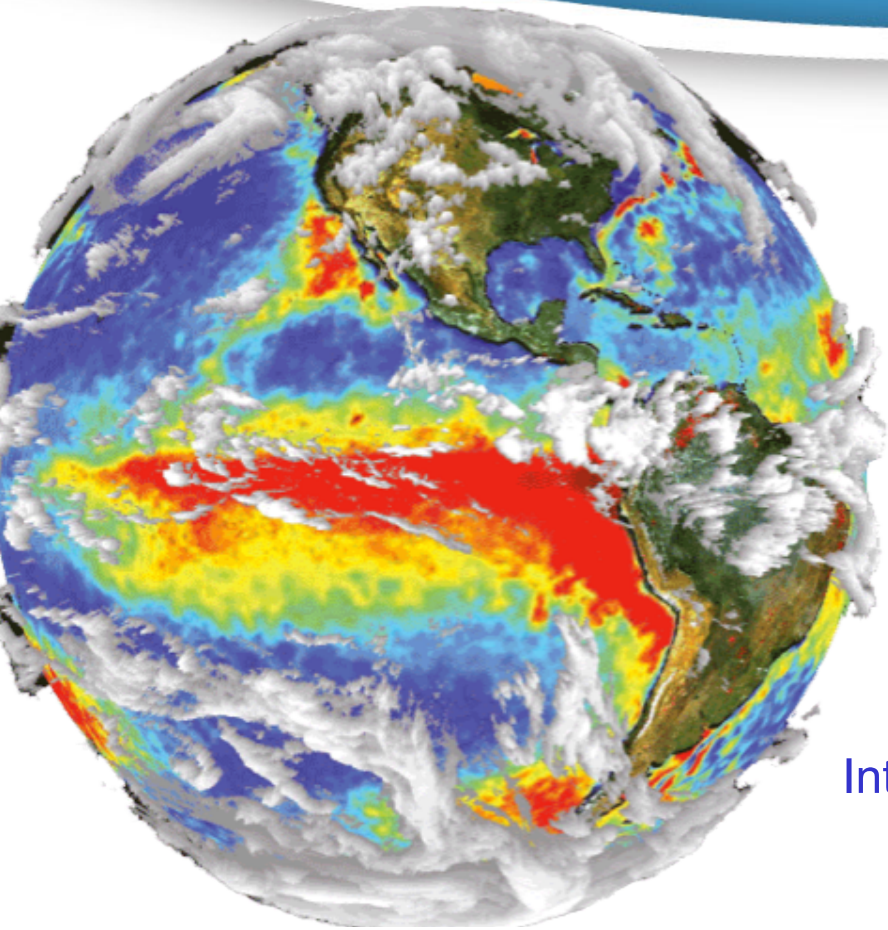
WCRP/CLIVAR efforts to understand El Niño in a changing climate



Eric Guilyardi

IPSL/LOCEAN, Paris

& NCAS-Climate, U. Reading

Thanks to Andrew Wittenberg, Mike McPhaden, Matthieu Lengaigne

2015 El Niño Conference

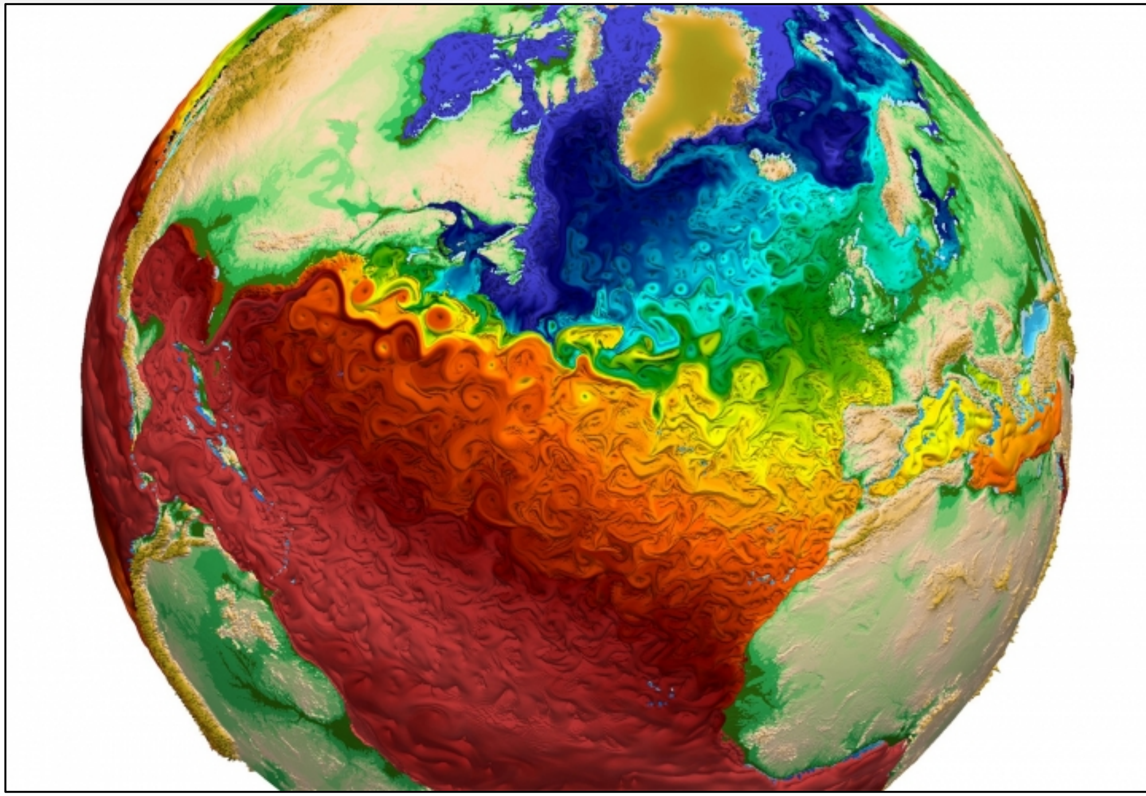
International Research Institute, November 2015

LOCEAN Sciences de l'environnement Institut Pierre Simon Laplace University of Reading National Centre for Atmospheric Science NATURAL ENVIRONMENT RESEARCH COUNCIL WCRP World Climate Research Programme CLIVAR

CLIVAR: CLIMATE & OCEAN

variability, predictability and change

- 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



Credit: Los Alamos National Laboratory

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CLIVAR

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
- ...

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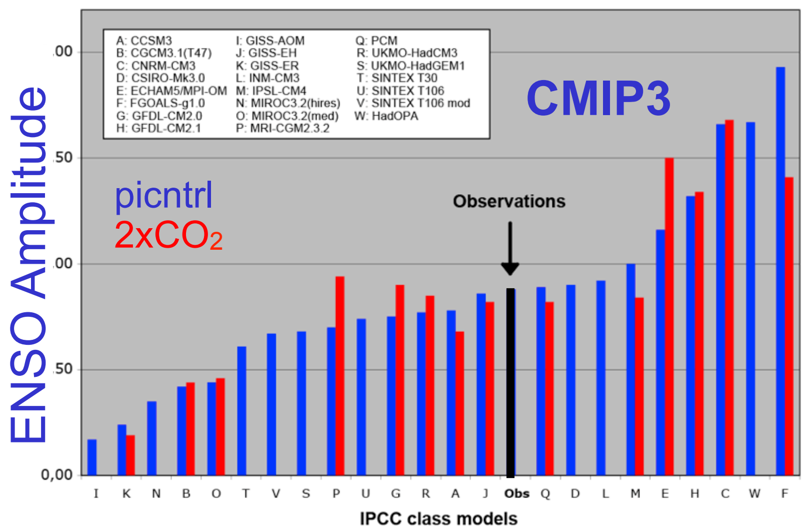
ENSO in a changing climate

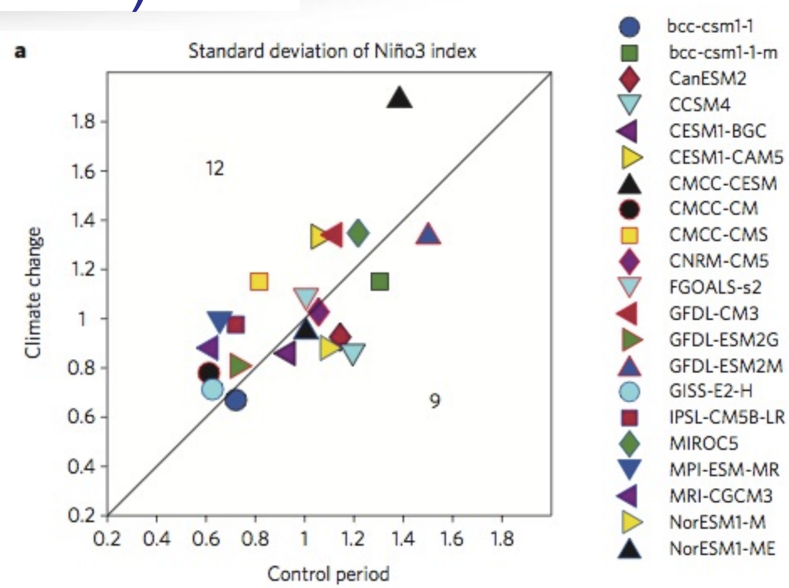
- Understanding ENSO and its underlying processes
- ENSO performance in GCMs
- ENSO diversity and unforced variations
- ENSO in a changing climate
- Some WCRP/CLIVAR community challenges

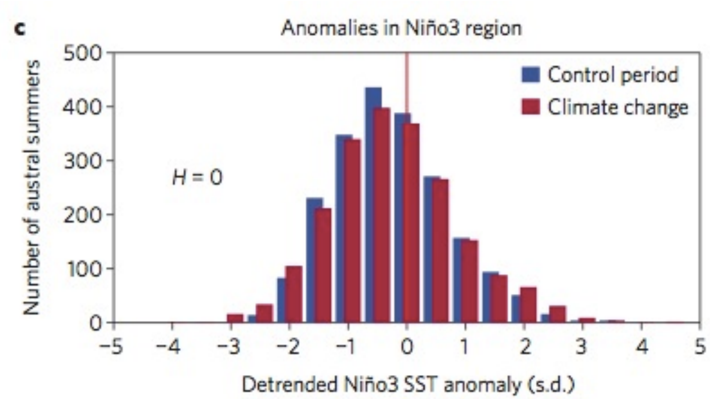
ENSO in a changing climate

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

CMIP5







Model biases dominate over scenario

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

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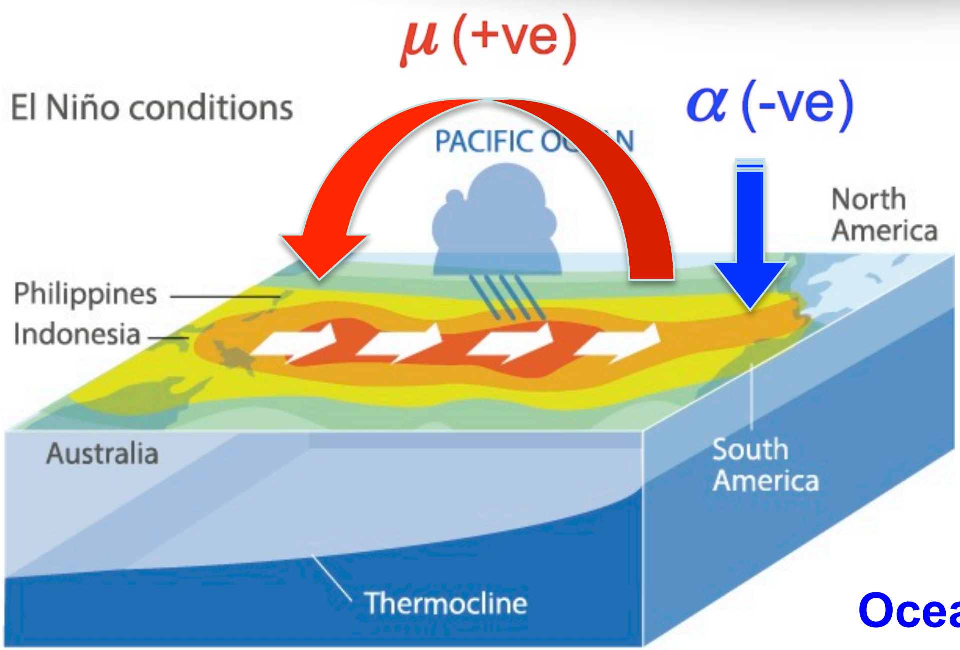
ENSO processes



Atmosphere response to SSTA

- Bjerknes wind stress feedback (μ)
- Heat flux response (α)

Ocean response to τ and HF anomalies

- Upwelling ("thermocline feedback")
- Zonal advection & Ekman feedbacks
- Wave dynamics
- Energy Dissipation

Non linear processes:

- NL ocean dynamical
- Impact of WWE

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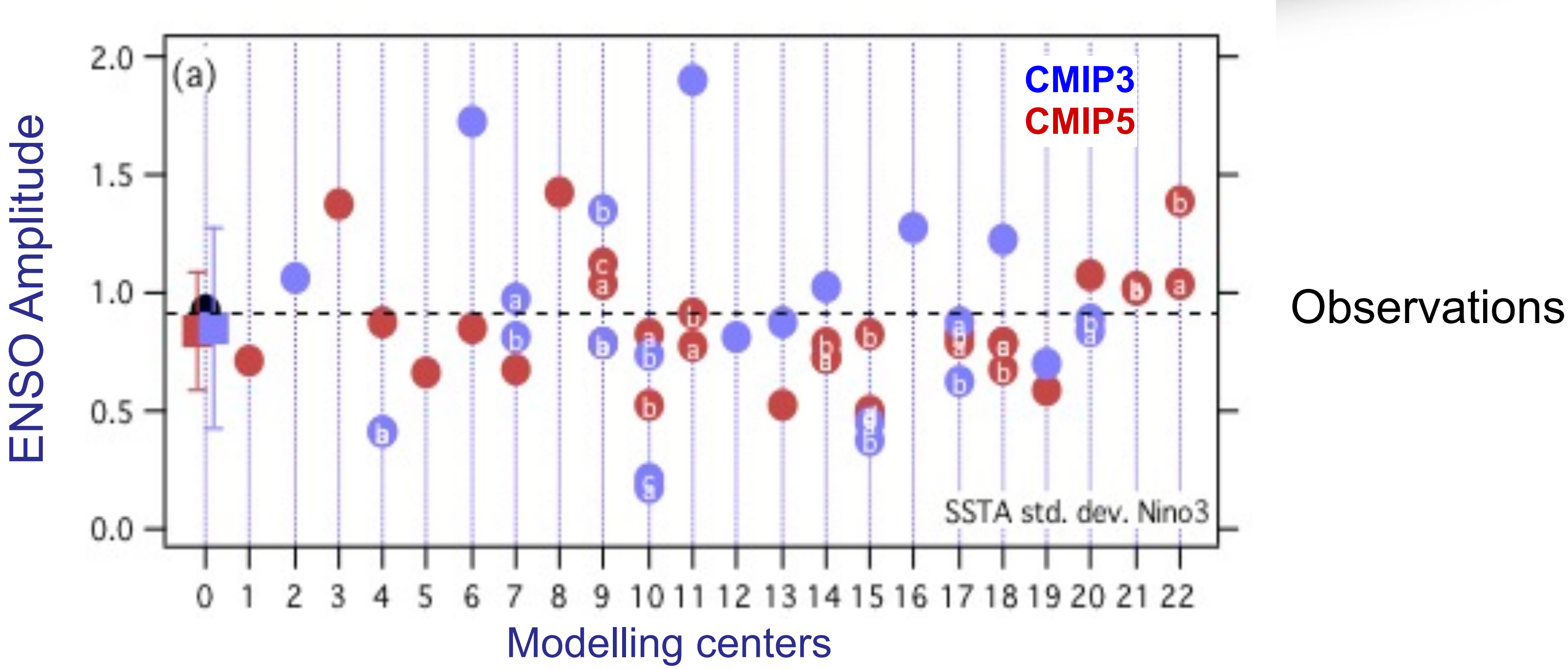
ENSO amplitude in GCMs

Standard deviation SSTA (C) in Niño3



- 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)

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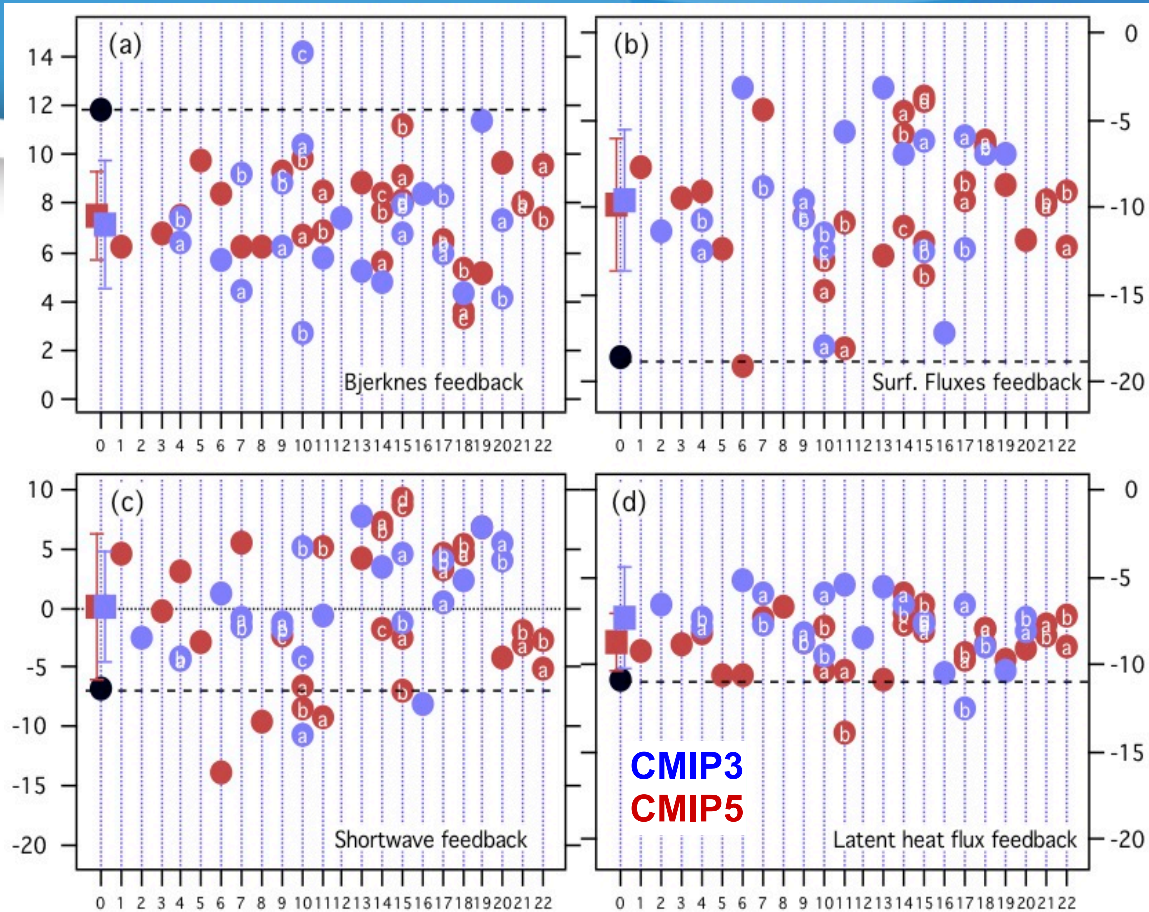
Atmosphere feedbacks in GCMs

Bjerknes
μ_1

Total Heat Flux
α



SW Heat Flux
α_{SW}

Latent Heat Flux
α_{LH}

Models underestimate both μ_1 and α (error compensation)

Shortwave feedback α_{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)

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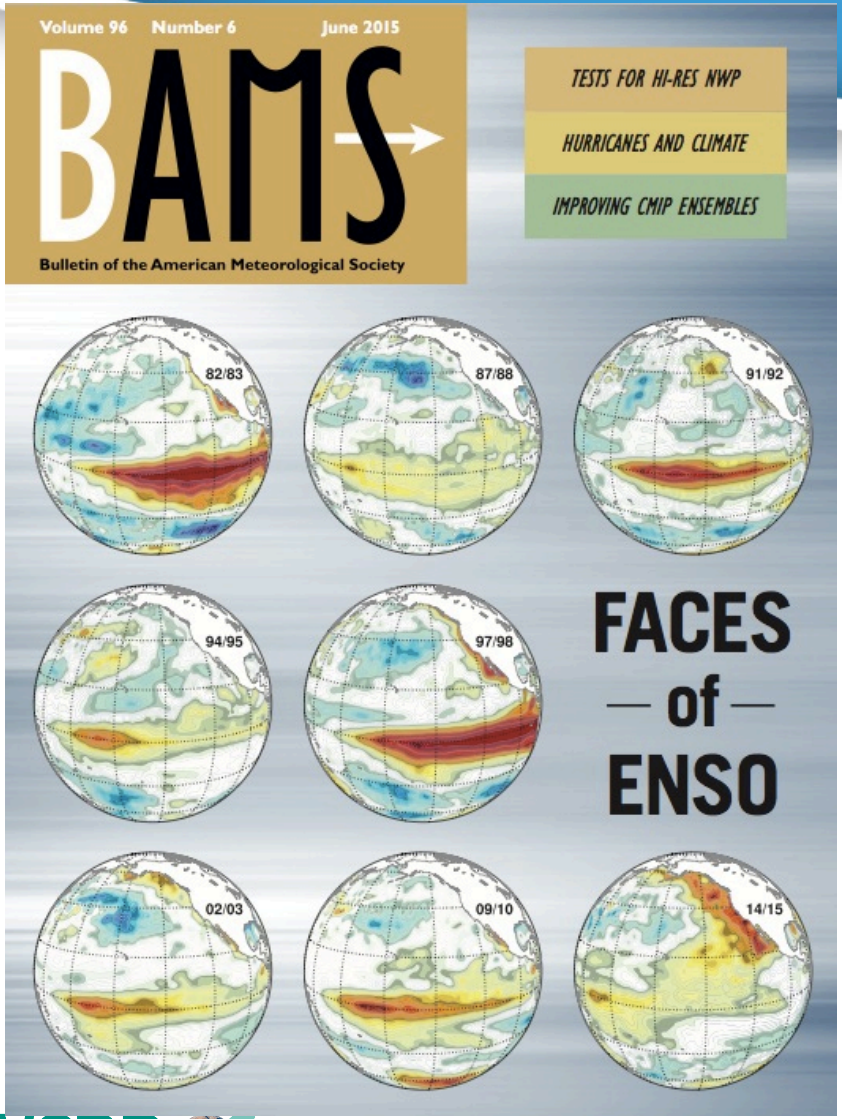
ENSO in GCMs

Need to simulate ENSO right for the right reasons

Performance metrics → Process-based metrics

ENSO diversity



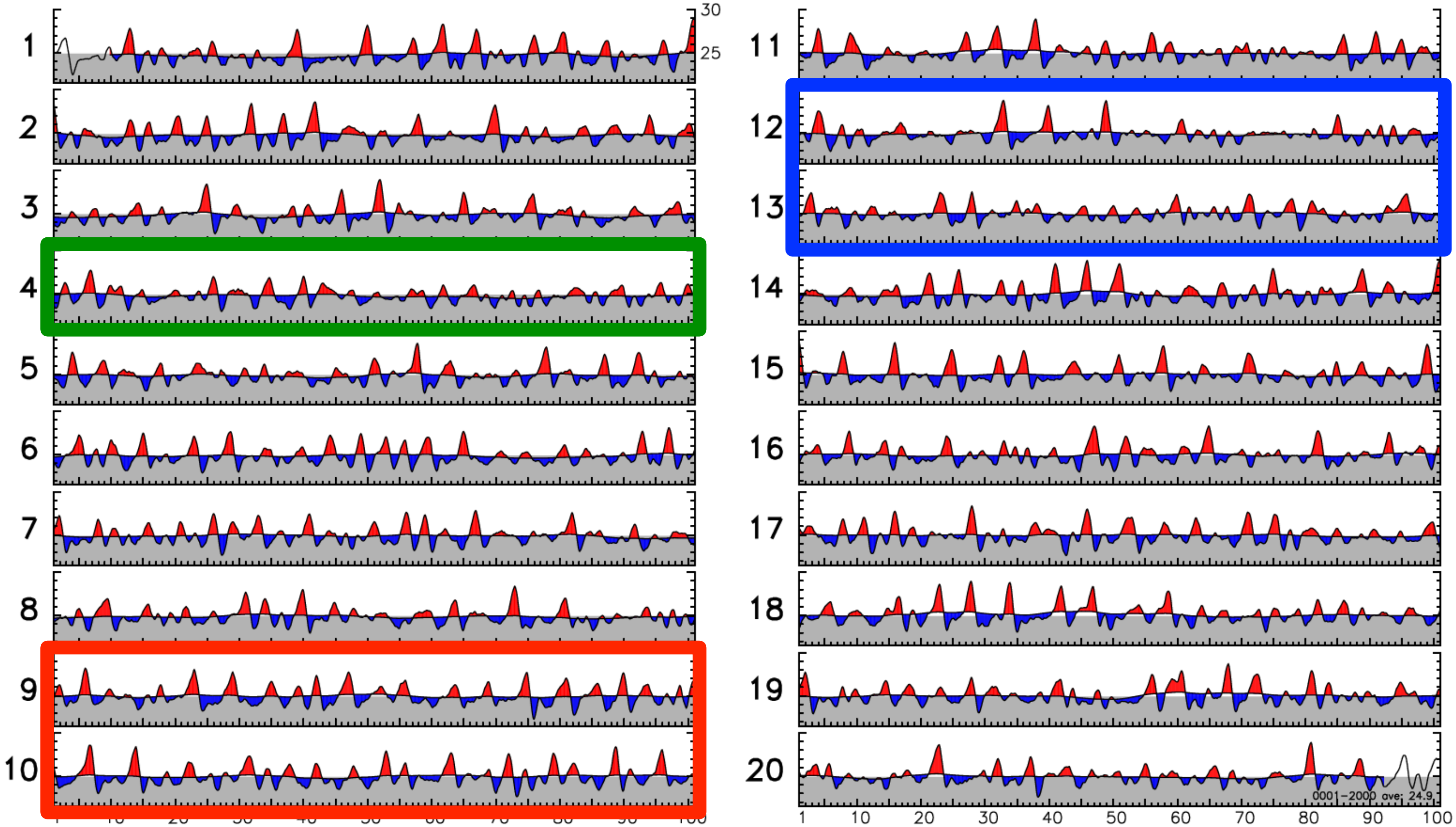
- No two El Niño events are alike
- Understanding this diversity is a challenge
- How long do we need to observe El Niño to detect a change ?

Capotondi et al. (2015)

20 centuries of NINO3 SSTs in GFDL 2.1

Pre-industrial unforced climate

Wittenberg (2009)



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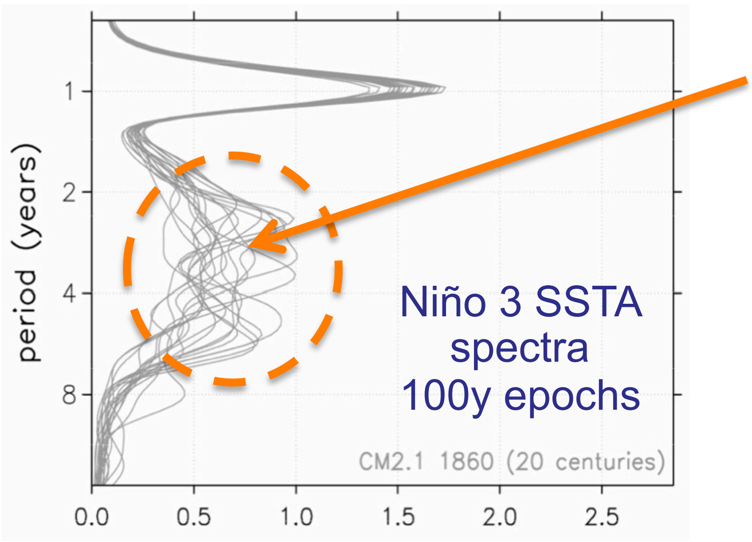
How long do we need to observe El Niño to detect a change ?

2000 years simulation **pre-industrial** control GFDL 2.1



Wittenberg (2009)

Stevenson et al. (2010):

Minimum length of simulation needed to statistically distinguish ENSO amplitude change = ~250 years

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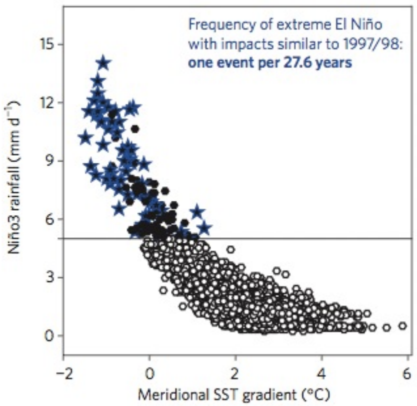
ENSO in changing climate

To understand if ENSO has changed, statistics (i.e. performance metrics) will only help us in 200 years. In the mean time we have to rely on physical understanding.

Performance metrics → Process-based metrics

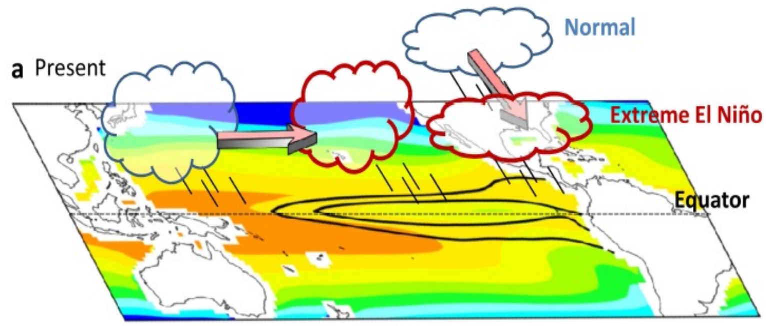
ENSO in changing climate

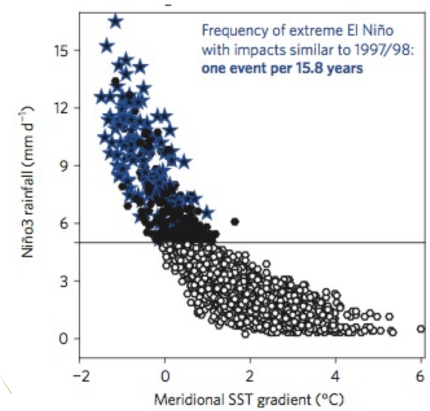
No change of *mean* El Niño SST statistics from CMIP scenario
Using a process-based criteria (rainfall > 5 mm/day in east Pacific)
Doubling of occurrence of extreme El Niños in unmitigated climate change



Historical

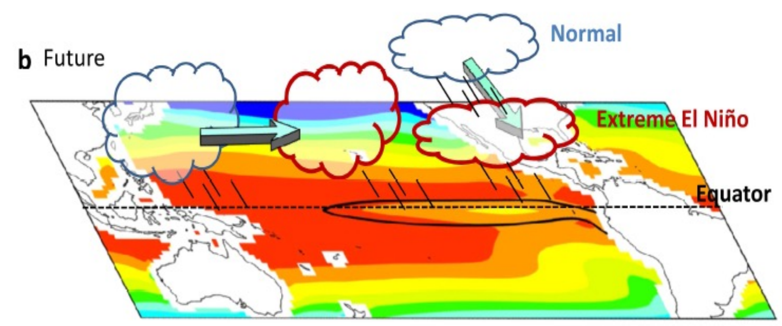
1 extreme El Niño every 6 events





RCP8.5

1 extreme El Niño every 3 events



See poster by Andrew Wittenberg

Cai et al. (2014, 2015)

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Summary

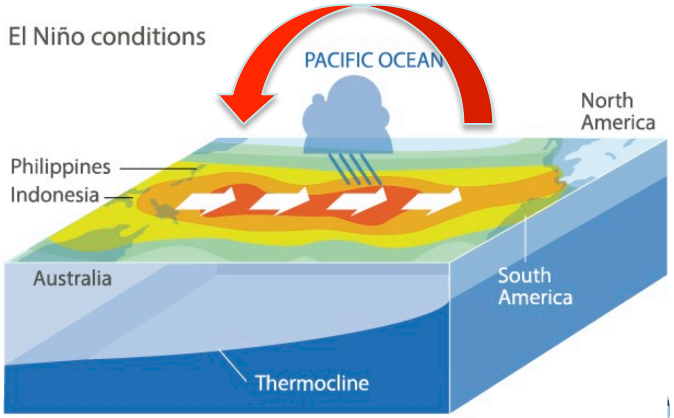
ENSO in a changing climate:

- 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

PAGES
PAST GLOBAL CHANGES

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

ENSO Observing System