

Climate Change and Society

GEOL-G490

Lecture 5: Observations: Cryosphere

WG1AR5_Chapter04_FINAL



<https://www.worldatlas.com/articles/what-is-the-cryosphere.html>

Cryosphere

The cryosphere is the collective term for the components of the Earth system that contain a substantial fraction of water in the frozen state (Table 4.1). The cryosphere comprises several components: snow, river and lake ice; sea ice; ice sheets, ice shelves, glaciers and ice caps; and frozen ground which exist, both on land and beneath the oceans

- 1. Sea ice**
- 2. Glacier**
- 3. Ice sheets**
- 4. Snow cover**
- 5. Frozen ground**



Ice sheets

An ice sheet is a chunk of glacier ice that covers the land surrounding it and is greater than 50,000 kilometers (20,000 miles) wide. An ice sheet is also known as a continental glacier.



Ice caps

Ice caps cover less than 50,000 square kilometers and usually feed a series of glaciers around its edges. While not hemmed in by any surface features (they lie on top of mountains), they are usually centered on a highest point (called a massif).

Ice shelves

An ice shelf is a thick, floating slab of ice that forms where a glacier or ice flows down a coastline. Ice shelves are found only in Antarctica, Greenland, and Canada. Thicknesses of floating ice shelves range from 100-1,000 meters.



Global Distribution of Cryosphere

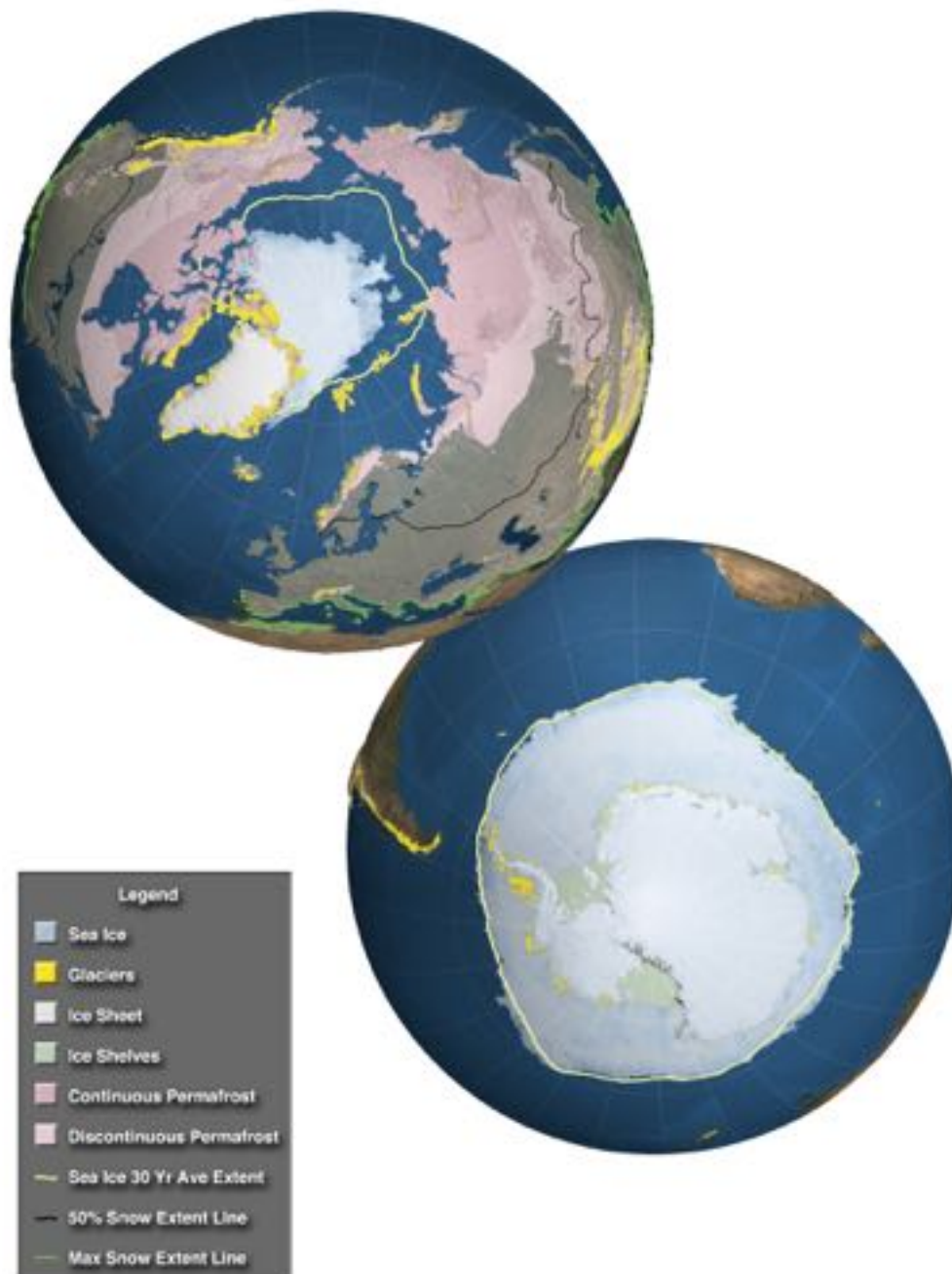


Fig. 4. 1

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	

1. Sea Ice

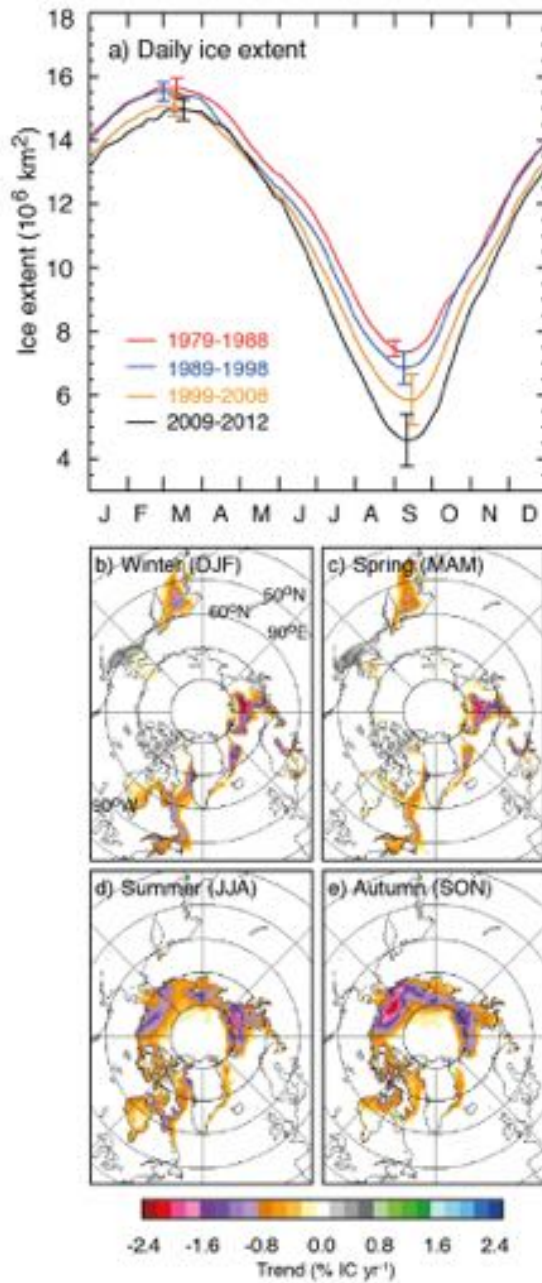


Fig. 4. 2

Sea Ice Extent and ice area

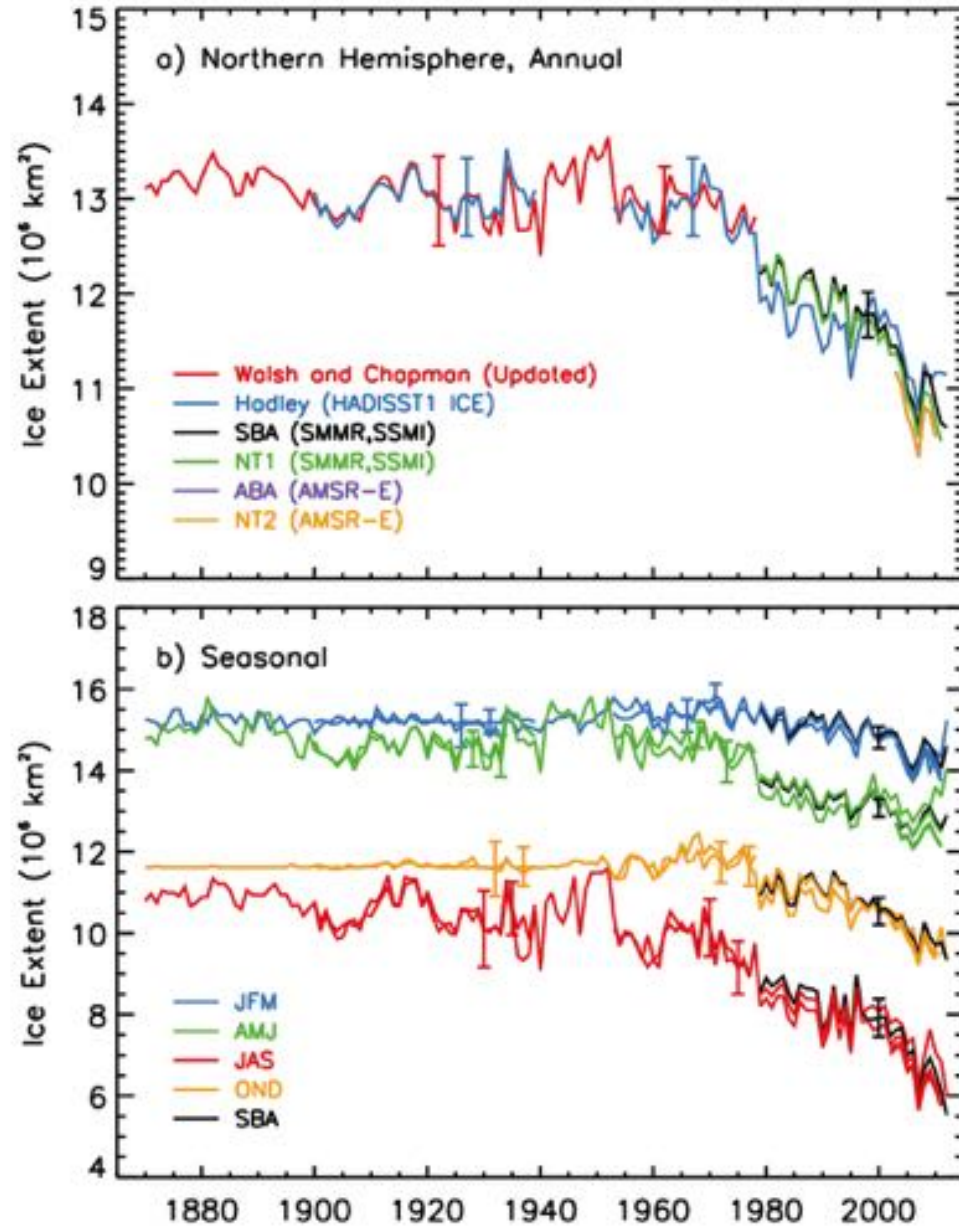


Fig. 4. 3

1. Sea Ice

Multi-year Sea Ice Extent and ice area

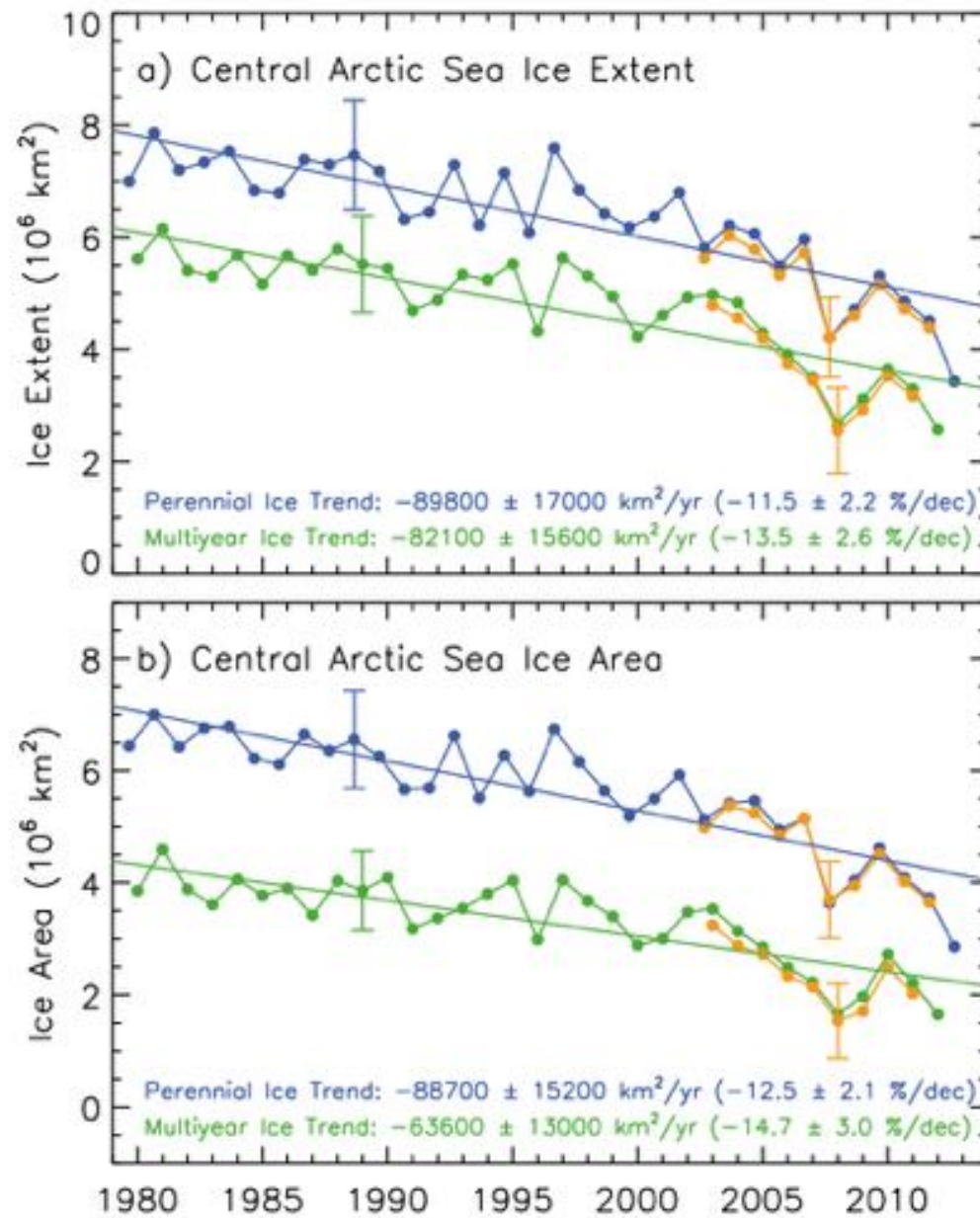


Fig. 4. 4

1. Sea Ice

Sea Ice Thickness

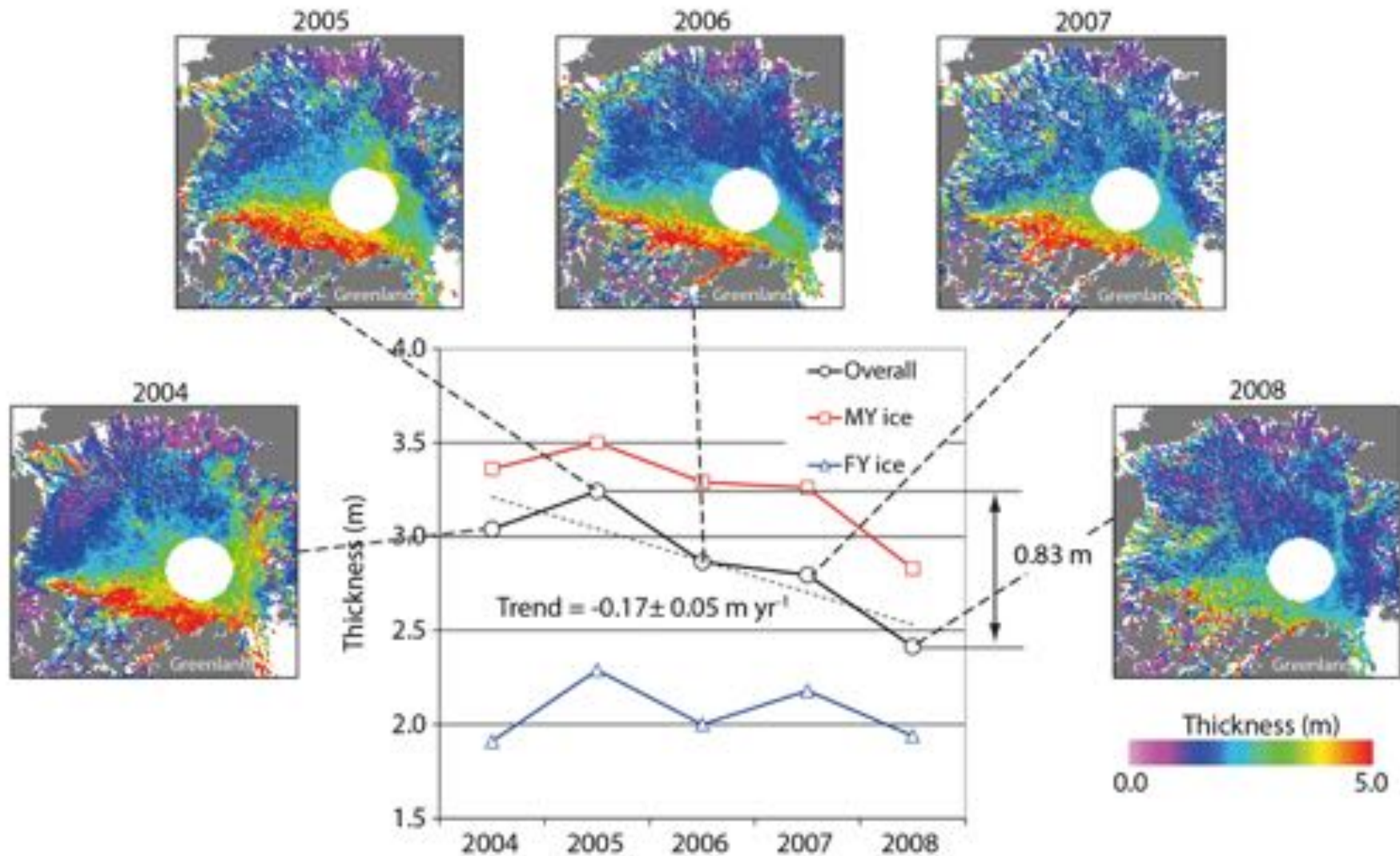


Fig. 4.5

1. Sea Ice

Arctic Sea Ice Summary

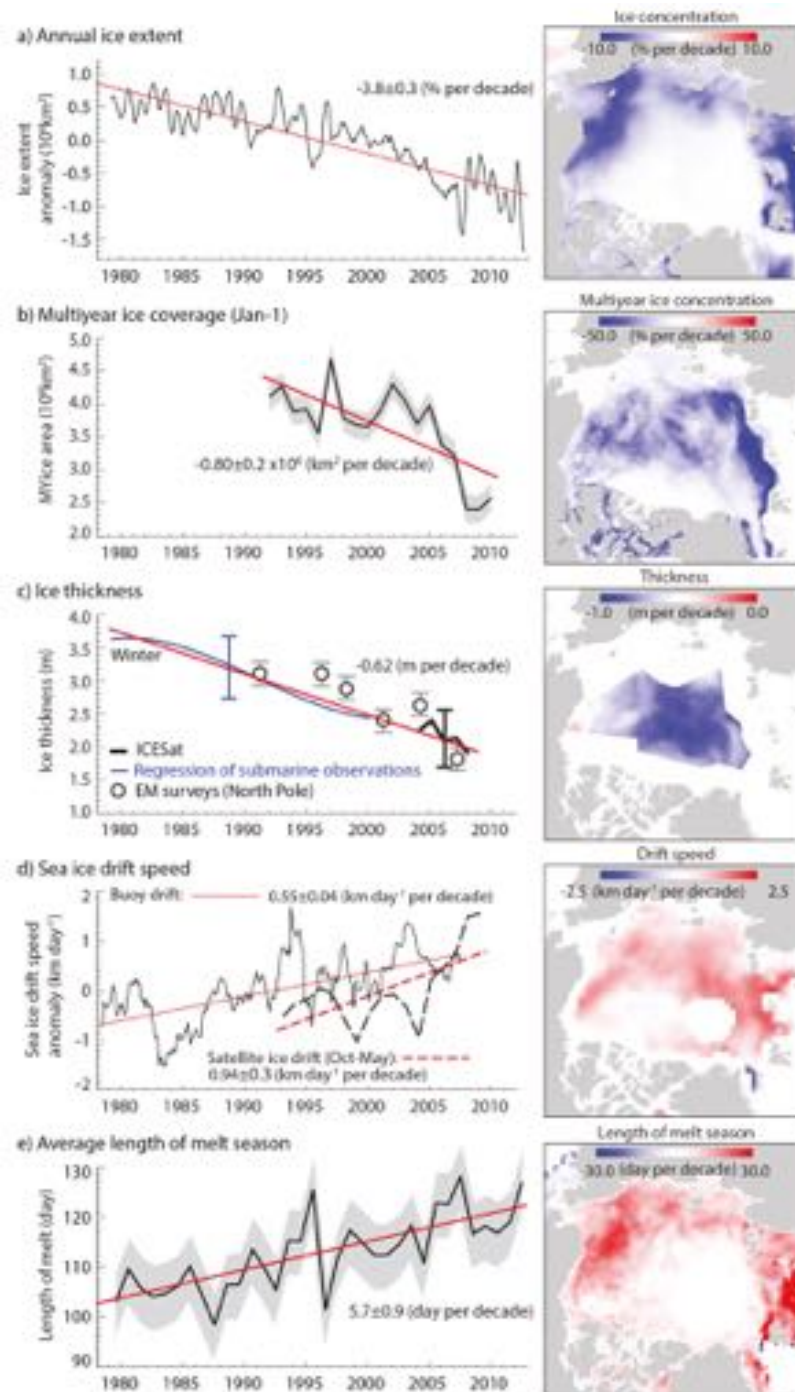


Fig. 4.6

1. Sea Ice Antarctic Sea Ice

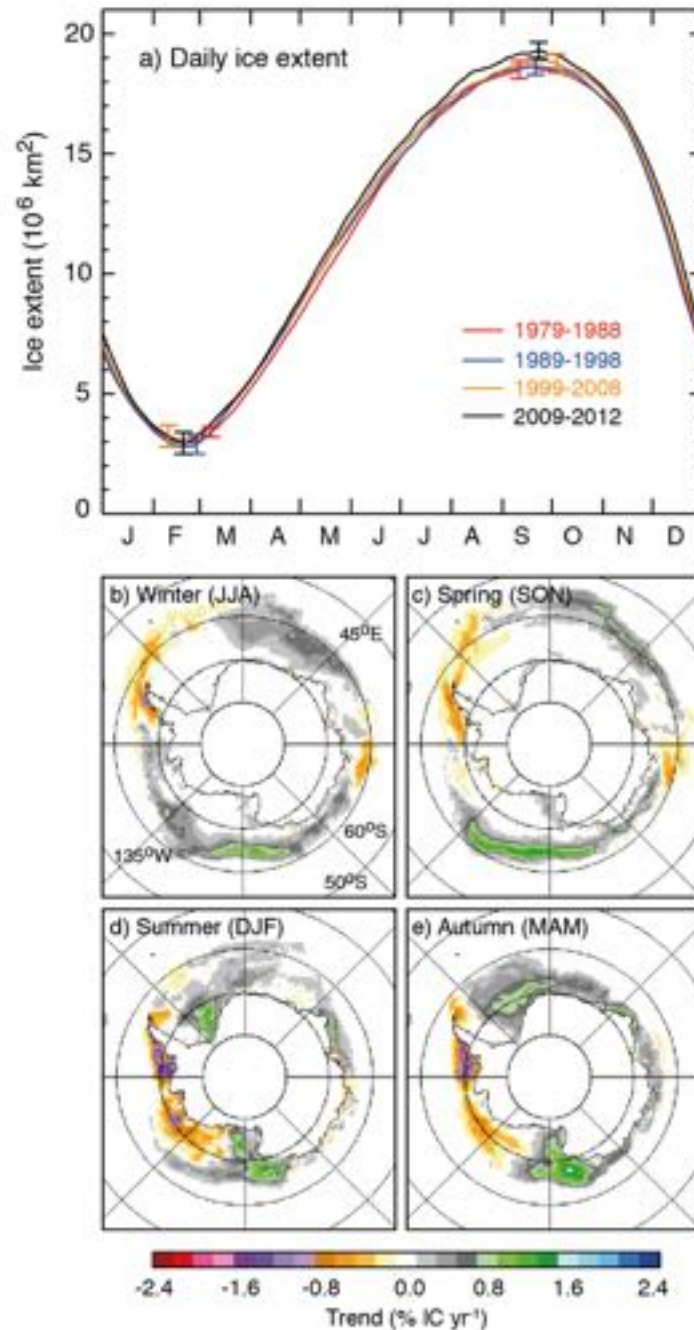
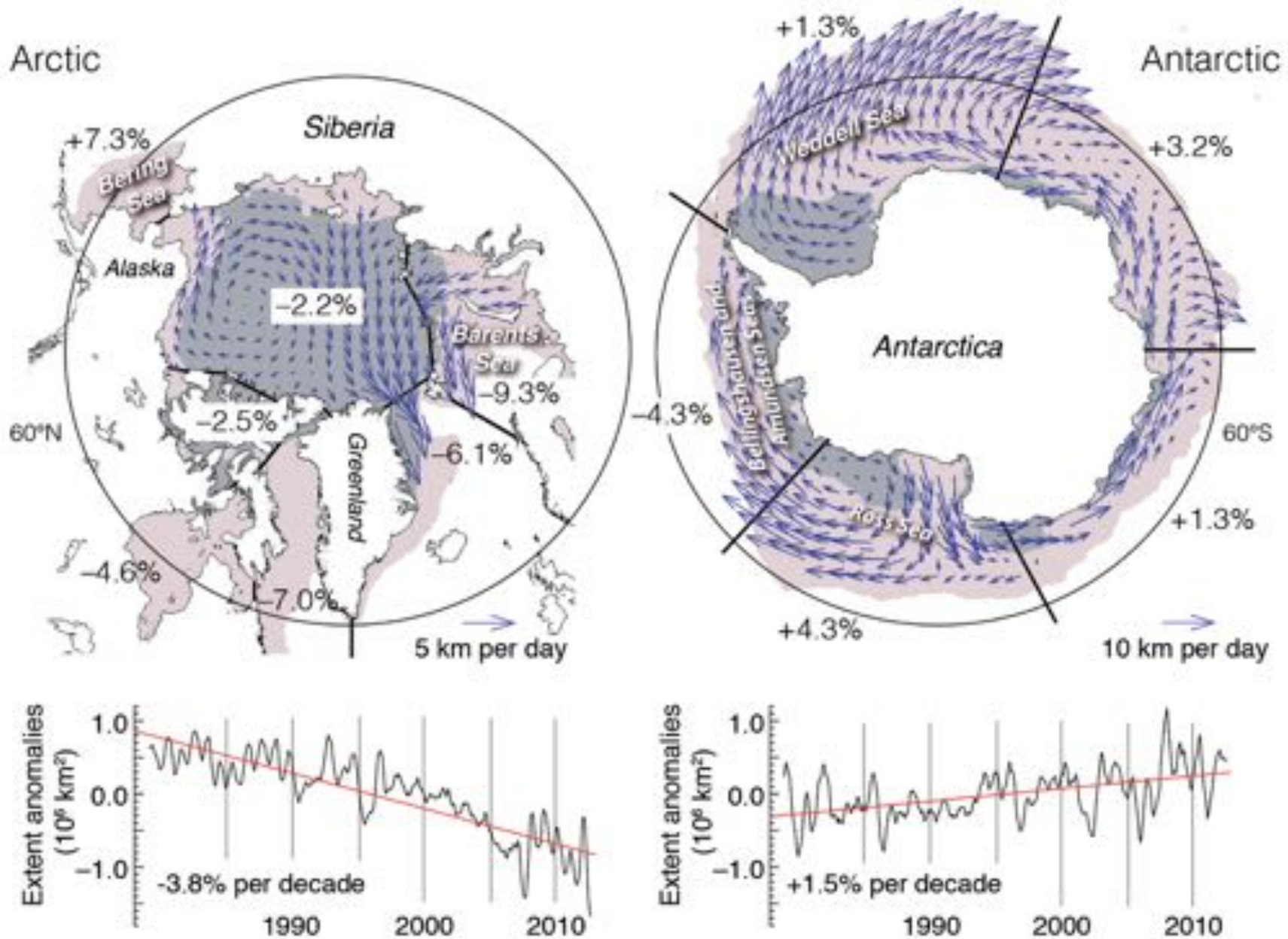


Fig. 4.7

For the Antarctic, any changes in many sea ice characteristics are unknown. There has been a small but significant increase in total annual mean sea ice extent that is *very likely* in the range of 1.2 to 1.8 % per decade between 1979 and 2012 (0.13 to 0.20 million km^2 per decade) (*very high confidence*). There was also a greater increase in ice area associated with an increase in ice concentration. But there are strong regional differences within this total, with some regions increasing in extent/area and some decreasing (*high confidence*). Similarly, there are

1. Sea Ice



2. Glaciers

Athabasca Glacier



2. Glaciers

Glaciers

All perennial surface land ice masses outside of the Antarctic and Greenland ice sheets.

Tidewater Glaciers

Glaciers that terminate in the sea



Glacier dynamics

Accumulation

Ablation

Glacier terminus



Grey Glacier, Chile

2. Glaciers

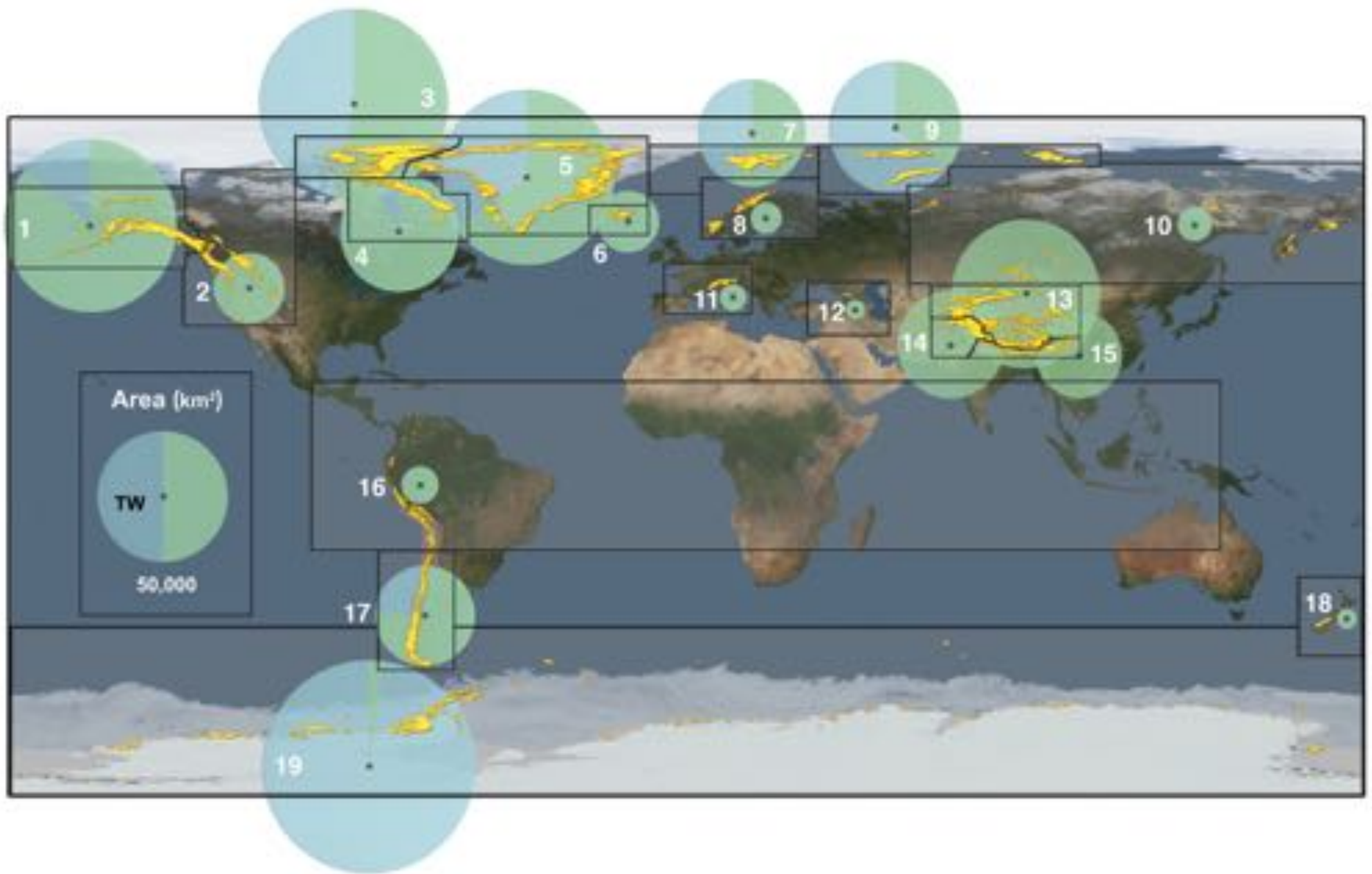


Fig. 4.8

2. Glaciers

Measuring methods

Parameter	Method	Technique	Typical Accuracy	Number of Glaciers	Repeat Interval	Earliest Data
Length change	Various	Reconstruction	10 m	Dozens	Decadal – centuries	Holocene
	Field	<i>In situ</i> measurement	1 m	Hundreds	Annual	19th century
	Remote sensing	Photogrammetric survey	Two image pixels (depending on resolution)	Hundreds	Annual	20th century
Area change	Maps	Cartographic	5% of the area	Hundreds	Decadal	19th century
	Remote sensing	Image processing	5% of the area	Thousands	Sub-decadal	20th century
Volume change	Remote sensing	Laser and radar profiling	0.1 m	Hundreds	Annual	21st century
	Remote sensing	DEM differencing	0.5 m	Thousands	Decadal	20th century
Mass change	Field	Direct mass balance measurement	0.2 m	Hundreds	Seasonal	20th century
	Remote sensing	Gravimetry (GRACE)	Dependent on the region	Global	Seasonal	21st century

Table 4.3

2. Glaciers

Length Change

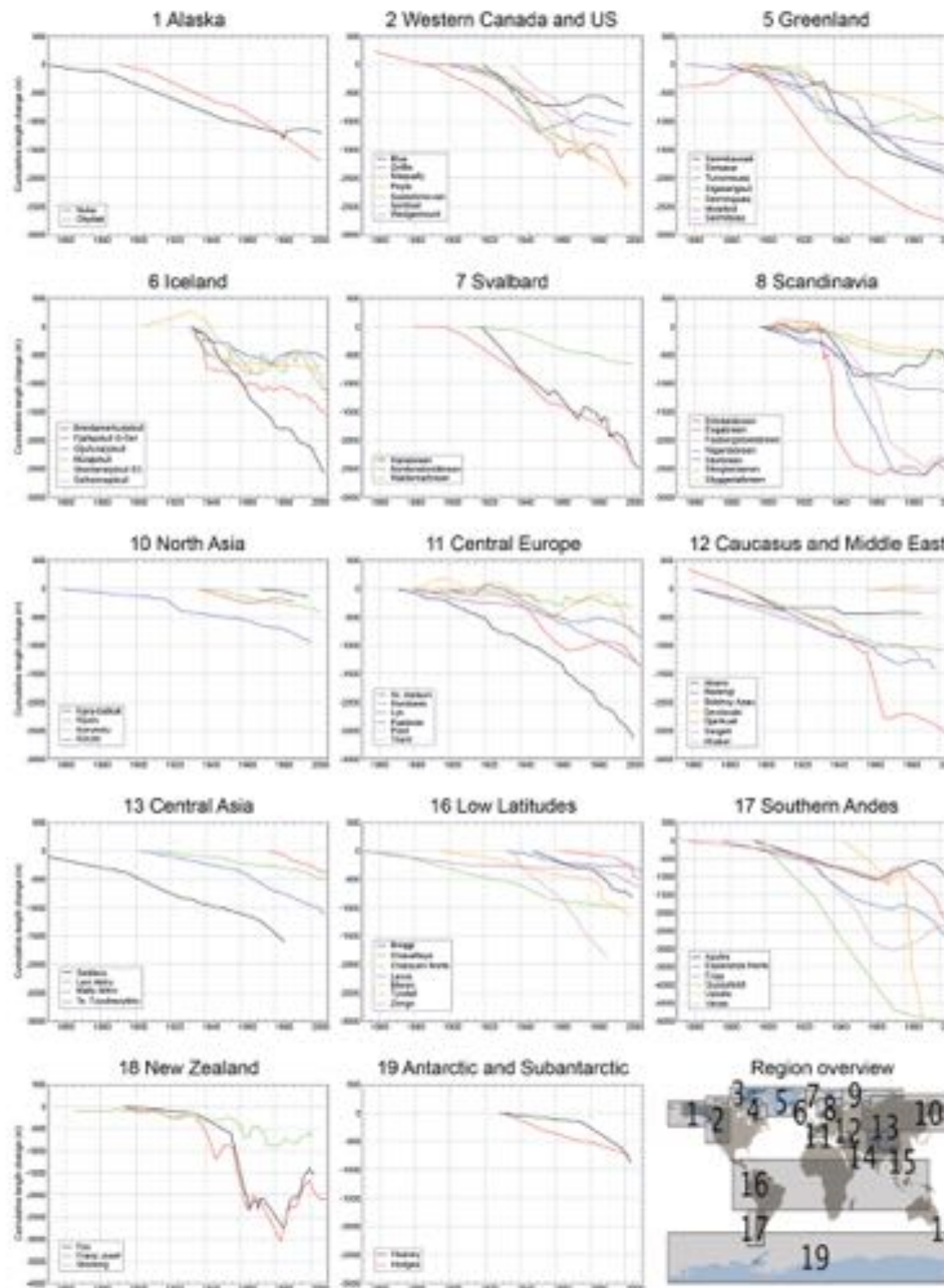


Fig. 4.9

2. Glaciers

Area Change

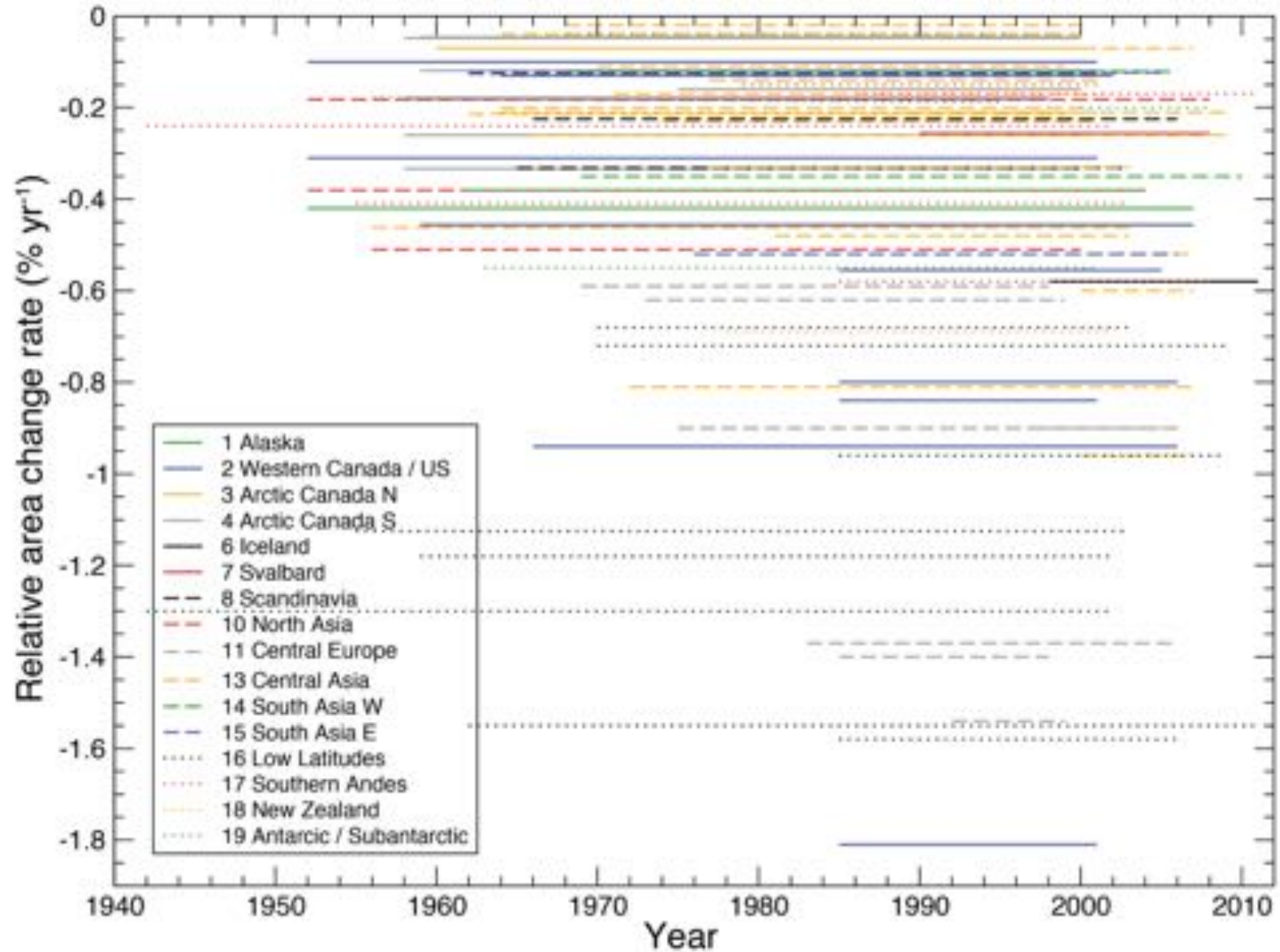


Fig. 4.10

2. Glaciers

Mass Change

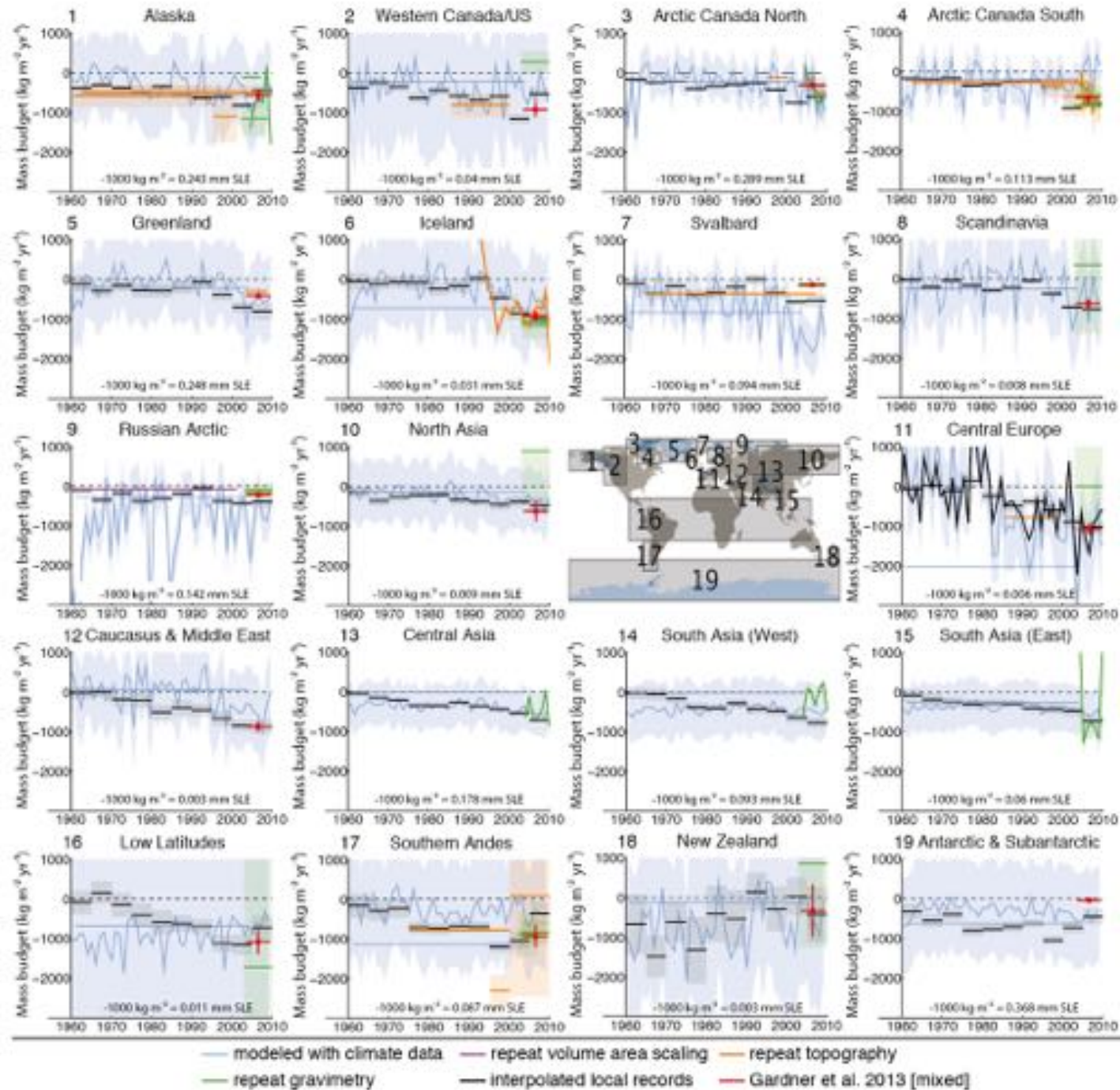
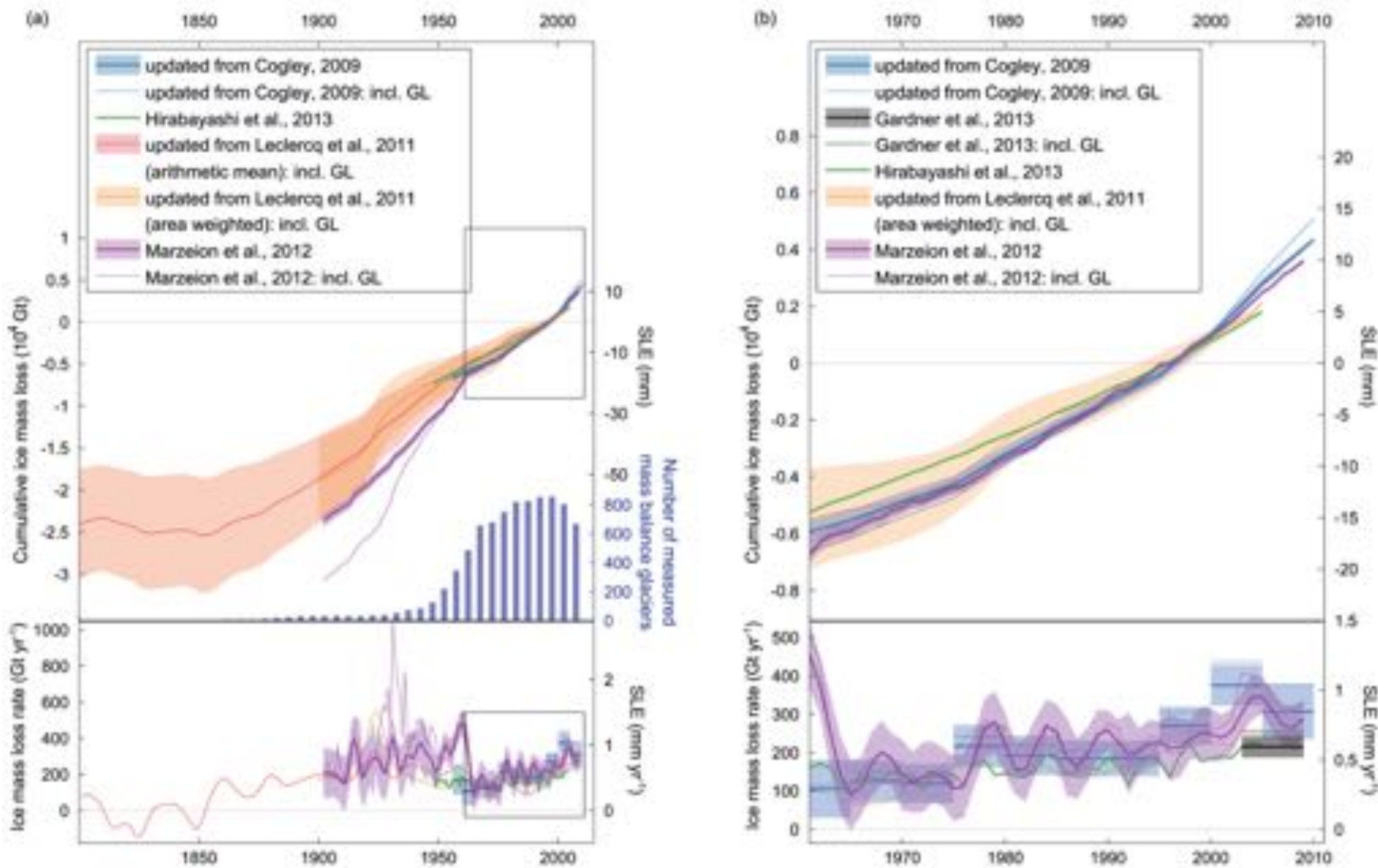


Fig. 4.11

2. Glaciers

Mass Change



Reference period 1986-2005

Fig. 4.12

3. Ice Sheets

Greenland

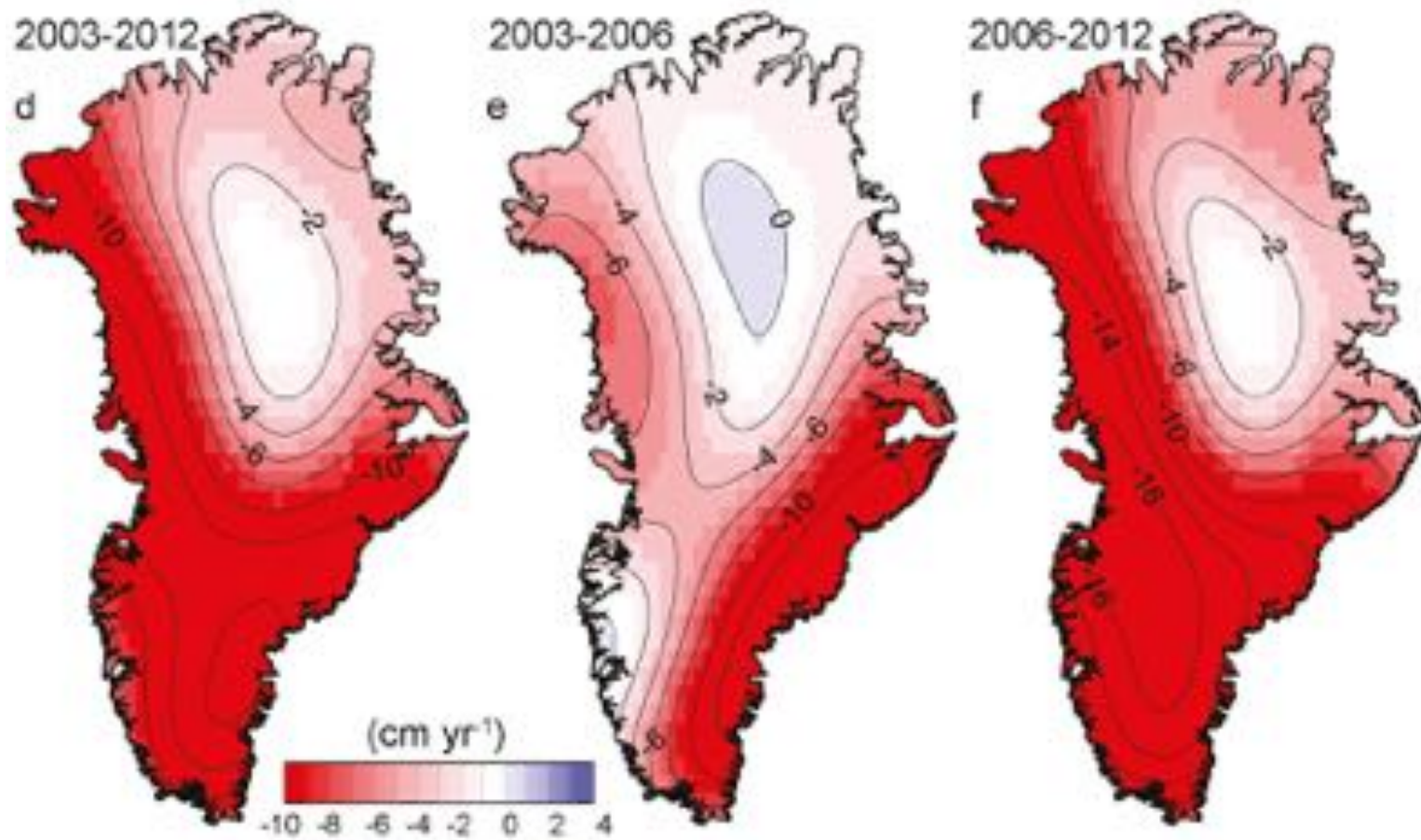


Fig. 4.13

3. Ice Sheets

Greenland

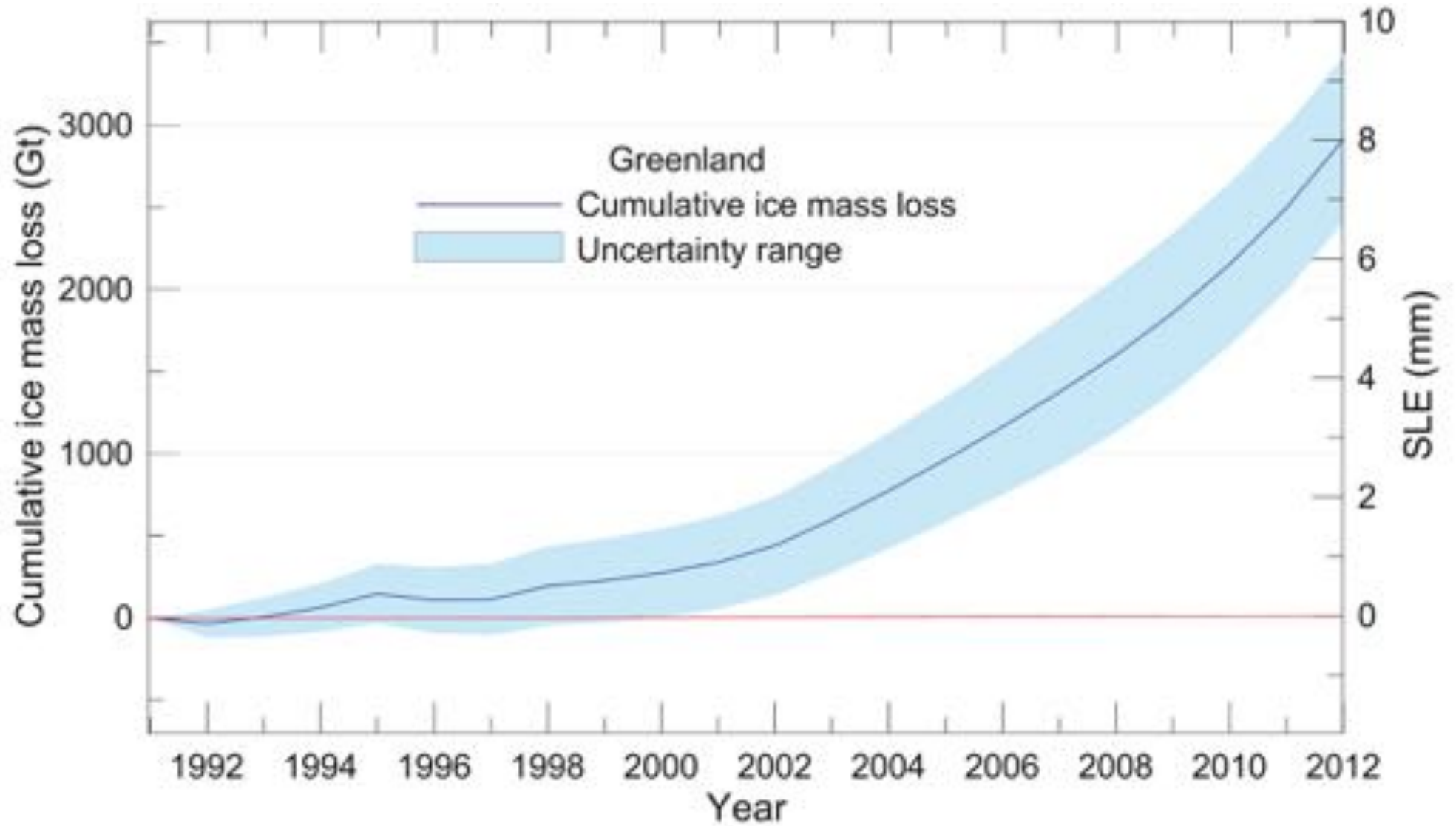


Fig. 4.15

3. Ice Sheets

Antarctica

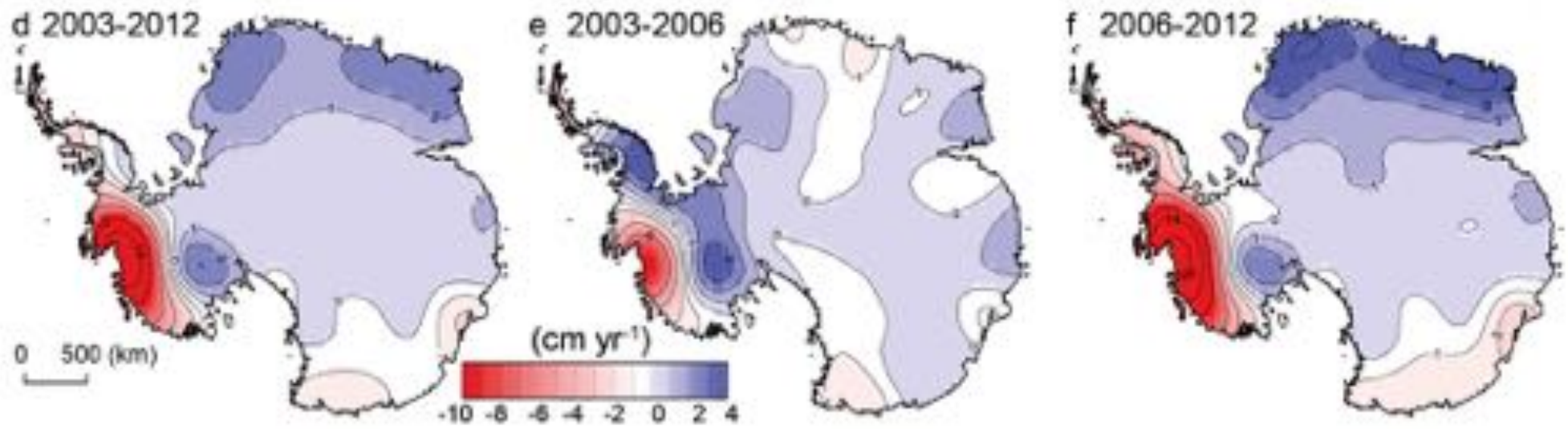


Fig. 4.14

3. Ice Sheets

Antarctica

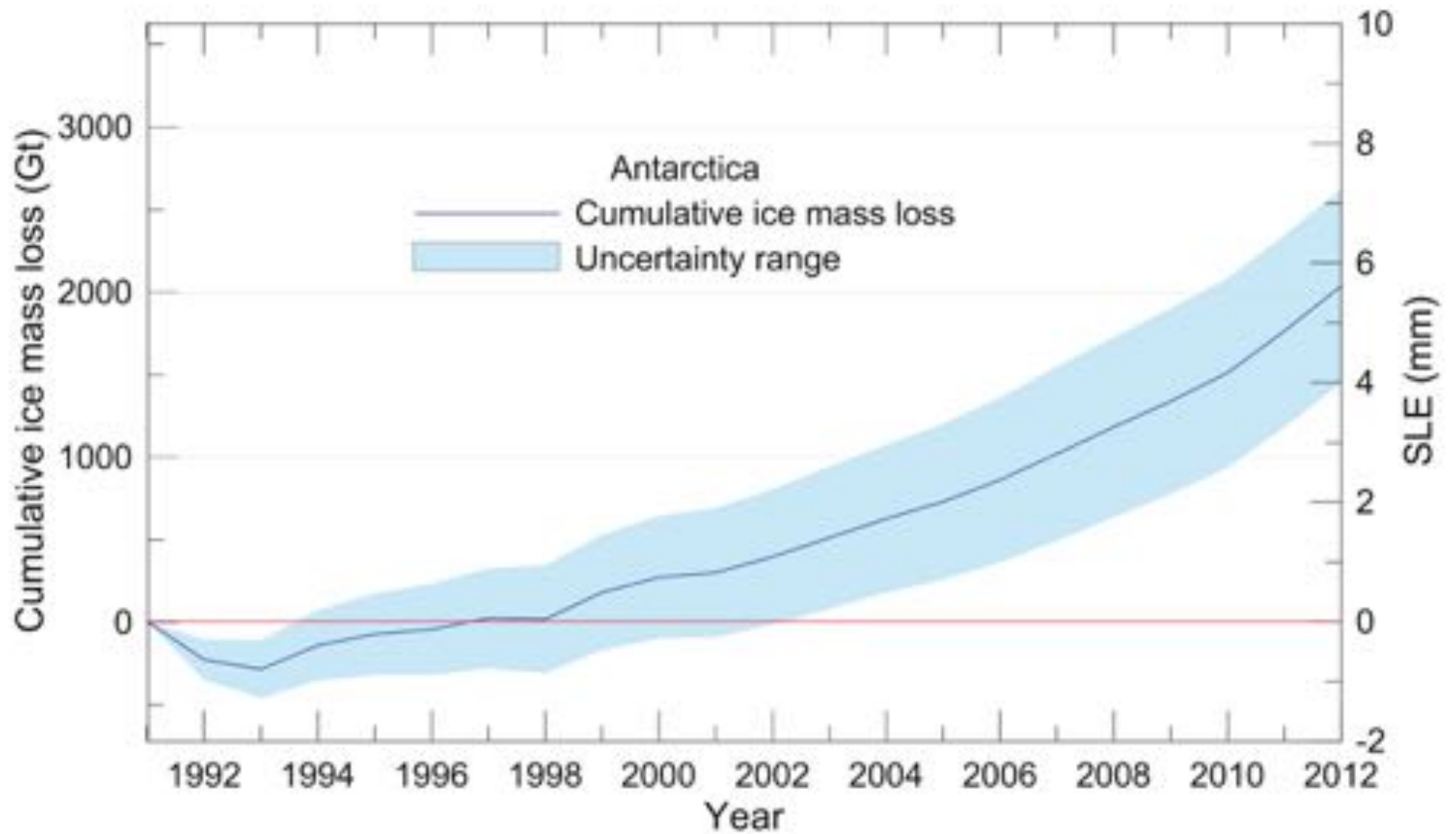


Fig. 4.16

3. Ice Sheets

Antarctica + Greenland

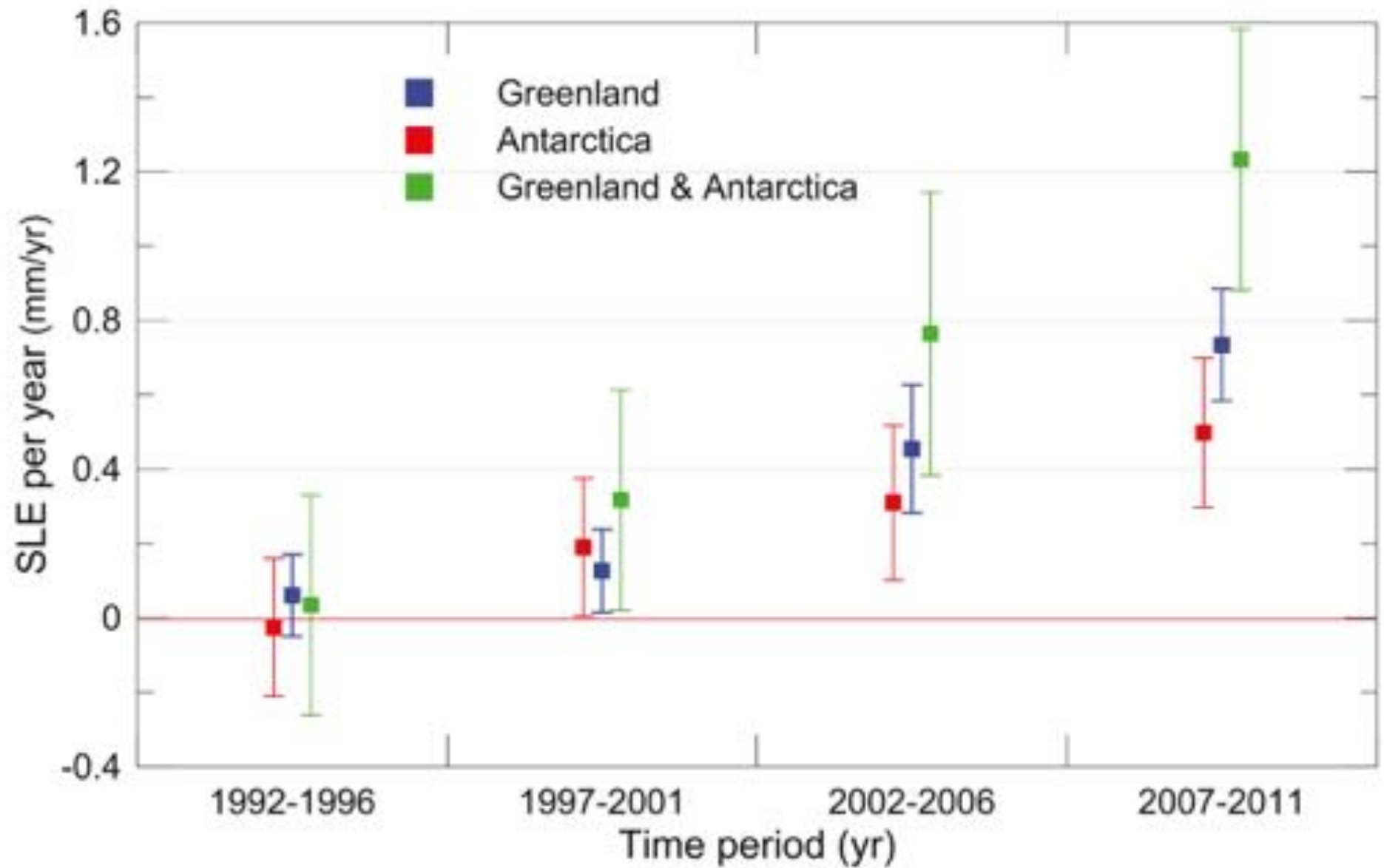
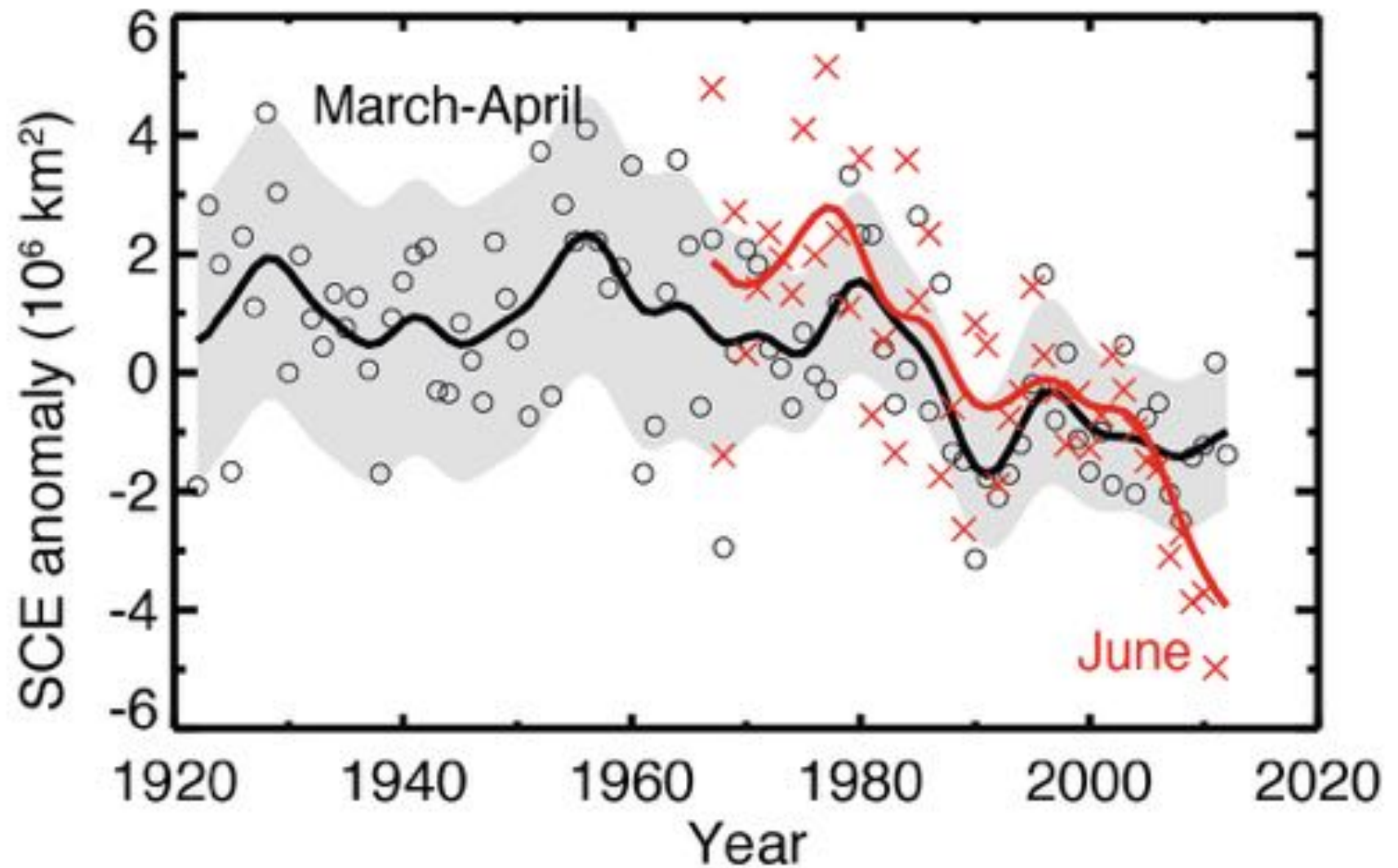


Fig. 4.17

4. Snow cover



Reference period 1971-2000

Fig. 4.19

4. Snow cover

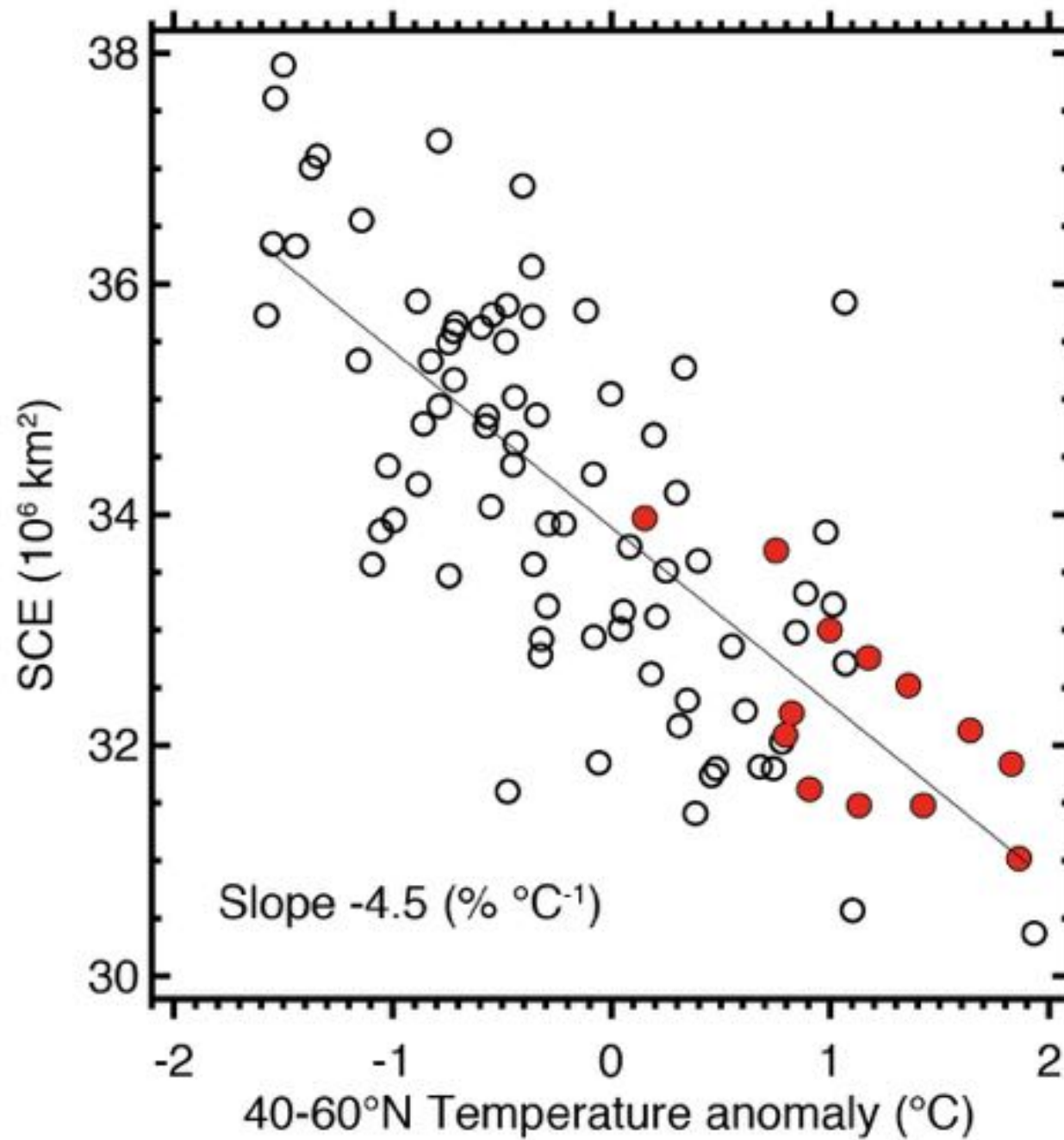


Fig. 4.20

5. Frozen Ground

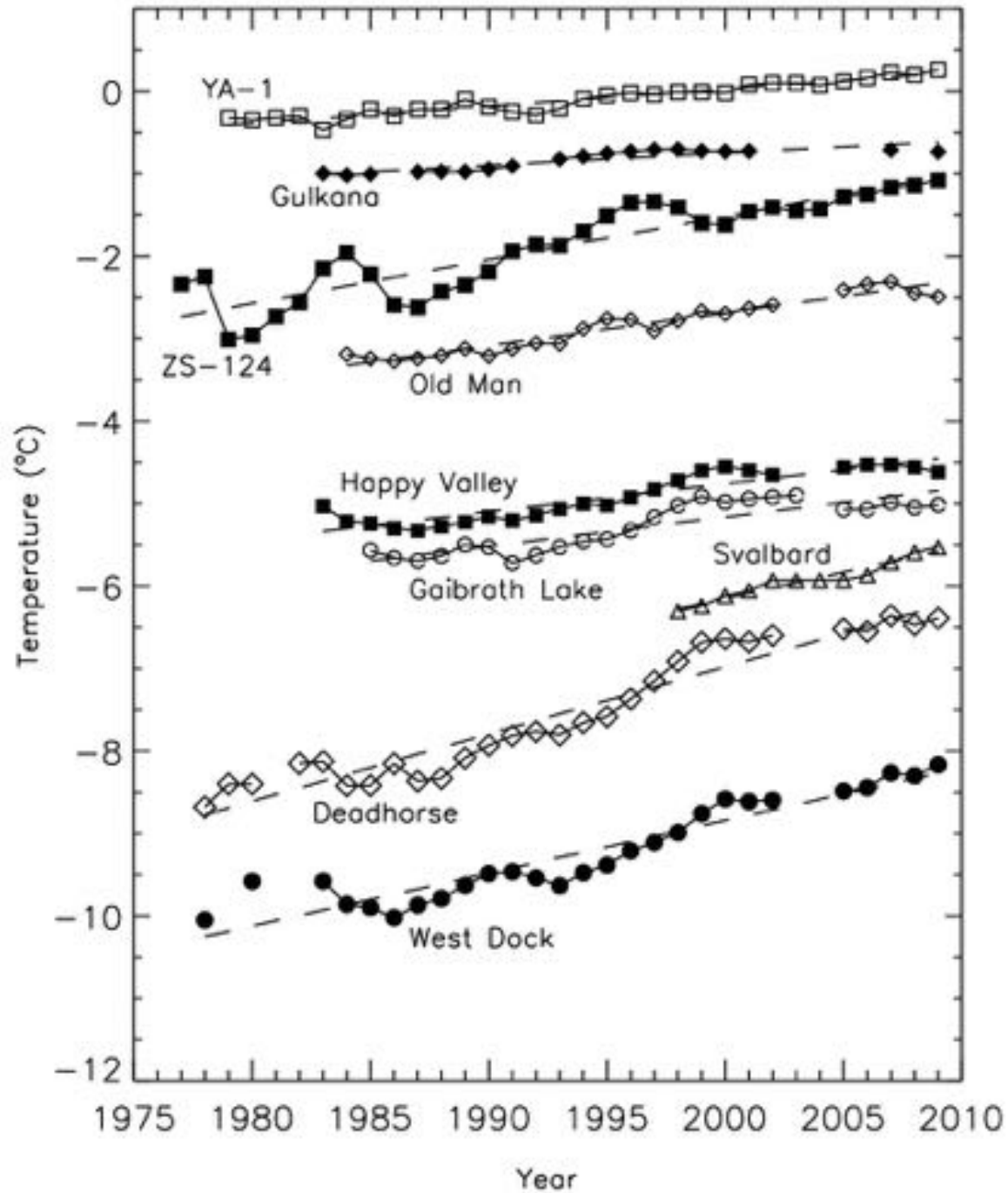


Fig. 4.22

5. Frozen Ground

Active Layer Depth

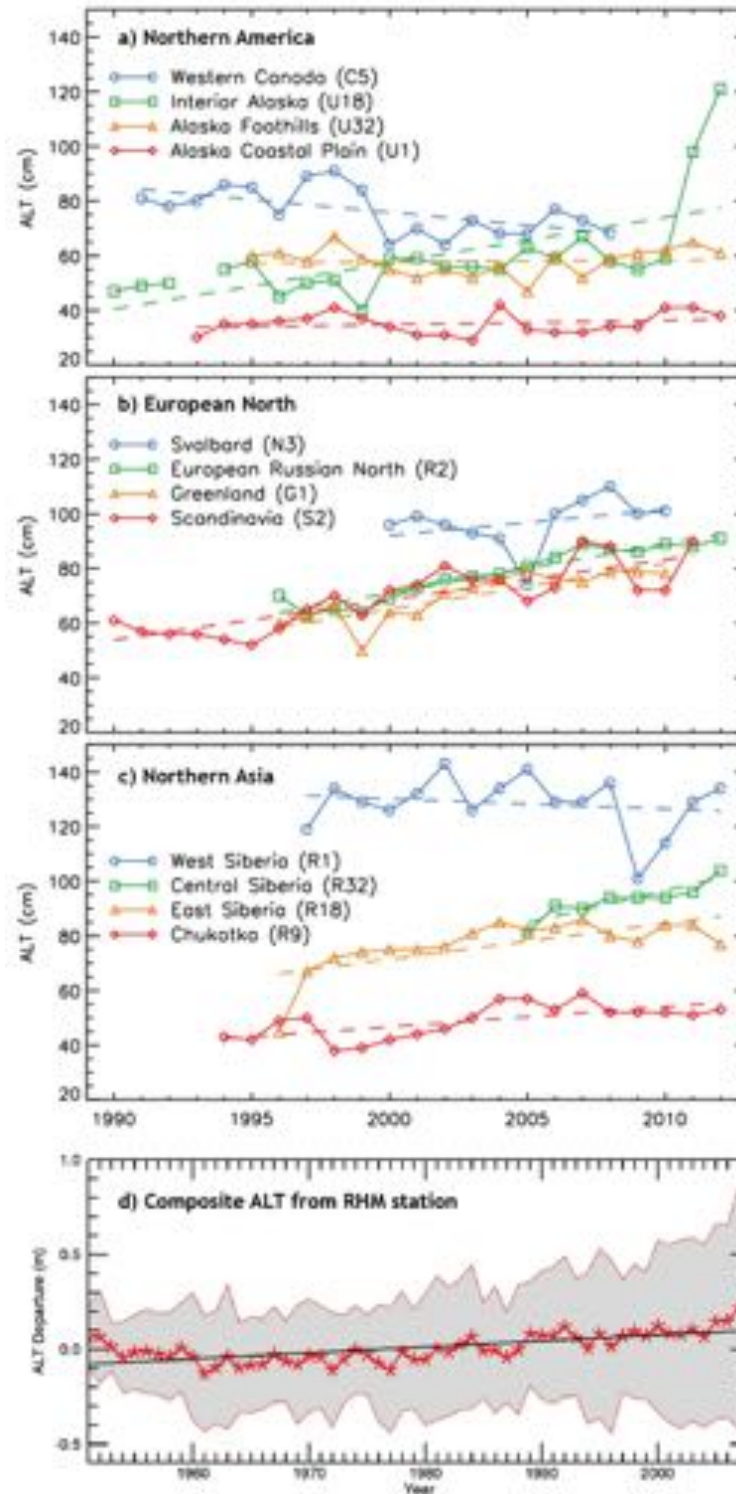
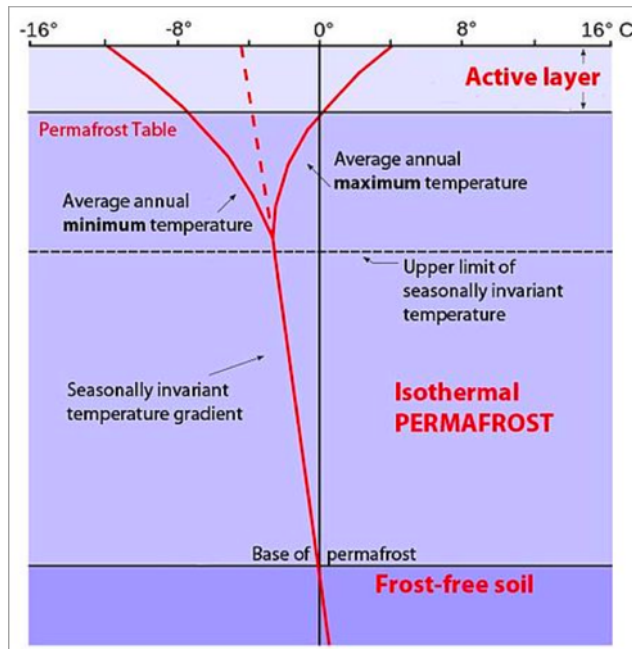


Fig. 4.23

5. Frozen Ground

Thickness of Frozen Ground

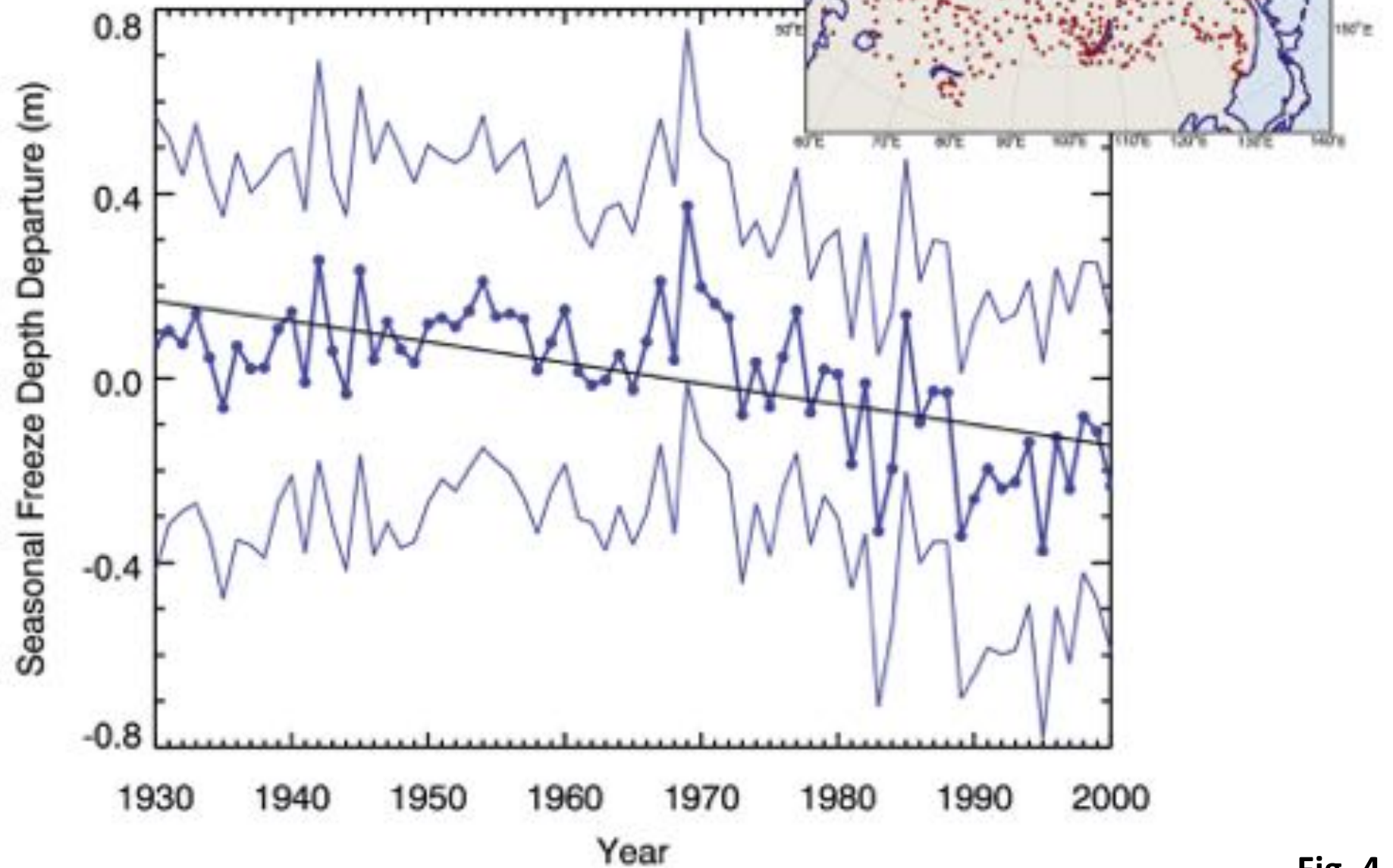


Fig. 4.24

Changes in the Cryosphere



Frozen Ground: increasing permafrost temperatures by up to 2°C 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 snow 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.

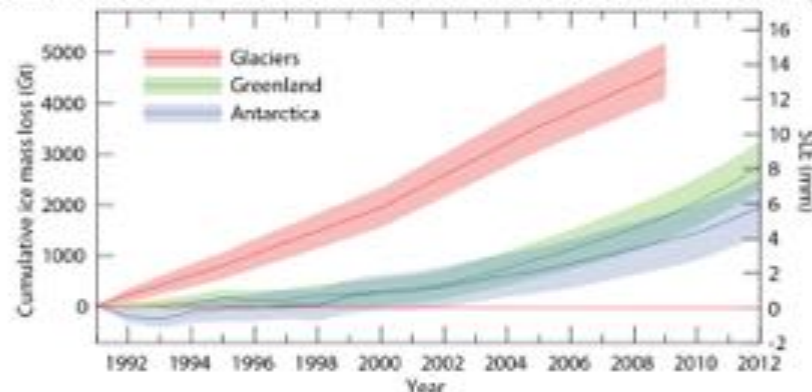
Glaciers: are major contributors to sea level rise. Ice mass loss from glaciers has increased since the 1960s. Loss rates from glaciers outside Greenland and Antarctica were 0.76 mm yr⁻¹ SLE during the 1993 to 2009 period and 0.83 mm yr⁻¹ SLE over the 2005 to 2009 period.

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.

Contribution of Glaciers and Ice Sheets to Sea Level Change



Cumulative ice mass loss from glacier and ice sheets (in sea level equivalent) is 1.0 to 1.4 mm yr⁻¹ for 1993-2009 and 1.2 to 2.2 mm yr⁻¹ for 2005-2009.

Fig. 4.25