A first look at ENSO in CMIP5

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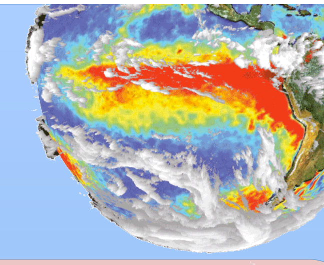


Preliminary results:

- ENSO amplitude and frequency: no revolution from **CMIP3** to **CMIP5** – about half the individual modeling centres show an improvement in ENSO amplitude
- Variance in **CMIP5** closer to observed in East Pacific (less extreme models)
- Reduced variance in west Pacific, improved atmos. response in Niño3 in **CMIP5**
- Much improved onset and peak location (no more West Pacific bias)
- No clear mean state error reduction from **CMIP3** to **CMIP5** in tropical Pacific
- No clear process-based analysis change (still mostly error compensations)
- No further indication of likehood of ENSO change in increased CO_2 scenario

ENSO and Pacific mean state metrics

Guilyardi and Wittenberg (2010), and the ENSO metrics WG of the CLIVAR Pacific Panel)

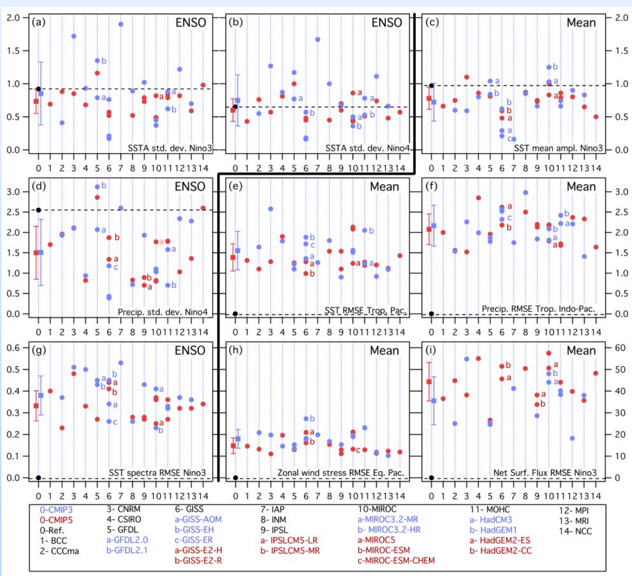


Fig. 1 - ENSO and mean tropical Pacific metrics for pre-industrial control simulations - CMIP3 (blue) and CMIP5 (red). (a) and (b) SSTA std. dev. in Niño 3 and Niño 4 (◦C), (c) SST annual cycle amplitude in Niño3, (◦C), (d) precipitation response (std dev) in Niño4 (mm/day), (e) SST RMS error in tropical Pacific, (◦C), (f) precipitation spatial RMS error over tropical Indo-Pacific, 30◦N-30◦S (mm/day), (g) ENSO power spectrum (Niño3) RMS error, (◦C^2), (h) zonal wind stress spatial RMS error over equatorial Pacific 5◦N-5◦S ($10^{-3}Nm^{-2}$), (i) net surface heat flux RMS error in Niño 3 (Wm^{-2}). Reference datasets, shown as black solid circles and dashed lines: HadISST1.1 for (a), (b), (c), (e) and (g); ERA40 for (h); CMAP for (d)(f); OAFlux for (i). The CMIP3 and CMIP5 multi-model mean are shown as squares on the left of each panel with the whiskers representing the model standard deviation.

Code	Modelling centre	CMIP3 model(s)	CMIP5 model(s)
1/A	BCC	n/a	BCC-CSM-1
2	CCCma	CGCM3.1	CanESM2
3/B	CNRM	CNRM-CM3	CNRM-CM5
4	CSIRO	CSIRO-Mk3.0	CSIRO-Mk3.6
5/Q O	GFDL	GFDL2.0 GFDL2.1	GFDL-ESM2M
6	GISS	GISS-AOM GISS-EH GISS-ER	GISS-E2-H GISS-E2-R
7	IAP	FGOALSg1.0	n/a
8	INM	INM-CM3.0	INM-CM4
9/C D	IPSL	IPSL-CM4	IPSL-CM5A-LR IPSL-CM5A-MR
10/H F G	MIROC	MIROC3.2-MR MIROC3.2-HR	MIROC5 MIROC-ESM MIROC-ESM-CHEM
11/I	MOHC	HadCM3 HadGEM1	HadGEM2-CC HadGEM2-ES
12	MPI	ECHAM5/MPI-OM	MPI-ESM-LR
13/L	MRI	MRI-CGCM2.3.2	MRI-CGCM3
14/N	NCC	-	NorESM1-M

Table 1. CMIP3 and CMIP5 models and codes

Simulations:
- Picontrol 240-300 yrs
- Historical 140 yrs

Process-based analysis

Atmosphere response:

- No multi-model mean improvement both for the Bjerkness feedback and the total heat flux response in Niño3
- Shortwave feedback in Niño3 well captured by several **CMIP5** models but degraded for others, leading to more inter-model diversity than in **CMIP3**

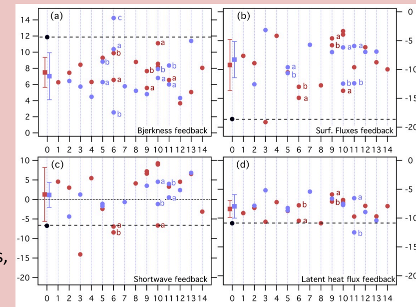


Fig. 2 - Atmosphere feedbacks during ENSO for pre-industrial control simulations - CMIP3 (blue) and CMIP5 (red). (a) Bjerknes feedback, computed as the regression of Niño 4 wind stress over Niño3 SST ($10^{-3}Nm^{-2}/C$); (b) heat flux feedback, computed as the regression of total heat flux over SST in Niño3 (Wm^{-2}/C); (c) Shortwave component of (b); (d) Latent heat flux component of (b). References: ERA40 for (a) and OAFlux for (b), (c) and (d). See Lloyd et al. 2011.

The sensitivity of atmospheric response to SST change is increased from **CMIP3** to **CMIP5** in Niño 3. This could explain the reduced ratio of SST variance between the western Pacific and the eastern Pacific from **CMIP3** to **CMIP5** (Fig. 1a/1b)

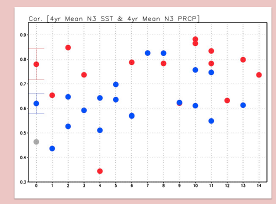
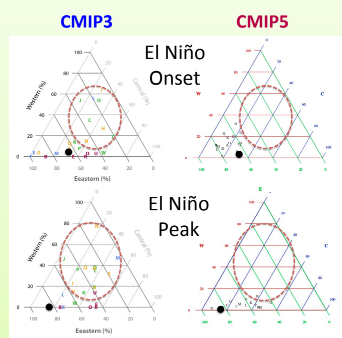


Fig. 3 - SST/precipitation anomaly correlation in Niño3 for historical simulations - CMIP3 (blue) and CMIP5 (red). Observations: MERRA (precip), ERSST.V3 (SST) from 1980-2010

Onset and peak location along the equator



The location of El Niño and La Niña onset, peak and termination is key for ENSO teleconnections.
Whereas **CMIP3** models locations where too much to the West (Leloup et al. 2008), this has been much improved in **CMIP5**.
This holds for both El Niño and La Niña and is less clear for the termination (not shown).

Fig. 4 Location of Niño onset and peak (E)ast, (C)entral, (W)est Pacific. Neural network analysis following Leloup et al. (2008). Observations: HadISST (black dot). Model codes in Table 1 above.

Mid-holocene (PMIP3)

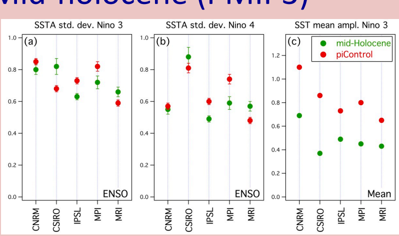


Fig. 5 - ENSO and mean tropical Pacific metrics for (red) pre-industrial control and (green) mid-holocene. (a) and (b) SSTA standard deviation in Niño 3 and Niño 4 (°C), (c) SST annual cycle amplitude in Niño 3 (°C).

- No coherent multi-model ENSO amplitude reduction in MH **CMIP5/PMIP3** (caveat CSIRO, MRI), unlike for **PMIP2** (Zheng et al. 2008)
- Coherent and robust SST annual amplitude reduction in Niño 3

The future of ENSO

As in **CMIP3**, **CMIP5** CGCMs exhibit a range of behaviour for ENSO variability in the future simulations, some showing an increase, others a decrease and some no change (Collins et al. 2009, Vecchi and Wittenberg 2010).

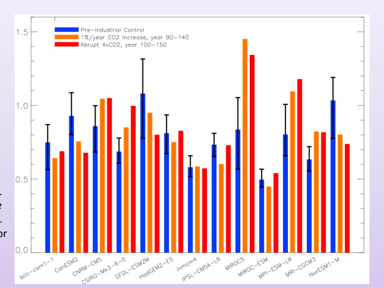


Fig. 6 - Standard deviation of Niño3 SST anomalies for CMIP5 model experiments. Blue bars, pre-industrial control experiments, orange bars, years 90-140 from the 1%/year CO_2 increase experiments, red bars years 50-150 from the abrupt $4xCO_2$. Calculations are performed for the models indicated on the x-axis. The black 'error bar' indicates the minimum and maximum of 50-year windowed standard deviation of Niño3 anomalies computed from the multi-century control experiments.

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