Palaeoclimate modelling and data-model synthesis

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Why palaeoclimate modelling?

- Data:
  - The real world
- Models:
  - Precise chronology
  - Complete spatial coverage, from bottom of ocean to top of atmosphere
  - As much temporal resolution as you need (hourly?)
  - Simulate actual physical variables (no transfer functions)
  - Just *not* the real world...

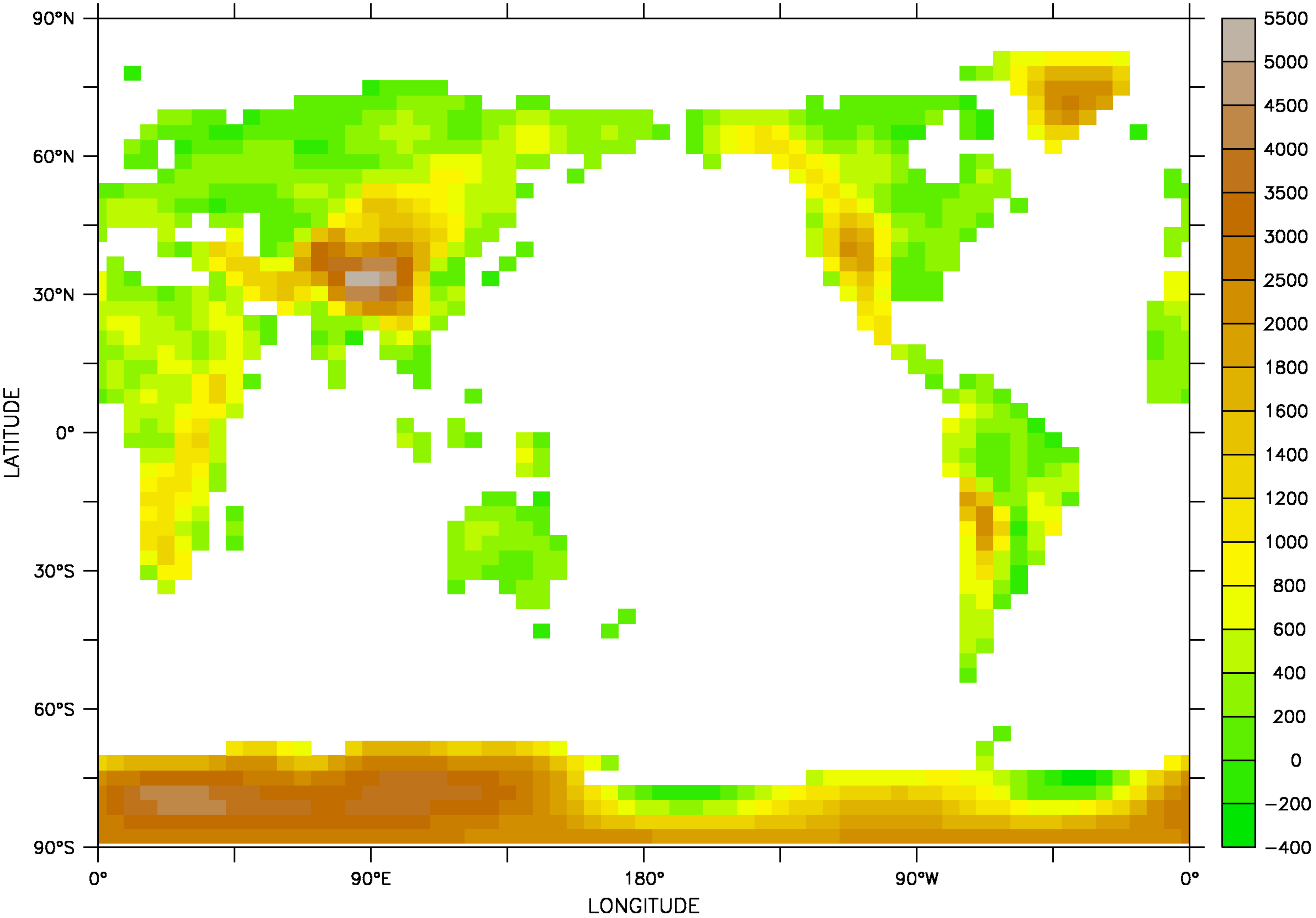
Palaeoclimate modelling: National efforts

- General circulation models (GCMs):
  - CSIRO Mk3L (UNSW, CSIRO, ANSTO?)
  - CCSM (UNSW, University of Sydney)
  - FOAM (Monash University, University of Western Australia)
- Earth System Models of Intermediate Complexity (EMICs):
  - UVic (UNSW)
- Different timescales, different questions:
  - ENSO variability during the Holocene
  - Changes in the Australian monsoon during the last glacial cycle
  - Deep time/past warm periods
  - Process studies (abrupt changes, carbon cycle, topography...)

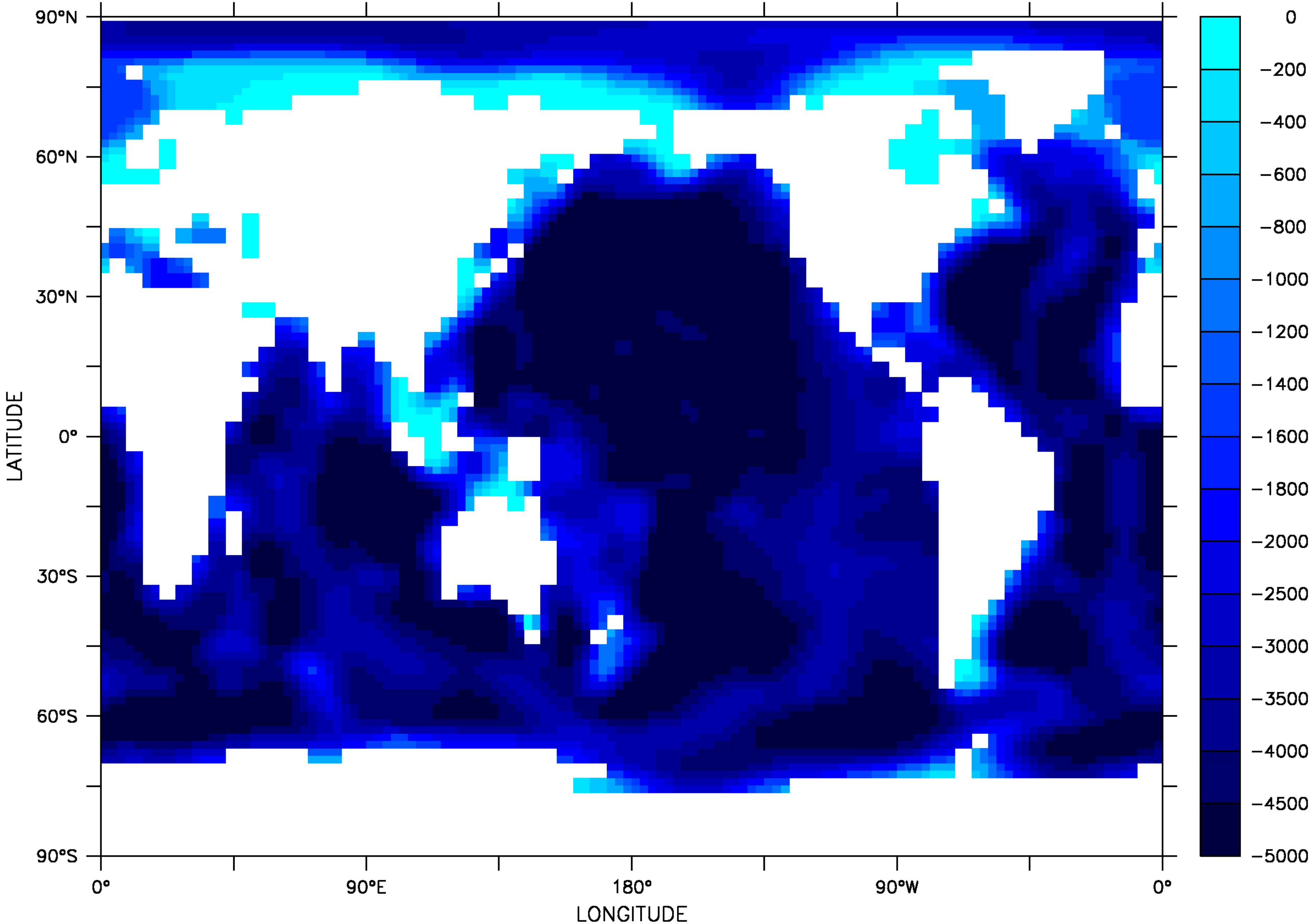
Exploring ENSO in a climate system model

- CSIRO Mk3L climate system model v1.1:
  - Atmosphere: $5.6^\circ \times 3.2^\circ$, 18 vertical levels
  - Ocean: $2.8^\circ \times 1.6^\circ$, 21 vertical levels
  - Sea ice: Dynamic-thermodynamic
  - Land surface: Static vegetation
  - Can simulate 1000 years in a month
- Three transient simulations of the past 8,000 years:
  - Only the Earth's orbital geometry is varied
  - Atmospheric CO_2 concentration = 280 ppm
  - Solar constant = $1365\,\mathrm{W m^{-2}}$
  - The three ensemble members differ only in the initial conditions

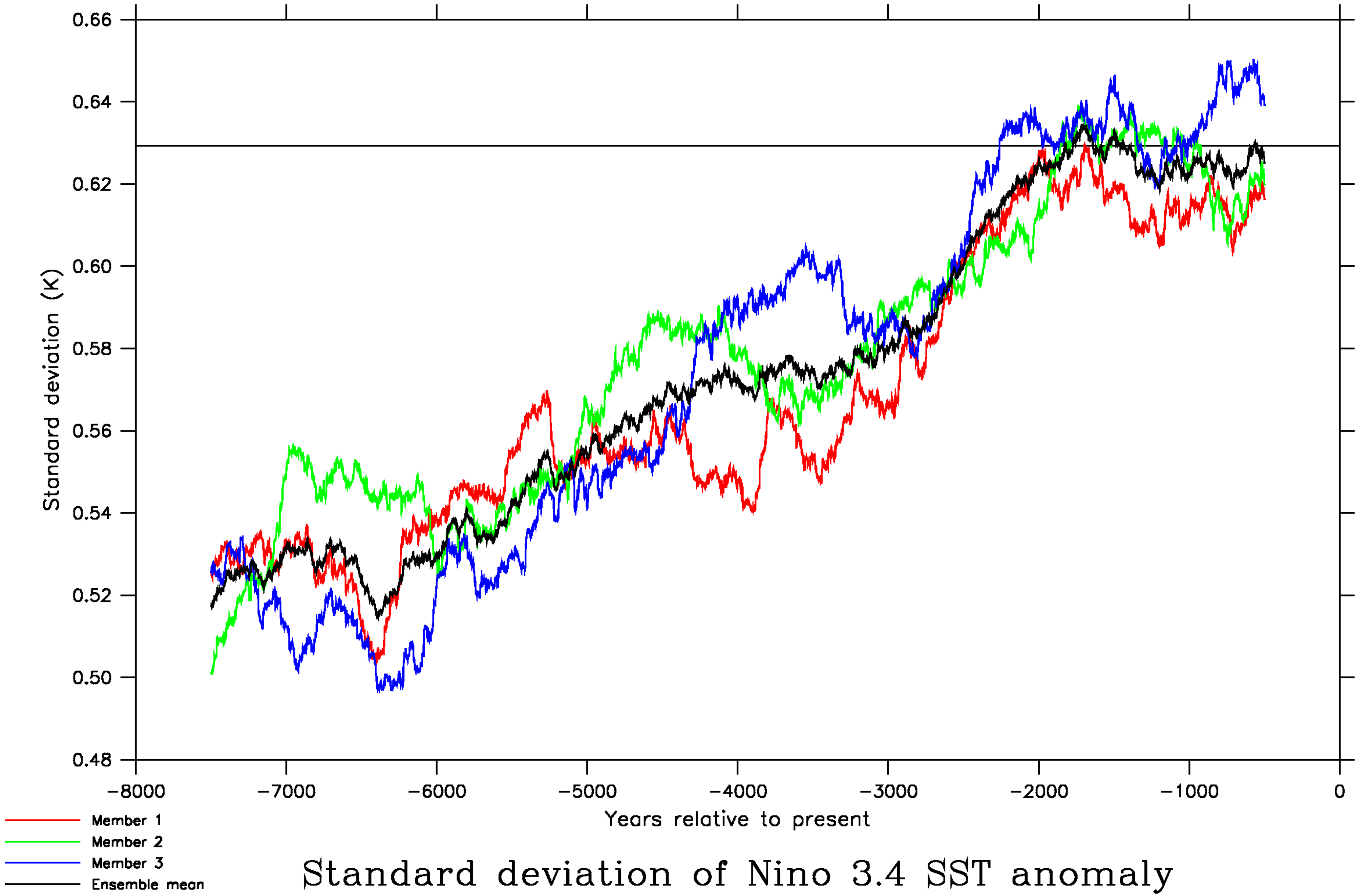
Topography of atmosphere model



Bathymetry of ocean model



Simulated changes in ENSO variability



Standard deviation of Nino 3.4 SST anomaly

Phipps and McGregor (in prep)

Simulated changes in the Australian monsoon

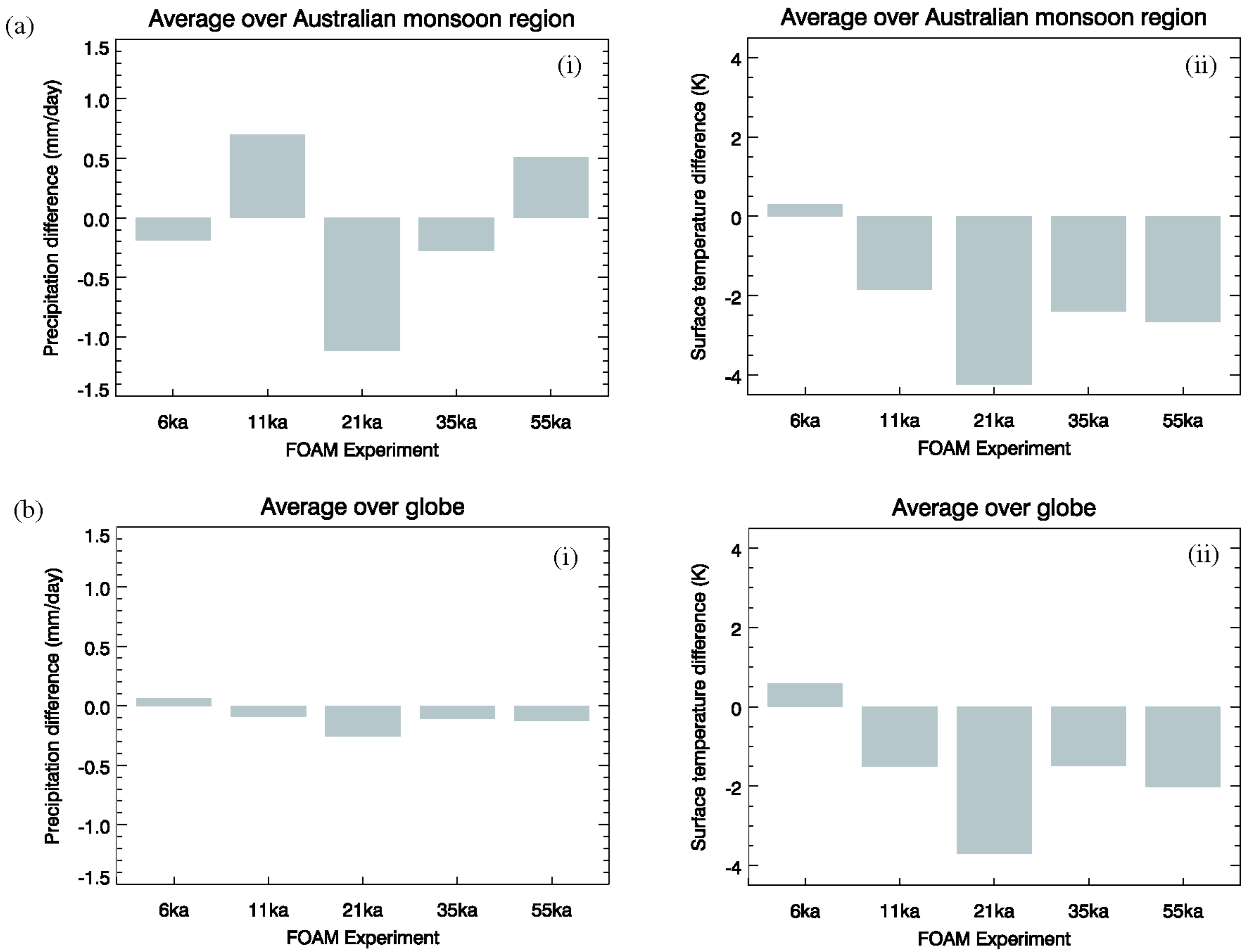


Figure 9 Summary of changes in (i) precipitation and (ii) surface temperature for (a) the Australian monsoon region and (b) the globe

Marshall and Lynch (2006), Journal of Quaternary Science

Palaeoclimate Modelling Intercomparison Project

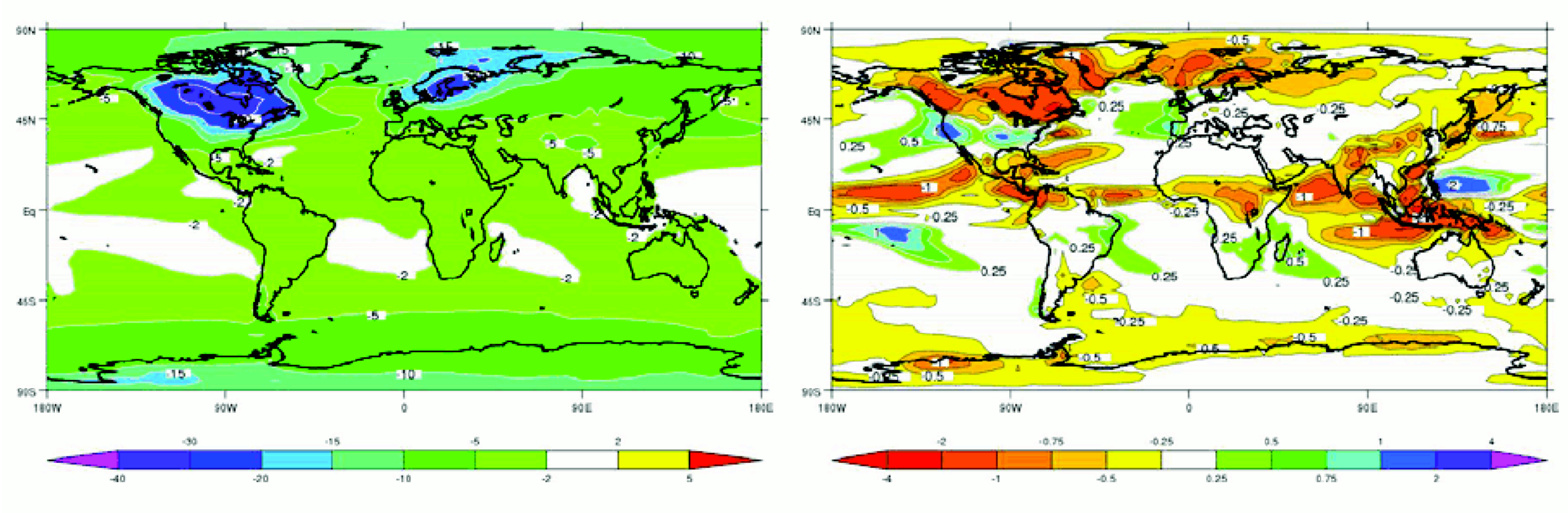
- Phase 1 (1991–2001) :
  - Atmospheric GCMs
  - Primary experiments were 6 ka (mid-Holocene) and 21 ka (LGM)
  - 22 models participated
  - Contributed towards IPCC TAR
- Phase 2 (2002–2008) :
  - Atmosphere-ocean(-vegetation) GCMs
  - Primary experiments were 6 ka (mid-Holocene) and 21 ka (LGM)
  - 18 models participated
  - Contributed towards IPCC AR4

Phase 3 (2009–)

- Theme 1: Evaluation of earth system models at 6 ka and 21 ka
  - Vegetation, biogeochemical cycles, chemistry, ice sheets...
  - Use of new data syntheses for model evaluation
- Theme 2: Interglacials and warm periods
  - Last interglacial (~130–115 ka) - snapshot and transient
  - Mid-Pliocene (~3.3–3.0 Ma) - snapshot (PlioMIP)
- Theme 3: Abrupt climate changes
  - Transient simulations of last deglaciation, 8.2 ka event...
- Theme 4: Uncertainties: characterisation and understanding
  - Uncertainties in reconstructions, boundary conditions...
  - Weight models according to a palaeoclimate skill index?
- Will contribute towards IPCC AR5

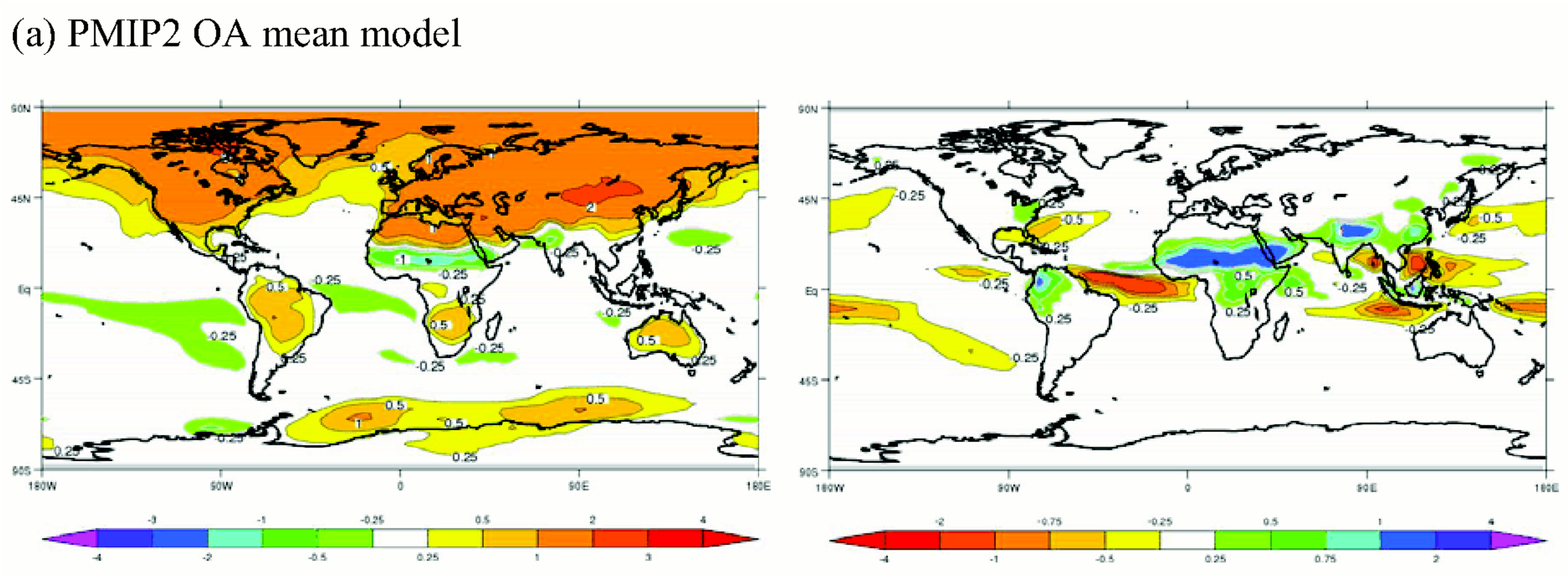
PMIP2: 21 ka temperature and precipitation anomalies

(a) PMIP2 OA mean model



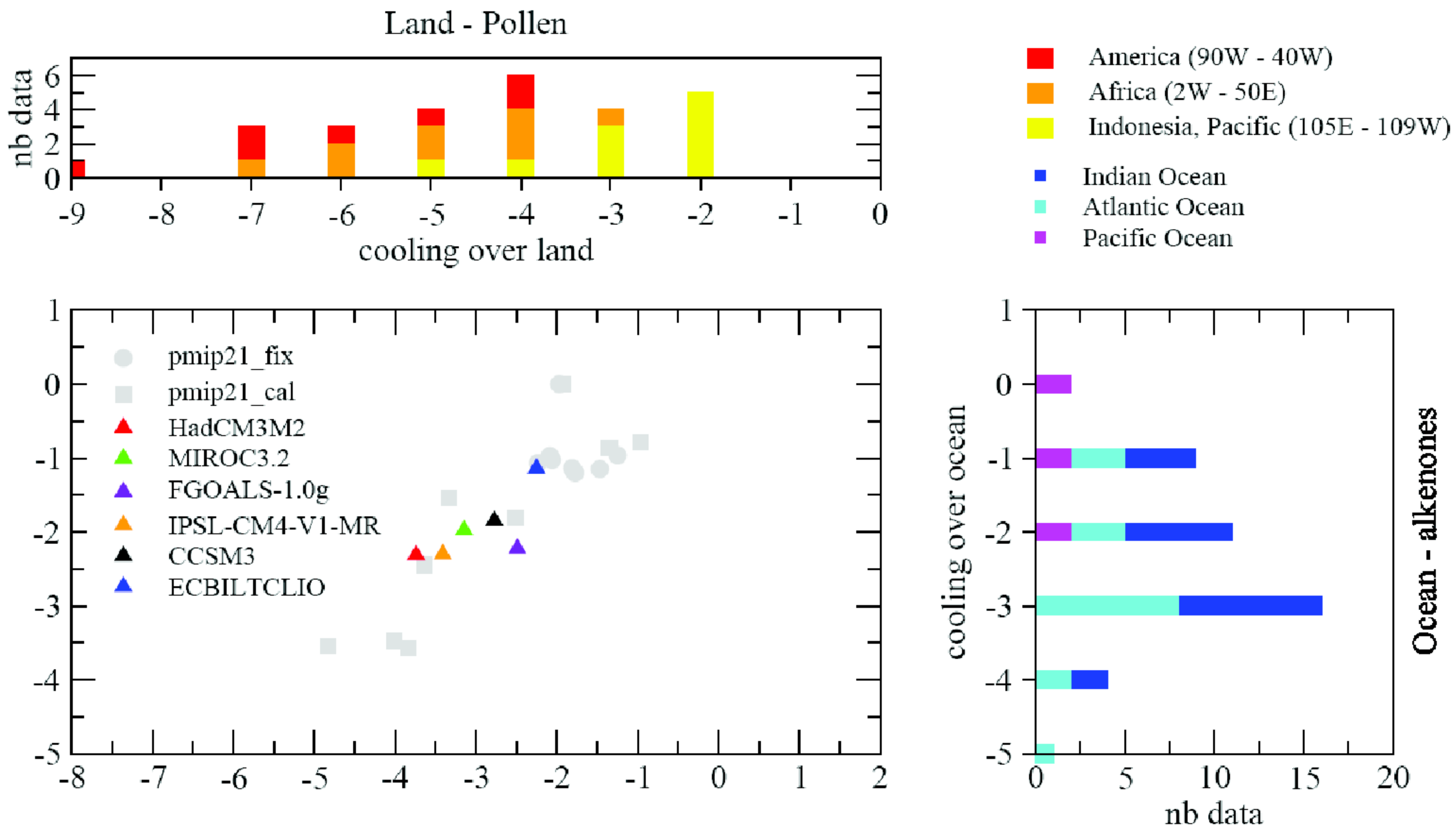
Braconnot et al (2007), Climate of the Past

PMIP2: 6 ka temperature and precipitation anomalies



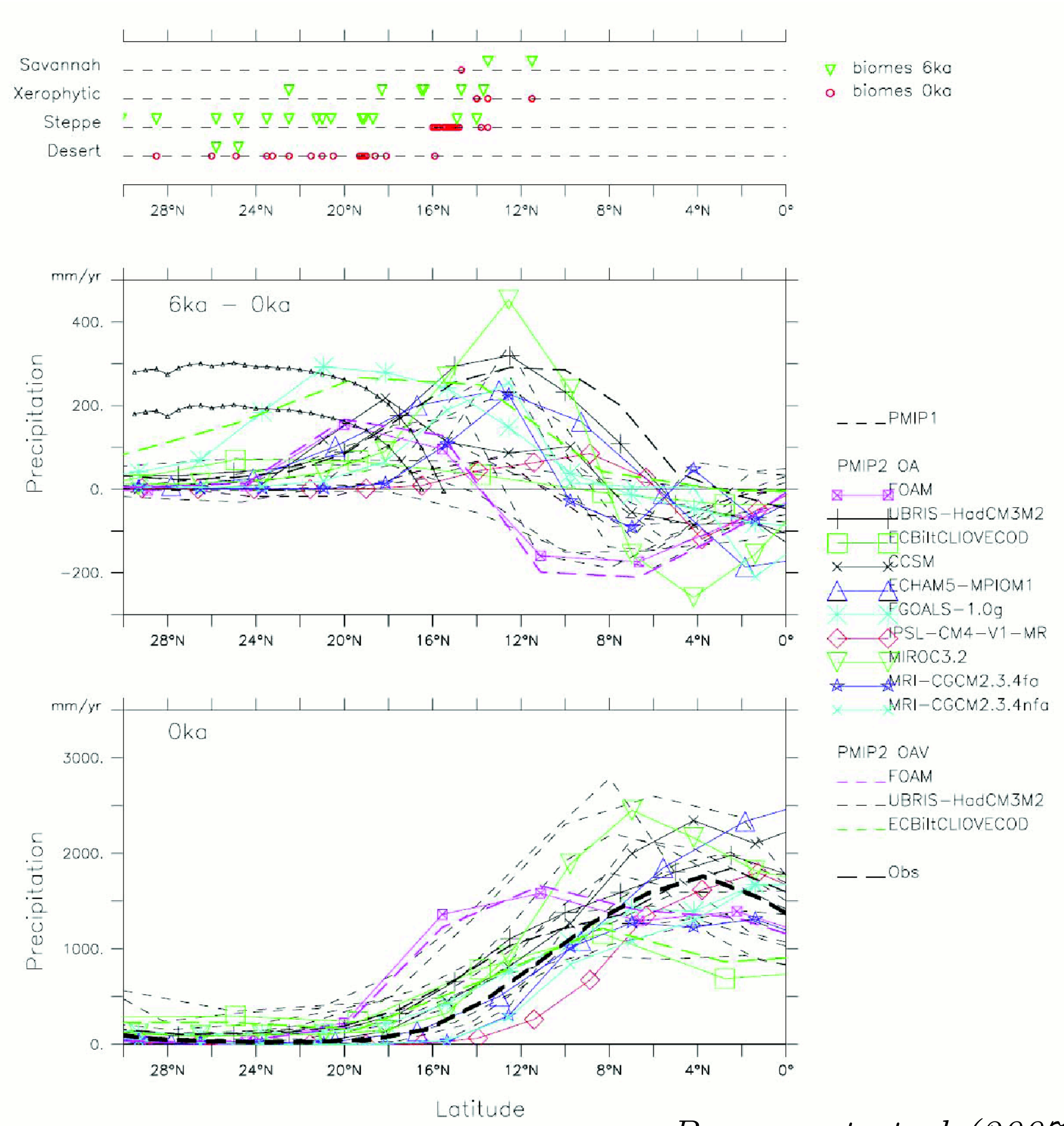
Braconnot et al (2007), Climate of the Past

PMIP2: 21 ka tropical cooling



Braconnot et al (2007), Climate of the Past

PMIP2: 0 ka and 6 ka precipitation over northern Africa



Braconnot et al (2007), Climate of the Past

PMIP2: 0 ka, 6 ka and 21 ka ENSO variability

Table 2 Main El Niño features for the different models and the observations

Model	Code	Amplitude	Period (year)	SST (°C) Niño3	TAUX (Pa) Niño4	Amplitude change (%)	
						6ka	21ka
Observed	OBS	0.80 ± 0.04	3.6/5.4	25.70 ± 0.06	–0.029 ± 0.001		
CCSM3	A	0.94 ± 0.06	2.0	25.24 ± 0.09	–0.033 ± 0.001	*–18.6*	*–35.8*
FGOALS–1.0g*	B	1.91 ± 0.11	4.5	25.19 ± 0.16	–0.033 ± 0.001	*–14.6*	–4.1
FOAM	C	0.76 ± 0.03	4.1	22.27 ± 0.05	–0.040 ± 0.001	*–11.6*	
IPSL-CM4*	D	1.03 ± 0.04	2.8	26.36 ± 0.08	–0.026 ± 0.000	*–2.9*	–1.3
MIROC3.2*	E	0.51 ± 0.03	4.3	24.85 ± 0.04	–0.041 ± 0.000	*–22.5*	*12.2*
MRI-CGCM2.3.4fa	F	0.65 ± 0.03	2.4	24.92 ± 0.05	–0.040 ± 0.001	3.3	
MRI-CGCM2.3.4nfa	G	0.63 ± 0.04	2.3	23.14 ± 0.05	–0.043 ± 0.001	*–12.9*	

The El Niño amplitude changes of 6ka and 21ka (when compared to 0ka) are shown in the last two columns. The El Niño amplitude is defined as the standard deviation of monthly SST anomaly in the Niño3 region. Errors were estimated with a moving block bootstrap to account for serial correlation (windows: El Niño period of Fig. 1 for standard deviation and 10 months for means). The amplitude change values italicized are significant at the 5% level by F test. The model with an asterisk means that the model version is the same as in CMIP3

Zheng et al (2008), Climate Dynamics

Palaeoclimate modelling and OZ-INTIMATE

- How the proxy people can help the modellers:
  - Evaluation of models and model simulations
- How the modellers can help the proxy people:
  - Dynamical interpretation of data
  - Fill spatial gaps in datasets
  - Enhance temporal resolution
  - Chronology?
  - Explore how teleconnections (transfer functions) evolve over time
- The future:
  - Data-model synthesis
  - Data assimilation