# Modelling of the last 2ka

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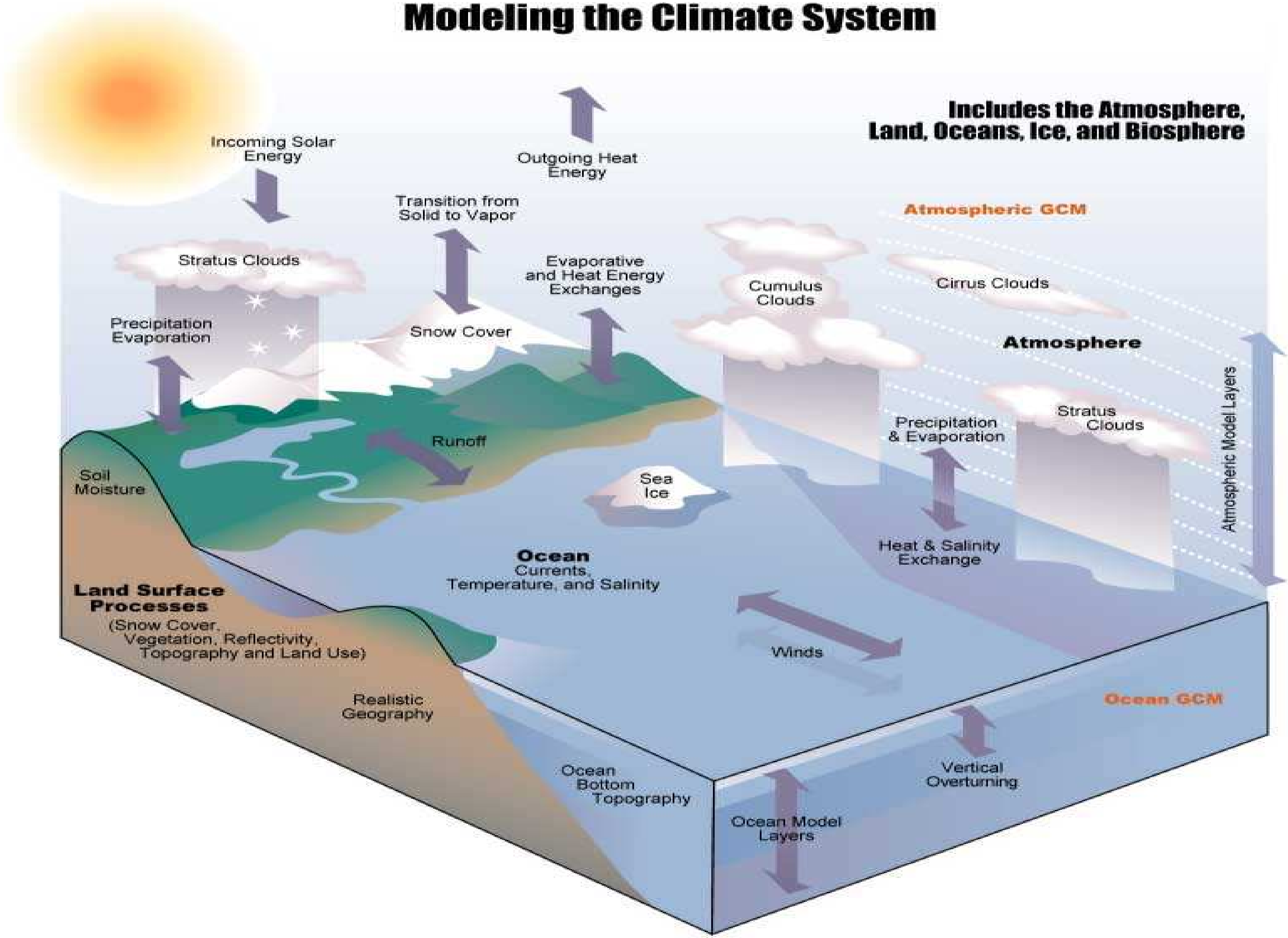
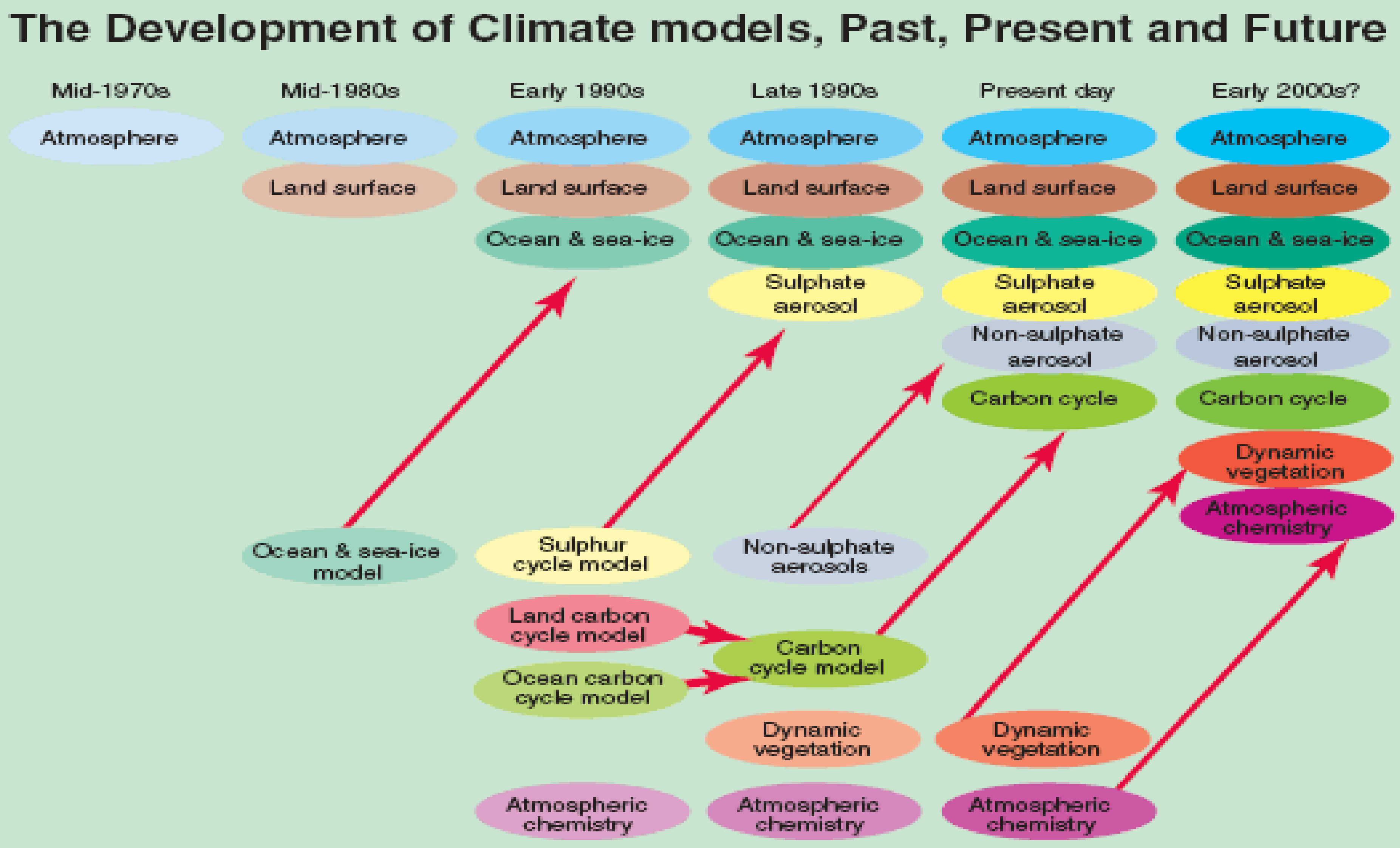
# Modeling the Climate System






**Box 3, Figure 1:** The development of climate models over the last 25 years showing how the different components are first developed separately and later coupled into comprehensive climate models.

# Modelling heirarchy

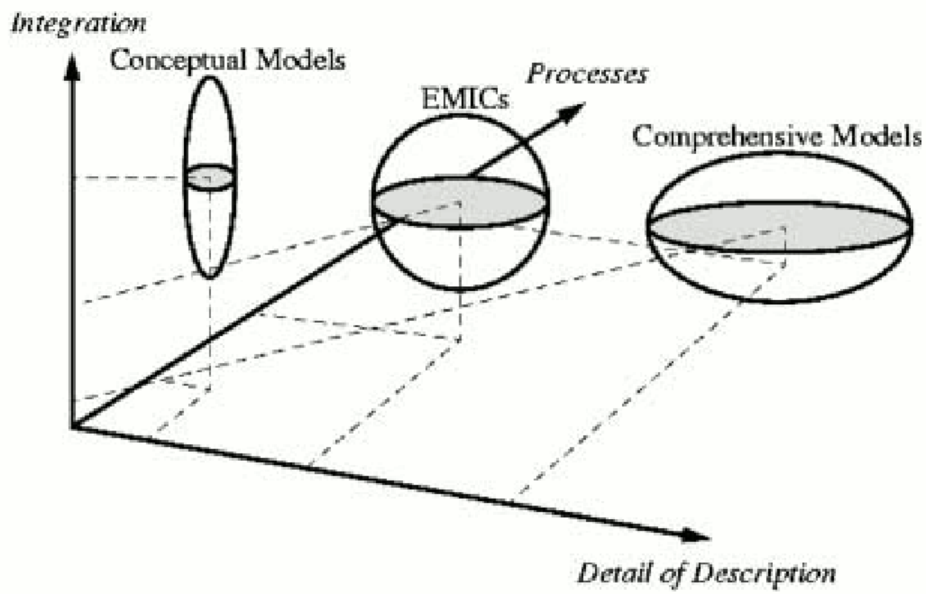



**Fig. 1.** Pictorial definition of EMICs. Adapted from Claussen (2000)

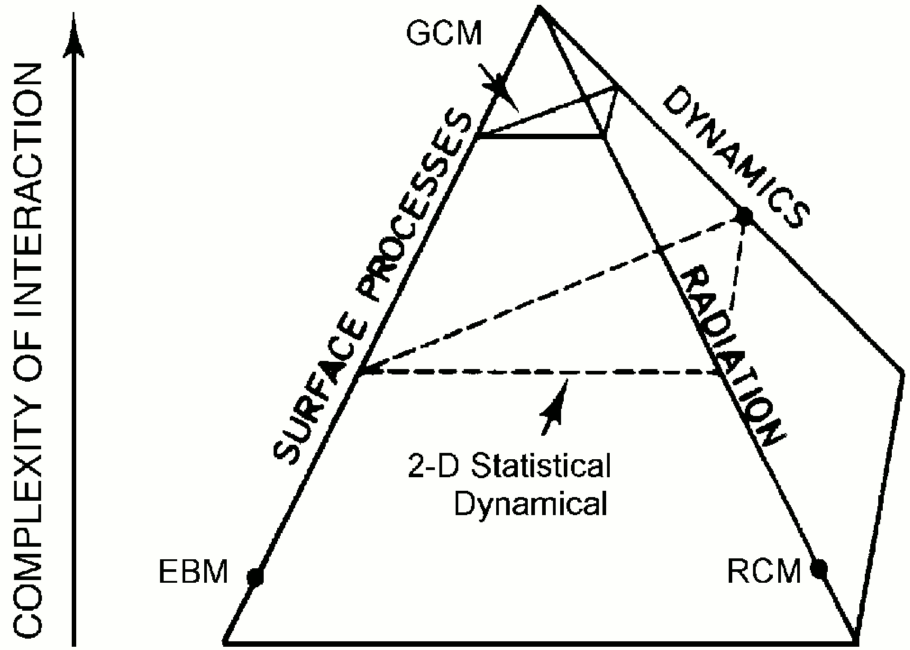
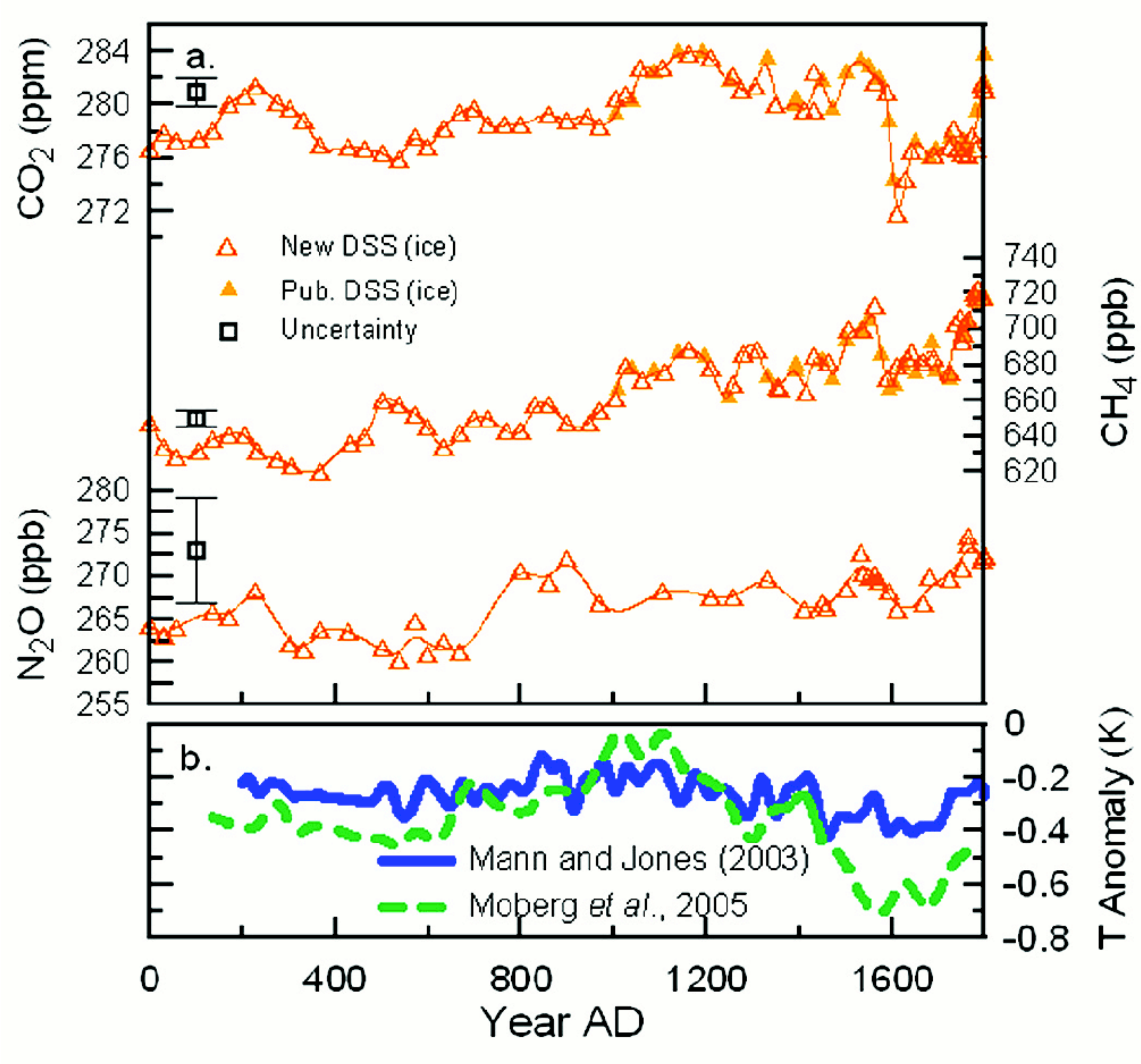



**Fig. 2.** The climate modeling pyramid. Adapted from Henderson-Sellers and McGuffie (1987)

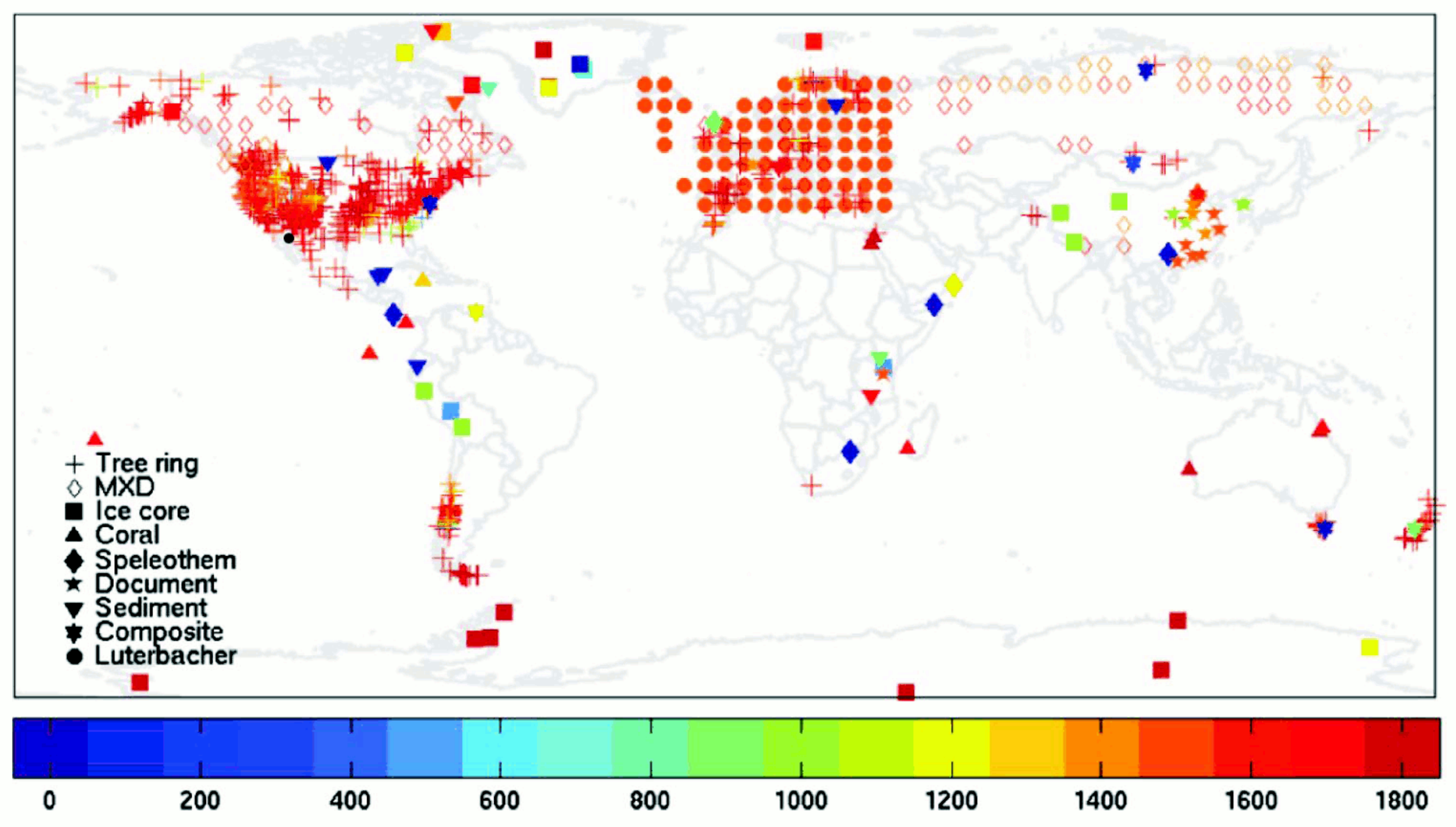
# National Facility, Canberra

# Last 2ka: Boundary conditions are well known




*MacFarling Meure et al., 2006*

# Last 2ka: Abundance of proxy data



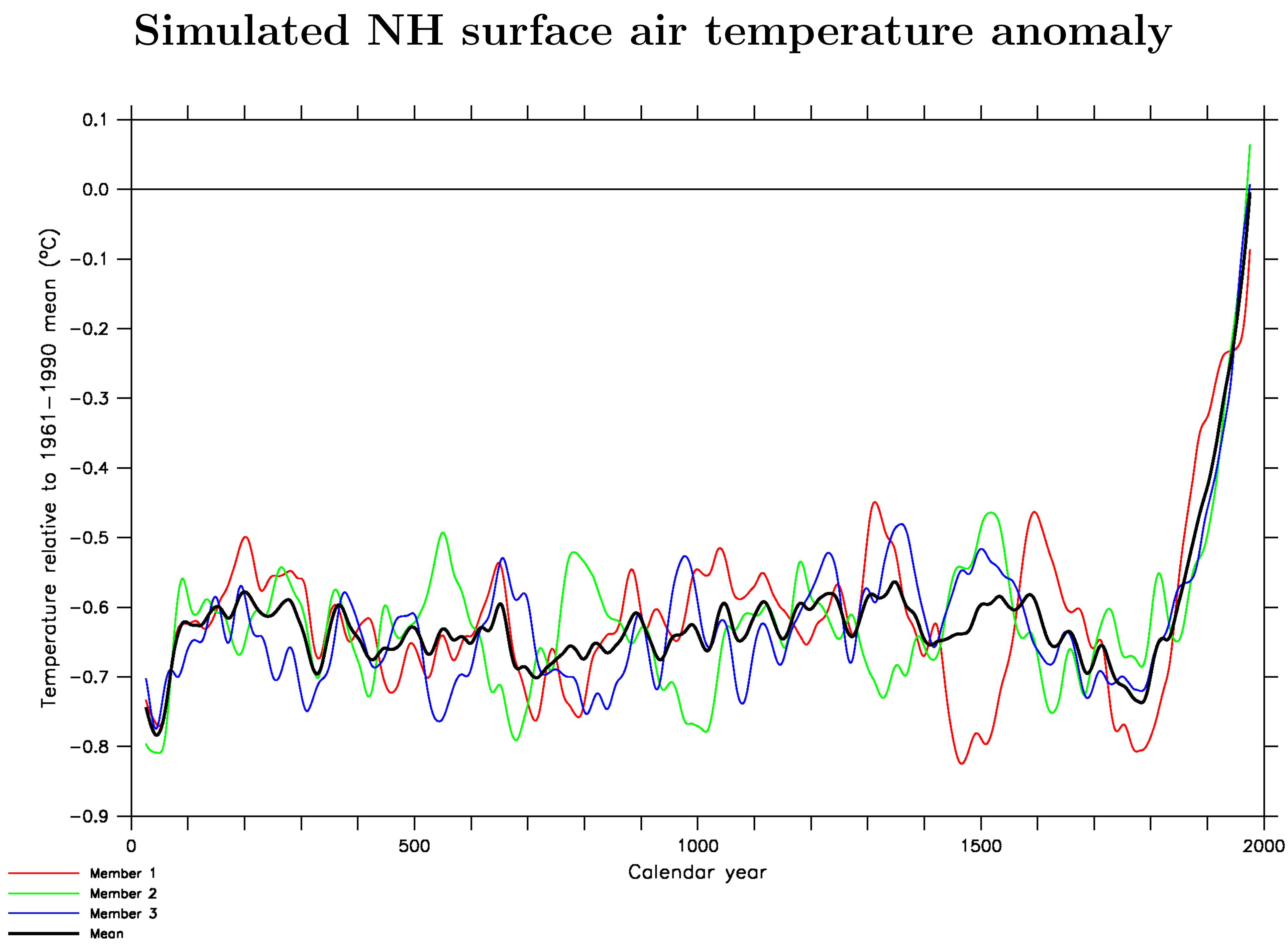

*Mann et al., 2008*

# Australian modelling capacity

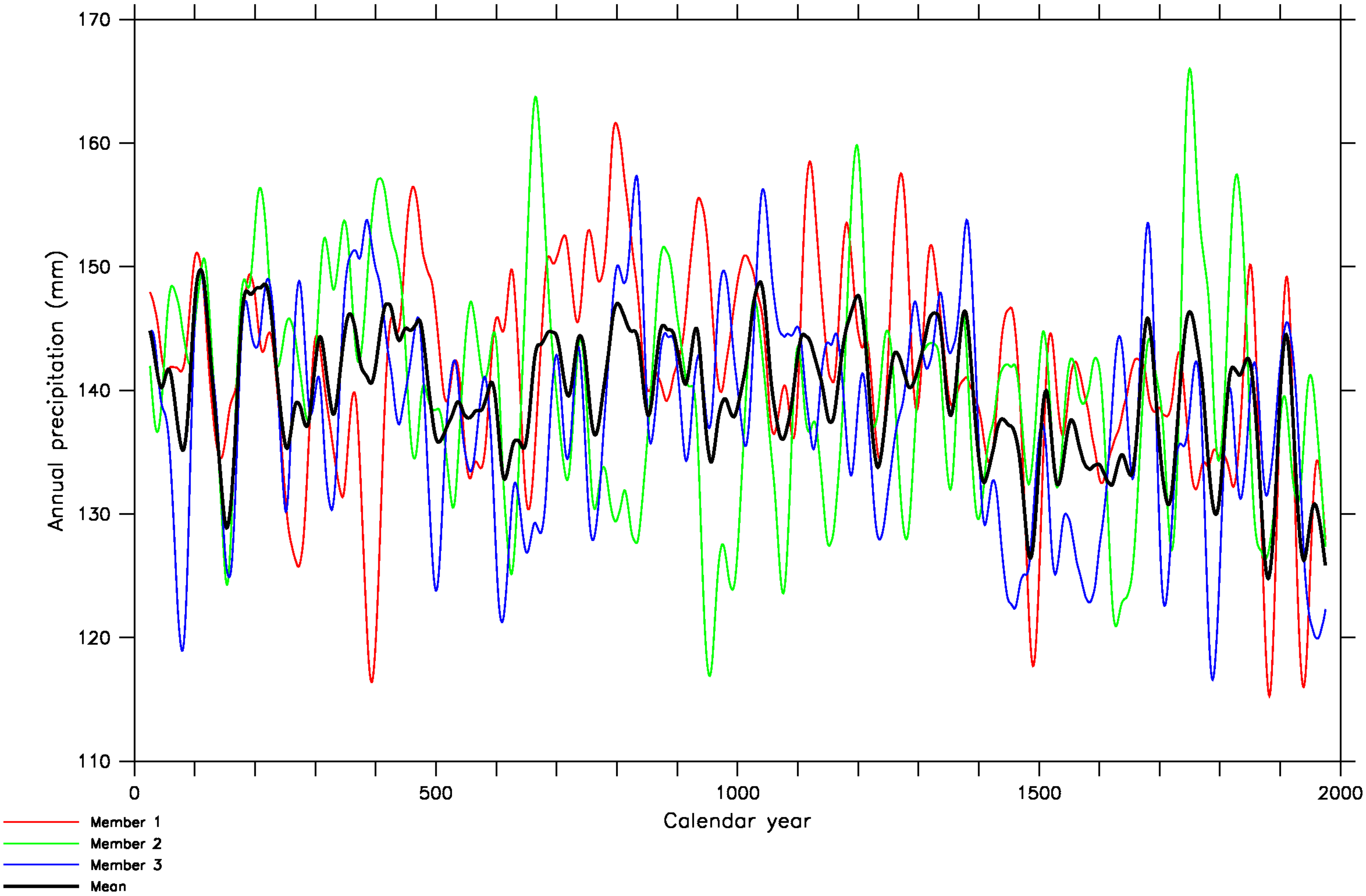
- Earth System Models of Intermediate Complexity (EMICs)
  - UVic
- Low-resolution General Circulation Models (GCMs)
  - CSIRO Mk3L
  - CCSM
  - FOAM
- IPCC-class models
  - CSIRO Mk3
  - ACCESS

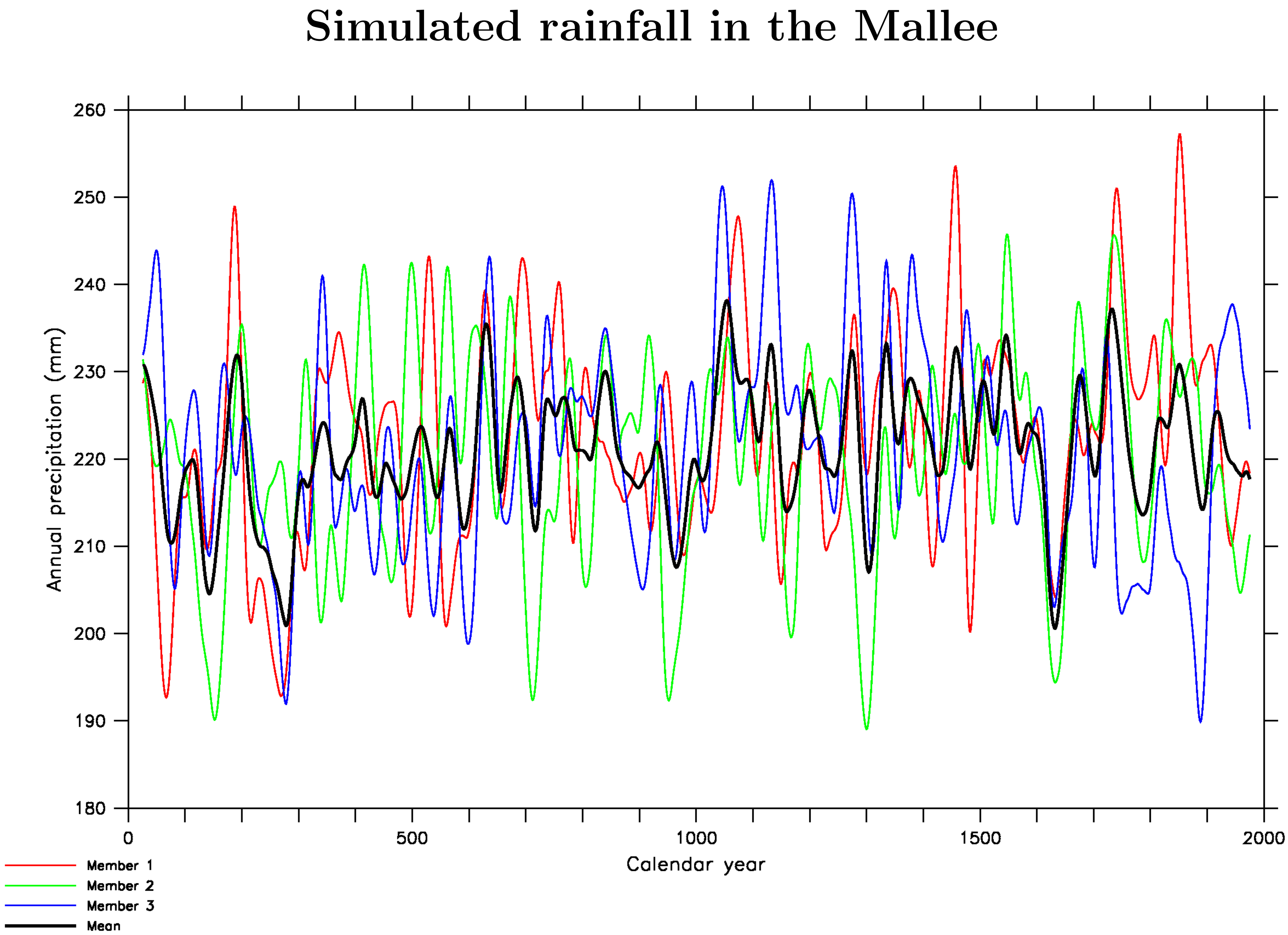
# Transient simulations of the past 2ka

- CSIRO Mk3L climate system model v1.2:
  - 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 three weeks
- Three transient simulations of the past 2,000 years:
  - Earth's orbital geometry is varied
  - Atmospheric $CO_2$, $CH_4$ and $N_2O$ concentrations varied according to Law Dome record (MacFarling Meure et al., 2006)
  - No solar or volcanic forcing
  - The three ensemble members differ only in the initial conditions


Simulated NH surface air temperature anomaly
Temperature relative to 1961−1990 mean (°C)
0.1
0.0
−0.1
−0.2
−0.3
−0.4
−0.5
−0.6
−0.7
−0.8
−0.9
0
500
1000
1500
2000
Calendar year
Member 1
Member 2
Member 3
Mean

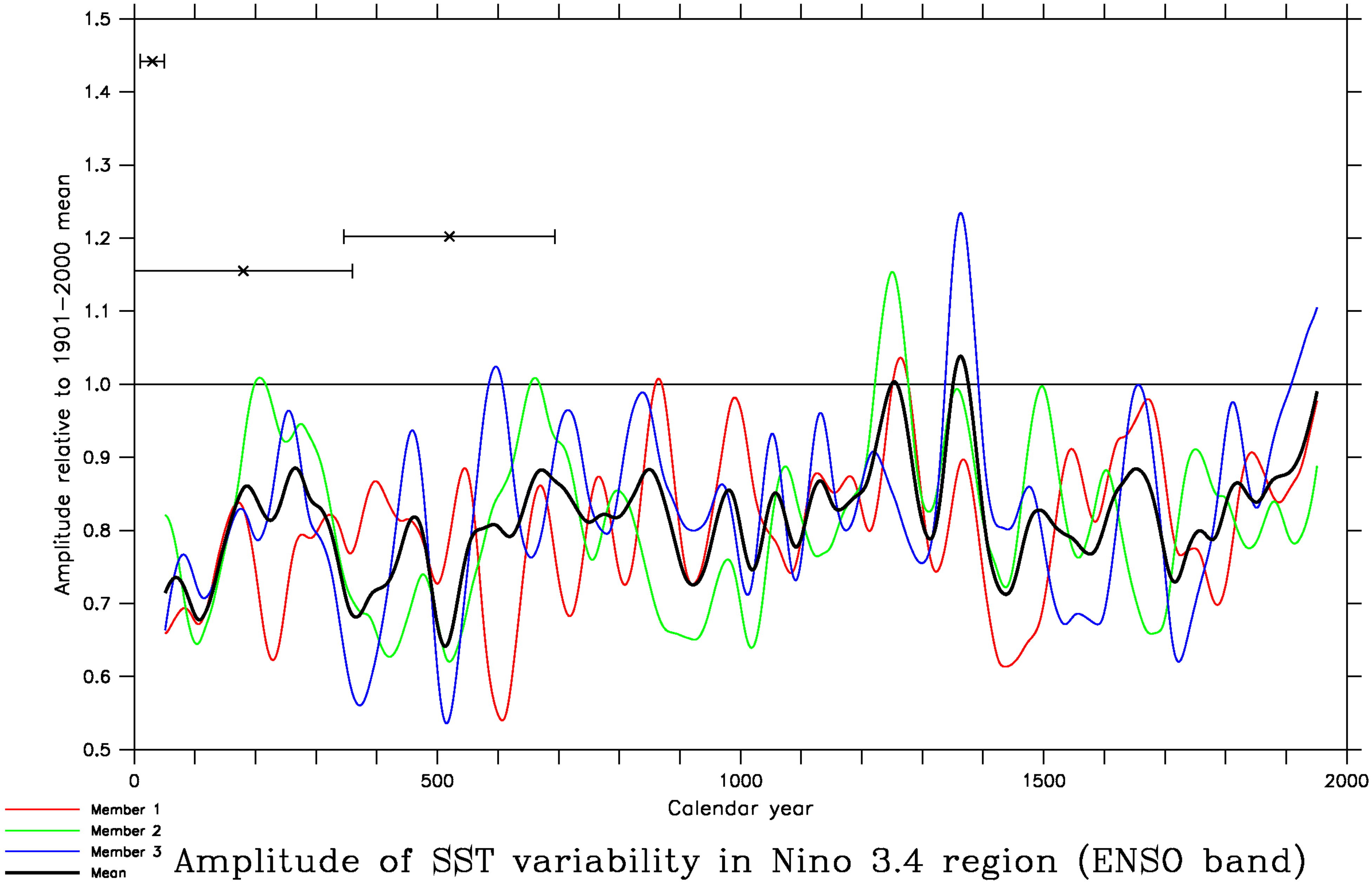
# Simulated rainfall in SW Western Australia





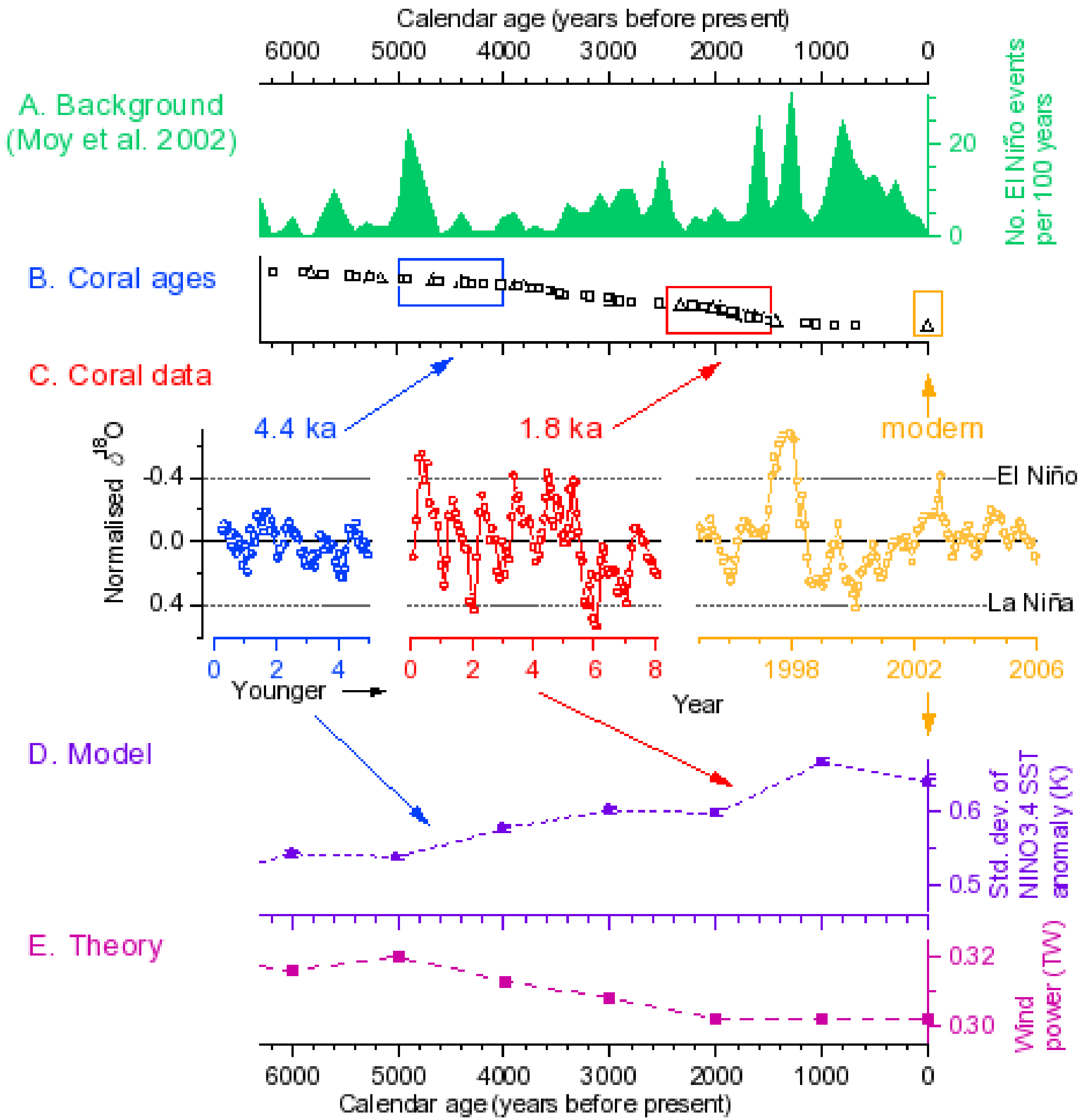
Simulated rainfall in the Mallee
Annual precipitation (mm)
260
250
240
230
220
210
200
190
180
0
500
1000
1500
2000
Calendar year
Member 1
Member 2
Member 3
Mean

# ENSO variability: Model simulations vs. Kiritimati $\delta^{18}O$



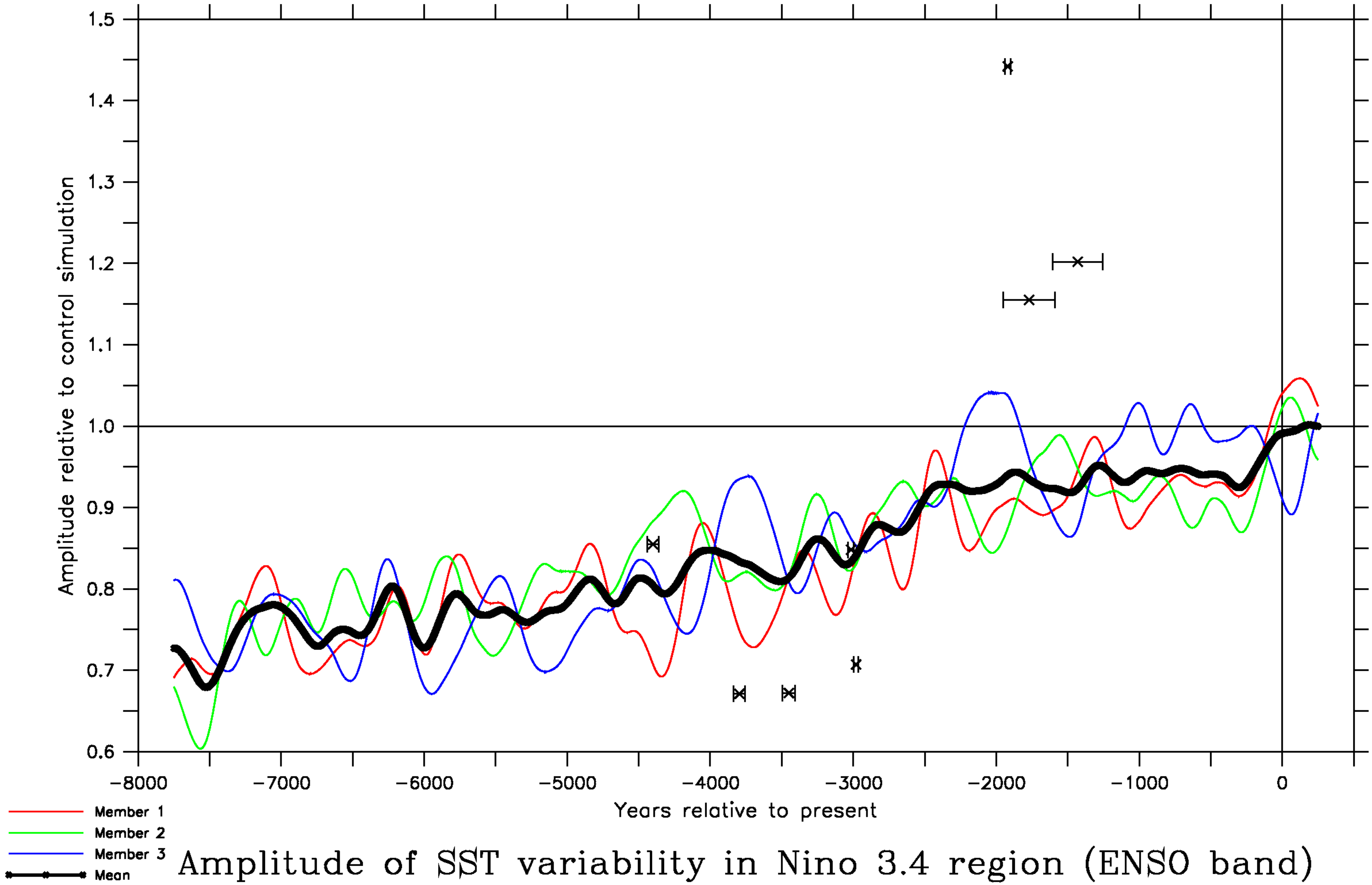

Amplitude of SST variability in Nino 3.4 region (ENSO band)

# Data-model integration



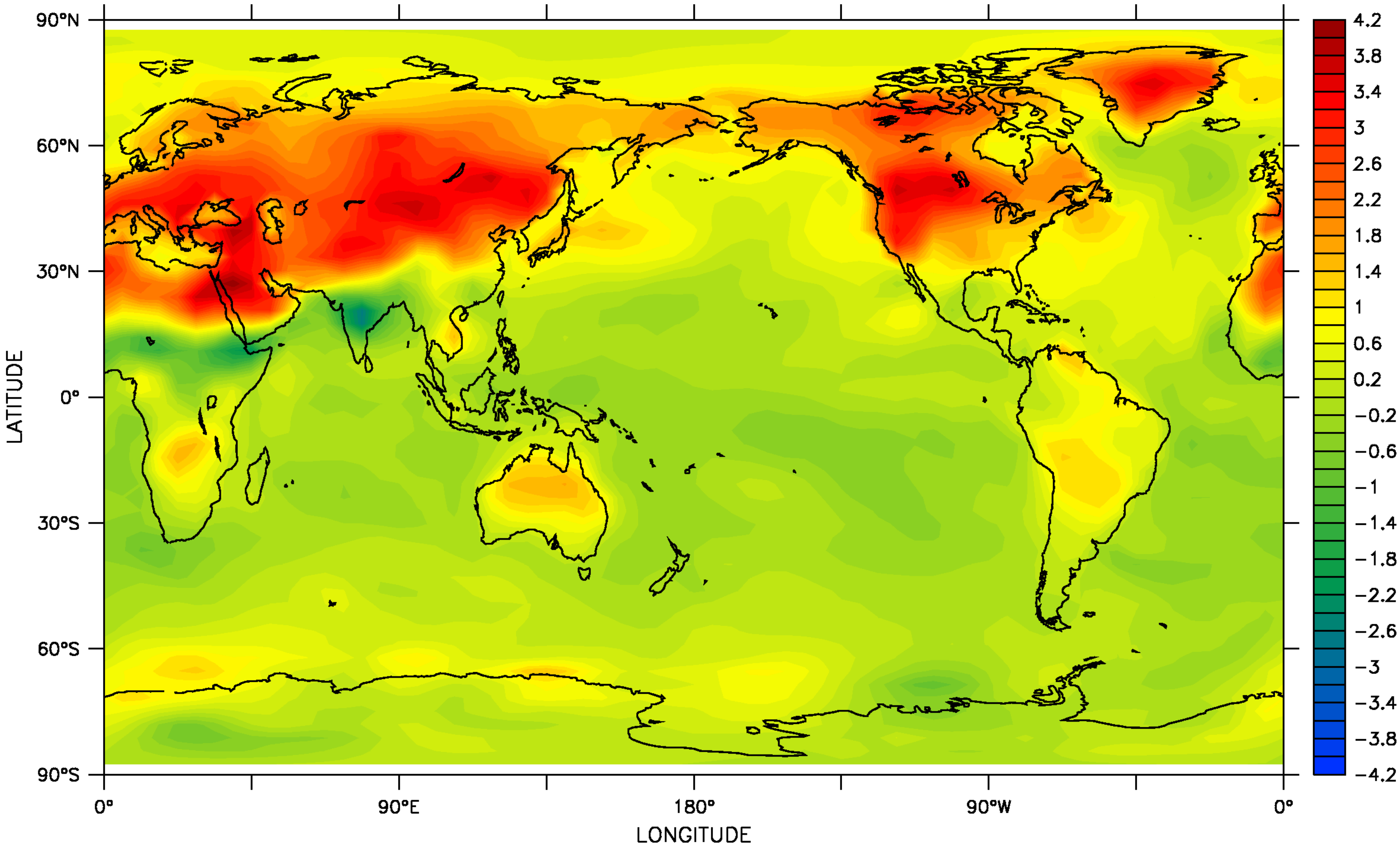

- Data-model integration is a two-way process
- The data constrains the model simulations
- The models provide the dynamical interpretation of the data

# Changes in ENSO variability: model-data comparison



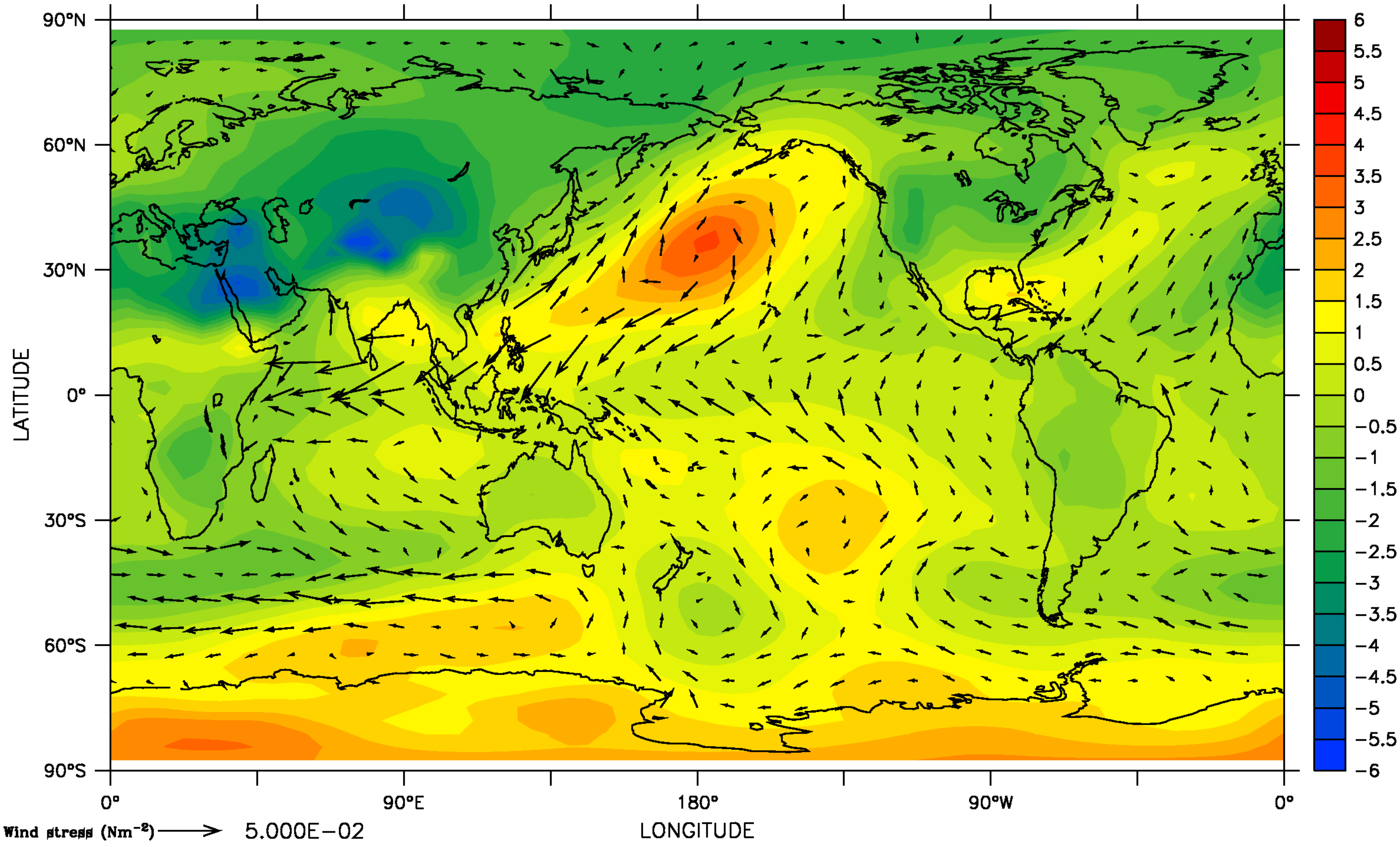

Amplitude of SST variability in Nino 3.4 region (ENSO band)

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



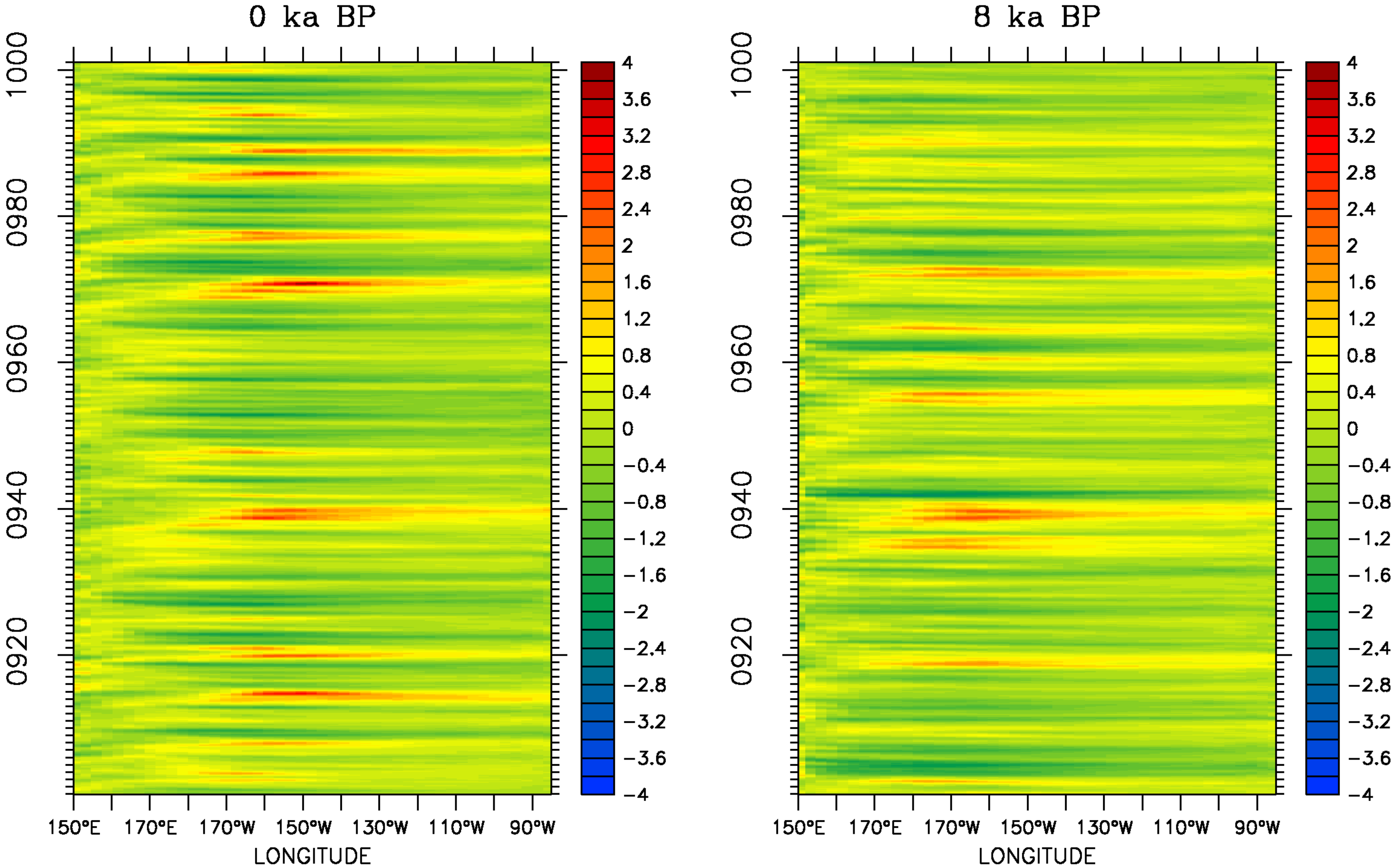

June–July–August surface air temperature, 8 ka minus 0 ka BP (K)

# … which enhanced the Asian summer monsoon system …



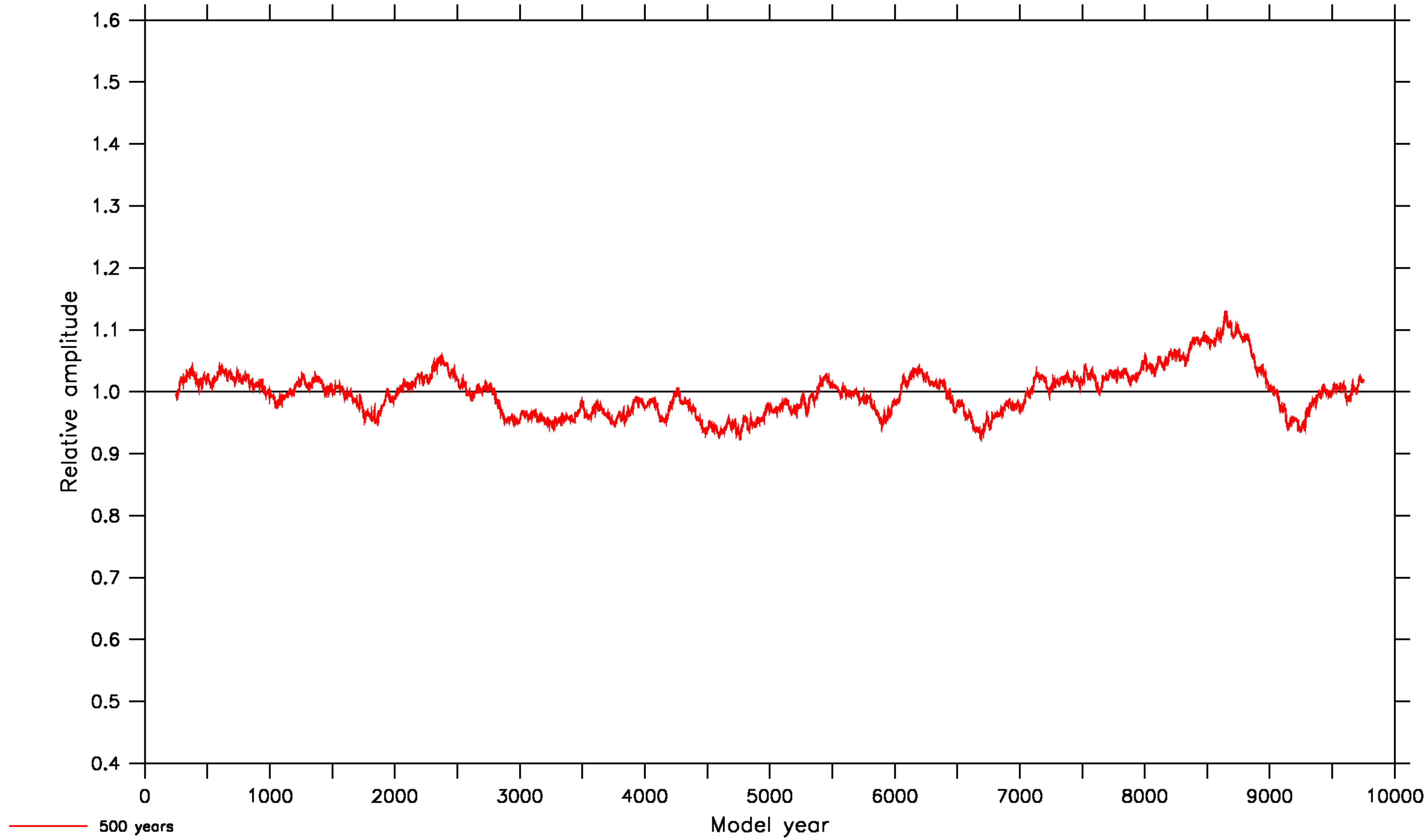

June–July–August mean sea level pressure, 8 ka minus 0 ka BP (hPa)

# … and made it harder for El Niño events to develop




SST anomaly (K)

# Variability as a function of sampling period in the model




Amplitude of SST variability in Nino 3.4 region

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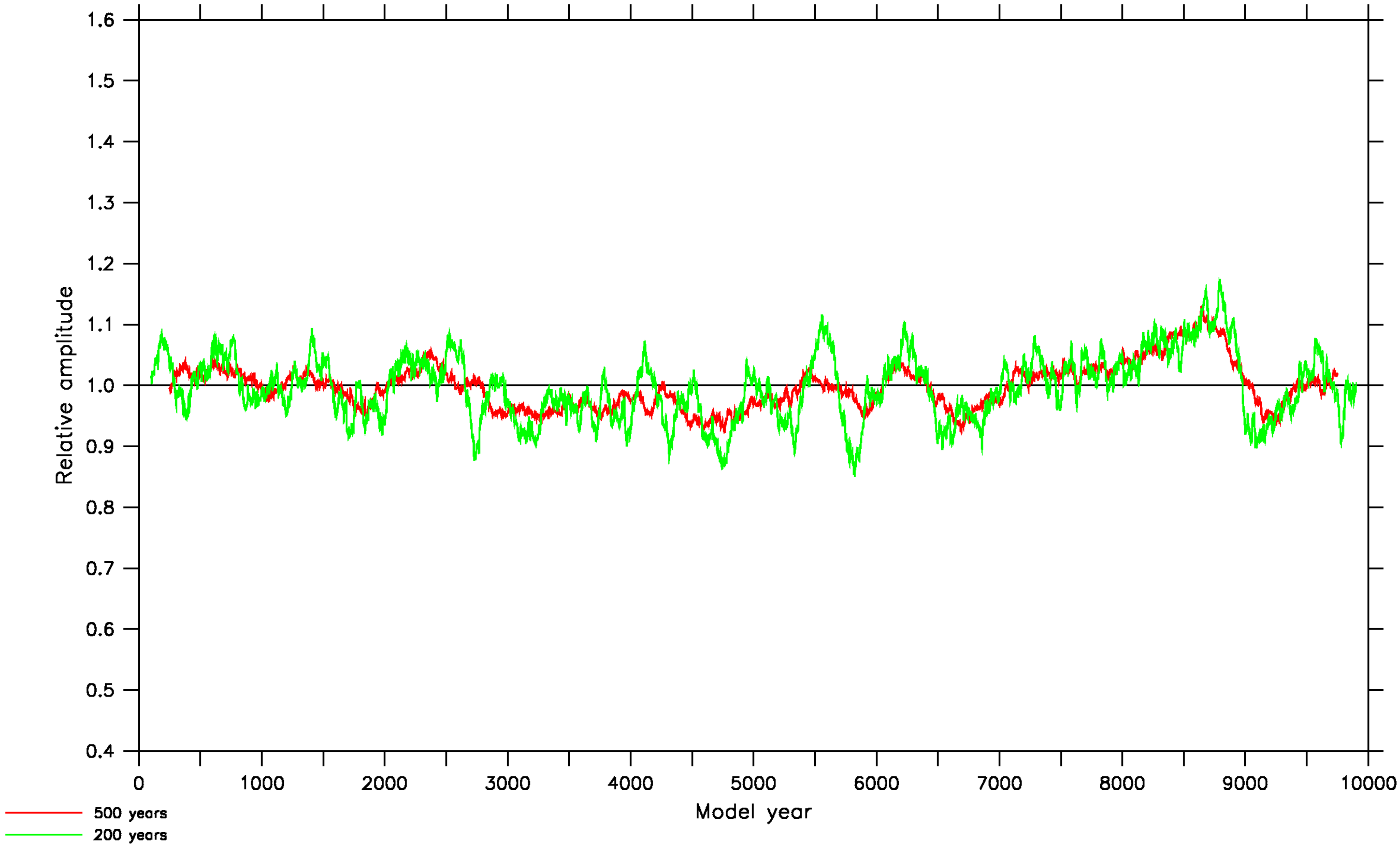


Amplitude of SST variability in Nino 3.4 region

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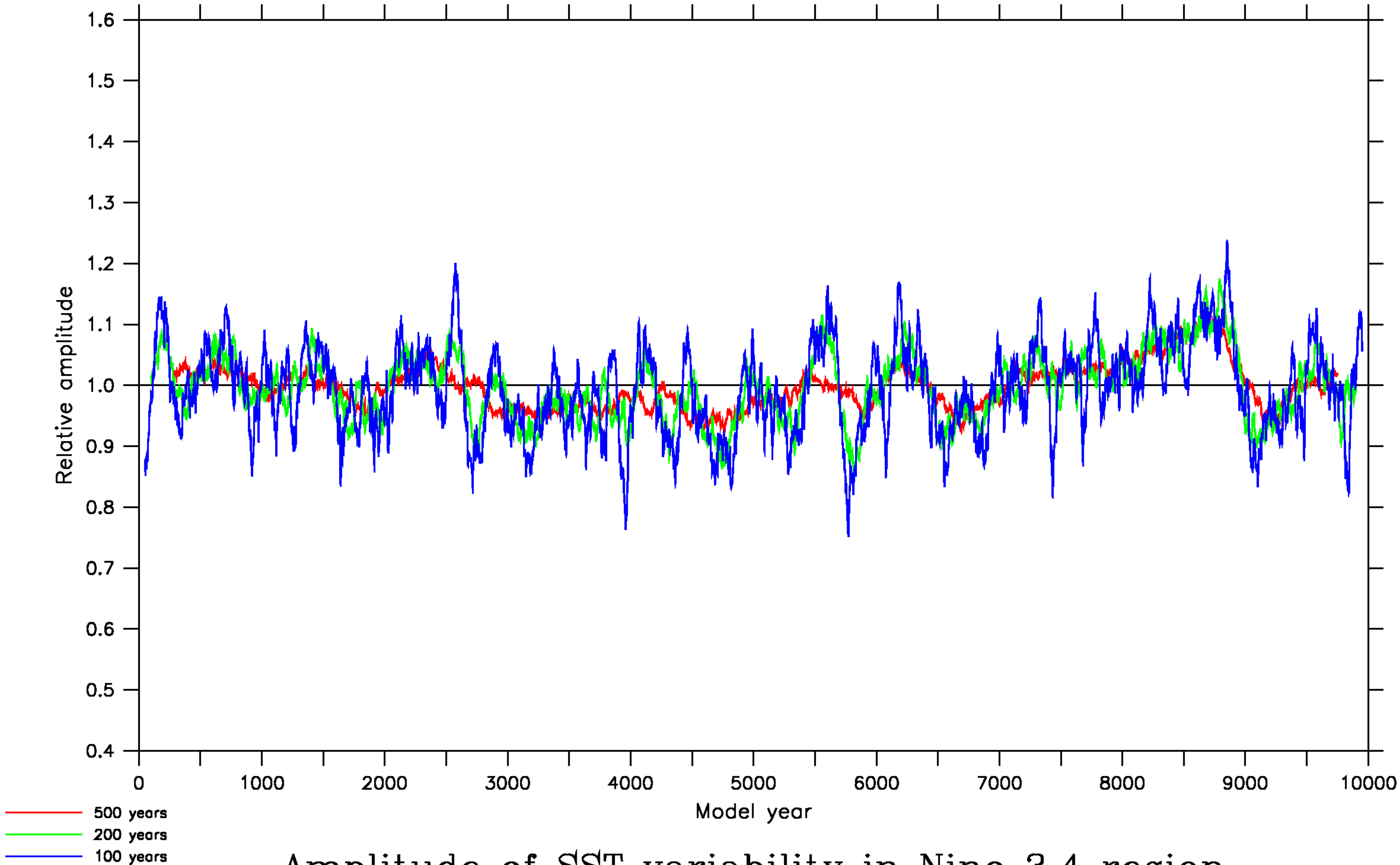


Amplitude of SST variability in Nino 3.4 region

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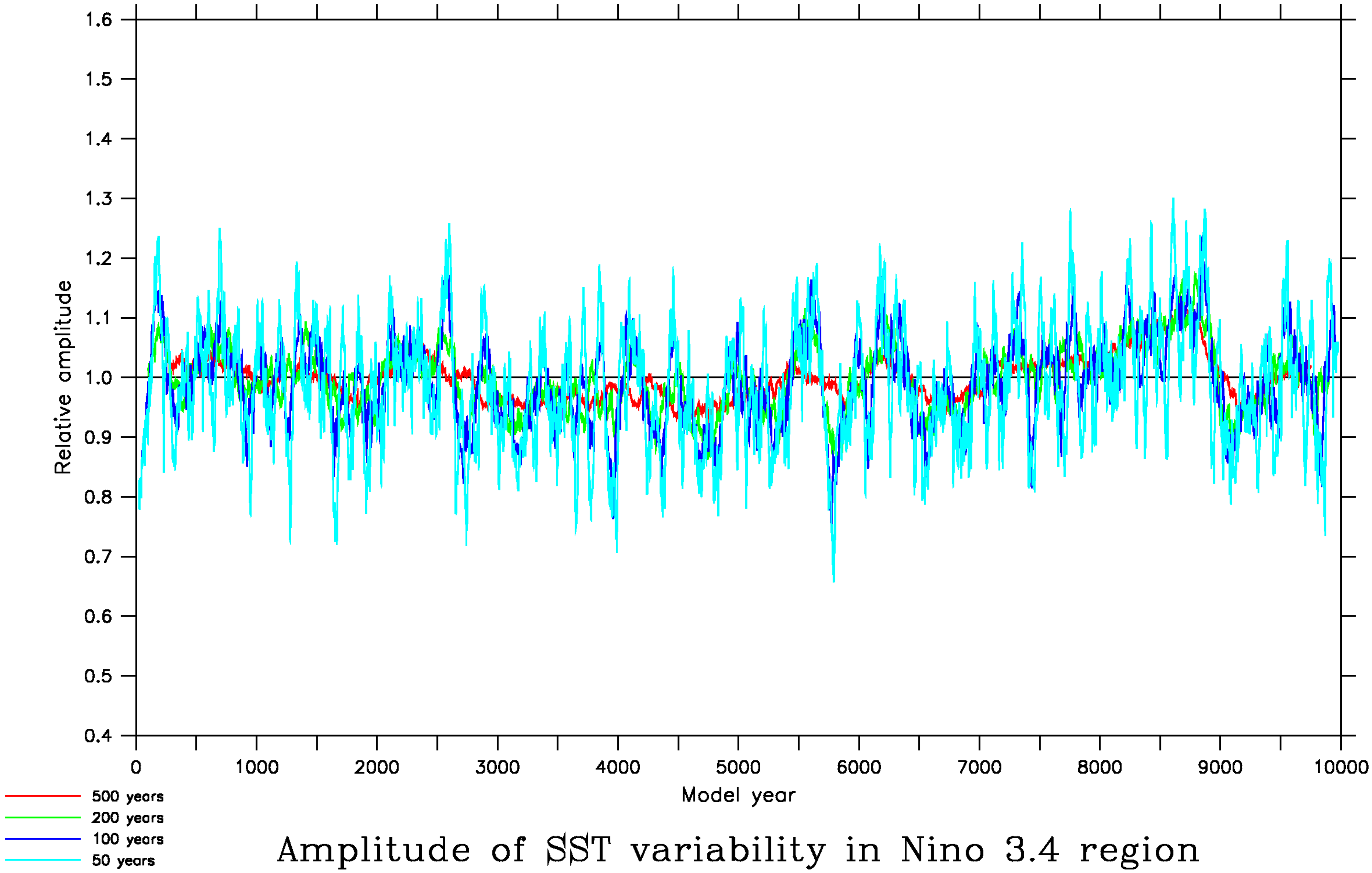


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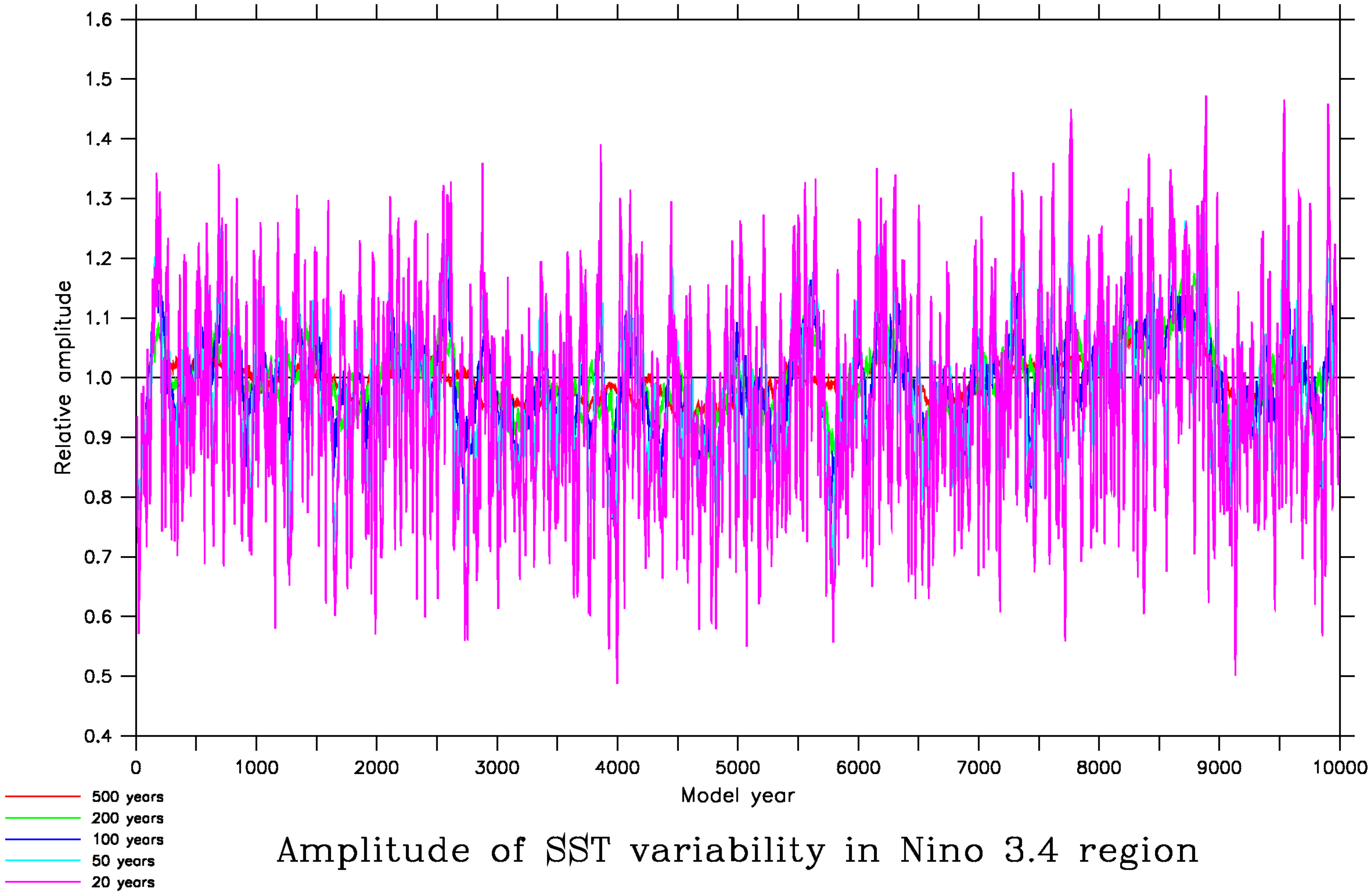


Amplitude of SST variability in Nino 3.4 region

# Future challenges and opportunities

- More comprehensive models
  - Carbon cycle (+ nitrogen + phosphorous + ...)
  - Ocean biogeochemistry
  - Stable isotopes ($^{18}$O, $^{13}$C, ...)
- Data-model integration - how do we do this?
  - Metrics
  - Baselines
  - Low-frequency variability
- Regional modelling for Australasia
- Palaeoclimate data simulation