hexagonal Grids With a Hybrid Vertical Coordinate

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This talk will present results from a new ocean general circulation model (OGCM). The ocean model uses an icosahedral-hexagonal grid to tile the surface of the sphere and hybrid (floating) coordinates to discretize the vertical depth of the ocean. The use of icosahedral-hexagonal grids leads to a highly uniform and isotropic discretization of the sphere and eliminates problematic grid singularities found in other grid systems. The hybrid coordinate used to discretize the vertical direction spans the limits between an Lagrangian-coordinate, such as isopycnal coordinates, and an Eulerian-coordinate, such as z-level coordinates. As a result, the model can be integrated forward in time for several days using Lagrangian vertical coordinates to minimize vertical diffusion and dispersion. At fixed time intervals, the vertical layers are mapped back to z-level coordinates and the integration continues forward in time. This type of coordinate is referred to as an Arbitrary Lagrangian Eulerian coordinate and is being developed at LANL. The model contains much of the functionality of a full production ocean model including convective adjustment, implicit vertical mixing, UNESCO equation of state. and subgrid scale mixing parameterizations. The results show realistic ocean circulations using 40962 grids cells in the horizontal (nominal 1 degree grid) and 33 layers in the vertical. The ocean is forced using monthly mean NCEP wind stresses and restoring to Levitus temperature and salinity in the top 5 meter layer. The results demonstrate that not only is this a viable approach to ocean modeling, but also provides an alternative approach to overcome many of the classical problems in ocean modeling.

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