IPCC projections of future climate change

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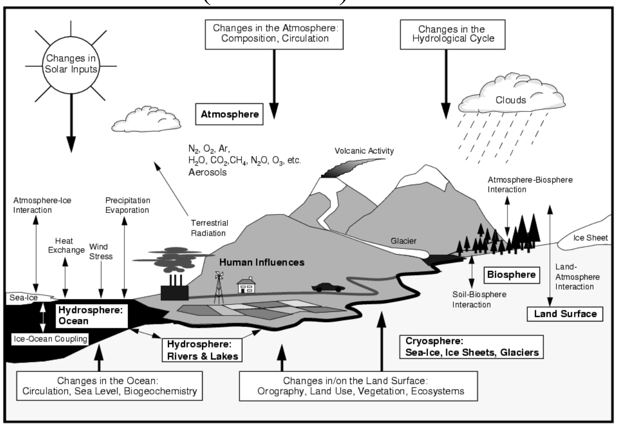
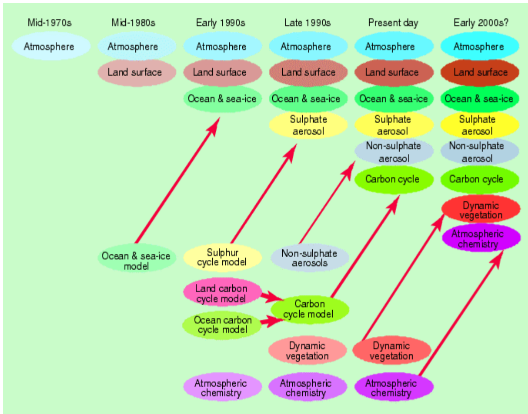
Climate Modelling

The Earth's climate system is a complex system because of the many interactions and feedbacks among its components (atmosphere, ocean, land surface, cryosphere and biosphere). Gradually more components of the climate system are incorporated in global climate models (AOGCMs).





Recent improvements in climate modelling are presented as well as the factors that continue to limit our ability to understand the current climate and to project what future climate changes may be.

Advances and sources of uncertainty in climate modelling

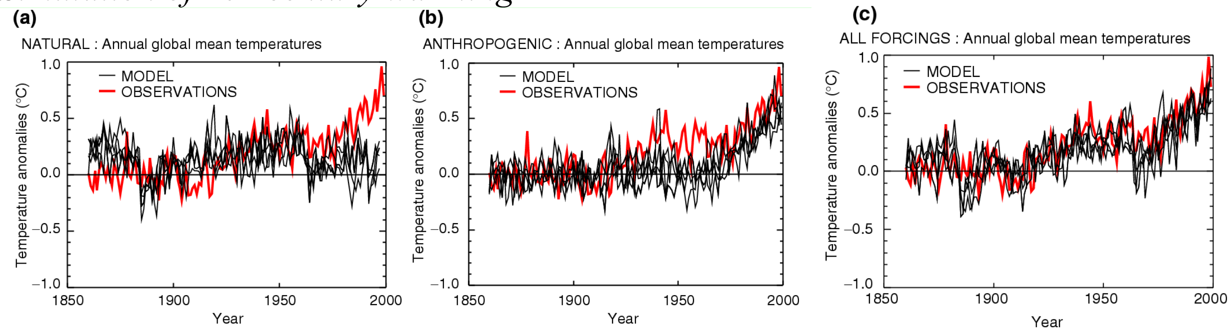
Climate processes and feedbacks

- Improved treatment of water vapour (water vapour feedback doubles warming)
- Probably greatest uncertainty arises from clouds; sign of net cloud feedback still uncertain
- Precipitation processes uncertain; difficulties with simulating precipitation amounts and frequencies
- Importance of stratosphere recognized because of changes in its structure
- Improved heat transport in ocean models as a result of increased resolution
- Improved representation of sea-ice processes; several models now incorporate ice dynamics
- Representation of land-ice remains rudimentary
- Recognition of feedbacks between vegetation and climate
- Improved terrestrial and ocean carbon cycle models

Overall ability of present models

- Many models now can run without flux adjustments
- Improved representation of modes of natural variability (ENSO, NAO)
- The growing capabilities of climate models are demonstrated in systematic model intercomparisons (e.g. CMIP)
- Several models are able to simulate aspects of palaeoclimates (e.g. PMIP)
- Several models reproduce the observed warming trends of the 20th century

Simulation of 20th century warming



The figure shows that when both natural forcings (e.g. volcanic and solar activity) and anthropogenic forcings (e.g. greenhouse gases and aerosols) are taken into account that the 20th century warming can be simulated satisfactorily (c). When only natural (a) or anthropogenic forcings are considered (b) simulation of the 20th century warming fails.

IPCC projections for the 21st century

The uncertainties in future climate projections remain large. In each step of the chain from greenhouse gas emissions to climate change impacts uncertainties are introduced such as for example the uncertainties in future emissions of greenhouse gases and aerosols, uncertainties in atmospheric chemistry and the carbon cycle, differences between climate model projections resulting from imperfect knowledge of the climate system, uncertainties due to natural variability of the climate system and uncertainties due to the non-linear behaviour of the coupled system with a possibility for rapid and irreversible changes.

In general the uncertainty of the climate change projections increases with decreasing spatial and temporal scales. Changes in the regional climates are therefore more uncertain than changes in the global mean climate. Also changes in extreme events are more uncertain than changes in the mean state. Unfortunately, for most climate change impacts changes in variability and extremes are at least as important, and quite often even more important, than changes in mean conditions

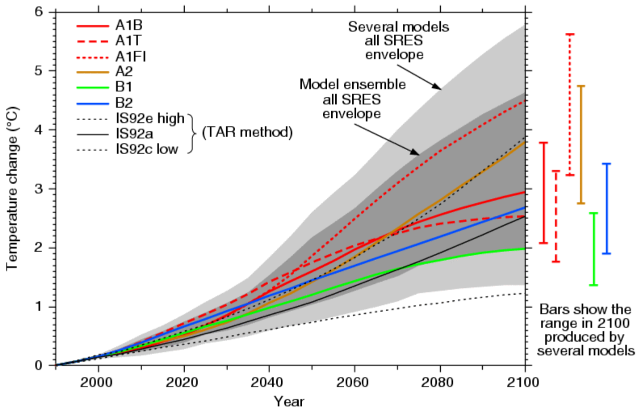
Simple climate models

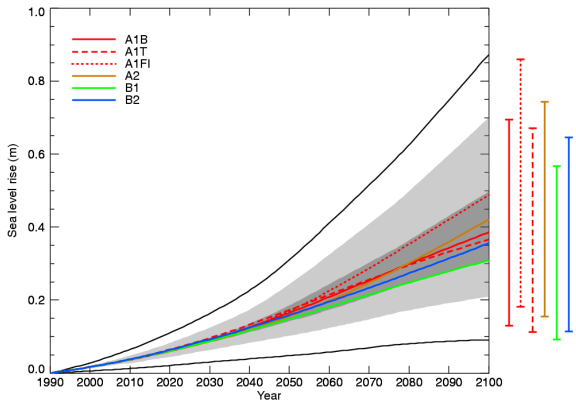
- Simple climate models are needed since AOGCMs are too expensive to run all 35 IPCC SRES emission scenarios (AOGCMs run only scenarios A2 and B2)

- Simple climate models consist of an upwelling diffusion-energy balance model (UD/EB). This model is tuned to each of 7 AOGCMs to represent the globally averaged temperature response
- For scenarios A2 and B2 tuning of the simple model is tested with AOGCM runs

Global mean temperature and sea level rise projections

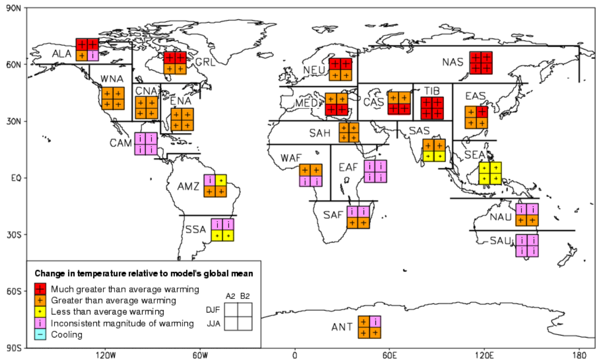
IPCC global mean temperature and sea level rise projections for the 21st century for six illustrative emission (SRES) scenarios are given below.

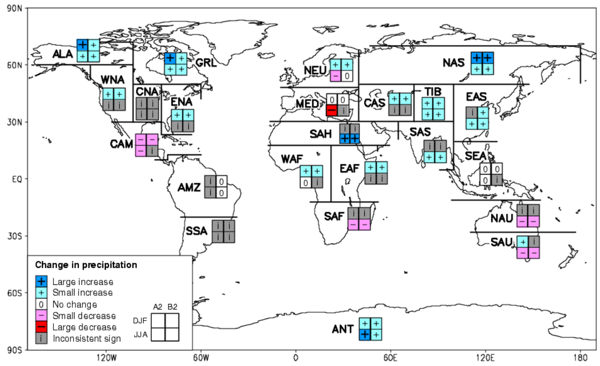




Consistency in regional climate change

For two SRES emission scenarios (A2 and B2) IPCC performed analyses of inter-model consistency (i.e. the consistency between 9 global climate models) in regional precipitation changes and regional relative warming (warming relative to the global mean warming).





Temperature projections from AOGCMs

- Land warms faster and more than the ocean
- Warming is greater in high latitudes
- Temperature increase in North Atlantic and the southern oceans smaller than the global mean
- Land areas warm more rapidly than the global average, in particular in the northern high latitudes in winter

- Decrease in diurnal temperature range; night temperatures increase more than day temperatures
- Decreased daily variability in winter and increased daily variability in summer (some models)
- Decrease of snow cover and sea-ice extent

Precipitation projections from AOGCMs

- Decrease of snow cover and sea-ice extent
- Globally average precipitation and evaporation are projected to increase
- Regionally both increases and decreases in precipitation are seen
- Increases in mean precipitation will likely lead to increases in variability
- The frequency of extreme precipitation events is projected to increase almost everywhere

Changes in extreme events

Mid-latitude storms:

- "There is little agreement among models concerning future changes in mid-latitude storm intensity, frequency, and variability"
- "Insufficient analyses has occurred of how extra-tropical cyclones may change"
- "Confidence in models and understanding is inadequate to make firm projections"

Changes in Phenomenon	Confidence in projected changes (during the 21st century)
Higher maximum temperatures and more hot days over nearly all land areas	Very likely
Higher minimum temperatures, fewer cold days and frost days over nearly all land areas	Very likely
Reduced diurnal temperature range over most land areas	Very likely
Increase of heat index[8] over land areas	Very likely, over most areas
More intense precipitation events[b]	Very likely, over many areas
Increased summer continental drying and associated risk of drought	Likely, over most mid-latitude continental interiors (Lack of consistent projections in other areas)
Increase in tropical cyclone peak wind intensities[c]	Likely, over some areas
Increase in tropical cyclone mean and peak precipitation intensities[c]	Likely, over some areas

Climate scenario development

Useful and reliable climate change information at the spatial and/or temporal resolution required for *impact studies* is often not directly available from global climate models (or the IPCC projections). Techniques used to enhance the regional/temporal detail have matured and are more widely applied since the previous IPCC report. Three main categories can be distinguished: pattern scaling; dynamical downscaling, with high and variable resolution global climate models or with high-resolution regional climate models (nested within a global climate model); and empirical/statistical downscaling. The choice and use of these techniques strongly depends on the needs of specific applications and the sensitivity of the system considered. The main strengths and weaknesses of these techniques are given below. But first a definition of climate scenario is given:

"A plausible representation of future climate constructed for exploring the impacts of anthropogenic climate change"

Pattern scaling

Patterns of temperature and precipitation change from (one ore more) AOGCMs are scaled using a simple climate model in order to obtain climate scenarios for different emission scenarios and different time horizons (e.g. the ACACIA scenarios).

Strenghts	**Weaknesses**
• Readily available,	• Only average changes (no extremes)
• for different levels of forcing	• Change pattern invariant (time/forcing)
• Ensemble-average change + Inter-model range of changes given	• (lack of) Physical consistency

RCMs/dynamical downscaling

RCMs are high-resolution regional climate models that are "nested" within an AOGCM. Nested means that the lateral boundaries for the RCM are obtained from an AOGCM. RCMs typically have horizontal resolutions of about 50 x 50 km^2, sometimes even less.

Strengths	**Weaknesses**
• High spatial resolution	• Large-scale circulation from AOGCM
• Many variables available	• Limited length (time slices of 10-30 years)
• Physical consistency	• Biases in control run
• Contains natural variability (daily, interannual, extremes)	• Statistics of daily precipitation
	• Specific domain

Statistical/Empirical downscaling

Statistical downscaling typically makes use of (statistical/empirical) relations between large-scale atmospheric variables (such as flow components, baroclinicity, vorticity and humidity) and local variables (such as precipitation) to enhance the spatial or temporal resolution.

Strengths	**Weaknesses**
• Tailoring (flexibility)	• Tailoring (advanced techniques)
• High temporal/spatial resolution (sub-daily/local)	• Historical data needed (to derive statistical relations)
• Computationally inexpensive	• Large scale circulation (i.e.predictors) from AOGCM
	• Assumes invariant statistical relations
	• Choice of predictors (predictors should contain the climate change signal)

Summary and final remarks

- Increasing confidence in model projections

- For global average temperature projections uncertainties from SRES scenarios and climate models are of similar size
- Larger model uncertainty at regional (and smaller) scales
- No single model (or climate scenario) can be considered "**best**"
- Use results from (a range of) different models to capture part of the uncertainty
- Uncertainties related to downscaling rather poorly known

References (IPCC Websites)

IPCC Reports:

http://www.ipcc.ch/

The IPCC Data Distribution Centre:

http://ipcc-ddc.cru.uea.ac.uk/