IPCC AR5: Projections, predictions and progress since AR4

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The IPCC AR5 Working Group One report, finalized in late-September 2013, provides the current state of human knowledge regarding climate variability and climate change. Here some of the main results are reviewed. One new area of climate science that has emerged since the AR4 is decadal climate prediction, where global coupled climate models are initialized with observations to produce near-term climate predictions. Results from such new model simulations, along with other lines of evidence, indicate that global warming in the near-term (2016-2035) is likely to be somewhat less than warming projected by uninitialized climate models. This relates in part to the current hiatus of global warming (little warming trend in the 2000s) which is mostly due to internally generated decadal timescale variability with some possible contributions from, for example, volcanic aerosols and solar variability. The climate change problem in the AR5 is framed in terms of mitigation targets in the four Representative Concentration Pathway (RCP) scenarios, which is a different perspective than in the AR4. In the CMIP5 multi-model dataset, the basis for much of the assessment of climate change for the AR5, global coupled high-top models, with better-resolved stratospheres, are represented along with the more traditional low-top models, thus providing new information regarding climate change.

Dynamical Cloud Feedback Mechanisms

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Cloud responses have long been known to dominate the spread of climate sensitivities in GCMs. Moreover, in many models the cloud feedback is the strongest positive feedback if the tightly-connected water-vapour and lapse-rate feedbacks are treated as one rather than separately. I will review recent results showing that many aspects of the cloud response in GCMs are consequences of relatively well understood changes in the general circulation of the atmosphere, giving us more confidence in them. The key circulation changes---a deepening of the troposphere, and a poleward shift of the storm tracks and associated expansion of the subtropics---each impinge to some extent on SPARC.

The crucial known exception lies in global changes in low-cloud cover, which differ dramatically among GCMs and have so far defied any obvious explanation or link to dynamics. I will present however new results offering a likely explanation for the tendency of models to produce less low cloud in warmer climates, and for why this is so inconsistent between models. About half the variance of climate sensitivity in the CMIP3 and CMIP5 models can now be explained on the basis of a new dynamical mechanism controlling low cloud cover change, whose strength can be diagnosed by observing the present-day climate.

Finally I will discuss what in my view are the crucial research needs and unanswered questions relating to cloud feedbacks. Key areas for SPARC include continuing uncertainties around the drivers and mechanisms of poleward expansion of the general circulation, and improving our understanding of the generation and maintenance of Earth's thin cirrus clouds, which remain a cloud-feedback wild card.

Polar Climate Predictability

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Over the last few decades, the polar regions have exhibited some of the most striking manifestations of climate change. Due to the polar amplification of the greenhouse-gas effect, the Arctic has been warming at a rate several times faster than the rest of the globe. Concurrently, Arctic sea ice extent has been retreating rapidly, more rapidly than predicted by most climate models, reaching a new record minimum in late summer (September) 2012. At the same time, the overall average Antarctic sea ice extent is observed to be slightly increasing, contrary to the model predictions, and a record late-summer *maximum* was seen in February 2013. The largest observed changes in Antarctic climate over the past few decades have occurred during the summer season and have been primarily attributed to the development of the ozone hole. On shorter time scales, modern seasonal prediction systems mostly rely on teleconnections originating from the tropical regions such as those associated with ENSO. However, recent studies have shown the existence of seasonal predictability associated with interactions in the climate system that involve aspects of mid- and polar latitudes such as soil moisture, snow cover, sea surface temperature, sea ice, solar variability, and stratospheric sudden warmings. Theoretical studies also suggest the possibility of having a predictable climate signal on the decadal time scale with maximal signal-to-noise ratio in subpolar ocean areas. However on such timescales the forced component of climate predictability is likely to be very significant, especially in the Arctic, which suggests that in polar regions the initial-value problem and the forced problem should be considered together.

The strong coupling between polar and subpolar oceans, sea ice, land surface, troposphere and stratosphere calls for an interdisciplinary approach to research on these regional climate systems and their interaction with global climate processes. Accordingly, the WCRP has recently established a “Polar Climate Predictability Initiative” (PCPI) to advance our understanding of the sources of polar climate predictability on a range of timescales ranging from seasonal to multi-decadal. Here “predictability” is understood to mean not just initial-value predictability but also predictability of the response to both natural and anthropogenic forcings. This talk will review the scientific issues that led to the establishment of the PCPI and describe the plans to move forward, with an emphasis on the role of SPARC within the initiative.

Long-standing Errors in Climate Models

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Climate models have developed far beyond their early use as tools of scientific inquiry and are now central to many decision-making processes in society, most notably those related to the mitigation of and adaptation to climate change. Close relatives of these models are used daily in weather and seasonal prediction adding further remarkable benefits to society. There is a high expectation that through the further development of weather and climate models the range of useful predictions can be extended as well as the quality of climate projections improved significantly, in particular on regional scales.

Despite much progress, there remain significant shortcomings in the simulation of the climate system. Many of these originate in the coupled atmosphere-land-ocean system and not only hinder model application but also significantly influence the addition of new model components in efforts to more comprehensively represent the whole Earth System. Errors in precipitation strongly influence the important biochemical process in the carbon cycle. Poor simulations of convection likely affect the transport and distribution of chemical species in more sophisticated treatments of atmospheric chemistry. Some of these key shortcomings have been present in several generations of climate models and have stubbornly resisted model improvement efforts.

This presentation will review some of the most long-standing model shortcomings. It will be shown that most of the errors originate in the representation of the flow of water through the climate system and are at least in part due to the need to parametrize many of the processes involved in that flow. We will highlight recent “process-oriented” approaches to model evaluation to show their potential in uncovering the reasons for the model behaviour. We will also attempt to analyse why solutions to the long-standing model problems have remained elusive and based on our analysis propose ways forward. We will show that to resolve the most burning model development issues will require a concerted effort by the entire climate science community and a renewed focus on “old” problems.

Temperature Trends: Our Evolving Understanding

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Stratospheric temperature is central to stratospheric chemistry and dynamics. It responds, on long and short time scales, to various natural and manmade climate forcings, including volcanic aerosols, solar variations, greenhouse gases, water vapor, and ozone-depleting substances. Stratospheric temperature changes are large compared with those at the surface and so are considered key indicators of global climate variability and change.

Since its early years (1990's), SPARC has sponsored a stratospheric temperature trends activity to assess and advance our understanding of temperature changes from observational and modeling perspectives. The resulting activities have led to several review papers (Ramaswamy et al. 2001, Randel et al. 2009, Seidel et al. 2011) and studies comparing model simulations with observations (e.g., Shine et al. 2003, Thompson et al. 2012). This work has also been a basis for contributions to both Intergovernmental Panel on Climate Change assessment reports and WMO/UNEP assessments of ozone depletion and has motivated deeper analyses.

This presentation will highlight some of the key advances (and retreats) over the past several decades in our understanding of stratospheric temperature trends, with particular focus on: the adequacy of the global observing system for monitoring stratospheric temperature, the complex temporal and spatial structure of temperature changes since the mid-20th century, and current outstanding questions.

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Impact of Aviation on Atmospheric Composition and Climate

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Aviation impacts the atmospheric composition and the climate by CO_2 and non-CO_2 emissions. Concerning CO_2, in 2000 aviation contributed about 2.2% to the total anthropogenic emissions. In the same year aviation contributed 3.6% of the anthropogenic emissions of CO_2-equivalent in EU-15. If EU-15 fulfill their 2020 target of 20% reduction relative to 1990, and if transport CO_2 emissions increase at rates similar to those during the last two decades, the fraction will reach 7.4%. Outside EU-15, aviation is expected to grow at a higher rate in many countries.

The atmospheric lifetime of most of the non-CO_2 aviation emissions is much shorter than the CO_2 lifetime. Nevertheless, the non-CO_2 climate effects from aviation are large in comparison to the CO_2 effect. This is mainly due to triggering new clouds (e.g., contrail cirrus) and modifying existing clouds, and due to the impact of nitric oxide emissions on the abundances of ozone and methane. In terms of radiative forcing (RF), aviation CO_2 was responsible for a about 1.6% of the anthropogenic RF in 2005. If all aircraft effects are included the fraction is about 5% (with a large uncertainty). Unlike many other anthropogenic impacts, the aviation impact can be substantially reduced by changing the location and time of emissions, i.e. by climate optimised flight trajectories.