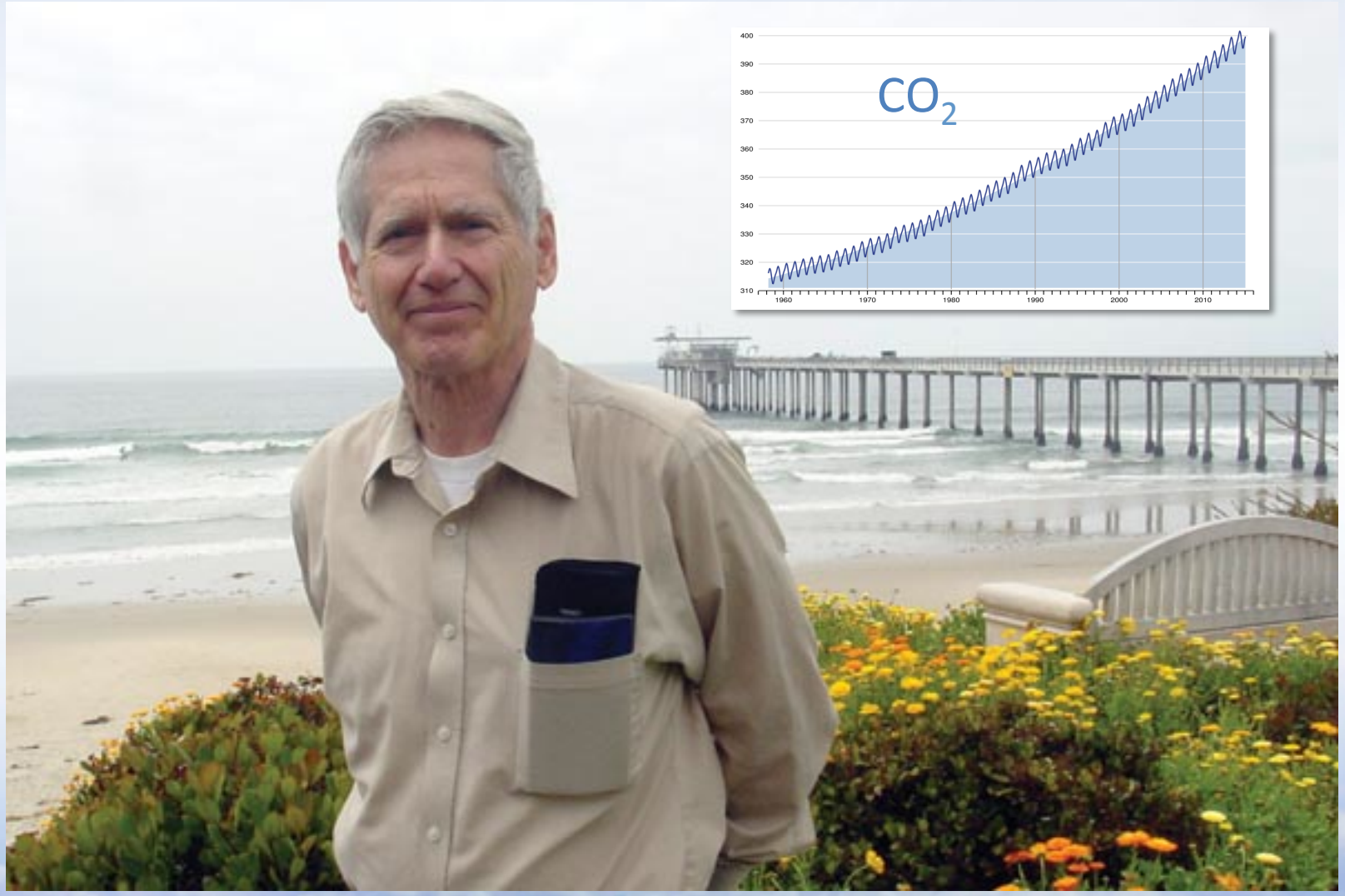
Natural and Human Causes of Past and Future Climate Change

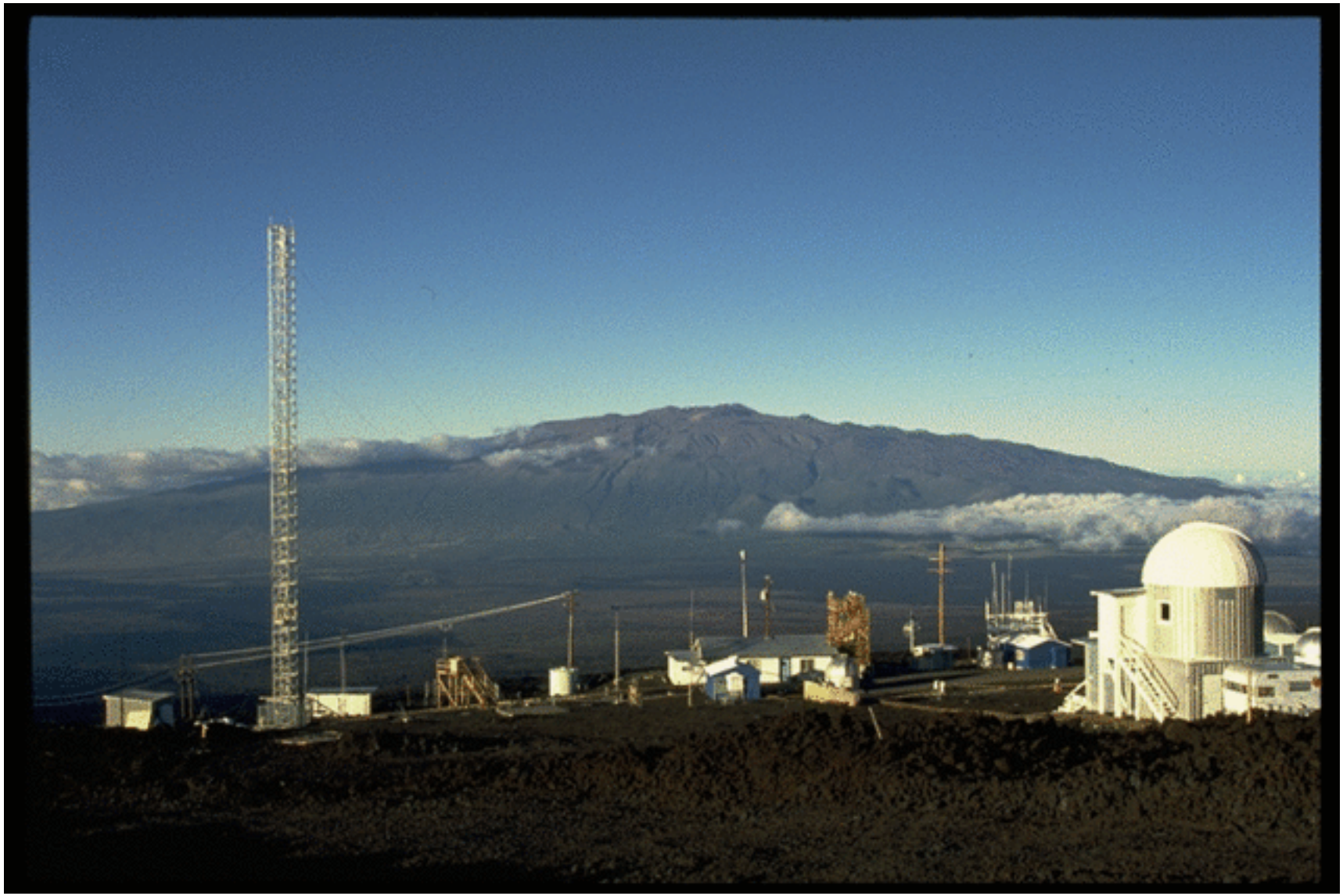
Clara Deser
National Center for Atmospheric Research
Boulder, CO

2015 Charles David Keeling Memorial Lecture
Birch Aquarium, Scripps Institution of Oceanography

Charles David Keeling



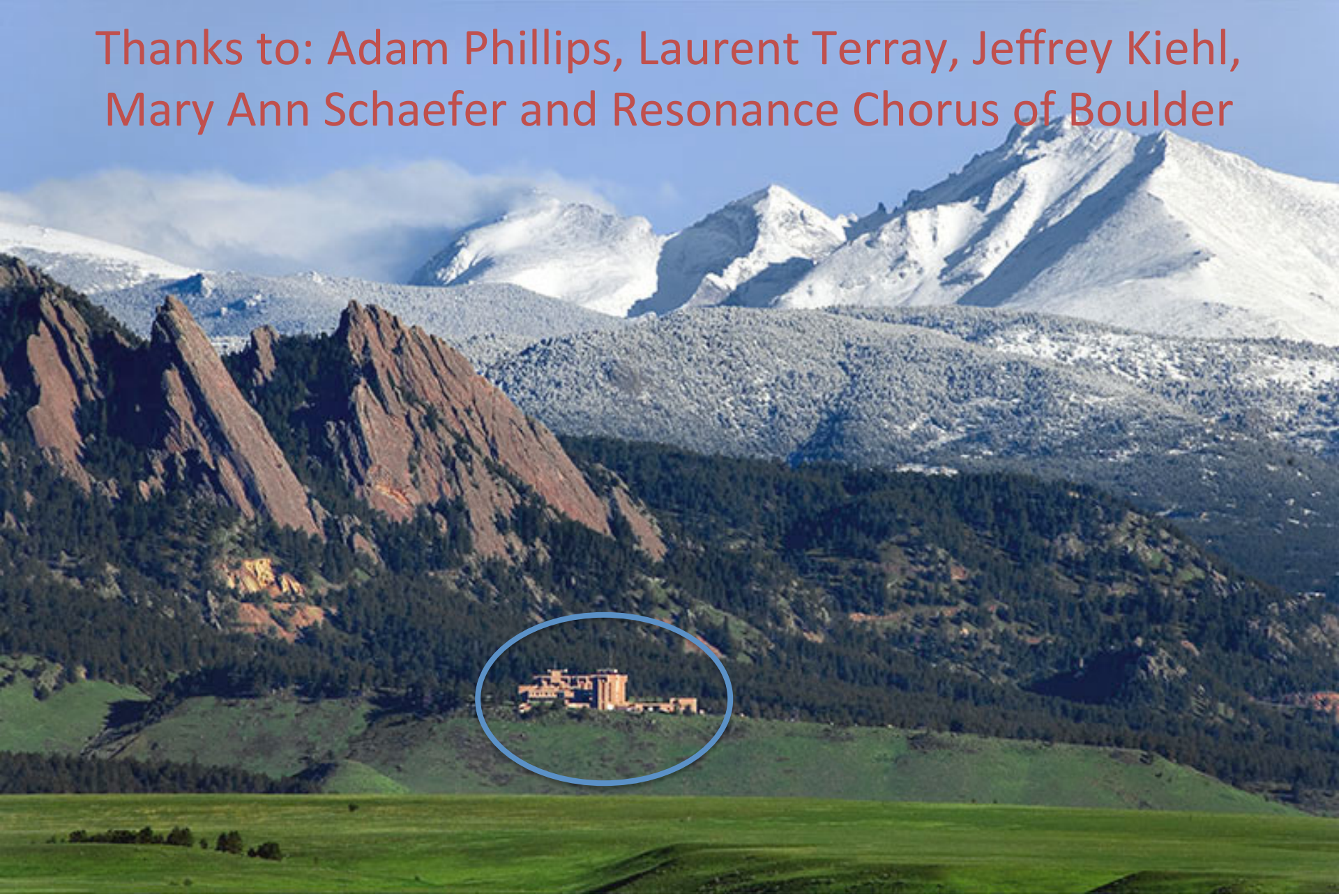
Mauna Loa Observatory



Site of Keeling's Carbon Dioxide Measurements

The National Center for Atmospheric Research

Thanks to: Adam Phillips, Laurent Terray, Jeffrey Kiehl,
Mary Ann Schaefer and Resonance Chorus of Boulder



The National Center for Atmospheric Research

Causes of Climate Change

Past and Future

Causes of Climate Change

Human

Natural

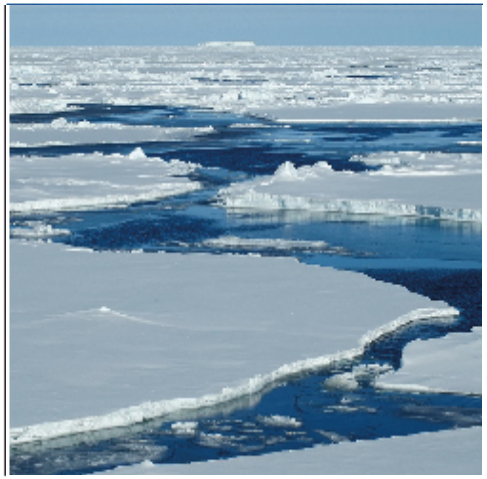
fossil fuel burning
deforestation

internal variability
volcanoes, solar cycle

Past and Future



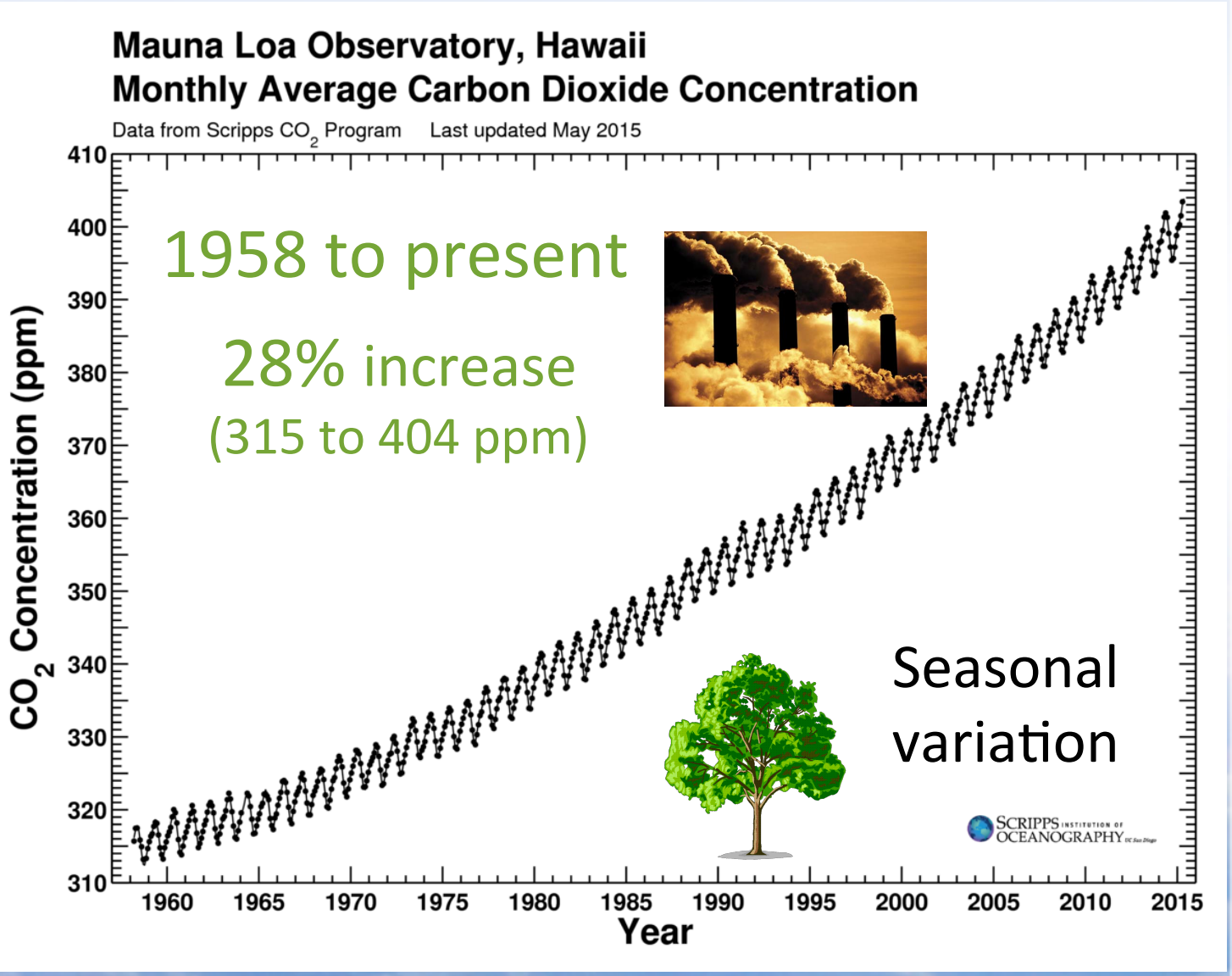


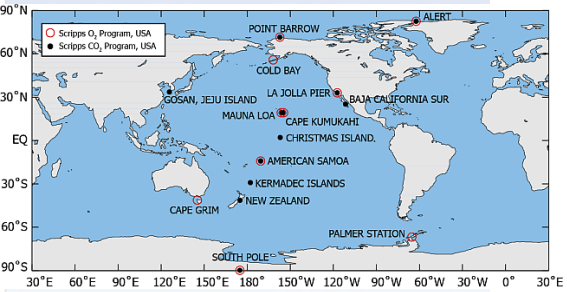



Natural and Human Causes of Past and Future Climate Change

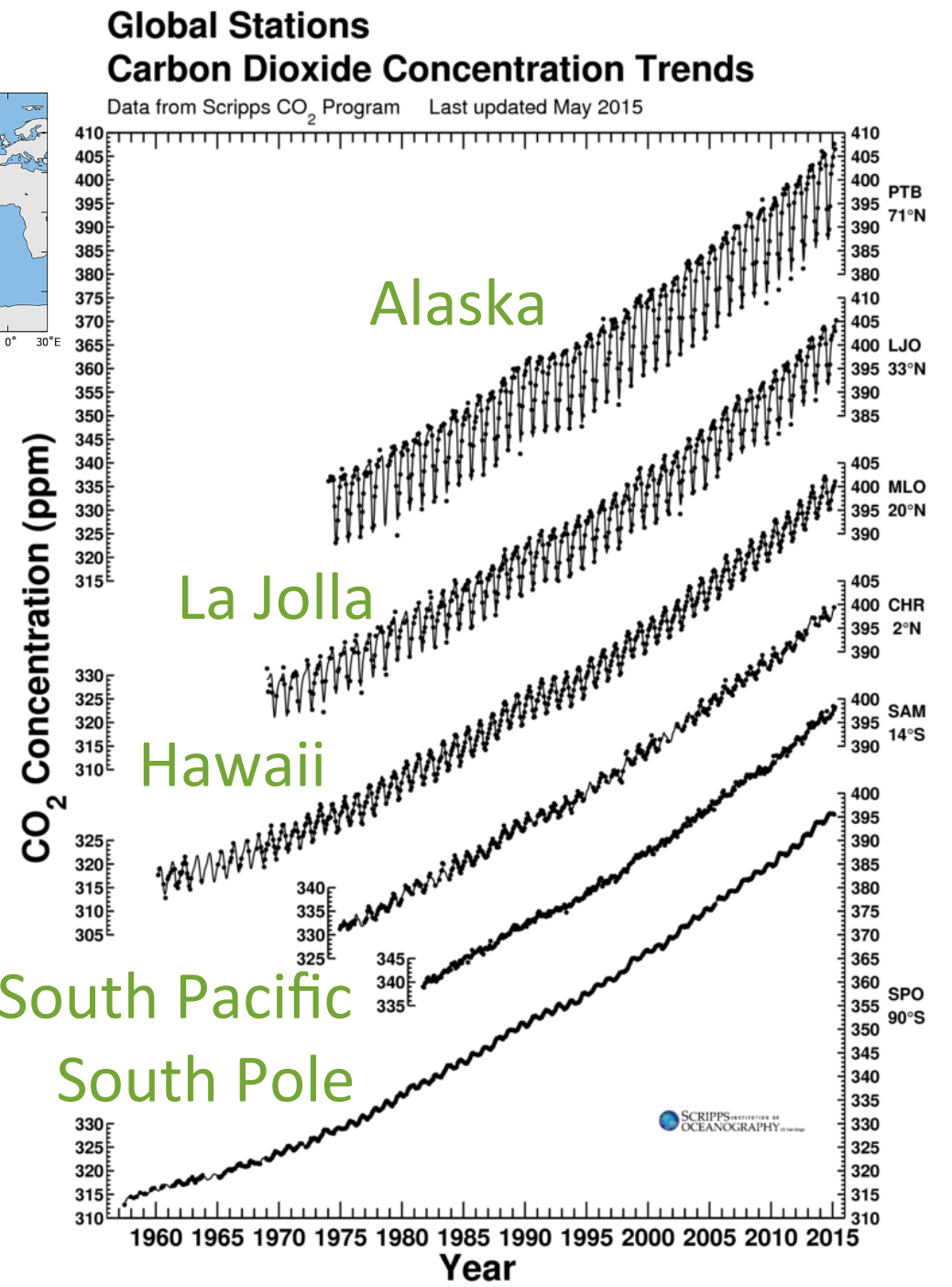
- Core concepts
- Global vs. local view
- Future: a range of outcomes

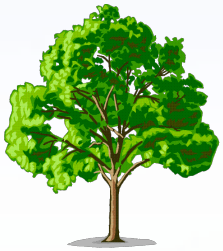
1. Observations Show an Increase in Atmospheric Carbon Dioxide.





Upward trend

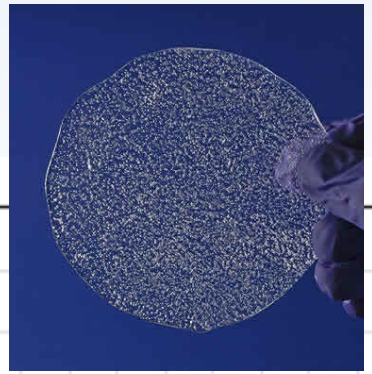




Seasonal variation

1. Observations Show an Increase in Atmospheric Carbon Dioxide.

Antarctic Ice Core



Last 2000 years

Source: Intergovernmental Panel on Climate Change, 2013

2. This CO_2 Increase is Due to Human Activity.

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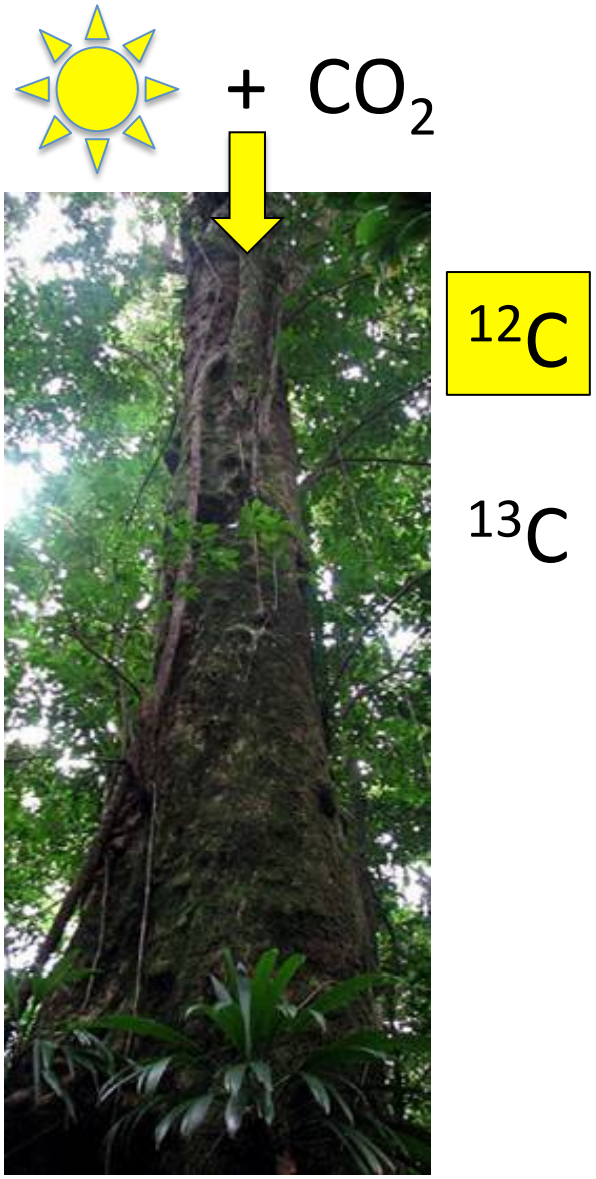


2. This CO_2 Increase is Due to Human Activity

+ CO_2

^{12}C

^{13}C

coal

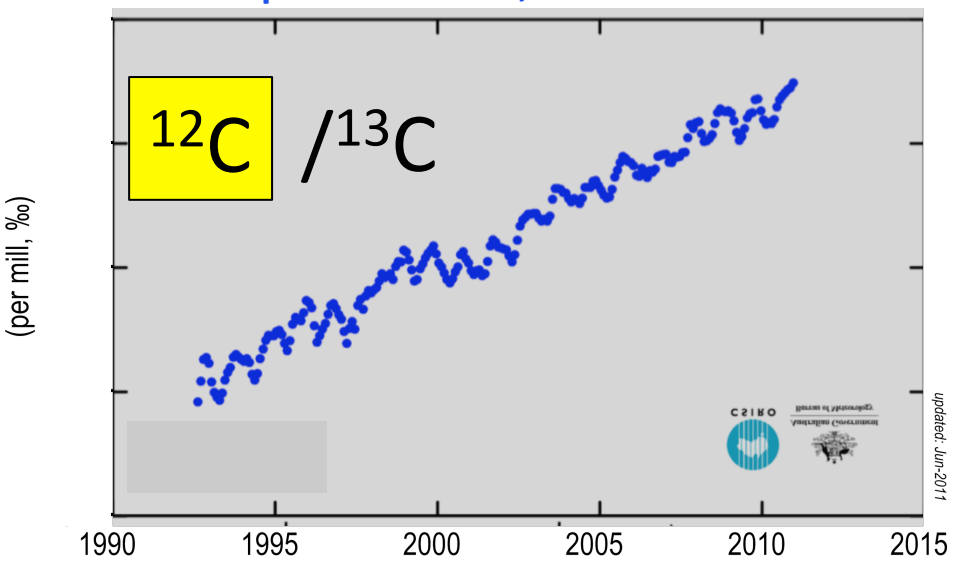
^{12}C + O_2

^{12}C

"Fossil fuel" 300 million years ago

2. This CO_2 Increase is Due to Human Activity

Cape Grimm, Tasmania



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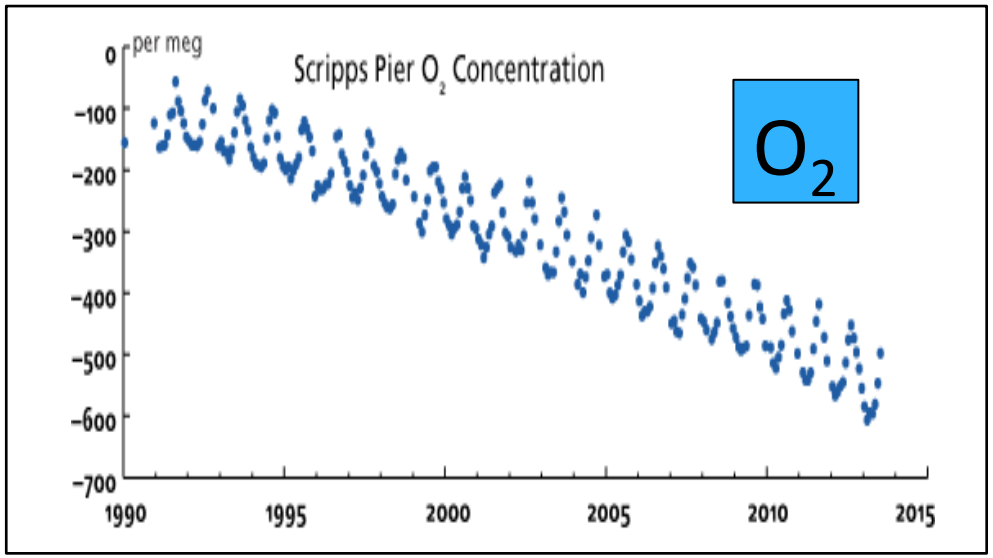
2. This CO_2 Increase is Due to Human Activity

Scripps Pier



O_2

+ CO_2

^{12}C

^{13}C

coal

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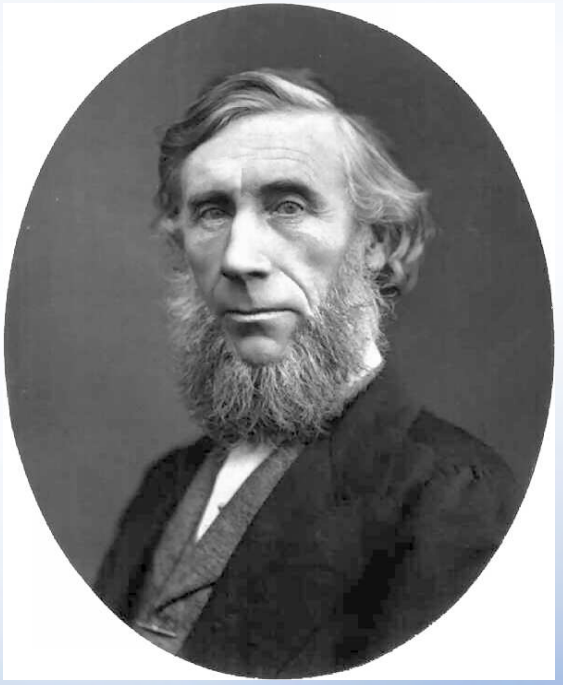
^{12}C + O_2

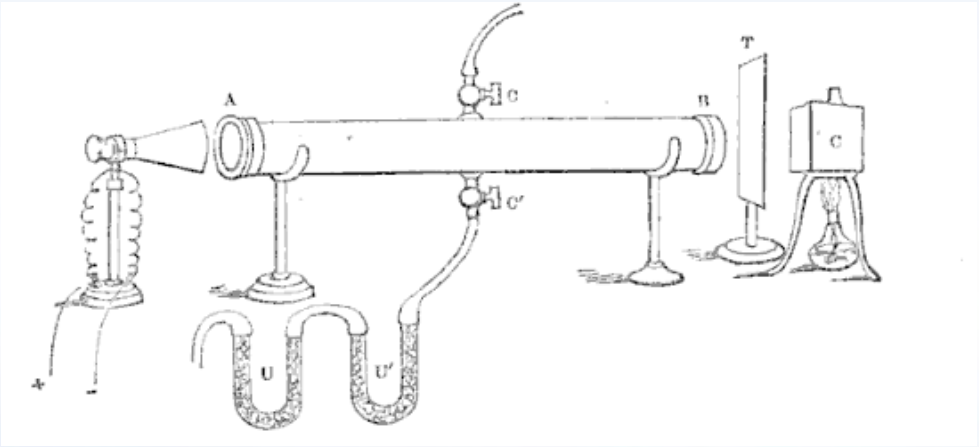
"Fossil fuel" 300 million years ago

3. CO_2 is an Efficient Greenhouse Gas.

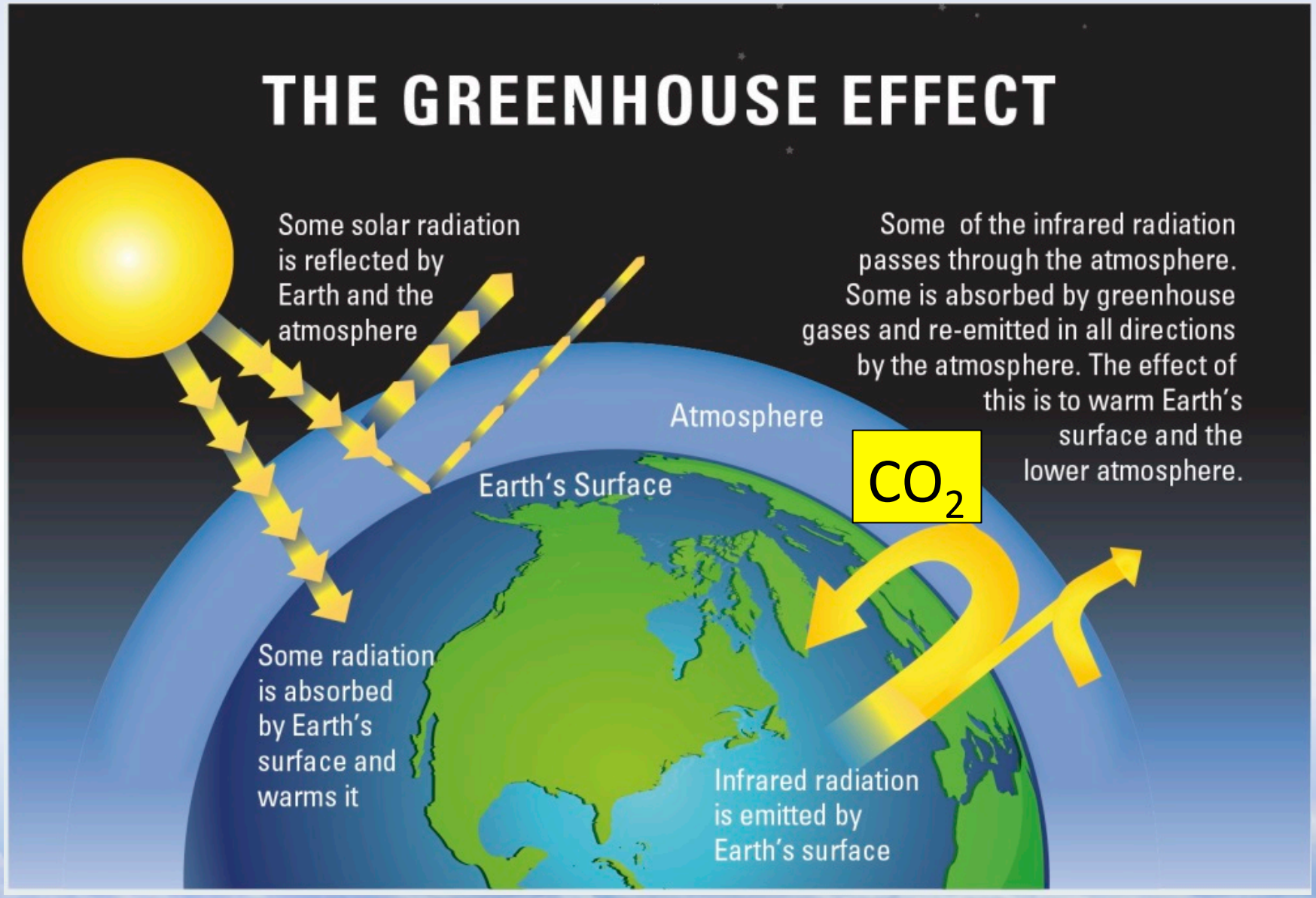
Laboratory Measurements by John Tyndall in the 1850s

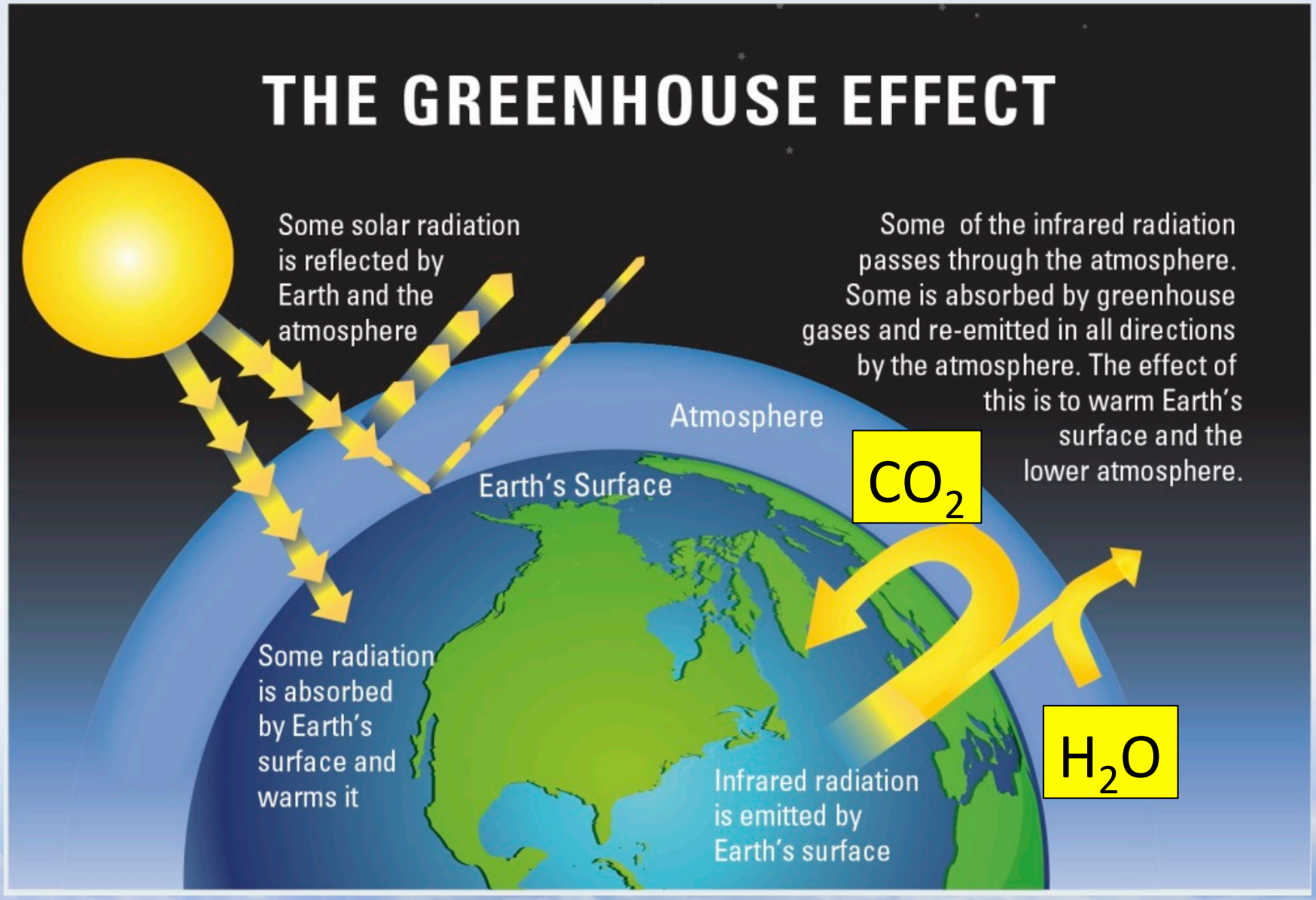


John Tyndall



The bearing of this experiment upon the action of planetary atmospheres is obvious ... the atmosphere admits of the entrance of the solar heat, but checks its exit; and the result is a tendency to accumulate heat at the surface of the planet (Tyndall, 1859a).


THE GREENHOUSE EFFECT
Some solar radiation is reflected by Earth and the atmosphere
Some of the infrared radiation passes through the atmosphere. Some is absorbed by greenhouse gases and re-emitted in all directions by the atmosphere. The effect of this is to warm Earth's surface and the lower atmosphere.
Atmosphere
Earth's Surface
CO_2
Some radiation is absorbed by Earth's surface and warms it
Infrared radiation is emitted by Earth's surface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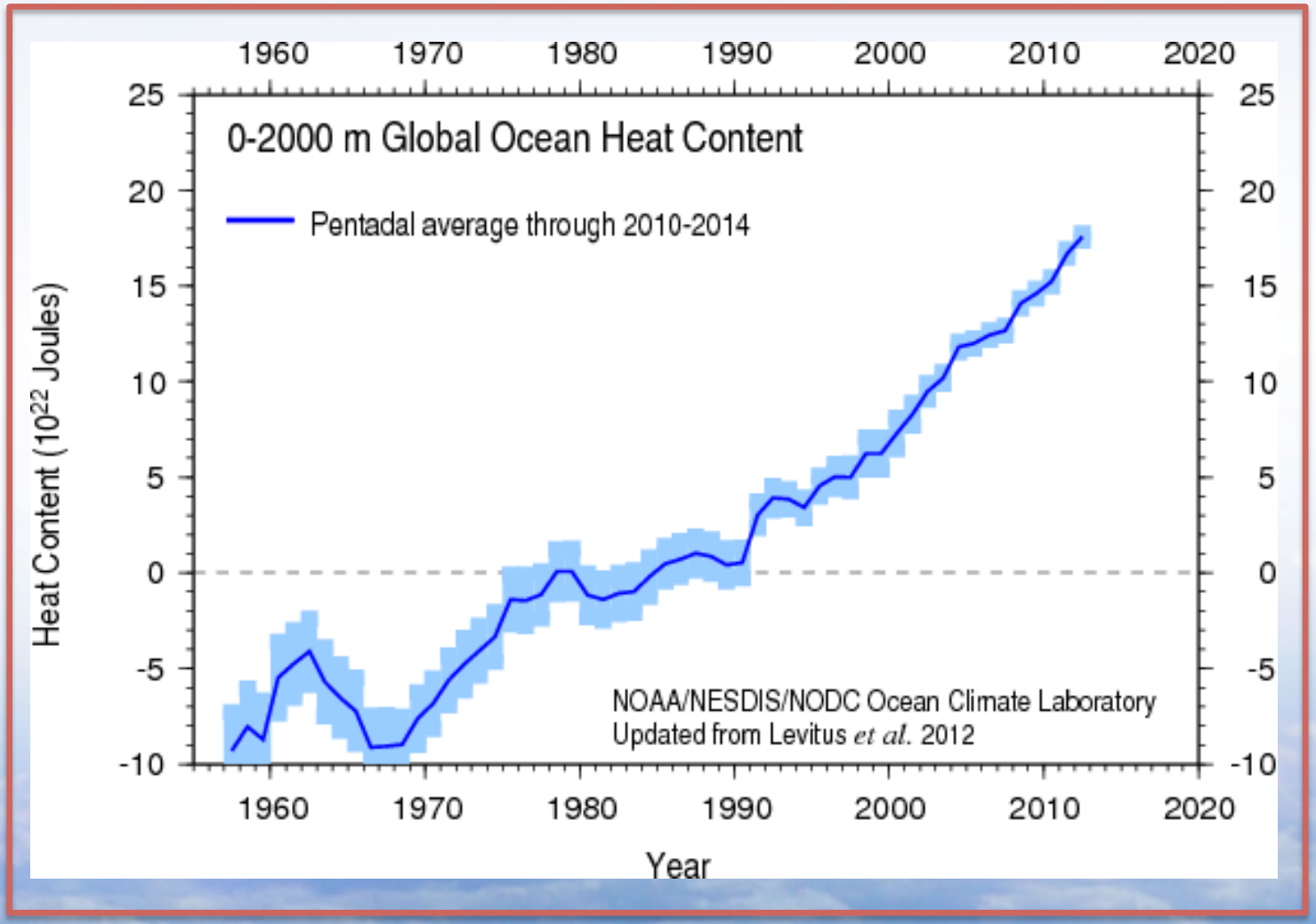
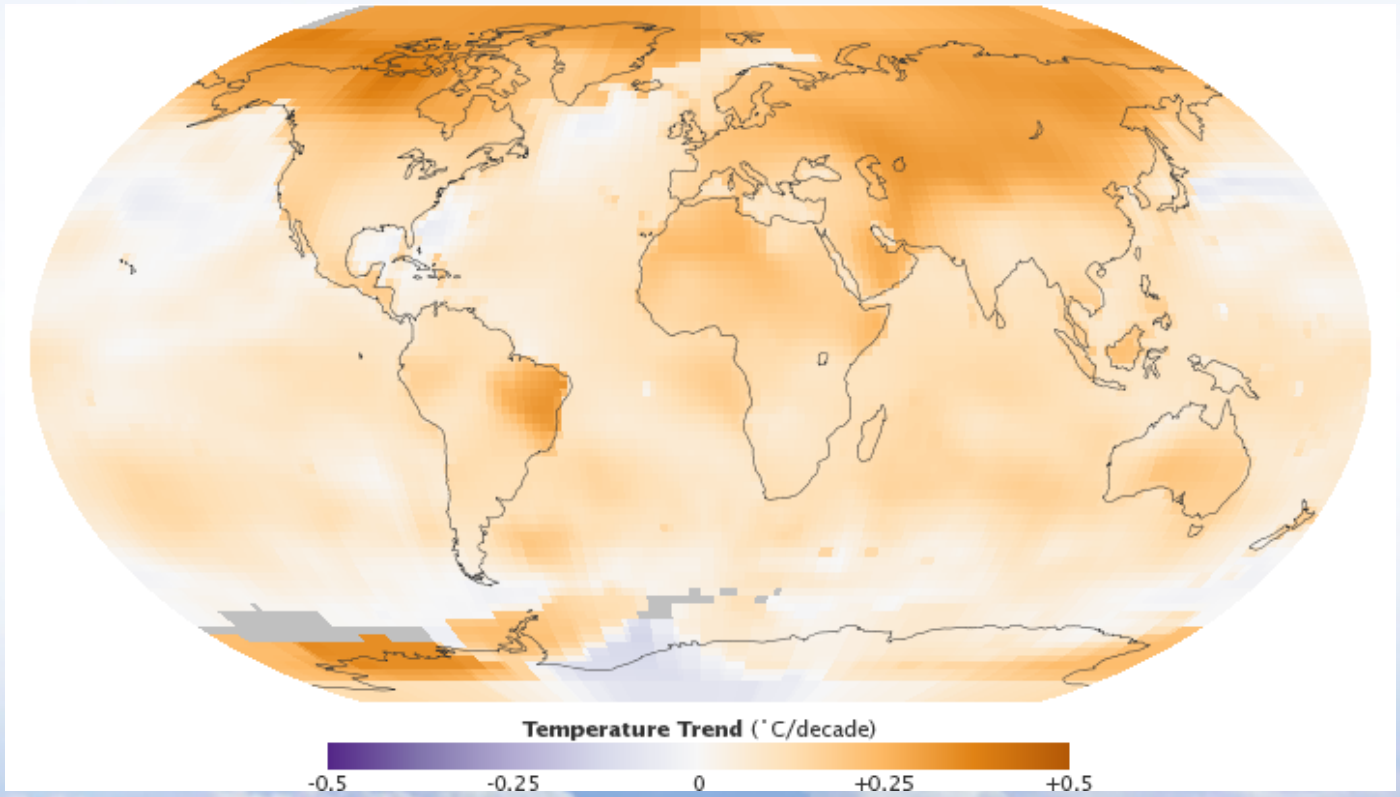
Atmosphere
Earth's Surface
CO_2
H_2O
Some radiation is absorbed by Earth's surface and warms it
Infrared radiation is emitted by Earth's surface

4. Increasing atmospheric CO_2 leads to a stronger greenhouse effect, which traps more energy in the climate system.



5. According to the law of conservation of energy, the trapped greenhouse energy must warm Earth.

Temperature change since 1950

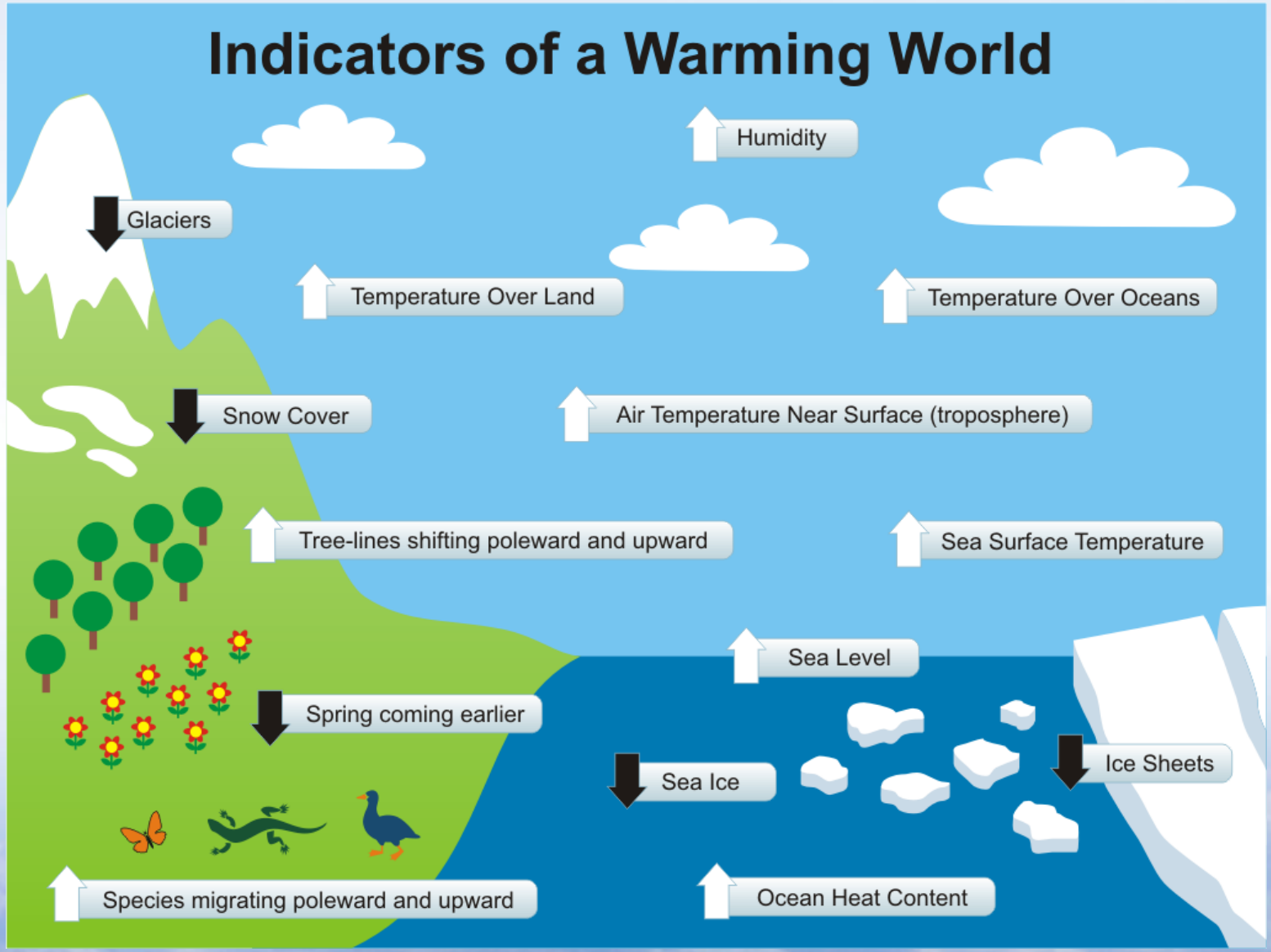


Land warms more than ocean

Arctic warms the most

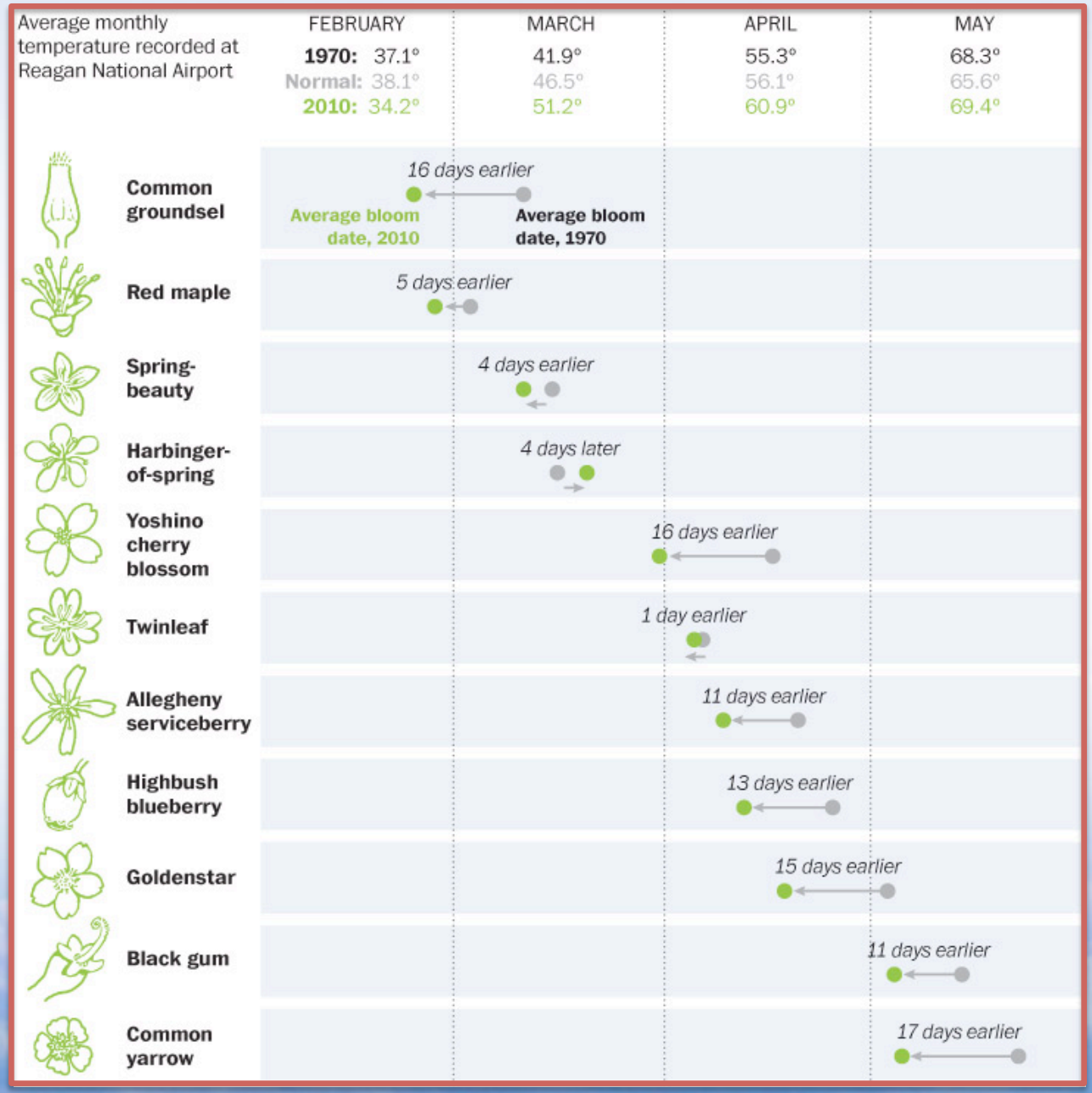
http://www.giss.nasa.gov

It's Not Just Temperature

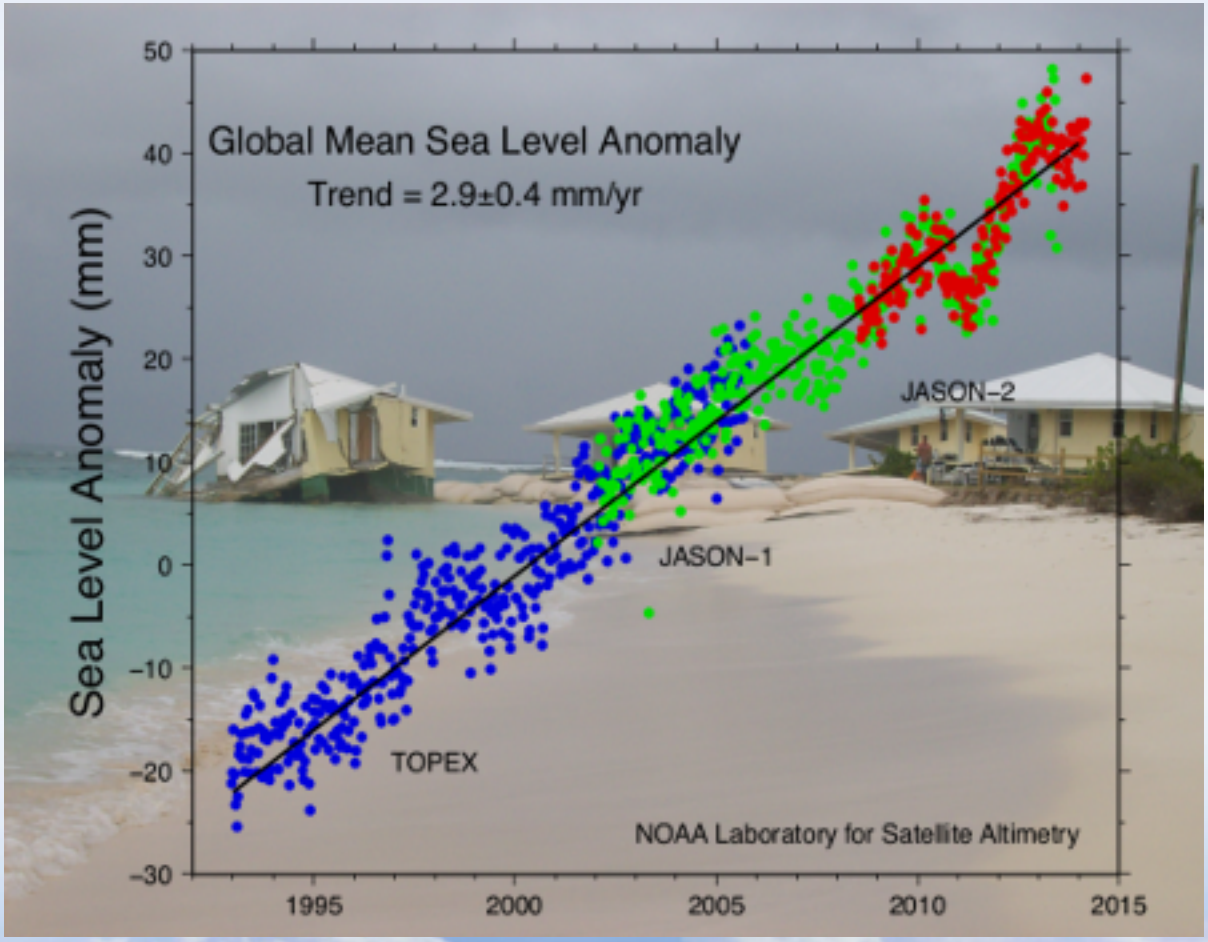


http://www.skepticalscience.com

Timing for East Coast Blooming

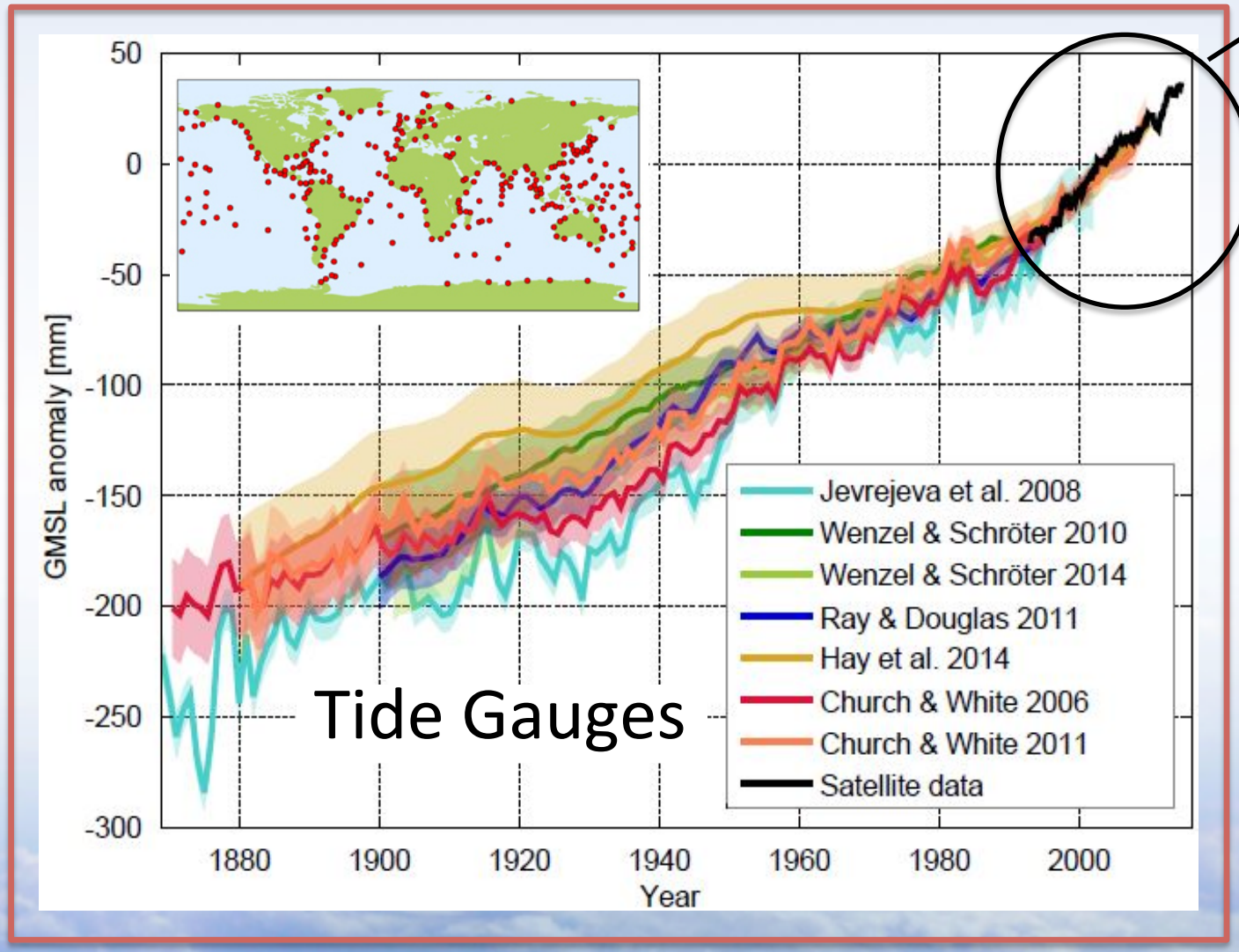


Sea Level Rise



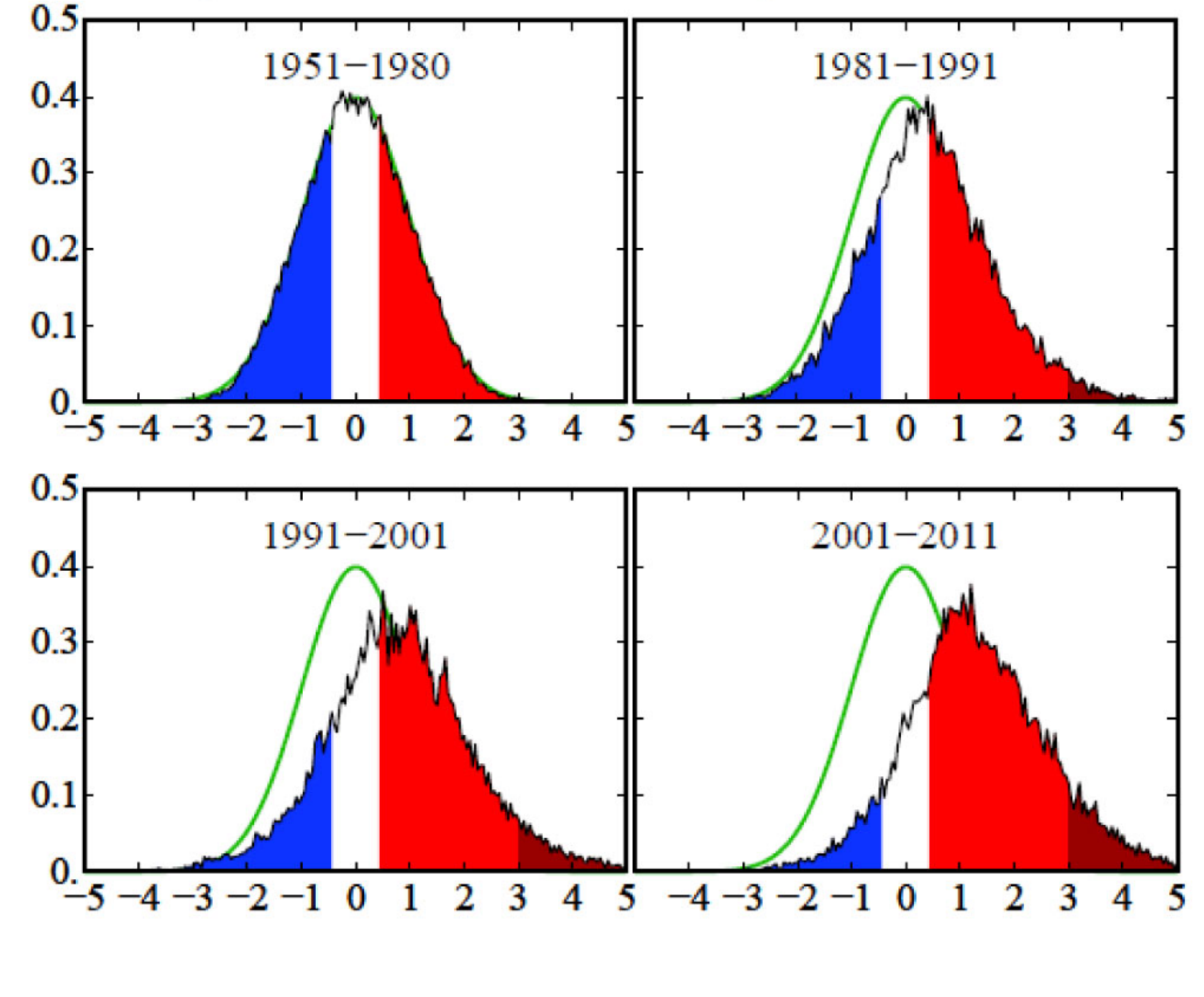
Satellite data: 1993-2014

Sea Level Rise



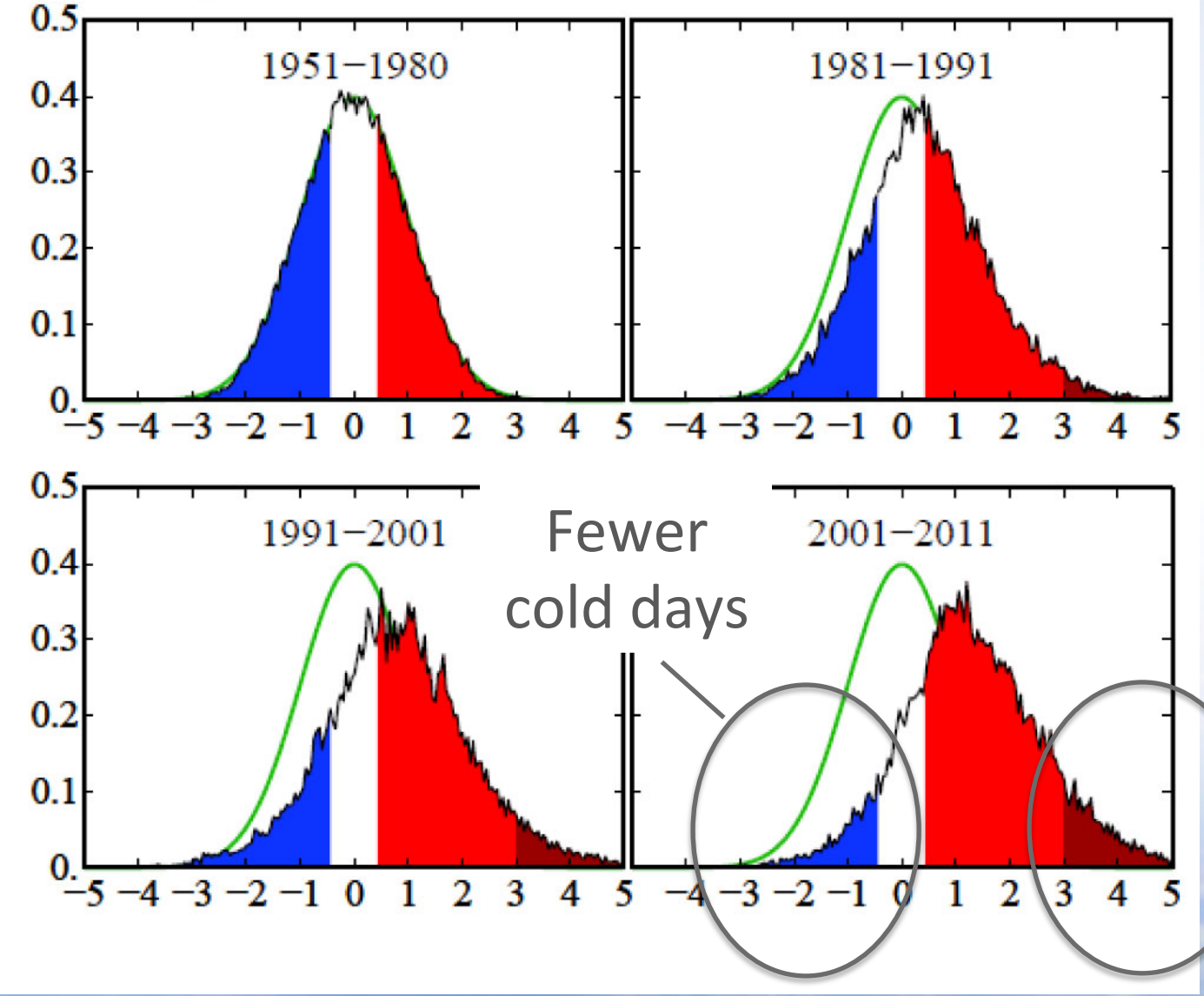
Hay et al. 2015

Shift in Summer Temperature Extremes



Hansen et al. 2012

Shift in Summer Temperature Extremes



Hansen et al. 2012

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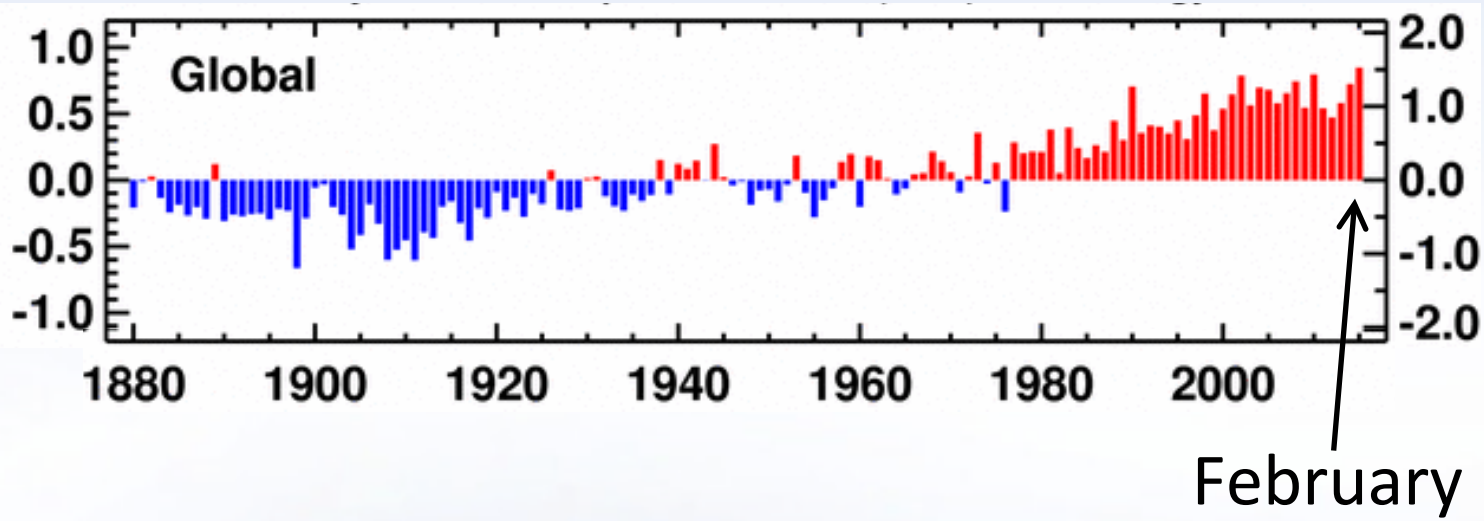
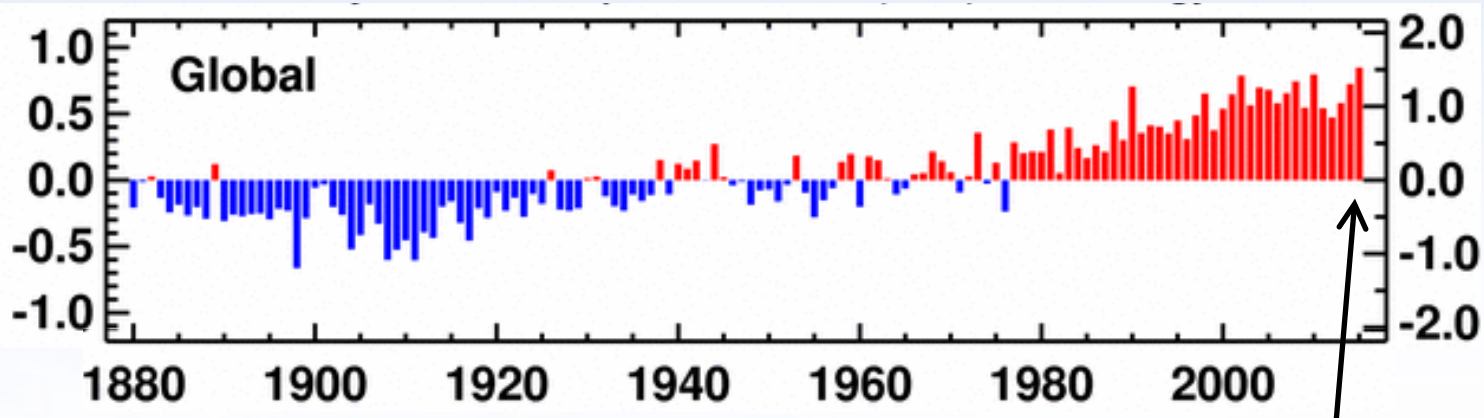
- Core concepts
- Global vs. local view
- Future: a range of outcomes

Global Temperature Record



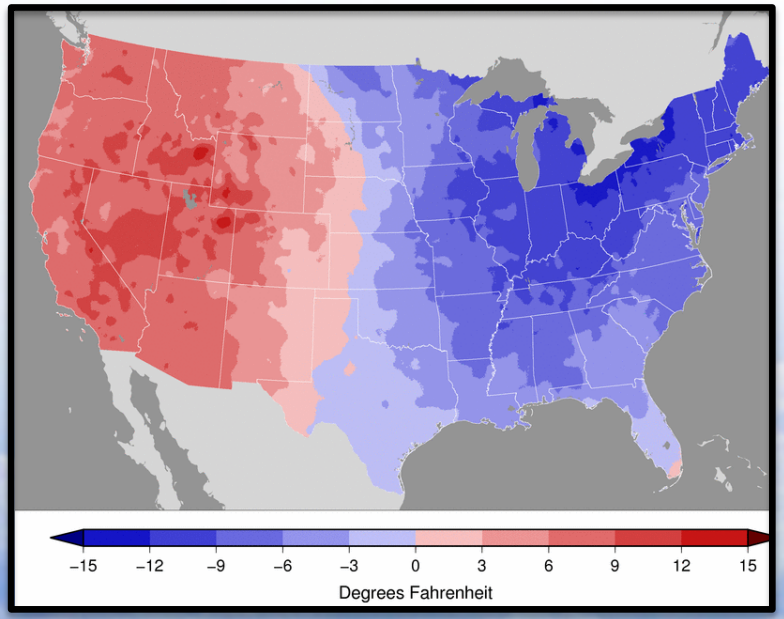
February 2015

Global Temperature Record



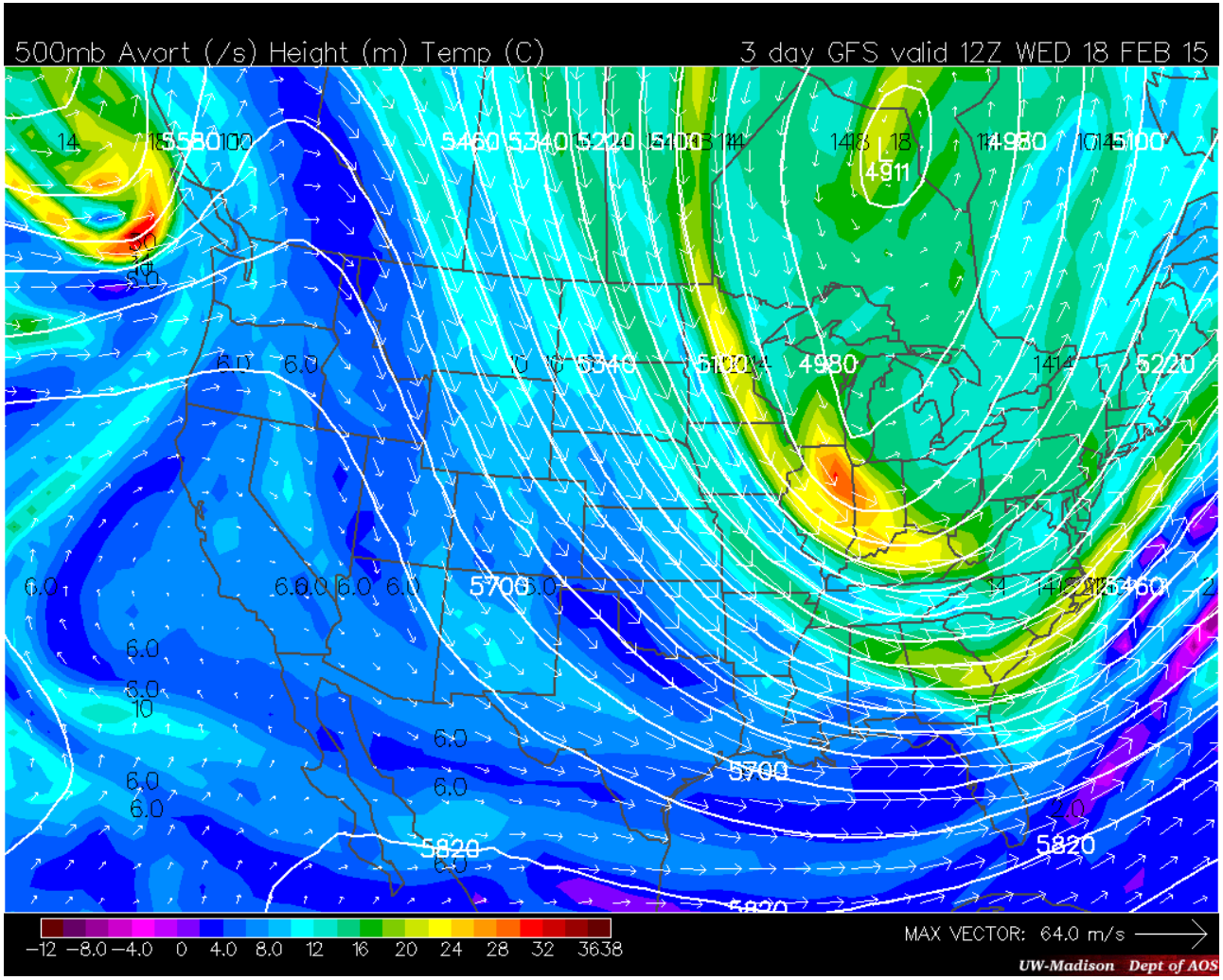
February 2015

record warm



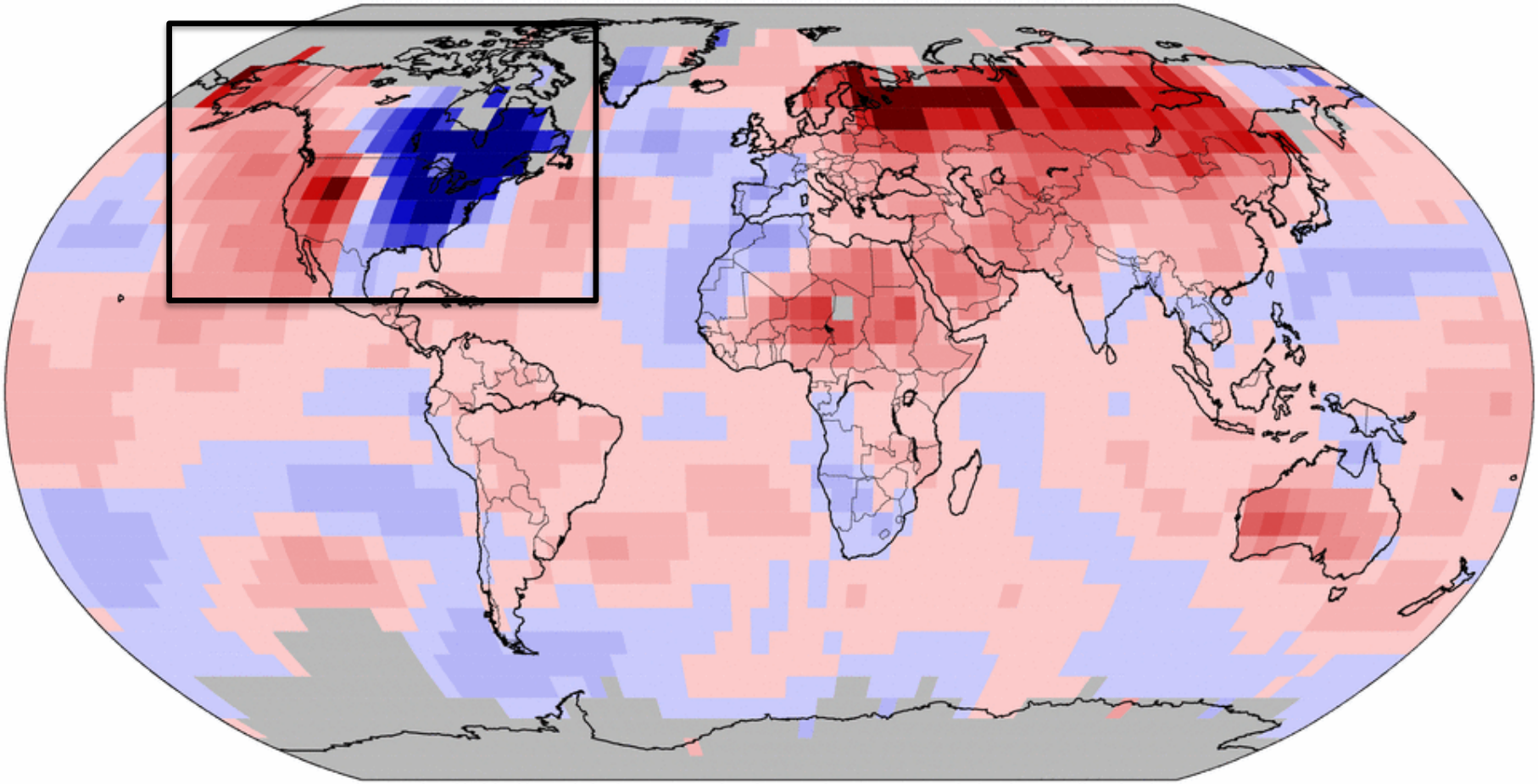
record cold

Jet Stream February 2015



Land & Ocean Temperature Departure from Average Feb 2015

(with respect to a 1981–2010 base period)

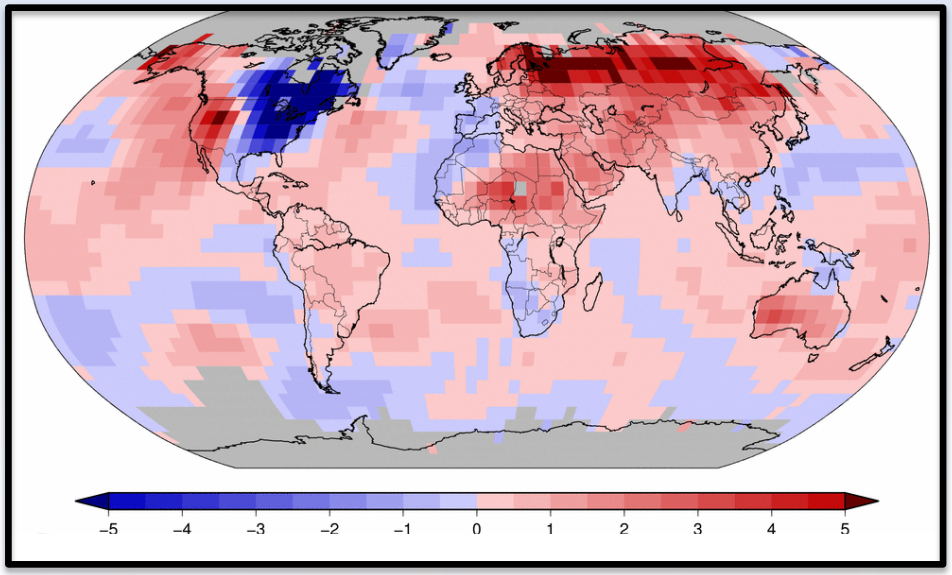


−5 −4 −3 −2 −1 0 1 2 3 4 5

Degrees Celsius

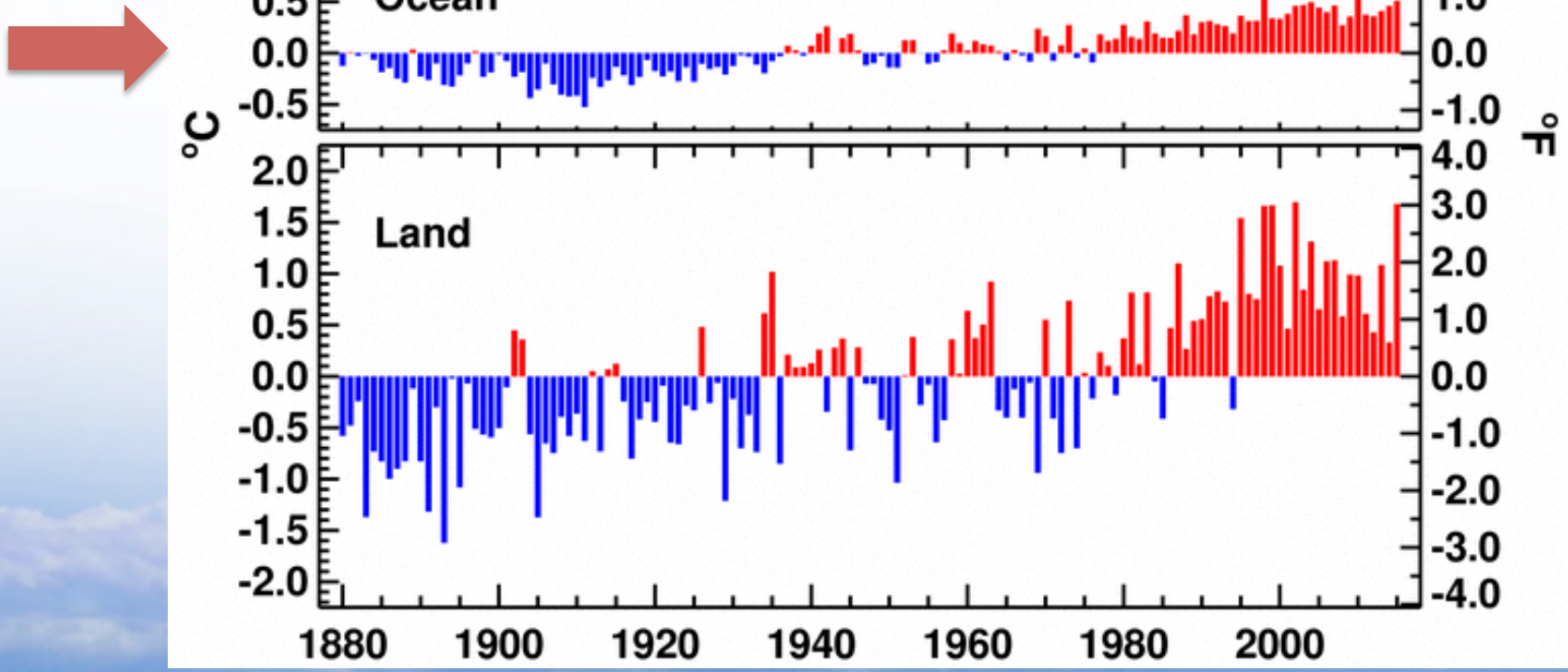
NOAA's National Climatic Data Center
Sun Mar 15 19:53:31 EDT 2015

Please Note: Gray areas represent missing data
Map Projection: Robinson



February

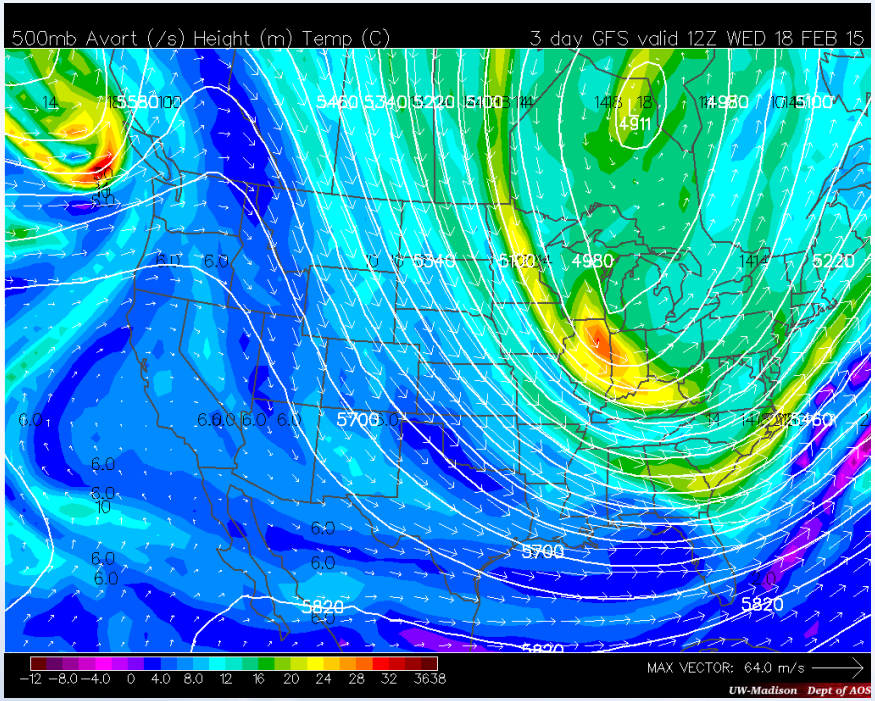
← 2015



Natural influences on local climate

Atmospheric Circulation

Chaotic, non-linear system with limited predictability.



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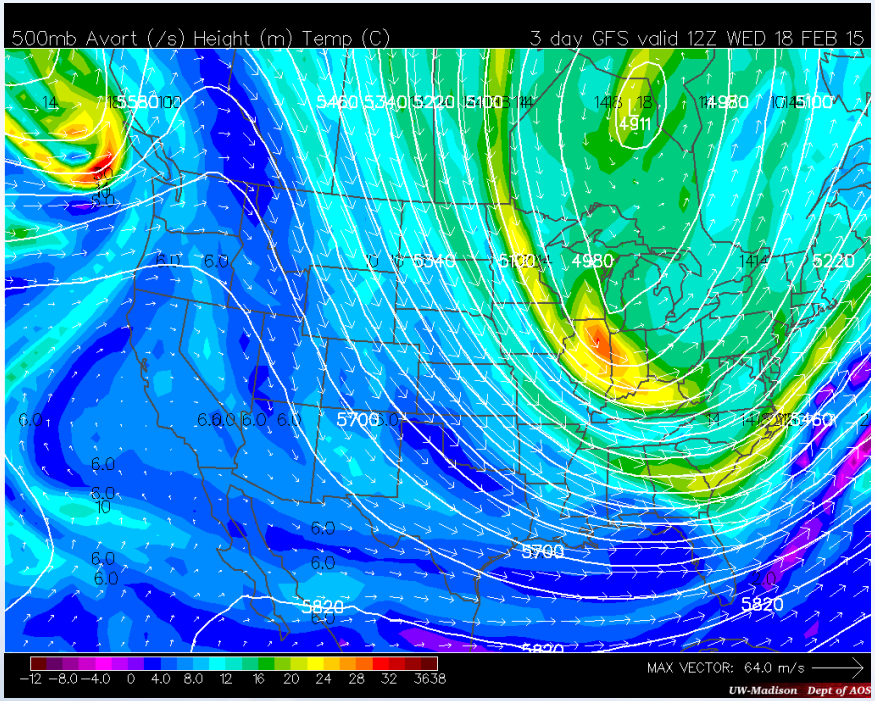
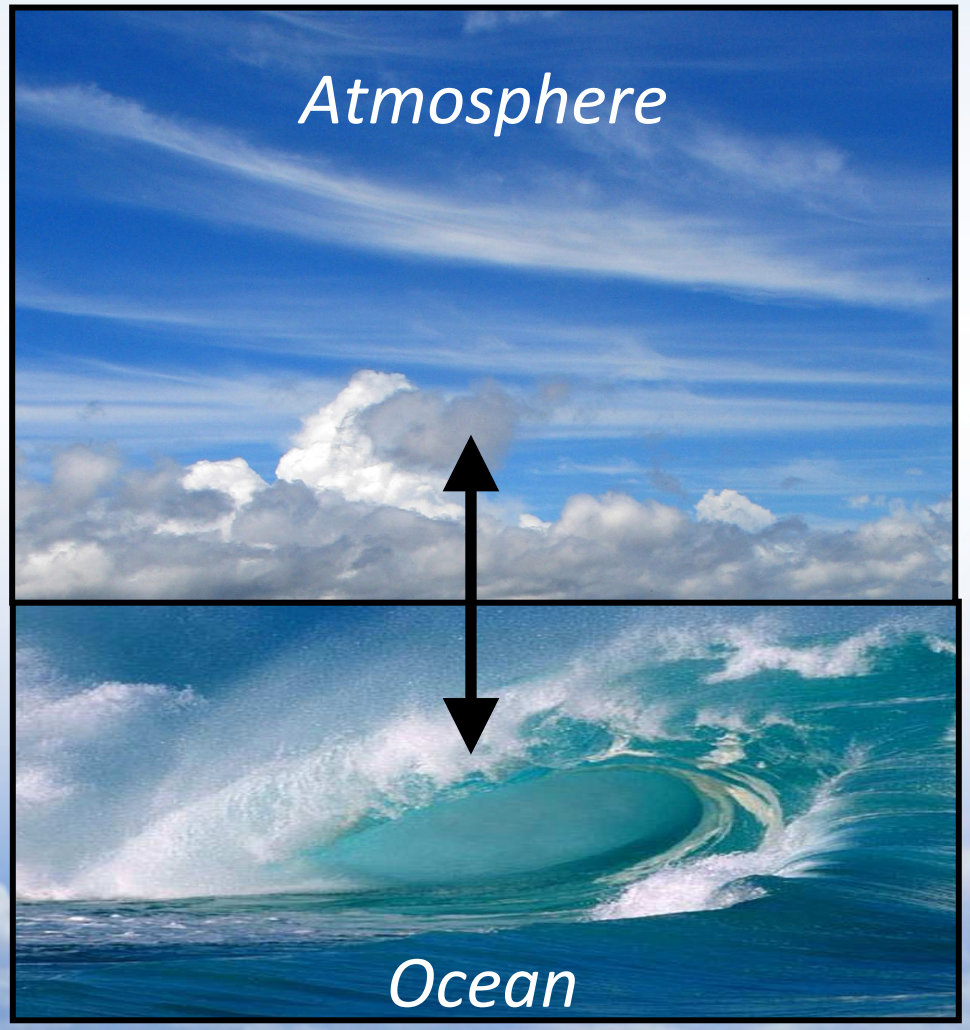


Gives rise to much of our local weather and climate variability.

Natural influences on local climate

Ocean-Atmosphere Interactions

Chaotic, non-linear system with longer, but still limited predictability.



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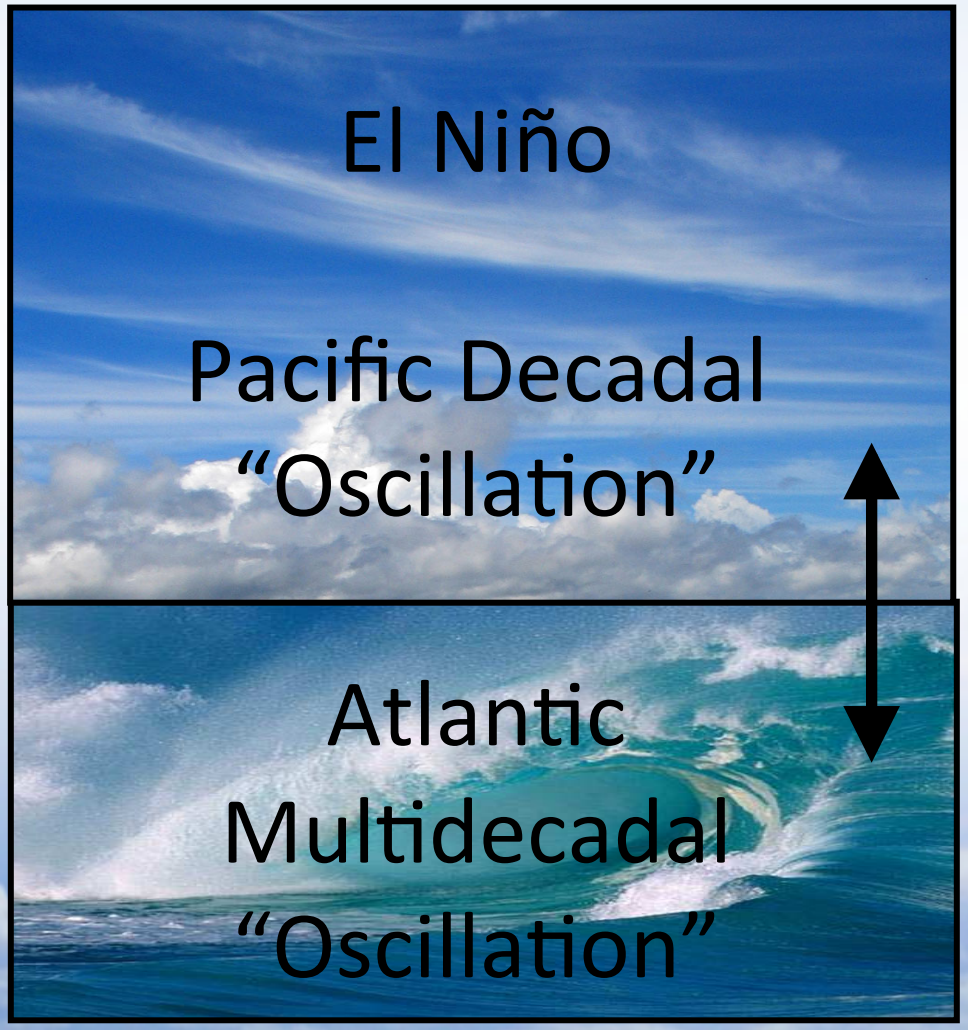
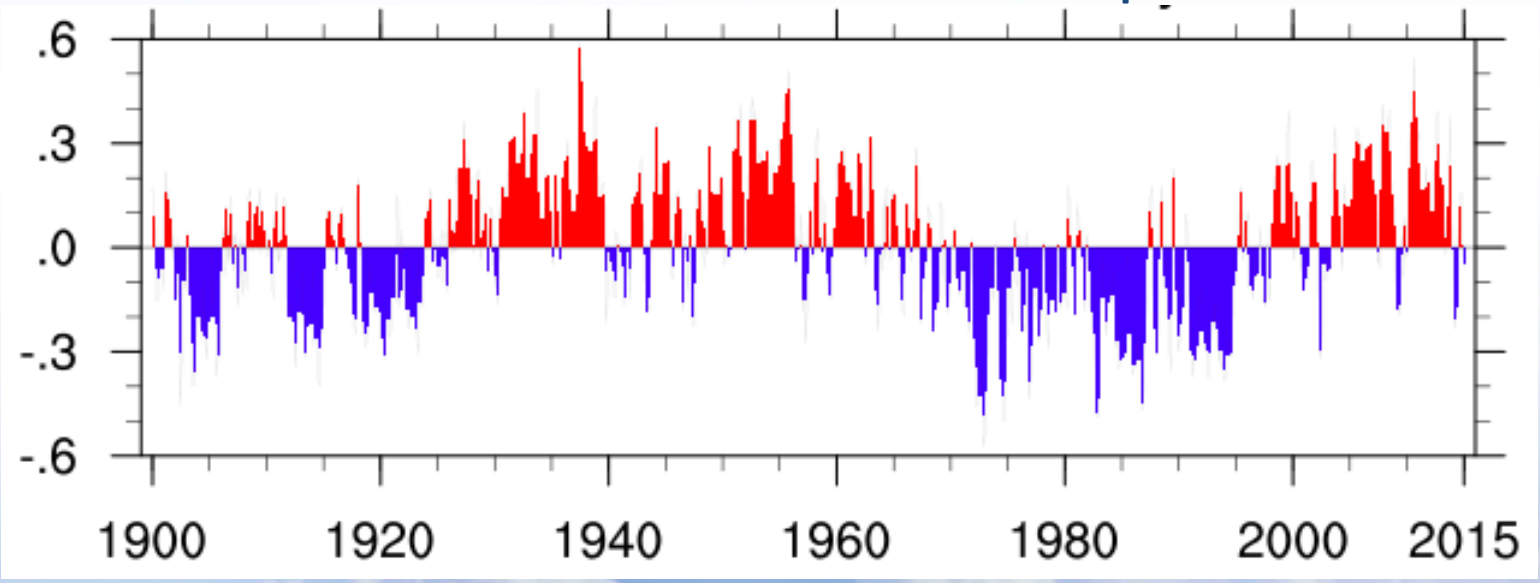


Natural Climate Variability

Atlantic Multi-decadal "Oscillation"

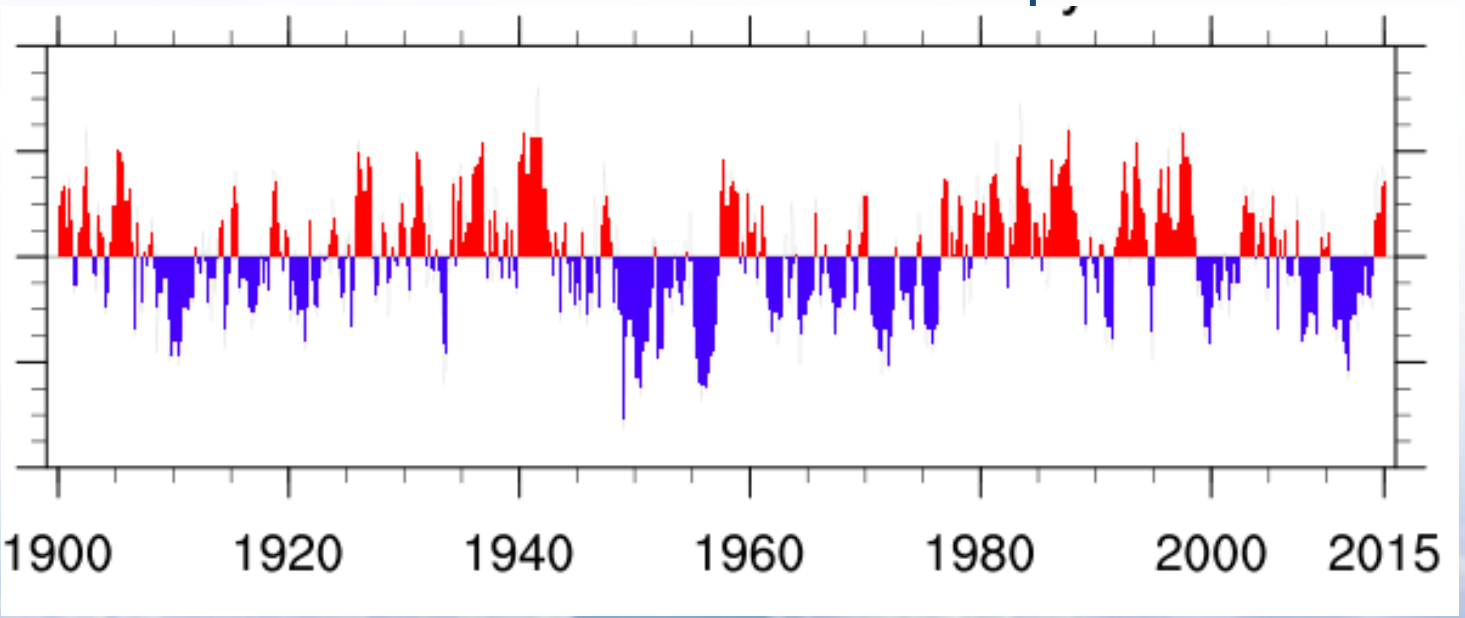
North Atlantic Sea Surface Temperature



Natural Climate Variability

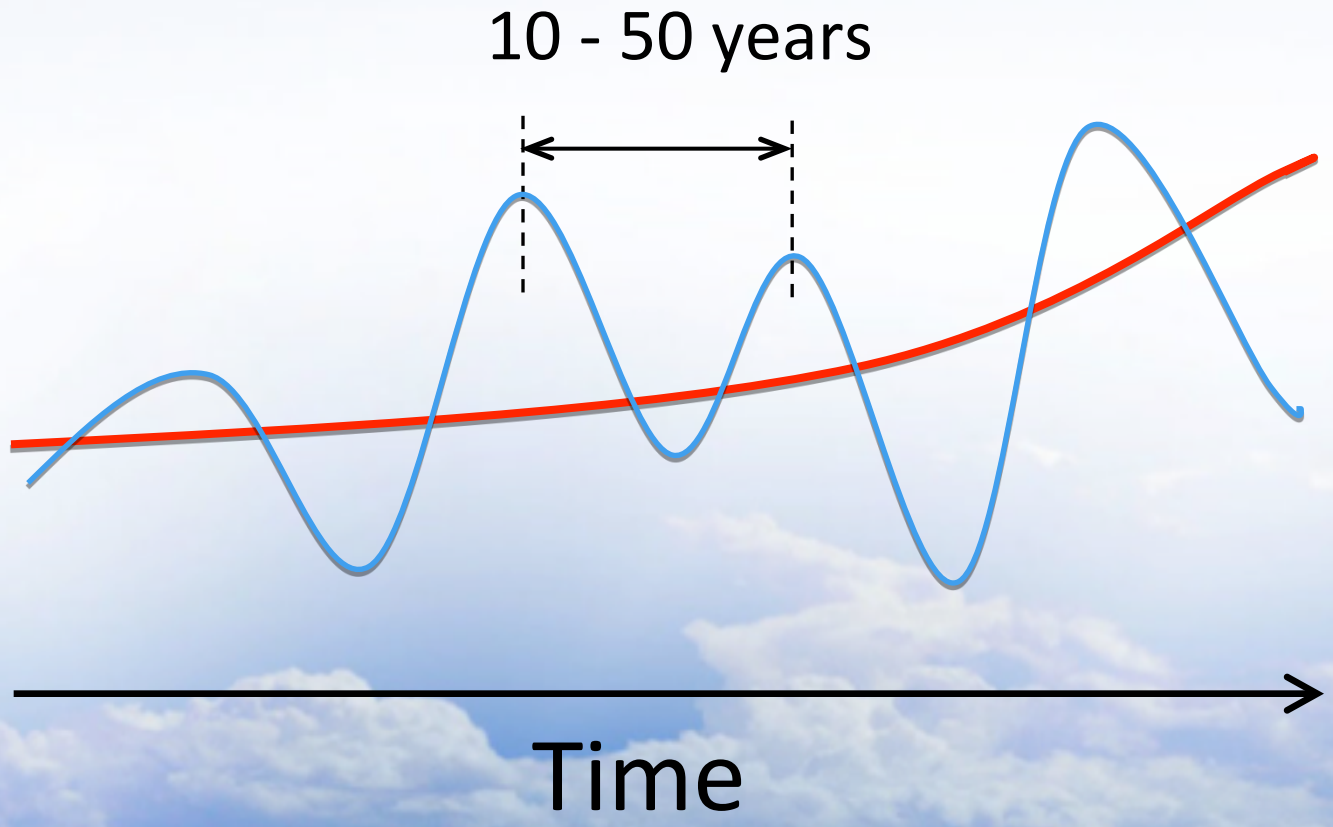
Pacific Decadal "Oscillation"

North Pacific Sea Surface Temperature

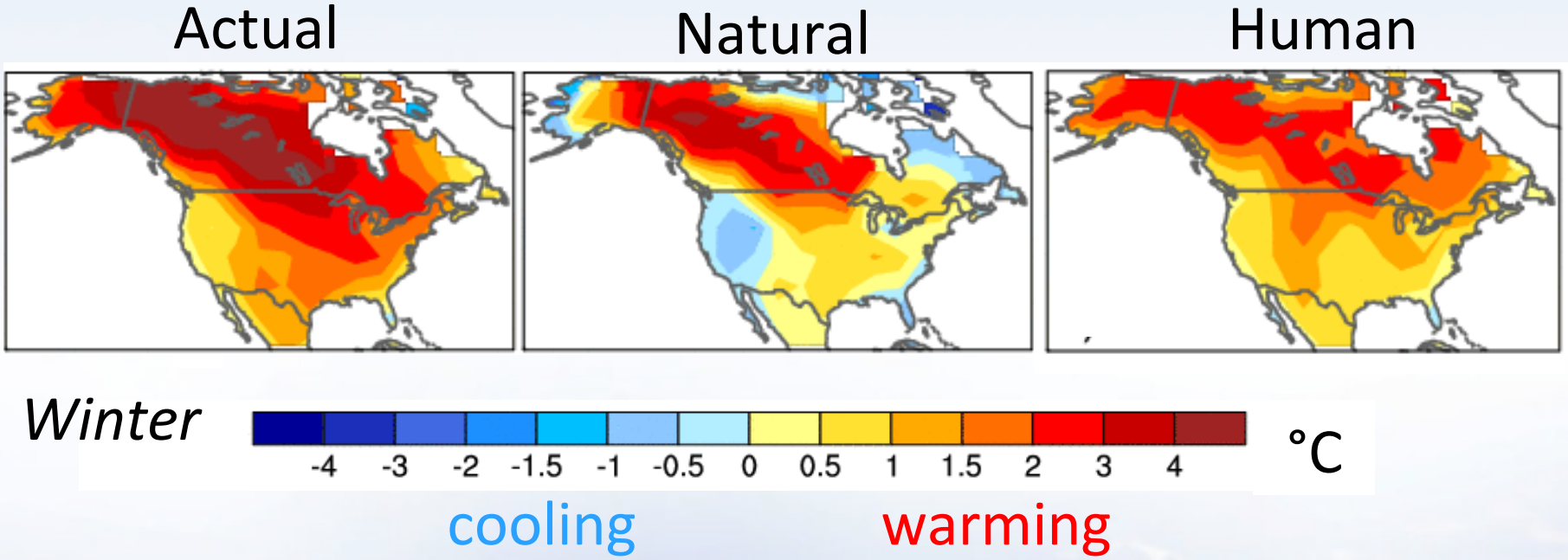


Local Climate Change

Natural & human influences co-exist



Temperature changes over the past 50 years



Deser et al., 2015

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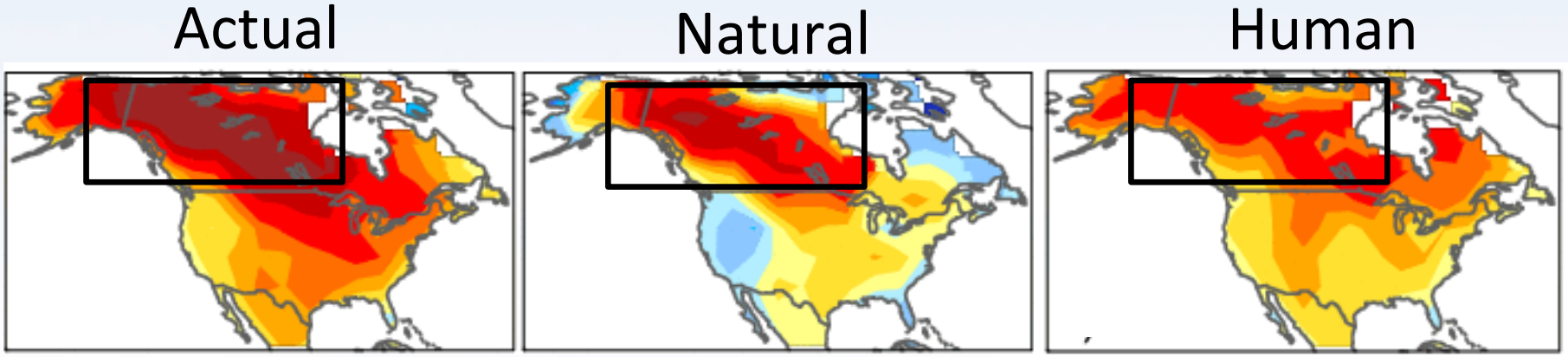

Winter

-4 -3 -2 -1.5 -1 -0.5 0 0.5 1 1.5 2 3 4 °C

cooling warming

Western Canada: 50% natural, 50% human

Deser et al., 2015

Natural and Human Causes of Past and Future Climate Change

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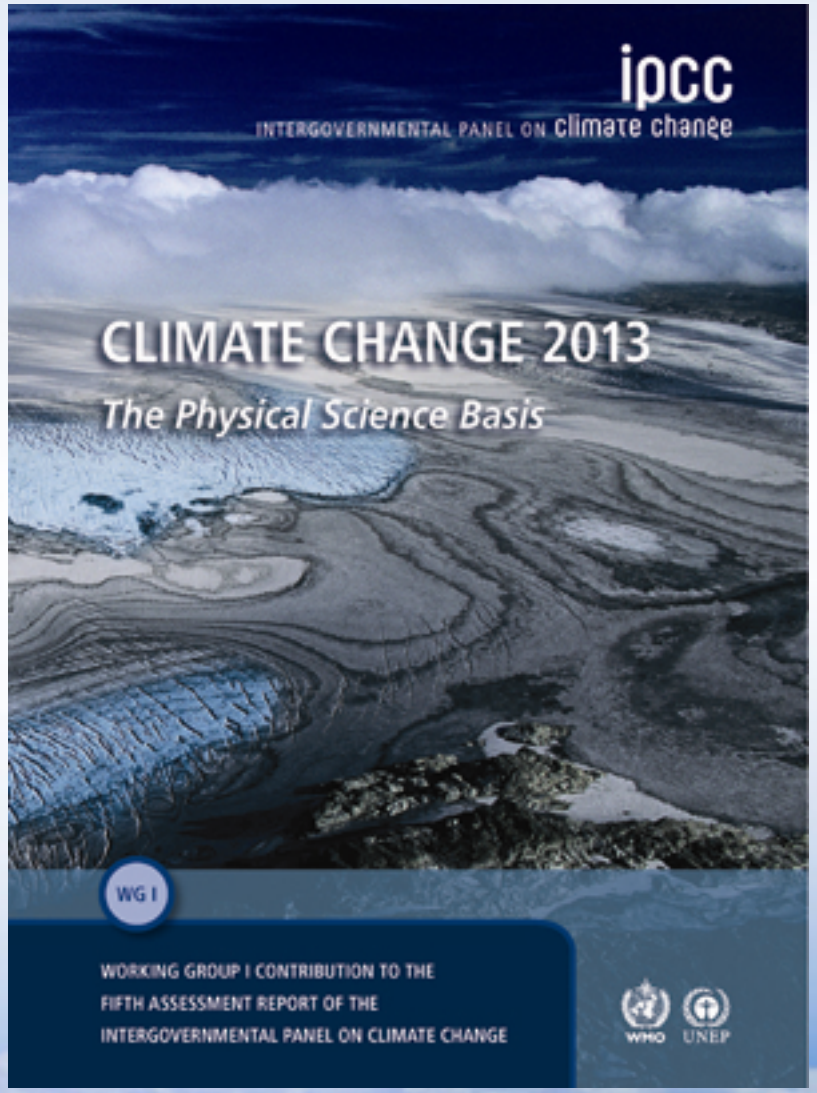
- Future: a range of outcomes

Future Climate Change

A range of outcomes

(depending on the natural variability)

Climate Projections



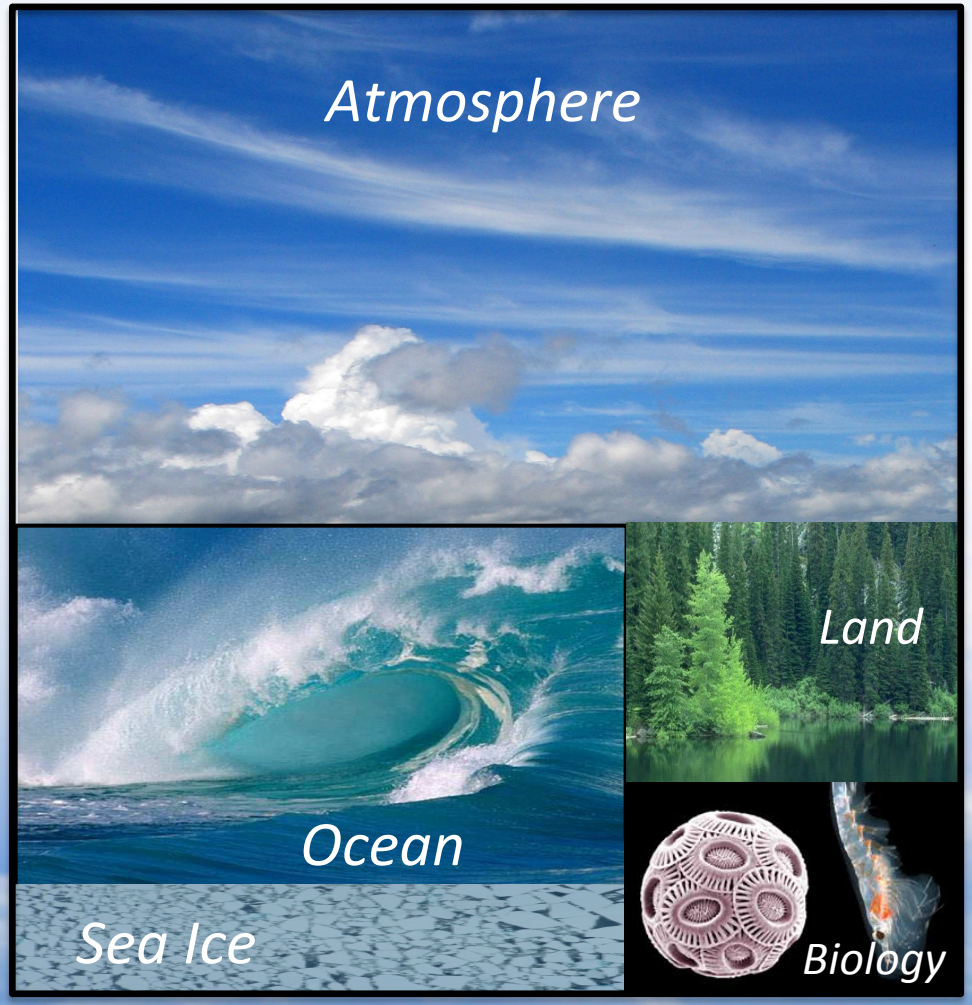
- Created in 1988
- Reports in 1990, 1995, 2001, 2007*, 2013
- Thousands of scientists worldwide
- Tens-of-thousands of pages

*Won the Nobel Peace Prize

Intergovernmental Panel on Climate Change

Climate Projections

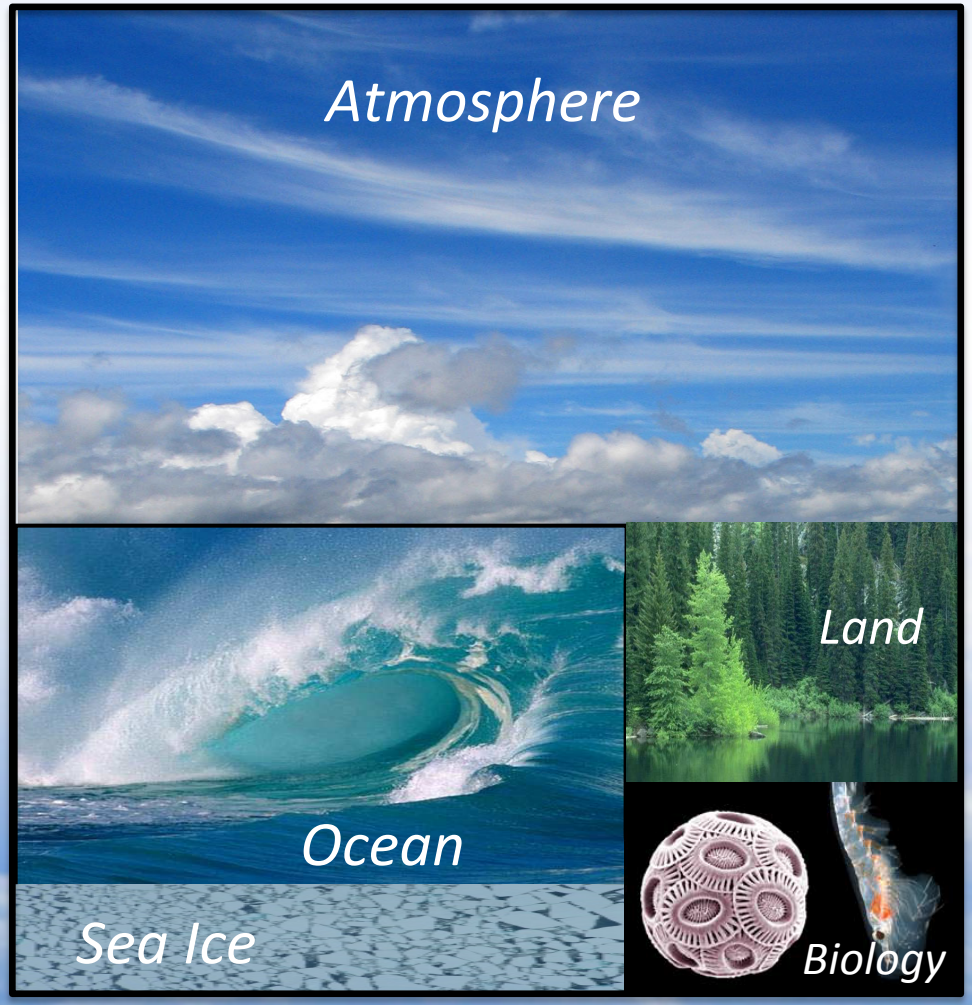
Computer models of the climate system



Climate Projections

Computer models of the climate system

CO_2



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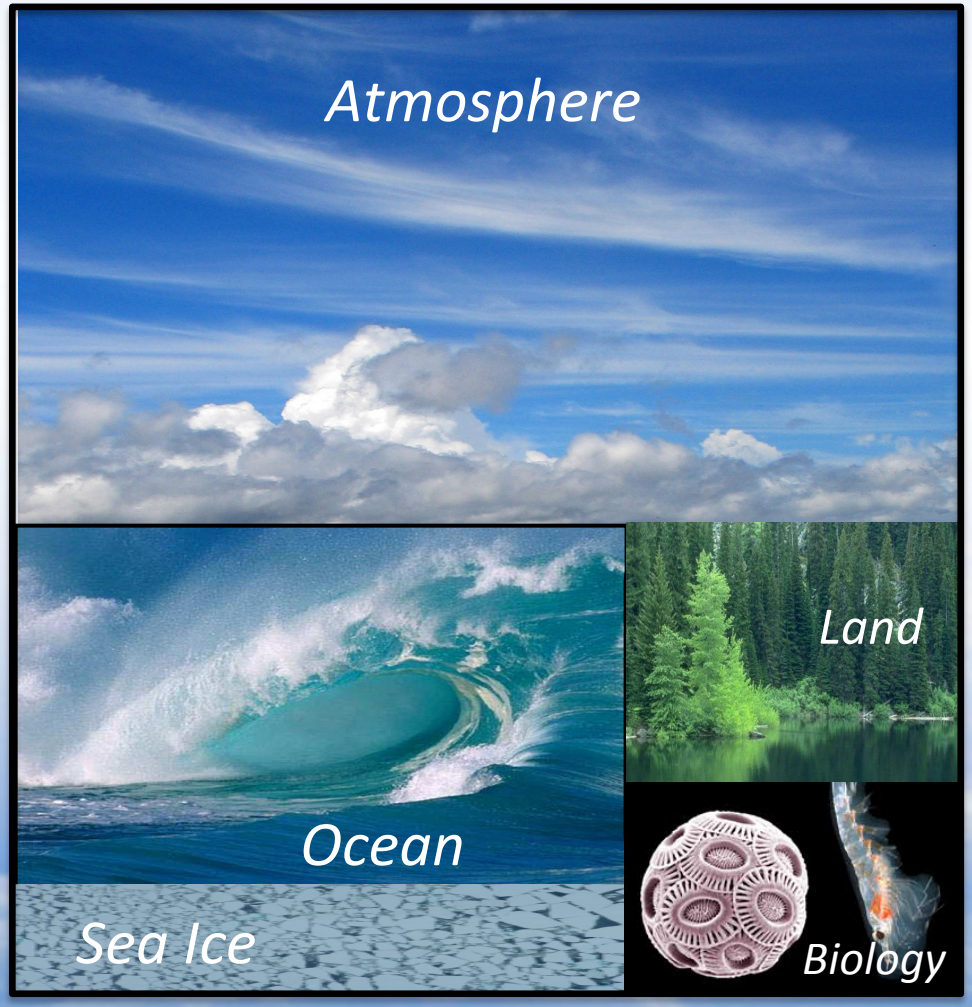
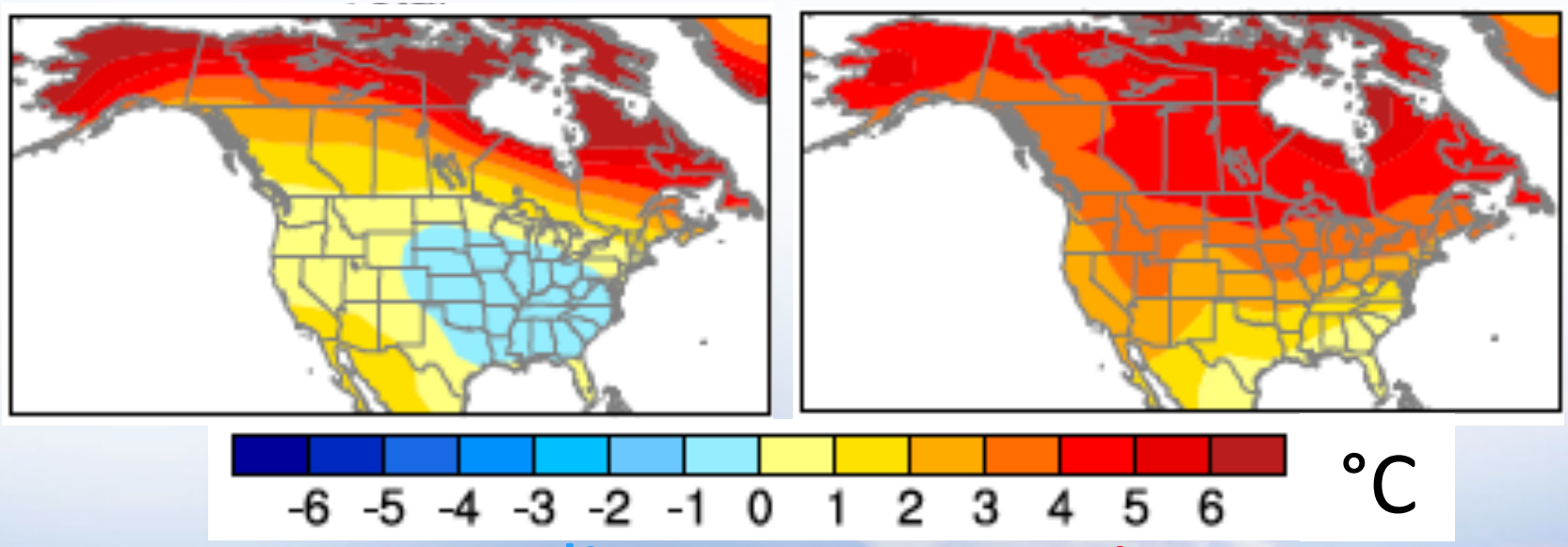


Temperature change in the next 50 years: A Range of Outcomes

CO_2 +



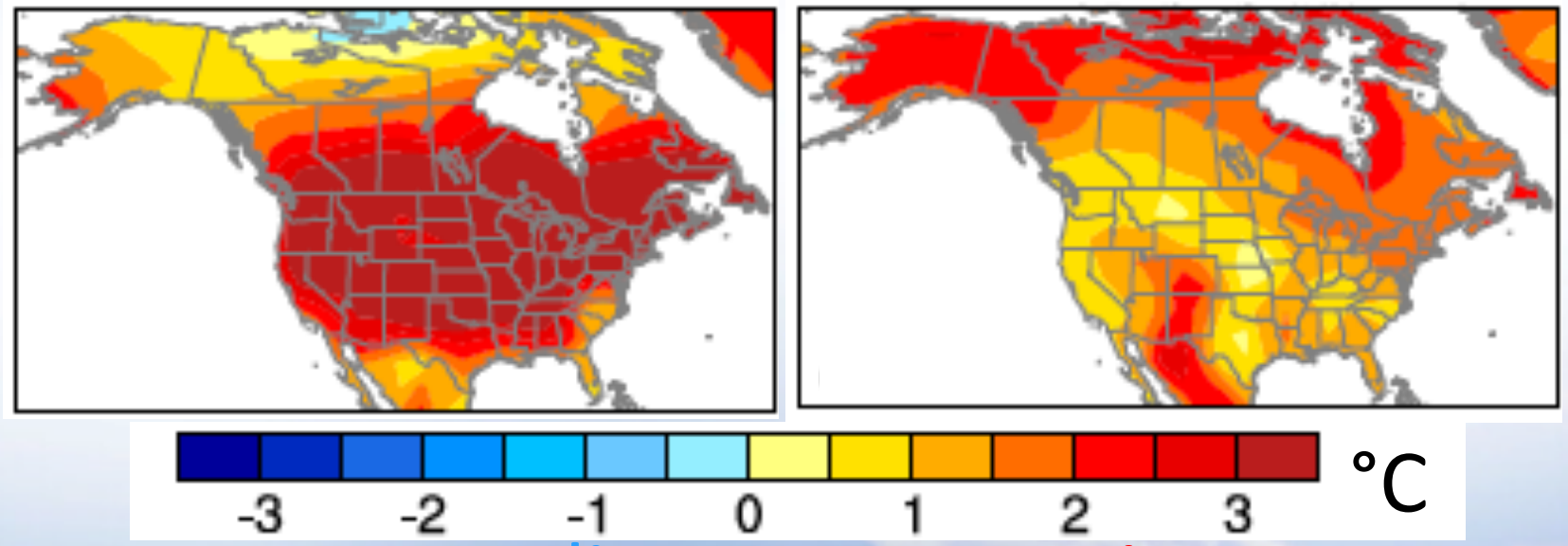
Winter

(double for °F)

Deser et al., 2014

Temperature change in the next 50 years: A Range of Outcomes

CO_2 +

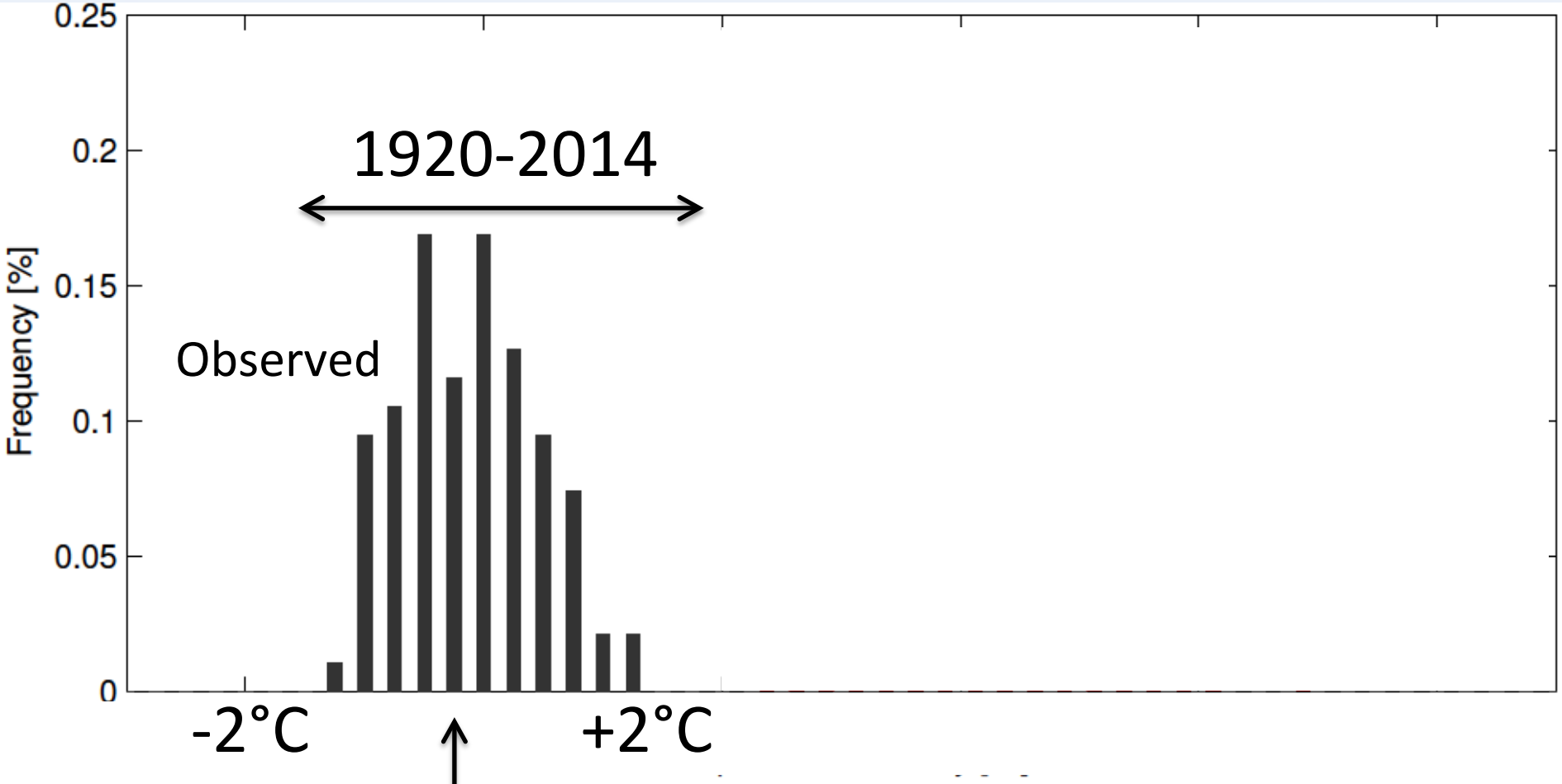


Summer

(double for °F)

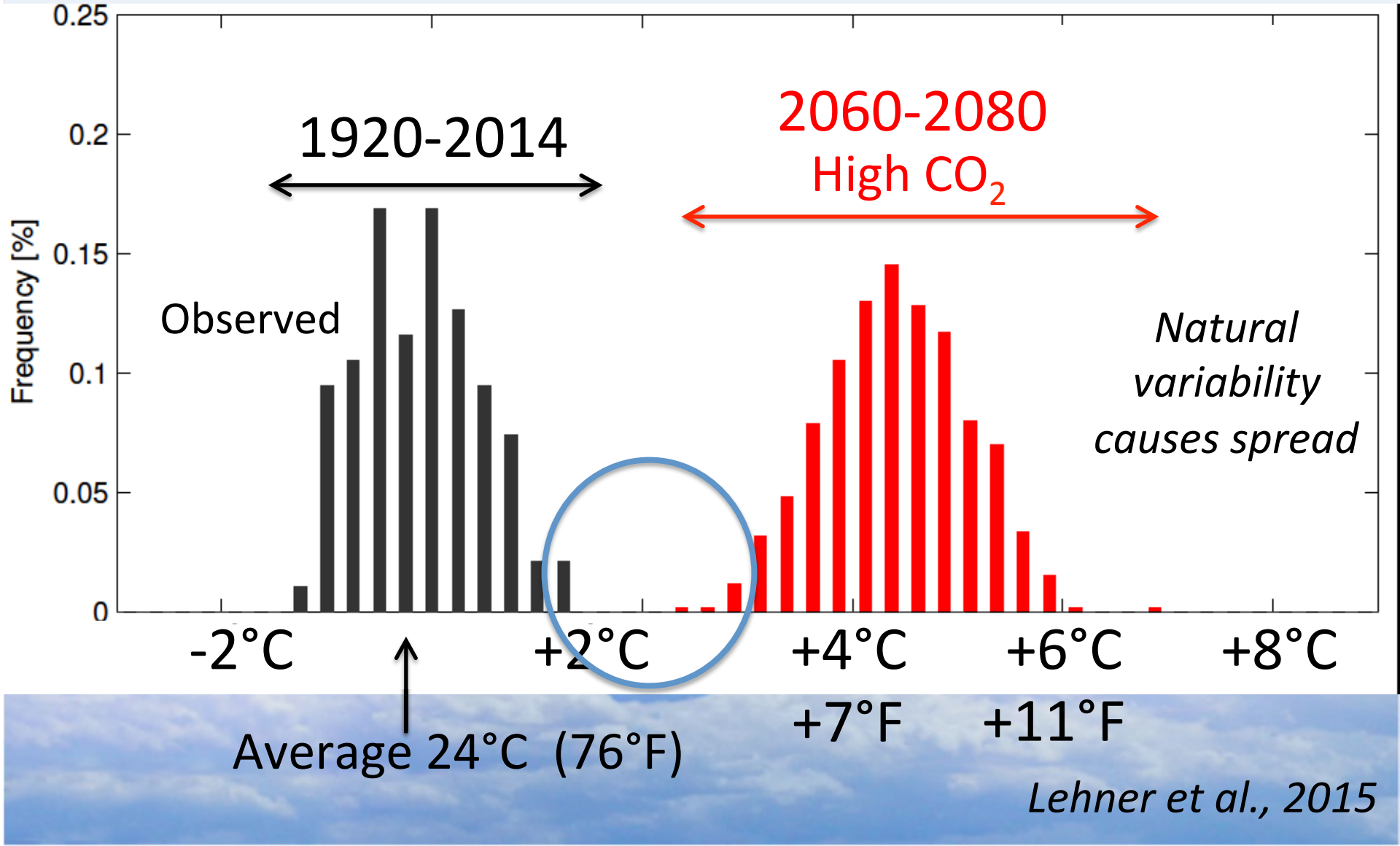
Deser et al., 2014

California Summer Temperatures



Lehner et al., 2015

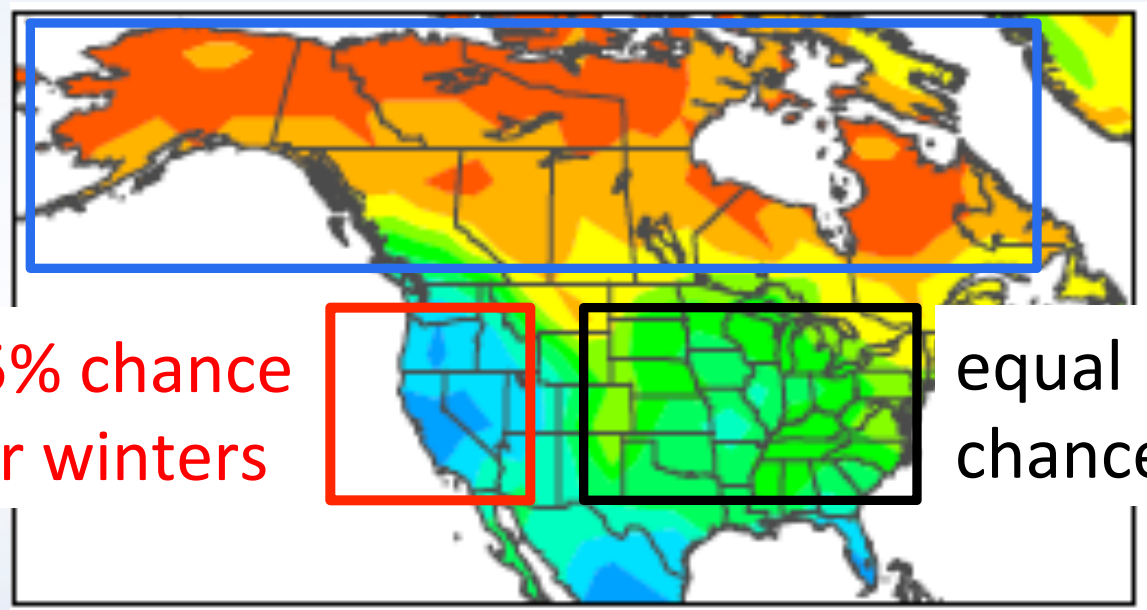
California Summer Temperatures



Lehner et al., 2015

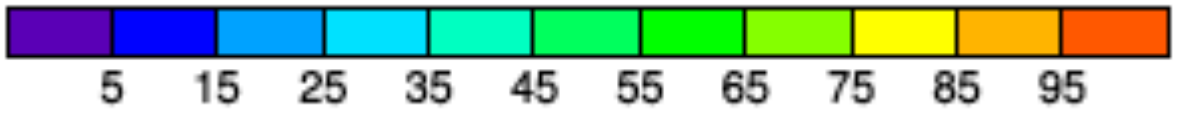
Risk of Precipitation Change in the next 50 years

> 85% chance wetter winters



> 65% chance drier winters

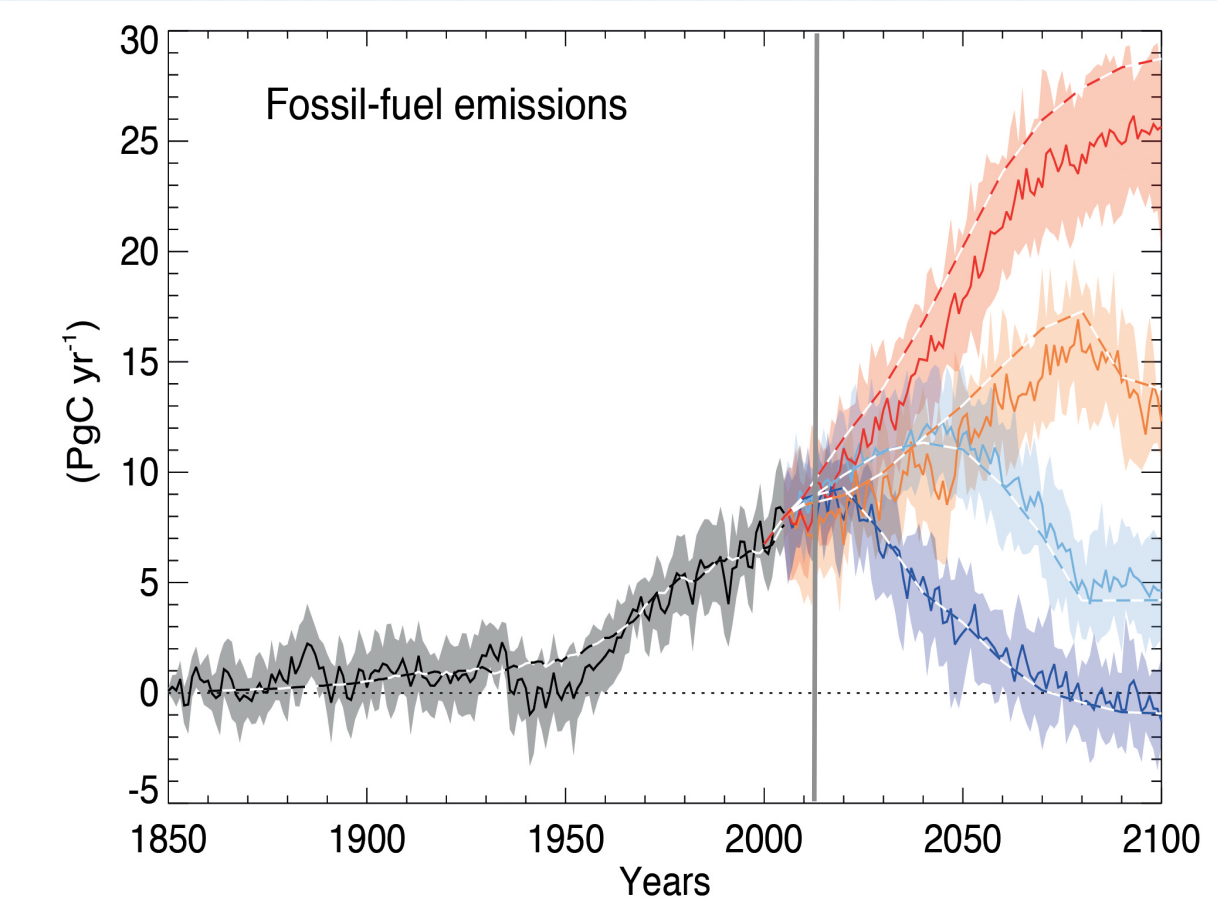
equal chances



%

CO_2 +

CO_2 Emissions Scenarios



Continued growth

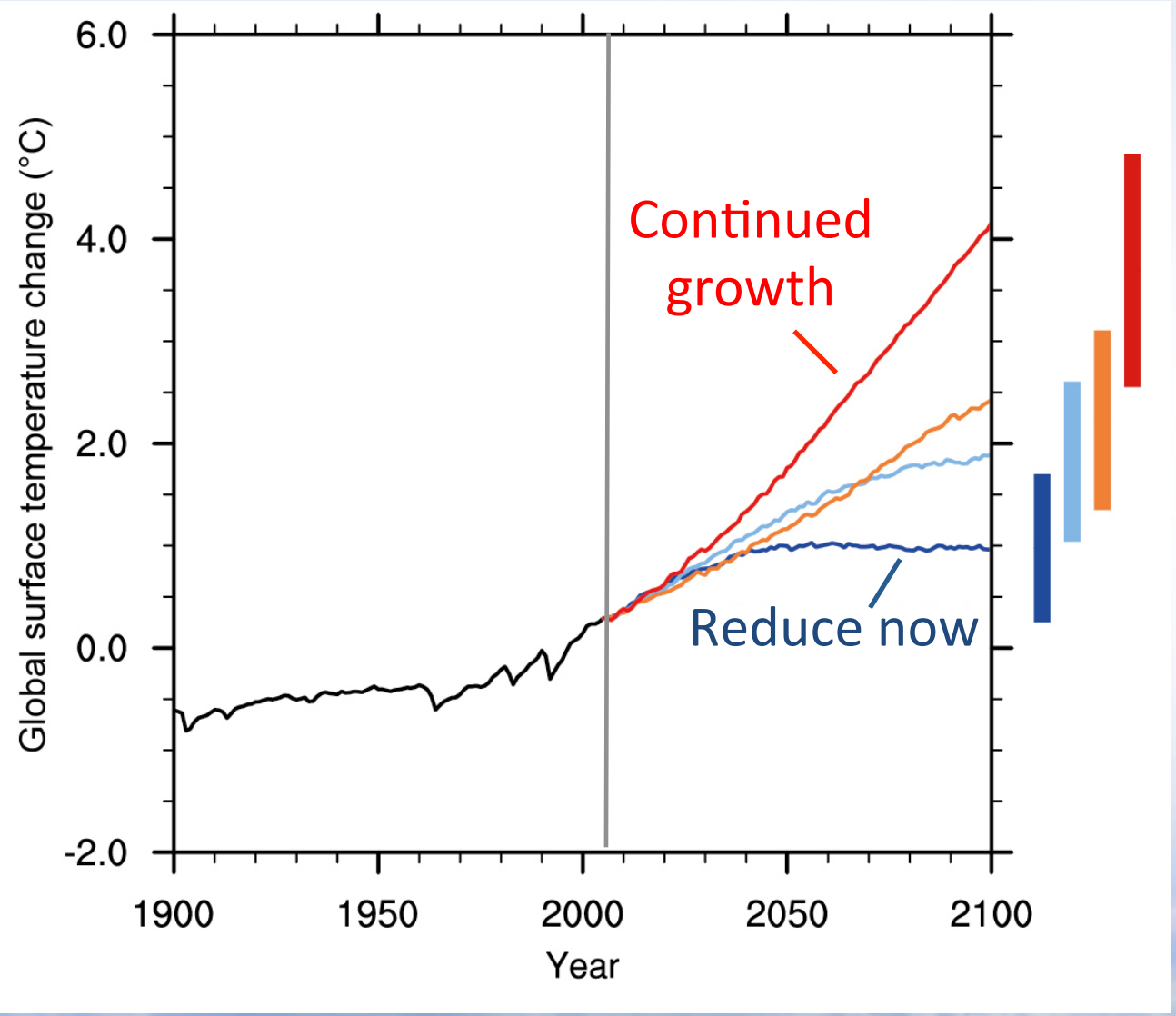
Reduce in 2075

Reduce in 2045

Reduce now

IPCC 2013

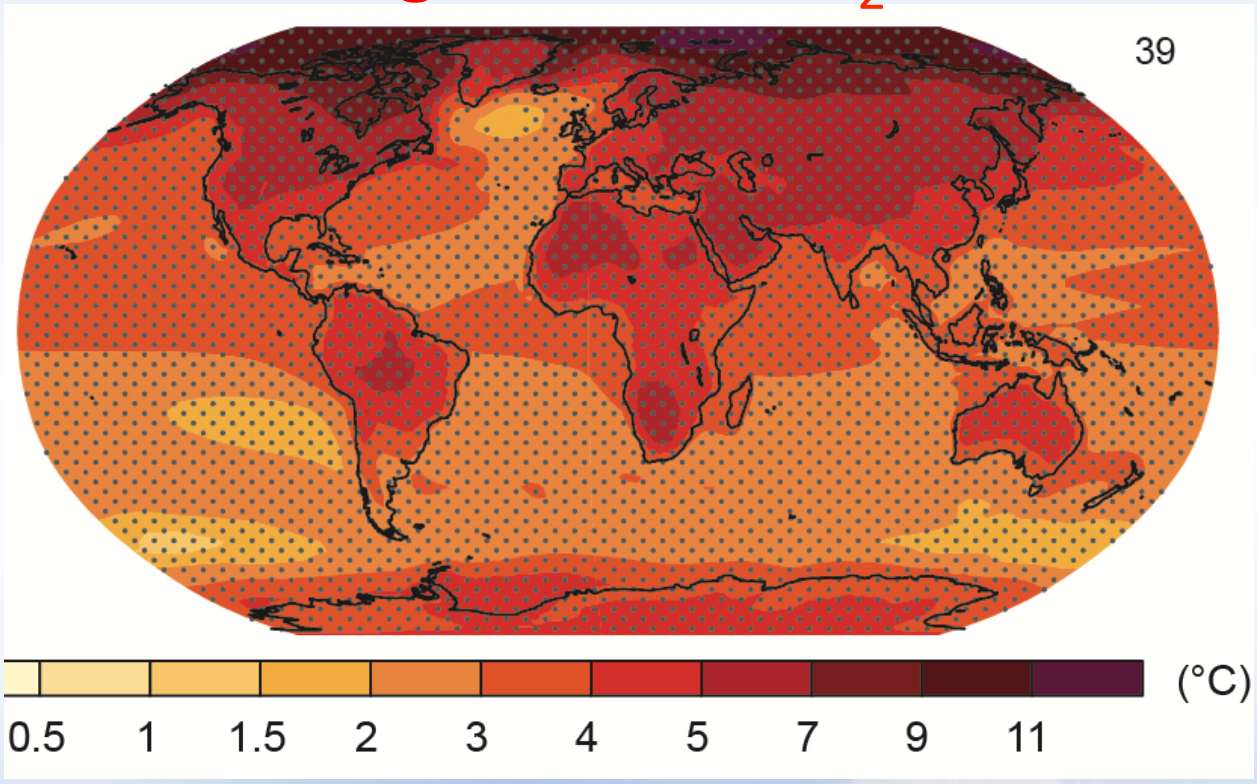
Global Temperature Projections



IPCC 2013

Temperature Change in 2100

Continued growth of CO_2 emissions



4°C global mean

Land > Sea, Arctic > Globe

IPCC 2013

Conclusions

Human

Natural

Keeling Curve

CO_2

+

Scale tips more toward the human influence (risk) for larger spatial scales and longer time horizons.

Thank you

Helpful Sites for Climate Information

www.realclimate.org

www.skepticalscience.com

climate.gov

www.climatecommunication.org

environment.yale.edu/climate-communication

www.ncdc.noaa.gov/sotc

scrippsco2.ucsd.edu