IPCC AR5: Process, Projections, and Predictions

Gerald Meehl
National Center for Atmospheric Research
Lead Author Chapter 11 “Near-term climate change: Projections and predictability”
Overview

I. Introduction
   • Overview IPCC
   • Structure and Timeline IPCC 5th Assessment WG I Report

II. What is new compared to AR4?
   • Observational Evidence for Climate Change
   • Understanding and Attributing Climate Change

III. Projections and predictions

IV. Outlook
Introduction
The Intergovernmental Panel on Climate Change (IPCC) consists of about 190 governments that commission assessments performed by the international climate science community to determine the current state of human knowledge of climate and climate change.

Working Group 1: Climate science
Working Group 2: Climate impacts and adaptation
Working Group 3: Mitigation
The IPCC 

established by the United Nations Environment Programme (UNEP) and the World Meteorological Organization (WMO) in 1988 to provide the world with a clear scientific view on the current state of knowledge in climate change and its potential environmental and socio-economic impacts. In the same year, the UN General Assembly endorsed the action by WMO and UNEP in jointly establishing the IPCC.
The IPCC assessments

--Provide the current state of human knowledge on climate variability and change

--An assessment, not a review

--Policy-relevant, but not policy-prescriptive

--Transparent (two stages of open international review; each comment documented and responded to by the lead authors; each chapter for each round of review receives ~1500 comments; all comments and responses can be traced and are available at the end of the process)

--Calibrated uncertainty language
IPCC “calibrated uncertainty language” to communicate assessment of uncertainty.

**Table 1. Likelihood Scale**

<table>
<thead>
<tr>
<th>Term*</th>
<th>Likelihood of the Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Virtually certain</td>
<td>99-100% probability</td>
</tr>
<tr>
<td>Very likely</td>
<td>90-100% probability</td>
</tr>
<tr>
<td>Likely</td>
<td>66-100% probability</td>
</tr>
<tr>
<td>About as likely as not</td>
<td>33 to 66% probability</td>
</tr>
<tr>
<td>Unlikely</td>
<td>0-33% probability</td>
</tr>
<tr>
<td>Very unlikely</td>
<td>0-10% probability</td>
</tr>
<tr>
<td>Exceptionally unlikely</td>
<td>0-1% probability</td>
</tr>
</tbody>
</table>

*Additional terms that were used in limited circumstances in the AR4 (extremely likely – 95-100% probability, more likely than not – >50-100% probability, and extremely unlikely – 0-5% probability) may also be used in the AR5 when appropriate.*
The IPCC assessments

First Assessment Report, 1990
Second Assessment Report, 1995
Third Assessment Report, 2001
Fourth Assessment Report, 2007
Fifth Assessment Report, 2013

Governments will meet after the conclusion of the AR5 to decide whether there will be an AR6
IPCC controversies

--After the Second Assessment Report in 1995, changes agreed to in the final plenary were authorized by the governments to be added to the SPM by the assigned lead authors. Later, there were charges that a few lead authors made changes on their own. These charges were unfounded, but lead authors were attacked directly by the media and critics.

--Subsequently, review editors (at least two per chapter) were instituted to oversee the review and editing process to stand between the lead authors and critics to explain and defend the process.
IPCC controversies

After the AR4 in 2009, thousands of emails were stolen from a server (“climate-gate”) and several AR4 lead authors’ emails were cited out of context to try and ruin those scientists’ credibility, with the goal of discrediting the IPCC AR4.

Multiple subsequent investigations in the U.S. and U.K. have cleared those scientists of any wrong-doing, and the IPCC AR4 science stands.

Errors in the AR4?

Two minor errors were found: both in WG II. These were on (i) Himalayan glaciers melt (this was correct in WG I), and (ii) The area of Netherlands below sea level.

These errors were corrected, and a better errata procedure has been instituted for the AR5.
Working Group I contribution to the IPCC Fifth Assessment Report

2009 Two scoping meetings: governments ask scientists for climate information on certain topics; an outline for the AR5 is proposed; Early 2010 Lead authors nominated by participating countries and chosen

November 2010 First Lead Authors Meeting (Kunming, China), work on Zero Order Draft

July 2011 Second Lead Authors Meeting (Brest, France), work on First Order Draft

December 2011-February 2012 Expert Review of the First Order Draft

April 2012 Third Lead Authors Meeting (Marrakech, Morocco) respond to comments on FOD, formulate Second Order Draft; formulate first drafts of Technical Summary (TS) and Summary for Policymakers (SPM)

(Jul. 31 WGI AR5 cut-off for submitted papers; cut-off for accepted papers Mar 15 2012)


January 2013 Fourth Lead Authors Meeting (Hobart, Tasmania, Australia) respond to comments on Second Order Draft; respond to comments on the Technical Summary and Summary for Policymakers

Jun-Aug 2013 Final Government Distribution of the WGI AR5 chapters, TS and SPM

September 2013 WGI AR5 SPM Approval Plenary, Stockholm, Sweden
Key SPM Messages

19 Headlines
on less than 2 Pages

Summary for Policymakers
27 pp, Took 4 days to approve line by line, word for word

14 Chapters
Atlas of Regional Projections

2 rounds of international review
54,677 Review Comments by 1089 Experts

255 authors from 39 countries
18% female; 24% DC/EIT; ~50% new to IPCC

2009: WGI Outline Approved
4 Lead author meetings over 4 years

Slide 12
Structure of the IPCC WG I AR5 Report

Chapter 1: Introduction
Observations and Paleoclimate Information
  Chapter 2: Observations: Atmosphere and Surface
  Chapter 3: Observations: Ocean
  Chapter 4: Observations: Cryosphere
  Chapter 5: Information from Paleoclimate Archives
Process Understanding
  Chapter 6: Carbon and other Biogeochemical Cycles
  Chapter 7: Clouds and Aerosols
From Forcing to Attribution of Climate Change
  Chapter 8: Anthropogenic and Natural Radiative Forcing
  Chapter 9: Evaluation of Climate Models
  Chapter 10: Detection and Attribution of Climate Change: from Global to Regional
Future Climate Change and Predictability
  Chapter 11: Near-term Climate Change: Projections and Predictability
  Chapter 12: Long-term Climate Change: Projections, Commitments and Reversibility
Integration
  Chapter 13: Sea Level Change
  Chapter 14: Climate Phenomena and their Relevance for Future Regional Climate Change

Technical Summary (about 150 pages)
Summary for Policymakers (27 pages)
The IPCC Final Plenary

Delegations from the IPCC governments convene to approve the final report

This involves going over the Summary for Policymakers (SPM) line-by-line

85% is an exercise of lead authors and government delegations working together to clarify wording and clearly communicating the main results so the governments understand the report

15% is governments trying to change certain conclusions

The scientists are there to make sure the science doesn’t change, and that the conclusions are communicated clearly
IPCC Plenary for approval of the Summary for Policymakers, Stockholm
Sept. 23-26, 2013

Roughly 110 governments and about 300 delegate
Simultaneous translation into the six UN languages

Four full days and two nights (until 2:20AM Thursday morning, and 5:20AM Friday morning) to approve 27 page document
The first sentence of the Summary for Policymakers:

started with:

The Working Group I contribution to the IPCC’s Fifth Assessment Report (AR5) considers new evidence of past and projected future climate change based on many independent scientific analyses ranging from observations of the climate system, paleoclimate archives, theoretical studies of climate processes and simulations using climate models.

40 minutes of discussion later…

Final approved version:

The Working Group I contribution to the IPCC’s Fifth Assessment Report (AR5) considers new evidence of climate change based on many independent scientific analyses from observations of the climate system, paleoclimate archives, theoretical studies of climate processes and simulations using climate models.
What is new compared to AR4
What is New?

• **Improved treatment of regional information**
  - by specifically assessing key climate phenomena (monsoon, El Niño, etc.)
  - Atlas of Global and Regional Climate Projections to enhance accessibility for users and stakeholders and ease the hand-over of relevant information from WG I to WG II.

• Assessment of the science of **clouds and aerosols (incl. Geoengineering)**

• An end-to-end assessment of **sea level change**

• An end-to-end assessment of the **carbon cycle (e.g. ocean acidification, feedbacks)**

• Future climate change broken down into **near- and long-term projections**
(1) CMIP 5 experimental design: Decadal Predictions
(observationally-based information used to initialize the models)

Why an emphasis on decadal predictions?
   i. a recognition of its importance to decision makers in government and industry;
   ii. new international research effort to improve understanding of interaction of internally generated variability and externally forced response in near-term climate;
   iii. a recognition that near-term projections are generally less sensitive to differences between future emissions scenarios than are long-term projections.

Estimates of near-term climate depend partly on
   i. committed change (caused by the inertia of the oceans as they respond to historical external forcing),
   ii. the time evolution of internally-generated climate variability, and
   iii. the time evolution of external forcing.

Chapter 11
Box 11.1, Fig. 2
Models have improved in terms of simulation capability

Of the roughly 45 “standard” models in the CMIP5 database:

14 are “high top” with a resolved stratosphere (only 1 in CMIP3)

19 are “Earth System Models” with at least interactive ocean biogeochemistry (none in CMIP3)

Most have some kind of prognostic aerosol formulation and can resolve direct and indirect effect (very few included prognostic indirect effect in CMIP3)

None use flux correction (about a third of the models in CMIP3 used flux correction)
Future scenarios: Representative Concentration Pathways (RCPs)

van Vuuren et al., 2011

- IPCC 5th Assessment made extensive use of model projections based on four representative concentration pathways (RCPs), three of which are mitigation scenarios, intended to span a broad range of plausible future greenhouse gas scenarios; RCP2.6 designed to meet goal of less than 2°C warming from pre-industrial by 2100.

van Vuuren et al., 2011

- Negative CO2 emissions after ~2075
A summary assessment of the effects of solar forcing on climate was included for the first time in the SPM:

- There is high confidence that changes in total solar irradiance have not contributed to the increase in global mean surface temperature over the period 1986 to 2008, based on direct satellite measurements of total solar irradiance. There is medium confidence that the 11-year cycle of solar variability influences decadal climate fluctuations in some regions. No robust association between changes in cosmic rays and cloudiness has been identified. {7.4, 10.3, Box 10.2}
Warming of the climate system is **unequivocal**, and since the 1950s, many of the observed changes are unprecedented over decades to millennia.

Each of the last three decades has been successively warmer at the Earth’s surface than any preceding decade since 1850.

In addition to robust multi-decadal warming, global mean surface temperature exhibits substantial decadal and interannual variability (see Figure SPM.1). Due to natural variability, trends based on short records are very sensitive to the beginning and end dates and do not in general reflect long-term climate trends. As one example, the rate of warming over the past 15 years (1998–2012; 0.05 [−0.05 to 0.15] °C per decade), which begins with a strong El Niño, is smaller than the rate calculated since 1951 (1951–2012; 0.12 [0.08 to 0.14] °C per decade). (2.4)
Multiple complementary indicators of a changing climate

(a) Northern Hemisphere spring snow cover

1967–2012 decreases: 1.6 [0.8 to 2.4] %/dec

(b) Arctic summer sea ice extent

1979–2012 annual mean decrease 3.5–4.1%/dec.

- Over the last two decades, the Greenland and Antarctic ice sheets have been losing mass, glaciers have continued to shrink almost worldwide, and Arctic sea ice and Northern Hemisphere spring snow cover have continued to decrease in extent (*high confidence*).
Multiple complementary indicators of a changing climate

- Ocean warming dominates the increase in energy stored in the climate system, accounting for more than 90% of the energy accumulated between 1971 and 2010 (high confidence).

- It is virtually certain that the upper ocean (0–700 m) warmed from 1971 to 2010, and it likely warmed between the 1870s and 1971.

- The rate of sea level rise since the mid-19th century has been larger than the mean rate during the previous two millennia (high confidence).

- Over the period 1901–2010, global mean sea level rose by 0.19 [0.17 to 0.21] m.

**Figure SPM.3**
The atmospheric concentrations of carbon dioxide (CO$_2$), methane, and nitrous oxide have increased to levels unprecedented in at least the last 800,000 years.

CO$_2$ concentrations have increased by 40% since pre-industrial times, primarily from fossil fuel emissions and secondarily from net land use change emissions.

The ocean has absorbed about 30% of the emitted anthropogenic carbon dioxide, causing ocean acidification.
Radiative Forcing in 2011 since 1750 (W m\(^{-2}\))
- grouped by *emissions*, rather than by *concentrations* to allow the indirect effects to be seen clearly -

- Total RF is positive, and has led to an uptake of energy by the climate system.
- The largest contribution to total radiative forcing is caused by the increase in the atmospheric concentration of CO\(_2\) since 1750.

### Table: Radiative Forcing by Emissions and Drivers

<table>
<thead>
<tr>
<th>Emitted compound</th>
<th>Resulting atmospheric drivers</th>
<th>Radiative forcing by emissions and drivers</th>
<th>Level of confidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO(_2)</td>
<td>CO(_2)</td>
<td>(1.68 [1.33 to 2.03])</td>
<td>VH</td>
</tr>
<tr>
<td>CH(_4)</td>
<td>CO(_2), H(_2)O, O(_3), CH(_4)</td>
<td>(0.97 [0.74 to 1.30])</td>
<td>H</td>
</tr>
<tr>
<td>Halocarbons</td>
<td>O(_3), CFCs, HCFCs</td>
<td>(0.18 [0.01 to 0.36])</td>
<td>H</td>
</tr>
<tr>
<td>N(_2)O</td>
<td>N(_2)O</td>
<td>(0.17 [0.13 to 0.21])</td>
<td>VH</td>
</tr>
<tr>
<td>CO</td>
<td>CO(_2), CH(_4), O(_3)</td>
<td>(0.23 [0.16 to 0.30])</td>
<td>M</td>
</tr>
<tr>
<td>NMVOC</td>
<td>CO(_2), CH(_4), O(_3)</td>
<td>(0.10 [0.05 to 0.15])</td>
<td>M</td>
</tr>
<tr>
<td>NO(_x)</td>
<td>Nitrate, CH(_4), O(_3)</td>
<td>(-0.15 [-0.34 to 0.03])</td>
<td>M</td>
</tr>
<tr>
<td>Aerosols and precursors</td>
<td>Mineral dust, Sulphate, Nitrate, Organic carbon, black carbon</td>
<td>(-0.27 [-0.77 to 0.23])</td>
<td>H</td>
</tr>
<tr>
<td>Cloud adjustments due to aerosols</td>
<td></td>
<td>(-0.55 [-1.33 to -0.06])</td>
<td>L</td>
</tr>
<tr>
<td>Albedo change due to land use</td>
<td></td>
<td>(-0.15 [-0.25 to -0.06])</td>
<td>M</td>
</tr>
<tr>
<td>Natural</td>
<td>Changes in solar irradiance</td>
<td>(0.05 [0.00 to 0.10])</td>
<td>M</td>
</tr>
</tbody>
</table>

### Figure SPM.5

- Total anthropogenic RF relative to 1750:
  - 2011: 2.29 [1.13 to 3.39] (H)
  - 1980: 1.25 [0.54 to 1.86] (H)
  - 1950: 0.57 [0.29 to 0.86] (M)
Evolution of assessment of human influence on climate:


“There is new and stronger evidence that most of the warming observed over the last 50 years is attributable to human activities”. --IPCC Third Assessment Report, 2001

“Most of the observed increase in globally averaged temperatures since the mid-20th century is very likely due to the observed increase in anthropogenic greenhouse gas concentrations”. --IPCC Fourth Assessment Report, 2007

It is extremely likely that human influence has been the dominant cause of the observed warming since the mid-20th century. --IPCC Fifth Assessment Report, 2013

It is extremely likely that more than half of the observed increase in global average surface temperature from 1951 to 2010 was caused by the anthropogenic increase in greenhouse gas concentrations and other anthropogenic forcings together. --IPCC Fifth Assessment Report, 2013
Evidence of human influence has grown since the AR4.

It is extremely likely that human influence has been the dominant cause of the observed warming since the mid-20th century.

*Figure SPM.6*

WGI AR5 Final Draft 07 June
Updated estimates of Global Mean Sea Level Rise (GMSLR)

The rate of GMSLR since the mid-19th century has been larger than the mean rate during the previous two millennia.

Rate during 1901-1990 was 1.5 [1.3 to 1.7] mm yr\(^{-1}\).

Rate during 1993-2010 was 3.2 [2.8 to 3.6] mm yr\(^{-1}\).
Causes of global mean sea level rise (GMSLR)

Global mean sea level rise is caused by an increase in the volume of the global ocean.
This in turn is caused by:
Warming the ocean (thermal expansion, global thermosteric sea level rise).
Adding mass to the ocean (barystatic sea level rise, not eustatic), due to:
  - Loss of ice by glaciers.
  - Loss of ice by ice sheets.
  - Reduction of liquid water storage on land.
Observed GMSLR 1993-2010 is consistent with the sum of observed contributions (*high confidence*)

- **High confidence** in an anthropogenic influence on these largest contributions
- **Likely** anthropogenic influence
- **Low confidence** in attributing the causes

Data from Table 13.1
Projections and predictions
Under all RCPs the rate of GMSLR will very likely exceed that observed during 1971–2010.

Earlier CO₂ emissions cause greater GMSLR.

Stabilising global mean surface temperature does not stabilise global mean sea level.

8–16 mm yr⁻¹ in 2081-2100
Collapse of marine-based sectors of the Antarctic ice sheet

Only this effect, if initiated, could cause GMSL to rise substantially above the likely range during the 21st century.

Medium confidence that this additional contribution would not exceed several tenths of a metre.

Current evidence and understanding do not allow a quantification of either the timing of its onset or of the magnitude of its multi-century contribution.
Regional sea level rise by the end of the 21st century due to ocean density and circulation change.

CMIP5 ensemble mean
Includes GSMLR due to thermal expansion of 0.18 m

Ensemble standard deviation

Fig 13.16
Projections

- Based on an assessment of the subset of models that most closely reproduce the climatological mean state and 1979 to 2012 trend of the Arctic sea ice extent, a nearly ice-free Arctic Ocean in September before mid-century is likely for RCP8.5 (medium confidence) (see Figures SPM.7 and SPM.8). A projection of when the Arctic might become nearly ice-free in September in the 21st century cannot be made with confidence for the other scenarios. (11.3, 12.4, 12.5)
Projections

Fig. SPM.8
What about the early-2000s hiatus?

Climate models have improved since the AR4. Models reproduce observed temperature trends over many decades, including the more rapid warming since the mid-20th century and the cooling immediately following large volcanic eruptions (very high confidence).

1998–2012: 0.04 °C/decade
1951–2012: 0.11 °C/decade
2016-2035 assessed temperature range is less than from uninitialized projections in part due to results from initialized decadal predictions.
Warming will persist for centuries

- Zero \( \text{CO}_2 \) emissions lead to near constant surface temperature.
- A large fraction of climate change persists for many centuries.
- Depending on the scenario, about 15-40% of the emitted carbon remains in the atmosphere for 1000 yrs.
Cumulative carbon determines warming

- Peak warming is approximately proportional to cumulative (total) emissions.
- Transient climate response to cumulative carbon emissions TCRE = Warming per 1000 PgC
Cumulative carbon determines warming
Cumulative carbon determines warming

Limiting the warming caused by anthropogenic CO₂ emissions alone with a probability of >33%, >50%, and >66% to less than 2°C since the period 1861–1880, will require cumulative CO₂ emissions from all anthropogenic sources to stay between 0 and about 1570 GtC (5760 GtCO₂), 0 and about 1210 GtC (4440 GtCO₂), and 0 and about 1000 GtC (3670 GtCO₂) since that period, respectively. These upper amounts are reduced to about 900 GtC (3300 GtCO₂), 820 GtC (3010 GtCO₂), and 790 GtC (2900 GtCO₂), respectively, when accounting for non-CO₂ forcings as in RCP2.6. An amount of 515 [445 to 585] GtC (1890 [1630 to 2150] GtCO₂), was already emitted by 2011. (12.5)
Outlook
WGI AR5 Production and Publication

• Printed version published in early 2014

The Working Group (WG) Reports and Synthesis Report will be completed in 2013/2014:

• WG I: The Physical Science Basis 23-26 September 2013, Stockholm, Sweden
• WG II: Impacts, Adaptation and Vulnerability 25-29 March 2014, Yokohama, Japan
• WG III: Mitigation of Climate Change 7-11 April 2014, Berlin, Germany
• AR5 Synthesis Report (SYR) 27-31 October 2014, Copenhagen, Denmark
• More than 830 authors are involved in writing the reports.

Will there be an AR6?
The governments, not the scientific community, make this decision

IPCC is a group of about 190 governments, and they will have a plenary some time in 2015 to address future assessments
Whether or not there is an AR6, the international climate science community has begun preparing for the Coupled Model Intercomparison Project Phase 6 (CMIP6)


1. Establish a set of CMIP ongoing model development evaluation and characterization (DECK) experiments to gain basic information about model performance and sensitivity (CMIP)

2. Organize sets of experiments to address science questions within the context of the WCRP Grand Challenges and AIMES input specific to CMIP6
   - Systematic biases,
   - Response to forcings,
   - Variability, predictability and future scenarios

3. Around these experiments build CMIP6 with additional, specialized intercomparisons (“MIPs”) that would make use of the same standards and infrastructure.

WCRP Grand Challenges: (1) Clouds, circulation and climate sensitivity, (2) Changes in cryosphere, (3) Climate extremes, (4) Regional climate information, (5) Regional sea-level rise, and (6) Water availability, plus an additional theme on “biospheric forcings and feedbacks”
Climate Change 2013: The Physical Science Basis
Working Group I contribution to the IPCC Fifth Assessment Report

Further Information
www.climatechange2013.org