HOW RELIABLE ARE CLIMATE MODELS?

SUMMARY

Climate models are the best tools available for making climate change projections. While the models still have shortcomings, there has been enormous progress over the past five years in our understanding of important climate processes and their representation in climate models. Confidence in the reliability of these models for climate projections has also improved, based on tests of the ability to simulate:

- the present average climate, including the annual cycle of seasonal changes;
- year-to-year variability;
- extreme events, such as storms and heatwaves;
- climates from thousands of years ago;
- observed climate trends in the recent past.

Present average temperature and pressure are better simulated than rainfall. Simulation of variability due to monsoons, the El Niño Southern Oscillation and the North Atlantic Oscillation has improved. Small-scale extreme events are harder to simulate, but tropical cyclone-like features are captured. Models can reproduce various aspects of climate changes that happened in the mid-Holocene (6,000 years ago) and the Last Glacial Maximum (21,000 years ago). Simulations that include estimates of natural and human influences can reproduce the observed large-scale changes in surface temperature over the 20th century, including the global warming that has occurred during the past 50 years.

Overall, climate models continue to develop to more comprehensively represent the climate system with reduced uncertainty. At present climate models can credibly simulate climatology at global and continental scales for most variables of interest for climate change. Regional models and downscaling techniques can make a contribution to understanding climate change at smaller scales.

Due to the complexity of the climate system, climate models are the best tools available for making climate change projections. Tests of the reliability of computer simulations are undertaken by individual research institutions and within international model comparison experiments. Such testing is central to assigning levels of confidence to model outputs. The tests include:

Present average climate, including the annual cycle of seasonal changes

An international comparison of 15 climate models showed that surface air temperature and mean sea level pressure are well simulated down to sub-continental scales (IPCC, 2001a). However, there remains scope for improvement in precipitation patterns. CSIRO’s (2001) climate change projections for the Australian region are based on models that adequately simulate the present average climate in those regions. No single model can be considered ‘best’, so it is important to use results from a range of models that perform well.

Year-to-year variability

Climate models typically produce global-average temperature variability quite well. There has also been an improvement in their ability to simulate monsoons, the El Niño Southern Oscillation (a see-saw of atmospheric pressure and ocean temperature in the Pacific affecting climate in many regions, including Australia) and the North Atlantic Oscillation (a see-saw of atmospheric pressure and ocean temperature in the North Atlantic, affecting climate from central North America to Europe and much of Northern Asia) (IPCC, 2001a).

Extreme events

Tropical-cyclone-like features can be simulated, with improved realism in models with finer spatial resolution (IPCC, 2001a). Models are more capable of reproducing the variability in maximum and minimum temperature at the global scale than daily precipitation variability. Further development of 'downscaling' techniques will allow better regional simulations of climate and extreme weather.

Climates from thousands of years ago

The Palaeoclimate Model Intercomparison Project provides an evaluation of simulations for the mid-Holocene (6,000 years ago) and the Last Glacial Maximum (21,000 years ago). The mid-Holocene was chosen to test the response of climate models to different orbital forcing with carbon dioxide at pre-industrial concentration and present ice sheet extent. The Last Glacial Maximum was chosen to test the model response to larger ice sheets, a much lower carbon dioxide concentration, but minor changes in solar radiation (IPCC, 2001a). The models were able to capture various aspects of the climate response documented in proxy records such as ice-cores, tree-rings and pollen data.

Observed climate trends in the recent past

The presence of natural climate variability in both the model simulations and the observed record guarantees that the observed and modelled data will not be exactly alike on a year-to-year, or even decade-to-decade basis. This is why an ensemble of climate simulations is needed – each simulation starting from a slightly different set of initial conditions, leading to a different evolution of climate, thereby capturing the effect of chaotic natural variability. Ensemble simulations that include estimates of natural and human influences typically reproduce the observed large-scale changes in surface temperature over the 20th century (see Figure 1 below). However, these simulations are subject to uncertainties associated with clouds and their interaction with radiation and aerosols. Models cannot yet account fully for the observed trend in the temperature difference between the surface and the troposphere (lower atmosphere) since 1979 (IPCC, 2001a). Reproducing past changes in regional climate is more challenging, particularly for rainfall since it is more variable than temperature.

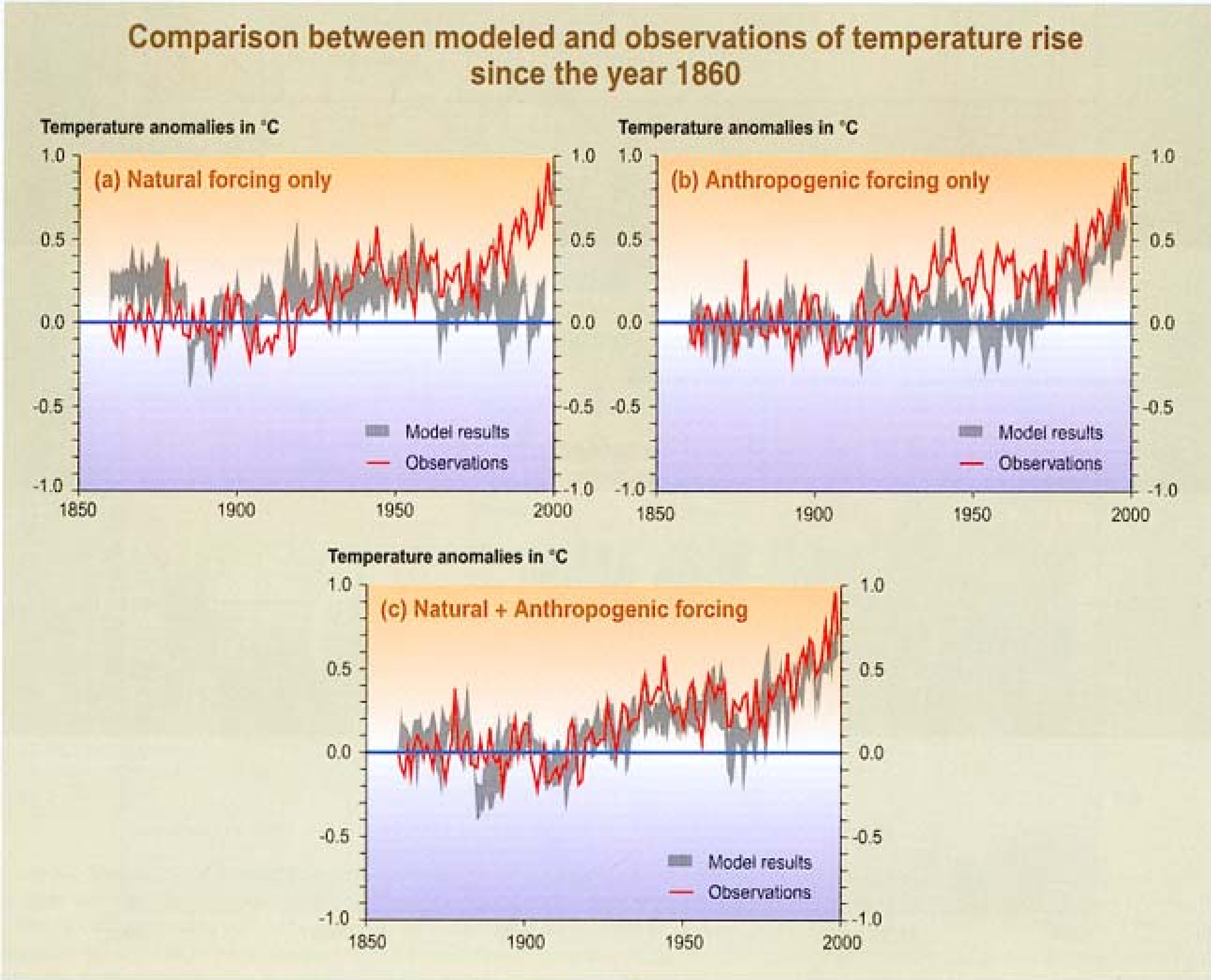

Figure 1: Comparison of observed changes in global-average surface air temperature over the 20th century with that from an ensemble of climate model simulations. Source: IPCC (2001b) http://www.grida.no/climate/ipcc_tar/vol4/english/022.htm

Model development

Figure 2 shows the development of climate models from the 1970s. Different components are first developed separately, tested, and then coupled into comprehensive climate models. The key components are the atmosphere, ocean, sea ice, land surface, aerosols and the carbon cycle. Over the past five years, scientists have improved their understanding of important climate processes such as the role of water vapour, sea-ice dynamics and ocean heat transport. Representation of these processes in climate models has also improved. New components being included are non-sulfate aerosols, indirect aerosol effects on cloud properties, and vegetation that responds dynamically to changes in climate.

Due to their coarse resolution, global climate models only provide broad-scale projections of climate change, whereas policy-relevant projections and impact assessments often require more detail. Consequently, regional climate models have been developed. These models typically include components for the atmosphere and land surface only, using a relatively fine grid (e.g. points 30 km apart) and covering a limited area (e.g. the Australian region). A regional model is driven at its boundaries by input from a global climate model. This technique is called ‘dynamical downscaling’ because it can zoom down to more local scales. Regional climate models give a much better representation of coastal and mountain effects and local-scale variations in climate.

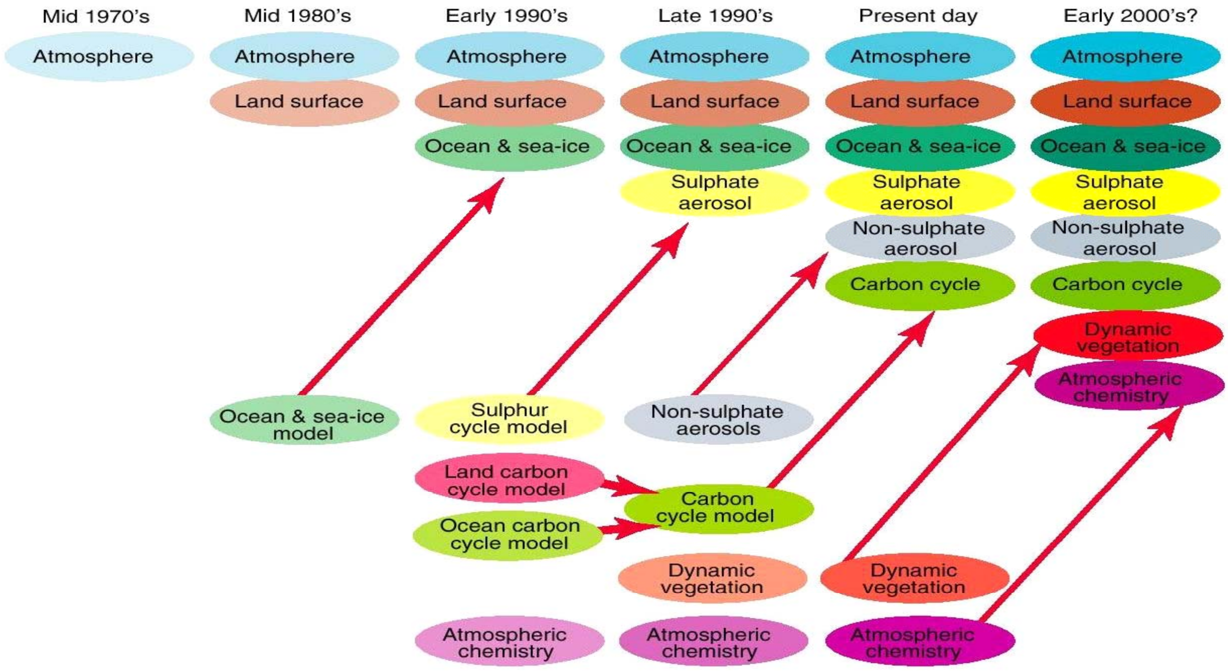

Figure 2: Different components are first developed separately, and then coupled into comprehensive climate models. From IPCC (2001a).

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