



Earth System Modelling and High-Performance Computing

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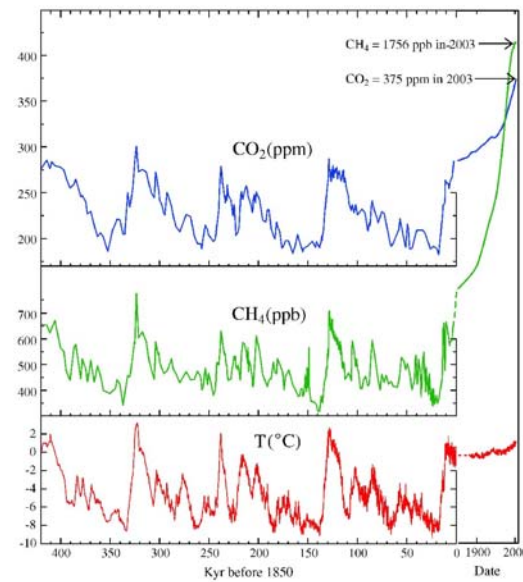
Overview



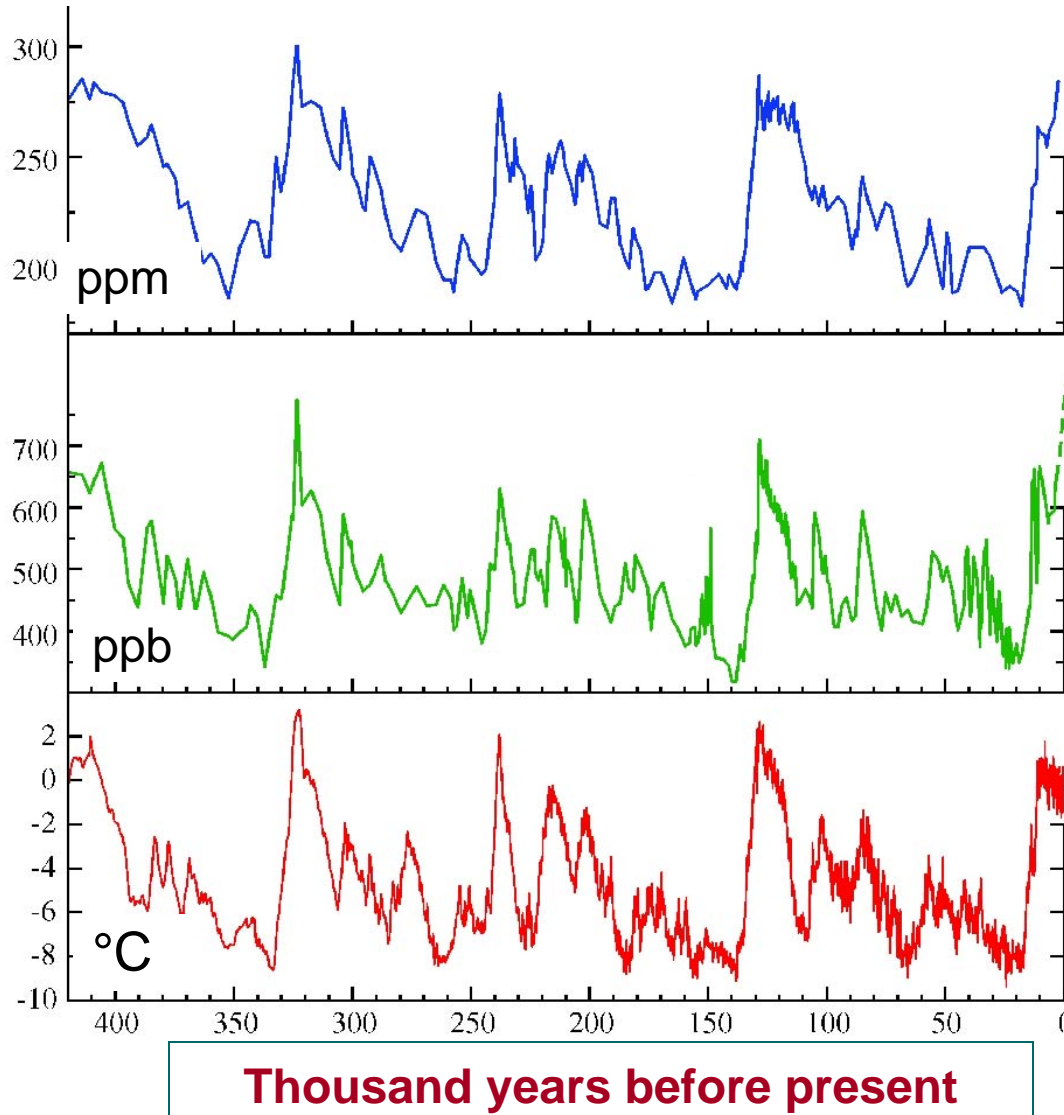
- Part 1 (Brief) : Introduction – Climate Change and Earth System Science
- Part 2 (Longer) : Simulations of Anthropogenic Climate Change
 - Interspersed: Enhanced HPC Requirements



Part 1: Climate Change and Earth System Science



Climate Records from Antarctic Ice Cores



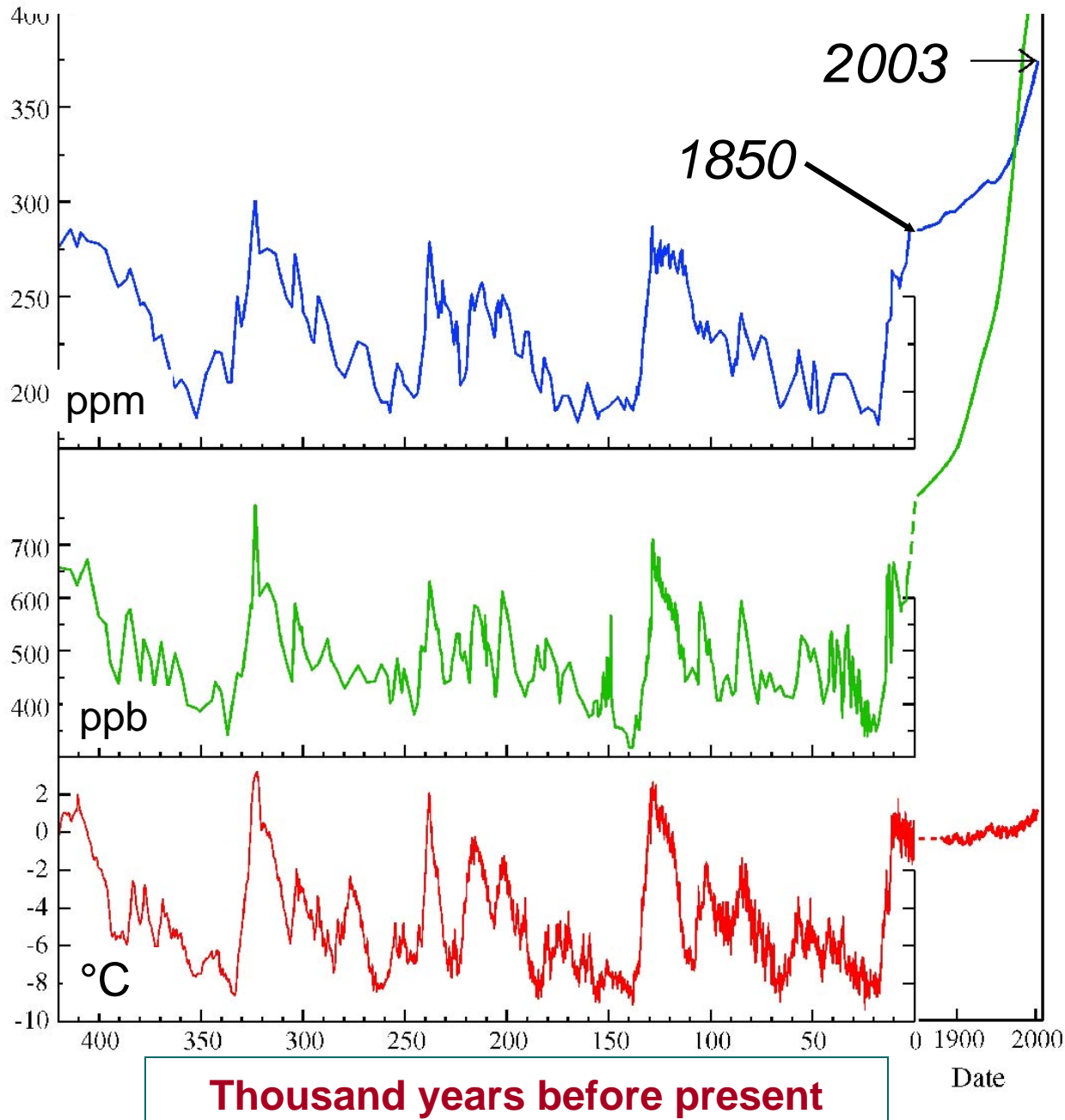
**Carbon dioxide
concentration in
atmosphere**

**Methane
concentration in
atmosphere**

**Ground temperature
Antarctica**

**Hansen (2005)
Petit et al. (1999)**

Climate Records from Antarctic Ice Cores



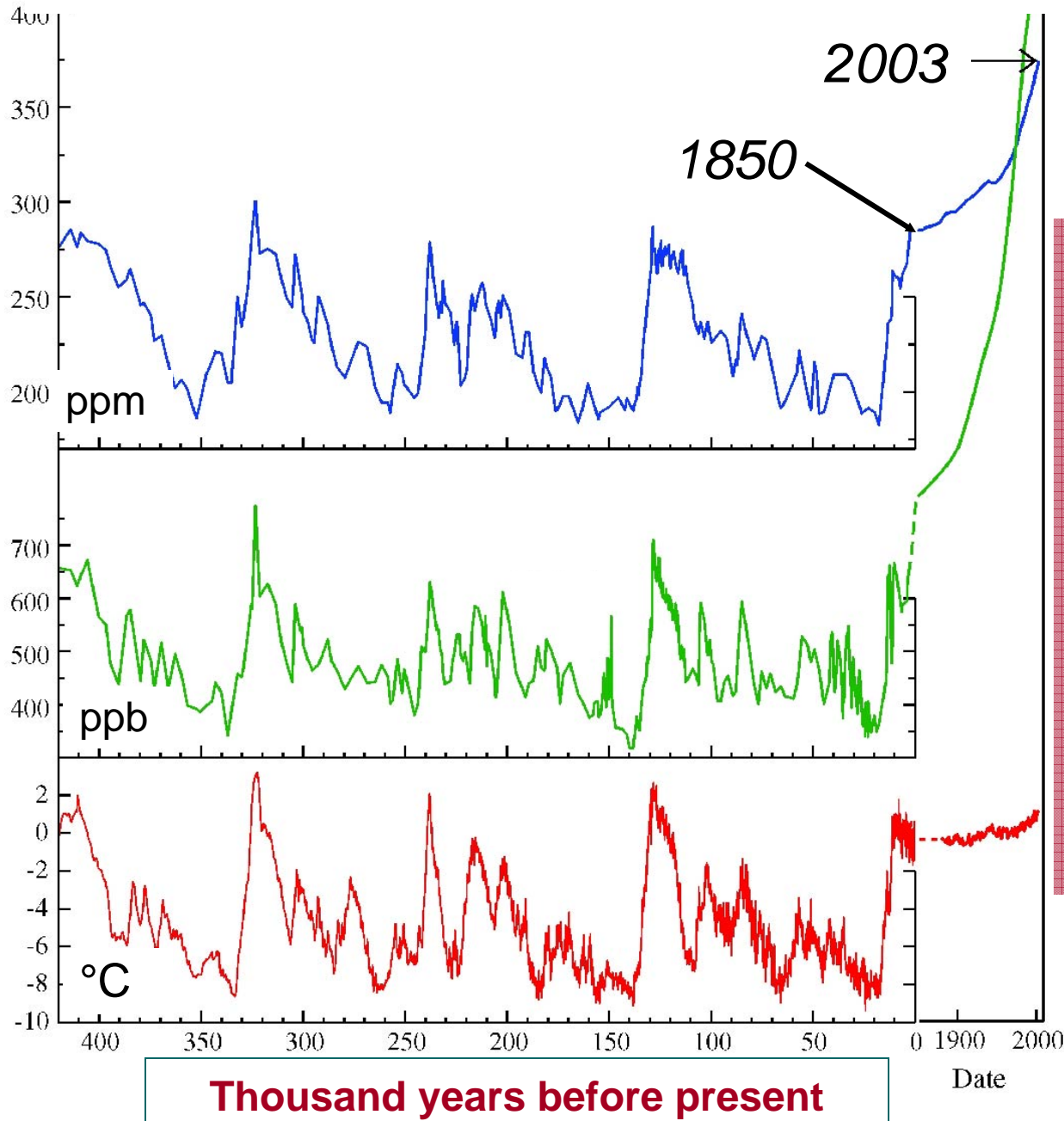
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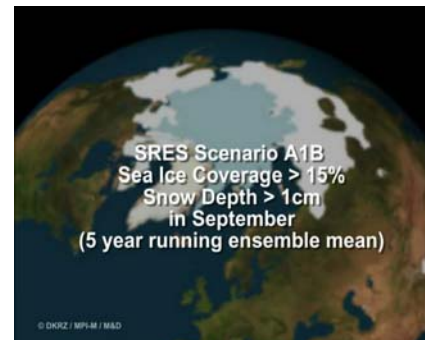
In the last 150 years, we have changed greenhouse gas concentrations more than happened naturally during the ice ages!

How will the system respond???

Hansen (2005)
Petit et al. (1999)



Part 2: Simulations of Anthropogenic Climate Change





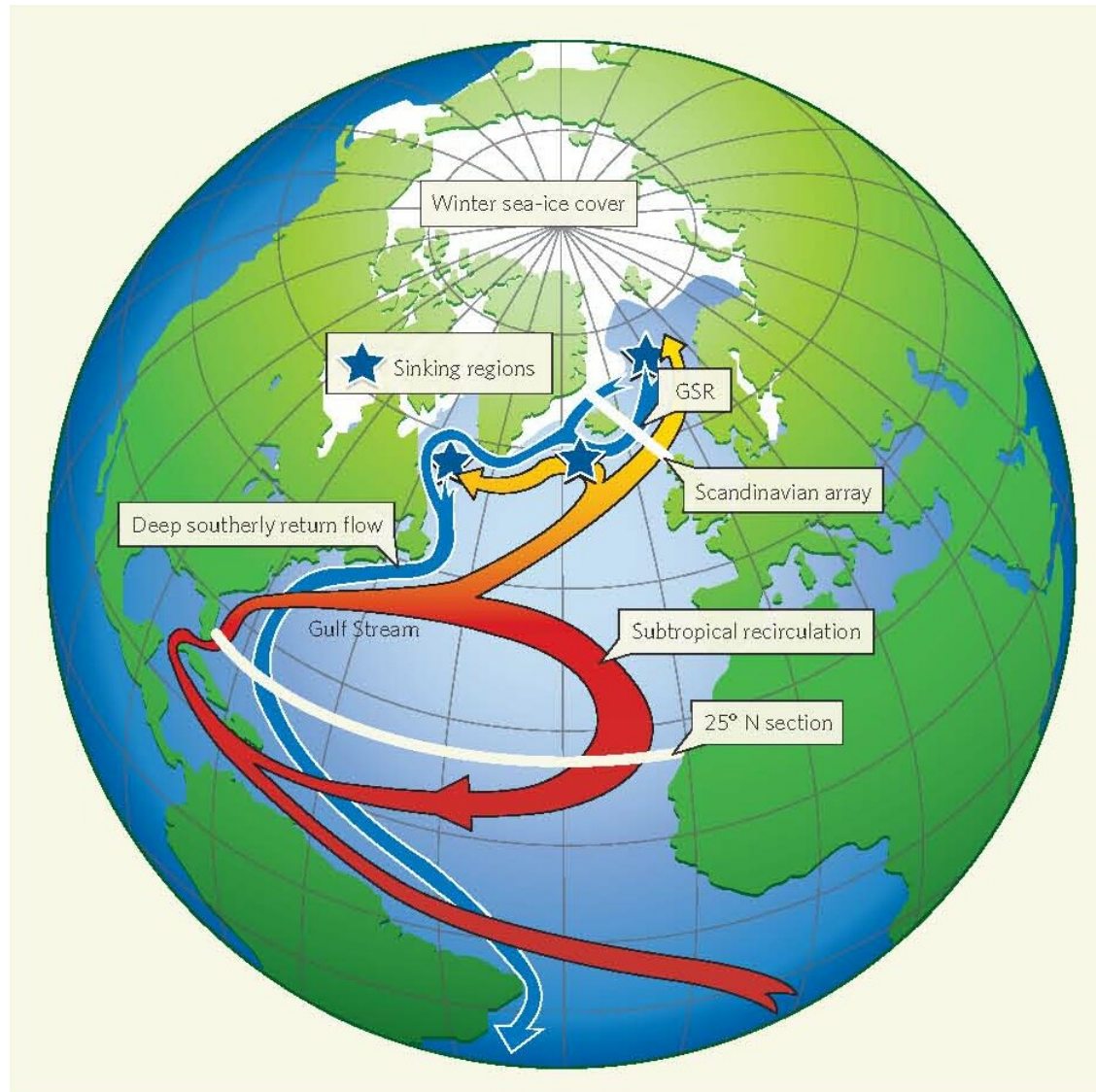
IPCC Scenario, MPI-M Climate Model, September



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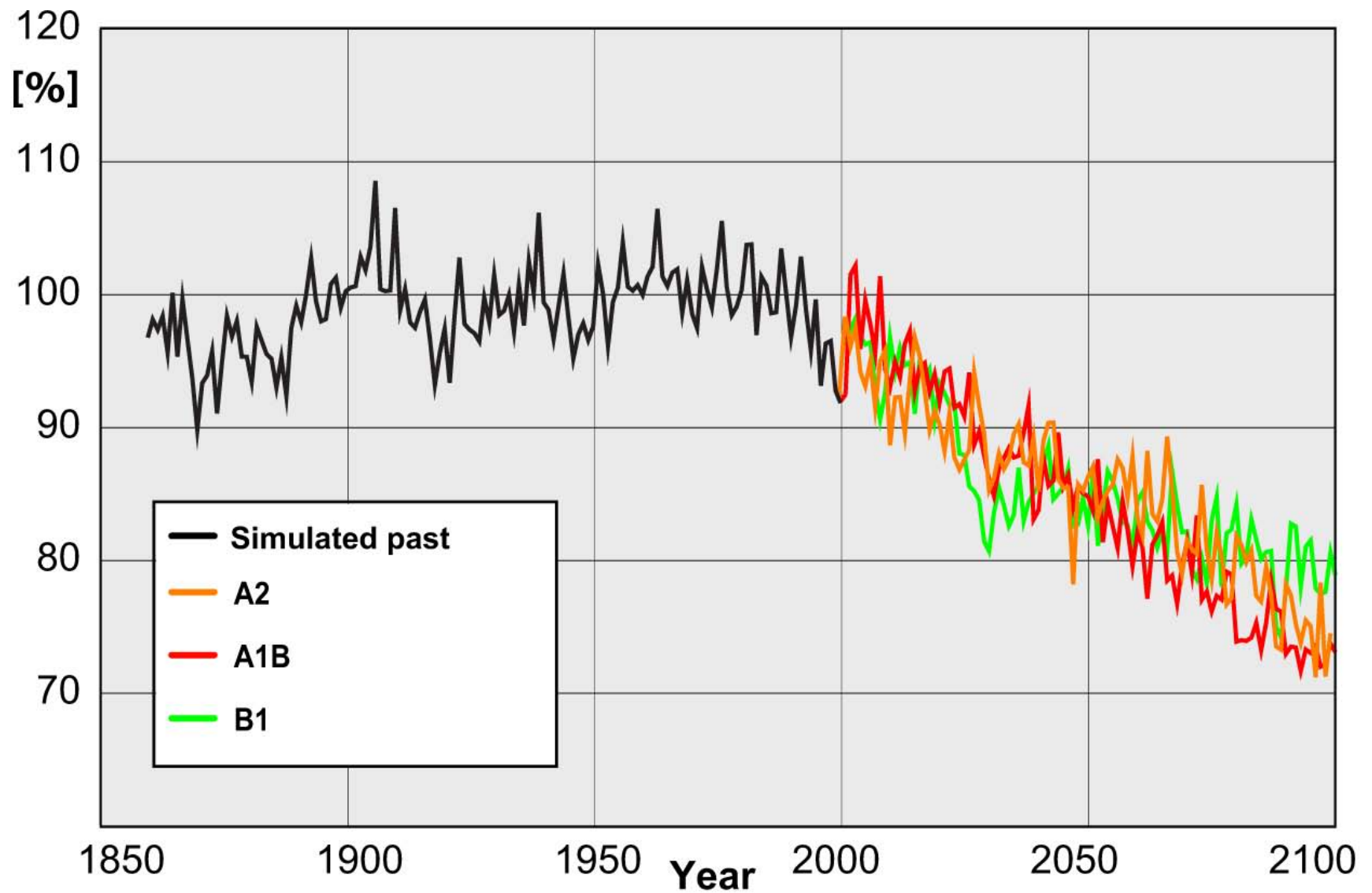


North Atlantic Circulation



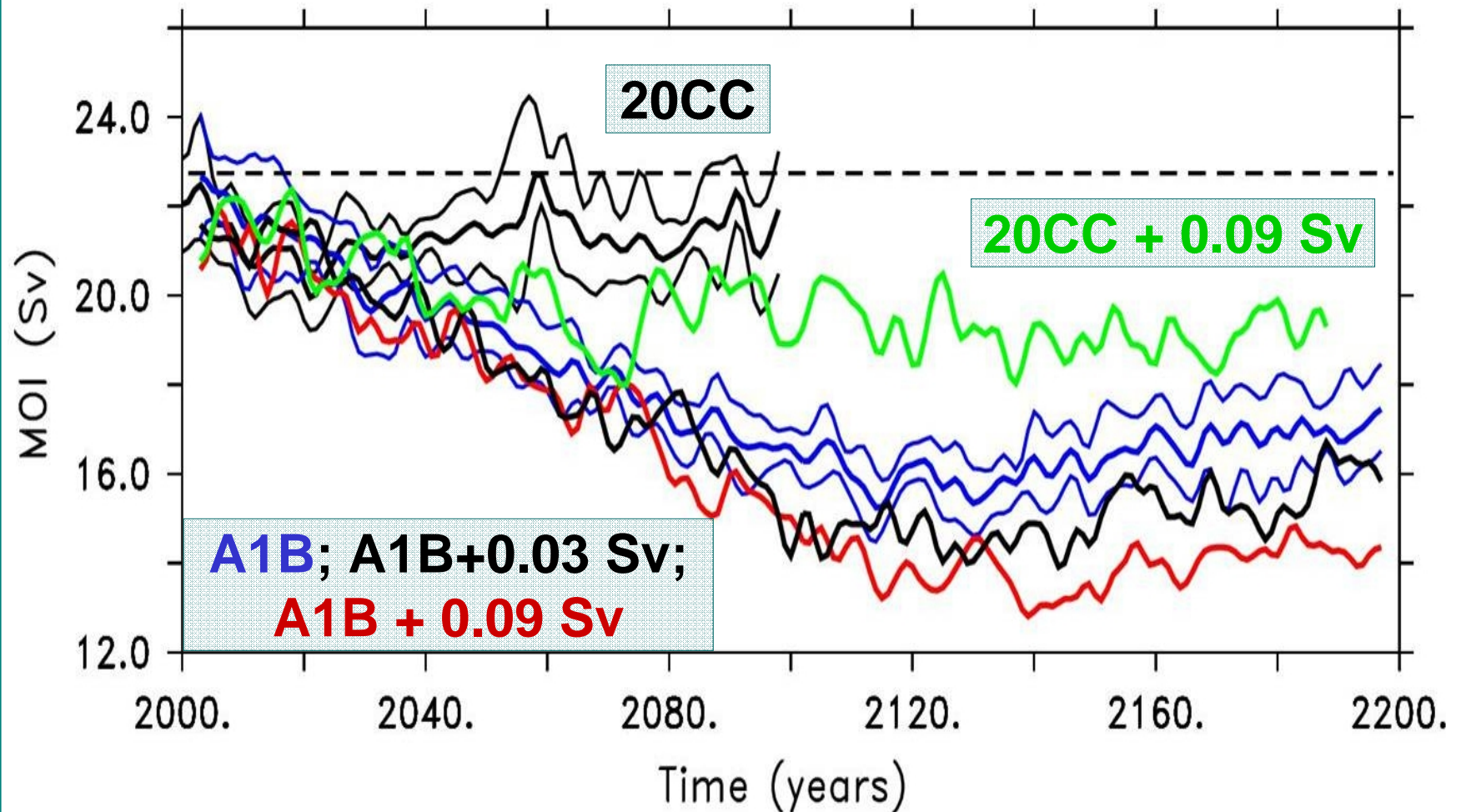


Simulated Atlantic Circulation, MPI-M Climate Model





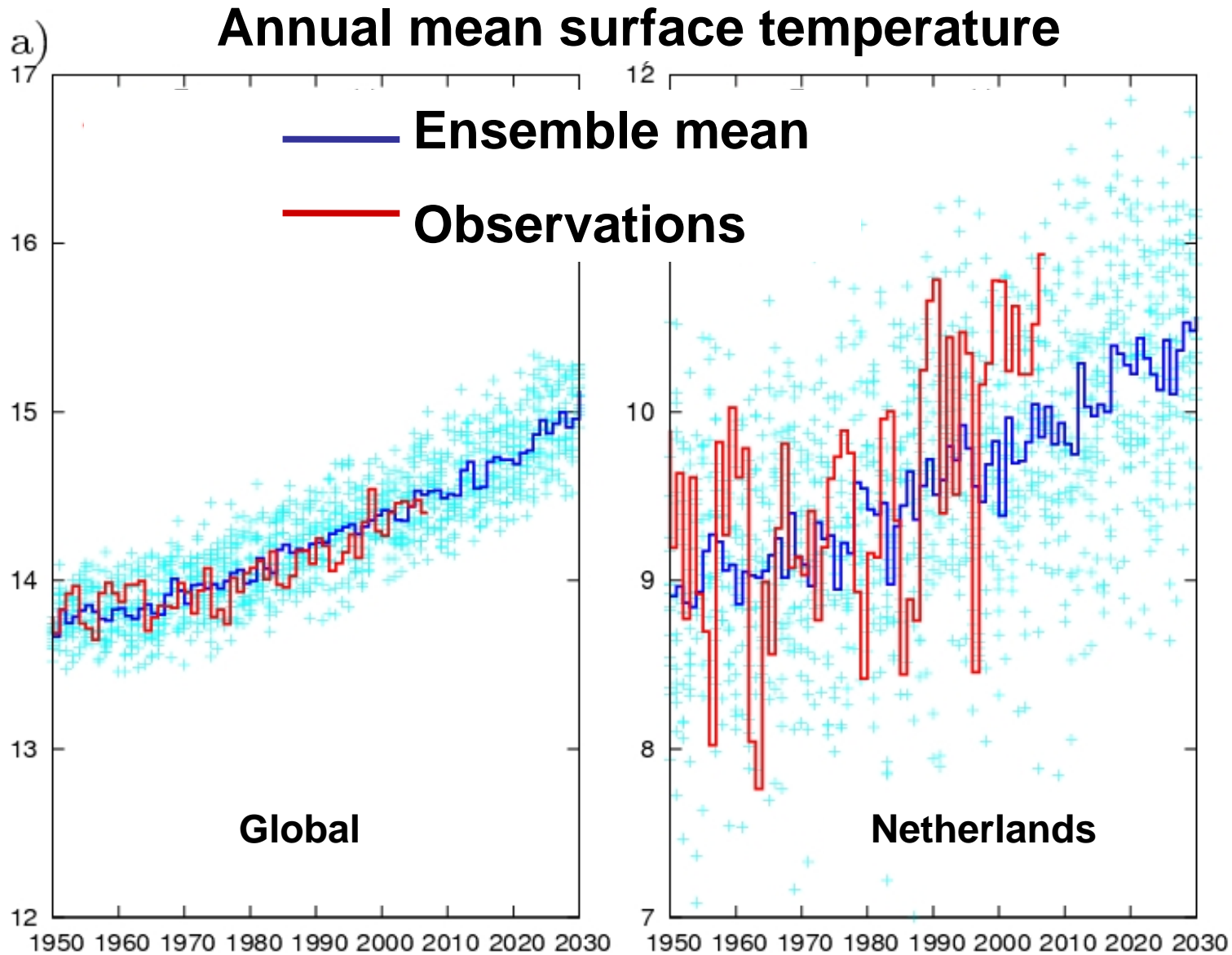
“Greenland Melts,” Strength Atlantic Circulation



- 20CC: CO₂ fixed at year 2000 levels (“20th century commitment”)
- Thin lines: Ensemble standard deviation



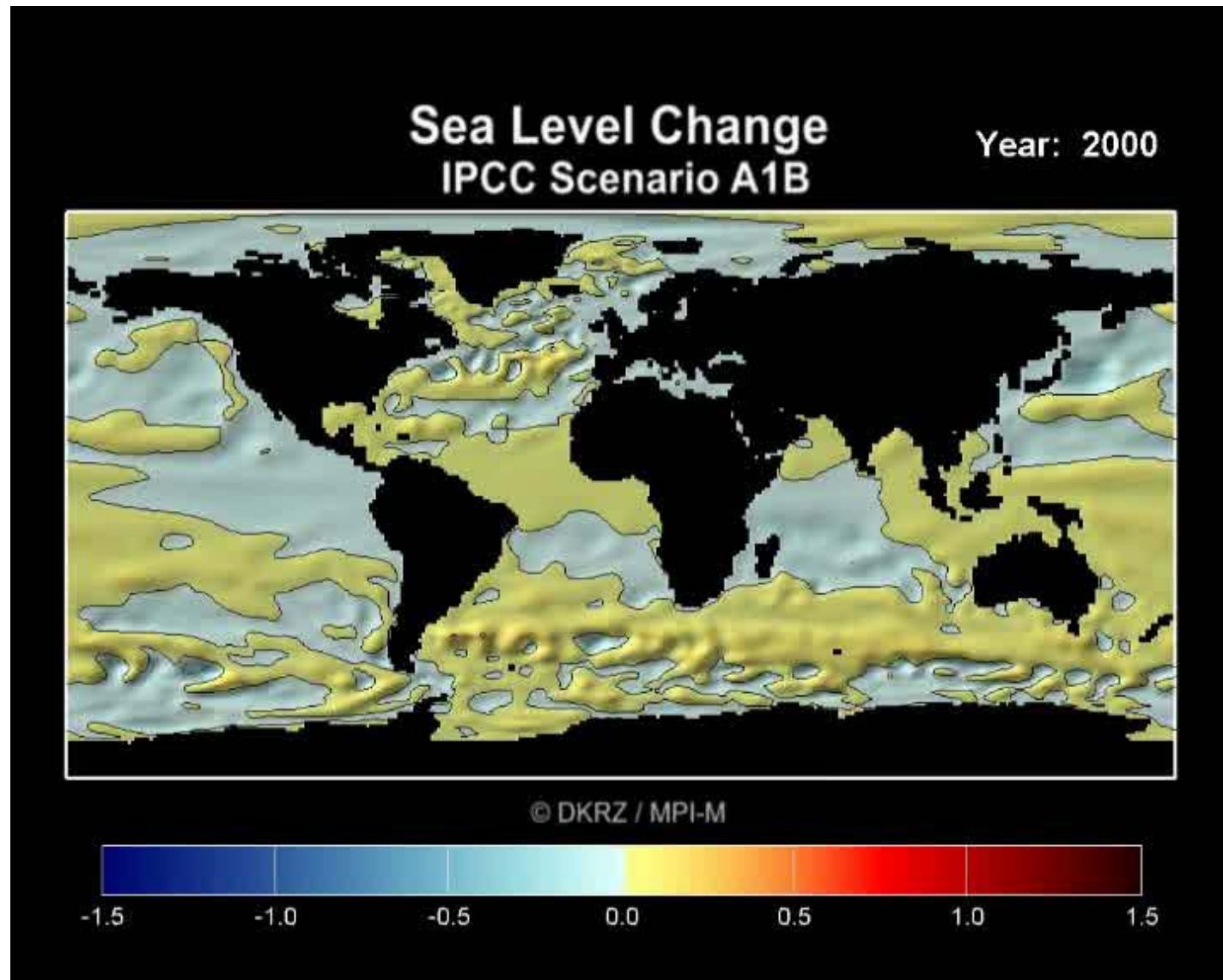
17-Member Ensemble of MPI-M Climate Model



Sterl et al. 2007 (KNMI, ESSENCE, DEISA)

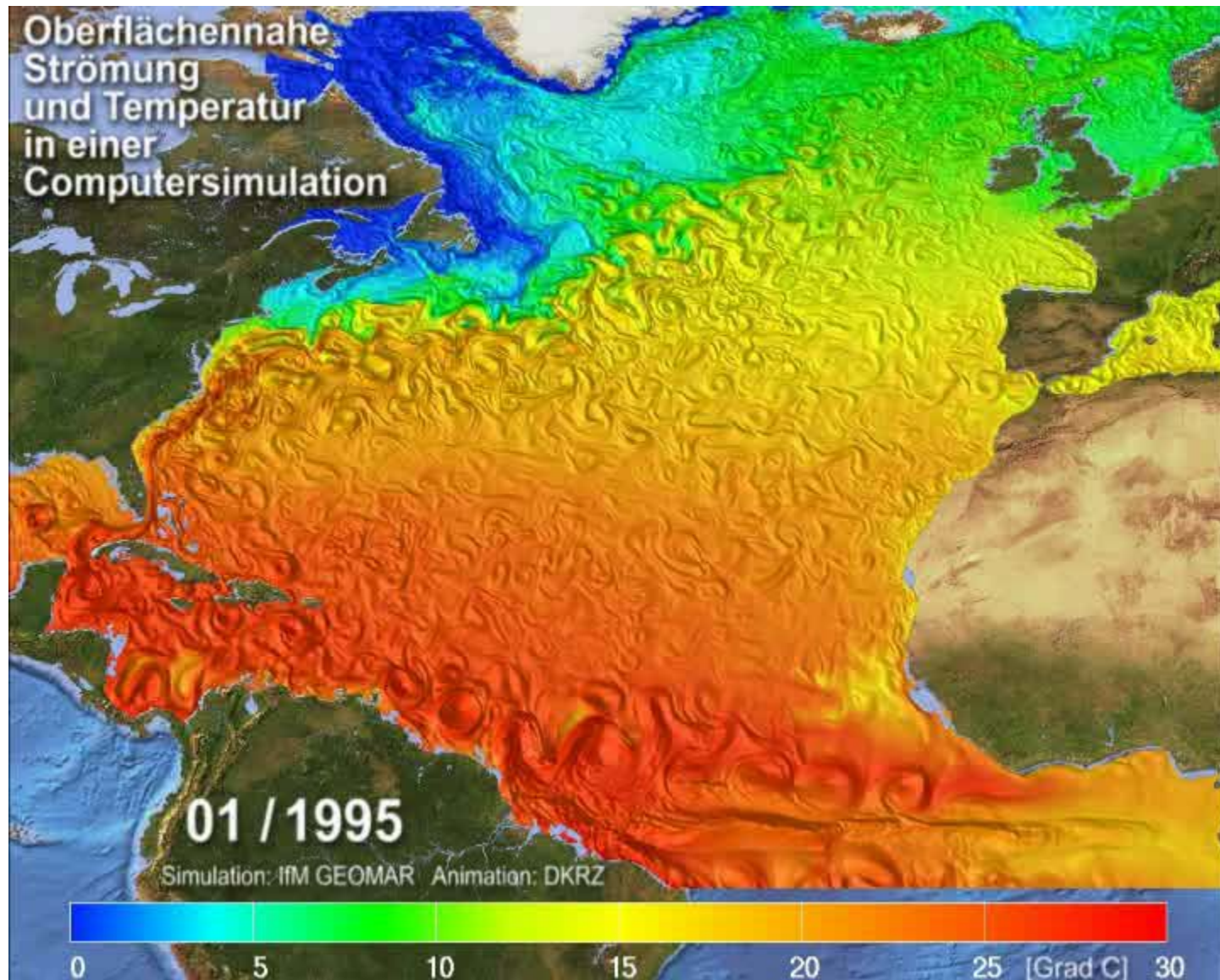


Simulated Sea Level Rise





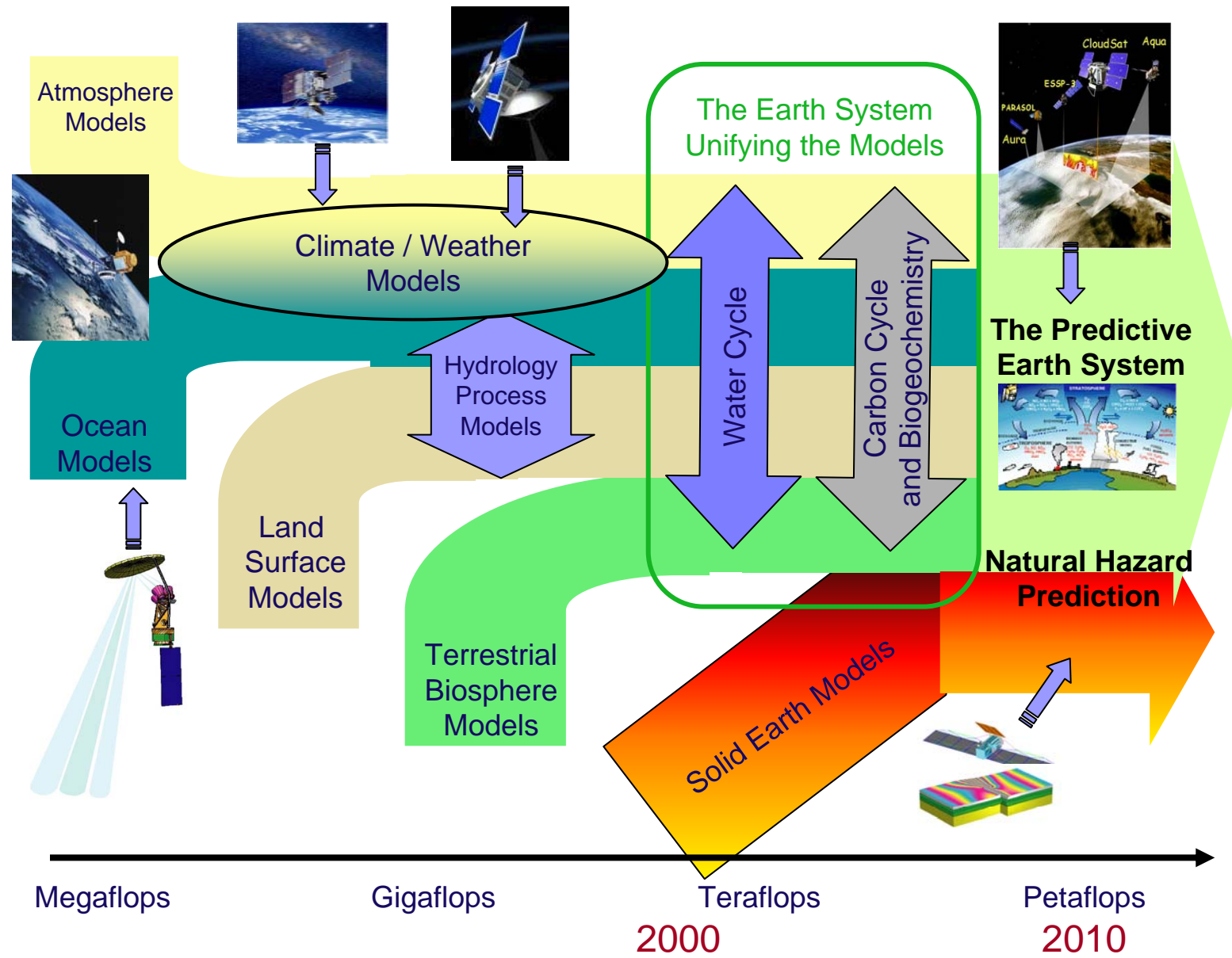
Enhanced Requirements: Resolution



Surface Flow and Temperature IfM-GEOMAR



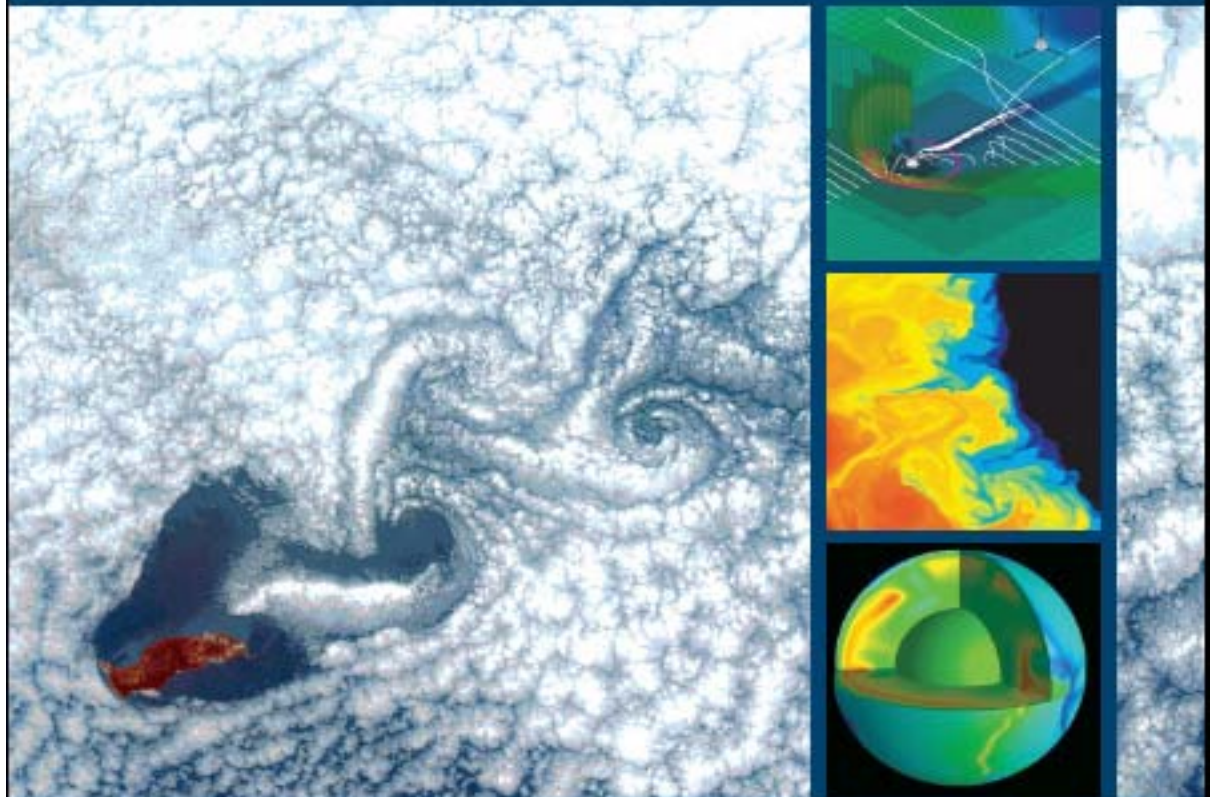
Enhanced Requirements: Model Complexity





**Infrastructures
needed to
address Earth
system
questions:
Super-
computing**

ESTABLISHING A PETASCALE COLLABORATORY FOR THE GEOSCIENCES



Scientific Frontiers



German Climate Computing Centre (DKRZ)

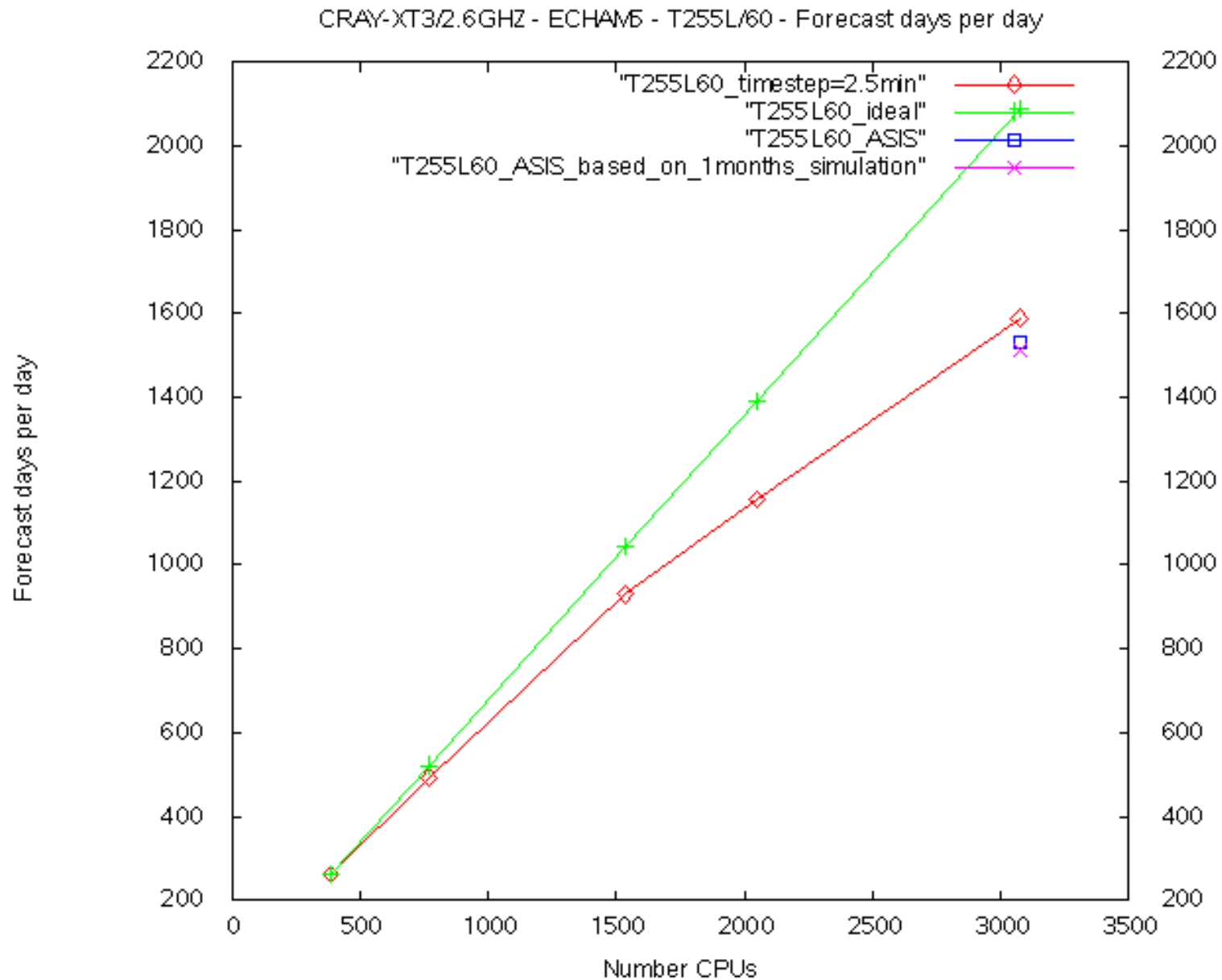


- Tier 1 in “ecosystem”; Hamburg “centre of excellence”
- In Europe, unique as a national service in its combination of
 - HPC
 - Data services (most model analyses offline)
 - Field-specific applications consulting
- HPC facilities require code adaptation for efficient use; requirement will increase as number of processors increases
- Typical lifetimes
 - HPC hardware: 5-7 years
 - Software: 25 years (e.g., a comprehensive climate model takes hundreds of person years to develop)





Scaling of ECHAM5 on CRAY-XT3





Standards



Earth System: Modelling and Analysis

Scripts:
file manipulation
job execution
etc.

Interfaces

Codes:
Correctness
performance
performance

Operating System_{1,...n} SW Stack_{1,...n}, incl. Compiler_{1,...n}

Hardware_{1,...n}



Conclusions: Enhanced HPC Requirements



- Higher resolution
 - Ocean: 10x higher resolution per horizontal dimension (to resolve processes with highest kinetic energy)
 - Atmosphere: 10x higher resolution per horizontal dimension (to resolve mountain-induced precipitation)
- Much larger ensemble size
 - Uncertainty
 - Predictability
 - Data assimilation
- Higher complexity (more model components)
 - Biogeochemical cycles & feedbacks (e.g., methane)
 - Atmospheric chemistry (climate change → air quality)



**Thank you for your
attention!**