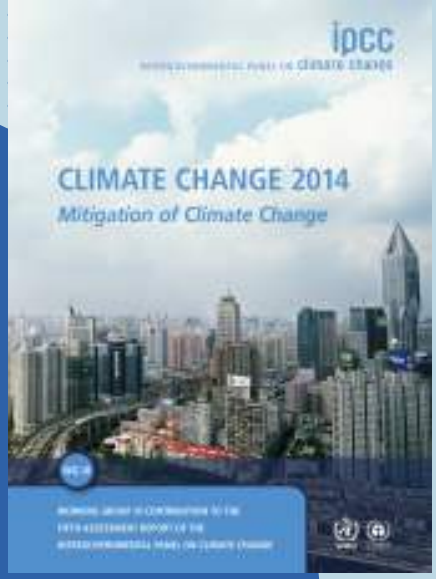







# Observed and future climate change

## Causes, consequenses and cures

CLIMATE ANALYTICS

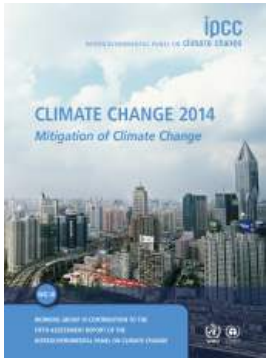
Ljubljana, September 23, 2014

Dr. Michiel Schaeffer

# Outline

- Introduction IPCC AR5
- Working Group I: Physical Science Basis
  - Advances in understanding
  - Climate observations
  - Climate model projections
- Working Group II: Impacts, Vulnerability and Adaptation
  - Impacts
  - Risks
- Working Group III: Mitigation
  - Recent emission trends
  - Feasibility of 2°C



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# IPCC – What is it and how does it work?


- Established in 1988 by the United Nations Environment Programme (UNEP) and the World Meteorological Organization (WMO) -> Legitimate scientific UN body
- Open to all member countries of the UN and WMO

- Publication of Assessment Reports on a regular basis (5 reports)
- More than 830 scientists particpate voluntarily to guarantee objectivity
- Governments participate in review and plenary Sessions
- Final Summary for Policy Makers (SPM) negotiated and endorsed by governments

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# IPCC AR5: Greater evidence of human influence since IPCC AR4 in 2007

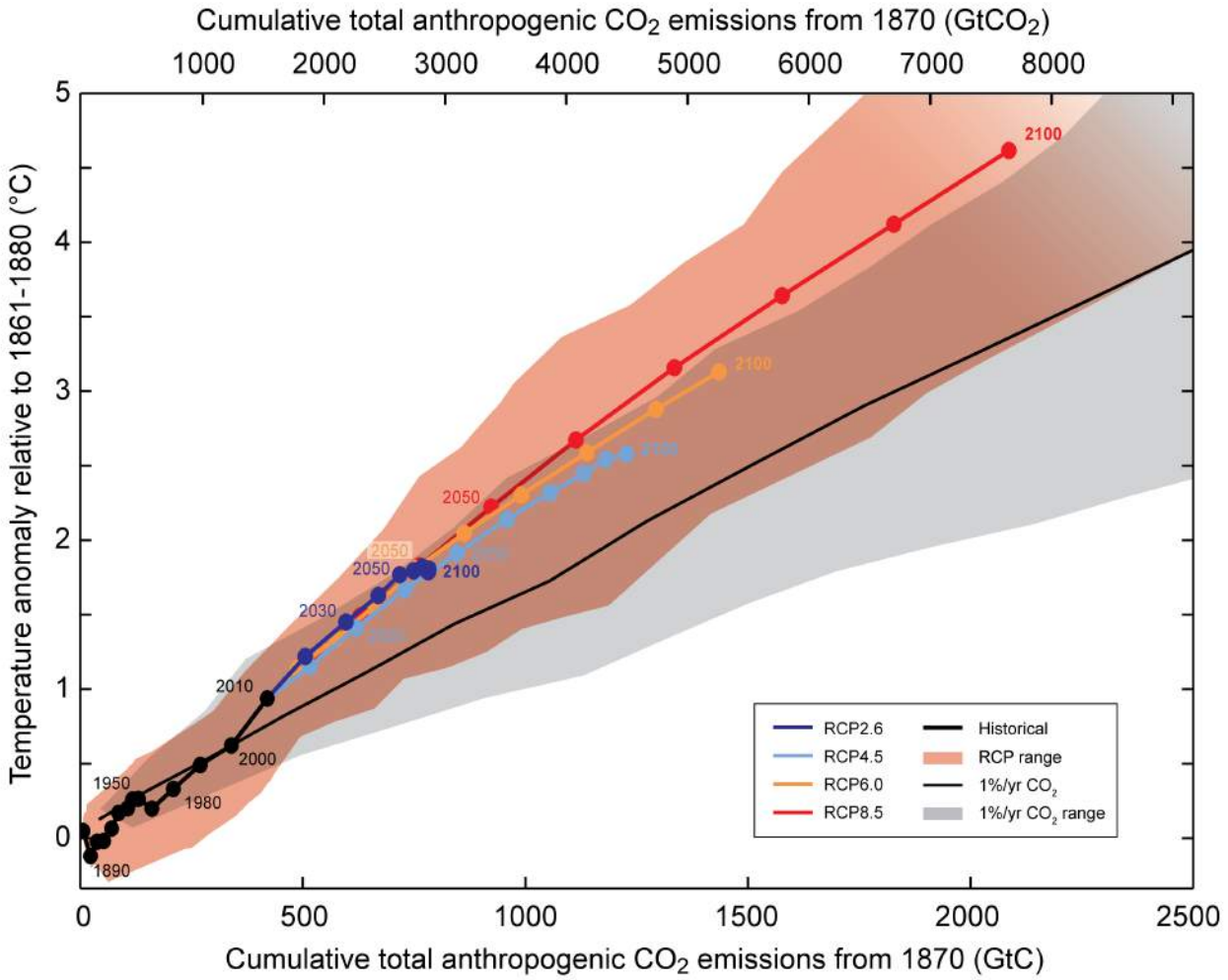
- Extremely likely that human influence has been the dominant cause of the observed warming since the mid-20$^{th}$ century.

- The evidence for human influence has grown since AR4.

# Warming proportional to cumulative CO2 emissions

**Global carbon budget**

- Total amount of carbon emissions to the atmosphere “ever”
- Higher emissions now, lower emissions later
- Budget “overspending” implies dependence on possibility of actively removing carbon from the atmosphere at large scale later

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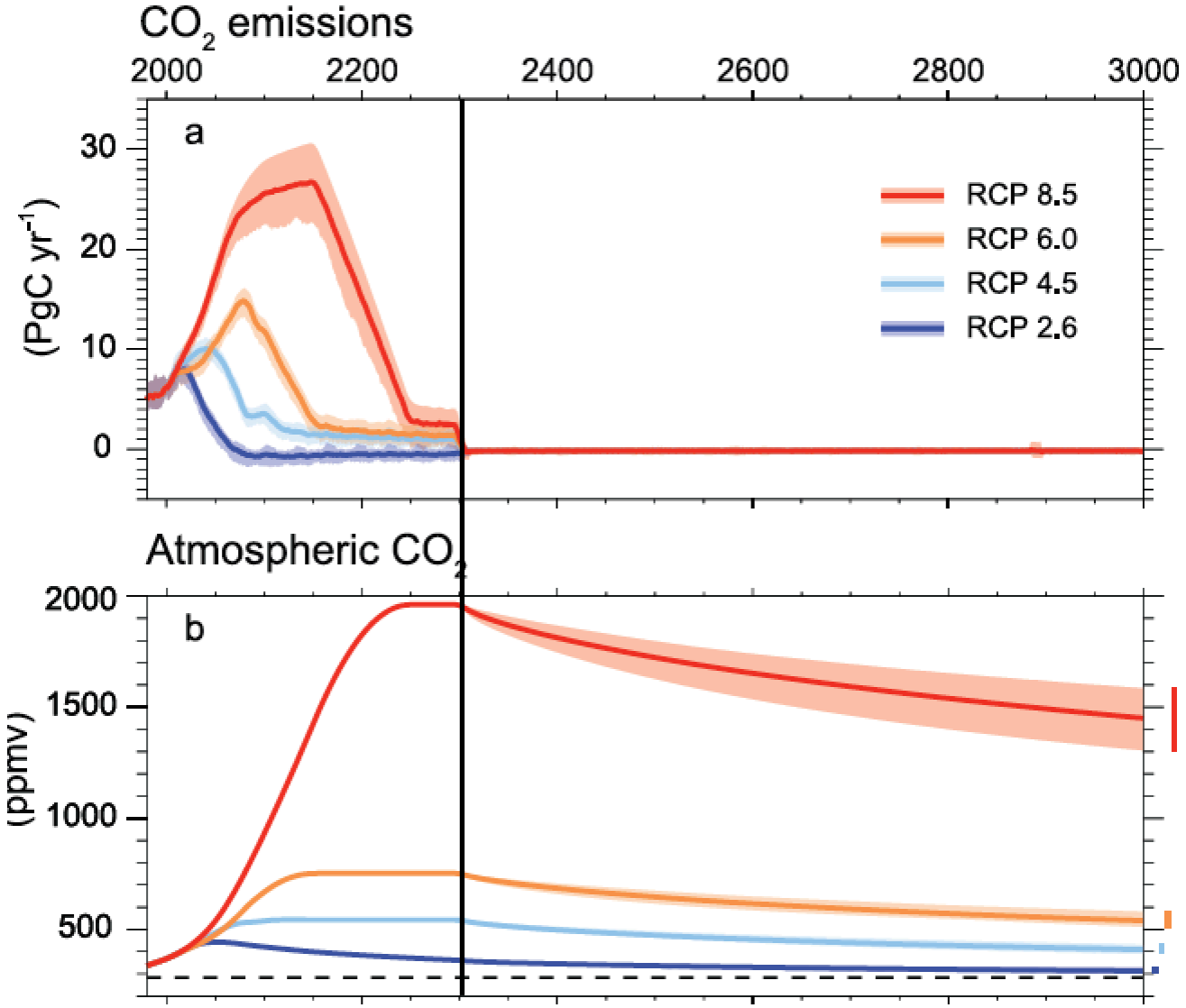
# Warming proportional to cumulative CO2 emissions also linked to long-term climate-change commitment

- Here $CO_2$ emissions follow (extended) RCP pathways until 2300
- RCP2.6: global net negative $CO_2$ emissions (BECCS)
- Emissions go to zero in 2300
- Concentration declines (very) slowly

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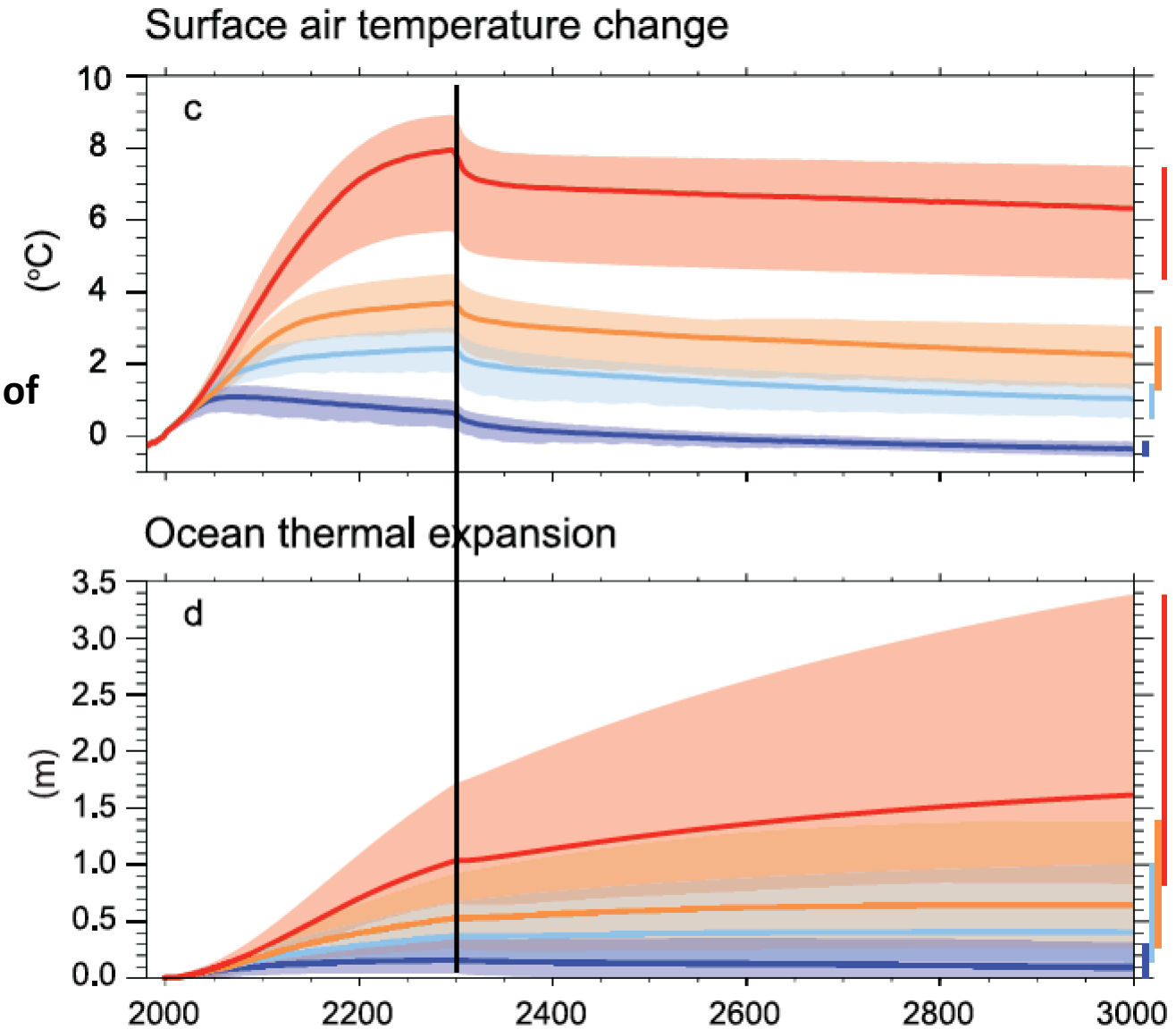
# Warming proportional to cumulative CO2 emissions also linked to long-term climate-change commitment

- Temperatures decline even slower

**Large time lags, therefore, again: Budget "overspending" implies dependence on possibility of actively removing carbon from the atmosphere at large scale later**

- While sea-level rise (from thermal expansion) continues, except in the lowest scenario

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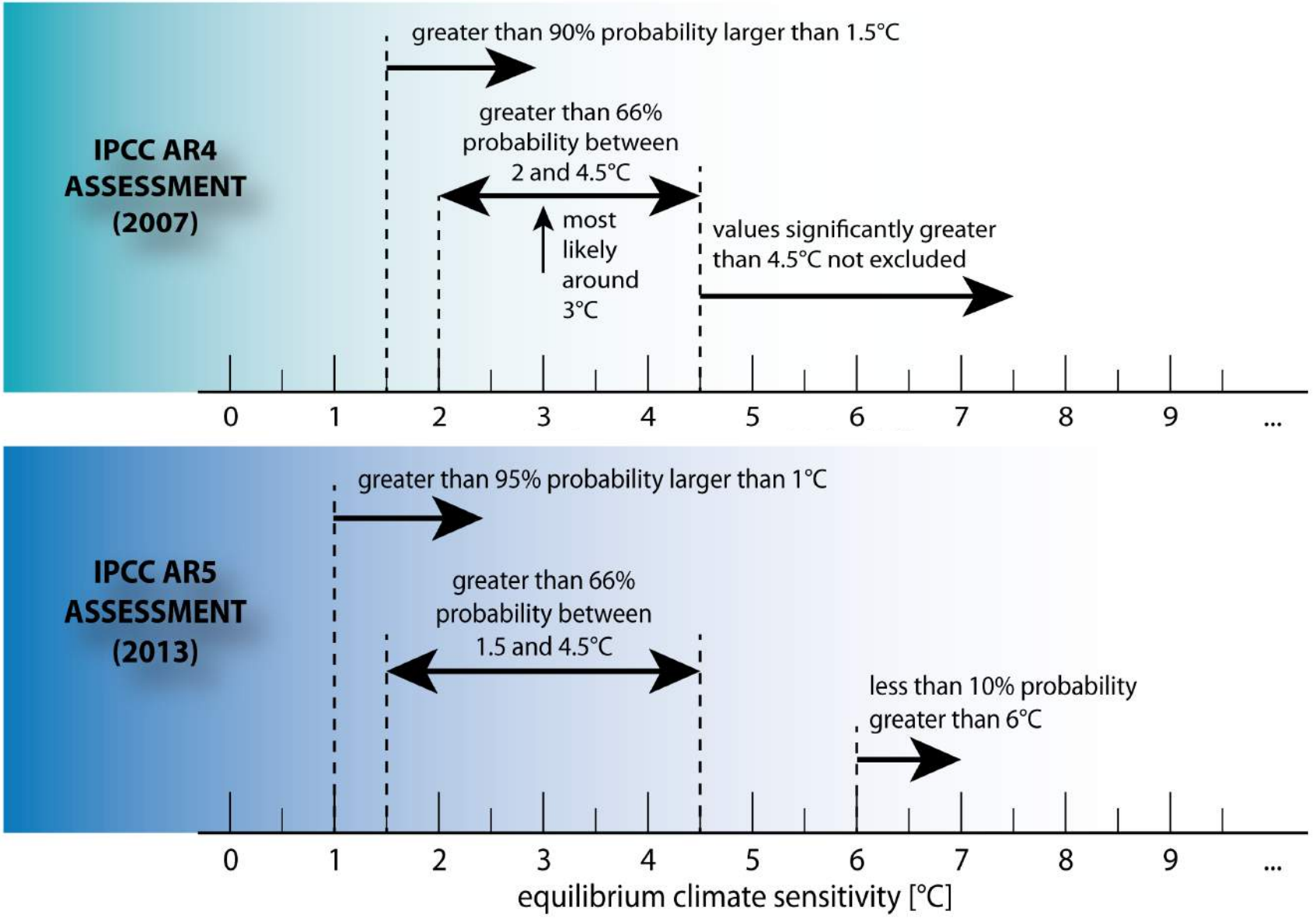
# What is climate sensitivity?

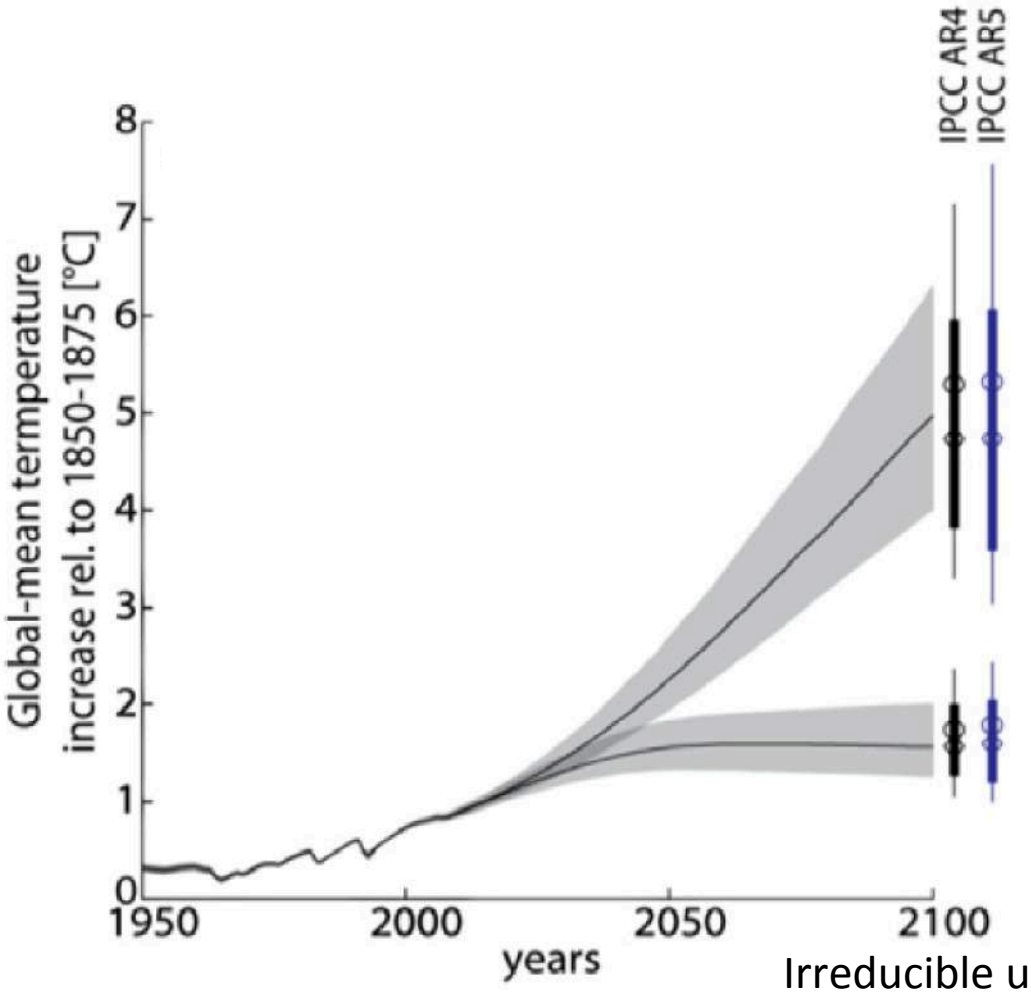
**Change** in global mean surface temperature **at equilibrium** that is caused by a **doubling** of the atmospheric $CO_2$ concentration

If doubling $CO_2$ concentration caused only 1°C of warming concern would be a lot less than if caused 3°C or higher….

# IPCC climate sensitivity estimates



# IPCC climate sensitivity estimates and climate policy implications




Overall warming projections are not changed by AR5 assessment

Projections under RCP8.5

Projections under RCP2.6

**Risk assessment:**

Irreducible uncertainty for now

- Estimates at the high end (> 6°C) remain a possibility
- Methods leading to current lower estimates are strongly influenced by last 15 years of data

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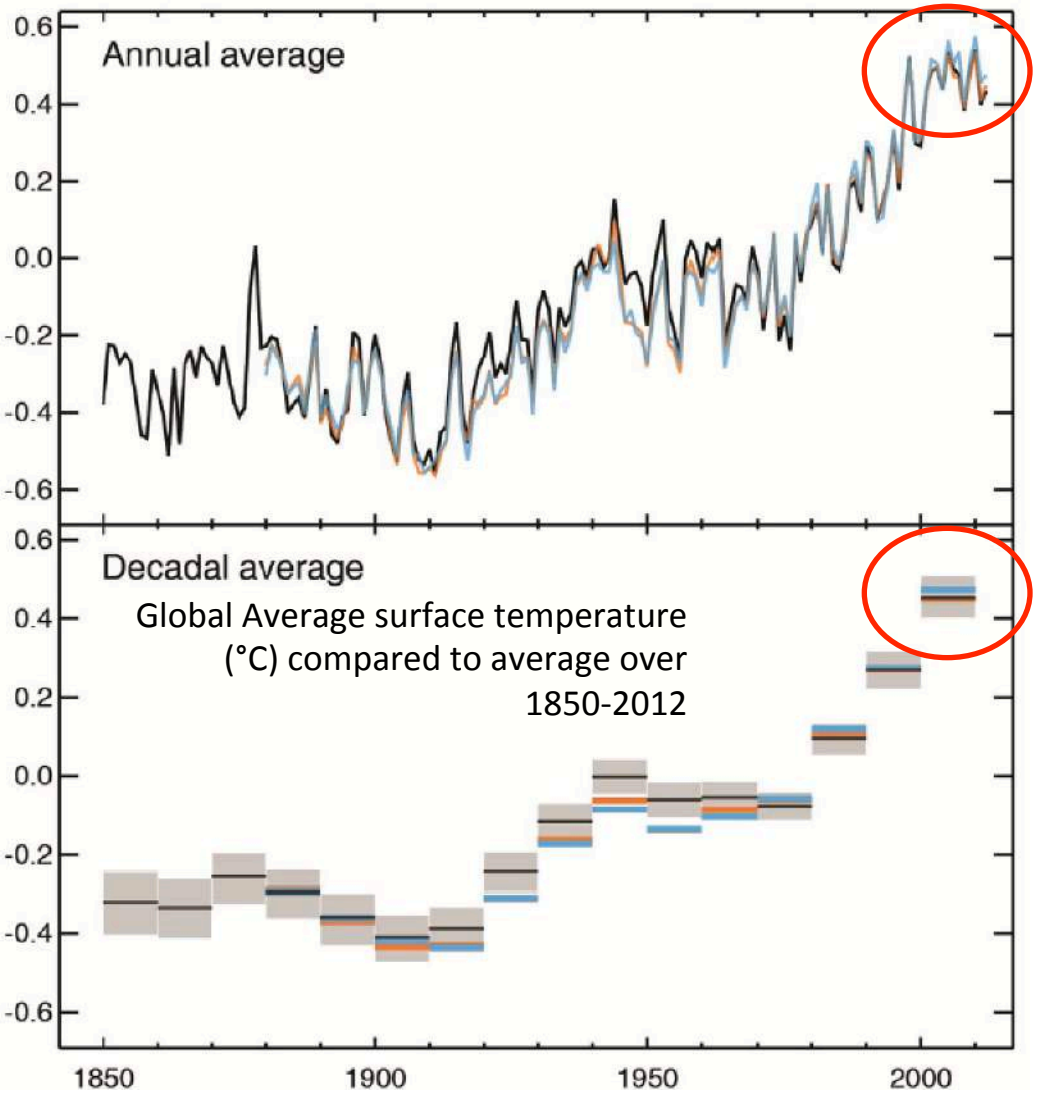
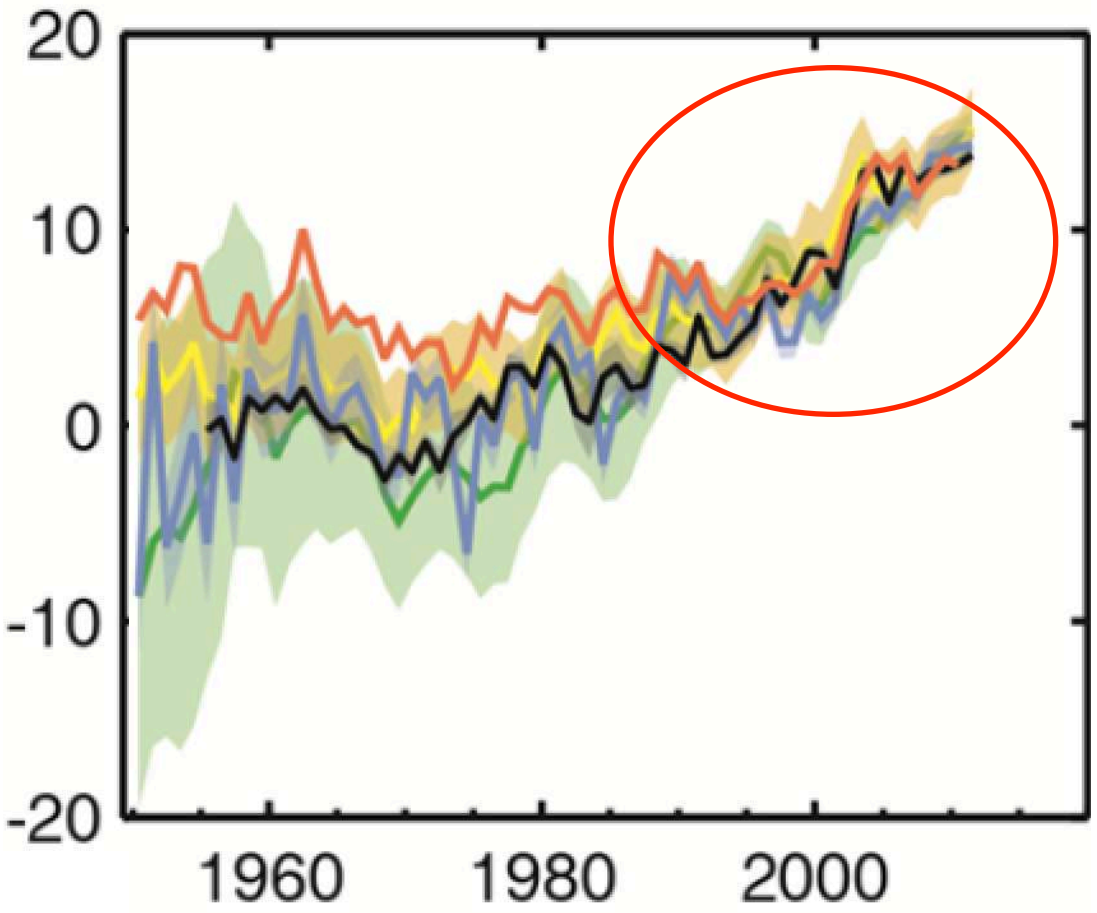
# Recent warming ”slowdown” or “hiatus”

- Past decade: **warmest on record**
- Periods of **slowdowns and accelerations occur regularly**
  - These are related to variations in forcing (e.g. volcanic eruptions, solar activity) and to internal redistribution of heat in ocean, causing **natural variations** of surface warming, and



# Ocean warming has continued over past 10-15 years

Change in global average upper ocean heat content ($10^{22}$ J)

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# Observations

- **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**
  - Also changes in many extreme weather and climate events have been observed since about 1950, for example, (a) an increase in the number of warm days and nights on the global scale and a decrease in the number of cold days and nights, (b) an increase in the frequency of heat waves in large parts of Europe, Asia and Australia, (c) an increase in the regions that experience heavy precipitation events
- **The rate of sea level rise since the mid-19th century has been larger than the mean rate during the previous two millennia**
  - Over the period 1901–2010, global mean sea level rose by 0.19 [0.17 to 0.21] m
- **Most of the energy added to the climate system is stored in the ocean under the form of ocean warming**
  - This accounts for more than 90% of the energy accumulated between 1971 and 2010

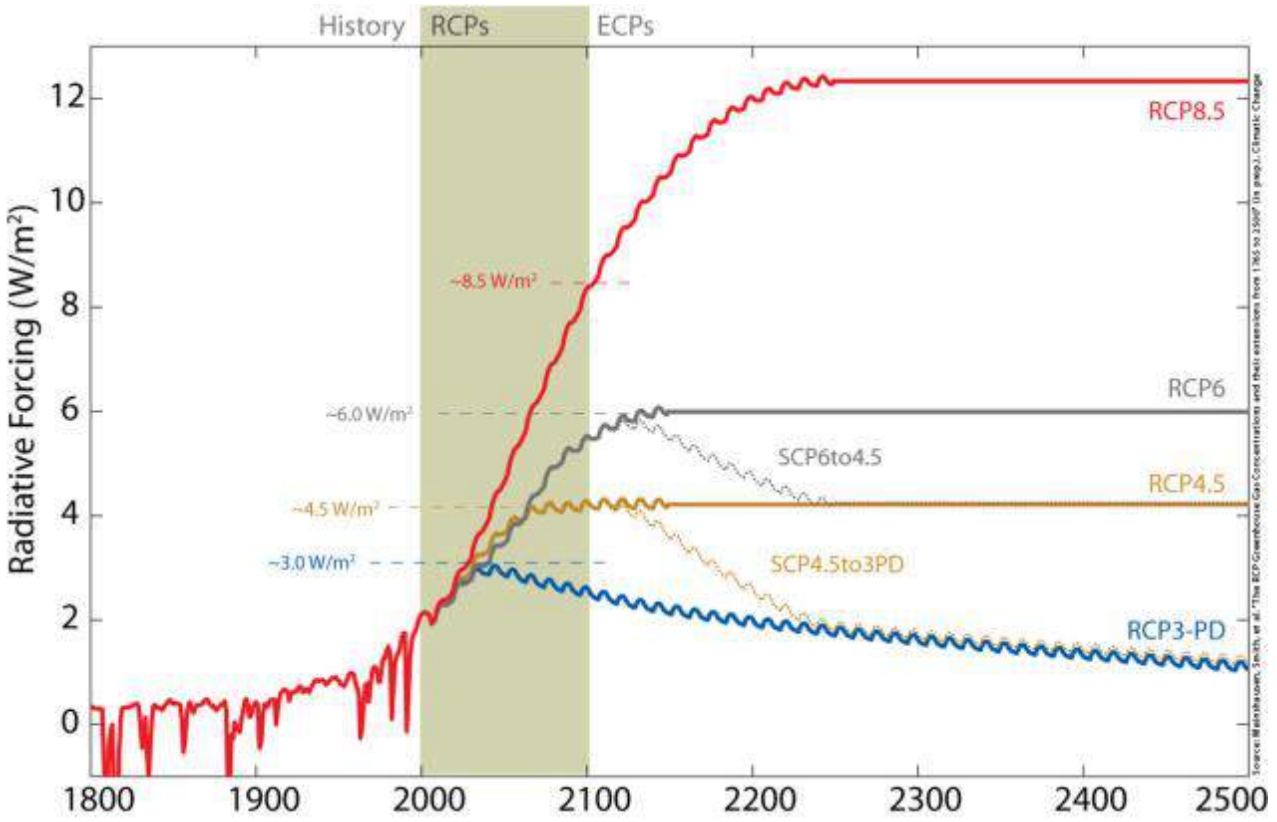
# Framing scenarios

- **4 GHG concentration pathways** provided to WG I in 2009
  RCPs: representative concentration pathways
- **RCPs used globally by climate science community**
- **Core of WG I assessment** → statements framed with respect to RCPs
- For example:
  Temperature in lowest scenario (RCP2.6 aka RCP3-PD):
  - *Likely* staying below 2°C (IPCC: "*Unlikely* to exceed 2°C")
  - *Likely to* exceed 1.5°C for all RCPs except RCP2.6

# Reference concentration paths

- 4 RCPs (2007)
- Used by climate community
- At core of WG I assessment

- RCP2.6/RCP3-PD:
  Likely <2°C
  T by 2100 ~1.6°C

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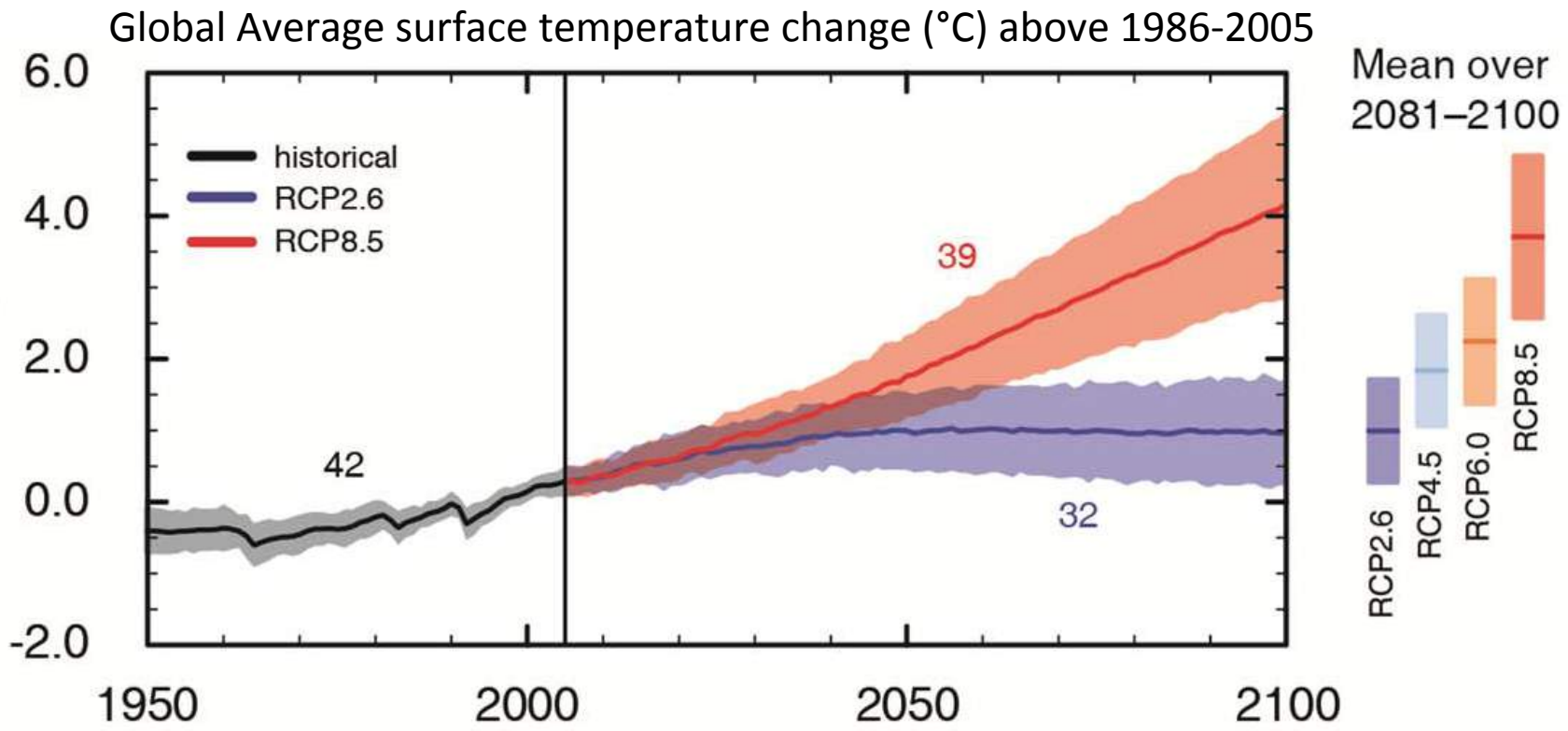
# AR5 confirms that substantial and sustained emission reductions needed

- **Continued emissions** of greenhouse gases will cause **further warming and changes** in all components of the climate system.
- **Limiting climate change** will require **substantial and sustained reductions** of greenhouse gas emissions
  *(IPCC AR5 SPM – headline statement)*

# Temperature projections




- Likely to exceed 1.5°C (and 2°C) for all new IPCC scenarios except the lowest (called RCP2.6)
  - Warming will continue beyond 2100 under all RCP scenarios except RCP2.6
- Warming **likely** to exceed 4°C by 2100 for highest of new IPCC scenarios (RCP8.5)
  - If carbon cycle feedbacks include range of warming is higher: 2.5-5.6°C in 2081-2100 above 1986-2005 or 3.1-6.2°C above pre-industrial

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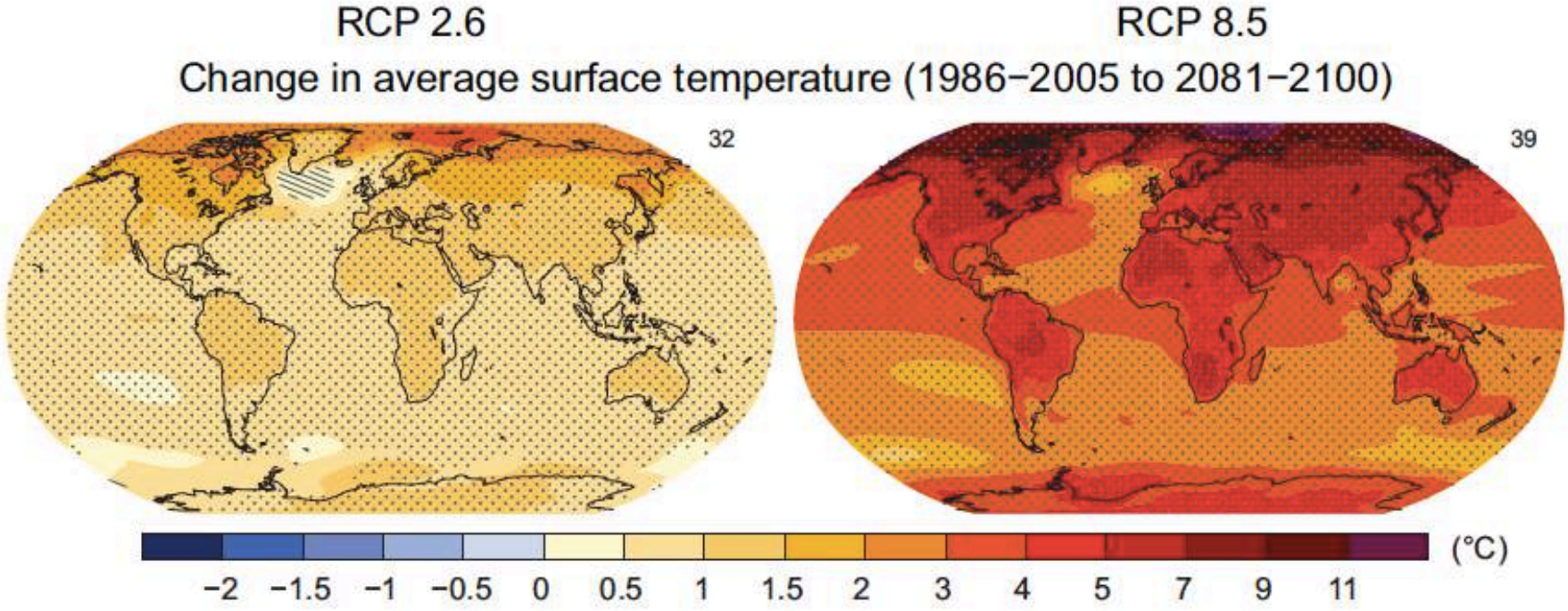
# Temperature




**Global surface temperature change for the end of the 21st century is likely to exceed 1.5 °C relative to 1850 to 1900 for all RCP scenarios except RCP2.6.**

**Warming will continue beyond 2100 under all RCP scenarios except RCP2.6.**

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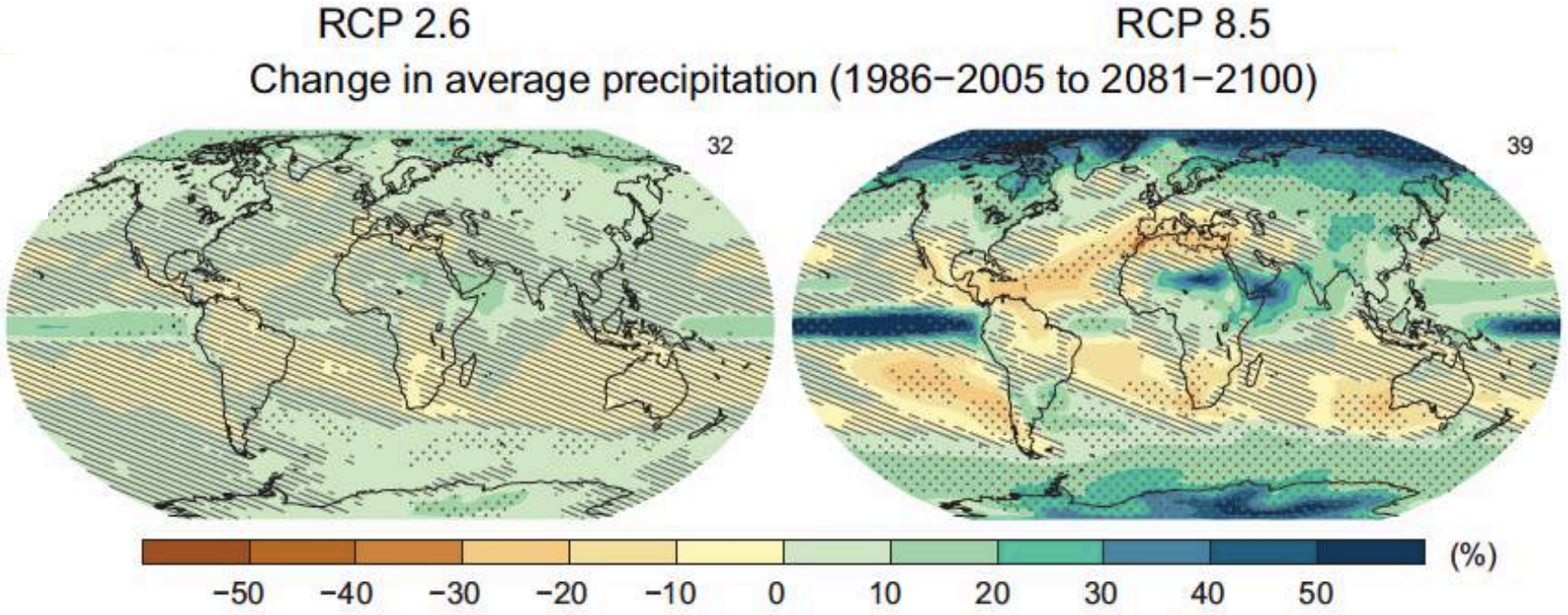
# Water cycle




**Changes in the global water cycle in response to the warming over the 21st century will not be uniform.**

**The contrast in precipitation between wet and dry regions and between wet and dry seasons will increase, although there may be regional exceptions.**

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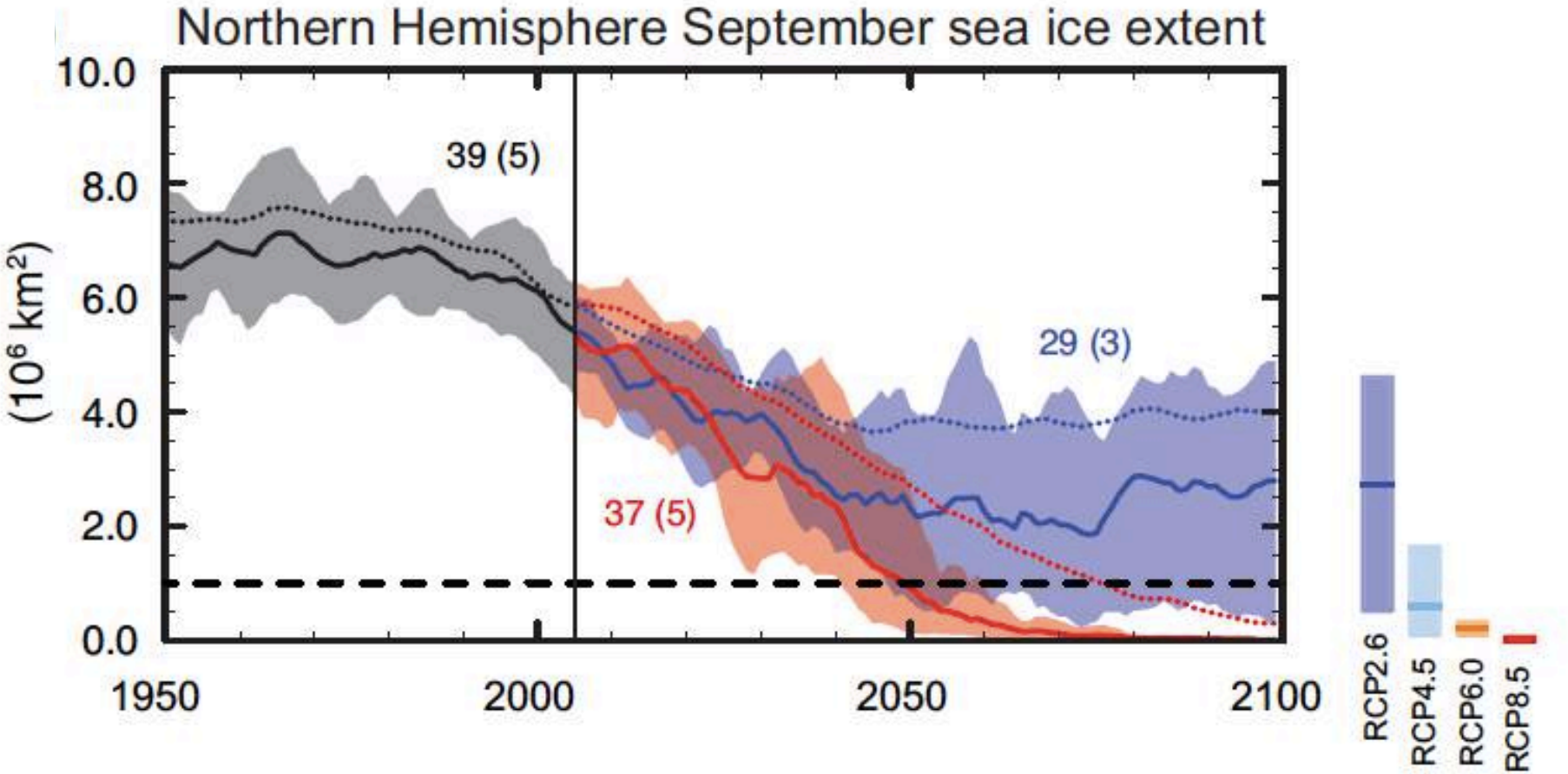
# Cryosphere


Northern Hemisphere September sea ice extent
10.0
8.0
6.0
4.0
2.0
0.0
(10⁶ km²)
1950
2000
2050
2100
39 (5)
29 (3)
37 (5)
RCP2.6
RCP4.5
RCP6.0
RCP8.5

# Sea level rise

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

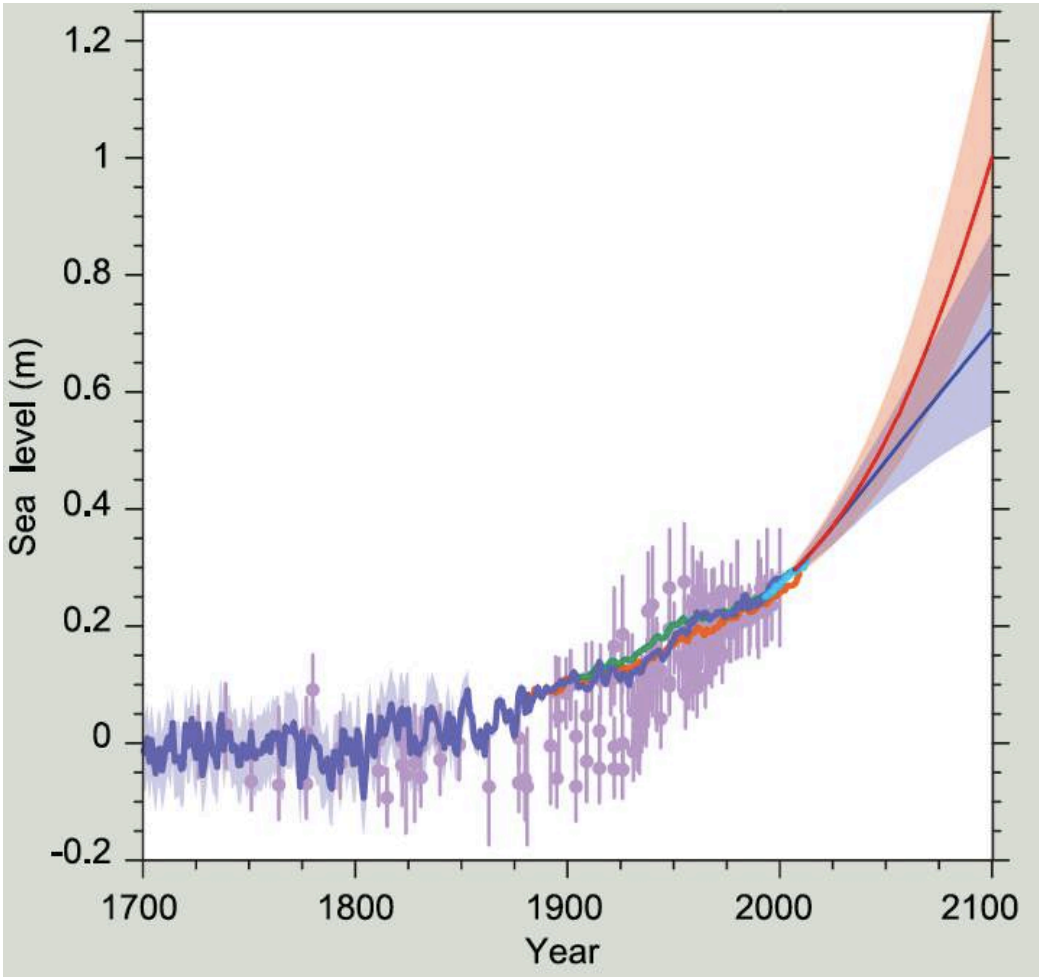
**Over the period 1901 to 2010, global mean sea level rose by 0.19 m.**

**Global mean sea level will continue to rise during the 21st century**

–0.5 to 1m* rise by 2100 projected for 4°C+ warming

–0.3 to 0.6m* rise by 2100 even if warming held below 2°C

*Numbers relative to 1986–2005

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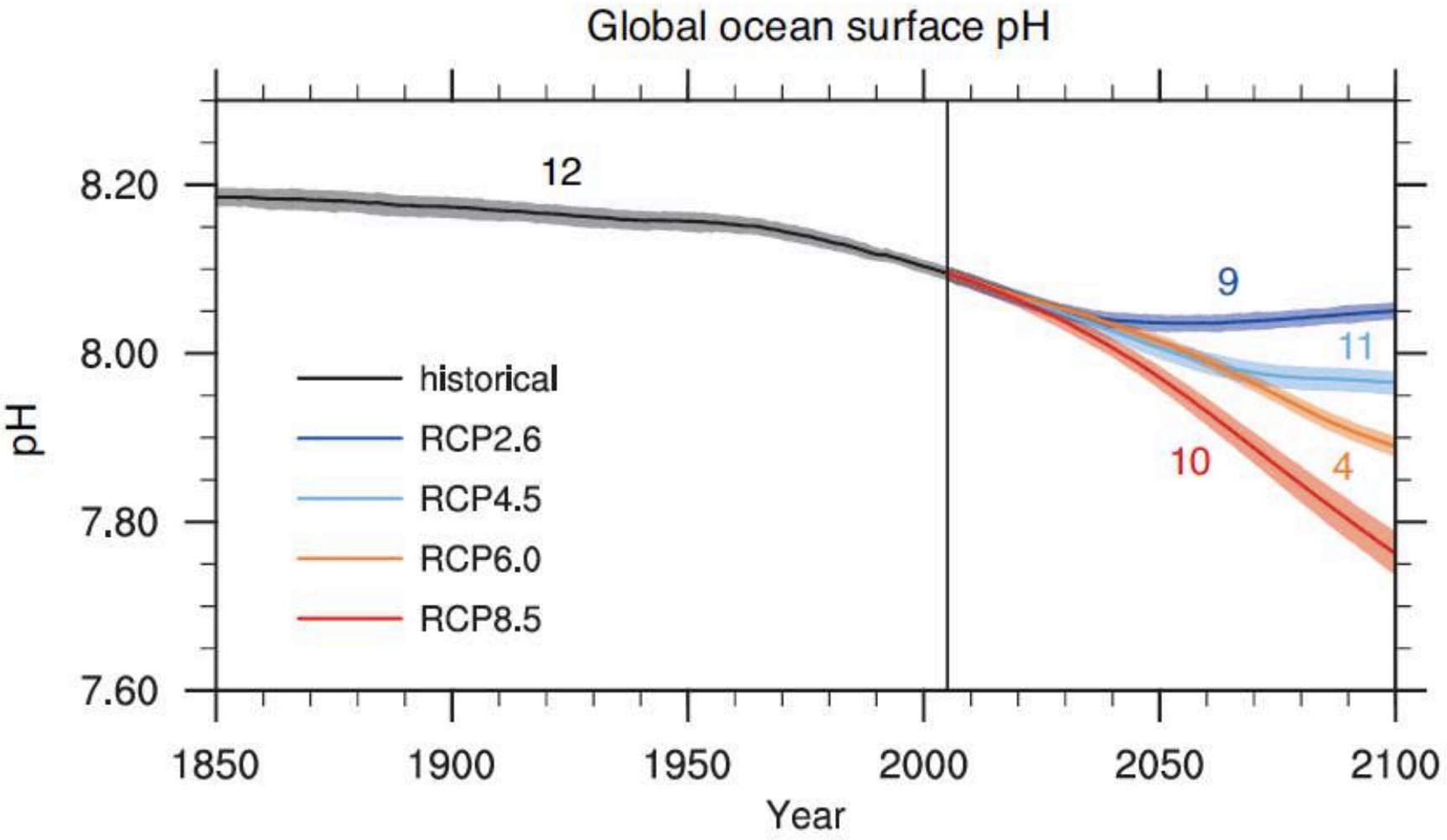
# Emerging issue: Ocean acidification



# WGII AR5: Observed Impacts

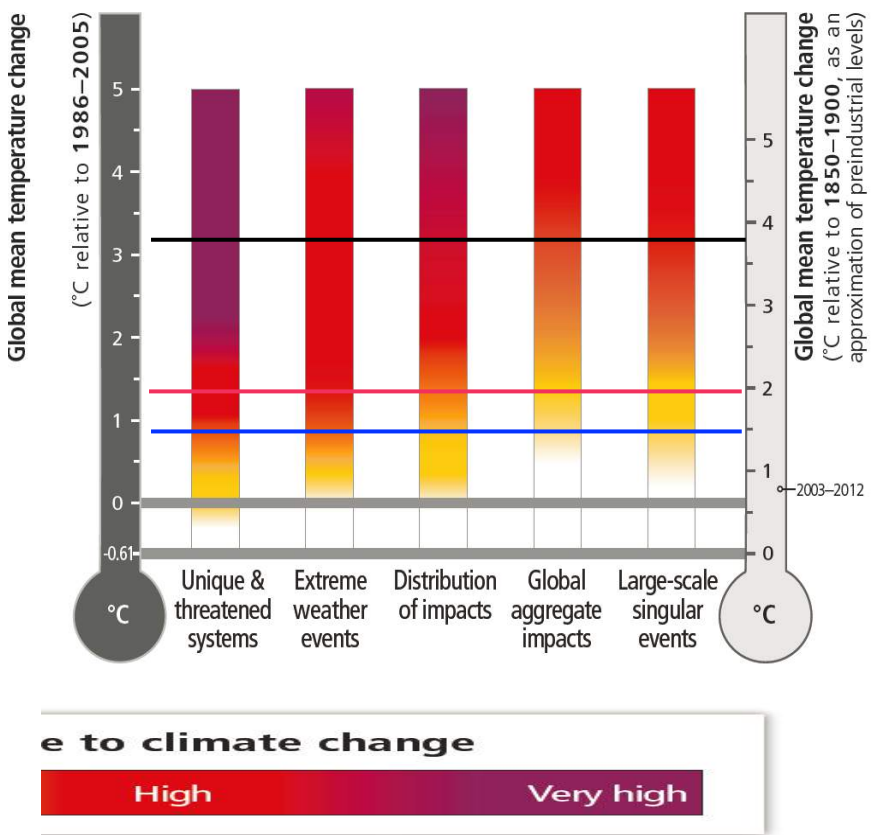


- **In recent decades, changes in climate have caused impacts on natural and human systems on all continents and across the oceans.**

- Evidence of climate-change impacts is **strongest and most comprehensive for natural systems.**

# IPCC WGII AR5: Reasons for Concern

IPCC AR5 identified 5 Reasons for Concern (RCFs) that should be assessed equally important




1. **Unique Systems:** Ecosystems and cultures, e.g. coral reef system. Already high at 1.5°C warming
2. **Extreme weather :** Tropical cyclones, droughts and floods. High impacts on crop yields and water availability. Risk assessed high to moderate at 1.5°C
3. **Distribution:** Unevenly distributed for countries at all levels of development. Tropical and low-lying countries most vulnerable
4. **Aggregate Impacts:** on global economy Moderate at 1.5/2°C. Aggregate nature insensitive to country differences
5. **Singular Events:** Irreversible tipping points.

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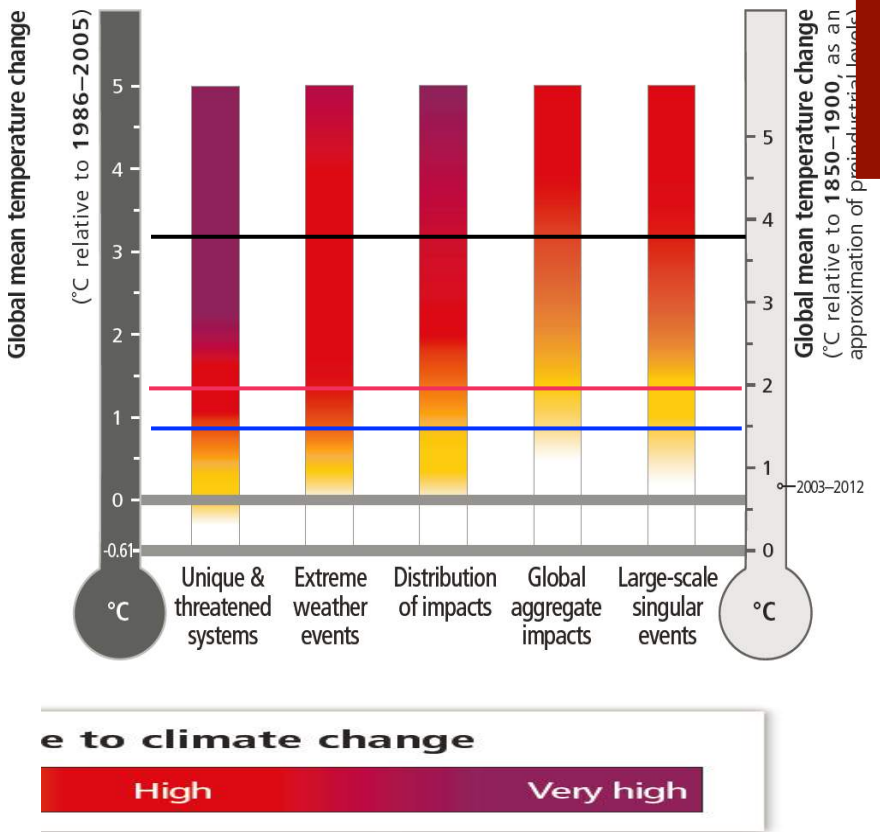


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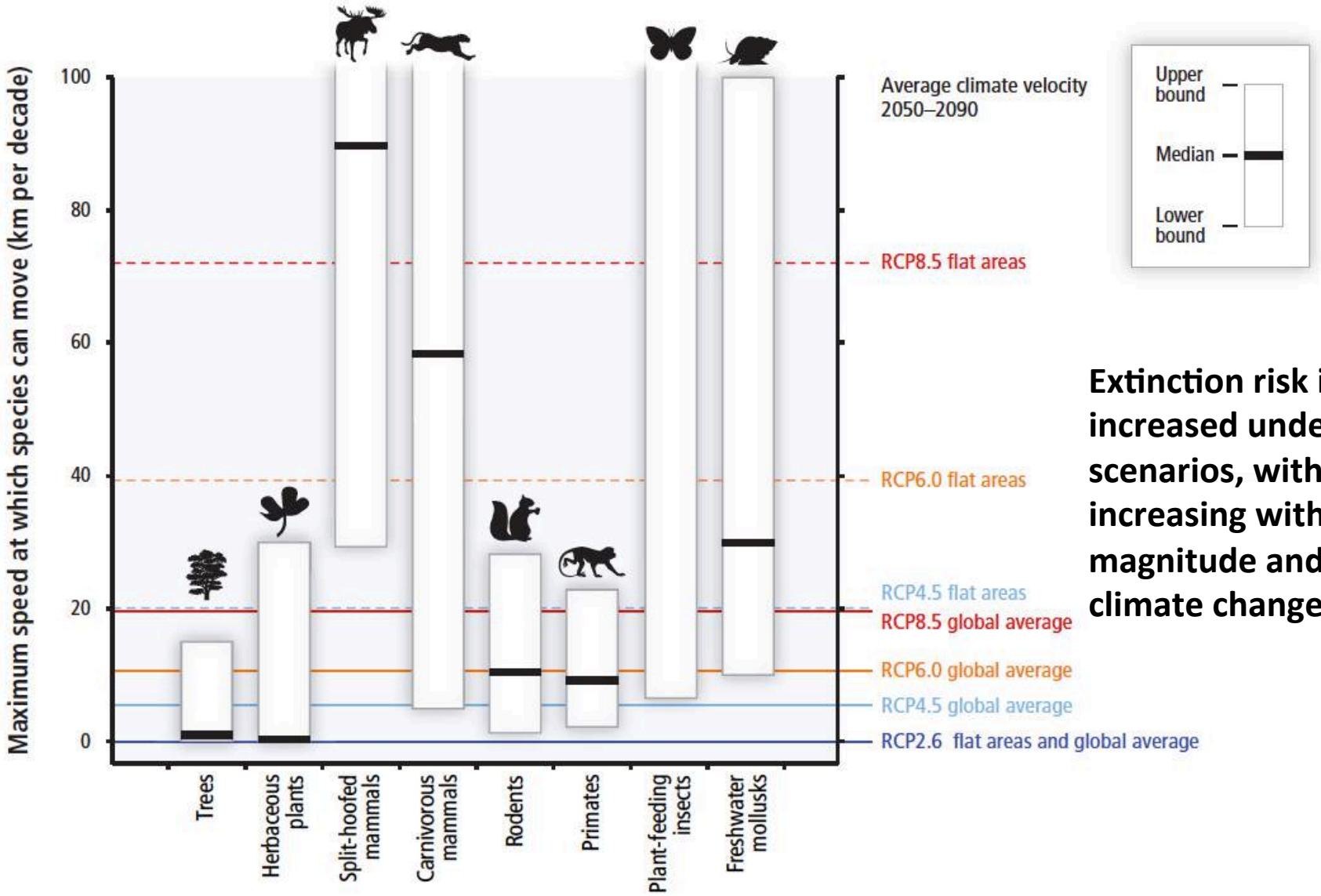
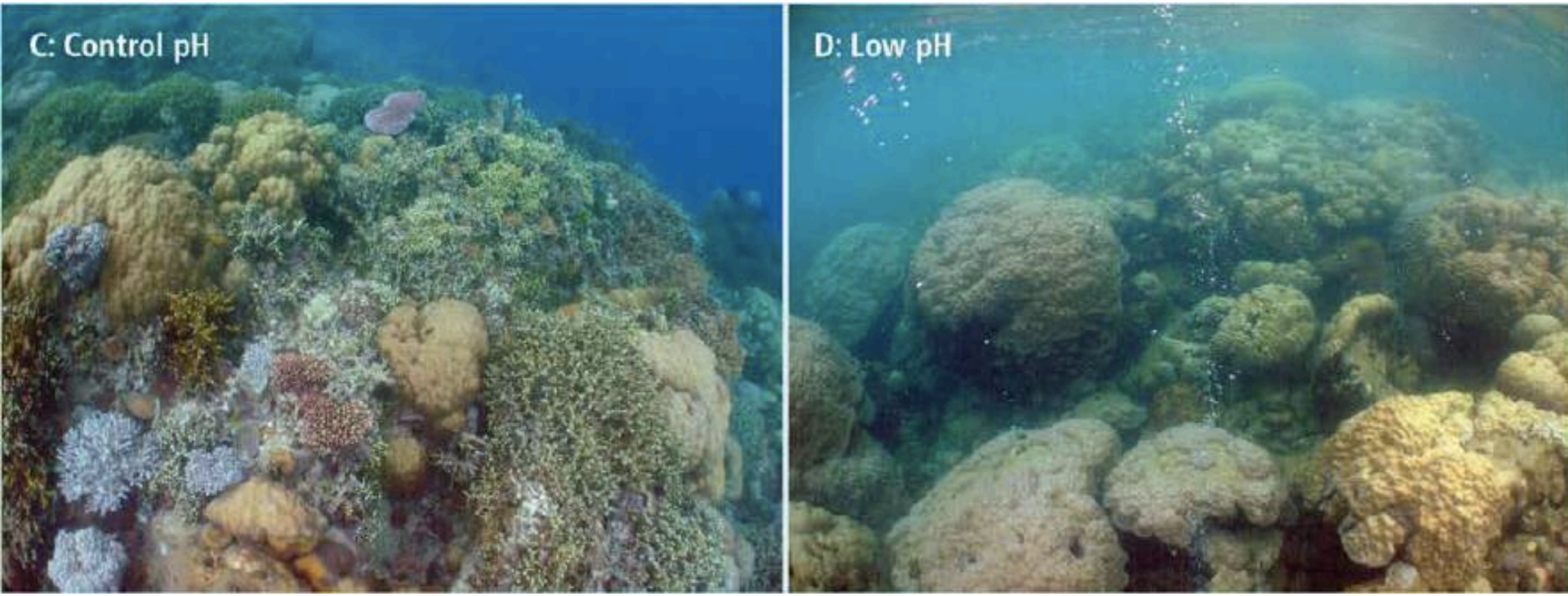
# IPCC WGII AR 5:

## Extinction




**Extinction risk is increased under all RCP scenarios, with risk increasing with both magnitude and rate of climate change.**

# Ocean acidification

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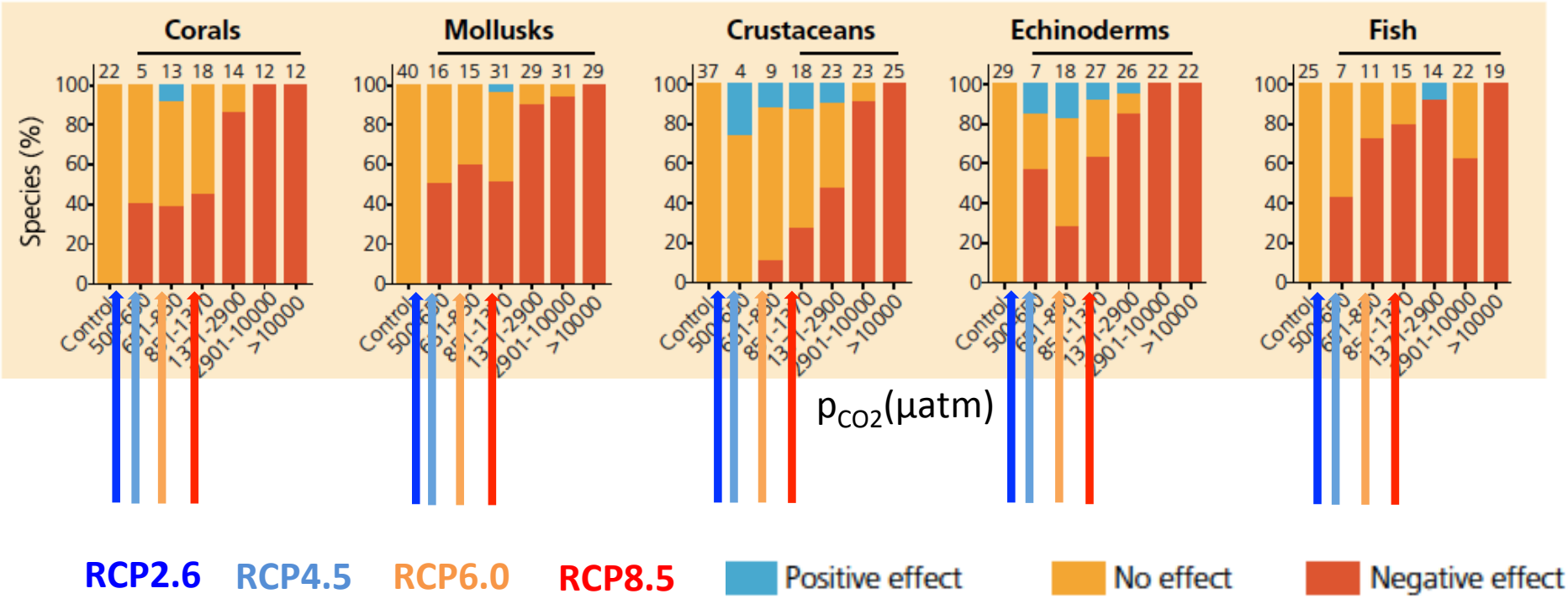
# Ocean acidification

**For medium- to high-emission scenarios (RCP4.5, 6.0, and 8.5), ocean acidification poses substantial risks to marine ecosystems, associated with impacts on the physiology, behavior, and population dynamics of individual species from phytoplankton to animals.**



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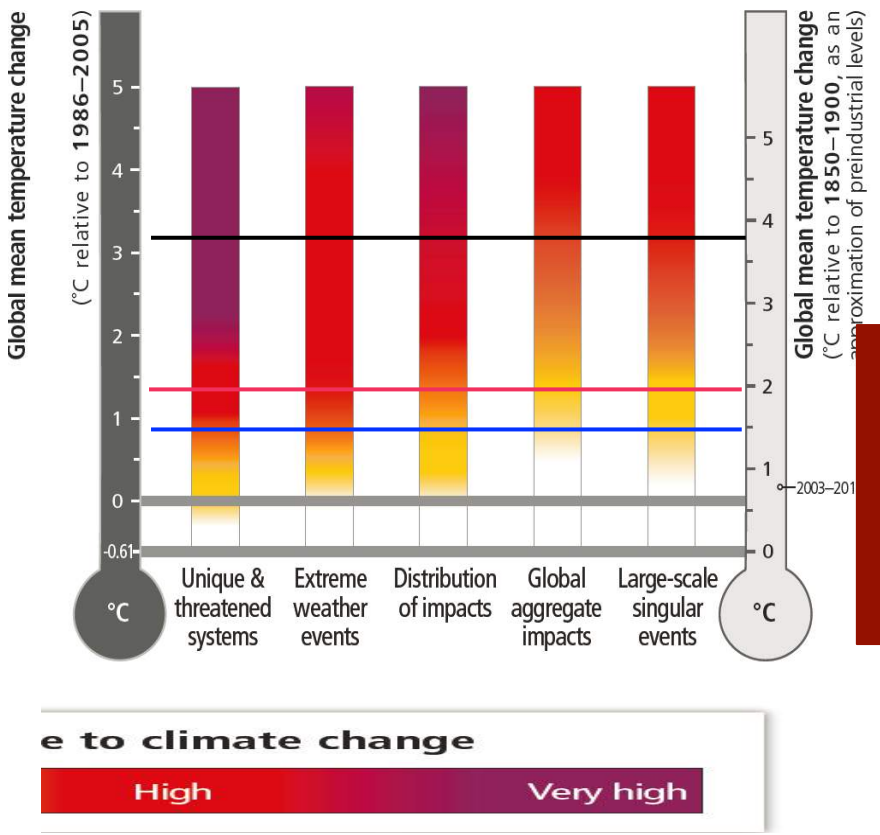


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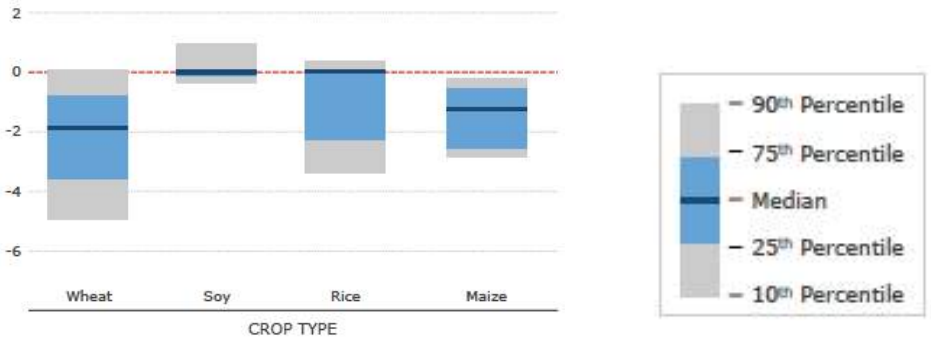
4. Moderate at 1.5/2°C. Aggregate nature insensitive to country differences
5. **Singular Events:** Irreversible tipping points.

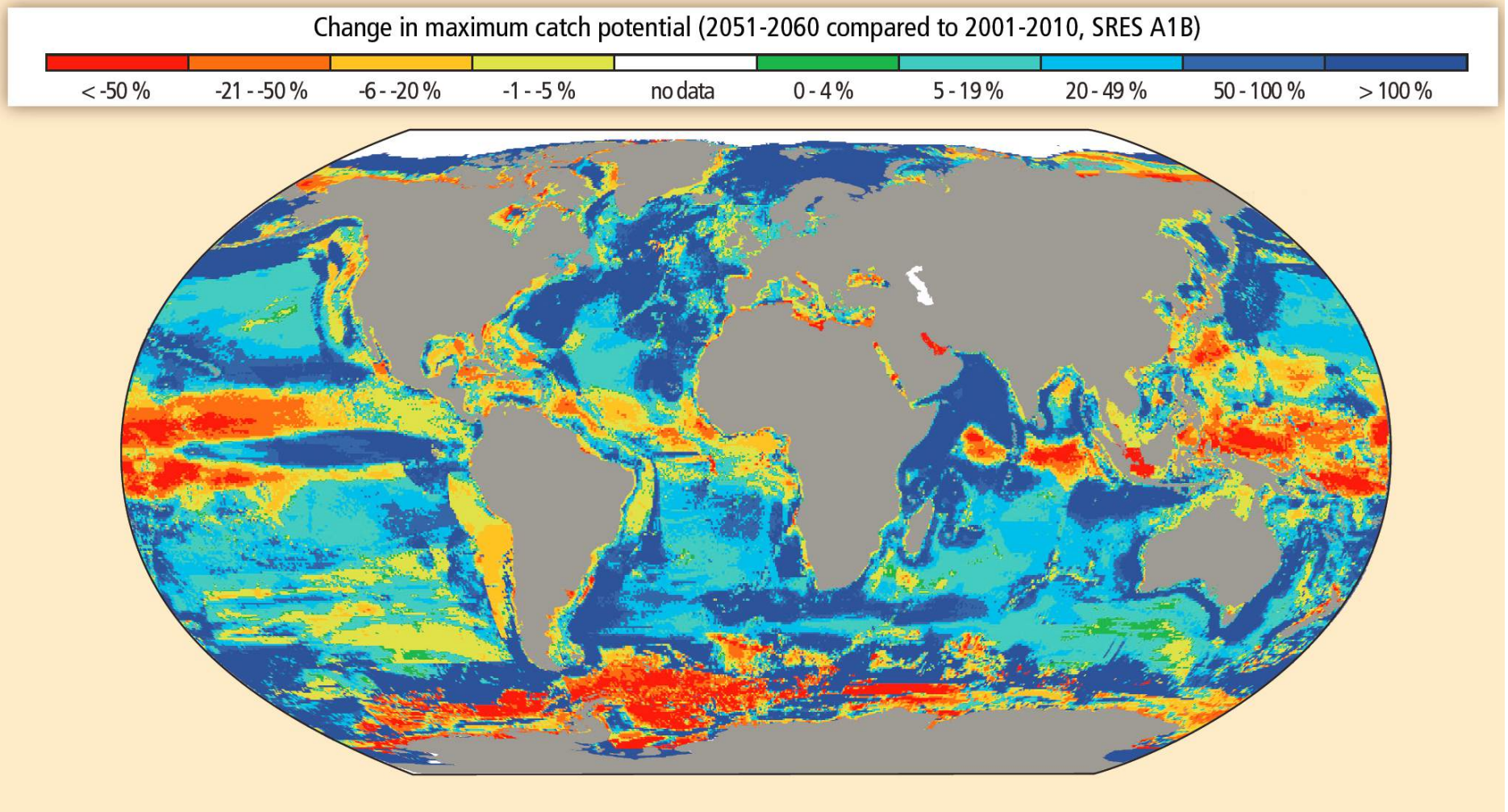
# WGII AR5: Observed Impacts – Food Security



- Significant observed impacts on crop yields over 1960-2013 period due to climate change
- Strongest impacts wheat and maize



# IPCC WGII AR 5:
# Marine fisheries catch potential

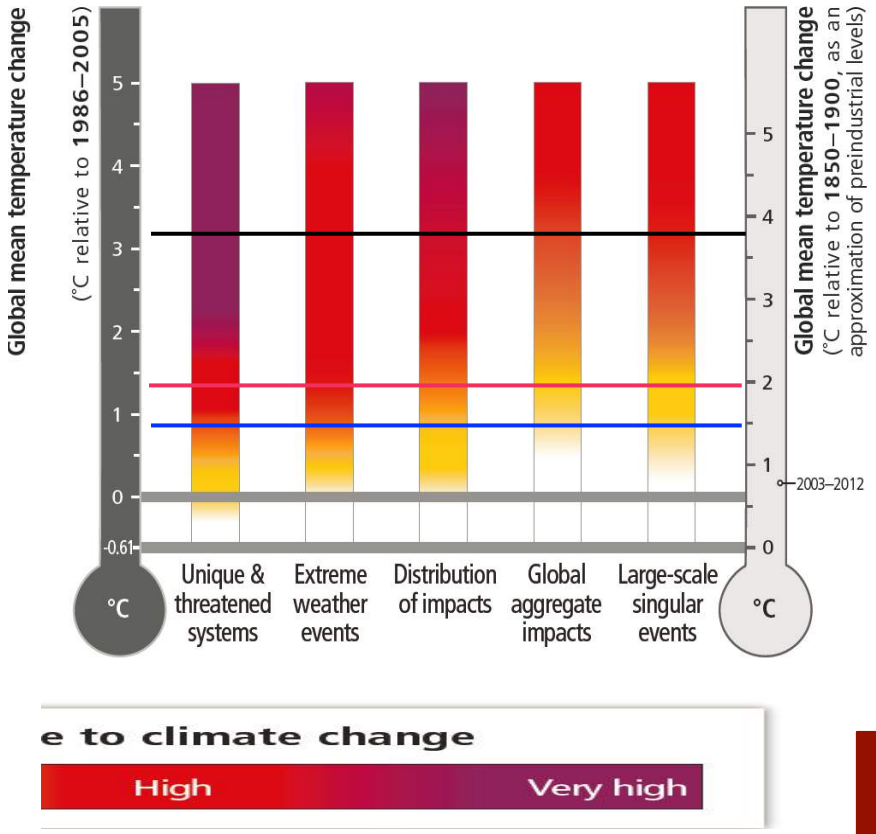



Global projected changes to catch potential under warming of approx. 2°C by 2050.

WGII Figure SPM.6 A

# IPCC WGII AR5: Reasons for Concern

- IPCC AR5 identified 5 Reasons for Concern (RCFs) that should be assessed equally important

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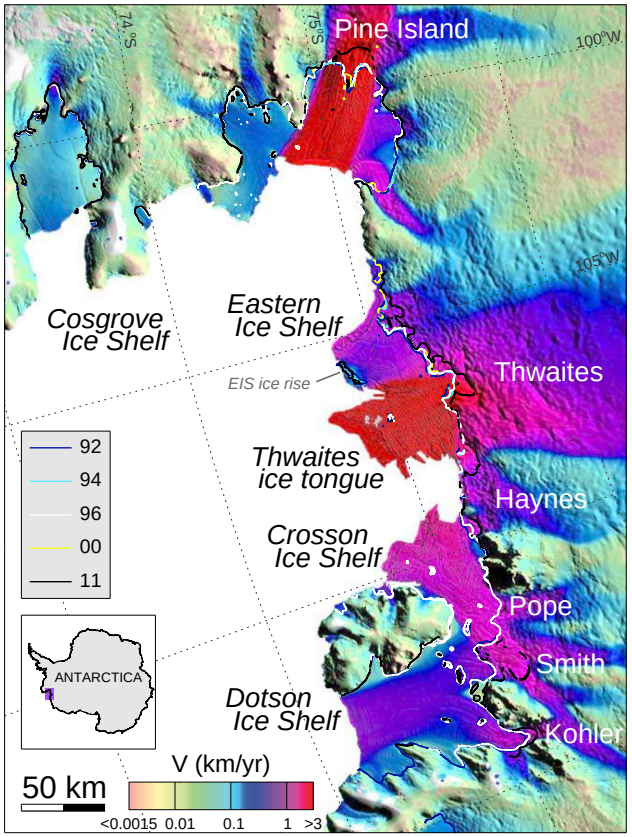
4. **Aggregate Impacts:** on global economy Moderate at 1.5°C. Aggregate nature [illegible]
5. **Singular Events:** Irreversible tipping points. Most relevant for sea-level rise

# Post IPCC Update: Risk for some large-scale singular events bigger than previously thought




Ice velocities in km/yr
Joughin et al. (2014)

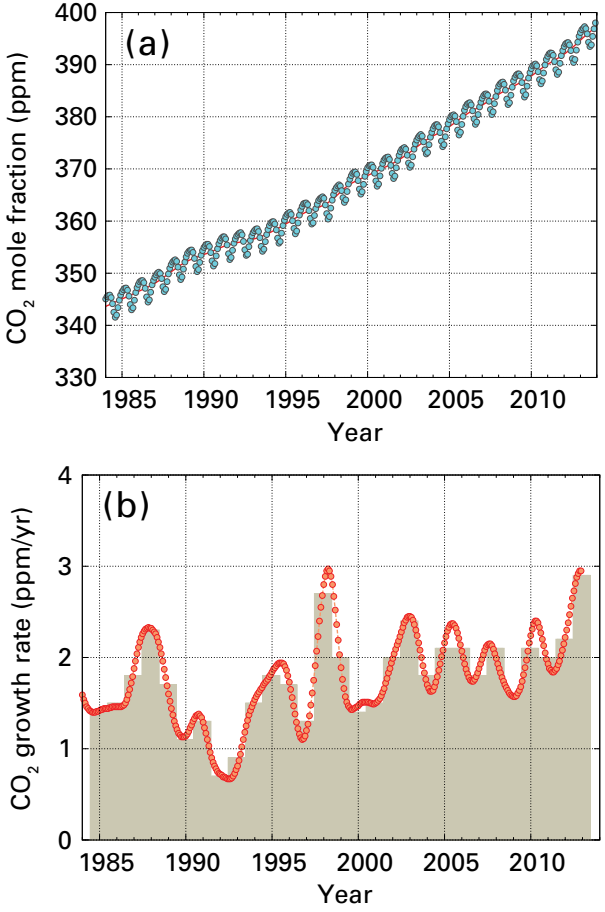
- Strong evidence from post-IPCC science that **several glacier systems in West Antartica are already "tipped"**
- This would lead to an **additional global sea-level rise of about 1m** with the potential of destabilizing the West Antarctic Ice sheet (about 4m global sea-level rise equivalent), but timescale much longer for lower levels of long-term warming
- New insights from **Greenland** indicate that also this ice sheet might be much more vulnerable to rapid ice loss than previously thought.

See Joughin et al. (2014), Rignot et al. (2014), Spence et al. (2014), Morlighem et al. (2014)

# Risks of climate change impacts can be reduced by limiting rate and magnitude of climate change.

- Reducing climate change can also **reduce the scale of adaptation** that might be required.
- Under **all** assessed scenarios for adaptation and mitigation, **some risk from adverse impacts remain**s (*very high confidence*).

# Is present action sufficient?




- GHG emissions rising faster than ever (WMO Sept 09 2014)
  - 0.74% increase in CO2 concentrations 2012-2013
  - 2013 CO2 concentrations **142% above preindustrial levels**

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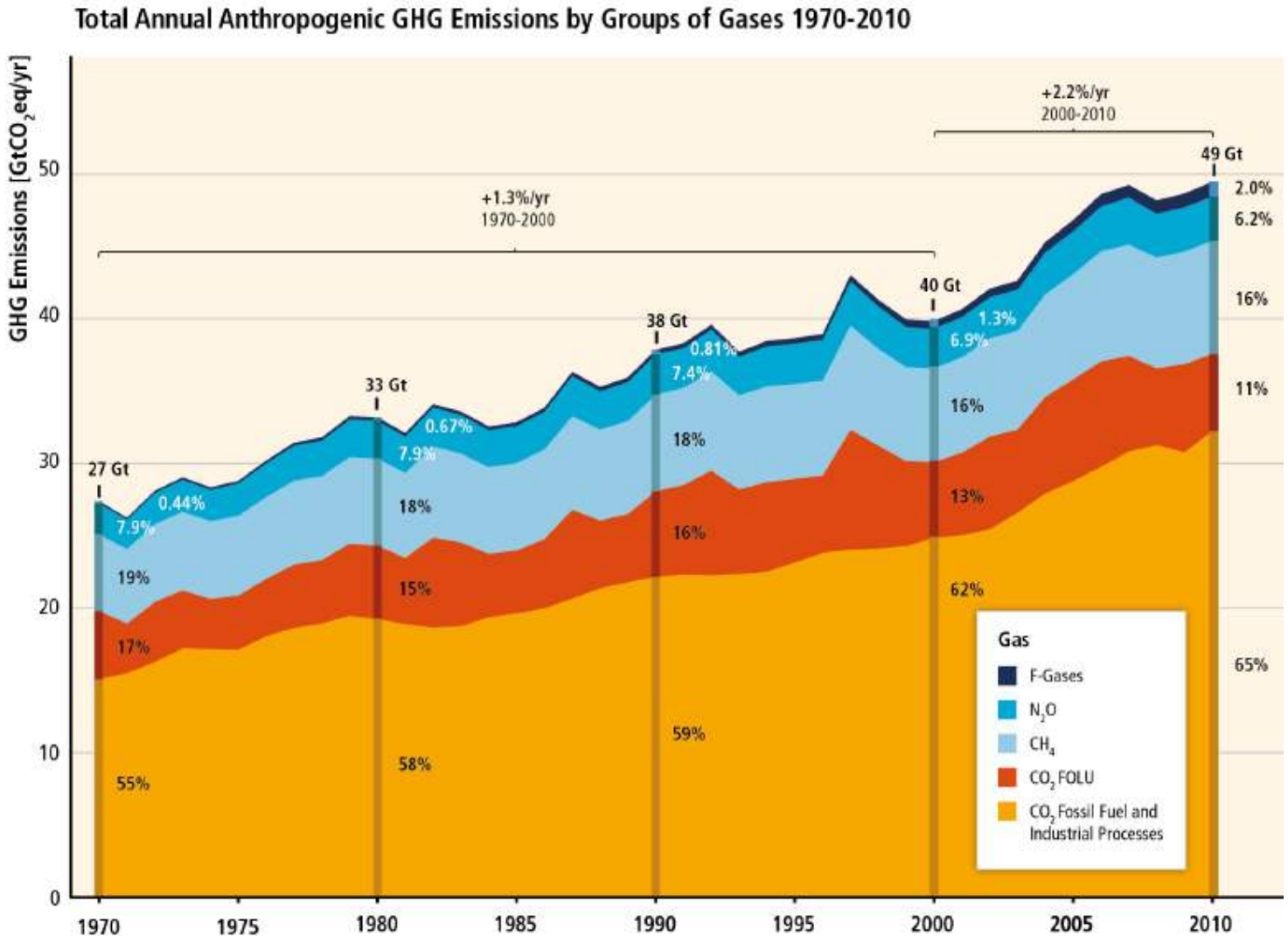
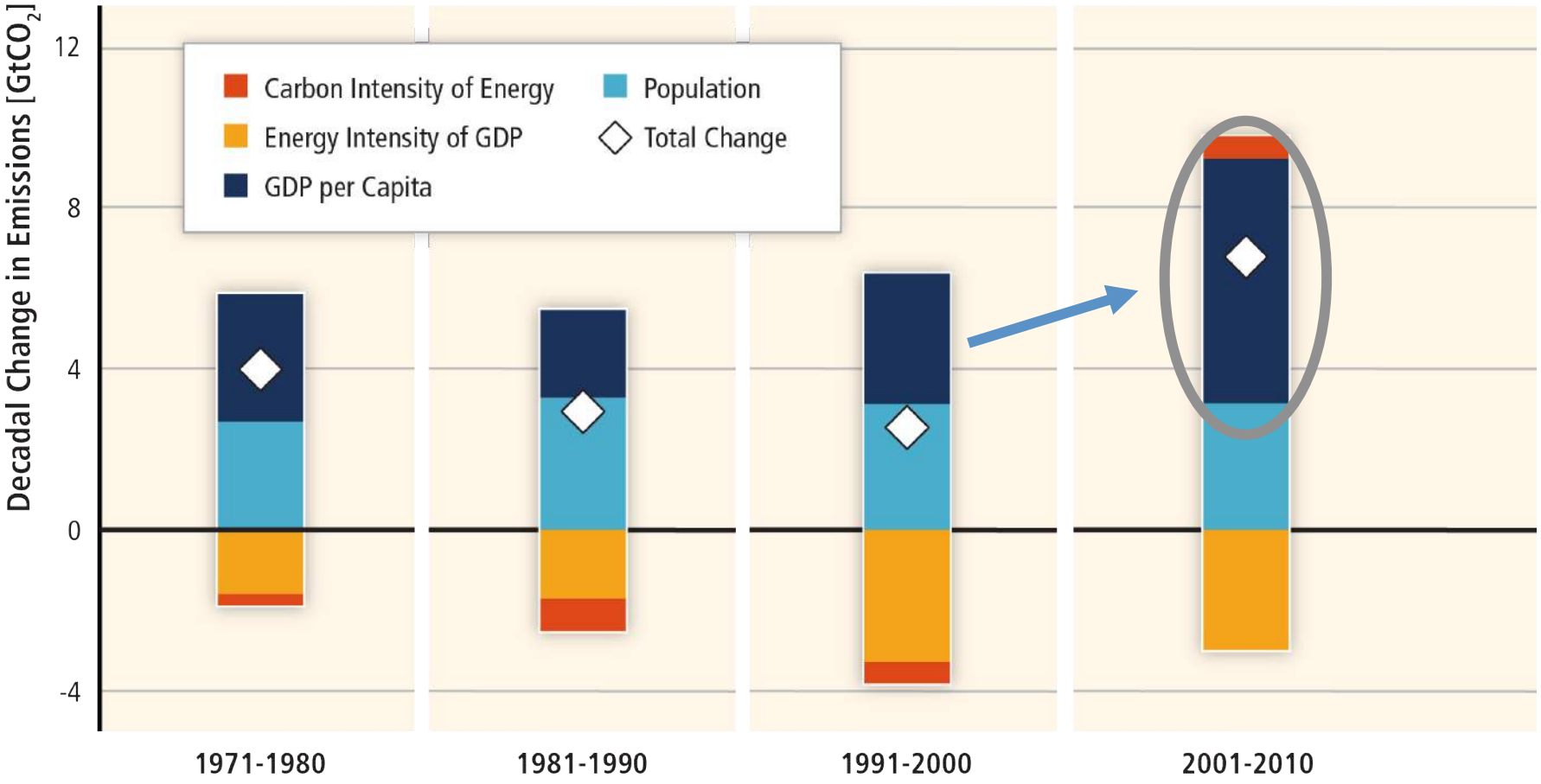
# IPCC WGIII AR5 Emission trends



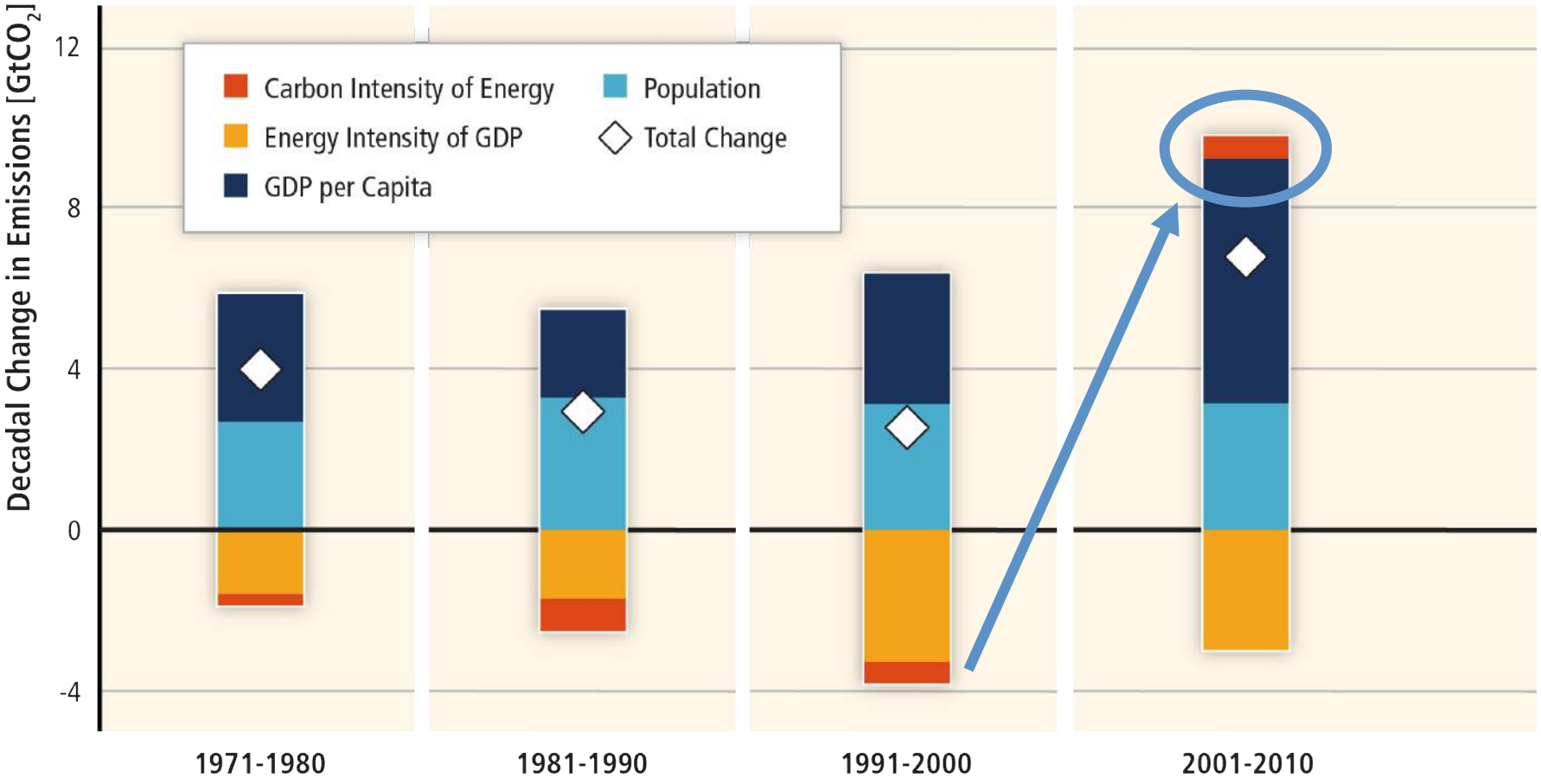

WGIII Figure SPM.1

# GHG emissions rise with growth in GDP and population; long-standing trend of decarbonisation of energy reversed.



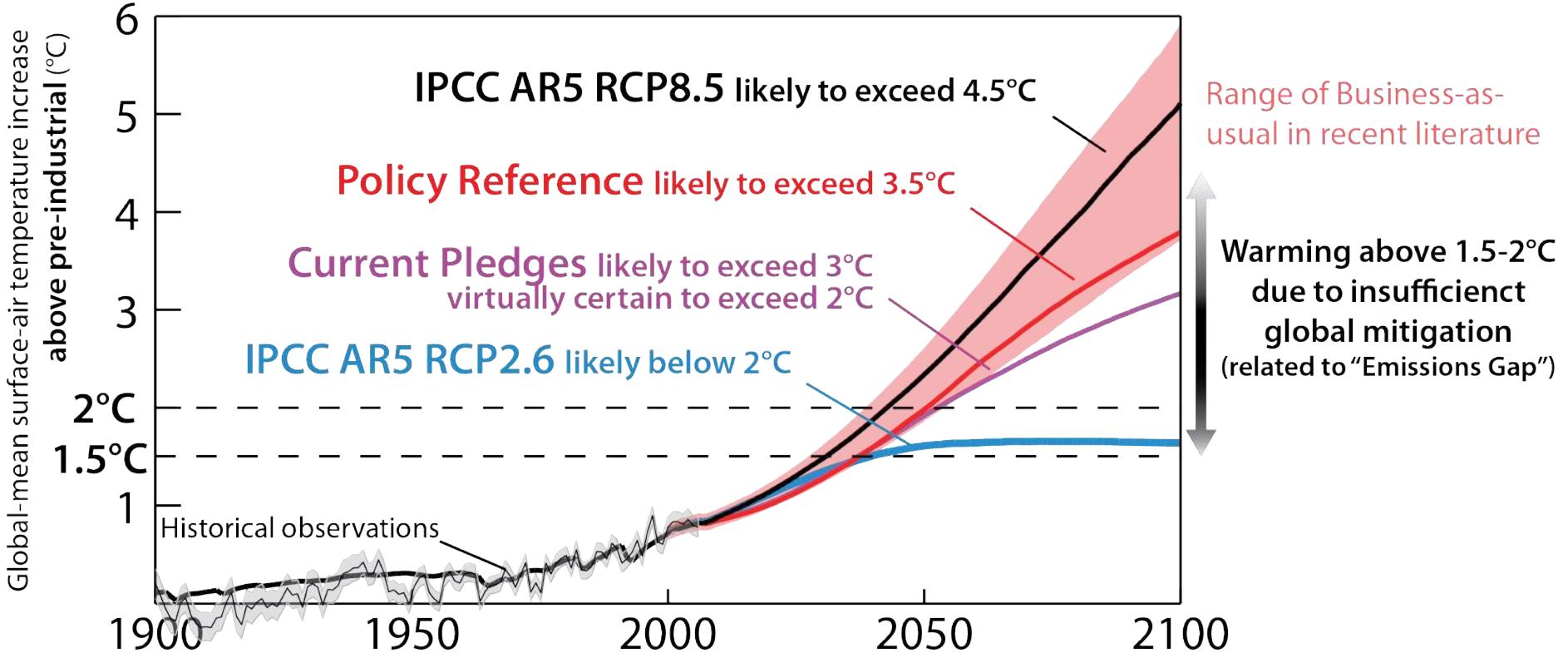

Based on Figure 1.7

# GHG emissions rise with growth in GDP and population; long-standing trend of decarbonisation of energy reversed.




Based on Figure 1.7

# Latest projections: global aggregation of countries' individual proposed efforts not sufficient

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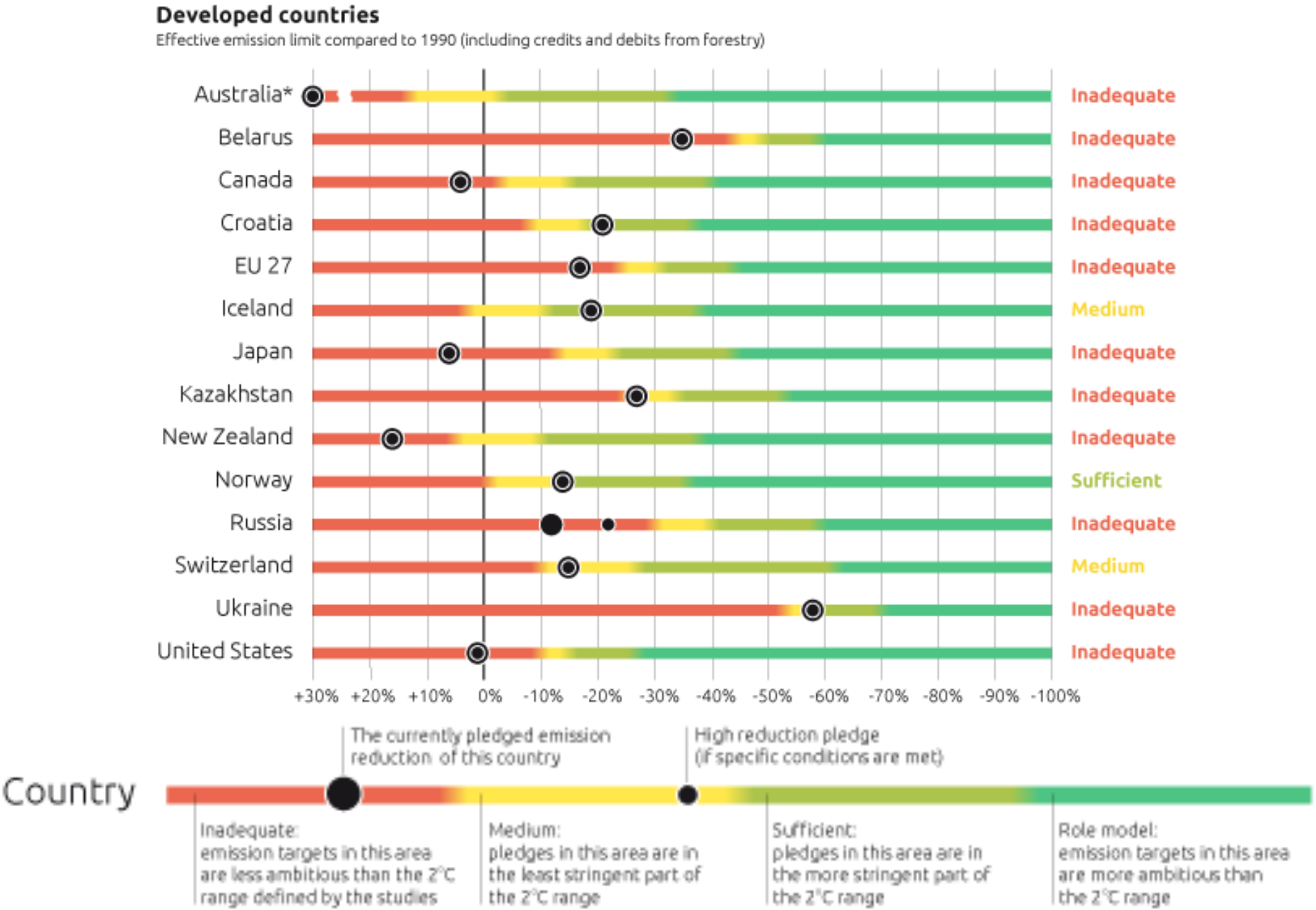
# But some countries propose more than others



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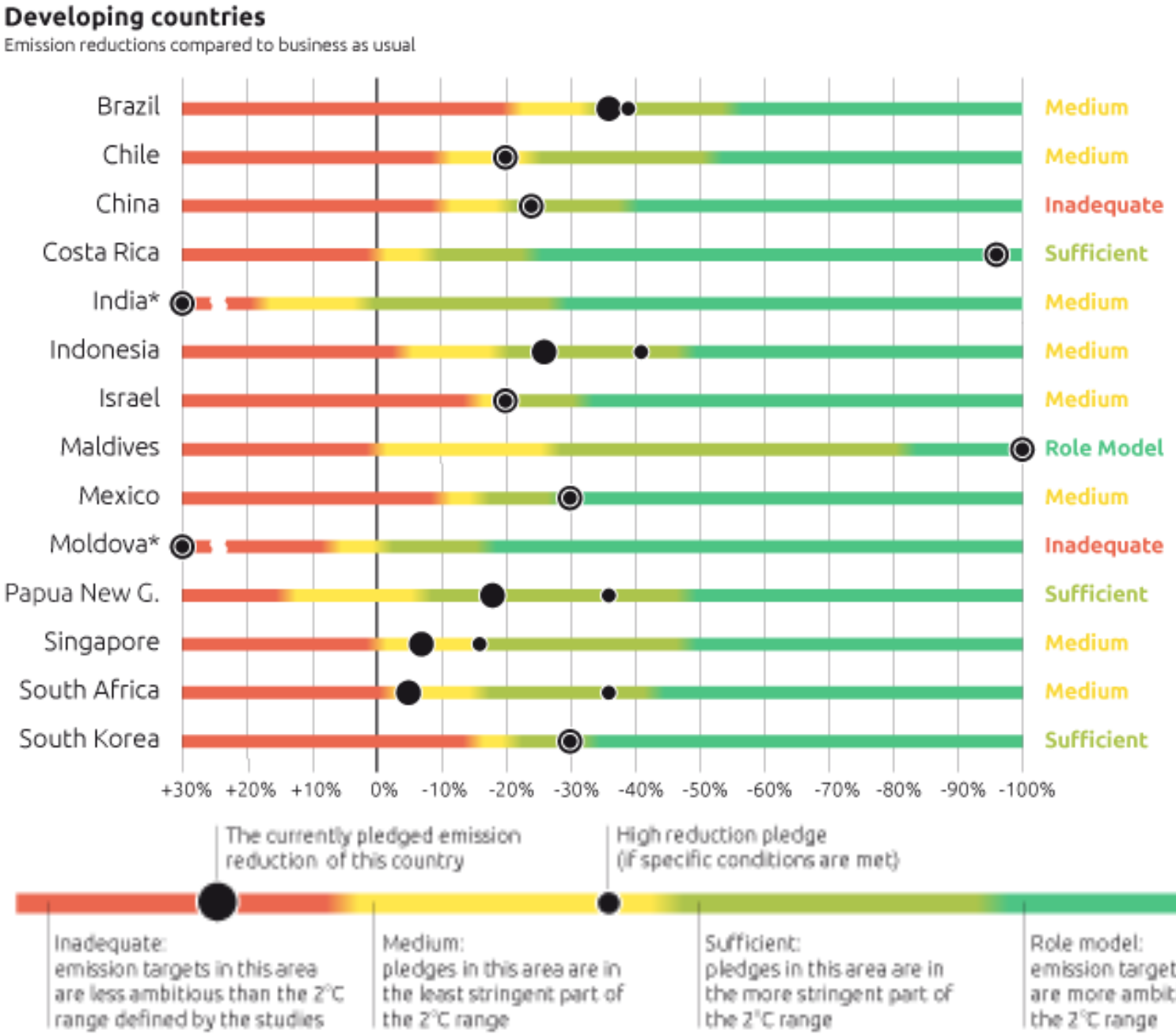


# IPCC WGIII AR5: Below 2°C is feasible

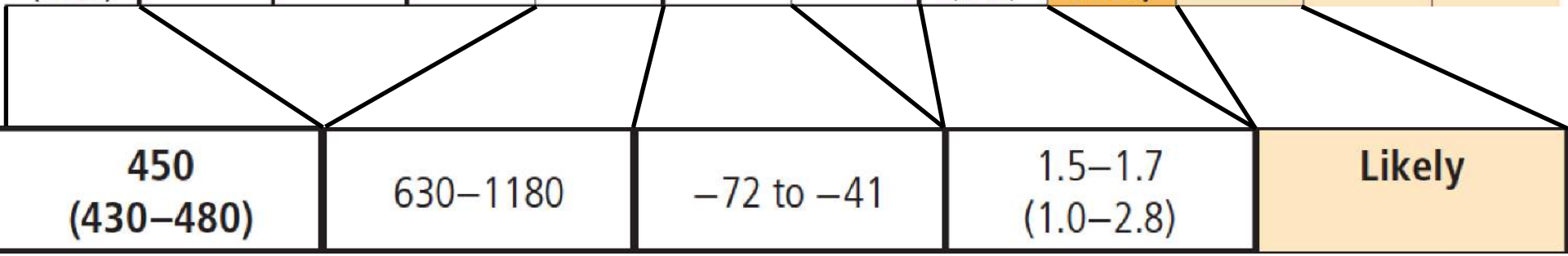
**Table SPM.1 |** Key characteristics of the scenarios collected and assessed for WGIII AR5. For all parameters, the 10th to 90th percentile of the scenarios is shown.[1,2] [Table 6.3]

| $CO_2$eq Concentrations in 2100 ($CO_2$eq) Category label (concentration range)[9] | Subcategories | Relative position of the RCPs[5] | Cumulative $CO_2$ emissions[3] ($GtCO_2$) | | Change in $CO_2$eq emissions compared to 2010 in (%)[4] | | Temperature change (relative to 1850–1900)[5,6] | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 2011–2050 | 2011–2100 | 2050 | 2100 | 2100 Temperature change (°C)[7] | Likelihood of staying below temperature level over the 21st century[8] | | | |
| | | | | | | | | 1.5 °C | 2.0 °C | 3.0 °C | 4.0 °C |
| < 430 | Only a limited number of individual model studies have explored levels below 430 ppm $CO_2$eq | | | | | | | | | | |
| 450 (430–480) | Total range[1,10] | RCP2.6 | 550–1300 | 630–1180 | −72 to −41 | −118 to −78 | 1.5–1.7 (1.0–2.8) | More unlikely than likely | Likely | Likely | Likely |
| 500 (480–530) | No overshoot of 530 ppm $CO_2$eq | | 860–1180 | 960–1430 | −57 to −42 | −107 to −73 | 1.7–1.9 (1.2–2.9) | Unlikely | More likely than not | | |
| | Overshoot of 530 ppm $CO_2$eq | | 1130–1530 | 990–1550 | −55 to −25 | −114 to −90 | 1.8–2.0 (1.2–3.3) | | About as likely as not | | |
| 550 (530–580) | No overshoot of 580 ppm $CO_2$eq | | 1070–1460 | 1240–2240 | −47 to −19 | −81 to −59 | 2.0–2.2 (1.4–3.6) | | More unlikely than likely[12] | | |
| | Overshoot of 580 ppm $CO_2$eq | | 1420–1750 | 1170–2100 | −16 to 7 | −183 to −86 | 2.1–2.3 (1.4–3.6) | | | | |
| (580–650) | Total range | RCP4.5 | 1260–1640 | 1870–2440 | −38 to 24 | −134 to −50 | 2.3–2.6 (1.5–4.2) | | | | |
| (650–720) | Total range | | 1310–1750 | 2570–3340 | −11 to 17 | −54 to −21 | 2.6–2.9 (1.8–4.5) | | Unlikely | More likely than not | |
| (720–1000) | Total range | RCP6.0 | 1570–1940 | 3620–4990 | 18 to 54 | −7 to 72 | 3.1–3.7 (2.1–5.8) | Unlikely[11] | | More unlikely than likely | |
| >1000 | Total range | RCP8.5 | 1840–2310 | 5350–7010 | 52 to 95 | 74 to 178 | 4.1–4.8 (2.8–7.8) | | Unlikely[26] | Unlikely | More unlikely than likely |

# IPCC WGIII AR5: Below 2°C is feasible

**Table SPM.1 |** Key characteristics of the scenarios collected and assessed for WGIII AR5. For all parameters, the 10th to 90th percentile of the scenarios is shown.[1,2] [Table 6.3]

| $CO_2$eq Concentrations in 2100 ($CO_2$eq) Category label (concentration range)[9] | Subcategories | Relative position of the RCPs[5] | Cumulative $CO_2$ emissions[3] ($GtCO_2$) | | Change in $CO_2$eq emissions compared to 2010 in (%)[4] | | Temperature change (relative to 1850–1900)[5,6] | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 2011–2050 | 2011–2100 | 2050 | 2100 | 2100 Temperature change (°C)[7] | Likelihood of staying below temperature level over the 21st century[8] | | | |
| | | | | | | | | 1.5 °C | 2.0 °C | 3.0 °C | 4.0 °C |
| < 430 | Only a limited number of individual model studies have explored levels below 430 ppm $CO_2$eq | | | | | | | | | | |
| 450 (430–480) | Total range[1,10] | RCP2.6 | 550–1300 | 630–1180 | −72 to −41 | −118 to −78 | 1.5–1.7 (1.0–2.8) | More unlikely than likely | Likely | Likely | |




WGI: Based on many models, but only one scenario, estimated about 1000 GtCO2 remains after 2011 for *likely* below 2°C

WGIII: 630-1180 GtCO2 for 2011-2100

# IPCC WGIII AR5: Below 2°C is feasible

**It is technically and economically feasible to keep warming below 2°C, with a likely probability.**

- Requires halving global emissions compared to 2010 levels by mid-century
- Zero or negative emissions by 2100

**If mitigation is considerably delayed keeping warming below 2°C becomes economically unfeasible**

- Key technologies, such as bioenergy, CCS and their combination (BECCS) are needed in many models

# IPCC WGIII AR5: 2°C mitigation costs

- **Average global macro-economic costs over the century are modest compared to expected economic growth**

- Under a cost-effective approach, macro-economic costs equal an average annual reduction of consumption of about **0.04-0.14 % per year**

- Baseline increase of consumption over 21st century projected 1.6-3% per year

# Renewable energy: good news for decarbonisation

- In 2012, **renewables made up just over half of total net additions** to electric generating capacity from all sources in 2012.
- **The effect on global GHG emissions** from increased renewables **is still leveled out** by increased use of coal and rising energy consumption.
- But could be paving the way to a full decarbonisation of the energy sector

# Conclusions

- WGI
  - Extremely likely that human influence has been the dominant cause of the observed warming since the mid-20th century
  - The evidence for human influence has grown since AR4
  - For warming to be limited, limited cumulative CO2 emissions are allowed (1000 GtCO2 from 2011 onwards for *likely* below 2°C)
  - Limiting climate change will require substantial and sustained reductions of greenhouse gas emissions
- WGII:
  - In recent decades, changes in climate have caused impacts on natural and human systems on all continents and across the oceans
  - Reducing climate change can also reduce the scale of adaptation that might be required.
  - Under all assessed scenarios for adaptation and mitigation, some risk from adverse impacts remains
- WGIII:
  - Remaining budget 630-1180 GtCO2 for 2011-2100
  - It is technically and economically feasible to keep warming below 2°C, with a likely probability
  - If mitigation is considerably delayed keeping warming below 2°C becomes economically unfeasible

**IPCC AR5**
**Synthesis report**
**due for completion in**
**Copenhagen, Denmark**
**27 - 31 Oct 2014**

**Thank you!**

CLIMATE ANALYTICS