Part 1:

PMIP3

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 (2002–2007) :
  - Atmosphere-ocean(-vegetation) GCMs
  - Primary experiments were 6 ka (mid-Holocene) and 21 ka (LGM)
  - 18 models participated
  - Contributed towards IPCC AR4

Phase 3 (2008–)

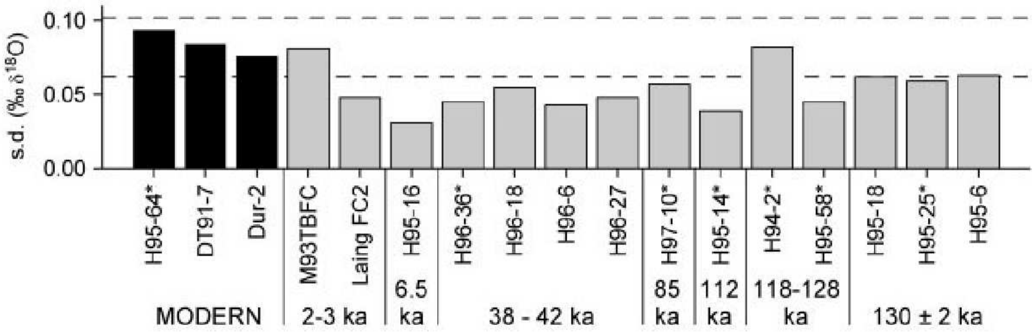
- Theme 1: Evaluation of earth system models at 6 ka and 21 ka
  - Vegetation, biogeochemical cycles, chemistry, ice sheets...
  - Use of new data syntheses for model evaluation
- Theme 2: Interglacials and warm periods
  - Last interglacial (∼130–115 ka) - snapshot and transient
  - Mid-Pliocene (∼3.3–3.0 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

Part 2:

Simulating the evolution of ENSO over the late Holocene

El Niño has changed...

- Proxy reconstructions from across the Pacific Basin show that:
  - "Modern" El Niño began 7-5 ka BP, with only weak decadal-scale events beforehand
  - El Niño was 15-60% weaker at 6 ka BP than at present
  - Gradual strengthening of El Niño thereafter
  - Evidence of a peak in strength at 2-1 ka, possibly earlier in the western Pacific than in the east



Tudhope et al. (2001), *Science*

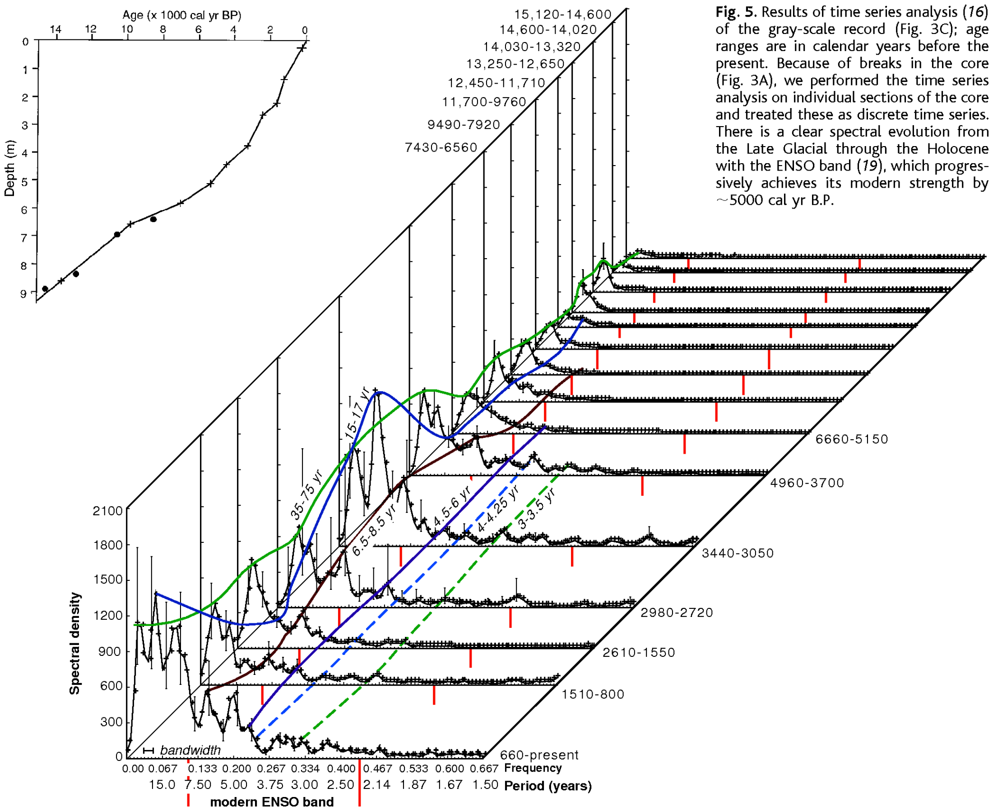
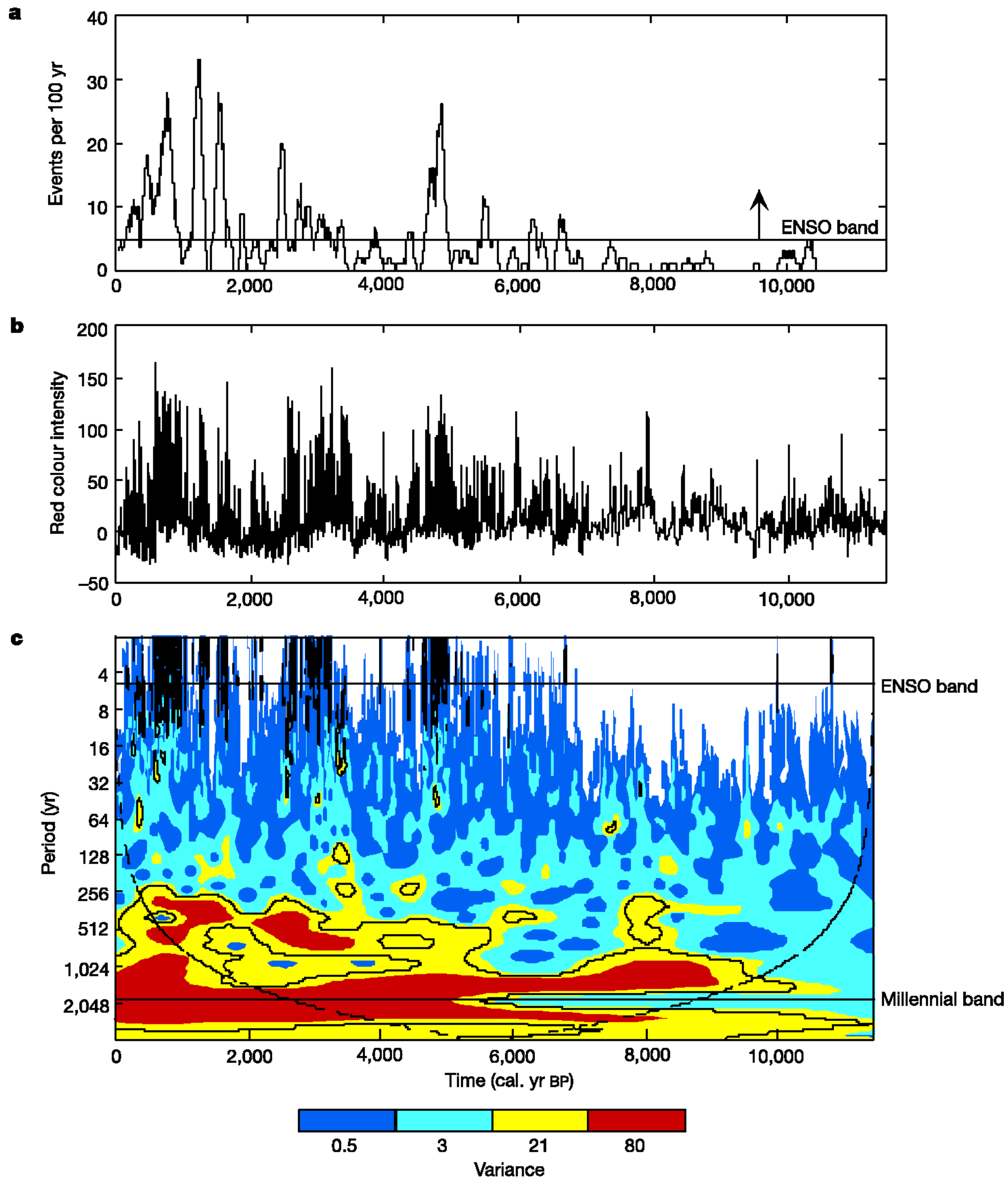


Fig. 5. Results of time series analysis (*16*) of the gray-scale record (Fig. 3C); age ranges are in calendar years before the present. Because of breaks in the core (Fig. 3A), we performed the time series analysis on individual sections of the core and treated these as discrete time series. There is a clear spectral evolution from the Late Glacial through the Holocene with the ENSO band (*19*), which progressively achieves its modern strength by ~5000 cal yr B.P.

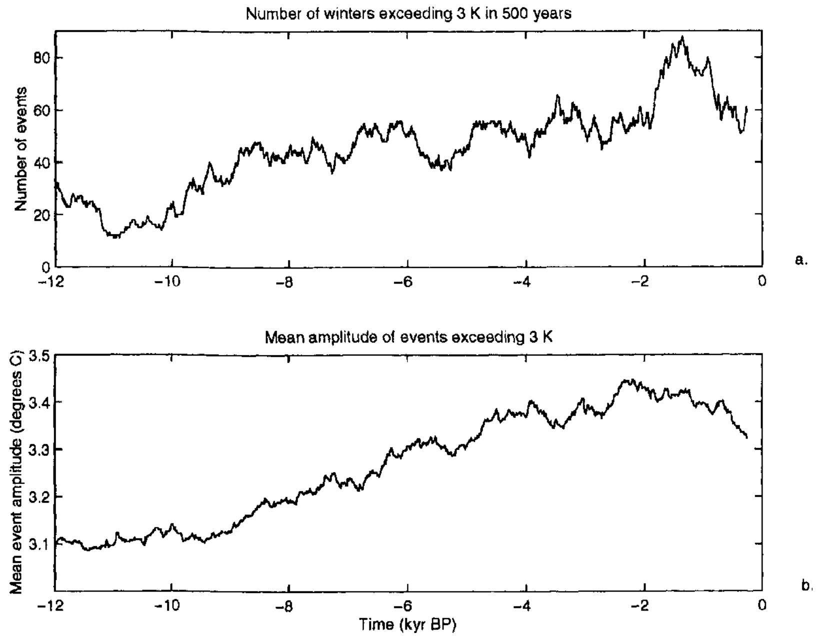
Rodbell et al. (1999), *Science*



Moy et al. (2002), *Nature*

Early modelling work

- Clement et al. (2000):
  - Used the Zebiak-Cane model to simulate the past 12 ka
  - Simple atmosphere-ocean model; restricted to the tropical Pacific
  - Established that orbitally-driven changes in the seasonal cycle of insolation in the tropics can alter ENSO behaviour



Coupled modelling studies: 6 ka versus 0 ka BP

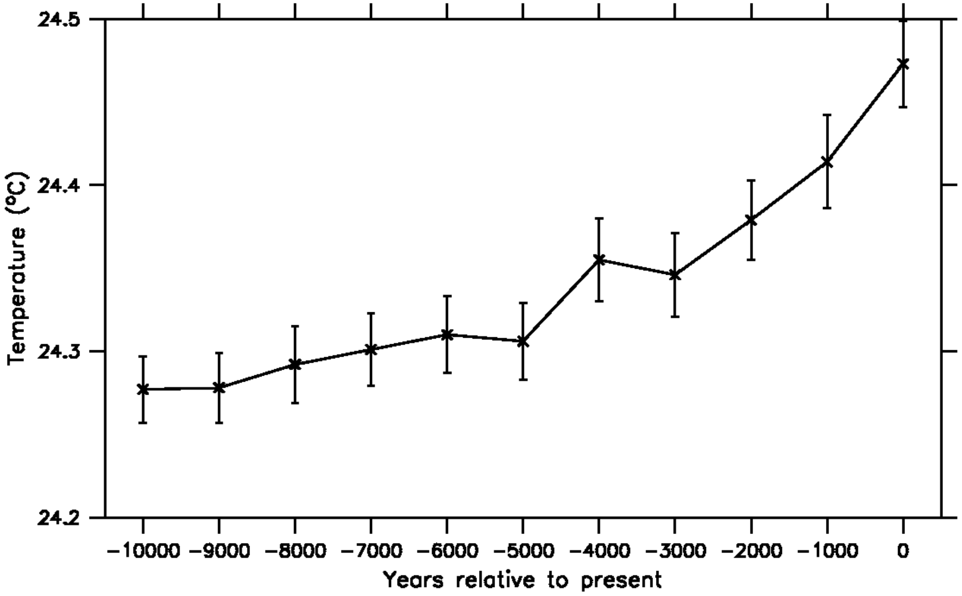
	Model	Diagnostic	% change
Otto-Bliesner (1999)	CSM	Niño 3	~0
Liu et al. (2000)	FOAM	Niño 3.4	-20
Phipps (2006)	Mk3L-1.0	Niño 3.4	-13
Brown at al. (2006)	HadCM3	Niño 3	-12
Brown et al. (2008)	HadCM3	Niño 3	[-14, +19]
Zheng et al. (2008) (PMIP2)	CCSM3	Niño 3	-18.6
	FGOALS-1.0g		-14.6
	FOAM		-11.6
	IPSL-CM4		-2.9
	MIROC3.2		-22.5
	MRI-CGCM2.3.4fa		+3.3
	MRI-CGCM2.3.4nfa		-12.9

A picture begins to emerge?

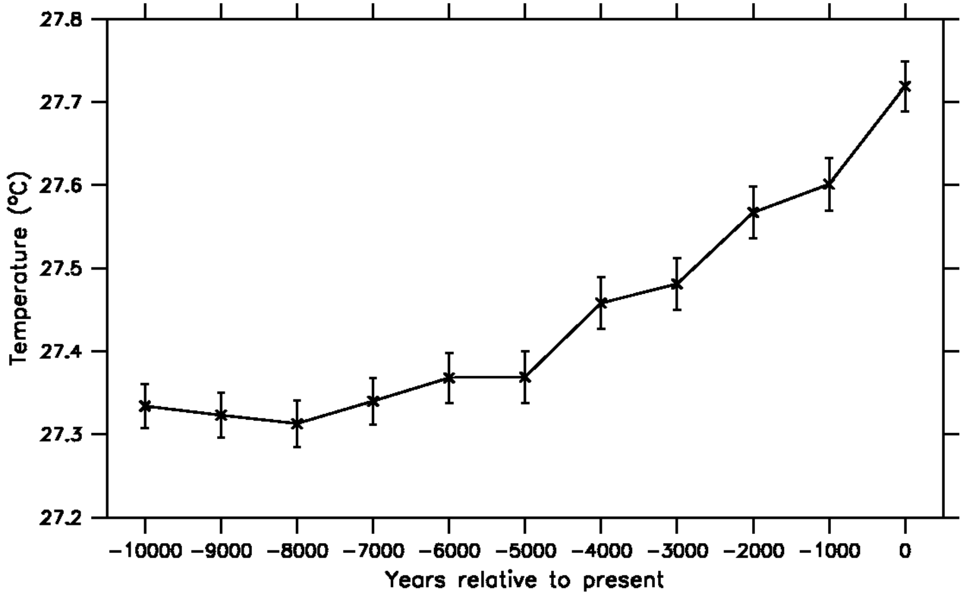
- Insolation changes result in enhanced seasonal cycle in NH
- Intensification of summer monsoon system
- Enhanced Walker circulation
- Stronger easterly trade winds in central and western Pacific
- Increased upwelling in central and eastern Pacific
- Suppresses development of El Niño events

Simulations of the late Holocene climate

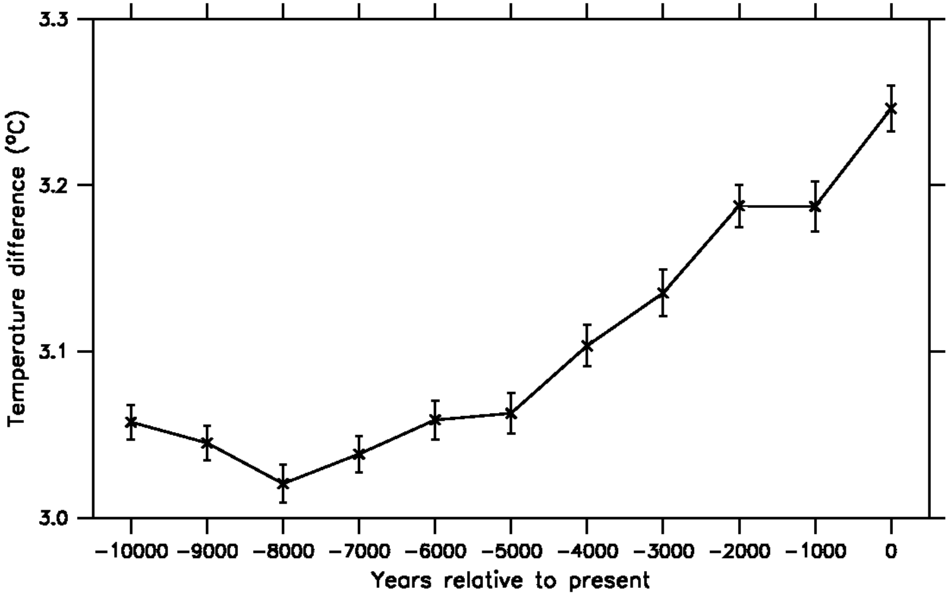
- CSIRO Mk3L climate system model v1.1:
  - Atmosphere: R21 ($5.6^\circ \times 3.2^\circ$), 18 vertical levels
  - Ocean: $2.8^\circ \times 1.6^\circ$, 21 vertical levels
  - Sea ice: Dynamic-thermodynamic
  - Land surface: Static vegetation
  - Flux adjustments applied
- Snapshot simulations for 10, 9, 8, 7, 6, 5, 4, 3, 2, 1 and 0 ka BP:
  - Only the Earth's orbital parameters are varied
  - Atmospheric CO_2 concentration = 280ppm
  - Solar constant = 1365 Wm^{-2}
  - Integrated for 1000 years
  - Simulations for 6 and 0 ka BP submitted to PMIP2



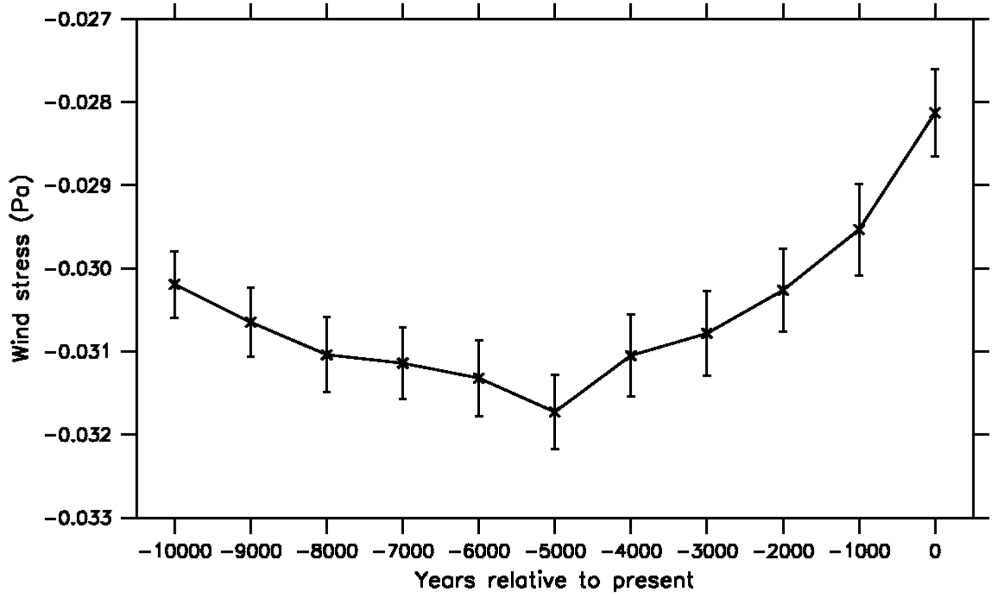
(a) Annual−mean Nino 3 SST



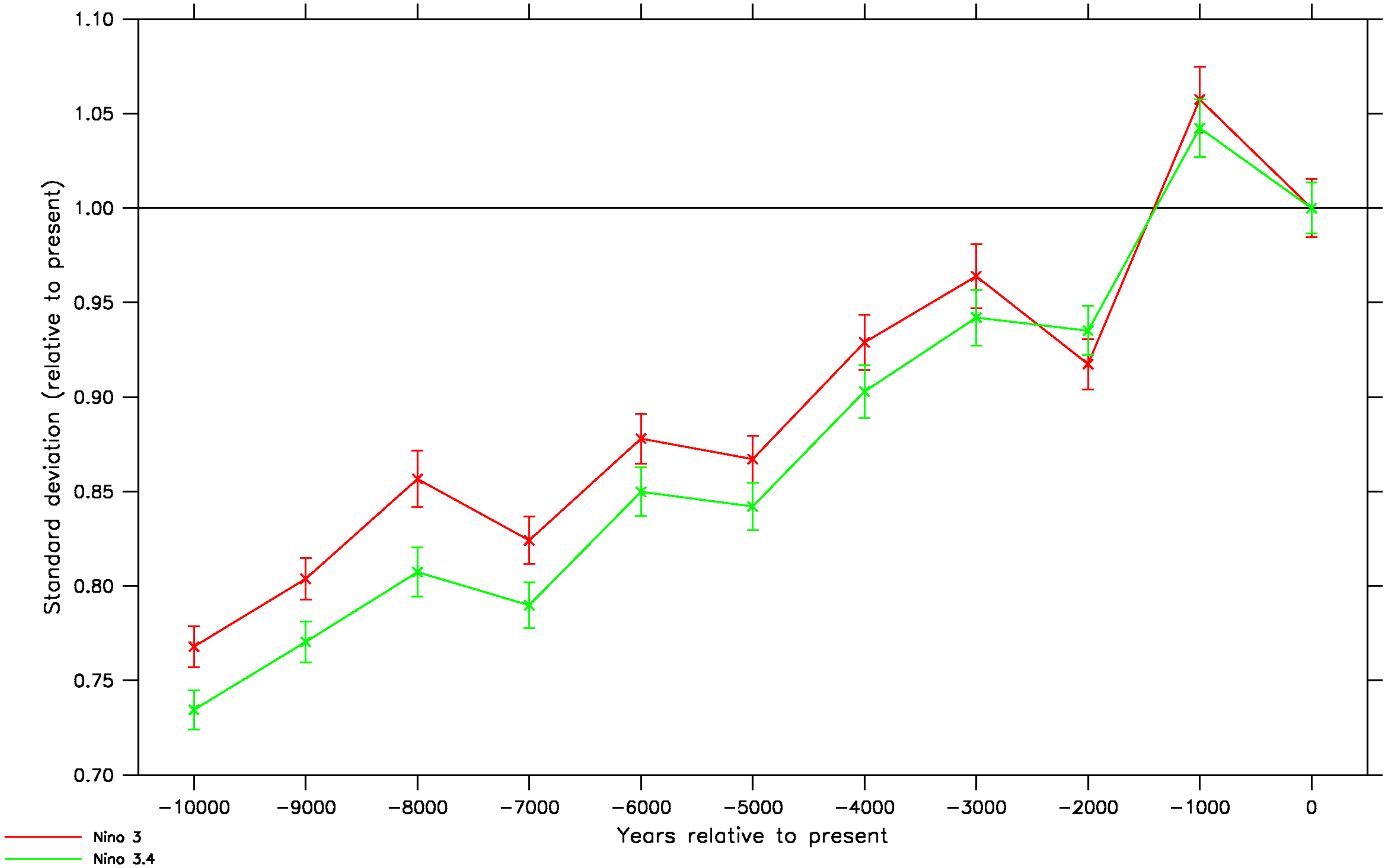
(b) Annual−mean Nino 4 SST



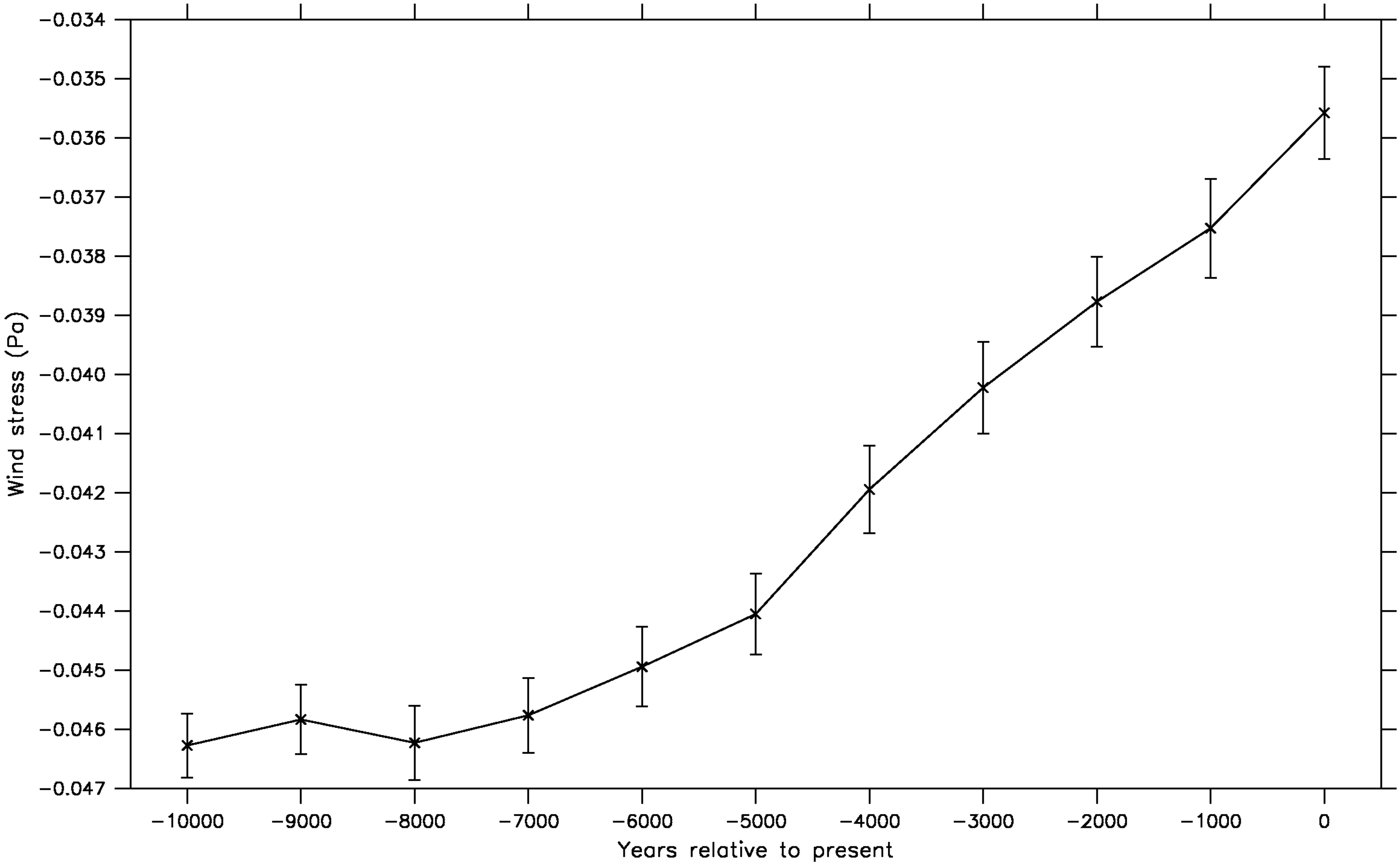
(c) Nino 4 SST minus Nino 3 SST



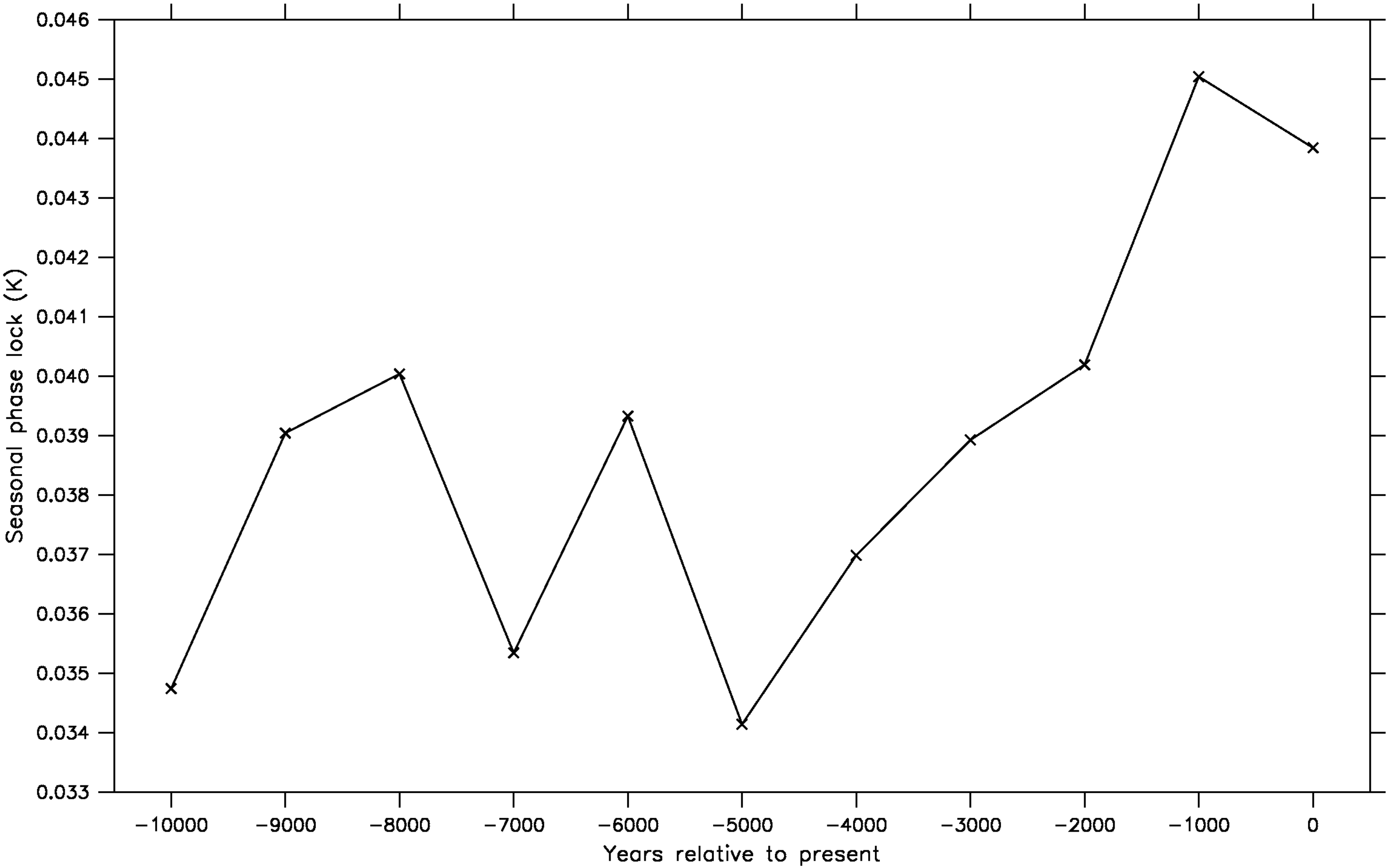
(d) Annual−mean Nino 4 zonal wind stress



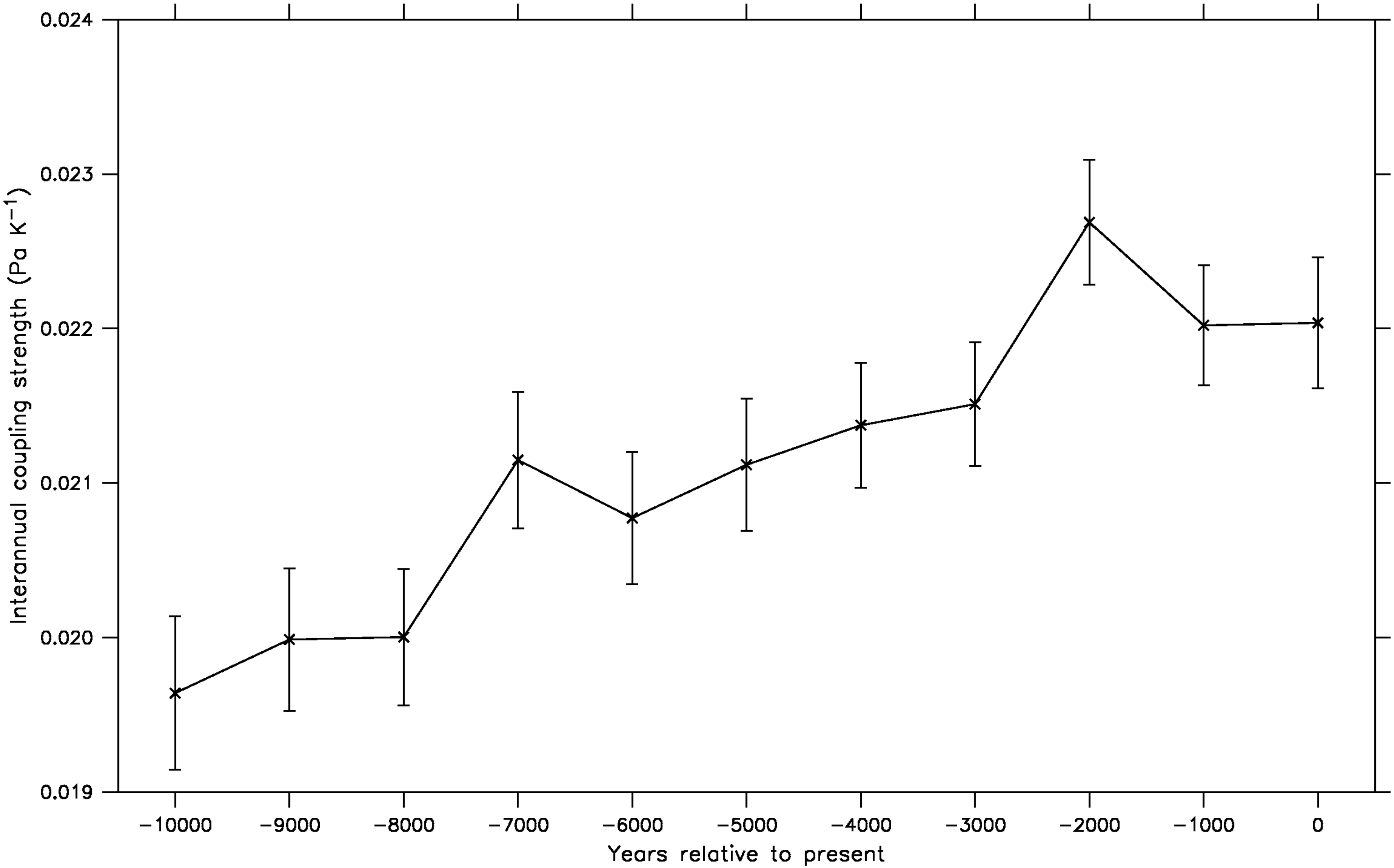
Standard deviation of Nino SST anomaly



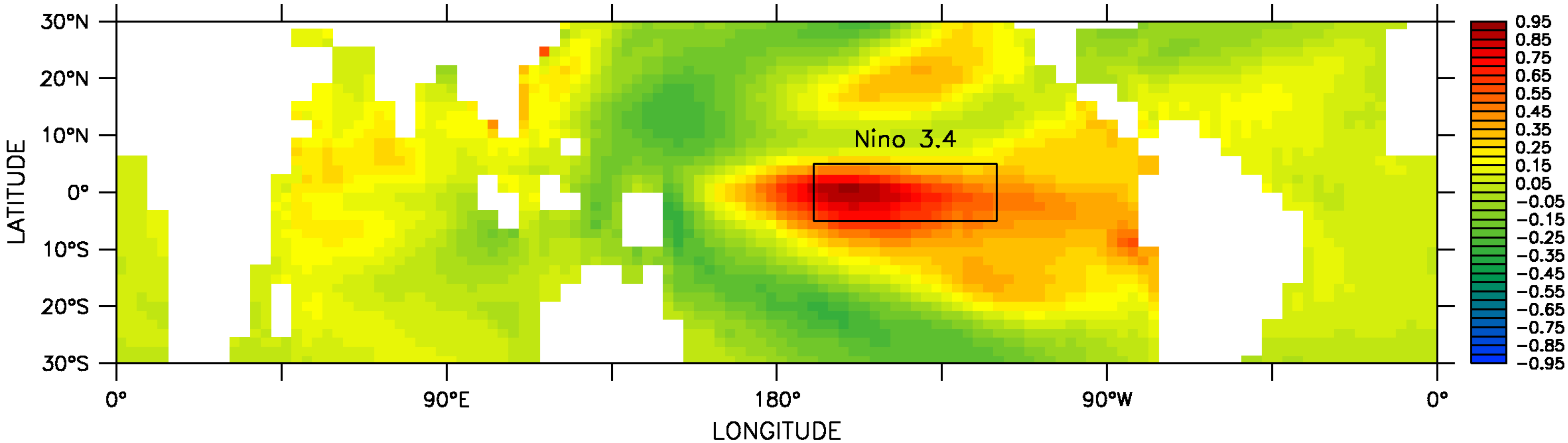
JASO zonal wind stress in Nino 4 region



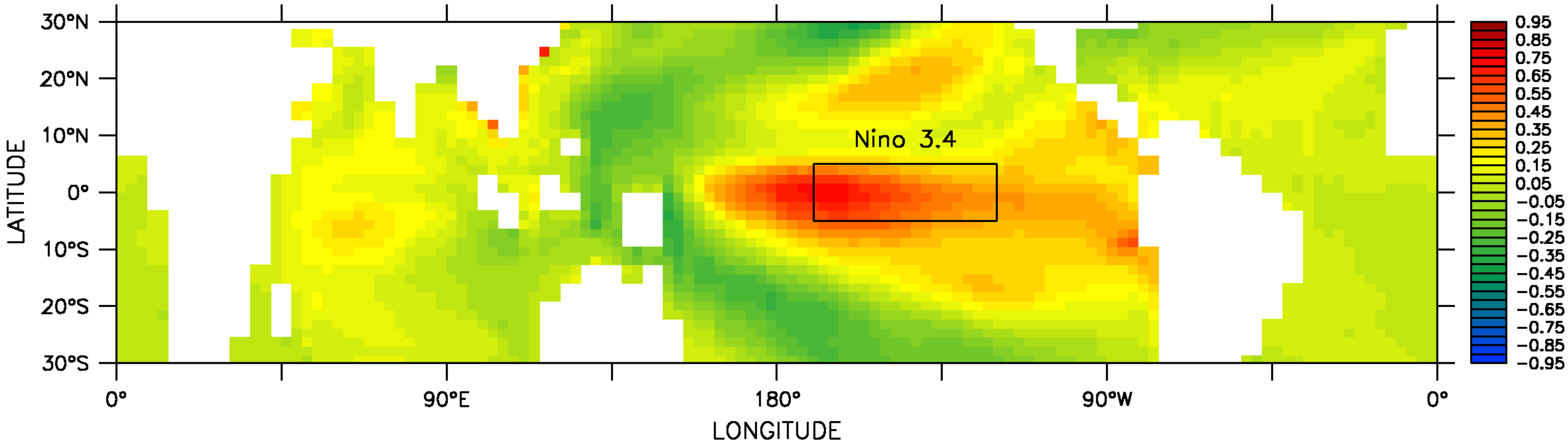
Seasonal phase lock



Summer interannual coupling strength



EOF1 of monthly−mean SST: 0 ka (°C)



EOF1 of monthly−mean SST: 6 ka (°C)

Conclusions

- Modelling studies suggest orbitally-driven insolation changes account for the changes in ENSO behaviour over the Holocene. However, models and proxy reconstructions disagree on the magnitude of the changes.
- Models (almost) exhibit a consistent link between insolation changes and reduced ENSO variability in the mid-Holocene.
- Exploring this mechanism further using Mk3L, we find that it does not explain the peak in ENSO variability at 1 ka, nor the changes in the early Holocene. Other mechanisms therefore appear to be at work.
- A full understanding of the processes that drive changes in ENSO variability may be within grasp. However, this will require an approach that integrates the theory, data and modelling communities.