Lecture 29: Detection of Climate Change and Attribution of Causes

1. The Meaning of Detection and Attribution

The response to anthropogenic changes in climate forcing occurs against a backdrop of natural internal and externally-forced climate variability that can occur on similar temporal and spatial scales.

Internal climate variability, by which we mean climate variability not forced by external agents, occurs on all timescales from weeks to centuries and millennia. Slow climate components, such as the ocean, have particularly important roles on decadal and century timescales because they integrate high frequency weather variability and interact with faster components. Thus the climate is capable of producing long timescale internal variations of considerable magnitude without any external influences.

Externally-forced climate variations may be due to changes in natural forcing factors, such as solar radiation or volcanic aerosols, or to changes in anthropogenic forcing factors, such as increasing concentrations of greenhouses gases or sulphate aerosols.

The presence of this natural climate variability means that the detection and attribution of anthropogenic climate change is a statistical "signal-in-noise" problem.

- *Detection* is the process of demonstrating that an observed change is significantly different (in a statistical sense) than can be explained by natural internal variability. However, the detection of a change in climate does not necessarily imply that its causes are understood.

- Unequivocal *attribution* of climate change to anthropogenic causes (i.e., the isolation of cause and effect) would require controlled experimentation with the climate system in which the hypothesised agents of change are systematically varied in order determine the climate's sensitivity to these agents. Such an approach to attribution is clearly not possible. Thus from a practical perspective, attribution of observed climate change to a given combination of human activity and natural influences requires another approach. This involves statistical analysis and the careful assessment of multiple lines of evidence to demonstrate, within a pre-specified margin of error, that the observed changes are:

    - unlikely to be due entirely to internal variability;
    - consistent with the estimated responses to the given combination of anthropogenic and natural forcing; and
    - not consistent with alternative, physically-plausible explanations of recent climate change that exclude important elements of the given combination of forcings.

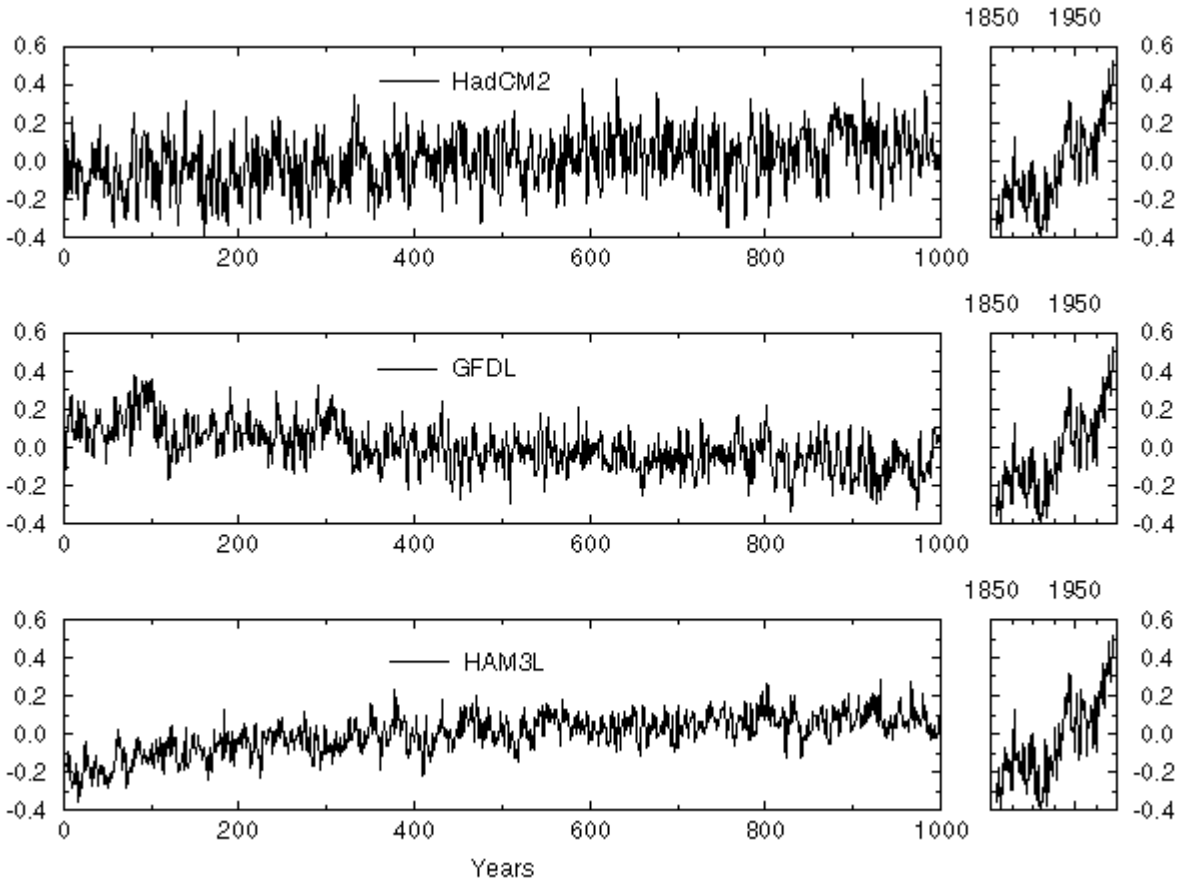
2. Internal Climate Variability

Detection and attribution of climate change is a statistical "signal-in-noise" problem, it requires an accurate knowledge of the properties of the "noise". Ideally, internal climate variability would be estimated from instrumental observations, but a number of problems make this difficult.

- The instrumental record is short relative to the 30-50 year time scales that are of interest for detection and attribution of climate change, particularly for variables in the free atmosphere.

- The instrumental record also contains the influences of external anthropogenic and natural forcing. Therefore, these data are not suitable for accurate estimation of internal climate variability.

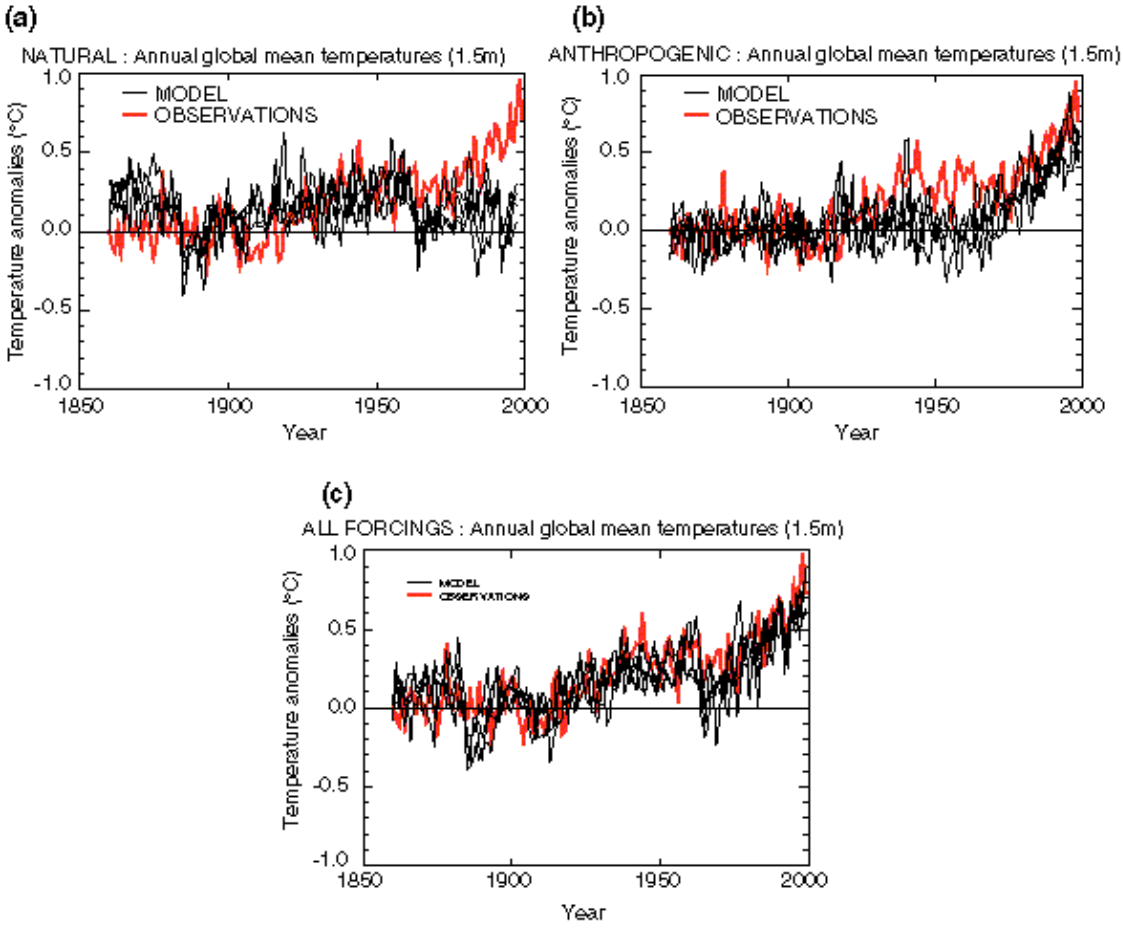
The following figure shows variability simulated in three 1000-year control simulations, that is, climate model runs without natural and anthropogenic forcings. None of the long model simulations produces a secular trend which is comparable to that observed.



3. Climate Response to Natural and Anthropogenic Forcings

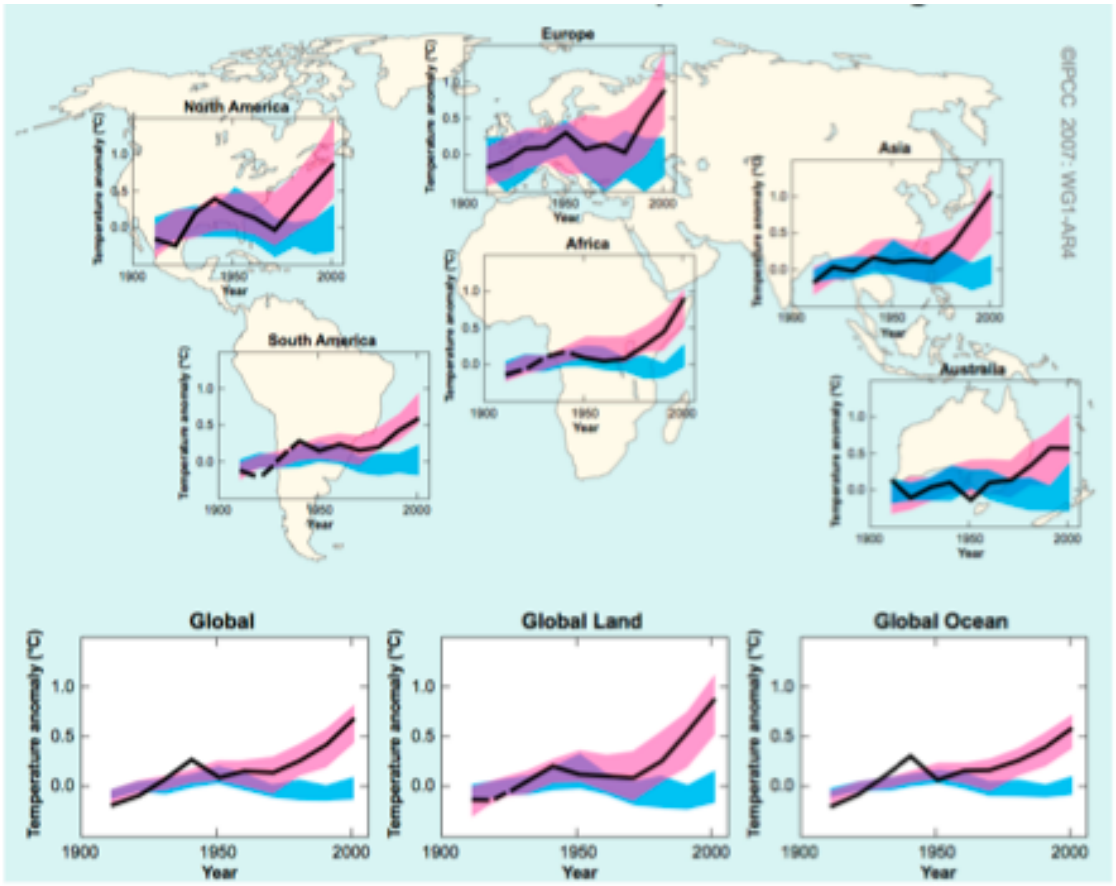
Climate forcing by changes in solar irradiance and volcanism have likely caused fluctuations in global and hemispheric mean temperatures. Studies suggest that natural forcings produce too little warming to fully explain the twentieth century warming.

The three panel below shows global mean surface temperature anomalies relative to the 1880-1920 mean from the instrumental record compared with ensembles of four simulations with a coupled ocean-atmosphere climate model forced (a) with solar and volcanic forcing only, (b) with anthropogenic forcing including well mixed greenhouse gases, changes in stratospheric and tropospheric ozone and the direct and indirect effects of sulphate aerosols, and (c) with all forcings, both natural and anthropogenic. The thick line shows the instrumental data while the thin lines show the individual model simulations in the ensemble of four members. The warming seen in the data is much better reproduced by the model when forced with a combination of natural and anthropogenic forcings.



4. Global and Continental Temperature Change

IPCC 2007 provides a detailed study on global and continental scale temperature changes. The figure below provides a comparison of observed continental and global scale surface temperature changes with model simulations using natural and anthropogenic forcings. The solid black line indicates measured surface temperature. Blue shading represents the average of multiple model simulations forced only with natural forcings. Pink shading denotes model simulations when forced with both natural and anthropogenic forcings.



IPCC 2007 concludes that "it is likely that there has been significant anthropogenic warming over the past 50 years averaged over each continent except Antarctica. The observed patterns of warming, including greater warming over land than over the ocean, and their changes over time, are only simulated by models that include anthropogenic forcing. The ability of coupled climate models to simulate the observed temperature evolution on each of six continents provides stronger evidence of human influence on climate than was available previously."

5. Summary from IPCC 2007

- Most of the observed increase in globally averaged temperatures since the mid-20th century is very likely due to the observed increase in anthropogenic greenhouse gas concentrations.

- It is likely that increases in greenhouse gas concentrations alone would have caused more warming than observed because volcanic and anthropogenic aerosols have offset some warming that would otherwise have taken place.

- The observed widespread warming of the atmosphere and ocean, together with ice mass loss, support the conclusion that it is extremely unlikely that global climate change of the past fifty years can be explained without external forcing, and very likely that it is not due to known natural causes alone.

- It is likely that there has been significant anthropogenic warming over the past 50 years averaged over each continent except Antarctica.

- The observed patterns of warming, including greater warming over land than over the ocean, and their changes over time, are only simulated by models that include anthropogenic forcing.