An efficient and portable climate system model for studying past, present and future climate

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Acknowledgements

- Nathan Bindoff, University of Tasmania/CMAR
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- CSIRO Marine and Atmospheric Research
- APAC, iVEC
- ARC Network for Earth Systems Science

Overview

1. The CSIRO Mk3L climate system model
2. Present climate
3. Future climate
4. Past climate
5. Future work

The CSIRO Mk3L climate system model

- Low-resolution version of the CSIRO climate system model

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  - projections of future climate
  - detection/attribution

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- Is it an EMIC?

Atmosphere model

- Based on the CSIRO Mk3 atmosphere model
- Spectral general circulation model
- Reduced horizontal resolution of R21 ($\Delta\lambda \approx 5.6°, \Delta\phi \approx 3.2°$)
- 18 vertical levels
- Orbital parameter code
- Dynamic-thermodynamic sea ice model
- Land surface model (static vegetation)

Ocean model

- Based on the CSIRO Mk2 ocean model
- z-coordinate general circulation model
- Same horizontal grid as atmosphere model
- 21 vertical levels
- Gent-McWilliams eddy diffusion

Coupled model

- Surface fields exchanged every one hour (3 atmosphere model timesteps for each ocean model timestep)
- Coupling rigorously conserves heat and freshwater
- Flux adjustments applied

Model source code

- Designed for maximum portability across computer architectures
- Should compile on any UNIX/Linux platform
- Shared-memory parallelism achieved using OpenMP
- Dependence on external libraries restricted to netCDF and FFTW
- Loop structure optimised for serial architectures

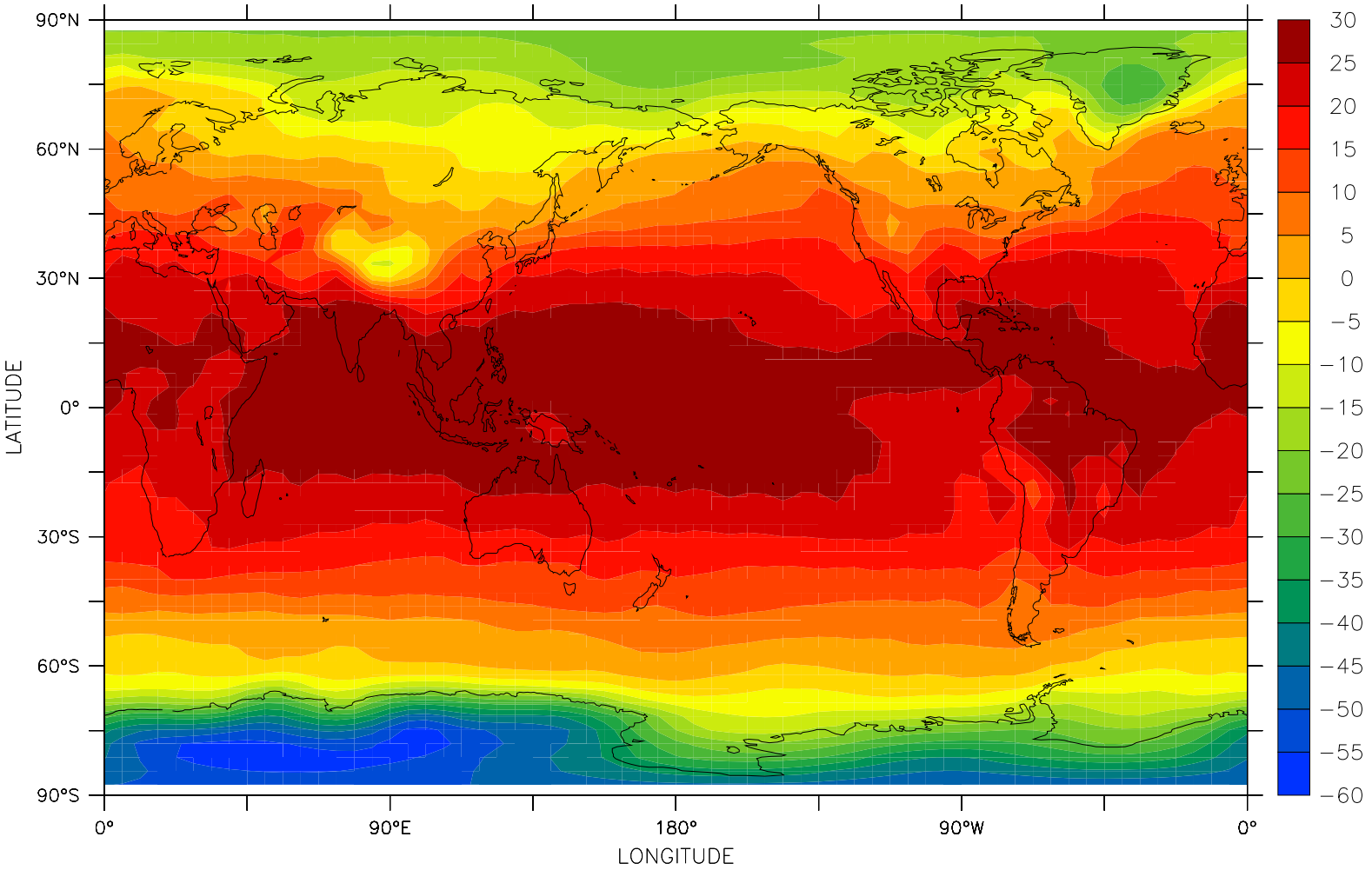
Benchmarks on APAC Facilities

Facility	**Processor type**	**Number of processors**	**Speed (years/day)**
AlphaServer SC	1GHz EV68	1	4.0
		2	7.2
		4	11.7
Linux Cluster	2.66GHz Pentium 4	1	4.6

Present climate

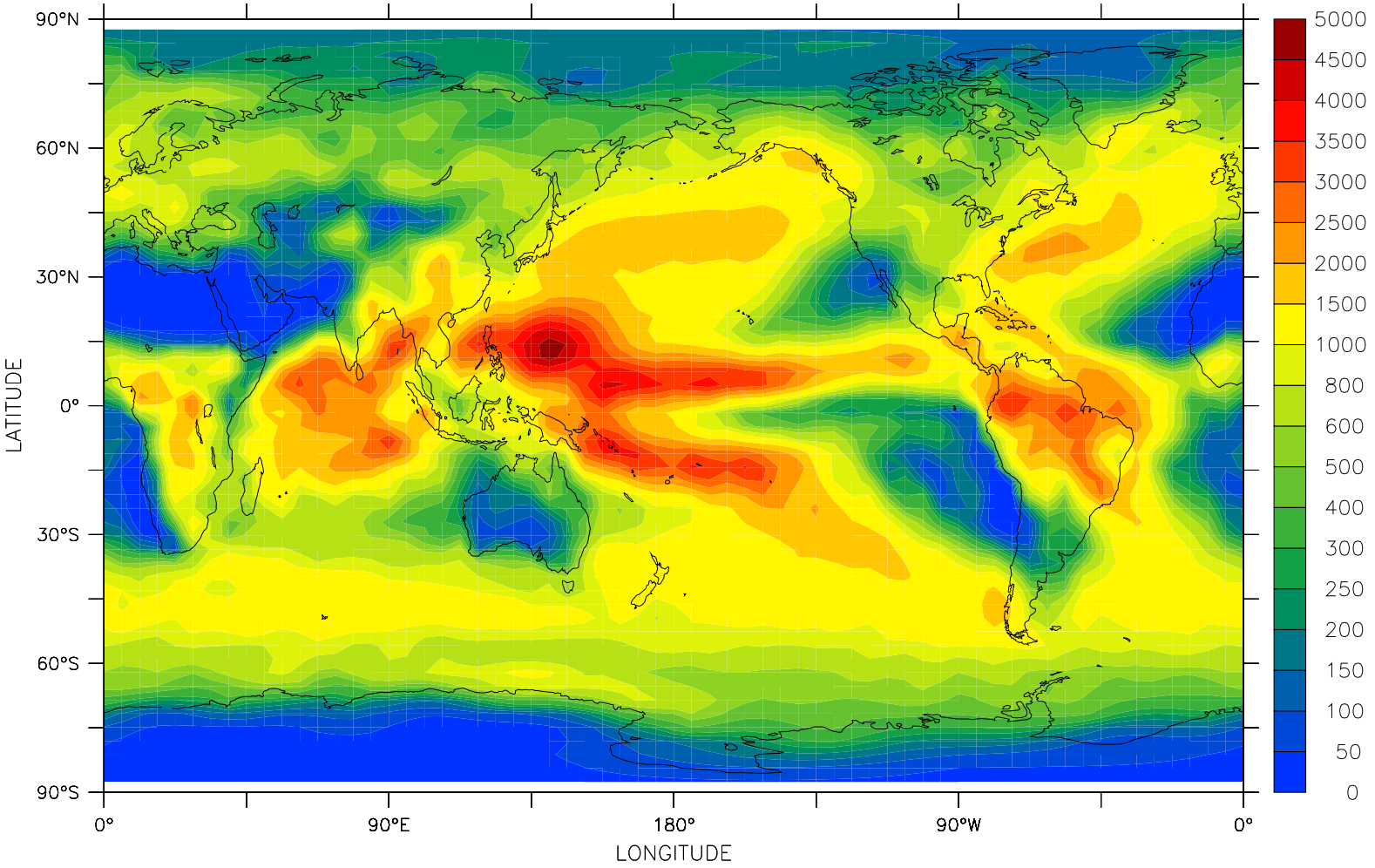
- Control run conducted for pre-industrial conditions
- Follows PMIP2 experimental design
- CO_2 concentration: 280ppm
- Solar constant: 1365 Wm^{-2}
- "Modern" orbital parameters (AD 1950)
- Ocean model initialised using Levitus 1998
- Atmosphere and ocean models spun up independently
- Coupled model initialised from final states of spin-up runs
- Integrated for 2000+ years

2. Present climate



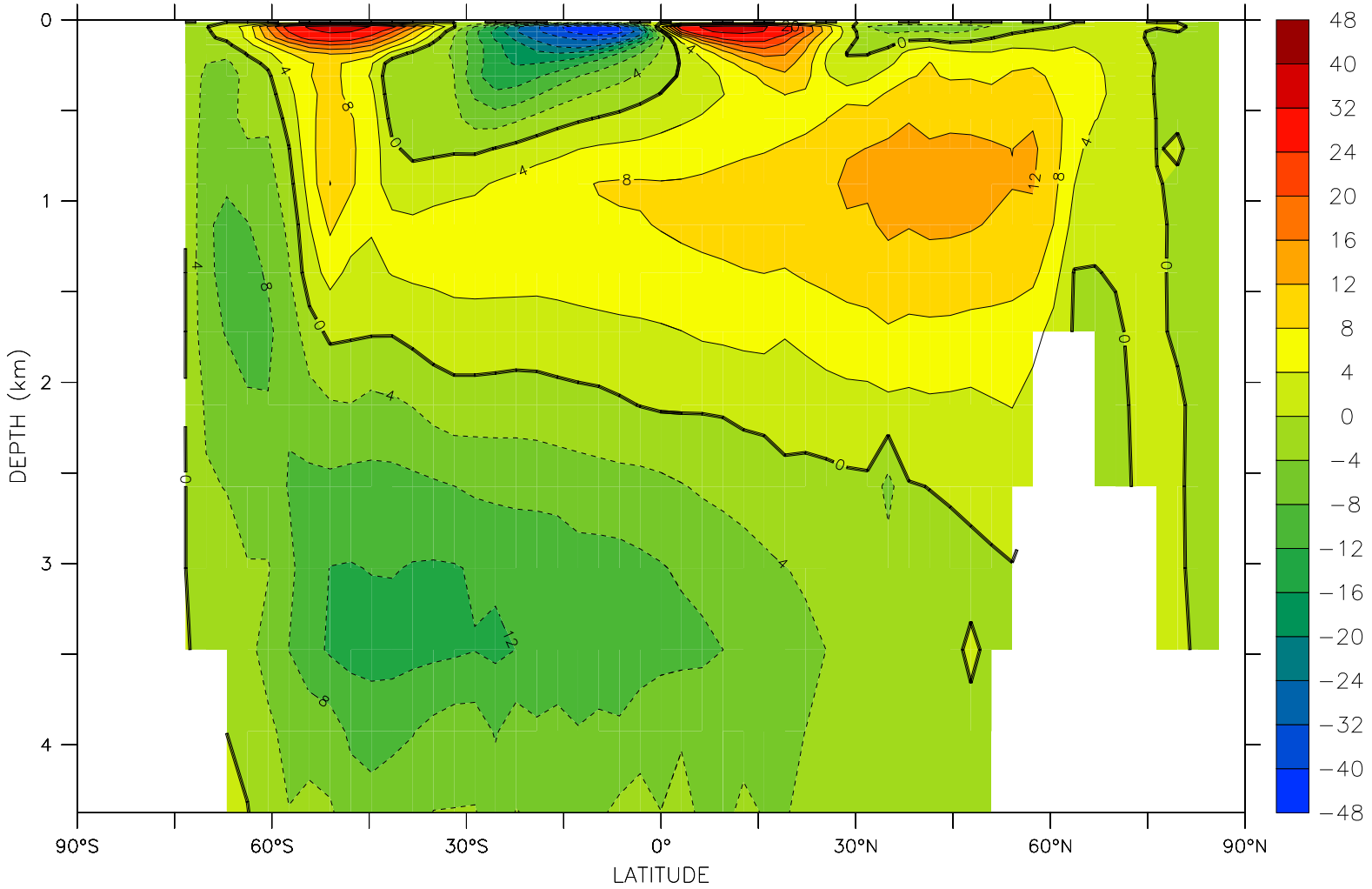
Annual−mean surface air temperature (°C)

2. Present climate



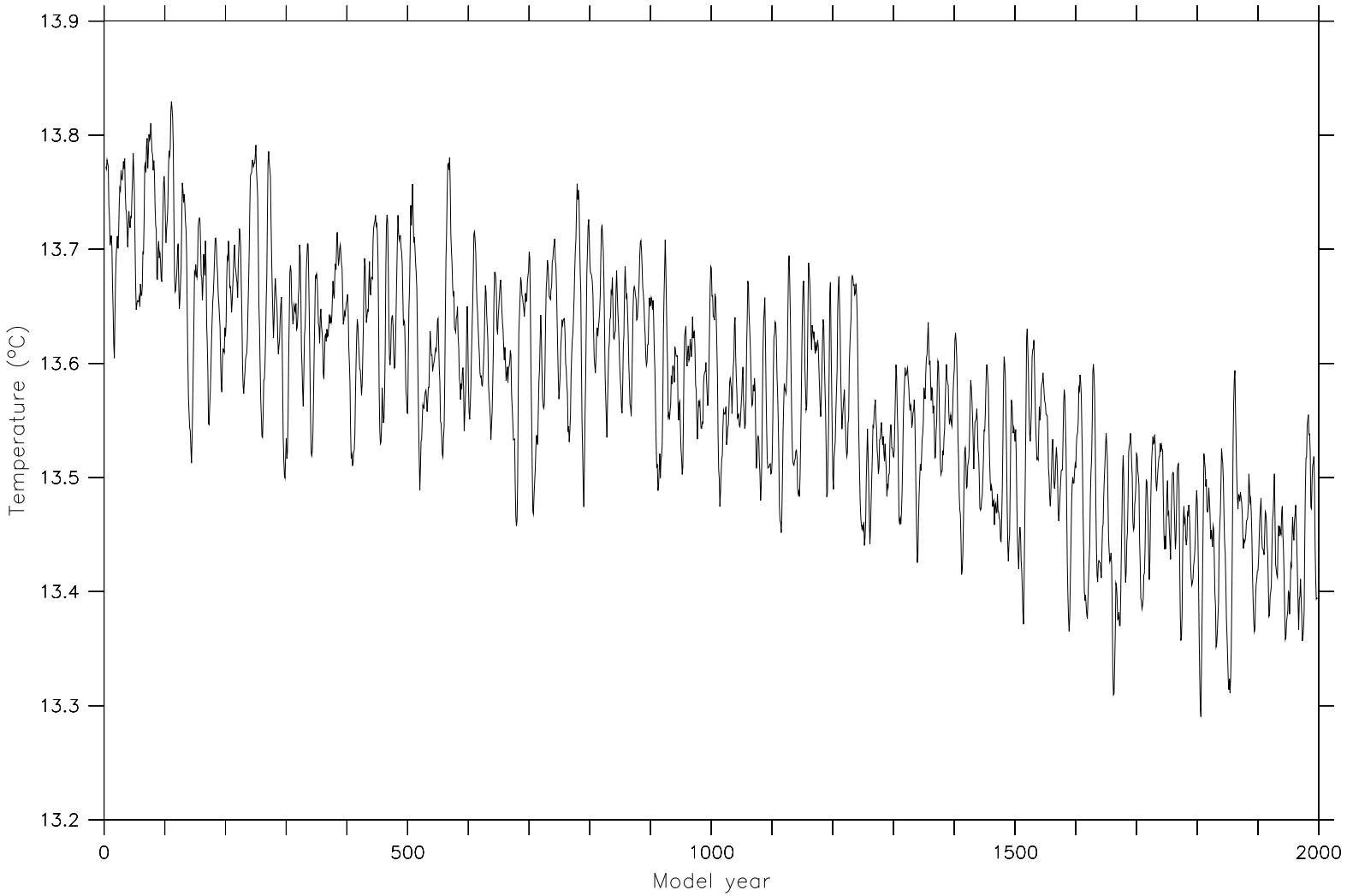
Annual precipitation (mm)

2. Present climate



Global meridional overturning streamfunction (Sv)

2. Present climate



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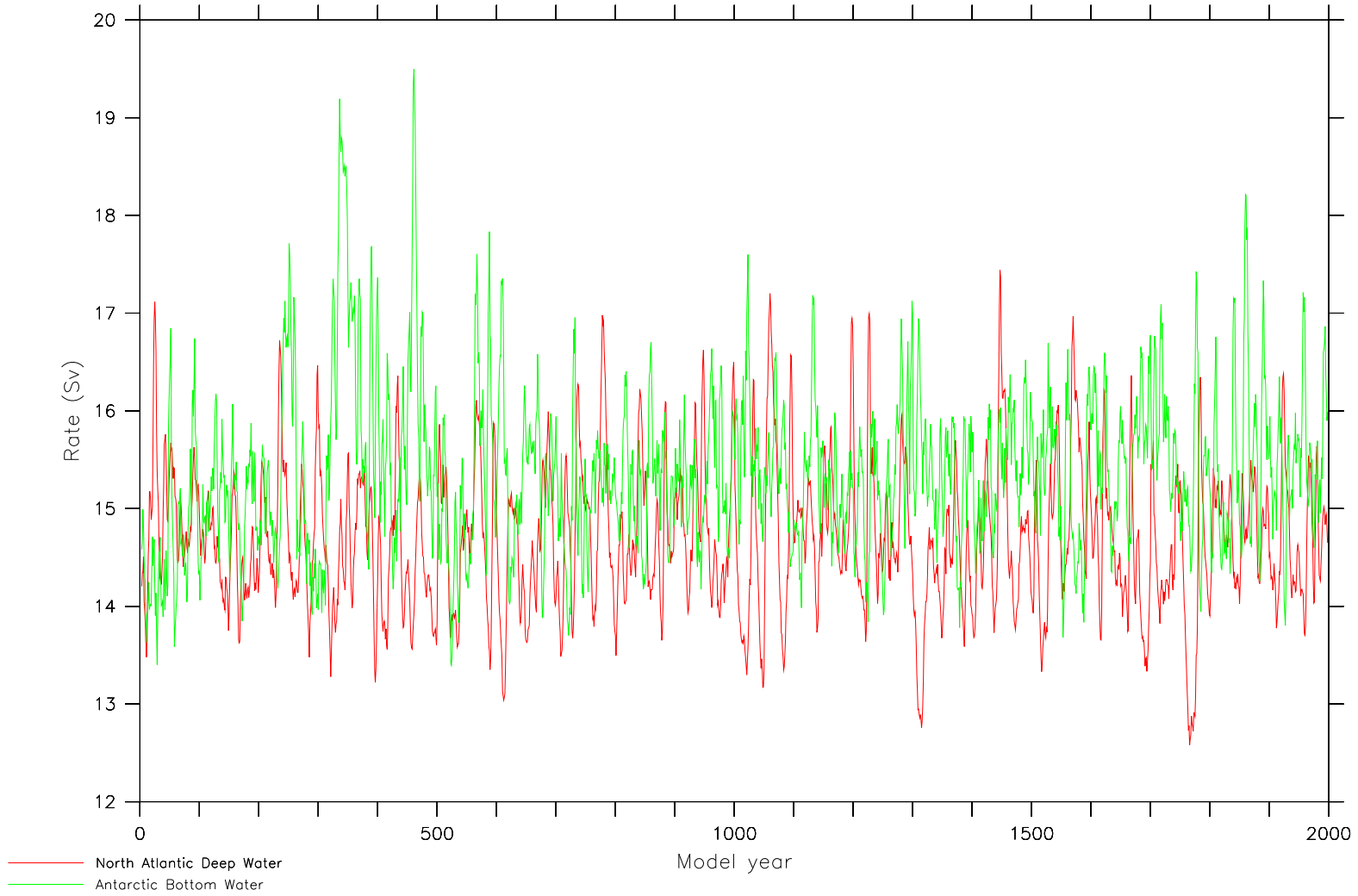
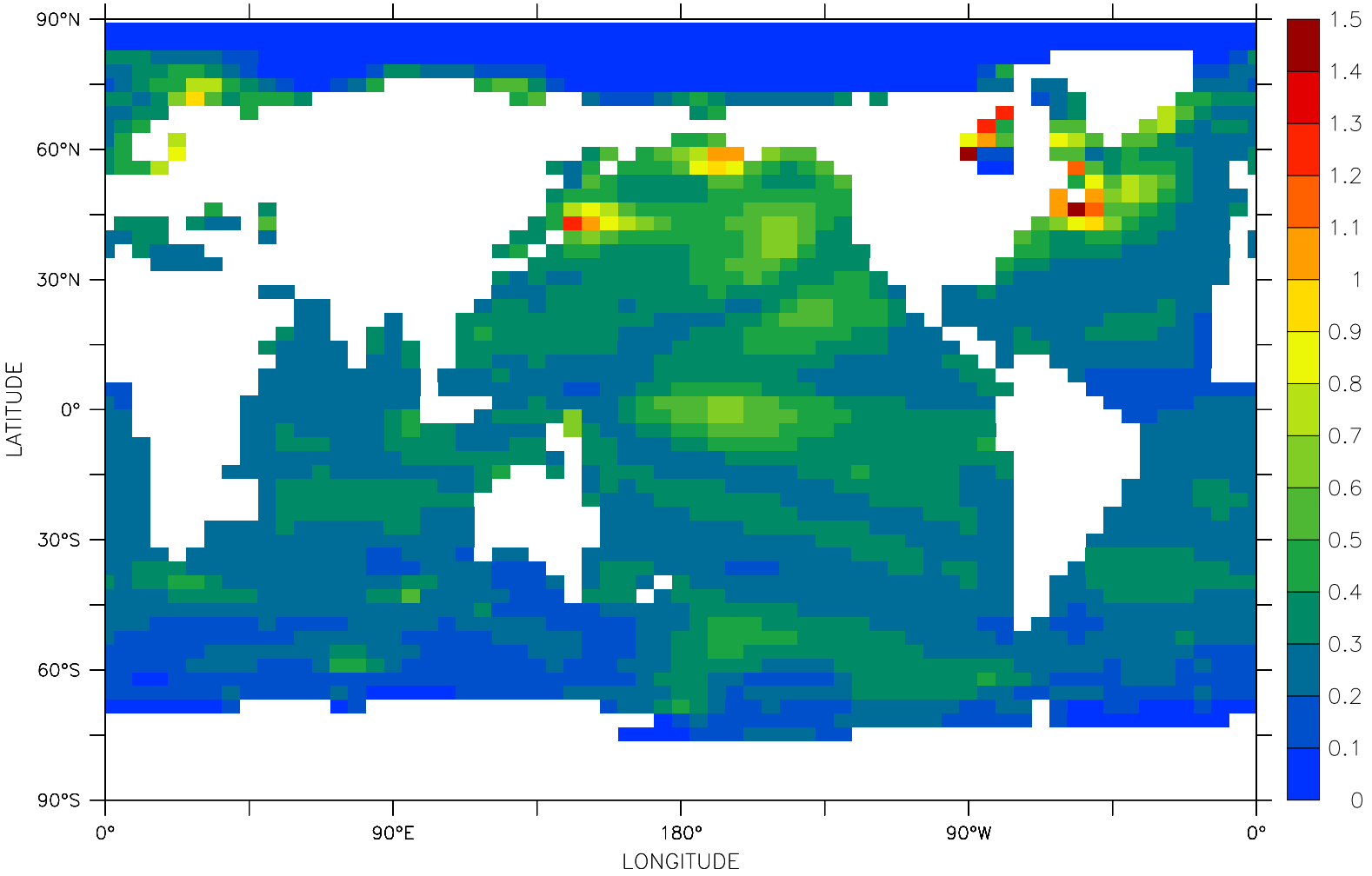


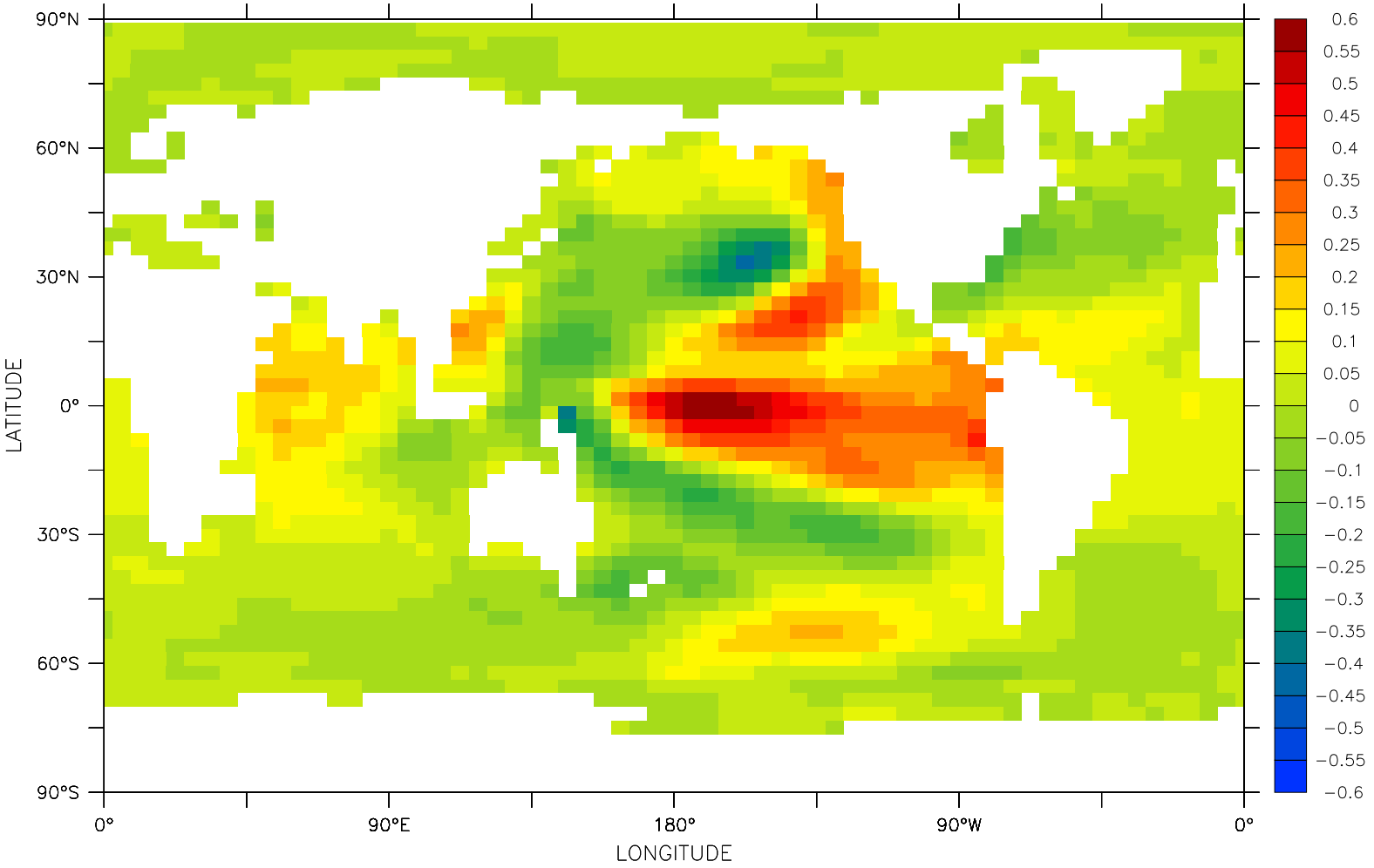
Deep water formation

2. Present climate



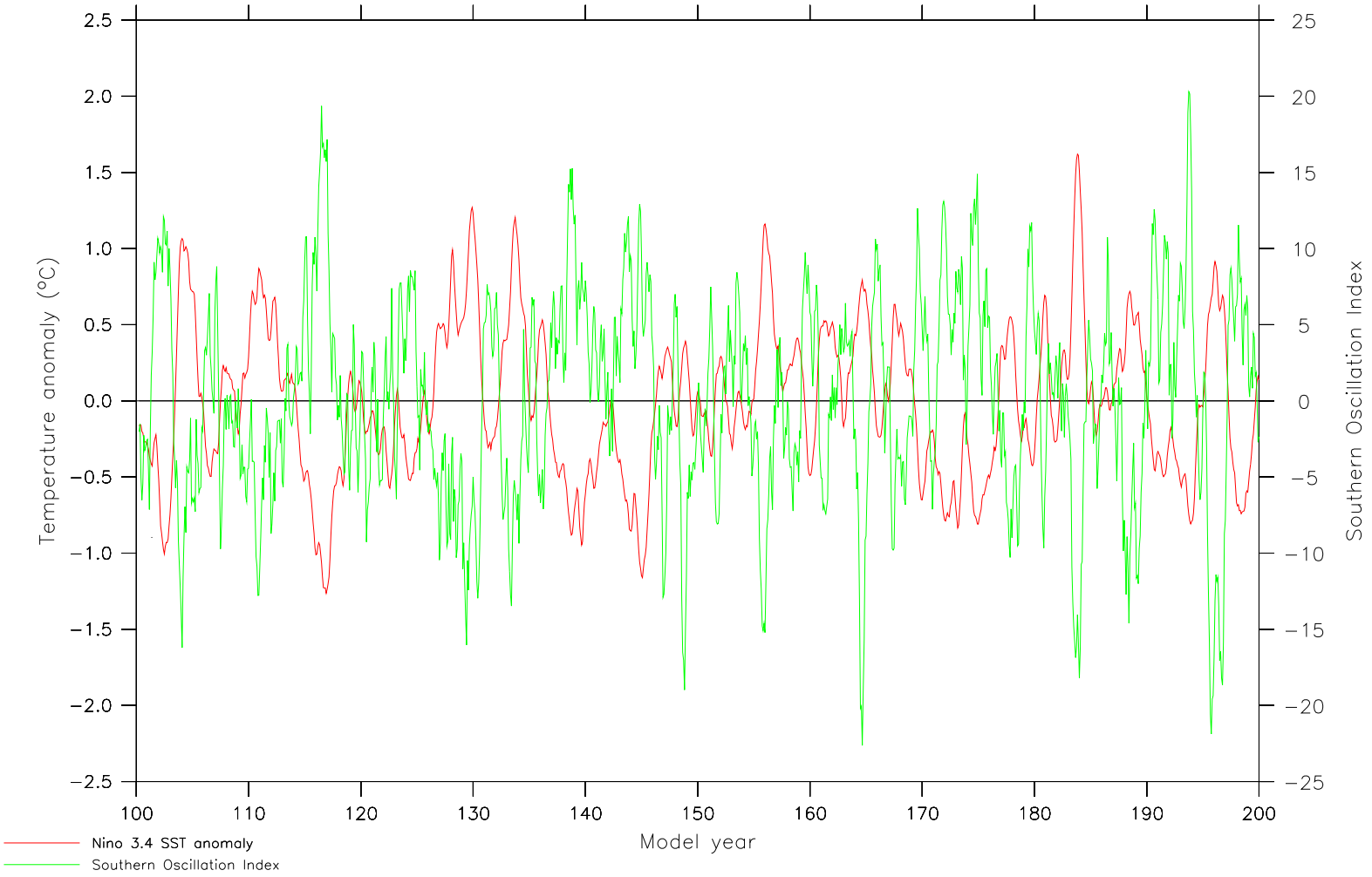
Standard deviation in sea surface temperature (°C)

2. Present climate



EOF1 of sea surface temperature (°C) – 22.3%

2. Present climate



Nino 3.4 SST anomaly and the Southern Oscillation Index

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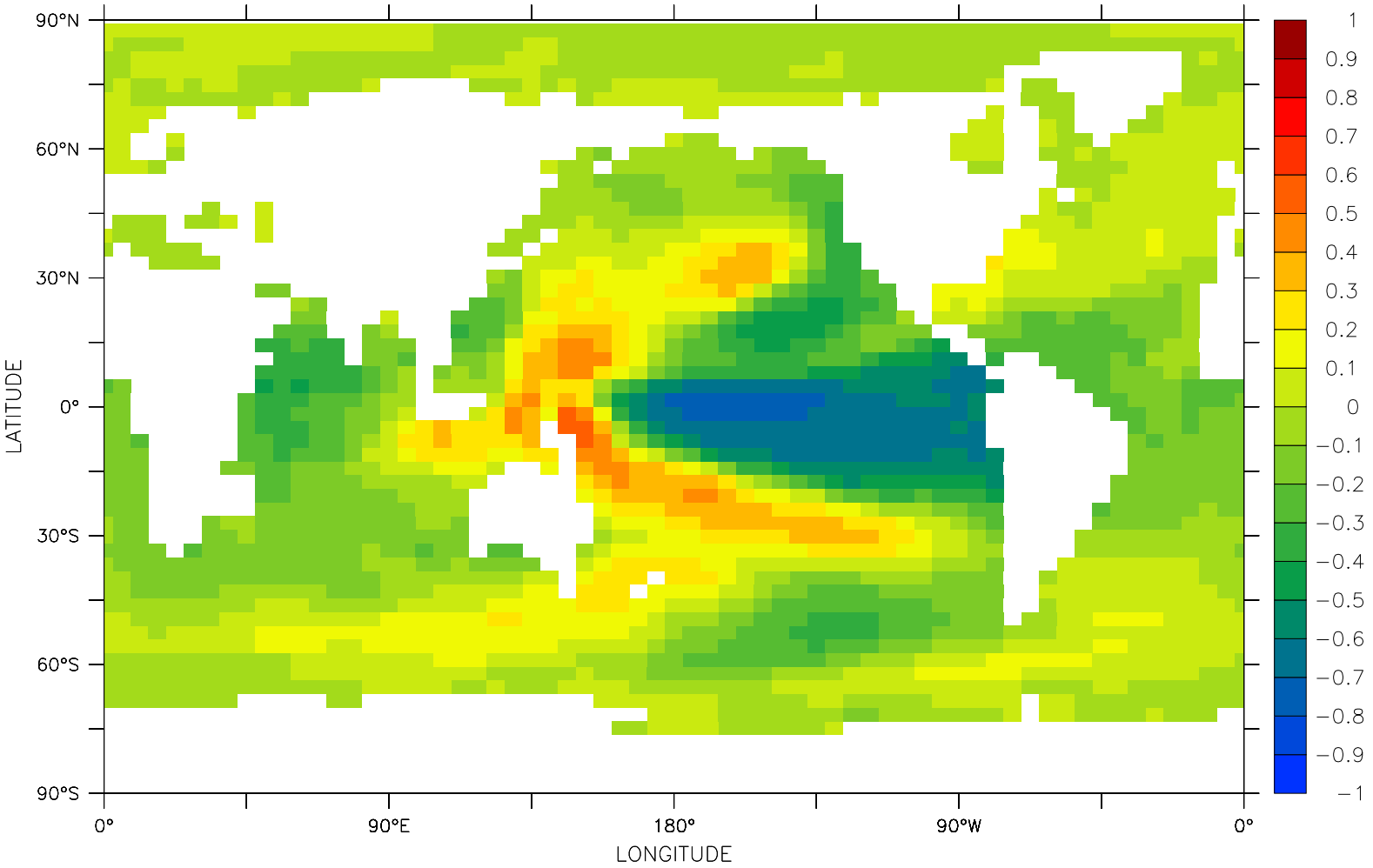


Correlation between SST and the Southern Oscillation Index

El Niño statistics

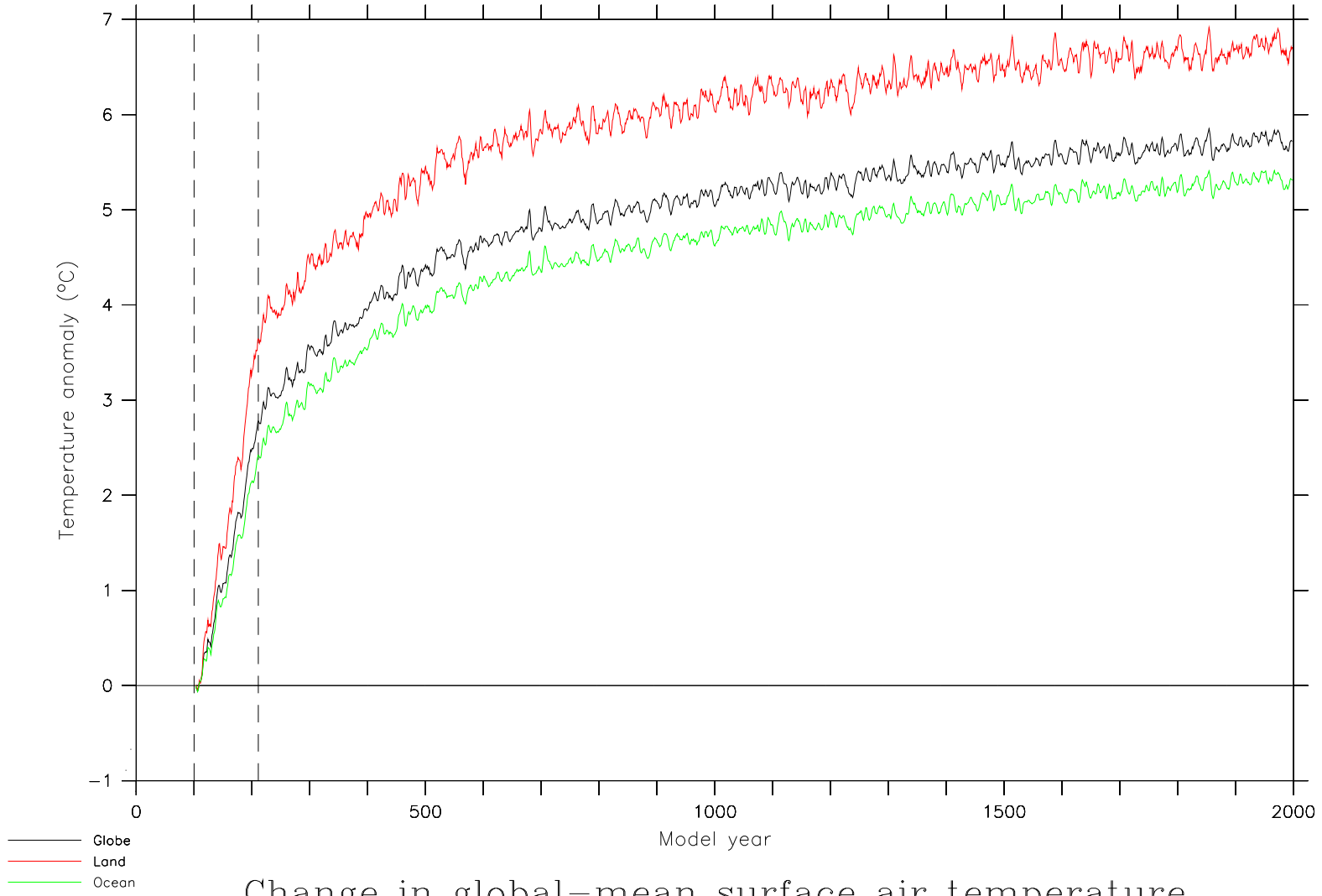
	Mk3L	**Observed**
Standard deviation of Niño 3.4 SST anomaly (°C)	0.48	0.71
Average period (years)	7.8 ± 0.5	∼3–6
Average duration (months)	17.2 ± 0.6	∼12
Average magnitude (°C)	0.86 ± 0.02	∼1.3

Observed values from Trenberth (1997)

Future climate

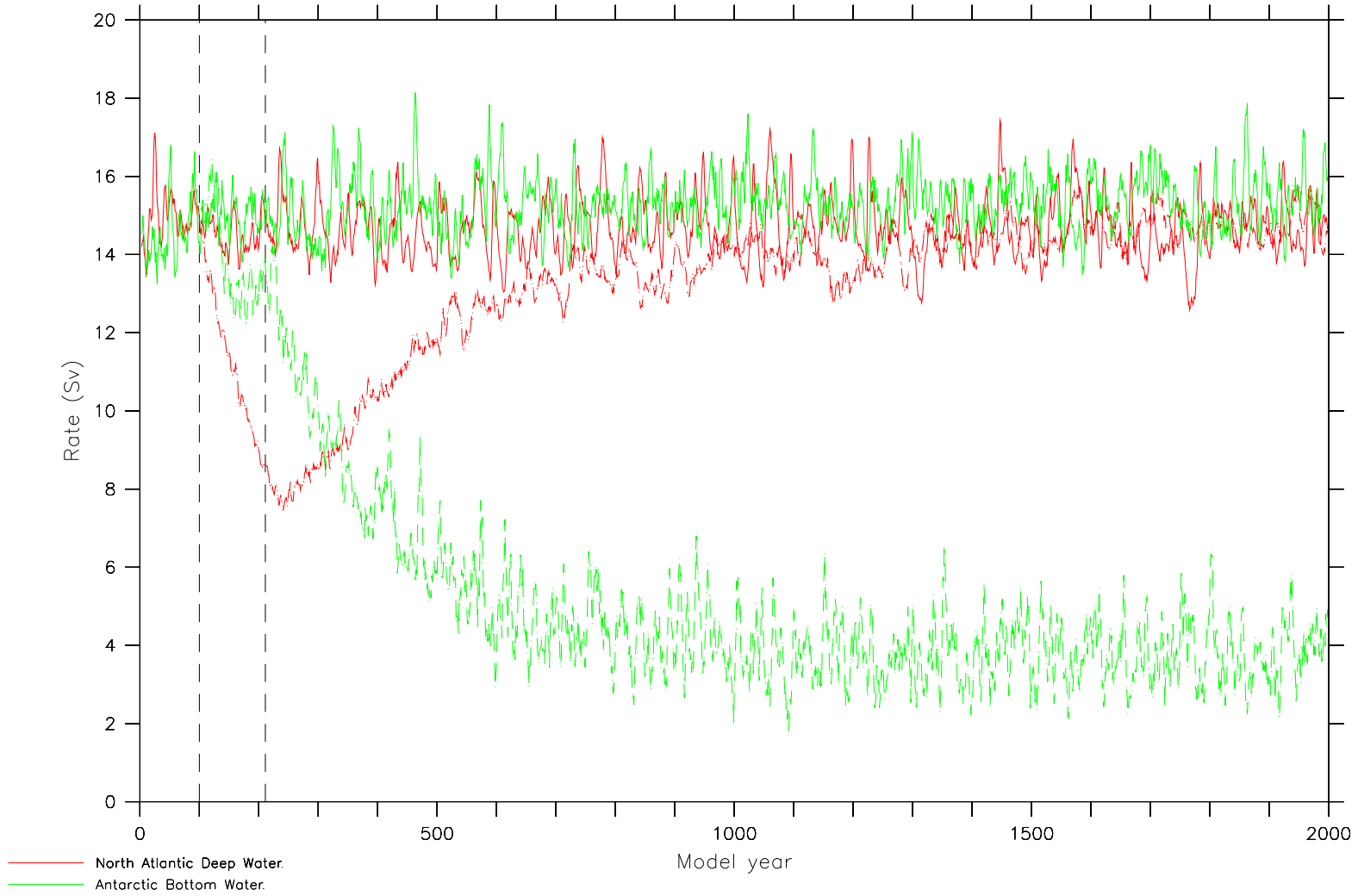
- 3xCO_2 stabilisation scenario
- Initialised from year 100 of control run
- Atmospheric CO_2 concentration increased at 1% p.a.
- Reaches 840ppm in year 211, and held constant thereafter
- Integrated for 2000+ years

3. Future climate



Change in global–mean surface air temperature

3. Future climate



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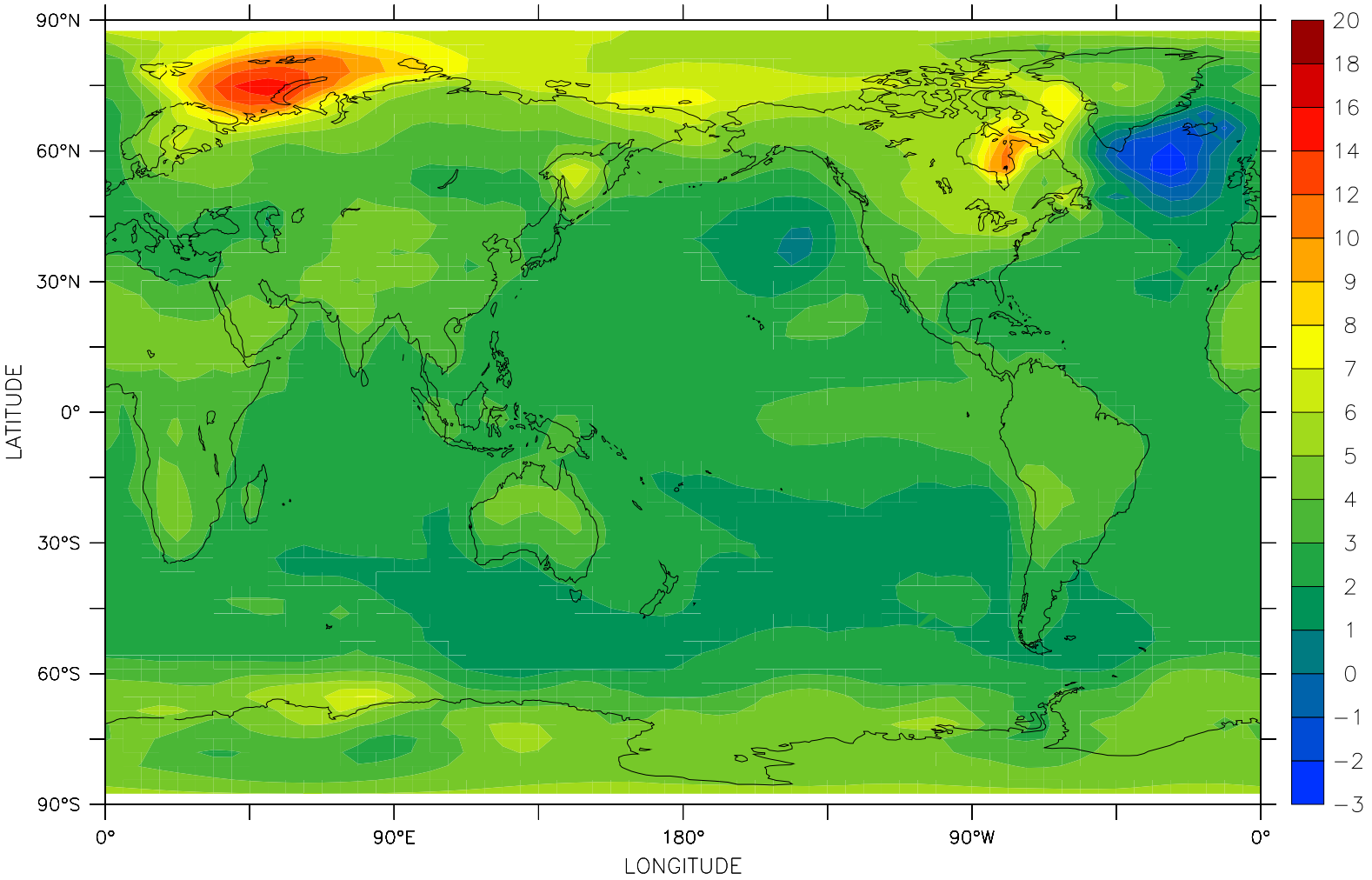

Change in annual−mean SAT (°C) − years 211−260

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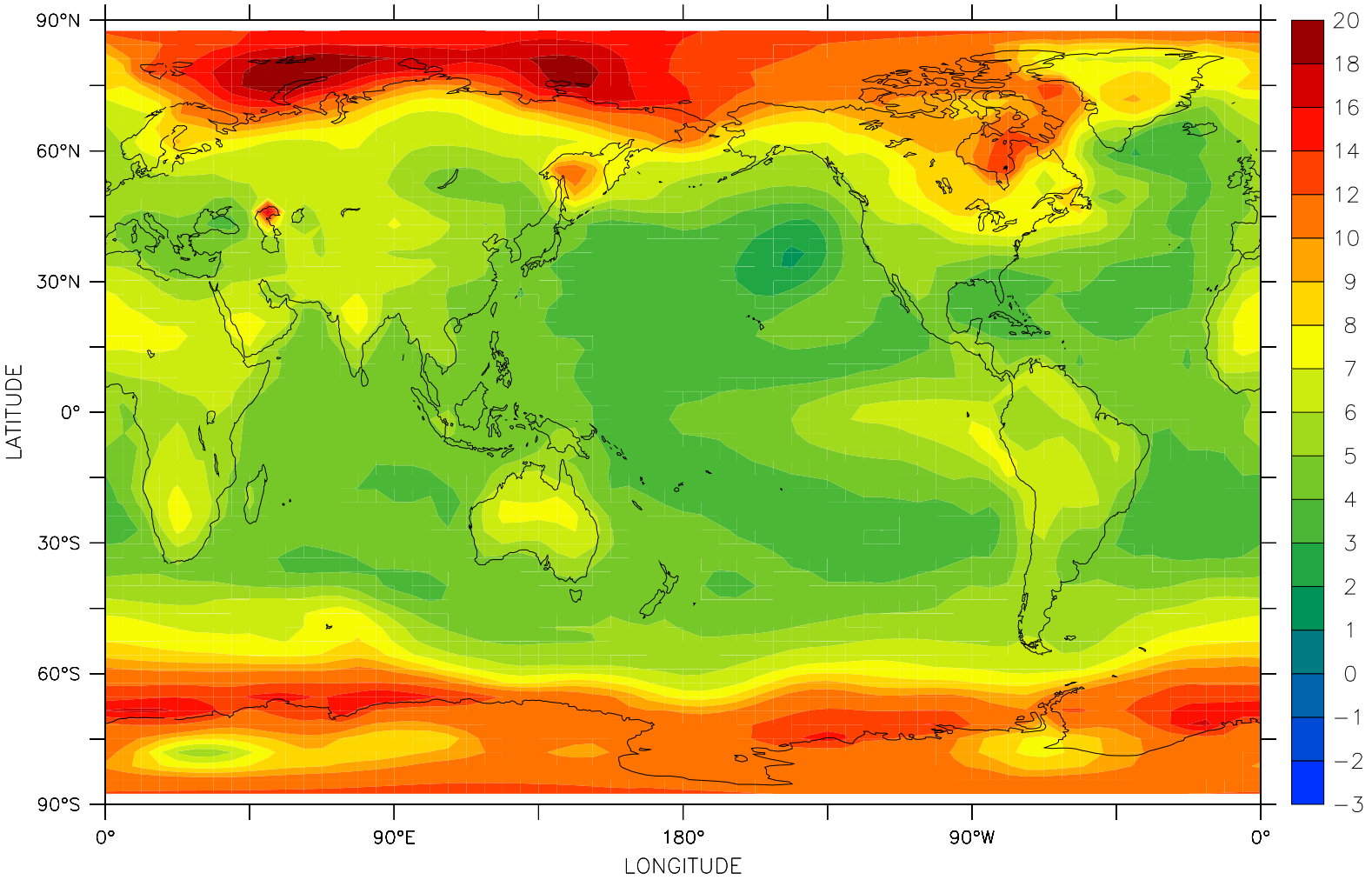

Change in annual−mean SAT (°C) − years 1951−2000

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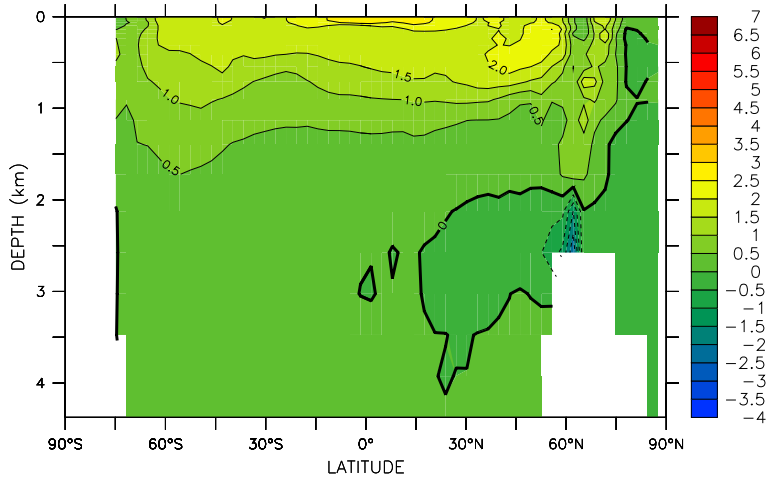
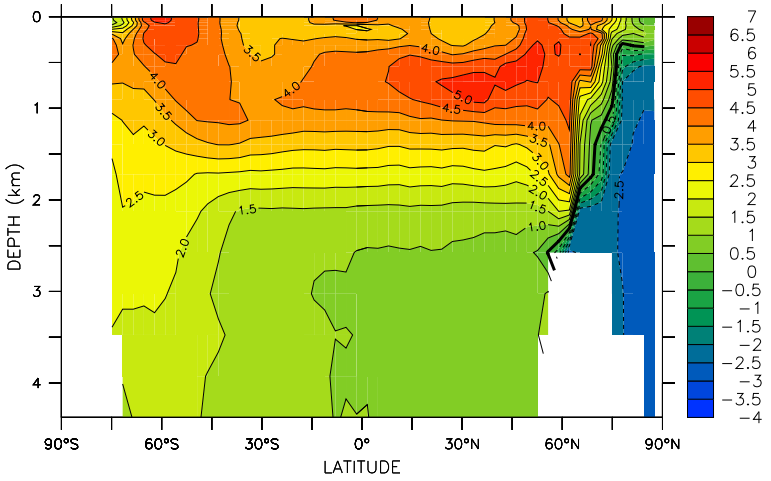
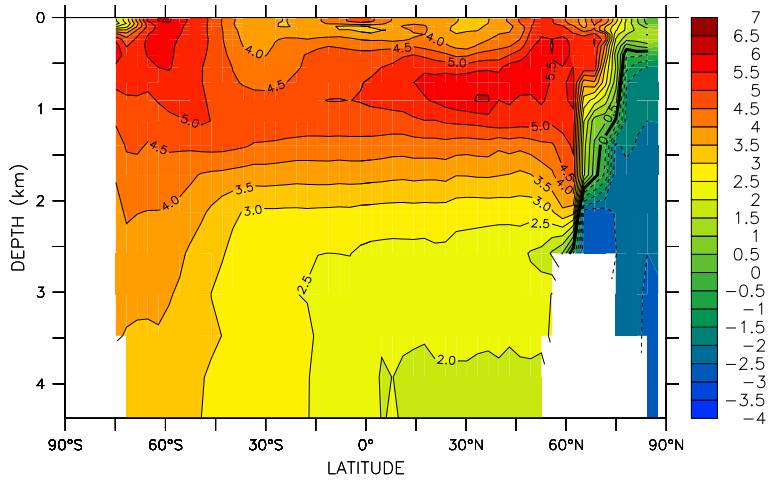


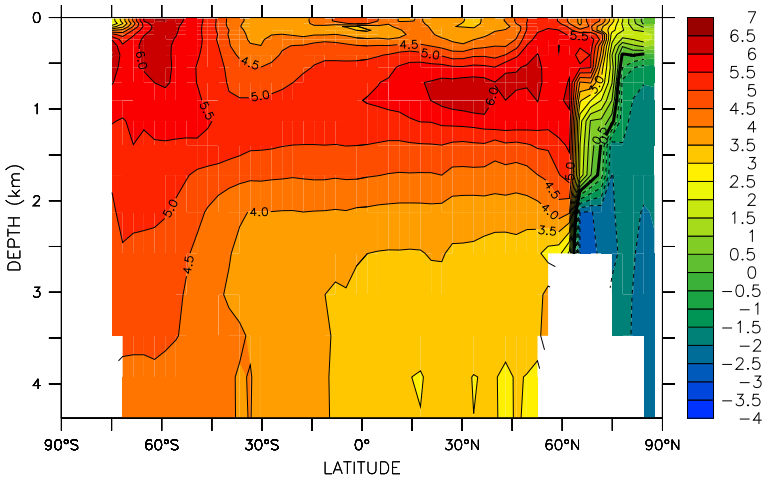
(a) Years 211–260



(b) Years 811–860

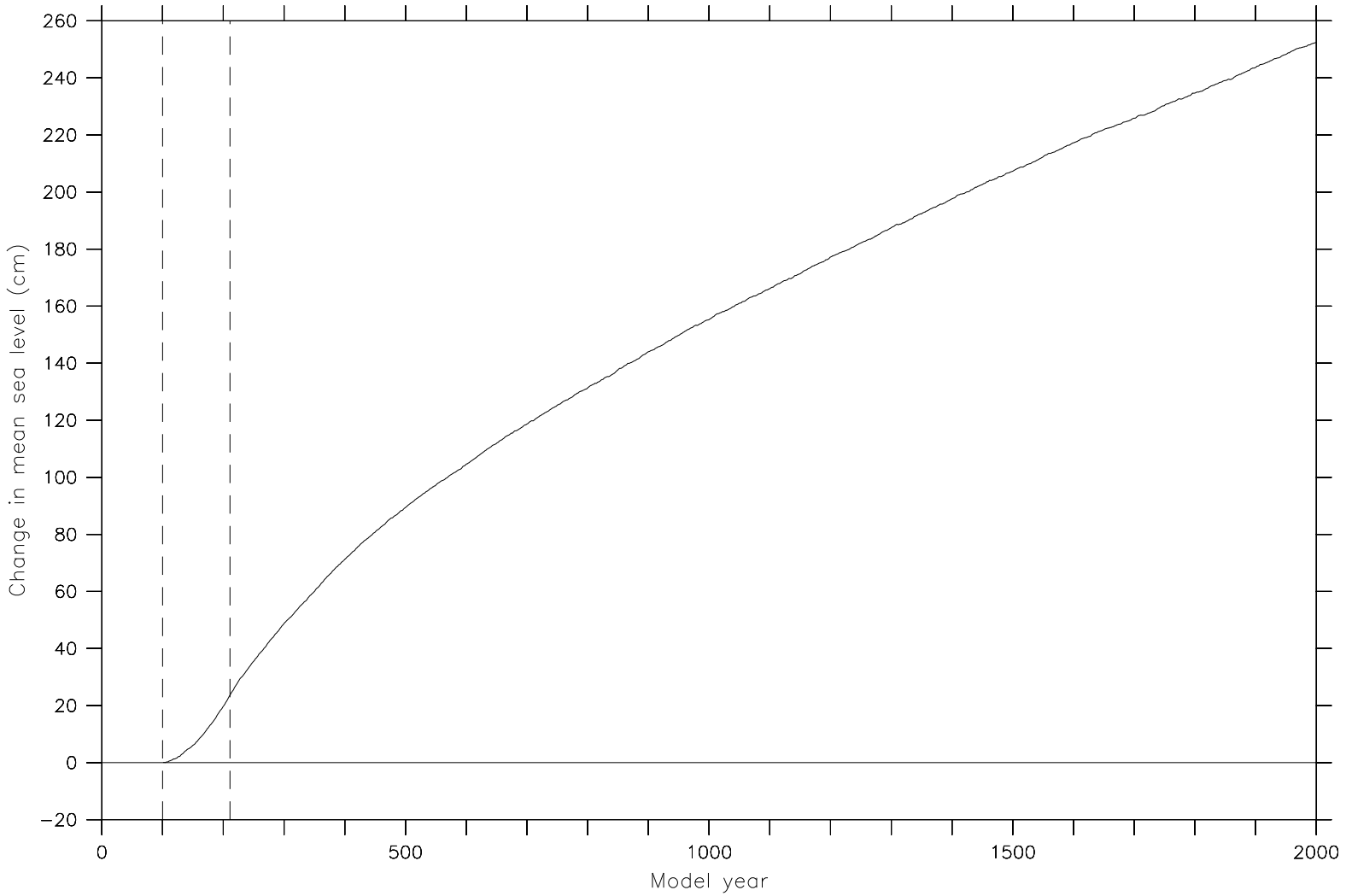


(c) Years 1411–1460



(d) Years 1951–2000

3. Future climate

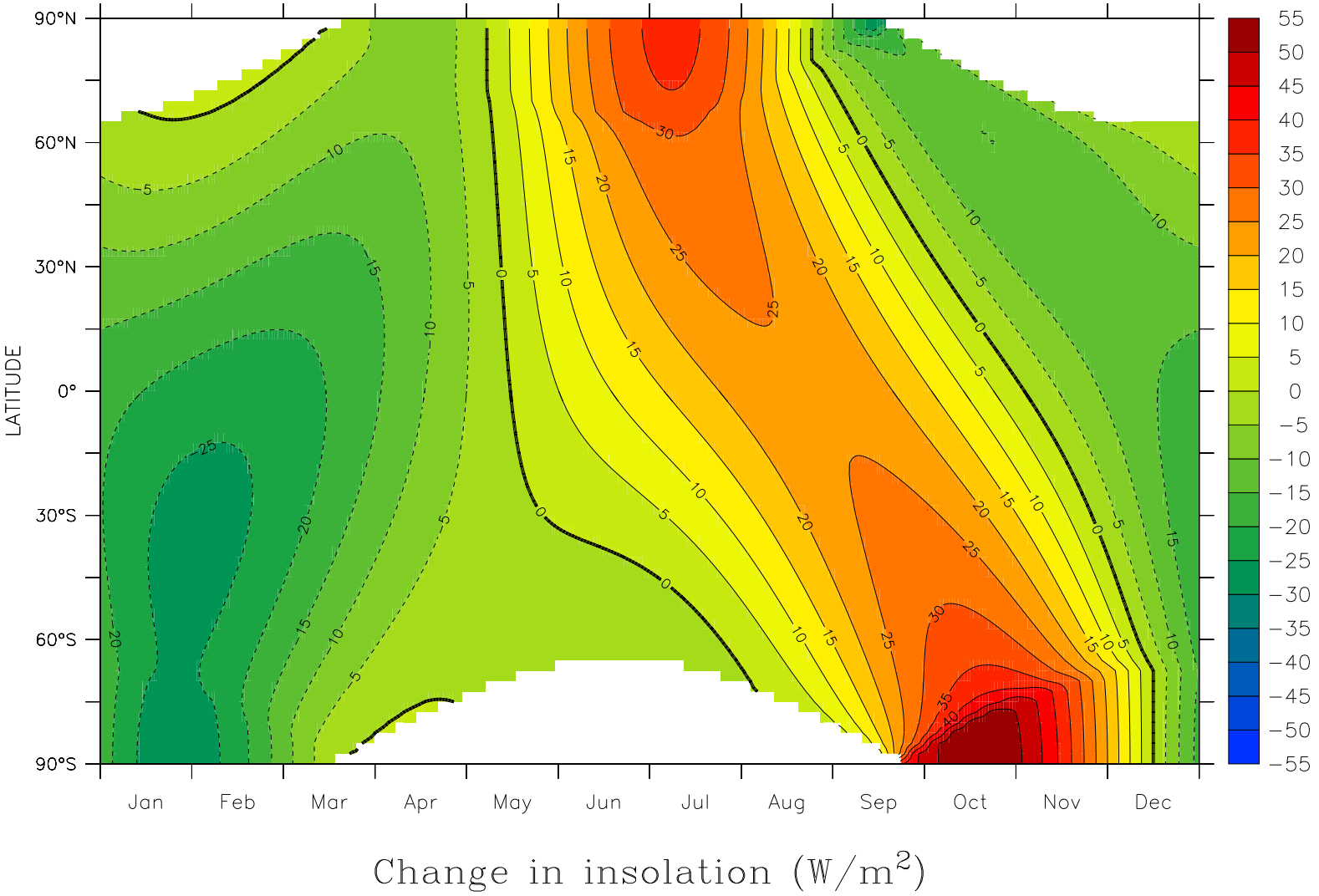


Change in mean sea level

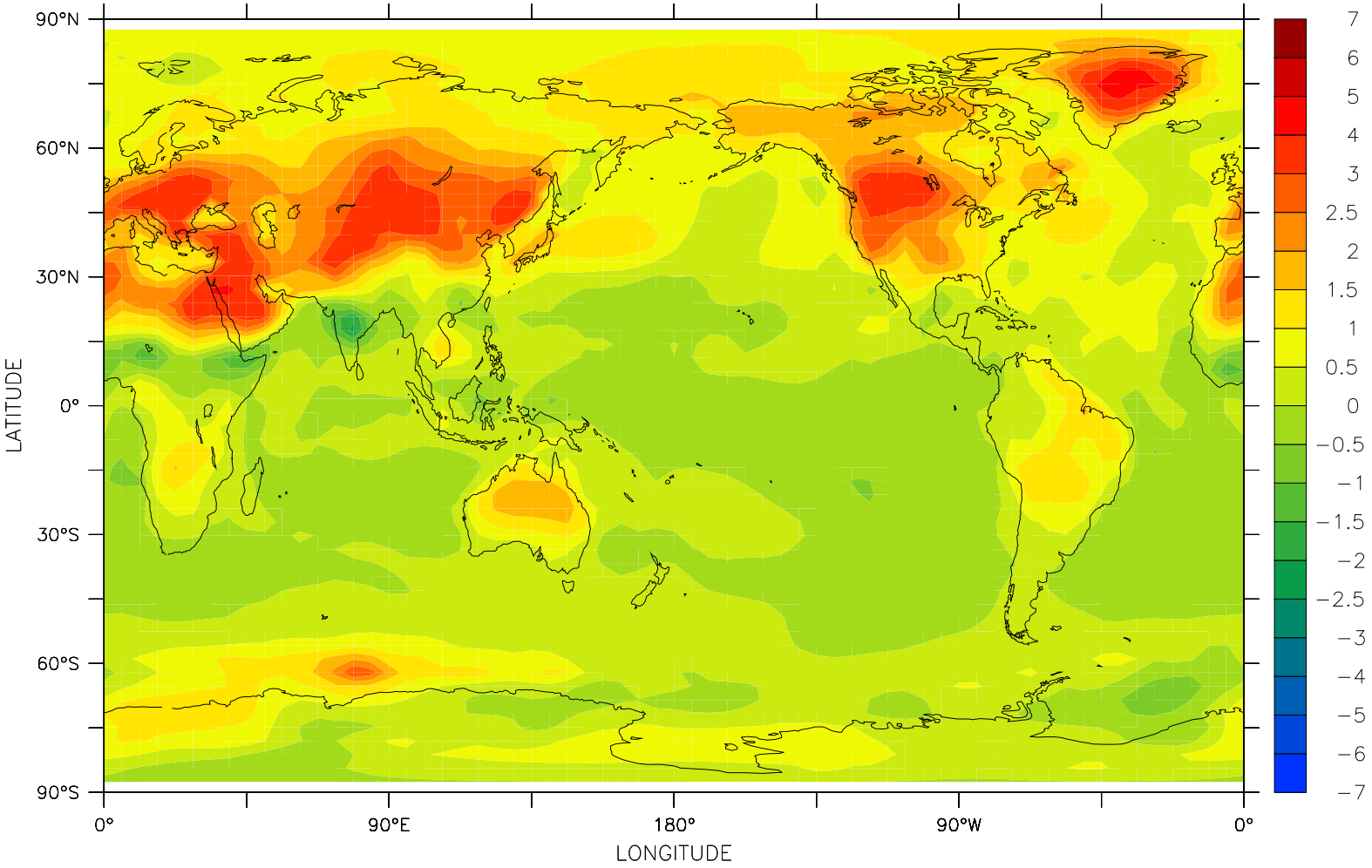
Past climate

- Equilibrium simulation conducted for the mid-Holocene (6ka BP)
- PMIP2 experiment
- Initialised from year 100 of control run
- Orbital parameters for 6ka BP
- Atmospheric CO_2 concentration reduced from 280ppm to 277ppm
  - equivalent to a reduction in the CH_4 concentration from 760ppb to 650ppb
- Integrated for 1200+ years

4. Past climate

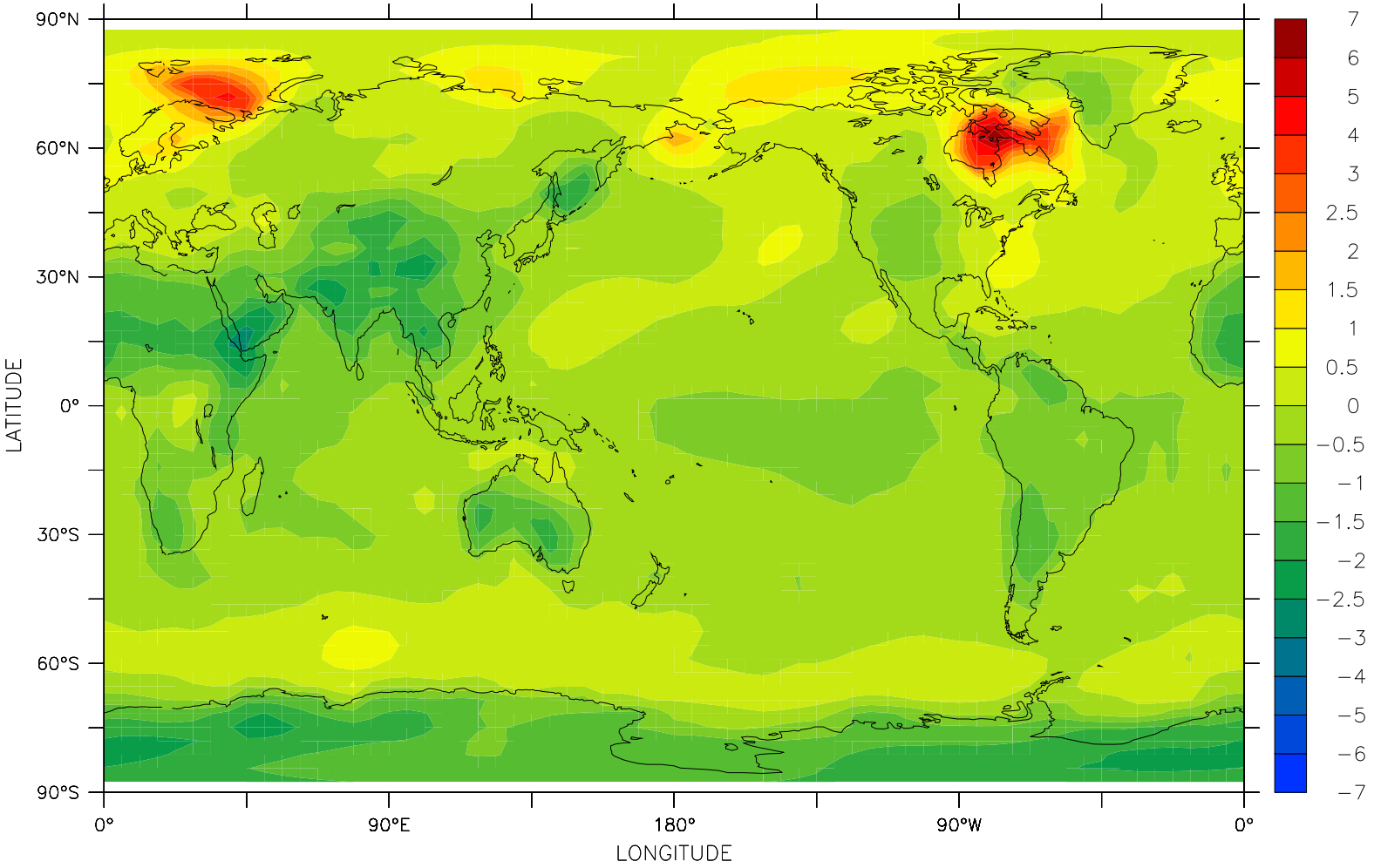


4. Past climate



Difference in August surface air temperature (°C)

4. Past climate



Difference in February surface air temperature (°C)

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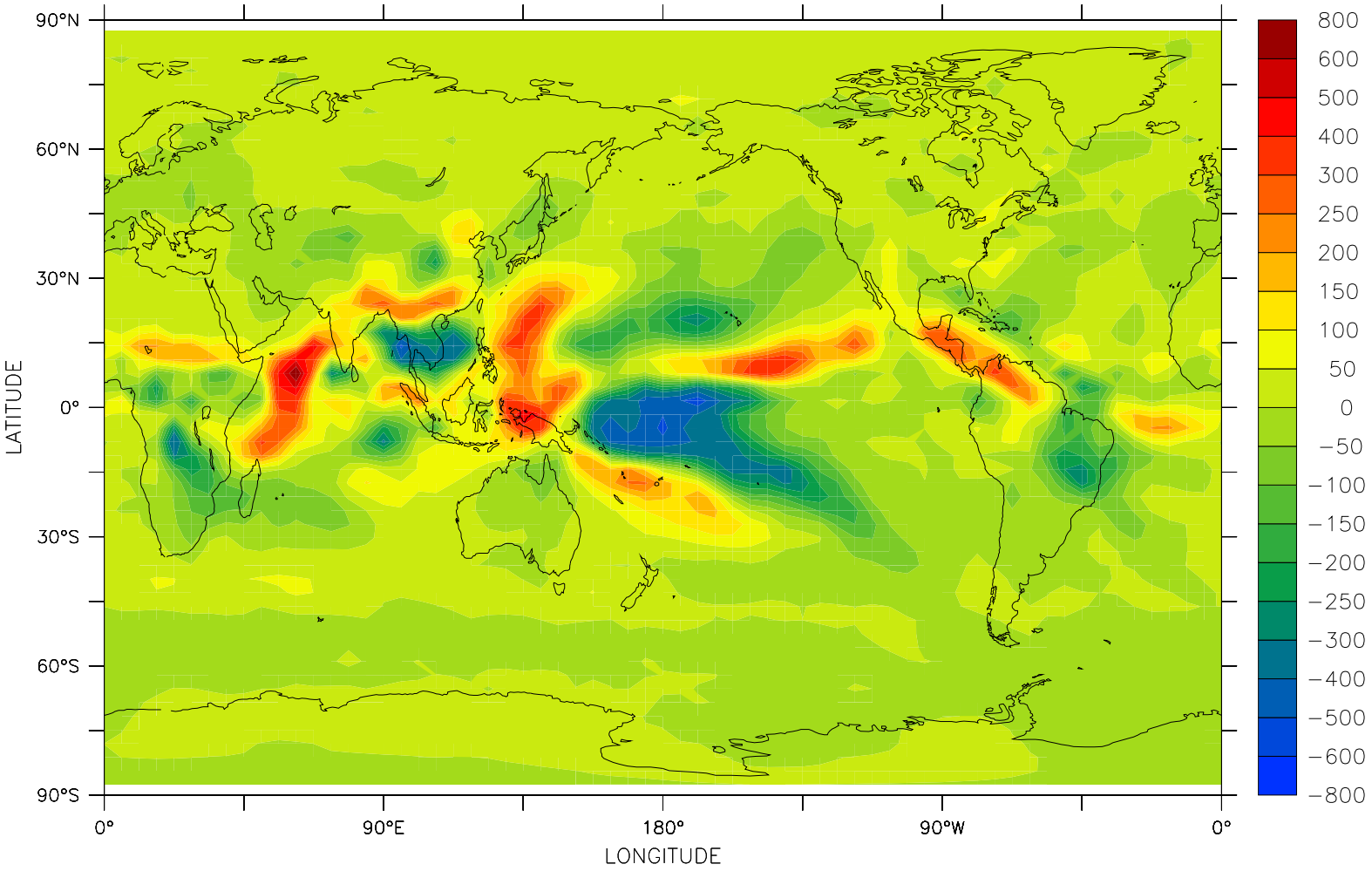

Difference in annual precipitation (mm)

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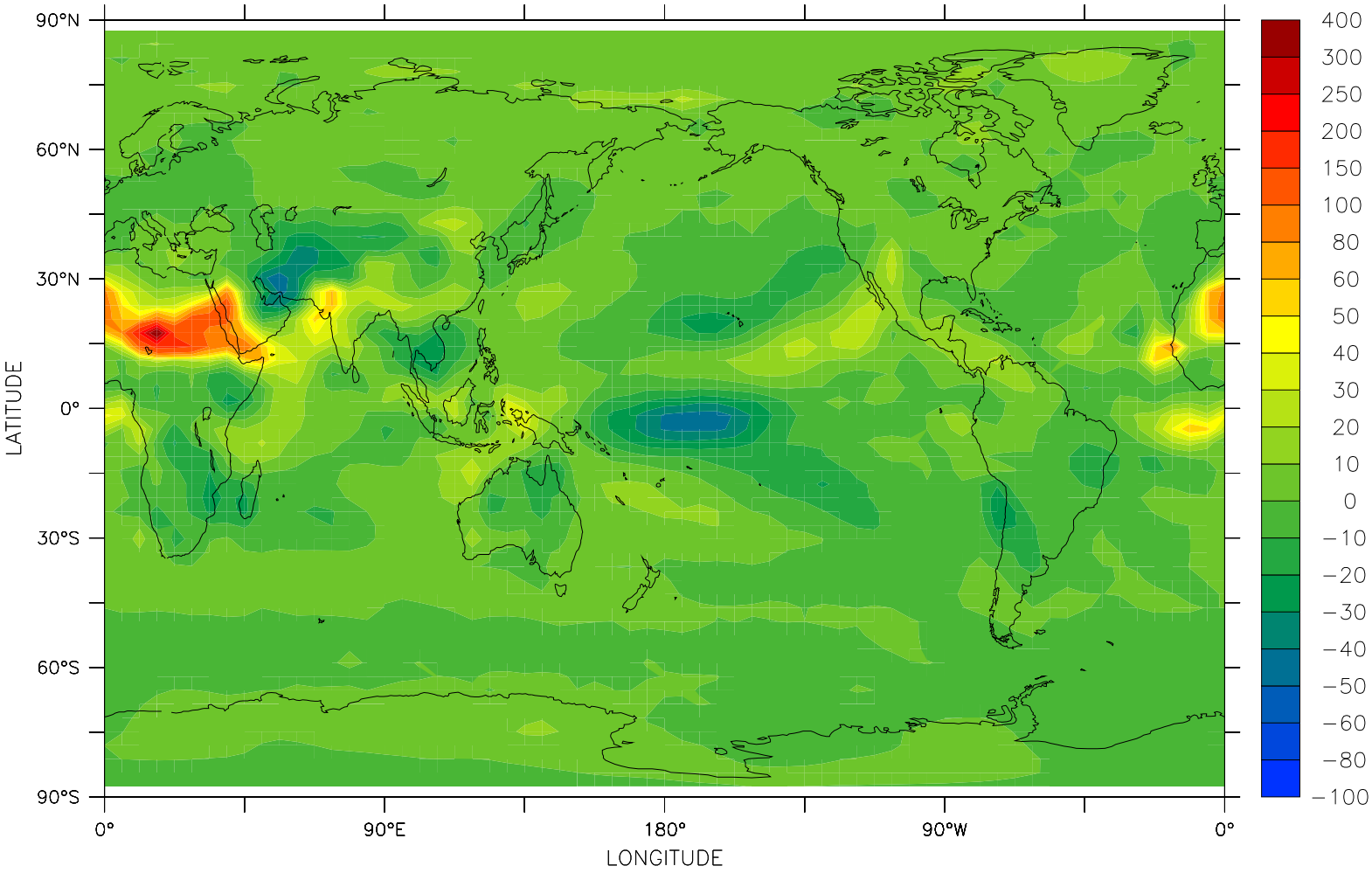

Difference in annual precipitation (%)

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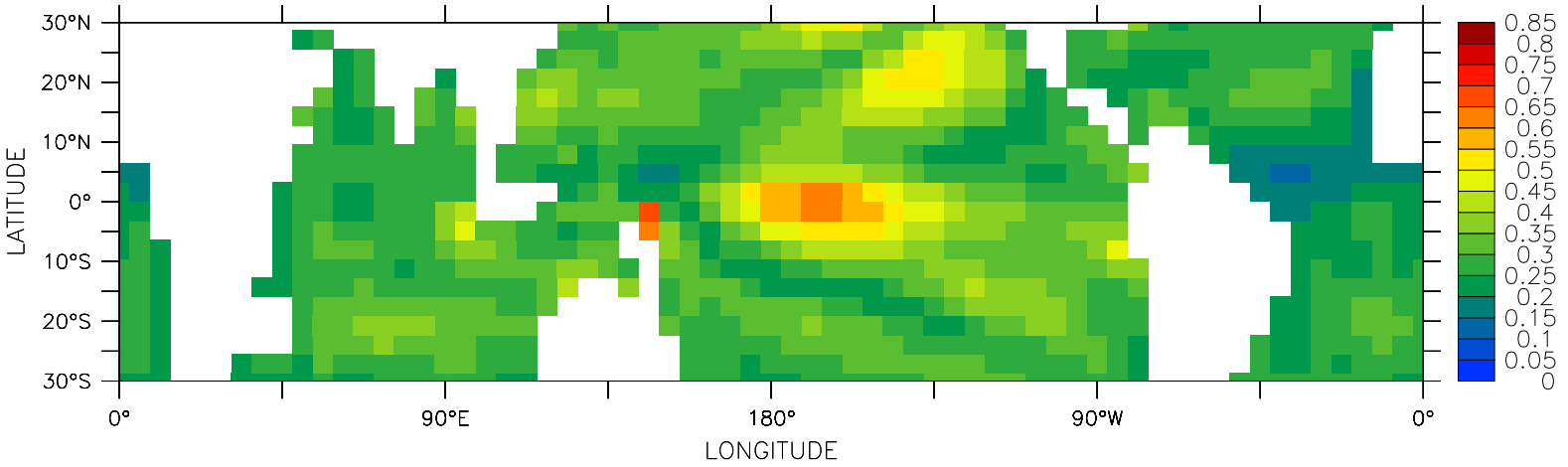
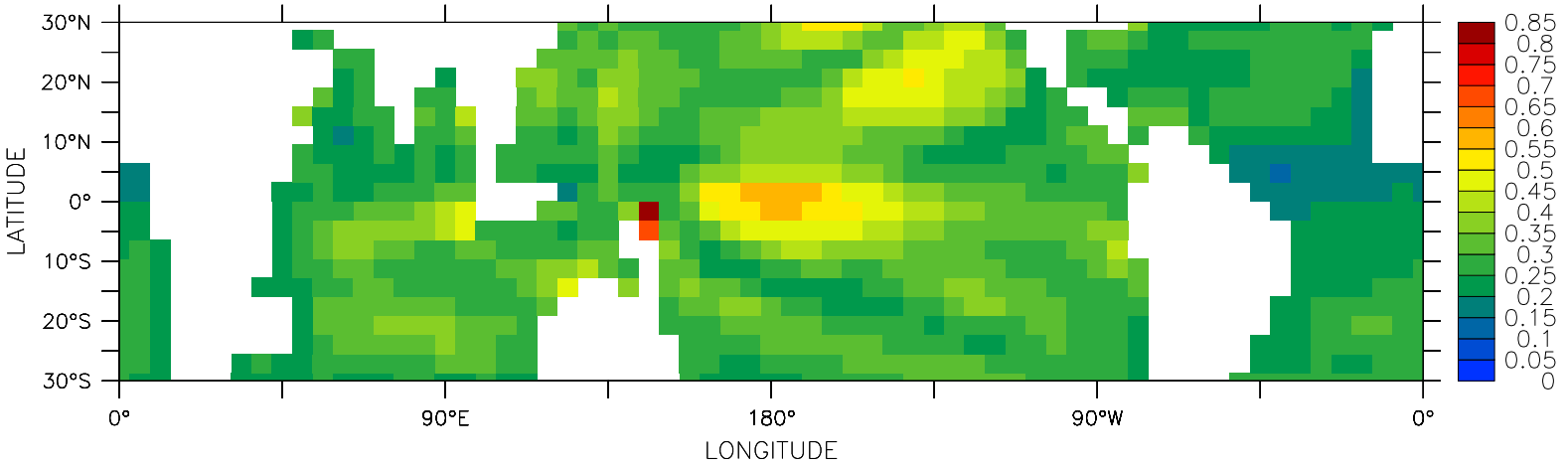
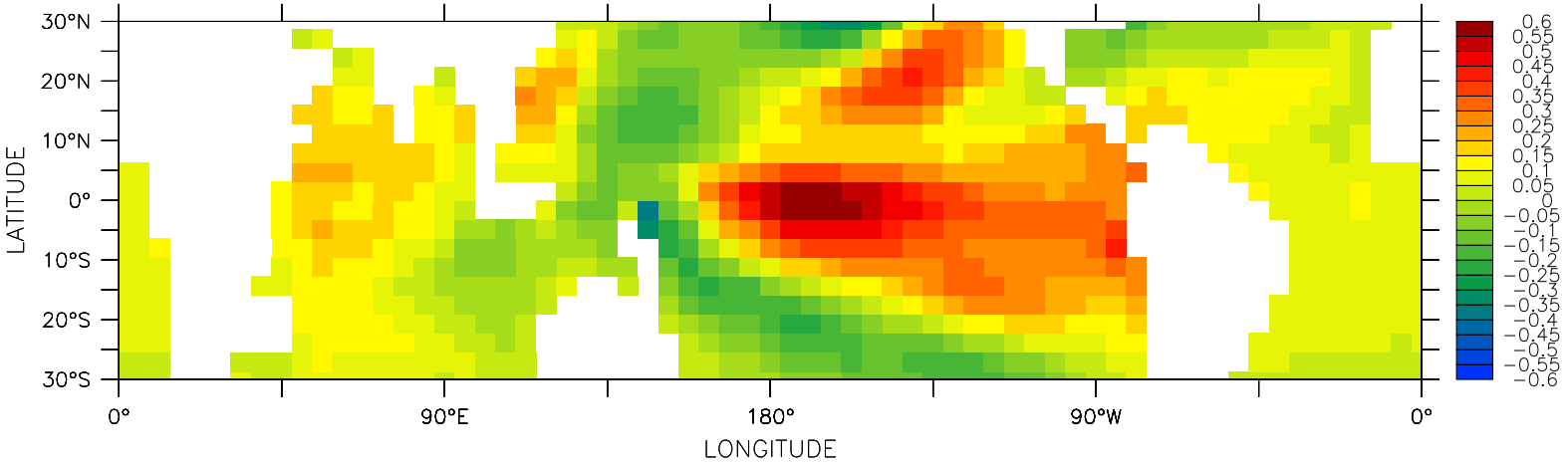


(a) Control

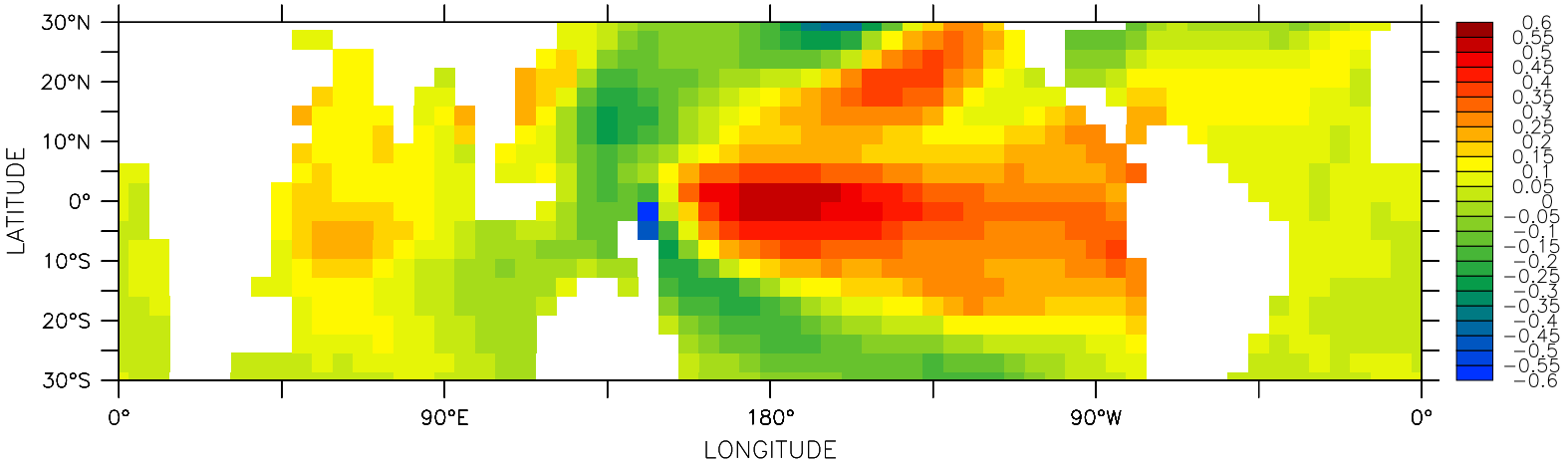


(b) 6ka BP

4. Past climate



(a) Control – 22.3%



(b) 6ka BP – 23.5%

El Niño statistics

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Duration (months)	17.2 ± 0.6	16.6 ± 1.0
Magnitude (°C)	0.86 ± 0.02	0.78 ± 0.02

Future work

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- Any other ideas?