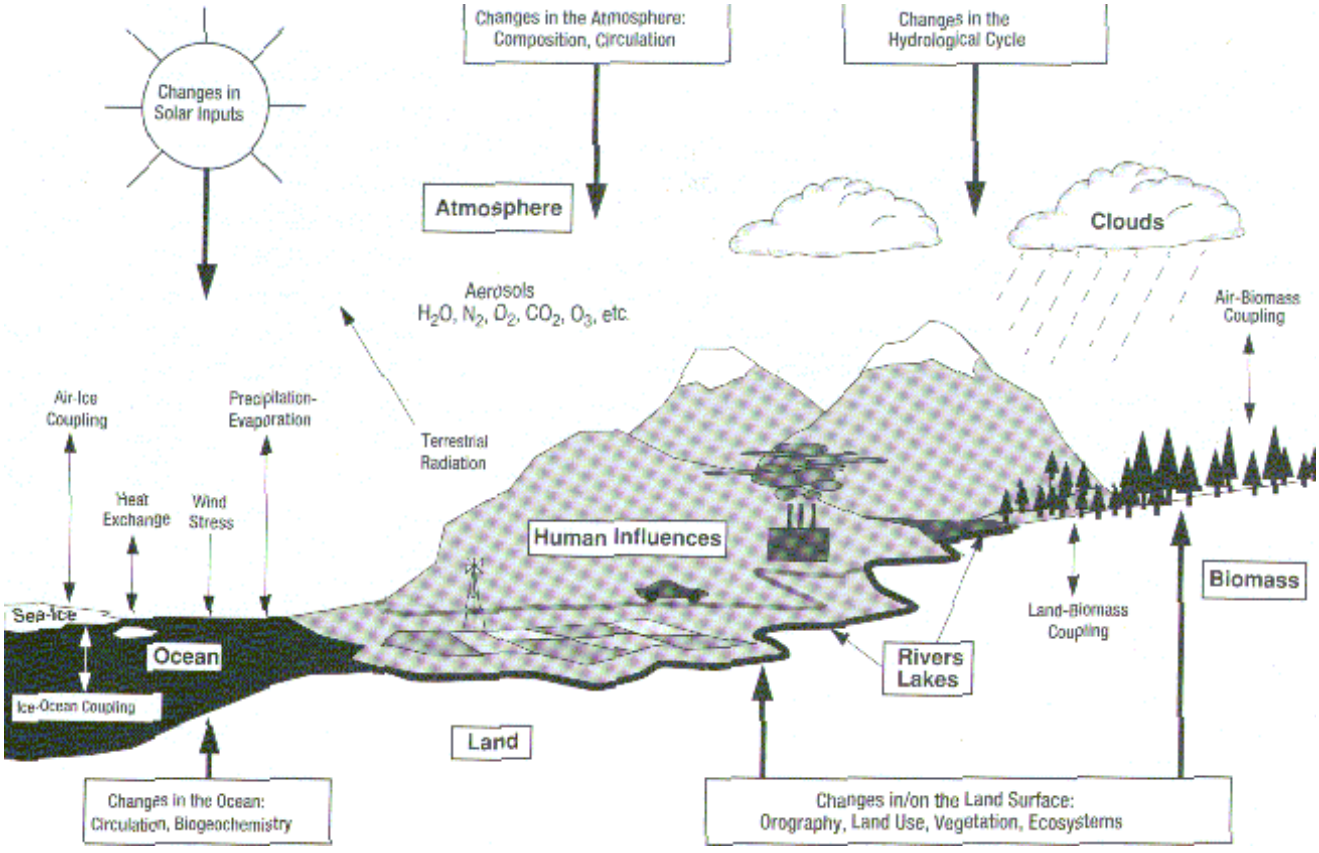
Lecture 30: Projections of Future Climate Change

1. Introduction

The purpose of this chapter is to assess and quantify projections of possible future climate change from climate models. So, what is a climate model?

Climate Models: In order to quantify the response of the climate system to changes in forcing, one must account for all the complex interactions and feedbacks between the various components of the climate system. As this is not possible to do reliably using statistical methods, one resorts to numerical models of the climate system based on sound well-established physical principles. Global climate models (GCMs*)* include as central components atmospheric and ocean general circulation models, as well as representation of land surface processes, sea-ice and all other processes shown in the figure below.



Models and their components are based upon physical principles represented by mathematical equations that describe the atmospheric and ocean dynamics and physics. Such equations are solved numerically at a finite resolution using a three-dimensional grid over the globe. Typical resolutions used for simulations are about 250 km in the

horizontal and 1 km in the vertical. Because of such coarse spatial resolution, many of physical processes cannot be properly resolved, and one resorts to including their average effect through parametric representations (also called parameterization). The coupling between the various components, especially between the atmosphere and ocean circulation models, has been challenging, and only recently and only in some cases, has this been done correctly. A frontier and future research challenge is to bring more complete chemistry, biology and ecology into the climate system models to improve the representation of the various physical processes.

2. Projections for the Next Two Decades

Since IPCC's first report in 1990, assessed projections have suggested global averaged temperature increases between about 0.15 and 0.3°C per decade for 1990 to 2005. This can now be compared with observed values of about 0.2°C per decade, strengthening confidence in near-term projections.

Model experiments show that even if all radiative forcing agents are held constant at year 2000 levels, a further warming trend would occur in the next two decades at a rate of about 0.1°C per decade, due mainly to the slow response of the oceans. About twice as much warming (0.2°C per decade) would be expected if emissions are within the range of the scenarios detailed at the end of this chapter.

3. Warming in the 21st Century

Projected globally-averaged surface warmings for the end of the 21st century (2090–2099) relative to 1980–1999 are shown in Table below. These illustrate the differences between lower to higher emission scenarios and the projected warming uncertainty associated with these scenarios. For example, the best estimate for the low scenario (B1) is 1.8°C (likely range is 1.1°C to 2.9°C), and the best estimate for the high scenario (A1FI) is 4.0°C (likely range is 2.4°C to 6.4°C).

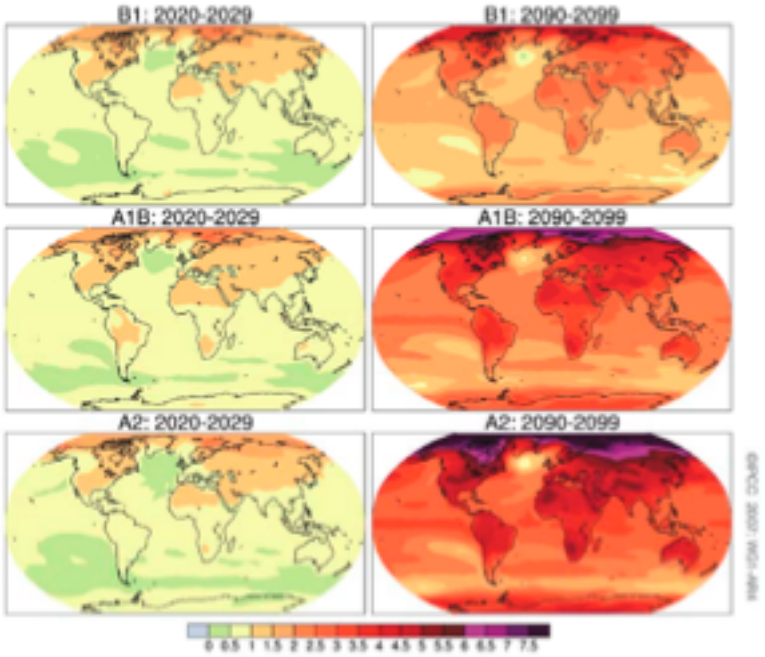
	Temperature Change (°C at 2090-2099 relative to 1980-1999) [a]		Sea Level Rise (m at 2090-2099 relative to 1980-1999)
Case	Best estimate	*Likely* range	Model-based range excluding future rapid dynamical changes in ice flow
Constant Year 2000 concentrations [b]	0.6	0.3 – 0.9	NA
B1 scenario	1.8	1.1 – 2.9	0.18 – 0.38
A1T scenario	2.4	1.4 – 3.8	0.20 – 0.45
B2 scenario	2.4	1.4 – 3.8	0.20 – 0.43
A1B scenario	2.8	1.7 – 4.4	0.21 – 0.48
A2 scenario	3.4	2.0 – 5.4	0.23 – 0.51
A1FI scenario	4.0	2.4 – 6.4	0.26 – 0.59

Table notes:

[a] These estimates are assessed from a hierarchy of models that encompass a simple climate model, several Earth Models of Intermediate Complexity (EMICs), and a large number of Atmosphere-Ocean Global Circulaion Models (AOGCMs).

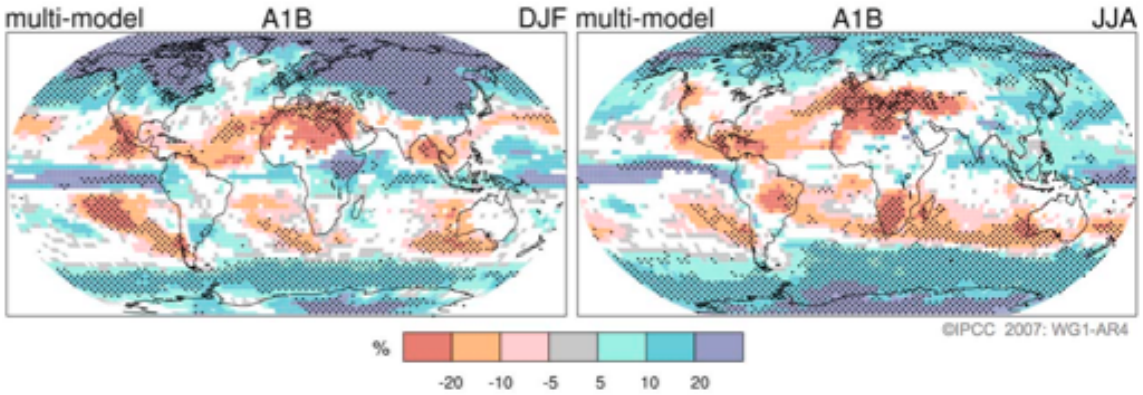
[b] Year 2000 constant composition is derived from AOGCMs only.

Projected warming in the 21st century shows scenario-independent geographical patterns similar to those observed over the past several decades (see figure below). Warming is expected to be greatest over land and at most high northern latitudes, and least over the Southern Ocean and parts of the North Atlantic ocean. Snow cover is projected to contract. Sea ice is projected to shrink in both the Arctic and Antarctic under all scenarios. In some projections, Arctic late-summer sea ice disappears almost entirely by the latter part of the 21st century.



4. Precipitation in the 21st Century

Increases in the amount of precipitation are very likely in high-latitudes, while decreases are likely in most subtropical land regions (by as much as about 20% in the A1B scenario in 2100, see Figure below), continuing observed patterns in recent trends. It is very likely that hot extremes, heat waves, and heavy precipitation events will continue to become more frequent. Based on a range of models, it is likely that future tropical cyclones (typhoons and hurricanes) will become more intense, with larger peak wind speeds and more heavy precipitation associated with ongoing increases of tropical SSTs.



5. Summary from IPCC 2007

For the next two decades a warming of about 0.2°C per decade is projected for a range of emission scenarios. Even if the concentrations of all greenhouse gases and aerosols had been kept constant at year 2000 levels, a further warming of about 0.1°C per decade would be expected.

Continued greenhouse gas emissions at or above current rates would cause further warming and induce many changes in the global climate system during the 21st century that would very likely be larger than those observed during the 20th century.

There is now higher confidence in projected patterns of warming and other regional-scale features, including changes in wind patterns, precipitation, and some aspects of extremes and of ice.

Anthropogenic warming and sea level rise would continue for centuries due to the timescales associated with climate processes and feedbacks, even if greenhouse gas concentrations were to be stabilized.

6. Emission Scenarios

A1. The A1 storyline and scenario family describes a future world of very rapid economic growth, global population that peaks in mid-century and declines thereafter, and the rapid introduction of new and more efficient technologies. Major underlying themes are convergence among regions, capacity building and increased cultural and social interactions, with a substantial reduction in regional differences in per capita income. The A1 scenario family develops into three groups that describe alternative directions of technological change in the energy system. The three A1 groups are distinguished by their technological emphasis: fossil intensive (A1FI), non-fossil energy sources (A1T), or a balance across all sources (A1B) (where balanced is defined as not relying too heavily on one particular energy source, on the assumption that similar improvement rates apply to all energy supply and end use technologies).

A2. The A2 storyline and scenario family describes a very heterogeneous world. The underlying theme is self reliance and preservation of local identities. Fertility patterns

across regions converge very slowly, which results in continuously increasing population. Economic development is primarily regionally oriented and per capita economic growth and technological change more fragmented and slower than other storylines.

B1. The B1 storyline and scenario family describes a convergent world with the same global population, that peaks in mid-century and declines thereafter, as in the A1 storyline, but with rapid change in economic structures toward a service and information economy, with reductions in material intensity and the introduction of clean and resource efficient technologies. The emphasis is on global solutions to economic, social and environmental sustainability, including improved equity, but without additional climate initiatives.

B2. The B2 storyline and scenario family describes a world in which the emphasis is on local solutions to economic, social and environmental sustainability. It is a world with continuously increasing global population, at a rate lower than A2, intermediate levels of economic development, and less rapid and more diverse technological change than in the B1 and A1 storylines. While the scenario is also oriented towards environmental protection and social equity, it focuses on local and regional levels.

An illustrative scenario was chosen for each of the six scenario groups A1B, A1FI, A1T, A2, B1 and B2. All should be considered equally sound.

The SRES scenarios do not include additional climate initiatives, which means that no scenarios are included that explicitly assume implementation of the United Nations Framework Convention on Climate Change or the emissions targets of the Kyoto Protocol.