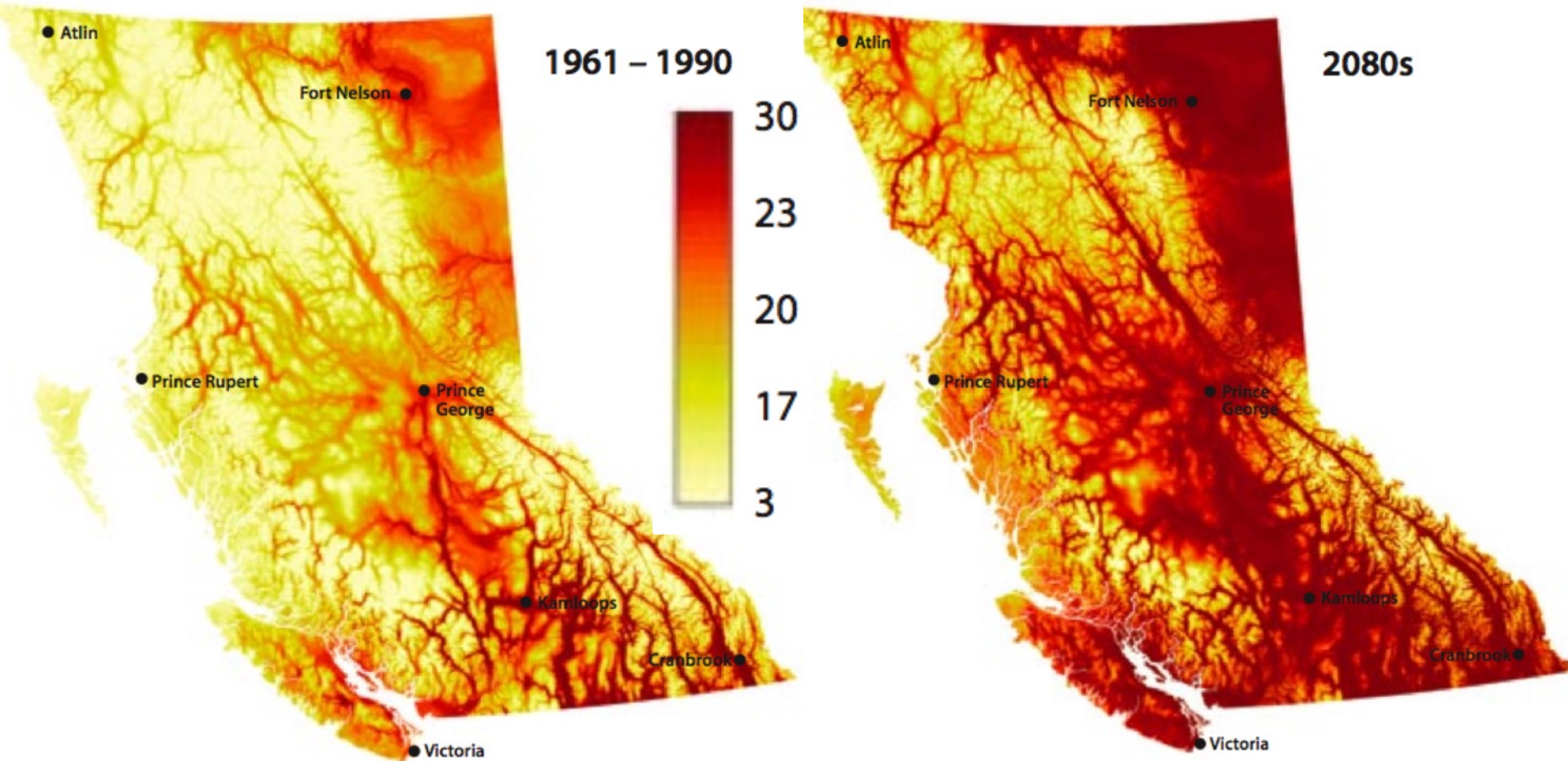


FRST 352 Entomology

Spring 2019



Climate Change

Jeff Lewis

Learning Outcomes

At the end of this lecture, you should be able to:

- Describe the main lines of evidence that climate is changing
- Explain the five main factors influencing global climate
- Outline current and future trends and impacts of global climate change
- Describe current and future changes in temperature, precipitation and biogeoclimatic zones in BC

Evidence of Climate Change

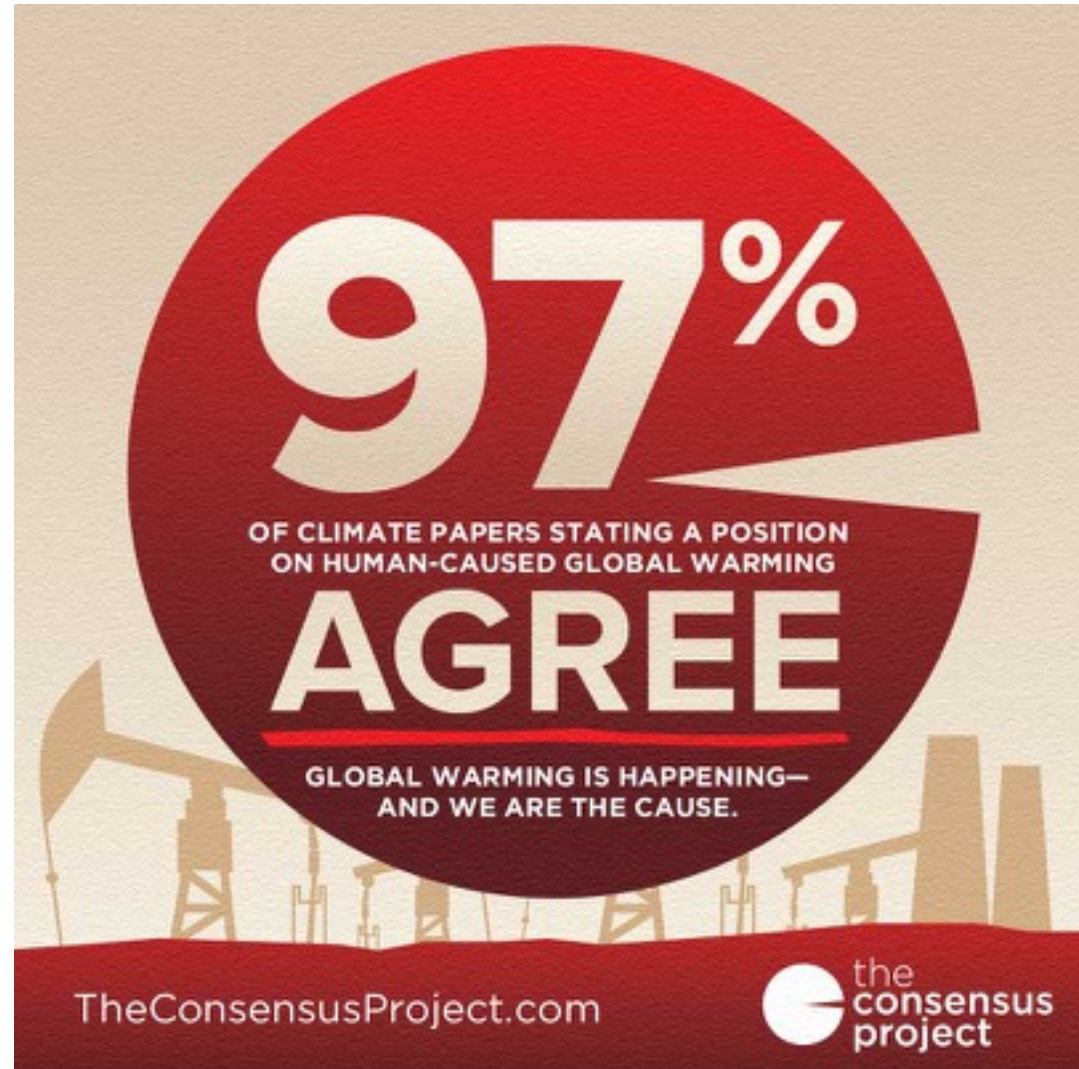
- Observational and satellite data show an increase in global average temperature
 - The 1990s were the warmest decade on record
 - The 2000s were then the warmest decade on record
 - The 2010s are on track to be warmer still
- Since 1980, most glaciers have lost mass
- Permafrost is warming and melting in many regions
- Snow and ice melt is occurring earlier in the spring
- Sea level is rising
- Arctic sea ice extent is decreasing
- The ocean is becoming more acidic (absorbing more CO_2)
- The frequency/severity of extreme events is increasing (e.g. floods, droughts, high temperature records, etc.)

Credibility of the Evidence

Intergovernmental Panel on Climate Change (IPCC)

www.ipcc.ch

2014: "It is extremely likely [$>95\%$] that human influence has been the dominant cause of observed warming since the mid-20th century"



2014 CLIMATE CHANGE ADAPTATION ROADMAP



- The U.S. military refers to climate change as a **“threat multiplier”**
- “The impacts of climate change will intensify the challenges of global instability, hunger, poverty, and conflict”
- “The Department of Defense sees climate change as a present security threat, not strictly a long-term risk”
- “Climate change threatens half of US bases worldwide”



2014 CLIMATE CHANGE
ADAPTATION ROADMAP



- The U.S. military refers to climate change as a **"threat multiplier"**
- "The impacts of climate change will intensify the challenges of global instability, hunger, poverty, and conflict"
- "The Department of Defense sees climate change as a present security threat, not strictly a long-term risk"
- "Climate change threatens half of US bases worldwide"

WORLDWIDE THREAT ASSESSMENT
OF THE US INTELLIGENCE COMMUNITY

- "The negative effects of environmental degradation and climate change" are a "global threat."

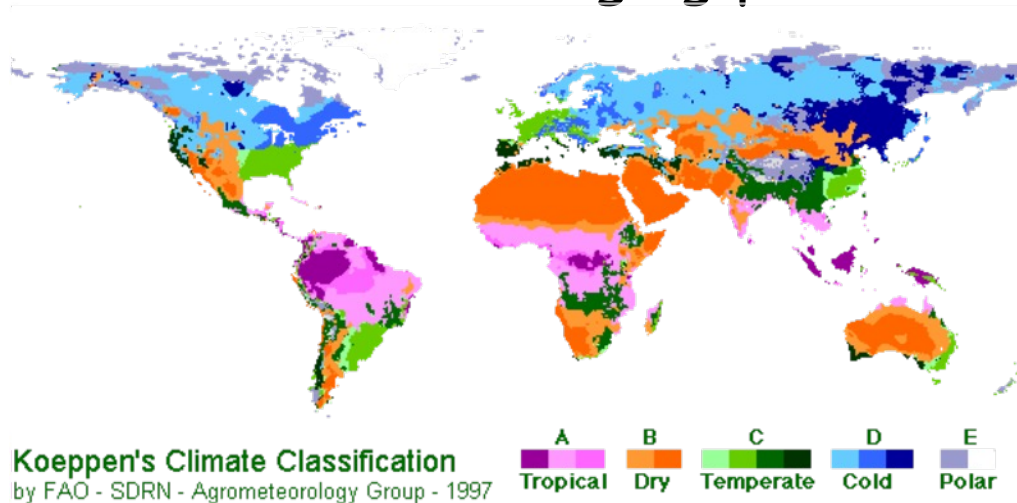
January 29, 2019

The Climate Record

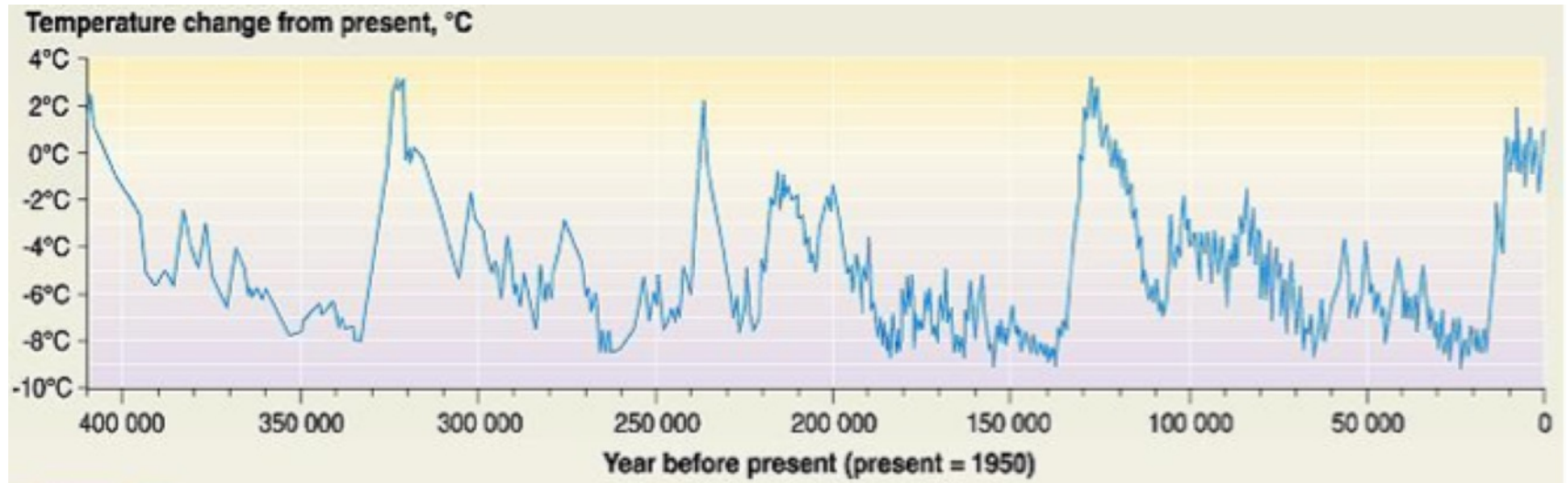
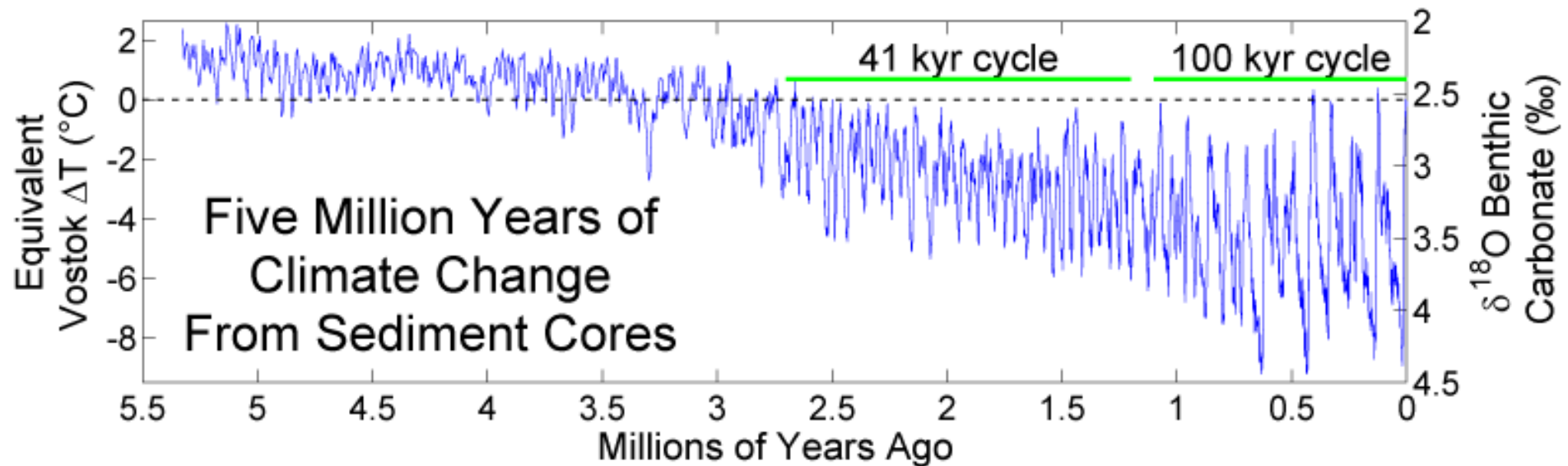
Weather is the state of the atmosphere at a specific place and time.



Climate is the average weather over a long period of time. The standard averaging period is 30 years.



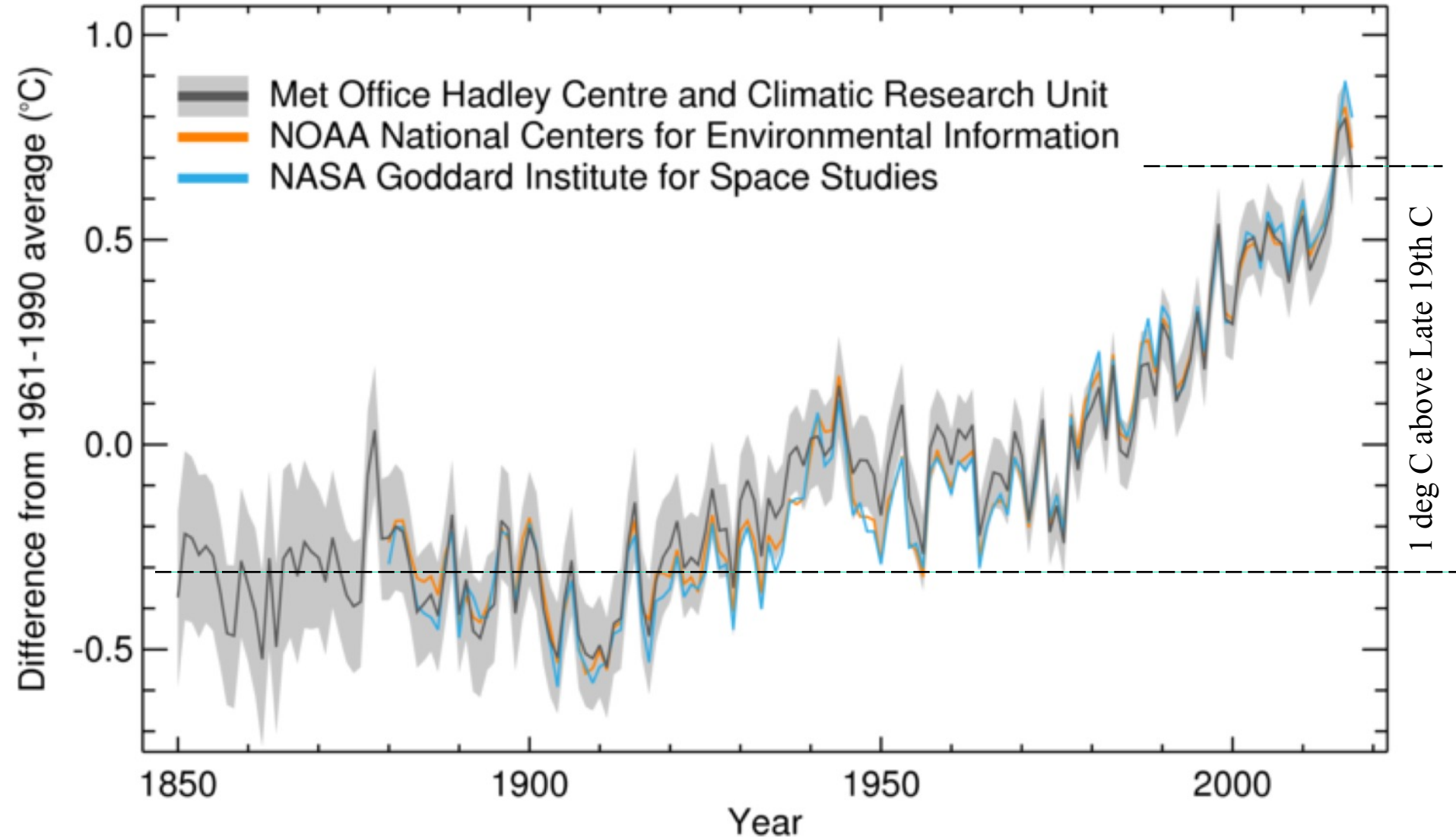
The Climate Record



The Climate Record



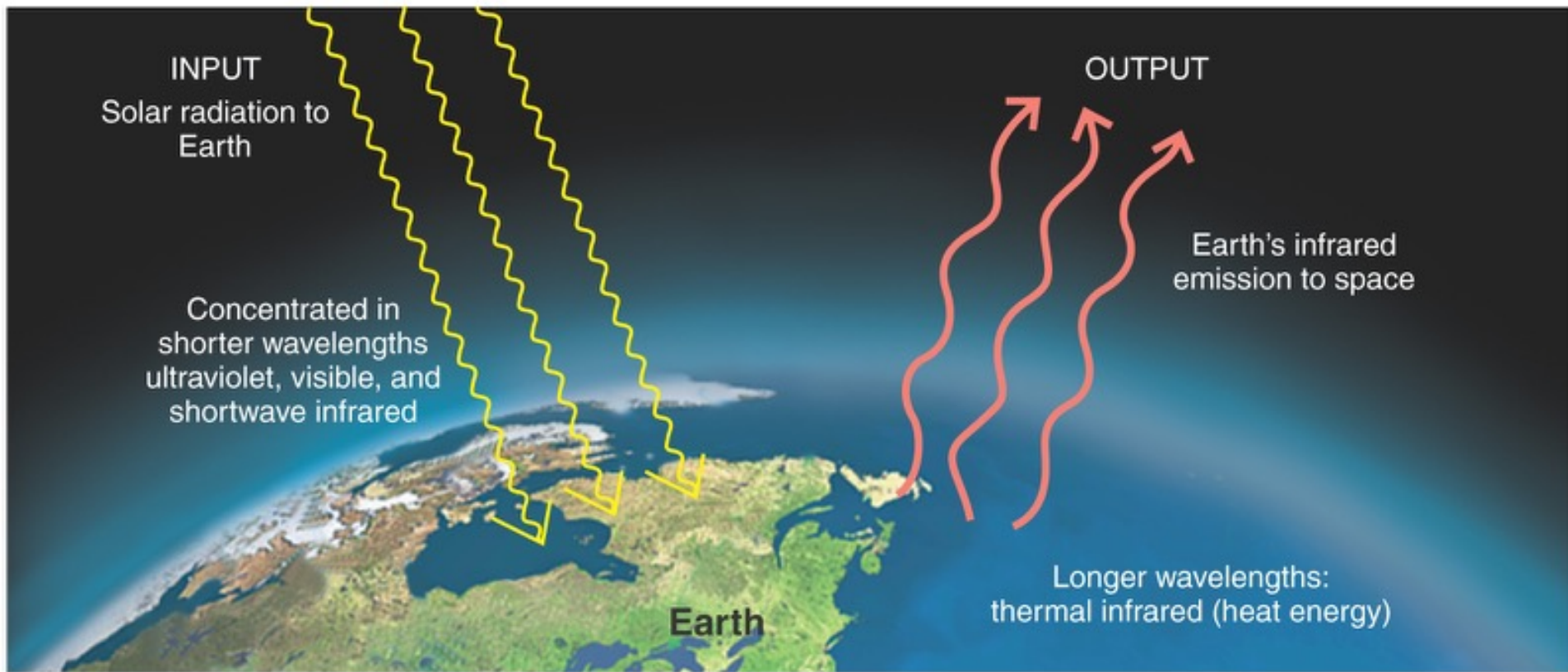
Global average temperature anomaly
(1850-2017)



1 deg C above Late 19th C

Causes of Climate Change

When the net outgoing thermal energy is equal to the net incoming solar radiation the Earth is in **radiative equilibrium**



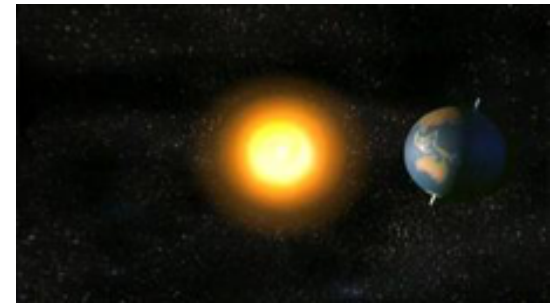
Causes of Climate Change

When the net outgoing thermal energy is equal to the net incoming solar radiation the Earth is in **radiative equilibrium**

Deviations from equilibrium imply a **radiative forcing**

Forcings may be **external**:

1. Changes in solar output
2. Changes in orbital parameters



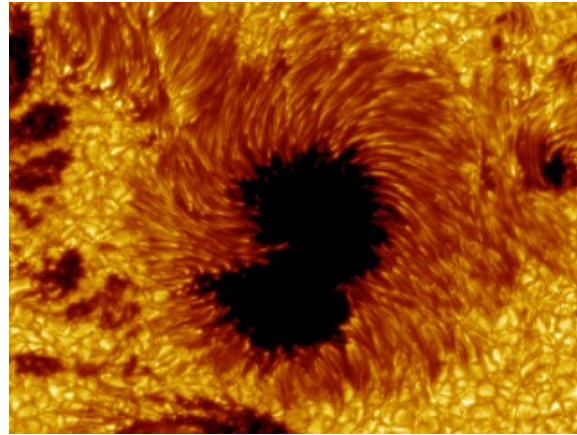
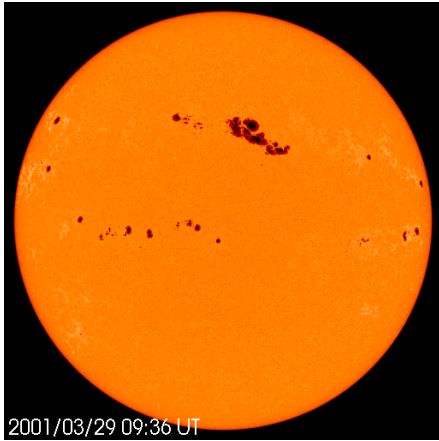
or **internal**:

3. Changes in surface energy balance
4. Changes in circulation
5. Changes in atmospheric composition



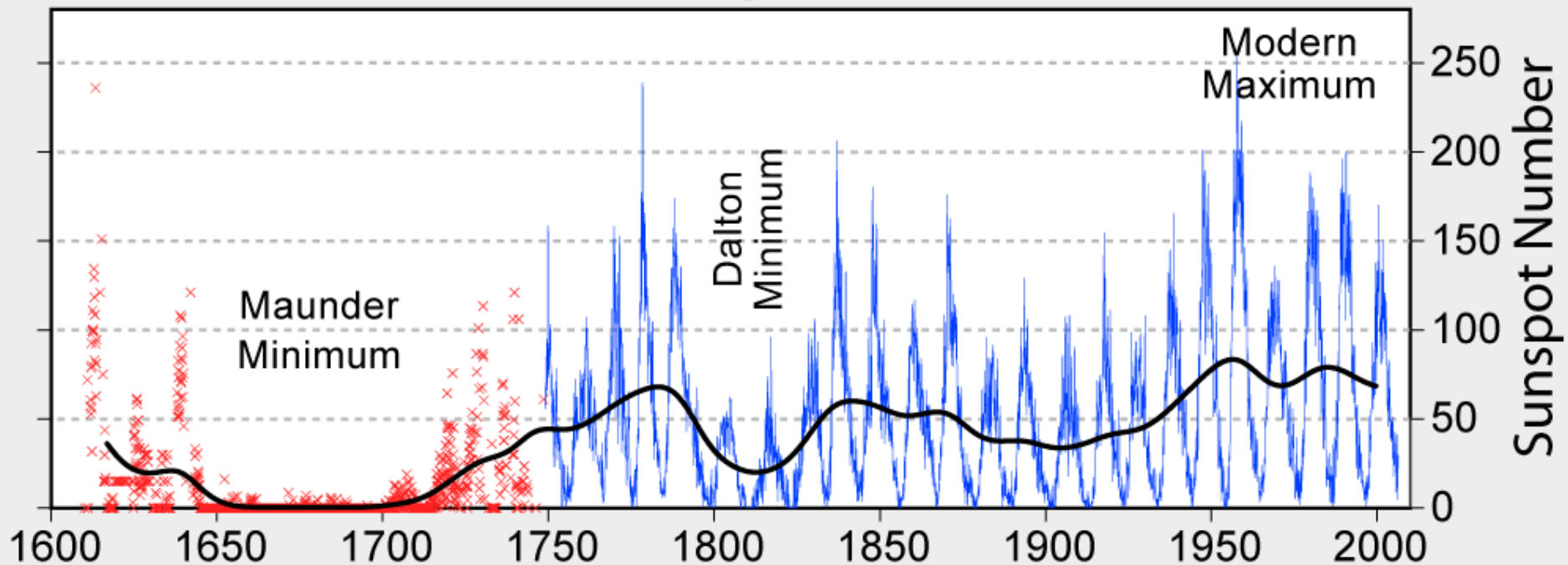
All act all the time but at varying strengths and time scales

1. Changes in Solar Output

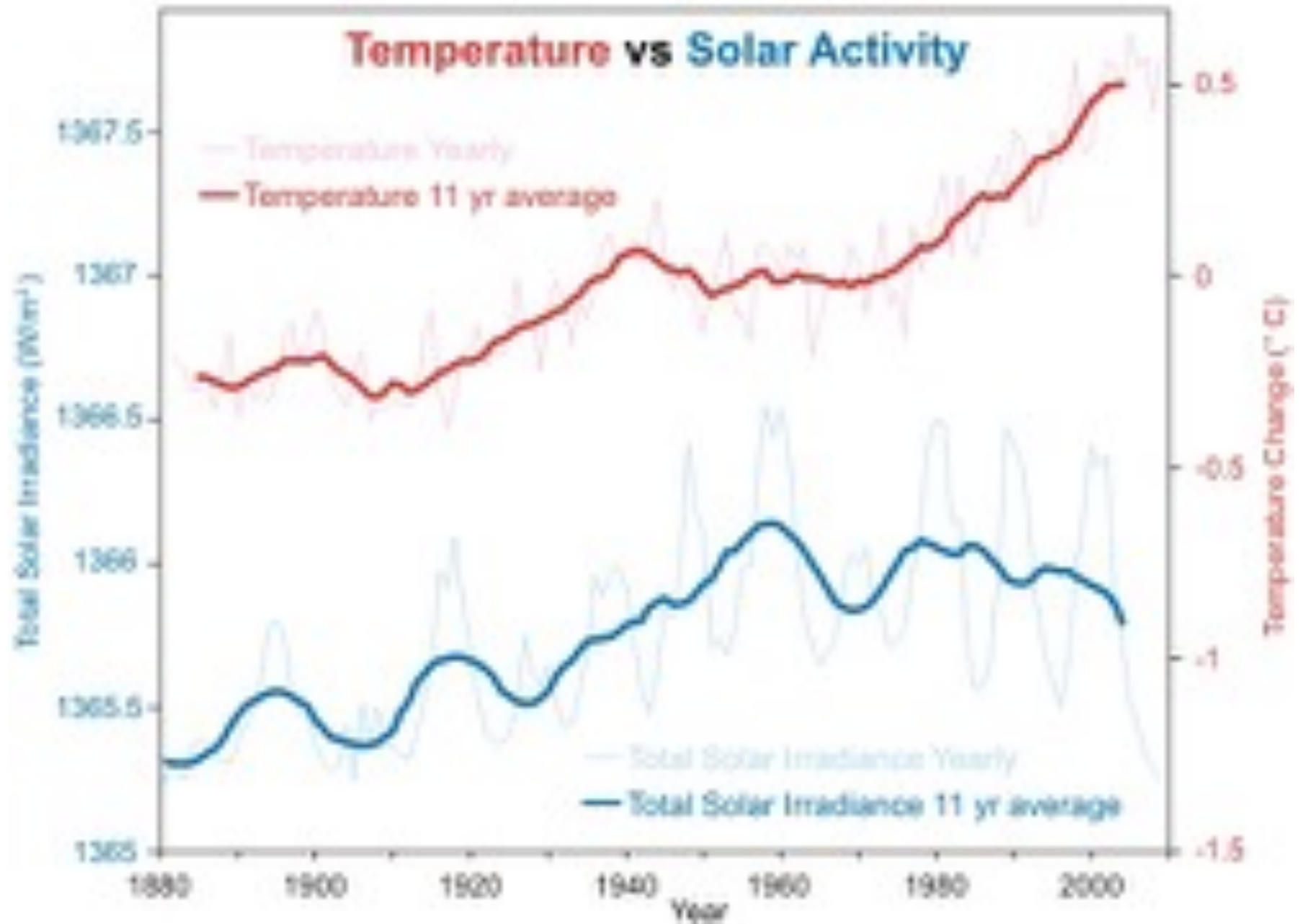


Sunspot number has a strong 11-year cycle with evidence of variability on longer time scales

400 Years of Sunspot Observations



1. Changes in Solar Output



2. Changes in Orbital Parameters



Eccentricity

100 thousand year cycle



Obliquity

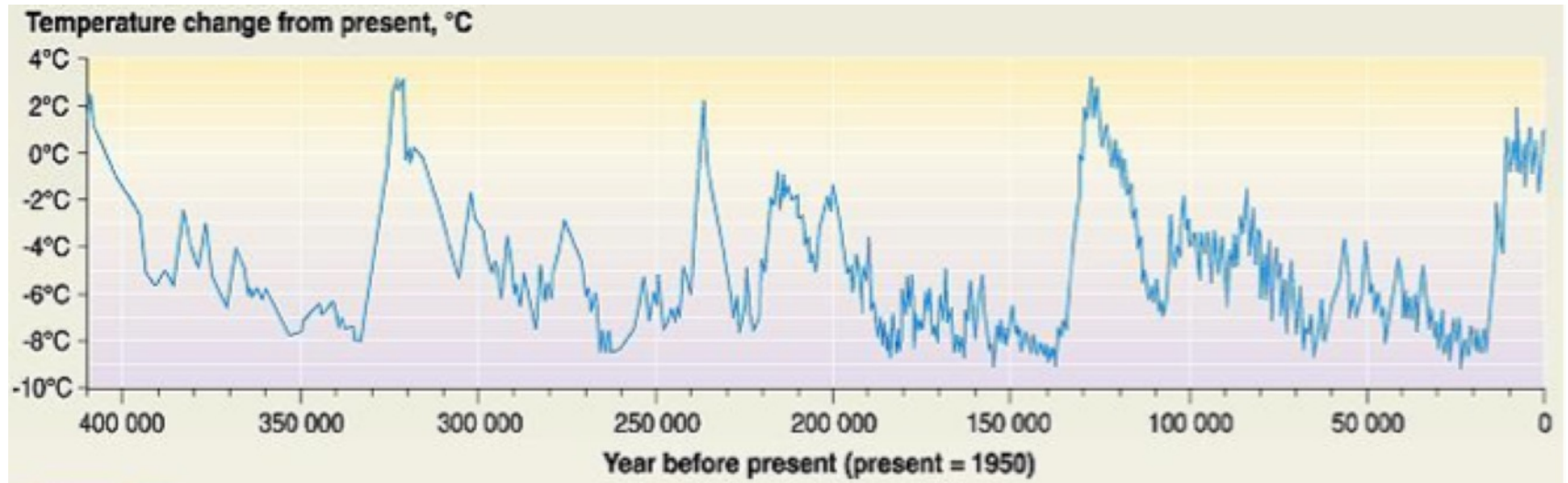
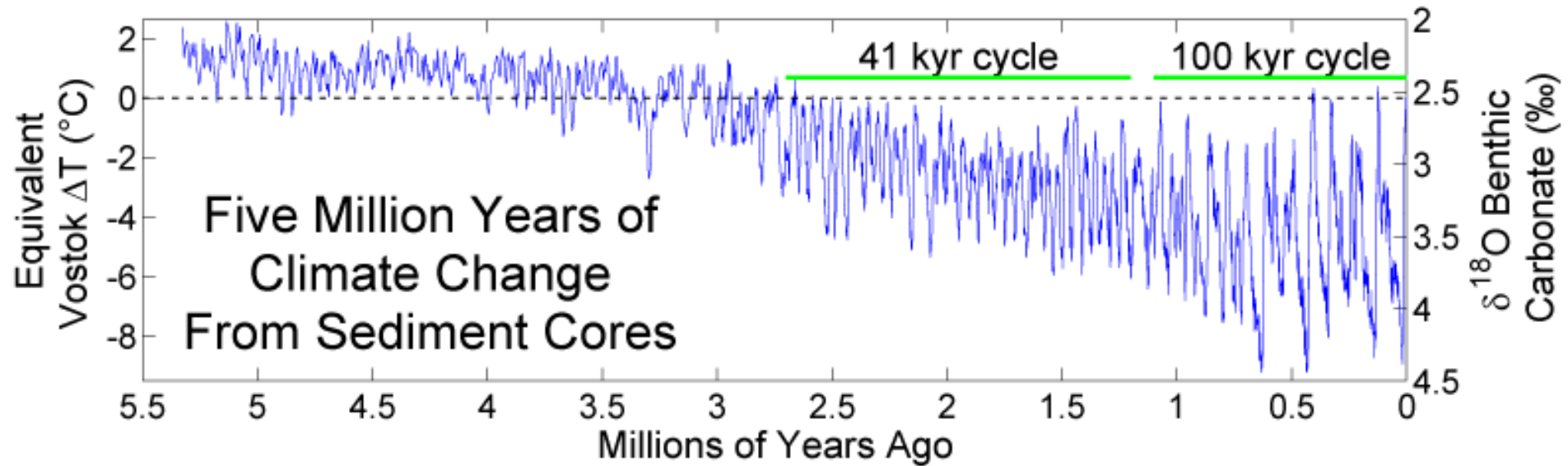
41 thousand year cycle



Precession

19 thousand year cycle

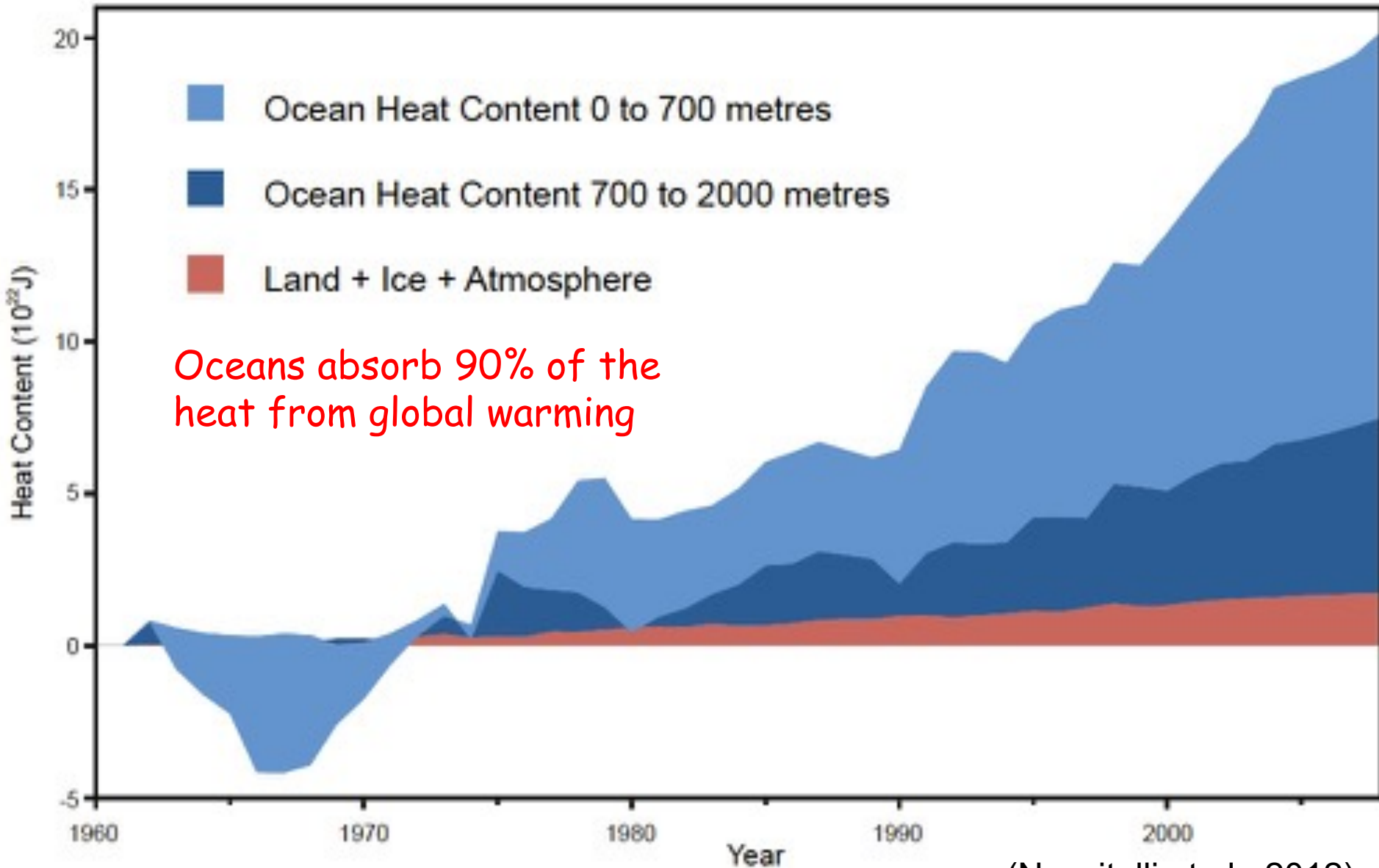
2. Changes in Orbital Parameters



3. Changes in Surface Energy Balance

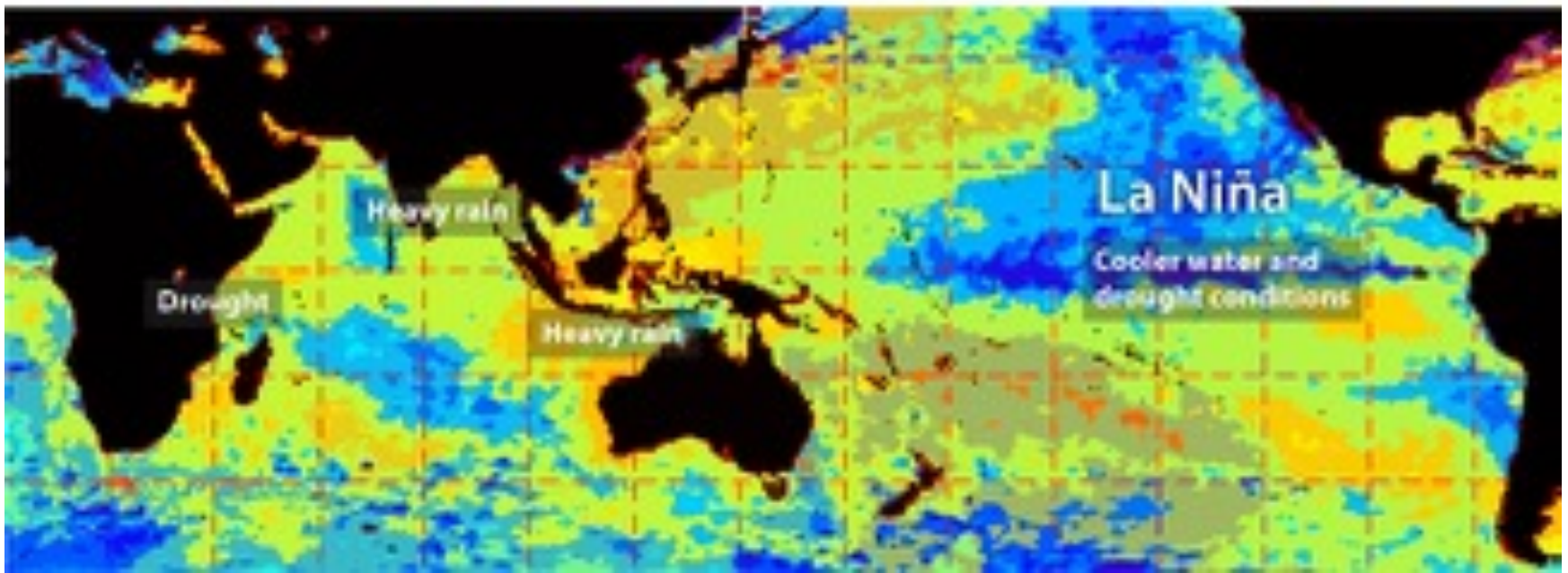
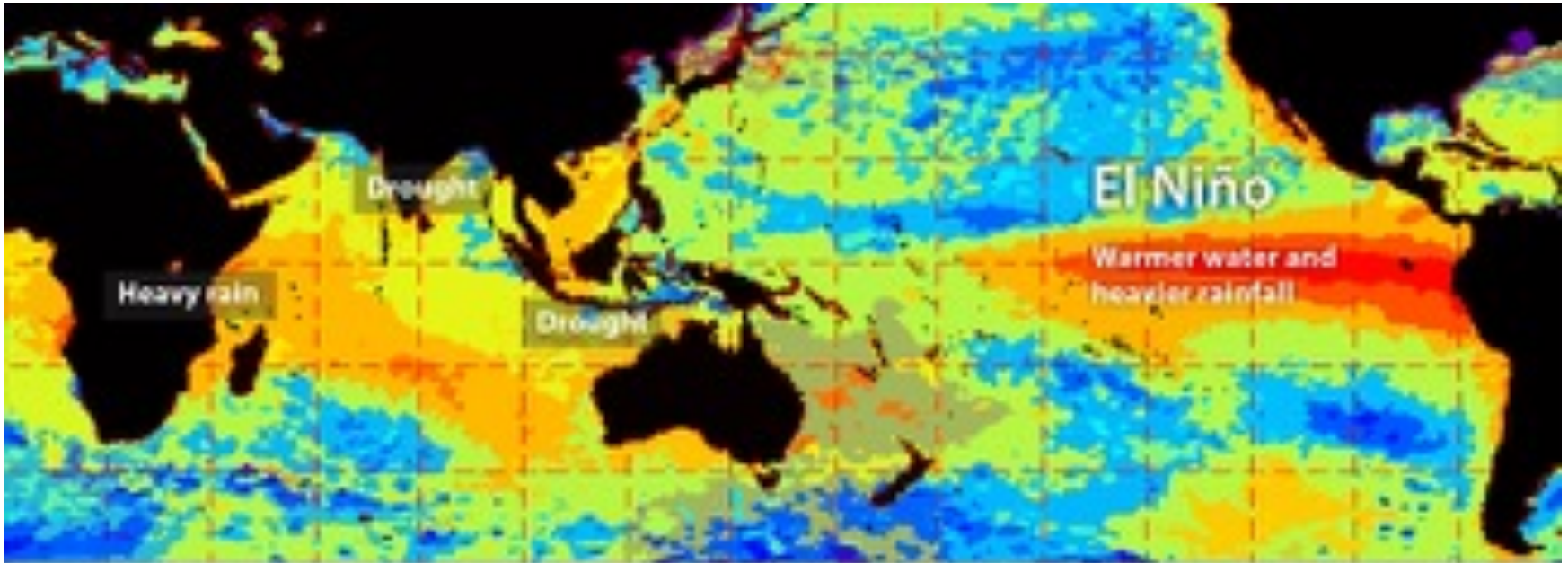


3. Changes in Surface Energy Balance

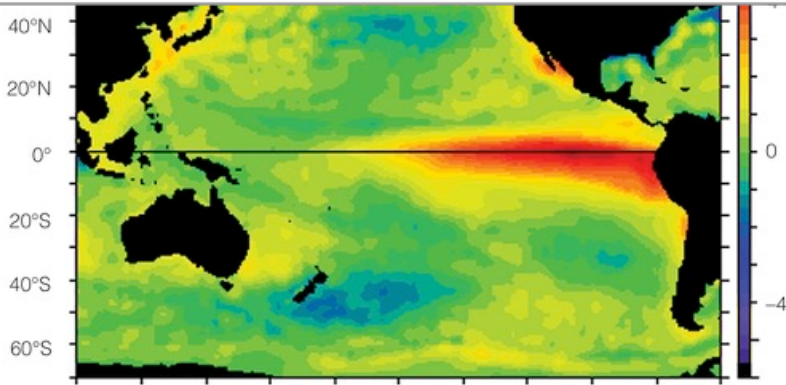
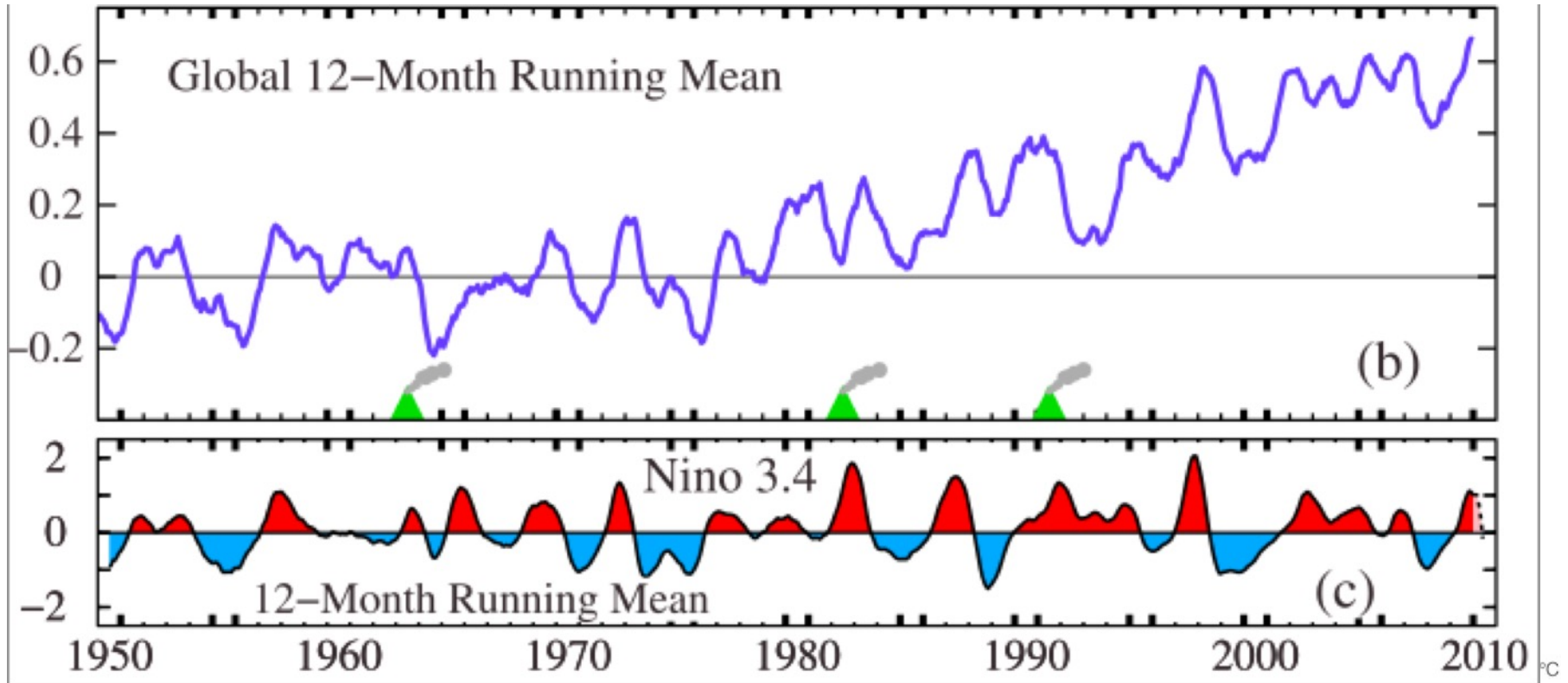


Oceans absorb 90% of the heat from global warming

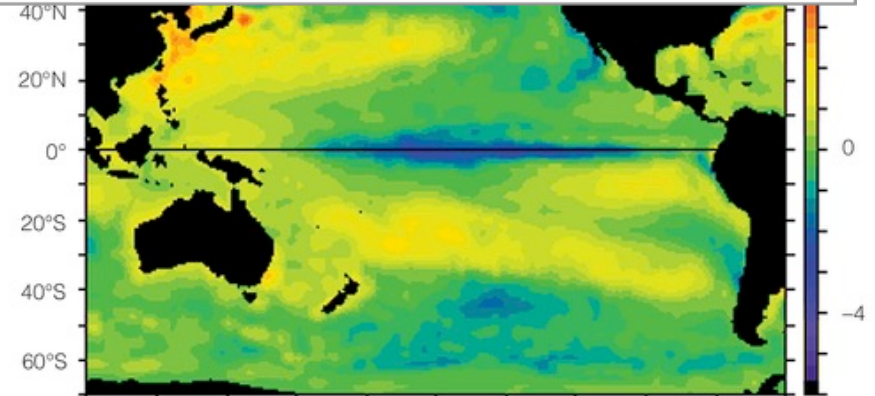
4. Changes in Circulation



4. Changes in Circulation



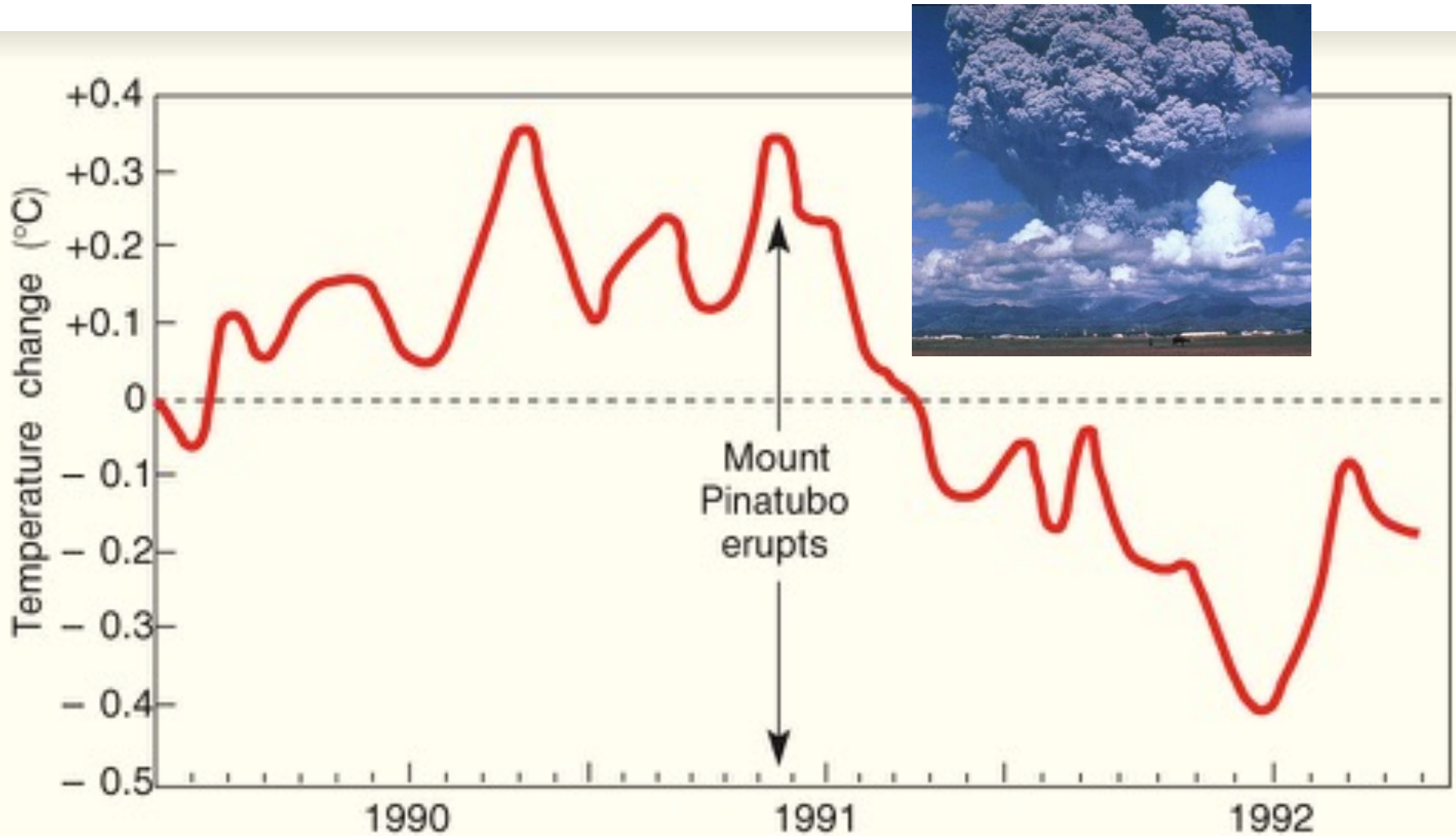
El Niño



La Niña

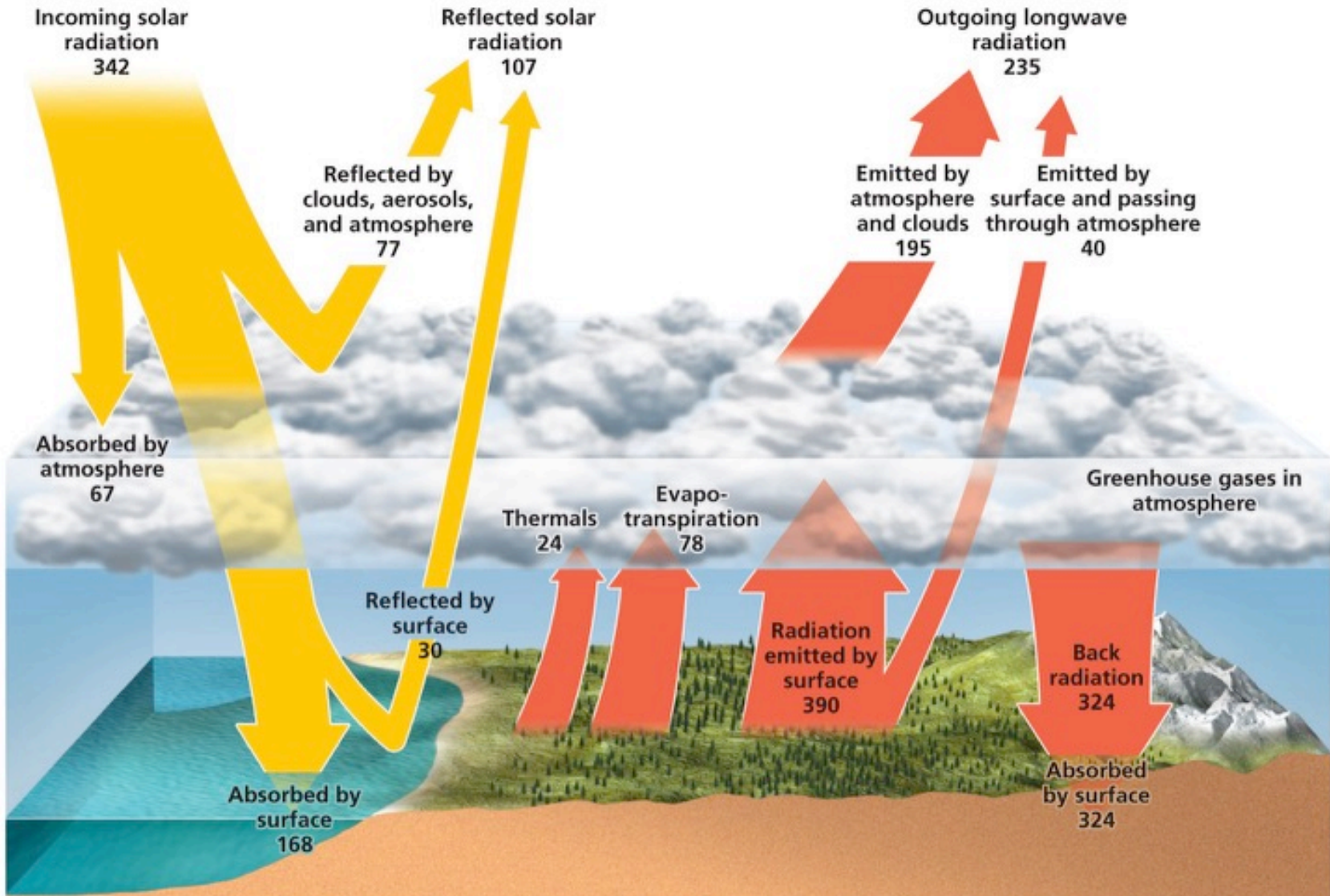
5. Changes in Atmospheric Composition

Aerosols: scatter incoming solar radiation

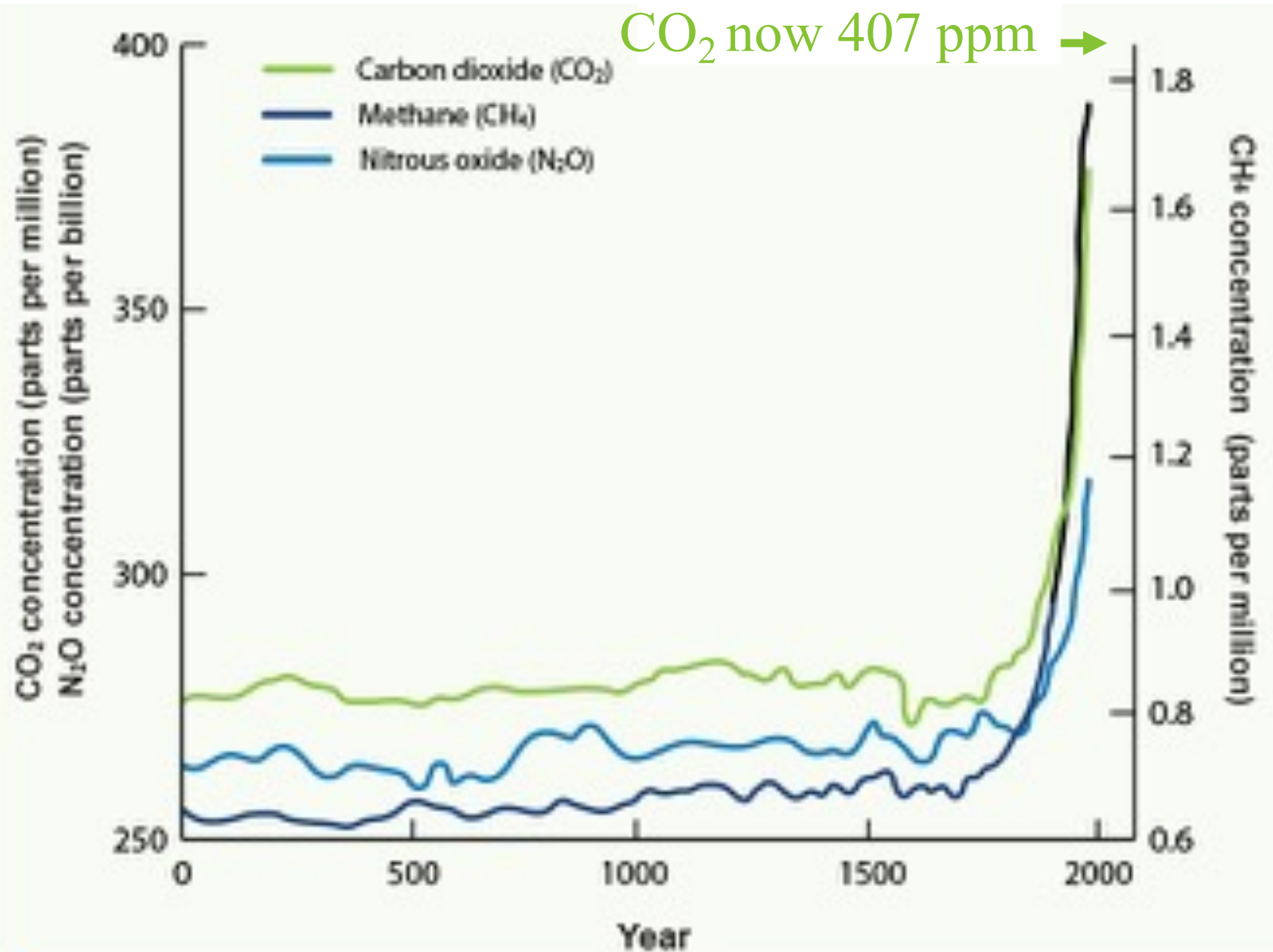


5. Changes in Atmospheric Composition

Greenhouse Gases: trap thermal energy from Earth



5. Changes in Atmospheric Composition



Climate Feedbacks

Any change in forcing can be amplified or reduced by the climate system.

Positive feedback: amplifies the original change
-Result increasingly differs from the starting state

Negative feedback: reduces original change
-Tends to preserve the starting state

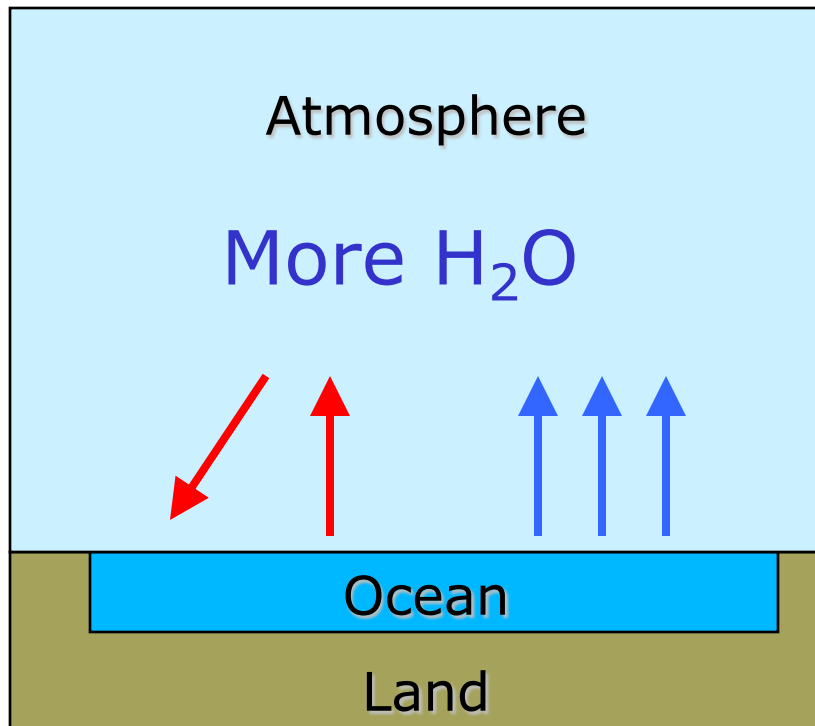
Different feedbacks involve different processes and act on different timescales.

Climate Feedbacks

Water Vapour

(positive feedback)

Temperature increases



Enhanced
greenhouse
effect

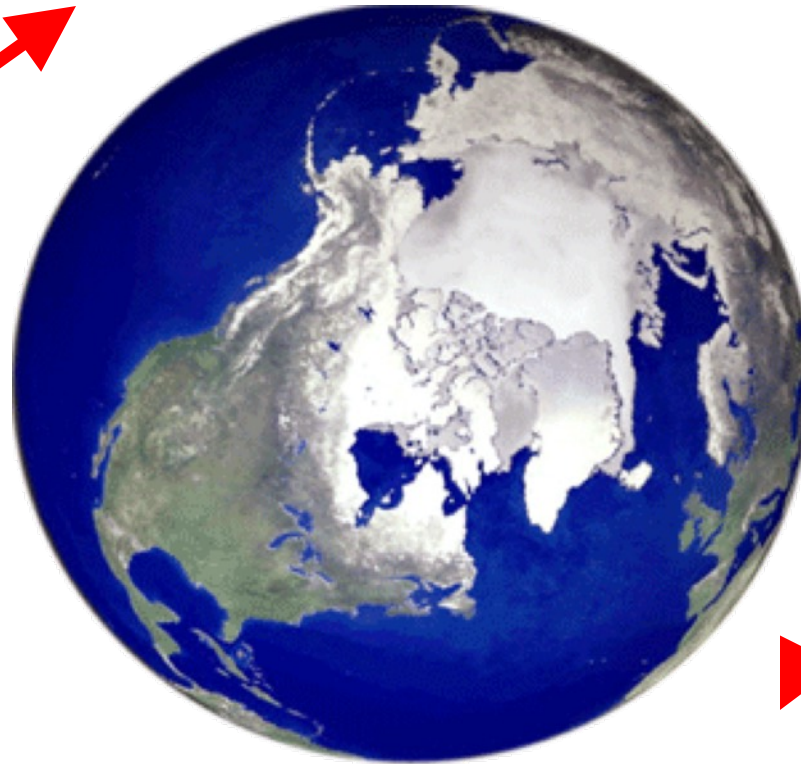
Warmer air can
hold more water
vapour

More water vapour in the atmosphere

Climate Feedbacks

Snow and Ice albedo
(positive feedback)

Temperature increases



More radiation
is absorbed

Ice melts

Reveals darker surface

Darker Arctic boosting global warming

Less ice, more open water made Arctic grow 8% darker between 1979 and 2011

The Associated Press | Posted: Feb 17, 2014 2:59 PM ET | Last Updated: Feb 17, 2014 3:54 PM ET

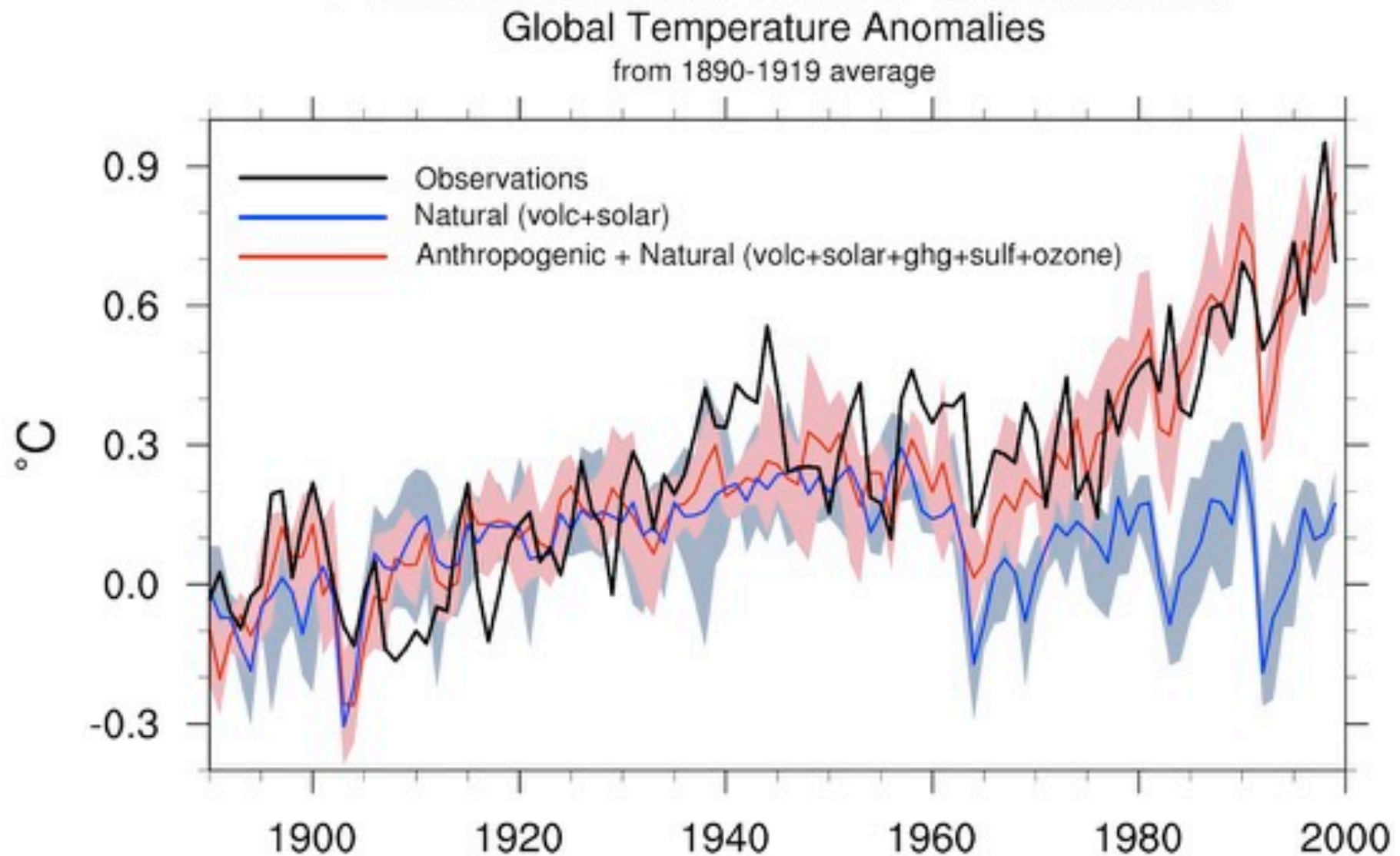


With more dark, open water in the summer, less of the sun's heat is reflected back into space. So the entire Earth is absorbing more heat than expected, according to a new study. (Jonathan Hayward/Canadian Press)

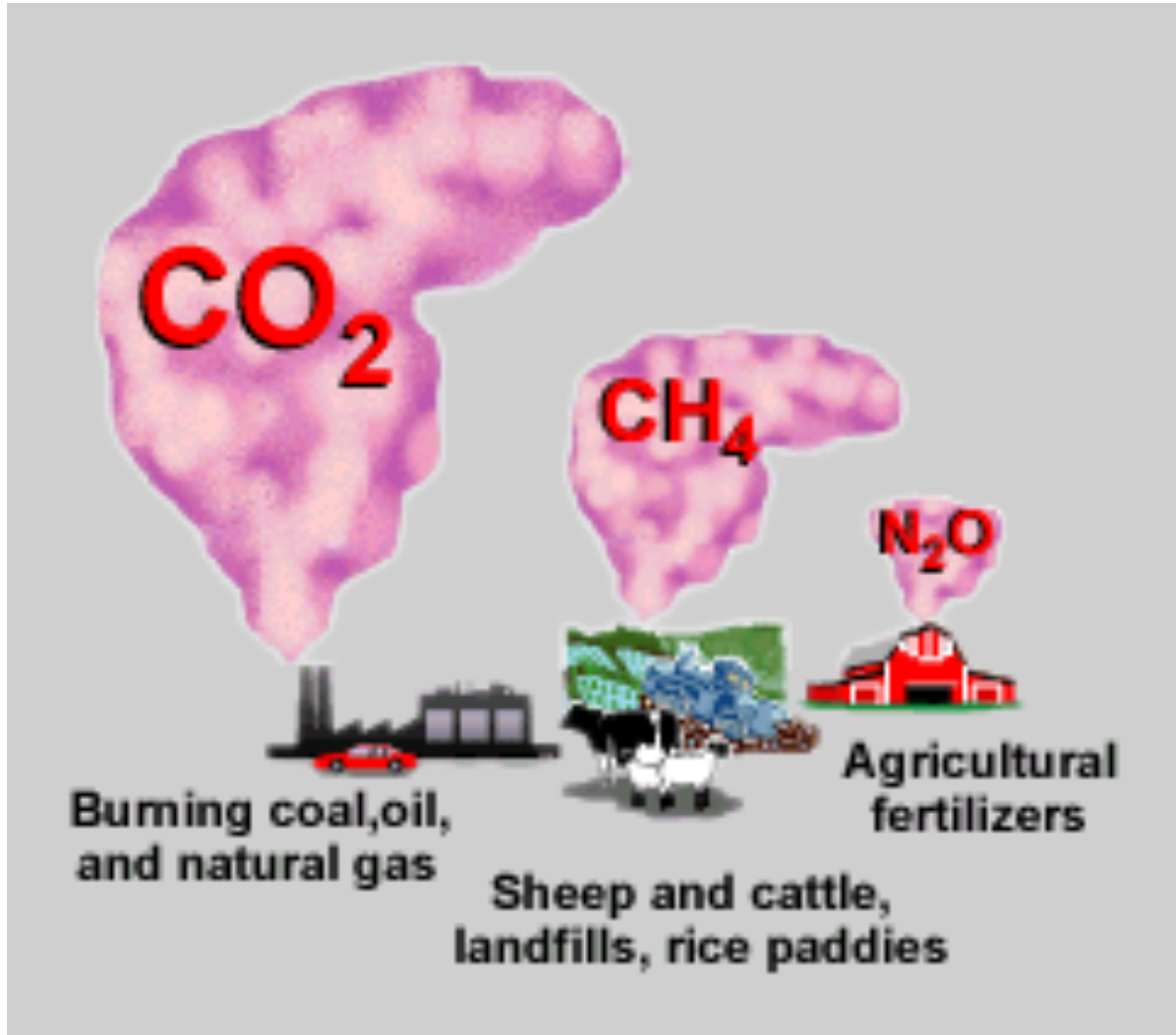
[CBC News](#)

Anthropogenic Climate Change

Global Average Temperature: With and without human influence



Anthropogenic Climate Change

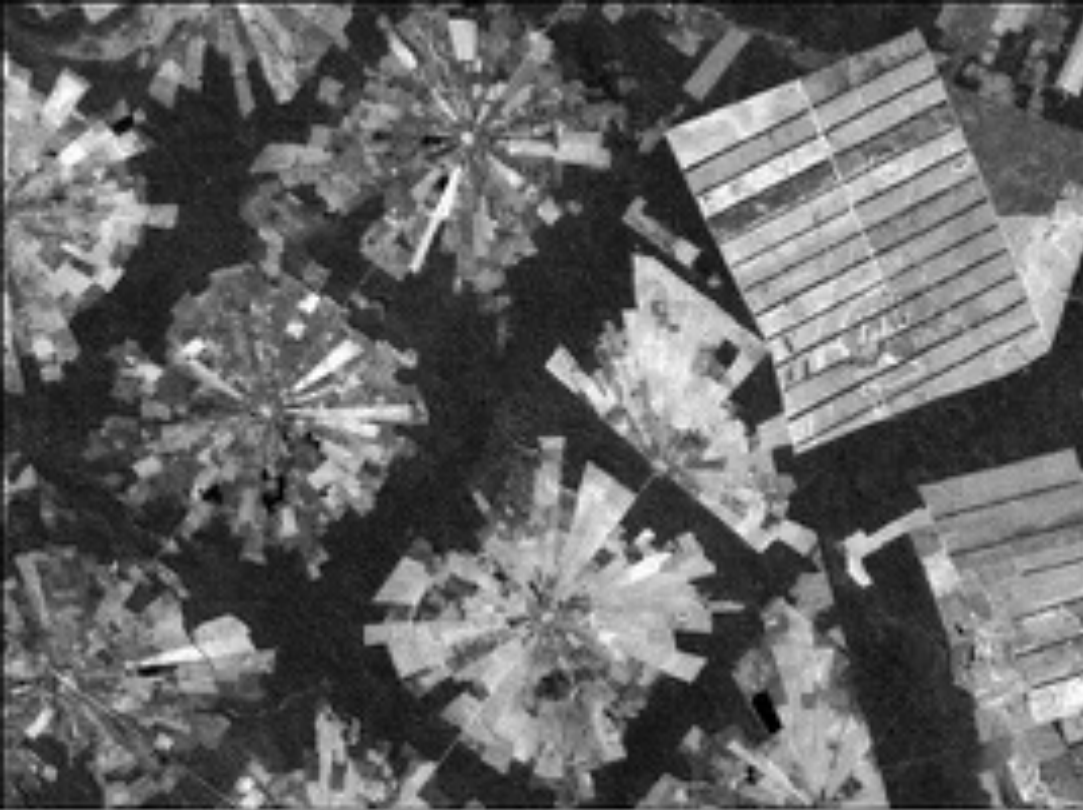


Carbon Dioxide

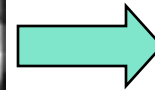
Methane

Nitrous Oxide

Anthropogenic Climate Change



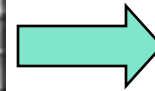
Loss of vegetation



burning releases CO_2

Leads to warming

More reflective ground



less sunlight absorbed

Leads to cooling





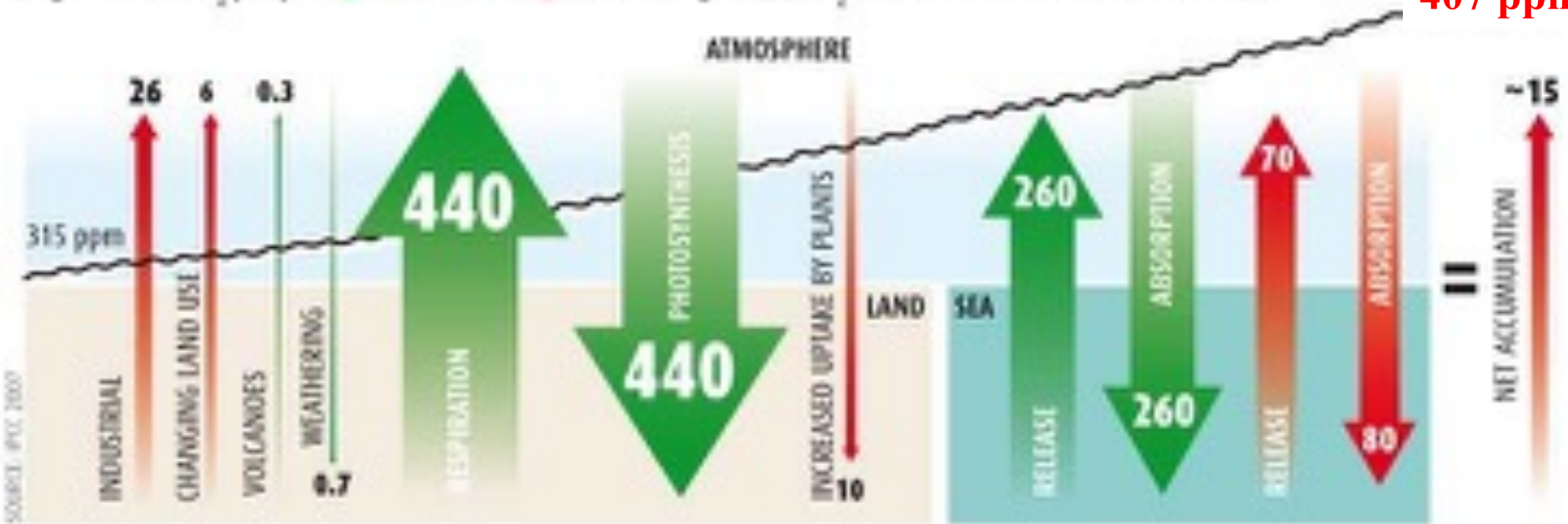
Anthropogenic Climate Change

CARBON DIOXIDE SOURCES AND SINKS

Before the industrial age, sources of CO₂ were balanced by sinks

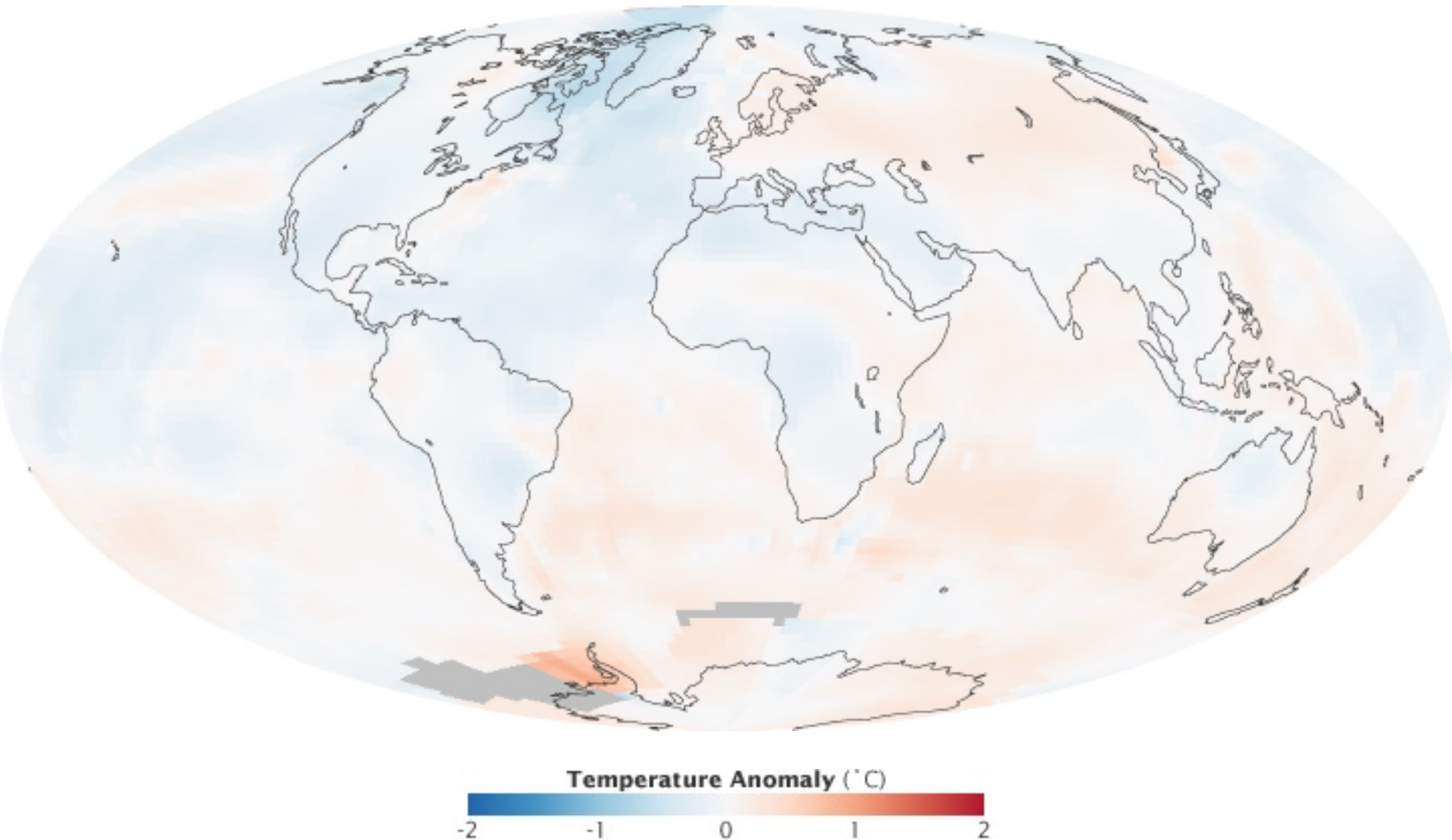
Gigatonnes of CO₂ per year ● Pre-industrial ● Recent changes ~ CO₂ levels at South Pole from 1958-2004

407 ppm



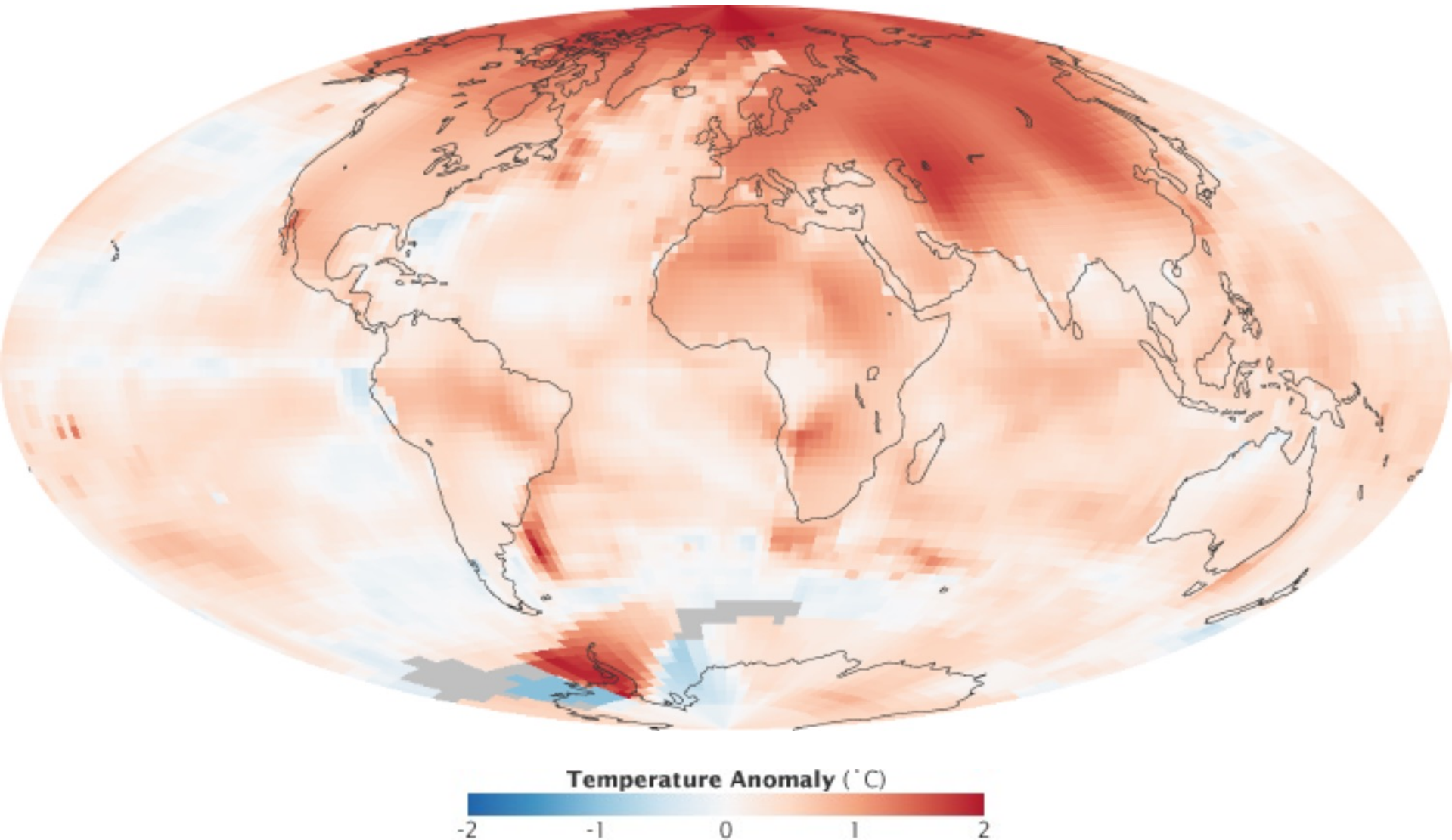
Impacts of Climate Change

1970-1979 compared to the average of 1951-1980



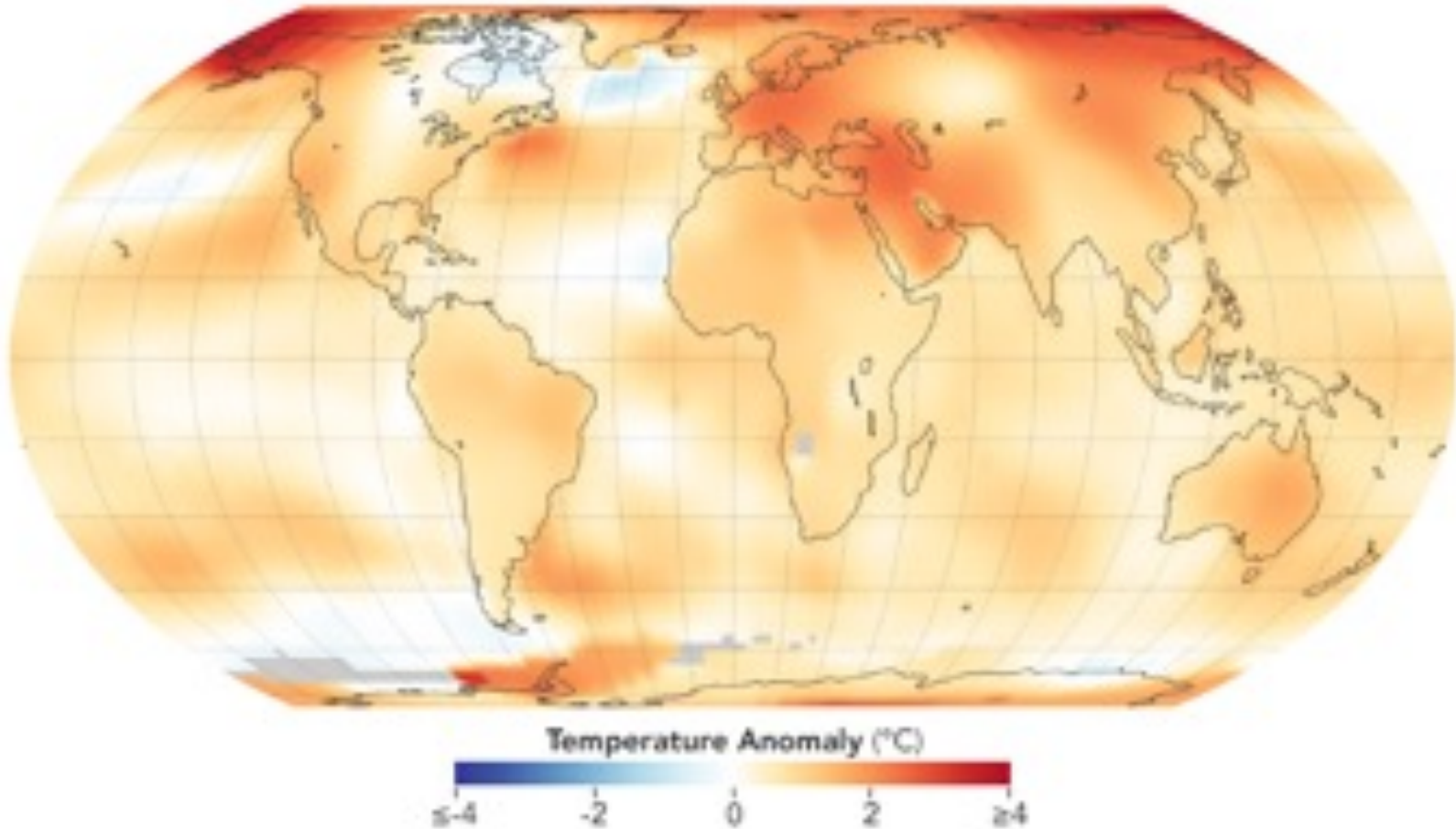
Impacts of Climate Change

2000-2009 compared to the average of 1951-1980



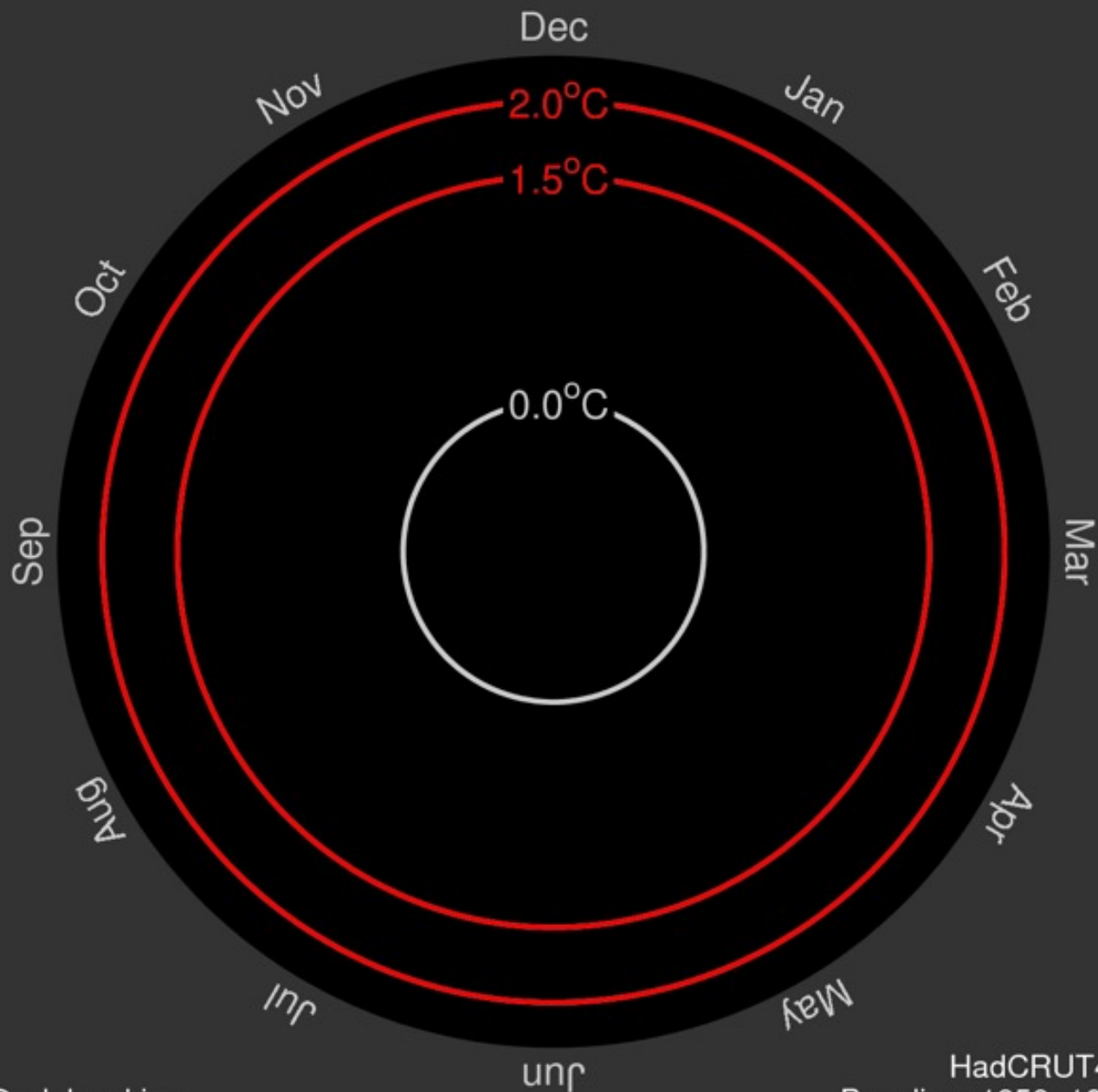
Impacts of Climate Change

2018 compared to (1951-1980)



- The last five years are the hottest years on record
- The last four years were all more than 1 degree Celsius warmer than the 19th Century average

Global temperature change (1850–2017)

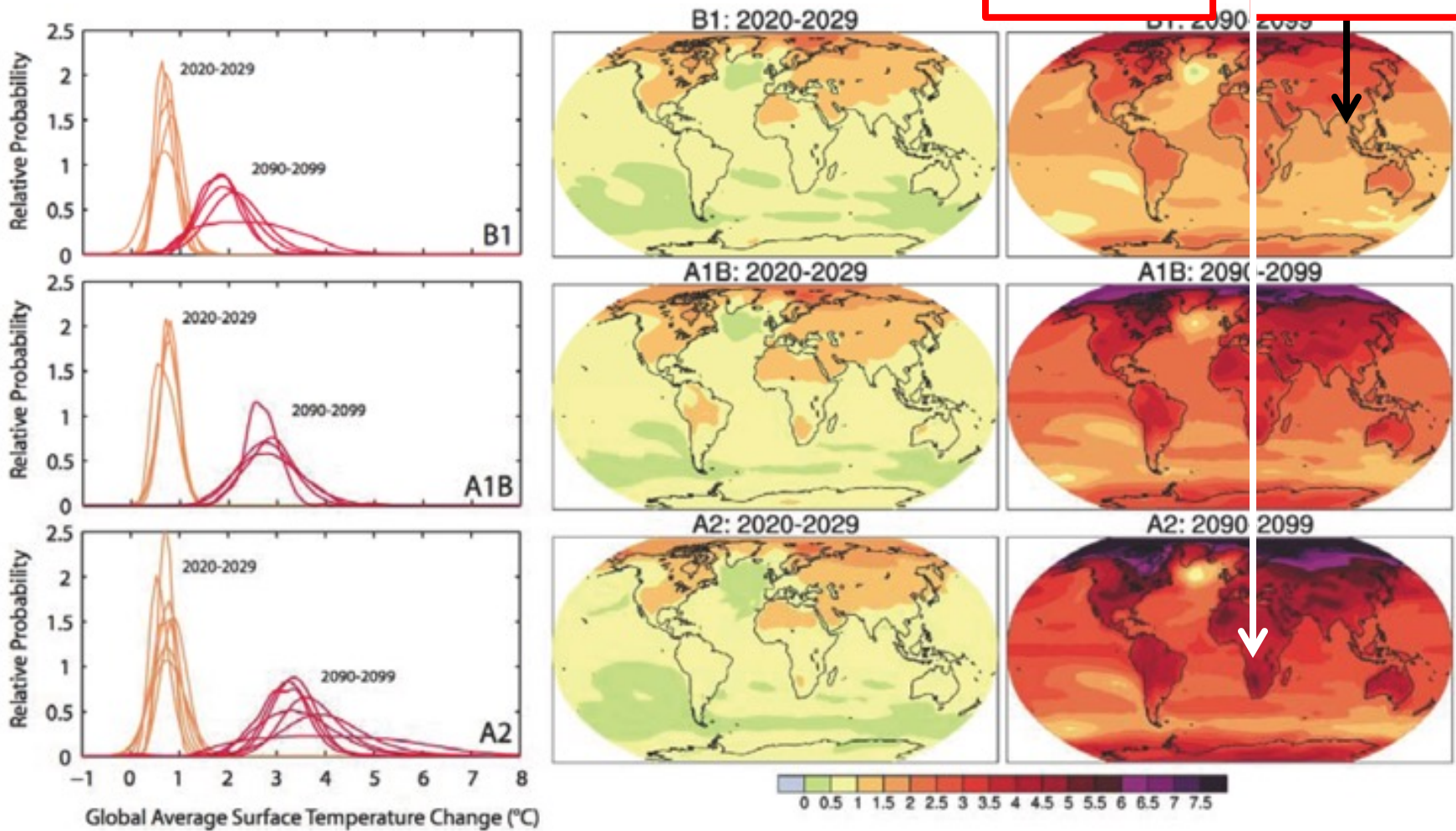


Impacts of Climate Change

Increased global average temperature

4.0° C
globally
warmer

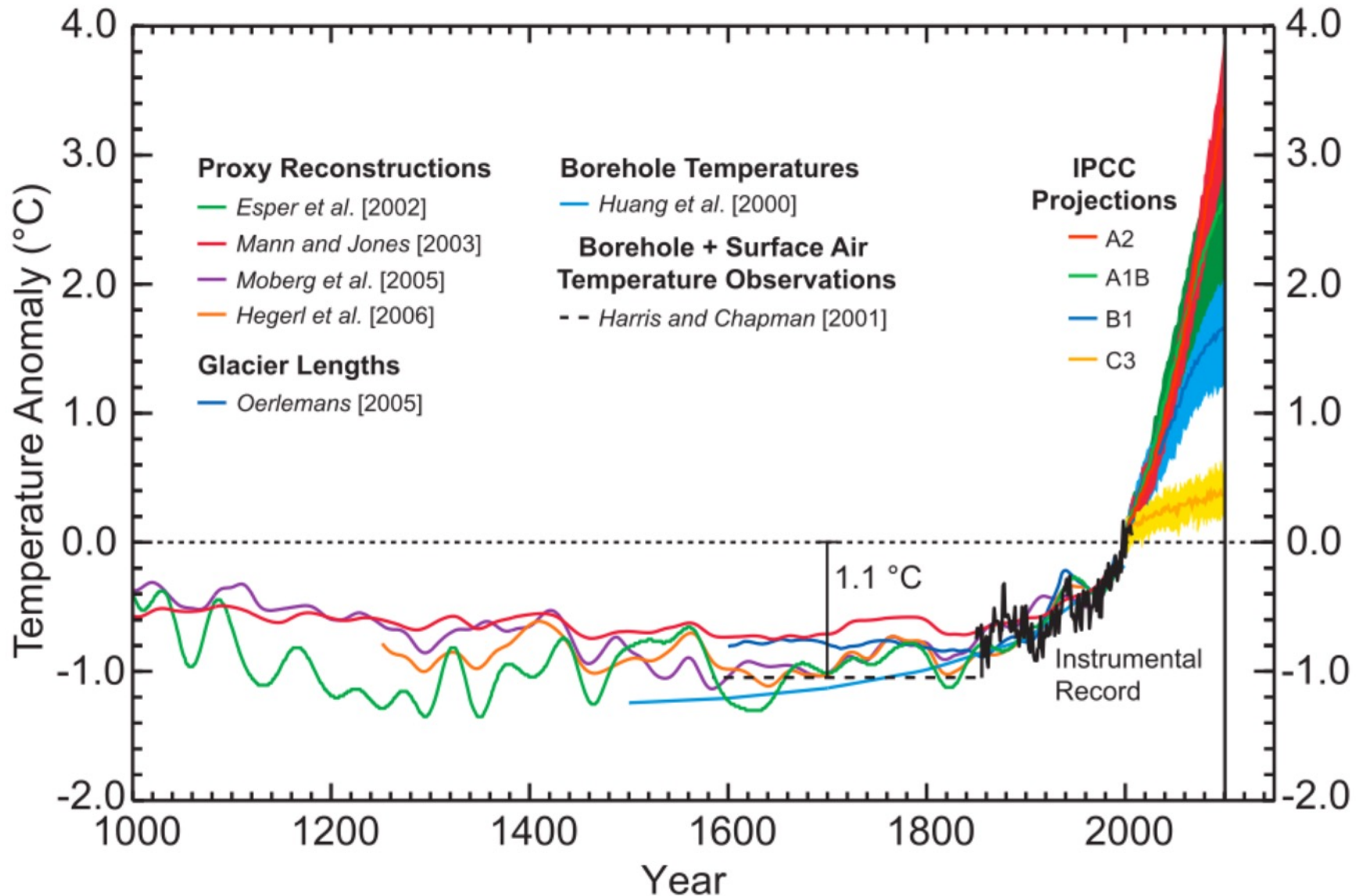
1.8° C
globally
warmer



Average from many models (relative to years 1980-1999)

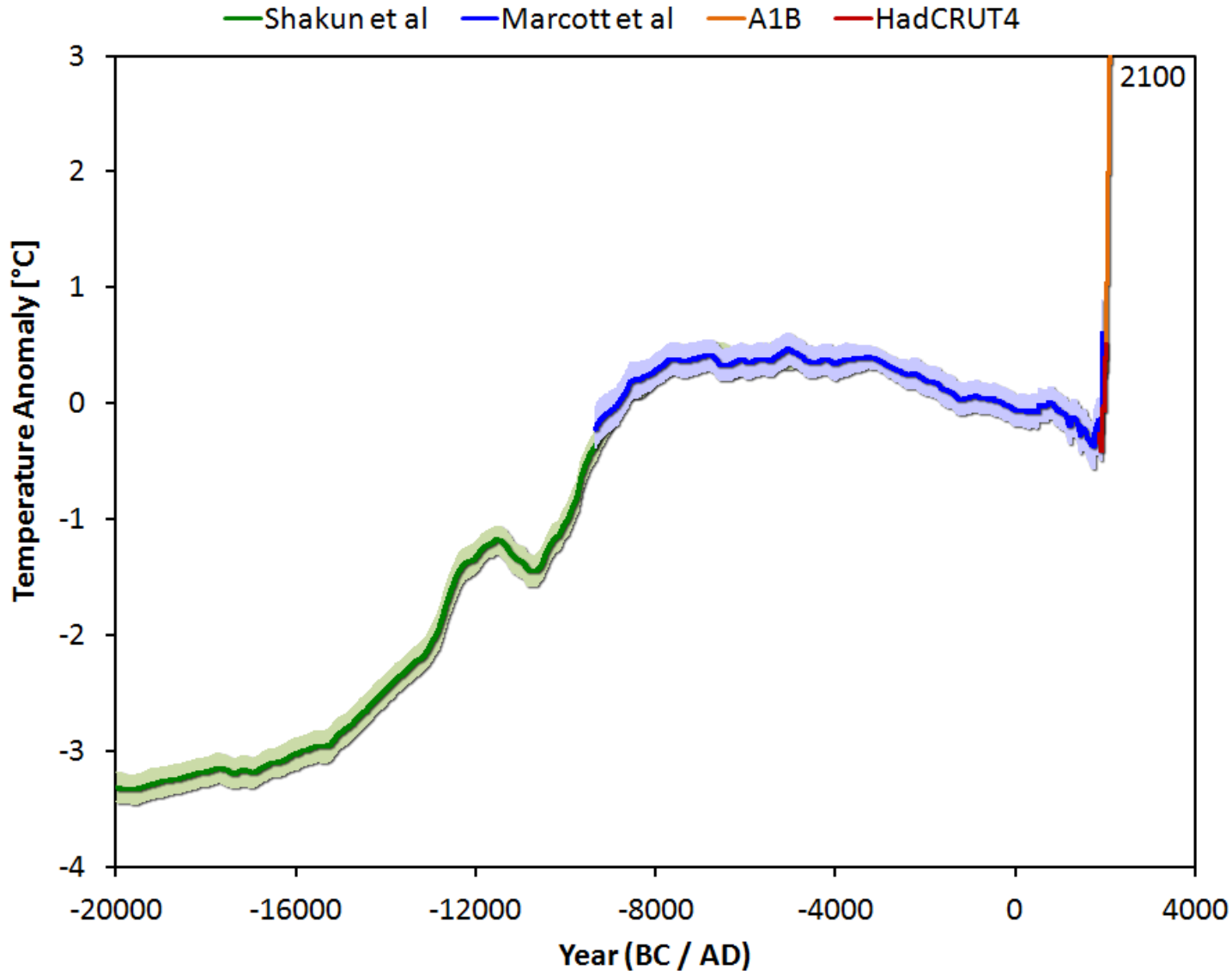
Impacts of Climate Change

Increased global average temperature

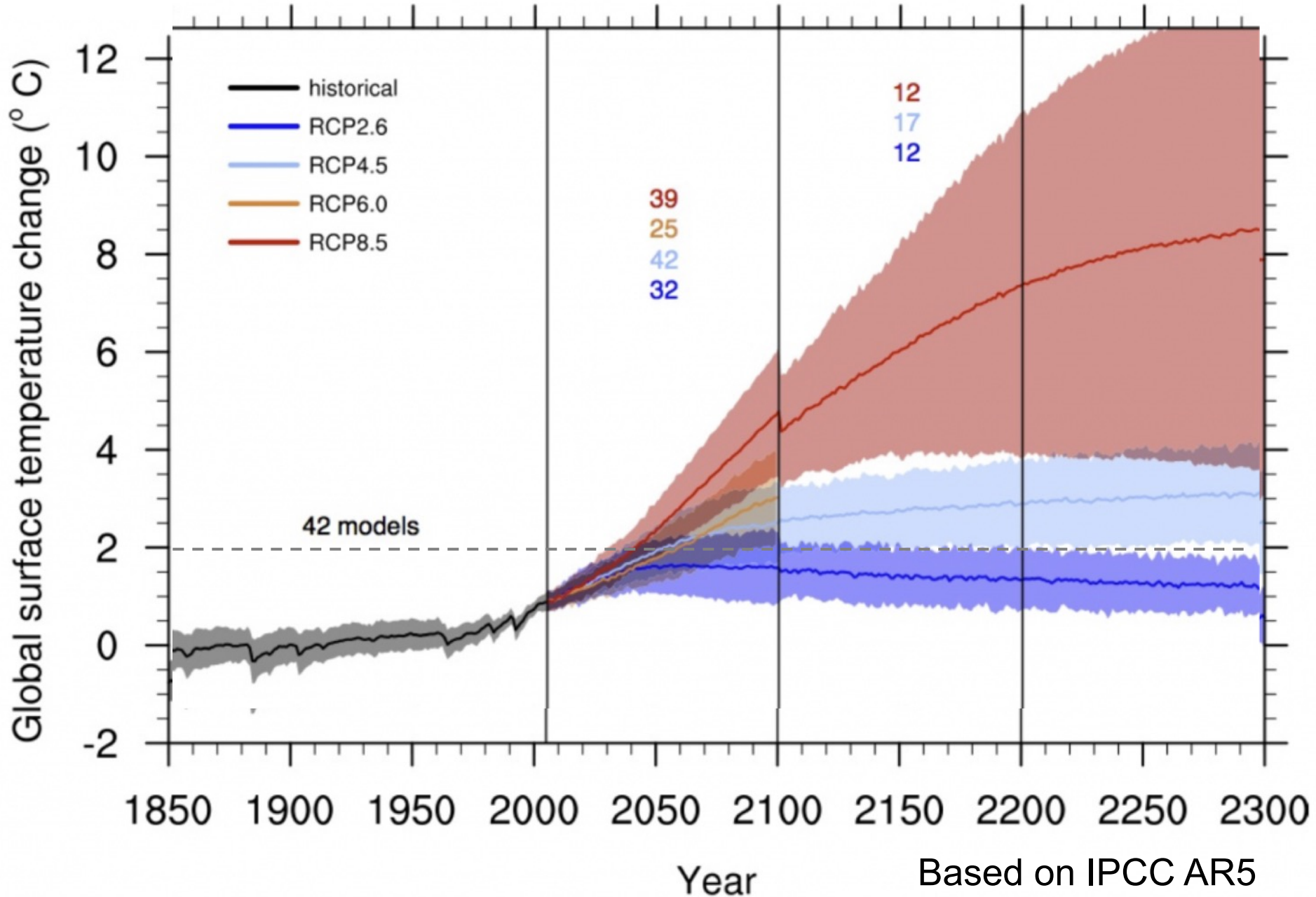


Impacts of Climate Change

Increased global average temperature



Impacts of Climate Change



Impacts of Climate Change

Increased glacial melting



Wedgemont Glacier, Whistler BC

Impacts of Climate Change

Sea Level Rise



Vancouver near top of list of cities threatened by rising sea levels

DENE MOORE

VANCOUVER — The Canadian Press

Published Tuesday, Aug. 20, 2013 10:23PM EDT

Last updated Wednesday, Aug. 21, 2013 12:34PM EDT



Canada's East Coast most vulnerable to rising sea levels

A new study says sea levels are rising at a rate never seen before.

Impacts of Climate Change

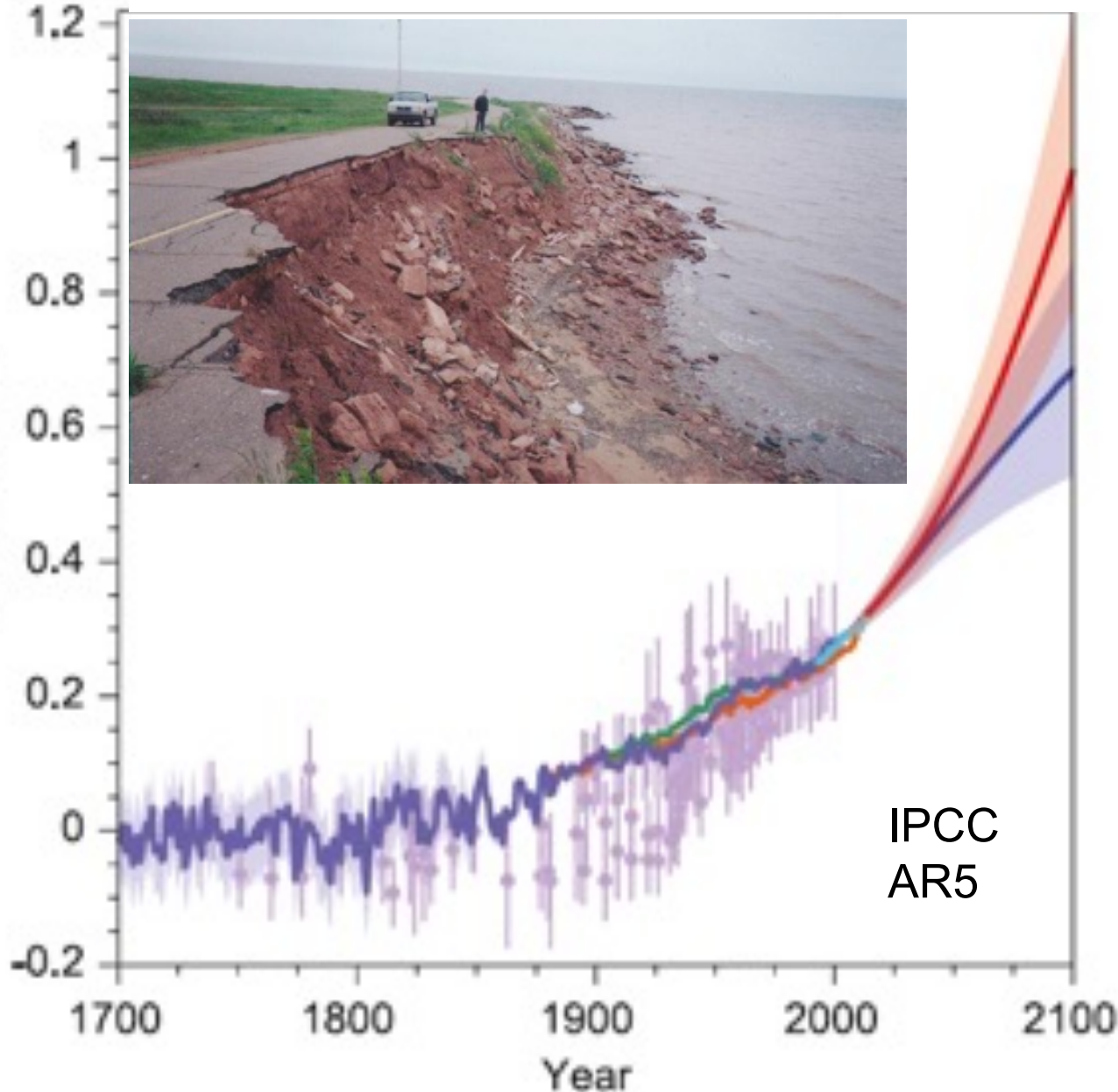
Sea Level Rise by Century

Centimeters:



Central reconstruction shown. Bars +/- 5 cm before 20th century
Source: Kopp et al. 2016 (PNAS)

Impacts of Climate Change

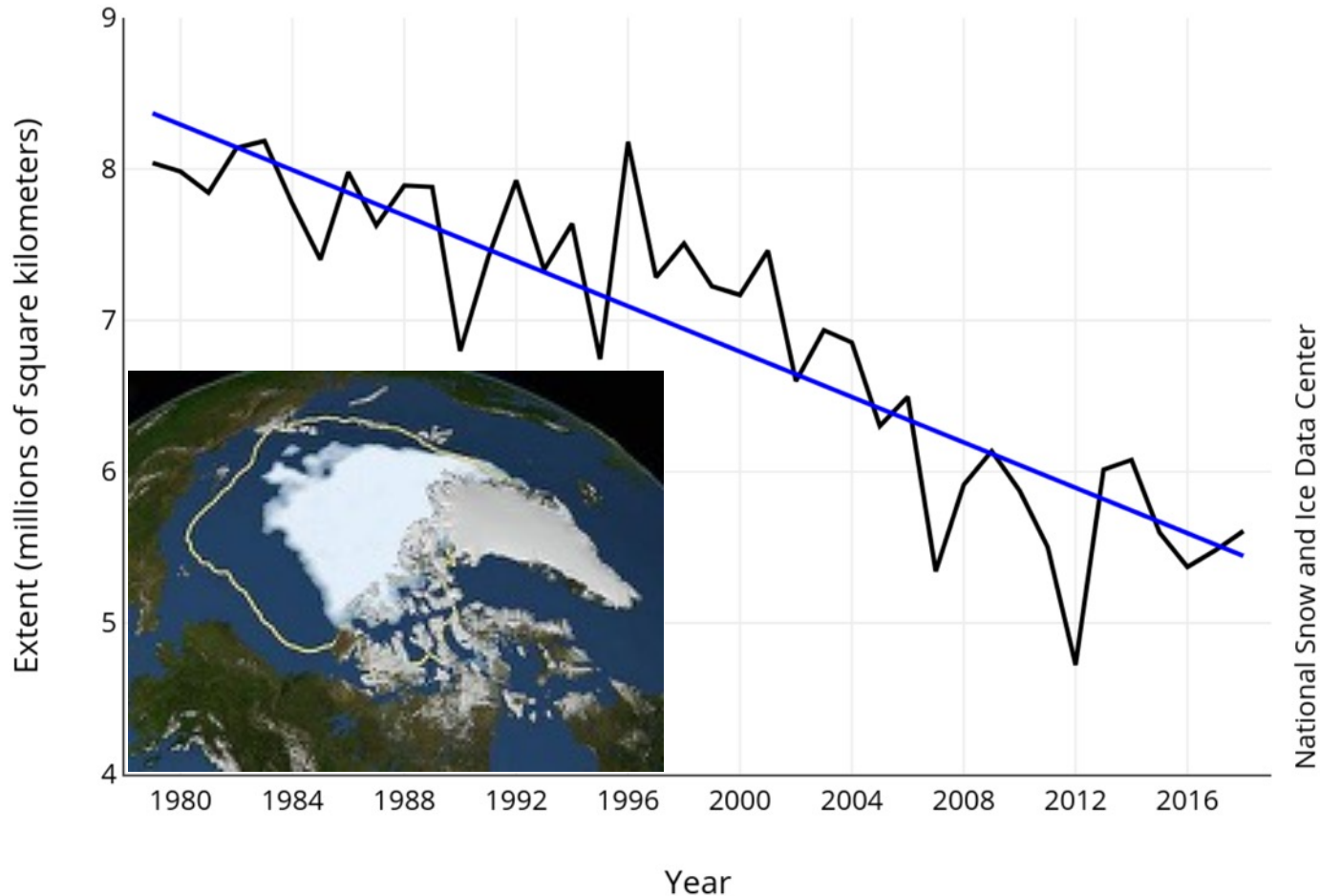


- 20 cm of sea level rise in the last century
- Sea level is currently rising at 3.4 cm per decade
- Average rate from 1950 - 2009 was 1.7 cm per decade

Impacts of Climate Change

Decrease in Arctic sea ice extent

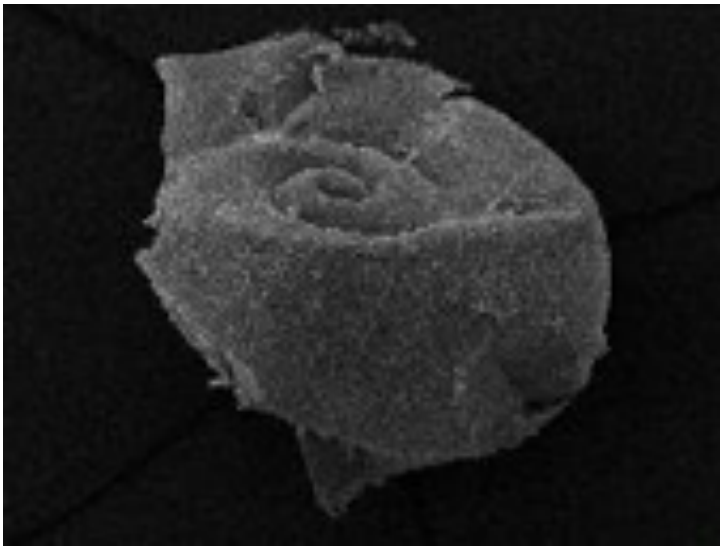
Average Monthly Arctic Sea Ice Extent
August 1979 - 2018



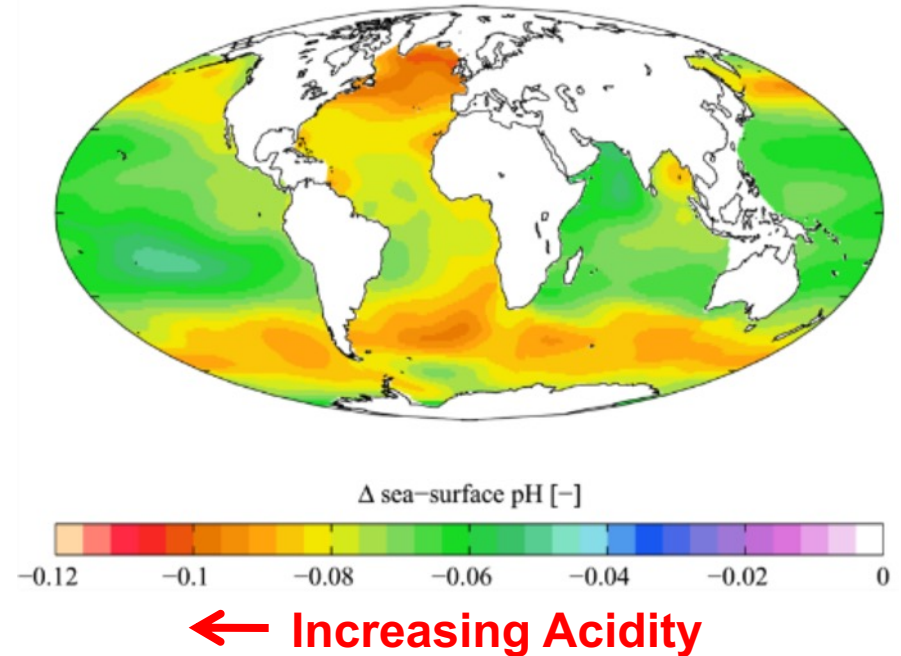
Impacts of Climate Change

Increasing Ocean Acidification

- Carbon dioxide dissolves in water to make carbonic acid
- Dissolves the shells of many marine organisms



shell dissolution



- UN Report: "The global economy could be losing as much as \$1 trillion annually by the end of the century if countries do not stop ocean acidification"
- Over the next 200 years, the oceans could become more acidic than during the past 300 million years!

Impacts of Climate Change

Increasing Extreme Events

Instead of asking:

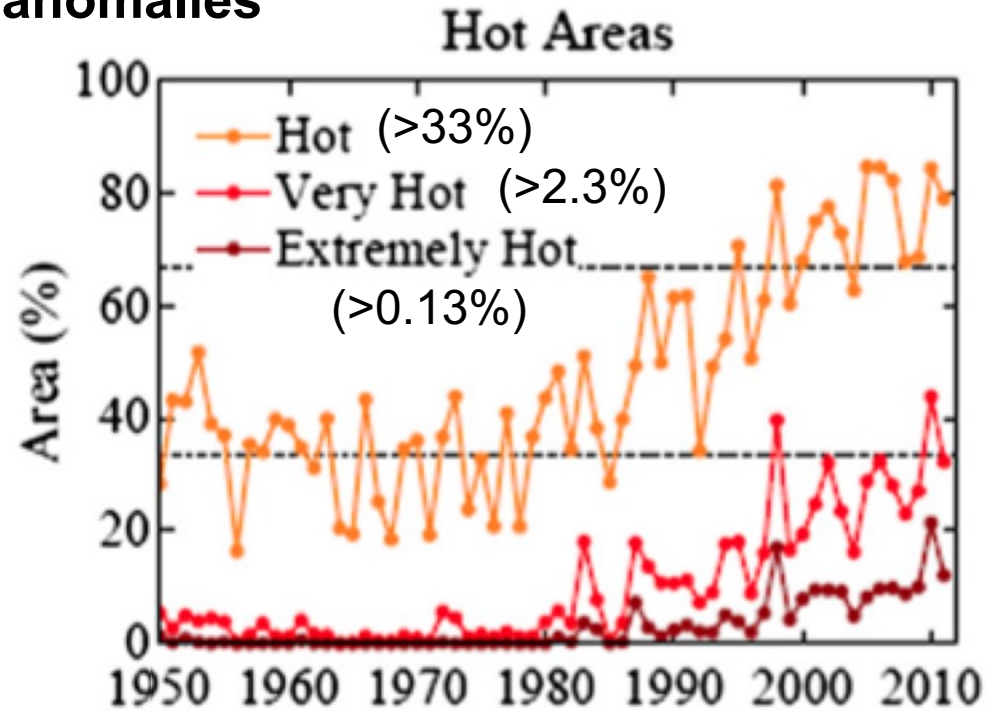
“Was this event caused by climate change”

Ask:

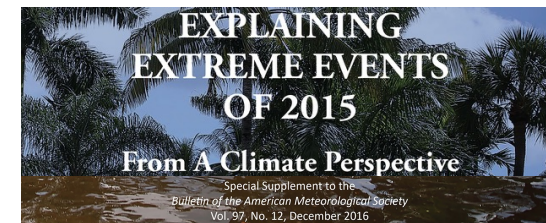
“What’s the chance that this event would occur without climate change?”

2015: “Without exception, all the heat-related events studied in this year’s report were found to have been made more intense or likely due to human-induced climate change”

Summer temperature anomalies



(Hansen et al., 2012)



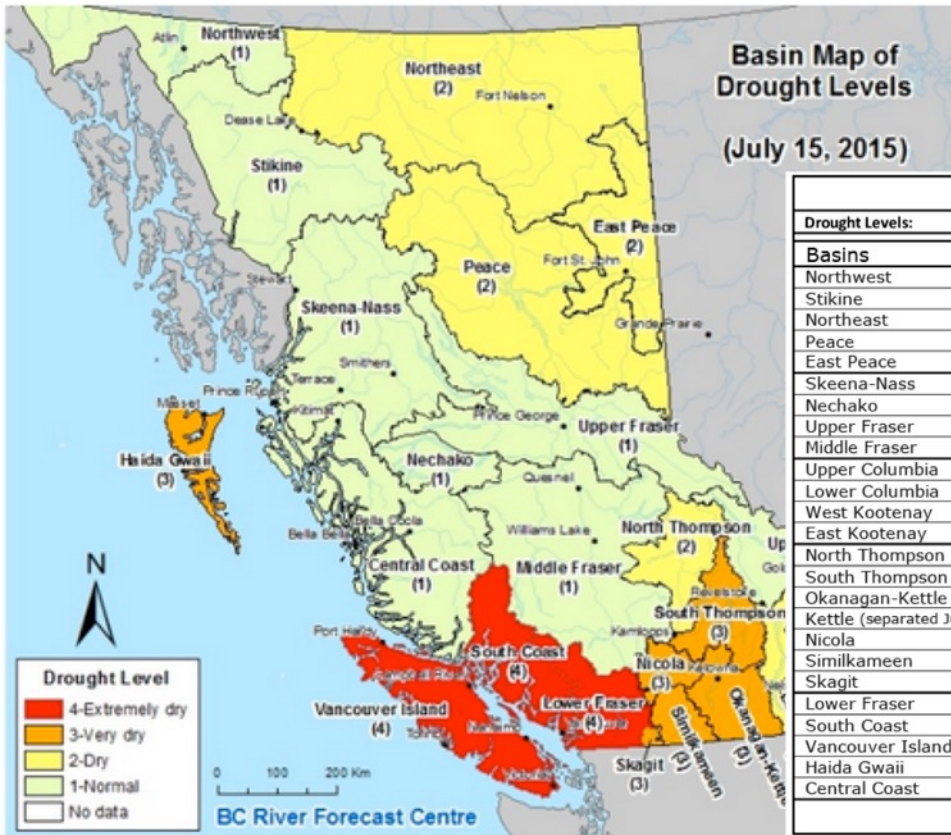
Impacts of Climate Change

Level 4 drought declared for South Coast and Lower Fraser

'Extremely dry' conditions mean water managers may soon bring in tighter restrictions

CBC News Posted: Jul 15, 2015 1:40 PM PT | Last Updated: Jul 15, 2015 4:41 PM PT

The 2015 Extreme Drought in Western Canada

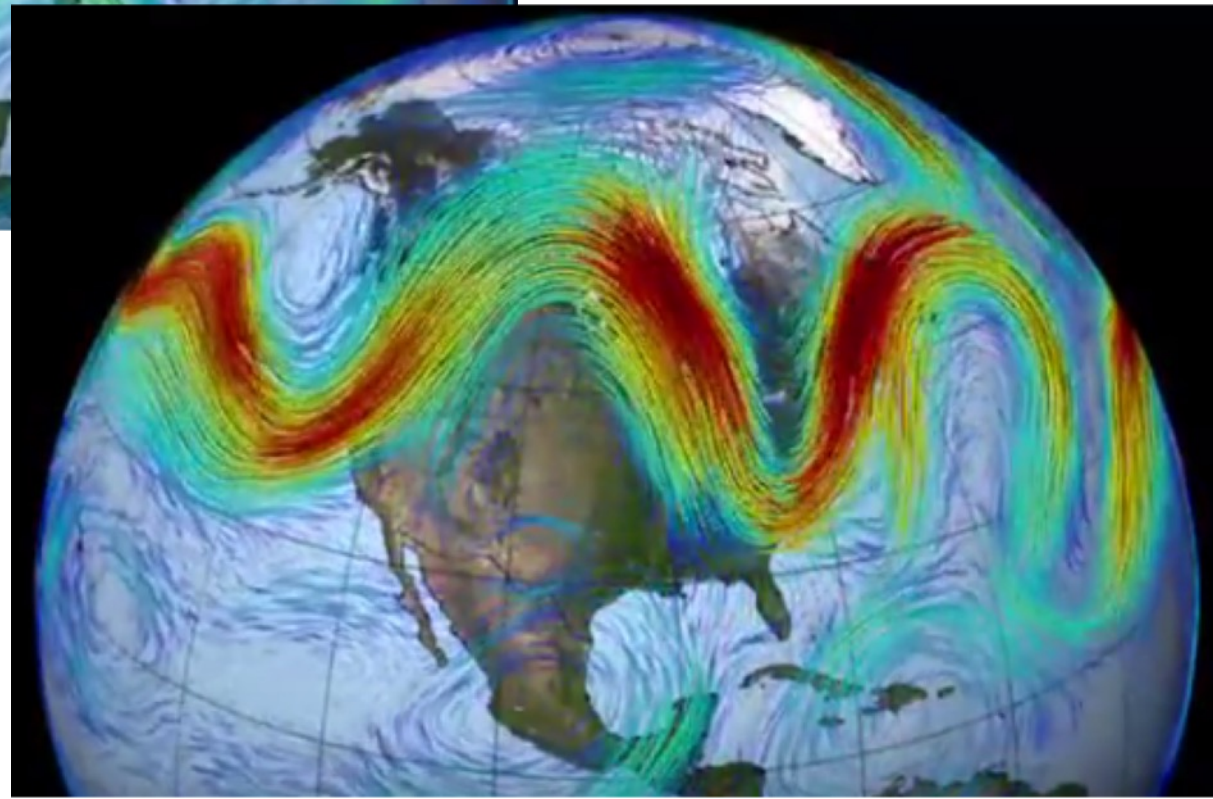
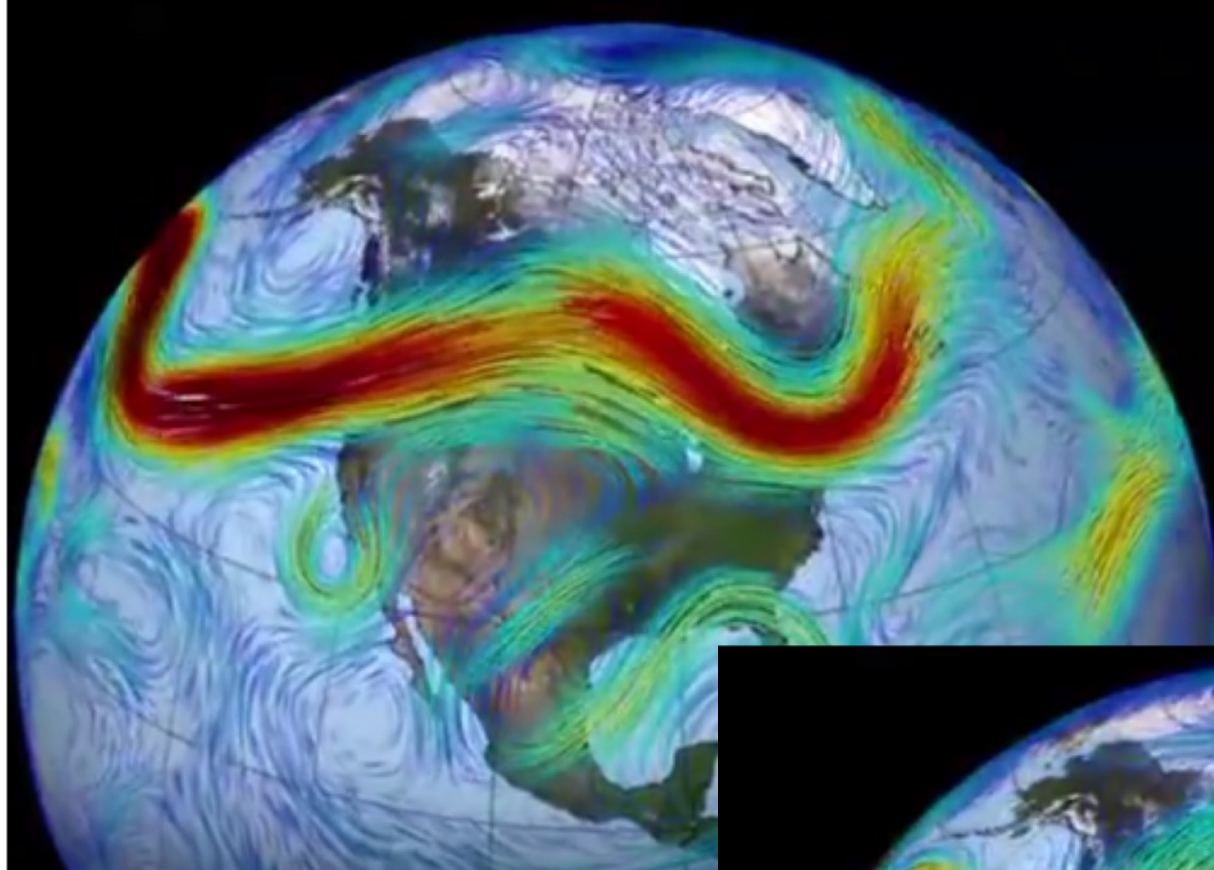


2015 DROUGHT LEVELS AT A GLANCE													
Drought Levels:	1 Normal	2 Dry	3 Very Dry	4 Extremely Dry									
Basins	15-May	28-May	25-Jun	03-Jul	09-Jul	15-Jul	21-Jul	23-Jul	05-Aug	06-Aug	20-Aug	03-Sep	17-Sep
Northwest	2	1	1	1	1	1	1	1	1	1	1	1	1
Stikine	2	1	1	1	1	1	1	1	1	1	1	1	1
Northwest	1	1	1	1	2	2	2	2	2	2	1	1	1
Peace	1	1	1	1	2	2	2	2	2	2	2	1	1
East Peace	1	2	1	1	2	2	2	2	2	2	2	1	1
Skeena-Nass	1	1	1	1	1	1	1	2	2	2	2	1	1
Nechako	1	1	1	1	1	1	1	1	1	1	1	1	1
Upper Fraser	1	1	1	1	1	1	1	2	2	2	2	2	1
Middle Fraser	2	1	1	1	1	1	1	2	2	3	3	3	2
Upper Columbia	1	1	1	1	1	1	1	2	2	2	2	2	1
Lower Columbia	1	1	2	2	2	2	2	2	2	3	3	3	2
West Kootenay	1	1	2	2	2	2	2	2	2	3	3	3	2
East Kootenay	2	1	2	2	2	2	2	2	2	3	3	3	1
North Thompson	1	1	1	1	2	2	2	2	3	3	4	4	2
South Thompson	1	1	2	2	3	3	3	4	4	4	4	4	3
Okanagan-Kettle	2	2	2	2	3	3	3	3	4	4	4	4	3
Kettle (separated July 23)								4	4	4	4	4	3
Nicola	2	2	2	2	3	3	4	4	4	4	4	4	3
Similkameen	2	2	2	2	3	3	3	4	4	4	4	4	3
Skagit	1	1	1	1	3	3	3	4	4	4	4	3	2
Lower Fraser	2	2	3	3	3	4	4	4	4	4	4	3	2
South Coast	2	2	3	3	3	4	4	4	4	4	4	3	2
Vancouver Island	2	3	3	4	4	4	4	4	4	4	4	3	2
Haida Gwaii	1	3	3	3	3	3	3	3	3	3	2	1	1
Central Coast	1	1	1	1	1	1	1	1	1	1	1	1	1

Prepared By: Water Management Branch, Ministry of Forests, Lands and Natural Resource Operations
Last Update: September 18, 2015

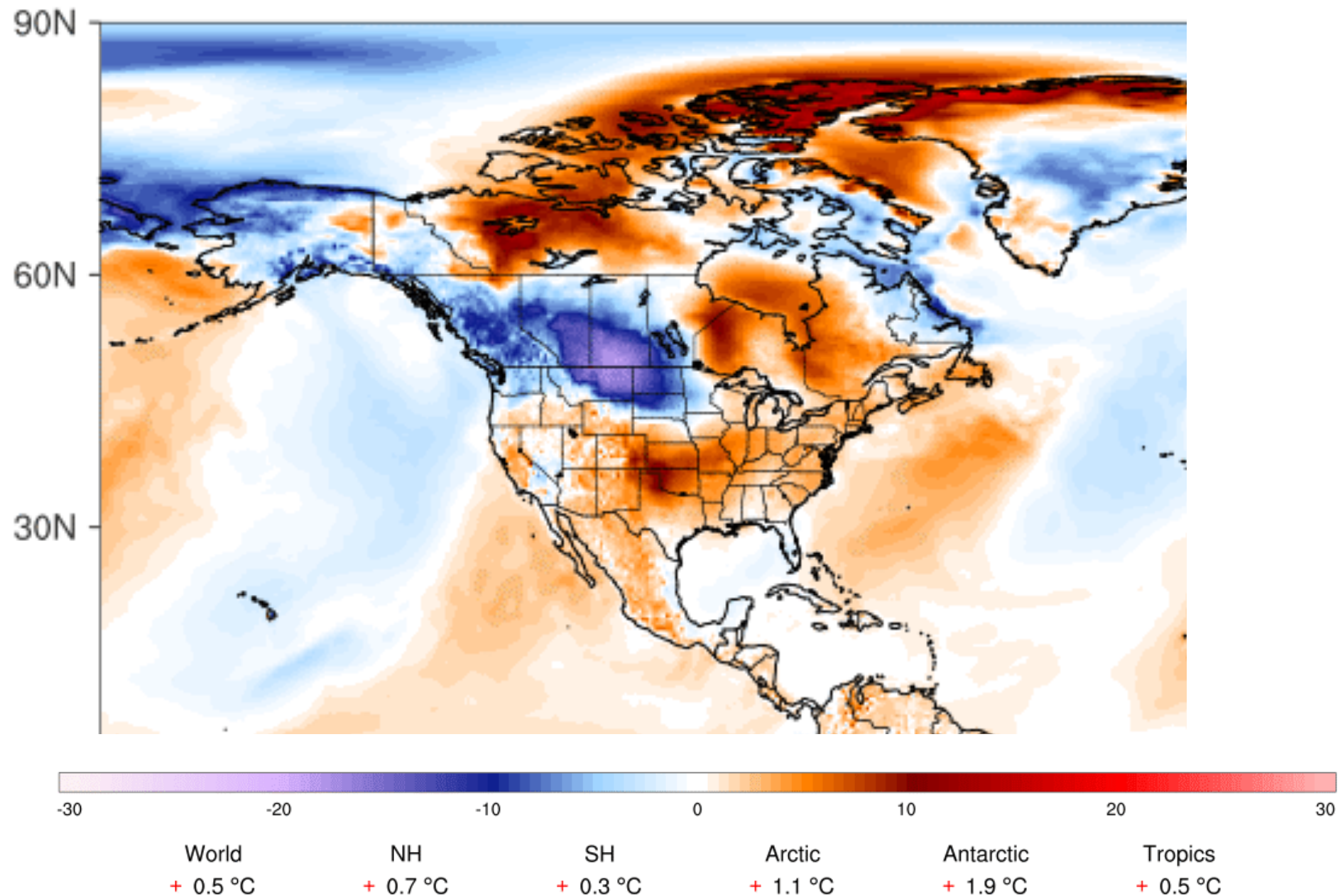
The South Coast and Fraser Valley joined Vancouver Island at Level 4 drought conditions on Wednesday, July 15th. Click for full image. (B.C. Government)

Warm late-winter temperatures and the associated reduction in snowpack set the stage for the 2015 drought



[Animation](#)

Climate Change Institute | University of Maine



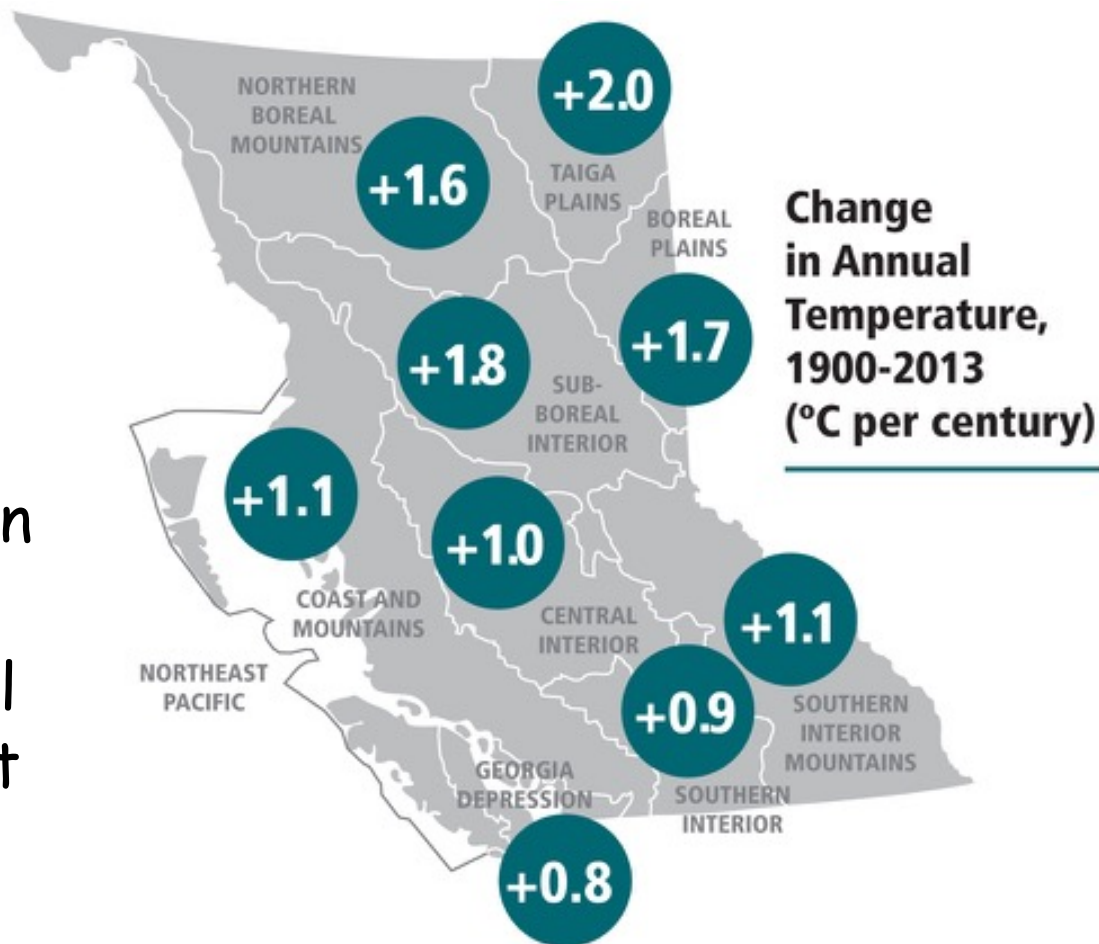
Climate Change Impacts in BC

Average Annual Temperature

Vancouver Island annual temp increased 0.8 °C

We should expect

- Relatively warm years will increase in frequency
- Year to year natural variation will persist



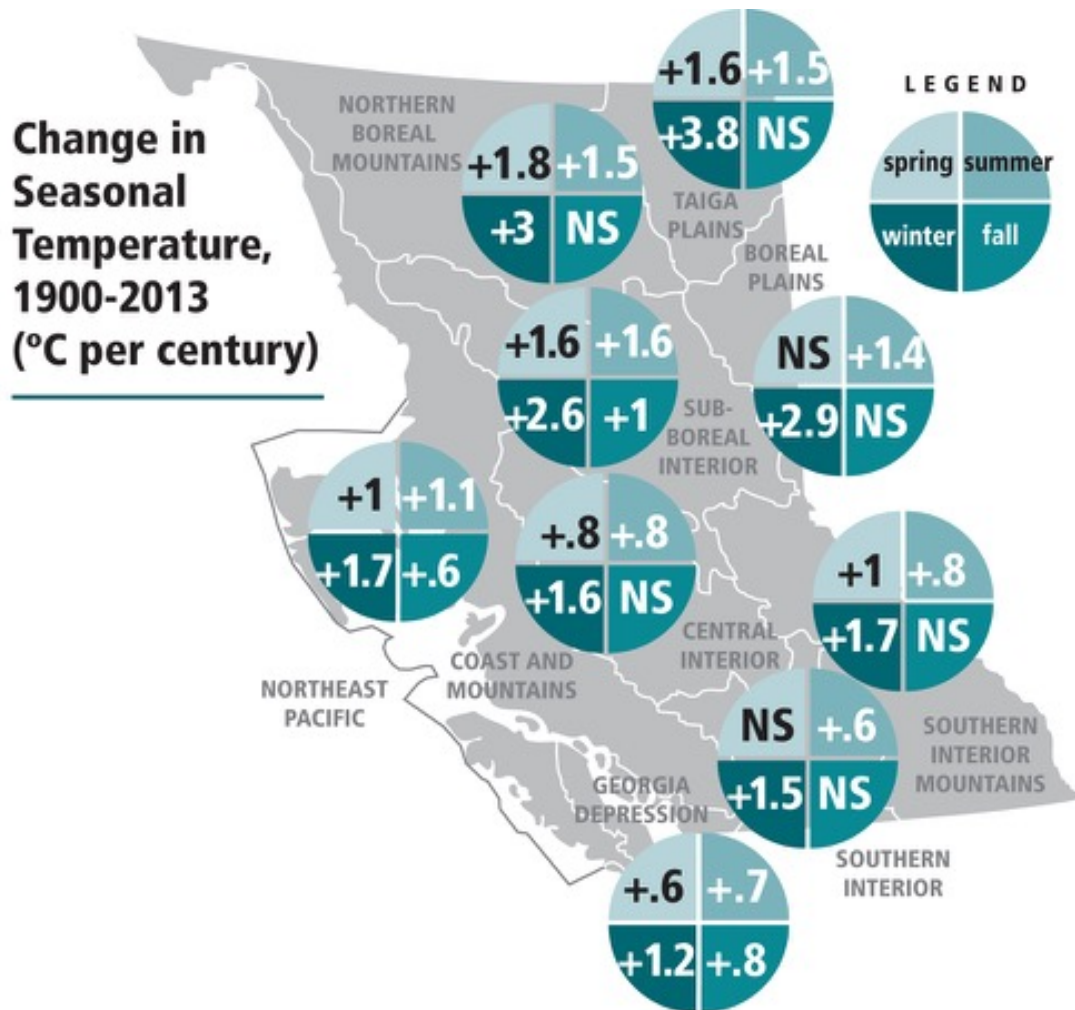
SOURCE: Data from Ministry of Environment Climate Related Monitoring Program and Environment Canada. Trend Analysis for 1900 through 2013 conducted by PCIC, 2014 for the Ministry of Environment Climate Action Secretariat. NOTES: All trends are positive and indicate warming.

Climate Change Impacts in BC

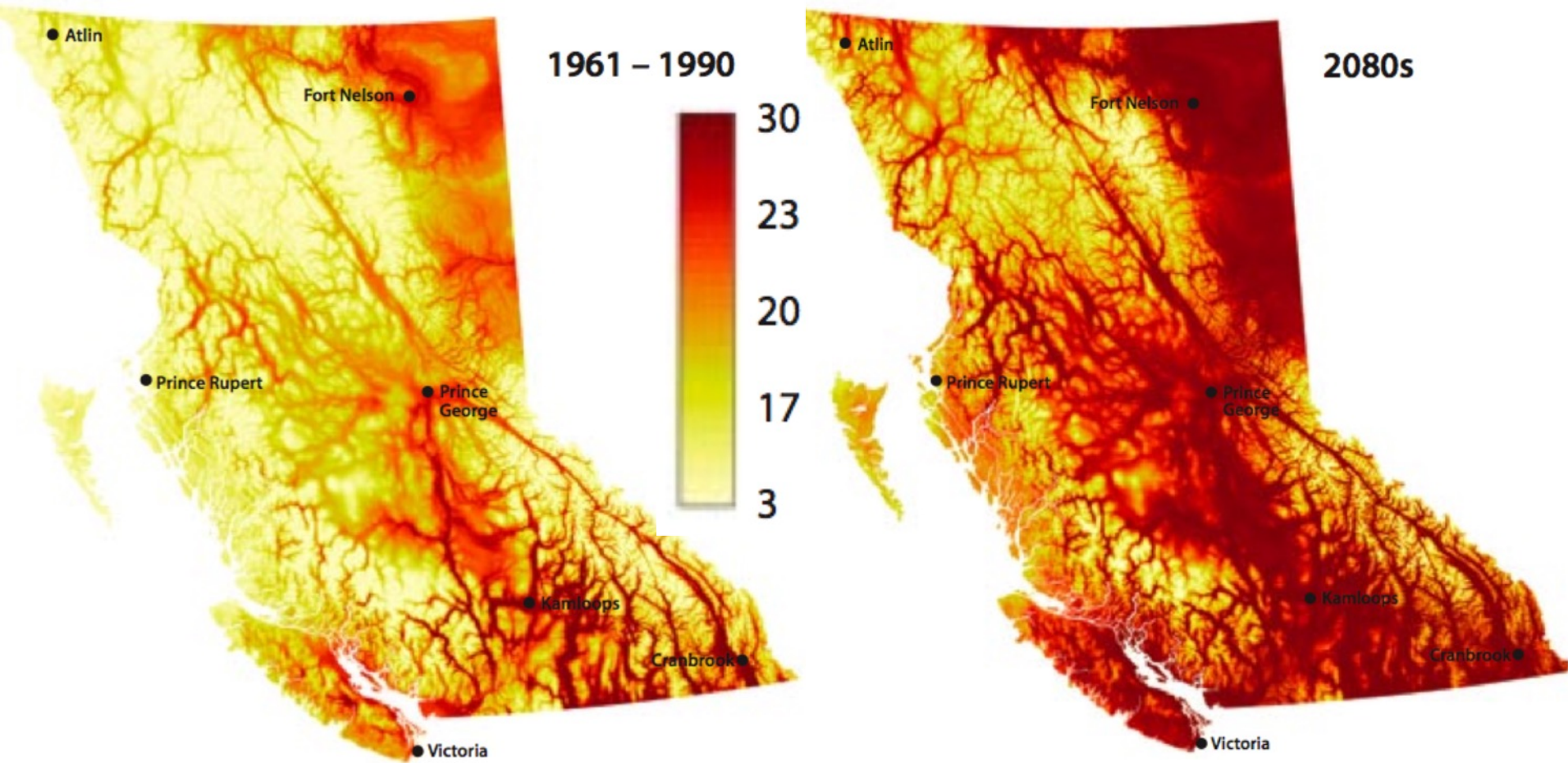
Average Seasonal Temperature

Vancouver Island
average winter
warming 1.2°C

Greater warming in
the winter than
in other seasons

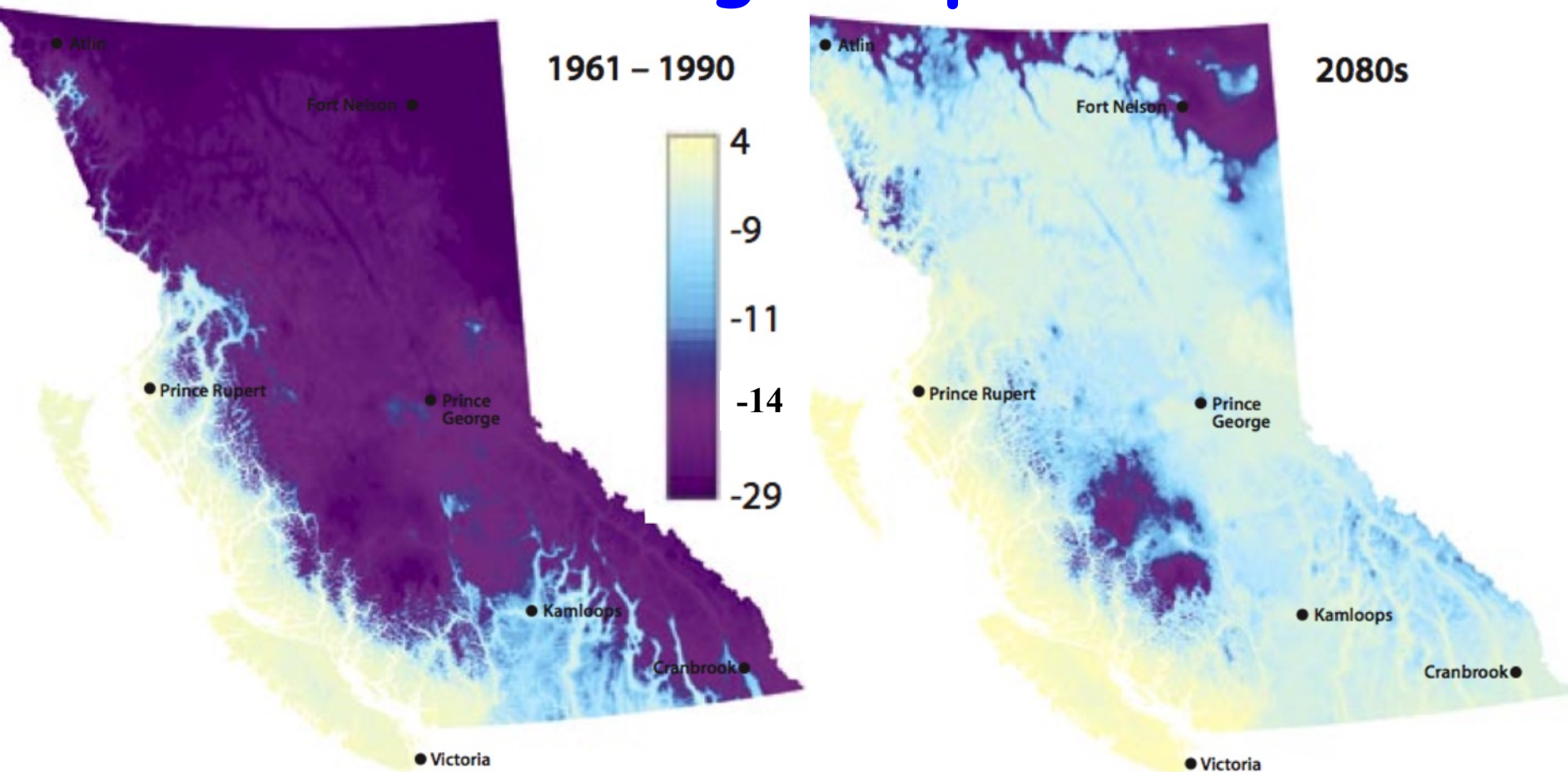


Climate Change Impacts in BC



Mean Maximum Temperature, July (° C)

Climate Change Impacts in BC

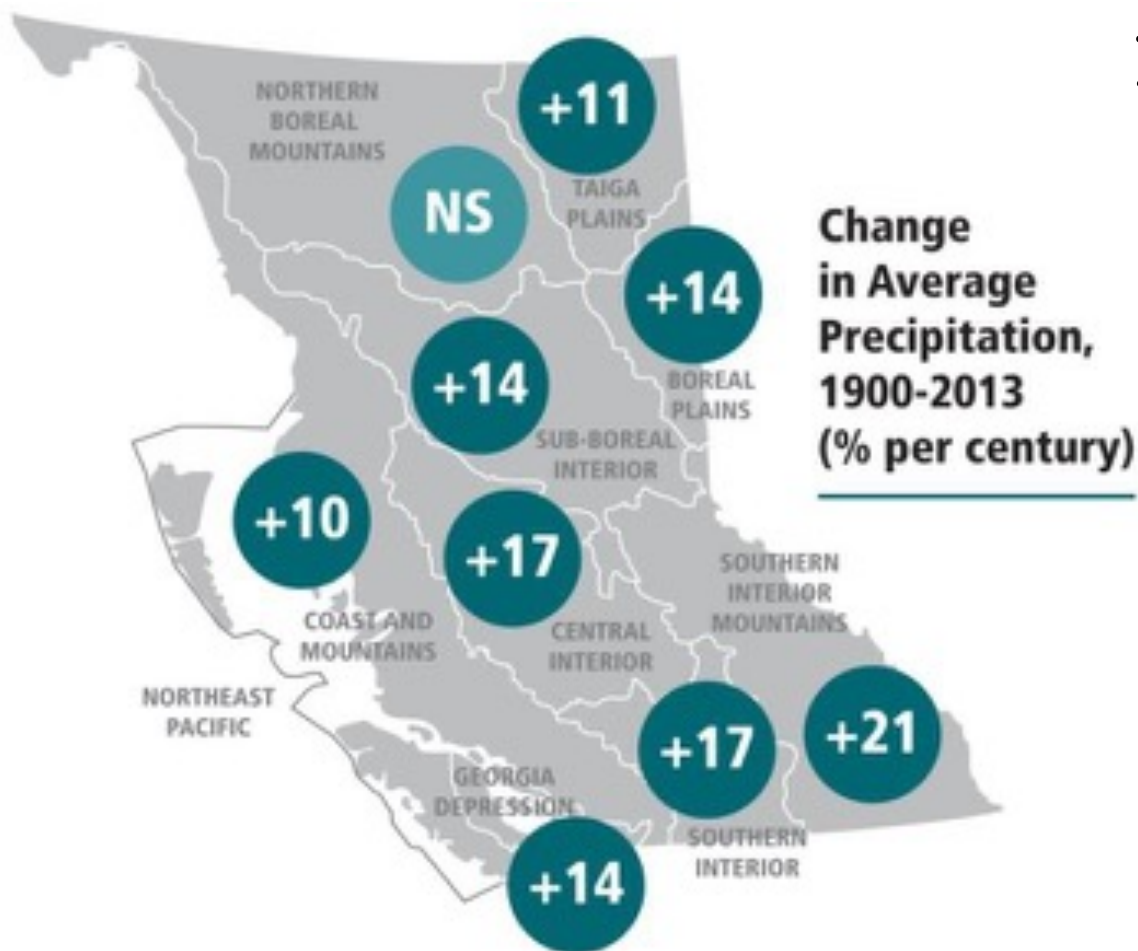


Mean Minimum Temperature, January (° C)

- Reduced snowpack and earlier snowmelt

Climate Change Impacts in BC

Average annual precipitation

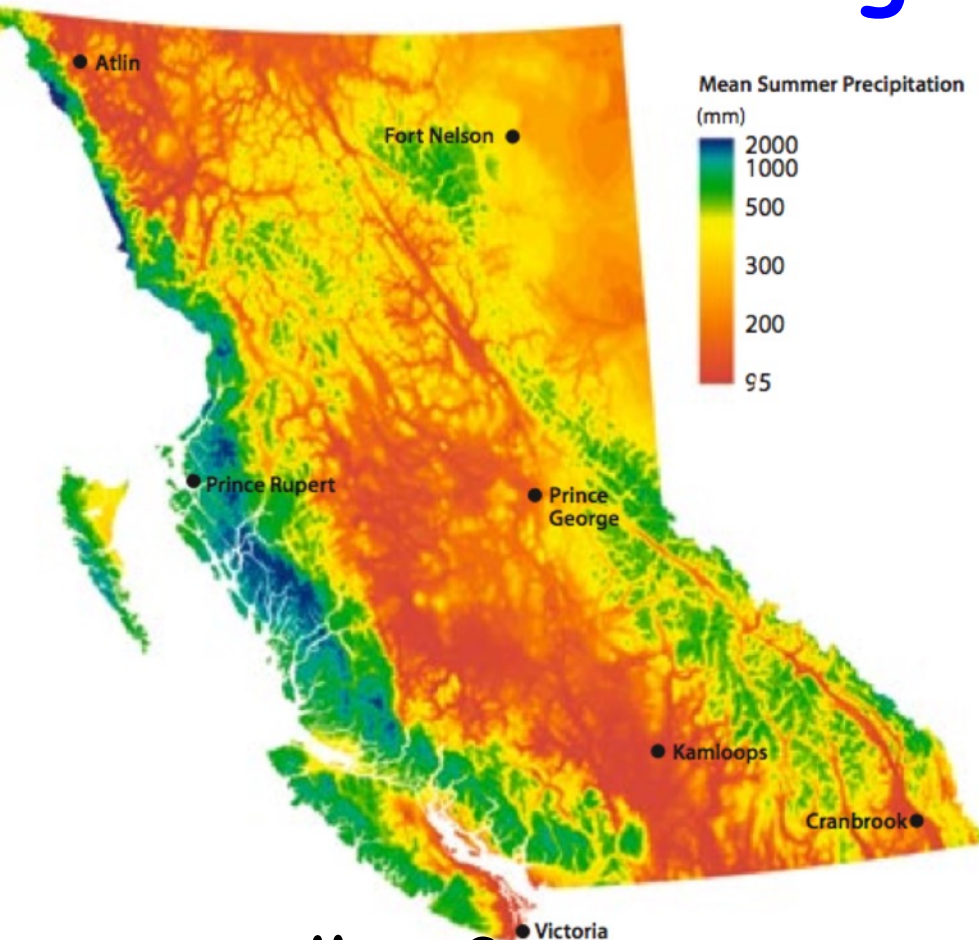


Increased 14% on Vancouver Island

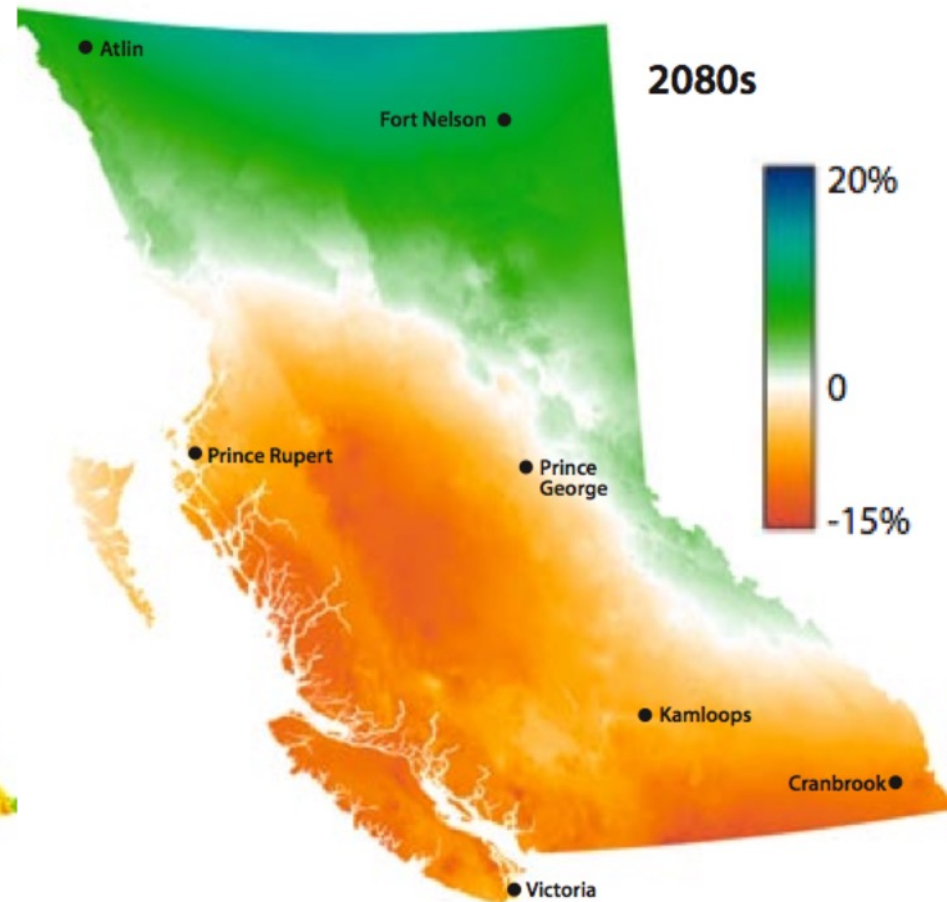
We should expect

- More frequent heavy precipitation events
- A shift poleward of mid latitude storms
- Increase in the strength of the most extreme storms

Climate Change Impacts in BC



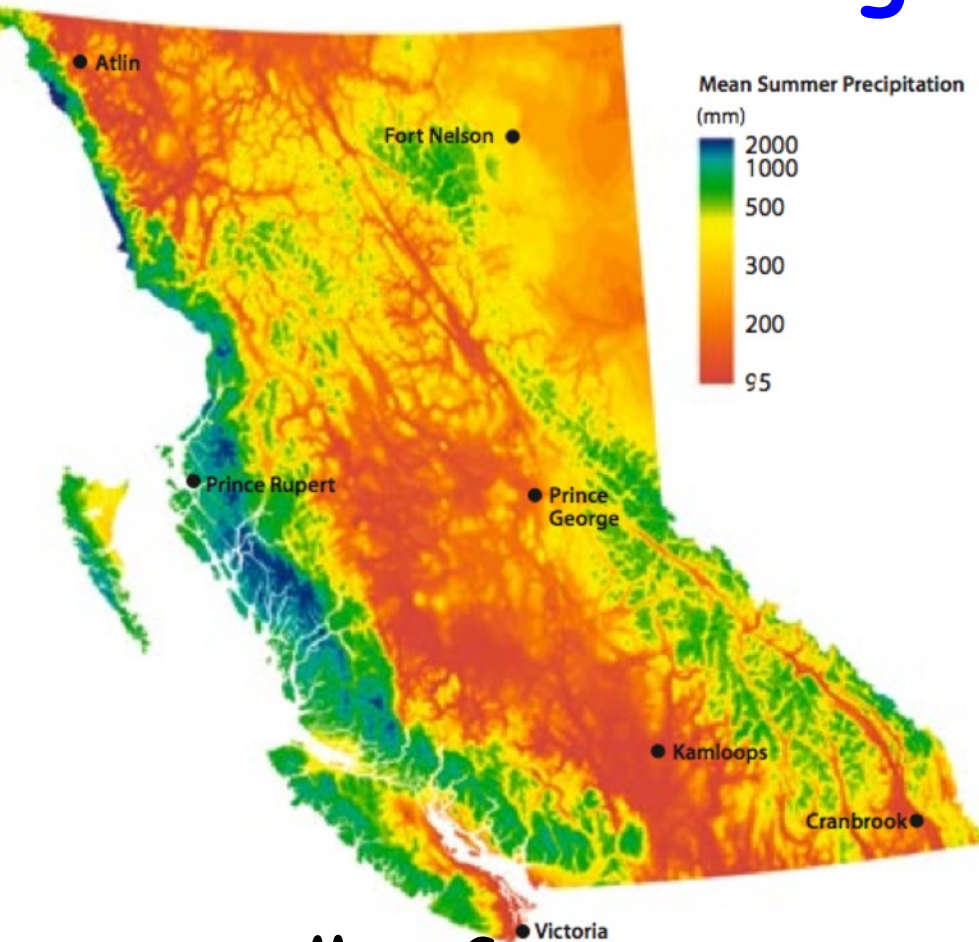
**Mean Summer
Precipitation (mm)**



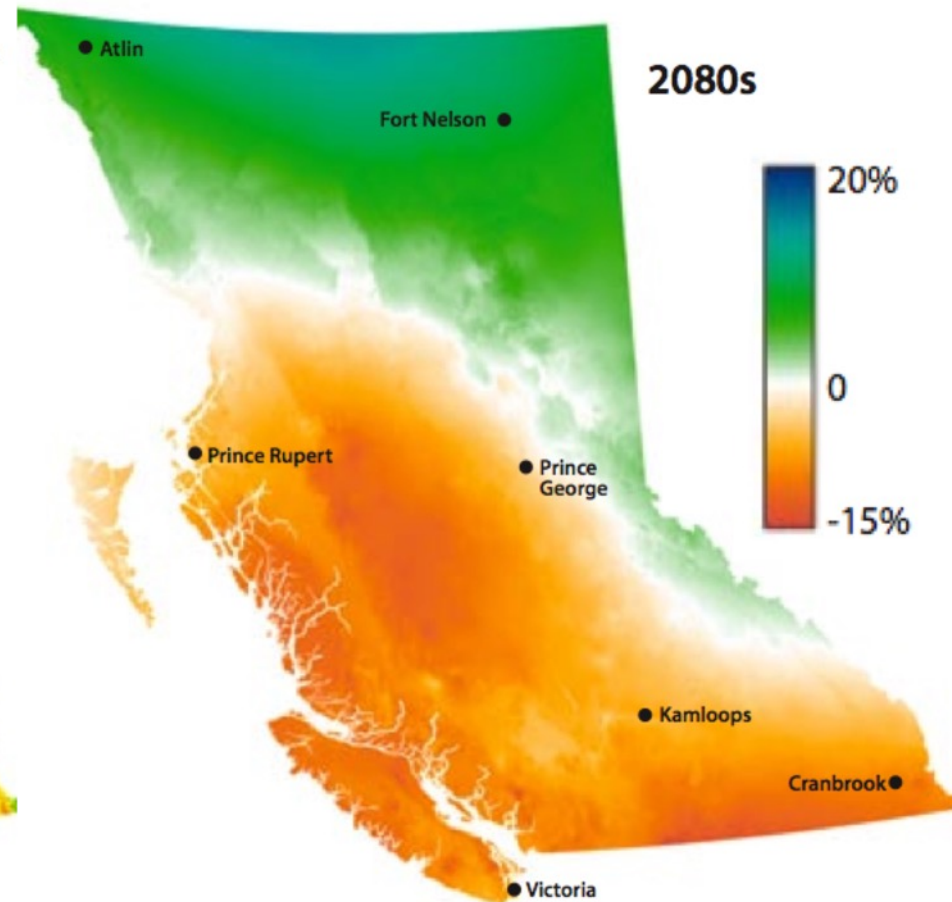
**Percent Change relative to
'Normal' (1961 - 1990)**

- Drier areas of the southern interior may experience regeneration problems due to an increase in summer droughts
- Increased forest fire frequency and severity due to warming and drying.

Climate Change Impacts in BC



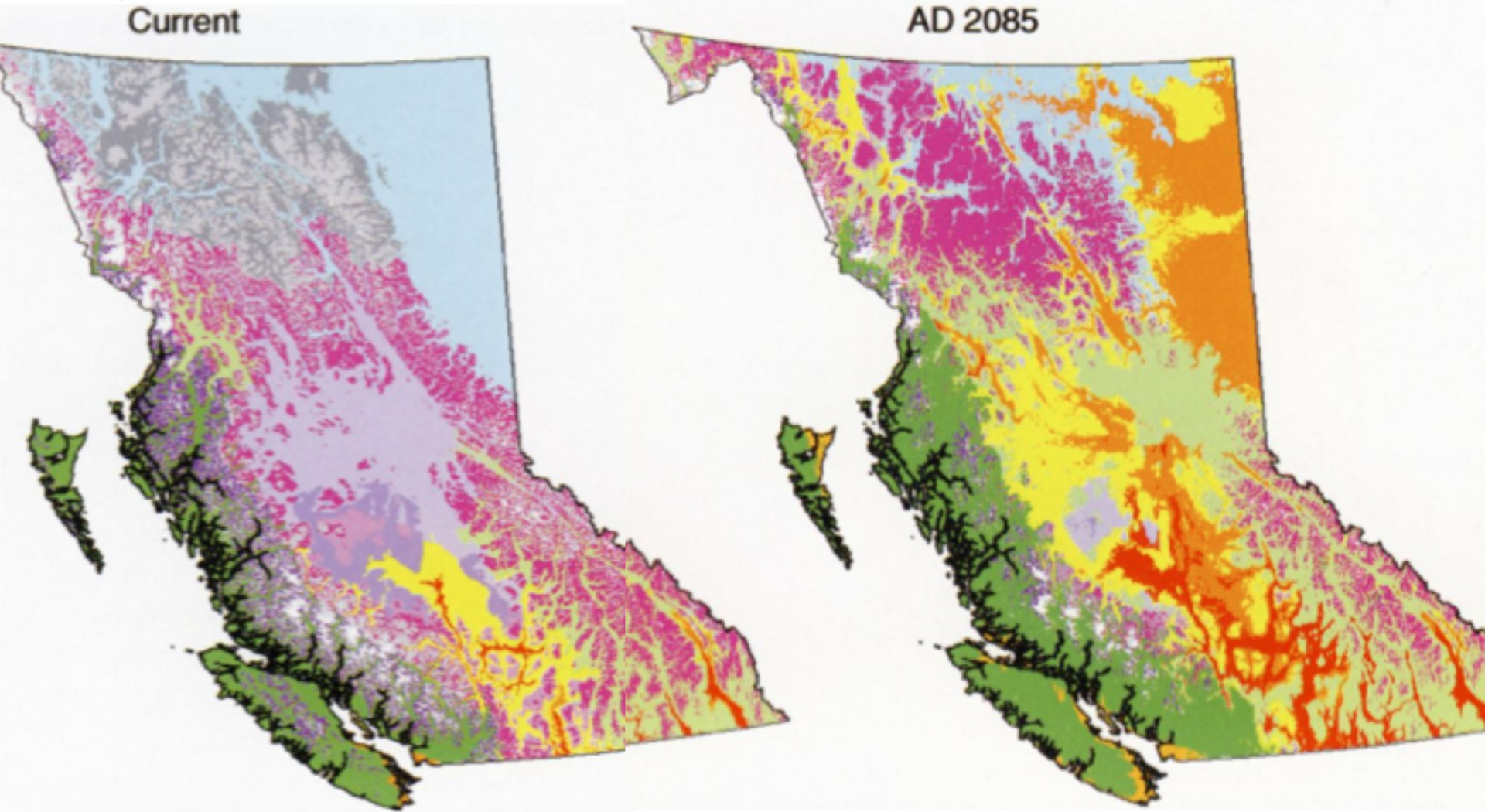
**Mean Summer
Precipitation (mm)**



**Percent Change relative to
'Normal' (1961 - 1990)**

- Changes in water levels and timing of peak flow events
- Reduced quality and quantity of fresh water

Climate Change and BC Ecosystems



Coast: CDF CWH

South: BG PP IDF ICH

Central/North: SBPS SBS BWBS SWB

Montane: MH ESSF MS AT

Climate Change Impacts in BC

Possible Impacts of Climate Change on BC's Forest

- Changes in growth rates
- Increased competition from other species more suited to the climate
- New assemblages of species will occur in space and time
- Northward or upslope shifts in terrestrial ecosystems
- Species may be unable to move into areas of suitable climate due to barriers to movement, slow migration rates, unsuitable growing substrate or lack of habitat
- Coastal forests will likely see an increase in the number and intensity of storms, thereby increasing windthrow damage



Forestry groups warns of climate change impact on B.C.'s ecosystems

MARK HUME

VANCOUVER — The Globe and Mail

Published Tuesday, Jul. 08 2014, 8:08 PM EDT

Last updated Tuesday, Jul. 08 2014, 8:08 PM EDT

21 comments



250



154



80



16



4



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AA

Associations representing more than 9,000 forest professionals, biologists and planners have issued a joint statement recognizing that “climate change is occurring and it has fundamental impacts on British Columbia’s communities and ecosystems.”

The groups say the declaration, released Tuesday, is unprecedented because it comes not from climate change scientists or environmental activists but professionals who work in the field, managing forests.



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SHAPING COMMUNITIES*

Professional Leadership in a Changing Climate: Joint Statement

Overwhelming Burden of Evidence

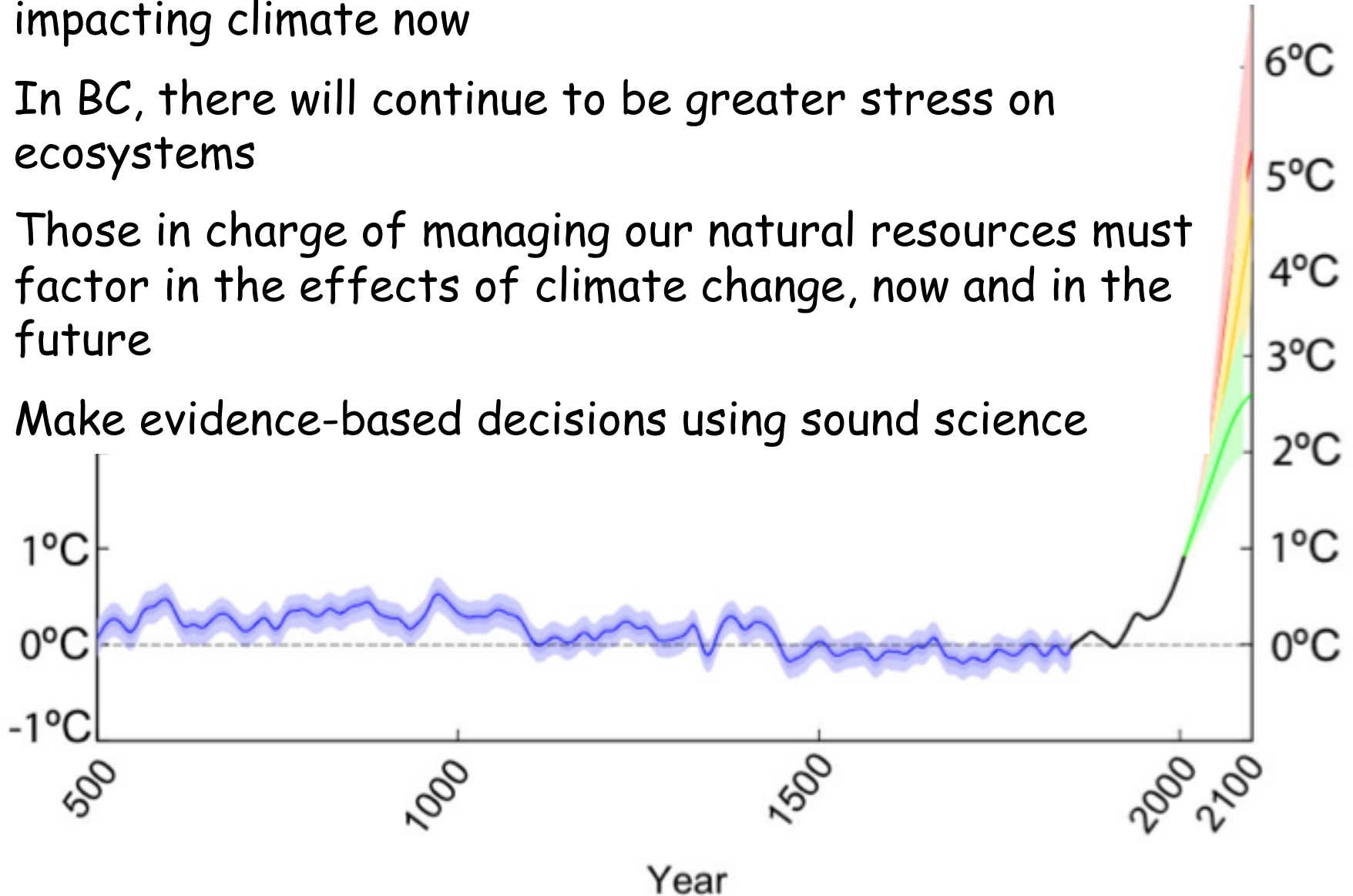
Intergovernmental Panel on Climate Change (IPCC) www.ipcc.ch

2014: 5th Assessment Report (AR5) Summary

- Humans have caused the majority of present day climate change
- The warming is largely irreversible
- Most of the heat is going into the oceans
- Current rates of ocean acidification are unprecedented
- To stay below 2 °C of warming, most fossil fuels must stay buried in the ground

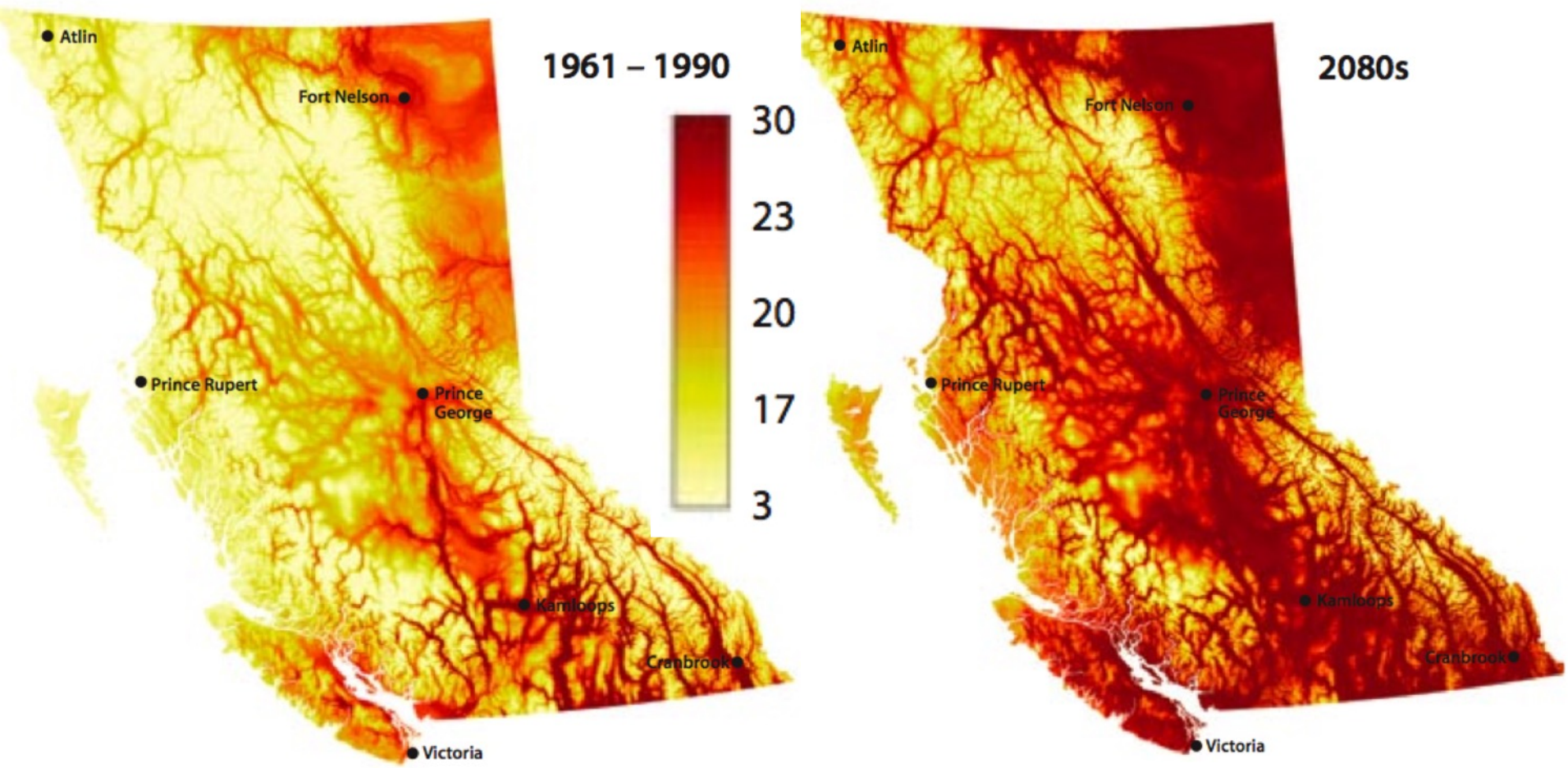
Conclusion

- Human emissions of greenhouse gasses are significantly impacting climate now
- In BC, there will continue to be greater stress on ecosystems
- Those in charge of managing our natural resources must factor in the effects of climate change, now and in the future
- Make evidence-based decisions using sound science



The End





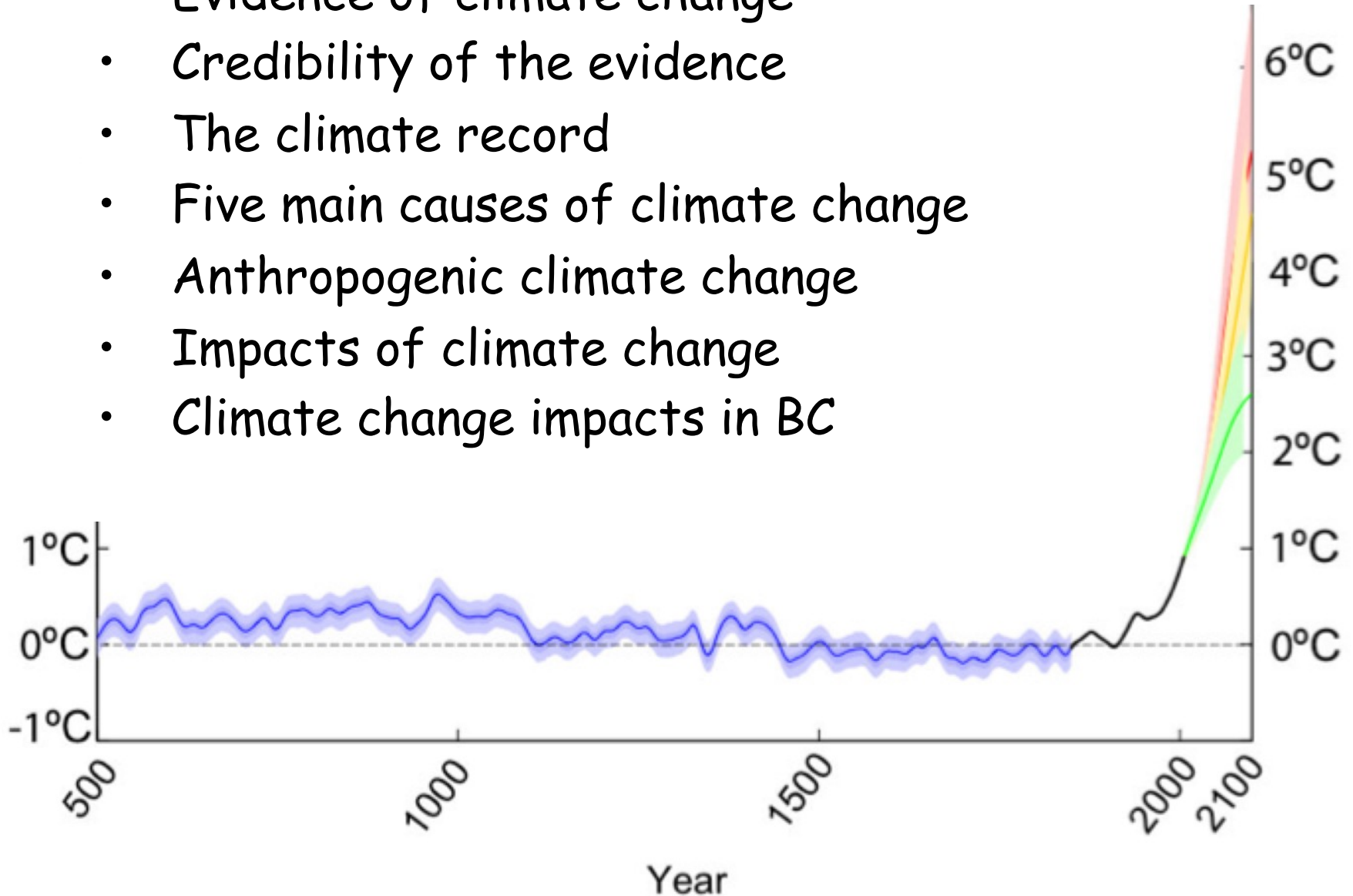
The End

The End

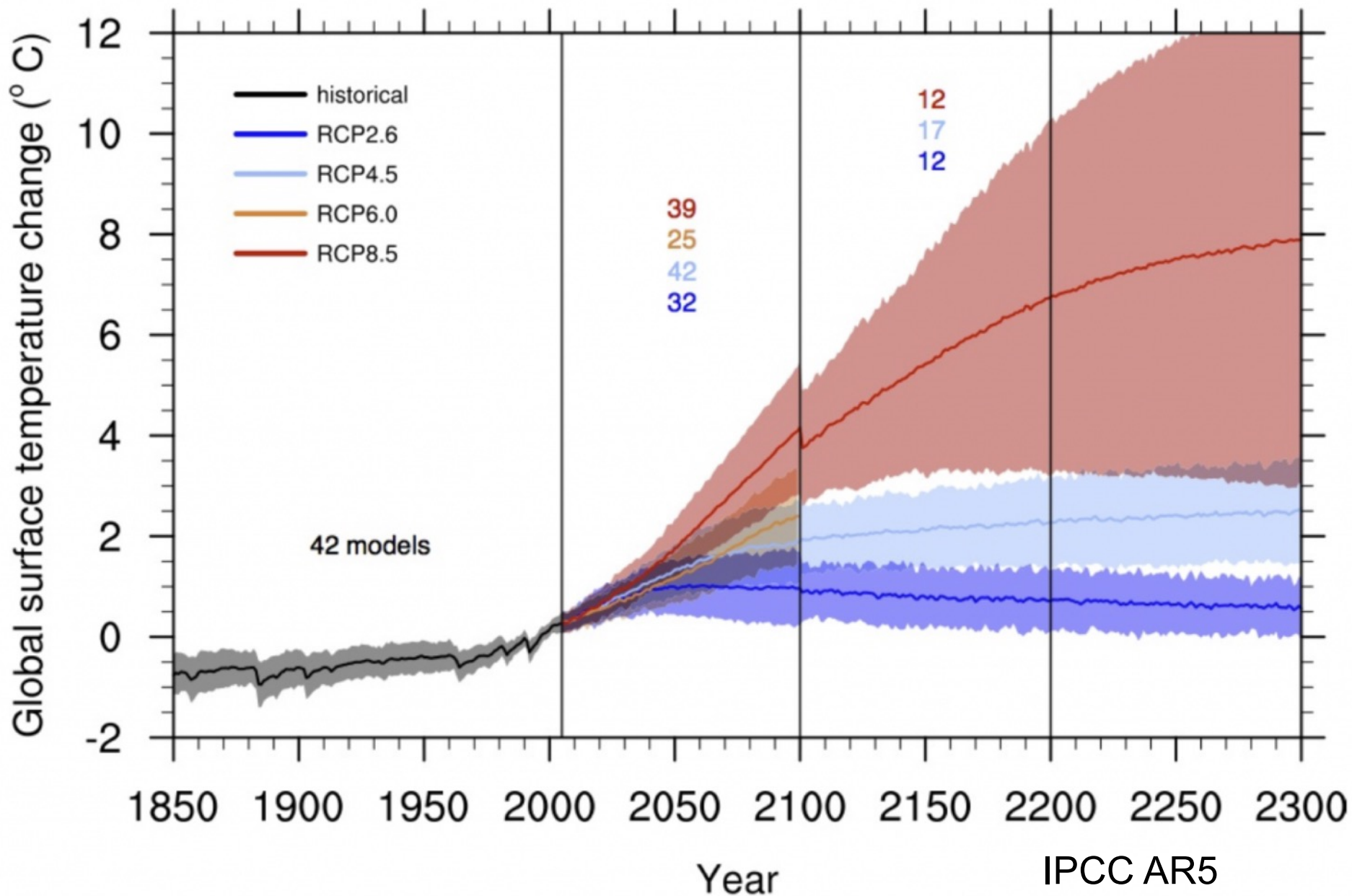


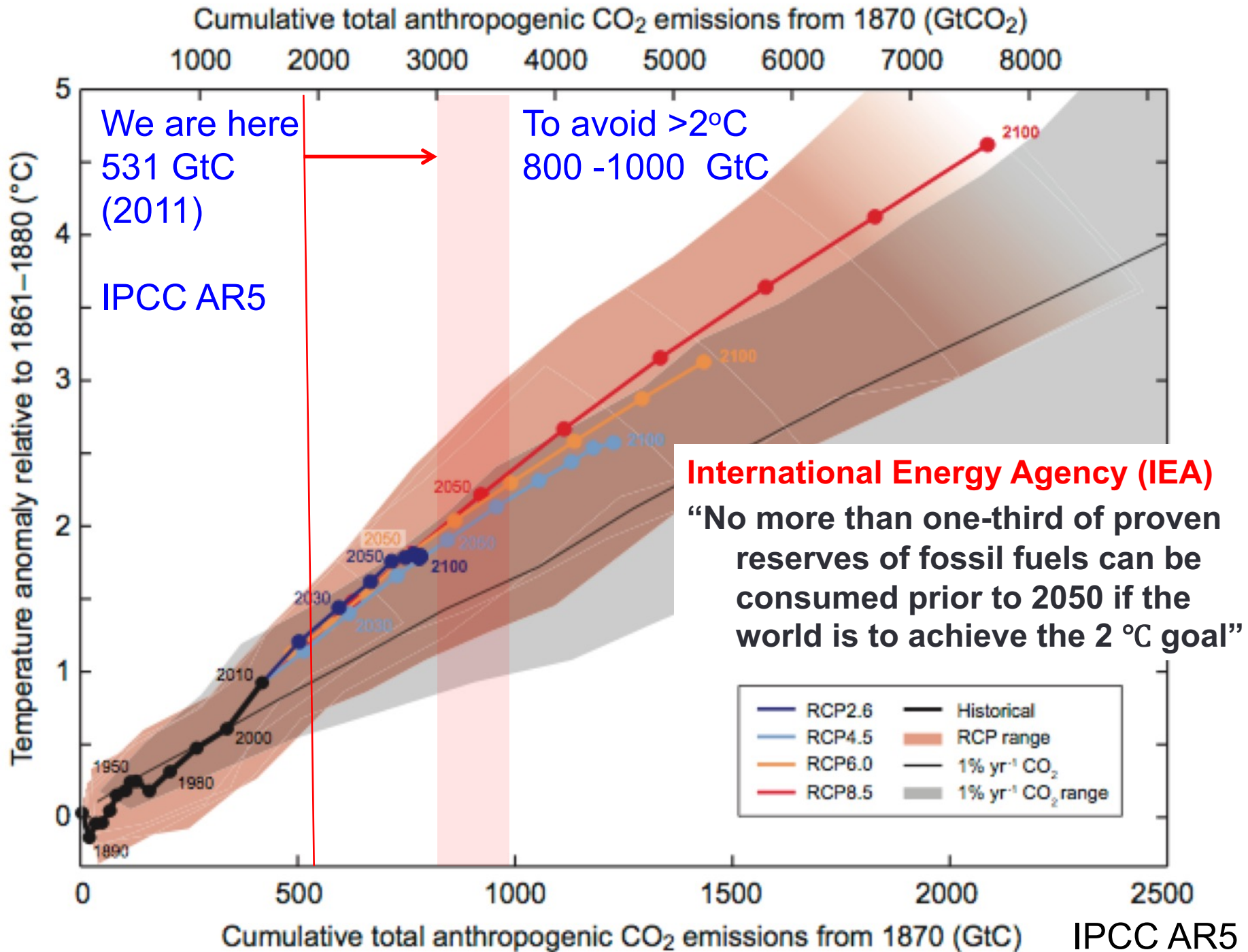
Outline

- Evidence of climate change
- Credibility of the evidence
- The climate record
- Five main causes of climate change
- Anthropogenic climate change
- Impacts of climate change
- Climate change impacts in BC



Avoiding more extreme climate change





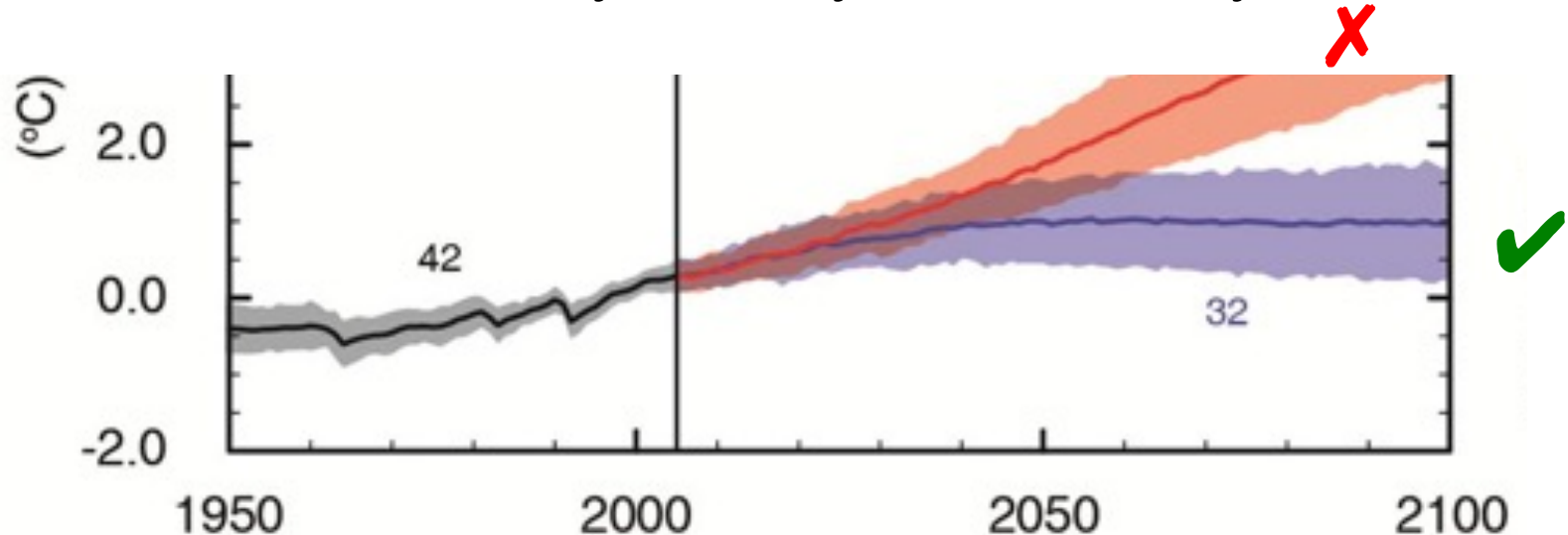
Avoiding more extreme climate change

“I have a dream...” Martin Luther King, Jr (1963)

The best strategy is a vision, not a plan

A sustainable vision for the future has to be:

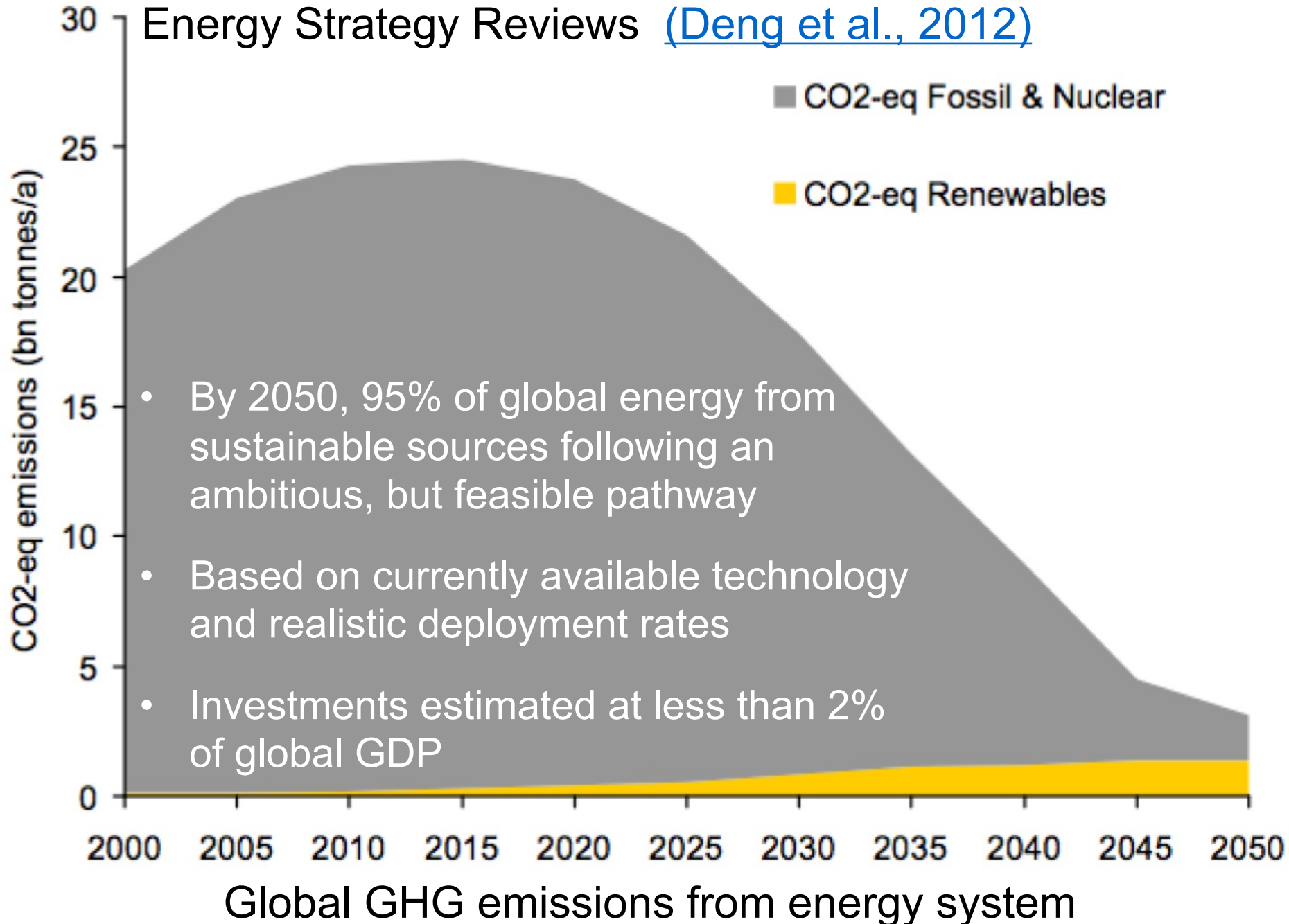
- 1) highly positive
- 2) believable
- 3) responsive (addresses multiple issues)
 - Environmentally, socially, economically sustainable



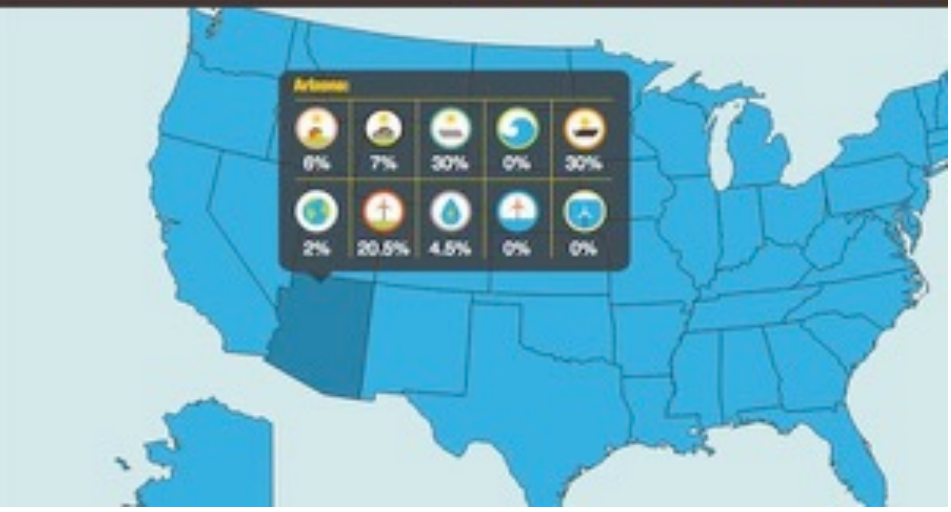
We need to actively advertise an attractive future!

Transition to a fully sustainable global energy system:

Energy Strategy Reviews ([Deng et al., 2012](#))



50 STATES | 50 PLANS | 100% RENEWABLE ENERGY BENEFITS



BETTER GROWTH BETTER CLIMATE

The New Climate Economy Report



To slash or to trim

Emission reductions by policies/actions, bn tonnes CO₂ equivalent



Policy/Action	Cumulative emissions	Period	Annual emissions*
Montreal protocol ¹	135.0bn	1989-2013	5.6bn
Hydropower worldwide ²	2.8bn	2010	2.8bn
Nuclear power worldwide ²	2.2bn	2010	2.2bn

Policy can make a significant difference!

The Copenhagen Diagnosis

Surging greenhouse gas emissions: Even if global emission rates are stabilized at present -day levels, just 20 more years of emissions would give a 25% probability that warming exceeds 2°C.

Recent global temperatures demonstrate human-based warming: Even over the past ten years, despite a decrease in solar forcing, the trend continues to be one of warming

Acceleration of melting of ice-sheets, glaciers and ice-caps: A wide array of satellite and ice measurements now demonstrate beyond doubt that both the Greenland and Antarctic ice sheets are losing mass at an increasing rate

Rapid Arctic sea-ice decline: Summer-time melting of Arctic sea-ice has accelerated far beyond the expectations of climate models.

Current sea-level rise underestimates: Satellites show great global average sea-level rise (3.4 mm/yr over the past 15 years) to be 80% above past IPCC predictions.

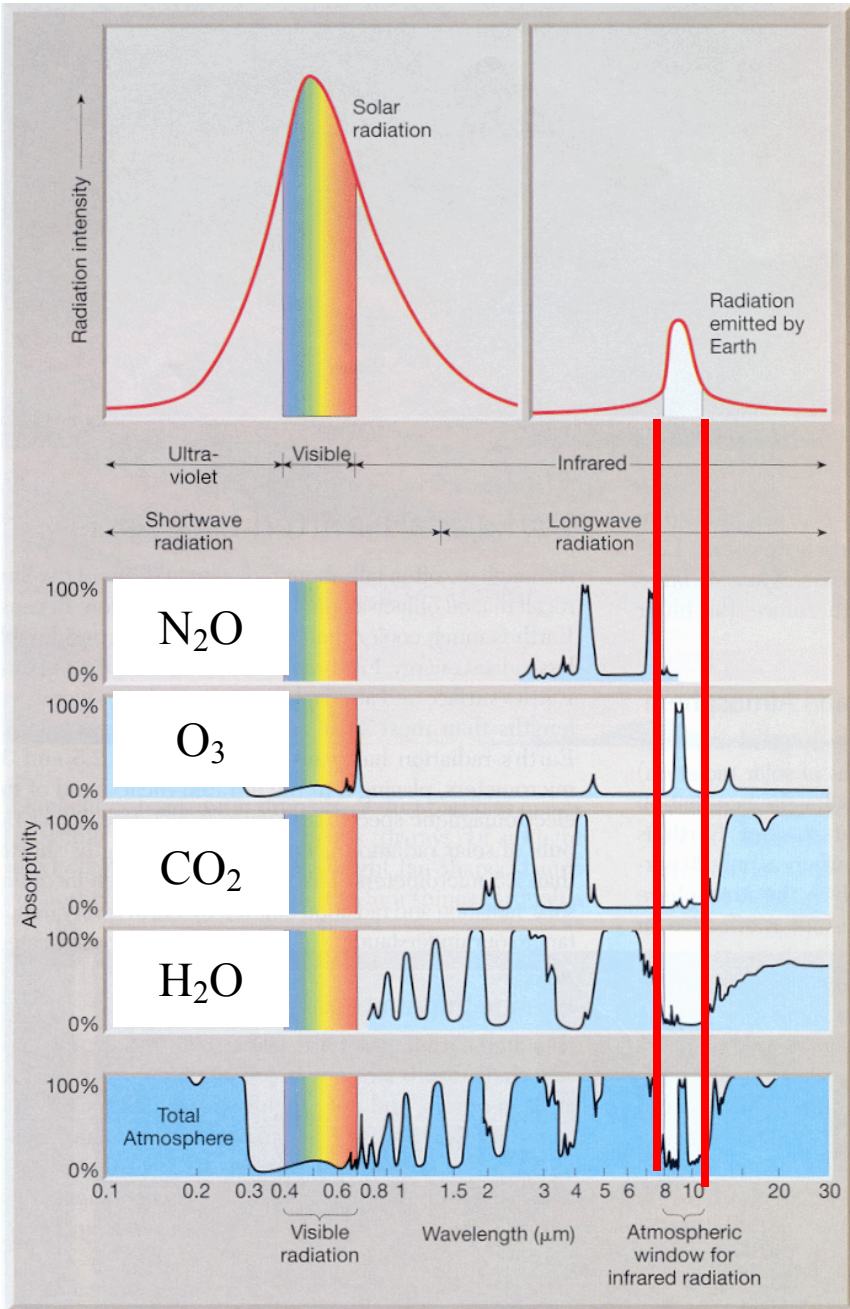
The Copenhagen Diagnosis

Sea-level prediction revised: By 2100, global sea-level is likely to rise at least twice as much as projected by the IPCC AR4, for unmitigated emissions it may well exceed 1 meter. The upper limit has been estimated as 2 meters sea-level rise by 2100.

Delay in action risks irreversible damage: Several vulnerable elements in the climate system could be pushed towards abrupt or irreversible change if warming continues in a business-as-usual way.

The turning point must come soon: If global warming is to be limited to a maximum of 2°C above pre-industrial values, global emissions need to peak between 2015 and 2020 and then decline rapidly. To stabilize climate, the average annual per-capita emissions will have to shrink to well under 1 metric ton CO₂ by 2050. This is 80-95% below the per-capita emissions in developed nations in 2000.

5. Changes in Atmospheric Composition



Greenhouse Gases:

transparent to incoming solar radiation but absorb and reradiate outgoing thermal energy

Main Greenhouse Gases:

H₂O - Water Vapour

CO₂ - Carbon Dioxide

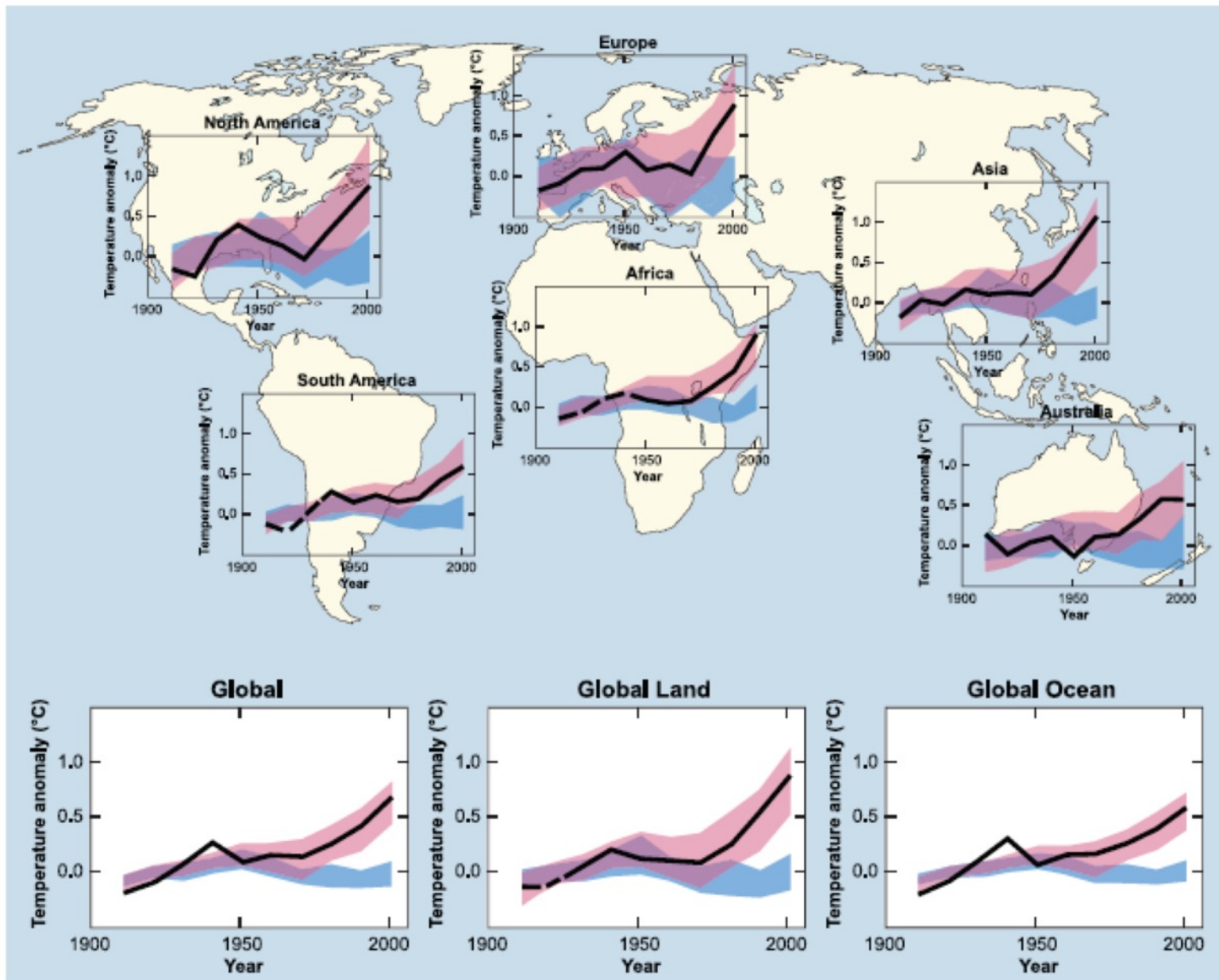
CH₄ - Methane

N₂O - Nitrous Oxide

O₃ - Ozone (Troposphere)

CFCs - Chloro-fluorocarbons

GLOBAL AND CONTINENTAL TEMPERATURE CHANGE



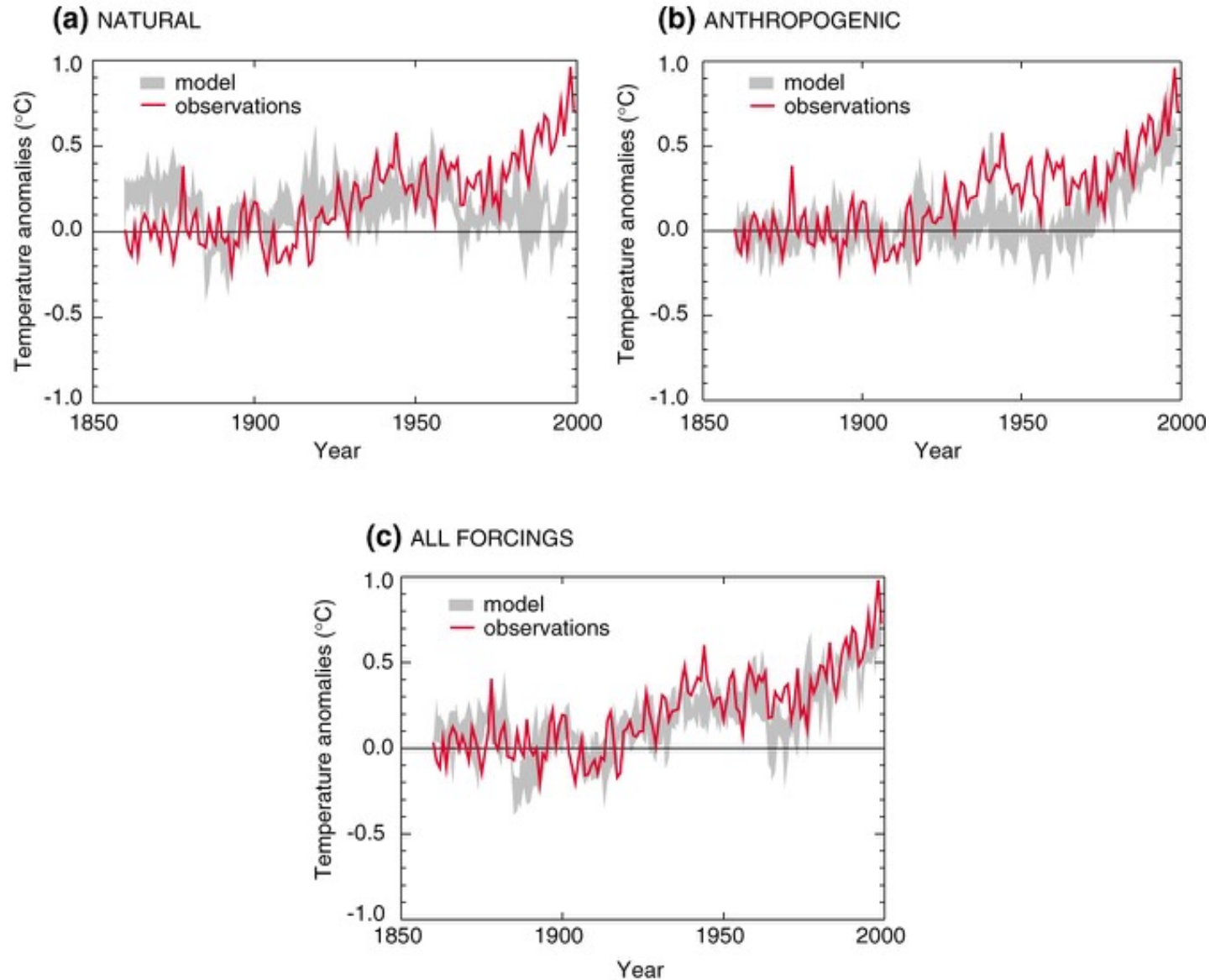
models using only natural forcings

models using both natural and anthropogenic forcings

observations

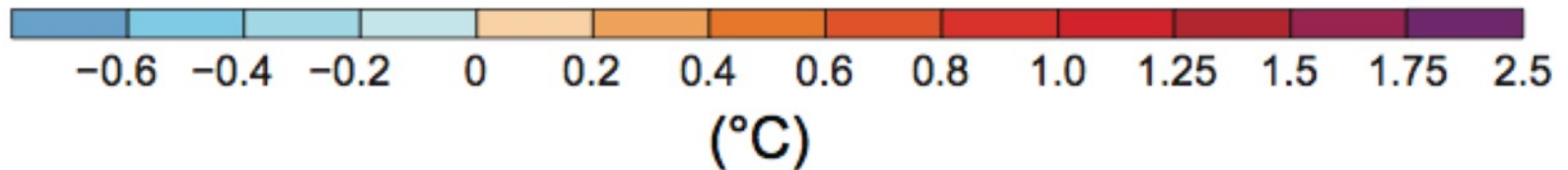
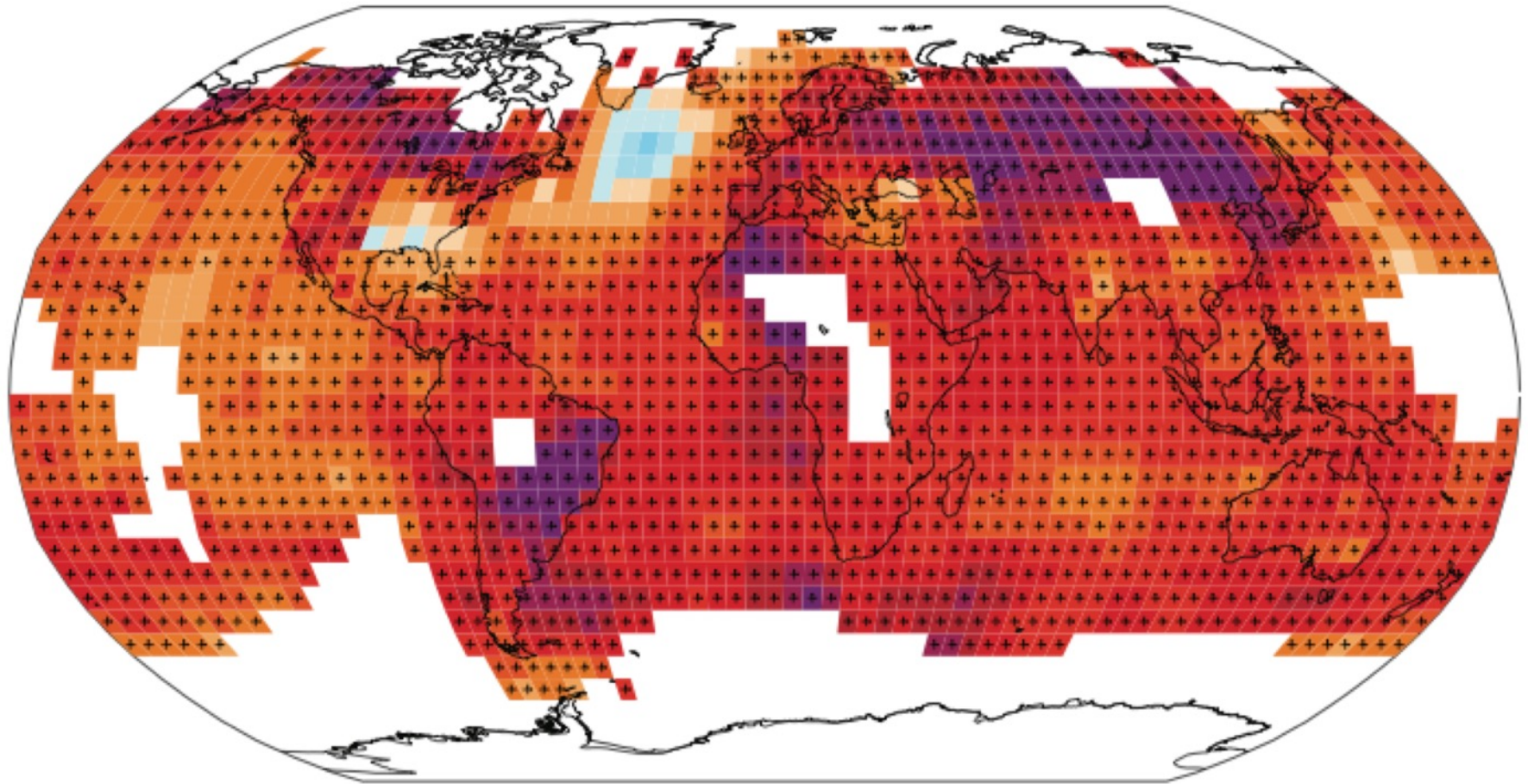
Anthropogenic Climate Change

Simulated annual global mean surface temperatures



Impacts of Climate Change

Observed change in surface temperature 1901–2012



Impacts of Climate Change

Sea level rise

