

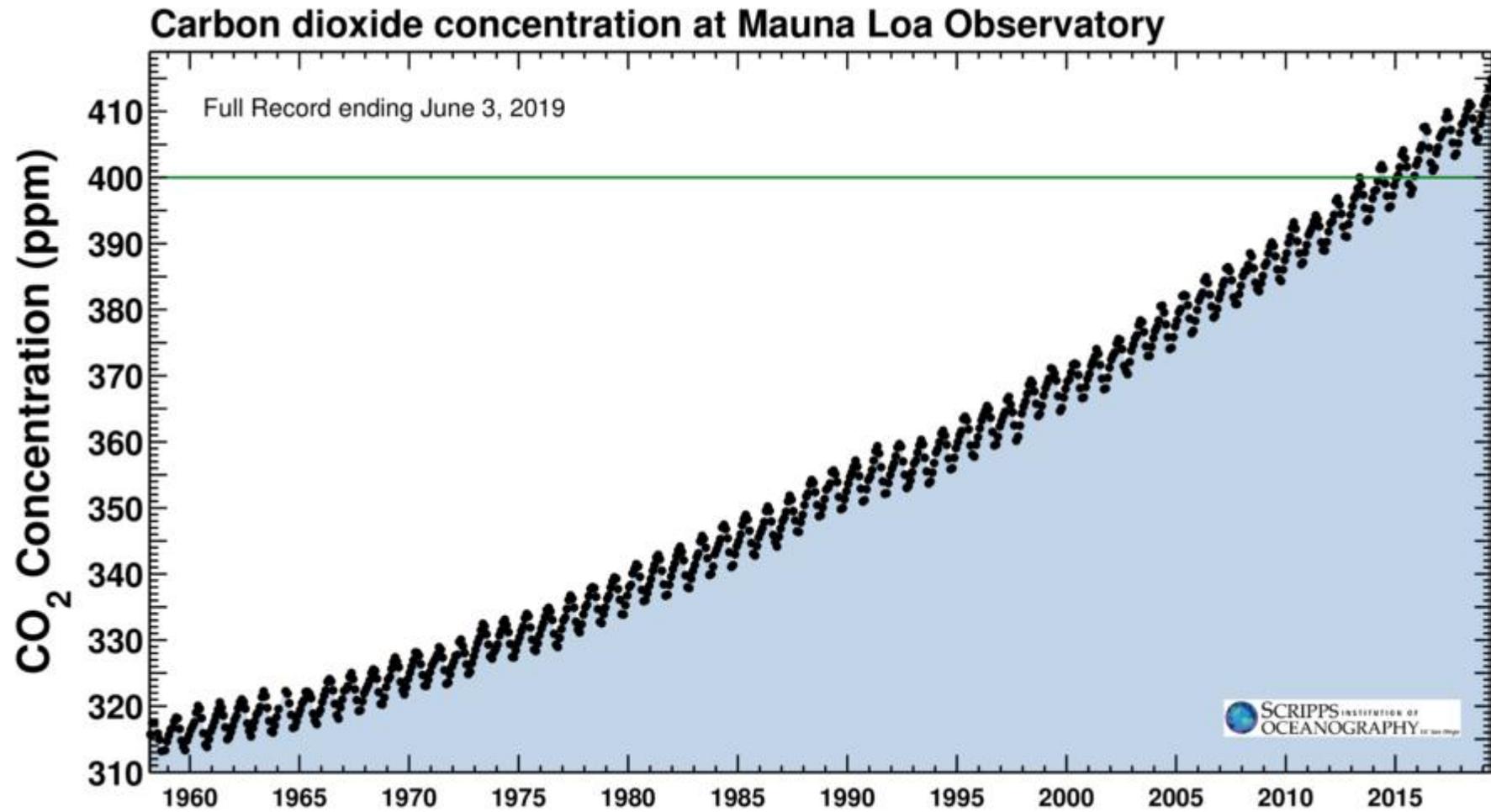
A polar bear is standing on a small, isolated piece of sea ice in a vast, dark, and fragmented Arctic sea. The bear is white and is looking towards the left. The sea is dark and filled with many small, broken pieces of ice. The sky is a pale, overcast blue.

The Passing of the White Silence: Climate Change in the Arctic

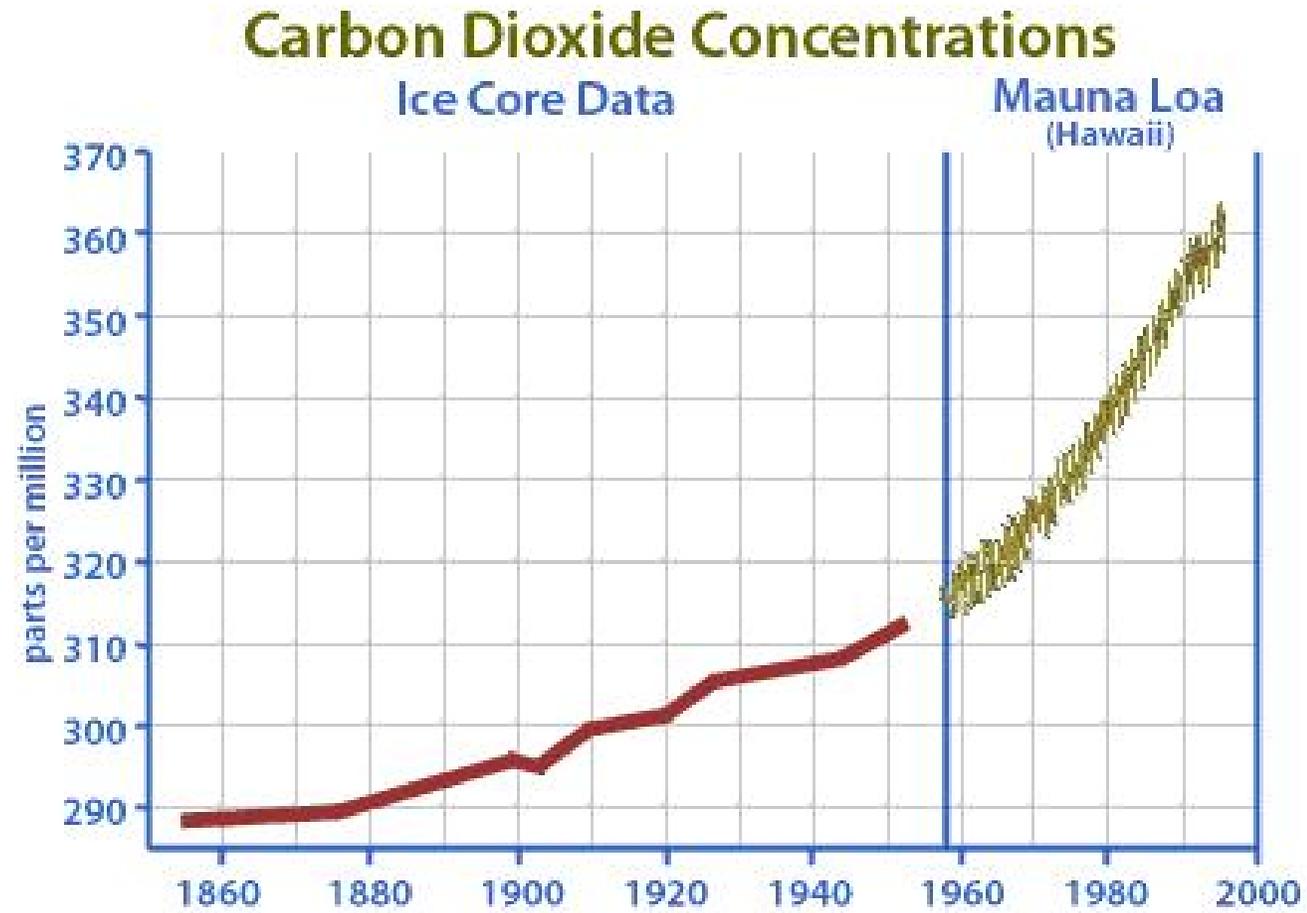
Leonid Polyak

Byrd Polar & Climate Res. Ctr., Ohio State Univ.

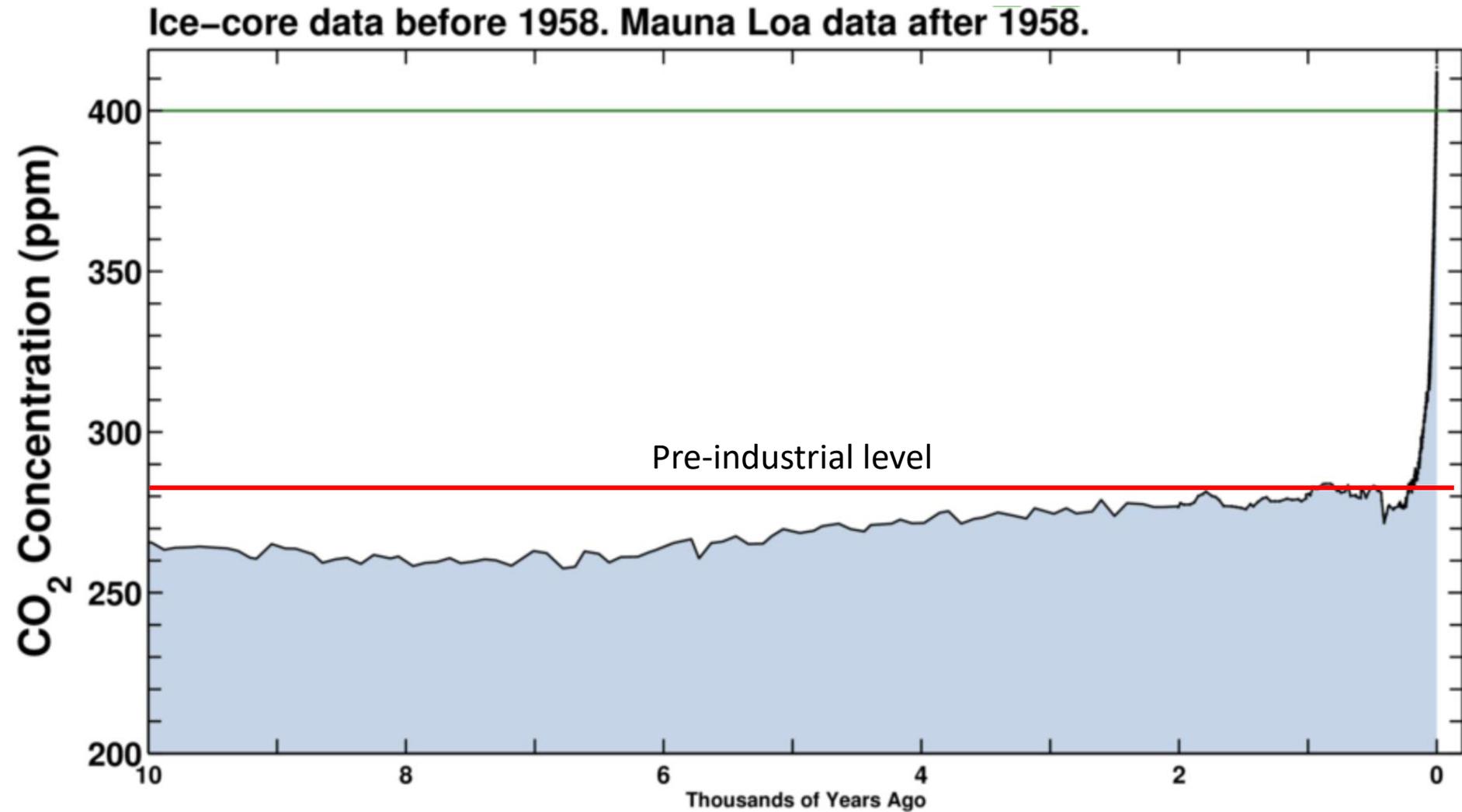
New record in atmospheric CO₂ concentration: 415 ppm



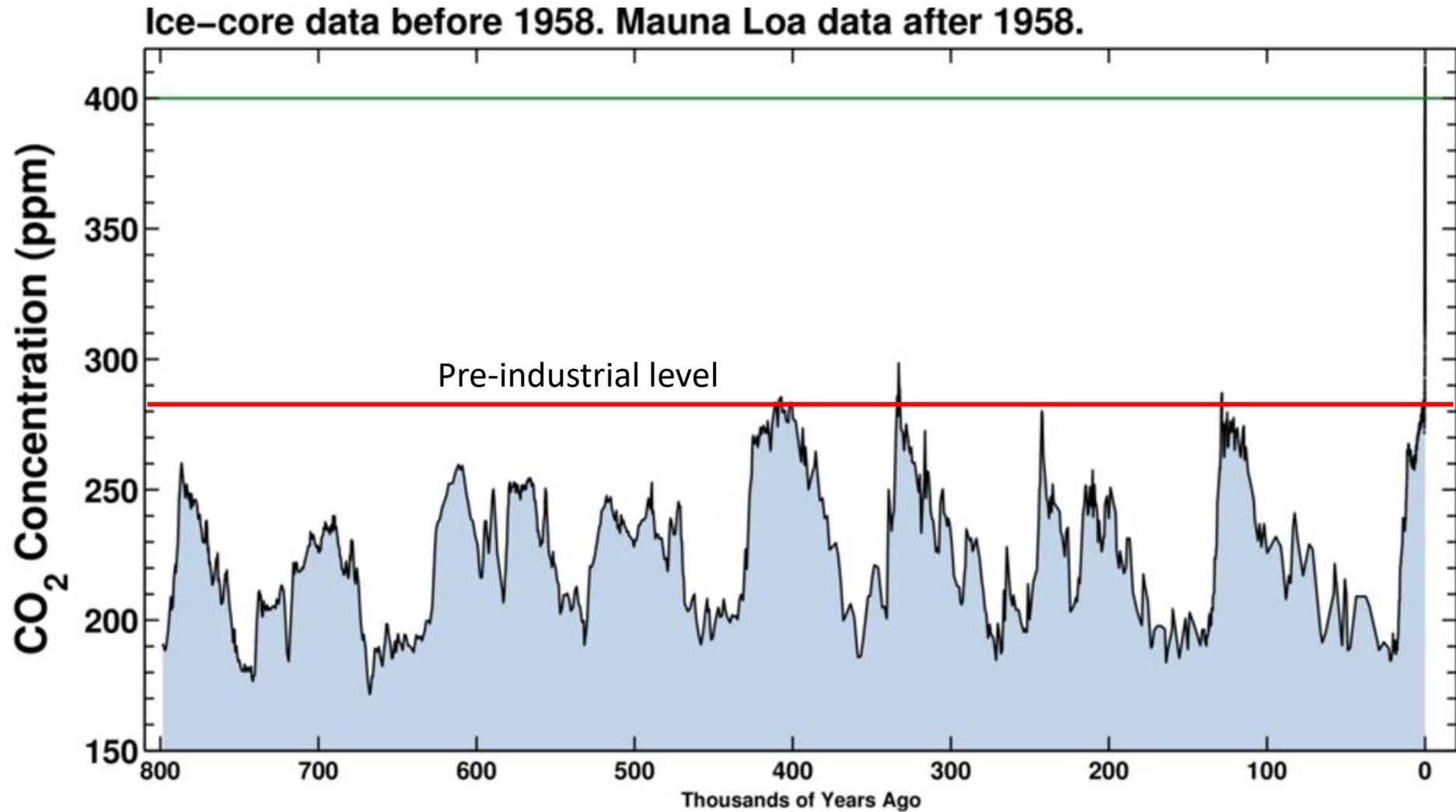
Atmospheric content: direct and proxy measurements



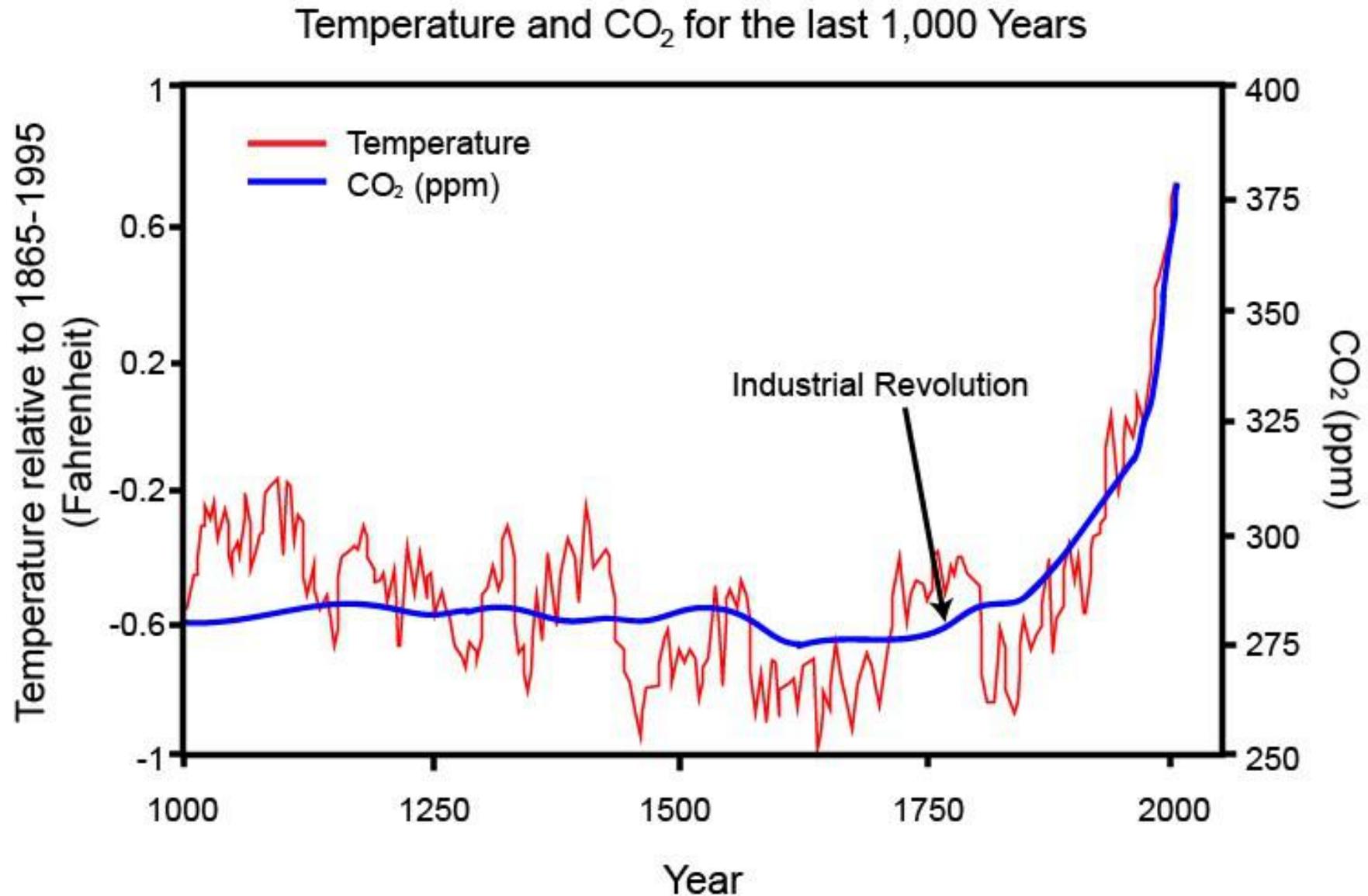
The Holocene (10,000 years) perspective



Glacial Pleistocene (800,000 years) perspective



Atmospheric CO₂ concentration and air temperature



Impacts of climatic warming

- Higher temperatures
- Climate imbalances
- Extreme events
- Ice and snow melting
 - Sea-level rise
 - Permafrost thawing

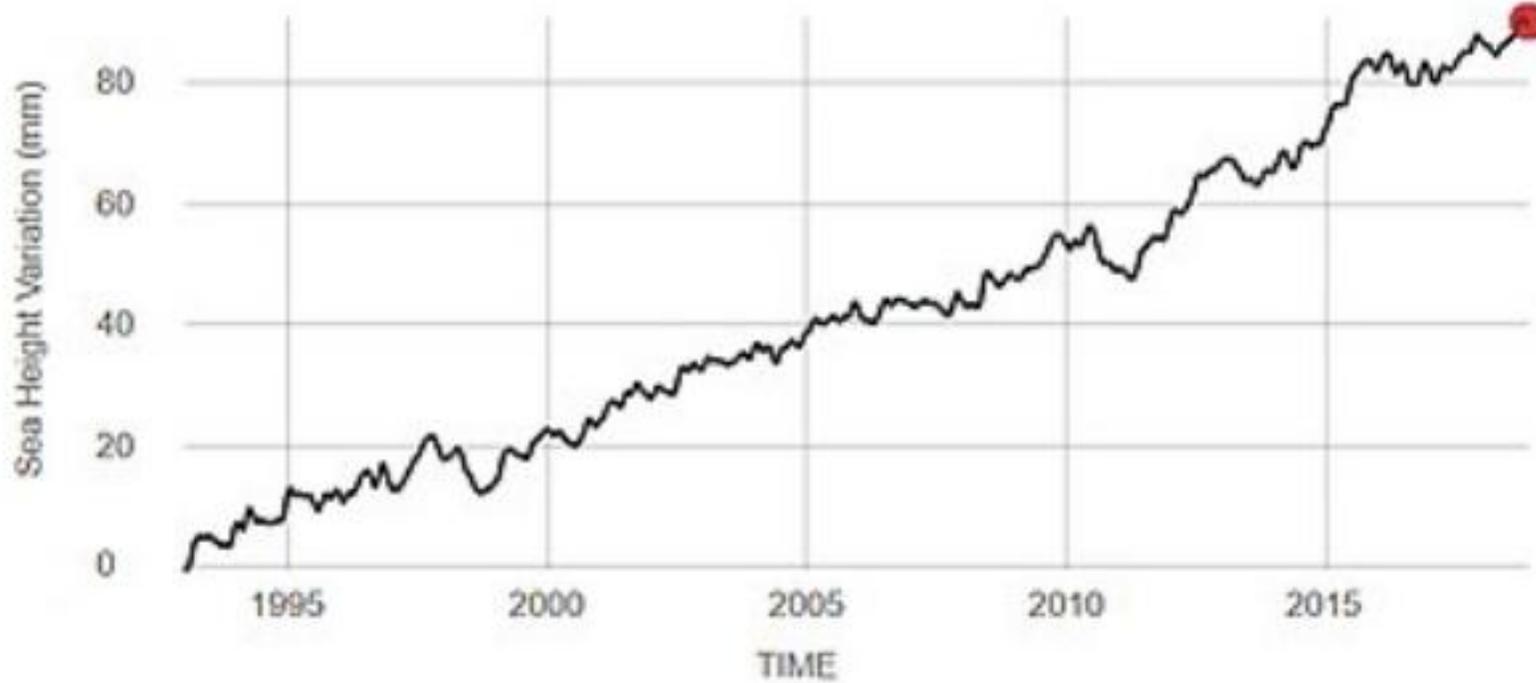
Sea level satellite observations 1993-2018

SATELLITE DATA: 1993-PRESENT

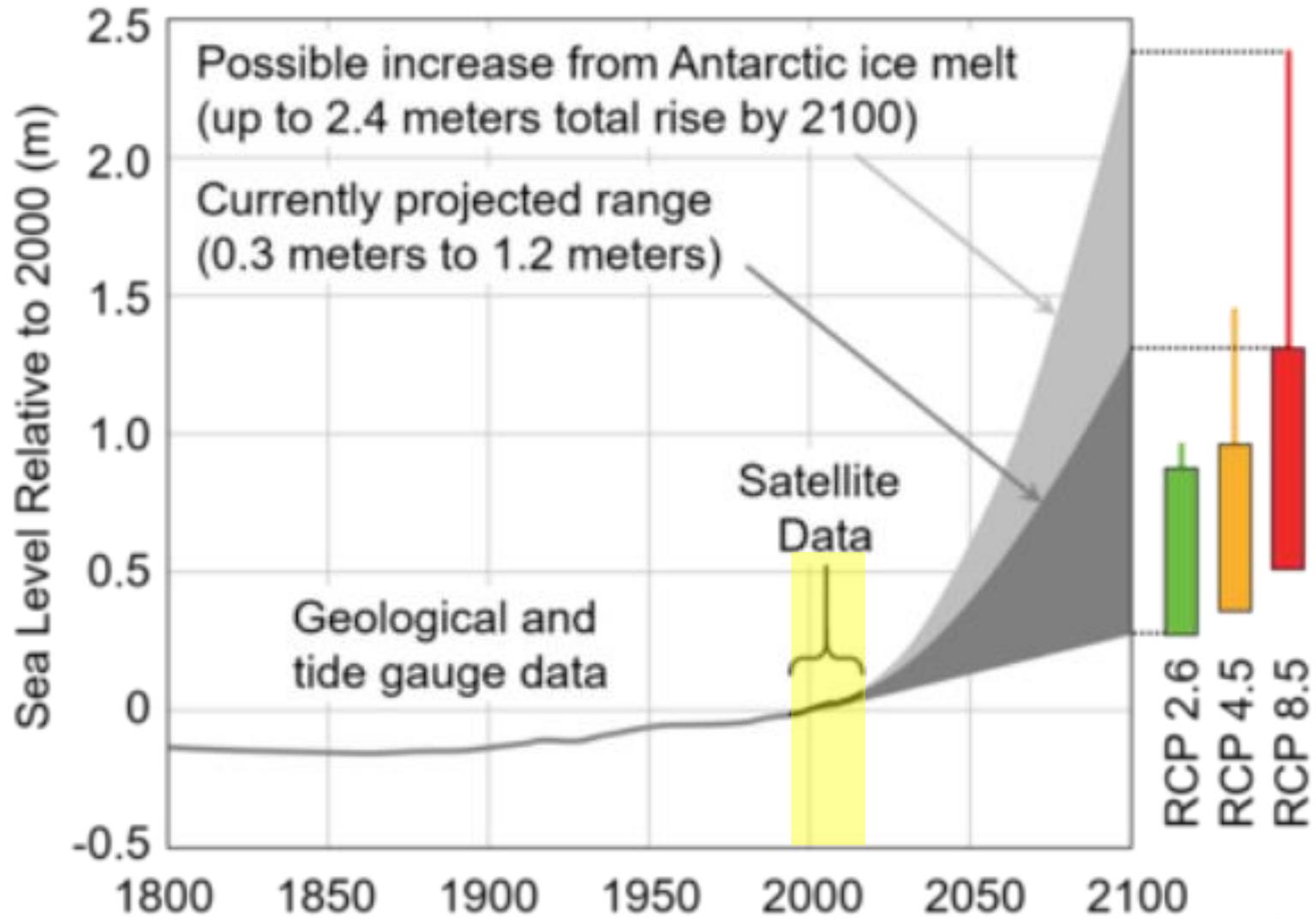
Data source: Satellite sea level observations.
Credit: NASA Goddard Space Flight Center

RATE OF CHANGE

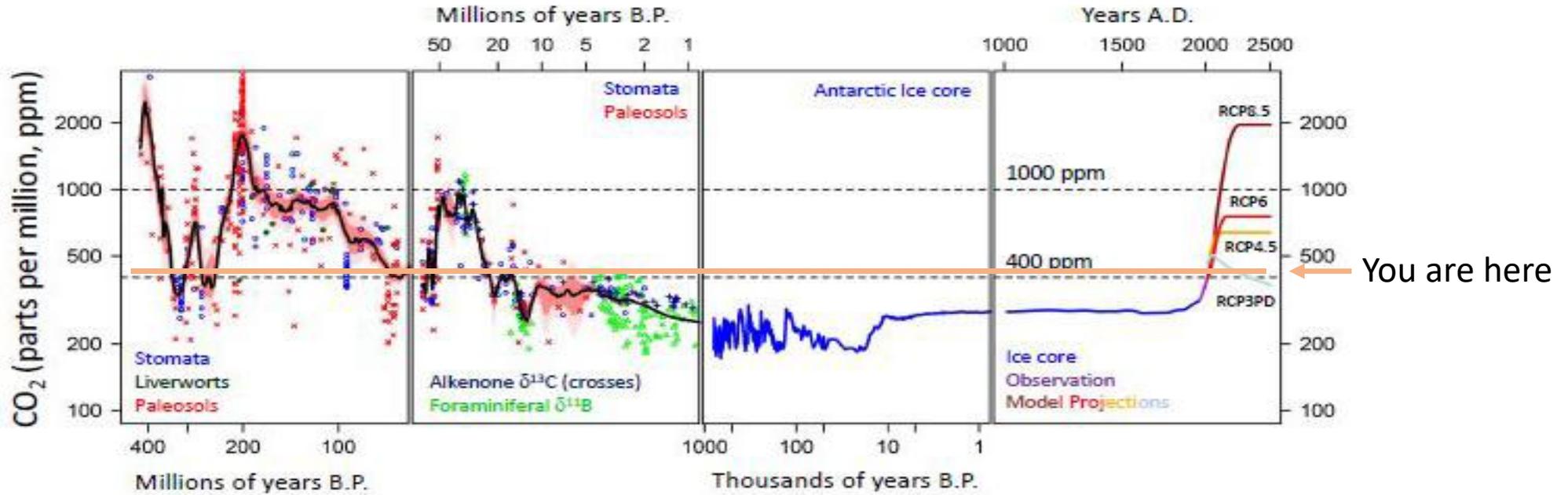
↑ 3.3
millimeters per year



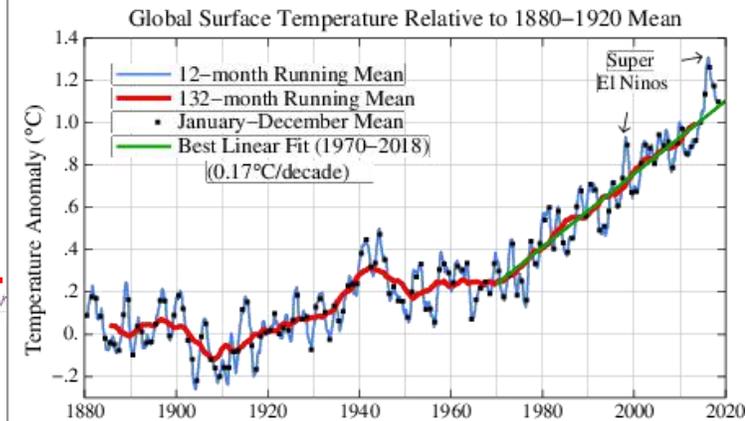
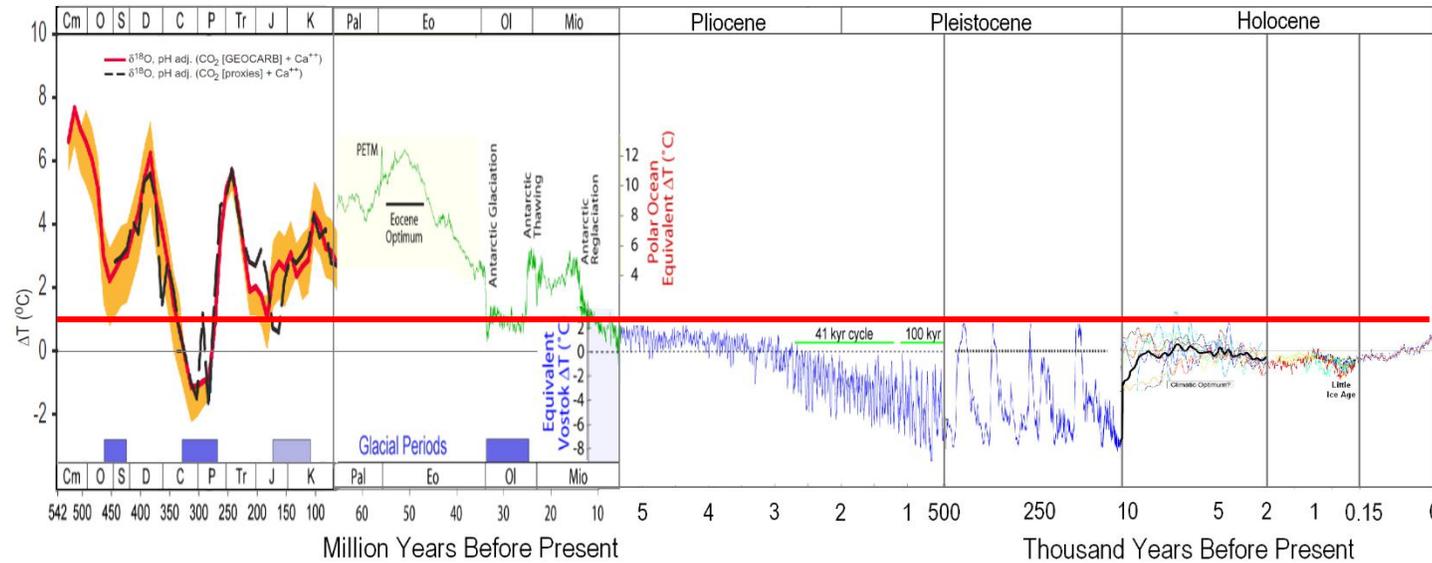
Global Mean Sea Level History and Projections



Cenozoic (500,000,000 years) perspective



Temperature of Planet Earth



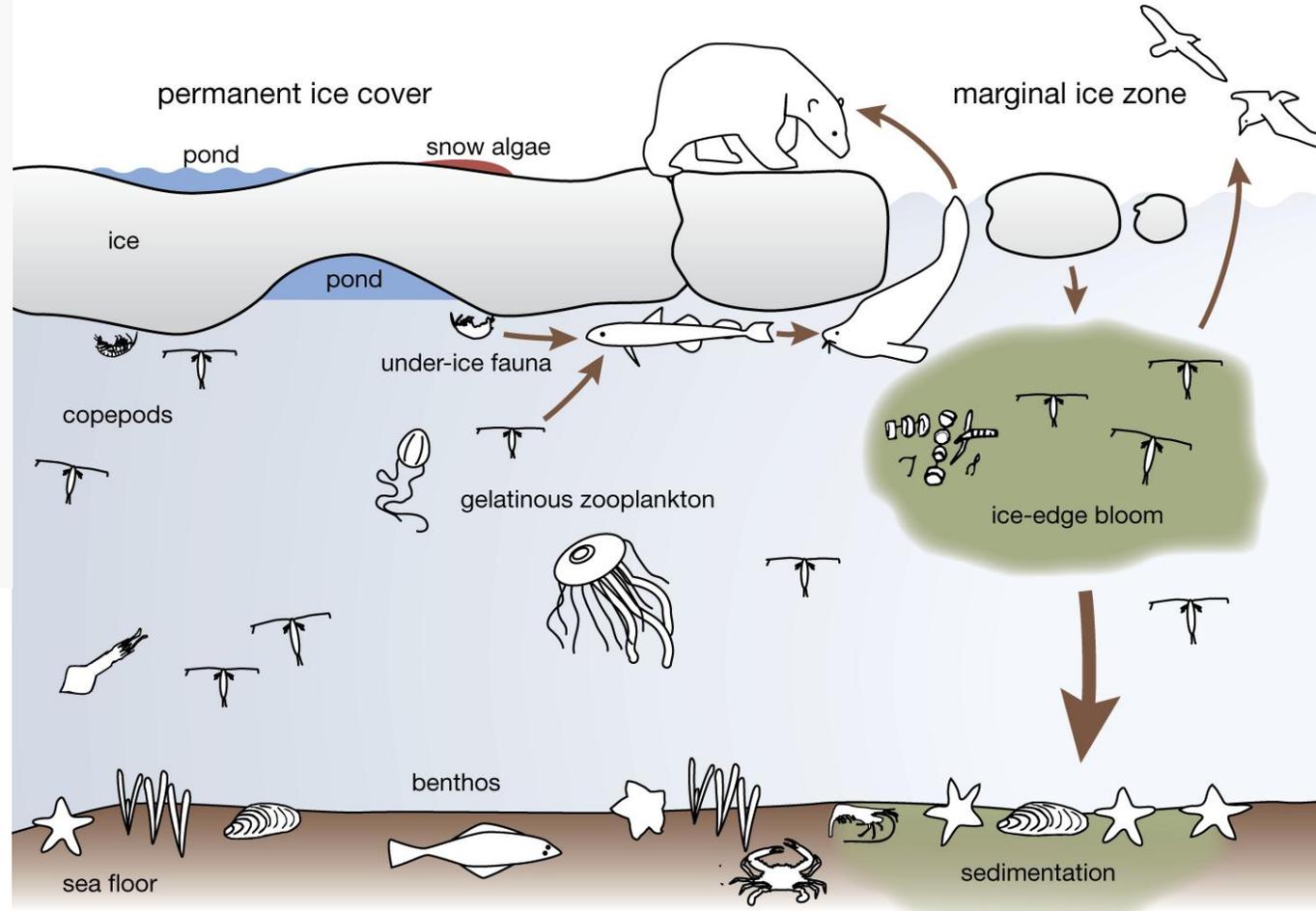
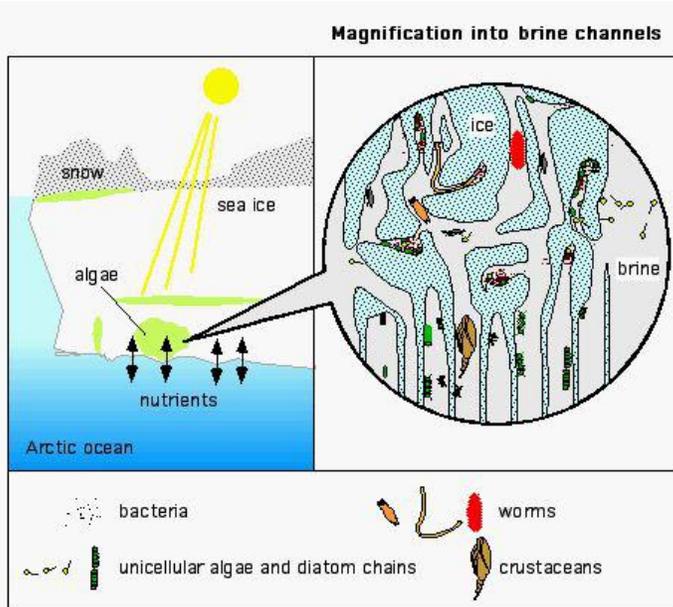
Arctic sea ice



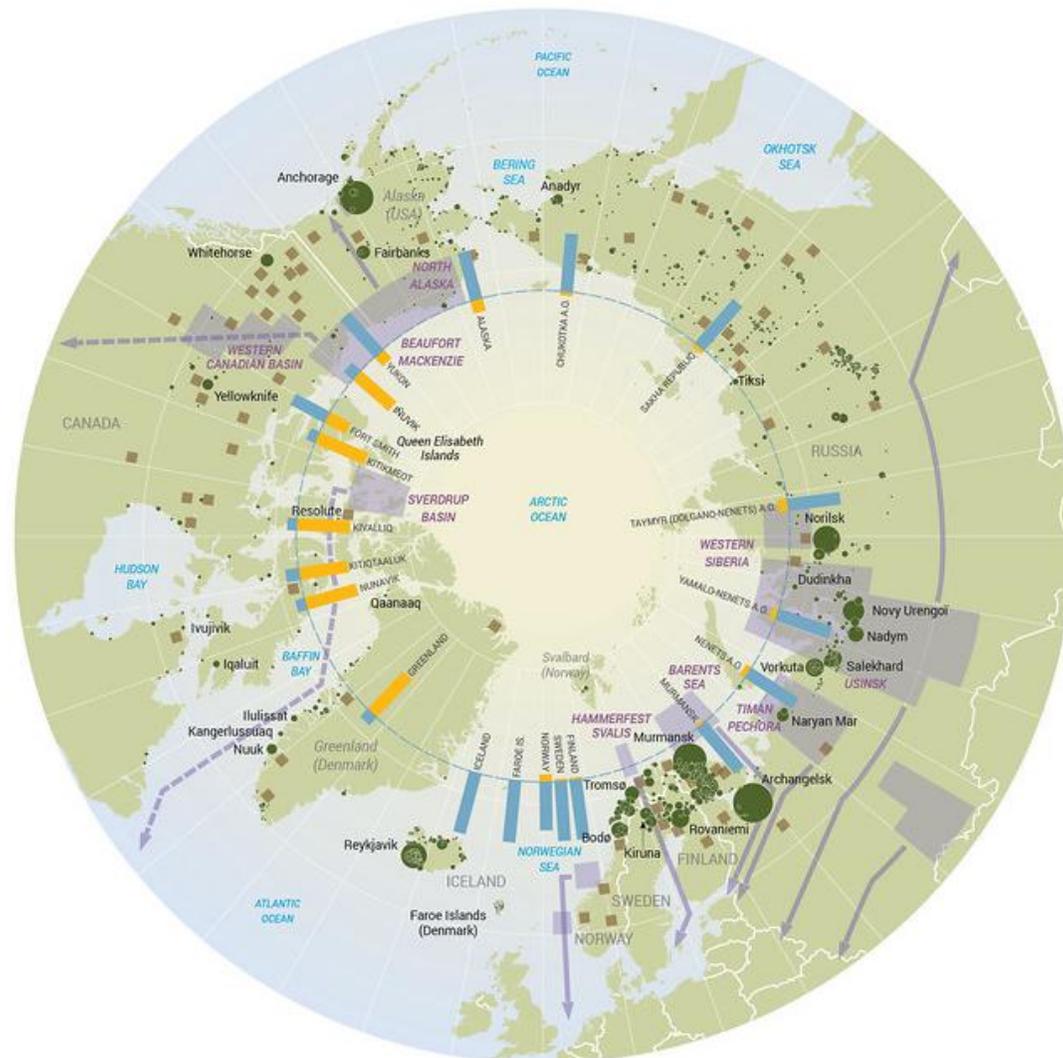
Arctic permafrost



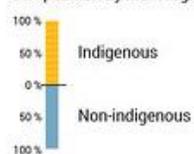
Sea-ice effects on biota



Arctic population



Population distribution, composition by main regions



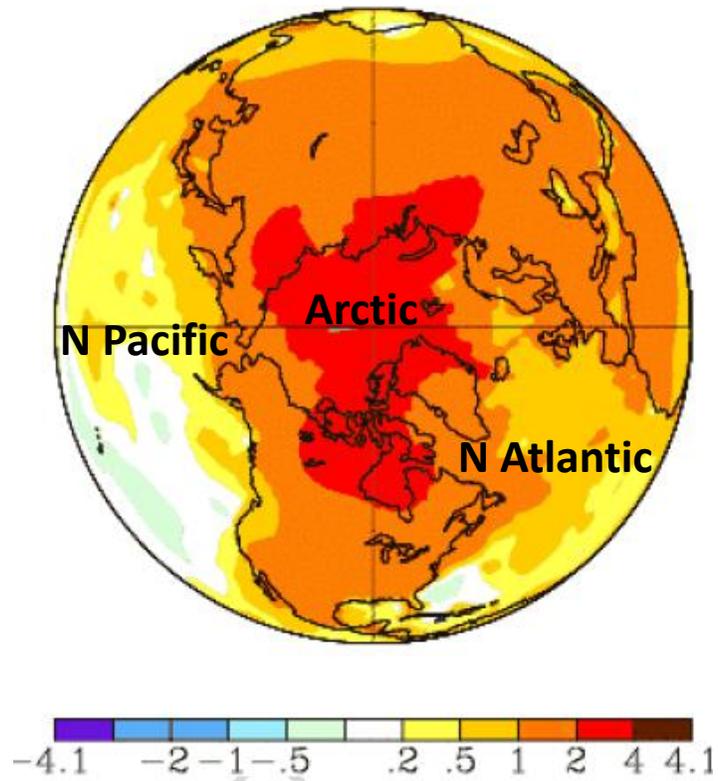
Population centres



A.O. : Autonomous okrug

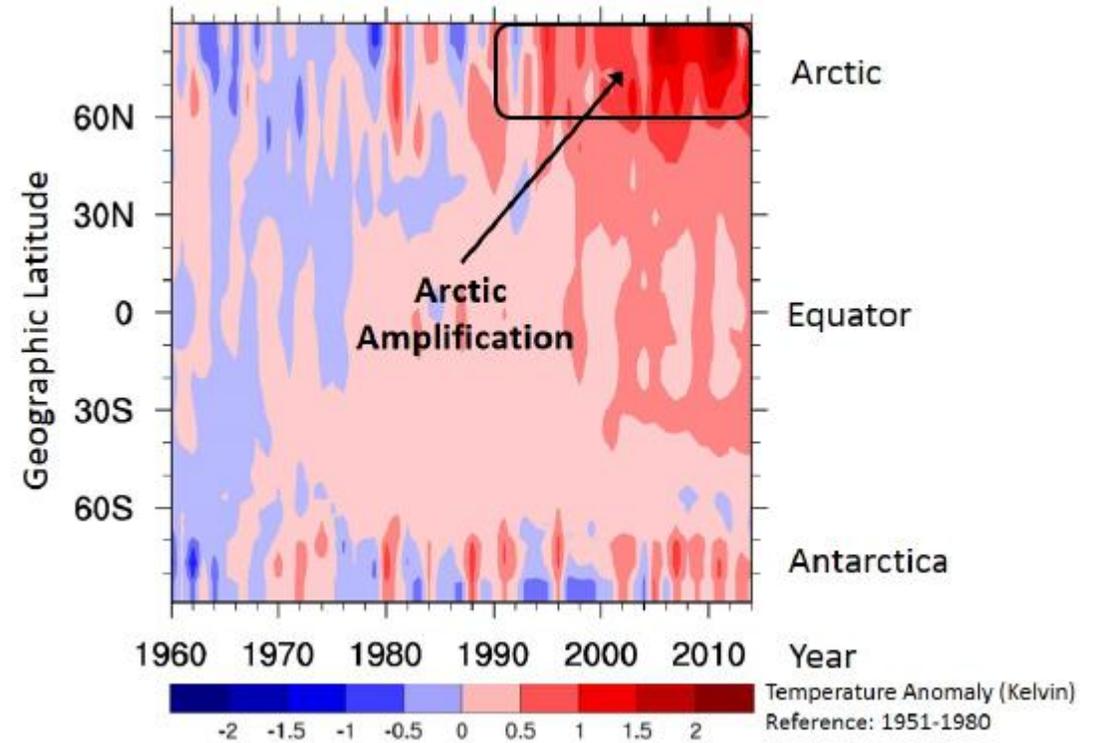


Amplified warming in the Arctic



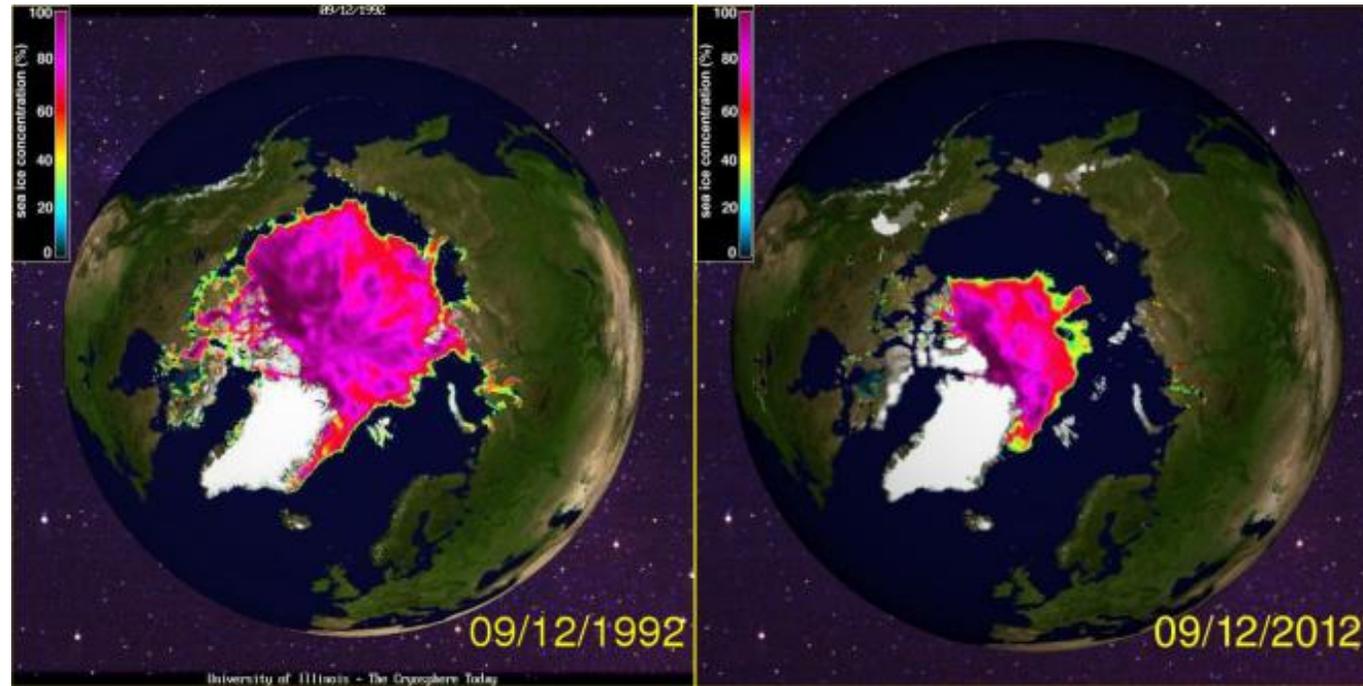
Change of annual surface air T (°C),
1963-2012

Data: NASA Goddard Institute for Space Studies



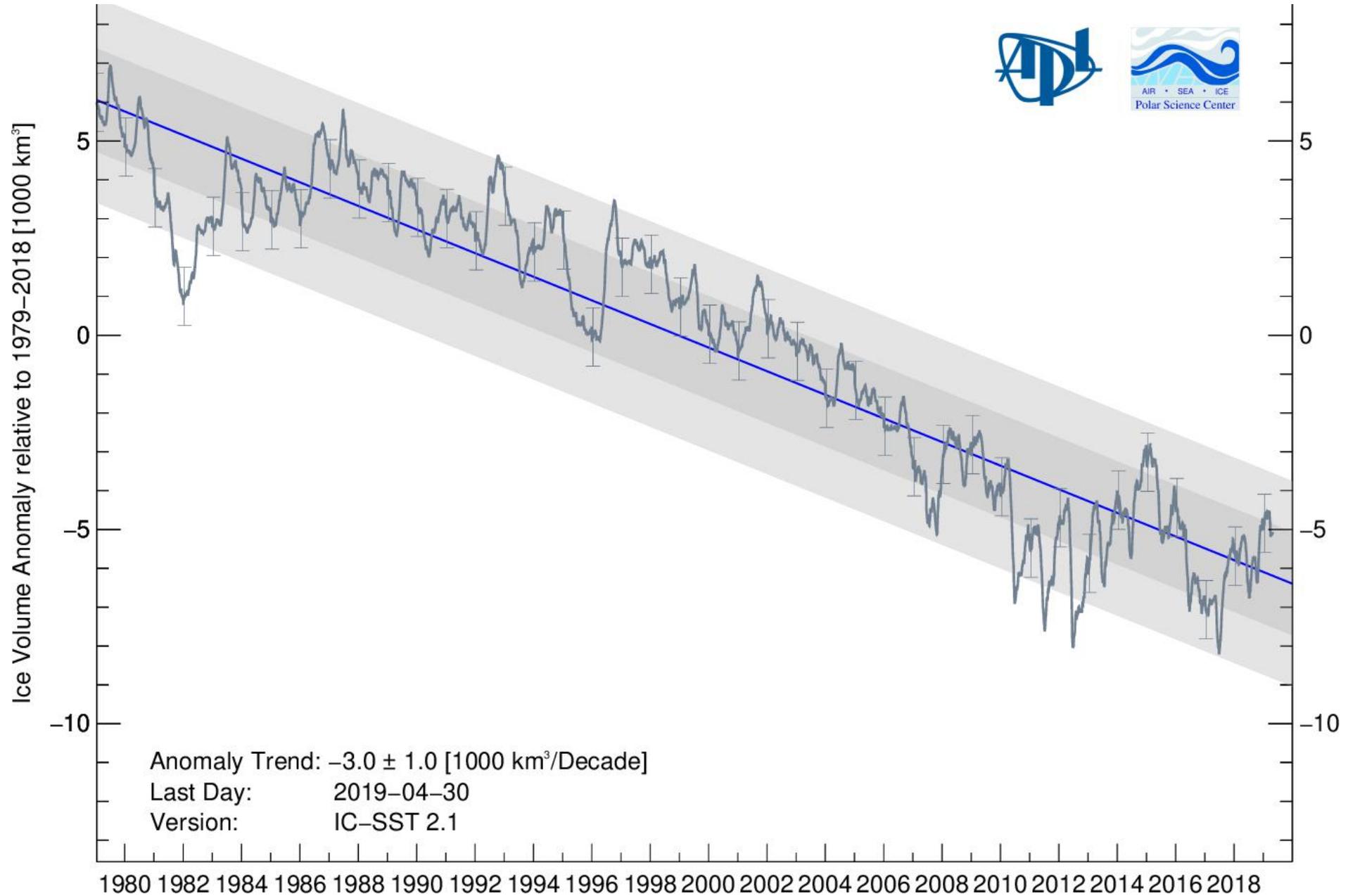
Yearly T anomalies from 1951-1980 mean

Change in Arctic sea-ice concentrations

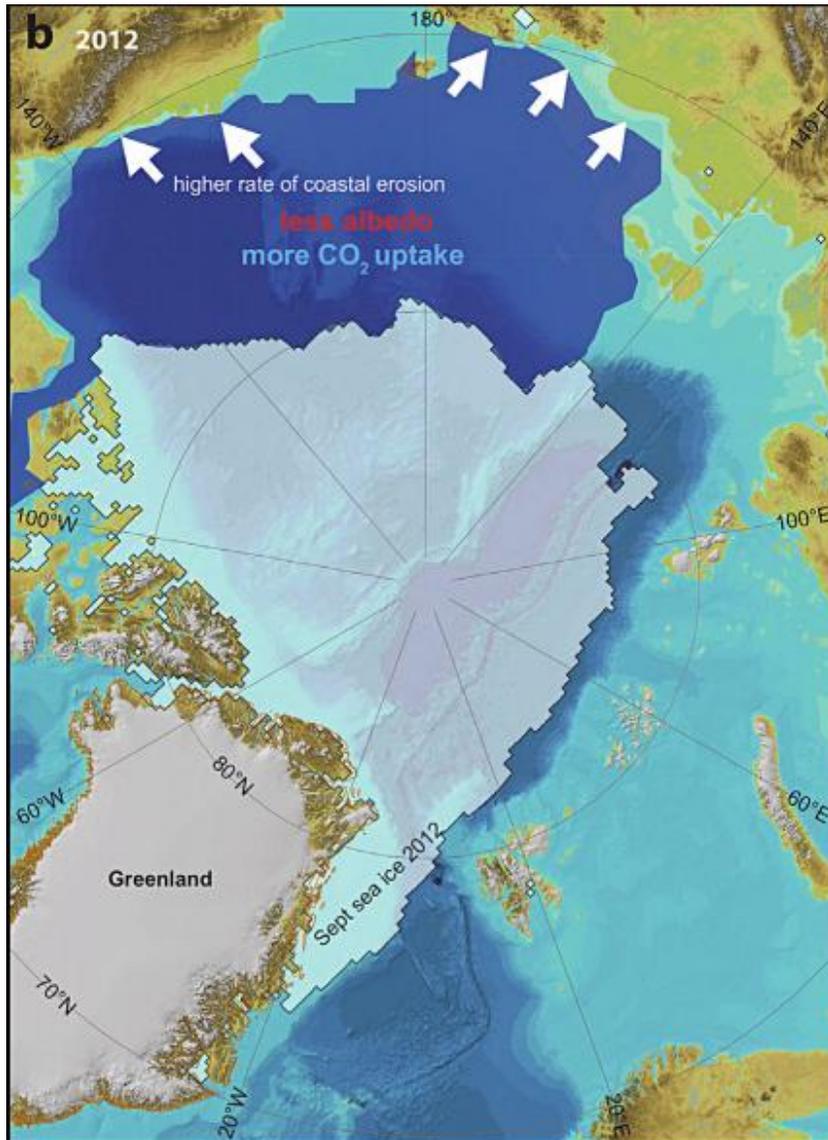


U. Illinois, Cryosphere Today, <http://arctic.atmos.uiuc.edu/cryosphere>

Arctic sea ice volume anomaly, 1980-May 2019



Impacts of sea-ice loss



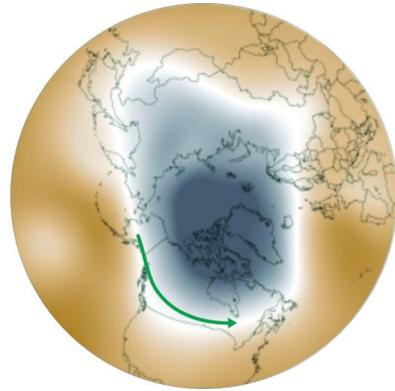
Hemispheric/Global

- Weather in mid-latitudes
- Freshwater effect on North Atlantic
- CO₂ balance, methane emissions

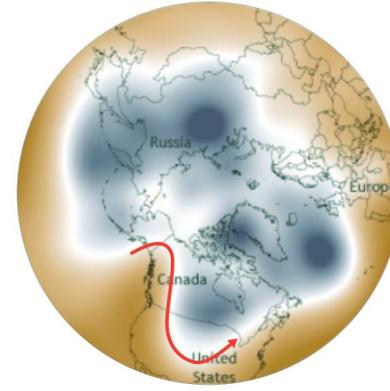
Arctic

- Ecosystems, biodiversity
- Socio-economic (indigenous peoples, shipping, resource developments)

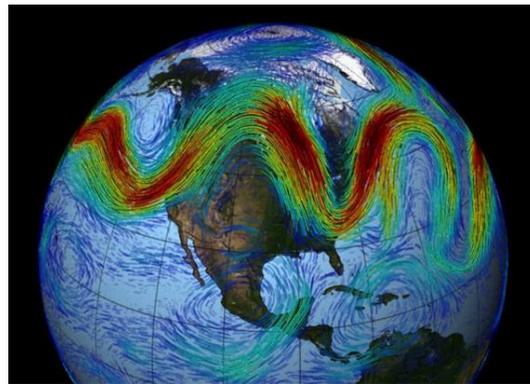
Impacts: Polar Jet Stream → weather in mid-latitudes



Typical sea-ice cover:
compact PJS configuration



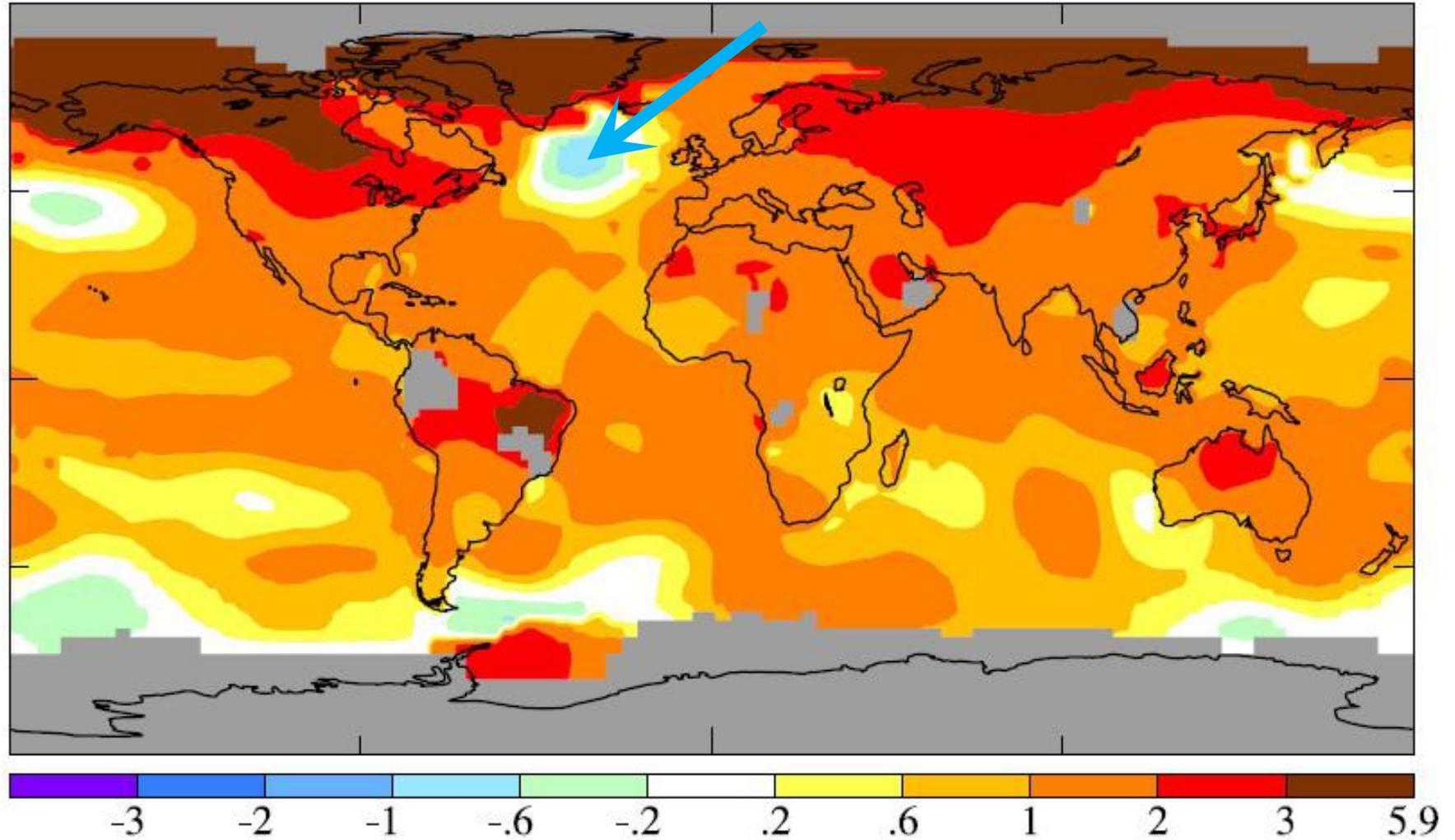
Reduced sea-ice cover:
wavy PJS (Polar Vortex)



NASA,
http://www.giss.nasa.gov/research/news/20120313/629341main_Earth_jet_stream.jpg

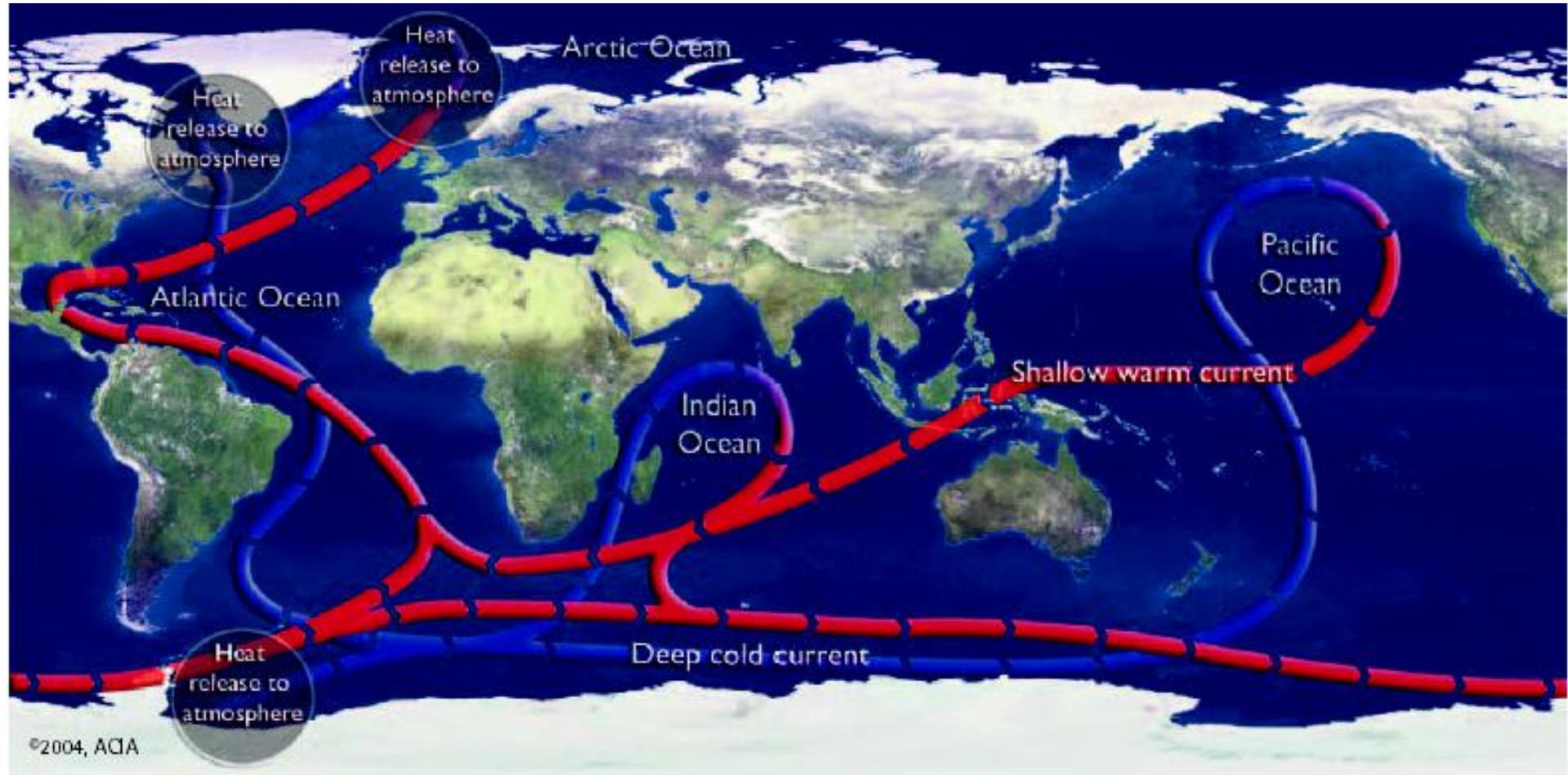
Super warm Arctic & “cold spot” in the North Atlantic

On time scales >20 yr,
the largest impact is
from melting Arctic
sea ice (Sevellec et al.,
NatClimChange 2017)



Global surface T anomalies, 2016 vs 1880-1920 (Goddard Space Flight Center)

Global circulation 'conveyor belt'

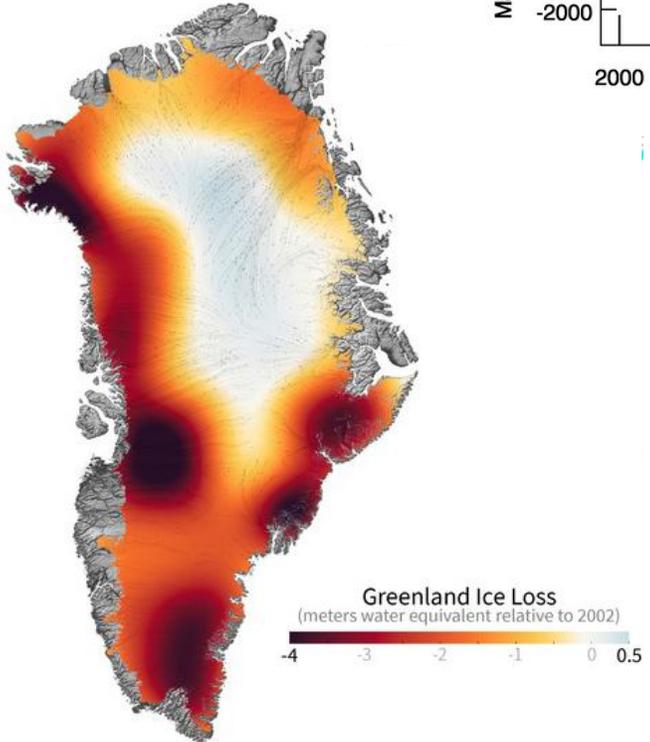
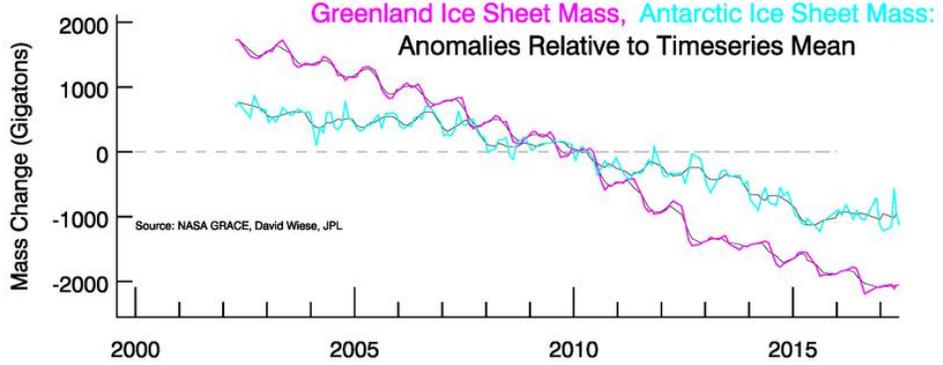


Permafrost degradation and forest invasion

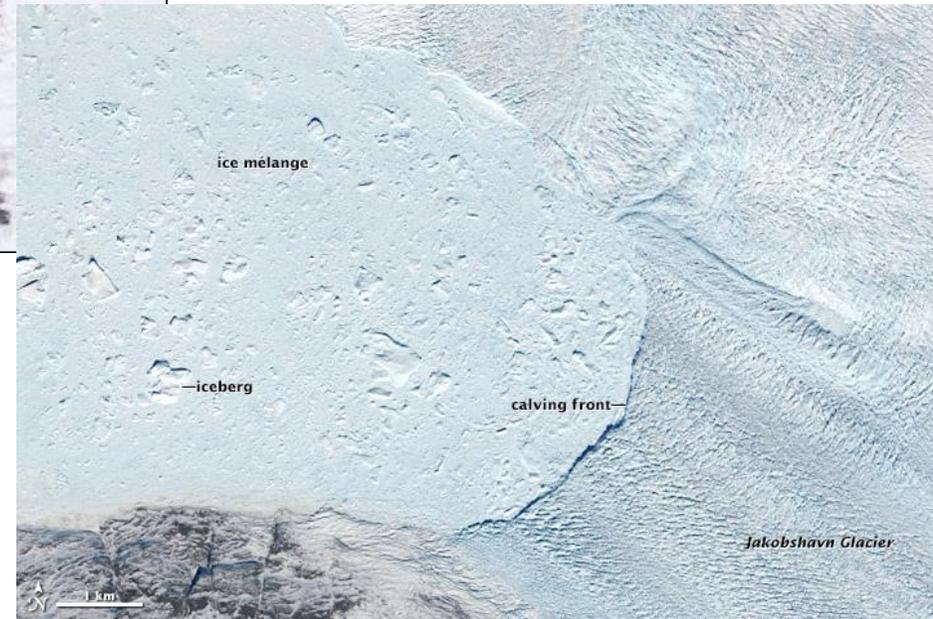
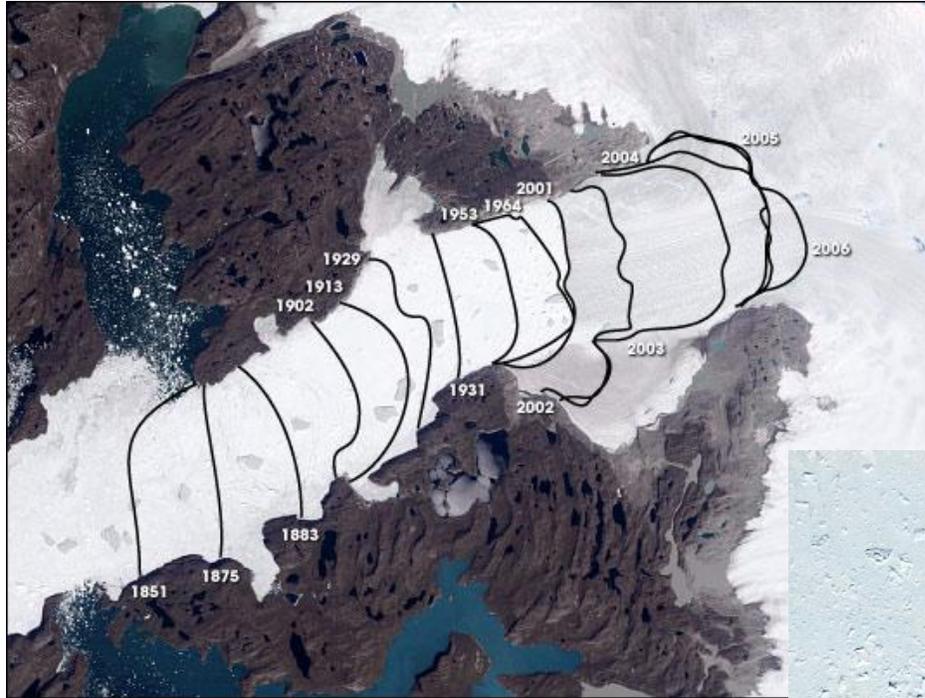


Photosynthesis increase (green) 1981-2005

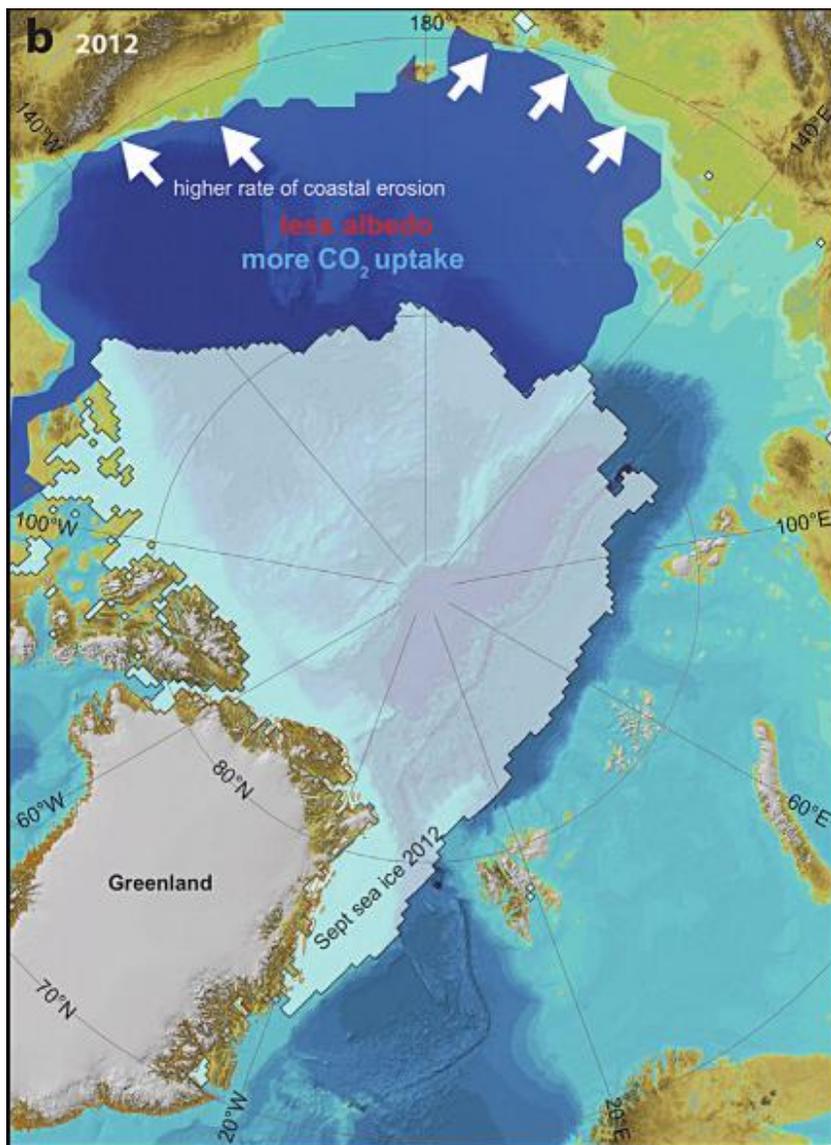
Greenland ice loss



Jakobshavn glacier calving



Impacts of sea-ice loss



from Jakobsson et al., QSR, 2014

Hemispheric/Global

- Weather in mid-latitudes
- Freshwater effect on North Atlantic
- CO₂ balance, methane emissions

Arctic

- Ecosystems, biodiversity
- Socio-economic (indigenous peoples, shipping, resource developments)

Threats to Arctic ecosystems

- Disappearance of sea ice
- Invasion of low-latitude species
- Acidification



Threats to Arctic humans



Stress on infrastructure



Beach erosion in Barrow, Alaska

Arctic shipping routes

Unlocking an Ocean

The Arctic ice cap is shrinking in summers and thinning, opening shipping lanes and access to valuable natural resources.

SHIPPING

Melting ice could soon open three polar passages historically clogged by ice, allowing shipping companies to greatly reduce the time it takes to cross the globe and deliver goods.

- Northwest Passage
- Northern Sea Route
- Arctic Bridge

Northwest Passage

The Northwest Passage would be the last of the three main routes to thaw, partly because it passes through straits that get blocked more easily by ice. But some Canadian officials estimate it will open within 20 years.

Northern Sea Route

During the Soviet era, millions of tons of cargo passed along this route with the help of nuclear-powered icebreakers. Transport plunged after the Soviet Union collapsed. If ice pulls back from the coast as many scientists project, ships moving between northern Europe and Asia could cut transit time by 10 to 15 days.

Arctic Bridge

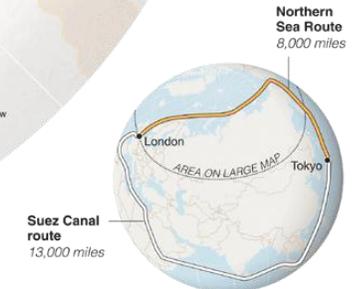
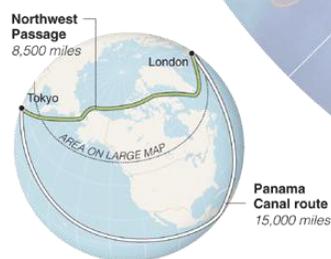
The route connecting Murmansk and Churchill is already open four months a year. But Hudson Bay is frozen over the remainder of the year, making it an impractical route. A warming climate would make it usable for longer periods.

NATURAL RESOURCES

Perhaps the biggest Arctic prize is oil and natural gas. The melting of the ice cap will allow energy companies to reach numerous petroleum deposits believed to exist under the Arctic seabed.

- Areas of known and prospective oil and gas reserves

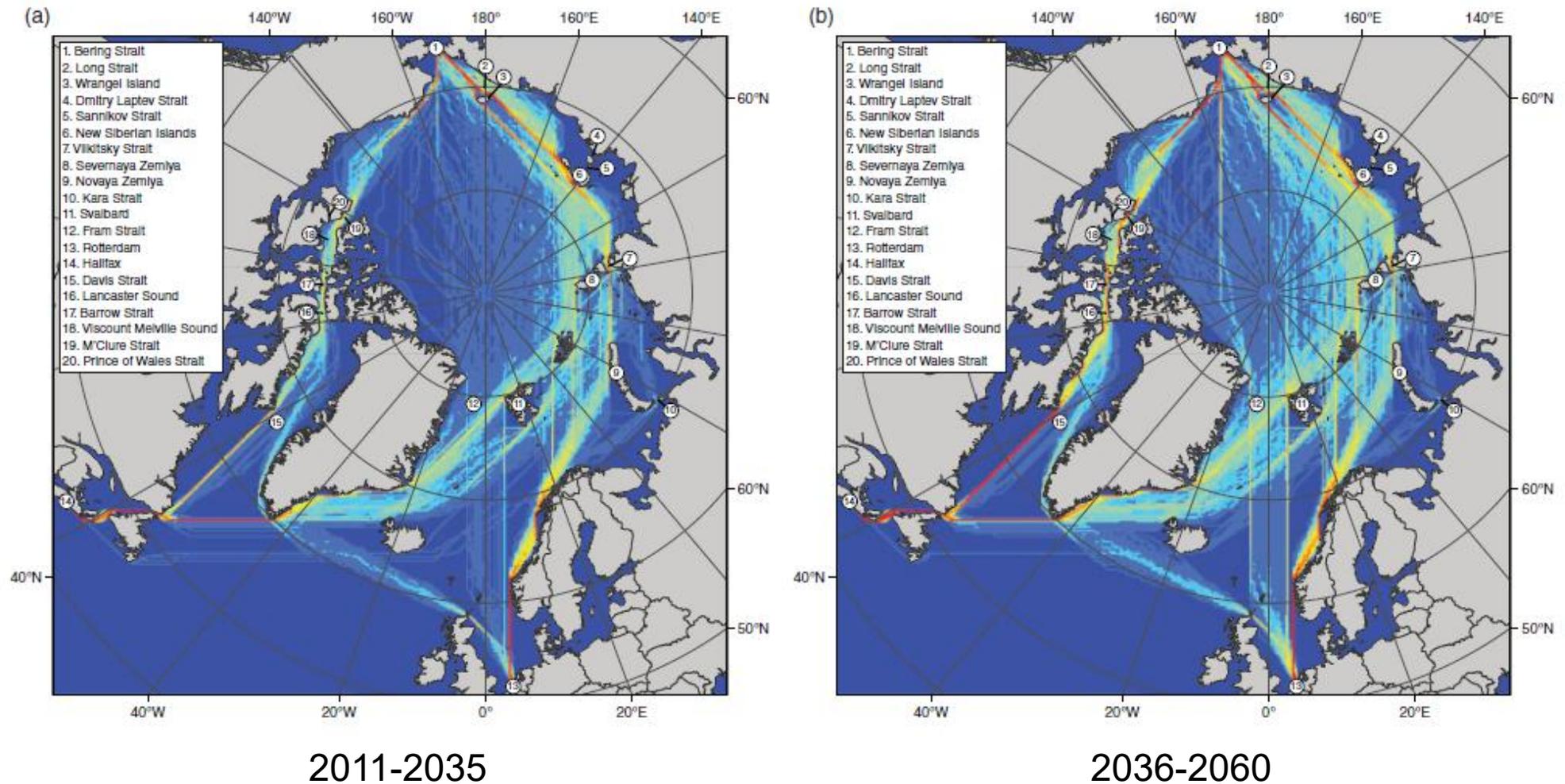
APPROXIMATE DISTANCES OF SHIPPING ROUTES



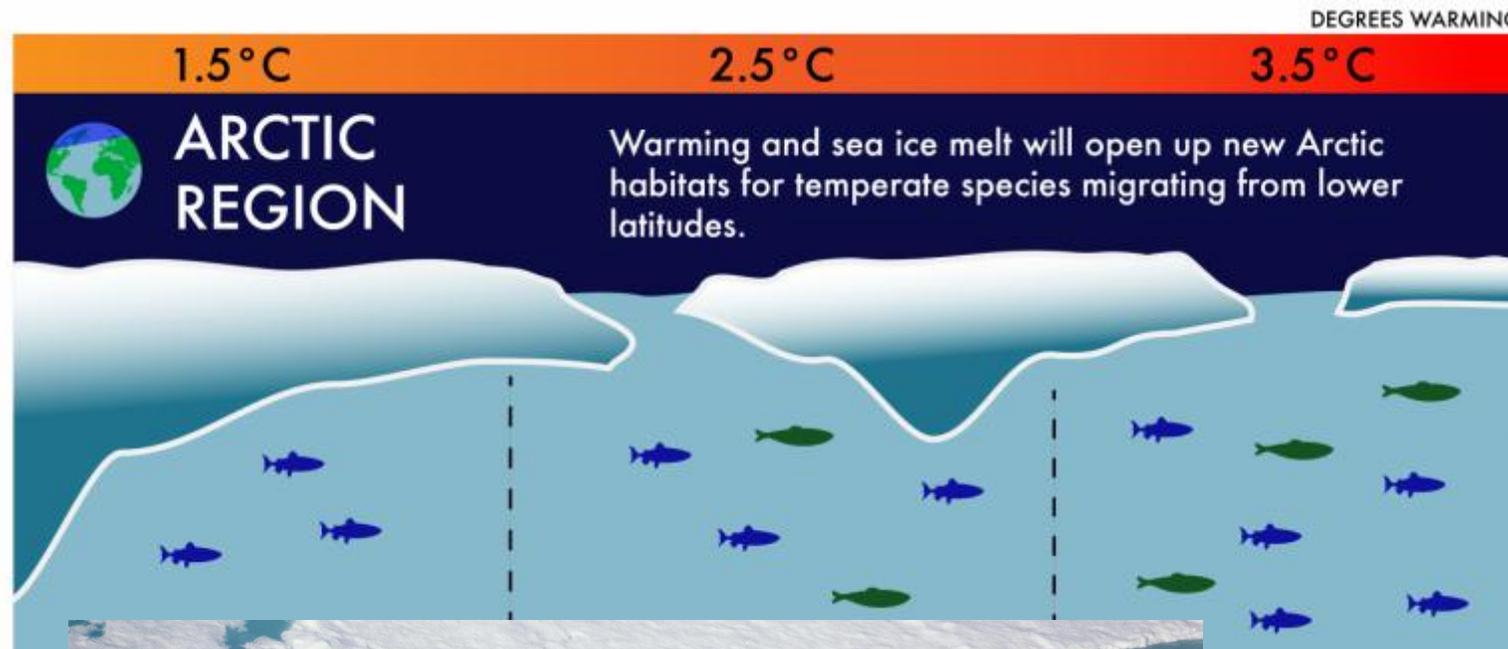
Sources: NOAA; U.S. Arctic Research Commission; Arctic Council; United Nations Environment Program; Arctic Climate Impact Assessment; International Atomic Energy Agency

Erin Aigner and David Constantine/The New York Times

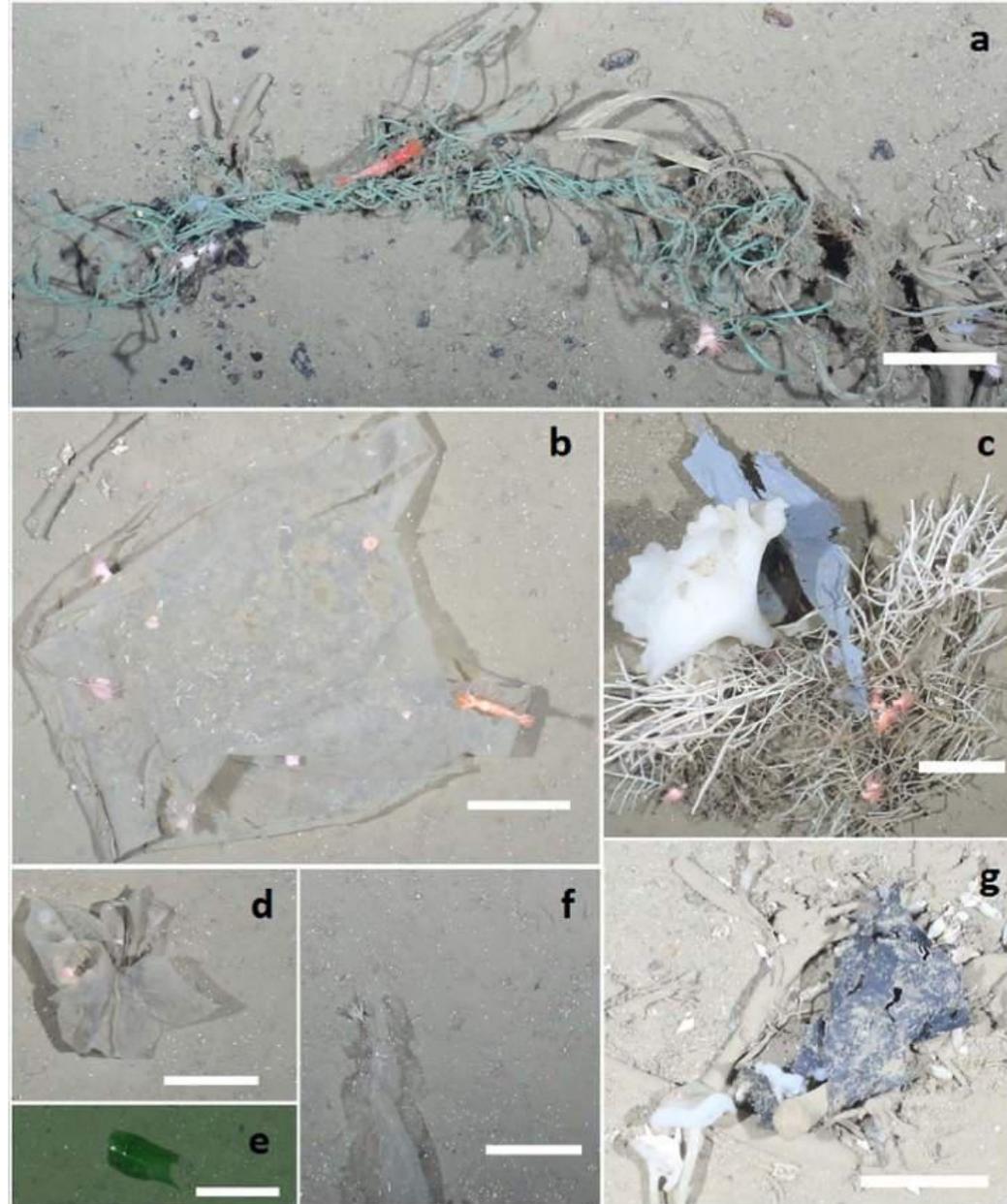
Modeling changes in shipping routes



Migration of fisheries



Seafloor litter in Fram Strait

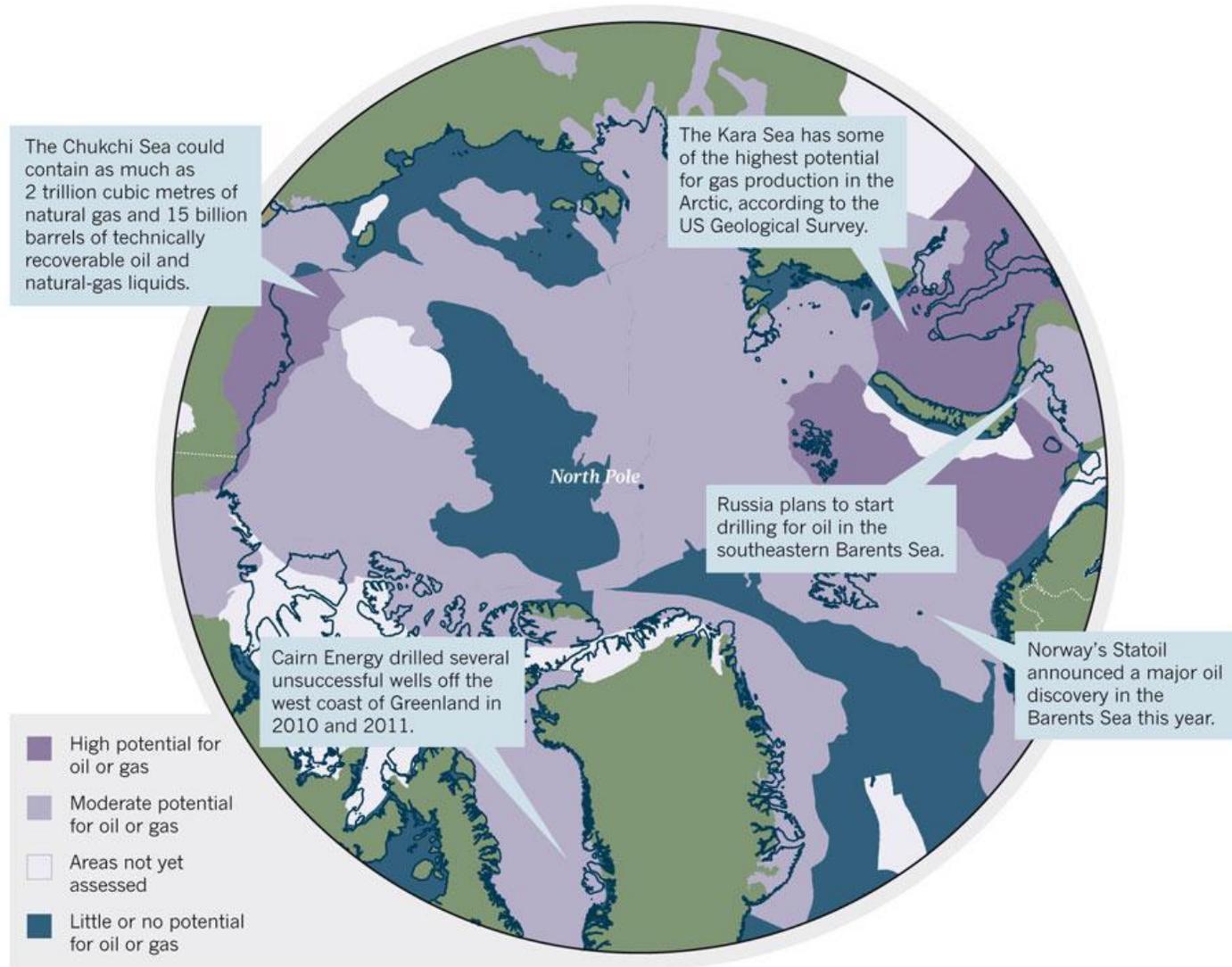


The first bulk freighter to pass through the NW Passage was carrying coal

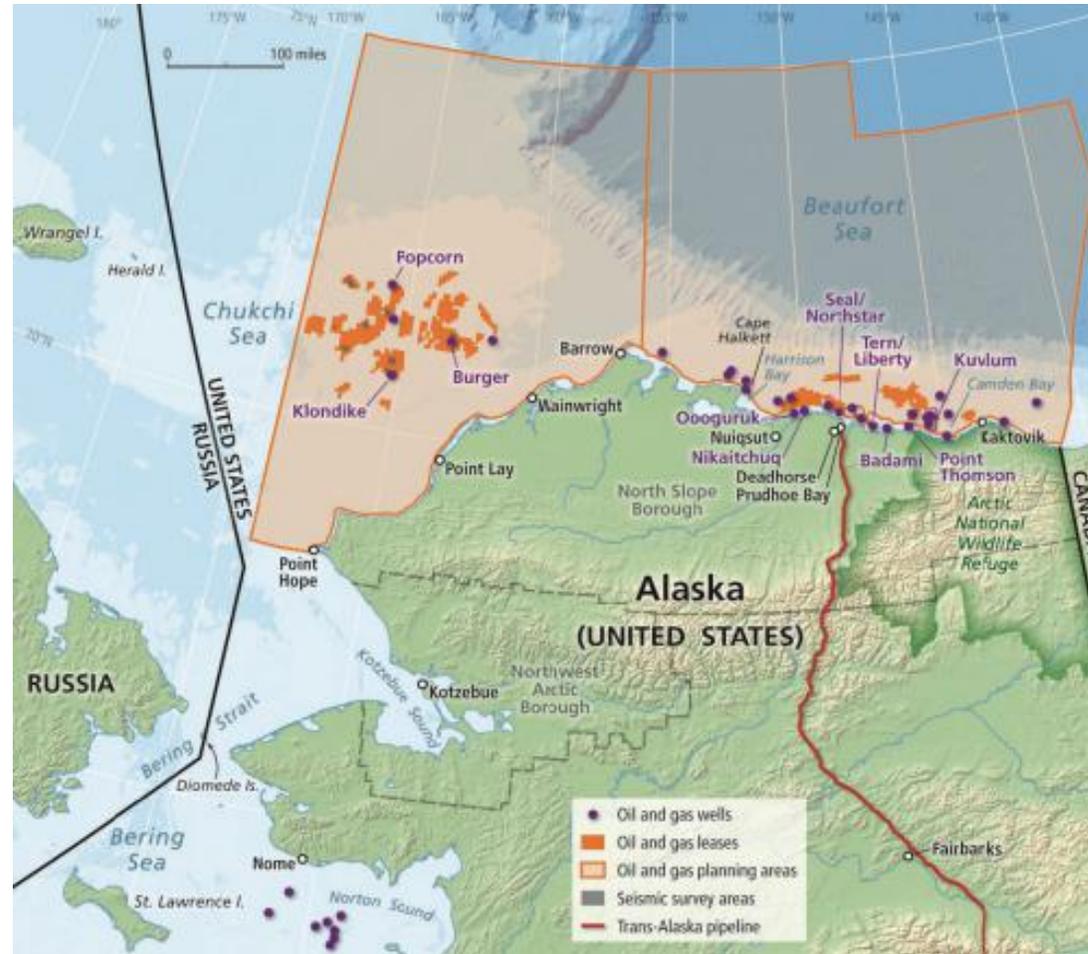


The 225-m *Nordic Orion* along the Northern Sea Route, Vancouver to Finland

Arctic Ocean oil and gas potential



Oil and gas planning areas in Alaskan Arctic waters



Imagine if the Gulf of Mexico oil spill happened in the Arctic Ocean

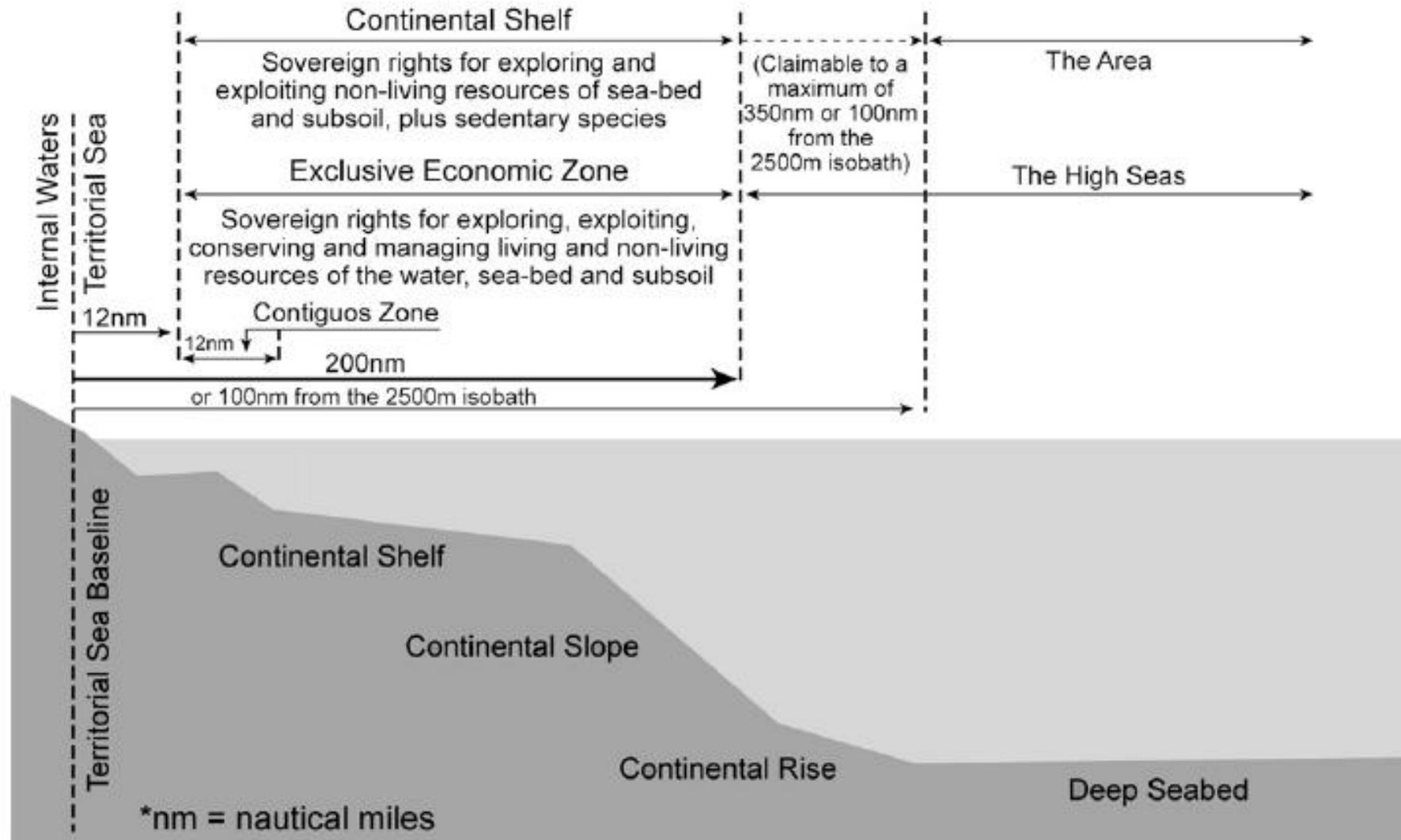
Below are two simulated oil slicks each comparable in size to BP's spill in the Gulf of Mexico.

Oiled areas are based on weekly satellite data from late April to late May 2010. The oil spill trajectory illustrates one possible outcome, but ocean currents and winds could vary the footprint of an actual spill (for example, pushing oil onshore in the Chukchi Sea or offshore in the Beaufort Sea).



* Data based on the Arctic Marine Synthesis: Atlas of the Chukchi and Beaufort Seas and SkyTruth's Gulf of Mexico oil spill database. Map created June 3, 2010.

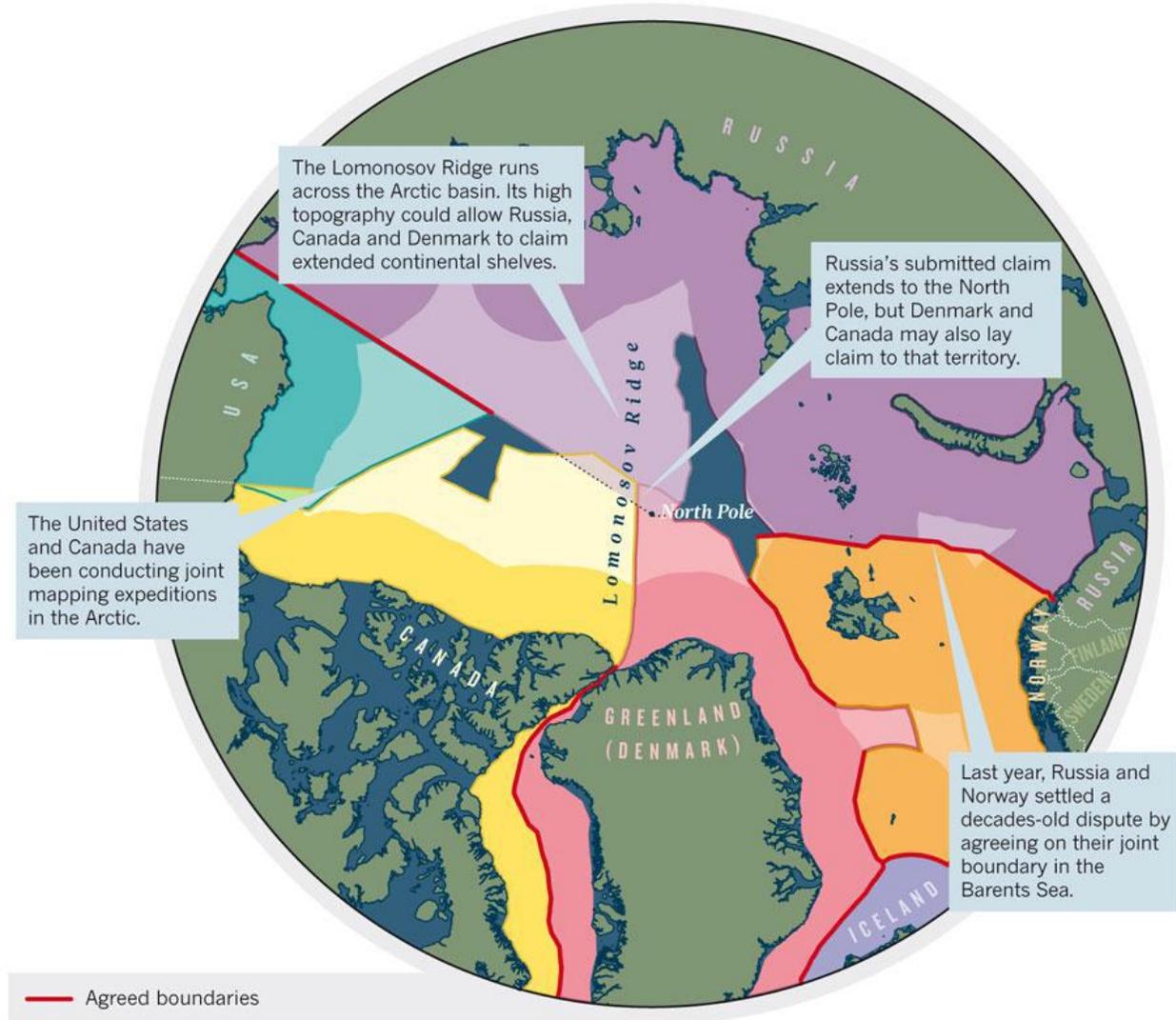
Application of the Law of the Sea (Article 76)



Arctic countries



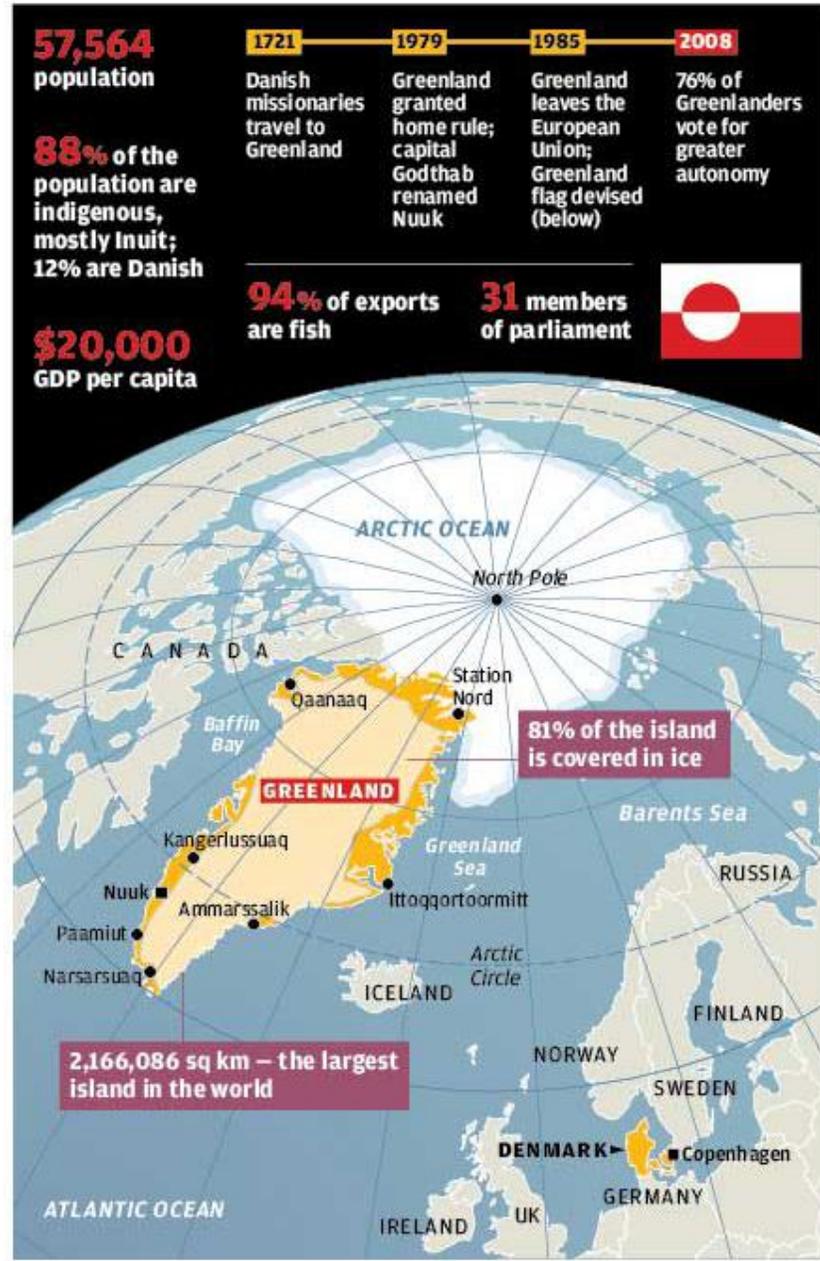
Article 76 claims in the Arctic



New players in the game



Unrest in the Kingdom of Denmark



Greenland is an autonomous constituent country of the Danish Realm ...

Should Greenland become independent?



Just headlines ...

[A Russian company is pushing forward with plans to bring container shipping to the Northern Sea Route](#)

[Chinese firm withdraws bid for Greenland airport projects, reports Sermitsiaq](#)

[Insulting Canada won't help the US with its Arctic ambitions](#)

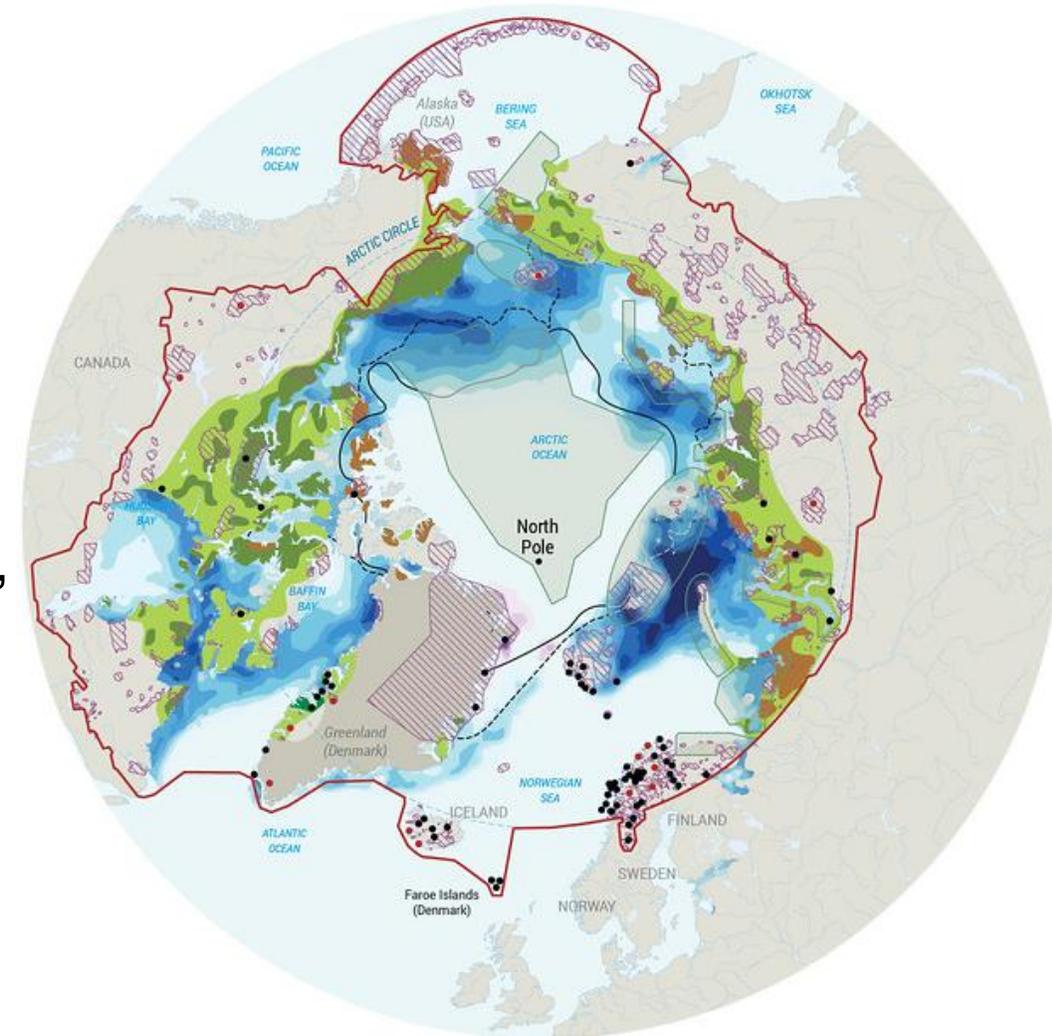
[In court and out, the Trump administration continues its push for offshore Arctic oil development](#)

[Like Denmark and Russia, Canada says its extended continental shelf includes the North Pole](#)

[For the first time ever, an Arctic Council ministerial meeting has ended without a joint declaration](#)

Where shall we go?

- Secretary Pompeo: ramp up security, no “climate”
- China (Korea, etc): international accessibility
- Or ... focus on reducing waste (including emissions), create more protected areas



Normalized difference vegetation index (NDVI)
Percent change 1982-2012

- 40% to 0
- 0 to +25%
- 25 to 50%
- Ecologically or biologically significant marine areas

Regulated areas

- Protected areas
- CAFF boundary
- Ramsar sites
- UNESCO heritage sites

Summer open water
Magnitude change 1982-2012

-40% -20% 0 20% 40%

Changes in sea ice extent

- Sea ice extent in September 1981
- Sea ice extent in September 2018