The Cryosphere

A GEOL-G 477 Project for IUPUI CEES

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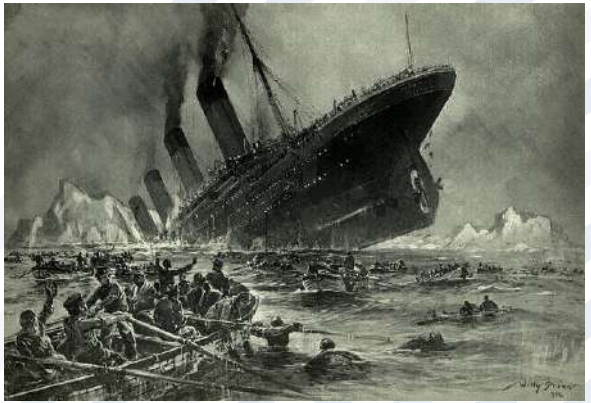
Climate change is impacting the cryosphere.

In this lesson, we will explore why and how.

The Associated Press (2018)

What is the cryosphere?

- **Parts of the earth containing frozen water**
  - **Sea ice**
    - Frozen ocean water
    - Thicker in colder months
    - Decline since 1950s/60s
  - **Glaciers**
    - Formed by years of compressed snow
  - **Ice caps**
    - Cover <19,000 mi^2
    - Feed glaciers around edges



"Untergang der Titanic" by Willy Stöwer (1912)

Vatnajökull in Iceland, Europe's largest ice cap by NASA (n.d.)

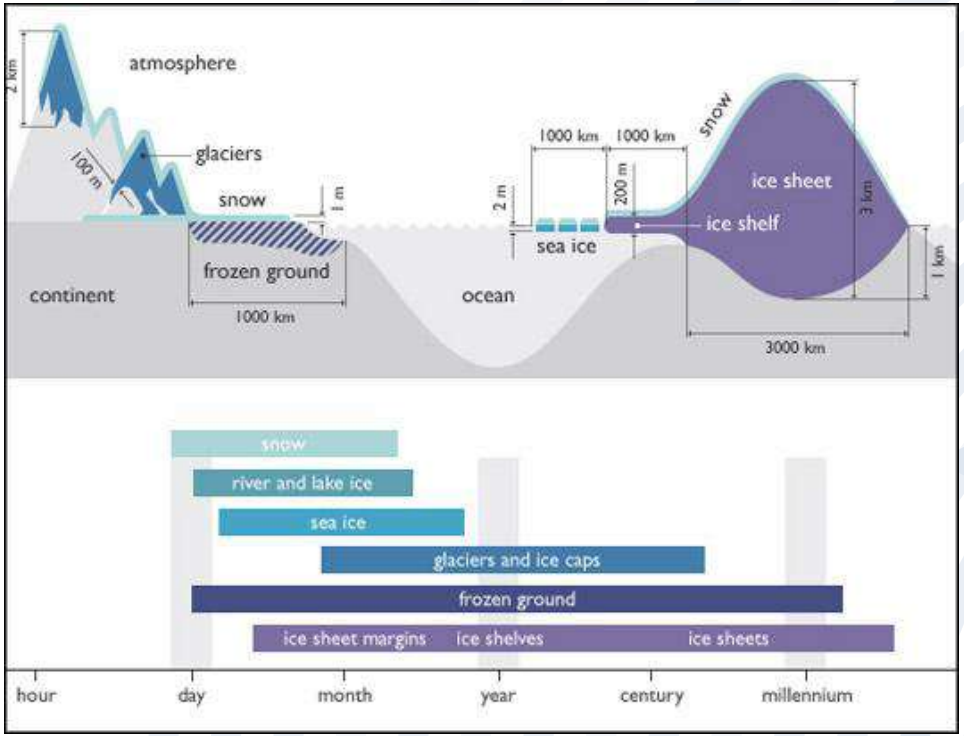
What is the cryosphere?

- **Ice sheets**
  - Chunk of glacier ice covering land >19,000 mi^2
  - Antarctica, Greenland (“continental glaciers”)
- **Ice shelves**
  - Floating platform of ice
- **Snow cover**
  - Most temporary
- **Frozen ground**
  - Permafrost: where ground is at/below freezing for >2 years
- **Lake and river ice**
  - Breaks up in spring

Melting ice in Antarctica, Reuters/Pauline Askin (2019)

Where is the cryosphere?

- On mountains, on the ground, in the ocean
- Each part has a different “lifespan”
  - Snow is least permanent, but layers form glaciers
  - Ice sheets are oldest



IPCC AR4, Figure 4.1 (2007)

Where is the cryosphere?

Ice on Land	Percent of Global Land Surface[a]	Sea Level Equivalent[b] (metres)
Antarctic ice sheet[c]	8.3	58.3
Greenland ice sheet[d]	1.2	7.36
Glaciers[e]	0.5	0.41
Terrestrial permafrost[f]	9–12	0.02–0.10[g]
Seasonally frozen ground[h]	33	Not applicable
Seasonal snow cover (seasonally variable)[i]	1.3–30.6	0.001–0.01
Northern Hemisphere freshwater (lake and river) ice[j]	1.1	Not applicable
Total[k]	52.0–55.0%	~66.1
Ice in the Ocean	**Percent of Global Ocean Area[a]**	**Volume[l] (10^3 km^3)**
Antarctic ice shelves	0.45[m]	~380
Antarctic sea ice, austral summer (spring)[n]	0.8 (5.2)	3.4 (11.1)
Arctic sea ice, boreal autumn (winter/spring)[n]	1.7 (3.9)	13.0 (16.5)
Sub-sea permafrost[o]	~0.8	Not available
Total[p]	5.3–7.3	

IPCC AR5, Table 4.1 (2013)

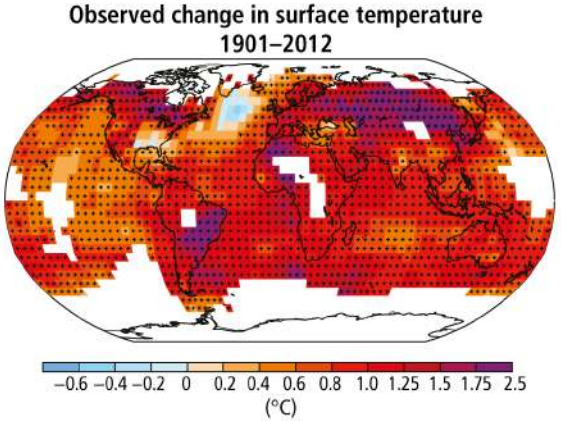
The cryosphere covers **52-55%** of global land surface and **5.3-7.3%** of global ocean area.
Almost **70%** of earth's freshwater is stored in **ice caps** and **glaciers**.
If all of Antarctica melted, sea levels would rise 58.3 meters, or **191.3 feet**!

Keeping it cool

- The cryosphere's **high albedo** helps keep the earth cooler.
  - Albedo: a surface's reflective quality
  - Snow and ice are **more reflective** than land or water
    - Incoming solar radiation bounces off snow and ice, sending heat back into space
  - **Ice-albedo feedback** = positive feedback loop that helps keep temperatures down
    - Cryosphere helps balance earth's "energy budget"

Hot topic

- Human activity causing **global warming** is harming the cryosphere.
  - Pollution is trapping heat and causing higher temperatures
    - Ex: carbon emissions from fossil fuels
  - Higher temperatures mean less snow and ice, causing even higher temperatures (ice-albedo)
  - By 2050s, Arctic may be ice-free in summer

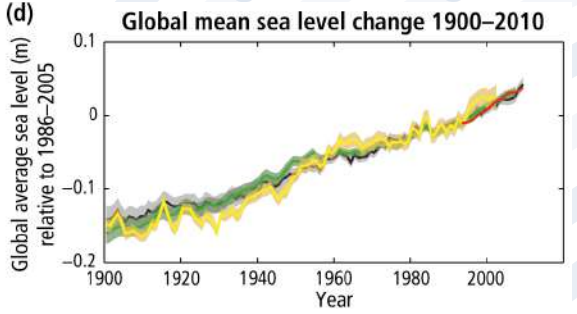


IPCC Synthesis Report, from Fig. 1.1 (2014)

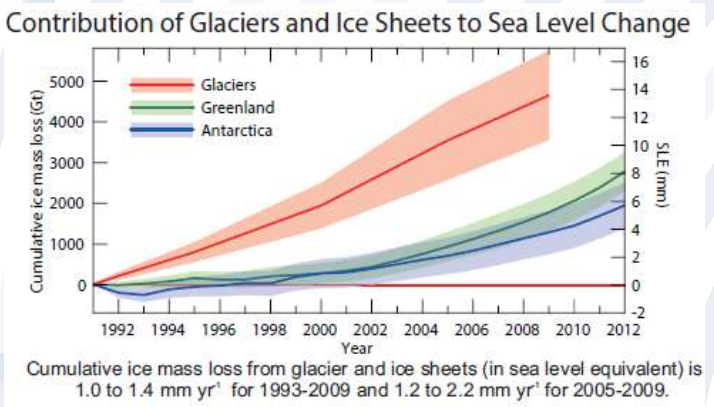
Photo by ALAMY (2014)

Sink or swim

- Melting **glaciers** and **ice sheets** is causing **rising sea levels**.
  - 40% of U.S. population lives in at-risk coastal areas
  - Ice-trapped methane, a potent greenhouse gas, could be released into atmosphere
- Melting sea ice does ***not*** cause sea level rise.
  - Less sea ice *does* impact energy budget and animal



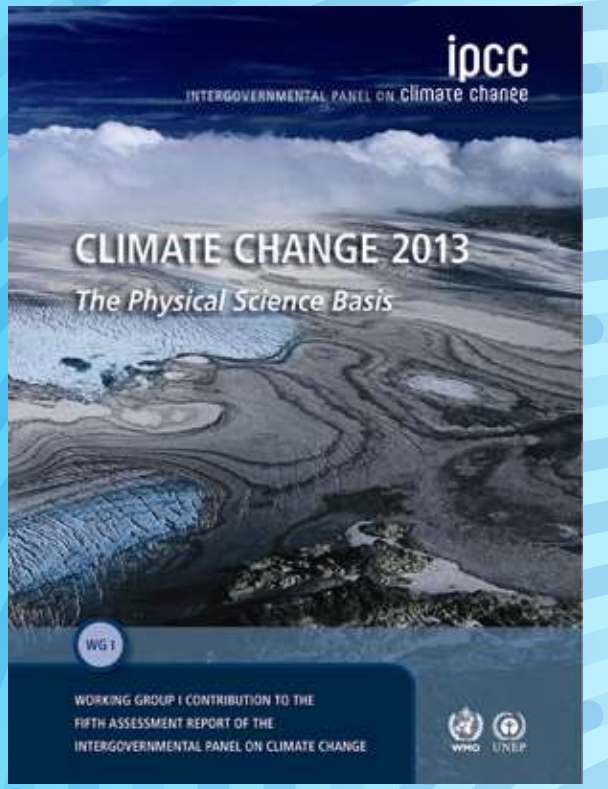
IPCC Synthesis Report, from Fig. 1.1 (2014)



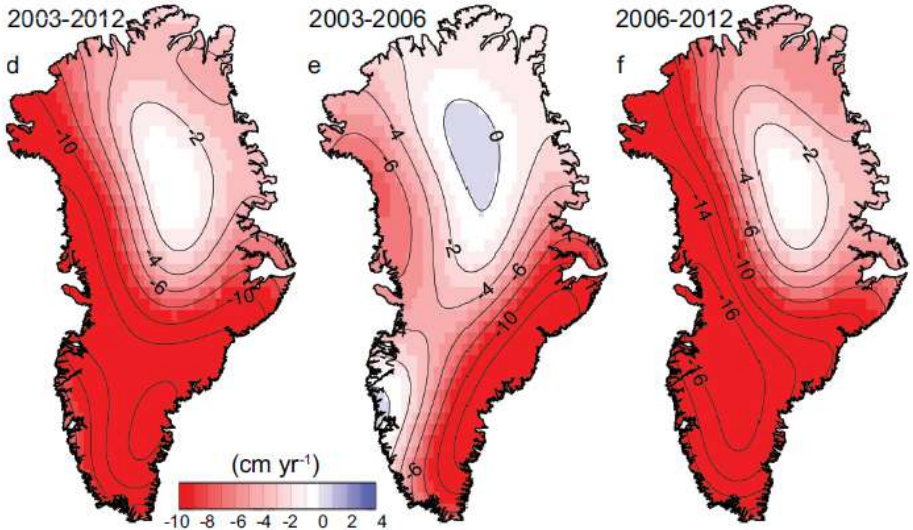
IPCC AR5, from Fig. 4.25 (2013)

What kinds of changes have been observed?

The IPCC, a part of the United Nations, is made up of scientists and researchers from 195 member states from around the world. Using information from their latest report, the following case study takes a look at one way that climate change is impacting the cryosphere.

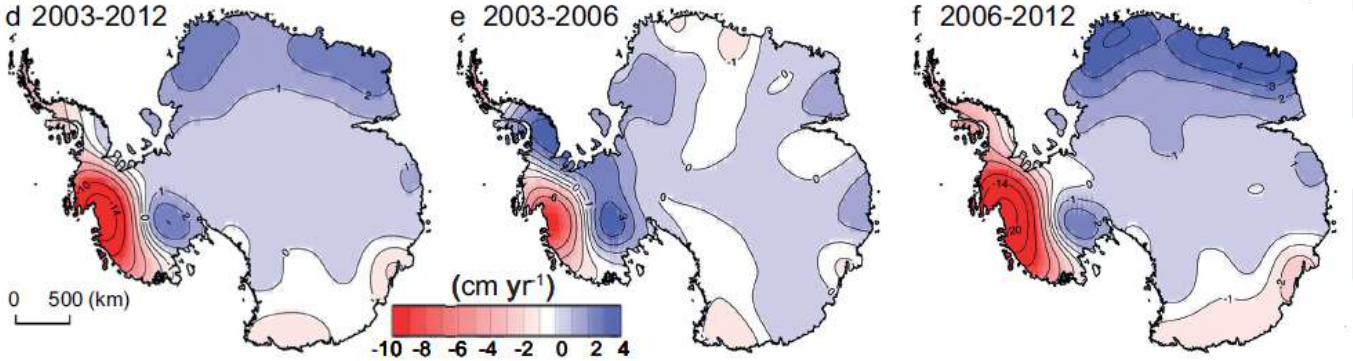


Case study: Greenland vs. Antarctica



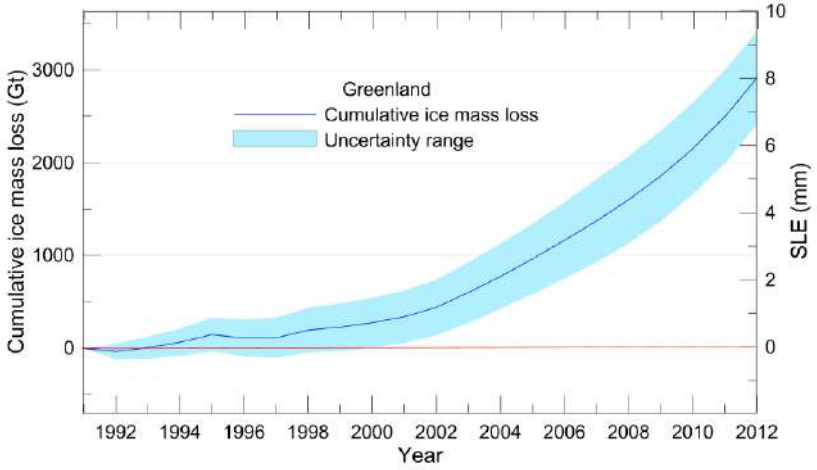
IPCC AR5, Fig. 4.13 (2013)

- The way that ice sheets are changing differs.
  - Greenland (left) is melting much faster
  - Antarctica (bottom) is both melting and adding ice, partly due to large size

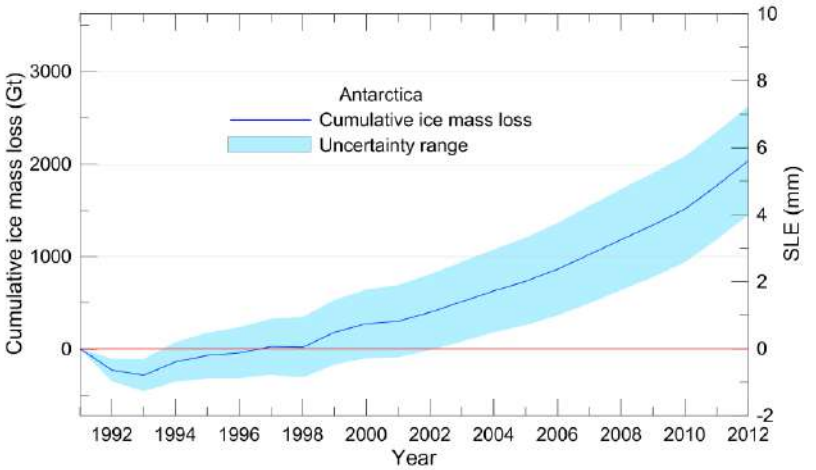


IPCC AR5, Fig. 4.14 (2013)

Case study: Greenland vs. Antarctica



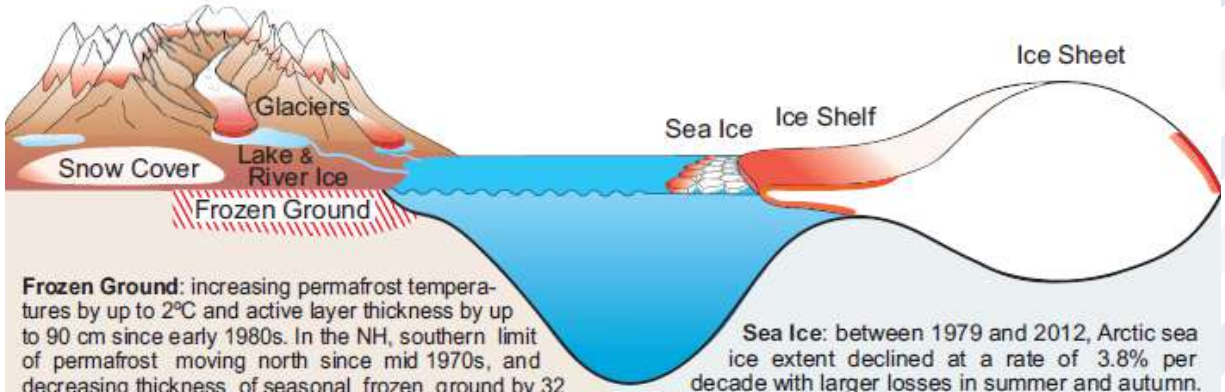
IPCC AR5, Fig. 4.15 (2013)



IPCC AR5, Fig. 4.16 (2013)

Although Greenland (left) is melting faster than Antarctica (right), both ice sheets are losing mass due to climate change, contributing to rising sea levels.

Summary: The changing cryosphere



Frozen Ground: increasing permafrost temperatures by up to 2ºC and active layer thickness by up to 90 cm since early 1980s. In the NH, southern limit of permafrost moving north since mid 1970s, and decreasing thickness of seasonal frozen ground by 32 cm since 1930s.

Snow cover: between 1967 and 2012, satellite data show decreases through the year, with largest decreases (53%) in June. Most stations report decreases in now especially in spring.

Lake and river ice: contracting winter ice duration with delays in autumn freeze-up proceeding more slowly than advances in spring break-up, with evidence of recent acceleration in both across the NH.

Glaciers: are major contributors to sea level rise. Ice mass loss from glaciers has increased since the 1960s. Loss rates from glaciers outside Greenland and Antarctica were 0.76 mm yr^{-1} SLE during the 1993 to 2009 period and 0.83 mm yr^{-1} SLE over the 2005 to 2009 period.

Sea Ice: between 1979 and 2012, Arctic sea ice extent declined at a rate of 3.8% per decade with larger losses in summer and autumn. Over the same period, the extent of thick multiyear ice in the Arctic declined at a higher rate of 13.5% per decade. Mean sea ice thickness decreased by 1.3 - 2.3 m between 1980 and 2008.

Ice Shelves and ice tongues: continuing retreat and collapse of ice shelves along the Antarctic Peninsula. Progressive thinning of some other ice shelves/ice tongues in Antarctica and Greenland.

Ice Sheets: both Greenland and Antarctic ice sheets lost mass and contributed to sea level change over the last 20 years. Rate of total loss and discharge from a number of major outlet glaciers in Antarctica and Greenland increased over this period.

IPCC AR5, from Fig. 4.25 (2013)

References

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Introduction slide photograph: a young polar bear on sea ice along the Northwest Passage above the Arctic Circle by Adrienne Tivy, 2016
Other photograph and table source information found in captions