

Assessing the Physical Science Basis of Climate Change

—

IPCC WGI from AR5 to AR6

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It is Relevant – COP 21 “Paris Agreement”

It is Exciting – the WGI Authors' Experience

Would you be willing to serve again?	Yes 68%
Rate your overall experience	Good to Excellent 90%
Amount of work was a challenge	Agree to strongly agree 83%
Dedicated assistance should be standard	Agree to strongly agree 80%

„*This is an Assessment, not a Review*“ (Sir John Houghton)

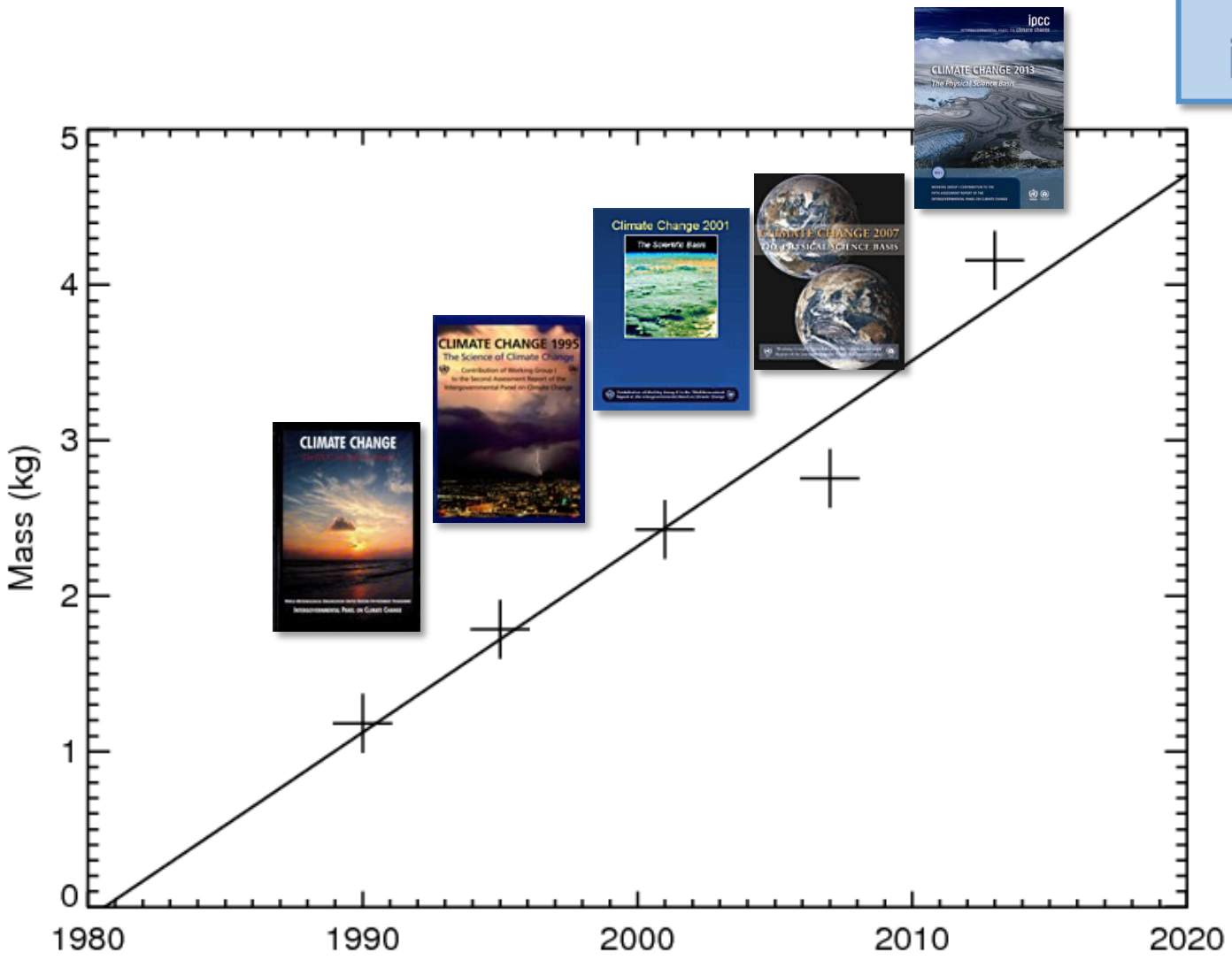
- **Comprehensive but not exhaustive**: Not every publication ever written on climate change needs to be cited
- **Focus on progress** since ca. 2013 (cutoff for AR5) but provide context where necessary
- **Develop a consensus** on important issues within a chapter, identify areas where consensus cannot be reached
- Determine robustness of the assessment, make use of the **uncertainty language** (e.g., *very likely*)
- **Multiple lines of independent evidence** produce the most robust statements

Outline

- General Introduction
- From IPCC WGI FAR to AR5
- Towards the WGI AR6
- A Look Beyond WGI
- Few Thoughts about Challenges

IPCC Working Group I Reports Since 1990

The Growing Mass of Scientific Evidence



Source: Jonathan Gregory, LA Chapter 13, WGI AR5

What Are the Elements of the WGI Assessment Report?

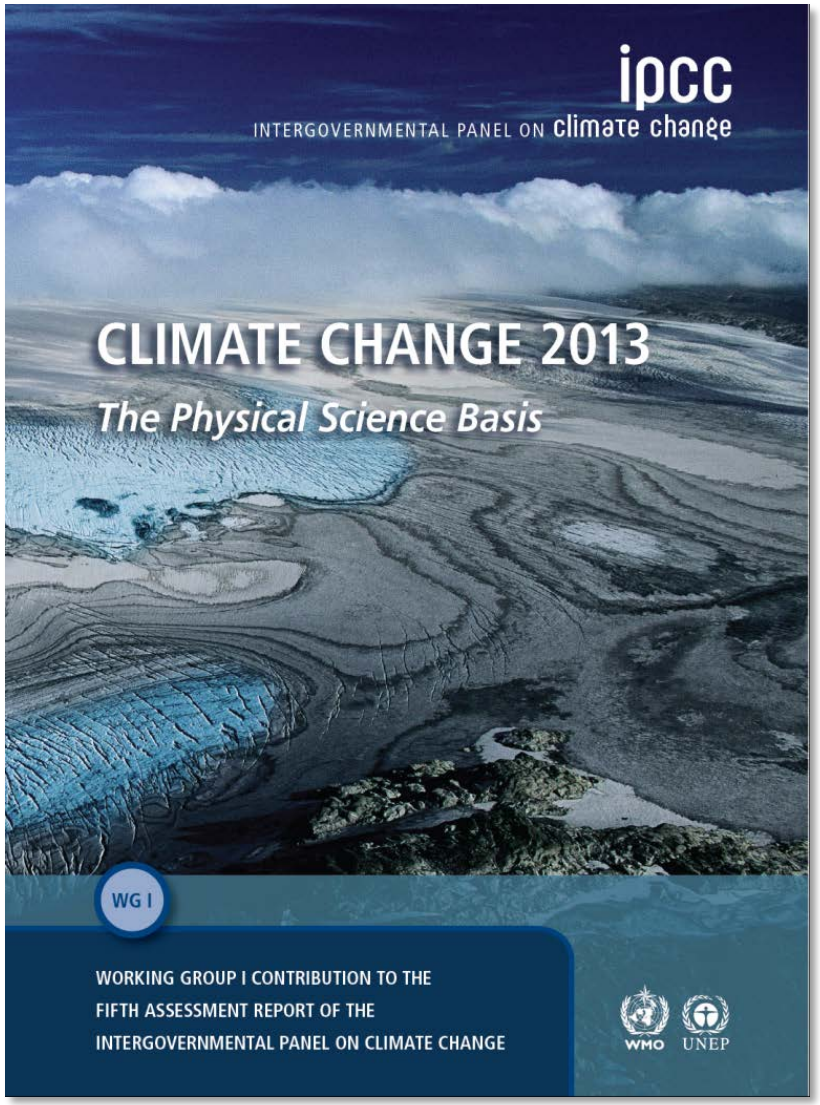
Report

14 Chapters, Annexes, Supplementary Material
Regional Projections in Digital Form
~1,100,000 words, 1535 pages

Technical Summary

Summary for Policymakers

Synthesis Report



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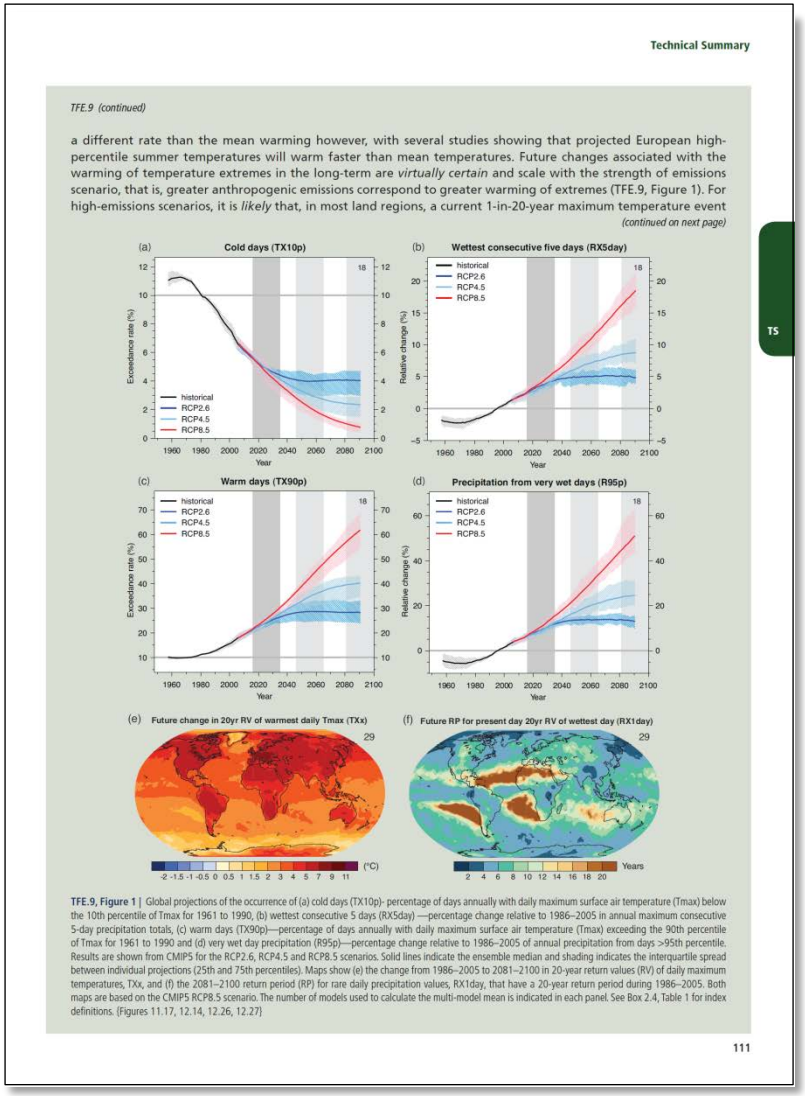
6 Sections, 9 Thematic Focus Elements
5,000 words, 81 pages

Summary for Policymakers

Synthesis Report



Technical Summary

TFE.9 (continued)

a different rate than the mean warming however, with several studies showing that projected European high-percentile summer temperatures will warm faster than mean temperatures. Future changes associated with the warming of temperature extremes in the long-term are *virtually certain* and scale with the strength of emissions scenario, that is, greater anthropogenic emissions correspond to greater warming of extremes (TFE.9, Figure 1). For high-emissions scenarios, it is *likely* that, in most land regions, a current 1-in-20-year maximum temperature event

(continued on next page)

TFE.9, Figure 1 | Global projections of the occurrence of (a) cold days (TX10p)- percentage of days annually with daily maximum surface air temperature (Tmax) below the 10th percentile of Tmax for 1961 to 1990, (b) wettest consecutive 5 days (RX5day) —percentage change relative to 1986–2005 in annual maximum consecutive 5-day precipitation totals, (c) warm days (TX90p)—percentage of days annually with daily maximum surface air temperature (Tmax) exceeding the 90th percentile of Tmax for 1961 to 1990 and (d) very wet day precipitation (R95p)—percentage change relative to 1986–2005 of annual precipitation from days >95th percentile. Results are shown from CMIP5 for the RCP2.6, RCP4.5 and RCP8.5 scenarios. Solid lines indicate the ensemble median and shading indicates the interquartile spread between individual projections (25th and 75th percentiles). Maps show (e) the change from 1986–2005 to 2081–2100 in 20-year return values (RV) of daily maximum temperatures, TXx, and (f) the 2081–2100 return period (RP) for rare daily precipitation values, RX1day, that have a 20-year return period during 1986–2005. Both maps are based on the CMIP5 RCP8.5 scenario. The number of models used to calculate the multi-model mean is indicated in each panel. See Box 2.4, Table 1 for index definitions. {Figures 11.17, 12.14, 12.26, 12.27}

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(IPCC 2013, Technical Summary)

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Summary for Policymakers

~14,000 words, 27 pages

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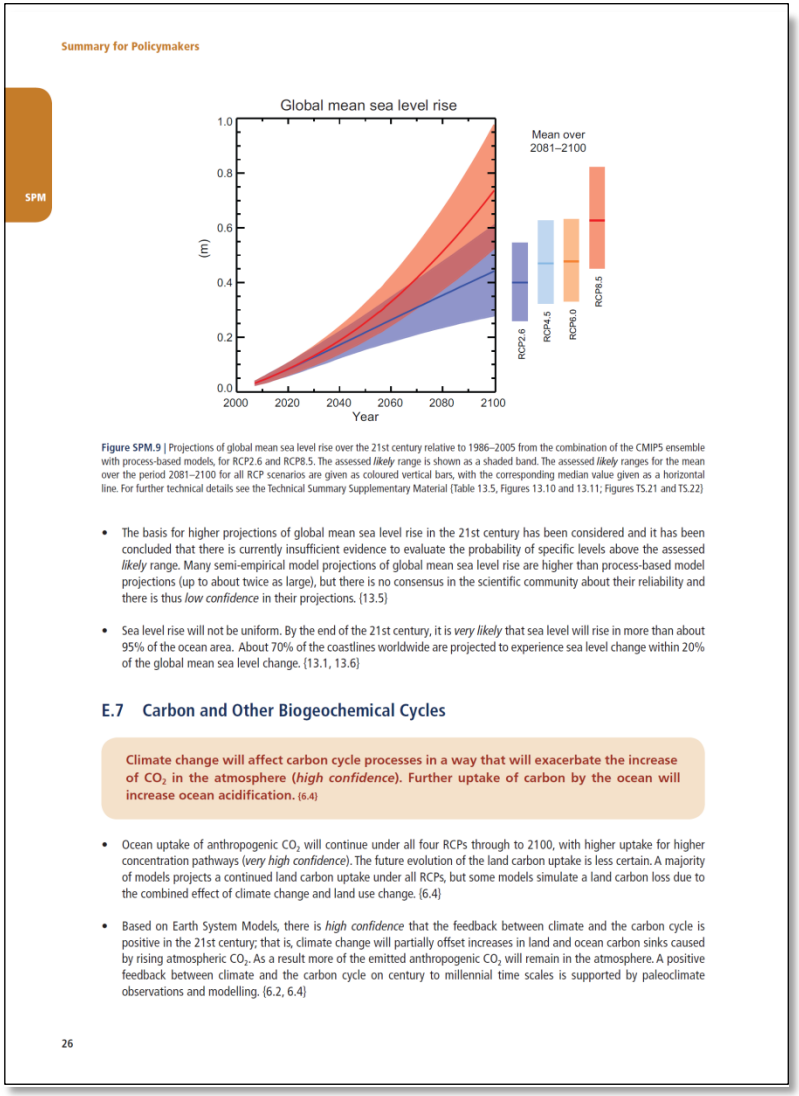

Summary for Policymakers

SPM

Global mean sea level rise

Figure SPM.9 | Projections of global mean sea level rise over the 21st century relative to 1986–2005 from the combination of the CMIP5 ensemble with process-based models, for RCP2.6 and RCP8.5. The assessed *likely* range is shown as a shaded band. The assessed *likely* ranges for the mean over the period 2081–2100 for all RCP scenarios are given as coloured vertical bars, with the corresponding median value given as a horizontal line. For further technical details see the Technical Summary Supplementary Material (Table 13.5, Figures 13.10 and 13.11; Figures TS.21 and TS.22)

- The basis for higher projections of global mean sea level rise in the 21st century has been considered and it has been concluded that there is currently insufficient evidence to evaluate the probability of specific levels above the assessed *likely* range. Many semi-empirical model projections of global mean sea level rise are higher than process-based model projections (up to about twice as large), but there is no consensus in the scientific community about their reliability and there is thus *low confidence* in their projections. {13.5}

- Sea level rise will not be uniform. By the end of the 21st century, it is *very likely* that sea level will rise in more than about 95% of the ocean area. About 70% of the coastlines worldwide are projected to experience sea level change within 20% of the global mean sea level change. {13.1, 13.6}

E.7 Carbon and Other Biogeochemical Cycles

Climate change will affect carbon cycle processes in a way that will exacerbate the increase of CO_2 in the atmosphere (*high confidence*). Further uptake of carbon by the ocean will increase ocean acidification. {6.4}

- Ocean uptake of anthropogenic CO_2 will continue under all four RCPs through to 2100, with higher uptake for higher concentration pathways (*very high confidence*). The future evolution of the land carbon uptake is less certain. A majority of models projects a continued land carbon uptake under all RCPs, but some models simulate a land carbon loss due to the combined effect of climate change and land use change. {6.4}

- Based on Earth System Models, there is *high confidence* that the feedback between climate and the carbon cycle is positive in the 21st century; that is, climate change will partially offset increases in land and ocean carbon sinks caused by rising atmospheric CO_2. As a result more of the emitted anthropogenic CO_2 will remain in the atmosphere. A positive feedback between climate and the carbon cycle on century to millennial time scales is supported by paleoclimate observations and modelling. {6.2, 6.4}

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(IPCC 2013, Summary for Policymakers)

What Are the Elements of the WGI Assessment Report?

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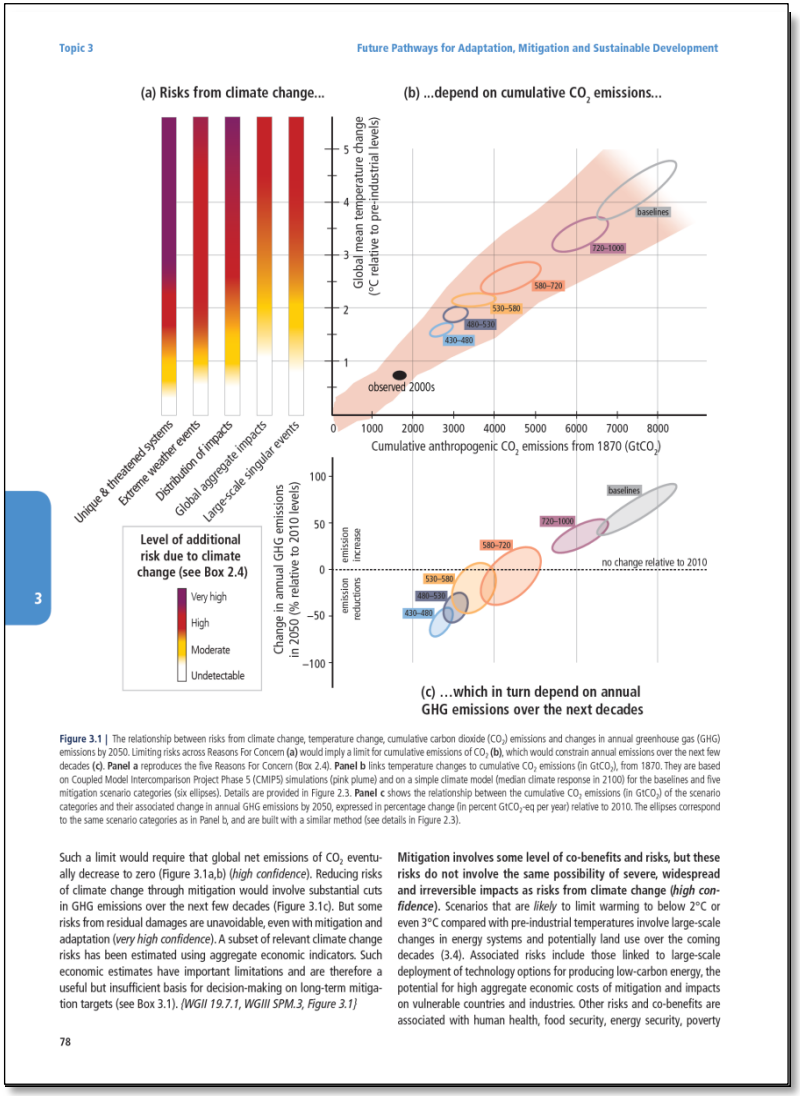
5,000 words, 81 pages

Summary for Policymakers

~14,000 words, 27 pages
19 Headline Statements

Synthesis Report

all WGs contribute
SPM 31 pages; Longer Report 77 pages



(IPCC 2014, Synthesis Report)

Observation

Understanding

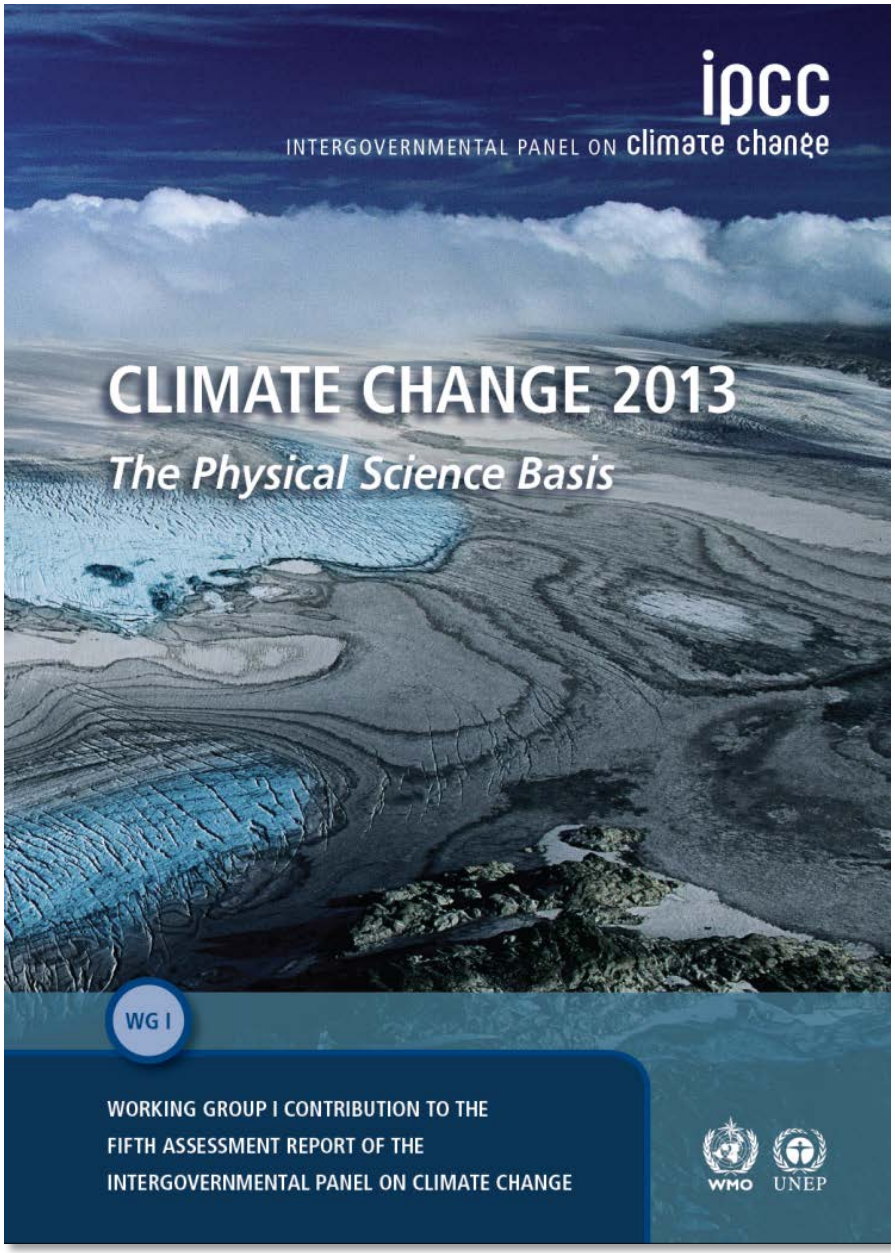
Future

www.climatechange2013.org

Warming in the climate system is unequivocal, […]

Human influence on the climate system is clear.

Limiting climate change will require substantial and sustained reductions of greenhouse gas emissions.



D. Understanding the Climate System and its Recent Changes

Understanding recent changes in the climate system results from combining observations, studies of feedback processes, and model simulations. Evaluation of the ability of climate models to simulate recent changes requires consideration of the state of all modelled climate system components at the start of the simulation and the natural and anthropogenic forcing used to drive the models. Compared to AR4, more detailed and longer observations and improved climate models now enable the attribution of a human contribution to detected changes in more climate system components.

Human influence on the climate system is clear. This is evident from the increasing greenhouse gas concentrations in the atmosphere, positive radiative forcing, observed warming, and understanding of the climate system. {2–14}

D.1 Evaluation of Climate Models

Climate models have improved since the AR4. Models reproduce observed continental-scale surface temperature patterns and 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*). {9.4, 9.6, 9.8}

- The long-term climate model simulations show a trend in global-mean surface temperature from 1951 to 2012 that agrees with the observed trend (*very high confidence*). There are, however, differences between simulated and observed trends over periods as short as 10 to 15 years (e.g., 1998 to 2012). {9.4, Box 9.2}

- 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}

- On regional scales, the confidence in model capability to simulate surface temperature is less than for the larger scales. However, there is *high confidence* that regional-scale surface temperature is better simulated than at the time of the AR4. {9.4, 9.6}

- There has been substantial progress in the assessment of extreme weather and climate events since AR4. Simulated global-mean trends in the frequency of extreme warm and cold days and nights over the second half of the 20th century are generally consistent with observations. {9.5}

- There has been some improvement in the simulation of continental-scale patterns of precipitation since the AR4. At regional scales, precipitation is not simulated as well, and the assessment is hampered by observational uncertainties. {9.4, 9.6}

- Some important climate phenomena are now better reproduced by models. There is *high confidence* that the statistics of monsoon and El Niño-Southern Oscillation (ENSO) based on multi-model simulations have improved since AR4. {9.5}

D. Understanding the Climate System and its Recent Changes

Human influence on the climate system is clear. This is evident from the increasing greenhouse gas concentrations, [...]

D.1 Evaluation of Climate Models

Climate models have improved since the AR4. Models reproduce [...]

- **10 bullet points** with numbers, likelihoods and confidence.

D.2 Quantification of Climate System Responses

Observational and model studies [..] provide confidence in the magnitude of global warming in response to past and future forcing.

- **7 bullet points** with numbers, likelihoods and confidence.

D.3 Detection and Attribution of Climate Change

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

- **12 bullet points** with numbers, likelihoods and confidence.

Communicating through Headline Statements in IPCC AR6

What are the characteristics of Headline Statements?

- firmly rooted in the scientific assessment
- avoid jargon and excessive use of numbers
- part of an overarching narrative
- **hierarchical: from complex to simple**

Outline

- General Introduction
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IPCC AR6 Working Group I Leadership: The Bureau

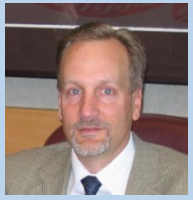
Co-Chairs

Valerie Masson-Delmotte
France

Panmao Zhai
China

Vice-Chairs

Edvin Aldrian
Indonesia



Gregory Flato
Canada

Muhammad Irfan Tariq
Pakistan

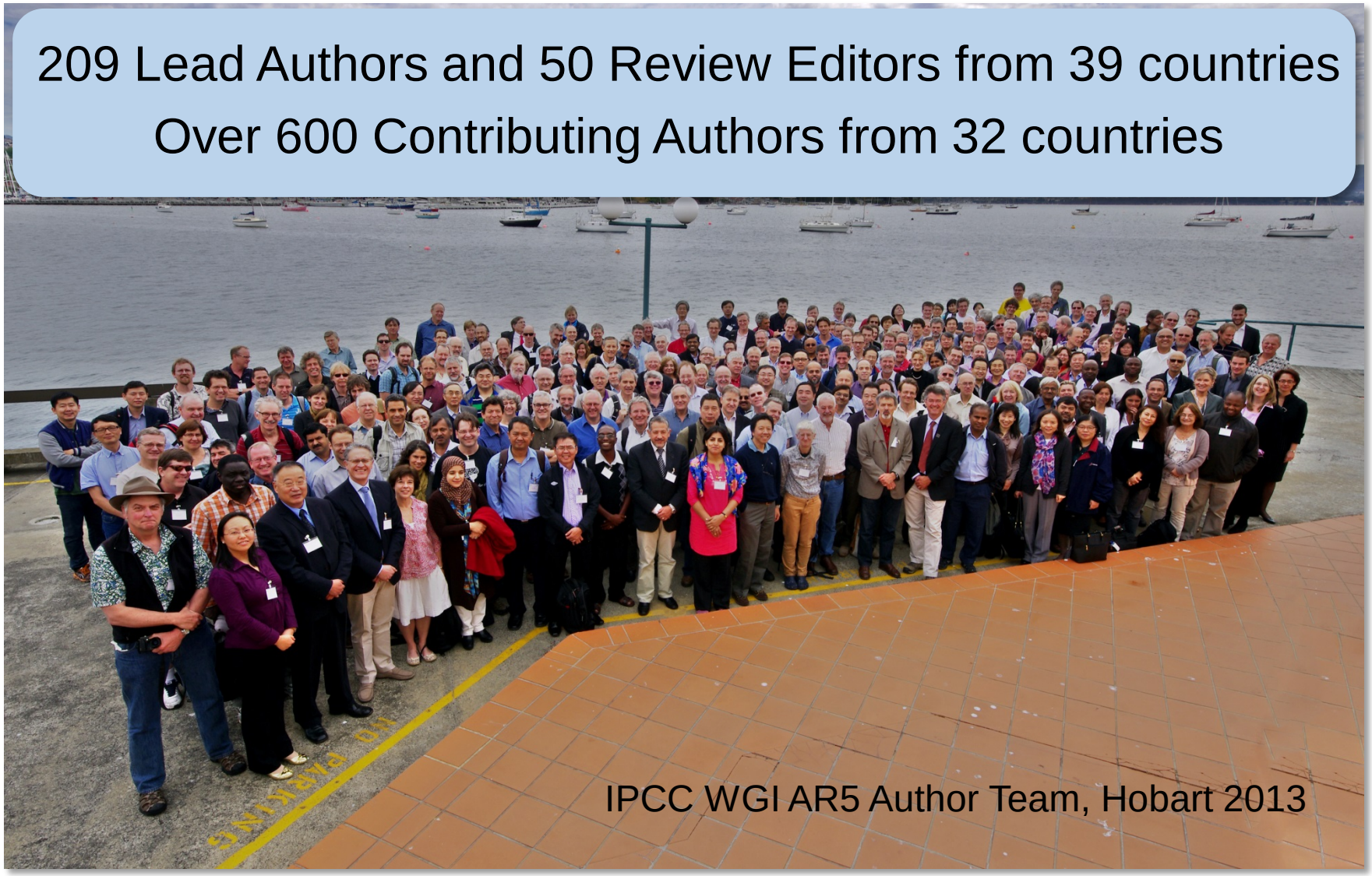
Nourredine Yassa
Algeria

Fatima Driouech
Morocco

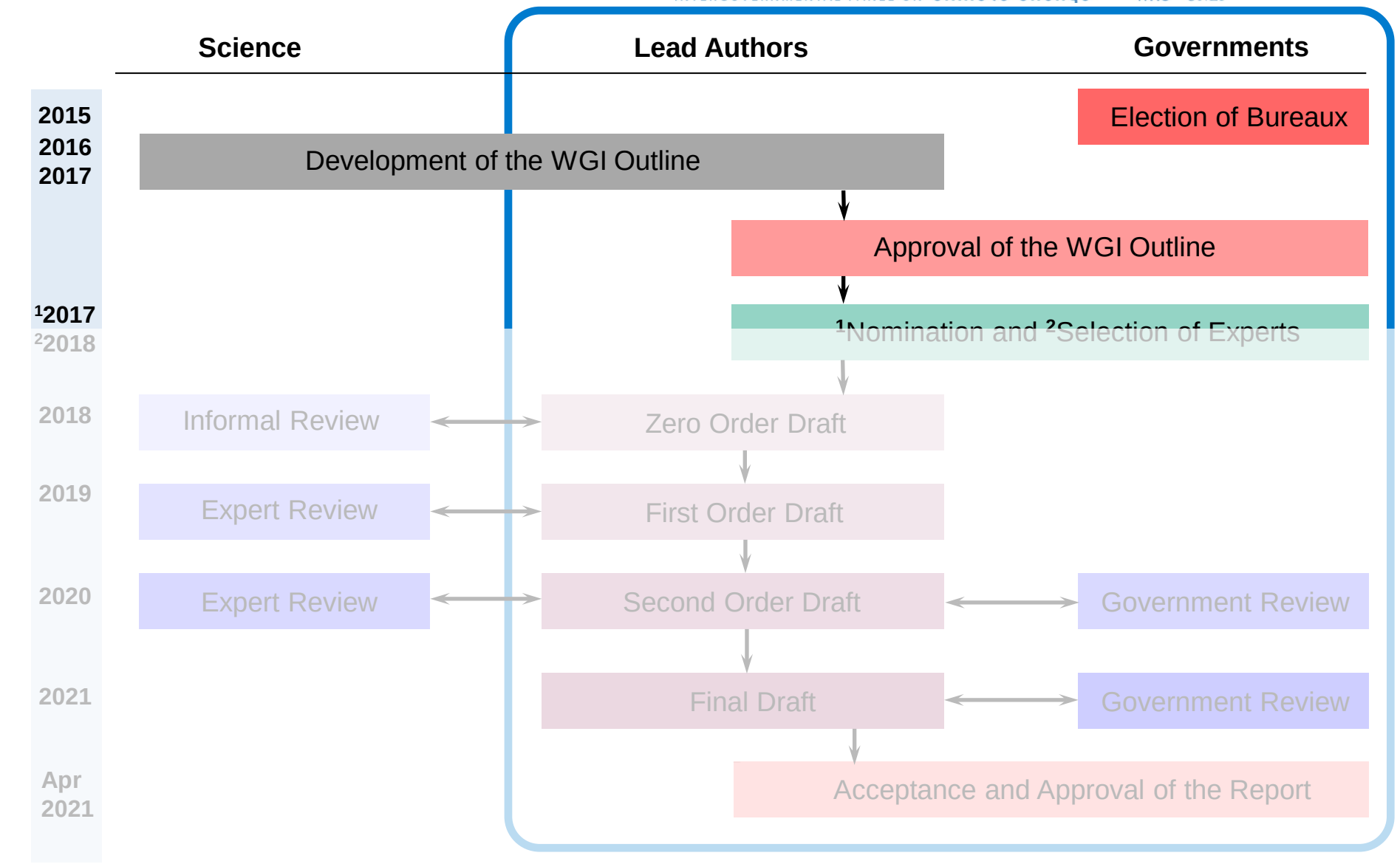
Jan Fuglestvedt
Norway

Carolina Vera
Argentina

IPCC Assessments: A Community Effort



The AR6 Process for IPCC Working Group I



Development of the Working Group I Outline of AR6

Summary for Policy Makers & Technical Summary

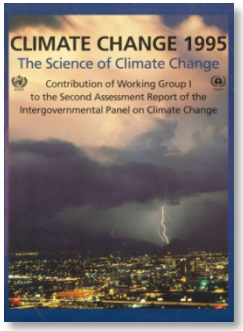
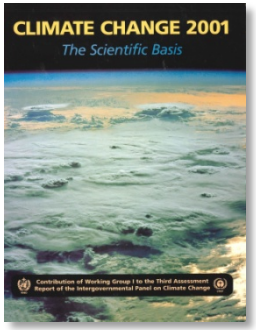
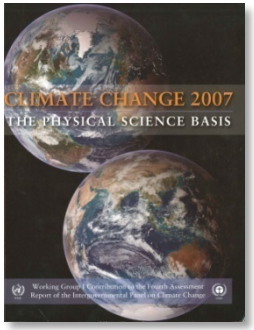
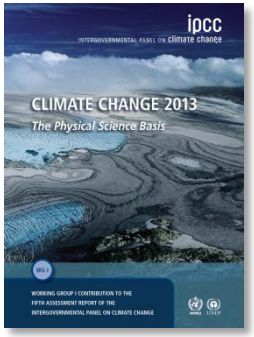
Approval April 2021

- Ch1: Framing, context, methods
- Ch2: Changing state of the climate system
- Ch3: Human influence on the climate system
- Ch4: Future global climate: scenario-based projections and near-term Information
- Ch5: Global carbon and other biogeochmical cycles and feedbacks
- Ch6: Short-lived climate forcers
- Ch7: The Earth's energy budget, climate feedbacks, and climate sensitivity
- Ch8: Water cycle changes
- Ch9: Ocean, cryosphere, and sea level change
- Ch10: Linking global to regional climate change
- Ch11: Weather and climate extreme events in a changing climate
- Ch12: Climate change information for regional impact and for risk assessment

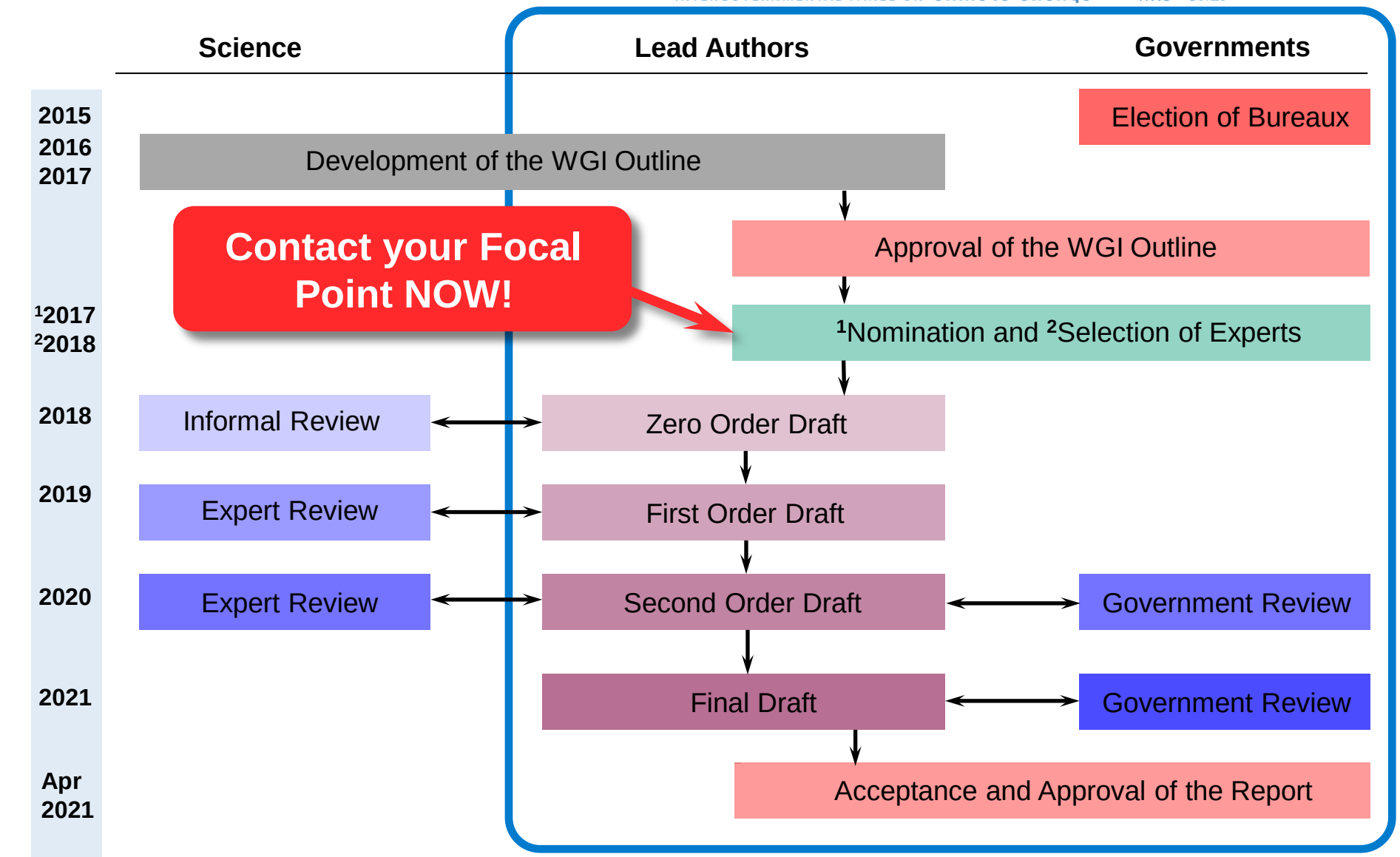
Annexes (incl. options for regional Atlas)

Development of the AR6 Working Group I Outline

Structure of WGI AR6 in perspective

						
	FAR 1990 **11 Chapters**	SAR 1995 **11 Chapters**	TAR 2001 **14 Chapters**	AR4 2007 **11 Chapters**	AR5 2013 **14 Chapters**	AR6 2021 **12 Chapters**
observations	✓	✓	✓	✓✓✓	✓✓✓	✓
paleoclimate				✓	✓	
sea level	✓	✓	✓		✓	✓
clouds					✓	
carbon cycle			✓		✓	✓
regional change			✓	✓	✓✓✓	✓✓✓
extremes						✓
shortlived forcers						✓
energy budget						✓

The AR6 Process for IPCC Working Group I



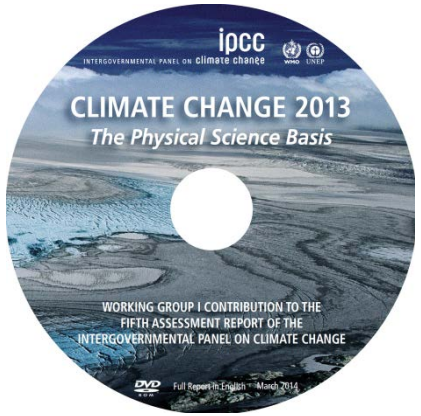
Preparatory SPM Author Meeting
Stockholm 20.-21.9.2013

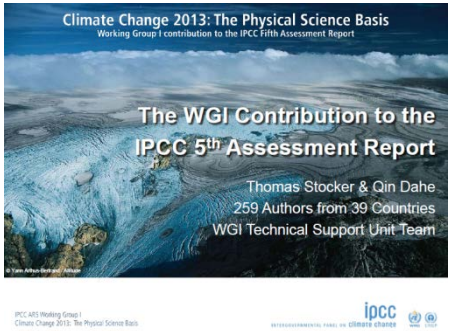
(Photo Credit: Johannes Frandsen, www.johannesfrandsen.com)

WGI 12th Plenary:
SPM Approval Plenary 23.-27.9.2013

(Photo Credit: Johannes Frandsen, www.johannesfrandsen.com)

www.climatechange2013.org





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

ipcc
INTERGOVERNMENTAL PANEL ON climate change
WMO UNEP

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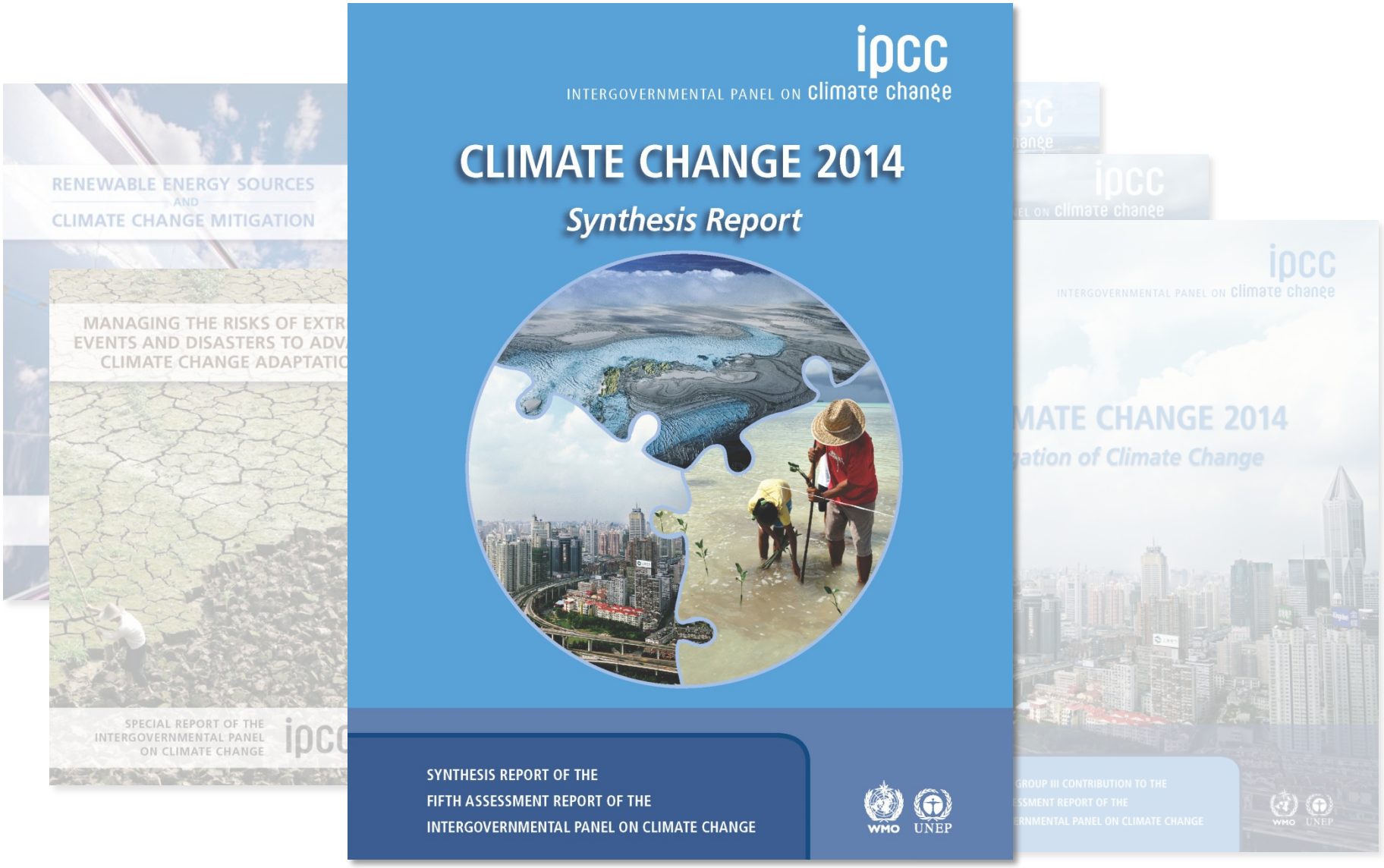
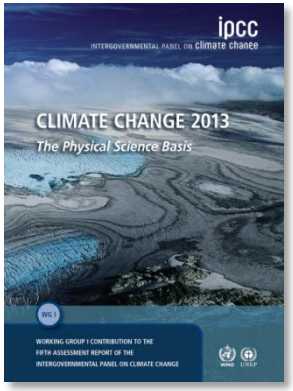
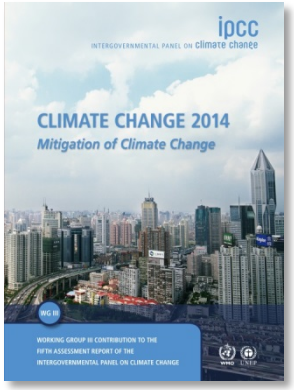
The 5th IPCC Assessment Report 2008 - 2014

The 5th IPCC Assessment Report 2008 - 2014





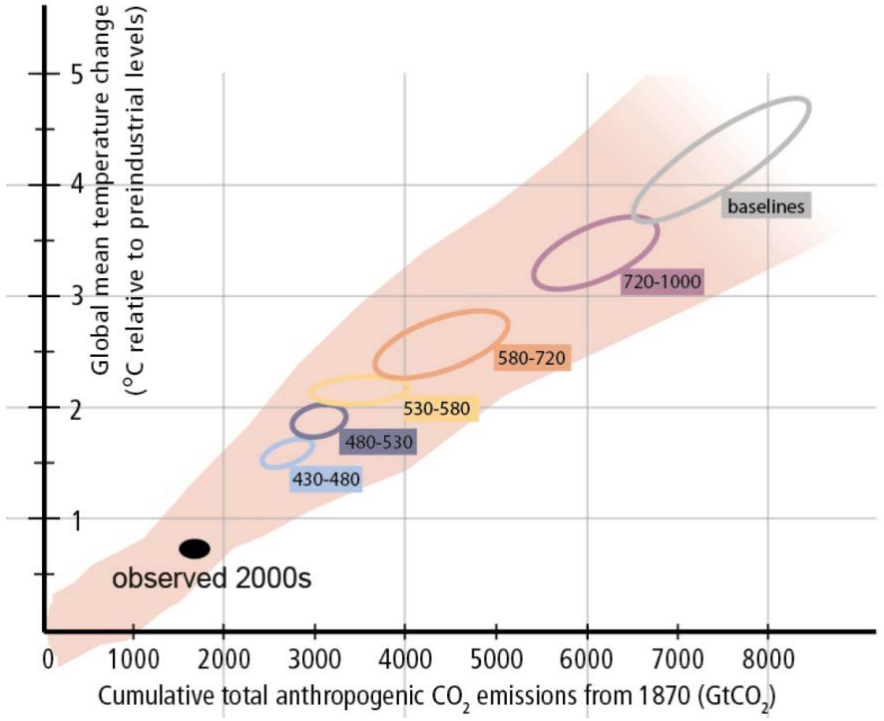


Human influence on the climate system is clear.

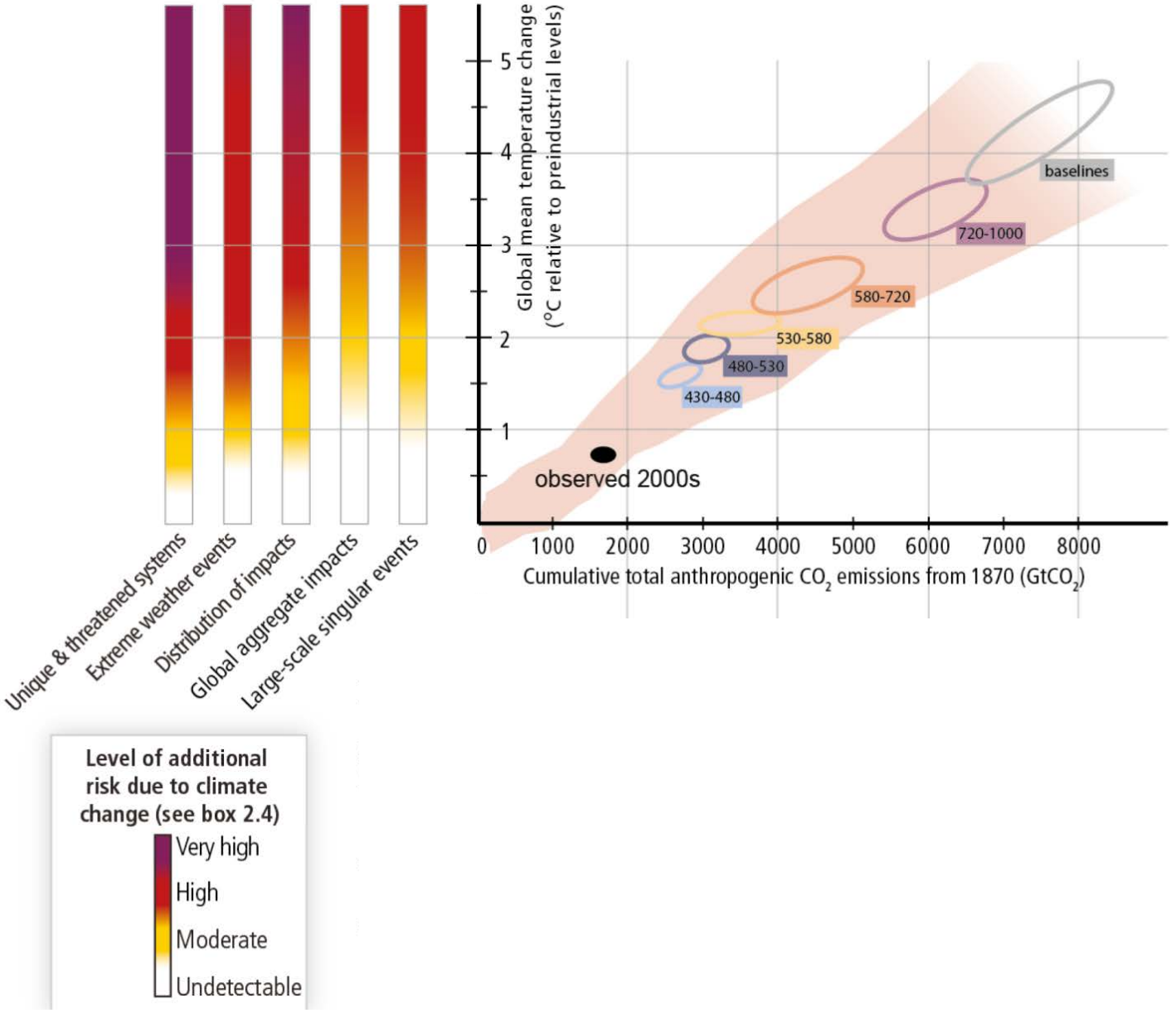
Changes in climate have caused impacts in natural and human systems.

Continued GHG emissions will cause further warming and amplify existing risks.

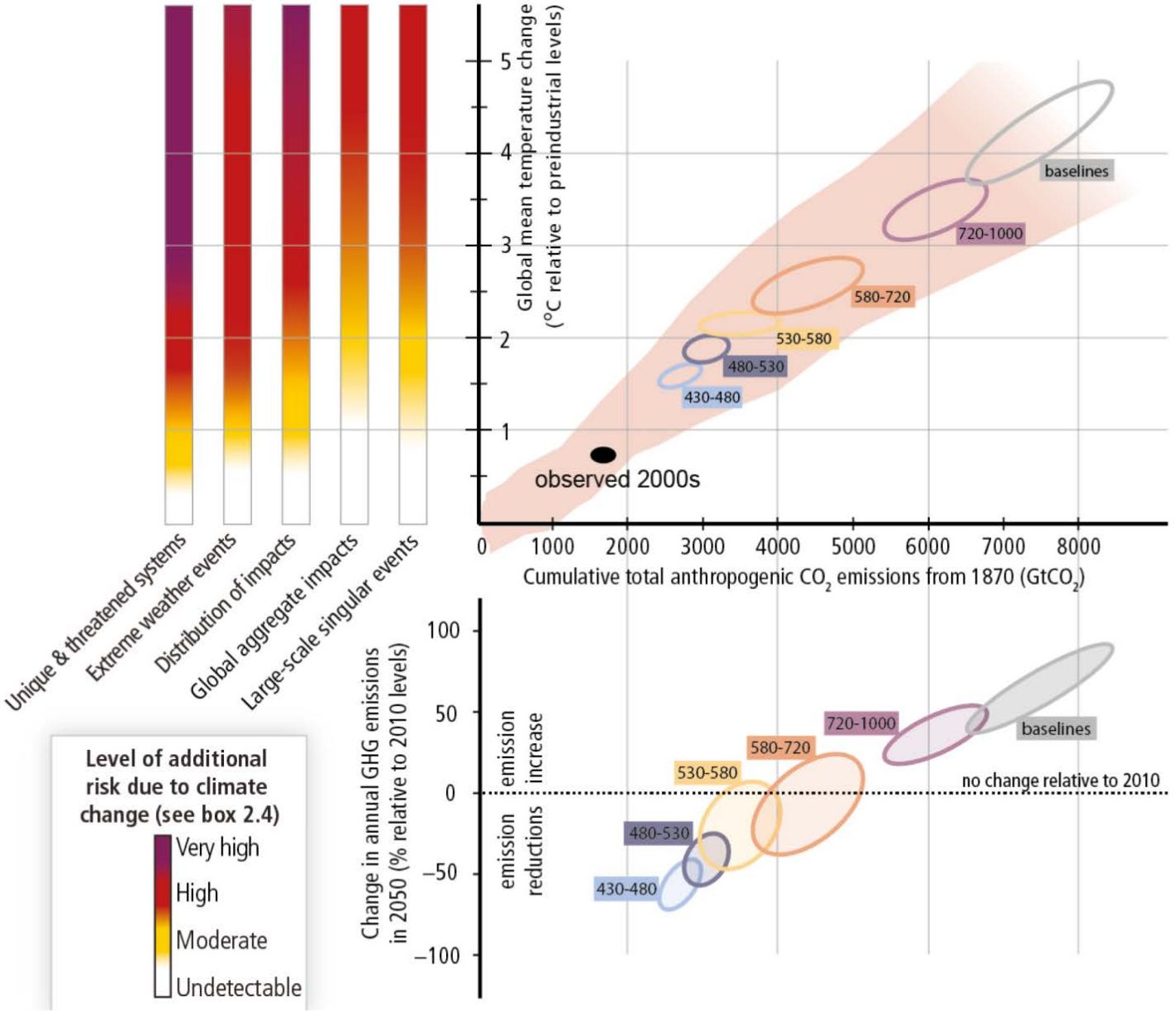
Multiple pathways exist to *likely* limit warming to below 2°C.



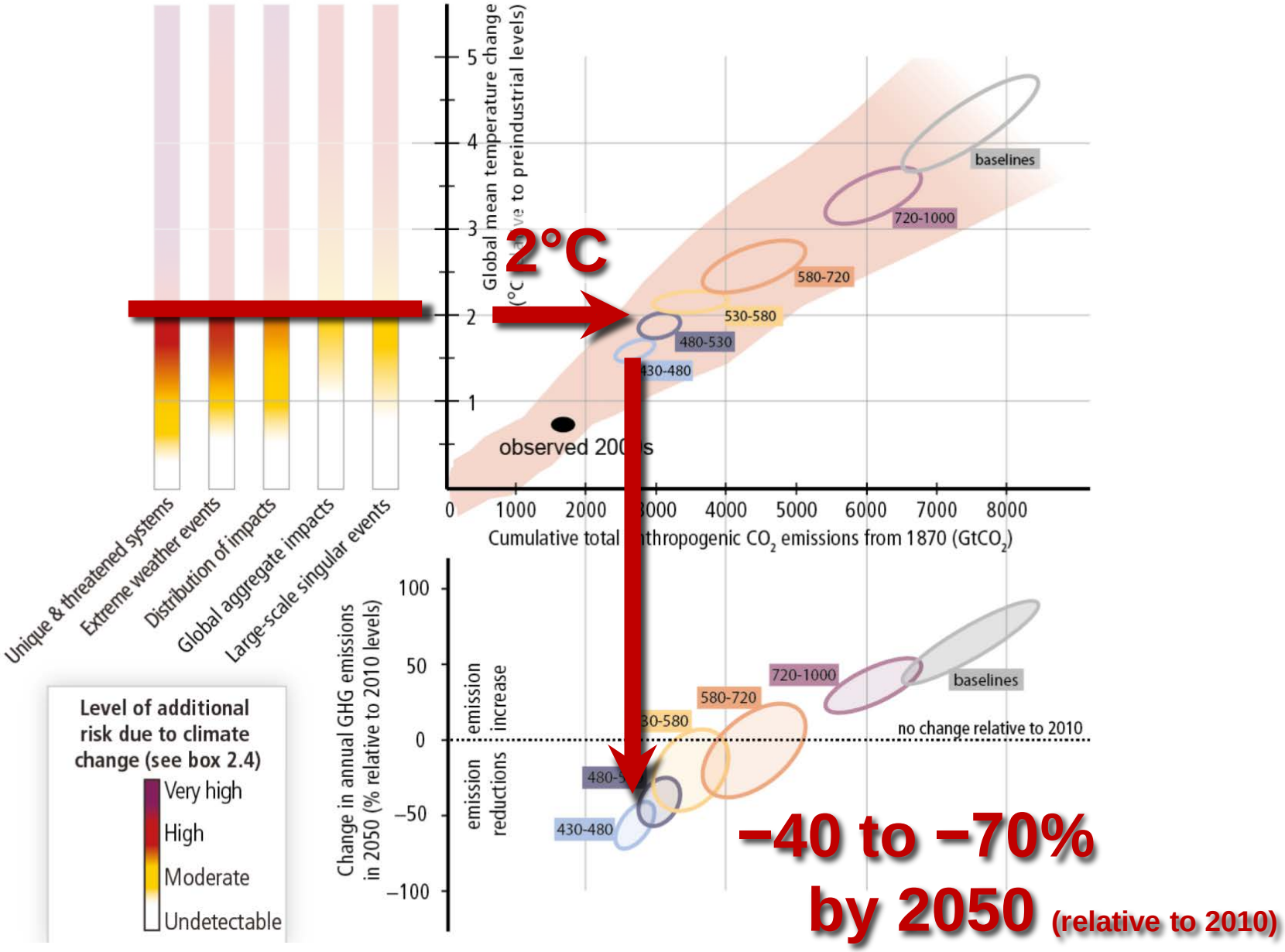
SYR Fig. SPM.10



SYR Fig. SPM.10



SYR Fig. SPM.10



SYR Fig. SPM.10

AR6 Sequence of IPCC Special Reports

- **Special Report on Global Warming of 1.5°C (SR15) – Sep 2018**

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

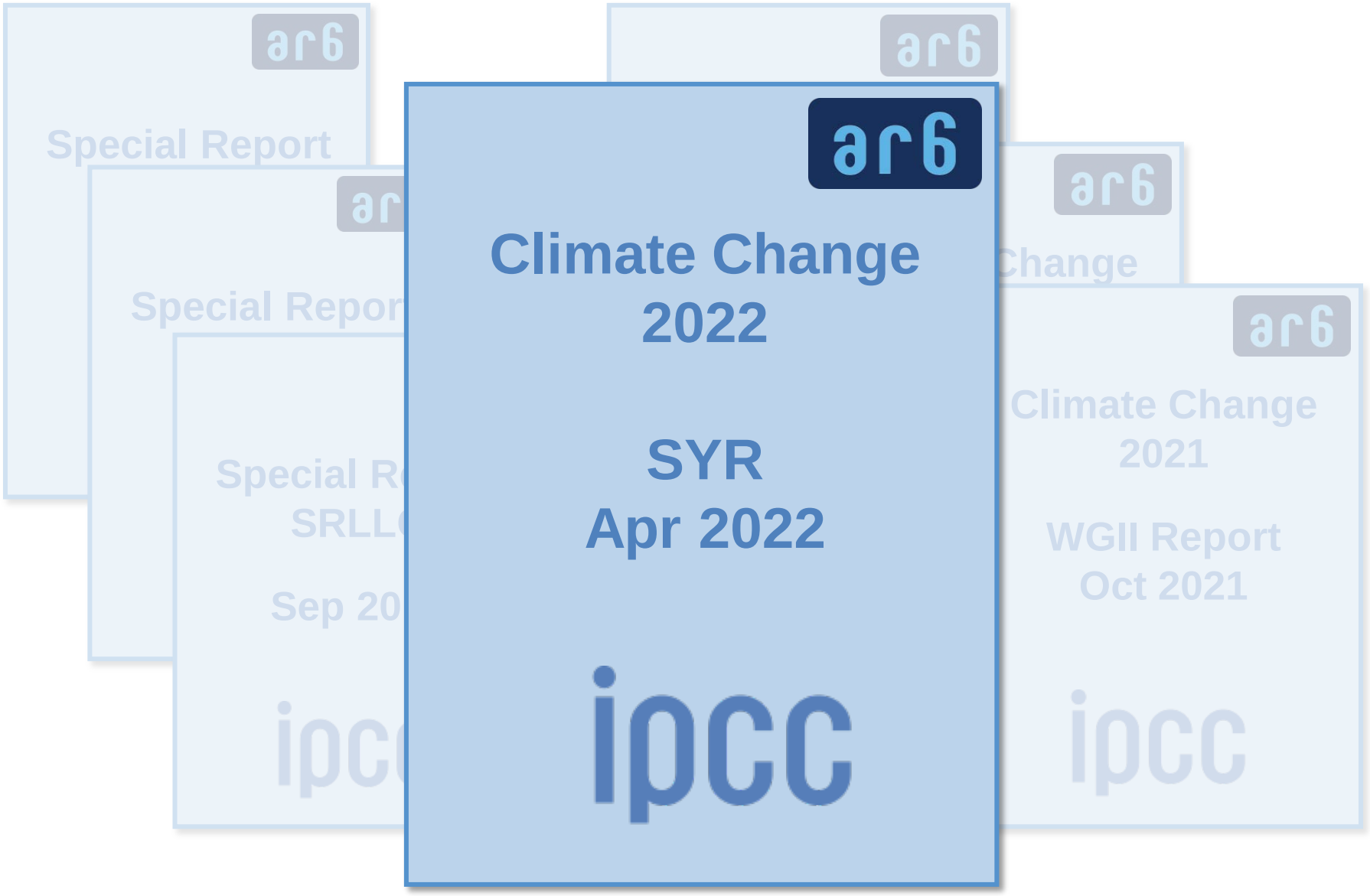
- **Special Report SROCC – Sep 2019**

IPCC Special Report on the Ocean and Cryosphere in a Changing Climate

- **Special Report SRCCL – Sep 2019**

IPCC Special Report on 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

The 6th IPCC Assessment Report 2015 - 2022



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Some Practical IPCC AR6 Challenges

- **Work load:** 3 Special Reports, 3 WG Assessment Reports and 1 Synthesis Report produced by authors and review editors volunteering time and expertise
- **Schedule:** very ambitious with a record fast production of SR1.5 in response to the UNFCCC request
- **Amount of information:** assessments must be rigorous, comprehensive, robust and transparent, but scientific information is growing at an ever increasing rate
- **Process:** reviews of IPCC drafts are open to all self-declared experts but comments number in the many thousands
- **x-Chapter/WG:** the expectation (and need) to coordinate and collaborate across Chapters/WGs/disciplines is growing with each Assessment Report

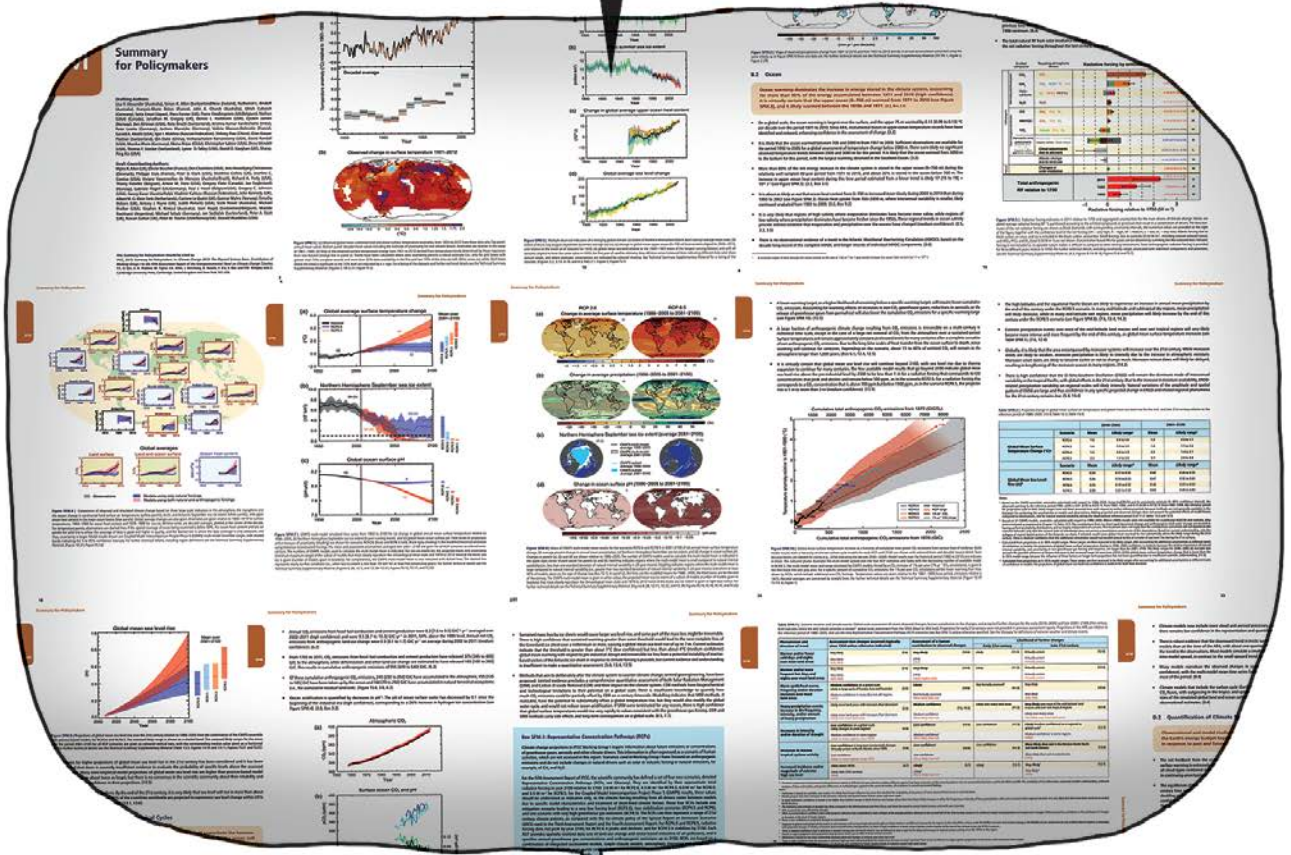
Some Scientific IPCC AR6 Challenges

- **Scenario-based projections:** AR6 projections and comparison to earlier assessment reports
- **Treatment of uncertainty:** determine, formulate, display and communicate uncertainty
- **Communication:** making it simple and relevant – use headline statements approach from WGI AR5 across AR6
- **Dealing with complexity of figures:** "*a figure is worth a 1000 words … but some IPCC figures need more than 1000 words of explanation*" (WGIII AR6 Co-Chair)

Challenging? Yes. But Exciting, Rewarding and Relevant, too!

Would you be willing to serve again?	Yes 68%
Rate your overall experience	Good to Excellent 90%
Amount of work was a challenge	Agree to strongly agree 83%
Dedicated assistance should be standard	Agree to strongly agree 80%

THE ARGUMENT FOR TAKING IMMEDIATE ACTION ON CLIMATE CHANGE AND GLOBAL WARMING.



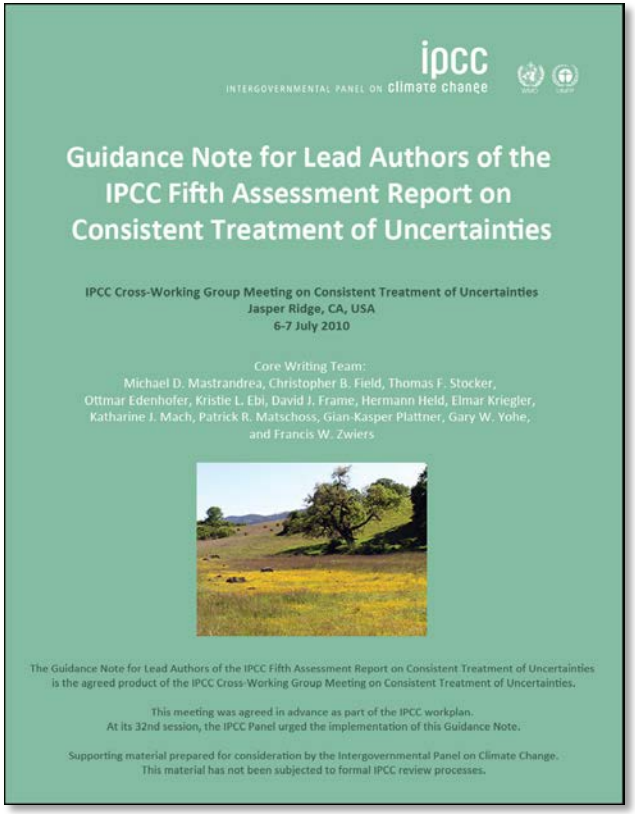
THE ARGUMENT AGAINST.

IT SNOWED AT MY HOUSE IN APRIL.

JOHN COLE
COMMENTS-TRIBUNE
SCRANTON, PA.
CAGLECARTOONS.COM

Treatment of Uncertainty in IPCC AR6

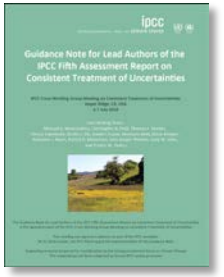
- How to determine uncertainty?
- How to formulate uncertainty?
- How to display uncertainty?
- How to communicate uncertainty?



→ Integrated framework for evaluating and communicating the degree of certainty in key findings.

→ Guidance on treating uncertainty in developing key findings of the assessment process.

Treatment of Uncertainty in IPCC AR6



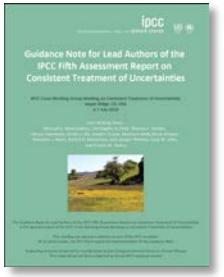
How to formulate uncertainty?

Qualitative:

level of ***agreement***
amount and quality of ***evidence***

} ***confidence***

Treatment of Uncertainty in IPCC AR6



How to formulate uncertainty?

High agreement Limited evidence	*High agreement Medium evidence*	*High agreement Robust evidence*
Medium agreement Limited evidence	*Medium agreement Medium evidence*	*Medium agreement Robust evidence*
Low agreement Limited evidence	*Low agreement Medium evidence*	*Low agreement Robust evidence*

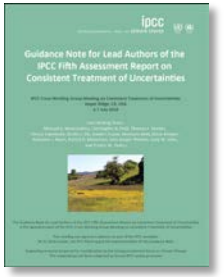
Agreement ↑

Evidence (type, amount, quality, consistency) →

Confidence Scale

(Mastrandrea et al., 2011)

Treatment of Uncertainty in IPCC AR6



How to formulate uncertainty?

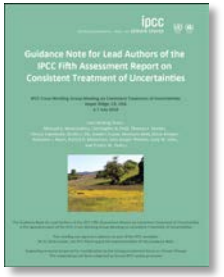
Qualitative:

level of ***agreement***
amount and quality of ***evidence***

} ***confidence***

- In WGI, assessments of *evidence and agreement* are usually reported *implicitly* in the form of **a traceable account** of the evidence.
- WGI makes many *explicit* confidence assessments.

Treatment of Uncertainty in IPCC AR6



How to formulate uncertainty?

Qualitative:

level of ***agreement***
amount and quality of ***evidence*** } ***confidence***

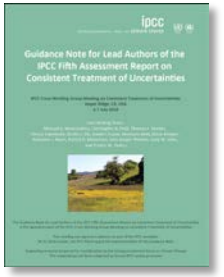
Quantitative:

quantified likelihood

virtually certain	≥ 99%
very likely	≥ 90%
likely	≥ 66%
unlikely	< 33%
...	

Statements of fact: «Warming of the climate system is unequivocal» (SPM, WGI AR4 & AR5)

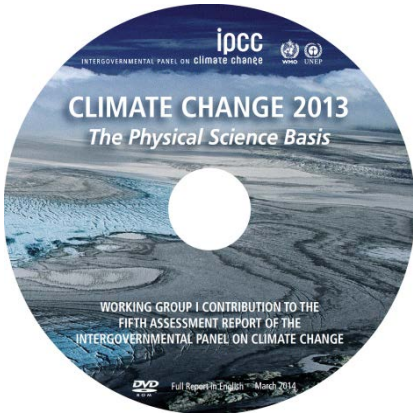
Treatment of Uncertainty in IPCC AR6

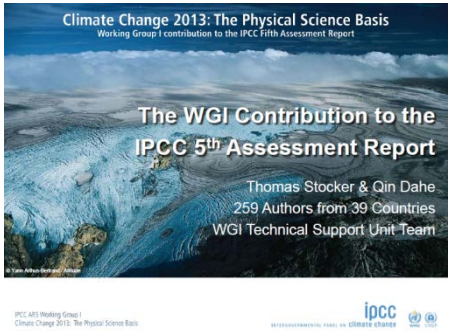


How to communicate uncertainty?

- Communicate uncertainty carefully
- Using calibrated language for key findings
- Provide traceable accounts describing evaluations of evidence and agreement in individual chapters

www.climatechange2013.org





IPCC Use of Literature Sources

- IPCC assesses all available scientific-technical literature
- priority is given to **peer-reviewed** literature
- emphasis is placed on the **assurance of the quality of all literature** cited
- **other sources** may provide essential information, esp. for adaptation and mitigation (WGs II & III)
- **extra responsibility** for author teams to ensure quality and validity of such sources

IPCC Special Report on Global Warming of 1.5 C (SR15)

IPCC Special report on the impacts of global warming of 1.5oC 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

Summary for Policy Makers

Approval September 2018

- Ch1: Framing and context
- Ch2: Mitigation pathways compatible with 1.5oC in the context of sustainable development
- Ch3: Impacts of 1.5oC global warming on natural and human systems
- Ch4: Strengthening and implementing the global response to the threat of climate change
- Ch5: Sustainable development, poverty eradication and reducing inequalities
- Boxes - integrated case studies/regional and cross-cutting themes

Annexes

IPCC Special Report SROCC

IPCC Special Report on the Ocean and Cryosphere in a Changing Climate

Summary for Policy Makers

Approval September 2019

- Ch1: Framing and context of the report
- Ch2: High mountain areas
- Ch3: Polar regions
- Ch4: Sea level rise and implications for low lying islands, coasts and communities
- Ch5: Changing ocean, marine ecosystems, and dependent communities
- Ch6: extremes, abrupt changes and managing risks
- Case studies, Frequently Asked Questions and Boxes
- Integrative cross-chapter box: low lying Iilands and coasts

Annexes

IPCC Special Report SRCCL

IPCC Special Report on 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

Summary for Policy Makers & Technical Summary	**Approval September 2019**
❖ Ch1: Framing and Context	
❖ Ch2: Land-Climate Interactions	
❖ Ch3: Desertification	
❖ Ch4: Land Degradation	
❖ Ch5: Food Security	
❖ Ch6: Interlinkages between desertification, land degradation, food security and GHG fluxes: Synergies, trade-offs and integrated response options	
❖ Ch7: Risk management and decision making in relation to sustainable development	
❖ Case studies, Frequently Asked Questions and Boxes	
❖ Integrative cross-chapter box: low lying islands and coasts	
Annexes	