Water in the atmosphere

Two recent papers of the atmospheric scientists Prof. Dr. Bjorn Stevens and Dr. Sandrine Bony address the Earth system´s essential component: water (in: Science and Physics Today, see references below). Prof. Stevens is Managing Director at the Max Planck Institute for Meteorology in Hamburg and leader of the department „The Atmosphere in the Earth system“. Dr. Bony works at the Institute Pierre Simon Laplace (IPSL) in Paris.

In an overview article in "Physics Today", the authors address the essential role of water in the atmosphere. Water - H_2O - is a small molecule with big impact. It exists in Earth's atmosphere in all three states of matter (solid, liquid, gas), with the distribution of each being strongly regulated by temperature. Water also interacts strongly with radiation, both in condensed and vapor forms and is the most important atmospheric constituent for Earth's energy cycle. Water's radiative effects also power the hydrological cycle, making it a crucial meteorological component of the Earth system that is linked to the dynamics of Earth's atmosphere.

In every respect water is fundamental to an understanding of the atmosphere and climate. Based on an understanding of robust and fundamental properties of water the authors' argue that the likely range of the climate sensitivity (the warming Earth will experience for a doubling of atmospheric CO_2) is better constrained than usually is thought, with a value between 2.2 and 3.4 K. But they go on to show that much of what we don't understand about weather and climate is closely linked to what we don't understand about water … like why the cloud responses are so different in different models as shown in the figure below.

The authors take up this point in a Perspectives article published by Science magazine (ref and link), where they argue that despite its importance the climate community has failed to focus sufficient attention on water, the atmospheres most important constituent. They point out that in the current climate and Earth system models, the representation of clouds and convection, or even more general, the coupling between the atmospheric water and circulation remains unsatisfactory, and that this distors their representation of the climate system and climate change. These distortions are particularly evident in the tropics (as shown in simple experiments with a water world, e.g., Fig) where the coupling of water and circulation is performed by smaller-scale processes that cannot be resolved by present day global models.

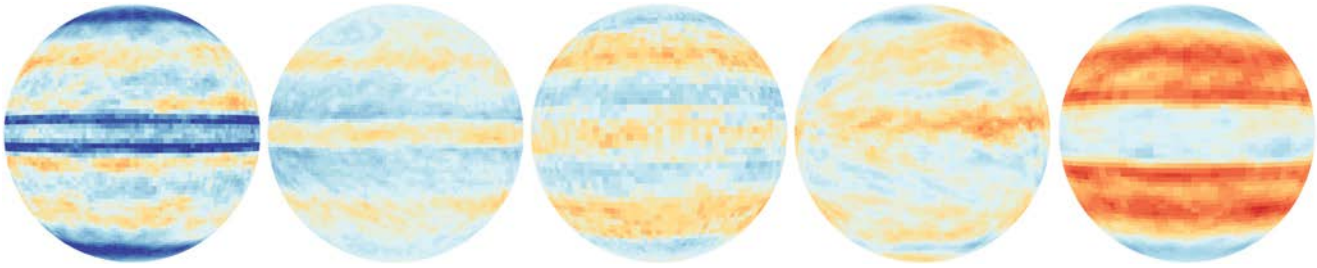

Fig.: The response patterns of clouds and precipitation to warming vary dramatically depending on the climate model, even in the simplest model configuration. Shown are changes in the radiative effects of clouds and in precipitation accompanying a uniform warming (4°C) predicted by four models from Phase 5 of the Coupled Model Intercomparison Project (CMIP5) for a water planet with prescribed surface temperatures.

Although we know enough about water to recognize global warming as a major and serious challenge, we do not know enough about the coupling of water with the circulation systems to predict regional changes with certainty, which are fundamental for the development of adaptation strategies. Understanding the coherence between water in the atmosphere and the large circulation systems, and thus the energy budget, is therefore also essential for progress in climate research. The authors come to the conclusion that what climate models are missing most is not a more comprehensive treatment of the Earth system, rather an adequate treatment of water. But fundamental progress, and eventually improvements in Earth system models, requires greater emphasis on these basic questions.

Recently the World Climate Research Program (WCRP) has endorsed these ideas through the identification of a focus on "Clouds, Circulation and Climate Sensitivity" which they asked Dr. Sandrine Bony and Prof. Bjorn Stevens to lead. Within this research program, the objective will be to guide the international community in articulating solvable problems related to water in the atmosphere and thus move climate research forward past some of the fundamental roadblocks that it now confronts.

Paper:

1. B. Stevens and S. Bony: What are Climate Models Missing? Science, Vol. 340, 31 May 2013.
2. B. Stevens and S. Bony: Water in the Atmosphere. Physics Today, accepted, June 2013.

Further information:

WCRP – Grand Challenges: http://www.wcrp-climate.org/index.php/gc-clouds

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