The Abdus Salam
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United Nations
Educational, Scientific and
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IAEA
International Atomic Energy Agency

1986-12

WCRP and ICTP Interpreting Climate Change Simulations: Capacity Building for Developing Nations Seminar

26 - 30 November 2007

The Climate Projection Problem
&
Volunteer Computing

Claudio Piani

ICTP
Physics of Weather and Climate Group
Strada Costiera 11 P.O. Box 586
34014 Trieste
Italy

Projection

The Climate ~~Prediction~~ Problem

&

Volunteer Computing

ICTP, Earth System Physics, 2007

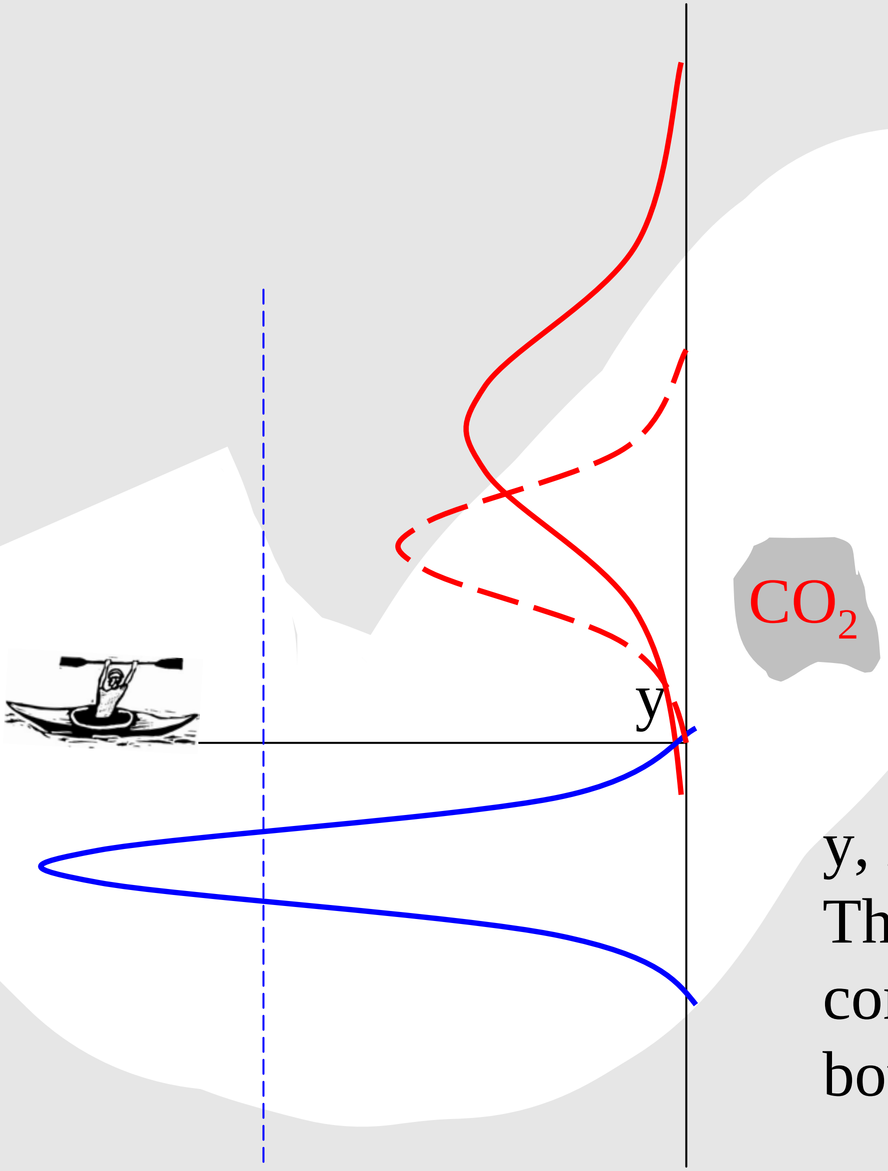
Claudio Piani

Outline

- Response to external forcing VS initial condition problem.
- End-user requirements. Decision making.
  - Risk and probability
- Distributed computing.
  - ClimatePrediction.net
  - Some study examples
- Climate sensitivity (final word).

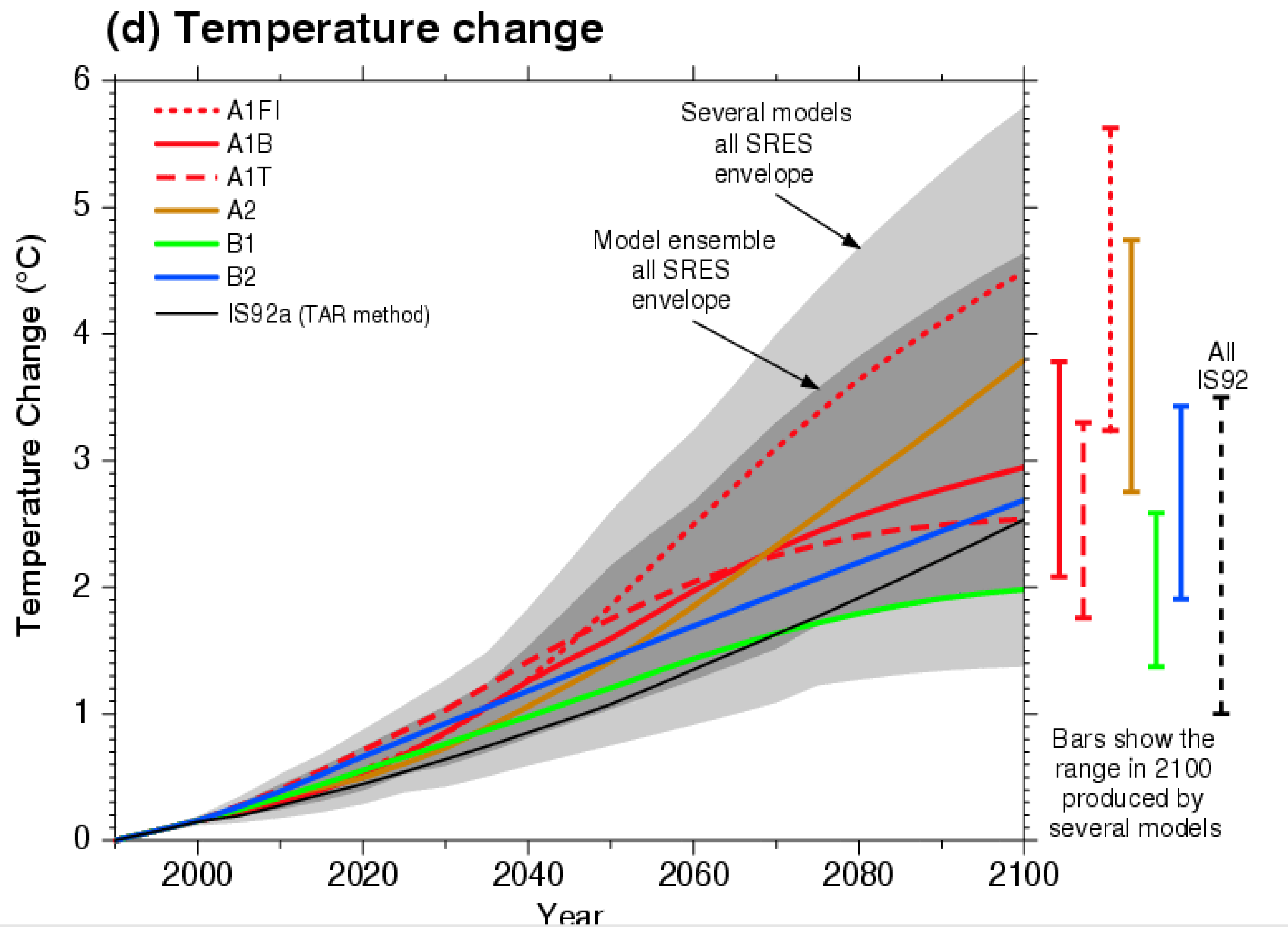
Initial condition vs boundary condition problem
How can we predict where the boat will end up?

Let’s simplify the problem…



y, is our climate variable.
The blu forecast depends on initial conditions. The red one depends on boundary conditions.

Emissions: the dominant source of boundary condition uncertainty



Why do we produce PDFs of future climate?

- Not just because it is the proper scientific framework.

- Because mitigation and adaptation strategists are concerned with risk and have no use for a forecasts without the associated uncertainty.

Public policy decisions

Are we being flooded?

Depends on your prior assumptions.

Why do we produce PDFs of future climate?

Because risk is couched in probabilistic terms.

Risk (event occurrence)= Damage (event) x probability (occurrence)

Example (crude and fictitious)

Event: Flooding intense enough to compromise dikes over next 50 years.

Damage=100 Ge

Probability (strength of dikes, climate change)=1%

Risk=1 Ge

How can we reduce risk?

Storm surge in East Anglia
UK, 1953

Storm surge in East Anglia
UK, Nov. 2007

15-20 million pounds spent a year in sea defences

Why do we produce PDFs of future climate?

Try reducing the probability

A) Adaptation policy = strengthen dikes (cost 0.01 Ge)

reduces probability 99%: Δrisk= risk x 99%= 0.99 Ge

Percentage gain = 0.99/0.01≈100

B) Mitigation policy = reduce CO_2 concentrations (cost ?? Ge)

reduces probability ??%: Δrisk= ??

Try reducing the damage

C) Adaptation policy = build away from flood plains (cost 0.1 Me)

Reduces damage 80%: Δrisk= risk x 80%= 0.8 Ge

Percentage gain = 0.8G/0.1M≈8000

C) is the best deal but you can't buy enough Δrisk.

A) Is more expensive but effective.

Catch: once you've done C, % gain of A drops to 20!!!

At a slightly more complex level:

Probabilities are time dependent

Damages have discount rates

Why do we produce PDFs of future climate?

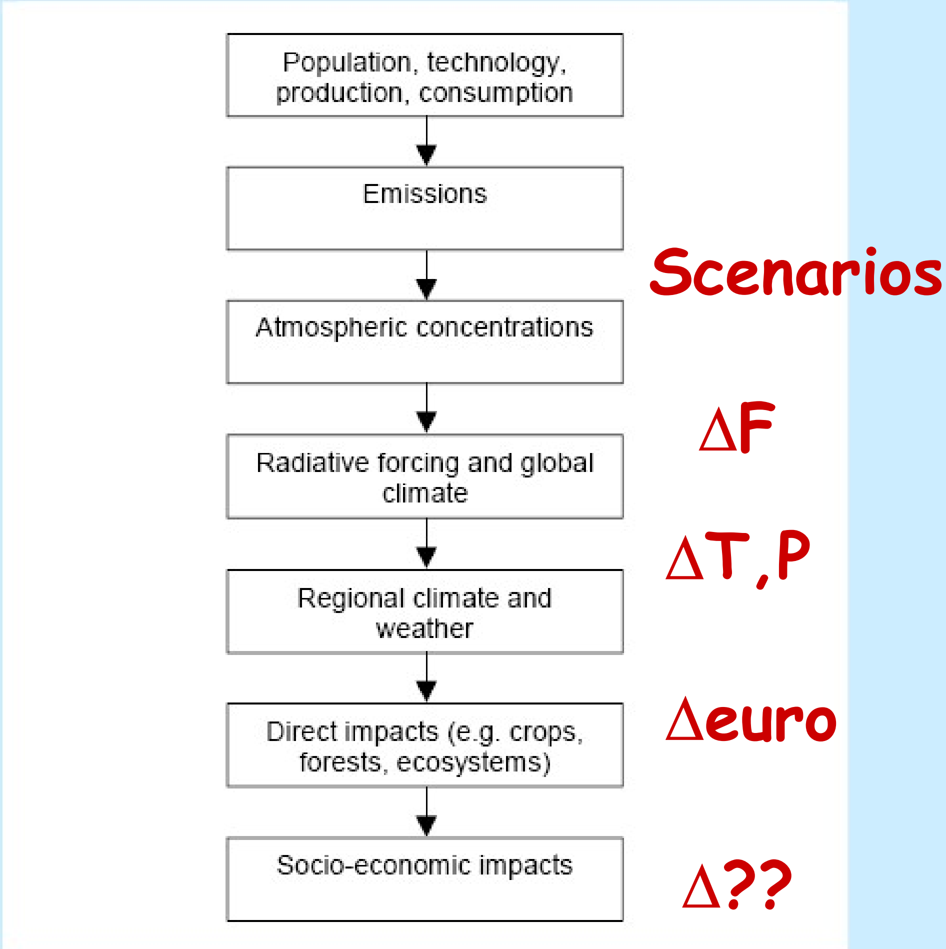
At a far more complex level:

Integrated Assessment Models (IAMs) try to account for all aspects of environmental, economic and social issues related to climate change impacts.

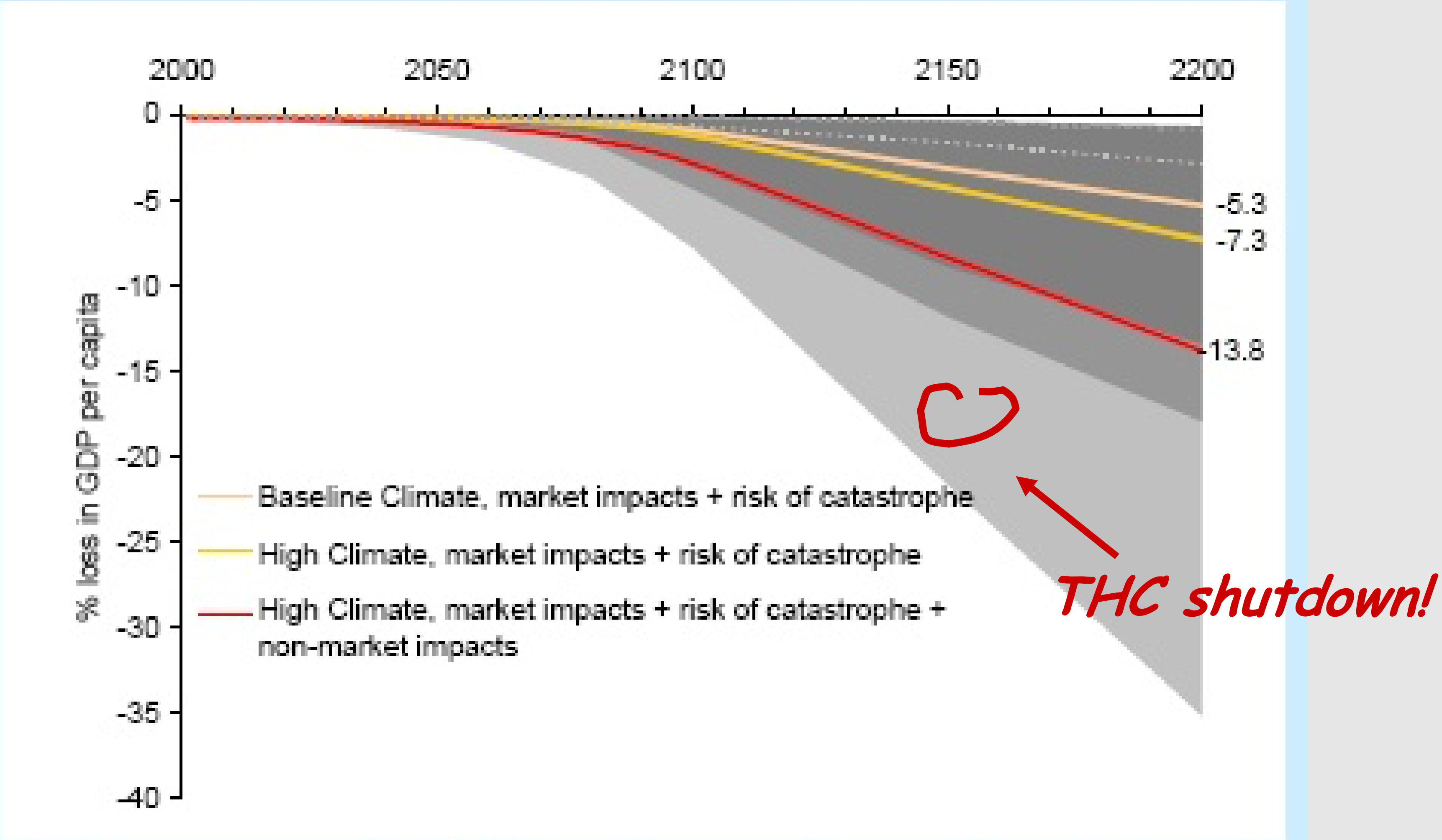
"*Making such estimates is a formidable task… with the result that such models must make drastic, often heroic, simplifications*…"
(Stern Review: The economics of climate change, 2006)

Figure 6.1 Modelling climate change from emissions to impacts.

This figure describes a simple unidirectional chain. This is a simplification as, in the real climate-human system, there will be feedbacks between many links in the chain.



Source: Hope (2005).

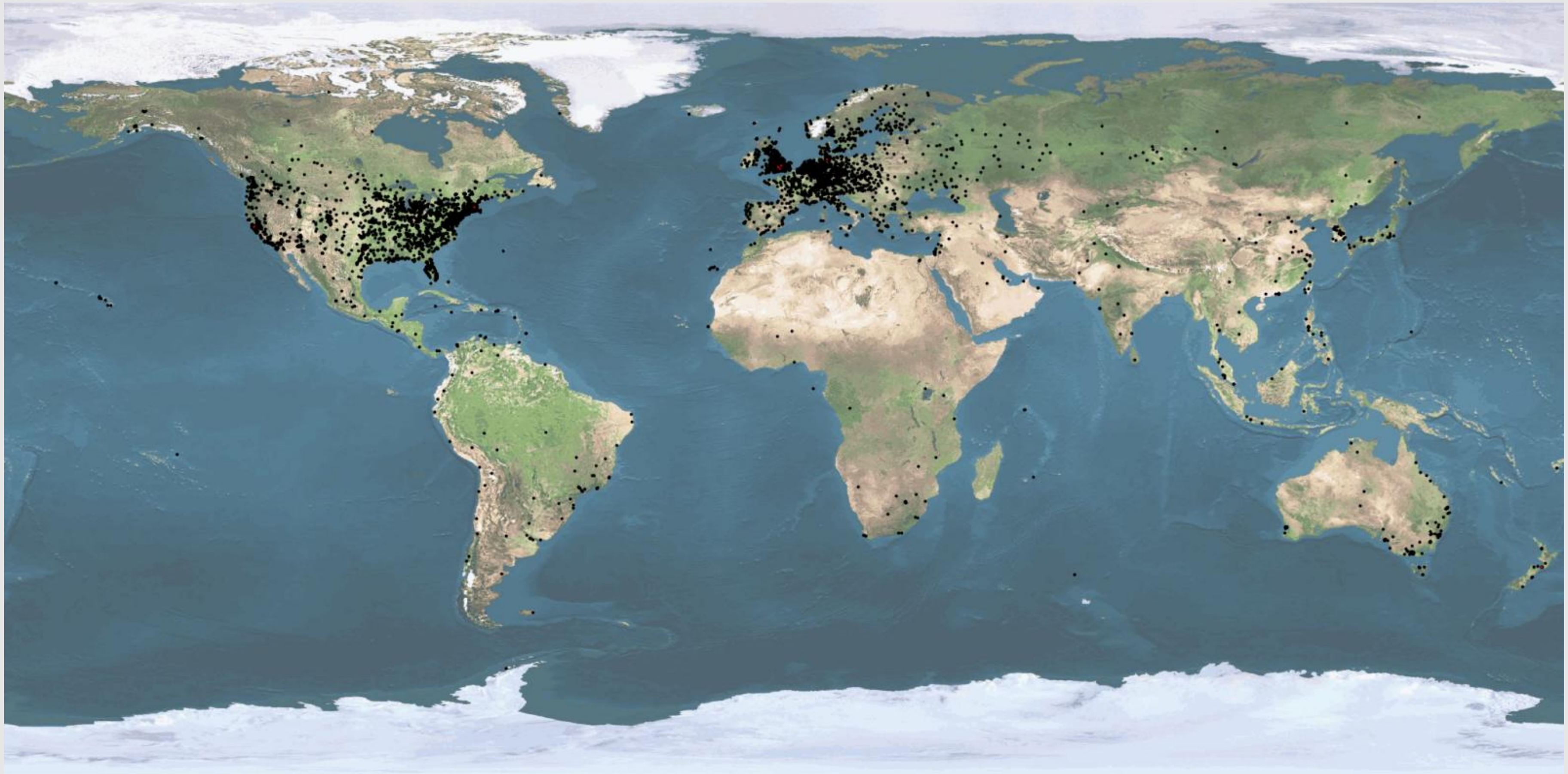


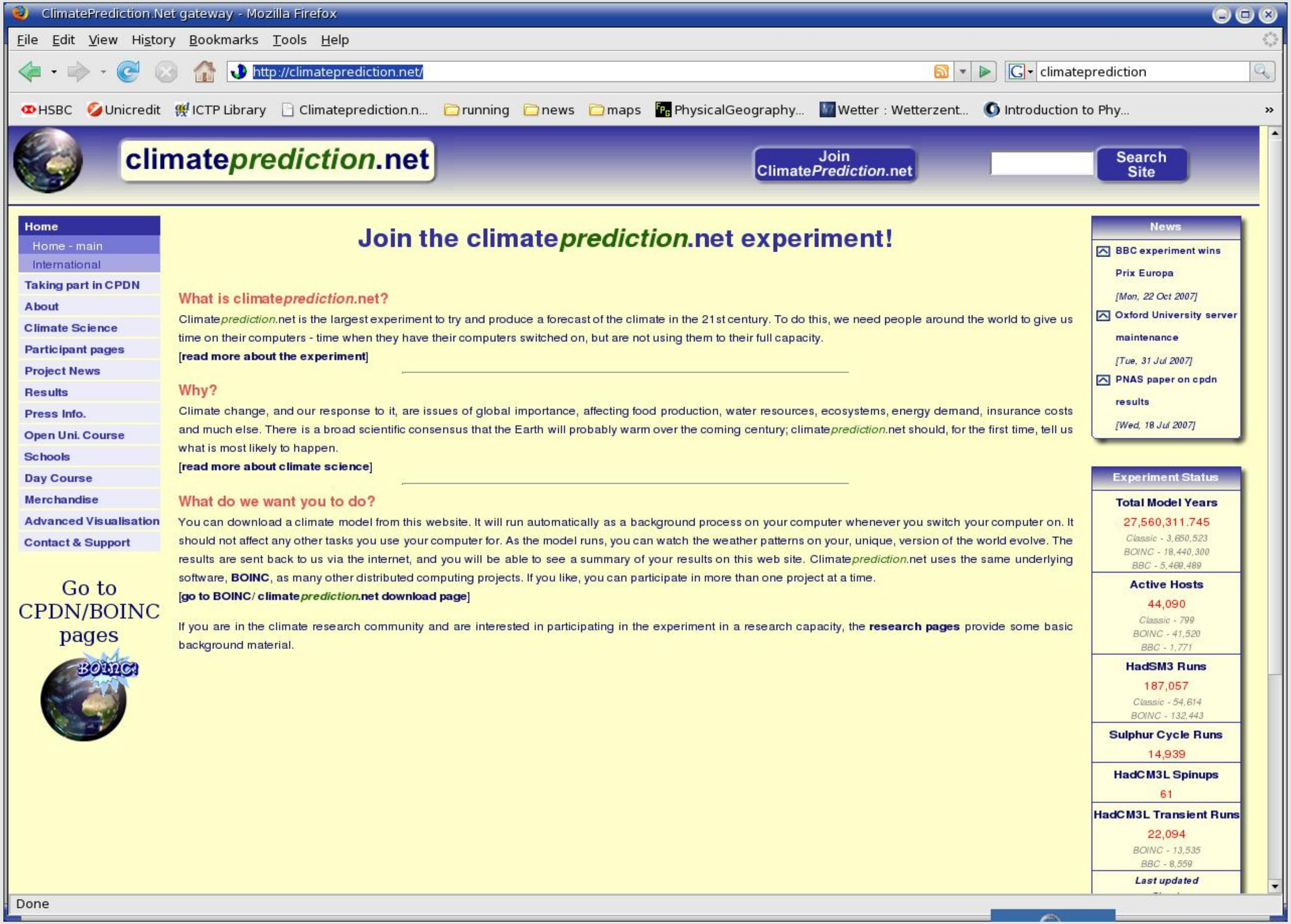
Loses in income per capita due to climate change over the next 200 years. The shaded areas represent 5% to 95% uncertainty range. (Stern review, 2006)

Why do we produce PDFs of future climate?

- Probabilistic results are required because decisions will be taken regardless.
- The most pressing needs involve regional scales and extreme events.
- To ignore all modeling results is a decision tantamount to assuming infinite uncertainty.
- To forgo any action is tantamount to deciding that climate change is not occurring.

climateprediction.net




ClimatePrediction.Net gateway - Mozilla Firefox
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http://climateprediction.net/
climateprediction
HSBC Unicredit ICTP Library Climateprediction.n... running news maps PhysicalGeography... Wetter : Wetterzent... Introduction to Phy...
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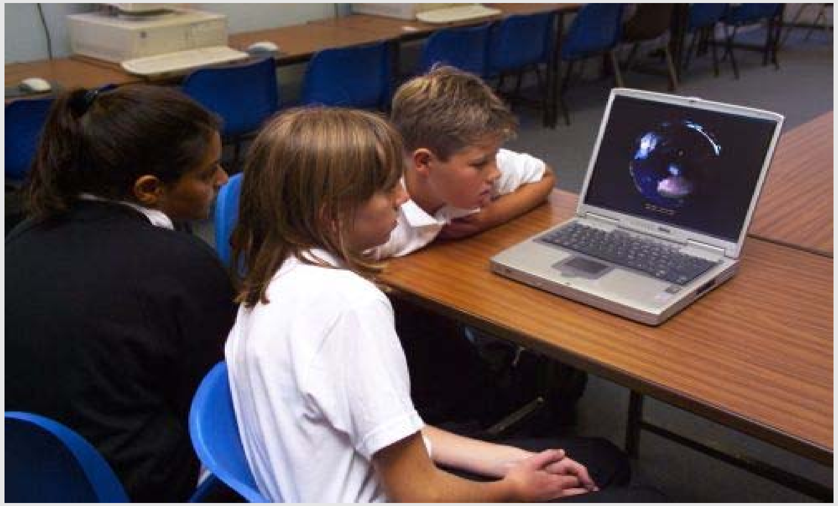
Taking part in CPDN
About
Climate Science
Participant pages
Project News
Results
Press Info.
Open Uni. Course
Schools
Day Course
Merchandise
Advanced Visualisation
Contact & Support
Go to CPDN/BOINC pages
BOINC
Join the climateprediction.net experiment!
What is climateprediction.net?
Climateprediction.net is the largest experiment to try and produce a forecast of the climate in the 21st century. To do this, we need people around the world to give us time on their computers - time when they have their computers switched on, but are not using them to their full capacity.
[read more about the experiment]
Why?
Climate change, and our response to it, are issues of global importance, affecting food production, water resources, ecosystems, energy demand, insurance costs and much else. There is a broad scientific consensus that the Earth will probably warm over the coming century; climateprediction.net should, for the first time, tell us what is most likely to happen.
[read more about climate science]
What do we want you to do?
You can download a climate model from this website. It will run automatically as a background process on your computer whenever you switch your computer on. It should not affect any other tasks you use your computer for. As the model runs, you can watch the weather patterns on your, unique, version of the world evolve. The results are sent back to us via the internet, and you will be able to see a summary of your results on this web site. Climateprediction.net uses the same underlying software, BOINC, as many other distributed computing projects. If you like, you can participate in more than one project at a time.
[go to BOINC/ climateprediction.net download page]
If you are in the climate research community and are interested in participating in the experiment in a research capacity, the research pages provide some basic background material.
News
BBC experiment wins Prix Europa
[Mon, 22 Oct 2007]
Oxford University server maintenance
[Tue, 31 Jul 2007]
PNAS paper on cpdn results
[Wed, 18 Jul 2007]
Experiment Status
Total Model Years
27,560,311.745
Classic - 3,650,523
BOINC - 18,440,300
BBC - 5,469,489
Active Hosts
44,090
Classic - 799
BOINC - 41,520
BBC - 1,771
HadSM3 Runs
187,057
Classic - 54,614
BOINC - 132,443
Sulphur Cycle Runs
14,939
HadCM3L Spinups
61
HadCM3L Transient Runs
22,094
BOINC - 13,535
BBC - 8,559
Last updated
Done

Volunteer Computing

- A specialized form of “distributed computing” which is really an “old idea” in computer science -- using remote computers to perform a same or similar tasks
- Was around before '99 but took off with SETI@home
- S@H capacity with 500K users about 1 PF = 1000 TF
- for comparison Earth Sim in Kyoto = 35TF max
- CPDN running at about 60 TF (30K users each 2GF machine average, i.e. PIV 2GHz)

Educational Outreach

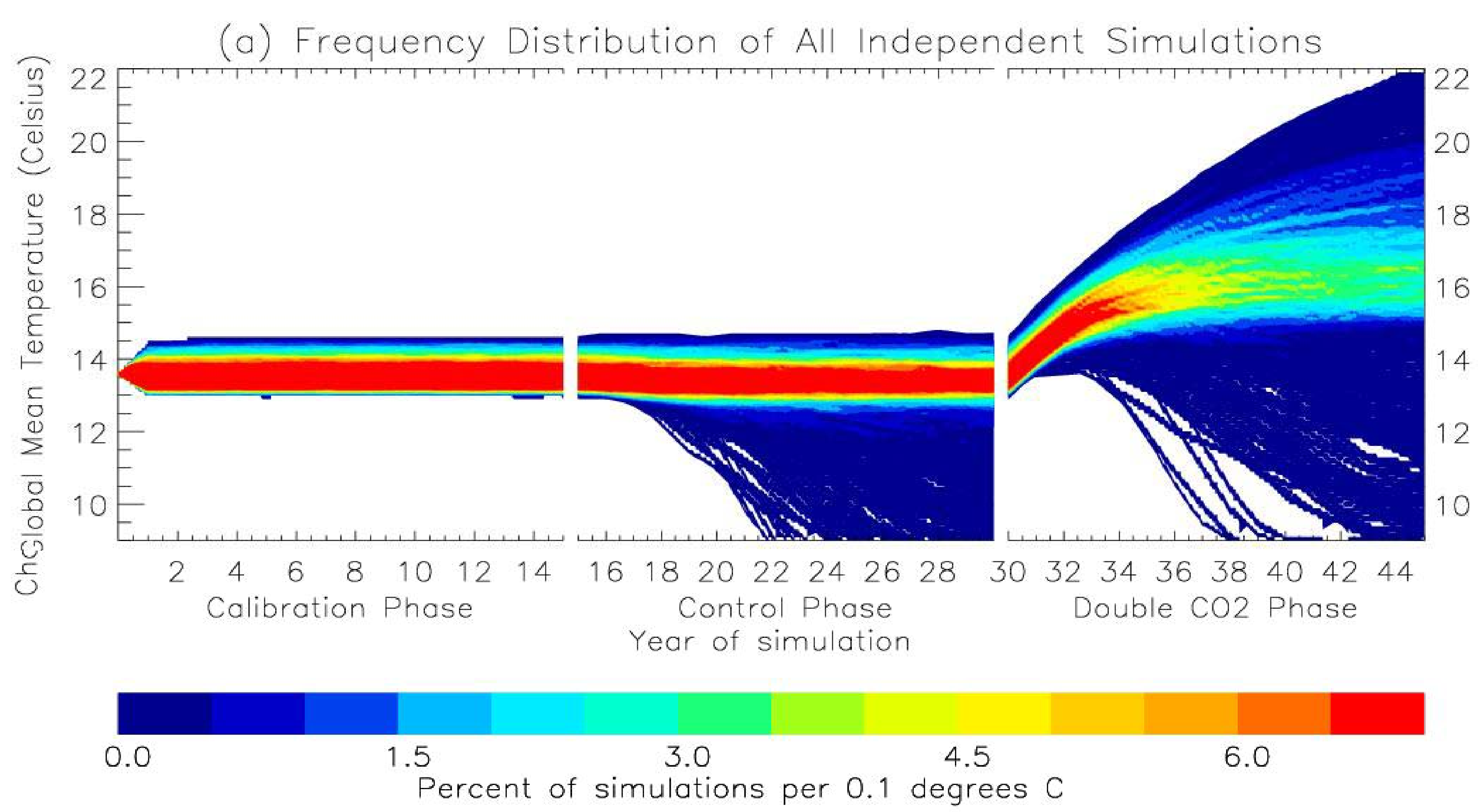
- **CPDN has public education via the website, media, and schools as an important facet of the project**
- **Website has much information on climate change and related topics to the CPDN program.**
- **Schools are running CPDN and comparing results, especially during National Science Week, with special events at U Reading.**
- **Students will host a debate on climate change issues, compare and contrast their results etc.**



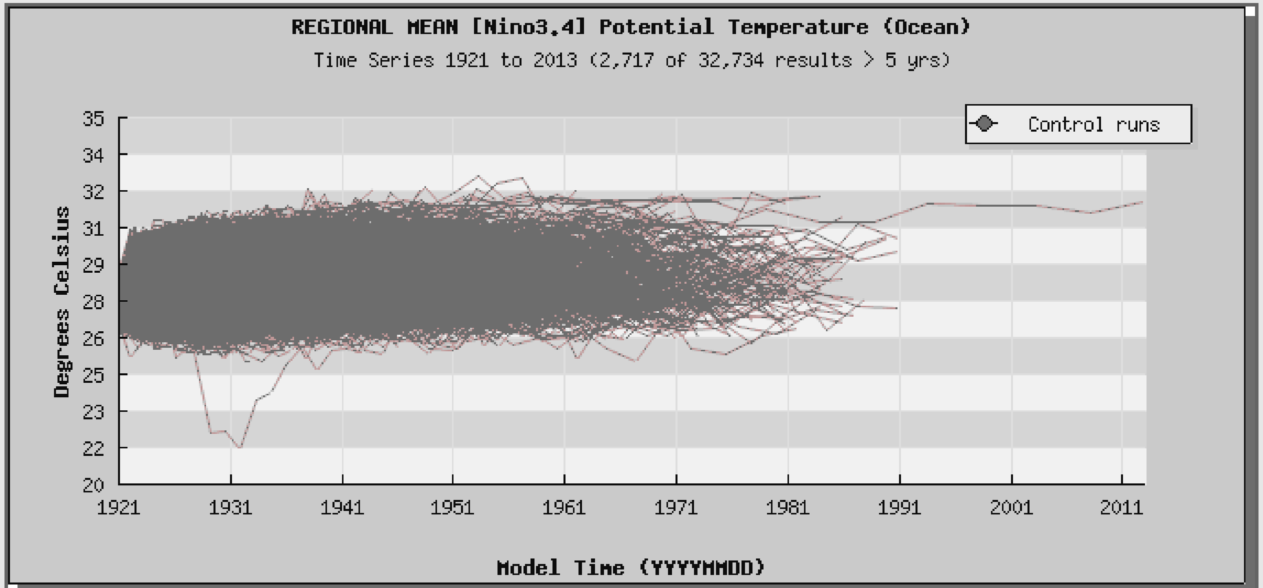
- Currently focused on UK schools, but as projects added and staff resources are gained plan to expand to other schools worldwide.

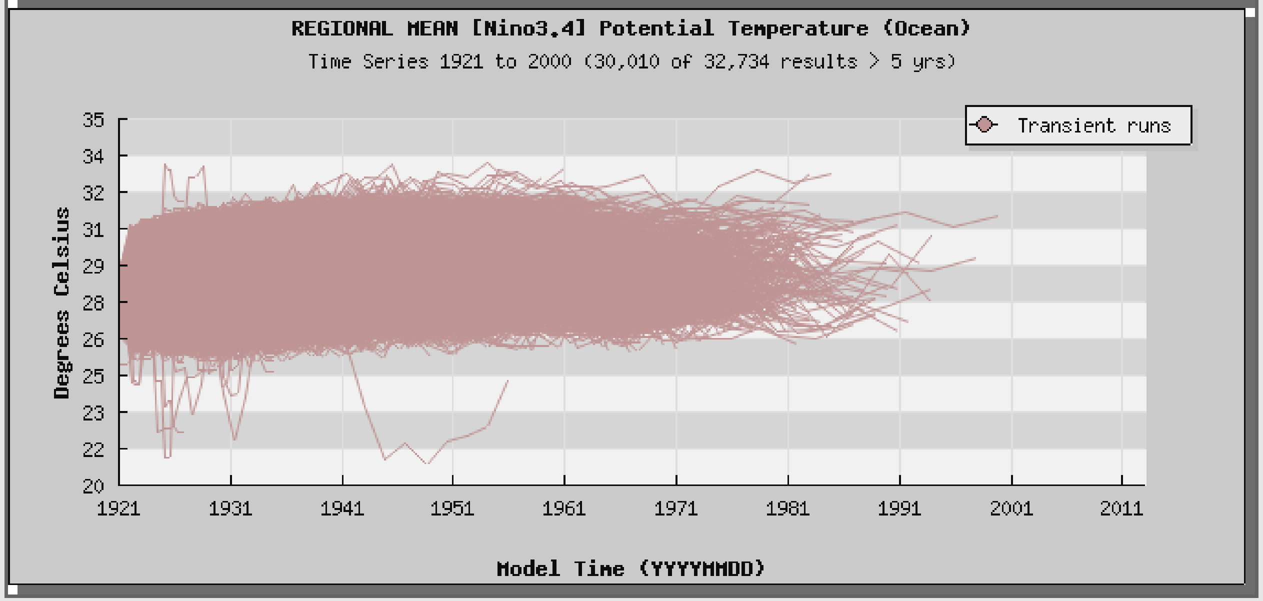
Students at Gosford Hill School, Oxon viewing their CPDN model

Frequency Distribution of Simulations



Over 50,000 active participants running HadCM3L, 1920-2080





Examples
Selected results from THC experiment

**Nick Faull, Tolu Aina, Dave Frame,
Mat Collins, S. Knight,
J. Kettleborough, D. Stainforth,
C. Christensen, M. Allen**

Motivation

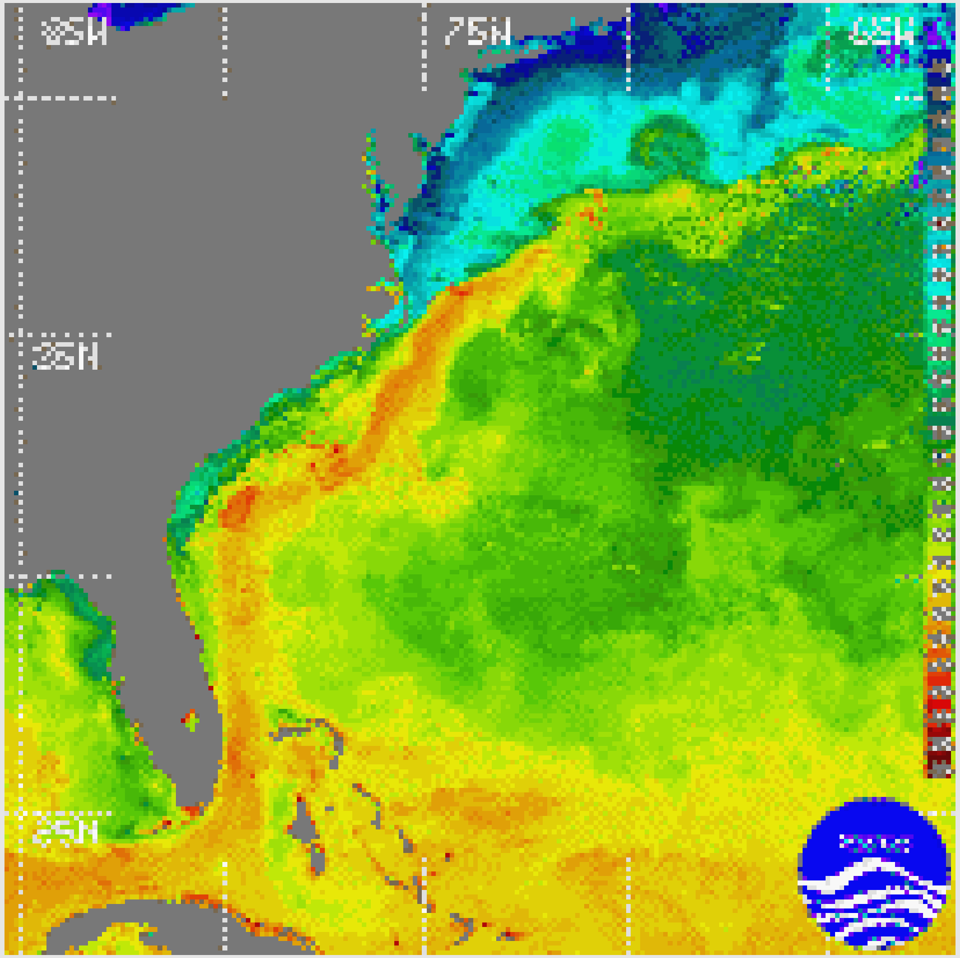
"Extreme scenarios make great films, but for practical planning we need to know how likely it is that such events will actually happen"

What is the THC?

- The THC is a global ocean current driven by heat and salt

- It is partly responsible for bringing warm tropical water into the North Atlantic. This gives us a warmer climate than we would otherwise have in Northern Europe

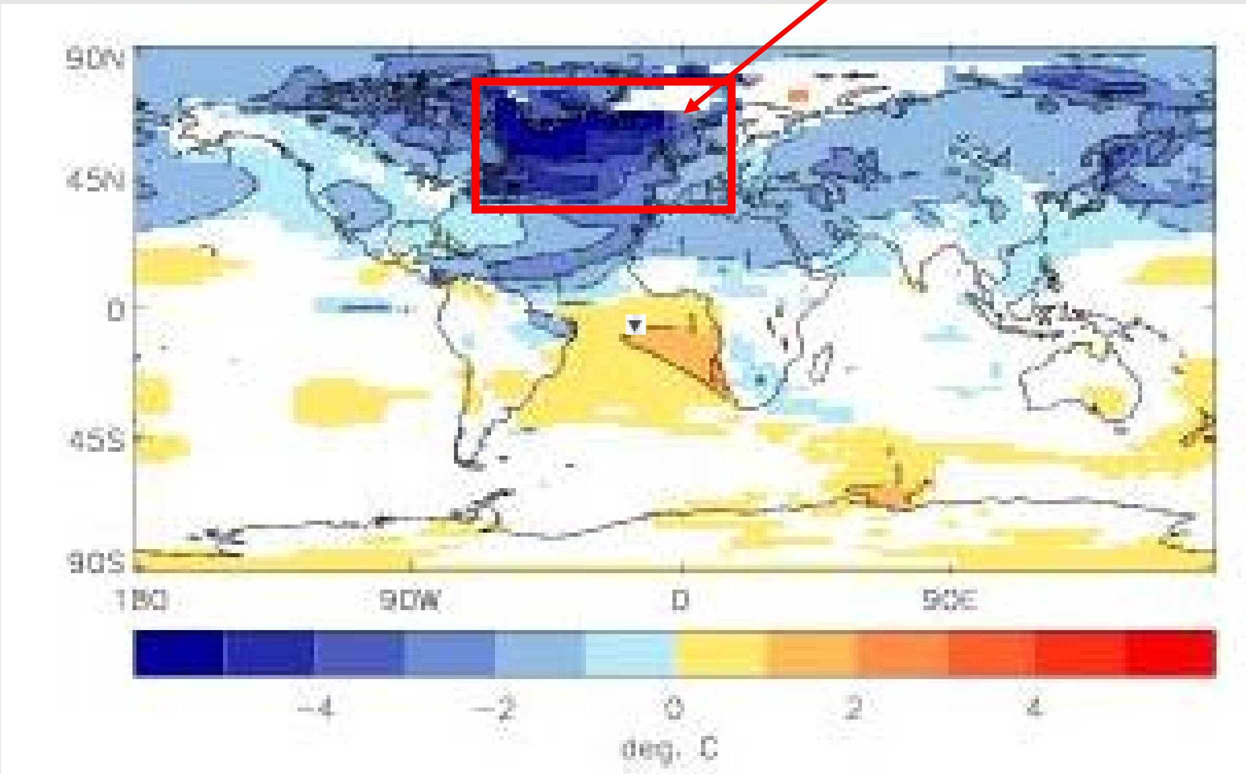
- What happens if it collapses…?



THC collapse

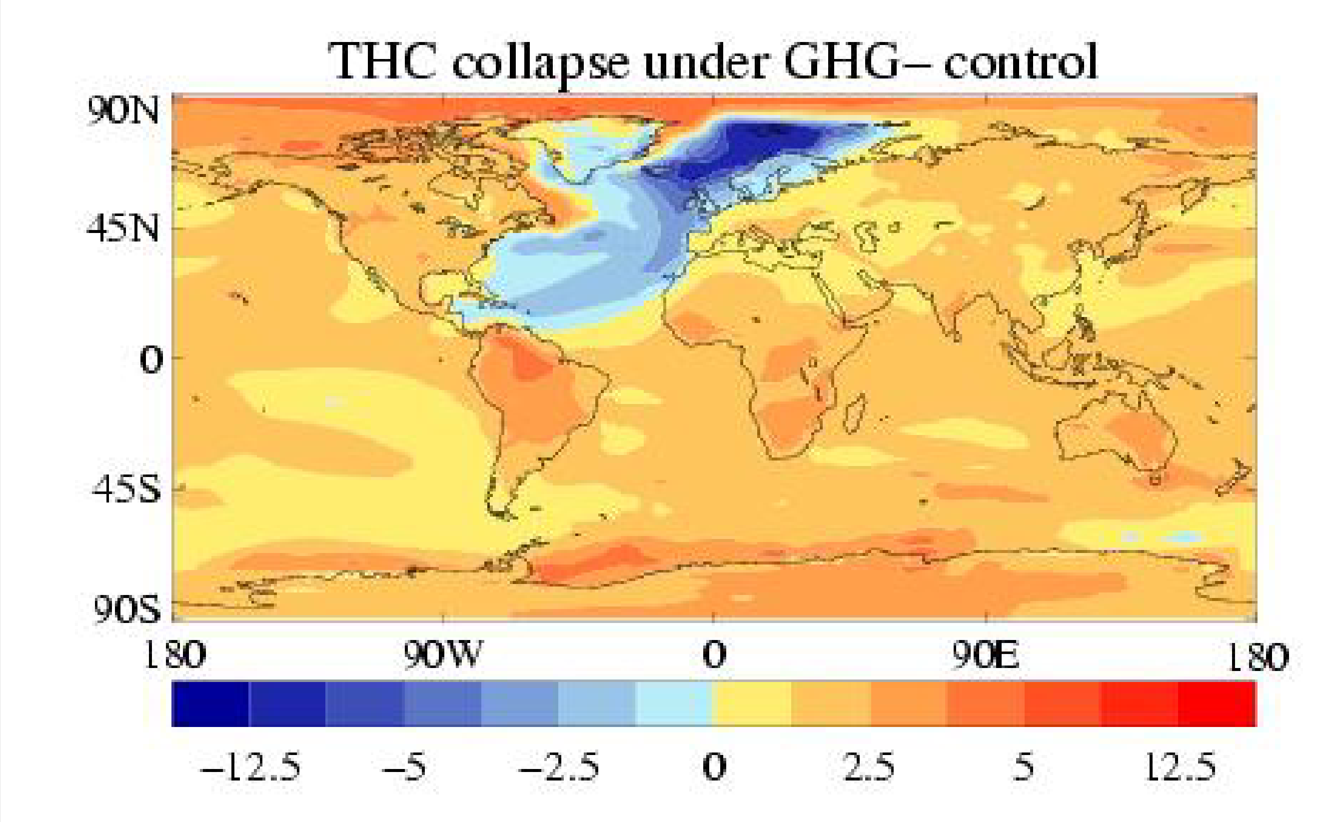
- **Vellinga and Wood (2001)**

6x10^{14} m^{3} fresh water pulse
~1/10th Greenland ice sheet



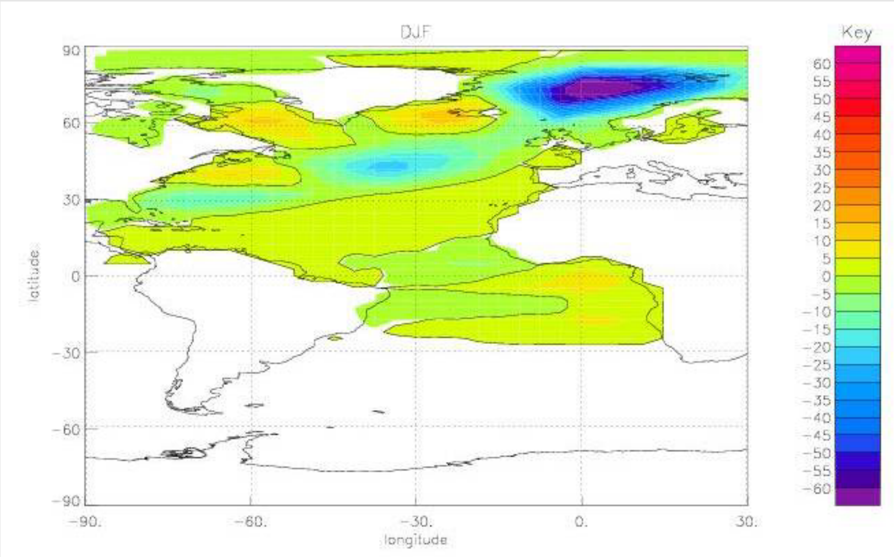
THC collapse under GHG

- **Vellinga (2004)**



Method

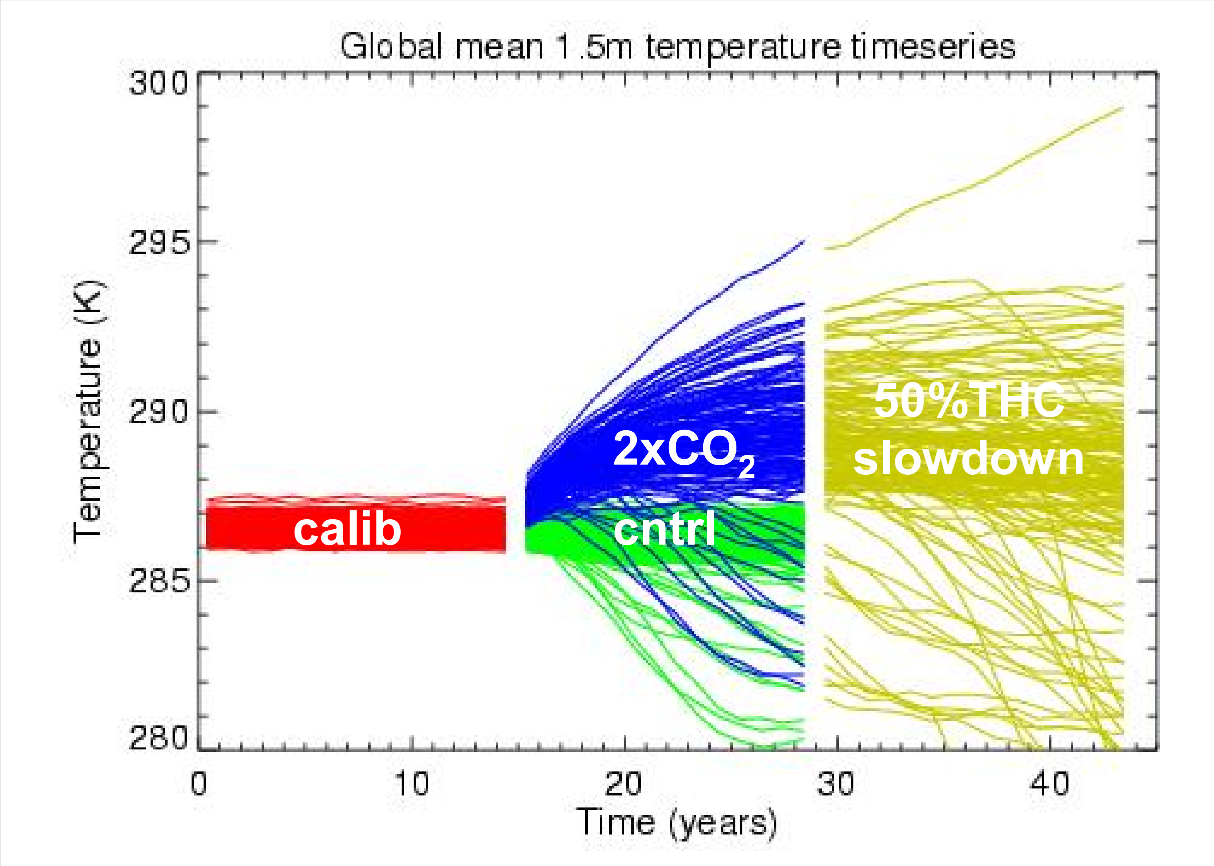
Palmer (2002), worked out an ocean heat flux anomaly field equivalent to a 50% slowdown of the THC



What effect does this have on the atmosphere in the Model?

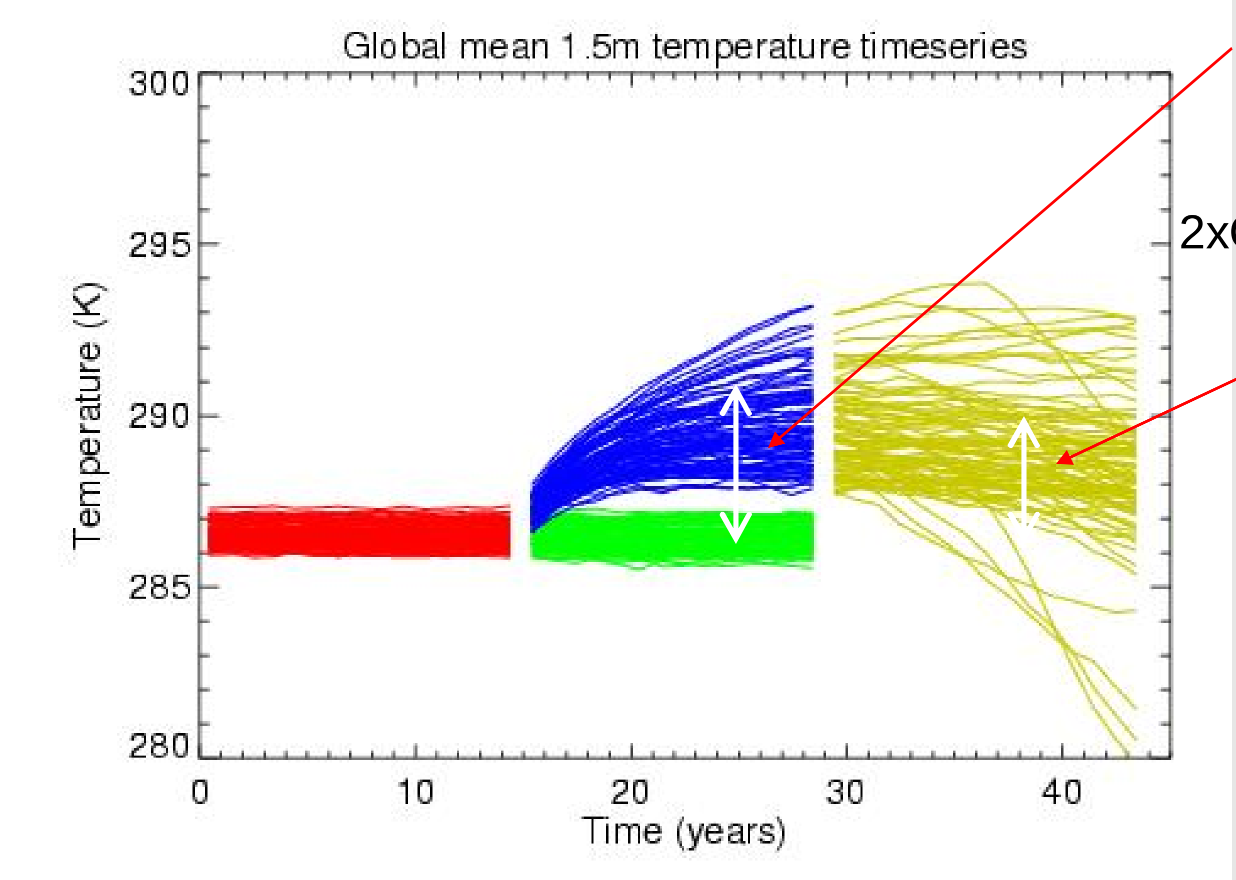
First results

- **155 model runs from perturbed physics ensemble**



First results

- 89 model runs, filtered out drifting controls

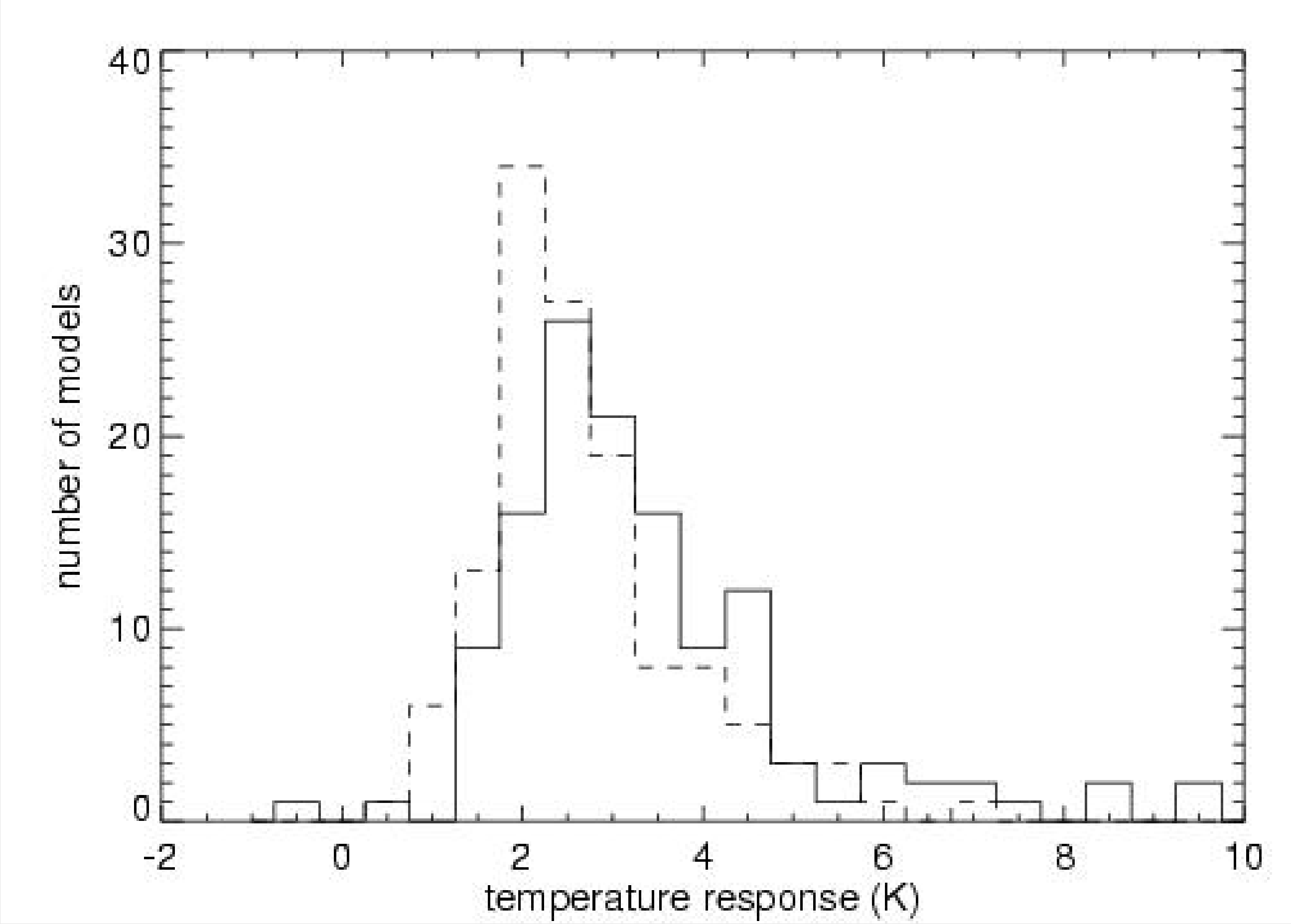


$2xCO_2$ response

$2xCO_2$ + 50%THC response

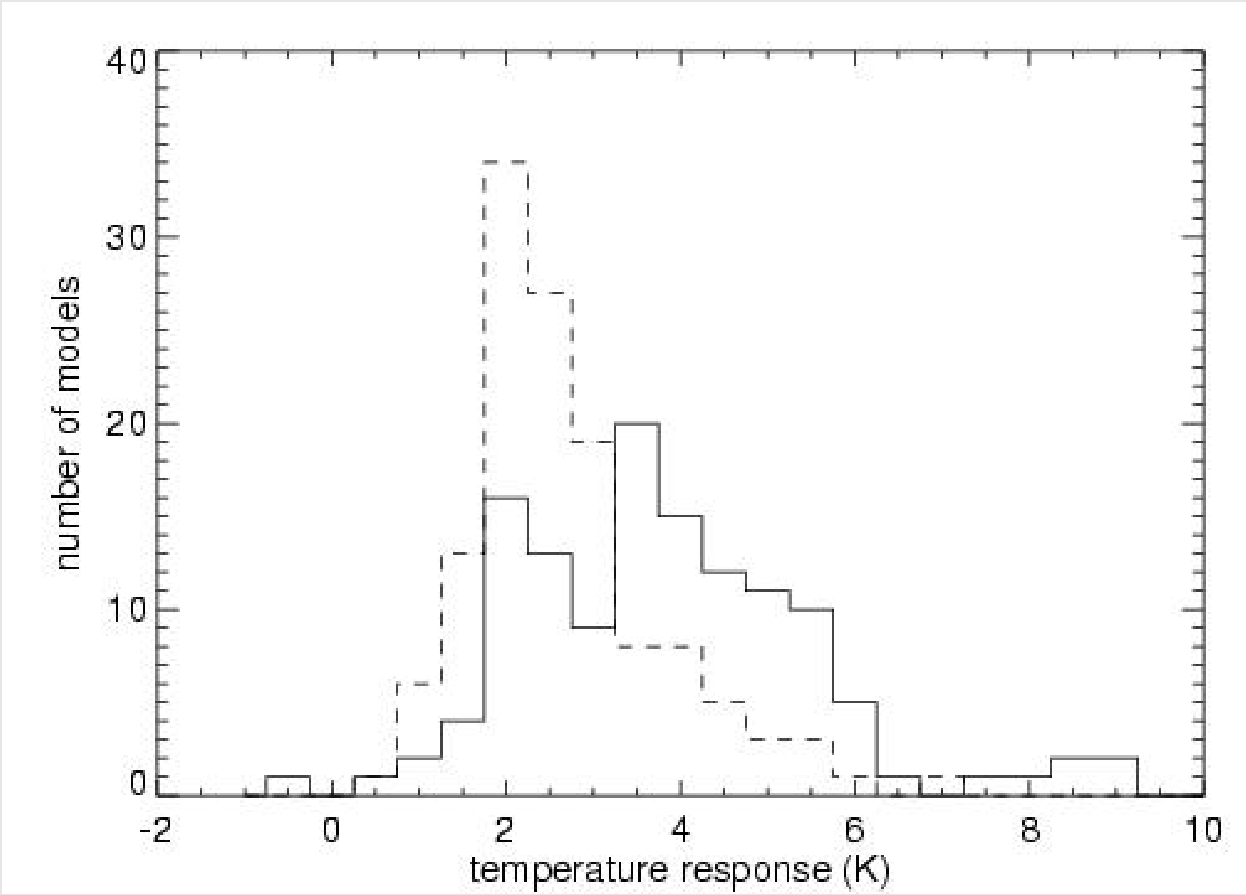
Global

- **Surface temperature response**



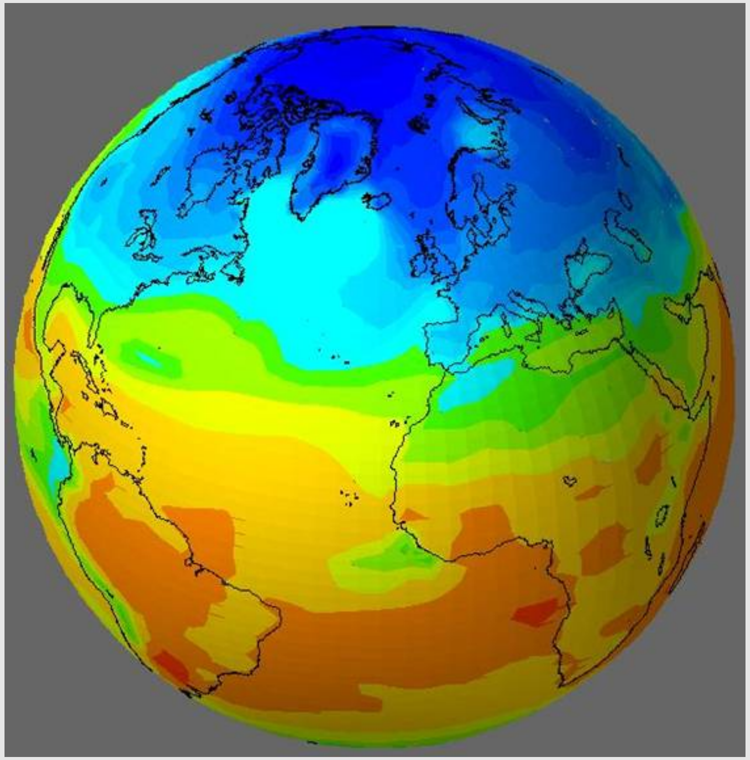
North European region

- **NEU land surface temperature response**

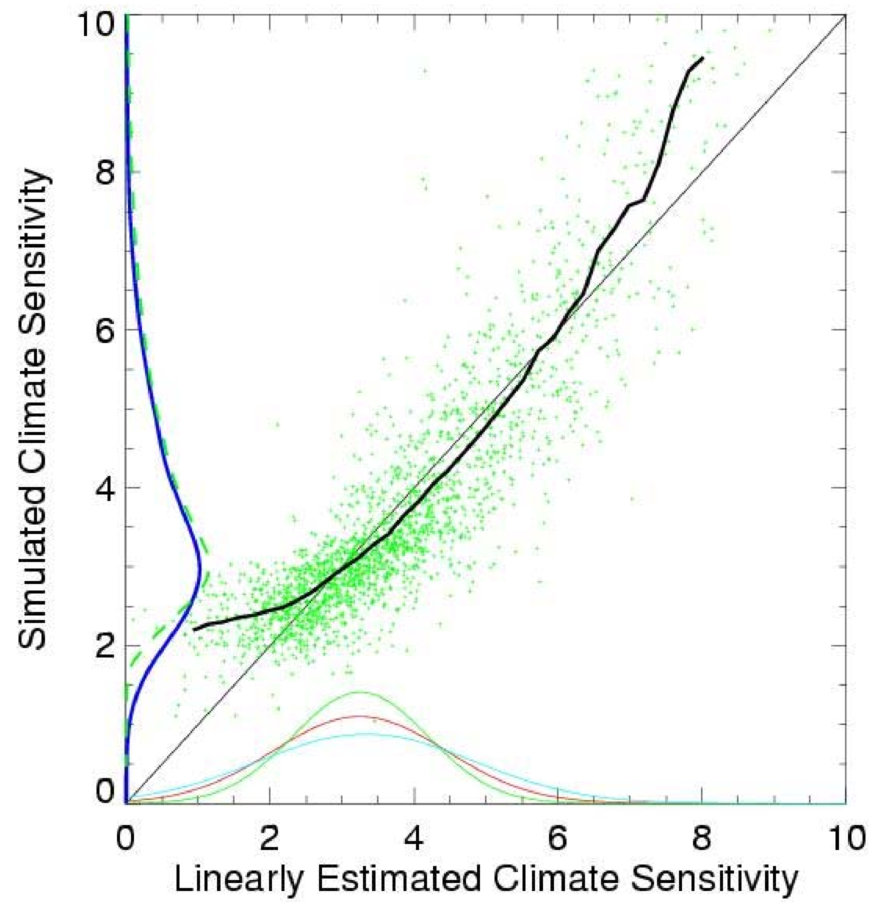


Summary

- Significant cooling response in NEU region to THC slowdown.
- Northern Europe could offset global warming consequences by melting Greenland.

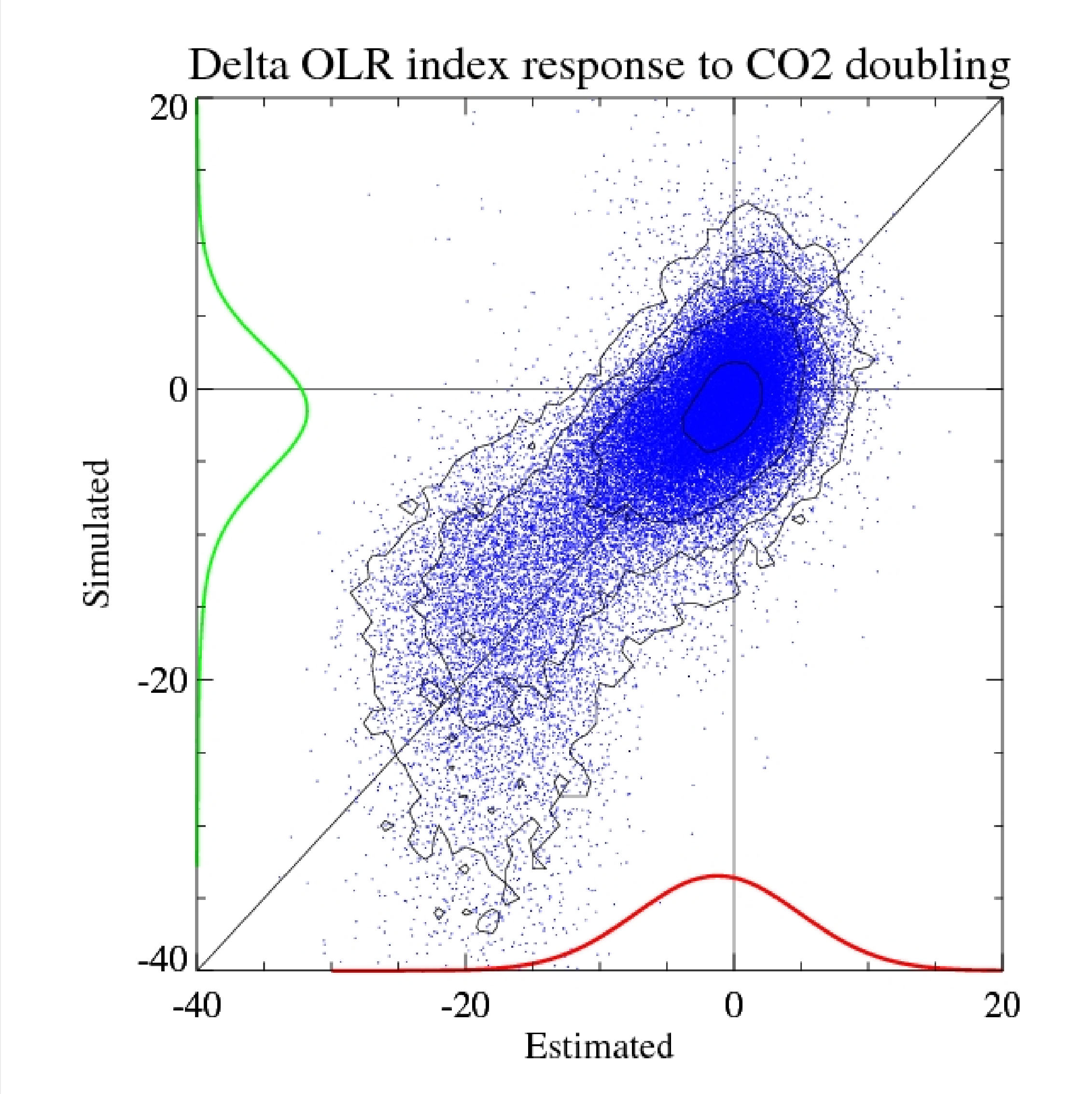


PDF of climate sensitivity from ~2000 models from CPDN.

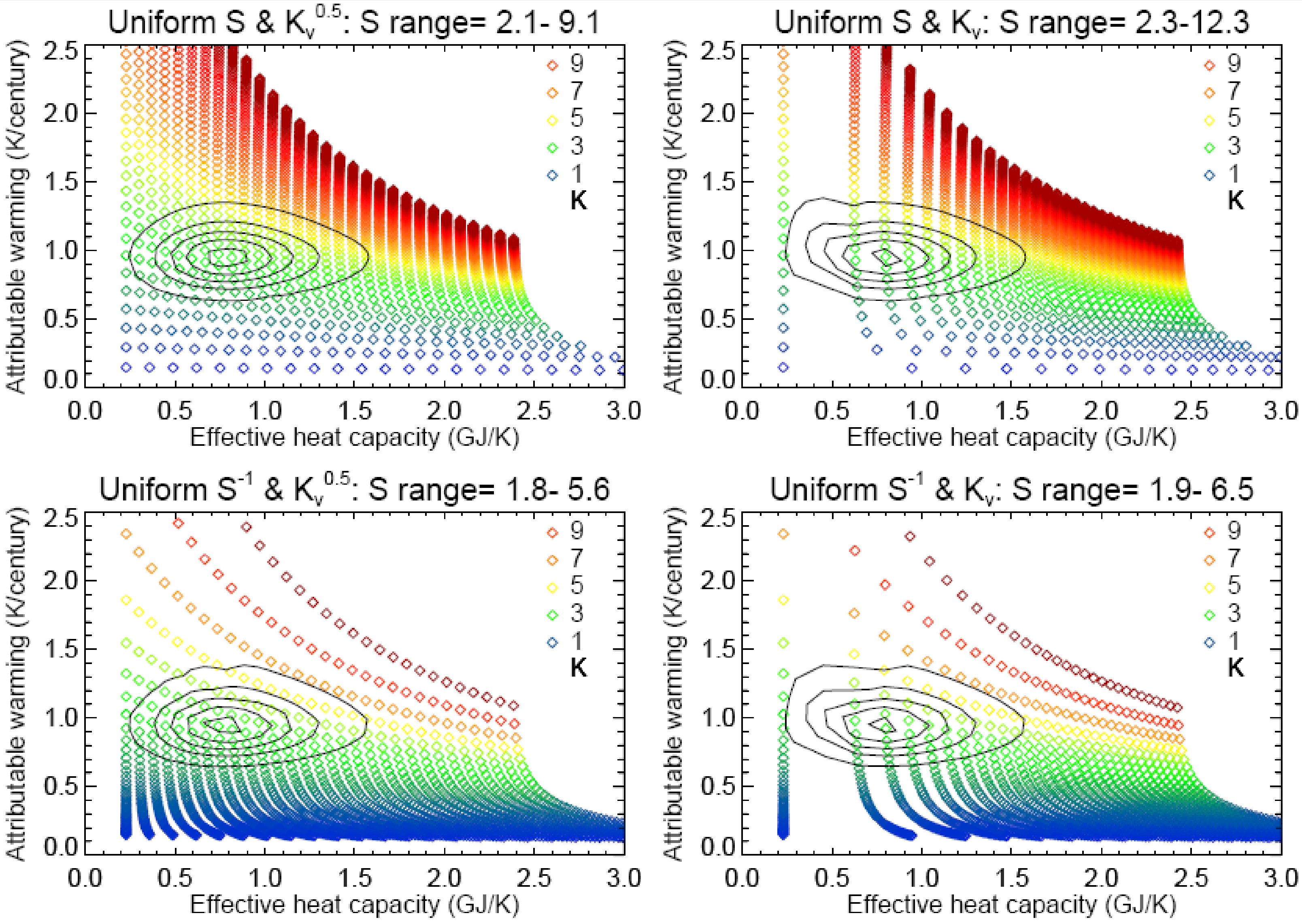


Piani et al. 2005

Another rexample: constraining monsoon response to CO2 doubling with 50694 models.



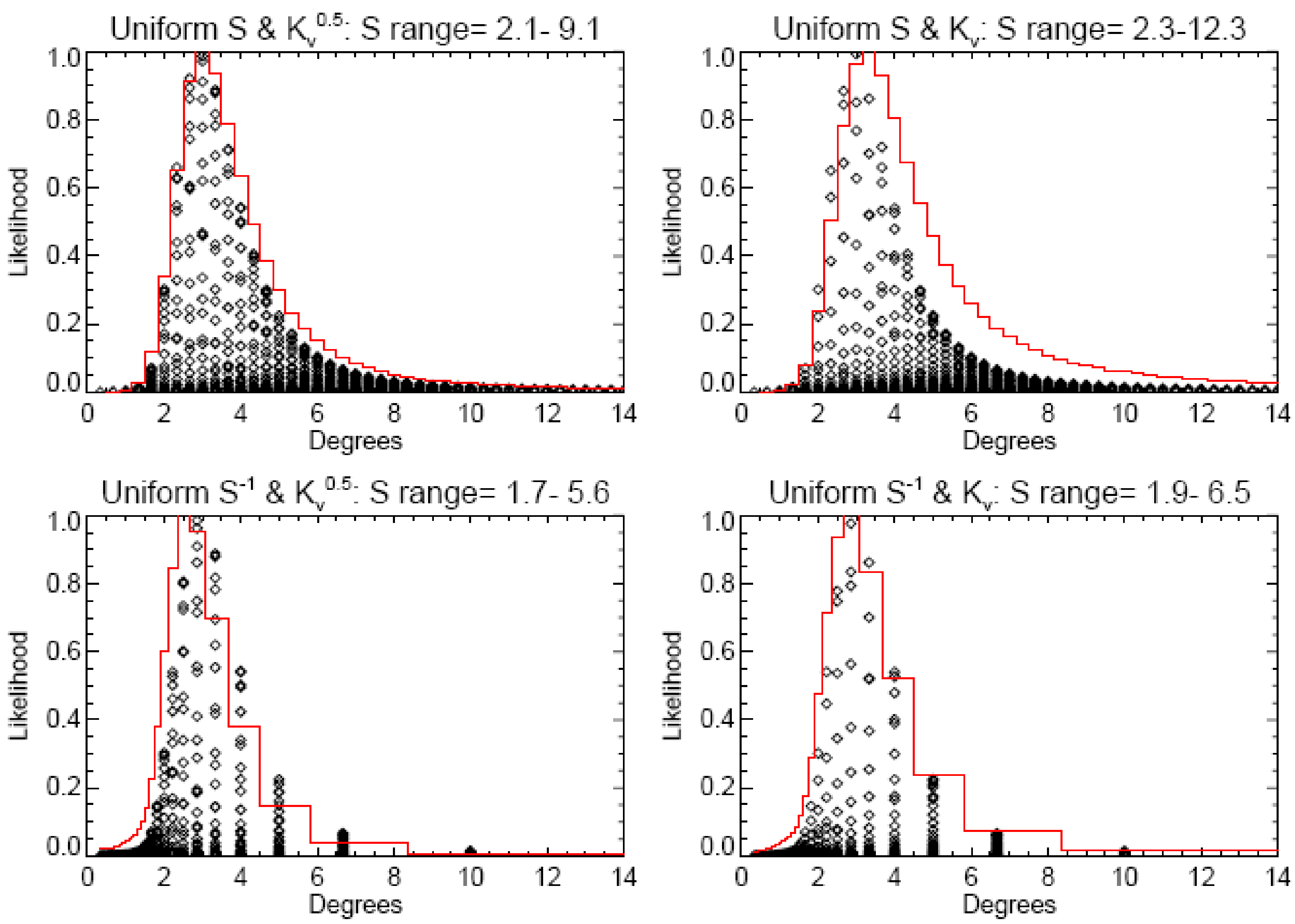
Impact of parameters sampling strategies



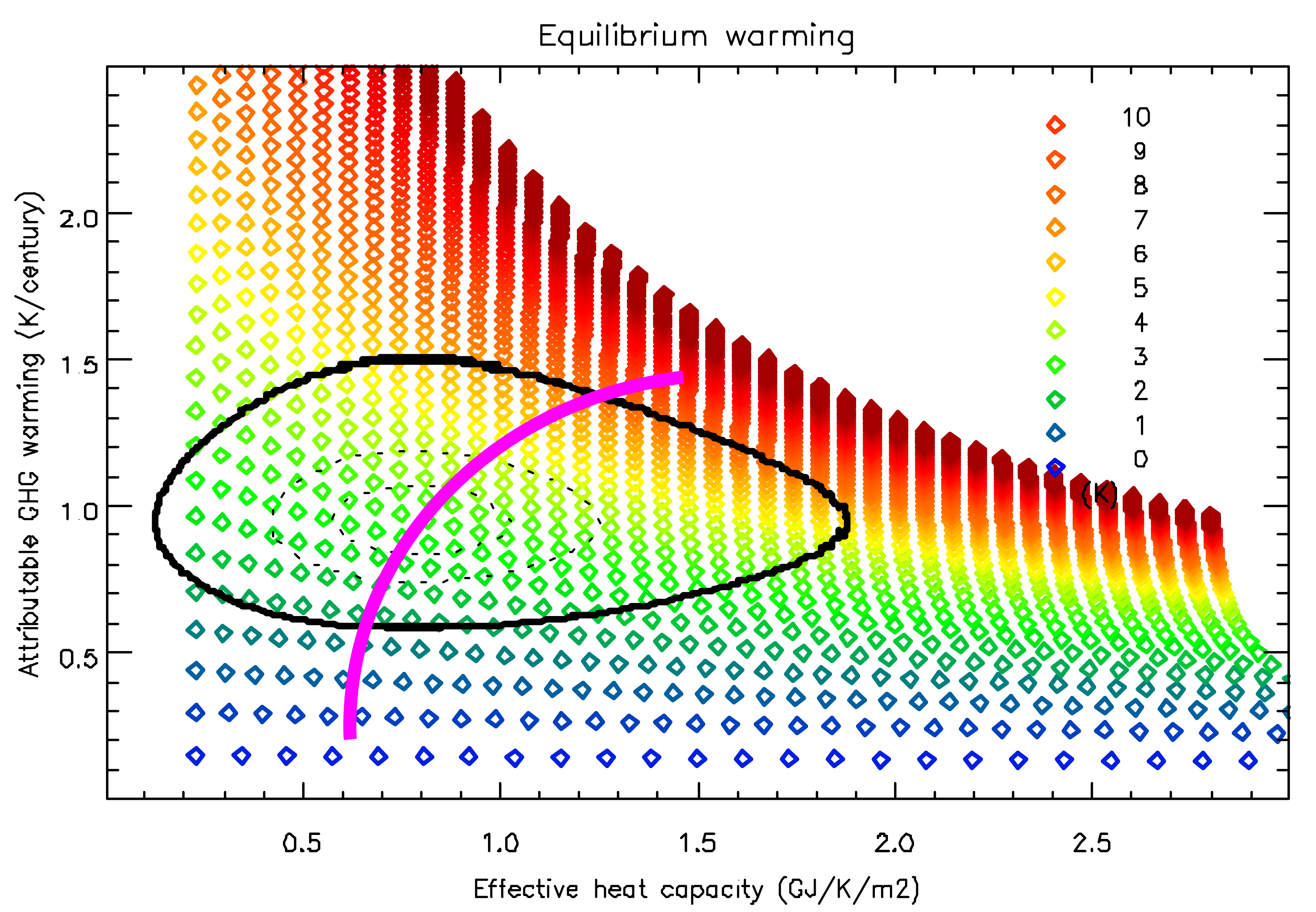
climateprediction.net

Oxford University

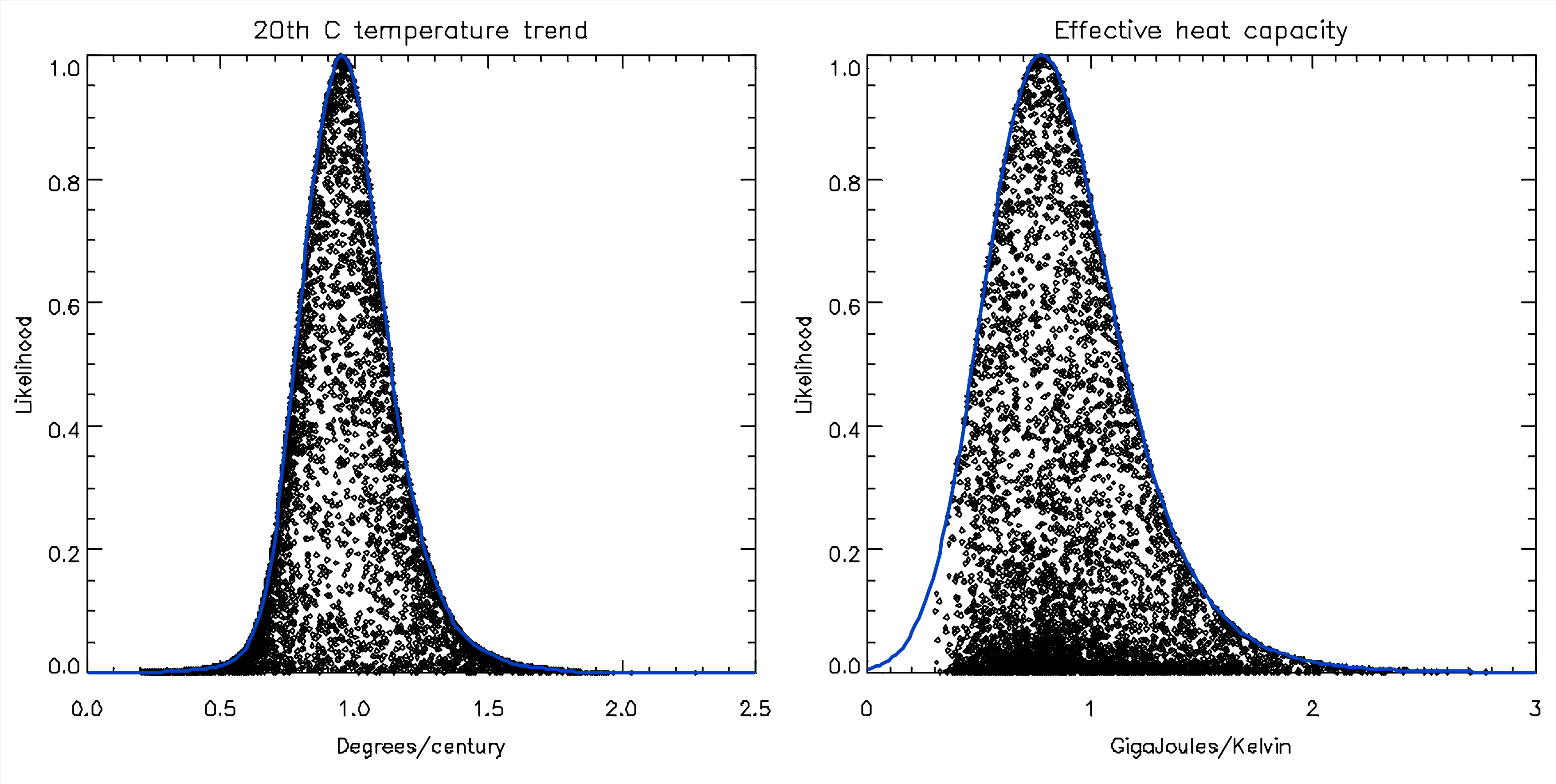
Impact of sampling “nuisance” parameters



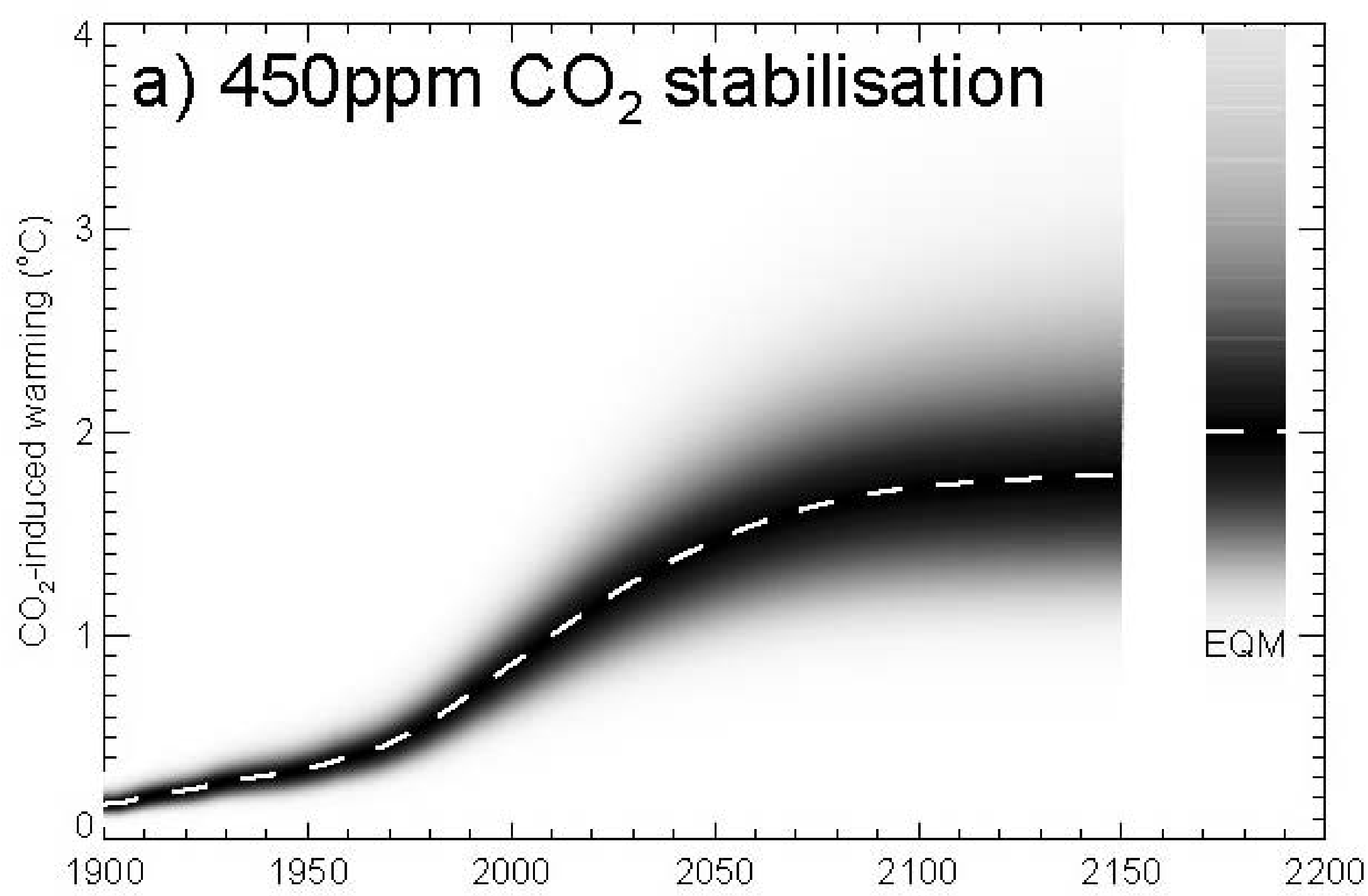
A more robust approach: Likelihood profiling



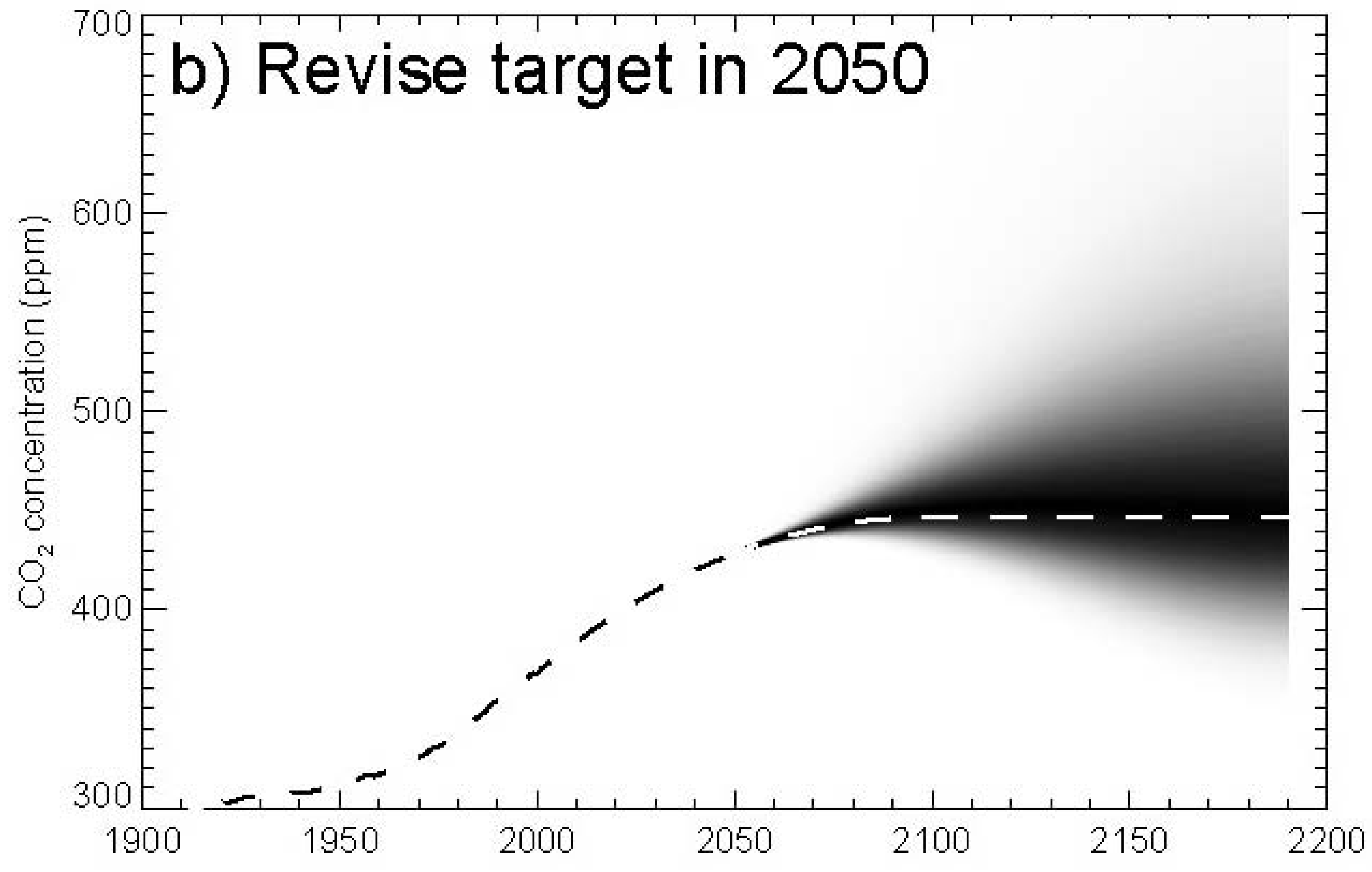
More systematically: Generating models consistent with quantities we can observe…



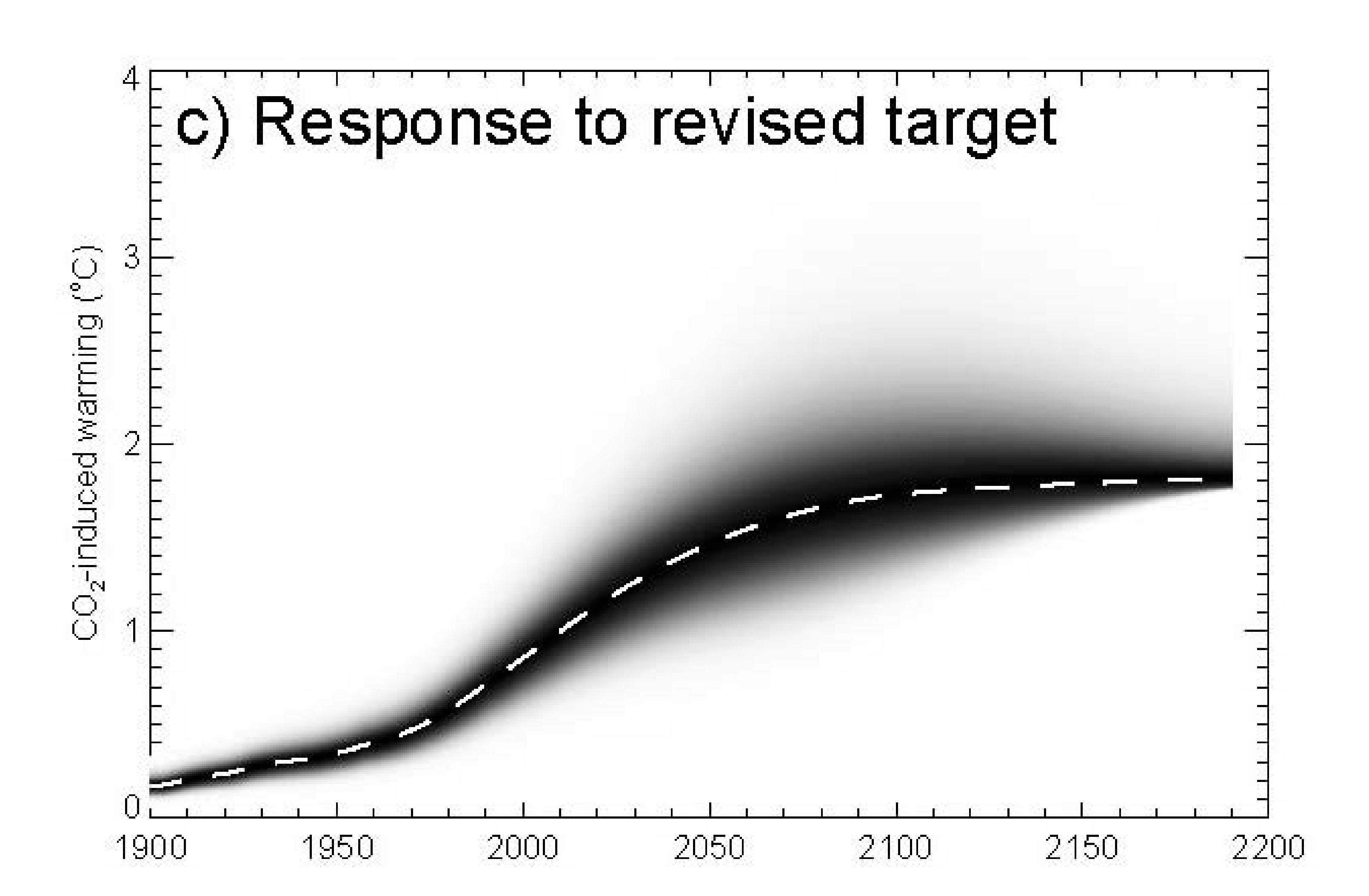
Does it matter anyway? Implications of uncertainty in S for S450 stabilization scenario.



Scale forcing target by over/undershoot of 2000-2050 trend…



…allows you to avoid DACC without *ever* knowing the climate sensitivity



Conclusions

- Distributed computing projects can access vast untapped computing resources allowing for unique statistical approaches to climate change constraining.

- Estimating sensitivity is inherently problematic because it is non-linear in things we can observe.

- Constraining on C_{2k} and accepting the possibility of future target revisions is a more coherent approach given current knowledge.