Will we ever be able to attribute individual weather events to anthropogenic climate change?

Santiago de Compostela, July, 2003

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Thanks: Daithi Stone, Hugo Lambert, Peter Stott, Jamie Kettleborough

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South Oxford on January 5th, 2003

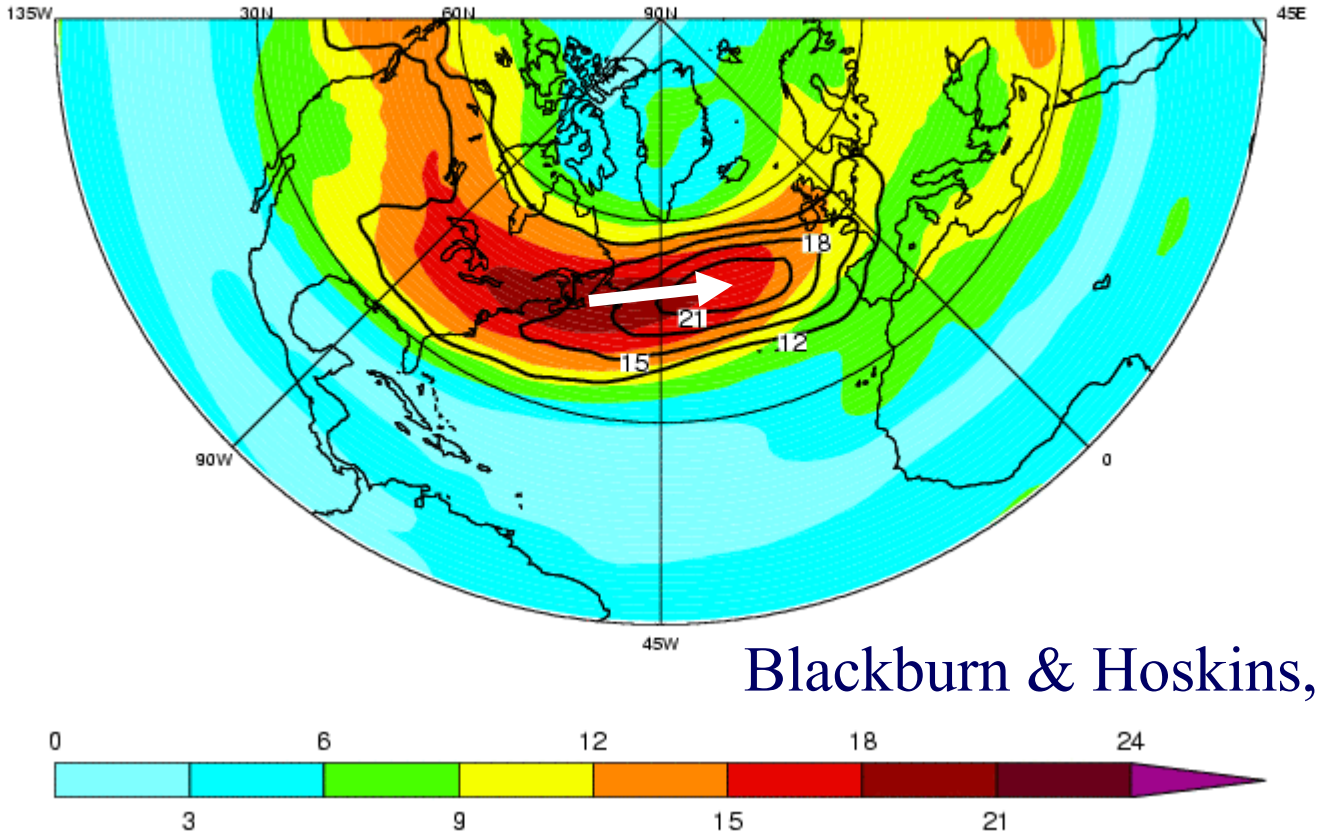
Photo courtesy of Dave Mitchell

Was this just another weather event, or was it something to do with climate change?

- The difference between weather and climate and its importance for attribution
- Attribution of recent observed large-scale temperature trends: the IPCC's conclusions
- What we can say about weather: attributing cause and effect in a chaotic system
- Who/what was to blame for the 2000 UK floods?
- Implications for climate modelling designs
- Why it matters

The problem in Autumn 2000: a *consistently* displaced Atlantic jet-stream

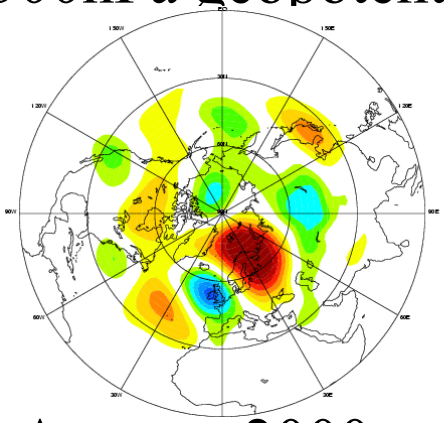
The Atlantic Jet Stream (500hPa wind speed)
Autumn climatology (colours) & Autumn 2000 (contours)



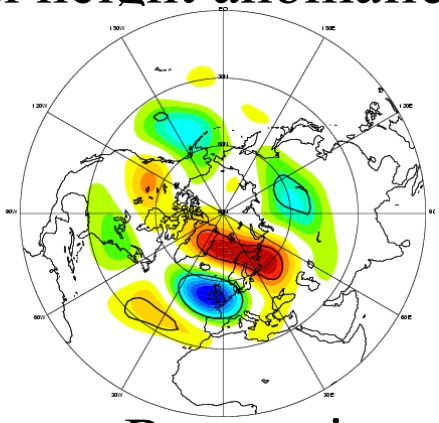
Blackburn & Hoskins, 2003

Blackburn & Hoskins, continued

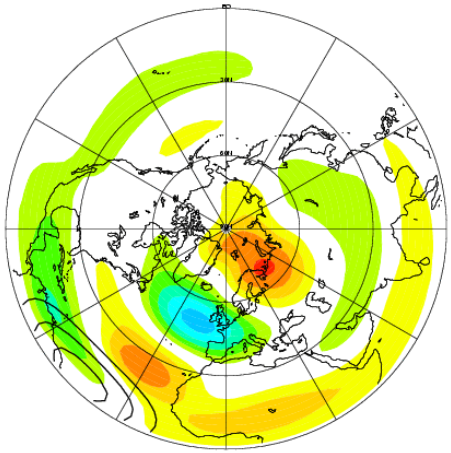
300hPa geopotential height anomalies



Autumn 2000



Regression on Autumn UK rainfall



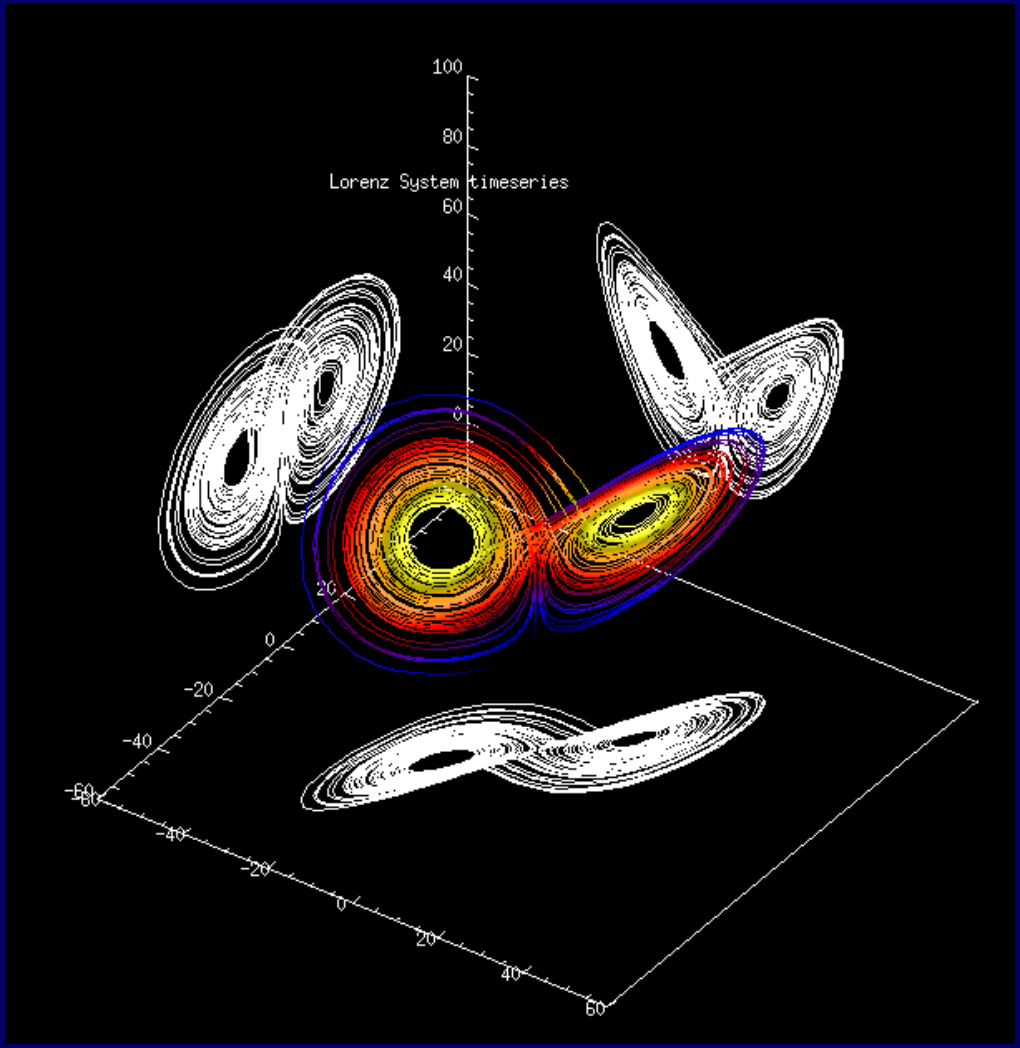
Barotropic response to tropical Atlantic forcing

(Blackburn & Hoskins)

But the jet-stream varies with the weather: how can we pin down the role of climate change?

- "Climate is what you expect, weather is what you get" (Lorenz, 1982)
- and in the 21st century:
- "Climate is what you affect, weather is what gets you"
- Climate means the weather we should *expect*, on average, at a given time of year
- Climate may be perfectly predictable, even though weather is not

The Lorenz (1963) model of deterministic chaos: unpredictable weather, predictable climate



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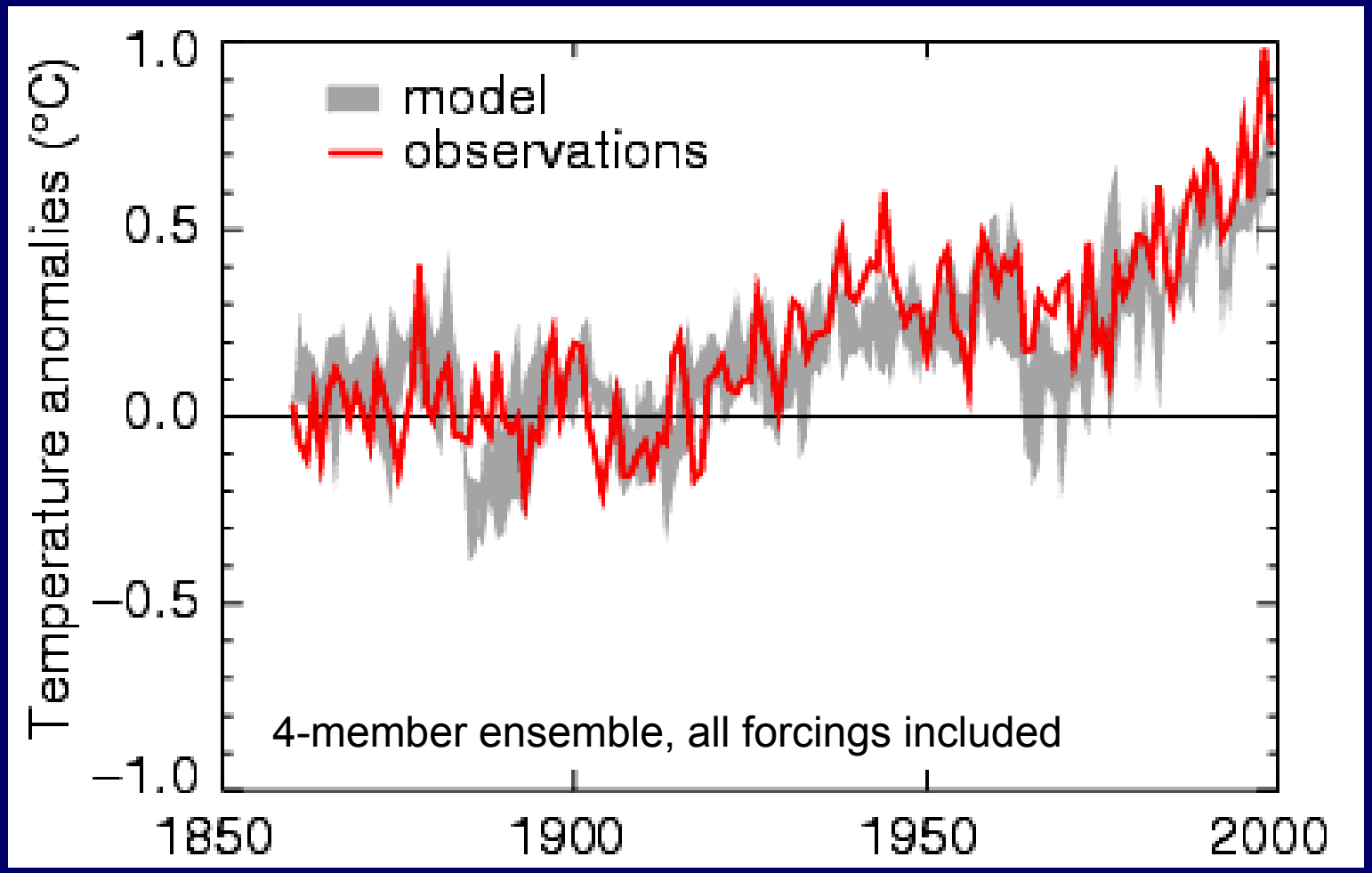
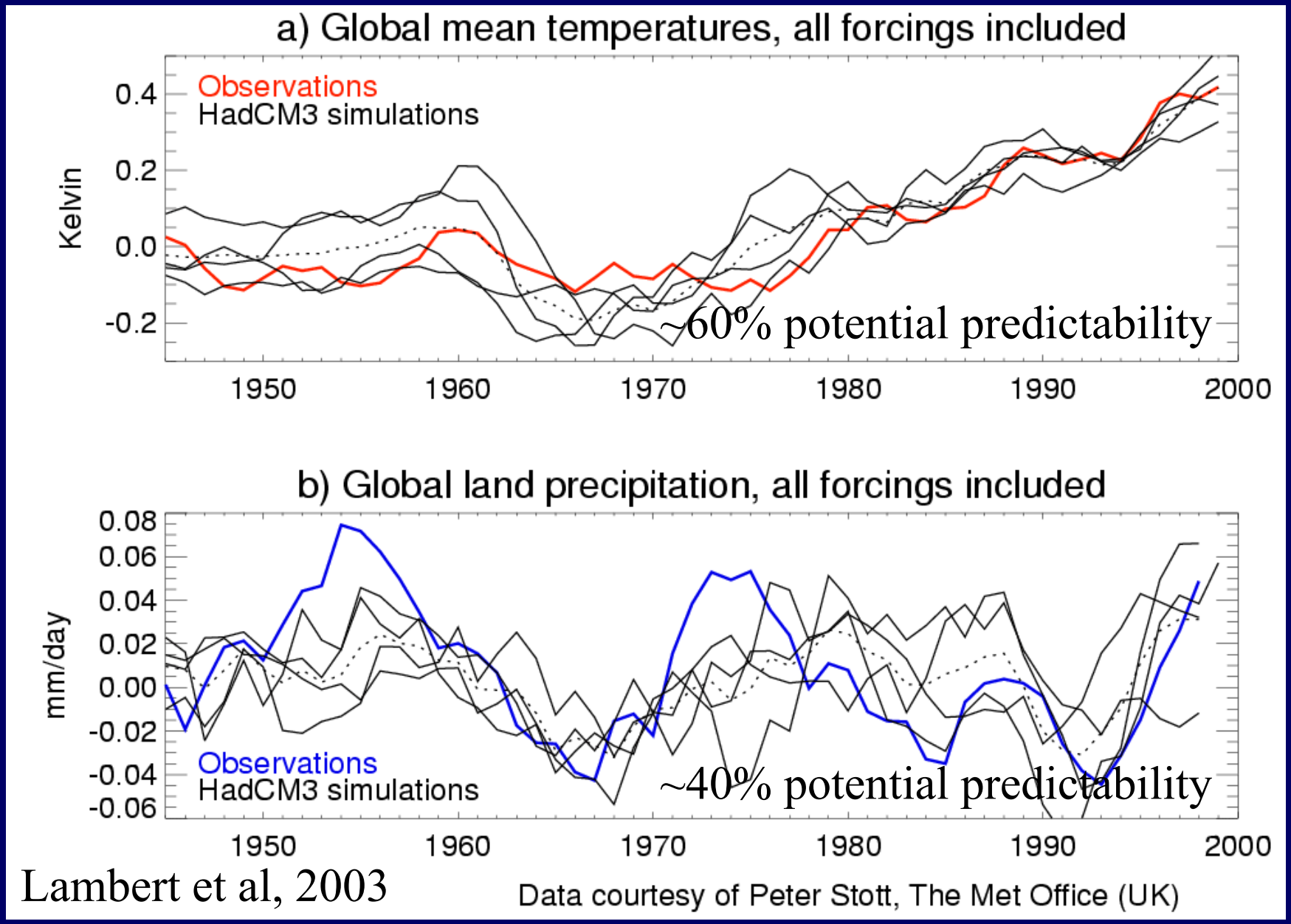
The Stott et al result: >60% of 10- to 50-year variability controlled by external forcing



Is global precipitation also externally controlled?



Lambert et al, 2003

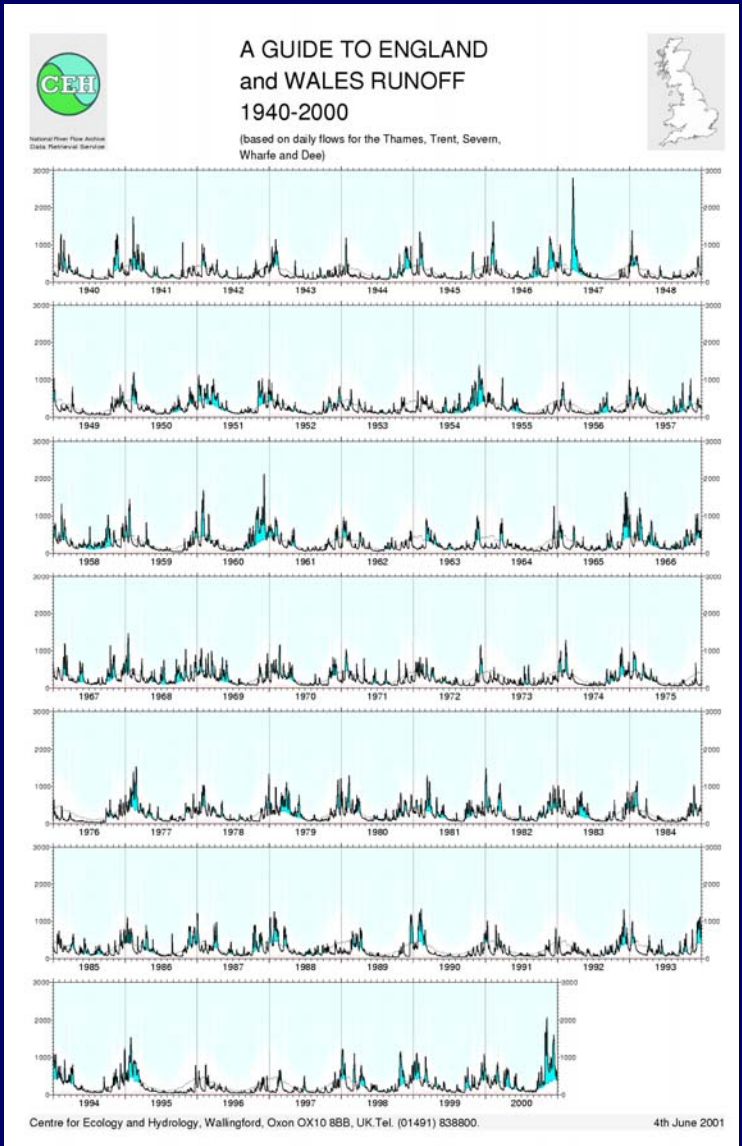
The IPCC attribution process applies to changes in *climate* (expected weather)

- IPCC assumes that we can add up the responses to different external drivers
- Probability arises from uncertainty in
  - how the climate is changing
  - how different factors contribute to that change
- Climate change itself is *deterministic*, controlled by external factors.

But who cares about global temperature?

- A single flood is not controlled by past greenhouse gas emissions as global temperatures appear to be.
- Hence we can never attribute “this flood” to past emissions as we can attribute the observed global warming.
- So the question “Is this flood due to climate change?” is vacuous.
- But this does not mean that nothing can be said at all.

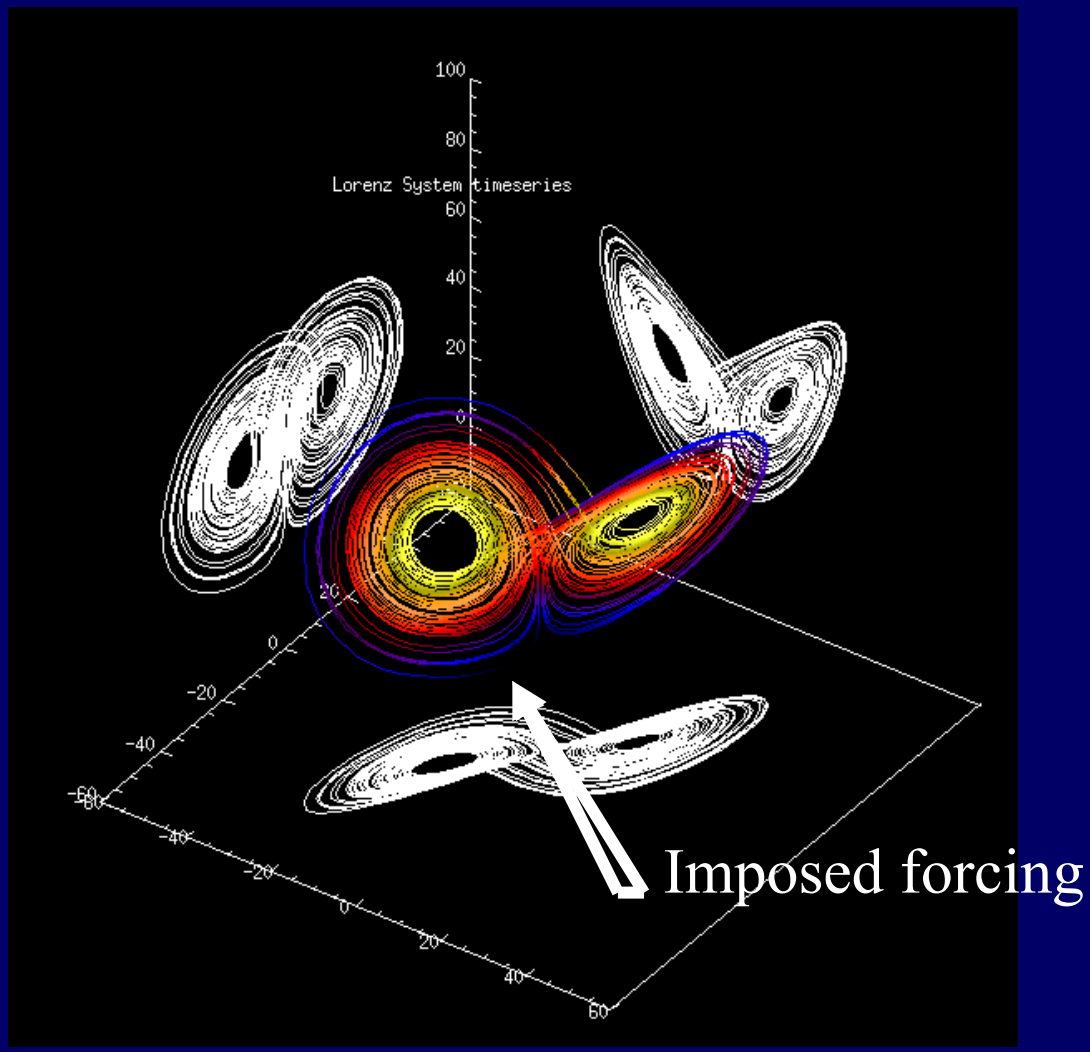
Autumn 2000 events "were extreme, but cannot *in themselves* be attributed to climate change."



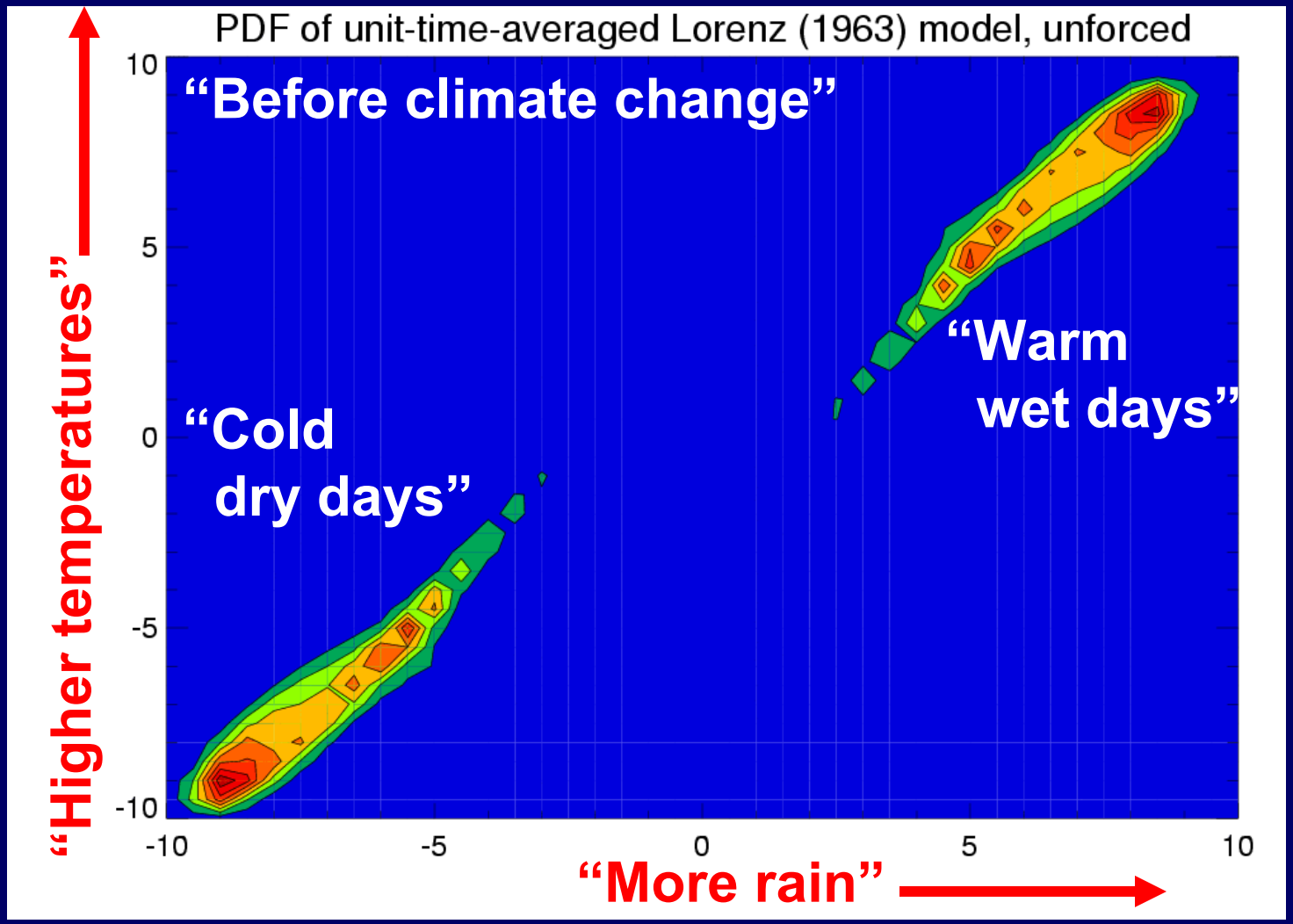
Can we be more quantitative? The challenge of probabilistic attribution.

- Lay definition of attribution: how would the climate be different if X had not occurred?
- Well-posed if and only if "climate" includes all moments of the weather attractor.
- For a specific weather event, we need:
  - P0: probability of that event if X is absent
  - P1: probability of that event if X is present
  - 1 - P0/P1: fraction of current risk attributable to X
  - Estimate distributions of P0 and P1 consistent with current knowledge

Back to our simple chaotic system, now with an "external driver of climate change"



Showing the impact of external driving on our simple chaotic system



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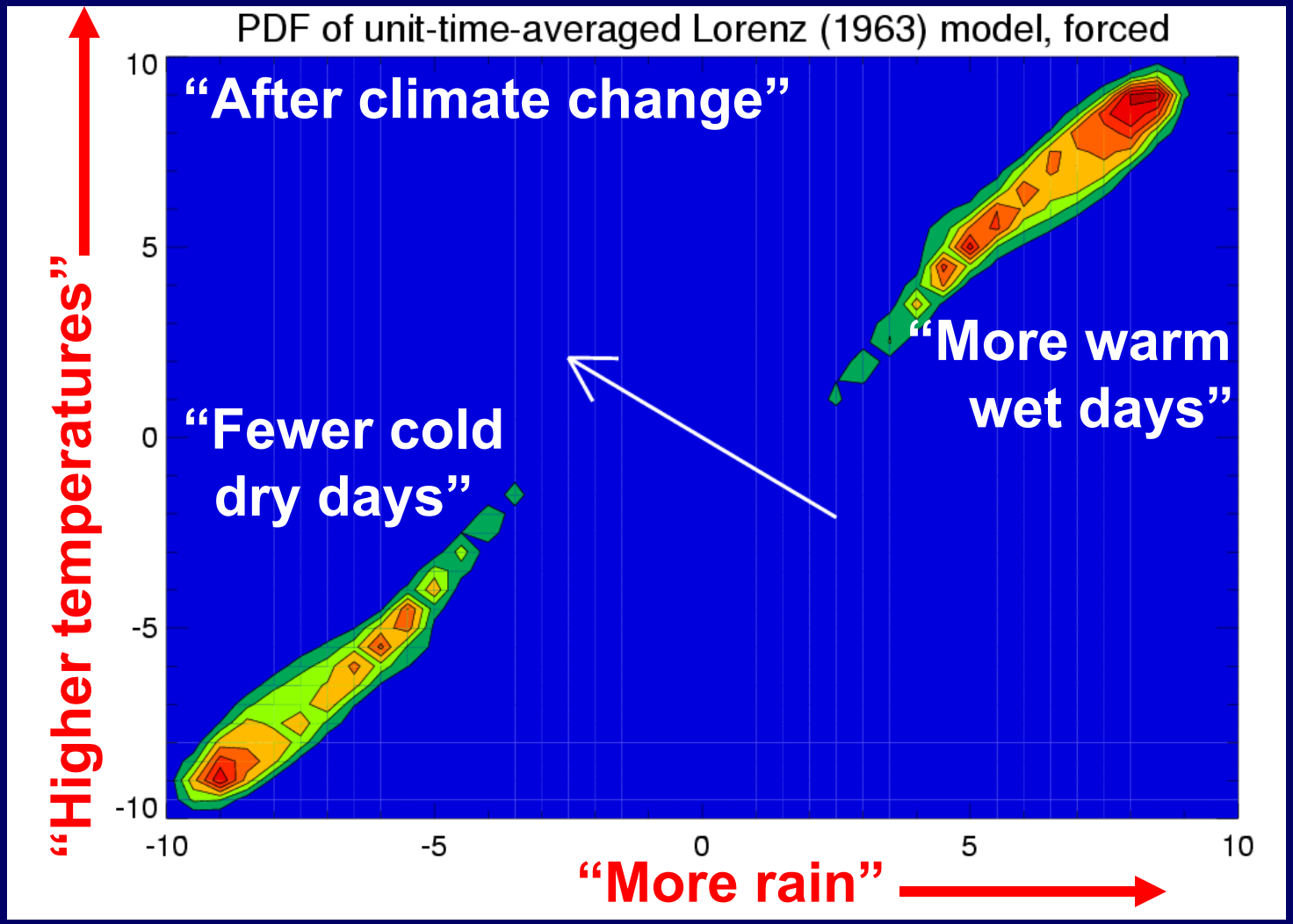

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How the distribution of "rainfall" changes as the external driving increases

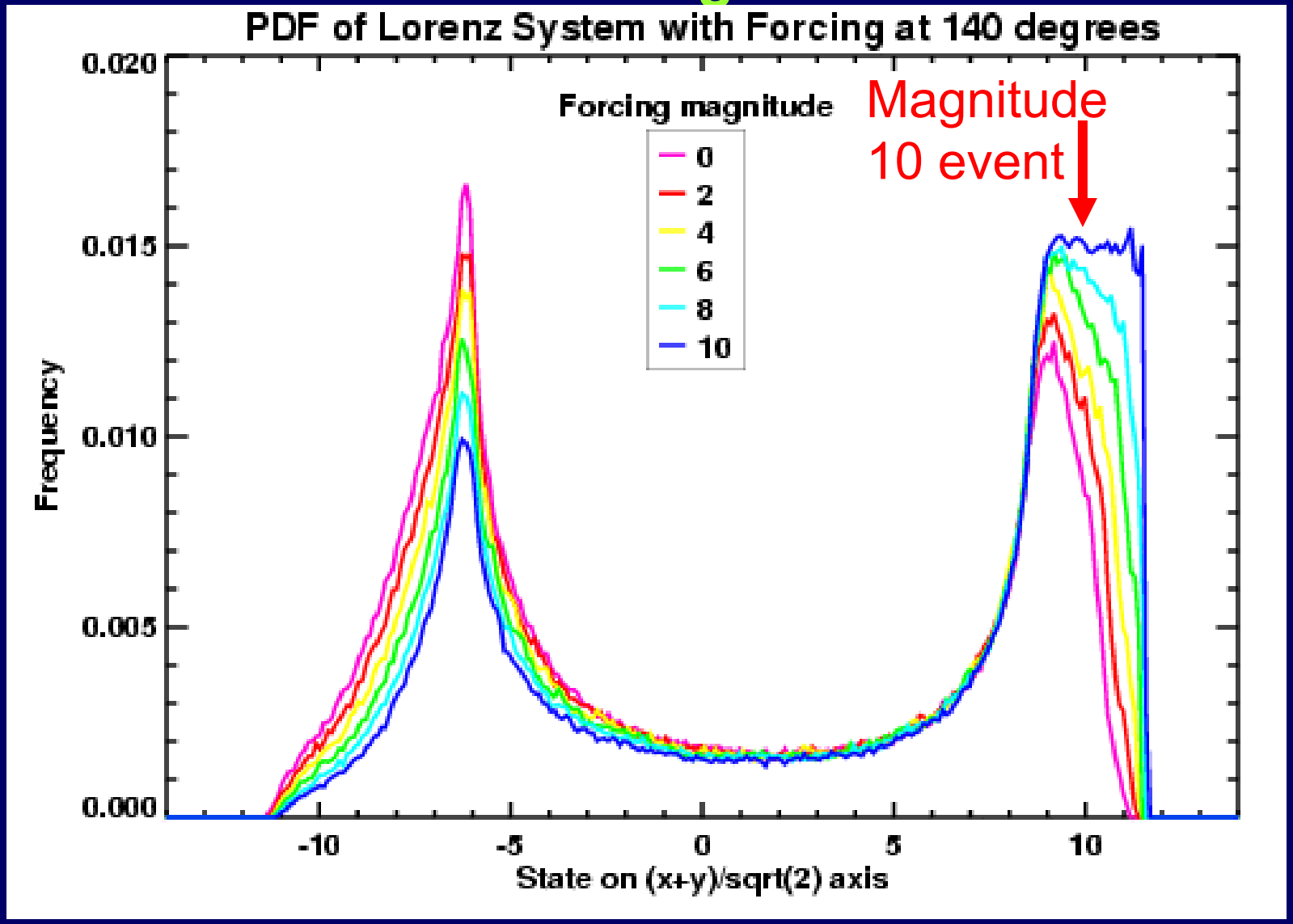
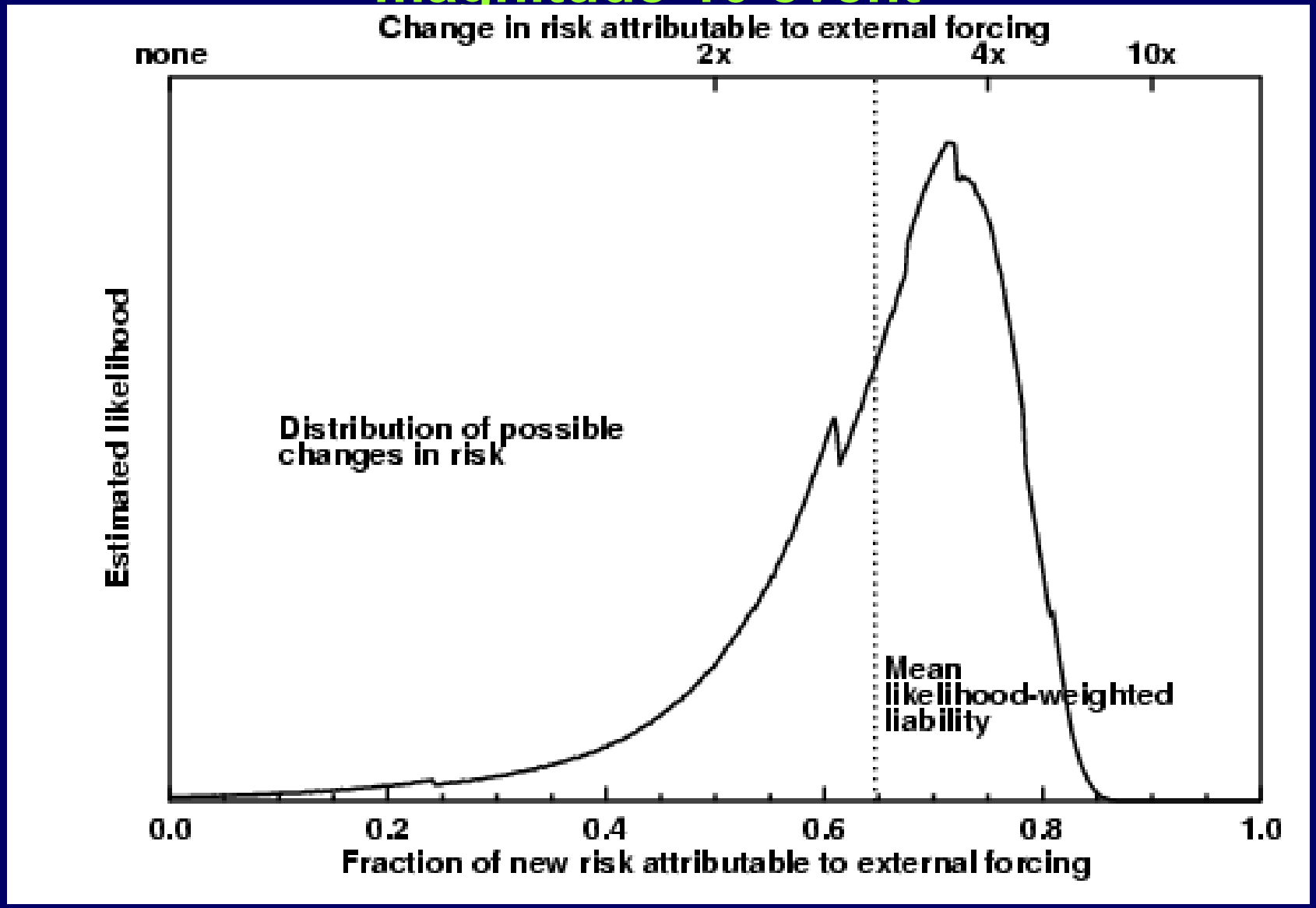


Figure courtesy of Daithi Stone

Distribution of possible changes in risk of a magnitude-10 event



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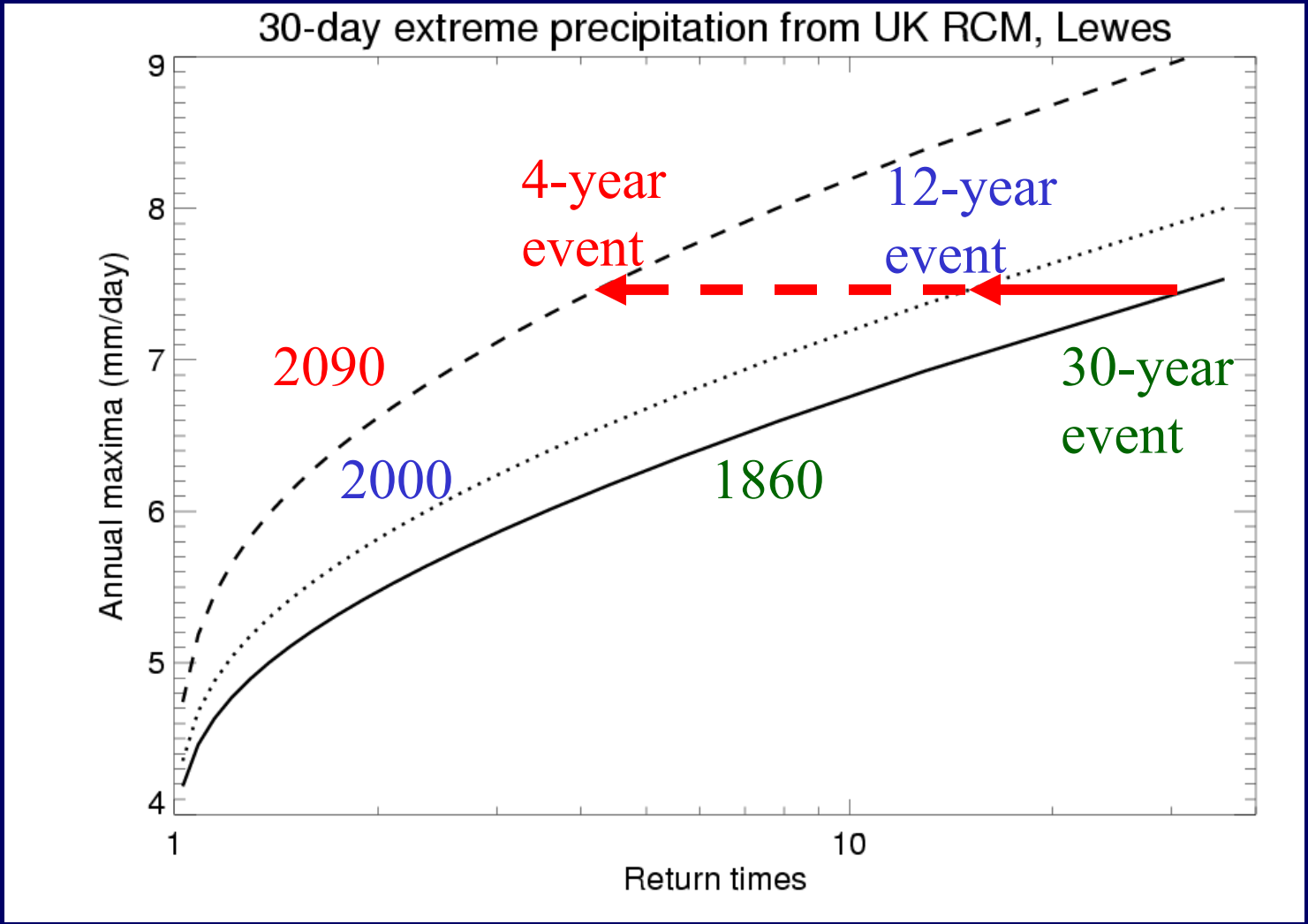
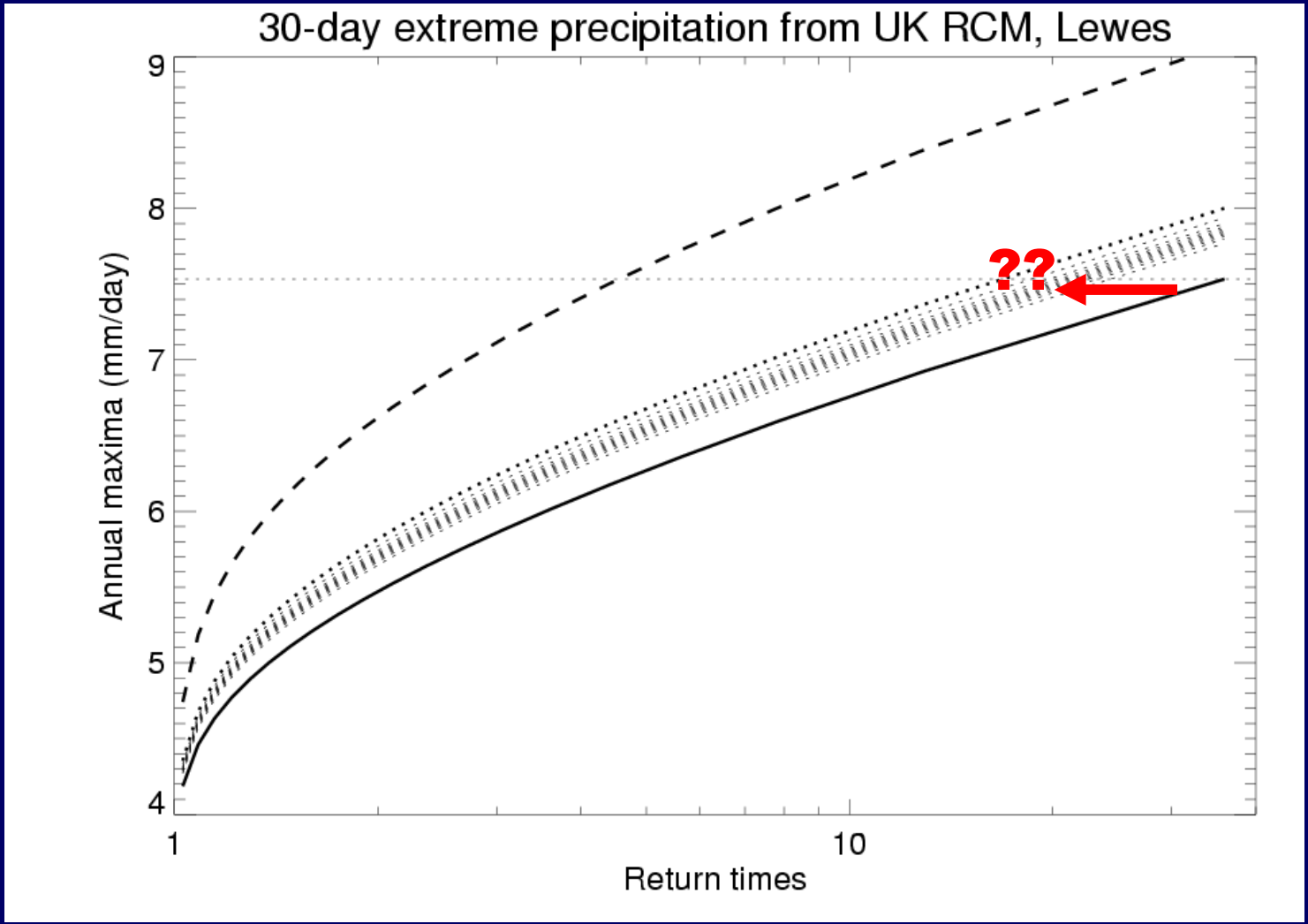
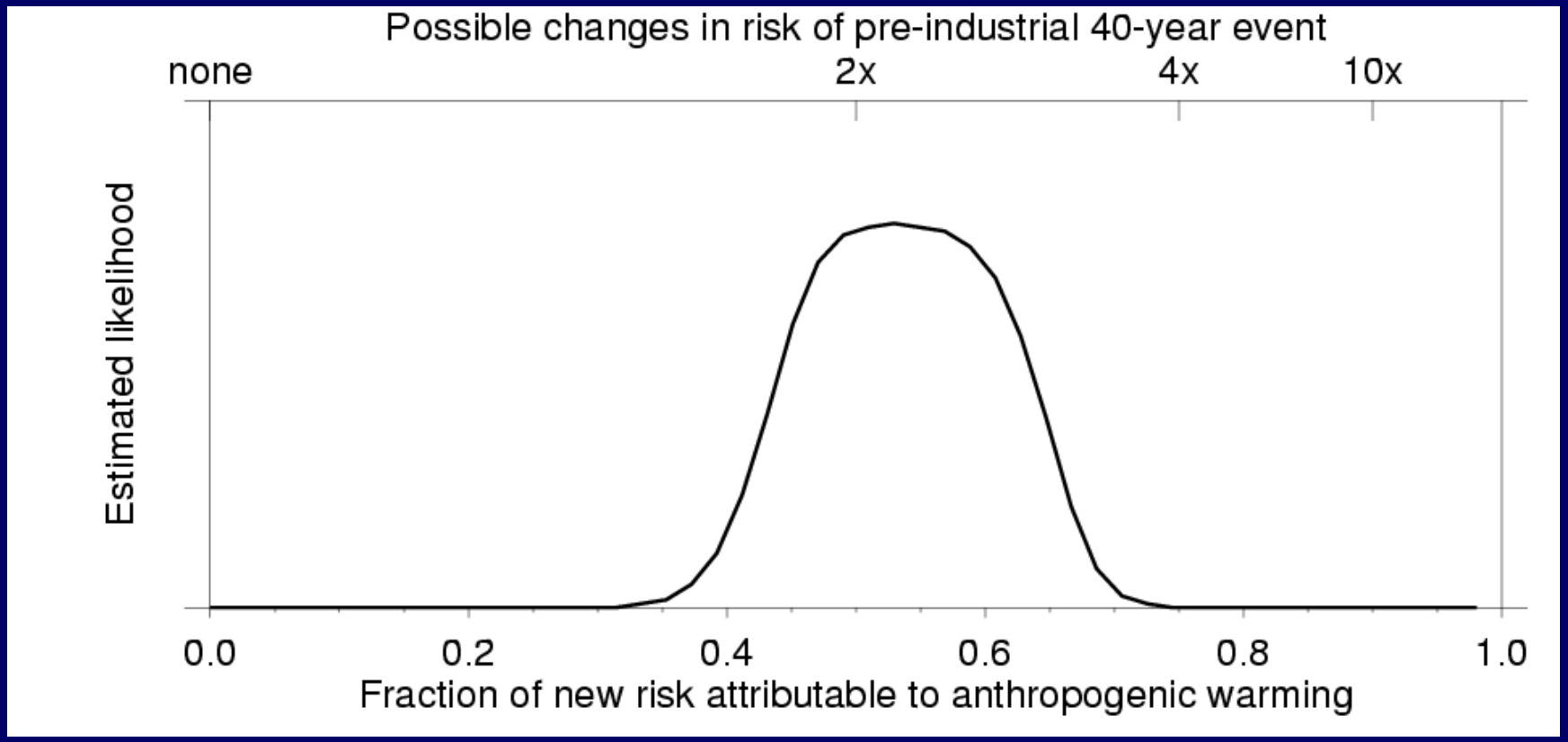
Model-simulated changes in extreme rainfall in southern England



Accounting for uncertainty in global mean response 1860-2000



How anthropogenic climate change may have contributed to the risk of the October 2000 floods (but only global response uncertainty)



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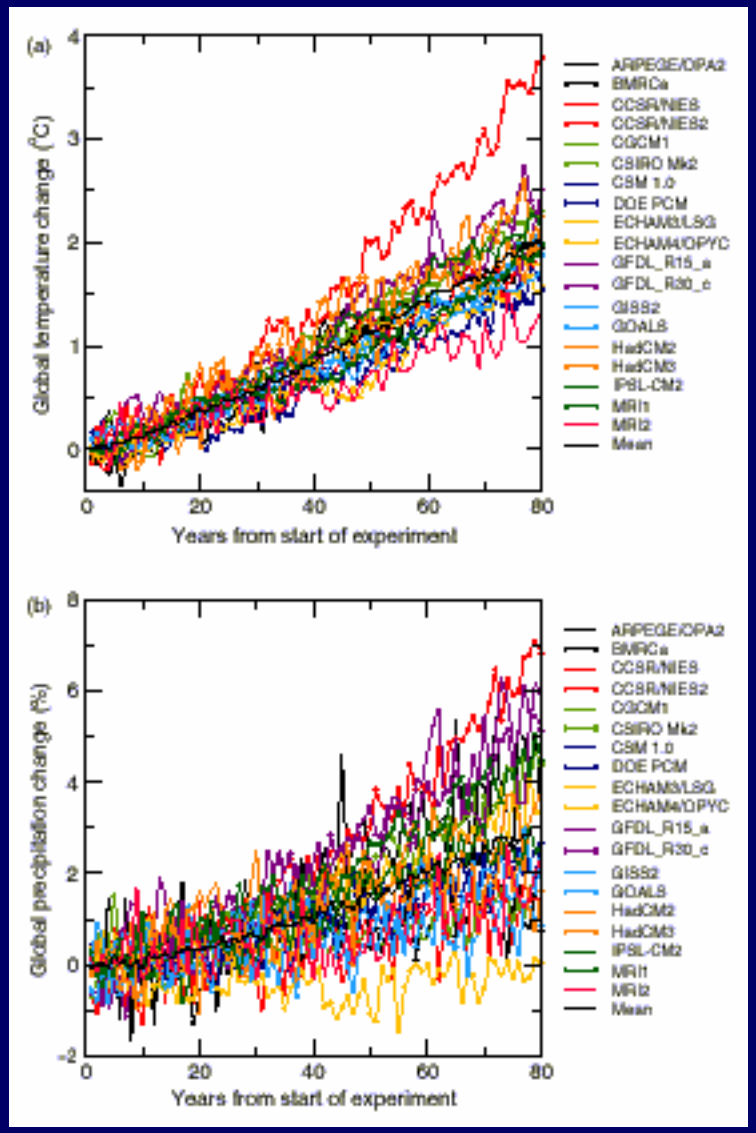
Allowing for more than global-mean response uncertainty using a multi-model ensemble

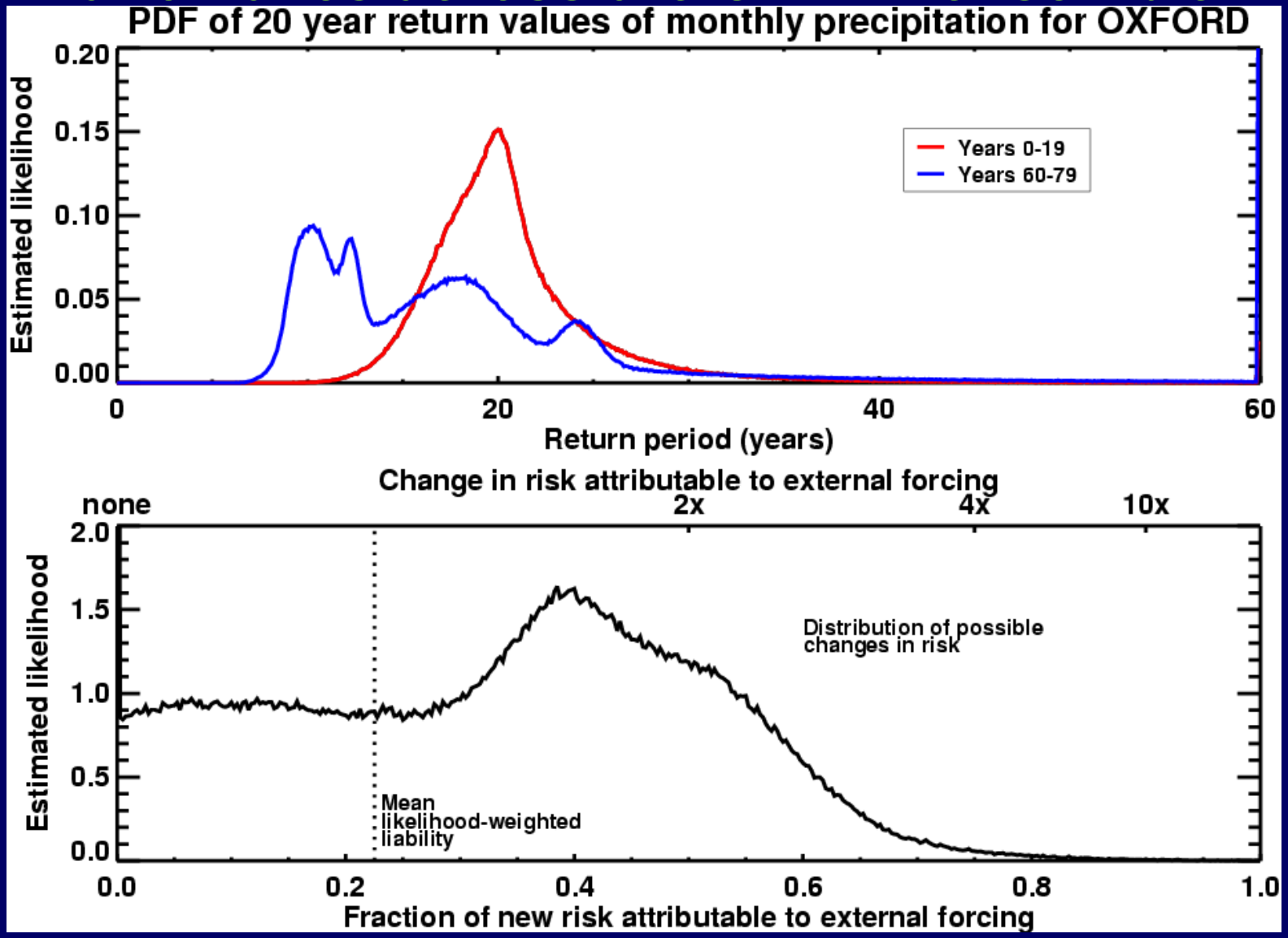
Global temperature change under 1% per year increasing CO_2

(CMIP-2 model inter-comparison)

Global precipitation change under 1% per year increasing CO_2



Change in risk of 20-year-return monthly rainfall anomalies across the CMIP-2 ensemble



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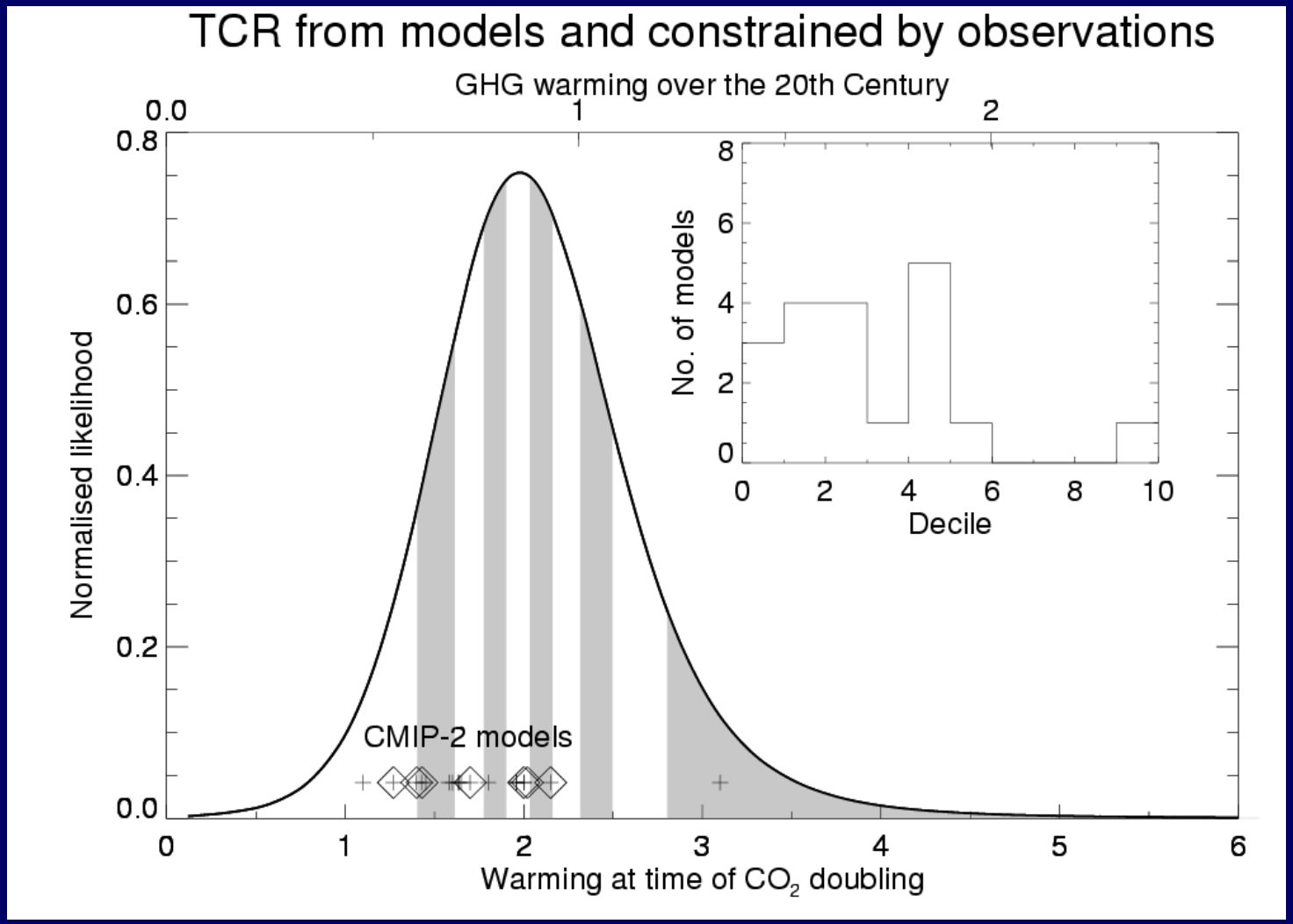
But do available models provide a representative sample of changes consistent with data?



Dealing with uncertainty in modelling climate change

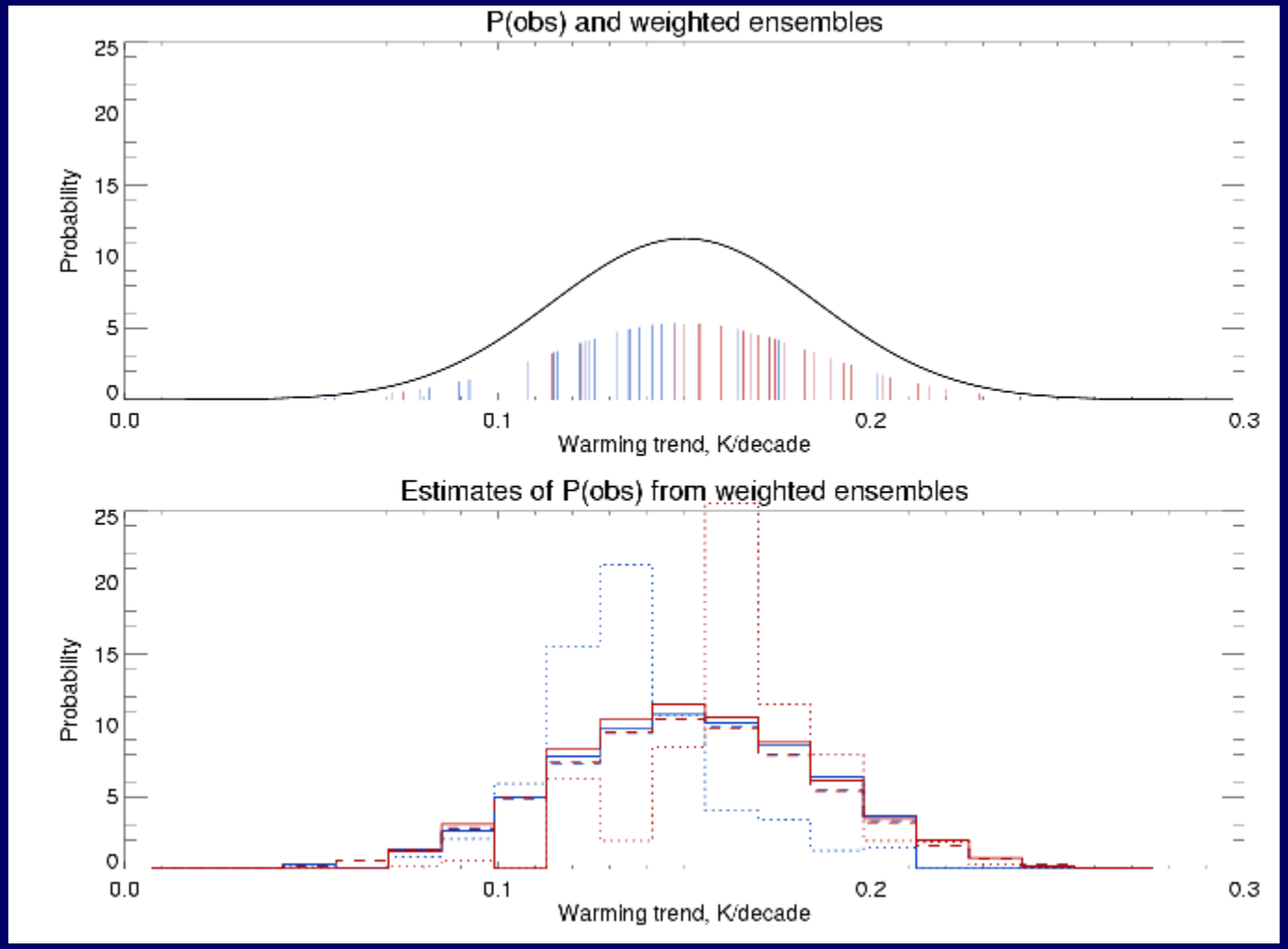
- Climate is predictable, but not directly observable. Weather is observable, but unpredictable.
- Any attribution statement about climate change is inherently probabilistic.
- We cannot verify a probabilistic statement about a single event...
- But we can test for convergence.
- The question to ask: are our conclusions STAID -- Stable Inference from Data?

A familiar theorem

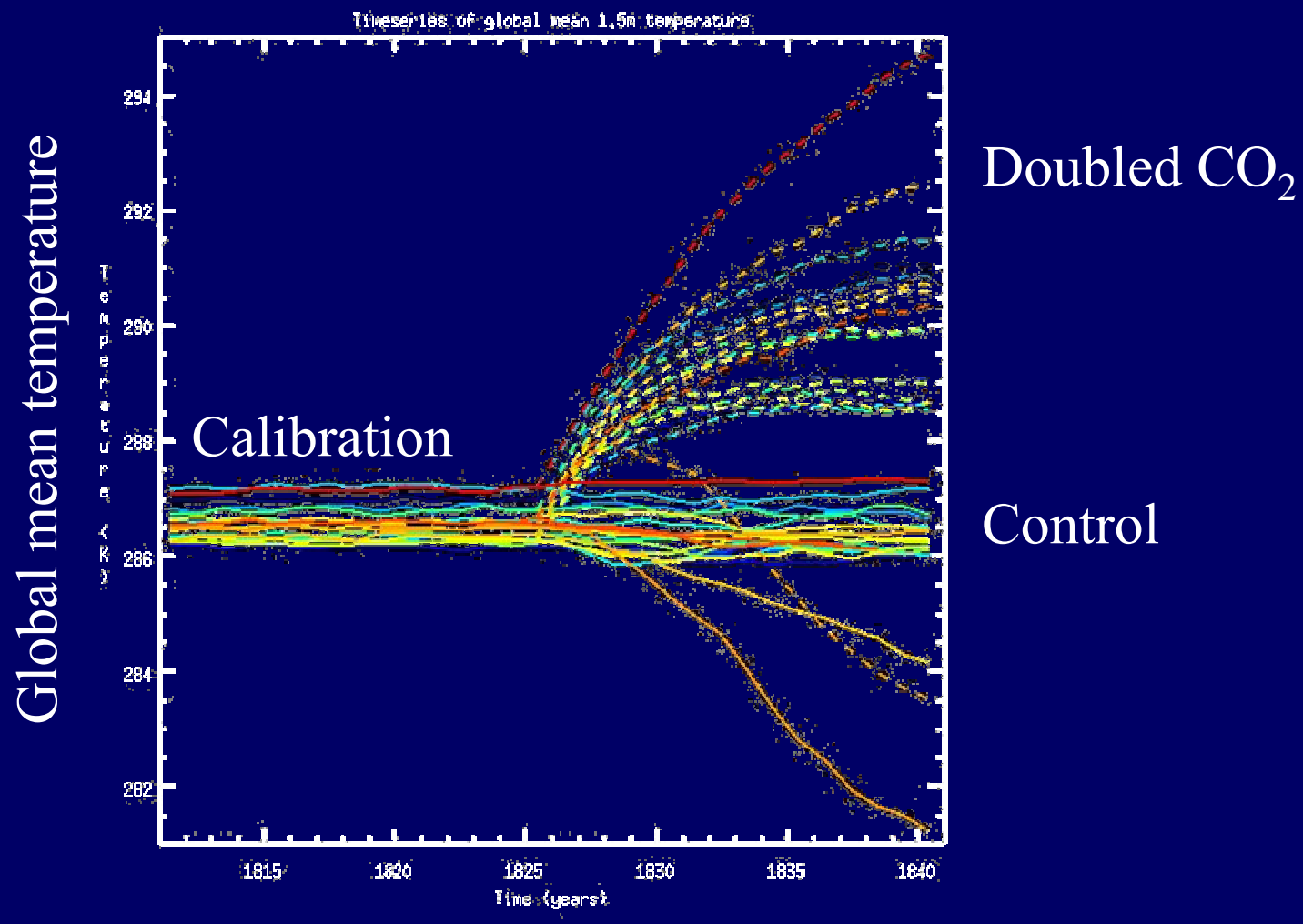
$$P(\mathbf{y}) \approx P(\hat{\mathbf{y}}) = \frac{P(\hat{\mathbf{y}} \mid \mathbf{x})P(\mathbf{x})}{P(\mathbf{x} \mid \hat{\mathbf{y}})}$$

- P(y)=Distribution of possible climates
- P(ŷ)=Distribution of observable variables
- P(x)=Distribution of models in an ensemble
- P(ŷ|x)=Likelihood of observables given model x
- P(x|ŷ)=Density of ensemble in space of observables
- Problem 1: P(x) is arbitrary, since the space of "all physically possible models" is undefined
- Solution: histogram renormalisation by P(x|ŷ)
- Problem 2: defining P(x|ŷ) requires large ensembles

Generating STAID ensembles: the importance of down-weighting the prior distribution



Towards a million-member ensemble: first results from climate*prediction*.net



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Why it matters

- Courts already accept "counterfactual definiteness" in tort actions
- The minimum attributable increase in risk required to assign liability is around a factor of two (Grossman, 2003)
- The contribution of past CO_2 emissions to some current climate risks may already exceed this threshold
- You can help pin down these probabilities: www.climate*prediction*.net/betatry