From the sun to the earth: climate 1879-2129

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South Oxford on January 5th, 2003
The problem in Autumn 2000: a \textit{consistently} displaced Atlantic jet-stream

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

Blackburn & Hoskins, 2003
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”
Autumn 2000 events “were extreme, but cannot in themselves be attributed to climate change.”
It has happened before
Osney lock flood marks, 1894 and 1947
Shillingford historic flood levels
Areas of risk in Oxford

You are here
Climate has changed in the past
Northern Hemisphere temperatures over the past millenium
Factors affecting climate
Volcanic eruptions: the main external driver of short-term fluctuations
Solar variability: the main external driver of long-term fluctuations -- until recently
Reconstructions of solar output, 1600-present
Evidence for solar influence on climate

North polar temperatures
Solar output

West-phase QBO

East-phase QBO
And some more contentious evidence
Anthropogenic drivers of climate change

- Carbon Dioxide
- Nitrous Oxide
- Methane
- Sulfur

Graphs showing the concentrations and radiative forcing of these gases over time.
Understanding the response: the Hadley Centre coupled climate model
How the drivers add up: anthropogenic sources

4-member ensemble, GHG and aerosol forcing
How the drivers add up: natural sources

4-member ensemble, solar and volcanic forcing
How the drivers add up: all known sources

4-member ensemble, all forcings included
Some evidence that models are underestimating the response to solar variability
The 2001 conclusions of the Intergovernmental Panel on Climate Change

- “Most of the warming over the past 50 years is likely (meaning a better than 2 in 3 chance) to have been due to the increase in greenhouse gas concentrations.”
- But what does this tell us about flooding in Oxford?
Some evidence of external influence on mean precipitation

a) Global mean temperatures, all forcings included

b) Global land precipitation, all forcings included

Data courtesy of Peter Stott, The Met Office (UK)
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)
And now for the next 125 years: prospects for the main driver of current climate change

Note different scale! Source: IPCC Third Assessment Report
Uncertainty in future greenhouse gas loading

Four scenarios of future greenhouse gas emissions, and Resulting CO$_2$ concentrations in the atmosphere
And uncertainty in the global temperature response
Warming rates under one emissions scenario compared to the responses of several models

Plume shows range consistent with recent observations: Models span c. 10-90% range.
How the probability envelope evolves into the future under one emissions scenario
Uncertainty in global warming under two scenarios of future emissions

- Fossil-intensive, high growth scenario (A1FI)
- Mixed energy sources, medium growth (B1)
Changing emission path buys time but does not eliminate risk

- **Fossil-intensive, high growth scenario (A1FI)**
- **Mixed energy sources, medium growth (B1)**
Ranges of uncertainty in more than global temperature require multi-model ensembles

Global temperature change under 1% per year increasing CO$_2$

(CMIP-2 model inter-comparison)

Global precipitation change under 1% per year increasing CO$_2$
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 cause-and-effect statement about climate change involves probabilities: looking at the spread of results from lots of climate simulations.
- On long time-scales, simulations must allow for uncertainty in modelling, not just chaotic variability in the atmosphere-ocean system.
- But full-scale climate models are expensive to run: the largest ensembles to date are only 20-50 members...
The world’s largest climate modelling experiment: www.climateprediction.net

~50,000 volunteers, 130 countries, ~2M GCM-years

50,000 participants (c.f. 500,000 on SETI@home);
>2M model years simulated (~1.5 Earth Simulators);
25,000 experiments already returned.

Already demonstrating much richer behaviour than could be explored with in-house ensembles.

The next step: choose a representative set of models to perform an explicit forecast to 2050.
Standard Visualisation Package

www.climateprediction.net
Warm front
Treacherous driving conditions
Good day to stay in bed

Surface temperature
Total precipitation

11th-18th December 1828, London
Initial results: a broad range of sensitivities
Choose a representative set of models to perform an explicit forecast to 2050.

Must explore range of responses to CO$_2$, but also range of atmosphere responses to ocean changes.

Launched last week: new experiment exploring the atmospheric response to a slowdown in the North Atlantic overturning circulation.
Not many of the models do this, but that’s kind of the point…
So what are the most important uncertainties in climate prediction?

- For global temperatures, response uncertainty dominates next few decades, with emissions scenario playing a larger role only in the second half of the 21st century.
- For regional changes and specific risks, local chaotic variability will play a larger role, but ranges still not quantified.
- So what do I think is going to happen to emissions?
June-August temperatures in 2003, relative to 1961-90 mean, in Mediterranean region
Modelling Southern European summer temperatures

- Future projection
- Instrumental observations
- Natural drivers only
- All drivers included
Human contribution to the risk of the 2003 heatwave
Why this matters

- We (Stott, Stone & Allen) estimate that there is a better than 9 in 10 chance that past human influence has more than doubled the risk of a heatwave equal or greater than the summer of 2003.

- “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)
By the 2030s, >50% of anthropogenic GHG loading will be due to post-1990 emissions
Why I think greenhouse gas emissions may come down faster than Kyoto progress indicates

- Contribution of past GHG emissions to some current climate risks may already exceed 50%, the threshold for civil tort actions.
- Over the coming decade, both the cost and inevitability of climate change will become much clearer, fuelling demands for compensation.
- Both plaintiffs (insurance companies & property owners) and defendants (energy companies) have very deep pockets.
- The risk, even quite remote, of a successful class-action suit would have far more impact than any conceivable intergovernmental negotiation.