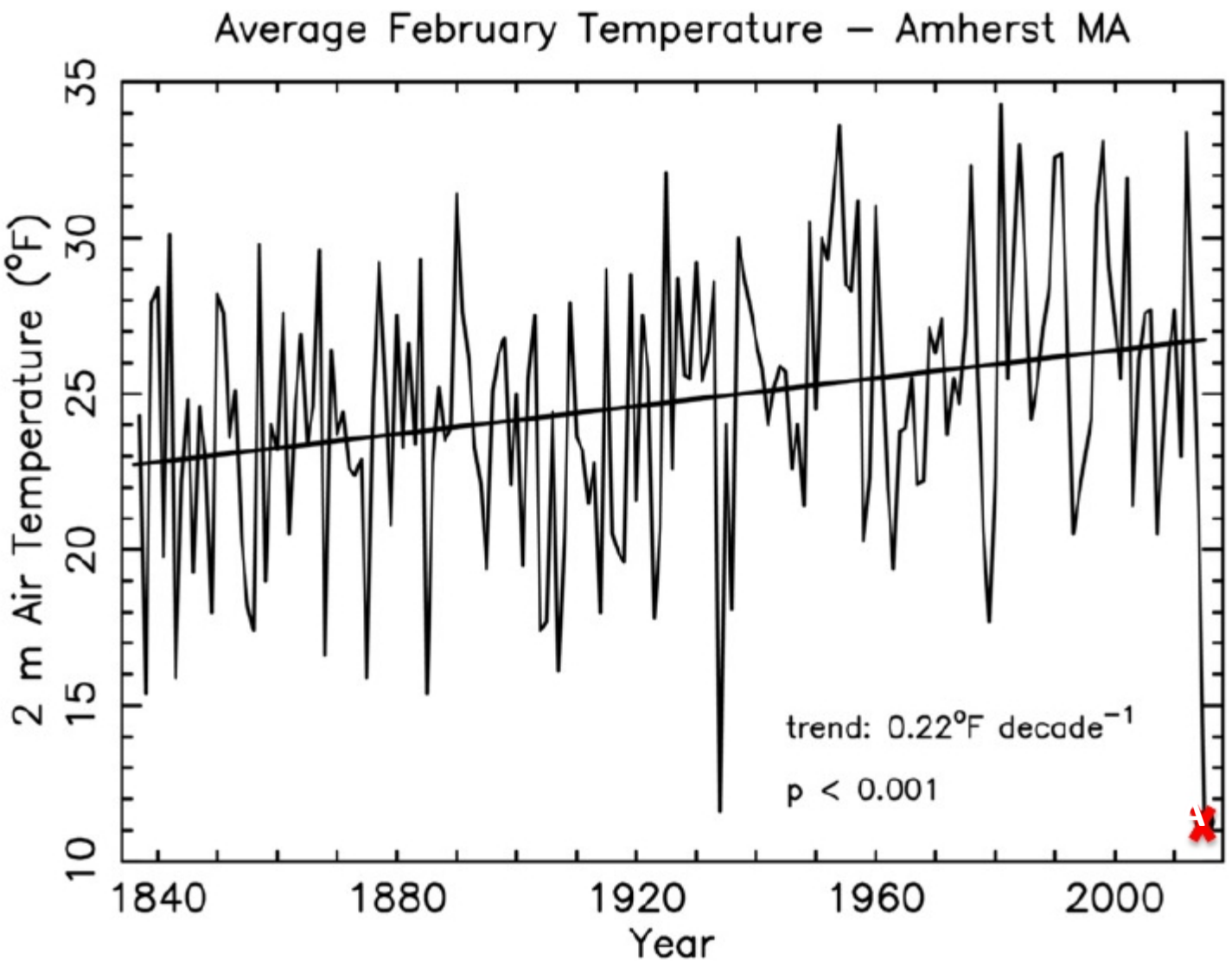
What Happened to Global Warming?

Ambarish Karmalkar, Ray Bradley
University of Massachusetts Amherst

12 May 2015
MWRA Meeting



Source: *M. Rawlins, CSRC, UMass*

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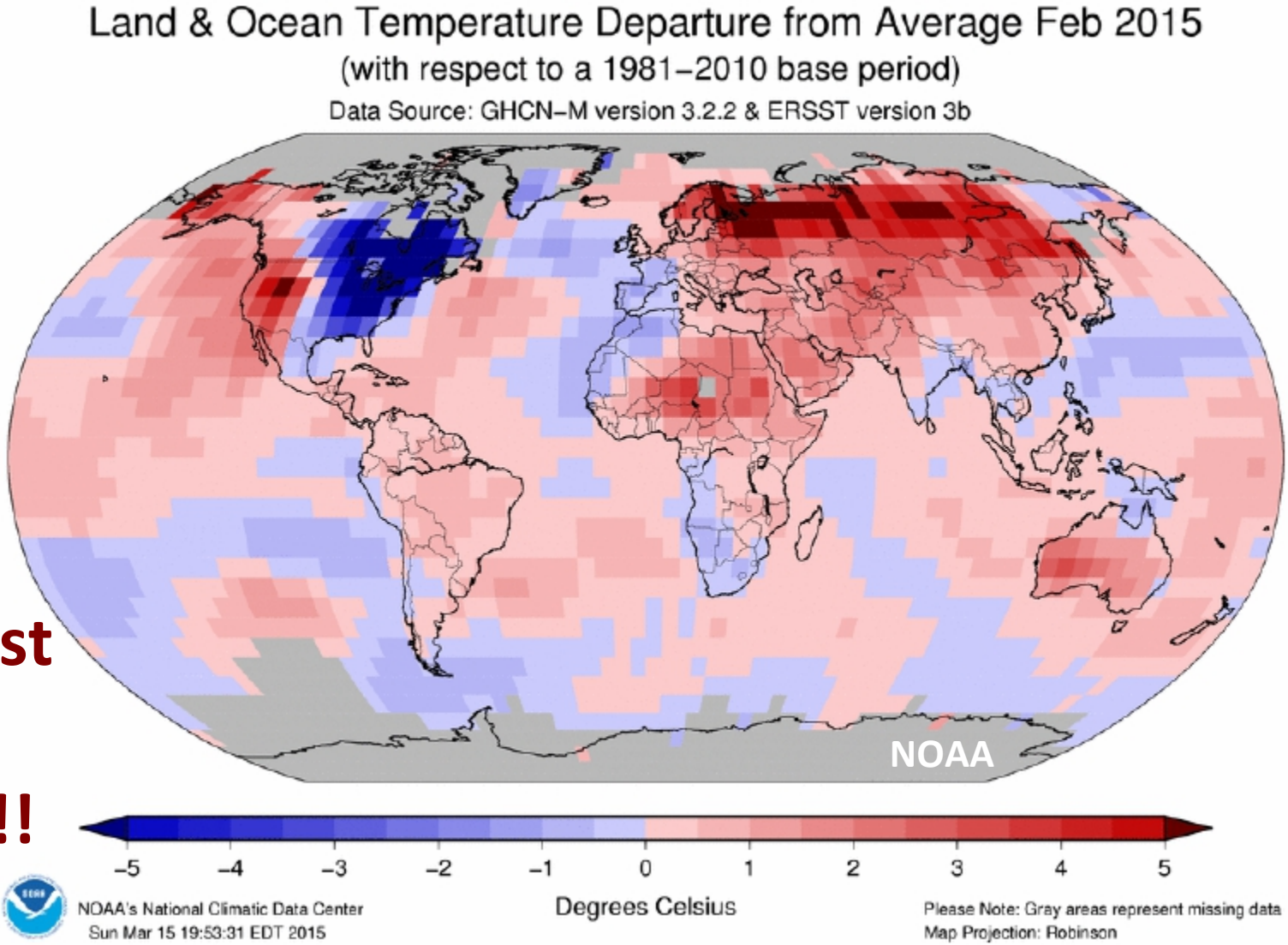
Globally, February was the 2nd warmest in the last 136 years!!



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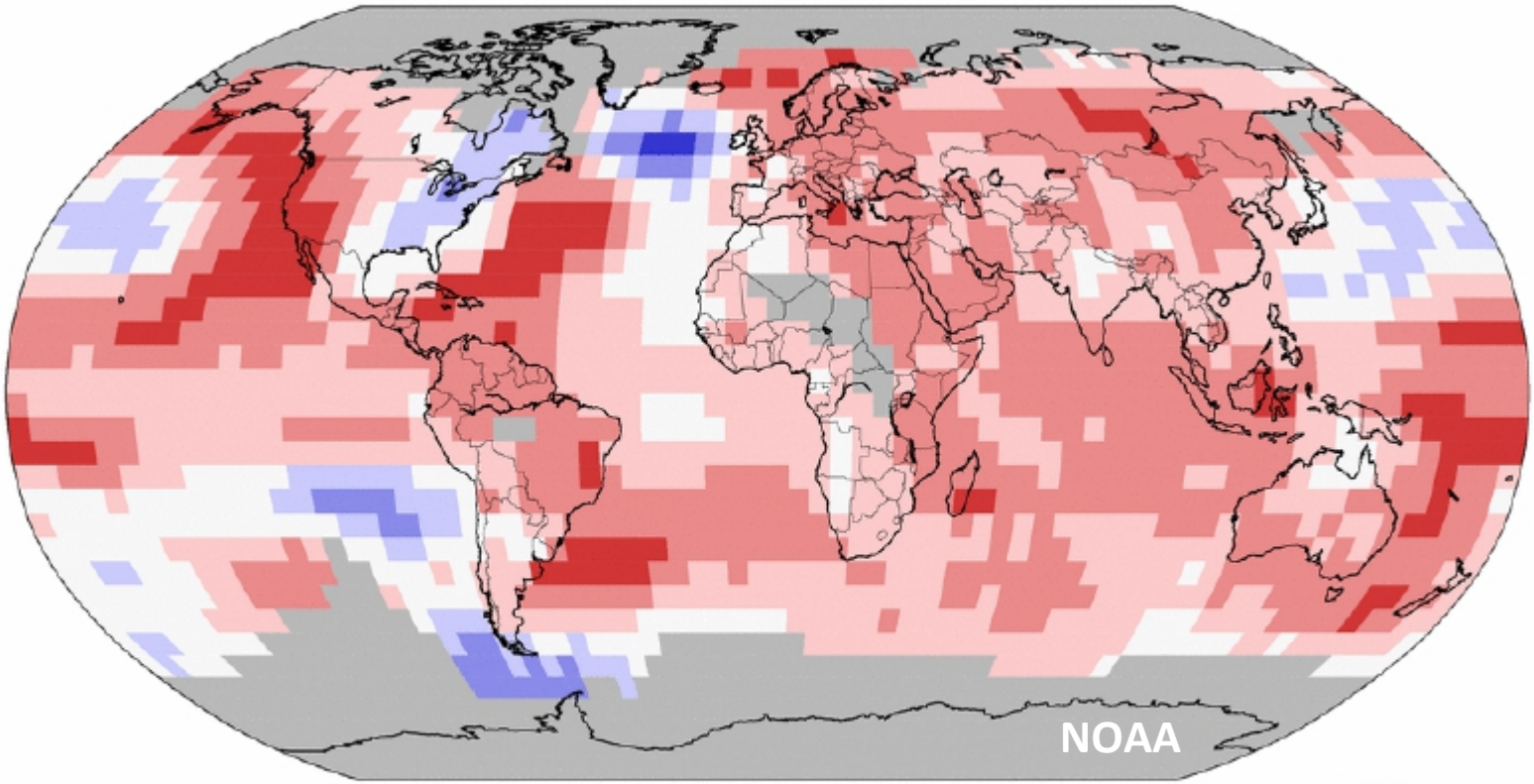
Land & Ocean Temperature Percentiles Dec 2014–Feb 2015

NOAA's National Climatic Data Center

Data Source: GHCN–M version 3.2.2 & ERSST version 3b



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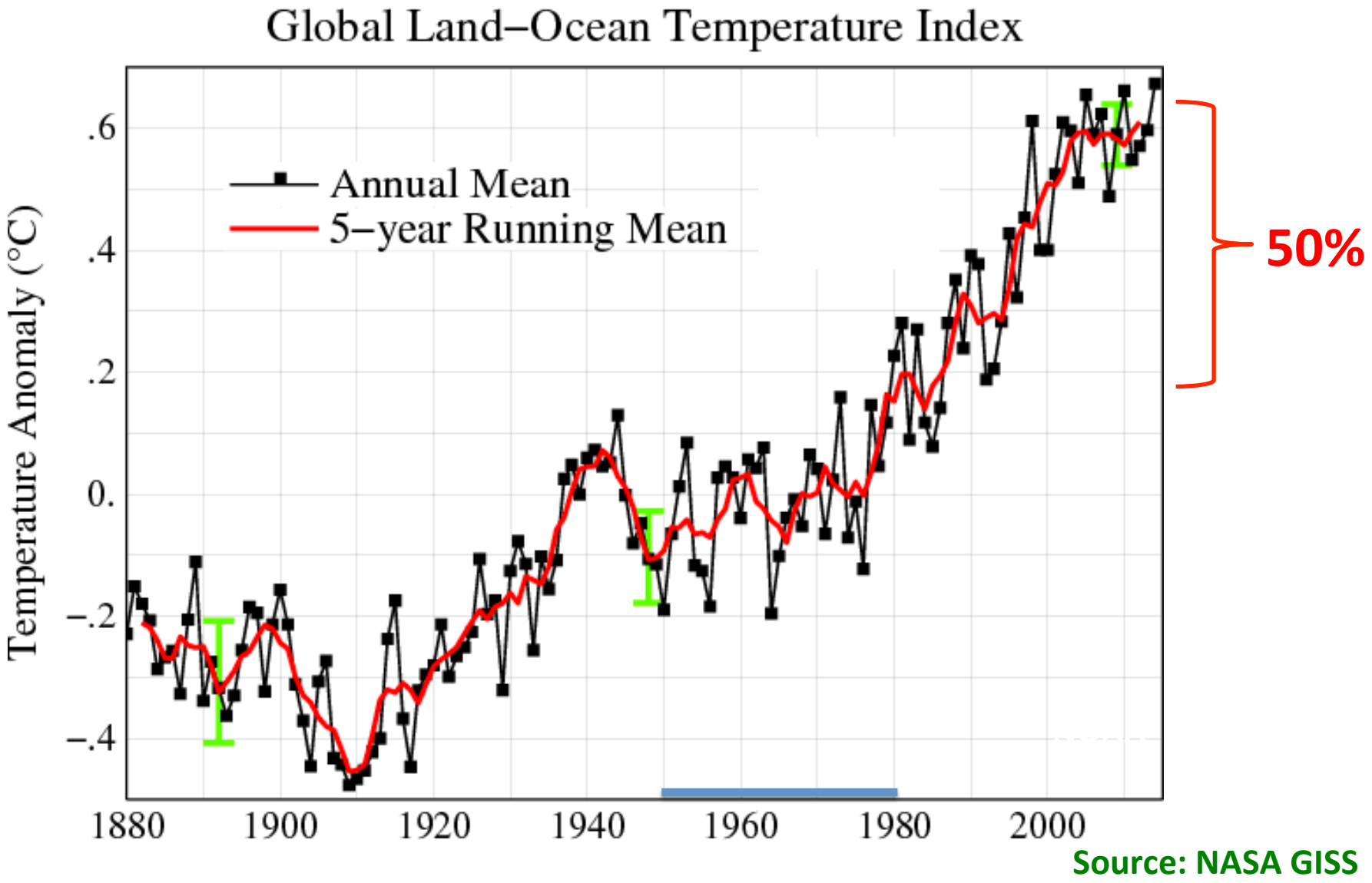

Source: NASA GISS

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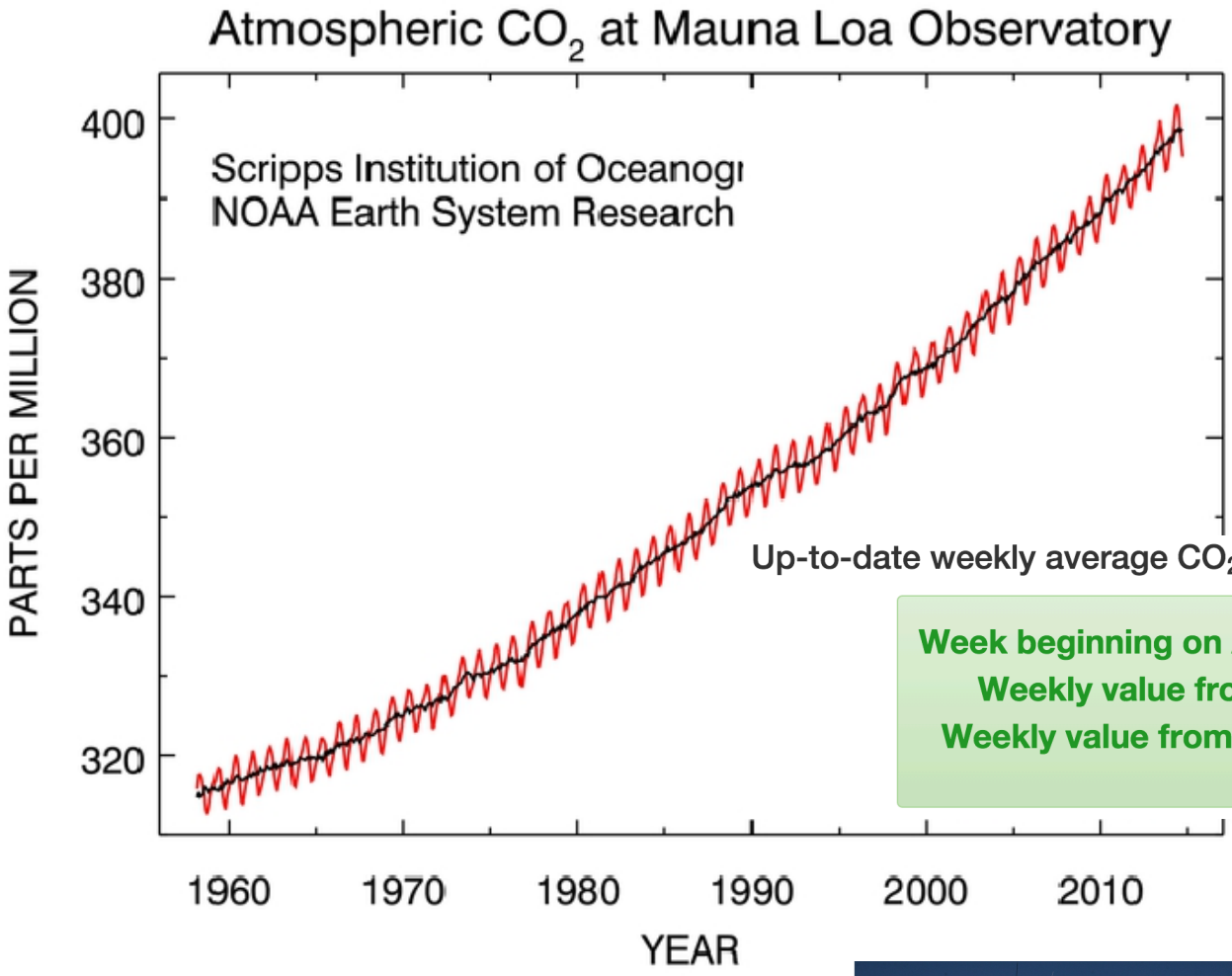
Global Warming Science

"Most of the observed increase in globally averaged temperatures since the mid-20th century is very *very likely due to the observed increase in anthropogenic greenhouse gas concentrations…"**
The Inter-Governmental Panel on Climate Change (IPCC) AR4 2007

"This evidence for human influence has grown since AR4. It is *extremely likely* that human influence has been the dominant cause of the observed warming since the mid-20th century…"
IPCC AR5 2013

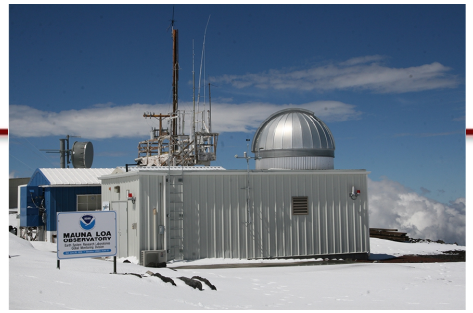
**** "very likely" => 90% probability; "extremely likely" => 95%***



Up-to-date weekly average CO_2 at Mauna Loa

Week beginning on April 26, 2015:	**403.78 ppm**
Weekly value from 1 year ago:	**401.73 ppm**
Weekly value from 10 years ago:	**382.52 ppm**

Last updated: May 9, 2015



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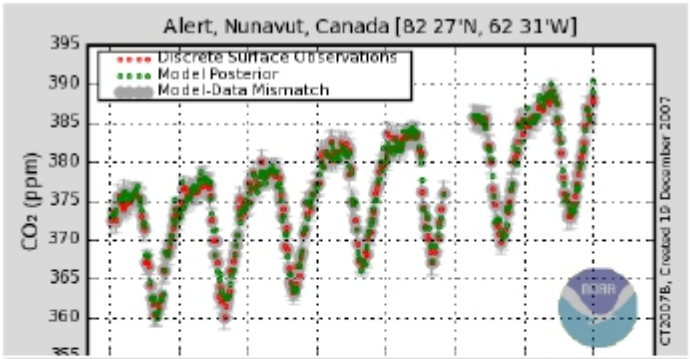

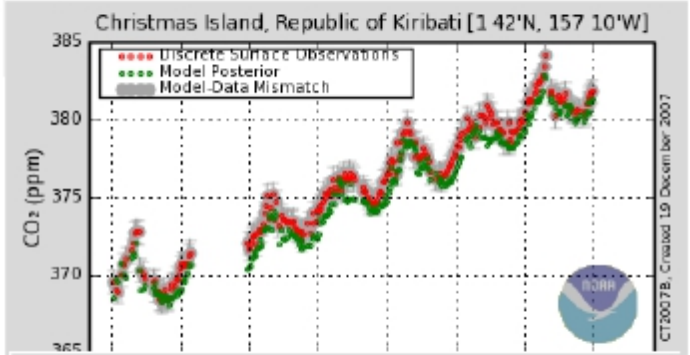

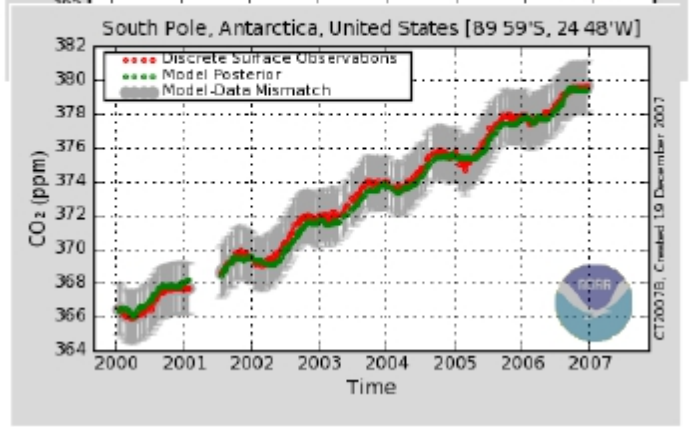

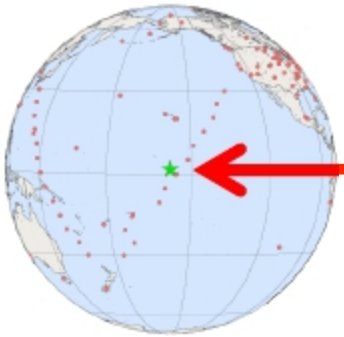

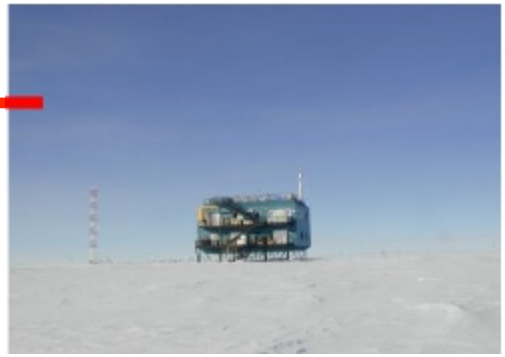

Source: *NOAA ESRL/GMD*

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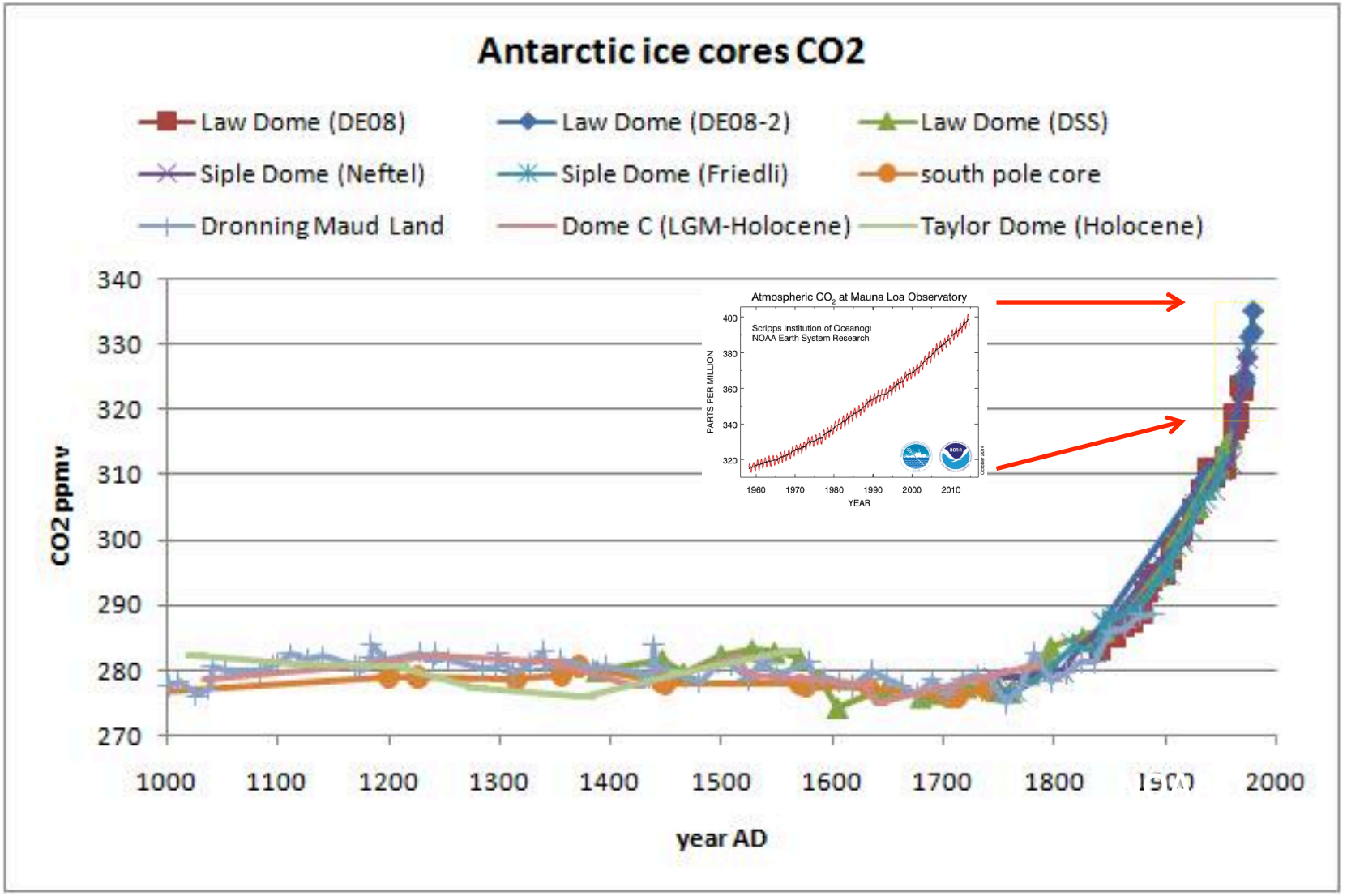

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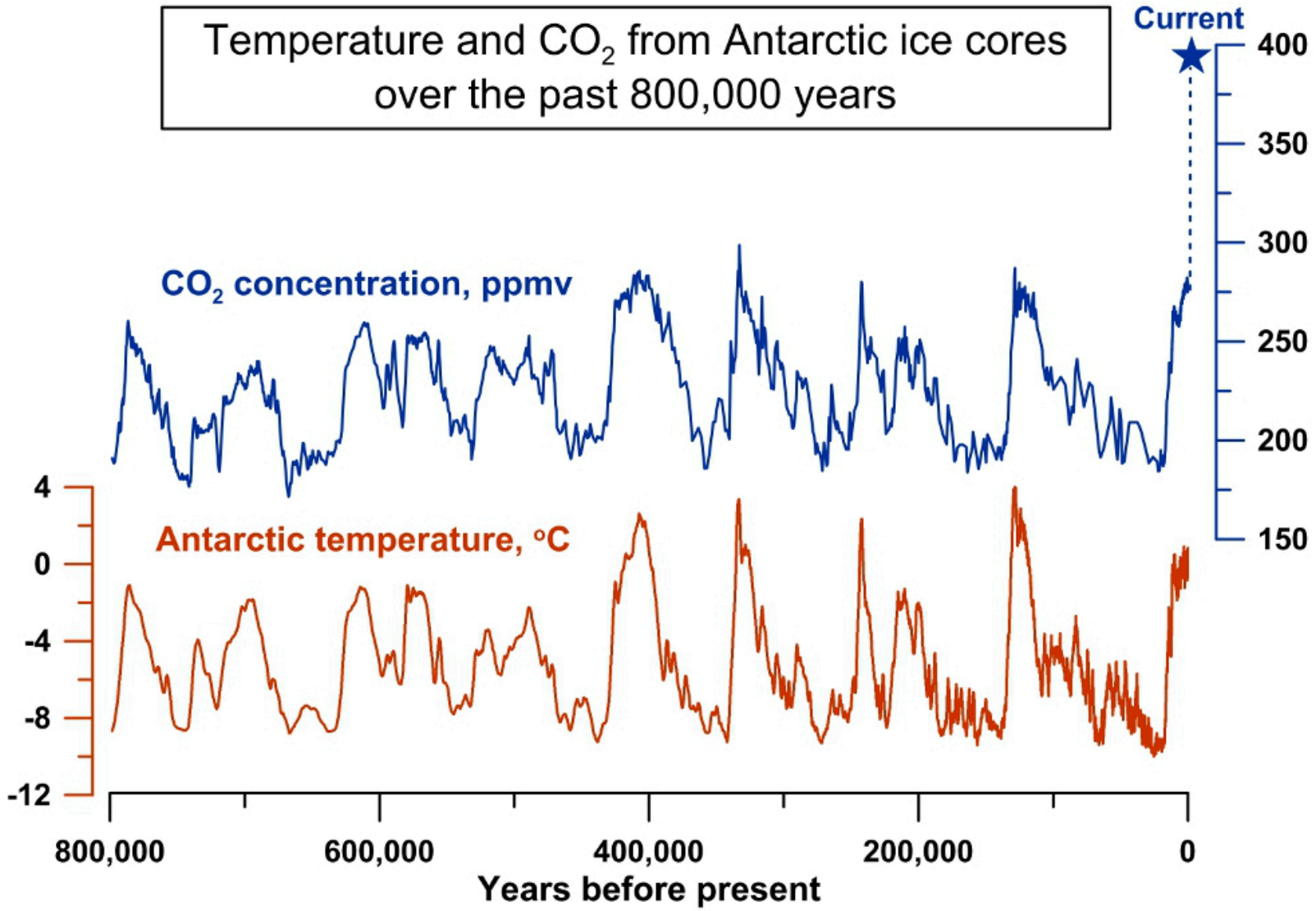

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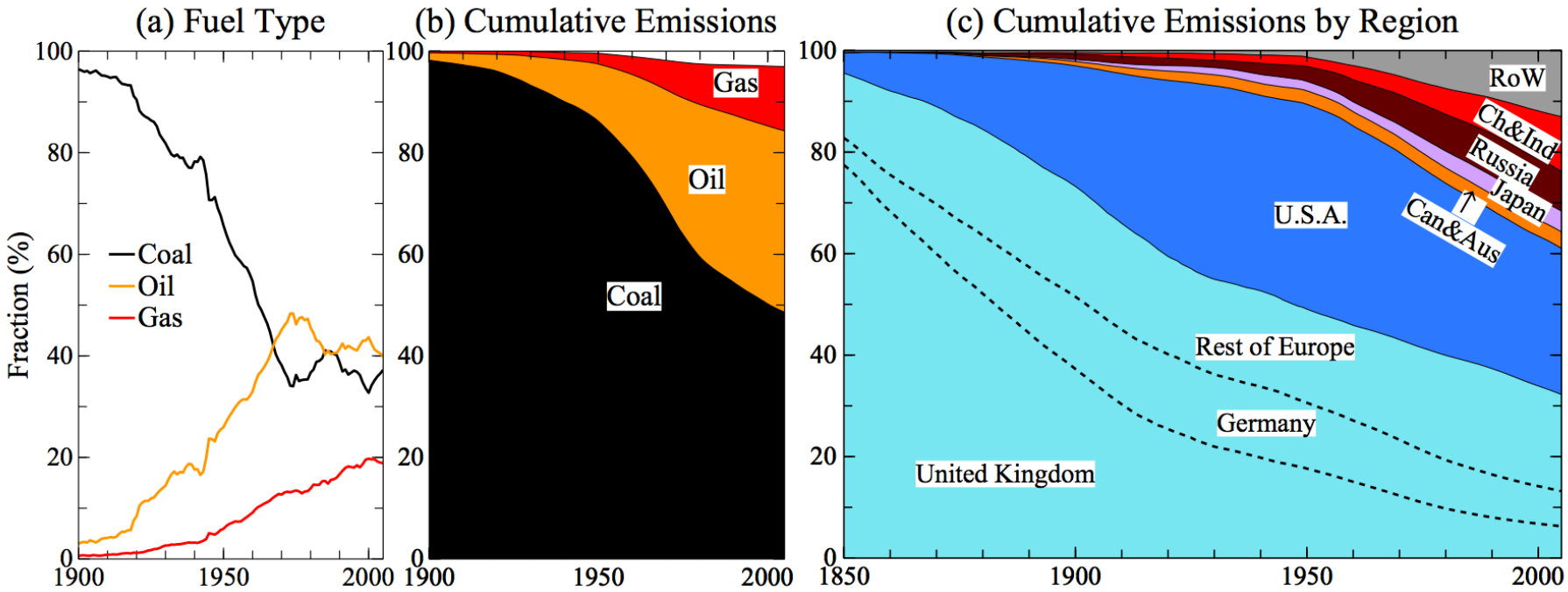
Anthropogenic greenhouse gases (CO_2, CH_4, N_2O…)

CO_2 is mainly produced by the combustion of fossil fuel: coal, gas, oil…

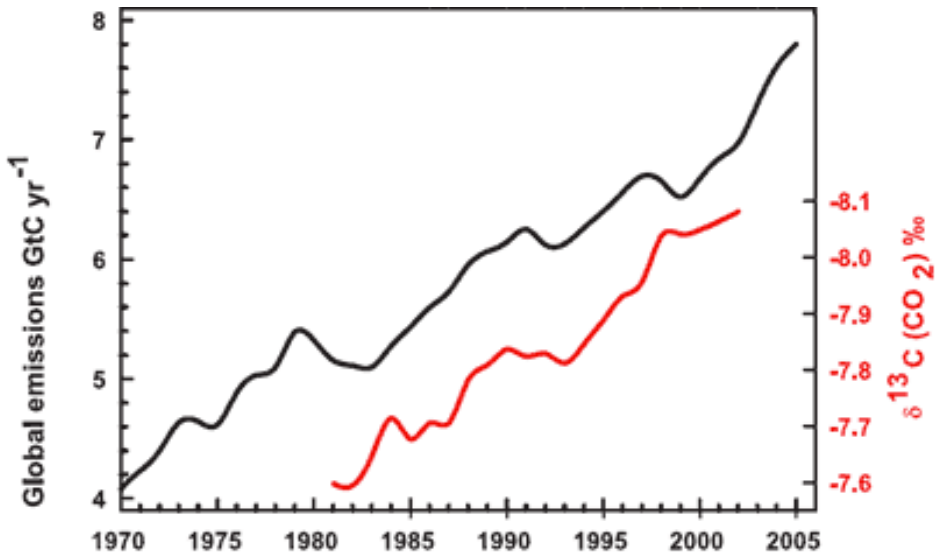


Result: 280ppm → 400ppm CO_2

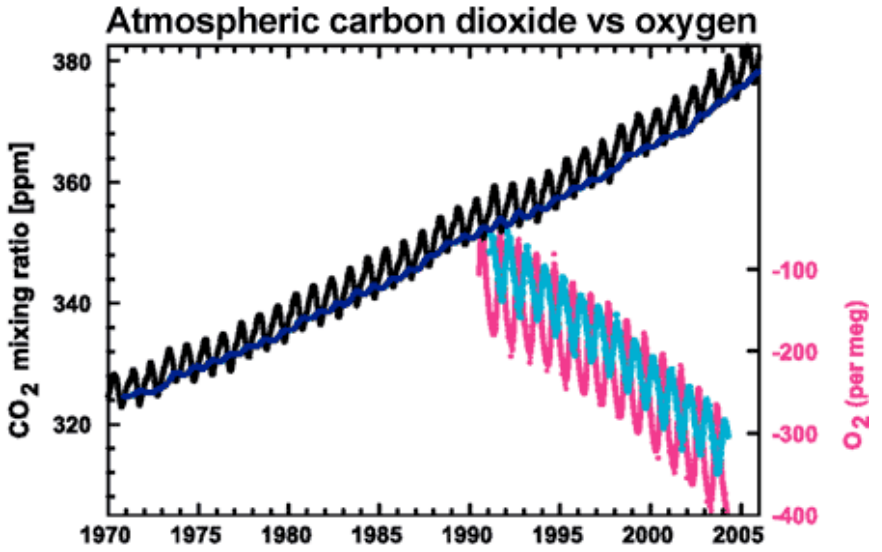
Source: *Hansen et al., 2007*

Confirmation that rising CO2 levels are due to human activity

Changes in the isotopic composition of carbon



Changes in the atmospheric concentration of oxygen



Source: *Ghosh 2003, Manning 2006*

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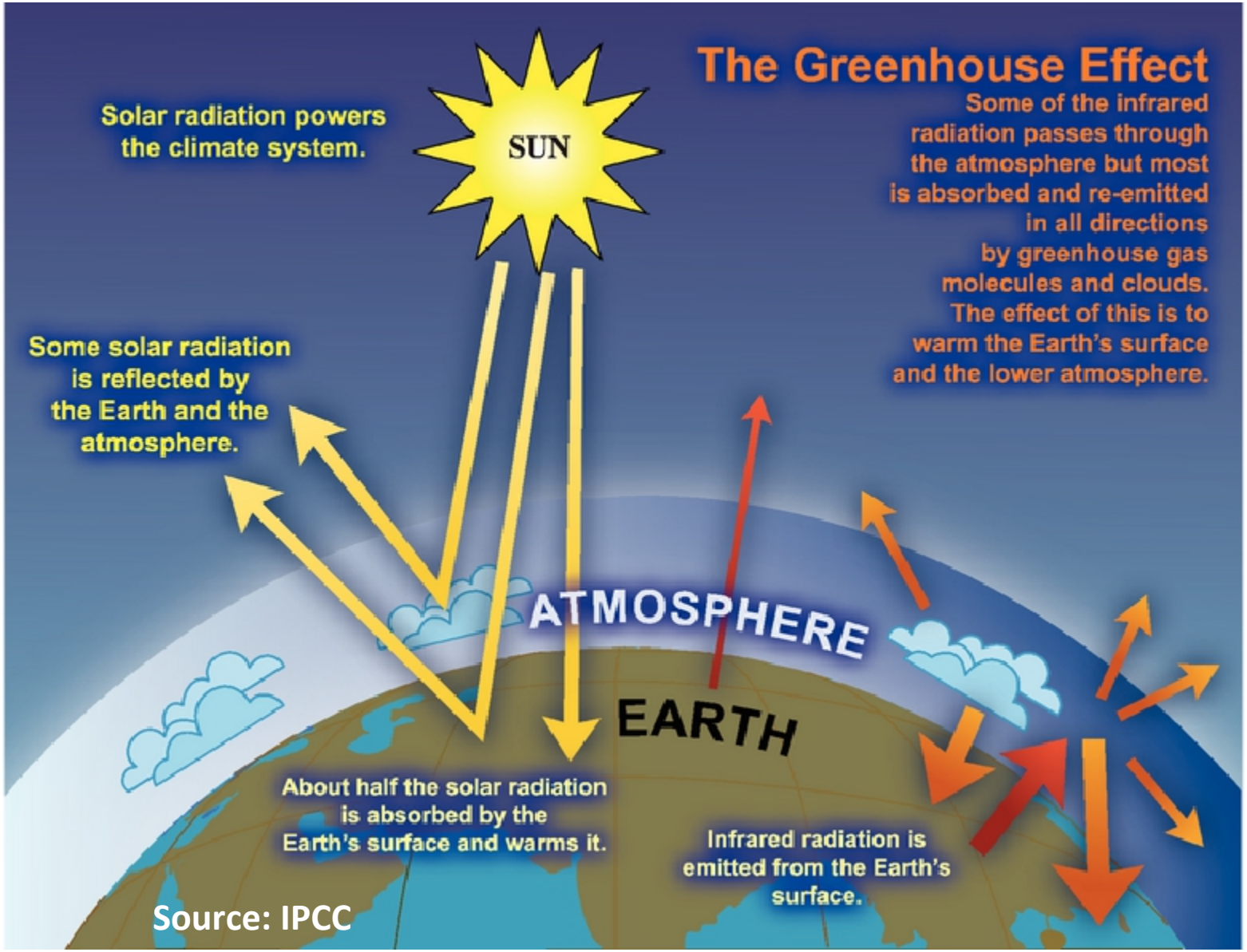
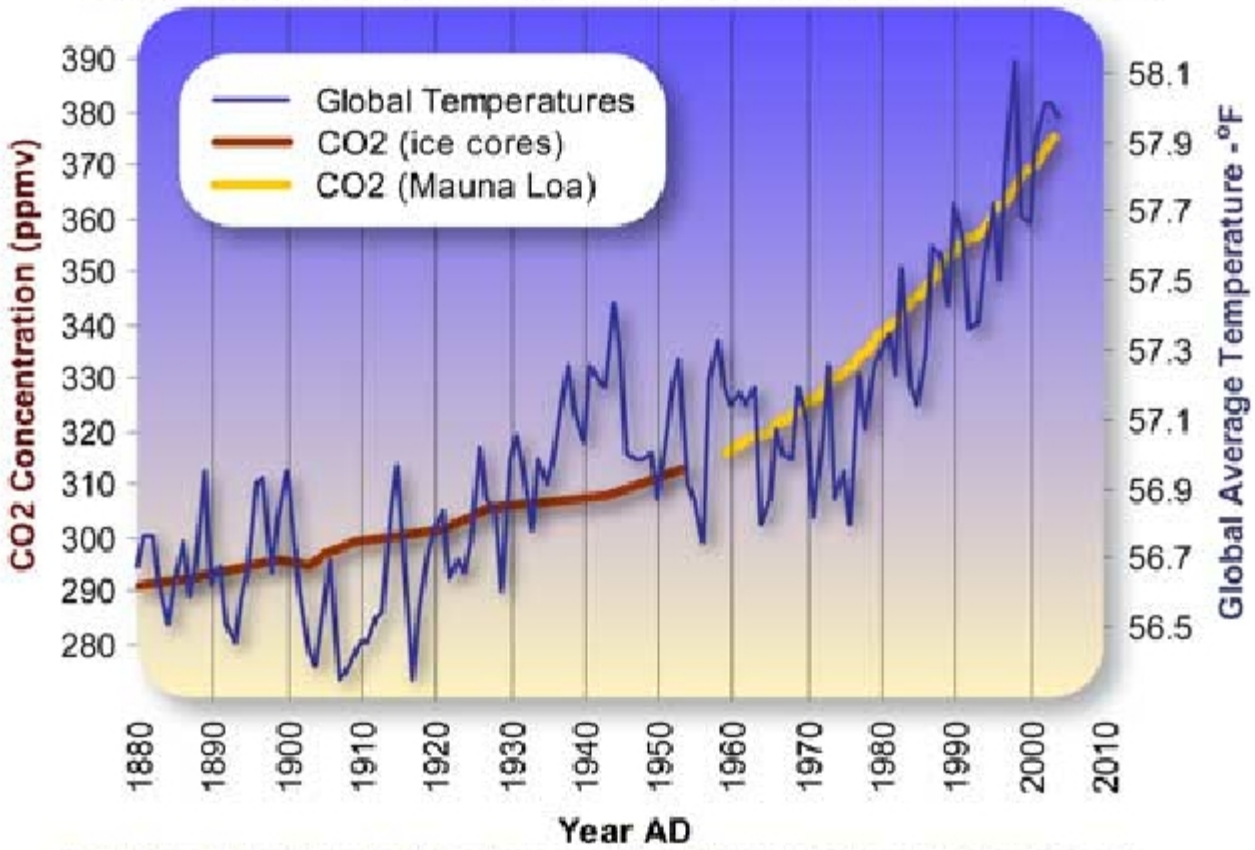

The Greenhouse Effect
Some of the infrared radiation passes through the atmosphere but most is absorbed and re-emitted in all directions by greenhouse gas molecules and clouds. The effect of this is to warm the Earth's surface and the lower atmosphere.
Solar radiation powers the climate system.
SUN
Some solar radiation is reflected by the Earth and the atmosphere.
ATMOSPHERE
EARTH
About half the solar radiation is absorbed by the Earth's surface and warms it.
Infrared radiation is emitted from the Earth's surface.
Source: IPCC

"If the quantity of carbonic acid [CO2] in the air should sink to one-half its present percentage, the temperature would fall by about 4°C. On the other hand, any doubling of the percentage of carbon dioxide in the air would raise the temperature of the earth's surface by 4°C; and if the carbon dioxide were increased fourfold, the temperature would rise by 8°C."

-- Arrhenius, 1908

Global Average Temperature and Carbon Dioxide Concentrations, 1880 - 2004



Data Source Temperature: ftp://ftp.ncdc.noaa.gov/pub/data/anomalies/annual_land_and_ocean.ts
Data Source CO2 (Siple Ice Cores): http://cdiac.esd.ornl.gov/ftp/trends/co2/siple2.013
Data Source CO2 (Mauna Loa): http://cdiac.esd.ornl.gov/ftp/trends/co2/maunaloa.co2

Graphic Design: Michael Ernst, The Woods Hole Research Center

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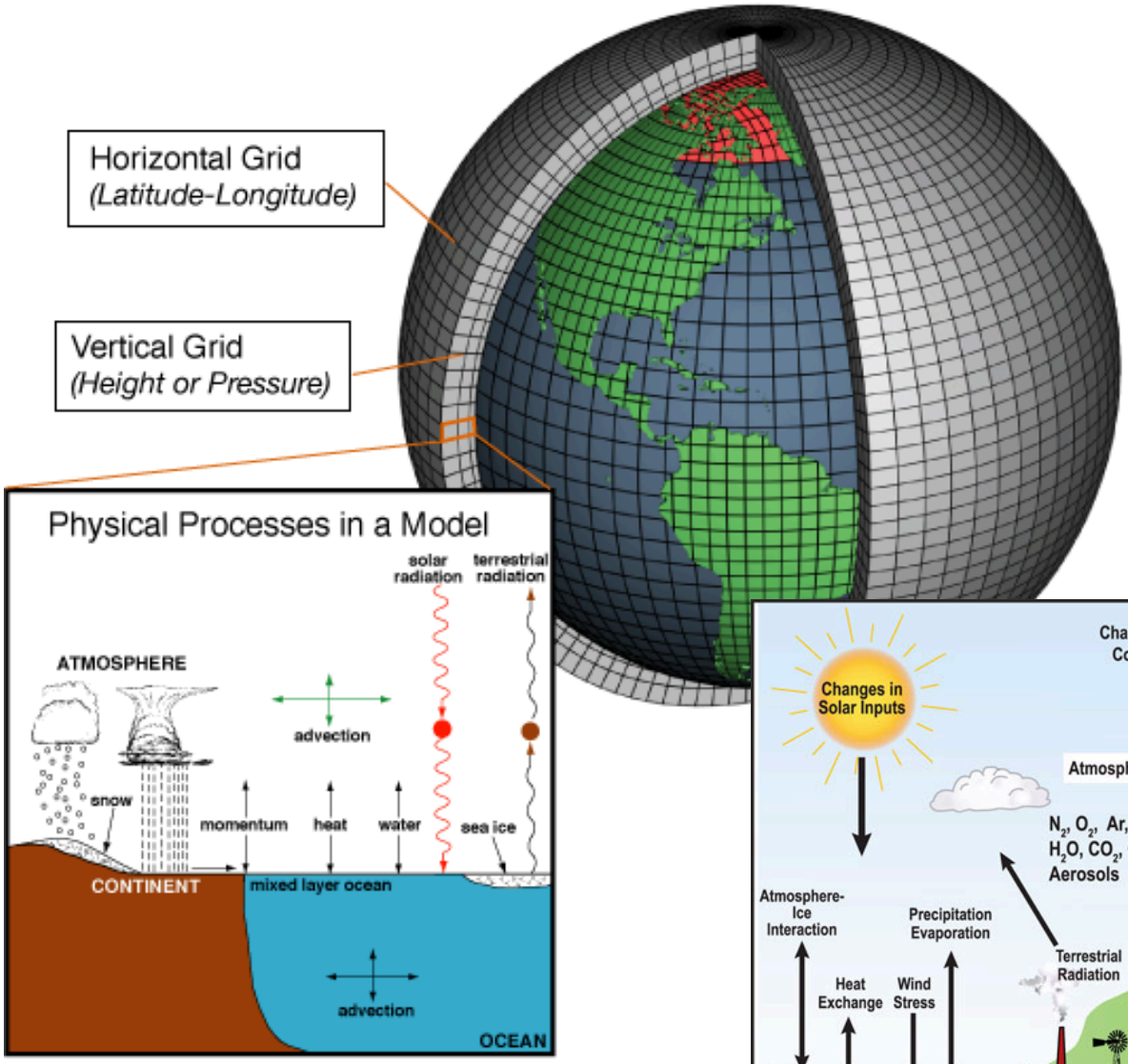
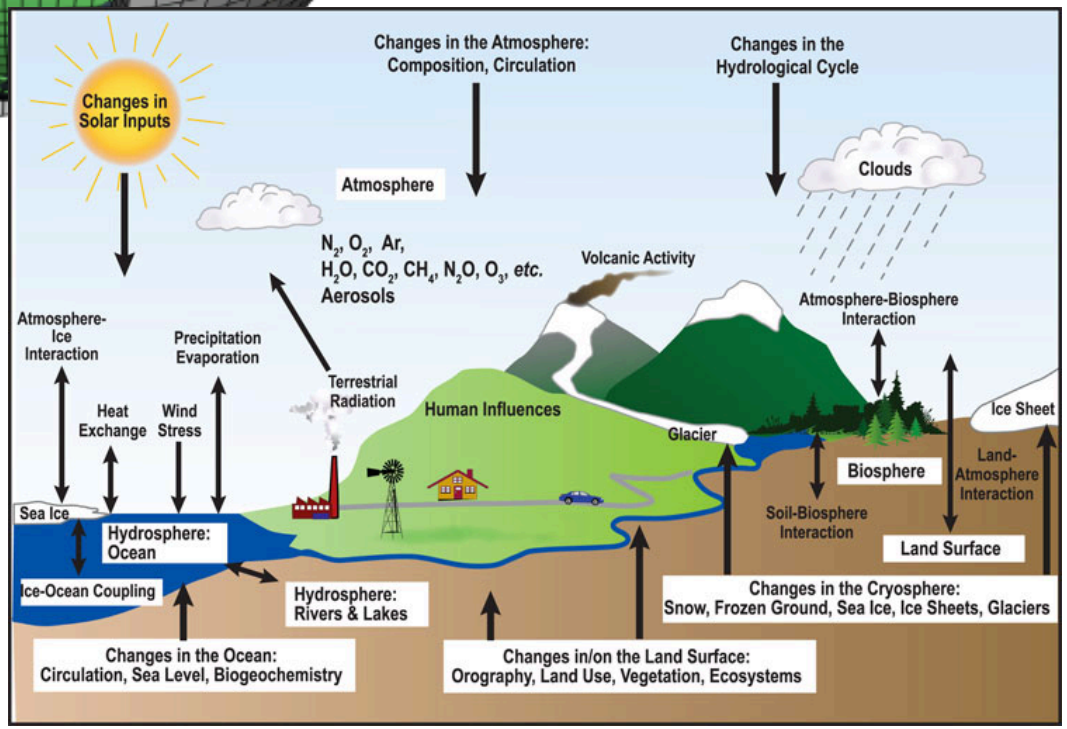
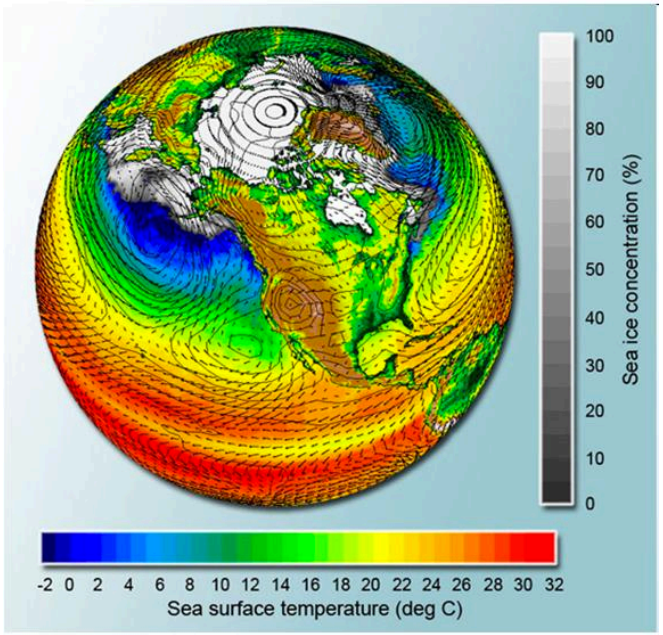
Climate Models

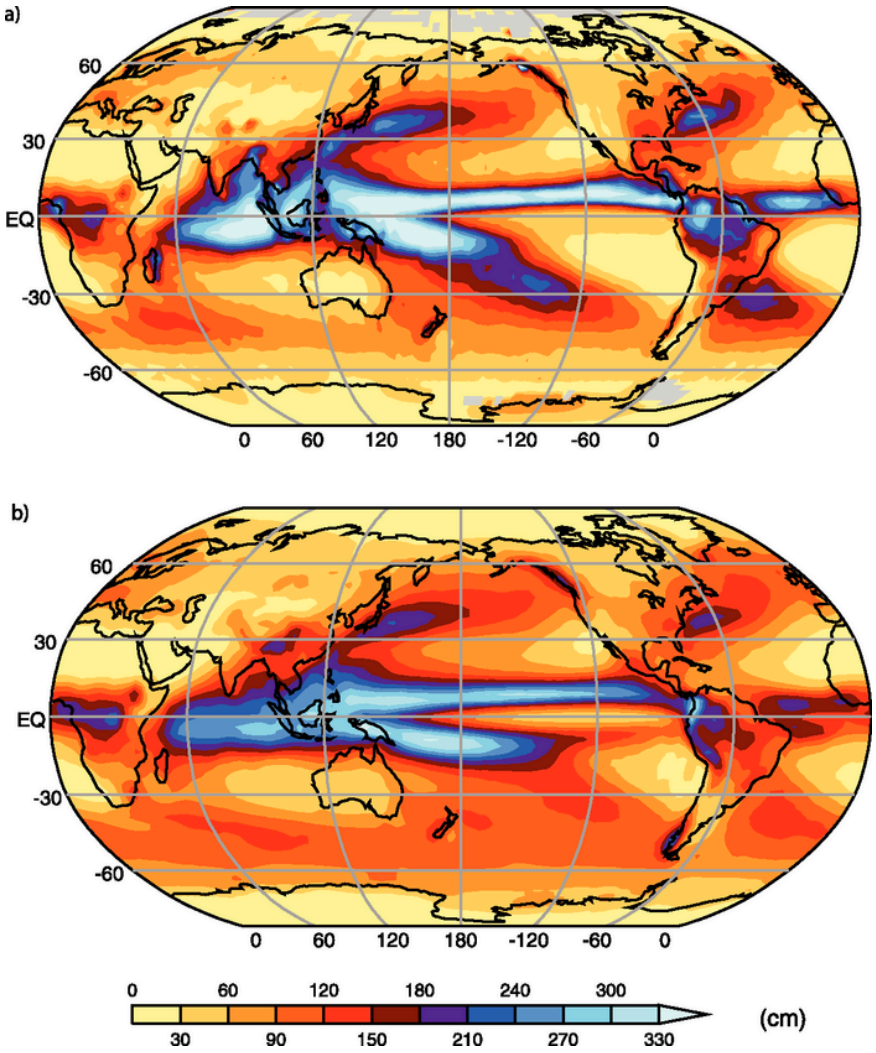




Climate Models



Precipitation Climatology 1980-1999



Obs

Model

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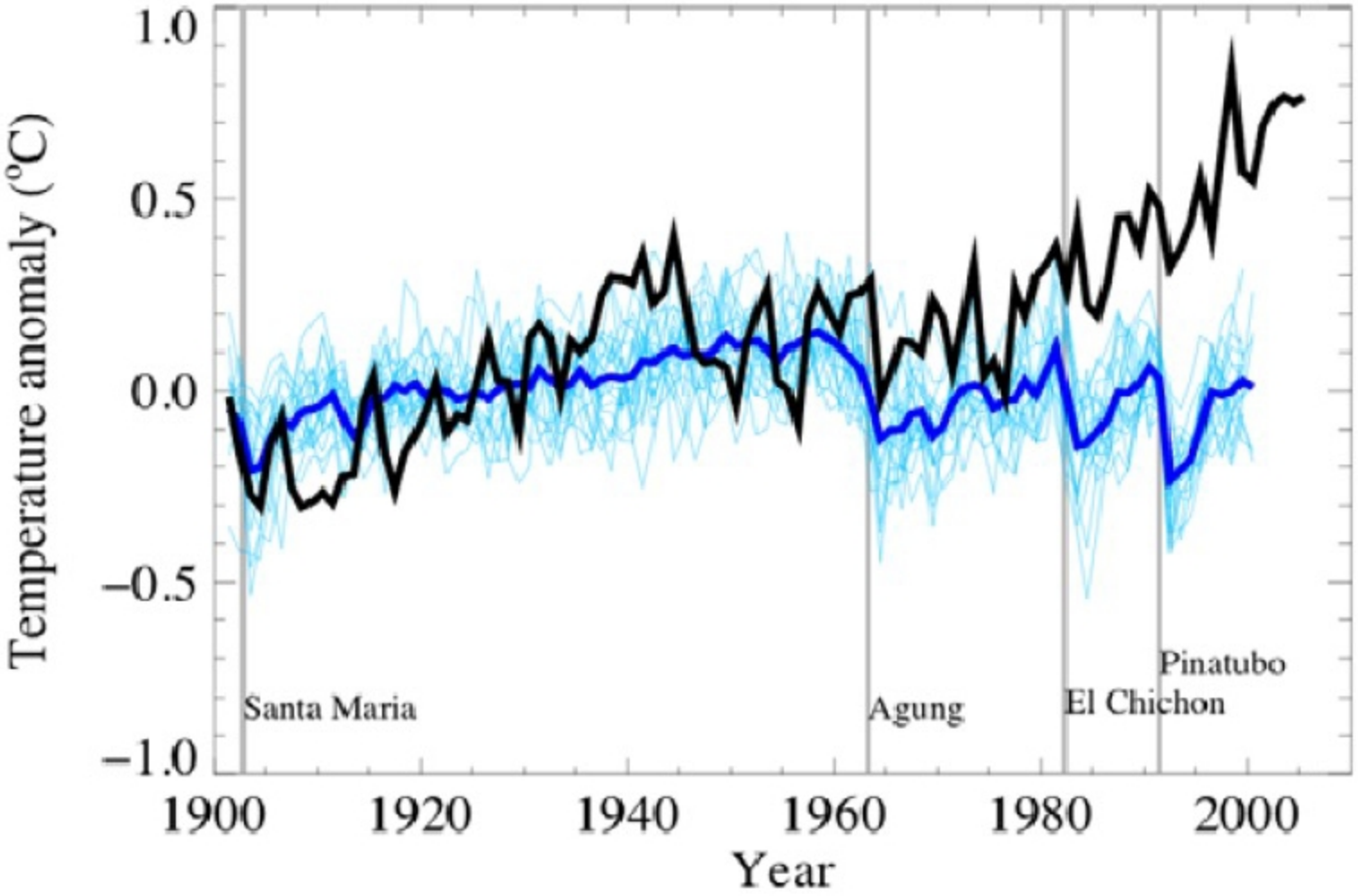
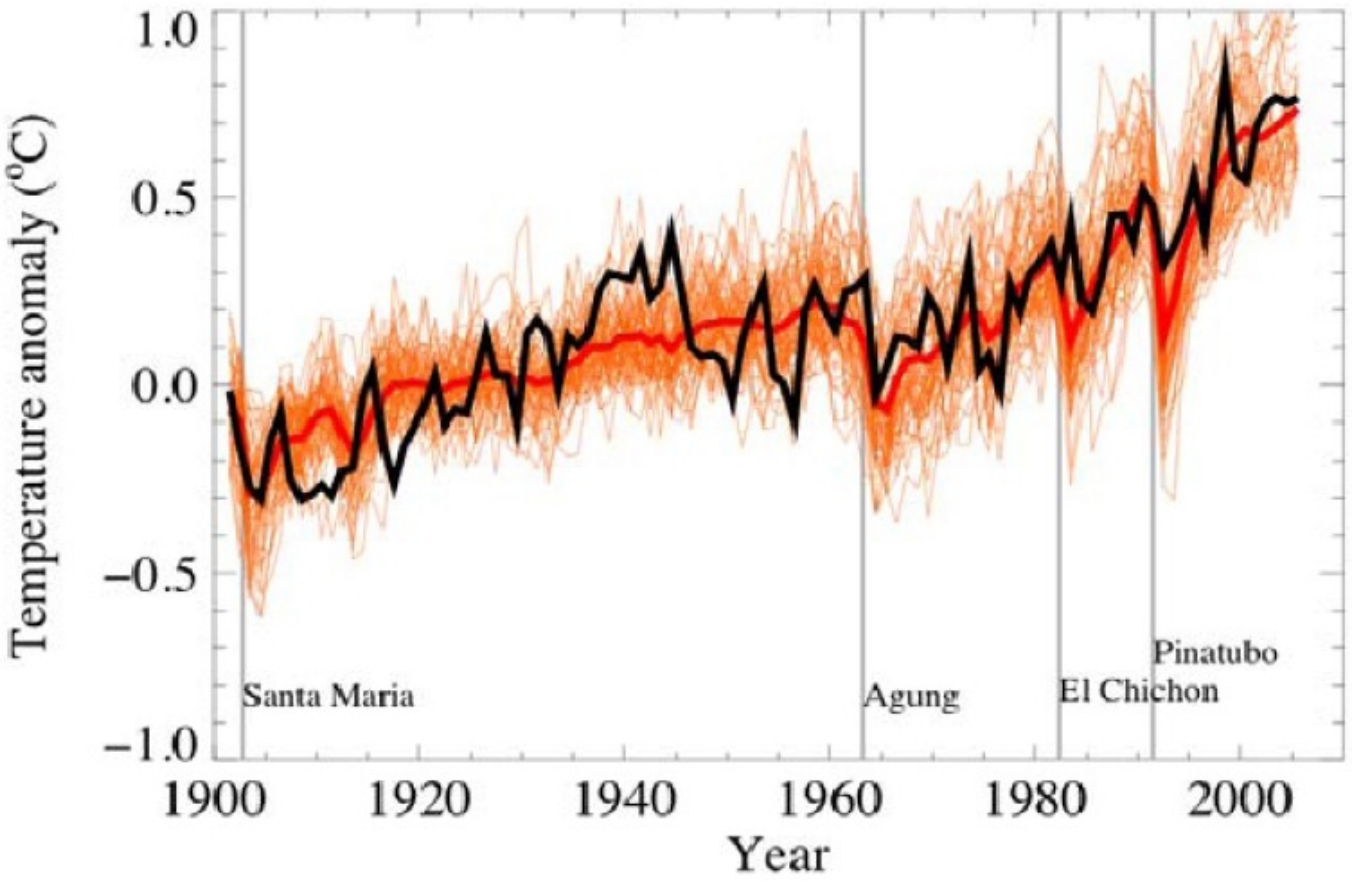
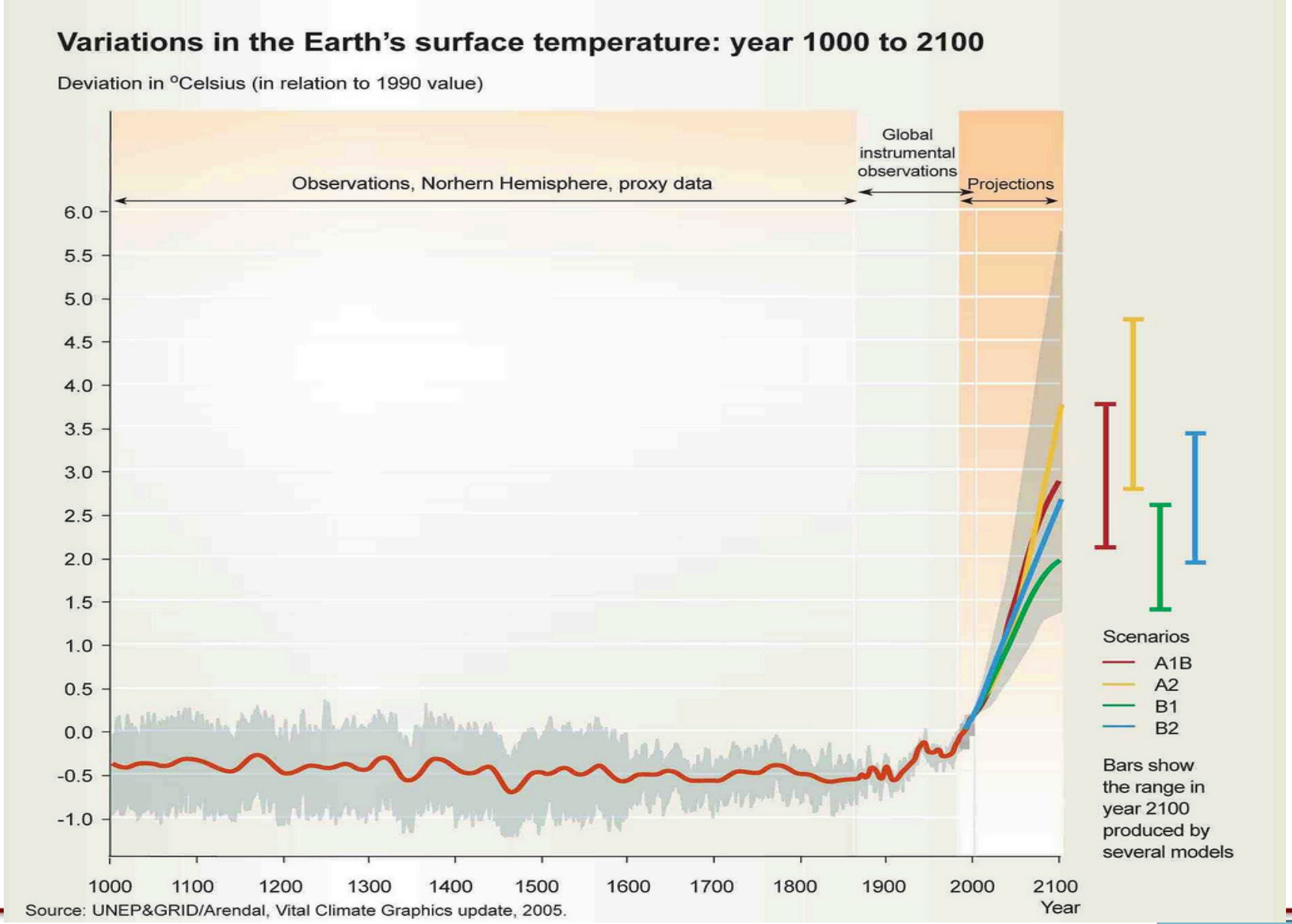
Natural factors only (solar, volcanic)



Natural + Anthropogenic (CO_2, CH_4 etc)





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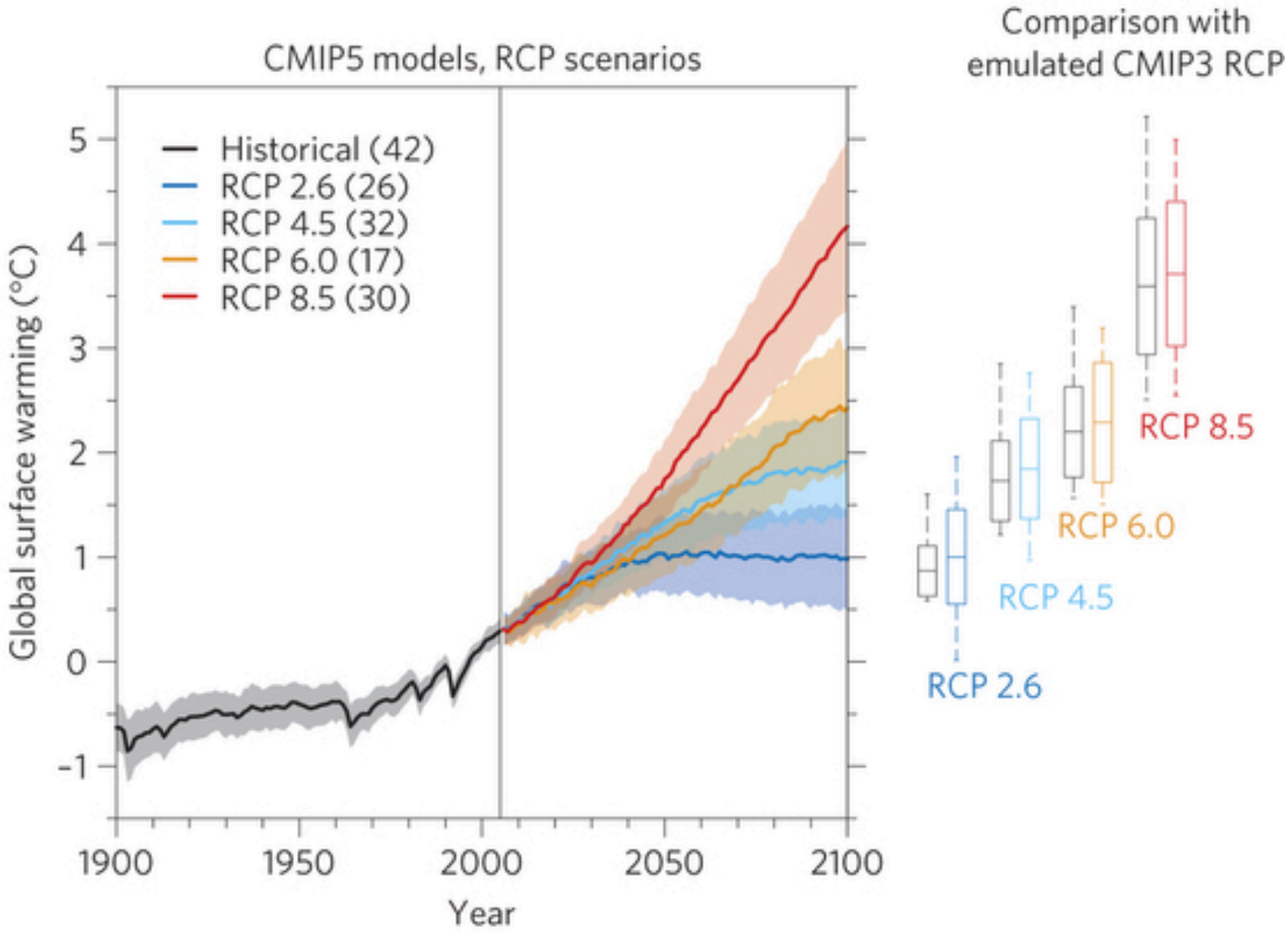
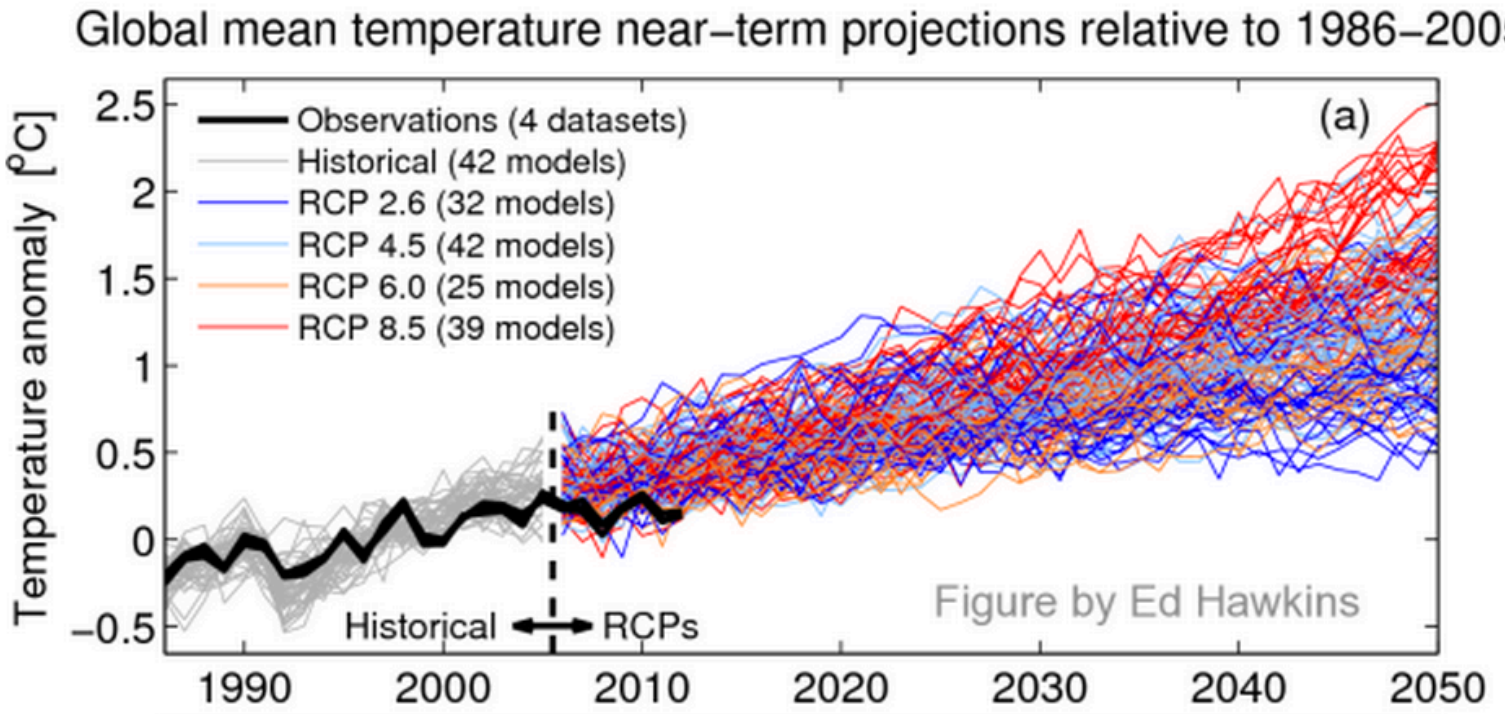
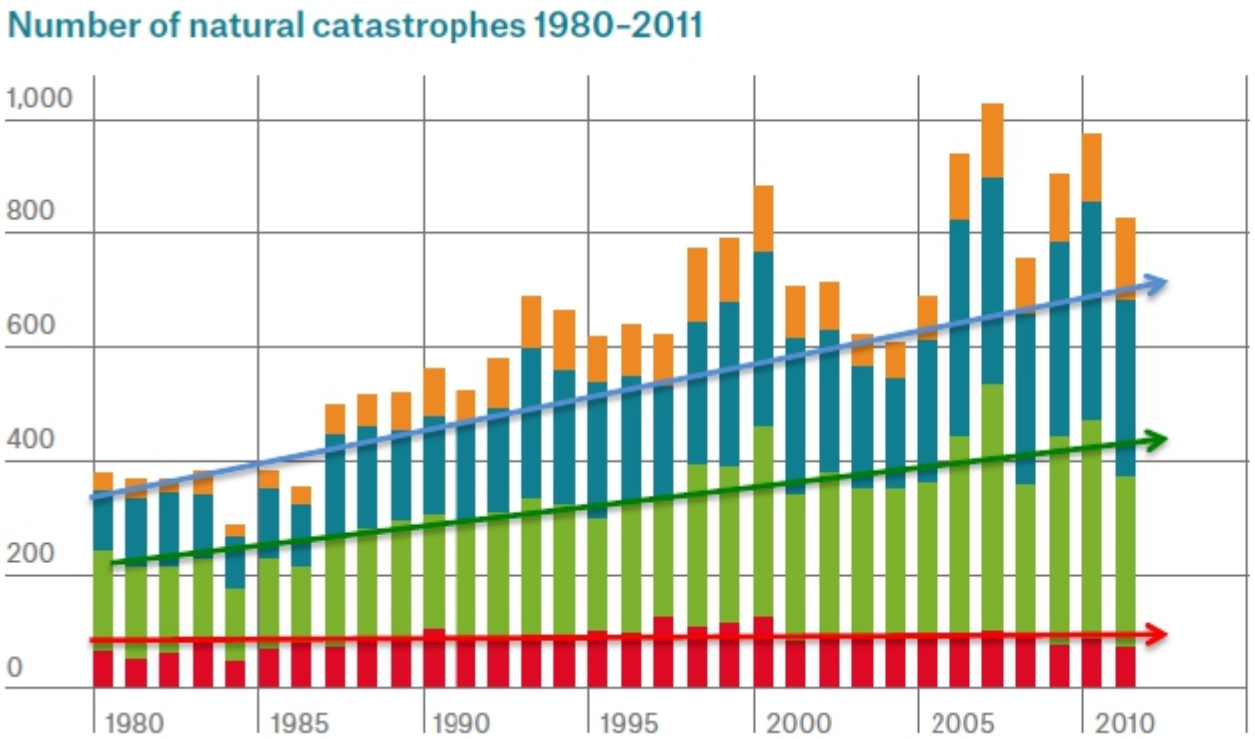

CMIP5 models, RCP scenarios
Historical (42)
RCP 2.6 (26)
RCP 4.5 (32)
RCP 6.0 (17)
RCP 8.5 (30)
Global surface warming (°C)
5
4
3
2
1
0
-1
1900
1950
2000
2050
2100
Year
Comparison with emulated CMIP3 RCP
RCP 8.5
RCP 6.0
RCP 4.5
RCP 2.6

Planning Horizons and Uncertainty





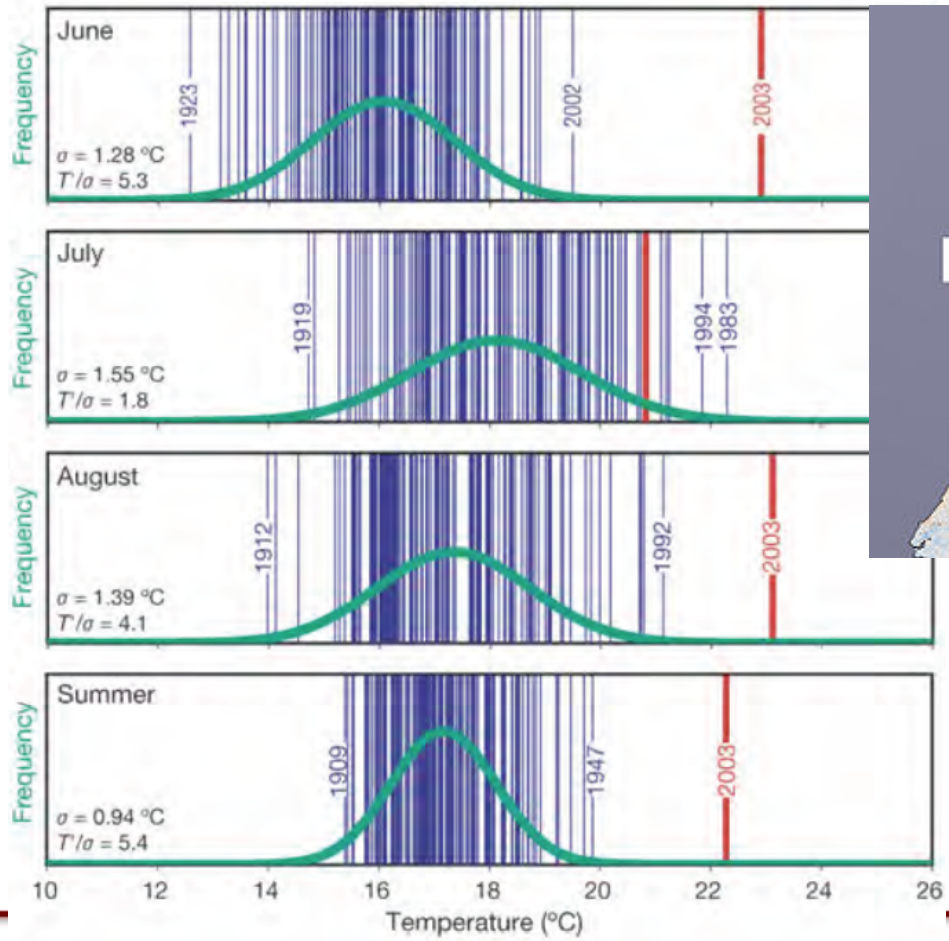
~90% of 2011's events were weather-related. Overall and insured losses from weather-related natural catastrophes were the second-highest on record since 1980 (taking inflation into account). Insured losses from meteorological, hydrological and Climatological causes in 2011 were $201B…"

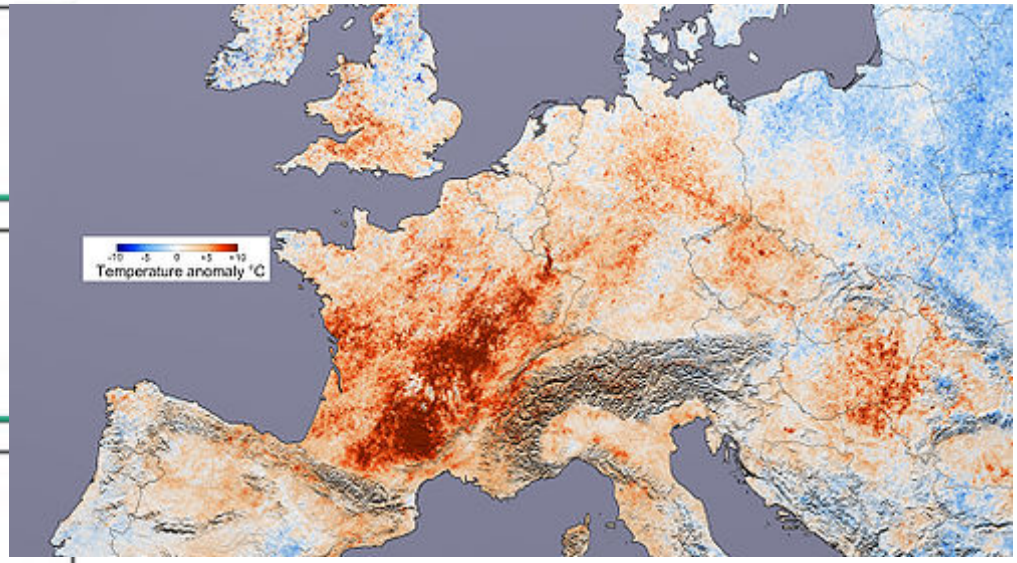
P. Höppe, Head of GeoRisks Research, MunichRe

The European Heat Wave of 2003

Hottest summer on record in Europe since at least 1540

Distribution of Swiss monthly and seasonal summer temperatures for 1864 – 2003.





"Economic costs exceeding **€13 billion** with a death toll of over **30,000** across Europe (UNEP, 2004)"

Source: *Schär et al., 2004*

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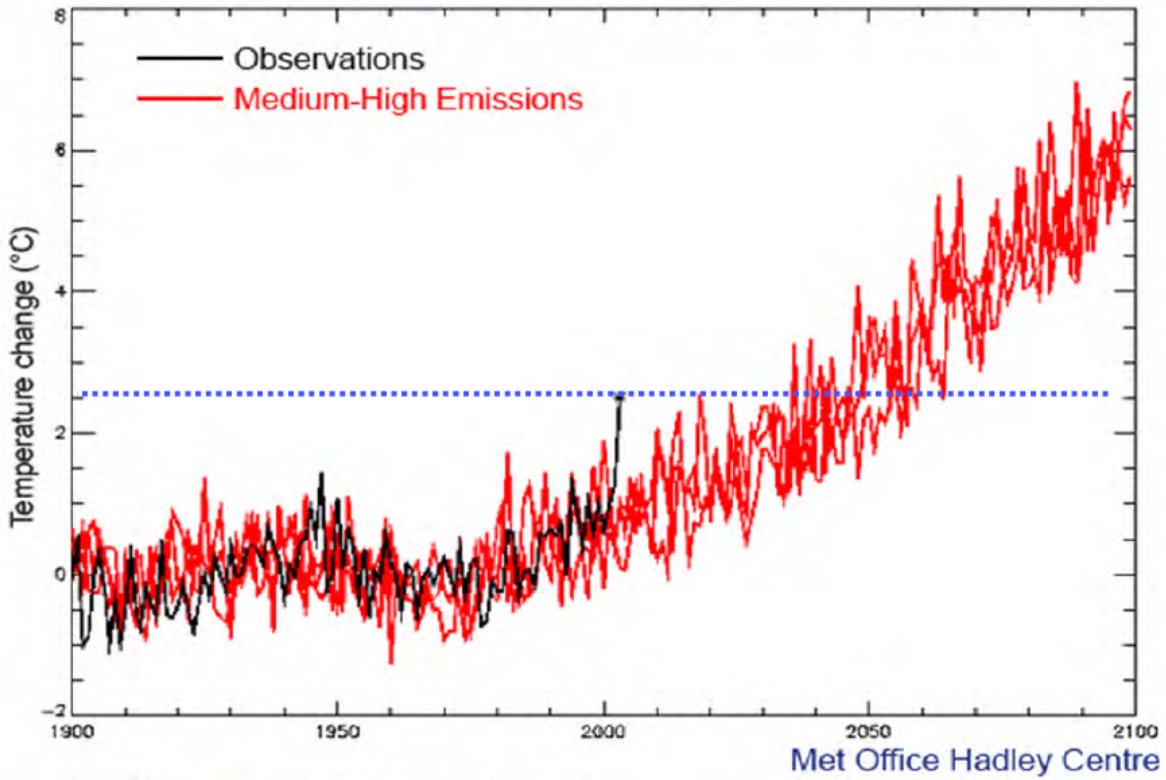
The European Heat Wave of 2003

Hottest summer on record in Europe since at least 1540

An event such as 2003 is expected to occur only once in 1000 years.
But by 2040, this will be an average year and by 2060 it will be a cold summer.



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Source: *Schär et al., 2004*

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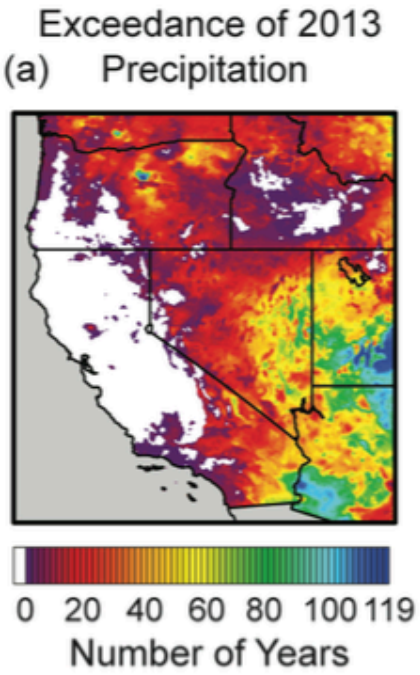
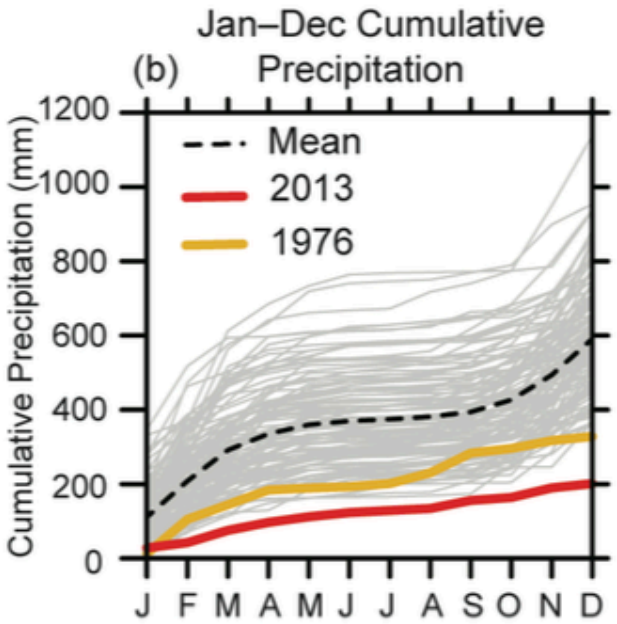
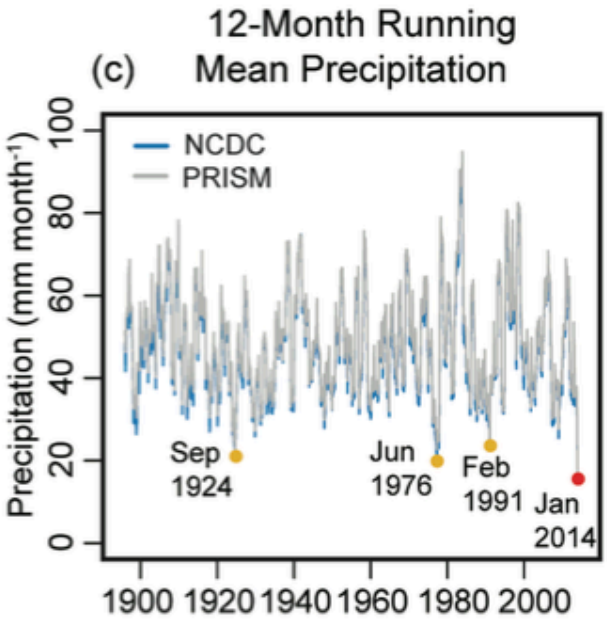
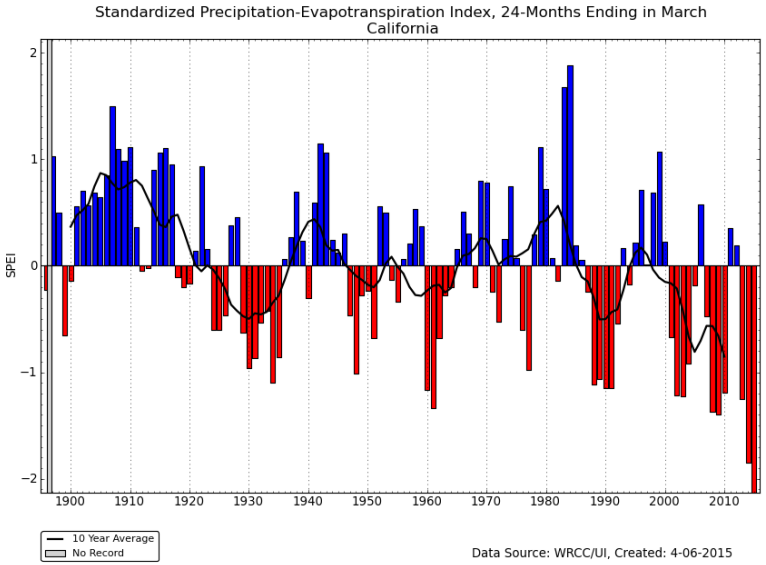
California Drought









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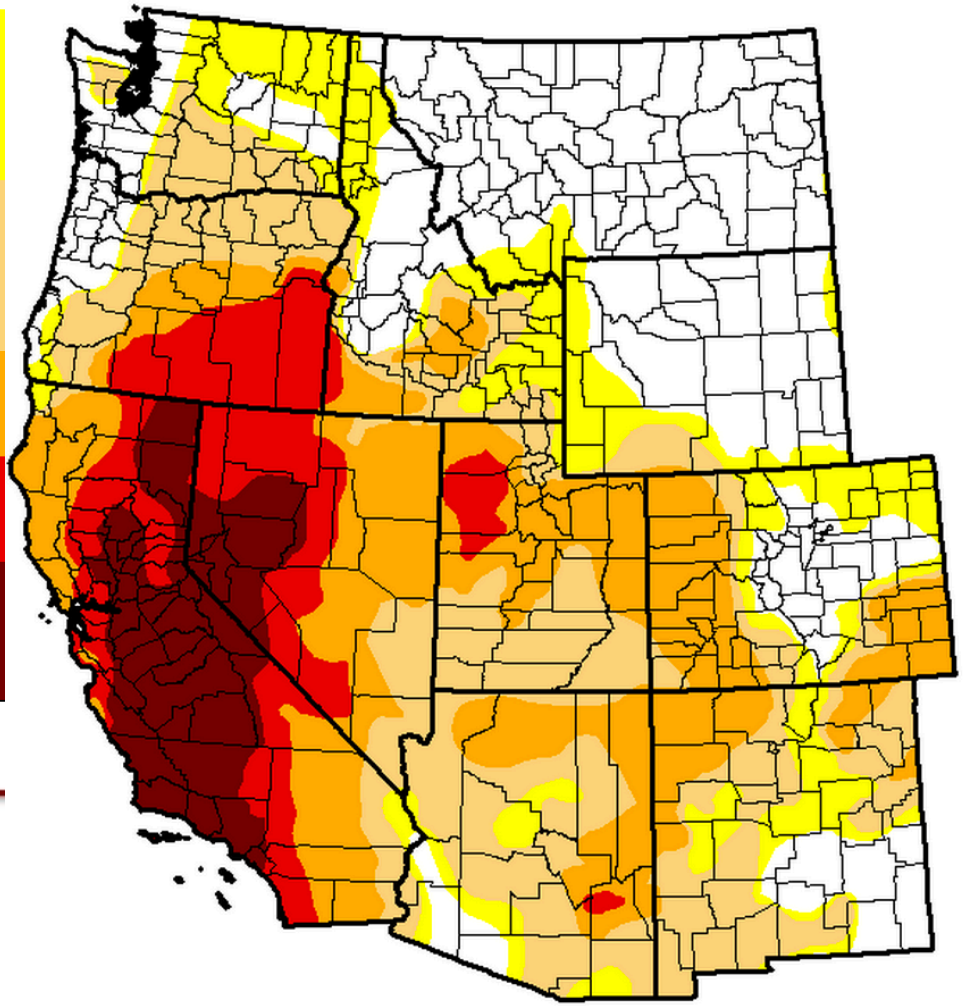
Droughts

Drought Severity Classification

Category	Description	Possible Impacts	Ranges: Palmer Drought Index	Ranges: CPC Soil Moisture Model (Percentiles)	Ranges: USGS Weekly Streamflow (Percentiles)	Ranges: Standardized Precipitation Index (SPI)	Ranges: Objective Short and Long-term Drought Indicator Blends (Percentiles)
D0	Abnormally Dry	Going into drought: short-term dryness slowing planting, growth of crops or pastures. Coming out of drought: some lingering water deficits; pastures or crops not fully recovered					
D1	Moderate Drought	Some damage to crops, pastures; streams, reservoirs, or wells low, some water shortages developing or imminent; voluntary water-use restrictions requested					
D2	Severe Drought	Crop or pasture losses likely; water shortages common; water restrictions imposed					
D3	Extreme Drought	Major crop/pasture losses; widespread water shortages or restrictions					
D4	Exceptional Drought	Exceptional and widespread crop/pasture losses; shortages of water in reservoirs, streams, and wells creating water emergencies					



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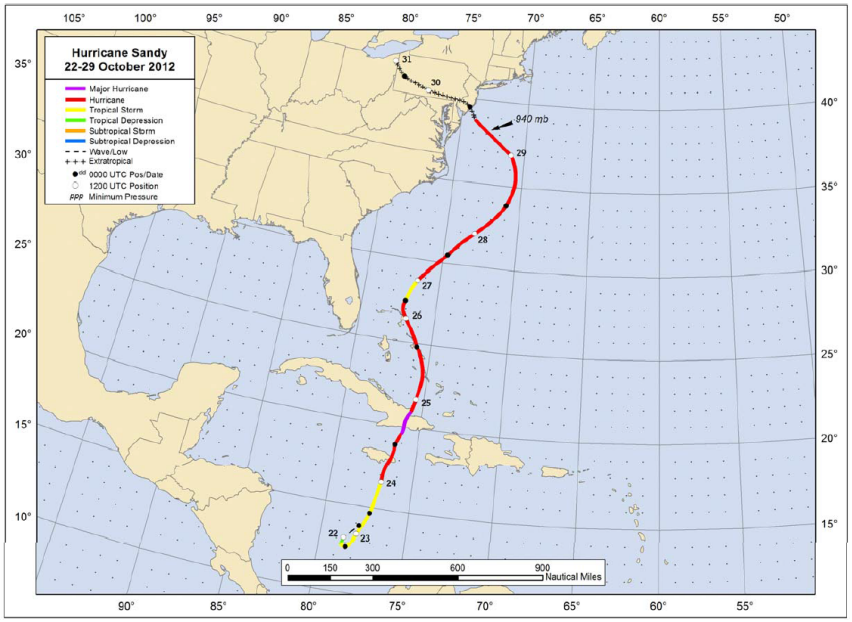
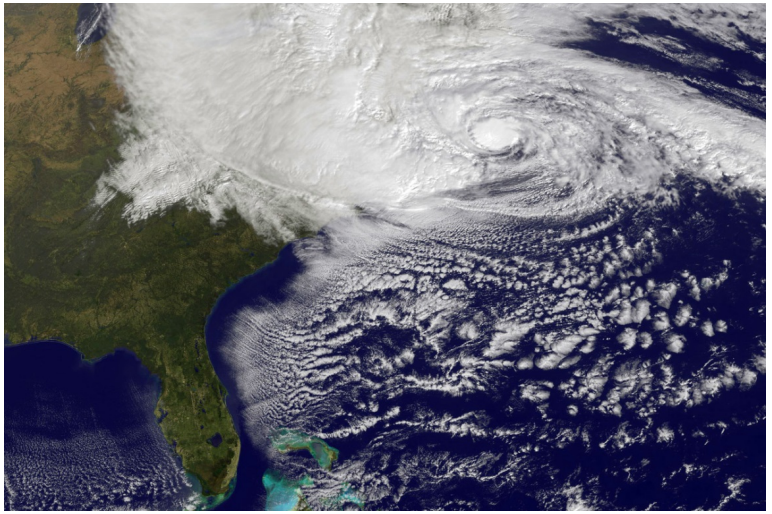
Hurricane Sandy

A billion-dollar event. Was it caused by climate change?

- a classic late-season hurricane
- 147 direct deaths
- $75 billion damage; second-costliest cyclone in US
- 2 business days close in the New York Stock Exchange





"Many uncertainties remain about the effects of climate change on hurricanes"

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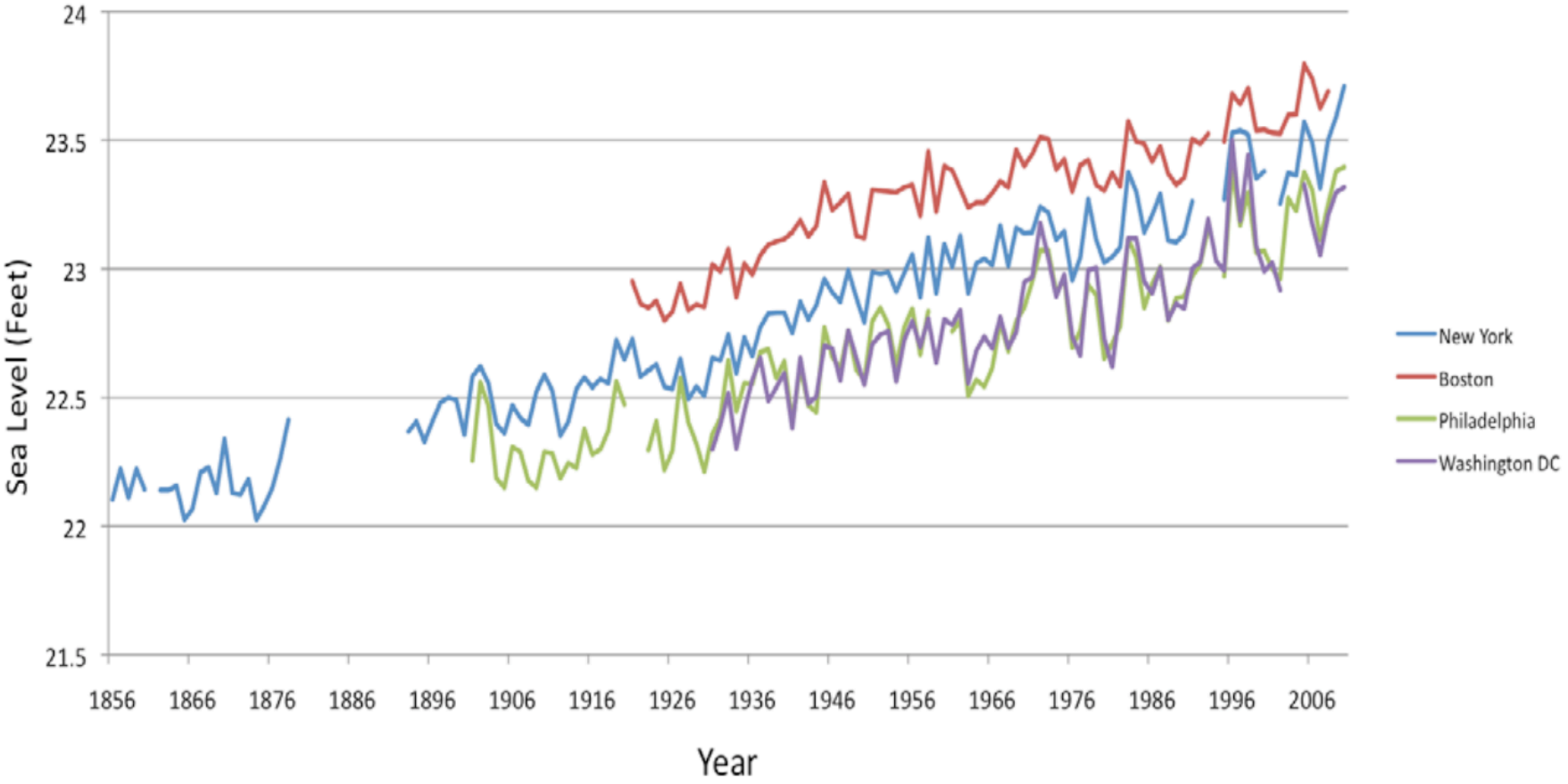
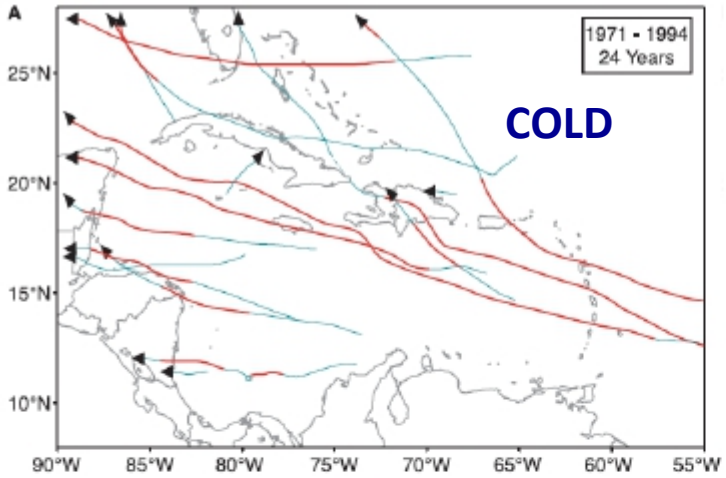
Hurricane Sandy

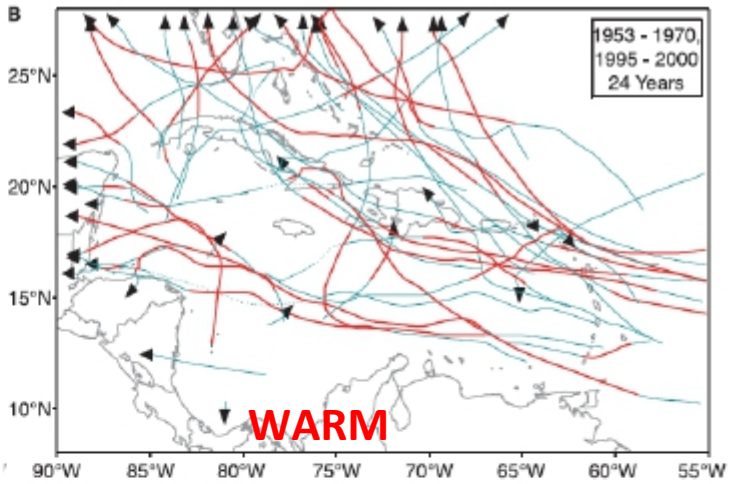
A billion-dollar event. Was it caused by climate change?

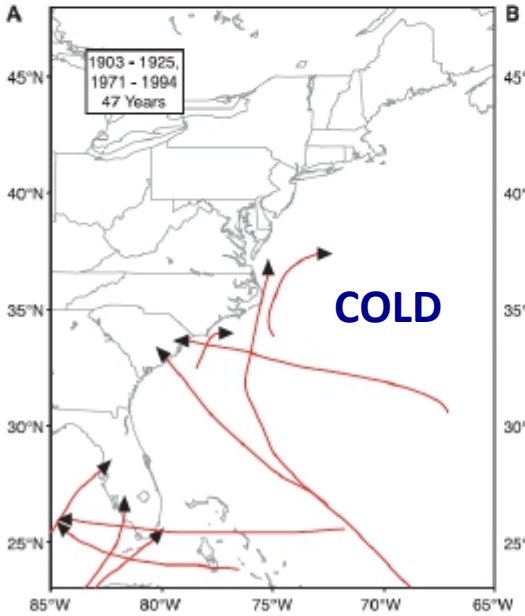


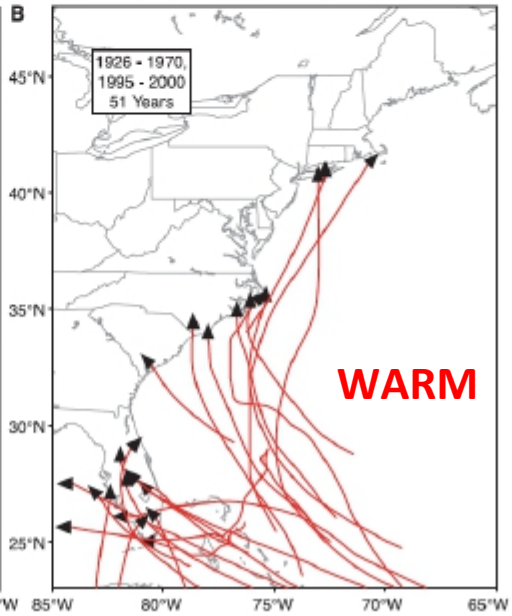
Kunkel et al., 2013 (PSMSL 2012)

Cold vs warm SSTs in the Main Development Region









Goldenberg et al. 2001

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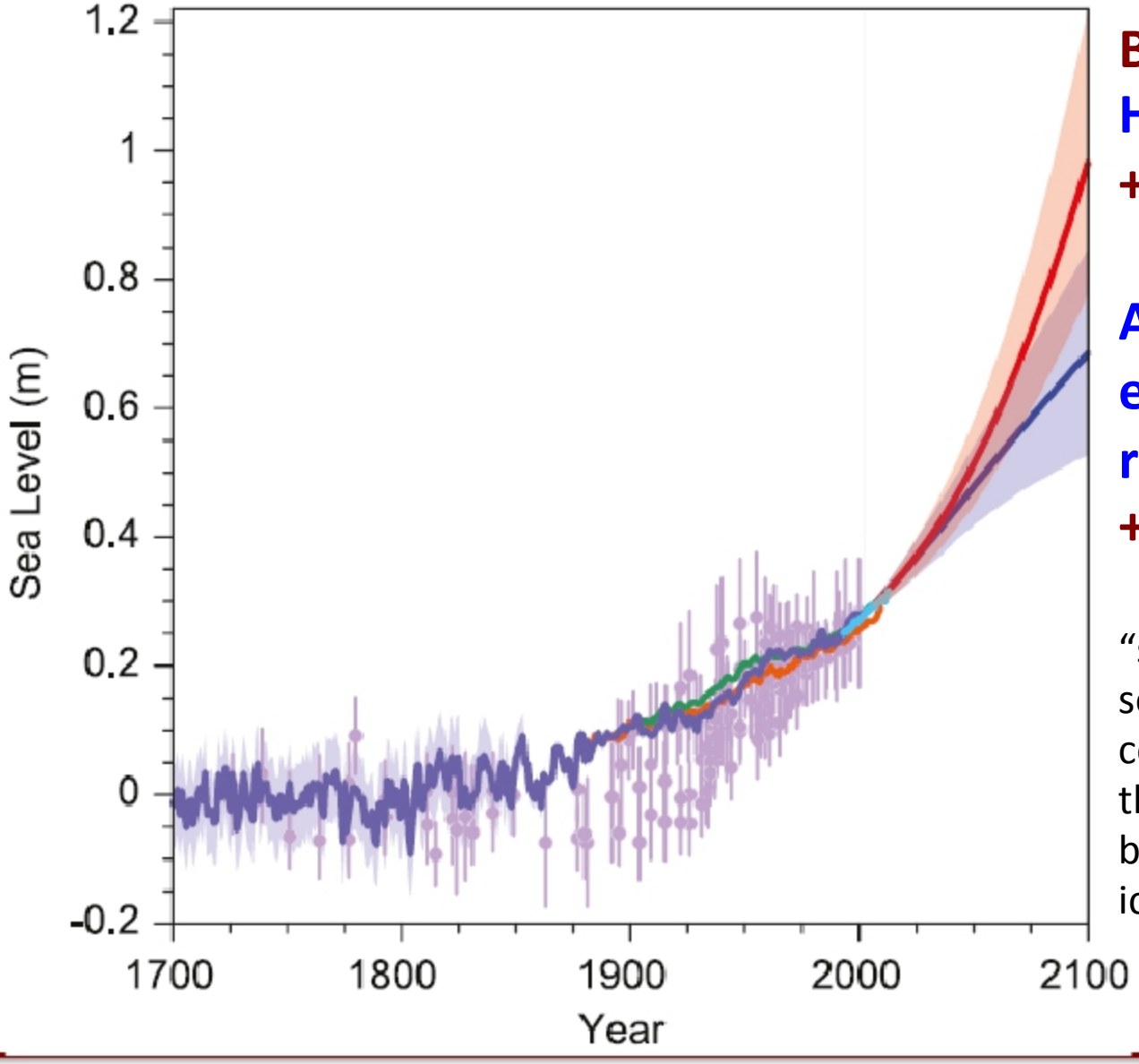


By 2100…

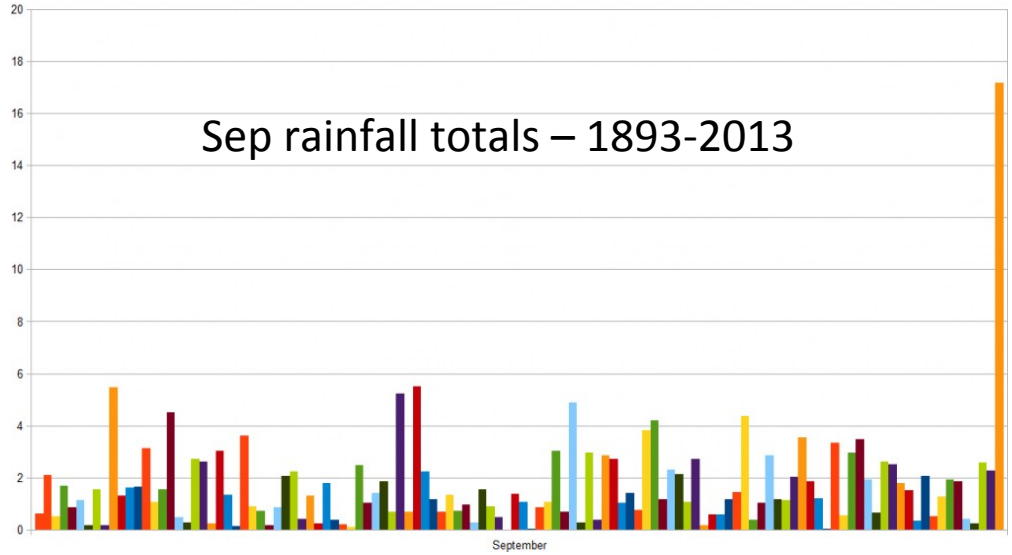
High emissions: +52-98cm

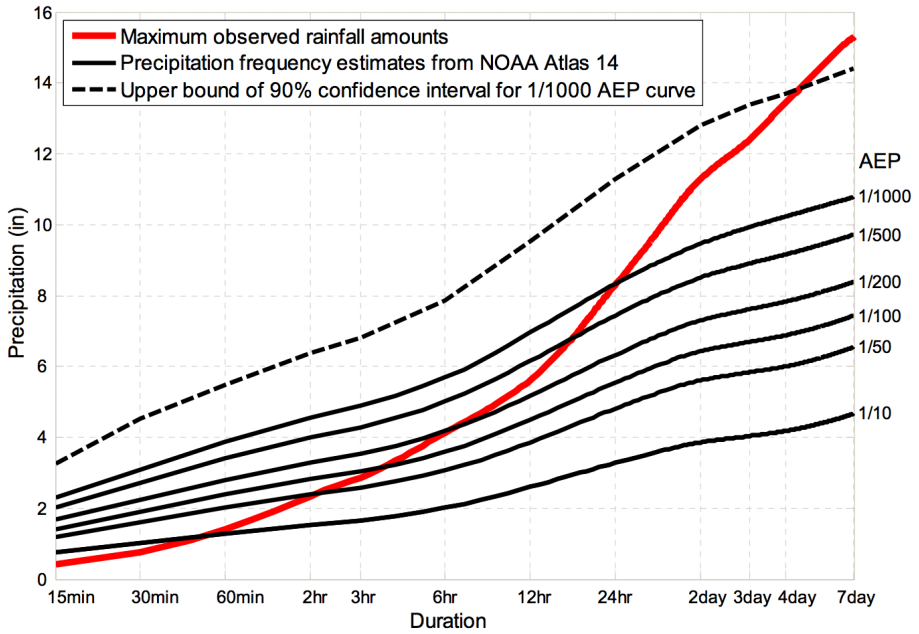
Aggressive emissions reductions: +28-61cm

"several tenths of a meter of sea level rise during the 21st century" could be added to this if a collapse of marine-based sectors of the Antarctic ice sheet occurs.

Source: *IPCC 2013*

Colorado Floods 2013





8 days,
1000-year rain,
100-year flood

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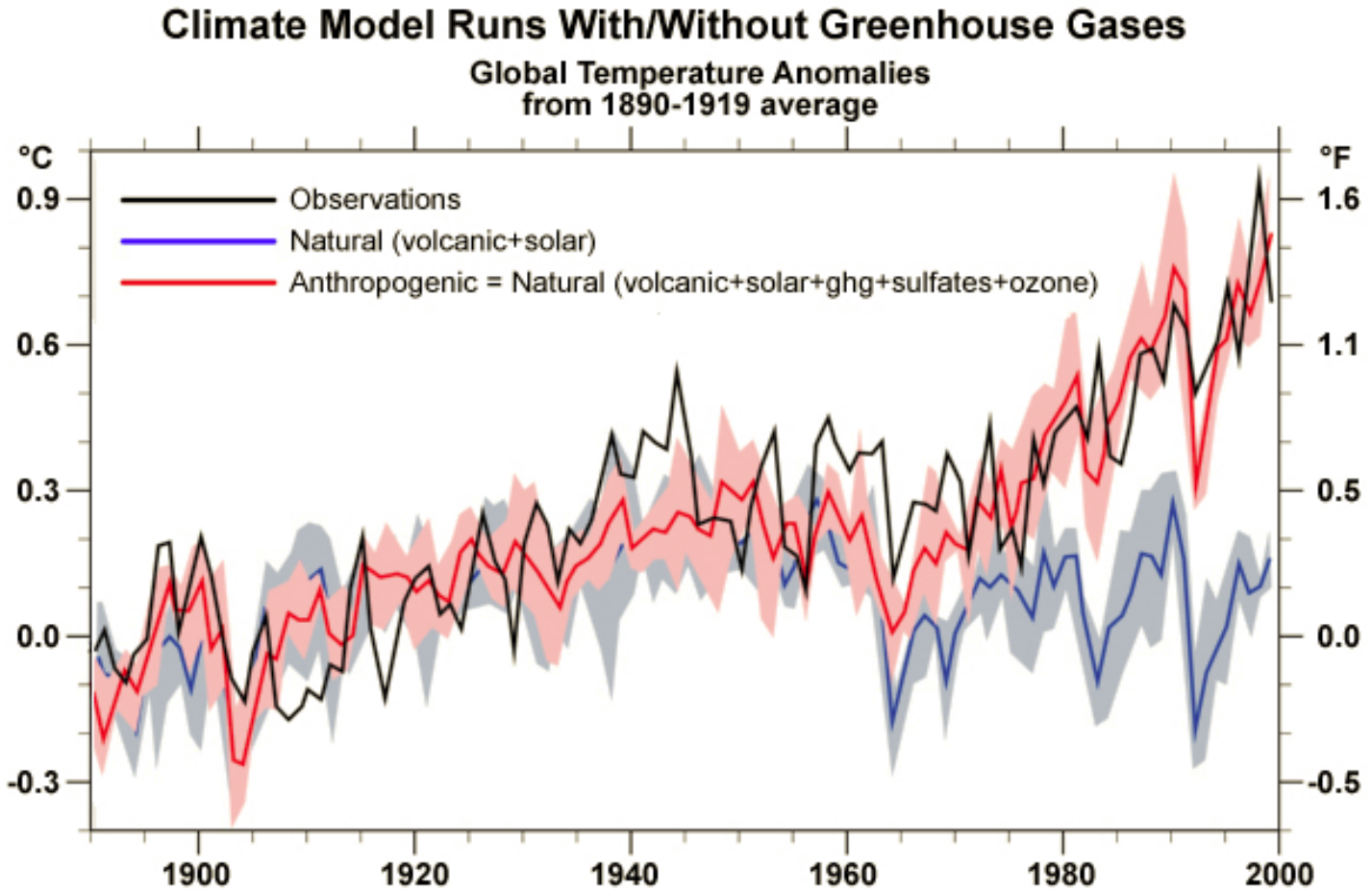
Extreme Event Attribution



the world we live in

the world that might have been

Meehl, G.A. and co-authors 2004: Combinations of Natural and Anthropogenic Forcings and 20th Century Climate. J. Climate, 17, 3721-3727 / NCU

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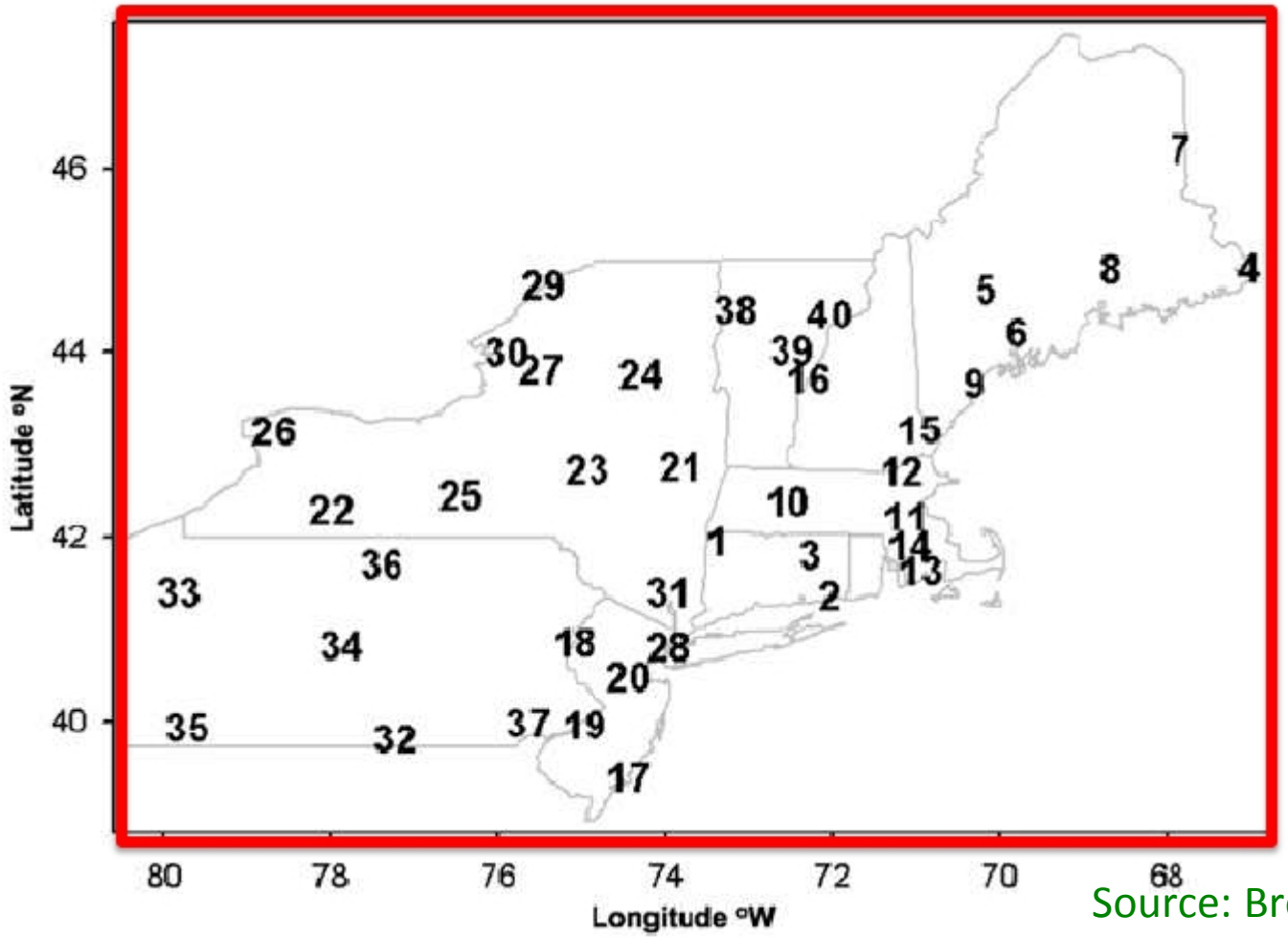
Distribution of long-term instrumental data sets in the NE U.S.



Source: Brown et al., 2010

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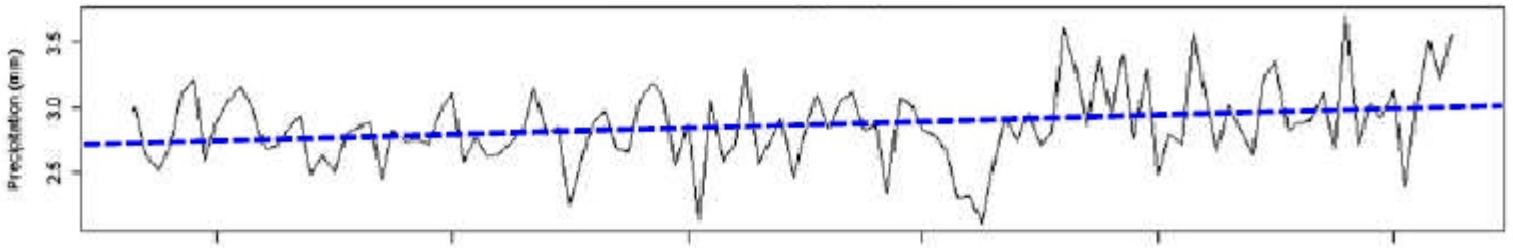
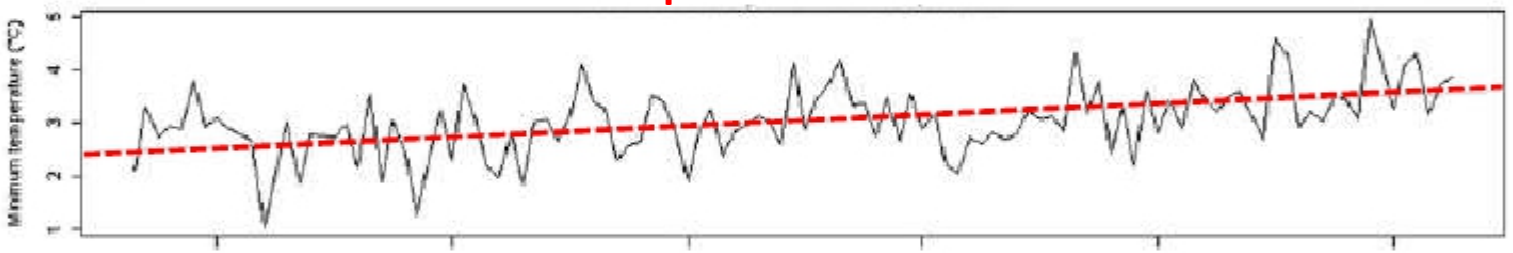
Annual precipitation: 1890-2005

5”

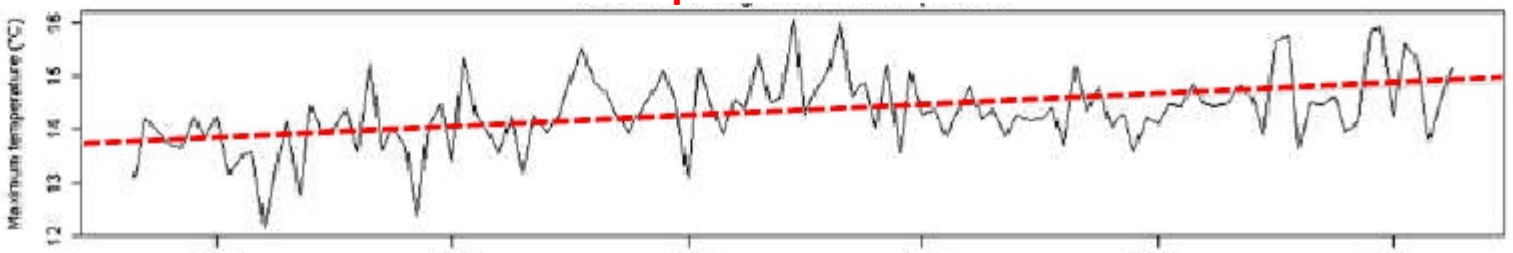


Mean annual minimum temperature: 1890-2005

1°C



Mean annual maximum temperature: 1890-2005



1900 1920 1940 1960 1980 2000

Source: Brown et al., 2010

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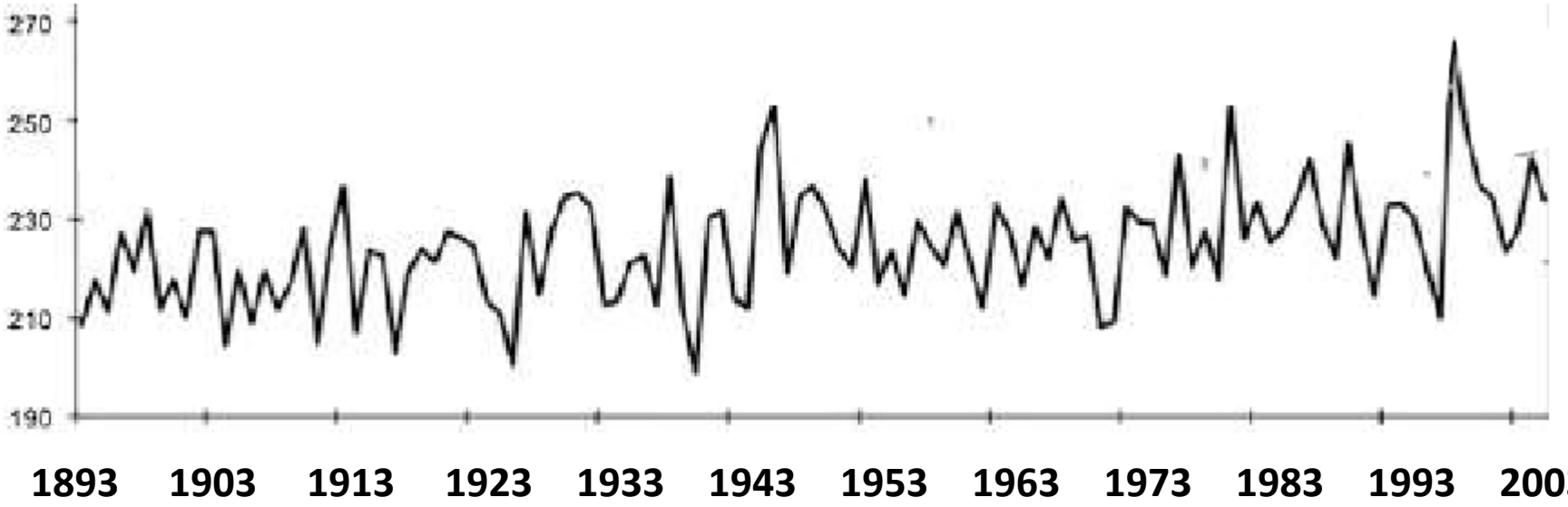
Length of growing season (days)

(Trend = 0.15 days/year or ~16.5 days over the period of record)



Number of days between first span of at least 6 days with daily mean temperature >5°C and first span after 1 July of 6 days with daily mean temperature <5°C

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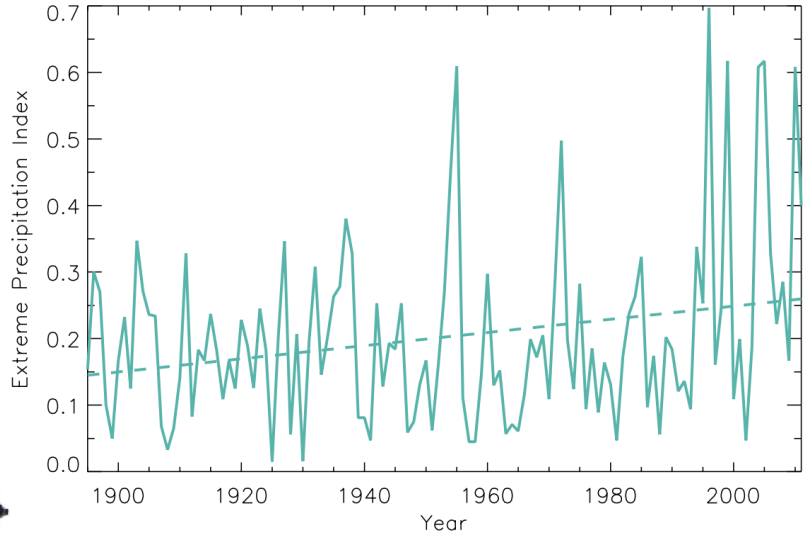
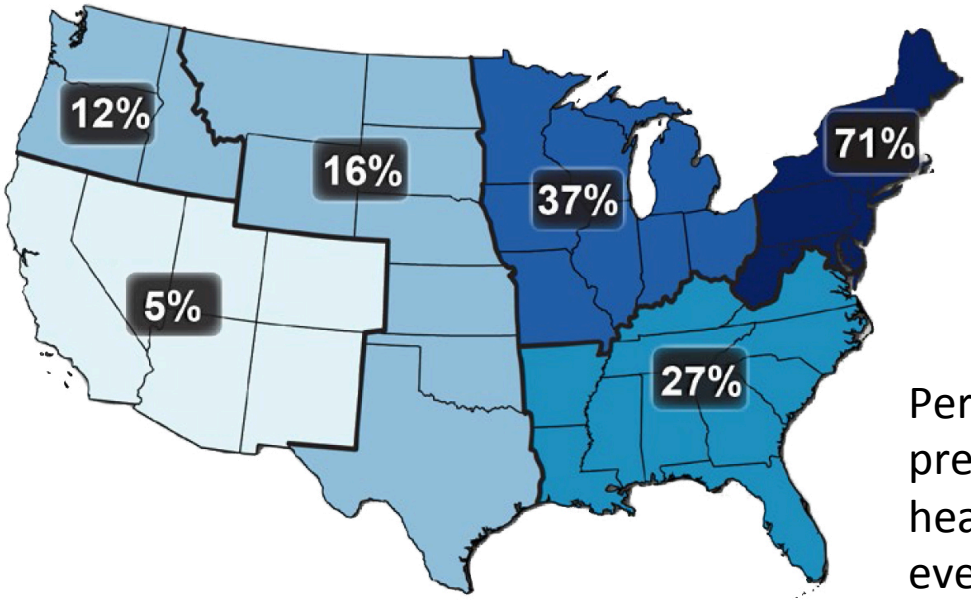
Extreme Precipitation





Percent increases in the precipitation amount falling in the heaviest 1% of daily precipitation events from 1958 to 2012.

Source: Kunkel et al., 2013

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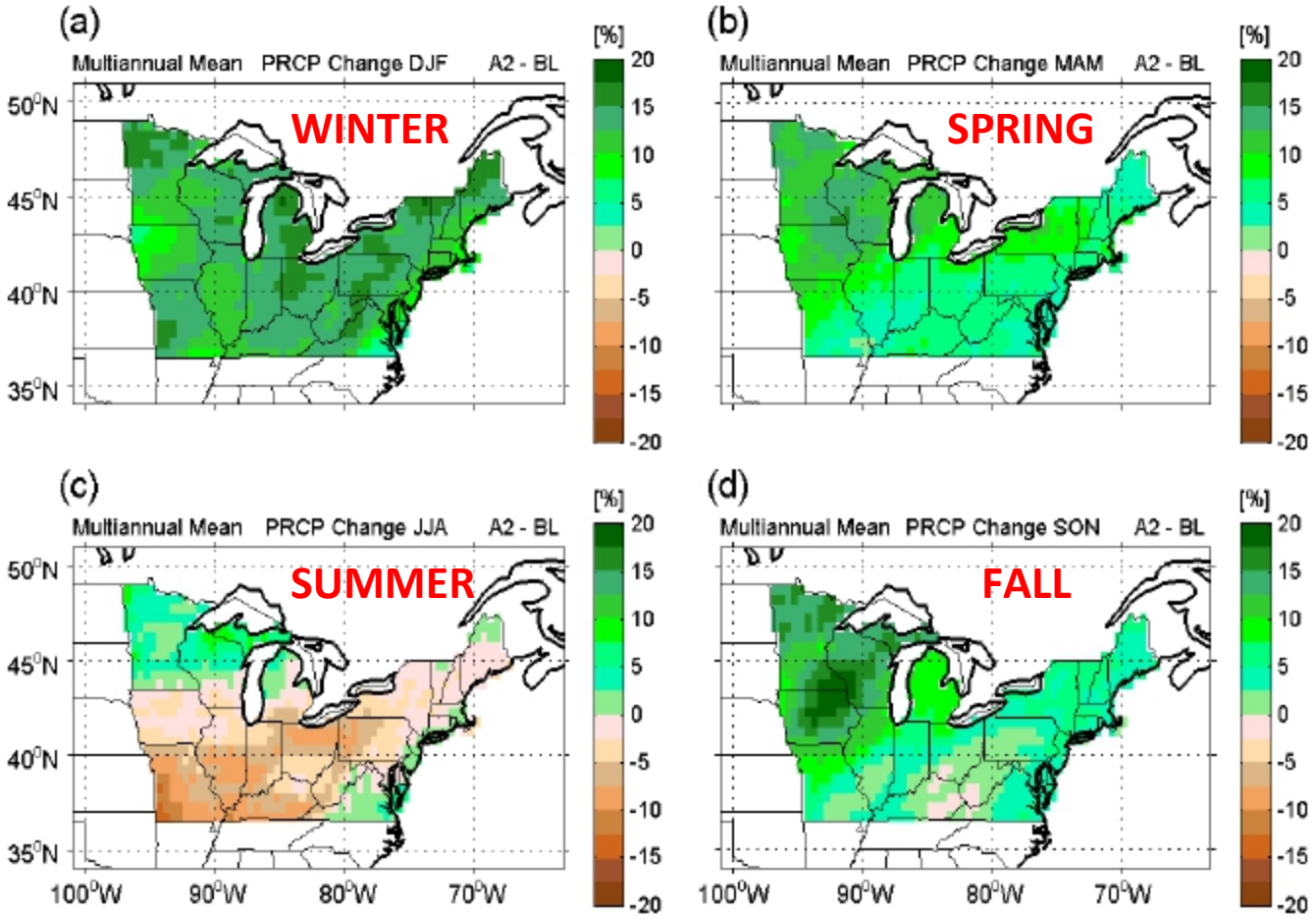
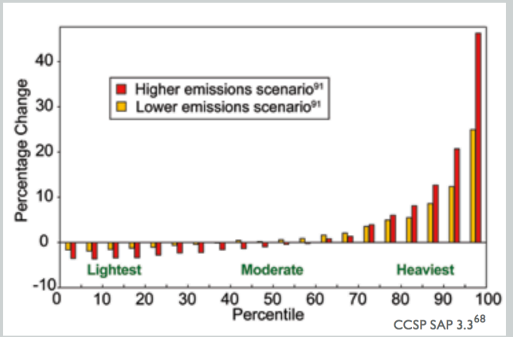
Seasonal precipitation changes (SRES A2-baseline): *multi-model means*



Projected Changes in Light, Moderate, and Heavy Precipitation (by 2090s)



The figure shows projected changes from the 1990s average to the 2090s average in the amount of precipitation falling in light, moderate, and heavy events in North America. Projected changes are displayed in 5 percent increments from the lightest drizzles to the heaviest downpours. As shown here, the lightest precipitation is projected to decrease, while the heaviest will increase, continuing the observed trend. The higher emission scenario[91] yields larger changes. Projections are based on the models used in the IPCC 2007 Fourth Assessment Report.

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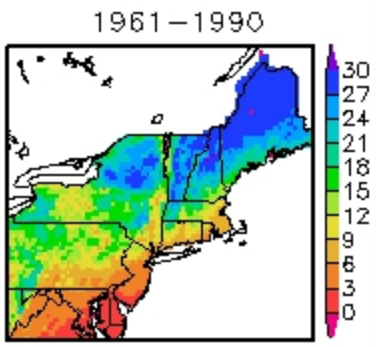
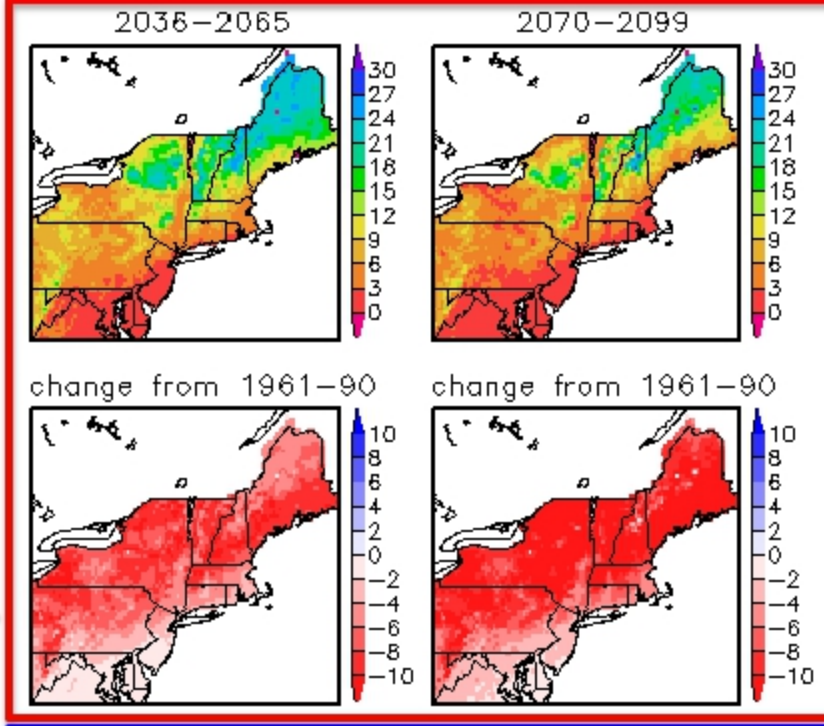
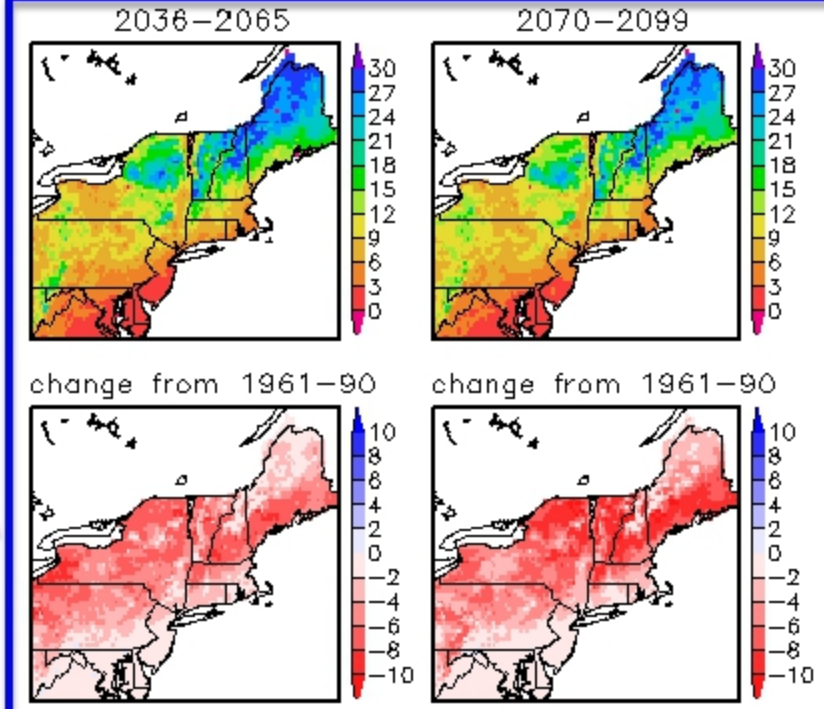


Observations



A1 scenario



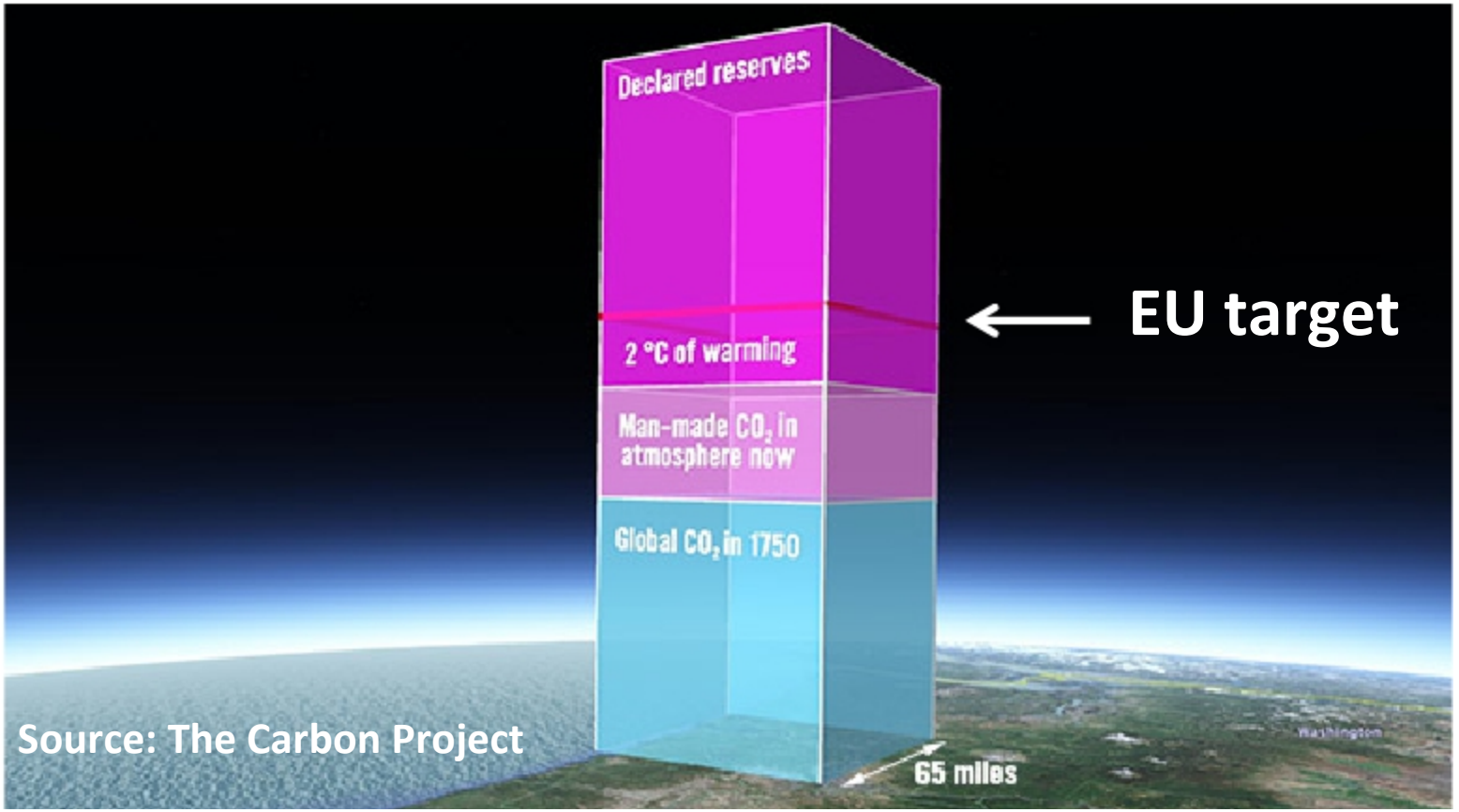
B1 scenario

Change in the number of snow-covered days per month in winter (D,J,F)

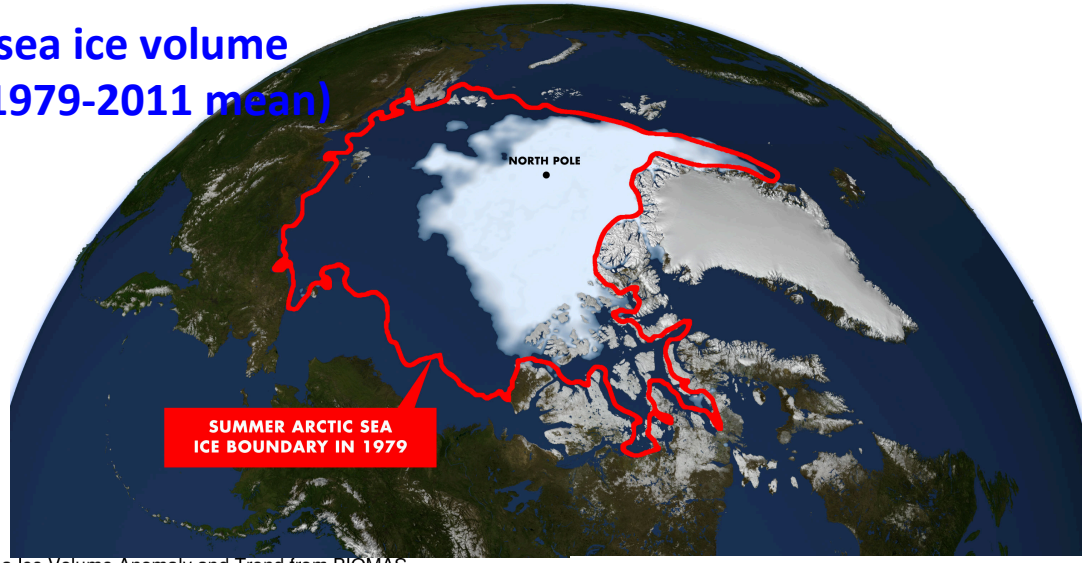
Values are the average of the HadCM3 and PCM-forced VIC simulations

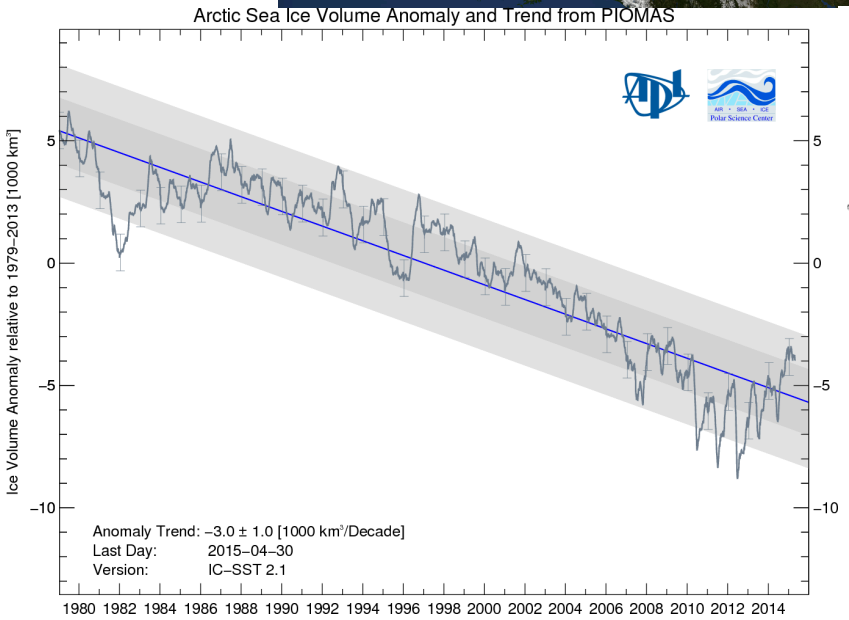
Source: Hayhoe et al. 2006

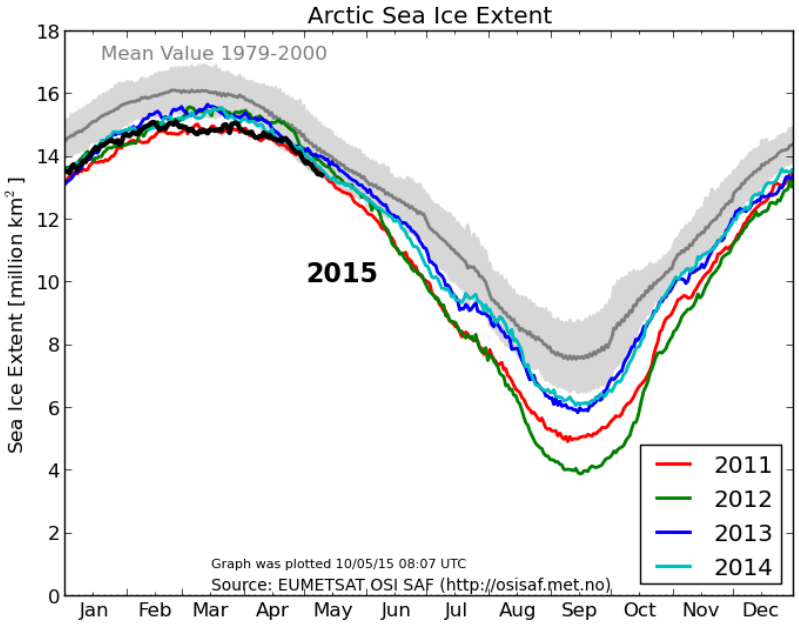
Most of the fossil fuel inventories that support valuations of major energy companies can not be consumed without massive changes in global climate….



Monthly Arctic sea ice volume (anomalies from 1979-2011 mean)







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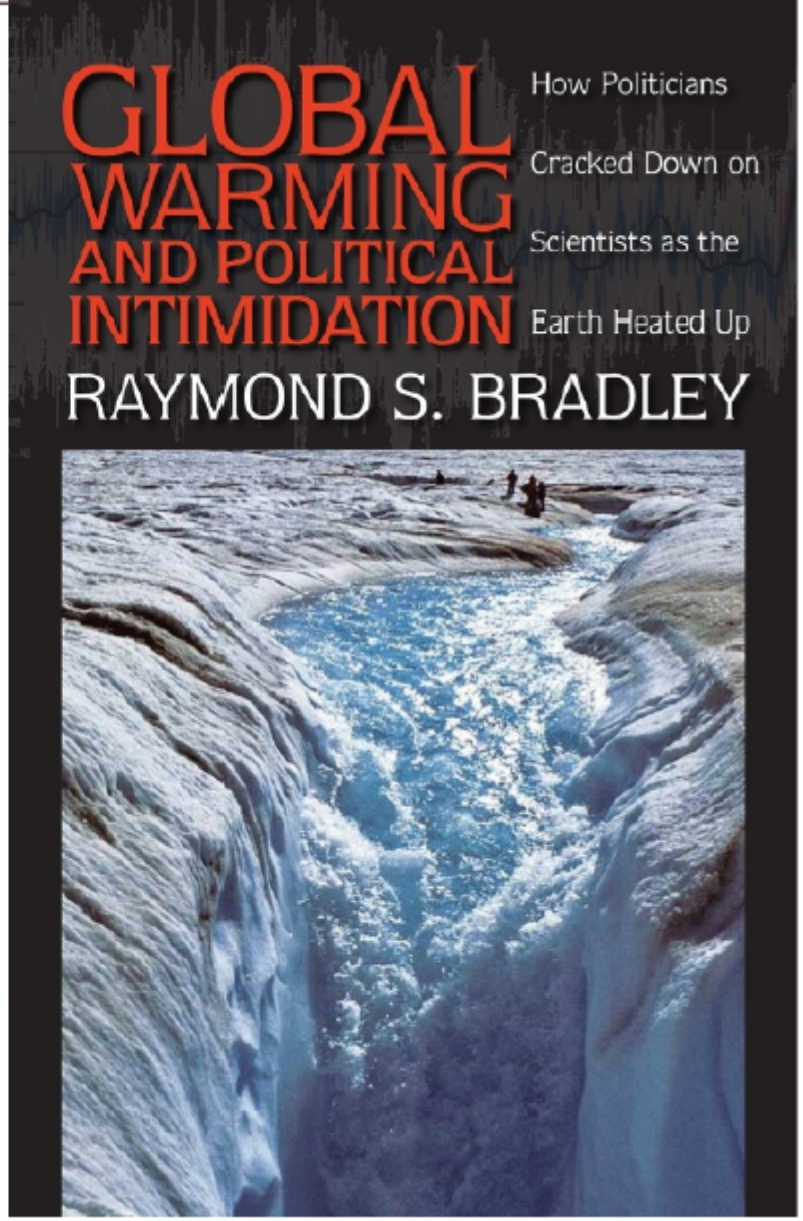
GLOBAL WARMING AND POLITICAL INTIMIDATION

How Politicians Cracked Down on Scientists as the Earth Heated Up

RAYMOND S. BRADLEY

A firsthand account of the political war on science and a primer on climate change that addresses the real questions at stake

Global warming is the number one environmental issue of our time, yet some prominent politicians have refused to accept scientific evidence of human responsibility and have opposed any legislation or international agreement that would limit greenhouse gas emissions. A few have gone even further and have tried to destroy the reputations of scientists researching climate change by deliberately undermining the credibility of their research. These politicians have sought to sow seeds of doubt in the minds of the public and to weaken public and political support for the control of fossil fuel use.



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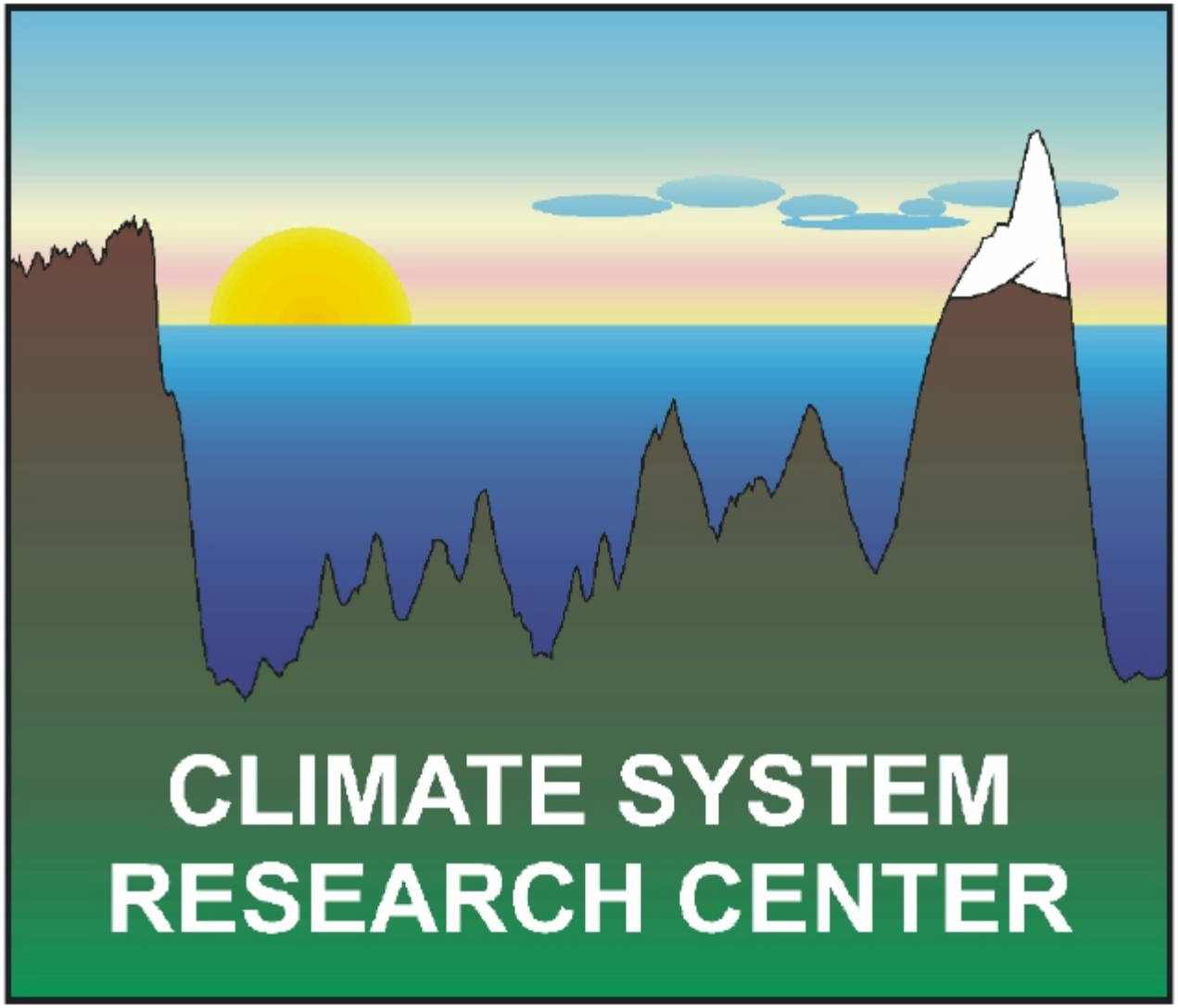
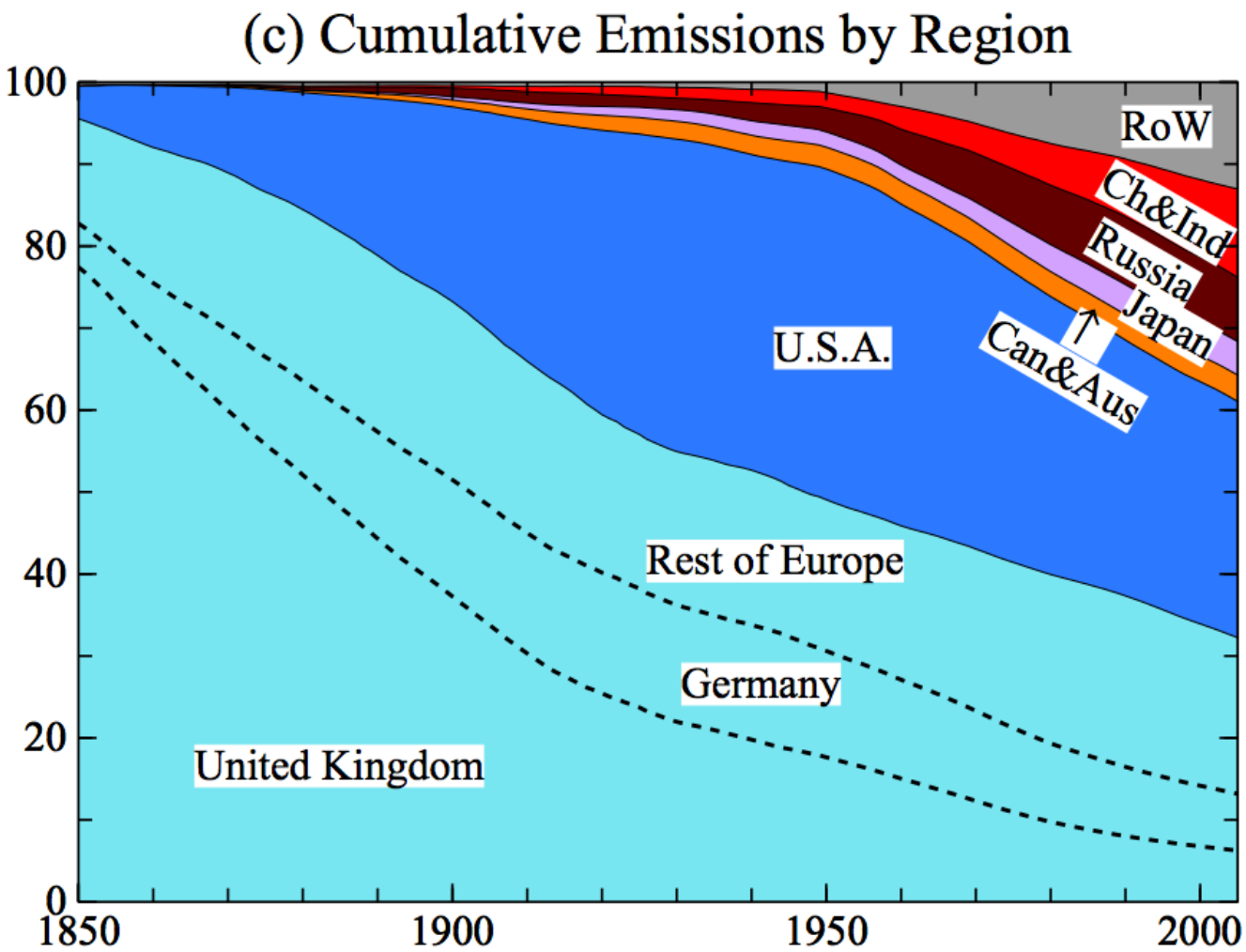
Thank you!

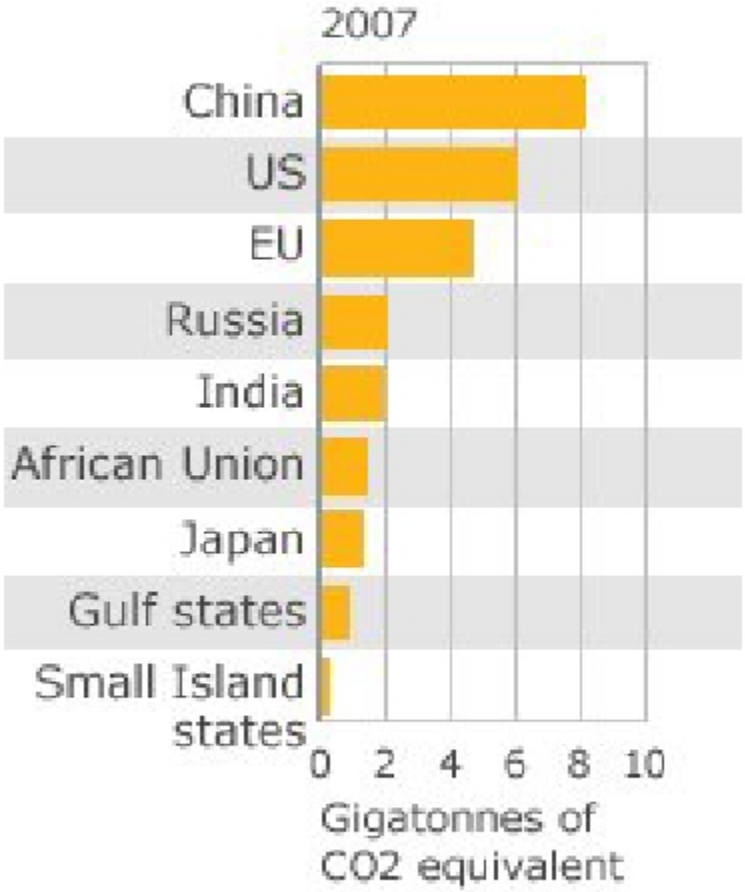


I am not willing to adopt multi-trillion dollar programs to reduce greenhouse gases in America. They don't call it America warming, they call it global warming."

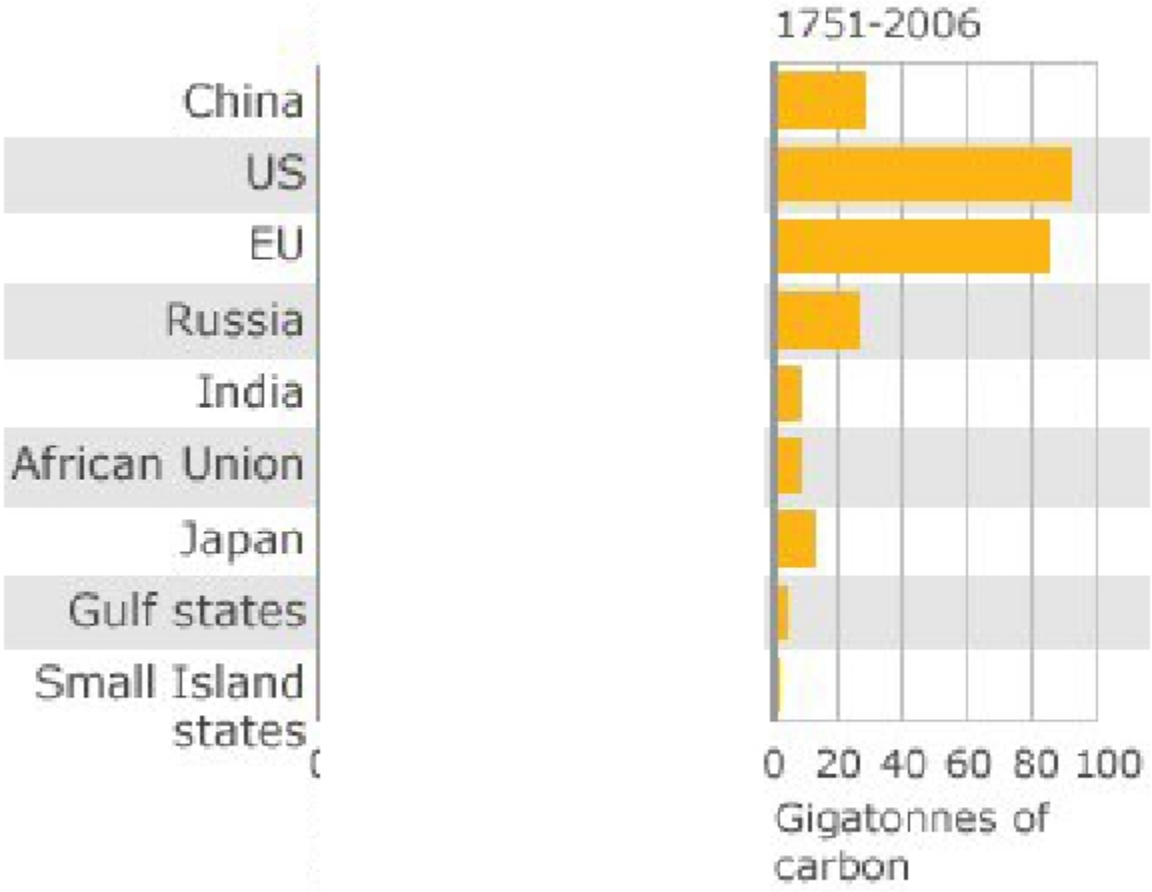
Mitt Romney, Oct 11, 2011


(c) Cumulative Emissions by Region
100
80
60
40
20
0
1850
1900
1950
2000
RoW
Ch&Ind
Russia
Japan
Can&Aus
U.S.A.
Rest of Europe
Germany
United Kingdom

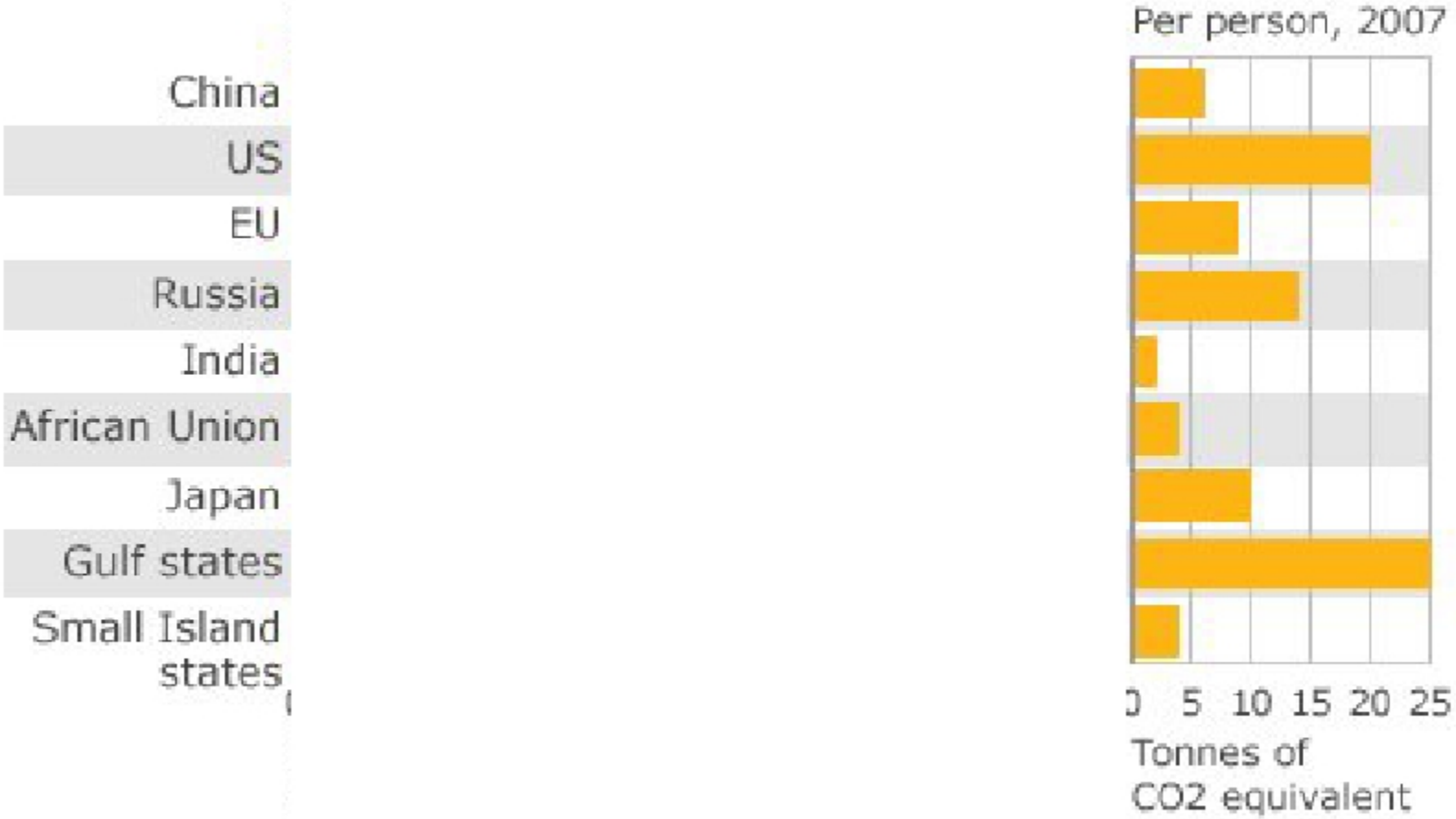
Carbon emissions: the view from the U.S. Congress:



Carbon emissions: the view from China:



Carbon emissions: the view from India:



How to reduce greenhouse gas emissions:

1. Use more energy efficient technology
2. Reduce waste (conservation)
3. Promote renewable energy (solar, wind, geothermal…)
4. Manage growth sustainably & promote local agriculture