HONR 229L: Climate Change: Science, Economics, and Governance

Discussion #10: Climate Models: Perspective of a Social Scientist

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Class Web Site: http://www.atmos.umd.edu/~rjs/class/honr229L

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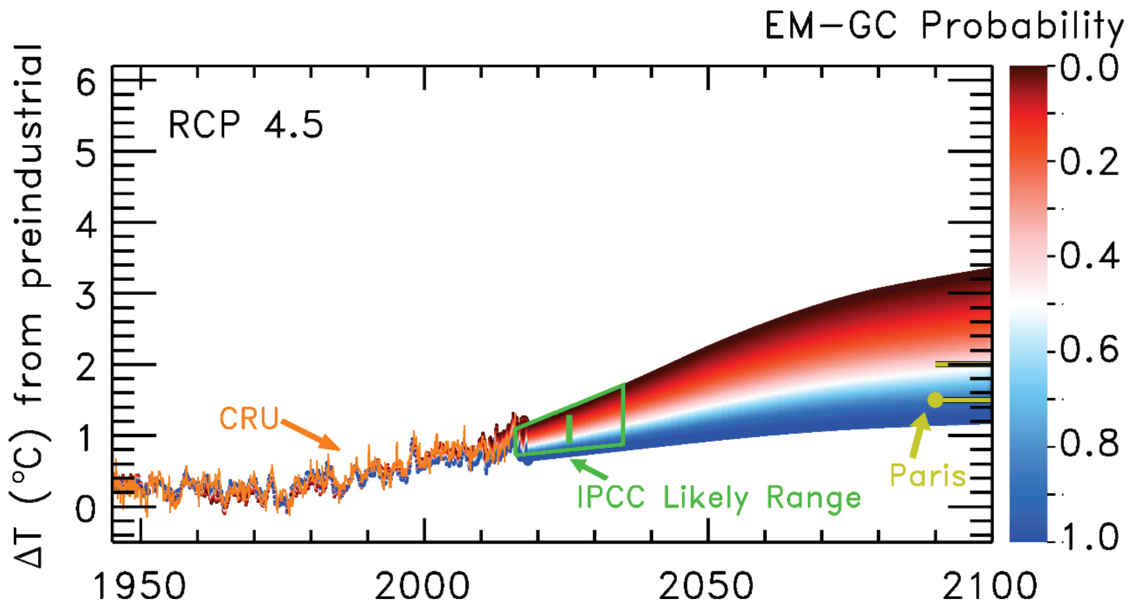

3 October 2019

HONR 229L: Climate Change: Science, Economics, and Governance

AT 9, Q1. The top of page 31 of the reading states that "the oceans play a large part in determining the existing climate on Earth ... they act on climate in four important ways". Summarize, using a phrase or single sentence, the essential aspect of each of the four important roles of the world's oceans, with regard to Earth's climate.

The close interaction between the ocean and the atmosphere. This happens in a coupled system such that for example, the *evaporation of ocean water is one of the greatest contributor to atmospheric vapor*, which is one of the largest atmospheric heating source.

Secondly the *ocean* has a high heat capacity, which means that it *warms much slower than the atmosphere*. This also means that the atmosphere then has to have a greater control over the rate of atmospheric temperature change, and ultimately, climate change.

Third, the ocean redistributes heat throughout the overall climate system. The issue though is that while the amount of heat transported form the equator to the atmosphere is the same as to the equator and polar regions, regional distribution is different and even the smallest changes in regional heat transport by the ocean can have drastic effects on climate change.

Finally, deep-ocean circulation affects the climate. *Cold, salty water from the North Atlantic and Antarctica sinks, and forms thermohaline circulation that runs all over the world*. Atmospheric warming melts sea ice, which makes this North Atlantic water less salty and less dense, which could interfere with this thermohaline circulation. The thermohaline circulation affects shallower currents like the Gulf Stream and sea ice formation in polar regions, and a weakened thermohaline circulation would also interfere with both sea ice and other ocean currents.

Interactions between the atmosphere and the world's oceans turn out to be quite important for understanding variations in global temperature, as well as regional variations in temperature and other climate signals, on a variety of time scales.

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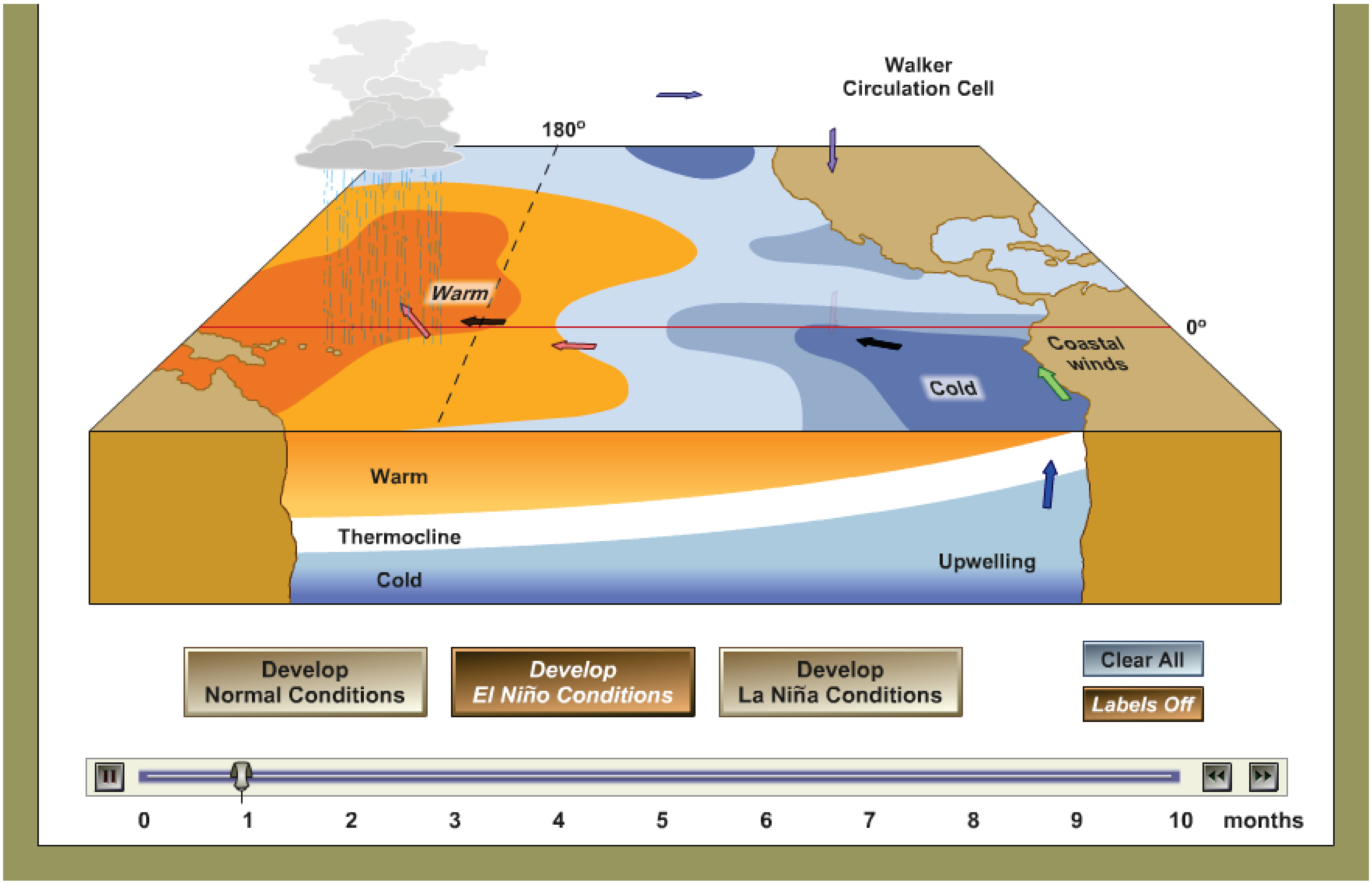
AT 9, Q2. In a few sentences, explain:

a) what is meant by an El Niño event (i.e., physically what happens in the ocean & where in the ocean does this happen)?

b) what are the weather related consequences associated with an El Niño event ?

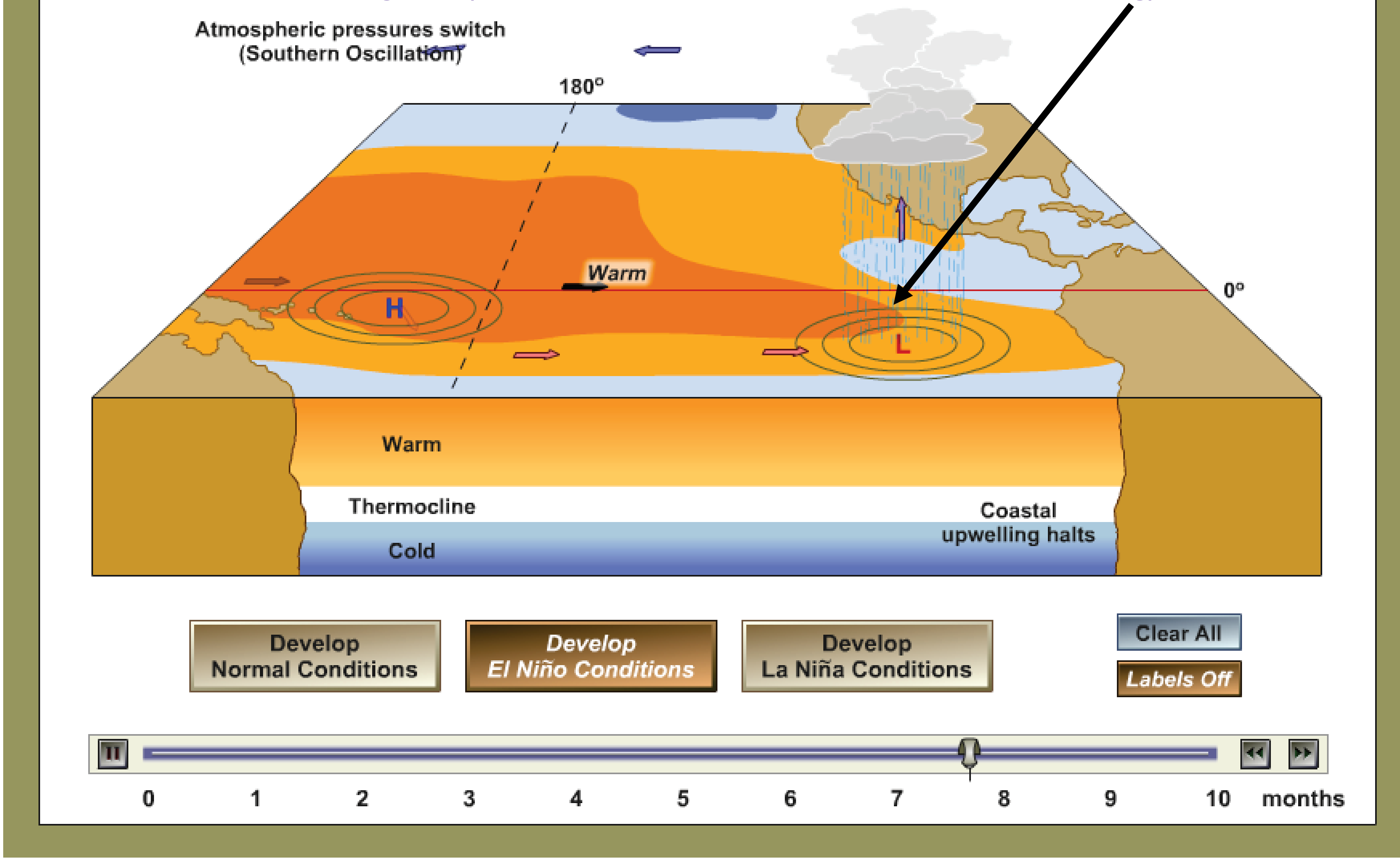
La Niña conditions



http://esminfo.prenhall.com/science/geoanimations/animations/26_NinoNina.html

El Niño conditions

Amazingly when an El Niño happens, globally averaged surface temperature can rise by as much as a few 10ths of a degree C (i.e., several decades' worth of human induced warming).



http://esminfo.prenhall.com/science/geoanimations/animations/26_NinoNina.html

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AT 9, Q3.

a) if the abundance of CO_2 were to double and no feedbacks were to occur, how would global surface temperature respond?

b) if the abundance of CO_2 were to double and feedbacks were to occur, according to our present understanding of how they actually operate, how would global surface temperature respond?

Table 5.1 Estimates of global average temperature changes under different assumptions about changes in greenhouse gases and clouds

Greenhouse gases	Clouds	Change (in °C) from current average global surface temperature
As now	As now	0
None	As now	−32
None	None	−21
As now	None	4
As now	As now but +3% high cloud	0.3
As now	As now but +3% low cloud	−1.0
Doubled CO_2 concentration otherwise as now	As now (no additional cloud feedback)	1.2
Doubled CO_2 concentration + best estimate of feedbacks	Cloud feedback included	3

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AT 9, Q3.

a) if the abundance of CO_2 were to double and no feedbacks were to occur, how would global surface temperature respond?

b) if the abundance of CO_2 were to double and feedbacks were to occur, according to our present understanding of how they actually operate, how would global surface temperature respond?

If the abundance of CO_2 were to double and no feedbacks were to occur, the global surface temperature would still rise by 1.2 degrees Celsius. However, if the abundance of CO_2 were to double and feedbacks were to occur the global surface temperature would rise by 3.0 degrees Celsius.

I think understanding feedbacks are very important when it comes to making accurate projections of climate change because feedbacks have naturally occurring effects on the system. *The effects of these feedbacks cannot be stopped because they naturally occur but can be amplified by humans*. An example of this would be the water vapor feedback system. Water will continue to evaporate and continue to have a greenhouse effect on the atmosphere … the increase in earth's temperature due to rising anthropogenic greenhouse gases causes more water to evaporate which amplifies the response.

The temperature will respond by increasing more drastically with the feedbacks. With the already higher temperatures caused by the doubling of atmospheric carbon dioxide, more ocean water would evaporate, increasing the presence of atmospheric water vapor, causing the positive feedback which further increases temperatures and water vapor in the atmosphere. In addition, some of that water vapor would form clouds; these clouds would act as a blanket and prevent more heat from being reflected into space, causing additional heating. And, while the oceans' circulation of heat may stabilize the temperature extremes to a degree, they can only carry so much heat before becoming too saturated to hold any more.

The factor of 3°C / 1.2° C or approximately 2.5 enhancement in direct warming due to rising CO_2 due to feedbacks is a vitally important detail to "get right" when attempting to forecast future warming.

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AT 9, Q4.

Q4. Describe, in a few sentences, how climate models are validated and note whether or not you are convinced, based on the material in the reading, that climate models have been properly validated.

Climate models can be validated by three different methods of testing, which have improved climate models. The first test is that the *climate model can be run for a certain number of years and then compared to current climate*. The second test is *comparing models against simulations of past climates*, when key variables were substantially different, such as the angle of the tilt of the Earth. The last test is using climate models to predict the effect of large perturbations on the climate. With all of these tests being performed on modern climate models, I am confident in their ability to predict future climate. The scientists who work on these models are constantly testing them for accuracy and have "caught" many of their mistakes so far, such as not including the importance of oceans in the previous models. So I feel confident that the current models are running at very accurately.

Research conducted by our group suggests the Houghton chapter takes a more optimistic view regarding model accuracy than is actually warranted. As I'll show during the "Last Word", our research suggests we have a bit more time to take action to alleviate the worst effects of global warming than indicated by the complex climate models.

However, very strong actions to reduce the emissions of GHGs are still needed, and soon!

Climate Models: Perspective of a Social Scientist

Rhea Lieberman

3 October 2019

AT Question 1: What are the two findings from the 1990 IPCC report that Nate Silver describes as being absolutely certain?

- The greenhouse effect exists and keeps the Earth warmer than it otherwise would be
  - Without it, Earth would be 0ºF (-18ºC)
  - Actual mean temperature: ~59ºF (15ºC)
- The presence of greenhouse gases in the atmosphere is increasing as a result of human activity
  - This will cause additional warming of Earth's surface
  - Water vapor will increase in response to global warming and further enhance it

Chart from Tuesday's Reading

Table 5.1 Estimates of global average temperature changes under different assumptions about changes in greenhouse gases and clouds

Greenhouse gases	Clouds	Change (in °C) from current average global surface temperature of 15°C
	As now	0
None	As now	−32
None	None	−21
As now	None	4
As now	As now but +3% high cloud	0.3
As now	As now but +3% low cloud	−1.0
Doubled CO_2 concentration otherwise as now	As now (no additional cloud feedback)	1.2
Doubled CO_2 concentration + best estimate of feedbacks	Cloud feedback included	3

AT Question 2: What are the "three prongs" of the critique of IPCC forecasts in the Armstrong and Green paper?

1. Agreement among forecasters is not related to accuracy
2. More complex models lead to less accurate predictions
3. Models do not capture the uncertainty of the global warming problem

Agreement among forecasters is not related to accuracy

- Consensus vs unanimity
  - Deliberative process vs complete agreement
  - Pros: thorough analysis and deliberation
  - Cons: subject to groupthink and bias
- Important to have diversity of models
  - Different models have different bugs and assumptions

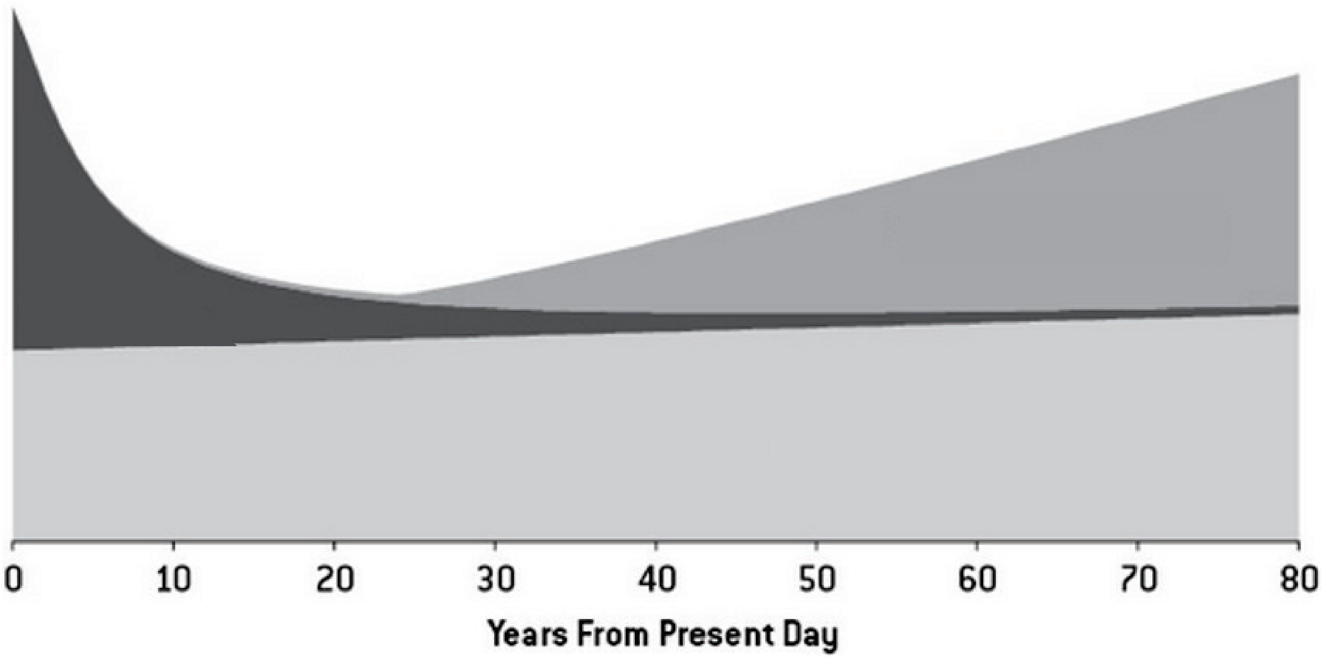
More complex models lead to less accurate predictions

- Derived from disciplines like economics where few physical models are available
  - In these fields, data is poor and theory is weak
  - In climate science, data is noisy but theory is strong
- Too much complexity can be just as bad as too little complexity

Models do not capture the uncertainty of the global warming problem

- Climate scientists recognize the limitations of climate forecasting
- However they do not always properly estimate this uncertainty

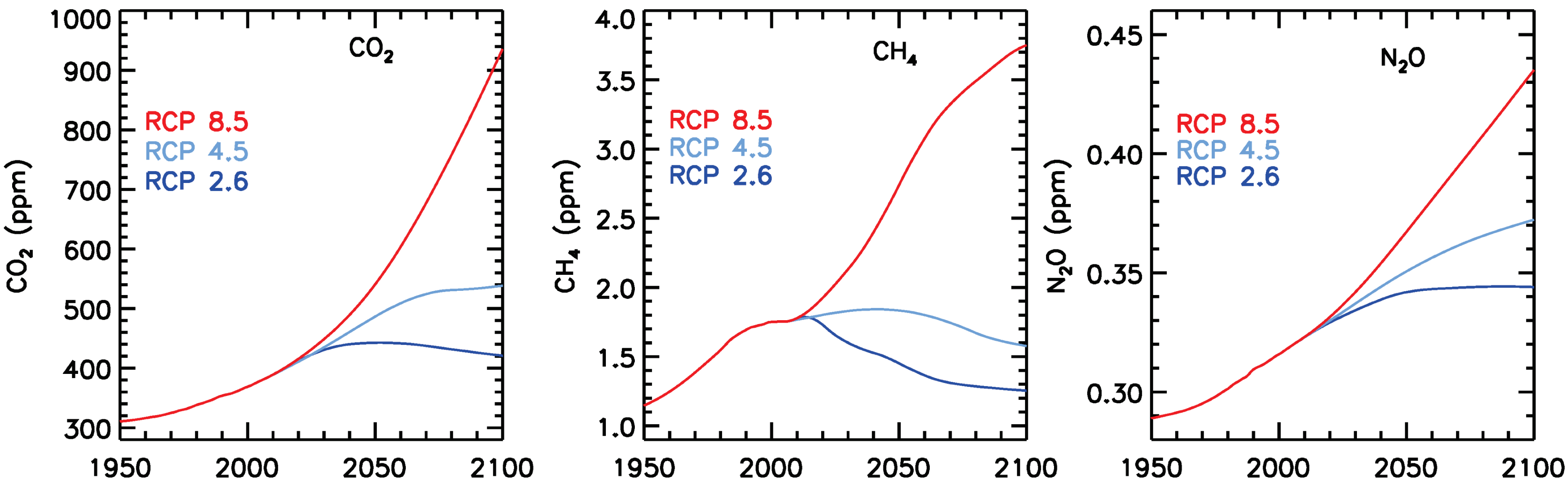
FIGURE 12-3: SCHEMATIC OF UNCERTAINTY IN GLOBAL WARMING FORECASTS



Initial Condition Uncertainty: short-term factors that interfere with the greenhouse effect
Scenario Uncertainty: uncertainty about the level of CO2 in the atmosphere
Structural Uncertainty: how well we understand climate and can represent it mathematically

Possible futures for the three most important anthropogenic GHGs

- Future abundances of CO_2, CH_4, N_2O & minor GHGs provided, for use as input to climate models
- Scenarios are called Representative Concentration Pathways (RCPs); number represents increase in RF of climate (units of W m^{-2}) that will occur at end of this century



ppm ⇨ parts per million

Today, CO_2 is at about 412 ppm, which means 412 out of every million molecules of air are CO_2 (rather than N_2, O_2, argon, etc)

https://www.co2.earth

Three Types of Climate Skepticism

- Self-interest
  - Lobbying by the fossil fuel industry
  - Heartland Institute
- Contrarianism
  - Some people like to be seen as persecuted outsiders
  - Especially common in US
- Scientific skepticism

FIGURE 12-5: GLOBAL TEMPERATURE ANOMALY RELATIVE TO 1951–80 BASELINE: SIX TEMPERATURE RECORDS

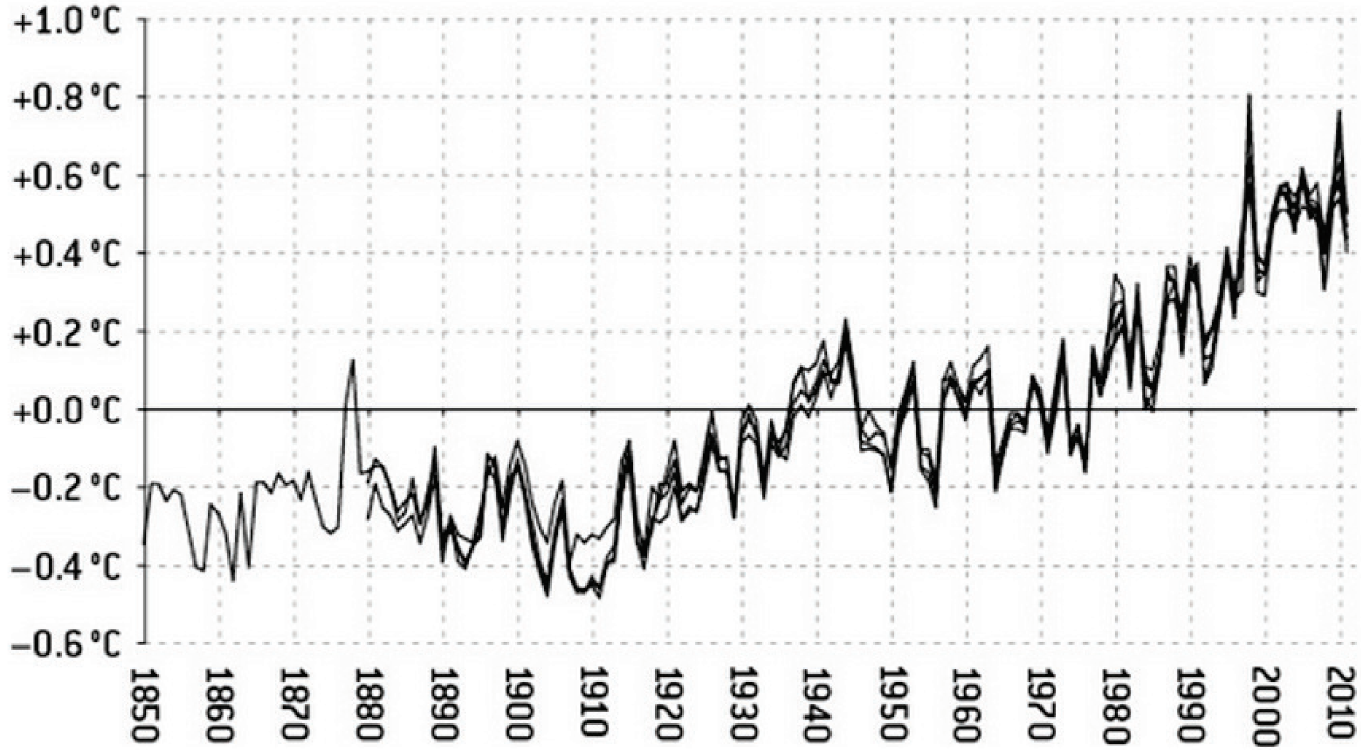


FIGURE 12-7: ACTUAL GLOBAL TEMPERATURES, 1990–2011 VS. 1990 IPCC FORECAST RANGE
Anomaly vs. 1951–1980 Baseline

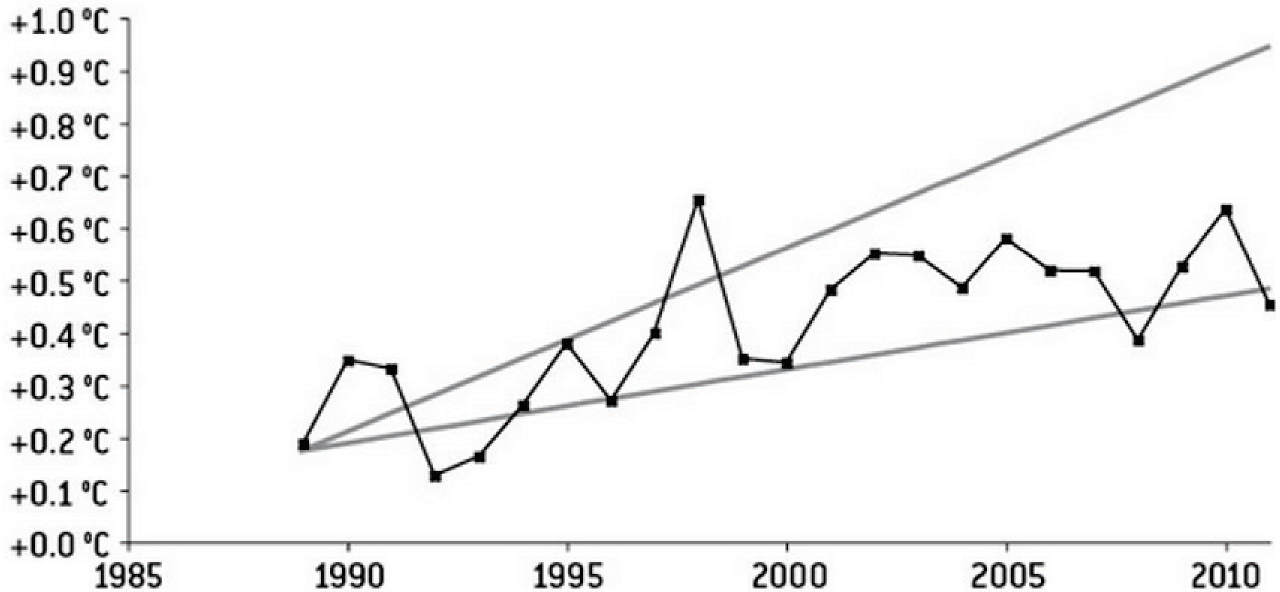
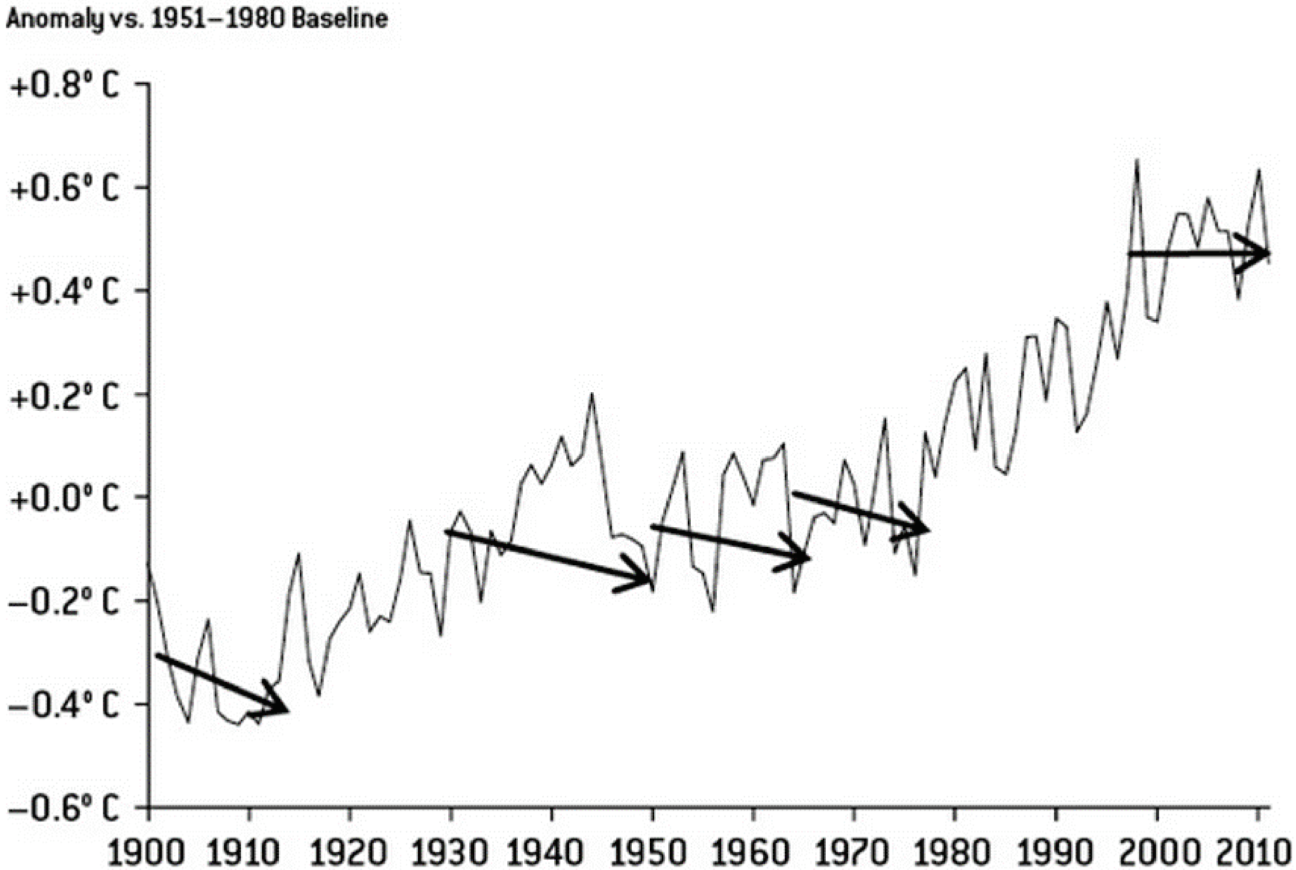
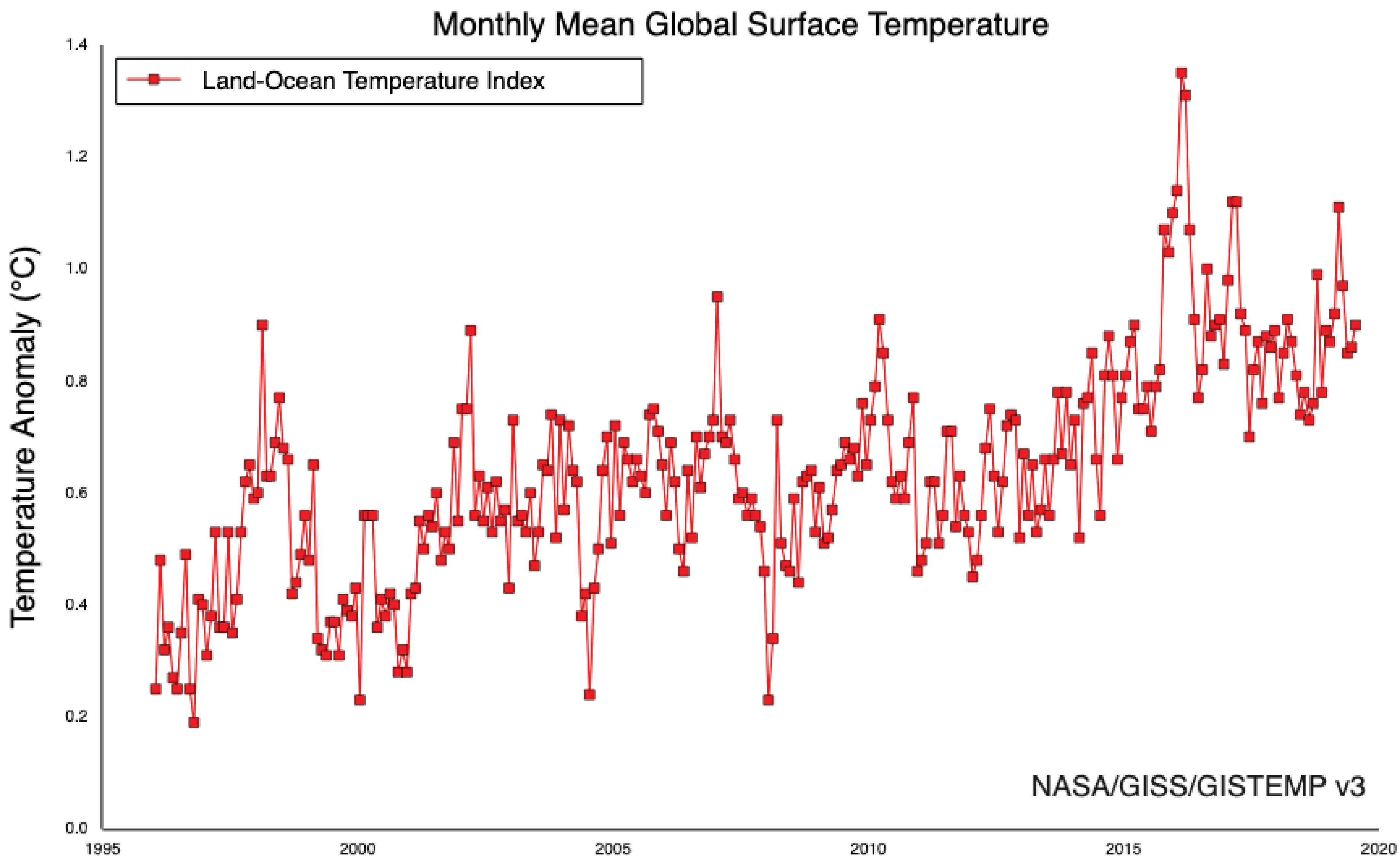


FIGURE 12-11: GLOBAL TEMPERATURES, 1900–2011 WITH NEAR-TERM FLATLINES AND DOWNSHIFTS HIGHLIGHTED





Monthly Mean Global Surface Temperature
Land-Ocean Temperature Index
Temperature Anomaly (°C)
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
1995
2000
2005
2010
2015
2020
NASA/GISS/GISTEMP v3

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Climate Models: Perspective of a Social Scientist

Last Word: Ross Salawitch

3 October 2019

Climate models under the microscope

CMIP5 (Climate Model Intercomparison Project 5) GCMs (General Circulation Models) warm too quickly compared to observations, resulting in "likely range" for rise in ΔT given in Chapter 11 of IPCC (2013) being considerably less than archived GCM values of ΔT

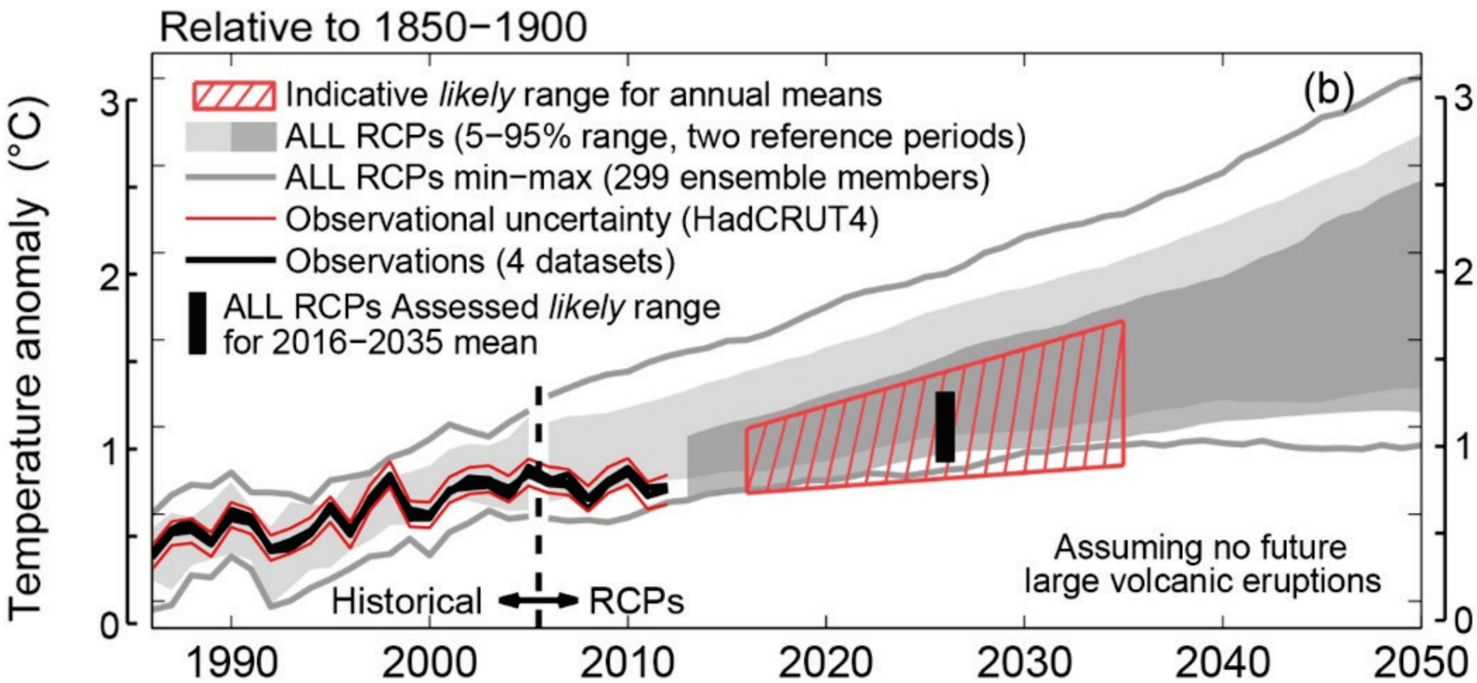


Fig 11.25b, IPCC (2013)

Three Futures

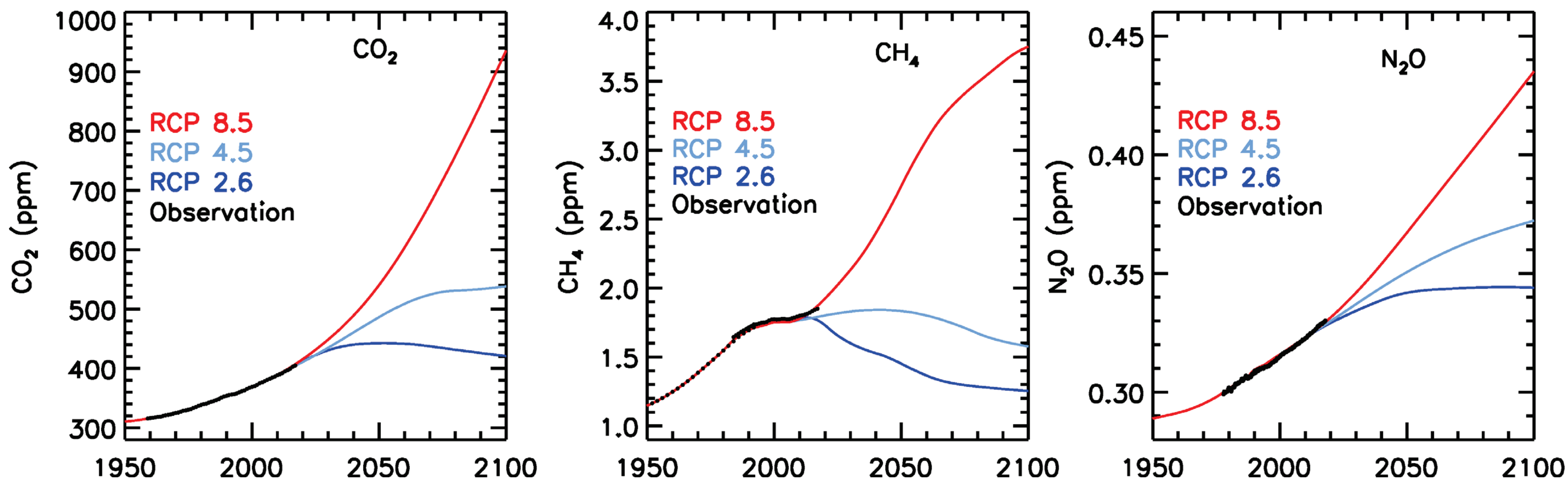


Fig 2.1, update
Paris Climate Agreement: Beacon of Hope

- Future abundances of CO_2, CH_4, N_2O & minor GHGs provided, for use as input to climate models
- Scenarios are called Representative Concentration Pathways (RCPs); number represents increase in RF of climate (units of W m^{-2}) that will occur at end of this century

ppm ⇨ parts per million

Today, CO_2 is at about 408 ppm, which means 408 out of every million molecules of air are CO_2 (rather than N_2, O_2, argon, etc) https://www.co2.earth

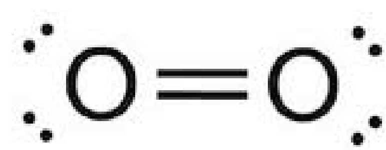
Excitation of Molecules

A greenhouse gas must have either

- naturally occurring **dipole moment**
- exhibit a **dipole moment** during vibration

Dipole moment ⇨ product of magnitude of charges & distance of separation between charges:
i.e., a molecule is said to have a dipole moment if it has a non-zero spatial distribution of charge

No dipole moment, either naturally or during vibration:



Excitation of Molecules

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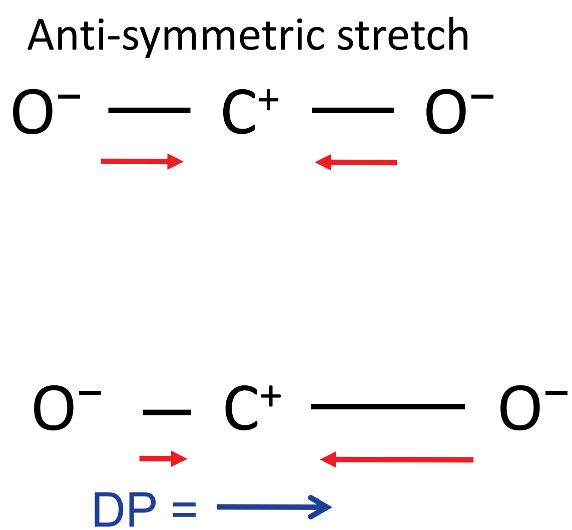
Anti-symmetric Stretch: *dipole moment*



Uncertainty in RF due to aerosols is a huge complication

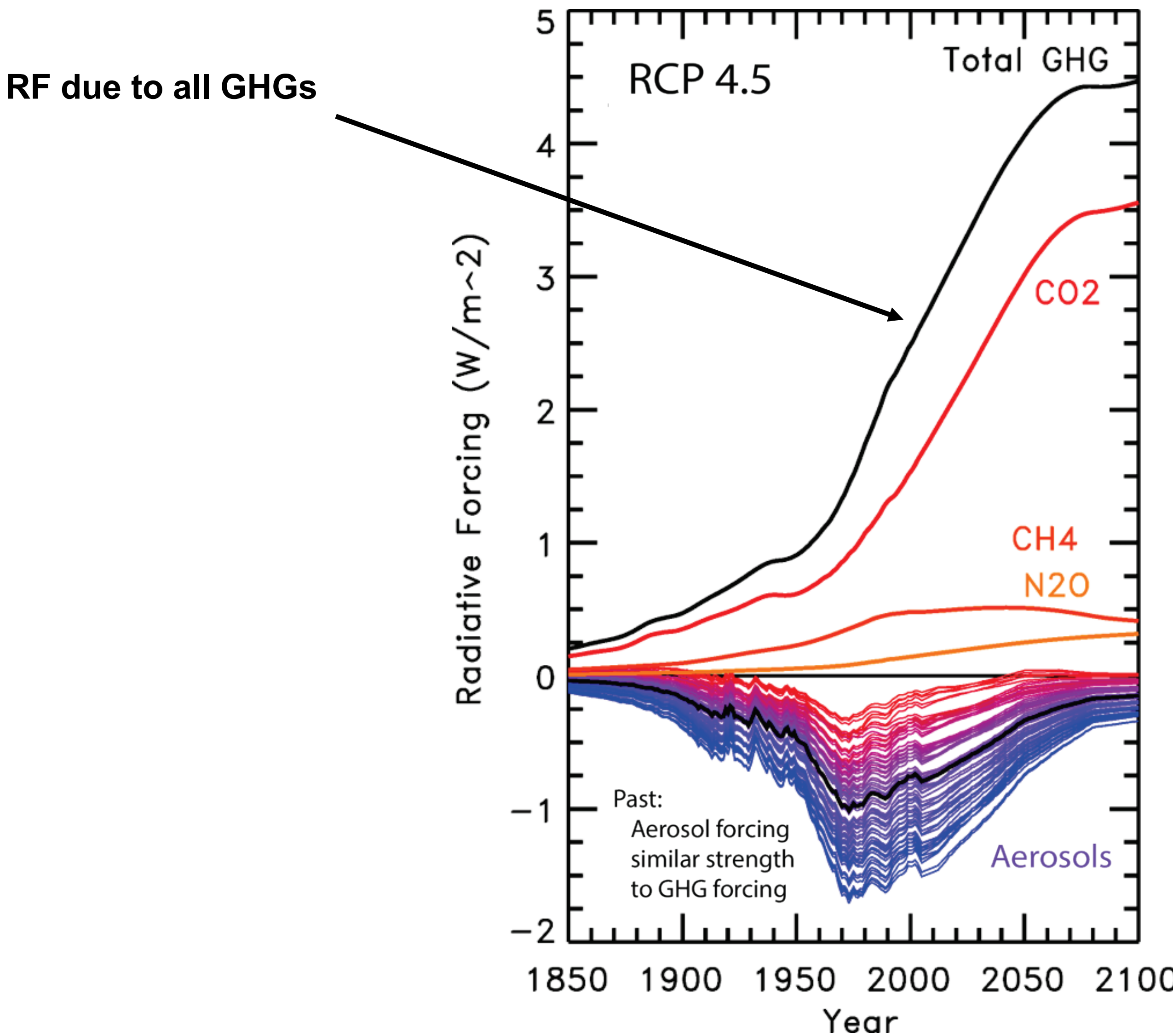


Fig 1.10,
Paris Climate Agreement: Beacon of Hope

Uncertainty in RF due to aerosols is a huge complication

RF due to all GHGs minus RF due to Aerosols, for curve with <u>–0.4 W m⁻²</u> in year 2011

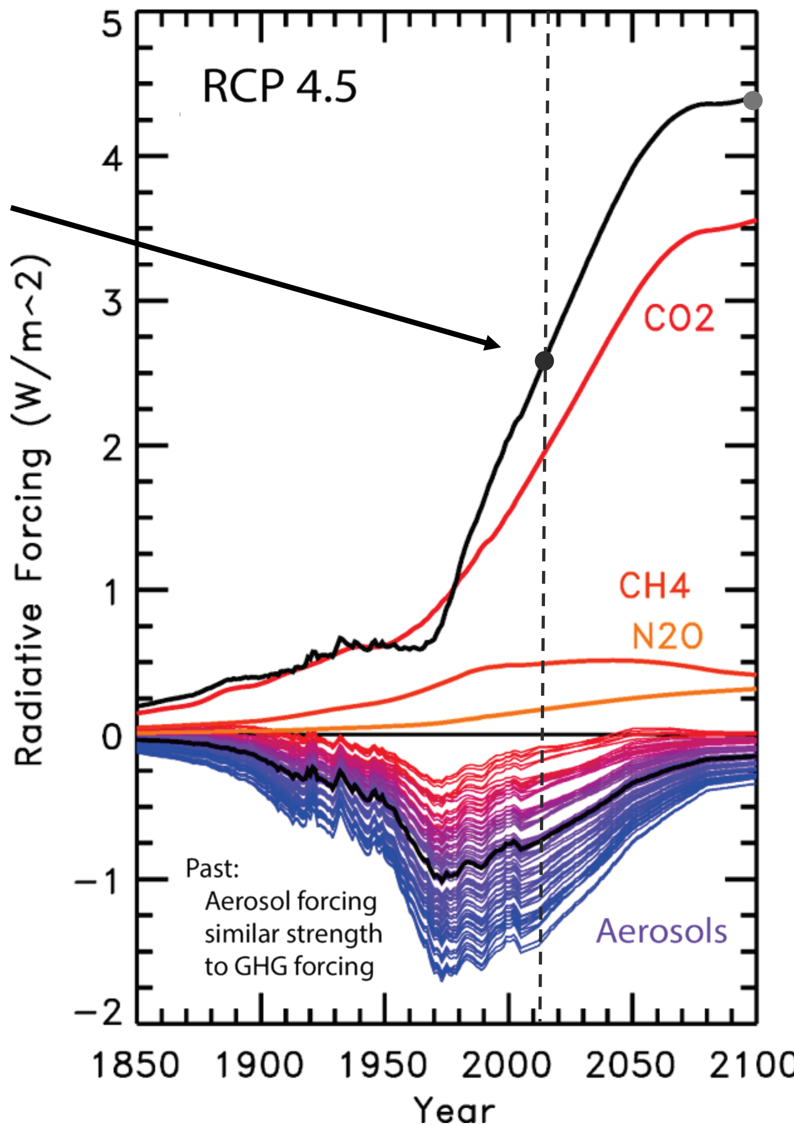


Fig 1.10 modified,
Paris Climate Agreement: Beacon of Hope

Uncertainty in RF due to aerosols is a huge complication

RF due to all GHGs minus RF due to Aerosols,
for curve with <u>–0.9 W m⁻²</u> in year 2011

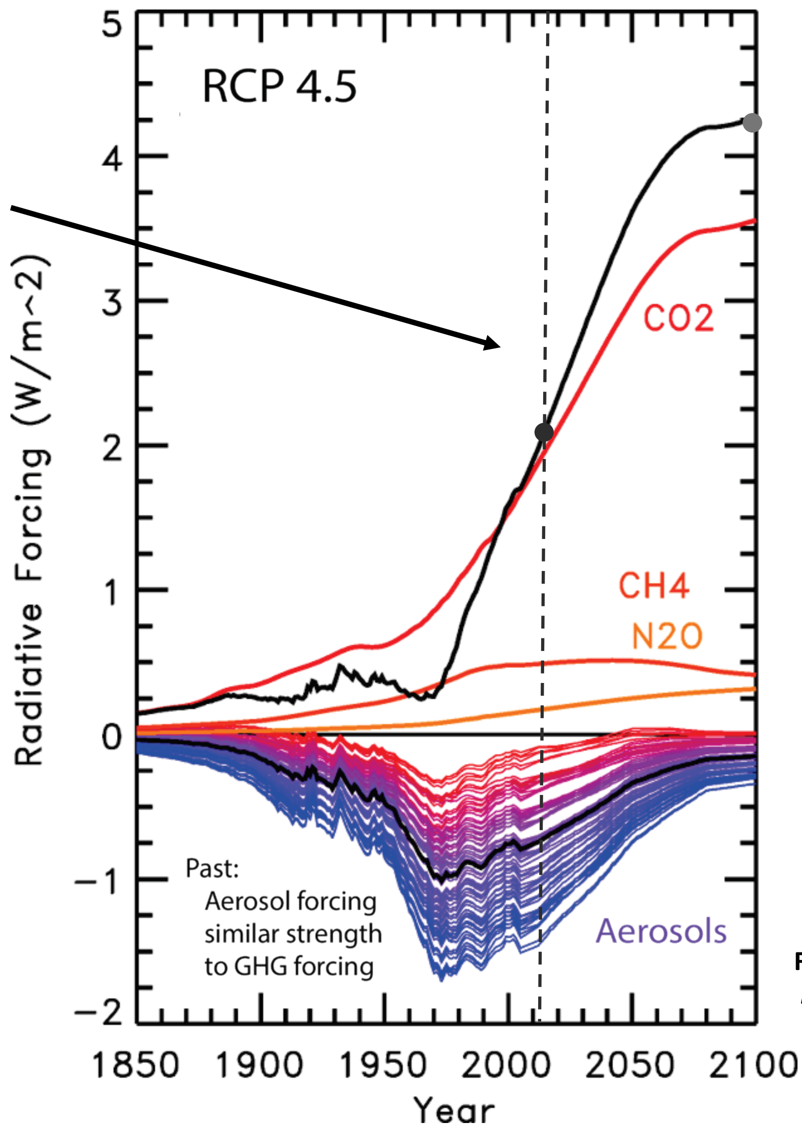


Fig 1.10 modified,
Paris Climate Agreement: Beacon of Hope

Uncertainty in RF due to aerosols is a huge complication

RF due to all GHGs minus
RF due to Aerosols,
for curve with <u>–1.5 W m^{-2}</u>
in year 2011

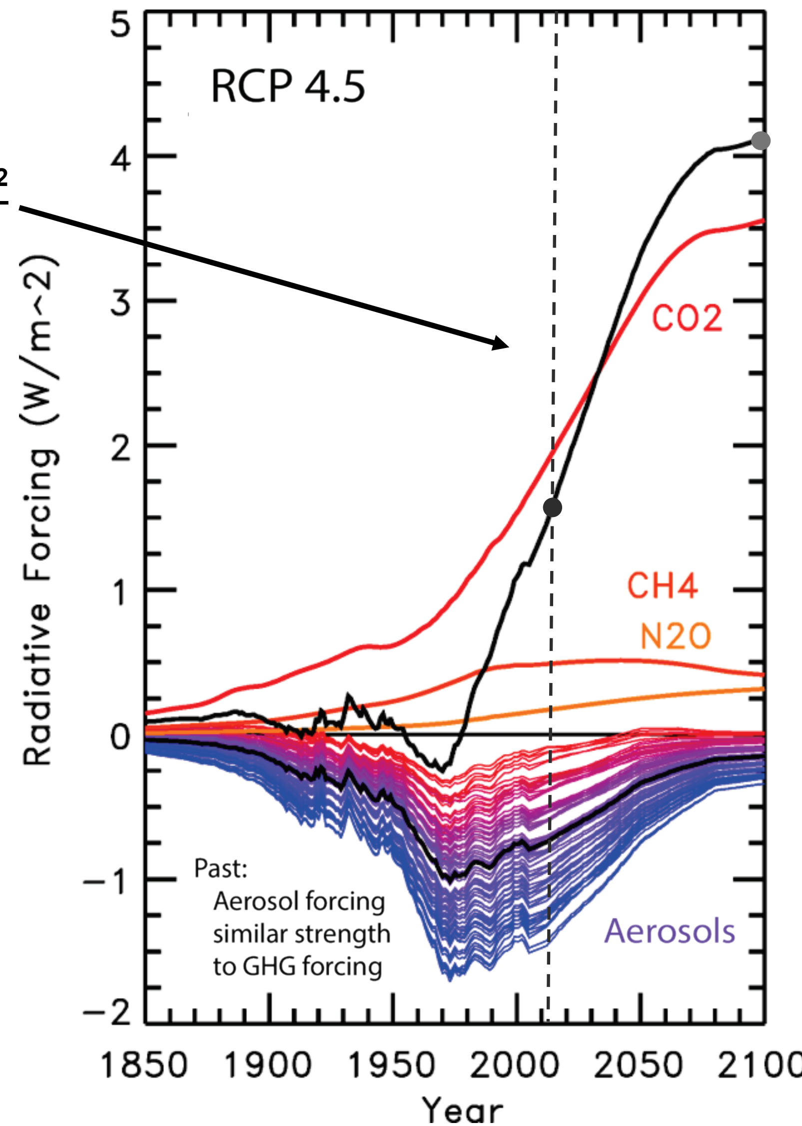


Fig 1.10 modified,
Paris Climate Agreement: Beacon of Hope

Uncertainty in RF due to aerosols is a complication that places a fundamental uncertainty on how well future global warming can be forecast

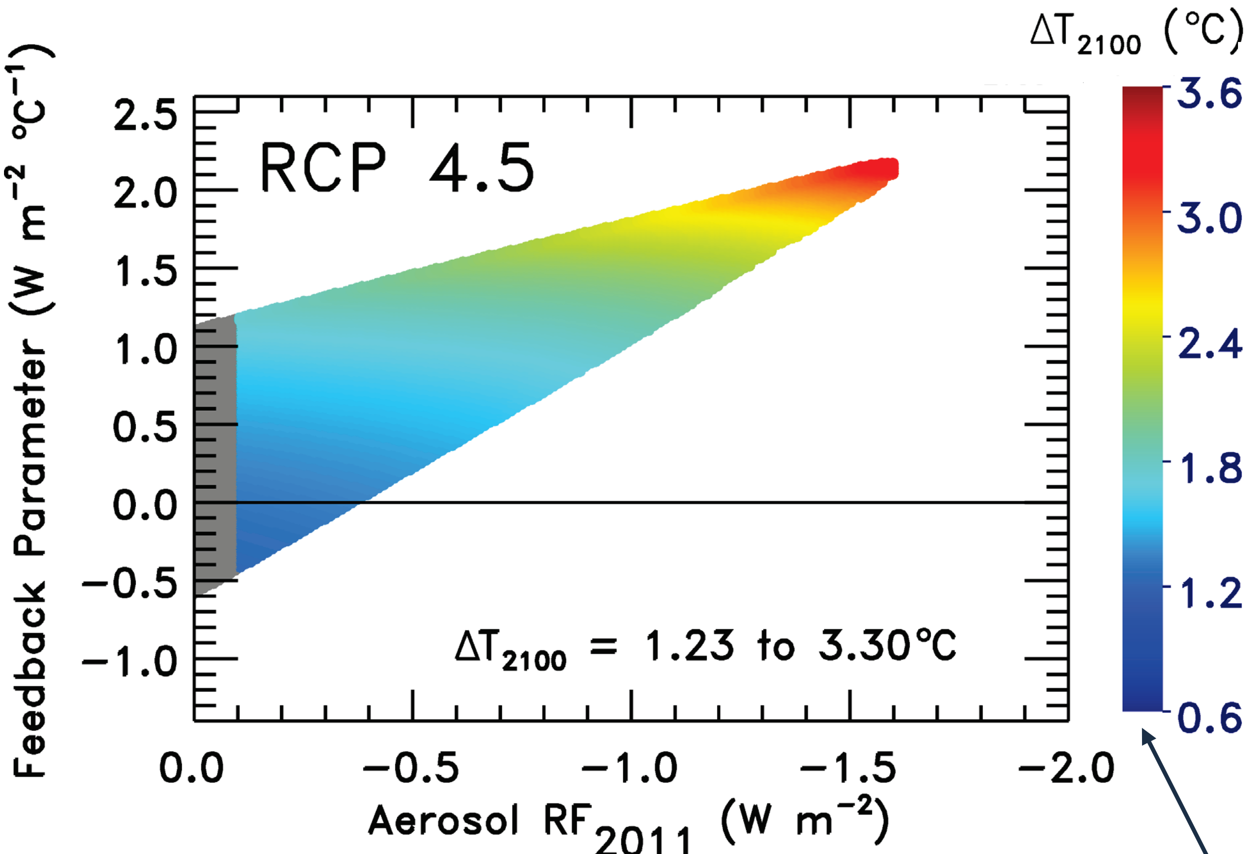
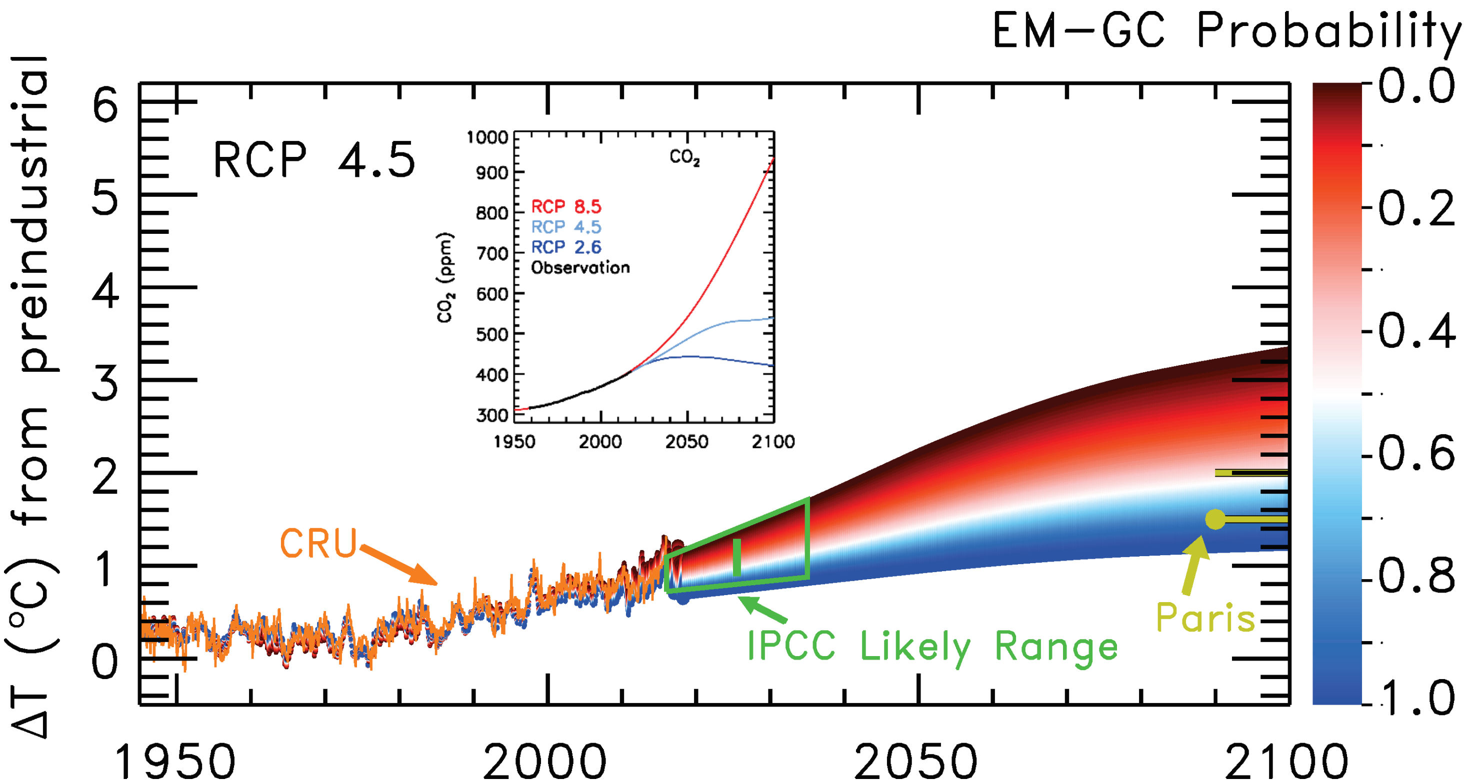


Fig 2.15 (updated)
Paris Climate Agreement: Beacon of Hope

FB_{Σ} units W m^{-2} °C^{-1} on EM-GC description slide

ΔT is rise in GMST (Global Mean Surface Temperature) relative to pre-industrial

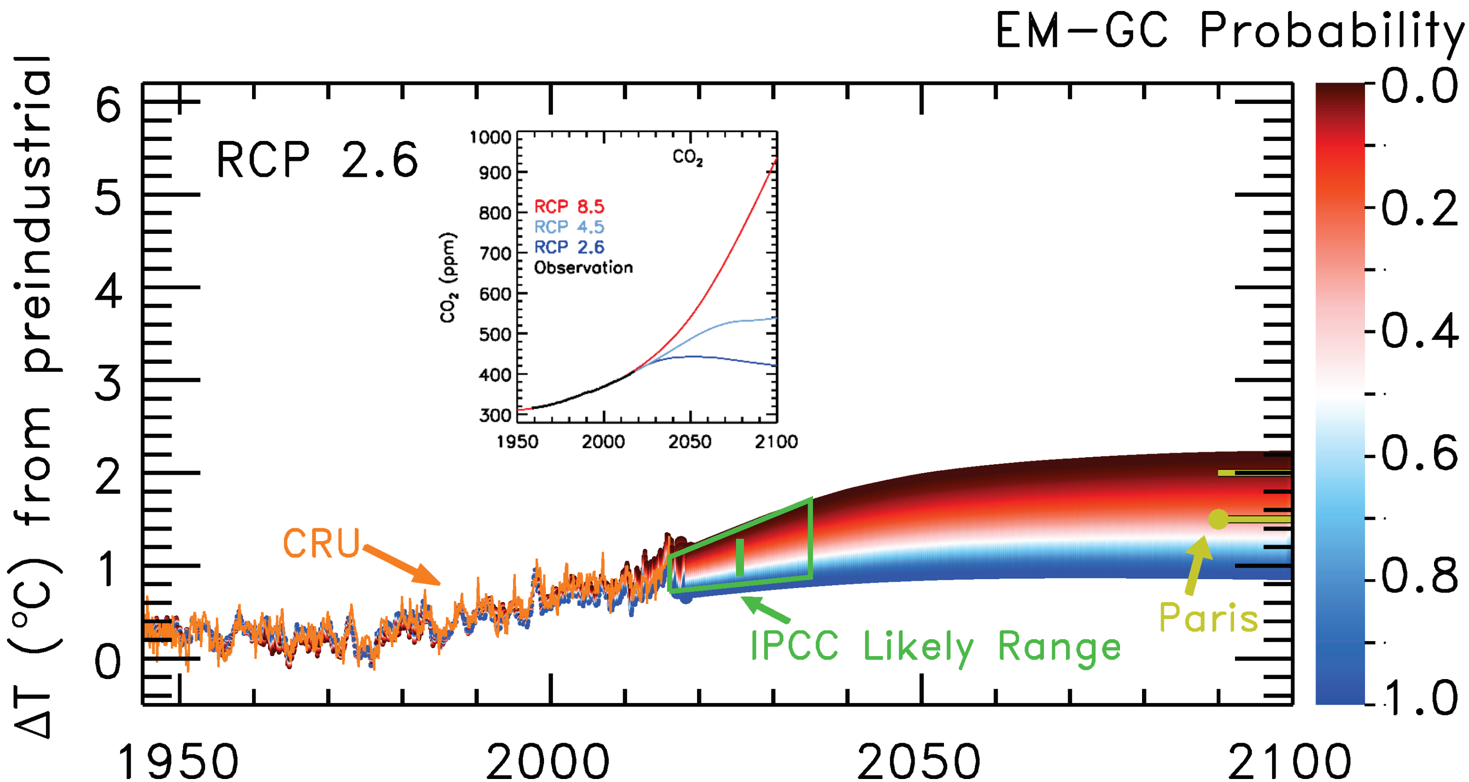
Probabilistic Forecast of Human-Induced Rise in GMST for model trained on data acquired until end of 2017 and future GHG levels from RCP 4.5



If GHGs follow RCP 4.5, **9%** chance rise GMST stays below **1.5°C** and **51%** chance stays below **2.0°C**

EM-GC: University of Maryland Empirical Model of Global Climate
ΔT: rise in GMST (Global Mean Surface Temperature) relative to pre-industrial
CRU: Climate Research Unit, Easy Anglia, UK: Premier source of data for ΔT
IPCC Likely Range of ΔT : From Fig 11.25b of the 2013 Intergovernmental Panel on Climate Change Report

Probabilistic Forecast of Human-Induced Rise in GMST for model trained on data acquired until end of 2017 and future GHG levels from RCP 2.6



If GHGs follow RCP 2.6, **68%** chance rise GMST stays below **1.5°C** and **96%** chance stays below **2.0°C**

EM-GC: University of Maryland Empirical Model of Global Climate

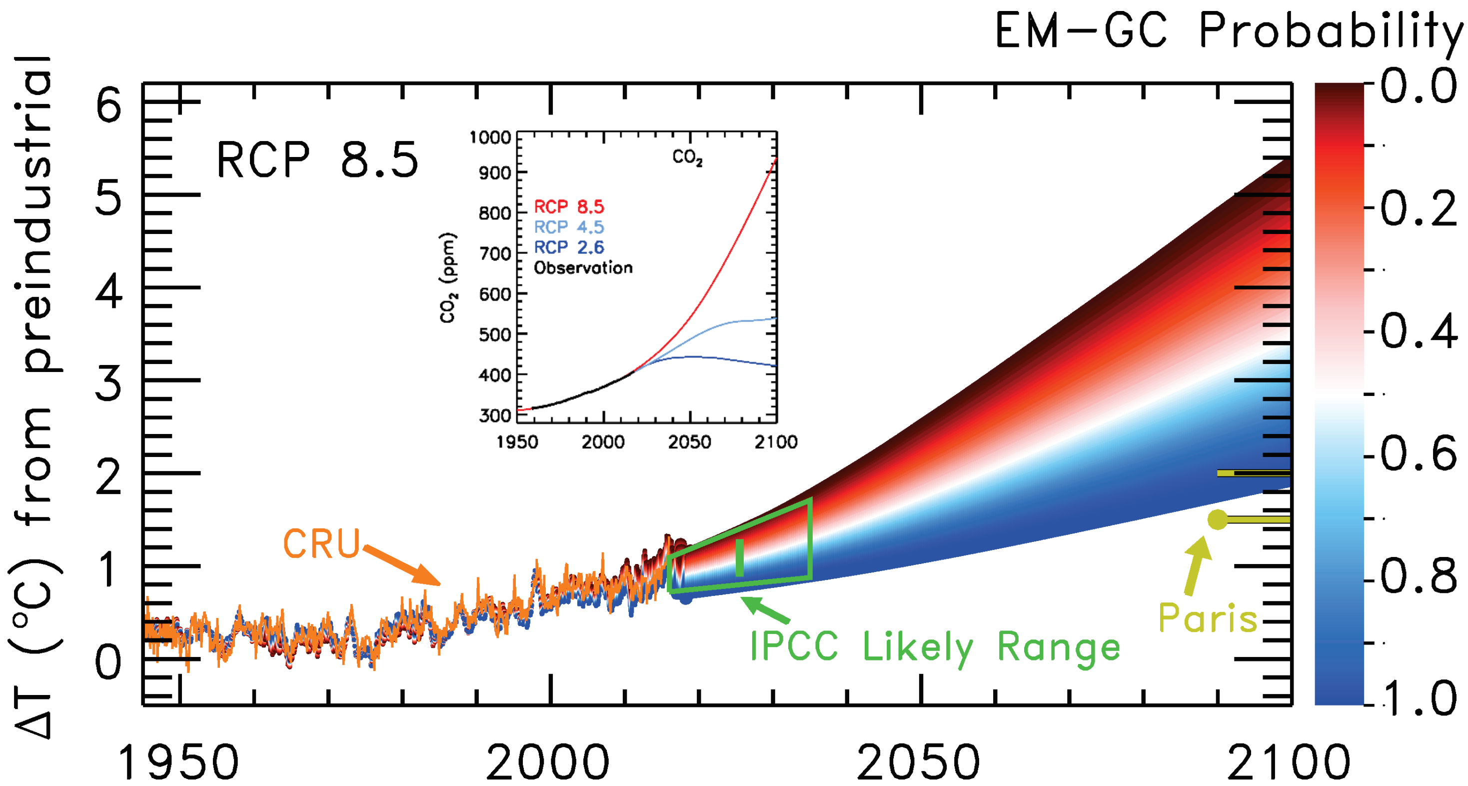
ΔT: rise in GMST (Global Mean Surface Temperature) relative to pre-industrial

CRU: Climate Research Unit, Easy Anglia, UK: Premier source of data for ΔT

IPCC Likely Range of ΔT : From Fig 11.25b of the 2013 Intergovernmental Panel on Climate Change Report

Probabilistic Forecast of Human-Induced Rise in GMST for model trained on data acquired until end of 2017 and future GHG levels from RCP 8.5

Fig 2.20 (updated) ***Paris Climate Agreement: Beacon of Hope***



If GHGs follow RCP 8.5, **0%** chance rise GMST stays below **1.5°C** and **0.1%** chance stays below **2.0°C**

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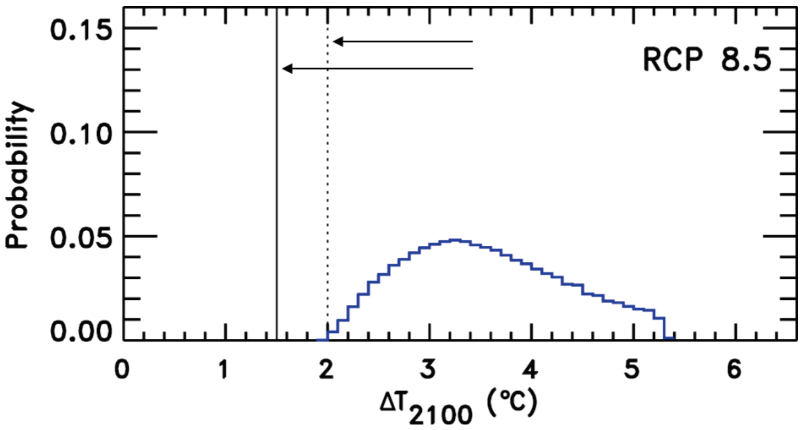
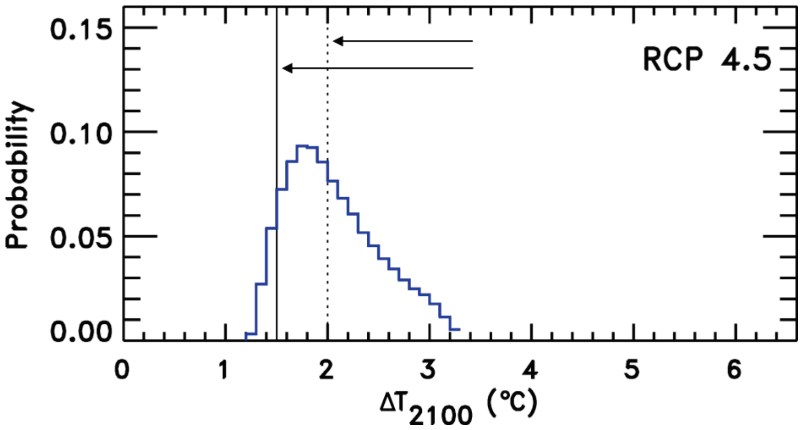


If GHGs follow RCP 8.5:
EM-GC: 0% chance rise GMST stays below **1.5°** and
0.1% chance stays below **2.0°C**



If GHGs follow RCP 8.5:
EM-GC: 9% chance rise GMST stays below **1.5°** and
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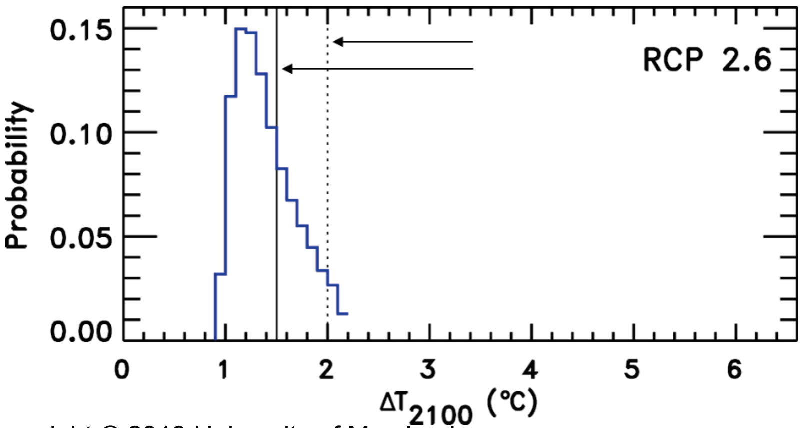


If GHGs follow RCP 8.5:
EM-GC: 68% chance rise GMST stays below **1.5°** and
96% chance stays below **2.0°C**

One more important detail:

CMIP5 (Climate Model Intercomparison Project 5) GCMs (General Circulation Models) warm too quickly compared to observations, resulting in "likely range" for rise in ΔT given in Chapter 11 of IPCC (2013) being considerably less than archived GCM values of ΔT

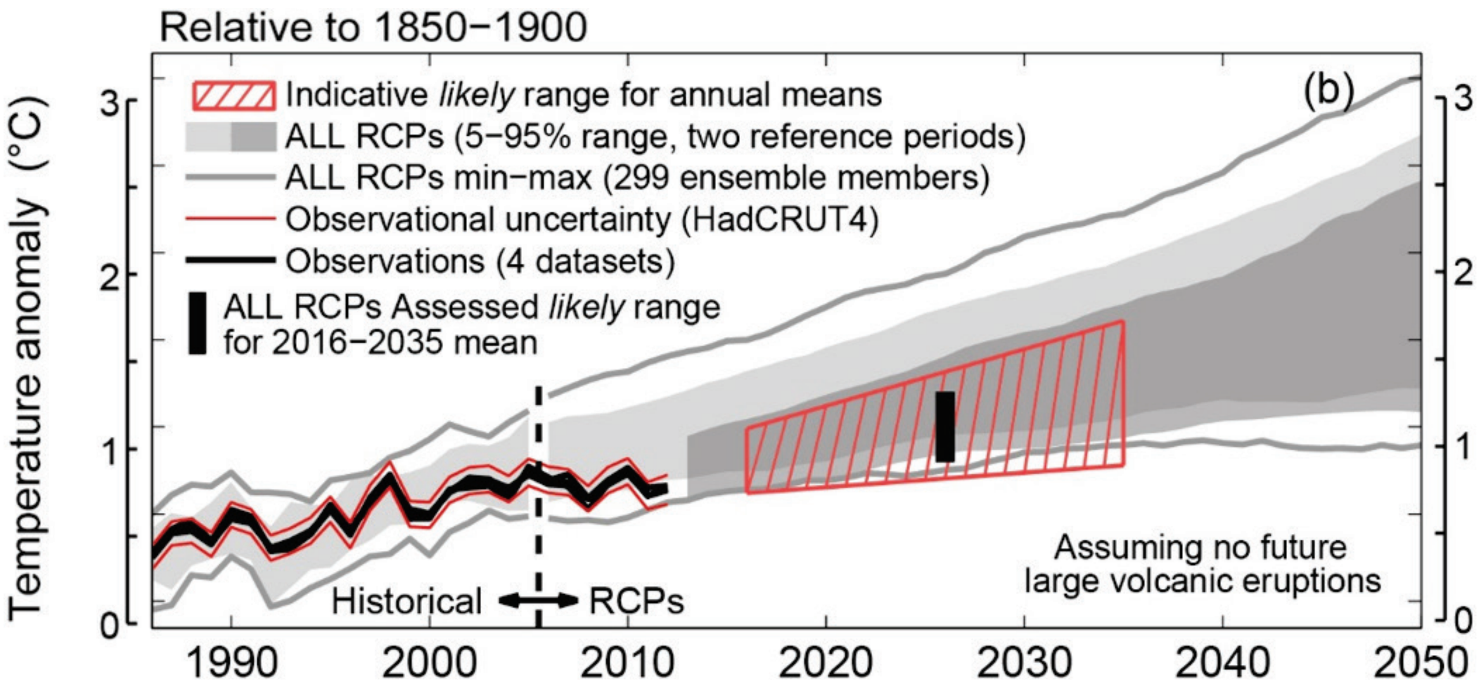
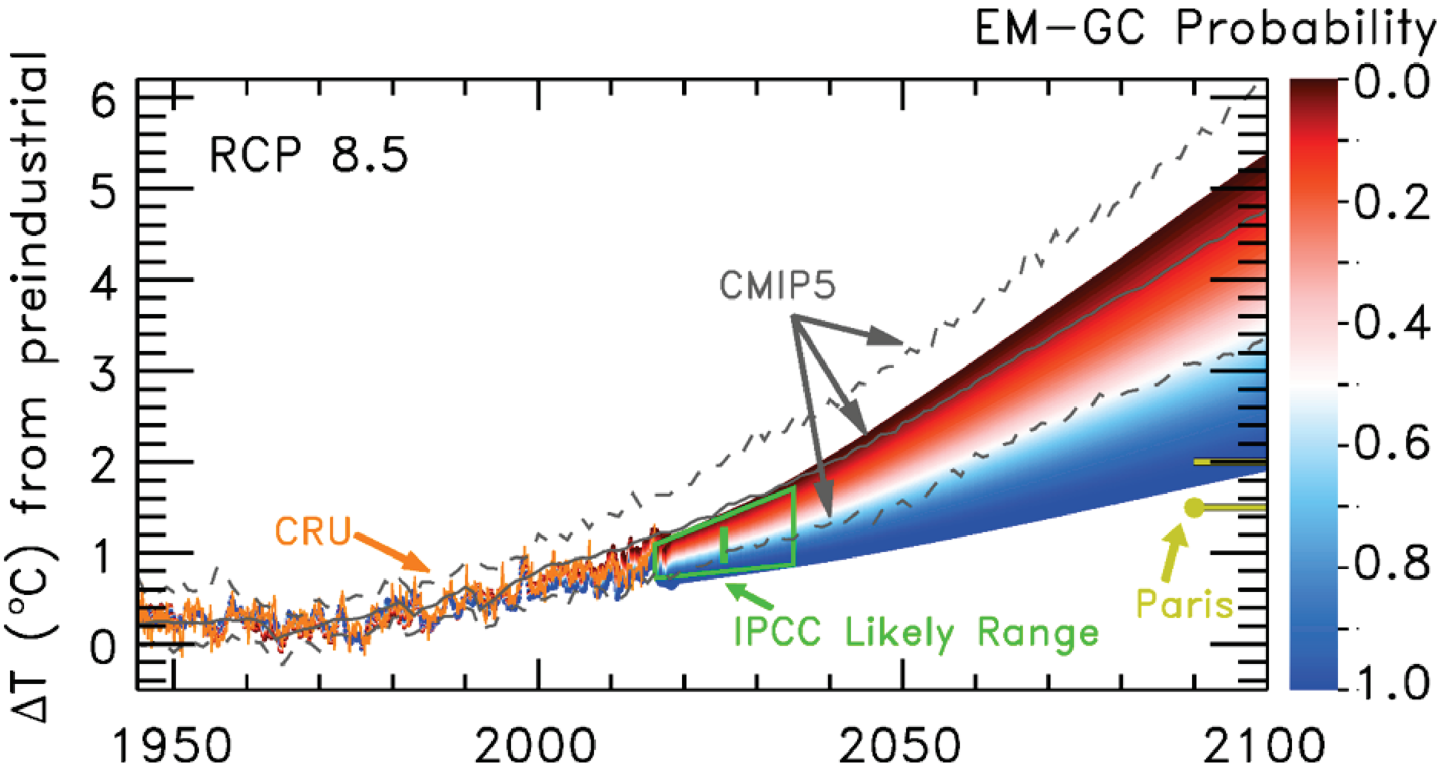
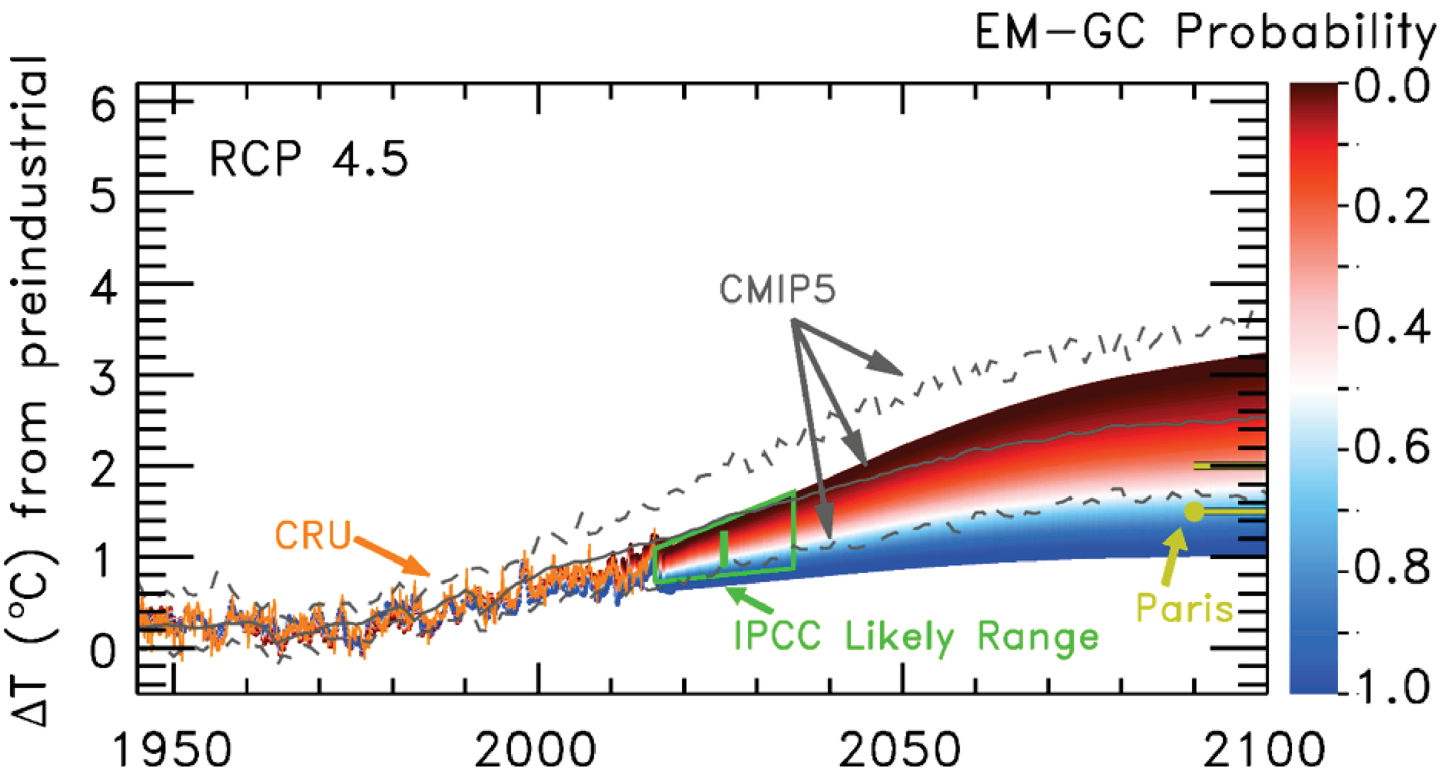


Fig 11.25b, IPCC (2013)


EM−GC Probability
RCP 8.5
CMIP5
CRU
IPCC Likely Range
Paris
ΔT (°C) from preindustrial
6
5
4
3
2
1
0
1950
2000
2050
2100
0.0
0.2
0.4
0.6
0.8
1.0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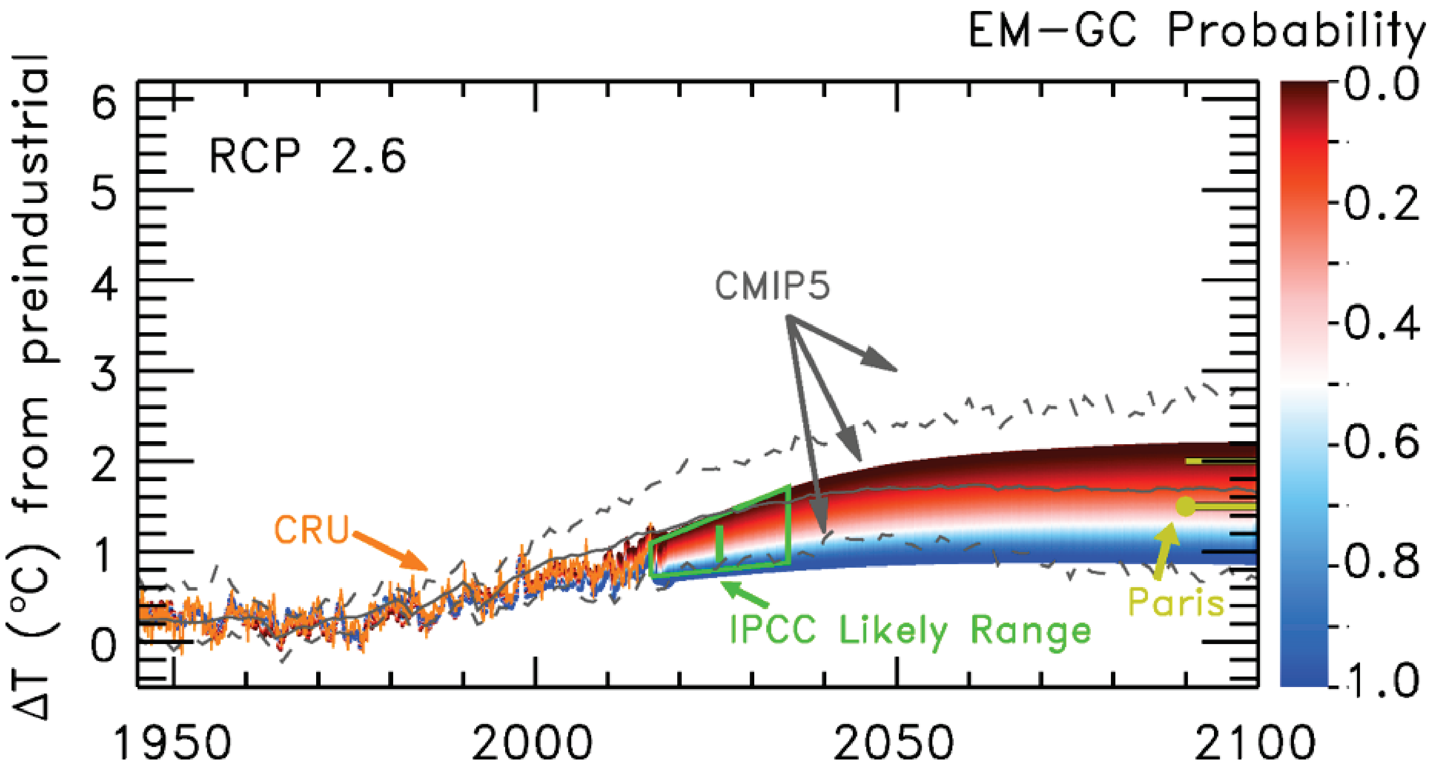
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0.6
0.8
1.0

Discussion for next Tuesday to be led by Luke:

Impacts of climate change with a focus on four topics:

1. **Longer and more damaging wildfire seasons**
2. **Ocean Acidification**
3. **Sea Level Rise**
4. **Infectious Disease**

Readings for Tuesday all web-based material

Students will be asked to explore 2 of these 4 topics, and address in a short essay:

a) How does climate change impact the chosen topic area (i.e., described the underlying science) ?

b) If human society does not reduce our emissions of greenhouse gases, what will be the consequences for society ?

Great if I can see Luke and Abhay after class