Southern Hemisphere climate variability over the past 8,000 years: an integrated data–model perspective

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SHAPE
INTEGRATION
Tools
Models
Proxies
Southern Hemisphere Assessment of PalaeoEnvironments

A smorgasbord of climate model simulations

List of PMIP3/CMIP5 participants
Information as of May 20th 2014

Up to date PMIP3 info: https://pmip3.lsce.ipsl.fr/wiki/doku.php/pmip3:database:status
Some ESGF access nodes: PCMDI IPSL DKRZ BADC
Node information: http://esgf-node.ipsl.fr/esgf-desktop

CMIP5 Errata: http://pcmdi-cmip.llnl.gov/cmip5/errata/cmip5errata.html
PMIP3 Errata: https://wiki.lsce.ipsl.fr/pmip3/doku.php/pmip3:database:errors
Models' documentation: http://q.cmip5.ceda.ac.uk/cmip5/publisheddocs/

	Institute	Country	0k *piControl*	6k *midHolocene*	21k *lgm*	LM *past1000* (1000 years)	1 % CO_2 *1pctCO2* (140 years)	CMIP5	PlioMIP	Last Interglacial	Holocene	Carbon cycle	Atm	Ocn	Model id	Term of Use	Data Node	Extra Doc Errata etc...
1	AWI	Germany	Completed	Completed	Completed			No	Yes	Yes	No	Yes	96×48 x L19	120×101 x L40	COSMOS-aso ?	?	DKRZ	
2	BCC	China	CMIP5 (500)	CMIP5 (100)		CMIP5	CMIP5	Yes	No	No	No	Yes	128×64 x L26	360x232 x L40	bcc-csm1-1	Unrestricted	BCC	
3	BCCR	Norway	Completed	Running Summer 2013	Completed	Running Summer 2013	Running Summer 2013	No	Yes	Yes	No	Yes	96×48 x L26	100×116 x L32	NorESM1-L	Unrestricted	DKRZ ?	
4	CAU-GEOMAR	Germany	PMIP3	PMIP3	Starting		PMIP3	No	Yes	Yes	Yes	No	96x48 x L19	182x149 x L31	KCM1-2-2	Non-commercial only	DKRZ	
5	CNRM-CERFACS	France	CMIP5 (850)	CMIP5 (200)	CMIP5 (200)		CMIP5	Yes	No	No	No	No	256x128 x L31	362x292 x L42	CNRM-CM5	Unrestricted	CNRM	Doc
6	FUB	Germany	PMIP3 (400)		PMIP3 (600)			No	No	No	No	Yes	96×48 x L19	120×101 x L40	COSMOS-ASO	Unrestricted	IPSL (DKRZ later?)	
7	NOAA-GFDL	USA	CMIP5 (470)		Not Successful		CMIP5	Yes	No	No	No	Yes	144x90 x L24	360x200 x L50 360x210 x L64	GFDL-ESM2M GFDL-ESM2G	Unrestricted	GFDL	
8	NASA-GISS	USA	CMIP5 (7 x)	CMIP5 (100)	CMIP5 (2 x 100)	CMIP5 (8 x 1000)	CMIP5 (151)	Yes	Yes	?	Yes	No	144x90 x L40	288x180 x L32	GISS-E2-R	Unrestricted	NCCS	Doc
9	IPSL	France	CMIP5 (1000)	CMIP5 (500)	CMIP5 (200)	CMIP5	CMIP5	Yes	Yes	Yes	Yes	Yes	96x95 x L39	182x149 x L31	IPSL-CM5A-LR	Unrestricted	IPSL	Doc
10	ICHEC (KNMI)	Netherlands	PMIP3 (40)	PMIP3 (40)				No	Yes	No	No	No	320×160 x L62	362x292 x L42	EC-Earth-2-2	Unrestricted	ICHEC	
11a	LASG-CESS		CMIP5 (900)	CMIP5 (100)	CMIP5 (100)		CMIP5		Yes	No	No		128x60 x L26		FGOALS-g2	Unrestricted	LASG	
11b	LASG-IAP	China	CMIP5 (501)	CMIP5 (100)		CMIP5	CMIP5	Yes	No	No	No	No	128x108 x L26	360x180 x L30	FGOALS-s2	Unrestricted	LASG	
11c			Completed			CMIP5				No	No		72x45 x L26		FGOALS-gl	Unrestricted	LASG	Doc
12	LOVECLIM	Belgium France Netherlands	Completed	Completed	Completed	Completed		No	No	Yes	Yes	No	32x64 x L3	122x65 x L20	LOVECLIM1-2	Unrestricted	IPSL	
13	MIROC	Japan	CMIP5 (531)	CMIP5 (100)	CMIP5 (100)	CMIP5	CMIP5	Yes	Yes	?	?	Yes	128x64 x L80	256x192 x L44	MIROC-ESM	Non-commercial only	DIAS	
14	MPI-M	Germany	CMIP5 (1156)	CMIP5 (2x100)	CMIP5 (2 x 100)	CMIP5	CMIP5	Yes	No	No	No	No	196x98 x L47	256x220 x L40	MPI-ESM-P	Unrestricted	DKRZ	
15	MRI	Japan	CMIP5 (500)	CMIP5 (100)	CMIP5 (100)	CMIP5	CMIP5	Yes	Yes	No	No	No	320x160 x L48	364x368 x L51	MRI-CGCM3	Non-commercial only	DIAS	
16	NCAR	USA	CMIP5 (501)	CMIP5 (1x301 + 1x30)	CMIP5 (1x101 + 1x31)	CMIP5	CMIP5	Yes	Yes	No	No	No	288x192 x L26	320x384 x L60	CCSM4	Unrestricted	NCAR	
17	OSUVic	USA	Completed	Completed (400)	Completed		Completed	No	No	No	No	No	128x64 x L10	100 x 100 x L19	OSUVic-0-3	Unrestricted	?	
18	CSIRO-QCCCE	Australia	CMIP5 (500)	CMIP5 (100)			CMIP5	Yes	No	No	No	No	192x96 x L18	192x192 x L31	CSIRO-Mk3-6-0	Non-commercial only	NCI	
19a	MOHC (UK groups)		CMIP5 (497)	CMIP5 (102)	Starting	Running Spring 2013	CMIP5	Yes	Yes	Yes	Yes	Yes	192x144 x L38	360x216 x L40	HadGEM2-ES	Unrestricted	BADC	Doc
19b		UK	CMIP5 (240)	CMIP5 (35)				Yes	No	No	No	Yes	192x144 x L60	360x216 x L40	HadGEM2-CC	Unrestricted	BADC	
19c	UOED		PMIP3 (1200)			PMIP3	CMIP3	Yes	Yes	Yes	Yes	No	96x73 x L19	288x144 x L20	HadCM3	Unrestricted	BADC	
20	UNSW	Australia	PMIP3 (1000)	PMIP3 (500)	Not Successful	PMIP3	PMIP3	No	No	Yes	Yes	No	64x56 x L18	128x112 x L21	CSIRO-Mk3L-1-2	Non-commercial only	IPSL (NCI later?)	Doc
21	UofT	Canada	Completed	Completed	Completed	Completed	Completed	No	No	No	No	No	256x128 x L26	320x386 x L40	UofT-CCSM3	Unrestricted	?	

Click for up-to-date exp check : piControl ? midHolocene ? lgm ? past1000 ? 1pctCO2 ?

Legend

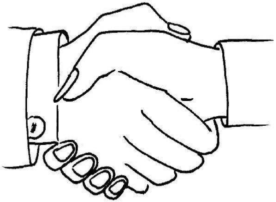
Status expected completion date	Available in CMIP5 DB (nb ens x nb years in CMIP5 DB)	Available in CMIP3 DB
No	Available in PMIP3 DB (nb years in PMIP3 DB)	Not Successful
Yes		

PMIP3 + PlioMIP groups: Note that the models used for PlioMIP are often not (exactly) the same as the ones used for PMIP3/CMIP5

PlioMIP-only (not in the table): LPAP, UoM

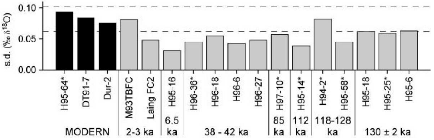
Come and see the SHAPE Climate Modelling Group poster this afternoon...

The “handshake” question

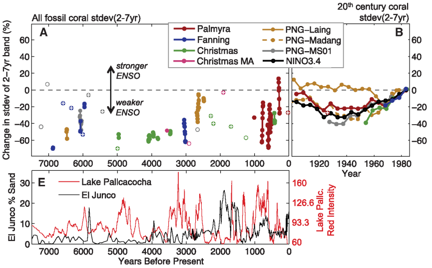


- Data-model integration is a two-way process
- Proxy data can be used to constrain climate model simulations
- Climate models can provide dynamical interpretation of proxy data
- Everyone wins: we learn more about the dynamics of the climate system than when we employ the two approaches separately

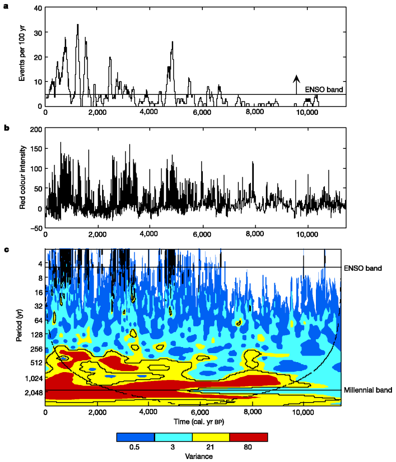
We know that ENSO has changed over the Holocene



Tudhope et al. (2001), *Science*

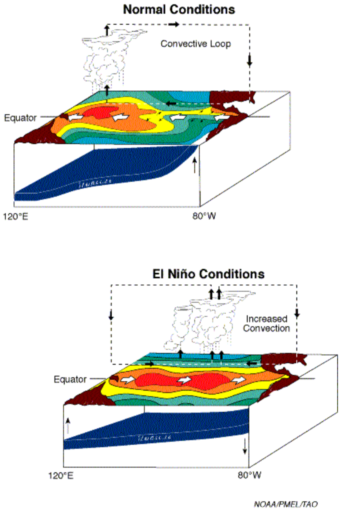


Cobb et al. (2013), *Science*



Moy et al. (2002), *Nature*

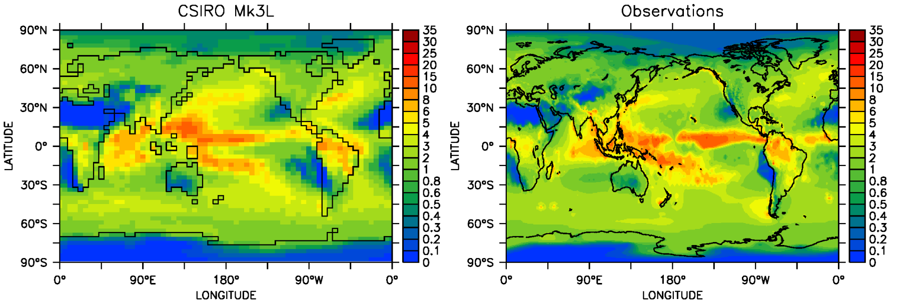
The dynamics of the El Niño–Southern Oscillation



- El Niño–Southern Oscillation (ENSO) is the dominant mode of internal variability within the coupled atmosphere-ocean system
- Irregular period of ∼2–7 years
- Average state of the system involves strong easterly trade winds pushing warm water to the west
- During an El Niño event, these winds slacken and the warm water flows eastwards

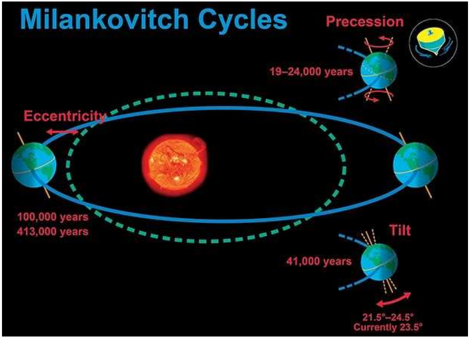
Simulating the role of orbital forcing

- The CSIRO Mk3L climate system model (Phipps et al., 2011, 2012)
  - Atmospheric general circulation model (5.6° × 3.2°, 18 levels)
  - Ocean general circulation model (2.8° × 1.6°, 21 levels)
  - Dynamic-thermodynamic sea ice model
  - Land surface scheme

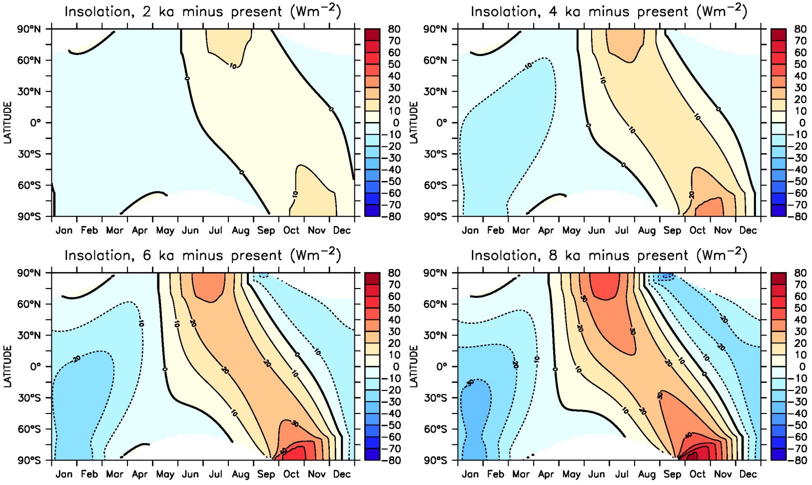


Simulating the role of orbital forcing

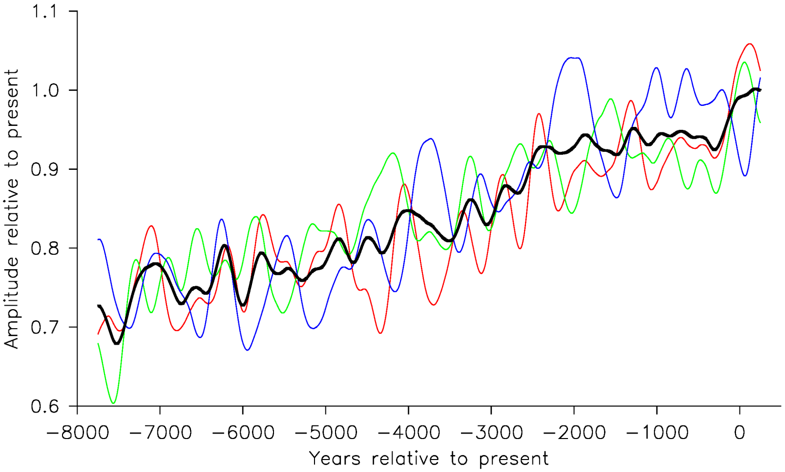
- Three transient simulations of the past 8,000 years:
  - Only the Earth's orbital geometry is varied (Berger et al., 1978)
  - Each ensemble member is initialised from different years of the control simulation (i.e. a perturbed initial conditions ensemble)



Orbital cycles cause large seasonal changes in insolation

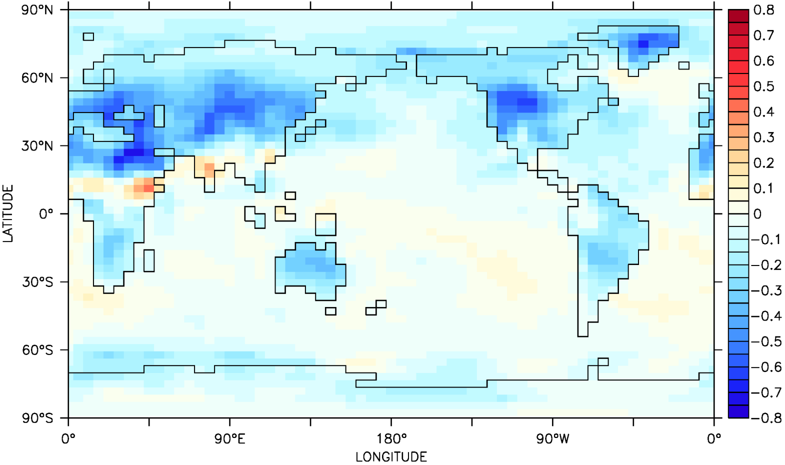


Simulated ENSO amplitude (with 500-year smoother)



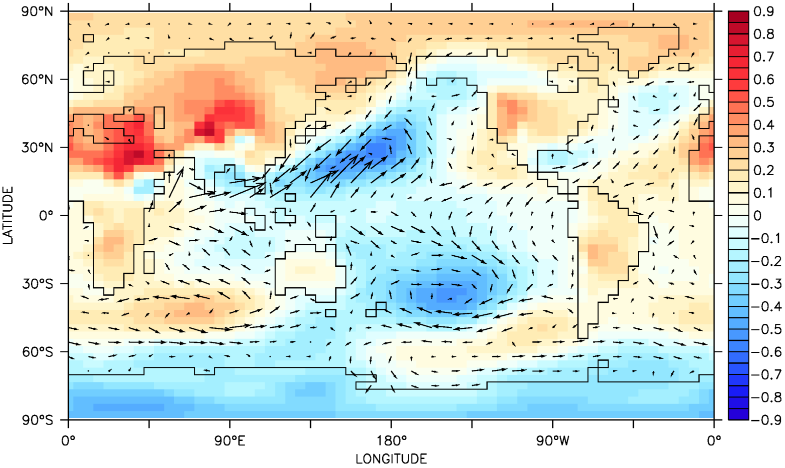
Updated from Phipps and Brown (2010), *IOP C. S. Earth Env.*

Trend in August surface air temperature (K ky^{-1})



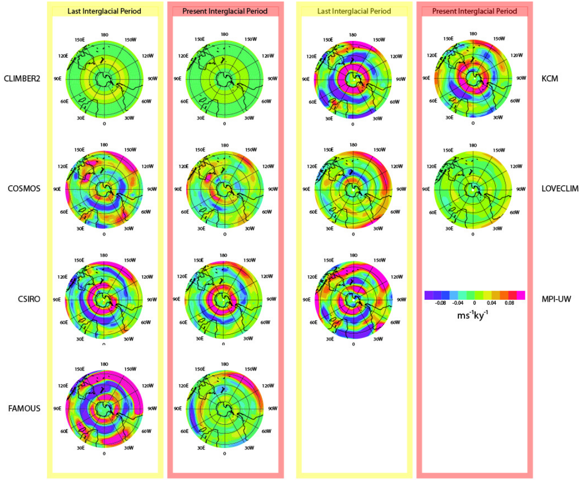
Updated from Phipps and Brown (2010), *IOP C. S. Earth Env.*

Trend in August MSLP (hPa ky^{-1}) and surface wind stress



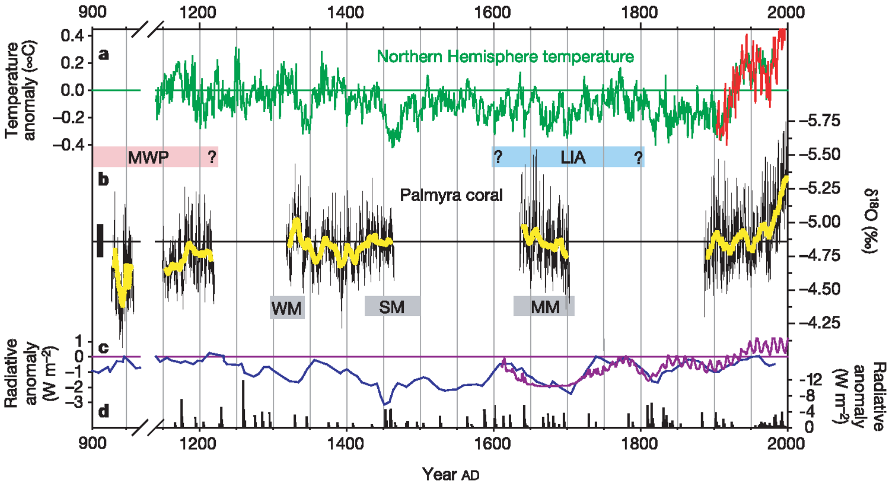
Updated from Phipps and Brown (2010), *IOP C. S. Earth Env.*

PMIP3: simulated trends in the SH westerly winds



Bakker et al. (in press), *Quaternary Science Reviews*

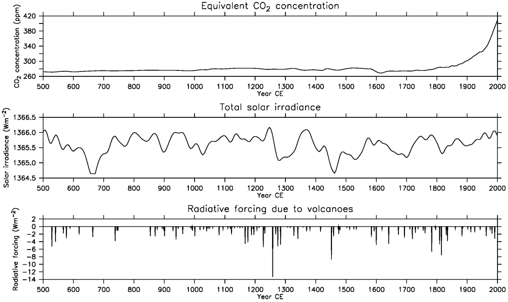
ENSO also changes on shorter timescales



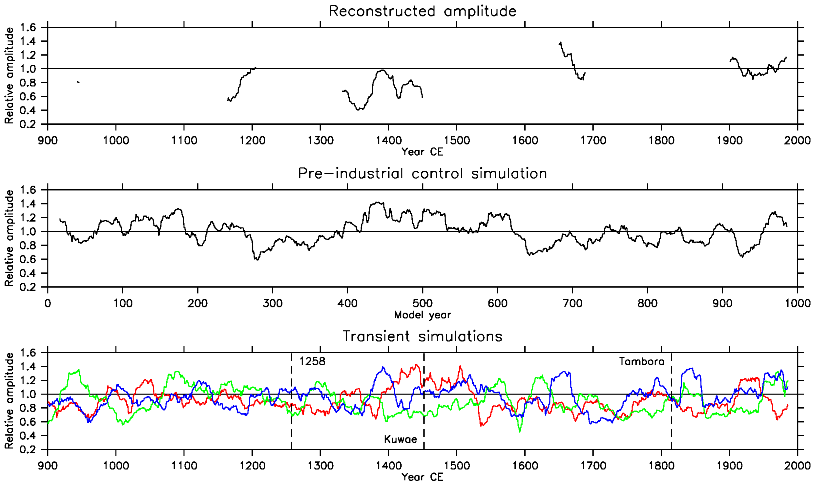
Cobb et al. (2003), *Nature*

Simulating the role of forcings over the past 1500 years

- Multiple ensembles of transient simulations of the past 1500 years:
  - Orbital changes (Berger, 1978)
  - Anthropogenic greenhouse gases (MacFarling Meure et al., 2006)
  - Solar irradiance (Steinhilber et al., 2009)
  - Explosive volcanism (Gao et al., 2008)

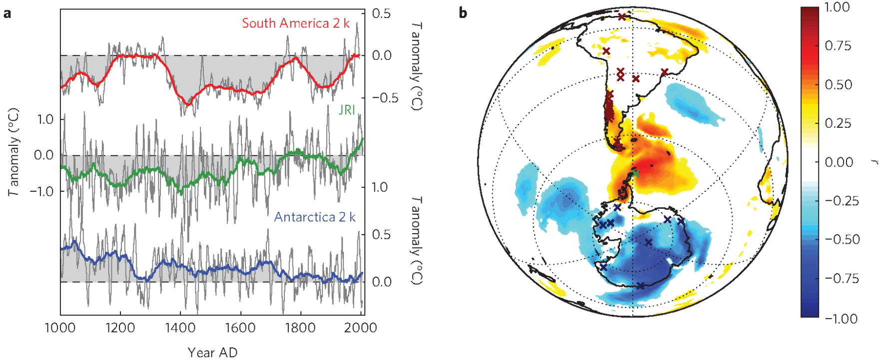


Reconstructed/simulated ENSO amplitude (30-year mean)



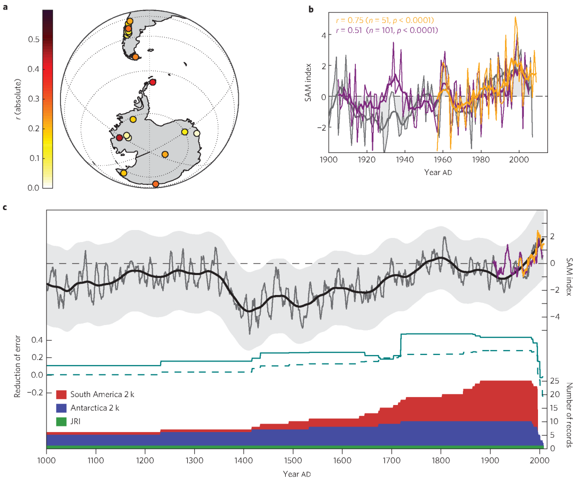
Phipps et al. (2013), *Journal of Climate*

Reconstructing the Southern Annular Mode (SAM)



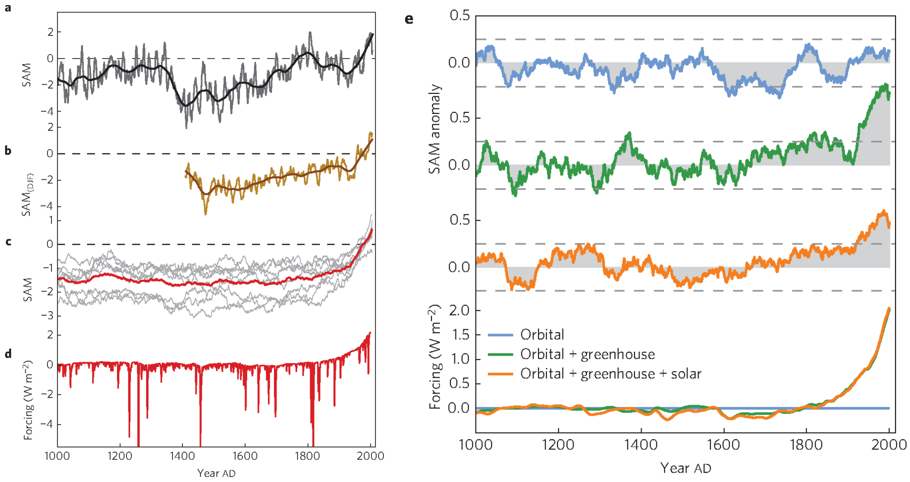
Abram et al. (2014), *Nature Climate Change*

Reconstruction of SAM over the last millennium



Abram et al. (2014), *Nature Climate Change*

Data–model comparison and role of external forcings



Abram et al. (2014), *Nature Climate Change*

Conclusions

- Orbital changes can explain long-term trends in ENSO and SAM over the past 8 ka. These are driven by changes in the seasonal and meridional distribution of insolation, which cause large-scale changes in the atmospheric circulation.
- On shorter timescales, internal variability dominates. There is no evidence that natural forcings influence ENSO or SAM, although anthropogenic forcings have caused a shift in the SAM.
- Overall, a picture emerges of high-frequency internal variability, superimposed on top of long-term trends driven by orbital changes.
- This suggests that care should be taken when interpreting proxy records, and particularly when synchronising records from different sites, as variations on sub-millennial timescales may simply represent random internal variability.