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Project report

Summary of 4th CLIVAR Workshop on the Evaluation of ENSO Processes in Climate Models

8 – 10 July, 2015 Paris, France

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Content

1. Summary of the workshop

The 4th CLIVAR workshop on the evaluation of El Niño / Southern Oscillation (ENSO) processes in climate models was held at Sorbonne-Universités in Paris in July 2015, in conjunction with the UNESCO “Our Common Future Under Climate Change” conference. The workshop (see Appendix A for the agenda), hosted by IPSL and attended by 50 experts including 12 early-career scientists (see Appendix for the list of participants), was organized as part of a new International CLIVAR Research Focus on “ENSO in a changing climate.” The workshop built upon a February 2015 workshop in Sydney, Australia, which focused on ENSO diversity and extremes. It also entrained members of the US CLIVAR working group on ENSO diversity, which has focused attention on understanding the substantial inter-event differences in ENSO mechanisms and impacts (see recent review by Capotondi et al., BAMS 2015). The workshop was co-sponsored by USCLIVAR, NOAA/ESS and NOAA/MAPP. The timing of the Paris workshop was auspicious, as it was concurrent with the development of a strong El Niño in the Pacific, just one year after an aborted El Niño.

Presentations highlighted ENSO mechanisms, the role of intraseasonal variability, climate change and decadal variability, modeling and prediction, and historical and paleo observations. Discussion sessions focused on model evaluation and metrics, and on envisioning future observations as part of the Tropical Pacific Observing System 2020 (TPOS 2020) initiative. The workshop made clear that there is a rich set of observed atmospheric and oceanic phenomena associated with ENSO. The importance of wind variability and of equatorial Pacific clouds and their seasonally-modulated feedbacks with sea surface temperatures (SSTs), were highlighted in several presentations. For example, the SST-wind relationship exhibits marked nonlinearities, with the central equatorial Pacific trade winds having a greater sensitivity to strong El Niños than to either La Niñas or moderate El Niños. The seasonally- and ENSO-modulated advective warming effects of tropical instability waves on the equatorial Pacific cold tongue were also highlighted.

The initial equatorial heat content has traditionally been viewed as an essential precursor for ENSO events. However, a presentation showed that coupled model simulations could spontaneously generate ENSO events without subsurface precursors or large-scale wind triggers, albeit with reduced amplitude. On the other hand, the interplay between westerly wind events and the initial subsurface conditions, whether recharged or in a neutral state, appears to contribute to ENSO diversity by influencing the location of the event along the equator. Intraseasonal atmospheric variability (both westerly and easterly wind events and the Madden-Julian Oscillation) was also addressed in several presentations, highlighting its importance for ENSO predictability. In particular, the temporal sequence of westerly wind events was shown to influence their subsequent impact. For example, a model study indicated that the aborted 2014 El Niño would have developed into a very strong event like that in 1997, had it simply been subjected to the (largely random) sequence of westerly wind events that occurred in April and June of 1997, instead of receiving the strong easterly wind burst that actually occurred in June 2014. Another model study highlighted the importance of off-equatorial wind events for recharging equatorial oceanic heat content, which may have helped to support the development of the 2015 El Niño so close on the heels of the aborted 2014 event. Another study indicated a substantial drop in model forecast skill between 2001-2014, not due to any degradation in the quality of the forecast system, but rather due to weaker signal-to-noise ratio associated with a lack of any strong ENSO events during that time. Such weak-ENSO epochs have occurred in the past, and also can appear at random in unforced simulations from both physical and statistical models of ENSO, with similar impacts on predictability.

Although there is still a large uncertainty about ENSO changes with global warming, most future model projections suggest a future increase in the intensity of the rainfall anomalies associated with ENSO. This results from a projected weakening of the equatorial trade winds and cold tongue, creating a favorable background for eastward and equatorward shifts of atmospheric deep convection. In contrast, observations indicate that the equatorial trade winds strengthened from 2001-2015, to a greater extent than the projections can account for -- even after including the effects of the model intrinsic decadal variability on individual realizations. This begs the question of whether models are missing some important physics of the Pacific response to anthropogenic forcings, and/or whether the models are able to generate a sufficient level of intrinsic decadal variability in the tropical Pacific.

The ENSO modelling session confirmed that although model simulations have improved, their remaining biases, both local and remote to the tropical Pacific, continue to limit our ability to simulate and predict ENSO. One example is the transition zone between the eastern equatorial Pacific cold tongue and the west Pacific warm pool, which occurs too far west in most models — affecting the structure of the wind response and remote teleconnections during ENSO. One presentation showed that increasing the model resolution can reduce many of these biases, but can also reveal previously unrecognized biases in other coupled components. Flux adjustments can be used to mitigate the effects of these biases on ENSO, particularly on the synchronization of ENSO to the end of the calendar year. Despite remaining biases, models continue to be essential tools for understanding and investigating ENSO behavior, especially when observations are limited. Models are particularly helpful for exploring extreme El Niño dynamics, and for distinguishing externally-forced trends from intrinsic low frequency variability.

Several presentations showed how paleo ENSO records offer a unique perspective to explore ENSO low frequency variations. For example, oxygen isotope ratios from living and fossil corals exhibit 60% weaker interannual variability 3-5ka ago, suggesting reduced SST and rainfall variations associated with ENSO. One presentation showed how ENSO's impacts on SPCZ variability, atmospheric energy transport, and teleconnections can differ between past, present, and future climates – presenting a challenge for attempts to reconstruct past ENSO variability from remote proxy records. Reconstructing historical observations carries challenges of its own, including estimating statistical robustness of trends. For instance, surface pressure observations from Darwin, Australia indicate that ENSO-related variance was particularly weak in the mid-20th century, a signal not seen in some historical SST reconstructions. Novel approaches based on historical atmospheric (e.g. surface pressure) and ocean temperature data have been used to produce climate reanalyses, with three-dimensional dynamical fields going back to the 1800s. These fields indicate that ENSO events prior to the 1950s are poorly resolved in SST-only reconstructions.

2. Recommendations

- Understanding ENSO underlying mechanisms is a very active field and should continue to be encouraged.
- The role of intraseasonal variations should be explored further – e.g. how the character of intraseasonal wind events may change in a warmer climate, how these events are modulated by ENSO itself, as well as the degree of their predictability, if any.
- Coordinated simulations (ENSOMIPs) could be performed to further explore several themes discussed during the workshop. The trend vs. decadal variability issue should be discussed with the CLIVAR and CMIP decadal groups, as they are

topics of common interest. Assessments of ENSO predictability, evaluating the roles of both large-scale precursors and stochastic wind forcing, would benefit from coordinated simulations. To better understand the teleconnections and impacts of ENSO in a warmer climate, SST-forced atmosphere-only ("AMIP" style) runs could be devised using present-day and projected future SST anomaly patterns, added to a projected future SST climatology.
- Climate model evaluation is a specific task of the CLIVAR Research Focus group, and should involve both the definition of the metrics, and identification of the observations needed (see TPOS recommendations below).
- Work is also needed to improve our ability to interpret changes in oxygen isotope records in paleo observations, in terms of changes in different physical variables, such as water temperature and salinity. Engagement from the atmospheric and oceanographic scientific community in this undertaking is encouraged.
- The role of CLIVAR ENSO research scientists in contributing to ENSO alerts was discussed, and the conclusion was that such alerts are best left to the operational centers.

3. TPOS recommendations

- Beyond direct measurements of the tropical Pacific ocean temperatures, surface fluxes, and currents, improved models, assimilation systems, and reanalysis efforts are needed to make optimal use of these observations. In addition, new measurement types, such as salinity and seawater oxygen isotope ratios, would help to constrain coral proxy reconstructions of ENSO's past, toward understanding ENSO's future. And in addition to TPOS, it is key to encourage and support the recovery of past observations that have not yet been digitized (e.g. from ships' logs), as proposed by several on-going community efforts.
- The surface wind stress on the ocean is critical to constraining ENSO air-sea feedbacks and capturing the impacts of equatorial wind bursts on ENSO dynamics and forecasts. Yet there remains surprisingly little convergence among the available observational and reanalysis estimates of the tropical Pacific wind stress. Improved collaboration among satellite and in situ observational communities is urgently needed to resolve these discrepancies.
- Work is also needed to explore what observations are required to improve the physics of the models as well as initialize ENSO forecast models. This will require close collaboration between the 'Model and Data Assimilation' task team of TPOS and the CLIVAR Research Focus group.
- There is a need for continued monitoring of the air-sea fluxes of heat, sunlight, momentum, and fresh water, and for dedicated field studies to understand the atmospheric and oceanic building blocks of tropical climate and variability (atmospheric convection and clouds, oceanic upwelling and mixing, diurnal cycle, tropical instability waves, and the space-time structure and nonlinearity of basin-scale feedbacks).
- Although the community would welcome enhanced tropical Pacific moorings with new instrumentation for monitoring ocean-atmosphere interactions, biogeochemical and carbon studies, and other aspects, TPOS should be cautious about making fundamental changes to the moored buoy array configuration, which has proved highly effective in providing a well-calibrated, reliable climate record and in supporting ENSO research and forecasting for the past 30 years.

Appendix A: Agenda

Wednesday, 8 July

8:30am - Registration opens
9:00am - Welcome
9:05am - **Eric Guilyardi**: Goals & logistics of the workshop

Session 1: ENSO Mechanisms

9:15	**Mike McPhaden**: Playing Hide and Seek with El Niño
9:40	**Tony Lee:** Ocean mixed-layer temperature balance associated with ENSO diversity: The relative importance of zonal advective and thermocline processes
10:05	**Soon-Il An:** Pre-conditions for extreme El Nino and the application to 2014-15 event

10:30 Coffee break

11:00	**Boris Dewitte**: On the diversity of moderate El Nino events evolution
11:25	**Dietmar Dommenget**: A link to atmospheric cloud feedbacks for the ENSO seasonal phase locking in model simulations and observations
11:50	**Aaron Levine**: The Role of ENSO Growth Rate Annual Cycle in Creating the Spring Predictability Barrier

12:15-1:20pm – lunch

1:20pm	**Fei-Fei Jin:** Dynamics of ENSO Frequency Cascade
1:45pm	**Sarah Larson**: Revisiting ENSO coupled instability theory and SST error growth in a fully coupled model

Session 2: ENSO and intraseasonal variability

2:10 pm	**Matthieu Lengaigne:** 2014 El Nino fate and the impact of intraseasonal variability on the occurrence of moderate/extreme El nino events
2:35 pm	**Shayne McGregor:** Charging El Nino with off-equatorial westerly wind bursts

3:00 pm Coffee break

3:30 pm	**Alexey Fedorov:** The impact of intraseasonal wind bursts on the diversity and predictability of El Nino: from the extreme event of 1997 to the nonevent of 2014
3:55 pm	**Andy Chiodi**: Reconstructing recent ENSO SSTA variability: A subseasonal wind event perspective

4:20 pm **Martin Puy**: Ocean-state dependency of the equatorial Pacific response to Westerly Wind Events

4:45 pm **Poster session**

6:30 pm Welcome cocktail

Thursday, 9 July

Session 3: ENSO: climate change and decadal variability

9:00 **Scott Power:** Inability of CMIP5 models to simulate recent interdecadal strengthening of the Walker circulation

9:25 **Wenju Cai:** Increasing frequency of extreme El Niño events due to greenhouse warming

9:50 **Sang-Wook Yeh:** Changes in ENSO amplitude from the historical run to the RCP8.5 run in the CESM large ensemble

10:15 **Jaci Brown:** Precipitation projections in the tropical Pacific are sensitive to different types of SST bias adjustment

10:40 Coffee break

11:10 **DeZheng Sun:** The Response of El Nino Events to Higher CO2 Forcing: A Role for Nonlinearity

11:35 **Christina Karamperidou:** The role of nonlinearities and seasonality in the response of ENSO to global warming

12:10 **David Halpern:** Decadal-to-Centennial Variability of the Pacific Equatorial Undercurrent Over the Next 400 Years Under Increasing Greenhouse Gas Emissions

12:15-1:20pm – lunch

1:45 pm **Malte Stuecker:** Recent Walker circulation strengthening and Pacific cooling amplified by Atlantic warming

2:05 pm **Myriam Khodri:** The triggering of El Niño by volcanic eruptions: the mega breeze effect

Session 4: ENSO modelling and prediction

2:30 pm **Andrew Wittenberg:** Evaluating ENSO in GFDL's next-generation models

2:55 pm **Antonietta Capotondi:** Assessing systemic ENSO changes

3:20 pm Coffee break

3:50 pm **Ken Takahashi:** Nonlinear convective processes in operational climate models and forecasting of extreme El Niño

4:15 pm **Masahiro Watanabe:** Retrogressive ENSO prediction skill in the 2000s

4:40-6:00 pm **ENSO in models** - discussion led by Mat Collins, rapporteur Wenju Cai

8:00 pm Workshop dinner

Friday, 10 July

Session 4: ENSO modelling and prediction (cont'd)

9:00 **Arun Kumar:** Low-frequency variability in ENSO and implications for seasonal predictions

9:25 **Matt Newman:** Diagnosing changes in ENSO variability and predictability from observations and models

9:50 **Eleanor Middlemas:** Unforced Decadal-Scale Global Mean Warming and Cooling in Climate Models

10:15 **Sandrine Bony:** WCRP Grand Challenge on Clouds, Circulation and Climate Sensitivity and ENSO

10:40 Coffee break

Session 5: Observations for ENSO understanding and model evaluation

11:10 **Kim Cobb:** Forced or unforced? New views of ENSO from 6,000yrs ago to present

11:35 **Marion Saint-Lu:** Relationship between El Niño and the hydrological cycle of tropical regions in different climatic contexts

12:10 **Weipeng Zheng:** ENSO variations in the mid-Pliocene

12:35-1:45pm Lunch

1:45 pm **Ed Harrison:** Aspects of the multi-decadal variability of ENSO from the historical record

2:10 pm **Ben Giese:** ENSO in a large ensemble of ocean reanalyses

2:35 pm **Billy Kessler:** The Tropical Pacific Observing System 2020 project

3:10 pm Coffee break

Actions and next steps

3:40-5:30 pm - Discussion led by Eric Guilyardi, rapporteur Andrew Wittenberg

5:30 pm Adjourn

List of posters

Esteban Abellán: The role of the southward wind shift in both, the seasonal synchronization and asymmetric duration of ENSO events

Pascale Braconnot/Julie Leloup: El Paso: confronting models and observations to understand from the past

Simon Borlace: The natural frequency of extreme El Nino events over multidecadal timescales in CMIP5 models

Emanuele Di Lorenzo: TBD

Okuku Archibong Ediang: Data management activities in est African coast and its teleconnections of Arctic Oscillation, Southern Oscillation, and Ocean Surges

Ramón Fuentes-Franco: The role of ENSO and PDO on variability of winter precipitation over North America from 21st century CMIP5 projections

Shineng Hu: An exceptional mid-summer easterly wind burst impeding 2014 El Nino

Jules Kajtar: Tropical Climate Variability: Interactions across the Pacific, Indian, and Atlantic Oceans

Bryam Orihuela Pinto: Assesment of the mechanisms in global climate models' forecasts of extreme El Niño in 2015-2016

Simon Wang: Evaluating the Changing ENSO Precursors and Impacts on North American Climate Extremes

Tchakoutio Sandjon Alain: TBD

Appendix B: List of Participants:

	Last Name	First name	Institution
1	Abellán	Esteban	University of New South Wales
2	An	Soon-Il	Yonsei University
3	Barrie	Dan	NOAA
4	Bony	Sandrine	LMD
5	Borlace	Simon	LOCEAN
6	Braconnot	Pascale	CEA-CNRS
7	Brown	Jaci	CSIRO
8	Cai	Wenju	CSIRO
9	Capotondi	Antonietta	NOAA
10	Chiodi	Andy	NOAA
11	Cobb	Kim	Georgia Institute of Technology
12	Collins	Mat	University of Exeter
13	Dewitte	Boris	IMARPE
14	Di Lorenzo	Emanuele	Georgia Institute of Technology
15	Dommenget	Dietmar	Monash University
16	Ediang	Okuku Archibong	Nigerian Meteorological Agency
17	Fedorov	Alexey	Yale University
18	Giese	Benjamin	Texas A&M University
19	Guilyardi	Eric	LOCEAN-IPSL
20	Han	Lei	CLIVAR project office
21	Halpern	David	JPL
22	Harrison	Ed	NOAA
23	Hu	Shineng	Yale University
24	Izumo	Taskeshi	LOCEAN/IPSL
25	Jin	Fei-Fei	University of Hawaii
26	Karamperidou	Christina	University of Hawaii
27	Katjar	Jules	CCRC
28	Kessler	Billy	NOAA
29	Khodri	Myriam	LOCEAN/IPSL
30	Kumar	Arun	NOAA
31	Larson	Sarah	University of Miami
32	Lee	Tony	JPL
33	Leloup	Julie	LOCEAN/IPSL
34	Lengaigne	Matthieu	IRD

35	Levine	Aaron	NOAA/PMEL
36	Lucas	Sandy	NOAA
37	McPhaden	Mike	NOAA
38	McGregor	Shayne	University of New South Wales
39	Menkes	Christophe	IRD
40	Middlemas	Eleanor	University of Miami
41	Newman	Matt	NOAA
42	Nigam	Sumant	University of Maryland
43	Pinto	Bryam Orihuela	National Agrarian University
44	Power	Scott	Bureau of Meteorology
45	Puy	Martin	Paris 6 University
46	Ramon	Fuentes Franco	ICTP
47	Saint-Lu	Marion	LSCE
48	Sun	DeZheng	NOAA
49	Takahashi	Ken	Instituto Geofisco del Peru
50	Tchakoutio Sandjon	Alain	University of Dschang, Cameroon
51	Vialard	Jérome	LOCEAN
52	Wang	Simon	Utah Climate Center
53	Watanabe	Masahiro	University of Tokyo
54	Wittenberg	Andrew	NOAA
55	Yeh	Sang-Wook	Hanyang University
56	Zheng	Weipeng	Institute of Atmospheric Physics

Photo courtesy Céline Le Helley