WCRP/CLIVAR efforts to understand El Niño in a changing climate

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To observe, simulate and predict changes in Earth’s climate system with a focus on the ocean-atmosphere system as part of the climate system

Enabling better understanding of climate variability, predictability and change

To the benefit of society and the environment in which we live
New CLIVAR Structure

Core Panels

- Ocean Model Development Panel
- Global Synthesis and Observations Panel
- Climate Dynamics Panel
- Monsoons Panel
- Atlantic Region Panel
- Pacific Region Panel
- Indian Ocean Region Panel
- Southern Ocean Region Panel

Research Foci

- Predictability of monsoon systems
- Decadal climate variability and predictability
- Biophysical interactions and dynamics of upwelling systems
- Regional sea-level change & coastal impacts
- Understanding and predicting weather & climate extremes
- ENSO in a changing climate
- Planetary energy balance & ocean heat storage
- ...
ENSO in a changing climate

- Understanding ENSO and its underlying processes
- ENSO performance in GCMs
- ENSO diversity and unforced variations
- ENSO in a changing climate
- Some WCRP/CLIVAR community challenges
ENSO in a changing climate

“No changes in mean ENSO SST statistics in a warmer climate” (IPCC AR4, AR5)

Model biases dominate over scenario

Guilyardi et al. (2009), Cai et al. (2015)
ENSO processes

Ocean response to $\tau$ and HF anomalies
- Upwelling ("thermocline feedback")
- Zonal advection & Ekman feedbacks
- Wave dynamics
- Energy Dissipation

Atmosphere response to SSTA
- Bjerknes wind stress feedback ($\mu$)
- Heat flux response ($\alpha$)

Non linear processes:
- NL ocean dynamical
- Impact of WWE
ENSO amplitude in GCMs

- ENSO in CMIP3: very large diversity of simulated amplitude
- Range reduced in CMIP5 (improved mean state ? tuned in modelling development process ?)

IPCC AR5, Bellenger et al. (2014)
Atmosphere feedbacks in GCMs

Models underestimate both $\mu$ and $\alpha$ (error compensation)
Shortwave feedback $\alpha_{SW}$ main source of errors (clouds, convection)
No clear evolution from CMIP3 to CMIP5

Bellenger et al. (2014), based on Lloyd et al. (2010, 2012)
ENSO in GCMs

Need to simulate ENSO right for the right reasons

Performance metrics  Process-based metrics
ENSO diversity

- No two El Niño events are alike
- Understanding this diversity is a challenge
- How long do we need to observe El Niño to detect a change?

Capotondi et al. (2015)
20 centuries of NINO3 SSTs in GFDL 2.1
Pre-industrial unforced climate

Wittenberg (2009)
How long do we need to observe El Niño to detect a change?

2000 years simulation pre-industrial control GFDL 2.1

What is the base line?

Niño 3 SSTA spectra 100y epochs

CM2.1 1860 (20 centuries)

Wittenberg (2009)

Stevenson et al. (2010):

Minimum length of simulation needed to statistically distinguish ENSO amplitude change = ~250 years
To understand if ENSO has changed, statistics (i.e. performance metrics) will only help us in 200 years. In the meantime we have to rely on physical understanding.
No change of \textit{mean} El Niño SST statistics from CMIP scenario
Using a process-based criteria (rainfall > 5 mm/day in east Pacific)
Doubling of occurrence of extreme El Niños in unmitigated climate change

**Historical**
1 extreme El Niño every 6 events

**RCP8.5**
1 extreme El Niño every 3 events

See poster by Andrew Wittenberg

Cai et al. (2014, 2015)
ENSO in a changing climate:

• Need to simulate right ENSO statistics for the right reasons (i.e. via correct processes)
• To understand if ENSO has changed, statistics will only help us in 200+ years. In the mean time we have to rely on physical understanding

Process-based metrics
Challenges in ENSO research

- Better understand
  - ENSO diversity and extremes
  - Role of intra-seasonal variations
  - Role of other oceanic basins

- Dynamics/physics interaction in the Tropics
  - Bjerknes feedback processes?
  - WCRP Grand Challenge on Clouds, Convection and Circulation
  - CLIVAR Climate Dynamics Panel
Challenges in ENSO research

- Process-based evaluation of ENSO in GCMs
  - Apply during model development phase
  - Collect (obs4MIP) and understand observation diversity (e.g. wind stress)
  - Address model systematic errors

- Interpretation/synthesis of paleo records
  - Long records
  - Out-of-sample test of models
Tropical Pacific Observing System

TAO-TRITON instrumental in ENSO progress

- Unique resource for model evaluation and process understanding
- TPOS 2020 to provide recommendations for next 20 years of observations
- Unique opportunity for community
- Caution required about making fundamental changes