Simulating the climate of the last glacial cycle

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PhD seminar

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Overview

- Background
- Aims
- Methodology
- Results so far
- Conclusions

Background

What is climate?

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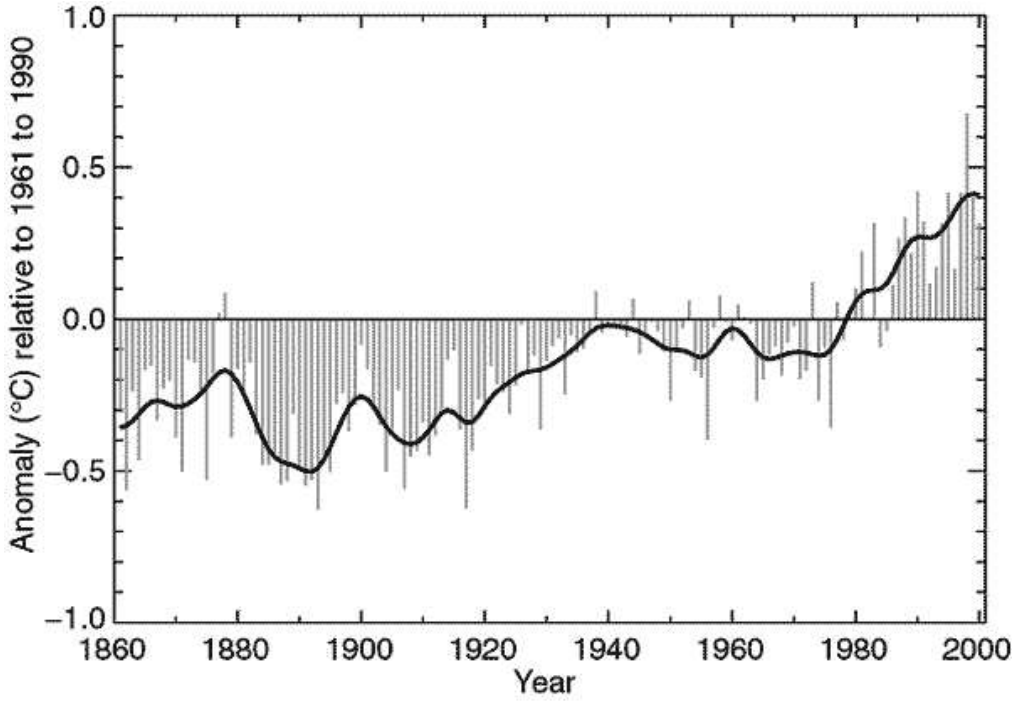
- timescale?

Climate variability or climate change?

- climate *variability*
  - refers to natural variations around the mean state
- climate *change*
  - refers to a change in the underlying mean state
  - can be used to refer to changes arising purely from human influences

Background

The Earth's climate exhibits variability on all timescales...



Global land-surface air temperature 1861-2000

Climate change 2001: The Scientific Basis

Background

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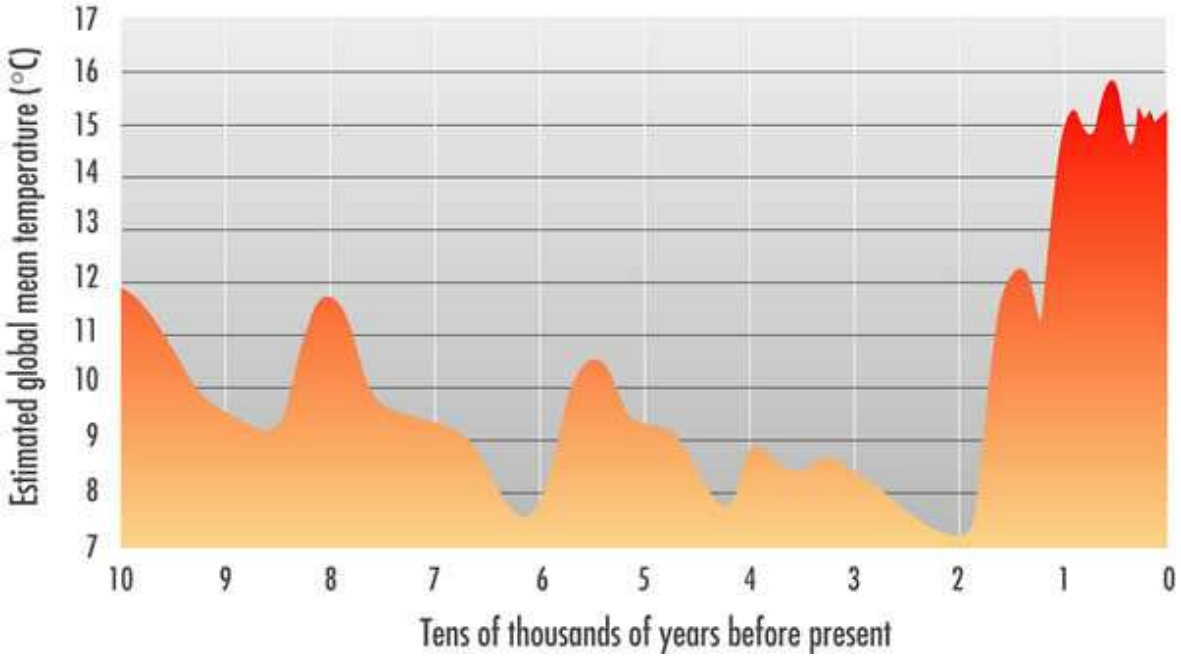
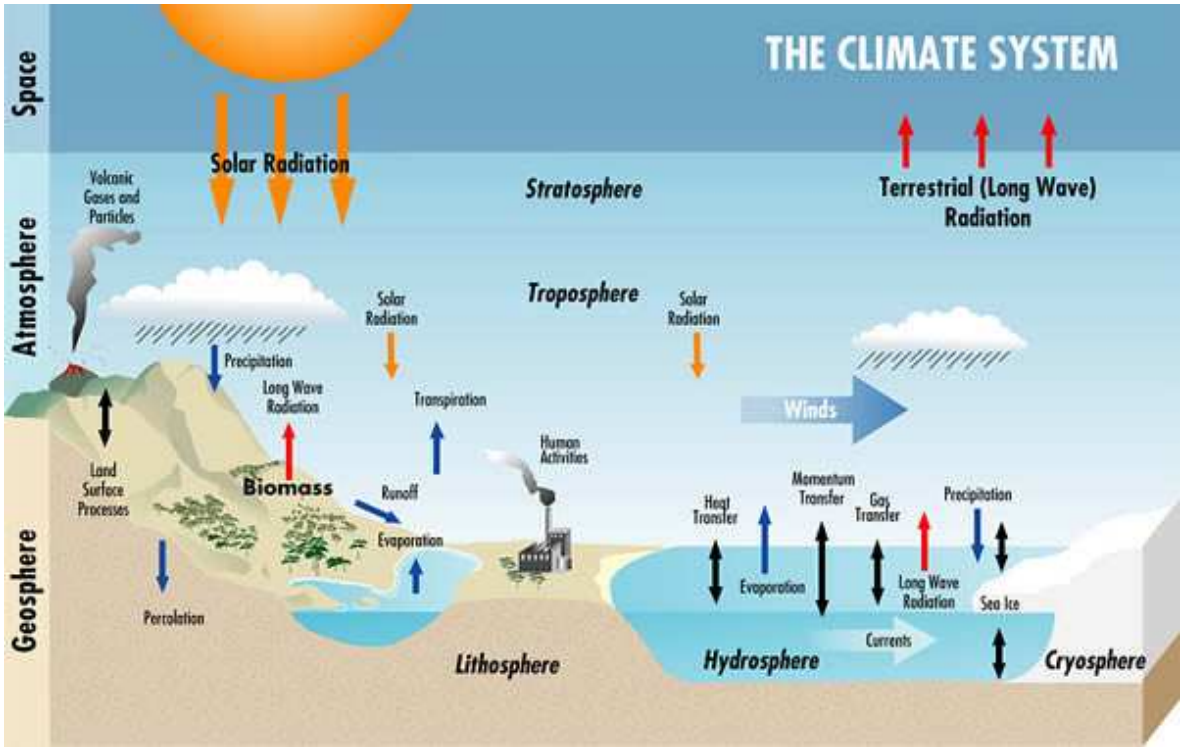


Estimated global-mean temperatures over the past 100,000 years

Bureau of Meteorology

Background

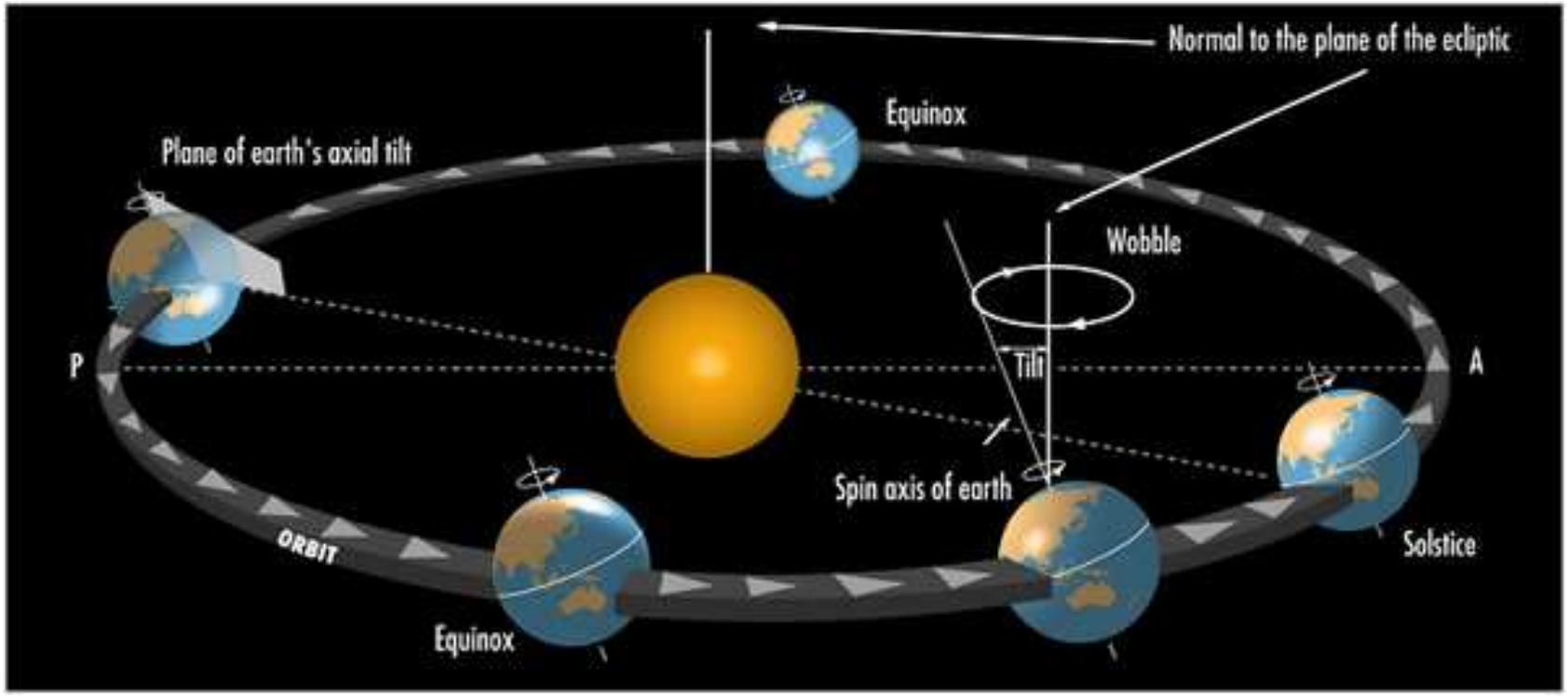
Natural variability arises from internal interactions within the climate system ...



Bureau of Meteorology

Background

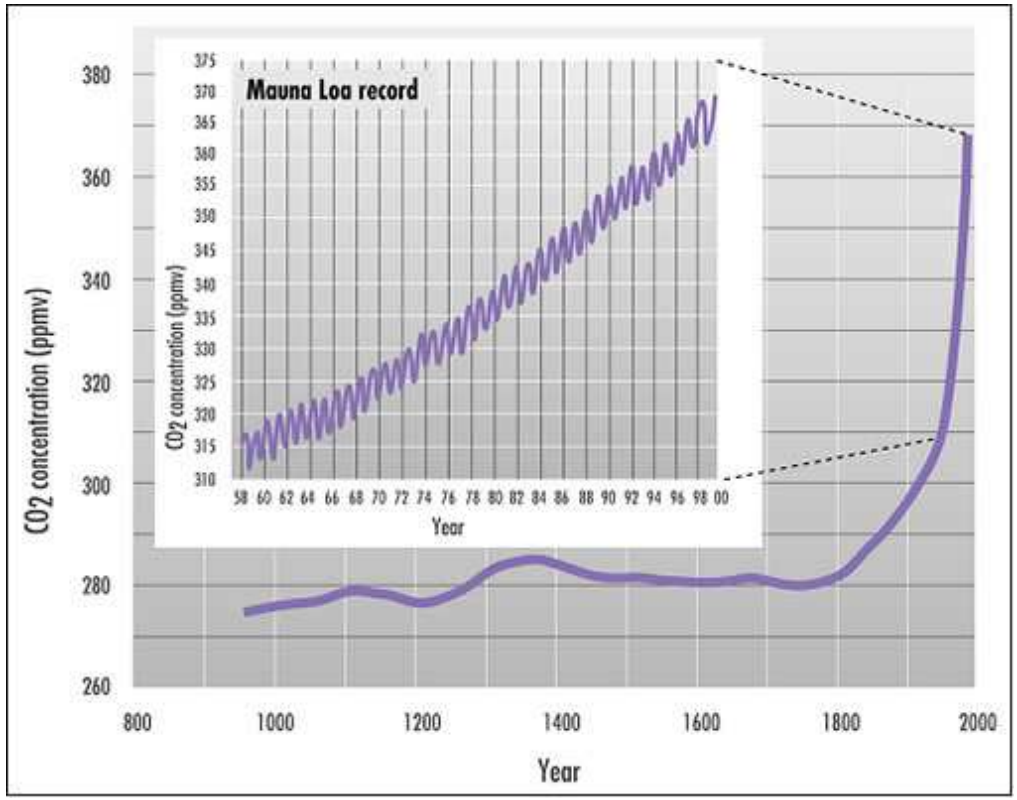
... and from external influences such as the Earth's orbital geometry.



Bureau of Meteorology

Background

The dominant human influence is increasing atmospheric CO_2.



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Understanding climate variability and climate change

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- What is the magnitude of natural climate variability?
- To what extent are recent changes due to human influences?
- What can we expect in the future?

Background

There are two ways that we can address these questions:

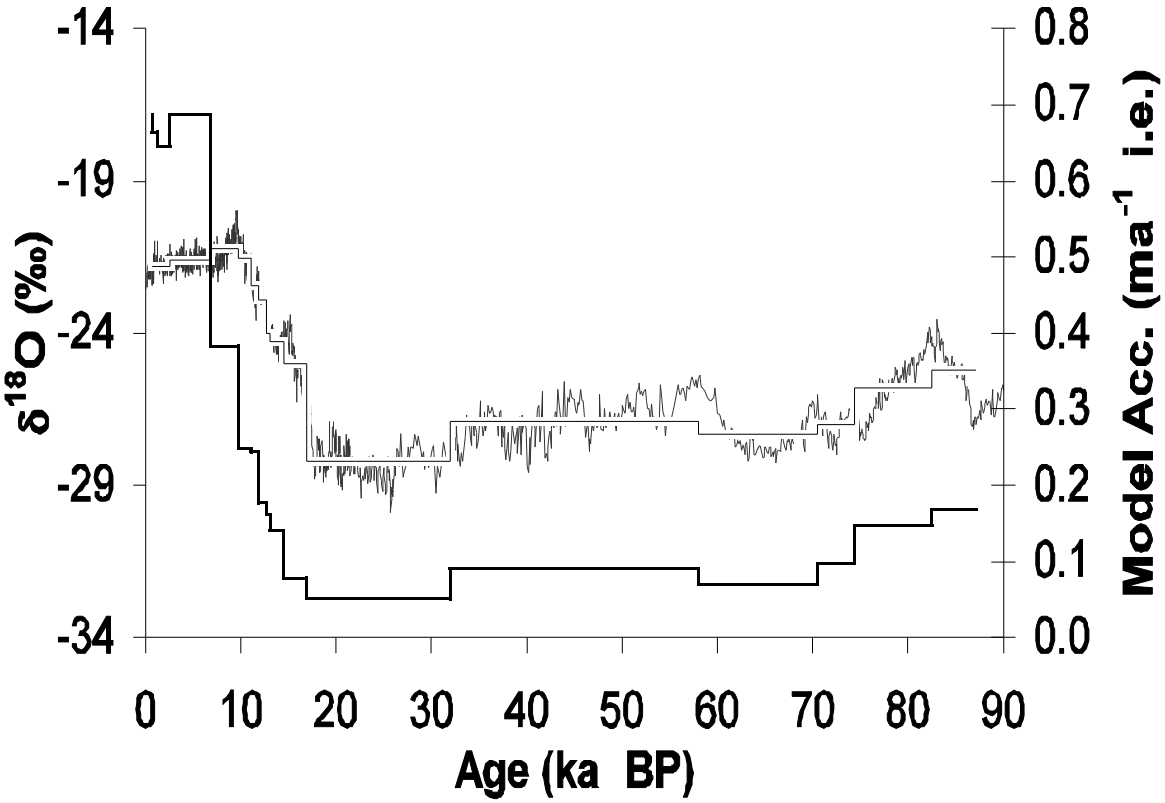
- Data
- Models

Data

Sources of data on past climates include:

- Direct measures
  - observations
- Indirect measures
  - ice cores
  - marine/lake sediments
  - tree rings
  - coral

Law Dome ice core



van Ommen et al, *Annals of Glaciology*, in press.

Models

- based upon the physical laws describing the processes occurring within the climate system
- underlying equations are solved numerically
- enable direct simulation of past, present and future climate states
- can be used to study both the mean climate state, and the degree of climate variability
- can help to understand past climate change
- require large computer resources

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- models are limited by the representation of the underlying physical processes, which is restricted by
  - the understanding of the processes
  - the comprehensiveness of the model
  - computational resources

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- models require *validation* before we can trust the results

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- the *maximum* extent to which we can have confidence in a model is the extent to which it can reliably simulate a range of climate states
- desirable to validate the model over as wide a range of climate states as possible
- the only feasible way of doing this is to simulate past climates

Aims

- To investigate how the Earth's climate has changed over the past glacial cycle
  - changes in the mean state
  - changes in the degree of natural variability
- To establish how well can a climate model simulate these changes

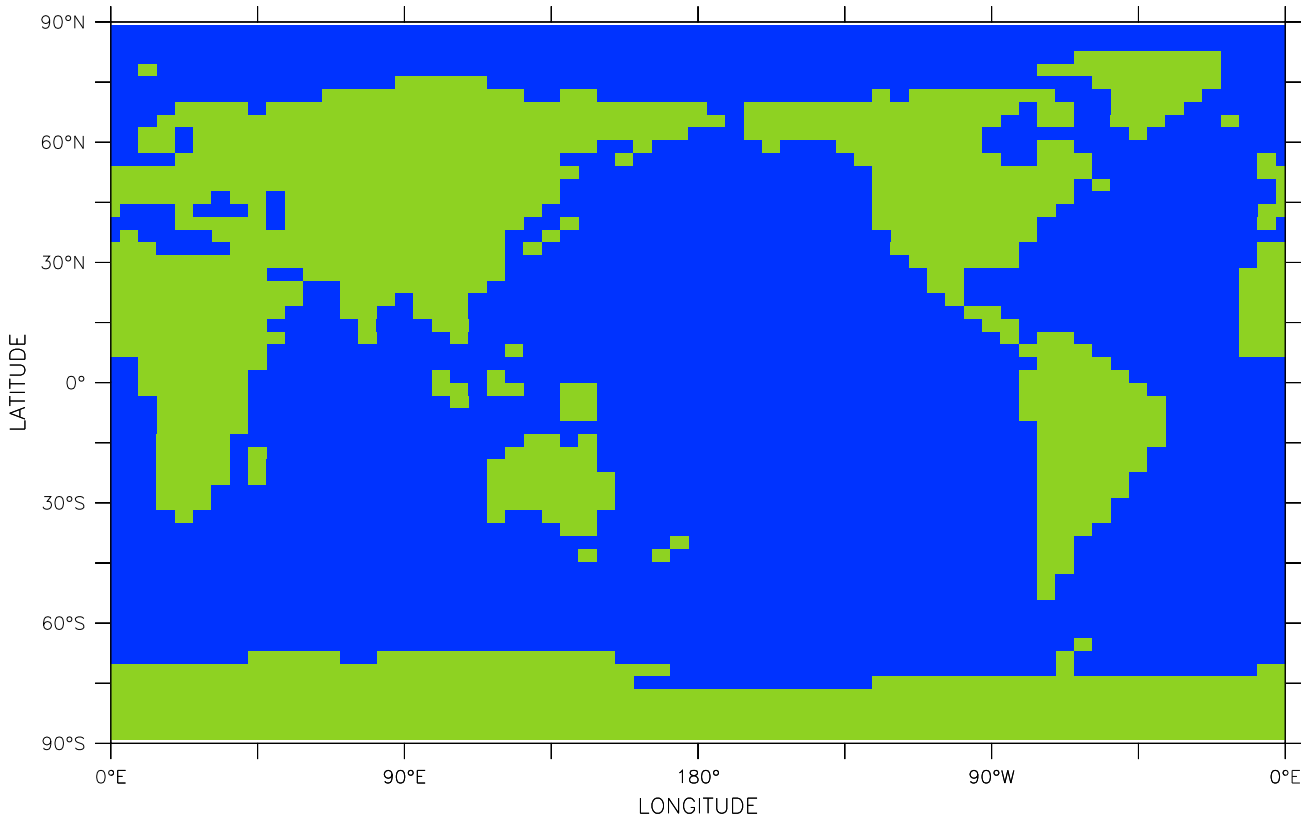
Methodology

The Model

- CSIRO climate system model
- coupled atmosphere-sea ice-ocean general circulation model
- low resolution version
  - 64 x 56 horizontal grid
  - 18 vertical levels in the atmosphere
  - 21 vertical levels in the ocean
- written in Fortran 77/90
- around 95,000 lines of code!

Methodology

The CSIRO model grid



The Computer

APAC National Facility, Canberra

The Computer

- AlphaServer SC cluster
- 508 1GHz processors
- 1.2 petabytes (= 1,200,000 gigabytes!) tape store
- a 1,000 year simulation can be completed in around 3 months
- multiple simulations can carried out simultaneously

Simulations

- Simulations to be carried out for four different epochs
  - "modern" control runs (around AD 1750)
  - the mid-Holocene (6,000 years ago)
  - the Last Glacial Maximum (21,000 years ago)
  - 3 x CO_2 stabilisation scenario

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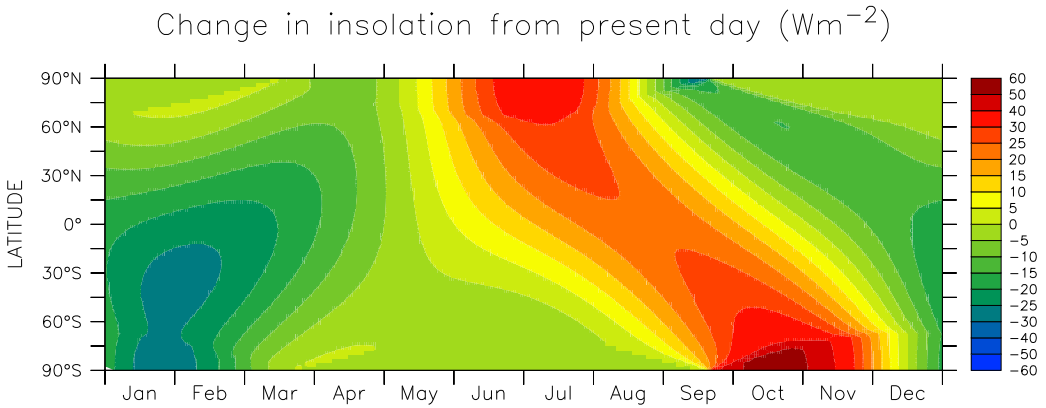
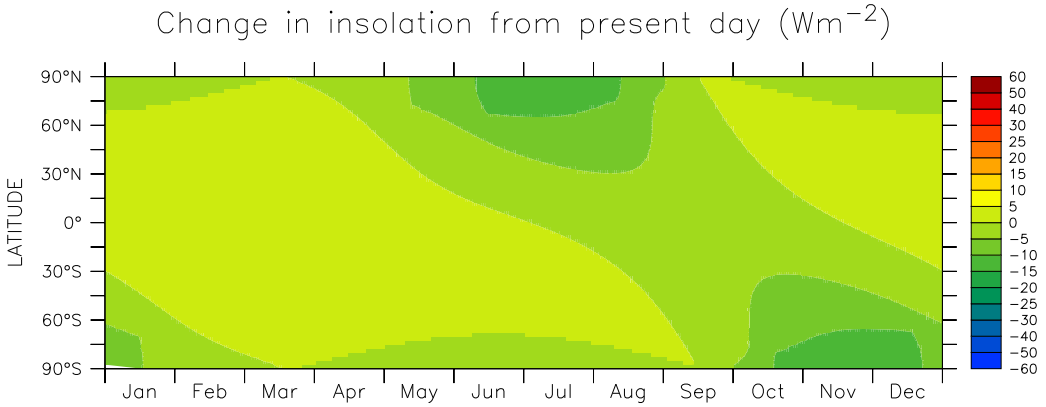
- Use two different configurations of the model
  - "slab ocean"
  - full coupled model
- each coupled model simulation to span at least 1,000 years, to enable the deep ocean to reach thermal equilibrium

Methodology



6,000 years BP



21,000 years BP

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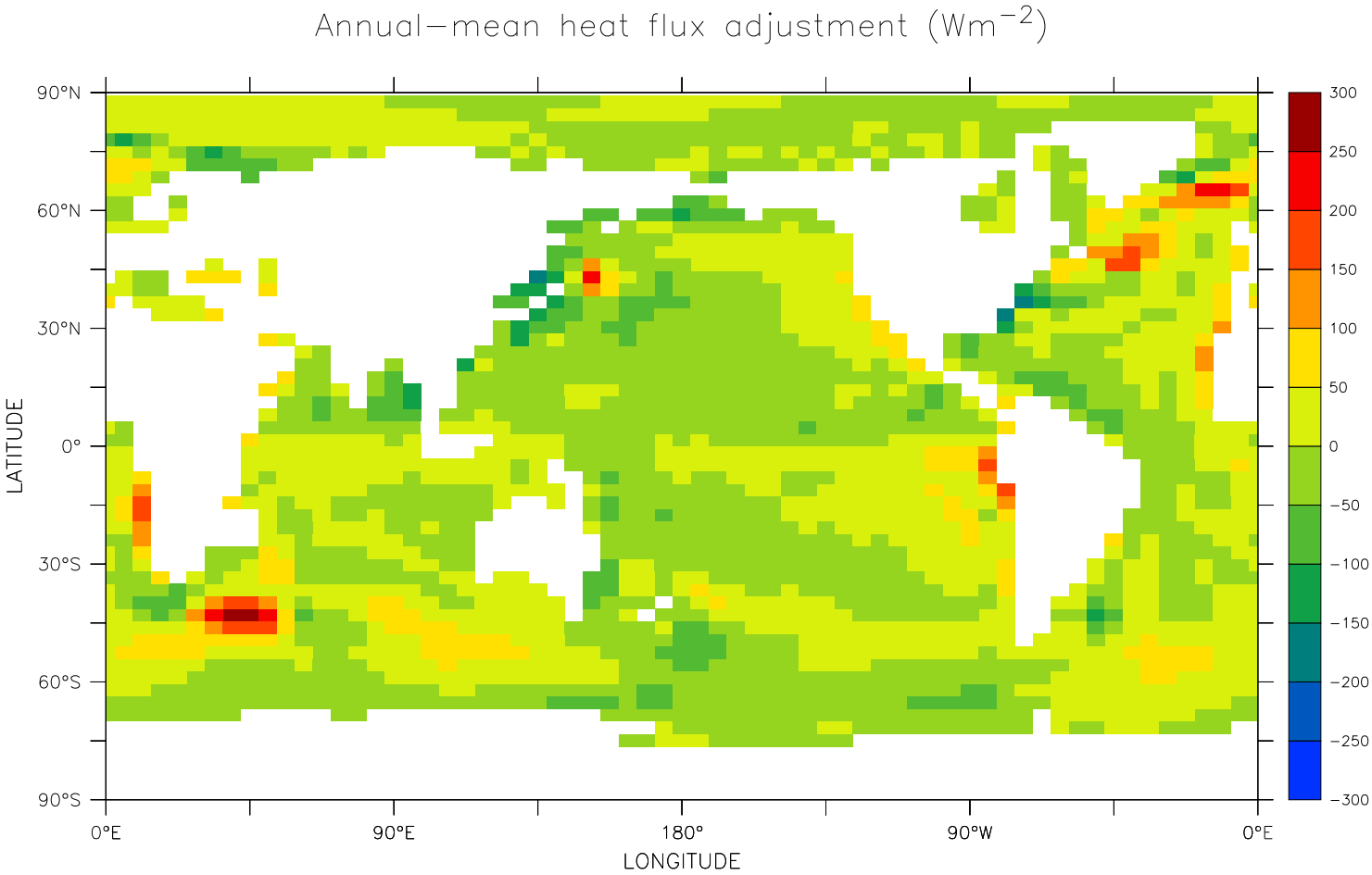
- their effect needs to be studied

Methodology



Typical heat flux adjustments

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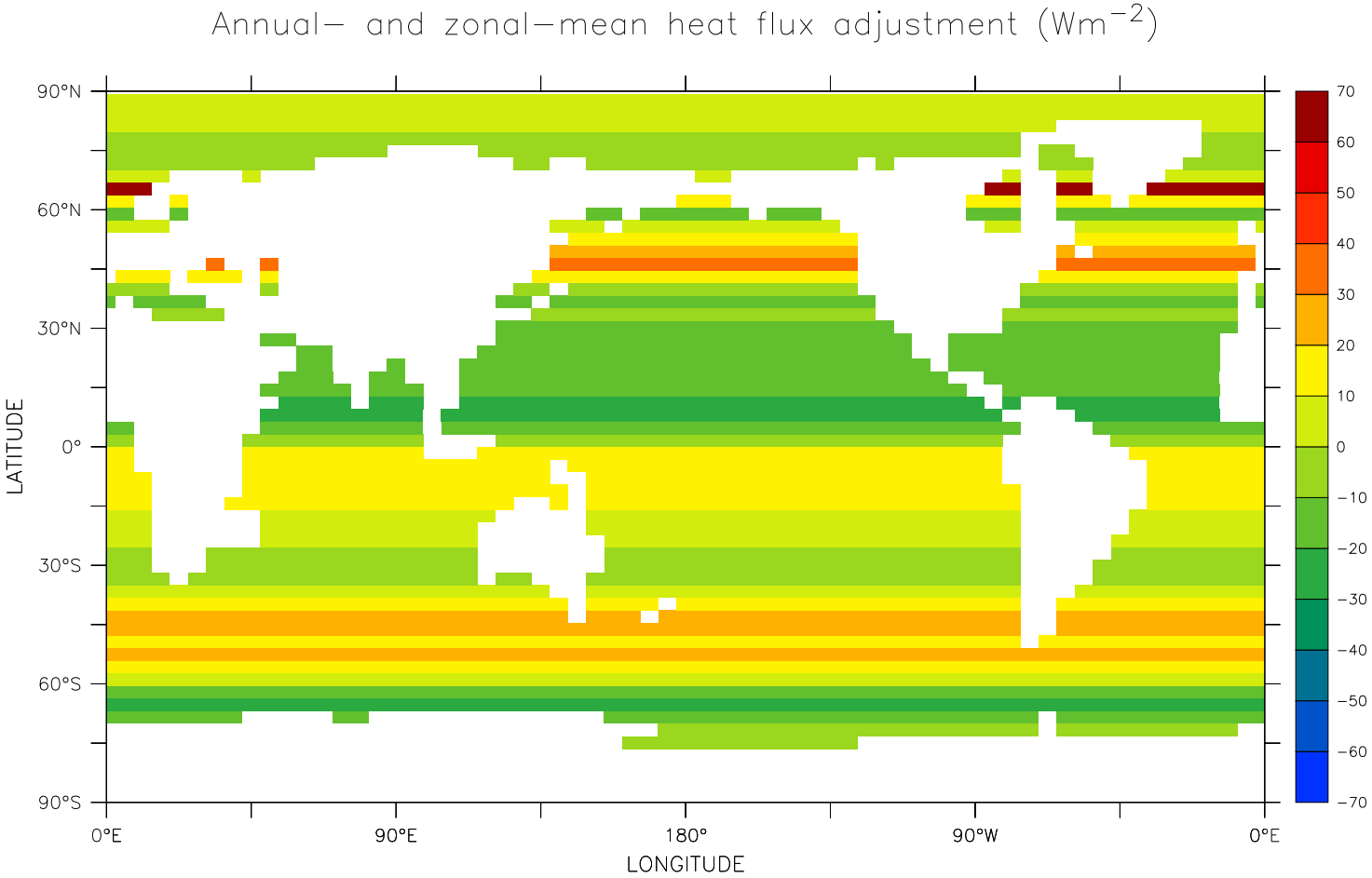
- simulations will be carried out both with and without flux adjustments
- simulated climate variability, and the response of the model, will be compared
- experiment with using zonal-mean flux adjustments, testing the concept developed by Weaver and Hughes (1996)
- enables the use of much smaller flux adjustments, while maintaining a realistic control climate

Methodology



Zonally averaged heat flux adjustments

Results so far

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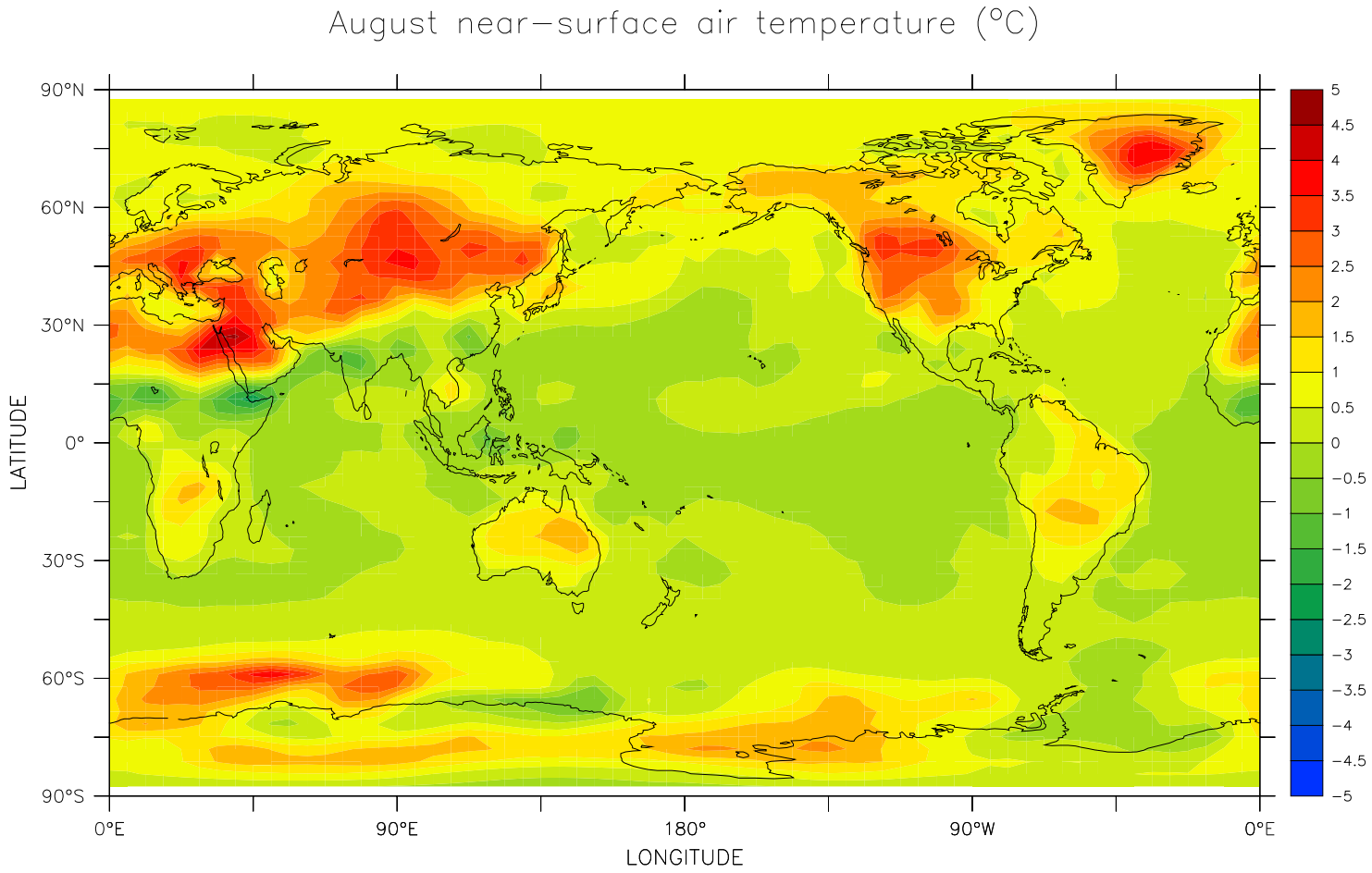

6,000 years BP minus modern

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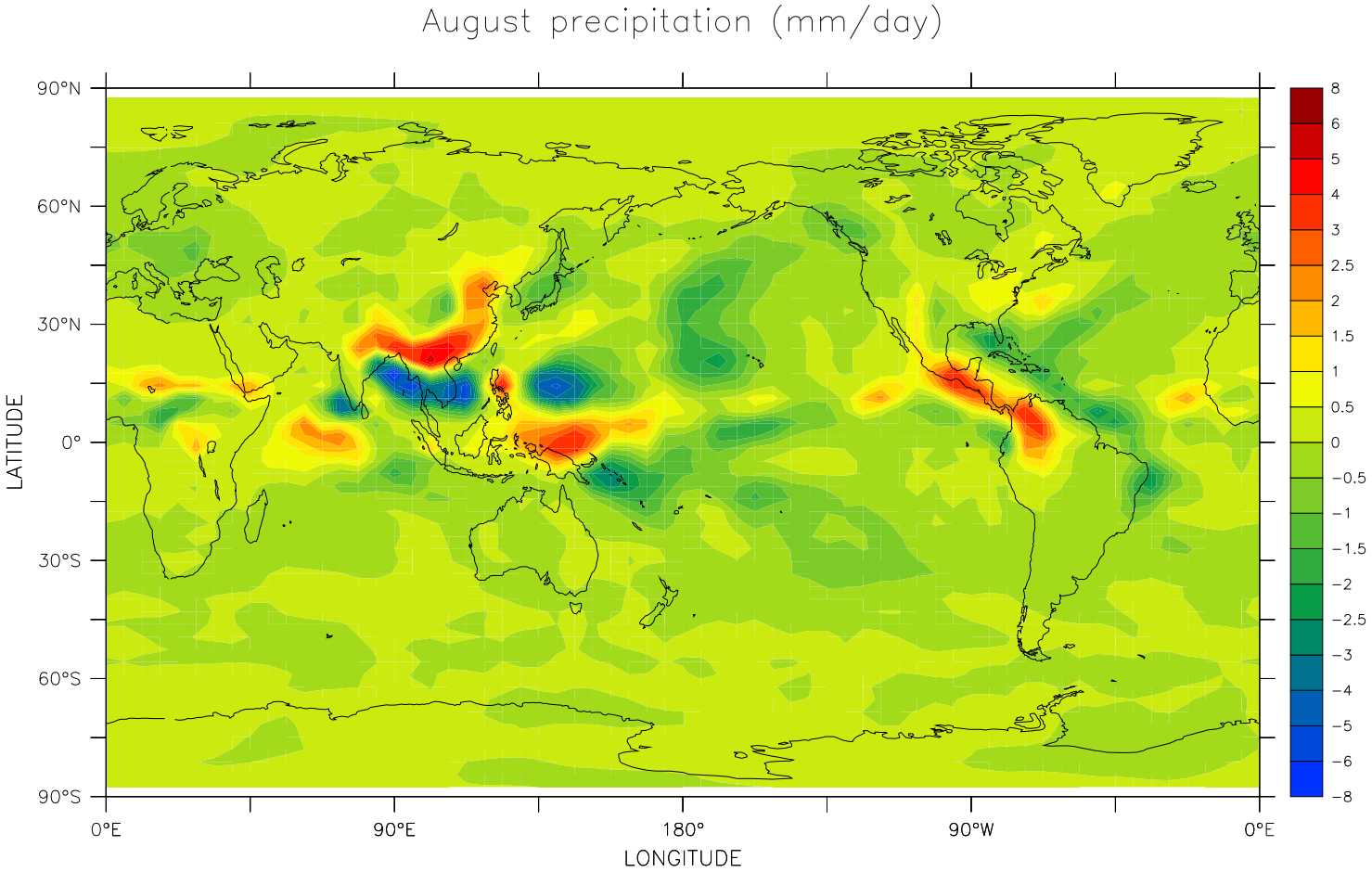

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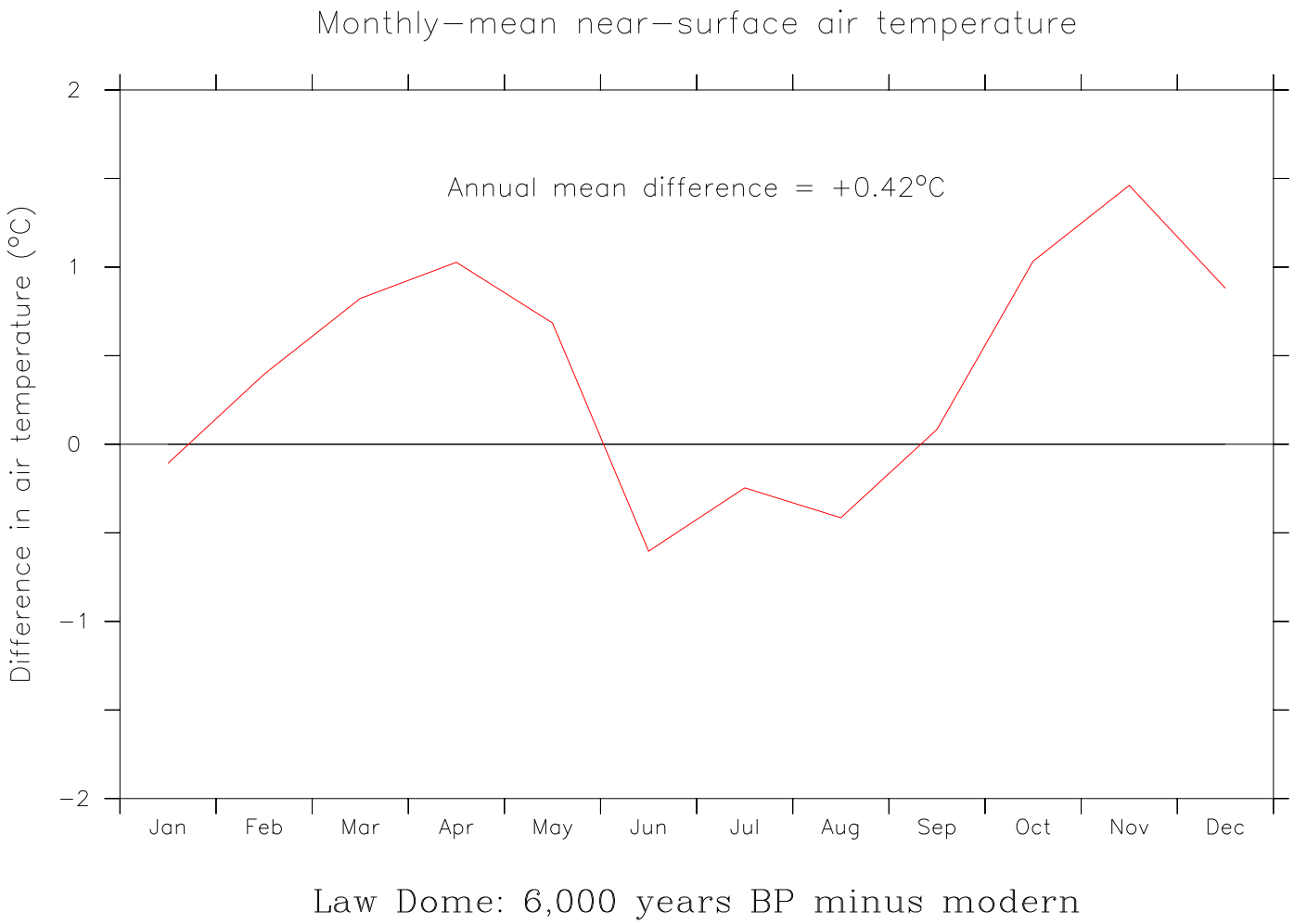

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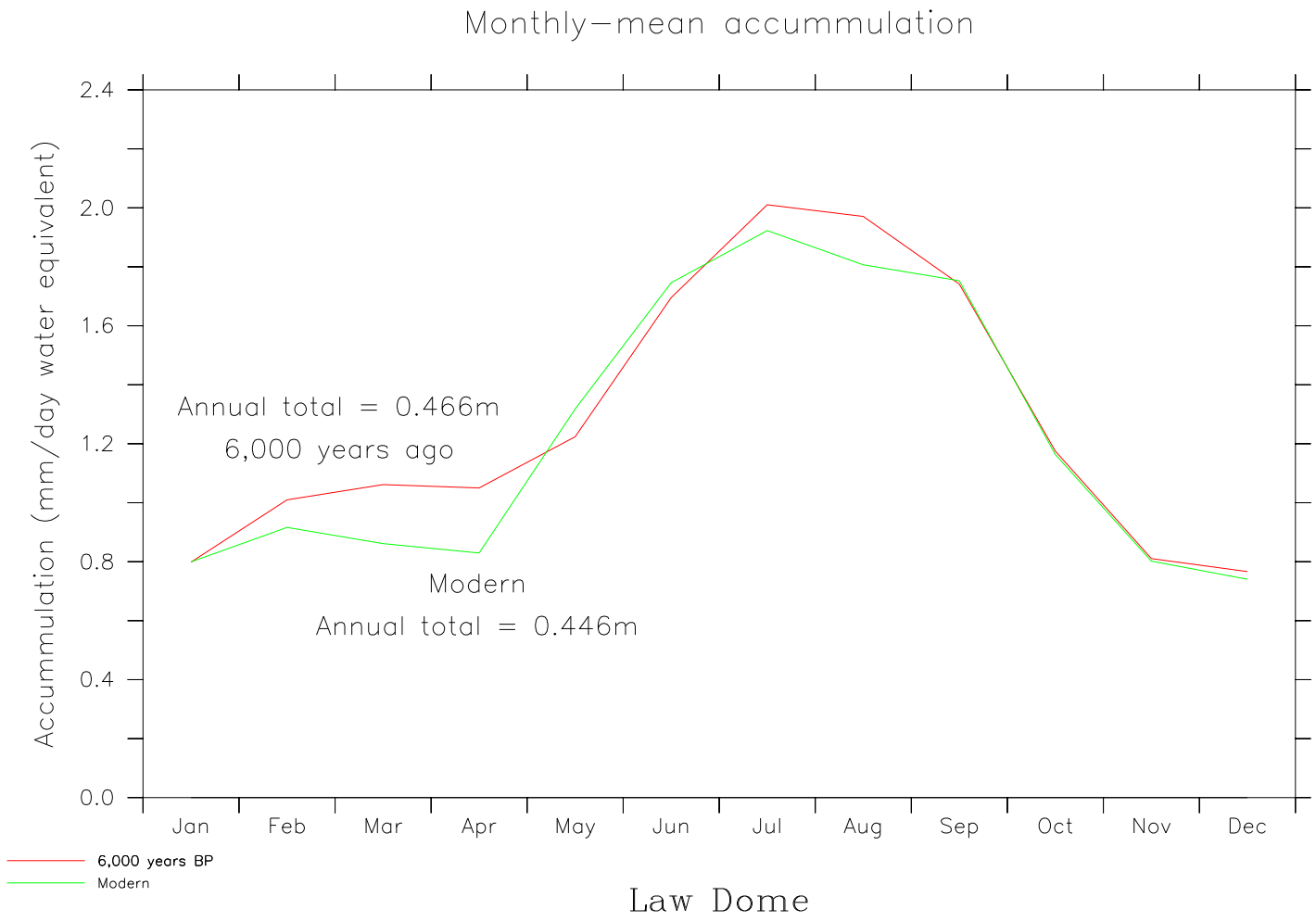

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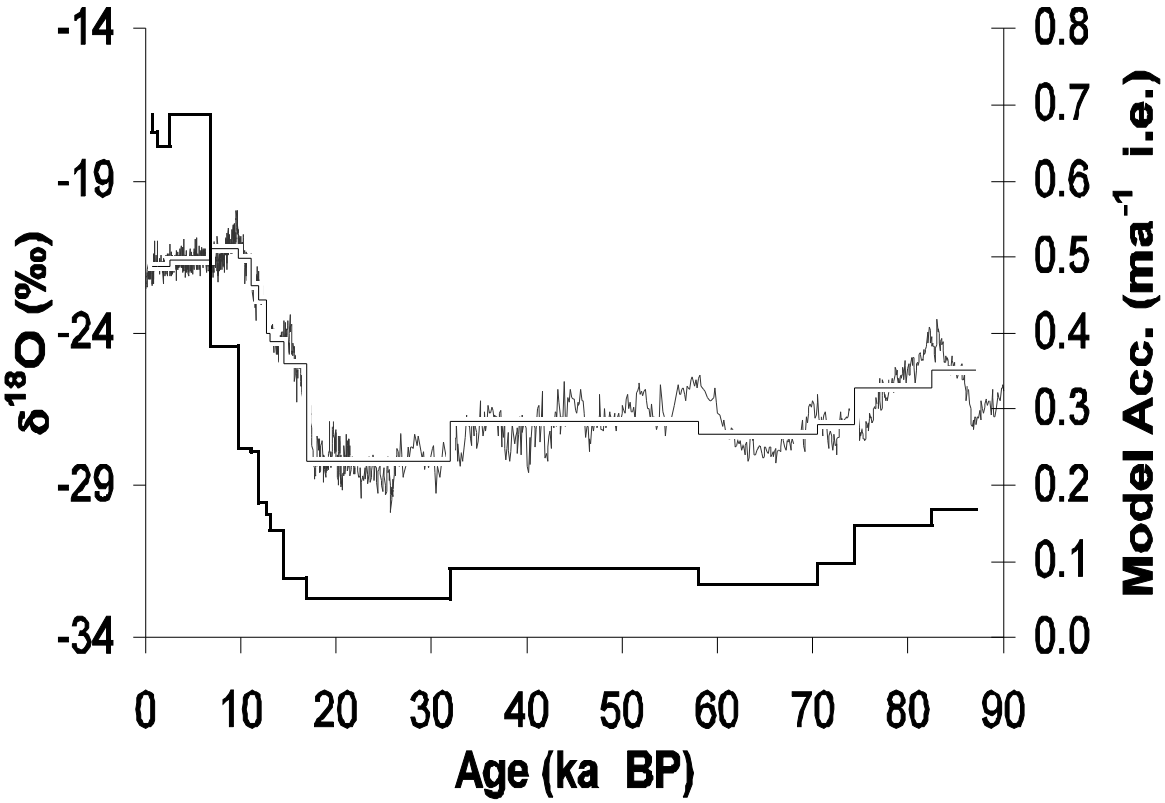

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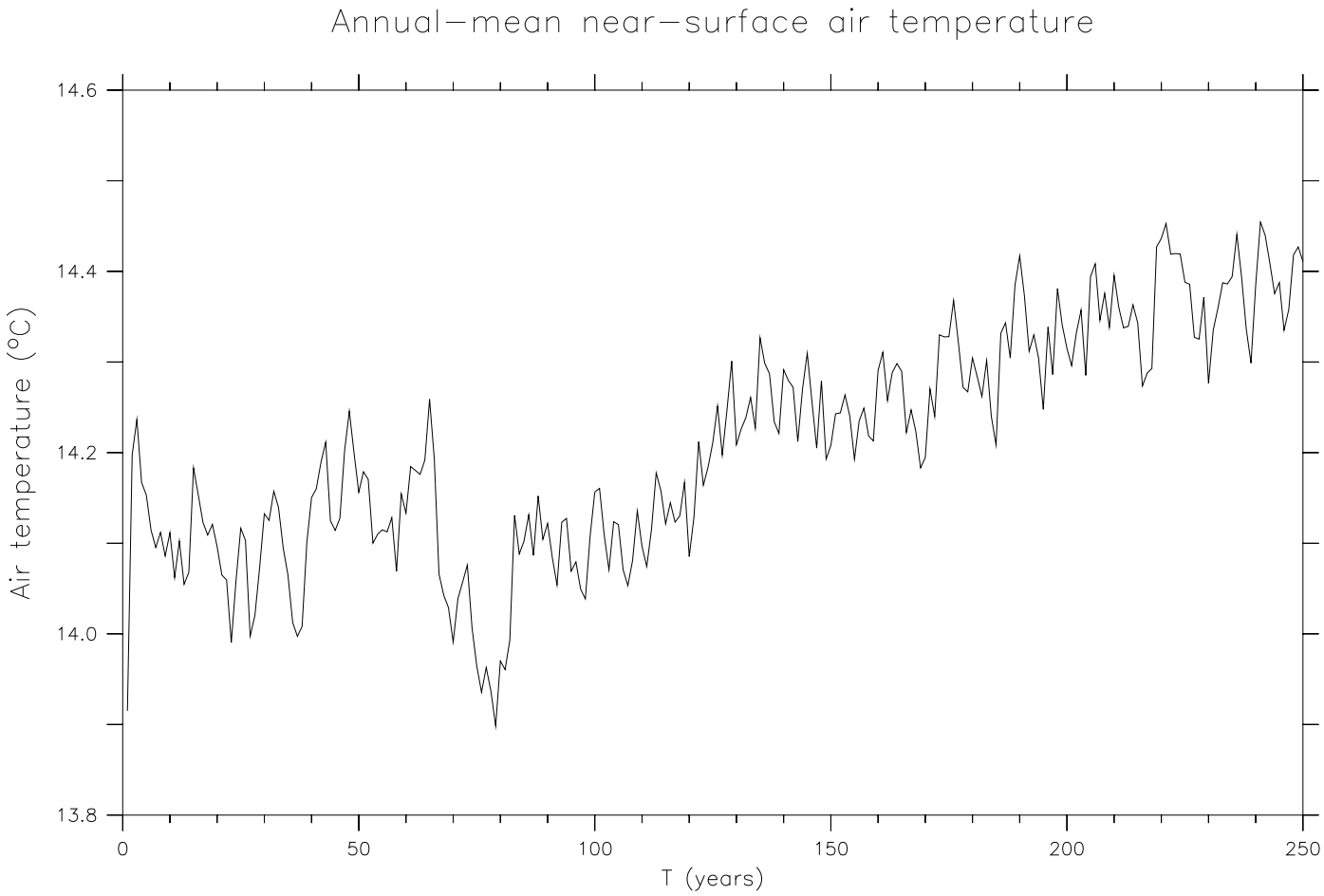
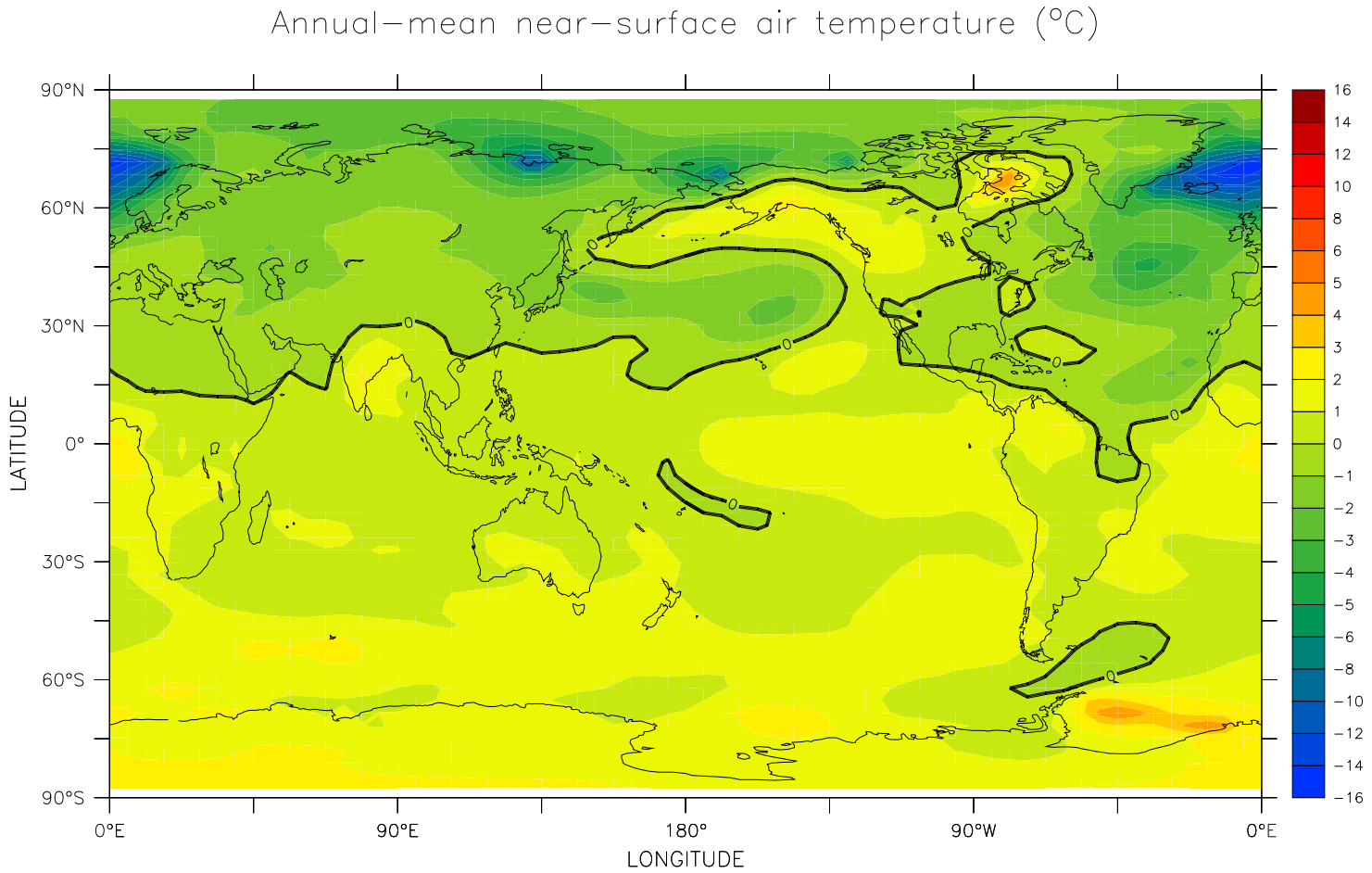


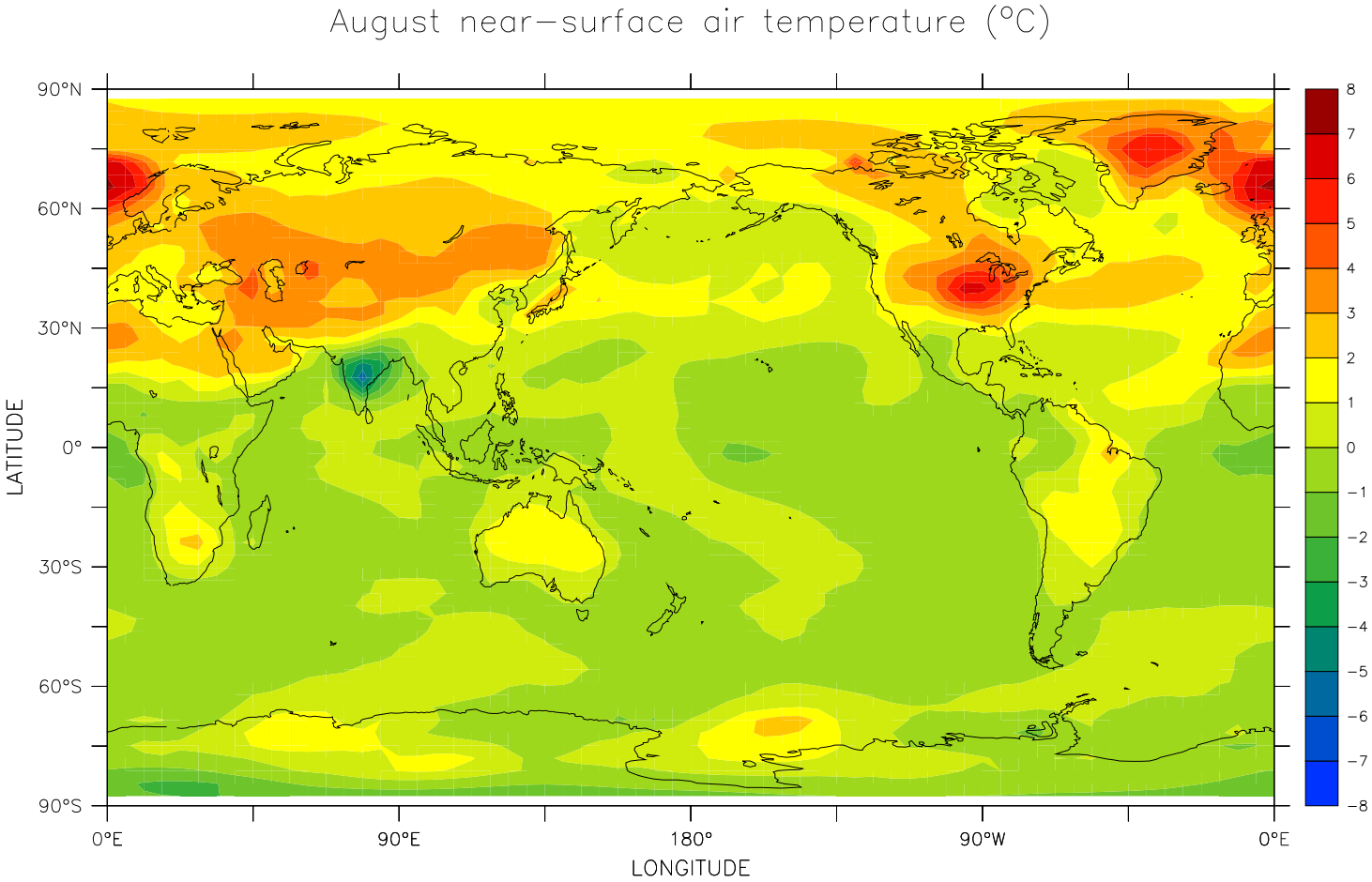
Coupled model: control run with no flux adjustments

Results so far



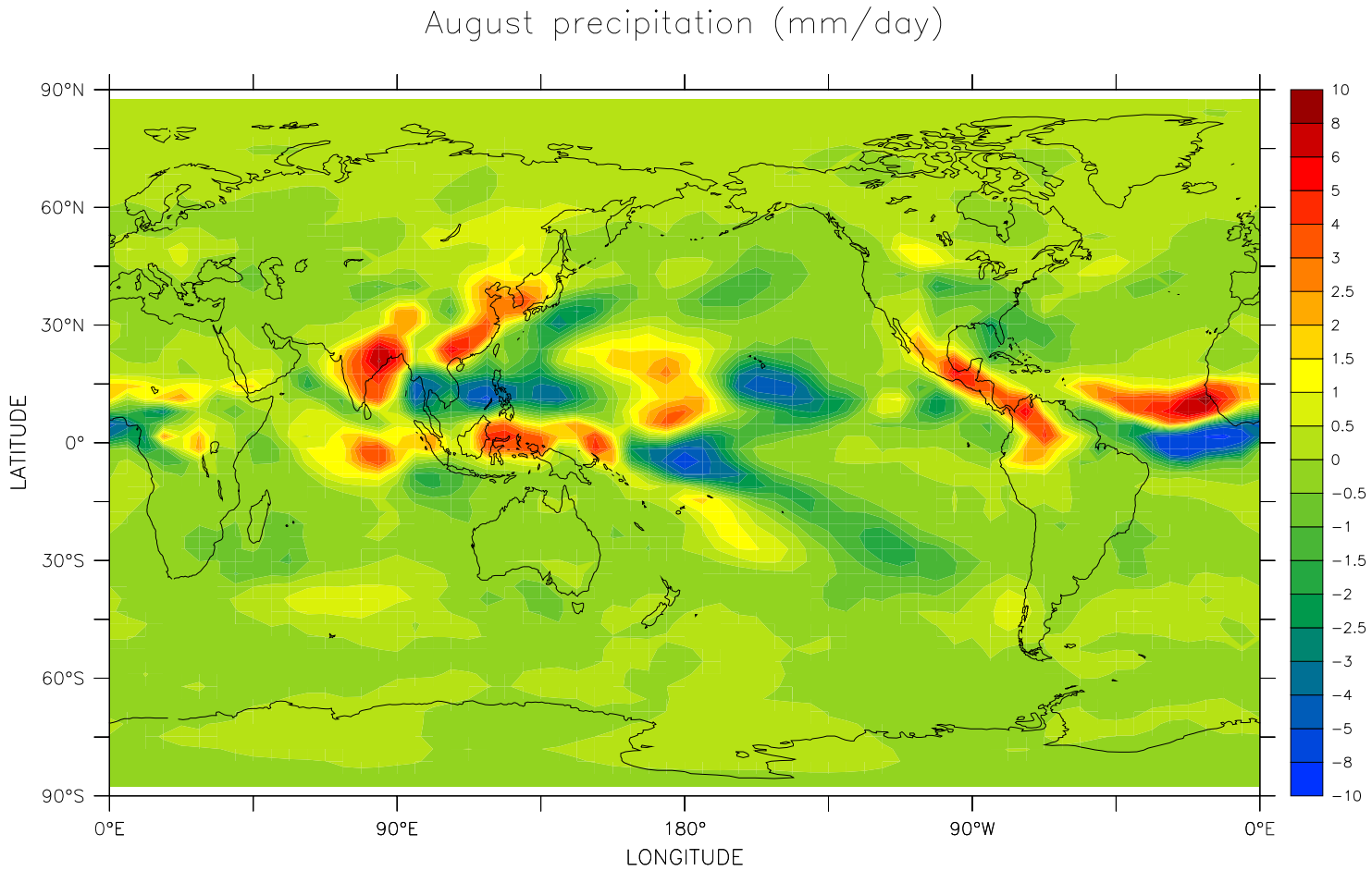
Coupled model: Drift during first 250 years

Results so far



Coupled model: 6,000 years BP minus modern

Results so far



Coupled model: 6,000 years BP minus modern

Conclusions

Results so far are encouraging:

- the model simulates the modern climate well
- initial simulations of past climates are encouraging
- the coupled model appears to be relatively stable, even without the use of flux adjustments

Conclusions

Thanks for coming!