Modelling of the last 2ka

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Modeling the Climate System

Includes the Atmosphere, Land, Oceans, Ice, and Biosphere

- Incoming Solar Energy
- Outgoing Heat Energy
- Transition from Solid to Vapor
- Evaporative and Heat Energy Exchanges
- Precipitation and Evaporation
- Stratus Clouds
- Cumulus Clouds
- Cirrus Clouds
- Atmospheric GCM

Land Surface Processes

- Soil Moisture
- Runoff
- Snow Cover
- Ocean
- Ocean Currents, Temperature, and Salinity
- Realistic Geography
- Ocean Bottom Topography
- Vertical Overturning
- Ocean Model Layers

Atmosphere

- Precipitation & Evaporation
- Stratus Clouds
- Atmospheric Model Layers

Ocean

- Heat & Salinity Exchange
- Ocean GCM

Biosphere

- Vertical Overturning
- Ocean Model Layers
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 hierarchy

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$_2$O 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
Simulated rainfall in SW Western Australia

![Simulated rainfall graph showing annual precipitation (mm) over calendar years from 0 to 2000. The graph includes multiple members and a mean line.](image-url)
Simulated rainfall in the Mallee

![Graph showing simulated rainfall over time with lines for different members and a mean line. The graph has a y-axis labeled 'Annual precipitation (mm)' and an x-axis labeled 'Calendar year'.]
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 ...
... and made it harder for El Niño events to develop
Variability as a function of sampling period in the model

Amplitude of SST variability in Nino 3.4 region
Variability as a function of sampling period in the model

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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 ($^{18}\text{O}$, $^{13}\text{C}$, ...)

- Data-model integration - how do we do this?
  - Metrics
  - Baselines
  - Low-frequency variability

- Regional modelling for Australasia

- Palaeoclimate data simulation