Future Rainfall Projections

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Abstract

The rainfall distribution in a future climate is calculated using global climate models. These models, frequently derived from weather forecast models, solve the physical equations on a grid representing Earth's atmosphere. As rainfall is very patchy, multiple simulations with various models developed by different research groups are combined. These models predict in the case of an enhanced greenhouse gas concentration in the mean an increase of precipitation due to the higher temperature, but the distribution is not even. Generally, dry regions become dryer, while wet regions become wetter. In the regions with rainfall, there is a tendency towards more intense precipitation. The grid of global models has a resolution of typically 200-400 square kilometres. This is too coarse to estimate the precipitation change on a regional scale, for example a country with the size of Spain, or river catchments. High resolution regional models are imbedded into the global models to estimate the climate change up to a horizontal resolution of 10 kilometres. Statistical models have also been developed to obtain information on a regional scale.

Key words: climate modelling, regional climate models, precipitation change, global warming

1. Introducción

The rainfall distribution of a future climate is estimated using global climate models (GCM). This is a much more challenging task than the calculation of the near surface temperature, because precipitation is spatially much more variable. In a global mean, the change of precipitation is coupled to the increase in temperature via the Clausius-Clapeyron equation, i.e. the atmosphere can hold more water vapour at higher temperatures.

Locally, the response in the precipitation pattern to the change in temperature is much more differentiated. Clouds and precipitation are calculated in the various climate models of the world with a number of parameterization approaches, thus generating quite different precipitation pattern. The fundamental problem is that the whole process of water vapour condensation and precipitation generation is barely understood, and that the database is not sufficient to calibrate the parameterizations in an optimal way.

As a consequence all the models show a different response of the precipitation change in certain regions, while they agree in others. At present, a statistical method is used by averaging the response of all the model simulations worldwide and to weight that response with the number of models agreeing.

2. The GCMs and the scenarios

The GCMs are based on the Newtonian equations of motion, the laws of thermodynamics and the ideal gas law. These equations are solved on a grid with a typical horizontal resolution of 200-400 square kilometre and about 20 to 40 layers in the vertical up to a typical vertical height of 20-30 km. Processes (e.g. cloud formation), which are smaller than a grid cell, are parameterized. These models, which are frequently derived from weather forecast models, are used to calculate the future climate under the assumption of future emission scenarios. These scenarios have been developed on behalf of the IPCC (Intergovernmental panel on climate change; IPCC, 2007) and are documented in the SRES-report (Nakicenovic, 2000) (Fig. 1). For the modelling studies, four marker scenarios have been recommended by IPCC for model experiments, which describe future developments ranging from a very ecological to a world relying almost entirely on carbon based energy production.

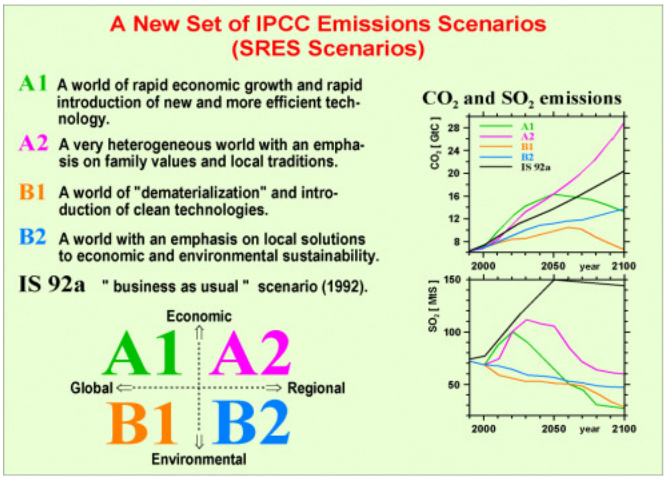


Figure 1. The SRES scenario families.

3. Global model results

Global climate model need a lot of computational effort. Only the major industrialized nations at present can afford to run such a model, and only for a limited number of cases. In order to obtain a larger sample and to make a statistical analysis of the confidence in the results, all the model experiments worldwide are collected and submitted to a common evaluation. The results of such a model average for an intermediate scenario (A1b) can be found in Fig. 2. To obtain this sample, 21 model experiments have been averaged.

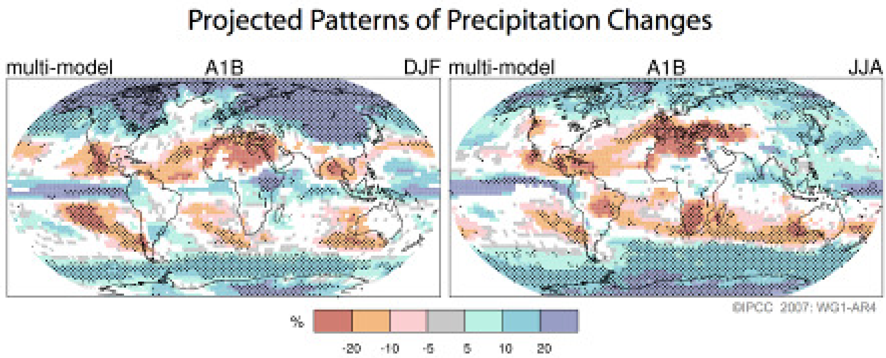
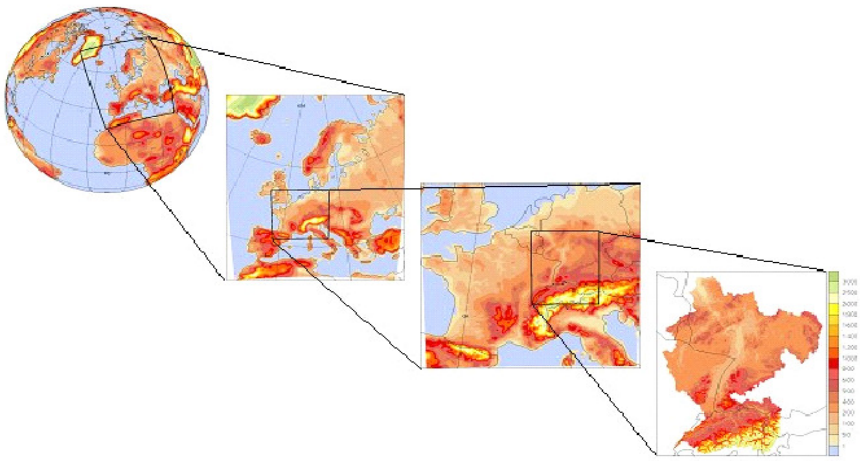


Figure 2. *The projected patterns of precipitation changes as simulated by a multi-model ensemble for December-January-February (left) and June-July-August (right). Stippling denotes where the magnitude of the multi-model ensemble mean exceeds the inter-model standard deviation (IPCC, 2007)*

In the tropics, the precipitation is reinforced. As the subtropical high pressure belts extents towards the poles, its dry climate is extended as well. In the latitudes pole-wards of the high pressure belt, the precipitation increases.

4. Downscaling

The horizontal resolution of the global models is too coarse to allow detailed local projections. A number of research groups, e.g. hydrologists and ecologists, are interested in high resolution information on the kilometre scale. To bridge this gap, so called downscaling techniques have been developed. The statistical downscaling method applies a statistical interpolation from the coarse GCM grid to the high resolution grid. This method is computationally inexpensive. It needs, however, long observational records for the point of interest. Another method, dynamical downscaling, nests a chain of high resolution regional dynamical models into the global GCM (Fig. 3).



x ~120 km 56 km 12 km 1km

Figure 3. *Schematic representation of the dynamical downscaling approach*

It needs large computation resources, but it can calculate non-linear effects, which is not possible with the statistical model. Combinations of dynamical and statistical downscaling can be found as well.

5. Regional precipitation change

The IPCC (2007) report describes the regional climate change for several continental scale regions of the world for the time period 2080 to 2099 for the intermediate scenario A1b. These regions have been simulated with high resolution regional models. The main findings can be summarized as follows (Fig. 4):

Africa: North Africa and South Africa will experience less rainfall than today, while the regions around the Equator and the eastern part of Africa (Athiopia, Somalia) benefit from an increased precipitation.

Europe: Southern Europe will become dryer in all seasons because the subtropical high pressure belt extents further northwards. Central Europe: The annual balance remains the same, but it will become dryer in summer and wetter in winter. This asks for a water management system in future to supply sufficient water to agriculture in summer. Northern Europe will generally become wetter.

Asia: The summer monsoon will become stronger. In winter large parts of Indochina will become dryer.

North America: The north and the east become wetter, the south and the west dryer. The snow line recedes in winter.

Central and South America: The Amazonas region will become wetter in the southern hemisphere summer, and dryer in the winter. Central America becomes generally dryer. A belt reaching from Ecuador to Uruguay and Paraguay will become wetter in every season.

Australia-New-Zealand: Australia experiences generally a dryer winter, in summer the eastern part of Australia becomes wetter, the western part dryer.
Arctic and Antarctic: The Arctic regions will generally become wetter.

6. Summary

While the rainfall in the global average increases, the local distribution will be quite different. Dry regions will extend due to a widening of the subtropical high pressure systems. The precipitation belt of the mid-latitudes is shifted towards the poles. In middle Europe, the seasonal cycle is shifted with more precipitation in winter and less in summer. The tropics will experience an increased rainfall. There is a tendency towards more intense precipitation events and longer drought periods.

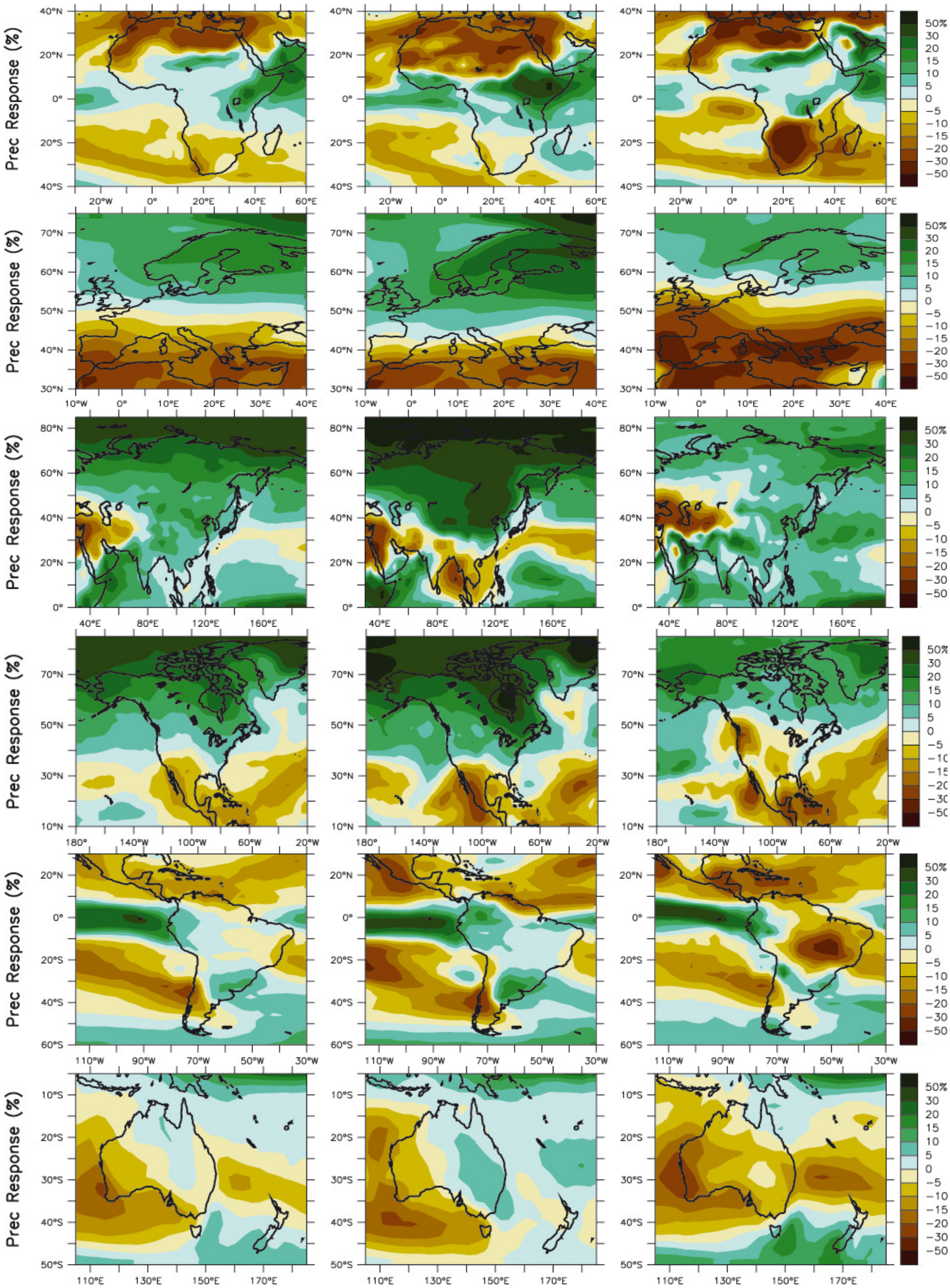


Figure 4. *The precipitation change for various regions of the world, calculated with high resolution regional models (left: annual mean; middle: DJF; right: JJA) (IPCC, 2007).*

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