Fizyka Procesów Klimatycznych
Wykład 6

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Wykorzystano slajdy dr Aleksandry Kardaś

Co obejmuje kriosfera?

Lodowce

Thomson Glacier, Kanada

Gross Aletschgletscher, Szwajcaria

SHAPE

CONSISTENCY AND DENSITY

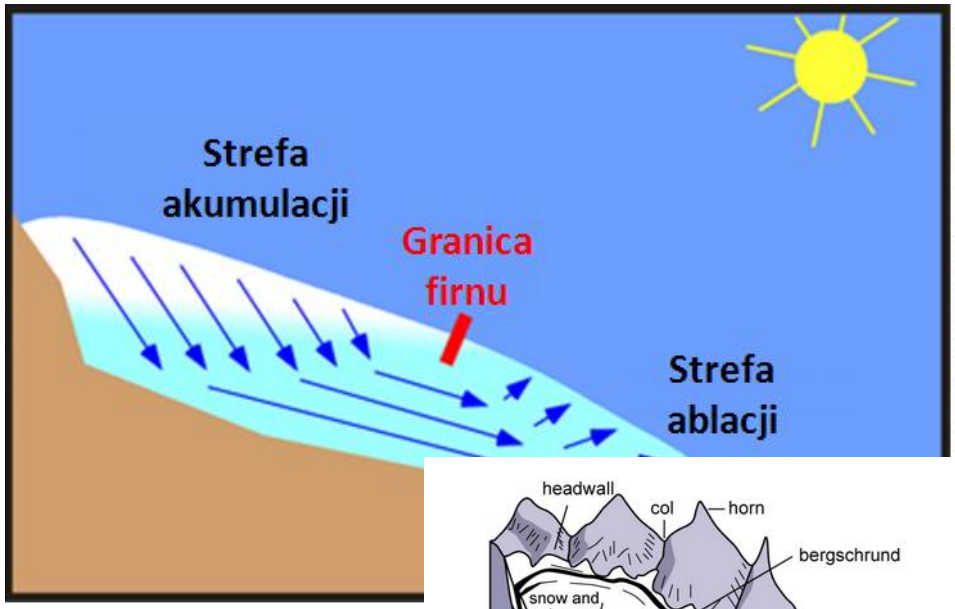
Snowflakes , 90% air, <0.1 g/cm^3

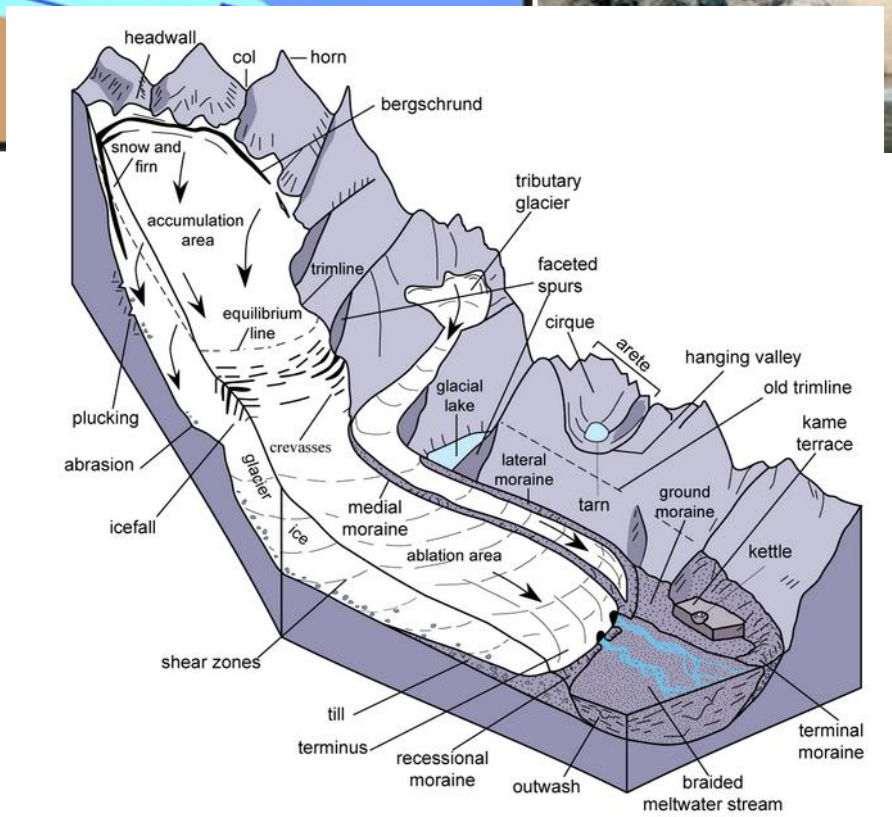
Ice granules, 50% air, ~0.3 to 0.5 g/cm^3

Firn, 30% air, ~0.5 to 0.7 g/cm^3

Ice, 20% air as bubbles, >0.7 g/cm^3

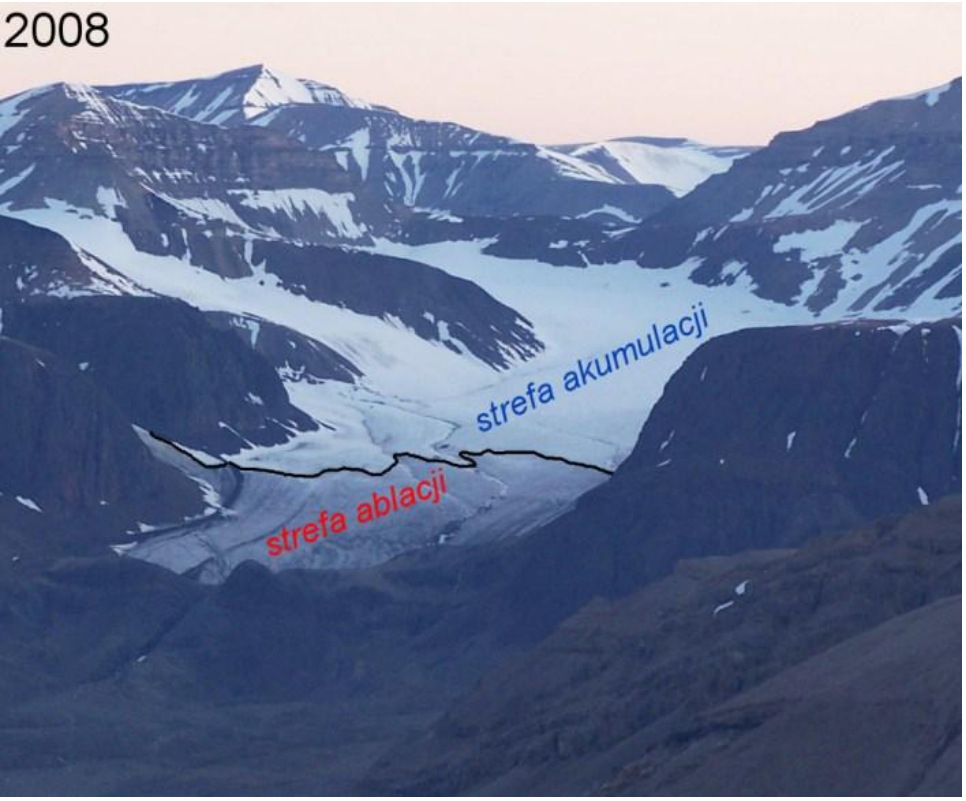
O co chodzi z ruchem?

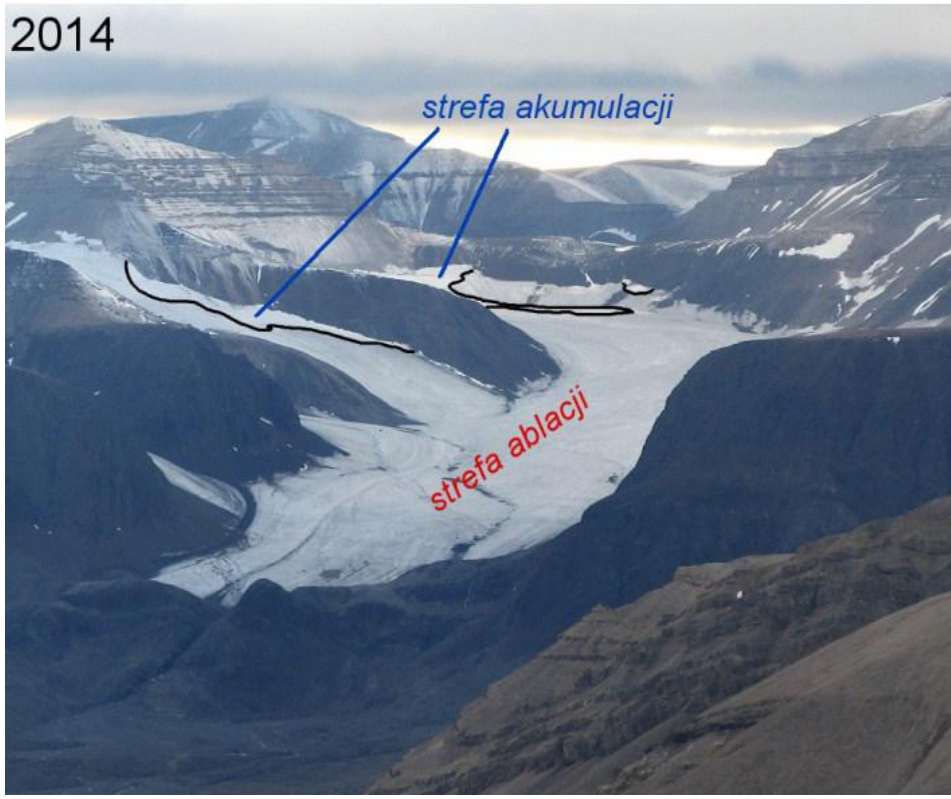




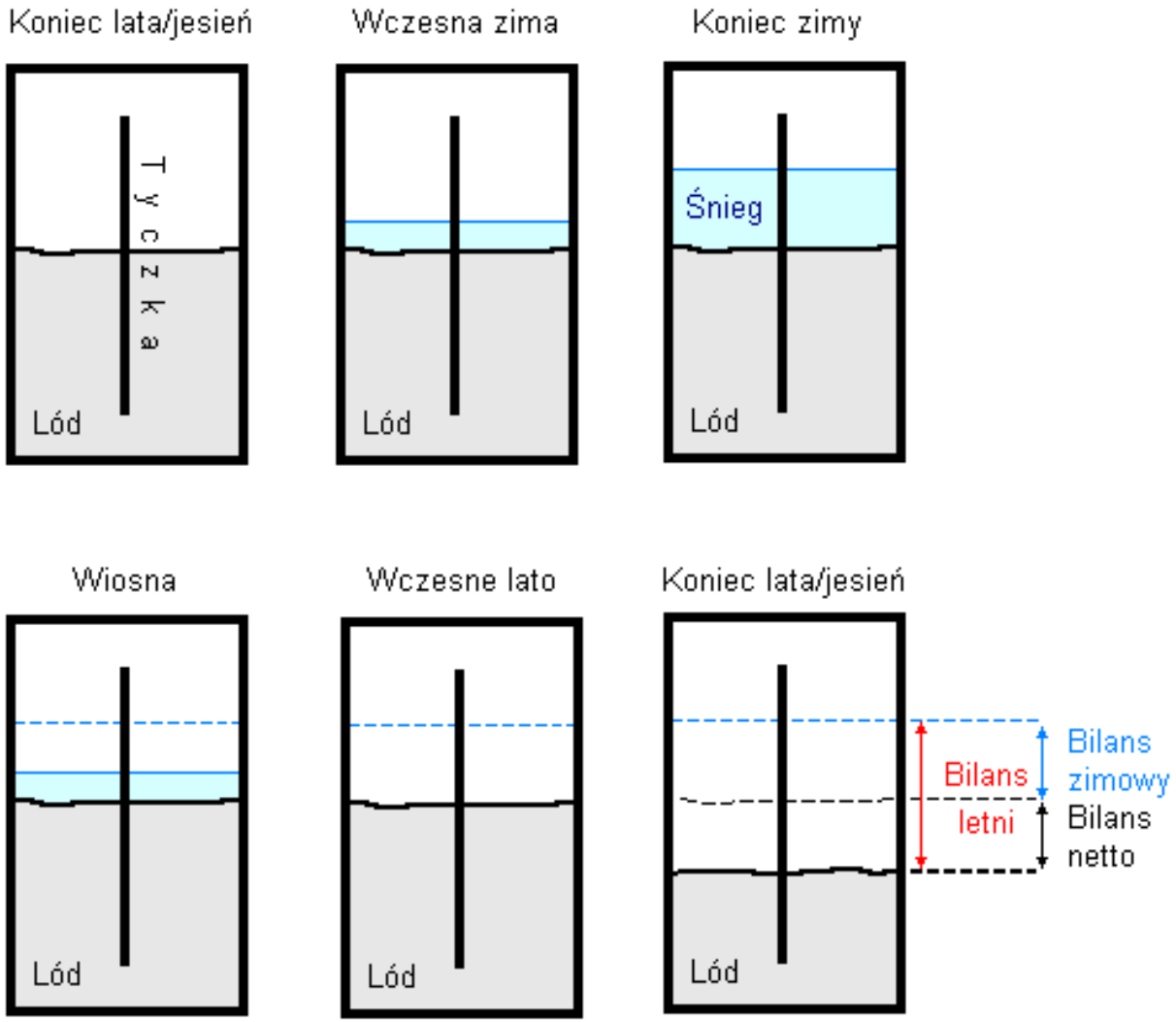
O co chodzi z ruchem?

Akumulacja i ablacja





Bilans masy lodowca w strefie ablacji



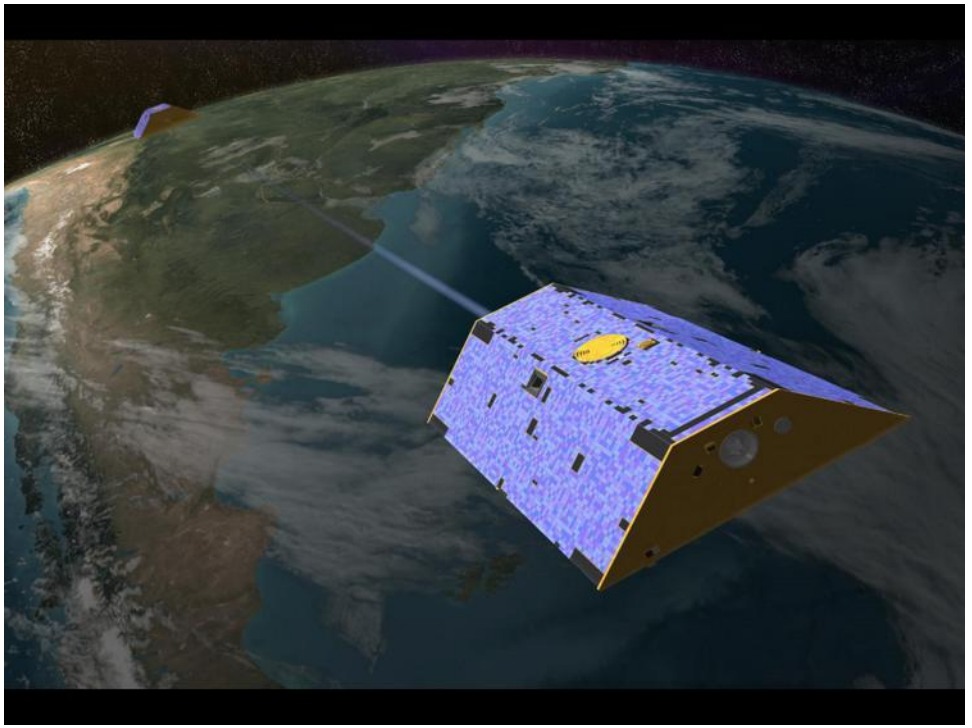
Pomiar bilansu masy lodowca

Narciarska wyprawa naukowa do AMUPS 2015.

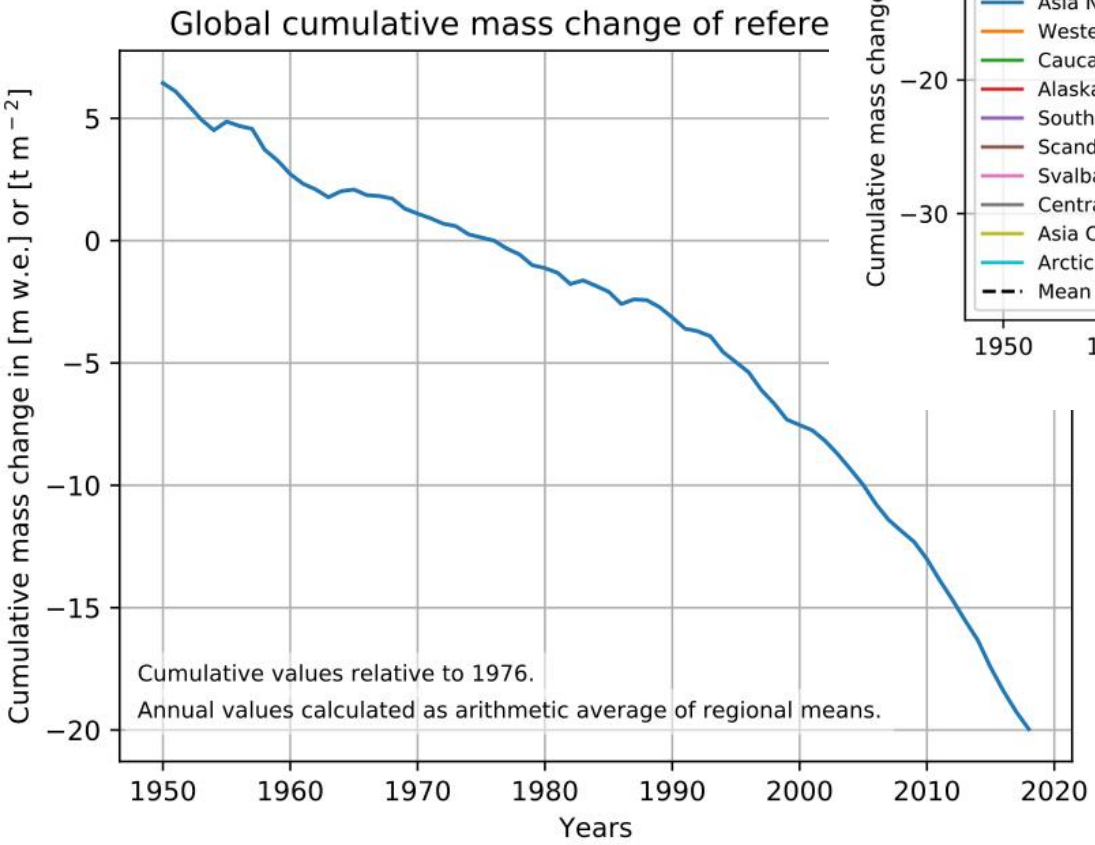
Pomiar bilansu masy lodowca

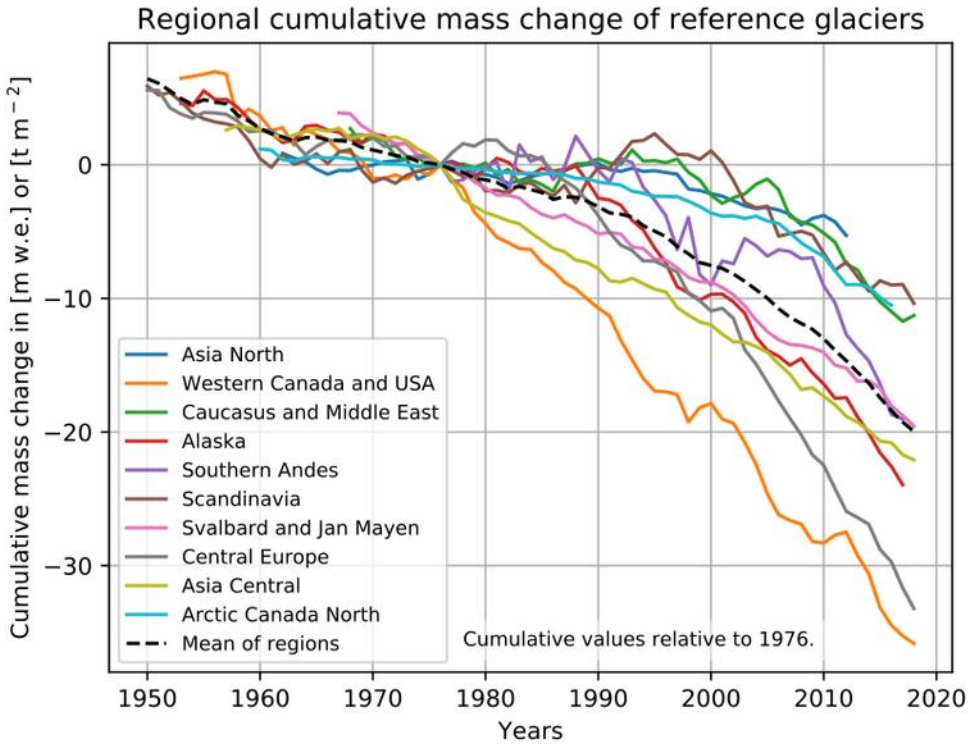
Foto:
Magdalena
Puczko

Pomiar bilansu masy lodowca



Światowy bilans masy lodowców





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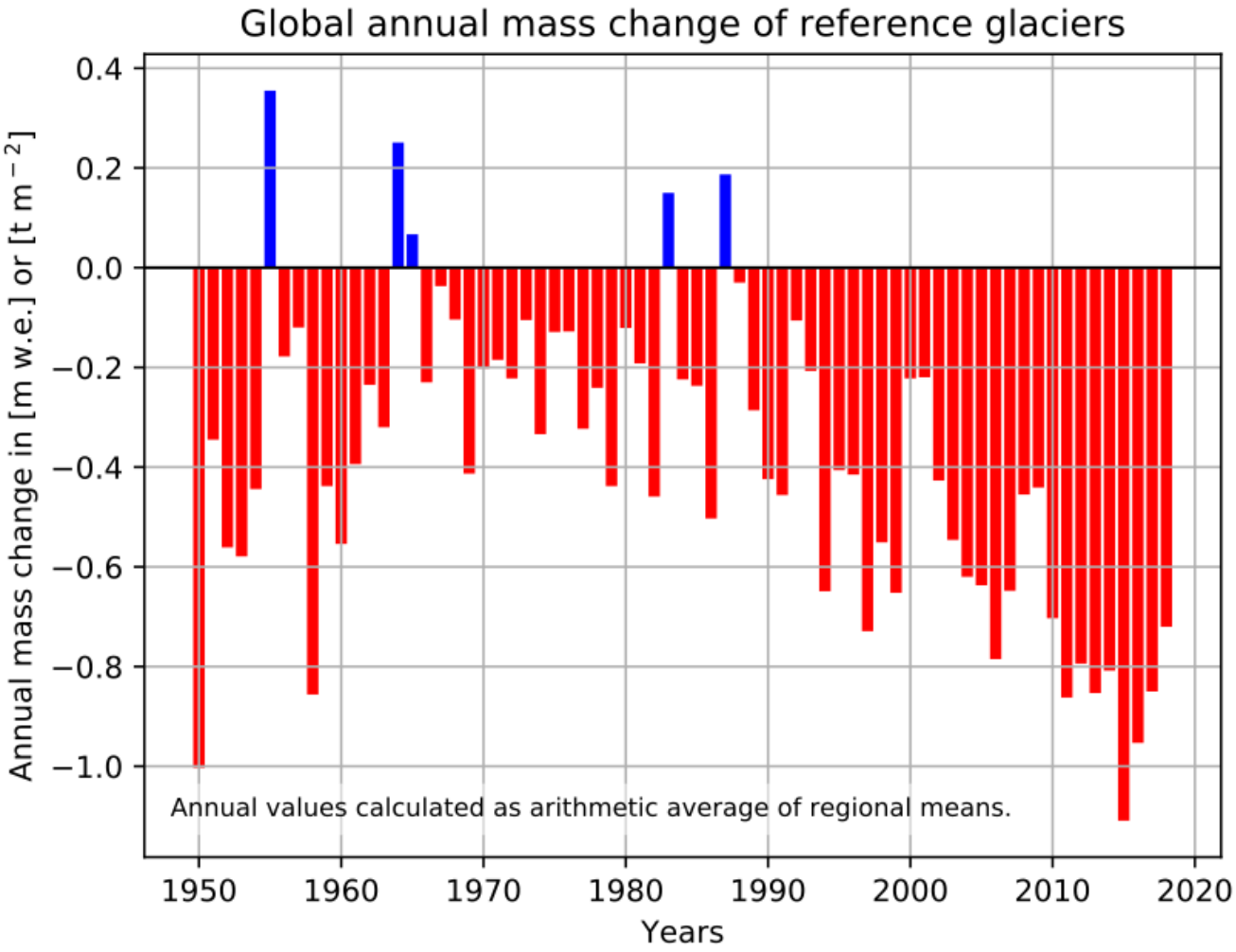
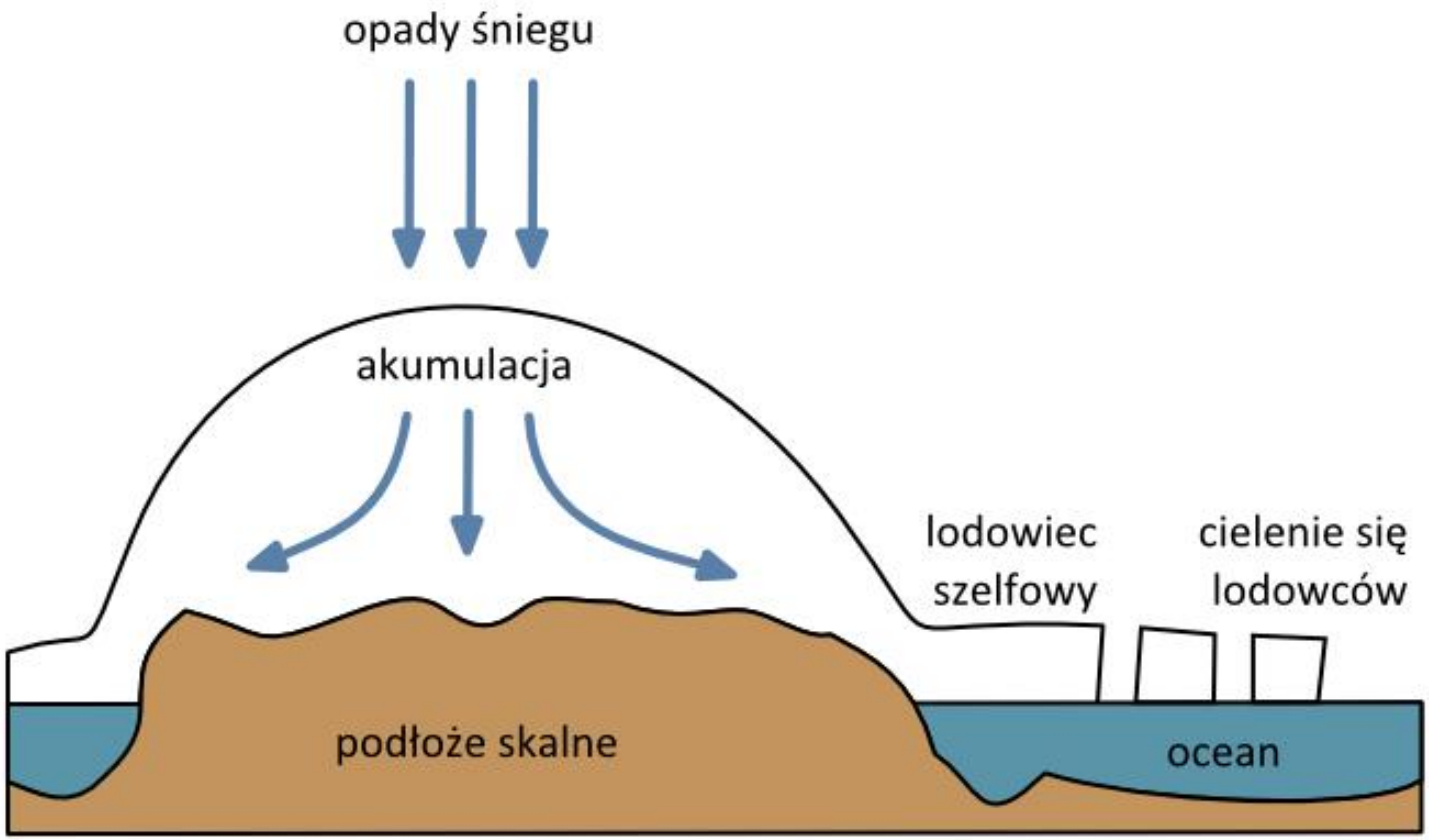
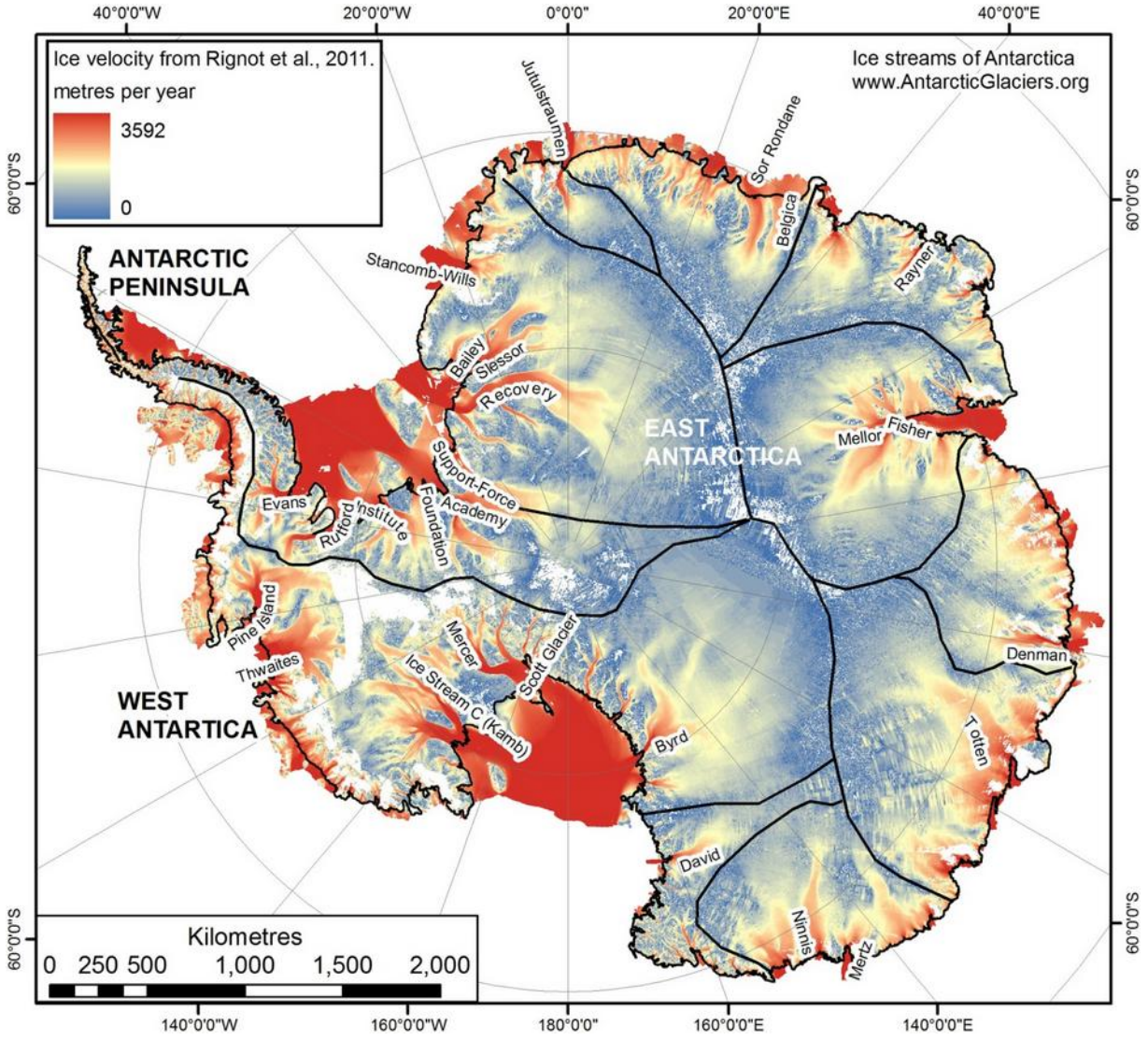


Lądolód


opady śniegu
akumulacja
lodowiec szelfowy
cielenie się lodowców
podłoże skalne
ocean

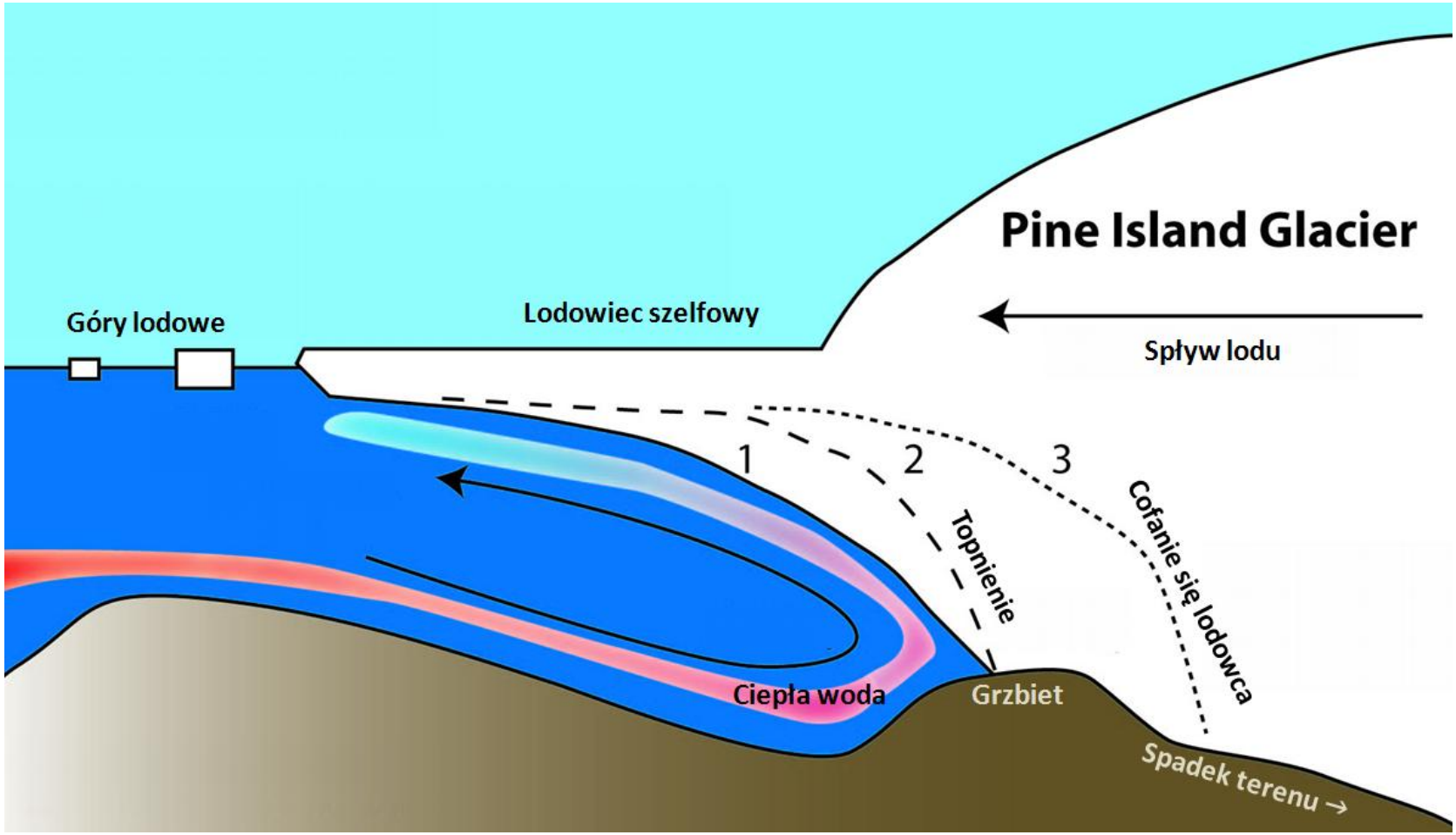
Antarktyda też płynie

Antarktyda też płynie

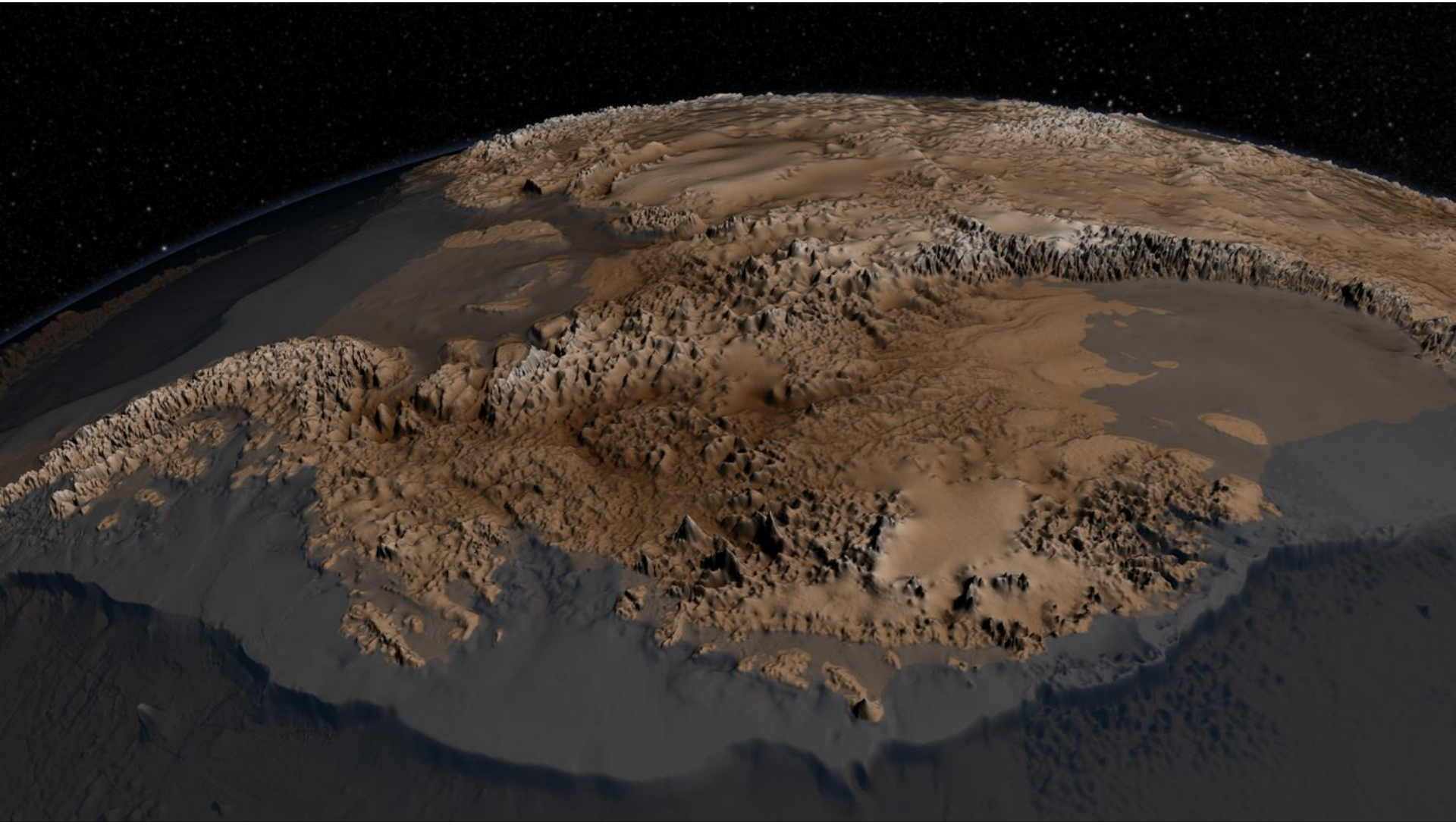


http://www.antarcticglaciers.org, dane Rignot et al. 2011

Jak znika lód Antarktydy?



Ukształtowanie podłoża Antarktydy



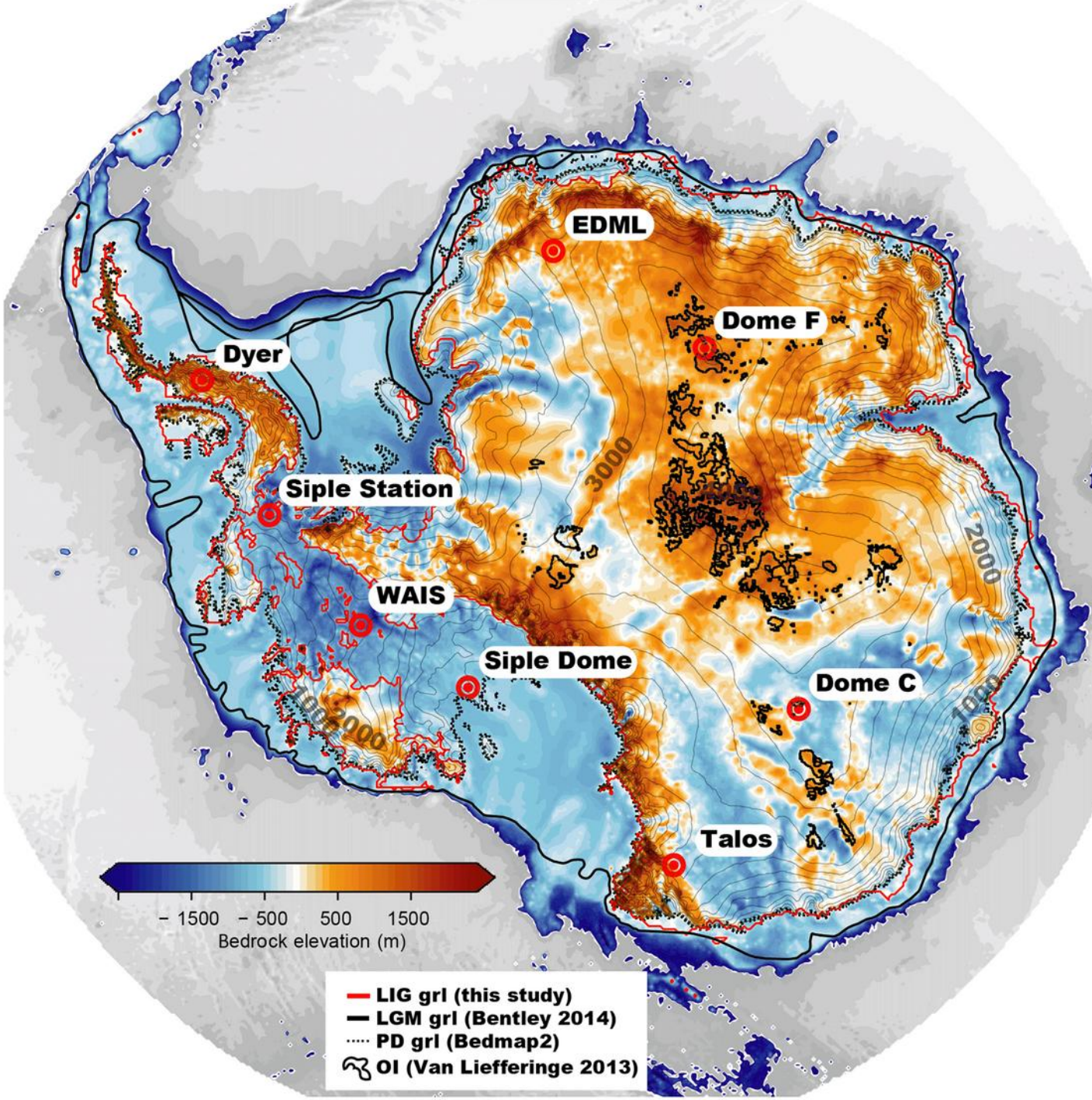


Figure 1. Antarctic bedrock topography overlain by surface contours (grey lines). The present-day (PD) grounding line (grl) from BEDMAP2 (Fretwell et al., 2013) depicted by the dashed black line. The Last Glacial Maximum (LGM) grounding line reconstruction from Bentley et al. (2014) (thick black lines) is compared to simulated grounding line retreat in one of the ensemble members for the Last Interglacial (LIG, red line). Regions previously identified as potentially viable sites for Oldest Ice (Van Liefferinge and Pattyn, 2013) are outlined by thick black lines. Eight ice core locations are highlighted, which are used as tuning targets with respect to ice core thickness and analysed in Figs. 9 (West Antarctica) and 10 (East Antarctica), respectively.

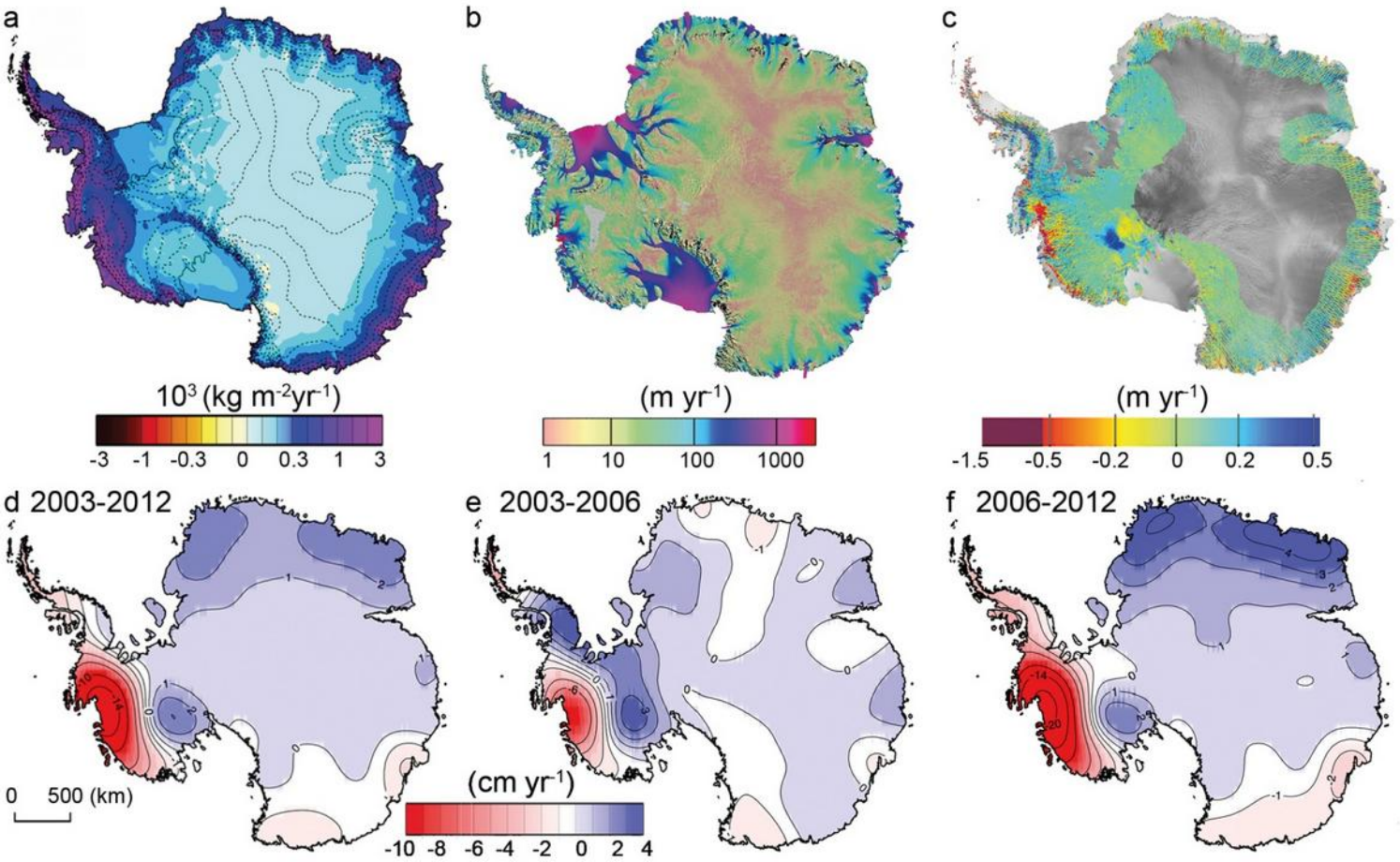
Sutter, J., Fischer, H., Grosfeld, K., Karlsson, N. B., Kleiner, T., Van Liefferinge, B., and Eisen, O.: Modelling the Antarctic Ice Sheet across the mid-Pleistocene transition – implications for Oldest Ice, The Cryosphere, 13, 2023–2041, https://doi.org/10.5194/tc-13-2023-2019, 2019

Jak znika lód Antarktydy?

Bilans masy
1989-2004

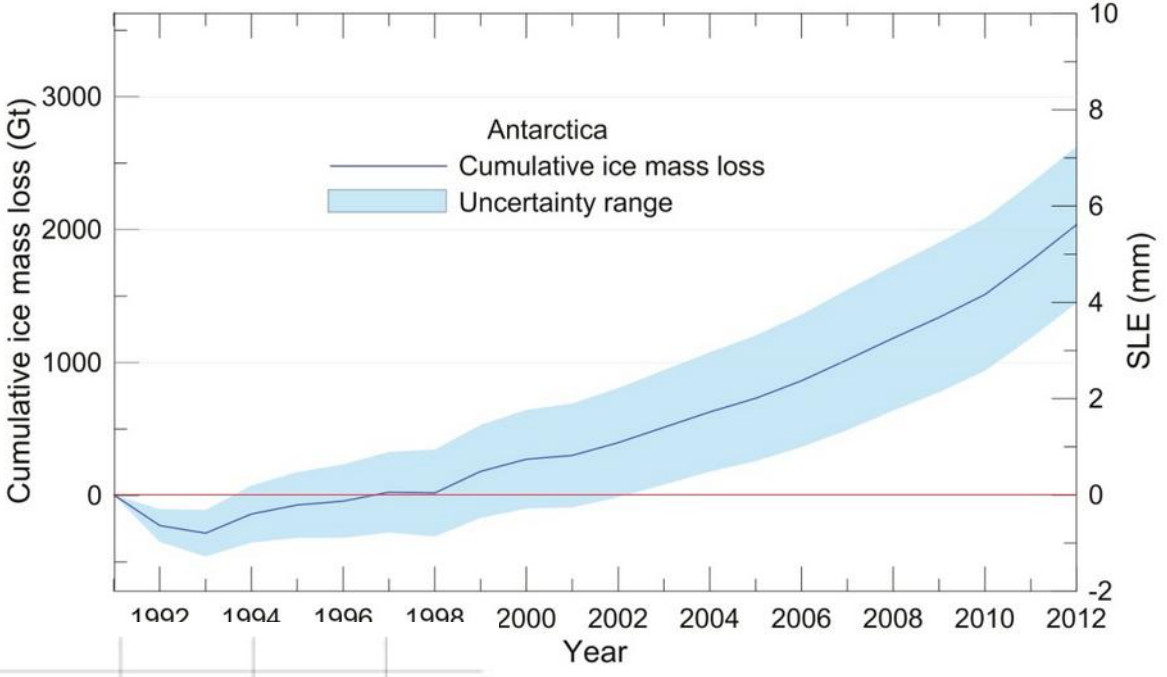
Prędkość
2007-2009

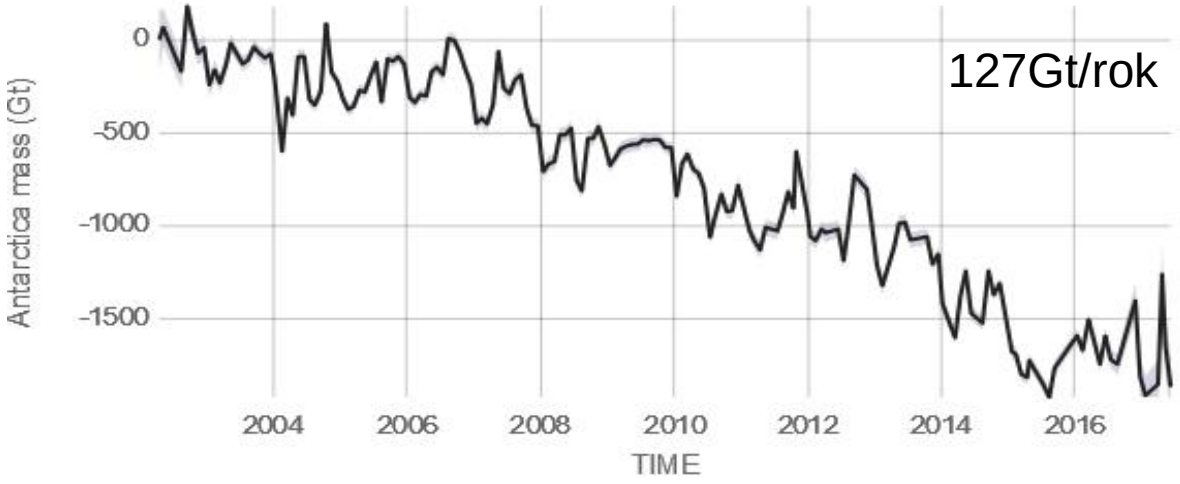
Zmiany wysokości
2003-2008



Straty lodu w ekwiwalencie wodnym

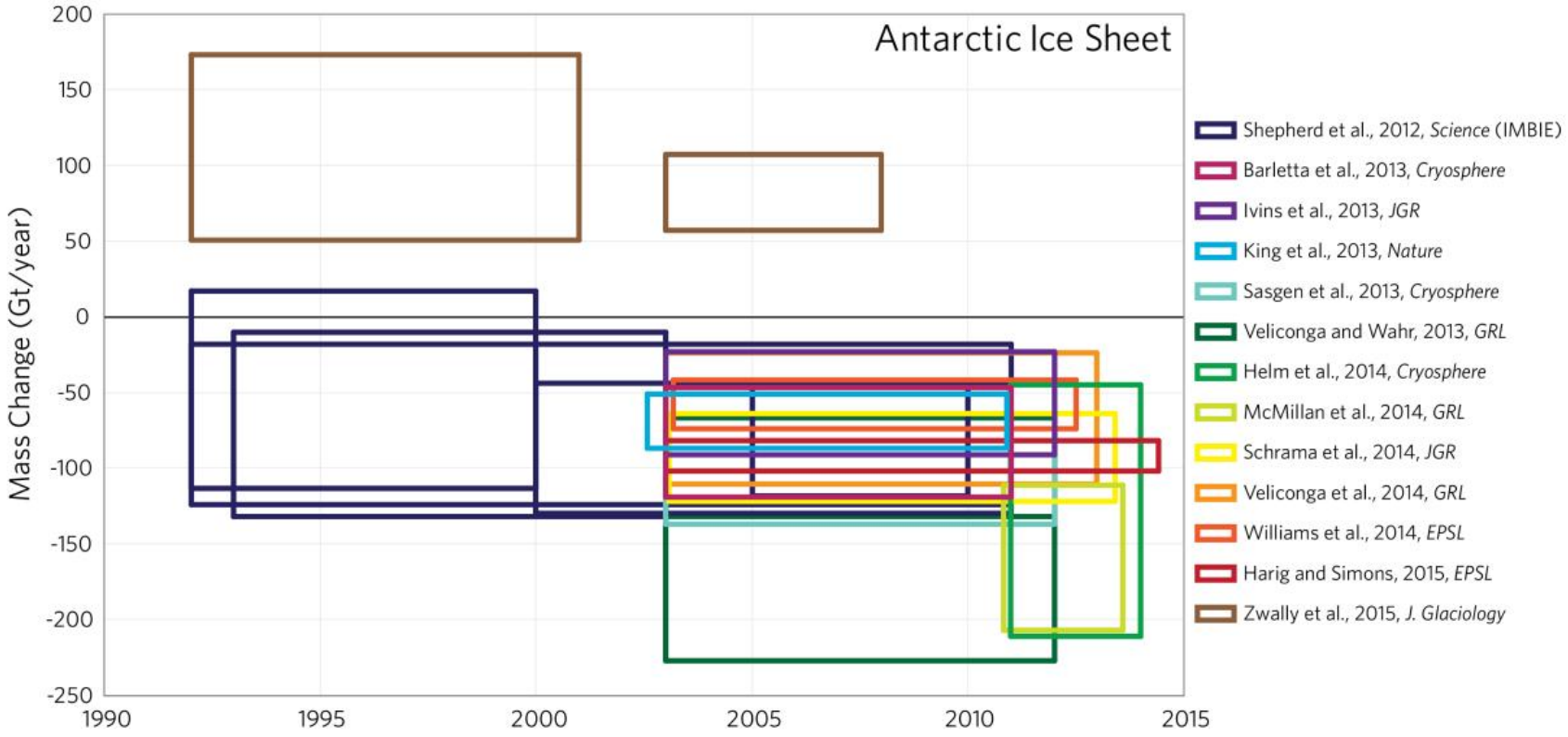
Jak znika lód Antarktydy?



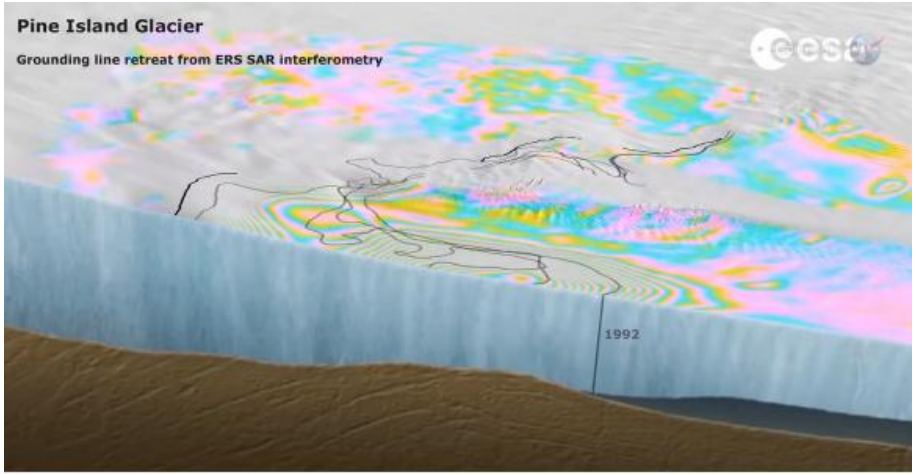


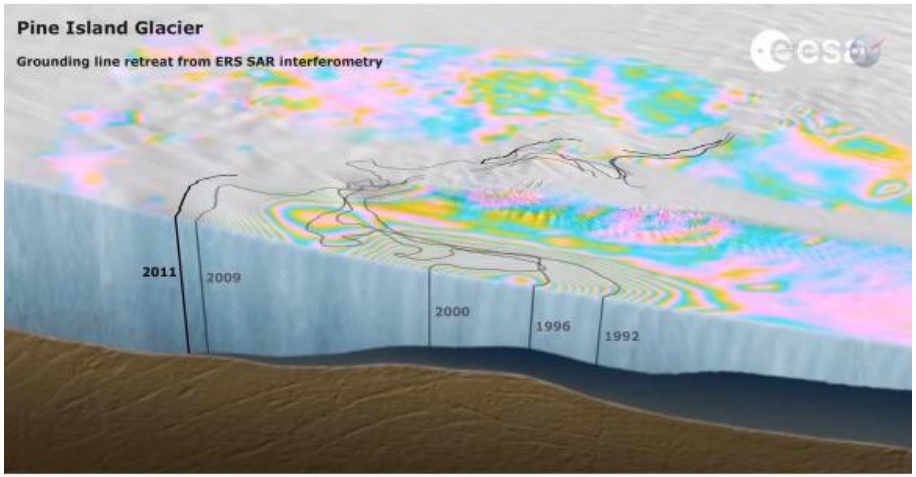
Source: climate.nasa.gov

Jak znika lód Antarktydy?

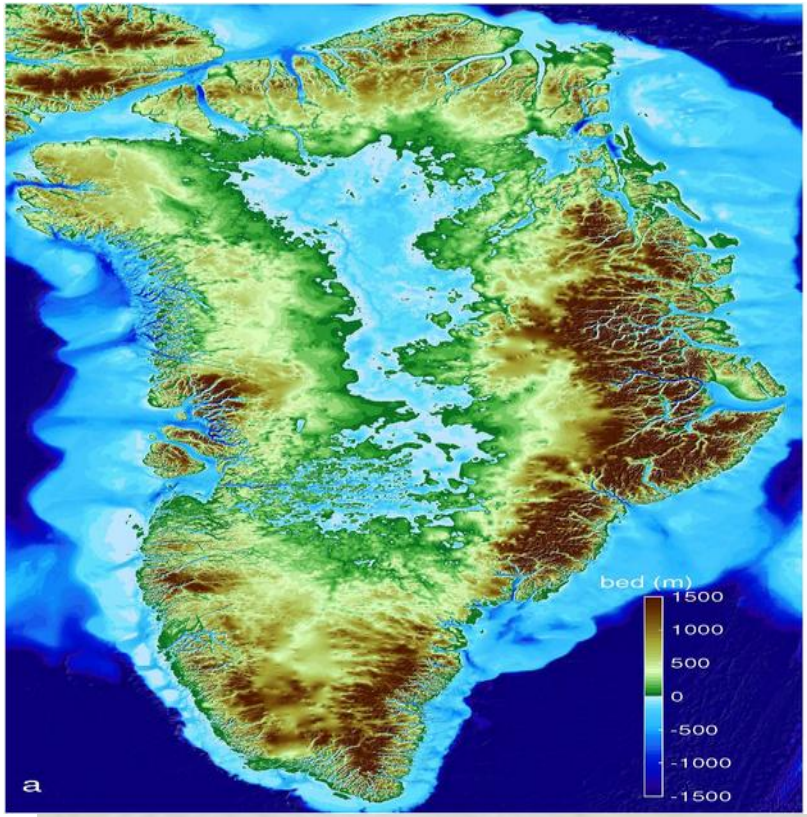


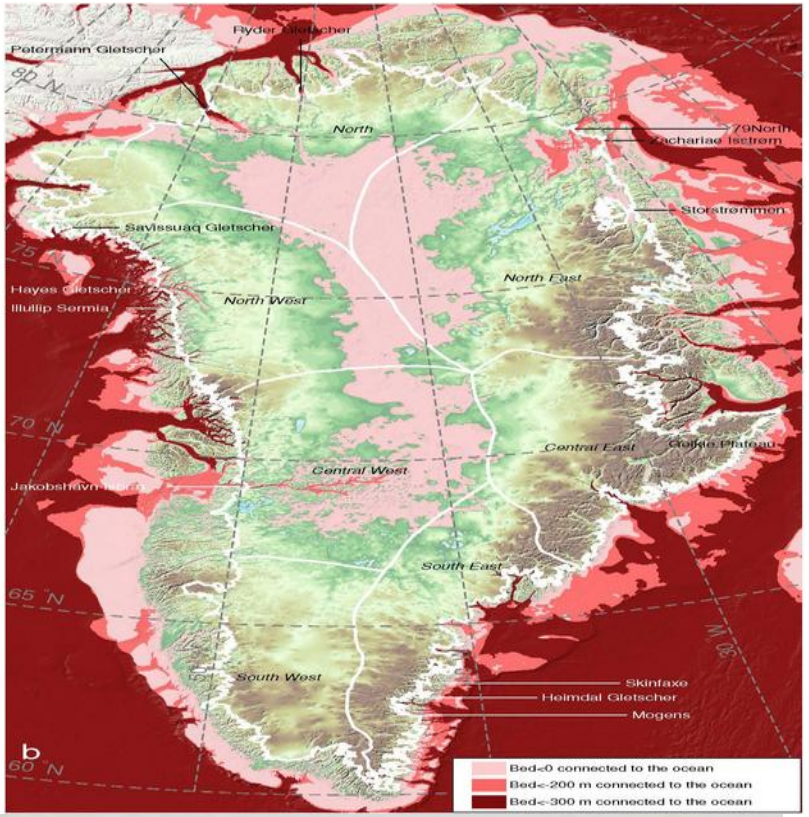
Jak znika lód Antarktydy?

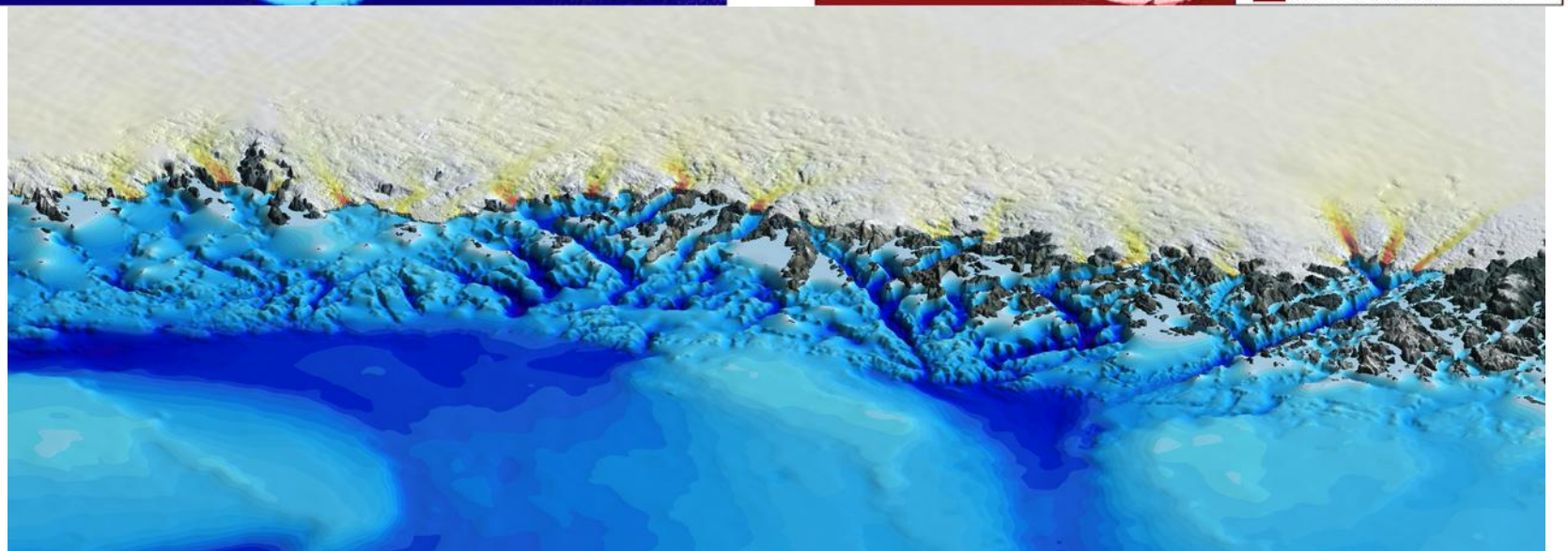




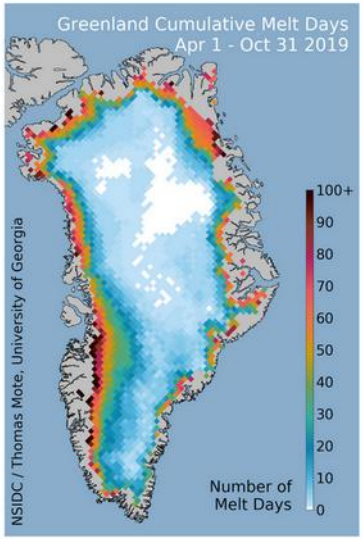
Grenlandia też płynie

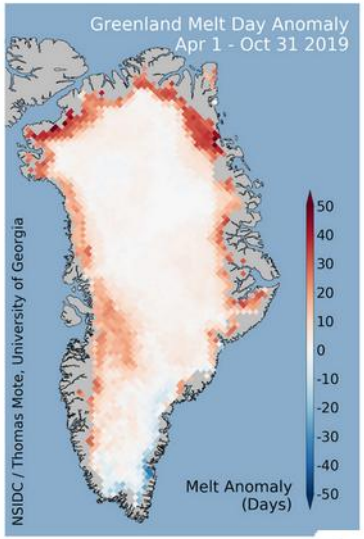

bed (m)
1500
1000
500
0
-500
-1000
-1500
a

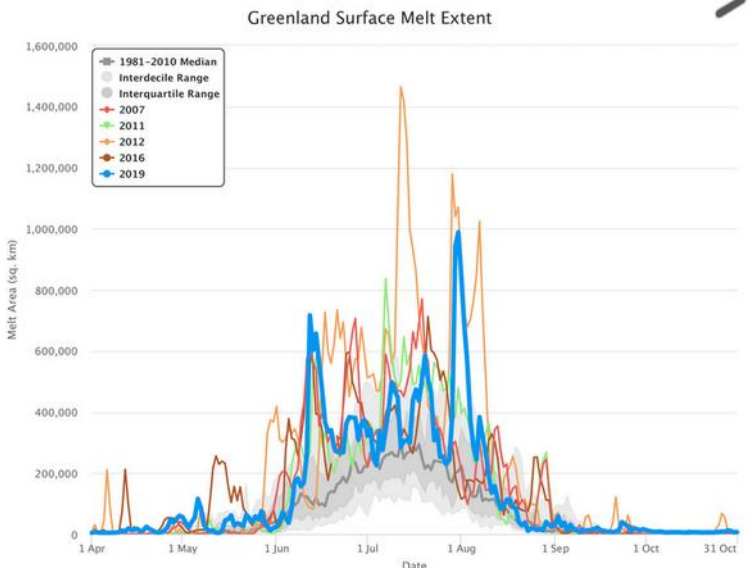

Petermann Gletscher
North
79North
Zachariae Isstrøm
Storstrømmen
Sarvissuaq Gletscher
Hayes Gletscher
Illullip Sermia
North West
North East
Central West
Central East
Greenland Plateau
Jakobshavn Isbræ
South East
South West
Skinfaxe
Heimdal Gletscher
Mogens
b
Bed<0 connected to the ocean
Bed<-200 m connected to the ocean
Bed<-300 m connected to the ocean



Topnienie powierzchniowe



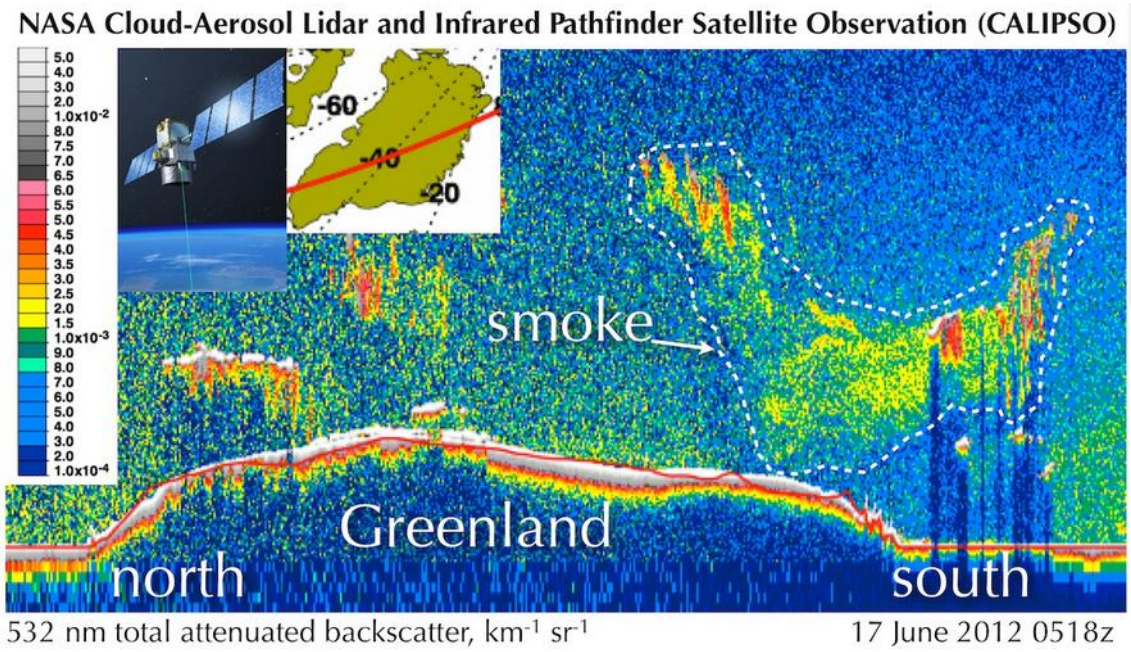


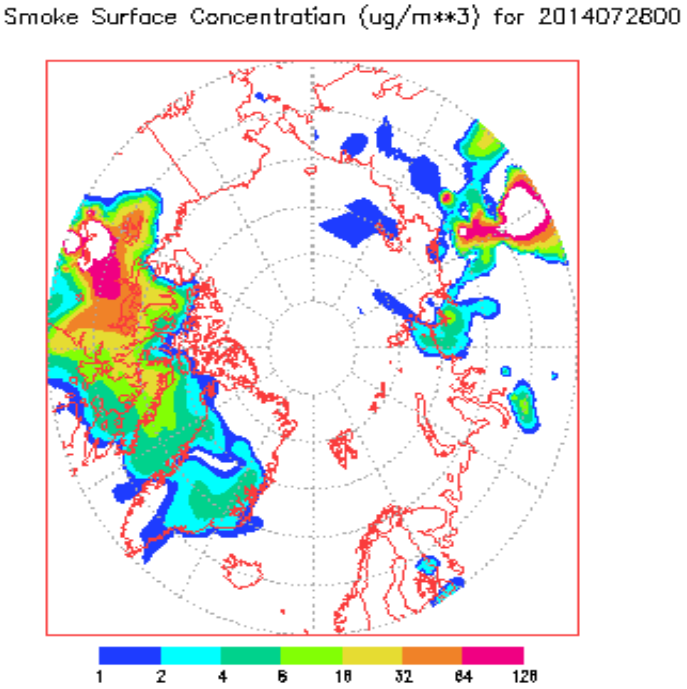


Czarny śnieg

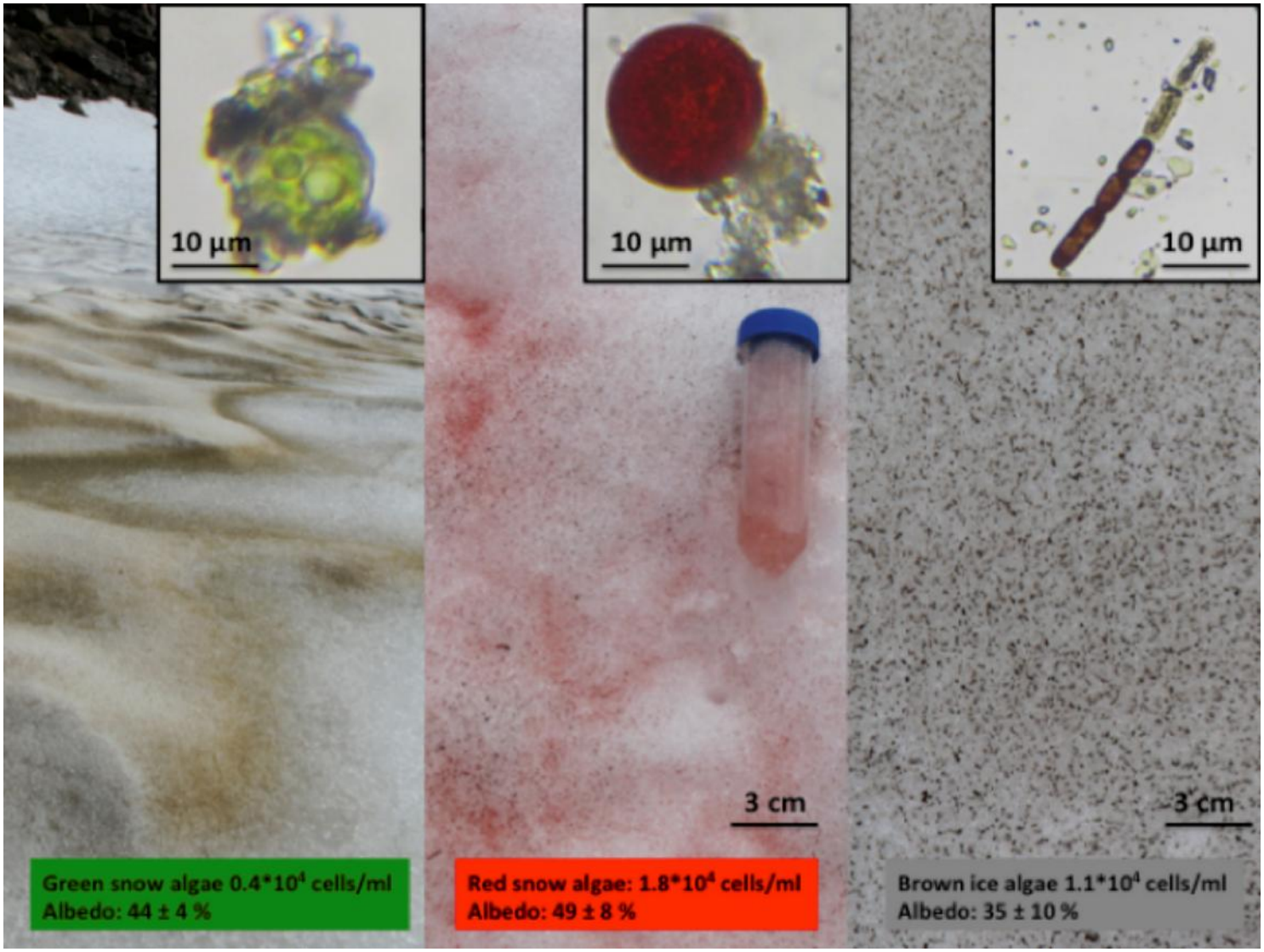
Jason Box, Dark Snow Project

Czarny śnieg - sadza



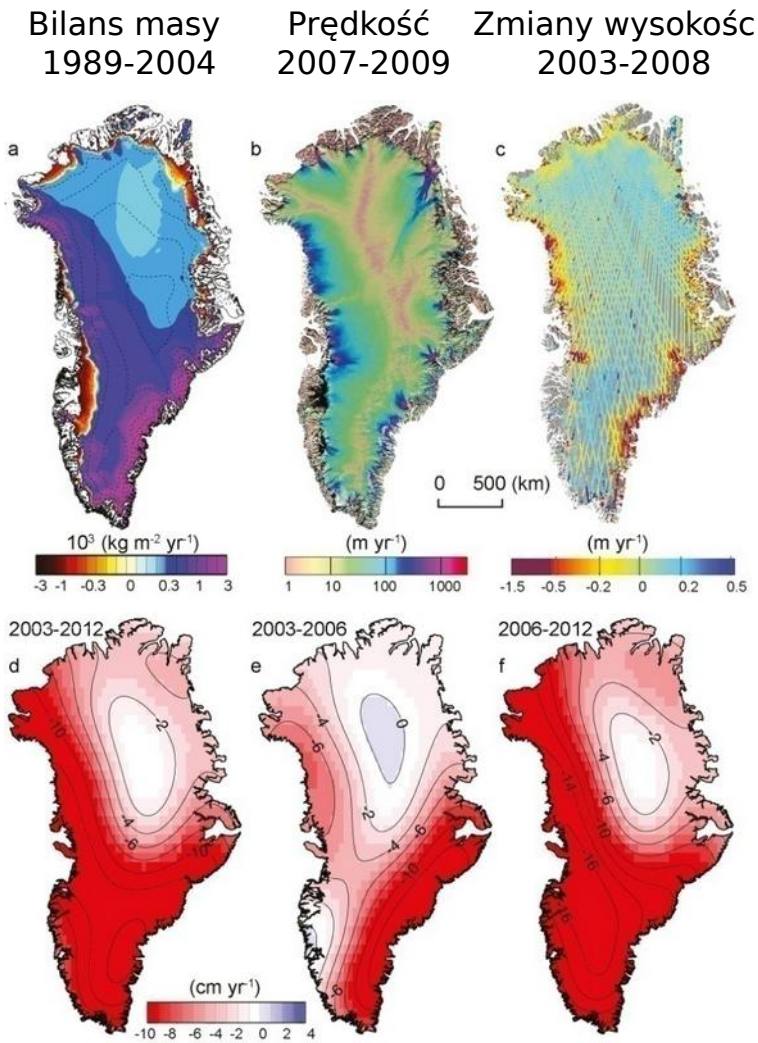


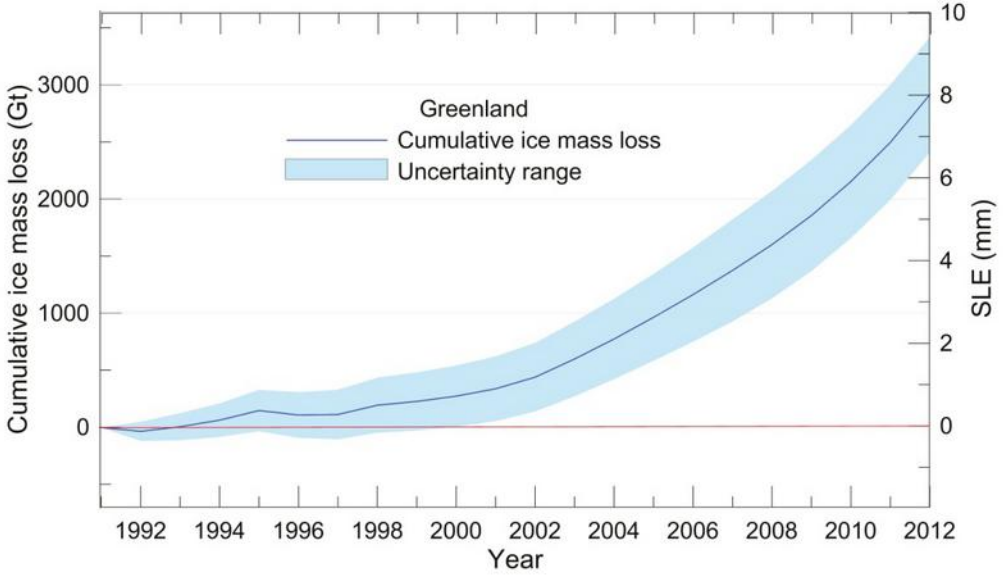
Ciemny śnieg - glony

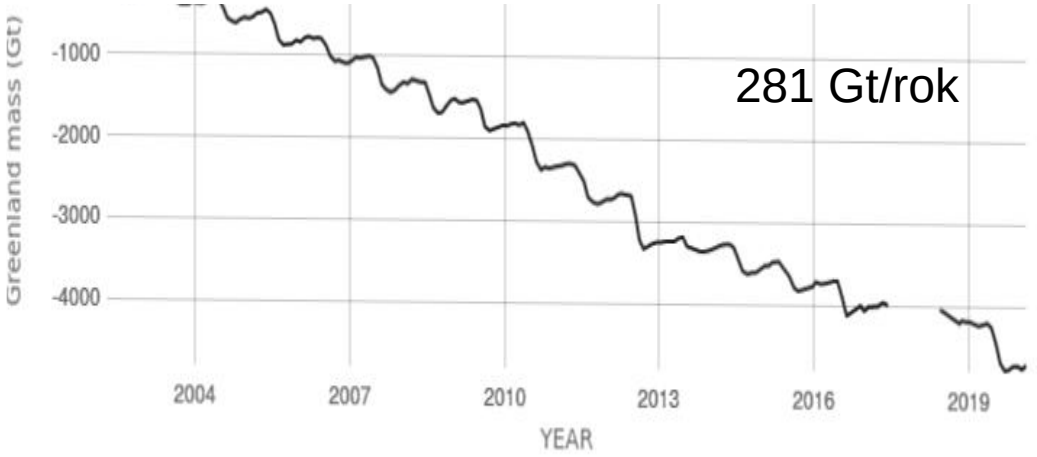


Dark snow project

Jak znika lód Grenlandii?



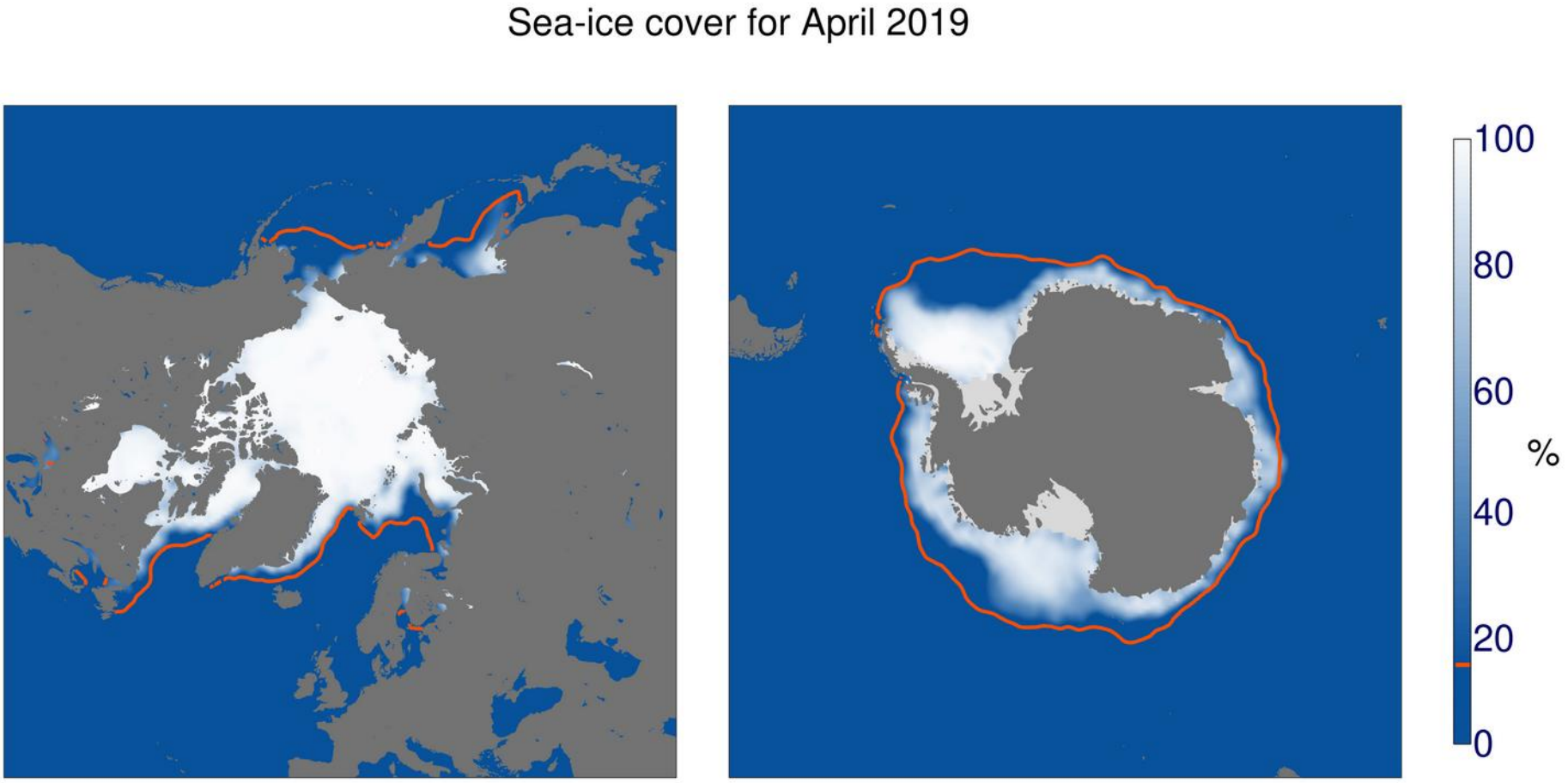




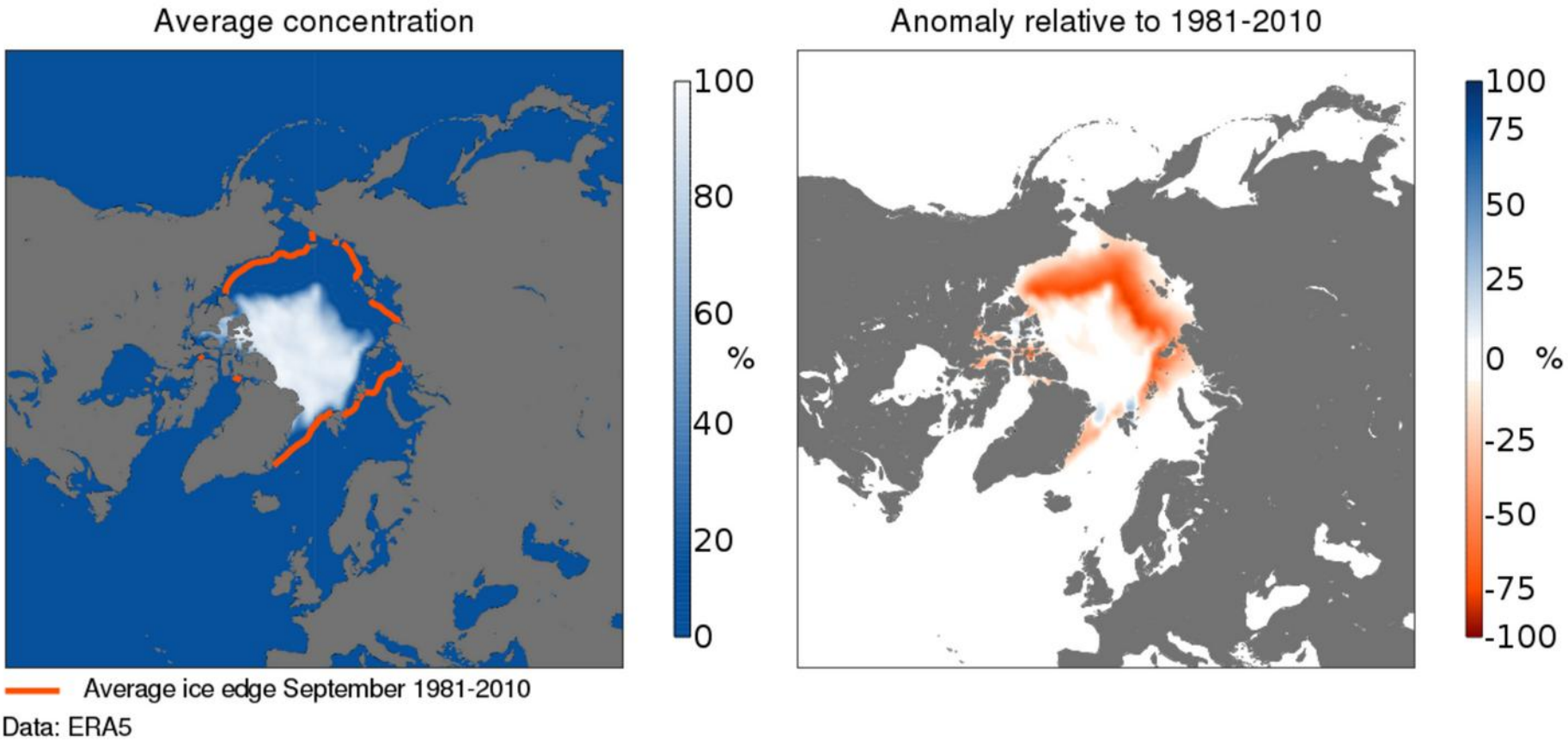
Source: climate.nasa.gov

Straty lodu w ekwiwalencie wodnym

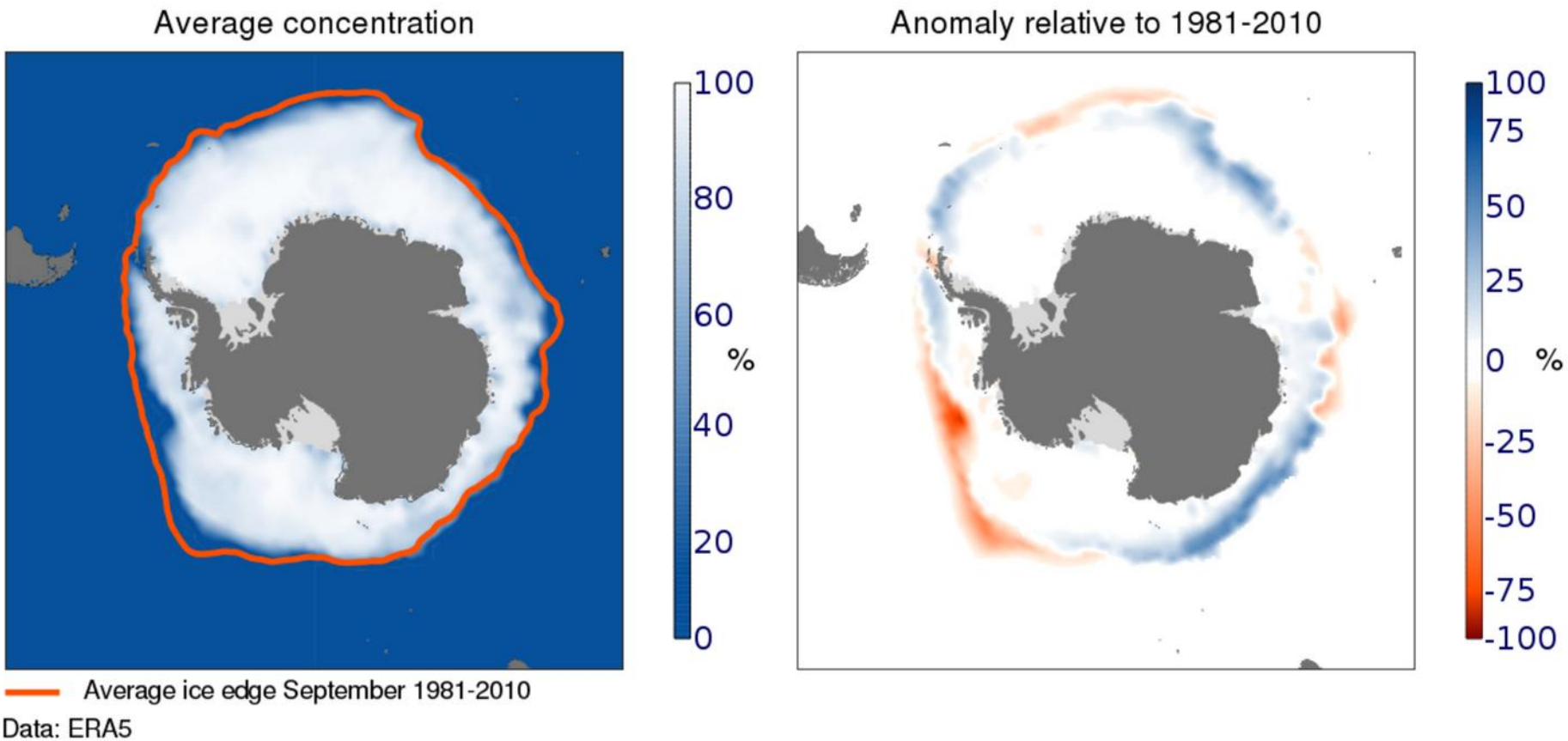
Lód morski



Arctic sea-ice concentration for September 2019



Antarctic sea-ice concentration for September 2019



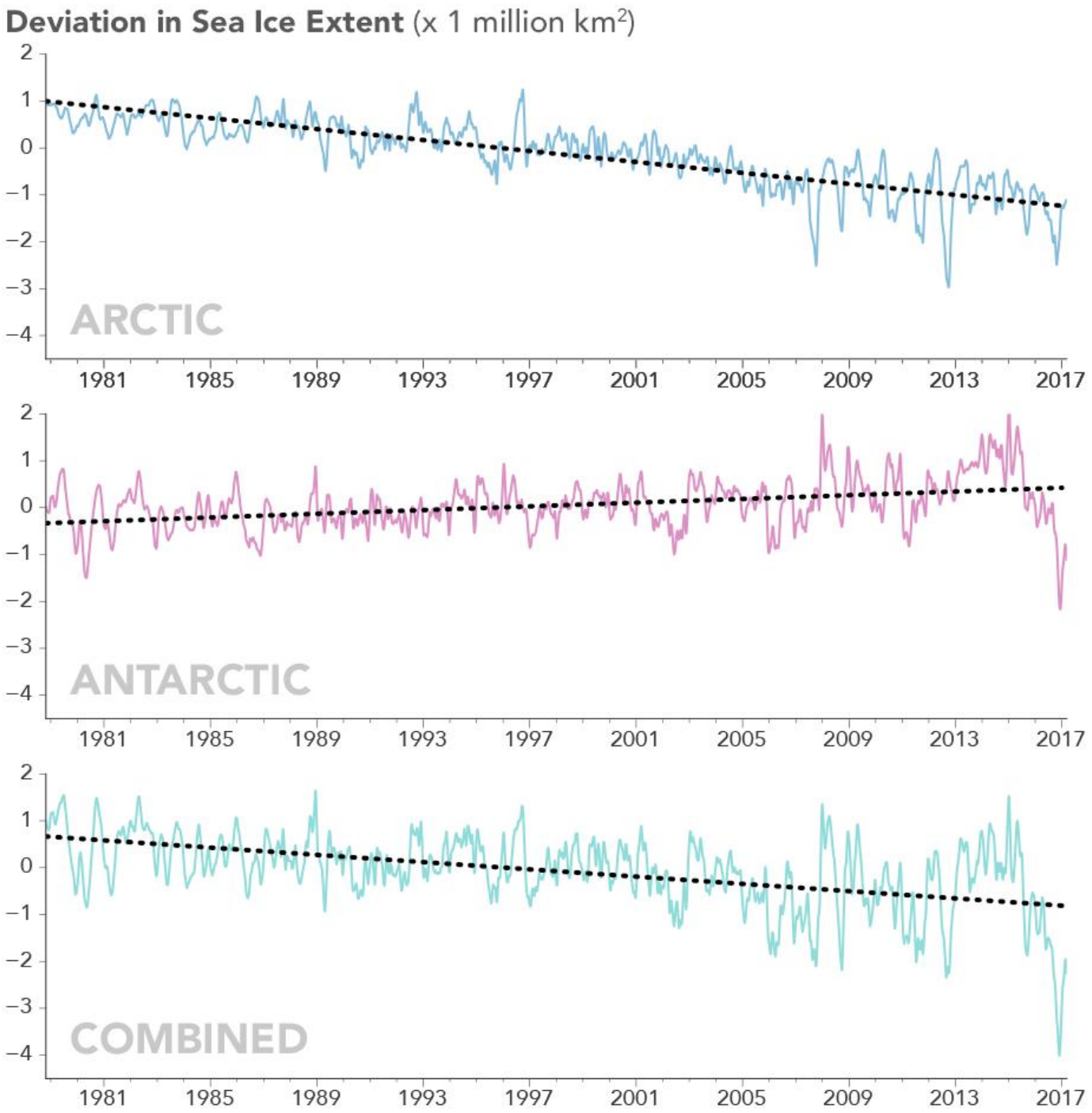
Data: ERA5

European Commission

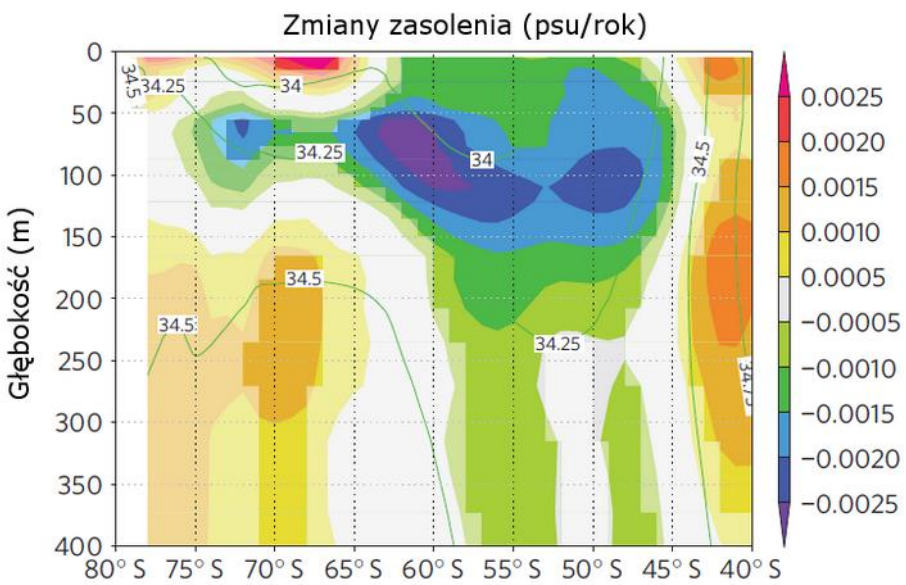
Copernicus
Europe's eyes on Earth

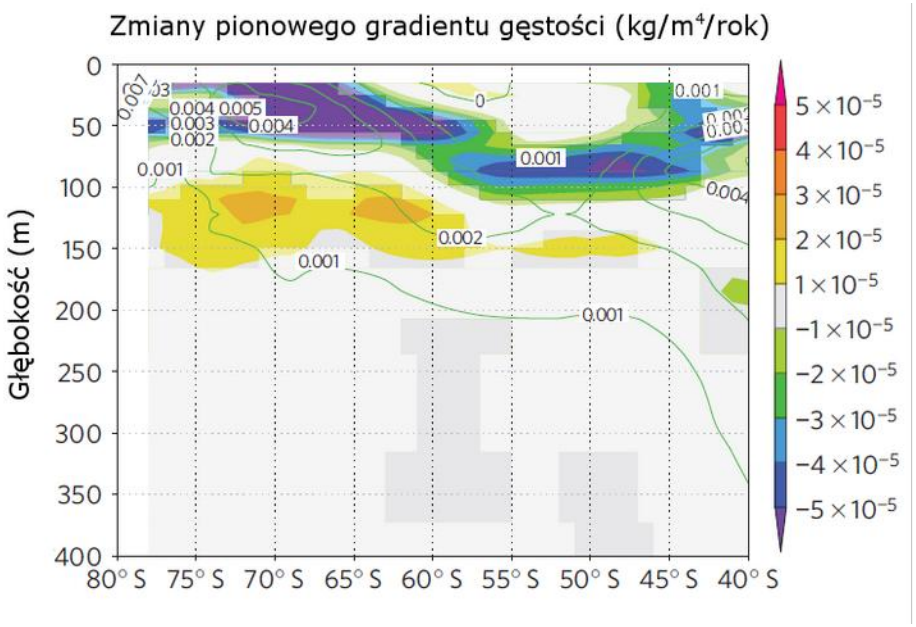
Climate Change Service
climate.copernicus.eu

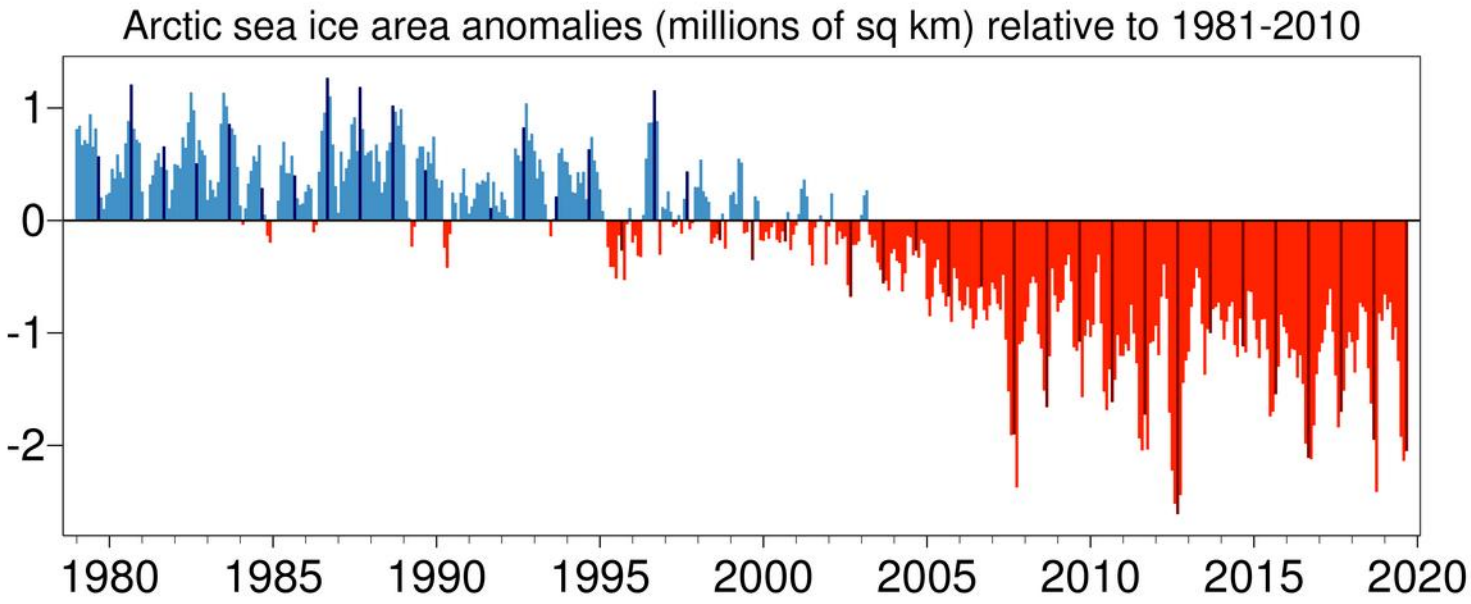
IMPLEMENTED BY ECMWF

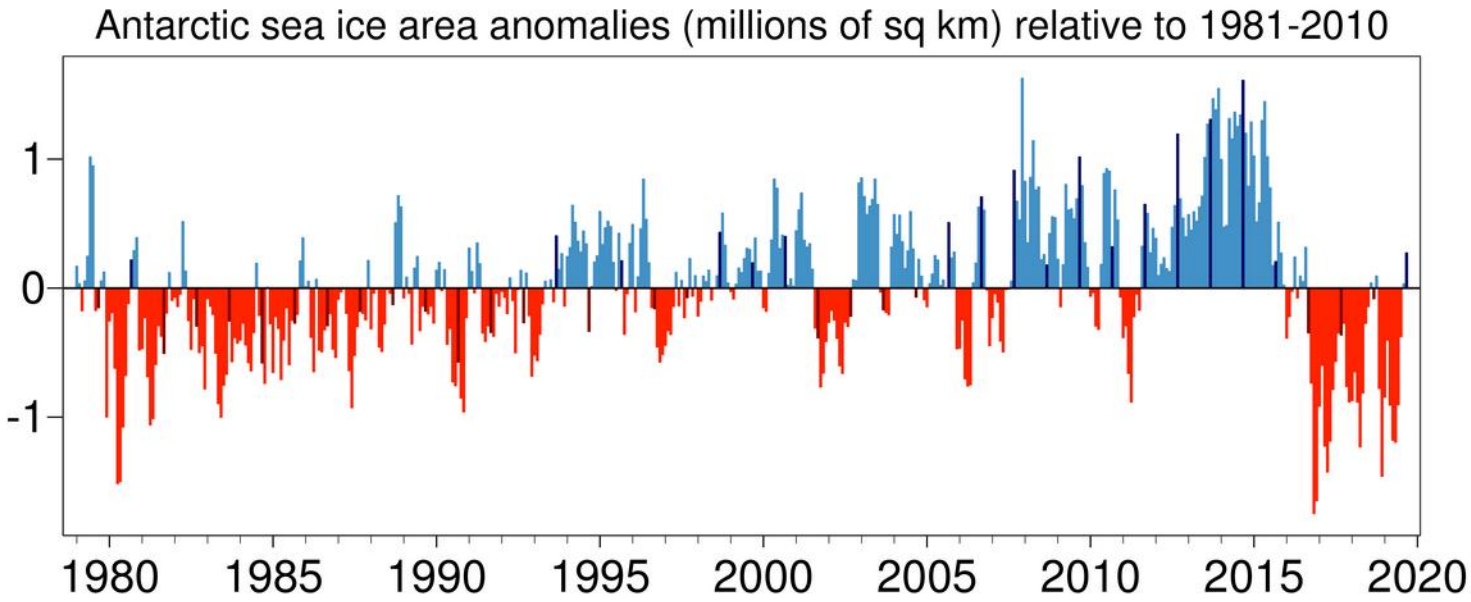

Deviation in Sea Ice Extent (x 1 million km²)
2
1
0
−1
−2
−3
−4
ARCTIC
1981
1985
1989
1993
1997
2001
2005
2009
2013
2017
ANTARCTIC
COMBINED

Czemu lód w Antarktyce przyrastał?









https://www.eea.europa.eu/data-and-maps/indicators/arctic-sea-ice-3/assessment-1

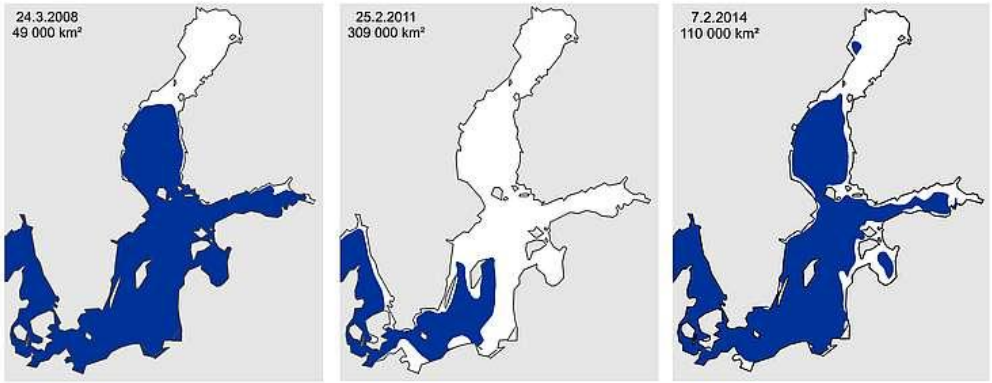
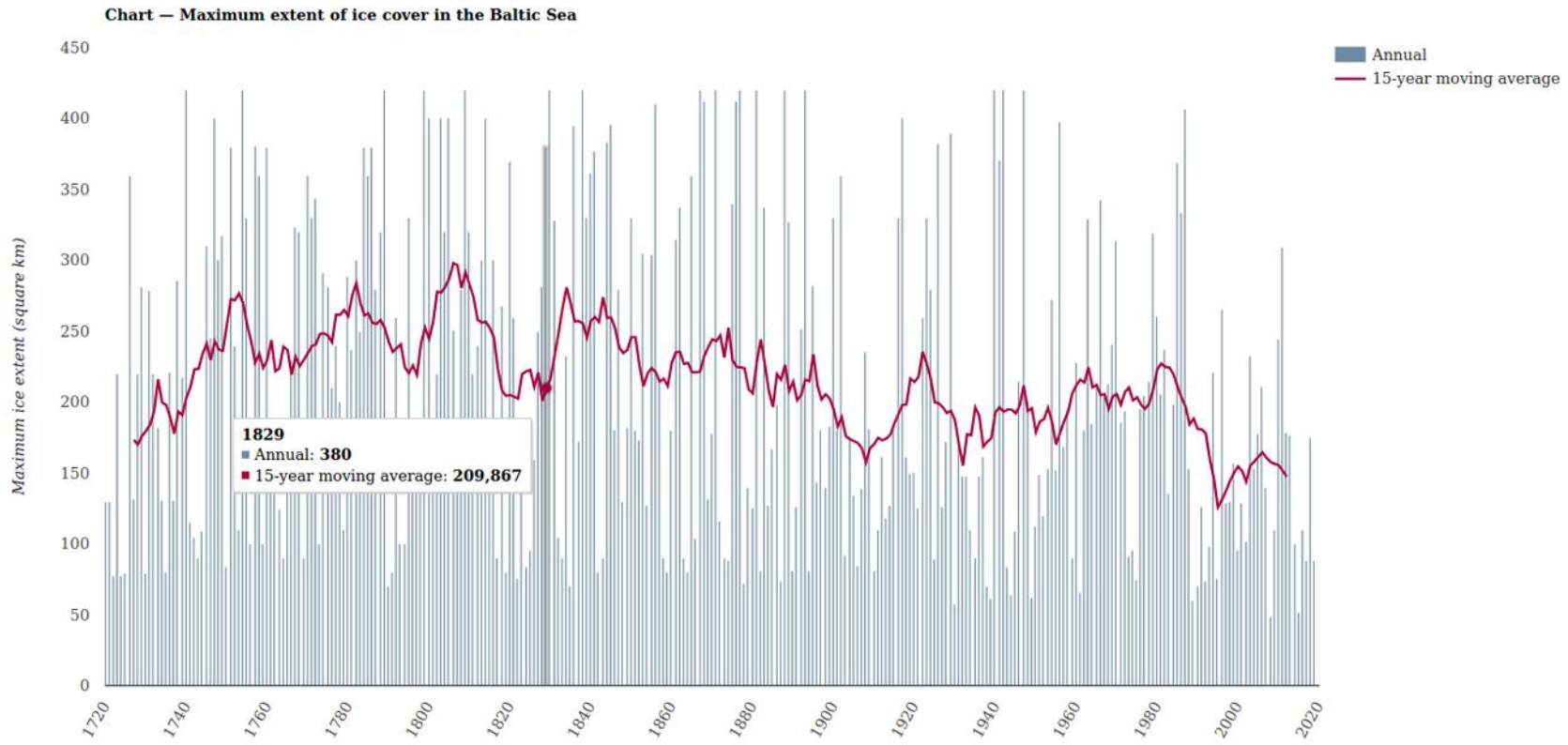


Fig. 2: Maximum extent of ice cover in the Baltic Sea

Chart

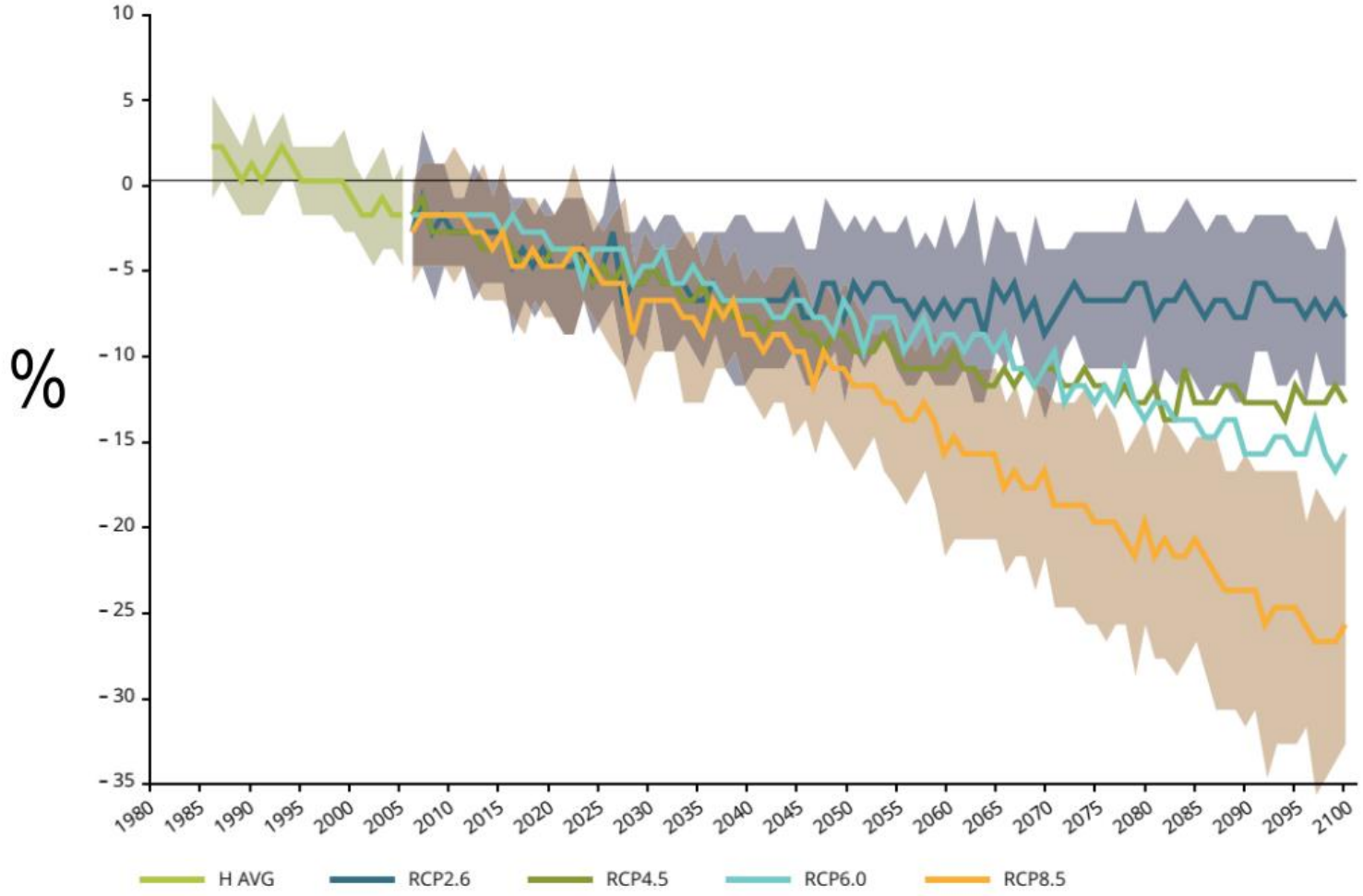


Note:
Maximum extent of ice cover in the Baltic Sea in winter in the period from 1719/1720 to 2018/2019 (blue bars) and 15-year moving average (red line).

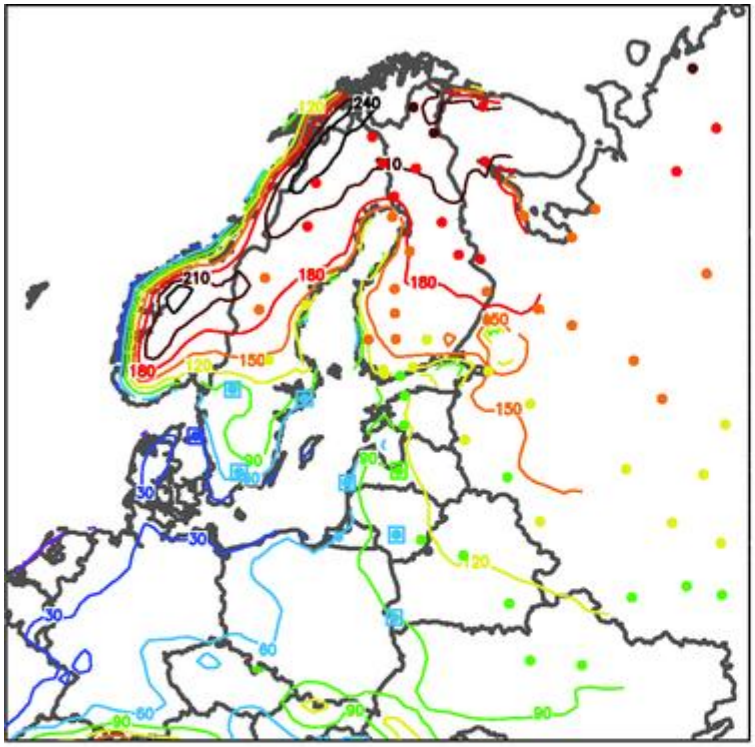
Pokrywa śnieżna

ZMIANY POKRYWY ŚNIEŻNEJ WIOSNĄ

marzec - kwiecień, półkula północna



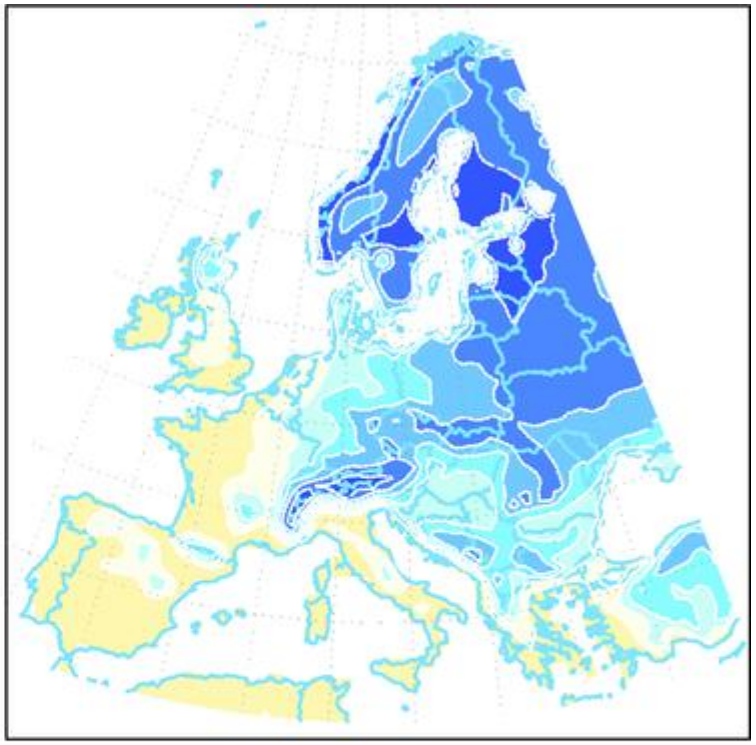
źródło: EEA: "Climate change, impact and vulnerability in Europe 2016, EURO-CORDEX



Annual number of days with snow cover

Observed means in nothern Europe, 1961–1990 (coloured dots) and modelled means for Europe, 1961–1990

5 30 60 90 120 150 180 210 240

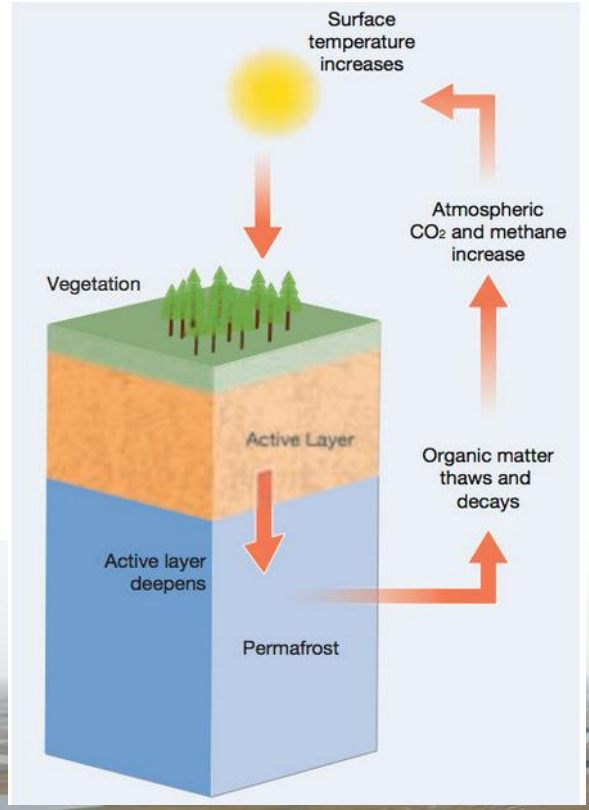


Projected change of annual number of days with snow cover

Projected multi-model mean changes for the period 2071–2100, relative to 1961–1990

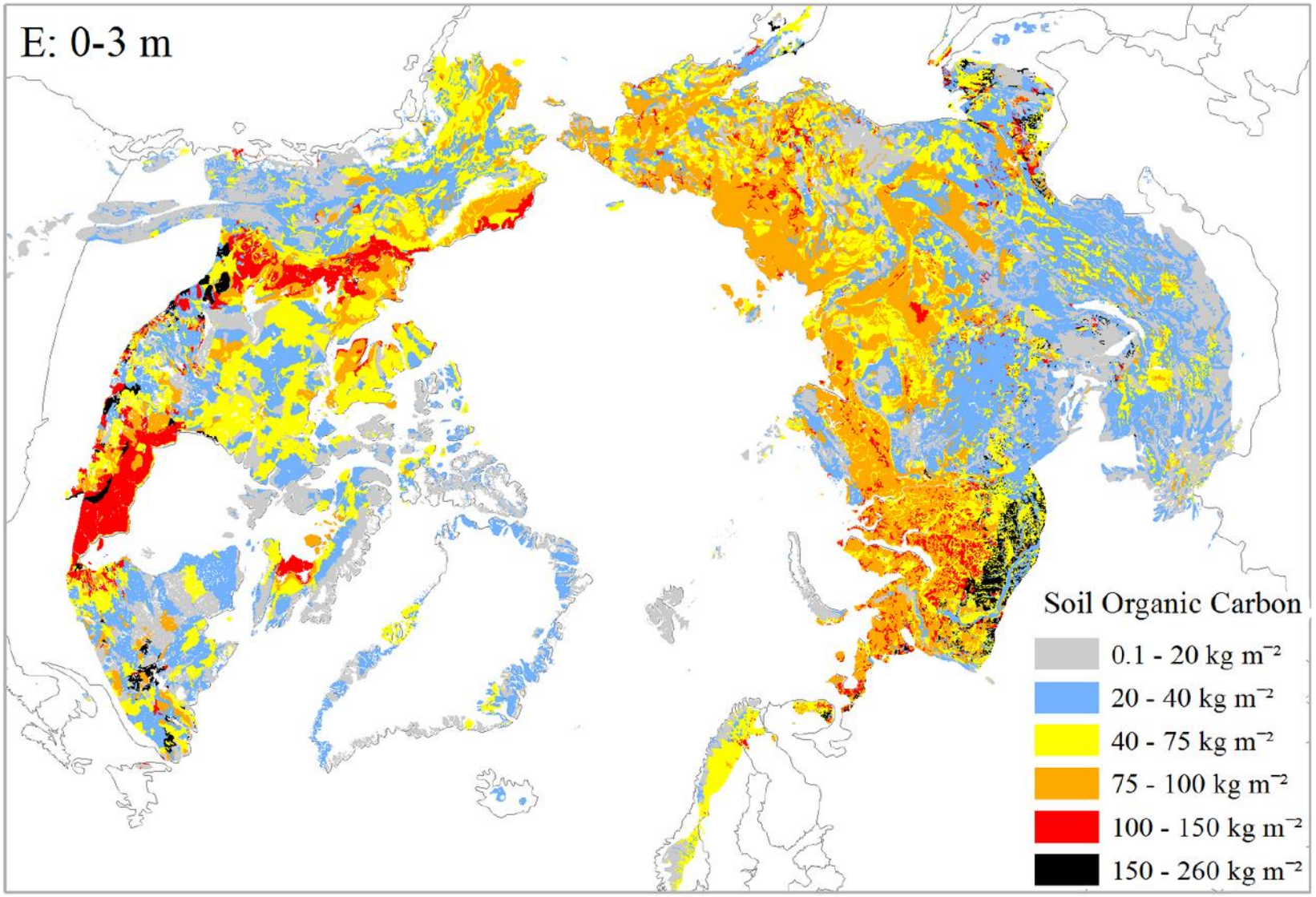
– 60 – 50 – 40 – 30 – 20 –10

Wieloletnia zmarzlina

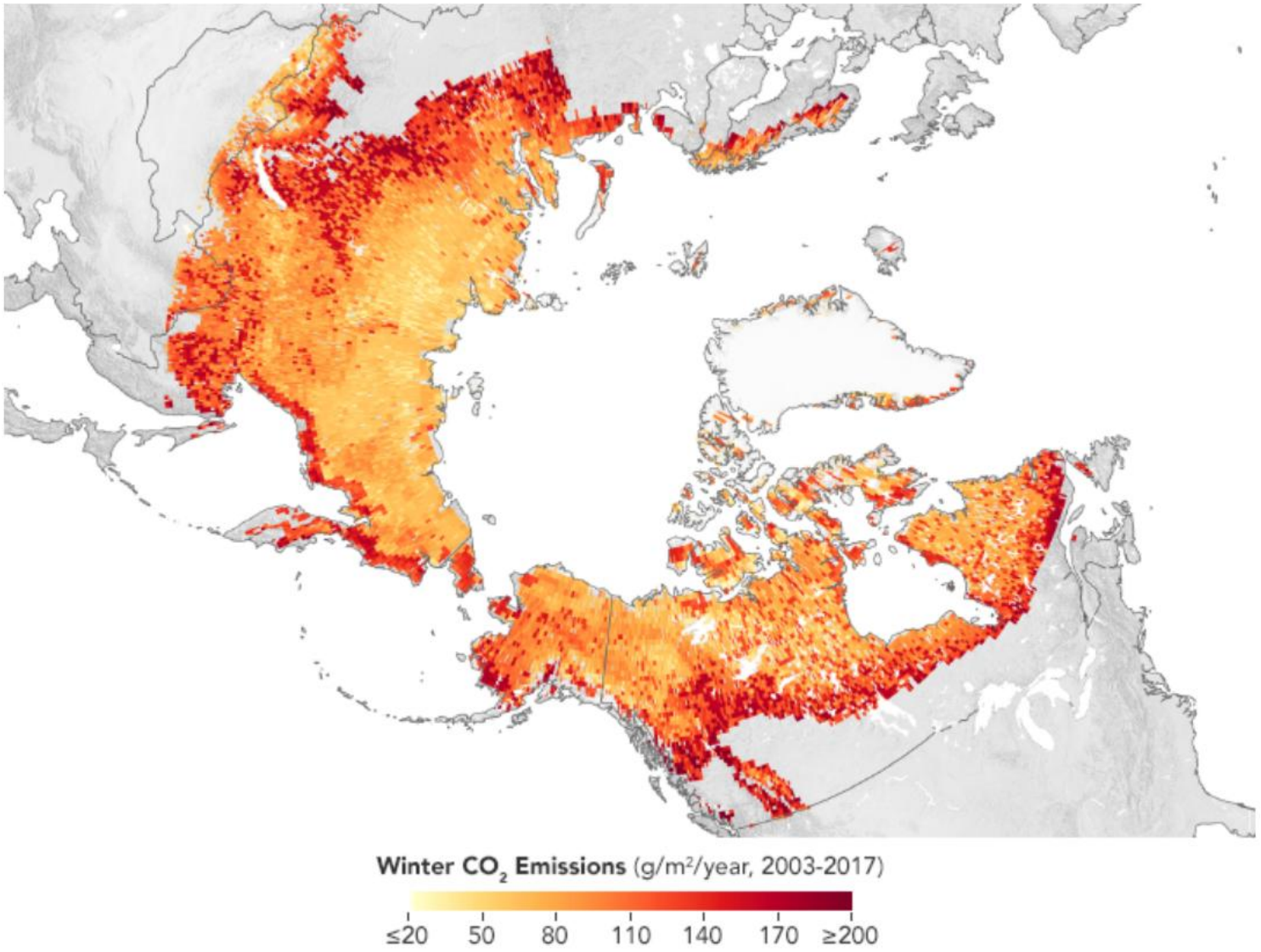


Delta Leny, lipiec 2012, Volkmar Kochan/rbb

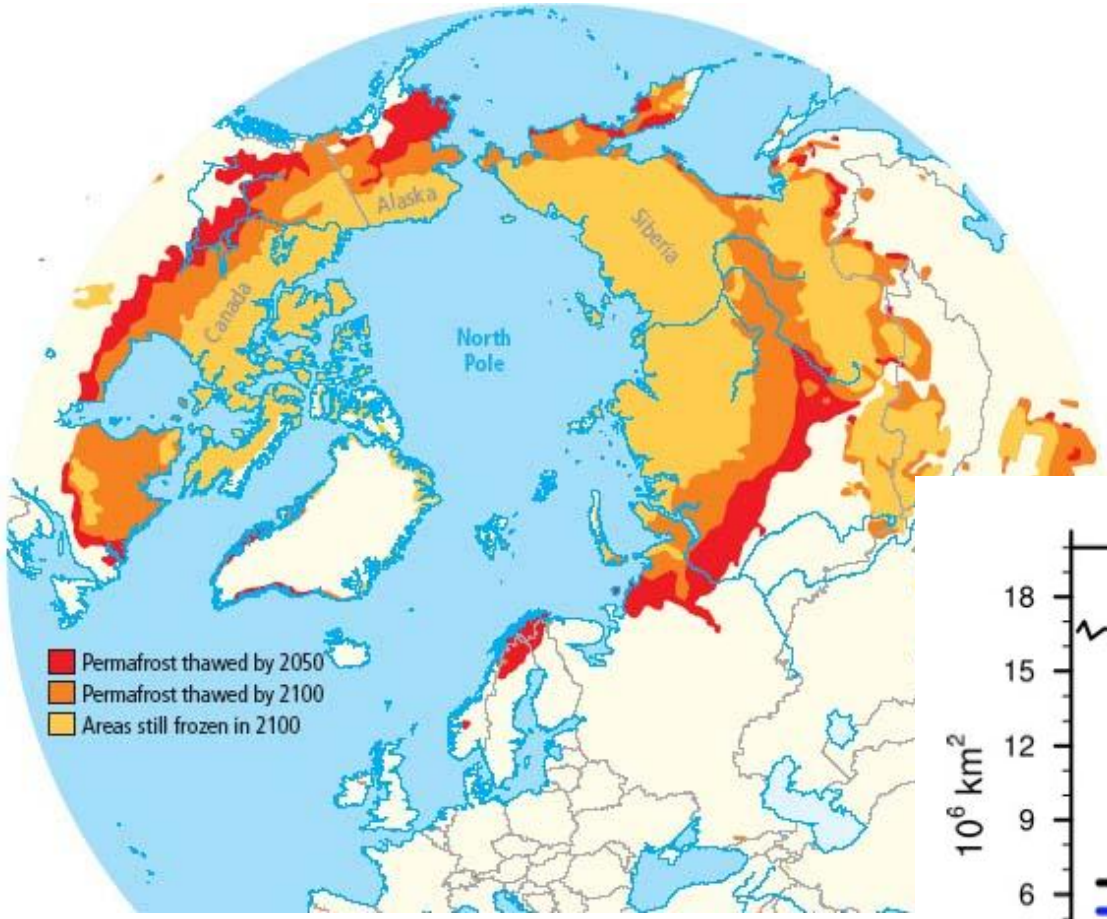
Wieloletnia zmarzlina – węgiel organiczny



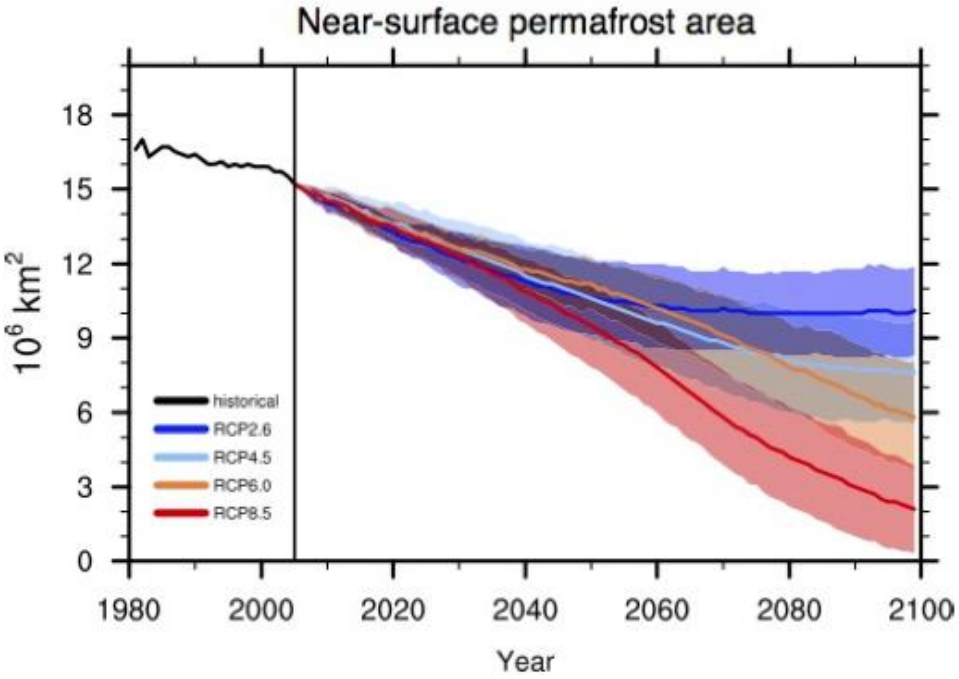
Natali, S.M., Watts, J.D., Rogers, B.M. et al. Large loss of CO2 in winter observed across the northern permafrost region. Nat. Clim. Chang. 9, 852–857 (2019). https://doi.org/10.1038/s41558-019-0592-8



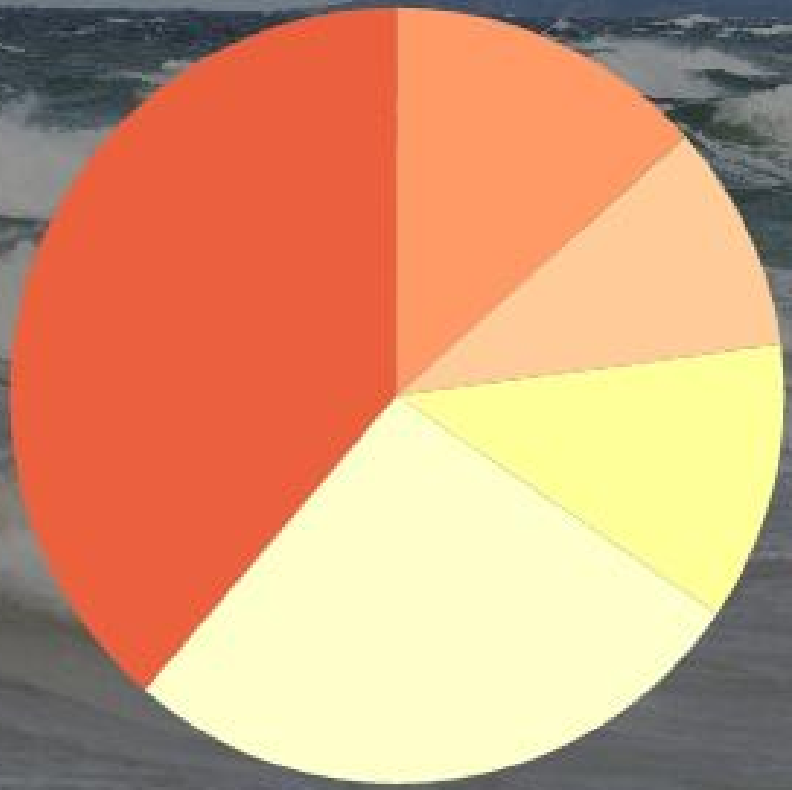
Wieloletnia zmarzlina



Vladimir Romanovsky, 2009



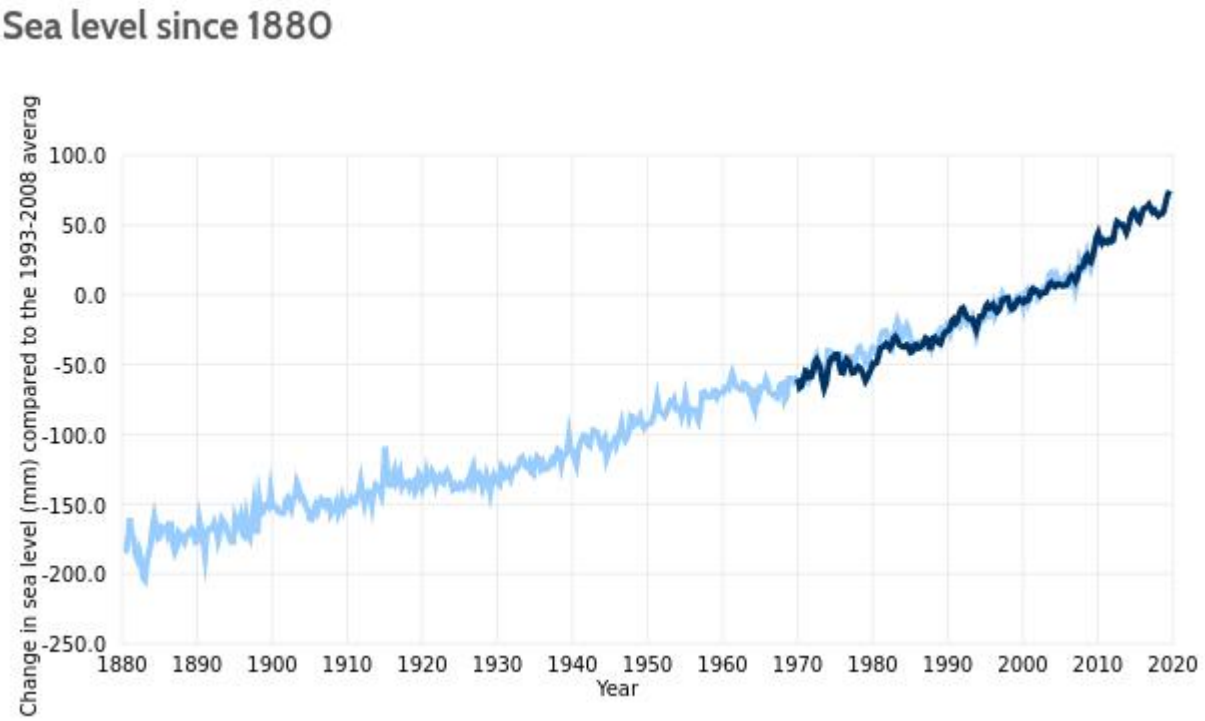
WZROST POZIOMU MORZA 1993-2010

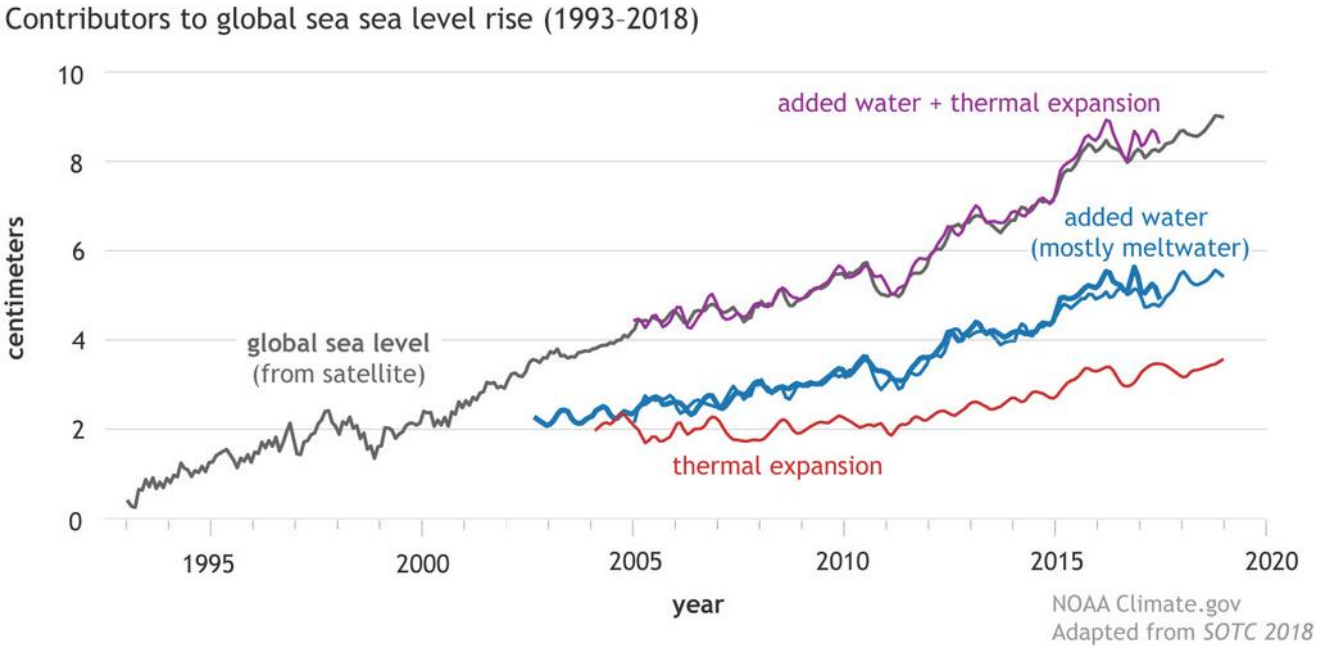


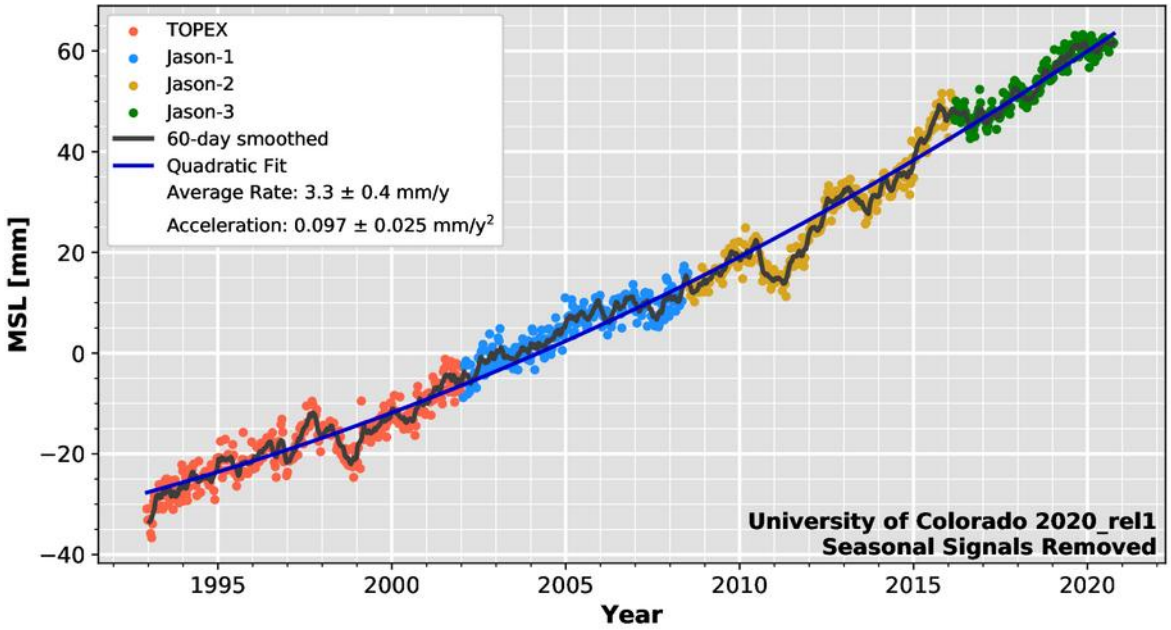
- rozszerzalność cieplna 1,1 mm/r
- lodowce 0,76 mm/r
- Grenlandia 0,33 mm/r
- Antarktyda 0,27 mm/r
- spływ z lądów 0,38 mm/r

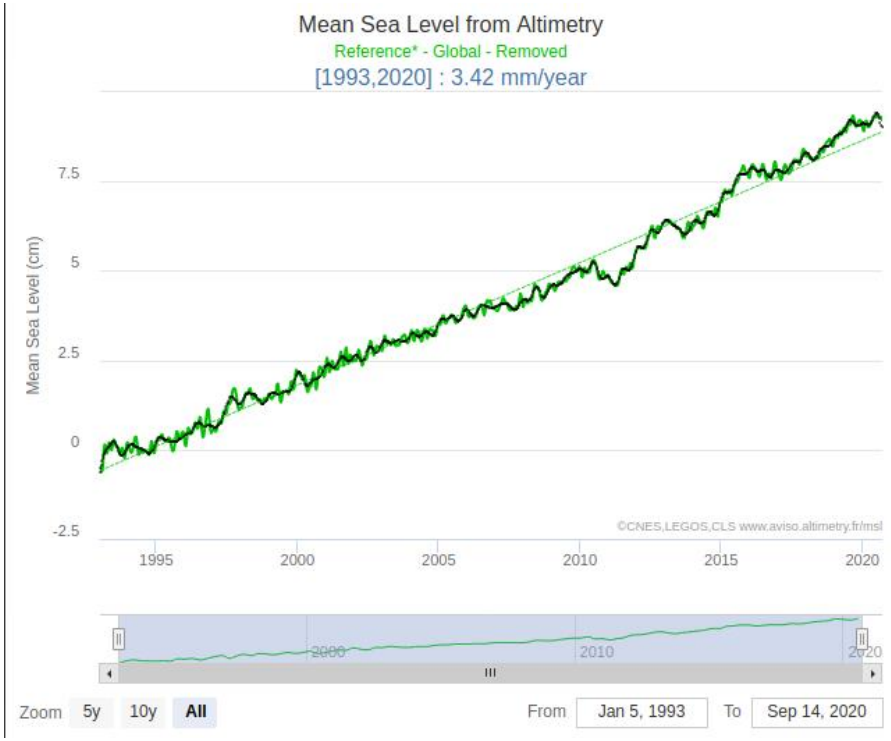
Źródło: V raport IPCC, www.climatechange2013.org

Wzrost poziomu morza






TOPEX
Jason-1
Jason-2
Jason-3
60-day smoothed
Quadratic Fit
Average Rate: 3.3 ± 0.4 mm/y
Acceleration: 0.097 ± 0.025 mm/y²
University of Colorado 2020_rel1
Seasonal Signals Removed
MSL [mm]
Year


Mean Sea Level from Altimetry
Reference* - Global - Removed
[1993,2020] : 3.42 mm/year
Mean Sea Level (cm)
©CNES,LEGOS,CLS www.aviso.altimetry.fr/msl
Zoom
5y
10y
All
From
Jan 5, 1993
To
Sep 14, 2020

Rola kriosfery w systemie klimatycznym

- wpływa na bilans energii (wysokie albedo śniegu i lodu)
- wpływa na poziom światowego oceanu
- wpływa na cyrkulację oceaniczną w wysokich szerokościach geograficznych i nie tylko
- bierze udział w szeregu sprzężeń zwrotnych w systemie klimatycznym