Is there a safe GHG stabilization level? Results from climate*prediction*.net

NERC Council, 2005

Myles Allen and David Stainforth

Department of Physics, University of Oxford

myles.allen@physics.ox.ac.uk

climate*prediction*.net

Oxford University

A potted history of climate*prediction*.net

1997: **Myles Allen**, perturbed physics ensemble with MIT 2-D model (**Chris Forest** et al.)
1999: March: **Dermot Dobson** introduced MRA to a beta-test version of SETI@home
1999: April: Proposal for “Casino-21” seed-corn funding rejected as utterly unrealistic
1999: July: **Andrew Heaps** got the Met Office climate model working on a Linux PC
1999: September: Concept presented at World Climate Modelling conference in Hamburg
1999: October: *Nature* commentary, “Do-it-yourself Climate Prediction”
1999: October: **Jim Hansen** suggest a web-site so people could sign up: thousands did.
1999: November: **David Stainforth** joined, half-time, on UGAMP seed-corn funding
2000: January: DAS, with input from Tessella, got the model working under Windows
2000: **NERC COAPEC** thematic programme agreed to fund DAS for a 3 year pilot study
2000: **Jamie Kettleborough** and **Mat Collins** started work on server-side & model devt.
2000: DAS, with **James Murphy** and **David Sexton**, Met Office, started perturbations
2000: June: first full-length test on secretarial Windows NT machine at RAL
2000: Summer: **Richard Gillis**, Tessella, developed first run-management system
2000: DAS & MRA spent much of the year seeking sponsorship from dying dotcoms
2001: Summer: **Richard Gault**, OU Computing Laboratory, started on **e-Science** pilot

climate*prediction*.net

A potted history of climate*prediction*.net

2001: December: successful presentation to **NERC e-Science** panel for launch funding

2002: **Bob Spicer, David Frame**, **Tolu Aina**, **Beth Grey** and **Martin Dzbor** joined, NERC e-Science

2002: February: **Andrew Martin** led successful bid to DTI core e-Science for server-side

2002: Summer: **Jeremy Walton**, NAG, produced "classic" public visualisation interface

2002: September: **Steve Bannerman** joined to work on server-side development

2002: November: **Carl Christensen**, SETI & dotcom veteran, joined on core e-Science

2002: December: "Friends and Family" testing begins, with numerous problems

2003: **Carl Christensen**, **Tolu Aina** and **Jamie Kettleborough** extensively rework client and server-side software to improve reliability

2003: **David Frame** takes over as project coordinator, DAS awarded a NERC Fellowship

2003: March: **Sylvia Knight** replaces DJF as communications person

2003: April: Beta-testing begins

2003: Friday, September 12th, public launch by **Carol Kirkwood**, BBC Weather Centre, at the National Museum of Science and Technology

2003: Saturday, September 13th, exceeded the capacity of the Earth Simulator to become the world's largest climate modelling facility

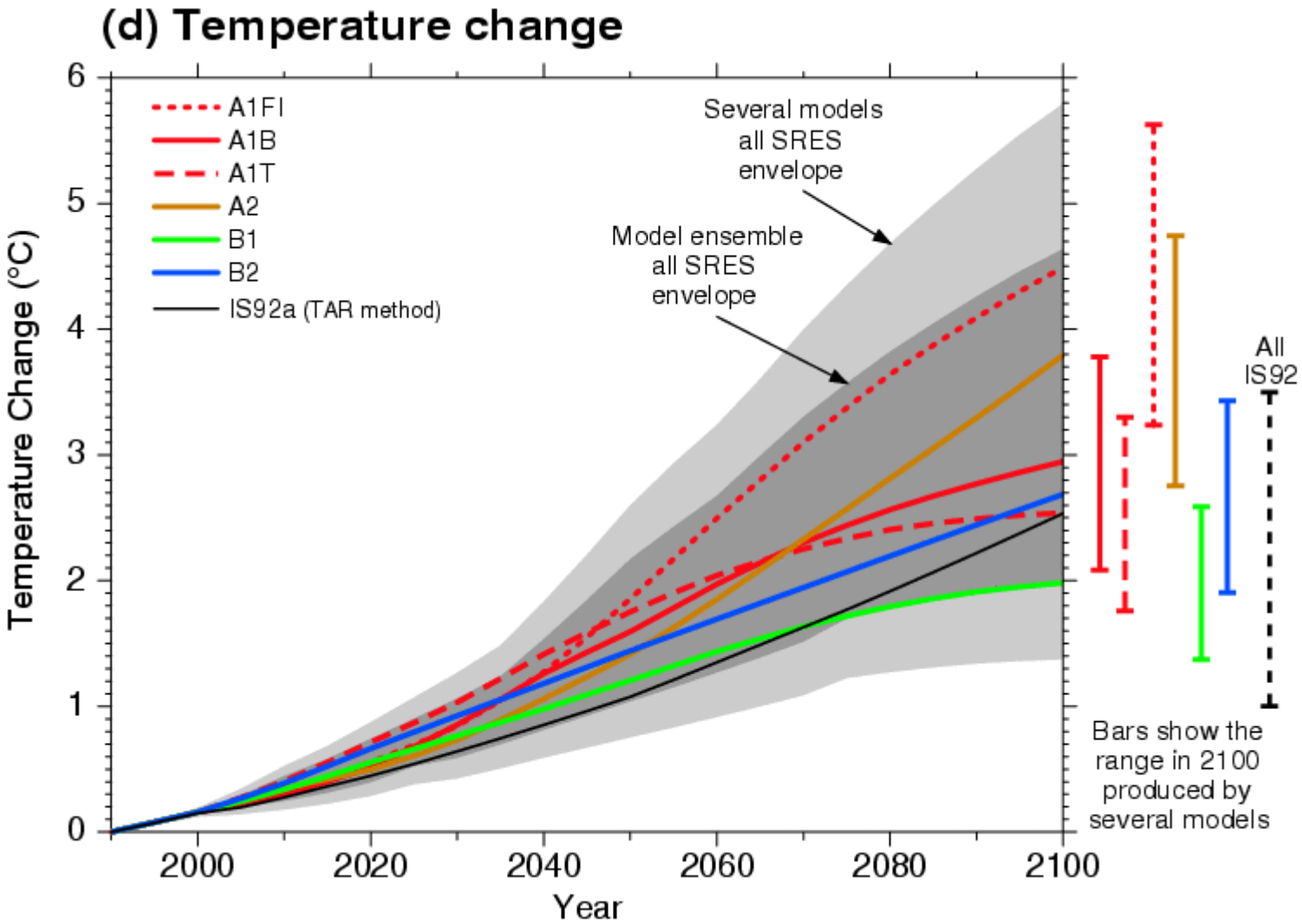
climate*prediction*.net

A potted history of climate*prediction*.net

2003: October: **Ellie Highwood** at Reading joins
2003: December: first million model years simulated
2004: April: **Stephen Pascoe** joins at RAL to work on results
2004: April: **Hannah Rowlands** takes over as project administrator
2004: May: Thermohaline circulation experiment launched after 'The Day After Tomorrow'
2004: May: **Neil Massey** joins at ComLab
2004: July: Advanced, interactive visualisation package launched
2004: July: climate*prediction*.net holds its first Open Day
2004: August: climate*prediction*.net goes BOINC
2004: December: Schools materials launched
2005: January: First results published in **Nature**
2005: March: climate*prediction*.net mugs available for purchase
2005: March: 5 million model years simulated

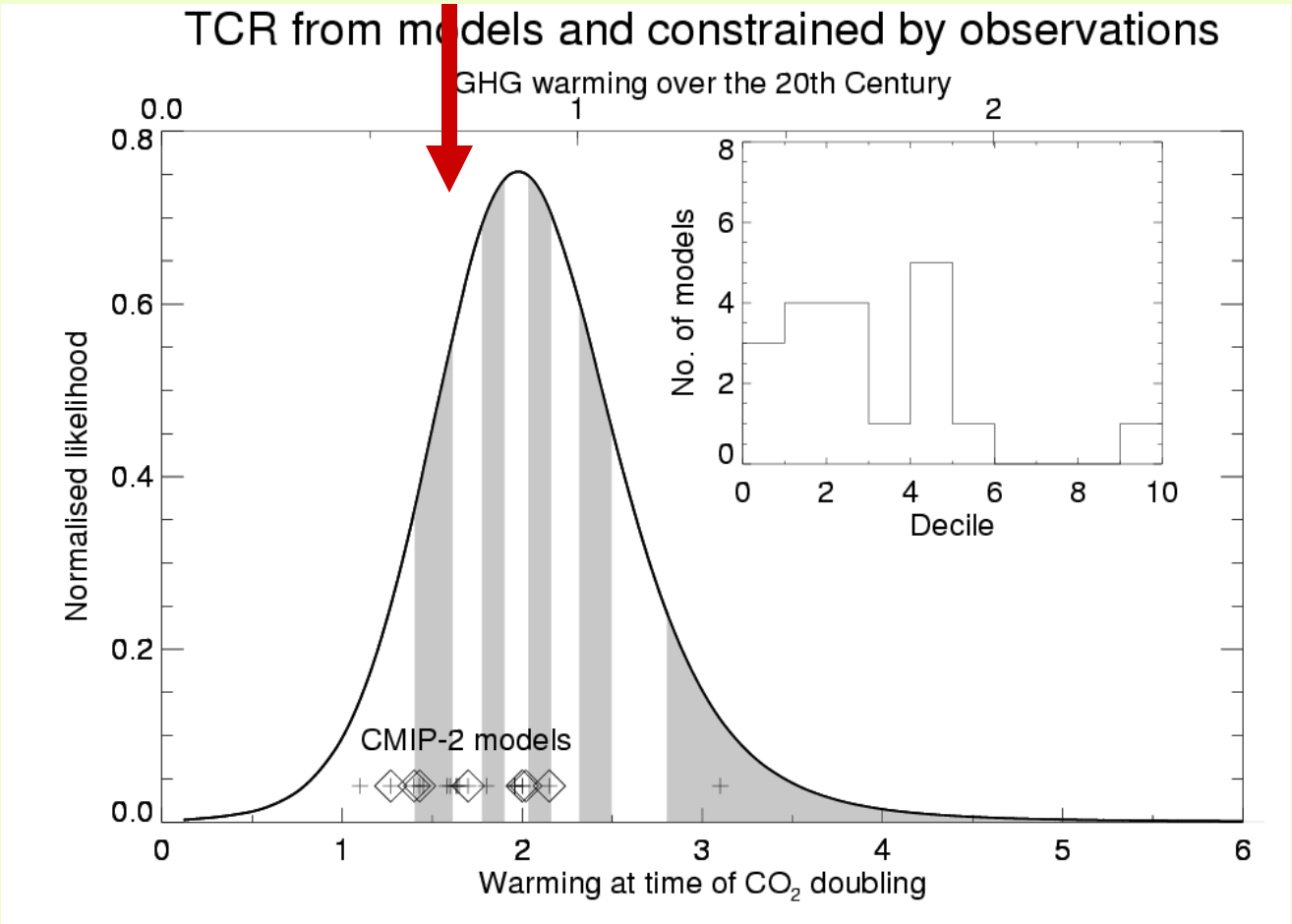
climate*prediction*.net

The traditional inter-model-range approach to quantifying uncertainty in climate predictions



But do inter-model-ranges span responses consistent with observations?

Observed warming

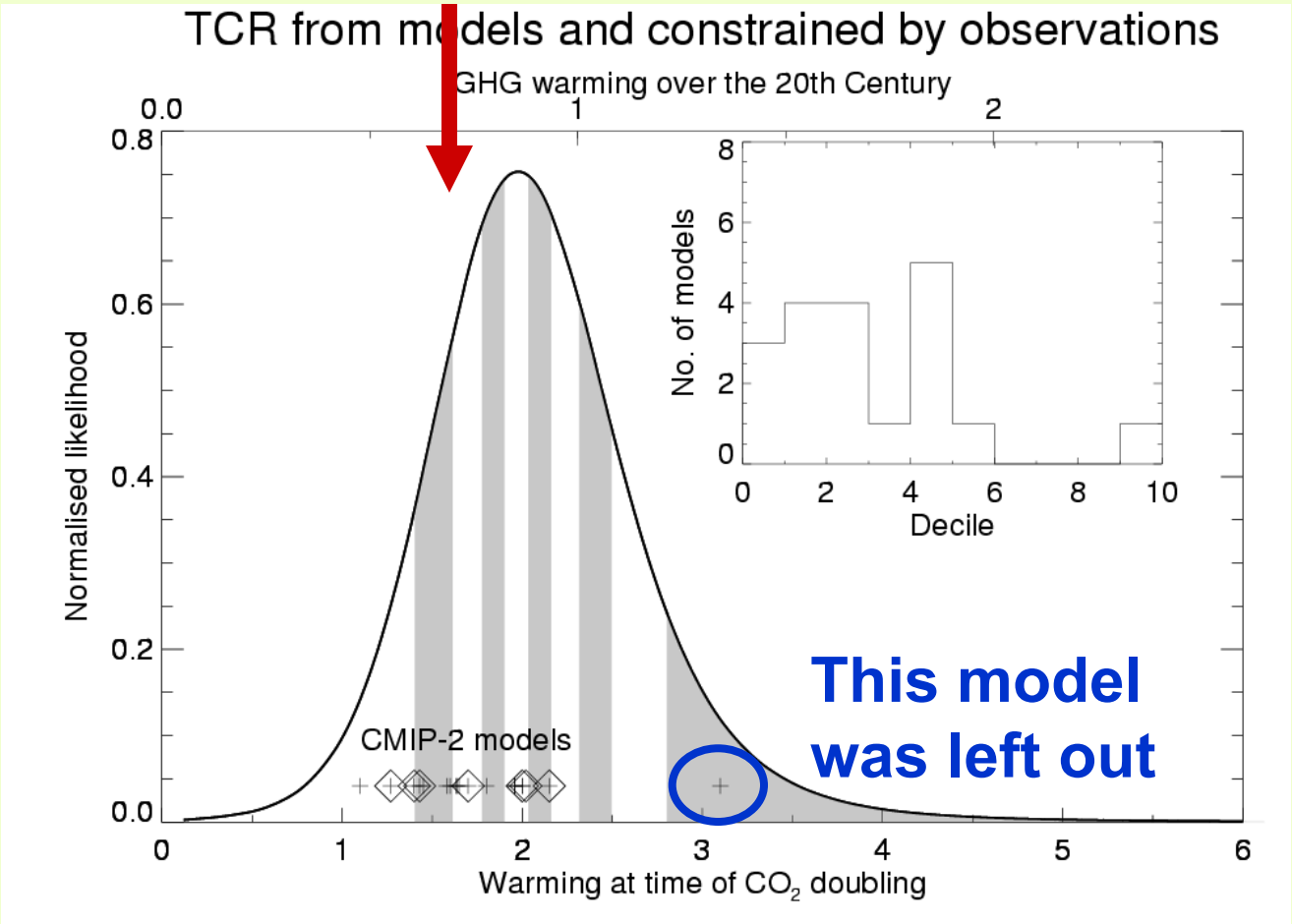


climateprediction.net

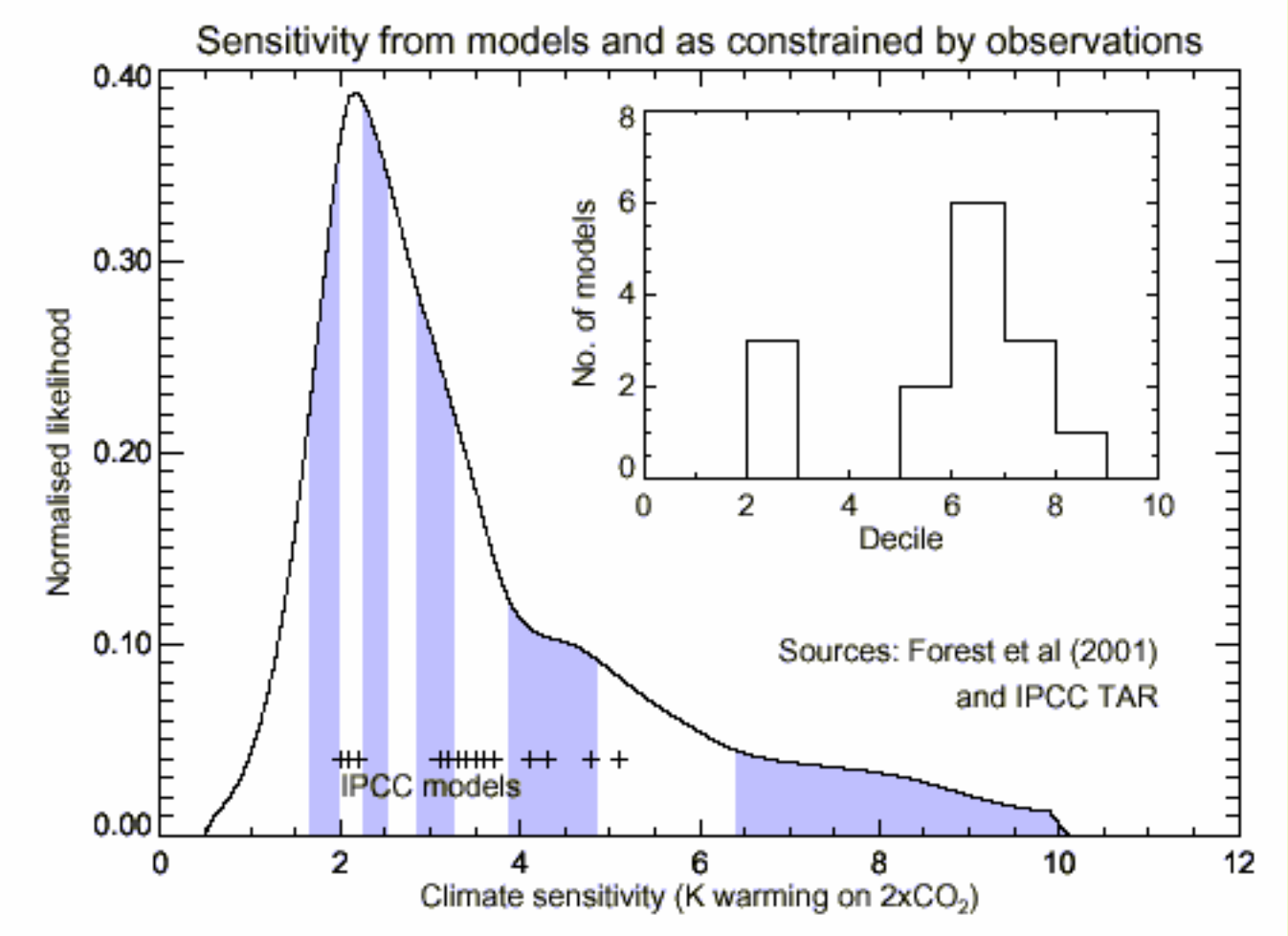
Oxford University

But do inter-model-ranges span responses consistent with observations?

Observed warming



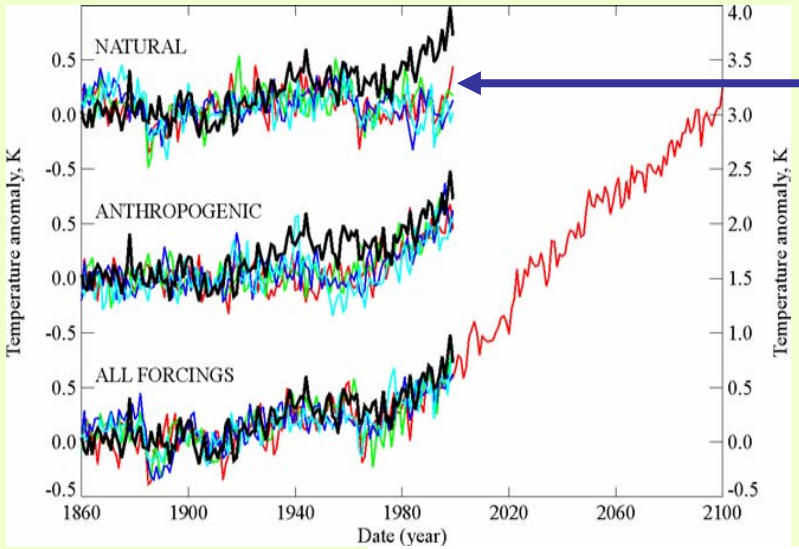
Even bigger discrepancies for high end equilibrium responses



climate*prediction*.net

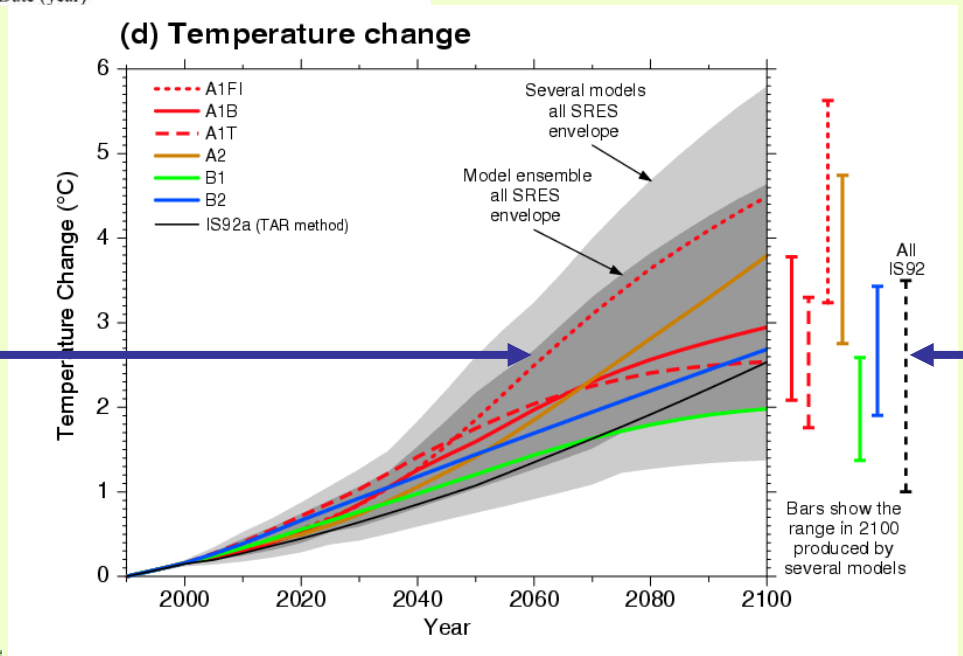
Oxford University

Sources of uncertainty in climate forecasts



Initial condition uncertainty

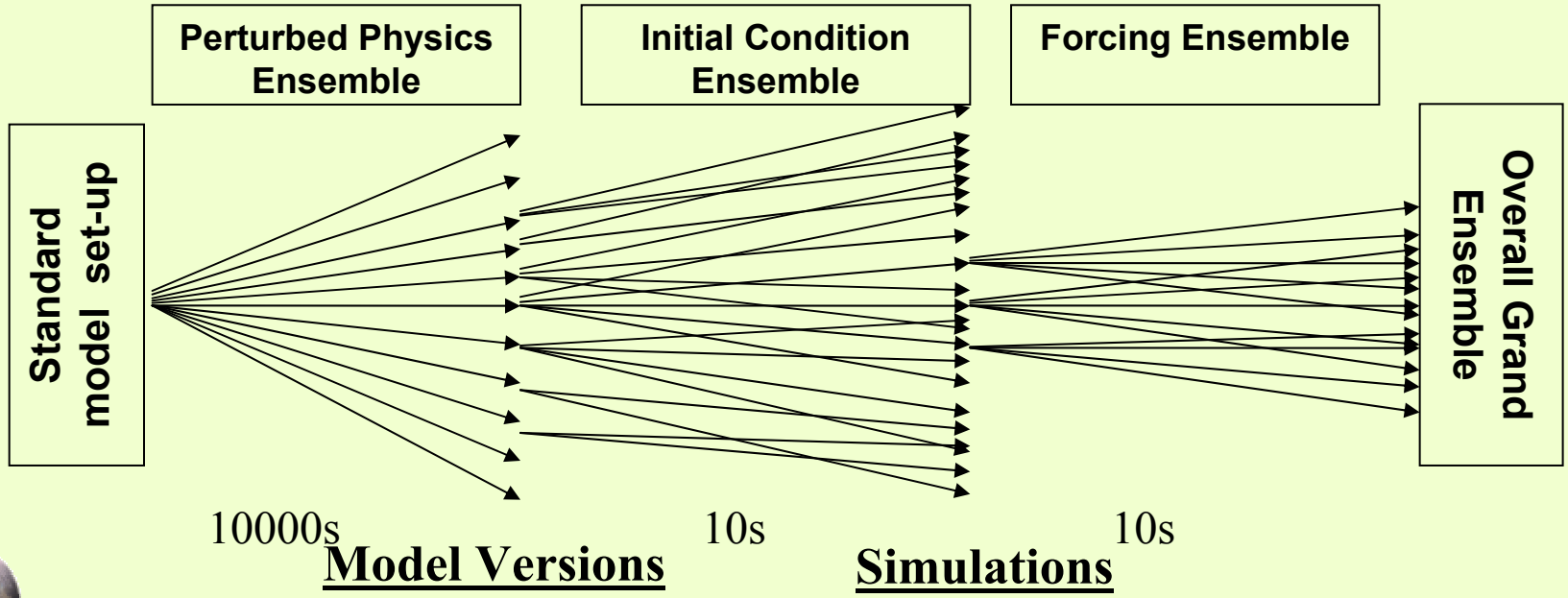
Boundary condition uncertainty



Response (model) uncertainty

Perturbed Physics Ensembles and Grand Ensembles

- **Perturbed physics ensemble: vary parameterisations to find alternative, equally realistic, model versions that respond differently to changing boundary conditions.**
- **Grand (nested) ensemble explores inter-dependence of the three main sources of uncertainty.**



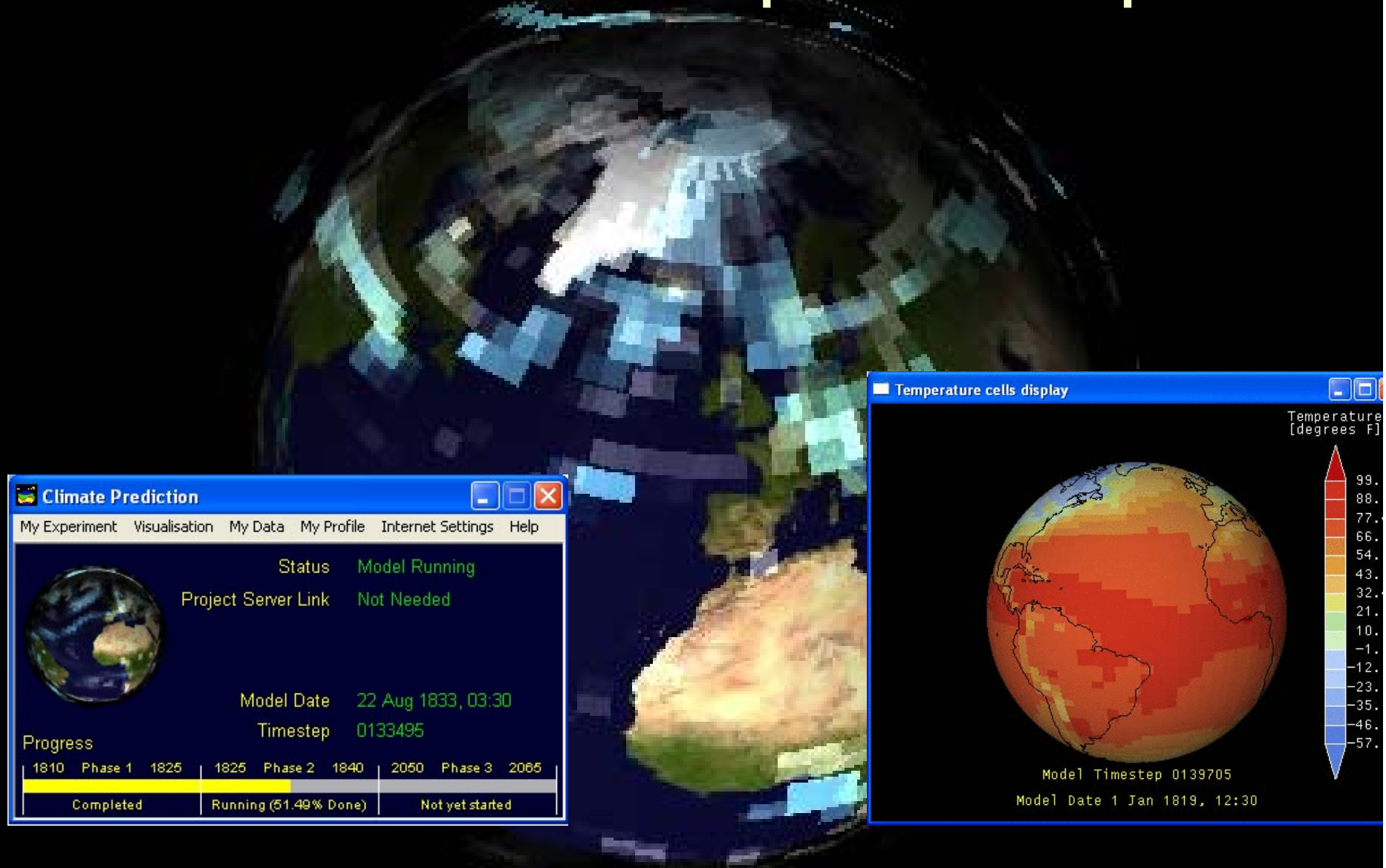
Objectives of climate*prediction*.net

- **Climate research: to improve estimates of uncertainty in climate forecasts by performing the first grand ensemble with a full 3-D climate model.**
- **E-Science: to develop and demonstrate the potential of public resource distributed computing (PRDC) for large-scale computational modelling tasks.**
- **Communication: to improve public understanding of the nature of climate modelling and sources of uncertainty in climate predictions.**

Climate*prediction*.net approach

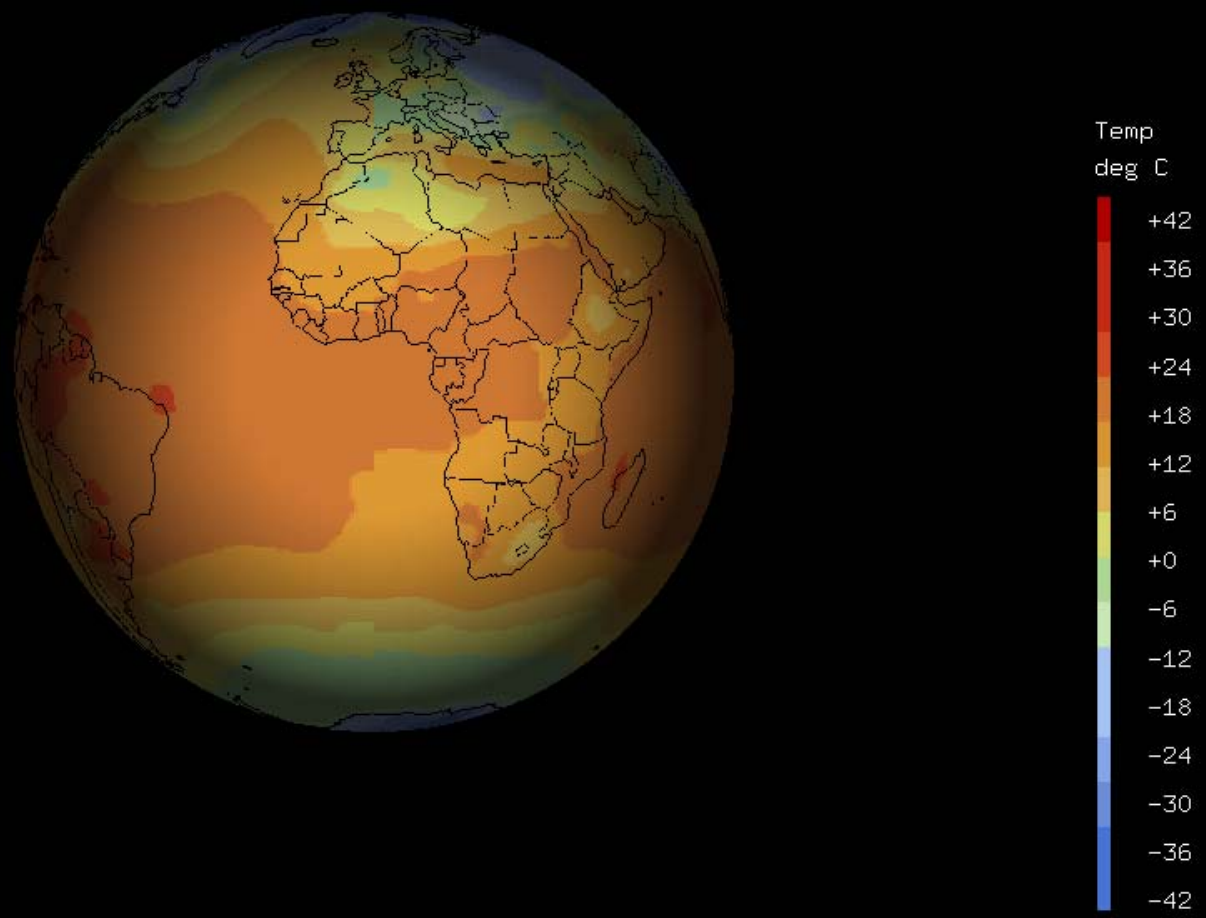
- Invite members of the general public to download a full-resolution 3-D climate model and run it locally on their personal computer.
- Each PC runs a single member of a massive grand ensemble, uploading key diagnostics when simulation is completed.
- Visualization software, educational packages and active user forum maintain interest and facilitate school and undergraduate projects.

Members of the public download and run a full 3-D climate model on their personal computers



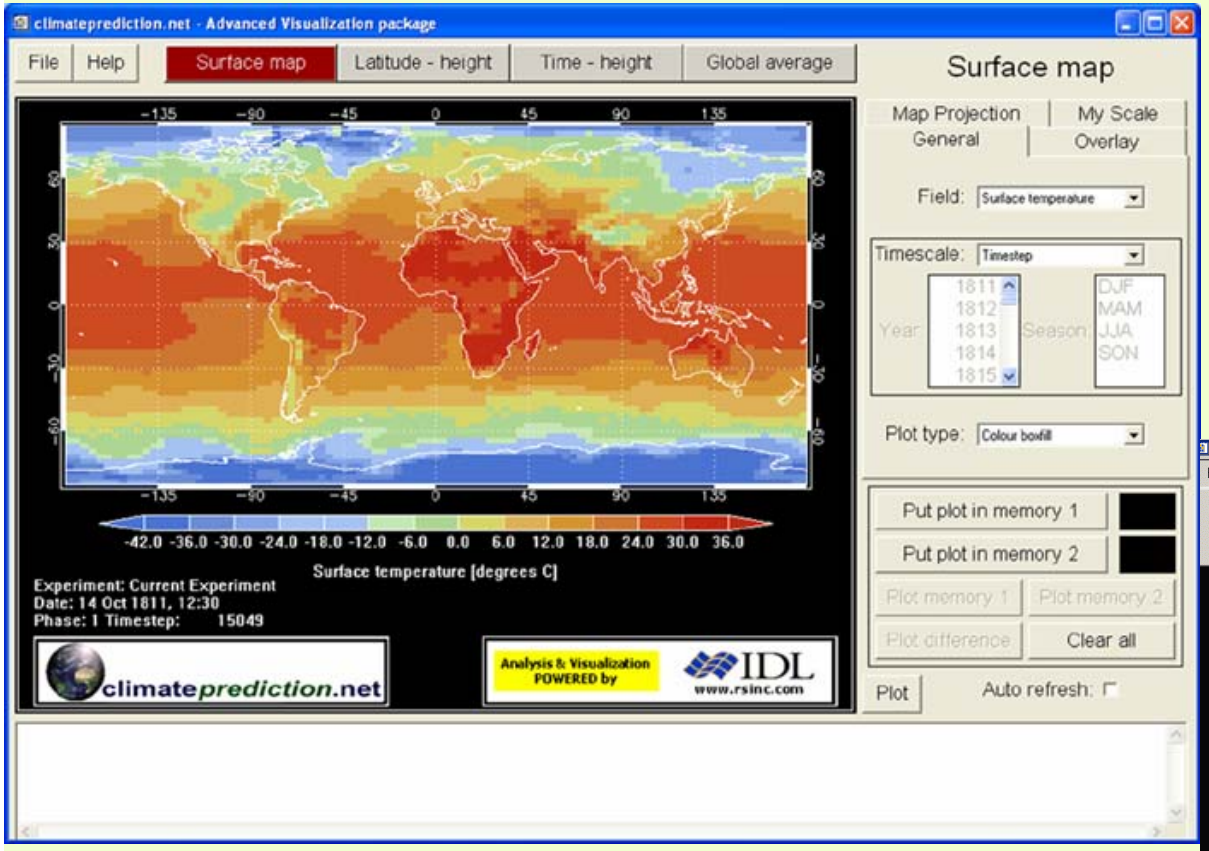
Model Phase 3, Timestep 0134187

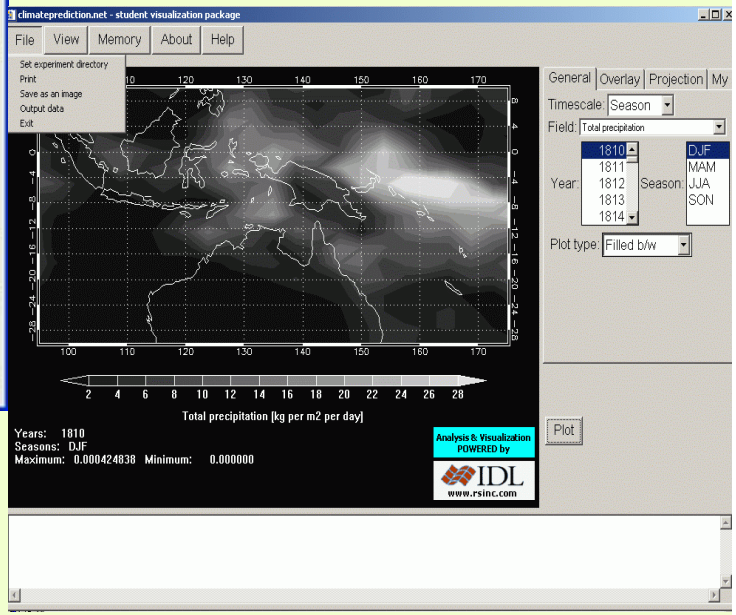
Now running on NERC computers (thanks to Andrew Kaye, Karen Lowther and Ron Price)



hadsm3 Run ID : ic1m_000000059
User : NERC; Team : <None>
Phase : 1 of 3 / Timestep : 331 of 259248
Model Date : 07/12/1810 21:30
CPU Time: 0000:13:23 (2.43 s/TS)

Visualization software for school and undergraduate projects





Active user forum to maintain interest (runs can take two to three months)

ClimatePrediction.Net Community Space :: Index - Microsoft Internet Explorer

File Edit View Favorites Tools Help

Back Search Favorites Media Links Climat

Address http://www.climateprediction.net/board/index.php?sid=4f3266f77c7564eb7326085817ece752

User Community CPDN

ClimatePrediction.Net Community Space

This site is for the current and future users and participants in an exciting climate modelling experiment

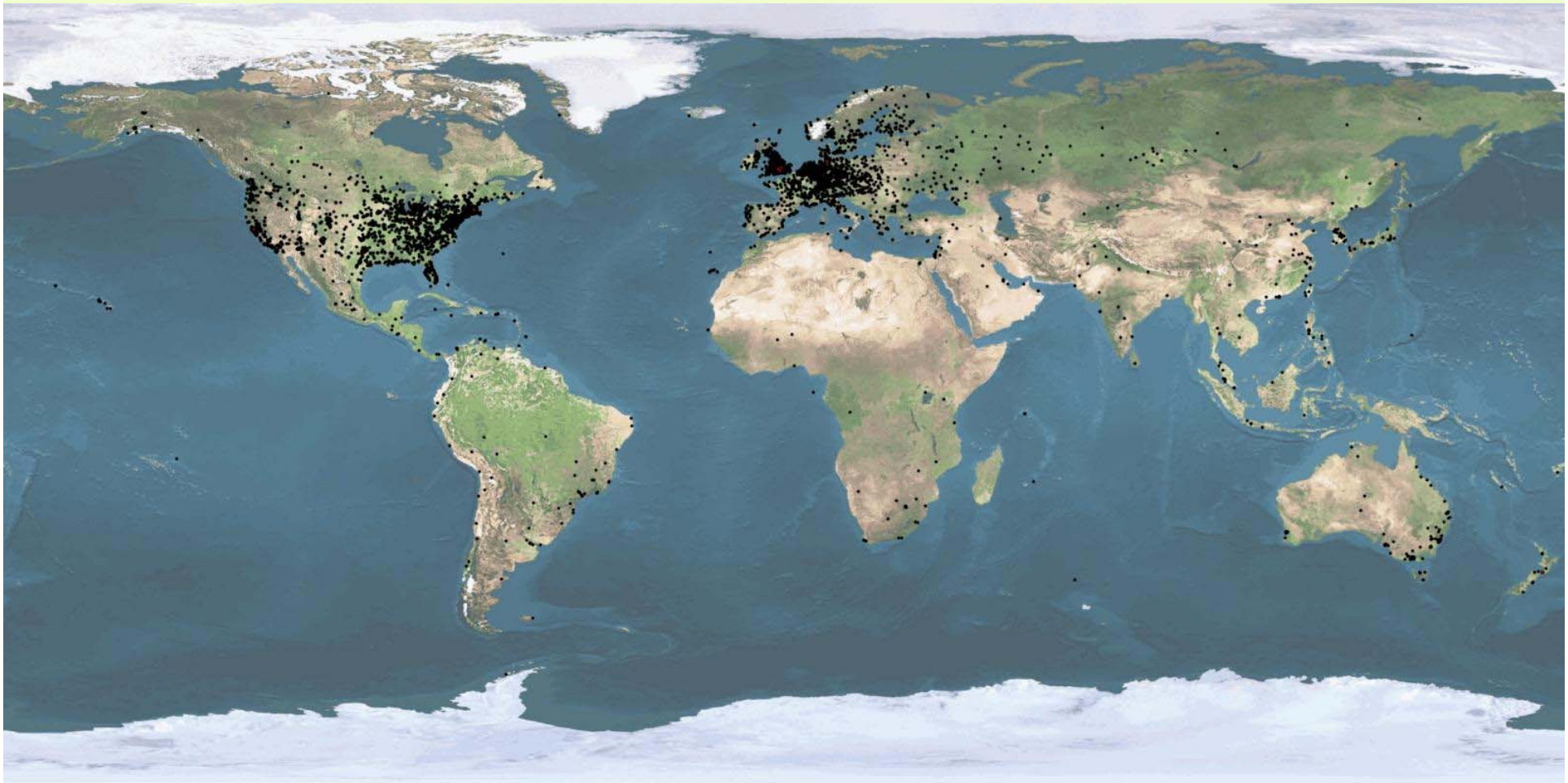
FAQ Search Memberlist Usergroups
Profile You have no new messages Log out [DaveF]

You last visited on Mon Jun 02, 2003 5:41 pm
The time now is Mon Jun 02, 2003 6:36 pm
ClimatePrediction.Net Community Space Forum Index

View posts since last visit
View your posts
View unanswered posts

Forum	Topics	Posts	Last Post
Beta testing experience			
Unexpected behaviour of your model? Does your model behave differently than expected (e.g. losing timesteps, etc.) - let us know... Moderators DaveF, Deamiter	7	39	Sat May 31, 2003 12:06 pm carl
Result and intermediate data upload Any strange behaviour in respect to uploading data or results? Moderator carl	4	13	Mon Jun 02, 2003 5:16 pm Madcat
Participation in the experiment Any remarks or suggestions about participating in our experiment? Moderators DaveF, Deamiter	1	4	Fri May 23, 2003 2:56 pm Independence
Technical issues/queries/suggestions			
Computing efficiency Any concerns about efficiency of modelling or data compressing or something else? Moderators carl, Deamiter	4	22	Mon Jun 02, 2003 6:15 pm Madcat
Climate model on Linux, commandline option, ... We are planning releases for other systems - e.g. Linux, Mac OS X? Any comments, suggestions, ideas what else... Moderator carl	3	13	Wed May 28, 2003 9:20 am mdzbor
Setup, debug, network install Comments/advice about such things as proxies, debugging, software parameters, memory leaks, etc. [shortly, things for geeks] Moderator carl	7	45	Mon Jun 02, 2003 12:38 pm Tim Hewison
Other problems when running model Troubles with overheating your computer? Concerned that your laptop is not powerful enough? Advice? Moderators carl, DaveF, Deamiter	3	15	Wed May 28, 2003 12:21 pm richard
Climatology/climate science			
Extreme climate If you think you've got something pretty cool (or hot) in your model, why not telling the others? Moderator DaveF	2	7	Mon Jun 02, 2003 5:53 pm Tim Hewison
Ozone, global warming Concerned about ozone and global warming in connection with this experiment? Moderator DaveF	2	3	Tue May 27, 2003 10:49 am carl
General discussion General forum about discussin climate issues. If anything attracts more attention it can be spawned as a separate topic...	1	3	Tue May 27, 2003 11:29 am mdzbor

Uploading results to a network of servers, linked by GRID software for distributed analysis

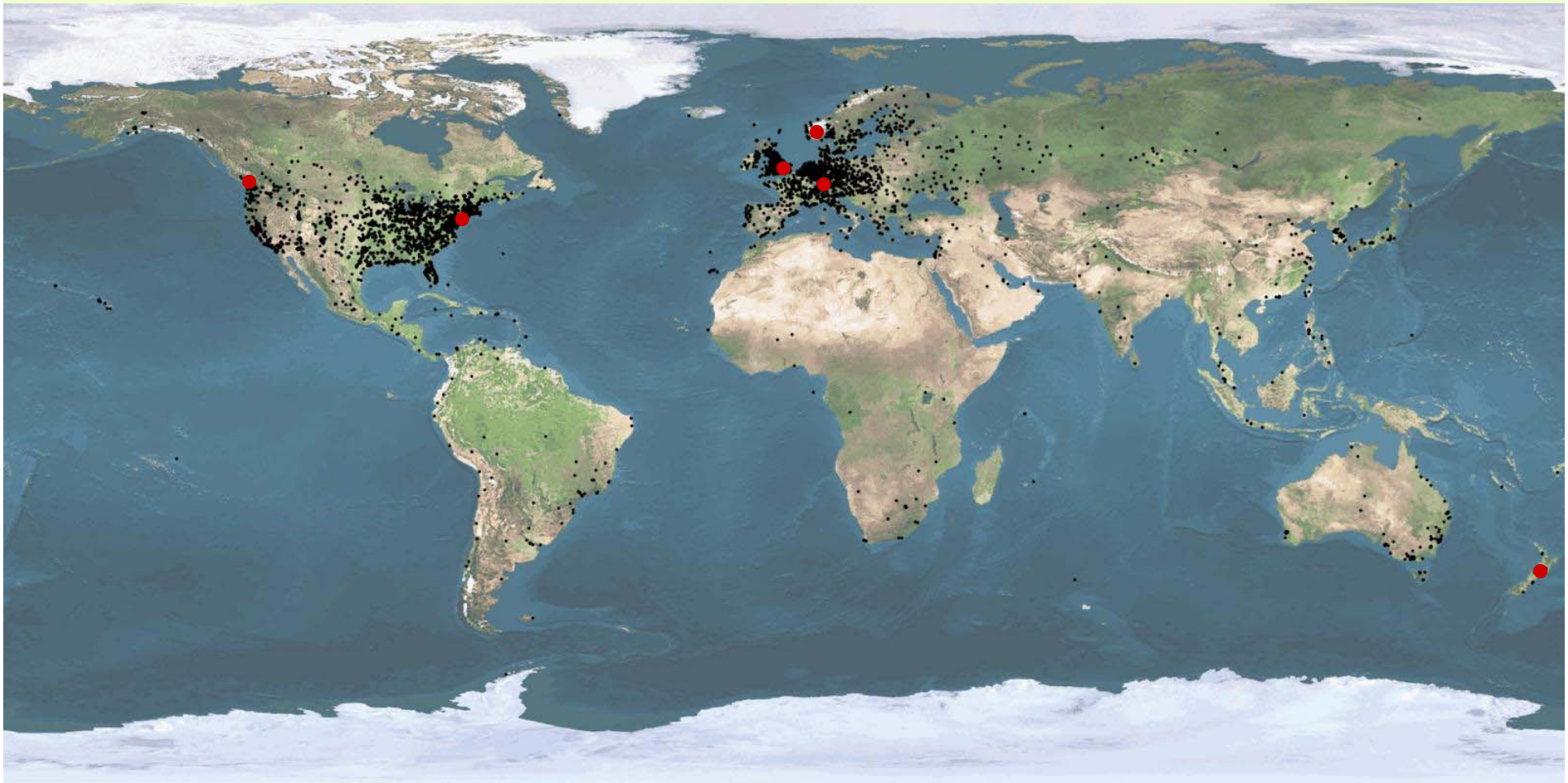


~100,000 volunteers, 130 countries, ~6M GCM-years

climateprediction.net

Oxford University

Uploading results to a network of servers, linked by GRID software for distributed analysis



~100,000 volunteers, 130 countries, ~6M GCM-years

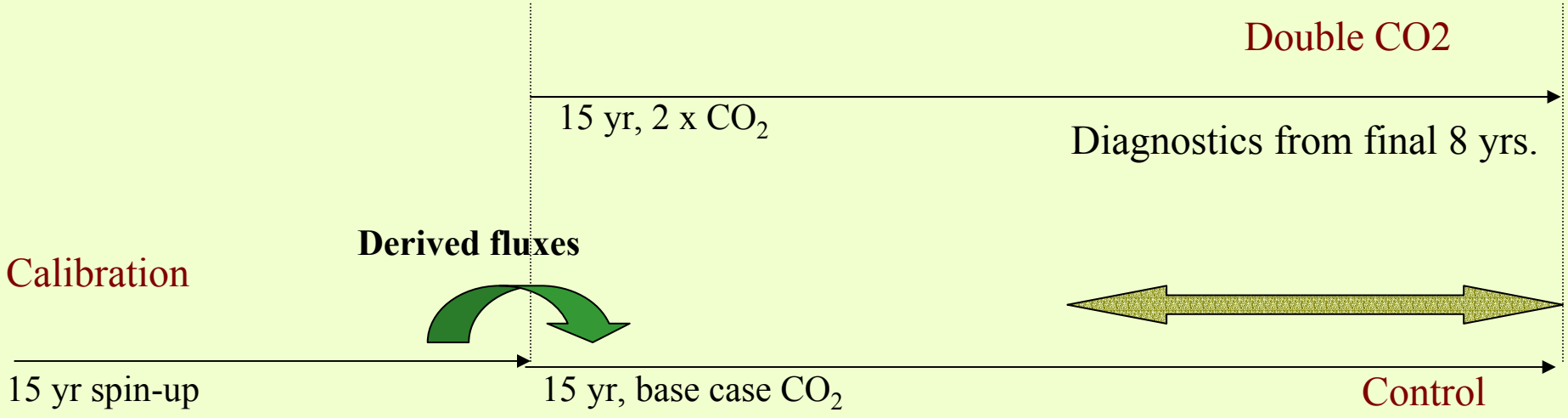
Upload servers

climateprediction.net

Oxford University

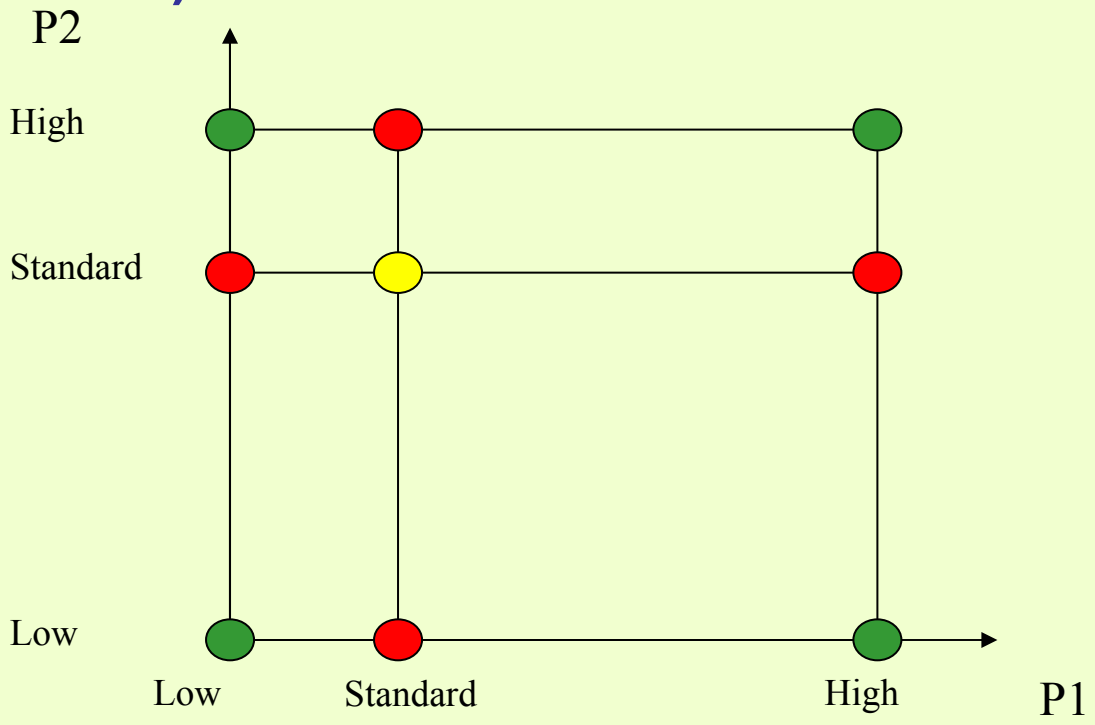
On to the results: initial experiment design

- Using HadSM3 model with thermodynamic ocean
- 15-year calibration, 15-year control, 15-year 2xCO_2
- Up to 10-member IC ensembles to reduce noise and quantify sampling variability

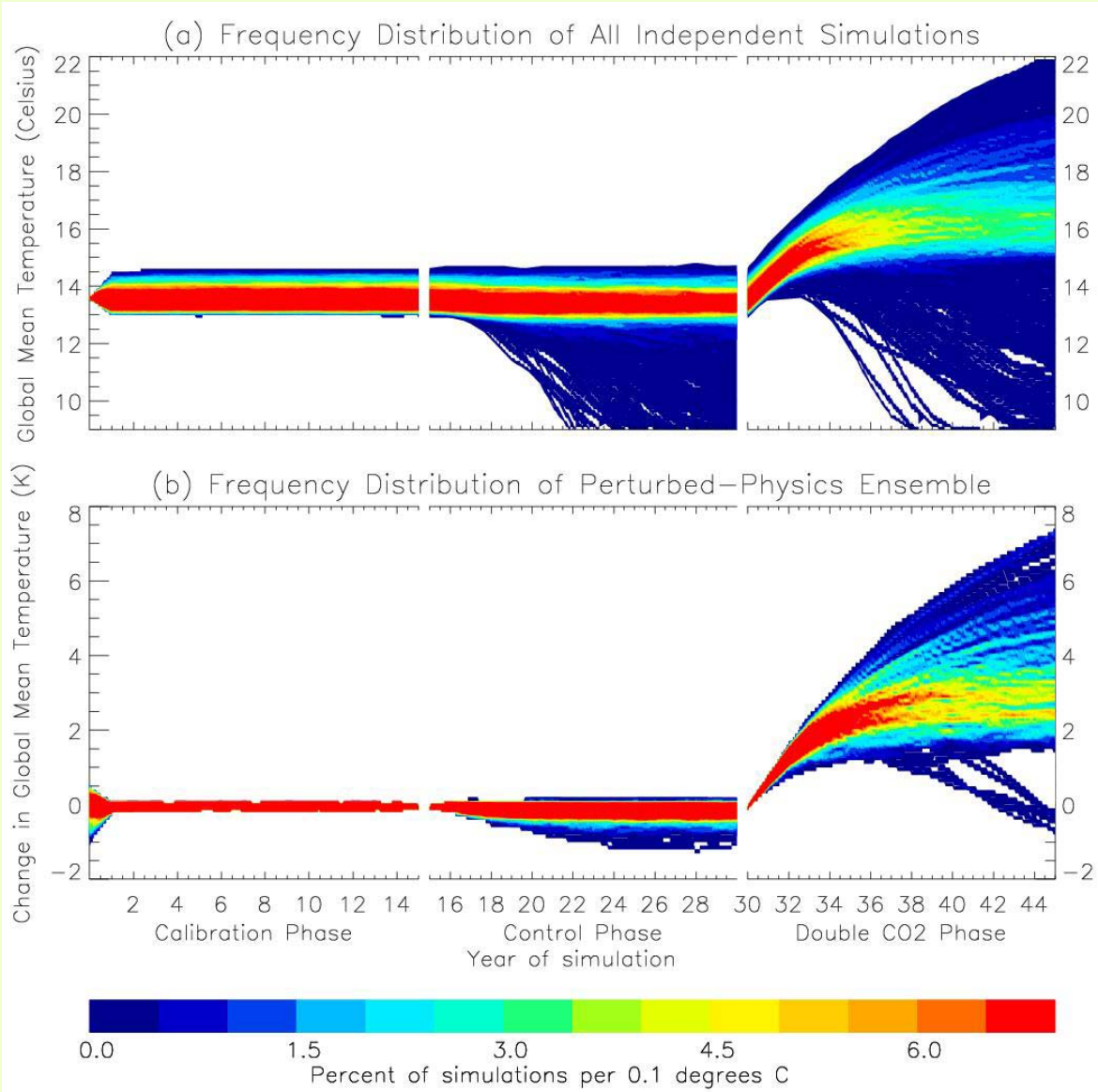


Exploration of parameter space, focussing on identifying non-linear interactions

- Perturbations to 21 parameters
- Three values each, including combinations
- Initial exploration of 6 parameters (clouds and convection)



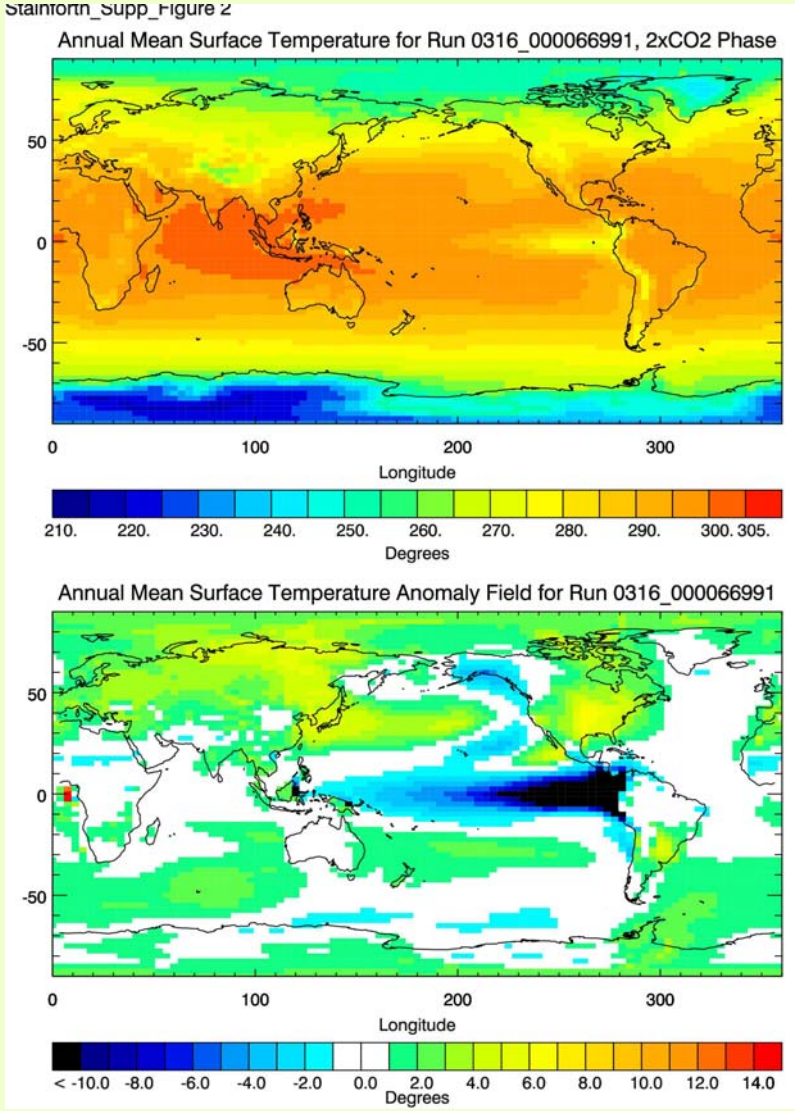
Time-evolving frequency distribution



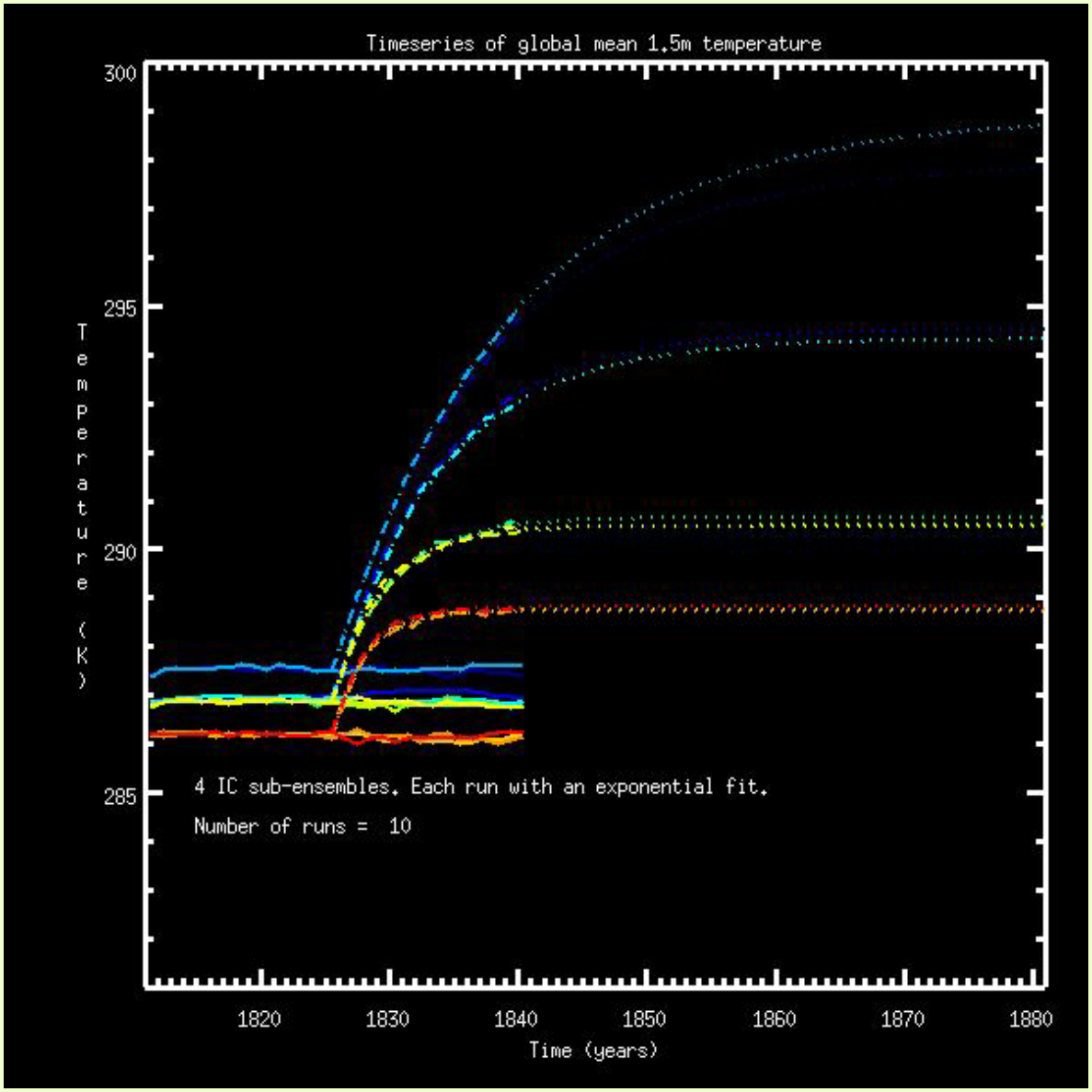
Remove models that are unstable in the control.

Few remaining negatively drifting $2xCO_2$ model versions are an unrealistic consequence of using a slab ocean.

Not The Day After Tomorrow: why we got some negative sensitivities…



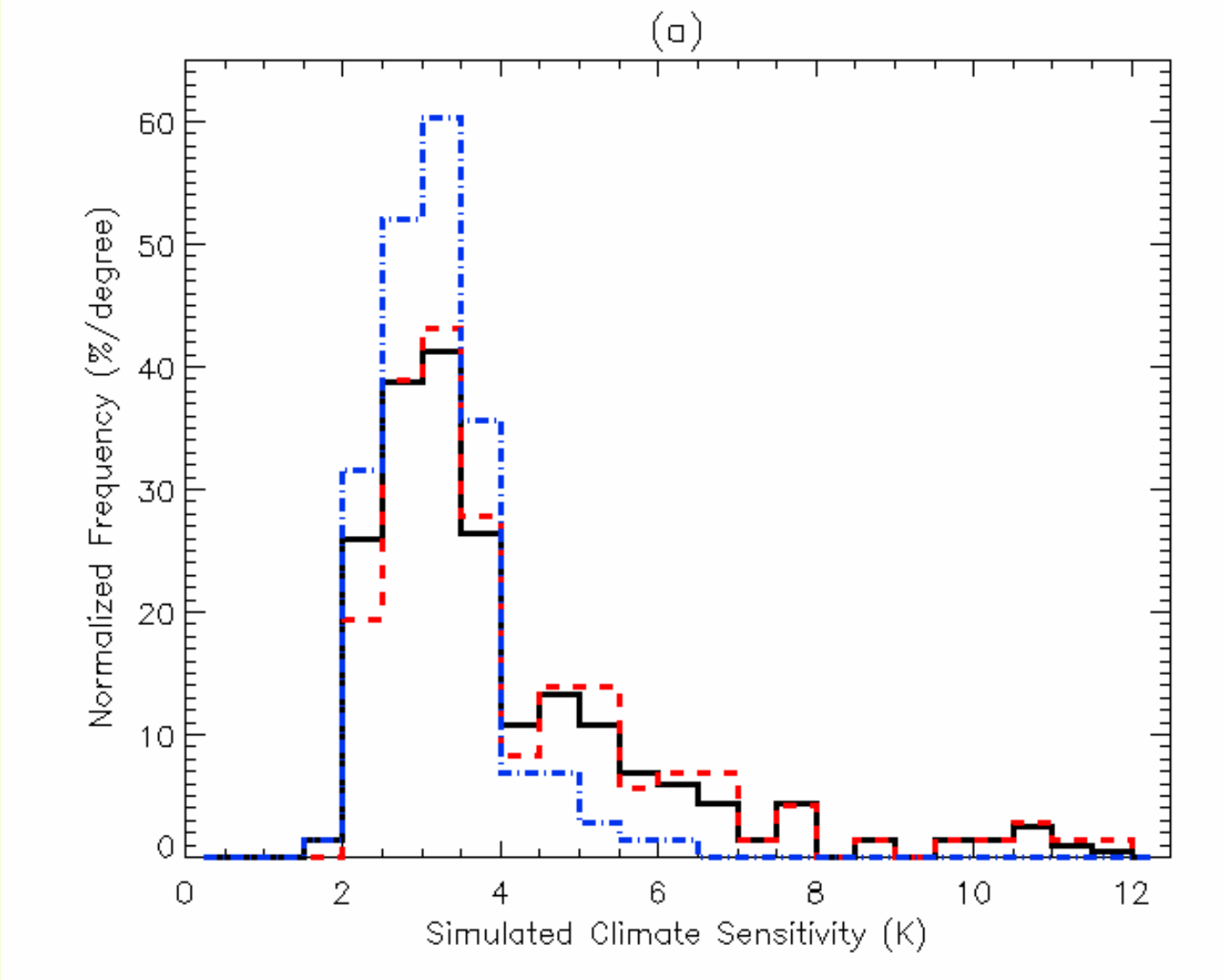
Estimating effective climate sensitivity from short $2xCO_2$ runs



climateprediction.net

Oxford University

Sensitivities from climate*prediction*.net

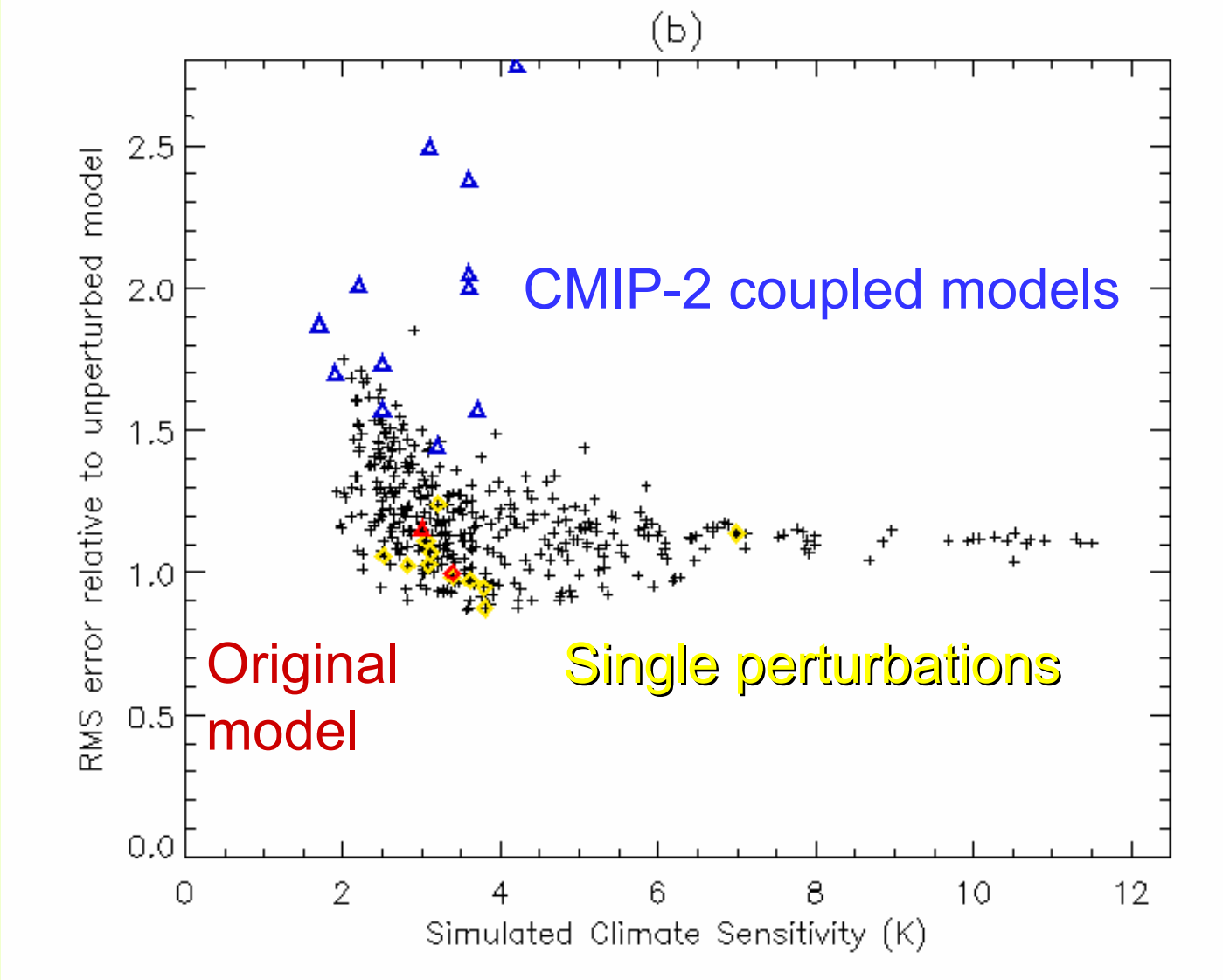


Stainforth et al, 2005

climate*prediction*.net

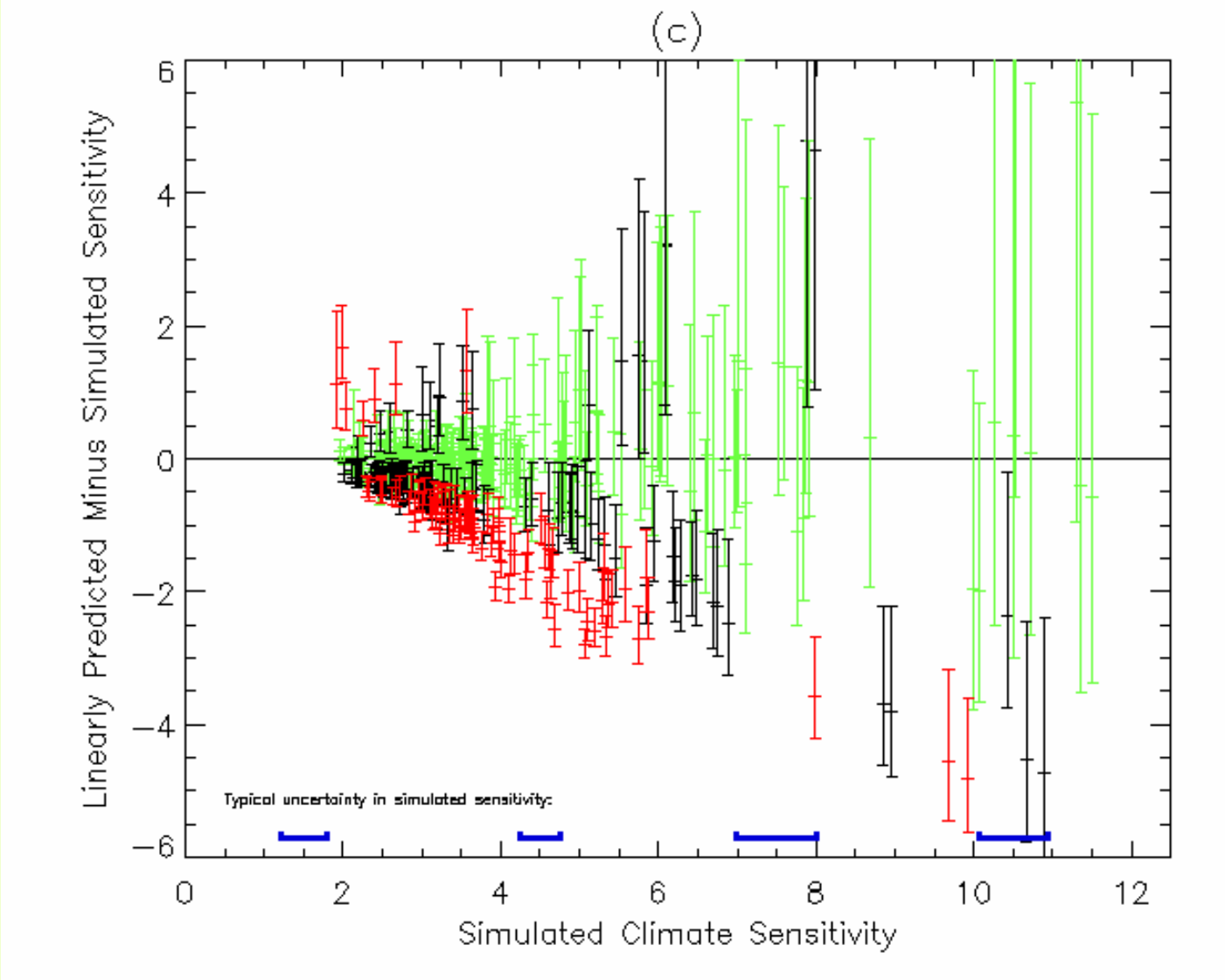
Oxford University

Can observations rule out high sensitivities?



Stainforth et al, 2005

Non-linear responses to parameter perturbations: we need these large ensembles



Stainforth et al, 2005

climateprediction.net

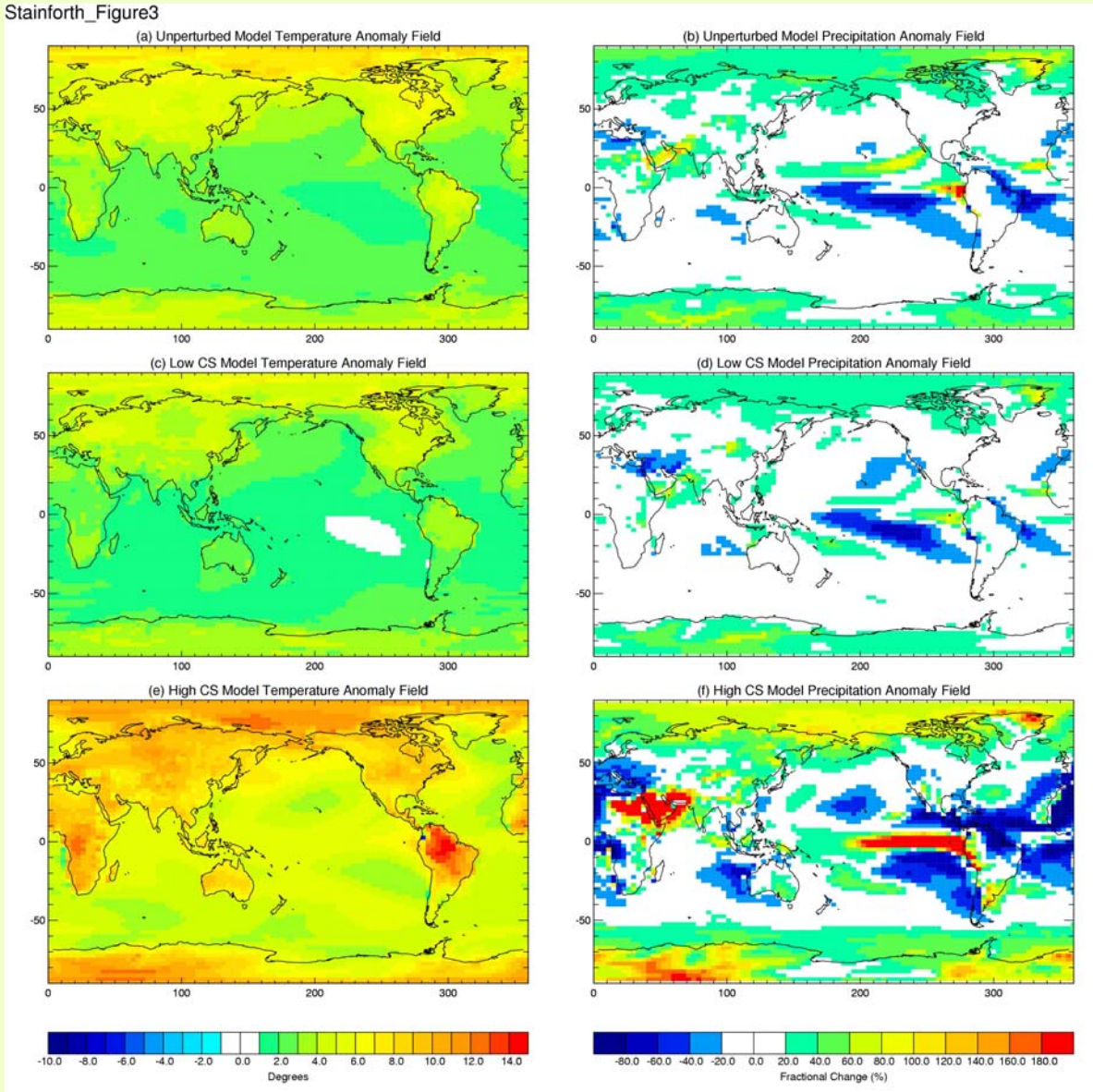
Oxford University

Regional responses: temperature and precipitation

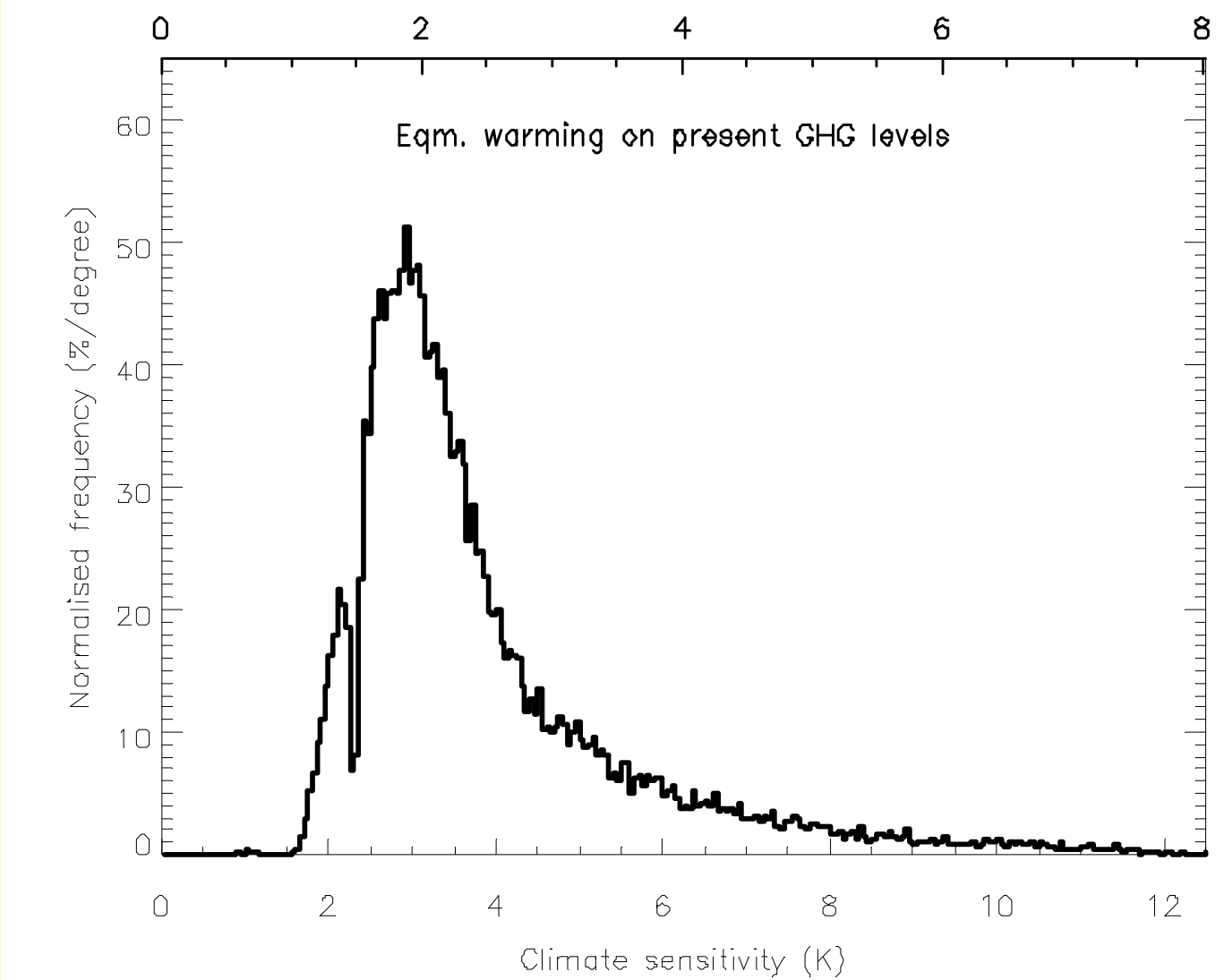
Standard model version

Low sensitivity model

High sensitivity model



Still they come: 47334 simulations passing initial quality control

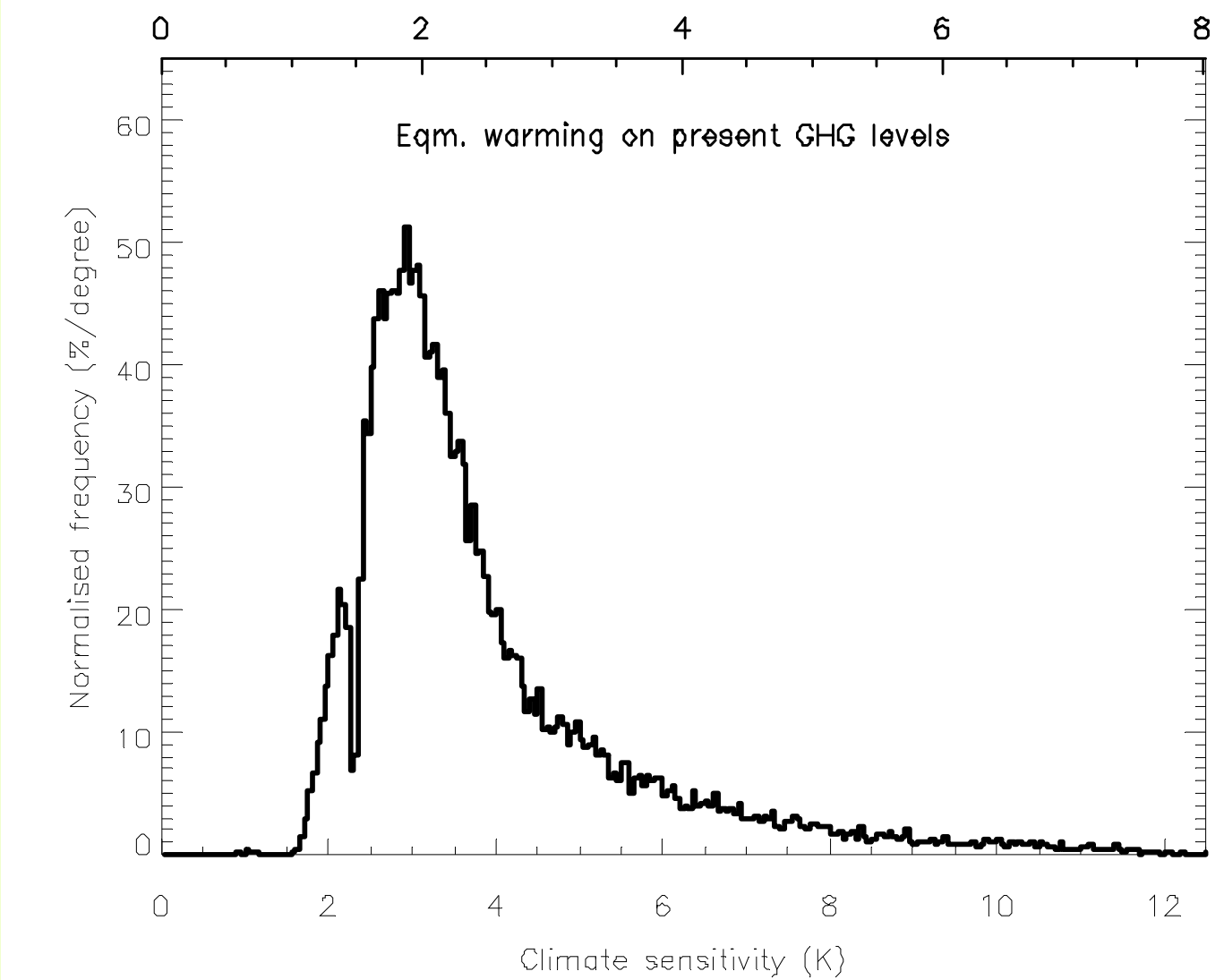


Courtesy of Ben Sanderson

climateprediction.net

Oxford University

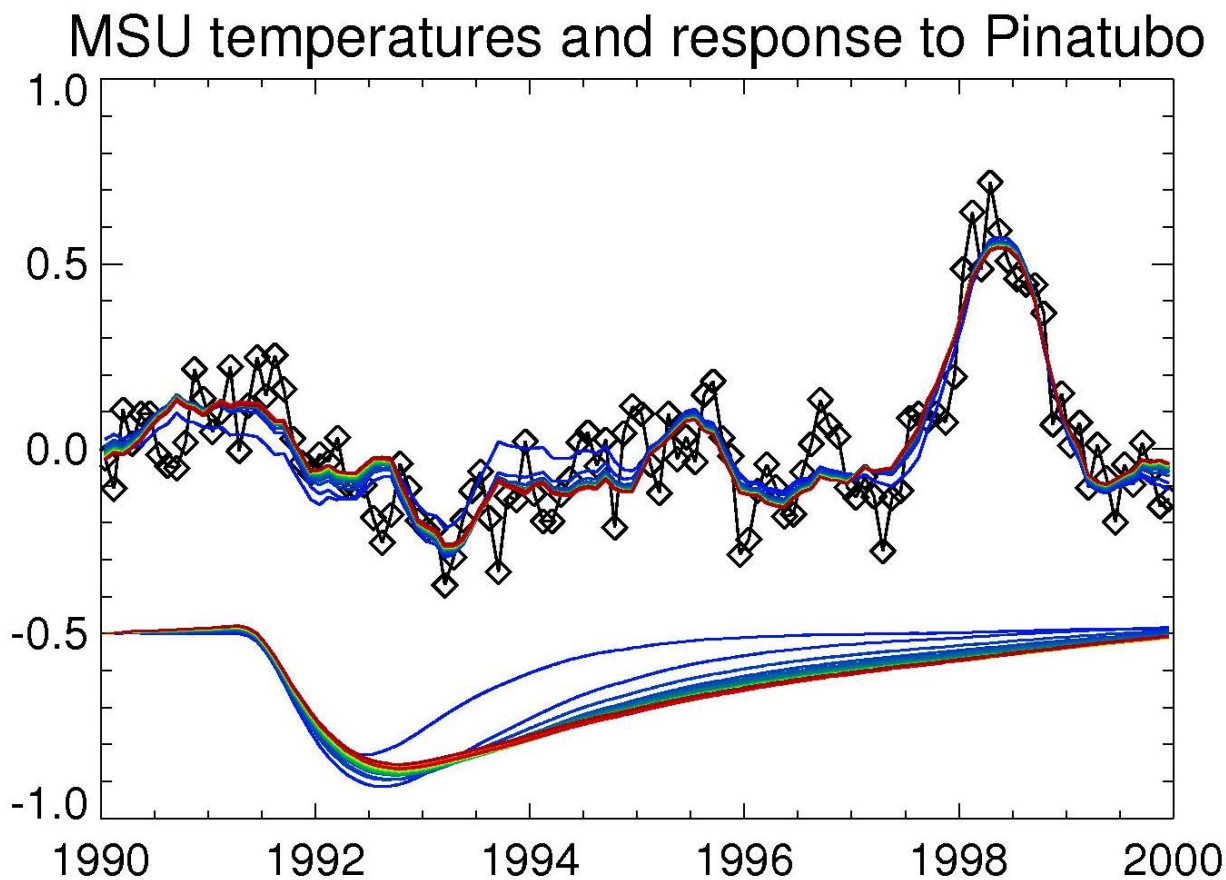
Are these high sensitivities ruled out by the observed response to Mount Pinatubo?



climateprediction.net

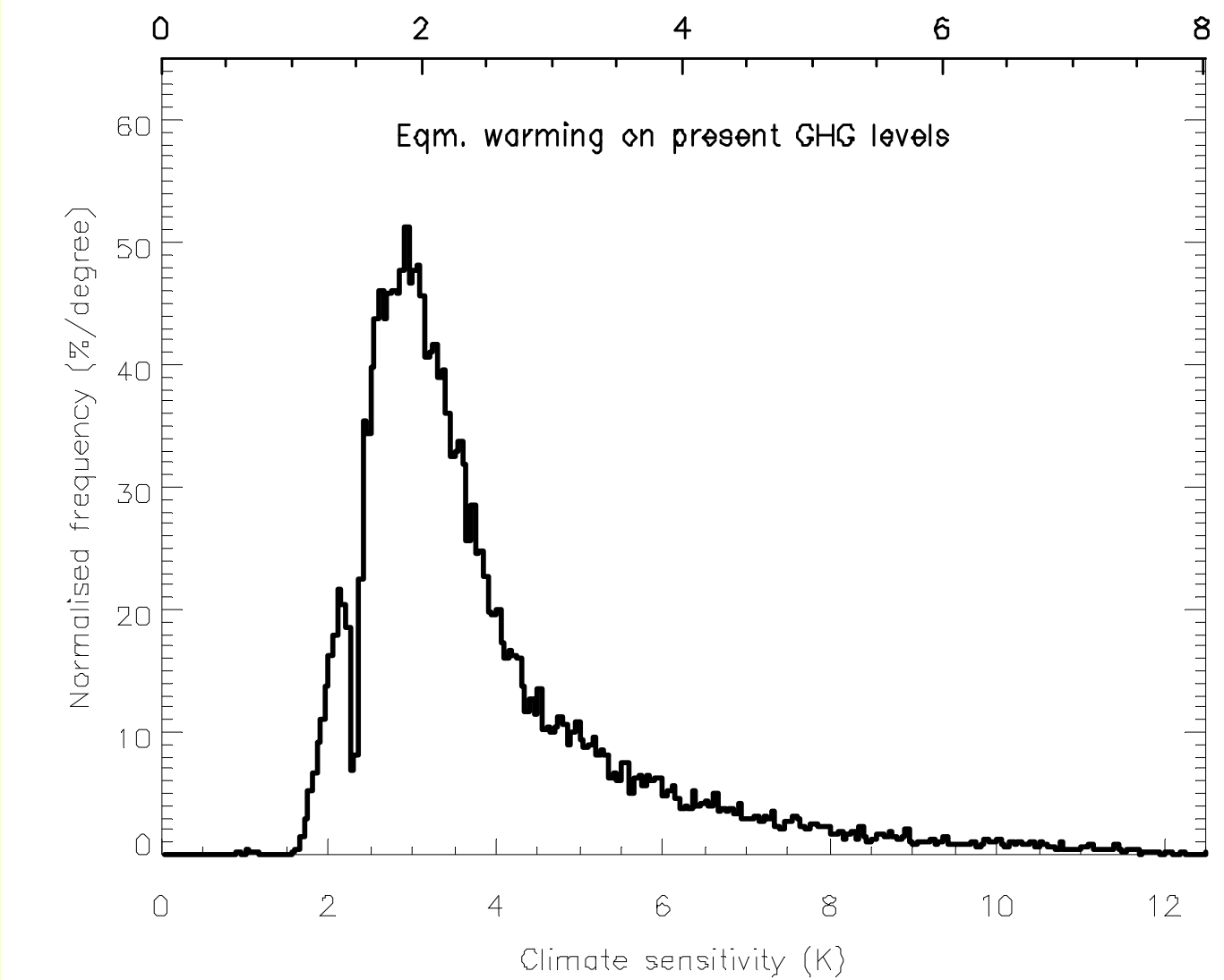
Oxford University

No: EBM responses to Pinatubo forcing
blue = 0.5K sensitivity, deep red = 20K sensitivity



Frame et al, 2005, also fitting ENSO, background climate and effective heat capacity

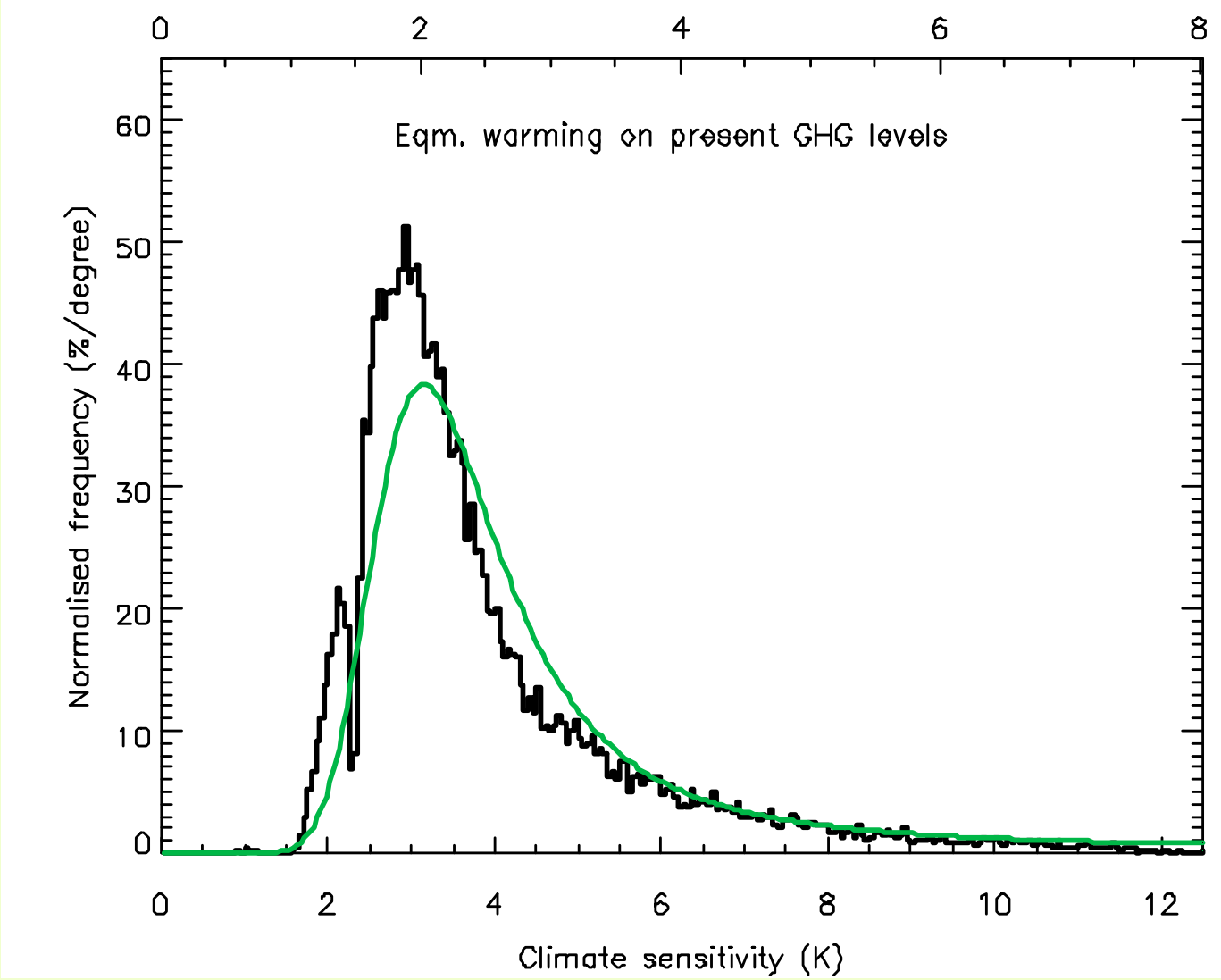
Are these high sensitivities ruled out by temperatures in the Last Glacial Maximum?



climateprediction.net

Oxford University

No: distribution of sensitivities consistent with $\Delta F=-6.6\pm1.5 W/m^2$ & $\Delta T=-5.5\pm0.5 W/m^2$

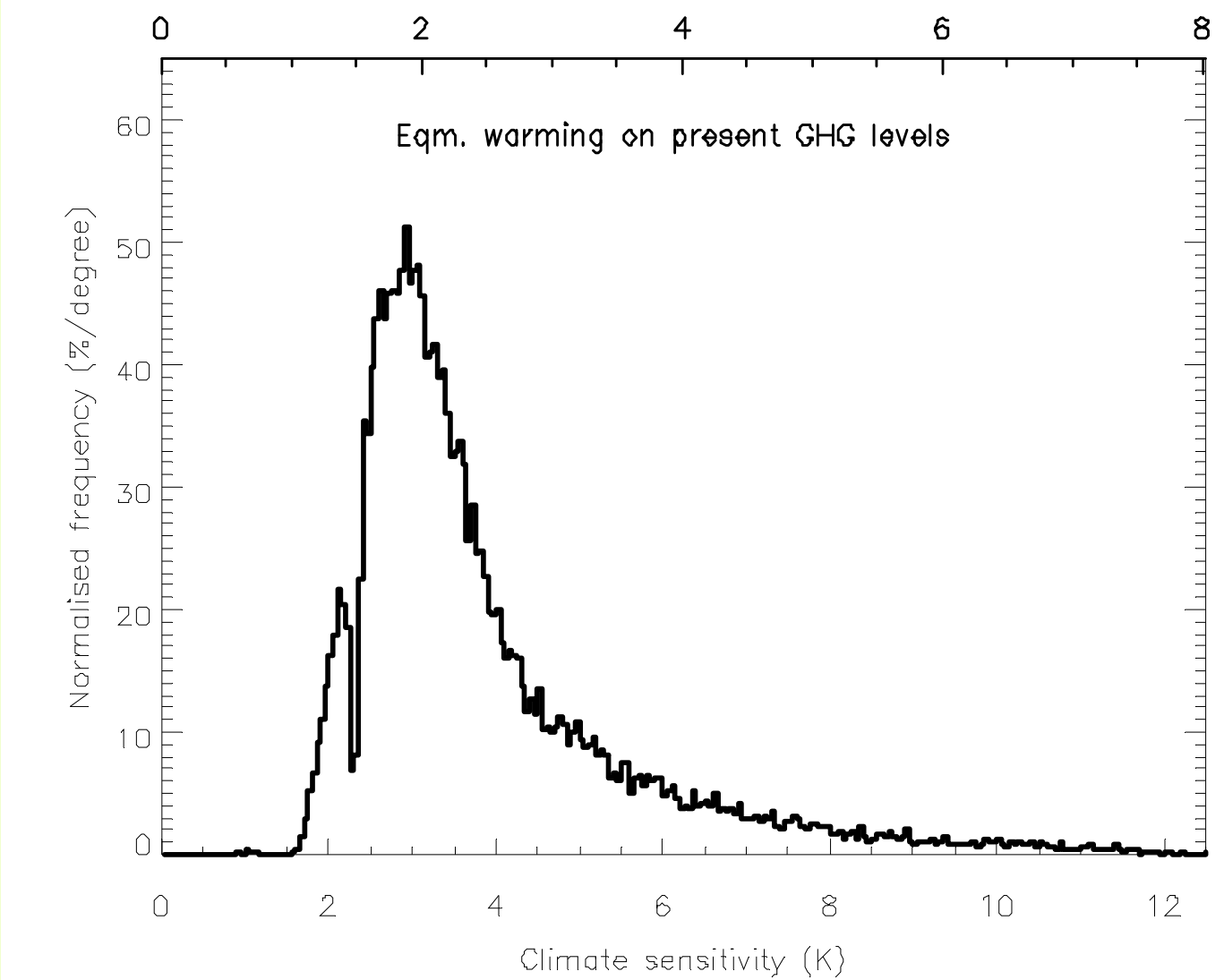


Numbers courtesy of Stefan Rahmstorf and Gavin Schmidt

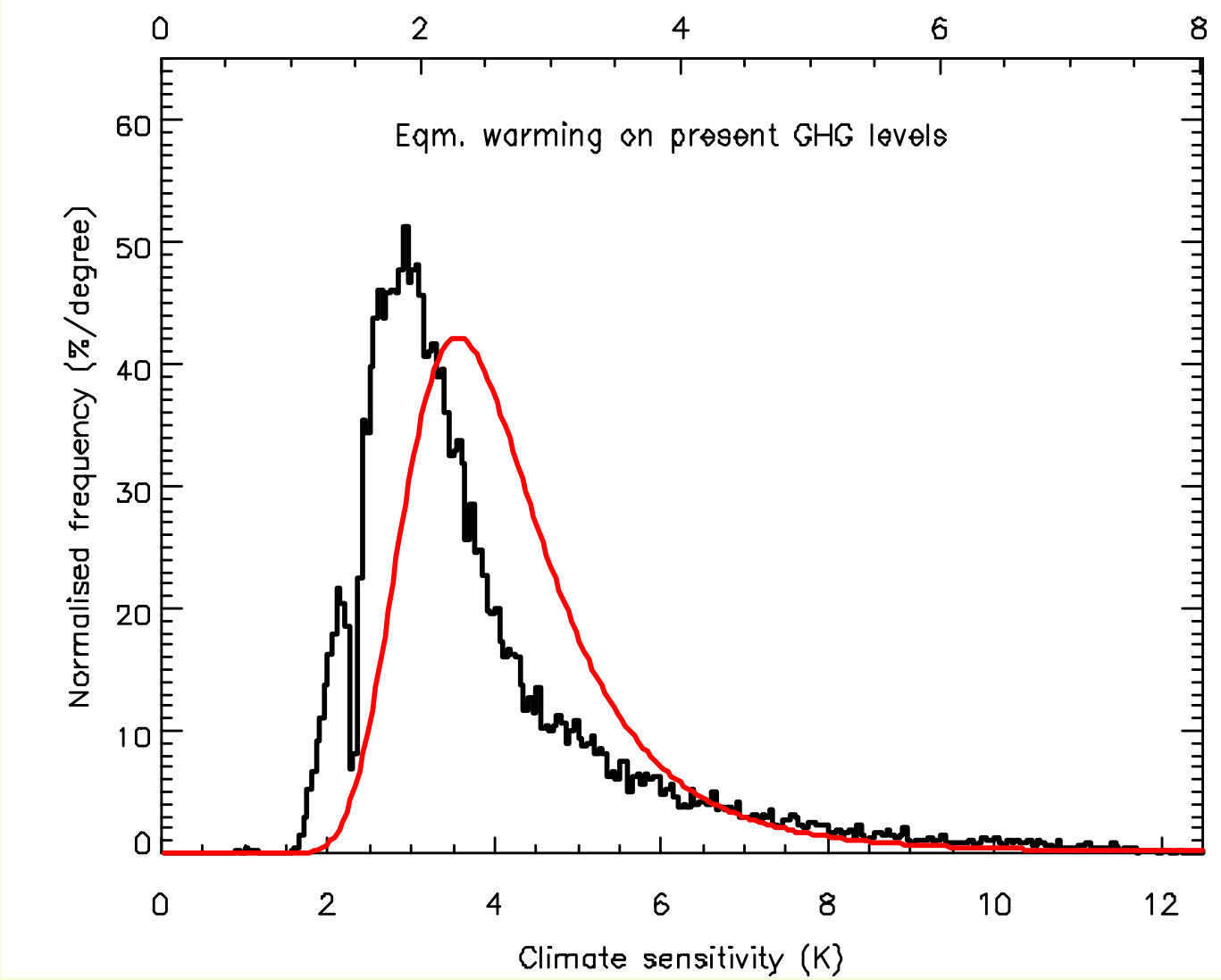
climateprediction.net

Oxford University

Would these high sensitivities be ruled out if we uploaded more diagnostics?



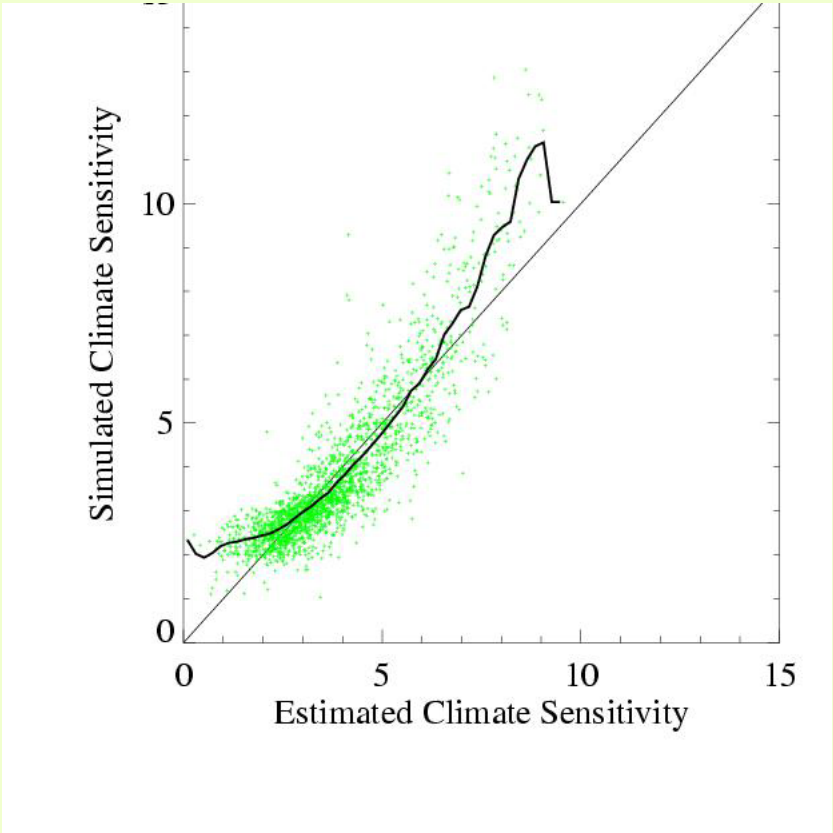
Not necessarily: Murphy et al, 2004, distribution without prior weighting towards low sensitivities



climateprediction.net

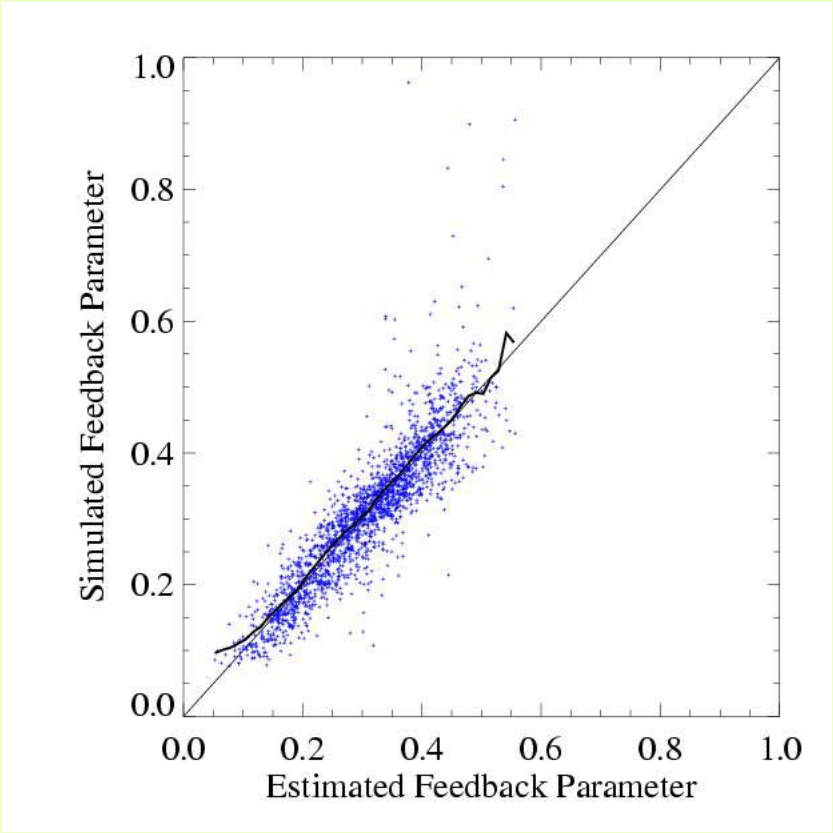
Oxford University

So how will we constrain S? Searching for predictors in the climate*prediction*.net ensemble



Piani et al, 2005

Linear prediction works best for the feedback parameter, or 1/S



climateprediction.net

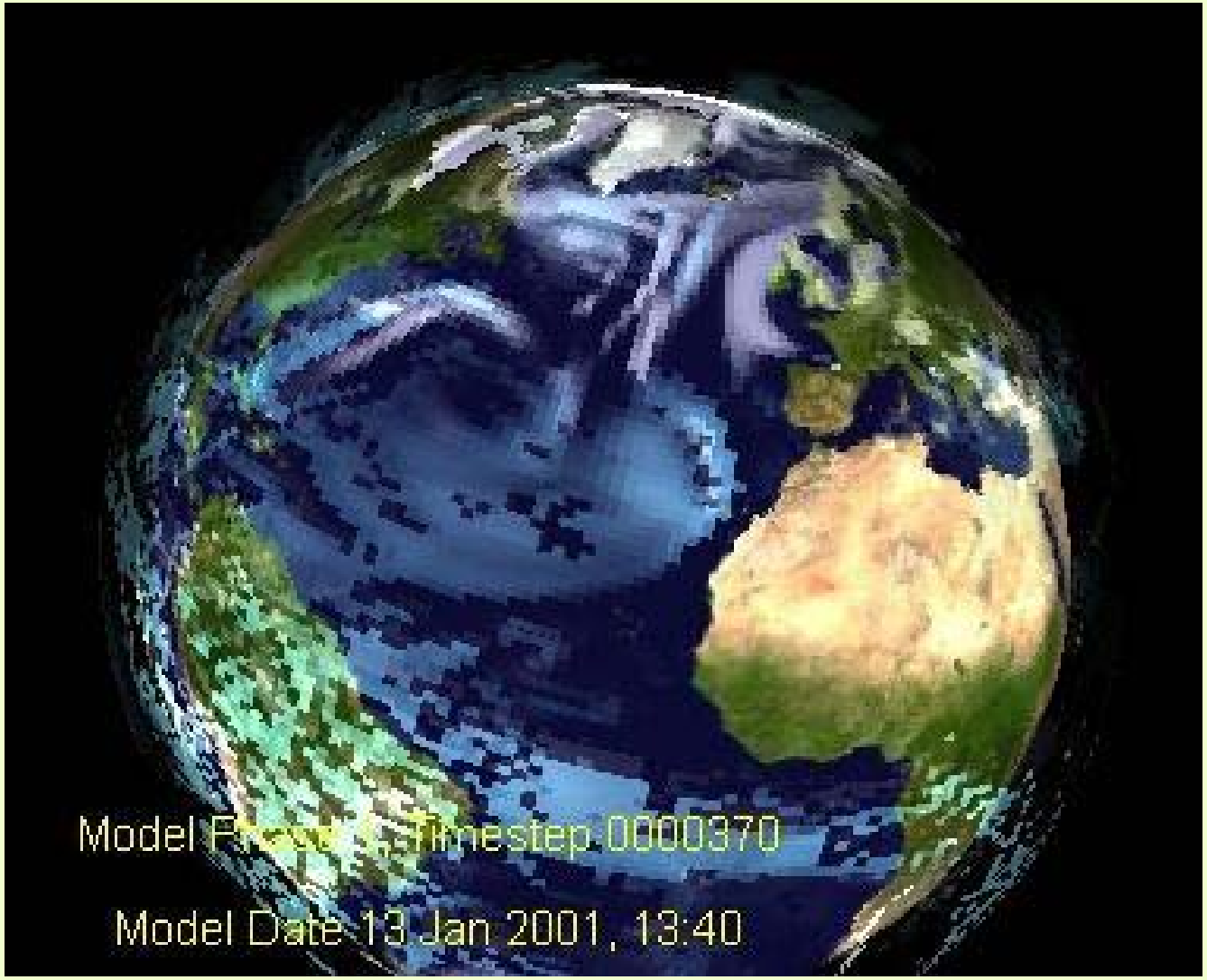
Oxford University

Where do we go from here?

- New applications for the world's largest climate modelling facility.
- Sulphur-cycle release (Highwood et al) under beta-test (feeding into Met Office DEFRA contract).
- Coupled simulations 1950-2050/2100 to follow.
- Local BOINC installation (testing at NERC) for secure intranet environments: provides low-hassle alternative to CONDOR.
- Ultimate goal: making Public Resource Distributed Computing an effective environment for ensemble Earth System Modelling.

climateprediction.net

New application: probabilistic attribution studies with forecast-resolution models



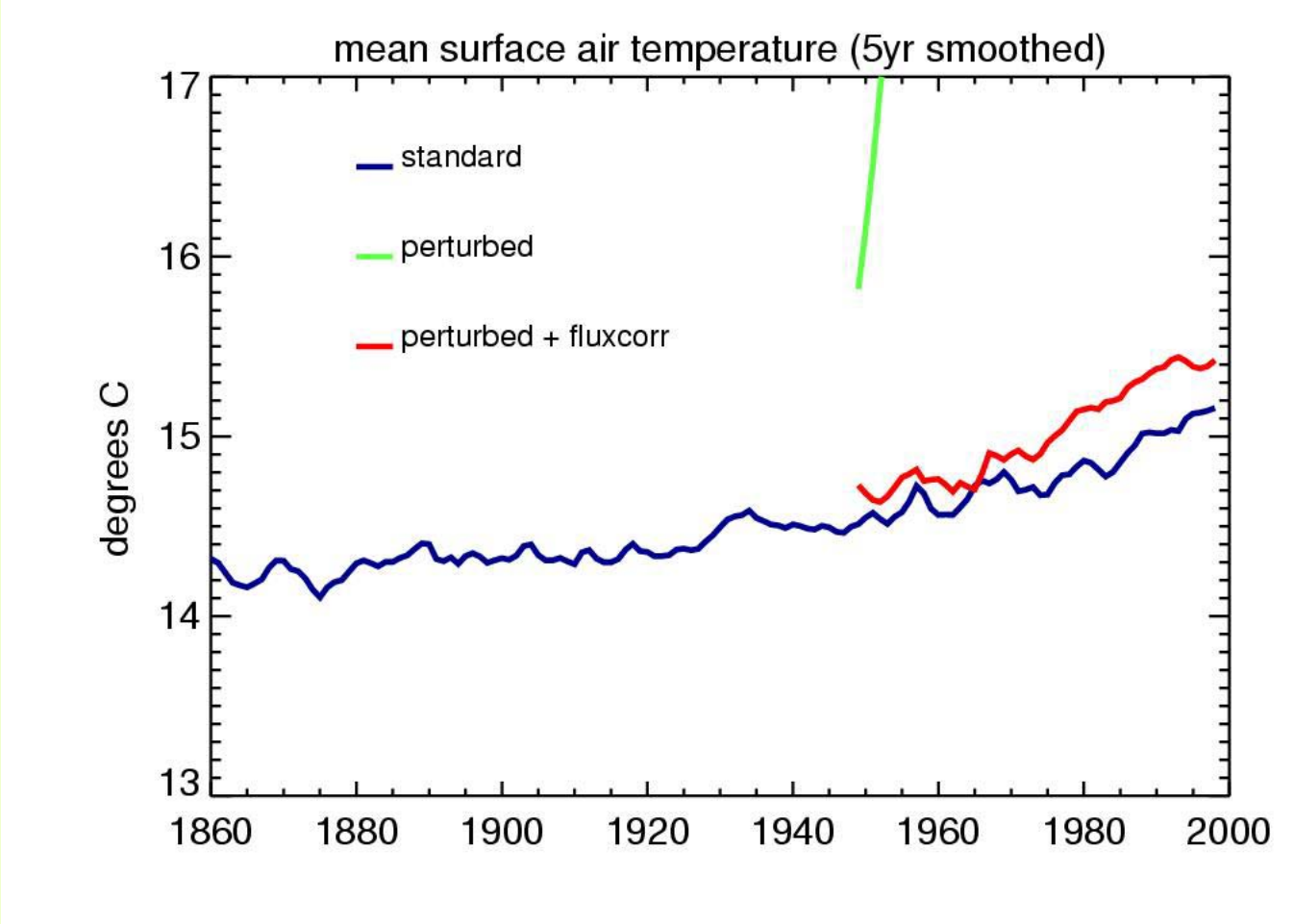
climateprediction.net

Using flux adjustment to generate large coupled ensemble without individual spin-ups

Replacing atmosphere in 1950 with more sensitive atmosphere:

Immediate drift with no flux adjustment

Small initial adjustment and slightly faster warming with flux adjustment



climateprediction.net

Potential Commercial Uses of BOINC Client

- Clinical trial modelling
- Nuclear engineering
- Transport predictions
- Financial hedging models
- Oil reservoir analysis
- Environmental modelling (eg, river catchments)
- Protein folding simulation

Tessella
Scientific software solutions

So, did we deliver?

- Climate research: watch this space - need to keep up the pressure on IPCC to take the possibility of extreme high sensitivities seriously.
- E-Science: “the first serious application of distributed computing” (*The Economist*) and a viable alternative to CONDOR.
- Communication: …

climate*prediction*.net

Still some way to go…

FREE METRO

Check out our great going out guide

Thursday, January 27, 2005 www.metro.co.uk

Life, starts Page 17

Smoke billows into the sky above the port of Dudinka in Russia yesterday

11°C That's how much hotter scientists believe the world will get ... and it will be worse in Britain

BY SUZY AUSTIN

THE world is likely to heat up by an average of 11°C by the end of the century, the biggest ever study of global warming showed yesterday.

And the effect could be even more marked in Britain, where temperatures could soar by up to 20°C unless greenhouse gases are cut.

Such a rise – far higher than the 2°C previously forecast – would see Britain endure tropical temperatures, flooding and devastating drought.

It would change the weather patterns of the world, melt the polar ice caps and warm the oceans, causing a surge in sea levels threatening the lives of billions of people.

The findings come from a study which tapped into the processing power of 100,000 home computers in 150 countries.

Researchers racked up the equivalent of 8,000 years of processing time as they ran 60,000 potential scenarios through the network, far more than the 128 scenarios the powerful computers at the Met Office can check in a year.

Each scenario was based on the assumption that carbon dioxide levels had reached double those of pre-Industrial Revolution times by the middle of this century.

Researcher David Stainforth, from Oxford University, said: 'An 11 degree warmed world would be a dramatically different world.

'Warming is not constant at all latitudes and tends to be greater at high latitudes.

'With a world warmed by 11 degrees there would be large areas of high latitude that could be 20 degrees warmer than they are today.

'I think it would probably not be a tropical paradise. The UK would be at the high end of this change, well into the teens as the temperature changes. I don't think we'll be building many snowmen in winter, or going sledging.'

The findings could mean world leaders need to toughen their commitment in the Kyoto agreements to cut CO_2 emissions to 5.2 per cent below 1990 levels by 2012.

The warning came as Tony Blair used the World Economic Forum in Switzerland to call for action on global warming and to pressure America to sign up to Kyoto.

Blair's call – Page 5

climateprediction.net

Scientific Output

- D. A. Stainforth, T. Aina, C. Christensen, M. Collins, N. Faull, D. J. Frame, J. A. Kettleborough, S. Knight, A. Martin, J. M. Murphy, C. Piani, D. Sexton, L. A. Smith, R. A. Spicer, A. J. Thorpe & M. R. Allen, *Uncertainty in predictions of the climate response to rising levels of greenhouse gases*, Nature, 433, pp.403-406, January 2005.
- James Murphy, David Sexton, David Barnett, Gareth Jones, Mark Webb, Matthew Collins & David Stainforth, *Quantification of modelling uncertainties in a large ensemble of climate change simulations*, Nature, 430, pp.768-772, August 2004.
- Arno Scharl (Ed.), *Environmental Online Communication*, Advanced Information and Knowledge Processing Series, (c)2004 Springer London, ISBN: 1-85233-783-4, Chapter 12 "climateprediction.net: a global community for research in climate physics"
- Myles Allen, Jamie Kettleborough and David Stainforth, *Model error in weather and climate forecasting*, from the Proceedings of the 2002 ECMWF Predictability Seminar, European Centre for Medium Range Weather Forecasting, Reading, UK, pp. 275-294, 2003.
- Myles Allen, *Possible or probable?*, Nature, 425, p.242, September 2003.
- David Stainforth, Jamie Kettleborough, Myles Allen, Matthew Collins, & Andy Heaps, *Climateprediction.com: Distributed Computing for Public Interest Modelling Research*. Computing in Science and Engineering, vol 4, no. 3, 2002.
- Myles Allen and William Ingram, *Constraints on future changes in climate and the hydrologic cycle*, Nature Insight article, Nature, 419, pp.224-232, 2002.
- Myles Allen & David Stainforth, *Towards objective probabilistic climate forecasting*, Nature, 419:230, 2002.
- David Stainforth, Jamie Kettleborough, Andrew Martin, Andrew Simpson, Richard Gillis, Ali Akkas, Richard Gault, Mat Collins, David Gavaghan, & Myles Allen, *Climateprediction.net: design principles for public resource modeling research*, Proc. 14th IASTED conf. on parallel and distributed computing systems, 2002.
- Jim Hansen, Myles Allen, David Stainforth, Andy Heaps and Peter Stott, *Casino-21: Climate Simulation of the 21st Century*, World Resource Review, 13, 2, pp.187-189, 2001.
- Myles Allen, *Do it yourself climate prediction*, Nature, 401, p.642, October 1999

Output and Performance Measures

Science and Society: *Events*

- Project representatives at: Adaptation Research Workshop, Stabilisation 2005, Royal Society Exhibition (2005), EGU exhibition, National Science Week, COP-10
- Climate*prediction*.net Open Day

Science and Society: *Publications*

Schools Teaching Materials

Press Coverage of Public Launch, September 2003

- Articles in more than 20 newspapers worldwide

Press Coverage of publication in Nature, January 2005

- Articles in more than 20 newspapers worldwide

Science and Society: *Media Activities*

Public Launch, September 2003

- Radio appearances on BBC Radio 4 (Today Programme), BBC Radio 5, BBC World Service, BBC Radio Northamptonshire, BBC Radio Berkshire, BBC Radio Oxfordshire, and BBC Radio Scotland
- TV coverage on BBC News, Newsround, Meridian TV

Publication in Nature, January 2005

- Radio appearances on BBC Radio 4 (Today Programme), BBC Radio 5, BBC World Service, BBC Radio Northamptonshire, BBC Radio Berkshire, BBC Radio Oxfordshire, and BBC Radio Scotland, CBC Radio-Canada,
- TV coverage on BBC News and Sky News