Change Happens:

Climate, uncertainty, and scale

Chris Swanston

MI SAF meeting

April 30, 2013

Scientists still disagree about climate change, right? So who am I supposed to believe?

DISAGREEMENT?

Intergovernmental Panel on Climate Change (2007)

- Evidence for climate change is "unequivocal"
- It is "extremely likely" that humans are major contributors
- Future changes depend partly on human actions

18 National Academies have endorse the consensus position in IPCC 2007

- National Academy of Sciences (USA)
- Royal Society of Canada

Disagreement?

Scientists still disagree about climate change, right? So who am I supposed to believe?

- No scientific debate on “if”.
- Current scientific debate revolves around how much, how fast, and feedback mechanisms.
- Most climate scientists agree humans are a driver.

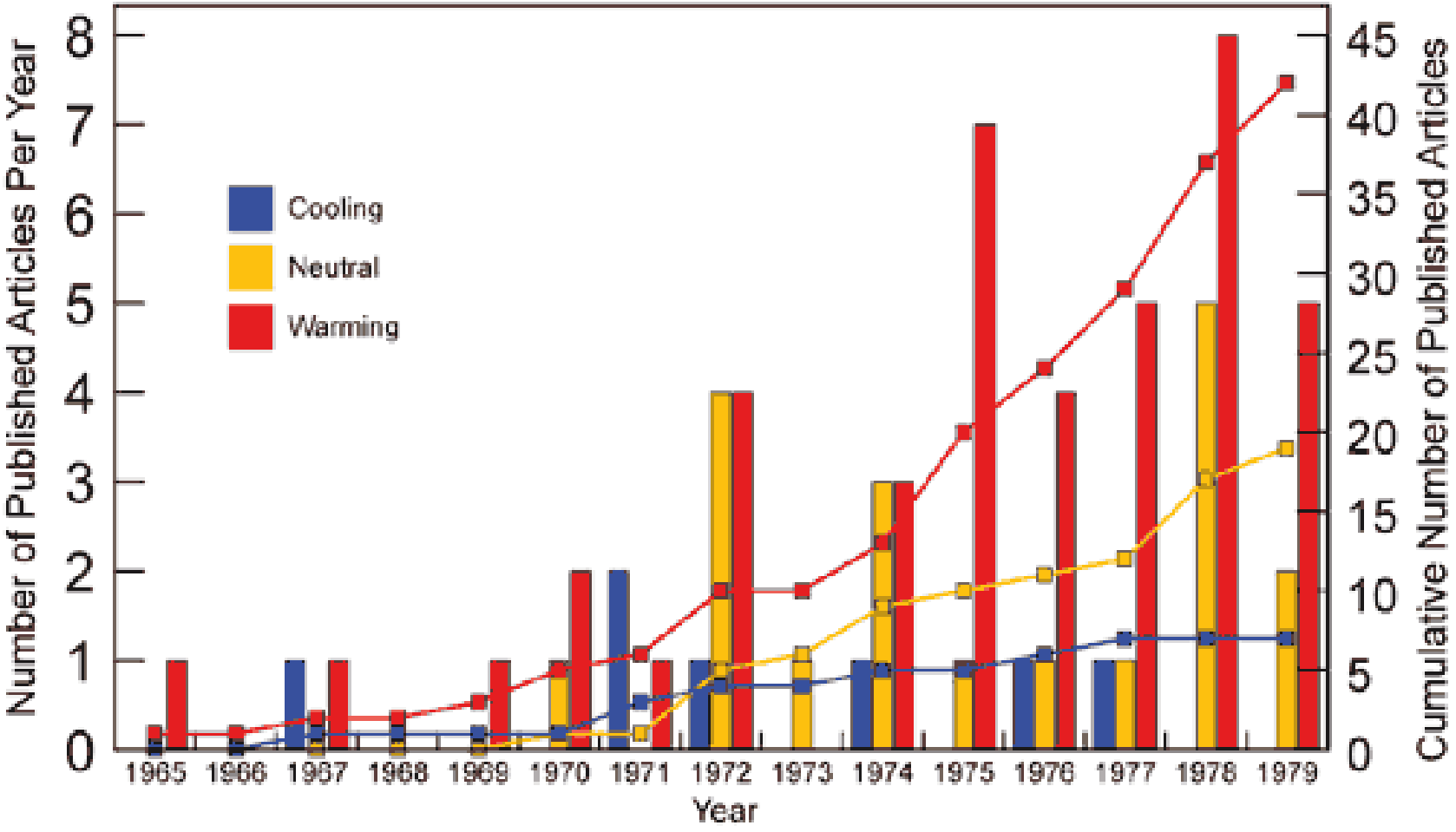
A practical risk assessment may be a better strategy than belief.

Now they say it's warming, but they previously told us we were entering a new ice age…, so which is true?

ICE AGE SCARE?

Cooling – 7 papers, warming – 42 papers

NEW ICE AGE!!!! – Time and Newsweek



Peterson et al. 2008

Now they say it's warming, but they previously told us we were entering a new ice age…, so which is true?

- Very few climate scientists suggested extreme cooling.
- Most climate change pubs suggested warming.
- There is some evidence that there would be cooling without anthropogenic warming.

The ice-age scare was a mass media thing – global warming is backed by nearly all climate scientists.

What about climate-gate?

CLIMATE-GATE?

Seven separate investigations

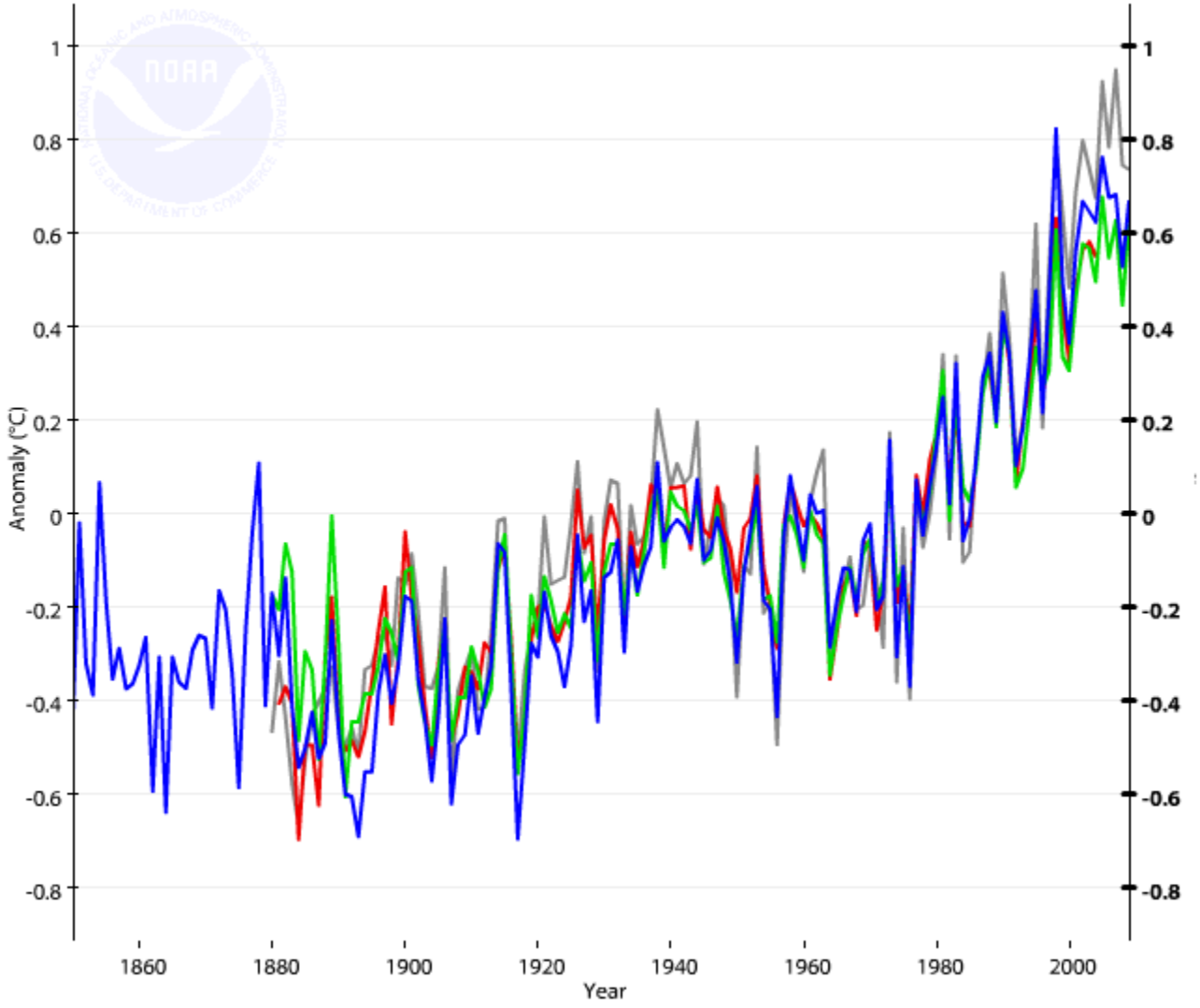
- Penn State University
- UK House of Commons
- University of East Anglia
- US EPA
- Dep't of Commerce Inspector General
- National Science Foundation
- *Each exonerated the scientists and work*

Bigger point – this involved just one dataset!

CLIMATE-GATE?

Multiple corroborating datasets

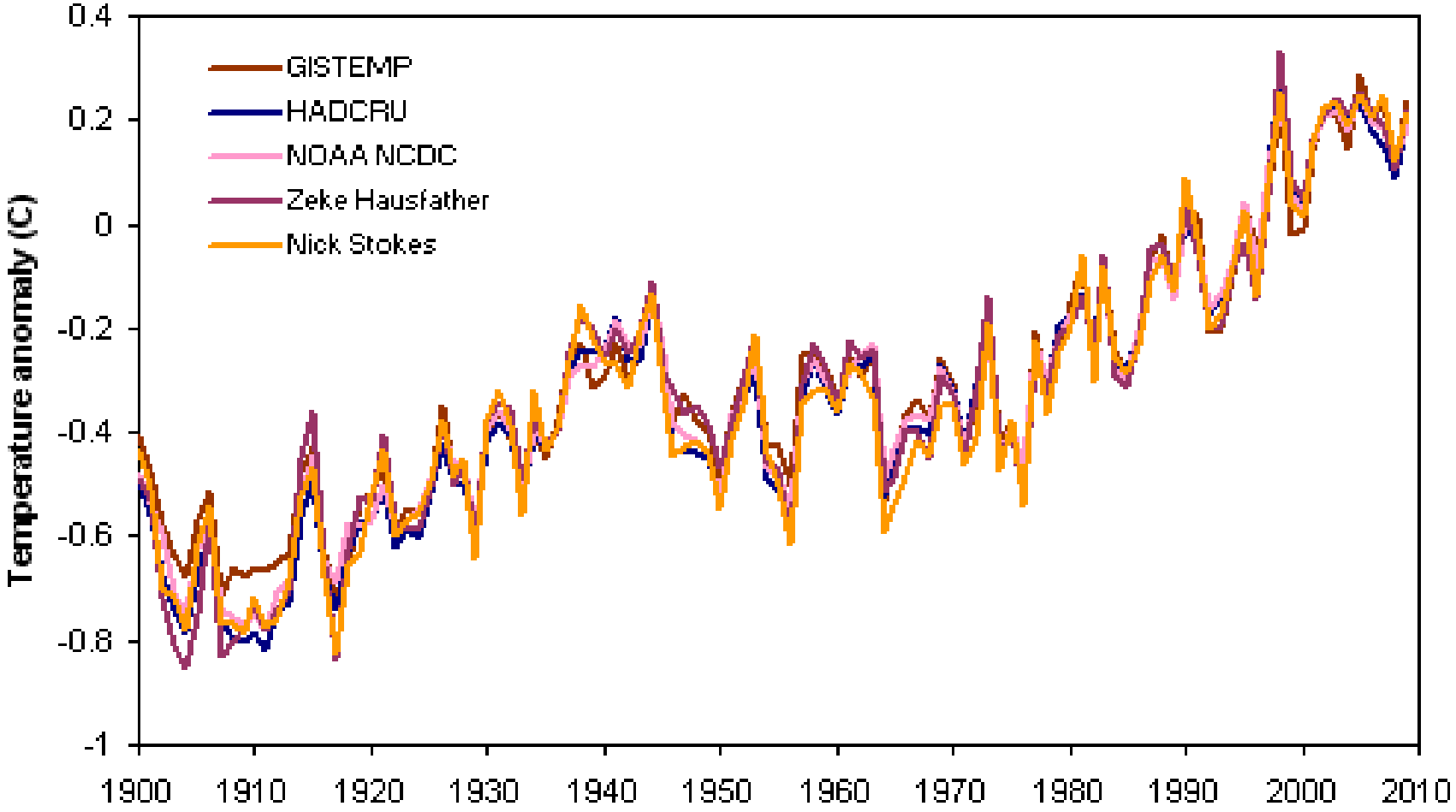
CRUTEM3
NASA
Lugina et al.
NOAA



www.ncdc.noaa.gov

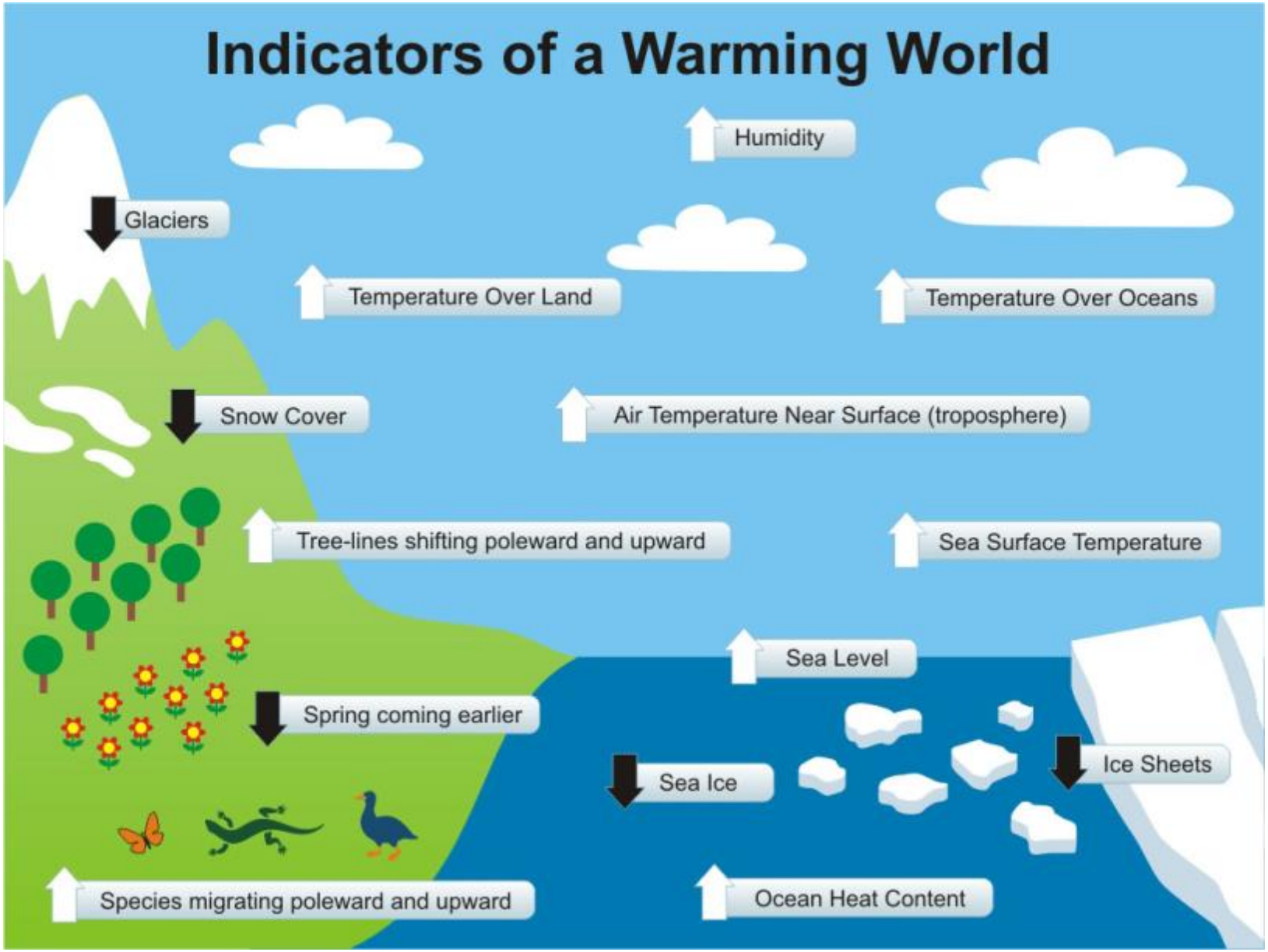
CLIMATE-GATE?

Multiple corroborating datasets



www.skepticalscience.com

CLIMATE-GATE?



www.skepticalscience.com

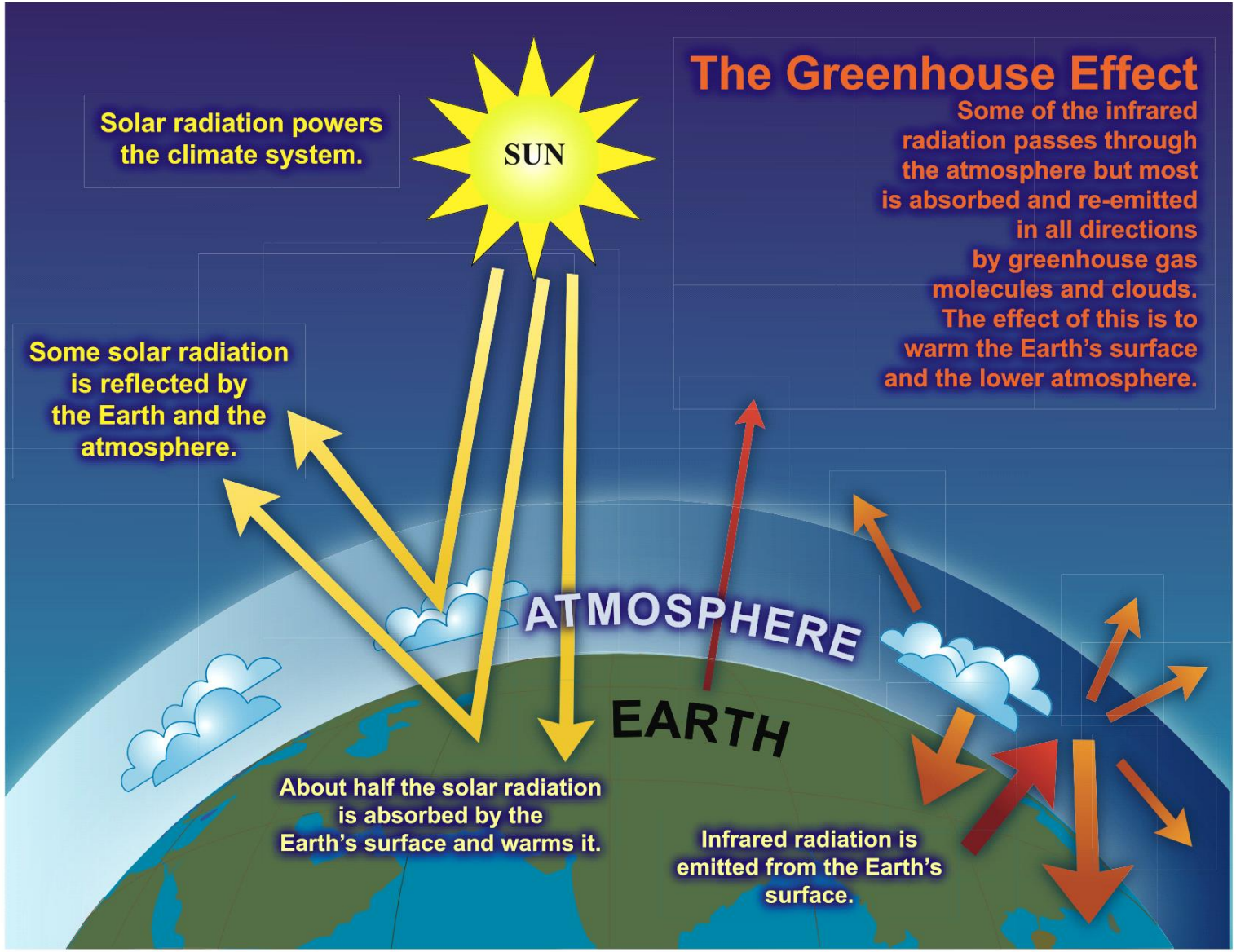
What about climate-gate?

- Seven investigations exonerated the scientists.
- There are several other surface temperature datasets – the results are the same.
- There are ***thousands*** of additional datasets.

The scope of evidence is enormous – far beyond any single dataset or research group.

The greenhouse effect hasn't really been proven, has it?

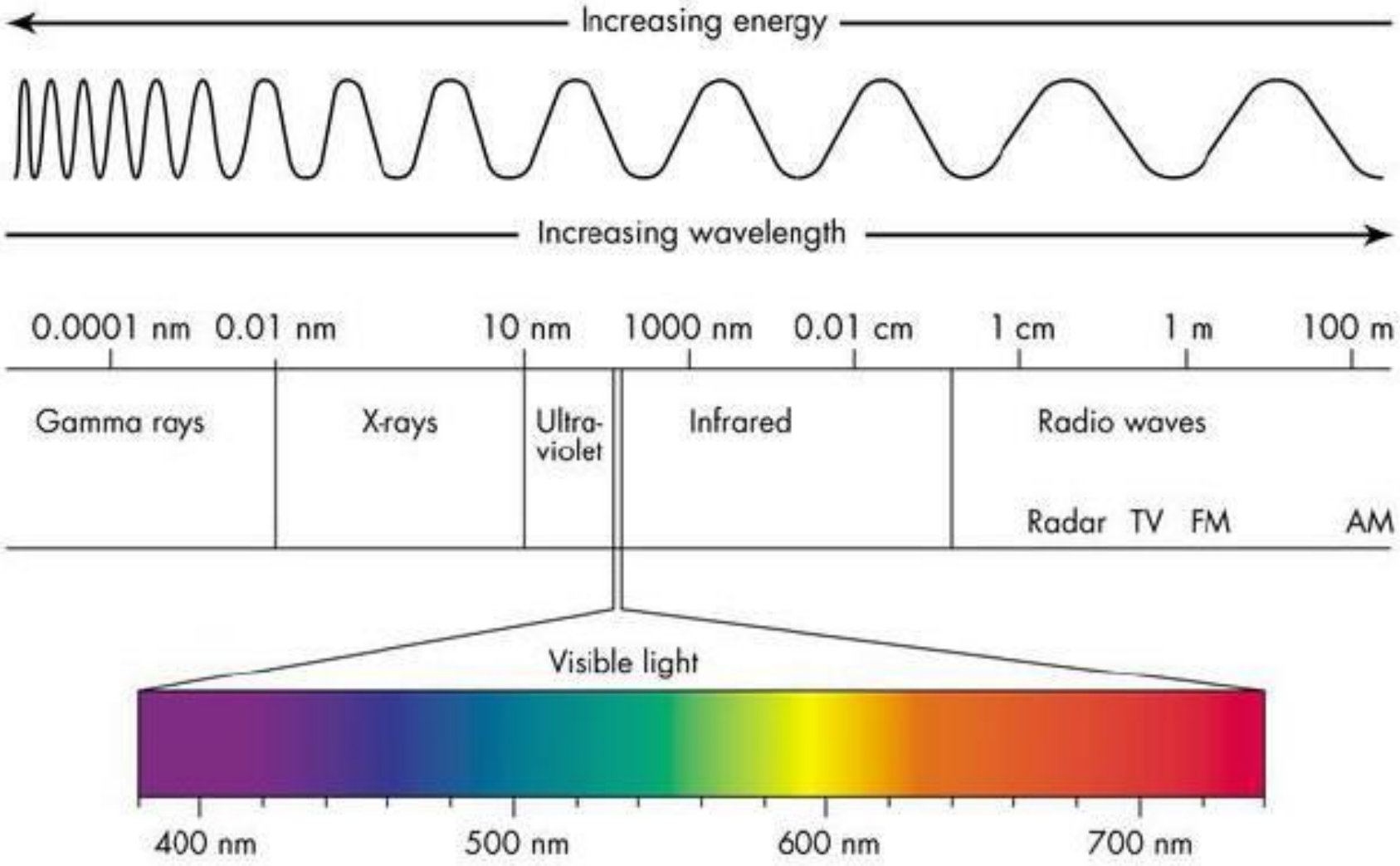
GREENHOUSE EFFECT?



IPCC 2007

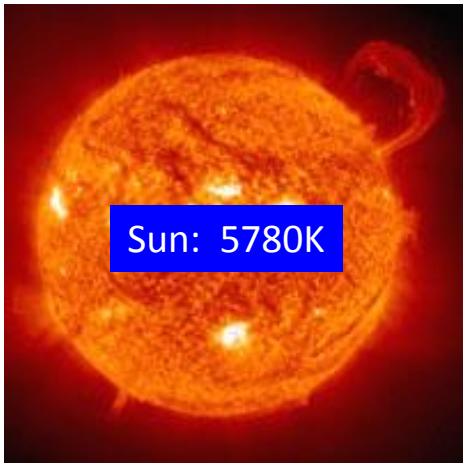
GREENHOUSE EFFECT?

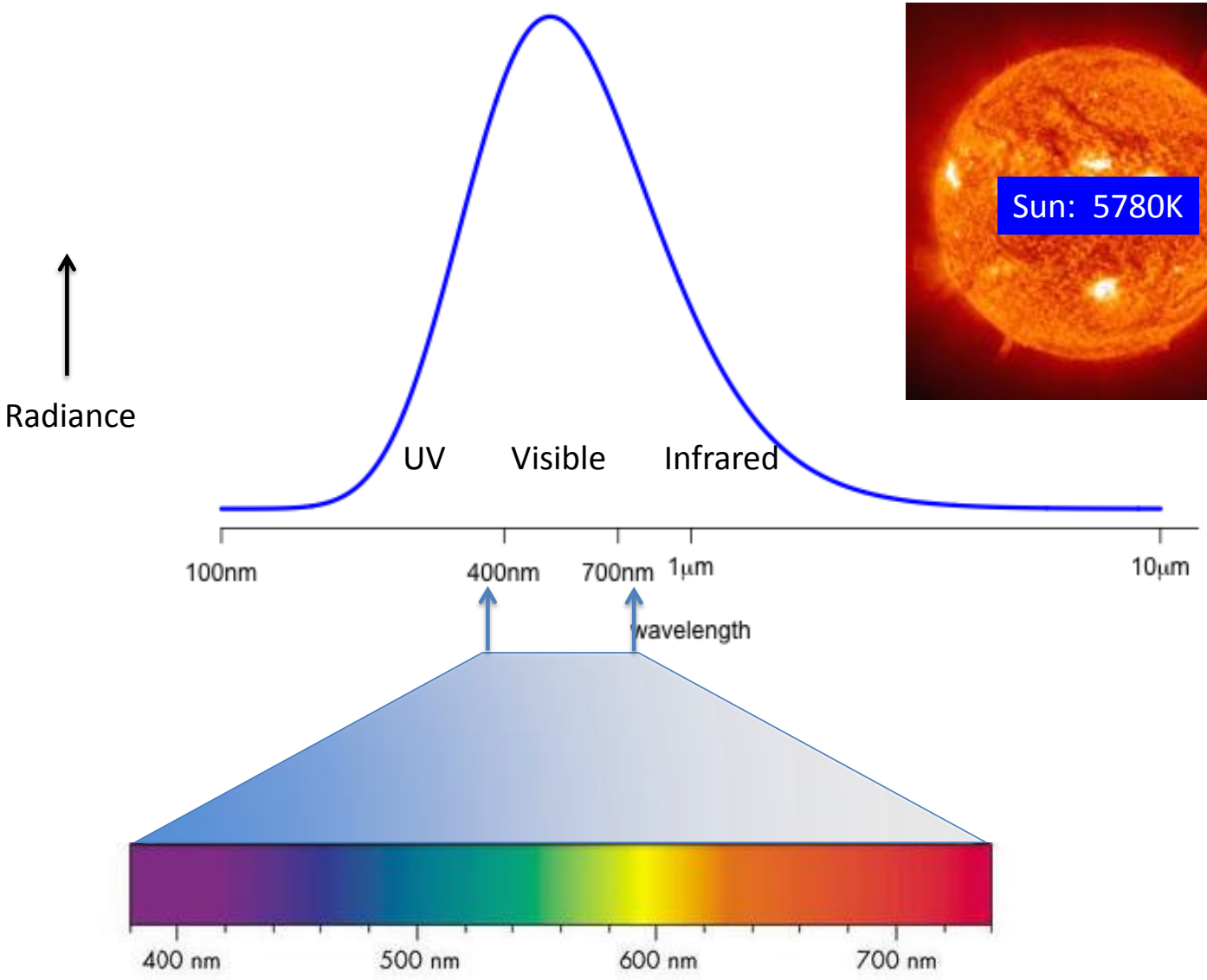
The Electromagnetic Spectrum



Courtesy of A. Jacobson, NOAA

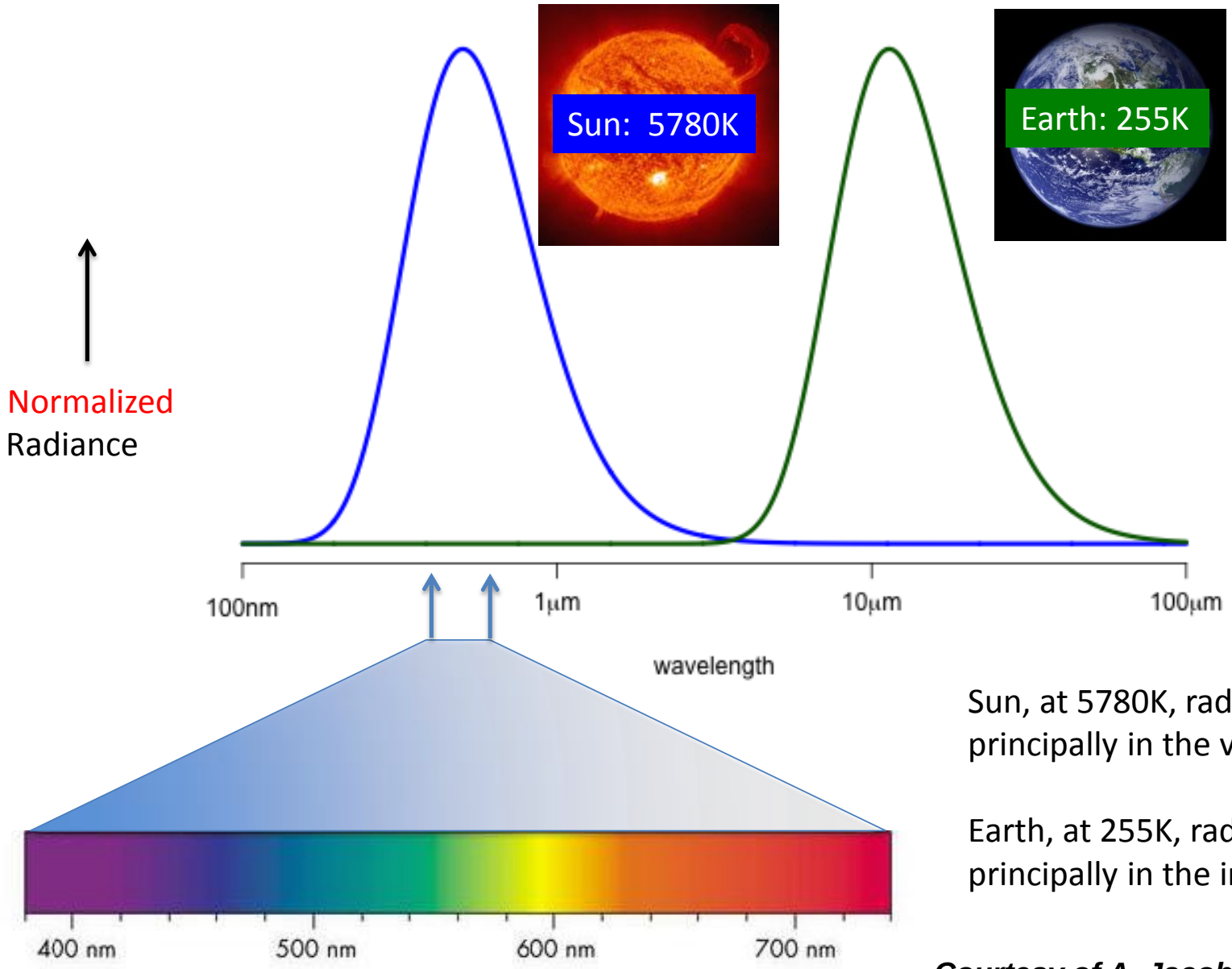
GREENHOUSE EFFECT?





Courtesy of A. Jacobson, NOAA

GREENHOUSE EFFECT?



Sun, at 5780K, radiates principally in the visible.

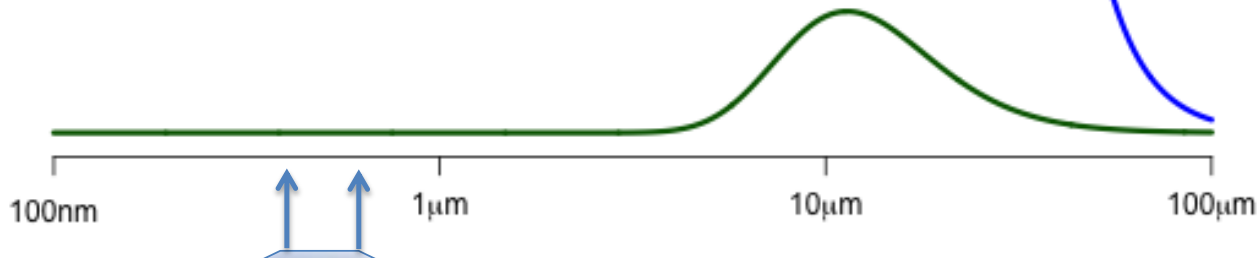
Earth, at 255K, radiates principally in the infrared.

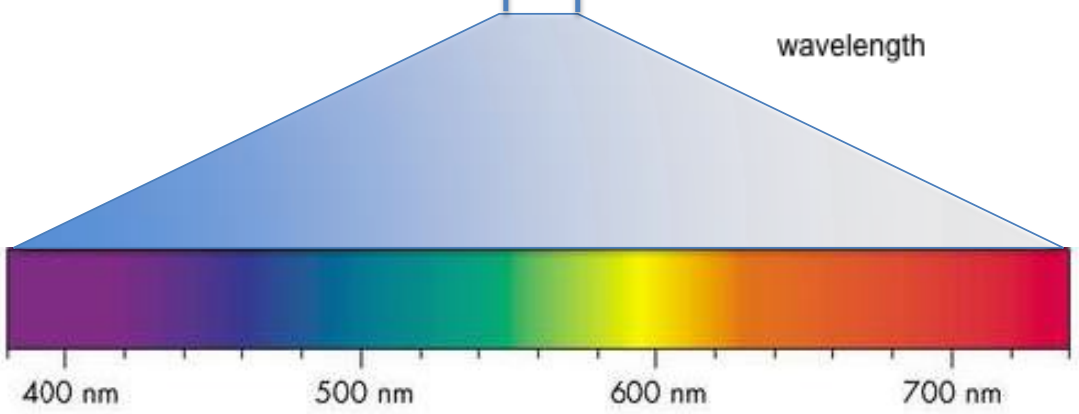
Courtesy of A. Jacobson, NOAA

GREENHOUSE EFFECT?

Peak radiance of sun ~ 6,000,000 x that of Earth

Non-normalized
Radiance





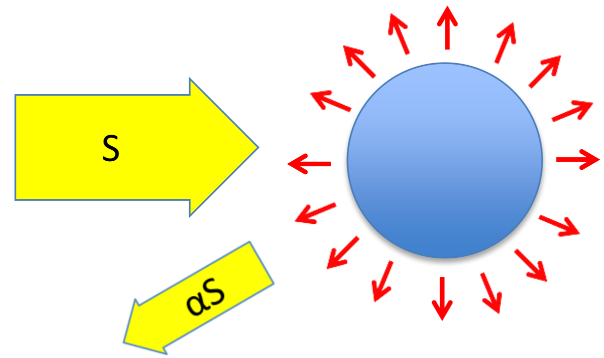
$E_{out} = \sigma T^4$

Stefan-Boltzmann Law: total power output (integrated across all wavelengths)

Courtesy of A. Jacobson, NOAA

GREENHOUSE EFFECT?

Planetary energy balance:
energy in = energy out



$E_{in} = (1-\alpha)\ S\ \pi R^2$

$E_{out} = 4\pi R^2\ \sigma T_E^{\ 4}$

$E_{in} = E_{out}$

α albedo of the Earth, 0.3
S solar flux at Earth, 1370 W m^{-2}
R radius of the Earth
σ Stefan-Boltzmann constant, 5.67 x 10^{-8} W $m^{-2}K^{-4}$
T_E effective Earth surface temperature, K

$$T_E = \left[\frac{(1-\alpha)\ S}{4\sigma}\right]^{1/4} = 255K\ :\ -0.4°F$$ ← below freezing!

Courtesy of A. Jacobson, NOAA

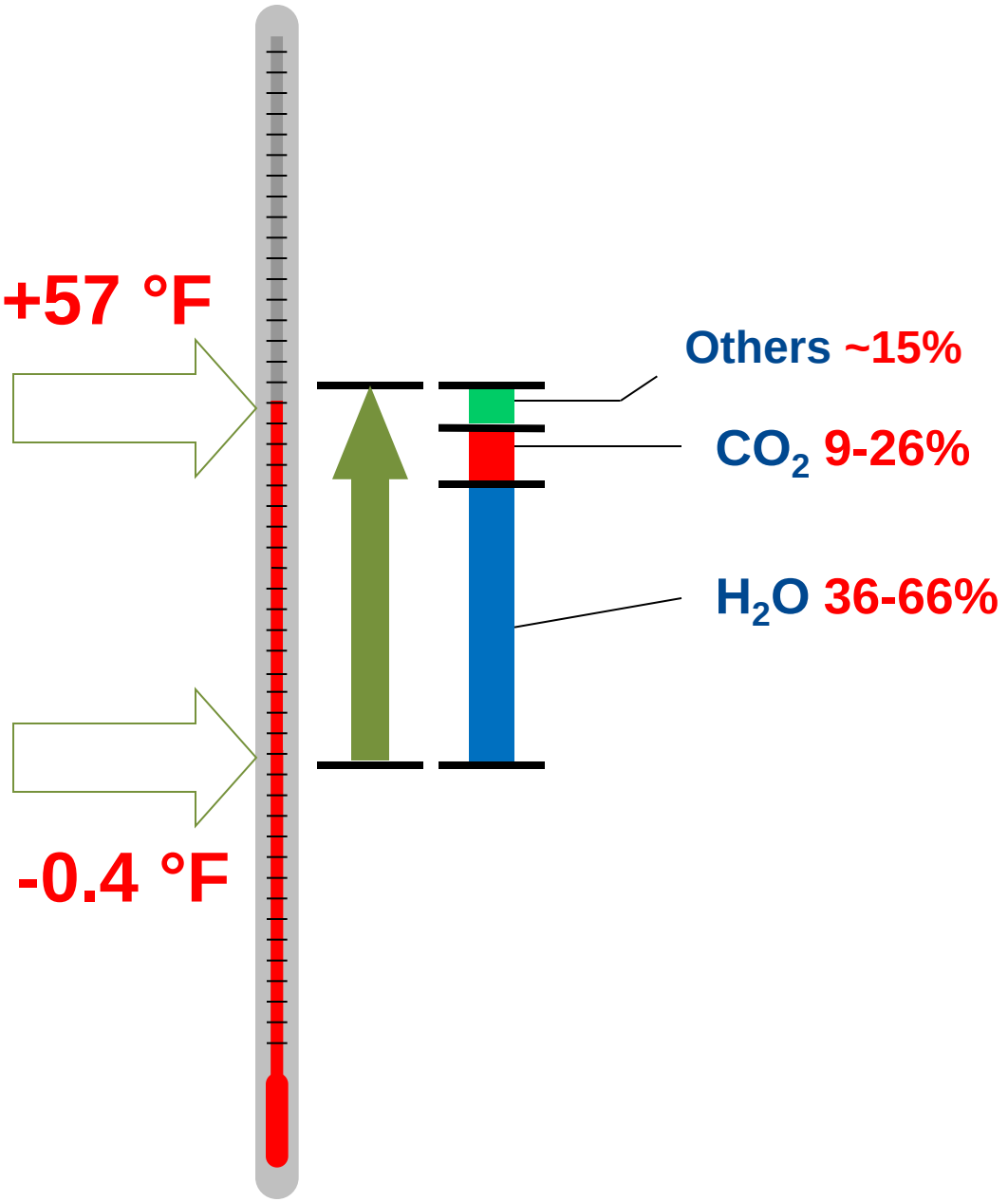
GREENHOUSE EFFECT?

Average Surface Temperature

+57 °F

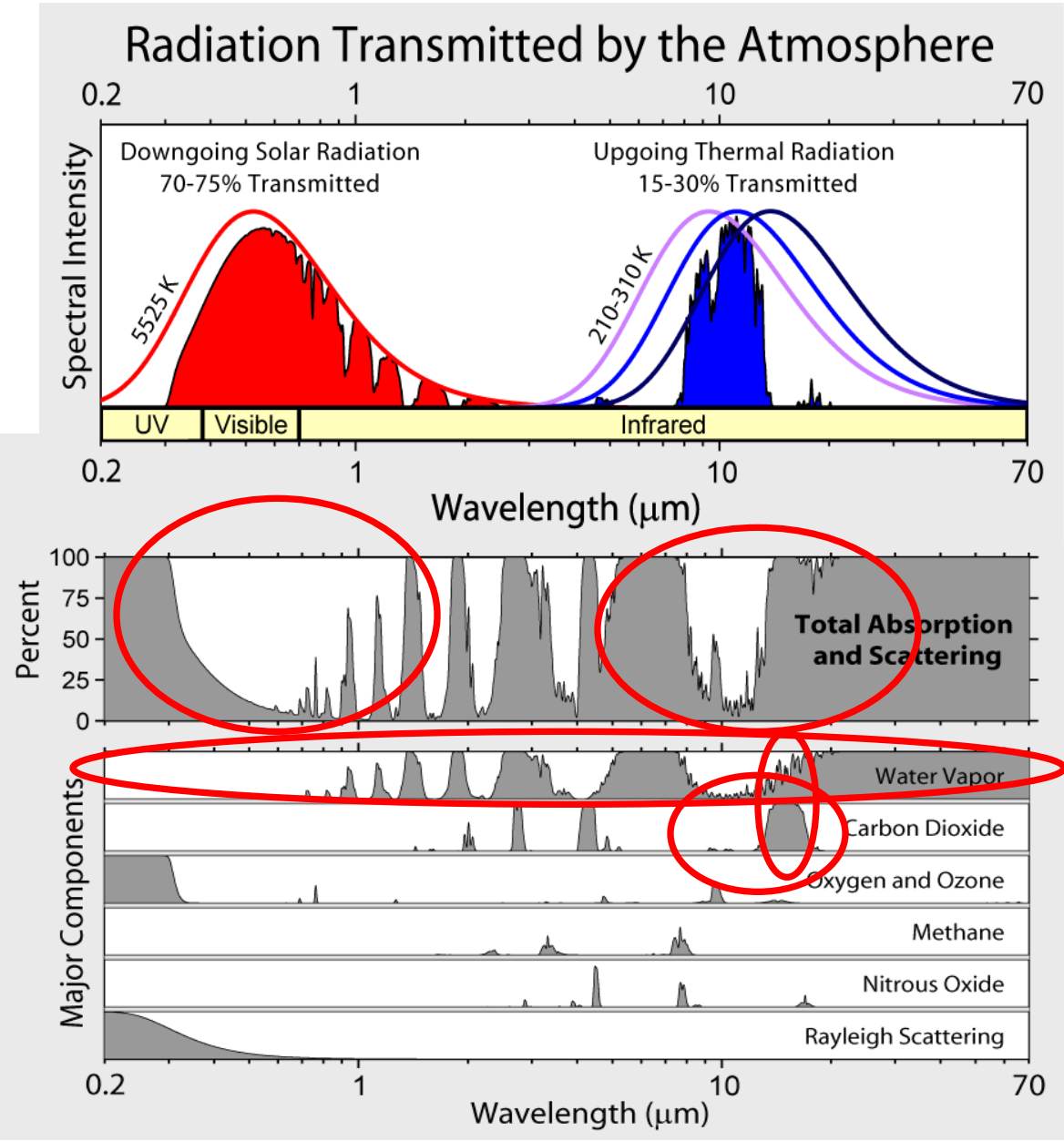
Temperature without greenhouse effect

-0.4 °F



Greenhouse effect?

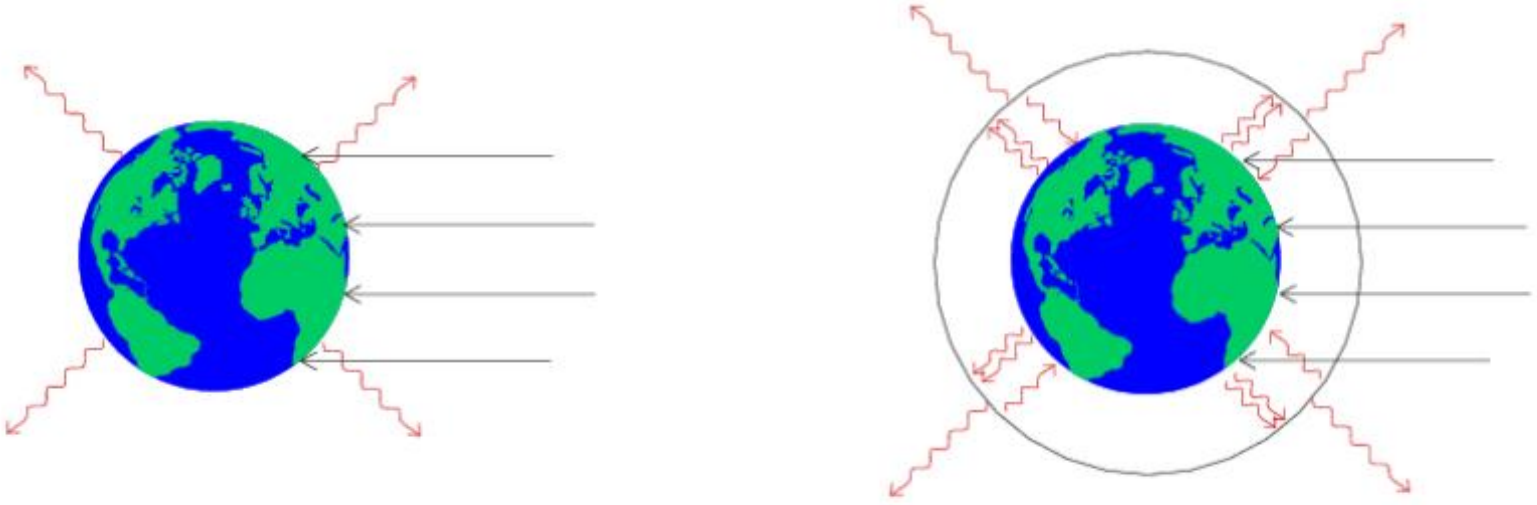
- More absorption and scattering for outgoing energy
- Water vapor is important
- CO_2 absorbs only outgoing energy
- Impact of CO_2 greatest in situations with less water vapor (dry, cold)
- Less heat escaping overall.



Harries et al. 2001

http://www.globalwarmingart.com

GREENHOUSE EFFECT?



Planet	Solar flux ($W\ m^{-2}$)	Albedo	Teff (C)	Actual Tsurf (C)	Greenhouse effect (C)
Earth	1370	0.3	-18	15	33
Venus	2613	0.75	-39	427	466
Mars	589	0.15	-56	-53	3

Venus is an example of a runaway greenhouse effect.

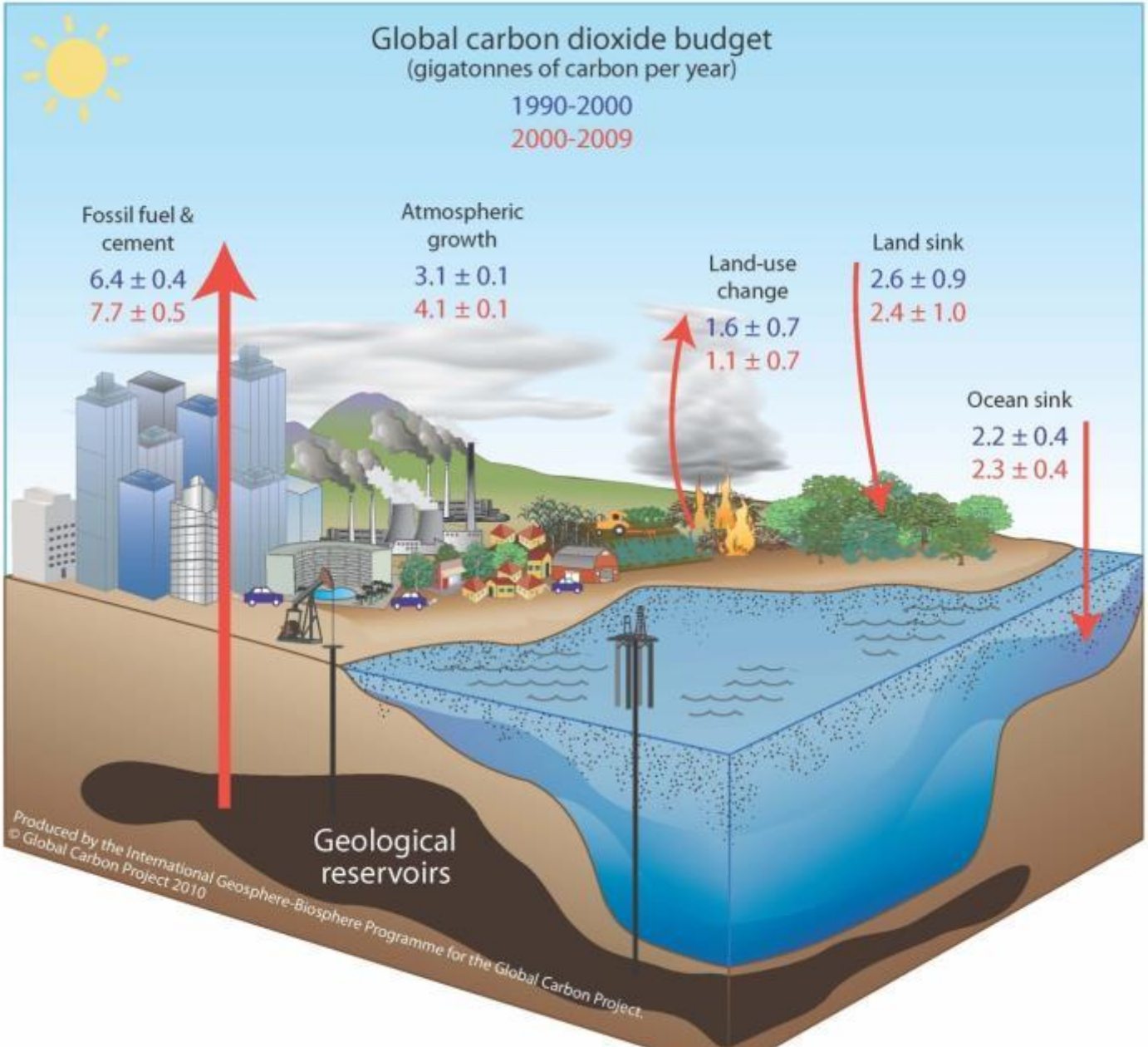
The greenhouse effect hasn't really been proven, has it?

- First suggested by Fourier in 1824, proven by Arrhenius in 1896.
- The fundamental mechanisms are not in question by modern physicists.
- We would be dead without it.

Yes, it has been proven.

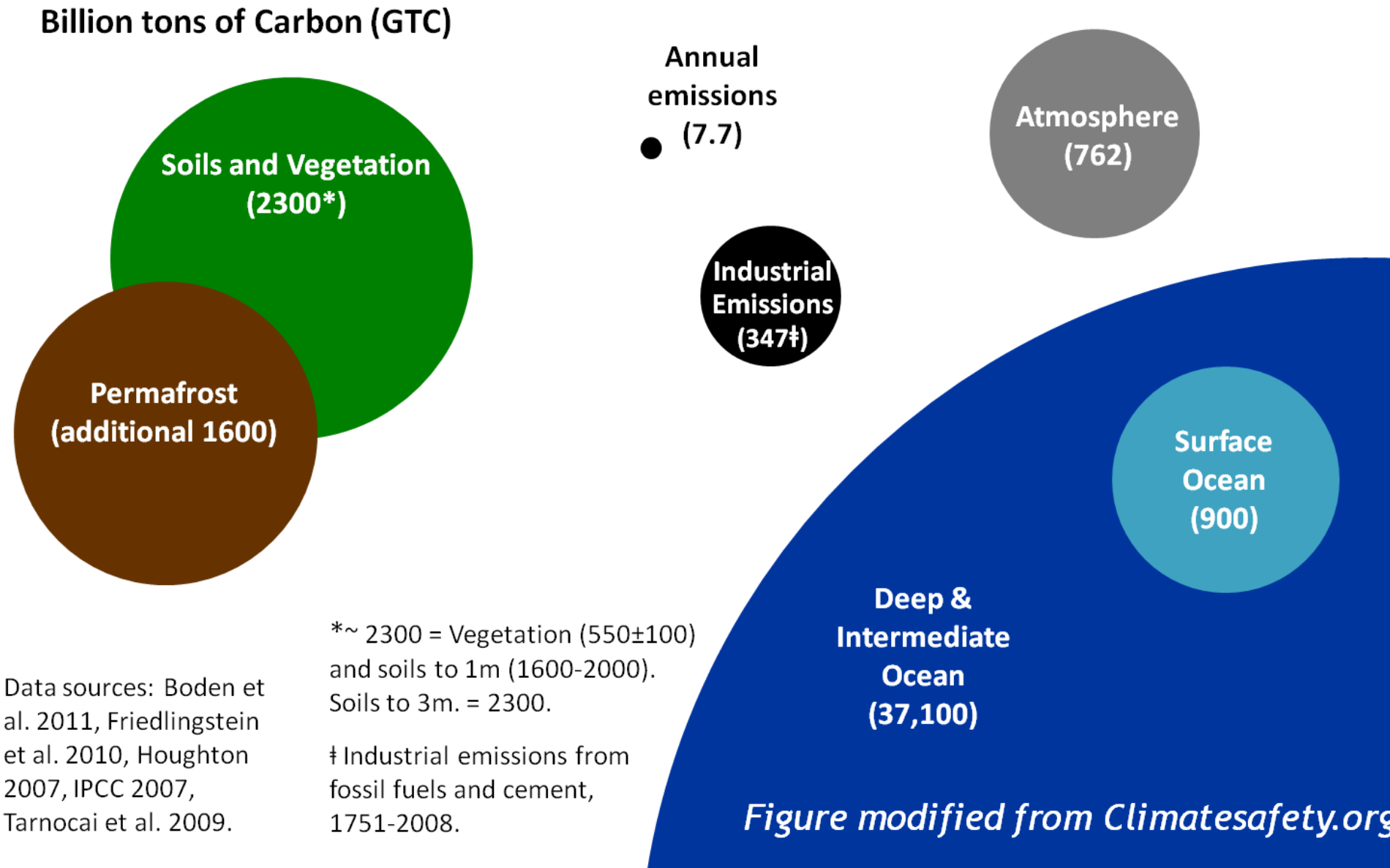
The atmosphere is massive, how can we actually change it?

ANTHROPOGENIC CHANGE?



Net sources and sinks

ANTHROPOGENIC CHANGE?



Data sources: Boden et al. 2011, Friedlingstein et al. 2010, Houghton 2007, IPCC 2007, Tarnocai et al. 2009.

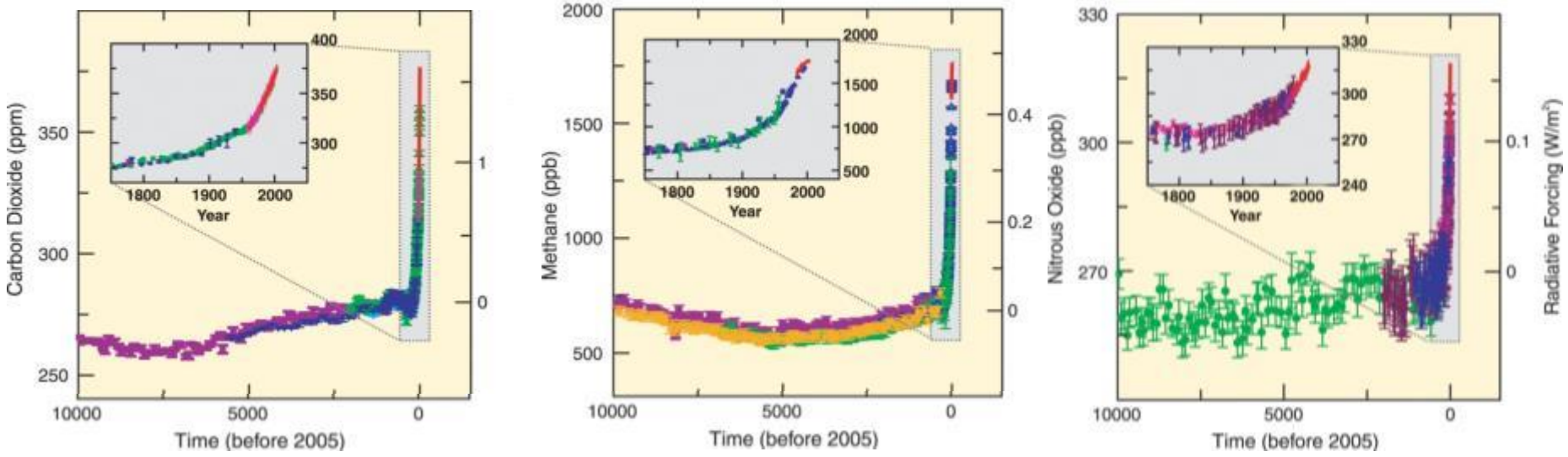
*~ 2300 = Vegetation (550±100) and soils to 1m (1600-2000). Soils to 3m. = 2300.

ǂ Industrial emissions from fossil fuels and cement, 1751-2008.

Figure modified from Climatesafety.org

ANTHROPOGENIC CHANGE?

- Global GHG emissions from human activities increased 70% between 1970-2004
- Emissions of CO_2, the most important anthropogenic GHG, grew about 80% between 1970 and 2004.



IPCC 2007

The atmosphere is massive, how can we change it?

- We move massive amounts of carbon into the atmosphere.
- Fossil carbon is an addition – it has been isolated from the carbon cycle for millions of years.
- Land cover change transfers carbon to the atmosphere.

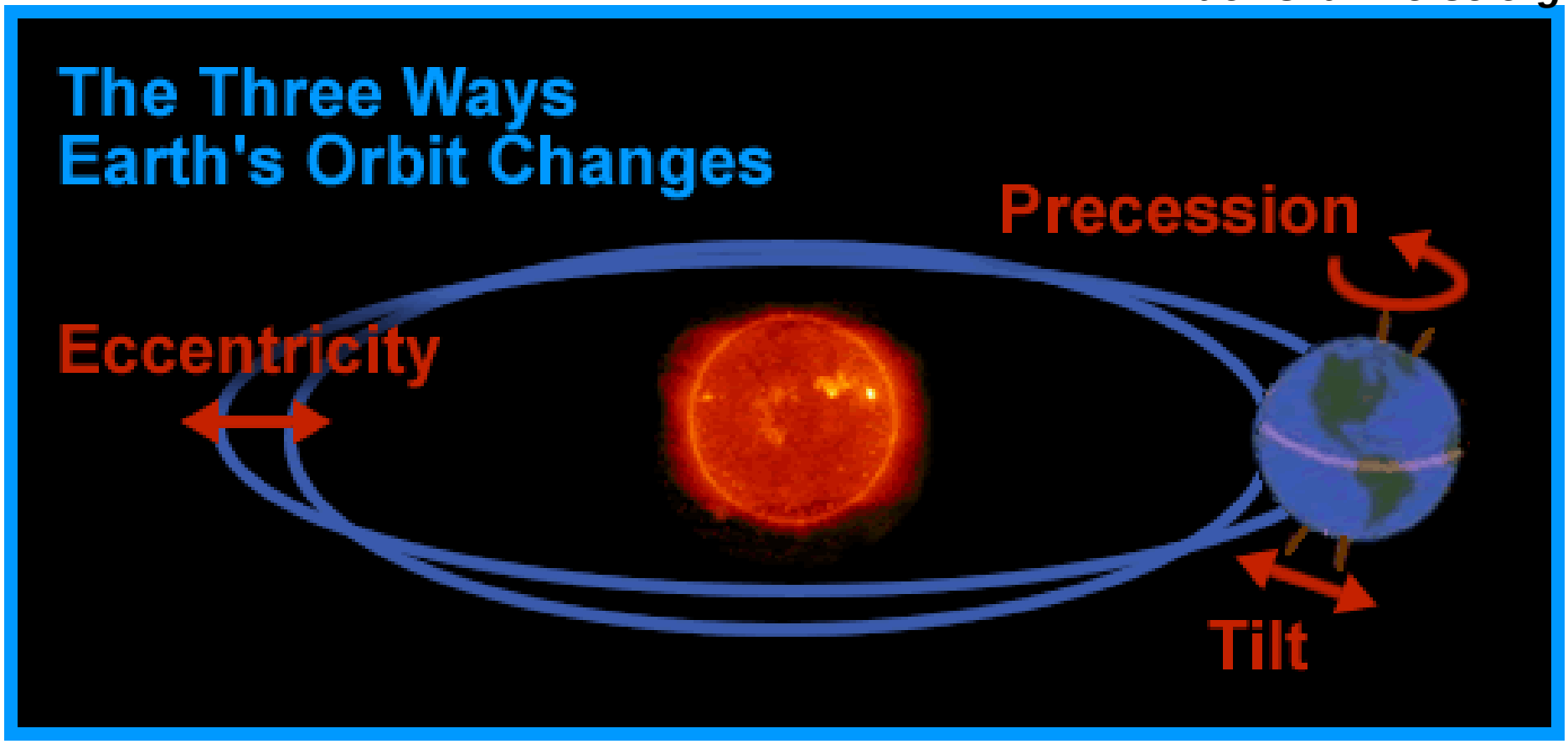
The measurement record clearly shows our additions to the atmosphere.

Hasn’t climate always changed? Why worry now?

CHANGE HAPPENS.

Milankovitch Cycles

www.windows2universe.org

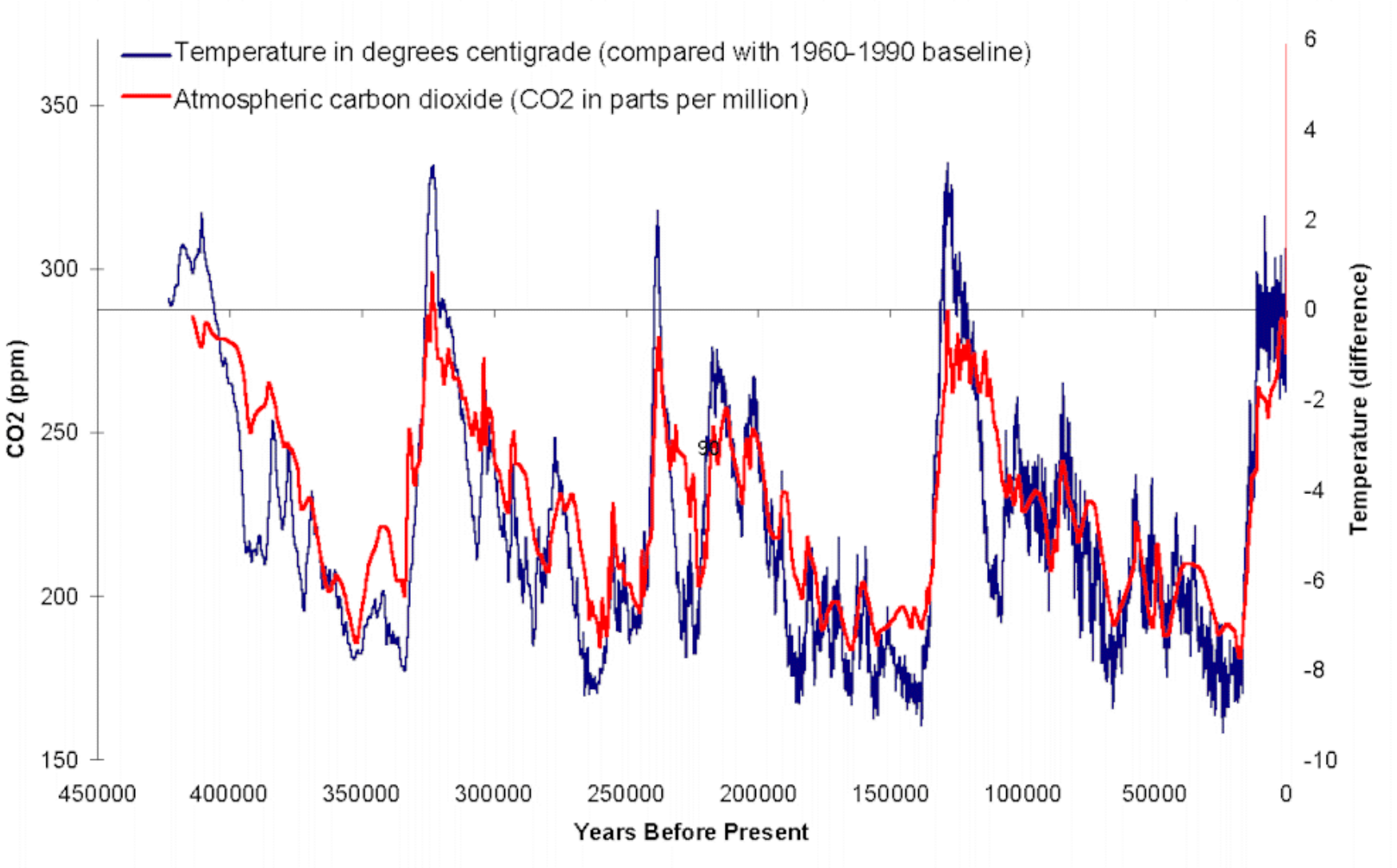


Eccentricity – more or less oval orbit, every ~100,000 years

Precession – earth wobbles on its axis, every ~23,000 years

Tilt – earth shifts its tilt every ~41,000 years

CHANGE HAPPENS.

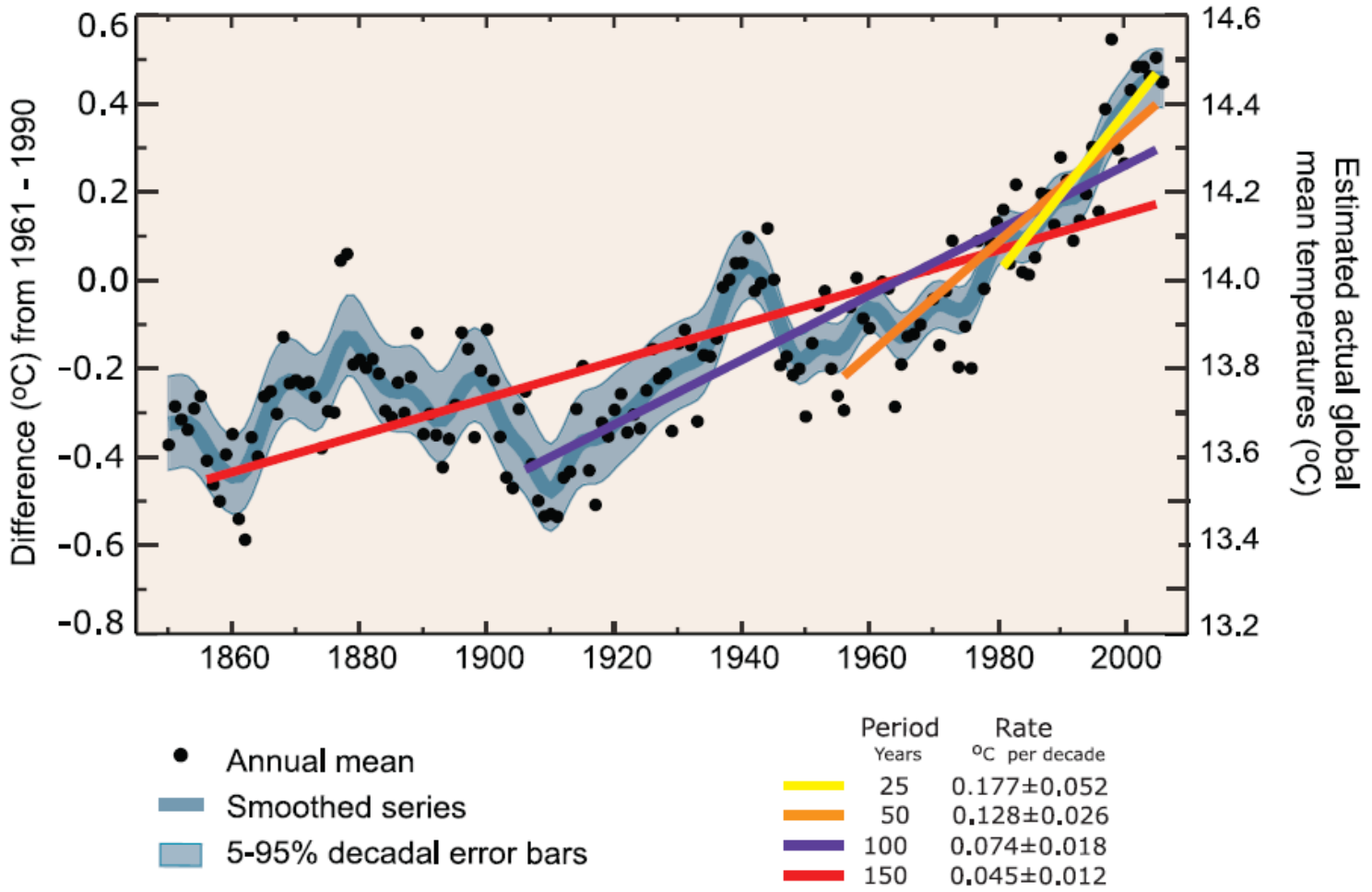


http://www.brighton73.freeserve.co.uk/gw/paleo/400000yrfig.htm;

see also: Hansen et al. 1990, Petit et al. 1999, Shackleton 2000, Ruddiman 2006, Shakun et al. 2012

CHANGE HAPPENS.

The average global surface temperature has risen 1.4 ºF over the past 100 years



IPCC 2007

Hasn't the climate always changed? Why worry now?

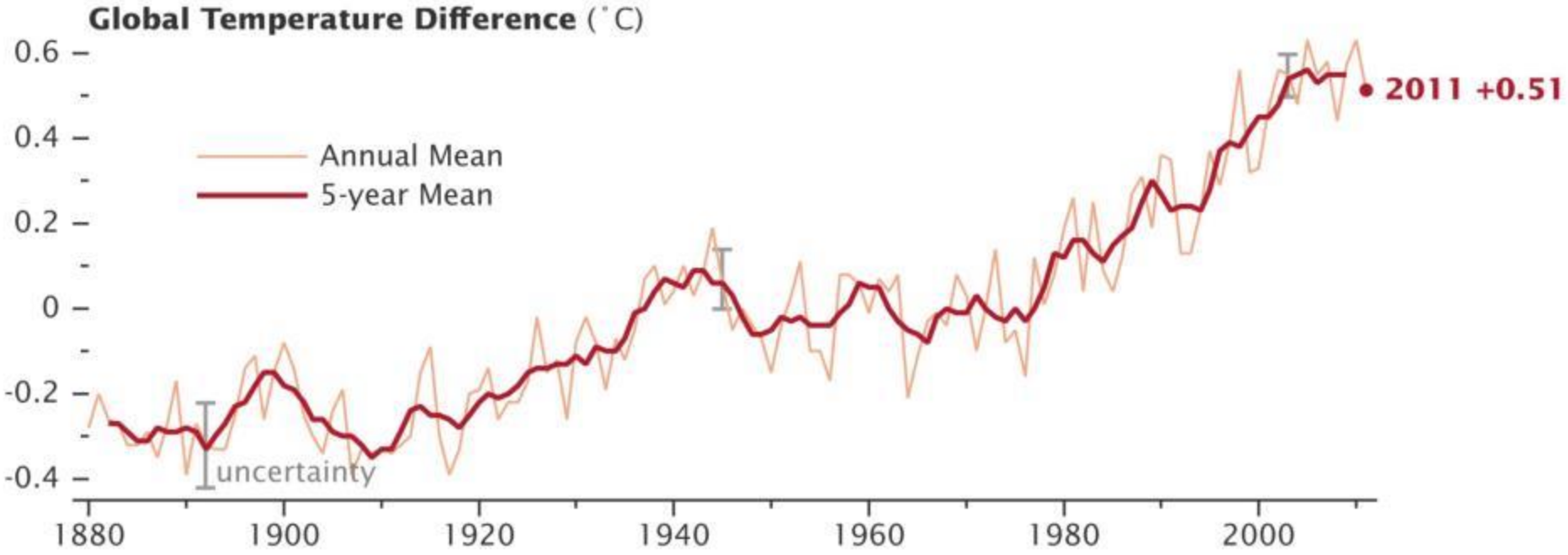
- Milankovitch cycles have previously driven climate changes.
- Humans are driving the current change.
- The change is very rapid.

The rapidity and potential severity of climate change will affect forestry, agriculture, infrastructure, demographics, economies, … virtually everything.

Hasn’t the climate stopped changing in the last 15 years?

ARE WE DONE YET?

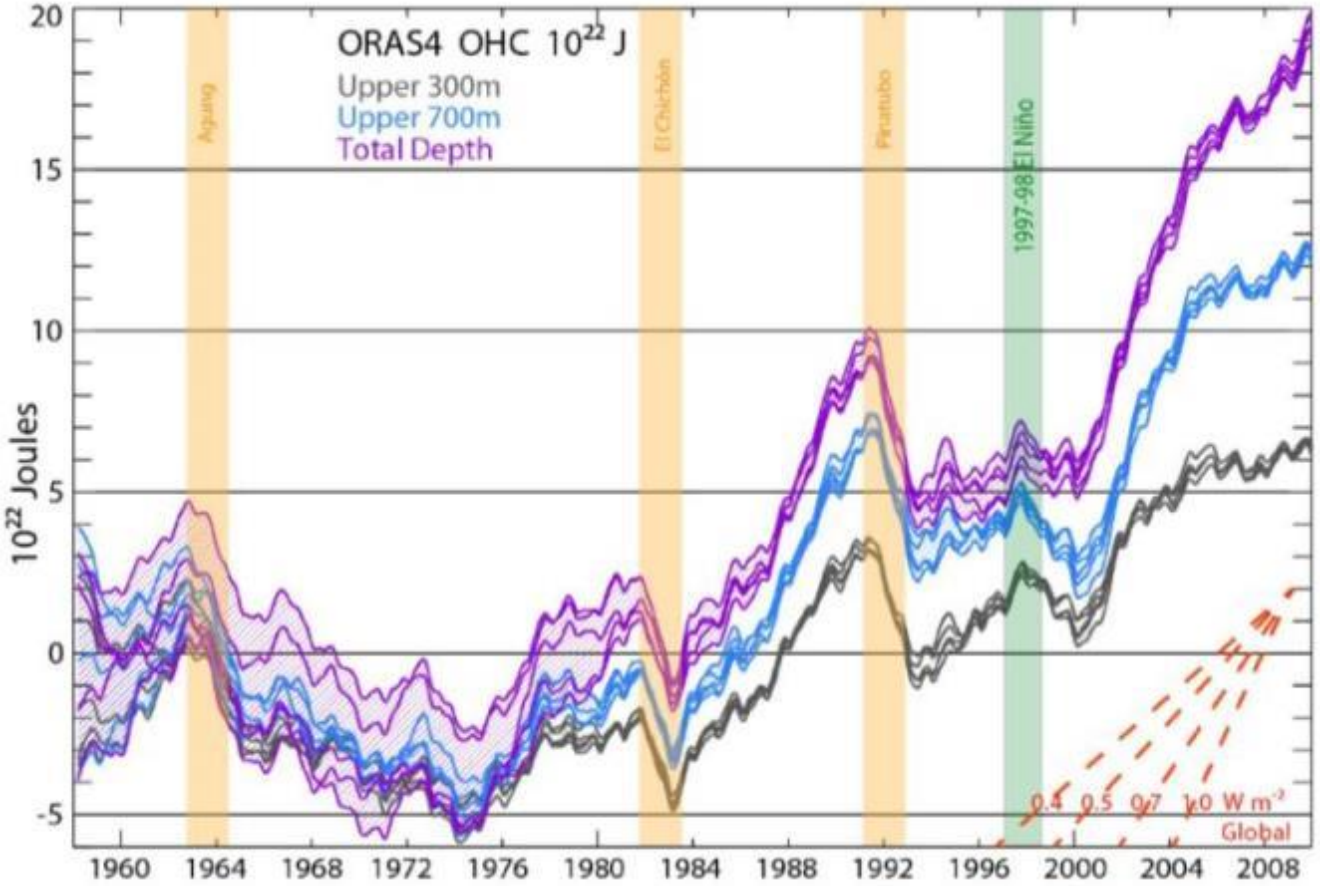
Recent years - La Niña, lower solar activity, and sulfate aerosols have reduced the rate of warming in surface air…



NASA GISS; NASA Earth Observatory, Robert Simmon

ARE WE DONE YET?

…but not in oceans – which account for 90-93% of earth system warming since 1955.



Levitus et al. 2012, Balmeseda et al. 2013; see also Guemas et al. 2013

ARE WE DONE YET?

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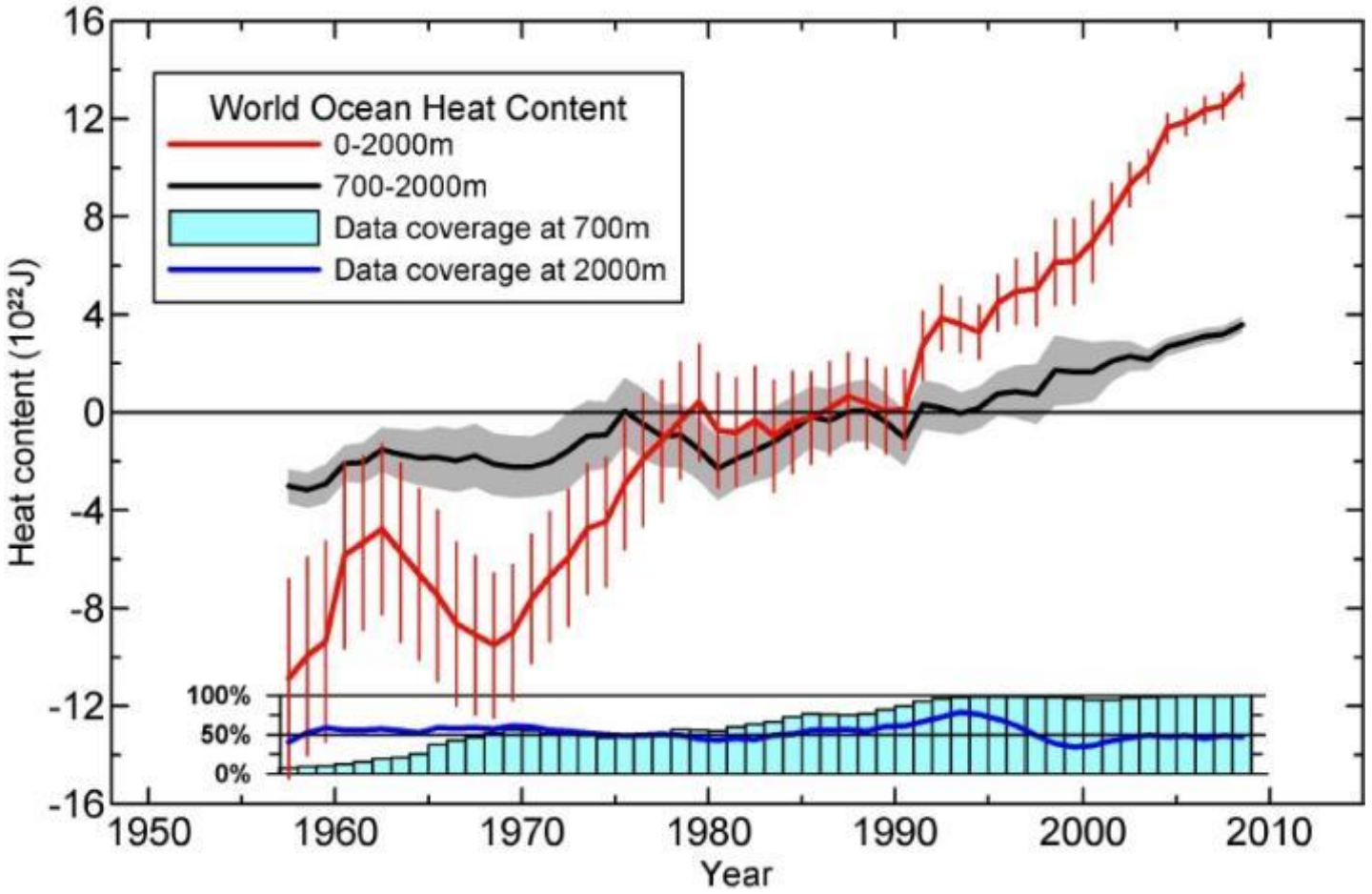


Levitus et al. 2012, Balmeseda et al. 2013; see also Guemas et al. 2013

Hasn't the climate stopped changing in the last 15 years?

- Global surface warming has paused.
- The oceans continue to absorb heat.
- The oceans have absorbed >90% of warming since 1955.

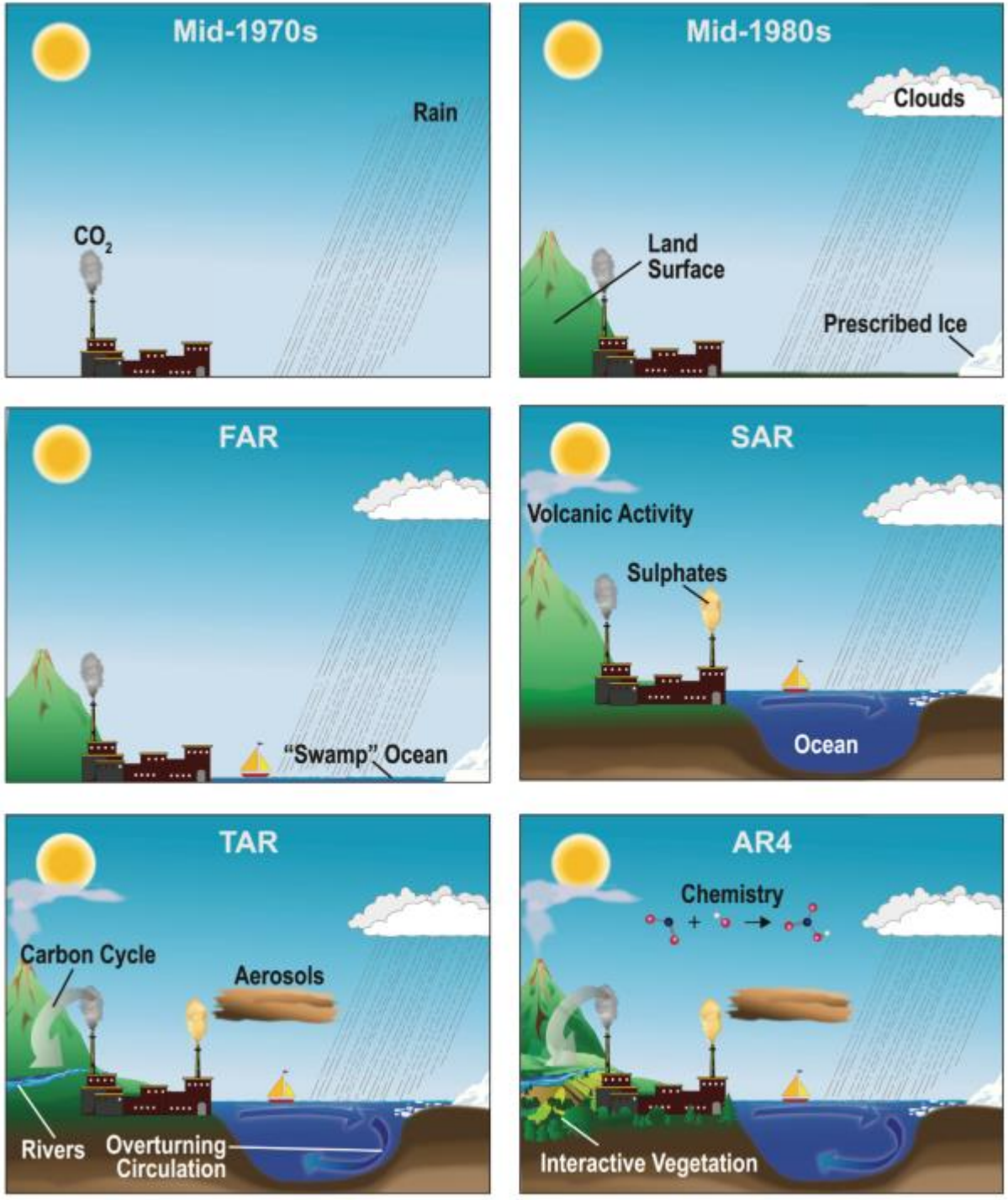
No – the earth is still warming.

I don’t trust climate models.

CLIMATE MODELS?

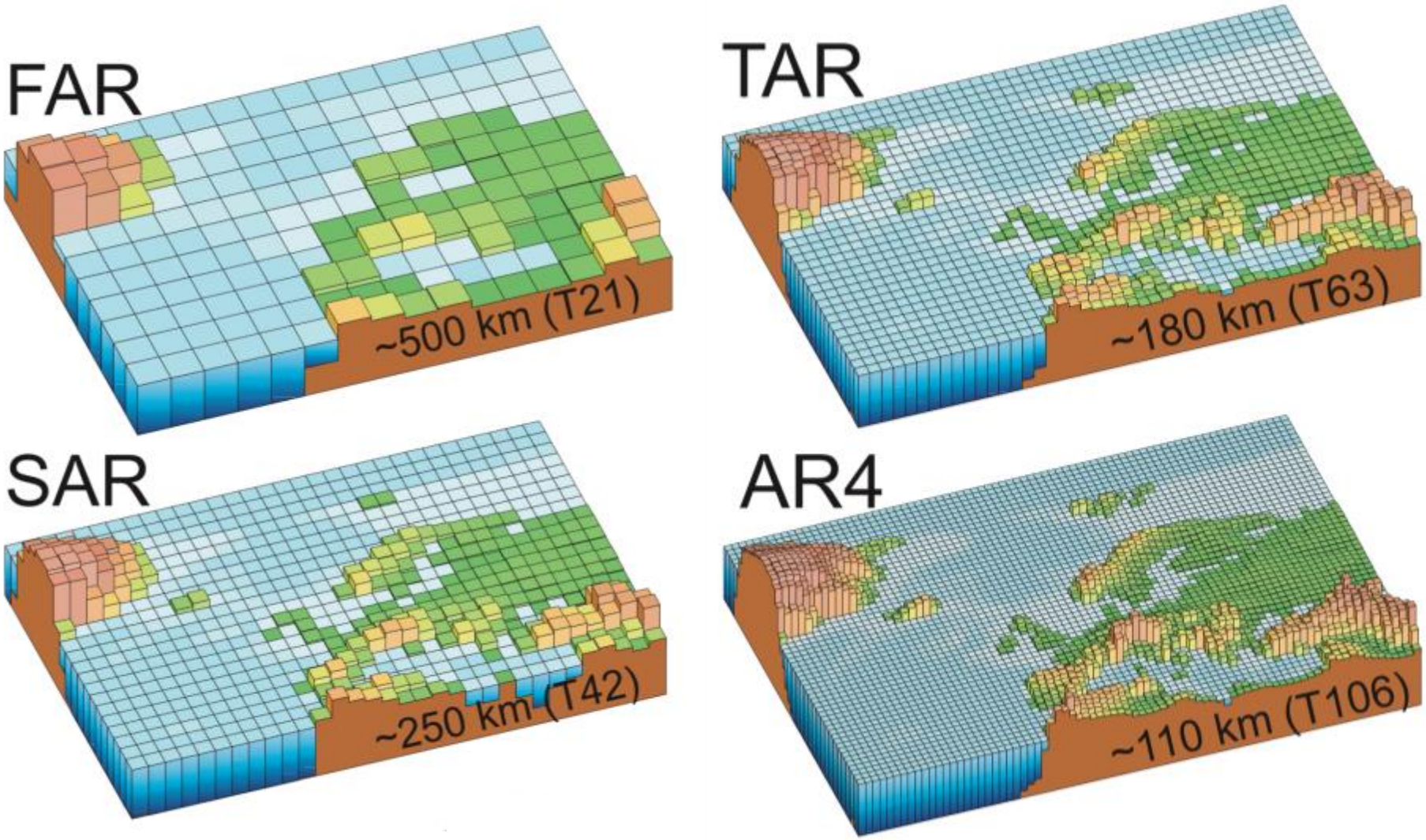
General circulation models

- Greenhouse gases
- Solar radiation
- Volcanic activity
- Clouds
- Atmospheric chemistry
- Ocean chemistry
- Carbon cycle
- Ice
- Randomness



IPCC 2007

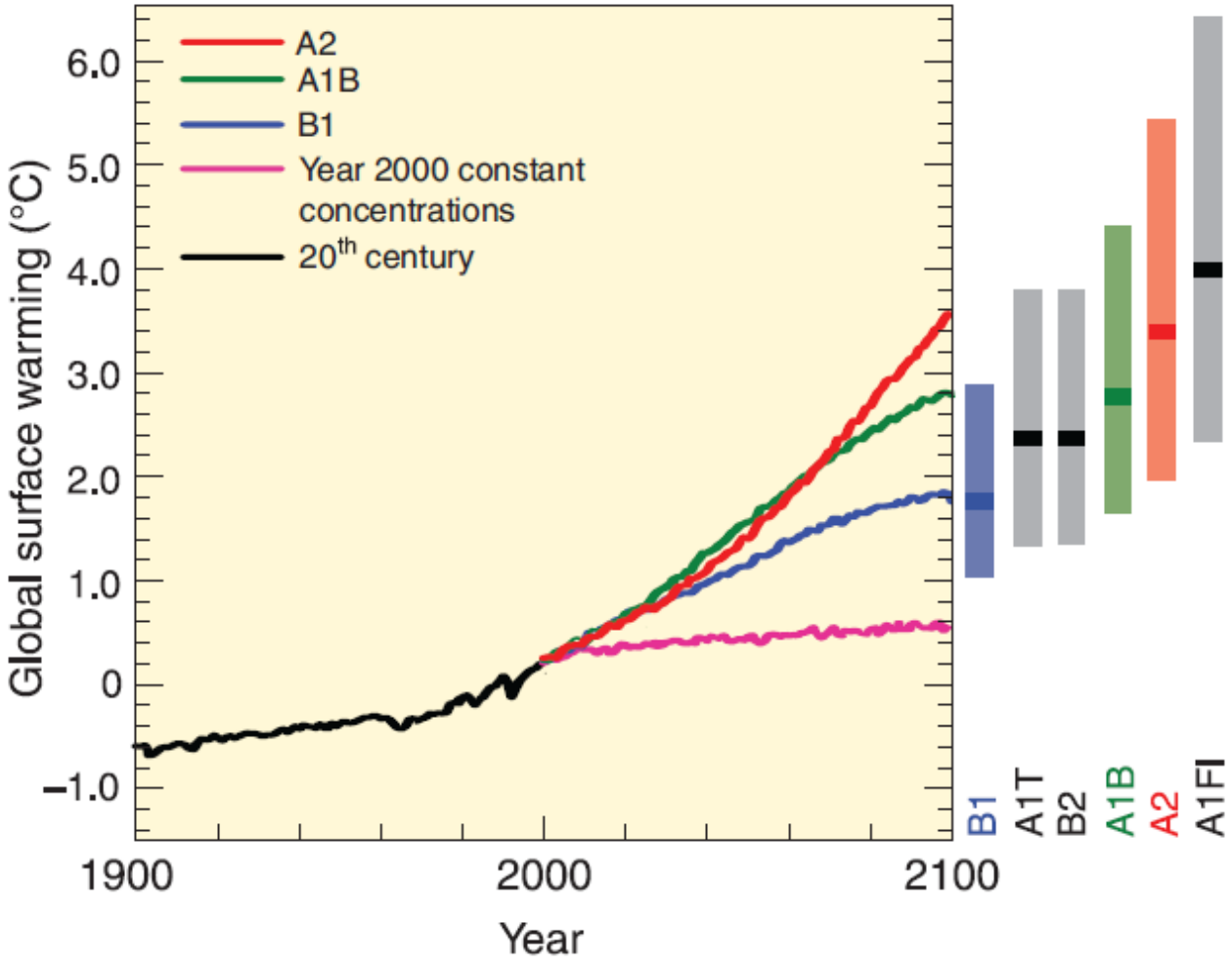
CLIMATE MODELS?



IPCC 2007

CLIMATE MODELS?

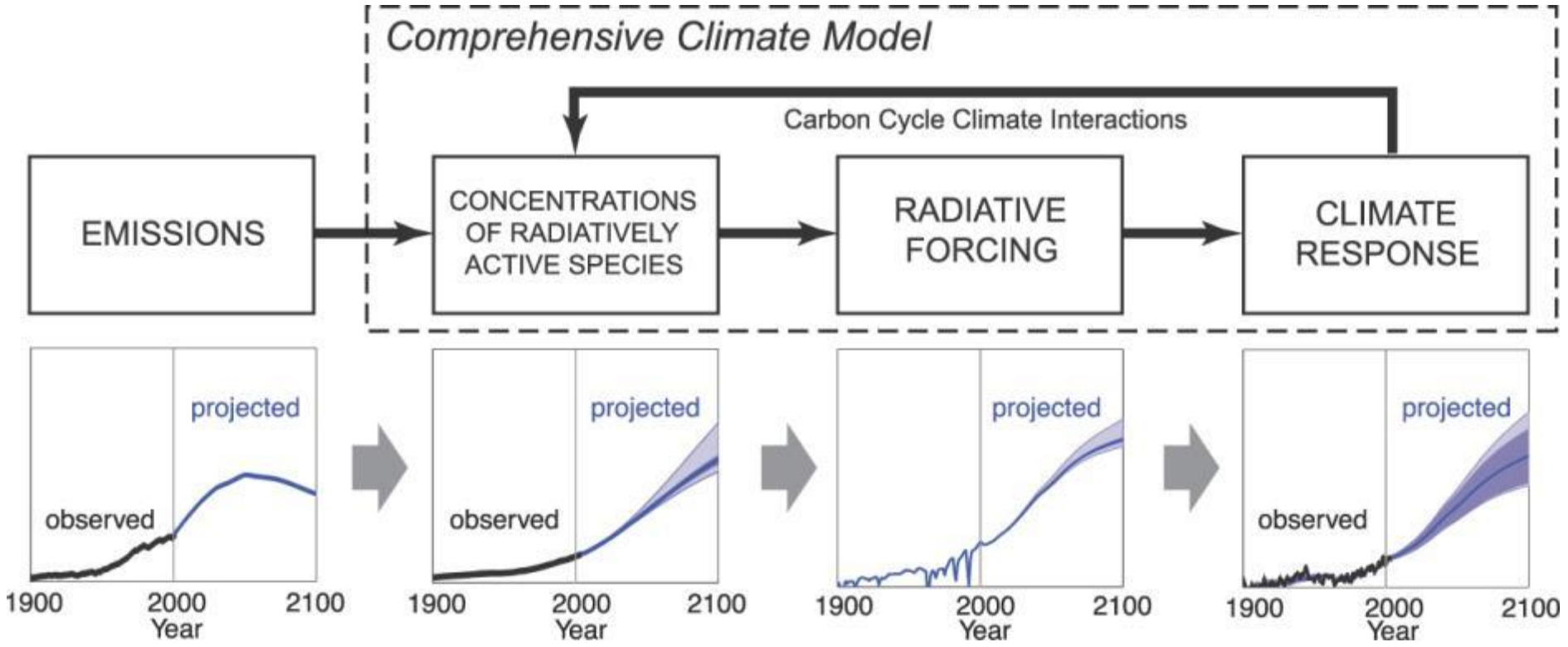
It's also about emissions scenarios….



IPCC 2007

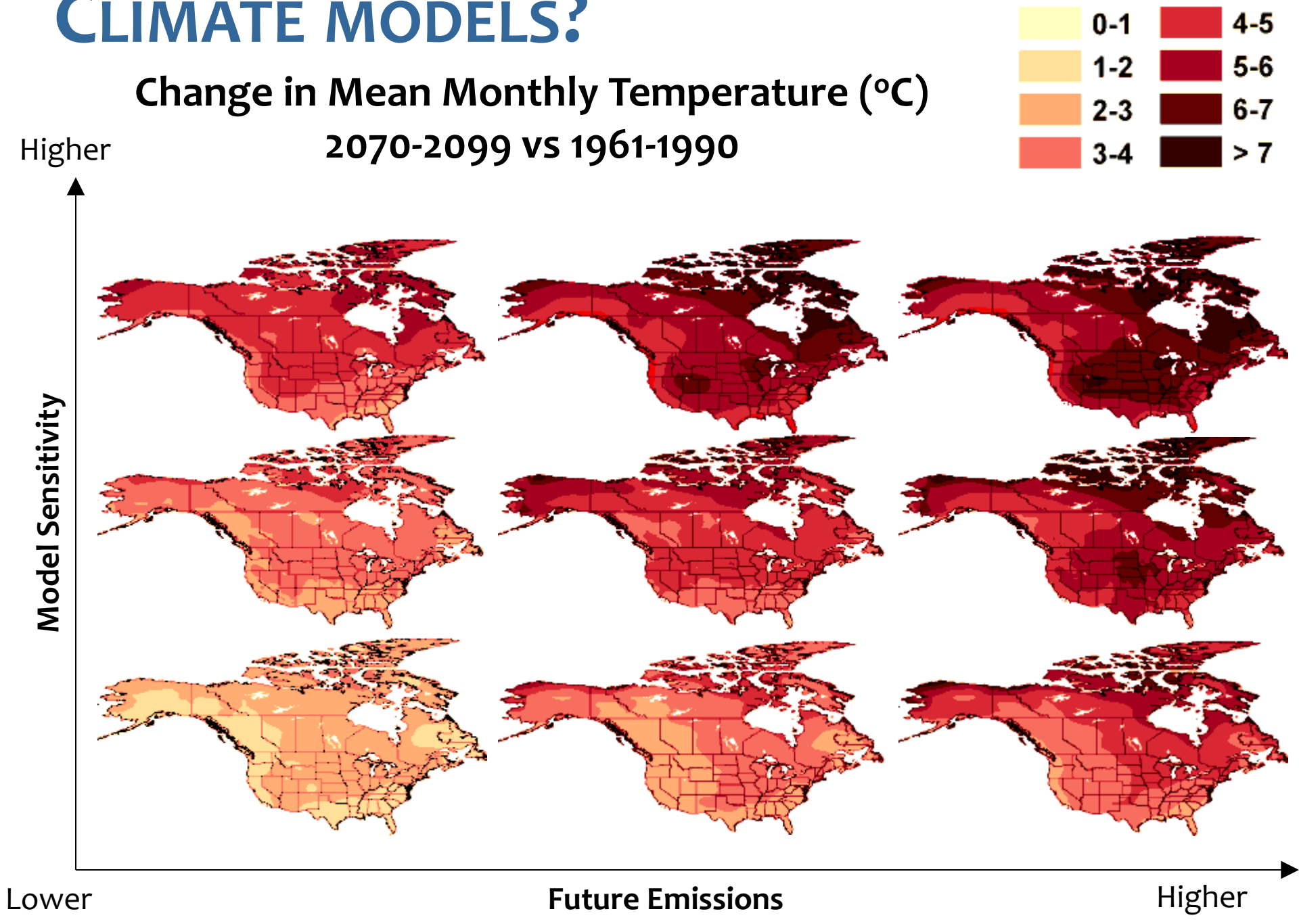
Climate models?

Climate models integrate a variety of information to project future climate:

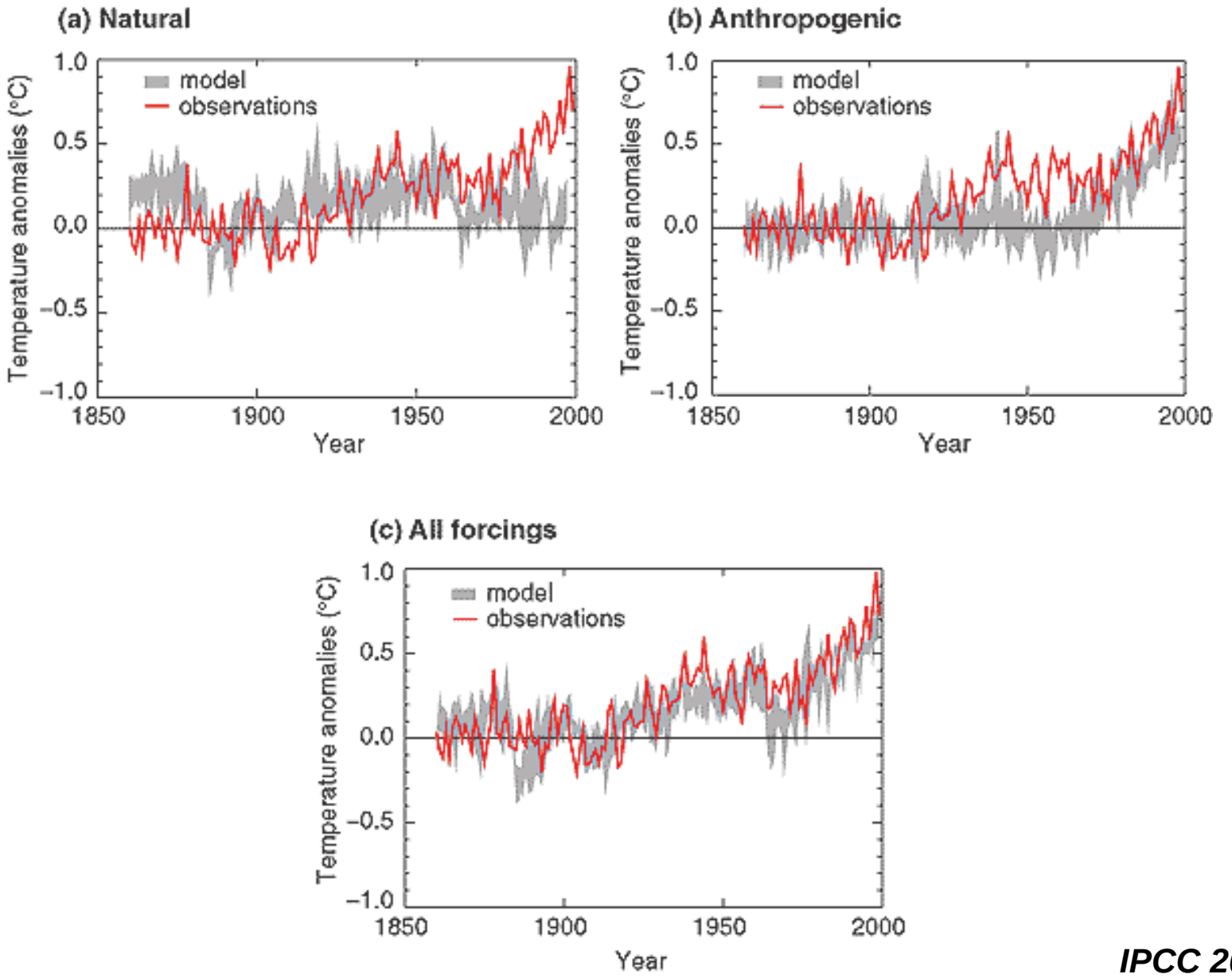


IPCC 2007

CLIMATE MODELS?



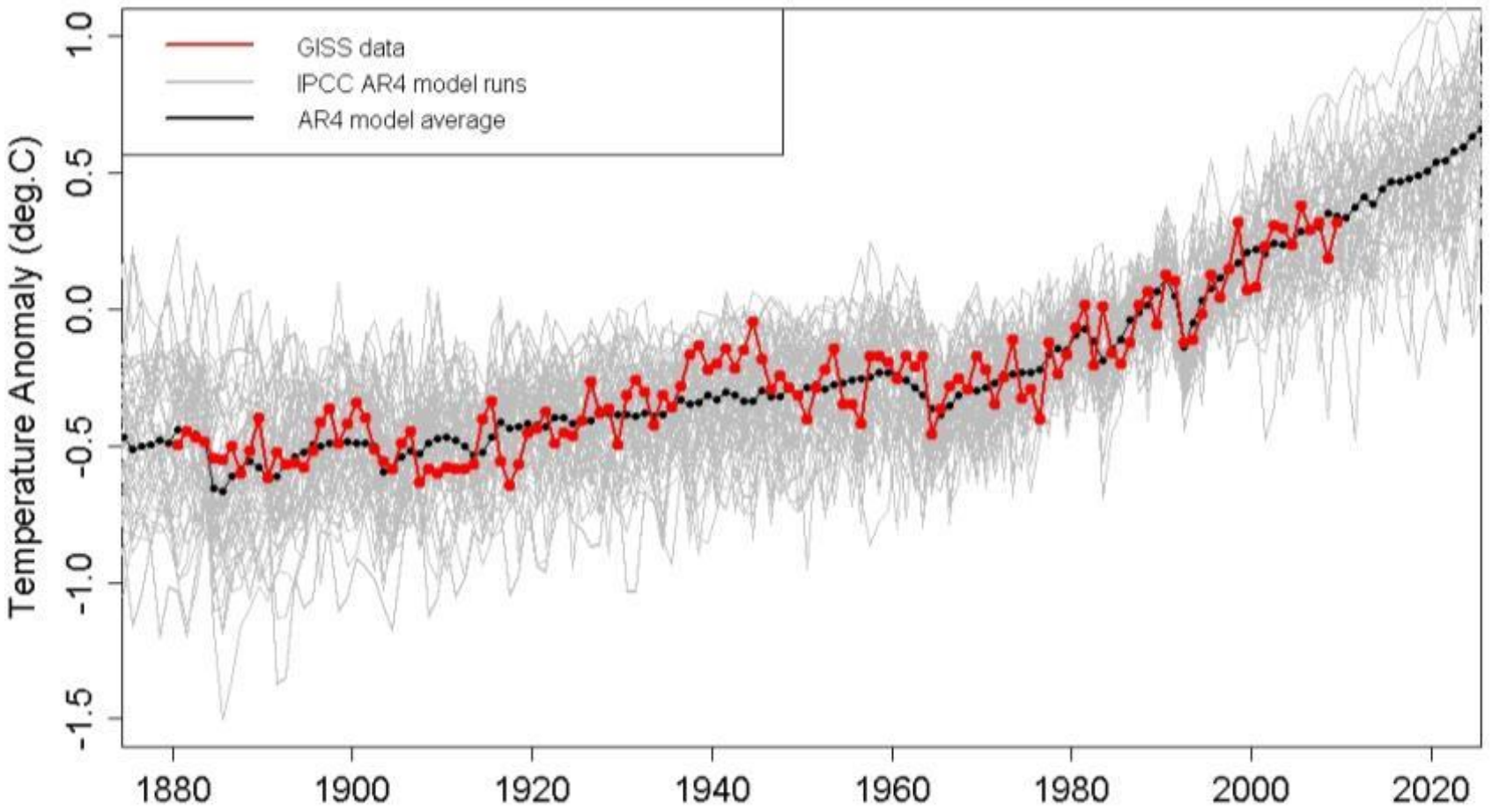
CLIMATE MODELS?



IPCC 2007

CLIMATE MODELS?

From IPCC AR4: 22 models, 106 runs

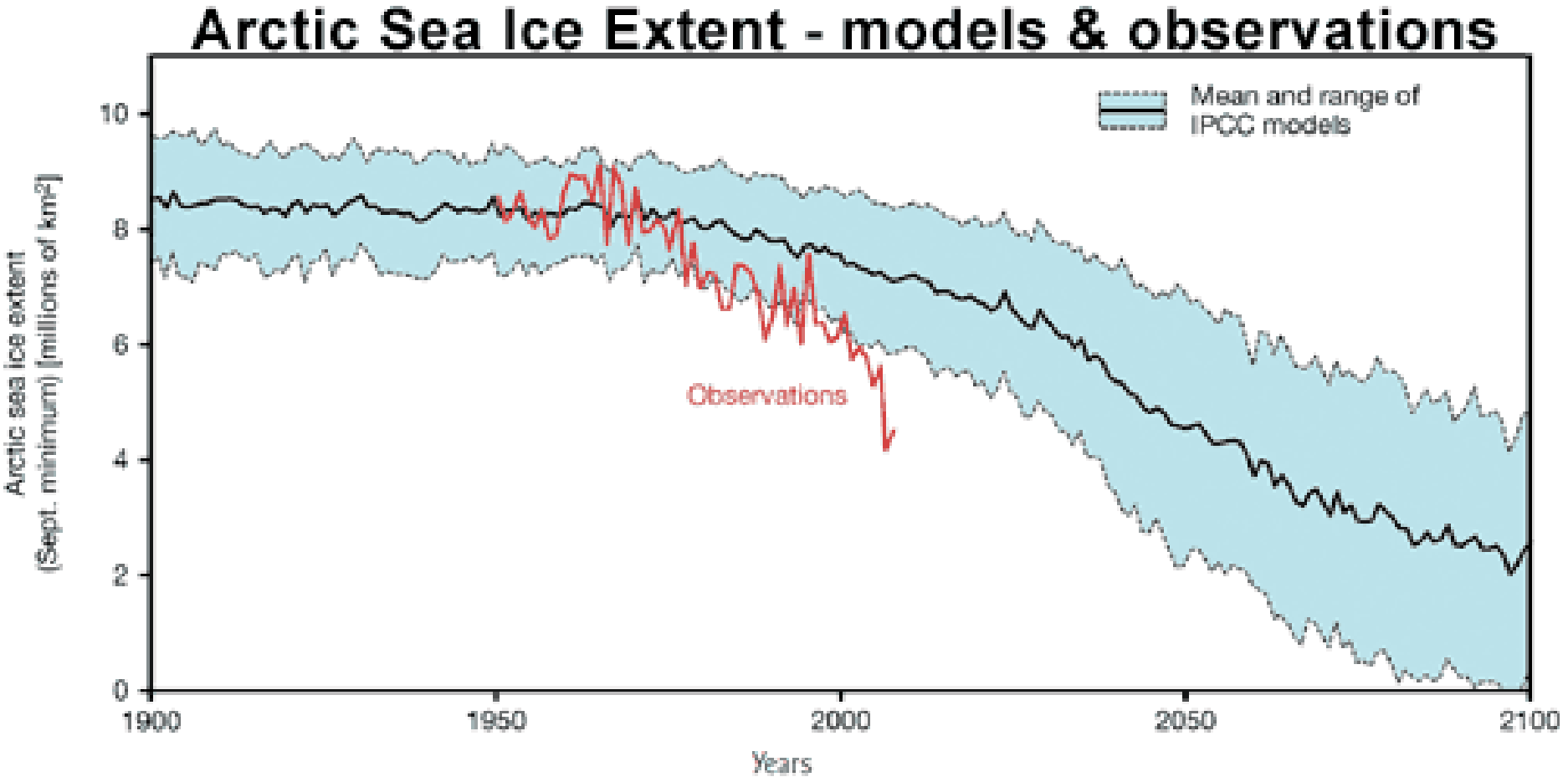


*Omits Canadian CCCMA

Tamino, 2010 (blog: http://tamino.wordpress.com/)

CLIMATE MODELS?

13 IPCC AR4 models

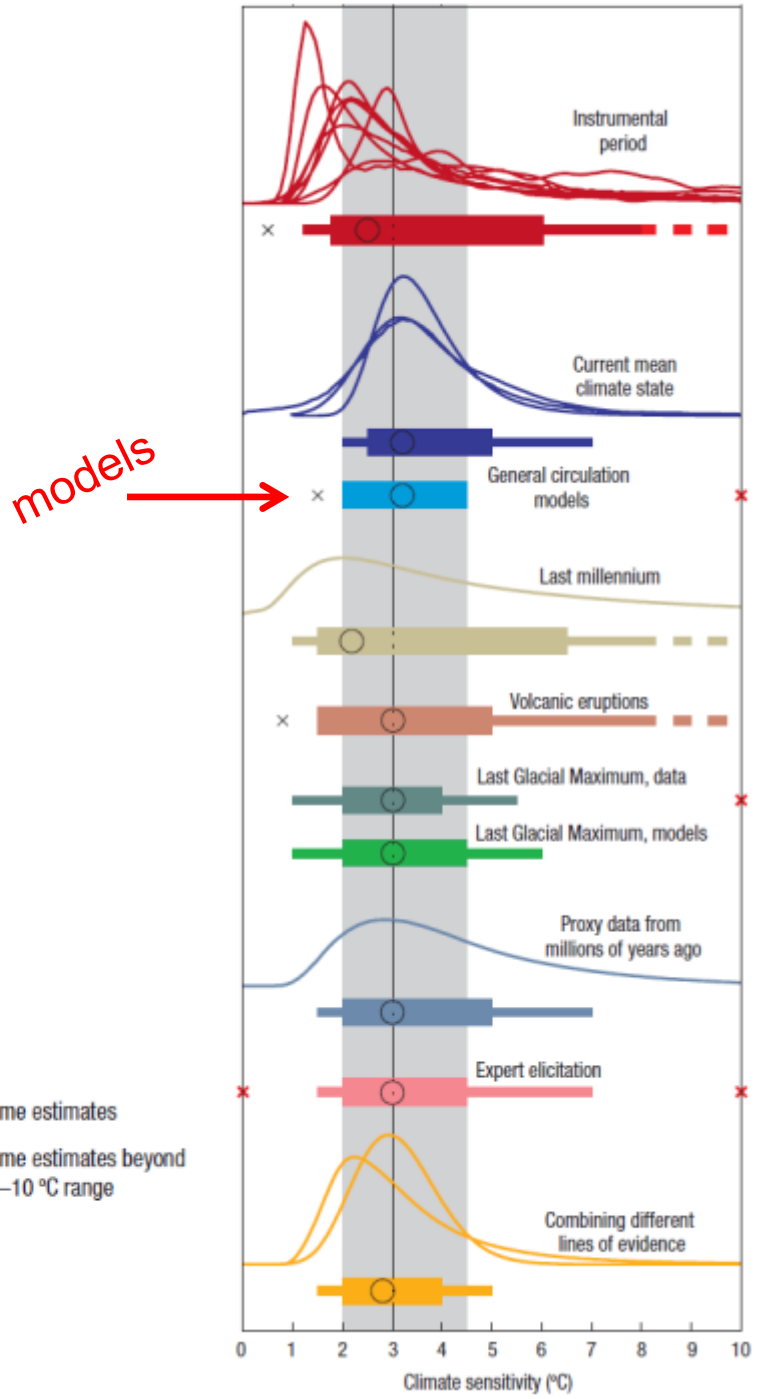


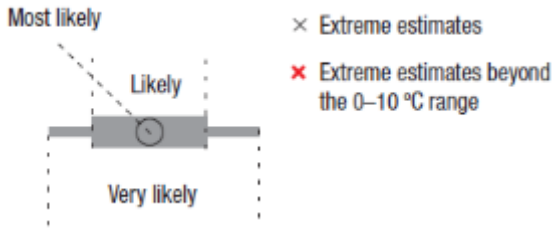
Copenhagen Diagnosis 2009

Climate models?

How do they measure up?

Climate sensitivity = how much the climate will warm with a doubling of CO_2.





Knutti and Hegerl 2008

I don't trust climate models.

- That's okay; they have acknowledged shortcomings.
- They do well globally with air temps, but will likely never be "good enough" at a management scale.
- Emissions uncertainties are inherent.

All models are wrong, some are useful – best to use multiple models and consider a range of futures.

Will you ever stop talking?

SUMMARY

Climate

- overwhelming evidence for change, from thousands of sources

  → old news

Uncertainty

- it's inherent in climate projections, and this will not change

  → we'll always have a **range** of plausible futures

Scale

- sub-regional projections will often vary from global projections

  → longer time horizons at finer scales will have greater uncertainty.

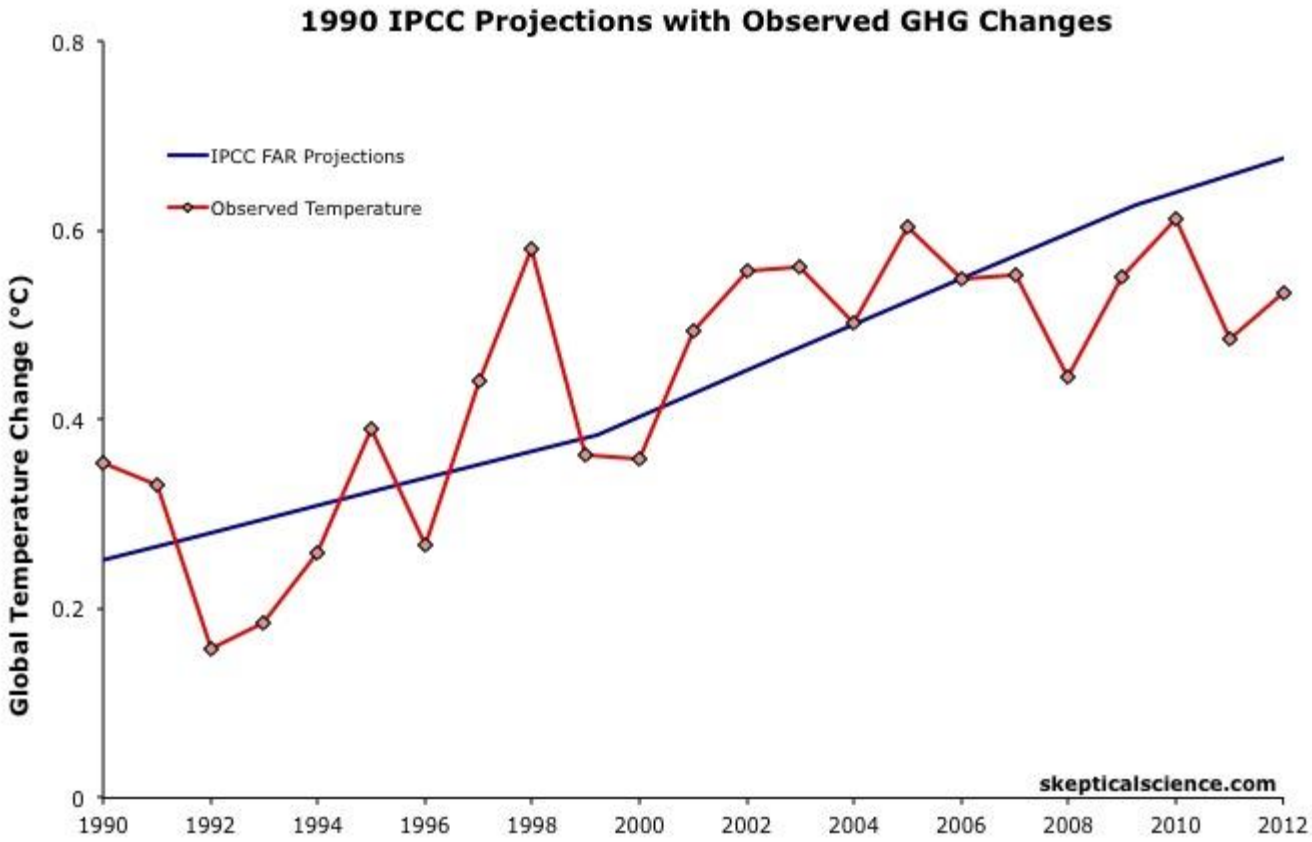
Thank you!

Chris Swanston
cswanston@fs.fed.us

Climate models?

How well have they done?

Actual warming 1990-1012 = 0.15 ± 0.08 °C
Projected warming 0.2 °C per decade



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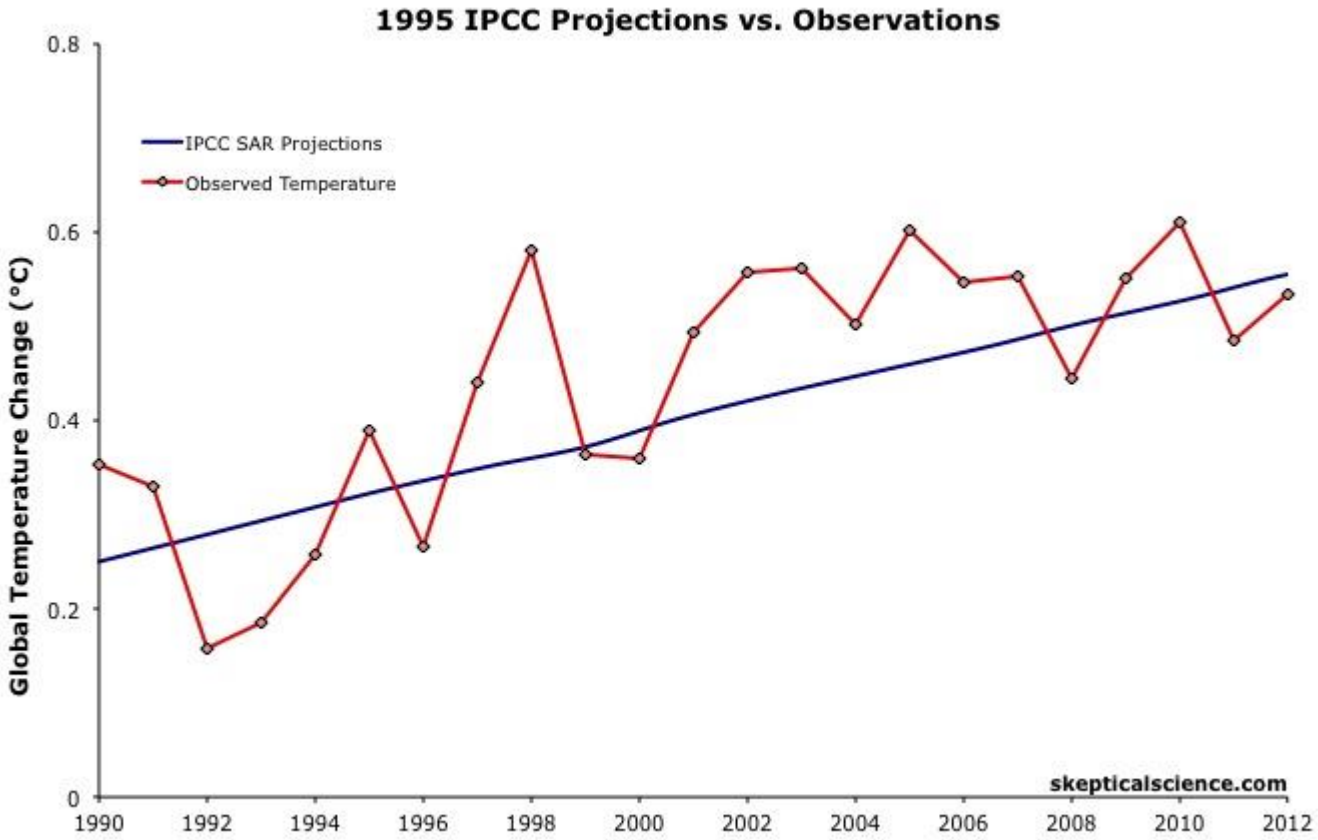
Climate models?

How well have they done?

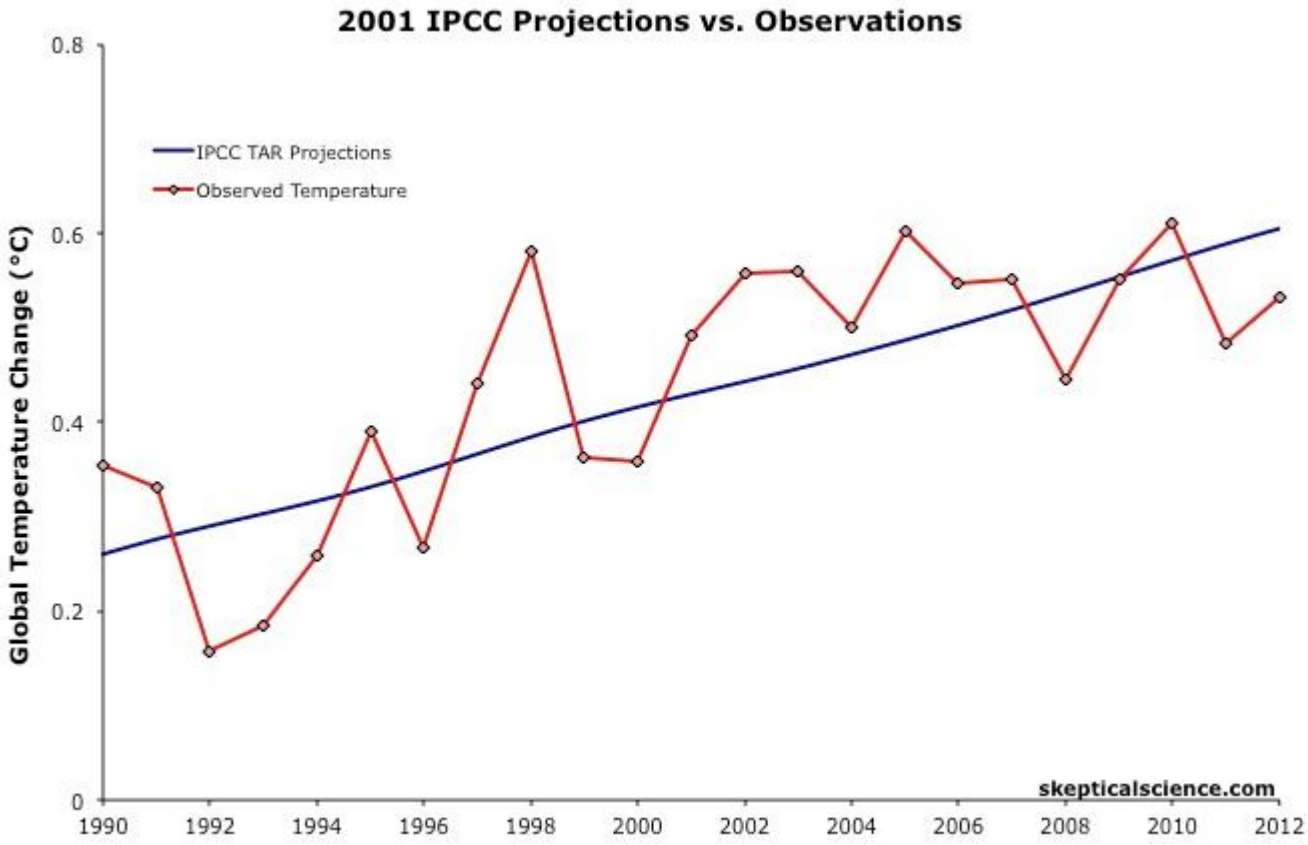
Actual warming 1990-1012 = 0.15 ± 0.08 °C
Projected warming 0.14 °C per decade



CLIMATE MODELS?

How well have they done?

Actual warming 1990-1012 = 0.15 ± 0.08 °C
Projected warming 0.16 °C per decade

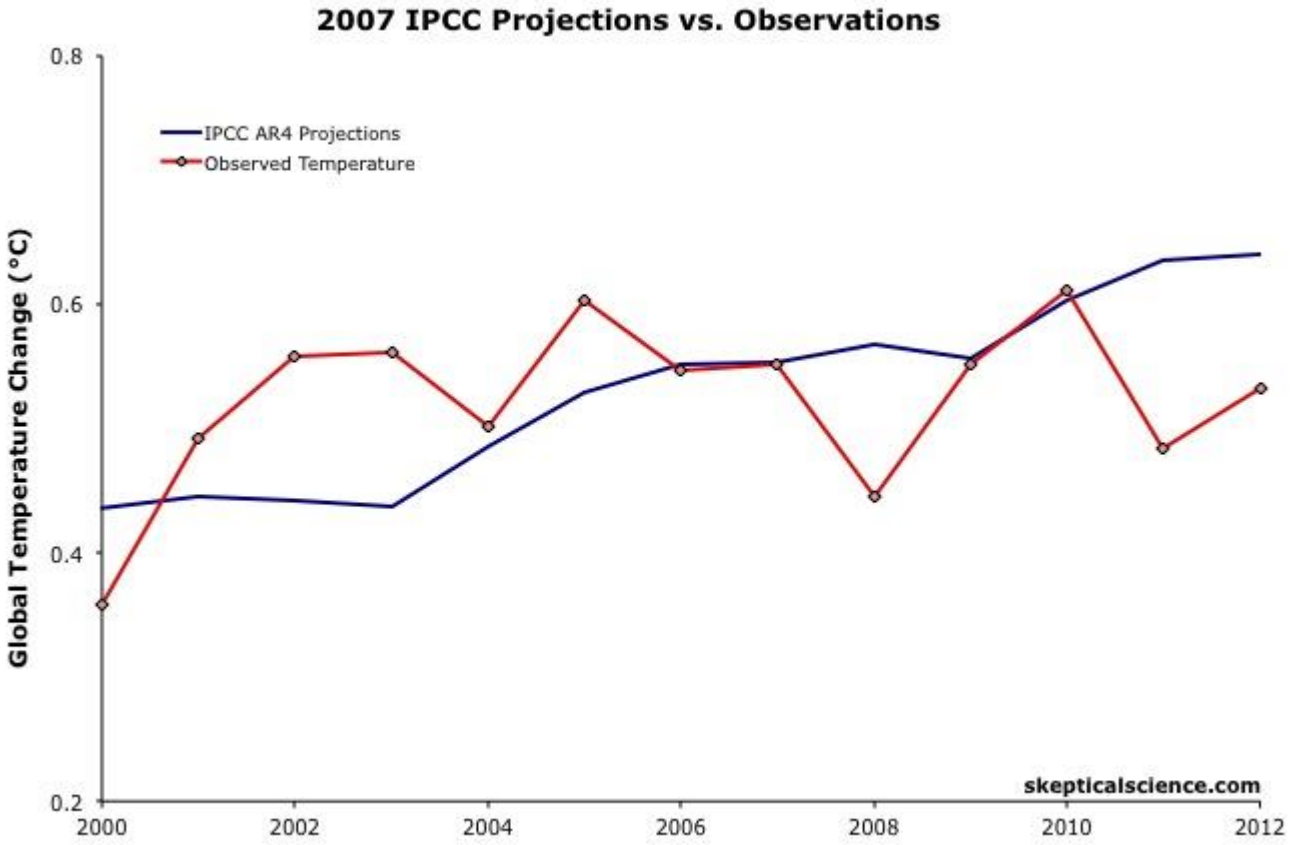


www.skepticalscience.com

Climate models?

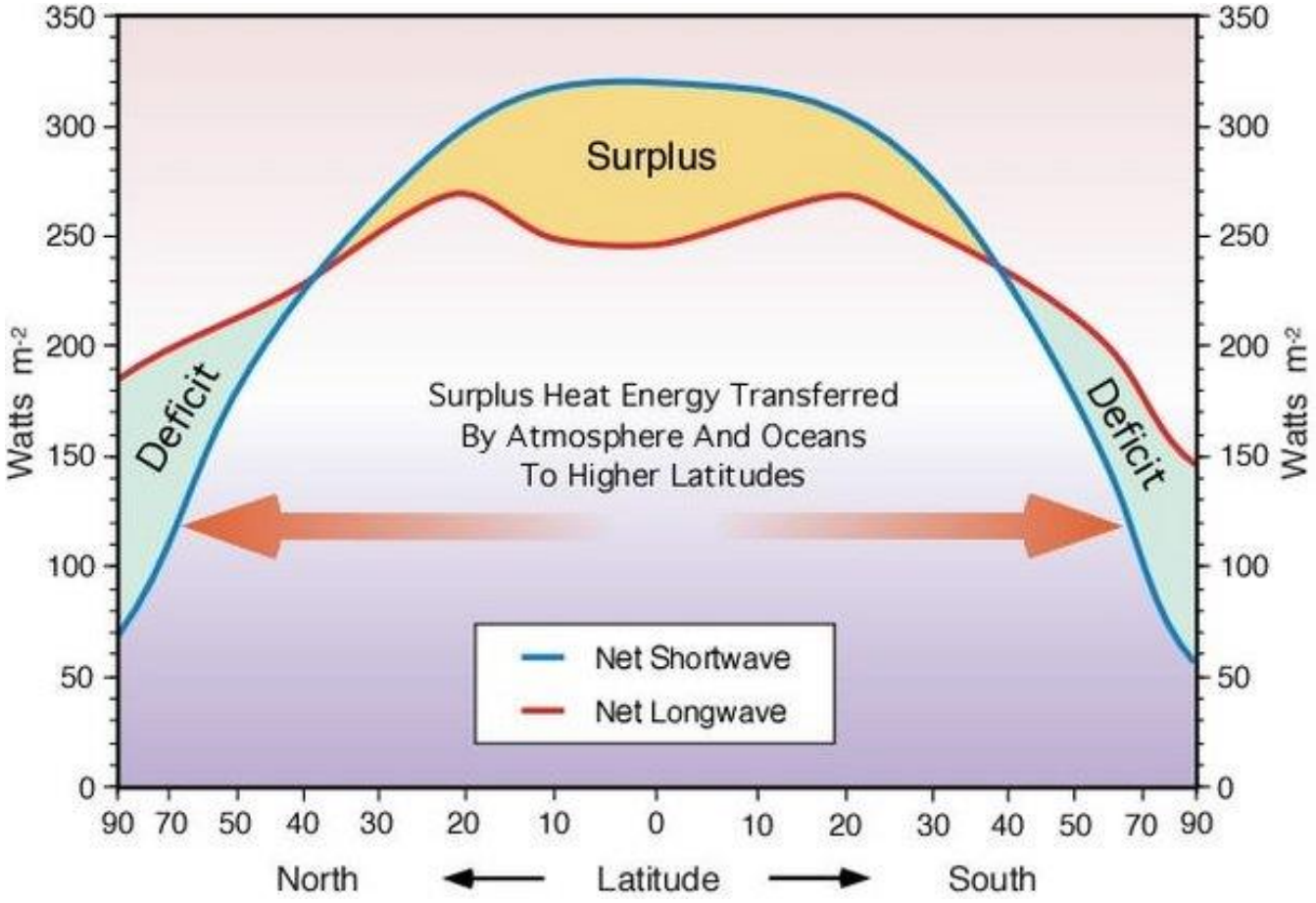
How well have they done?

Actual warming 2000-2012 = 0.06 ± 0.16 °C
Projected warming 0.18 °C per decade



www.skepticalscience.com, Rahmstorf et al. 2012

GREENHOUSE EFFECT?

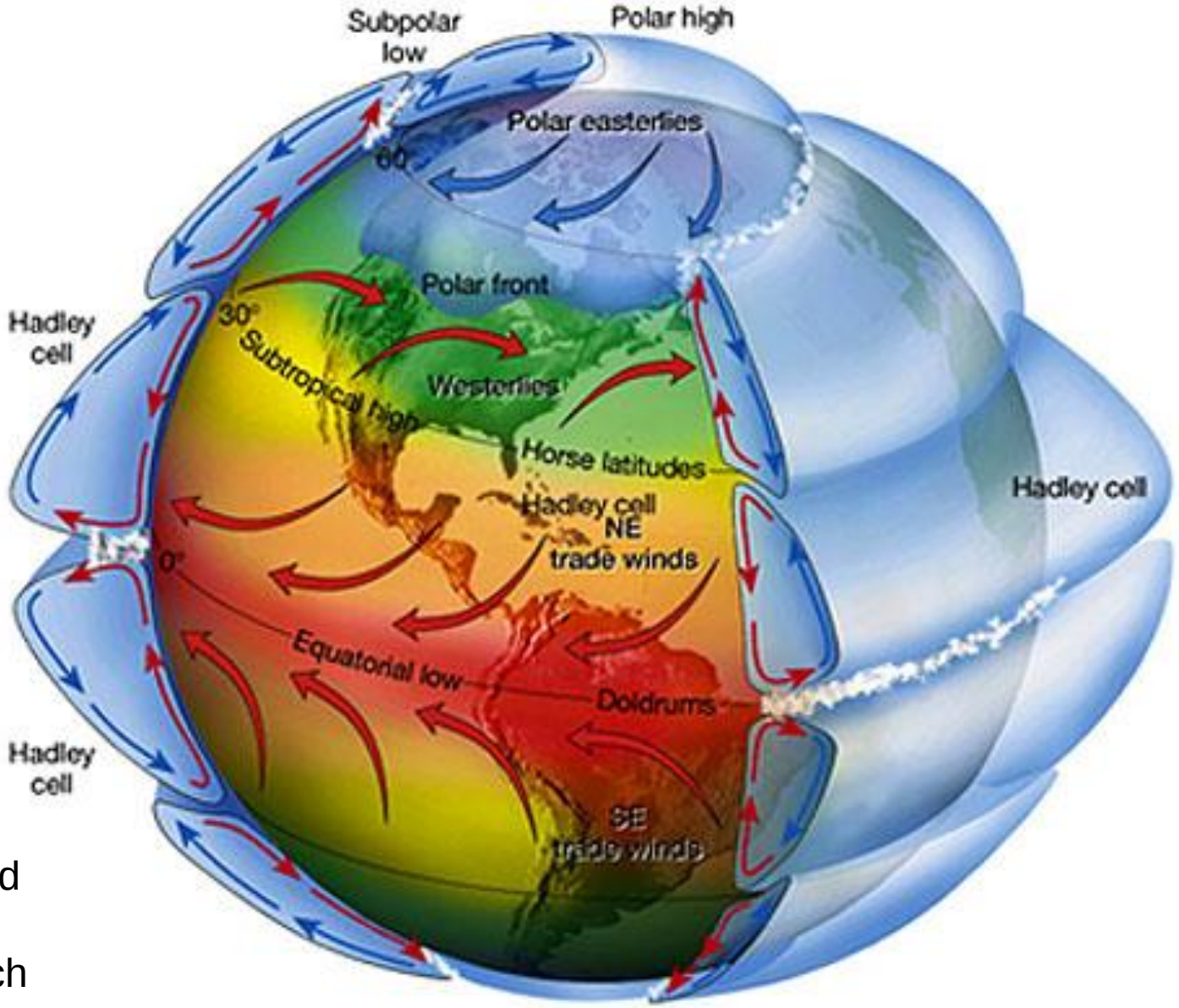


The Earth is unevenly heated by the sun

This is why the wind blows!

Source: NASA ERBE project and
M. Pidwirny (2006) Fundamentals of Physical Geography

circulation



Rising air is associated with rainfall. Descending air is much drier. Where are the world's great deserts?

Image source: NASA Remote Sensing Tutorial: The Water Planet - Meteorological, Oceanographic and Hydrologic Applications of Remote Sensing.