State of the science

The Intergovernmental Panel on Climate Change (IPCC) released its fifth assessment report (AR5) on the physical science of climate change on 27th September this year. *Nature Climate Change* speaks to the co-chair of the working group responsible for the report, Thomas Stocker.

The IPCC Working Group I AR5 has recently been released. What is the most important finding?

I think the most important finding is in the last part of the Summary for Policymakers, regarding the cumulative carbon budget (that is, the total emissions since the late 1800s) and the linear relationship to the temperature response of the climate system (Fig. 1). Cumulative emissions will largely determine the increases in global surface temperature and the effects of climate change will persist for many centuries even if emissions are stopped. For the first time, we present this evidence — which is firmly anchored in the science of a complex system — to policymakers. It is a compelling way to make a policy relevant statement: a specific temperature target implies a limited carbon budget. This has direct implications for policy, as limiting climate change will require sustained and substantial reductions in greenhouse gas emissions.

In your view, has public interest in climate change decreased? Why?

The decreased public attention on climate started some time ago. People have been confronted with other serious issues — particularly in the last 5 years or so — such as the financial crisis, migration and associated problems that are affecting people's living conditions. What is important to realise is that climate change also affects conditions of living in a fundamental way, but does not always manifest across regions in the same manner. Take precipitation, for example: there are areas where it is becoming much drier, and others where they say "Oh we don't suffer from drought, but we have our frequent floods". Regional climate challenges are becoming evident to people, but they are not as immediate an impact as these other problems that people have to deal with daily.

What is your role as co-chair and how did the experience differ from your previous IPCC positions as a draft author of a summary report and a leading author?

The role of co-chair is very different. I have been a coordinating lead author of chapters in the third and fourth assessment

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reports (TAR and AR4). In 2008 I was elected to co-chair. Together with my Chinese colleague Dahe Qin, we took responsibility for the production of the Working Group I (WGI) contribution to AR5, which means the basic assessment report, the technical summaries and the Summary for Policymakers. Obviously this is together with authors and a technical support unit (which is customarily funded by the government of the developed country co-chair), who assist the co-chair and lead authors to organize and steer the process.

After AR4 it was discovered that non-peer reviewed publications had been cited. What measures were put in place to ensure that the best science was used in the latest report?

Working Group I bases its assessment primarily on peer-reviewed literature, but other scientific literature is also admissible, for example, information on specific regional issues. We instructed the lead authors right from the beginning to centre our assessment firmly in the scientific community. It is not enough to have 10 or 12 lead authors per chapter; it's important that you mobilize the scientific community through the inclusion of contributing authors. This is a long tradition in WGI and in my view, one of the elements that ensures we have an additional mechanism for error correction before we publish. In other words, we realise that the expertise of an elected lead author team is not fully comprehensive, with knowledge of every little detail. A humble author team needs to realize that it has some gaps and bring in other experts from outside. We recommended this at every lead author meeting, and I have personal experience of how to bring in further expertise at this scale. Colleagues are very willing to contribute a figure, a paragraph, check specific parts of the assessment and so on — we have collaborated with more than 600 scientists, who will be listed in the report as contributing authors. Having said that, I cannot guarantee that there won't be any errors. It is a human endeavour, so there may be mistakes that we have overlooked but we have a clear protocol for addressing necessary corrections.

Are there research and knowledge gaps that need to be addressed?

It is not our task to identify and point to research gaps or to suggest that governments direct funding to specific areas. However, when you make a comprehensive assessment of the current science you can easily identify areas where you would like to have more science and more progress — fields where the state of knowledge does not provide conclusions with more than medium confidence, there is an absence of best estimates or there are projected ranges that you would like reduced.

I can name a few areas, which are already evident from the chapter structure that we identified and outlined for this report. There is still large uncertainty in the understanding of clouds and aerosols, although it doesn't impact globally on the stringency of the overall message we deliver in the Summary for Policymakers. But we would prefer much lower uncertainties. Another issue concerns the availability, coverage and quality of precipitation measurements. This is a big limitation as we don't have a sufficient number of observations to properly assess model simulations of changes in the water cycle, and the detection and attribution of climate change.

How does knowledge of regional climate change measure up to that of global change?

From a scientific point of view it's actually in a much more embryonic state. We have large uncertainties in various factors — such as model capability — and we are hampered by our limited knowledge of processes that are important to understand the physical drivers relevant to regional-scale changes. We tried to address this in the report by producing an atlas of global and regional climate change, which I think should serve the community very well for the next couple of years (see Annex I of AR5). In addition to having the new atlas, research needs to continue to produce better models and to make sure that we have the observational data at the regional scale to actually test these improved models.

There has been a lot of discussion about the current warming hiatus and the inability of scientists to predict or explain it. What are your thoughts on this?

To me, the hiatus is a phenomenon that has been recently observed, and the hype was actually pushed by the media far beyond its relevance for long-term climate change. In 2009, the hiatus was not a topic of note in the public, and yet the scientists, stakeholders, and governments who scoped the content of our assessment identified near-term climate change and predictability as a highly relevant issue that merits an entire chapter. This was a fortunate foresight. During the assessment it became clear that the current phase of reduced warming was becoming a topic of increasing public debate. The scientists have reacted within our working groups to this evolving situation, and as a collective came to the consensus that we wanted to produce information about this interesting climate trend.

It is worth considering that a hiatus needs to continue for a certain time period to be distinguished from the natural variability and for scientists to start investigating. Researchers came to realize that there was a change in the global mean surface temperature trend, but it is only in the last two years that relevant studies have been published and model simulations have become available for analysis. I would call it, in summary, an emerging science topic and I would emphasize that, despite the public perception, there were very few publications that were available for inclusion in the report. Many studies that are being discussed now, at science meetings and in the media, have been published after the cut-off date for the AR5 report.

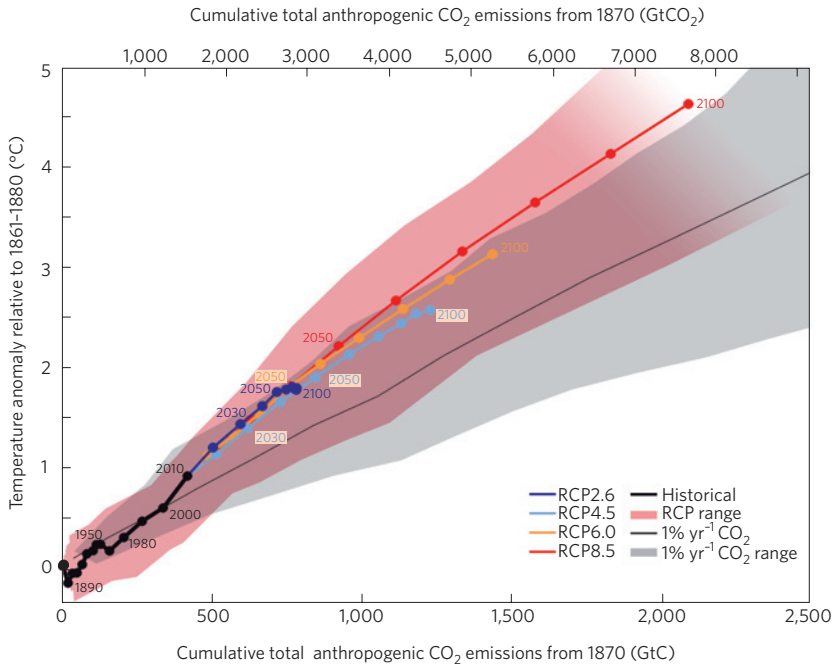

Figure 1 | Increases in global mean surface temperature as a function of cumulative CO_2 emissions using various future scenarios. The multimodel projections for historical emissions (1860–2010) and the different future scenarios are shown by the decadal means (dots), which are connected by straight lines. Each dot represents a decade, for example 2050 shows the mean emissions for 2040–2049. Figure reproduced with permission from *Summary for Policymakers, Climate Change 2013: The Physical Science Basis* © 2013 IPCC.

The implications of geoengineering for the physical climate were covered in the report for the first time. What prompted this inclusion and what were the findings?

Policymakers were asking for information about geoengineering, if sufficient information was available, and so we provided a section in the report. Although the literature is not as comprehensive as the projections of temperature and precipitation, for example, there were some model simulations and studies available. Concerted community efforts have started and some of these results on the consequences of geoengineering were used in this report.

We have gone as far as we could with the published material to reflect the state of research. We also made the point that we should include the topic in the Summary for Policymakers.

What is next for you?

For me personally it is outreach; with many lectures already scheduled. I will visit various communities and bring the message to the wider public and to the policymakers. More importantly, outreach will be carried out around the world by the best ambassadors of our science: the lead authors and coordinating lead authors who have performed this assessment over the past four years.

There is a lot of speculation on the future of the IPCC, what is going to happen? What are your thoughts on the best path?

I think, in a nutshell, this report has shown that the IPCC is strong, alive and kicking. We are continuing to produce top-level reports that are policy relevant, not policy prescriptive. I know of no other document that has been reviewed in such a thorough way, and no other scientific community that is volunteering their time, effort and intellectual power to assess their science — in an open and comprehensive way — and bring it to the public for free.

One thing that has been missing when it comes to shaping future of the next assessment is the voice of the scientists. For example, can the community still carry the burden of comprehensively assessing the literature in this ever expanding field? To discuss these issues and challenges I have organized and will chair a town hall meeting at the American Geophysical Union Fall Meeting on 9 December (http://go.nature.com/5yBcRc) to collect their views. I am very curious about what will come out of that.

INTERVIEW BY BRONWYN WAKE