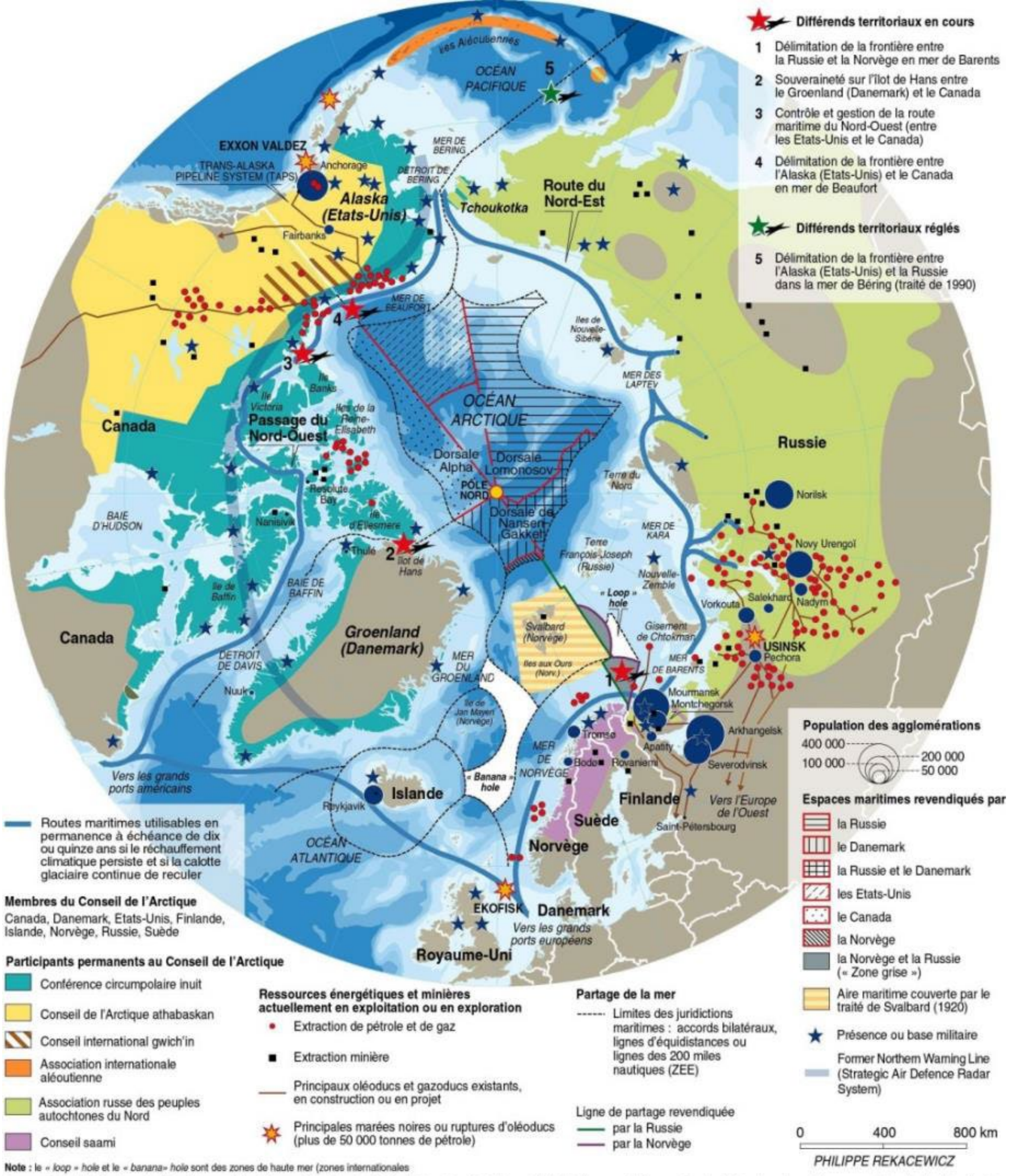
19 settembre 2024 – SSPT

Sfide artiche: dalla geopolitica alla scienza
Il contributo dell'ENEA nella ricerca polare

Alcide Giorgio di Sarra

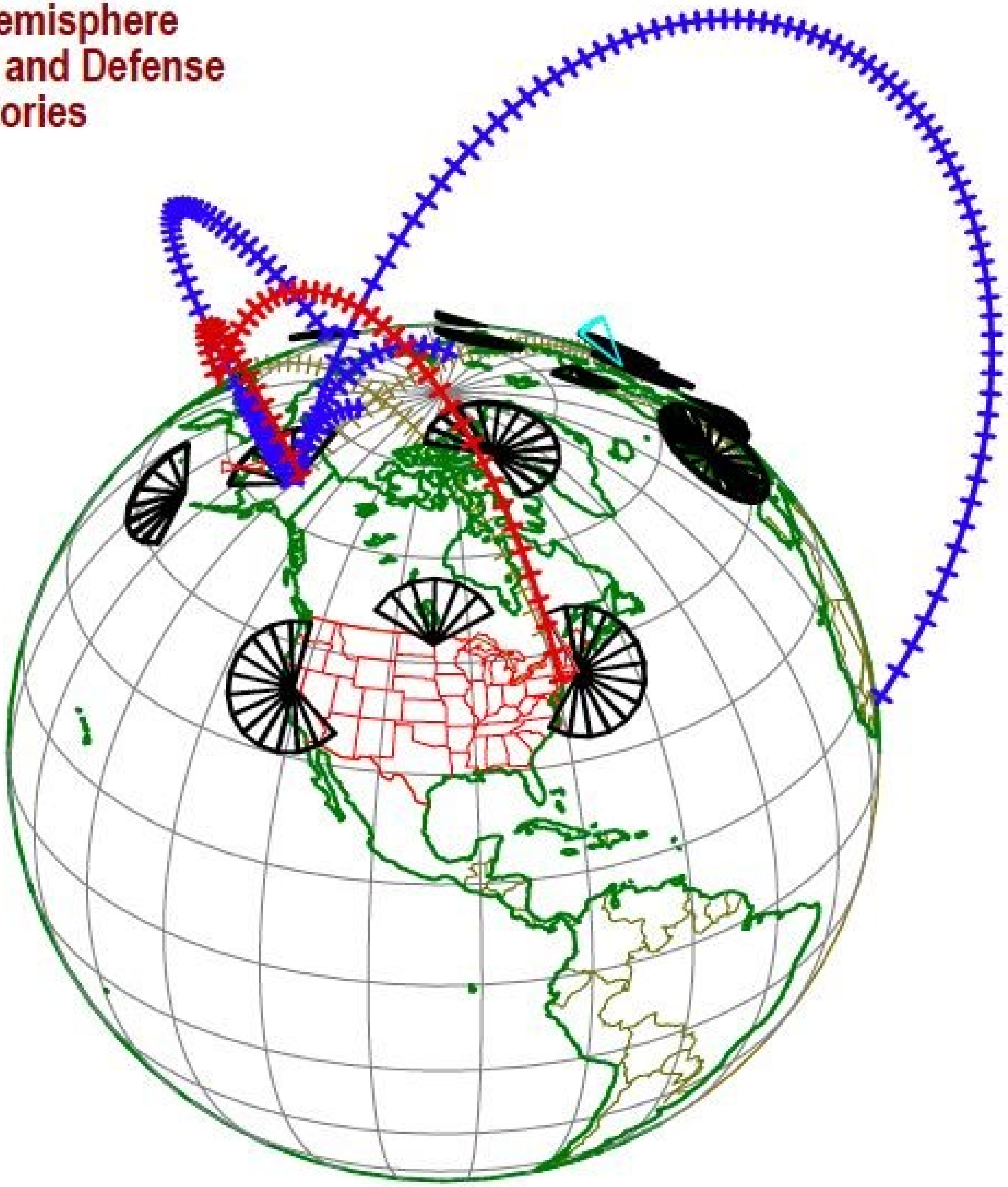
SSPT-CLIMAR-AOC



Note : le *« loop » hole* et le *« banana» hole* sont des zones de haute mer (zones internationales

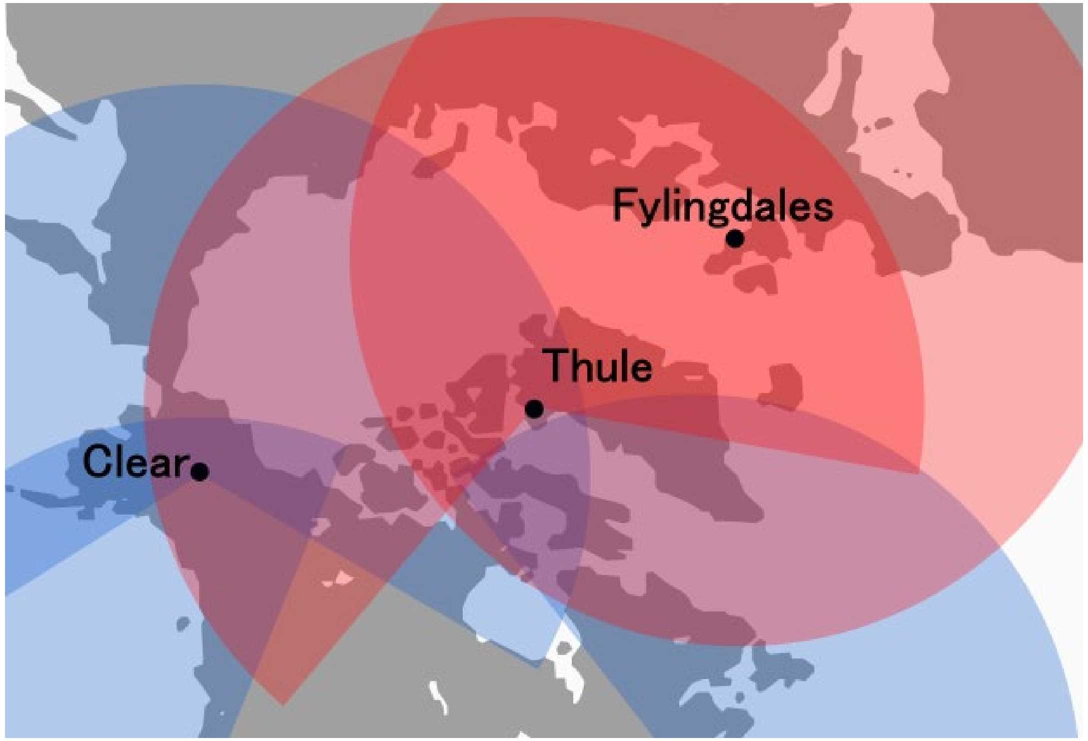
Sources : Conseil de l'Arctique ; Institut polaire norvégien, *Permanent Participants of the Arctic Council*, carte établie par Winfried Dallmann ; ministère canadien des affaires étrangères et du commerce international ; International Boundaries Research Unit Database, University of Durham (IBRU) ; Bureaux statistiques nationaux ; United States Energy Information Administration (EIA) ; National Oceanic and Atmospheric Administration (NOAA) ; *Impacts of a Warming Arctic*, Arctic Climate Impact Assessment (ACIA) Overview Report, Cambridge University Press, 2004 ; *Vital Arctic Graphics, People and Global Heritage on our Last Wild Shores*, Norvège, PNUE/GRID-Arendal, 2005 ; Division for Oceans Affairs and Law of the Sea, Commission on the Limits of the Continental Shelf (CLCS) ; ministère norvégien des pêches et de l'énergie (Oslo, Norvège) ; Alaska Science Forum, Geophysical Institute, université d'Alaska Fairbanks

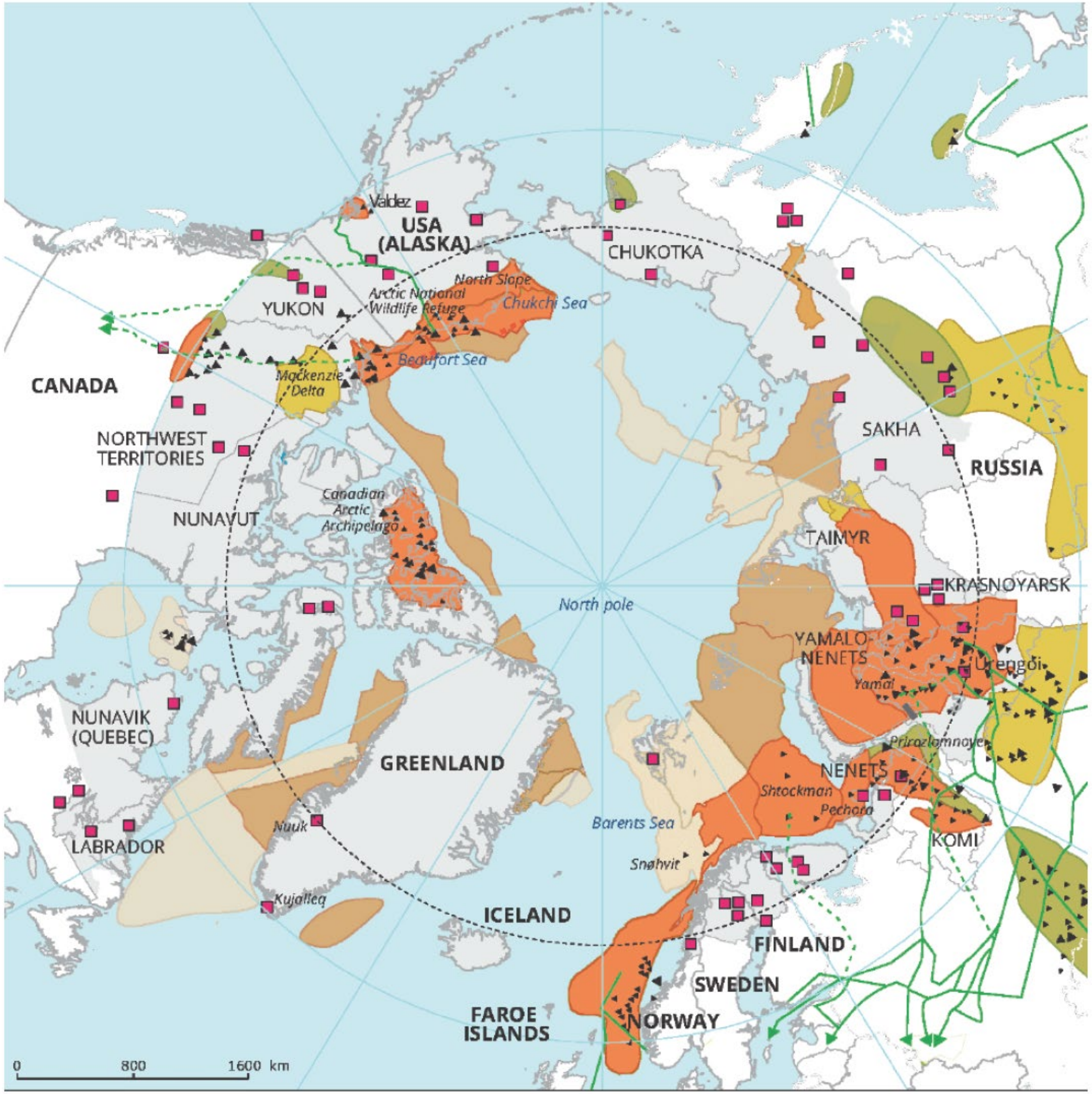
American Hemisphere View of Attack and Defense Trajectories




Fylingdales
Thule
Clear
Beale
Cape Cod


BALLISTIC MISSILE EARLY WARNING SYSTEM (BMEWS)
U.S. AIR FORCE PROJECT
U.S. ARMY CORPS OF ENGINEERS


Fylingdales
Thule
Clear



Artic resources

Oil, gas and mining

- Oil and gas exploration and production sites
- Main mining sites
- Main projected pipeline
- Main existing gas and oil pipeline
- Prospective areas and reserves

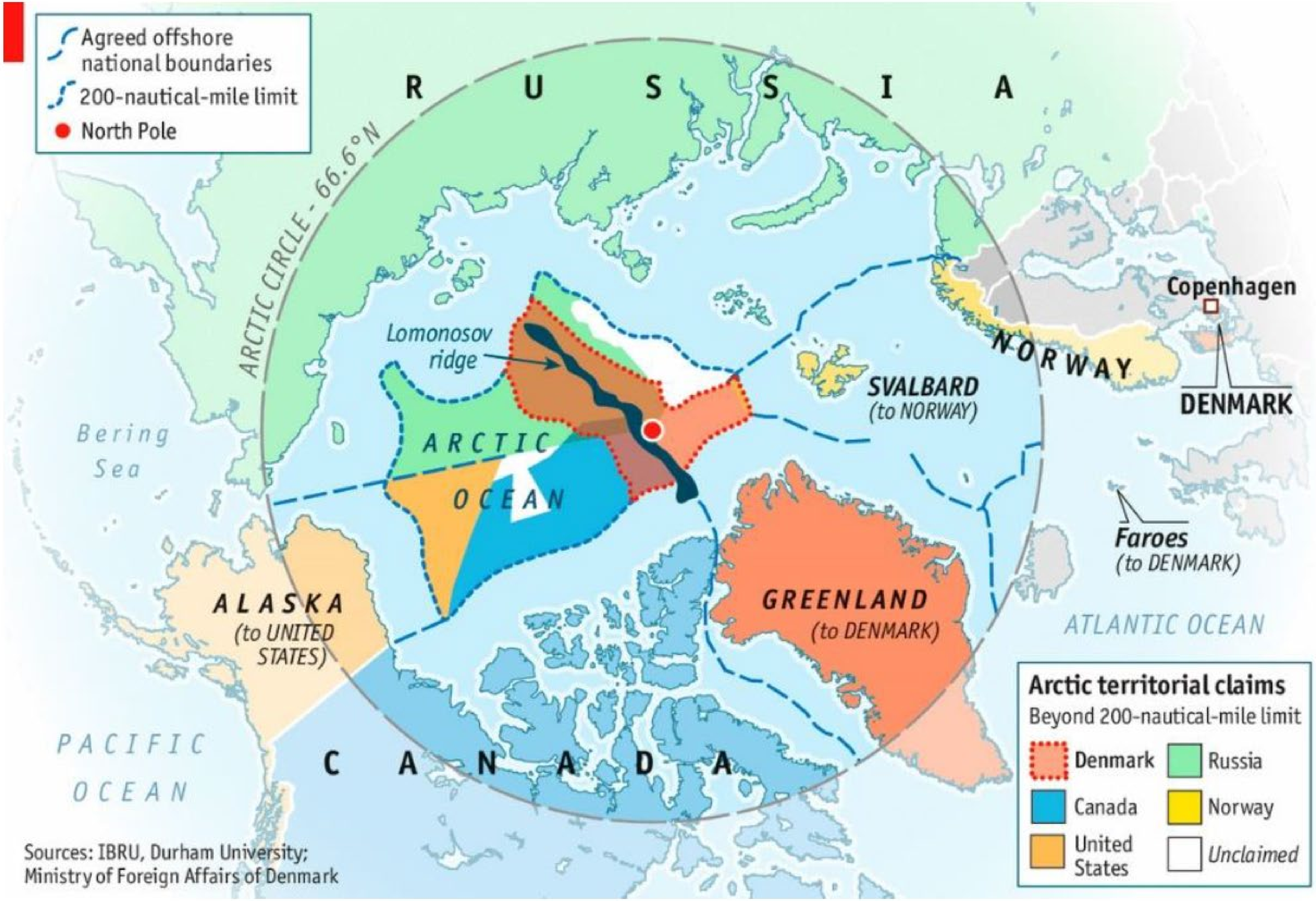
Potential oil and/or gas field

- Medium (30-50%), sea
- High (>50%), sea
- Medium (30-50%), land
- High (>50%), land

Other features

- Arctic circle
- National/regional boundaries
- Arctic region defined as in Arctic Human Development project

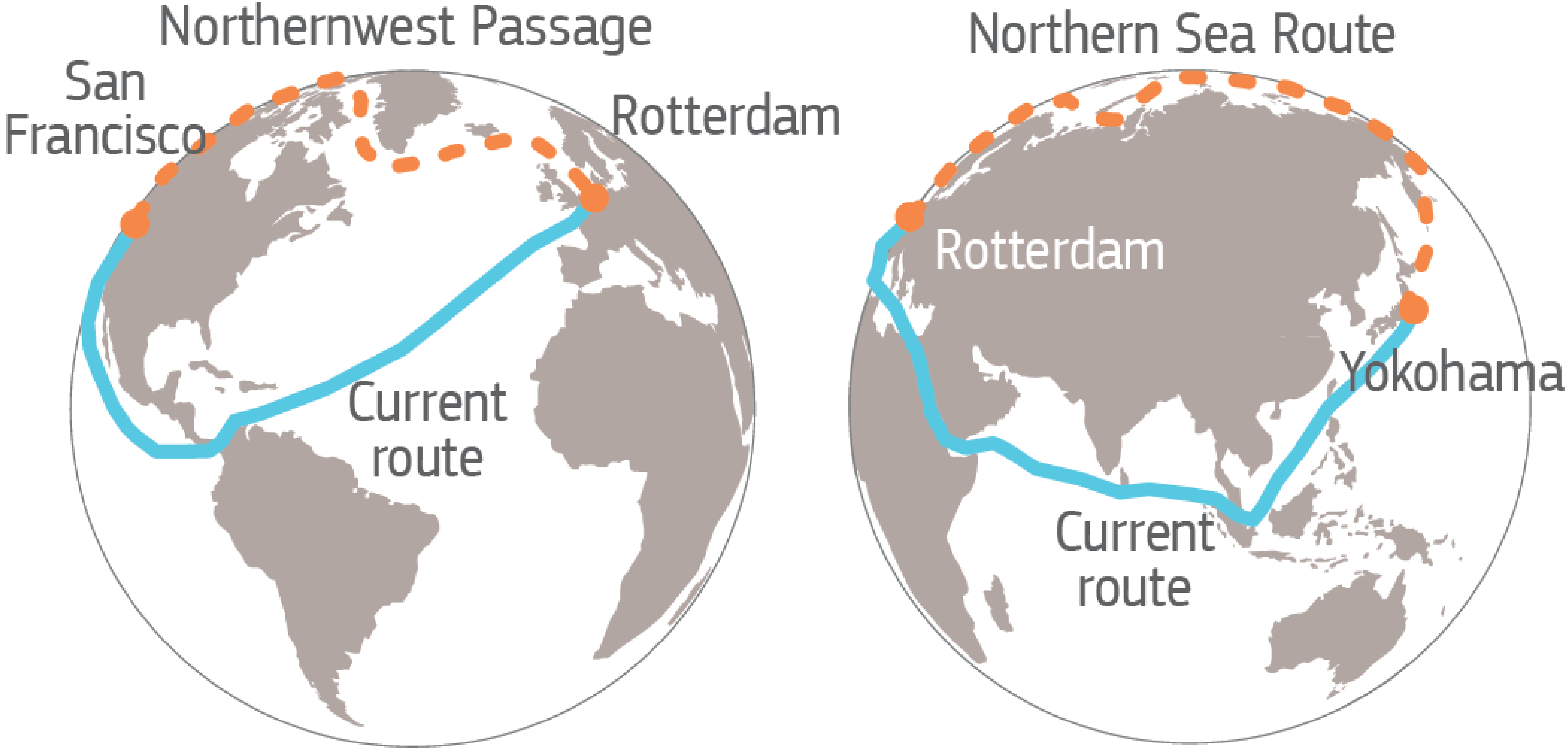
Sources: European Environment Agency, Nordregio



Agreed offshore national boundaries
200-nautical-mile limit
North Pole
RUSSIA
ARCTIC CIRCLE - 66.6°N
Lomonosov ridge
ARCTIC OCEAN
Bering Sea
Copenhagen
NORWAY
DENMARK
SVALBARD (to NORWAY)
Faroes (to DENMARK)
GREENLAND (to DENMARK)
ATLANTIC OCEAN
ALASKA (to UNITED STATES)
PACIFIC OCEAN
CANADA
Arctic territorial claims
Beyond 200-nautical-mile limit
Denmark
Russia
Canada
Norway
United States
Unclaimed
Sources: IBRU, Durham University; Ministry of Foreign Affairs of Denmark


PACIFIC OCEAN
U.S.
ARCTIC CIRCLE
NORTH AMERICA
CANADA
ARCTIC OCEAN
ASIA
RUSSIA
North Pole
DENMARK / GREENLAND
NORWAY
ATLANTIC OCEAN
DENMARK

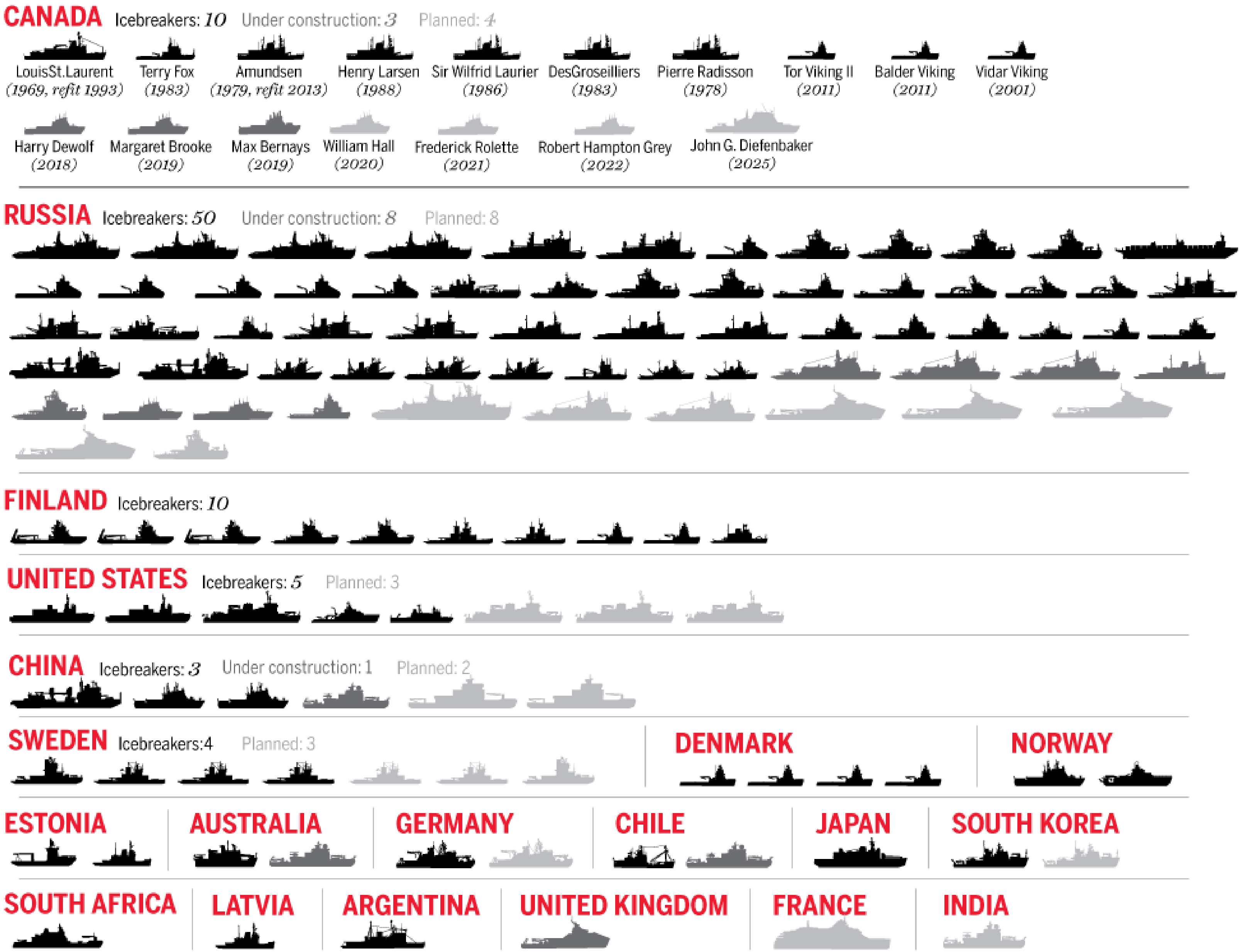
Northwest Passage and Northern Sea Route compared to current routes



Source: GRID-Arendal

THE WORLD'S ARCTIC ICEBREAKERS*

Here is how Canada's icebreaker fleet compares with the rest of the world

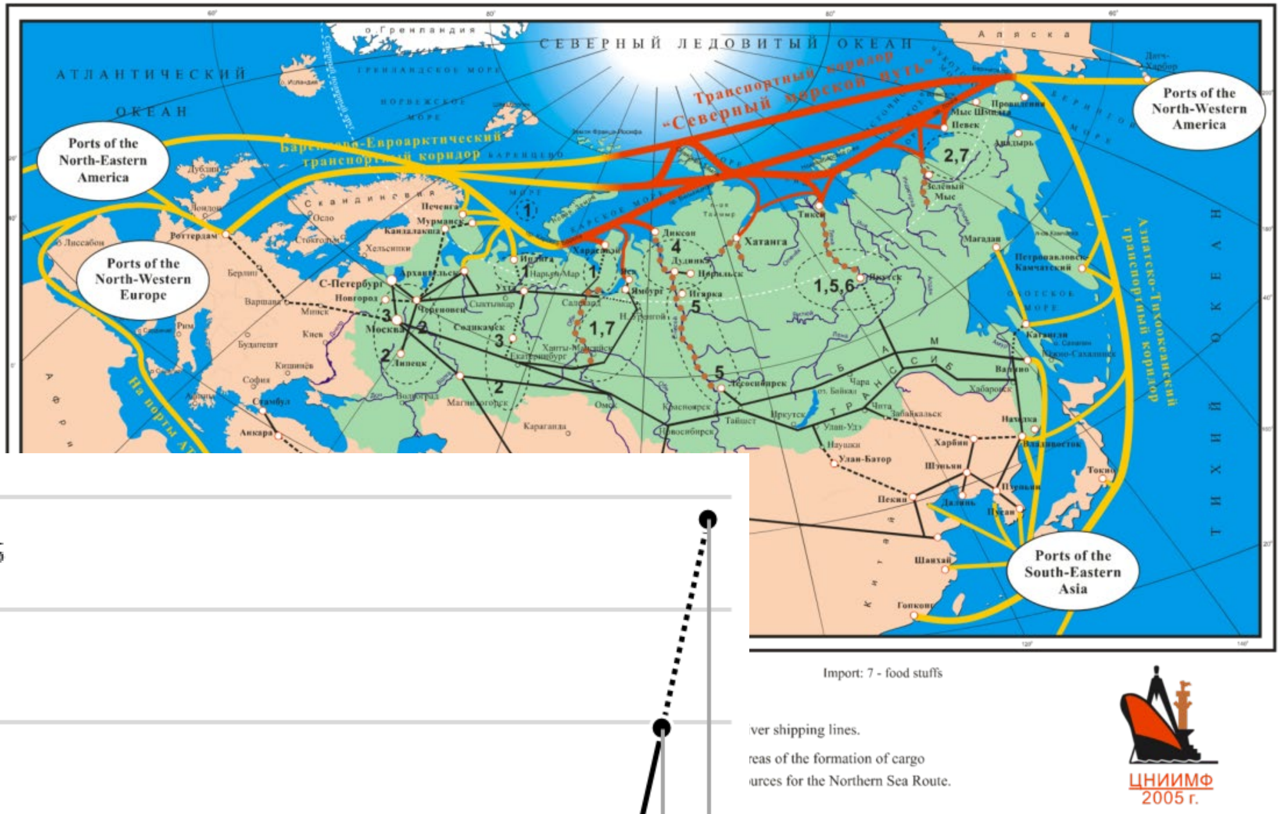


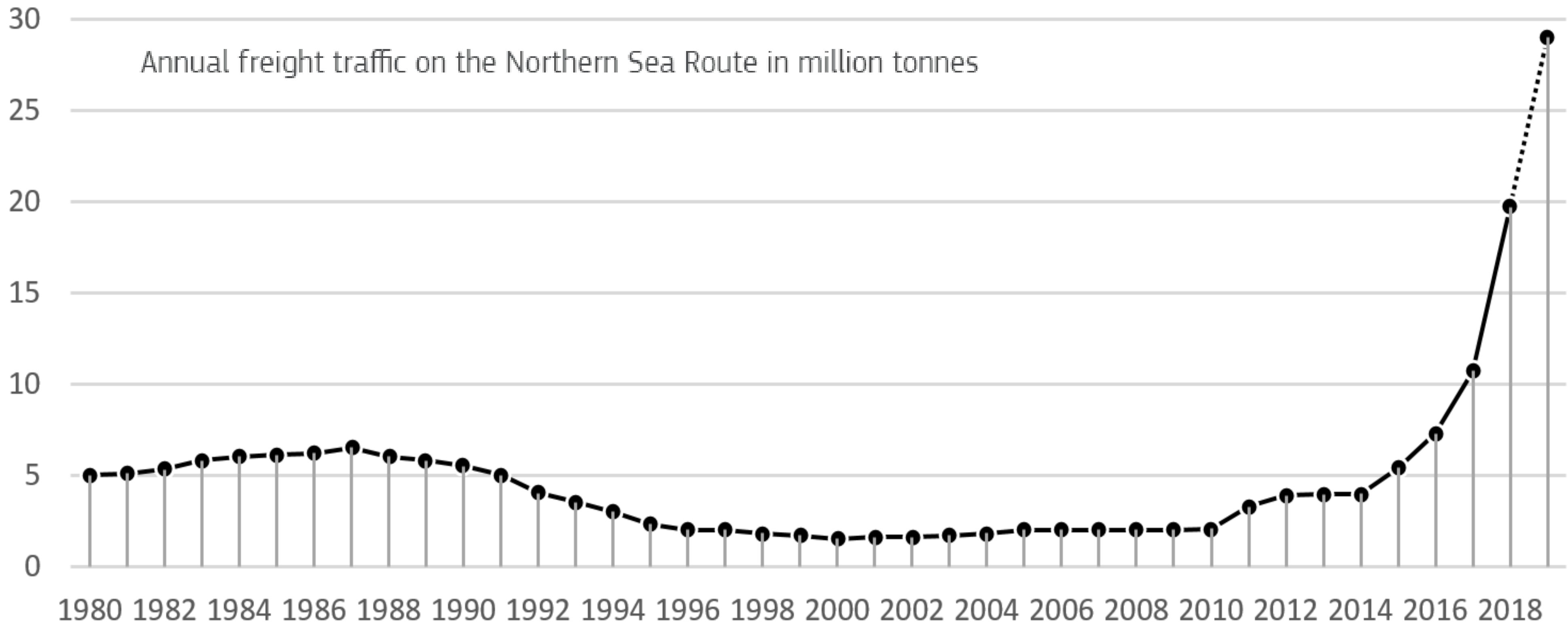
*Vessels included considered capable of independent Arctic operation. Vessel outlines reflect relative sizes.

WWW.DCO.USCG.MIL

NATIONAL POST

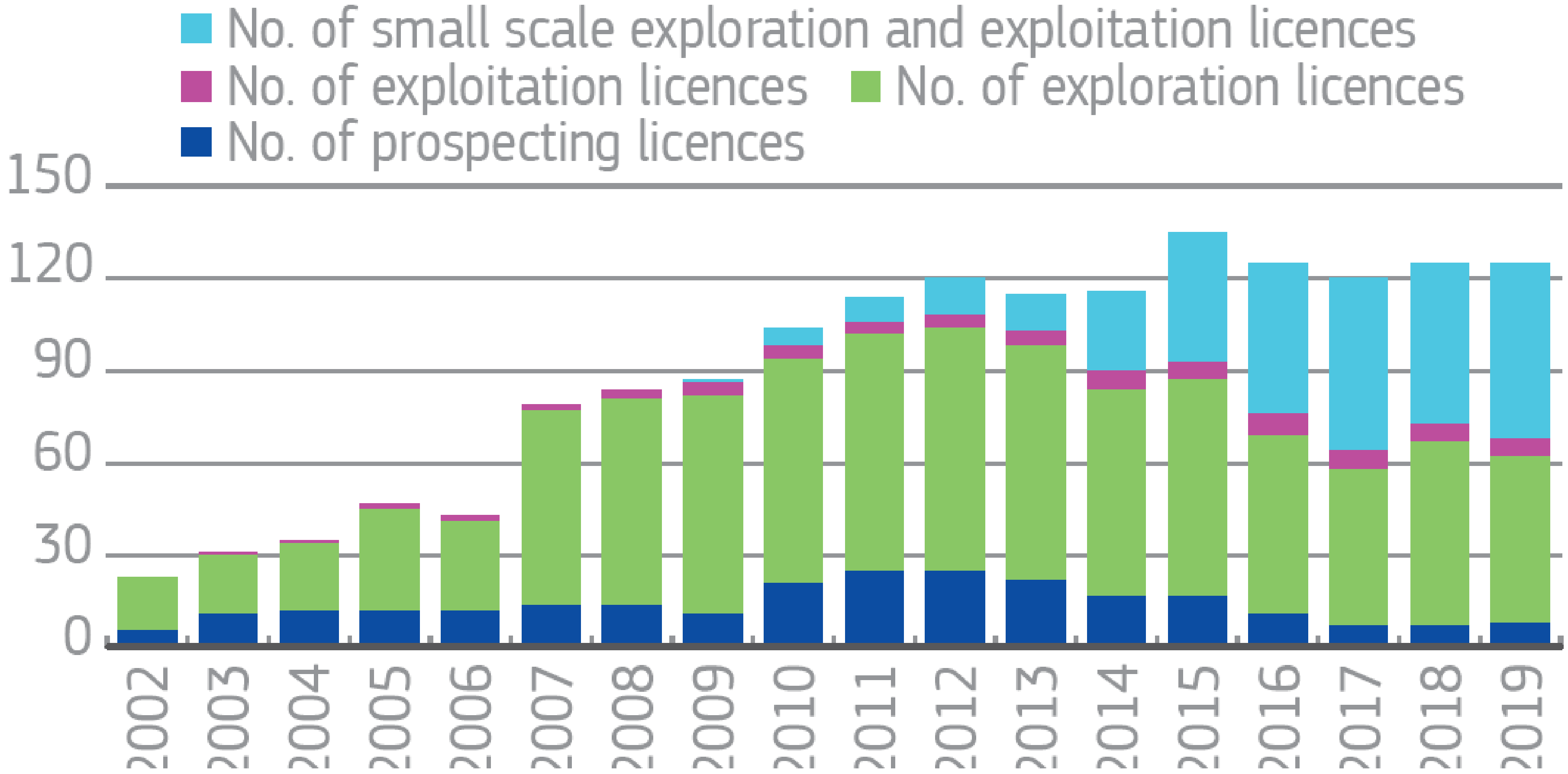
SYSTEM OF INTERNATIONAL TRANSPORT CORRIDORS "East-West-East"



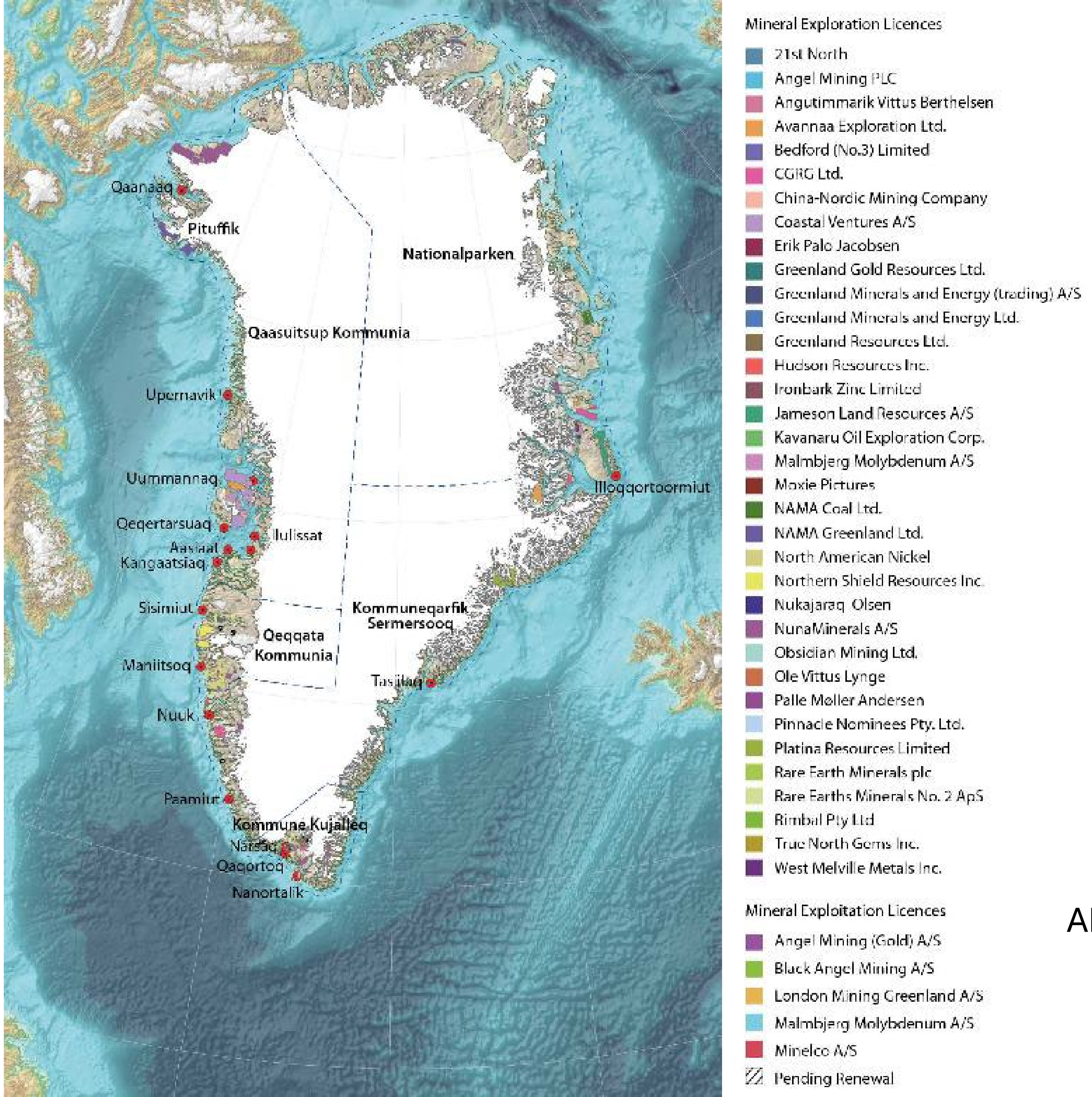


Source: [Atomflot, 2019]

Figure 4: The number of licenses issued for mineral mining in Greenland increased fivefold since 2002

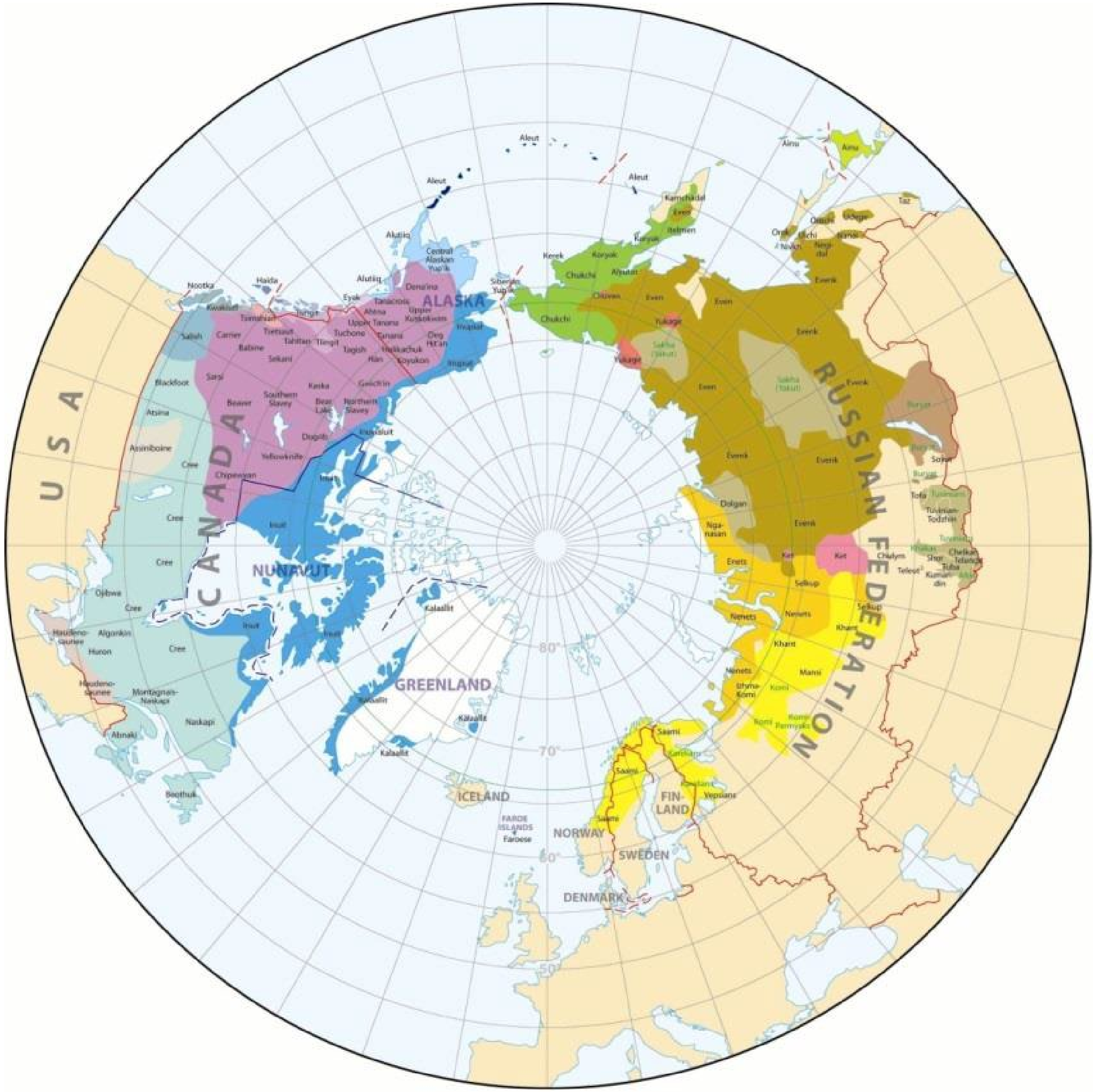


Source: Government of Greenland, 2019


Mineral Exploration Licences
21st North
Angel Mining PLC
Angutimmarik Vittus Berthelsen
Avannaa Exploration Ltd.
Bedford (No.3) Limited
CGRG Ltd.
China-Nordic Mining Company
Coastal Ventures A/S
Erik Palo Jacobsen
Greenland Gold Resources Ltd.
Greenland Minerals and Energy (trading) A/S
Greenland Minerals and Energy Ltd.
Greenland Resources Ltd.
Hudson Resources Inc.
Ironbark Zinc Limited
Jameson Land Resources A/S
Kavanaru Oil Exploration Corp.
Malmbjerg Molybdenum A/S
Moxie Pictures
NAMA Coal Ltd.
NAMA Greenland Ltd.
North American Nickel
Northern Shield Resources Inc.
Nukajaraq Olsen
NunaMinerals A/S
Obsidian Mining Ltd.
Ole Vittus Lynge
Palle Møller Andersen
Pinnacle Nominees Pty. Ltd.
Platina Resources Limited
Rare Earth Minerals plc
Rare Earths Minerals No. 2 ApS
Rimbal Pty Ltd
True North Gems Inc.
West Melville Metals Inc.
Mineral Exploitation Licences
Angel Mining (Gold) A/S
Black Angel Mining A/S
London Mining Greenland A/S
Malmbjerg Molybdenum A/S
Minelco A/S
Pending Renewal
Qaanaaq
Pituffik
Nationalparken
Qaasuitsup Kommunia
Upernavik
Uummannaq
Qeqertarsuaq
Ilulissat
Aasiaat
Kangaatsiaq
Sisimiut
Qeqqata Kommunia
Maniitsoq
Nuuk
Paamiut
Kommune Kujalleq
Narsaq
Qaqortoq
Nanortalik
Kommuneqarfik Sermersooq
Tasiilaq
Illoqqortoormiut

AMAP, 2014

Indigenous peoples of the Arctic countries



Subdivision according to language families

Na'Dene family
- Athabaskan branch
- Eyak branch
- Tlingit branch
- Haida branch

Penutan family

Macro-Algonkian family
- Algonkian branch
- Wakasha branch
- Salish branch

Macro-Sioux family
- Sioux branch
- Iroquois branch

Indo-European family
- Germanic branch

Eskimo-Aleut family
- Inuit group of Eskimo branch
- Yupik group of Eskimo branch
- Aleut group

Uralic-Yukagiran family
- Finno-Ugric branch
- Samodic branch
- Yukagiran branch

Altaic family
- Turkic branch
- Mongolic branch
- Tunguso-Manchurian branch

Chukotko-Kamchatkan family

Ket (isolated language)

Nivkh (isolated language)

Ainu (isolated language)

Notes:

For the USA, only peoples in the State of Alaska are shown. For the Russian Federation, only peoples of the North, Siberia and Far East are shown.

Majority populations of independent states are not shown, not even when they form minorities in adjacent countries (e.g. Finns in Norway).

Areas show colours according to the original languages of the respective indigenous peoples, even if they do not speak these languages today.

Overlapping populations are not shown. The map does not claim to show exact boundaries between the individual groups.

In the Russian Federation, indigenous peoples have a special status only when numbering less than 50,000. Names of larger indigenous peoples are written in green.

compiled by W.K. Dallmann

1991 Arctic Environment Protection Strategy

Canada, Denmark, Finland, Iceland, Norway, Sweden, the Soviet Union, and the United States; participation of indigenous people’s organizations; observers: Germany, Poland, UK, UN

1996 Ottawa declaration

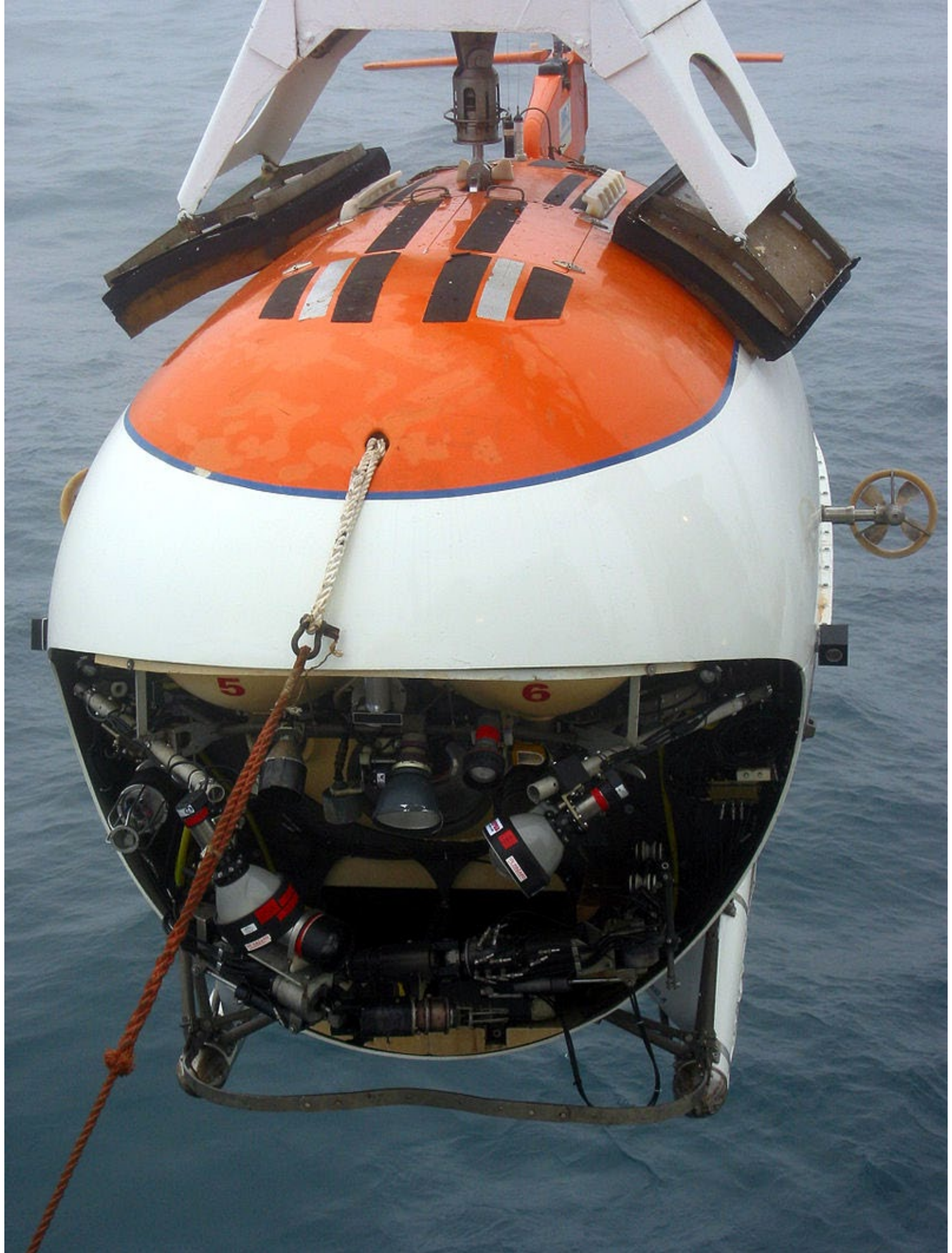
establishes the **Arctic Council** (climate change, sustainable development)

Canada
Denmark; representing Greenland and Faroe Islands
Finland
Iceland
Norway
Russia
Sweden
United States

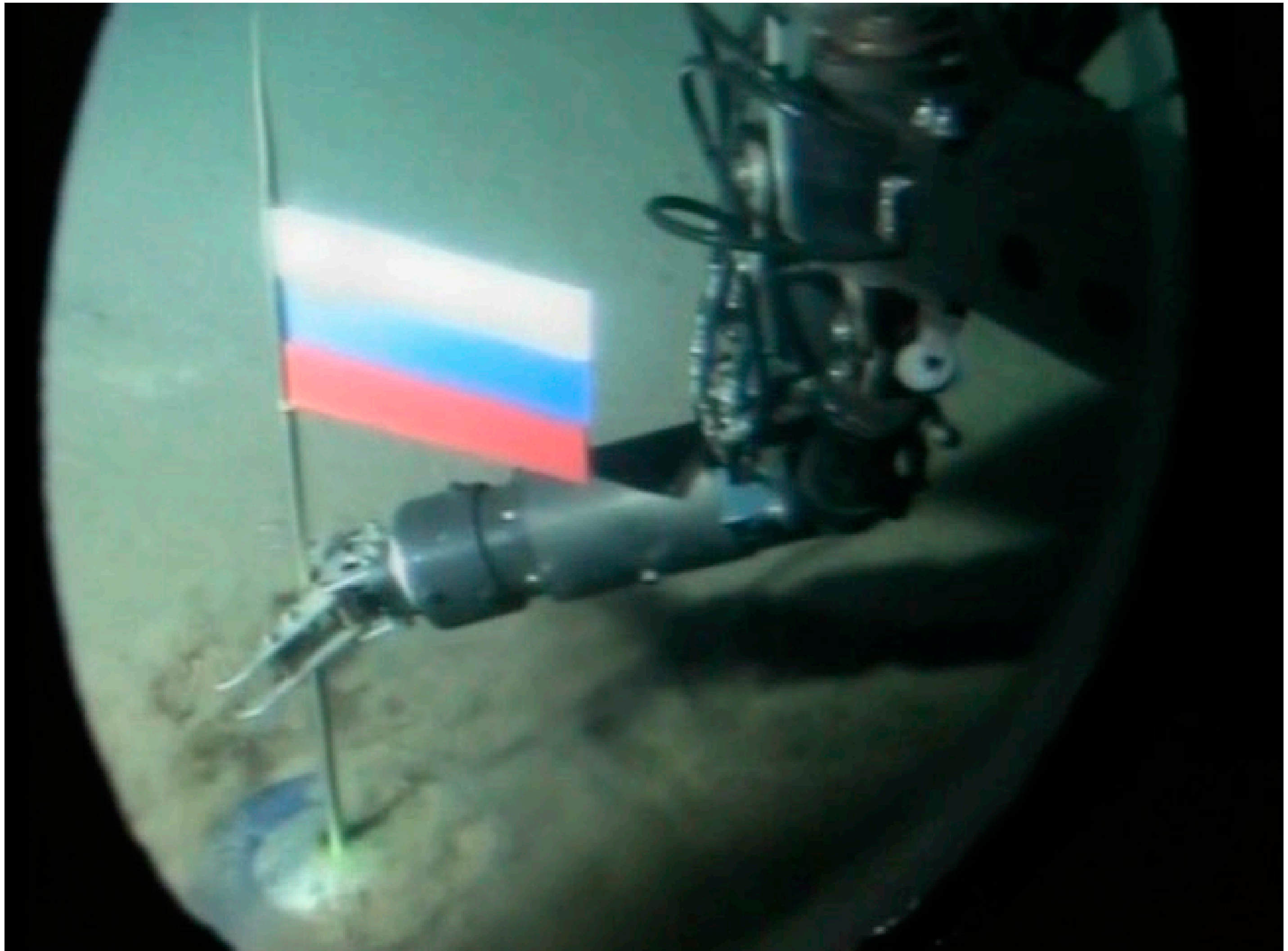
Observer states:

Germany (1998), Netherlands (1998), Poland (1998), United Kingdom (1998), France (2000), Spain (2006), China (2013), India (2013), Italy (2013), Japan (2013), South Korea (2013), Singapore (2013), Switzerland (2017)

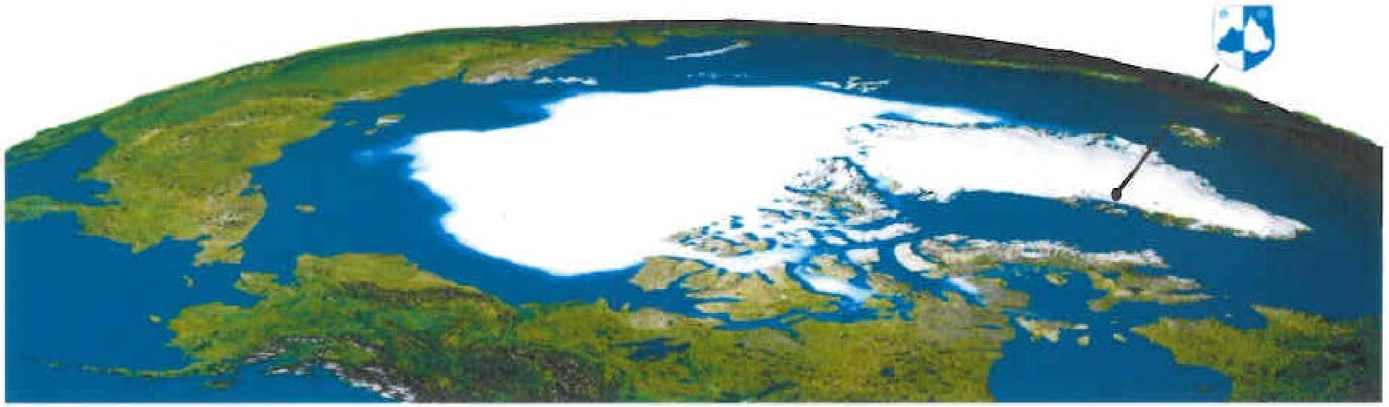
Six Arctic indigenous communities have Permanent Participant status. These groups are represented by the Aleut International Association, the Arctic Athabaskan Council, the Gwich'in Council International, the Inuit Circumpolar Council (ICC), the Russian Association of Indigenous Peoples of the North (RAIPON), and the Saami Council.



August 2007



28 May 2008



THE ILULISSAT DECLARATION

ARCTIC OCEAN CONFERENCE
ILULISSAT, GREENLAND, 27 – 29 MAY 2008

Notably, the law of the sea provides for important rights and obligations concerning the delineation of the outer limits of the continental shelf, the protection of the marine environment, including ice-covered areas, freedom of navigation, marine scientific research, and other uses of the sea. We remain committed to this legal framework and to the orderly settlement of any possible overlapping claims.

This framework provides a solid foundation for responsible management by the five coastal States and other users of this Ocean through national implementation and application of relevant provisions. We therefore see no need to develop a new comprehensive international legal regime to govern the Arctic Ocean. We will keep abreast of the developments in the Arctic Ocean and continue to implement appropriate measures.

Figure 8: The EU's Arctic Strategy as defined in the 2016 Joint Communication on an integrated European Union policy for the Arctic

Climate Change and Safeguarding the Arctic Environment

Research

Arctic research funding (Horizon 2020 and ESIF), EUPolarNet Initiative, Space programmes, pan-
Ar

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20
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Protecting the environment

Multilateral engagement (2015 Paris Agreement, ongoing UN BBNJ process), support to phasing out organic pollutants, measures against invasive species, oil & gas standards

Sustainable Development in and around the Arctic

Support for sustainable innovation

Funding of projects through Horizon 2020's InnovFin

Investment

Through EFSI, EBRD, EIB, TEN-T

Space technology

Copernicus and Galileo support monitoring and navigation, support of GEO Cold Region Initiative

Safe and secure maritime activities

Funding of an emergency preparedness network, enhancing Search and Rescue

Sustainable Development in and around the Arctic

International organisations and fora

Support of UNCLOS, Arctic Council, Barents Euro-Arctic Council, Northern
n policy

l cooperation

Fisheries management

Agreement to prevent unregulated high seas Fisheries in the Central Arctic Ocean

Scientific cooperation

Multi-resolution map of the seabed, European Marine Observation and Data Network

Source: European Political Strategy Centre

13 October 2021

JOINT COMMUNICATION TO THE EUROPEAN PARLIAMENT

- contributing to peaceful and constructive cooperation;
- addressing climate change;
- supporting the region's sustainable development.

January 2018

Full text: China's Arctic Policy

Updated: Jan 26,2018 1:50 PM Xinhua

BEIJING — The State Council Information Office of the People's Republic of China published a white paper titled "China's Arctic Policy" on Jan 26.

Following is the full text of the white paper:

China's Arctic Policy

The State Council Information Office of the People's Republic of China

January 2018

First Edition 2018

Contents

Foreword

I. The Arctic Situation and Recent Changes

II. China and the Arctic

III. China's Policy Goals and Basic Principles on the Arctic

IV. China's Policies and Positions on Participating in Arctic Affairs

1. Deepening the exploration and understanding of the Arctic

2. Protecting the eco-environment of the Arctic and addressing climate change

3. Utilizing Arctic Resources in a Lawful and Rational Manner

4. Participating Actively in Arctic governance and international cooperation

5. Promoting peace and stability in the Arctic Conclusion

Conclusion

ATMOSPHERIC AND OCEANIC SCIENCE LETTERS
2020, VOL. 13, NO. 1, 1–7
https://doi.org/10.1080/16742834.2020.1675137

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Overview of the 9th Chinese National Arctic Research Expedition

WEI Zexun[a], CHEN Hongxia[a], LEI Ruibo[b], YU Xiaoguo[c], ZHANG Tao[c], LIN Lina[a], TIAN Zhongxiang[d], ZHUANG Yanpei[c], LI Tao[e] and YUAN Zhuoli[b]

[a]First Institute of Oceanography, Ministry of Natural Resources, Qingdao, China; [b]Polar Research Institute of China, Shanghai, China; [c]Second Institute of Oceanography, Ministry of Natural Resources, Hangzhou, China; [d]National Marine Environmental Forecasting Center, Beijing, China; [e]College of Oceanic and Atmospheric Sciences, Ocean University of China, Qingdao, China

ABSTRACT

The 9th Chinese National Arctic Research Expedition was carried out from 20 July to 26 September 2018. The expedition was successful in undertaking multidisciplinary comprehensive surveys in the fields of physical oceanography, marine meteorology, sea ice, marine chemistry, marine biology, marine ecology, geology, and geophysics in the Bering Sea, Chukchi Sea, Chukchi Plateau, Mendeleev Ridge, and Canada Basin. This paper gives an overview of the main achievements of this expedition and highlights the scientific achievements.

ARTICLE HISTORY
Received 19 April 2019
Revised 12 June 2019
Accepted 8 July 2019

KEYWORDS
Chinese National Arctic Research Expedition; Chukchi Sea; Canada Basin; Bering Sea; Arctic Ocean

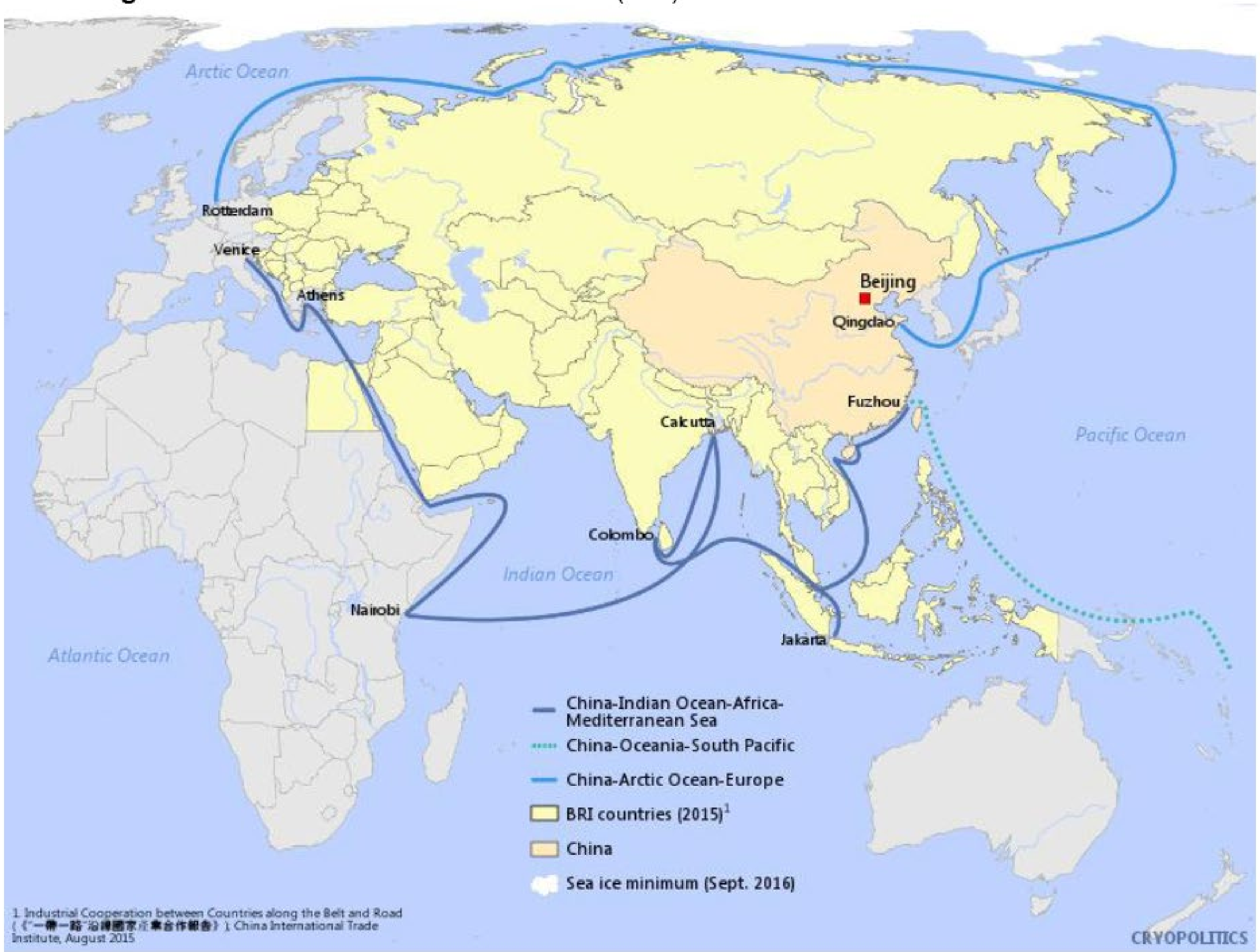
中国第9次北极考察概述

摘要

中国第9次北极考察航次于2018年7月20日至9月26日执行，在白令海、楚科奇海、楚科奇海台、门捷列夫海岭和加拿大海盆开展了物理海洋、海洋气象、海冰、海洋化学、海洋生物、海洋生态、地质和地球物理等多学科综合考察。本文对中国第9次北极考察取得的主要成果进行了概述。

关键词
中国第9次北极考察；楚科奇海；加拿大海盆；白令海；北冰洋

Figure 4: China's Belt and Road Initiative (BRI) moves into the Arctic



Source: China International Trade Institute, 2015

Connolly, G.E., NATO and security in the Arctic, NATO, 2017.

PRA
PROGRAMMA DI RICERCHE IN ARTICO

2010: MAECI fa nascere il «Tavolo Artico»

2013: L'Italia diviene Paese Osservatore del Consiglio Artico

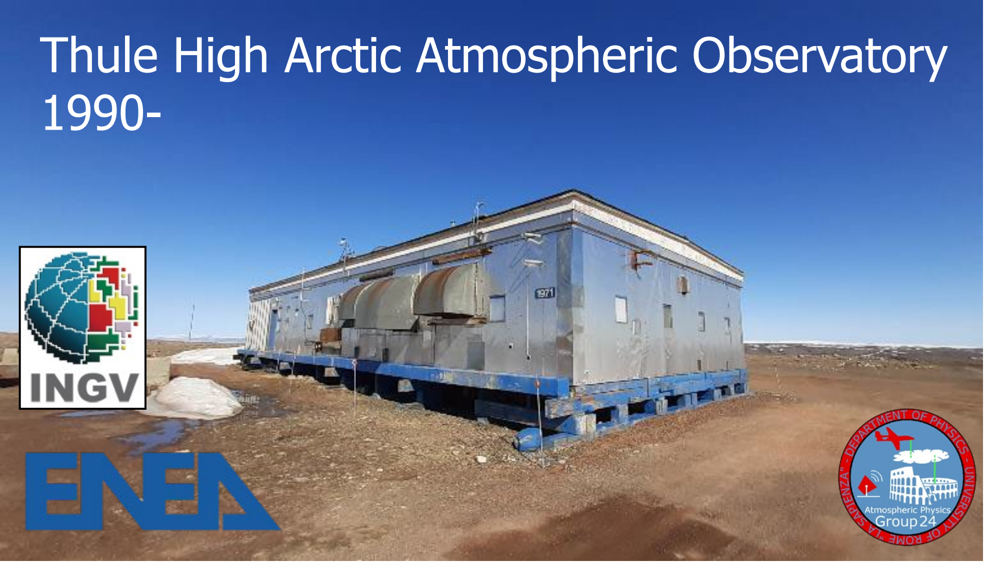
2018: Nasce il Programma di Ricerca in Artico (n. 205 del 27 dicembre 2017, punti da 1170 a 1177), con il Comitato Scientifico per l'Artico (9 membri: MAECI, MUR, CNR, ENEA, INGV, OGS, rappr. IASC, rappr. Ny Aalesund + 1 esperto internazionale)

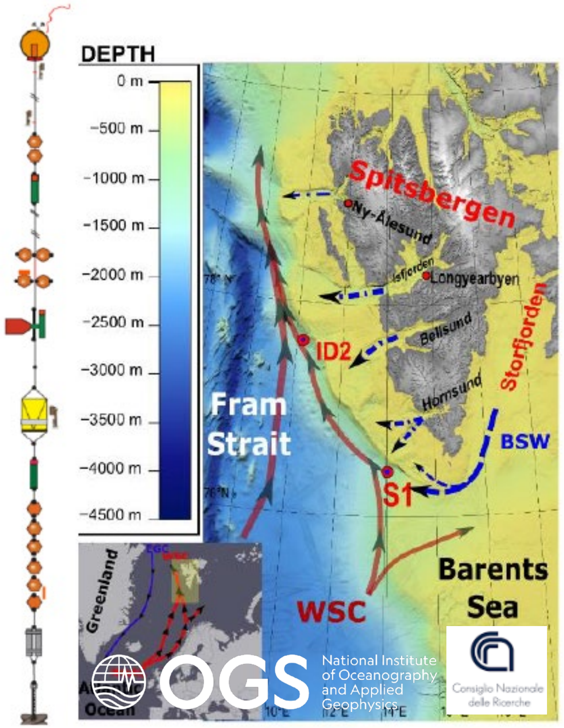
2021: Il finanziamento del PRA va sul FOE del CNR

<table>
<tr><th>Anno</th><th>Finanziamento (k€)</th><th>Per Bandi di ricerca (k€)</th></tr>
<tr><td>2018</td><td>1000</td><td>710</td></tr>
<tr><td>2019</td><td>1000</td><td rowspan="2">800 ricerca
910 infrastrutture</td></tr>
<tr><td>2020</td><td>1000</td></tr>
<tr><td>2021</td><td>1000</td><td rowspan="2">1404</td></tr>
<tr><td>2022</td><td>1000</td></tr>
<tr><td>2023</td><td>1100</td><td>864 infrastrutture</td></tr>
</table>

Temi di ricerca:

A. La comprensione quantitativa dei complessi processi responsabili della **“Arctic Amplification**”, ovvero i motivi per cui l’Artico si sta scaldando a un ritmo molto più veloce del resto del pianeta. Saranno da considerare tutti gli aspetti del sistema climatico artico, privilegiando un approccio integrato che affronti i cambiamenti della criosfera, dell’atmosfera neutra e ionizzata, dell’oceano, della biosfera e delle loro interazioni anche con gli aspetti geologici e geomorfologici e del georischio.
B. La caratterizzazione dei **cambiamenti della composizione, della dinamica, della stabilità e della struttura verticale dell’atmosfera e della colonna d’acqua** dei mari artici, inclusi il rilievo batimetrico e i cambiamenti nella circolazione oceanica, dei fiordi e le interazioni fra circolazione costiera e oceanica, i cambiamenti nel ciclo idrologico artico, e considerando anche l’analisi dei possibili effetti dei cambiamenti che avvengono in Artico sulle condizioni meteoclimatiche alle medie latitudini.
C. I **cambiamenti degli ecosistemi artici**, sia marini sia terrestri, e le relative conseguenze sulla dinamica e distribuzione delle popolazioni animali e vegetali, sulle interazioni suolo-vegetazione-atmosfera, sui cambiamenti della fenologia e sulla biodiversità nel contesto dell’attuale rapida deglaciazione continentale e marina. L’effetto degli inquinanti sull’ecosistema e più in generale sull’ambiente artico, e lo sviluppo di approcci che permettano di ridurne le conseguenze negative.
D. Le **ricostruzioni paleoclimatiche** e l’analisi e la modellazione dei processi che influenzano e hanno influenzato durante transizioni climatiche la criosfera nell’Artico, tramite l’integrazione di dati geochimici, geologici e geofisici dell’ambiente marino e delle carote di ghiaccio.
E. Gli **effetti dei cambiamenti climatici e ambientali sul benessere, sulla salute e sulla sicurezza delle popolazioni che vivono in Artico**, nonché sullo **sviluppo sostenibile della regione e la preservazione delle culture tradizionali indigene**, sia per la mutata disponibilità di risorse, sia per l’aumentata variabilità ambientale, sia per l’effetto degli inquinanti.


Thule High Arctic Atmospheric Observatory
1990-
INGV
ENEA
Atmospheric Physics Group24


DEPTH
0 m
-500 m
-1000 m
-1500 m
-2000 m
-2500 m
-3000 m
-3500 m
-4000 m
-4500 m
Spitsbergen
Ny-Ålesund
Longyearbyen
Bellsund
Hornsund
Storfjorden
ID2
S1
BSW
Fram Strait
Barents Sea
WSC
Greenland
OGS
National Institute of Oceanography and Applied Geophysics
Consiglio Nazionale delle Ricerche

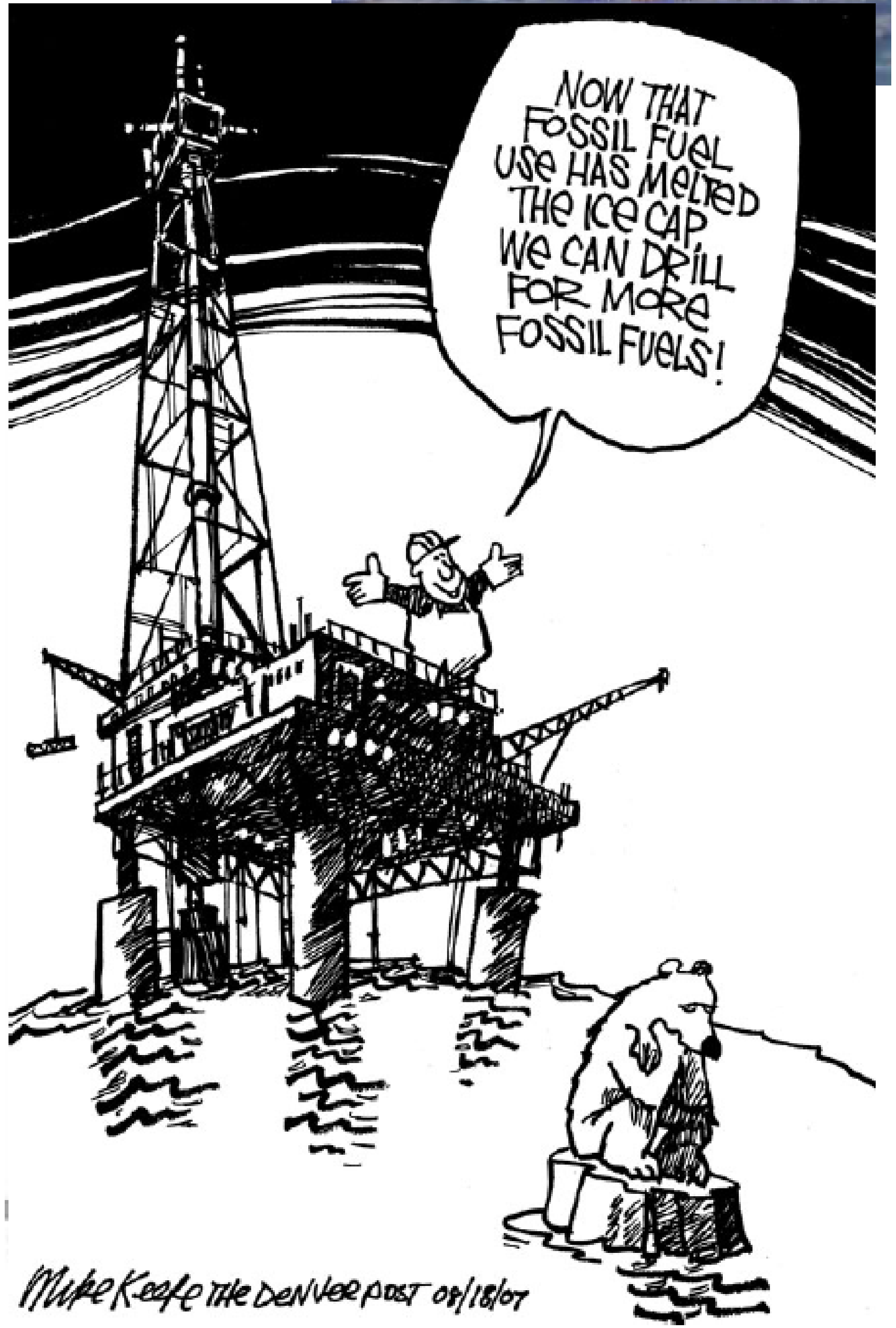

Laura Bassi
2021
OGS
National Institute of Oceanography and Applied Geophysics
LAURA BASSI


Dirigibile Italia
1997-
Consiglio Nazionale delle Ricerche
Foto Mauro Mazzola (CNR-ISP)


INGV


Gaia Blu
???
Consiglio Nazionale delle Ricerche


High North
2017-
ISTITUTO IDROGRAFICO DELLA MARINA
ITALIA
A 5345


NOW THAT FOSSIL FUEL USE HAS MELTED THE ICE CAP WE CAN DRILL FOR MORE FOSSIL FUELS!
Mike Keefe THE DENVER POST 08/18/07

I grandi temi di ricerca

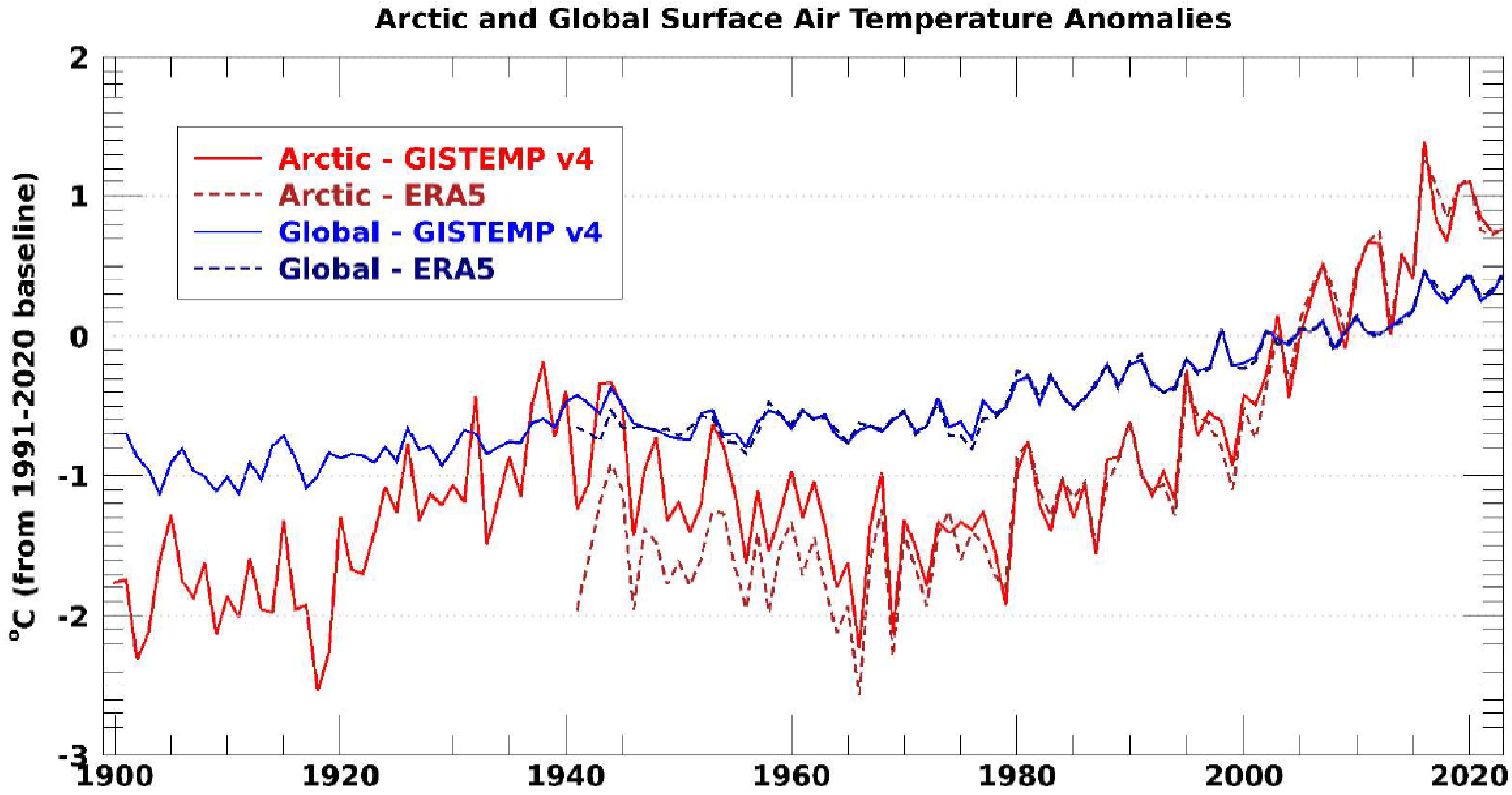
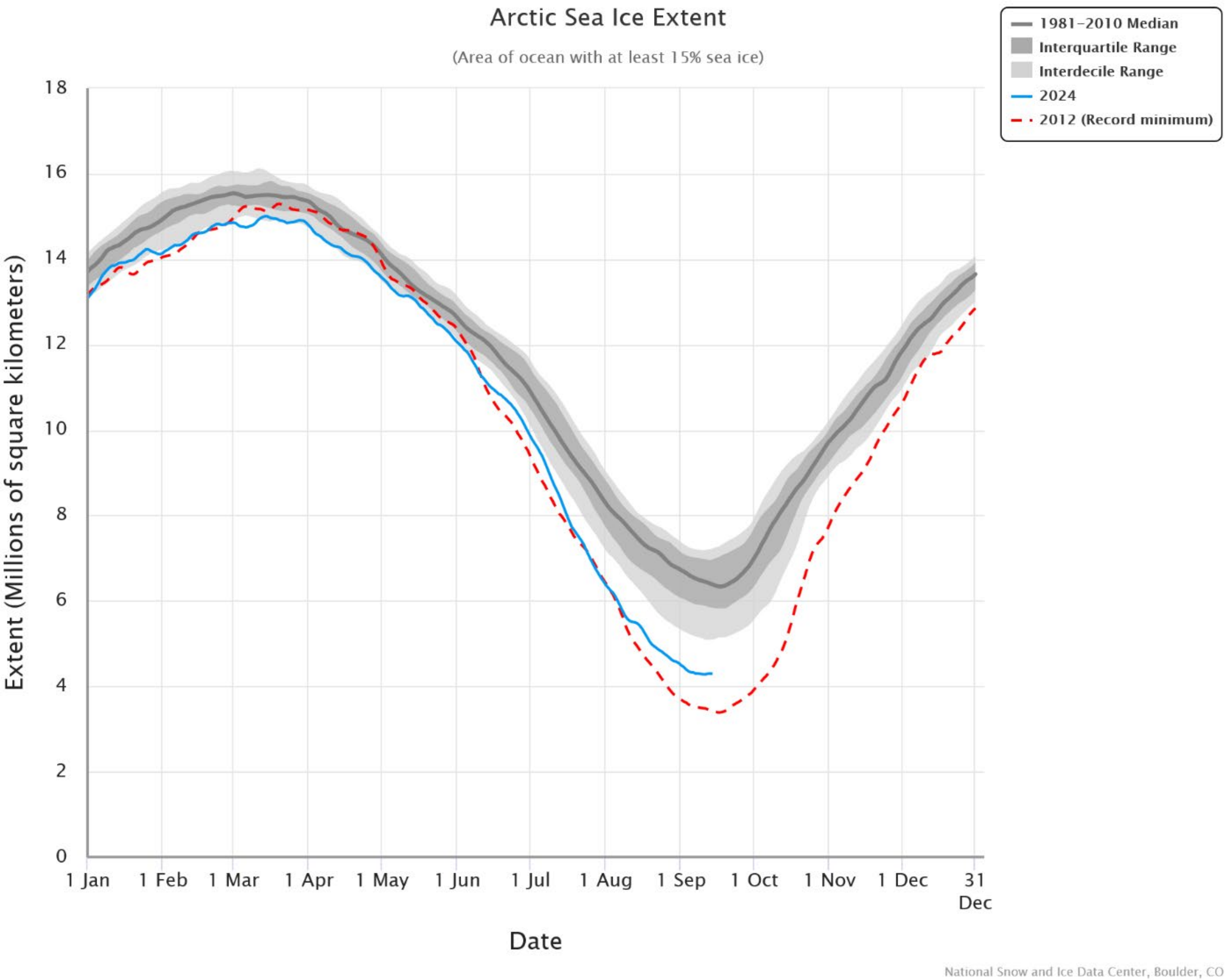
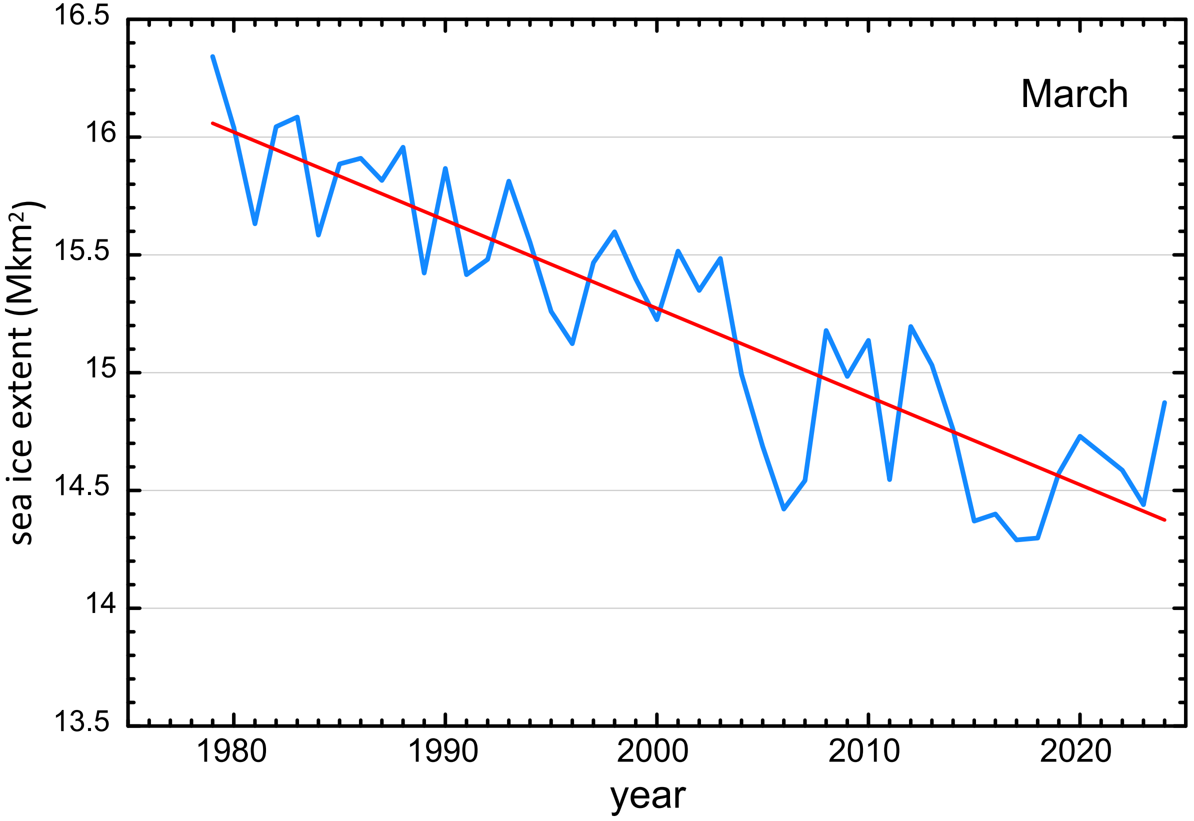


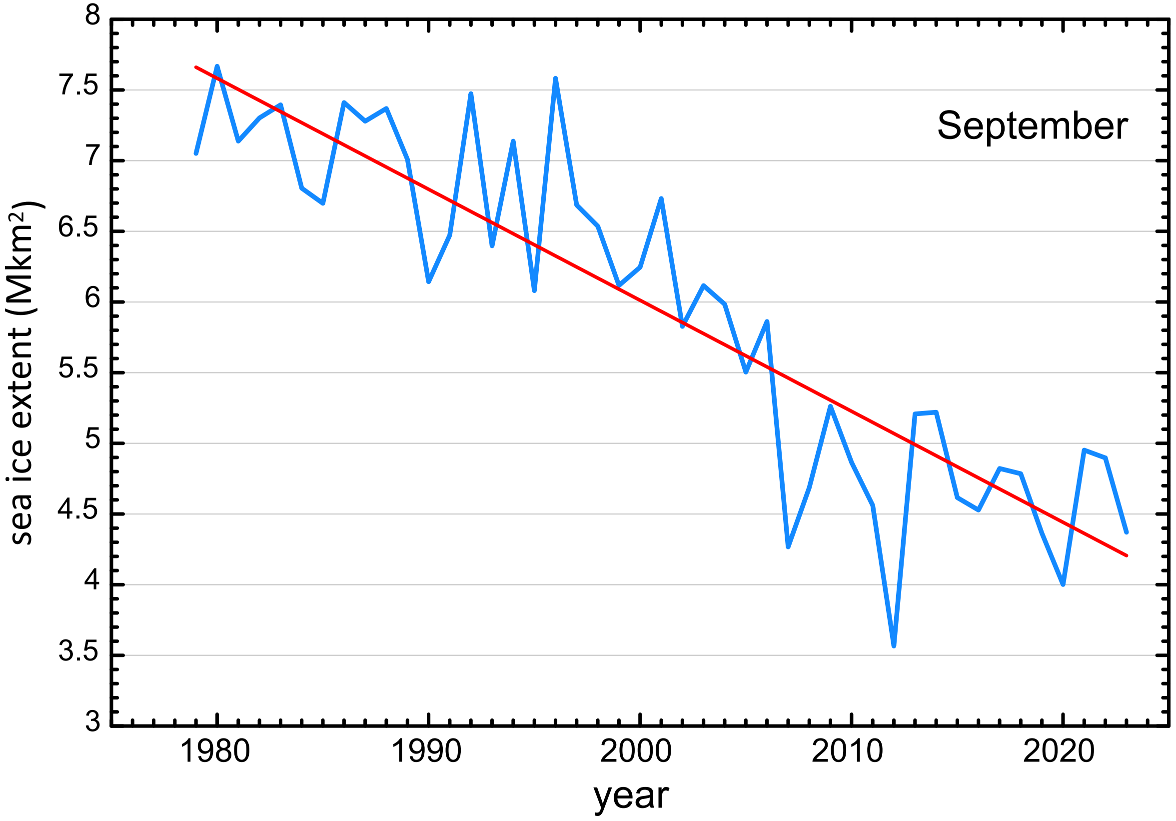
Fig. 1. Arctic (60-90° N) and Global (90° S-90° N) surface air temperature anomalies (in °C) averaged across land and ocean areas. Each year's air temperature reflects the water year average (e.g., October 2022-September 2023 represents the 2023 SAT value). Source: NASA GISTEMP v4 data are obtained from the NASA Goddard Institute for Space Studies and ERA5 data are retrieved from the Copernicus Climate Change Service.

Ballinger et al., 2023

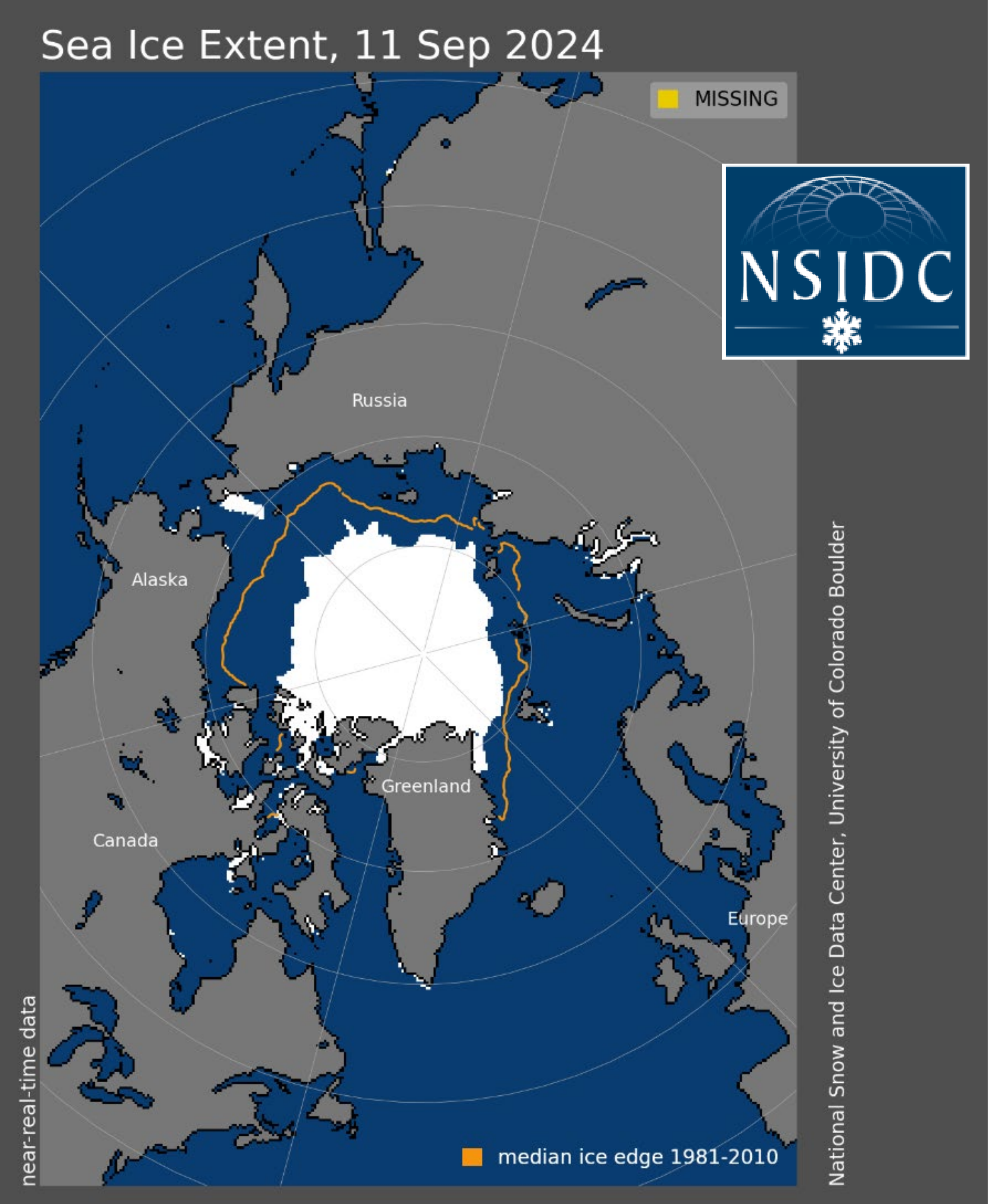

Arctic Sea Ice Extent
(Area of ocean with at least 15% sea ice)
1981–2010 Median
Interquartile Range
Interdecile Range
2024
2012 (Record minimum)
Extent (Millions of square kilometers)
18
16
14
12
10
8
6
4
2
0
1 Jan
1 Feb
1 Mar
1 Apr
1 May
1 Jun
1 Jul
1 Aug
1 Sep
1 Oct
1 Nov
1 Dec
31 Dec
Date
National Snow and Ice Data Center, Boulder, CO

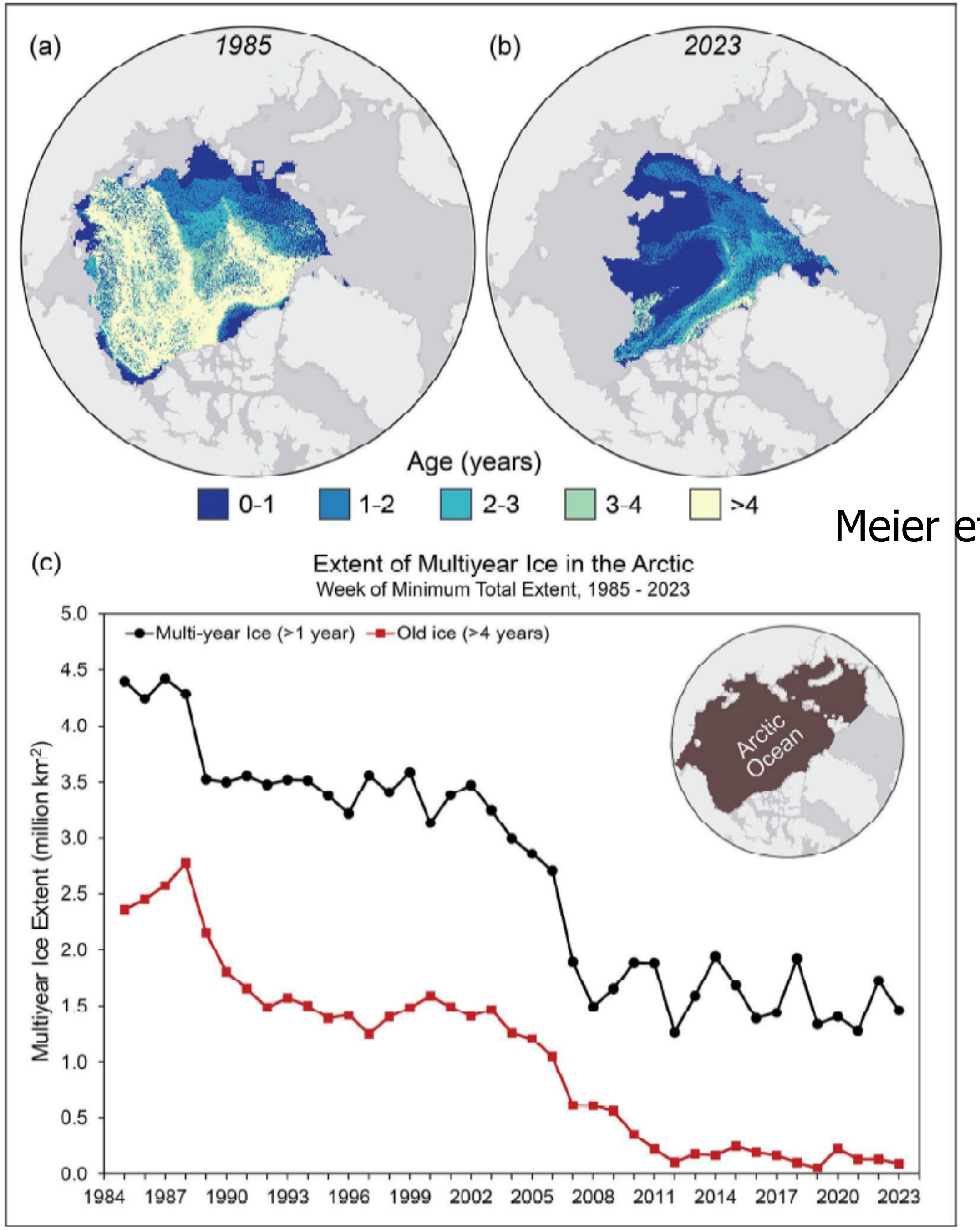


March
sea ice extent (Mkm²)
year
16.5
16
15.5
15
14.5
14
13.5
1980
1990
2000
2010
2020



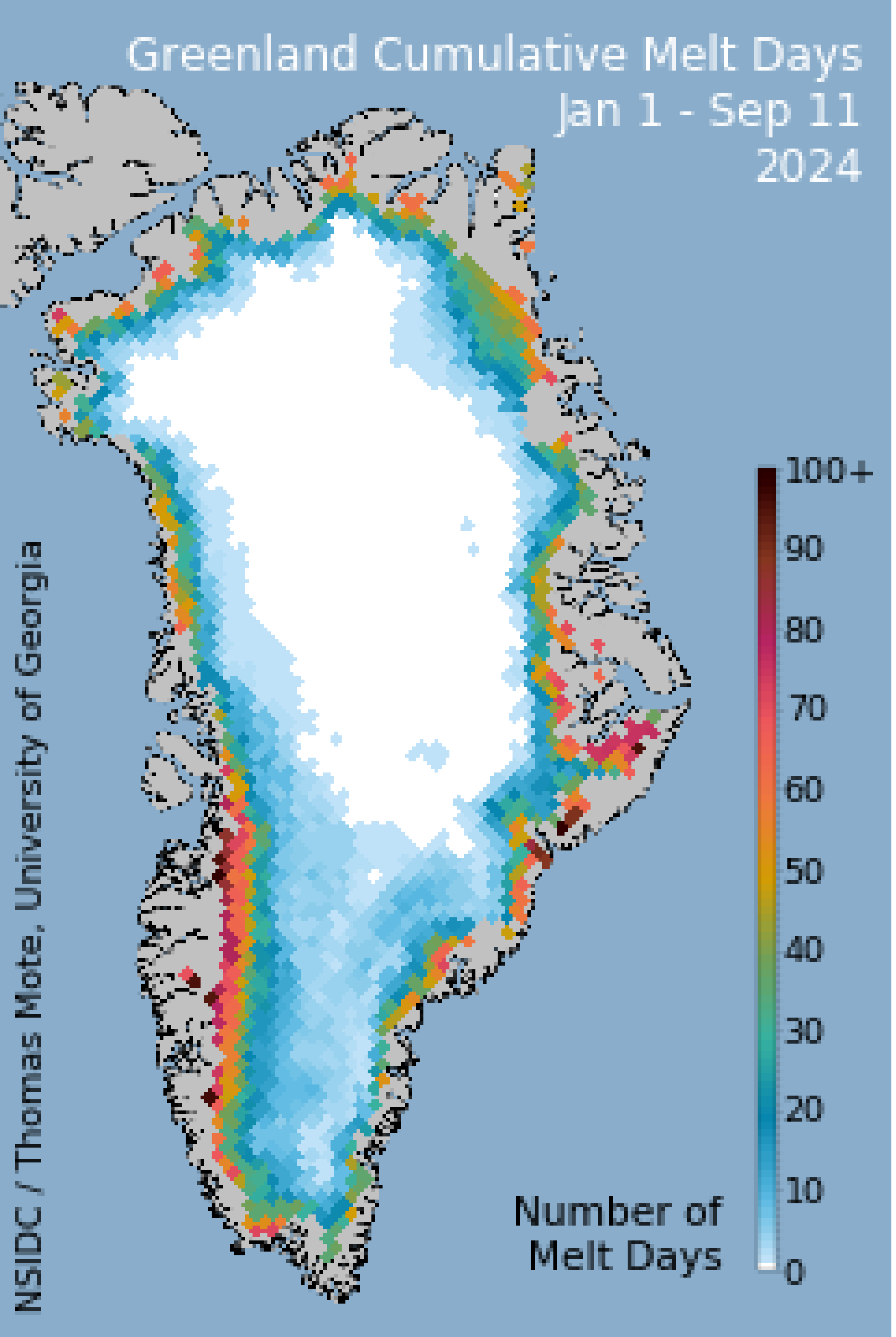
September
sea ice extent (Mkm²)
year
8
7.5
7
6.5
6
5.5
5
4.5
4
3.5
3
1980
1990
2000
2010
2020

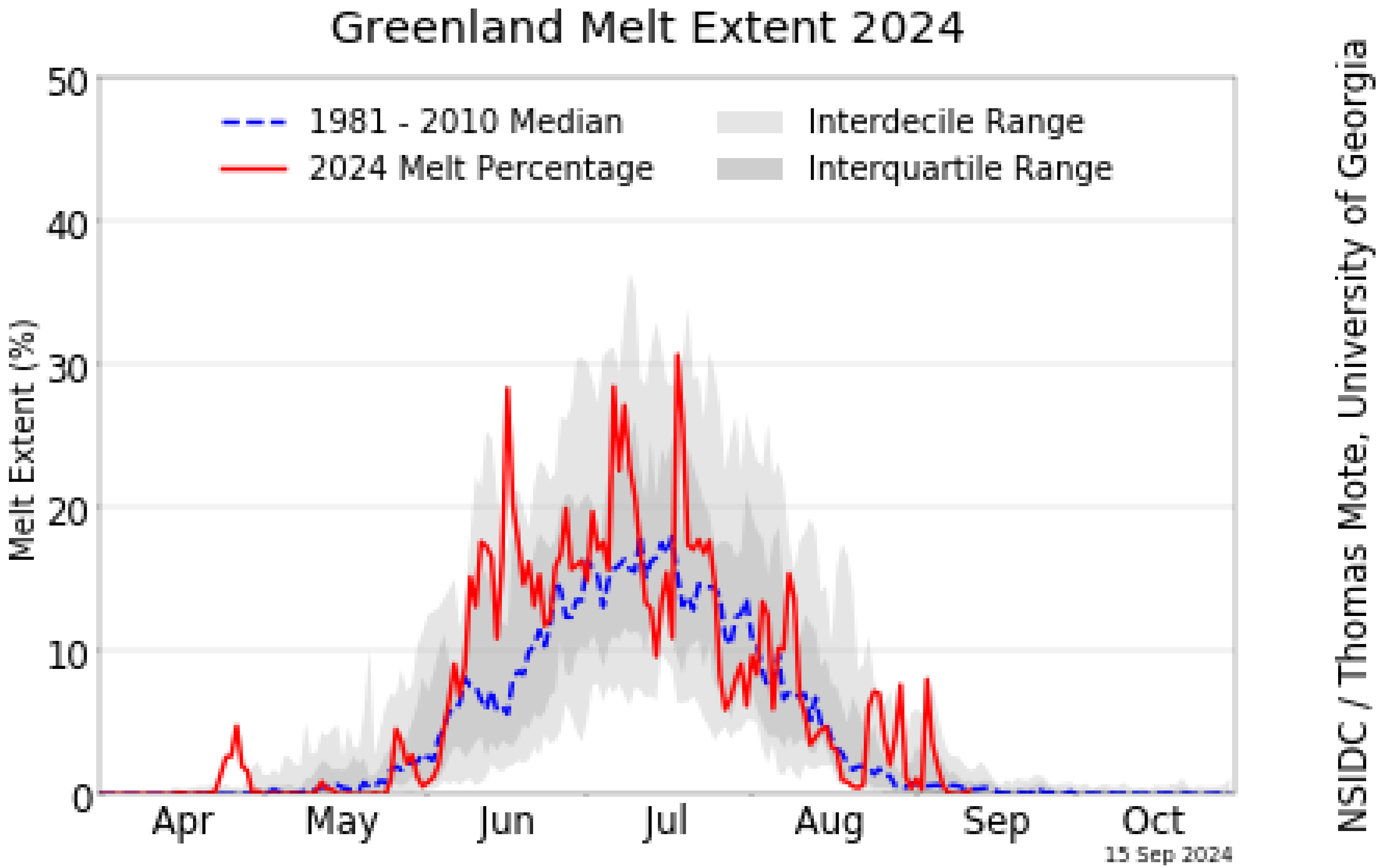




Meier et al., 2023

Fig. 3. Sea ice age coverage map for the week before minimum total extent (when age values are incremented to one year older) in (a) 1985, and (b) 2023; (c) extent of multiyear ice (black) and ice >4 years old (red) within the Arctic Ocean region (inset) for the week of the minimum total extent.


Greenland Cumulative Melt Days
Jan 1 - Sep 11
2024
100+
90
80
70
60
50
40
30
20
10
0
Number of
Melt Days
NSIDC / Thomas Mote, University of Georgia


Greenland Melt Extent 2024
1981 - 2010 Median
2024 Melt Percentage
Interdecile Range
Interquartile Range
Melt Extent (%)
50
40
30
20
10
0
Apr
May
Jun
Jul
Aug
Sep
Oct
15 Sep 2024
NSIDC / Thomas Mote, University of Georgia

NSIDC

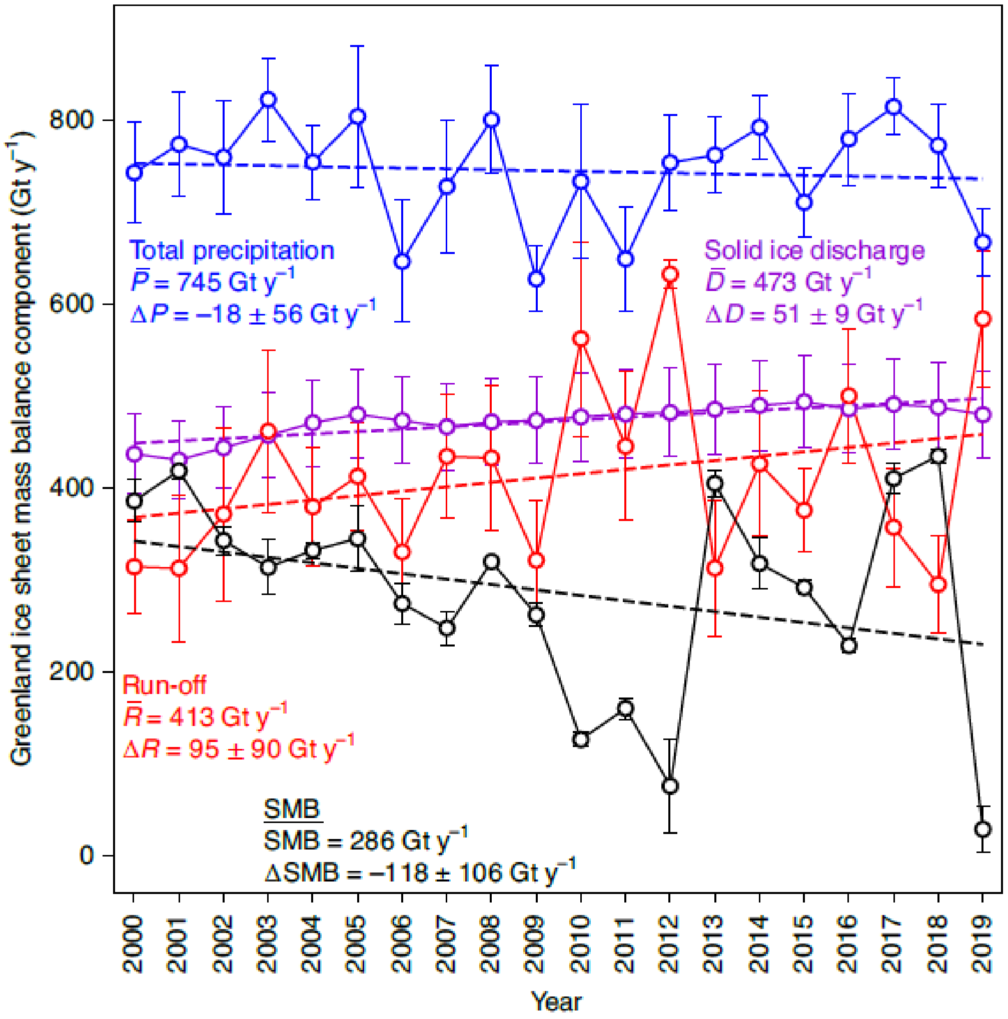


Fig. 2 | Greenland contiguous ice mass balance components. Ice flow discharge[4] and surface mass fluxes from the average of RACMO2.3p2-ERA5-3h-1 km and MARv3.12.1-15 km data (circles) with uncertainty whiskers equal to the absolute difference between the RACMO and MAR values. Mass balance MB = SMB − *D*. In this presentation, data are integrated for calendar years. Standard deviations (σ) presented after temporal change (Δ), for example, $\Delta D \pm \sigma$, are measured after linear temporal detrending.

Box et al., 2022

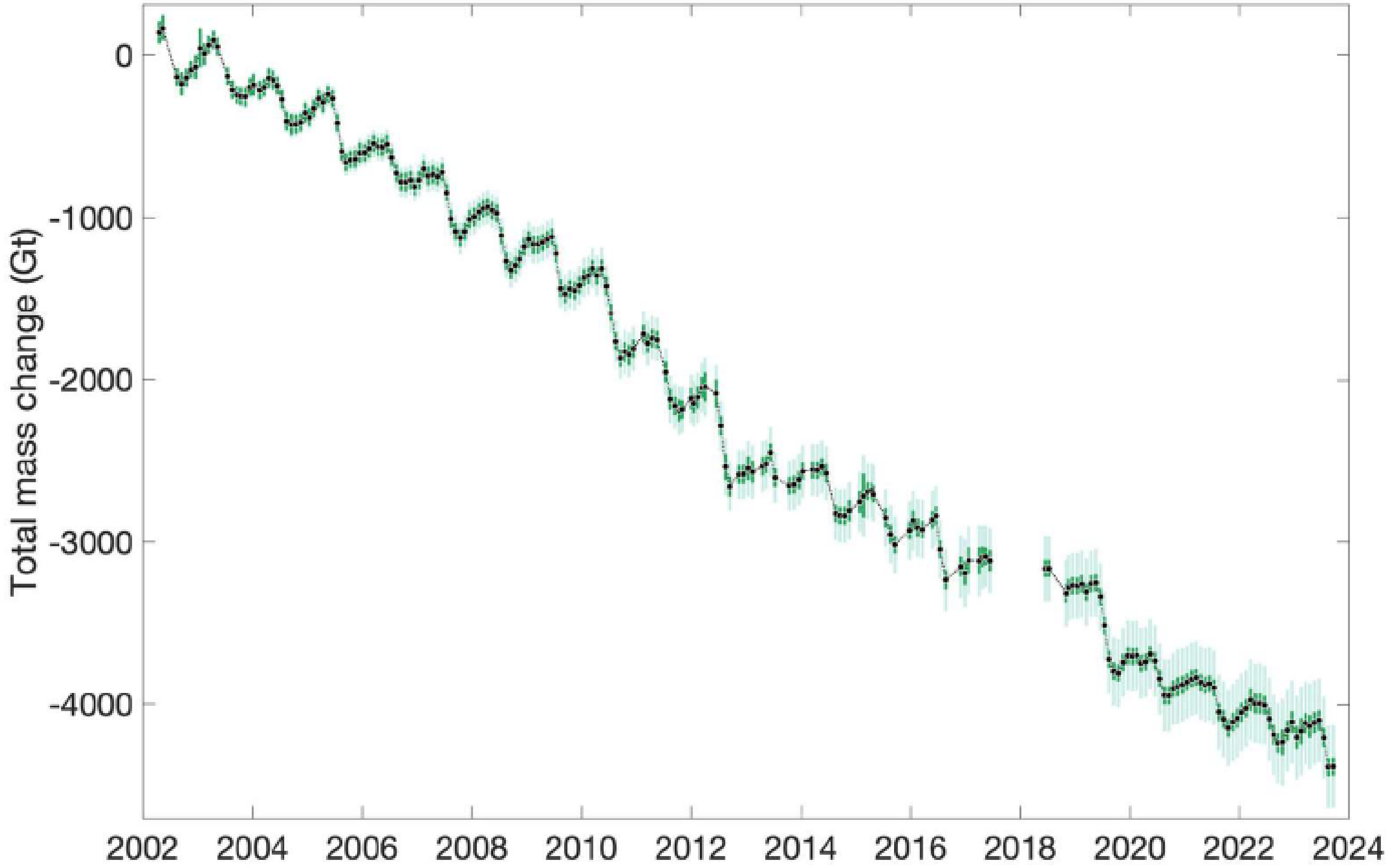
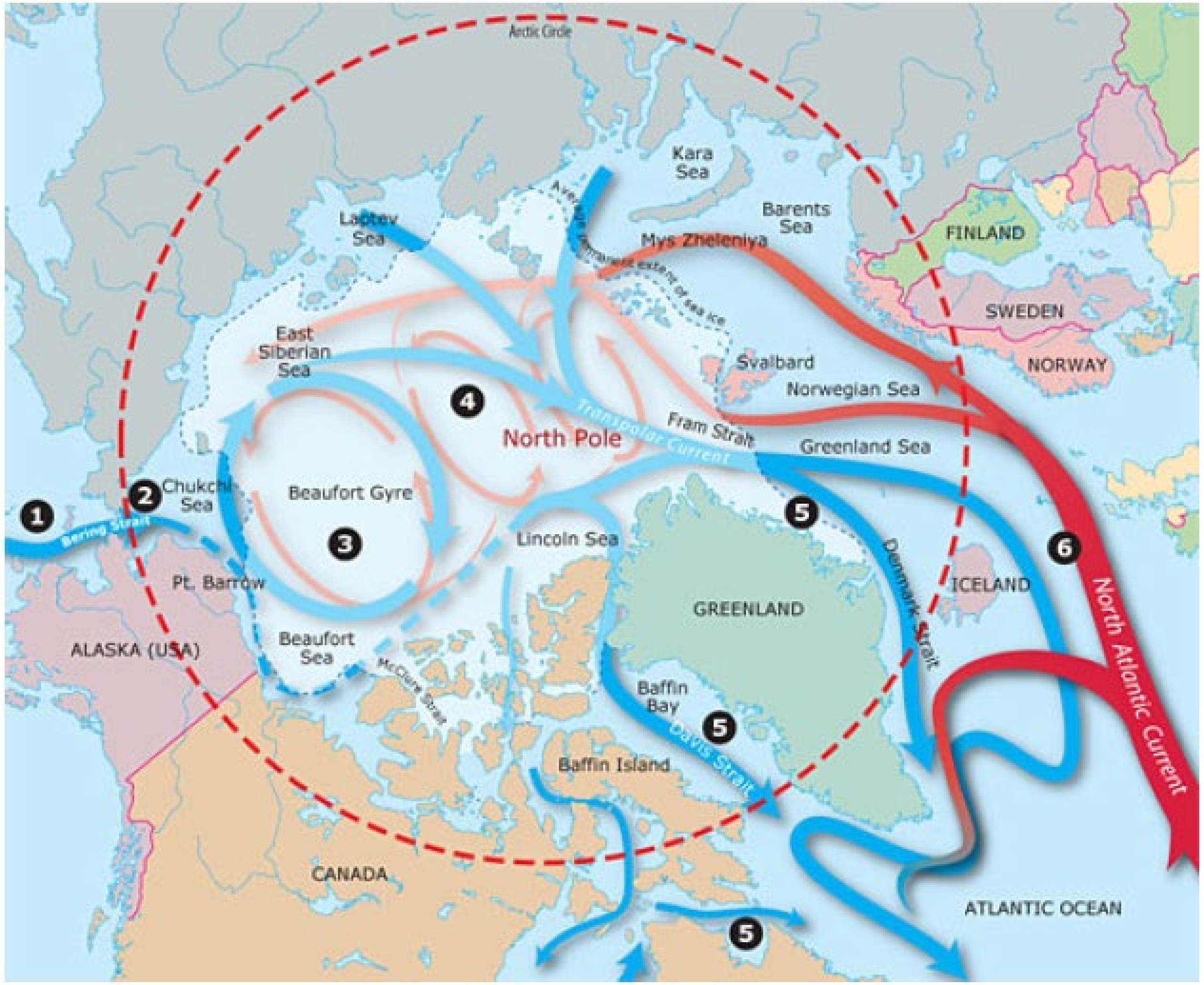


Fig. 1. GRACE-based mass balance. Total mass change, in gigatons (Gt), of the GrIS from April 2002 through September 2023 determined from the satellite gravimetry missions GRACE (2002-17) and GRACE-FO (2018-present) (Tapley et al. 2019). Black circles show monthly estimates, with 2-st. dev. uncertainties shown with (light green) and without (dark green) errors due to leakage of external signals (i.e., mass changes near Greenland but not associated with the GrIS). The time series has been scaled by 0.84 to remove the peripheral glaciers and ice caps from the GRACE-based estimates.

Poinar et al., 2023



Major surface (blue) and deep currents (red and orange) of the Arctic Ocean, along with the approximate summer limit if sea ice.

Courtesy Woods Hole Oceanographic Institution

Arctic Monitoring and Assessment Programme

Arctic Climate Issues 2011

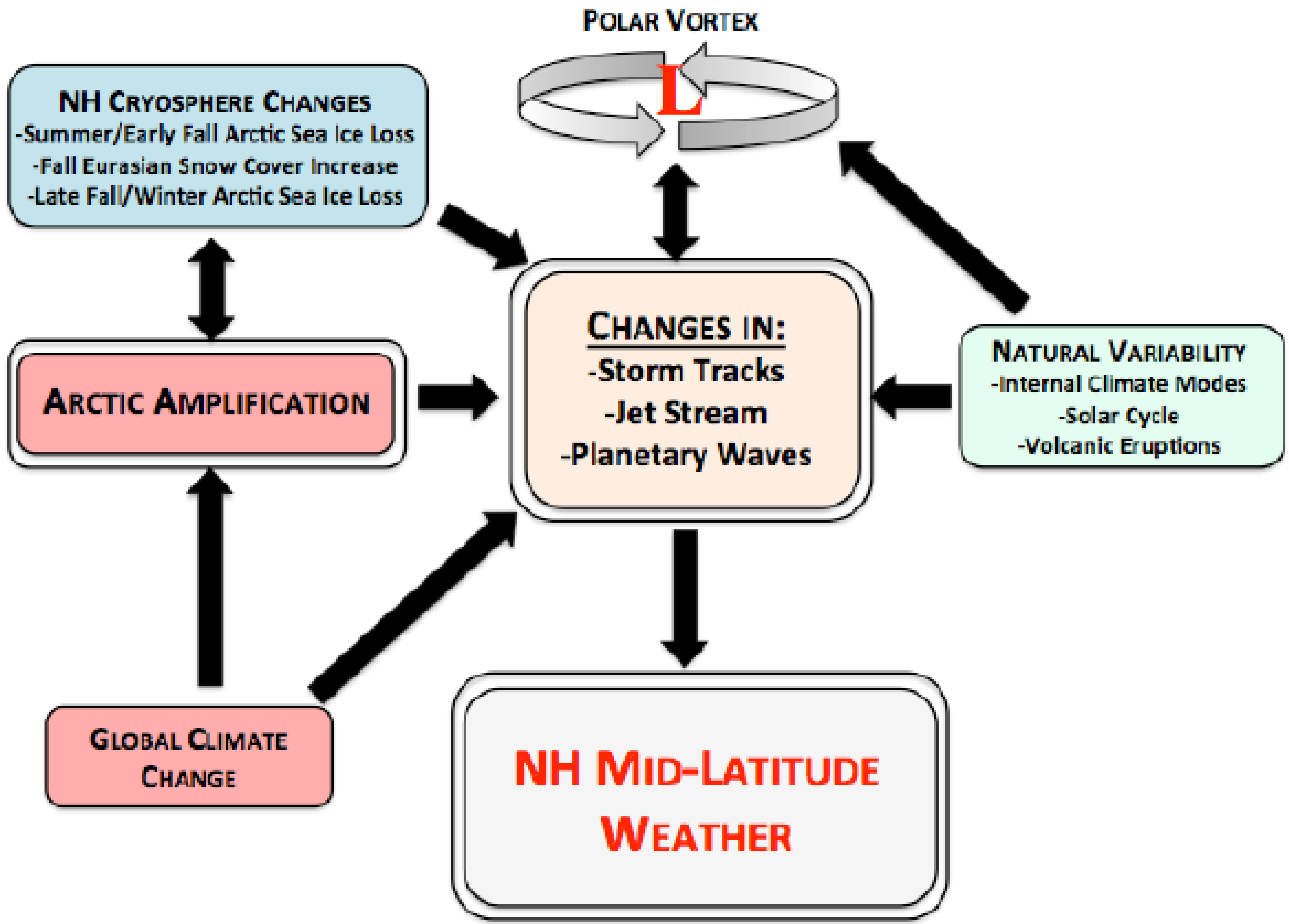
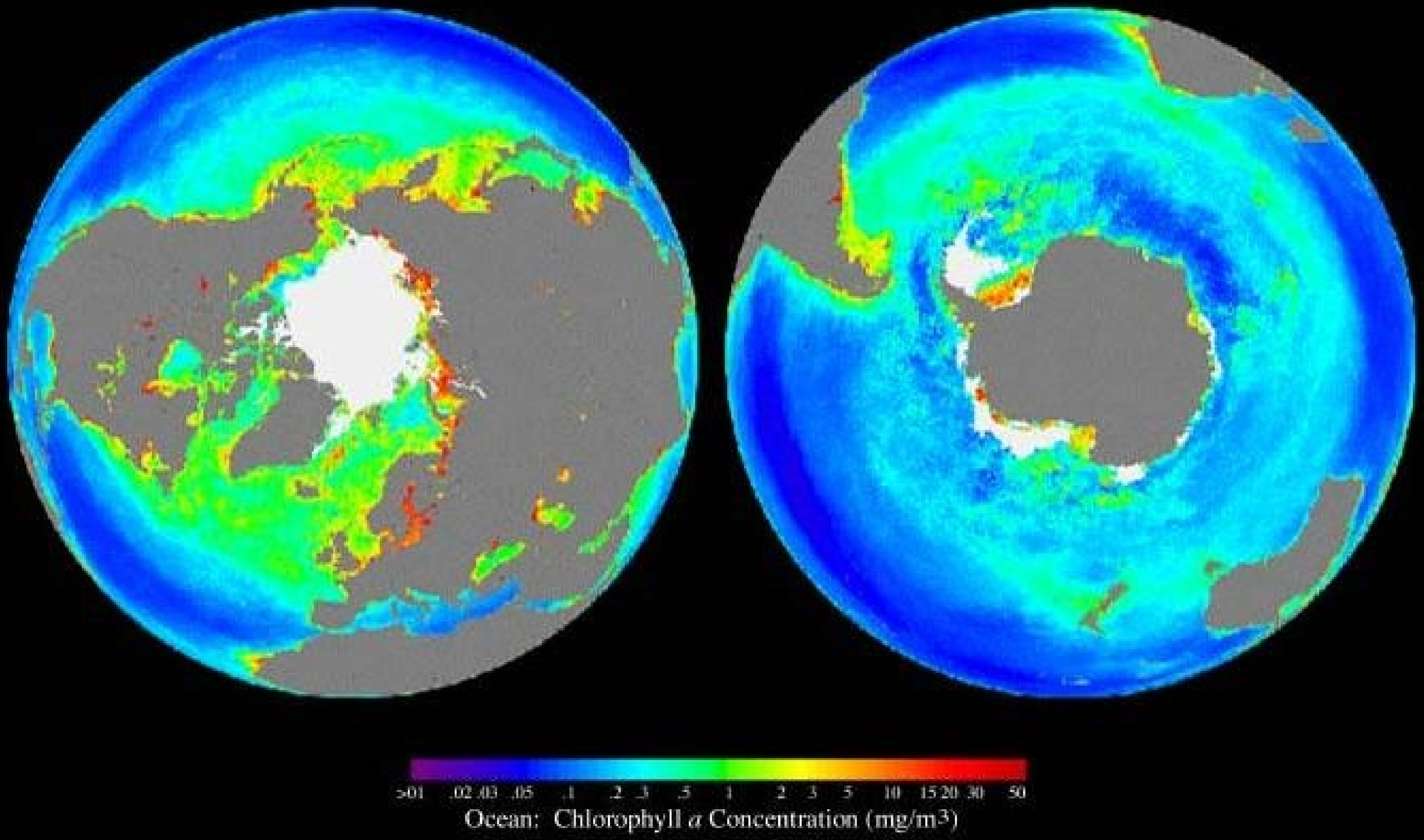


Figure 5. Complexity of linkage pathways. (Figure from Cohen et al. 2014).

SeaWiFS Global Chlorophyll: Polar Projections

September 1997 - July 1998



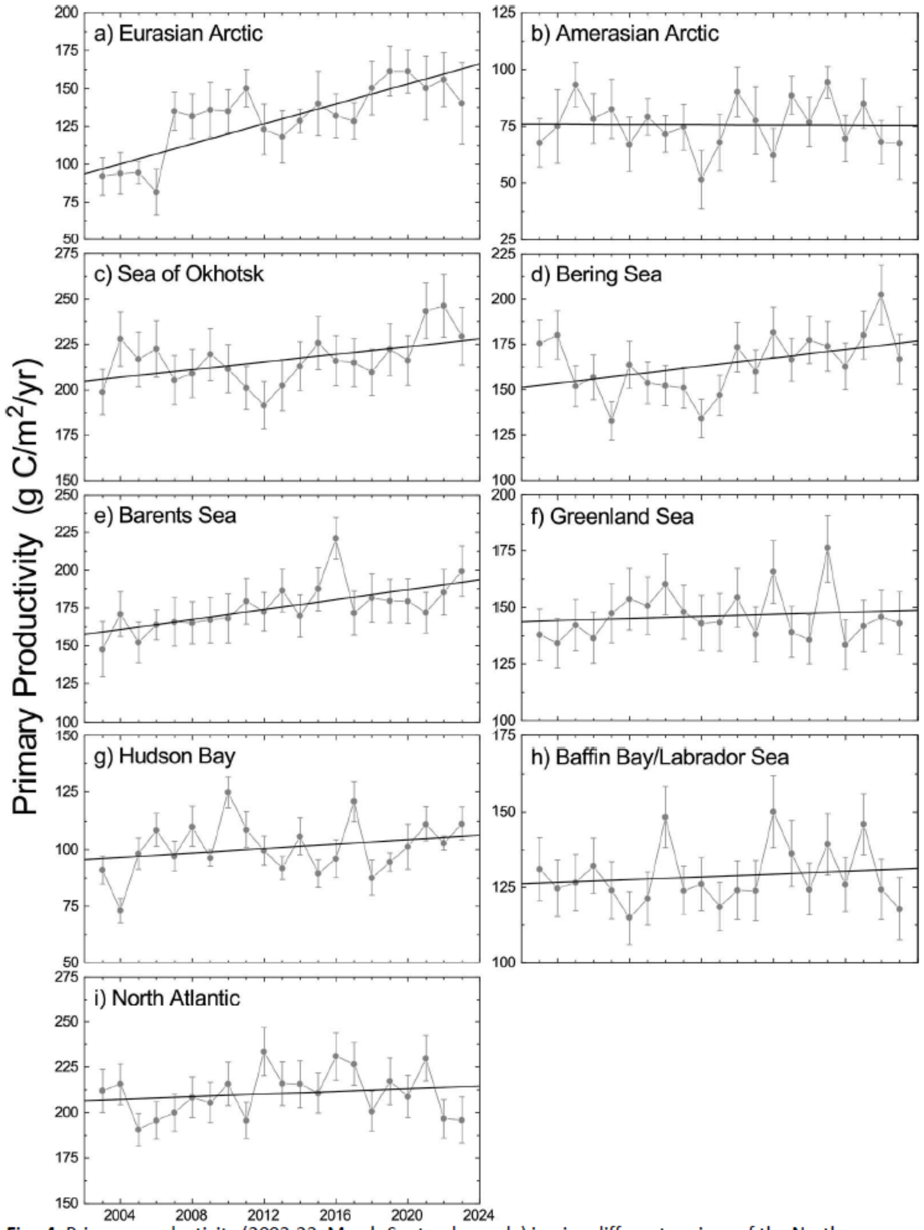
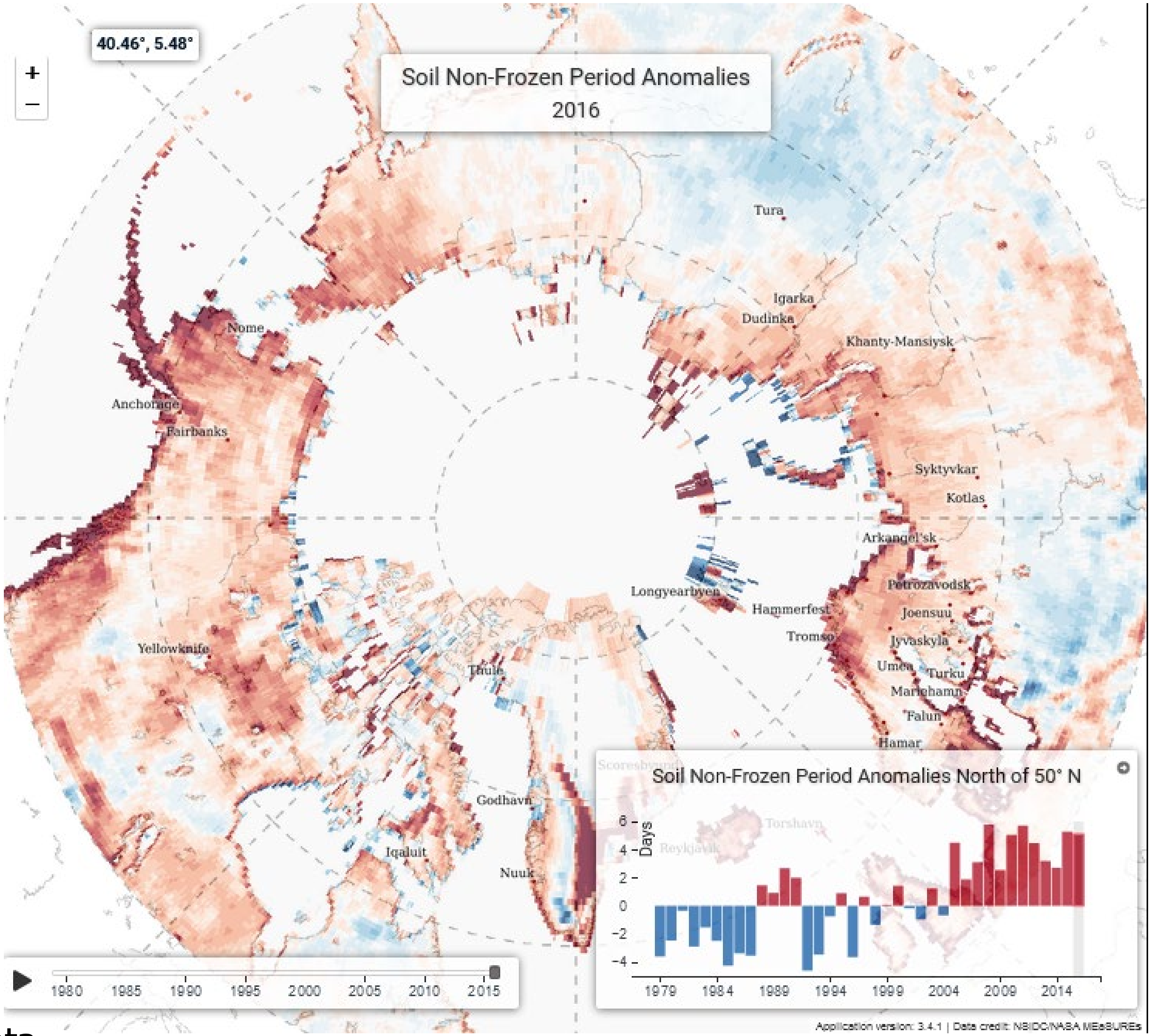
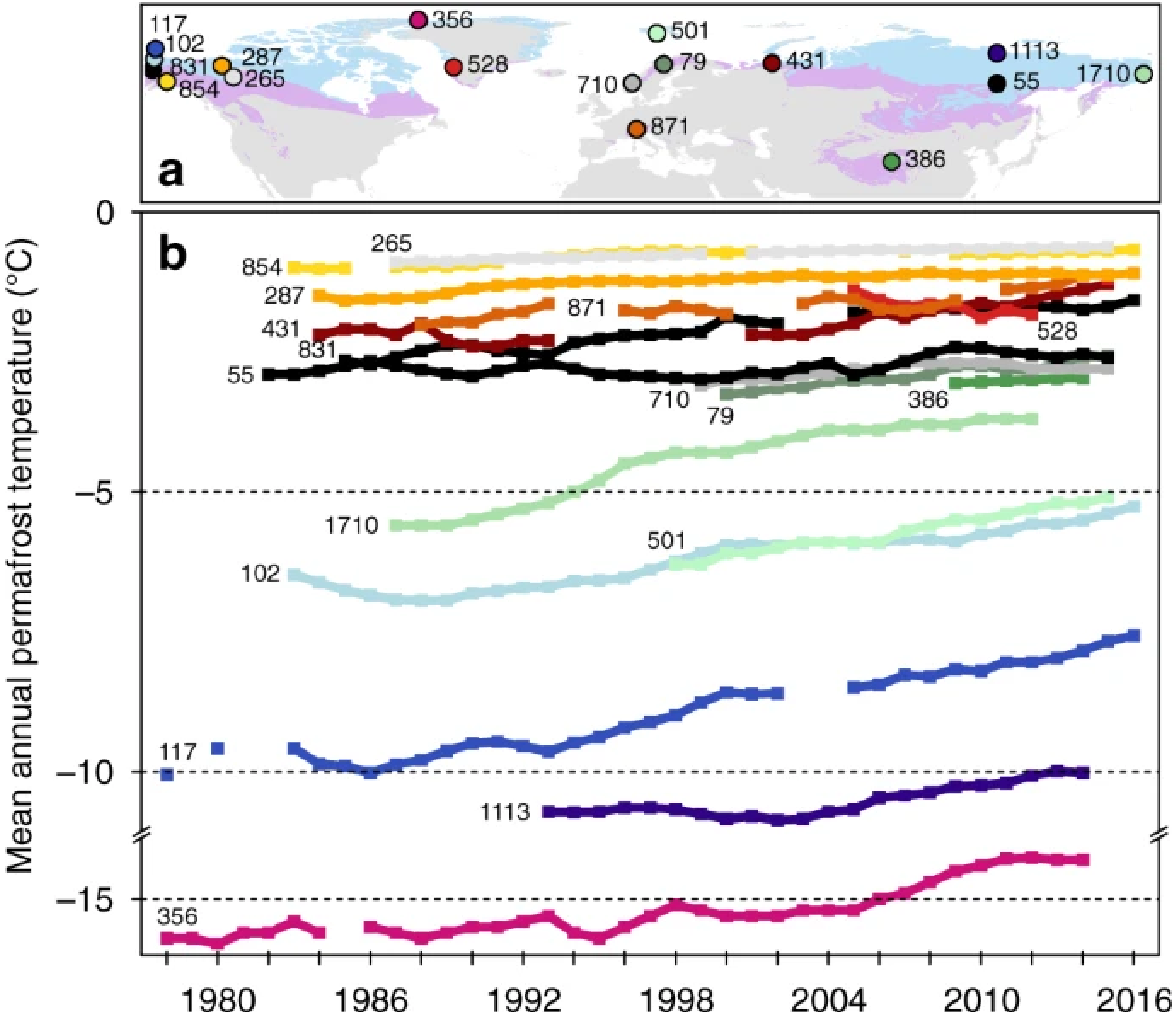


Fig. 4. Primary productivity (2003-23, March-September only) in nine different regions of the Northern Hemisphere (for a definition of the regions see Comiso (2015)). The statistical significance of the trends (based on the Mann-Kendall test), *p*-values, and additional information regarding these data can be found in Table 1. See *Methods and data* section for primary productivity calculation details.

Frey et al., 2023



https://nsidc.org/data



Long permafrost temperature records for selected sites. **a** Location of boreholes with long time-series data. Because some regions lack long temperature records, shorter temperature records from Greenland and Chinese mountains are included for comparison. Depth of measurements is according to the Global Terrestrial Network for Permafrost ID[16]: 24.4 m (ID 356), 20 m (ID 55, 79, 102, 117, 501, 710, 831, 1113, and 1710), 18 m (ID 386), 16.75 m (ID 871), 15 m (ID 854), 12 m (ID 287), 10 m (ID 265, 431), and 5 m (ID 528). The light blue area represents the continuous permafrost zone (>90% coverage) and the light purple area represents the discontinuous permafrost zones (<90% coverage). **b** Mean annual ground temperature over time. Colors indicate the location of the boreholes in a. Permafrost zones are derived from the International Permafrost Association (IPA) map[46]. World Borders data are derived from http://thematicmapping.org/downloads/world_borders.php and licensed under CC BY-SA 3.0 (https://creativecommons.org/licenses/by-sa/3.0/)

Biskaborn et al., 2019

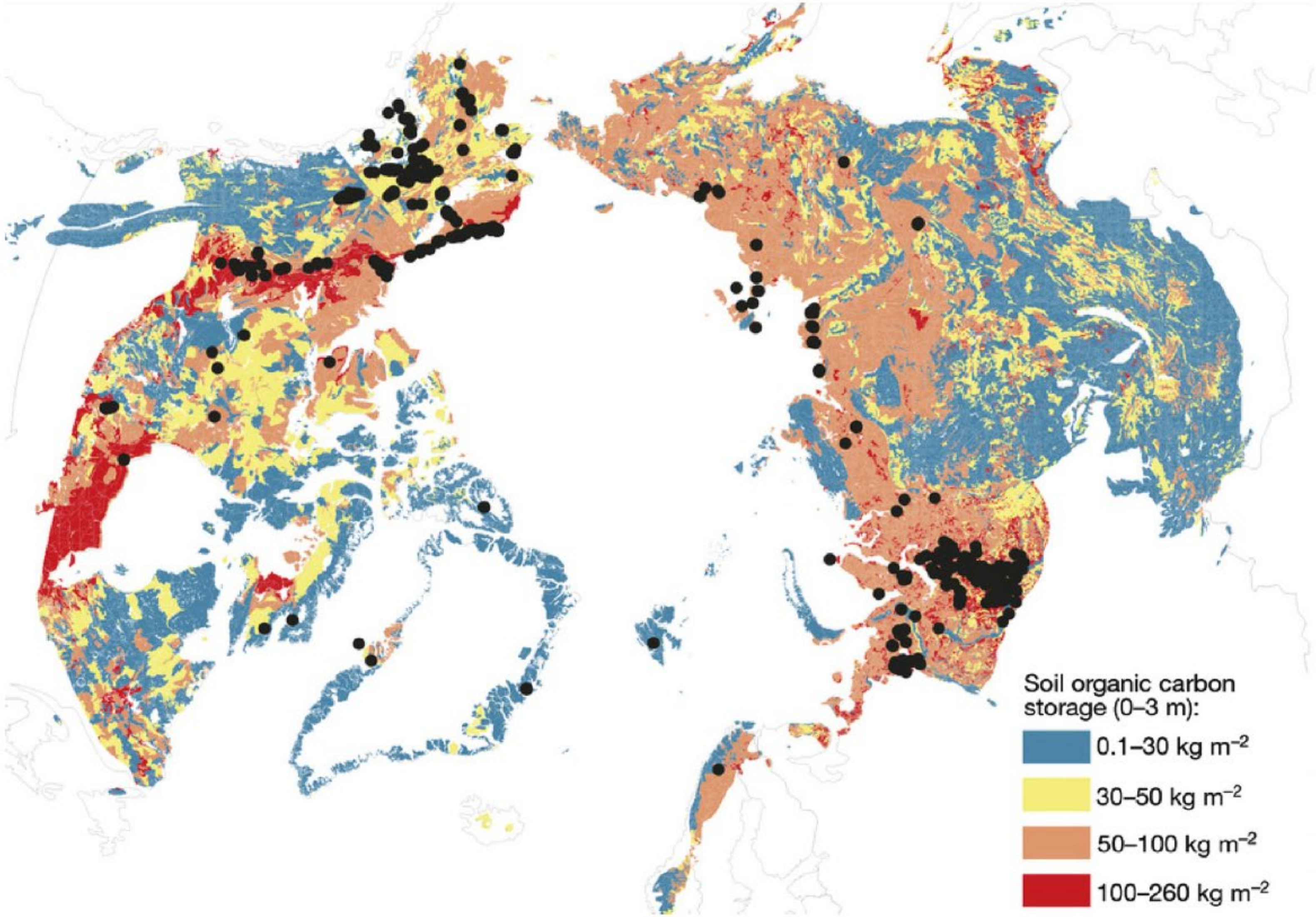
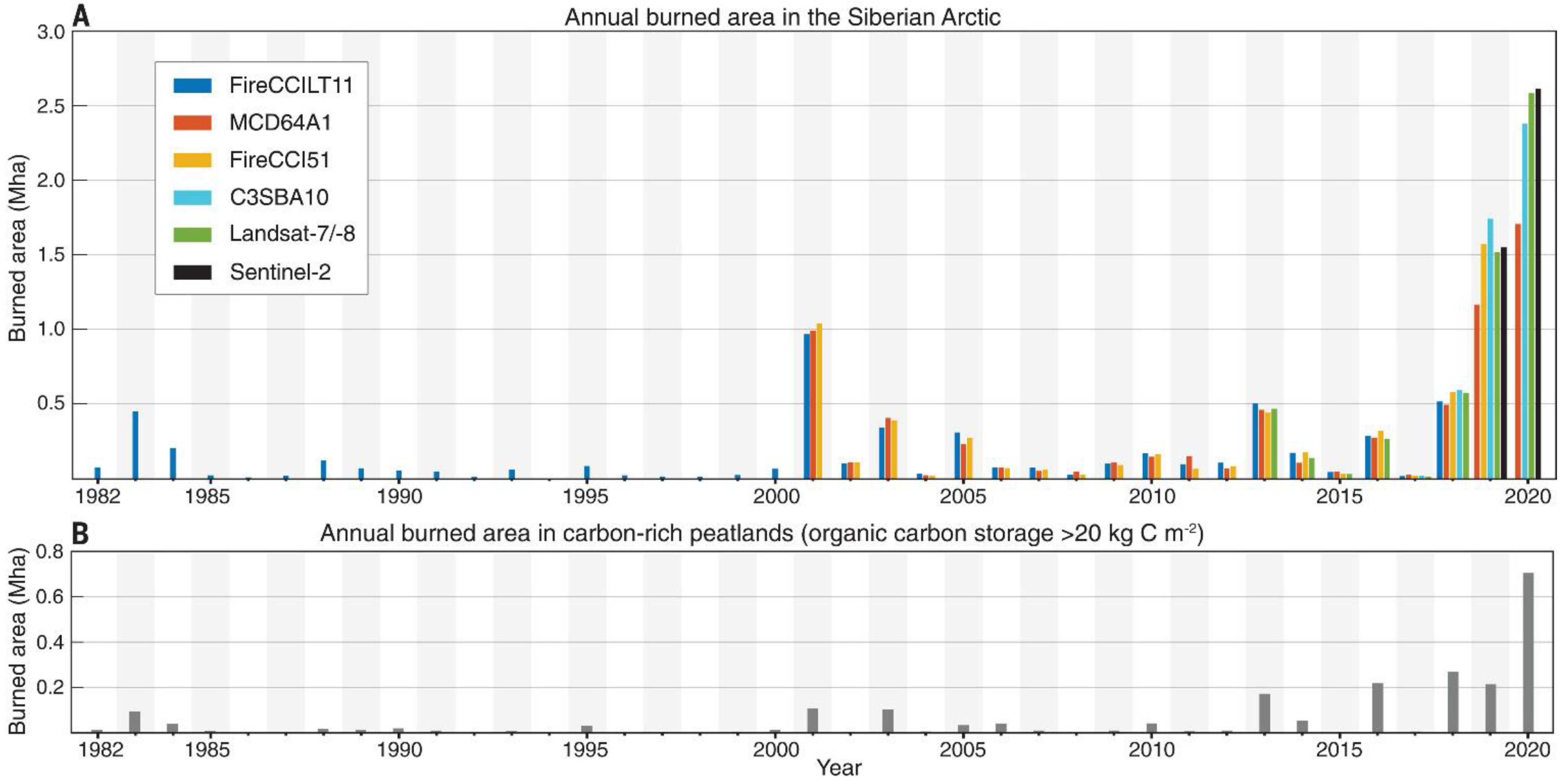
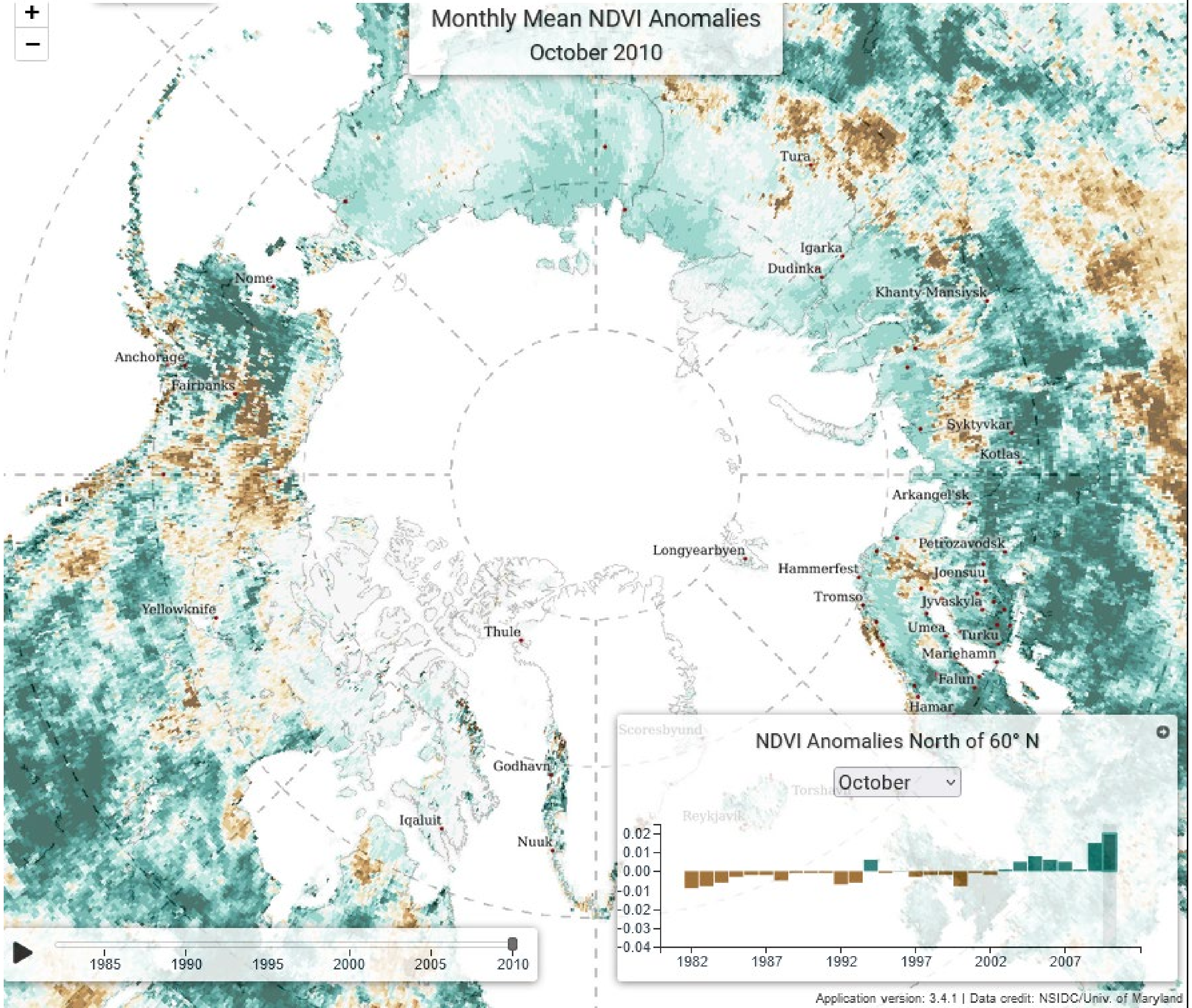


Fig. 4 Soil organic carbon pool (kg C m^{-2}) contained in the 0–3 m depth interval of the northern circumpolar permafrost zone. *Points* show field site locations for 0–3 m depth carbon inventory measurements; field sites with 1 m carbon inventory measurements number in the thousands and are too numerous to show. Adapted from Hugelius et al. (2014)

Parmentier et al., 2017



Descals et al., 2022



Monthly Mean NDVI Anomalies
October 2010
Tura
Igarka
Dudinka
Khanty-Mansiysk
Nome
Anchorage
Fairbanks
Syktyvkar
Kotlas
Arkangel'sk
Petrozavodsk
Longyearbyen
Hammerfest
Joensuu
Tromso
Jyvaskyla
Yellowknife
Umea
Turku
Thule
Mariehamn
Falun
Hamar
Scoresbysund
Godhavn
Torshavn
Reykjavik
Iqaluit
Nuuk
NDVI Anomalies North of 60° N
October
0.02
0.01
0.00
-0.01
-0.02
-0.03
-0.04
1982
1987
1992
1997
2002
2007
1985
1990
1995
2000
2005
2010
Application version: 3.4.1 | Data credit: NSIDC/Univ. of Maryland

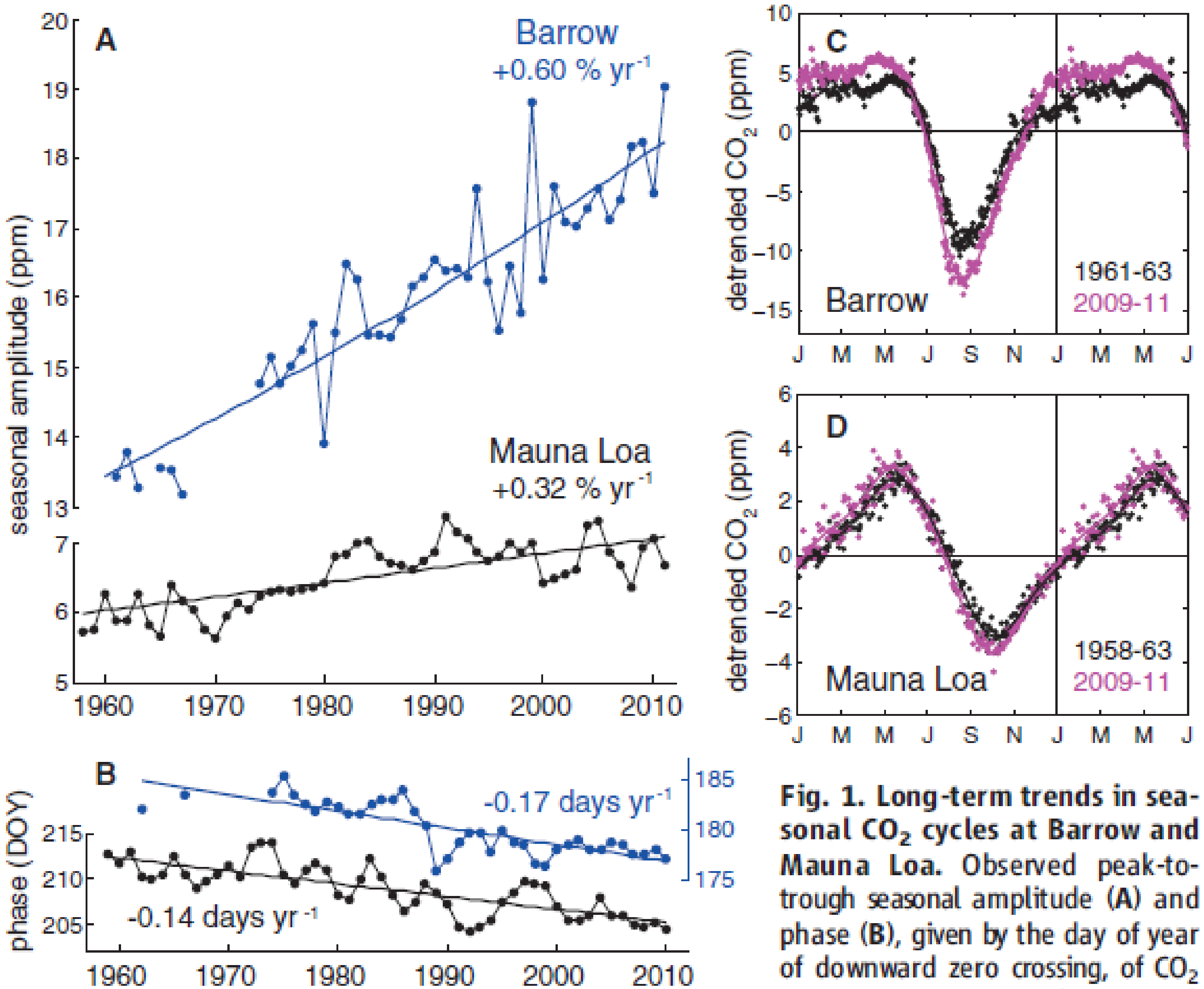


Fig. 1. Long-term trends in seasonal CO_2 cycles at Barrow and Mauna Loa. Observed peak-to-trough seasonal amplitude (**A**) and phase (**B**), given by the day of year of downward zero crossing, of CO_2 concentration at Barrow (71°N, blue) and Mauna Loa (20°N, black) measured by the Scripps CO_2 Program (*7*, *8*) and the NOAA Global Monitoring Division (*9*). Growth rate of amplitude is given in percentage change per year, with 1 SD uncertainty of ±0.05 to 0.07% $year^{-1}$. Seasonal CO_2 cycles observed at Barrow (**C**) and Mauna Loa (**D**) for the 1961 to 1963 or 1958 to 1963 and 2009 to 2011 time periods. The first 6 months of the year are repeated.

Graven et al., 2013

Chen and Liu, 2016

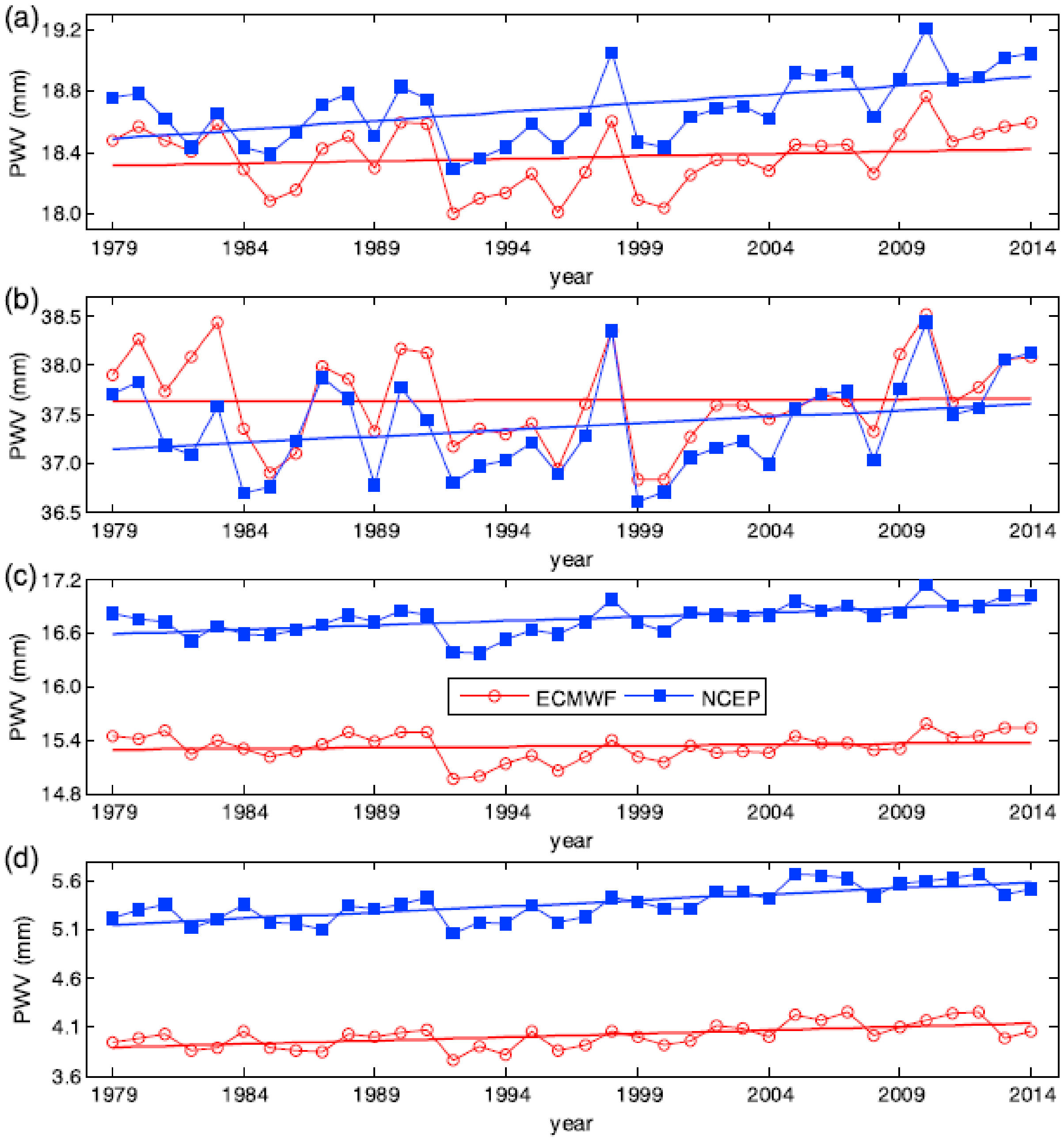


Figure 7. ECMWF and NCEP PWV time series averaged over (a) global, (b) tropical, (c) temperate, and (d) polar regions during the period 1979–2014.

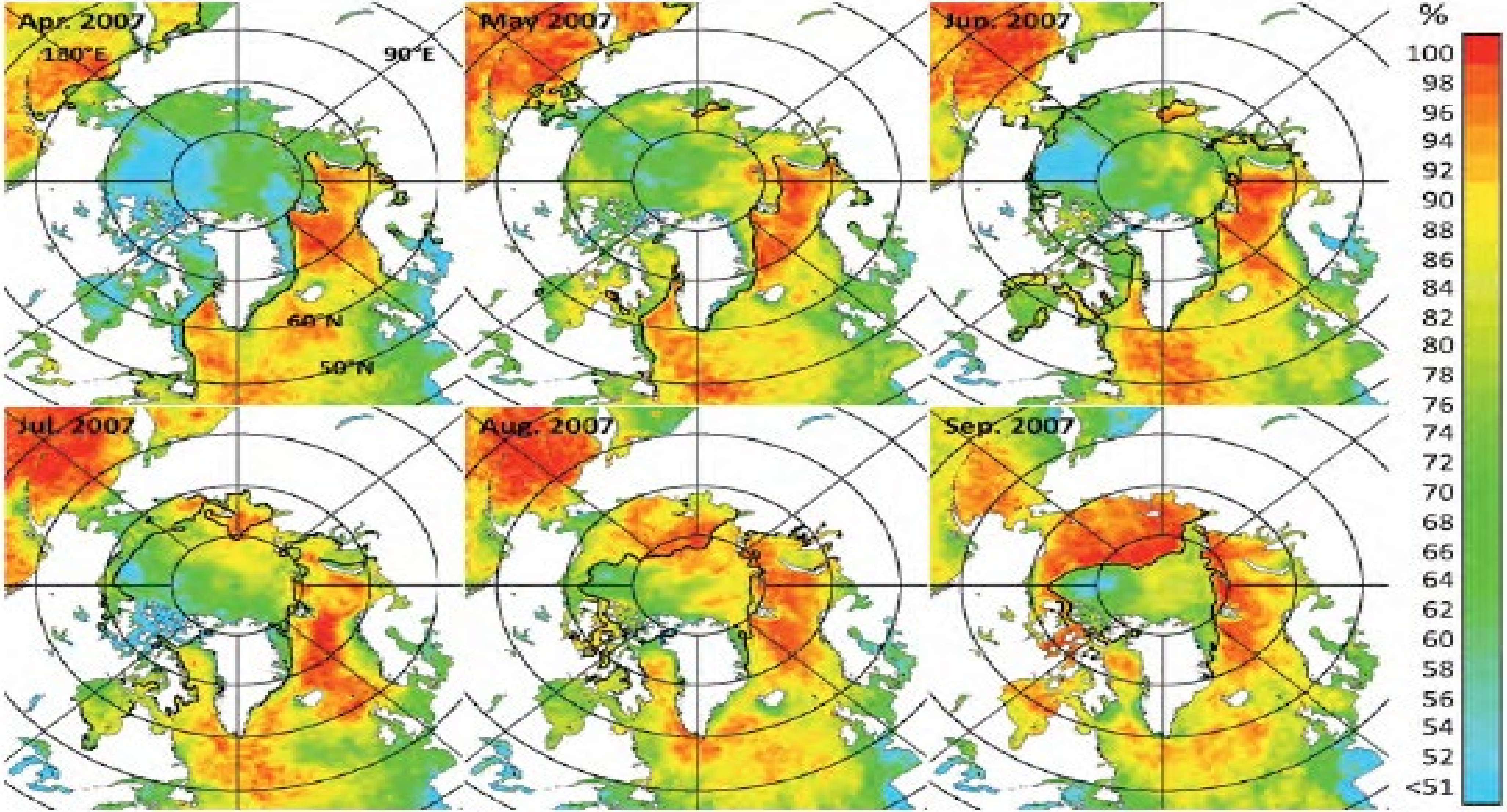


Figure 2.3 Colour-coded monthly cloud fraction in the Arctic in April to September, 2007. The sea-ice extent is also presented (solid black lines).

LETTER

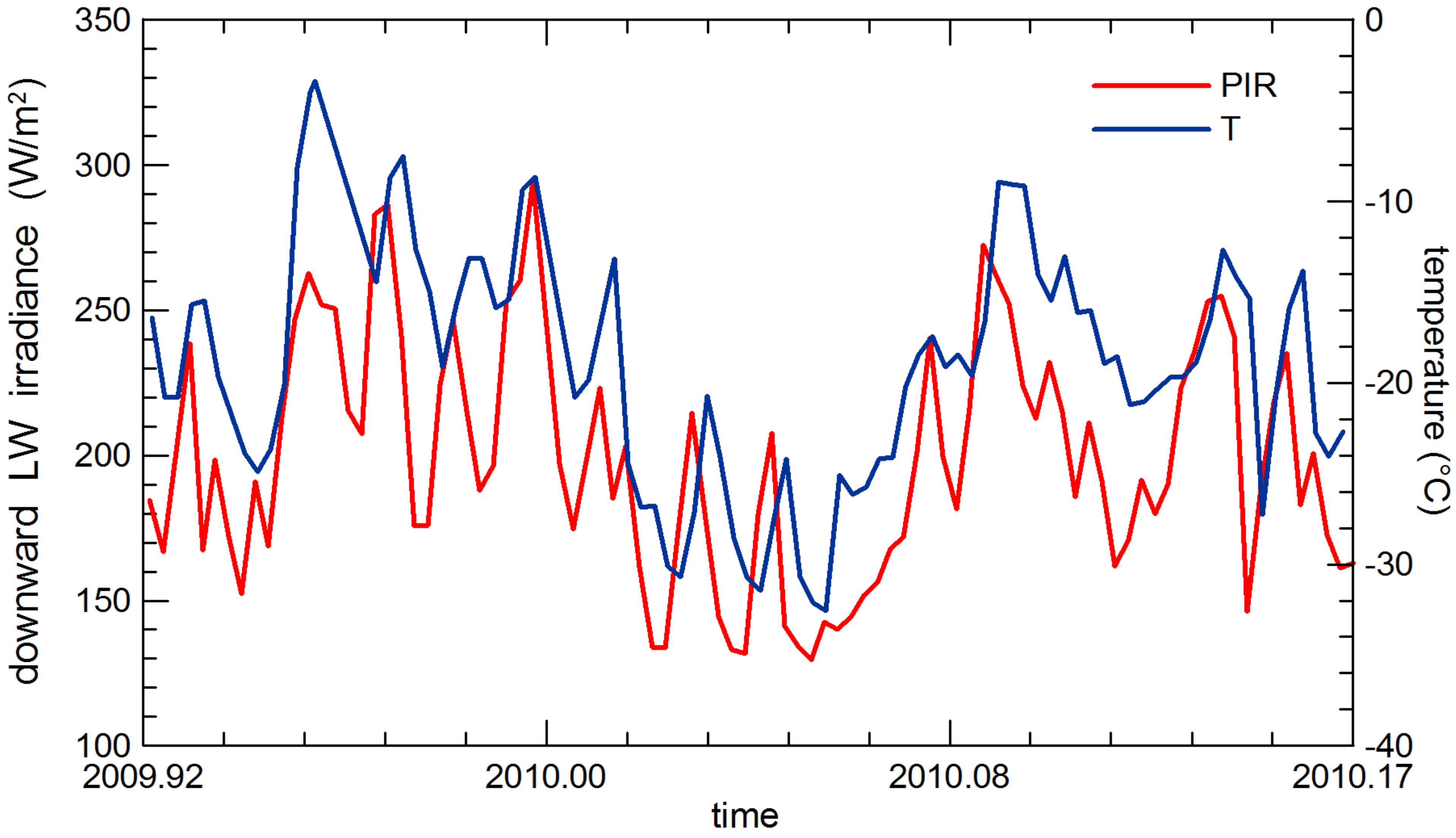
doi:10.1038/nature12002

July 2012 Greenland melt extent enhanced by low-level liquid clouds

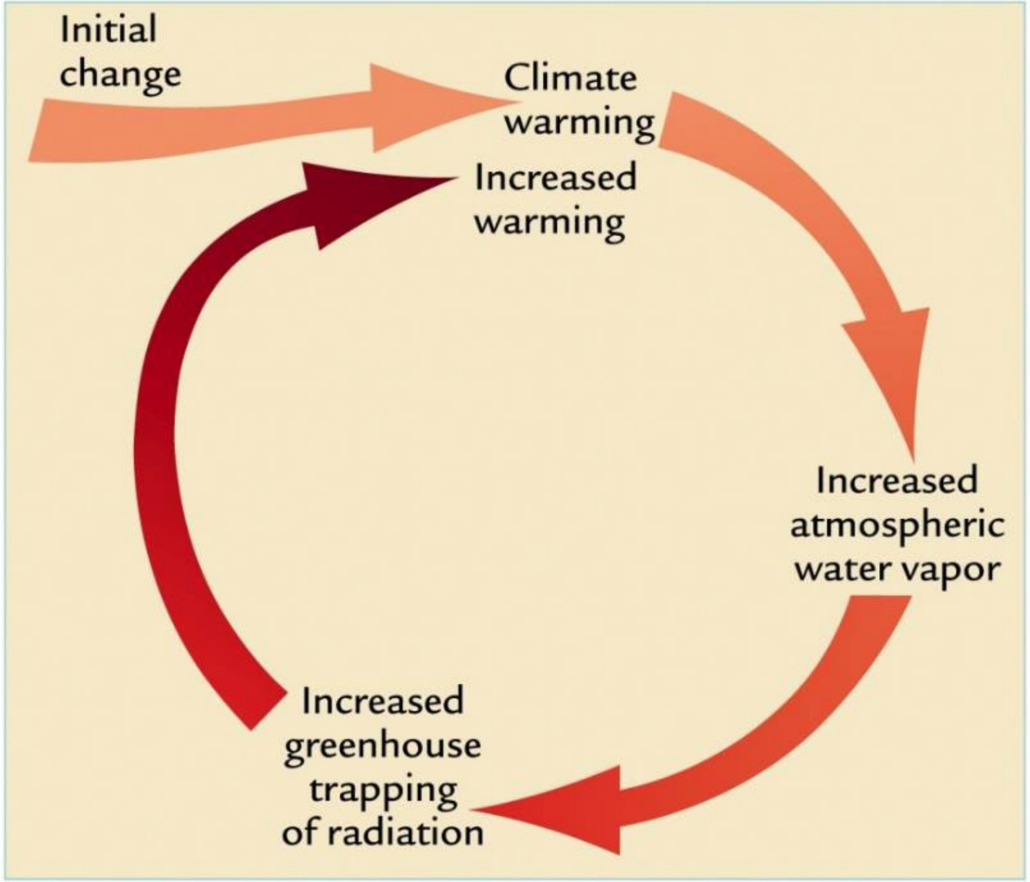
R. Bennartz[1], M. D. Shupe[2], D. D. Turner[3], V. P. Walden[4], K. Steffen[2,5], C. J. Cox[4], M. S. Kulie[6], N. B. Miller[6] & C. Pettersen[6]

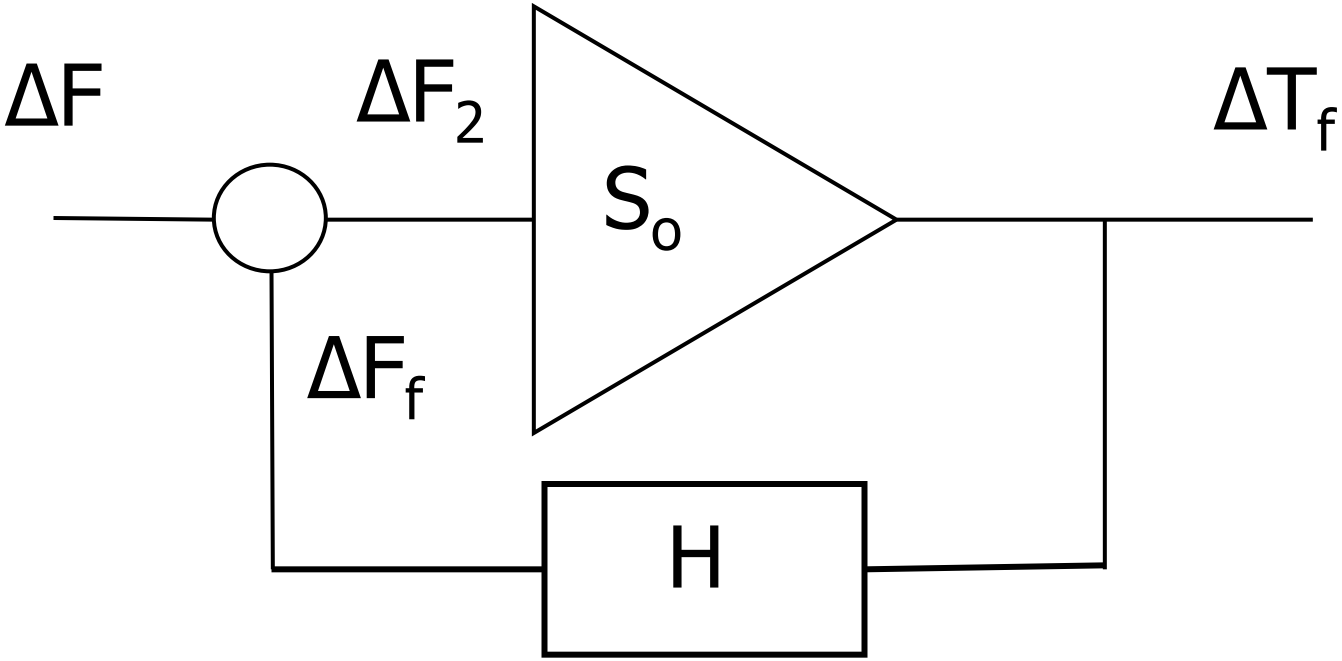
Melting of the world's major ice sheets can affect human and environmental conditions by contributing to sea-level rise. In July 2012, an historically rare period of extended surface melting was observed across almost the entire Greenland ice sheet[1,2], raising questions

This model is used here to study the effect of clouds on the temporal development of surface temperature. In equation (1), T_S is the surface temperature, t is time, H is the height of the inversion layer, α is a shape parameter characterizing the form of the temperature profile in the



PIR
T
downward LW irradiance (W/m²)
temperature (°C)
time
350
300
250
200
150
100
0
-10
-20
-30
-40
2009.92
2010.00
2010.08
2010.17





$S/S_o = 1/(1-S_oH) = 1/(1-f)$

$\Delta T_f/\Delta T = 1/(1-f)$

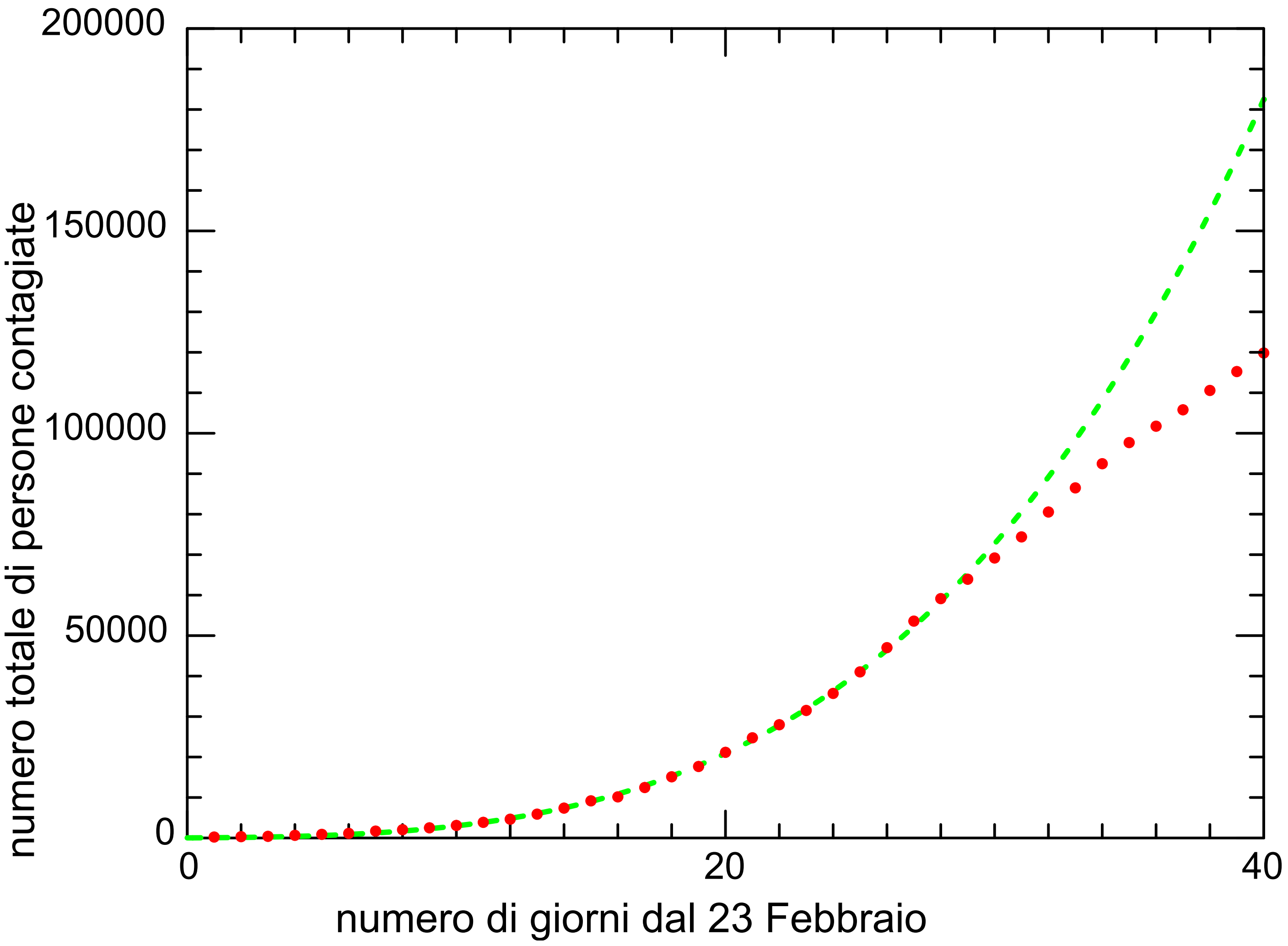
Water vapour feedback:
f is about 0.4
$\Delta T_f/\Delta T$ is about 1.7

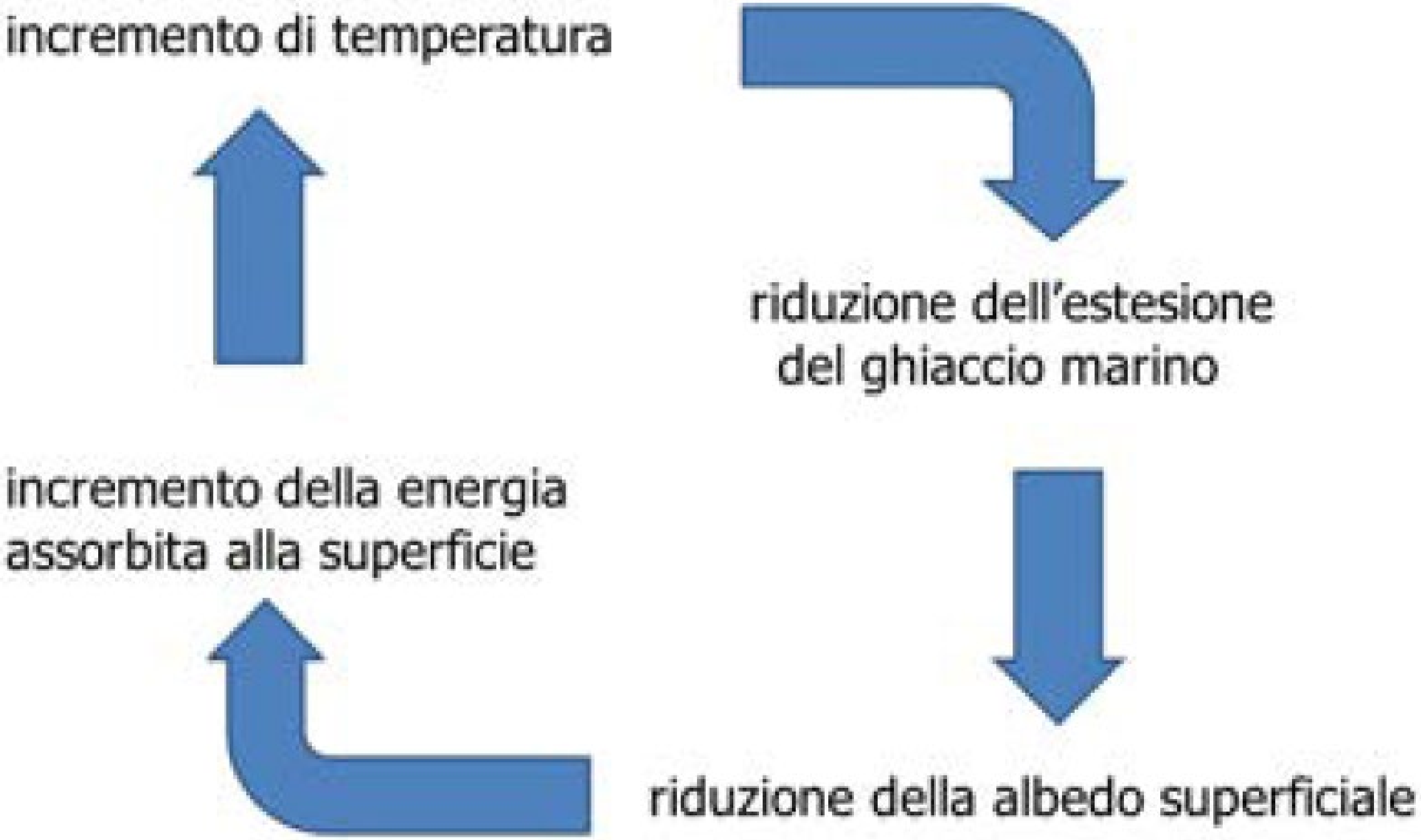
$$dx = kx\, dt$$

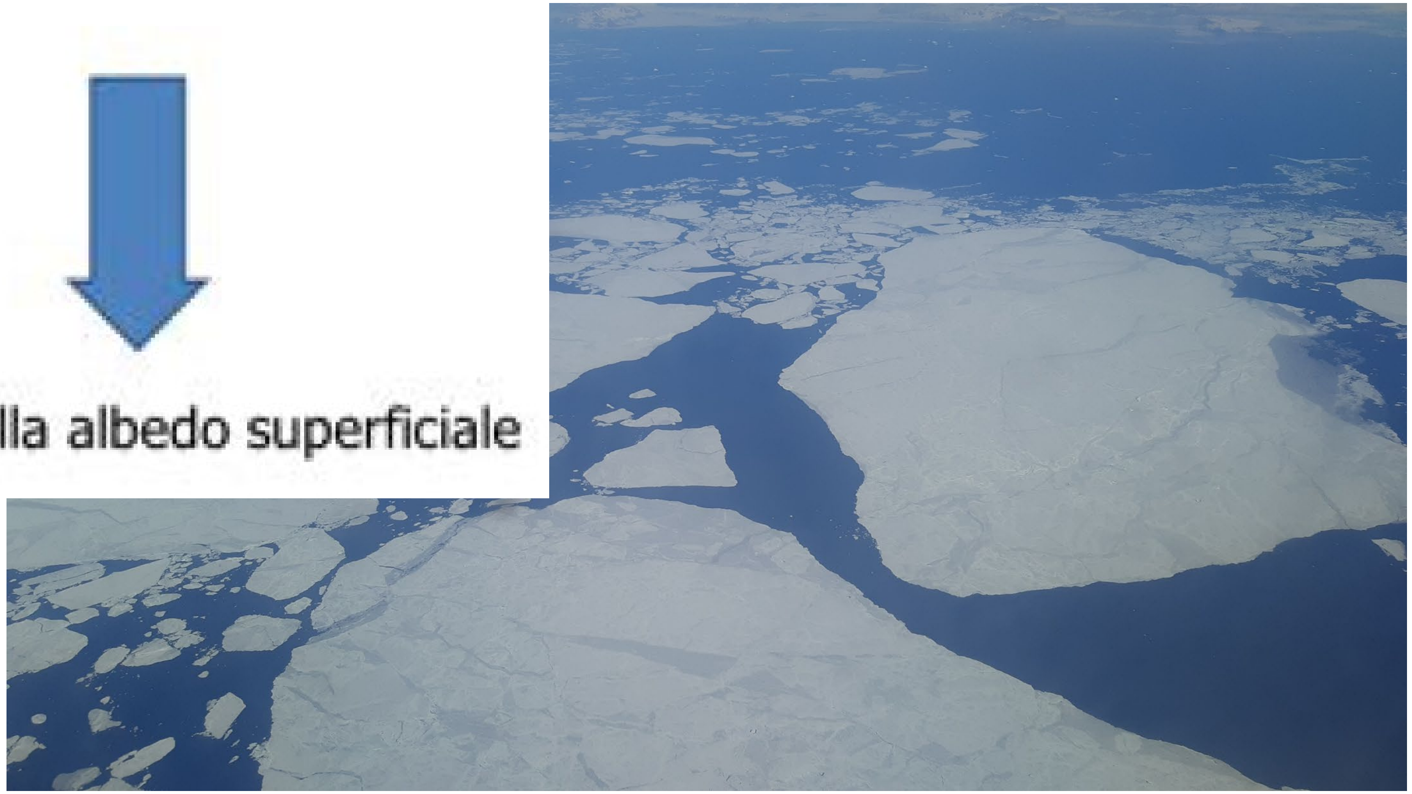
$$\frac{dx}{x} = k\, dt$$

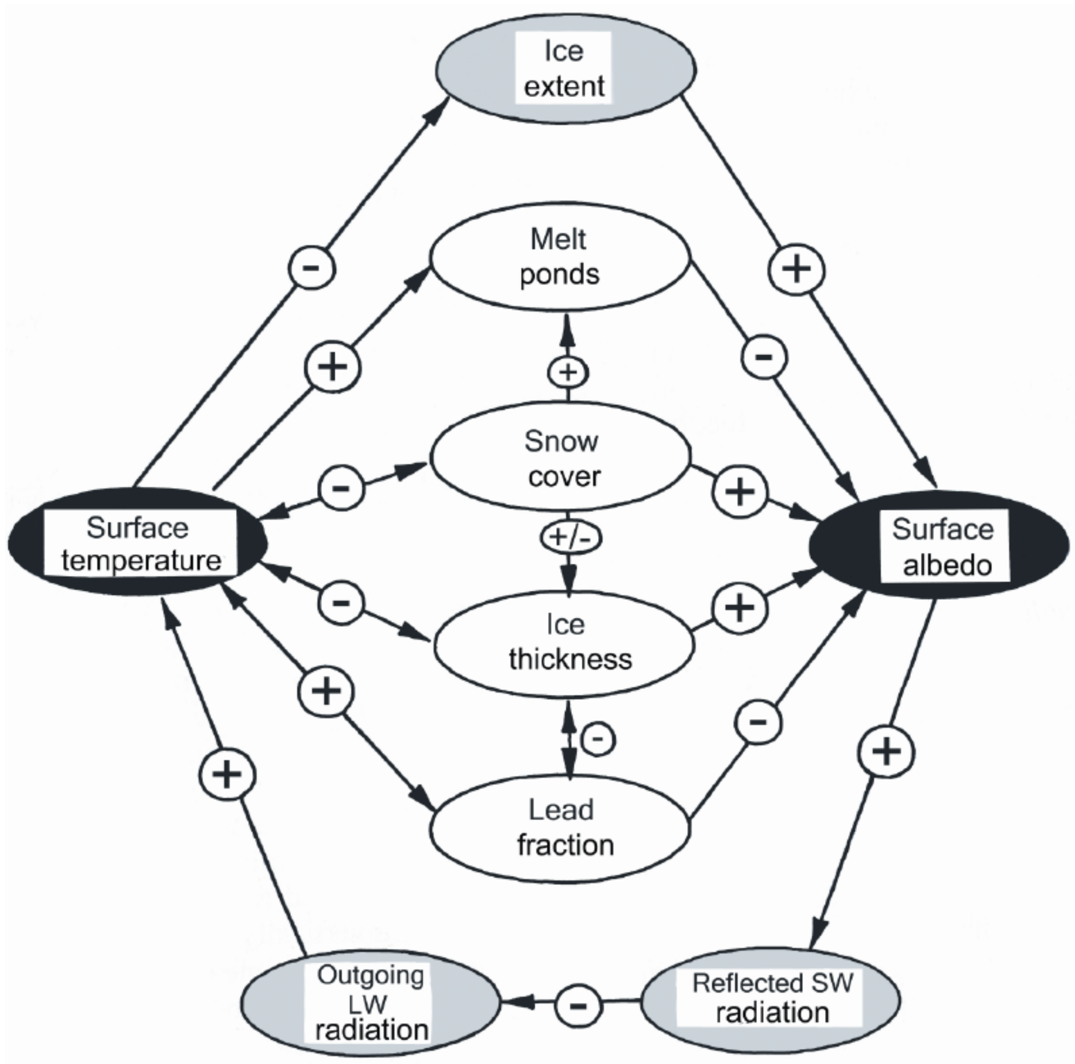
$$d \ln x = k\, dt$$

$$x = x_0 \exp[kt]$$

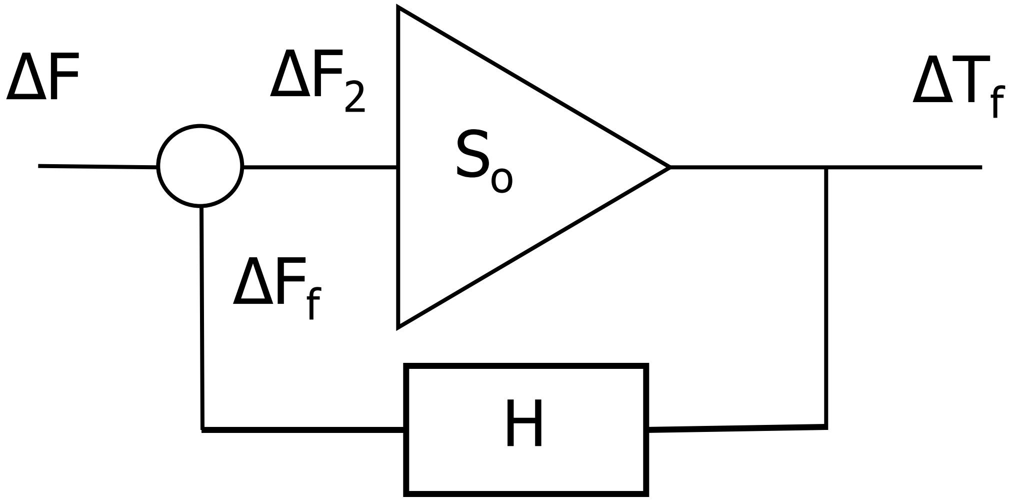

200000
150000
100000
50000
0
numero totale di persone contagiate
0
20
40
numero di giorni dal 23 Febbraio


incremento di temperatura
riduzione dell'estesione del ghiaccio marino
riduzione della albedo superficiale
incremento della energia assorbita alla superficie





Schematic of the ice- albedo feedback mechanism using the framework of Kellogg [1973]. The direction of the arrow indicates the direction of the interaction. A "+" indicates a positive interaction (an increase in the first quantity leads to an increase in the second). A "-" indicates a negative interaction (an increase in the first quantity leads to a decrease in the second quantity). A "+/-" indicates that the sign of the interaction is uncertain or that the sign changes over the annual cycle [from Curry *et al*., 1996, by permission of AMS].

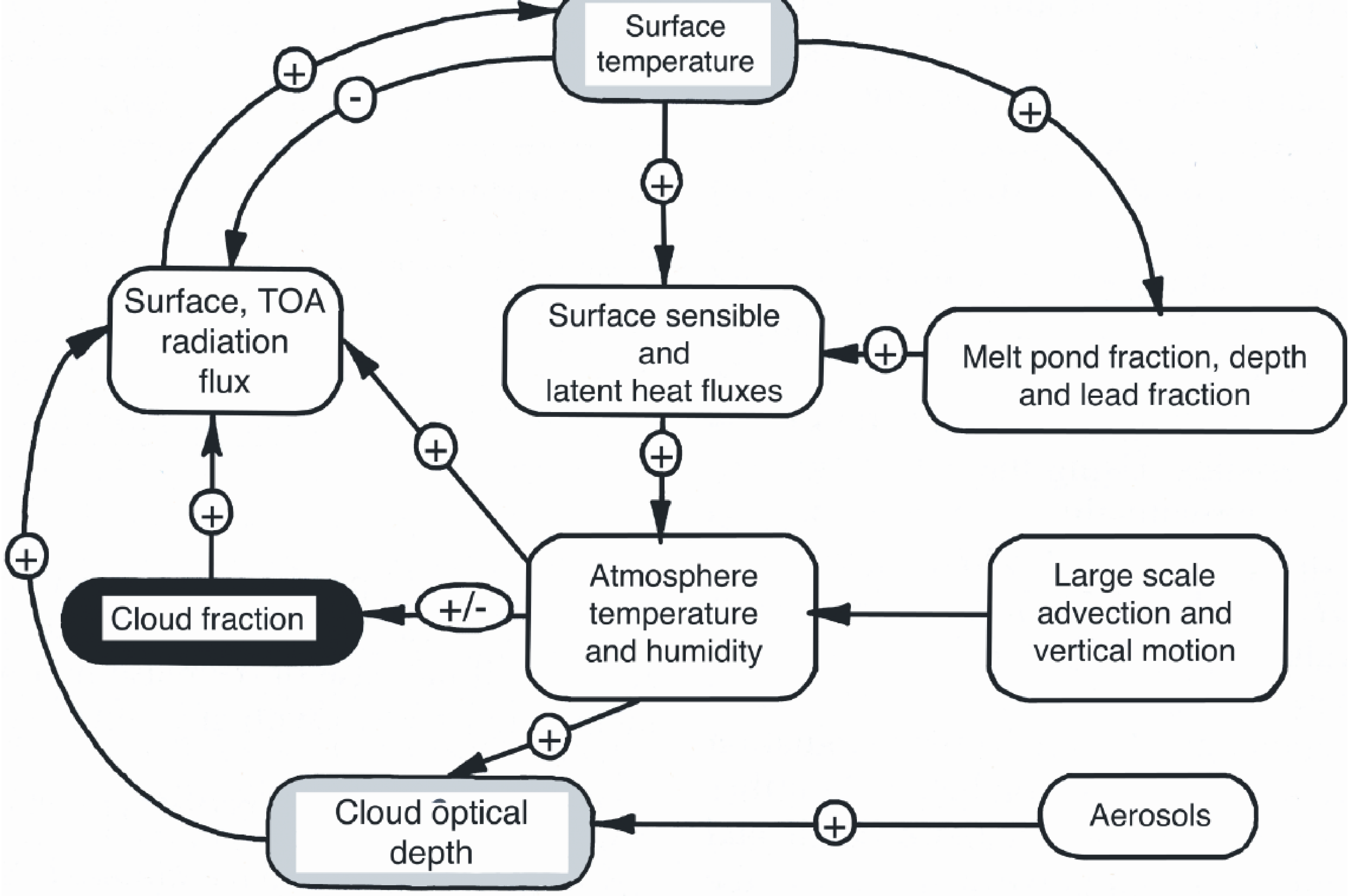


$$S/S_o = 1/(1-S_oH) = 1/(1-f)$$

$$\Delta T_f/\Delta T = 1/(1-f)$$

Feedback di ghiaccio-albedo:

f è circa 0.3 $\quad\quad$ $\Delta T_f/\Delta T$ circa 1.45



The cloud-radiation feedback mechanism [from Curry *et al*., 1996, by permission of AMS].

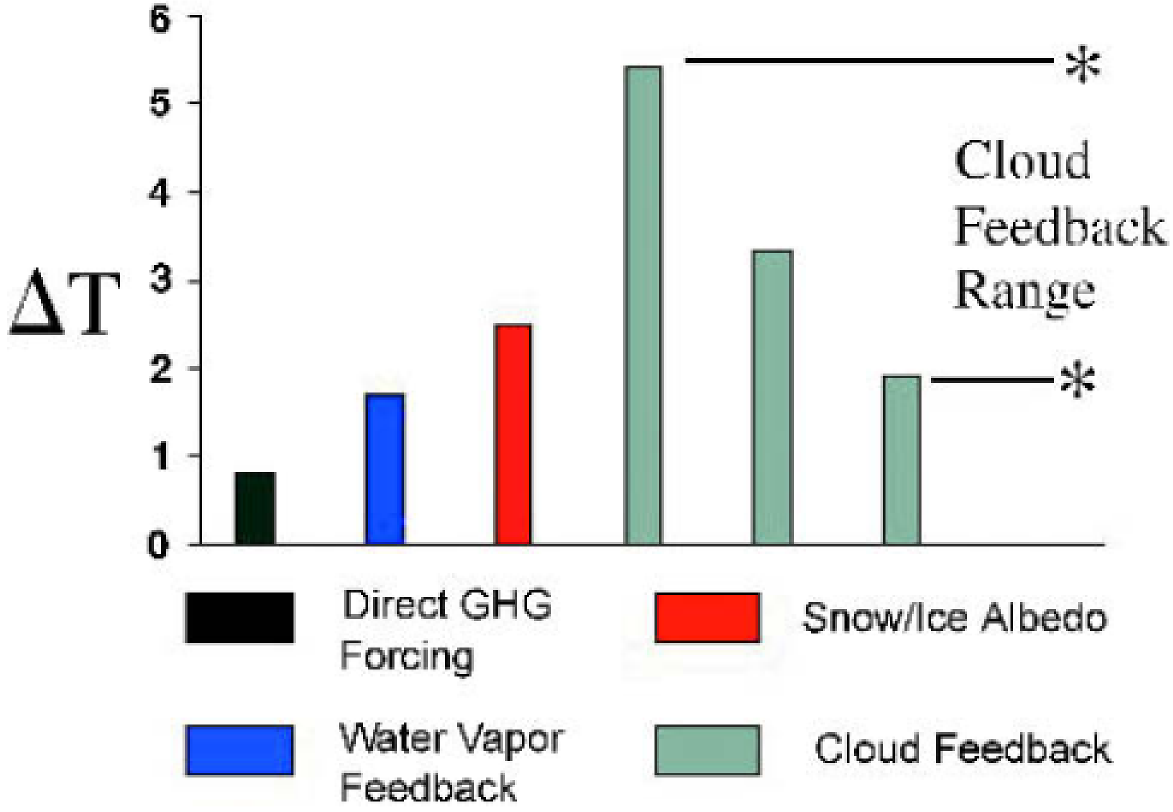
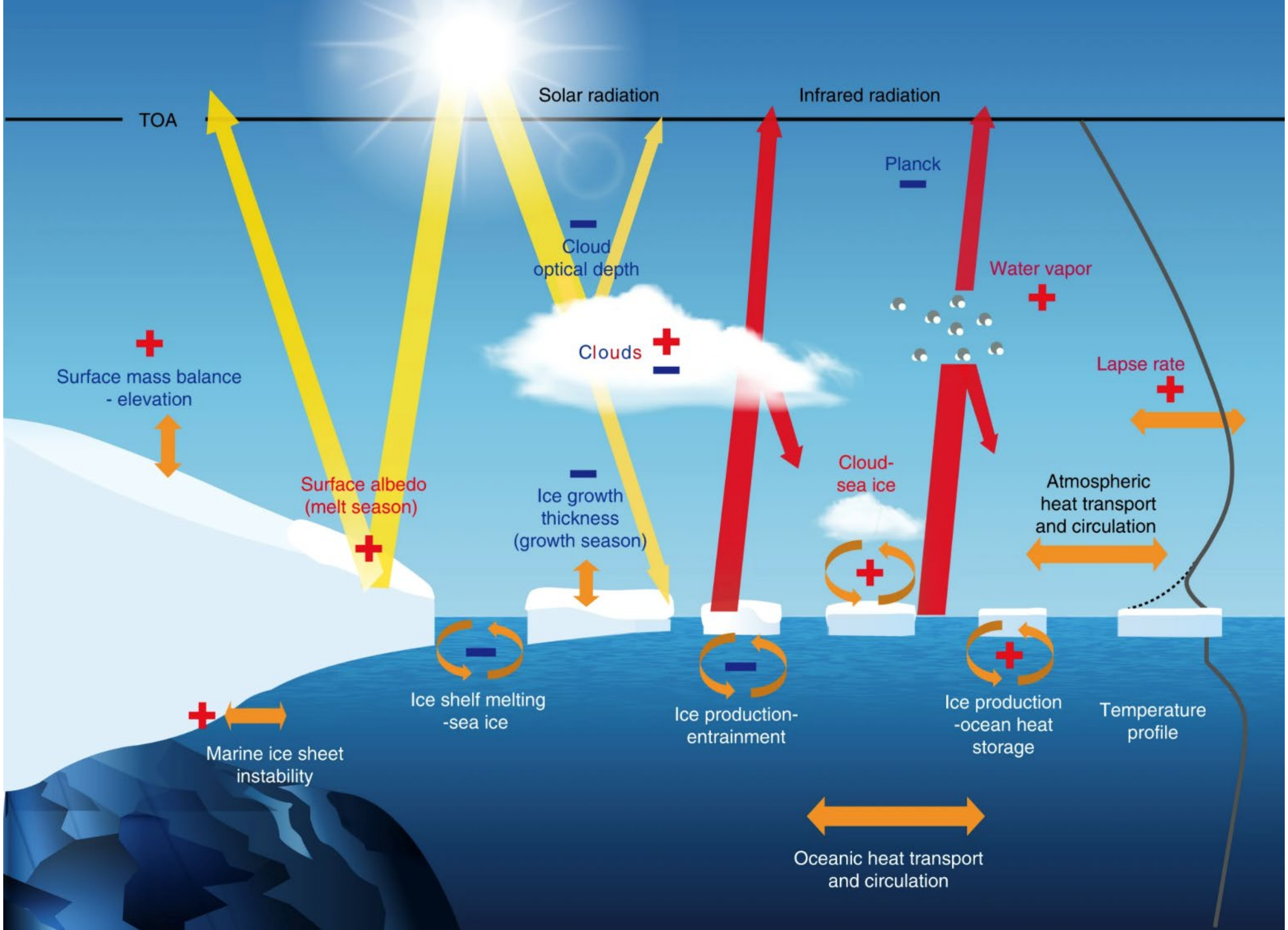
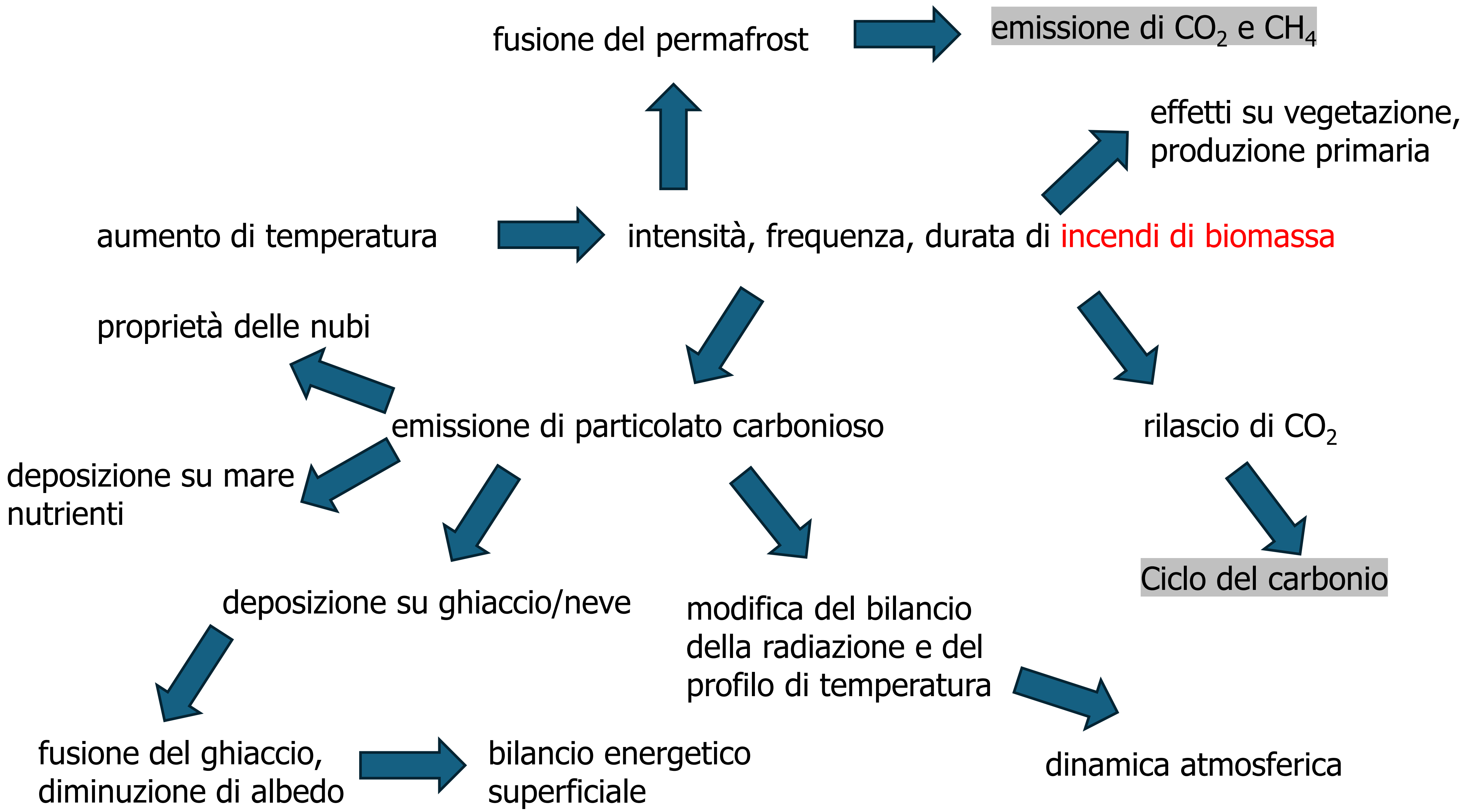


FIG. 13. The response of a single climate model to an imposed doubling of CO_2 as different feedbacks are systematically added in the model (adapted from Senior and Mitchell 1993). Different treatments of cloud processes in the model produce a large spread in predicted surface temperature due to CO_2 doubling.



TOA
Solar radiation
Infrared radiation
Planck
Cloud
optical depth
Water vapor
Clouds
Surface mass balance
- elevation
Lapse rate
Surface albedo
(melt season)
Ice growth
thickness
(growth season)
Cloud-
sea ice
Atmospheric
heat transport
and circulation
Ice shelf melting
-sea ice
Ice production-
entrainment
Ice production
-ocean heat
storage
Temperature
profile
Marine ice sheet
instability
Oceanic heat transport
and circulation


fusione del permafrost
emissione di CO_2 e CH_4
effetti su vegetazione, produzione primaria
aumento di temperatura
intensità, frequenza, durata di incendi di biomassa
proprietà delle nubi
emissione di particolato carbonioso
rilascio di CO_2
deposizione su mare nutrienti
Ciclo del carbonio
deposizione su ghiaccio/neve
modifica del bilancio della radiazione e del profilo di temperatura
fusione del ghiaccio, diminuzione di albedo
bilancio energetico superficiale
dinamica atmosferica

2022-2026: International Conference on Arctic Research Planning (ICARP) Process

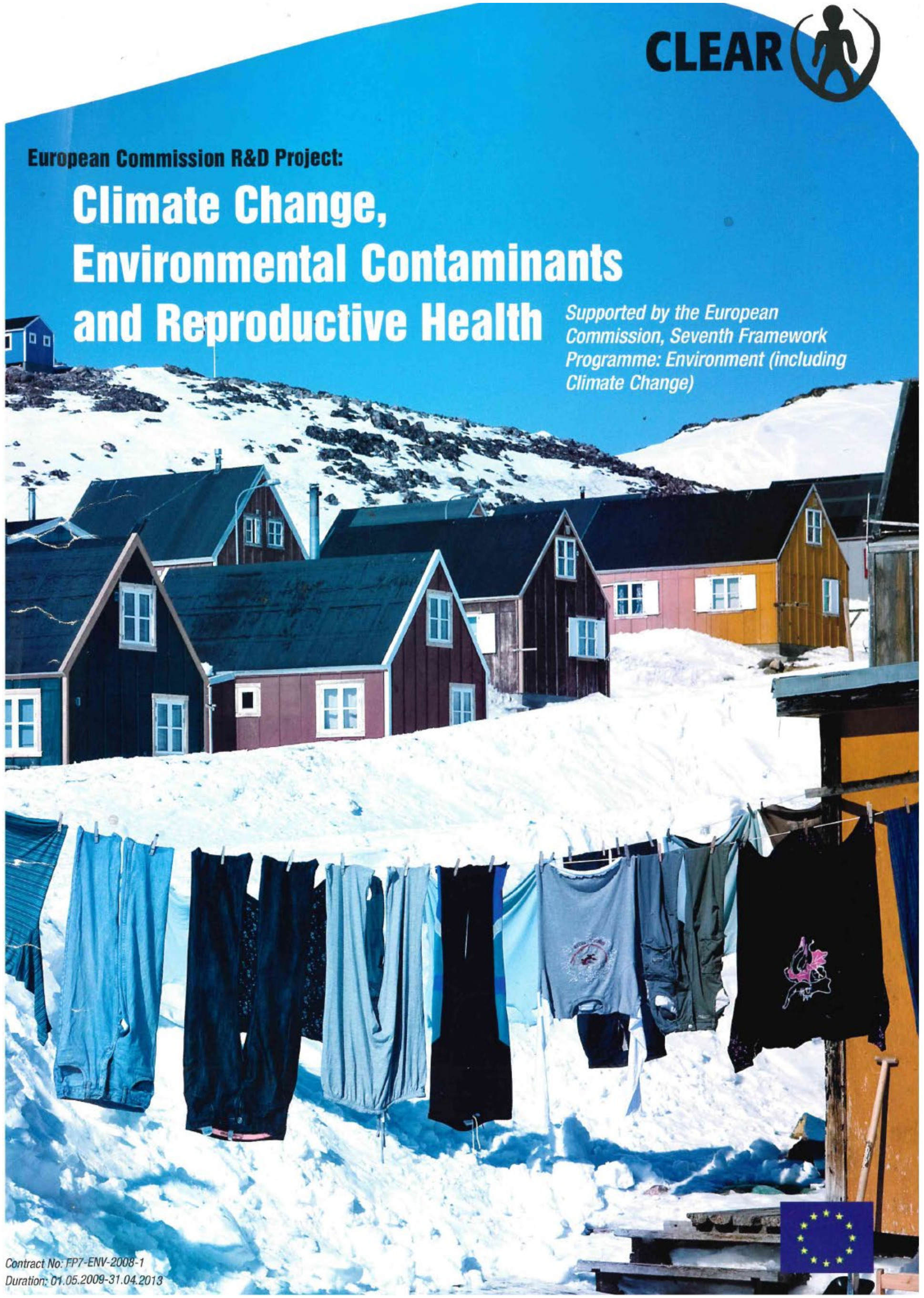
RPT 2: Observing, Reconstructing, and Predicting Future Climate Dynamics and Ecosystem Responses

2025: Fourth (ICARP IV)/Arctic Science Summit Week (ASSW) 2025 in Boulder, Colorado (USA), 20–28 March 2025

2032-33: IPY

ENEA research activities


INUENDO
European Commission R&D Project:
Human Fertility at Risk from Biopersistent Organochlorines in the Environment?
Supported by the European Commision, quality of life and Management of Living Resources, Key action 4 on environment and health
Contract No: QLK4-CT-2001-00202
Duration: 01.01.02 to 30.06.05


CLEAR
European Commission R&D Project:
Climate Change, Environmental Contaminants and Reproductive Health
Supported by the European Commission, Seventh Framework Programme: Environment (including Climate Change)
Contract No: FP7-ENV-2008-1
Duration: 01.05.2009-31.04.2013

2009-2013

Sedimentary processes studies since 1996

Since 1996 the ENEA Marine Environment Research Centre S. Teresa (Lerici, Italy) has been partner of European research programs - "ARMARA" (1996-1999) - "REMOTRANS" (2000-2003) - "CABANERA" (2003-2006) on the topics of:

- ✓ **radioactivity and contaminants in the Arctic marine environment;**
- ✓ **long-term processes of accumulation, dispersion and remobilization of artificial radionuclides released or dumped in the Arctic marine environment.**

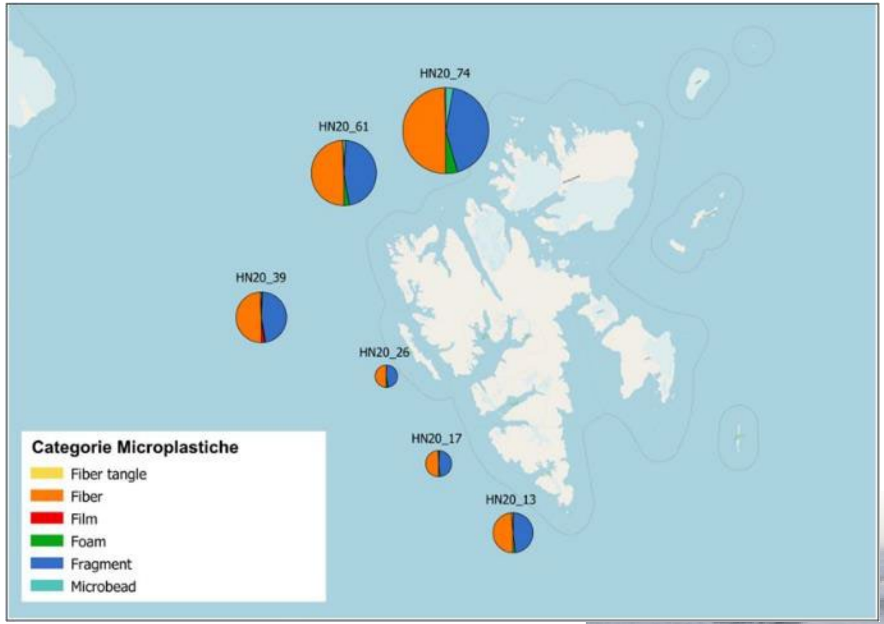
12 oceanographic campaigns in the Svalbard Archipelago were carried out in the period 1996 – 2006 to study sedimentary processes: the role of marine sediments in the dynamics of the radionuclides associated with them.

ENEA ongoing research in the Arctic Ocean

Study of sedimentary processes, contamination and microplastics

Since 2017 ENEA, like other Italian research institutes, joins the High North programme of the Italian Navy.

Sediment cores are collected and analysed to reconstruct the sediments dating and their chemical contamination.



Moreover, the presence of MPs (microplastics) is detected in the surface sea-water and in sea-ice around the Svalbard Archipelago.

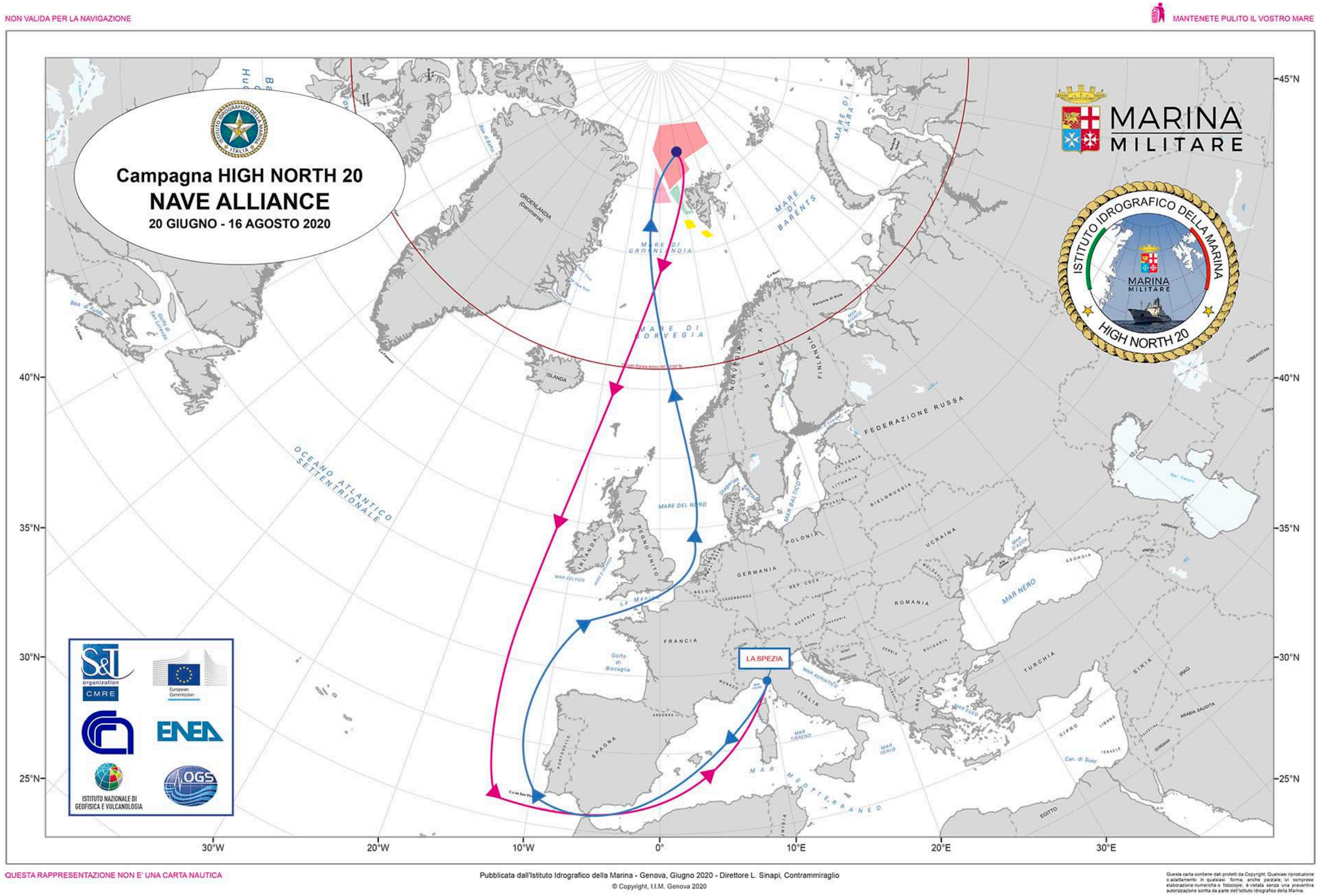
Radioactive tracers and microplastics in the Arctic Ocean

The joint use of **radioactive tracers and indicators (microplastics)** in the marine environment:

- contributes to a better definition of the environmental health of the Arctic Ocean.
- it is a valid tool for the study of sedimentary processes
- defines the time scale of sedimentary records
- allows us to reconstruct the history of contamination and the anthropic pressures in remote areas such as the Arctic Ocean

The data collected will help answer key questions in studies on climate changes:

- ➢ What contaminants are present in sediments?
- ➢ When and how did they arrive in the Arctic?
- ➢ What’s their accumulation rates?



Campagne con lidar a fluorescenza per clorofilla, NUC

Studi sull'ozono Artico con esperimenti su pallone e aereo

31. N. H. Sleep, K. Zahnle, *J. Geophys. Res.* **103**, 28529 (1998).
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22 August 2000; accepted 20 October 2000

Nitric Acid Trihydrate (NAT) in Polar Stratospheric Clouds

Christiane Voigt,[1] Jochen Schreiner,[1] Andreas Kohlmann,[1] Peter Zink,[1] Konrad Mauersberger,[1*] Niels Larsen,[2] Terry Deshler,[3] Chris Kröger,[3] Jim Rosen,[3] Alberto Adriani,[4] Francesco Cairo,[4] Guido Di Donfrancesco,[4] Maurizio Viterbini,[4] Joelle Ovarlez,[5] Henri Ovarlez,[5] Christine David,[6] Andreas Dörnbrack[7]

A comprehensive investigation of polar stratospheric clouds was performed on 25 January 2000 with instruments onboard a balloon gondola flown from Kiruna, Sweden. Cloud layers were repeatedly encountered at altitudes between 20 and 24 kilometers over a wide range of atmospheric temperatures (185 to 197 kelvin). Particle composition analysis showed that a large fraction of the cloud layers was composed of nitric acid trihydrate (NAT) particles, containing water and nitric acid at a molar ratio of 3:1; this confirmed that these long-sought solid crystals exist well above ice formation temperatures. The presence of NAT particles enhances the potential for chlorine activation with subsequent ozone destruction in polar regions, particularly in early and late winter.

Since the early 1980s, the formation of a large ozone hole above Antarctica during southern spring has become a yearly event. Stratospheric air isolated within the polar vortex cools during winter to temperatures that allow the formation of polar stratospheric clouds (PSCs) at altitudes between 15 and 25 km (*1*). The cloud particles provide surfaces for the activation of otherwise relatively unreactive chlorine-containing molecules. Upon the return of sunlight in the spring, regions have shown that many PSCs exist well above the frost point of water, T_{ICE}, the temperature in the stratosphere near 188 K below which ice particles can form (*4–6*). For those PSCs the important role of the trace gas nitric acid (HNO_3) has been recognized. Early atmospheric models predicted the formation of solid nitric acid hydrate crystals at temperatures above T_{ICE} (*7, 8*). Laboratory studies revealed that nitric acid trihydrate (NAT, $HNO_3 \cdot 3H_2O$) and is only possible through the formation of crystalline PSC particles. Despite their importance, no direct chemical analysis of NAT particles in the stratosphere has been made, although they have been identified in many laboratory studies (*9, 13*) and inferred from atmospheric measurements (*6*).

In January 1998, a direct particle composition measurement was performed in lee wave–induced PSCs above Scandinavia (*14–16*). STS droplets containing water, nitric acid, and sulfuric acid were observed. As expected from STS theory, a close correlation between low atmospheric temperatures and the presence of PSCs was found. A more comprehensive set of instruments to investigate chemical, physical, and optical properties of PSCs was launched at 20 UT (universal time) on 25 January 2000 from the balloon facility Esrange, near Kiruna, Sweden. The crucial instrument on both flights was an aerosol composition mass spectrometer (ACMS) that uses an aerodynamic lens to focus particles into a narrow beam (*17*) and separates them from ambient gases. The particles are then evaporated inside a small sphere, and the evolving gases are analyzed with a mass spectrometer. Simultaneous measurements of particle number density and size were performed with particle counters (*18, 19*). Backscatter ratios and depolarization were measured with two backscatter sondes (*20, 21*). A water vapor experiment determined the frost point T_{ICE} (*22*). A number of sensors measured the ambi-

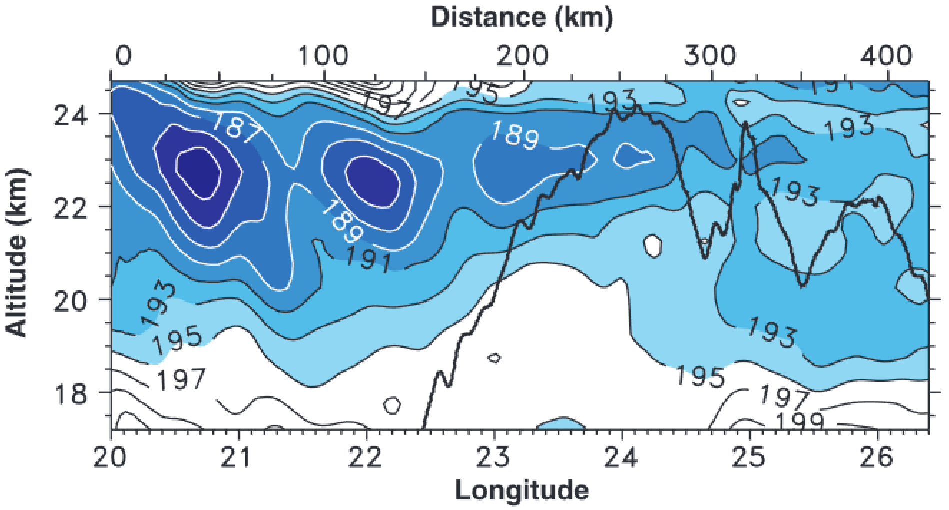


Fig. 1. Simulated temperatures (kelvin) during the balloon flight on 25 January 2000 at 22 UT, using the mesoscale MM5 model (*23*). The mesoscale simulation with 2.6 km horizontal grid size, initialized on 25 January 2000 at 6 UT, was forced by global analysis at 0.5° × 0.5° resolution by the European Center for Medium Range Weather Forecast (ECMWF). The balloon trajectory shows the ascents and descents during the 2-hour time period when measurements were taken, which started and ended at 20-km altitude. The air parcels encountered by the balloon had previously experienced very low temperatures above the Scandinavian mountains. The balloon launch was near Kiruna at 21.1° longitude.

Kvitøya
NORDAUSTLANDET
SPITSBERGEN
Ny-Ålesund
Longyearbyen
Kong Karls Land
Barentsøya
Edgeøya
GREENLAND SEA
BARENTS SEA
NORWEGIAN SEA
Hopen
© Norwegian Polar Institute

PROGRAMMA DI RICERCHE **IN ARTICO**

Small MICROplastics (<100 µm) bioindicaToRs in the changing ArctiC EnviRonment (MICROTRACER) (PRA21_0005)

THE RESEARCH TEAM

Research Unit 1- CNR-ISP (Messina and Venice): *Gabriella Caruso (Principal Investigator), Fabiana Corami (RU Leader), Giulia Vitale (on site), Massimiliano Vardè (on site), Beatrice Rosso, Elena Gregoris*

Research Unit 2- University of Padua: *Sara Bogialli (RU Leader), Lucio Litti*

Research Unit 3- ENEA: *Valentina Iannilli (RU Leader), Claudia Trotta, Francesca Lecce*

Research Unit 4- Sapienza, University of Rome: *Marco Oliverio (RU Leader), Andrea Setini*

THE BUDGET

MICROTRACER has been funded with 95.953,60 Euro for 24 months

AIMS

MICROTRACER focuses on plastic pollution, an emerging threat for Svalbard region. An innovative multi-disciplinary research approach is applied, covering chemical, microbiological and zoological features.

Research Plan Workflow

WP1
- Coordination

WP2
- Sampling of biota and sediments

WP3
- Sorting of small MPs and NPs in biota and sediments

WP4
- Analysis of MPs-associated microbiota and pathogens

WP5
- Chemical characterization of biota and sediments and of pollutants on MPs

WP6
- Biomarkers application and molecular pathways (Coord. ENEA)

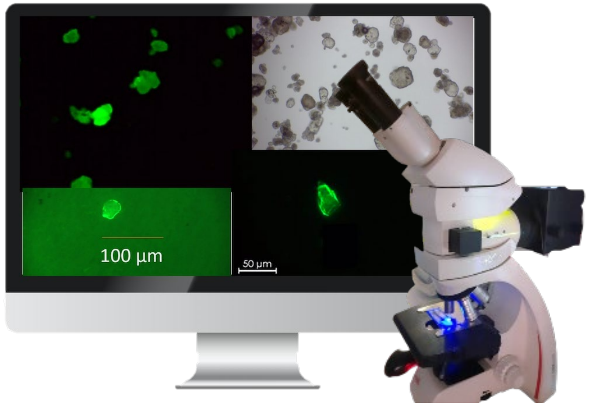
WP7 Dissemination

RESEARCH IN SVALBARD (RIS): RIS 11919 (https://www.researchinsvalbard.no/project/f6e50000-7757-d25d-4af6-08d9e43b4340/project-info).

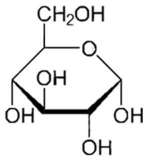
Amphipod species found at sampling sites

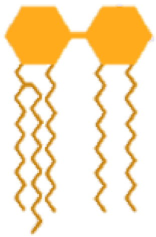
Quantitative Analysis of Microplastic Ingestion in *Gammarus setosus*: Particle Size, Distribution, and Biochemical Effects

Study Species: *Gammarus setosus*, collected from all sampling sites
Methodology: Digestive tracts dissected, treated with H_2O_2, and stained with Nile red
Observation: Samples observed under fluorescence microscopy
Findings: 350-400 microplastics ingested per individual, with a slight increase in individuals from Ny Ålesund
Particle Size: 99% of particles are smaller than 50 µm, with an average size of 10 µm, and a low percentage of fibers (2-6%).

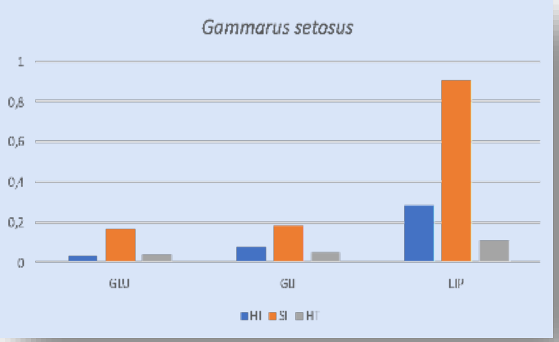


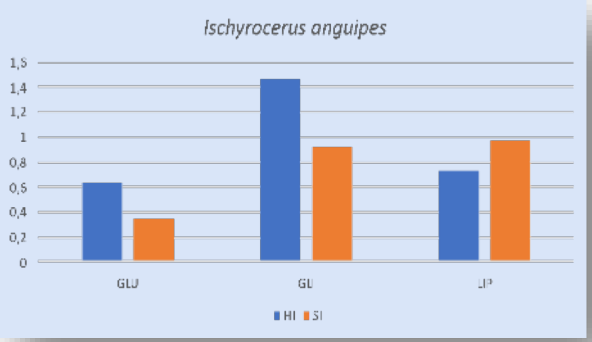
Analyze the effects of microplastics on amphipods

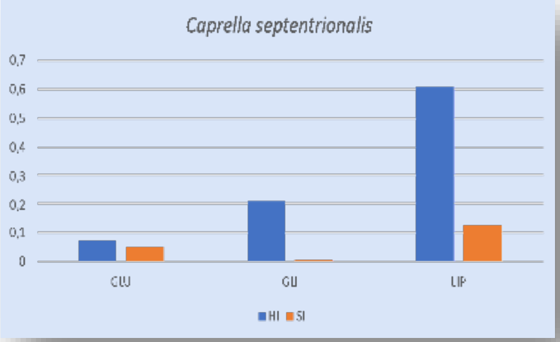




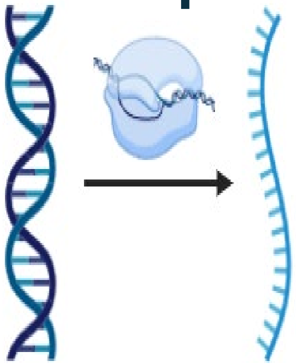
Biomarkers Examined: Proteins, Glucose, Glycogen, SOD, Glutathione
Biological Descriptors: Biochemical composition, energy allocation, antioxidants, and detoxifying agents
Final Evaluation: Identify a correlation between microplastic ingestion and observed biochemical effects







Investigate Molecular Pathways Affected by Microplastic Exposure



Species Studied: *Gammarus setosus*

- Approach: transcriptomic response evaluation
- Performed: complete RNA Sequencing
- Current Status: transcriptomic analysis underway

Challenges:

- no reference genomes available
- Approach: *de novo* transcriptome assembly
- Next Steps: Align individual samples using the assembled transcriptome

The impact of sea ice diSappearance on highEr North aTlantic clImate and atmospheric bromiNe and mErcury cycLes (SENTINEL)
Arctic Research Program (PRA) call 2018

ISP Istituto di Scienze Polari
Consiglio Nazionale delle Ricerche

PRA
PROGRAMMA DI RICERCHE IN ARTICO

ENEA

VENETIARUM UNIVERSITAS IN DOMO FOSCARI

CNR ISAC

The project is funded for 36 months from 22/07/2021 – extended until 20/01/2024. The total budget is € 178,750.00 with € 143,000.00 financed by the CNR and €35,750.00 in co-financing from the proposing institutions.

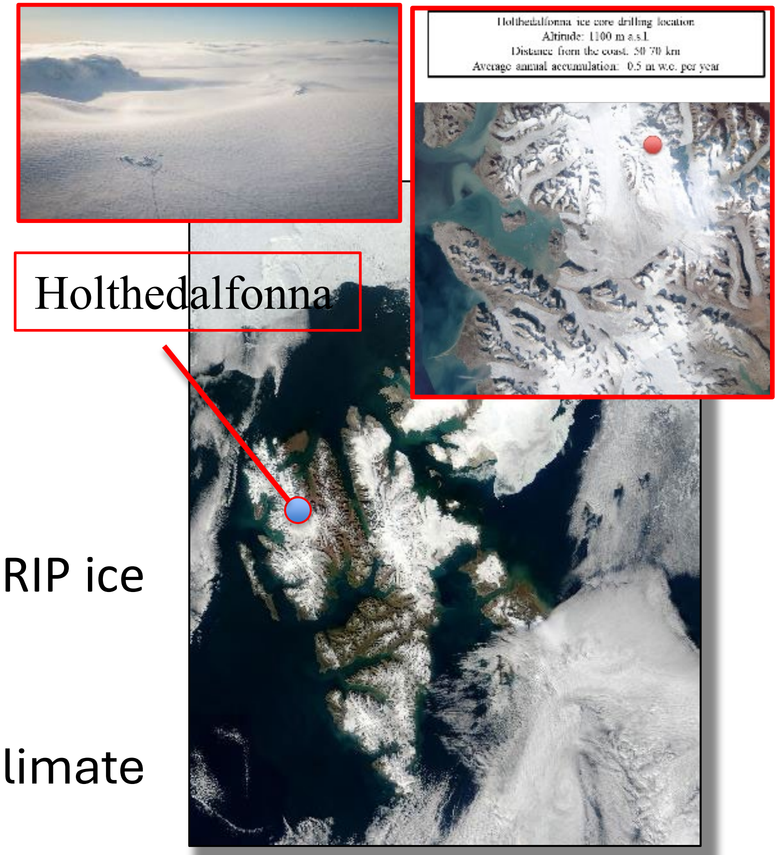
The ***main objectives*** of SENTINEL are to evaluate the impact of the sea ice retreat on:

- regional climate and the water vapor cycle
- the biogeochemical cycle of bromine and consequently on those of mercury and ozone.

To demonstrate that sea ice ***strongly impacts*** also atmospheric chemical processes such as the ozone, bromine and mercury atmospheric cycles.

Photos: Riccardo Selvatico, ISP-CNR

*disappearance of sea ice in the **Barents Sea** and the changing sea ice conditions in the **Fram Strait** impact heat exchanges between the sea surface and the atmosphere. These in turn could affect mercury deposition rates and the ozone atmospheric lifetime through changes in the amount of bromine radicals released from the first sea ice surface.*



- water stable isotopes from 2 ice cores (Holthedalfonna, Svalbard and EGRIP ice core, Greeenland) as a fingerprint of air mass sources

- climate model simulations and atmospheric re-analysis to evaluate the climate impact of sea ice disappearance on the two Arctic basins

ENEA contribution:

1. ***characterization of the precipitation (quantities, main spatial patterns and spatio/temporal variability) using model outputs and experimental data when available.***

2. ***Calculatinon of the main pathways of the air masses related to precipitation events from their origin to the deposition site to understand moisture source areas.***

Photos: Riccardo Selvatico, ISP-CNR

The Thule High Arctic Atmospheric Observatory

THAAO (76.52° N, 68.76° W, 220 m amsl) within the Pituffik Space Base.

MODIS Terra true color image
(https://worldview.earthdata.nasa.gov)

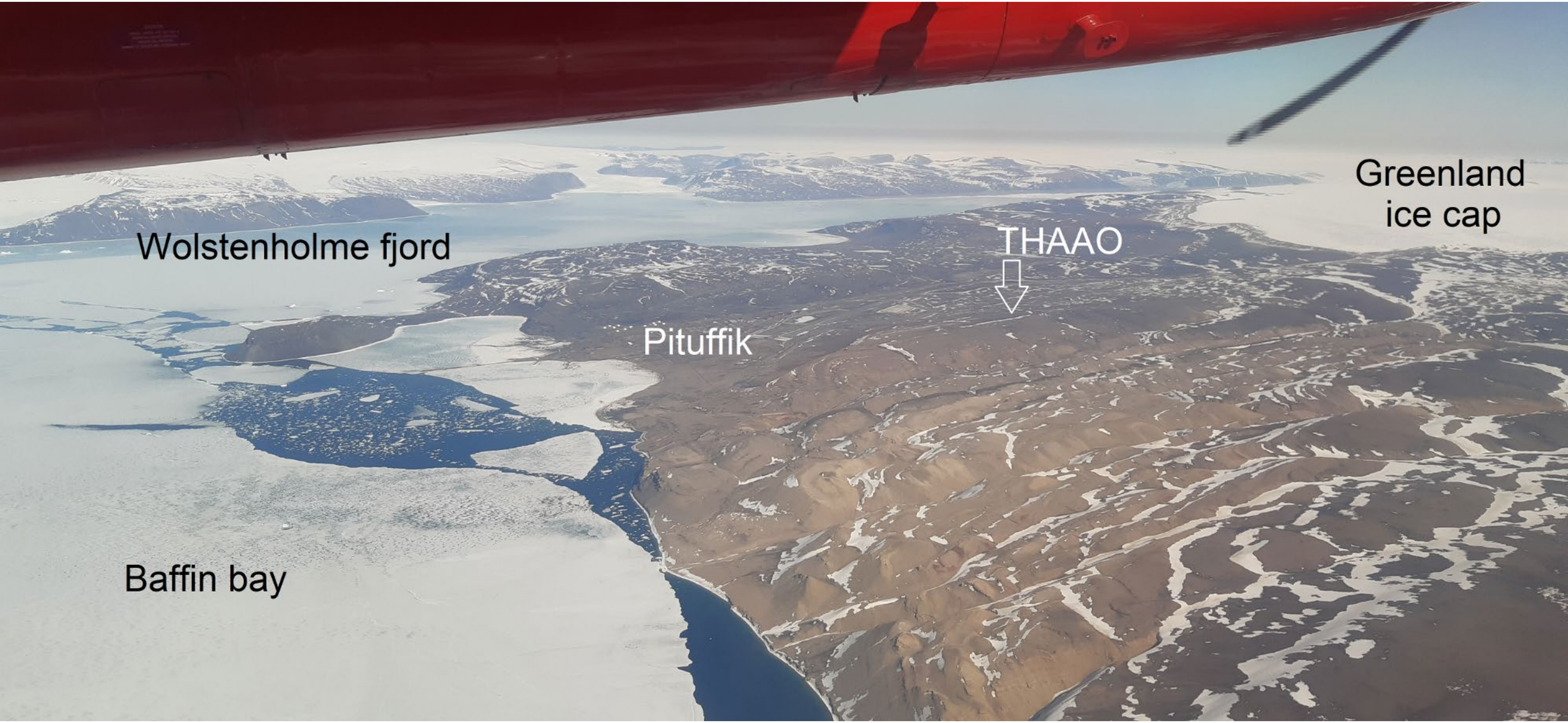
ARCSIX
Arctic Radiation-Cloud-Aerosol-Surface Interaction Experiment

YOPP
YEAR OF
POLAR
PREDICTION

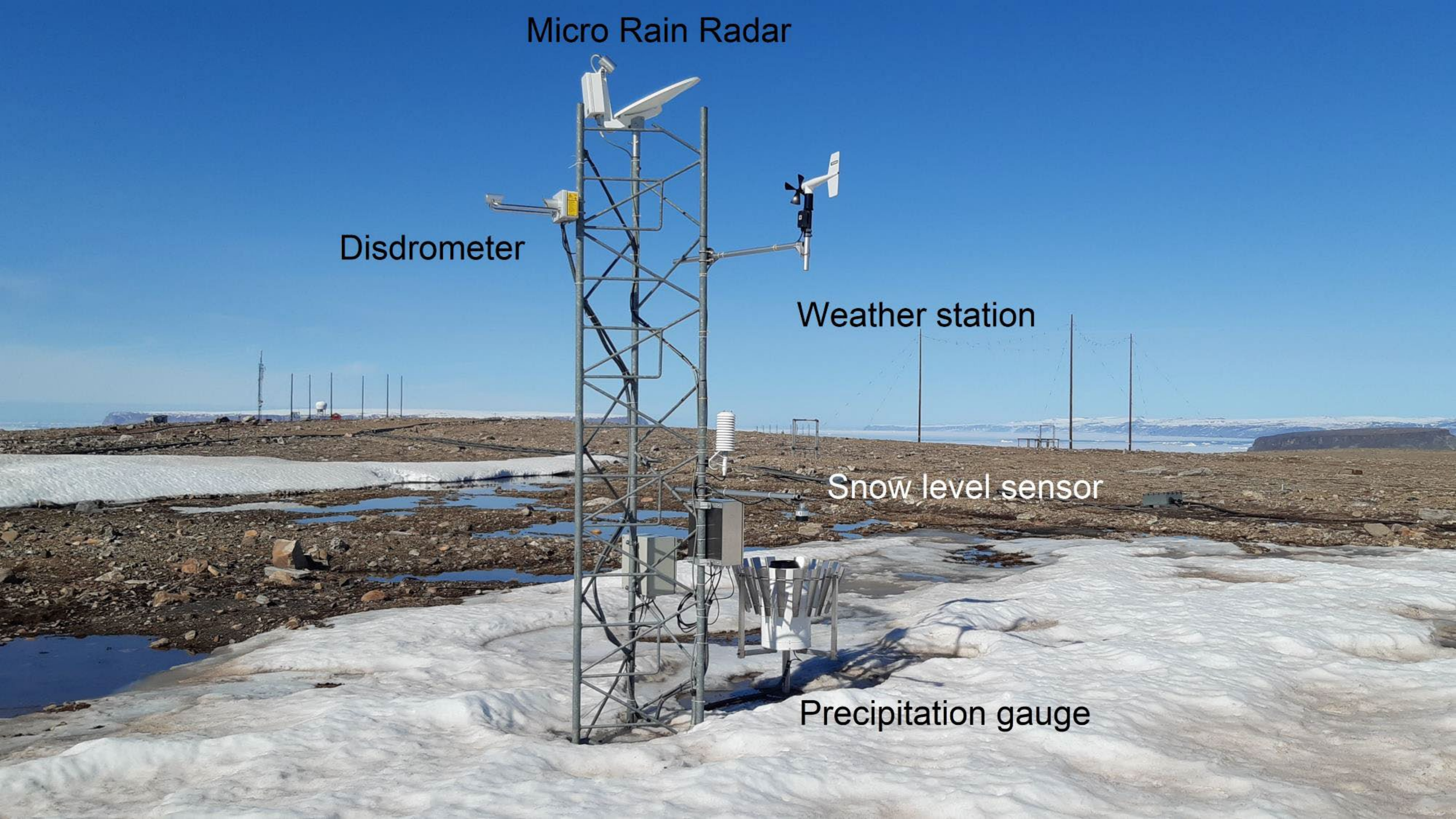
SEANA
Shipping Emissions in the Arctic and North Atlantic atmosphere

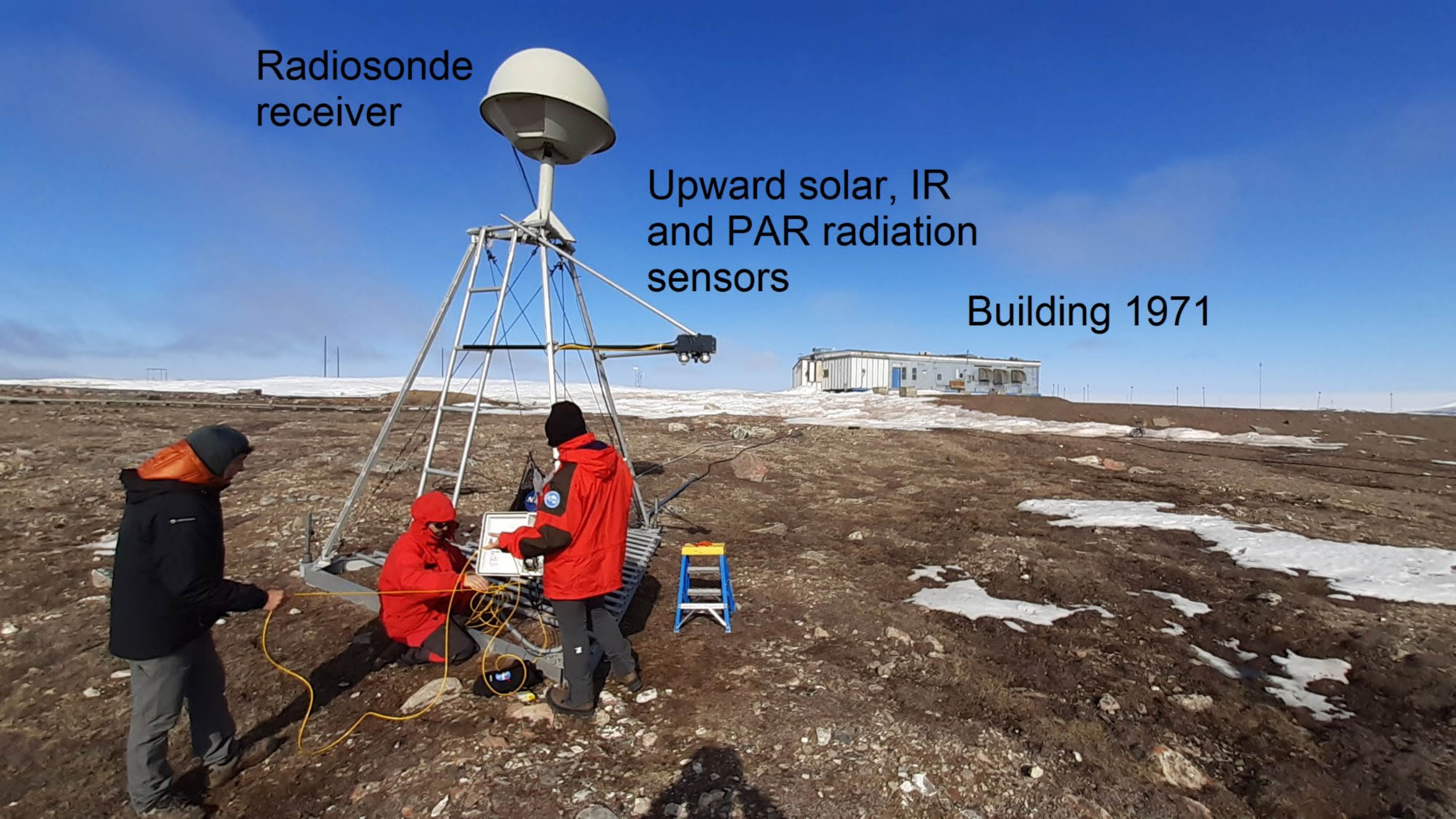
ECAPAC

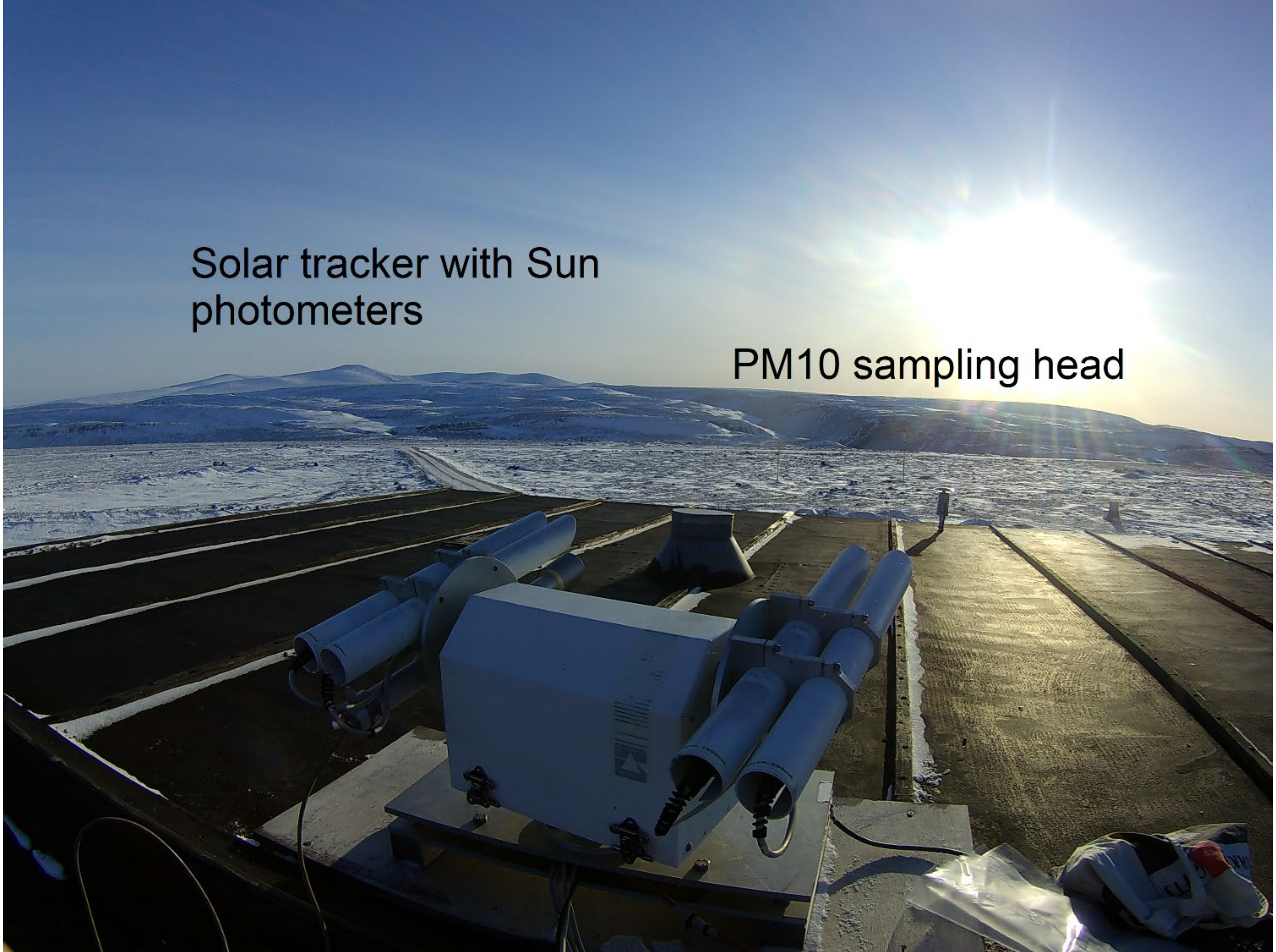
https://www.thuleatmos-it.it

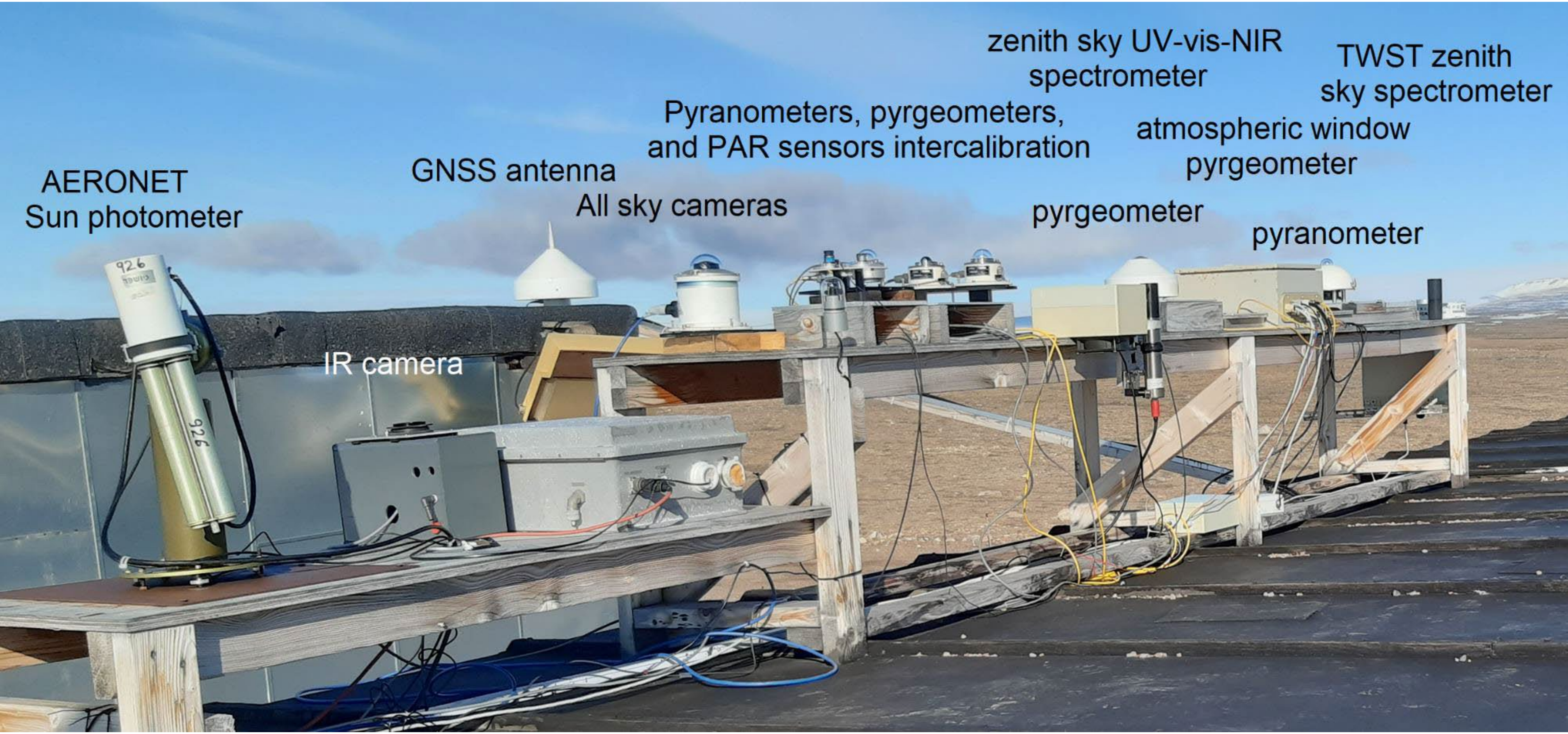

Greenland
ice cap
Wolstenholme fjord
THAAO
Pituffik
Baffin bay


Building 1971 with
active/passive radiation sensors,
PM samplers, spectrometers, ...
Balloon house
for radiosonde
launches
MRR-2
Disdrometer
Weather station
Snow level sensor
Precipitation gauge

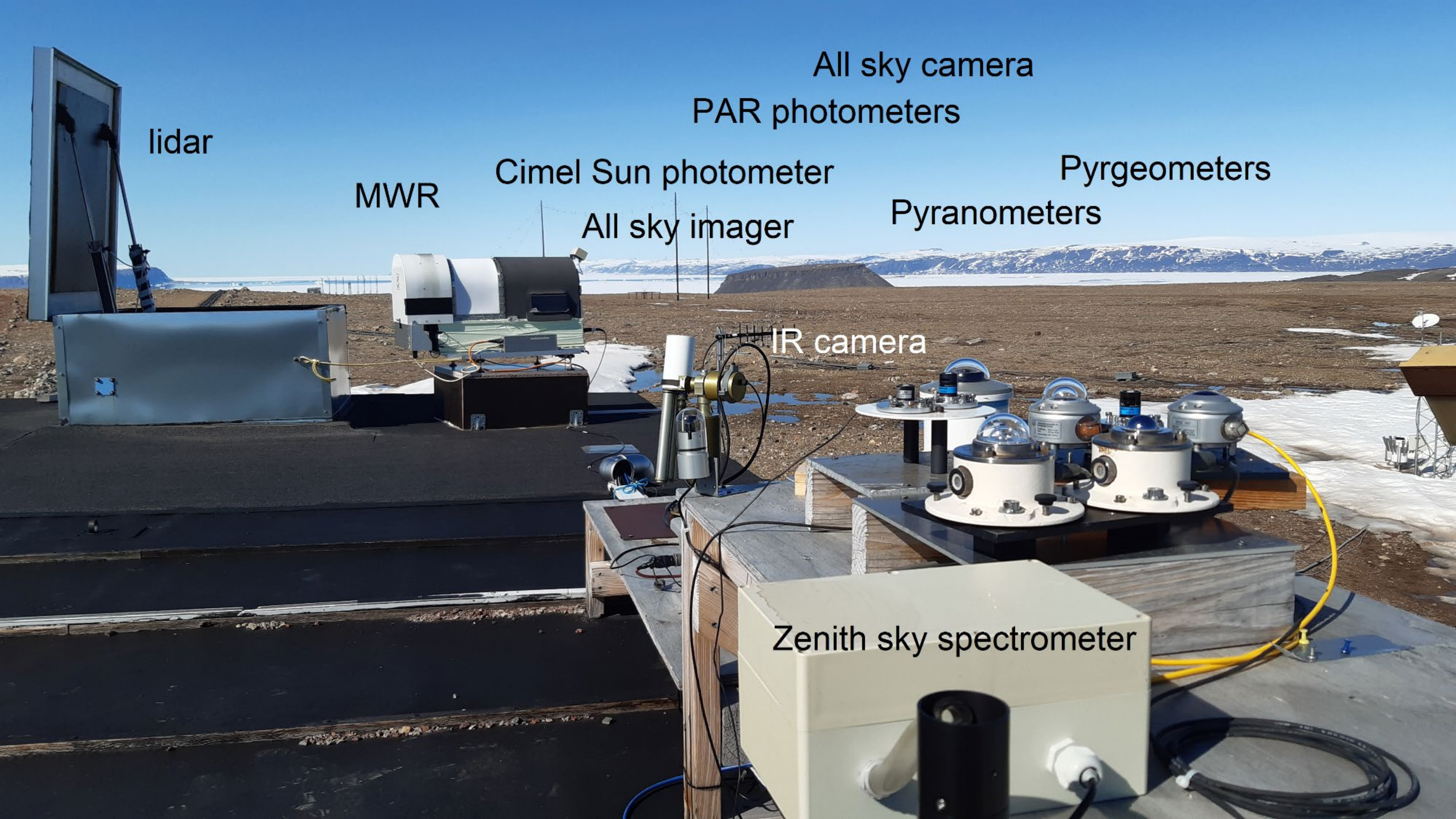

Micro Rain Radar
Disdrometer
Weather station
Snow level sensor
Precipitation gauge


Radiosonde
receiver
Upward solar, IR
and PAR radiation
sensors
Building 1971


Solar tracker with Sun photometers
PM10 sampling head


AERONET
Sun photometer
GNSS antenna
All sky cameras
IR camera
Pyranometers, pyrgeometers,
and PAR sensors intercalibration
zenith sky UV-vis-NIR
spectrometer
TWST zenith
sky spectrometer
atmospheric window
pyrgeometer
pyrgeometer
pyranometer
926


Lidar
MicroWave Radiometer
All sky cameras
AERONET
Zenith IR pyrometer
Solar, IR, PAR radiometers
Zenith UV-vis-NIR spectrometers
AERODYNE RESEARCH, Inc.
Cloud Properties Spectroradiometer


All sky camera
PAR photometers
lidar
Cimel Sun photometer
Pyrgeometers
MWR
All sky imager
Pyranometers
IR camera
Zenith sky spectrometer


AERONET
MWR
Lidar hatch
22 GHz
water vapour
spectrometer
Ceilometer

di Sarra et al., 1998

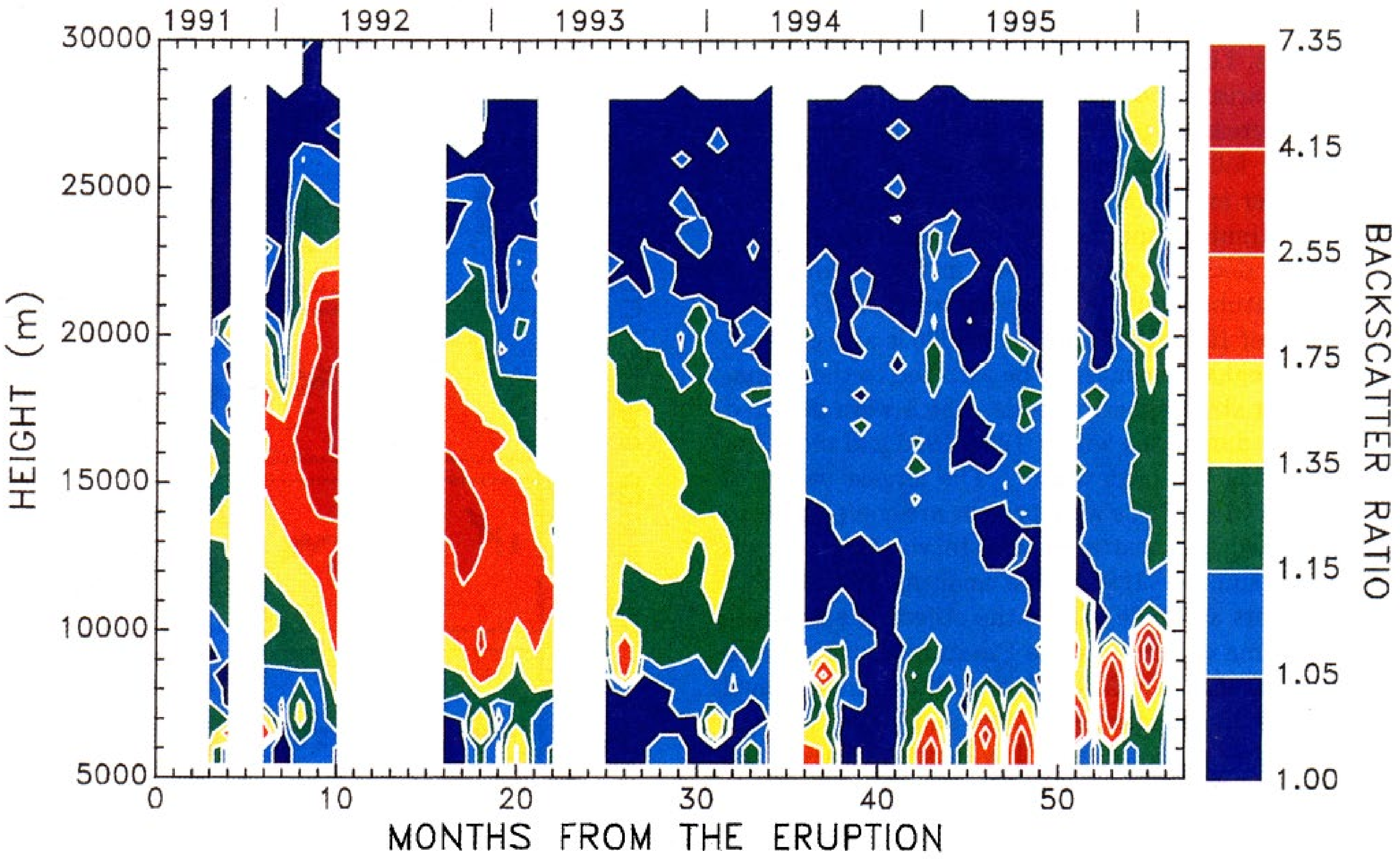
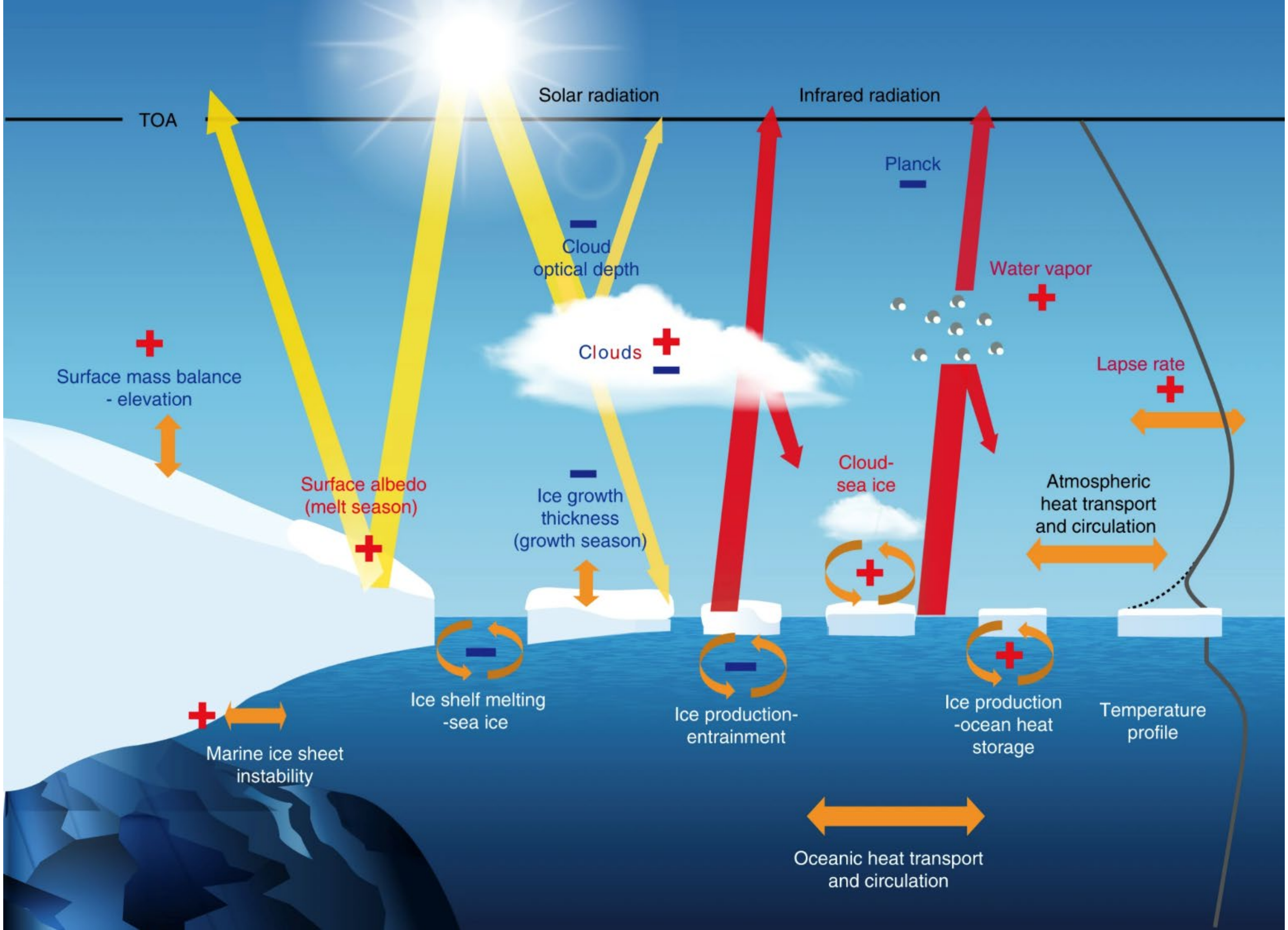
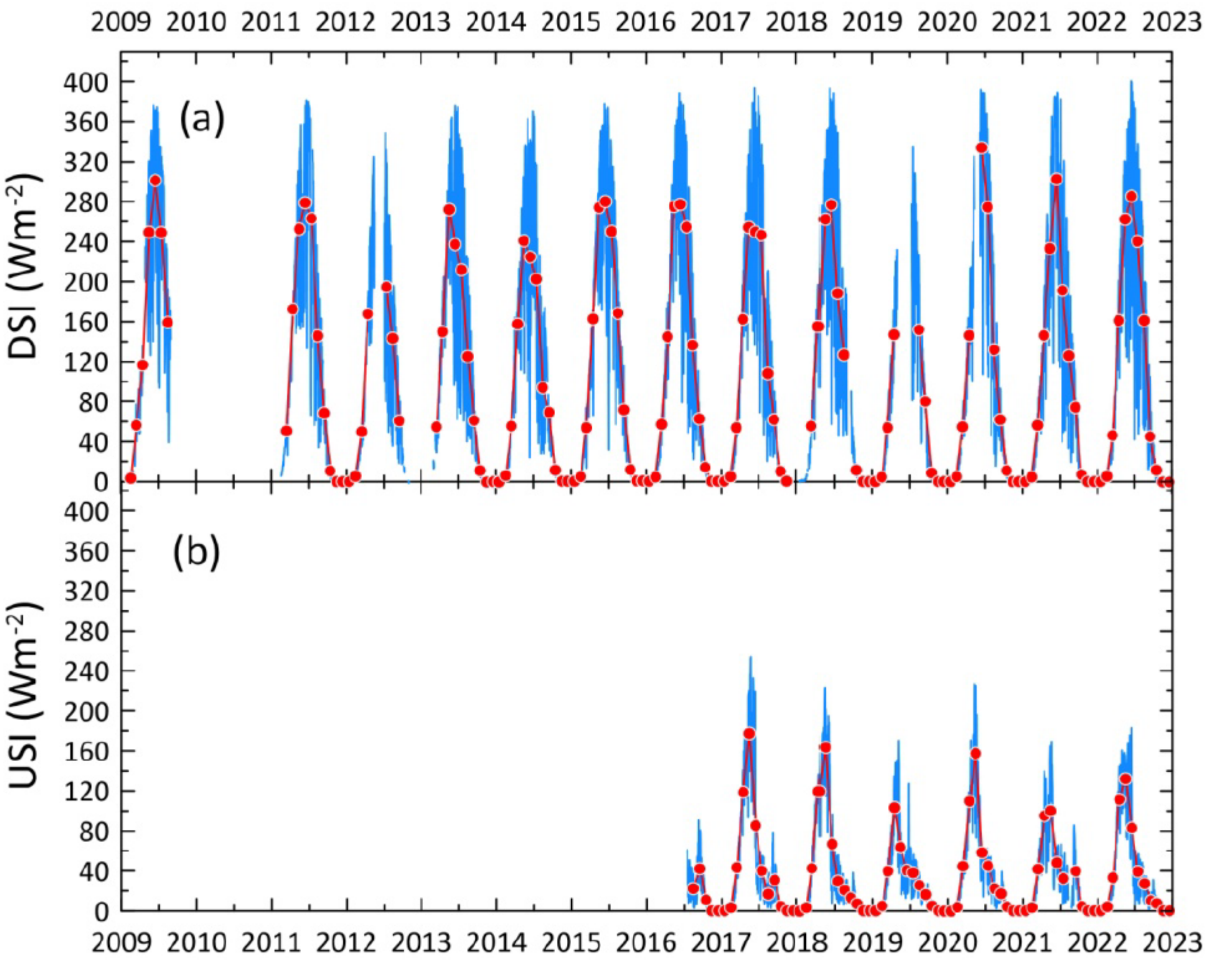
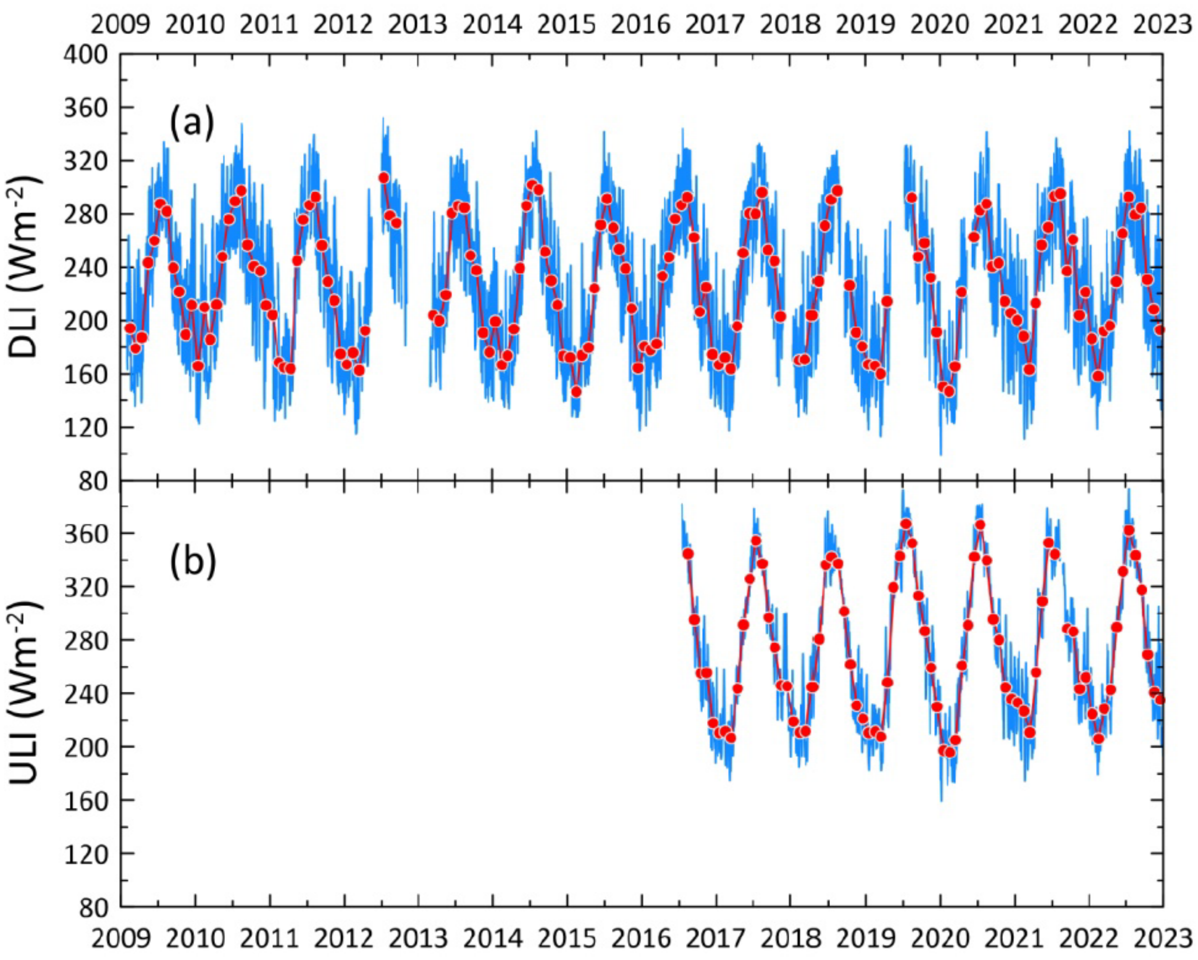


Plate 1. Backscatter ratio as a function of height and time between September 1991 and February 1996. The contour plot is obtained from monthly average profiles.



Solar radiation
Infrared radiation
TOA
Planck
Cloud
optical depth
Water vapor
Clouds
Surface mass balance
- elevation
Lapse rate
Surface albedo
(melt season)
Ice growth
thickness
(growth season)
Cloud-
sea ice
Atmospheric
heat transport
and circulation
Ice shelf melting
-sea ice
Ice production-
entrainment
Ice production
-ocean heat
storage
Temperature
profile
Marine ice sheet
instability
Oceanic heat transport
and circulation





Meloni et al., 2024

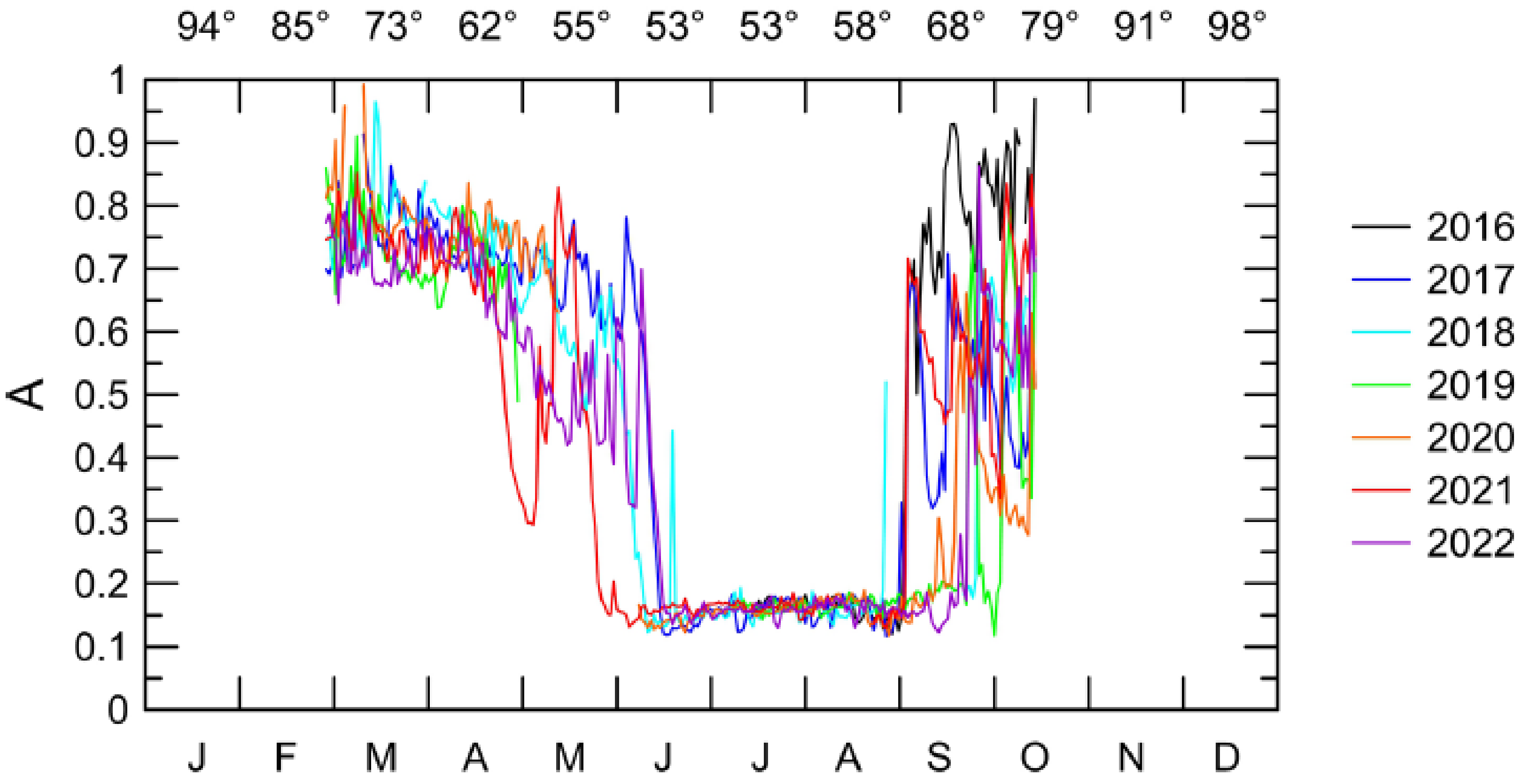
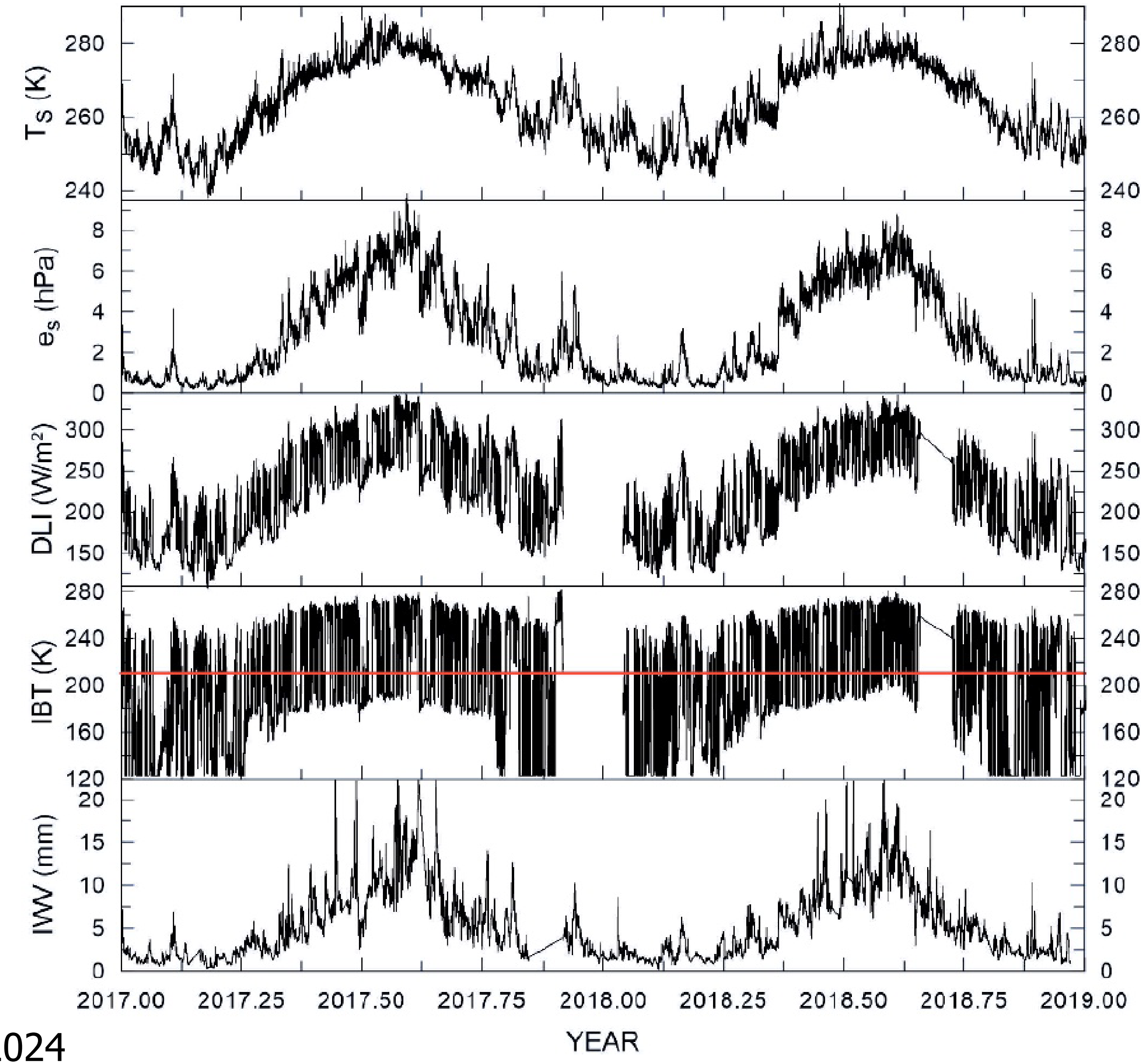


Figure 11. Annual evolution of the daily average surface albedo values from 2016 to 2022. The upper x axis indicates the minimum SZA for each month.

Meloni et al., 2024



Pace et al., 2024

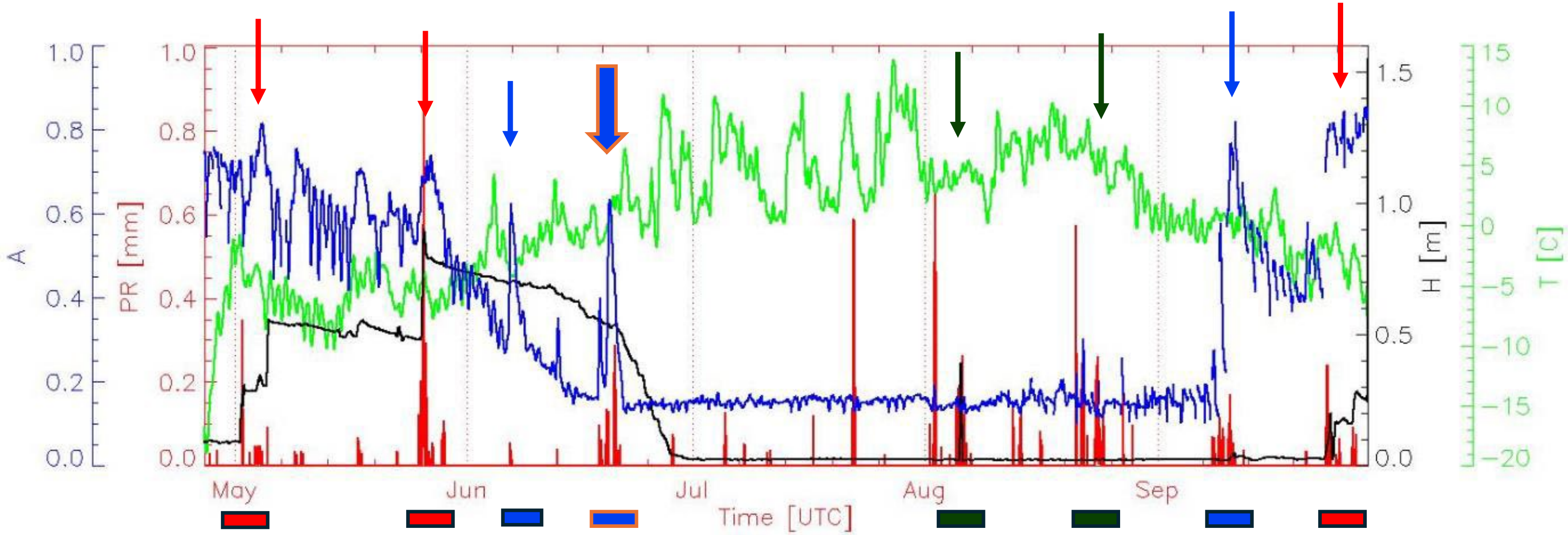
2023

ECAPAC

T<0; PR solida (H cresce); 0.6<A<0.9, terreno con neve o ghiaccio

periodi di transizione; forti variazioni di A; PR mista

T>0; PR liquida (H~0); A < 0.2 (terreno scoperto)

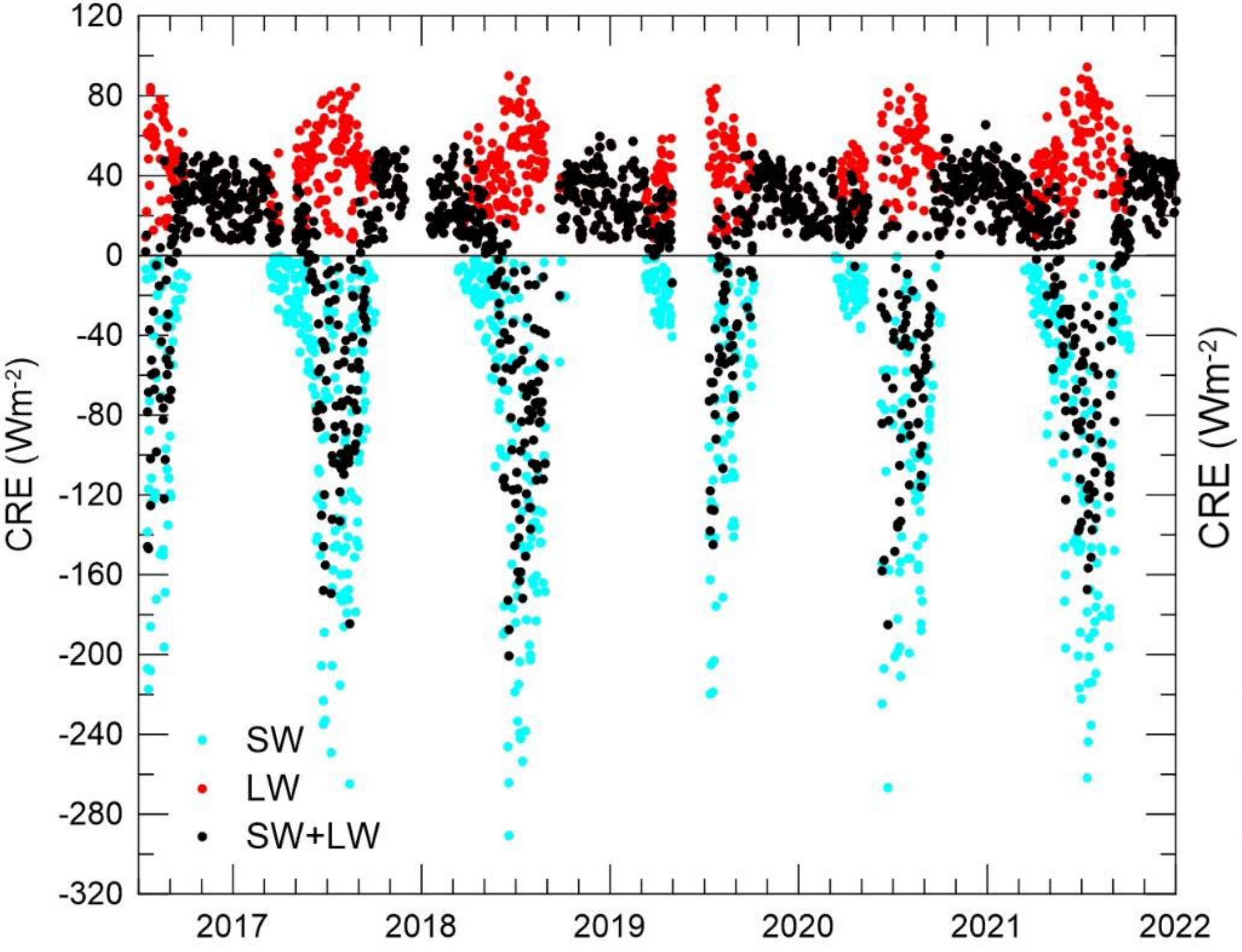


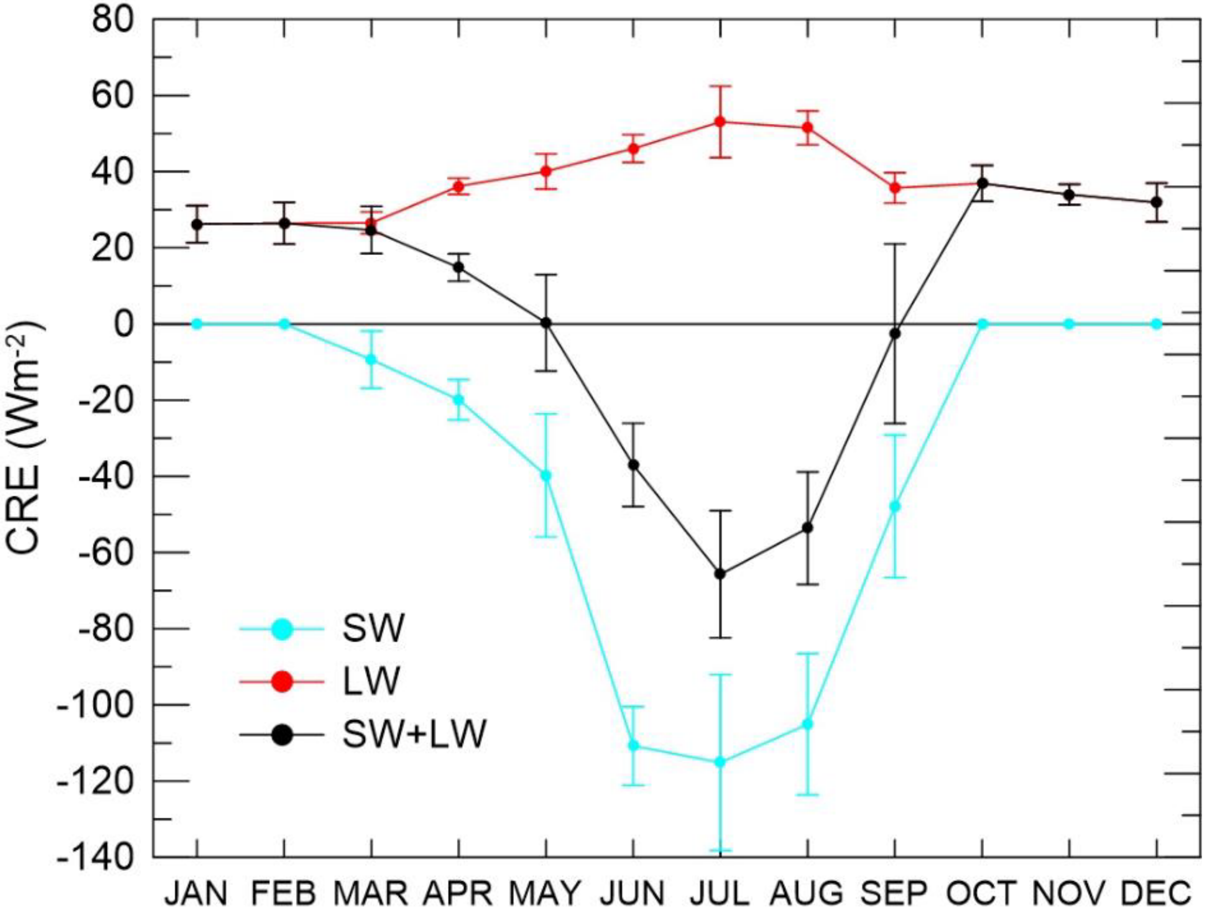
Serie temporale della media a 5 minuti della precipitazione (PR, in rosso), dell'albedo superficiale (A, in blu), dell'altezza del manto nevoso (H, in nero) e della temperatura (T, in verde). Sono evidenziate (frecce e barre) le principali variazione di albedo.

Ciardini et al., in preparation

Clouds radiative effect

$$CRE = NET_{all\text{-}sky} - NET_{cloud\text{-}free}$$





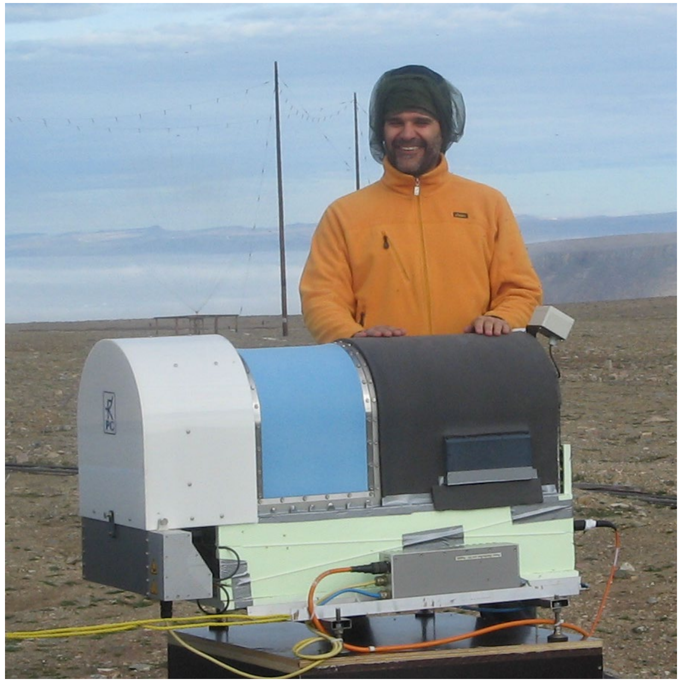
Meloni et al., in preparation

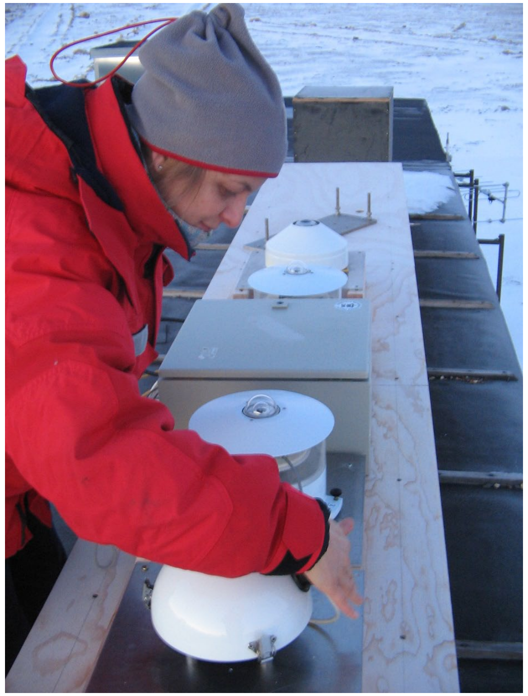
Grandi campagne internazionali

MOSAIC (Multidisciplinary drifting Observatory for the Study of Arctic Climate), 2019-2020, 140 M€
ArcSix (Arctic Radiation-Cloud-Aerosol-Surface Interaction Experiment), 2024, 15 M$

SSPT-CLIMAR-AOC

Colleghi ENEA + studenti, collaborazioni con INGV, Univ. Sapienza di Roma, Univ. Firenze, Univ. Valencia, etc.





Conclusioni

La regione Artica gioca un ruolo chiave nel sistema climatico terrestre; le variaizoni in corso sono le più ampie riscontrabili sul pianeta

Lo studio dei cambiamenti in Artide e dei meccanismi connessi è fondamentale per capire il funzionamento del clima della terra

Per comprendere questi meccanismi sono necessarie misure di lungo periodo ed esperimenti intensivi che permettano di seguire l’evoluzione del sistema e determinare il funzionamento dei vari processi in atto

E’ fondamentale mantenere attivi i pochi siti osservativi esistenti e garantire misure di qualità su lungo periodo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Grazie!