Class 16: Projections I – Temperature, weather, sea level

- Emissions scenarios – what's likely
- Where does all the carbon go?
- Temperature, precipitation, cryosphere, biosphere, sea level and societal changes

Learning Objectives

- **Know the range of possible CO2 emission scenarios between now and 2100 used by climate scientists**
- **Explain how the pulse of CO2 emitted by humans will be distributed among Earth's carbon reservoirs**
- **Identify and describe two decadal Earth system responses to the pulse of atmospheric CO2 we are emitting**
- **Explain two Earth system responses the next ~100 years and how they will affect society**

Climate in the News


nytimes.com

cc science Lyme Disease...yme Disease film revkin Nemmers Priz...n University mann Climate CC pi Qtube Rec G 54 Driving YouTube Converter Invading

CLIMATE

The New York Times

How Climate Change Could Shift California's Santa Ana Winds, Fueling Fires

Firefighters at the Kincade fire in Geyserville, Calif., last week.

Eric Thayer for The New York Times

This is not a new idea…2004

Eos, Vol. 85, No. 31, 3 August 2004

EOS
EOS, TRANSACTIONS, AMERICAN GEOPHYSICAL UNION

VOLUME 85 NUMBER 31
3 AUGUST 2004
PAGES 289–300

Climate, Santa Ana Winds and Autumn Wildfires in Southern California

PAGES 289, 296

Wildfires periodically burn large areas of chaparral and adjacent woodlands in autumn and winter in southern California. These fires often occur in conjunction with Santa Ana weather events, which combine high winds and low humidity, and tend to follow a wet winter rainy season. Because conditions fostering large fall and winter wildfires in California are the result of large-scale patterns in atmospheric circulation, the same dangerous conditions are likely to occur over a wide area at the same time.

Furthermore, over a century of watershed reserve management and fire suppression have promoted fuel accumulations, helping to shape one of the most conflagration-prone environments in the world [*Pyne*, 1997]. Combined with a complex topography and a large human population, southern Californian ecology and climate pose a considerable physical and societal challenge to fire management.

October 2003 Wildfires

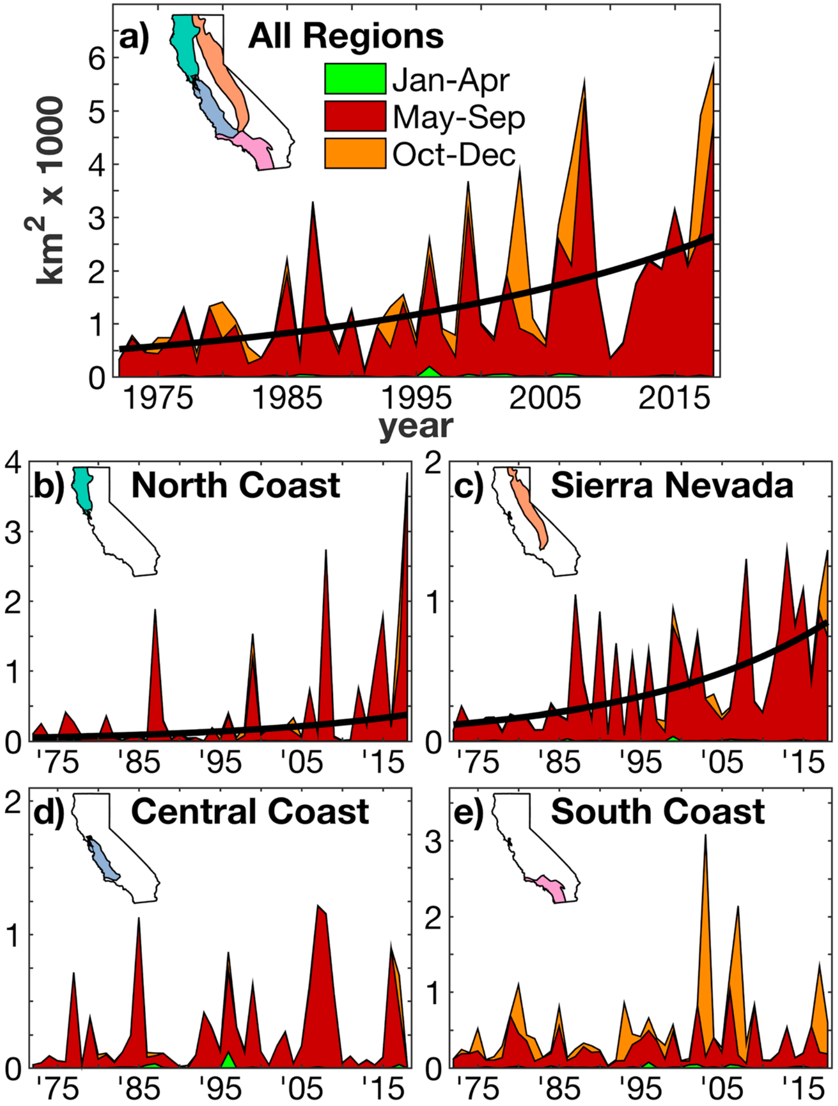
Both antecedent climate and meteorology played important roles in the recent extreme wildfires in southern California. After a multi-year drought contributed to extensive mortality in western forests and chaparral, late winter precipitation and a cool spring and early summer fostered the growth of grasses that were cured out during a hot summer and autumn in 2003, producing an extensive fine fuel coverage. Fanned by moderate Santa Ana winds, 12 major fires started between 21 October and 27 October in southern California and another began on 28 October near Ensenada in Baja California, Mexico (see Figure 1). Together, the fires had burned over 300,000 hectares by November. All of these human-induced fires started in chaparral on or below the western slopes of California's coastal mountain ranges and initially burned toward the Pacific Ocean. Their paths toward the sea were, in many cases, coincident with some of the most densely populated urban areas in the United States.

The Santa Ana winds that fostered the rapid growth of these fires were not in themselves extraordinary, though the hot and dry conditions leading up to the fire events were at record or near-record levels. Large wildfires in chaparral in the autumn and winter months are also not extraordinary events in southern California. They have occurred frequently

By Anthony L. Westerling, Daniel R. Cayan, Timothy J. Brown, Beth L. Hall, and Laurence G. Riddle

Fig. 1. Smoke from southern California wildfires is shown on 26 October 2003. Active fire perimeters are outlined in red in Ventura, San Bernardino, Los Angeles, and San Diego counties, and in Baja California, Mexico. Selected city names are in black; fire names in white. Source image courtesy of NASA/MODIS Rapid Response Team.

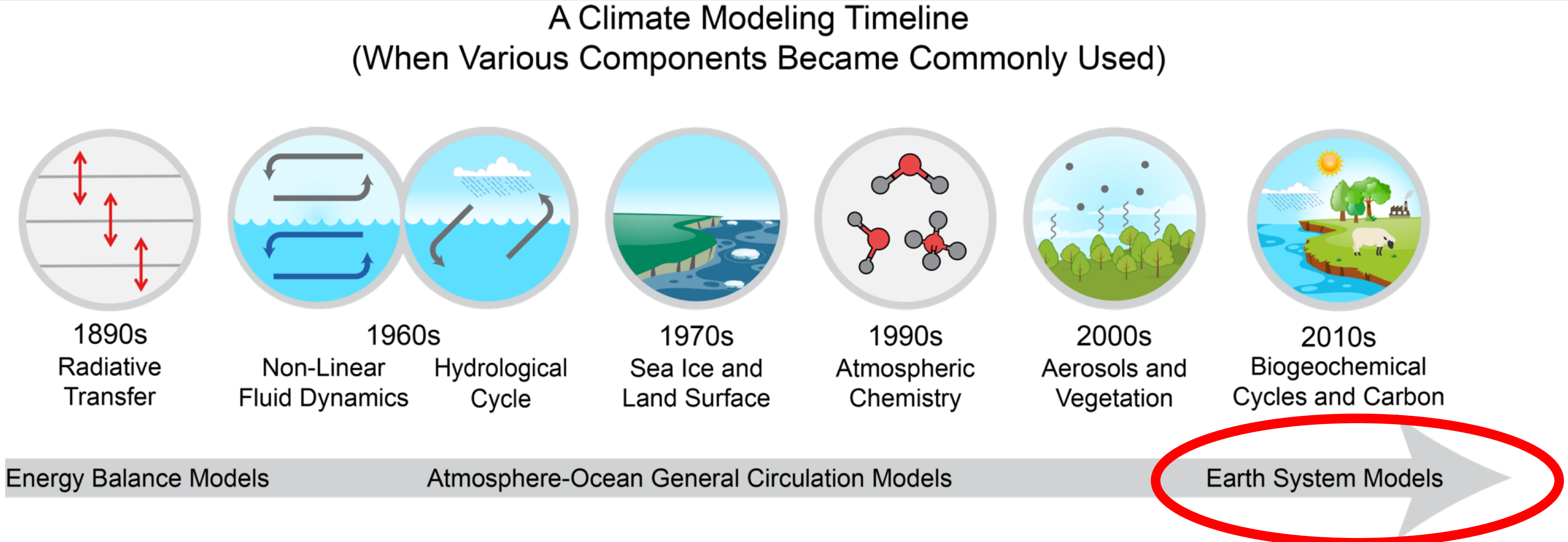
Area burned



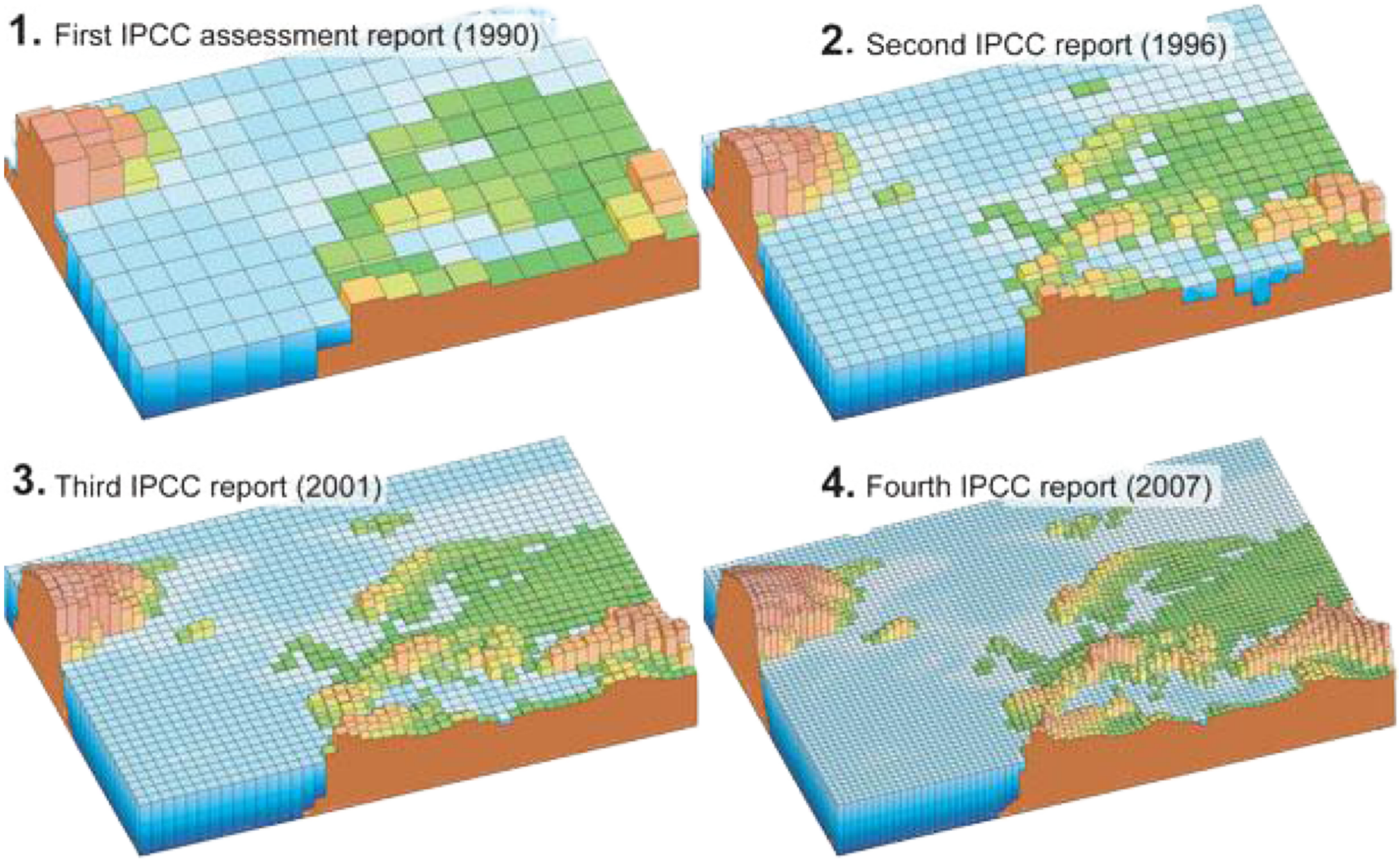

CALIFORNIA WILDFIRES
CLIMATE CHANGE INCREASES RISKS OF EXTRE
INSIDE
THE AMERICAS
FRANCE 24

Review - What exactly is a climate model?

- Computer simulation of the climate system; reduces our understanding to a series of equations
- Used to predict the future given scenarios regarding emissions and land use
- Based on our best understanding of Earth's systems – there are still things we don't know well (clouds and moist air convection)
- Limited by computing power and time to run programs



Grid size, the size of the boxes, is key for accurate representation but expensive in time and $$$ and computing power

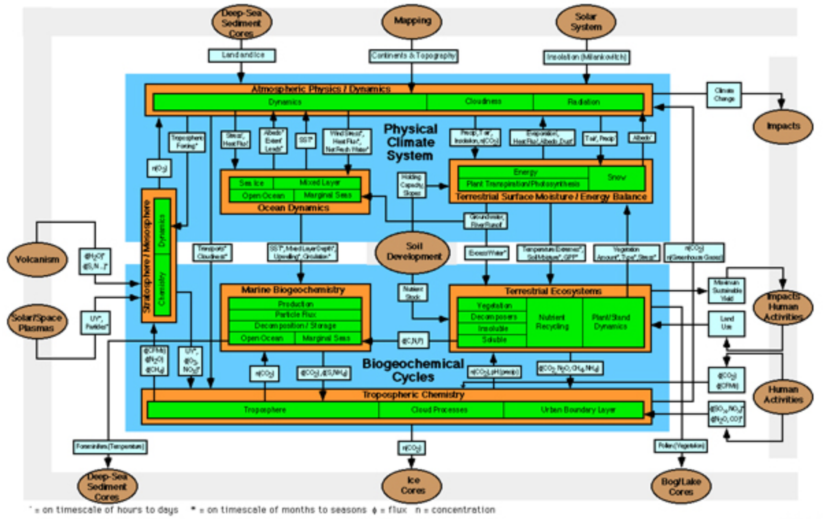


Models can be tested against data and thus validated

They work pretty well at the global scale

Climate models are NOT reality

Conceptual Model of Earth System Processes Operating on Timescales of Decades to Centuries



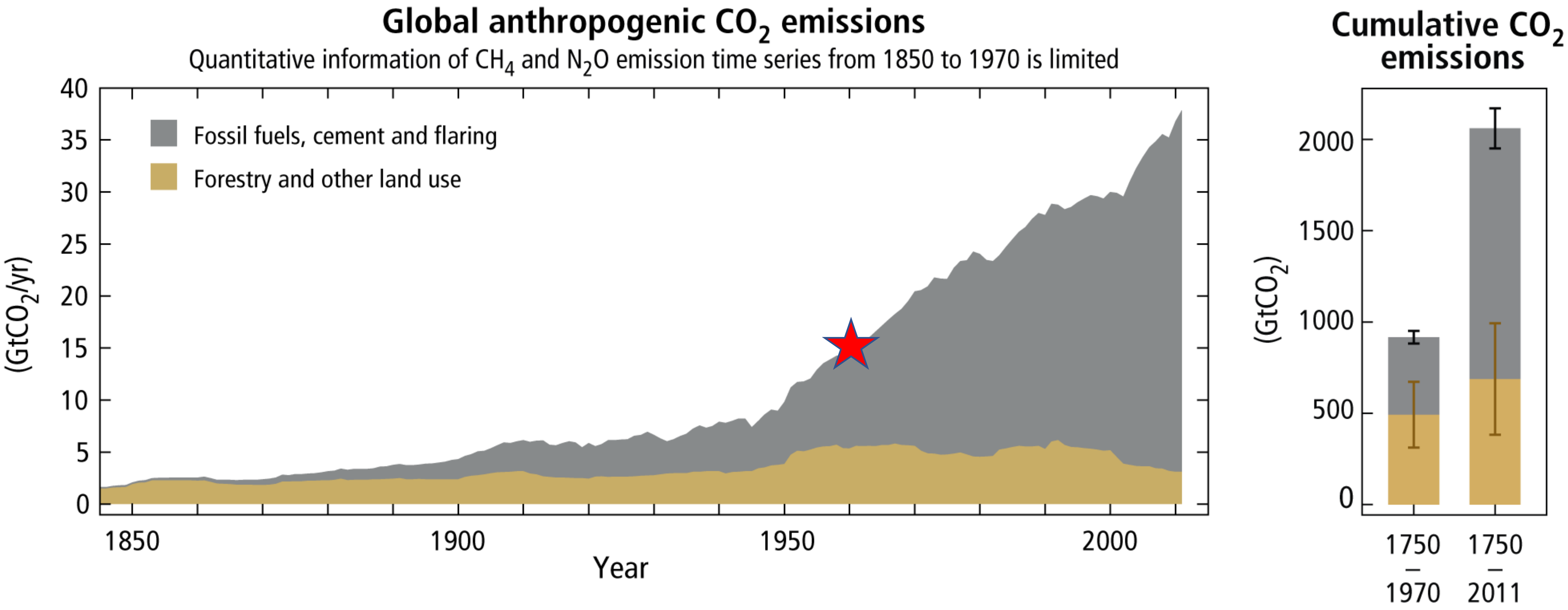
NASA

- All are simplifications of reality; complexity has evolved over time
- Some processes (such as clouds) are difficult to model from first principals (physics)
- Increases in computing efficiency have allowed increased model resolution
- Climate models are now coupled to ocean, ice sheet, and solid Earth models – **Earth System Models**

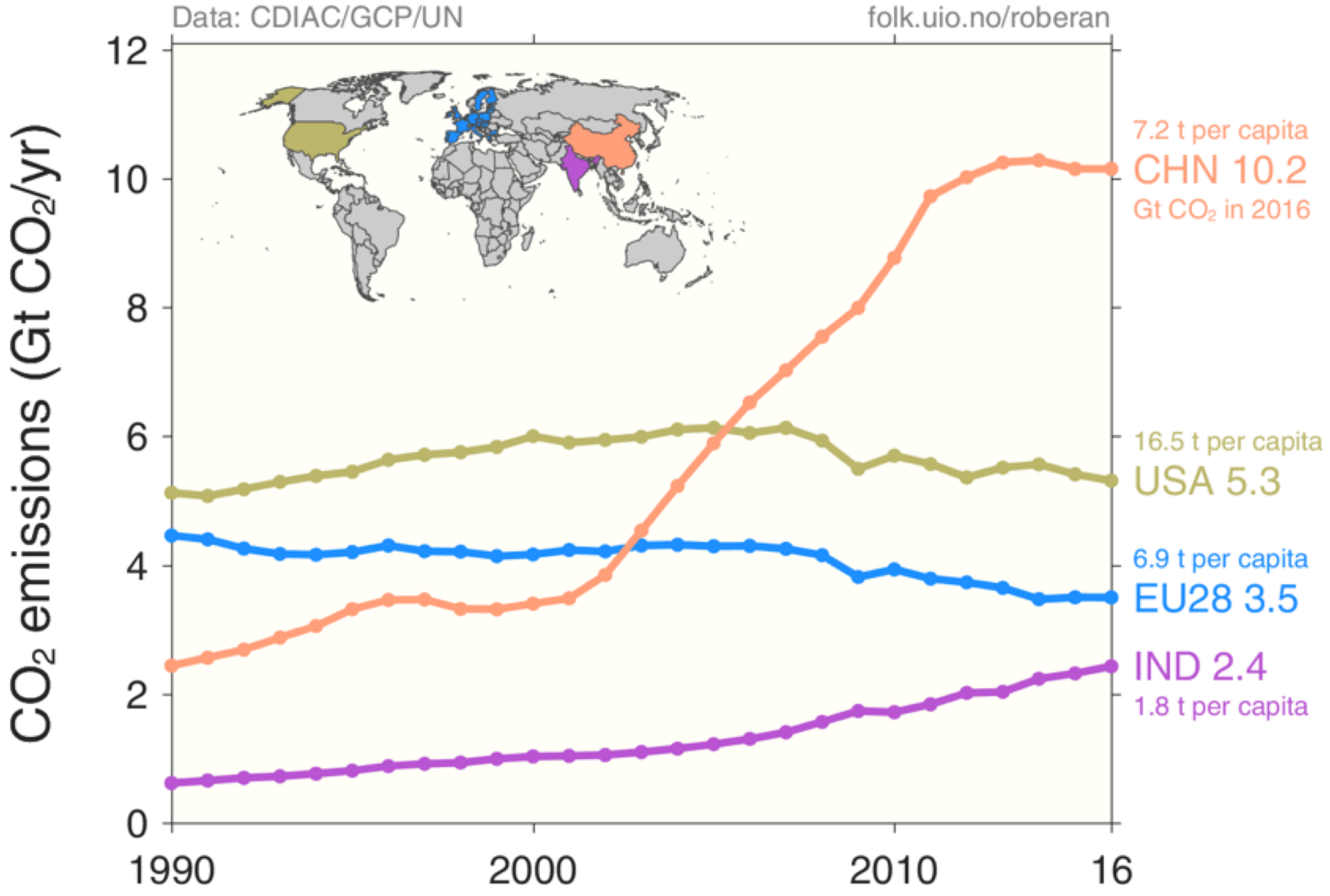
Class 16: Projections I – Temperature, weather, sea level

- **Emission Scenarios – how much carbon will we release by 2100?**
- Where will all that carbon end up?
- What do the models project for changes in global and regional temperature, sea level, precipitation, the cryosphere, the biosphere, and the ocean.
- What will be the societal changes – the effects on people?

Carbon emissions over time – most in my life time.



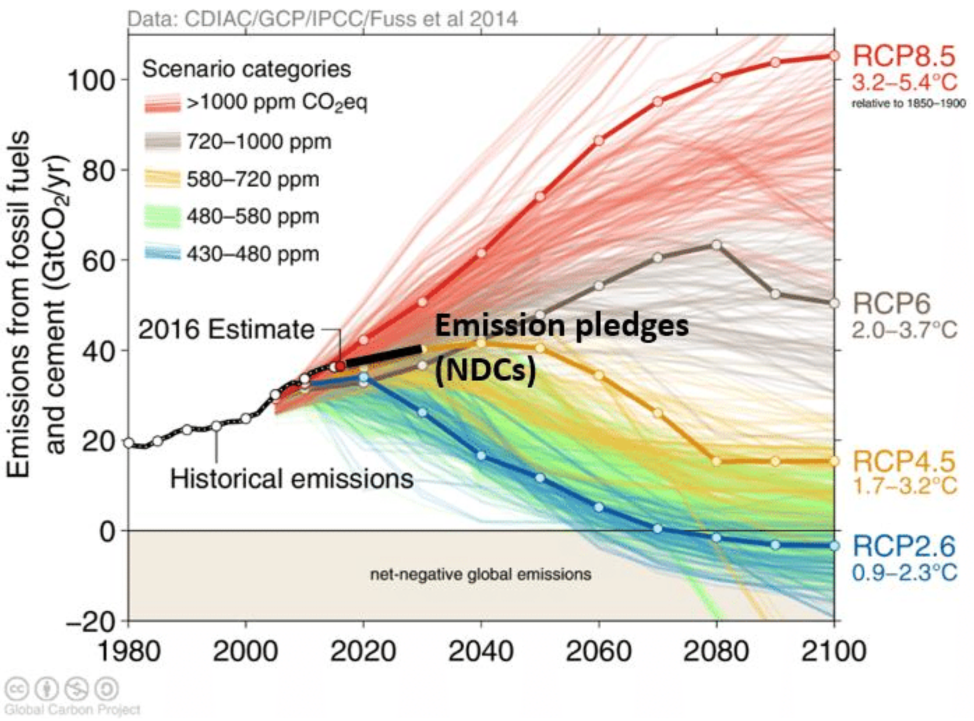
Who done it?



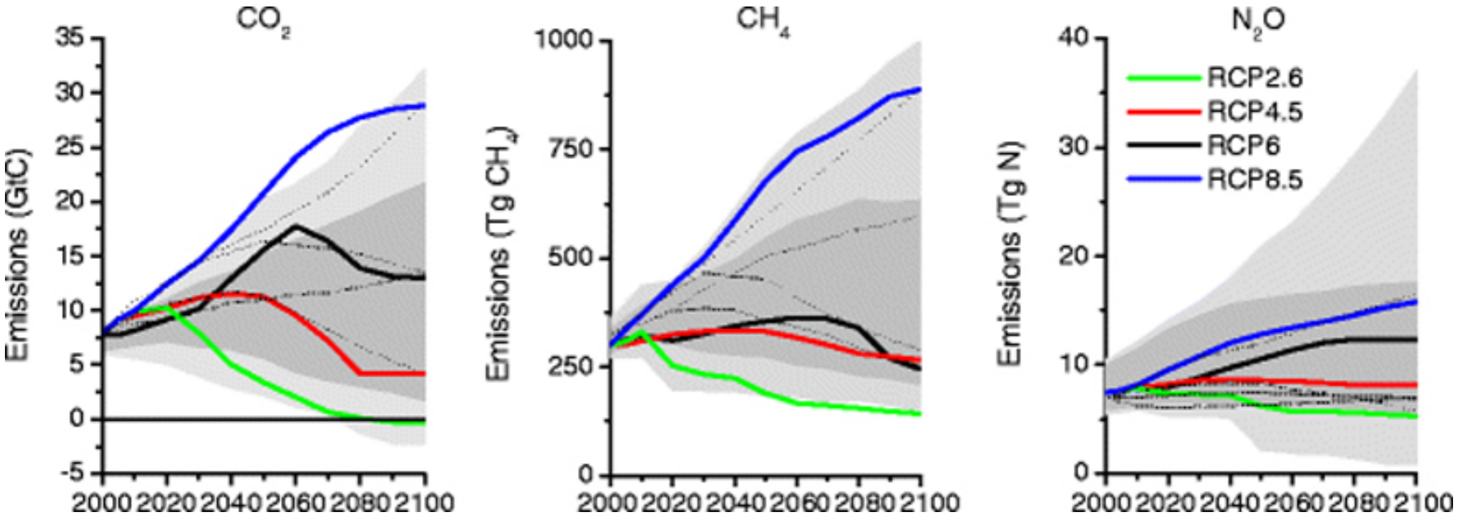
Think-pair-share

Work with your neighbor to consider carbon impact over time by country and by citizen (per capita)

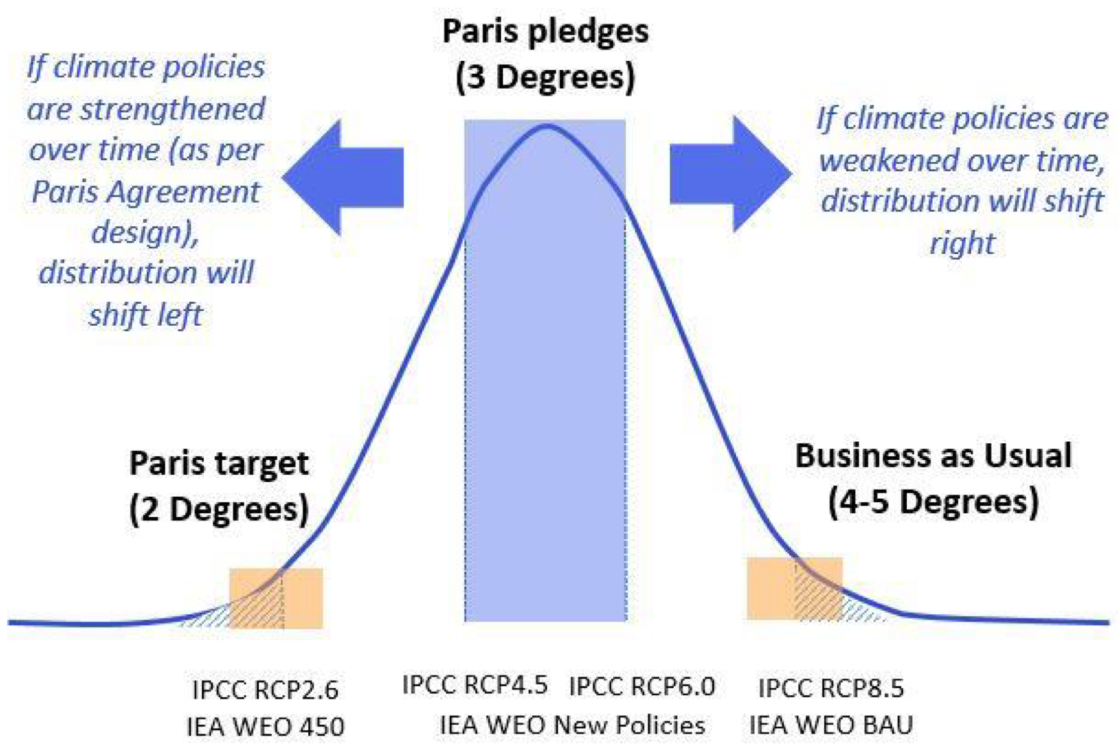
Looking forward – IPCC uses Representative Concentration Pathways (RCPs)

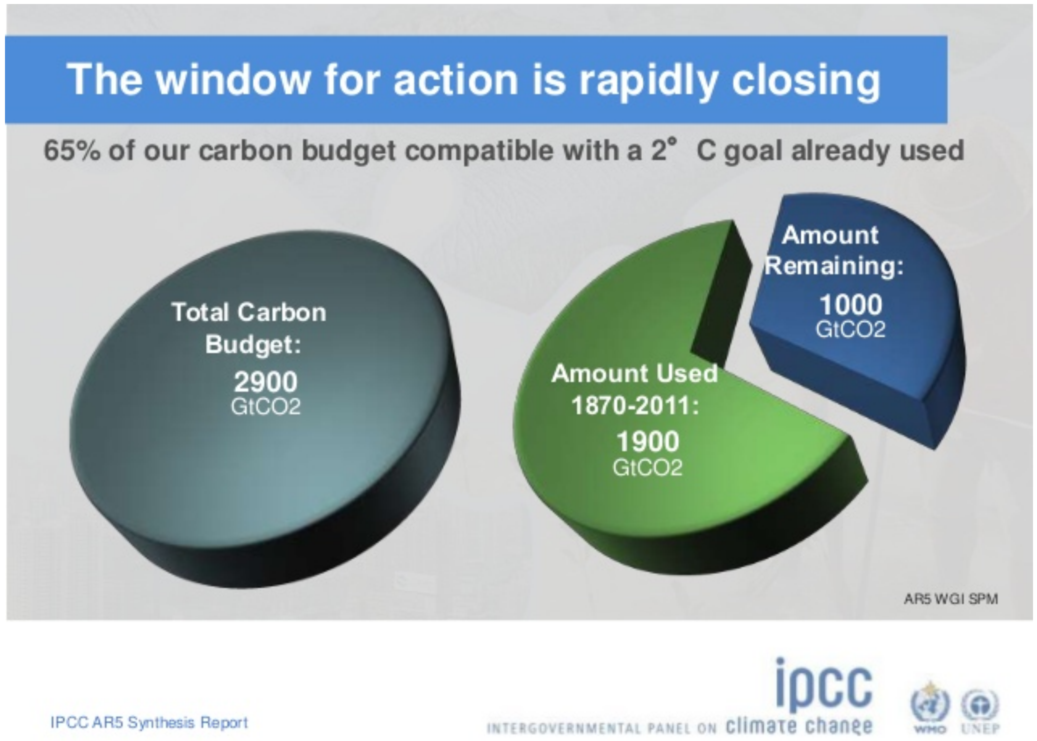


Four pathways were developed based on their end-of-century radiative forcing: RCP2.6(indicating a 2.6 watts per metre squared – W/m2 – forcing increase relative to pre-industrial conditions), RCP4.5, RCP6.0, and RCP8.5.



Looking at the RCPs in terms of likely warming and Paris accords





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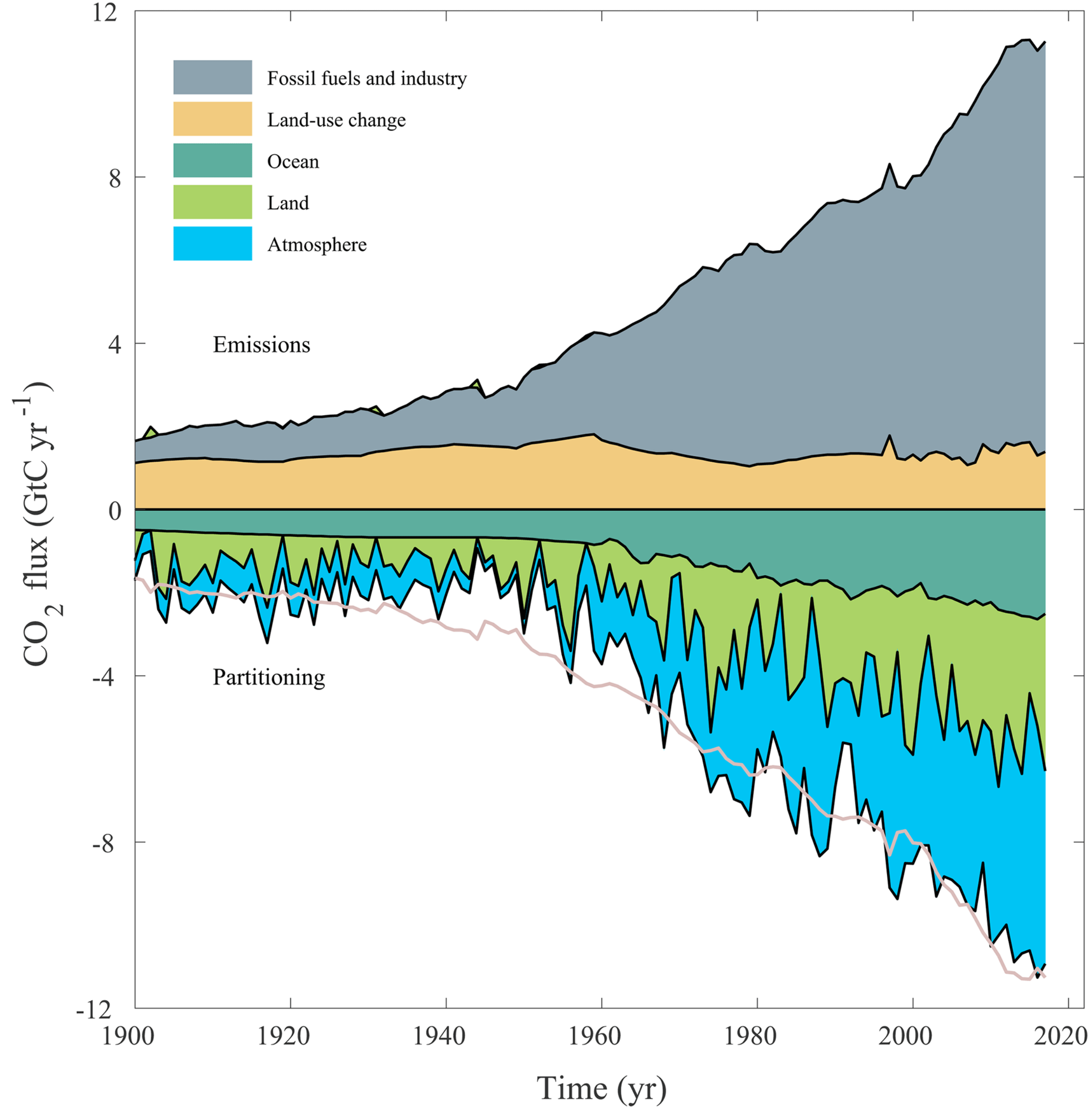
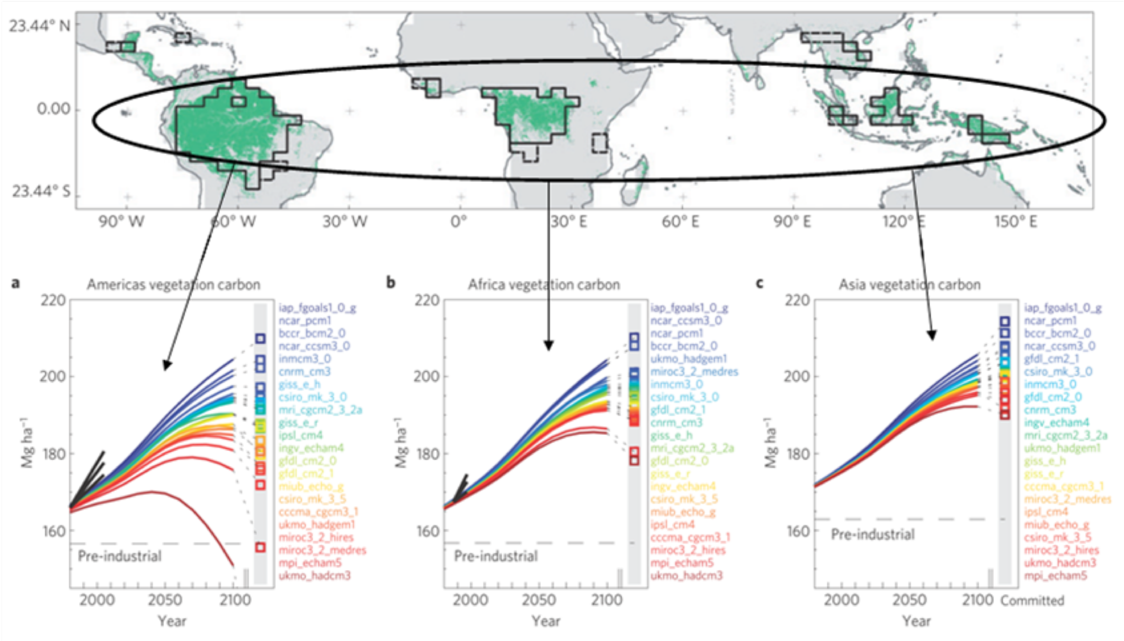
- **What will be the societal changes – the effects on people?**

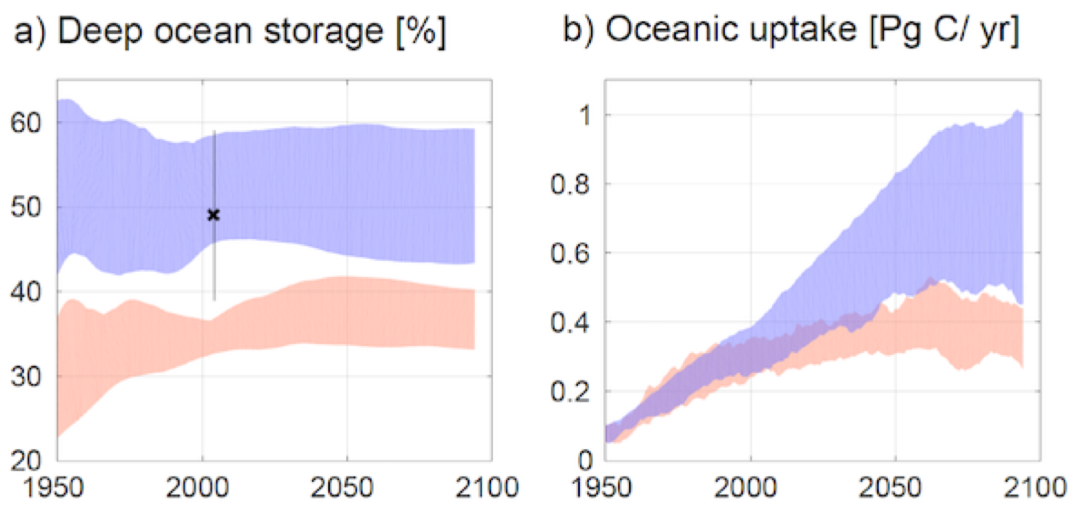
Where will all that carbon end up?



Oceans and atmosphere mostly – land is ???



Anthropogenically altered carbon in the North Atlantic



Class 16: Projections I – Temperature, weather, sea level

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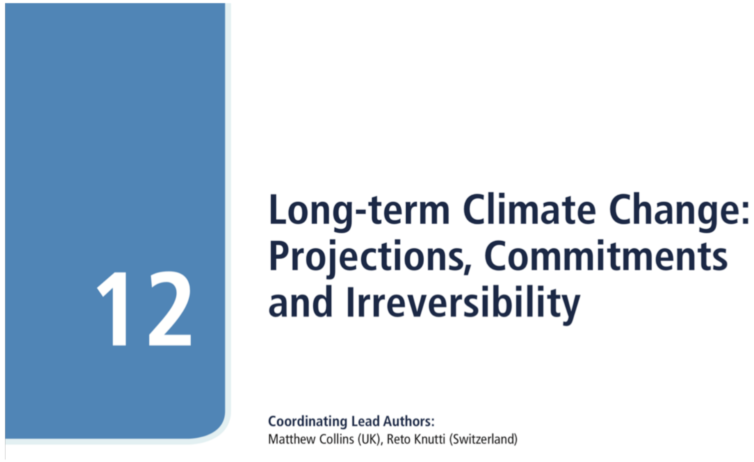
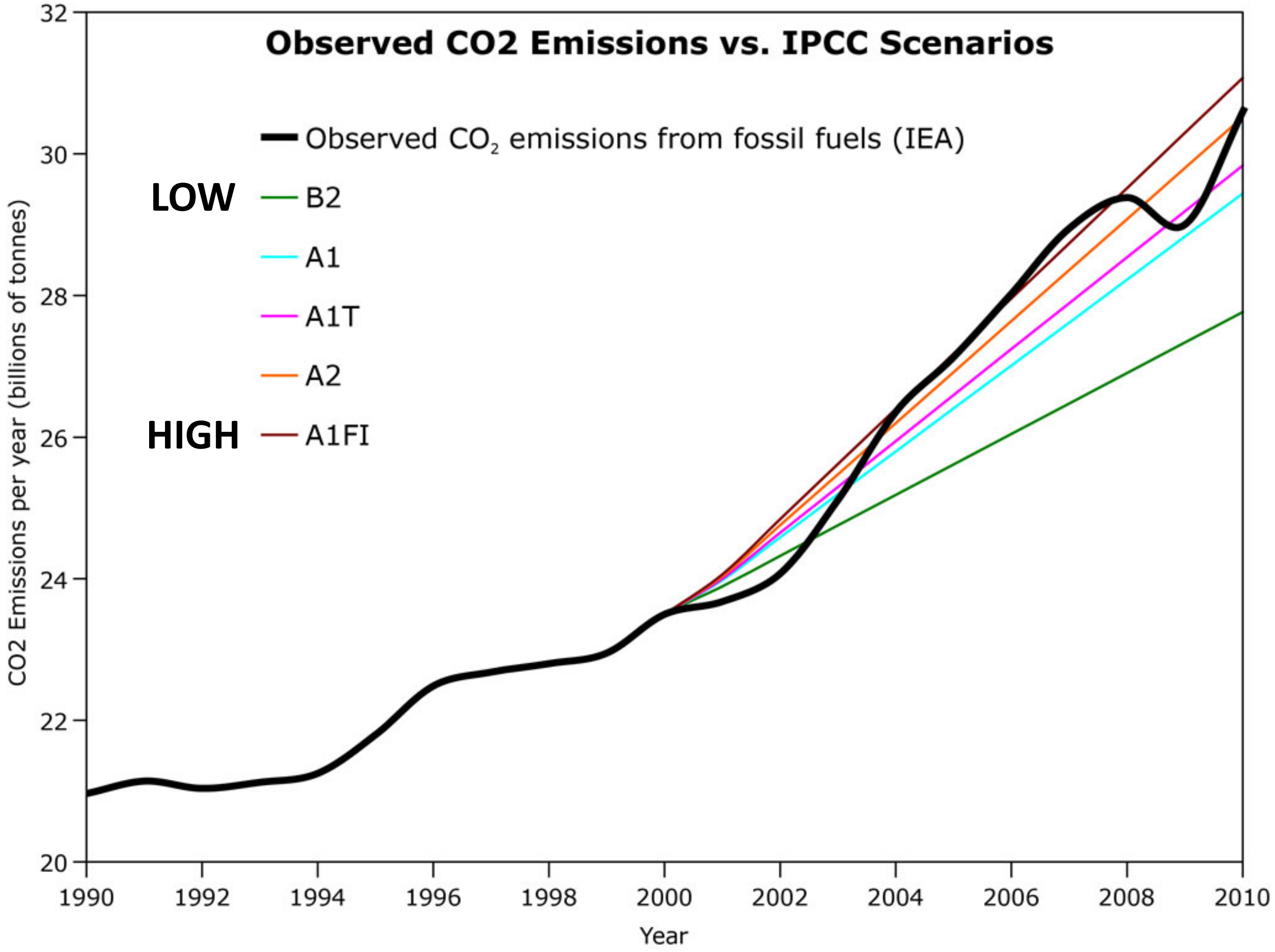


Which scenario to pick? If the past is the key to the future, pick the worst one.



James Hanson – Climate Modeler

Thirty years ago, James Hansen, a scientist at NASA, issued a warning about the dangers of climate change. The predictions he and other scientists made at the time have proved spectacularly accurate.

THE NEW YORKER

LISTENING TO JAMES HANSEN ON CLIMATE CHANGE, THIRTY YEARS AGO AND NOW

By Elizabeth Kolbert June 20, 2018

“I happened to interview Hansen last year, for a video project. I asked him if he had a message for young people. “The simple thing is, I’m sorry we’re leaving such a fucking mess”. Could the message be any clearer than that?”

Jim Hansen, NASA scientist, 1988 – testimony to congress

"All the News That's Fit to Print"

The New York Times

Late Edition

New York: Today, sunny, cool. High 74-79. Tonight, increasing clouds. Low 57-65. Tomorrow, morning clouds, then windy and warmer. High 79-88. Yesterday: High 87, low 67. Details, page A18.

VOL.CXXXVII . . . No. 47,546 NEW YORK, FRIDAY, JUNE 24, 1988 50 cents beyond 75 miles from New York City, except on Long Island. 30 CENTS

Global Warming Has Begun, Expert Tells Senate

Temperature in Degrees Fahrenheit: 60.0, 59.5, 59.0, 58.5, 58.0, 57.5

1950-1980 Average

1880 1890 1900 1910 1920 1930 1940 1950 1960 1970 1980 '88

Global Warming: Greenhouse Effect?

Average global temperatures through the first five months of 1988. As a baseline, scientists use the global average from 1950 to 1980.

Source: James E. Hansen and Sergej Lebedeff

The New York Times/June 24, 1988

Sharp Cut in Burning of Fossil Fuels Is Urged to Battle Shift in Climate

By PHILIP SHABECOFF

Special to The New York Times

WASHINGTON, June 23 — The earth has been warmer in the first five months of this year than in any comparable period since measurements began 130 years ago, and the higher temperatures can now be attributed to a long-expected global warming trend linked to pollution, a space agency scientist reported today.

Until now, scientists have been cautious about attributing rising global temperatures of recent years to the predicted global warming caused by pollutants in the atmosphere, known as the "greenhouse effect." But today Dr. James E. Hansen of the National Aeronautics and Space Administration told a Congressional committee that it was 99 percent certain that the warming trend was not a natural variation but was caused by a buildup of carbon dioxide and other artificial gases in the atmosphere.

An Impact Lasting Centuries

Dr. Hansen, a leading expert on climate change, said in an interview that there was no "magic number" that showed when the greenhouse effect was actually starting to cause changes in climate and weather. But he added, "It is time to stop waffling so much and say that the evidence is pretty strong

Drought Raising Food Prices; Inflation Effect Seems Minor

By ROBERT D. HERSHEY Jr.

Special to The New York Times

Cañon Zapata in Tijuana, Mexico, the busiest illegal crossing point.

The New York Times/Larry Rohter

IMMIGRATION LAW IS FAILING TO CUT FLOW FROM MEXICO

ECONOMIC FACTORS CITED

Illegal Entries Are on the Rise as More Come From Large Cities and Stay Longer

By LARRY ROHTER

Special to The New York Times

TIJUANA, Mexico, June 18 — The 1986 immigration law is failing to stem the illegal flow of Mexicans into the United States and may be creating new problems on both sides of the border by distorting traditional immigration patterns, Mexican and American researchers say.

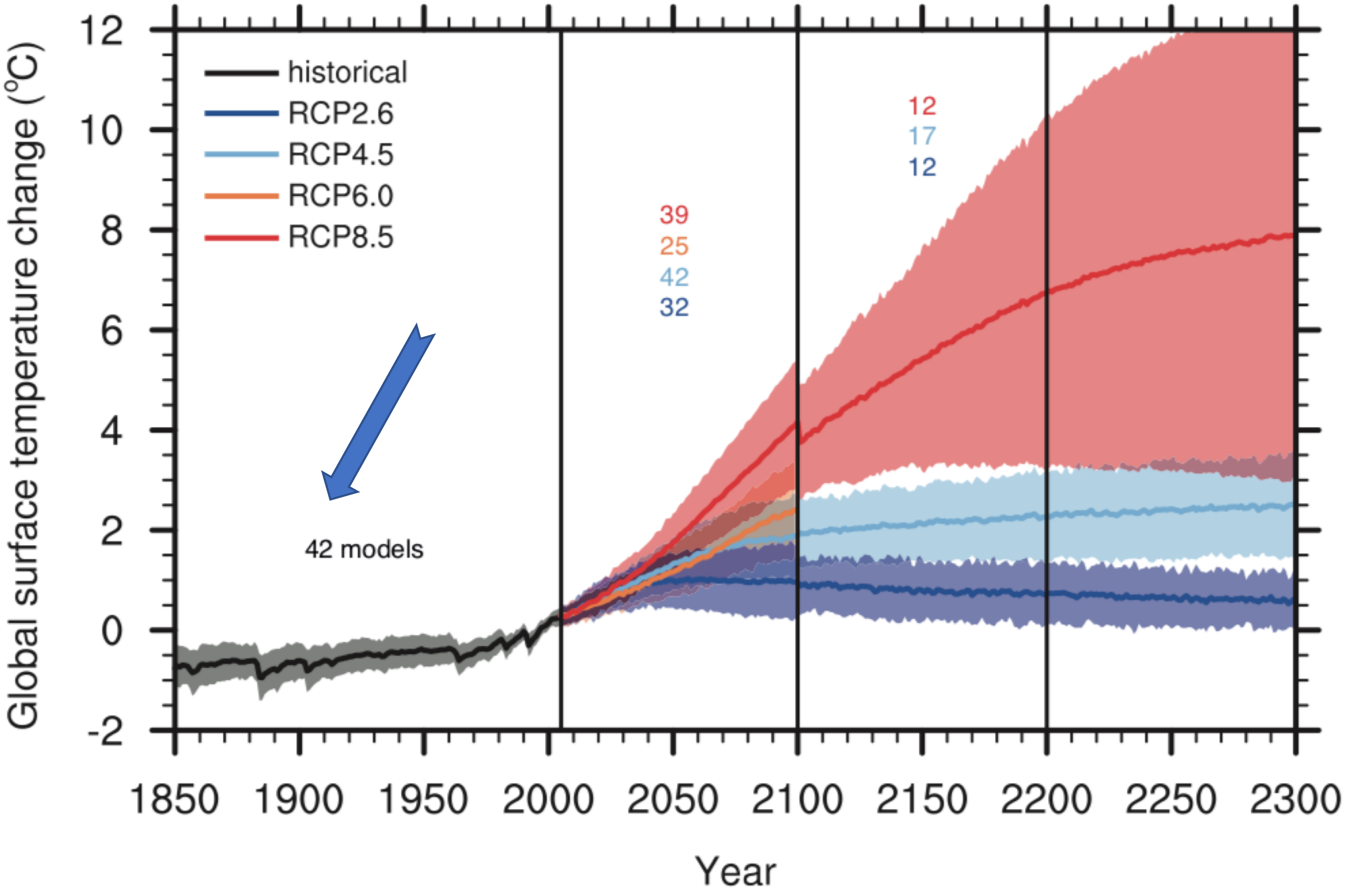
Studies by immigration specialists at the College of the Northern Border in Tijuana and the Center for United States-Mexican Studies at the University of California, San Diego, indicate that the number of Mexicans illegally seeking work in the United States has actually increased in recent months.

The data also show that these illegal immigrants are staying in the United States longer, are increasingly arriving in family groups and are coming in growing numbers from parts of Mexico that have not sent many migrants in the past.

Jim Hansen, 2011 – Arrested, Tar Sands protest

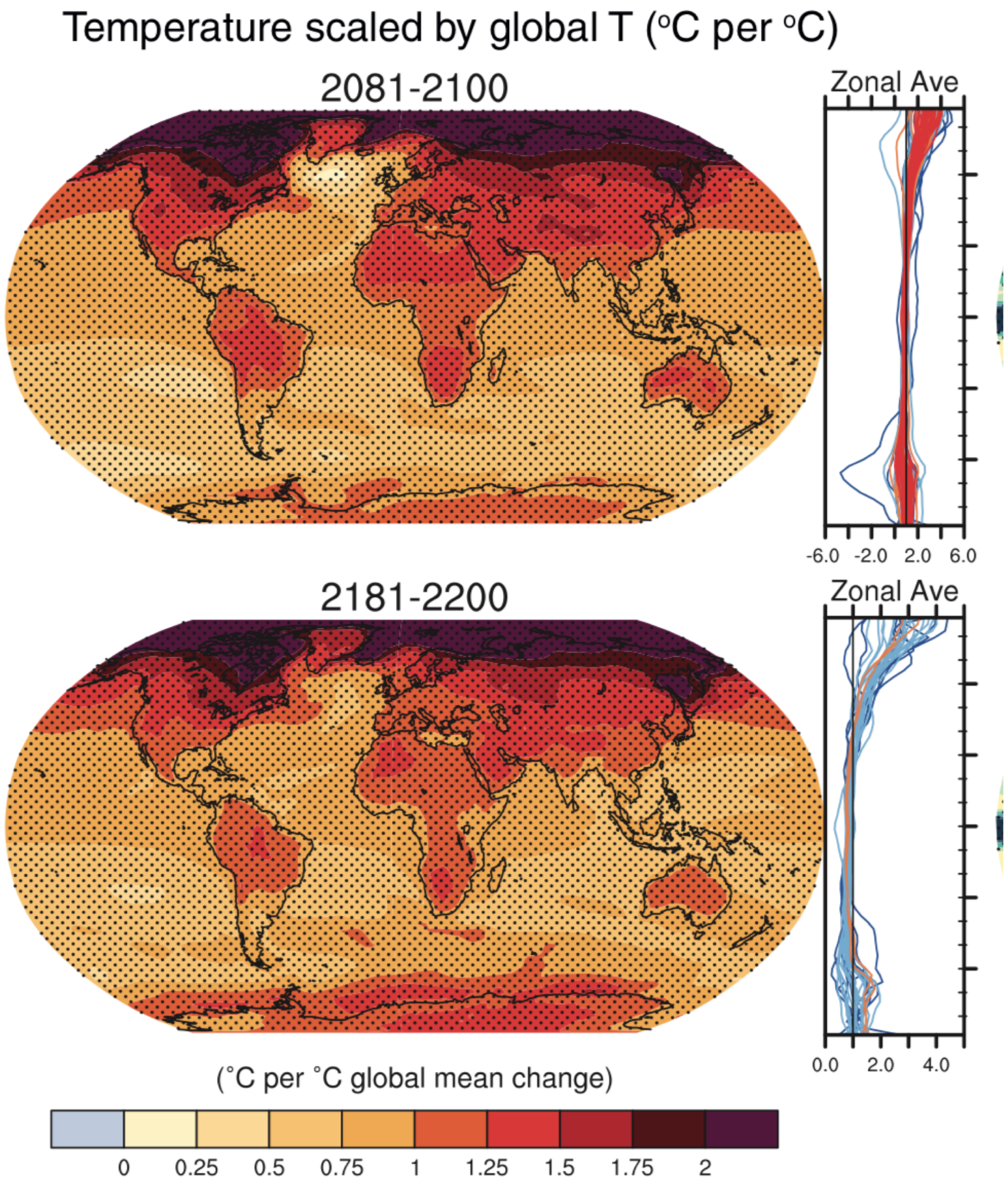
Former director of NASA Goddard Institute for Space Studies in New York, 2011 protests of pipe line to bring tar sands oil to the US from Canada

Different RCPs give different results for global temperature over time – all rising



Global temperature – differs by place and time and with RCP

		RCP2.6 (ΔT in °C)	RCP4.5 (ΔT in °C)	RCP6.0 (ΔT in °C)	RCP8.5 (ΔT in °C)
Global:	2046–2065	1.0 ± 0.3 (0.4, 1.6)	1.4 ± 0.3 (0.9, 2.0)	1.3 ± 0.3 (0.8, 1.8)	2.0 ± 0.4 (1.4, 2.6)
	2081–2100	1.0 ± 0.4 (0.3, 1.7)	1.8 ± 0.5 (1.1, 2.6)	2.2 ± 0.5 (1.4, 3.1)	3.7 ± 0.7 (2.6, 4.8)
	2181–2200	0.7 ± 0.4 (0.1, 1.3)	2.3 ± 0.5 (1.4, 3.1)	3.7 ± 0.7 (-,-)	6.5 ± 2.0 (3.3, 9.8)
	2281–2300	0.6 ± 0.3 (0.0, 1.2)	2.5 ± 0.6 (1.5, 3.5)	4.2 ± 1.0 (-,-)	7.8 ± 2.9 (3.0, 12.6)
Land: 2081–2100		1.2 ± 0.6 (0.3, 2.2)	2.4 ± 0.6 (1.3, 3.4)	3.0 ± 0.7 (1.8, 4.1)	4.8 ± 0.9 (3.4, 6.2)
Ocean: 2081–2100		0.8 ± 0.4 (0.2, 1.4)	1.5 ± 0.4 (0.9, 2.2)	1.9 ± 0.4 (1.1, 2.6)	3.1 ± 0.6 (2.1, 4.0)
Tropics: 2081–2100		0.9 ± 0.3 (0.3, 1.4)	1.6 ± 0.4 (0.9, 2.3)	2.0 ± 0.4 (1.3, 2.7)	3.3 ± 0.6 (2.2, 4.4)
Polar: Arctic: 2081–2100		2.2 ± 1.7 (-0.5, 5.0)	4.2 ± 1.6 (1.6, 6.9)	5.2 ± 1.9 (2.1, 8.3)	8.3 ± 1.9 (5.2, 11.4)
Polar: Antarctic: 2081–2100		0.8 ± 0.6 (-0.2, 1.8)	1.5 ± 0.7 (0.3, 2.7)	1.7 ± 0.9 (0.2, 3.2)	3.1 ± 1.2 (1.1, 5.1)

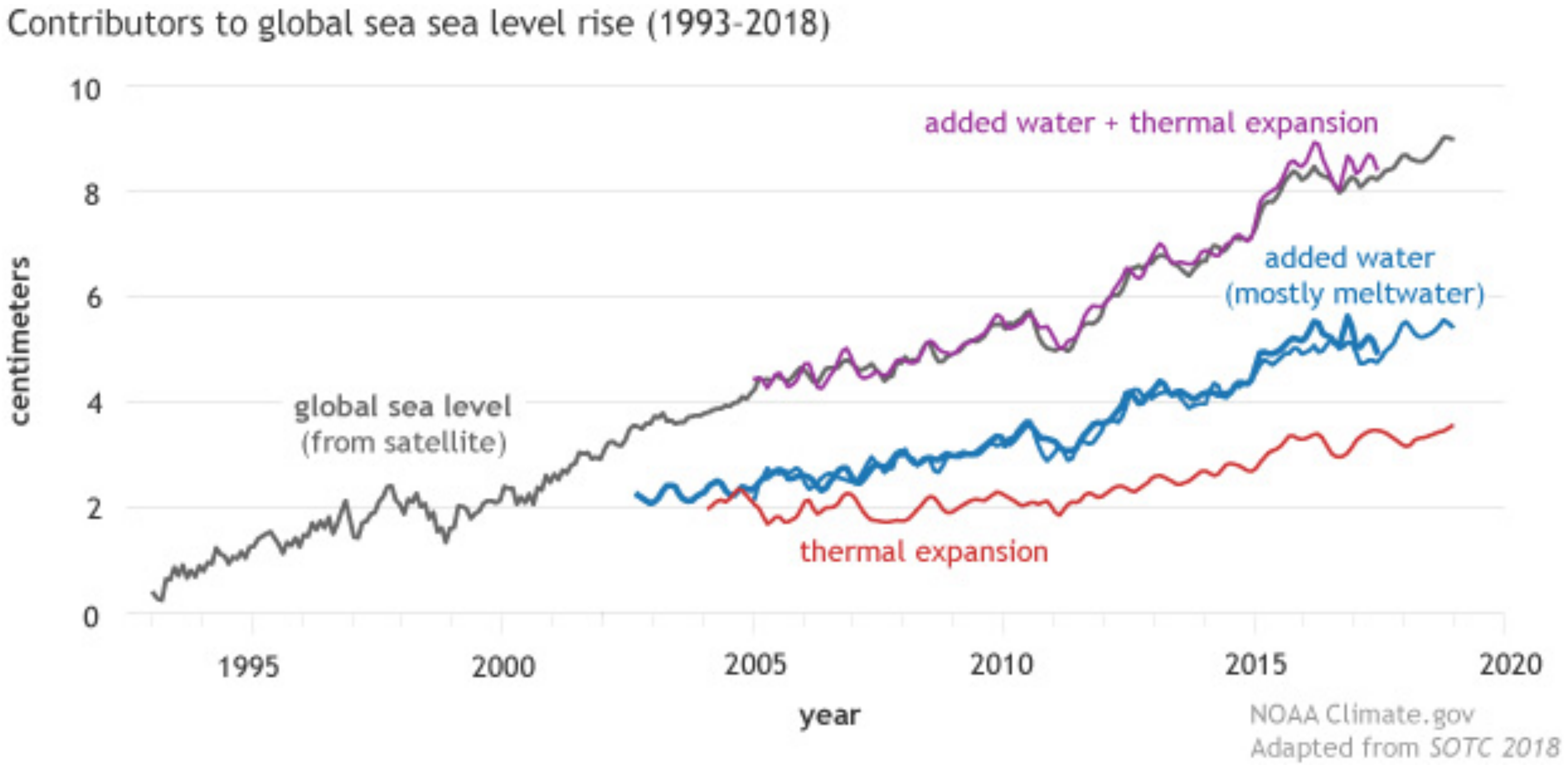


Global temperature – differs by place and time.

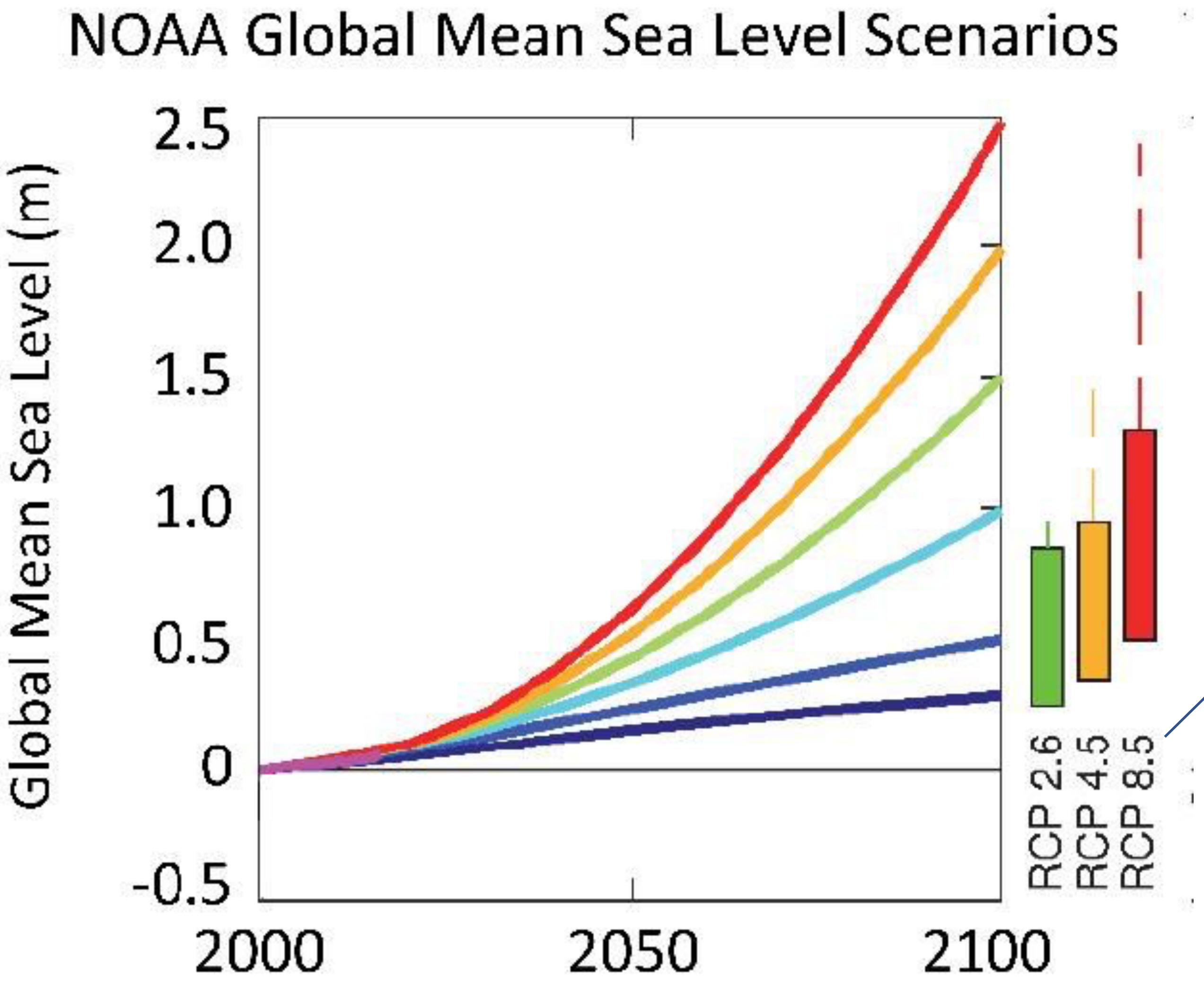
Note these are ratio plots….not absolute temperature rise

Sea level – headed up- how much? Ask Greenland!

Causes of sea level rise are warming/expansion and ice melt



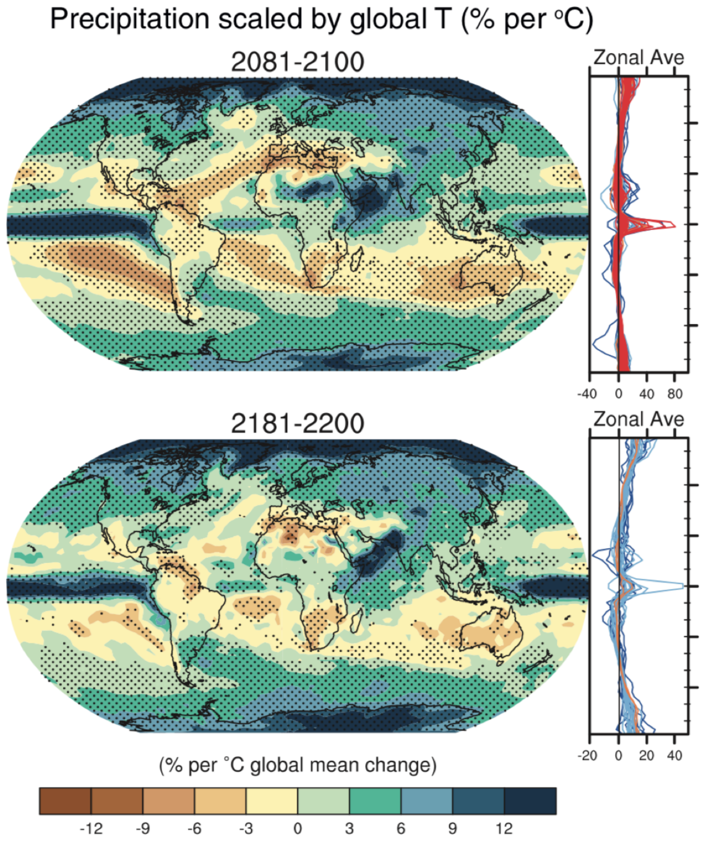
NOAA vs IPCC – who's right? (Hansen on the side of NOAA!

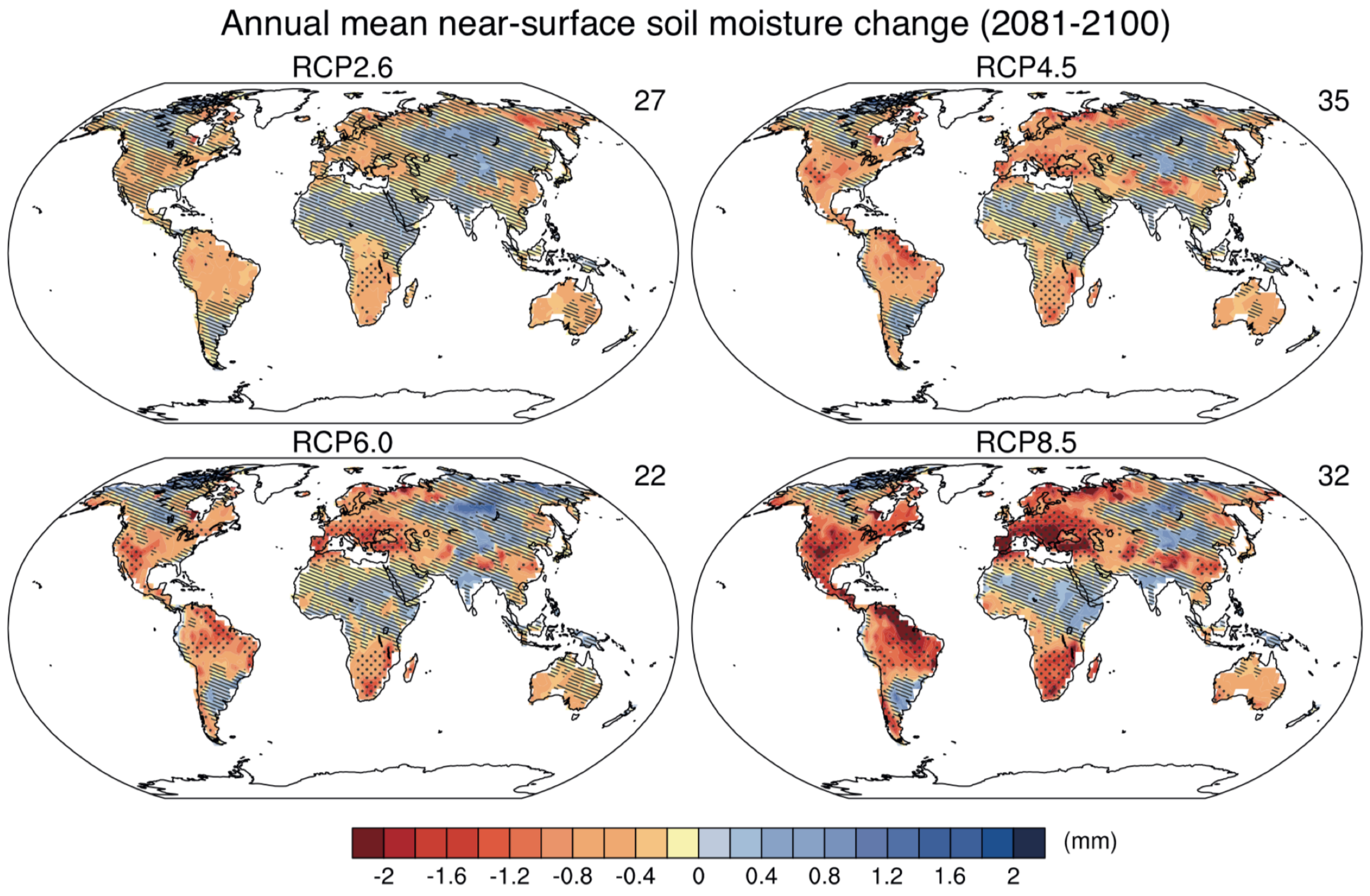


IPCC < 1 meter; Hansen and NOAA meters; the difference, Greenland!

IPCC

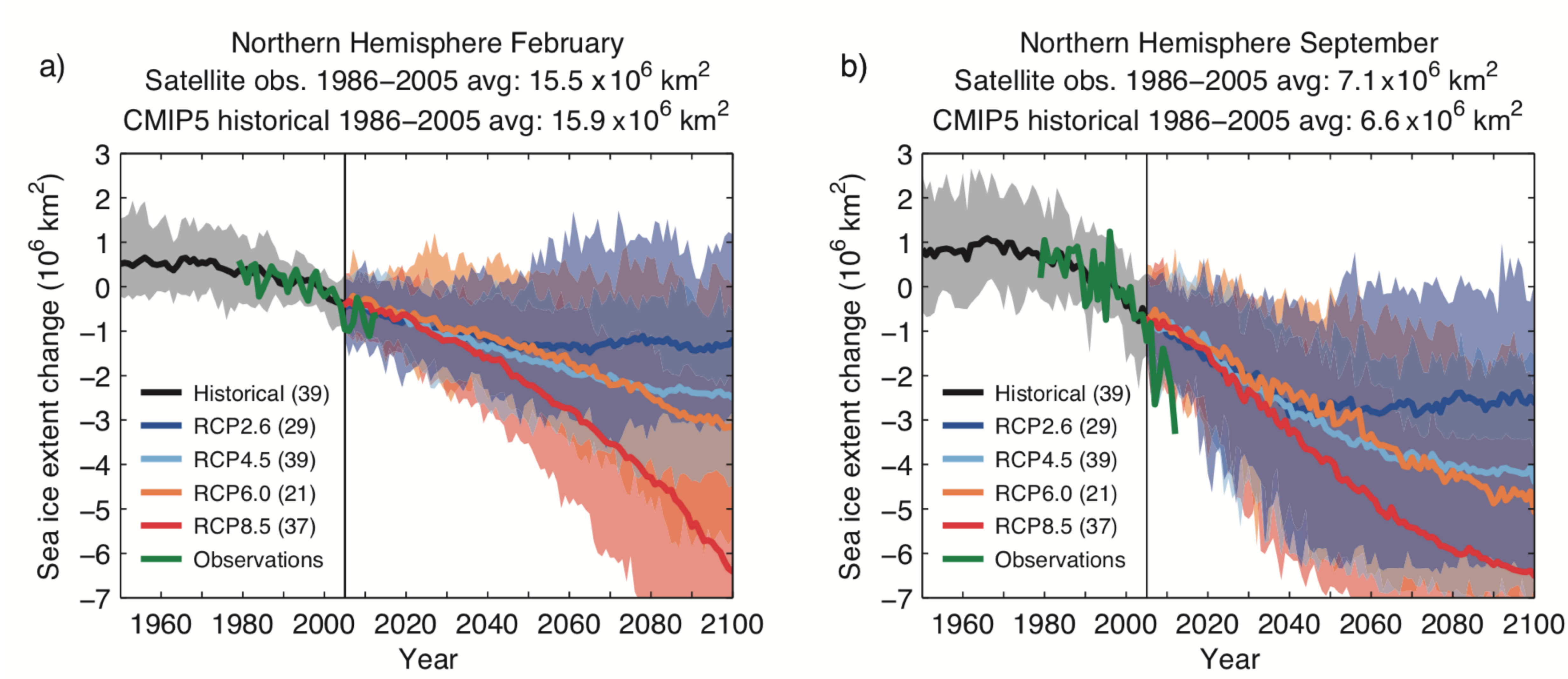
Precipitation – wet places get wetter, dry places get drier



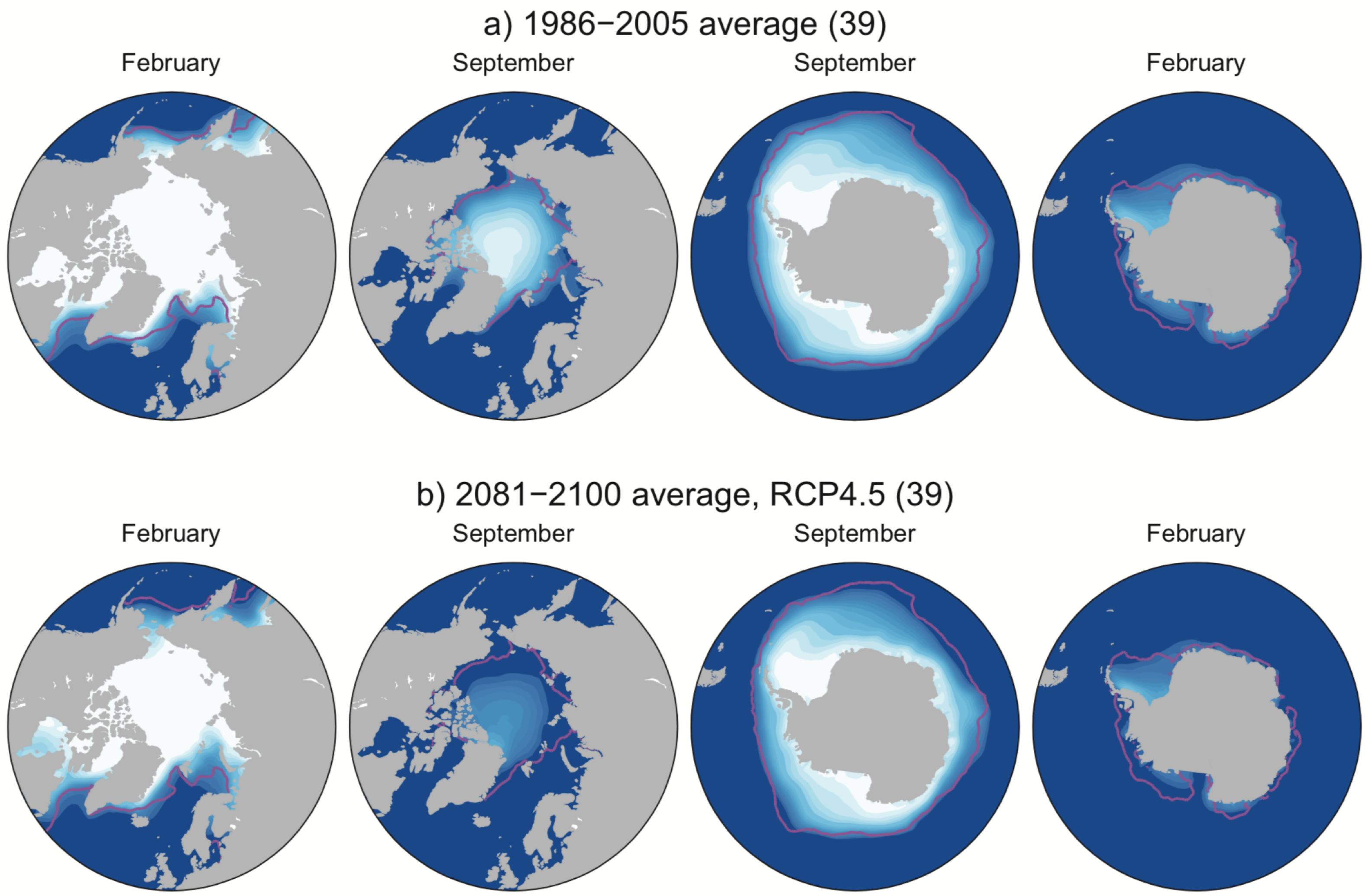


The cryosphere – greatly impacted and therefore, albedo

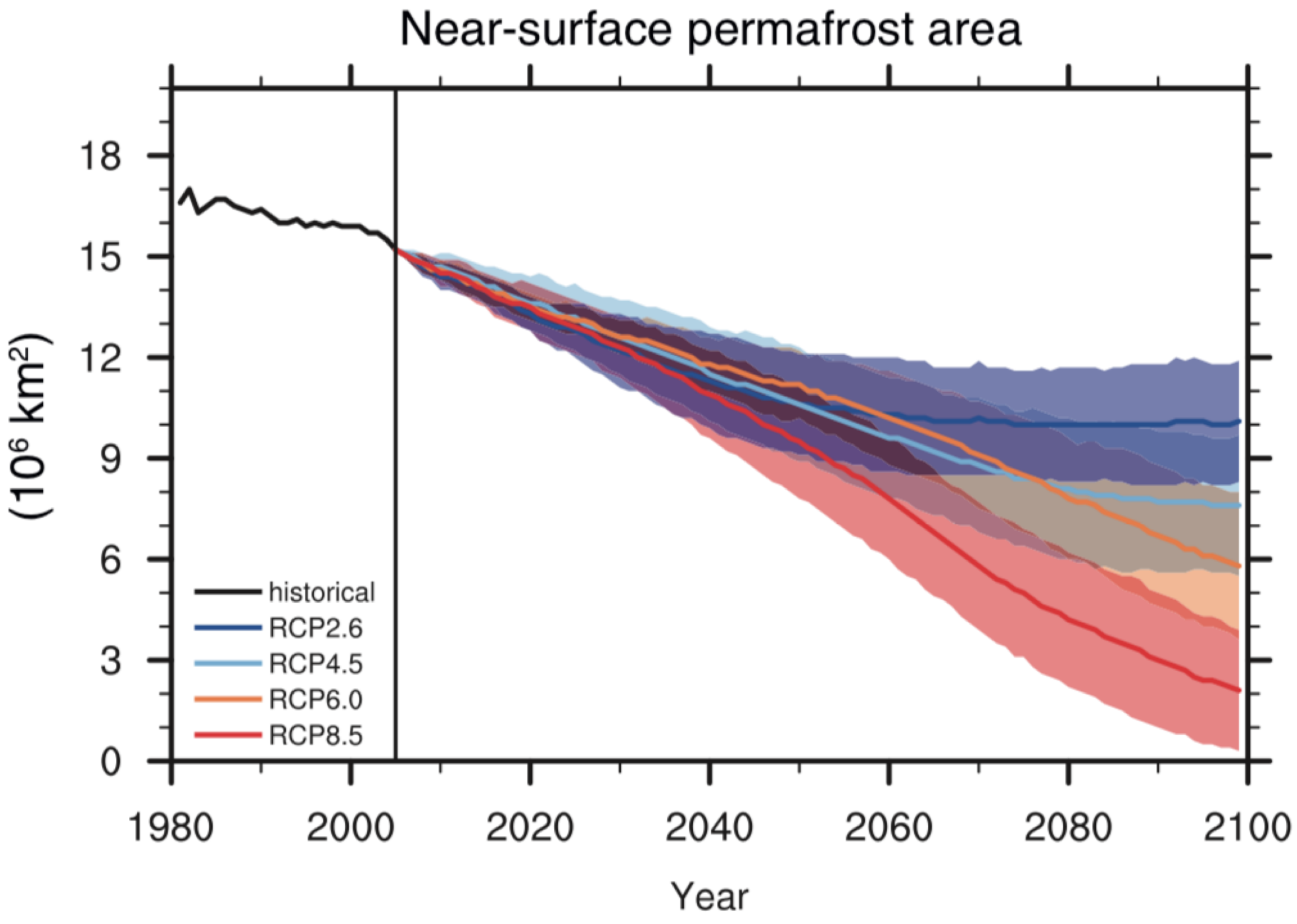
Sea ice much diminished or even gone



Mostly an arctic issue of summer sea ice loss – when it matters for albedo



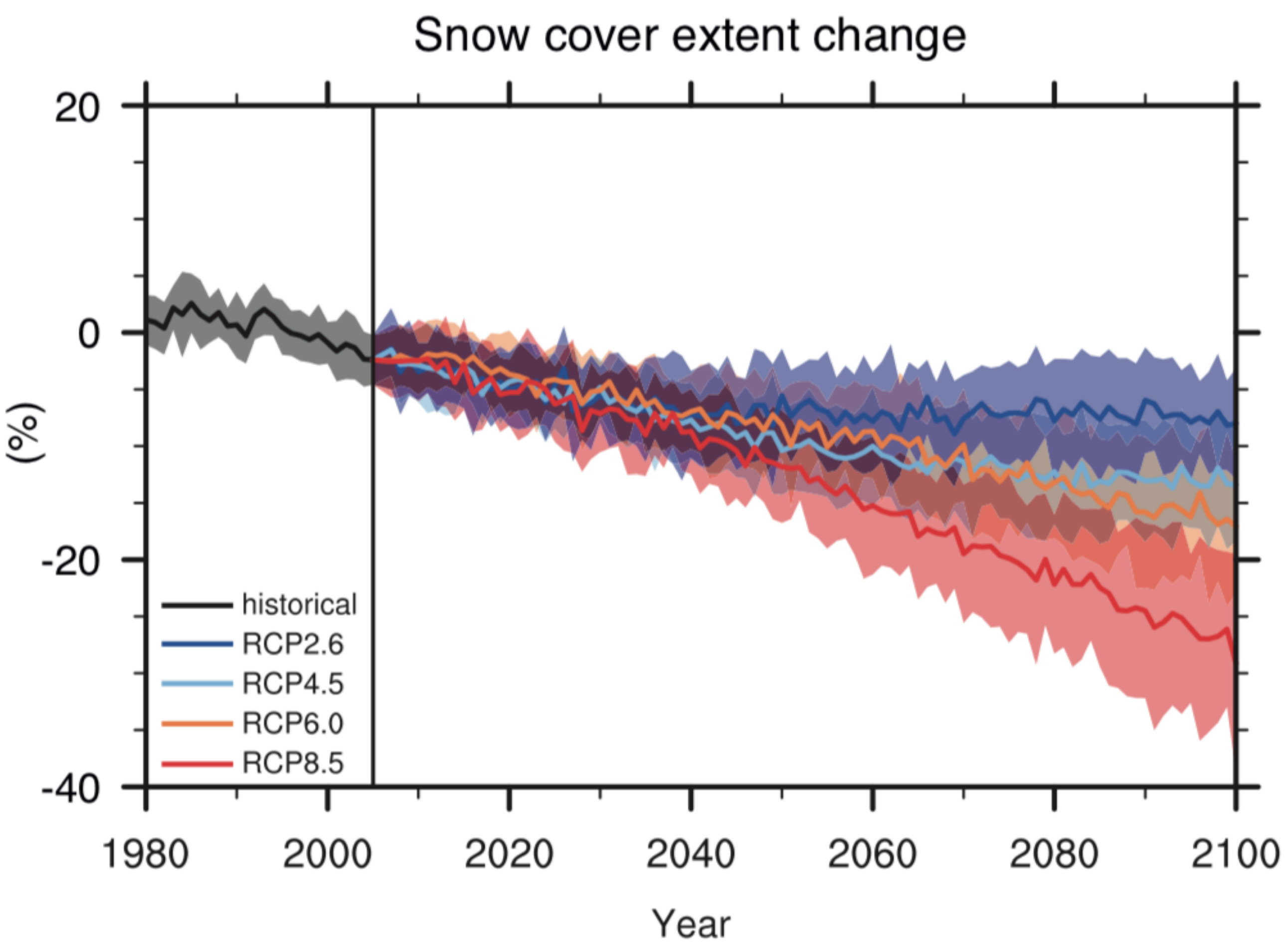
Permafrost shrinks dramatically – carbon release and landscape instability



Alaska Thaw Slump

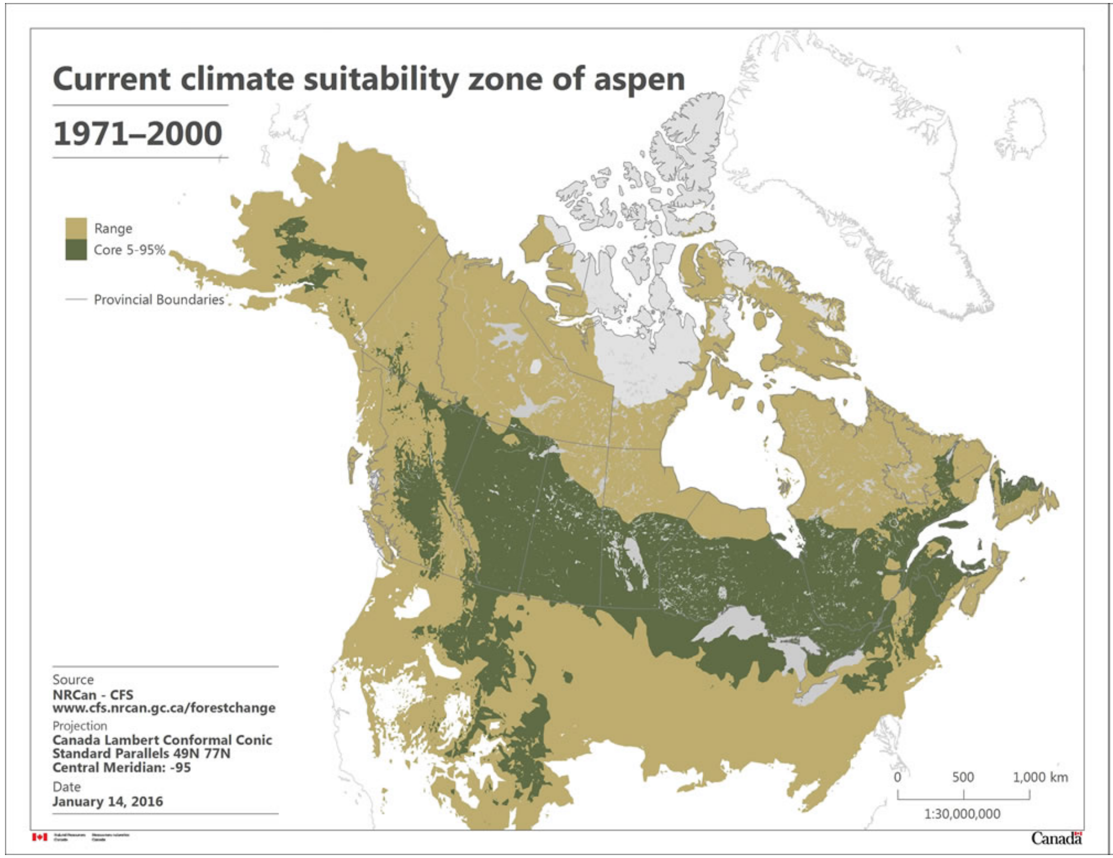
https://www.youtube.com/watch?v=0RCTqd0WEfM

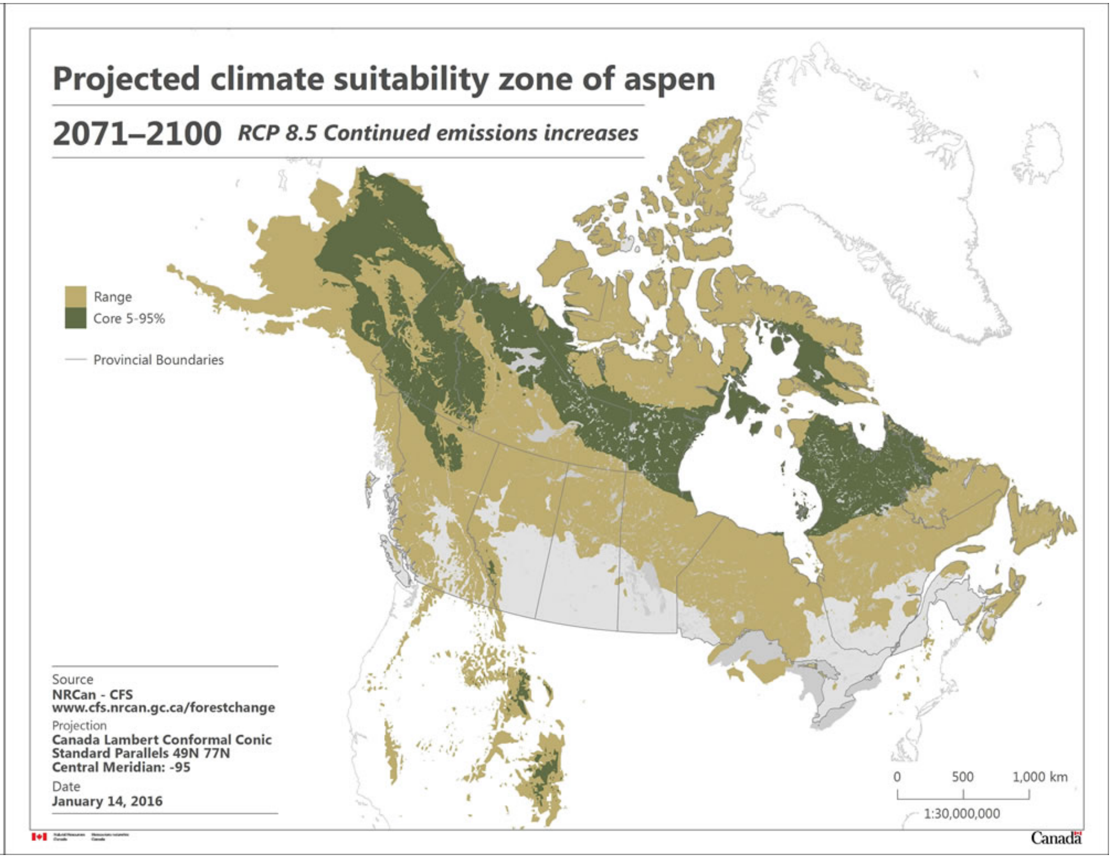
Snow cover diminishes and albedo rises



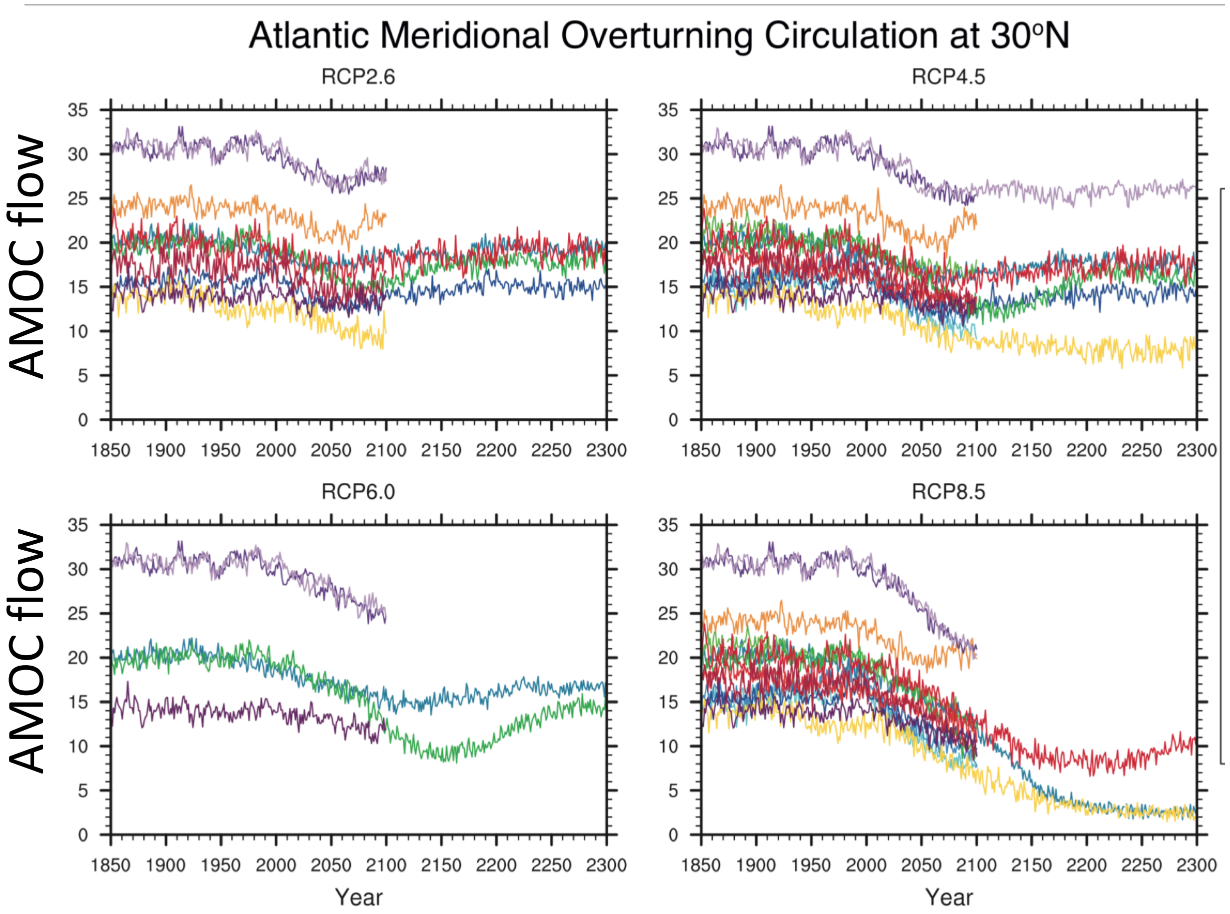
This is Northern Hemisphere spring snow cover

The biosphere. Major changes in species distribution

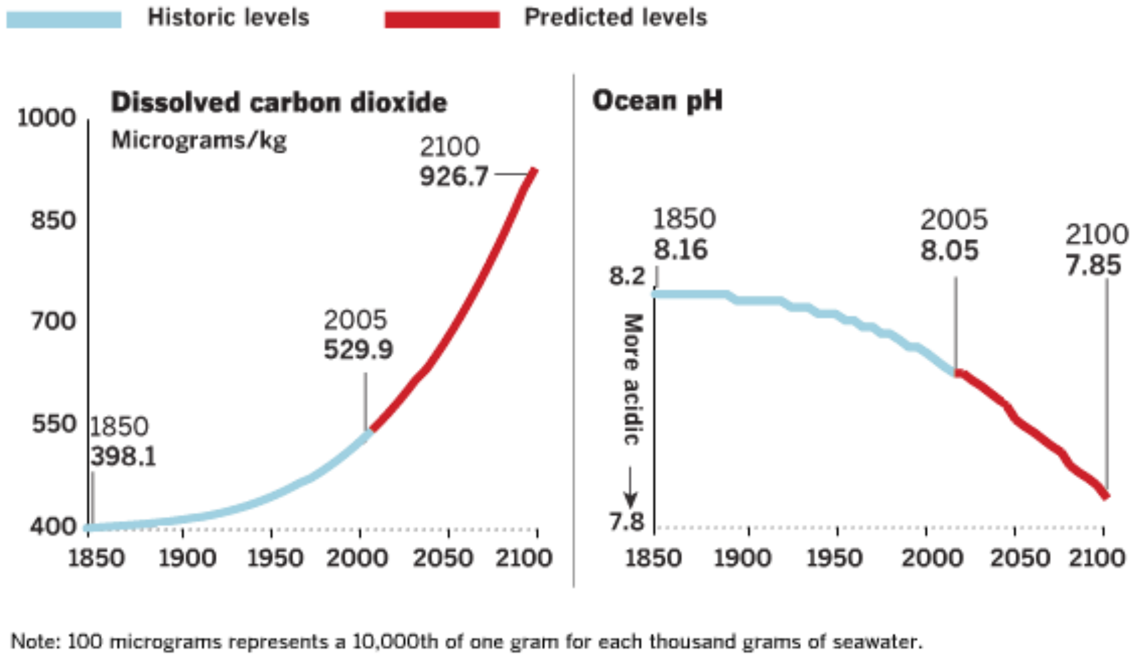




Ocean Circulation and Chemistry



AMOC could slow



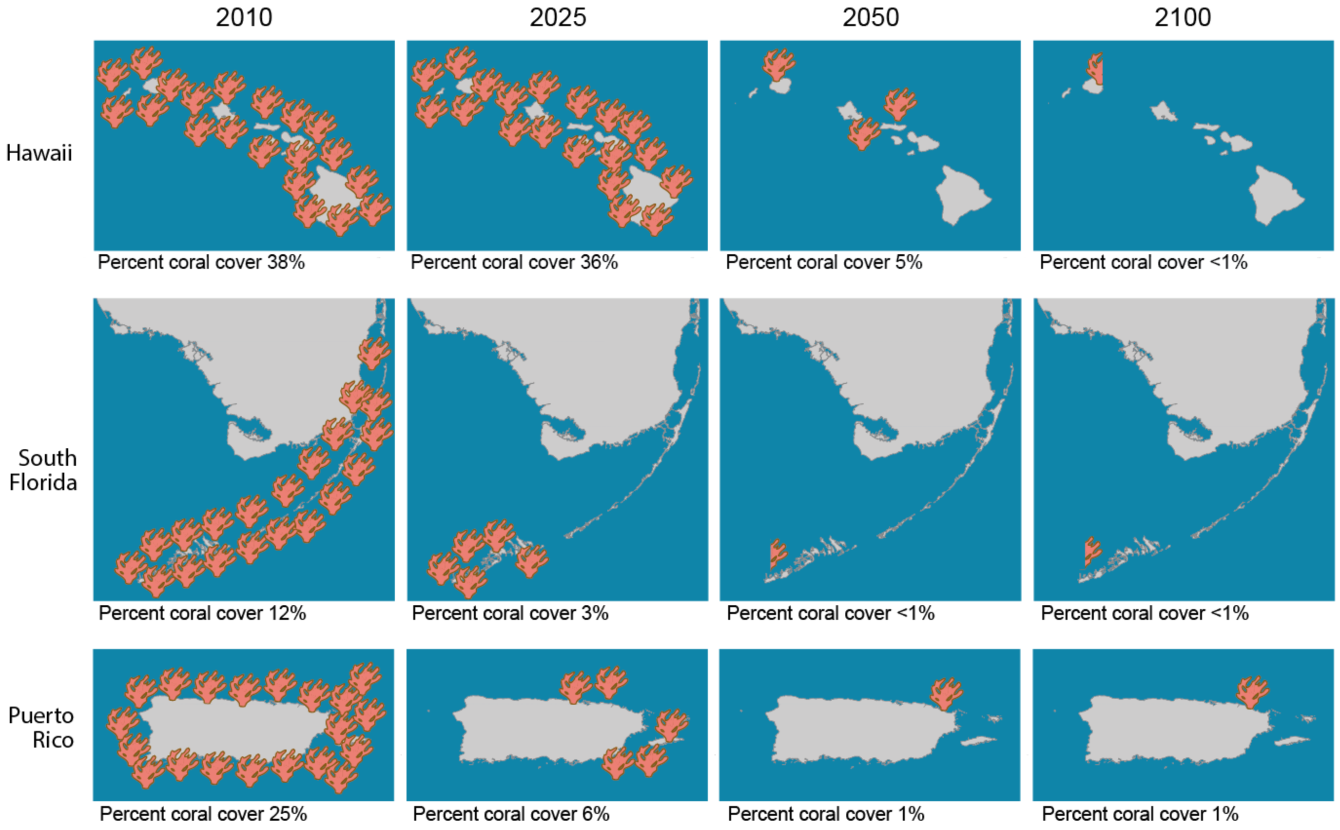
The oceans will become more acidic

http://www.ccdatacenter.org/

The end of coral reefs as we know them

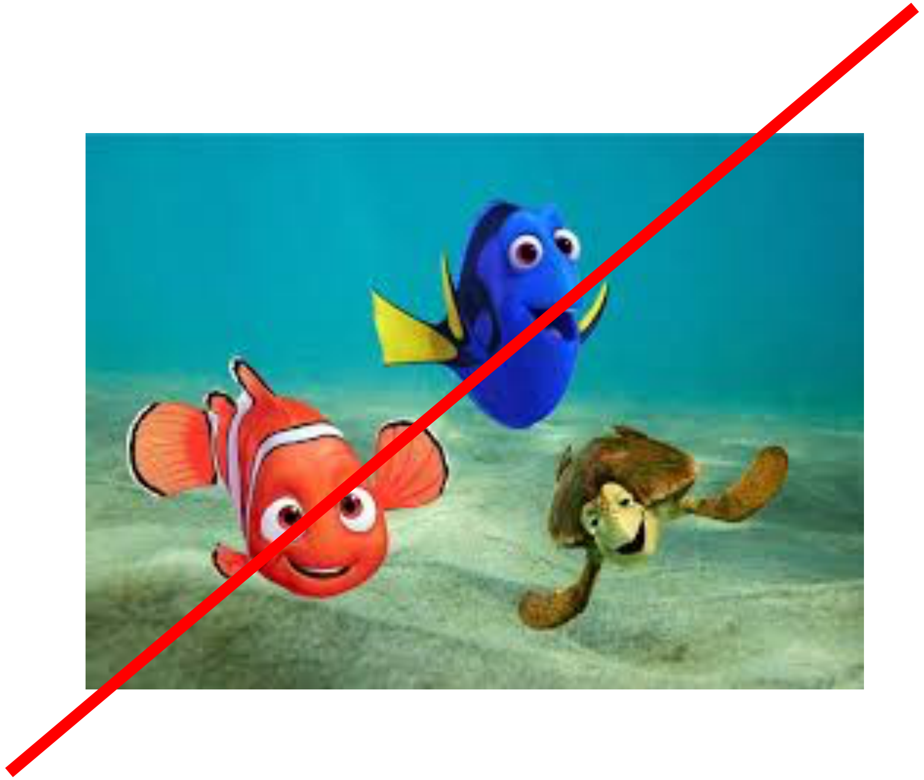
Figure 1. Projected Impact of Unmitigated Climate Change on Coral Reef Cover in the U.S.

Approximate reduction in coral cover at each location under the Reference scenario relative to the initial percent cover. Coral icons do not represent exact reef locations. Results for 2075 are omitted as there is very little change projected between 2050 and 2100.



For more information, visit EPA's "Climate Change in the United States: Benefits of Global Action" at www.epa.gov/cira.

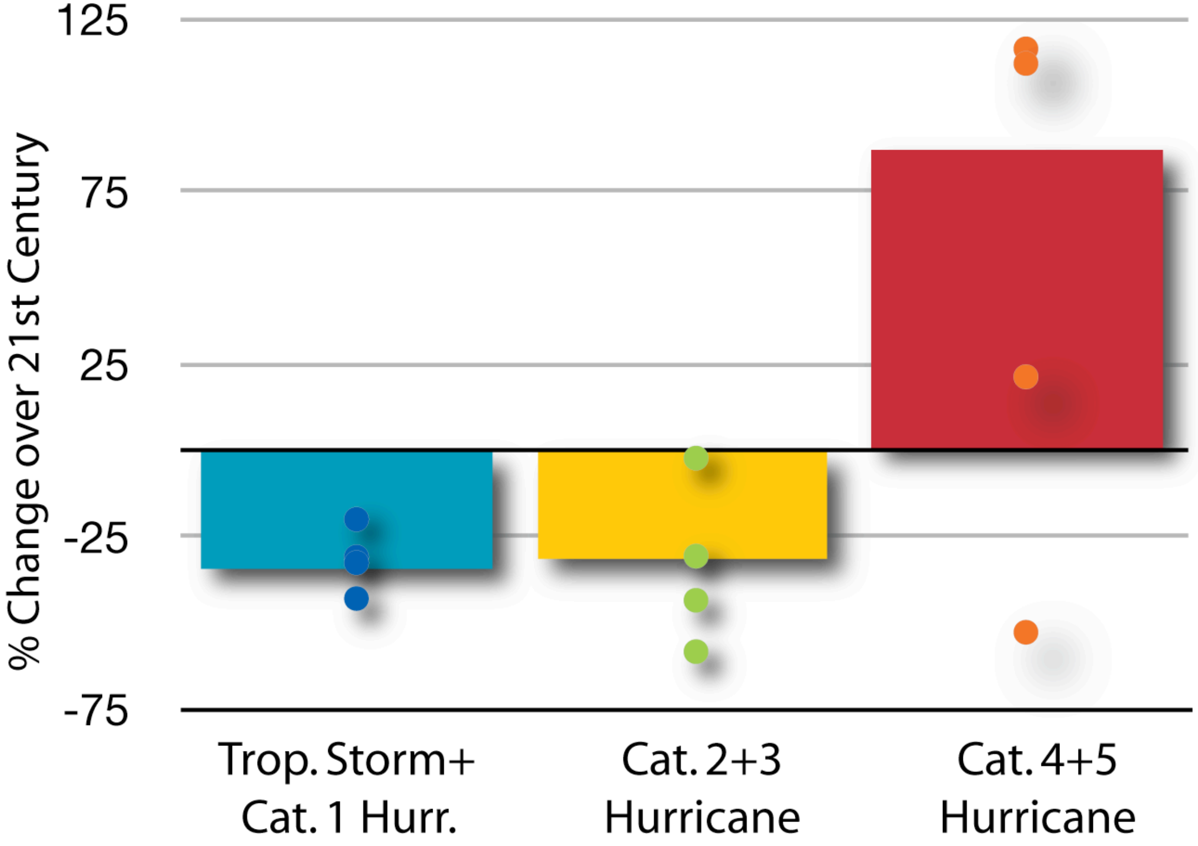
Combined effect of warming and acidifying ocean water



Intense storms will increase

Projected Changes in Atlantic Hurricane Frequency over 21st Century

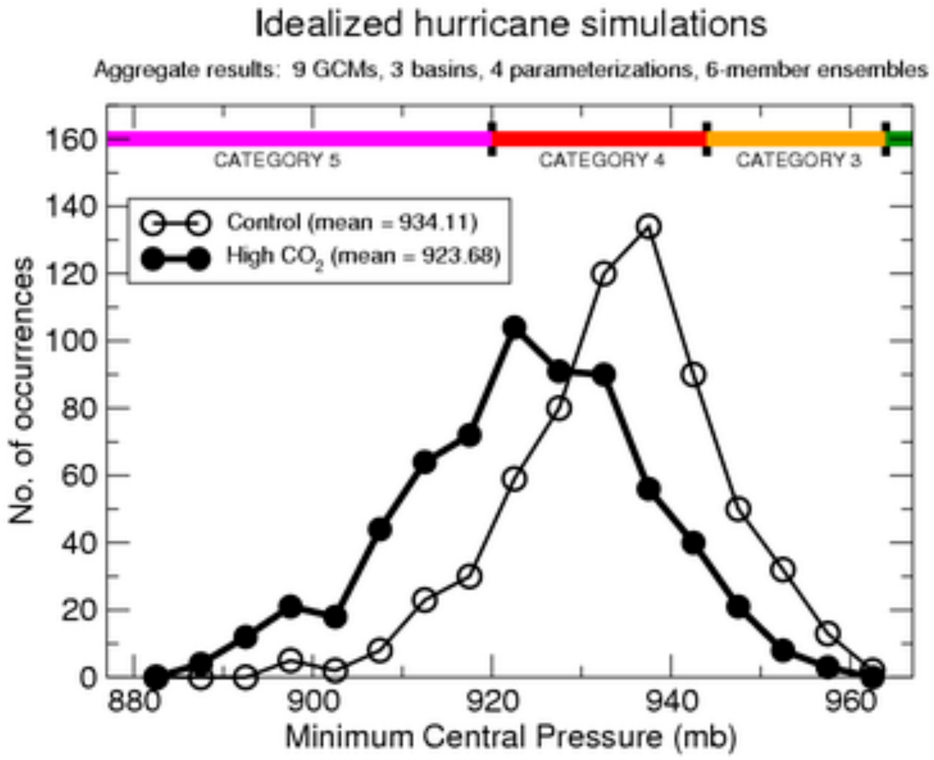
bars indicate "best" estimate, dots indicate alternative estimates.



REPORT

Modeled Impact of Anthropogenic Warming on the Frequency of Intense Atlantic Hurricanes

Morris A. Bender[1,*], Thomas R. Knutson[1], Robert E. Tuleya[2], Joseph J. Sirutis[1], Gabriel A. Vecchi[1], Stephen T. Garner[1], Is
+ See all authors and affiliations



The model projects nearly a doubling of the frequency of category 4 and 5 storms by the end of the 21st century, despite a decrease in the overall frequency of tropical cyclones

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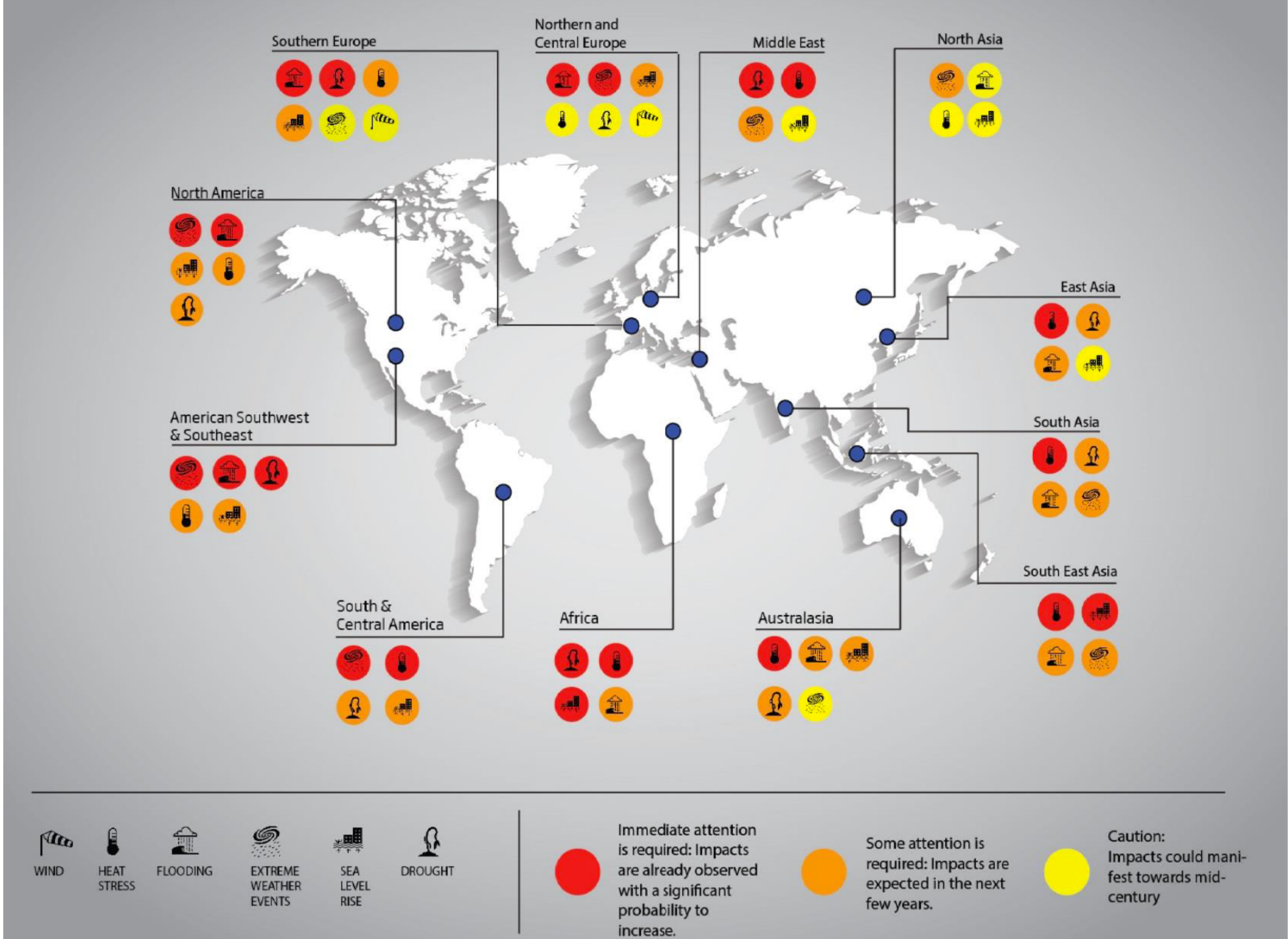
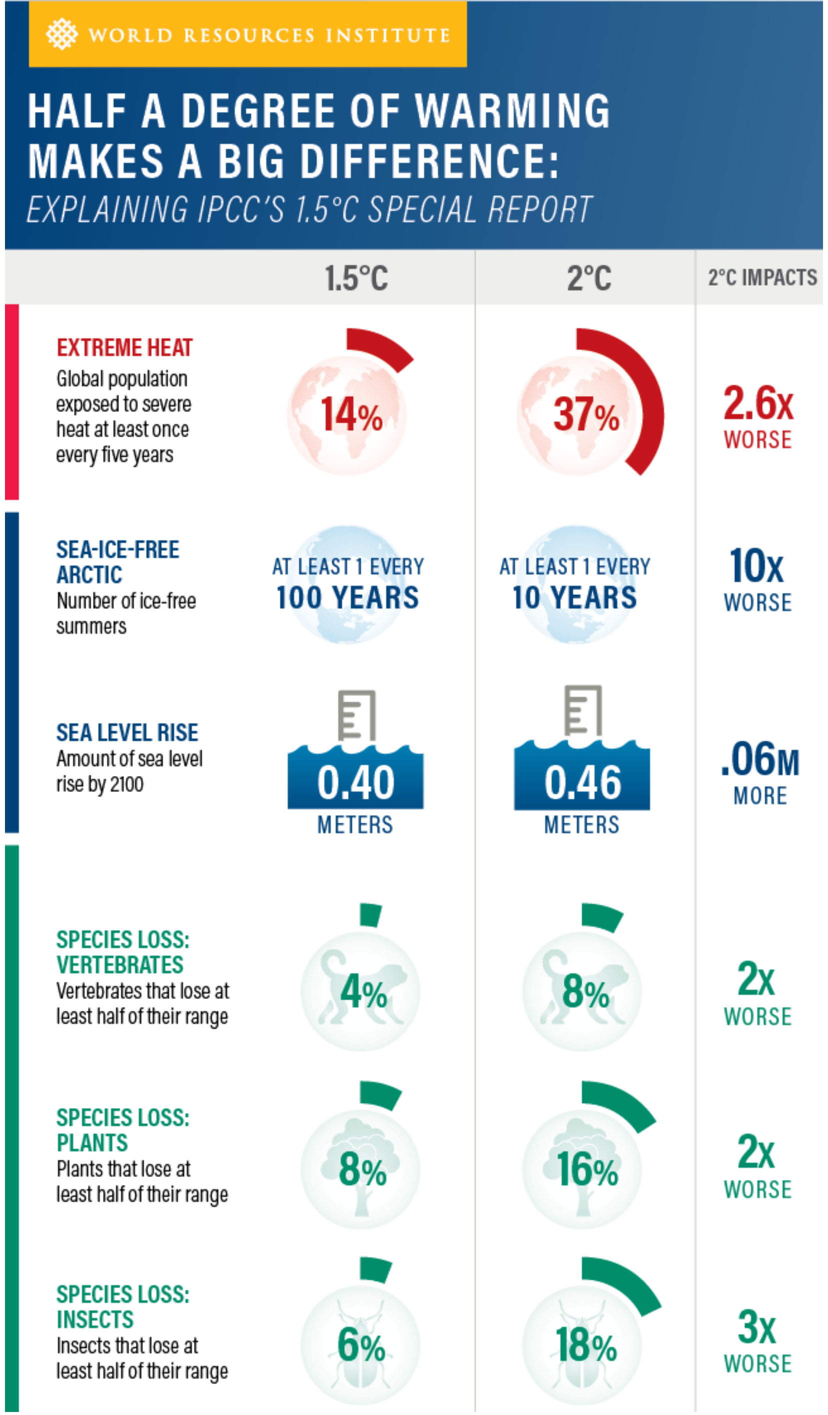
Global reach of climate change impacts on socirty



The amount of warming makes a major difference on impact severity



Drying rivers and shrinking glaciers imperil water supply

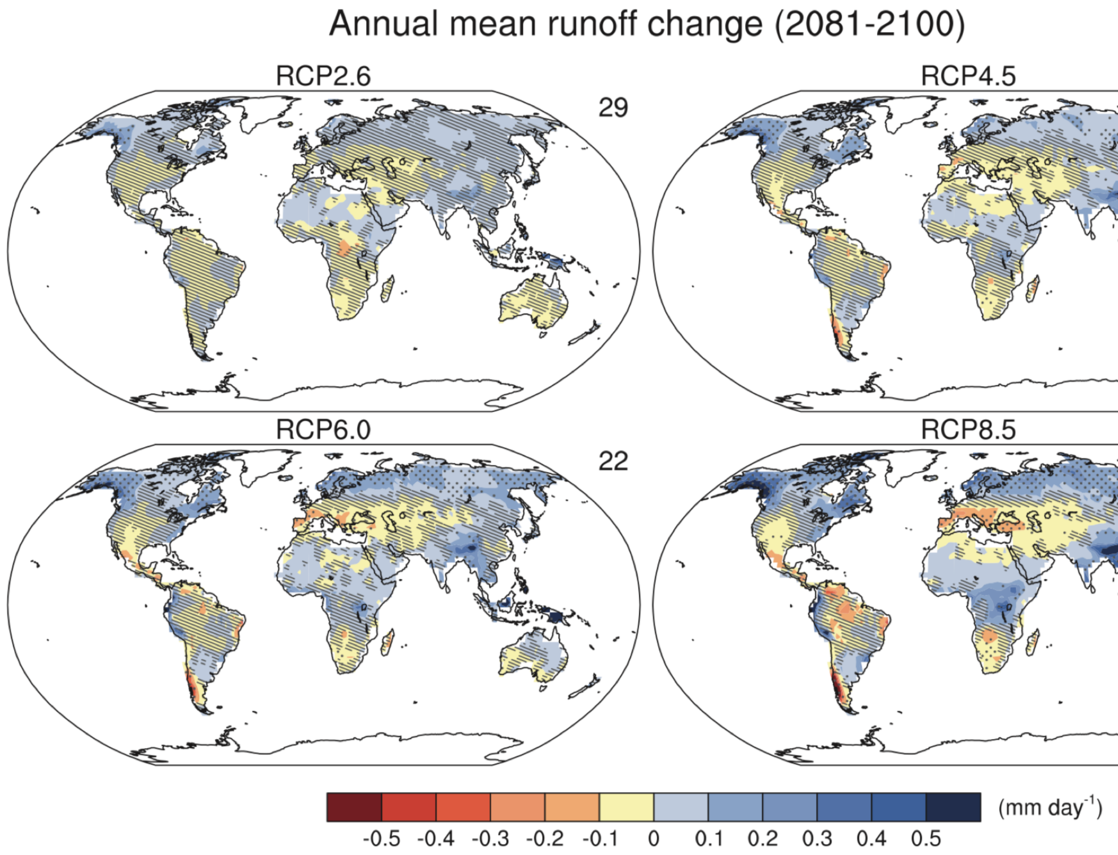
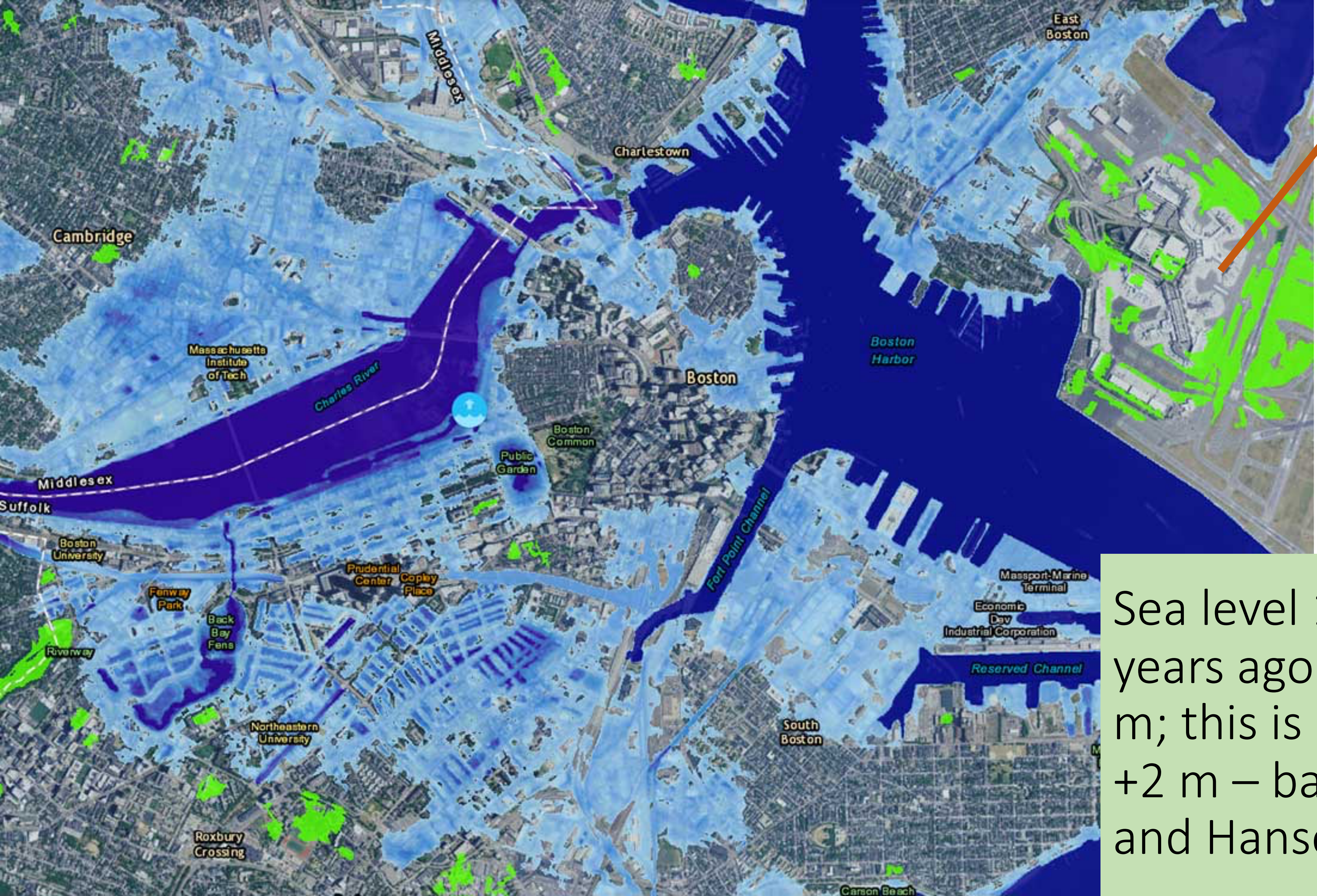


Figure 12.24 | Change in annual mean runoff relative to the reference period 1986–2005 projected for 2081–2100 from the CMIP5 ensemble. Hatching indicates regions where

Global and Planetary Change
Volume 159, December 2017, Pages 61-76

Glacier loss and hydro-social risks in the Peruvian Andes



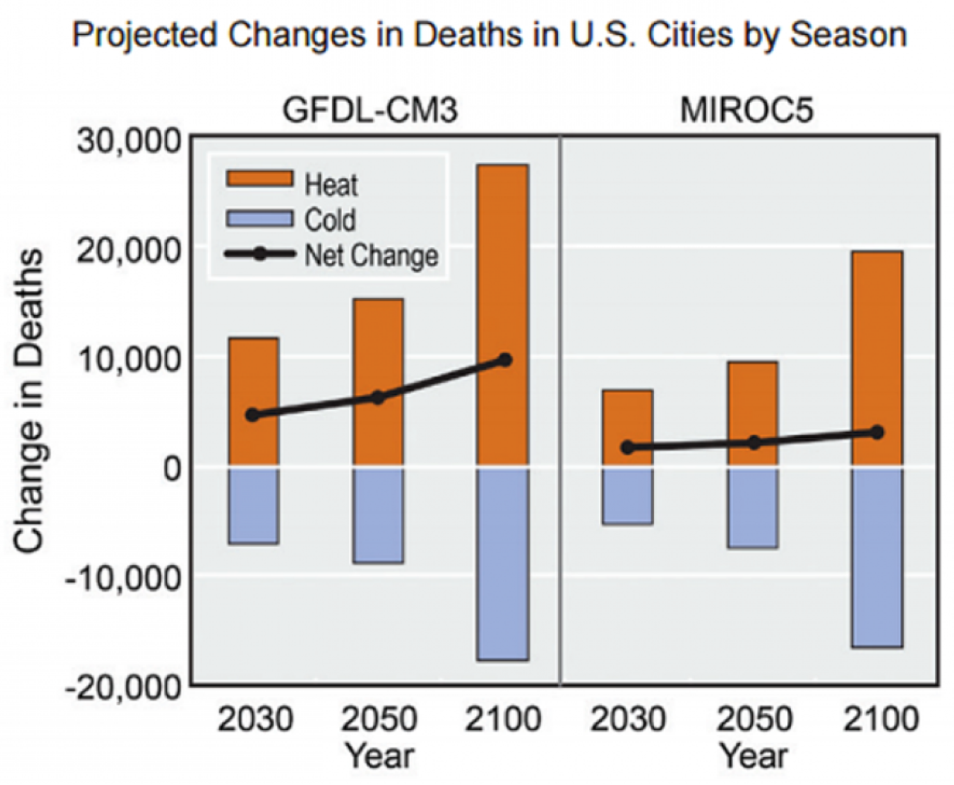
Take a sea plane from Logan?

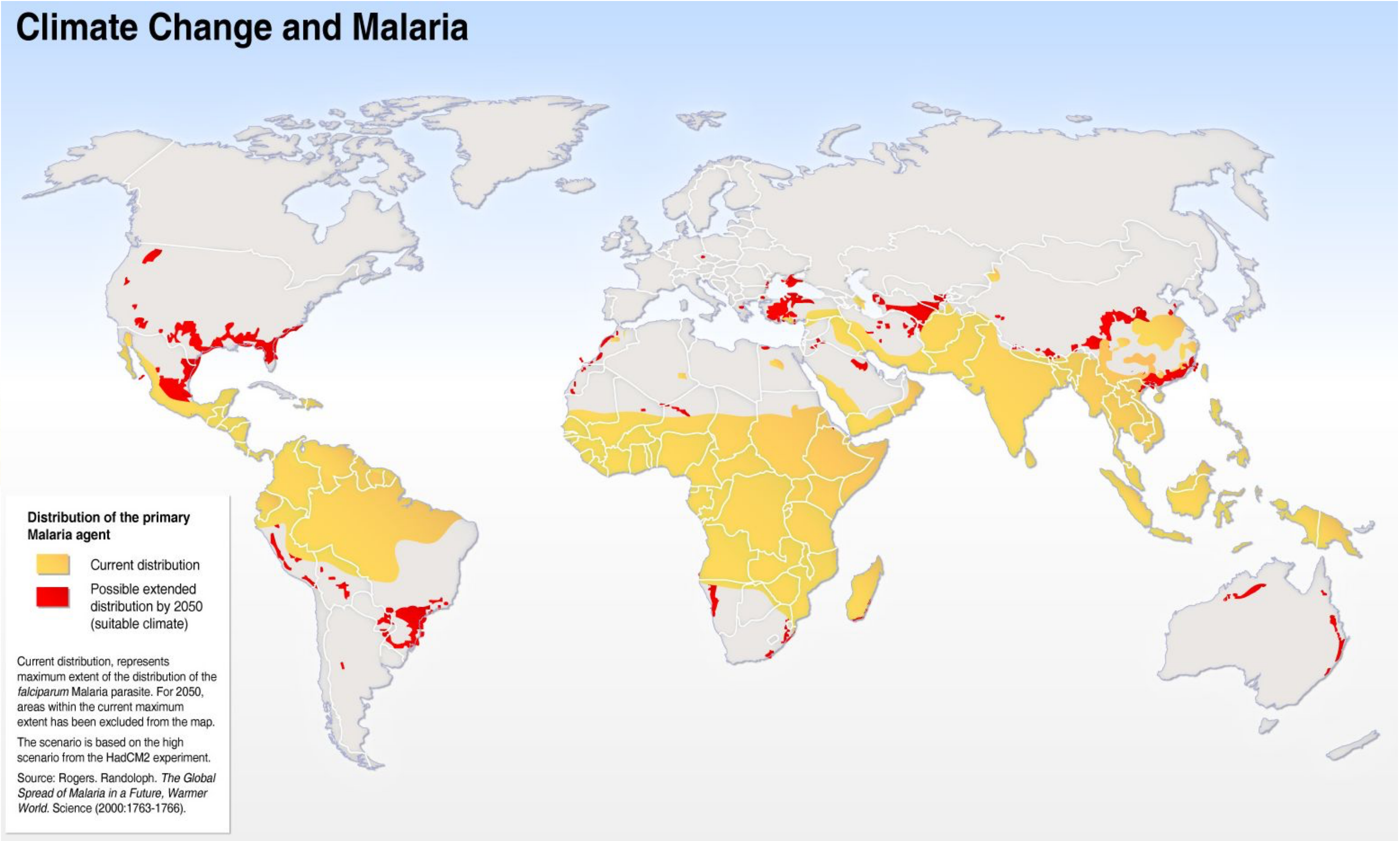
Models matter for planning

Sea level 125,000 years ago was +6-9 m; this is Boston at +2 m – back to NOAA and Hansen vs IPCC.

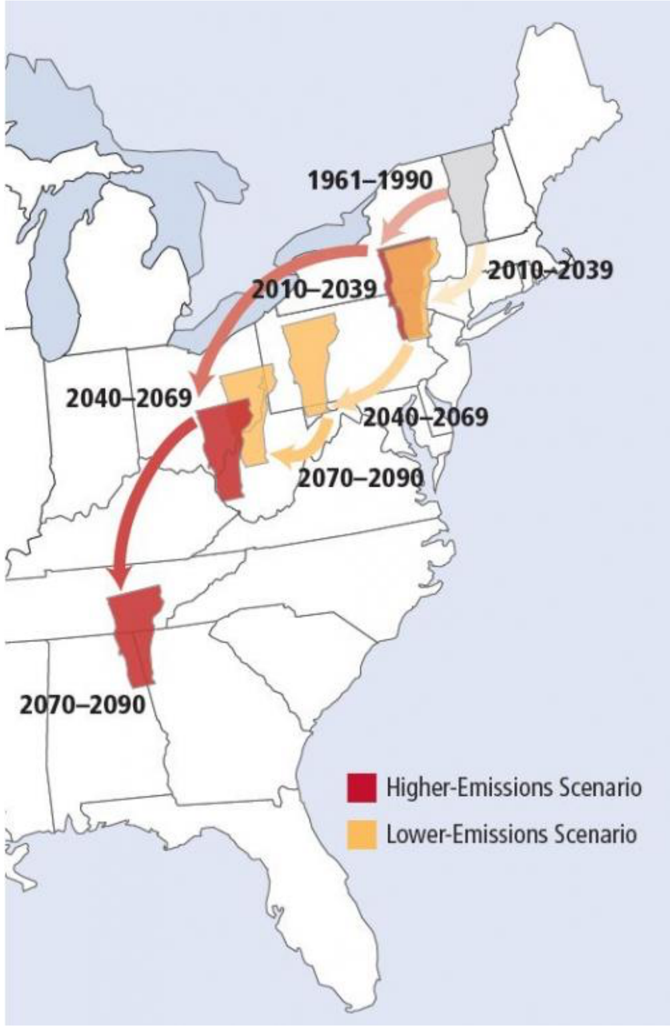
Predicitng Sea level effects - https://coast.noaa.gov/slr/

Human health effects could be severe

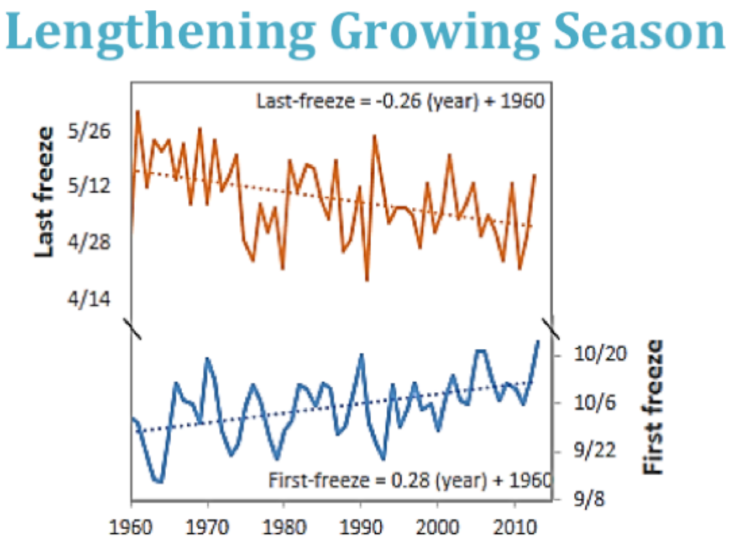


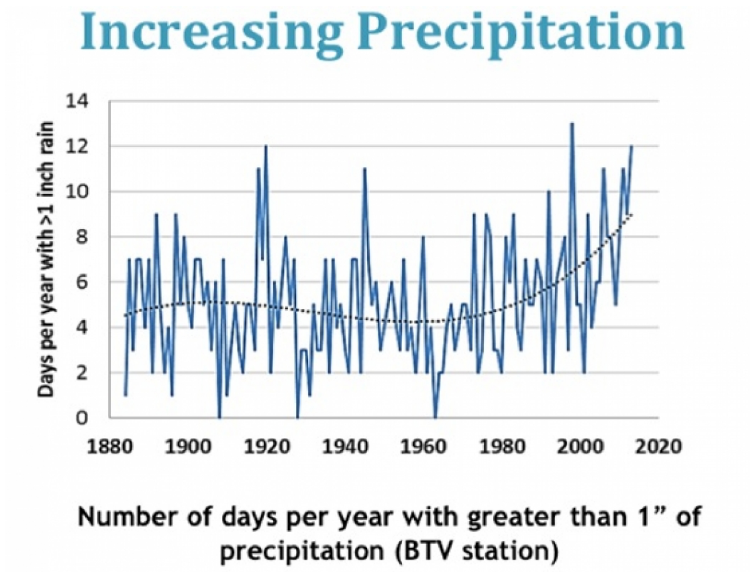


Vermont – what this means for us



It's as though we, as a State, are taking a road trip south. Vermont will get warmer and wetter.





http://vtclimate.org/vts-changing-climate/

http://www.globalcarbonatlas.org