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Climate is "Hot"

by David M. Legler, Director

December is always an interesting time in Washington, this year being especially energetic as Capital Hill and the White House wrestle over appropriations for this year (FY08), deliberate new policies and programs addressing the impacts of climate change and reducing future carbon emissions, and finally consider new and additional areas for climate research. While the seemingly endless undulations of these negotiations are likely to be of interest only to policy wonks and insiders, it is important for climate researchers to keep an eye on the overall direction of the discussions, identify questions of national importance which climate research can help address, and look for opportunities to inform the public on our successes and the need for continued climate research. Terms such as "climate impacts", "climate services", and "assessments" are encountered more frequently during discussions of climate research. There is now good future direction as evidenced by the impact of the IPCC assessments - climate research can impact policy and decision mak-

Continued on Page Two

IN THIS ISSUE

Estimating the Circulation and Climate of the Ocean – (The ECCO Consortia)

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With the advent of the World Ocean Circulation Experiment (WOCE), the oceanographic community had for the first time nearly global, time-continuous, but diverse, data sets as well as rapidly improving general circulation models (GCMs). The need to fully exploit those data and models for the purpose of describing and understanding the global ocean circulation and its variability led to proposals to demonstrate the viability of methods for optimal combination of models and data, and the scientific utility of the results for understanding climate-time scale influences. The ECCO consortium was established in 1998, initially formed under the National Ocean Partnership Program (NOPP), with funding provided by the National Science Foundation (NSF), the National Aeronautics and Space Administration (NASA), the Office of Naval Research (ONR), and now the National Oceanic and Atmospheric Administration (NOAA). An extension of ECCO, called ECCO-GODAE, was subsequently funded through NOPP. (Much credit is owed Dr. Eric Lindstrom of NASA for his vision and support over the years.)

Model/data combination efforts are best-known through numerical weather prediction (NWP), and are usually called "data assimilation". From the outset, however, the ECCO groups have sought to emphasize the differences between the present major oceanographic problems and those of weather prediction. In particular, ECCO has sought three-dimensional time-evolving oceanographic estimates which were fully consistent with the particular GCM being used (primarily the MIT GCM), which is in turn subject to central conservation principles (volume, energy, fresh water, etc.). To the degree the GCM was dynamically consistent, the time evolution was not subject to artificial jumps or the injection of unphysical sources and sinks e.g. of heat. The forecasting emphasis of NWP lead to very different priorities and pragmatic practices that are not necessarily appropriate for study and understanding of decadal time scale ocean evolution. A drastic example of how so-called atmospheric "re-analyses" products of NWP differ from the type of state estimates sought within ECCO, is their conservation properties through time. As emphasized by, e.g., Beranger et al. (2006), reanalysis products do not normally produce atmospheric states conserving fresh water or enthalpy through time. Global mean annual imbalances in freshwater budgets are as much as 3 to 6 cm/year on average over the last decade. Of little concern for weather forecasting, such imbalances are of major importance e.g., to the study of oceanic sea level change over decades, where, as described by Wunsch et al. (2007), detection of trends of the order of 3 mm/year is attempted, and accounting for shifts in fresh water and enthalpy are of primary importance. The science goals of ECCO include the understanding and explanation of the transfers of enthalpy and fresh water to and from the atmosphere and subject sea ice fields, and so known

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Continued from Page One

ing. That doesn't make it any less important to carry out traditional research to improve our knowledge of climate variability, characterize predictability, and improve prediction capabilities, but it does portend that new end-users, opportunities and directions will likely be introduced in the next few years. CLIVAR should be considering these in our own long-term research plans.

Our best wishes for a productive and enjoyable 2008....

The U.S. CLIVAR Staff

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consistency with basic conservation laws and closed property budgets are essential.

Ongoing efforts and available products

The various ECCO efforts are best understood as being part of the larger subjects of statistical estimation and control theory as applied to the ocean and climate. As originally formulated, ECCO was intended to (1) demonstrate the feasibility of dynamically self-consistent solutions to a GCM having fully known misfits to the entire WOCE-era data sets, (2) to explore different methods of optimizing the model-data fits; (3) show the scientific utility of the results. (1) Has been fully described by Stammer et al. (2002, 2003) and Fukumori (2002). The methods chosen for exploration and comparison were the so-called method of Lagrange multipliers (MLM), often known in oceanography as the "adjoint method" and in meteorology as 4DVAR, and so-called sequential methods based upon the Kalman filter and RTS smoother algorithms. The first approach was the primary focus of the MIT/SIO partners and the latter of JPL, although considerable overlap occurred. A simplified, but useful, conclusion is that both methods are workable, and like all variant numerical algorithms, have varying advantages of computational efficiency, coding ease, ability to approximate, and conceptual accessibility, but there is no fundamental advantage of one over the other(for linear, or nearly linear problems, one can prove equivalency of the solutions, e.g., Wunsch, 2006).

A summary of the overall ECCO effort is provided in Table 1 which lists the available and forthcoming ECCO products. In what follows here, because of limitations of space, we will describe primarily the work at MIT and its partner, AER Inc., leaving a fuller description of the JPL ECCO products to a separate article. Documentation of the extensive JPL effort can be accessed through their webpage link at http://www.ecco-group.org.

A brief summary is that ECCO-JPL has focussed its efforts on the tropical Pacific, on studies of upper ocean heat variability and the mixed layer using the data of greatest impact there, with an emphasis on including the most recent data, while the MIT/SIO and MIT/AER efforts have been directed primarily to the full three-dimensional global circulation while attempting to use all available data to understand the global mean and decadal variability as well as the data quality.

ECCO MIT/SIO

The original ECCO, here called ECCO-1, involved the first global oceanographic use of the Lagrange multiplier method with D. Stammer the consortium PI. The solutions were closely analogous to those still being produced today. A crucial ingredient was (and remains) the availability of a model for the so-called adjoint solution of the MIT GCM (Marshall et al., 1997a,b). Originally developed for the Pacific acoustic tomography program (ATOC Group, 1998), the model was written to be compatible with the automatic differentiation (AD) tool TAMC developed by R. Giering (now at FastOpt in Germany). This source-to-source tool permits direct differentiation of the GCM code to produce a second code representing the adjoint model (e.g., Marotzke et al., 1999, Heimbach et al., 2005, Heimbach, 2008).

Conceptually, the ECCO procedure is identical to that developed long ago by Lagrange and others for solving constrained least-squares mechanics problems (like beads rolling on the sides of containers), the "only" difference being the very large dimension of the oceanic problem and with Lagrange's analytical differential operators being replaced by Fortran codes. Although these differences raise all kinds of difficult practical problems, understanding the underlying conceptual simplicity is the only essential element. (The engineer who builds an airplane has a very different problem from the fluid dynamicist who can explain why it flies.)

As in any least-squares problem, one must decide which parameters are to be adjusted to effect the fit. In ECCO-1, these parameters were chosen to be the initial conditions, and the surface meteorological forcing. In the control theory terminology that we use, these are called the "control vector" and which, in later solutions, is greatly extended to include internal model parameters such as the water depth, and mixing coefficients. Specifiying the magnitude of permitted

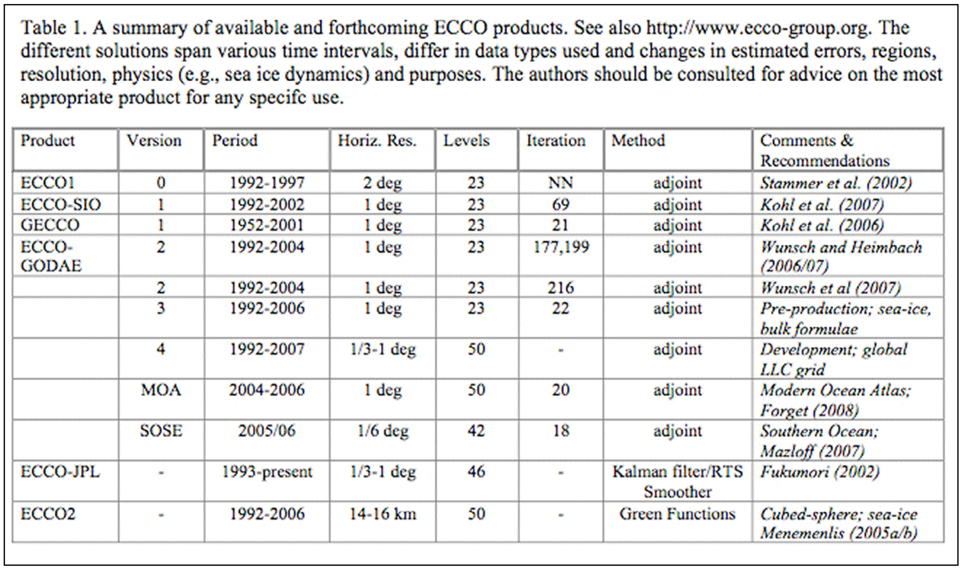

Table 1. A summary of available and forthcoming ECCO products. See also http://www.ecco-group.org. The different solutions span various time intervals, differ in data types used and changes in estimated errors, regions, resolution, physics (e.g., sea ice dynamics) and purposes. The authors should be consulted for advice on the most appropriate product for any specifc use.

Product	Version	Period	Horiz. Res.	Levels	Iteration	Method	Comments & Recommendations
ECCO1	0	1992-1997	2 deg	23	NN	adjoint	*Stammer et al. (2002)*
ECCO-SIO	1	1992-2002	1 deg	23	69	adjoint	*Kohl et al. (2007)*
GECCO	1	1952-2001	1 deg	23	21	adjoint	*Kohl et al. (2006)*
ECCO-GODAE	2	1992-2004	1 deg	23	177,199	adjoint	*Wunsch and Heimbach (2006/07)*
	2	1992-2004	1 deg	23	216	adjoint	*Wunsch et al (2007)*
	3	1992-2006	1 deg	23	22	adjoint	*Pre-production; sea-ice, bulk formulae*
	4	1992-2007	1/3-1 deg	50	-	adjoint	*Development; global LLC grid*
	MOA	2004-2006	1 deg	50	20	adjoint	*Modern Ocean Atlas; Forget (2008)*
	SOSE	2005/06	1/6 deg	42	18	adjoint	*Southern Ocean; Mazloff (2007)*
ECCO-JPL	-	1993-present	1/3-1 deg	46	-	Kalman filter/RTS Smoother	*Fukumori (2002)*
ECCO2	-	1992-2006	14-16 km	50	-	Green Functions	*Cubed-sphere; sea-ice Menemenlis (2005a/b)*

adjustments and acceptable misfits to the data are a crucial, if widely ignored, element of finding solutions. (We use the terminology “data” to refer only to observations, as opposed to “estimates” or “solutions”.)

The ECCO-1 solutions were originally based upon a two-degree horizontal resolution version of the GCM (Stammer et al., 2002, 2003),and then replaced by a one-degree version (Kohl et al., 2007). Several papers both documenting the method and then analyzing the solutions e.g., for heat and fresh water budgets, have been published (Stammer et al., 2004; and see the website http://www.ecco-group.org for a complete listing).

With the move of D. Stammer to the Institut fur Meereskunde (IfM) at the U. of Hamburg, the MIT/SIO ECCO effort shifted back to MIT, with the new collaboration in ECCO-GODAE of scientists at AER Inc (R. Ponte, co-PI). The IfM is now a partner through the German ECCO (GECCO) and which has focussed its attentions on a full 50-year NCEP/NCAR re-analysis period (Kohl et al., 2006), as well as to regional higher-resolution estimates in the North Atlantic and the Nordic Seas (Kohl, 2005).

ECCO-GODAE

The continuation of ECCO-1 as ECCO-GODAE at MIT/AER has led to a very long list of changes to the GCM, to the treatment and addition of data, and modifications of the methods, and which are far too many to discuss here. The overall recent approach has been described at length by Wunsch and Heimbach (2007a), and only a very rough summary is presented. Data in use as of about one year ago can be seen in Table 2 and encompass many (still not all!) of the very diverse data sets oceanographers employ. Results from different data durations, model configurations, and estimates of data error, and all the quality conrolled observations themselves, are available from the public servers (e.g., LAS, DODS/OPENDAP, Ingrid) from the overall ECCO project website. These solutions are referred to e.g. as version 2.177, 2.216 etc. with the leading “2” denoting the ECCO version number (the MIT/SIO solutions being version 1), and the following digits representing the number of iterations used to minimize the model-data misfits. The servers describe the different assumptions leading to these solutions. We urge that anyone using these solutions should contact one of us for a discussion of the most appropriate one to use in any given application.)

The first MIT/AER ECCO-GODAE version 3 solutions are anticipated to have been made available by the time this note appears. A large number of improvements have again been made in shifting from version 2 to 3, but the major ones are the introduction of a full sea ice model—which has a strong high latitude influence—and the use of atmospheric state variables (e.g., the wind) along with bulk formulae instead of derived quantities (e.g., the stress) as a first step toward a fully coupled atmosphere/ocean system.

As one example of the many uses to which such solutions can be put, we display in Fig. 1 a summary of the rate of global mean sea level rise as measured by satellite altimetry, many of the published estimates and attributions from in situ measurements, and the ECCO-GODAE estimate (see Wunsch et al., 2007, for a full discussion including e.g., the various

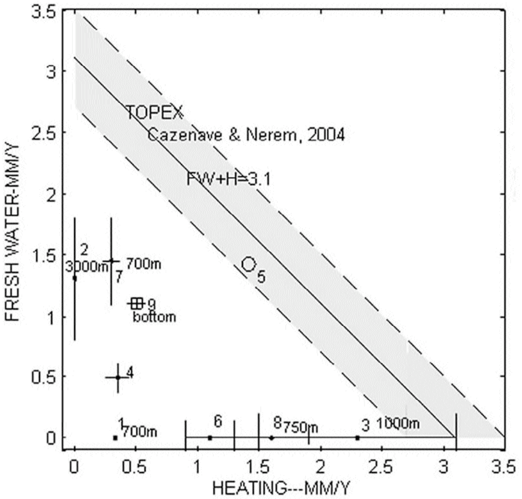

Figure 1. Estimated fresh water and thermal anomaly contributions to global average sea level (Wunsch, Ponte, Heimbach, 2007) including (No. 9) the MIT/AER ECCO-GODAE estimate, 1993-2004. Straight line is the altimetric estimate of Cazenave and Nerem (Rev. Geophys., 2004) which sees only the total change, covering 66S to 66N in latitude. That there is a general lack of consistency among the estimates is a central issue in understanding what is happening with modern sea level rise. Numbers denote the reference paper and the depth to which the investigator carried an integration of temperature or salt anomaly. The ECCO-GODAE solution is integrated from top-to-bottom. Note that all error bars are purely formal and do not include systematic errors. (Version 2.216 was used. (1: Antonov et al., 2005; 2: Antonov et al., 2002; 3: Carton et al., 2005; 4: Plat, 2006; 5:Miller &Douglas, 2004; 6: Hansen et al., 2005; 7: Ishii et al., 2006; 8:Willis et al., 2004; 9:ECCO-GODAE))

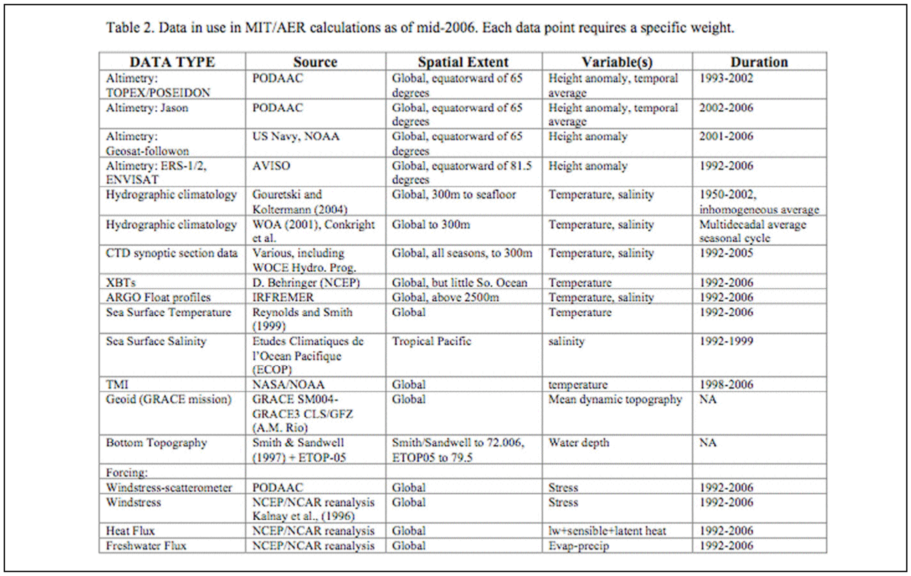

Table 2. Data in use in MIT/AER calculations as of mid-2006. Each data point requires a specific weight.

DATA TYPE	Source	Spatial Extent	Variable(s)	Duration
Altimetry: TOPEX/POSEIDON	PODAAC	Global, equatorward of 65 degrees	Height anomaly, temporal average	1993-2002
Altimetry: Jason	PODAAC	Global, equatorward of 65 degrees	Height anomaly, temporal average	2002-2006
Altimetry: Geosat-followon	US Navy, NOAA	Global, equatorward of 65 degrees	Height anomaly	2001-2006
Altimetry: ERS-1/2, ENVISAT	AVISO	Global, equatorward of 81.5 degrees	Height anomaly	1992-2006
Hydrographic climatology	Gouretski and Koltermann (2004)	Global, 300m to seafloor	Temperature, salinity	1950-2002, inhomogeneous average
Hydrographic climatology	WOA (2001), Conkright et al.	Global to 300m	Temperature, salinity	Multidecadal average seasonal cycle
CTD synoptic section data	Various, including WOCE Hydro. Prog.	Global, all seasons, to 300m	Temperature, salinity	1992-2005
XBTs	D. Behringer (NCEP)	Global, but little So. Ocean	Temperature	1992-2006
ARGO Float profiles	IRFREMER	Global, above 2500m	Temperature, salinity	1992-2006
Sea Surface Temperature	Reynolds and Smith (1999)	Global	Temperature	1992-2006
Sea Surface Salinity	Etudes Climatiques de l'Ocean Pacifique (ECOP)	Tropical Pacific	salinity	1992-1999
TMI	NASA/NOAA	Global	temperature	1998-2006
Geoid (GRACE mission)	GRACE SM004-GRACE3 CLS/GFZ (A.M. Rio)	Global	Mean dynamic topography	NA
Bottom Topography	Smith & Sandwell (1997) + ETOP-05	Smith/Sandwell to 72.006, ETOP05 to 79.5	Water depth	NA
Forcing:				
Windstress-scatterometer	PODAAC	Global	Stress	1992-2006
Windstress	NCEP/NCAR reanalysis Kalnay et al., (1996)	Global	Stress	1992-2006
Heat Flux	NCEP/NCAR reanalysis	Global	lw+sensible+latent heat	1992-2006
Freshwater Flux	NCEP/NCAR reanalysis	Global	Evap-precip	1992-2006

references). Alone among the various estimates, the ECCO-GODAE one includes the ocean from top-to-bottom, all of the available hydrographic and altimetric data, etc. (see Table 2). Another example of the use the ECCO solutions is in Fig. 2 showing the seasonally averaged zonal mass flux through time in the Pacific Ocean at 26N, and which is the counterpart to that at the same latitude in the North Atlantic discussed by Wunsch and Heimbach (2006). Similar estimates are now available globally.

Many applications of the various ECCO-GODAE solutions now exist or are underway, including their use in carbon uptake studies (e.g., Verdy et al., 2007, Gruber et al., 2007), mapping of physiology-based ocean microbial populations (Follows et al, 2007), paleo-tracer calculations (Khatiwala, 2007, Wunsch and Heimbach, 2007b), earth rotation and polar motion (Ponte et al., 2001), the detection of climate trends (Wunsch and Heimbach, 2006), the interpretation of time-variable gravity (Ponte, et al., 2007), and others.

We reiterate that all MIT/AER ECCO-GODAE solutions are computed from the freely running MITgcm, after the control vector elements have been modified to bring it into (near) consistency with the various data. In that sense, the solutions are dynamically self- consistent—at least as much as the GCM itself is.

The Future

Several major developments are underway. The MIT/AER ECCO-GODAE group expects to begin producing next-generation version 4 solutions in the very-near future. They will be based on a truly global, equatorially refined grid which has been generated via advanced grid generation algorithms (Hill et al., 2007). The most important improvements will be the inclusion of a full Arctic (with an optimized polar grid), higher resolution at most latitudes, many more layers, a more diverse control vector, etc. Within the existing effort, graduate student M. Mazloff has almost completed state estimates from an eddy-permitting (1/6 horizontally) Southern Ocean version 3 model (see Fig.3). Another graduate student, I. Fenty, is using another high resolution model of the Labrador Sea, focussing on the computation of the sea ice variability over several years.

New data are continually adopted. For example, we use the profiles from elephant seals that have been instrumented with CTD-logging devices and telemetry as part of the Southern Elephant seals as Oceanigraphic Samplers (SEaOS) project at UK's University of St. Andrews Sea Mammal Research Unit (Fedak, 2004, Biuw et al., 2007), have added surface drifters, data from the recent RAPID/MOCHA mooring array (Cunningham et al., 2007, Baehr et al., 2007), and transport estimates through the Straits of Florida from flow-induced voltage measurements in a telephone cable at the sea floor (Baringer and Larsen, 2001).

Another component, called ECCO2 –High-Resolution Global-Ocean and Sea-Ice Data Synthesis" (J. Marshall and L.L. Fu, PIs) which is part of NASA's Modeling and Analysis Project (MAP), has not been discussed here (e.g. Menemenlis et al., 2005). It anticipates the need to move the overall ECCO computations toward fully eddy-resolving models. This effort, involving collaborators at MIT, JPL, Harvard, and elsewhere is deserving of its own description. Again, the ECCO website can be used to find extensive documentation.

As models improve (and the ECCO/MIT ocean model has changed continuously over the past decade), as new data arrive both in type and with the passage of time (e.g., the original ECCO results ran until 2000 and now some run through 2006, and Argo profile data only

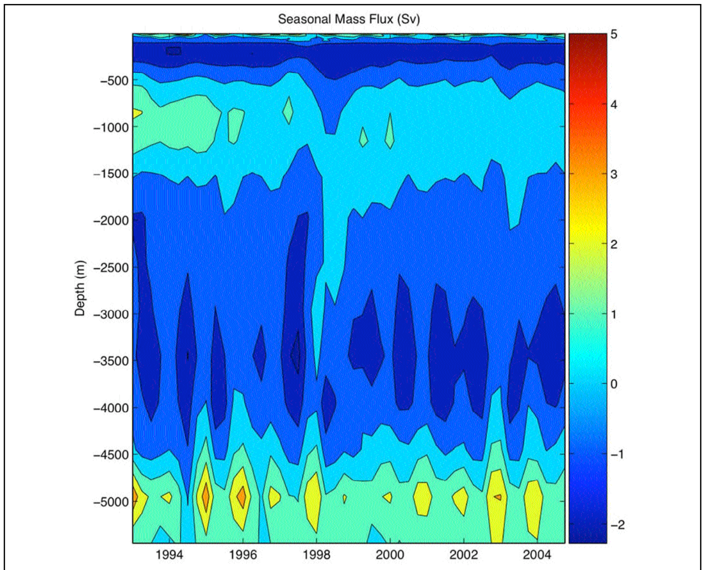

Figure 2. Zonally integrated mass transports (Sv) as function of depth through time, averaged over 3 month intervals, for the Pacific at 26N. From version 2.130 (but little chang from one iteration to another). There is much variability but no obvious trends. This result can be compared to the section at the same latitude in the North Atlantic, discussed by Wunsch and Heimbach (2006).

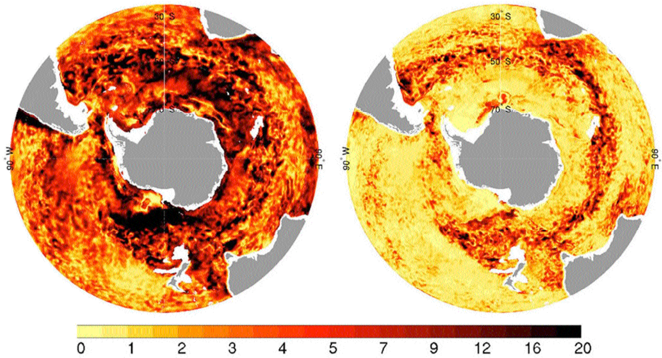

Figure 3. Annual mean squared misfit (cost) between the Southern Ocean State Estimate (SOSE) and observed SST for the year 2005, with the unconstrained model in the left panel, and after 21 iterations in the right panel. Mean on the left is 8.0 and the median is 5.4. Values on the right are 1.6 and 0.9 for the mean and the median, respectively, showing the much better fit to these data.

become available very recently), and as understanding of both model and data errors improves, new solutions are continuously found. No solution is ever the "final" one, merely the best solution available at the time of calculation. The need for integrating more components of the climate system into a coupled state estimates will grow. Of immediate concern are the coupled ocean/sea-ice in order to improve our understanding of variability of Arctic sea-ice cover. Given the large imbalances besetting today's analysis and re-analysis products, a dynamically consistent coupled atmosphere/ocean/sea-ice climate state estimate with closed property budgets will be needed in the future (Bengtsson et al., 2007) to narrow uncertainties e.g. in the nature and cause of (multi-) decadal global and regional sea-level change.

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The U.S. CLIVAR Working Group on Western Boundary Current Ocean-Atmosphere Interaction

Bo Qiu, University of Hawaii at Manoa, co-chair
Kathie Kelly, University of Washington, co-chair
Mike Alexander, NOAA Climate Diagnostics Center, co-chair

The Western Boundary Current (WBC) Ocean-Atmosphere Interaction Working Group (WG) was formed in January, 2007, to focus on the contributions of mid-latitude WBCs (specifically the Kuroshio Extension in the North Pacific and the Gulf Stream in the North Atlantic) to air-sea interaction. This WG topic is timely because the U.S. CLIVAR-endorsed field programs, Kuroshio Extension System Study (KESS; http://uskess.org) and CLIvar MOde water Dynamic Experiment (CLIMODE; http://www.climode.org) are beginning their analysis phase, so the findings from both programs could be enhanced by joint analyses and comparisons between the two regions. In addition, high-resolution satellite observations (with lengthening data records) and more accurate ocean and climate models are spurring increased interest in midlatitude WBCs.

Scientific Motivation

The large transfer of heat from the ocean to the atmosphere over the WBCs have the potential to fuel intense cyclogenesis and to impact low-frequency changes in the large-scale atmospheric circulation. Variations in the heat fluxes are associated with changes in the amount of heat in the WBC regions, which are, in turn, caused by changes in the wind-forced ocean circulation through advection by the Gulf Stream and Kuroshio currents. Attempts to understand the midlatitude ocean-atmosphere interaction have been hampered by the relatively coarse resolution of global models that do not resolve the ~100-km wide boundary currents, and by sparse observations of air-sea interaction near the currents. Over the past ~25 years a substantial research effort on ENSO and its teleconnections to the extratropics, while air-sea interaction inherent in midlatitudes has received somewhat less attention.

A combination of recent extensive field programs, high-resolution satellite observations, and improving models suggests the need for a re-examination of ocean-atmosphere interaction in the vicinity of midlatitude WBCs. Regions of high air-sea flux variability correspond well to regions of high current variability in both the Kuroshio Extension and Gulf Stream, despite the coarse resolution of current reanalysis products (Fig. 1). To obtain improved estimates, air-sea fluxes are now being monitored at the Kuroshio Extension Observatory (KEO; http://www.pmel.noaa.gov/keo) mooring and in CLIMODE from a mooring and a drifting buoy. High resolution satellite observations of sea surface temperature, currents, vector winds and stratus clouds show persistent small-scale air-sea interactions that are generally not reproduced in current climate models, Recently developed, high resolution ocean models, however, are able to reproduce large-scale climate signals and simulate more complex variability near fronts (Fig. 2). Surface fluxes associated with this frontal variability are directed from the ocean to the atmosphere: positive SSTAs are collocated with anomalous upward fluxes and vice versa suggesting that the ocean is forcing the atmosphere. In addition, some climate models exhibit coupled extratropical atmosphere-ocean interactions. Recent analysis of the Community Climate System Model Version 2 (CCSM2) has shown that variations in the strength/position of the Kuroshio Extension influence the SST and local sea to air fluxes 1-2 years later (Fig. 3). The fluxes affect the local precipitation and the atmospheric circulation over the North Pacific, that in turn, feeds back on the ocean circulation leading to coupled decadal oscillations. This suggests that aspects of climate variability may be predictable several years in advance.

WG Goals

A primary objective of the working group is to encourage better understanding of WBC atmosphere-ocean interaction that may improve the decadal and longer timescale predictability of the climate system. Specific goals include:

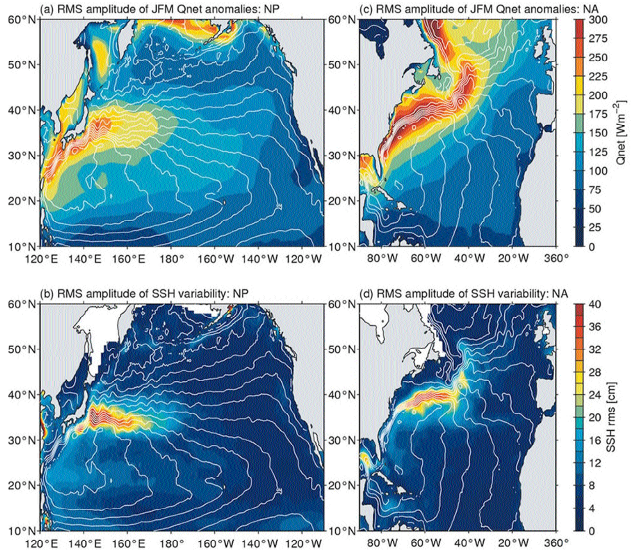

Figure 1. Root-mean-squared amplitudes of (a) the wintertime (JFM) net surface heat flux anomalies and (b) the sea surface height variability in the North Pacific Ocean. Based on the daily NCEP2 reanalysis data of 1979-2006 for (a) and the weekly AVISO SSH data of October 1992-June 2007 for (b). White contours denote the mean sea surface dynamic height field with a contour interval of 0.1 m. (c) and (d) are the same as (a) and (b), except for the North Atlantic Ocean.

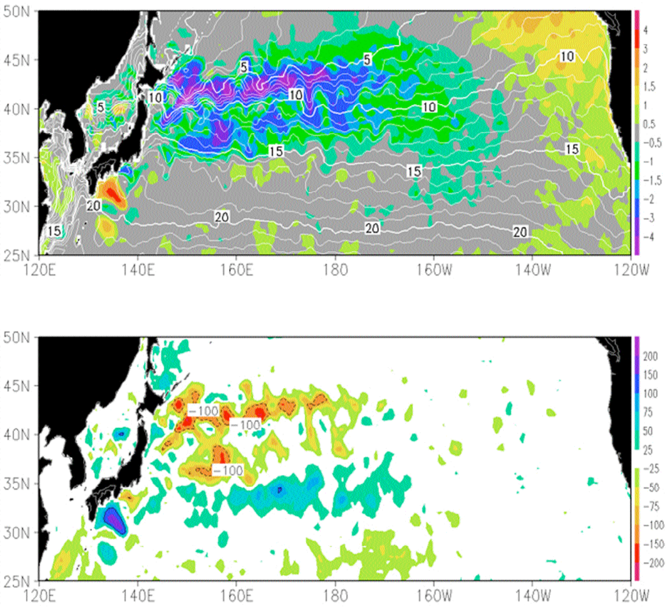

Figure 2. a) Mean SST for 1984-88 (contour) and the difference [1984-88] – [1968-72] (color, scale right) for a) SST and b) surface heat flux obtained from the ocean model for the Earth Simulator (OFES). The model indicates that SSTAs are concentrated along the core of the subarctic front. The anomalous fluxes are directed from the ocean to the atmosphere. Reduced (enhanced) surface heat due to the cooler (warmer) water is associated with meridional displacement of the front. Adapted from Nonaka et al. (2006, J. Climate)

1. Bring together the KESS, CLIMODE and other western boundary current atmosphere-ocean interaction groups for a synthesis of results

2. Identify shortcomings in atmosphere, ocean, and coupled models that need to be addressed to accurately model WBC atmosphere-ocean interaction

3. Identify observational gaps and modeling experiments that would answer outstanding issues

4. Frame key science issues, such as: * How does air-sea interaction compare in the western North Atlantic and North Pacific? What are the implications of the differences?

* What is the nature of atmosphere-ocean interaction in WBC regions? On what temporal and spatial scales does this occur? Is there predictability in the system?

* To what extent are coupled models getting the interaction right? Can we identify specific problems in ocean or atmosphere models? Is there "coupled" interaction? What numerical experiments need to be done to test hypotheses?

* To what extent does air-sea interaction extend beyond the boundary layer and influence broader climate variability in both the atmosphere and ocean? What role do stratiform and convective clouds play in the atmospheric response?

WG Activities

Following its inception in January, 2007, the WBC WG has conducted numerous teleconferences reviewing the existing research and knowledge about the WBC ocean-atmosphere interaction. The review has focused on the three topics: (1) KESS and CLIMODE, their background and scientific rationales, (2) small-scale air-sea interaction along oceanic WBC fronts, and (3) large-scale air-sea interaction in the North Pacific versus North Atlantic. The teleconference minutes, as well as the powerpoint presentation materials related to these topics can be found at http://www.usclivar.org/Organization/wbc-wg.html .

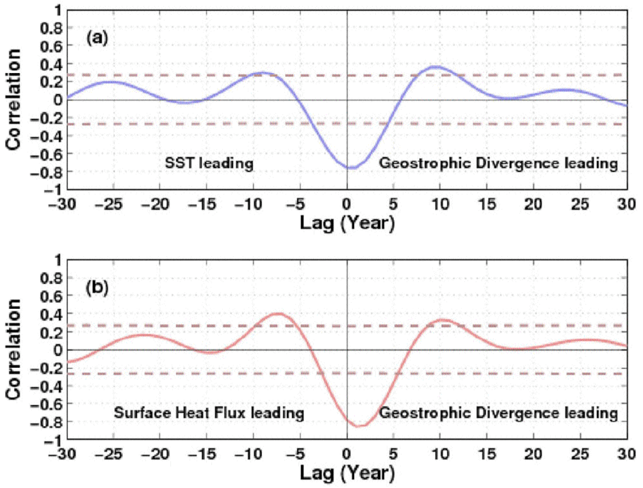

Figure 3. Lag correlations of the winter (DJFM) horizontal geostrophic ocean heat flux divergence in the upper 200 m with (a) SST and (b) net surface heat flux from the 650-year long NCAR CCSM2 control integration. All three variables are averaged over the Kuroshio Extension (35-45N, 140-180E), and low-pass filtered to retain periods longer than 10 years. Dashed lines indicate correlations significant at 99 %. Adapted from Kwon and Deser (2007, J. Climate).

A WG meeting was convened on August 23-24, 2007 in conjunction with the AMS's 15th Conference on Air-Sea Interaction, in Portland, OR. During the meeting, we summarized the WBC science issues reviewed in our preceding teleconferences, explored what the WG could achieve as a group as opposed to individual PIs, and laid out the tasks the WG wants to complete in the coming year. The followings are some of the concrete tasks the WG will strive to complete:

1. Foster and coordinate parallel KESS/CLIMODE analyses by defining a set of synthesis analyses

2. Write review papers on the Kuroshio Extension/Gulf Stream intercomparison and on the large-scale atmosphere-ocean interaction related to the WBCs

3. Examine the mean state and variability of the WBCs in the coupled IPCC models. Develop WBC metrics for GCMs and long-term ocean observing system

4. Utilize the knowledge from in-situ KESS/CLIMODE measurements to evaluate the ability of high-resolution atmospheric models to reproduce these effects, and to foster boundary layer and other atmospheric and climate model improvements

5. Organize a community-wide workshop focusing on WBC ocean-atmosphere interaction.

Calendar of CLIVAR and CLIVAR-related meetings

Further details are available on the U.S. CLIVAR and International CLIVAR web sites: www.usclivar.org and www.clivar.org

AMS Annual Meeting

20-24 January 2008
New Orleans, Louisiana
Attendance: Open
Contact: http://www.ametsoc.org

3rd WCRP Reanaylsis Conference

28-30 January 2008
Tokyo, Japan
Attendance: Open
Contact:
http://www.jra.kishou.go.jp/3rac_en.html

2008 Ocean Sciences Meeting

3-7 March 2008
Orlando, Florida
Attendance: Open
Contact: http://www.aslo.org

3rd CLIVAR Global Synthesis Observation Panel Meeting

13-14 March 2008
Southhampton, UK
Attendance: Invited
Contact: http://www.clivar.org

ARGO Steering Team - 9

18-20 March 2008
Exeter, UK
Attendance: Invited
Contact:
http://www.argo.ucsd.edu/AcAST-9.html

Variability of the American Monsoon System (VAMOS) Meeting

26-29 March 2008
Miami, Florida
Attendance: Invited
Contact: http://www.clivar.org

Third JCOMM Workshop on Advances in Marine Climatology (CLIMAR-III)

6-9 May 2008
Gdynia, Poland
Attendance: Open
Contact: http://icoads.noaa.gov/climar3/

International Workshop on Evaluating Climate Change and Development

10-13 May 2008
Alexandria, Eqypt
Attendance: Open
Contact: http://www.esdevaluation.org/

CLIVAR/GOOS Indian Ocean Panel Meeting - 5th session

12-14 May 2008
Bali, Indonesia
Attendance: Invited
Contact: http://www.clivar.org

3rd CCl/CLIVAR/JCOMM Expert Team on Climate Change Detection and Indices meeting

12-14 May 2008
De Bilt, The Netherlands
Attendance: Invitation
Contact: http://www.clivar.org

Symposium on the "Effects of Climate Change on the World's Oceans"

19-23 May 2008
Gijon, Spain
Attendance: Open
Contact:
http://www.pices.int/meetings/international_symposia/2008_symposia/Climate_change/climate_media.aspx

Workshop on Uncertainties in High-Resolution Climate Proxy Data

9-11 June 2008
Trieste, Italy
Attendance: Invited
Contact: http://www.clivar.org

2nd Joint Global Ocean Surface Underway Data (GOSUD)/Shipboard Automated Meteorological and Oceanographic System(SAMOS) Workshop

10-12 June 2008
Seattle, Washington
Attendance: Open
Contact: Shawn Smith
(smith@coaps.fsu.edu)

PAGES-CLIVAR Panel Meeting

12 June 2008
Trieste, Italy
Attendance: Invited
Contact: http://www.clivar.org

2008 IEEE International Geoscience & Remote Sensing Symposium

6-11 July 2008
Boston, MA
Attendance: Open
Contact: http://www.igarss08.org/

US CLIVAR Summit

14-16 July 2008
Irvine, CA
Attendance: Invited
Contact: http://www.usclivar.org

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U.S. CLIVAR contributes to the CLIVAR Program and is a member of the World Climate Research Programme