Attribution of individual weather events to external drivers of climate change

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With material from:

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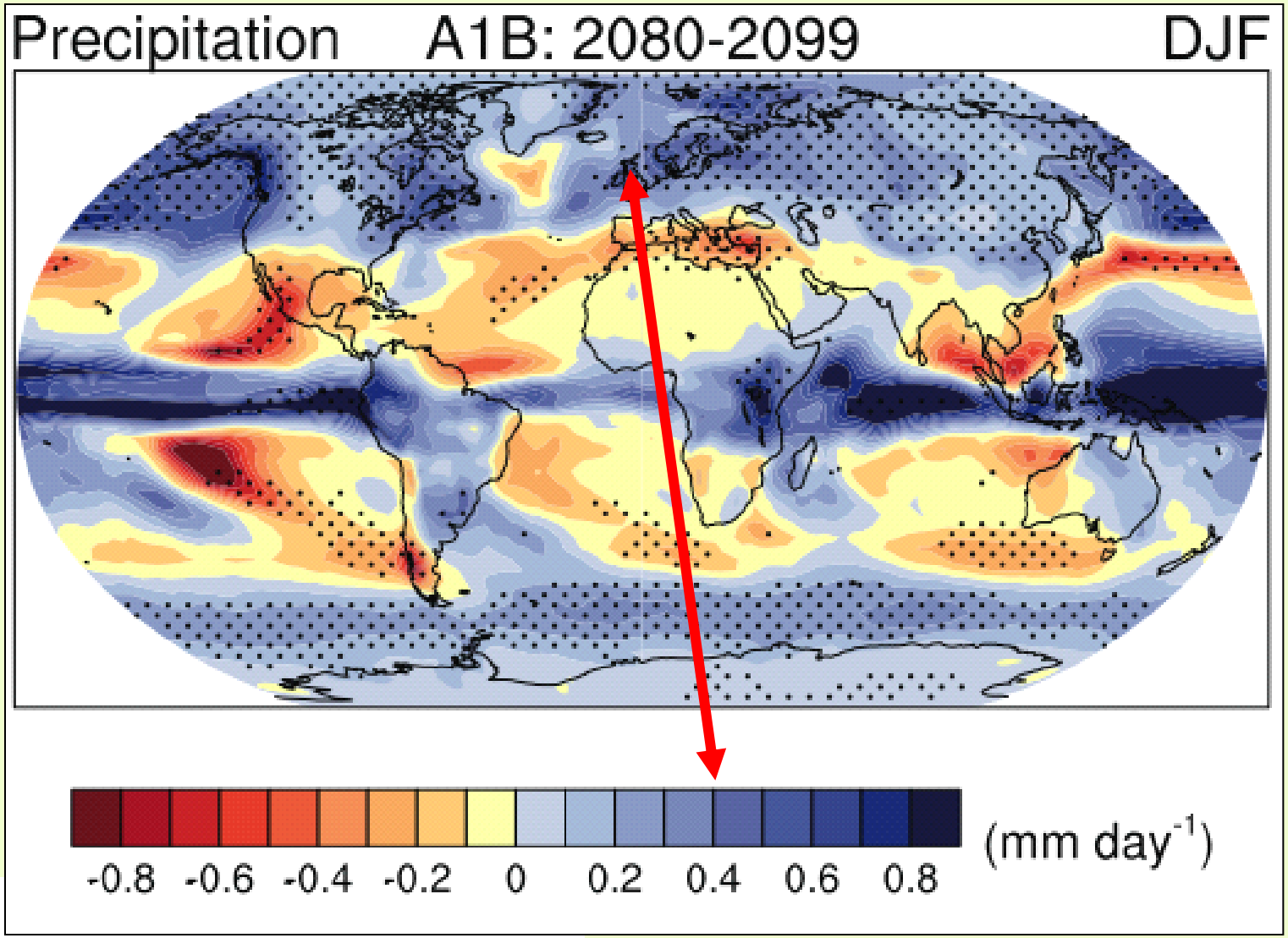
Motivation

Photo: Dave Mitchell

South Oxford on January 5th, 2003

“The kind of event we might expect to become more frequent under climate change.”



IPCC

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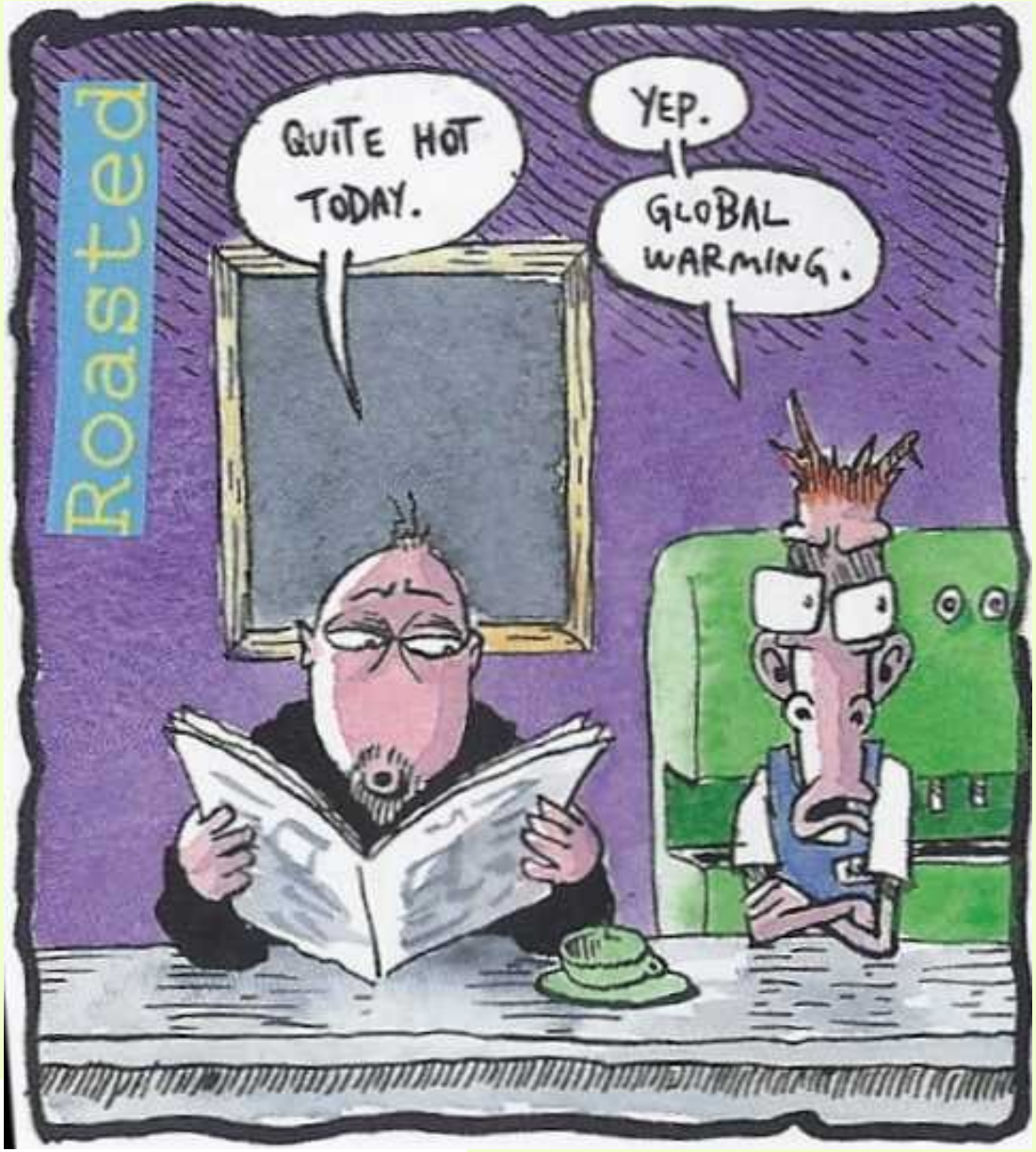
What are we trying to do, and why?

- Specific science question: If an event occurs, how has an external driver like human influence contributed to the risk of that event?
- Public interest: understanding current climate change, the need for adaptation and, potentially, mitigation.
- Legal implications: suits alleging harm from human influence on climate are being filed, with no consistent or systematic science base.
- Adaptation funding: distinguishing impacts of climate change from the consequences of bad weather – a UNFCCC “inventory of impacts”.

The attribution challenge



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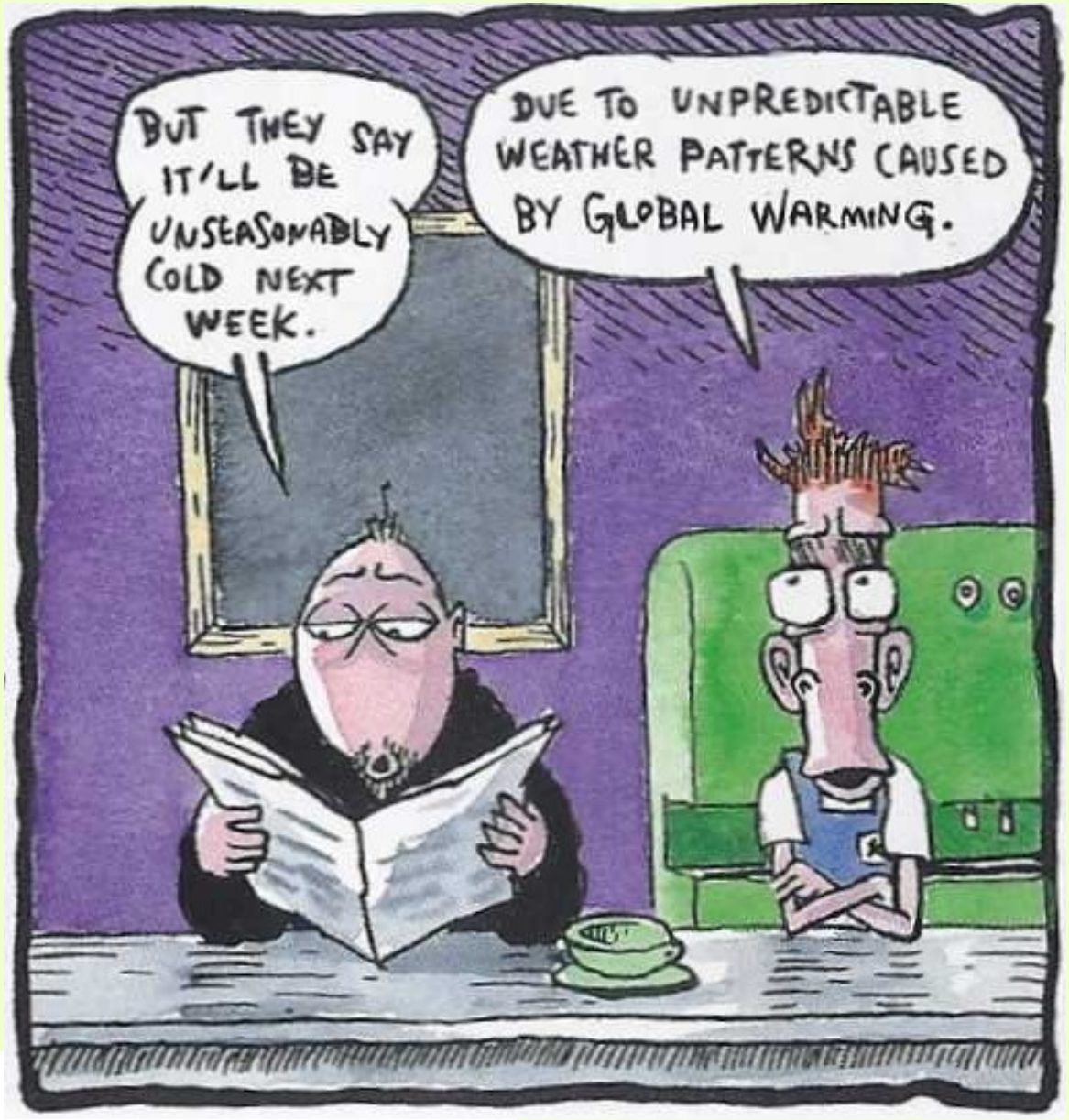
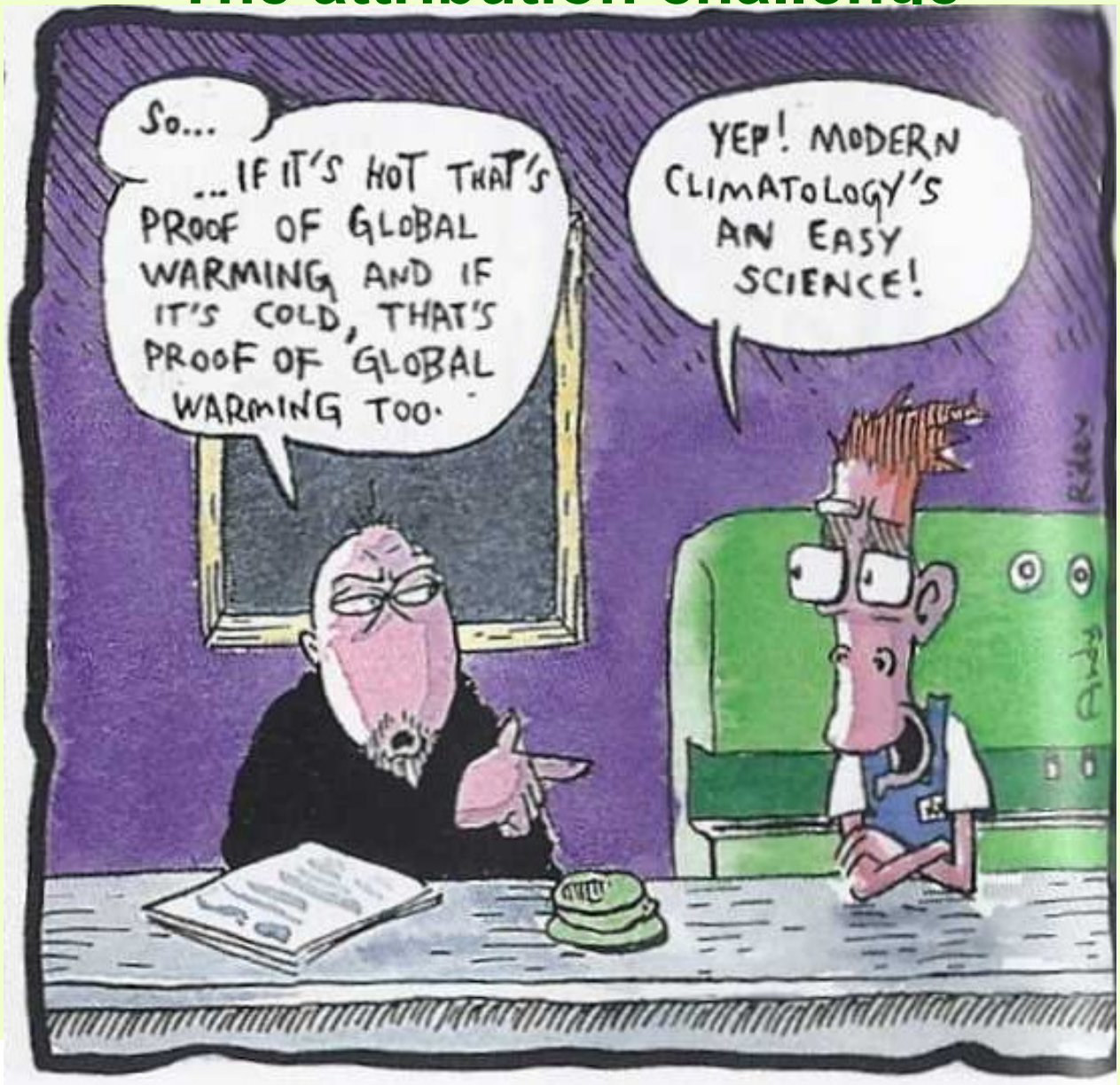
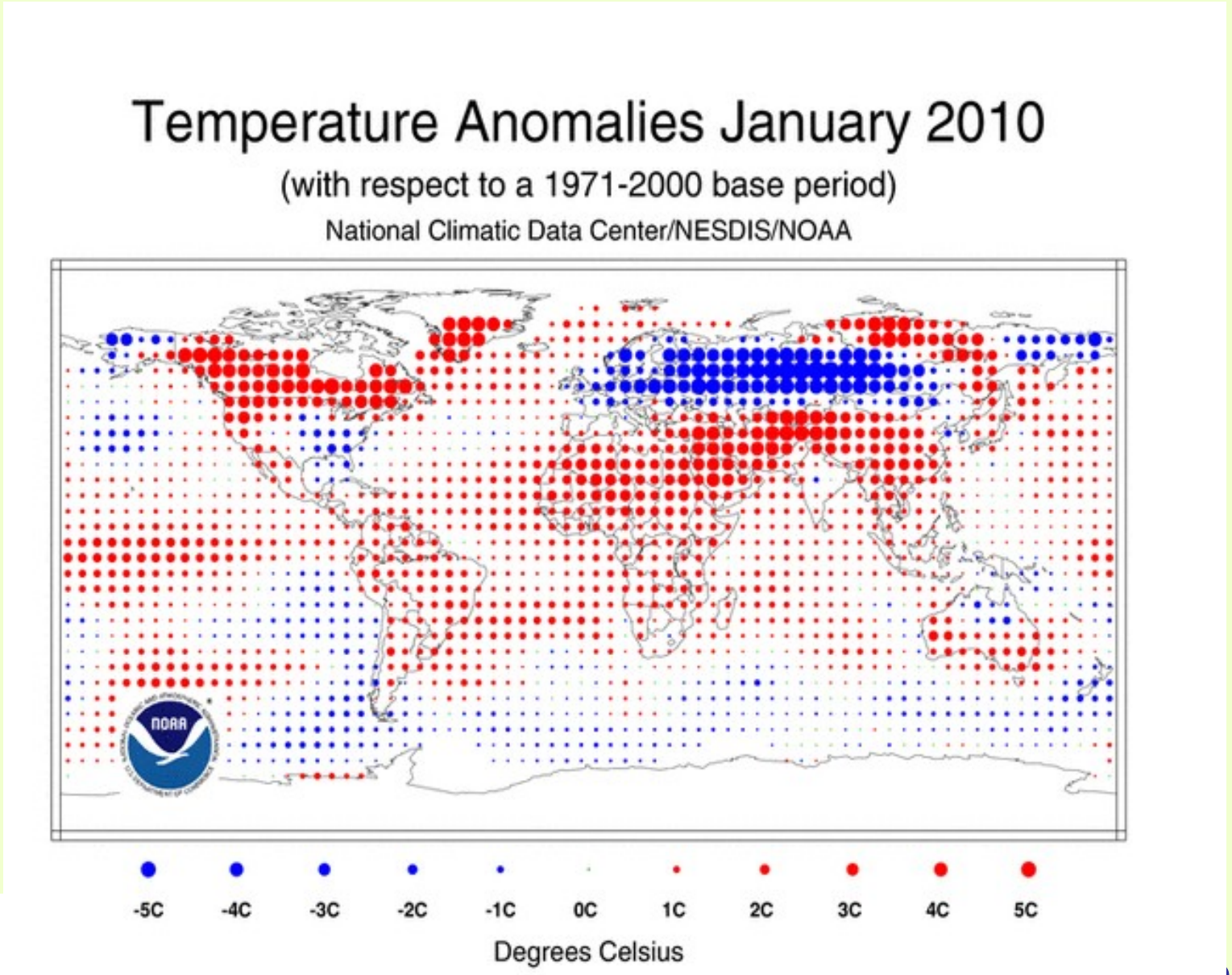


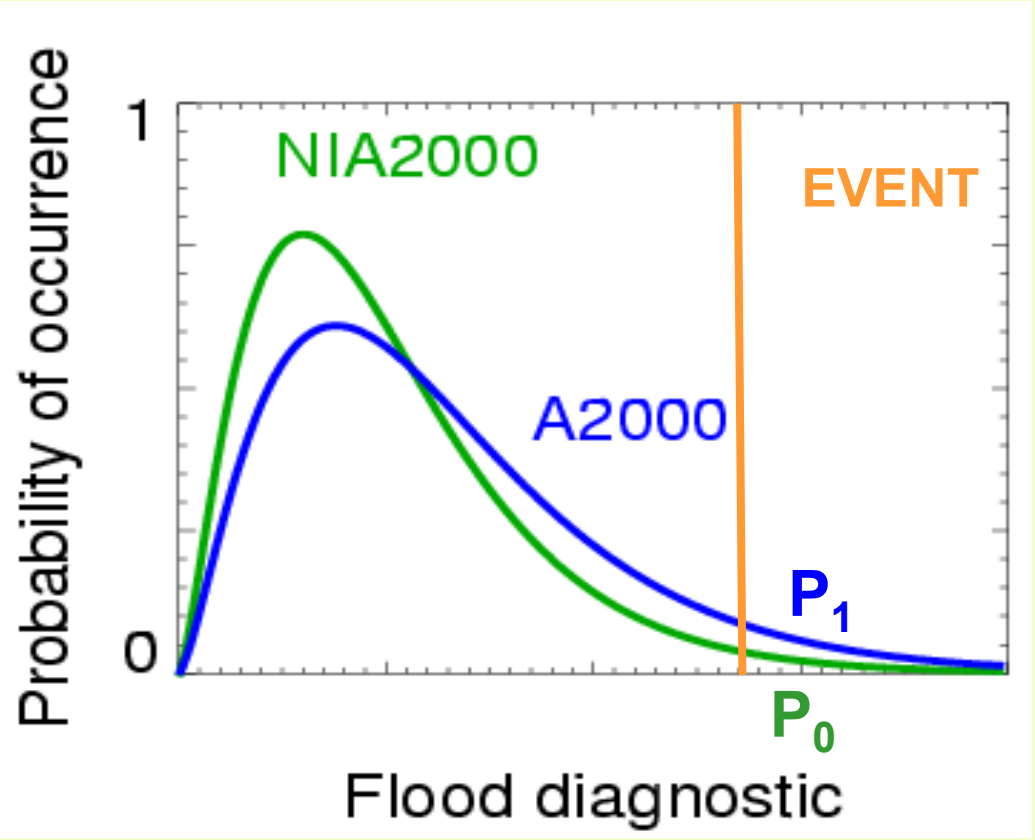
The attribution challenge



All politics is local: Temperatures in one of the warmest Januaries on record.



Attribution beyond mean climate: Fraction Attributable Risk



If human influence doubles the risk of a flood, and that flood occurs, then human influence is "to blame" for half the risk.

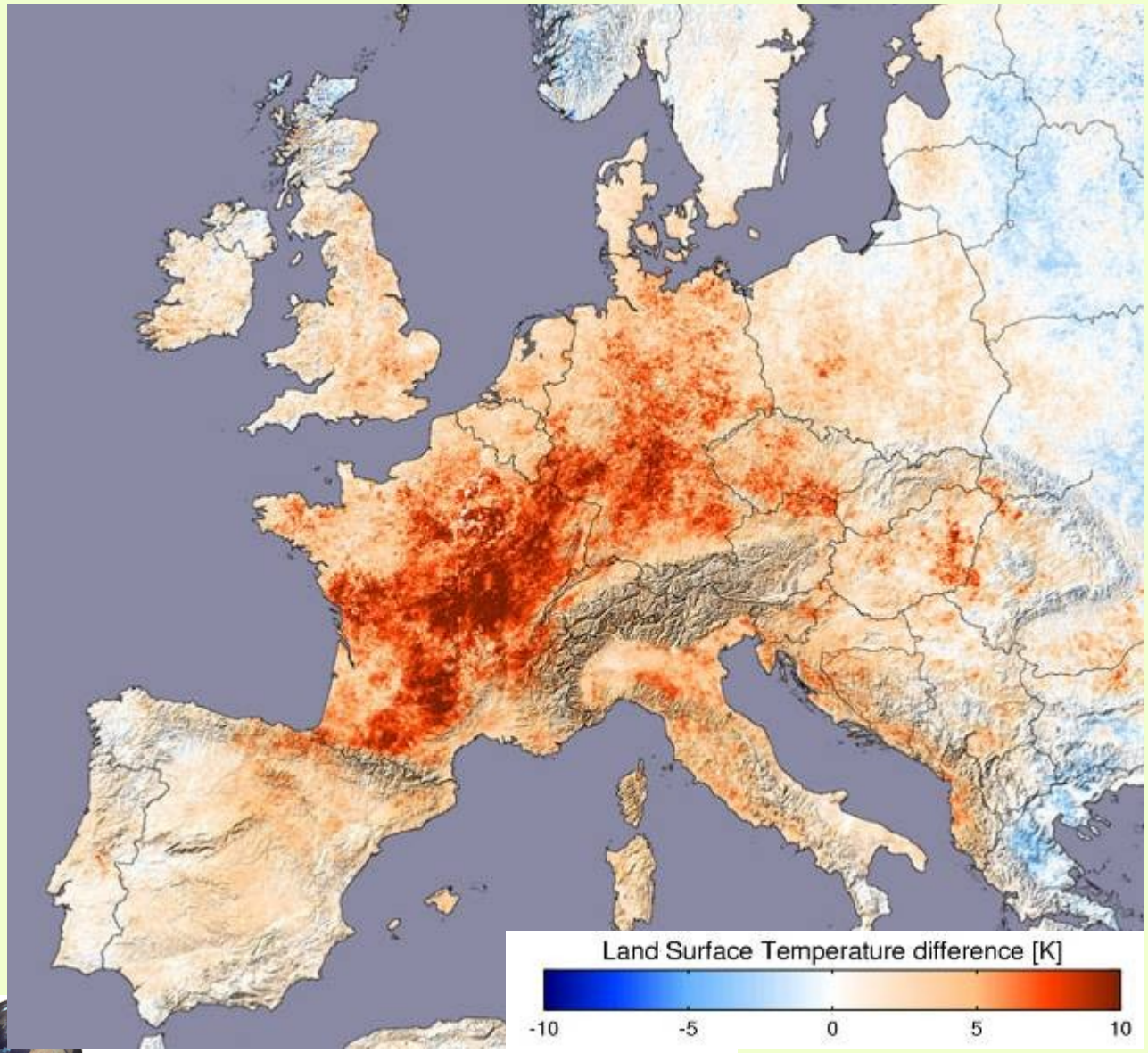
Fraction Attributable Risk:

FAR = 1 – P_0/P_1

P_0 = risk with human influence "removed" (more uncertain)

P_1 = current risk, including human influence (less uncertain)

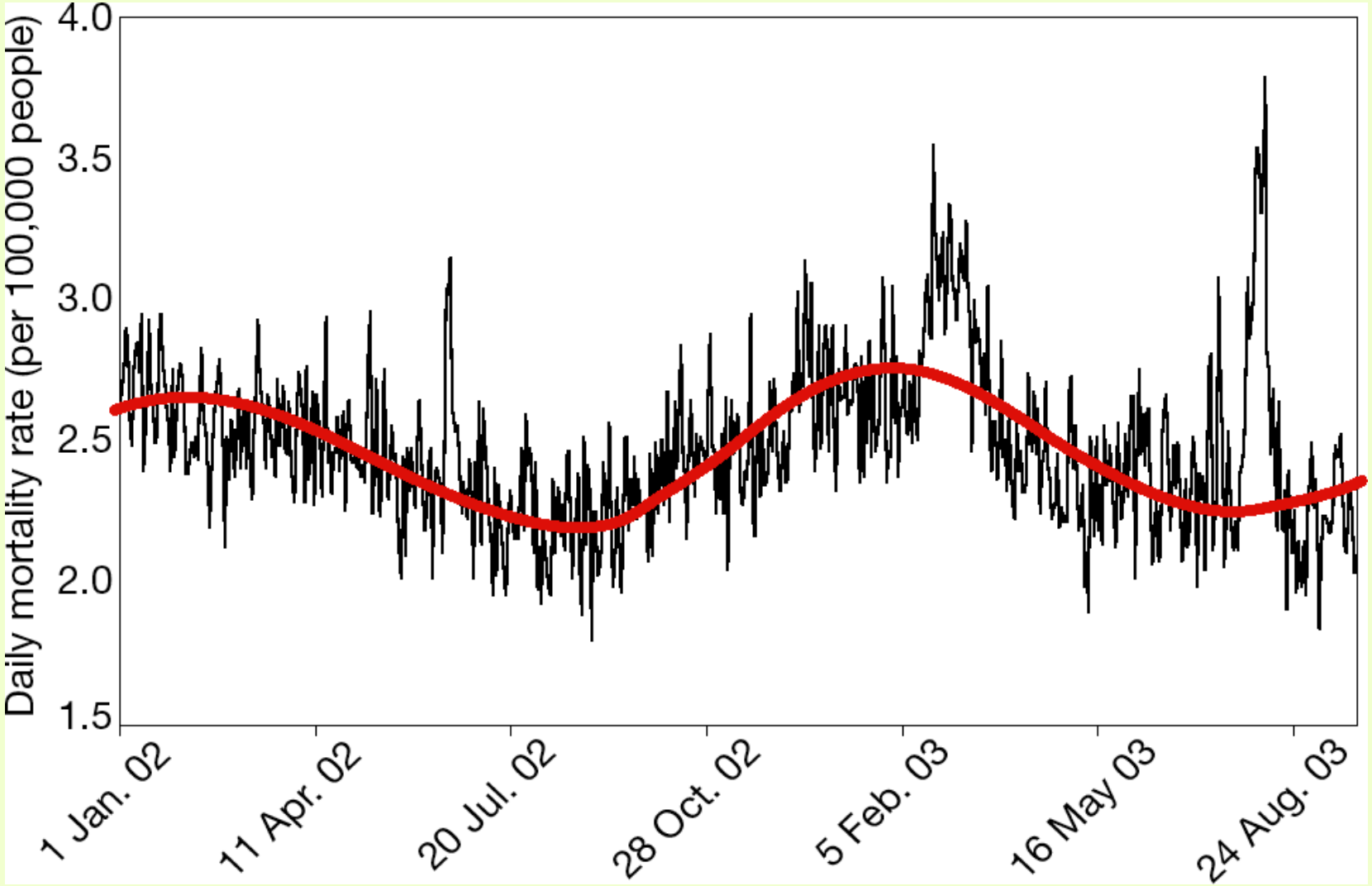
An example of a weather event…



Temperatures in August 2003 relative to normal

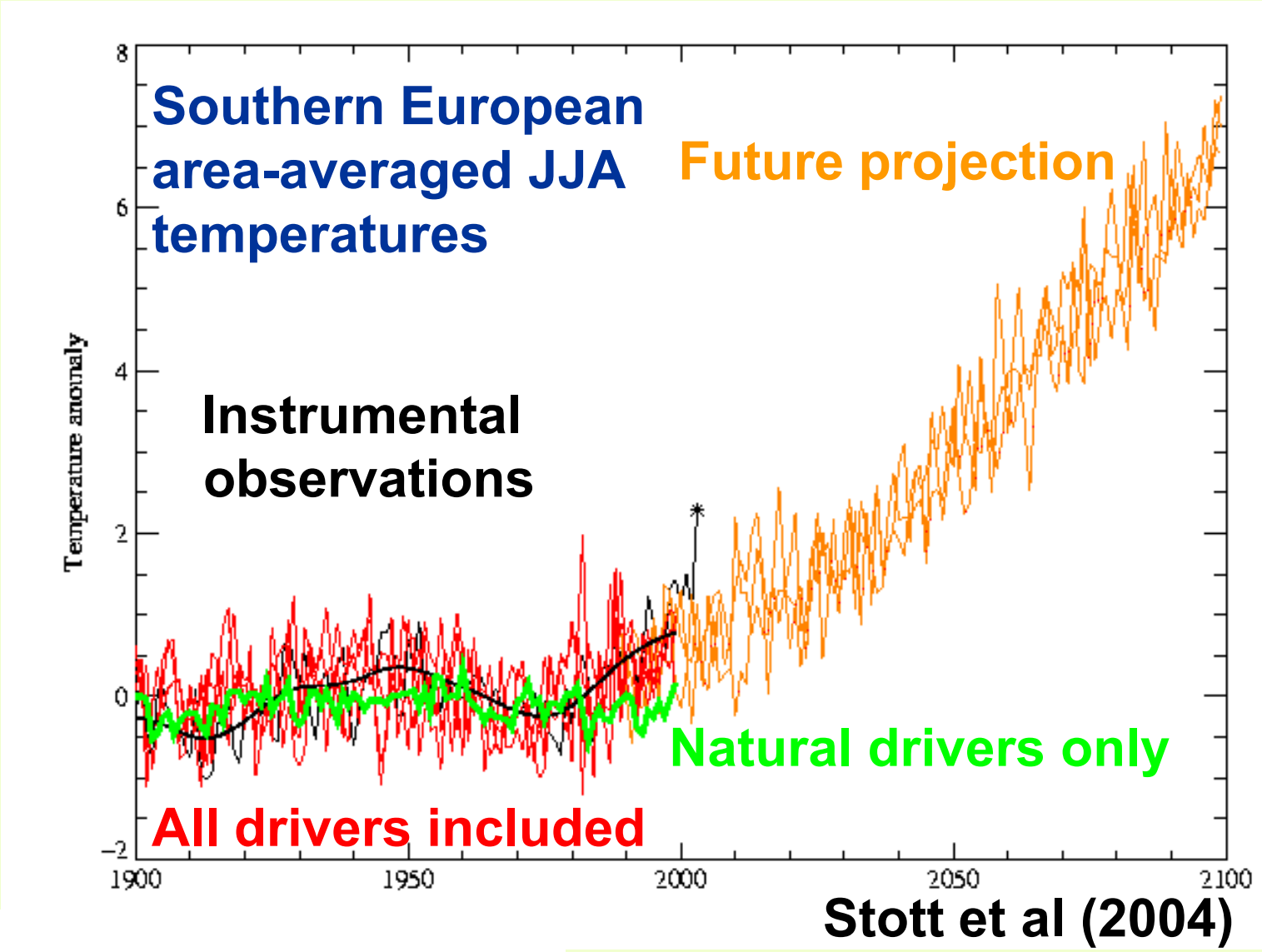
From NASA's Moderate Resolution Imaging Spectrometer, courtesy of Reto Stöckli, ETHZ

…with very substantial impacts



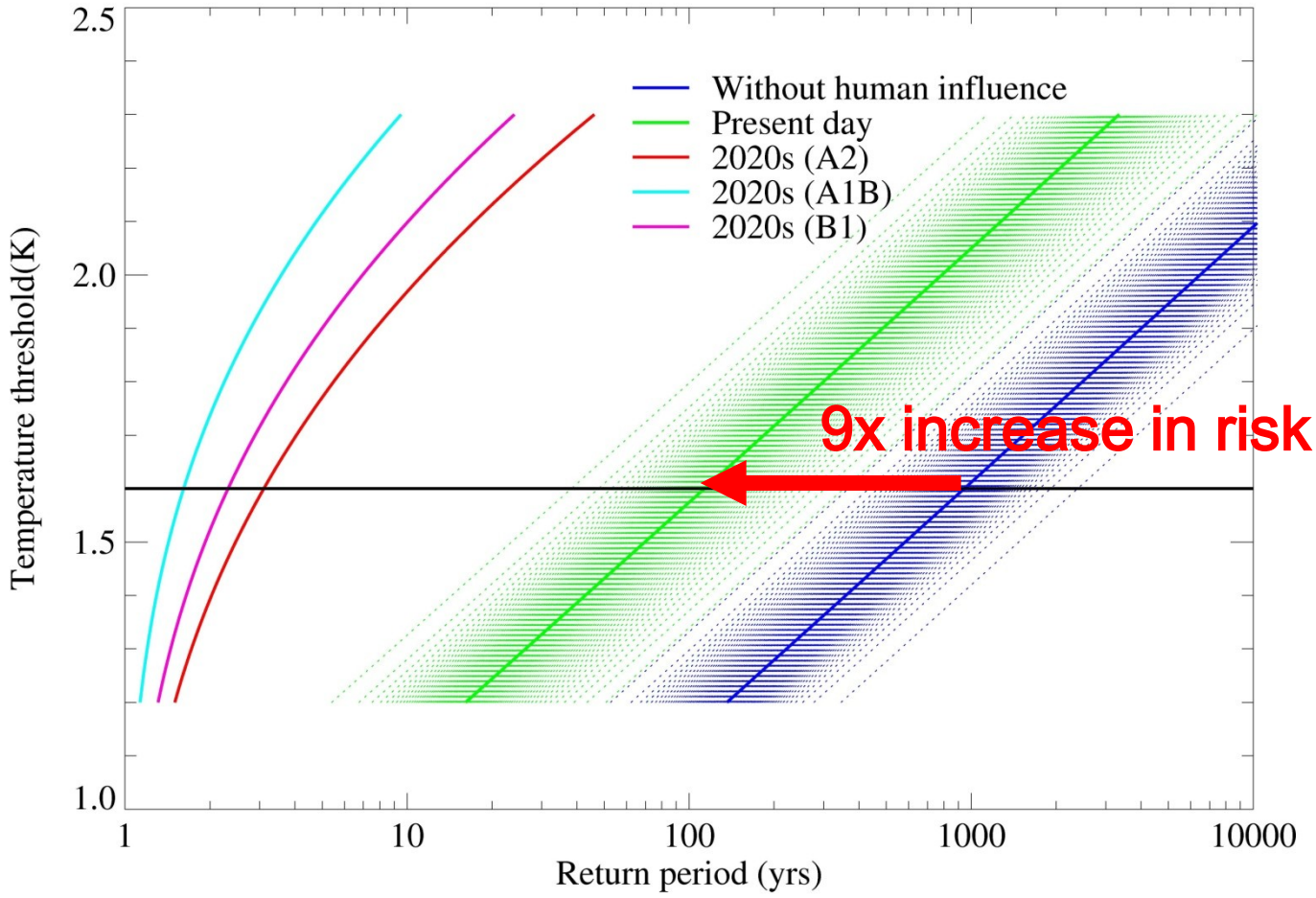
Daily mortality in Baden-Württemberg

Simulating the climate that might have been…



…to estimate the role of human influence in the risk of a Summer-2003-like heatwave

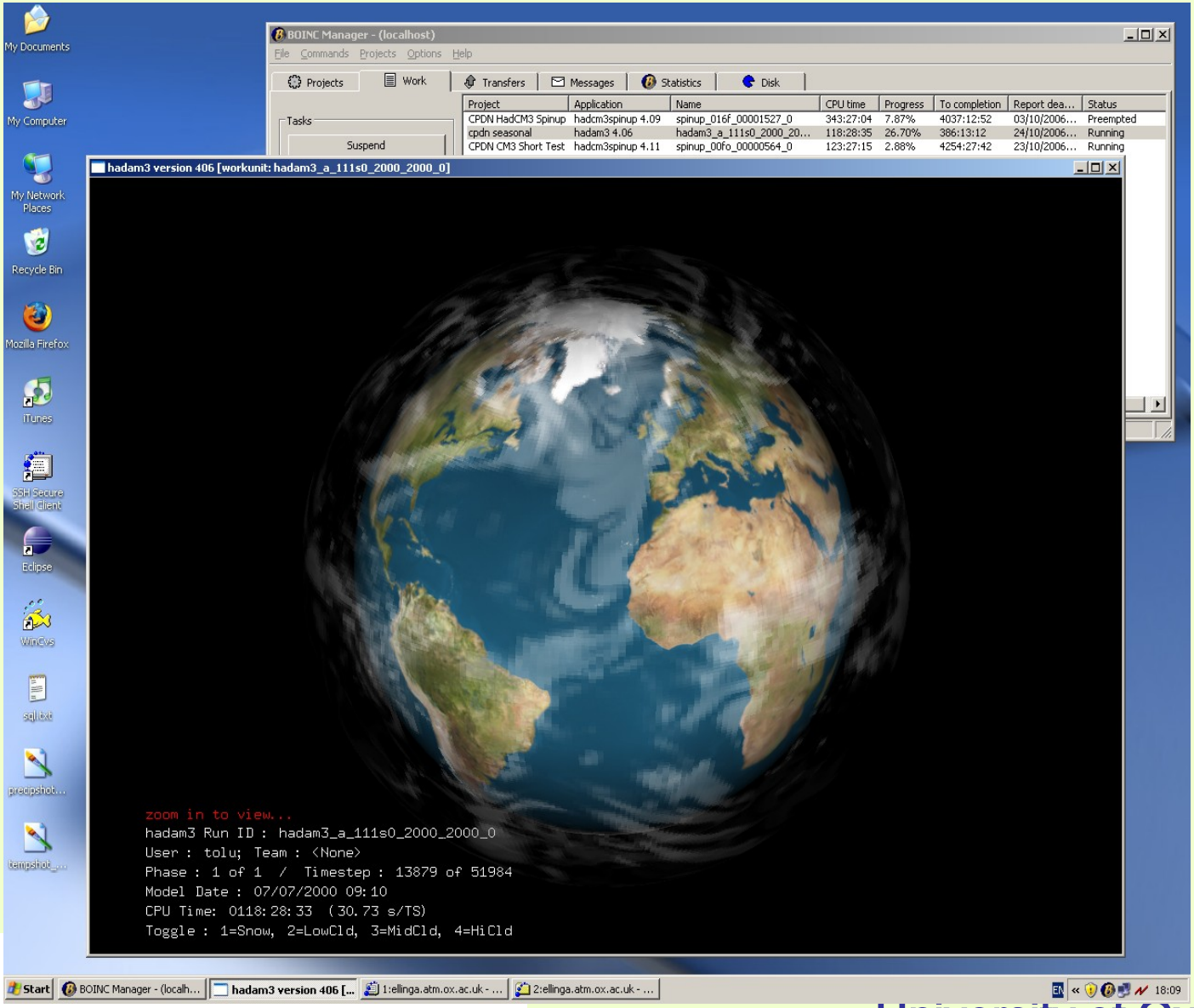
Return periods for European heat-waves



Are recent UK floods affected by climate change? The Pall et al experiment

- Aim: to quantify the role of increased greenhouse gases in precipitation responsible for 2000 floods.
- Challenge: relatively unlikely event even given 2000 climate drivers and sea surface temperatures (SSTs).
- Approach: large (multi-thousand-member) ensemble simulation of April 2000 – March 2001 using 90km resolution global model to resolve weather systems.
- Identical "non-industrial" ensemble removing the influence of increased greenhouse gases, including attributable SST change, allowing for uncertainty.

Performing simulations using distributed computing: http://attribution.cpdn.org



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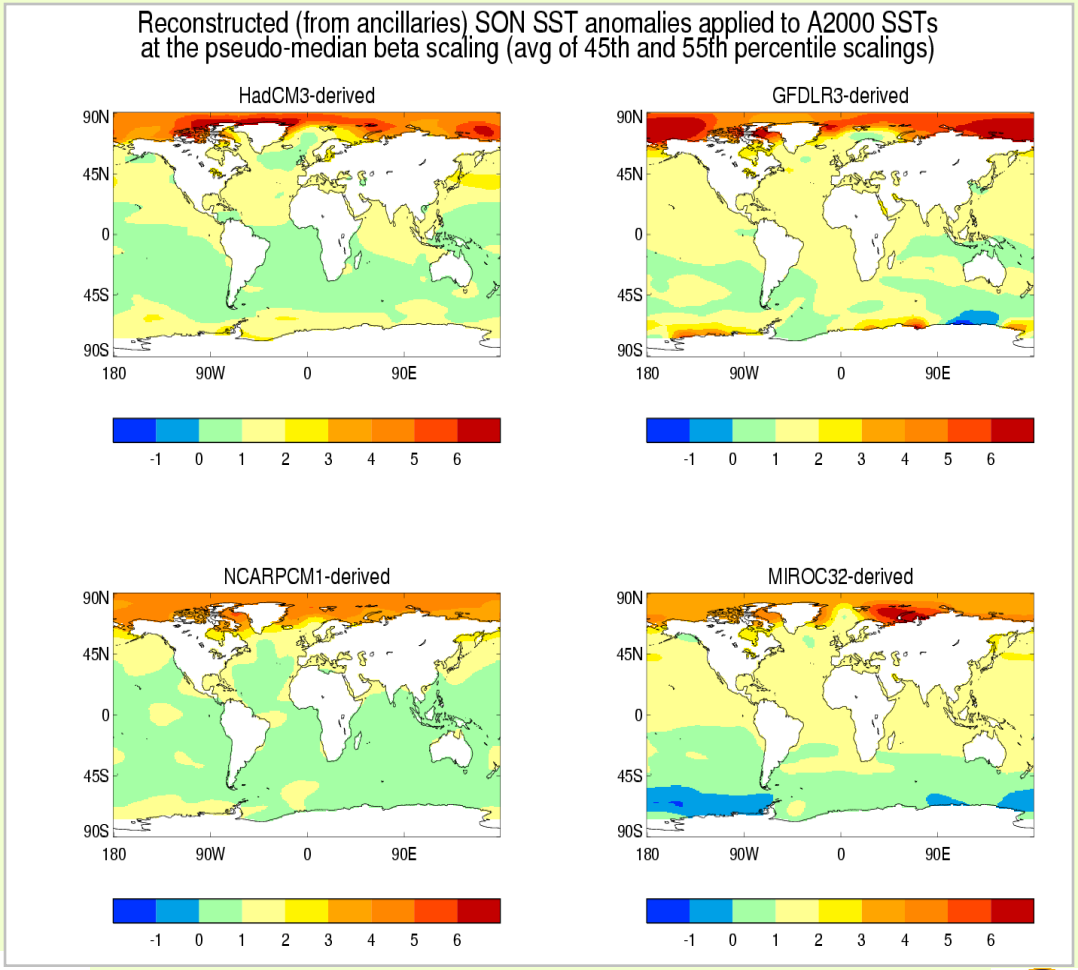
Constructing the “non-industrial climate”

- Reduce GHGs and remove four patterns of GHG-attributable SST warming (HadCM3, GFDLR30, PCM, MIROC3.2).
- Estimate 10 equi-probable pattern amplitudes from a conventional optimal detection study (Stott et al 2006) = 40 possible “alternate climates”.



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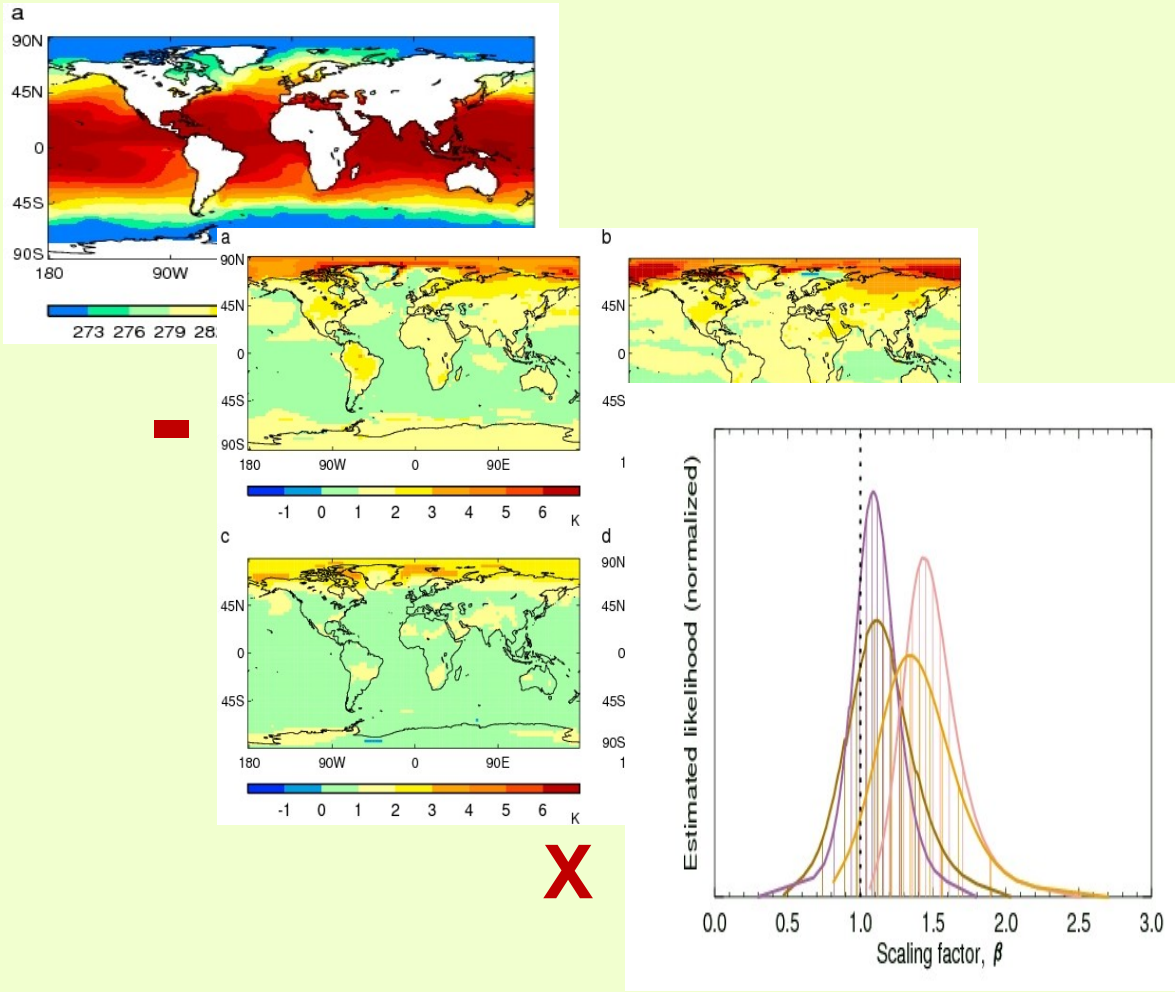
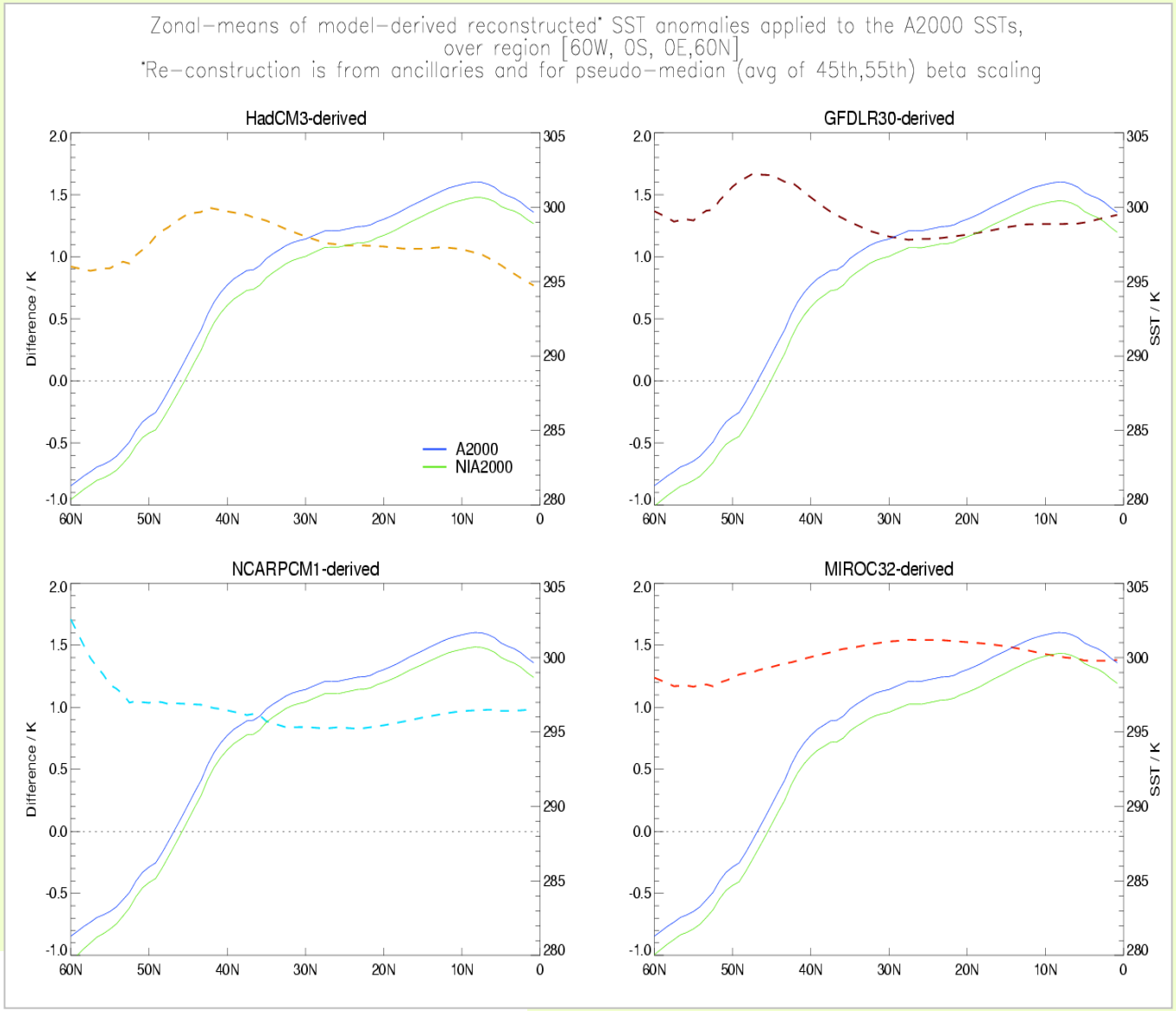


Range of SST gradients in simulated greenhouse warming over North Atlantic



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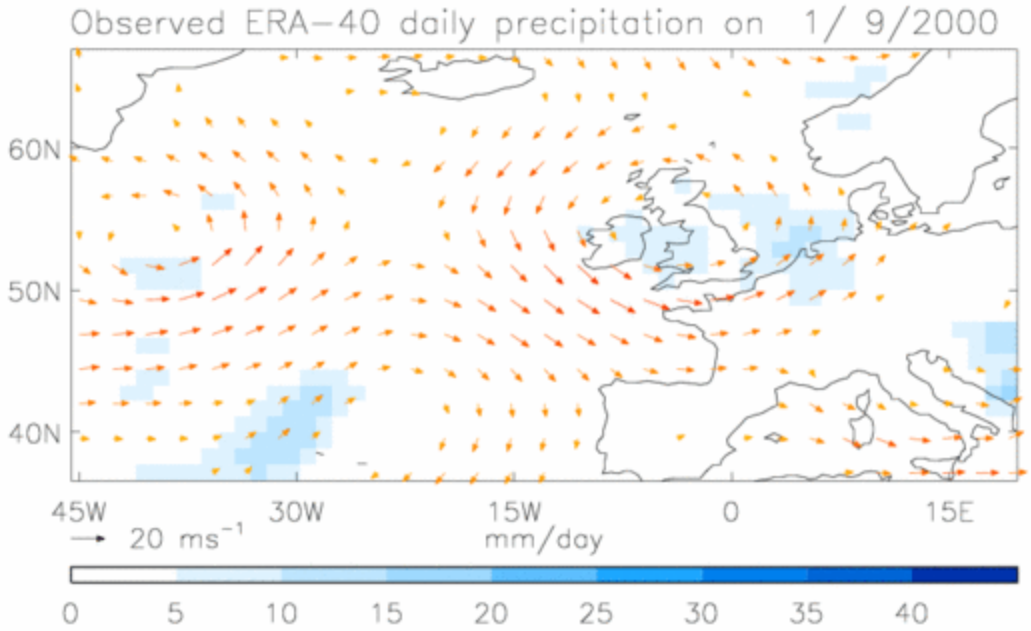
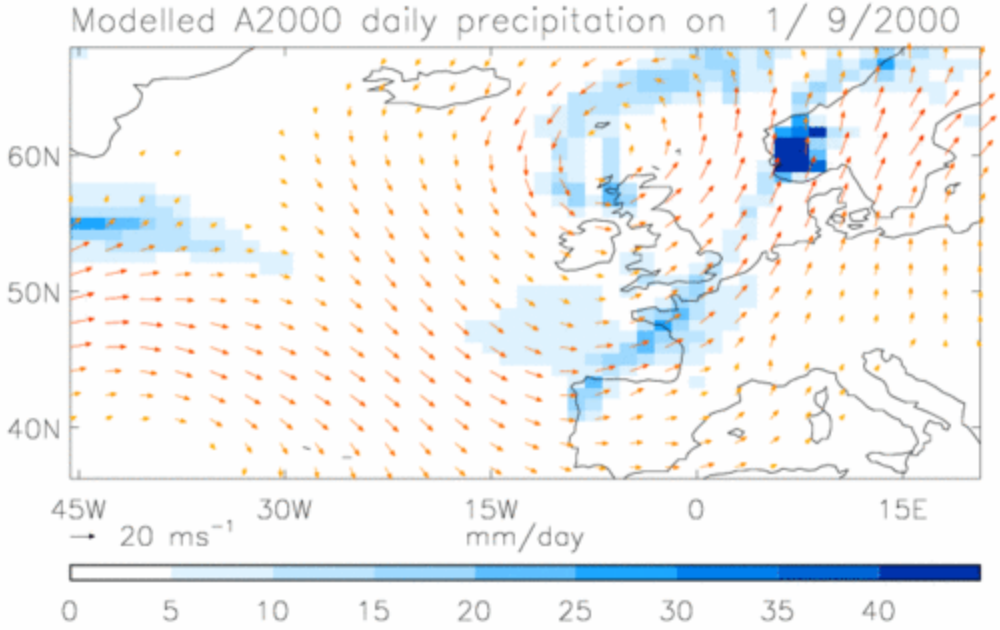




Autumn 2000 in the ERA-40 reanalysis…

…and in one of the wetter members of our ensemble.

Precipitation-runoff model

- **Simple statistical ARIMA-based model (Lohmann et al. 96,98)**
- **Derived from fitting to long runs of a hydrologic-hydraulic scheme calibrated for England & Wales catchments**
- **Accounts for slow and fast runoff to and within a river, and includes longer-memory reservoir storage term.**

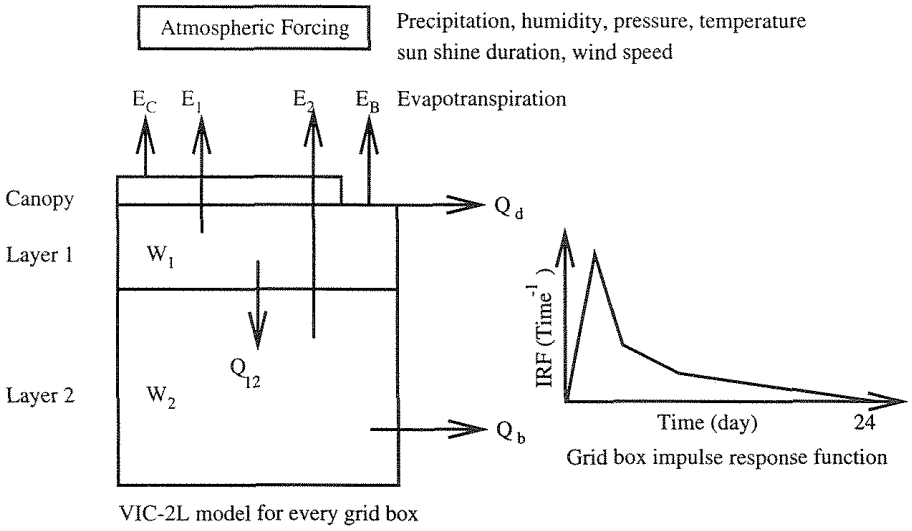
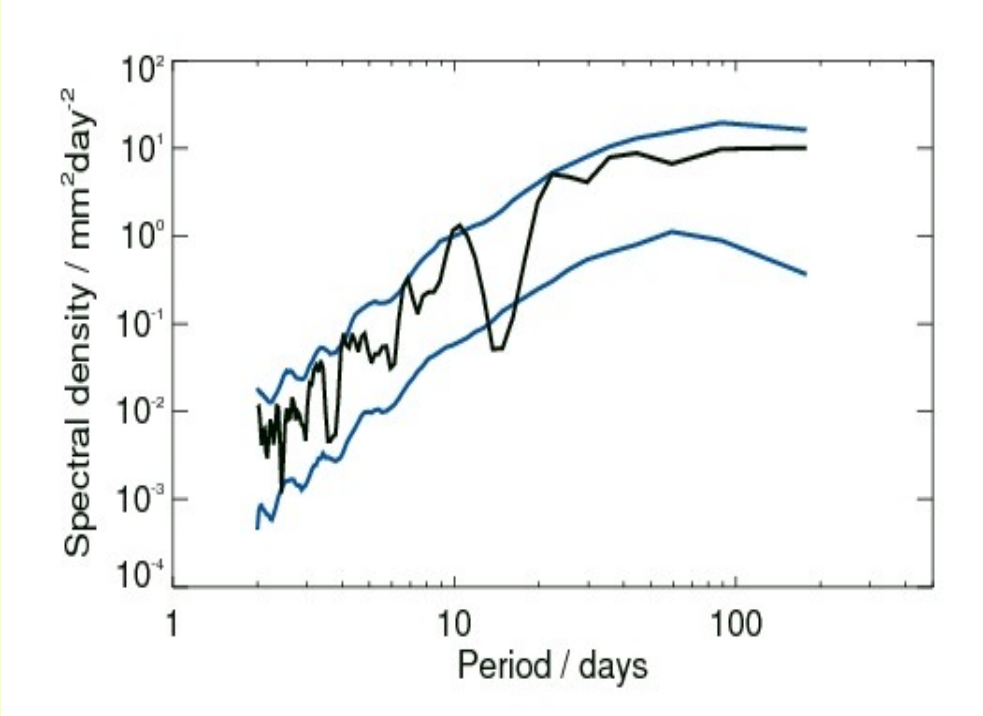


Fig. 2 Coupled VIC-2L model and the routing scheme. (W_1 and W_2 are the upper and lower soil water contents; E_C is the canopy interception evaporation; E_1 and E_2 are the evapotranspiration from the two soil layers; E_B is the evaporation from bare soil; Q_d is the direct surface runoff; and Q_b is the baseflow. On the left are the two impulse response functions (IRF) for the internal gridbox routing and the river routing (see also Lohmann *et al.*, 1996)).

Results: Hydrology

- **Power spectra of synthesized daily river runoff for England & Wales autumns.**
- **Runoff variability adequately represented for a range of timescales**



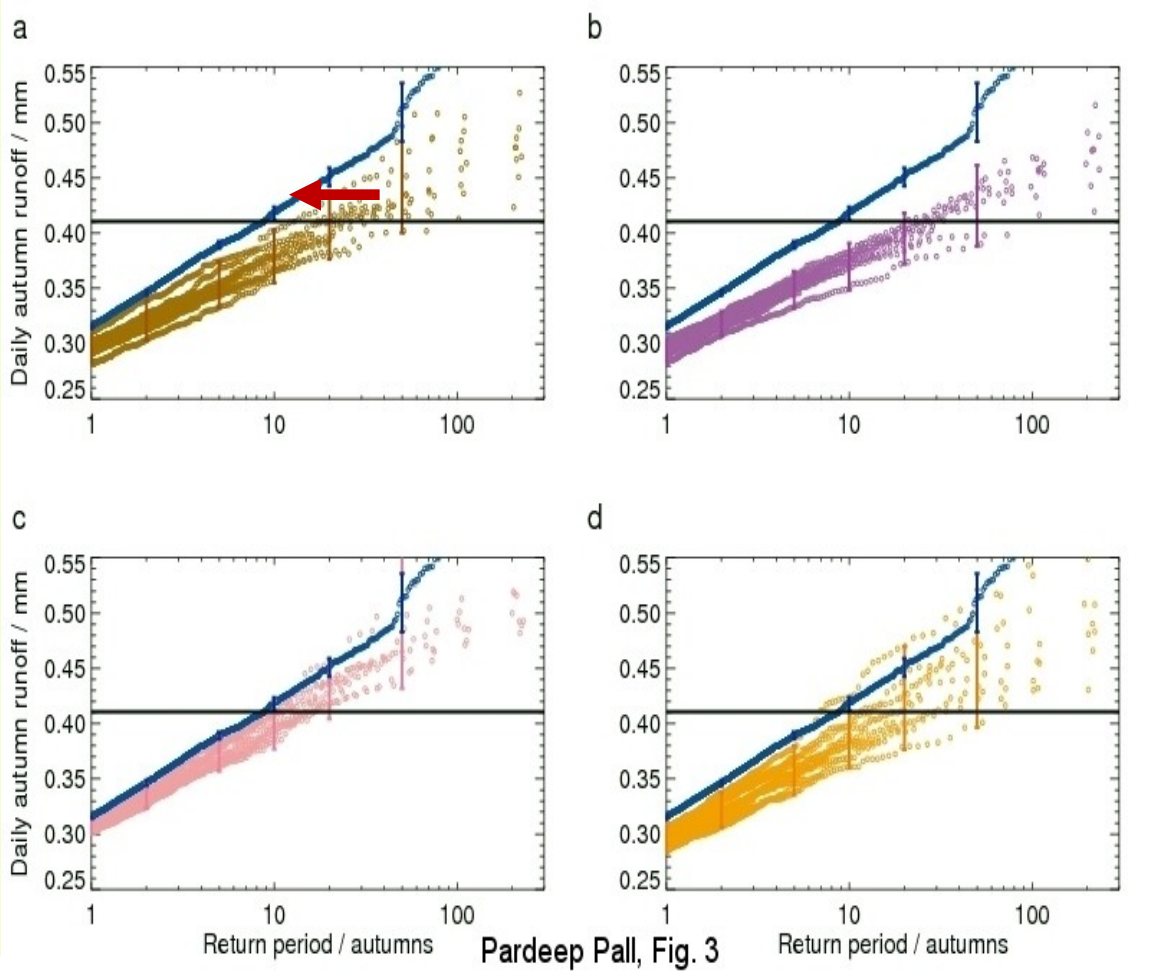
ERA-40 = black line

A2000 climate 5-95% conf. = blue lines

Results:
Change in daily runoff returns

- **Return periods generally decrease in the A2000 climate, relative to 39 out of 40 "non-industrial" climates**

  ⇨ **GHG increase responsible for more frequent heavy runoff events**

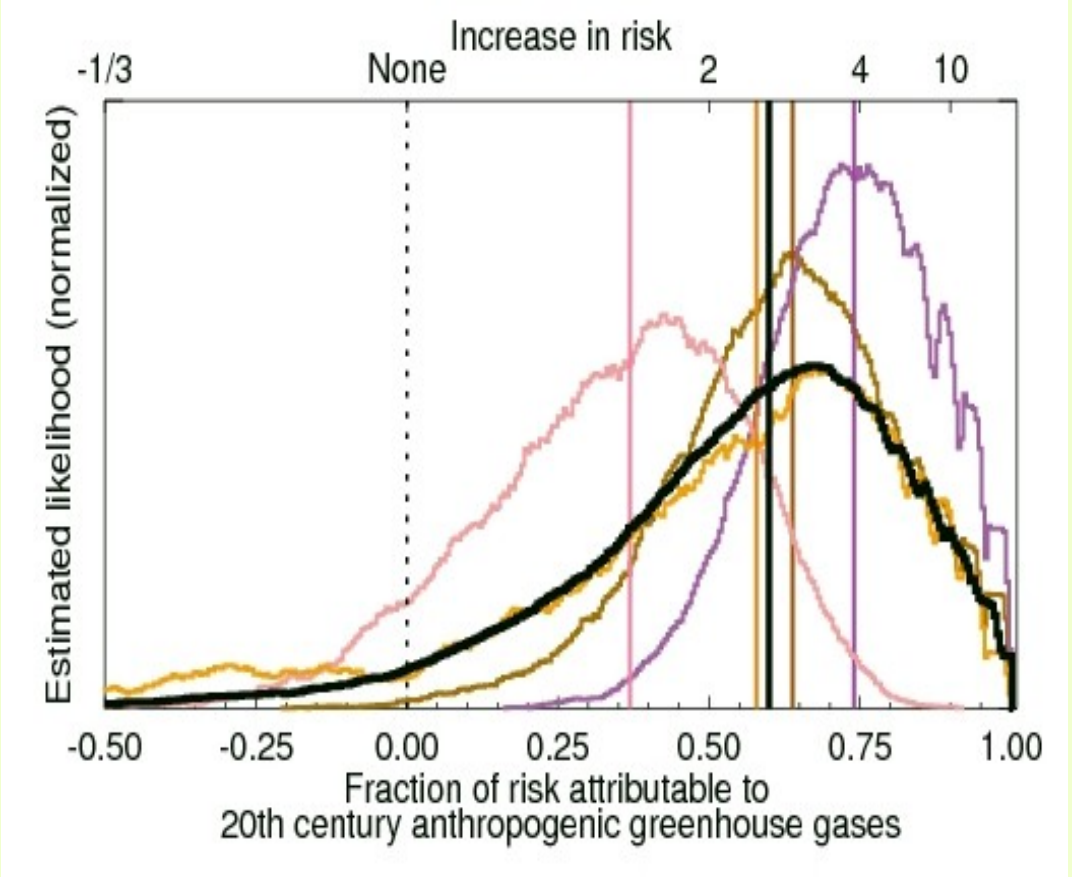


Results:
Attributable risk of Autumn 2000 flooding

- **Significantly increased (10% level) risk of A2000 climate flooding, relative to *all four* GCM-based estimates of non-industrial climates.**

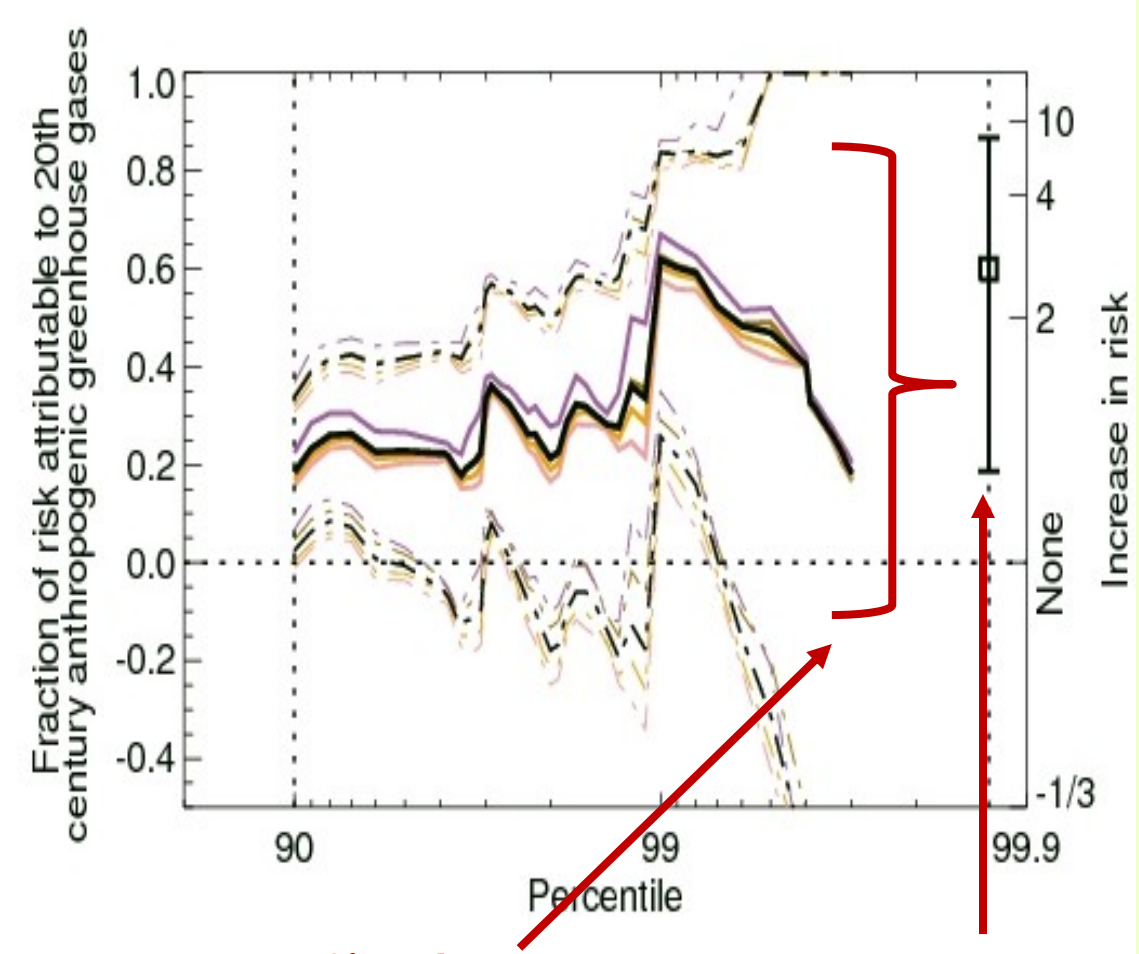
⇨ **Aggregate 'best guess' is a near-trebling of risk**

⇨ **FAR of UK Autumn 2000 flooding = 0.6**

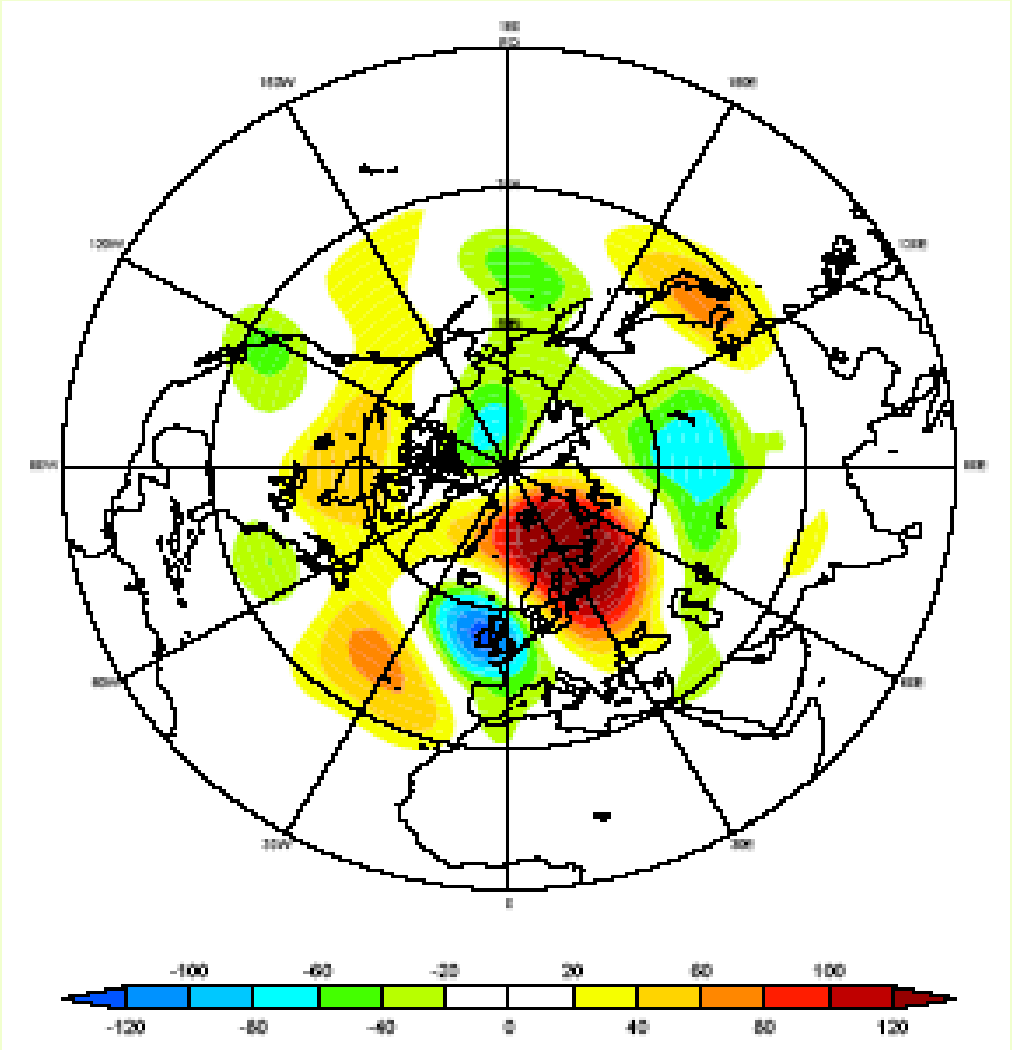


Results:
Robustness to atmospheric model used?

- FAR = combination of thermodynamic and circulation response.
- Similar values predicted by observed rainfall distribution, range of temperature changes and Clausius-Clapeyron.
- Result is not dominated by circulation response: more likely to be robust.

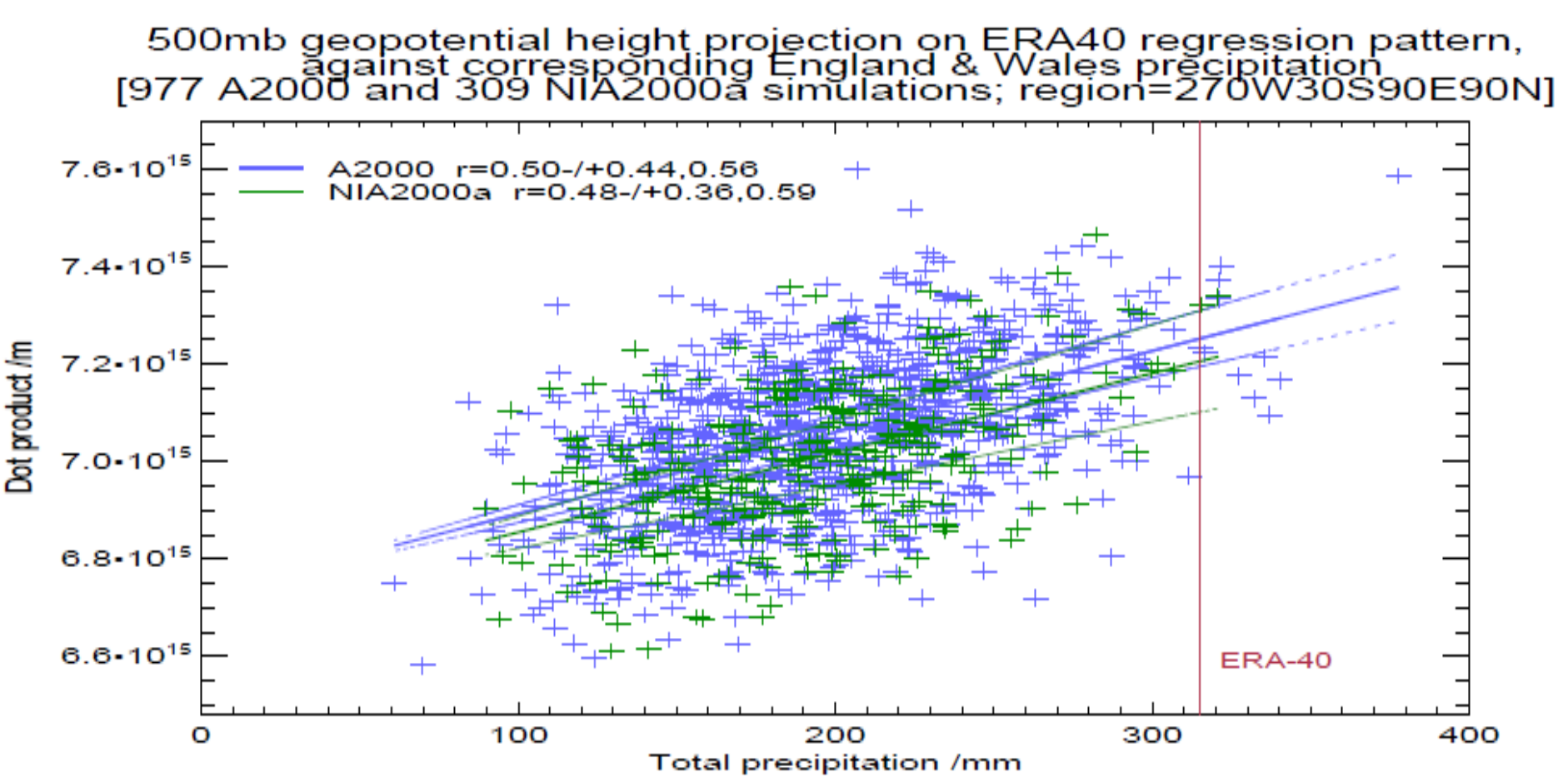


The circulation pattern of interest: Autumn 2000 geopotential height anomaly at 300hPa

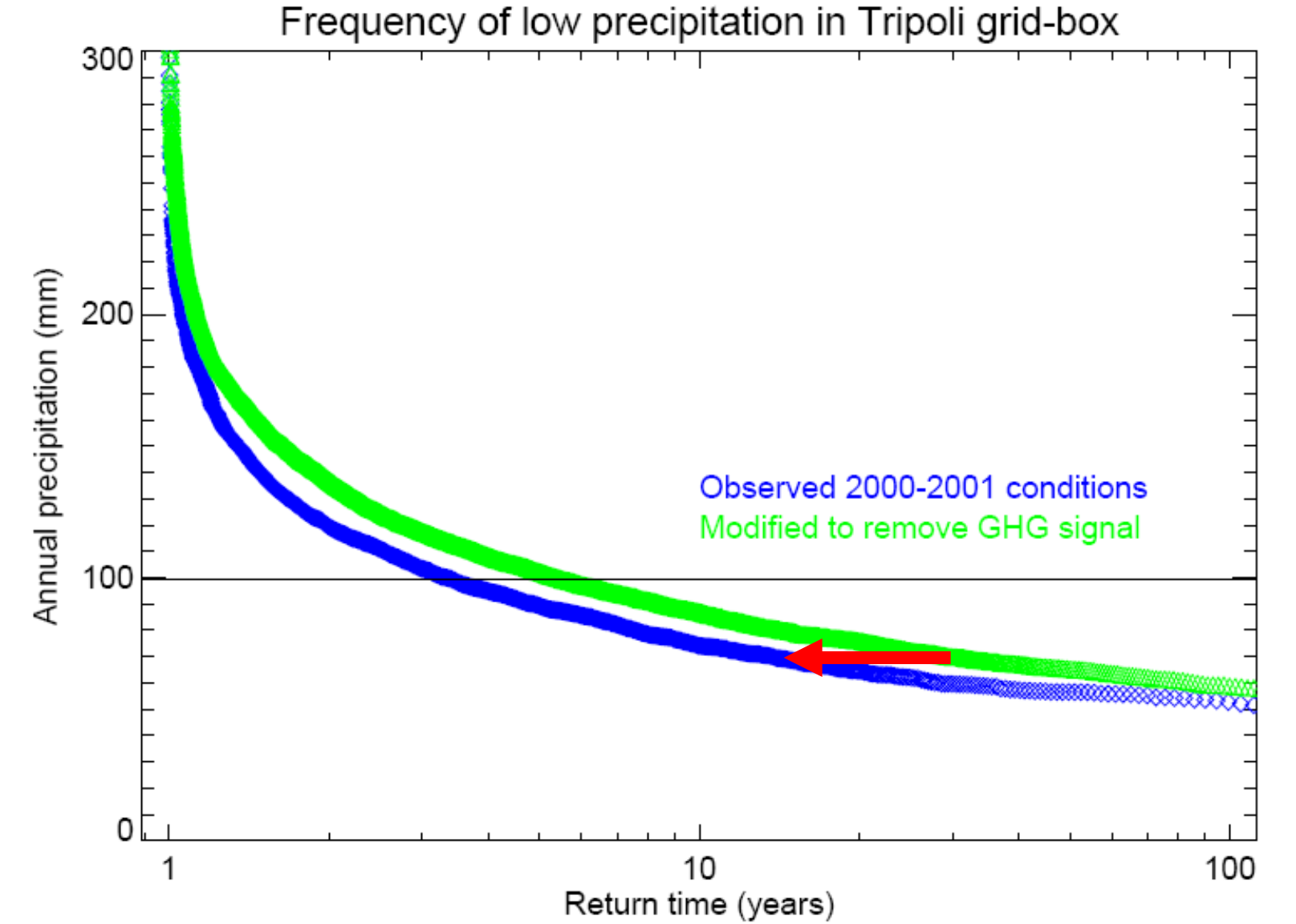


Blackburn & Hoskins (2001)

The role of circulation: which way does the cloud move?



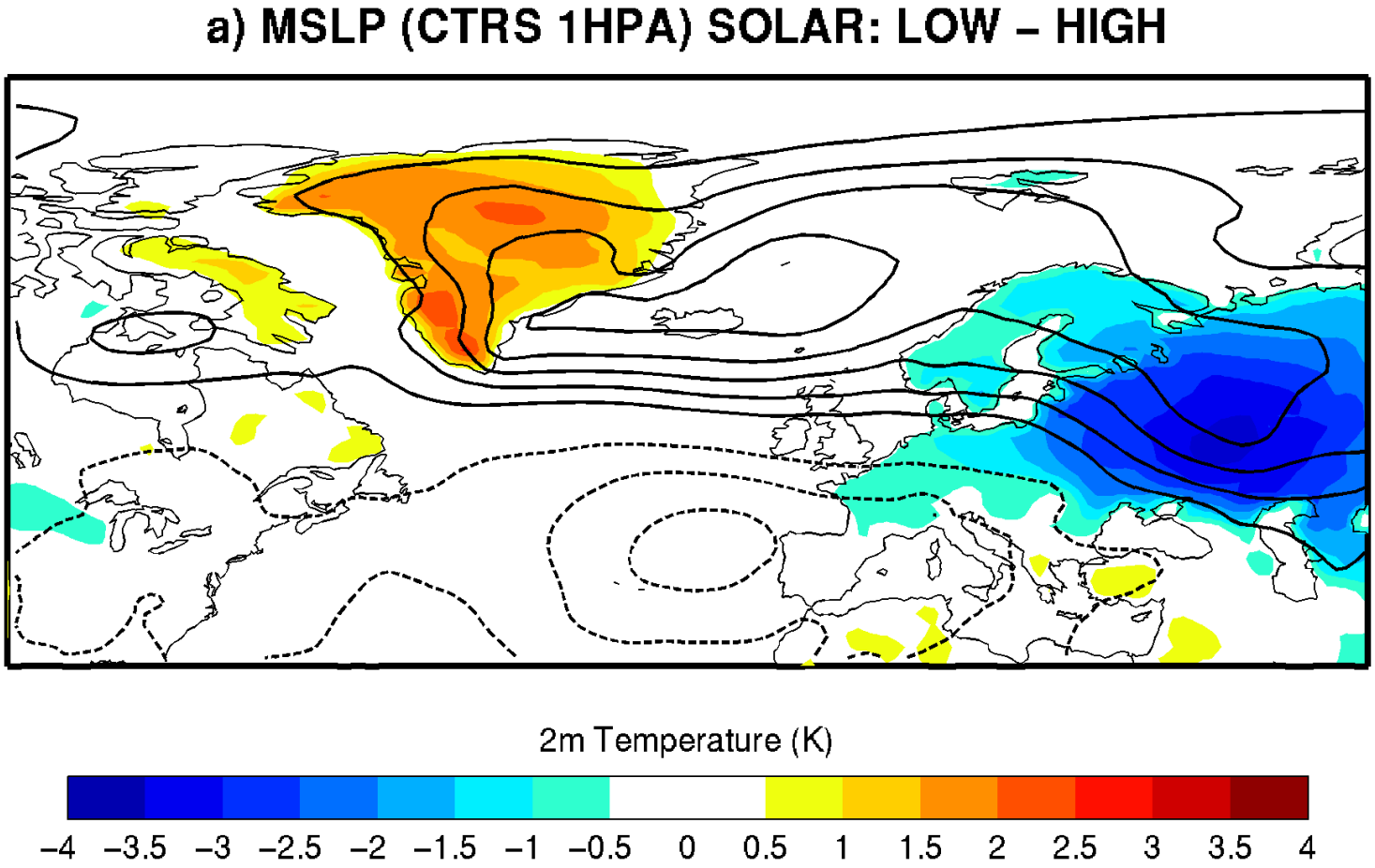
Other variables: Increased drought risk in North Africa due to greenhouse warming to 2000



Methodological issues

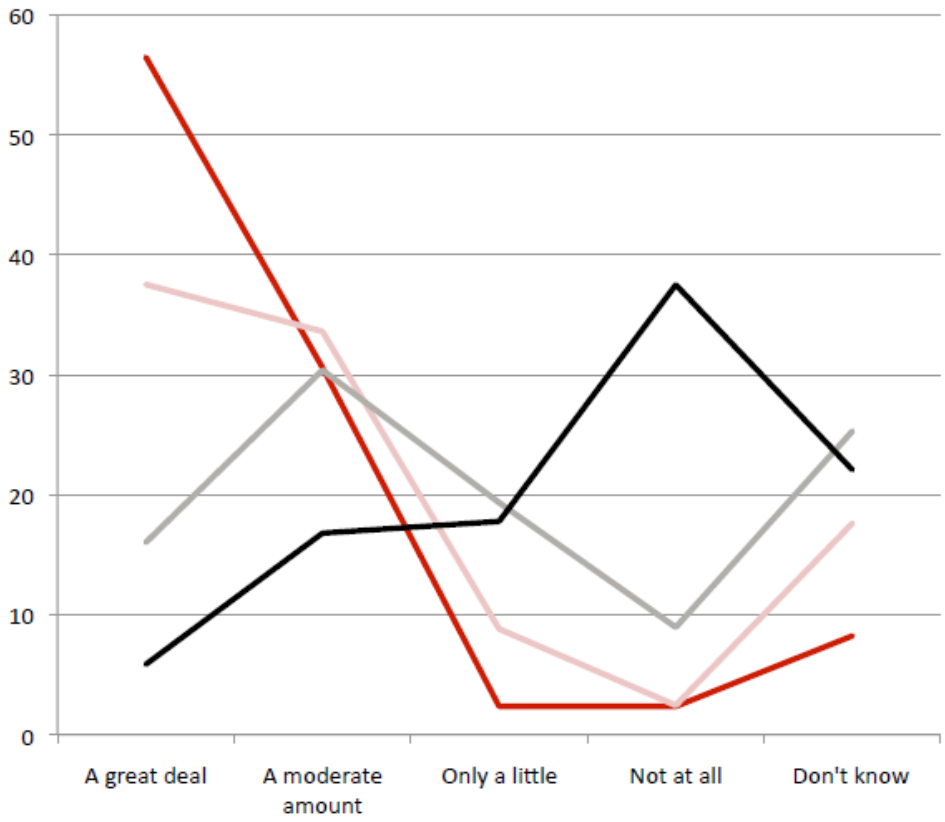
- Experimental design: prescribed SSTs, interactive mixed layer relaxed to observed SSTs, fully coupled?
- Modelling set-up: allowing for uncertainty in atmospheric model through perturbed physics or multi-model ensembles.
- Identical problem to seasonal forecasting, could use identical tools.
- Problem of selection bias: only solved with a regular assessment.

And, of course, human influence is not the only factor to be explored: Woollings et al, 2010, on the role of solar variability in European winters



Who cares? Impact of "personal experience" on public perceptions of global warming

How much do you think global warming will harm ...
people in the United States?



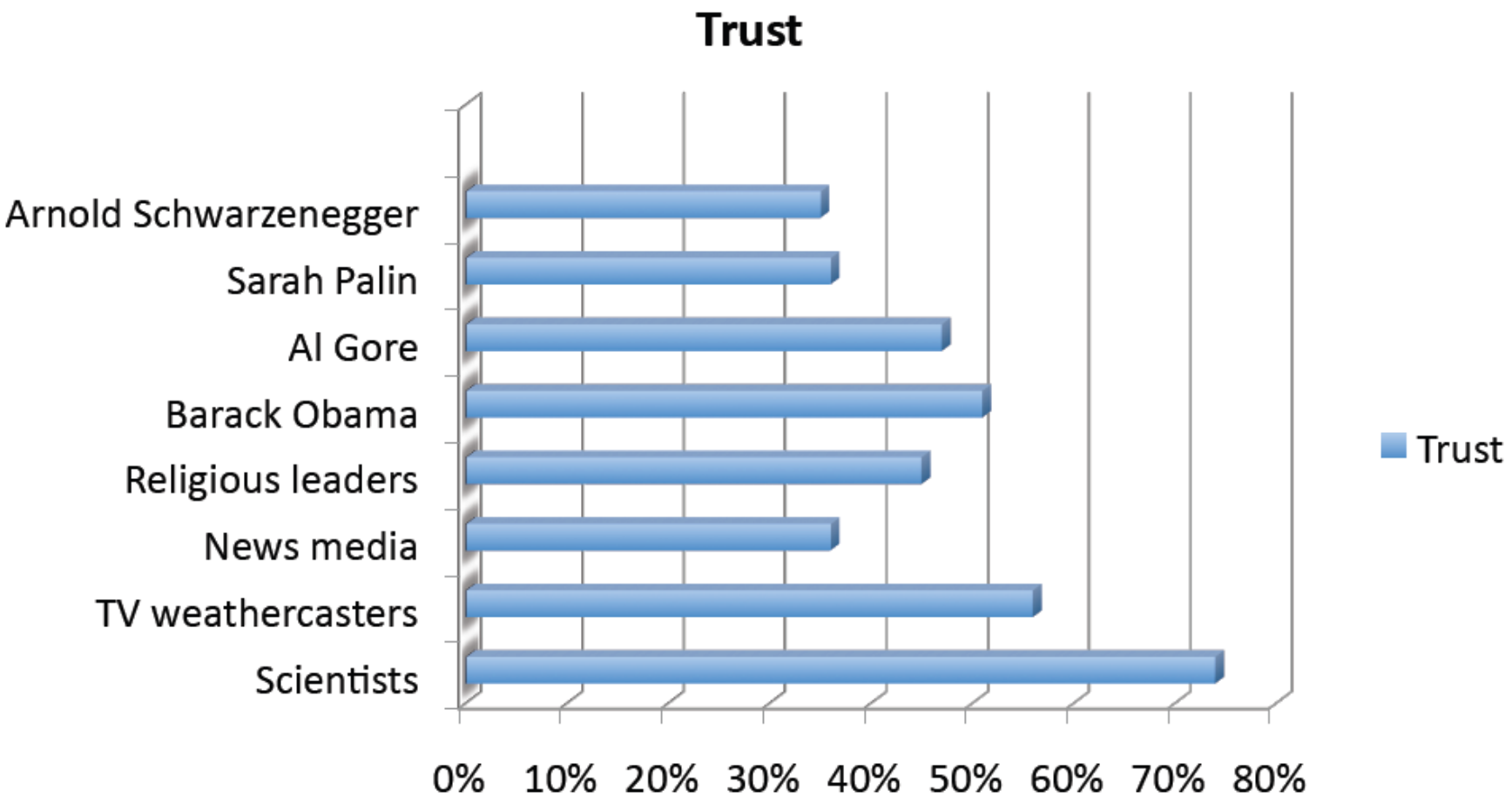
"I have personally experienced the effects of global warming."

Strongly Agree	4%
Somewhat Agree	29%
Somewhat Disagree	43%
Strongly Disagree	24%

Source: Maibach, NOAA Attribution Workshop, 2010

Trust in Sources of Information about Climate Change:

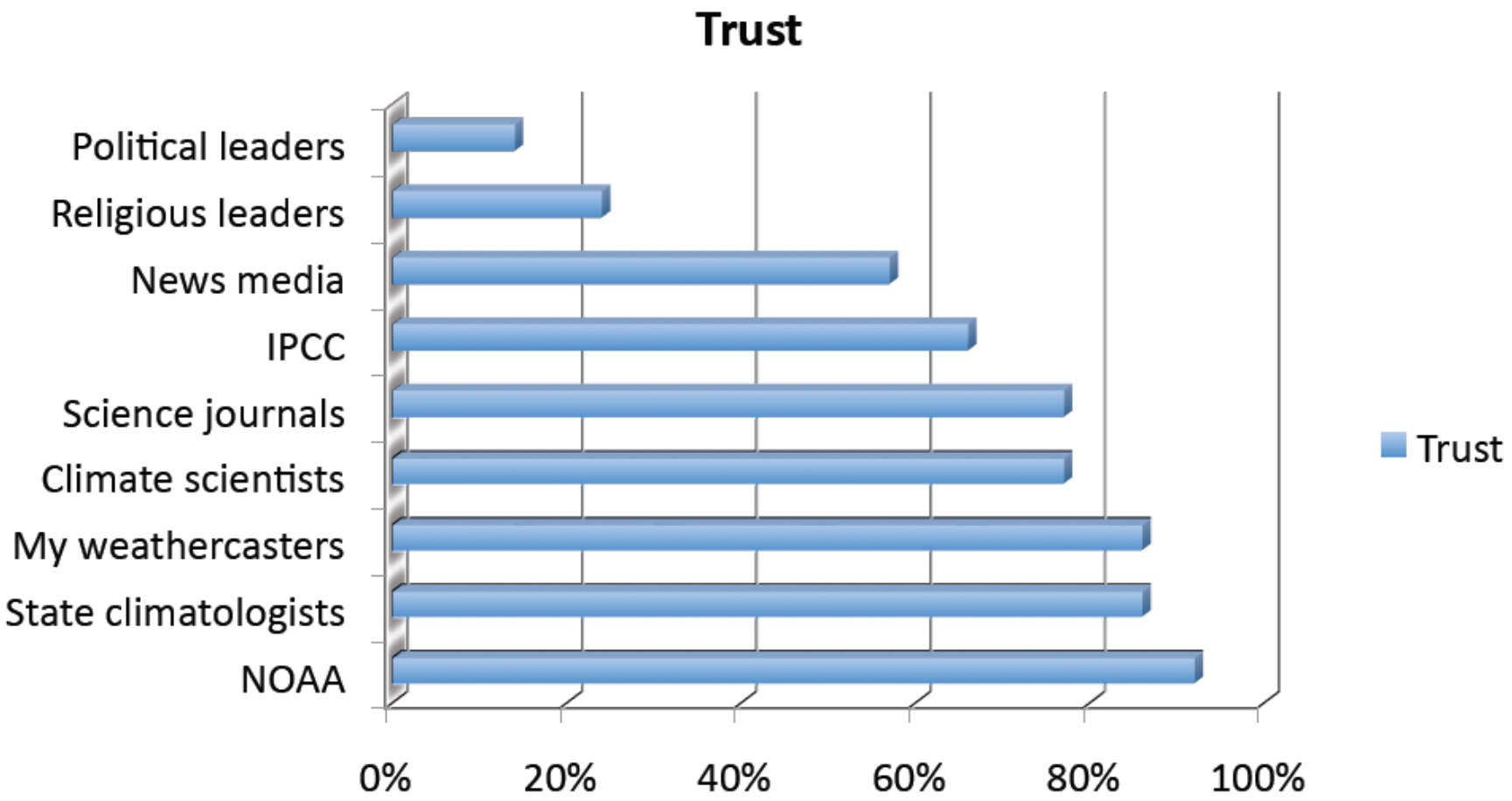
General Public



Source: Leiserowitz, A., Maibach, E., & Roser-Renouf, C. (2010) *Climate change in the American Mind: Americans' global warming beliefs and attitudes in January 2010. Yale University and George* Mason University. New Haven, CT: Yale Project on Climate Change.

Trust in Sources of Information about Climate Change:

Local TV News Directors



Source: Maibach et al (2010). Forthcoming report. Please do not circulate or cite.

Who cares? The lawyers…

- "Plaintiffs ... must show that, more probably than not, their individual injuries were caused by the risk factor in question, as opposed to any other cause. This has sometimes been translated to a requirement of a relative risk of at least two." (Grossman, 2003)
- Those who suspect they are being harmed by climate change (or by climate change litigation) will need an objective scientific framework for causal attribution.
- But current evidence is that non-scientific issues will keep courts busy for the foreseeable future.

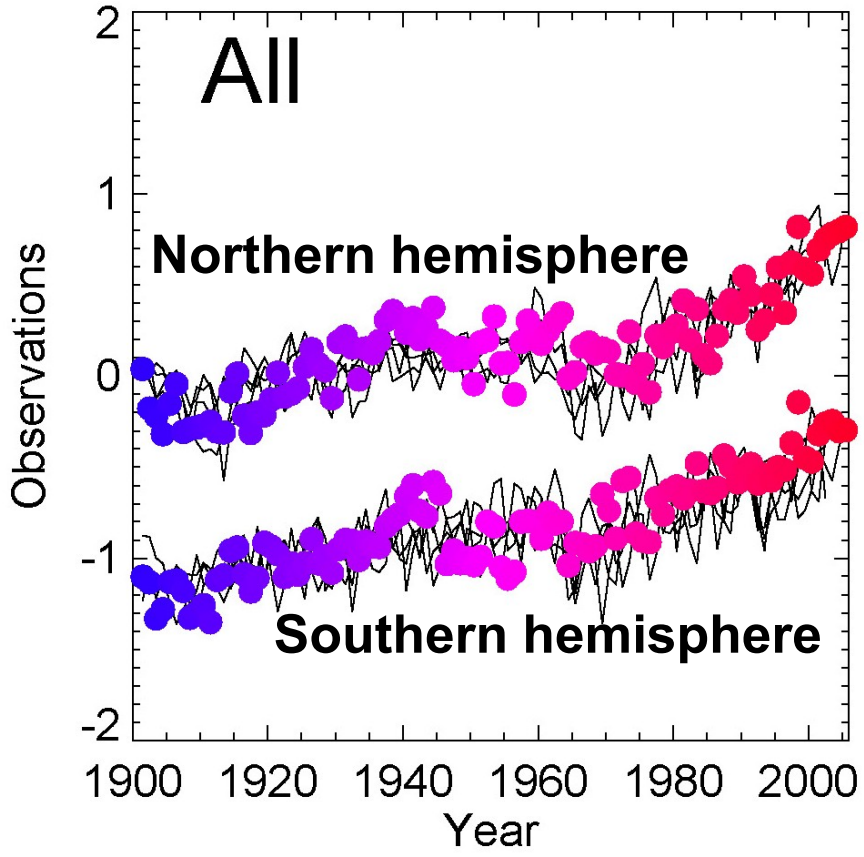
Who cares? The UNFCCC

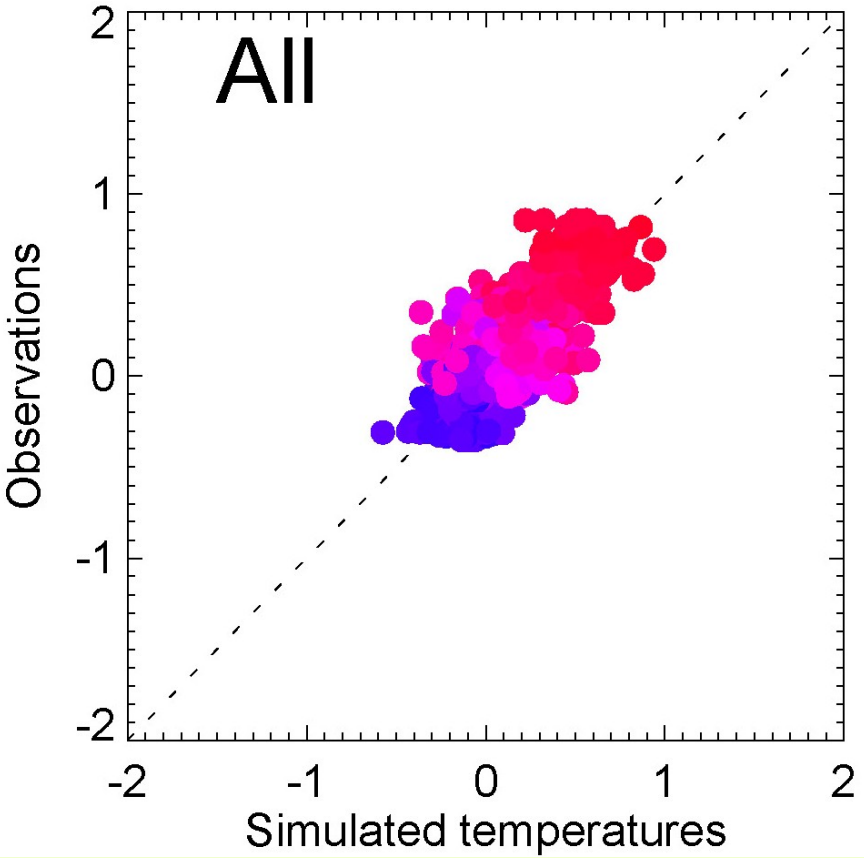
- $100 billion per year by 2020 pledged to assist poor countries in adapting to climate change.
- Much larger sums in national adaptation plans.
- But what adaptation measures are eligible?
  - Heatwave resilience in Russia?
  - Riverine flood protection in Pakistan?
  - Home insulation against cold winters in Europe.
- Urgent need to agree methods of impact attribution and develop a global impact inventory.

Global attribution: how confidence has evolved

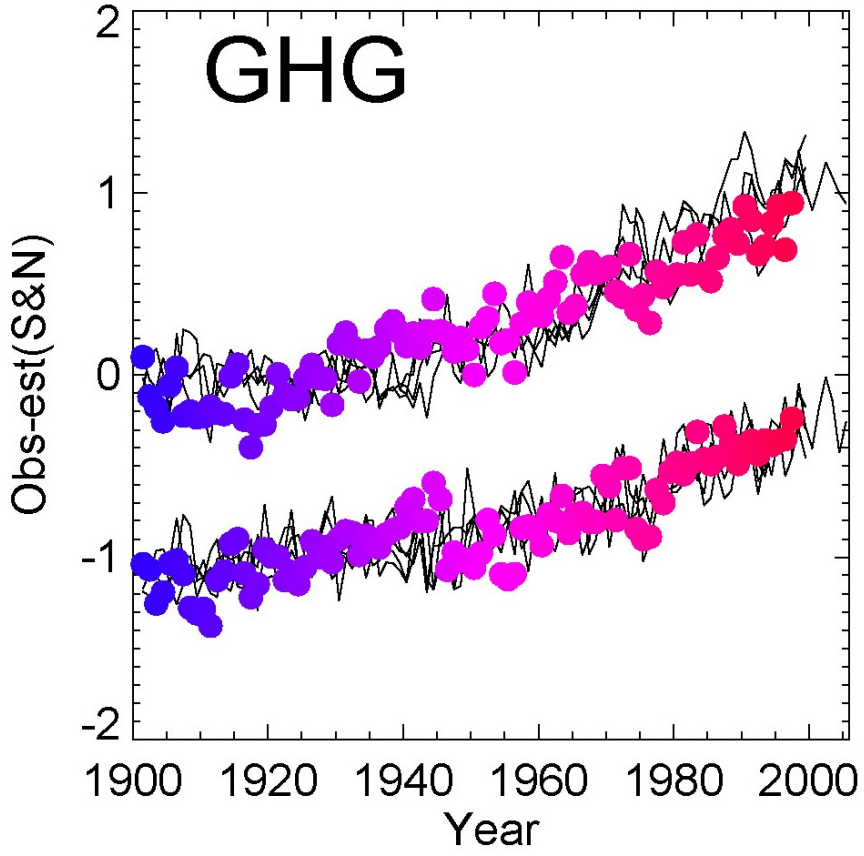
- "The balance of evidence suggests a discernible human influence on global climate." (IPCC, 1995)
- "Most of the observed warming over the last 50 years is *likely* to have been due to the increase in greenhouse gas concentrations." (IPCC, 2001)
- "Most of the observed increase in global average temperatures since the mid-20th century is *very likely* due to the observed increase in anthropogenic greenhouse gas concentrations." (IPCC, 2007)
- Where do these statements come from?

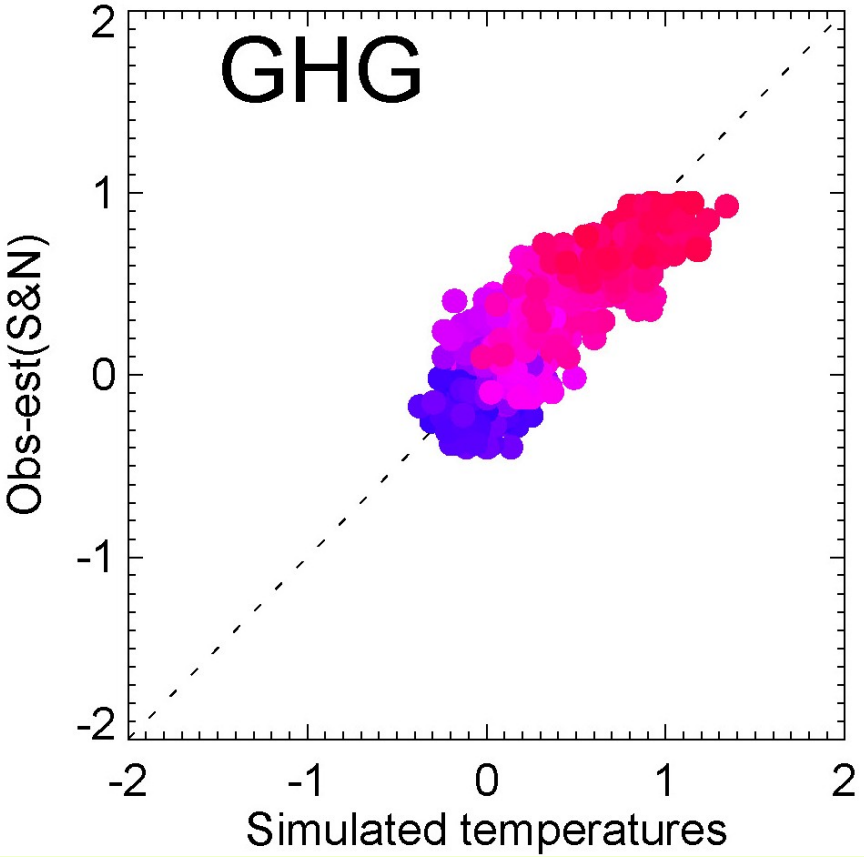
Observed (dots) and simulated (lines) temperature response to all external drivers



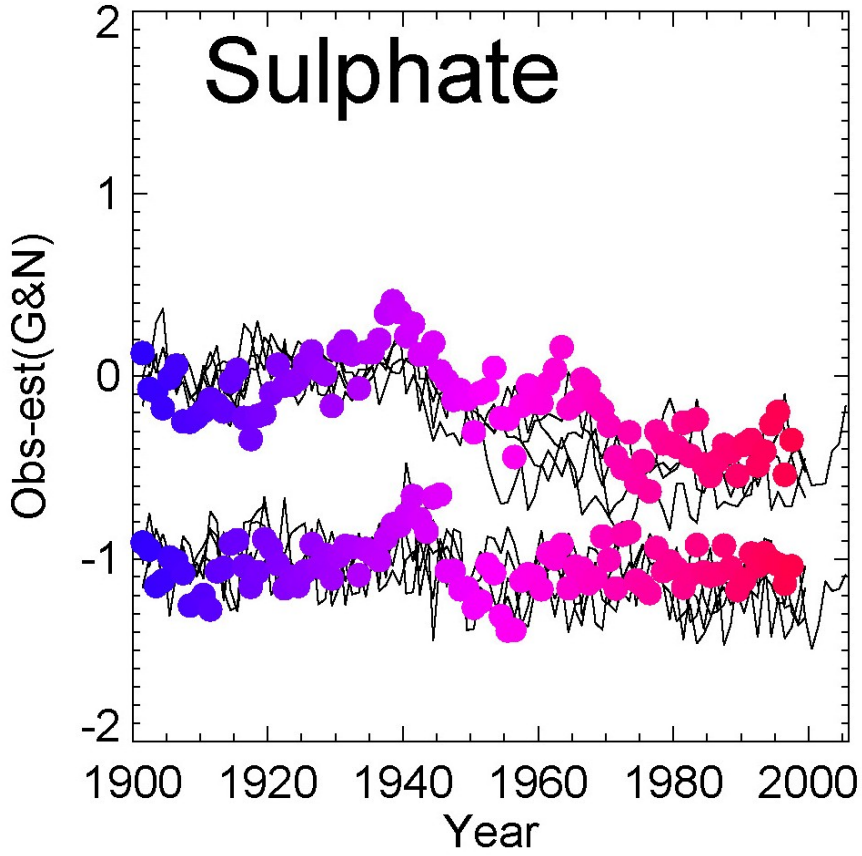


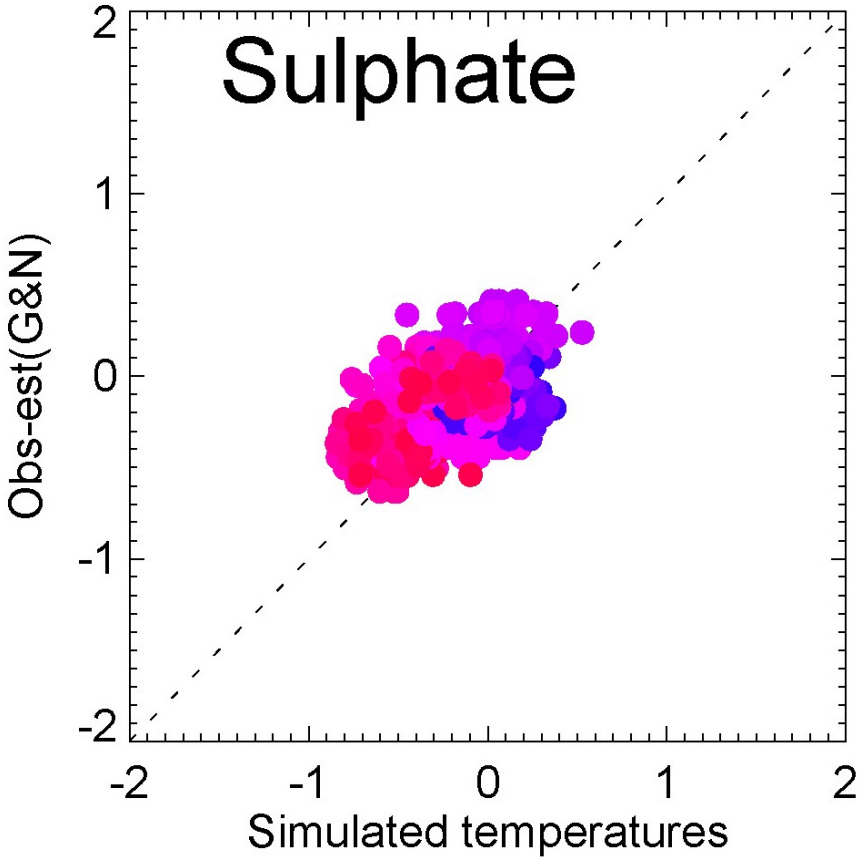
After subtracting best-fit response to sulphates and natural drivers





After subtracting best-fit response to greenhouse gas and natural drivers





After subtracting best-fit response to all anthropogenic drivers