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We investigate an important feedback loop in the climate-carbon cycle system that involves increase in atmospheric CO2 and the resulting changes in temperature, the hydrological cycle, ocean circulation, and oceanic carbon uptake. This study is conducted using the coupled atmosphere-ocean-carbon cycle component of the Integrated Science Assessment Model (ISAM). The coupled model includes an energy-moisture balance atmosphere module, a thermodynamic sea-ice module, and a zonal mean ocean module. The ocean component resolves major ocean basins and is based on the balance equations of momentum, temperature, salinity and carbon and its isotopes. The coupled model has the ability to successfully simulate historical and current climates, the ocean thermohaline circulation (THC), oceanic carbon uptake, and bomb 14C. Global warming may cause a weakening or even a collapse of the THC through the increased sea surface temperature and an enhanced hydrological cycle, which can reduce oceanic carbon uptake, thus accelerate the global warming. Recent studies find that the change in the THC is dependent not only on the concentration of atmospheric CO2, but also on the rate of CO2 increase. Using a variety of CO2 increase scenarios (e.g., 0.5%, 1%, 2%/yr CO2 increase from present concentration to the level of doubling or quadrupling of CO2), we extend previous studies by assessing the effect of the rate of CO2 increase, temperature, and hydrological cycle not only on the THC but also on the oceanic carbon uptake. We also explore the threshold values of the rate of CO2 increase and the absolute amount of atmospheric CO2 that are likely to induce the collapse of the North Atlantic Deep Water (NADW) formation, which can have dramatic effects on oceanic uptake of CO2.

OS12C MCC: 3000 Monday 1600h

Changes in the Heat and Fresh Water Budget of the Ocean from Decades to Centuries II *(joint with H, C, GC)*

Presiding: **I Yashayaev,** Bedford Institute of Oceanography**; A Proshutinsky,** Woods Hole Oceanographic Institution**; B Dickson,** Centre for Environment, Fisheries and Aquaculture Science**; R W Schmitt,** Woods Hole Oceanographic Institution

OS12C-01 1600h INVITED

Observing and Modeling the Arctic-Atlantic Climate Connection

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Communication of fresh water, heat, volume and tracers between Arctic and subpolar oceans bears on the meridonal overturning circulation and climate. The spectrum of fresh water transport will be discussed, and illustrated using observations from Davis Strait and several numerical circulation models. Glaring sensitivity in both models and observations is seen on shallow continental shelves and in neighboring boundary currents. The steric height contributed by low-salinity surface waters provides a dominant resistance to deep convection, and its geography is particularly rich and difficult to resolve. As a result, our image of the balance between Labrador Sea Water and deeper overflow waters in the construction of North Atlantic Deep Water is model-dependent and observational-array dependent. It follows that the intensity and focus of decadal variability of models also depends on this balance. A somewhat analogous problem exists in the atmospheric storm track overhead, whose location and intensity bears heavily on these oceanic fluxes. The Atlantic storm track involves continous propagation of cyclonic systems from mid-latitudes to high in the Arctic. These storms are embedded in the larger cyclonic backgroung low which invades the Arctic in years of high NAO index. Wind ducts exist in the complex, strong topographies of the Canadian Arctic Archipelago and the Greenland ice cap, and the slipperiness of upper-ocean low-salinity water (owing to its buoyant inhibition of mixing) makes it susceptible to this stress. Strategy for long-term observations of ocean circulations and atmospheric forcing critcial to decadal climate variability in the Arctic/SubArctic system will be discussed.

URL: http://www.ocean.washington.edu/research/gfd/gfd.html

OS12C-02 1620h INVITED

Inter-basin Versus Meridional Ocean Freshwater Disparity and Global Ocean Conveyor

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This presentation contributes to the ongoing discussion on the role of freshwater transport in the global ocean thermohaline circulation (THC). The current paradigm presumes that the meridional freshwater transport and northern high-latitudinal freshwater impacts in the Atlantic Ocean are the most critical for THC dynamics. Not only does this paradigm belittle the role of the southern freshwater impacts, it also underrates the role of the well-known asymmetry in sea surface salinity (SSS) between the Atlantic and Pacific Oceans and to a lesser extent between other parts of the World Ocean. A disparity in redistribution of freshwater between the Atlantic and Pacific Oceans, both by the atmosphere and by the ocean circulation itself, has long been recognized as a major cause of the observed asymmetry in SSS. However, it has not yet been examined whether this asymmetry accounts for the functioning of the global ocean conveyor, and whether there is a threshold that would trigger such a conveyor. In fact, although the significance of the zonal inter-basin SSS contrasts has never been disputed, their role in driving the global conveyor has inspired far fewer modeling efforts than the more obvious high-latitudinal sea surface freshening, especially in the North Atlantic Ocean and Nordic Seas. In a series of recent publications, we have shown that even if SSS is zonally averaged and thus retains only schematic inter-basin contrasts, it can yield a reasonable global conveyor. In a subsequent series of sensitivity experiments, we have also shown that despite the southern (versus the northern) freshwater impacts are indeed the important controls of THC dynamics, the inter-basin SSS contrasts may be even more important. Our results favor zonal versus meridional SSS contrasts as most critical for building up and maintaining the global THC. Based on those results, we have introduced a hypothesis that inter-basin SSS gradients, regardless of their genesis and even with only rudiment SSS latitudinal distributions in different basins, can be accountable for the global character of THC. To test this hypothesis, we have used an ocean circulation model in a series of sensitivity experiments with an idealized SSS that mimics either meridional, or zonal freshwater disparity, or both. Our experiments have revealed the Atlantic-Pacific SSS asymmetry being one of the most critical elements, if not the most critical one for sustaining the global character of THC. We have also estimated how freshwater must be redistributed consistently in order to facilitate a genuinely global ocean conveyor. We also conclude, albeit preliminary, that high-latitudinal freshwater impacts, as a mechanism of altering the global THC, may be less effective than inter-basin freshwater communications.

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

OS12C-03 1635h

Nonlinear Gulf Stream interplay With the Deep Western Boundary Current: Observations and Model Results

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Results from a two-way-coupled duo grid adaptation of the DieCAST ocean model to the North Atlantic/Gulf of Mexico/Caribbean Sea system are discussed, including animations. The model Deep Western Boundary Current (DWBC) strongly affects the Gulf Stream (GS) separation and path. Labrador-Sea-modified dense DWBC water arrives in the Grand Banks shelfbreak area after 10 model years. Its arrival results in: GS separation near its observed Cape Hatteras separation location; GS path much closer to observations; offshore thermocline outcropping along an intense GS front; and relatively flat time mean isopycnals between 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. The wedge shaped region between the separated Gulf Stream and continental shelf slope is filled with eddies, including intense warm core eddies that pinch off the northern tips of Gulf Stream meanders. The flattened isopycnals in this region's interior, in both climatology and model results, suggests that the nonlinear eddy system is fueled at least partly by regional potential energy release because, by their very nature (in contrast to diffusive mixing), such potential energy releasing eddies act to REDUCE isopycnal slopes in the region's interior; the larger slopes at the region's boundaries are maintained by open boundary transports from outside the wedge shaped region. This is analagous to the nonlinear wave regime of the rotating annulus experiments, whose interior isotherms have significantly less slope than in more dissipative wave and axisymmetric regimes, while the larger slopes at the boundaries are maintained by conduction at the annular walls. The strikingly flat nature of the time mean interior isopycnals and strength of the eddies suggests that dissipation is small and that little potential energy release is needed to maintain the eddy energy. Based on these observations and model results, we suggest that climatologically important, eddy-available-potential-energy generating, cross-mean-isopycnal potential density transports are small, but concentrated near the edges of the wedge as a result of frontal eddies. The resulting potential energy release fuels the eddy field, which disperses the energy away from its frontal source regions. To simulate such climatologically important behavior, models must have realistically low dissipation. arrives in the Grand Banks shelfbreak area after 10 model years. Its arrival results in: GS separation near its observed Cape Hatteras separation location; GS path much closer to observations; offshore thermocline outcropping along an intense GS front; and relatively flat time mean isopycnals between 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.

OS12C-04 1650h

Deep North Atlantic Freshening Simulated in a Coupled Climate Model

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We have analysed an ensemble of four coupled climate model (HadCM3) simulations with all major historical forcings (natural and anthropogenic). The model has simulated a sustained freshening trend in the deep sub-polar North Atlantic Ocean during the past four decades, which is very similar to recent observations. The source of the freshening is associated with decreased ice cover and increased river runoffs in the Arctic. We do not find any significant changes in E-P over the polar ocean regions. Along with this deep ocean freshening, we find an upward trend in the North Atlantic overturning circulation. The model projects a rapid reverse in the early 21st century of the freshening trend in Labrador Sea due to the collapse of deep convection under increasing anthropogenic forcing.

OS12C-05 1705h

Diagnostic Studies of Global Oceanic Evaporation Variations

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Analyses of global oceanic evaporation derived from the version 2 of the Goddard Sea Surface turbulent Flux data set (GSSTF2) show significant long-term trends and large inter-annual variations. Parameters that affect the oceanic evaporation such as surface wind speed, sea-air humidity difference, presented in the

same data set were examined. The purpose is to determine the cause of the increasing trend in the GSSTF2 latent flux data over the period of 1988-2000. An increase of domain average wind speed (6%) was found over the same period, along with an increase of sea-air humidity difference (11%). These results are consistent with the trends in latent heat flux, which is approximately proportional to the product of the two. Sea-air humidity difference is computed as sea surface humidity minus sea surface air humidity, therefore these two parameters were examined as well. A 1% increase and a 2.4% decrease were found in sea surface humidity and sea surface air humidity respectively, which explains the increase of sea-air humidity difference. The boundary layer (lowest 500 meters) precipitable water was also examined and a 3% decrease was found. Because it is the basis for deriving sea surface air humidity its decrease is consistent with the decrease of the sea surface air humidity. An EOF analysis will be performed for each parameter to evaluate the contribution to variances associated with the trends and interannual variations. An Empirical Mode Decomposition will be applied to the principal EOF time series to examining the intrinsic modes of the time series. Combined EOF analysis will also be applied to selected parameters to examine the coupling between the different parameters.

OS12C-06 1720h INVITED

The Aquarius/SAC-D salinity mapping satellite mission: Science and measurement objectives for studying the ocean freshwater budget

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The scientific motivation for measuring sea surface salinity (SSS) from satellites is to study the interactions between the Earth's water cycle, ocean circulation and climate on intra-seasonal to interannual time scales. The key science objectives are 1) to improve closure of the mean and seasonal global ocean-atmosphere freshwater balance, 2) to study the influence of SSS variability on tropical dynamics and ENSO, and 3) to monitor large scale SSS changes in high latitudes that influence ocean convective overturning circulation and long term climate variability. Aquarius/SAC-D is a dedicated salinity mapping mission being developed by the United States and Argentina for launch in 2008 and a three-year baseline mission life. Aquarius/SAC-D is designed to optimize the salinity retrieval accuracy for global climate studies. The satellite will provide global maps every 8-9 days at 100 km resolution with a three-beam push-broom configuration of 60-90 km single-beam resolution. The measurement requirements prescribe an rms uncertainty <0.2 psu globally on monthly time scales. The satellite data will be validated and jointly analyzed with the growing array of in situ salinity observations from Argo, surface drifters, moored buoys and ships of opportunity. Perhaps the most significant scientific advances to come from Aquarius/SAC-D will be understanding the atmosphere-ocean fresh water budget. In many regions, today's uncertainties are on the same order as the net fresh water flux. Simulations show that the Aquarius/SAC-D measurement accuracy will resolve the range of SSS responses in an ocean model forced with various different commonly used precipitation fields. Aquarius/SAC-D will be launched in the same time frame as the Global Precipitation Measurement (GPM) and the European Soil Moisture Ocean Salinity (SMOS) missions, providing an unprecedented opportunity to address simultaneously the atmosphere-ocean-land components of the global water cycle.

URL: http://aquarius.gsfc.nasa.gov/

OS12C-07 1740h

On the Construction of Reanalysis Argo Dataset Using a 4DVAR Data Assimilation System

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The Argo program is known as a major component of the ocean observing system. It will measure the upper layer profiles of temperature and salinity by a global array of 3,000 profiling floats. When the Argo float network is completed, 100,000 profiles of temperature and salinity will be reported every 10 days. The Argo data will provide a quantitative description of the evolving state of the upper ocean and patterns of ocean climate variability. The in-situ Argo data, however, can only give us discontinuous information on the ocean state, since the Argo float is a floating buoy and the sampling time and position vary continuously. Therefore, it is necessary to create a 3-dimensional grid dataset from the sparsely measured Argo data for the effective use of the observational data. To make such a physically integrated Argo dataset, we developed a 4DVAR data assimilation system, which is constituted on the basis of MOM3 and its adjoint by using 4-dimensional variation method, and tried to apply it to the Argo data. An experiment was carried out, in which the assimilation duration was set as 2 year from 2001 to 2002, and a global ocean model with the resolution of 1x1 deg. in horizontal and 36 levels in vertical was used. The 22 years of simulation beginning from 1980 was firstly conducted by using the sea surface heat flux, fresh water flux, and wind stress of the NCEP reanalysis data. Then, we started the assimilation by using the profiles of temperature and salinity obtained with the Argo float during 2001 to 2002. Comparisons of the results with and without the Argo data revealed that both fields of temperature and salinity are significantly improved by the Argo data. Meanwhile, results of the volume transport and heat transport are also reasonable. Further study is still needed for the operational use of this assimilation system.

OS21A MCC: 3000 Tuesday 0800h

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

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

OS21A-01 0800h INVITED

The National Tsunami Hazard Mitigation Program

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The National Tsunami Hazard Mitigation Program (NTHMP) is a state/Federal partnership that was created to reduce the impacts of tsunamis to U. S. Coastal areas. It is a coordinated effort between the states of Alaska, California, Hawaii, Oregon, and Washington and four Federal agencies: the National Oceanic and Atmospheric Administration(NOAA), the Federal Emergency Management Agency (FEMA), the U. S. Geological Survey (USGS), and the National Science Foundation(NSF). NOAA has led the effort to forge a solid partnership between the states and the Federal agencies because of it's responsibility to provide tsunami warning services to the nation. This successful partnership has established a mitigation program in each state that is preparing coastal communities for the next tsunami. Inundation maps are now available for many of the coastal communities of Alaska, California, Hawaii, Oregon, and Washington. These maps are used to develop evacuation plans and, in the case of Oregon, for land use management. The partnership has successfully upgraded the warning capability in NOAA so that earthquakes can be detected within 5 minutes and tsunamis can be detected in the open ocean in real time, paving the way for improved tsunami forecasts. NSF's new Network for Earthquake Engineering (NEES) program has agreed to work with the NTHMP to focus tsunami research on national needs. An overview of the NTHMP will be given including a discussion of accomplishments and the new collaboration with NEES.

URL: http://www.pmel.noaa.gov/tsunami-hazard/

OS21A-02 0815h INVITED

NTHMP Product Example: Tsunami Forecasting

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Long- and short-term tsunami forecast products for Hazard Assessment and Warning Guidance advance the goals of Mitigation, the third NTHMP component. Thus, an inundation map for Hazard Assessment can be considered a long-term forecast on a time scale appropriate to the history of tsunami attacks in the area, typically on the order of years to decades. Inundation maps are used by State and local officials to develop Mitigation tools that include evacuation maps, public workshops, educational brochures, and other outreach programs. Short-term tsunami forecasts provide Warning Guidance on time scales appropriate to tsunami travel time from the source region to coastal communities, typically on the order of minutes to hours. Such tsunami forecasts help improve the accuracy and reliability of warnings issued by NOAA's Tsunami Warning Centers. Observational technology and numerical modeling technology are both critical to development of these products – inundation maps are produced by numerical models that must be tested and improved through case studies that include field measurements; short-term tsunami forecast systems must integrate real-time data with numerical simulations. This presentation will provide an overview of the methodologies used in these products, the progress and accomplishments thus far, and future plans.

OS21A-03 0830h INVITED

NEES Tsunami "Product" Example : Standards and Guidelines for Construction of Coastal Structures.

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In the past decade, considerable progress has been achieved in improving tsunami inundation models. In addition to the availability of high qualify field survey data, comparisons with small and larger scale laboratory data as in NSF's Friday Harbor workshop (Yeh et al., 1996) have allowed validation of inundation predictions. By contrast, there has been far less progress in predicting forces or in translating inundation predictions to standards and guidelines. One example of addressing this issue is in a companion FEMA study undertaken jointly by the Marine Facilitiies Division of the State Lands Commission (CSLC) with USC to develop standards and guidelines for marine terminals in Los Angeles, Ventura and Orange Counties in Southern California, referred to as MOTEMS. Poorly or inadequately designed oil terminals can pose significant risks to public safety; SLC regulates the operation of marine facilities in California waters and and has the mandate to adopt performance standards for the construction and maintenance of these terminals. Prior to this study, no standards existed for seismic or tsunami hazards. The consortium comprised of USC, SLC and LLNL first completed a probabilistic hazard assessment to suggest combined probabilities for ground accelerations from different events that might affect marine terminals in the Southland. Then both tsunamigenic faults and offshore landslide-prone areas were identified and the associated runup modeled (Borrero, 2002). SLC then integrated the seismic and tsunami results and developed engineering standards for marine oil terminals, now in the final stages to state adoption as regulations (Eskijian et al, 2003). While the tsunami-specific standards allow for safer design of marine facilities, they are currently stated in terms of expected tsunami wave heights and return periods. Consulting engineers and the CSLC have to make their own assessments as to the adequacy of resulting force predictions for the design tsunami heights, as well as impact loads from ships and floating debris. While small scale data on forces on piles and walls have been obtained in collaborative NSF-funded studies (Harry Yeh, pers. comm.), predictions from these data sets at prototype scales have yet to be validated. Also, no predictions for tsunami forces from numerical models have