www.climate*prediction*.net

The Goals:

- **To harness the power of idle PCs to help quantify uncertainty in predictions of the 21st century climate.**
- **To improve public understanding of the nature of uncertainty in climate prediction.**

The Method:

- **Invite the public to download a full resolution, 3D climate model and run it locally on their PC.**
- **Use each PC to run a single member of a massive, perturbed physics ensemble.**
- **Provide visualization software and educational packages to maintain interest and facilitate school and undergraduate projects etc.**

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Sources of Uncertainty

Basic sources of model uncertainty:

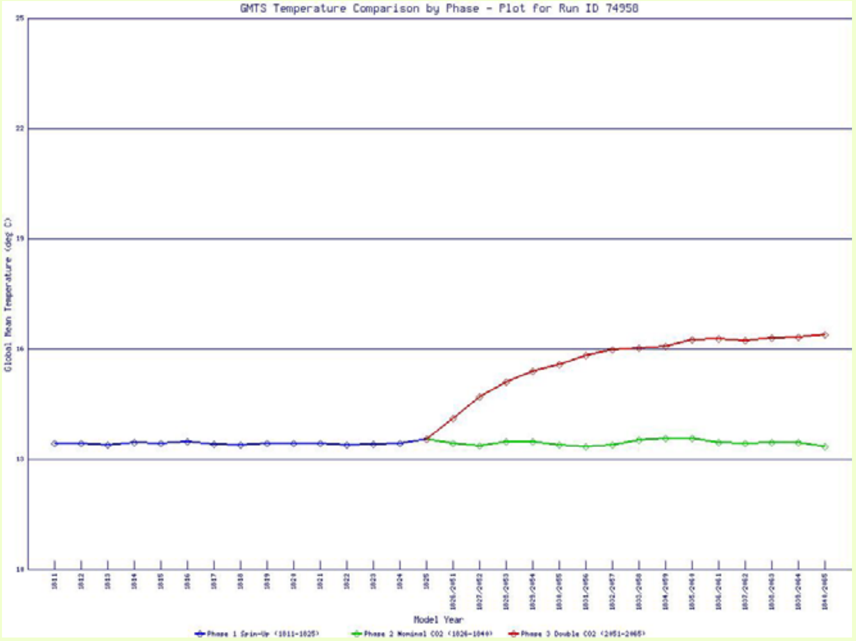
1. **Incomplete knowledge of the initial state of the system**
2. **Uncertainty in future forcings**
3. **Uncertain models - poor/incomplete representation of the physical processes that govern the climate**

climate*prediction*.net targets model uncertainty.

To systematically explore model uncertainty requires large numbers of simulations, due to the non-linear interaction of parameters. Hence the need for climate*prediction*.net to carry out such an ensemble.

Climate Sensitivity

- **Climate sensitivity is defined as the change in global mean temperature, T2x, that results when the climate system, or a climate model, attains a new equilibrium with the forcing change F2x resulting from a doubling of the atmospheric CO2 concentration**



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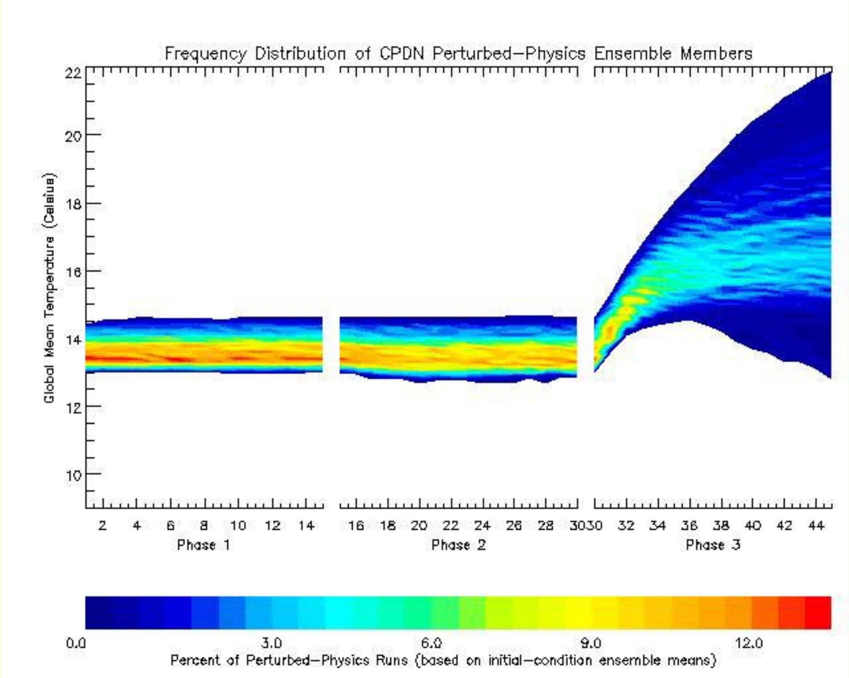
Climate Sensitivity

- Climate sensitivity is difficult to evaluate directly, because we've never doubled CO2 (and nothing else) and sat back and taken temperature measurements.
- Numerous studies have attempted to place distributions on climate sensitivity
- These often agree on lower bounds and modal values, but disagree about upper bounds



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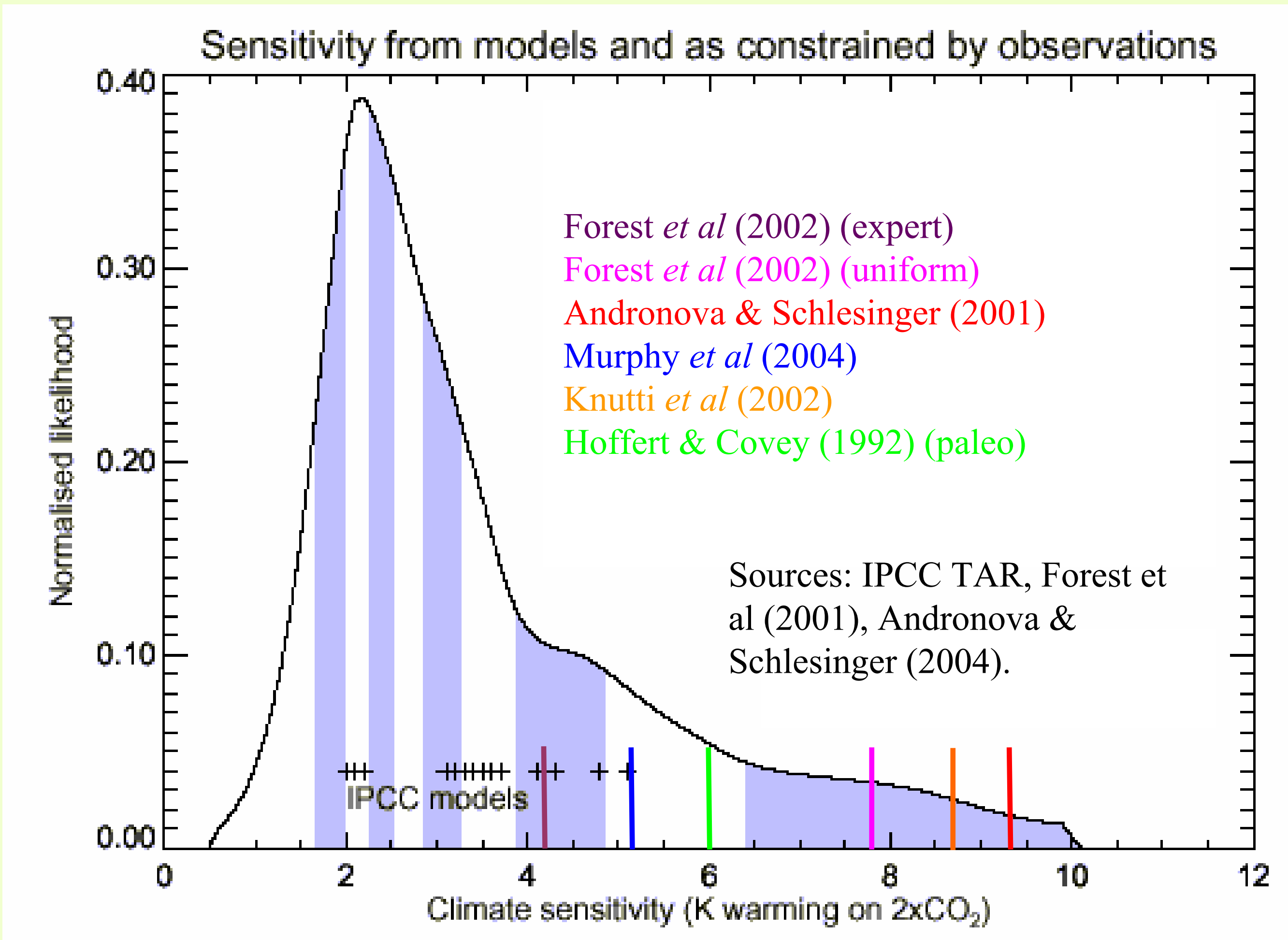
Uncertainty in climate sensitivty



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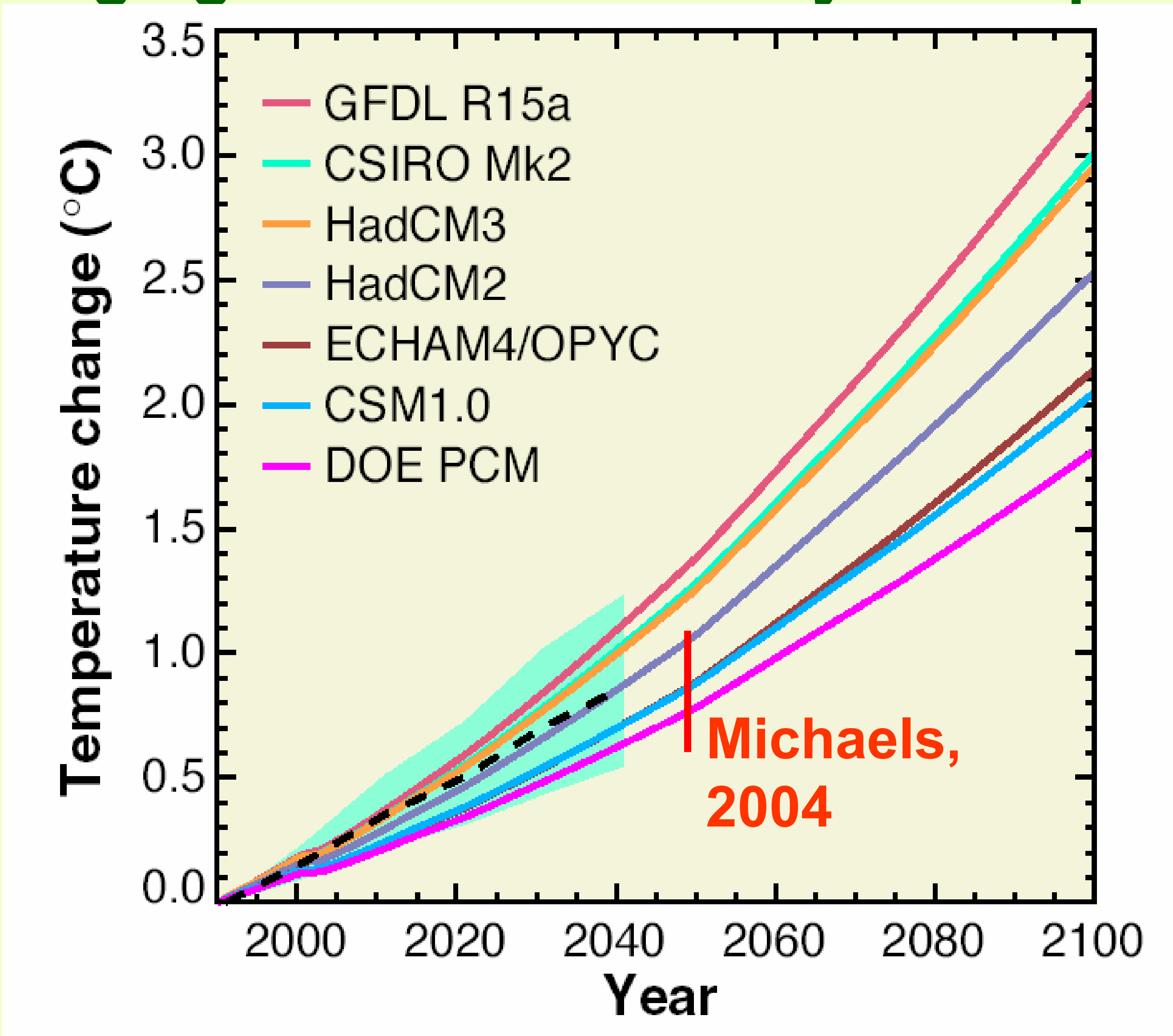
Emerging consensus on 50-year response



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Constraining climate sensitivity: probabilistic approaches

Attempting to constrain perturbed-physics ensembles with observational data.

- Observational constraints from ocean heat content changes.
- Observational constraints from Detection and Attribution studies.
- Physical constraints from perturbed-physics ensembles.
- Inferring probabilistic climate forecasts from these.

Comparing individual simulations with observations

- Use detection and attribution analysis to estimate attributable greenhouse warming, ΔT_{GHG} (linear trend 1900-2000), allowing for uncertainty in forcing. [Data from Stott & Kettleborough (2002).]
- Estimate effective heat capacity c_{eff} from observed $\Delta Q_{1957-1994}/\Delta T_{1957-1994}$, allowing for uncertainty in both. [Data from Levitus *et al* (2005); CRU.]
- Sample sensitivity and heat capacity in a simple climate model.

$$c_{eff} \frac{d\Delta T}{dt} = F - \lambda \Delta T$$

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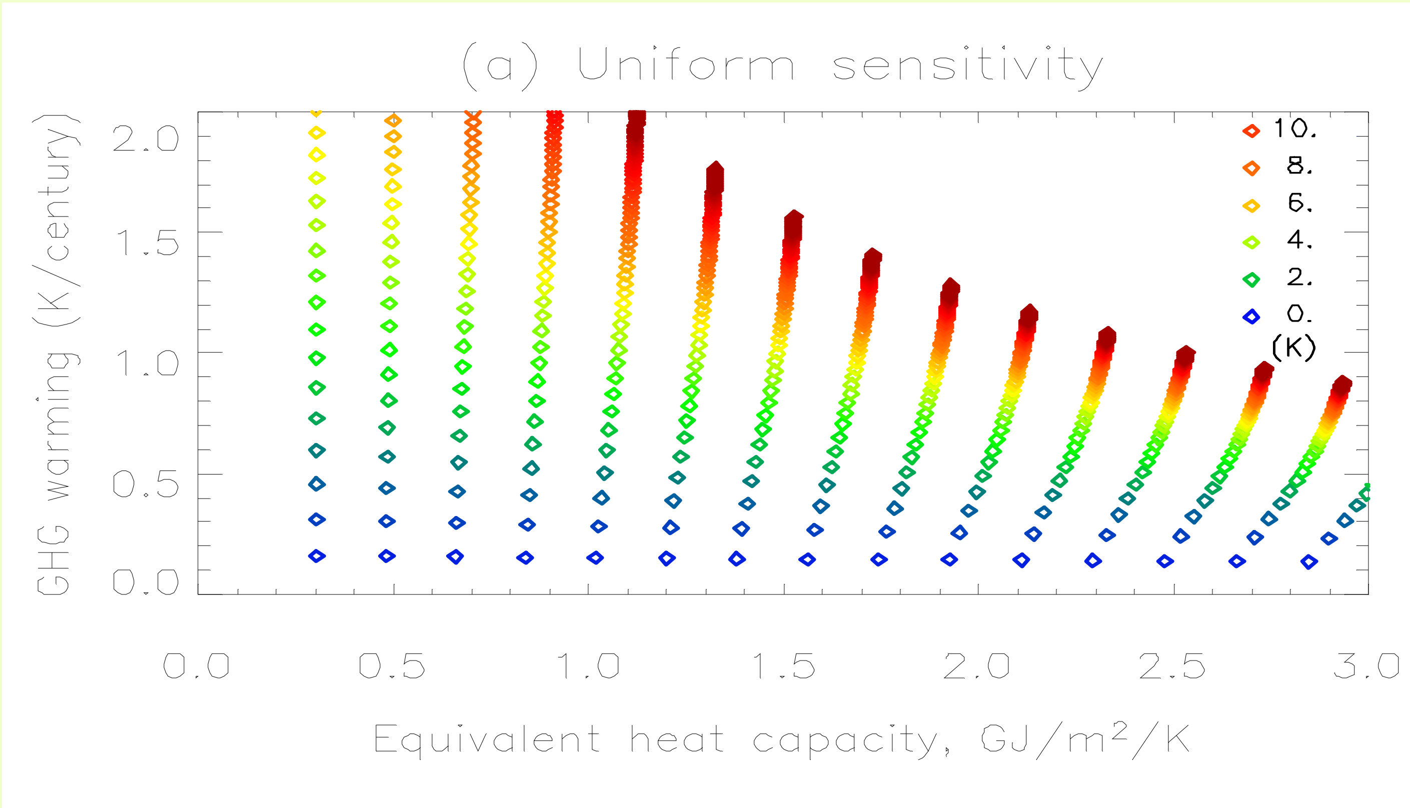
Sampling sensitivity and heat capacity in a simple climate model (Hansen et al, 1985)



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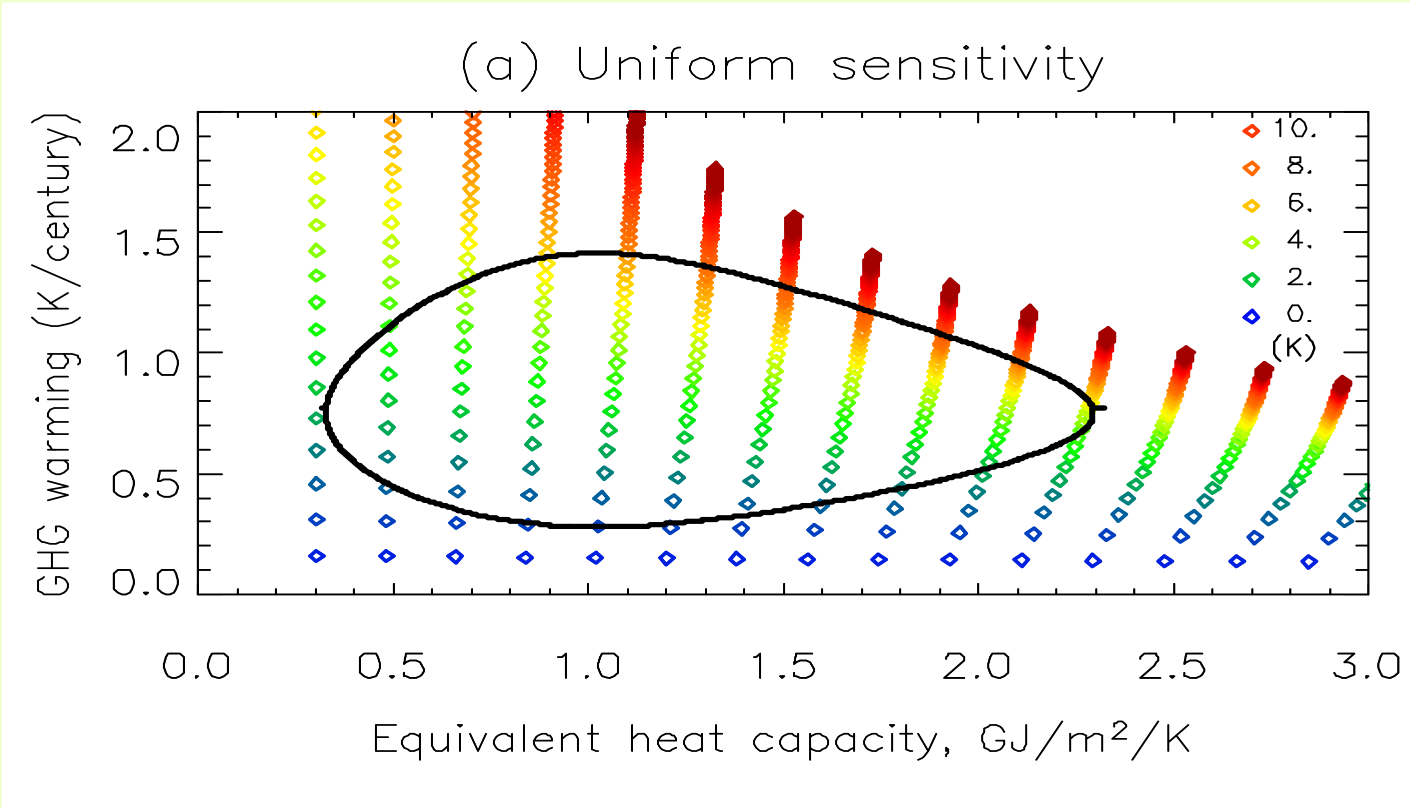
Uniform sampling in sensitivity



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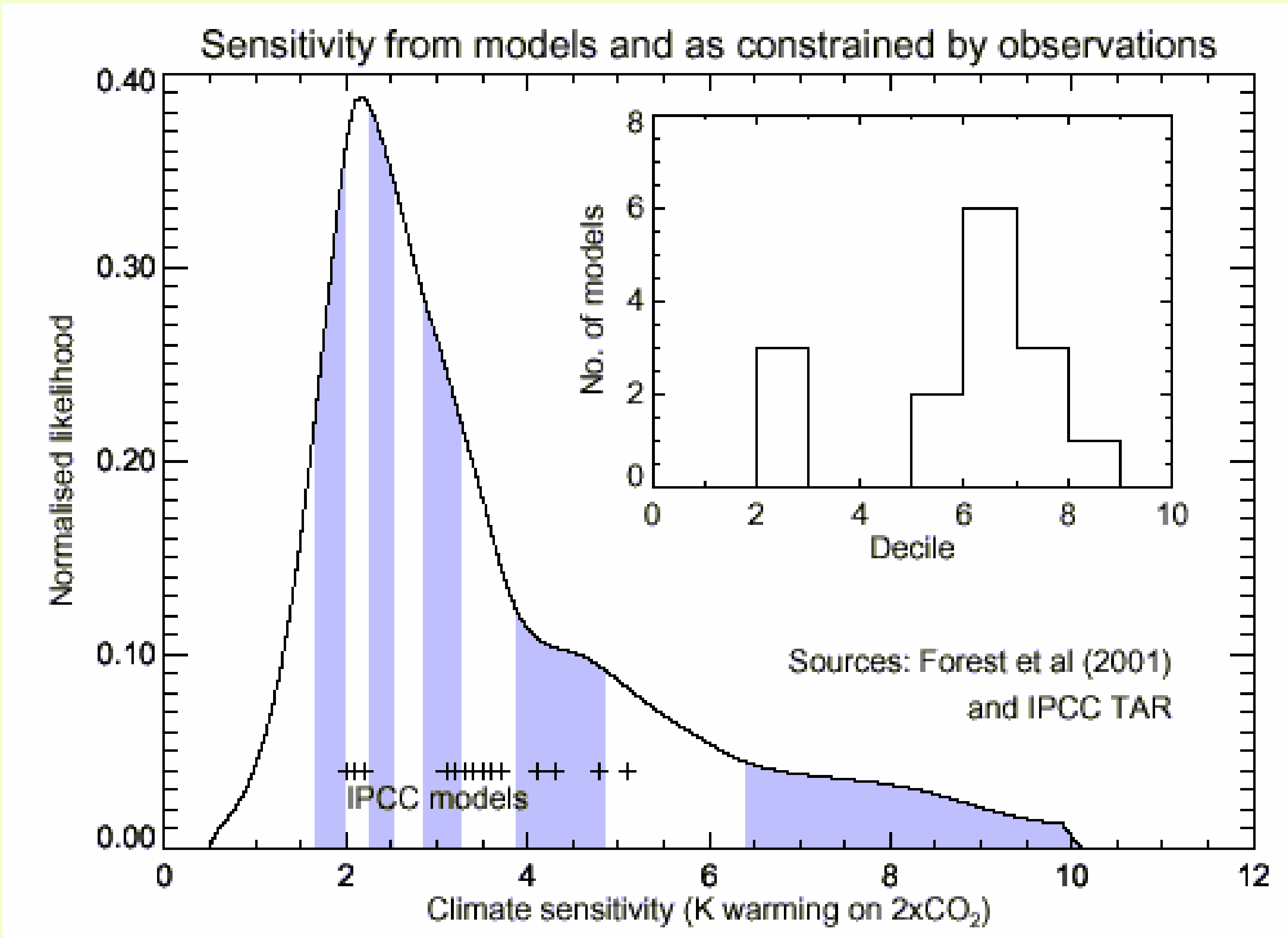
Uncertainty in climate forecasts



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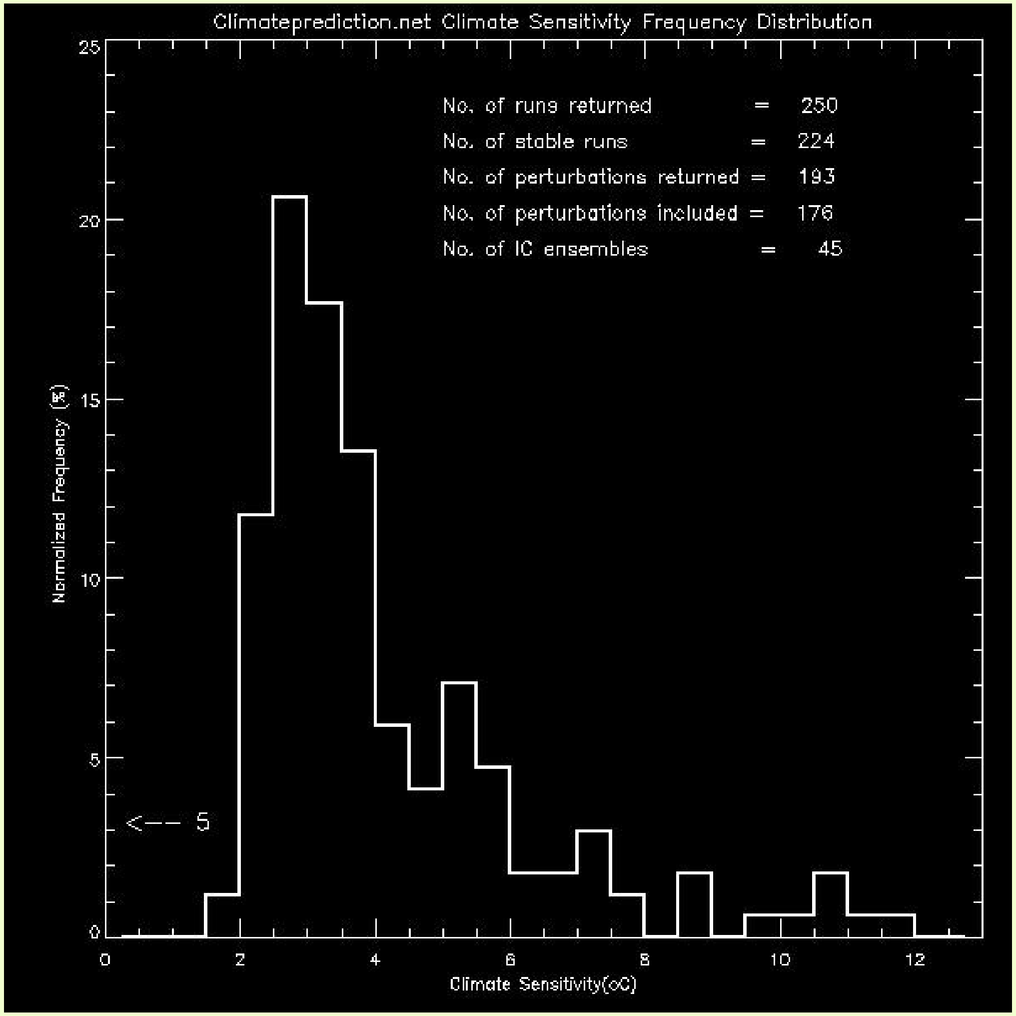
Initial Results: Climate Sensitivity Frequency Distribution



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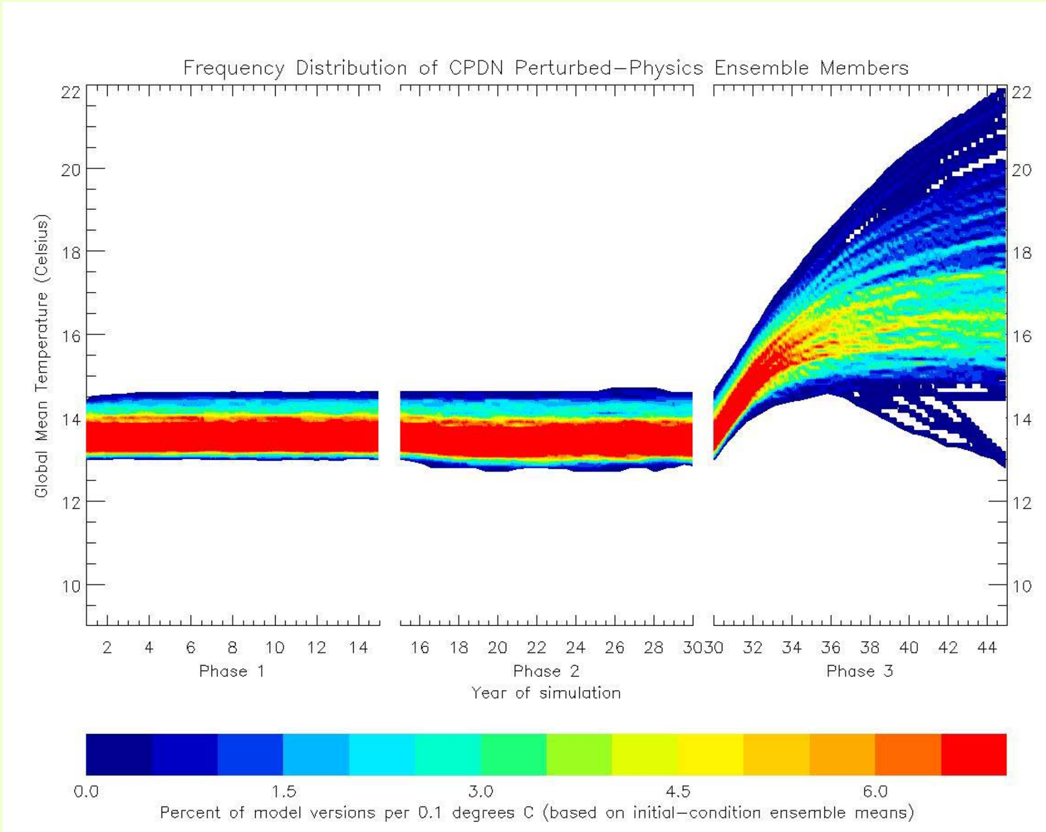
Courtesy David Stainforth

Initial Results: Complete Ensemble

30000+ runs completed and returned to us

Our model ensemble is already more than a hundred times bigger than any other ensemble climate forecast

The results of the CO2 doubling experiment let us access a wider range of climate sensitivities than has been possible before – illustrates the value and validity of the approach



Courtesy David Stainforth

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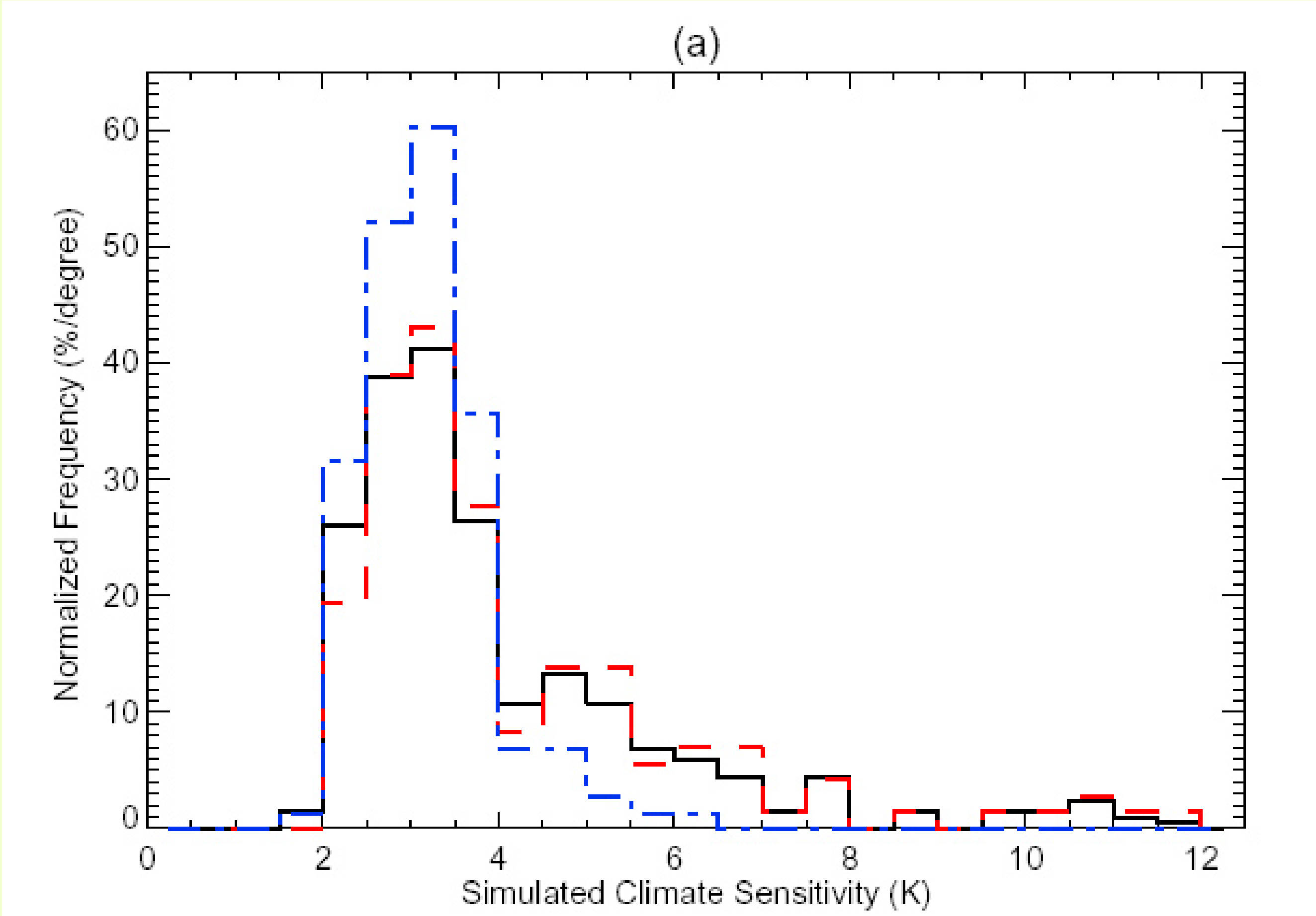
Verifying experimental integrity

- Initial analysis shows that the model runs fine on a 32bit PC (Windows, Linux, Mac).
- Analysis of duplicate runs and initial condition ensembles validates experimental integrity
- Analysis of subset of the ensemble shows that changes in model physics add, generally, non-linearly, necessitating the large ensemble approach
- Analysis of ensemble against observations shows we can't rule out high sensitivity (10K) models

Initial Results

- Physics Perturbations add non-linearly.
- The cumulative effects of these perturbations is to span a wider set of model behaviours than has previously been seen,
- especially at the high end of the sensitivity range
- More efficient methods which interpolate across the phase space of the model succeed some 75% of the time, but fail in many of the most interesting cases

Wide range of sensitivities



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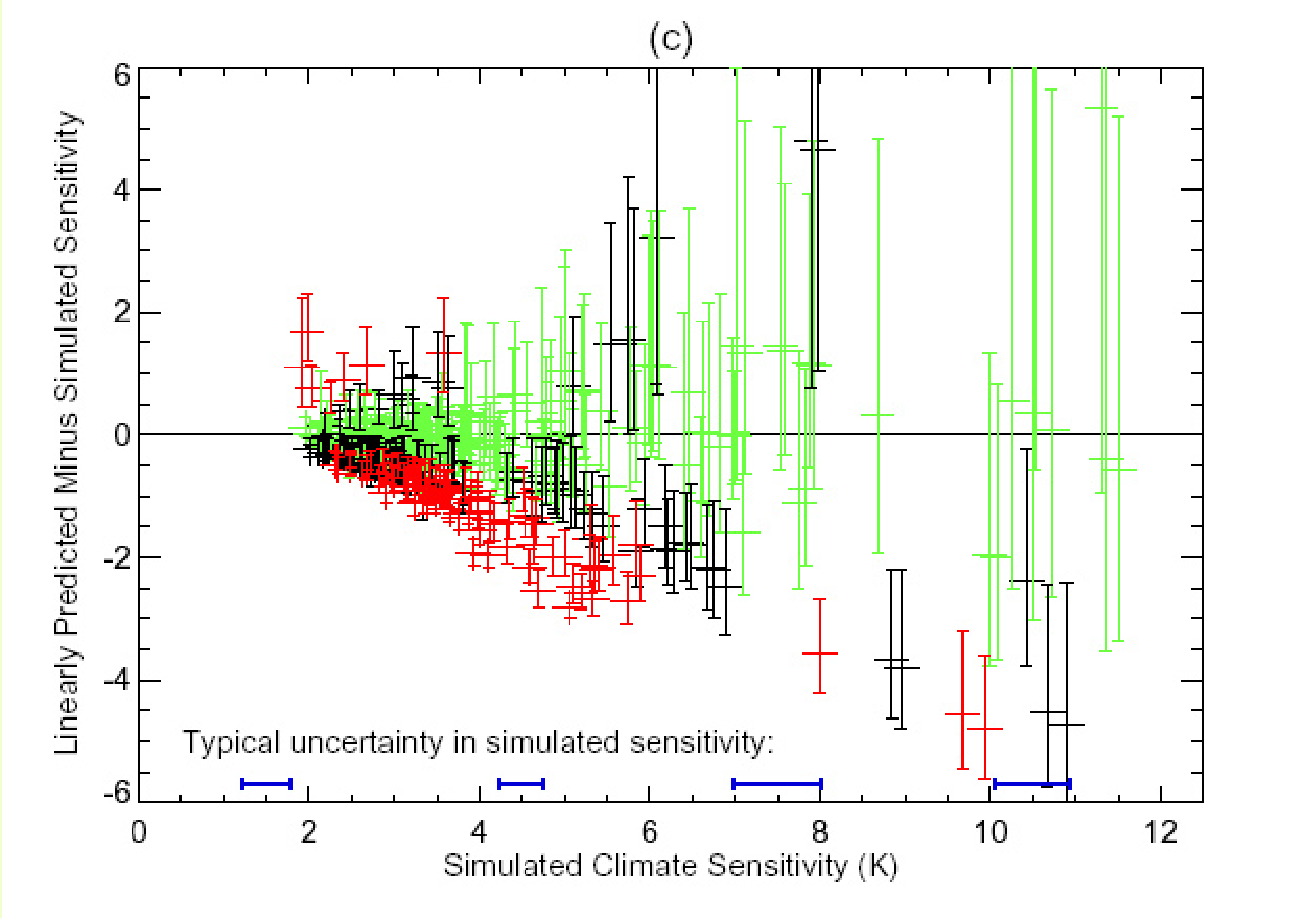
Perturbations add non-linearly



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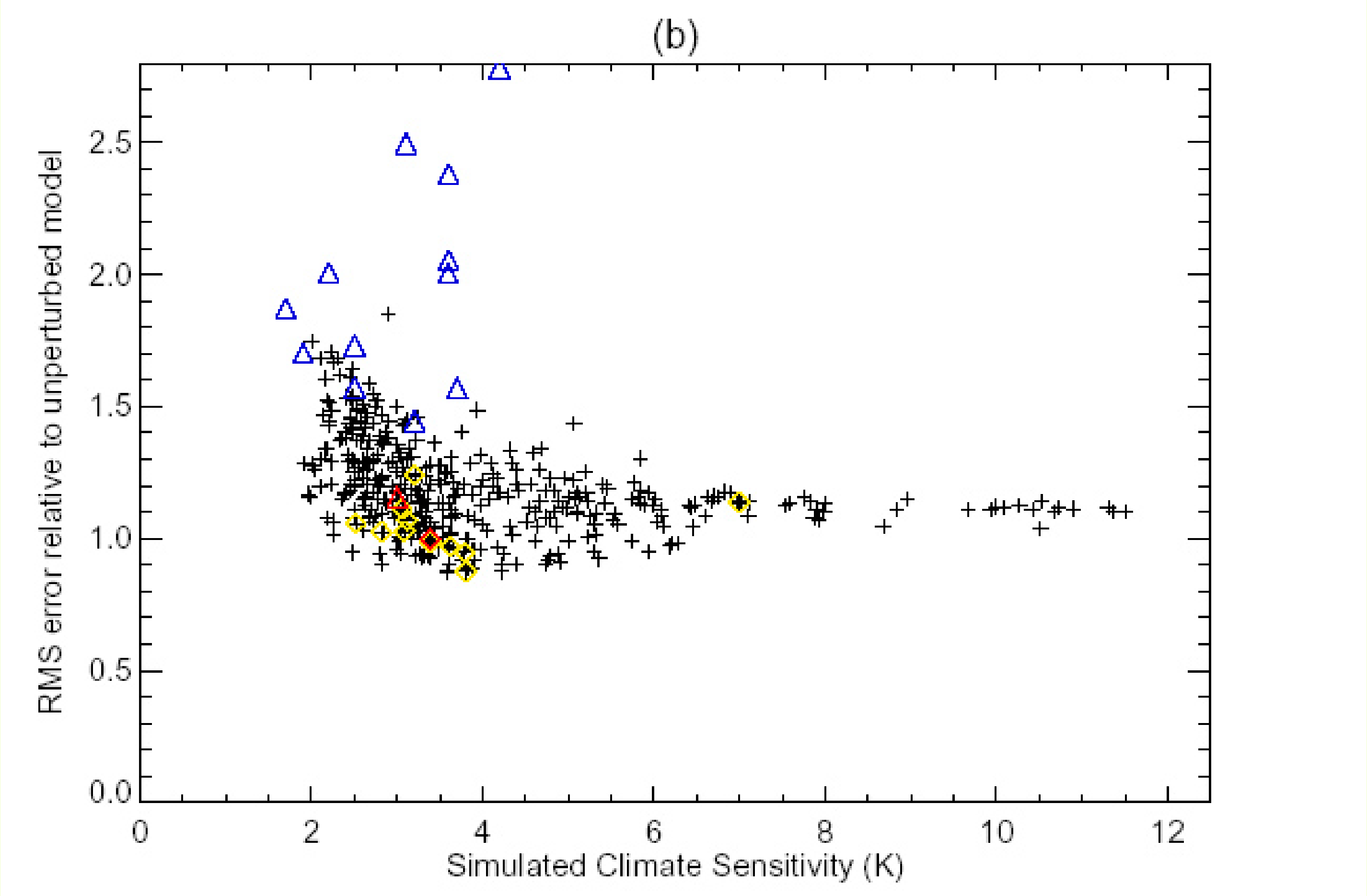
Model "quality" vs Sensitivity



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Initial results

- On-going task to compare models against observations
- Building on CMIP-II's experience
- Models that give us high sensitivities not yet ruled out by observations
- There are a number of interesting models that give us a range of sensitivities (<2K to >11K) that do not appear to be worse climate models than HadCM3

Next steps, analysis

- Systematic quality control process
  - Models vs physics, vs other models
  - Models vs observations
- More full analysis of the entire ensemble
- Several subprojects already suggested
  - New variables (precip, mslp,
  - Regional analyses
- Ultimately want this to become a dataset like CMIP-II or a satellite dataset – a community resource (we just have to build the infrastructure, first!)

Next steps, experimental development

- **Sulphur cycle experiment**
  - Perturbations to the S-cycle, sensitivity experiment to changes in aerosols, similar to current experiment
  - currently being tested
- **Coupled model spinups**
  - Perturbations to ocean to give range of Kv, thermohaline behaviours
- **Coupled model hindcast experiment**
  - run 1950-2000 using historical forcings as a test of the models from the slab phase(s)
- **Coupled model 21st century experiment**
  - run 2000-2100 using range of future forcings, having run the hindcast and found models which are both interesting (phase 1) and good (phase 2)
  - Predictive experiment with the goal of a "probabilistic" forecast

Research aspects in climate*prediction*.net

- **Physical/Climate Science**
  - outputs include a fascinating dataset, quality research papers
  - most comprehensive "probabilistic forecast" for 21st century
- **Computer Science**
  - outputs include a functioning, easy-to-use web-services-based interface to data (including quality control)
  - Grid-enabled analysis toolkit to analyse very large distributed dataset
- **Public Involvement**
  - outputs include materials for university (Open Univ., UK) and schools (UK, NZ) students to learn about climate, statistics, etc
  - Thousands of participants who are willing to donate resources, learn about climate, engage with others in a virtual community

Participation in climateprediction.net

Participants can:

- **Run up to 145 years of the Hadley Centre's state of the art climate model**
- **View (and analyse) their model output**
- **Compare results on the web**
- **Take an OU short course associated with climate*prediction*.net**
- **Utilise Open University's distance learning resources to find out more about climate (& modelling)**
- **Participate in our lively community discussion forums**
- **Browse our educational web-site**

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Computer science

- **Integration into Berkeley's BOINC gives us:**
  - **The benefit of their extensive expertise and experience**
  - **Improved, more flexible control software**
  - **More stable server-client software**
  - **Allows us to join the world's largest and most advanced DC community, fits well with our long-term plans**

- **Server side development**
  - **Curating and maintaining very large database (*harder than you'd think!*)**
  - **Automatic quality control**
  - **Distributed analysis capability**
  - **BADC to control access, authentication, authorization, etc.**

Long term plans

- **Sister projects:**
  - **climate*prediction*.eu**
  - **climate@home**
  - **paleoprediction.net..?**
- **Distributed computing is a great way to solve problems in:**
  - **Ensemble modelling**
  - **Environmental modelling**
- **Opportunity for BOINC/climateprediction.net infrastructure to play an important role in a burgeoning field within scientific problem solving**

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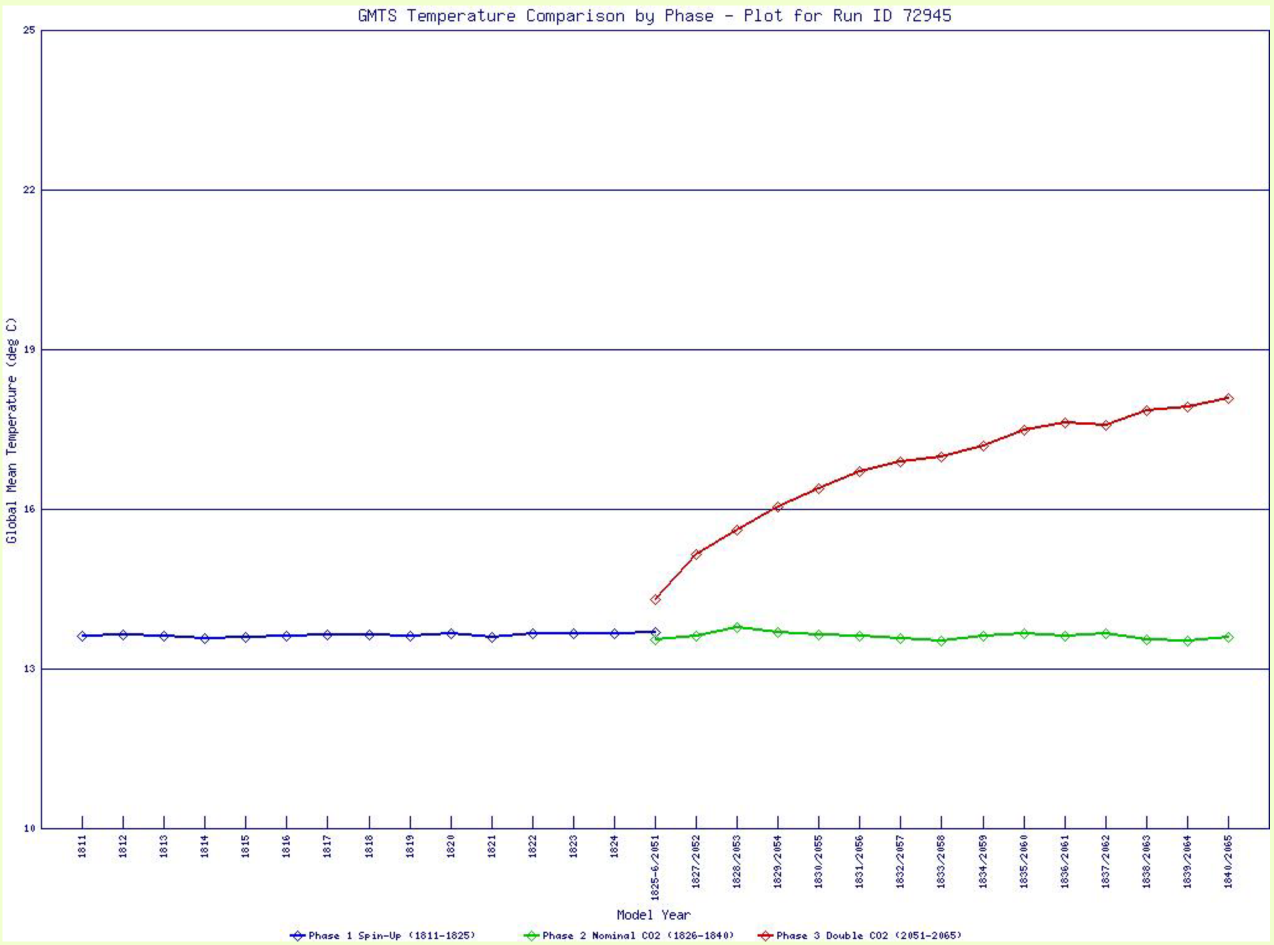
See the effects of a doubling of CO_2 on your Earth-like planet



(To be integrated with the data on the previous slide in order to give context for your run within the ensemble as a whole.)

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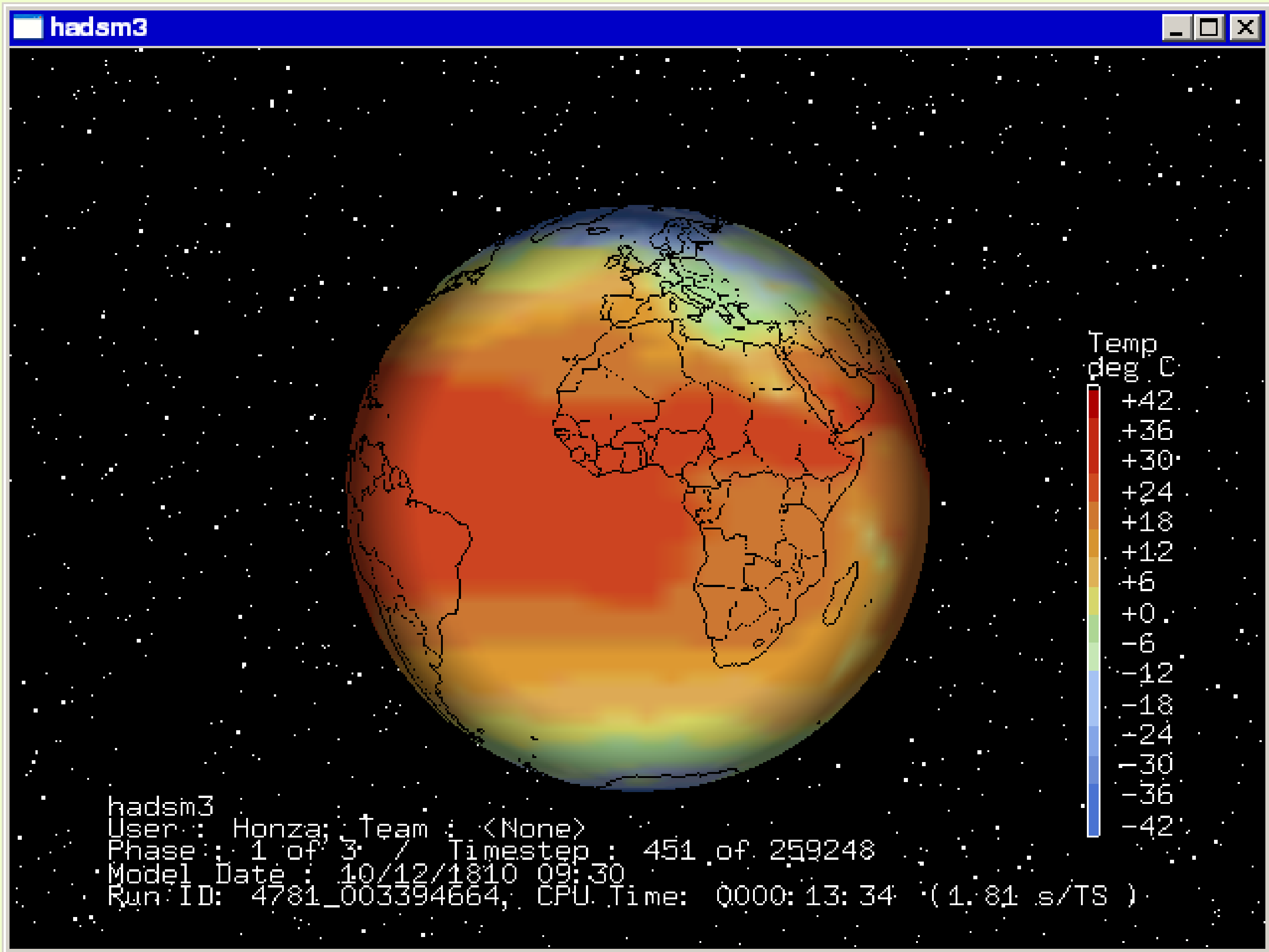
View your model as it changes over hours, days, seasons and years



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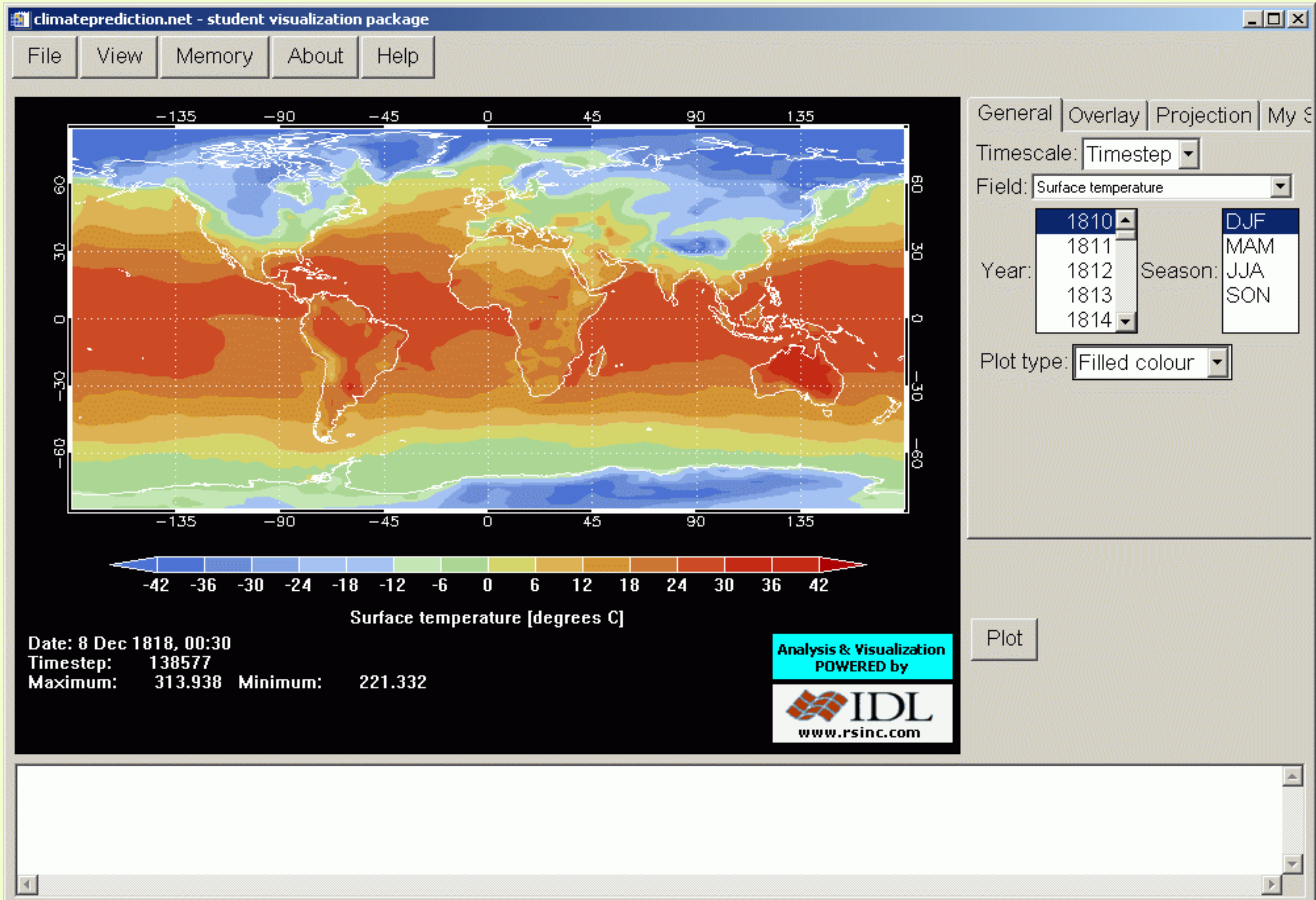
Advanced Visualisation 1



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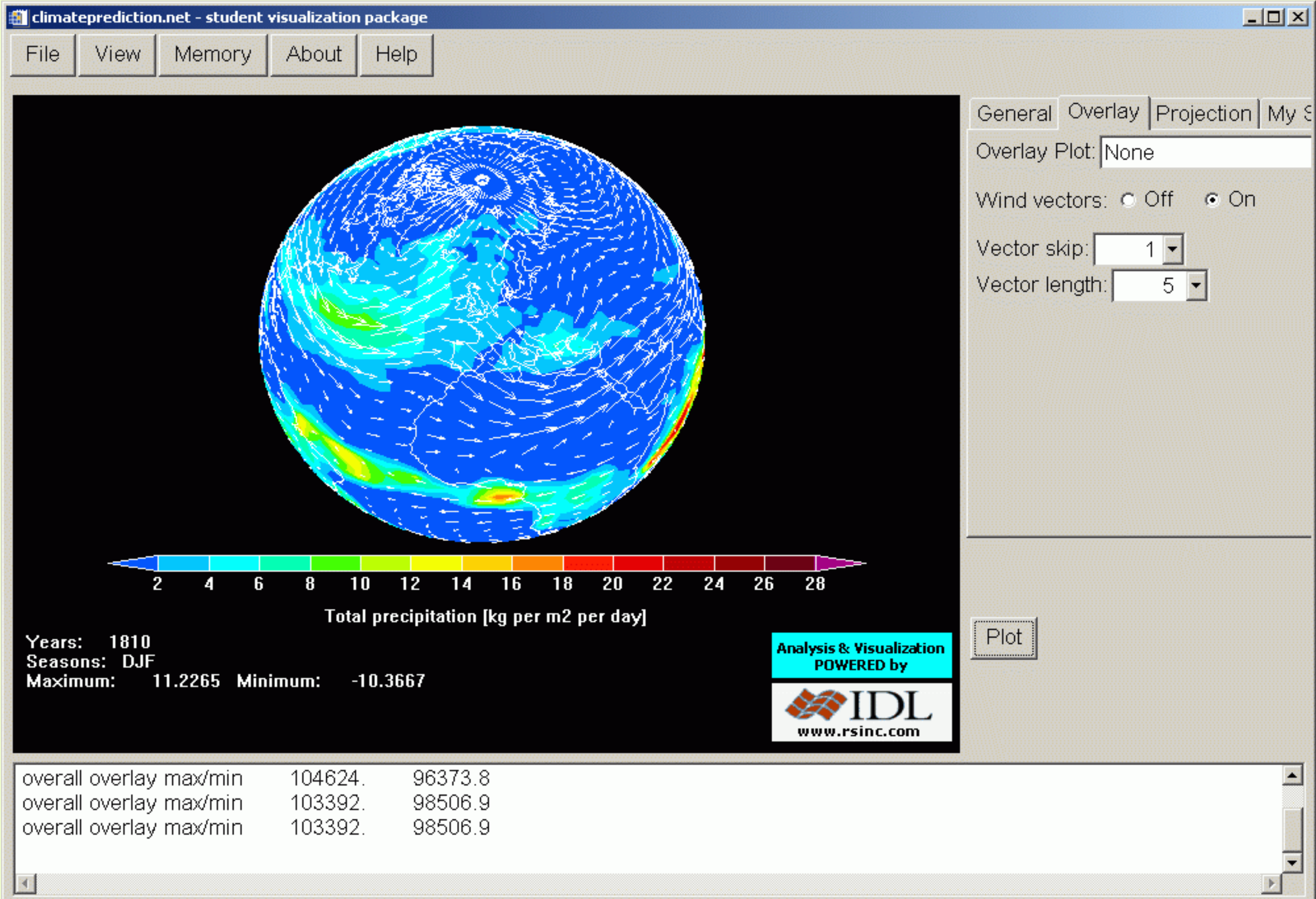
Advanced Visualisation 2



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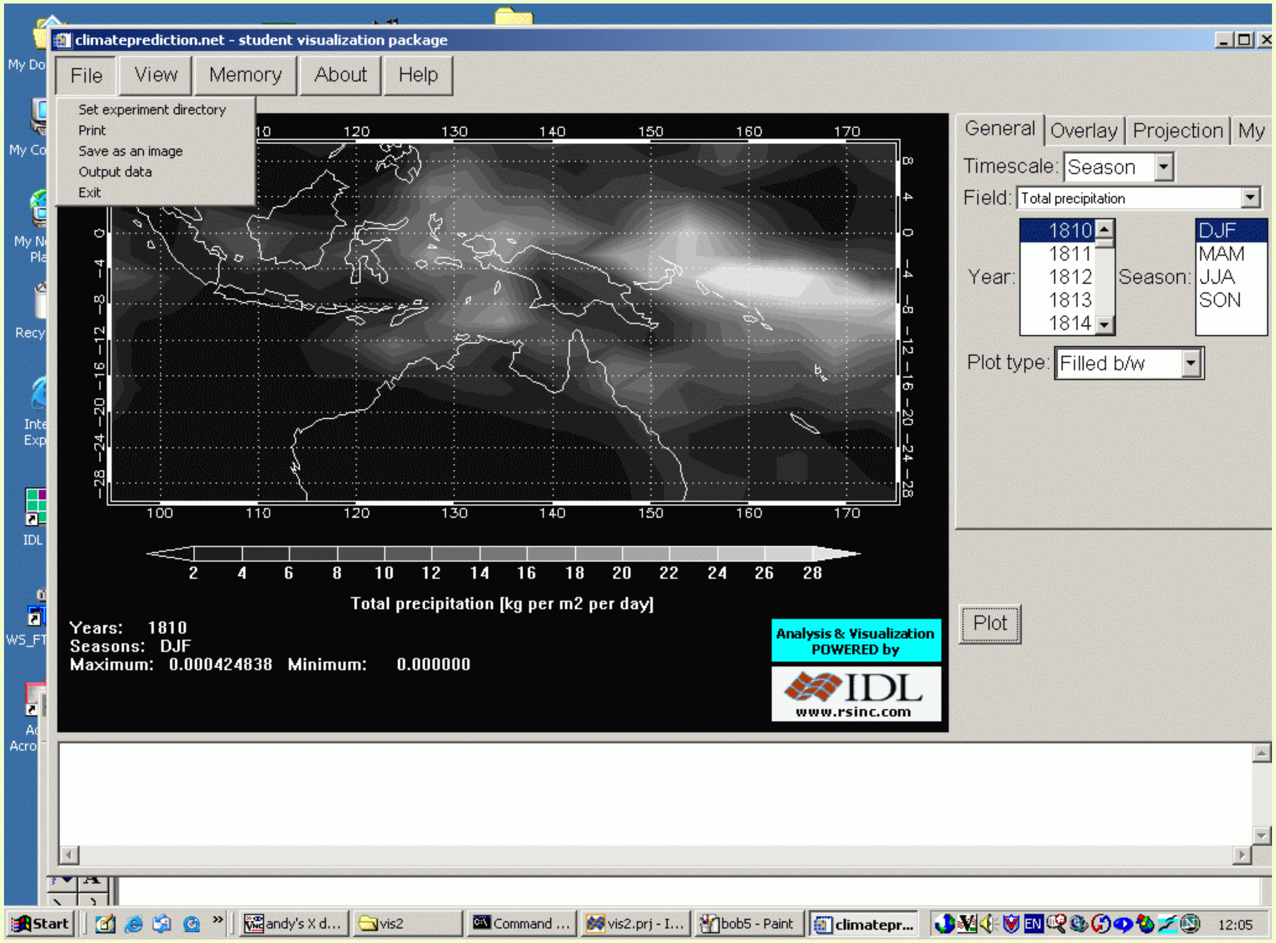
Advanced Visualisation 3



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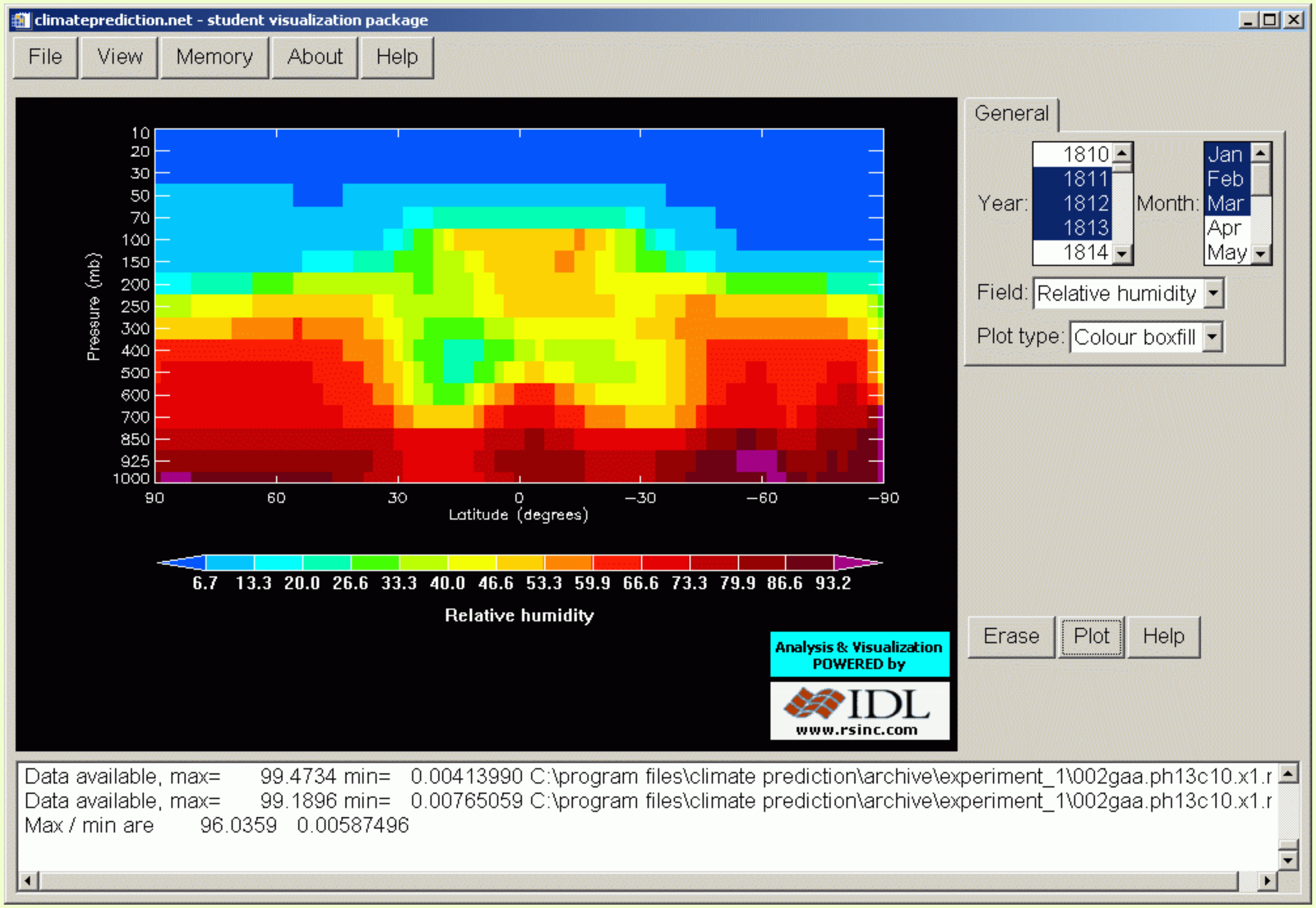
Advanced Visualisation 4



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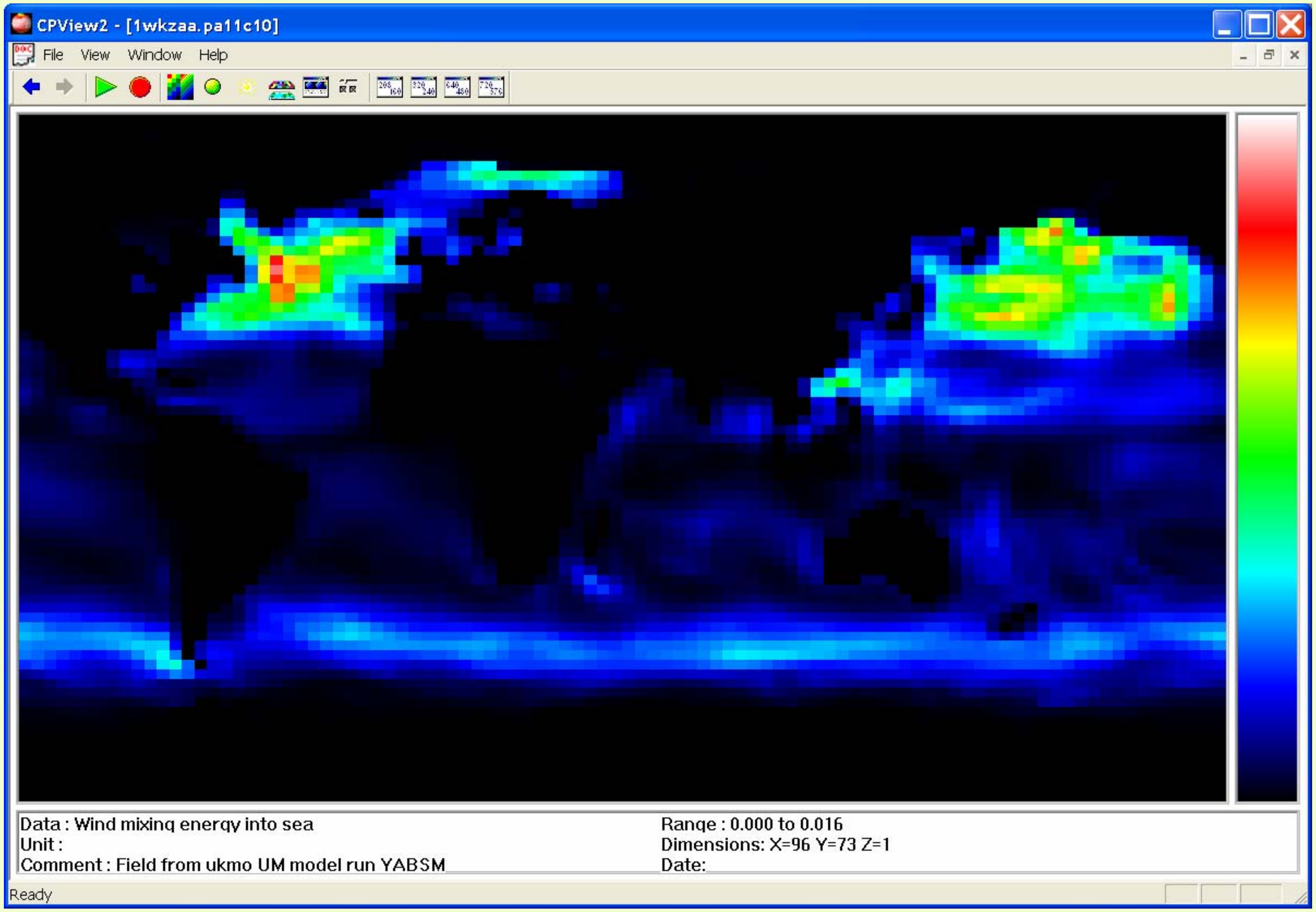
User-developed software!



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Maintaining Interest

- Elementary visualisation package lets casual users explore their world
- Web-server technology lets them learn more about how their world changes over time
- Advanced visualisation package lets interested users investigate their world more thoroughly
- Open University (UK) entry level course based on climate*prediction*.net currently under development – launching in February 2005
- Working with secondary school educators (UK, NZ) to develop resources for teachers to tie climate*prediction*.net into syllabus
- WAP-phone technology to keep you posted about your run!

- Very keen to develop further international links in education sector – very much an international project

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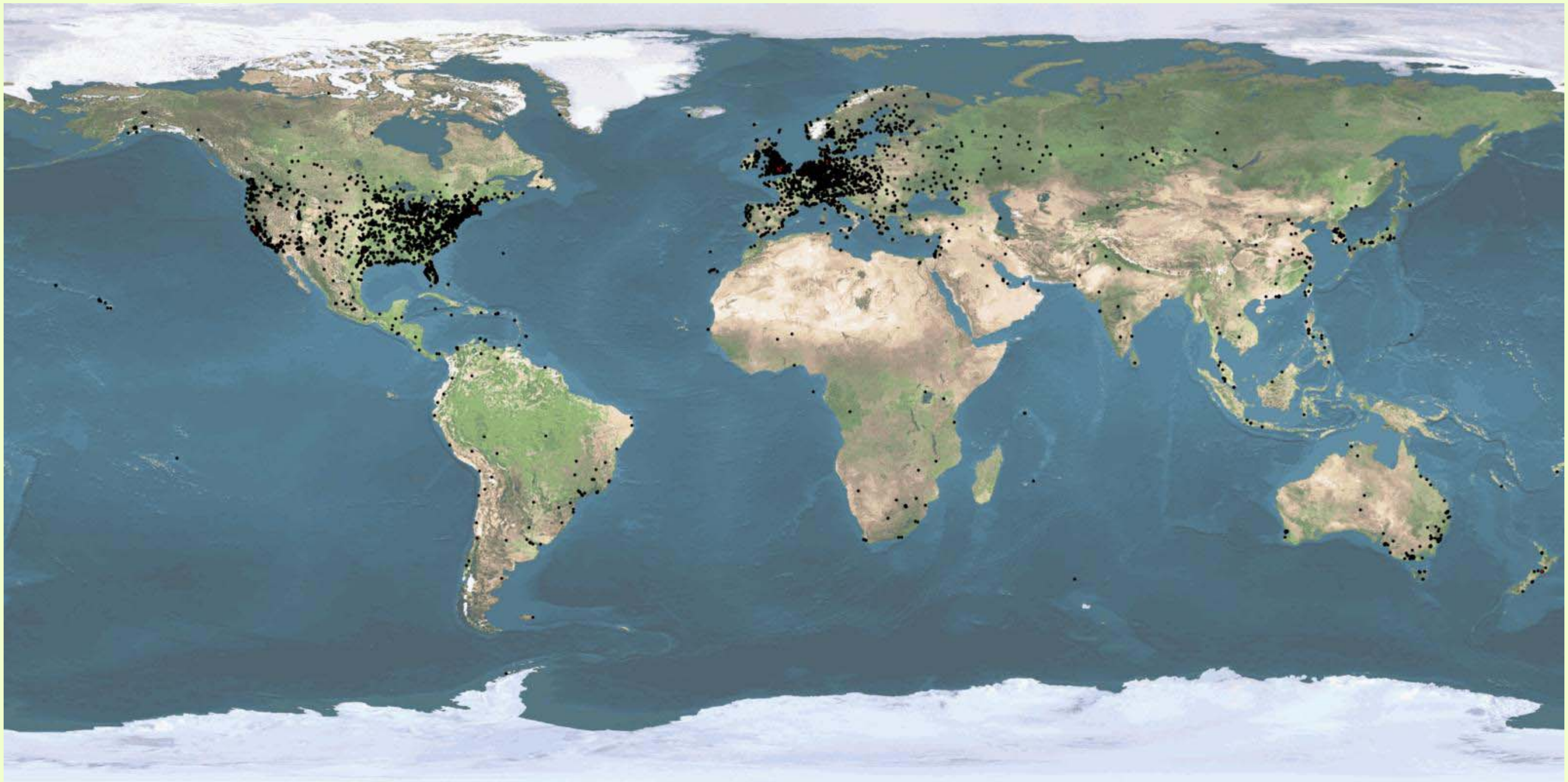
Status and Plans

- Publicly available:
  - ~ 75,000+ simulations complete.
  - > 5,500,000 years simulated.
  - > 100,000+ registered participants
- Available on Linux, Mac, Windows
- Develop educational materials
- Import new models
- Develop new visualisation and analysis software

Our Participants



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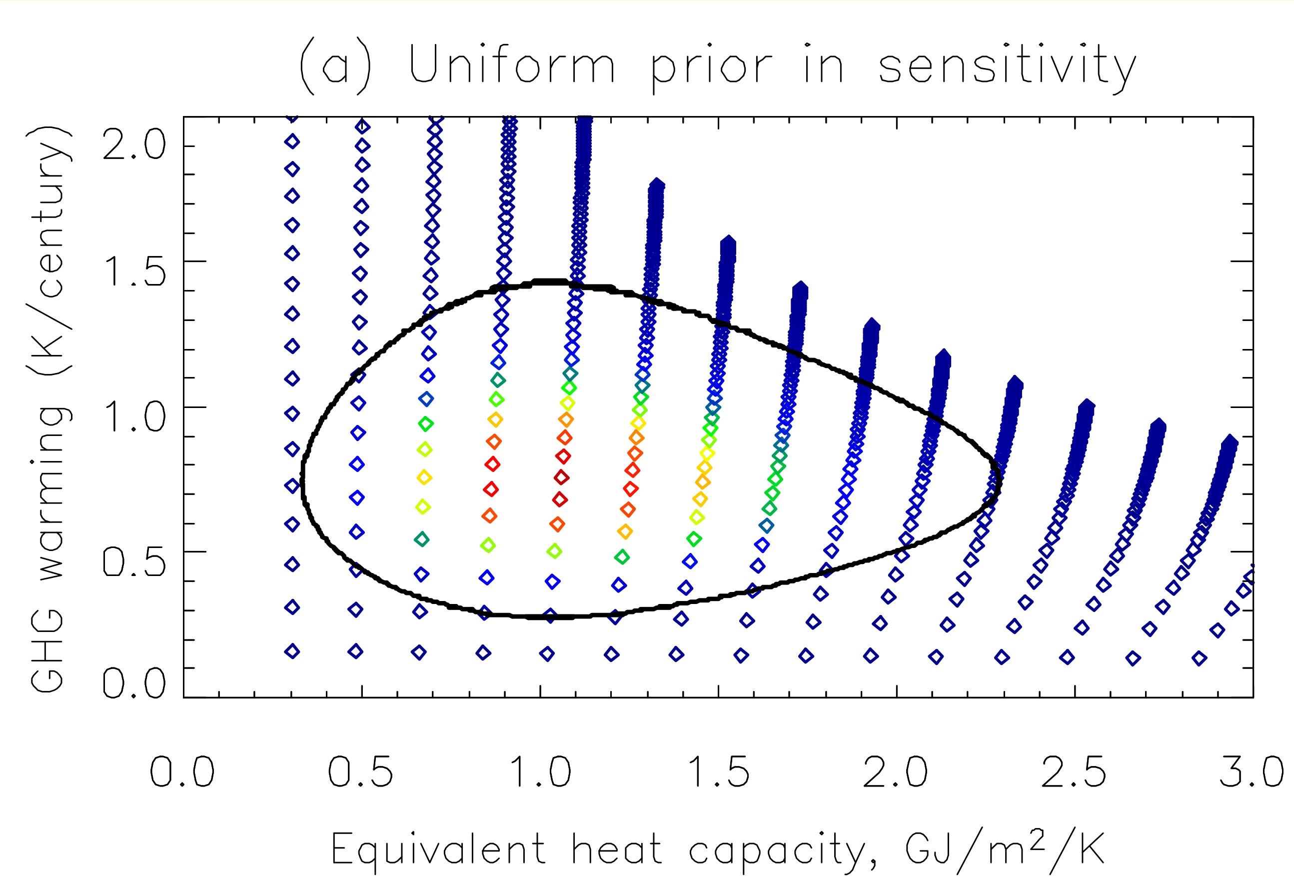
Likelihood weighting



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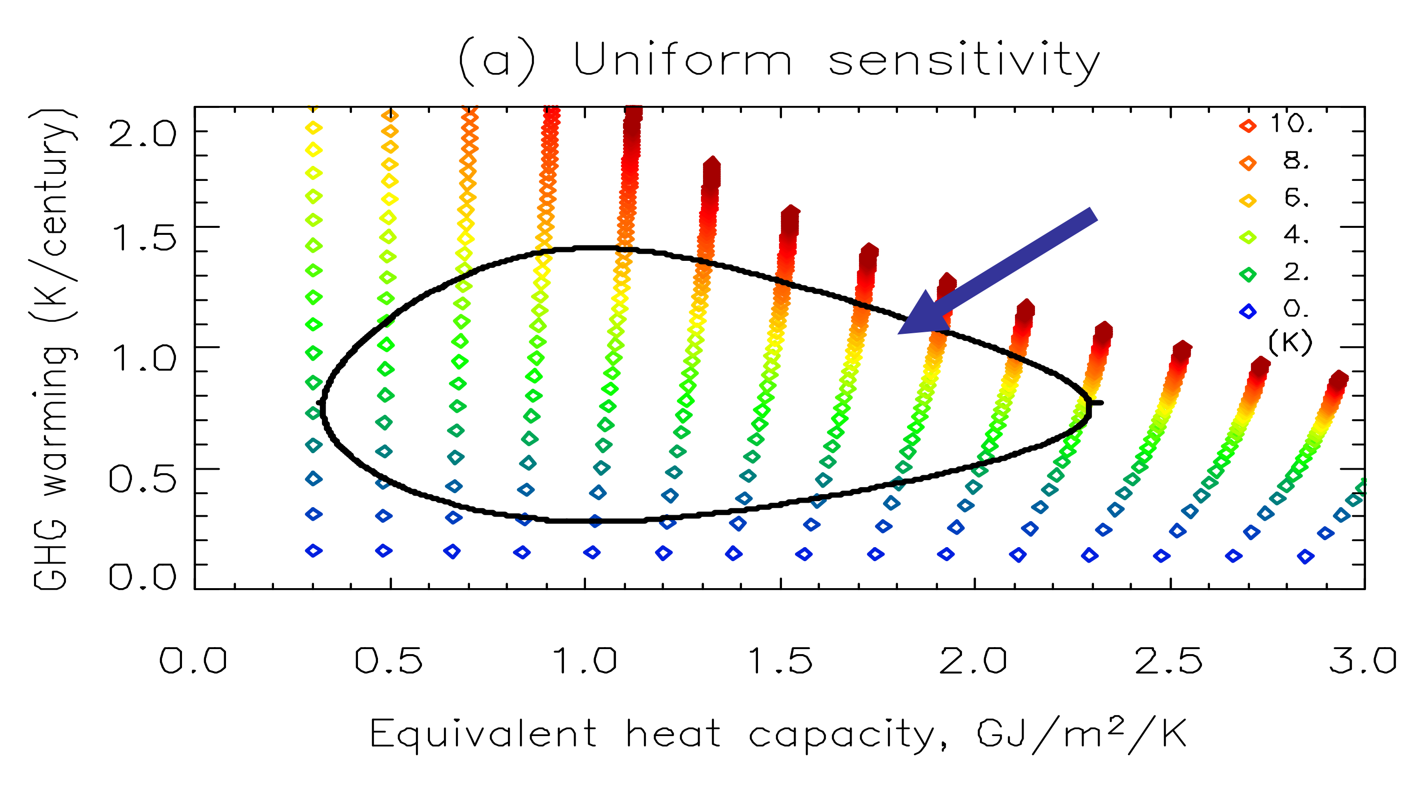
Constraints implied by observations



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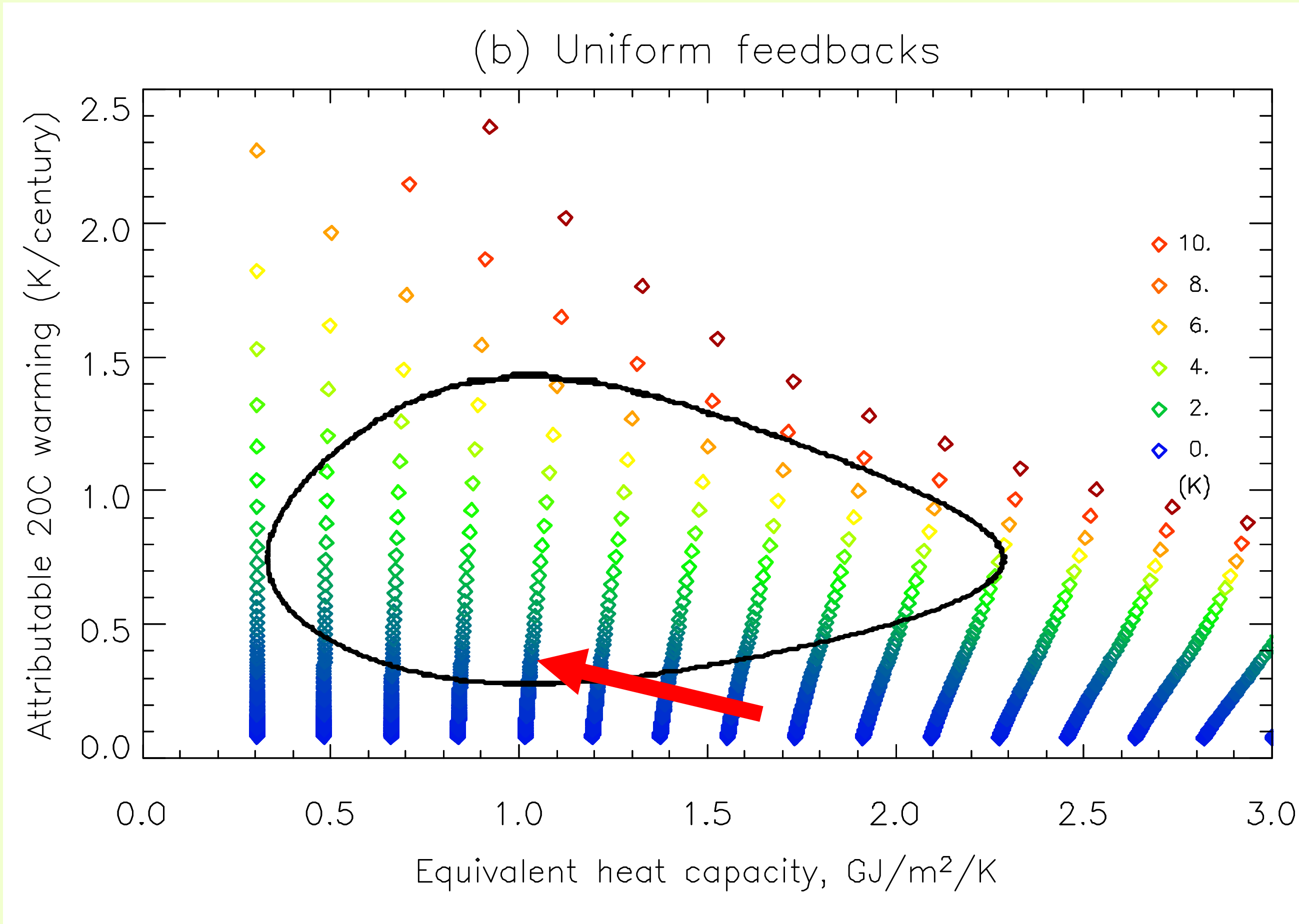
Using a different prior gives a different result



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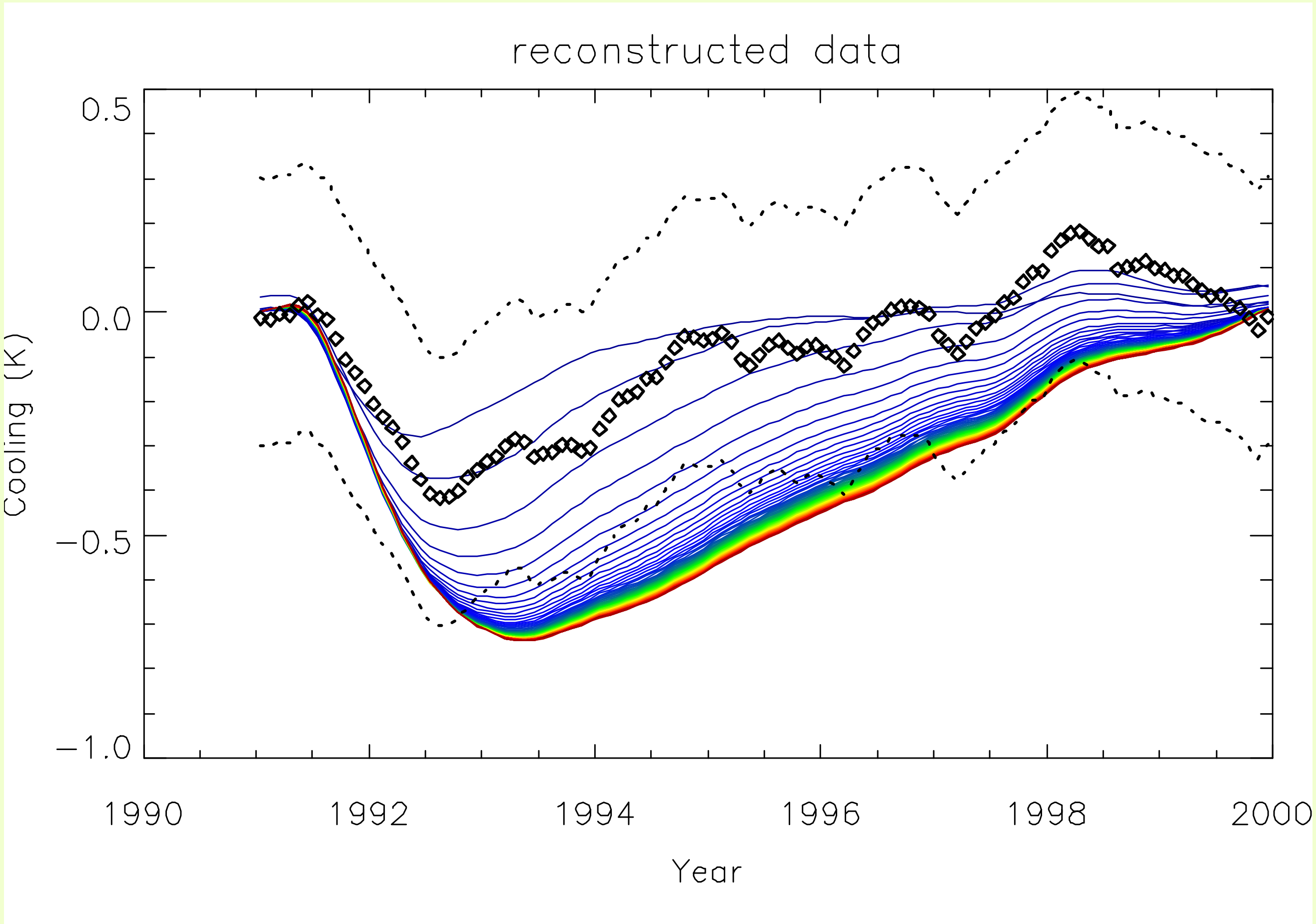
Have been claims that volcanoes provide a constraint on sensitivity (best guess heat uptake)



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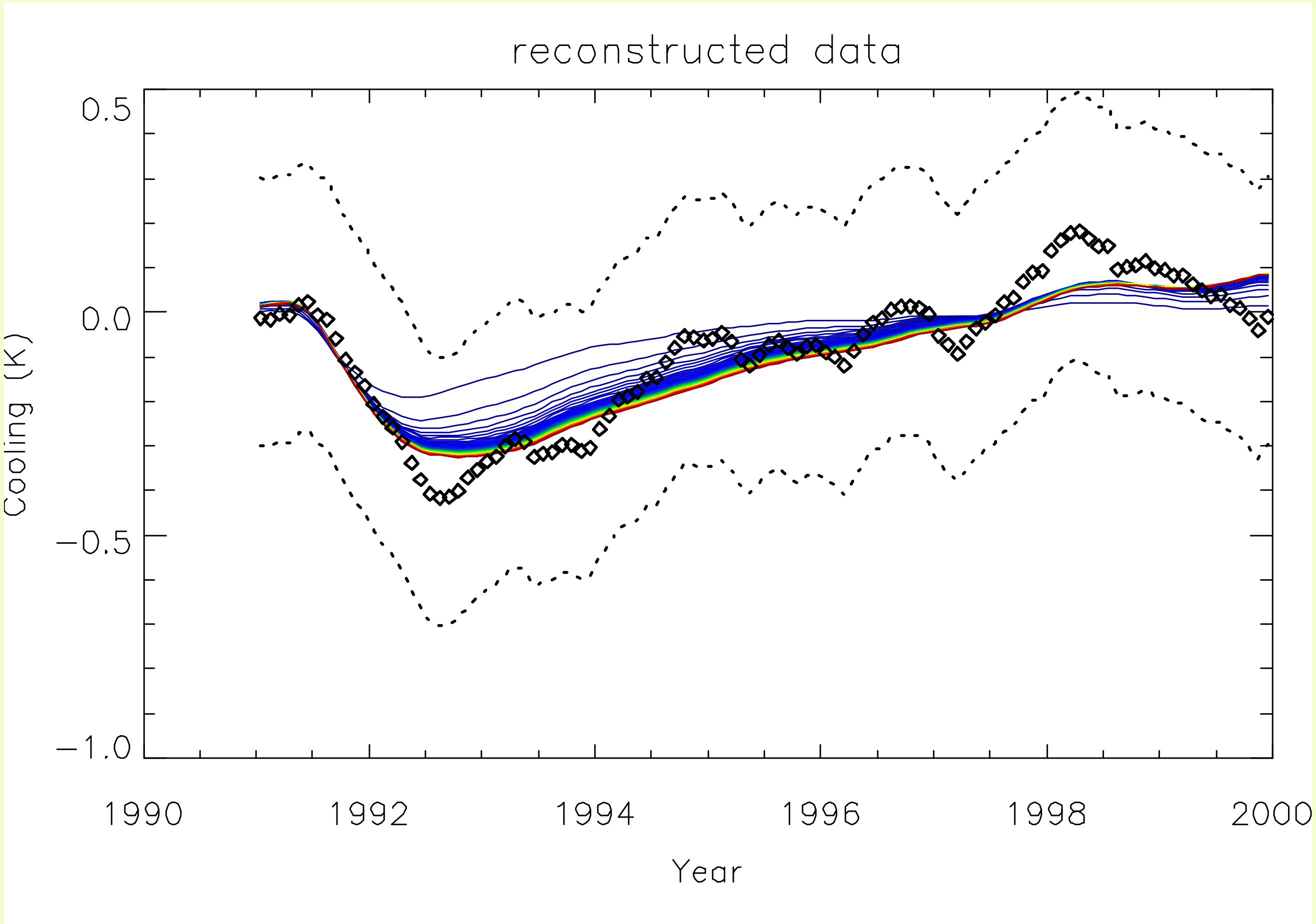
Have been claims that volcanoes provide a constraint on sensitivity (high heat uptake)



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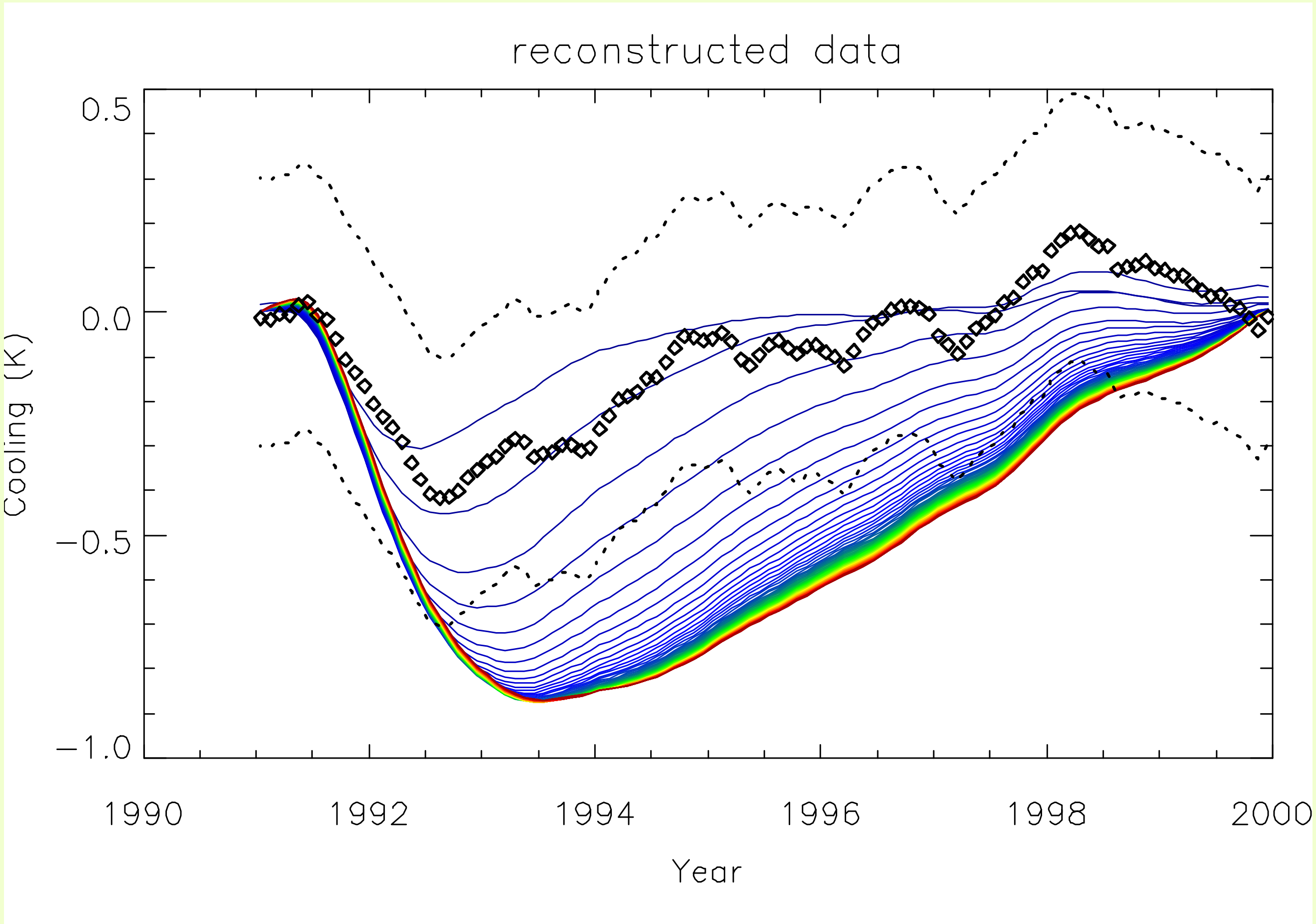
Have been claims that volcanoes provide a constraint on sensitivity (low heat uptake)



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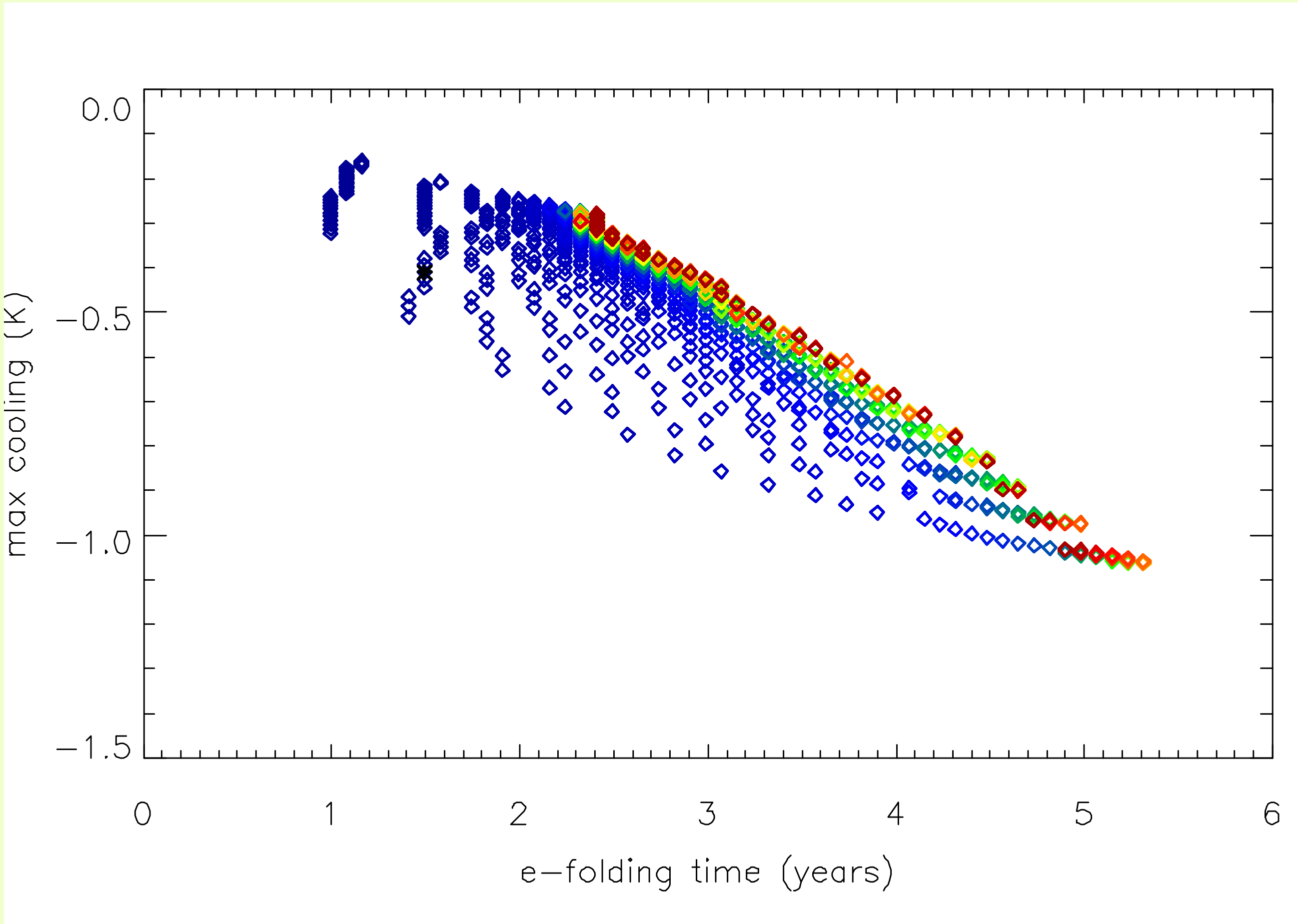
Remaining neutral in observable quantities



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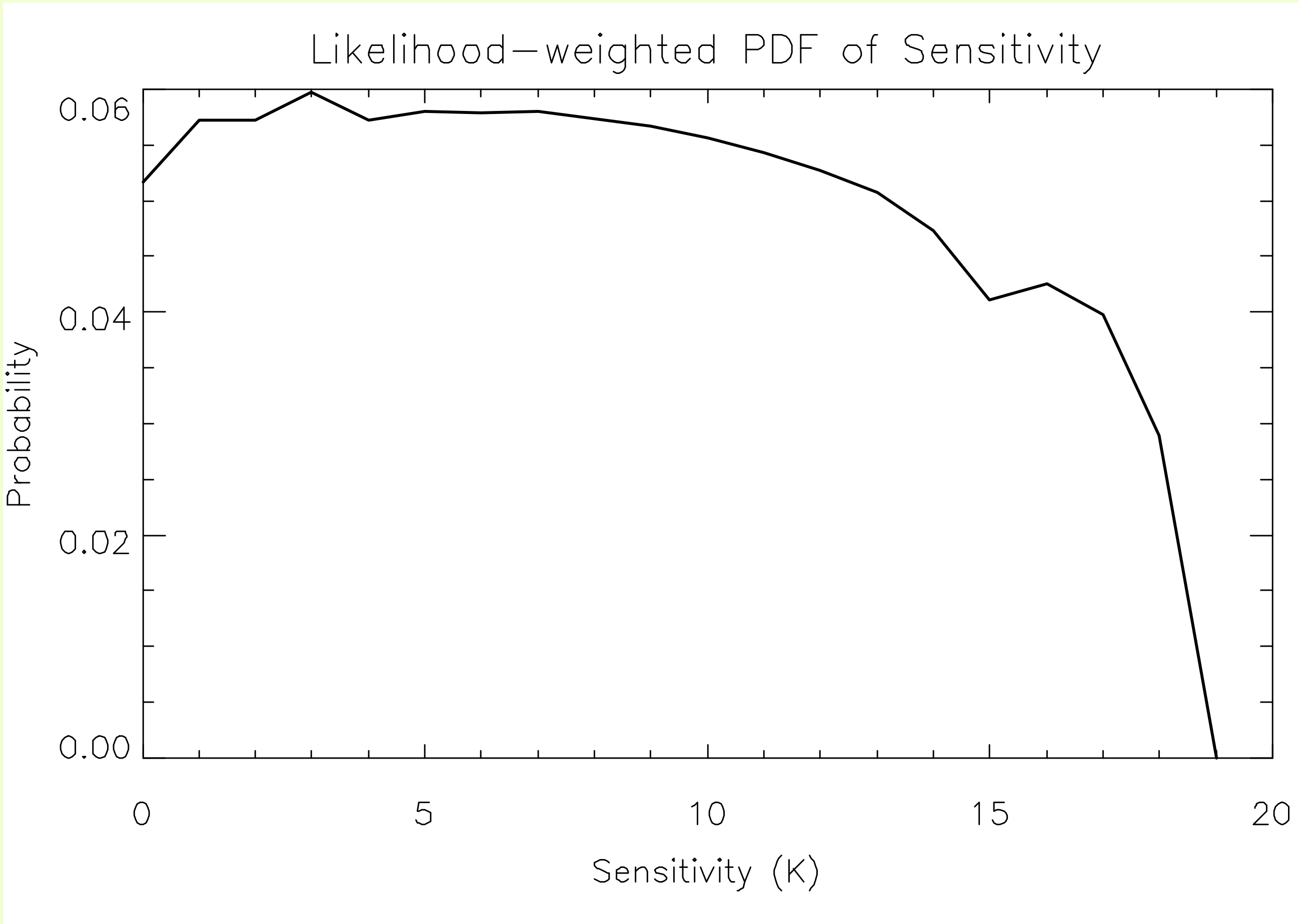
Remaining neutral in observable quantities

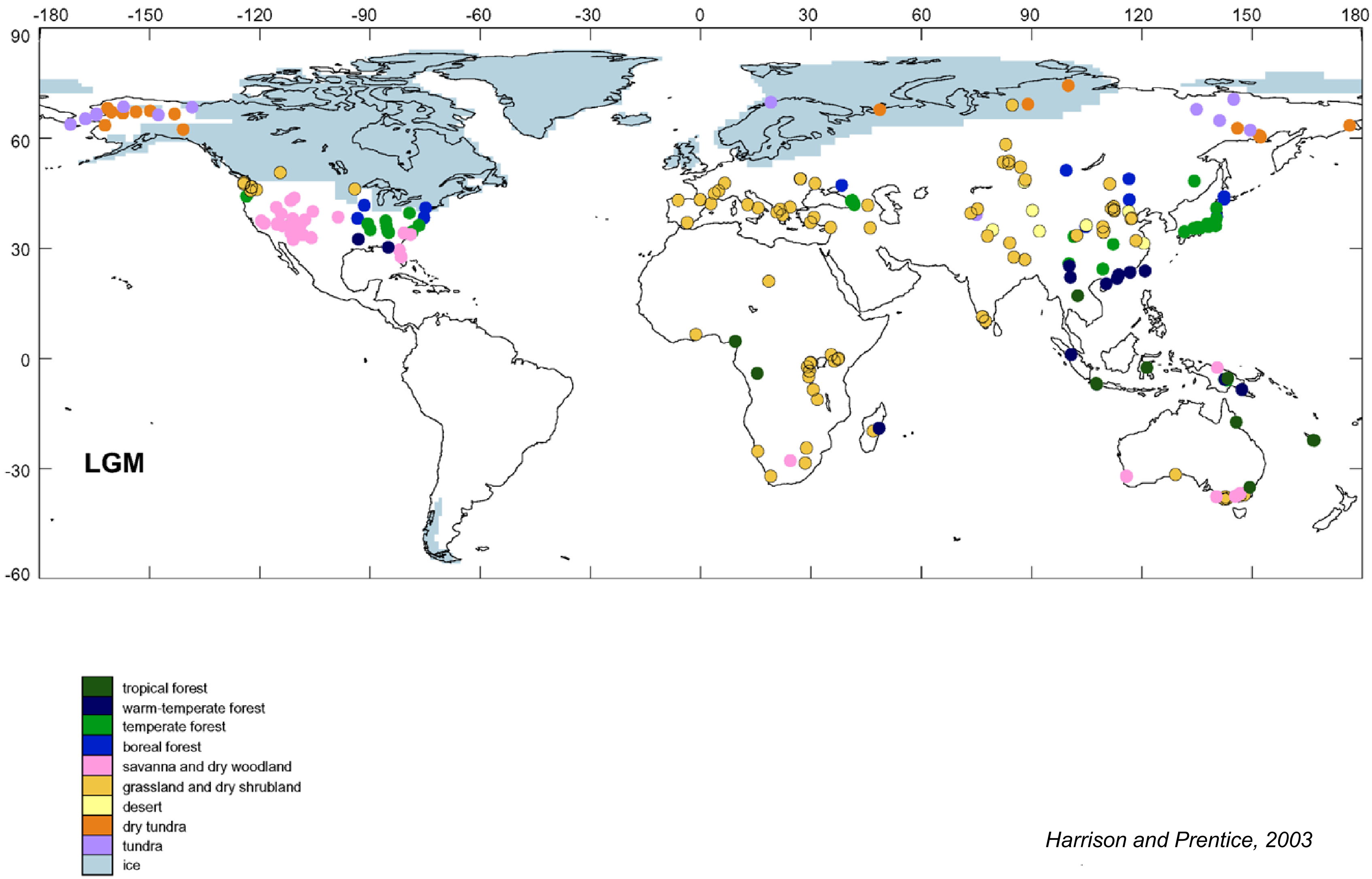


Paleo constraints

- We lack data to say what the global mean change is during LGM ("or any other period")
- Reconstructions flawed, MARGO suggests that results are proxy-dependent
- Forcing uncertainties are a problem

- Long time scales☑
- Data constraints☒
- Forcing uncertainties ☒

LGM BIOME DATA Coverage



Harrison and Prentice, 2003

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Failure of the GCMS