



Towards a Risk Assessment for Shutdown of the Atlantic Thermohaline Circulation

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Avoiding Dangerous Climate Change, Exeter 1 Feb 2005

Overview of current knowledge

- Impact of THC on climate
- Thresholds and irreversible THC shutdown
- Rapid change

Stabilisation scenarios

- 'Safe' stabilisation pathways?

Model uncertainty

- Reducing it
- Living with it
- Observations – is the THC weakening?

Summary and prospects

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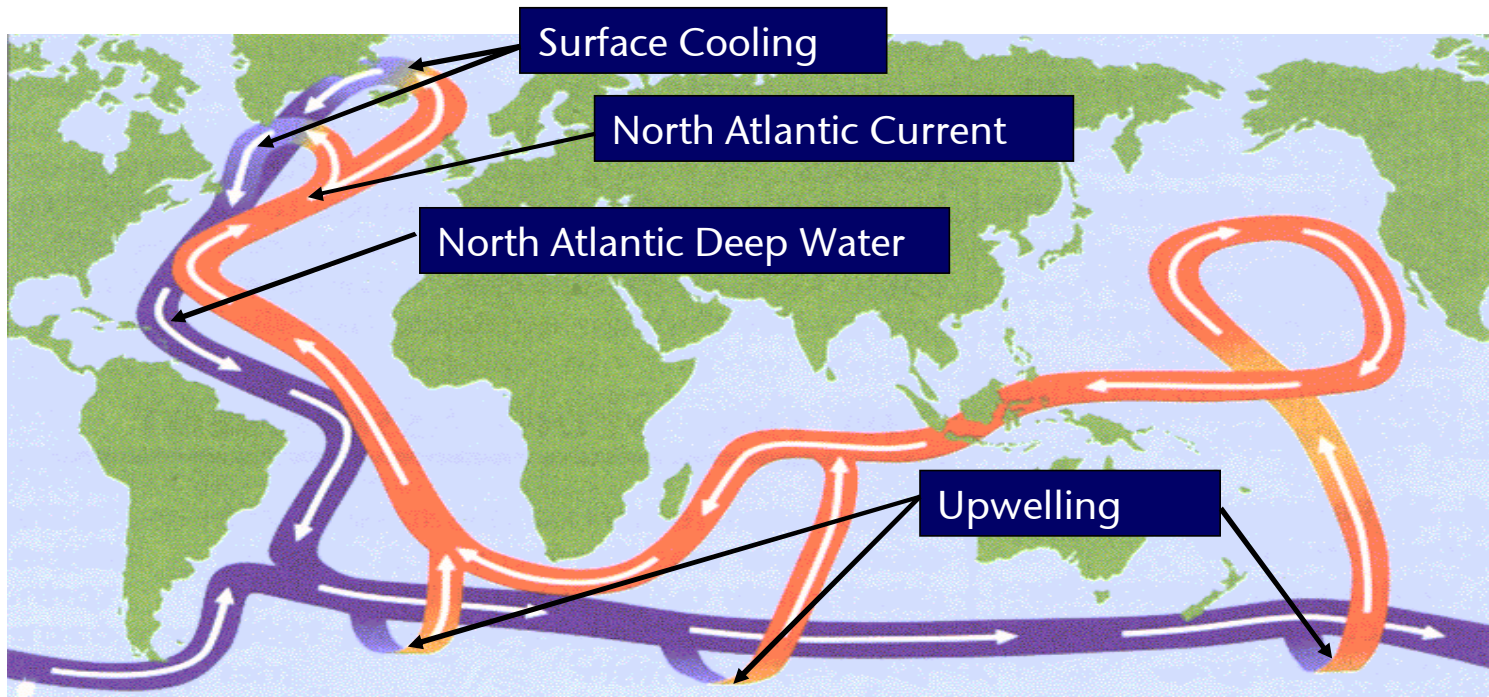
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What is the THC?

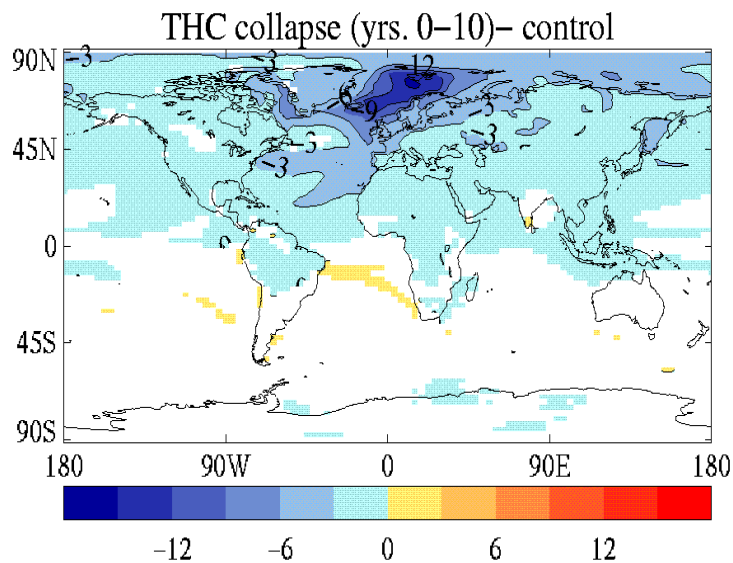


Warm water goes north, Cold water goes south \Rightarrow heat transport into N. Atlantic
Role of salinity is complex: transient brake, long-term accelerator?

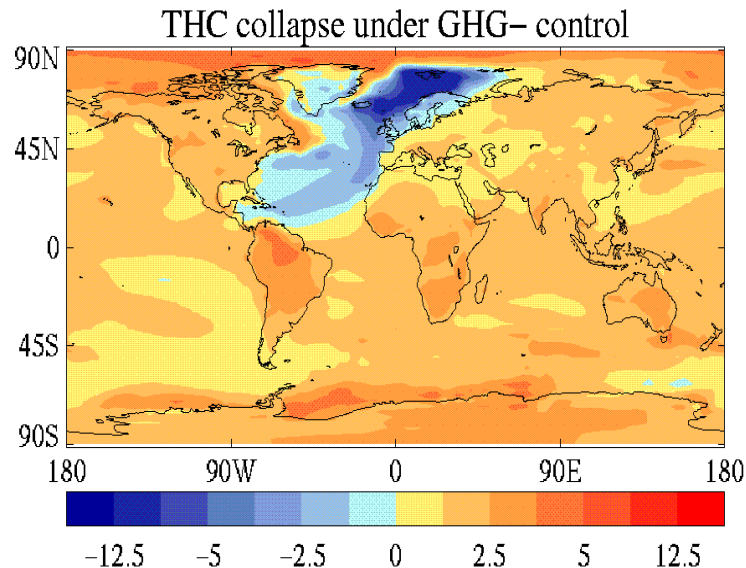
Impact of THC on surface temperature



Artificially induced THC shutdown in HadCM3 model



In preindustrial climate



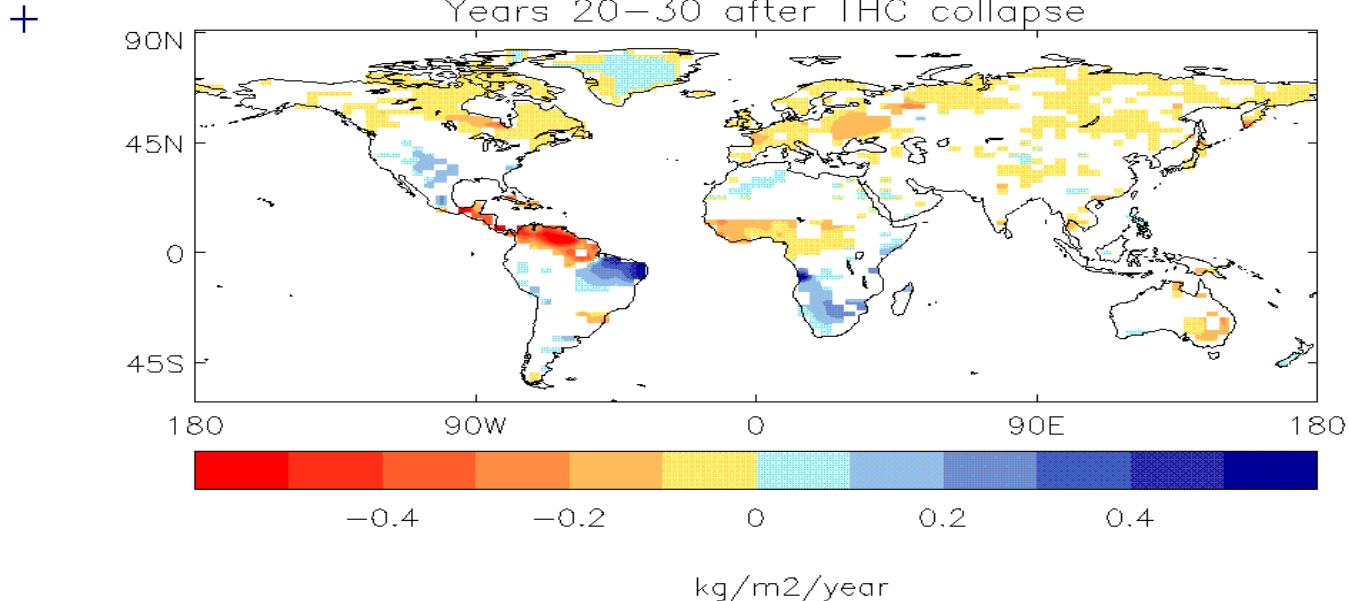
In 2049 after global warming (IS92a)

(Vellinga & Wood *Climatic Change* 2002, Wood et al. *Phil. Trans. Roy. Soc. A* 2003)

Impact of THC on primary production of carbon



Change in annual mean net primary production of carbon
Years 20–30 after THC collapse



Assumes current vegetation types continue

Significant regional changes:

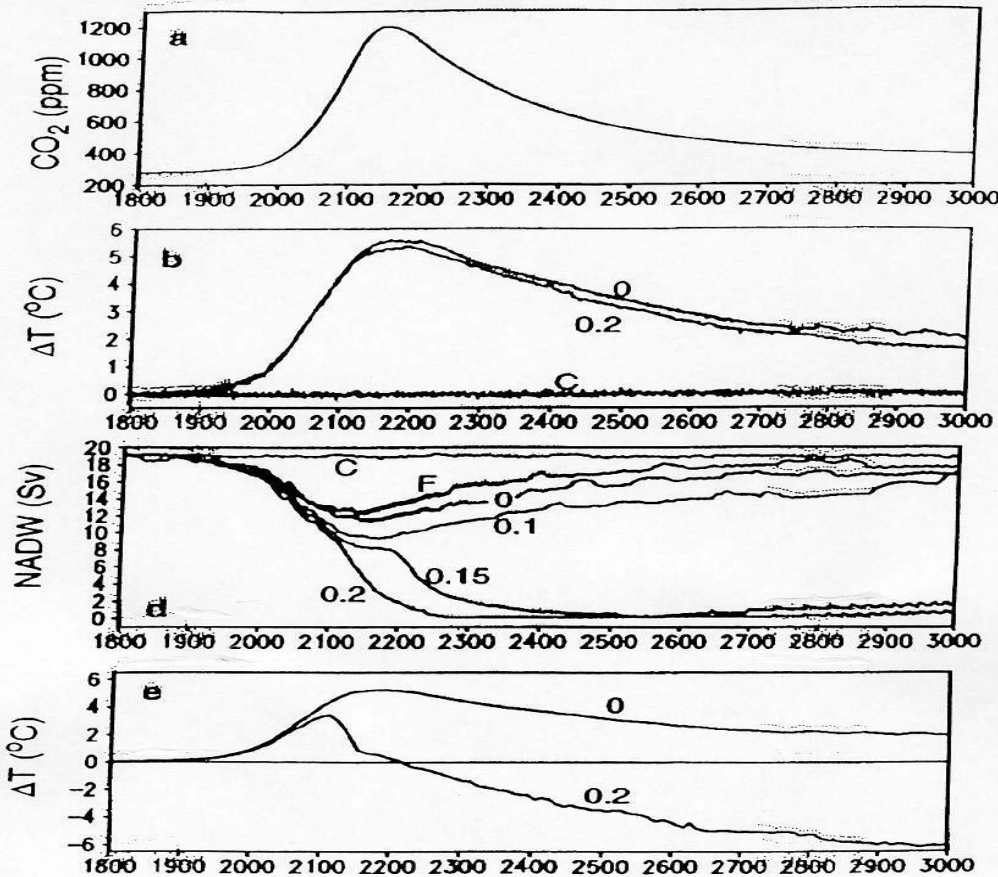
Europe: -16%

Asia: -10%

Indian subcontinent: -36%

Central America: -109% (current vegetation types unsustainable)

Irreversible THC shutdown (in *some* models)



CO₂ (ppm)

Global mean ΔT

THC strength (Sv)

Winter ΔT
Atlantic 55°N

(Rahmstorf & Ganopolski *Climatic Change* 1999)

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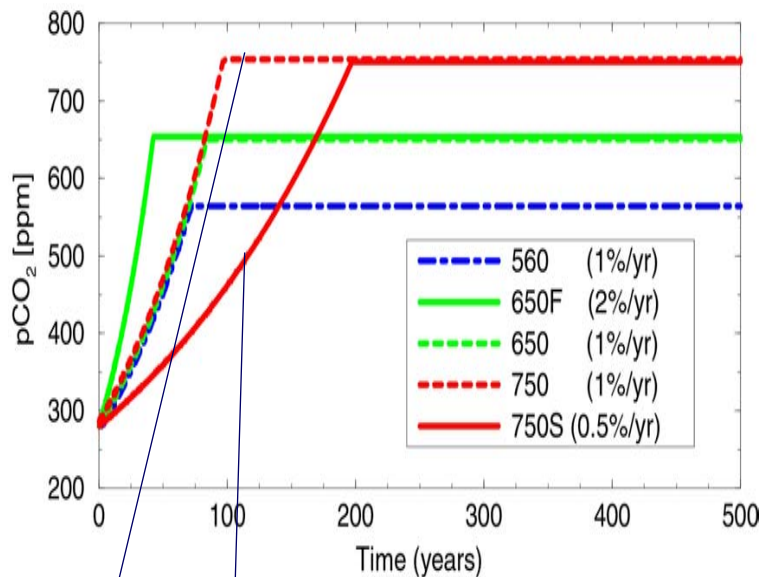
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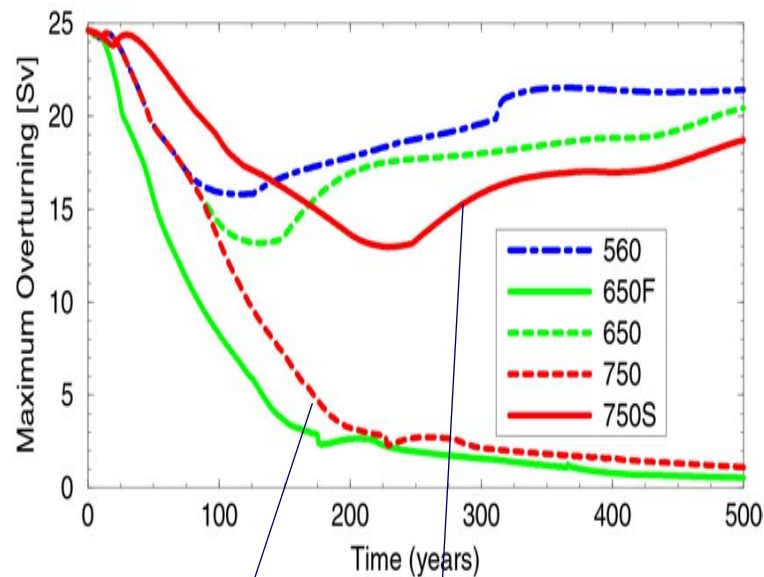
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Rate of CO₂ increase could be important



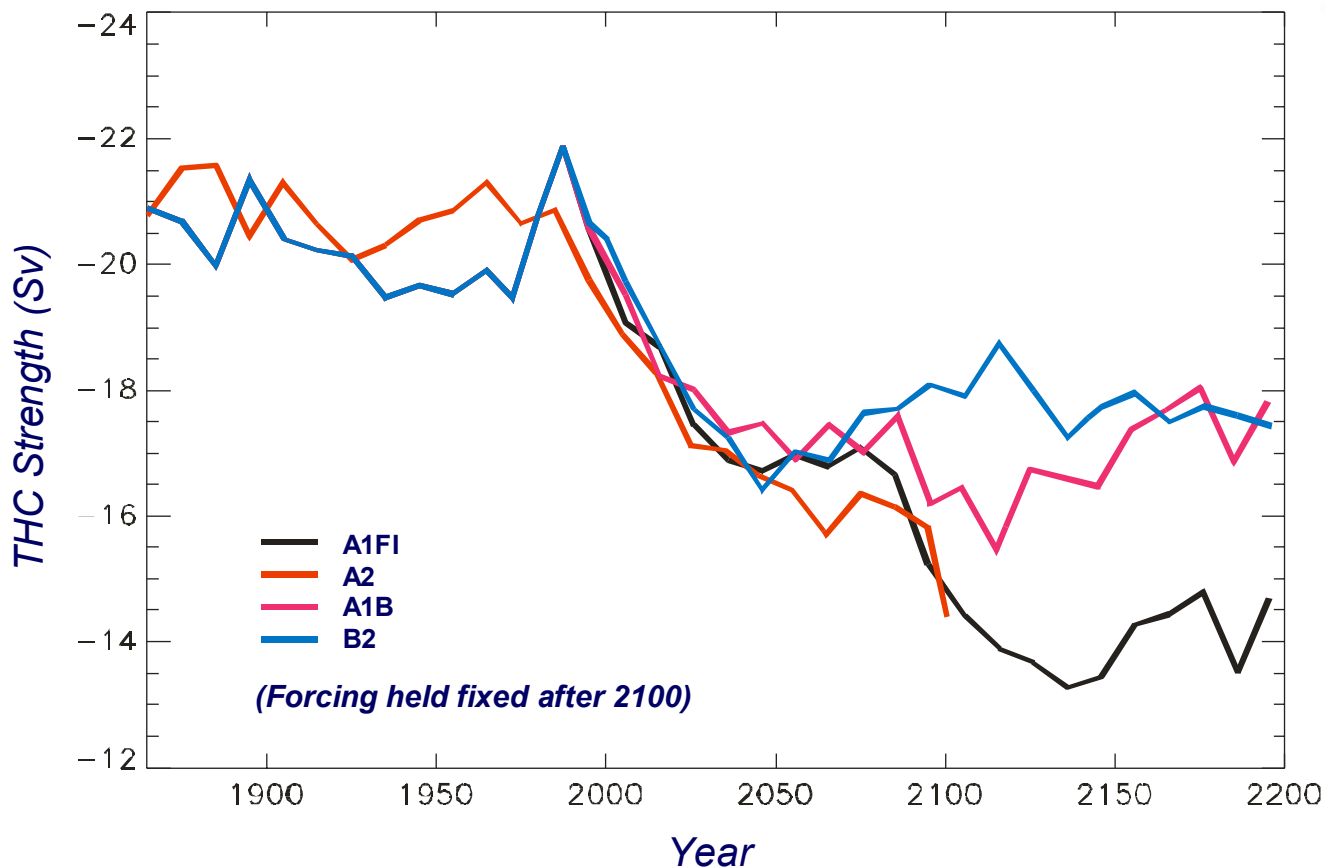
750/750S: stabilise at 750 ppm after fast or slow rate of increase



THC shutdown may be more likely with faster than slower rate

N.B. Results (especially numerical values) are likely to be strongly model-dependent!

Stabilisation experiments in HadCM3



No scenario produces a shutdown in HadCM3

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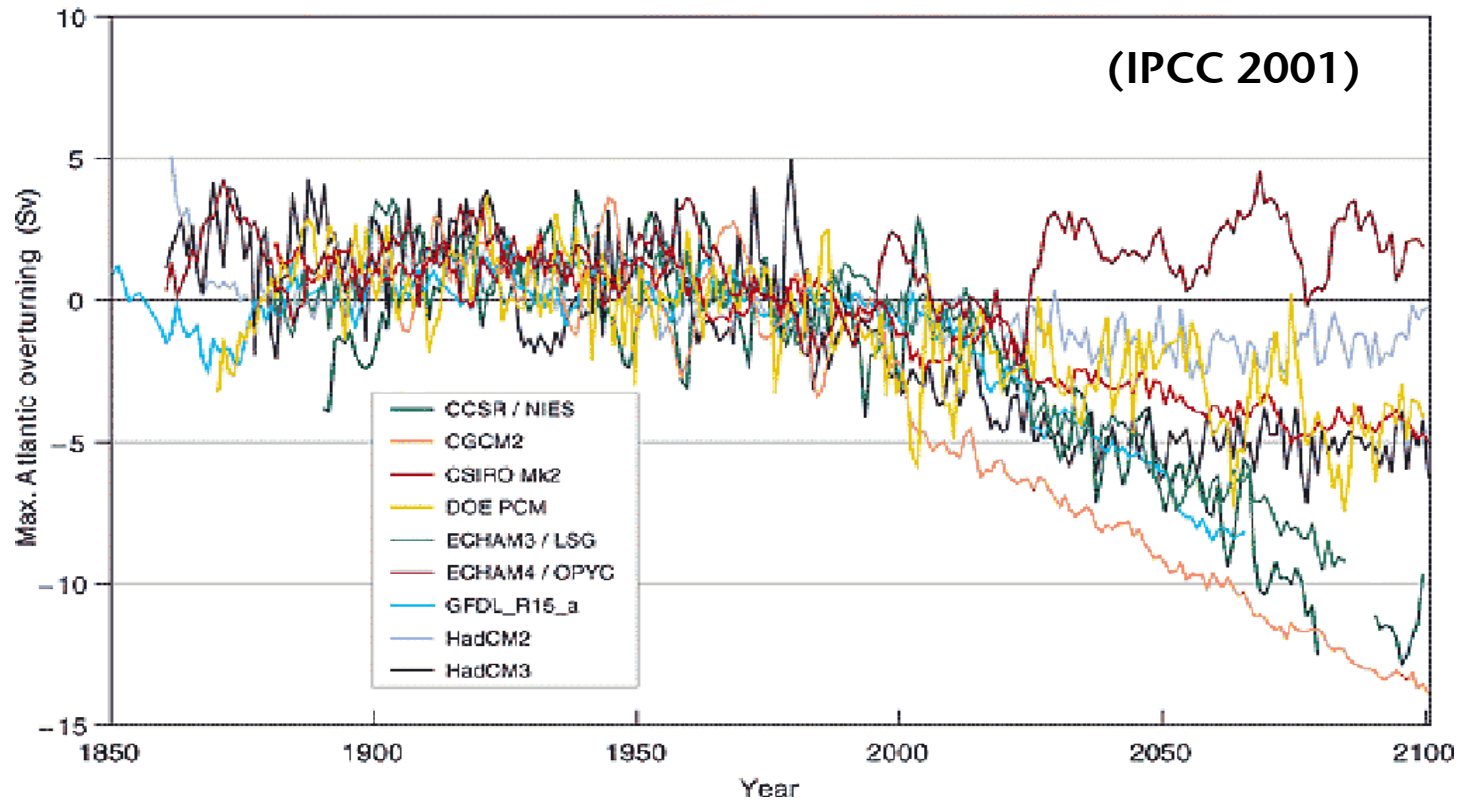
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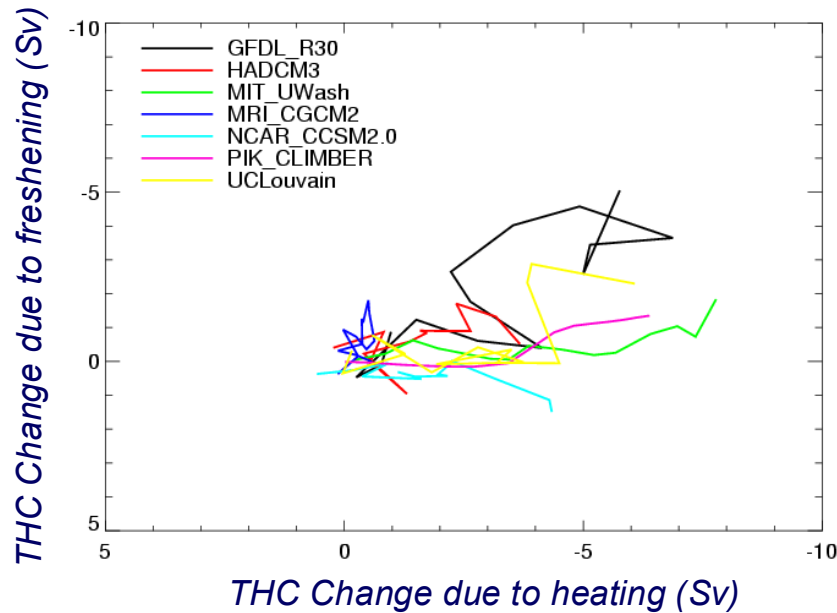
Summary and prospects

Model Uncertainty



Various model THC responses to IS92a

Understanding the sources of uncertainty



CMIP Coordinated Experiment on THC Stability

Analyse processes of THC response in a number of models, with standard forcing

In most models, temperature dominates salinity in the initial THC response

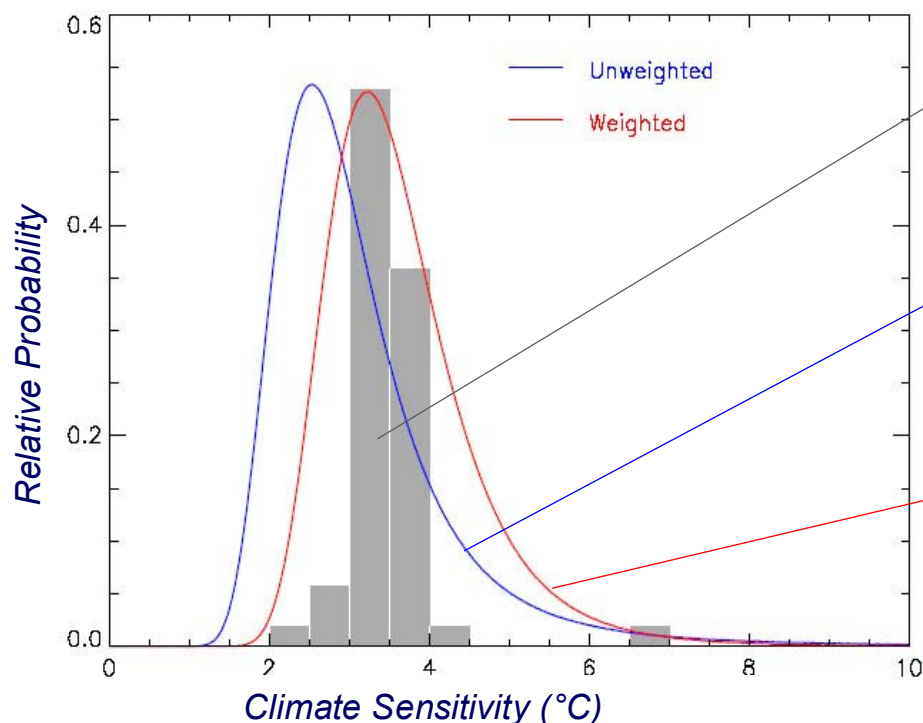
But there is a large inter-model difference in salinity part

(Courtesy Jonathan Gregory)

Living with Model Uncertainty - Ensembles



(See Collins et al. poster at this meeting)



1. Generate ensemble of models (from a family), spanning the plausible parameter space
2. Build a statistical emulator to 'fill in the gaps' in parameter space (see next talk)
3. Use **appropriate observational constraints** to weight the likelihood of each solution

N.B. Beware 'structural constraints' built in to your chosen model family!

A Coupled GCM Ensemble for THC projections



Most parameter choices are likely to lead to large errors (climate drift) in a coupled model

To avoid drift, either:

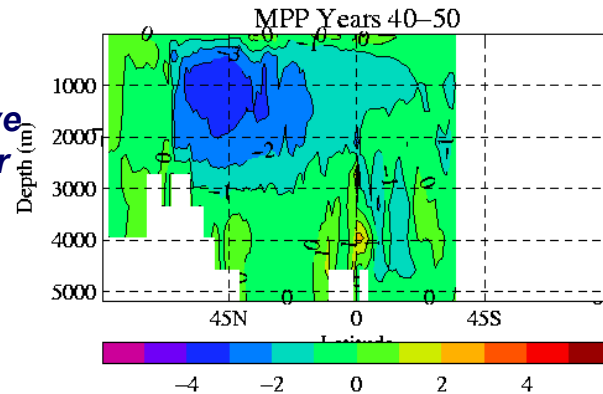
Use 'flux adjustments'

or

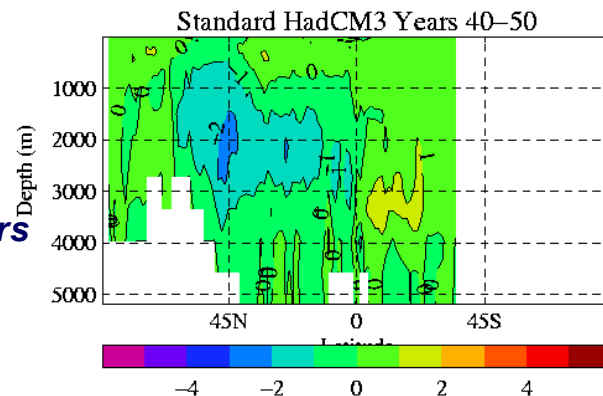
Use knowledge of global heat balance from atmosphere-only ensemble to select regions of parameter space which are likely to give good coupled simulations

Change in THC after 4 decades of 1% p.a. CO₂ increase

Alternative parameter set



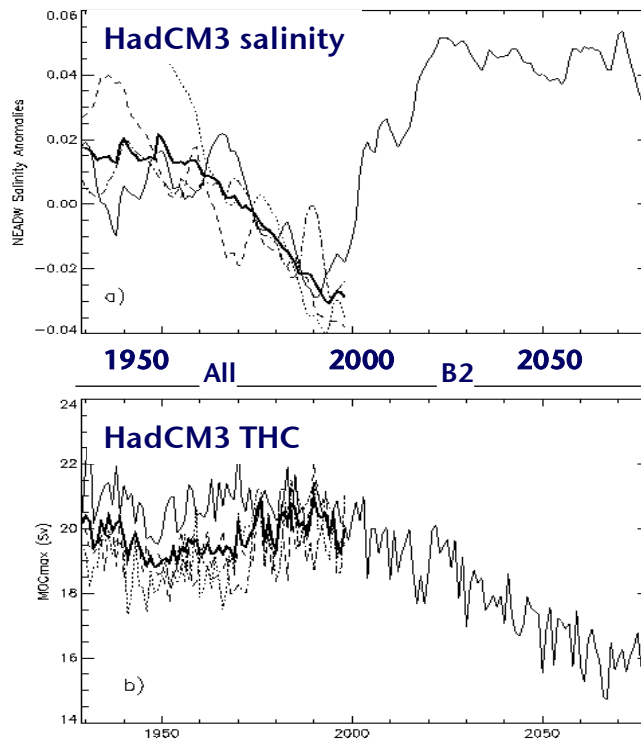
Standard HadCM3 parameters



Has the THC been weakening?



A freshening of 0.04 psu has been observed in the deep Labrador Sea since the 1960s. Is this evidence that the THC has been weakening? No.



Some large changes have been observed in the Arctic and North Atlantic oceans in recent decades. But as yet there is no evidence of a weakening THC.

Models suggest that signals of anthropogenic THC change will become detectable in the near future – provided the necessary observations are made.

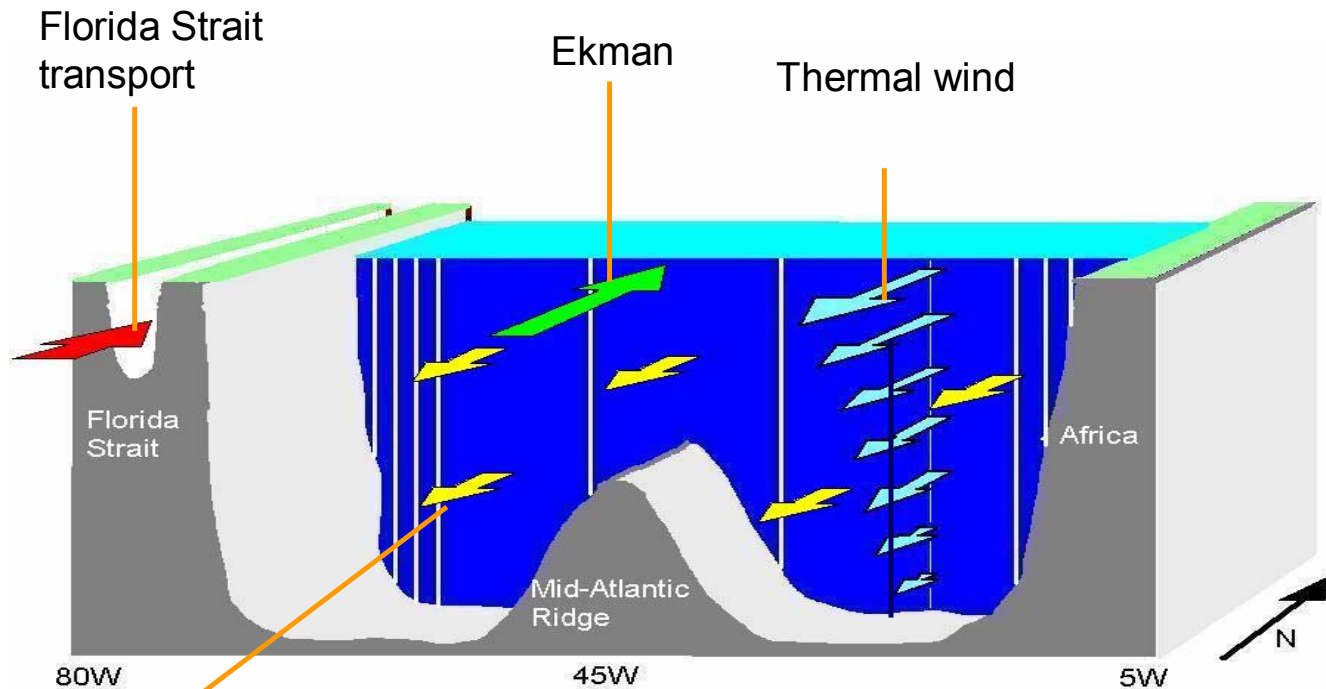
Monitoring the Overturning at 26°N



Joint NERC RAPID / NSF project

Continuous monitoring of MOC 2004-2008 (and beyond...?)

Deployed April 04. First data recovery March/April 05



Mass balance

(Hirschi et al. *GRL* 2003)

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Summary: the story so far



THC shutdown is possible in response to global warming

It could be rapid (years to decades) and/or irreversible

Climate impacts would be substantial – not just for Europe

‘High impact, low probability’ – no current GCM suggests shutdown in 21st Century under SRES forcing scenarios

No detectable THC weakening yet (consistent with model predictions)

Defining ‘safe’ stabilisation may involve pathway as well as final CO₂ concentration

Large modelling uncertainty is currently the key limiter on quantitative advice

Over the next 5 years:

- * Understand and robustly quantify current uncertainties using ensembles of (today's) state-of-the-art coupled models. Provide broad limits on 'THC-safe' stabilisation pathways
- * Define key observations to reduce uncertainty

Begin to refine understanding using early results from THC observation/monitoring systems.

Use new generation models to understand structural limitations of today's models (e.g. is it important to resolve boundary currents?)

Over the next 10 years:

- * Use *continuous* observations (*started today*) and new generation models to reduce uncertainty substantially

Begin to detect anthropogenic change in THC?



The End