ENSO in the climate system and how it may change in a warmer world
Proposal for a CLIVAR ENSO Task Team

16 April 2013

Background

The El Niño–Southern Oscillation (ENSO) phenomenon is a naturally occurring fluctuation that originates in the tropical Pacific region and affects ecosystems, agriculture, freshwater supplies, hurricanes and other severe weather events worldwide (Goddard and Dilley 2005; McPhaden et al. 2006). Despite considerable progress in our understanding of the impact of climate change on many of the processes that contribute to ENSO variability (e.g., Collins et al. 2010), it is not yet possible to say whether ENSO activity will be enhanced or damped, or if the frequency of character of events will change in the next decades. As changes in ENSO have the potential to be one of the largest manifestations of anthropogenic climate change, this status has profound impacts on the reliability of regional attribution of climate variability and change. Two main reasons can be invoked for these shortcomings. First there is a lack of long and comprehensive enough observations of the various ENSO processes to be able to detect past changes. It may be that we need to observe ENSO for another several decades to detect and attribute significant ENSO changes (Wittenberg 2009). Second, as ENSO involves a complex interplay of numerous ocean and atmospheric processes, accurately modeling this climate phenomenon with CGCMs, and understanding, anticipating, and predicting its behaviour on seasonal to decadal and longer time scales still pose formidable challenges (Guilyardi et al. 2009). Even though the ability of CGCMs to simulate El Niño has largely improved over the last few years, the diversity of model simulations of present-day El Niño characteristics indicate current limitations in our ability to model this climate phenomenon and anticipate changes in its properties on short and long time scales.

Since the establishment of the basic physical mechanisms 30 years ago, major progress in ENSO research has been made (Sarachik and Cane 2010, Wang and Picaut 2004). New theoretical insights, together with longer and more comprehensive observations, increased computer power, and improved physical parameterizations of subgrid-scale processes, have resulted in better understanding of ENSO dynamics and much improved simulations of ENSO statistics in CGCMs (Guilyardi et al. 2009, Delworth et al. 2012, Bellenger et al. 2013). Although forecast models, assimilation systems, and data availability have all improved in past decades, ENSO forecast skill has declined in the last decade because of reduced predictability (Barnston et al, 2012). If the basic properties of ENSO are now better understood and simulated, the community is nevertheless now faced with the much harder problem of addressing its detailed properties (e.g. skewness, diversity of events, physical feedbacks, asymmetries between El Niño and La Niña, etc.) and how these evolve in a slowly (decadally to centennially) varying background (An et al. 2005, Power et al. 2006). Further progress will require coordination of diverse research communities, a process recently undertaken through intercomparison of state-of-the-art CGCMs (Coupled Model Intercomparison Project - CMIP3 and CMIP5).

Over the past few years, new promising methods have emerged, which can improve ENSO simulations, for example by bridging ENSO theoretical frameworks and CGCM modeling.

Examples include the development of indices that can be used to assess the stability of ENSO in CGCMs and intermediate models that can be used to predict ENSO characteristics from aspects of the mean state. By focusing on the key processes affecting ENSO dynamics (e.g., the thermocline feedbacks or the wind stress response to SST anomalies), these new approaches have strong potential to accelerate progress and improve representation of ENSO in complex climate models (Dewitte et al. 2007, Kim and Jin 2010, Philip and van Oldenborgh 2010, Roberts and Battisti 2011, Bellenger et al. 2013). The relative role of the ocean and the atmosphere in shaping ENSO is being significantly revisited (Kitoh et al. 1999, Guilyardi et al. 2004, Dommenget 2010, Clement et al 2011, Lloyd et al. 2011). A number of studies suggest that regions outside the tropical Pacific have a role in triggering El Niño (Vimont et al. 2003, Zhang 2005, Izumo et al. 2010, Terray 2011, Wang et al. 2011), for instance via zonal or meridional atmosphere or oceanic teleconnections, such as the Madden-Julian Oscillation, the proposed seasonal footprinting mechanism (Alexander et al. 2010) or the meridional mode (Chang et al. 2007). Not only can these new methods and research areas help address the question of whether the characteristics of ENSO are changing in a changing climate (e.g. Yeh et al. 2009, Collins et al. 2010, McPhaden et al. 2011), but potentially they can also improve reliability of centennial-scale climate projections and predictions on seasonal time scales.

Two CLIVAR-sponsored workshops held in 2010 in Paris, France (Guilyardi et al. 2012) and in 2013 in Hobart, Australia[1] reviewed "new strategies for evaluating ENSO processes in climate models". A main recommendation was to continue to "bring together the different communities of experts to collectively make significant progress in the representation of ENSO in CGCMs and in the use of CGCMs in addressing open questions in ENSO science." The present proposal aims to establish such a task team in the community.

A CLIVAR ENSO Task Team

A 3 year ENSO task team is proposed to bring experts together towards three main goals: 1) better understand processes that control ENSO characteristics in nature and in the models, 2) propose a standard ENSO evaluation protocol for CGCMs and 3) understand how ENSO characteristics might be modified in the next decades, namely under the influence of anthropogenic climate change. Working towards these ambitious goals requires a synthesis of existing ENSO evaluation methods for CGCMS, including metrics, process based evaluation methods and El Niño Models of Intermediate Complexity (ENMICs). Another step is to identify gaps and duplication in these methods, which observations are essential, and how they can be better used. In particular paleo and last millennium observations have a large mostly untapped potential. A next step is to use the proposed rich and coordinated multi-model evaluation in innovative ways to inform society and other stakeholders how ENSO may, or may not, evolve in the next decades. Last but not least, the task team will also help capacity building in the community by bringing together an interdisciplinary group and by training young scientists. The protocol and methods proposed will be used to document ENSO performance of existing multi-model databases (e.g. CMIP) and contribute to the Metrics Panel set up under WGCM guidance. CLIVAR is the natural place to formalise this cross-cutting task team, as many of its Panels and

[1] http://www.clivar.org/organization/pacific/activities/third-workshop-evalution-enso-processes-climate-models

topical groups should be involved (Pacific and Indian ocean Panels, WGSIP, WGOMD), Links with WGCM, WGNE, SOLAS and PAGES will also be central. This Task Team has also the potential to be a central contribution of CLIVAR to both the model development process and the IPCC assessment.

ENSO Task Team Terms of Reference

1. To better understand the role of different physical processes that influence ENSO characteristics.
2. To provide a synthesis of existing ENSO evaluation methods in GCMs.
3. To propose ENSO evaluation protocols and develop a strategy for coordinated ENSO analysis of CMIP models, including development and maintenance of an interactive website, in coordination with the WGCM Metrics Panel.
4. To identify new observations needed to better constrain ENSO processes, both for the current climate and for past climates (via paleo proxies).
5. To provide a better understanding of how ENSO might change in the future.
6. To promote and coordinate international collaboration between observationists and modelers for studies of ENSO
7. To build research capacity by contributing to the development of the next generation of talent dealing with ENSO science.

Strategy and timeline

1. Processes responsible for ENSO characteristics

Approach: convene a workshop to bring together an interdisciplinary group of experts (ENSO processes, atmosphere and ocean physics, …). This workshop will build on the previous such CLIVAR meeting and initiatives, including the recent US CLIVAR work group on ENSO diversity.

Deliverables: a workshop report (within 3 months of workshop) and a review paper about physical mechanisms responsible for ENSO characteristics (origin, amplitude, diversity,…) (within 18 months of workshop)

2. Model ENSO evaluation protocol

Approach: from material from the Paris 2010 and Hobart 2013 CLIVAR workshops and recent CMIP analysis, establish a list of existing ENSO evaluation methods in CGCMS. Convene focused experts workshop (followed by a series of video/telephone conferences of a core group) to 1) define steps to compare methods and identify potential gaps, 2) propose an ENSO evaluation protocol for CGCMs, 3) review observations available and those missing and 4) apply protocol to CMIP3+5. The protocol will require standard CMIP simulations but may also involve specific simulations (e.g. seasonal hindcasts). Work for this phase will require a full time postdoctoral fellow for 2 years. CSIRO and IPSL have tentatively committed to jointly fund it. This will contribute to the on-going CMIP metrics panel and activities within WGCM.

Deliverables: a report/paper on the proposed ENSO evaluation protocol (month 12) and a web site, including web services to compute the metrics/analysis required for the protocol (prototype month 18, final version month 36)

3. ENSO in a changing climate

Approach: Based on improved understanding of ENSO characteristics and ENSO evaluation protocols, analyse CMIP scenarios to better understand for ENSO changes in the future. Will use innovative approaches such as Bayesian methods and the use of ENMICS to emulate possible ENSO changes. Also, we will explore the possibility of a coordinated set of model experiments and/or coordinated set of model diagnostics to test hypotheses about future changes in ENSO. If preliminary experiments/diagnostics prove useful, we would propose their inclusion in the next incarnation of CMIP.

Deliverable: peer review paper on ENSO in a changing climate providing latest estimates of likely ENSO changes over the next few decades

4. Research capacity and community building

Approach: contribute to young scientists training by inviting a selection to the workshops held during the Task Team lifetime and by organising an ENSO summer school for graduate students, (following the successful 2009 Pacific Panel ENSO summer school). Enhance general public information on ENSO with how we analyse ENSO in models (web site, wikipedia,…).

Deliverables: final open workshop on ENSO (month 36), ENSO summer school for graduate students (year 3).

Besides CLIVAR contribution (10 keur per year would be requested), the Task Team will actively seek other sources of funding (both local and international) for workshops and summer school support.

Suggested Task Team Members and Qualifications

Eric Guilyardi (ENSO metrics) *co-chair*
Andrew Wittenberg (ENSO metrics) *co-chair*
Soon-Il An (ENSO-mean state, non-linearity)
David Battisti (ENSO theory)
Pascale Braconnot (Paleo ENSO and WGCM)
Wenju Cai (Pacific Panel)
Mat Collins (ENSO and climate change, Pacific Panel)
Lisa Goddard (ENSO impacts)
Ben Kirtman (WGSIP)
Mike McPhaden (ENSO observations, Indian Ocean Panel)
Masahiro Watanabe (ENSO in CGCMs)
WGNE /WGCM *tbd* (tropical biases in CGCMs)

Proposed invited observers:
Antonietta Capotondi (US CLIVAR ENSO WG), Stephen Griffies (WGOMD), Matthieu Lengaigne (ENSO and ISO, Indian Ocean Panel)

Other possible experts that could be considered for the task team:

Sang Wook Yeh (ENSO diversity), Arun Kumar (ENSO prediction, WGSIP), Fei-Fei Jin (ENSO theory), Gokhan Danabasoglu (ENSO in CGCMs), John Fasullo (ENSO in CGCMs), Amy Clement (role of atmos, paleo ENSO), Ken Sperber (MJO WG), SOLAS person, Axel Timmermann (paleo ENSO), Matt Newman (ENSO diags), Sandrine Bony (tropical processes), Gabriel Vecchi (tropical processes), Ken Takahashi (ENSO diversity).

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