Science and the international climate negotiations

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Introduction

Climate change has been recognised as one of the major challenges facing the world today. Its effects are becoming increasingly apparent. But it was the scientific community which first alerted politicians and decision makers to the threat, as a result of their curiosity about the Earth and their observations of environmental change. It is not unusual for scientists to be the first to predict the development of environmental risks – this was also the case with the potential damage to the ozone layer.

This paper reviews how climate change became mainstream, how the science initiated and subsequently influenced the policy debate, the complex interaction between science and policy, and related institutional developments. From 1988 to 2016 I served as a senior science advisor on climate change in central Government, which gave me first-hand experience of the scientific and policy debates around climate change, the working of the Intergovernmental Panel on Climate Change (IPCC) and the United Nations Framework Convention on Climate Change (United Nations, 1992). My aim is to review, from a personal perspective, some of the key steps along the way and some of the important science and policy interactions that eventually led to the Paris Agreement (UNFCCC, 2015b). I will focus on the climate science in this article, although clearly the evidence required to assess and respond to climate change requires a broad range of scientific disciplines, including social science and economics.

Science raises the issue of climate change

The earliest identification of the radiative properties of trace gases was made by John Tyndall in the 1860s. Then Svante Arrhenius published work in 1897 suggesting that the average temperature of the Earth would be affected by different levels of carbon dioxide in the atmosphere. Such views did not gain widespread recognition, however, and for many years climate was regarded as a stable background to our lives. Any changes were commonly seen as a part of a natural fluctuation. Significant climate changes (such as periods of glaciations) were viewed only as being relevant to longer geological timescales. Of primary interest were the geographical differences in climate across the world. Engineers needed climate data for designing structures that could withstand extremes, but these largely assumed a stationary statistic, often based on statistics from the most recent three decades. Few thought about the global climate. A growth in the study of past climates through proxy indicators (tree rings, ice cores, lake sediments, etc.) brought the attention of the scientific community to the possibility that climates might have changed more rapidly in the past than had been hitherto supposed. The media, ever interested in the sensational, ran stories about an impending ice age (Calder, 1974). At the same time there was a growing awareness of the changes in atmospheric composition, most notably through observation by Keeling of rising CO_2 concentrations at Mauna Loa (CO_2 record to present at https://www.esrl.noaa.gov/gmd/ccgg/trends/full.html). Alarm bells were beginning to ring, leading to the First World Climate Conference, hosted by the World Meteorological Organization (WMO) in 1979, which identified climate change as an urgent world problem and urged governments: *To foresee and prevent potential man-made changes in climate that might be adverse to the well-being of humanity* (World Meteorological Organization, 1979). The conference also brought about the formation of the World Climate Programme (Zillman, 2009).

In the 1980s other atmospheric environmental issues had come to the fore – acid rain, photochemical smog and depletion of the ozone layer. Pollution, which had tended to be seen as a local or at most a national issue, became a trans-boundary matter and eventually a global issue. Even so, there was much resistance to the idea that humans could affect the global atmosphere. Although ozone loss had been predicted, the discovery in 1985 of almost total loss of ozone in the stratosphere over Antarctica in the austral spring – the ozone hole – was a shock, since it was largely unpredicted. At the same time climate concerns were growing in two directions – the potential warming impact of rising levels of greenhouses gases and the potential for a dramatic drop in temperatures following a massive nuclear exchange, dubbed a 'nuclear winter'. The latter provided a strong impetus for efforts to limit the nuclear arms race (Oreskes and Conway, 2010).

The first truly international scientific assessment of climate change was undertaken under the auspices of the International Council of Scientific Unions (ICSU), WMO and the United Nations Environment Programme (UNEP) at a meeting in Villach (1985). Subsequent meetings in Villach and Bellagio (1987) set out the main conclusions and policy options for dealing with greenhouse gases (Jaeger, 1988). Importantly, it recognised the need for a global convention to address climate change. It is also of interest to note that the recommendations identified the main direction of travel required to address climate change which we would recognise today – namely, energy efficiency, development of non-fossil energy systems, reduced deforestation, limiting the growth of non-CO_2 gases, planning for sea-level rise and enhanced support for policy-related research. The initial Villach conference also called for periodic assessment of climate science, which eventually led WMO and UNEP to set up the IPCC in 1988.

Up to this point it would be reasonable to say that climate change was still viewed largely as a scientific matter, although political awareness was rising, particularly on the back of the publication of the Brundtland Report, *Our Common Future*, which looked at the challenges of environment and development together (WCED, 1987).

Initial political responses

By 1988, the political pressure to address climate change had grown. In June 1988 the Canadian Government hosted the first ministerial-level meeting on climate change (WMO, 1988), in Toronto. The meeting proposed a global cut in emissions of 20% by

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2005, which was in line with the science but optimistic politically, as subsequent events have shown. The difficulty for Toronto was very limited thinking about climate change by governments and a scientific view that the course of climate change was uncertain. The meeting was held with a background of unprecedented heatwaves and drought in the USA and Canada, which led Jim Hansen to state that this was part of the evidence that climate change was happening (Schneider, 2010). The UK approached the meeting with a measured view: we should recognise the potential risks of climate change, take 'no-regrets' measures to reduce our contribution to climate change and enhance climate research aimed at reducing uncertainty. The UK's emphasis on science led to its prominent role in the IPCC and to the establishment of the Hadley Centre at the Met Office in 1990, with a major uplift in funding for supercomputing.

But despite all this, the public profile of the climate change debate was relatively low. That was about to change – first in the UK and then more widely. The then Prime Minister Margaret Thatcher, a scientist herself, had been invited to give a speech to the Royal Society in September 1988. In that speech she highlighted climate change as being one of the major issues facing the world, noting that *we have unwittingly begun a massive experiment with the system of this planet itself* (Thatcher, 1988).

This speech had the immediate effect of raising the issue of climate change to a whole new level in the UK and eventually abroad. The author was a senior science advisor in the Department of the Environment and one of only a few officials dealing with climate change at the time. In the weeks that followed, the level of interest in climate change exploded, with a resulting massive increase in workload. Climate change had in effect become a mainstream political issue. From then on events moved rapidly, with the establishment of the IPCC in 1988 and a Ministerial Declaration from the Second World Climate Conference, in 1990, calling for countries to work towards a climate treaty by 1992.

It should be recognised that there was also considerable pushback on action on climate change from powerful industrial and political interests from early on, which manifested itself as the fostering of scientific scepticism largely to muddy the waters and slow any response (Gelbspan, 1997). There is insufficient space for me to treat this at length here, but note that attacks on the science (and scientists) and the promotion of alternative views at variance with the scientific consensus have been a feature of the climate story all the way through to the present (Schneider, 2010). This is not a phenomenon which is confined to climate change but is an approach which has been taken by vested interests in other areas of science and public policy, including tobacco and the ozone layer (Oreskes and Conway, 2010). The announcement in the summer of 2017 of the United States intention to withdraw from the Paris Agreement shows that, despite the overwhelming scientific evidence for man-made climate change and its attendant risks, the political and ideological debate over climate change has not been resolved – in the USA, at least.

Institutional developments – IPCC and UNFCCC

The formation of the IPCC and the UNFCCC provided the international institutional foci for understanding of, and action on, climate change, with the IPCC assessing the science of climate change and the Convention negotiating and supporting implementation of agreements to deal with climate change. The two have a complementary relationship, and the interaction between the two has been a key element in progressing actions on climate change.

It would take too much space to provide a detailed picture of each organisation here, but I will draw your attention to what I think are key elements in the way they operate, particularly with regard to climate science.

The IPCC

Formally sponsored by WMO and UNEP, the IPCC is governed by representatives of the world's governments who are also members of the WMO and UNEP. It is both an intergovernmental and scientific body, whose task is as follows:

> *to assess on a comprehensive, objective, open and transparent basis the scientific, technical and socio-economic information relevant to understanding the scientific basis of risk of human-induced climate change, its potential impacts and options for adaptation and mitigation. IPCC reports should be neutral with respect to policy, although they may need to deal objectively with scientific, technical and socio-economic factors relevant to the application of particular policies* (IPCC, 2013)

Thus its remit covers a wide range of scientific disciplines and includes economics and social science. The mandate for its work is agreed by its members; its reports are prepared through three scientific working groups covering climate science, impacts and adaptation, and mitigation. It is important to note that the main strength of the IPCC lies in its working groups, which are supported by hundreds of scientists with proven track records, drawn from many disciplines and many countries. It is they who prepare each Assessment Report (AR), which usually consists of a large detailed report, a technical summary and a summary for policymakers (SPM).[1] Their job is to review the scientific literature and to reflect the current state of the science of climate change for use by governments. A guiding principle is that the reports should be policy relevant but not policy prescriptive. It is important to recognise that the IPCC assesses what is already published. It does not undertake its own research, although it has from time to time made recommendations for research.

Each report is reviewed in a two-stage process by a wider scientific community of peers and by governments, but responsibility for each report rests with its authors.

One of the most striking things about the IPCC is the involvement of governments both in the review process and in the agreement of the SPMs. Some would argue that this is not appropriate and that it risks diminishing the independence of the science. However, it is also recognised, including by authors, that involving governments provides a challenge to the science and ensures that relevant questions are being addressed. In my experience as the UK's lead on the IPCC for some 20 years I would firmly support the current arrangements for the following reasons: firstly, the full reports are wholly owned by the authors, so we know what they think; secondly, the SPMs are agreed with lead authors and may not contain material that is not reflected in the underlying reports. Furthermore, the involvement of governments ensures that the writers are challenged on the balance and clarity of their report and its relevance to policy questions. Finally, the reports are accepted by governments, who, by being part of the process, have had to engage intimately with the contents. The remarkable thing is that, despite disagreements, the reports have, with few exceptions, been accepted by governments and provided an authoritative body of information which can be drawn on in the negotiations in the UNFCCC. It is noteworthy that governments acting through the UNFCCC have endorsed the IPCC Assessment Reports and their usefulness to the negotiations (UNFCCC, 2014). The IPCC was also awarded the Nobel Peace Prize, jointly with Al Gore, following publication of the 4th Assessment Report in 2007, in recognition of the work of the many scientists engaged in its reports.

The UNFCCC

The Convention (United Nations, 1992) recognises the importance of science and indeed depends on science. One of its two subsidiary bodies, the Subsidiary Body for Scientific and Technological Advice (SBSTA)

[1]All the IPCC Reports are available on its website at www.ipcc.ch

is responsible for providing scientific and technical advice (See Article 9 of the Convention (UNFCCC, 1992)). This involves a wide range of technical issues of relevance to the wider negotiations. Convention Article 4.1(g) commits the Parties to the Convention to:

> *Promote and cooperate in scientific, technological, technical, socio-economic and other research, systematic observation and development of data archives related to the climate system and intended to further the understanding and to reduce or eliminate the remaining uncertainties regarding the causes, effects, magnitude and timing of climate change and the economic and social consequences of various response strategies.*

Article 5 commits the Parties to support research and systematic observations and the help developing countries play a full part in this. As such these items are generally included on the agenda of the SBSTA.

At the first meeting of the SBSTA in 1995 there were some suggestions that SBSTA should take over the role of the IPCC, but Parties generally recognised the benefit of the IPCC being separate from the more political UNFCCC and reaffirmed their support for the IPCC:

> *The SBSTA expressed strong support for the continued functioning of the IPCC as one of the independent and prominent sources of scientific and technical information relevant to the implementation of the Convention, as specified in Article 9* (UNFCCC, 1995).

The interaction between the IPCC and the UNFCCC is an interesting one; both are independently governed, but the IPCC is in practice recognised by the UNFCCC as its primary source of scientific information. The main assessment reports, which have been published every 5–7 years, are agreed wholly within the IPCC, though some mutual adjustment of timing has been agreed on occasion to ensure material is available in a timely fashion. The IPCC also prepares Special Reports focused on specific issues – some of these are wholly proposed by the IPCC and some have been requested by the UNFCCC. It is probably less well known that the IPCC also prepares technical guidelines. The most significant of these are guidelines on the preparation of greenhouse gas emission inventories. These guidelines provide the basis for preparing emission inventories by governments for formally reporting their emissions to the UNFCCC. Emission inventories are generally built up from proxy data (such as coal or oil use) as there is no simple way of measuring the multitude of diverse emission sources. So the UNFCCC has a broad and a specific dependency on the IPCC.

Over the lifetime of the Convention its engagement on scientific and technical matters has gradually increased. On systematic observation there has been a regular interaction with the Global Climate Observing System (GCOS), which has regularly provided reports and plans to the UNFCCC. There is, however, a mismatch in ambition. Inevitably the key political issue has been the funding of observations, particularly in developing countries. Although the UNFCCC has generally accepted the value of and need for observations, it has recognised that other UN Agencies are more appropriate for supporting implementation, for example under the WMO's Global Atmospheric Watch.

On research the interaction is different. At the suggestion of the EU, the Parties agreed to set up a Research Dialogue between the delegates and representatives from the scientific community. It was recognised that although the IPCC would always be the main source of scientific advice to the UNFCCC, there was a need for a forum which would alert the Parties to emerging relevant science and would also give them the opportunity to signal research questions that they might have. Both the relevance of and interest in the dialogue meetings have grown steadily over the past decade. In the two years before the Paris negotiations, a more formal assessment of science related to the Long Term Global Goal was undertaken under a so-called 'Structured Expert Dialogue', which is discussed later.

The Convention has had to address more specific technical scientific and technology questions – for example, negotiations on the role of land use, land-use change and forestry (LULUCF) in both being a source and sink for emissions of greenhouse gases. This is a highly complex and technical area and one which is both scientifically challenging and expensive for Parties to assess. When the Kyoto Protocol was agreed the treatment of LULUCF was quite basic, and more complex rules needed to be agreed subsequently. To aid its deliberations the Parties requested a special report from the IPCC on the scientific issues around LULUCF (UNFCCC, 1998). This report (IPCC, 2000) helped Parties to resolve their differences on LULUCF and reach agreement on the accounting rules for emissions and uptake of CO_2 by LULUCF in the Kyoto Protocol.

Another important scientific issue was the use of Global Warming Potential (GWP) to allow inter-comparison of the warming effect of different greenhouse gases. GWPs had been published in the IPCC First Assessment Report (FAR; IPCC, 1990) and updated in subsequent reports. But some countries with high methane emissions raised concerns that methane was being over-emphasised. This lead to quite a long debate in the run up to the Paris negotiations in 2015, and a special workshop was convened to consider the validity of using GWPs and whether alternative metrics, such as Global Temperature Change Potential, would be more appropriate. Arguments can be made in both directions, but the outcome was that countries tended to support the metric that suited them as there was not a strong scientific steer on which was preferable. In the end it was agreed that GWPs from the IPCC's 4th Assessment Report (AR4) would be used for reporting against Kyoto Protocol commitments for developed countries for the 2nd Kyoto commitment period (2013–2020). The issue remains unresolved for reporting under the Nationally Determined Contributions, through which Parties indicate what actions they will take to meet their obligations under the Paris Agreement. Discussions continue.

Influence of science on the overall political response

It is worth noting that key policy developments often followed the publication of IPCC reports, such as the formation of the UNFCCC (1992) after the FAR (1990); the agreement of the Kyoto Protocol (1997), which set emission reduction targets for developed countries and introduced emission trading, after the 2nd Assessment Report (SAR); the Marrakech Accords (2001), which made Kyoto operational after TAR (2001); the major but stalled Copenhagen meeting (2009) after AR4 (2007); and the Paris Agreement (2015), which agreed actions for all countries after the 5th Assessment Report (AR5; 2014). Table 1 summarises the key milestones on climate change through to the present.

Throughout the period there were two key scientific questions which interested policymakers: was the climate actually changing due to greenhouse gas emissions, and were the risks of climate change significant and costly enough to warrant a fundamental change in society's production and use of energy?

Table 2 summarises the IPCC's conclusions to the first question. It clearly shows the strengthening of the view that human-induced climate change was underway. In addition, the AR4 drew attention to evidence that other factors were changing due to greenhouse gases, including extreme events, sea-level rise and ecosystem changes. But it is the SAR that was first to recognise that anthropogenic climate change was underway, which certainly contributed to the agreement of the Kyoto Protocol.

Table 3 summarises the climate change projections through the sequence of IPCC reports. As well as showing an ongoing rise in temperature from the end of the ninteenth century, we have a fairly consistent picture of warming by the end of the twenty-first century, but with variations

Table 1

Overview of key international climate science and policy activities.

Year	*Body*	*Outcome*
1979	WMO	1st World Climate Conference
1985	WMO/UNEP/ICSU	Villach – SCOPE 29
1988	Canada/UN	Toronto conference and establishment of the IPCC
1990	IPCC	1st Assessment Report (FAR)
1990	WMO	2nd World Climate Conference – establishment of the International Negotiating Committee for a UN Convention on Climate Change
1992	UNCED	Adoption of the Framework Convention on Climate Change UNFCCC at Rio Summit
1994	UNFCCC	Entry into force of the Convention
1995	IPCC	2nd Assessment Report (SAR)
1995	UNFCCC	COP1 – Agreement to develop a protocol
1997	IPCC	Special Report on the Regional Impacts of Climate Change
1997	UNFCCC	COP3 – Adoption of the Kyoto Protocol
1999	IPCC	Special Report on Aviation and the Global Atmosphere
2000	IPCC	Special Reports on Emission Scenarios, Technology Transfer and Land Use, Land-Use Change and Forestry
2001	IPCC	3rd Assessment Report (TAR)
2001	UNFCCC	COP7 – Agreement of the Marrakesh Accords
2003	Russia	World Climate Change Conference
2005	UK	Exeter science meeting – *Avoiding Dangerous Climate Change* as part of UK Presidency of the G8
2005	IPCC	Special Reports on Carbon Capture and Storage and Safeguarding the Ozone Layer and the Climate System
2005	UNFCCC	Entry into force of the Kyoto Protocol and COP11 – 1st Meeting of the Kyoto Protocol
2005	UNFCCC	Nairobi Work Programme on adaptation
2006	UNFCCC	COP12 – Montreal agreements on future action
2007	IPCC	4th Assessment Report (AR4)
2007	UNFCCC	COP13 Bali Action Plan
2009	WMO	3rd World Climate Conference – *Framework for Climate Services*
2009	UNFCCC	COP15 Copenhagen conference
2010	UNFCCC	COP16 Cancun agreements
2011	IPCC	Special Reports on Renewable Energy and Extreme Events
2013/2014	IPCC	5th Assessment Report (AR5)
2015	UNFCCC	COP21 Paris Agreement – *agreement to limit global temperature rise to 2 degC and pursue efforts to limit it to 1.5 degC, peak emissions as soon as possible and reach net zero emissions by end of century.*
2018	IPCC	Special Report on Global Warming of 1.5 degC
2019	IPCC	Special Reports on Oceans and Cryosphere in a Changing Climate; and Climate Change and Land
2020	UNFCCC	Start of new agreement on emissions limitations
2021/2022	IPCC	6th Assessment Report

largely due to changes in the greenhouse gas emission scenarios upon which the temperature projections were made. The range reflects scenarios which at the top end were deemed to be high economic growth and high fossil fuel use ('business as usual') and at the low end low growth and/or introduction of sustainable development and emission reduction policies. The key issue for governments was the message that continuing high emissions would lead to a rate of temperature rise over the twenty-first century that was unprecedented since the last ice age, accelerating rises in sea level which would continue for several centuries afterwards, intensifying extreme weather events and leading to a wide variety of increasingly damaging impacts across the world affecting both the natural world and human society. In addition, the spectre of uncontrolled and irreversible climate change was identified.

The IPCC reports right from the beginning made it clear that business as usual would lead to unprecedented climate change, with increasingly damaging effects on economics and society as well as the natural world. But that raised the question of how emissions should be reduced and by how much to achieve a stable, albeit warmer, climate which avoided the worst effects of climate change. The Climate Convention's goal is as follows:

> *To achieve … stabilization of greenhouse gas concentrations in the atmosphere*

Table 2

Is mankind changing the climate?

Year	*IPCC*	*Conclusion*
1990	FAR Overview 1.05	*The size of the warming over the last century is broadly consistent with the prediction by climate models, but is also of the same magnitude as natural climate variability.* *The unequivocal detection of the enhanced greenhouse effect from observations is not likely for a decade or more.*
1995/1996	SAR SPM WG1 (4)	*Our ability to quantify the human influence on global climate is currently limited because the expected signal is still emerging from the noise of natural variability, and because there are uncertainties in key factors.* *Nevertheless, the balance of evidence suggests that there is a discernible human influence on global climate.*
2001	TAR Synthesis Report Q2	*There is new and stronger evidence that most of the warming observed over the last 50 years is attributable to human activities.*
2007	AR4 Synthesis Report 2	*Most of the observed increase in global average temperatures since the mid-twentieth century is very likely due to the observed increase in anthropogenic greenhouse gas concentrations.*
2013/2014	AR5 Synthesis Report SPM1.2	*Anthropogenic greenhouse gas emissions have increased since the pre-industrial era, driven largely by economic and population growth, and are now higher than ever.* *Their effects, together with those of other anthropogenic drivers, have been detected throughout the climate system and are extremely likely to have been the dominant cause of the observed warming since the mid-twentieth century.*

Table 3

Observed and projected climate change.

	FAR (1990)	*SAR (1996)*	*TAR (2001)*	*AR4 (2007)*	*AR5 (2014)*
Temp. rise (degC) since the late 19th century	0.3–0.6	0.3–0.6	0.4–0.8	0.74 (0.56–0.92)	0.85 (0.65–1.06)
Sea-level rise (cm) over the record	10–20	10–25	10–20	17 (12–22)	19 (17–21)
Equilibrium Climate Sensitivity for doubling CO_2 concentration	1.5–4.5	1.5–4.5	1.5–4.5	2.0–4.5	1.5–4.5 >1.0 <6.0
Warming (degC) by 2100 relative to 1990	3 (1–5) IPCC A-D	1–3.5 (IS92a-e)	1.4–5.8 (SRESB1-A1F1)	1.1–6.4 (SRESB1-A1F1)	0.3–4.8 (RCP2.6-8.5)
Sea-level rise (cm) by 2100 relative to 1990	65 (25–110)	50 (15–95)	9–88	18–59 + unknown contribution from ice sheets	26–82

> *at a level that would prevent dangerous anthropogenic interference with the climate system.* (United Nations, 1992, Article 2)

And yet it proved rather difficult in the early years of the Convention to have a meaningful debate on this issue. The EU initially proposed, in 1996, as part of the preparations for Kyoto, that global warming should be limited to 2 degC above pre-industrial levels, and this remained its objective throughout the negotiations up to Paris. Other Parties were reluctant to follow the EU's lead. As part of its G8 Presidency Programme in 2005, the UK hosted a conference at Exeter on Avoiding Dangerous Climate Change (Schellnhuber *et al*., 2006) which re-vitalised consideration of the long-term goal and became an important element of the negotiations at Copenhagen in 2009. Although Copenhagen didn't achieve its aim of reaching a global and comprehensive agreement, it did recognise the long-term goal of limiting the temperature rise to 2 degC, which was agreed in Cancun the following year. The Small Island States and Least Developed Country group had also been pressing their proposed limit of 1.5 degC, which was also recognised in the Cancun decision. To help reconcile the two proposals, the UNFCCC agreed a process of workshops and negotiations which drew evidence from the IPCC and a wider group of experts under a Structured Expert Dialogue. Its report (UNFCCC, 2015a) confirmed the need to keep temperature rises well below 2 degC and the desirability of aiming to keep the temperature rise below 1.5 degC, a conclusion that is largely reflected in Article 2 of the Paris Agreement:

> *1. This Agreement, in enhancing the implementation of the Convention, including its objective, aims to strengthen the global response to the threat of climate change, in the context of sustainable development and efforts to eradicate poverty, including by:*
>
> *(a) Holding the increase in the global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels, recognizing that this would significantly reduce the risks and impacts of climate change;*

Parties to the UNFCCC had previously decided that the long-term global temperature goal should be reviewed every 5 years and requested advice from the IPCC. Interestingly the IPCC never proposed the 2 degC goal – that would have been policy prescriptive – but it does refer to it often in its reports, simply because much work has been done on it by the science community in response to the EU's proposal to limit warming to 2 degC. By contrast there had been relatively little work done on a 1.5 degC goal, although that is now changing in the light of the Paris Agreement and the IPCC's decision to prepare a special report on a 1.5 degC goal by the autumn of

2018 at the request of the UNFCCC, in time for the UNFCCC to review the global goal later that same year.

The future role of science in the climate regime

It is clear that the role of the IPCC has increased over the years. It initiated concerns about climate change and has motivated a political response to the threat. There is a strong and effective international process for assessing the science of climate change which has played an increasing role in the negotiations. At the same time climate change policy challenges have raised new questions which have provoked new scientific research. The future regime will continue to need scientific evidence to inform its deliberations, particularly on the urgency and scale of the responses required and on the options for reducing emissions and stabilising the climate system. This is already embedded in the UNFCCC's decision to seek advice from the IPCC with respect to the review of the long-term global goal, mentioned above, and the expectation that the IPCC's assessments will feed into the Paris Agreement's decision to undertake a global stock take every 5 years on progress towards implementation of the agreement. The first stock take will be in 2023, a year after completion of the IPCC's 6th Assessment Report. Such high-level political demand for scientific guidance implies that research into climate change, through ongoing monitoring and modelling of the climate system, the effects of climate change and the options for meeting the long-term goals will need to not only continue but be significantly enhanced, particularly in developing countries.

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References

Calder N. 1974. *The Weather Machine and the Threat of Ice*. British Broadcasting Corporation: London.

Gelbspan R. 1997. *The Heat is on*. Addison-Wesley Publishing Company, Inc.: Reading, MA.

IPCC. 1990. IPCC first assessment report 1990 (FAR). http://ipcc.ch/publications_and_data/publications_ipcc_90_92_assessments_far.shtml (accessed 13 October 2017).

IPCC. 2000. *Land Use, Land-Use Change and Forestry*. Cambridge University Press: Cambridge, UK.

IPCC. 2013. Principles governing IPCC work. http://www.ipcc.ch/pdf/ipcc-principles/ipcc-principles.pdf (accessed 13 October 2017).

Jaeger J. 1988. *Developing Policies for Responding to Climate Change*. WMO/TD 225: Geneva.

Oreskes N, Conway EM. 2010. *Merchants of Doubt: How a Handful of Scientists Obscured the Truth on Issues from Tobacco Smoke to Global Warming*. Bloomsbury Press: New York, NY.

Schellnhuber HJ, Cramer W, Nakicenovic N *et al.* (eds) 2006. *Avoiding Dangerous Climate Change*. Cambridge University Press: Cambridge, UK.

Schneider SH. 2010. *Science as a Contact Sport: Inside the Battle to Save the Earth's Climate*. National Geographical Society, Washington, DC.

Thatcher M. 1988. Margaret Thatcher Foundation. http://www.margaretthatcher.org/document/107346 (accessed 13 October 2017).

UNFCCC. 1995. *Report of the Subsidiary Body for Scientific and Technological Advice on the work of its first session held at Geneva from 28 August to 1 September 1995*. FCCC/SBSTA/1995/3 Para 24(a). http://unfccc.int/resource/docs/1995/sbsta/03.pdf (accessed 13 October 2017).

UNFCCC. 1998. *Report of the Subsidiary Body for Scientific and Technological Advice on its eighth session, Bonn, 2–12 June 1998*. FCCC/SBSTA/1998/6 Para 45(d-f). http://unfccc.int/resource/docs/1998/sbsta/06.pdf (accessed 13 October 2017).

UNFCCC. 2014. *Report of the Conference of the Parties on its twentieth session, held in Lima from 1 to 14 December 2014, part 2*. Decision 12/CP.20. http://unfccc.int/resource/docs/2014/cop20/eng/10a02.pdf#page=39 (accessed 13 October 2017).

UNFCCC. 2015a. Report of the structured expert dialogue on the 2013–2015 review. https://unfccc.int/resource/docs/2015/sb/eng/inf01.pdf (accessed 13 October 2017).

UNFCCC. 2015b. *T*he Paris Agreement http://unfccc.int/files/essential_background/convention/application/pdf/english_paris_agreement.pdf (accessed 13 October 2017).

United Nations. 1992. *United Nations framework convention on climate change*. https://unfccc.int/files/essential_background/background_publications_htmlpdf/application/pdf/conveng.pdf (accessed 13 October 2017).

World Commission on Environment and Development. 1987. *Our Common Future*. Oxford University Press: Oxford, UK.

World Meteorological Organisation. 1979. WCC-1 Declaration. WMO: Geneva.

World Meteorological Organisation. 1988. *The Changing Atmosphere, Implications for Global Security: Conference Proceedings*, Toronto, Canada, 27–30 June 1988. WMO (Series) No 710, WMO: Geneva.

Zillman J. 2009. A history of climate activities. *WMO Bull.* **58**(3): 141.

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David A. Warrilow and EU colleagues during a meeting of the Structured Expert Dialogue (SED) on the Long Term Global Goal, Geneva, February 2014. (Photo by IISD/ENB (enb.iisd.org/climate/ipcc40/27oct.html))