Predicting future changes in **climate** and **sea level**

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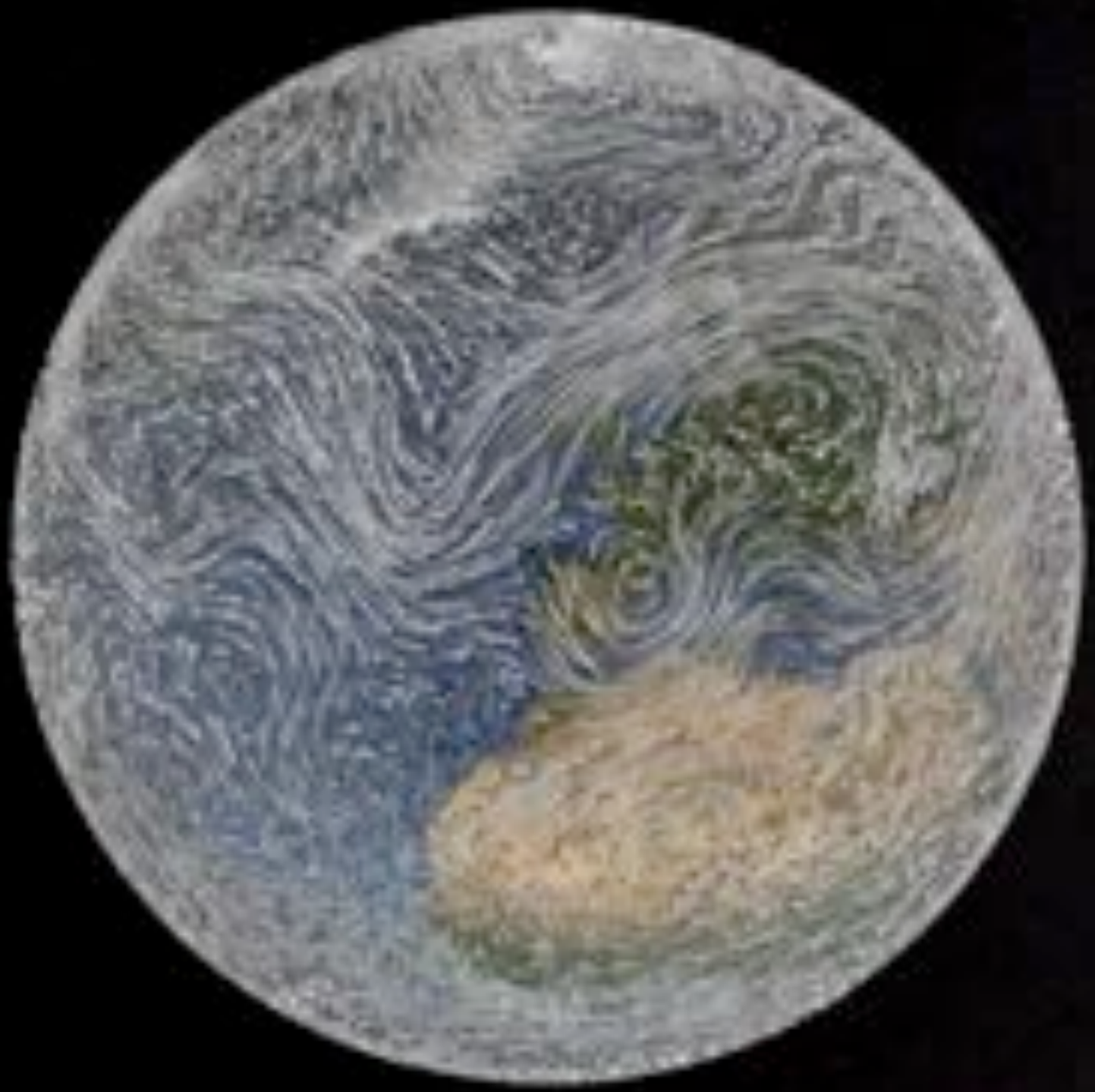
University of Bristol

How can we predict the future

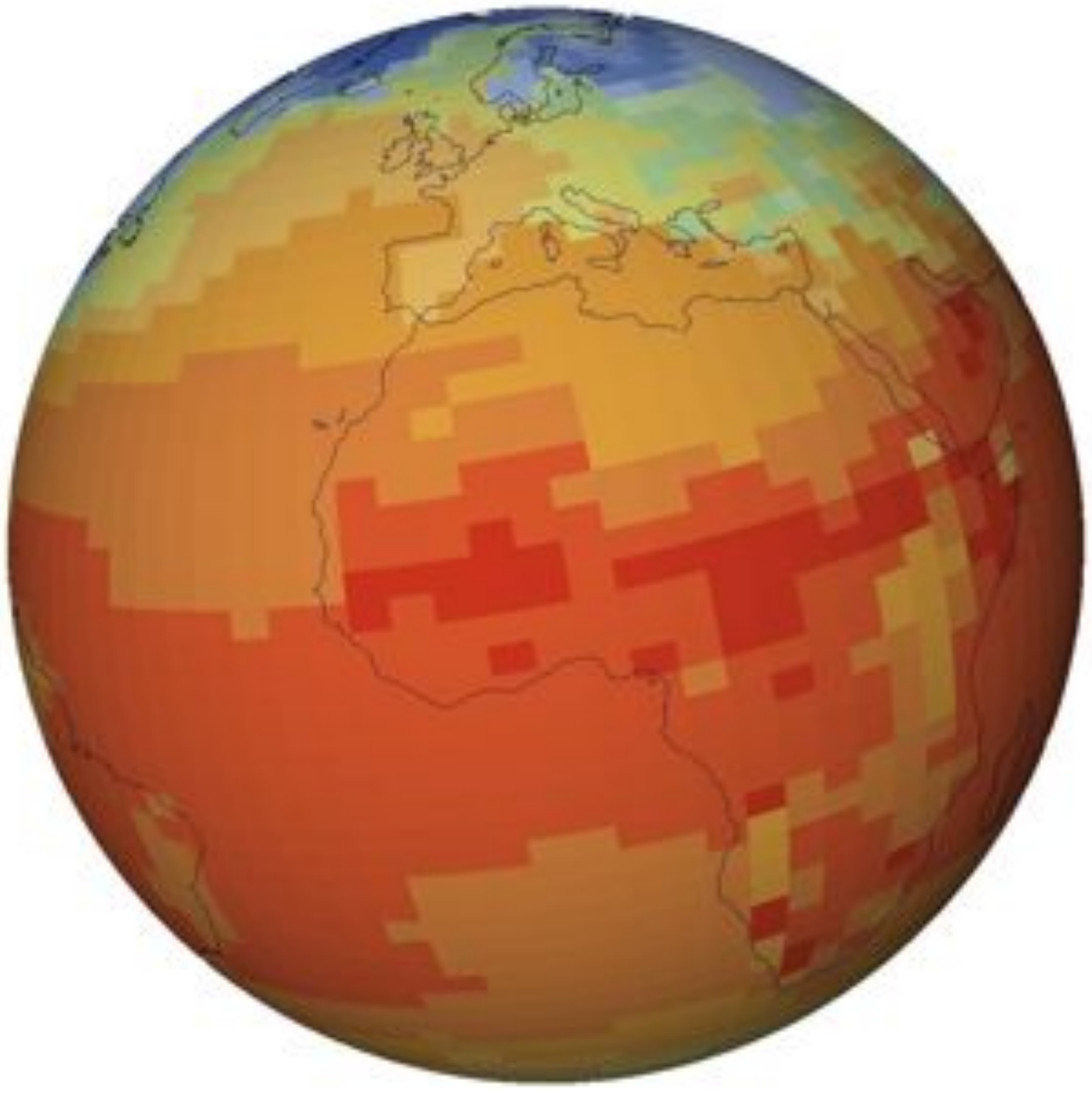
of our planet?

No full-sized control experiment

Dynamic Earth



More usually...



HadCM3

climateprediction.net

The Earth System

"A simplistic conceptual model"

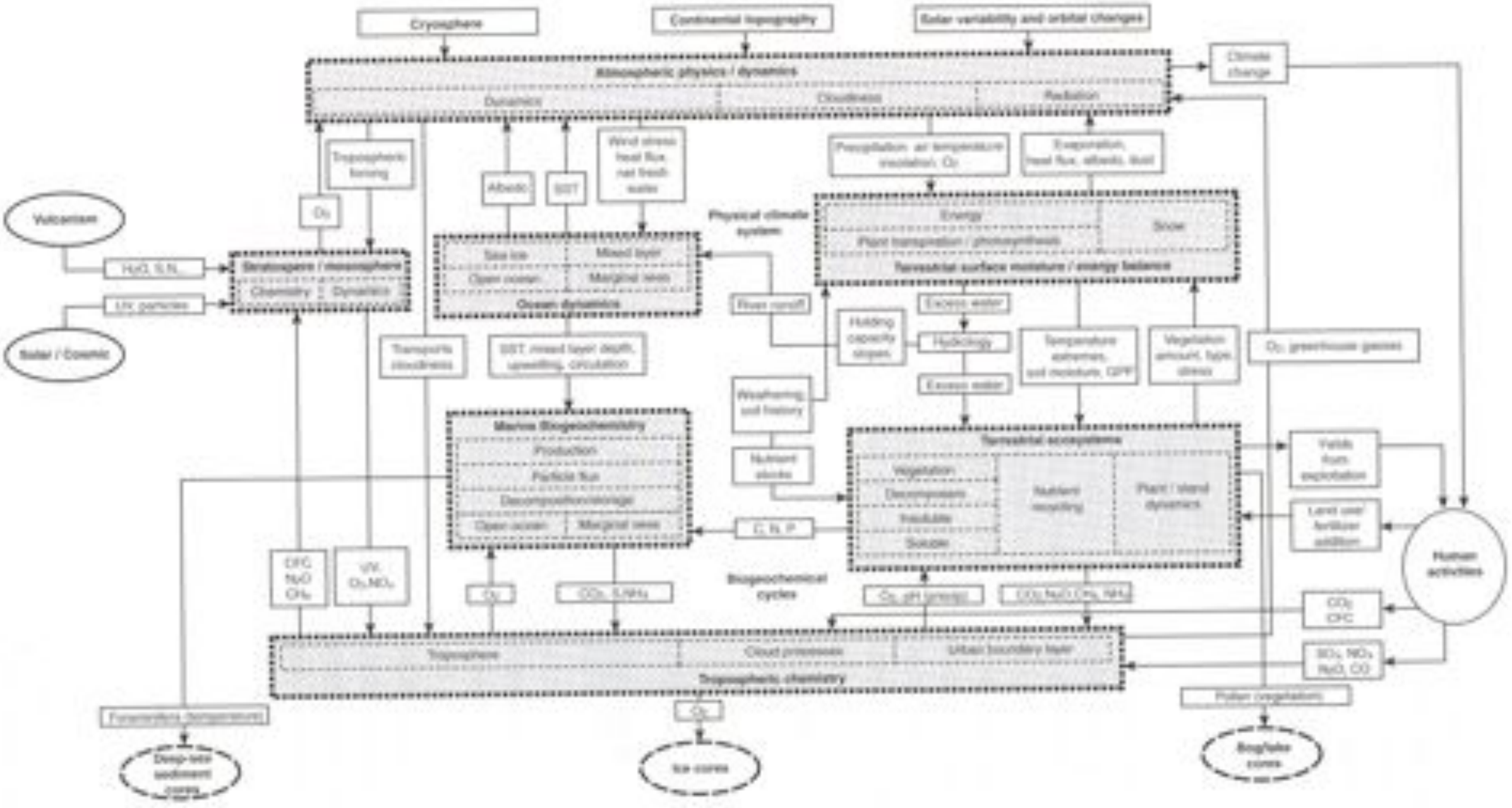
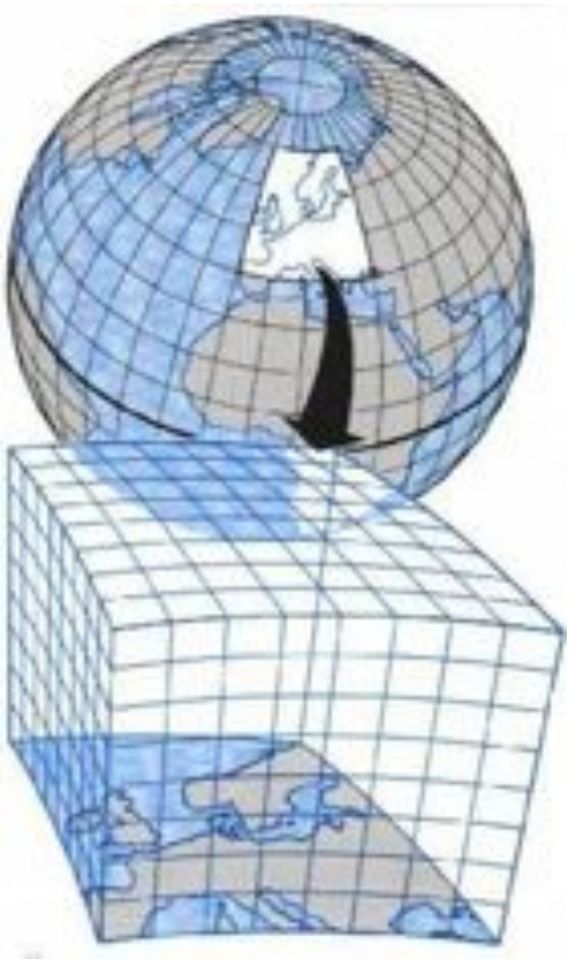


Figure 1.2 A wiring diagram of the Earth system. Key boundary conditions and major external forcings are at the top and left-hand side of the diagram. Human activities are indicated down the right-hand side. Some of the main environmental archives recording past changes are shown along the bottom. (Based on Schellnhuber, 1999.)

General Circulation Models (GCMs)



$$\frac{dV}{dt} + fk \times V + \nabla\phi = F$$

$$C_p \frac{dT}{dt} - \omega\alpha = Q$$

$$\frac{dq}{dt} = S$$

$$\nabla \cdot V + \frac{\partial \omega}{\partial p} = 0$$

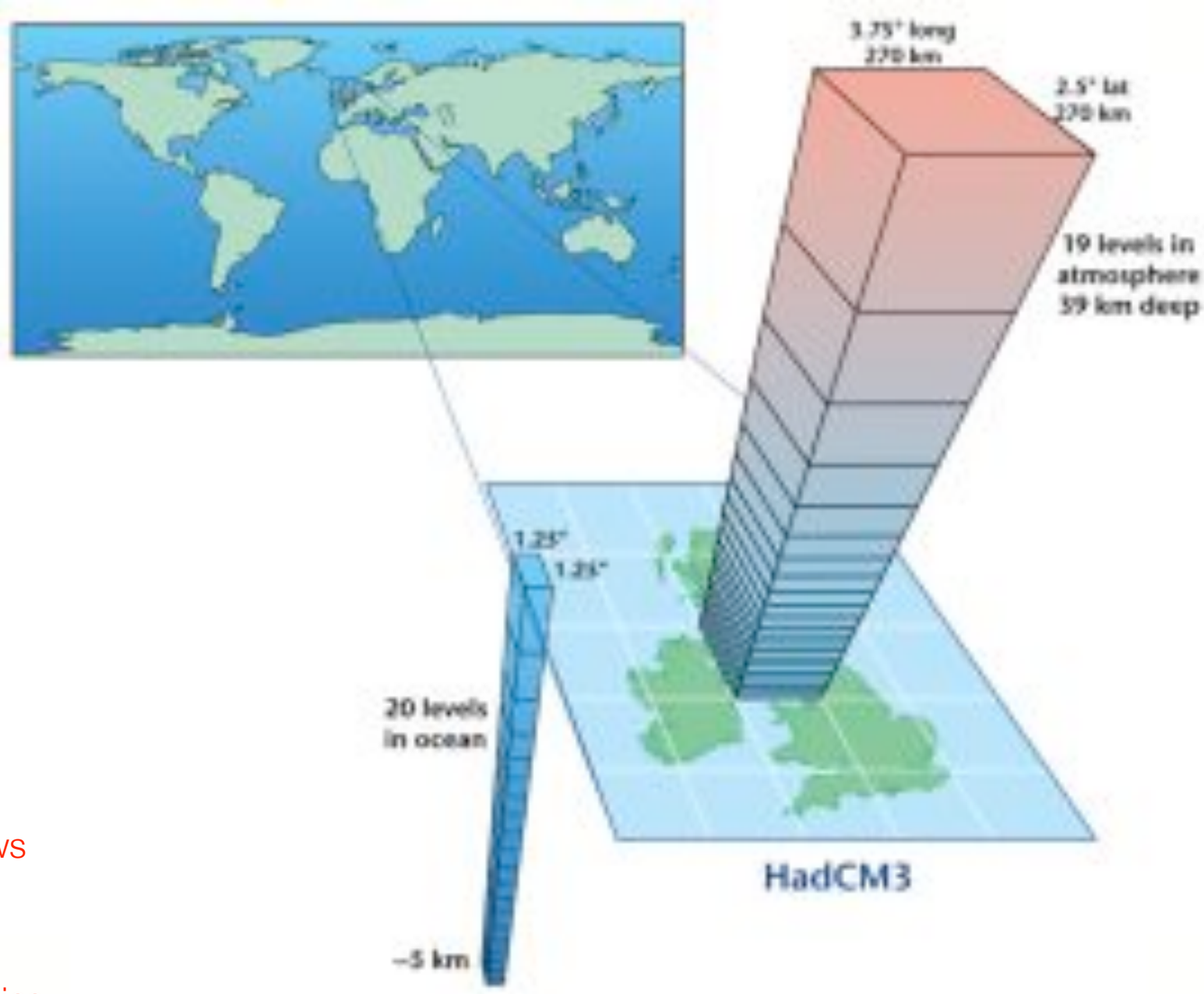
$$\frac{\partial \phi}{\partial p} = -\alpha$$

$$p\alpha = RT$$

Newton's laws

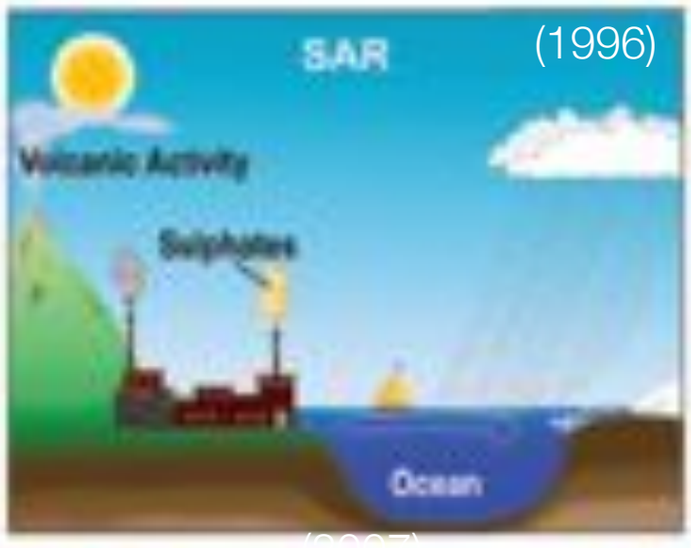
Laws of thermodynamics

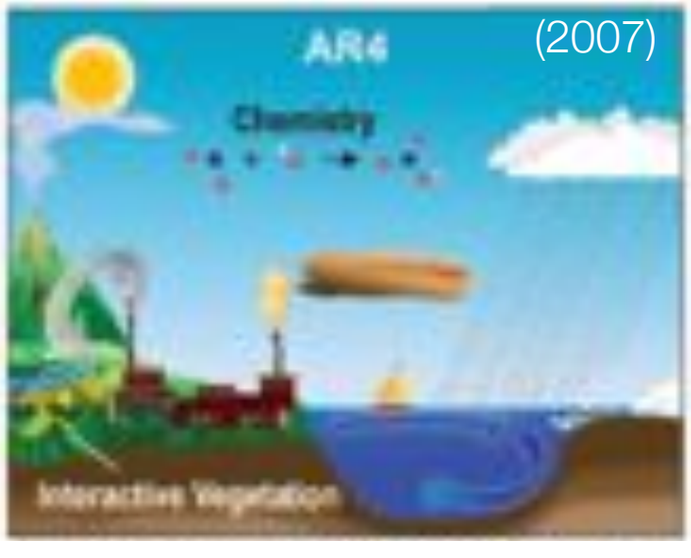
Conservation of mass, energy, water



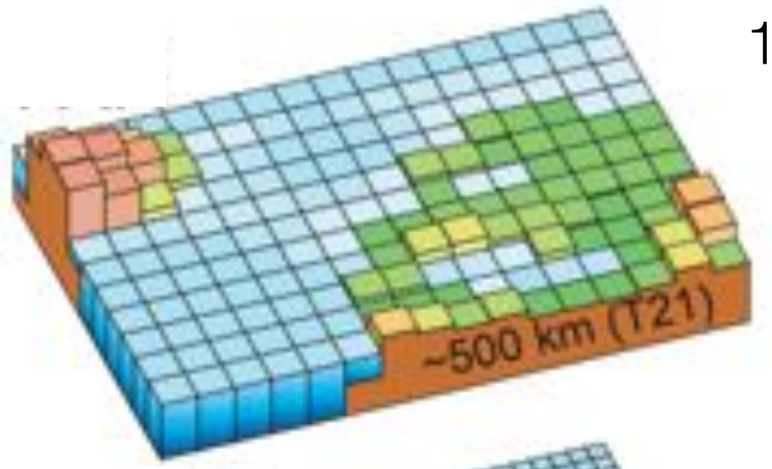
UK Met Office Hadley Centre GCM in 2000

History

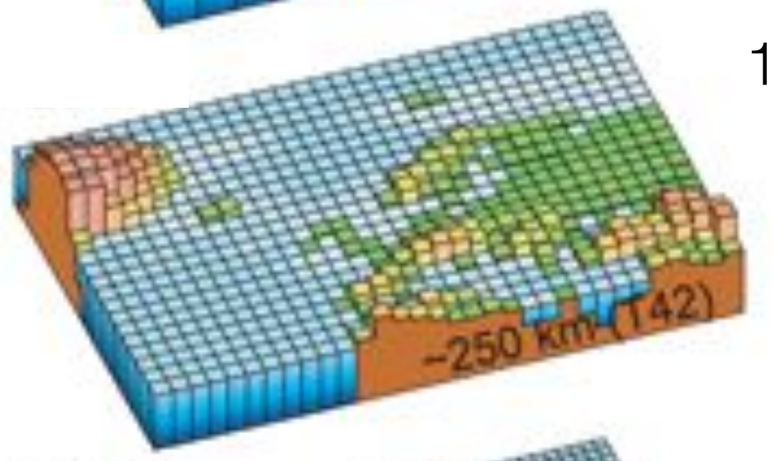




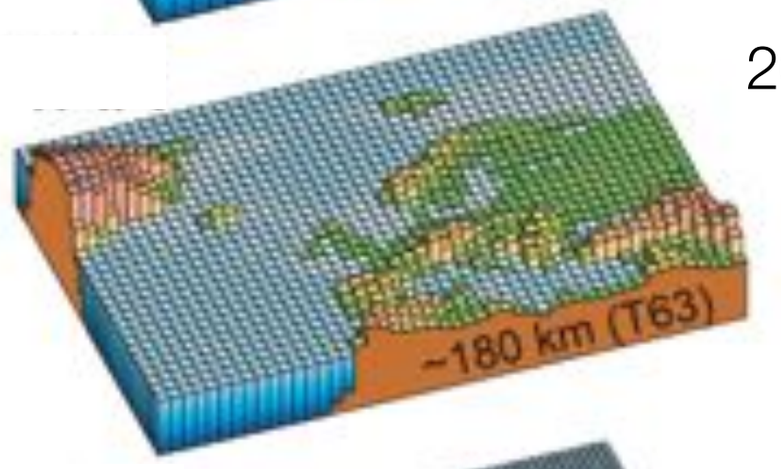
1990



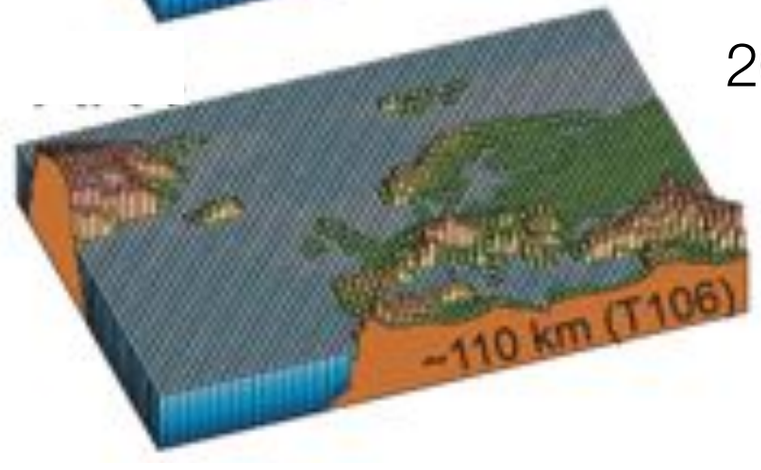
1996



2001

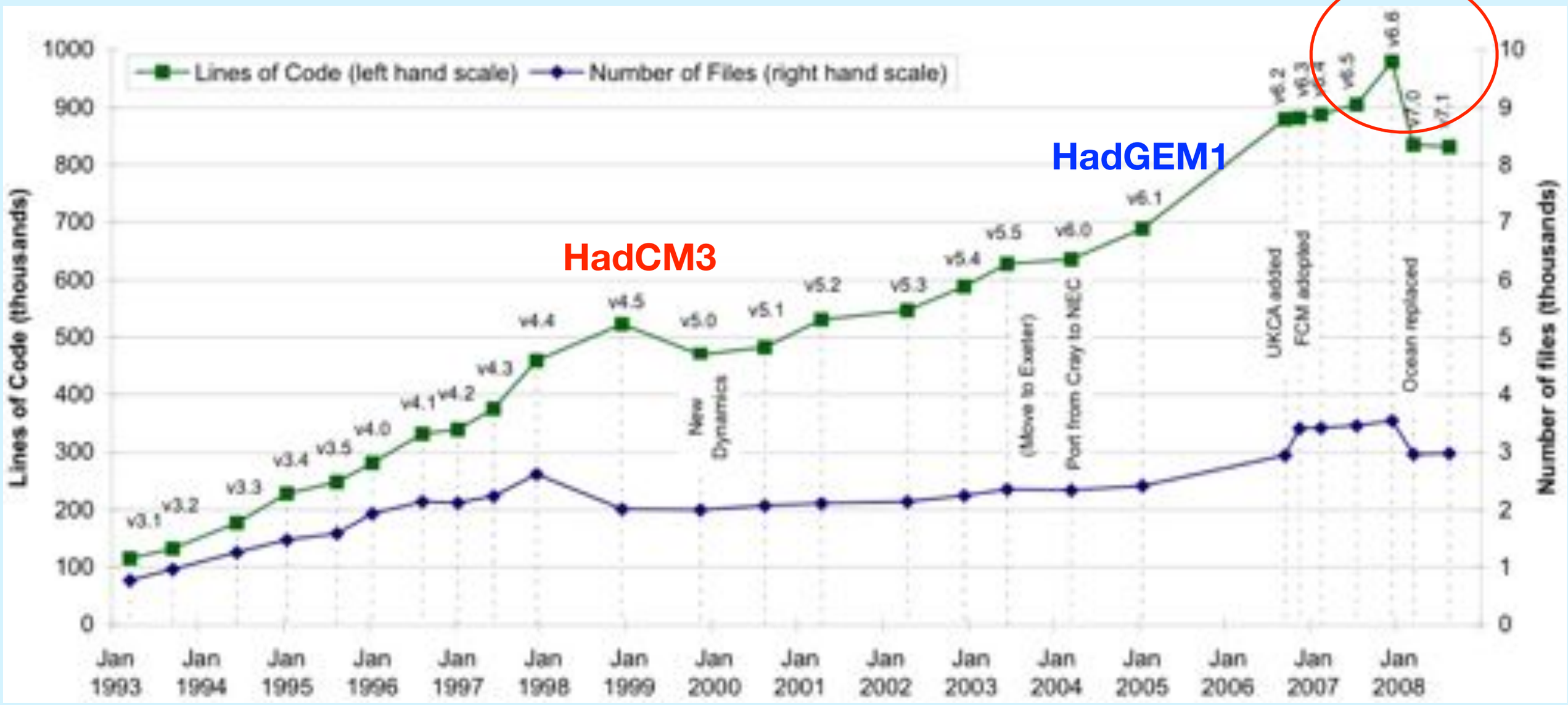


2007



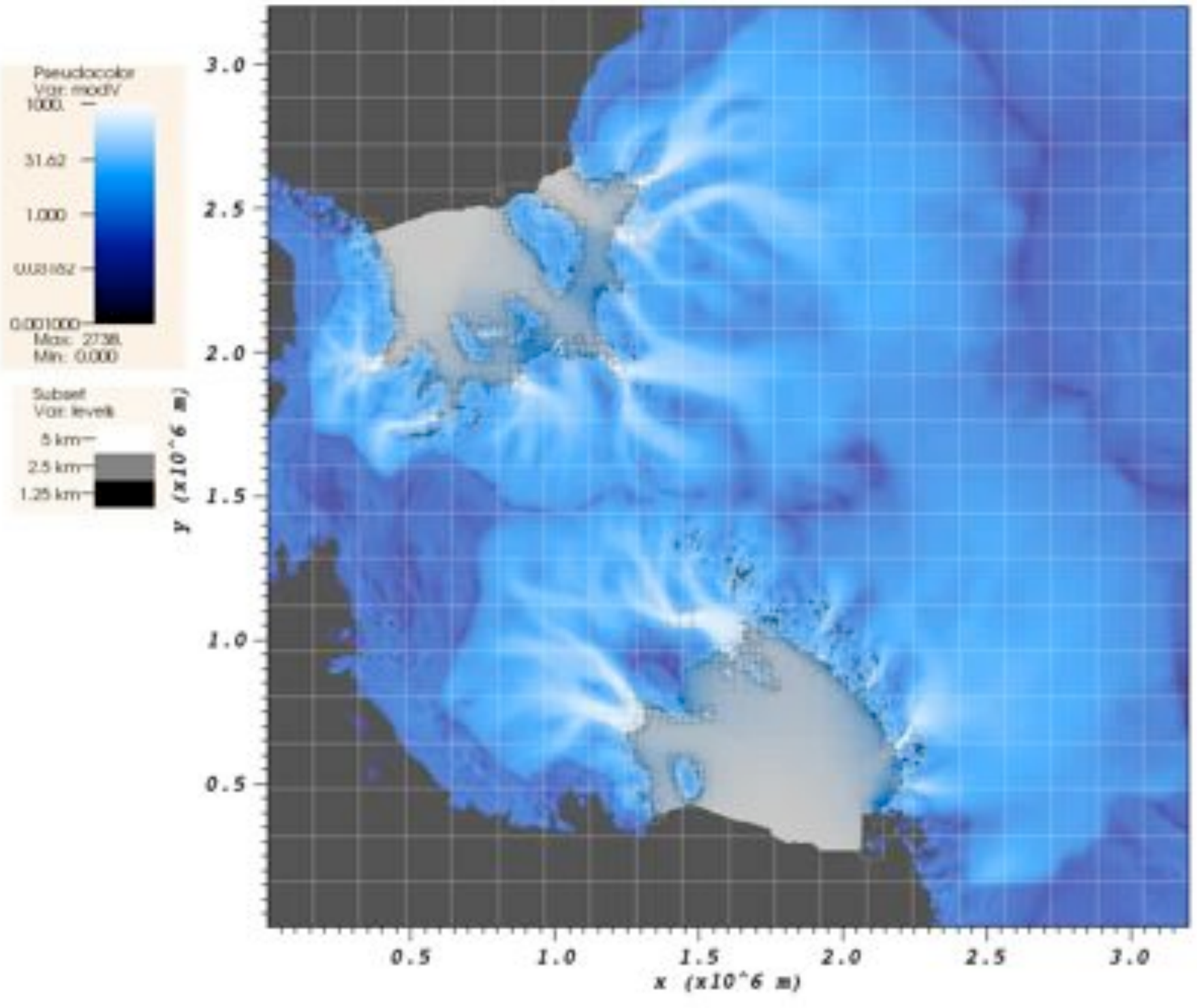
Complexity

One million lines



Slooooow....

Modelling Antarctica



Steph Cornford

How do we know if the models are RIGHT?

George Box

All models
are WRONG

...but some are
USEFUL

allmodelsarewrong.com

Parameter uncertainty

models need tuning

clouds

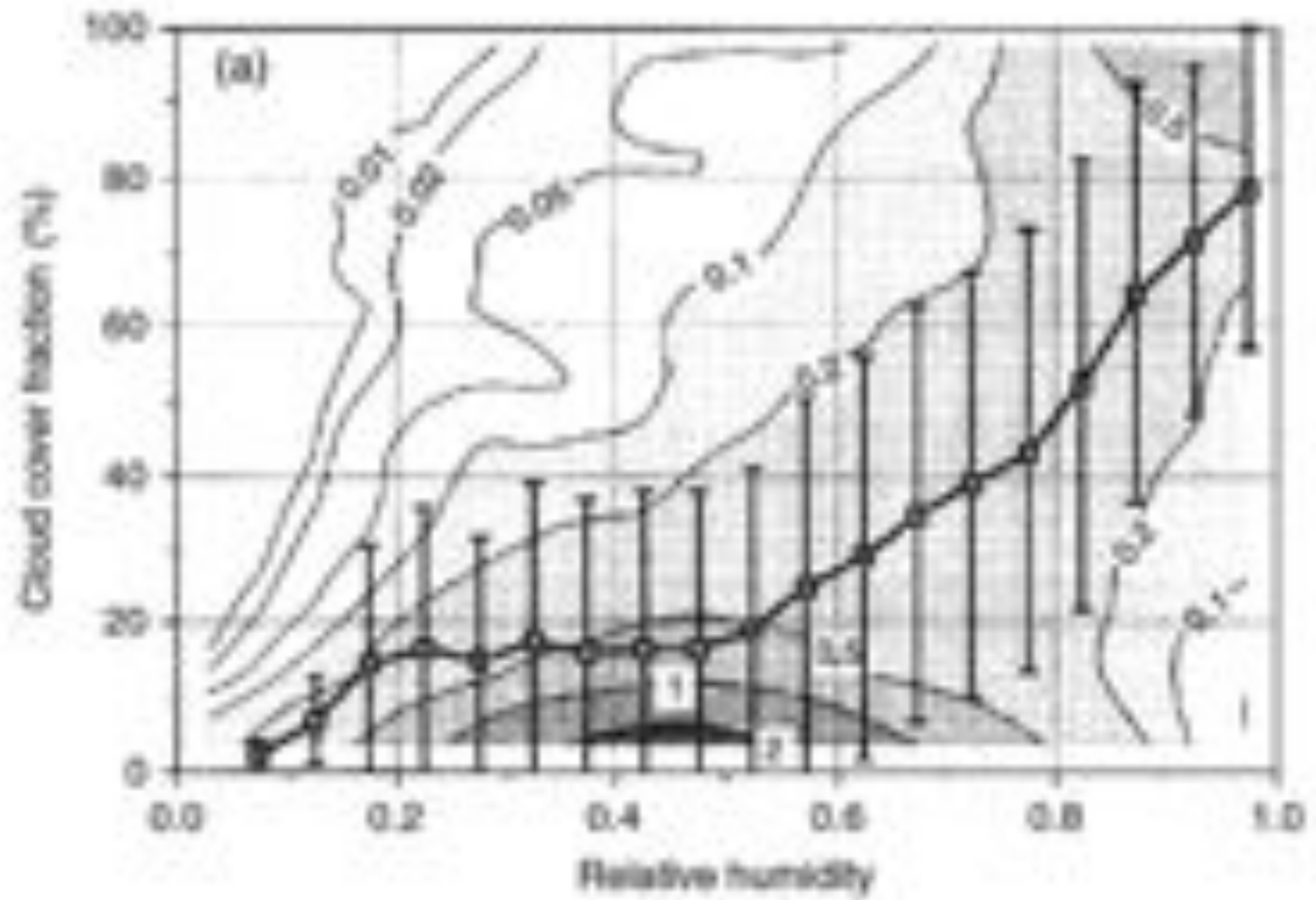
convection

radiation

land surface

boundary layer

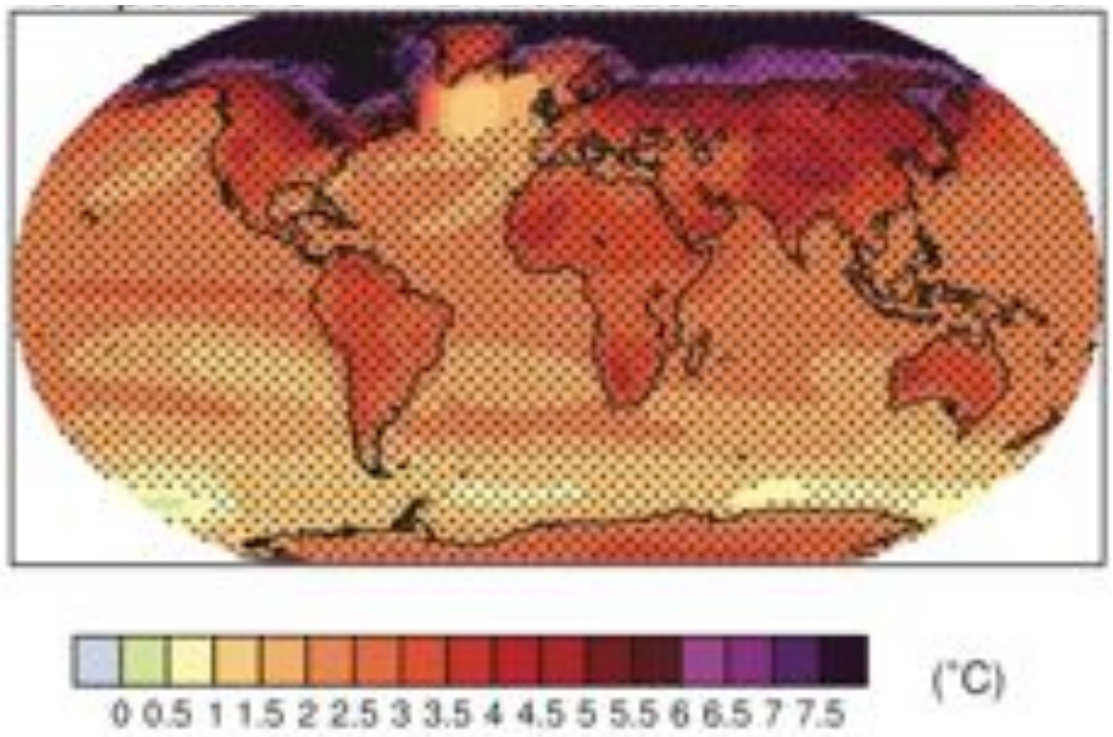
sea-ice



Structural uncertainty

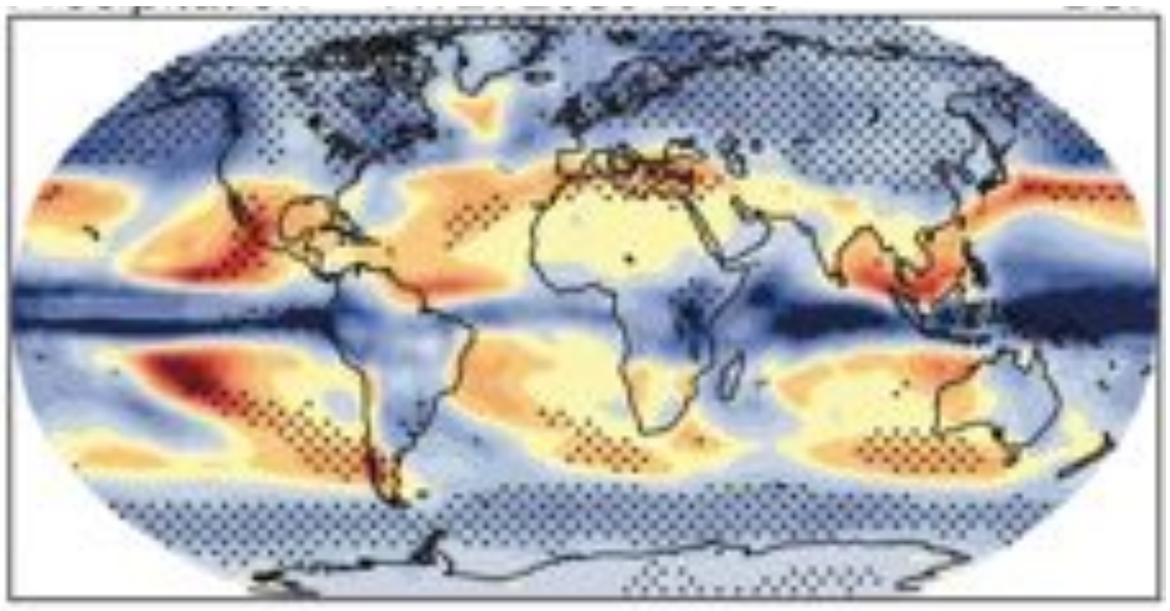
tuned models are still imperfect

winter temperature change

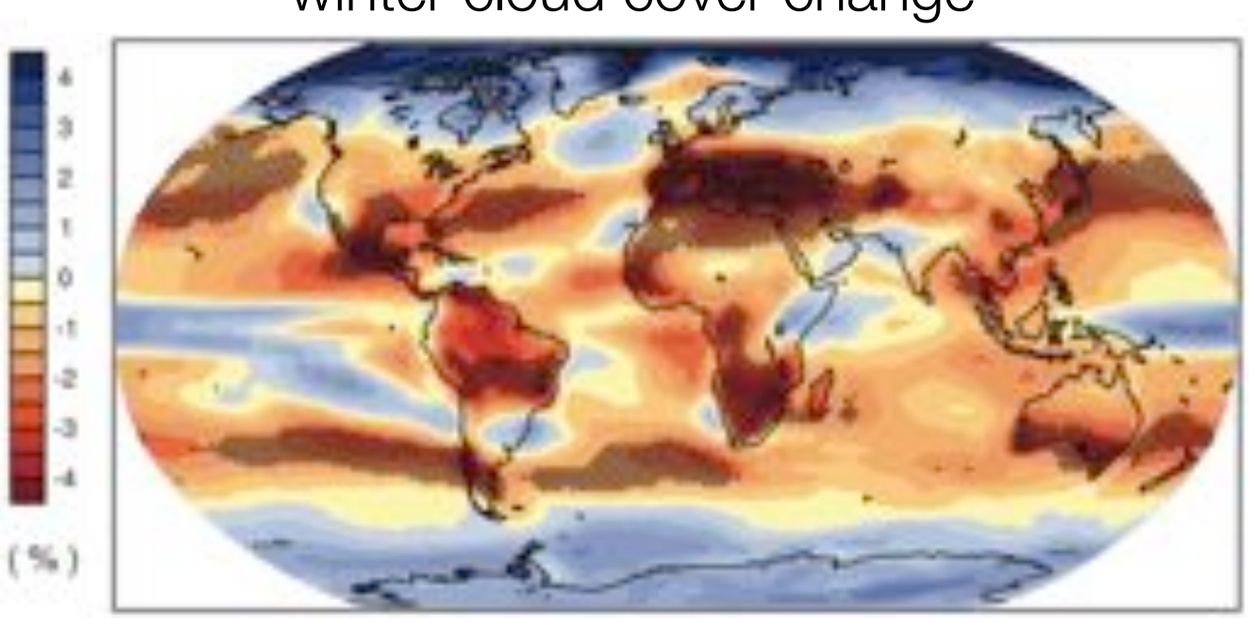


Stippled: 80% or more of models agree on **sign** of change

winter precipitation change

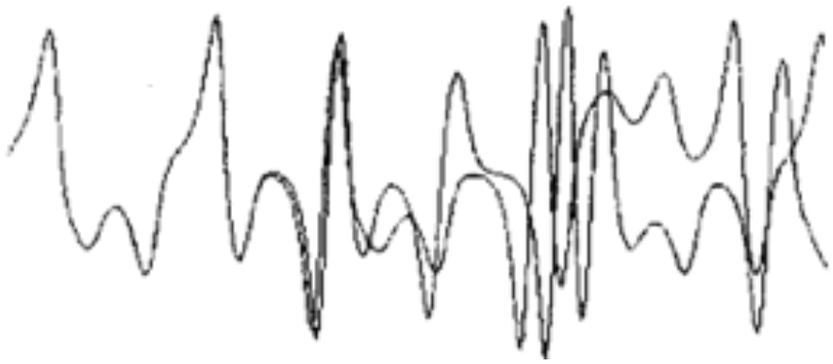


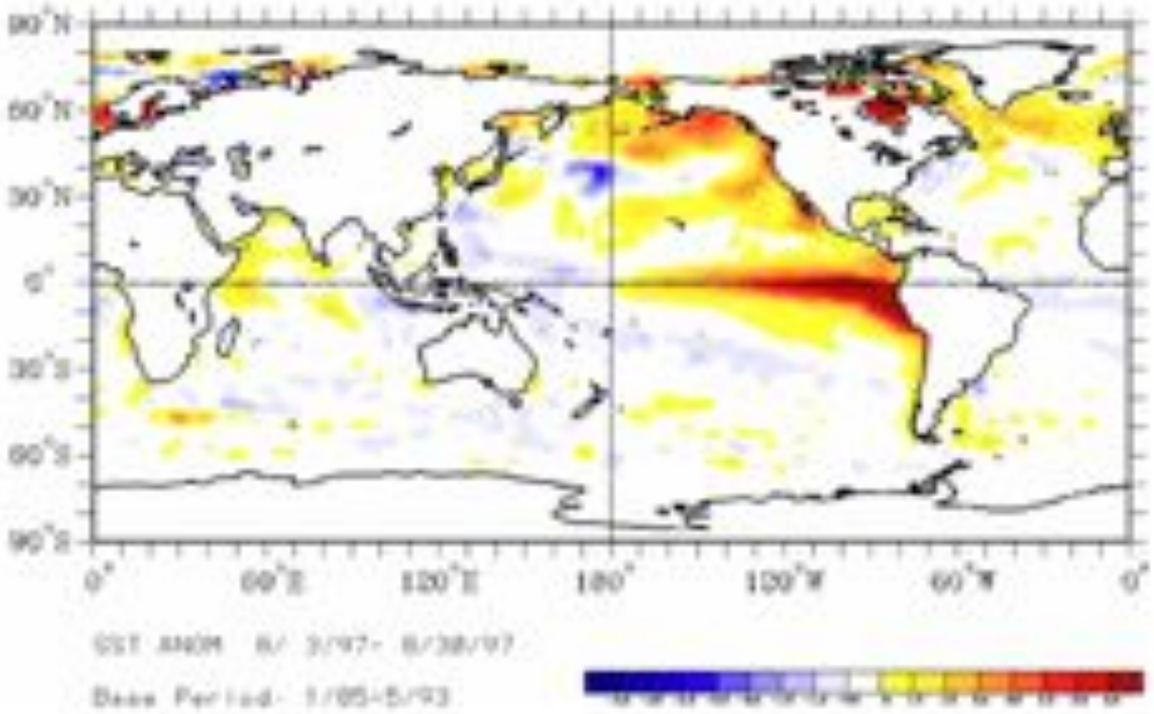
winter cloud cover change

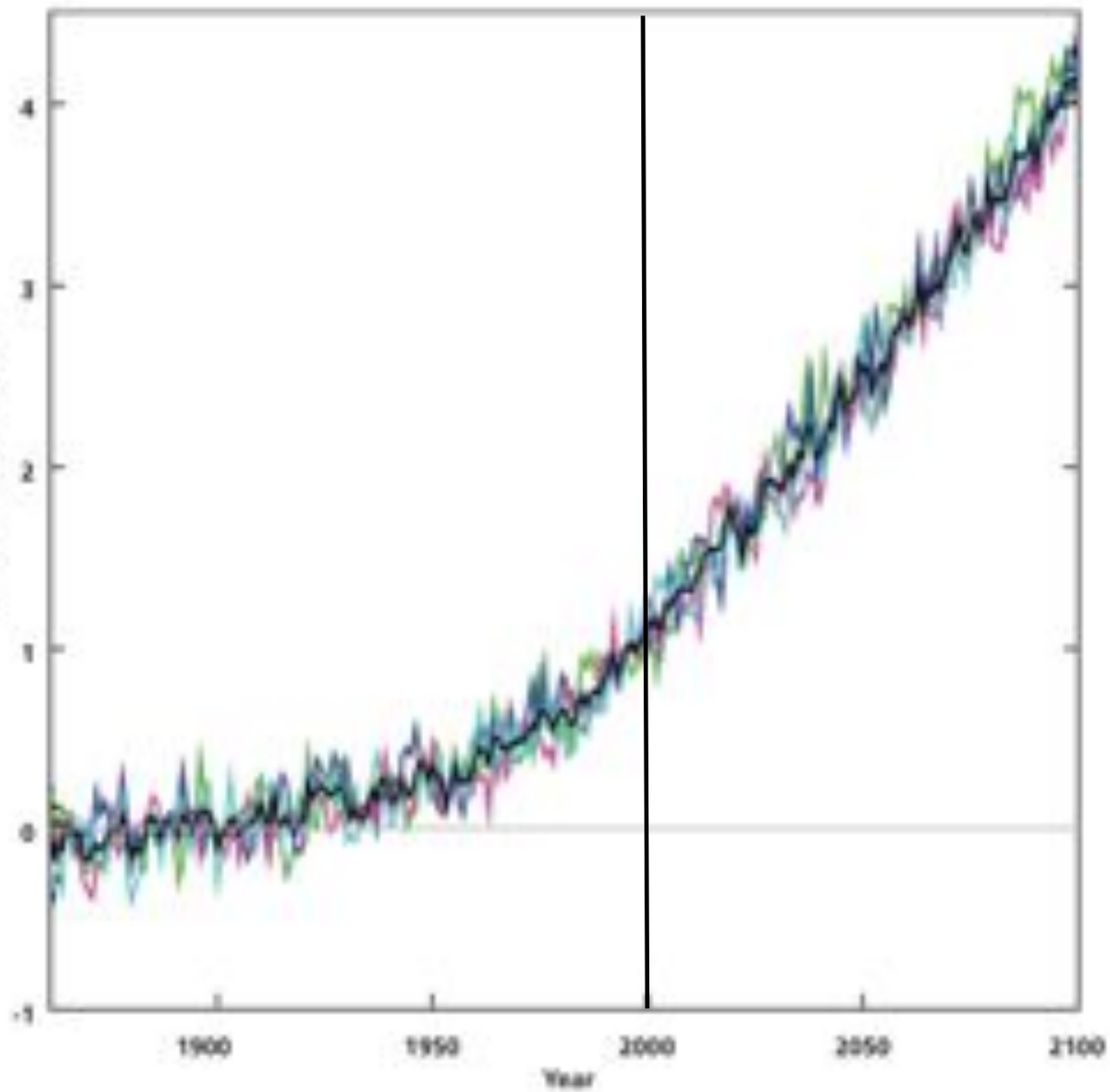


Initial condition uncertainty

imperfect knowledge of today's weather







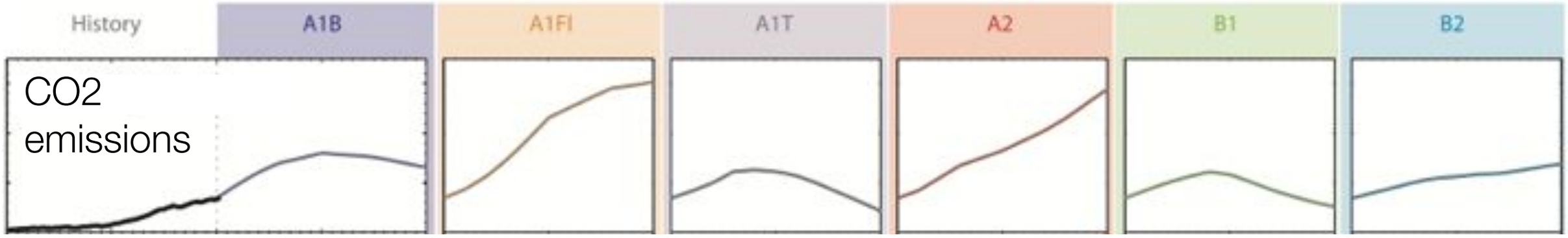
How do we predict OUR future?

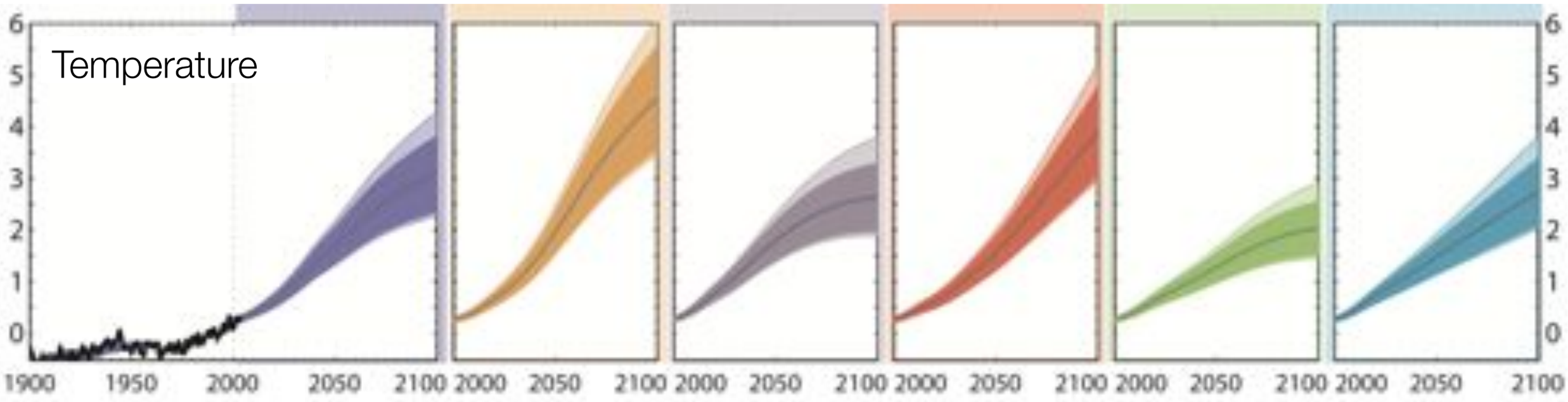
"Prediction is very difficult, especially if it's about the future"
(thanks Niels)

"Trying to predict the future is a mug's game"
(thanks Douglas)

Boundary condition uncertainty

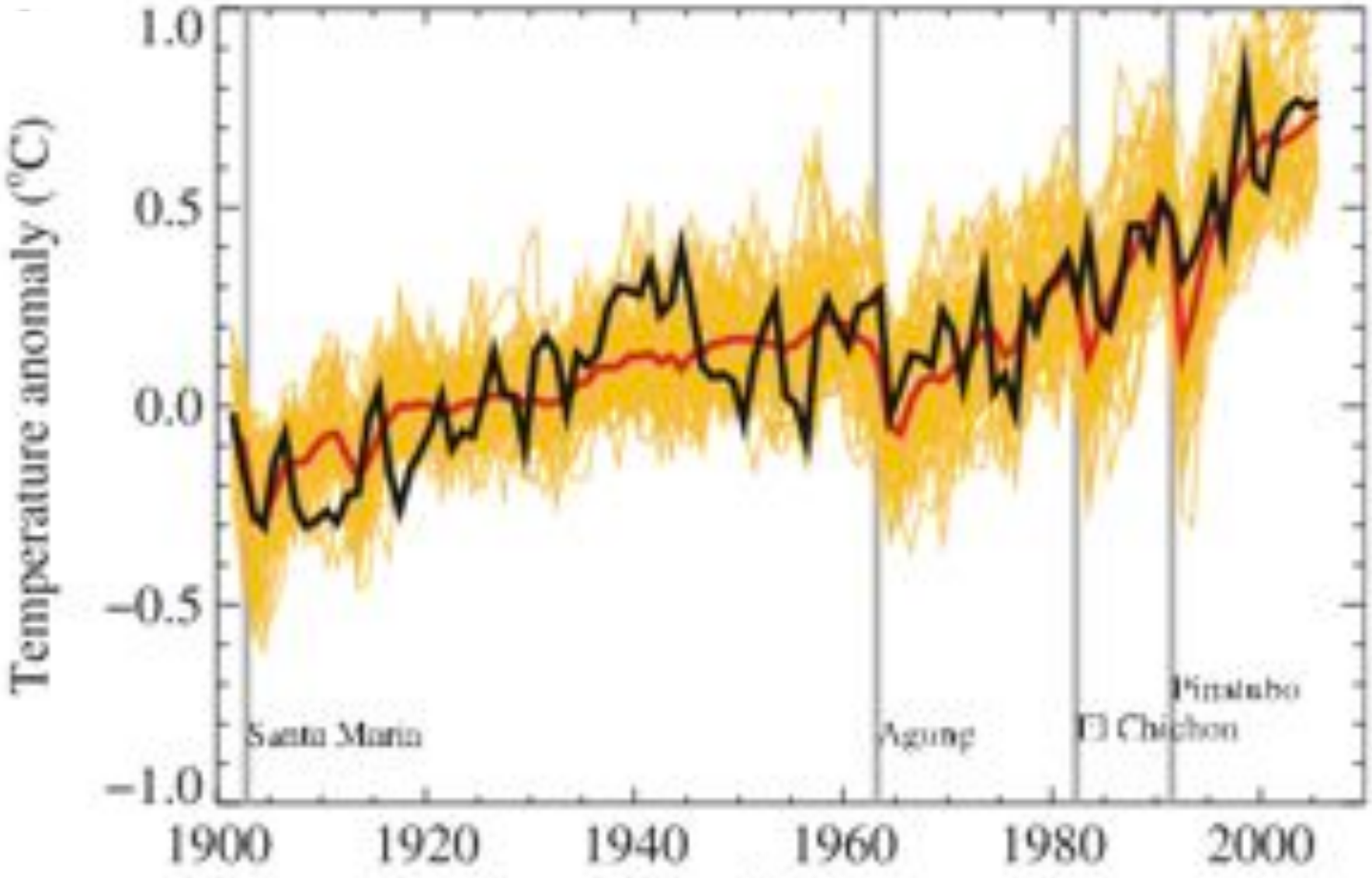
imperfect knowledge of the future drivers of change





How do we know how WRONG the models are?

Climate hindcasts



observations

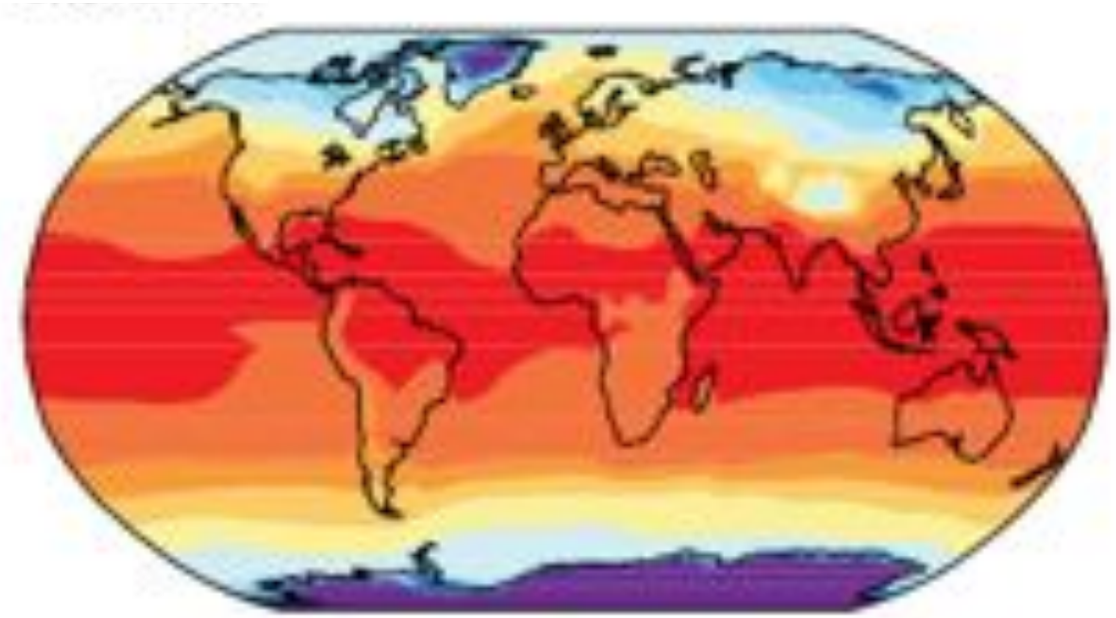
simulations

mean of simulations

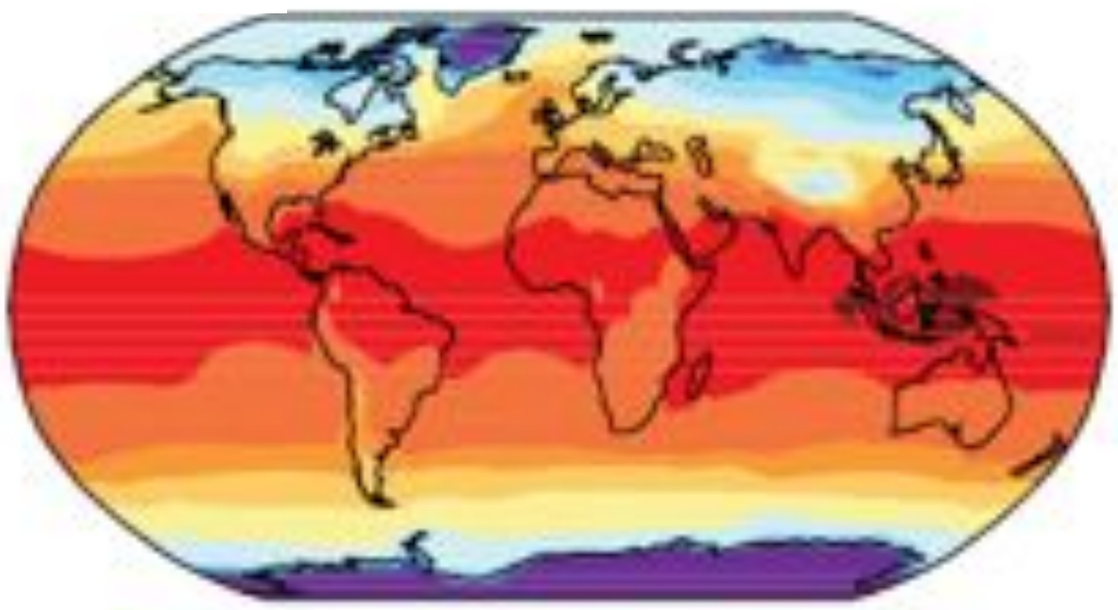
IPCC Working Group 1 (2007), Fig 9.5

Climate hindcasts

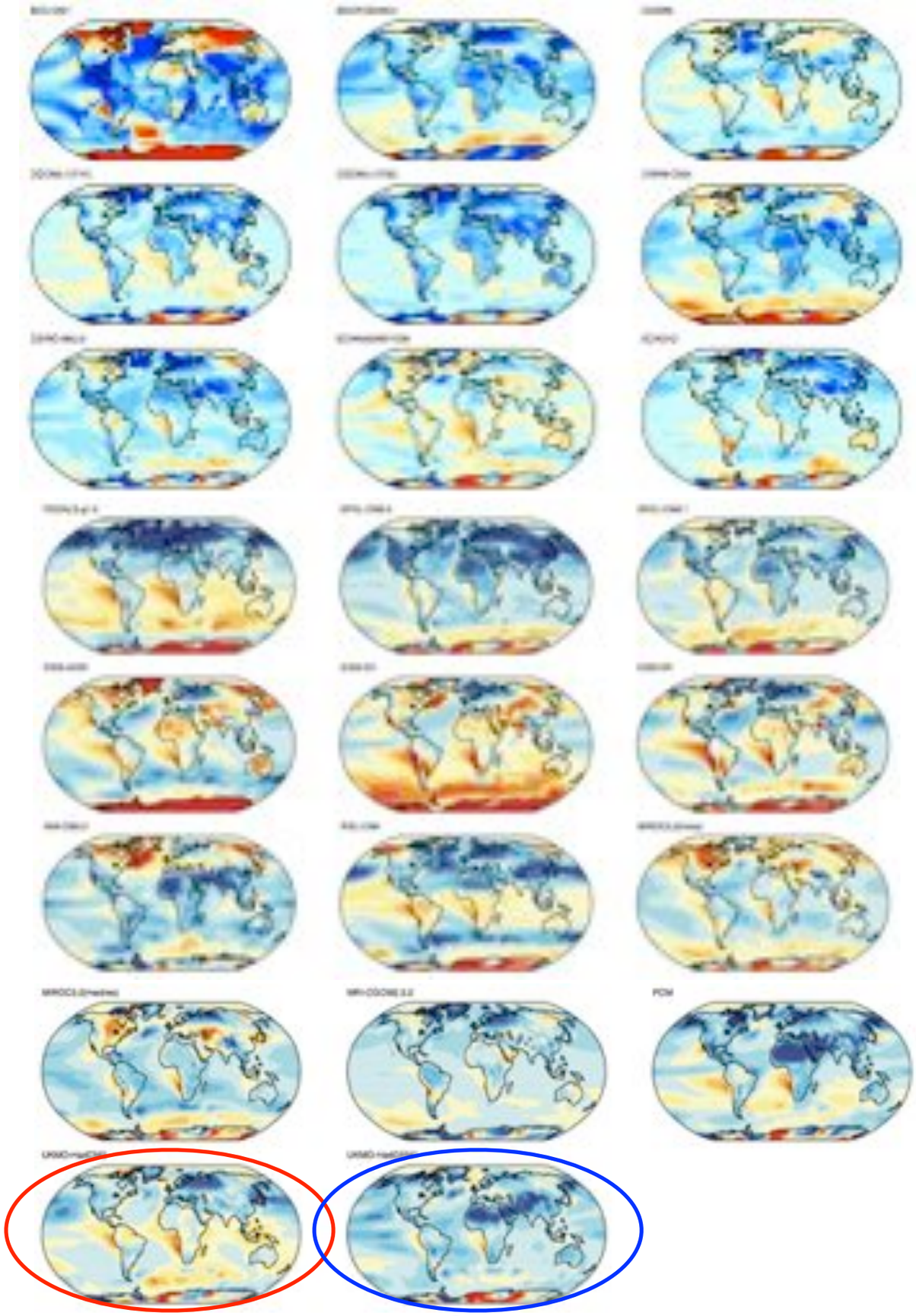
Observations



HadCM3

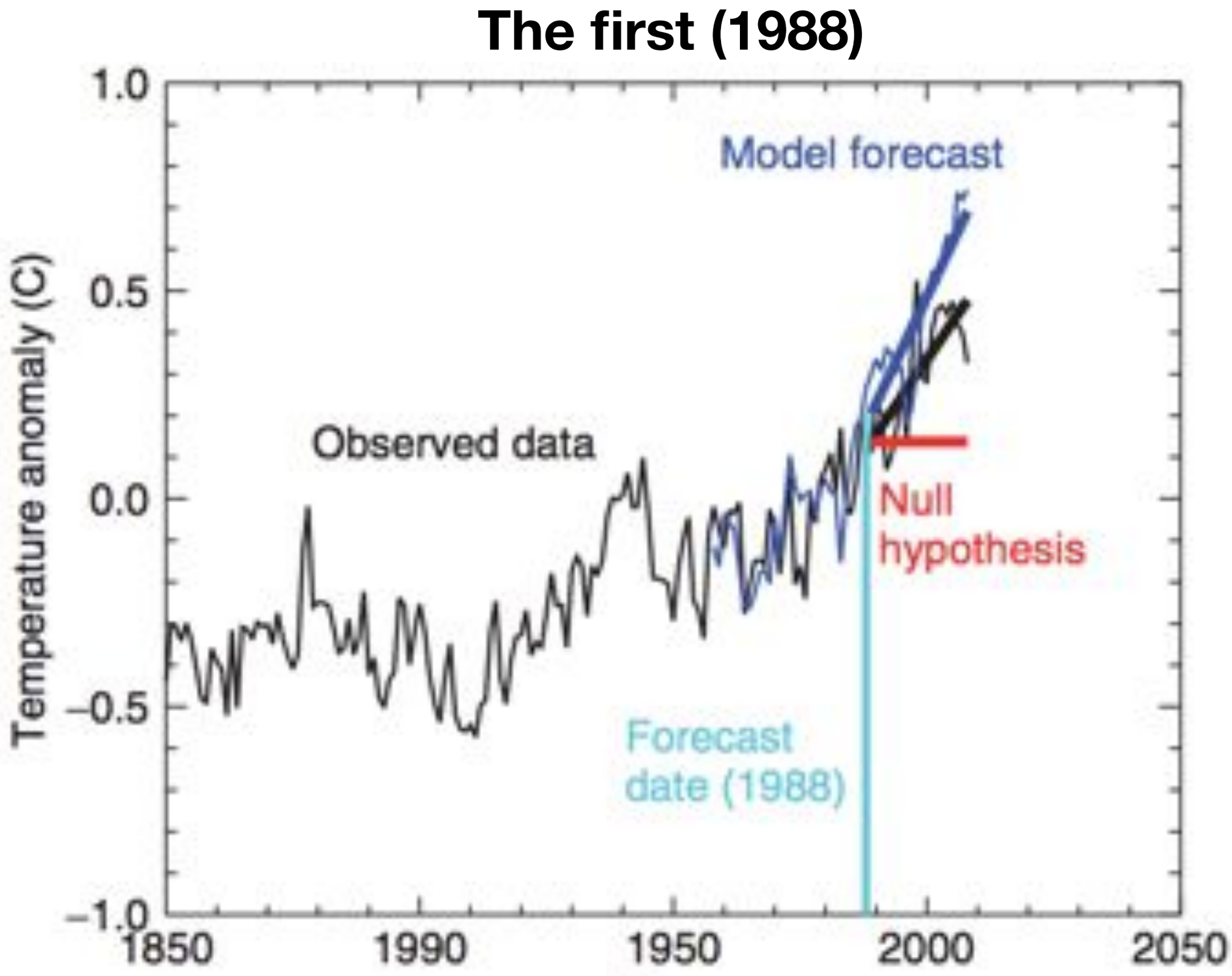


IPCC (2007) WG1, Chap 8 Supp. Mat., Figs 8.1a, b



HadCM3 HadGEM1

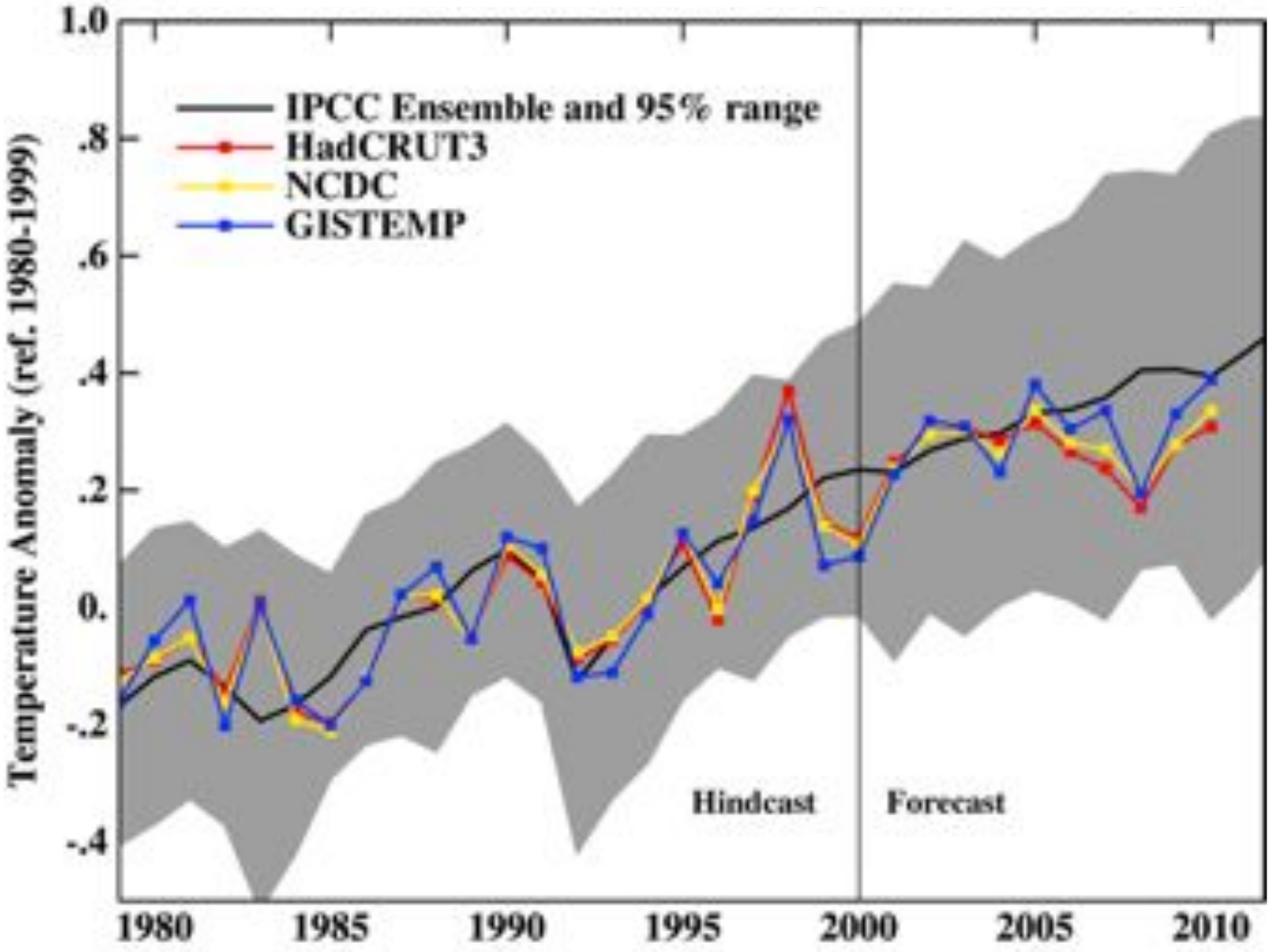
Climate forecasts



Hargreaves et al. (2010), WIREs Climate Change

Climate forecasts

In 2007:



http://www.realclimate.org/index.php/archives/2011/01/2010-updates-to-model-data-comparisons/

How do we incorporate model success into predictions?

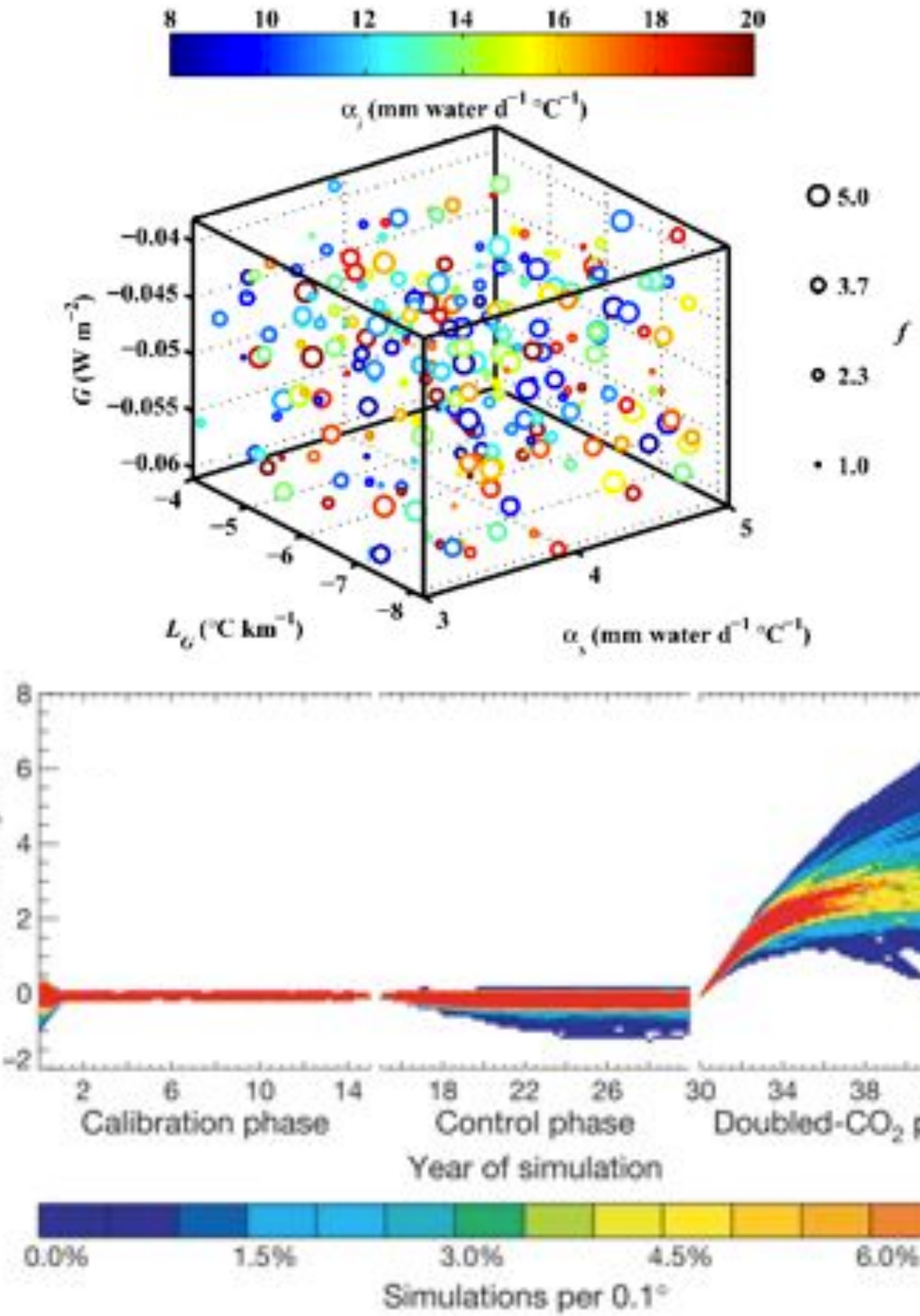
Incorporating success in predictions

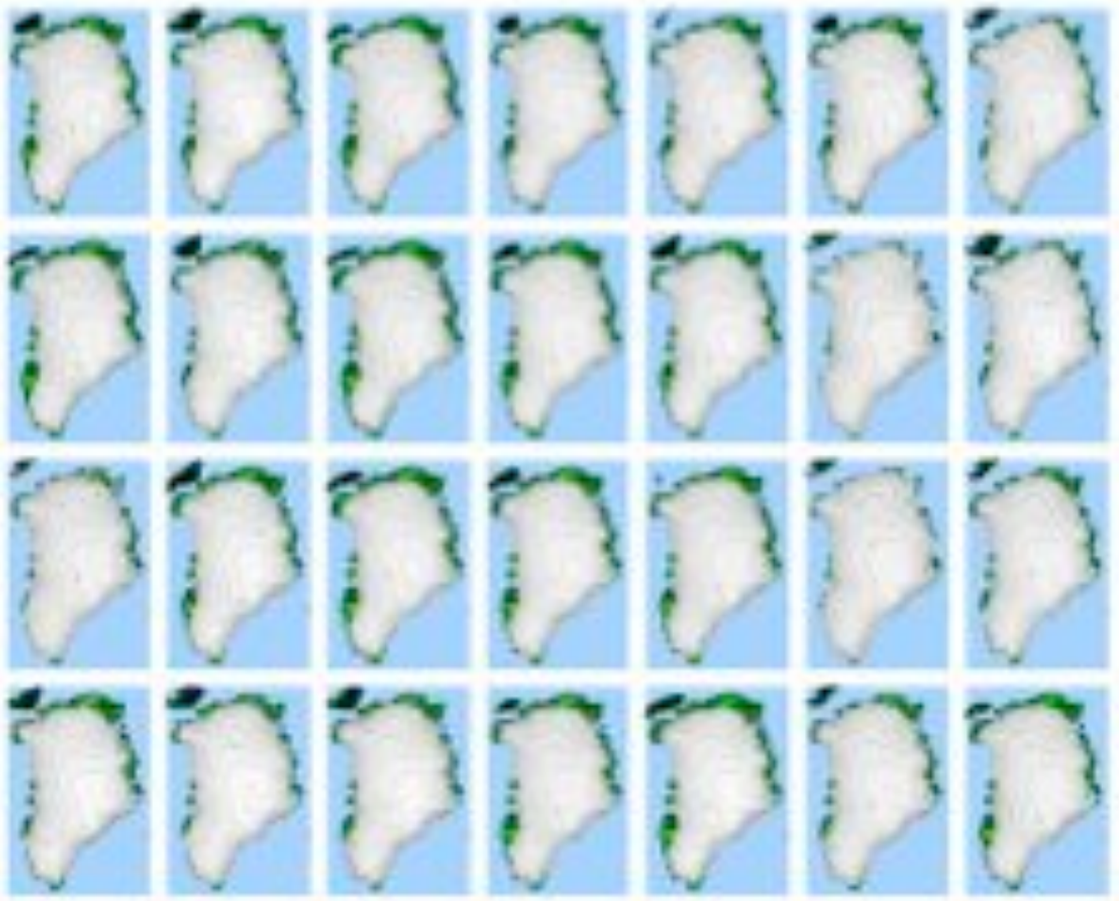
Bayes to the rescue

"first guess" probability + observations
= better prediction of probability

probability as *belief*

Detuning the model





Stone et al. (2010) The Cryosphere

climateprediction.net

Stainforth et al. (2005), Nature

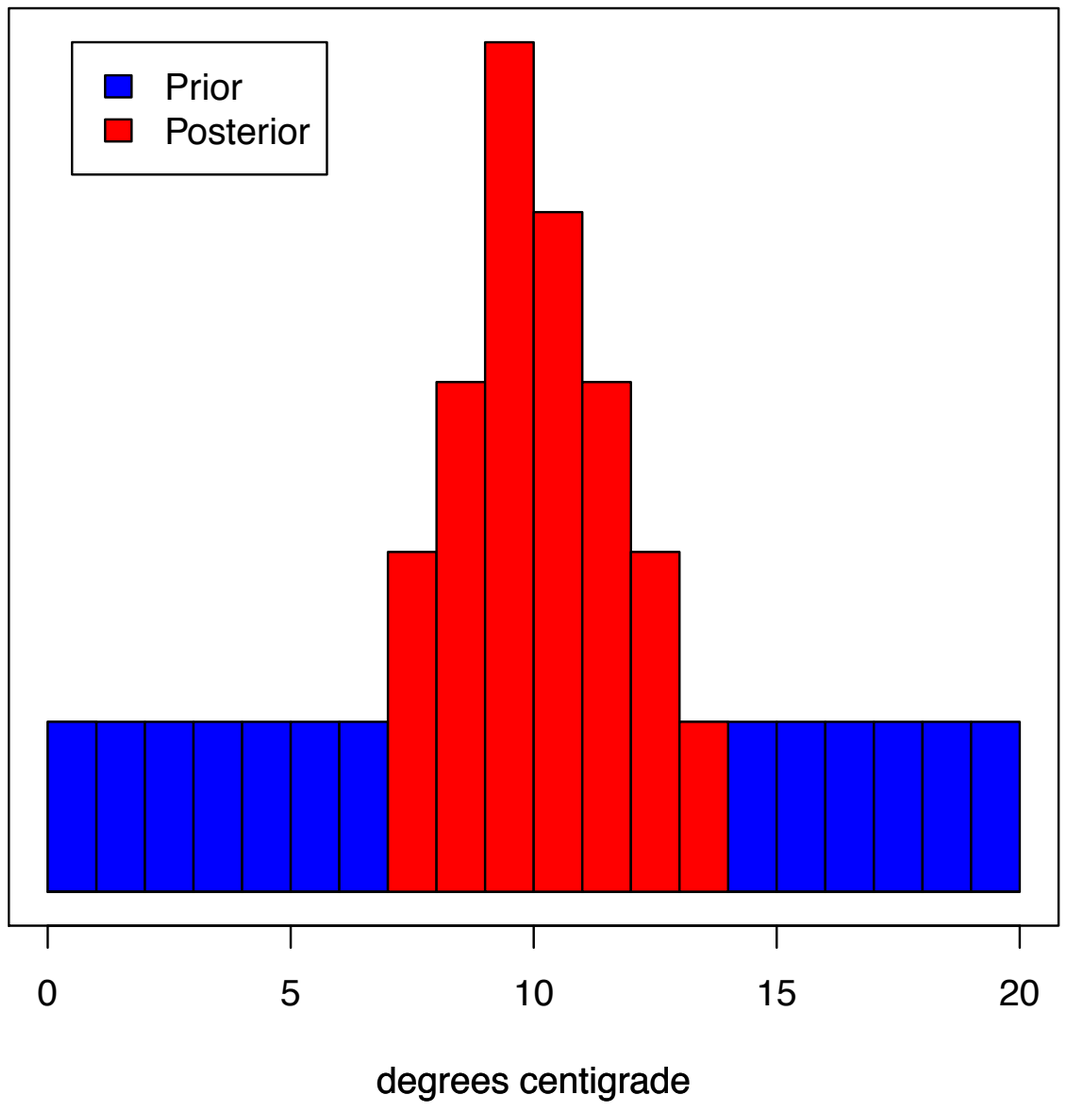
Bayes' Theorem

prior probability: ensemble of detuned model versions...

likelihood: score with observations

=> posterior probability

$$\text{posterior} = \frac{\text{prior} \times \text{likelihood}}{\text{normalisation}}$$



Simplest application

N detuned model versions

θ parameter values

$f(\theta)$ model simulation of observed quantity/-ies

σ_m model uncertainty

z observation(s)

σ_o observation uncertainty

1. Likelihood function: Gaussian

model errors normally distributed

if multiple observations: independent

2. Calculate scores

don't need normalising constant

$$w(\theta) \propto \exp\left[-\frac{1}{2}\sum_{\mathrm{i}}\frac{(\mathrm{z_i}-\mathrm{f_i}(\theta))^2}{(\sigma_{\mathrm{o}}^{\mathrm{i}})^2+(\sigma_{\mathrm{m}}^{\mathrm{i}})^2}\right]$$

3. Normalise scores

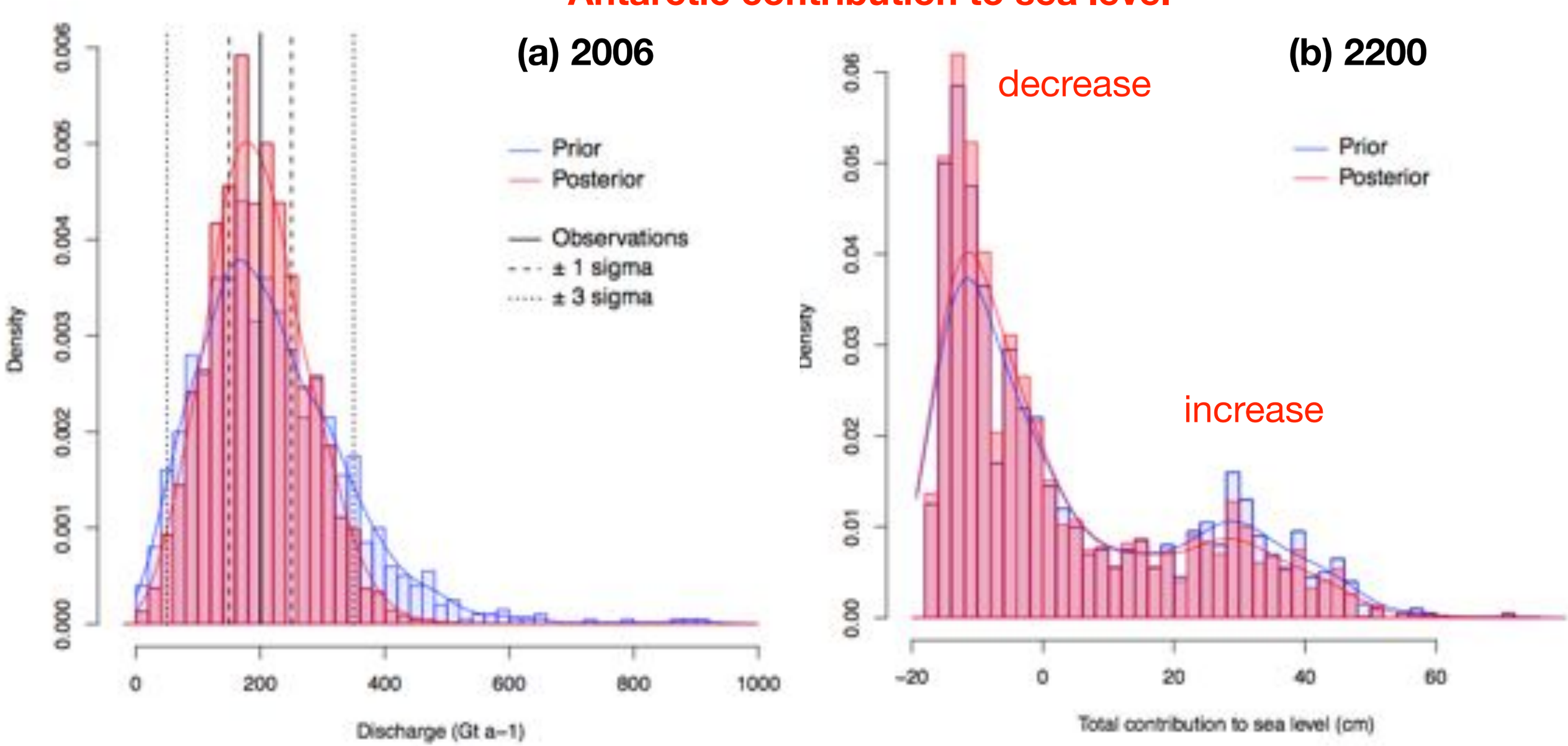
$$\sum_N w(\theta) = 1$$

σ_m expected success at best parameter values; can tune to distribute weights

Simple application

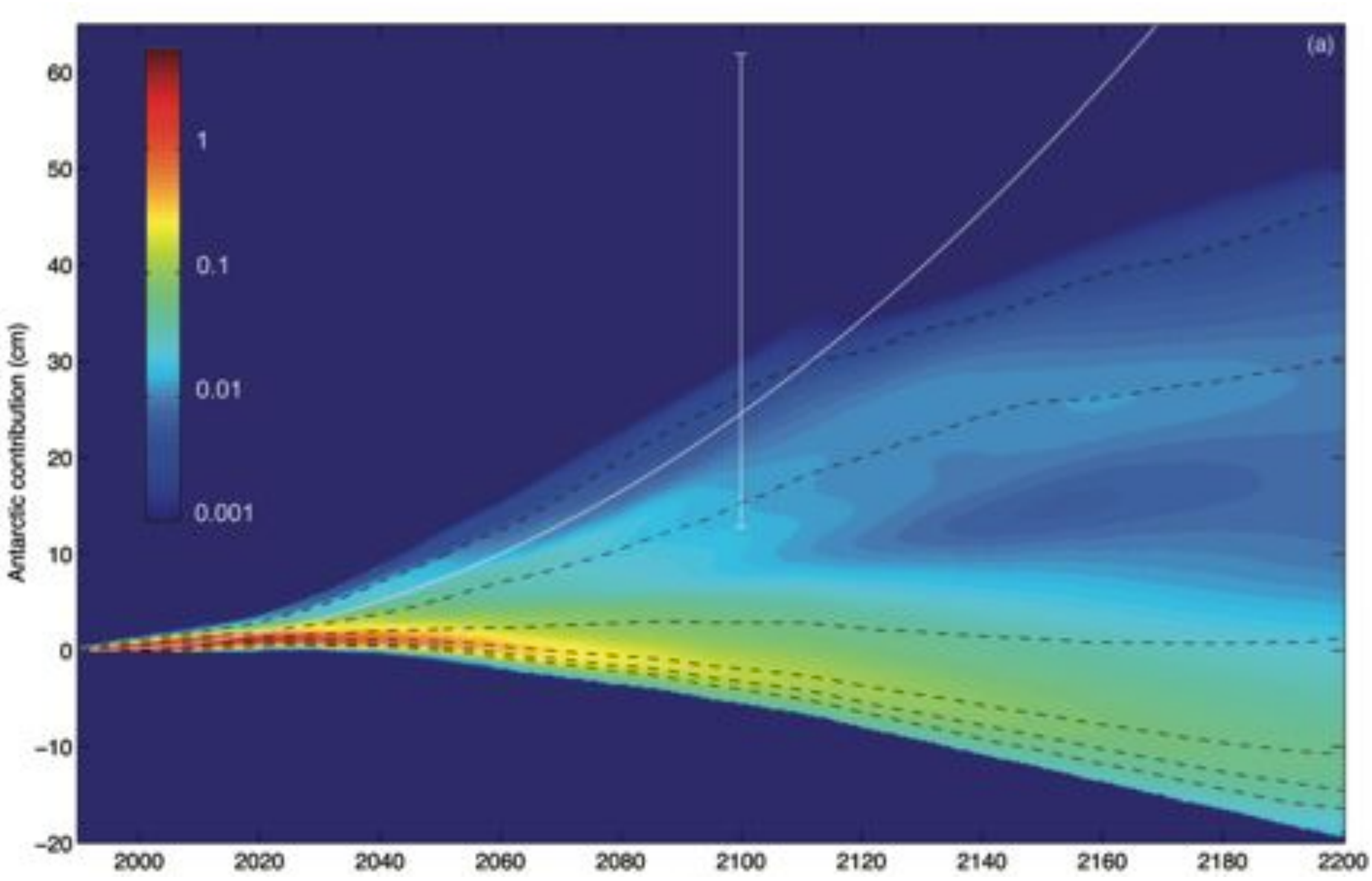
4. Use scores to reweight histograms

(a) observed quantity
(b) future prediction



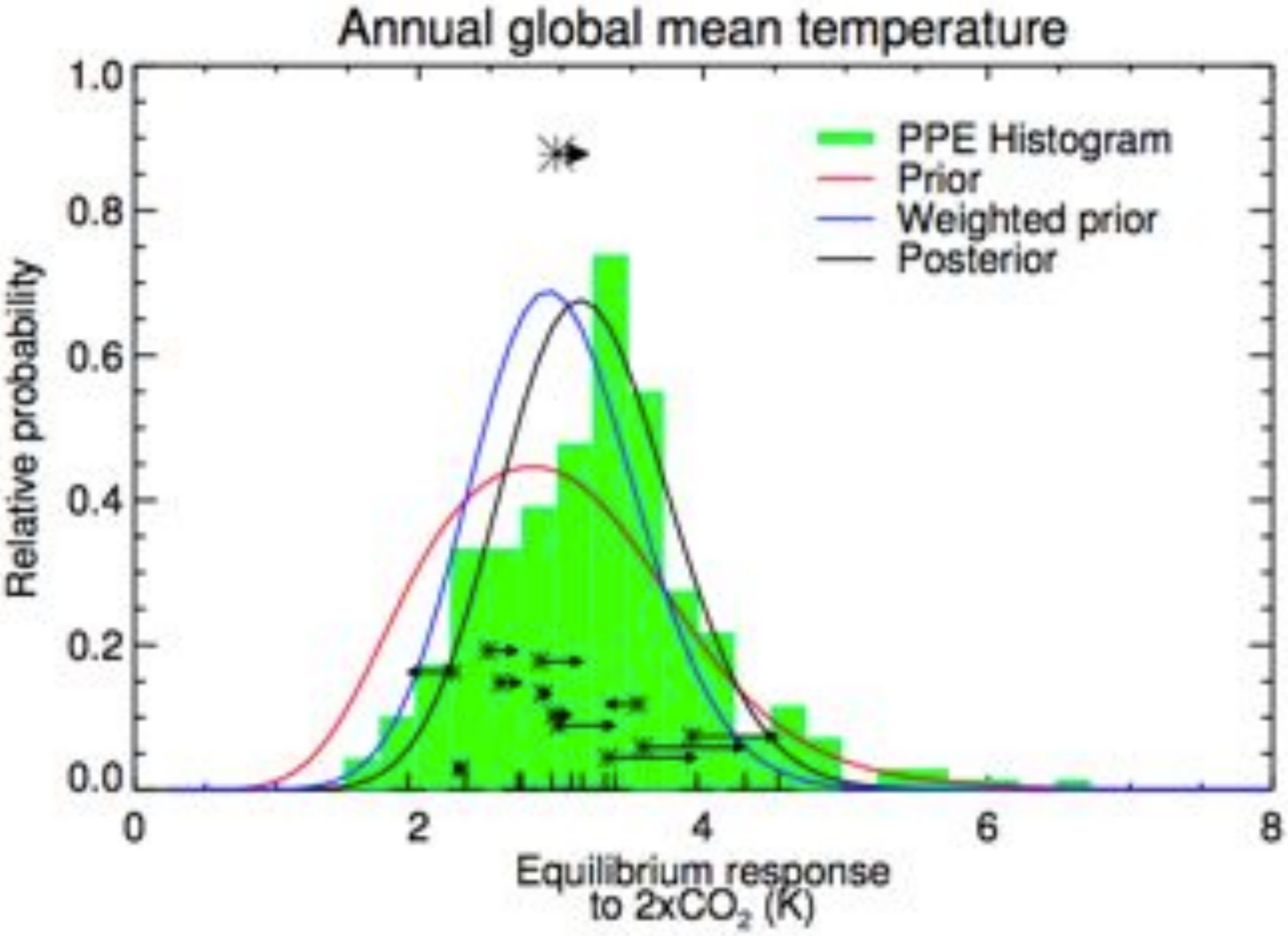
Ritz, C., Durand, G., Edwards, T.L., et al. *Bimodal probability of the dynamic contribution of Antarctica to future sea level.* Submitted to Nature

Antarctic contribution to sea level



Ritz et al.

UK Climate Projections



Sexton et al. (2011) Climate Dynamics

Your future


Say hello:
@flimsin
allmodelsarewrong.com
Buy a calendar:
http://www.sciencegrrl.co.uk