Prospectus for a US CLIVAR Working Group

Upper-Ocean Heat Budget Synthesis for the Eastern Equatorial Pacific and Atlantic Oceans

Paquita Zuidema, Simon de Szoeke, Roberto Mechoso, Rob Wood

Most contemporary coupled atmospheric/oceanic GCMs produce a climate that is significantly more symmetric about the equator than in observations. Warm tropical SST errors south of the equator are associated with a spurious intertropical convergence zone (ITCZ) precipitation band, creating a double ITCZ configuration not found in nature. The 'double-ITCZ' error propagates into errors in the simulated Hadley circulation, seasonal cycle and winds on the equator, and equatorial modes of variability such as ENSO. An additional outstanding feature in coupled GCMs performance is the large SST errors in eastern tropical Pacific (usually too warm by ~2°C; Mechoso et al. 1995, Davey et al. 2002, de Szoeke et al. 2008). Similar and even stronger errors are obtained in the eastern tropical Atlantic. As a consequence of this fundamental feature of the equatorial oceans – an east-west equatorial SST gradient and eastward shoaling thermocline - cannot be reproduced by most of coupled climate models for the Atlantic (e.g., Richter and Xie 2008). These errors in the tropical oceans limit predictability at both regional and climate scales.

The reasons for the warm SST errors in the eastern ocean basins are complex. According to the current consensus, an important contributor to the errors comes from radiative inaccuracies of simulated stratocumulus clouds (Ma et al. 1996, Yu and Mechoso 1999). In most IPCC AR4 models, clouds inadequately shade the ocean from sunlight. Yet, because the modeled oceans warm until surface longwave radiative cooling and evaporation again balance the warmer state, the error in the evaporation can exceed that in shortwave radiation (de Szoeke et al. 2010). The newer-generation NCAR CCSM4, which has an improved deep convective and land surface parameterization, has an overall reduced SST bias compared to CCSM3, but it nevertheless stubbornly retains a similar SST-bias spatial pattern (Gent et al., 2011).

A workshop was held at the University of Miami in Miami, Florida in March, 2011, to specifically focus on the physical processes underlying the bias problem in the tropical Atlantic. This is discussed in the dedicated Summer 2011 issue of US CLIVAR *Variations* (articles led by Kirtman, Lee, Medeiros, Patricola and Zuidema listed in references), with presentations available at http://www.clivar.org/organization/atlantic/meetings/tropical_bias/miami.php. The 2.5 day workshop succeeded in demonstrating clear, high interest in the problem of Atlantic SST biases, and in setting up a framework for development of a careful, consensual synthesis of state-of-the-art Atlantic SST model biases and their causes. The workshop participants agreed on the following major issues. First, even though several observational campaigns have been held in the Atlantic (e.g. PIRATA, TACE) , the many and important datasets obtained have not been organized at a level comparable to those in the eastern Pacific by EPIC and VOCALS. Further organization and improved accessibility of data are required in support of modelling research. Second, the hypotheses that organized research in the tropical Pacific may have to be revised for the Atlantic. It seems clear that the ocean circulation plays a stronger role due to the special configuration of the African coast. Third, improvement in regional processes may not suffice since the Atlantic is influenced by the climate over the American, African, and Asian continents. Errors in the trade winds may have a large impact on the simulation of the equatorial cold tongue in the Atlantic, and subsidence associated with the monsoons over those three continents affect the subtropical highs to a stronger extent than in the larger Pacific. Fourth, the potential for societal impacts is very large ranging from droughts in Northeast Brazil and the Sahel to widespread destruction over Central and North America by tropical depressions. Altogether, the workshop demonstrated that a scientifically and societally important problem is mature and that significant progress can be achieved by a coordinated community effort. The current proposal aims to set up such an effort.

Hypotheses on the importance of eddy-mixing processes in the ocean, presented at the US CLIVAR Summit meeting in July 2011, emerge from experience in the southeast tropical Pacific, where recent work highlights deficiencies in the simulated ocean circulation. Direct observations of surface fluxes in the Pacific Ocean from the Woods Hole Stratus mooring (Colbo and Weller 2007), the VAMOS Ocean Cloud Atmosphere Land Study (VOCALS; Wood et al. 2010), and intervening research cruises (de Szoeke et al. 2010) show that the time-mean upper ocean heat budget in the southeast Pacific is not balanced by the surface fluxes and large-scale ocean circulation alone. Hypotheses for the additional cooling include subsurface ocean eddy advection and/or vertical mixing, either through near inertial oscillations (e.g., Large and Crawford, 1995) or salt fingering (e.g., Wong and Johnson, 2003). Available ocean measurements are not definitive, and ocean models do not currently agree on the importance of eddy mixing (Colas et al. 2011; Toniazzo et al. 2010; Zheng et al. 2011). The working group will identify available upper-ocean heat budget observations to facilitate evaluation of existing ocean models simulations in the Atlantic and Pacific. The working group will also recommend coordinated community eddy-permitting ocean modeling activities to better quantify ocean eddy effects on tropical SST, given the diversity of existing high-resolution ocean model results.

For the Pacific, we will build on a large set of existing observations and modelling activities to quantify the effect of ocean eddies, since these seem to be the largest remaining uncertainty determining the SST. For the Atlantic, we will first take advantage of relatively high recent Atlantic scientific activity (e.g., PIRATA, AMMA, cruises) to develop an observational-model surface heat budget comparison for all CMIP5-type models and other contributed models. The table below summarizes the state of the synthesis activity for the Pacific and Atlantic basins.

	Pacific	Atlantic
Identify observations	done	begun
Assess CMIP5 models	underway	Presumed begun
Assess eddy-permitting models	begun	begun
Recommend model simulations	Not done	Not done

Previous proposals that US CLIVAR has entertained and rejected, communicated a high degree of interest in this problem. We believe the current proposal has the advantage of reaping low-hanging fruit from observations that did not exist even a few years ago. For the Pacific, some of the working group objectives have already been achieved thanks to VOCALS. None have been completed for the Atlantic. We hope experience gained in the Pacific can jump-start efforts in the Atlantic. The time is now, and it is best done within a Working Group structure that can integrate diverse observationalists and modelers.

Working Group Objectives:

1. Promote collaboration between observationalists and modelers, and atmospheric scientists and oceanographers, active in the southeast oceanic basins.
2. Coordinate a model assessment of surface flux errors similar to de Szoeke et al. (2010) for the equatorial Atlantic, mining all available observations. These include both CMIP5 and recent higher-resolution coupled models (e.g., GFDL, MRI). Observable metrics that have been used in the Pacific (besides the SST) include the net surface radiative budget (both shortwave and longwave), the surface latent and sensible heat fluxes, and the winds and wind stress. Larger-scale indices of the atmospheric circulation, such as location and strength of atmospheric anticyclones, and of the ocean circulation will also be assessed. Data sources include the PIRATA buoys at 8E, 8S and 0E, 0S (which includes a subsurface mooring) and 6 research cruises in the Gulf of Guinea as part of the AMMA/EGEE program. These will help determine model-observational comparison regions and lines.
3. Identify recent model improvements and common and persistent model errors, in both CMIP5 and higher-resolution coupled models.
4. Provide recommendations of cases for community simulation and evaluation using eddy-permitting ocean models, sharing specified model conditions and output datasets.

Working Group Activities, Timeline, and Outreach:

Coordination will take place through ongoing telecons, ~6/year; an actively updated website and email list; and annual WG meetings held contemporaneously at meetings of convenience. The WG will publish its findings in BAMS or EOS.

Year 1: Establish a website, identify and begin assembling the satellite datasets, buoy and research cruise datasets, begin model assessment. Identify the geographical region in which to compare observations and models. Identify the anticipated contributions from WG members. Propose convening an AGU session with a 1-day WG meeting appended. Propose BAMS/EOS publication.

Year 2: Populate the website with synthesis observational data sets and results from participating modeling groups, Hold 1-day WG meeting at a meeting of interest. Write BAMS/EOS publication. Finalize recommendations for the community case specification for ocean model simulations. These case recommendations will foster simulation and evaluation of model cases, though they are likely to be completed outside the two-year time line of the WG.

Working Group Membership:

Members will provide input on observational-modeling comparison metrics and help implement them. We value a balance of observationalists, high-resolution ocean modelers, and atmospheric boundary layer specialists, all of whom would be actively engaged. None of the other potential members have been contacted. Listed alphabetically below, we suggest:

Peter Brandt PIRATA PI (Max-Planck Institute)
Ping Chang high-resolution ocean modeling (Texas A&M)
Ruth Curry physical oceanographer, observationalist (WHOI)
Simon de Szoeke south-east Pacific expert (Oregon State U.)
Takeshi Doi coupled model developer (GFDL)
Tom Farrar ocean eddy observationalist (WHOI)
Carmen Grados near-coastal ocean circulation (IMARPE, Peru)
Alban Lazar near-coastal Atlantic expert (French institute in Guinea)
Ben Kirtman coupled model developer (U of Miami)
Yochanan Kushnir Atlantic climate (Lamont-Doherty)
Roberto Mechoso coupled climate modeler (UCLA)
Ingo Richter Atlantic coupled climate expert (IPRC, U of Hawaii)
Matthieu Rouault Benguela current observationalist (South Africa)
Irina Sandu atmospheric boundary layer model developer (ECMWF)
Shang-Ping Xie large-scale air-sea interaction (IPRC, U of Hawaii)
Rob Wood cloud microphysical processes expert (U of Washington)
Paquita Zuidema cloudy boundary layer observationalist (U of Miami)

Budget

To achieve the ambitious objectives of this proposal, the working group will use CLIVAR support to leverage and coordinate funded scientific efforts already underway by authors of this proposal and other proposed group members. The four co-authors of this prospectus alone include the VOCALS contribution to two CPTs by Mechoso and Wood, an ongoing CMIP5 assessment by Mechoso, his postdoctoral associate, and Thomas Toniazzo, a student working with de Szoeke, and a French and a Nigerian student working with Zuidema specifically on the southeast Atlantic region.

We request funding to help support the website, two working group meetings, and a publication.

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