

Die Polarregionen im Klimawandel

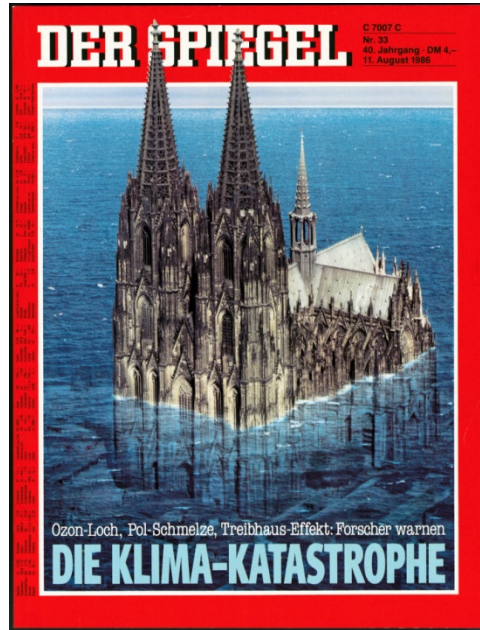
Heinrich Miller

Alfred-Wegener-Institut Helmholtz Zentrum für Polar- und Meeresforschung

1979



1986



1995



1997



1997

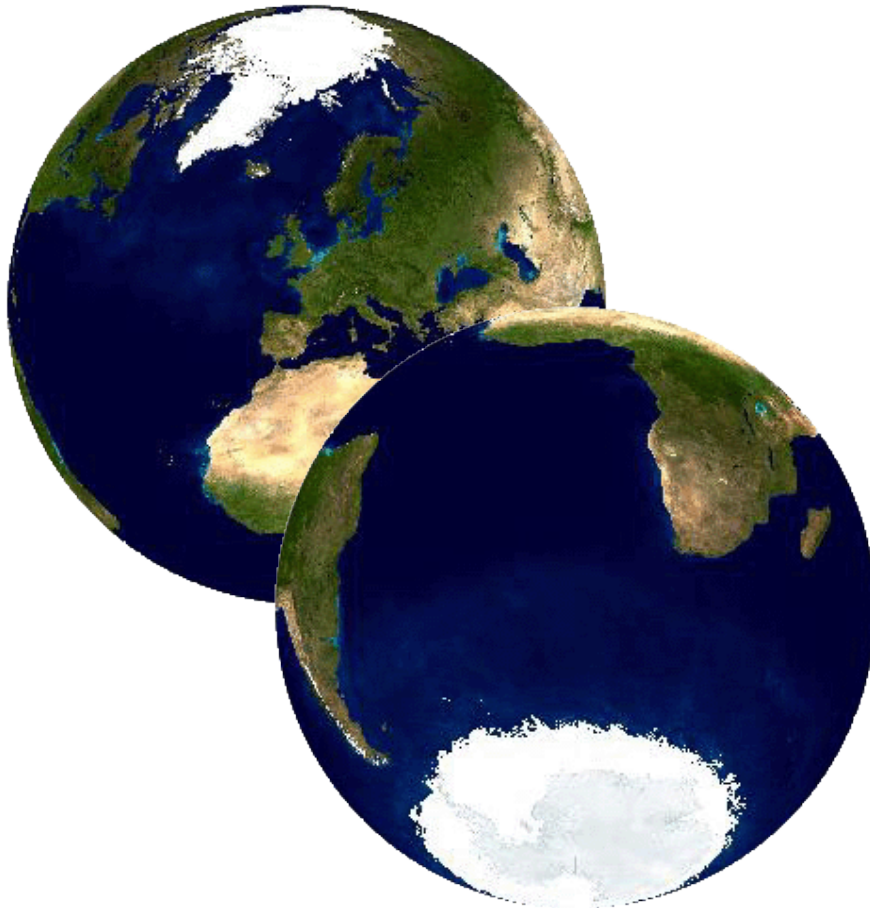


1999



2002





Polare Regionen

Treiben die globale Klimaentwicklung und reagieren darauf

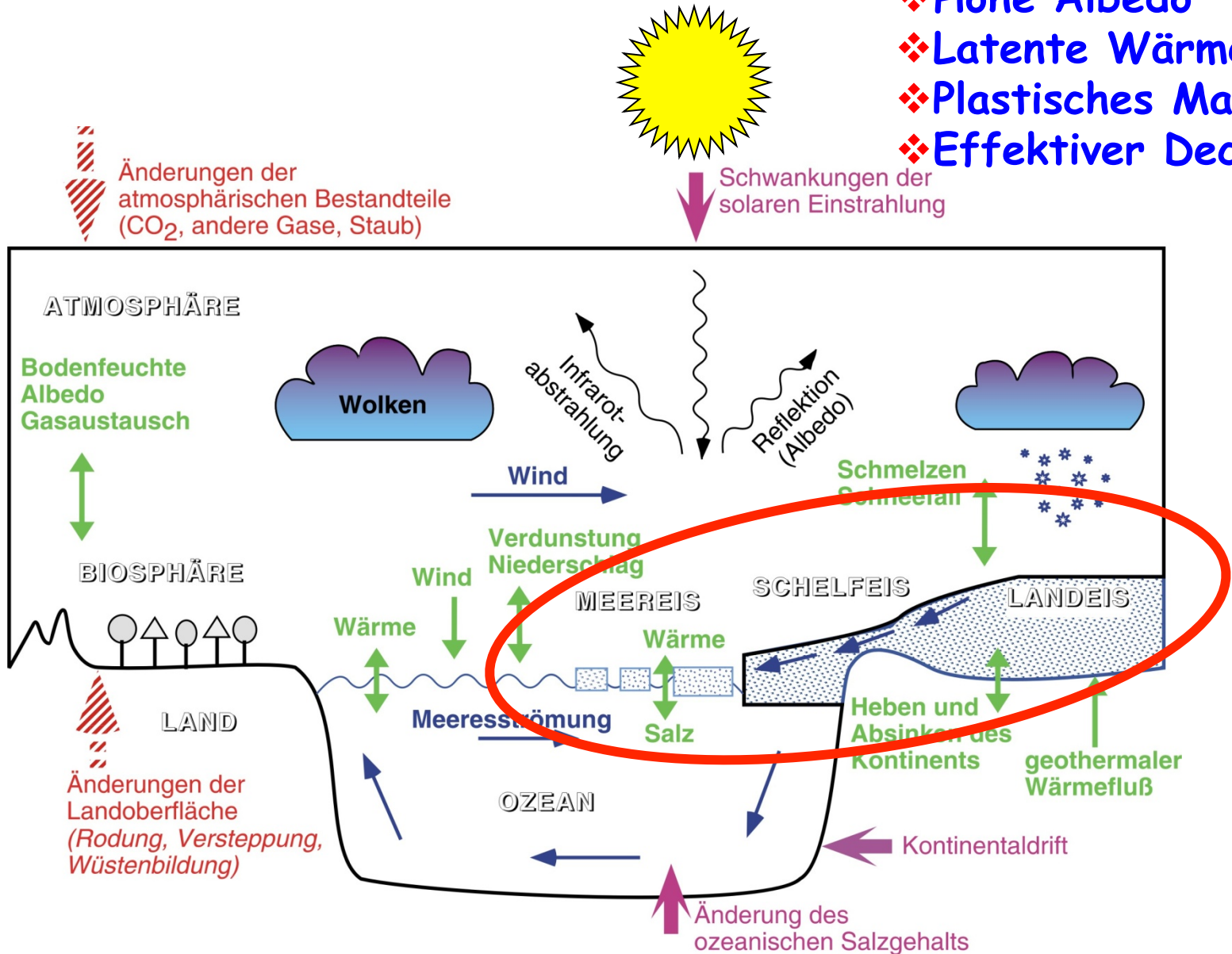
Sie sind Frühwarnsysteme für künftige Veränderungen

Ihre Eismassen beeinflussen den Meeresspiegel und stellen ein herausragendes Klimaarchiv dar

Ihre Ökosysteme sind spezifisch angepaßt.

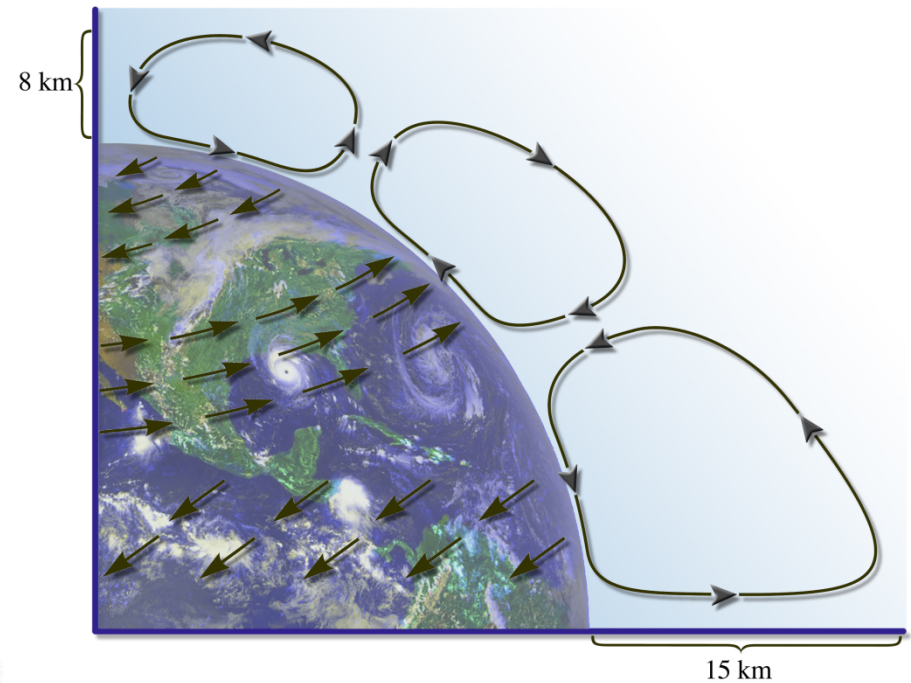
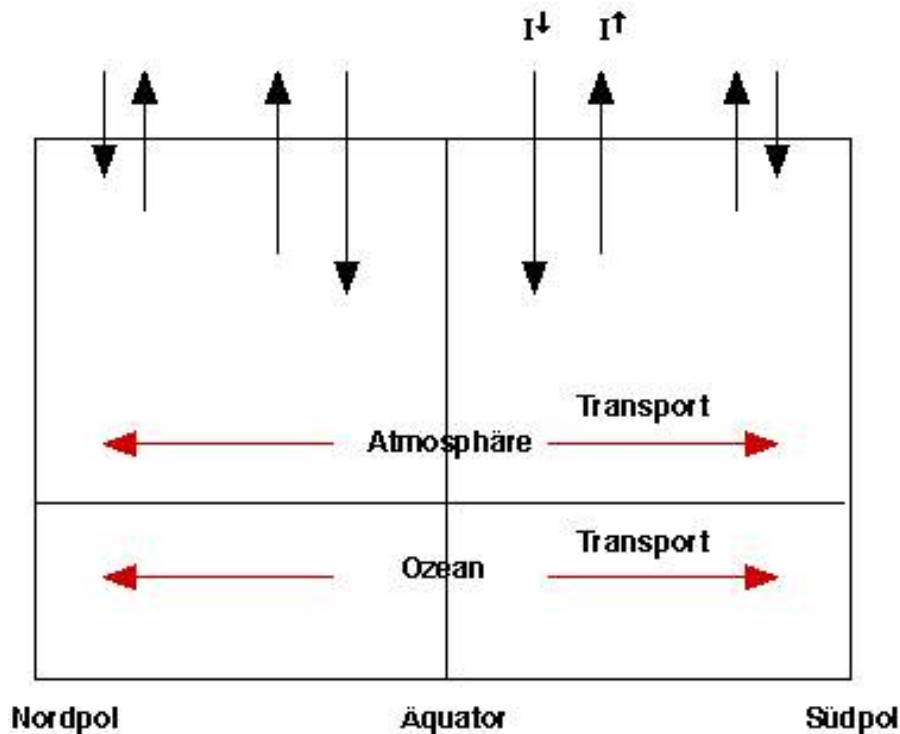
Klimasystem

- ❖ Hohe Albedo
- ❖ Latente Wärme
- ❖ Plastisches Material
- ❖ Effektiver Deckel



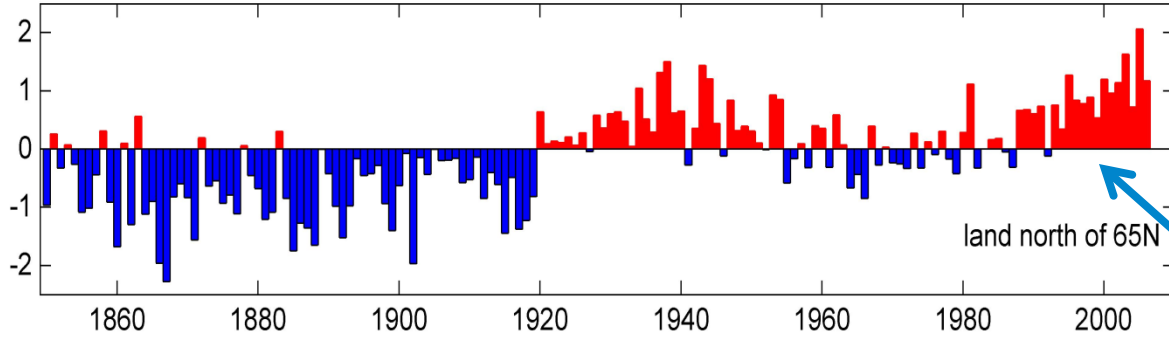
Polargebiete \Leftrightarrow Globales Klima

- ❖ Niedere Breiten sind Energie-Kollektoren
- ❖ Hohe Breiten sind Energie-Radiatoren
- ❖ Ausgleich durch Energietransport in Ozean und Atmosphäre
- ❖ Energietransport wird durch Temperaturgegensätze Äquator - Pol gesteuert



Temperaturen in den Polargebieten

Surface Air Temperature Anomalies (w.r.t. 1961-1990)



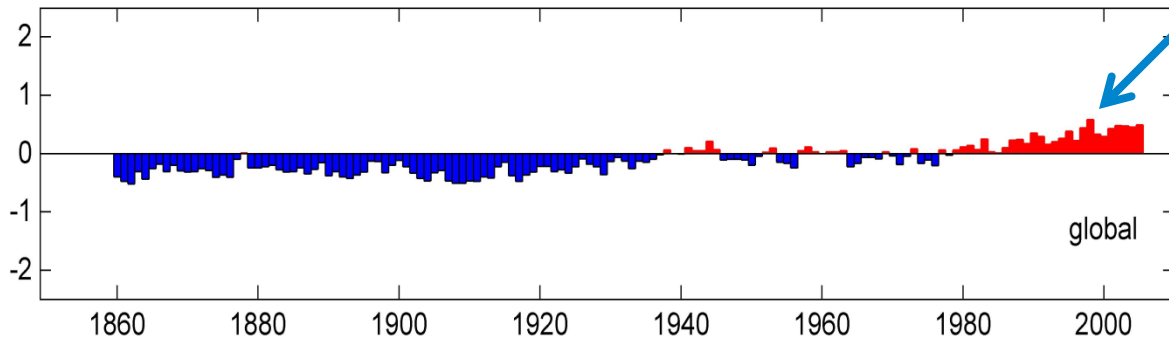
land north of 65N

**Trend
(letzten 50 Jahre)**

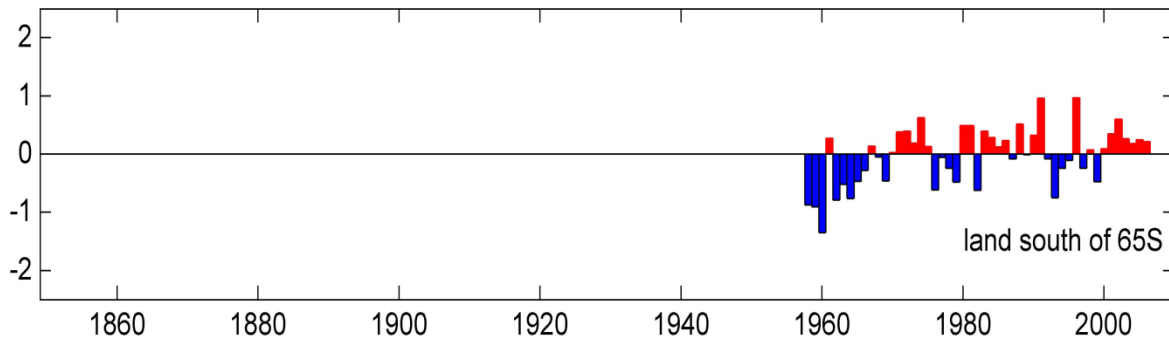
$T_{\text{Arktis}} = 1,1^{\circ}\text{C}$

$T_{\text{global}} = 0,6^{\circ}\text{C}$

temperature anomalies [°C]



global



land south of 65S

year

Dispersion von Teilchen aus dem arktischen Raum (Modellergebnisse)

T. Orgis et al., 2008



0 days



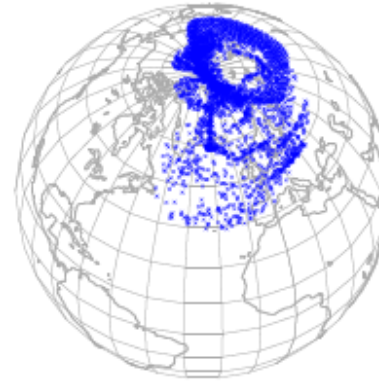
0.2 days



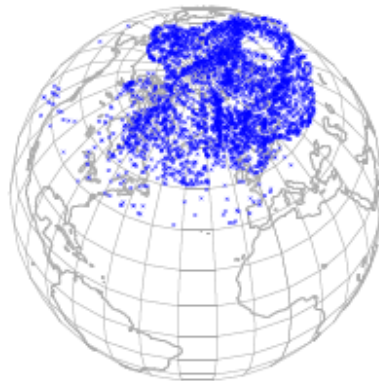
0.5 days



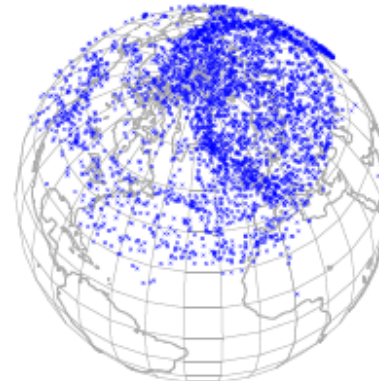
2 days



5 days

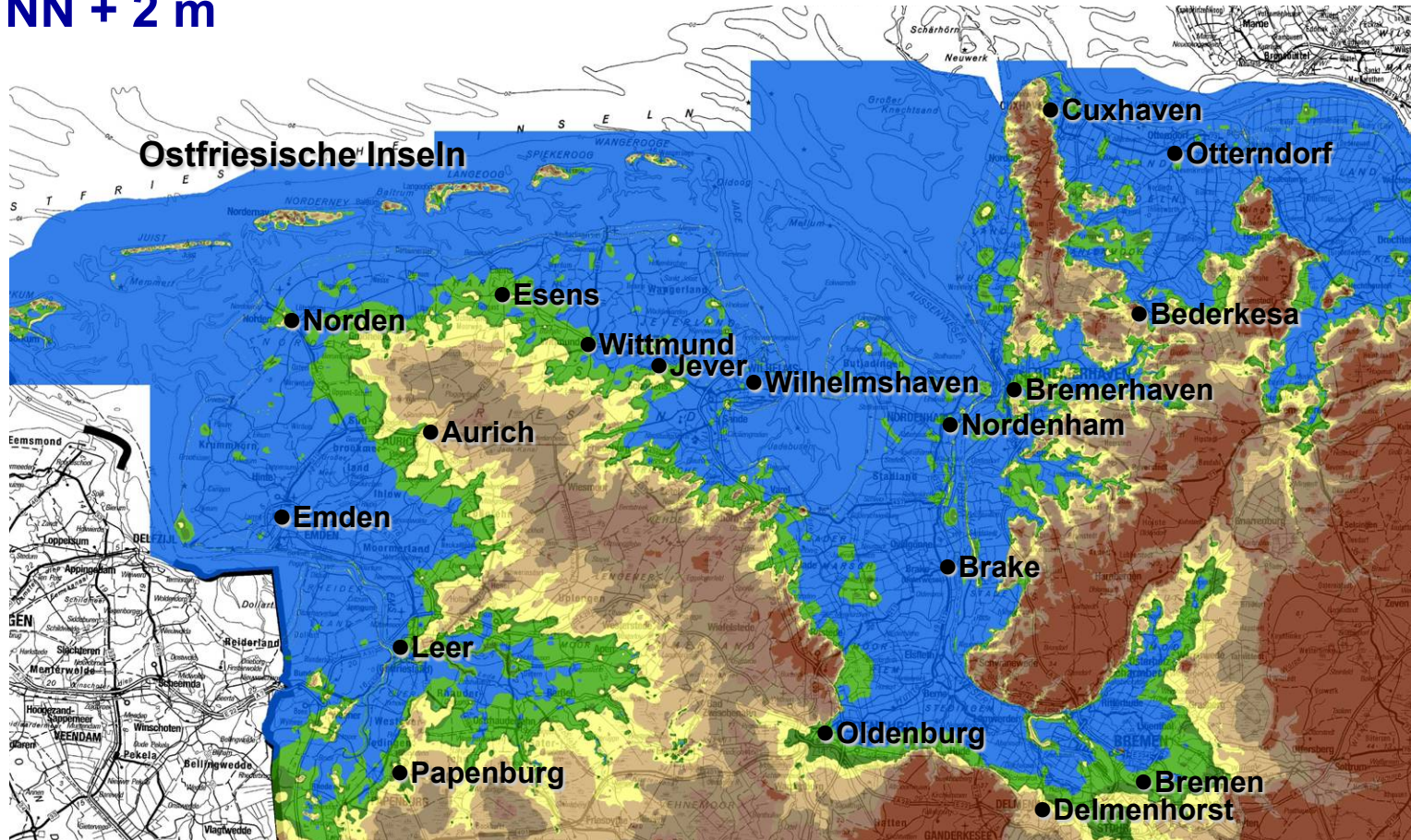


10 days



Küstenschutz - Topografische Verhältnisse

NN + 2 m



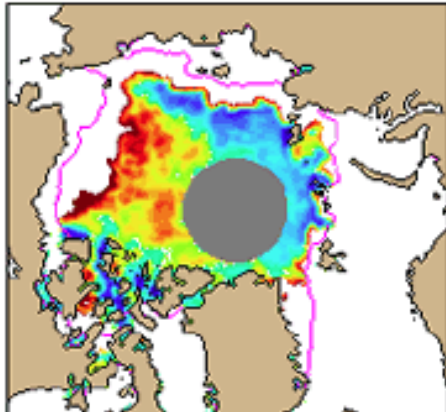
- *Größere Teile Norddeutschen Küstengebiete würden ohne Küstenschutzanlagen bereits bei mittlerem Tidehochwasser oder leicht erhöhten Tiden überflutet*

Meereis - gefrorenes Wasser

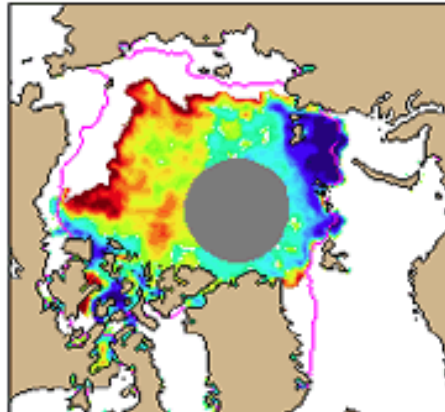


Arktische Meereis-Ausdehnung im Sommer

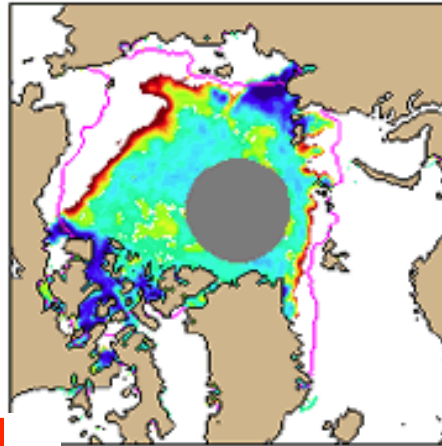
2002



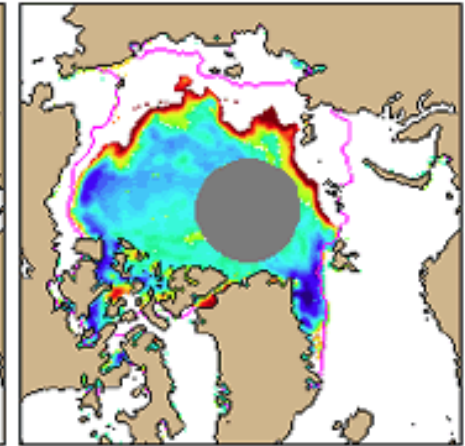
2003



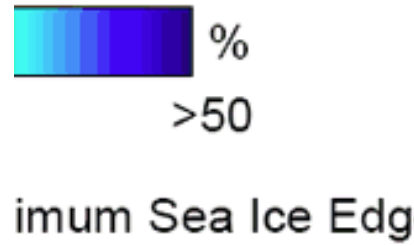
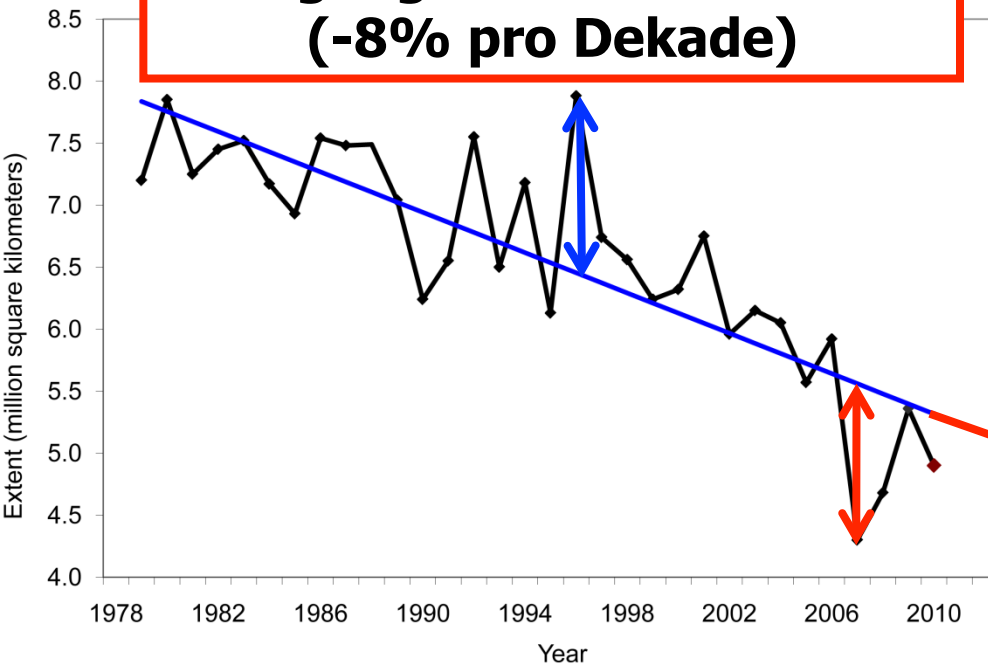
2004



2005



**Rückgang Sommer-Minimum
(-8% pro Dekade)**

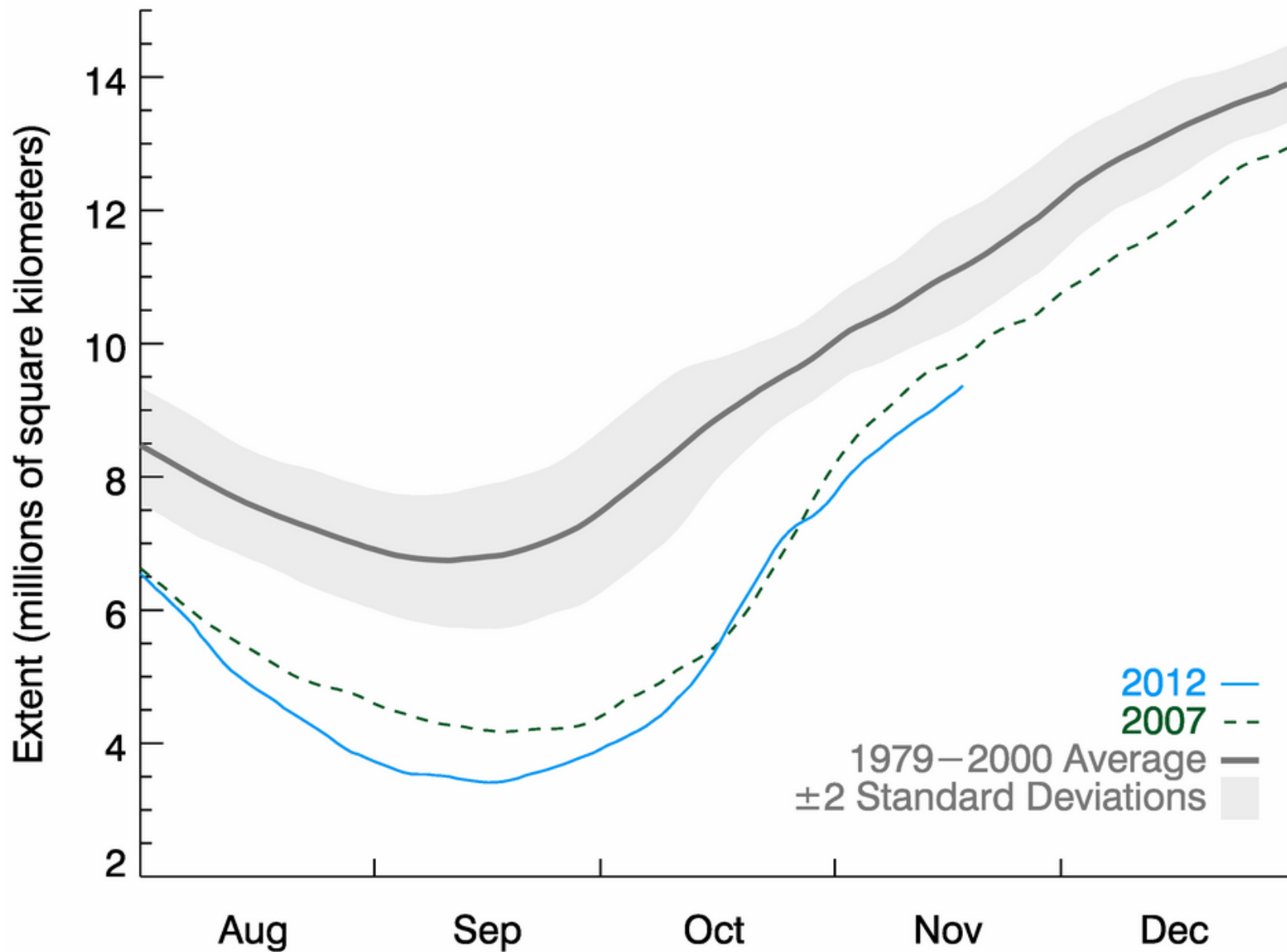


2070

Arktis eisfrei im Sommer

Arctic Sea Ice Extent

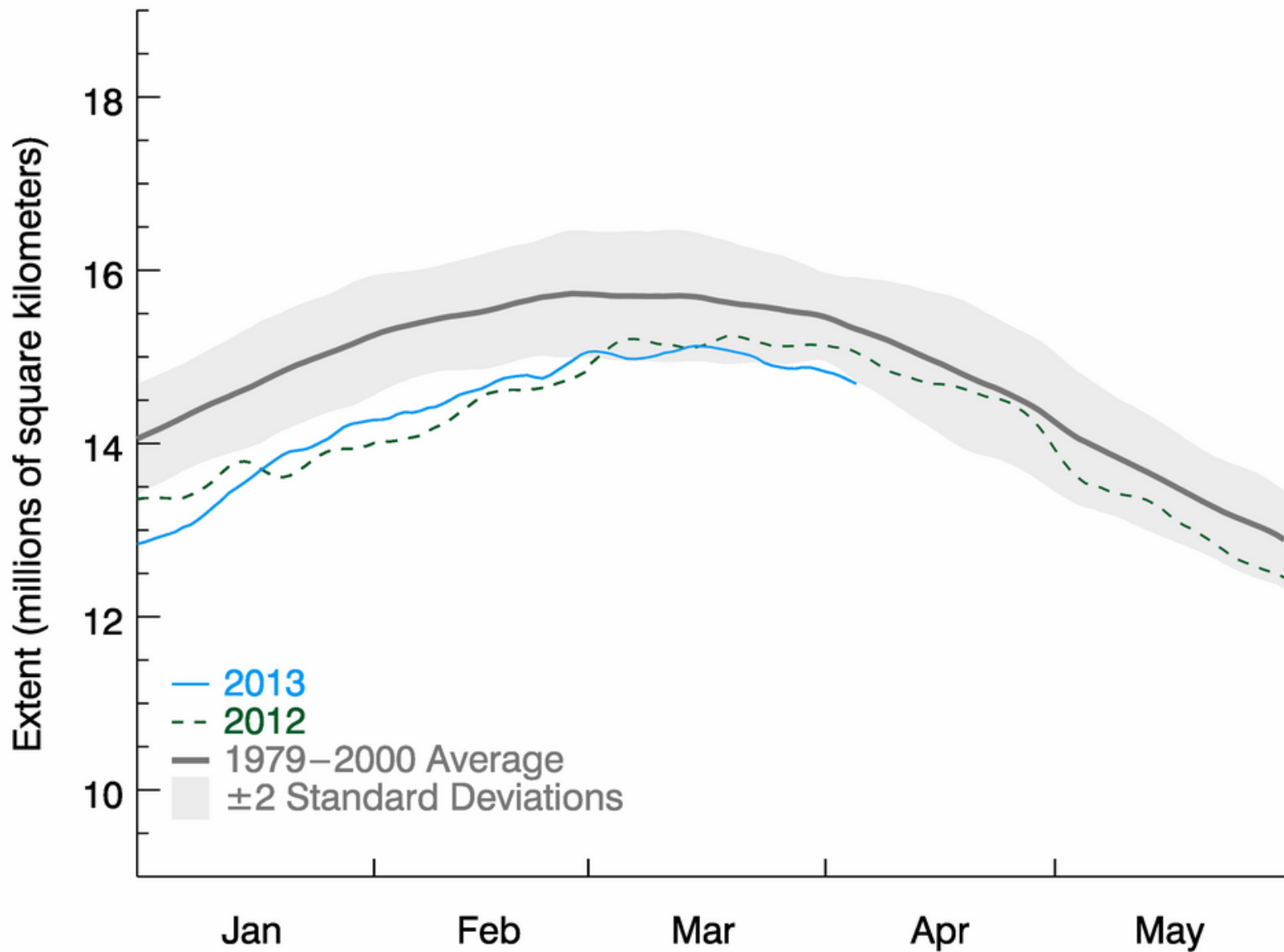
(Area of ocean with at least 15% sea ice)



National Snow and Ice Data Center, Boulder CO

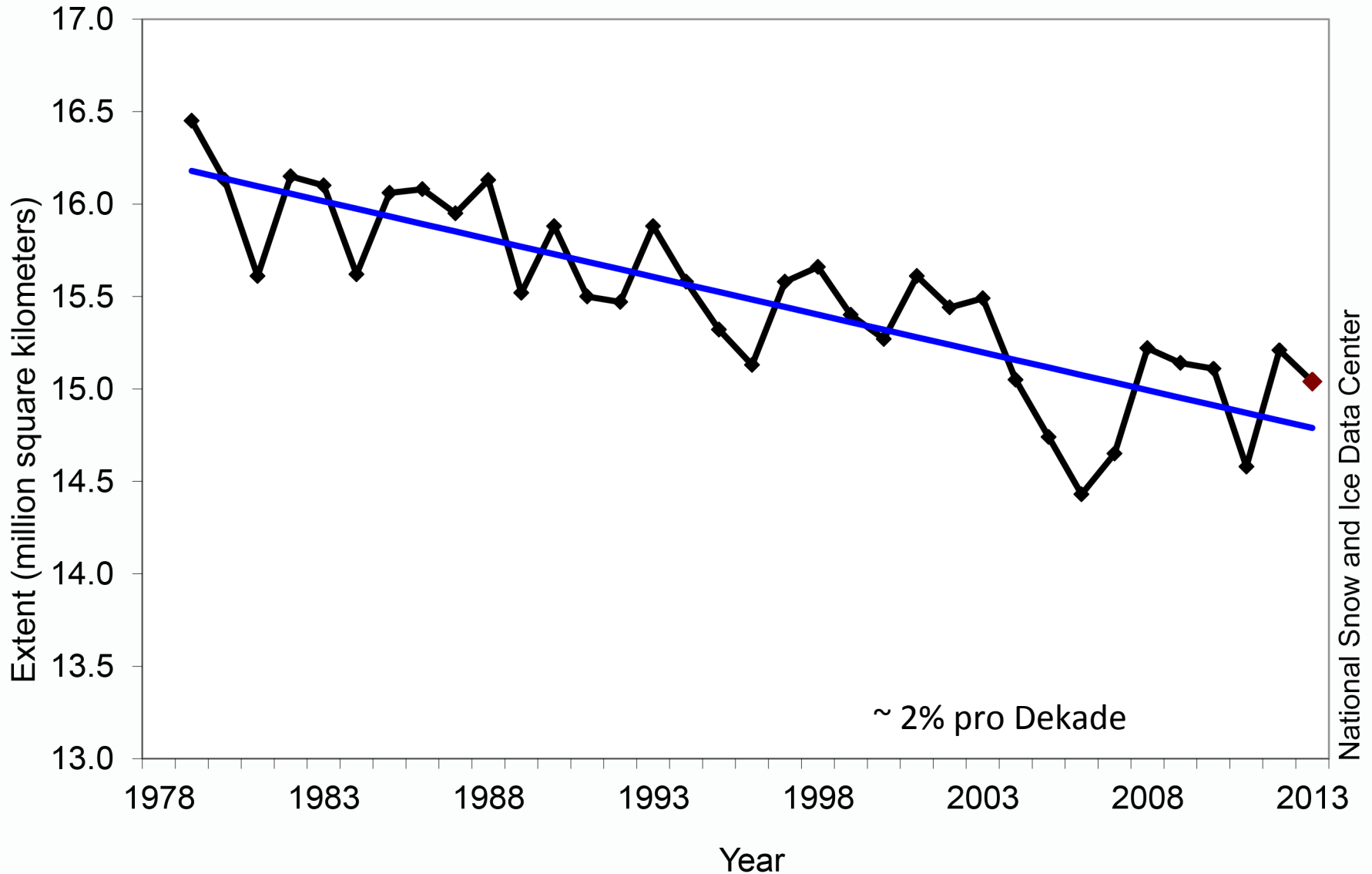
Arctic Sea Ice Extent

(Area of ocean with at least 15% sea ice)



National Snow and Ice Data Center, Boulder CO

Average Monthly Arctic Sea Ice Extent March 1979 - 2013

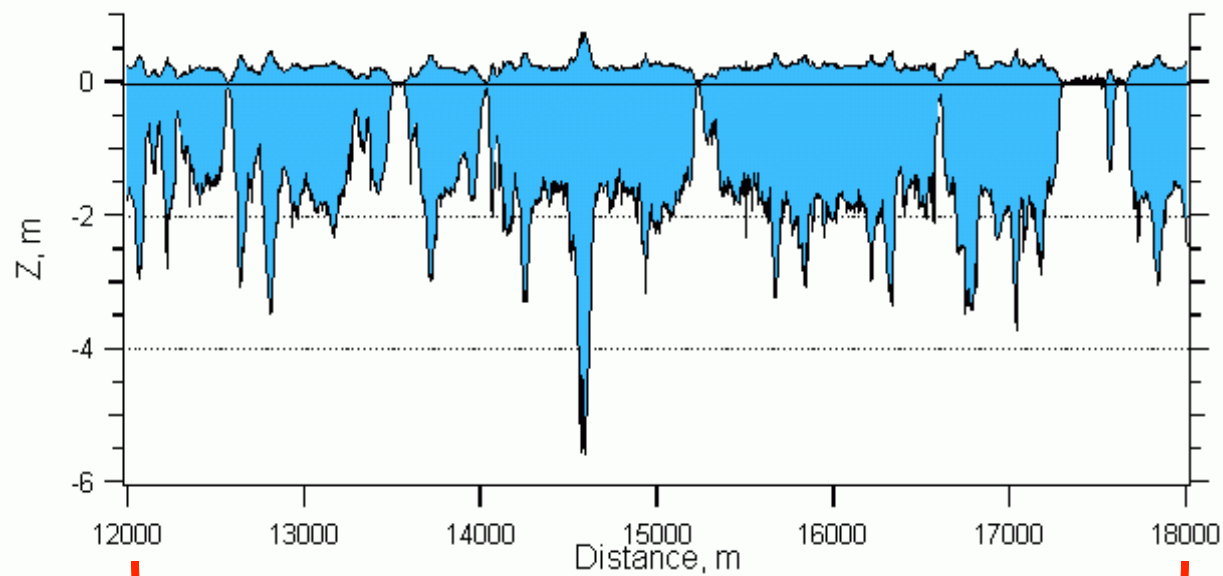


Messungen der Meereisdicke

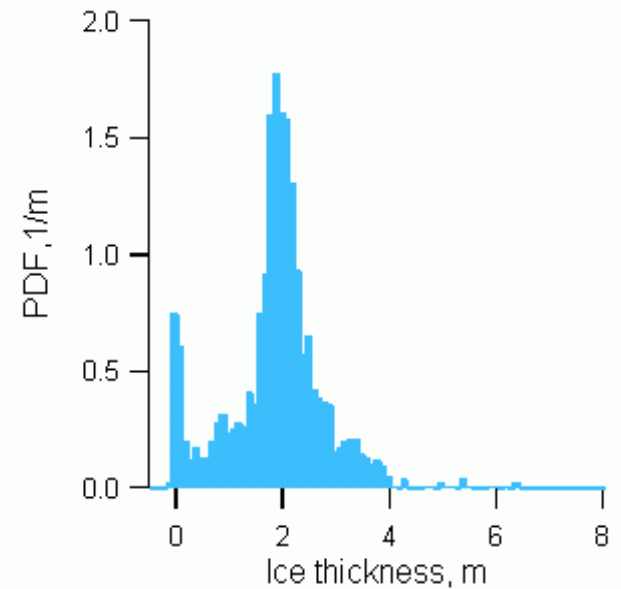


EM bird

EM Meereis-Dickenprofile

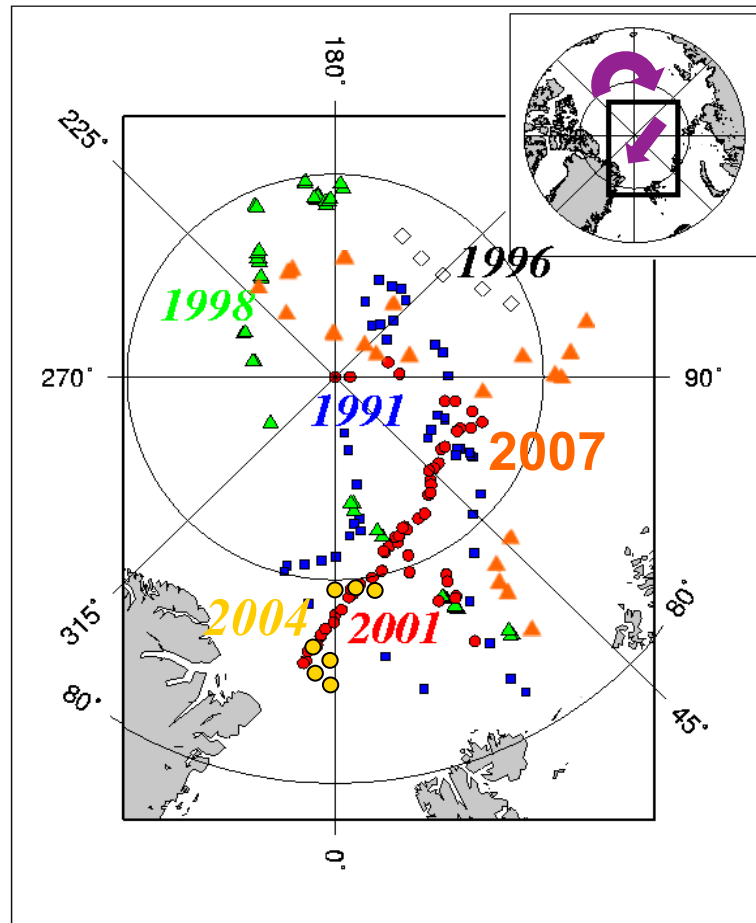


6 km

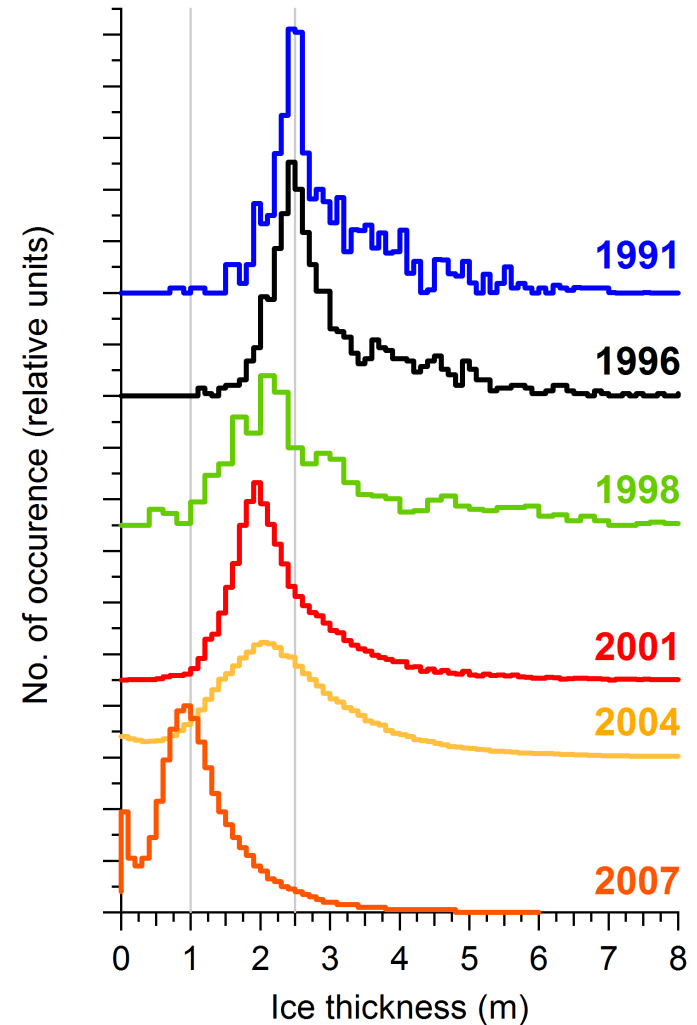


Dicken-
Häufigkeits-
verteilung

Variabilität der Meereisdicke im Transpolaren Driftstrom (1991, 1996, 1998, 2001, 2004 & 2007)

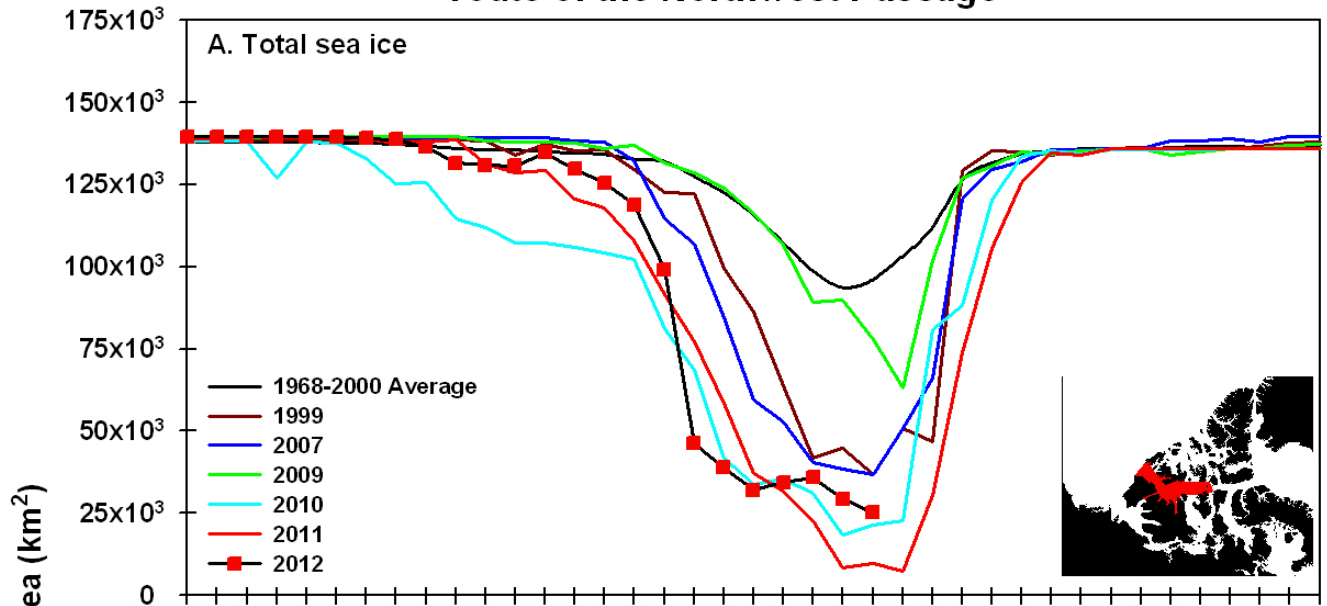


Haas, 2004

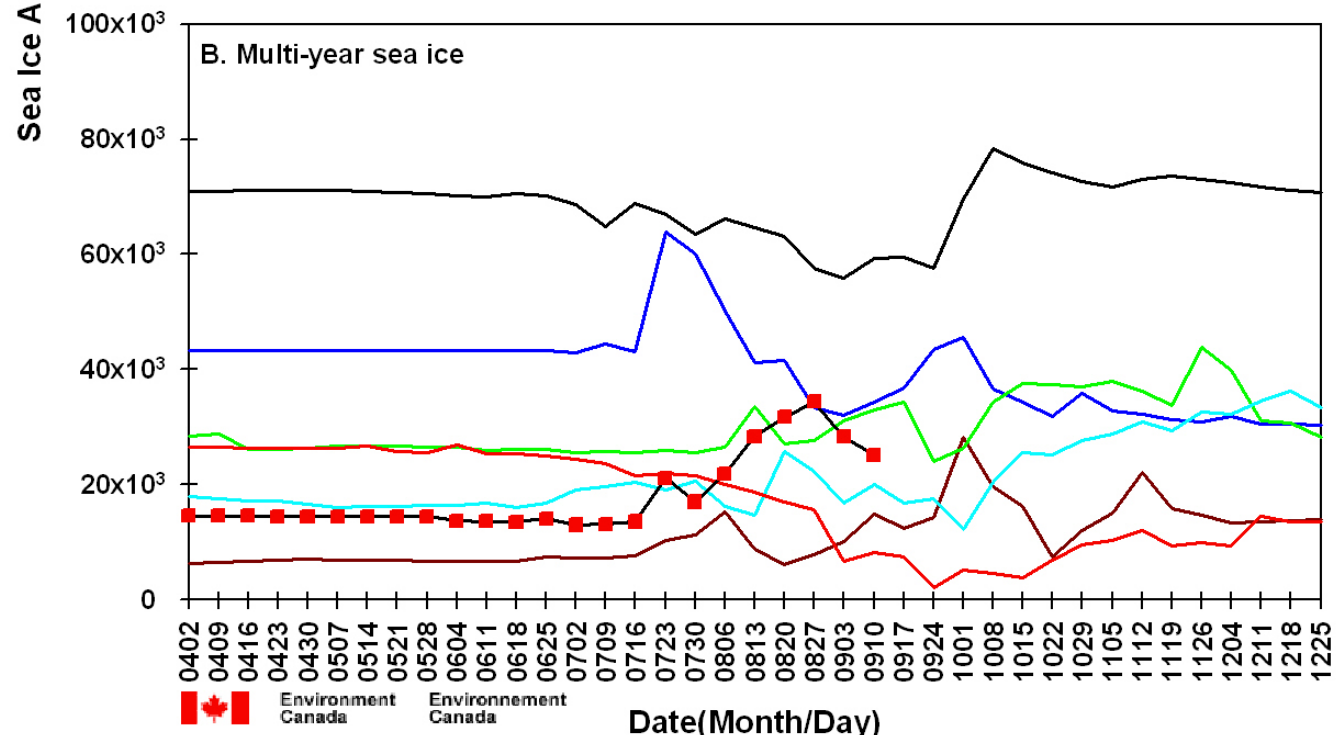


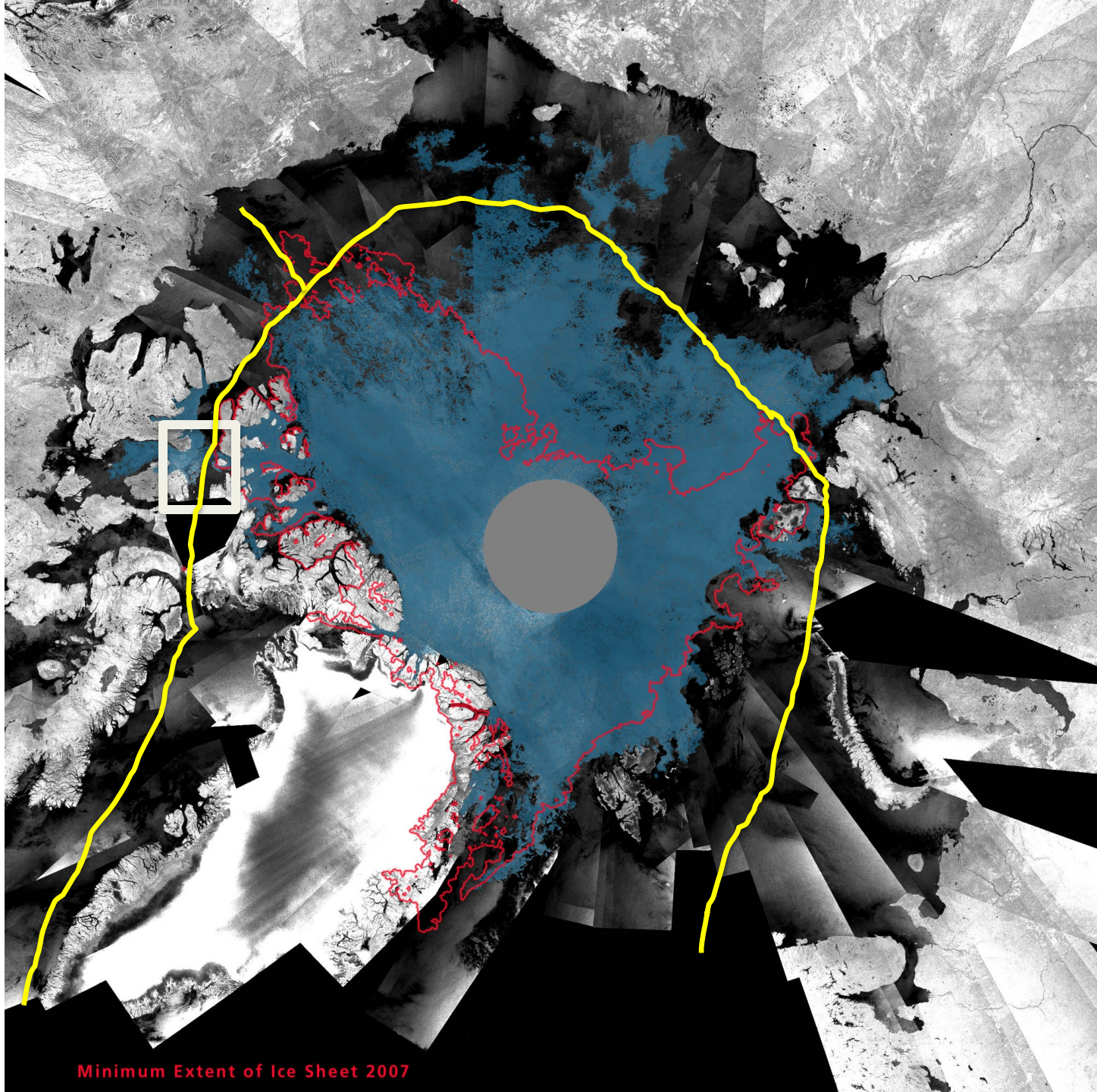
Rabenstein, Hendricks, Leinweber, 2007

Sea ice conditions in the Western Parry Channel route of the Northwest Passage



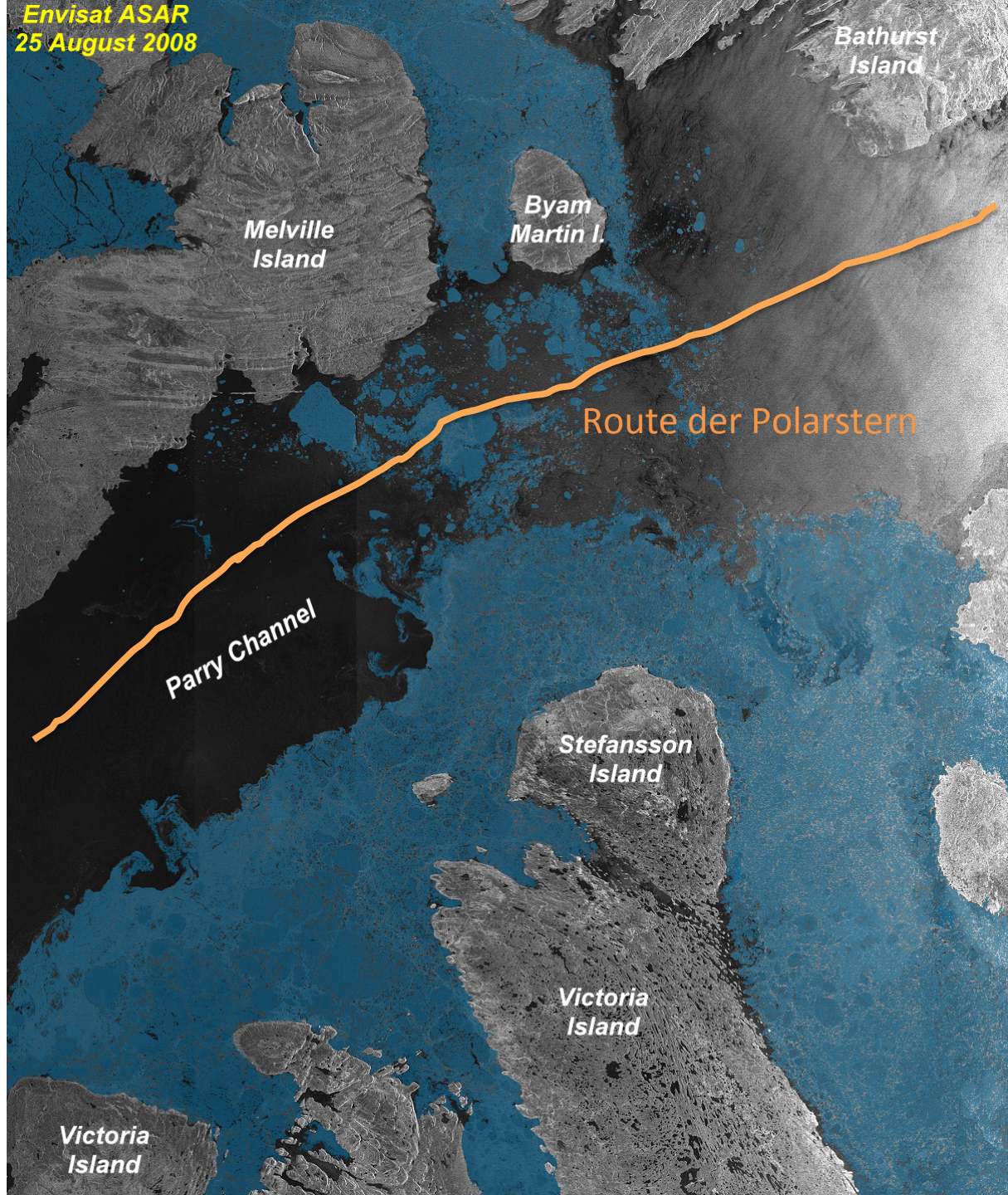
Wie steht es um die Schiffbarkeit der Northwest Passage ?

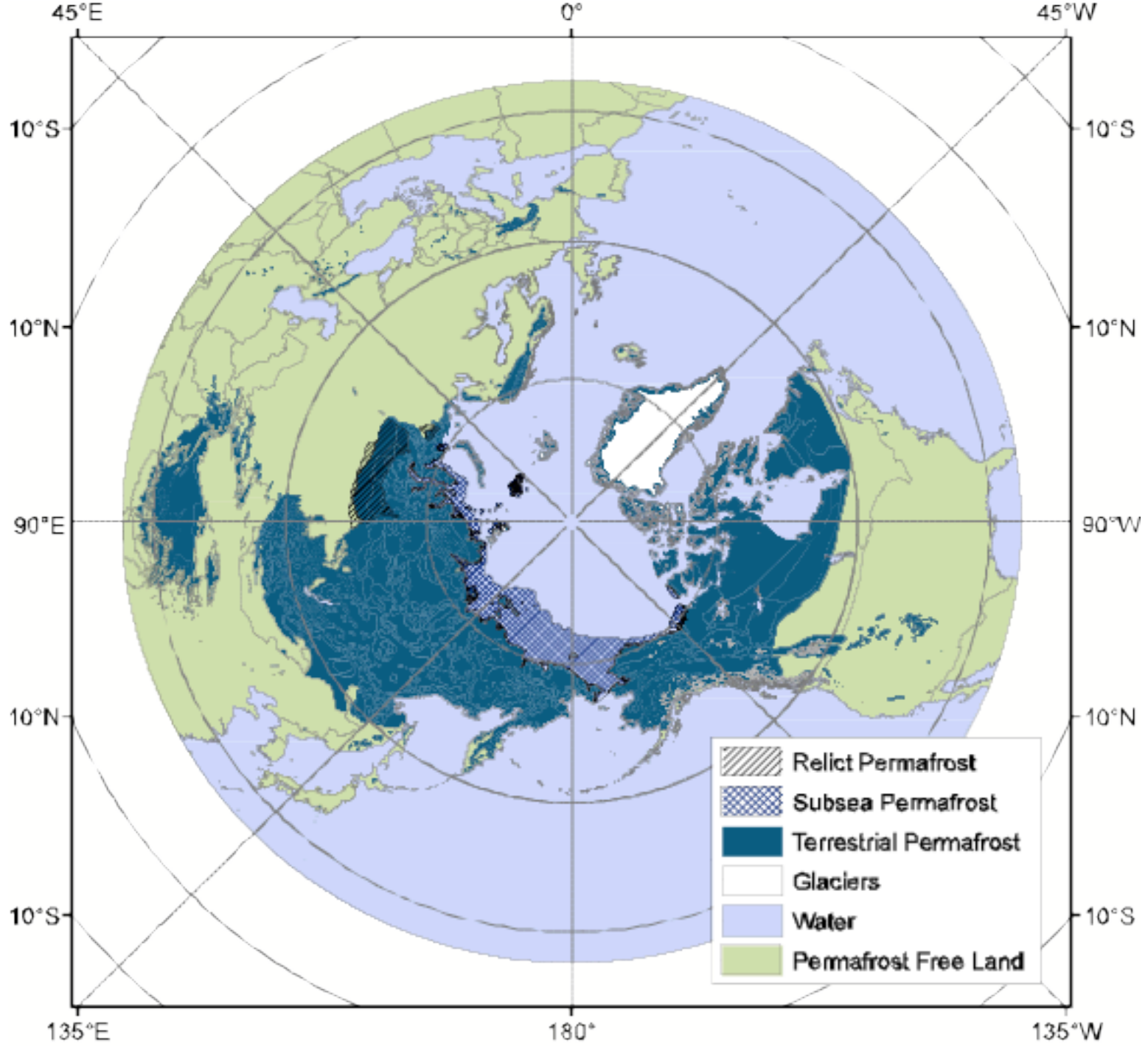




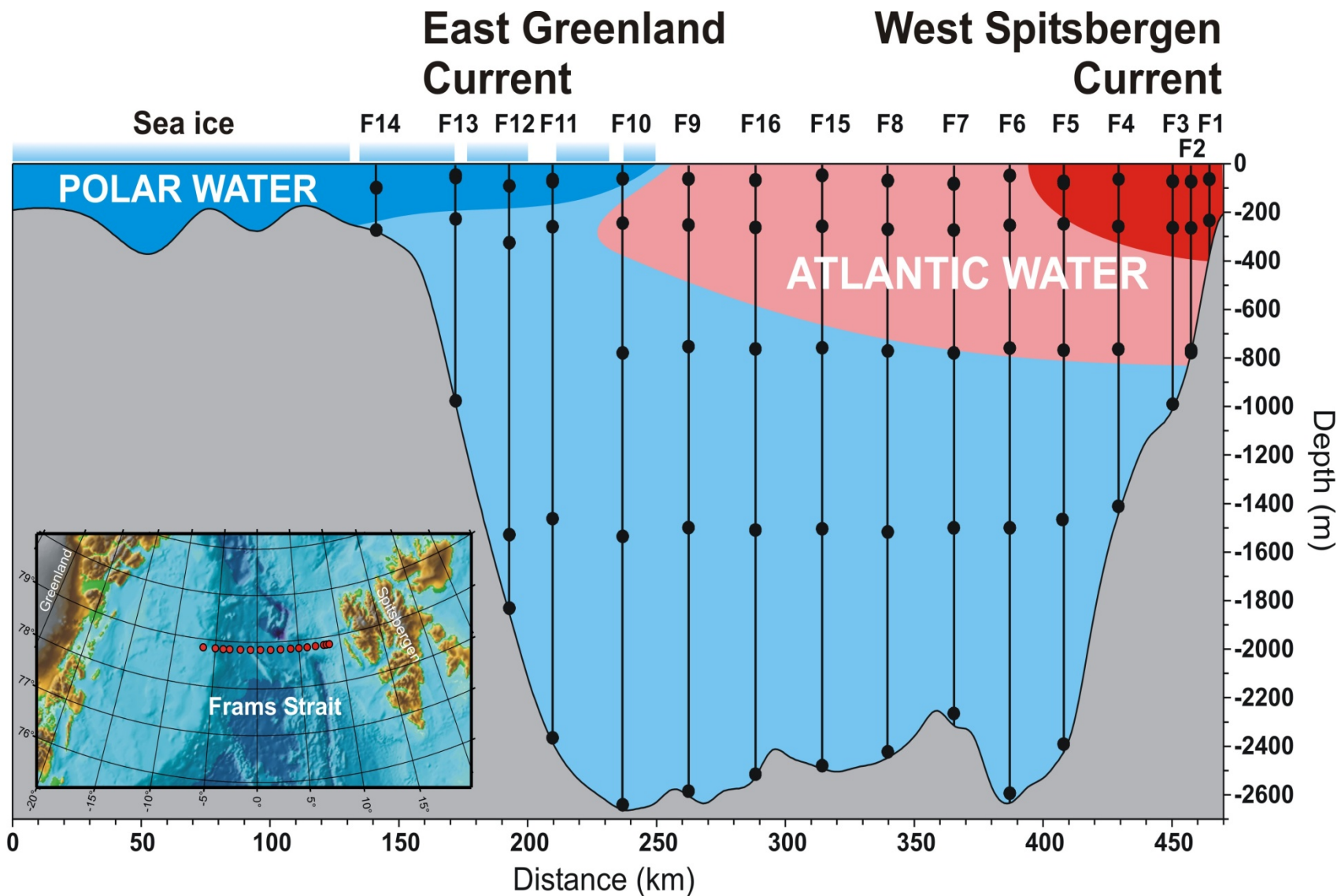
Minimum Extent of Ice Sheet 2007

Envisat ASAR
25 August 2008

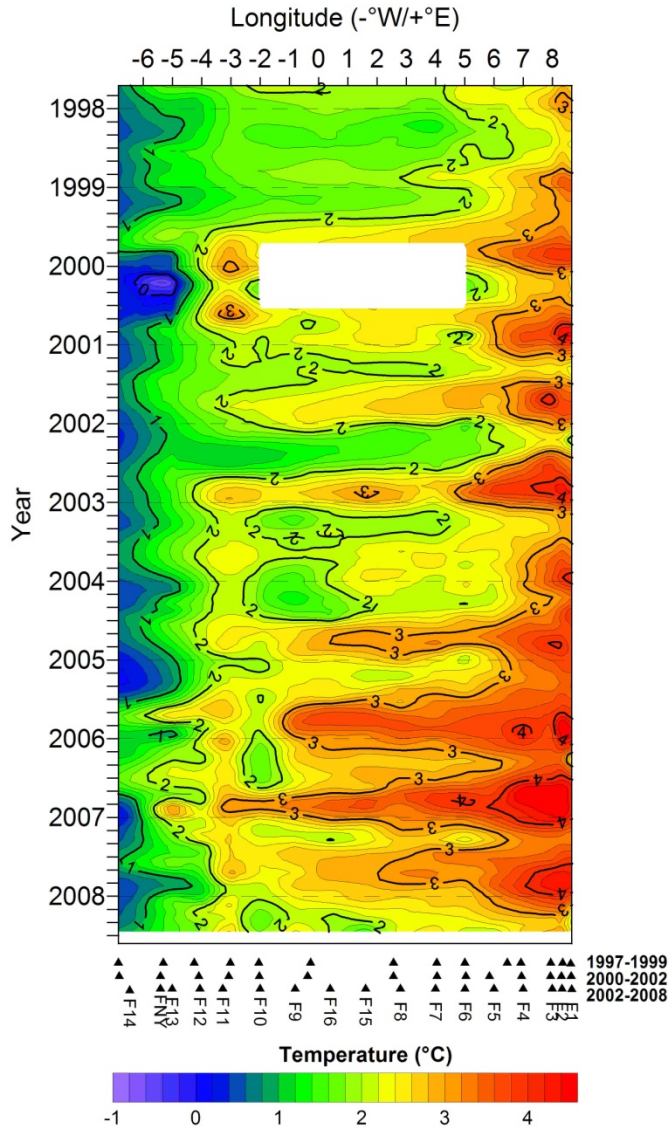




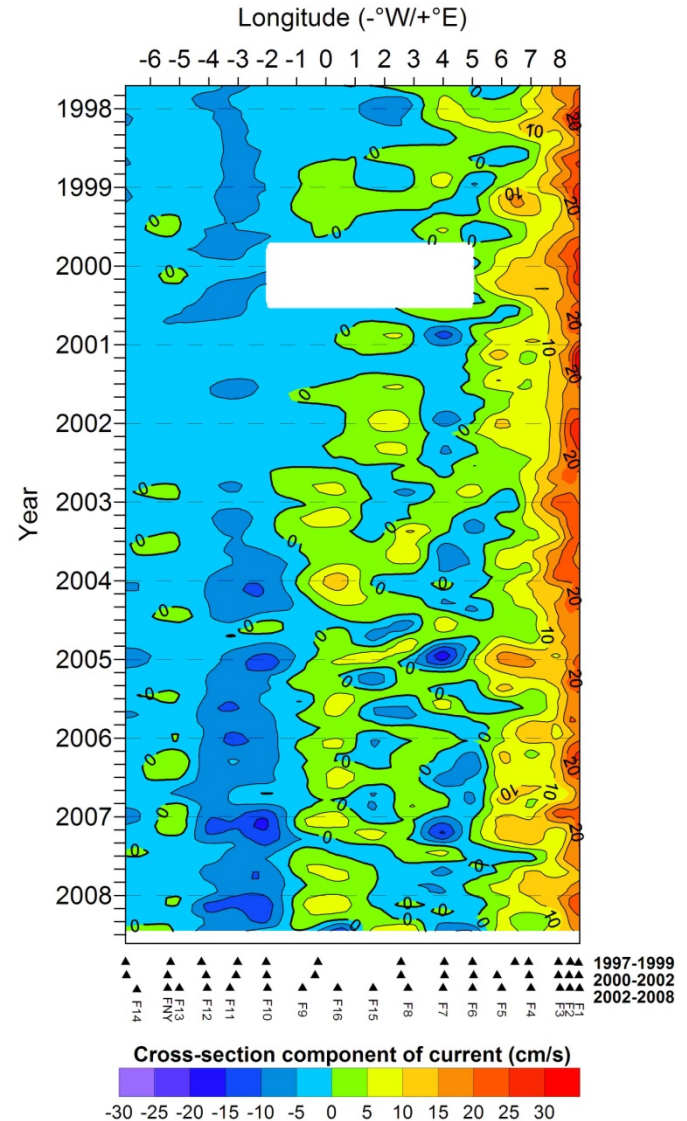




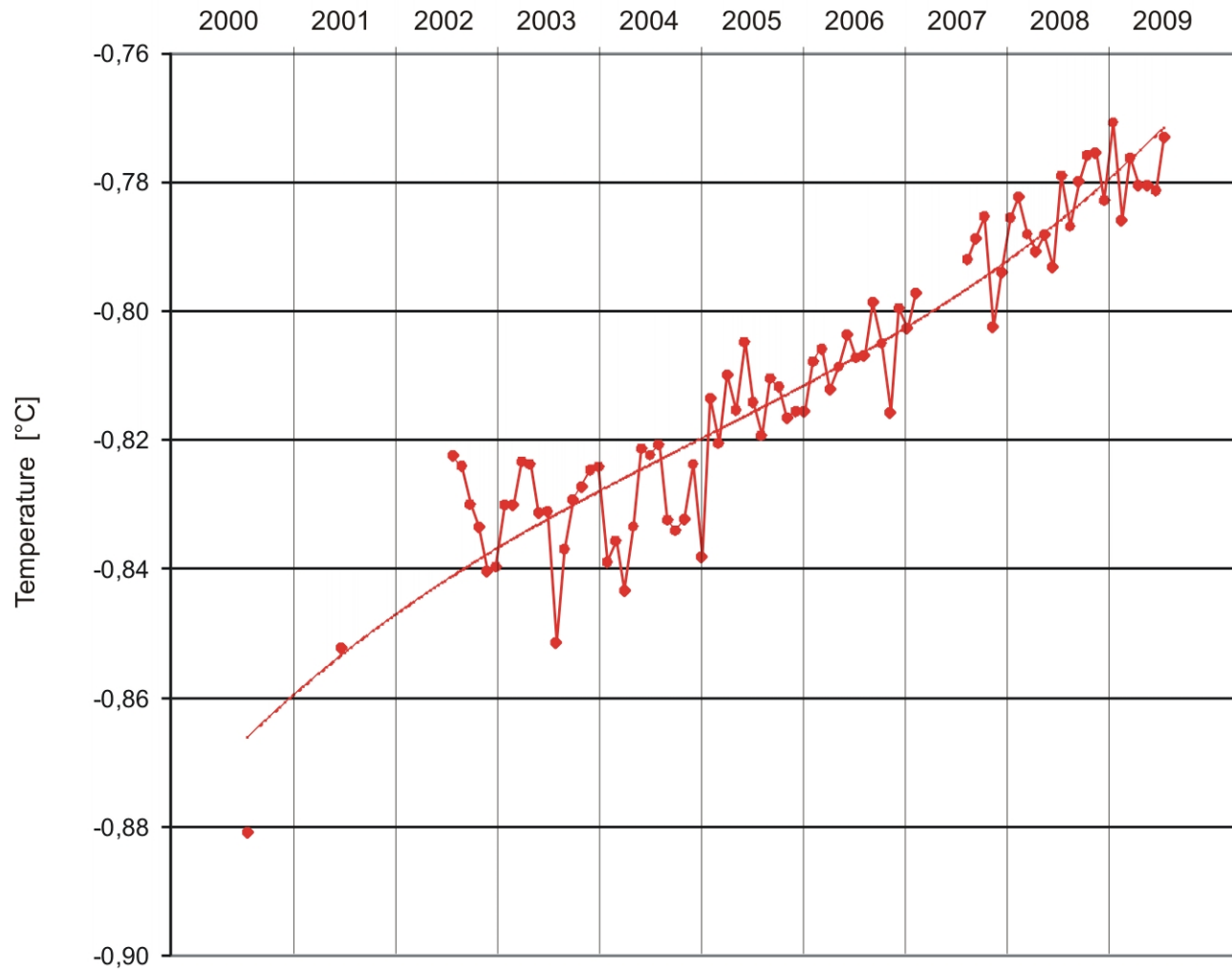
Temperature (°C)



Cross-section current (cm/s)

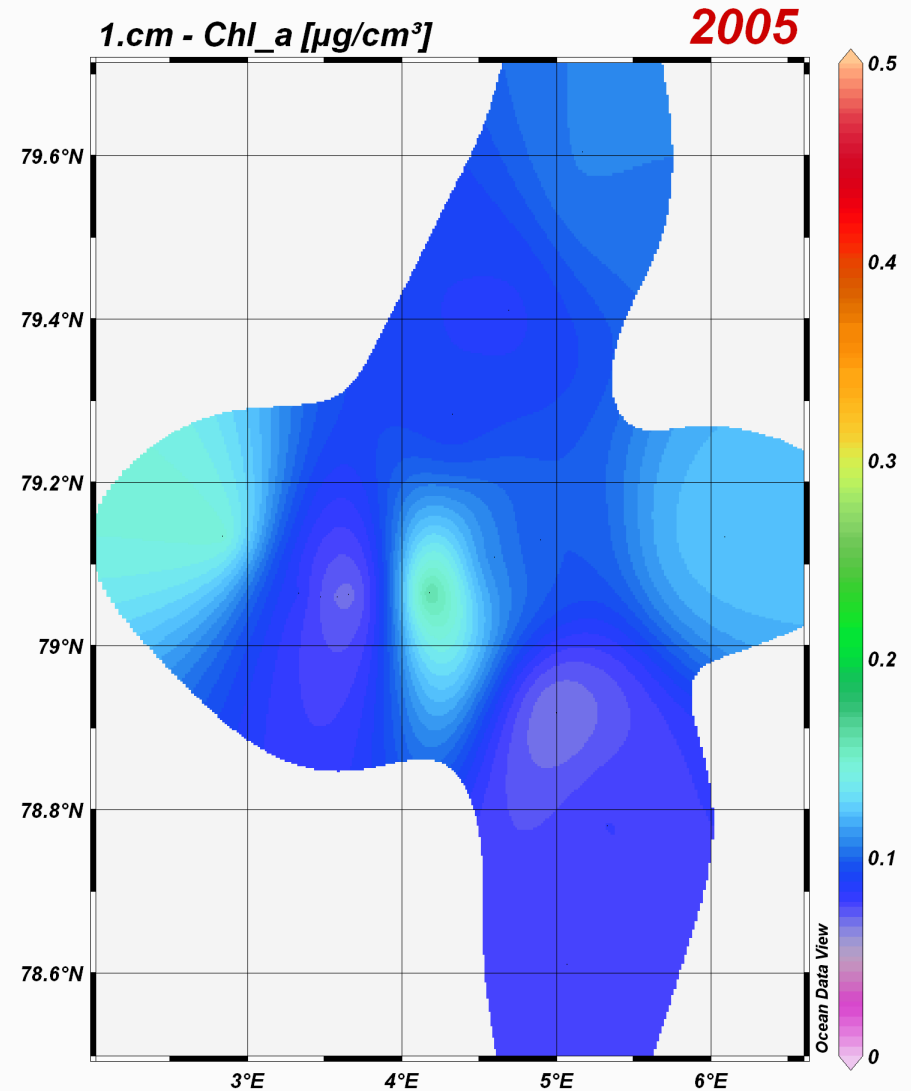
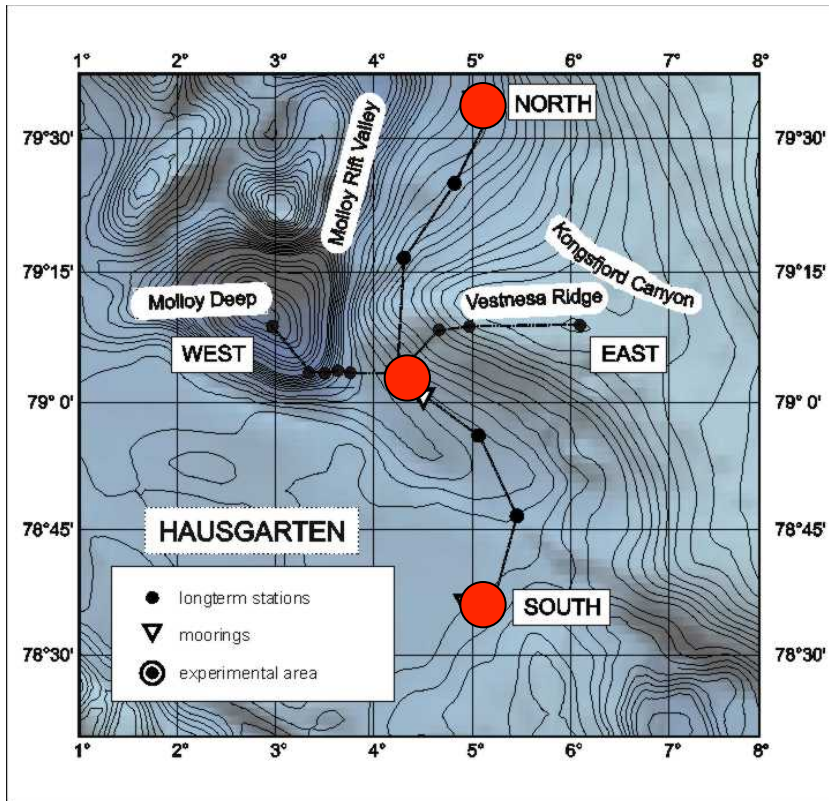


Wassertemperatur in 2500 m Tiefe - der Trend hält an



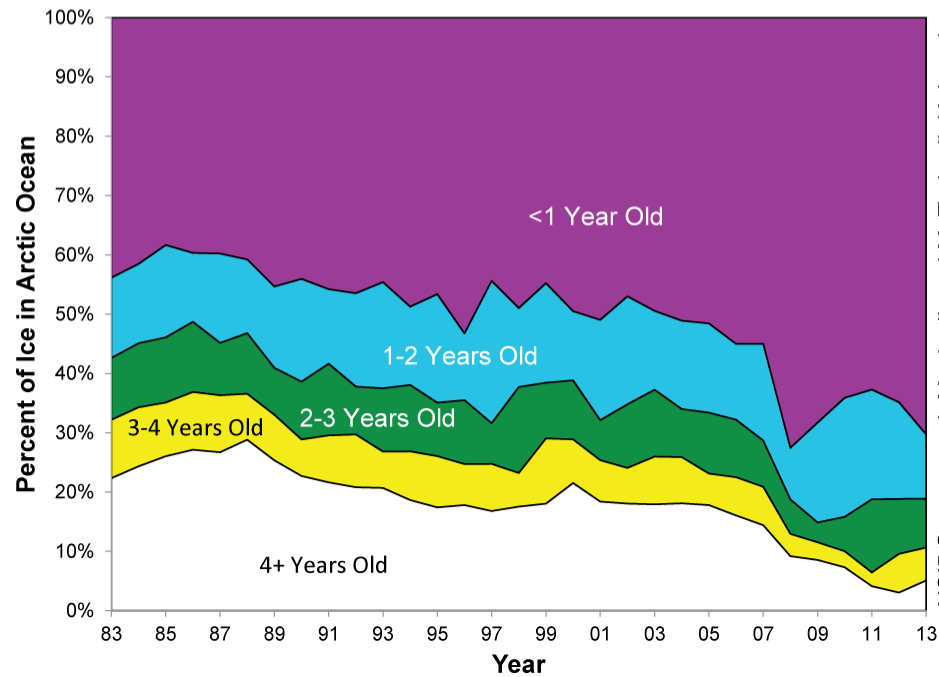
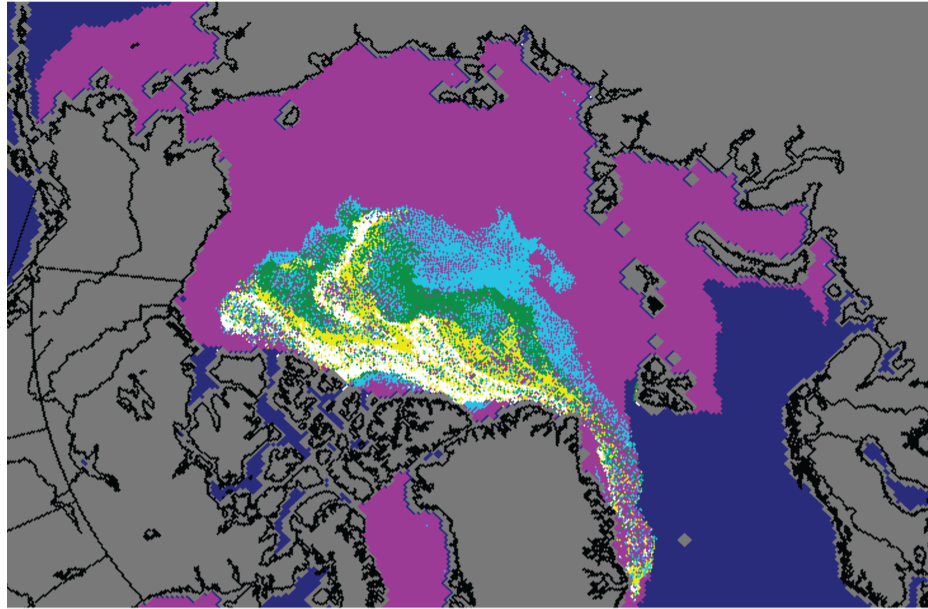
AWI-Hausgarten – Klages, pers. Mitt.

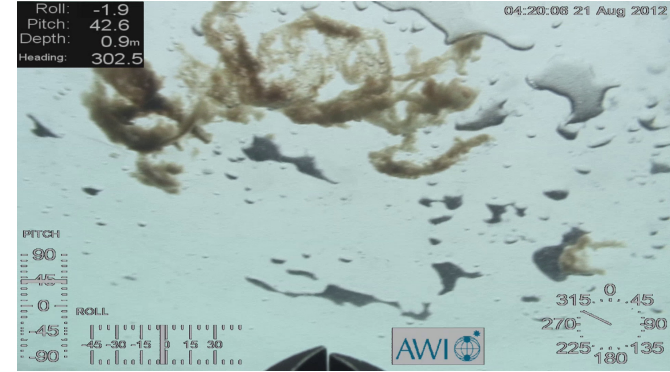
Abnahme des Eintrags frischen organischen Materials entlang des Tiefentranssekts und des latitudinalen Transekts



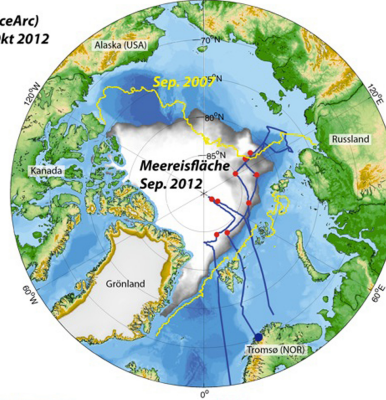


Arctic Sea Ice Age, March 2013





ARK-XXVII/3 (IceArc)
02. Aug - 08. Okt 2012



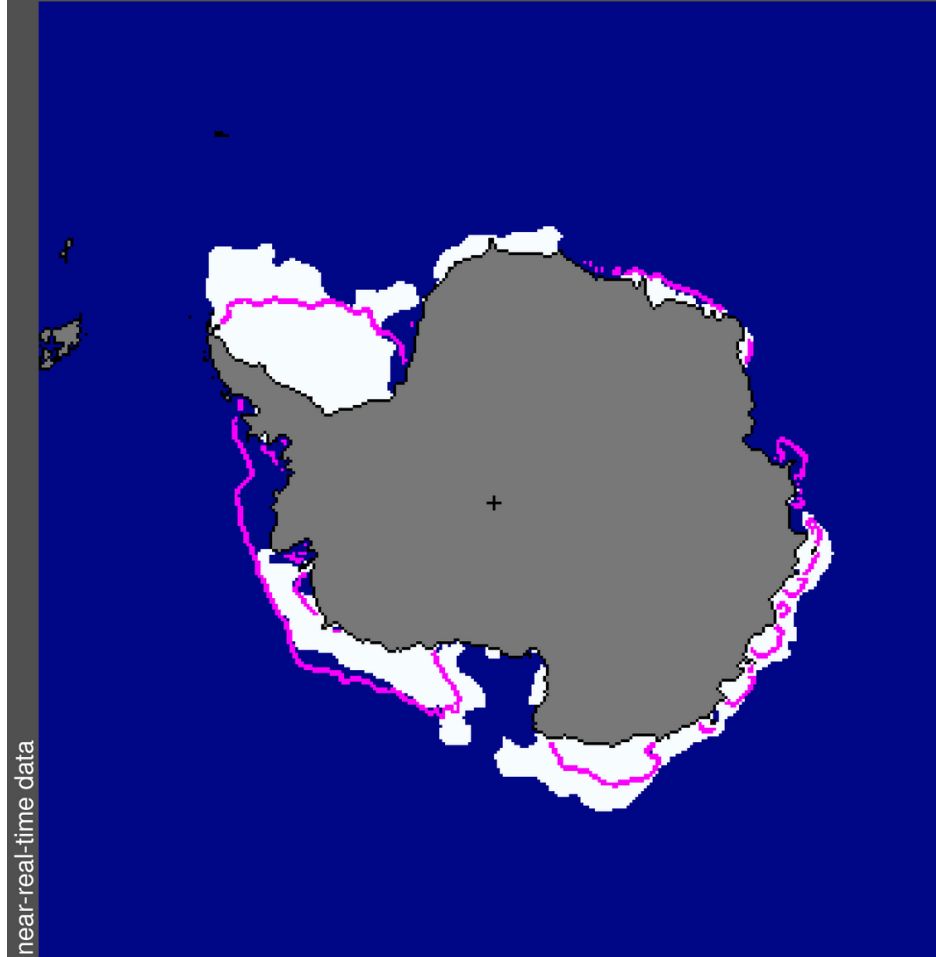
AWI Alfred-Wegener-Institut
für Polar- und Meeresforschung
in der Helmholtz-Gemeinschaft

Universität Bremen



Boetius et al. Science Express, 2013,
DOI:10.1126/Science.1231346





National Snow and Ice Data Center, Boulder, CO

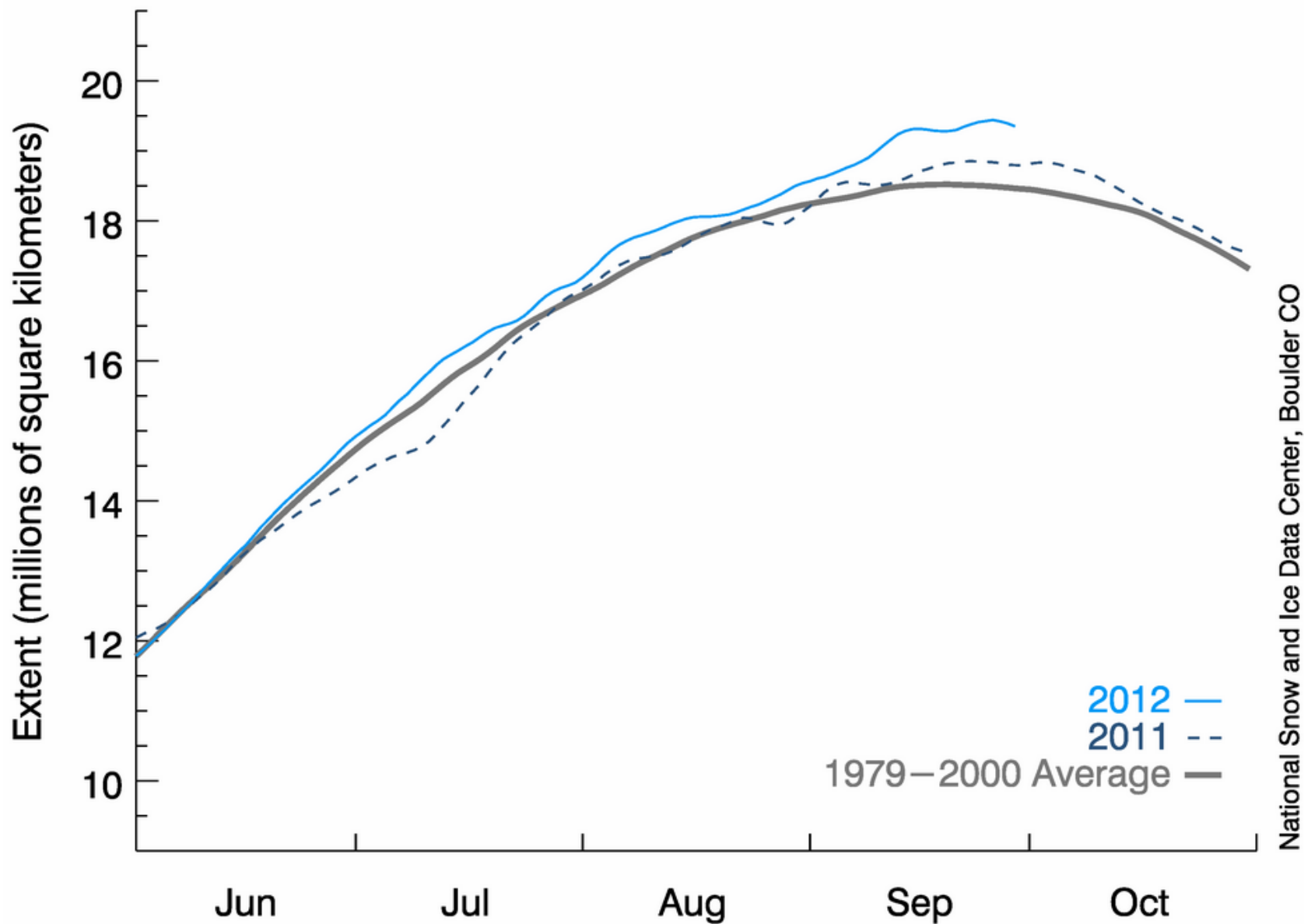
median
ice edge

Total extent = 3.8 million sq km

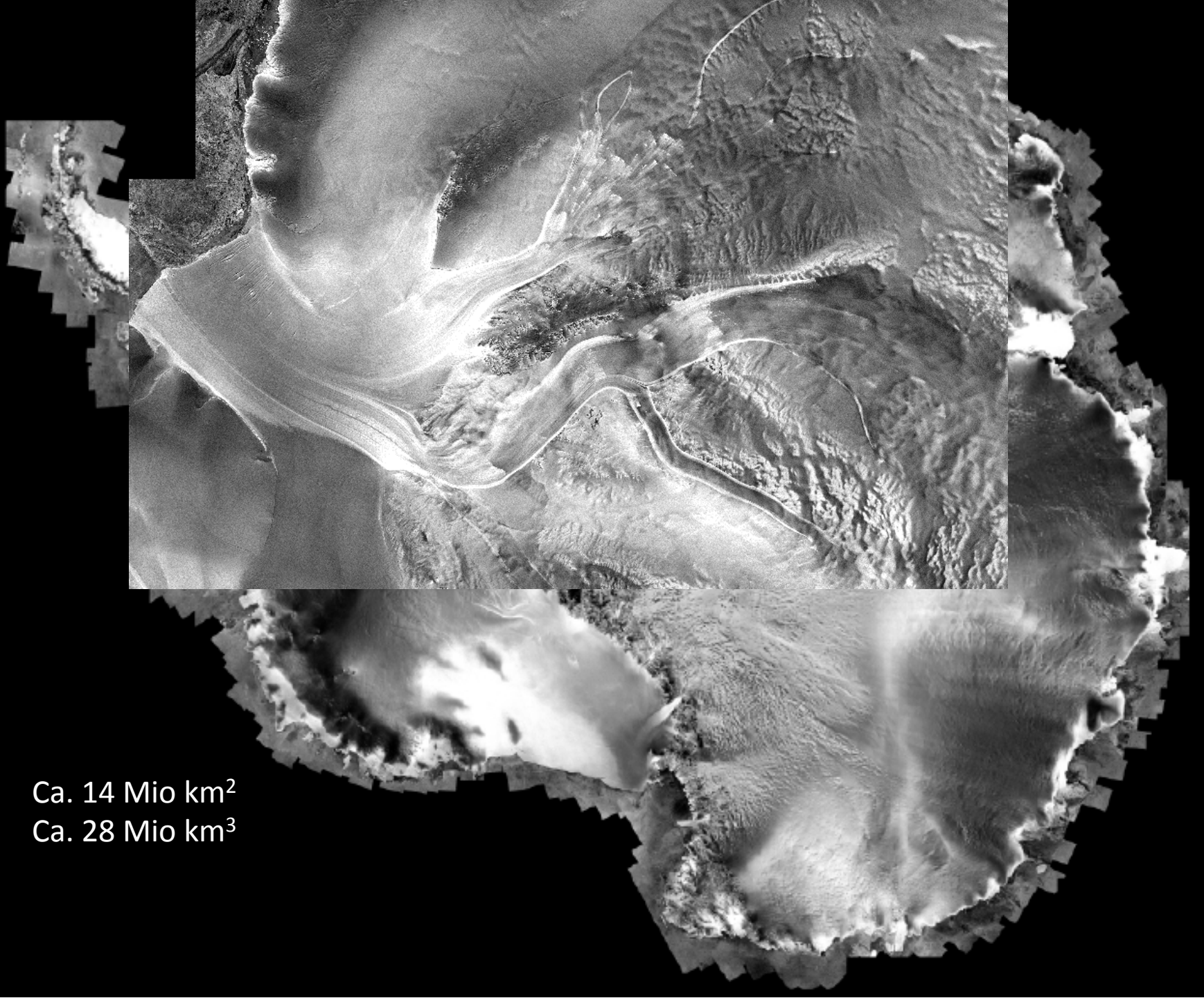
NSIDC

Antarctic Sea Ice Extent

(Area of ocean with at least 15% sea ice)



National Snow and Ice Data Center, Boulder CO



Ca. 14 Mio km²
Ca. 28 Mio km³



M. Studinger, 2011

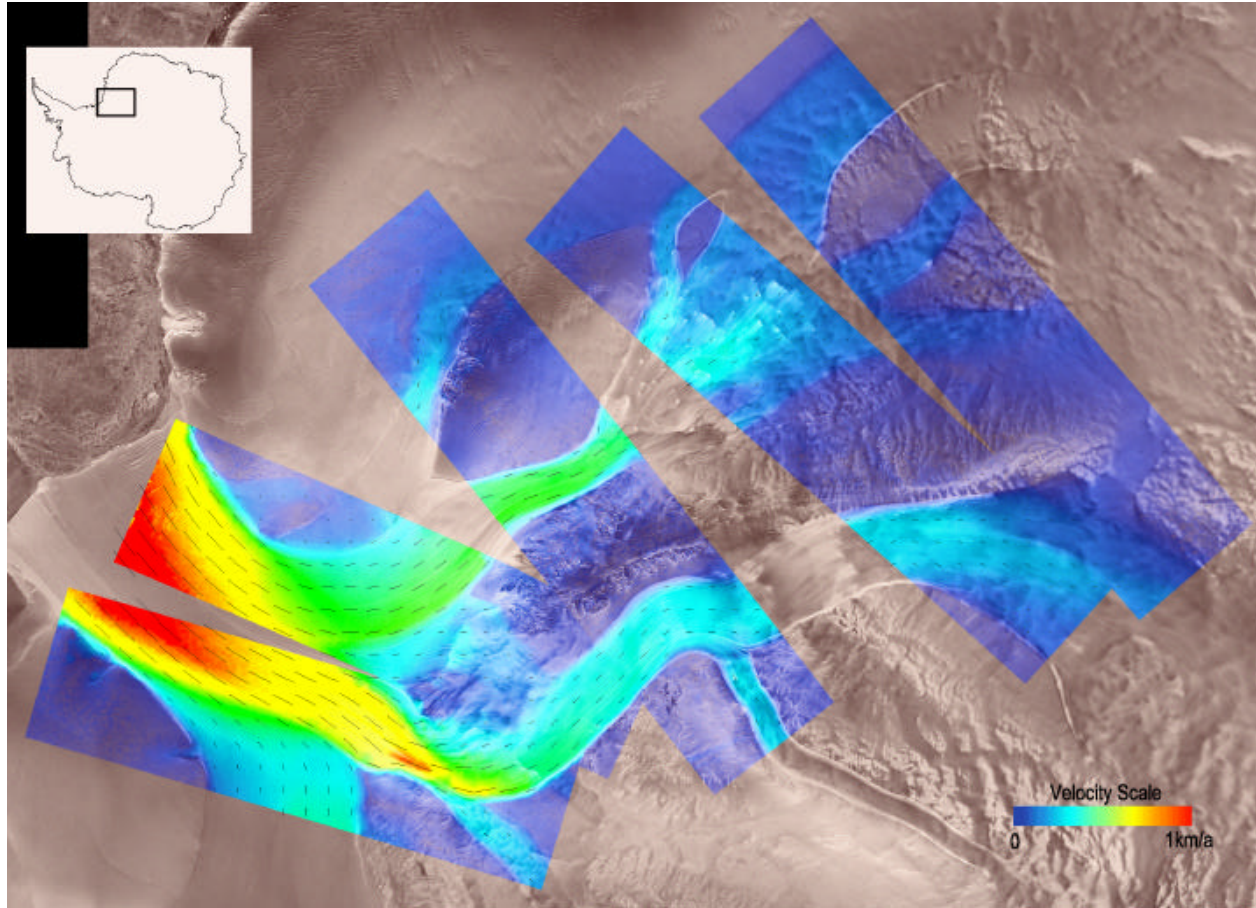


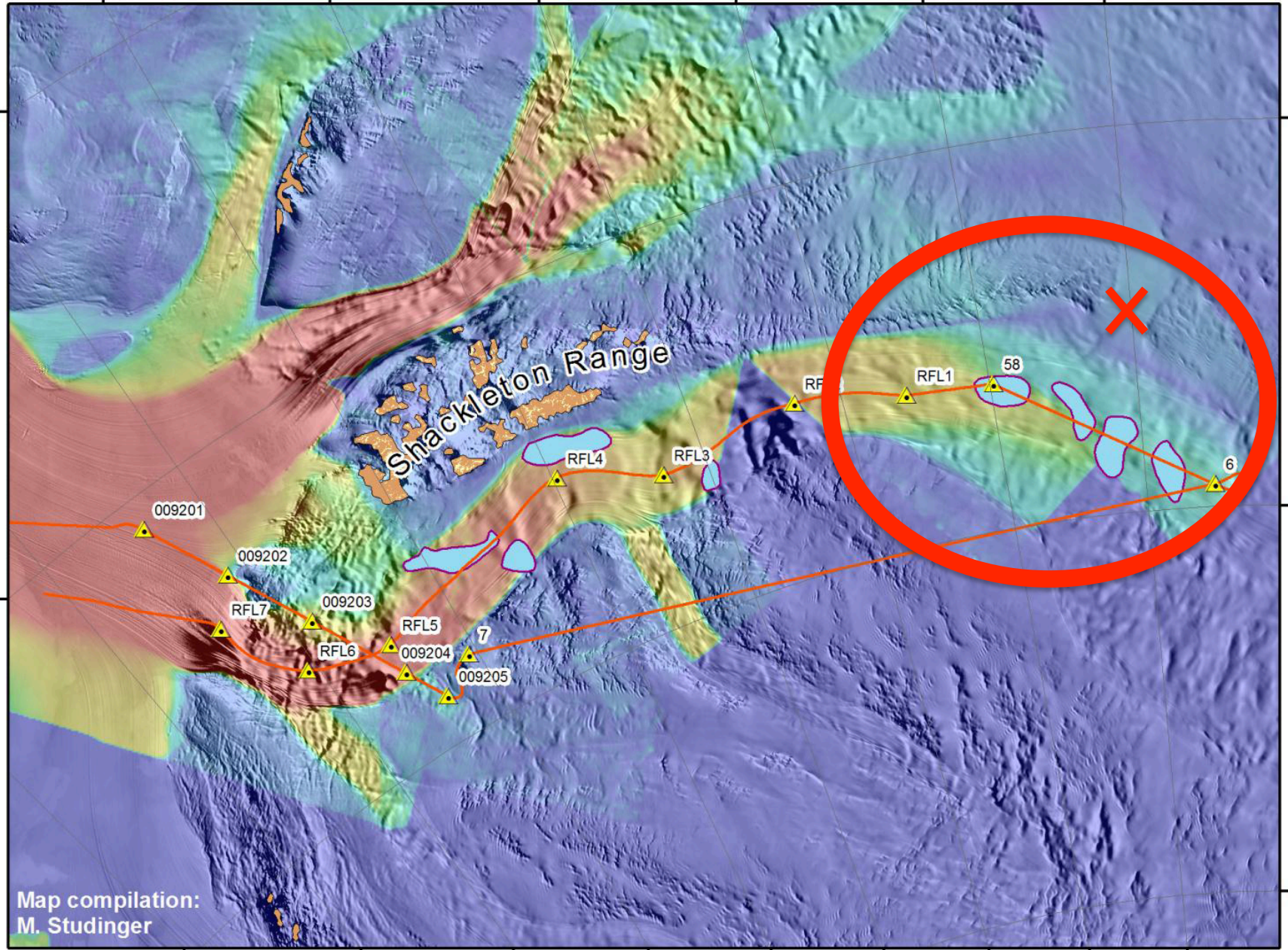
Figure 6.8: Surface velocity mosaic of the east Antarctic Ice Streams. The speed is encoded as hue and SAR is encoded as intensity in the HSV color model

30°W 25°W 20°W 15°W 10°W 5°W

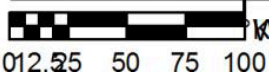
78°S 80°S

80°S 82°S

84°S

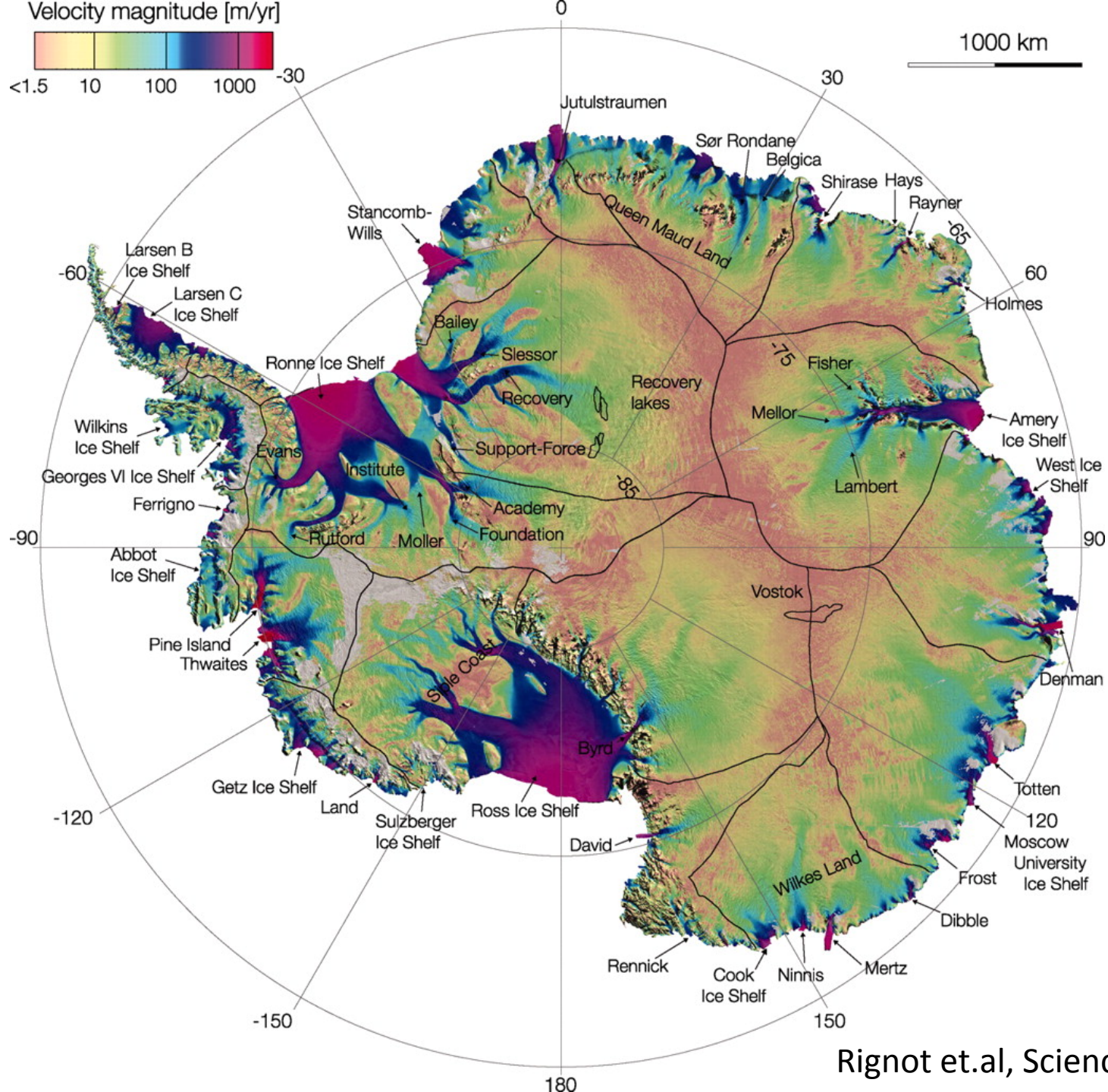


Map compilation:
M. Studinger



40°W 35°W 30°W 25°W 20°W 15°W 10°W 5°W

Studinger 2011



Rignot et.al, Science 2011

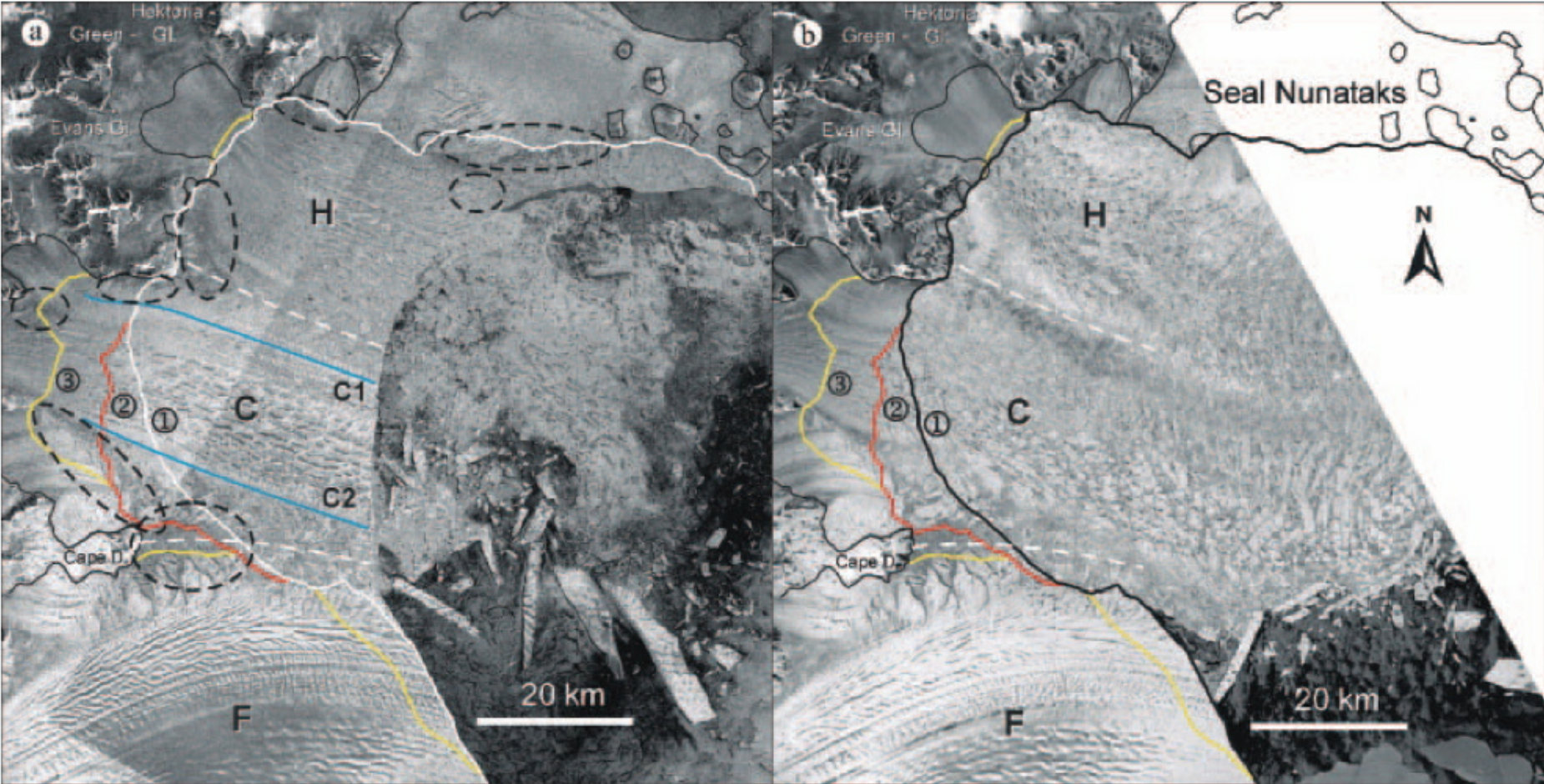
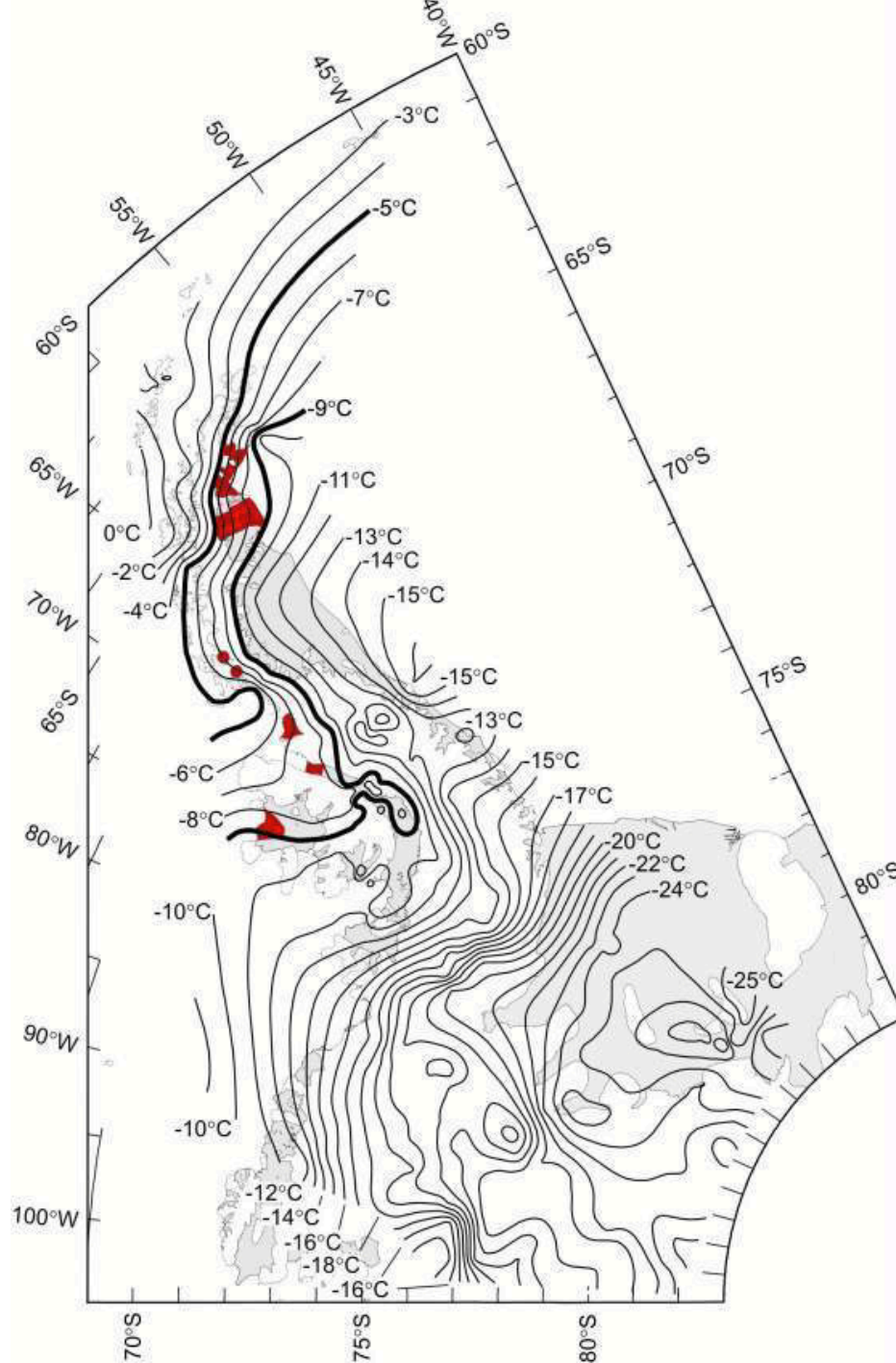


Fig. 3. ERS-2 SAR images showing Larsen B on (a) 24/27 February 2002 and (b) 6 March 2002. Dashed circles in (a) surround rifts cutting through the ice shelf. Lines 1, 2 and 3 show the ice-edge positions on 5, 6 and 7 March respectively.



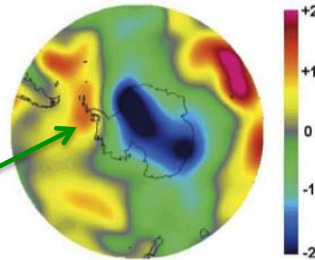
Jahresmitteltemperaturen im Bereich der Antarktischen Halbinsel.

Die Schelfeise, die in den letzten Jahren verschwunden sind, liegen zwischen der -5 und -9° Isotherme.

Hellgrau: existierende Schelfeise

Continent cools while peninsula warms

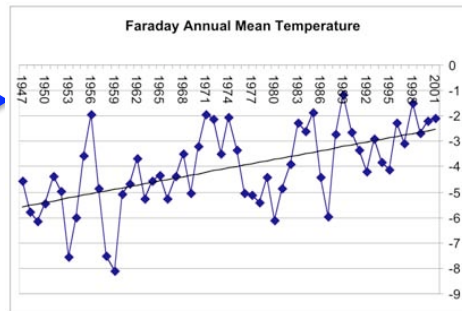
Change in mean Ann. Temp. °C (1969-2000)



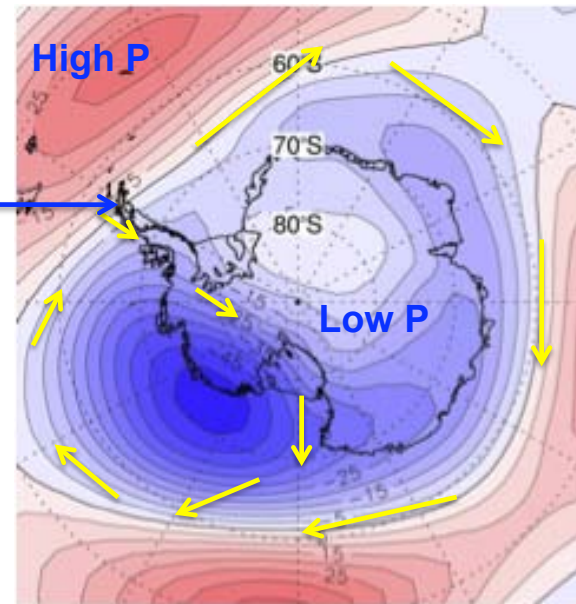
West peninsula

Warm air is brought in from the north by Amundsen Sea Low.

Air warms at $0.53^{\circ}\text{C}/\text{decade}$ at Faraday/Vernadsky since 1950. ($1.03^{\circ}\text{C}/\text{decade}$ in winter)



Correlates with decrease in sea ice.



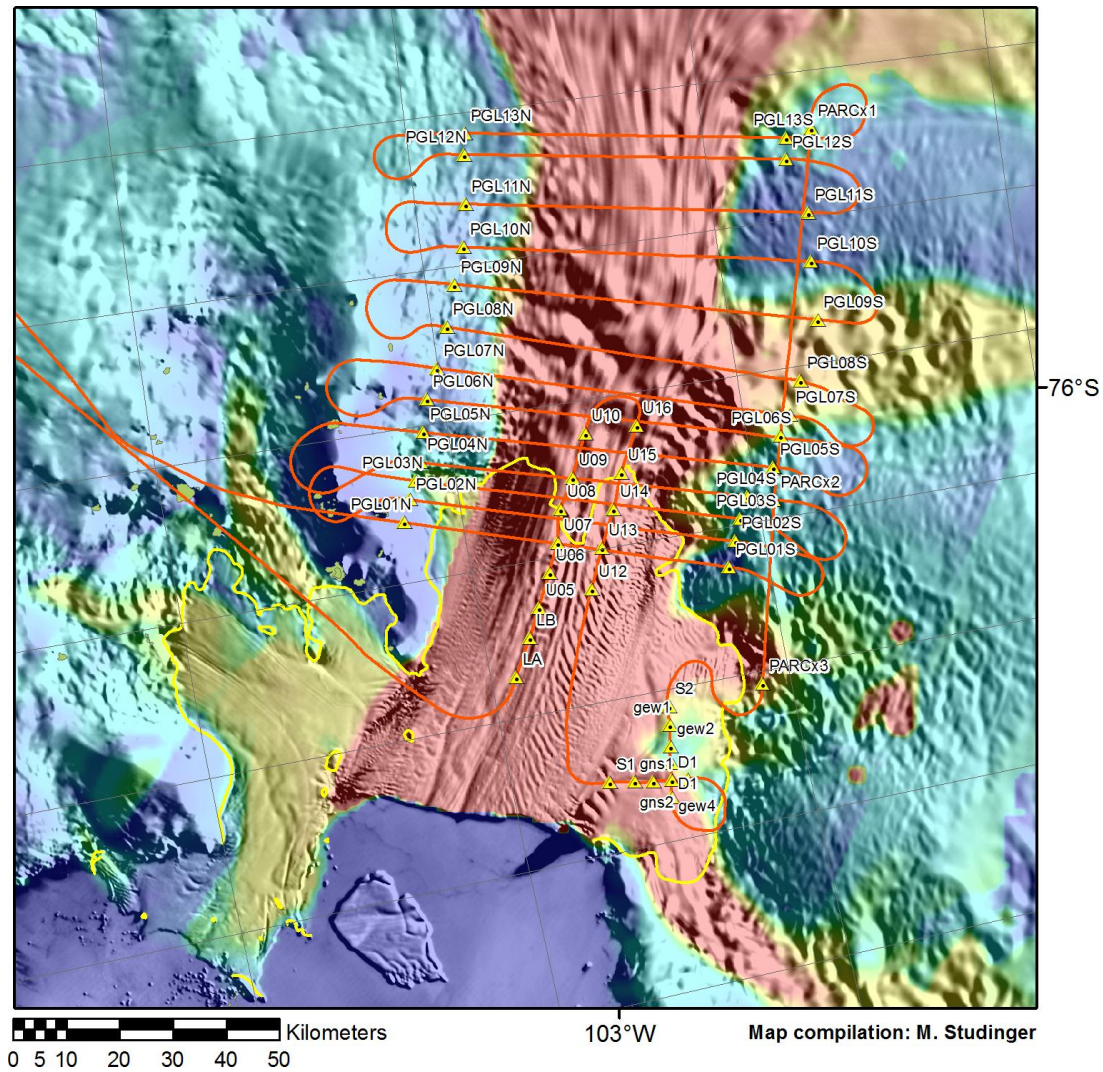


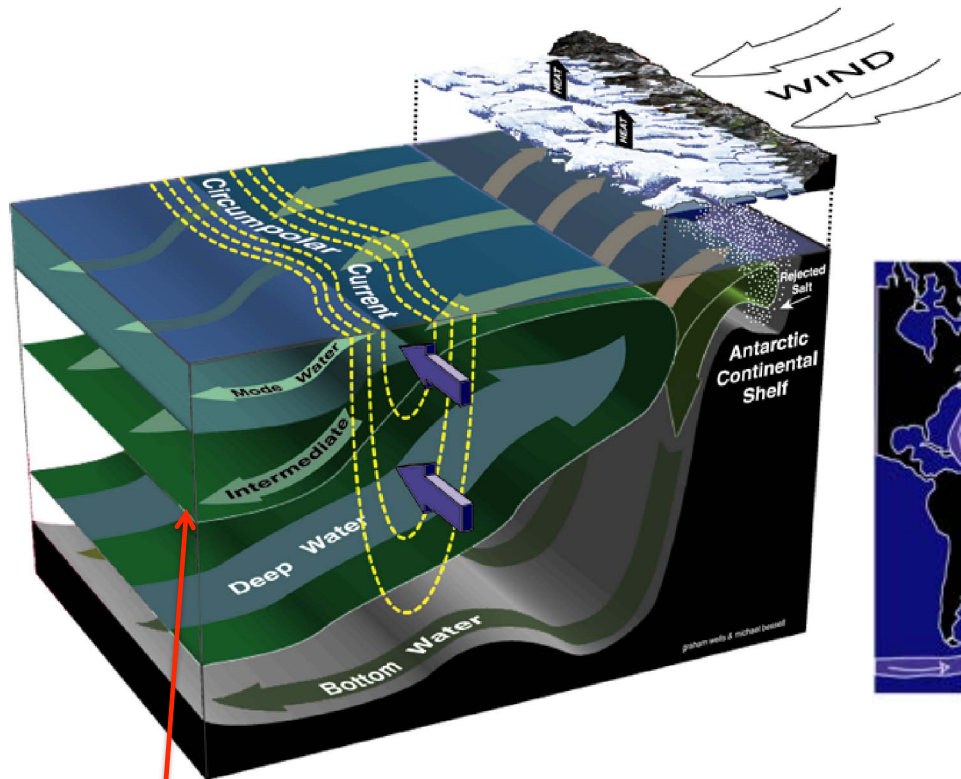
Figure 1: DC-8 trajectory over Pine Island Glacier. Background image is MODIS mosaic and ice surface velocity from InSAR.



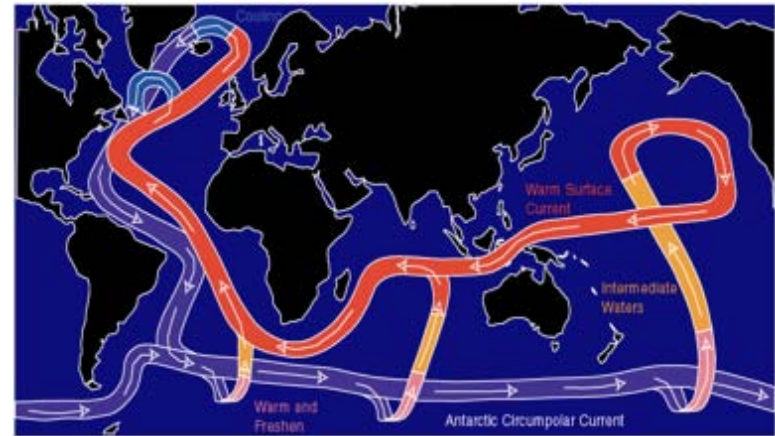
The Oceans Connect Everything

Climate signals are shared

- Pole-to-Pole
- Ocean-to-Ocean



Rintoul, 2001



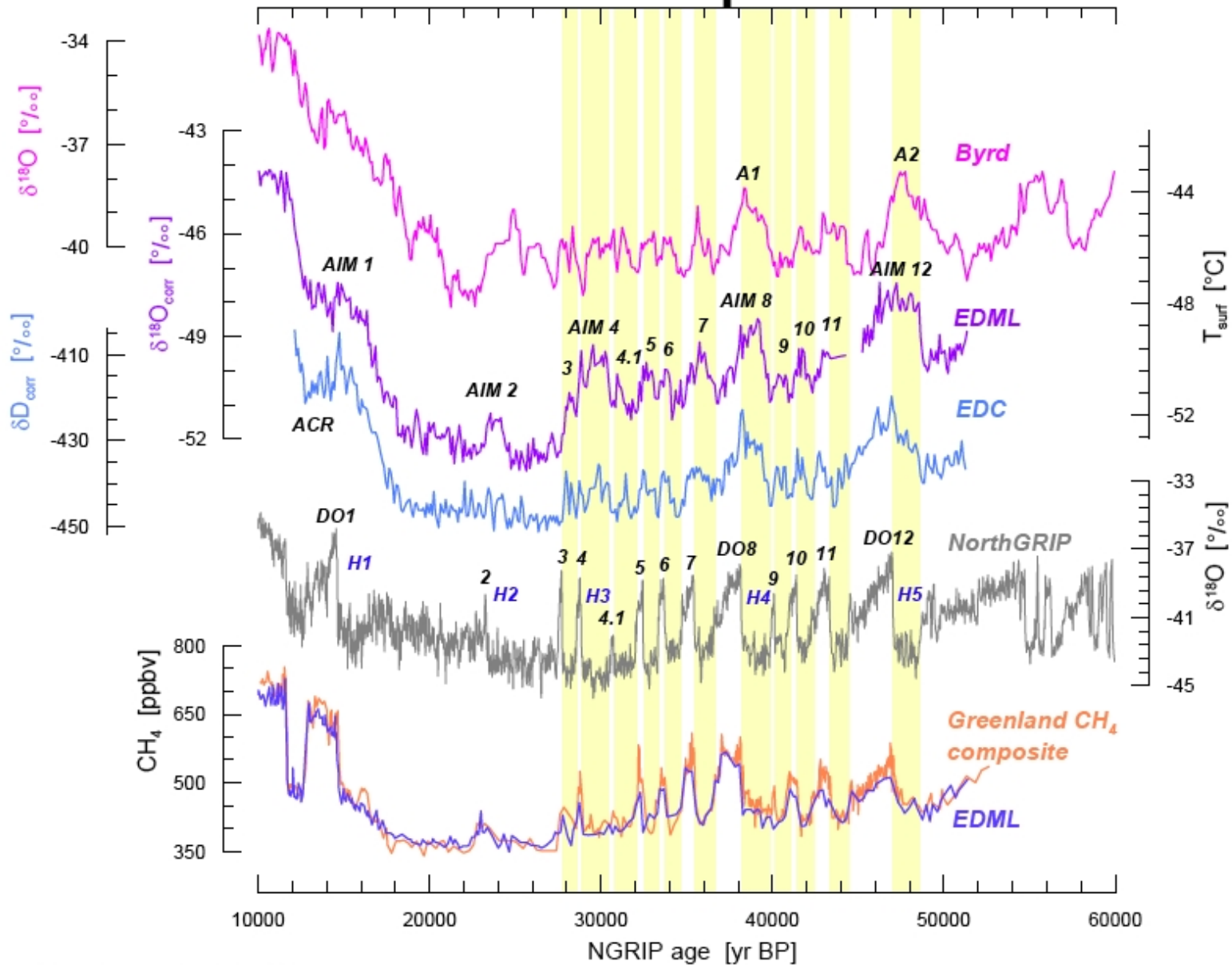
Thermohaline Conveyor Belt (after Doos and Webb)

196g_ocean/thermohaline2



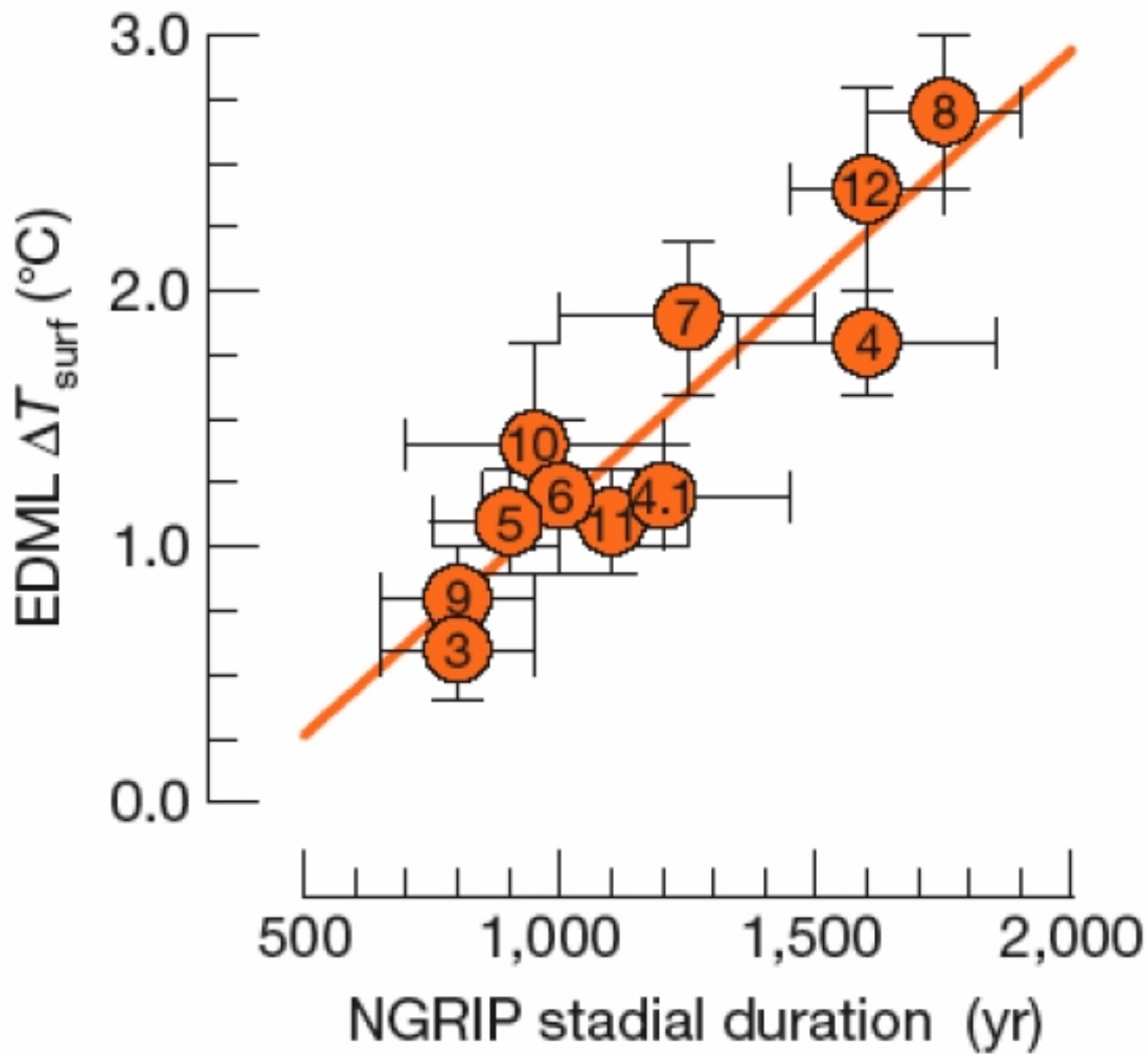
nutrients exported north provide 75% of global ocean productivity north of 30S.

Link Hemispheres



EPICA DML, NGRIP

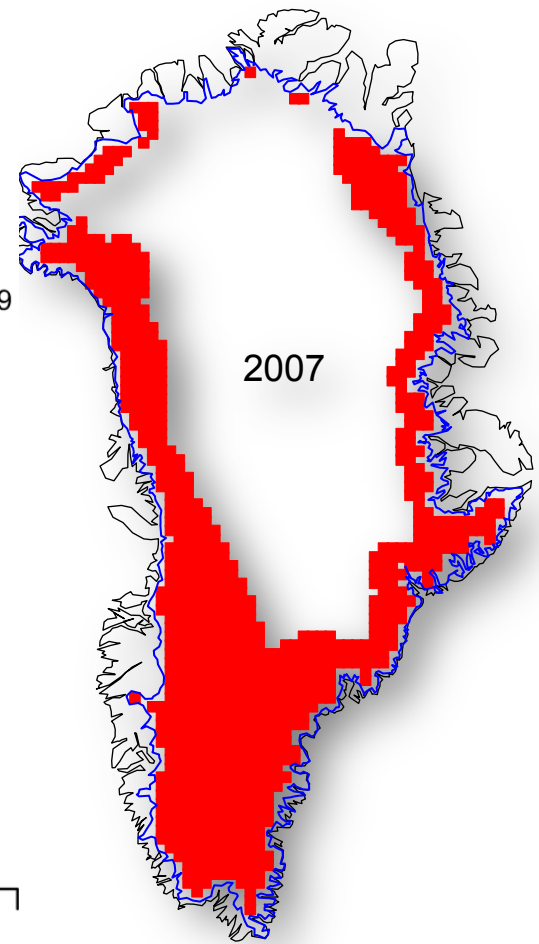
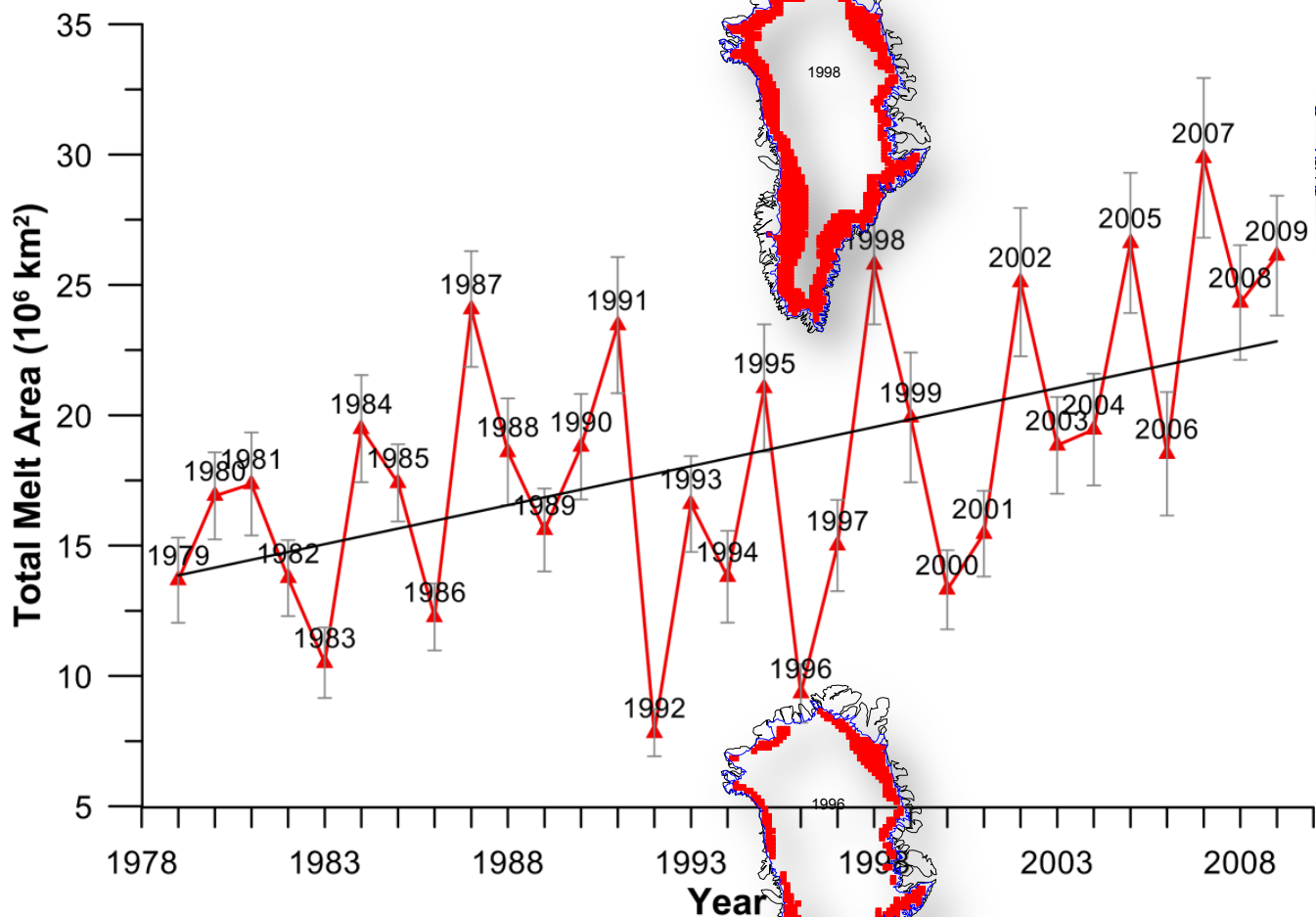
EPICA community members, Nature 2006



EPICA community members, Nature, 2006

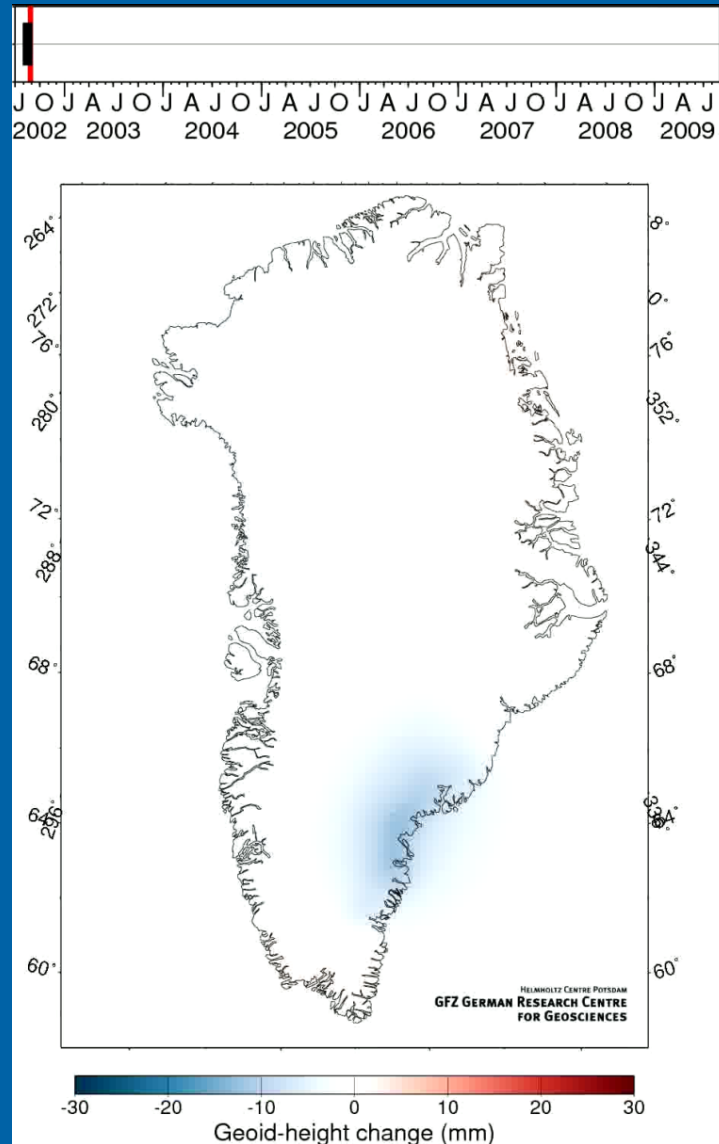
Greenland Total Melt Area: 1979-2009

Total Greenland ice sheet melt area increased 65% since 1979 over the 30 year record; on average 2%/year.

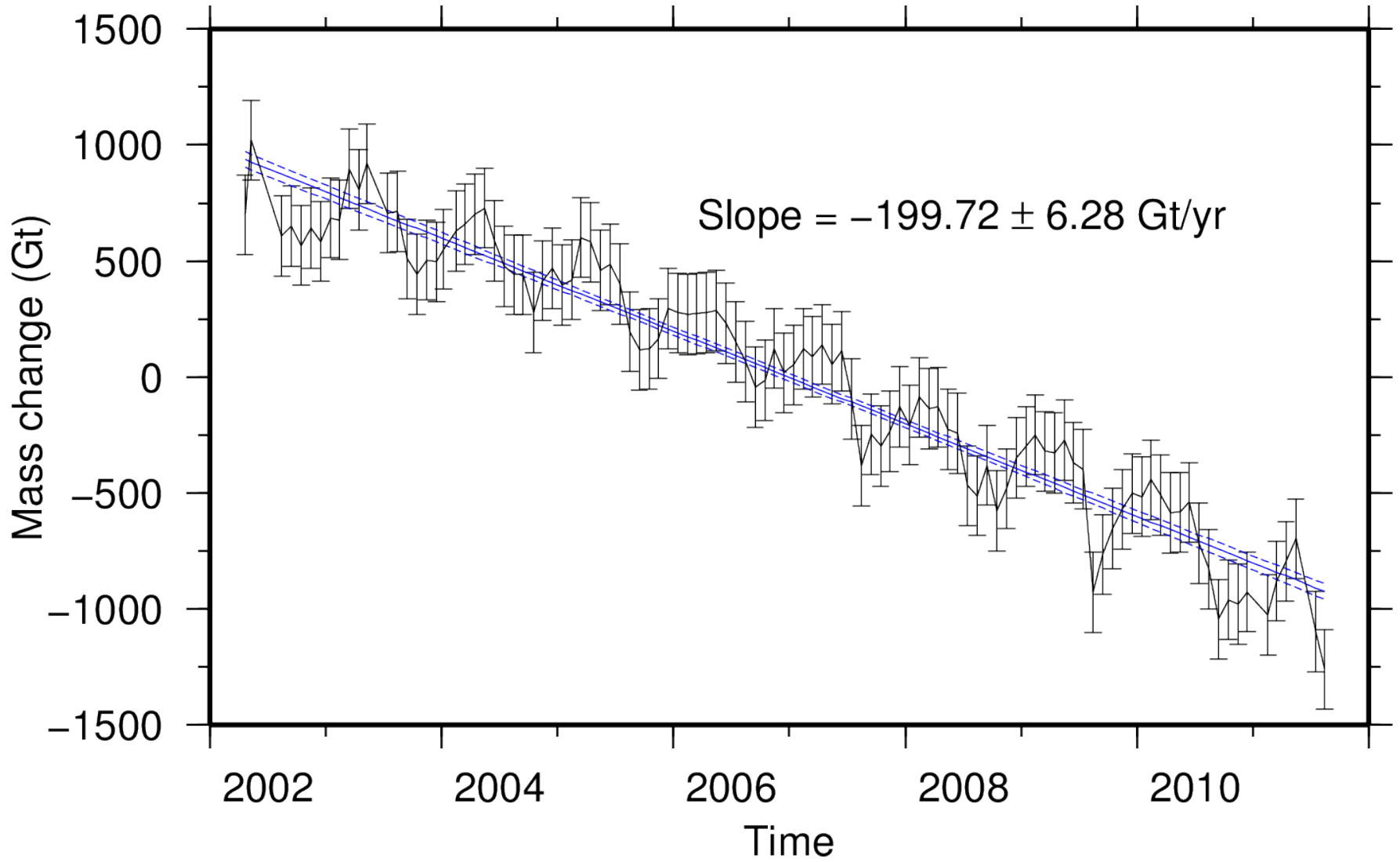


The increasing trend in the total area of melting bare ice is at 13% per year

GRACE observations over Greenland



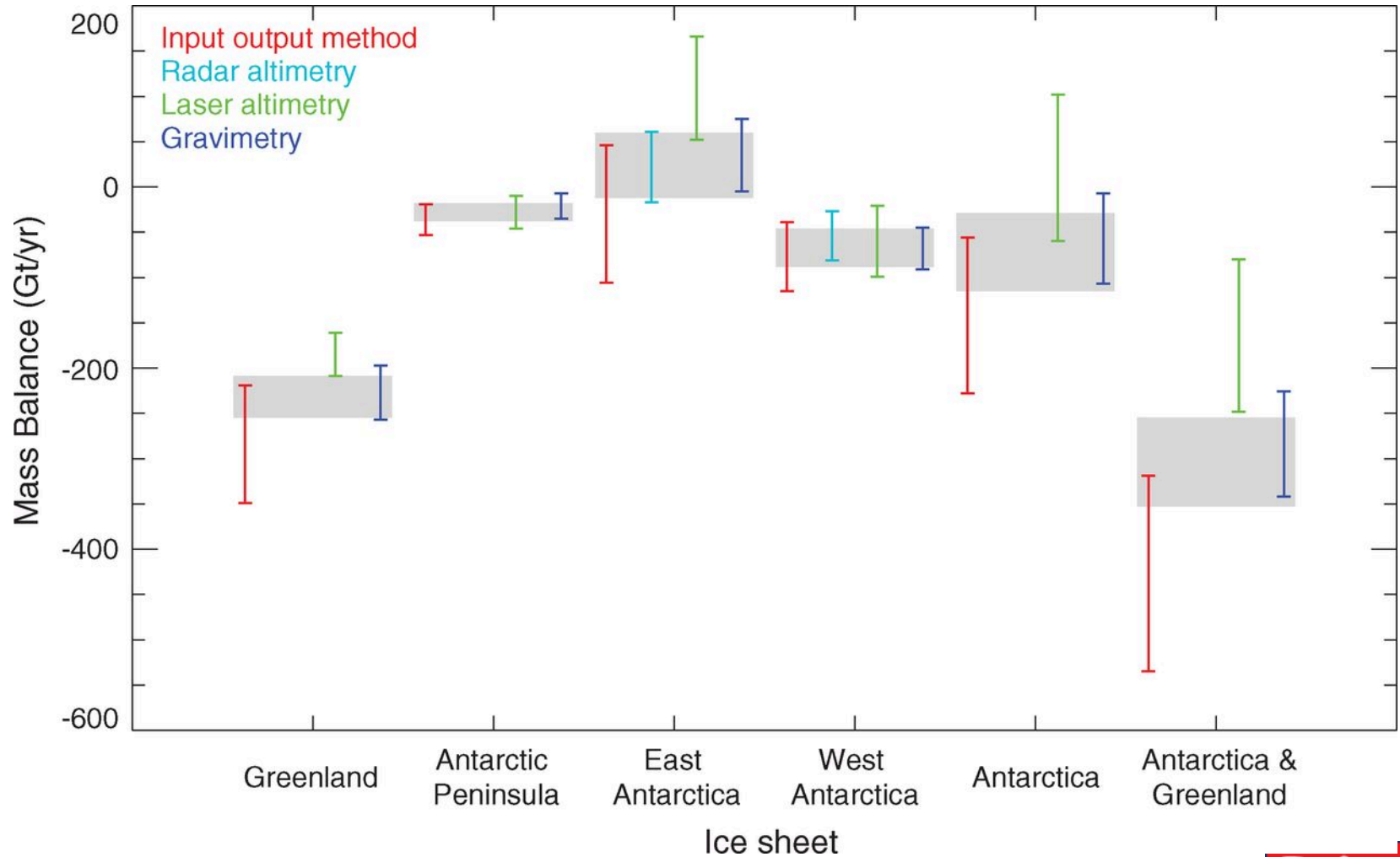
Total Mass Change
L = 60, Region = 0.5 deg.



Grönland Massenverlust

Harig & Simons, 2012

Fig. 3 Intercomparison of mass balance estimates of the GrIS, APIS, EAIS, WAIS, AIS, and the AIS plus GrIS, derived from the four independent geodetic techniques of RA (cyan), IOM (red), LA (green), and gravimetry (blue) over the period 2003 to 2008.



A Shepherd et al. Science 2012;338:1183-1189



Komponenten des Meeresspiegelanstiegs

Table SPM-1. Observed rate of sea level rise and estimated contributions from different sources. {5.5, Table 5.3}

Source of sea level rise	Rate of sea level rise (mm per year)	
	1961 – 2003	1993 – 2003
Thermal expansion	0.42 ± 0.12	1.6 ± 0.5
Glaciers and ice caps	0.50 ± 0.18	0.77 ± 0.22
Greenland ice sheet	0.05 ± 0.12	0.21 ± 0.07
Antarctic ice sheet	0.14 ± 0.41	0.21 ± 0.35
Sum of individual climate contributions to sea level rise	1.1 ± 0.5	2.8 ± 0.7
Observed total sea level rise	1.8 ± 0.5 ^a	3.1 ± 0.7 ^a
Difference (Observed minus sum of estimated climate contributions)	0.7 ± 0.7	0.3 ± 1.0

1.2 ± 0.4 mm/Year

31 cm/100 years

Table note:

^aData prior to 1993 are from tide gauges and after 1993 are from satellite altimetry.

(2012)
~1.6 mm/year

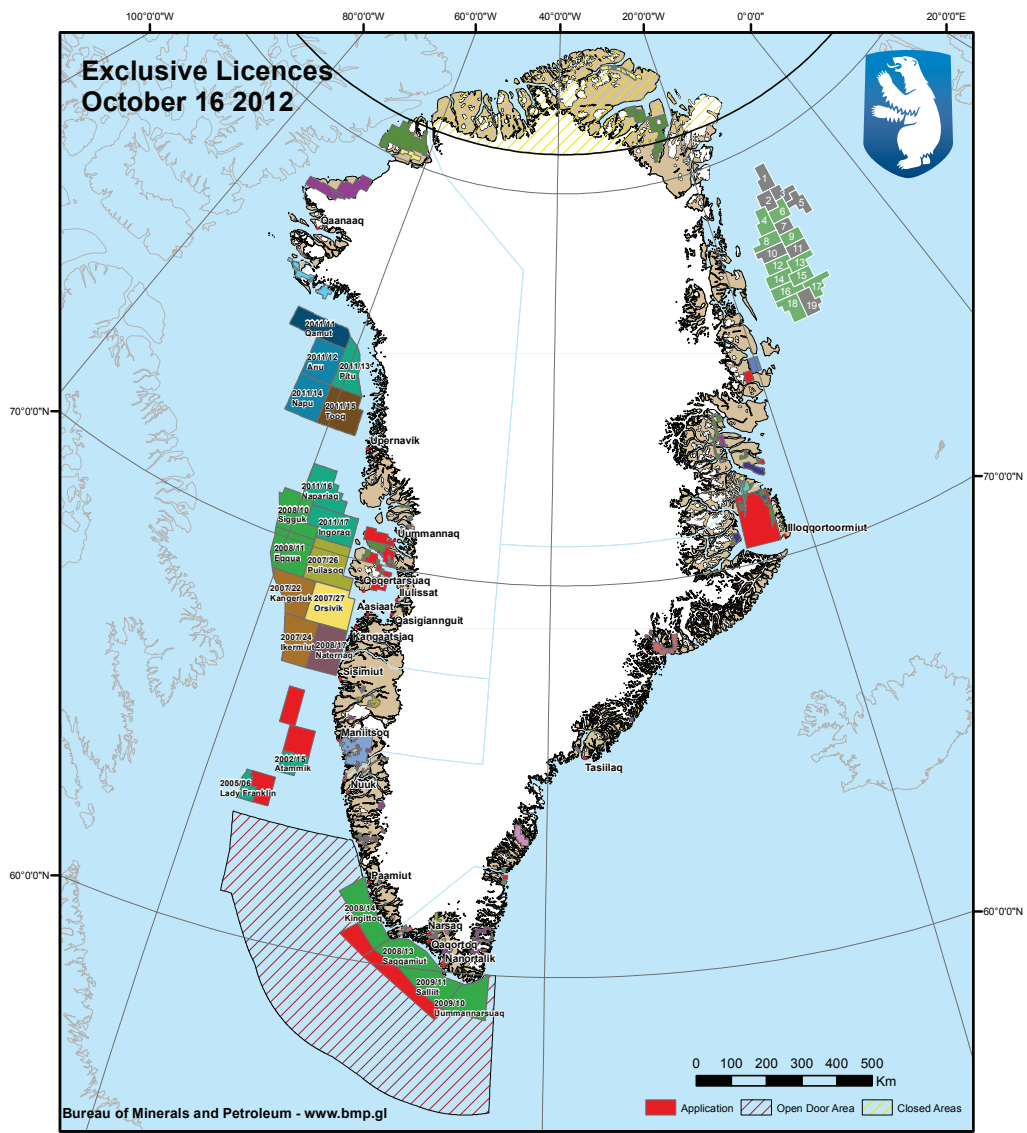
(2010)
~2.0 mm/year



Offene Fragen zum Meeresspiegelanstieg

- ❖ Beitrag durch Erwärmung des tiefen Ozeans
- ❖ Zukünftiger Gletscher-Beitrag (Gesamtmasse)
- ❖ Dynamik der Eisschilde (Ausfluss-Gletscher)
- ❖ Instabilität der Eisschilde
- ❖ Einfluss des Ozeans auf Schelfeis/Inlandeis





Exclusive Hydrocarbon Licences

- Cairn Energy, NUNAOIL
- Cairn Energy, Petronas, NUNAOIL
- ConocoPhillips, DONG Energy, NUNAOIL
- DONG Energy, ExxonMobil, Chevron, NUNAOIL
- Husky Oil, ExxonMobil, NUNAOIL
- Husky Oil, NUNAOIL
- Maersk Oil, NUNAOIL
- PA Resources AB, NUNAOIL
- Shell, Statoil, GDF Suez, NUNAOIL

Greenland Sea Licensing Round

- Pre Licensing Round
- Ordinary Licensing Round

Exclusive Mineral Licences

- 21st North
- Angel Mining (Gold)
- Angel Mining PLC
- Avannaq Exploration
- Bedford (No.3)
- Black Angel Mining
- CGRG
- East Coast Minerals (Australia)
- Greenland Gold Resources
- Greenland Minerals & Energy
- Greenland Resources
- Hudson Resources
- Hunter Minerals
- Ironbark Zinc
- London Mining Greenland
- Malmberg Molybdenum
- Minelco
- NAMA Coal
- NAMA Greenland
- Nordic Mining
- North American Nickel
- North Star Minerals
- NunaMinerals
- Pinnacle Nominees
- Platina Resources
- Plymouth Minerals
- Power Resources
- RAM Resources
- Rare Earths Minerals No. 2
- Rimbal
- Sirius Minerals
- Talbot Group Investments
- Tanbreez Mining Greenland
- True North Gems
- West Melville Metals

Zukünftige Herausforderungen

- ❖ Inventur für Eis auf der Erde (Fläche, Masse!)
 - ❖ Eis-Massenbilanz (Gletscher & Eisschilde)
 - ❖ Permafrost-Änderungen (Gas-Austausch)
 - ❖ Rolle der polaren Prozesse und Rückkopplungen
 - ❖ Antwort der terrestrischen und marinen Ökosysteme auf Klimaänderungen in den Polargebieten (Resilienz gegenüber Störungen)
-
- ❖ Beobachtungssysteme (Prozesse, Feedbacks, **Klima!**)
 - ❖ Datenanalyse zum Verständnis des Klimasystems
 - ❖ Assimilation, **Vorhersage**, Szenarien als Basis für **Anpassung- und Vermeidungsstrategien**
 - ❖ **Nachhaltige (institutionelle) Finanzierung**



ACCESS
Feldstationen

Research Base Zackenberg



NyAlesund



Research Bases

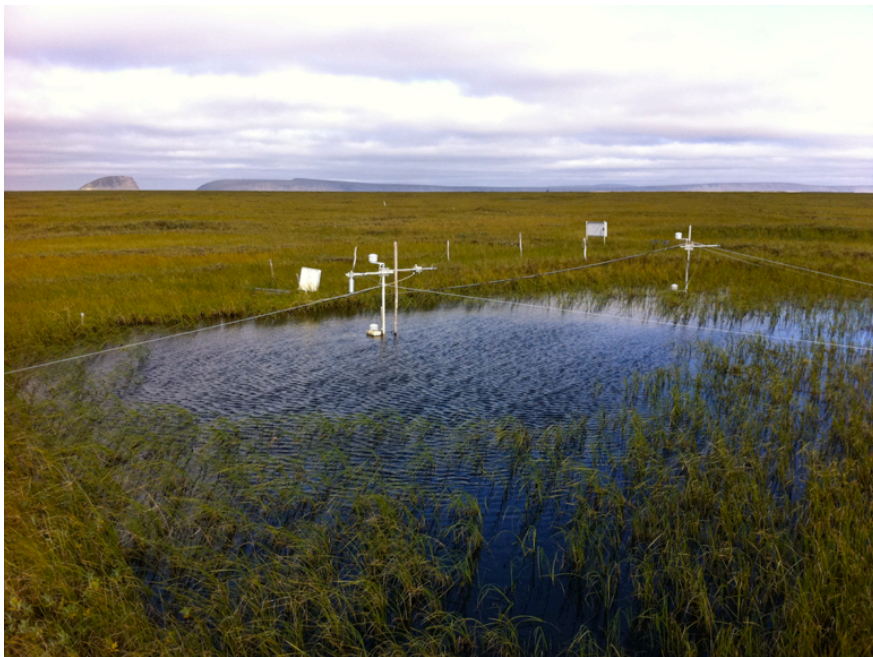
Research Base Samoylov

of the Lena-Delta-Reserve with research focus on greenhouse gas production and atmospheric exchange in Arctic Tundra and Permafrost landscape.

New Base jointly with RAS as of 2013.



Samoylov Island
(N 72°22, E 126°28)



ARICE – Arctic Research Icebreaker Consortium for Europe

A strategy for meeting the needs for marine research in the Arctic



20 partners from Europe, USA and Canada, „Letters of support“ from IASC, ISAC and SAON

Initiated & coordinated by:



Vielen Dank für Ihre Aufmerksamkeit!

