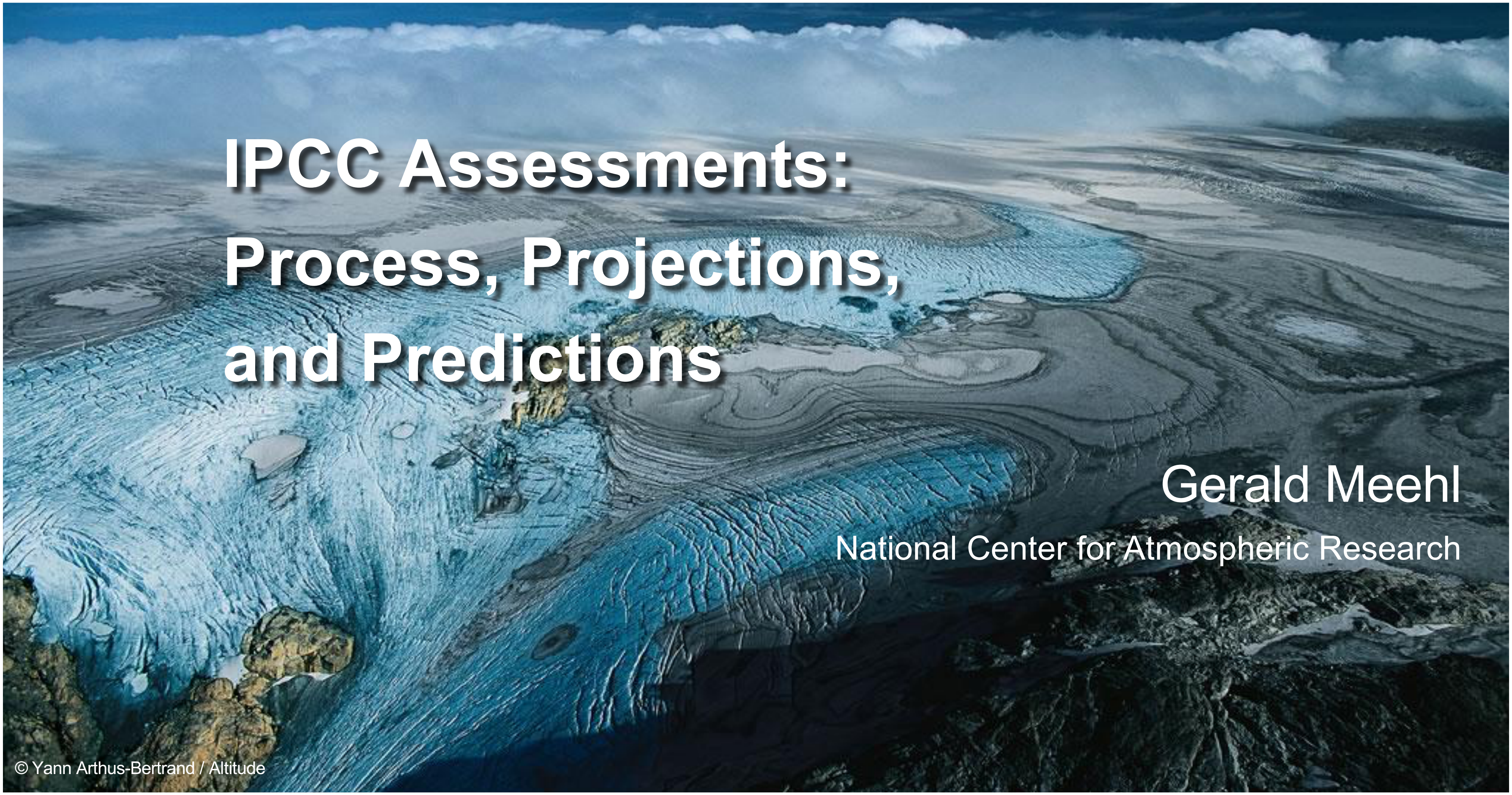

IPCC Assessments: Process, Projections, and Predictions

Gerald Meehl
National Center for Atmospheric Research

IPCC
INTERGOVERNMENTAL PANEL ON climate change

WMO UNEP

Overview

I. Introduction

- Overview of the IPCC
- Structure and Timeline IPCC 6th Assessment
- How do the three Working Groups connect?

II. What was in the most recent (2013) IPCC Fifth Assessment Report (AR5), and how may this evolve in the AR6 currently underway?

- Observational Evidence for Climate Change
- Understanding and Attributing Climate Change

III. Projections and predictions

IV. Current status of the AR6

Introduction

The IPCC Assessments

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, adaptation, and vulnerability

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 (requested by the governments)

--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

--How do you get to be an IPCC lead author? (typically about 15 to 20 per chapter)

--governments nominate scientists from their countries to be lead authors (the total number of nominations summed over all governments numbers hundreds of scientists from around the world)

--the IPCC Bureau and the working group co-chairs make the selection based on expertise, country representation, demographics, experience level

--the lead-author teams for each chapter represent their respective countries in the assessment process—like a "science Olympics"

ipcc
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The IPCC assessments

First Assessment Report, 1990 ("FAR")

Second Assessment Report, 1995 ("SAR")

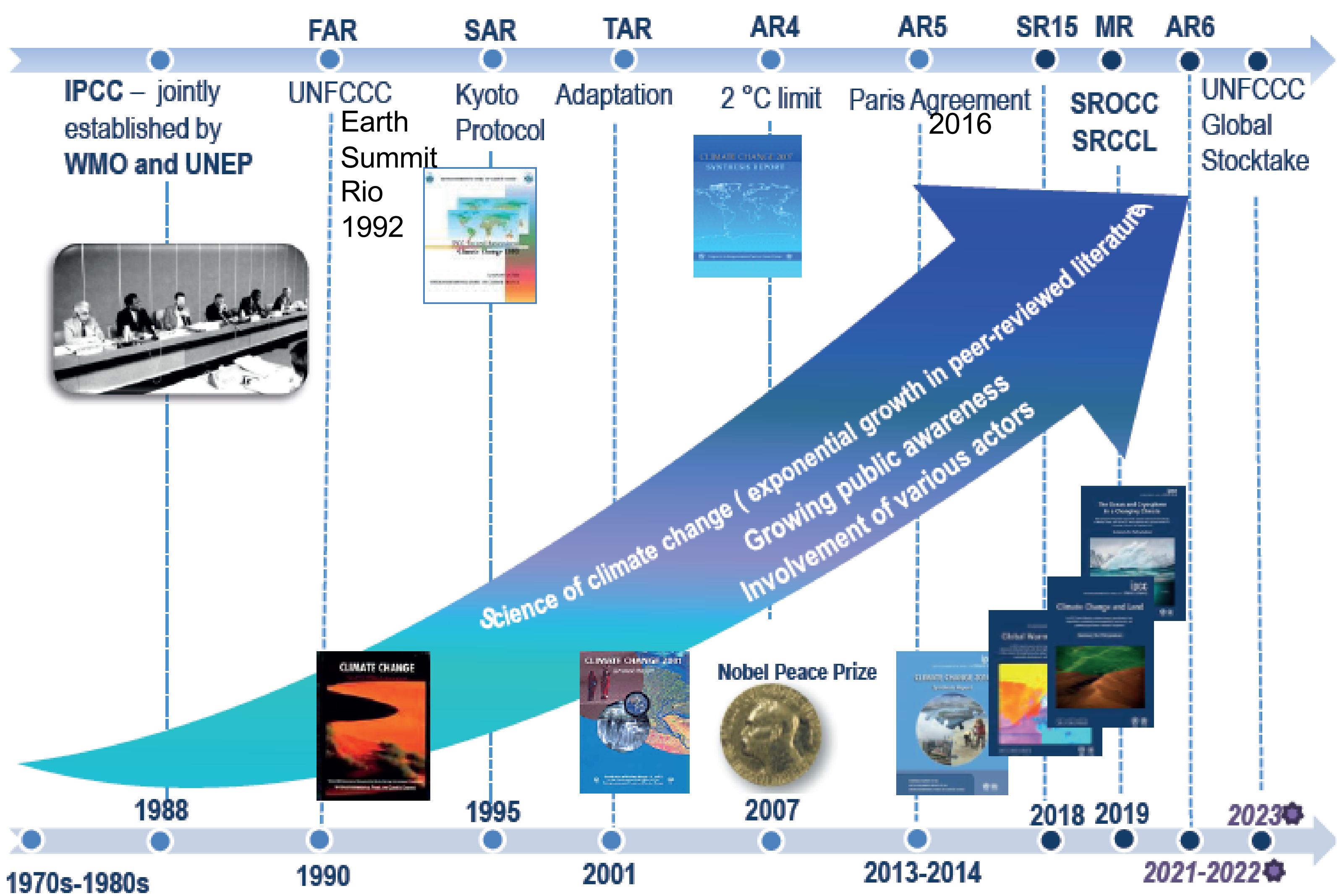
Third Assessment Report, 2001 ("TAR")

Fourth Assessment Report, 2007 ("AR4")

Fifth Assessment Report, 2013 ("AR5")

Sixth Assessment Report, 2021 (tentative) ("AR6")

IPCC contribution to climate science and policymaking



These dates are subject to change.

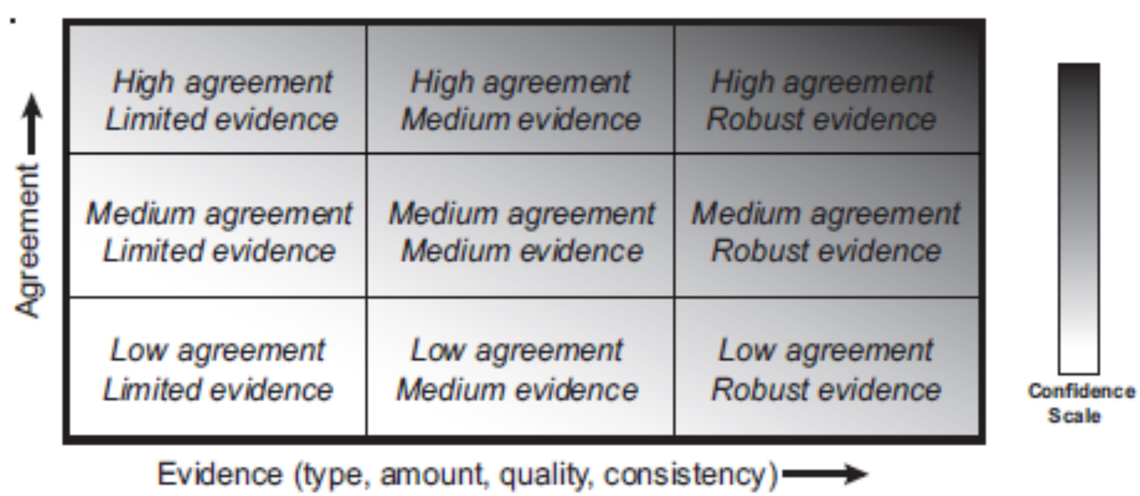
IPCC A
Climate

IPCC "calibrated uncertainty language" to communicate assessment of uncertainty

Table 1. Likelihood Scale

Term*	Likelihood of the Outcome
Virtually certain	99-100% probability
Extremely likely	95-100% probability
Very likely	90-100% probability
Likely	66-100% probability
About as likely as not	33 to 66% probability
Unlikely	0-33% probability
Very unlikely	0-10% probability
Exceptionally unlikely	0-1% probability

* 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.



IPCC AR5 Working Group I
Climate Change 2013: The Physical Science Basis

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 personally attacked directly by the media and critics for the first time

--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. 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 was 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)

Oct. –Nov. 2012 Expert and Government Review of Second Order Draft, TS and SPM

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

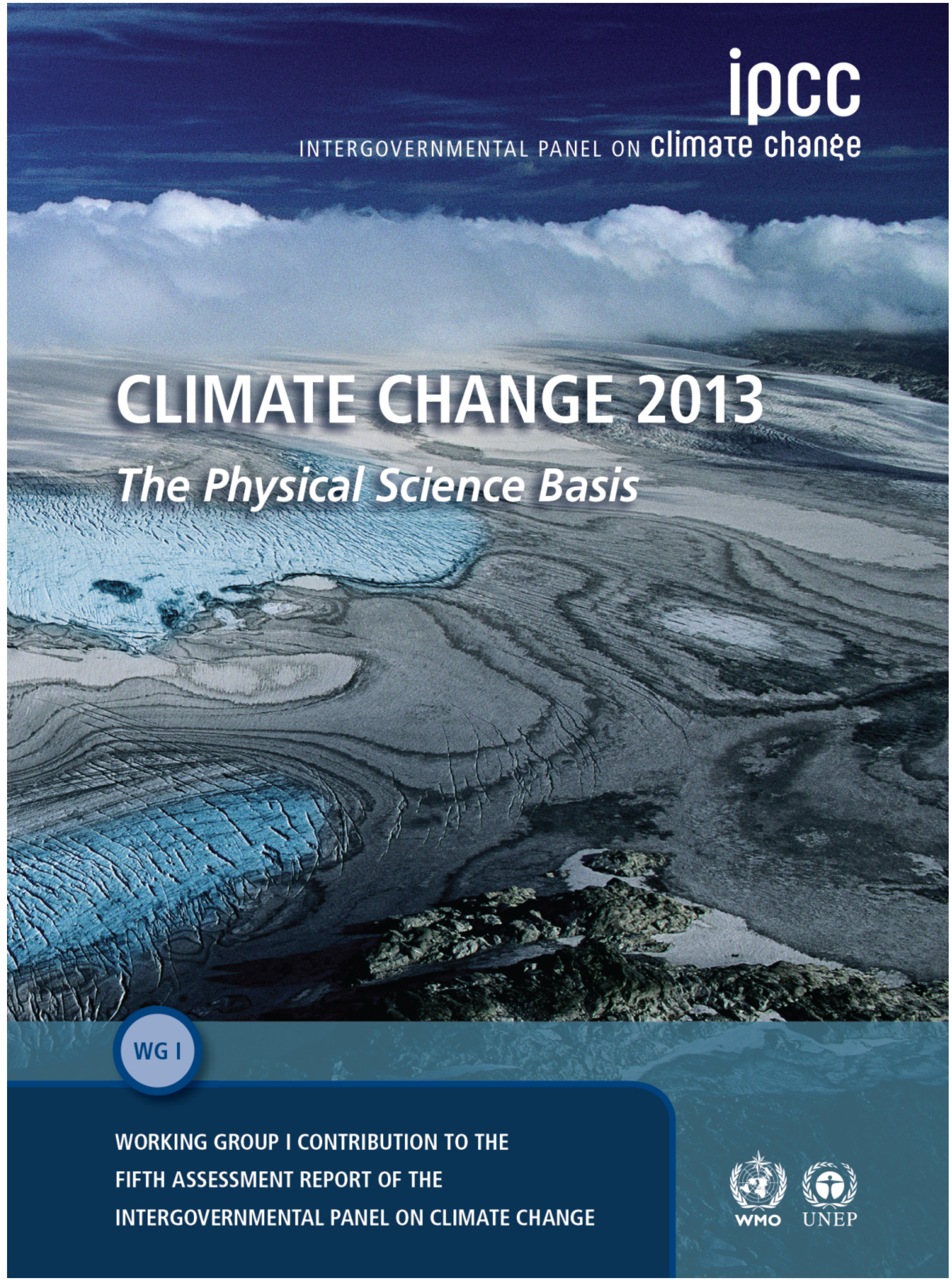
Summary for Policymakers
27 pp, Took 4 days to approve
line by line, word for word

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



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

Annex: Annex I: Atlas of Global and Regional Climate Projections, Annex II: Climate System Scenario Tables, Annex III: Glossary

Technical Summary (about 80 pages)
Summary for Policymakers (27 pages)

Structure of the IPCC WG II AR5 Report (page 1)

PART A: GLOBAL AND SECTORAL ASPECTS

Context for the AR5

1. Point of departure
2. Foundations for decisionmaking

Natural and Managed Resources and Systems, and Their Uses

3. Freshwater resources
4. Terrestrial and inland water systems
5. Coastal systems and low-lying areas
6. Ocean systems
   Supplementary Material
7. Food security and food production systems

Human Settlements, Industry, and Infrastructure

8. Urban areas
9. Rural areas
10. Key economic sectors and services
    Supplementary Material

Human Health, Well-Being, and Security

11. Human health: impacts, adaptation, and co-benefits
12. Human security
13. Livelihoods and poverty

Structure of the IPCC WG II AR5 Report (page 2)

Adaptation
14. Adaptation needs and options
15. Adaptation planning and implementation
16. Adaptation opportunities, constraints, and limits
17 Economics of adaptation
Multi-Sector Impacts, Risks, Vulnerabilities, and Opportunities
18. Detection and attribution of observed impacts
19 Emergent risks and key vulnerabilities
20. Climate-resilient pathways: adaptation, mitigation, and sustainable development

PART B: REGIONAL ASPECTS
21. Regional context
    Supplementary Material
Regional Chapters
22. Africa
23. Europe
    Supplementary Material
24. Asia
    Supplementary Material
25. Australasia
26. North America

Structure of the IPCC WG II AR5 Report (page 3)

Regional Chapters (continued)

27. Central and South America
28. Polar Regions
29. Small Islands
30. The Ocean

Supplementary Material

Summary for Policymakers (32 pp)
Technical Summary (94 pp)
Frequently Asked Questions
Cross-chapter box compendium

Structure of the IPCC WG III AR5 Report

1. Introductory Chapter
2. Integrated Risk and Uncertainty Assessment of Climate Change Response Policies
3. Social, Economic and Ethical Concepts and Methods
4. Sustainable Development and Equity
5. Drivers, Trends and Mitigation
6. Assessing Transformation Pathways
7. Energy Systems
8. Transport
9. Buildings
10. Industry
11. Agriculture, Forestry and Other Land Use (AFOLU)
12. Human Settlements, Infrastructure and Spatial Planning
13. International Cooperation: Agreements and Instruments
14. Regional Development and Cooperation
15. National and Sub-national Policies and Institutions
16. Cross-cutting Investment and Finance Issues

Summary for policymakers (30 pp)
Technical summary (107 pp)

How do the three working groups communicate with each other?

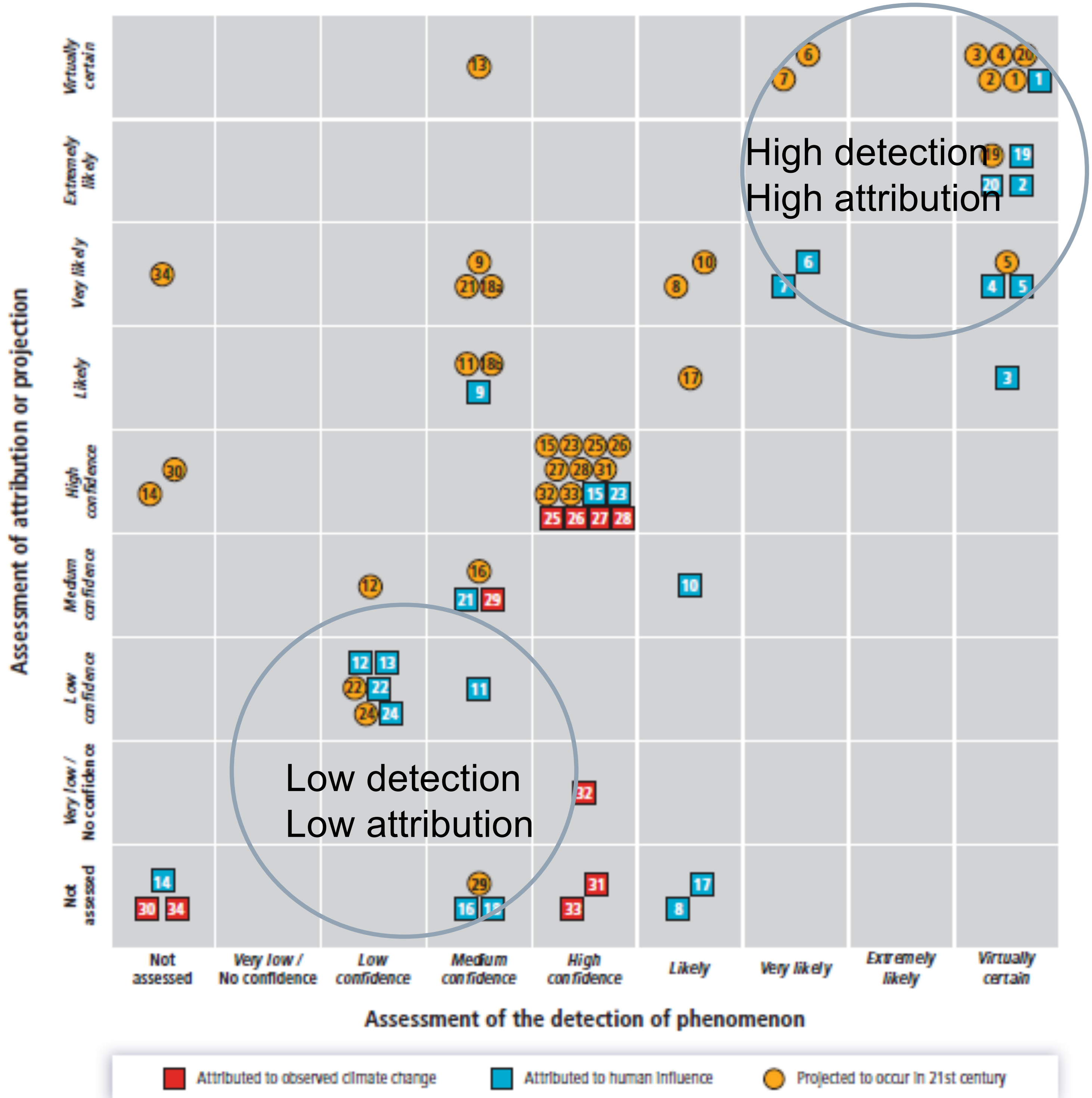
Synthesis Report (151 pages, across all three working groups)

WGIII (integrated assessment modelers) connects with WGI (physical climate scientists, World Climate Research Programme--WCRP—Working Group on Coupled Models--WGCM) in formulating future emission scenarios

WGI (physical climate scientists) connects with WGII (impacts, adaptation, vulnerability, IAV or lately VIACS Advisory Board) through the Coupled Model Intercomparison Project (CMIP) whereby WGII scientists use climate model output in CMIP for impacts studies

WGII connects with WGIII through integrated assessment of impacts (but this is relatively new)

Table in WGII report assessing **detection (has there been a change)** and **attribution (can the change be attributed to human activity)** of climate changes related to impacts



IPCC AR5 Working Group I
Climate Change 2013: The Physical Scie

Clicker question 1 (polling): What is the IPCC?

a. A group representing industry to determine if climate change is real

b. An international sports regulatory group

c. A group of governments who commission climate change assessments from scientists

IPCC Final Plenary (one for each WG, and one for the Synthesis Report)

Delegations from the IPCC governments convene to approve and accept 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 delegates
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.

Final sentence gaveled down at 5:20AM Friday morning (press conference started at 10AM)

What was in the AR5?

What was 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

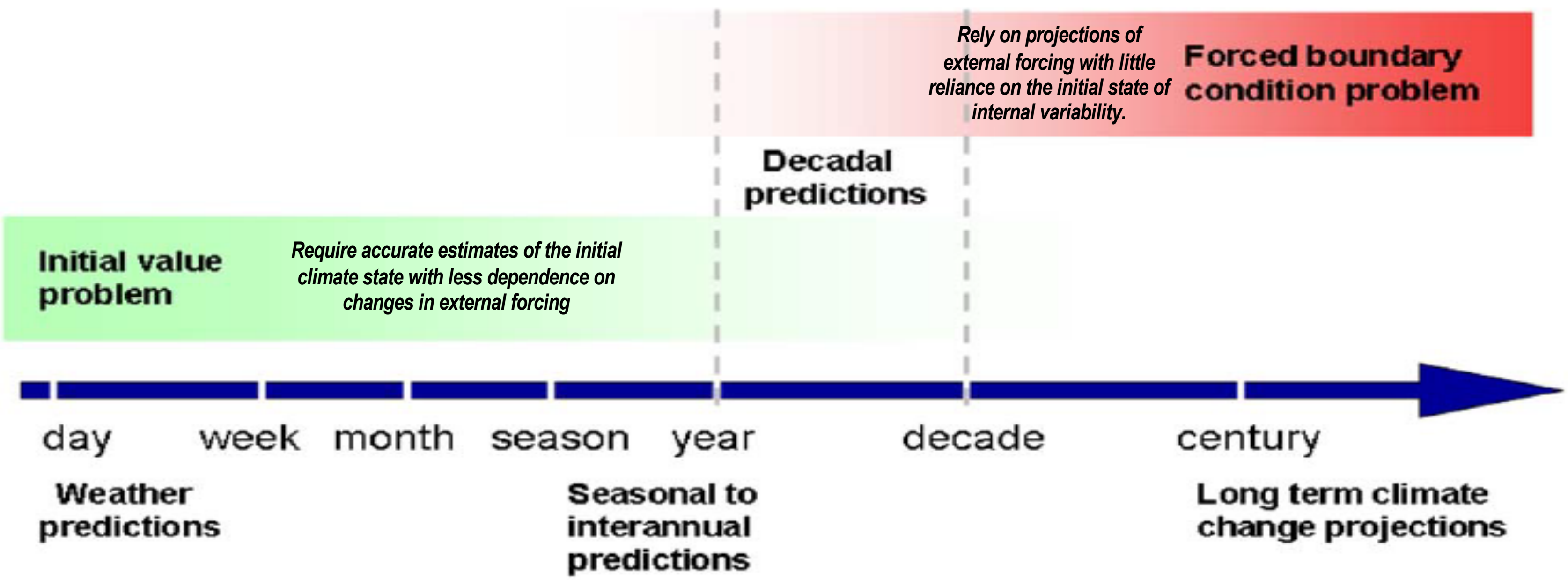
(observationally-based information used to initialize the models)

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 Coupled Model Intercomparison Project phase 5 (CMIP5) database assessed in the AR5:

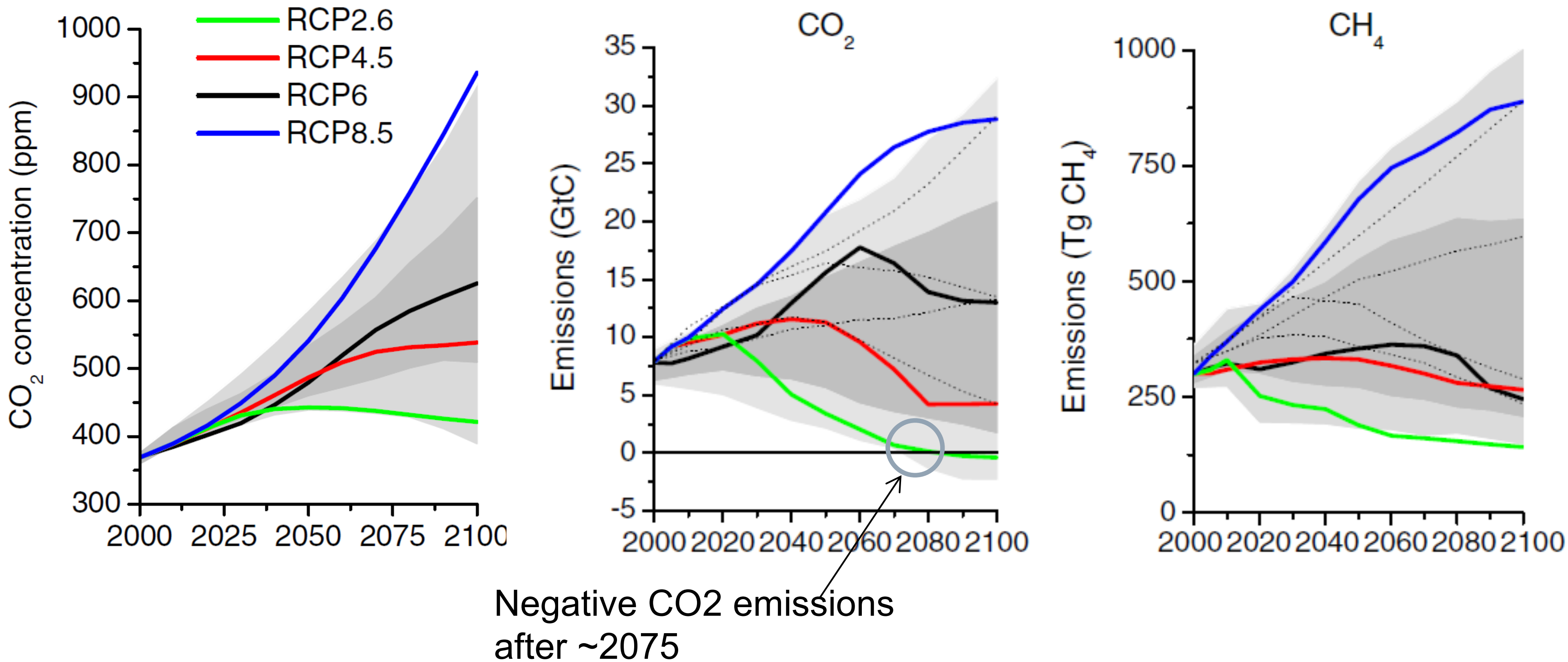
14 are “high top” with a resolved stratosphere (only 1 in CMIP3)

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

Most have some kind of prognostic aerosol formulation and can simulate 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) (in the AR6 the comparable scenarios are "SSPs")



- 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.

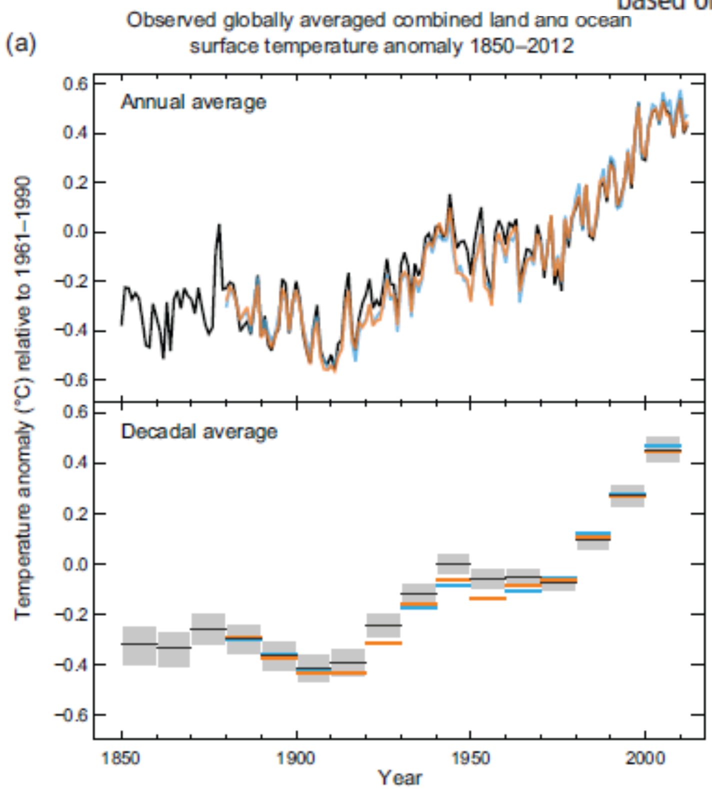
van Vuuren et al., 2011

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}

Observed Global Mean Surface Temperature Time Series

- The globally averaged combined land and ocean surface temperature data as calculated by a linear trend, show a warming of 0.85 [0.65 to 1.06] °C[3], over the period 1880 to 2012, when multiple independently produced datasets exist. The total increase between the average of the 1850–1900 period and the 2003–2012 period is 0.78 [0.72 to 0.85] °C, based on the single longest dataset available[4] (see Figure SPM.1). {2.4}

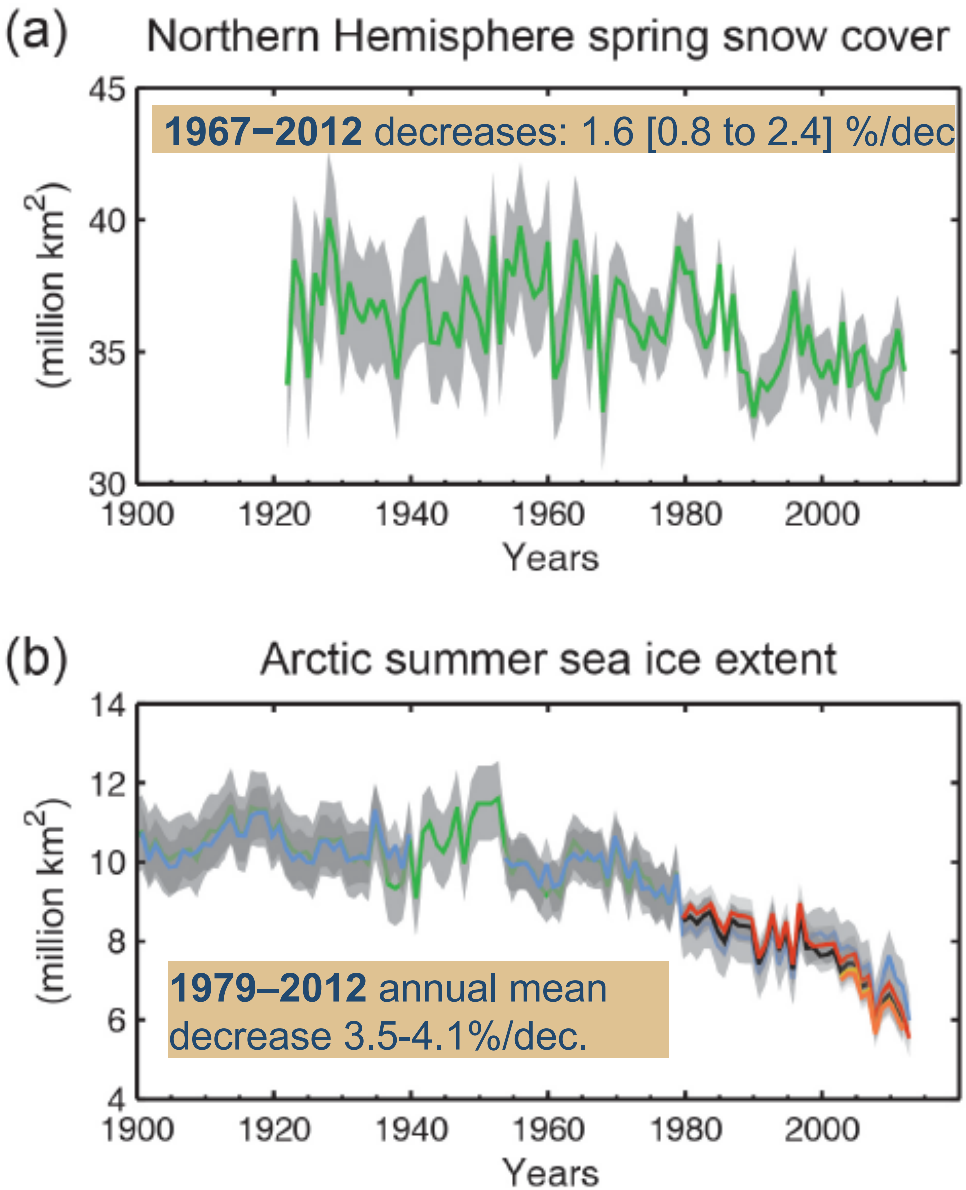


- Warming of the climate system is **unequivocal**, and since the 1950s, many of the observed changes are unprecedented over decades to millennia.
- Each of the last three decades has been successively warmer at the Earth's surface than any preceding decade since 1850.

- 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)[5]. {2.4}

Figure SPM.1

Multiple complementary indicators of a changing climate

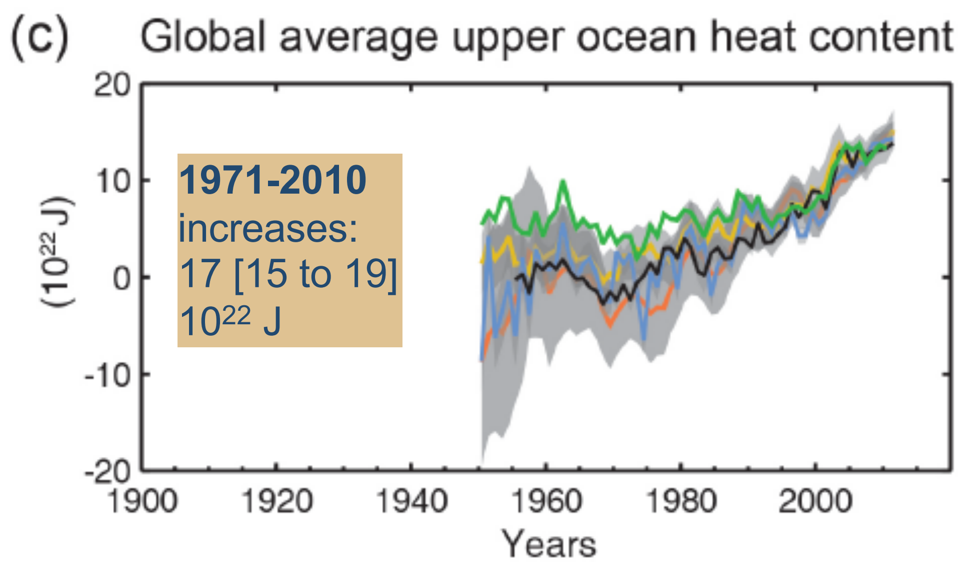


- Over the last two decades, the Greenland and Antarctic ice sheets have been losing mass, glaciers have continued to shrink almost worldwide, and Arctic sea ice and Northern Hemisphere spring snow cover have continued to decrease in extent *(high confidence).*

Figure SPM.3

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.

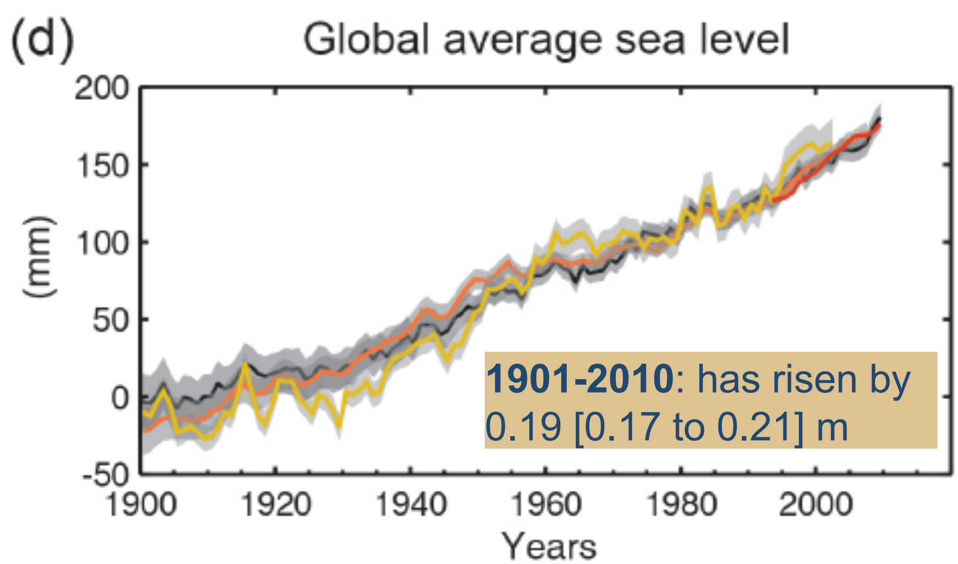
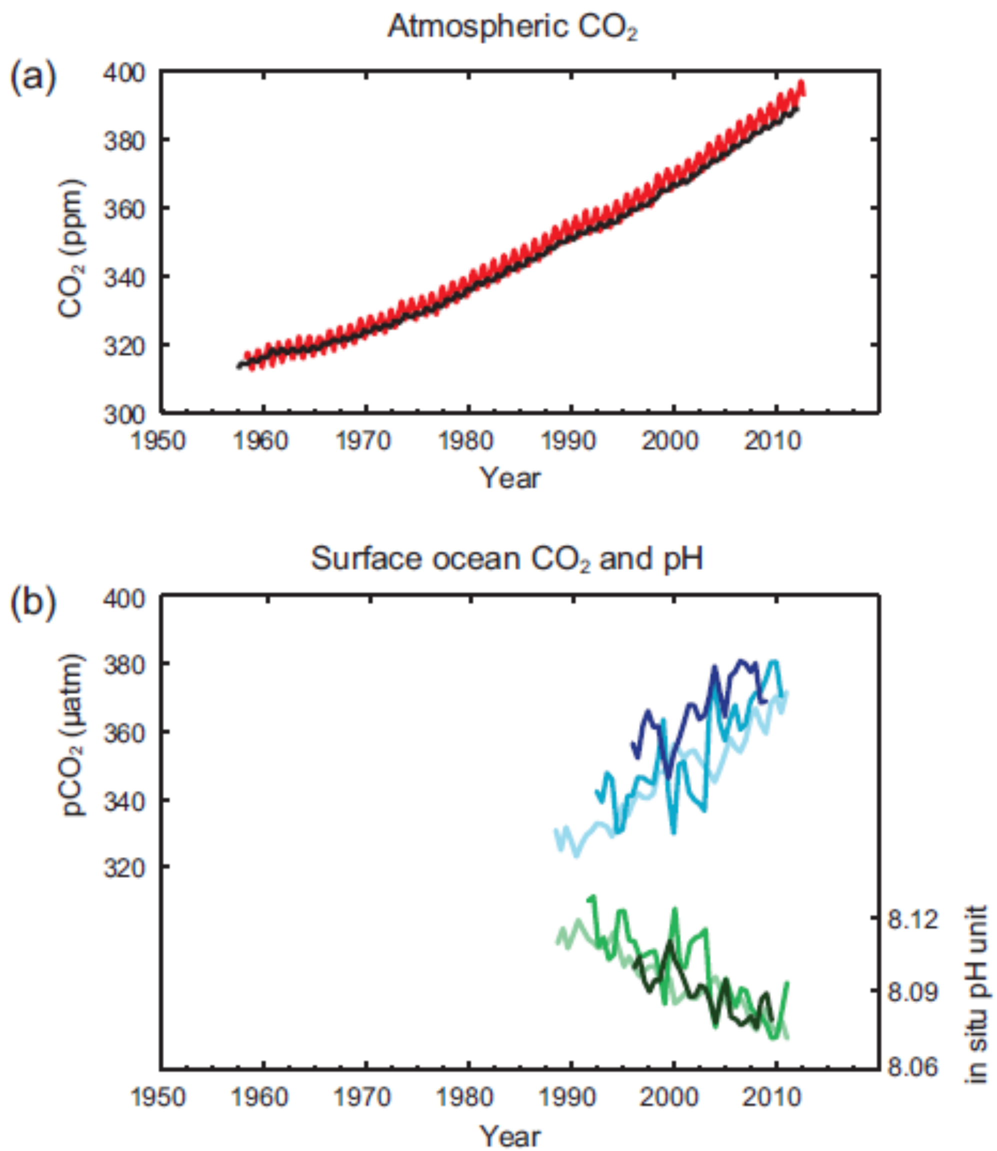


Figure SPM.3

Carbon and Other Biogeochemical Cycles



- 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

Figure SPM.4

Evolution of assessment of human influence on climate (the "smoking gun" statement):

"The balance of evidence suggests a discernible human influence on global climate". --IPCC Second Assessment Report, 1995

"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***

Human influence on the climate system is clear

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**.

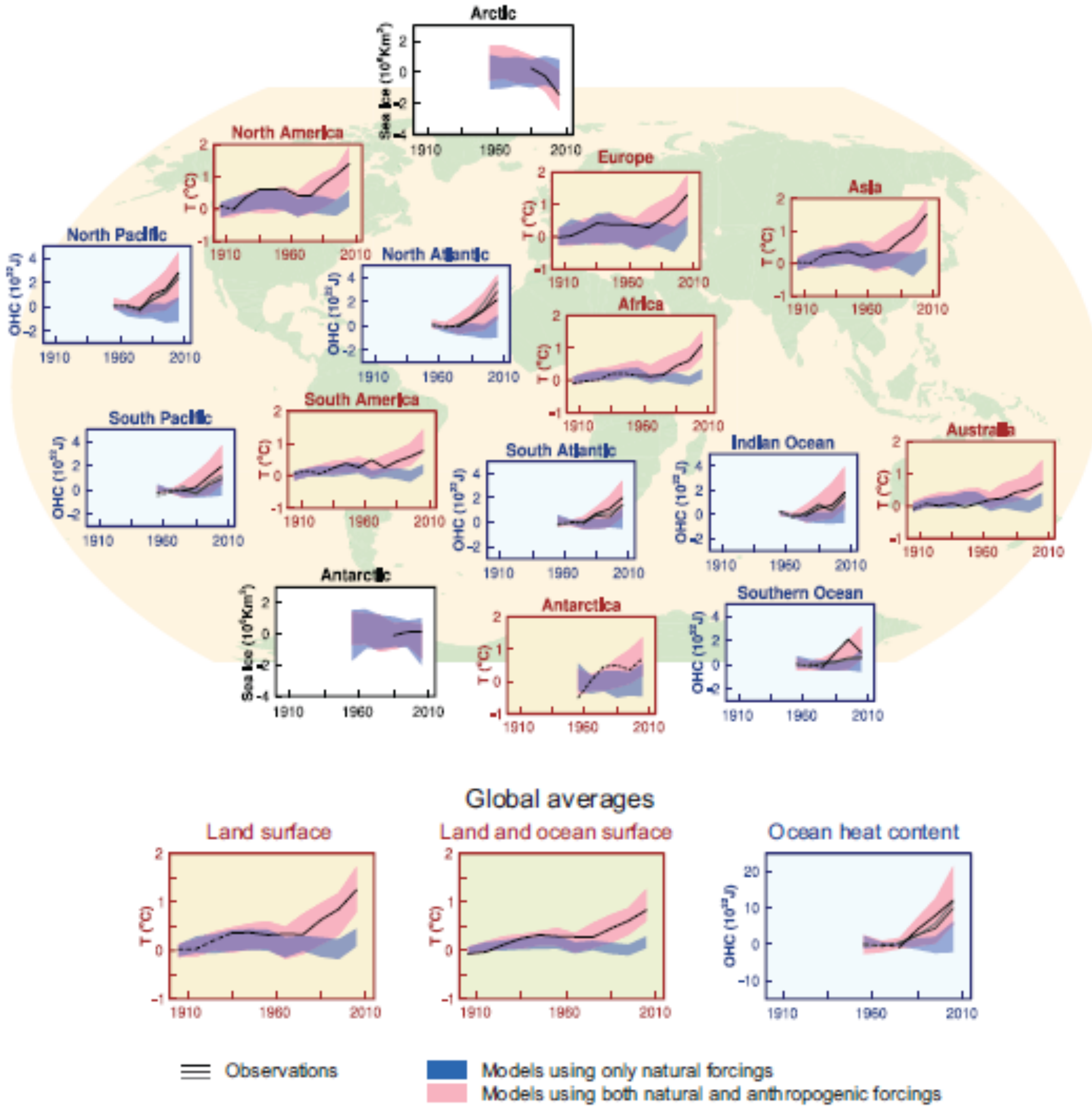


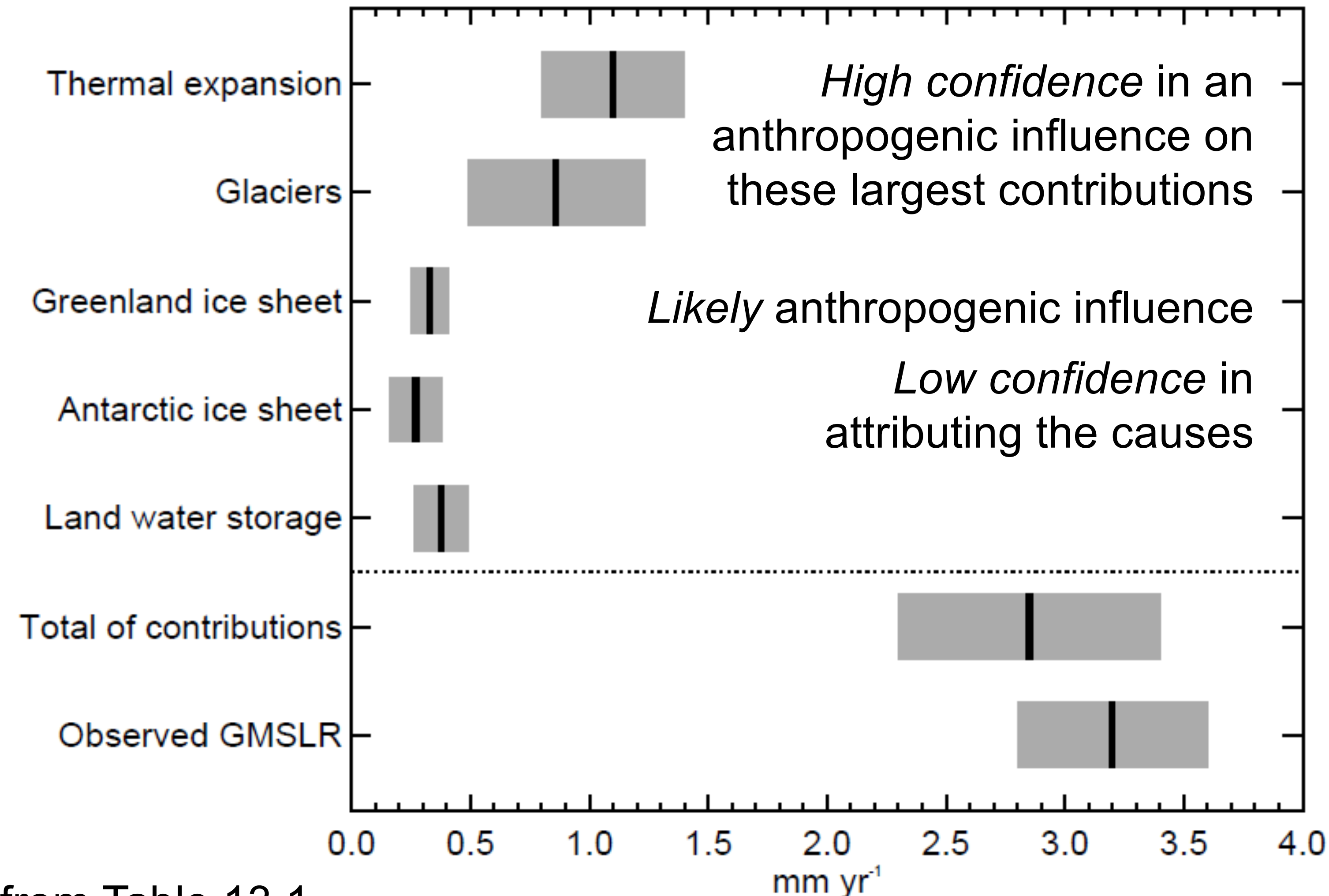
Figure SPM.6
WGI AR5 Final Draft 07 June

INTERGOVERNMENTAL PANEL ON climate change

Observed sea level rise 1993-2010 is consistent with the sum of observed contributions (*high confidence*)

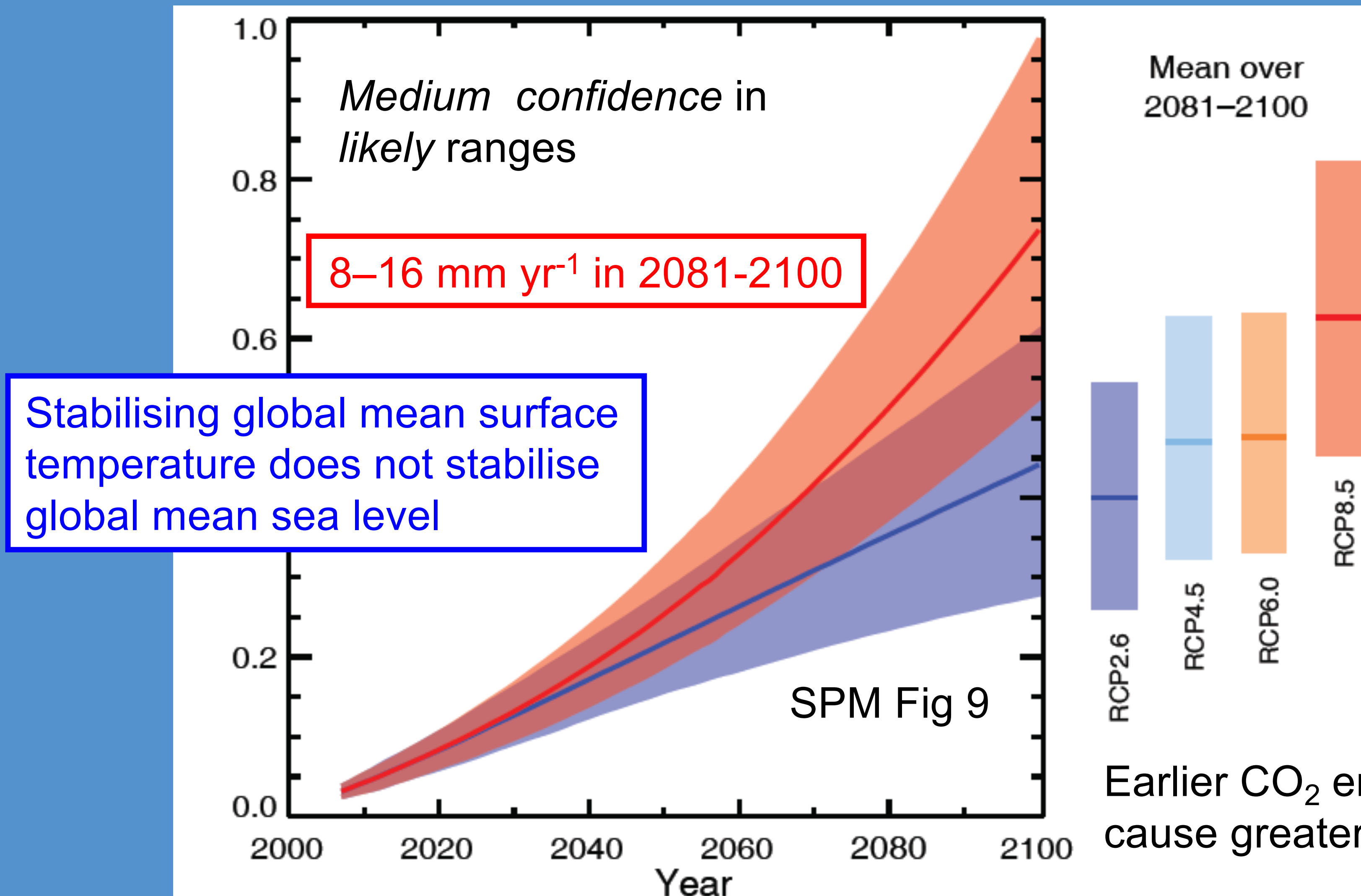
Rate during 1901-1990 was 1.5 [1.3 to 1.7] mm yr^{-1}.

Rate during 1993-2010 was 3.2 [2.8 to 3.6] mm yr^{-1}.



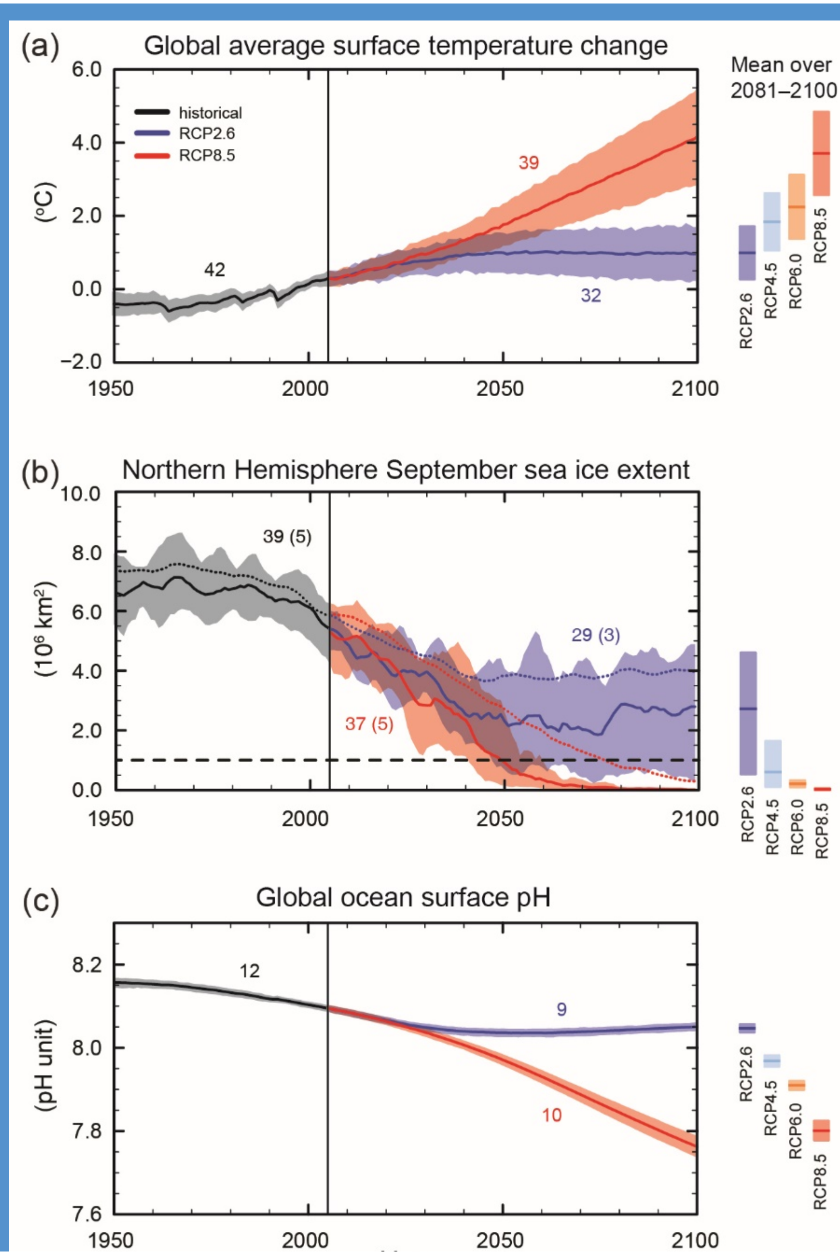
Data from Table 13.1

Under all RCPs the rate of sea level rise will *very likely* exceed that observed during 1971–2010



Earlier CO_2 emissions cause greater GMSLR

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[19] 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}

Fig. SPM.7

Click question 2 (polling): How do we attribute a human cause to climate change?

a. Take a poll of scientists to assess their opinion

b. Run climate models with and without human-caused greenhouse gases

c. It is the collective opinion of elected officials

Projections

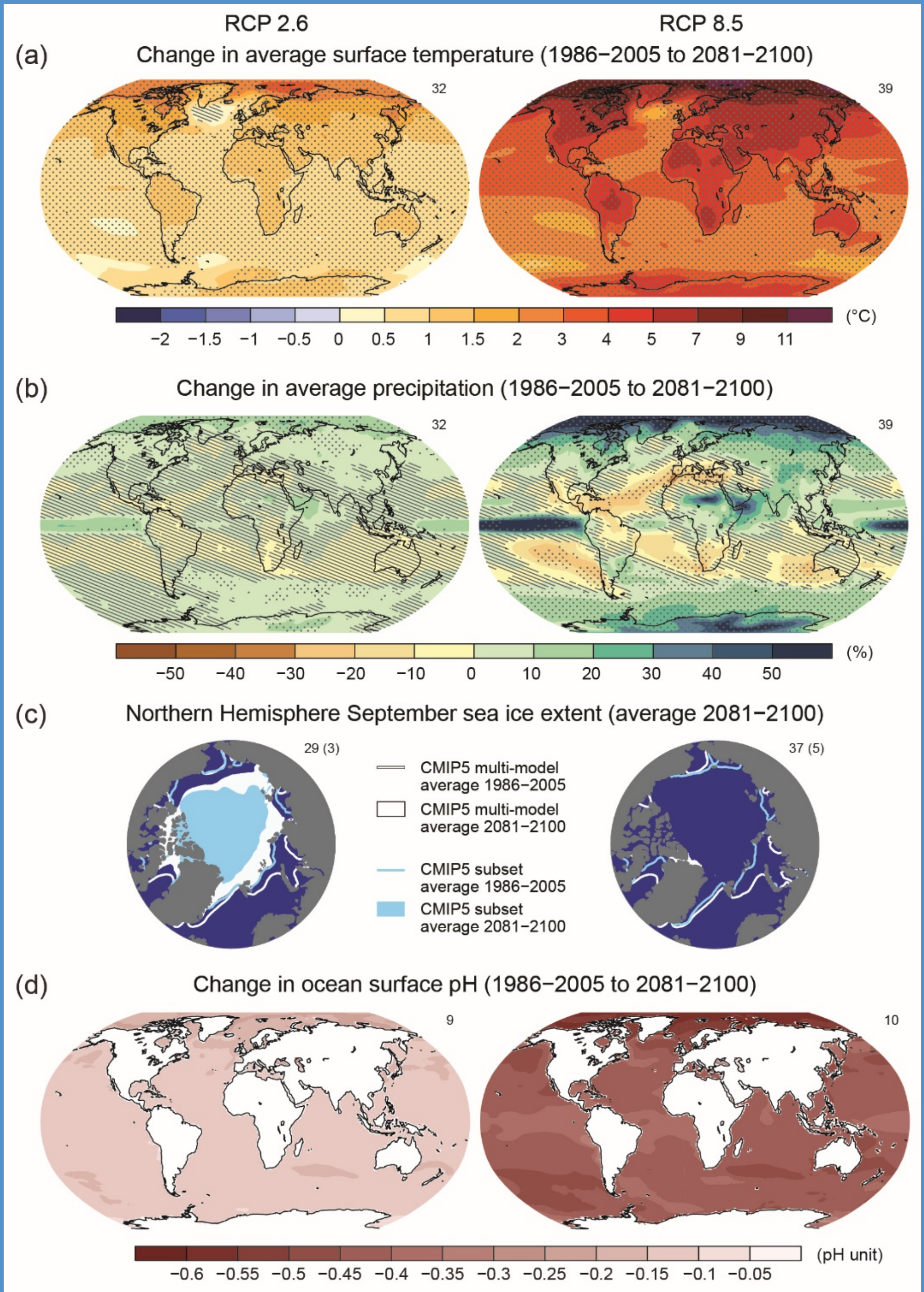
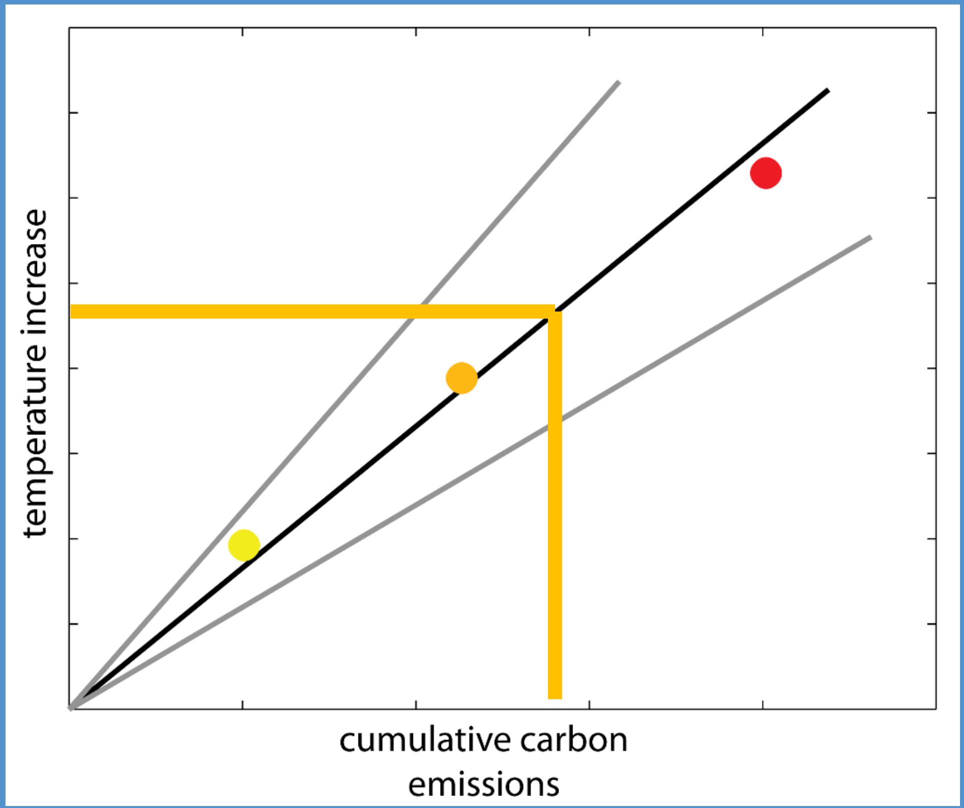


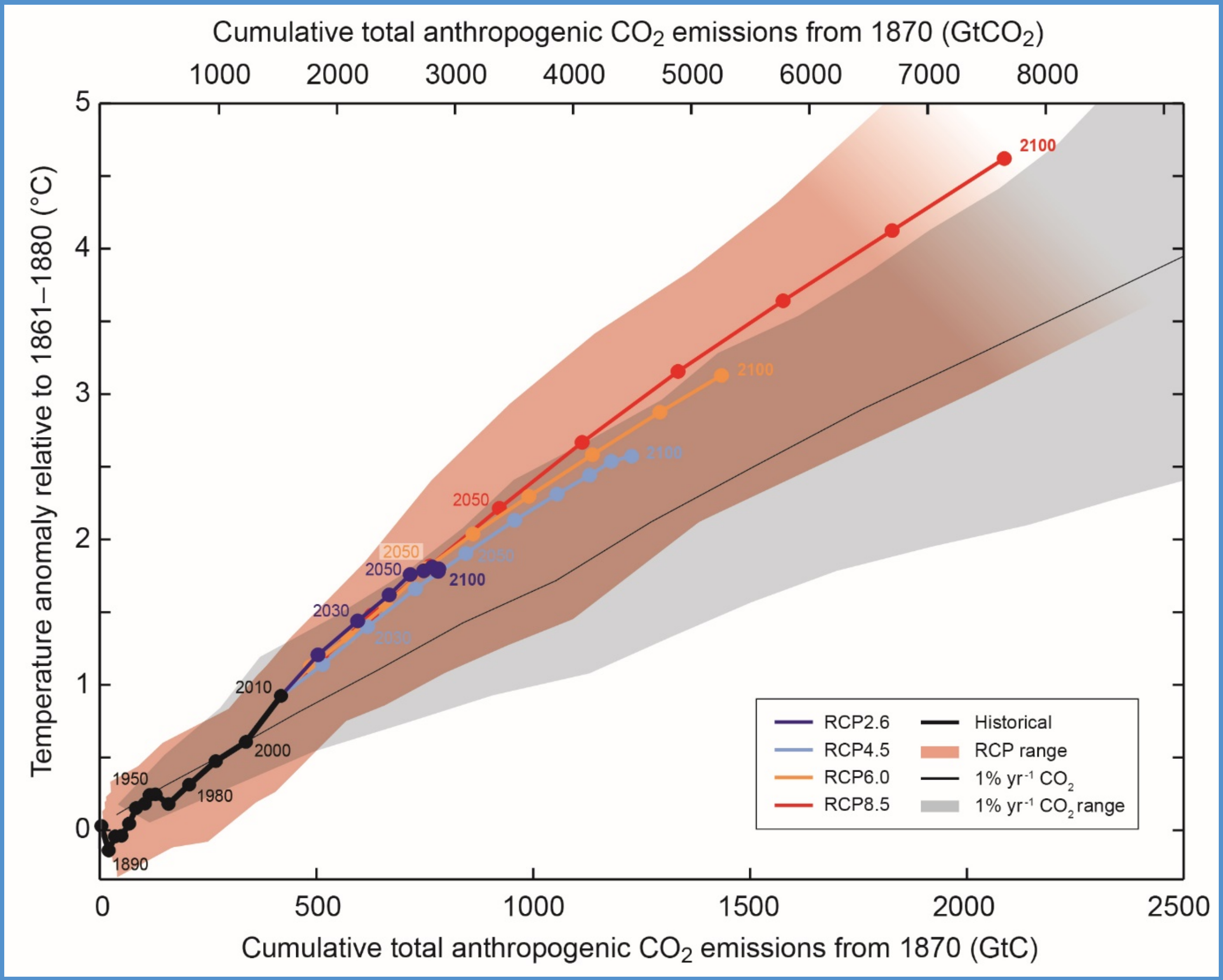
Fig. SPM.8

Cumulative carbon determines warming



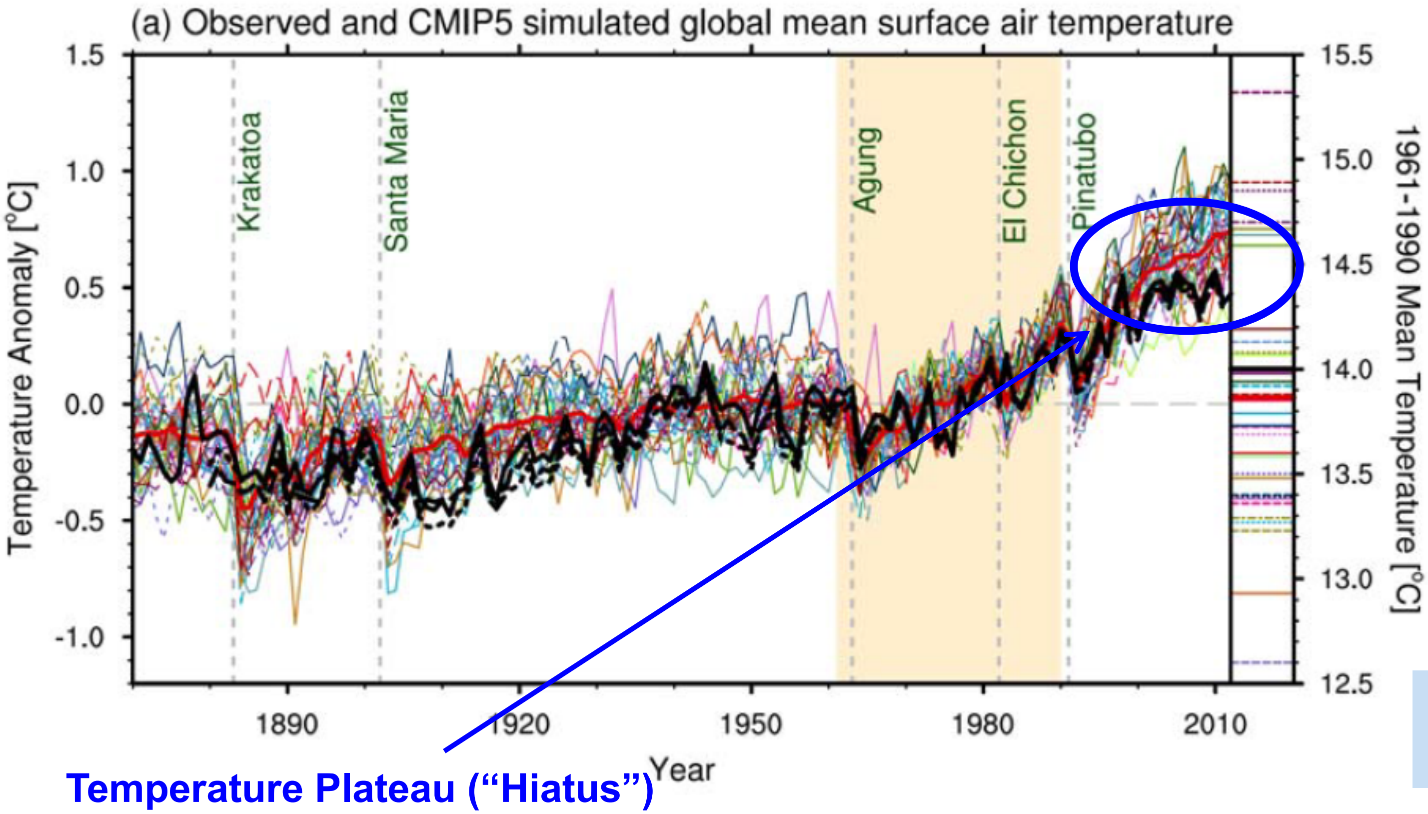
- Peak warming is approximately proportional to cumulative (total) emissions.
- Transient climate response to cumulative carbon emissions TCRE = Warming per 1000 PgC

Cumulative CO2 emissions determine warming



SPM.10

What about the early-2000s "hiatus" or slowdown?



Climate models have improved since the AR4.

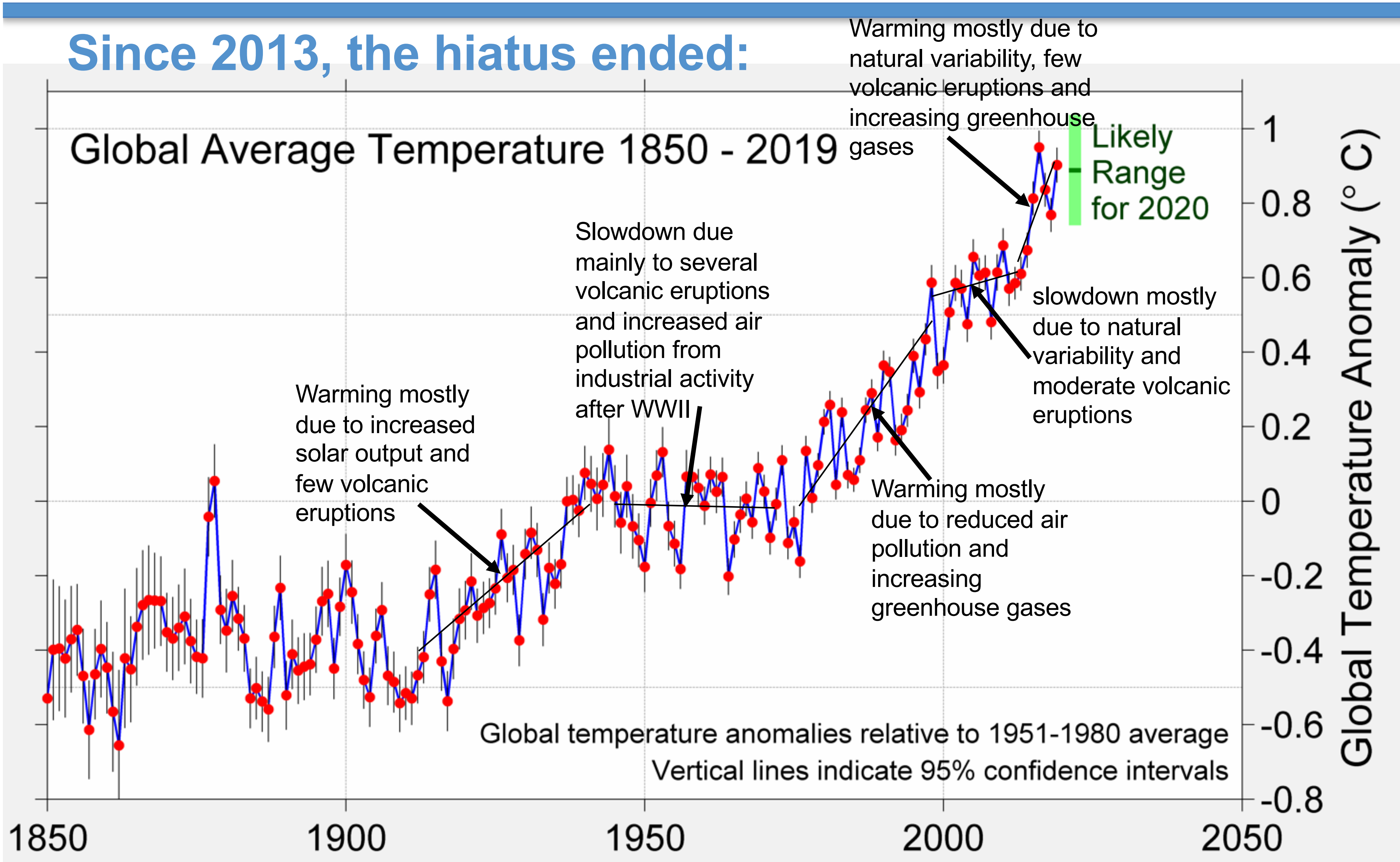
Models reproduce observed temperature trends over many decades, including the more rapid warming since the mid-20th century and the cooling immediately following large volcanic eruptions (*very high confidence*).

1998–2012: 0.04 ºC/decade
1951–2012: 0.11 ºC/decade

- The observed reduction in surface warming trend over the period 1998 to 2012 as compared to the period 1951 to 2012, is due in roughly equal measure to a reduced trend in radiative forcing and a cooling contribution from natural internal variability, which includes a possible redistribution of heat within the ocean (*medium confidence*). The reduced trend in radiative forcing is primarily due to volcanic eruptions and the timing of the downward phase of the 11-year solar cycle. However, there is *low confidence* in quantifying the role of changes in radiative forcing in causing the reduced warming trend. There is *medium confidence* that natural internal decadal variability causes to a substantial degree the difference between observations and the simulations; the latter are not expected to reproduce the timing of natural internal variability. There may also be a contribution from forcing inadequacies and, in some models, an overestimate of the response to increasing greenhouse gas and other anthropogenic forcing (dominated by the effects of aerosols). {9.4, Box 9.2, 10.3, Box 10.2, 11.3}

Chapter 9, Fig. 9.8

Since 2013, the hiatus ended:



(Source for temperature data: Berkeley Earth http://berkeleyearth.org/2019-temperatures/)

Current status of the AR6

The Sixth Assessment cycle

Special Reports

- **October 2018** — Global warming of 1.5°C
  An IPCC special report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty
- **August 2019** — Climate Change and Land:
  An IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems
- **September 2019** — Special Report on the Ocean and Cryosphere in a Changing Climate

Methodology Report

- **May 2019** — 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories

Sixth Assessment Report *

- **April 2021** — Working Group I contribution
  The physical science basis
- **September 2021** — Working Group III contribution
  Mitigation of climate change
- **October 2021** — Working Group II contribution
  Impacts, adaptation and vulnerability
- **May 2022** — Synthesis Report

Others

- **Cities** — A conference on cities and special attention to cities in the Sixth Assessment Report with the intention of a Special Report on climate change and cities in the Seventh Assessment Cycle
- **Expert Meetings** — Several Expert Meetings and workshops are held to support the preparation of the Sixth Assessment Report. Reports of these meetings are published as supporting materials
- **Outreach** — Communication and outreach of the IPCC process and its findings

The AR6 process started with a scoping meeting in April, 2016 where the structure and schedule was determined for the AR6 and three “special reports”

This was followed by the nomination and selection process for lead authors

IPCC AR6 Working Group 1outline

Chapter 1: Framing, context, methods

Chapter 2: Changing state of the climate system

Chapter 3: Human influence on the climate system

Chapter 4: Future climate: scenario-based projections and near-term information

Chapter 5: Global carbon and other biogeochemical cycles and feedbacks

Chapter 6: Short-lived climate forcers

Chapter 7: The Earth's energy budget, climate feedbacks, and climate sensitivity

Chapter 8: Water cycle changes

Chapter 9: Ocean, cryosphere, and sea level change

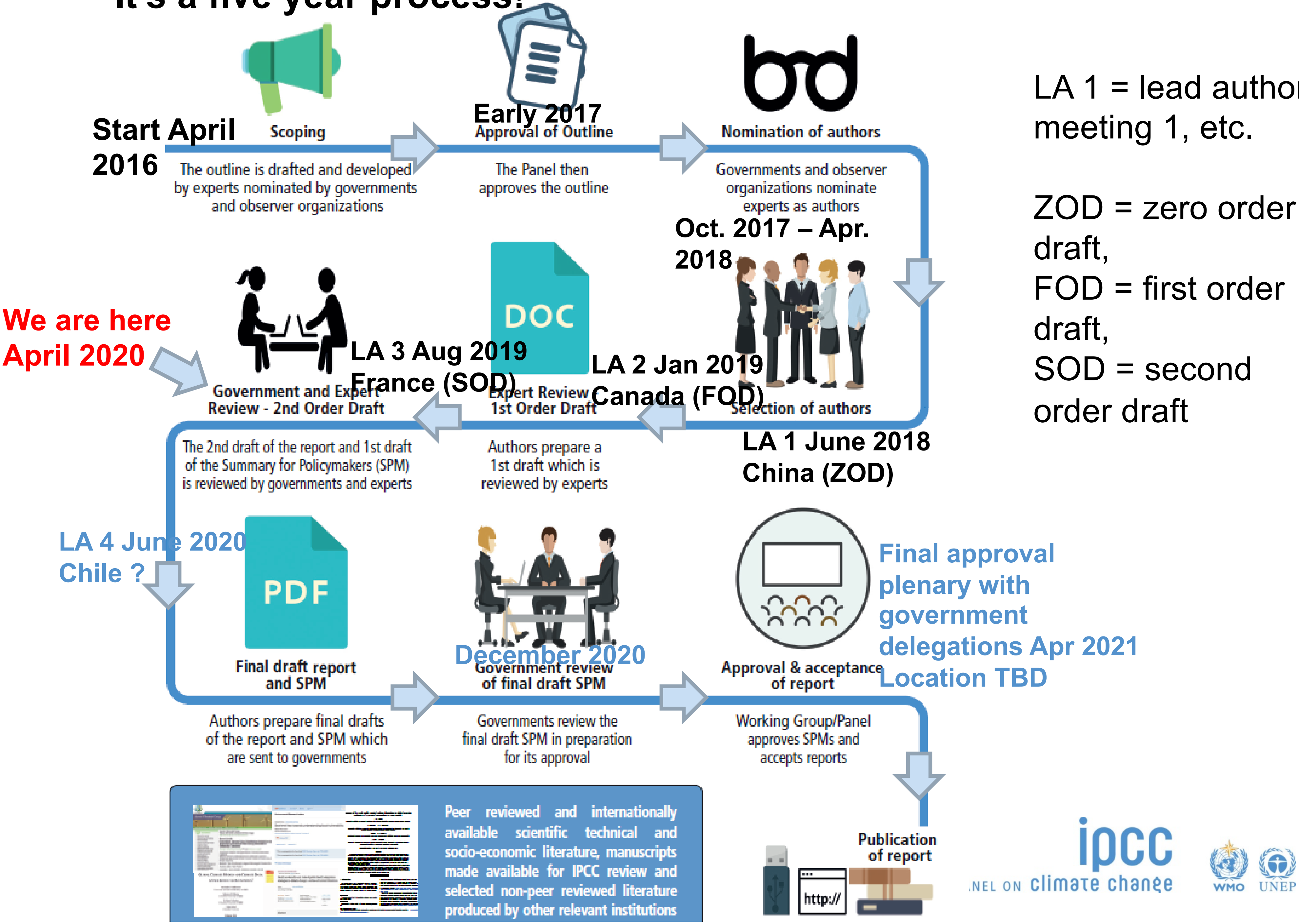
Chapter 10: Linking global to regional climate change

Chapter 11: Weather and climate extreme events in a changing climate

Chapter 12: Climate change information for regional impact and risk assessment

How the IPCC prepares its report

It's a five year process!



LA 1 = lead author meeting 1, etc.

ZOD = zero order draft,
FOD = first order draft,
SOD = second order draft

https://www.ipcc.ch/assessment-report/ar6/