Rapid Climate Change in the Arctic
(And Why Everybody Should Care)

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THE WHITE HOUSE
(January 2009 – January 2017)

A Lecture Hosted By
Xue Lan, Dean of Schwarzman Scholars
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Topics to be covered

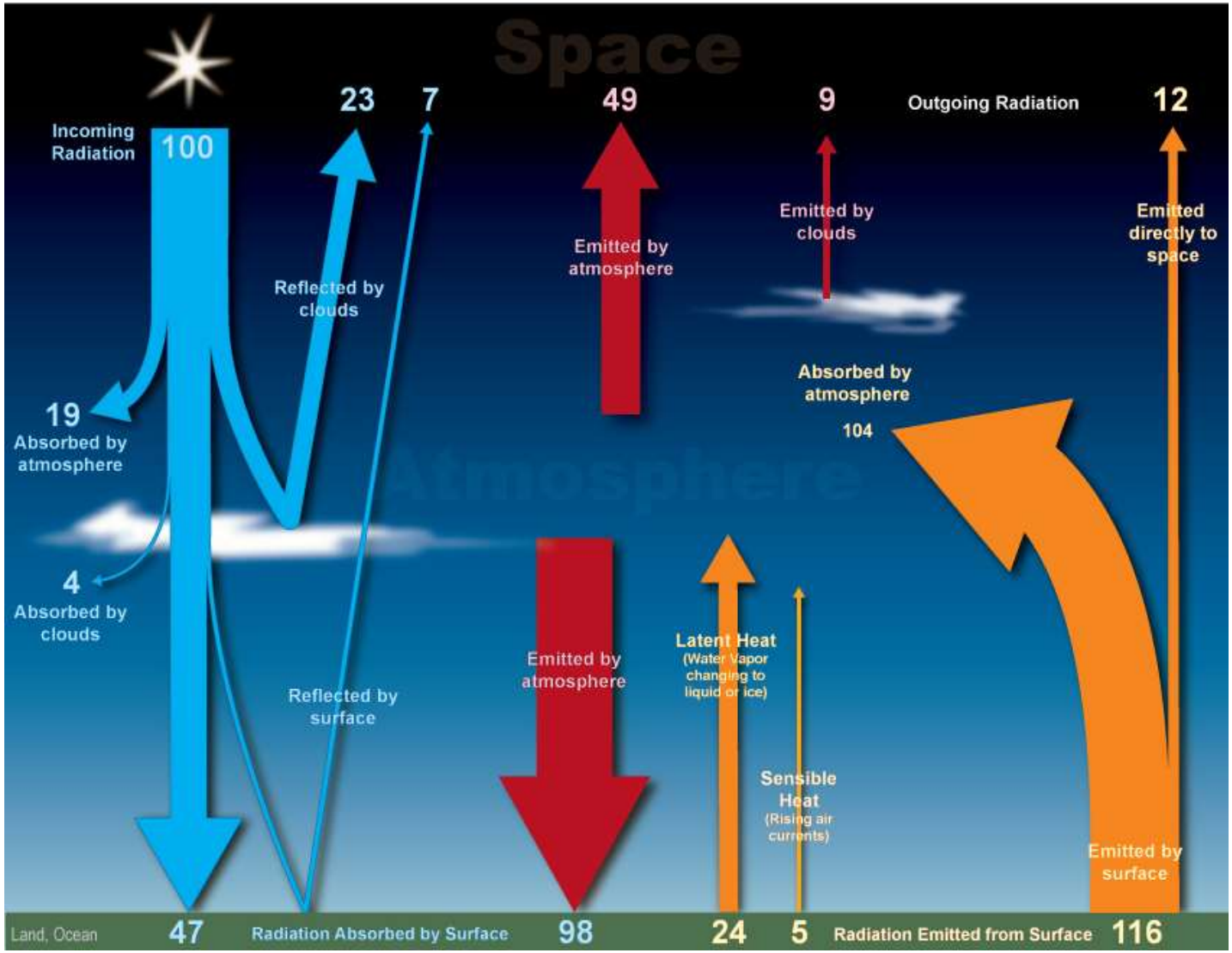
- Human-caused climate change globally
- Human-caused climate change in the Arctic
- Why everybody should care about climate change in the Arctic
- What is being done about…
  - the pace of climate change worldwide
  - impacts <u>in</u> & propagating <u>from</u> the Arctic
- What more is needed

Human-Caused Climate Change Globally

"Science is true whether or not you believe in it."

Neil deGrasse Tyson

Earth's temperature depends on the balance between incoming & outgoing energy



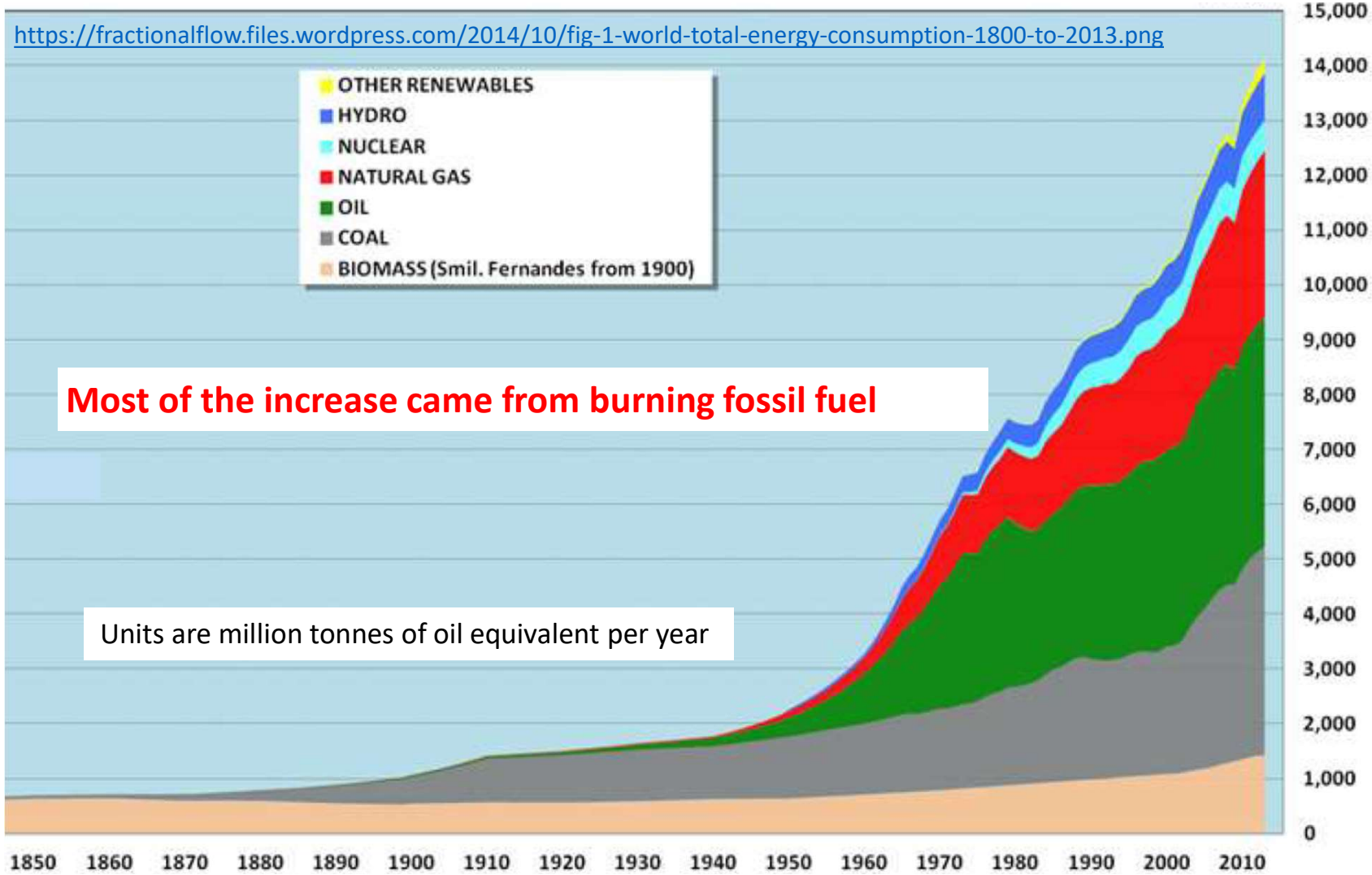
The quantity of "greenhouse gases" in the atmosphere influences this balance.

Some greenhouse gases exist in the atmosphere naturally; some are added by human activities.

- The most important naturally occurring greenhouse gases are water vapor (H_2O) and carbon dioxide (CO_2).
- Without them, the surface of the Earth would be too cold to support life as we know it.
- When humans burn coal, oil, and natural gas ("fossil fuels") or wood, the combustion products, CO_2 and H_2O, go into the atmosphere.
- The H_2O remains in the atmosphere only briefly and so does not add much to the natural water vapor there.
- But much of the CO_2 remains for centuries, and so its concentration in the atmosphere builds up over time as fossil fuels and forests are burned.

Fundamentals of human-caused climate change

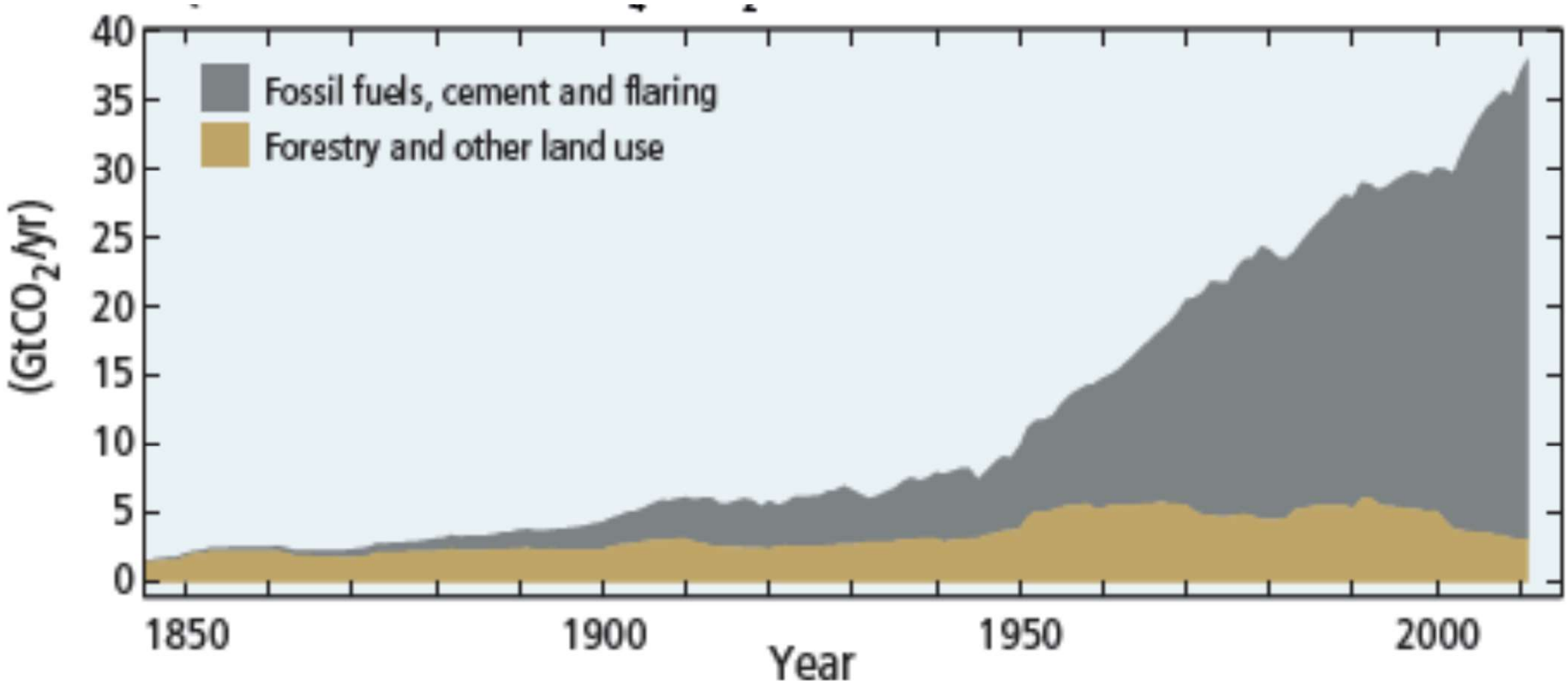
Growth of population & prosperity from 1850 to the present increased world energy use by over 20-fold



In 2019, coal, oil, & natural gas still supply about 80% of world energy consumption and two-thirds of electricity generation.

Civilization's CO_2 emissions grew along with deforestation and fossil-fuel use

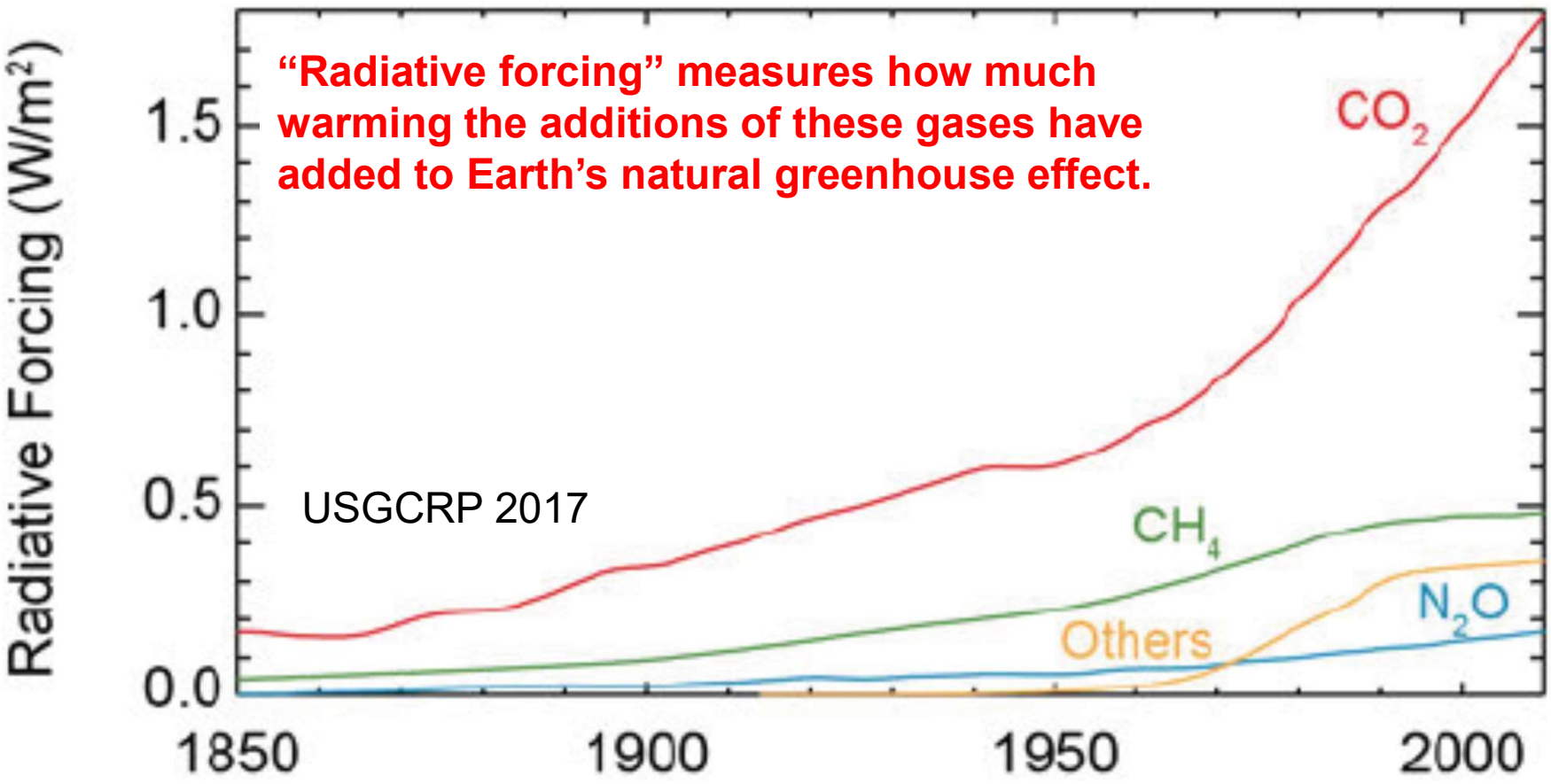
Global CO_2 emissions from human activities



IPCC AR5 SYN Fig SPM-1

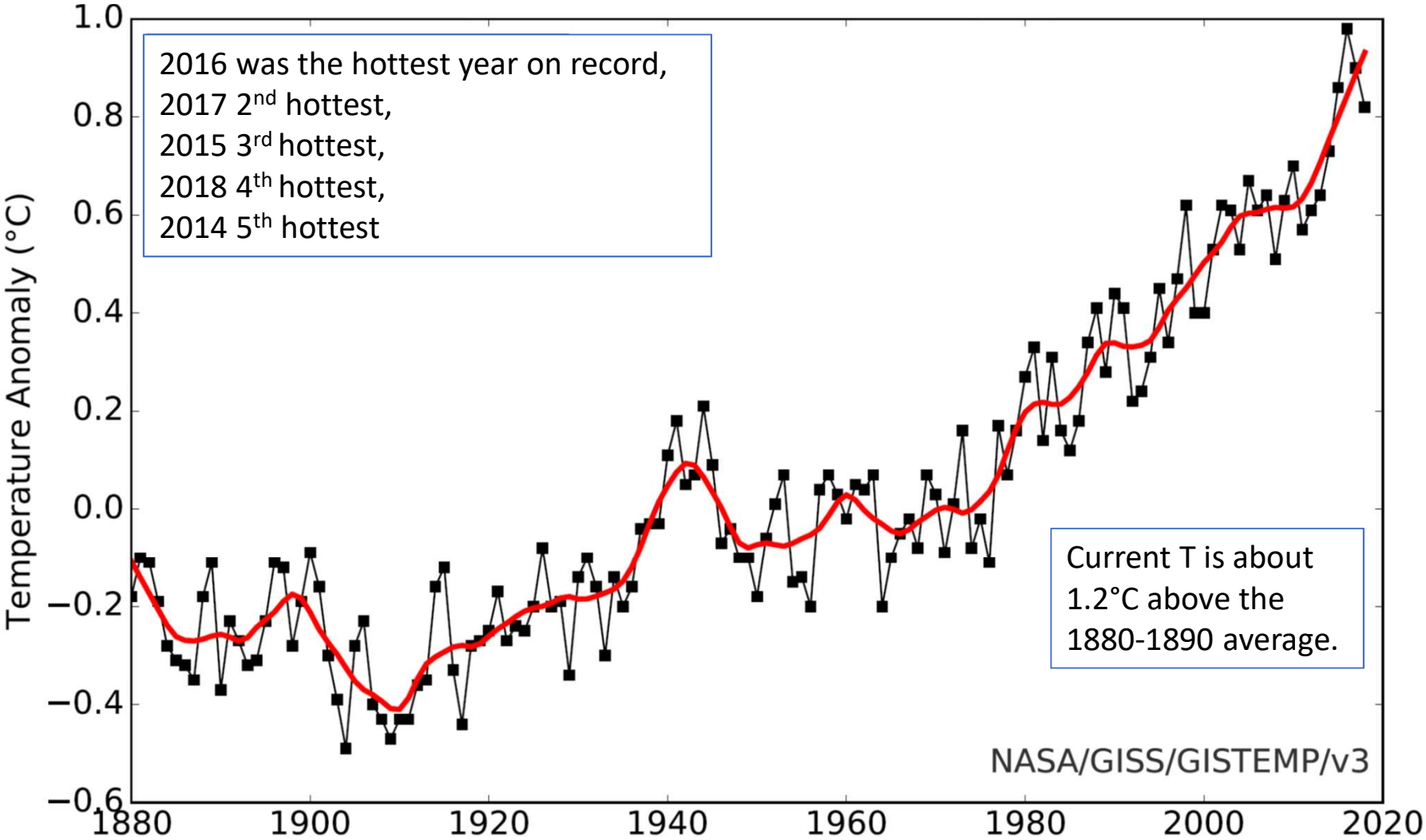
The buildup of CO_2 and other greenhouse gases changed the energy balance of the Earth.

Methane (CH_4) and nitrous oxide (N_2O) come from energy, agriculture, & decomposition of dead organic matter



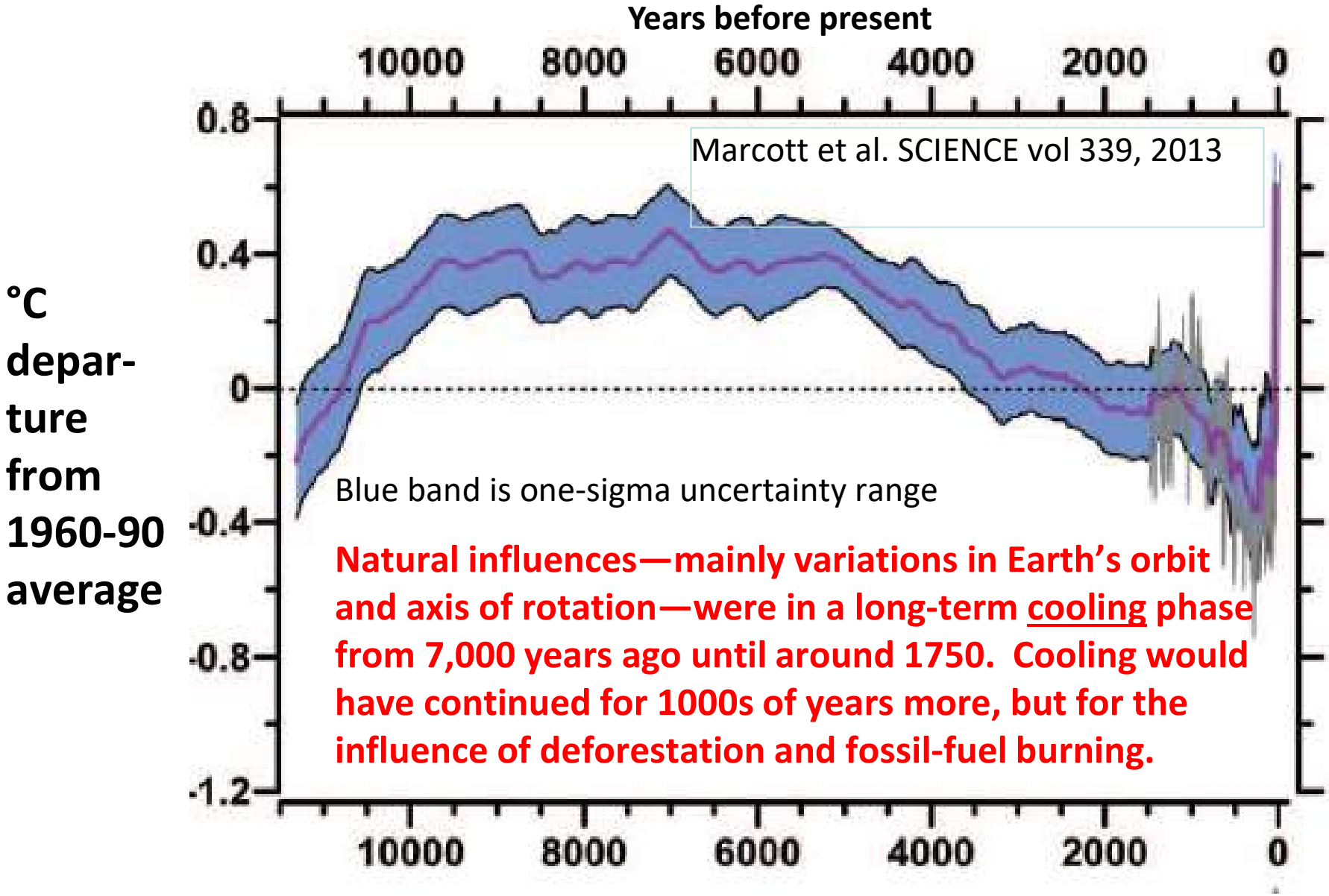
The warming from forcing by GHGs is evident

Global average surface air temperature from thermometer measurements



From 1750 to 1900 natural cooling & human-caused warming were in rough balance, so globally and annually averaged temperature stayed roughly constant. The 20th century saw global warming because the human influences had become dominant.

The human warming influence overcame slow natural cooling that started 7,000 years ago



Climate change is not only about temperature

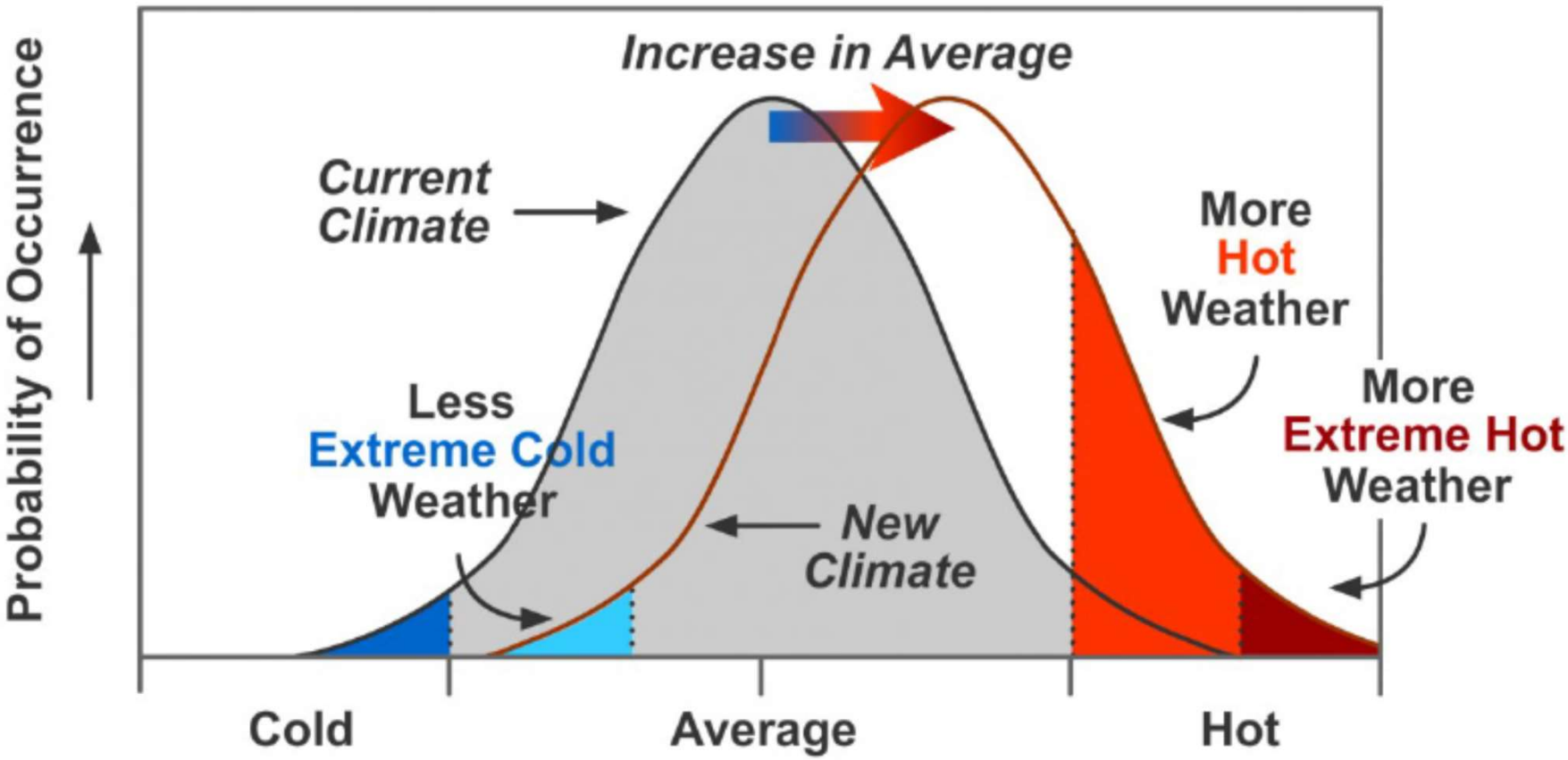
Climate = weather patterns, meaning averages, extremes, timing, and spatial distribution of…

- not only hot & cold, but also…
- humid & dry
- cloudy & clear
- drizzles, downpours, sleet, hail
- snowfall, snowpack, snowmelt
- breezes, blizzards, tornadoes, hurricanes

Climate change entails disruption of the patterns.

Global average T is just an index of the state of the global climate system as expressed in these patterns. Small changes in the index correspond to big changes in the system (much like your body temperature).

Modest increase in average T → very large change in extremes



In a warmer climate, extreme high temps that previously were very improbable now occur much more frequently. The accentuation of extremes accompanying small changes in the average occurs with any normally distributed variable.

Some all-time high temperatures reached in 2017-18

• Iran	129°F	June 2017
• Pakistan	128°F	May 2017
• South Africa	122°F	Nov 2018
• Spain	117°F	July 2017
• Chile	113°F	Jan 2017
• Los Angeles	111°F	July 2018
• Argentina	110°F	Jan 2017
• Shanghai	106°F	July 2017
• San Francisco	106°F	Sept 2017
• Denver	105°F	June 2018
• Hong Kong	102°F	Aug 2017

Already, working outdoors in the hottest months risks heat stroke in many regions.

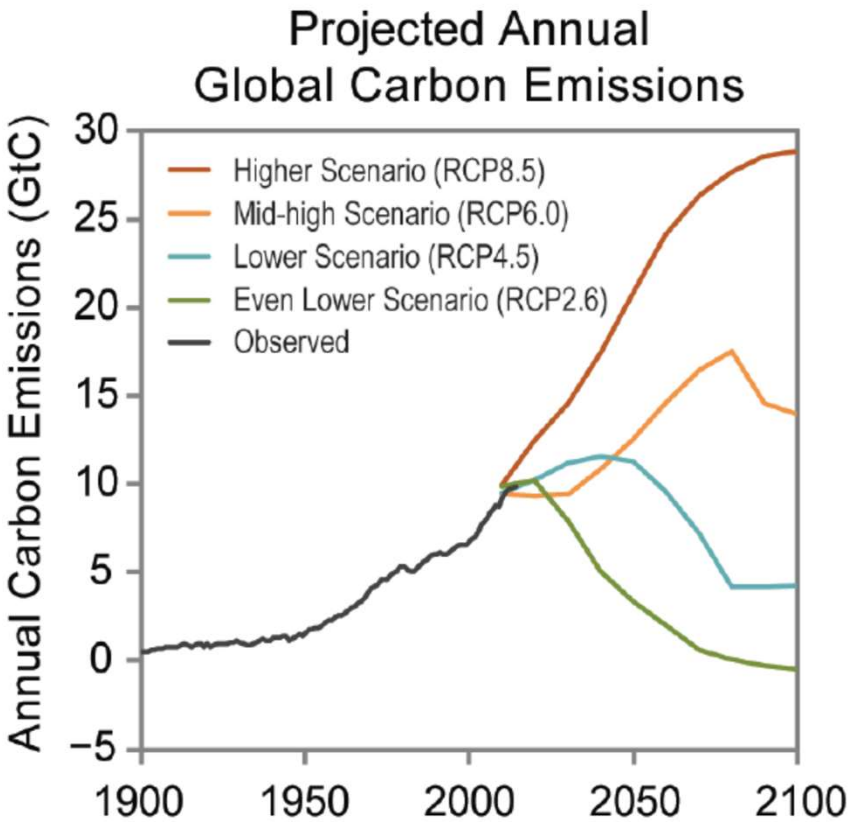
Changes in average & extreme weather are producing widespread harm <u>today</u>, including increases in…

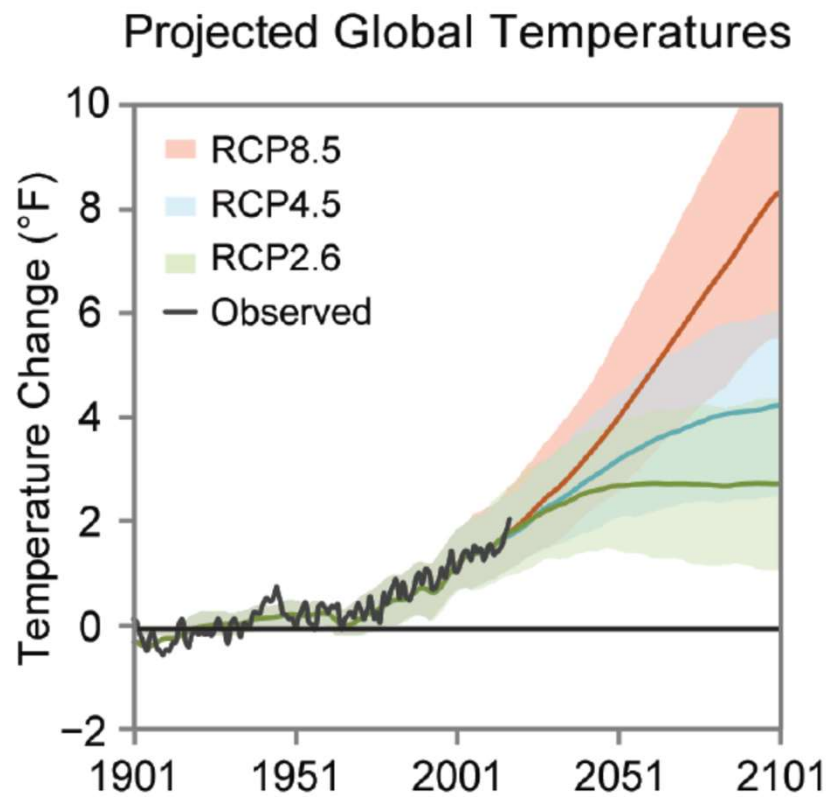
- severe floods
- intense droughts
- bigger, hotter wildfires
- power of strongest storms
- heat waves and heat stress
- other harm to human health
- coastal erosion and inundation
- impacts of crop and forest pests
- permafrost thawing and subsidence
- ocean impacts of warming and acidification
- distribution and abundance of valued species

<u>All</u> are plausibly linked to climate change by theory, models, and observed "fingerprints"; most growing <u>faster</u> than projected.

What's coming is worse: temps will keep rising

But <u>how much</u> they rise depends strongly on emissions.





Momentum in the climate system means T continues to go up even after atmospheric conditions stabilize. And sea level continues to go up even after T stabilizes.

NCA4 Science Report, 2017

Absent big, fast emissions cuts, we can expect…

- Record heat waves as "the new normal"
- Far more torrential downpours & flooding
- Large expansion in area burned by wildfires
- Destruction of most of the world's coral reefs
- Wider disruption of marine food webs & fisheries
- Big increases in frequency & intensity of droughts
- More Cat 3-5 hurricanes/typhoons making landfall
- More sickness & death from heat stress, tropical diseases
- Falling agricultural yields for maize, wheat, rice, soybeans…
- Sea-level rise reaching $\geq$0.5 m by 2050, $\geq$1 m by 2100, 6-10 m eventually
- And, as a result, much bigger flows of environmental refugees

Human-Caused Climate Change

In the Arctic

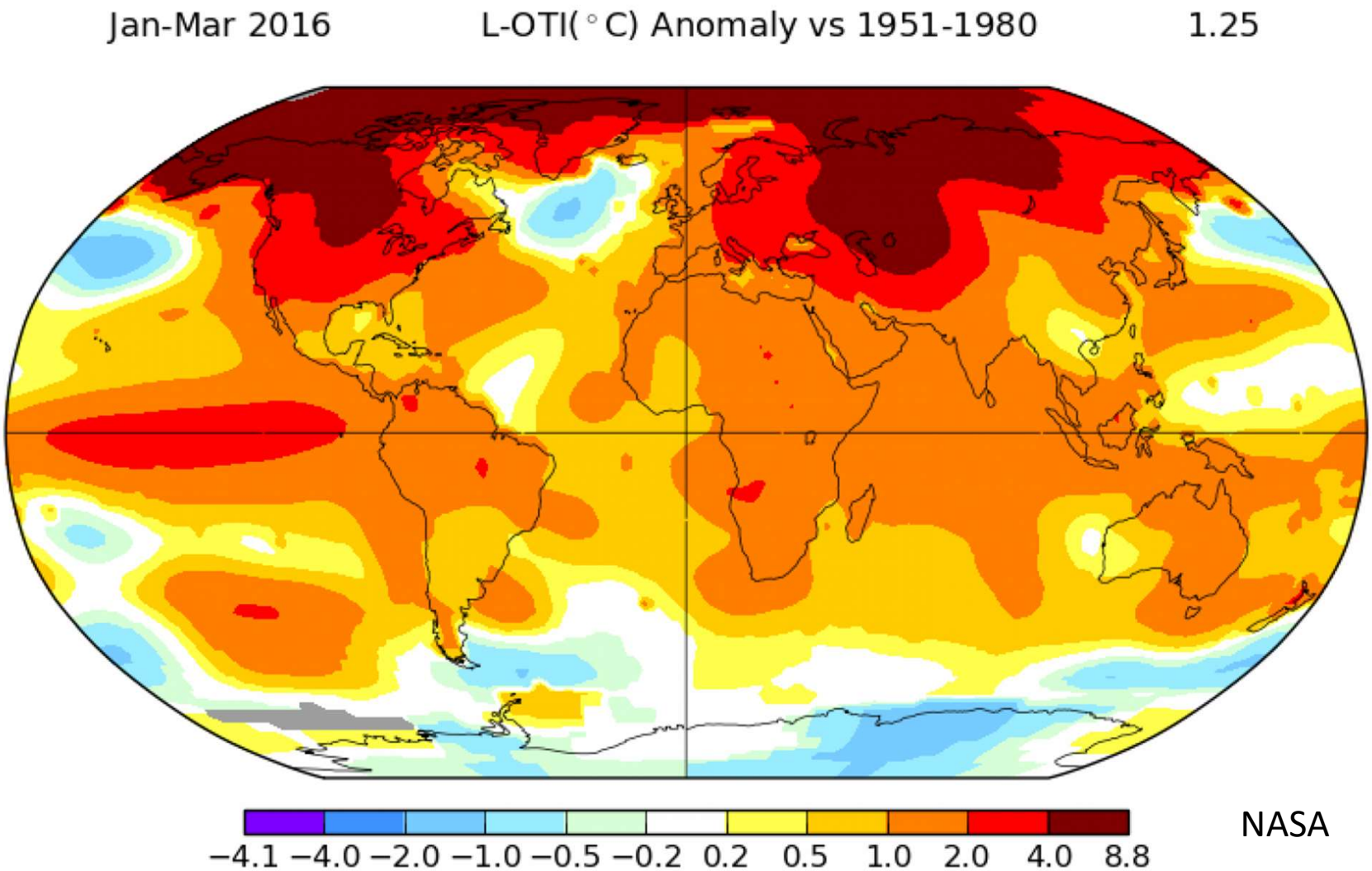
"No place on Earth is changing faster than the Arctic."

James J. McCarthy

Dimensions of the Arctic

- Area N of Arctic Circle is 20×10^6 km^2
  - 70% is open & ice-covered ocean
  - Eight nations have land or territorial waters in the Arctic
  - Largest share of Arctic land area is Russian
- Population north of the Arctic Circle
  - Total is 4 million, about half in Russia.
  - Indigenous people make up 10% of the total, spread across two dozen ethnolinguistic groups (e.g., Aleut, Chukchi, Inuit, Inupiat, Sami, Yupik…).
  - Largest city N of the Arctic Circle is Murmansk, Russian Federation (~350,000)

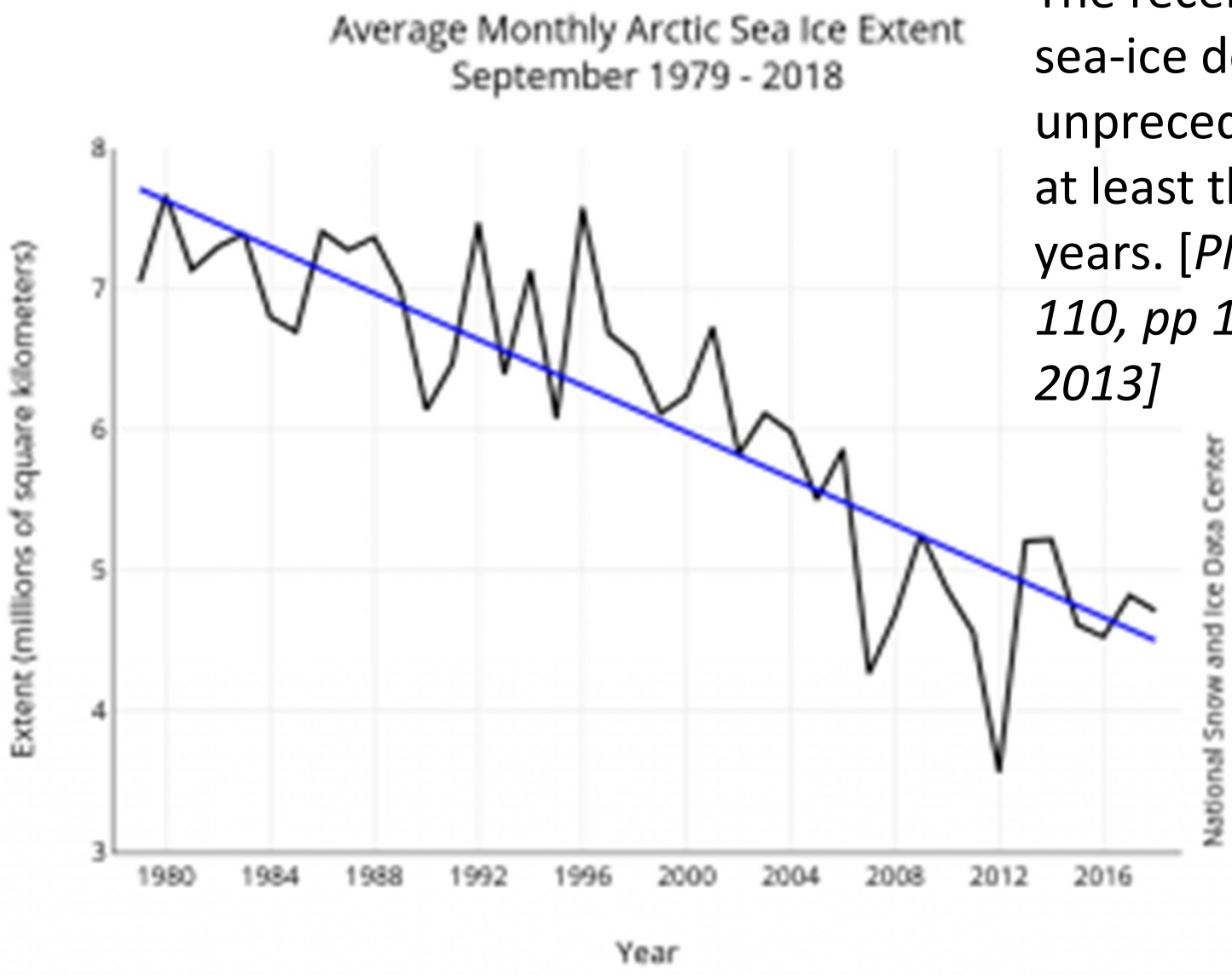
Amplification of T increase in the Arctic



NASA

The pace of T in increase in the Arctic is 2-4 times the global average.

Arctic sea-ice extent in September, 1979-2018

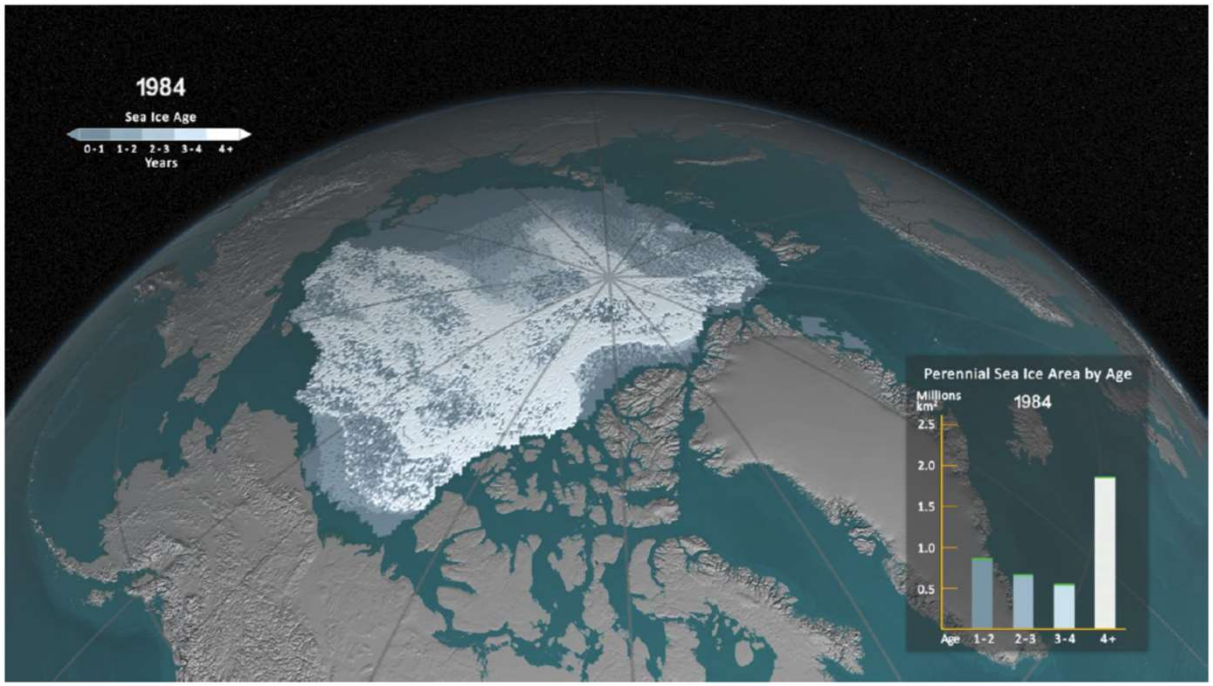


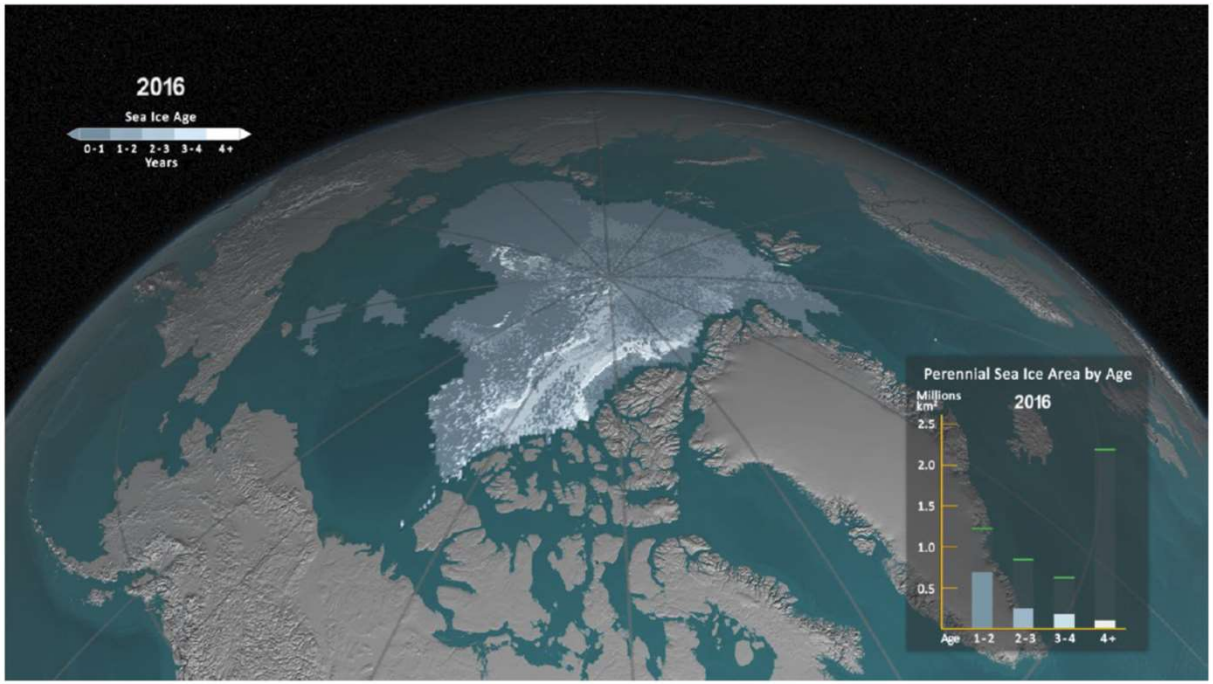
The recent pace of sea-ice decline is unprecedented over at least the last 500 years. [*PNAS, vol. 110, pp 19737-19741, 2013]*

NSIDC 2018

Extent & thickness of Arctic sea ice, Sept 1984 and Sept 2016

The recent pace of sea-ice decline is unprecedented in at least the last 1450 years.





NCA Science Report, 2017

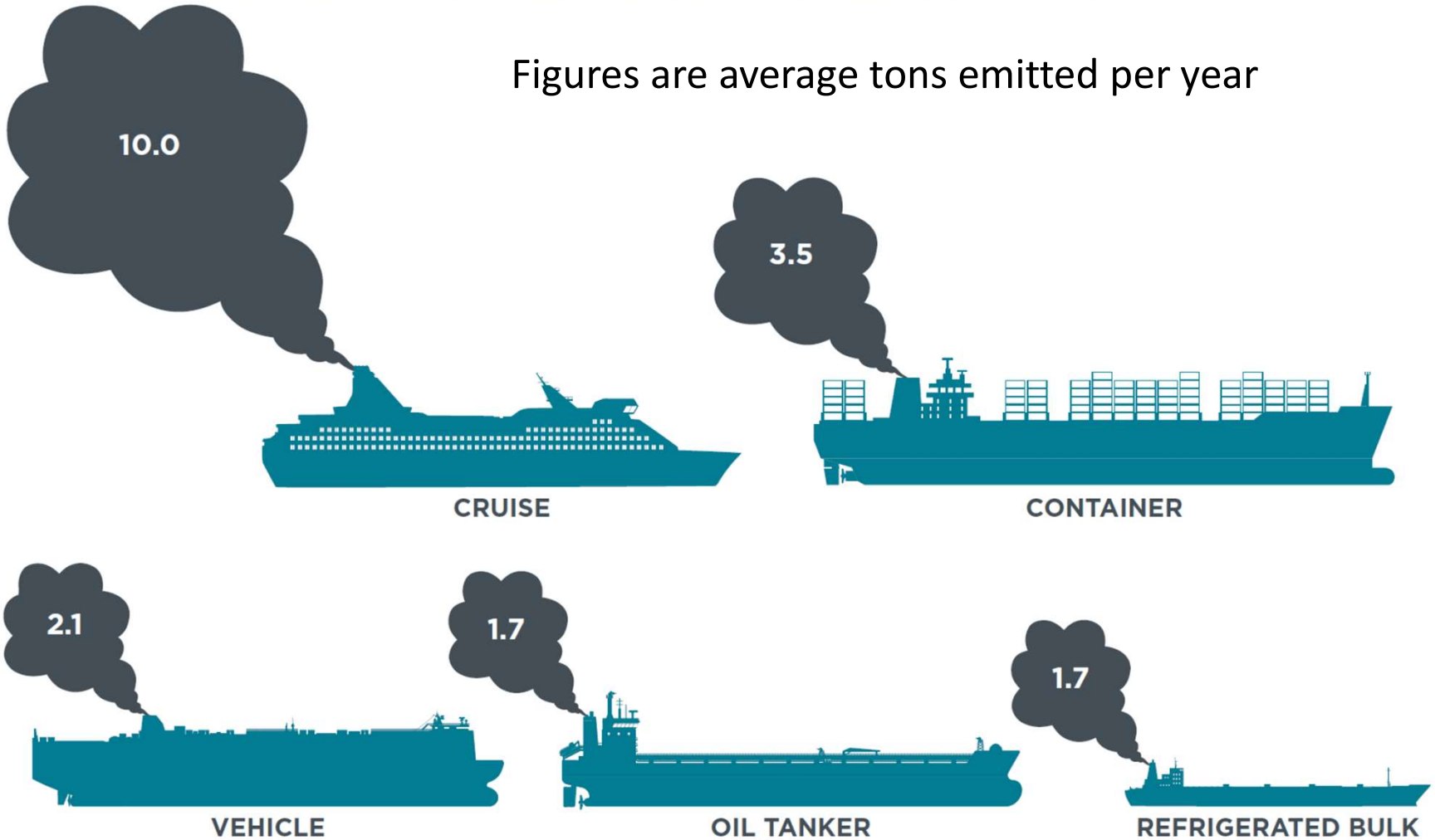
Effects of shrinking sea ice

- More open water means increased maritime activity and new fishing and seabed resource development opportunities, with potential economic benefits but new challenges with climate-altering pollution, oil spills, international interactions.
- Open water instead of ice also means…
  - bigger waves and loss of shoreline protection leading to coastal erosion and damage, even evacuation, for coastal settlements (made worse by sea-level rise);
  - feeding/breeding/survival challenges for seals, walruses, whales, and polar bears, impacting subsistence hunting;
  - more absorption of incident sunlight, thus increased heating and accelerated further temperature increase in the Arctic.

Ships emit heat-trapping black carbon…

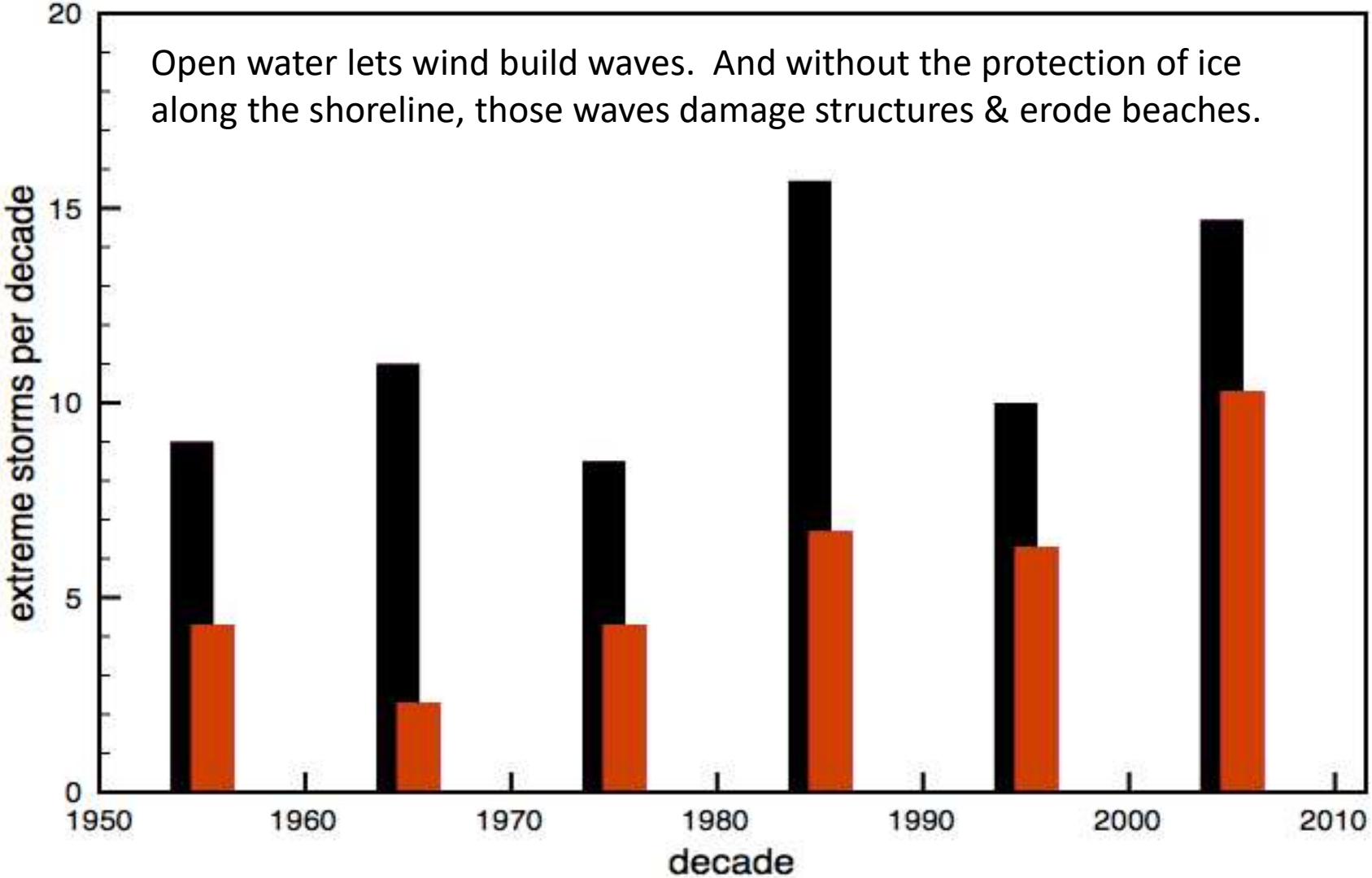
…which will accelerate Arctic warming

Figures are average tons emitted per year



ICCT 2015

Sea-ice loss means more storm damage



(Black = total # of extreme storms; red = those with open water)

Courtesy J. Walsh and W. Chapman, U of Alaska Fairbanks, 2015

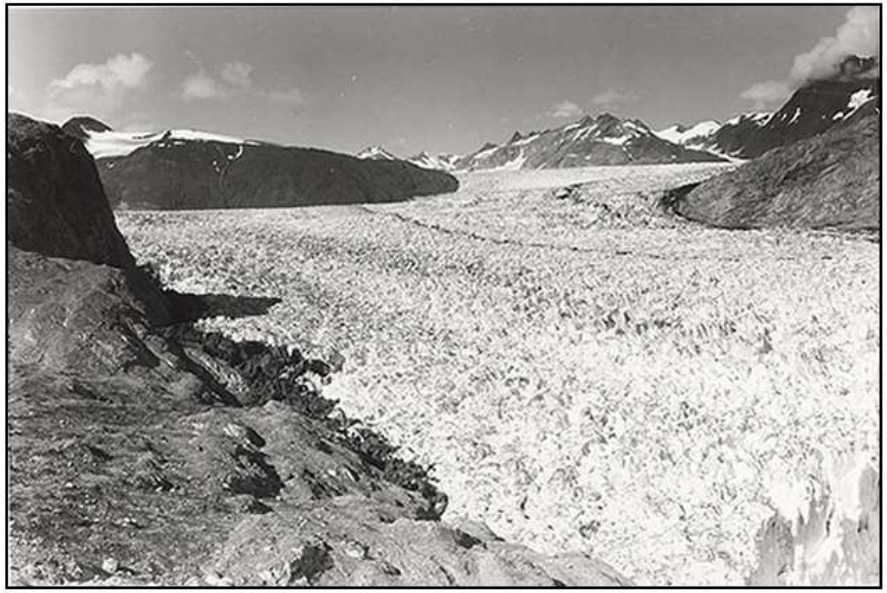
Coastal erosion in Shishmaref, Alaska

Courtesy Gary Braasch

Shrinking land ice

- Most mountain and coastal glaciers across the Arctic are shrinking, which increases river discharge and turbidity, in turn affecting erosion and, potentially, fisheries in the ocean as well as in the rivers. Alaska's glaciers alone are losing 75 gigatons of ice annually.

Alaska's Muir Glacier

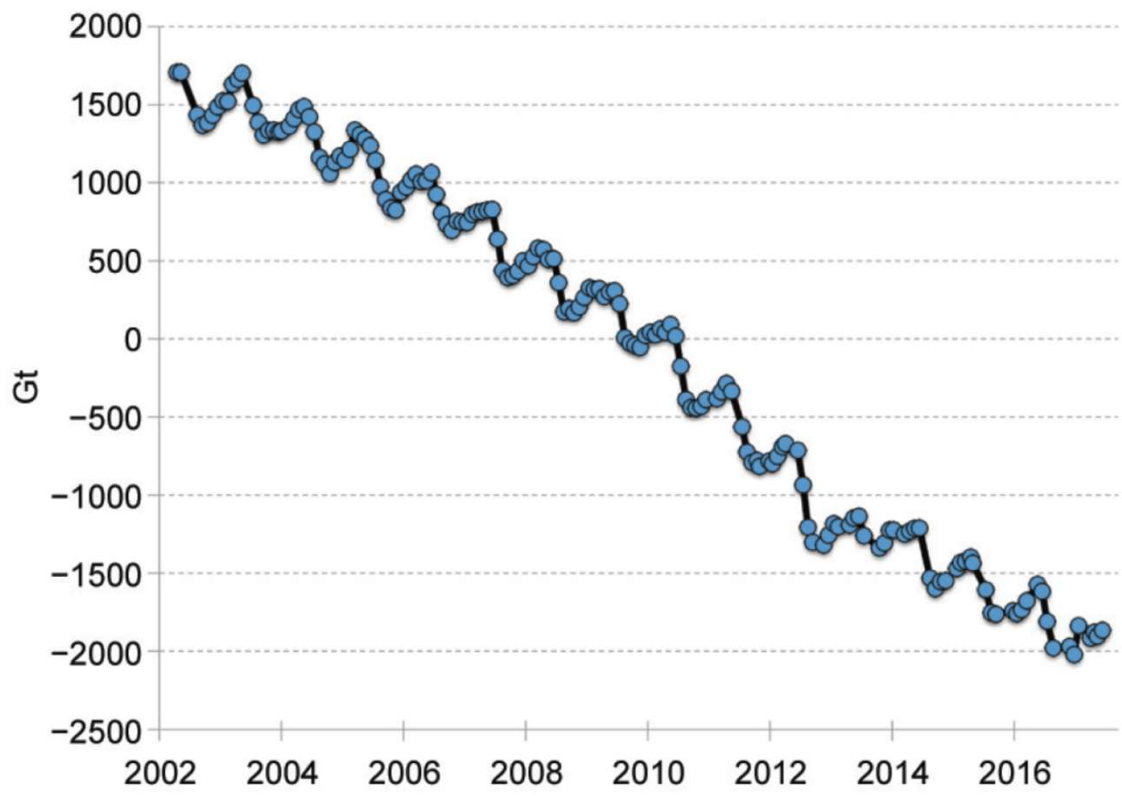


August 1941

August 2004

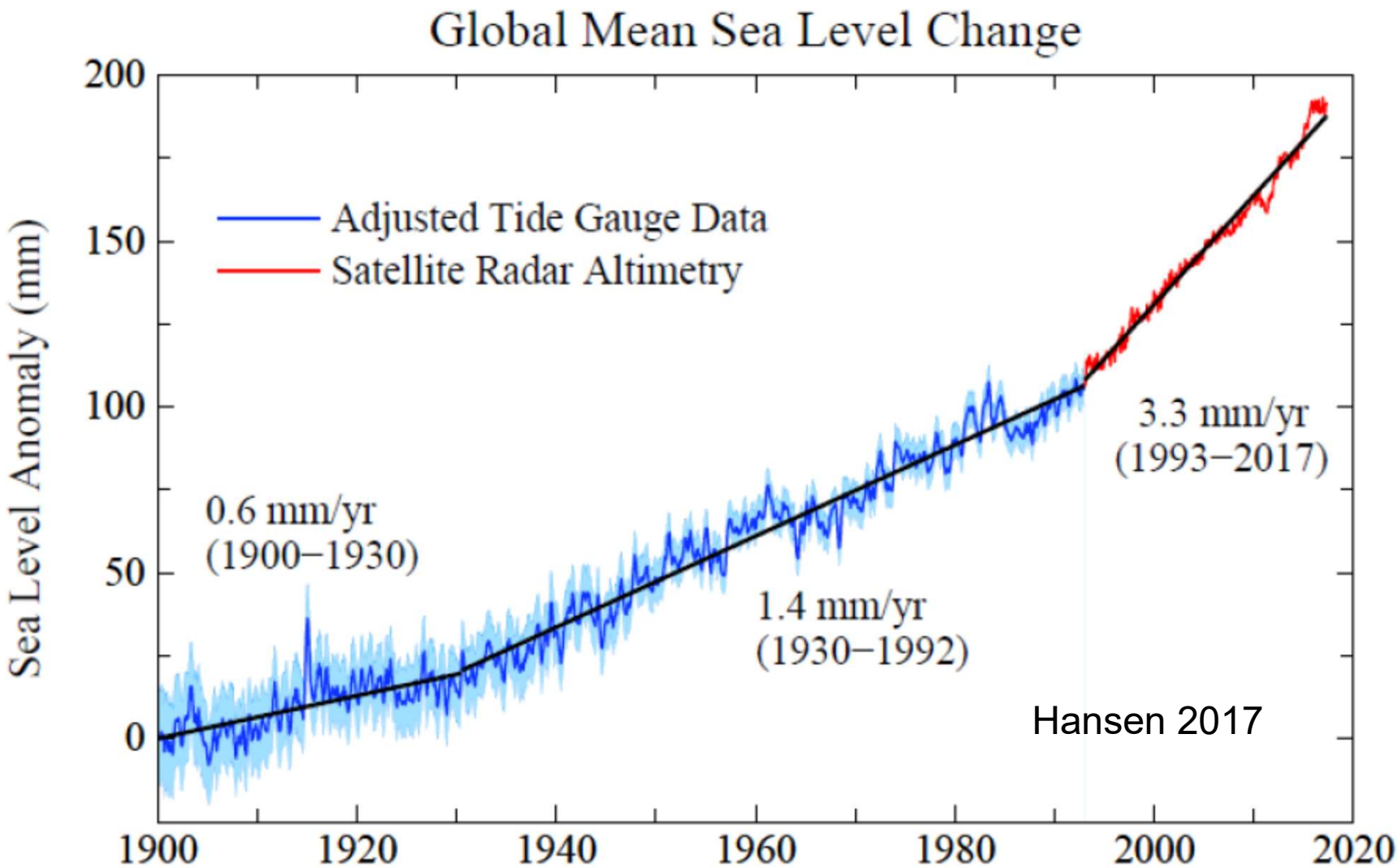
Shrinking land ice (continued)

- The Greenland Ice Sheet is experiencing extensive surface melting in summer, as well as acceleration of the flow of major coastal glaciers to the sea.
  - Water on the surface of the ice increases absorption of sunlight and thus produces further melting.
  - Total loss of ice from Greenland is averaging 250-350 gigatons annually, up 4X in the last 2 decades.



Change in Greenland ice mass, billions of tons

Melting of Arctic glaciers & the Greenland Ice Sheet accelerates sea-level rise



Post-2010 rate is actually 5.5 mm/yr!

Expanding wildfires

- Higher temperatures, drier landscapes, trees killed by insect infestations, and more lightning (all related to climate change) mean more, bigger, hotter wildfires.
- The combined acreage burned in wildfires in 2015 in Siberia, Canada and Alaska was about 15 million ha (37 million acres). Now even the tundra is burning.
- In Alaska, the annual number of large wildfires has doubled since the 1980s, and the average annual area burned has quadrupled.
- Wildfires destroy infrastructure, timber, and habitat; create massive smoke pollution; directly add large quantities of CO_2 to the atmosphere; expose soil carbon to microbial action (producing more CO_2); and contribute to permafrost thawing.

Thawing permafrost

- A high proportion of land in the Arctic and sub-Arctic is in the permafrost region. (For the state of Alaska, the proportion is 80 percent.)
- As soil temperature rises along with air temperature, the upper layers of permafrost in the warmer regions start to thaw. This is happening over much of the permafrost region.
- Impacts of thawing permafrost include…
  - land subsidence, threatening buildings, roads, and energy infrastructure;
  - increased vulnerability to coastal erosion & wildfires;
  - exposure of previously frozen soil carbon to release as CO_2 and methane.

Thawing permafrost: Subsidence

Norwegian Polar Institute, 2009

Thawing perma-frost: Accelerated release of CO_2 and methane

Methane is bubbling from "thermokarst" lakes (created or expanded by voids left by melting permafrost).

Some of this methane may be coming from unfrozen fossil fuel rather than from bacterial action.

Chris Mooney 09-22-18

Changing ocean chemistry

- In addition to reduced salinity & increased turbidity as a result of increased discharge to the ocean of glacial fresh water, the Arctic Ocean (like the rest of the global ocean) is becoming more acidic.
- Ocean acidification is intensified in the Arctic by the low temperature and low salinity of the ocean there.
- The effects of these changes include…
  - impacts of acidification on marine organisms that make their shells or skeletons with calcium carbonate;
  - interaction of salinity changes with changes in temperature to alter ocean circulation;
  - impacts of all of this together on marine fisheries, with consequences still largely unknown but potentially severe.
- Pollution by microplastics is also impacting Arctic Ocean life.

Future impacts of Arctic climate change under "business as usual" global GHG emissions

- Summer temperatures in the Arctic in 2080-2100 will average 6-8°C above pre-industrial Arctic temps.
- Sea ice in the Arctic ocean in late summer could disappear altogether as early as 2040 and no later than 2100.
- Alaska wildfires, already burning 2x the area they did 50 years ago, likely to double that area again by 2050; similar growth in area burned is expected across the Arctic.
- Permafrost thawing will be widespread, with major impacts on communities & infrastructure and increased releases of CO_2, CH_4, and mercury.
- Loss of ice from glaciers & Greenland Ice Sheet will accelerate, making ever bigger contributions to global sea-level rise.

Why Everybody Should Care

“What happens in the Arctic doesn’t stay in the Arctic.”

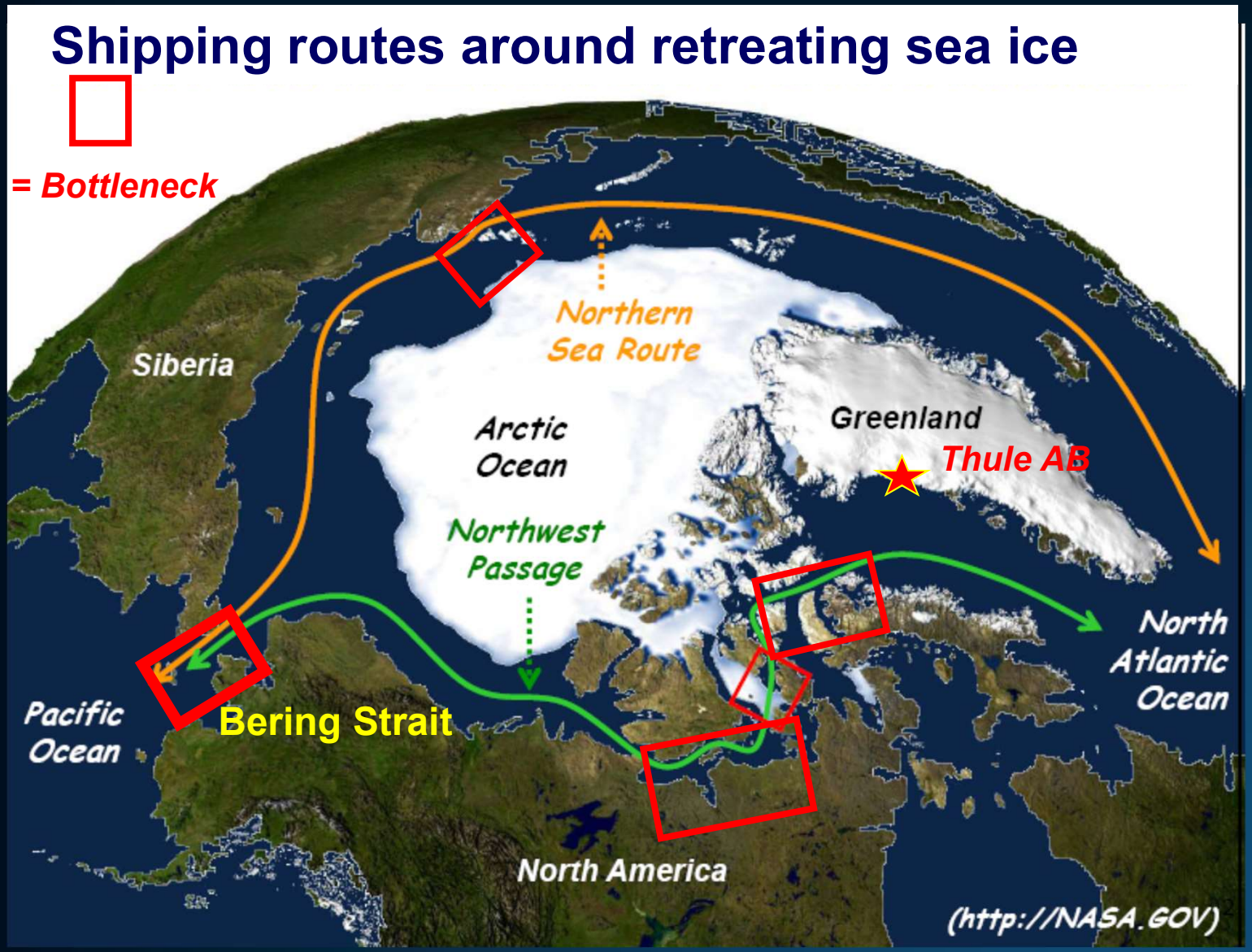
Judah Cohen

Why care? International security challenges

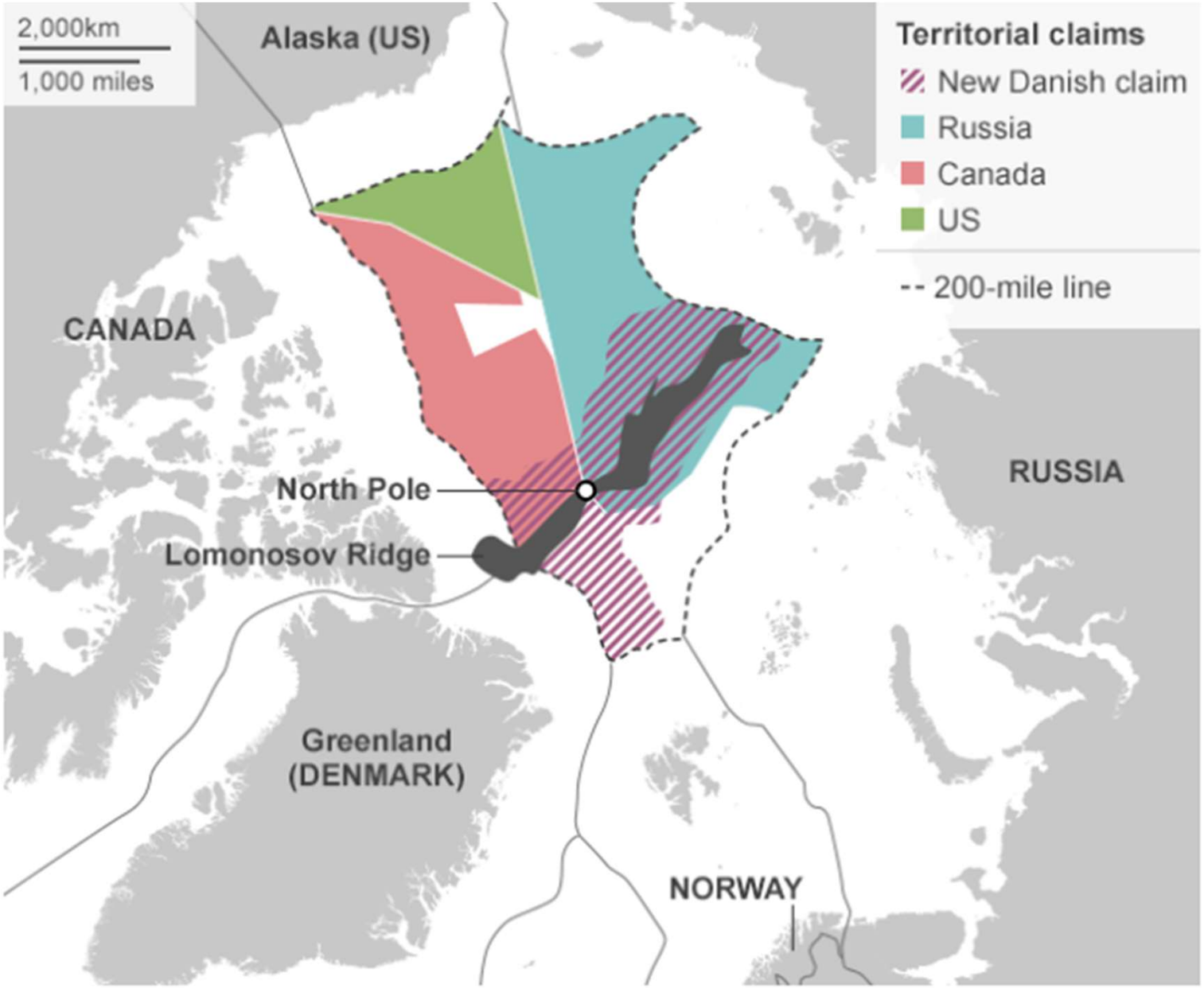
International security challenges exacerbated by climate change in the Arctic

- Protecting borders, coastal waters, and shipping routes around an increasingly open Arctic Ocean
- Managing tensions around territorial & resource claims and the interests of non-Arctic nations
- Addressing climate-change risks to national-defense infrastructure
- Understanding and coping with Russian military expansion in the region

Security (cont.): Protecting coasts, shipping



Security (continued)**: Territorial claims**

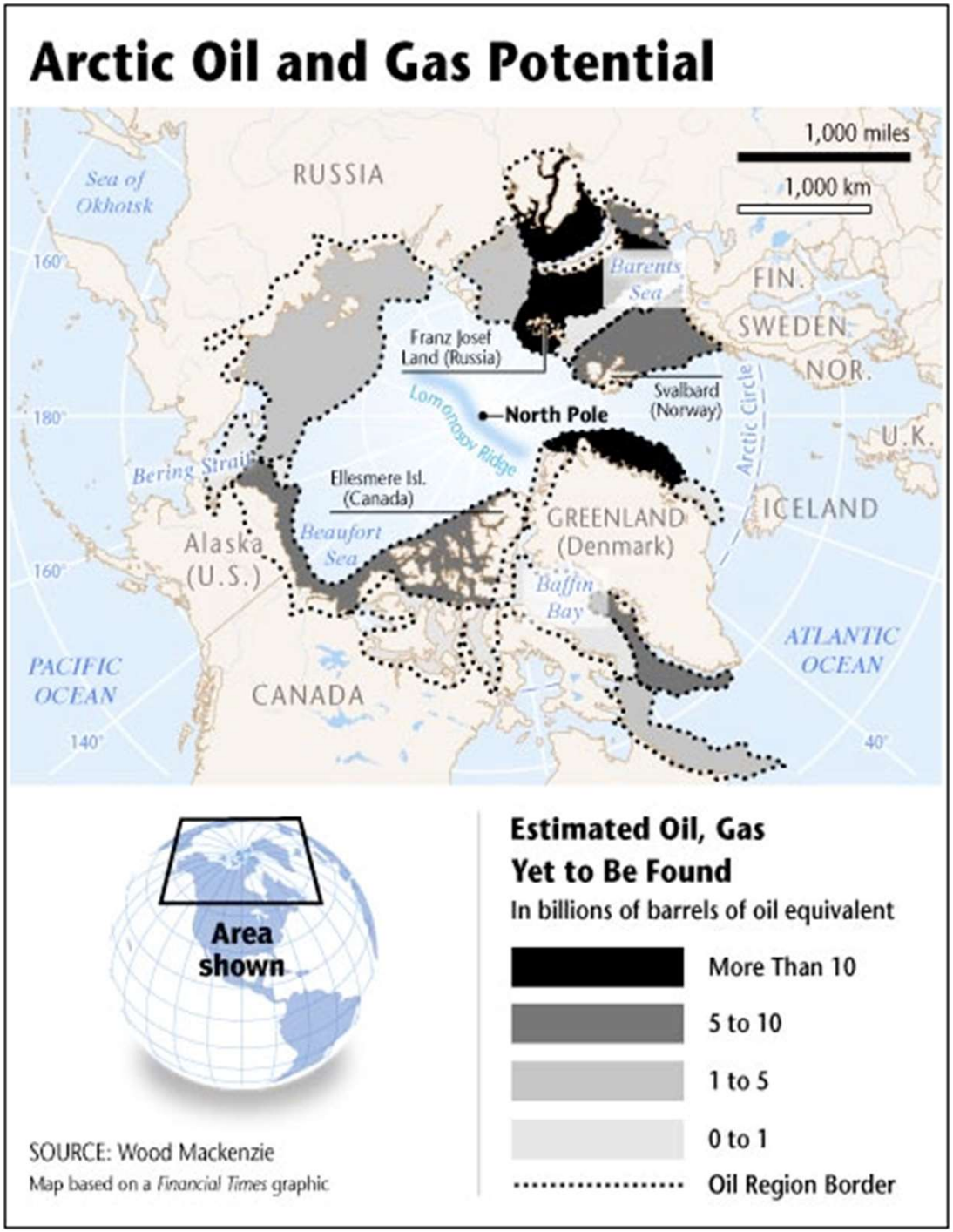


Security (cont.): Tensions & risks from access to Arctic oil and gas

Some think these are the largest unexploited oil & gas resources in the world.

Tensions may arise over rights or international impacts of spills.

And extracting and burning this oil & gas would be a huge further boost to global climate change.



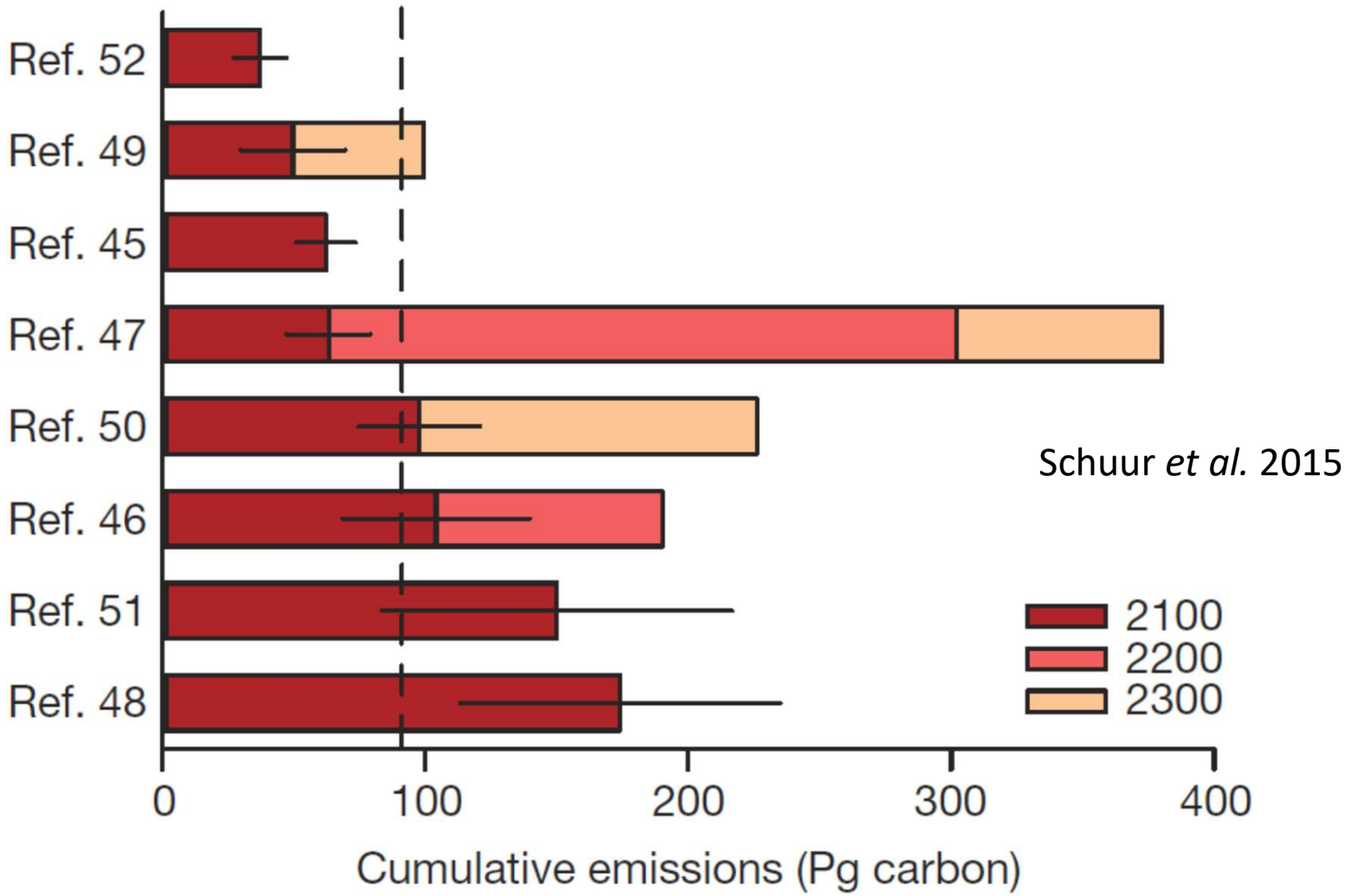
Security (cont.)**: Putin on Russian Arctic interests**

"I would ask you to pay special attention to the deployment of infrastructure and military units in the Arctic. … Russia is actively exploring this promising region, returning to it, and should use all possible channels to protect its security and national interests."

Speech to Expanded Meeting of the Defense Ministry Board

Why care? Carbon release from a warming Arctic will accelerate climate change worldwide

Estimates of C release from thawing permafrost



Schuur *et al.* 2015

1 petagram (Pg) = 10^{15} g = 1 billion tons; current global fossil-fuel emissions ≈ 10 Pg/yr

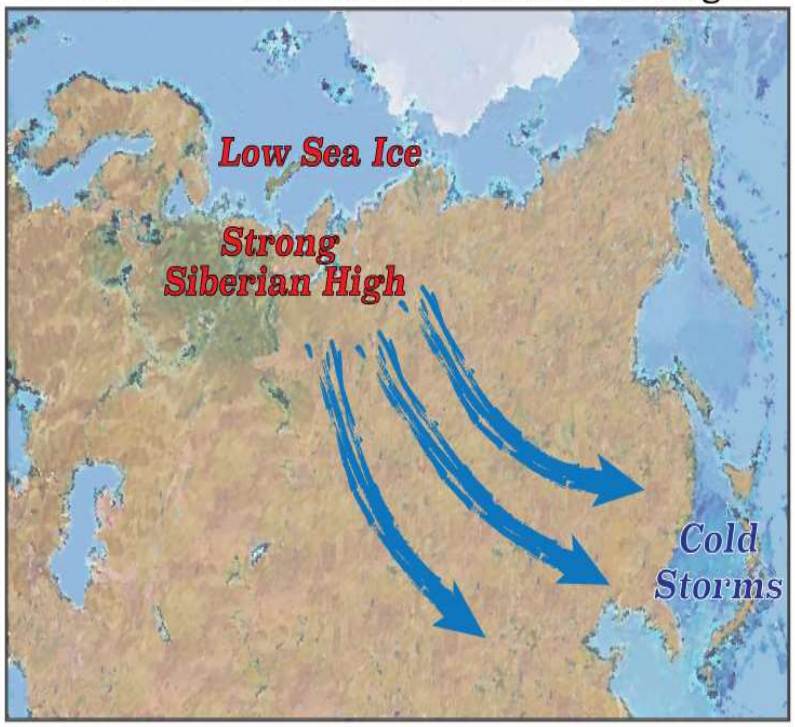
Why care? Impacts of Arctic climate change on Northern Hemisphere mid-latitudes

- Changes in Northern Hemisphere atmospheric circulation patterns
  - blocking highs, plus jet-stream slowdown and waviness bringing "polar vortex" phenomena to mid-latitudes, because of faster warming in Arctic
  - acceleration of the differential warming by black soot from increasing ship traffic
- Impacts on human health—as well as on visibility, sunlight reaching ground, and atmospheric heating—from long-distance transport of smoke from Arctic wildfires

Why care? Impact of Arctic change on extreme mid-latitude weather

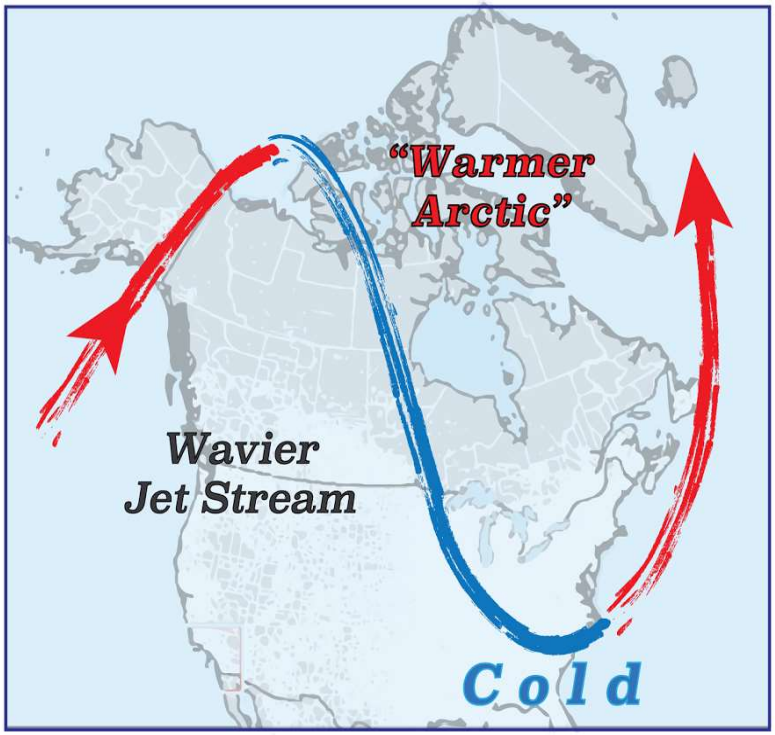
"High confidence" –
from observational and modeling studies

Asia: Arctic-Midlatitude Weather Linkages



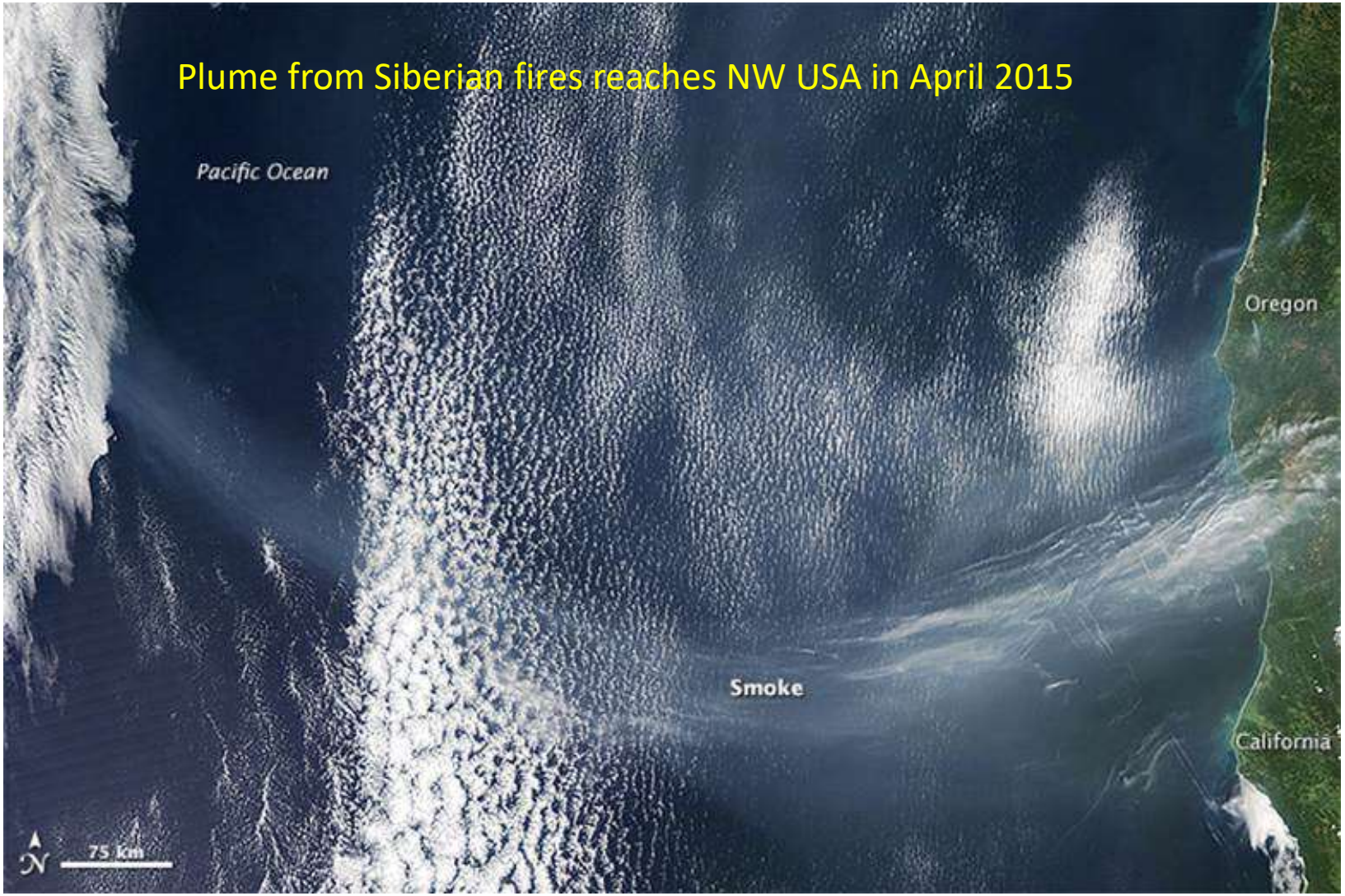
"Lesser confidence" –
weaker signal-to-noise ratio

North America: Warmer Arctic Temperatures
Can Reinforce Wavy Jet Stream



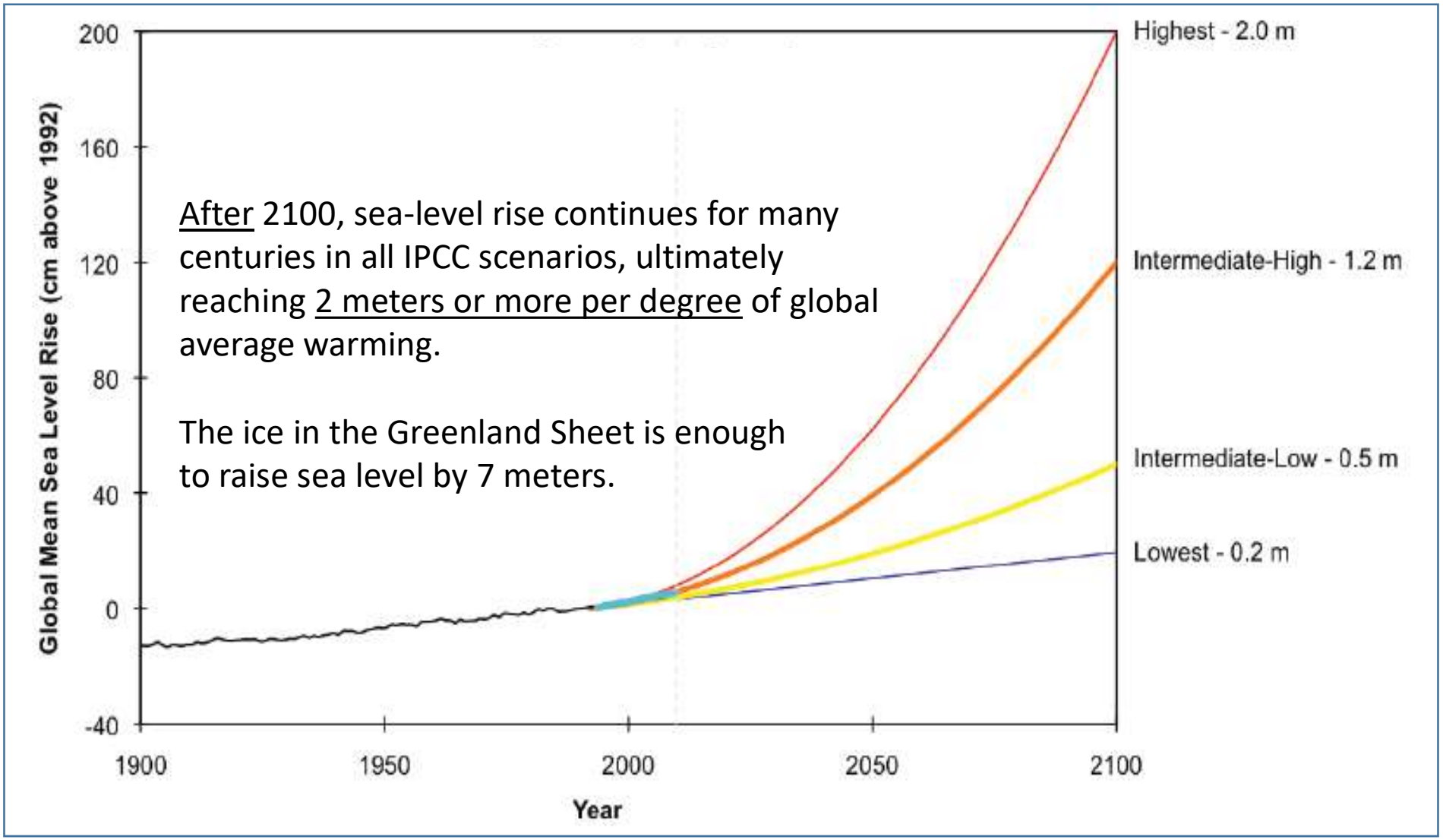
Source: J. Overland (NOAA/PMEL) and J. Francis (Rutgers Univ.)

Why care? Smoke from huge Arctic fires pollutes mid-latitudes



http://earthobservatory.nasa.gov/NaturalHazards/view.php?id=85724

Why care: Arctic contribution to global sea-level rise



NOAA OAR CPO-1, December 2012

What Is Being Done

“If you don’t change direction, you’ll end up where you’re heading.”

Lao Tzu

…about the pace of climate change worldwide

- Intergovernmental Panel on Climate Change (IPCC), created in 1988, has produced periodic assessments of climate science that have solidified & propagated understanding of the imminence of major climate-change impacts globally and in the Arctic.
- United Nations Framework Convention on Climate Change (UNFCCC), agreed in 1992, has focused on national commitments to reduce emissions and assist countries in need with technologies for doing so (and with adaptation to changes in climate that can no longer be avoided).
  - Obama-Xi announcement in Beijing in 2014 prepared the basis for the Paris Agreement one year later
  - In 2015 in Paris, 195 countries agreed to intended nationally determined commitments for emissions reductions by 2025 or 2030
  - Also in Paris, a coalition of 20 nations, including USA & China, announced “Mission Innovation”, to double clean-energy R&D funding over 5 years

Action on climate change worldwide (continued)

- Increases in energy end-use efficiency and energy supply from low- and no-carbon sources have reduced carbon emissions in many countries, but few are on track to meet their Paris targets.

- President Trump announced in 2017 that US would withdraw from Paris Agreement, stopped US assistance to countries in need, and rescinded essentially all of the Obama initiatives on both emissions reduction & adaptation.

- Global emissions of CO_2, which had seemed to level off in 2016 and 2017, rose significantly in 2018.

Action on climate change in the Arctic

- The Arctic Council was established 1996 to promote cooperation & coordination among the 8 nations with Arctic territory—with involvement of Arctic Indigenous communities—on sustainable development, environmental protection, shipping, research.
  - Standing working groups focus on sustainable development, emergency prevention & response, protection of marine environment, conservation of Arctic flora & fauna, toxic contaminants, and monitoring & assessment.
  - It has produced agreements on search & rescue, oil-spill response, and cooperation on Arctic monitoring & research; and it is seeking an agreement to stop use of heavy fuel oil in Arctic shipping (to avoid emissions of black carbon)
- The United States and Europe have led international conferences of foreign ministers and science ministers to advance research, monitoring, and action on Arctic climate change.
- Academic & civil-society initiatives in cooperation with Arctic governments are proliferating.

What More Needs to Be Done

"Between fatalism and complacency lies urgency."

Jake Sullivan

In the Arctic we need…

- National and internationally collaborative efforts to make the monitoring of climate change in the Arctic and its impacts more comprehensive, pervasive, and continuous, in order to better understand ongoing and potential impacts on…
  - the Arctic ocean, its sea ice, and its creatures
  - land ice: coastal & mountain glaciers, the Greenland Ice Sheet
  - permafrost, tundra, and forest ecosystems
  - Arctic communities and infrastructure
- Innovative policies, programs, and projects—regional, national, & international—to find adaptive responses that minimize harm to ecosystems, communities, and infrastructure in the region as climate change continues and development to exploit new opportunities continues

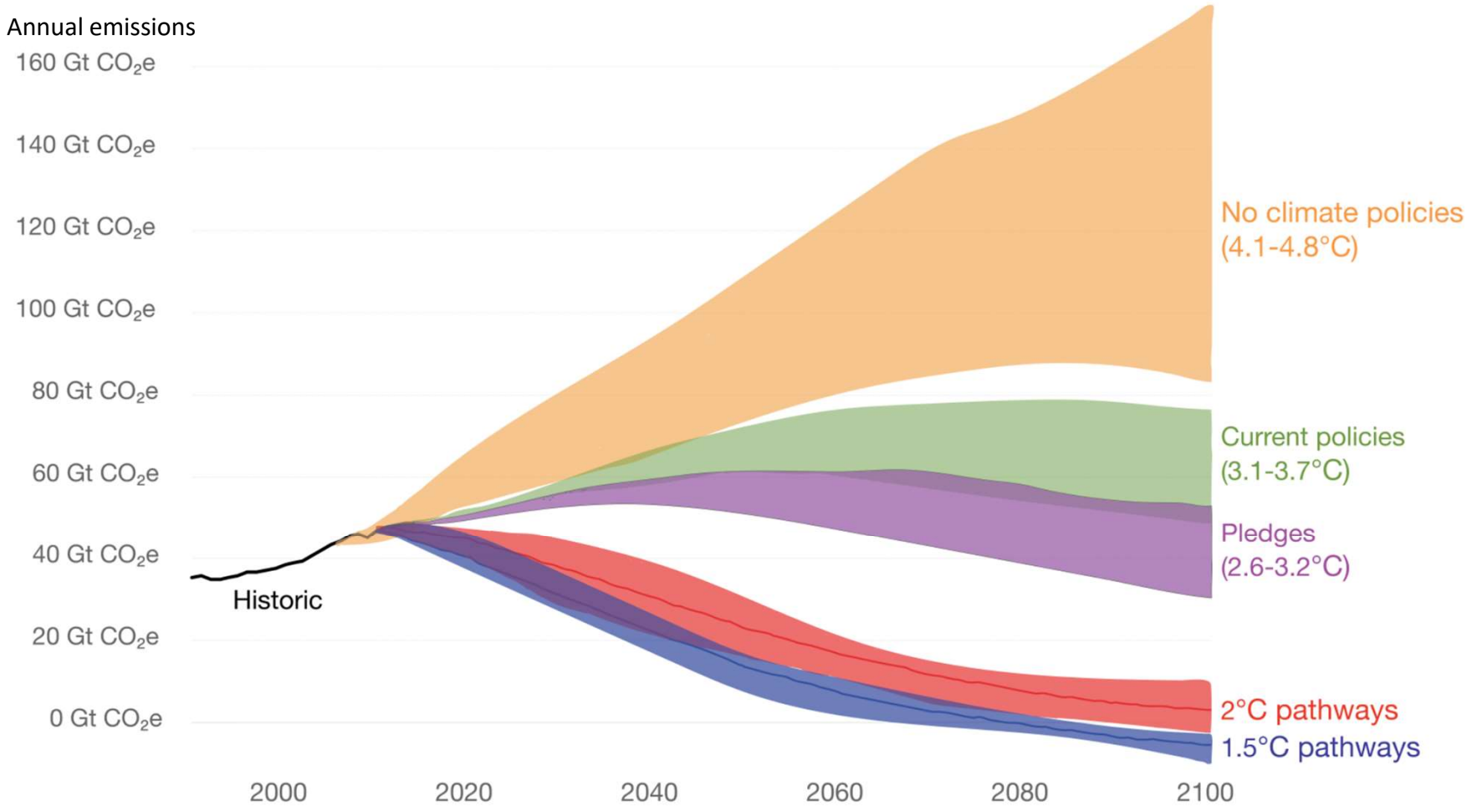
In the Arctic we need…

- Completion of the pending international agreement to ban vessels using black-soot-producing heavy fuel oil from the Arctic
- Increased capacity for patrol and search & rescue in Arctic waters:
  - More icebreakers
  - Enhanced aerial surveillance of Arctic waters
  - Improved ports & supporting infrastructure in Alaska
- Increased security collaboration and communication around Arctic waters and airspace among the 8 Arctic nations and others operating in Arctic waters

Worldwide, deep emissions cuts are needed

Our World in Data

Potential future emissions pathways of global greenhouse gas emissions (measured in gigatonnes of carbon dioxide equivalents) in the case of no climate policies, current implemented policies, national pledges within the Paris Agreement, and 2°C and 1.5°C consistent pathways. High, median and low pathways represent ranges for a given scenario. Temperature figures represent the estimated average global temperature increase from pre-industrial, by 2100.



Based on data from the Climate Action Tracker (CAT).
The data visualization is available at OurWorldinData.org. There you find research and more visualizations on this topic.

The deep cuts needed to limit warming to 1.5-2.0°C will likely require…

- A global carbon tax starting soon and escalating from around \$30/tCO_2e initially to at least \$100/tCO_2e by 2030, collected by national governments and rebated on a per-capita basis.

  This would incentivize using best available low- and no-emission technologies now and investing in RD&D to get better ones.

- A massive program of technological innovation on clean energy and energy efficiency, advanced through partnerships among government, industry, & universities, and including…
  - CO_2 capture & sequestration for fossil & biomass power plants
  - Sustainable biomass production for power plants & aviation fuel
  - Cheaper wind & solar power and better electricity storage
  - Innovation to make nuclear-energy expansion safe & affordable
  - Pursuit of practical fusion power

The world will also need…

- A similarly massive set of public-private-university partnerships focused on developing & implementing adaptation measures to limit the harm from the changes in climate that can no longer be prevented.

* * * *

The political will to get all this done could materialize faster than many think, as the combination of

rapidly increasing damages from climate change

and

declining costs of remedial action (as a result of innovation)

makes ever clearer that action is much cheaper than inaction.

Thank You!