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The Scientific Assessments of the Intergovernmental Panel on Climate Change (IPCC)

The Intergovernmental Panel on Climate Change (IPCC) was formed in November 1988. Its formal origins were in resolutions passed by the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP) (Bolin 2007). In its first twenty years, the IPCC released four major assessments, in 1990, 1995, 2001, and 2007. Over this time, the reports of the IPCC have served as a gold standard for authoritative assessments of the state of scientific knowledge about climate change. This unique credibility is grounded in four components of the way the IPCC assessment process works. Specifically these are (Skodvin 2000):

1) The IPCC, using a process based in nominations from governments, engages hundreds of the leading scientific experts in climate science, impacts of climate change, and opportunities for mitigating or managing climate change to review and assess the scientific literature. Most of these scientists participate as volunteers.

2) The experts conduct a comprehensive assessment, considering all of the relevant scientific literature, and not only the literature that comes from a particular perspective or uses a particular set of approaches. The assessment summarizes the main findings and assesses the confidence associated with each finding. If a particular response is very likely (defined as 90 to 99% probability), the assessment reports this, but if it is unlikely (10 to 33% probability), it reports this find as well. Stakeholders receive a quantitative assessment, based on findings across the entire scientific literature.

3) The assessments are subjected to a rigorous, multi-stage, monitored review process. In the first stage of outside review, called the "expert" review stage, the draft report is available to experts around the world. These experts comment on every detail of the assessment, including the completeness of the literature review, the thoroughness of the evaluation, and the interpretation of the results. A twenty page chapter often receives hundreds of pages of detailed comments. Author teams are required to prepare an individual response to each comment, explaining how the chapter will be modified in response to the comment or explaining why the comment does not warrant changing the chapter. All of the comments and all of the responses are then evaluated by a set of review editors who make an independent evaluation of whether the responses are sufficient and whether the changes to the chapter conform to the spirit of the response. When this is complete, the next draft of the assessment is sent to the world's governments, who recruit their own experts to conduct another detailed review, focusing on the same issues – comprehensiveness, balance, and accuracy in the interpretations. This second stage of review also receives detailed responses, and both are again evaluated by independent review editors. After two rounds of review, hundreds of pages of comments, and thorough monitoring of the review and response process by outside experts, the chapters consistently address the wide range of relevant scientific information.

4) Before assessment reports are released, they are approved by consensus, by delegations from all of the world's governments that are members of the IPCC. Each Summary for Policymakers (SPM) is evaluated and approved line-by-line, with country delegations frequently challenging aspects of wording, presentation, or substance. Only when there is not a single challenge, from a single one of the more than 120 countries that typically participate in a plenary approval meeting, does a sentence make it into the SPM. The requirement for line-by-line approval by consensus sets a very high standard, largely insuring that the SPM has nothing that can be interpreted as unsubstantiated or carelessly worded. The underlying technical chapters are accepted without this line-by-line approval process, but both country delegations and authors invest a huge amount of effort into insuring that, prior to acceptance, everything in the SPM is consistent with the underlying technical material.

This highly standardized, thoroughly monitored assessment process insures that the assessment reports of the IPCC are based on the underlying scientific information. The assessments of the IPCC have no place for unfounded speculation, politically motivated opinion, or overstated confidence. If a process is poorly known or it more information is needed, the assessment is explicit about this. In fact, within the scientific community the IPCC assessment reports are widely used as one of best sources for crystallizing focus on the scientific challenges for the future.

The 4th assessment report of the IPCC, released in stages through 2007, provides the authoritative picture on the status of climate change science to within a few months of the release of each report. To the maximum extent possible, each report is completely up to date, with the demands of the review, approval, and publication process effectively setting the gap between the newest material in the assessment and the release date.

Findings from the 4th Assessment Report of the IPCC

The Fourth Assessment Report of the IPCC provides a scientifically rich picture of a changing climate, the mechanisms that underlie observed and projected changes, impacts of climate change on individuals, ecosystems, economies, and regions, and the costs and benefits of changing practices to decrease the amount of climate change from a business-as-usual scenario.

Among the important messages from the Fourth Assessment Report of the IPCC are the following. These statements are a verbatim selection from the four SPMs approved line-by-line, by consensus, by all of the delegations present at the approval meeting.

- Global atmospheric concentrations of carbon dioxide, methane and nitrous oxide have increased markedly as a result of human activities since 1750 and now far exceed pre-industrial values determined from ice cores spanning many thousands of years. The global increases in carbon dioxide concentration are due primarily to fossil fuel use and land use change, while those of methane and nitrous oxide are primarily due to agriculture. (IPCC 2007a)

- Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level. (IPCC 2007a)

- The understanding of anthropogenic warming and cooling influences on climate has improved since the TAR, leading to very high confidence that the global average net effect of human activities since 1750 has been one of warming, with a radiative forcing of +1.6 [+0.6 to +2.4] W m^{-2}. (IPCC 2007a)

- At continental, regional and ocean basin scales, numerous long-term changes in climate have been observed. These include changes in arctic temperatures and ice, widespread changes in precipitation amounts, ocean salinity, wind patterns and aspects of extreme weather including droughts, heavy precipitation, heat waves and the intensity of tropical cyclones. (IPCC 2007a)

- Some aspects of climate have not been observed to change. (IPCC 2007a)

- Palaeoclimatic information supports the interpretation that the warmth of the last half century is unusual in at least the previous 1,300 years. The last time the polar regions were significantly warmer than present for an extended period (about 125,000 years ago), reductions in polar ice volume led to 4 to 6 m of sea level rise. (IPCC 2007a)

- 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. This is an advance since the TAR's conclusion that "most of the observed warming over the last 50 years is likely to have been due to the increase in greenhouse gas concentrations". Discernible human influences now extend to other aspects of climate, including ocean warming, continental-average temperatures, temperature extremes and wind patterns. (IPCC 2007a)

- For the next two decades, a warming of about 0.2°C per decade is projected for a range of SRES emission scenarios. Even if the concentrations of all greenhouse gases and aerosols had been kept constant at year 2000 levels, a further warming of about 0.1°C per decade would be expected. (IPCC 2007a)

- Continued greenhouse gas emissions at or above current rates would cause further warming and induce many changes in the global climate system during the 21st century that would very likely be larger than those observed during the 20th century. (IPCC 2007a)

- Anthropogenic warming and sea level rise would continue for centuries due to the time scales associated with climate processes and feedbacks, even if greenhouse gas concentrations were to be stabilised. (IPCC 2007a)

- Observational evidence from all continents and most oceans shows that many natural systems are being affected by regional climate changes, particularly temperature increases. (IPCC 2007b)

- Drought-affected areas will likely increase in extent. Heavy precipitation events, which are very likely to increase in frequency, will augment flood risk. (IPCC 2007b)

- Over the course of this century, net carbon uptake by terrestrial ecosystems is likely to peak before mid-century and then weaken or even reverse, thus amplifying climate change. (IPCC 2007b)

- Approximately 20-30% of plant and animal species assessed so far are likely to be at increased risk of extinction if increases in global average temperature exceed 1.5-2.5°C. (IPCC 2007b)

- Increases in the frequency of droughts and floods are projected to affect local crop production negatively, especially in subsistence sectors at low latitudes. (IPCC 2007b)

- Many millions more people are projected to be flooded every year due to sea-level rise by the 2080s. Those densely-populated and low-lying areas where adaptive capacity is relatively low, and which already face other challenges such as tropical storms or local coastal subsidence, are especially at risk. The numbers affected will be largest in the mega-deltas of Asia and Africa while small islands are especially vulnerable. (IPCC 2007b)

- Many estimates of aggregate net economic costs of damages from climate change across the globe (i.e., the social cost of carbon (SCC), expressed in terms of future net benefits and costs that are discounted to the present) are now available. Peer-reviewed estimates of the SCC for 2005 have an average value of US$43 per tonne of carbon (i.e., US$12 per tonne of carbon dioxide), but the range around this mean is large. For example, in a survey of 100 estimates, the values ran from US$-10 per tonne of carbon (US$-3 per tonne of carbon dioxide) up to US$350 per tonne of carbon (US$95 per tonne of carbon dioxide). (IPCC 2007c)

- The large ranges of SCC are due in the large part to differences in assumptions regarding climate sensitivity, response lags, the treatment of risk and equity, economic and non-economic impacts, the inclusion of potentially catastrophic losses, and discount rates. It is very likely that globally aggregated figures underestimate the damage costs because they cannot include many non-quantifiable impacts. Taken as a whole, the range of published evidence indicates that the net damage costs of climate change are likely to be significant and to increase over time. (IPCC 2007c)

- Non-climate stresses can increase vulnerability to climate change by reducing resilience and can also reduce adaptive capacity because of resource deployment to competing needs. For example, current stresses on some coral reefs include marine pollution and chemical runoff from agriculture as well as increases in water temperature and ocean acidification. Vulnerable regions face multiple stresses that affect their exposure and sensitivity as well as their capacity to adapt. These stresses arise from, for example, current climate hazards, poverty and unequal access to resources, food insecurity, trends in economic globalisation, conflict, and incidence of diseases such as HIV/AIDS. Adaptation measures are seldom undertaken in response to climate change alone but can be integrated within, for example, water resource management, coastal defense and risk-reduction strategies. (IPCC 2007c)

- Even the most stringent mitigation efforts cannot avoid further impacts of climate change in the next few decades, which makes adaptation essential, particularly in addressing near-term impacts. Unmitigated climate change would, in the long term, be likely to exceed the capacity of natural, managed and human systems to adapt. (IPCC 2007c)

- Global greenhouse gas (GHG) emissions have grown since pre-industrial times, with an increase of 70% between 1970 and 2004 (high agreement, much evidence). (IPCC 2007c)

- With current climate change mitigation policies and related sustainable development practices, global GHG emissions will continue to grow over the next few decades (high agreement, much evidence). (IPCC 2007c)

- Both bottom-up and top-down studies indicate that there is substantial economic potential for the mitigation of global GHG emissions over the coming decades, that could offset the projected growth of global emissions or reduce emissions below current levels (high agreement, much evidence). (IPCC 2007c)

- In 2030 macro-economic costs for multi-gas mitigation, consistent with emissions trajectories towards stabilization between 445 and 710 ppm CO_2-eq, are estimated at between a 3% decrease of global GDP and a small increase, compared to the baseline. However, regional costs may differ significantly from global averages (high agreement, medium evidence). (IPCC 2007c)

- Changes in lifestyle and behaviour patterns can contribute to climate change mitigation across all sectors. Management practices can also have a positive role (high agreement, medium evidence). (IPCC 2007c)

- While studies use different methodologies, in all analyzed world regions near-term health co-benefits from reduced air pollution as a result of actions to reduce GHG emissions can be substantial and may offset a substantial fraction of mitigation costs (high agreement, much evidence). (IPCC 2007c)

- Energy efficiency options for new and existing buildings could considerably reduce CO2 emissions with net economic benefit. Many barriers exist against tapping this potential, but there are also large co-benefits (high agreement, much evidence). (IPCC 2007c)

- In order to stabilize the concentration of GHGs in the atmosphere, emissions would need to peak and decline thereafter. The lower the stabilization level, the more quickly this peak and decline would need to occur. Mitigation efforts over the next two to three decades will have a large impact on opportunities to achieve lower stabilization levels (high agreement, much evidence). (IPCC 2007c)

- The range of stabilization levels assessed can be achieved by deployment of a portfolio of technologies that are currently available and those that are expected to be commercialised in coming decades. This assumes that appropriate and effective incentives are in place for development, acquisition, deployment and diffusion of technologies and for addressing related barriers (high agreement, much evidence). (IPCC 2007c)

- In 2050 global average macro-economic costs formulti-gas mitigation towards stabilization between 710 and 445 ppm CO_2-eq, are between a 1% gain to a 5.5% decrease of global GDP. For specific countries and sectors, costs vary considerably from the global average. (high agreement, medium evidence). (IPCC 2007c)

- Decision-making about the appropriate level of global mitigation over time involves an iterative risk management process that includes mitigation and adaptation, taking into account actual and avoided climate change damages, co-benefits, sustainability, equity, and attitudes to risk. Choices about the scale and timing of GHG mitigation involve balancing the economic costs of more rapid emission reductions now against the corresponding medium-term and long-term climate risks of delay (high agreement, much evidence). (IPCC 2007c)

- Policies that provide a real or implicit price of carbon could create incentives for producers and consumers to significantly invest in low-GHG products, technologies and processes. Such policies could include economic instruments, government funding and regulation (high agreement, much evidence). (IPCC 2007c)

- The literature identifies many options for achieving reductions of global GHG emissions at the international level through cooperation. It also suggests that successful agreements are environmentally effective, cost-effective, incorporate distributional considerations and equity, and are institutionally feasible (high agreement, much evidence). (IPCC 2007c)

Specific findings for North America are the following (all from (IPCC 2007b)):

- Warming in western mountains is projected to cause decreased snowpack, more winter flooding and reduced summer flows, exacerbating competition for over-allocated water resources.

- In the early decades of the century, moderate climate change is projected to increase aggregate yields of rain-fed agriculture by 5 to 20%, but with important variability among regions.

- Major challenges are projected for crops that are near the warm end of their suitable range or which depend on highly utilised water resources.

- Cities that currently experience heat waves are expected to be further challenged by an increased number, intensity and duration of heat waves during the course of the century, with potential for adverse health impacts.

- Coastal communities and habitats will be increasingly stressed by climate change impacts interacting with development and pollution.

Impacts of Climate Change on the United States

The United States frequently experiences weather-related challenges, with substantial economic costs from severe storms, drought, flood, extreme heat, and extreme cold (Field et al. 2007). Weather-related impacts are persistent features of the American landscape. Over the last several decades, however, the United States has experienced substantial amounts of warming, especially in Alaska, and recent scientific research documents an increasing number of impacts that appear to be a result of climate changes that have already occurred (Field et al. 2007). For one-time events, like heat waves, drought, or wildfires, it will rarely be possible to say with certainty that a single event was caused by climate change (Hegerl et al. 2007). Nevertheless, several kinds of extremes will likely become more common with climate change. Increasingly, it is possible to assess the probability that a heat wave, wildfire, or drought would have occurred in the absence of climate change (Hegerl et al. 2007).

In recent decades, the United States has experienced an increasing number of stresses projected to increase in a warming climate. Some of these are iconic one-time events like the need to move the Alaskan village of Shishmaref, which is being progressively lost to the sea after 400 years of habitation, a consequence of melting of the permafrost on which it sits and increased wave action related to a decreased period when ice protects the village (http://www.arctic.noaa.gov/detect/human-shishmaref.shtml). Others are more gradual and progressive. Examples include the clear decrease in the season for high-latitude ice roads, the dramatic decrease in water stored in the snowpack of the Western mountains, or the strong increase in the area burned in Western wildfires (Field et al. 2007). Drought is among the largest climate-related concerns for the United States. Many parts of the Western US have limited water security. Some of these are in parts of the country where decreased snowpack is cutting into water storage capacity or where groundwater pumping has led to large drops in the water table (Field et al. 2007). Projected decreases in precipitation (Meehl et al. 2007) could push many of these areas from water insecure to chronically critically short of water.

With climate change in coming decades, the United States will have vulnerable people, businesses, and activities in all regions. The people most vulnerable to impacts of climate change tend to be those who are very young, old, sick, or poor. People who live in communities dependent on single industries based on resources at risk (e.g. fisheries) will likely experience large impacts, especially if they cannot switch activities or relocate (Field et al. 2007). Continuing increases in the value of the infrastructure in the coastal zone exacerbate the risks from sea-level rise. The United States has abundant adaptive capacity with the potential to provide an important measure of protection, but deploying that capacity to effectively provide protection will require mainstreaming adaptation at a level far above the historical norm (Field et al. 2007).

Updates from New Advances in Climate Science

The authoritative reports of the IPCC are released every five to seven years. This is a substantial time in the trajectory of a rapidly developing field like climate science, and many important new results appear between assessments. One of the great strengths of the IPCC is that, in evaluating thousands of papers, it can evaluate the results stand up to independent validation and which do not. Between assessments, it can be more difficult to determine the confidence to associate with any particular result. Those results, however, that use well established methods and focus on extending observations or calculations already assessed in the IPCC can be used with confidence. Several recent results warrant particular attention.

Emissions of carbon dioxide to the atmosphere from fossil fuel combustion have been increasing rapidly. From 2000 to 2007, the annual rate of increase was 3.5% per year, compared to 0.9% per year for the period from 1990 to 1999. Actual emissions since 2000 have been running at the top end of the range in the family of scenarios used by the IPCC (Raupach et al. 2007).

Observed warming has been confirmed for the continent of Antarctica. For many years, temperature measurements over Antarctica were too sparse to allow a confident assessment of temperature trends, and some records indicated that Antactica might be cooling. Recently published data, based on a larger set of measurements than previously available, confirms that the continent is warming at a rate of more than 0.1˚C per decade over the last 50 years (Steig et al. 2009).

Sea level rise has risen over the last century. The 4^{th} Assessment report of the IPCC reports an average rate of 1.8 mm per year over the 20^{th} century, increasing to 3.1 mm per year for the period from 1993 to 2003 (IPCC 2007a). New research confirms that most of the rise since 2003 is from the melting of land ice, with contributions from melting glaciers, Greenland, and Antarctica (Cazenave et al. 2008).

Summer sea ice in the Arctic has been decreasing for many years, with good records going back to the late 1970s. The summer of 2007 saw exceptionally low ice cover at the September minimum, with an area of 3.77 million square km or 38% below the long term average. From 1996 to 2007 the summer area minimum decreased at an annual rate of 10.7% per decade, compared to 3% per decade for 1979 to 1996 (Comiso et al. 2008). The minimum area of Arctic ice was only slightly greater than the 2007 minimum in 2008 (http://www.arcus.org/search/seaiceoutlook/summary_report.php).

Increasing evidence points to the possibility of potentially strong feedbacks, amplifying climate change, from terrestrial ecosystems. The 4^{th} assessment report of the IPCC undertook a preliminary assessment of the feedbacks from coupling the carbon cycle and climate. The conclusion of this assessment is that, over the century, coupling increases the emissions of carbon dioxide to the atmosphere. In climate simulations using the highest emission scenario explored in detail by the IPCC (A2), coupling released an additional 100 to 500 billion tons of carbon to the atmosphere by 2100 (Meehl et al. 2007). New research indicates that substantial amounts of carbon could also be released from melting permafrost (Khvorostyanov et al. 2008), now estimated to be a store of nearly a billion tons of carbon, or almost three times the cumulative release from fossil fuel combustion since the beginning of the industrial revolution (Schuur et al. 2008).

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