Atmosphere feedbacks and ENSO predictability

Proposal for a CHFP sub-project

Eric Guilyardi - Dec 2008

1. Concept and objectives

1.1 ENSO in CGCMs

As ENSO involves many different feedbacks, understanding and predicting both its occurrence and amplitude is still a scientific challenge (McPhaden et al. 2006). Coupled ocean-atmosphere GCMs still have errors in reproducing the observed characteristics of El Niño events (AchutaRao and Sperber 2006, van Oldenborgh et al. 2005, Guilyardi 2006, Leloup et al. 2008). These errors give rise to such a diversity of simulated ENSO that IPCC AR4 scenarios do not show any clear evolution of ENSO properties in a warmer climate (Meehl et al. 2007a). The reasons for this large diversity of simulated ENSO and for such an uncertainty on ENSO evolution in climate change scenarios must be unravelled so that the next generation of IPCC-class models provide reliable projections of the likely evolution of ENSO in the future.

Among the many studies that addressed this issue (see Guilyardi et al. 2009a for a review of the current state of the art), several pointed out the dominant role of the atmosphere component in setting ENSO characteristics in these models (Schneider 2002, Guilyardi et al. 2004, Neale et al. 2008, Sun et al. 2008, Guilyardi et al. 2009b). It is nevertheless unclear why and further analysis of the ocean-atmosphere feedbacks is a key to understand and eventually correct ENSO biases. Atmosphere feedbacks during ENSO are of two types: dynamical and thermodynamical, both operating at large-scale and intraseasonal (ISO) scales. While the large-scale dynamical feedback (a.k.a. Bjerknes feedback) is well documented, the large-scale thermodynamical feedback (involving cloud, radiation and moisture feedbacks via air-sea heat fluxes) is less known. The objective of this sub-project is to use the CHFP multi-model ensemble to further investigate the link between the simulation of clouds, precipitation and radiation and ENSO simulation and predictability.

1.2 Using CHFP

Seasonal forecasts can provide a powerful test these feedbacks for IPCC-class CGCMs (Palmer et al. 2008). The classical analysis of ENSO in IPCC integrations (either basic statistics or more advanced evaluation of feedbacks) usually concentrates on the long (at least multi-decadal) time series statistics needed to compute robust signals. Yet, this strategy cannot fully explain how the model's errors (in the mean state but also in the feedbacks) were generated in the first place. This is an issue as the initial model errors result in a balance (a new mean state and annual cycle) that then becomes difficult to link to particular model deficiencies (such as arising from model parameterizations). Hence there is a need for an experimental framework which would focus on the initial adjustment of these models. Such a framework can be provided by the seasonal forecast approach as embodied by CHFP.

The CHFP hindcast simulations provide rich diagnostic possibilities, to see how (and sometimes why) coupled errors develop in the tropics, in the context of detailed observations. For instance, they provide a good configuration to look at cloud-convection-radiation-SST interactions, in conditions specific to a given year, allowing detailed comparison with observations such as satellite data. In an era in which model errors are very large, then comparison of any short-term integration with an observed "climatology" would show the large errors adequately, regardless of which years were chosen for comparison. But as short-term coupled model errors become comparable to observed interannual variability, proper referencing of the model integrations to specific observed years becomes important to make further progress.

By carefully analyzing the models' departure from the observed state, one should be able to more precisely identify the parameterization(s) responsible for any drift. For example, if a forecast is launched before an observed El Niño event and the model fails to reproduce the event, a careful analysis might show that the surface heat flux damping feedbacks were too strong in the model to allow the event to develop, or if the event has a too weak amplitude, that the wind response to the SST anomaly was too confined near the equator or that the ocean dissipation was too strong to sustain intra-seasonal signals (Woolnough et al. 2007).

2. Methodology

We will examine the relationship between the simulation by climate models of cloud and moist processes and the simulation of ENSO. This will be based both on the detailed analysis of the physical processes controlling this mode of variability, and on the examination of the link between the cloud metrics developed within CFMIP and the ENSO metrics developed by CLIVAR. In particular, the extent to which moisture, cloud and radiation feedbacks play a role respectively in the too large diversity of simulated ENSO in CHFP will be investigated. The analyse of the CHFP simulations will allow a direct comparison with observations and help describe which processes are responsible for ENSO errors in latest generation climate models. Interannual heat flux feedbacks will be initially analysed following Guilyardi et al. (2009b[1]) and Sun et al. (2008).

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References:

AchutaRao, K. and Sperber, K., 2006: ENSO simulations in coupled ocean-atmosphere models: are the current models better? *Clim. Dyn.* **27**, 1-16.

Guilyardi E., P. Braconnot, F.-F. Jin, S. T. Kim, M. Kolasinski, T. Li and I. Musat, 2009b: Atmosphere feedbacks during ENSO in a coupled GCM with a modified atmospheric convection scheme. *J. Clim.,* submitted

Guilyardi E., A. Wittenberg, A. Fedorov, M. Collins, C. Wang, A. Capotondi, G.J. van Oldenborgh, T. Stockdale, 2009a: Understanding El Niño in Ocean-Atmosphere General

[1] Available at http://ncas-climate.nerc.ac.uk/~ericg/ENSO_KE_TI_JC08s.pdf

Circulation Models : progress and challenges. *Bull. Amer. Met. Soc.,* published online, in press
Guilyardi E., 2006: El Niño- mean state - seasonal cycle interactions in a multi-model ensemble. *Clim. Dyn.,* **26**:329-348, DOI: 10.1007/s00382-005-0084-6
Leloup, J., M. Lengaigne and J.-P. Boulanger, 2008: Twentieth century ENSO characteristics in the IPCC database, *Clim. Dyn.,* doi: 10.1007/s00382-007-0284-3
McPhaden, M. J., Zebiak, S. E. and Glantz, M. H., 2006: ENSO as an Integrating Concept in Earth Science. *Science,* **314**, 1739-1745.
Neale R. B., J. H. Richter and M. Jochum, 2008: The Impact of Convection on ENSO: From a Delayed Oscillator to a Series of Events. *J. Clim*. In press
Palmer et al. 2008: Toward seamless prediction: Calibration of Climate Change Projections Using Seasonal Forecasts. Bull. Amer. Met. Soc. 89, 459-470.Schneider, E. K., 2002: Understanding differences between the equatorial Pacific as simulated by two coupled GCMs. *J. Climate* **15**, 449-469.
Sun D., Y. Yu and T. Zhang, 2008: Tropical Water Vapor and Cloud Feedbacks in Climate Models: A Further Assessment Using Coupled Simulations. *J. Clim*. In press
van Oldenborgh, G. J., Philip, S. and Collins, M., 2005: El Niño in a changing climate: a multi-model study. *Ocean Science* **1**, 81-95.
Woolnough S. J., F. Vitart, and M. Balmaseda, 2007: The role of the ocean in the Madden-Julian Oscillation: Sensitivity of an MJO forecast to ocean coupling. *Quart. J. Roy. Meteor. Soc.,* **133**, 117–128