Understanding ENSO dynamics through the exploration of past climates

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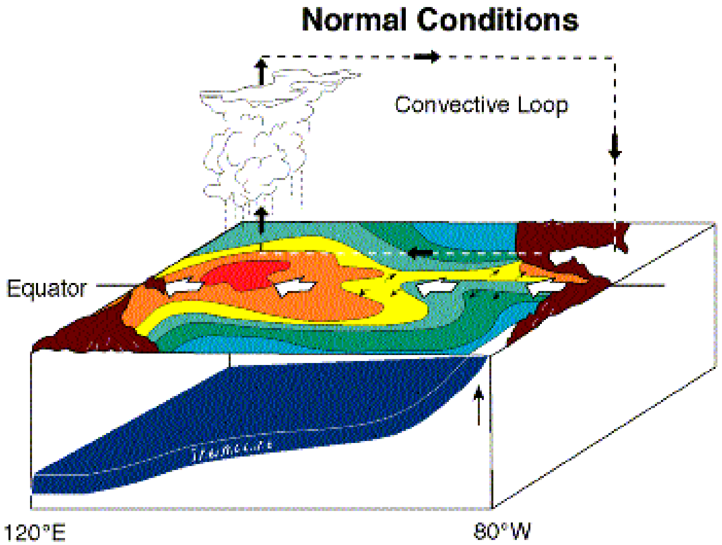
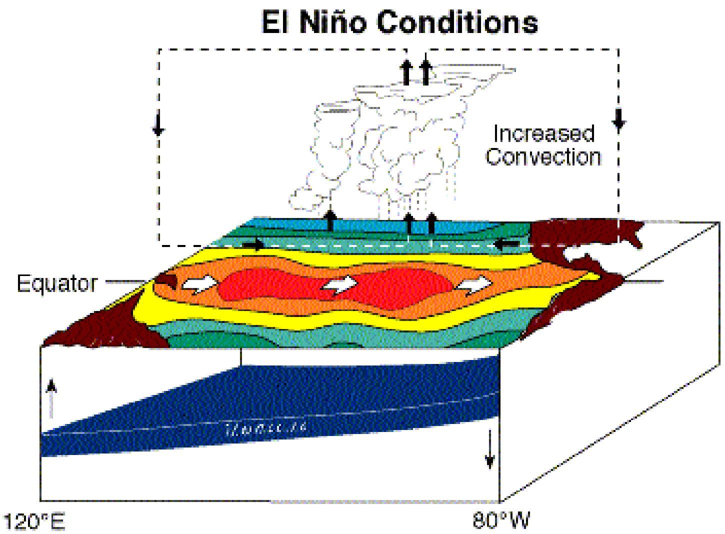
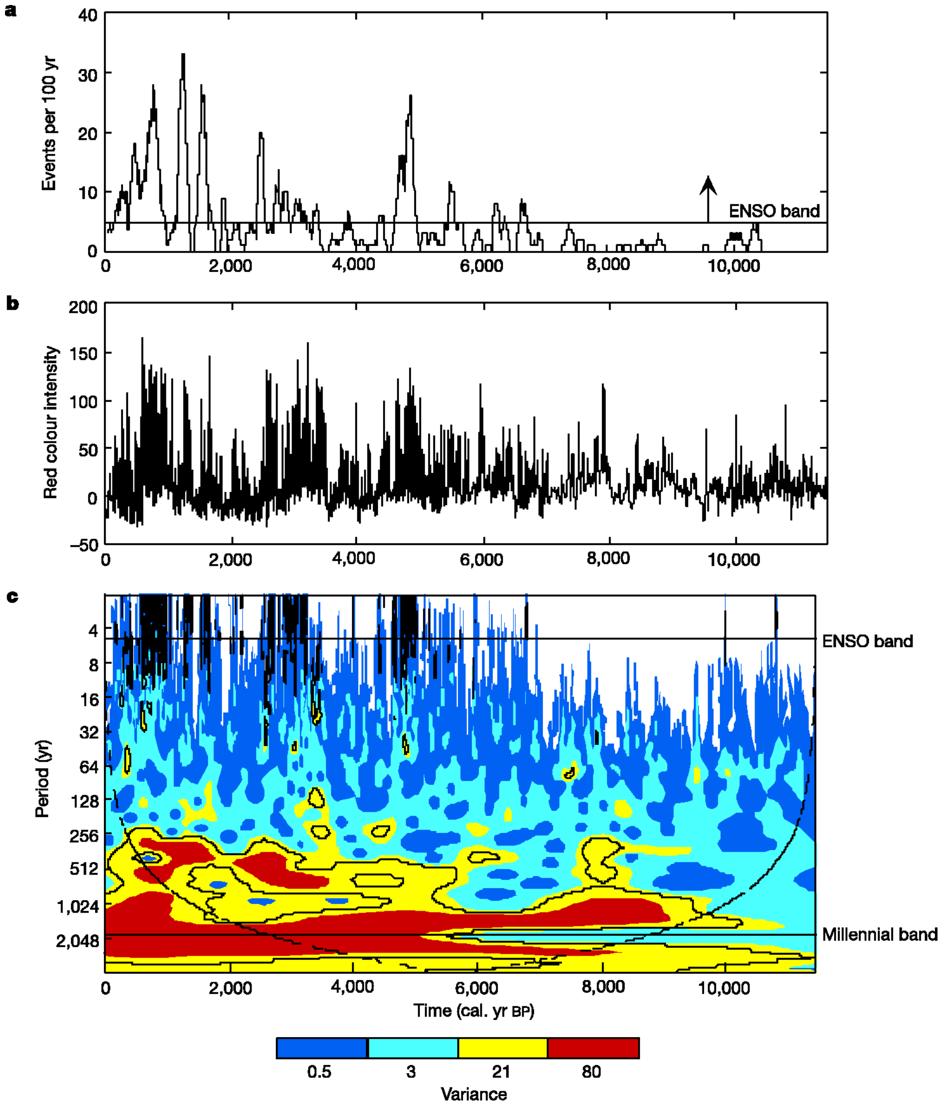
What is El Niño?





- 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 east
- In an El Niño event, these winds slacken and the warm water flows eastwards
- Increased rainfall in the eastern Pacific, reduced rainfall in the west

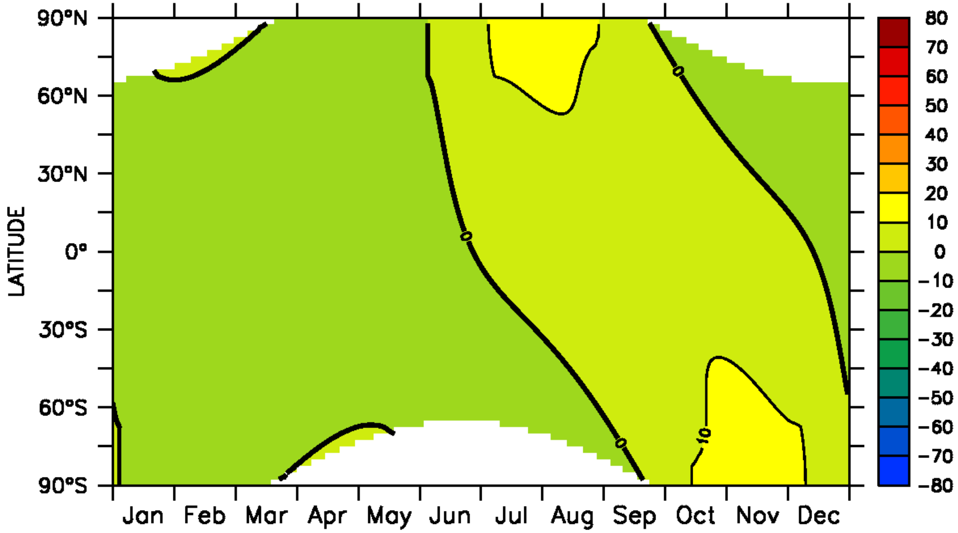
El Niño has changed ...



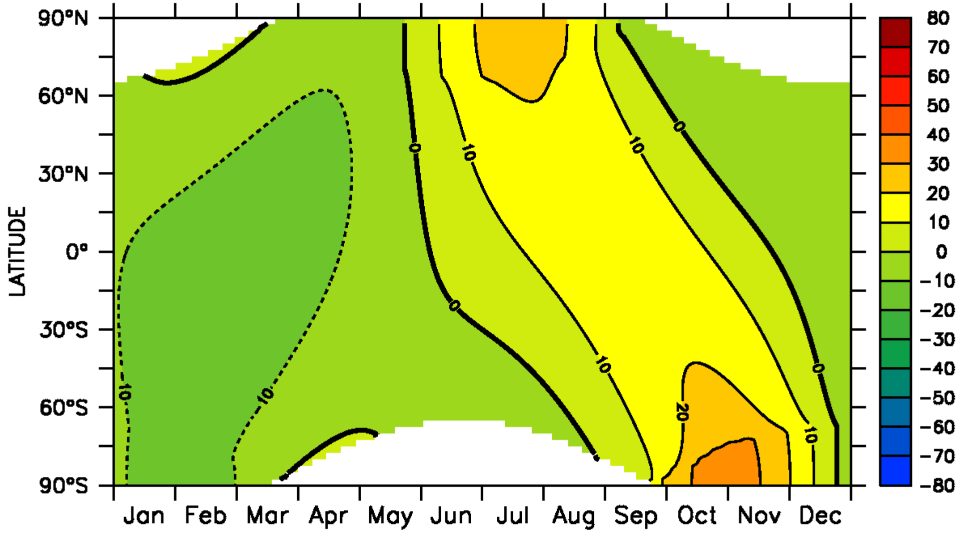
Moy et al. (2002), *Nature*

- "Modern" El Niño began 7–5 ka BP, with only weak decadal-scale variability 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 variability at 2–1 ka, possibly earlier in the western Pacific than in the east

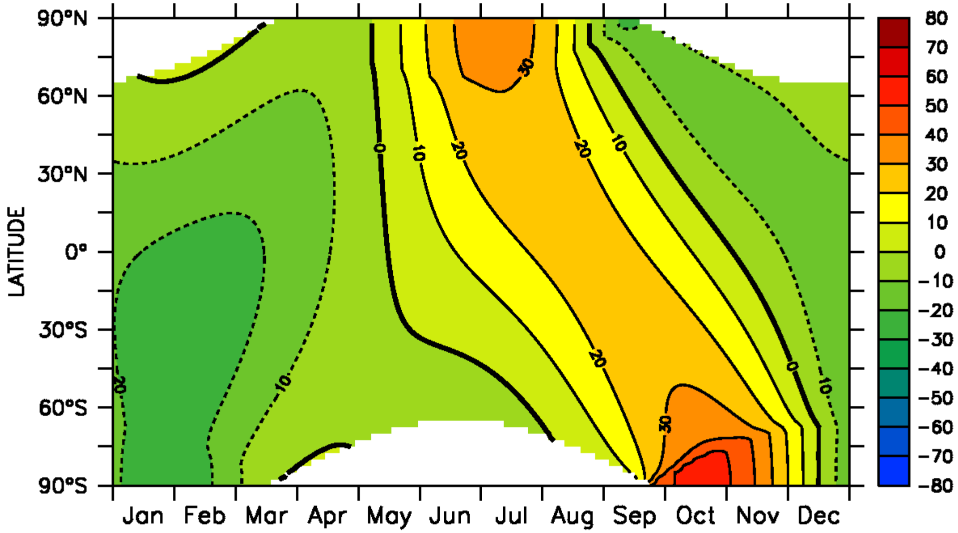
… driven by large changes in seasonal insolation



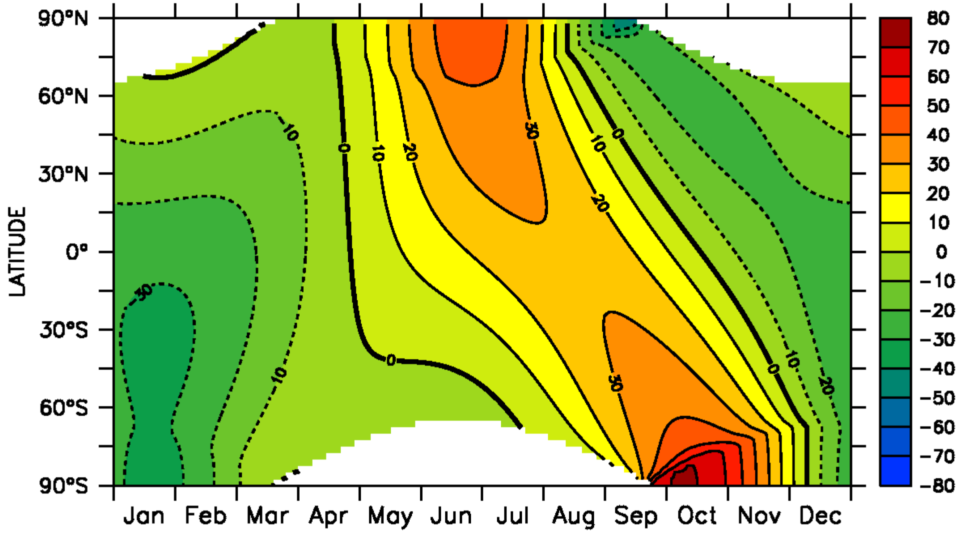
Insolation anomaly (Wm^{-2}): 2 ka BP



Insolation anomaly (Wm^{-2}): 4 ka BP



Insolation anomaly (Wm^{-2}): 6 ka BP

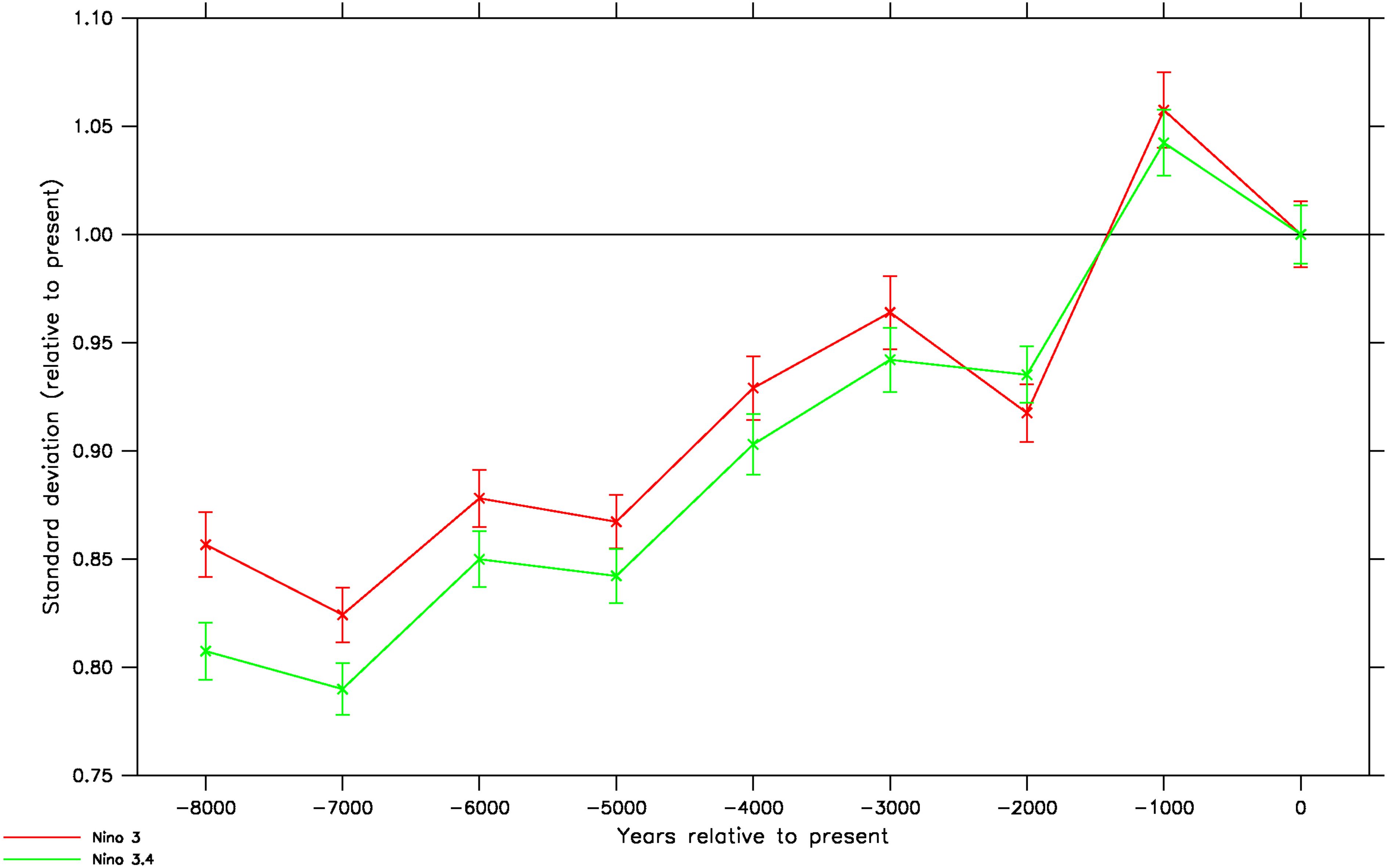


Insolation anomaly (Wm^{-2}): 8 ka BP

Exploring ENSO in a climate system model

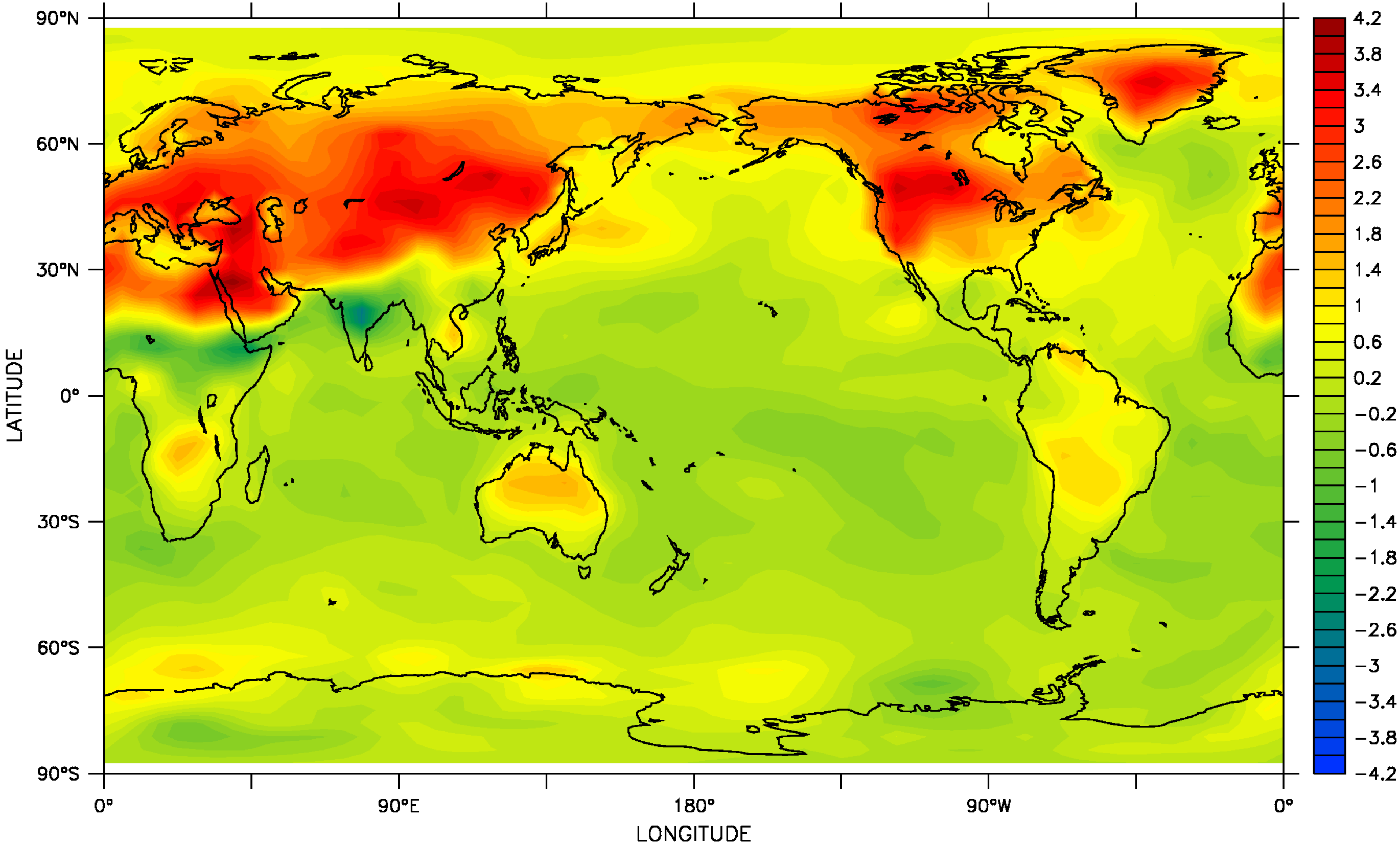
- CSIRO Mk3L climate system model v1.1:
  - Atmosphere: $5.6° \times 3.2°$, 18 vertical levels
  - Ocean: $2.8° \times 1.6°$, 21 vertical levels
  - Sea ice: Dynamic-thermodynamic
  - Land surface: Static vegetation
  - Can simulate 1000 years in a month
- Simulations for 8, 7, 6, 5, 4, 3, 2, 1 and 0 ka BP:
  - Only the Earth's orbital geometry is varied
  - Atmospheric CO_2 concentration = 280ppm
  - Solar constant = 1365 Wm^{-2}
  - Integrated for 1000 years

Simulated changes in ENSO variability



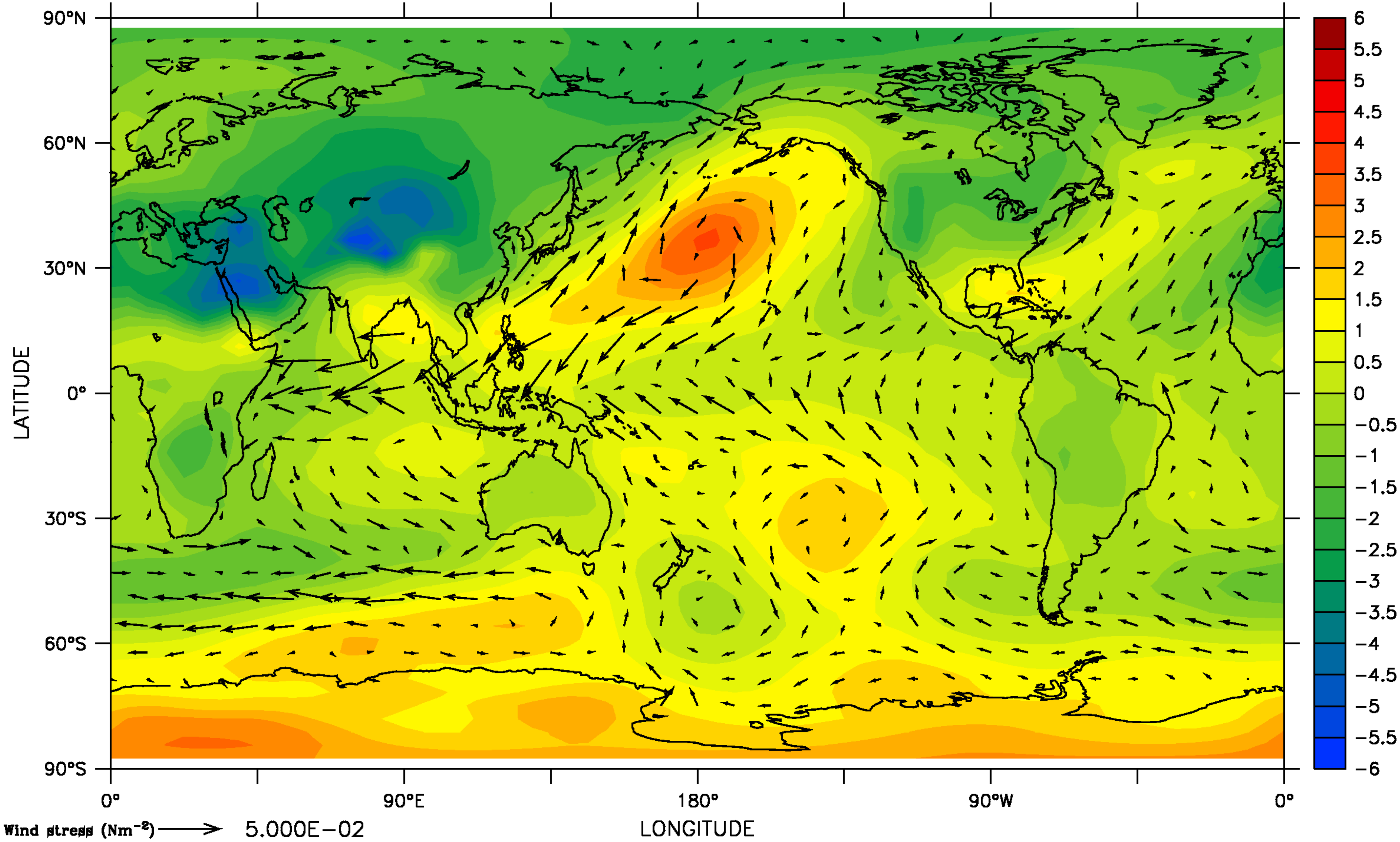
Standard deviation of Nino SST anomaly

Northern Hemisphere summers were warmer at 8 ka BP ...



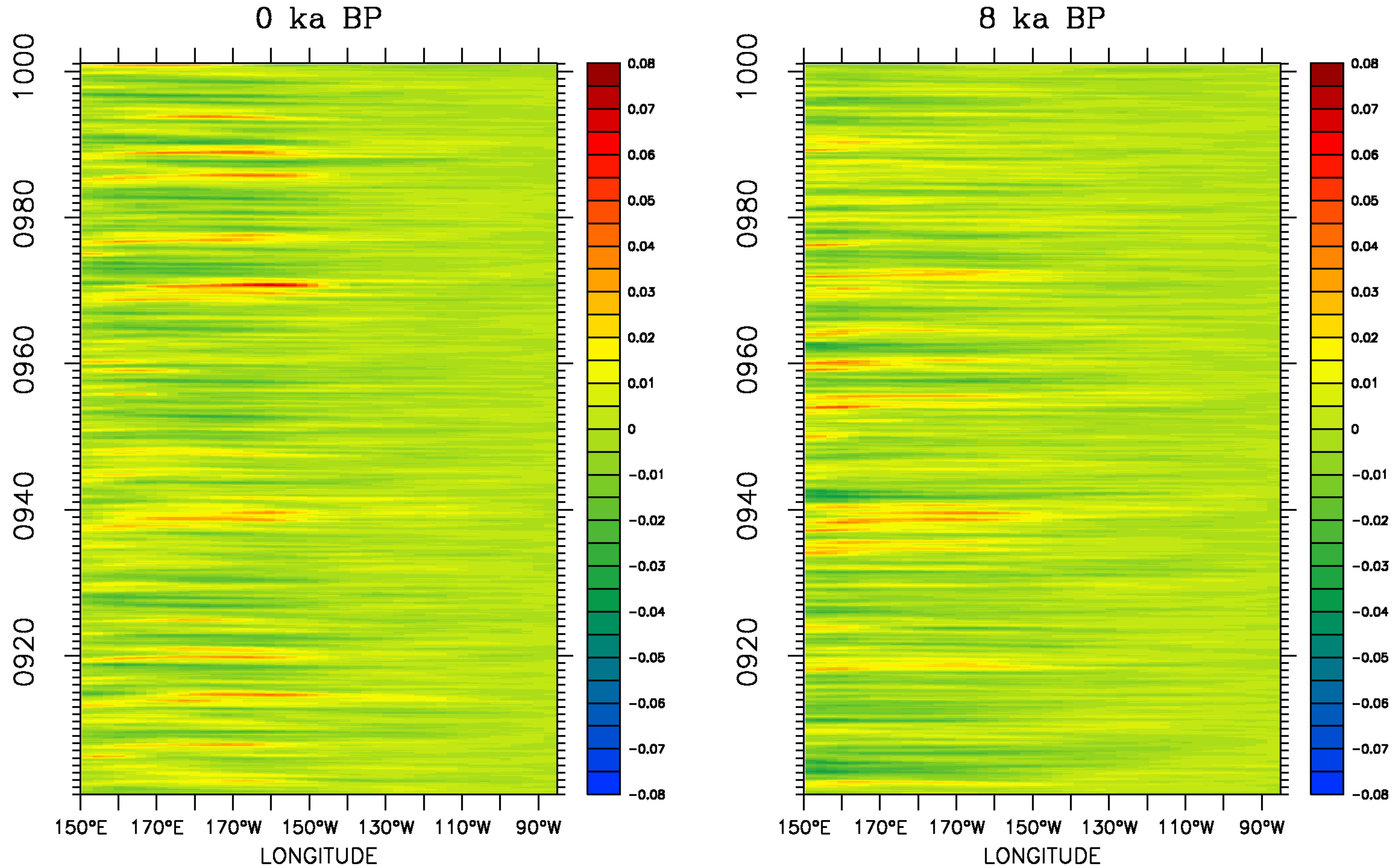
June−July−August surface air temperature, 8 ka minus 0 ka BP (K)

... which enhanced the Asian summer monsoon system



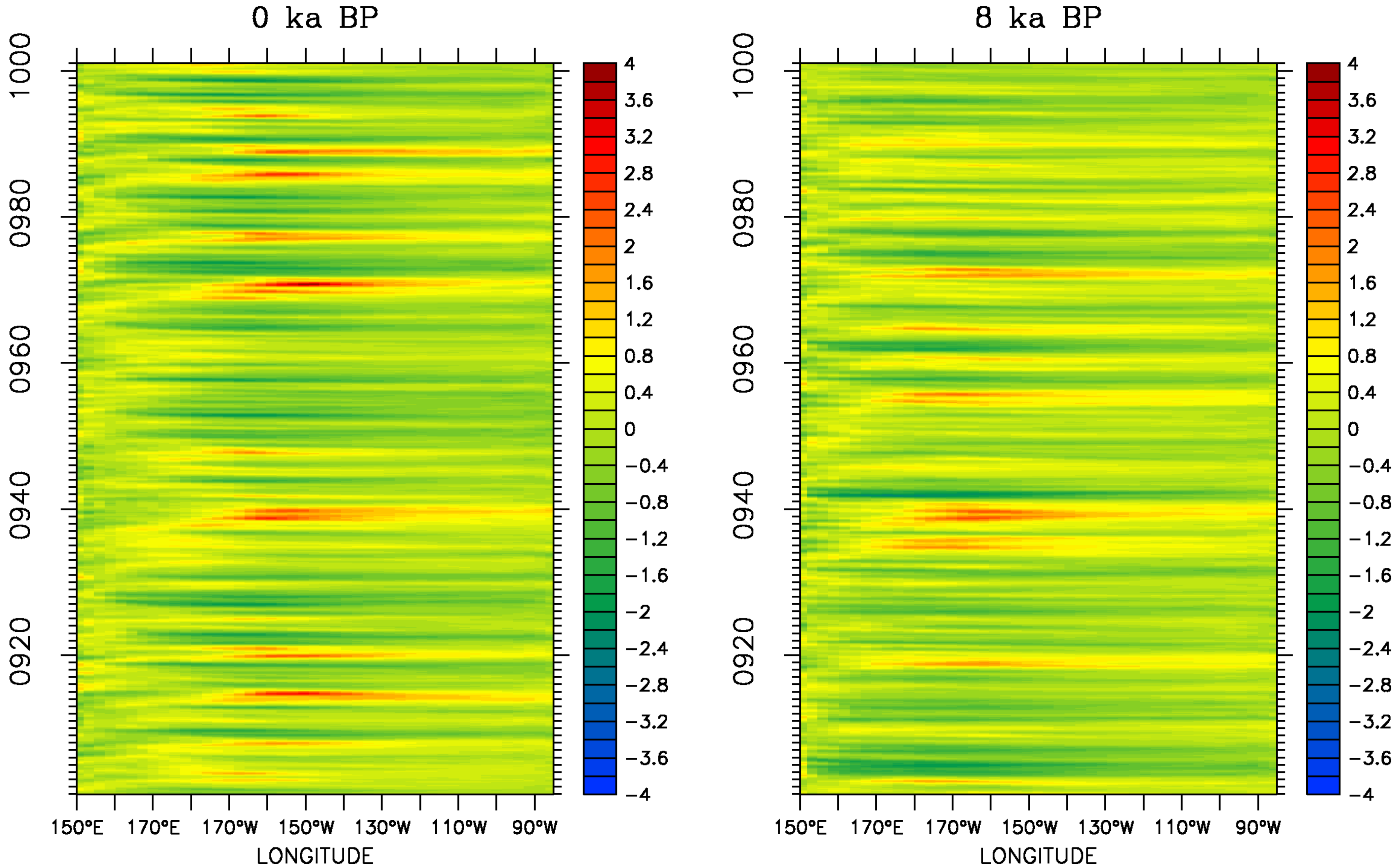
June–July–August mean sea level pressure, 8 ka minus 0 ka BP (hPa)

Westerly wind bursts were "blocked" at 8 ka BP ...



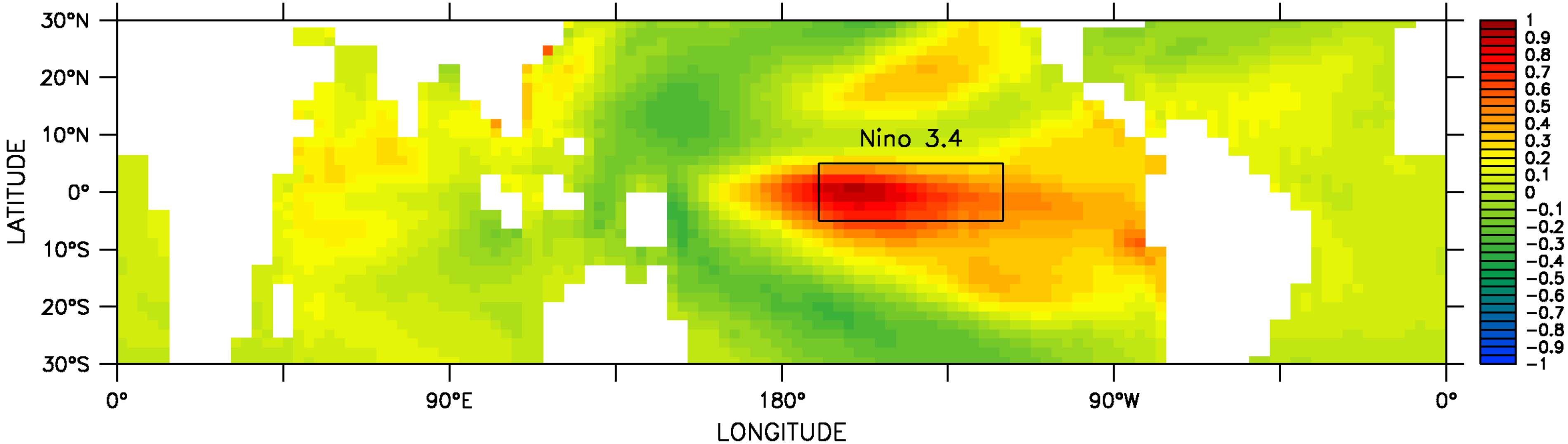
Zonal wind stress anomaly (Nm^{-2})

… which made it harder for El Niño events to develop

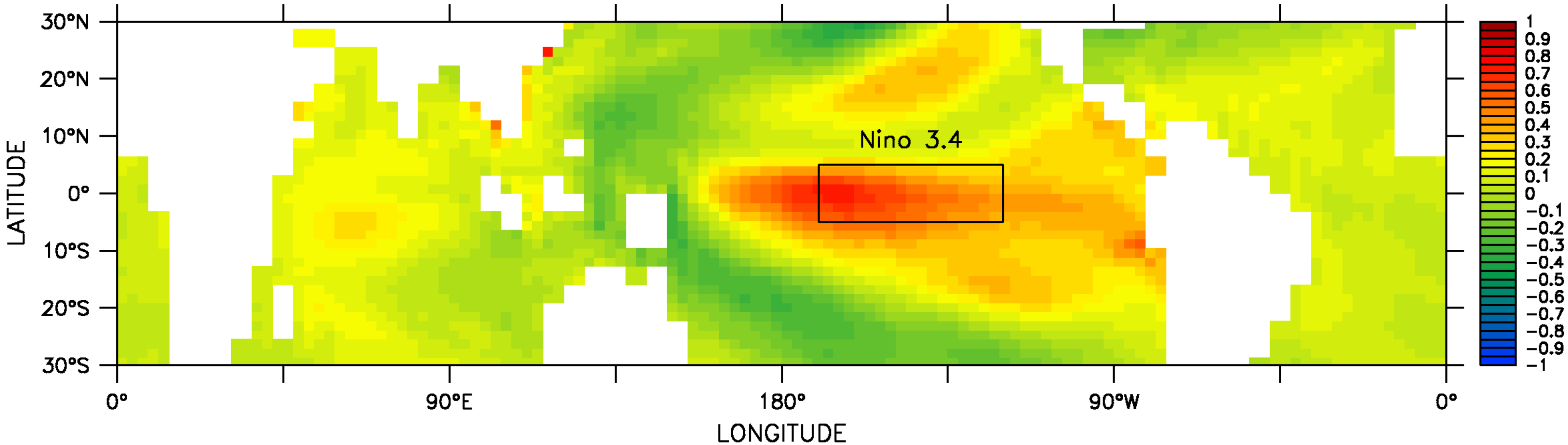


SST anomaly (K)

ENSO has strengthened and shifted eastwards ...

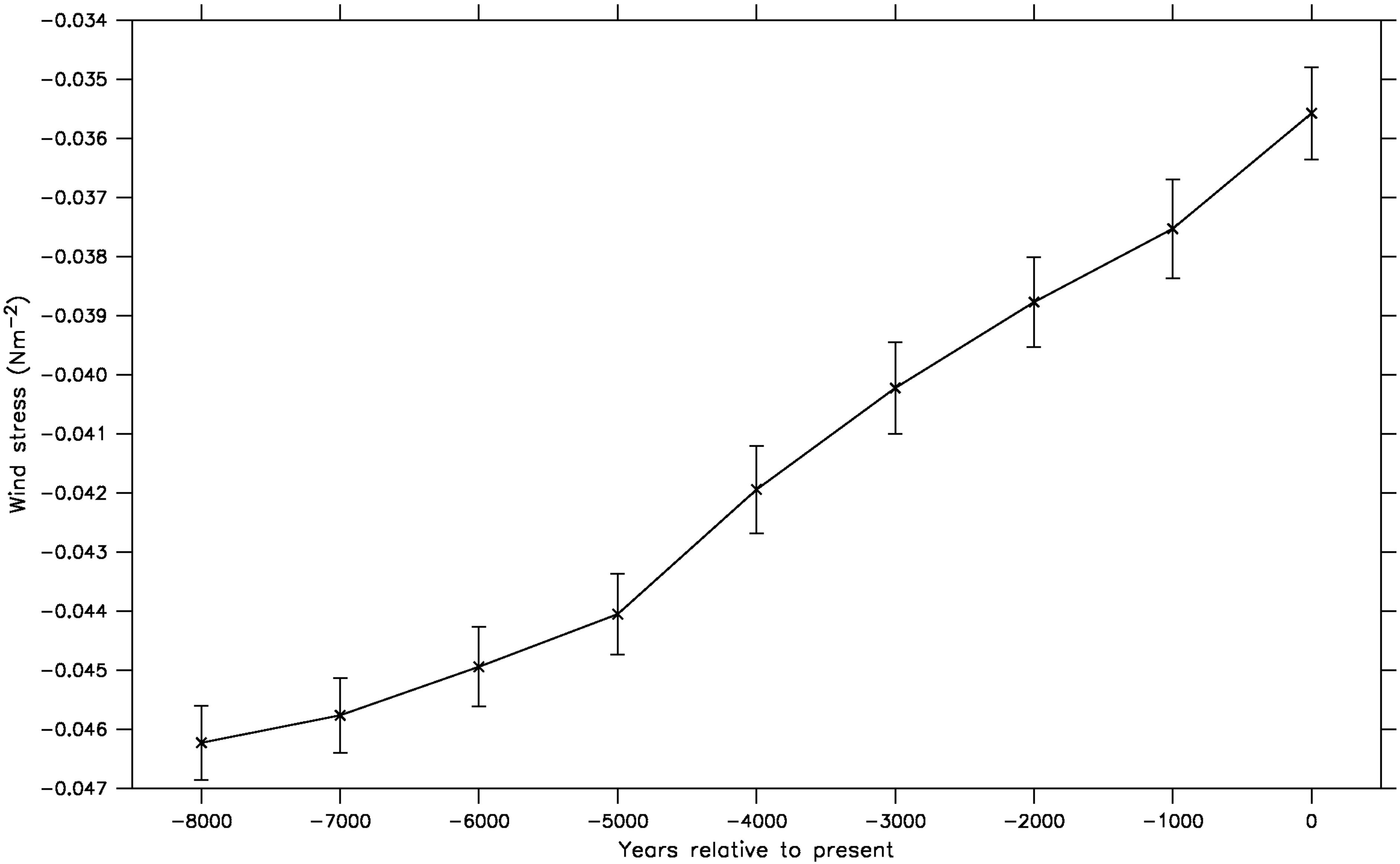


EOF1 of monthly SST anomalies (K): 0 ka BP



EOF1 of monthly SST anomalies (K): 8 ka BP

... as the Walker Circulation has weakened



July−August−September−October zonal wind stress in Nino 4 region

Conclusions

- The study of past climates allows us to learn more about ENSO dynamics, and to explore the links between ENSO and the global climate system.
- By forcing a climate system model with orbitally-driven insolation changes only, we have been able to reproduce the trends in ENSO variability over the past 8,000 years.
- Decreasing summer insolation over this period has resulted in a weakening of the Asian monsoon. This has reduced the stability of the background state of the tropical Pacific, making it easier for El Niño events to develop.
- However, other mechanisms also 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 data, modelling and theory communities.