21 IPCC Working Group I: The Swiss contribution 1988–2014

Thomas F. Stocker

University of Bern, Physics Institute, Climate and Environmental Physics, Bern

21.1 Introduction

The foundation of the Intergovernmental Panel on Climate Change (IPCC) by both the World Meteorological Organization (WMO) and the United Nations Environment Programme in 1988 was prompted by the determination to provide scientific information to the planned United Nations Conference on Environment and Development in Rio de Janeiro in June 1992 [Bolin, 2008]. Three international conventions were opened for signature at this conference: the Convention on Biological Diversity, the United Nations Convention to Combat Desertification and the United Nations Framework Convention on Climate Change (UNFCCC). The UNFCCC is the most comprehensive, but probably also the most difficult document that resulted from this first Earth Summit. It entered into force on 21 March 1994, within less than 2 years from the first Earth Summit – an astoundingly short period of time considering the challenges associated with the implementation of the goals laid down in this document. The scientific evidence provided by the First Assessment Report of the IPCC (FAR), published in 1990, made a convincing case that climate change will alter in a significant way the physical conditions on Earth, and that this will have an impact on the ecosystems around the world.

This chapter reflects on the role of the Swiss scientific community in IPCC and highlights its various important contributions over the years. I focus on Working Group I (WGI), the group that deals with the natural science aspects, the science area to which Switzerland has so far made the most numerous and substantial contributions. Swiss climate research has long focused on the physical aspects of the problem: the first research institution at a Swiss university to include the term "climate" in its name was the division of Climate and Environmental Physics at the University of Berne founded by Hans Oeschger [Stocker, 1999]. Hans Oeschger and his colleague Uli Siegenthaler were Lead Authors of a chapter in the WGI contribution to the FAR [Watson et al., 1990].

Understanding climate change requires an approach that encompasses many disciplines of science: the natural sciences, biology, ecology, risk analysis and many others. If response strategies to anthropogenic climate change are also included, as foreseen in the mandate of the IPCC, economics, social science and even philosophy are making important contributions to a comprehensive understanding of the problem. The three IPCC working groups (WGI – the Physical Science Basis, WGII – Impacts, Adaptation, and Vulnerability and WGIII – Mitigation) cover these areas of science in their three comprehensive reports [IPCC, 2013; 2014a, 2014b, 2014c], and provide the basis for a collective and integrated assessment in the Synthesis Report [IPCC, 2014d]. Because of this complexity, a well-structured process of scientific assessment that brings the wide ranging science to the user in digestible form is indispensable.

Various approaches could be envisaged to convey the science to the decision-makers and governments with different degrees of effectiveness and robustness. There are the voices of eminent scientists, such as James Hansen, who in 1988 testified that "the global warming is now sufficiently large that we can ascribe with a high degree of confidence a cause and effect relationship to the greenhouse effect …" [Hansen, 1988]. Or notably 10 years earlier, by the two scientists from the Physics Institute of the University of Berne in a landmark paper in *Science*: "… a maximum atmospheric CO_2 level might be found which should not be exceeded if the atmospheric radiation balance is not to be disturbed in a dangerous way" [Siegenthaler and Oeschger, 1978]. Alternatively, one could establish a "think-tank" with a few eminent scholars which would select the information and communicate it to the policymakers. Or the collection and digestion of scientific information could be tasked to a union of scientific academies. A "modern" approach would be the outsourcing to a private company. Yet another way would be to simply leave this crucial problem to the well-oiled machinery of classic lobbying by which filtered "information" is delivered to the policymakers on a "free market" basis.

During the preparations towards the Rio Summit, and in light of the experience of the Brundtland Report "Our Common Future," published in 1987, Bert Bolin, the founding Chair of the IPCC, and others realized that none of the above approaches would be an effective way to bring the scientific knowledge authentically and authoritatively to politicians. Statements by individual researchers could be taken out of context and result in a "chaotic debate between scientists and the public," as noted by Bolin [2008]. Elitist "think-tanks" might produce very valuable information, but they would not have the broad support of the scientific community and the governments. Finally, academy reports or "free market" information would not have the important buy-in by governments worldwide, and their production process might risk a lack of transparency. Instead, thorough scientific information was sought from findings in the peer-reviewed literature – and therefore transparently available to all – assessed by the leaders in the respective scientific fields, reviewed and commented on critically by experts and governments, and finally distilled into understandable information.

Fortunately, for man-made climate change, "one of the greatest challenges of our time," as stated in UNFCCC [2010], the IPCC was able to establish itself as the authoritative source of comprehensive scientific information on this problem. The consistent efforts by the IPCC to increase awareness about man-made climate change and its impacts on resources and potential conflicts in the near future caused by it were prominently recognized by the Noble Peace Prize in 2007. Certainly, the early years of IPCC were important and formative, and the very small number of colleagues who served as authors in various reports were pioneers and laid the solid ground for this success.

It must have been evident that the scientific information provided by the IPCC would be a threat to some interests outside science. Before long, therefore, there were massive attacks from various quarters, often by illegal means, launched towards IPCC and directly towards scientists. Despite a continuing string of biased, spin-doctored and even plain wrong media coverage on the IPCC's work and findings [Oreskes and Conway, 2010] – even despite numerous *ad hominem* attacks on scientists – the scientific community has continued to deliver robust information through IPCC to governments since the release of the FAR in 1990.

The firm position of the IPCC is the consequence of three characteristics. First, the panel is constituted by the participating governments and is the supreme body of the IPCC. This implies that it elects the leadership of the IPCC, and defines the work program and the products. The panel also approves, line-by-line, the "Summary for Policymakers" of the assessment and adopts the underlying reports. Second, the reports, including the "Summary for Policymakers," are written by the scientists who are selected by the panel on the basis of their expertise and given the mandate to carry out the scientific assessment. The clear separation between the panel requesting the report and the scientists writing it guarantees that the science is upheld, and that particular policy interests do not influence or bias these assessments. And third, because of the complexity of the task, the IPCC has clear procedures (the Principles Governing IPCC Work), which are established and agreed upon by the panel. In addition to defining the structure and work flow, two elements of the Principles are crucial for the integrity of the assessment: (1) scientific assessments need to be policy-relevant but policy neutral, and (2) assessments undergo multiple stages of expert and government review.

However, the greatest asset of IPCC, which is also the bedrock of the authority of its reports, is the fact that, in the 27 years of its existence, IPCC has always been able to recruit the best scientists to contribute, on a voluntary and unpaid basis, their time and expertise to prepare comprehensive assessments. I know of no other scientific community that has rendered such a service to the public during such a long time.

Climate research has experienced a tremendous growth in the past few decades. A trivial but telling example is the fact that a search for "climate change" in the Thomson Reuters Web of Science yields 7,106 articles from 1900 to 2000, the time of the TAR, a mere 70 mentions per year. Since 2001, however, more than 110,000 articles appear in the search for the term "climate change." This exceptional growth of the field is also evident in the increase of volume of the comprehensive assessments by Working Group I. Figure 21.1 shows the cover of the five successive WGI contributions to the IPCC assessment and their increase in page numbers. While

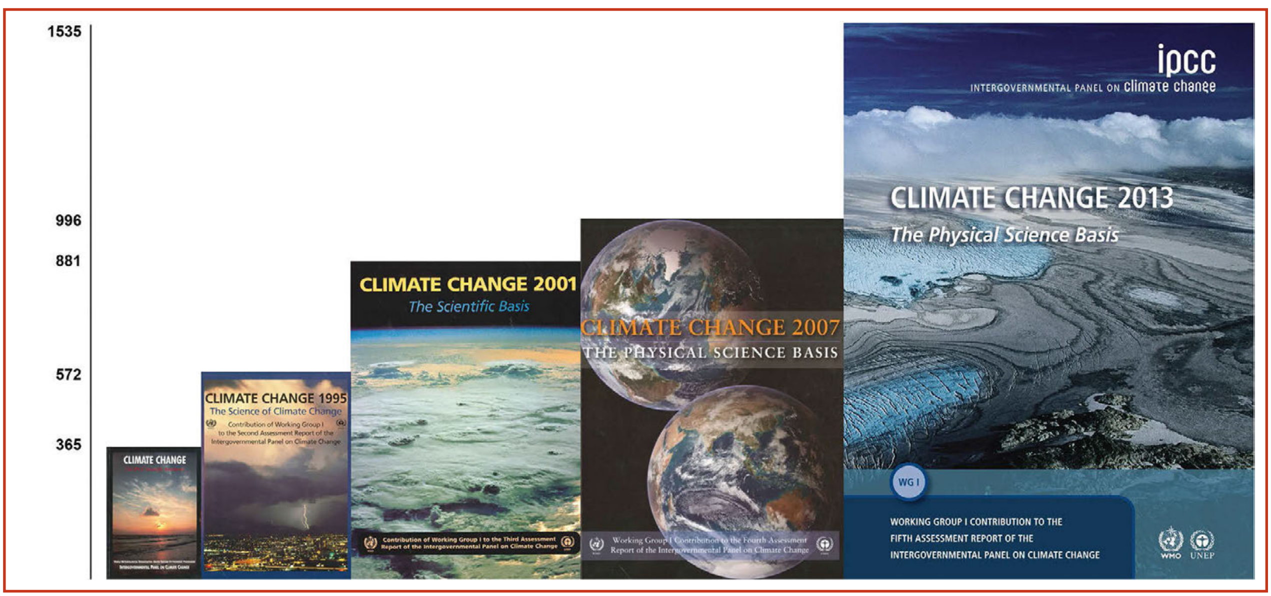


Figure 21.1:
The five successive assessment reports of IPCC Working Group I. In this figure the height of the cover image scales with the number of pages of the report, which is indicated on the left axis.

some of this growth can be attributed to a certain laxness of the Co-Chairs leading the process – distinguished colleagues excluded – it is obvious that the ever-increasing number of published papers in this field demands some increase of volume of an assessment that has the ambition to be comprehensive.

21.2 Production Process: Complex but Transparent

The production process of a scientific assessment is very complex, and the work cannot be completed successfully without a Technical Support Unit (TSU) under the direct leadership of a Co-Chair, who bears co-responsibility with a colleague Co-Chair for all products of the working group. The TSU coordinates and handles the entire workflow, which entails creating a working space for the lead authors and providing the end-to-end service necessary to bring a number of chapters written by more than 200 scientists around the world into one coherent and internally consistent assessment report. Figure 21.2 illustrates the flow of work of WGI during the fifth assessment cycle. This work flow is shared in principle by the three working groups, albeit with different timeframes for the drafts of their reports. The cycle starts with the election of the leadership of a working group, which consists of two Co-Chairs, from a developing and a developed country, and six Bureau Members from different UN regions. During the entire cycle, three groups closely

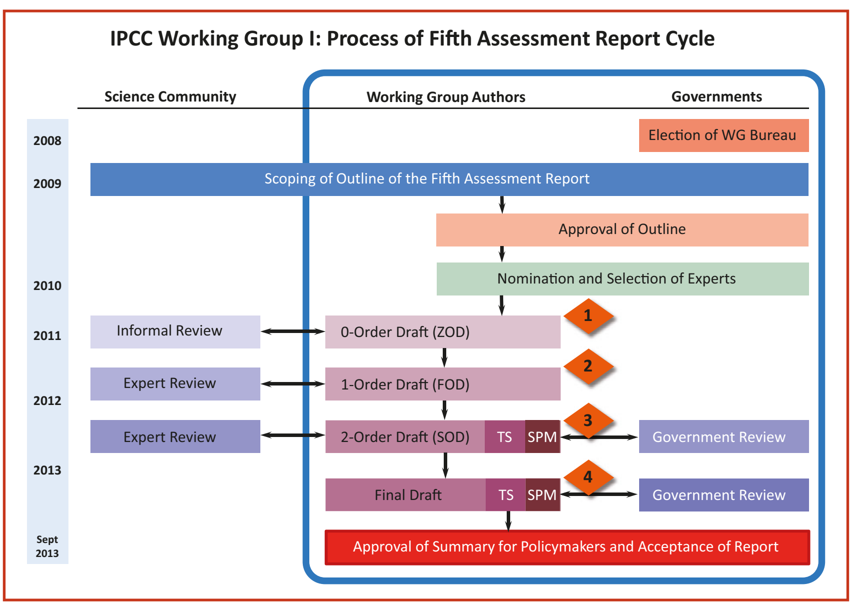


Figure 21.2:
The complex, interactive process between the scientific community, the selected authors and the governments during the fifth assessment report cycle. The timeline is for Working Group I, but all three working groups followed this process from the election to the approval and acceptance of their report. The timing of the four Lead Author Meetings of WGI is indicated by numbered diamonds.

interact: the governments represented in the panel, the authors of the assessment, and the worldwide community of scientists and experts.

The first action of invited representatives of the three groups is to work out an outline of the assessment, which consists of the list of the proposed chapters of the report plus a few bullet points to inform the prospective author team about the desired content of the chapters. This scoping document is discussed by the Panel. After approval, it becomes the primary guidance for the authors of a working group. The outline also determines the expertise needed on the author team. For the fifth assessment cycle, in 2010 WGI received 1,014 nominations from governments and international organisations. It is worth remembering that this was a period during which IPCC was under heavy attack in the media in the wake of stolen emails in November 2009. These were the stormy months of the so-called "Climategate." Critics were many, and the most extreme proponents even called for the complete dissolution of the IPCC. It was therefore very reassuring to see so many nominations of experts for all three working groups. With this the science community demonstrated that they stood firmly behind the IPCC process and the broader purpose of its work.

Once the author team has been selected, considering the required expertise and taking into account regional and gender balance, a sequence of drafts is prepared by the authors, which are then submitted to the TSU, usually several weeks after the face-to-face meetings of the entire author team and the working group leadership. These lead author meetings, usually 4 days long, are absolutely crucial to the consensus finding process on which the assessment relies. It turns out that, as the report matures, these meetings are the one opportunity to deal with important cross-cutting issues that emerge during the assessment. Important examples for WGI AR5 include the implication of changes in the perturbation of the Earth's radiative balance (Chapter 8) on the energy content of the ocean (Chapter 3), on attribution of climate change (Chapter 10), on climate sensitivity and other metrics (Chapter 12) and on sea level rise (Chapter 13).

The parallel production of the summary documents, the Technical Summary and the Summary for Policymakers (SPM) is also indicated in Figure 21.2. It starts once the first order draft of the report is ready. These additional key documents make the management of the process increasingly challenging because of the risk that inconsistencies might develop in the course of the many text revisions. A further challenge is the Summary for Policymakers, which needs to be written in an understandable and yet scientifically accurate language. The relevant scientific information, including numbers and uncertainties, must be available in the SPM, while at the same time messages should be clear. The text must be traceable back to the chapters of the assessment, and it should include only material that is robust and relies on multiple lines of independent evidence. It must have the support of the author team and have undergone a thorough review. Finally, it is debated and approved, line-by-line, by the panel. This is a lengthy and sometimes cumbersome process, but eventually it transfers special power to this document. Provided excellent authorship and good leadership throughout the process, this approach is able to generate a strong document that is the true voice of the science and at the same time accepted by governments. It forms the scientific basis for informed decisions without actually prescribing them.

The most important element ensuring transparency in the production of the IPCC assessment is the multi-stage review process. The first- and second-order drafts undergo a wide expert review. In AR5 this was an internet-based review by which an expert could sign up and obtain access to the draft documents and then submit a review. The bar of what constitutes expertise was kept deliberately low: A self-declaration of expertise was sufficient to be invited to participate. In addition to the two expert reviews, there are also two government reviews (Figure 21.2). In total, WGI has received 54,677 comments, all of which have been responded to in writing by the author team. The responses are public, so again transparency is ensured in the process.

An additional element of transparency was achieved by the implementation of a Conflict of Interest policy for all authors and functionaries of IPCC, first designed and implemented by WGI already in October 2010 and then adopted by the panel in November 2011.

Today, many agencies and organizations carry out "assessments." However, because of the rigorous procedures that guide the IPCC process, the breadth of the author teams, the multi-stage review of the successive drafts and the government approval process, the IPCC assessment remains one of a kind. The price paid for this thoroughness and comprehensiveness is the overall duration of the assessment: Generally 4 years or more pass from the scoping to the final approval. Rapid responses or updates, as often called for, are fundamentally at odds with the current approach and quality standards of an IPCC assessment.

21.3 Switzerland and IPCC: Contributions by the Swiss Scientists to IPCC WGI

Since the FAR of the IPCC, Swiss scientists have held leading roles in WGI, then simply called "The Scientific Assessment" [IPCC, 1990]. Hans Oeschger and Uli Siegenthaler of the University of Berne served as two of the only four lead authors of the first chapter on greenhouse gases and aerosols. Siegenthaler continued this role in the first special report on radiative forcing [IPCC, 1995], which laid an important foundation for projections. For this report he used the "Berne model," a simplified climate-carbon cycle model [Siegenthaler and Joos, 1992]. This Swiss contribution was among the first systematic projections using a carbon cycle component in the model, and it became the representative model to project CO_2 concentrations resulting from fossil fuel emissions.

Fortunat Joos from the University of Berne was elected Lead Author of chapter 2 on radiative forcing in IPCC [1996] and carried out the calculations of future CO_2 concentrations using the Bern model as one of three models employed in the second assessment report. The model provided updated values of the Global Warming Potential which were used in the Kyoto Protocol to calculate the CO_2 equivalence of anthropogenic emissions of various greenhouse gases.

For the third assessment cycle, Fortunat Joos was nominated by Switzerland and was elected WGI Vice-Chair, a member of the leading body of WGI. This third comprehensive assessment reflected significant advances in climate sciences by presenting a chapter on aerosols and their direct and indirect effects on the radiative forcing, a chapter on the carbon cycle, and a much extended assessment on the detection and attribution of climate change [*IPCC*, 2001]. The Berne model was one of the leading models in the assessment of the carbon cycle and related processes on a global scale [Joos et al., 2001]. I was tasked to coordinate the chapter on Physical Climate Processes and Feedbacks and take a very broad view of the climate system ranging from water vapour and cloud feedbacks, to processes involving modes of natural variability and nonlinear changes and thresholds, such as those associated with the Atlantic meridional overturning circulation [Stocker et al., 2001]. The major challenge of this assignment, however, was the diverse composition of the authors of this chapter, as it included personalities with firm convictions regarding the causes of observed climate change, ranging from unequivocal human-caused climate change to essentially primarily natural variations and irreducible uncertainties in the climate system. It was personally a very demanding task, but ultimately highly educational for me to lead this interesting group of colleagues, find consensus on hotly debated issues, and finally arrive at acceptable and robust formulations.

Following the third assessment report (TAR) the number of Swiss scientists increased significantly, not the least because of a higher activity and visibility of climate research in Switzerland. The National Centre for Competence in Research, NCCR Climate, which was created in 2001 with the University of Berne as the leading house, indirectly contributed to this enhanced role. In the fourth assessment report (AR4), three scientists served as lead authors (Fortunat Joos, University of Berne, and Ulrike Lohmann and Reto Knutti, later at ETH Zurich), who contributed their expertise in paleoclimate, aerosols and cloud physics, and climate modelling, respectively. I was charged with co-leading the chapter on climate change projections [Meehl et al., 2007], which combined projections across an entire hierarchy of climate models.

The fifth assessment report cycle (AR5) then saw a further strengthening of the Swiss contribution to IPCC by the willingness of the government of Switzerland to nominate me for the position of Co-Chair of WGI. A secret ballot was necessary as for the first time four nominations were submitted for the developed-country co-chair position. On September 3, after two rounds of ballot, I was elected Co-Chair of WGI and took joint leadership with Qin Dahe from China.

The first task was to establish a Technical Support Unit (TSU) at the University of Berne, which was funded by a special grant of the Swiss Federal Office for the Environment. The premises, IT and administrative embedding were provided by the University of Berne. The TSU formally started operations with the appointment of Melinda Tignor (USA) and Gian-Kasper Plattner. Melinda Tignor brought in unique experience as the Administrative Officer of the WGI TSU of AR4 and ensured a smooth transition with continuing institutional memory. With Gian-Kasper Plattner I was able to recruit an excellent scientist and colleague as Director of Science, a former PhD student and postdoc at the University of Berne who has had ample knowledge on the carbon cycle and who had carried out and coordinated the projections based on simulations using Earth System Models of Intermediate Complexity (EMICs) for AR4. What was important for this new position in a TSU was the combination of deep scientific understanding with a keen interest in the political process and the societal implications of our assessment work. Pauline Midgley joined as the Head of TSU with previous experience as the leader of the German IPCC Coordination Office and member of the German delegation to IPCC plenaries, providing the important perspective of the policymakers. Judith Boschung joined as an all-round Administrative Assistant, and Vincent Bex served as IT Officer. The starting phase of the work was extremely demanding since the panel had already requested information about the current state of knowledge on greenhouse gas metrics, an issue of highest policy relevance, and the scoping of a special report on extreme events and disaster reduction [IPCC, 2012a], jointly with Working Group II in the lead. The latter required the appointment of a Science Officer, Simon Allen, a young postdoc from New Zealand. Later in the process, Yu Xia and Alexander Nauels joined the TSU as Science Officer and Science Assistant, respectively. With this international team of excellent and dedicated colleagues forming the WGI TSU, we were ready for the challenging task to once more produce a comprehensive assessment on the physical science basis of climate change. Working with this fine TSU, on which I and the entire author team could rely anytime, anywhere and under any circumstance, was one of the most rewarding experiences of my co-leading WGI.

After the scoping of the special report and the later scoping of the WGI report, scientists were nominated by the governments for the various functions of Coordinating Lead Authors, Lead Authors, and Review Editors. The WGI contribution to the special report consisted of one chapter for which Sonia Seneviratne (ETH Zurich) served as Coordinating Lead Author. For the comprehensive report of Working Group I, the involvement of scientists from institutions in Switzerland was substantial (Table 21.1).

The selection of the author team is a crucial task at the start of the assessment process; it determines the success of the venture. It takes several weeks serious consideration and requires the full attention of the TSU, the working group Bureau and the Co-Chairs. The TSU prepared for each of the 1,014 nominated scientists a documentation that included the curriculum vitae, a list of publications, information about the areas of scientific expertise and an overview of their most recent research. Based on the requirement to have expertise on all topics mentioned in the panel-approved WGI scoping document, ideally covered by more than one scientist, and taking into consideration regional and gender balance, a team of 259 scientists was selected by the panel. It is remarkable that Switzerland could contribute expertise to all but one chapter of the WGI contribution (Table 21.1).

Finally, it should be emphasized that Swiss scientists engaged in all reports produced in the IPCC's fifth assessment cycle, i. e., not only in the comprehensive assessment reports of the three working groups, but also in the two Special Reports of that cycle (Table 21.2).

Table 21.1: Scientists working in Switzerland contributing to the 14 chapters in the Working Group I contribution to the IPCC Fifth Assessment Report [IPCC, 2013], in their roles as Coordinating Lead Authors (CLA), Lead Authors (LA), Review Editors (RE) and Contributing Authors.

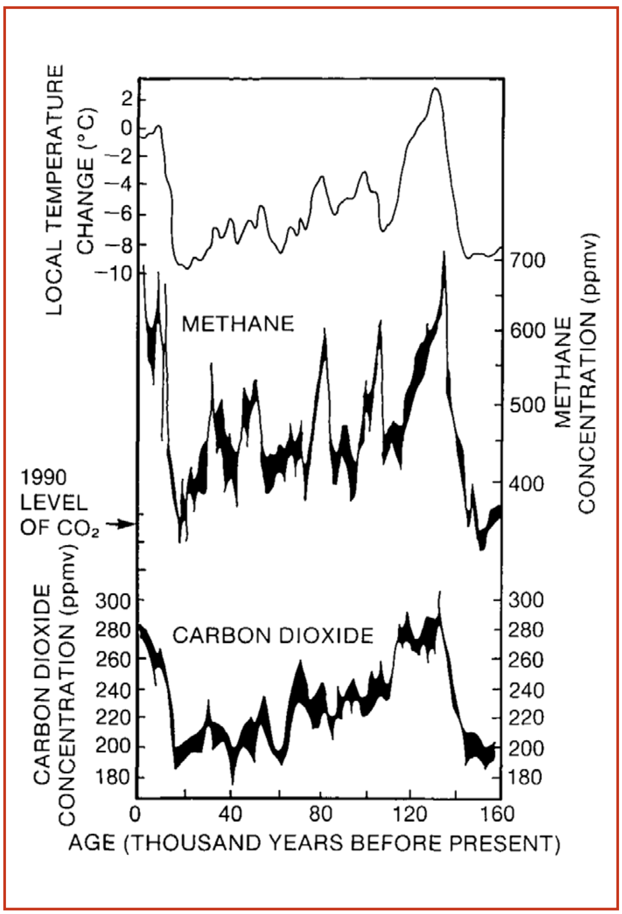
Ch	CLA and LA	RE	Contributing Authors
1			Richter
2	Brönnimann, Wild		E. Fischer
3			N. Gruber
4	Paul, Steffen		S. Gruber, Huss
5	Beer	Wanner	H. Fischer, Fröhlich, Knutti, Sedláček
6			N. Gruber, Joos, Kaplan, Spahni, B. Stocker
7	Lohmann		
8			Kaplan, Roth
9			Knutti
10			Beer, Knutti, Lohmann, Mahlstein, Rogelj, Wild
11	Schär		Sedlàček
12	Knutti		Beyerle, E. Fischer, Huber, Rogelj, Sedláček
13			
14			Sedlàček

*Table 21.2: Scientists working in Switzerland contributed to all assessment reports produced during the fifth assessment cycle of the IPCC. SREX and SRREN are the two special reports [IPCC, 2012a; b]. * indicates a Chapter Scientist, an informal assisting role created by WGII.*

	CLA and LA	RE	Contributing Authors
WGI	Beer, Brönnimann, Knutti, Lohmann, Paul, Schär, Steffen, Wild	Wanner	Beer, Beyerle, E. Fischer, H. Fischer, Fröhlich, N. Gruber, S. Gruber, Huber, Huss, Joos, Kaplan, Knutti, Lohmann, Mahlstein, Richter, Rogelj, Roth, Sedlàček, Spahni, B. Stocker
SREX	Campbell-Lendrum, Maskrey, Peduzzi, Seneviratne		Allen, Ash, Della-Marta, Gerber, Huggel, Rist, Orlowski, Peduzzi, Seneviratne, Zodrow
SRREN	Wüstenhagen		Bauer, Burgherr, Meier, Panitchpakdi, Truffer
WGII	Huggel, Karapinar	Fischlin	Beniston, Frölicher, Lischke, Sedlàček, Buob*
WGIII	Cottier, Michelowa, Müller, Patt, Robledo Abad		Holzer, Michelowa, Rogelj, Sedlàček, Stadelmann
SYR	Plattner, Stocker		Sedlàček

21.4 Key Scientific Contributions by the Swiss Research Community

Of course, the continually growing climate science community of Switzerland has made numerous contributions relevant to IPCC since its beginning in 1988. One could, for example, count the cumulative number of references in IPCC with Swiss lead. It is, however, more instructive to showcase two examples of Swiss involvement, which are very substantial and have had an impact right up to the top-level documents.



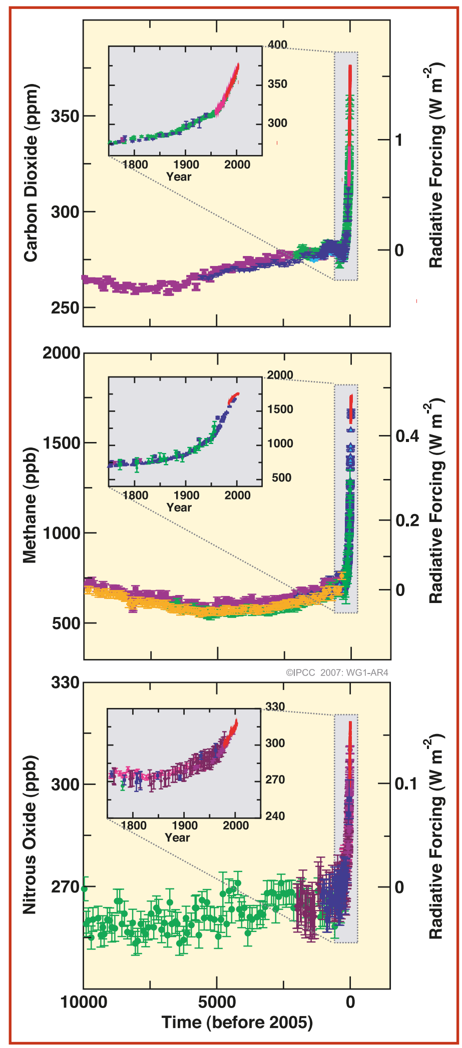


Figure 21.3:
The paleoclimate record of greenhouse gases has been a cornerstone result in IPCC assessment reports since 1990. Above: Figure 2 of the Policymakers Summary of the FAR [IPCC, 1990]; right: first figure of the Summary for Policymakers of the AR4 [IPCC, 2007].

The long-term reconstructions of greenhouse gas concentrations in the atmosphere provide the most important context for the observations of atmospheric composition change in the past decades. CO_2 and CH_4 records along with the Antarctic temperature estimates based on stable water isotopes were prominently presented in the second figure of the Policymakers Summary of the FAR [*IPCC*, 1990] (Figure 21.3).

CO_2 and CH_4 concentrations over the past 160,000 years were based on measurements on ice taken from the Vostok Station in Antarctica, providing for the first time information on an entire ice age cycle [Barnola et al., 1987; Chappellaz et al., 1990] and were supported by detailed measurements covering the last 50,000 years carried out at the University of Berne [Neftel et al., 1982; Stauffer, 1984; Neftel et al., 1988; Stauffer et al., 1988]. "Berne data" in high resolution were also featured in the SPM of IPCC [2001] and IPCC [2007] allowing a comparison not only of the magnitude, but also of the speed of the anthropogenic perturbation with natural greenhouse gas variations (Figure 21.3). The most recent reconstructions back to 800,000 years were referred to in AR5 [Loulergue et al., 2008; Lüthi et al., 2008; Schilt et al., 2010], notably in the first and third headline statements of the SPM of the Synthesis Report [IPCC, 2014d]. These data are not proxies, but rather direct measurements of past atmospheric composition, the best example of quantitative paleoclimatic reconstructions, which provided many new insights on variations of drivers and climate indicators before the instrumental era. This branch of climate research has particularly grown and matured during the IPCC assessment cycles, the result being that dedicated chapters on paleoclimatic archives were included in AR4 and AR5.

A second example of an important early contribution of the Swiss science community was the concept of the accumulated anthropogenic emissions, although the link to temperature and the policy importance had not yet been emphasized by IPCC then. Based on simulations using the Berne model, the near linear dependence between the stabilized CO_2 concentrations and future accumulated emissions was recognized (Figures 21.4a, 21.4b), and the result was presented in the SPM of IPCC [1995]. The authors already pointed out the fact that this dependence was relatively insensitive to the concentration profile used. These early insights became a prominent and highly policy-relevant finding in AR5 (Figure 21.4c). This was based on a series of modelling studies that went a step further by linking the peak warming in the 21st century, instead of the CO_2 stabilization concentration, with the cumulative emissions [e.g., Allen et al., 2009; Matthews et al., 2009; Meinshausen et al., 2009]. This is clearly a relationship that is more easily communicated

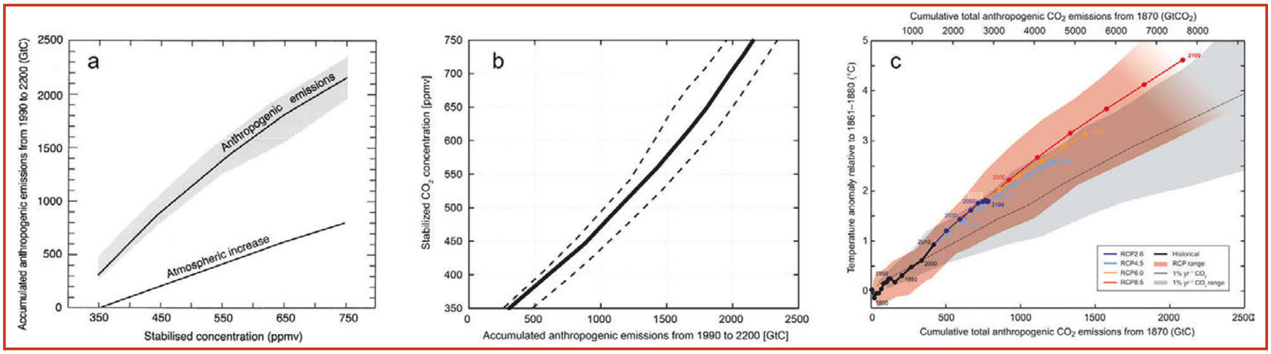


Figure 21.4:
Concept of cumulative CO_2 emissions: (a) as shown already in the SPM of IPCC [1995]; (b) anthropogenic emissions of (a), plotted in a diagram with swapped axes, for comparison with panel (c); (c) Figure 10 in the SPM of IPCC [2013].

as it directly connects the global climate impact, i. e., the warming, with the totality of anthropogenic carbon emissions.

The final figure (Figure 21.4c) as accepted in the SPM of IPCC [2013] was the result of many months of iterations among the lead authors, the TSU and the Co-Chairs. The first-order draft of the SPM did not include such a figure; but given the need for a policy relevant statement derived from the wealth of information from climate model projections carried out under CMIP5 and models of reduced complexity, the author team finally converged on the basic layout shown in Figure 21.4c. It was a challenge to include information from the entire model hierarchy and combine it with a careful assessment of uncertainty, in order to have a figure based on multiple lines of independent evidence, a requirement for all figures in the WGI SPM. Here, the research group of Reto Knutti at ETH Zurich generated from their numerical database literally hundreds of different figure versions until a solid consensus on this figure was reached in the author team. This produced sufficient confidence to present it to the policymakers in the final draft of the SPM and to defend it during the approval plenary.

21.5 The IPCC Work as a Unique Stimulus of Scientific Research

Participating as a Lead Author or Coordinating Lead Author in an IPCC represents a significant commitment for a period of over 4 years. The contribution is voluntary, unpaid and mostly unassisted. Yet, for the past 27 years the IPCC has succeeded in recruiting many of the best and most active scientists to join the author teams. A recent survey carried out by the TSU of WGI among the AR5 author team showed that more than 90 % rated their overall experience as good or very good, and 68 % would serve again in the same setting [Stocker and Plattner, 2014]. With the growth of climate science, as evidenced in the size of the reports (Figure 21.1), the burden on the scientists to carry out a comprehensive assessment has increased substantially. What is then the motivation of these scientists to continue to participate?

Based on my personal experience since the TAR, the secret lies in the combination of three elements: (1) you are working on one common product that will have a high international impact, far beyond the quarters of the specialists; (2) you are debating contentious and scientifically difficult issues with many of the leading colleagues and competitors in the attempt to find consensus; and (3) the process is intellectually challenging and stimulating for your own research, which pushes you forward. In talking to many scientists and observing the process over the years – and leading it from 2008 to 2015 – I have concluded that this truly scientific interaction with colleagues, despite the many administrative, procedural and sometimes political vagaries that the IPCC work entails, remains the most effective motivator for a scientist to be part of it and contribute to.

Participation stimulates: Here I present a few examples from the Swiss climate science community where the participation in the IPCC assessment has directly inspired subsequent research.

During the first two assessment reports and the special report on radiative forcing, the need arose to calculate the response of the coupled climate-carbon cycle system for many emission profiles and in particular to determine the metrics, e. g., the Global Warming and Global Temperature change Potentials, that are extensively used in economic calculations of emission pathways and in climate negotiations of the UNFCCC. A very efficient approach is to convolve the emission profile with the pulse response of a specific climate-carbon cycle model [Joos et al., 1996]. Only very few and highly simplified climate-carbon cycle models were available in these earlier assessments. Now, a total of 15 models participated in the latest intercomparison stimulated by the approaching completion of the AR5 [Joos et al., 2013].

For the first time the TAR contained a dedicated chapter on the carbon cycle, so that climate-carbon cycle feedbacks and their quantification became a focus. The Berne model hierarchy addressed both land and marine carbon-climate feedbacks. For example, we have used the Berne 2.5CC model to investigate the effect of ocean warming and circulation changes on the ocean uptake of carbon [Joos et al., 1999]. The warming increases the atmospheric CO_2 concentration by only 4 % compared to a model simulation in which the ocean feedback is ignored. While this is a moderate positive feedback, a collapse of the thermohaline circulation would reduce the uptake profoundly, as these model simulations demonstrated.

The very large uncertainty about the aerosol indirect effect in the Earth's radiative balance was another important finding of the TAR. This prompted us to use the Berne 2.5D model of reduced complexity to perform extensive Monte Carlo simulations, which were constrained by observations of surface warming and ocean heat uptake. The simulations yielded probabilistic estimates of the equilibrium climate sensitivity and the indirect aerosol effect [Knutti et al., 2002].

By the time of AR4, Earth System Models of Intermediate Complexity (EMICs) have closed the gap between the comprehensive climate models, then available from CMIP3, and the simple climate models that have been used since the IPCC FAR. EMICs were included in the climate model projections for the first time in a systematic way in AR4 [Meehl et al., 2007]. This motivated a study comparing various EMICs and presenting projections based on them [Plattner et al., 2008]. Because these models are computationally efficient, they were well suited to estimate the long-term climate change commitments.

The visualization of uncertainty is an important issue in multimodel ensemble simulations. The first attempt at this was made in AR4 when presenting precipitation projections in the SPM [IPCC, 2007]. The goal was to provide a multimodel-based guidance for the uncertainty language, e. g., in which regions a likely (> 66 % probability) increase or decrease of precipitation was projected. A small number of authors of the chapters dealing with projections in AR4 held intensive discussions at the last lead author meeting and in the few weeks thereafter, and after many iterations we settled on a convention to stipple areas where more than 90 % of the models agreed in the sign of the change and to leave areas uncolored where models did not agree in the sign of the projected change (Figure 21.5a). This was critically revisited in the subsequent assessment. The new author team of AR5 favoured showing all information as multimodel means but using two patterns instead, i. e., indicating areas where the signal-to-noise ratio is too small for a robust statement and where model agreement is strong, respectively. This issue continued to be debated during three lead author meetings involving several chapters until finally a consensus was found (Figure 21.5b). These lead author discussions motivated three groups involved in AR5 to publish their considerations in the peer-reviewed literature [Tebaldi et al., 2011; Power et al., 2012; Knutti and

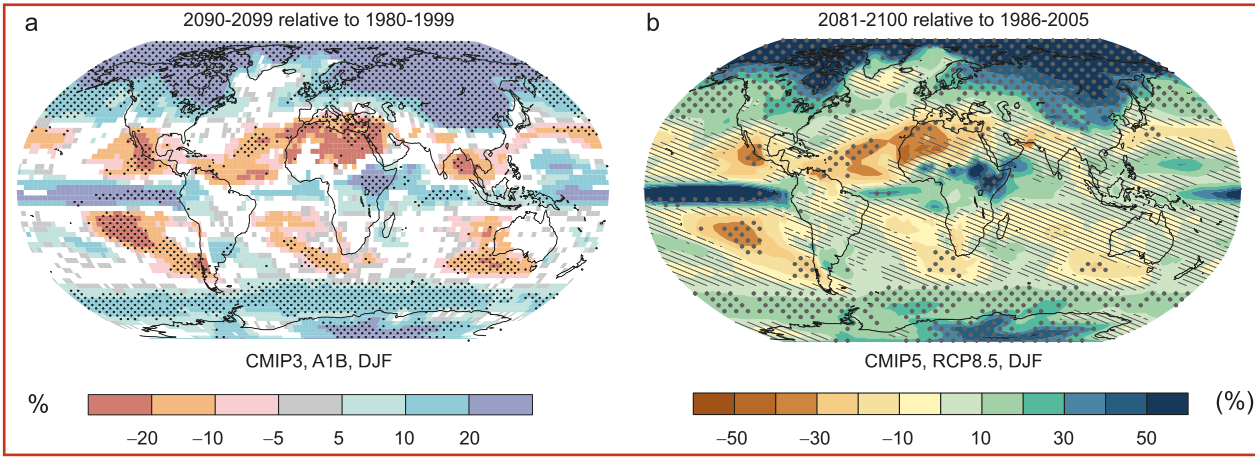


Figure 21.5:
Visualization of uncertainty for multimodel precipitation projections as presented in AR4 (left) and in AR5 (right) and using patterns (stippling and hatching) to qualify the model projections. (a) In AR4, the white areas indicate where less than 66 % of the models agree in the sign of the change, and stippled areas show where more than 90 % of the models agree in the sign of the change. (b) In AR5, the amount of information was augmented by using two patterns (hatching for less than one standard deviation of the natural internal variability in 20-year means, < 1σ; stippling for > 2σ; and at least 90 % of the models agree on the sign). Note that the figures cannot be compared quantitatively as the two assessments used two generations of climate models as well as emission scenarios, although the patterns do look very similar. From IPCC [2007] and Collins et al. [2013].

Sedlàček, 2013], and it has resulted in a very instructive comparison presented as a Box in Collins et al. [2013]. This is an example where the stimulation of own research returned a product that then improved the assessment report.

As mentioned, the development of a compelling and robust figure in the WGI SPM informing on climate targets was challenging, and such a figure was missing until the final draft of the SPM. As Co-Chair I pushed hard that such a figure was produced. In that final draft the figure showed the multimodel means of the CMIP5 simulations up to year 2100, as well as uncertainties estimated using models of reduced complexity and simple climate models. This was a fine example of showing a robust assessment finding that is based on multiple lines of independent evidence. As such, the figure was still very complex and not easy to communicate. The message firmly embedded in that figure is that the option to limit the global mean warming to less than 2 °C is rapidly vanishing. This has inspired me to think of other ways of displaying this policy relevant information. It felt to me like much of the message was being lost in the complicated discussions on details of the emission scenarios, the different mixtures of drivers and levels of stabilization. A way to avoid this is to go back to extremely simplified, "academic," scenarios of exponential increases and decreases of emissions – a choice that incidentally is also the basis for the definition of two climate system metrics, the transient climate response and the transient climate response to cumulative emissions. Such scenarios, and the assumption of a linear relationship between the peak warming and cumulative emissions, permit a straightforward illustration of the fact that climate targets are disappearing at an increasing speed with continuing CO_2 emissions [Stocker, 2013; Allen and Stocker, 2014] (Figure 21.6).

The intense discussion about climate targets stimulated another study using our climate-carbon cycle model of reduced complexity, the Berne 3D model [Steinacher et al., 2013]. By varying a large number of model parameters and using observed constraints, the model could generate a distribution of plausible model configurations to be used for climate projections. Recognizing that Article 2 of the UNFCCC [UNFCCC, 1992] is not fully covered by just requiring the limitation of the global mean warming, a purely physical metric, we then formulated a set of combined climate targets: In addition to the warming, the rise of sea level, the loss of soil carbon and ocean acidification should also be limited, the latter two being indicators that are connected with terrestrial and marine food production and thus address the other concerns mentioned in Article 2. Results indicate a significant further reduction of allowable carbon emissions for the multitarget, which demonstrates that combined protection of climate stability and ecosystem service is not being achieved by exclusively focusing on a global mean temperature target (Figure 21.7).

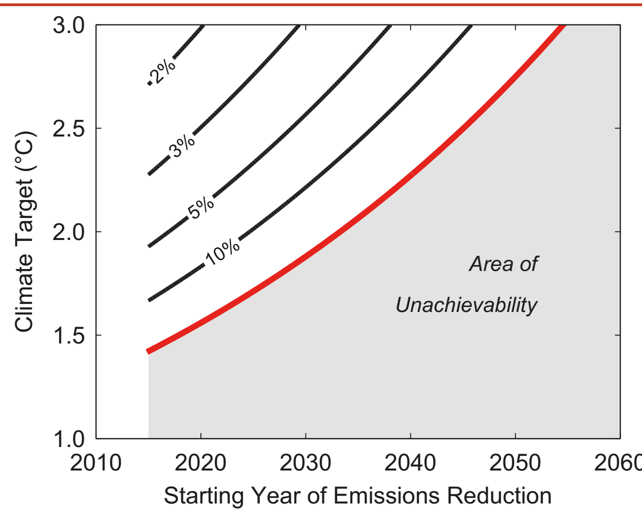


Figure 21.6:
Contours of the required continuous rates of emission reduction (in % per year) for a given climate target and the starting year of implementation. The figure is based on Stocker [2013] with updated parameters representative for 2013. The red line marks the boundary where a selected climate target becomes unachievable, i. e., the associated carbon budget is exhausted.

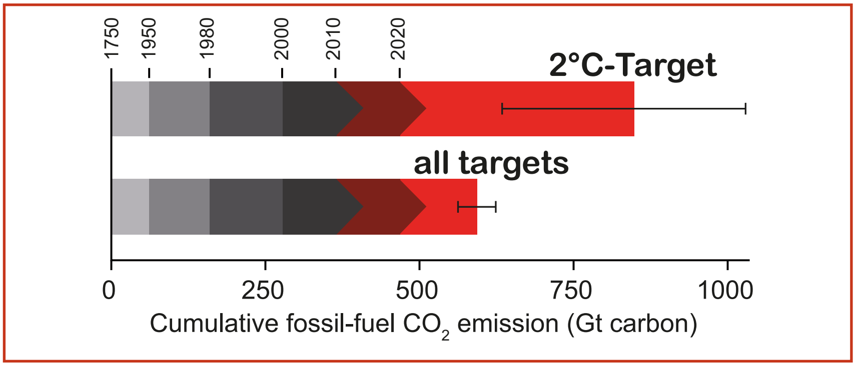


Figure 21.7:
Allowable carbon emissions compatible with staying below the global mean temperature target of 2 °C, and the associated Earth System multitargets consisting of limiting simultaneously global mean temperature, sea level rise, acidification in the Southern Ocean and globally, productive cropland area loss, and carbon loss on croplands. Results are based on Steinacher et al. [2013]; the figure was designed by M. Steinacher.

21.6 Evolution of Communication in IPCC

It is instructive to revisit the evolution of how the findings in the top-level documents of the IPCC reports have been communicated and how this has changed with the advent of electronic tools since the FAR in 1990. The Policymakers Summary of the FAR had a well-designed structure, organized along specific questions, such as "What are the greenhouse gases and why are they increasing?", or "How much confidence do we have in our predictions?" The document was preceded by a succinct 2-page Executive Summary, which again was structured along assertions: "We are certain of the following …", "We calculate with confidence …", or "Based on current model results, we predict …" The Policymakers Summary was rather long, with 33 text pages and 13 figures, all in black and white. Nevertheless, the access for the reader was certainly facilitated by such structuring along simple questions.

This strategy was changed fundamentally in the second assessment report. Here, the SPM was very short, only 7 pages with no figures. The scientific substance with detailed numbers and figures was deferred to a Technical Summary, an innovation in that assessment.

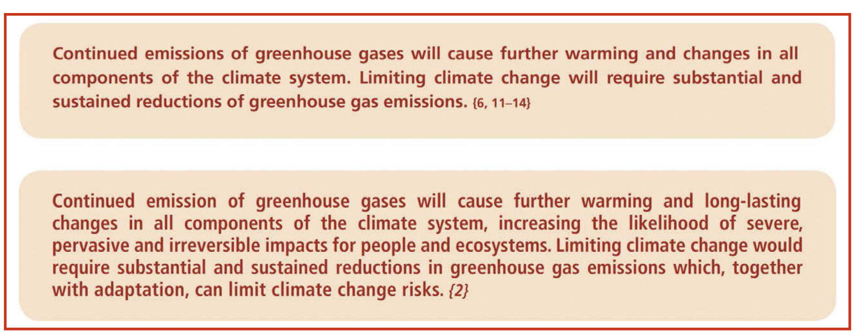
The TAR presented a 20-page SPM with coloured figures and two types of headline statements. Although the scientific details were back again in the SPM, the Technical Summary was also retained, now larger in size and complexity, like the entire report compared to its predecessors. The headline statements in this assessment were short and succinct, for example, "An increasing body of observations gives a collective picture of a warming world and other changes in the climate system" or

"There is new and stronger evidence that most of the warming observed over the last 50 years is attributable to human activities."

The AR4 report followed this successful template as each of the SPM sections had one or more such highlighted statements. The most quoted ones were the following: "Warming of the climate system is unequivocal …" and "Most of the observed increase in global average temperatures since the mid-20th century is very likely due to the observed increase in anthropogenic greenhouse gas concentrations."

The concept of headline statements was refined, and for the first time consistently applied in the WGI SPM of AR5. Each section and subsection now had such a headline statement, with the section statements more general than the subordinate statements. The language was kept simple in order to make the text as accessible as possible. Furthermore, great care was taken to develop the headline statements in such a way that they could be read on their own and still provide a coherent narrative of the entire SPM. The result was that the SPM could be summarized compactly on two printed pages by simply extracting all the headline statements. Examples of section headlines in AR5 are: "Warming of the climate system is unequivocal," a repeat of the AR4 headline in order to affirm consistency with the preceding assessment; "Human influence on the climate system is clear" and "Limiting climate change will require substantial and sustained reductions in greenhouse gas emissions" (Figure 21.8). The last statement has been criticised as being policy-prescriptive or even advocacy, but careful reading reveals that it is not.

The power of these statements lies in the fact that they are an integral part of the SPM and therefore verbatim approved by governments in consensus. Their language is understandable and free of jargon, which makes them attractive to quote them unchanged. In effect, many media included these statements in their reporting, thus making them an excellent communication vehicle [O'Neill et al., 2015;



Continued emissions of greenhouse gases will cause further warming and changes in all components of the climate system. Limiting climate change will require substantial and sustained reductions of greenhouse gas emissions. {6, 11–14}

Continued emission of greenhouse gases will cause further warming and long-lasting changes in all components of the climate system, increasing the likelihood of severe, pervasive and irreversible impacts for people and ecosystems. Limiting climate change would require substantial and sustained reductions in greenhouse gas emissions which, together with adaptation, can limit climate change risks. *{2}*

Figure 21.8:
Evolution of a headline statement of the Summary for Policymakers of Working Group I (top) to a top-level headline statement in the Summary for Policymakers of the Synthesis Report (bottom), combining information from the three working groups. The headline statements in the WGI SPM and the Synthesis Report are graphically distinct from the rest of the text and highlighted by crimson text in boxes.

Stocker and Plattner, 2016]. Implicitly, communication was again back in the hands of the scientists who created these headline statements. Unfortunately, Working Groups II and III did not manage to have headline statements in their SPMs, so it required quite some effort to bring this effective communication tool into the Synthesis Report and into its SPM, the top-level document of the entire fifth assessment. After debating the matter during two meetings of the Core Writing Team of the Synthesis Report, I finally succeeded to convince the authors, and the team started to craft headline statements from their material. The combination of the findings from the three working groups, the synthesis, is now also reflected in the synthesis headline statements. An example is shown in Figure 21.8 (bottom). I hope that government approved headline statements will become the standard of all IPCC products [Stocker and Plattner, 2016].

Another element of a more streamlined outreach and communication is the consistent branding that we have implemented for the WGI products (Figure 21.9): All

Figure 21.9:
Products of Working Group I for AR5. The consistent appearance enhances the recognition effect and supports outreach efforts.

feature the WGI title photograph of the Folgefonna glacier in Norway, a rapidly melting body of ice. This consistent appearance supports the recognition effect and enhances outreach. Various additional products were also developed: a Summary Volume, a brochure with the FAQs (Frequently Asked Questions), the sheets of the extracted headline statements in all UN languages, a USB containing all WGI material, a professionally produced video and presentation slides (Figure 21.9). For scientists, WGI also made available all of the more than 9,000 references in electronic bibliographic formats and the more than 1,200 figures of the report, almost all of which are embedded in vector format and therefore in unlimited resolution, in the published pdf files.

21.7 Outlook

The fifth assessment has impressively demonstrated the limits that the scientists are confronted with when carrying out a comprehensive task on a voluntary, unpaid and largely unassisted basis. Given the continuing growth of scientific information about the Earth System, and the call of governments and stakeholders to receive ever more and more detailed information on regional changes and impacts, begs the question whether the scientists will be able to deliver another assessment in the next 5 to 7 years at the same level of quality and rigor. The willingness of the scientific community is certainly intact: Most colleagues are convinced that contributing to an assessment is indeed a duty and represents one way to "give back" to society by making the best information available for smart decisions regarding the future of us all. However, the amount of work during AR5 was staggering. More than 9,000 publications from the peer-reviewed literature were considered in this assessment, more than 2 million GB of numerical data were produced by climate models, and more than 50,000 comments were responded to, by WGI. None of these numbers are expected to become smaller in the next assessment if no changes are implemented in the assessment process, nor will it be possible to deliver an equally comprehensive and robust report without having more hands on deck.

In a recent article in *Nature*, Gian-Kasper Plattner and I have considered how to ensure the success of the next assessment [Stocker and Plattner, 2014]. We propose that those who commission these assessments – the governments – should consider some form of institutionalized support for scientists in leading or particularly demanding positions such as those coordinating a chapter, working on cross-cuts or serving in more than one working group. The extension of the assessment cycle would not only reduce the time pressure, it would open up the possibility for enhanced cross-working group collaboration. For example, climate model simulations so far could not be used to the full potential for impact studies because the time-lag between the schedules of the different working groups was too short. Assessing specific common topics jointly between working groups would reduce the workload and ease the synthesis towards the end of the cycle. On the other hand, smaller, more focused reports such as a series of Special Reports, would likely not generate the broad and worldwide impact that a series of well-coordinated working group assessment reports enjoys.

As this book is being published, the sixth assessment cycle of the IPCC has started. At its 41st Plenary Session in February 2015, the IPCC decided to keep the current structure of Working Groups I, II and III as well as a Task Force on National Greenhouse Gas Inventories, and requested each working group to produce a comprehensive assessment report within the next 5 to 7 years. More regional participation of scientists, particularly from developing countries, was a recurrent request by the member countries of the IPCC. Several suggestions for Special Reports during the next cycle were also made. In summary, the Panel chose the conservative approach of "business-as-usual" and did not really come to grips with the ever-growing burden put on the shoulders of the scientific community by this process. This is an issue the future leadership must address in a proactive way, for example, by enhancing the scoping of the reports, modifying the way chapters cutting across working groups are produced or considering how the Synthesis Report will be written, the goal being to make the process overall more efficient for the scientific community – without jeopardizing the high level of respect and international recognition that the IPCC has built up in the past 27 years of its existence.

Any adjustment to the IPCC process, however, needs to be mindful of the fact that a rigorous and comprehensive assessment can be delivered to the policymakers and stakeholders only if it is based on the wide support of the scientific community, foremost the leading scientists of their field.

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