

# Monitoring of the sea ice cover in a changing polar environment using satellite remote sensing

Robert Ricker<sup>1</sup>, Stefan Hendricks<sup>1</sup>, Frank Kauker<sup>1</sup>,  
Stephan Paul<sup>2</sup>, Thomas Krumpfen<sup>1</sup>, et al.

<sup>1</sup> Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research

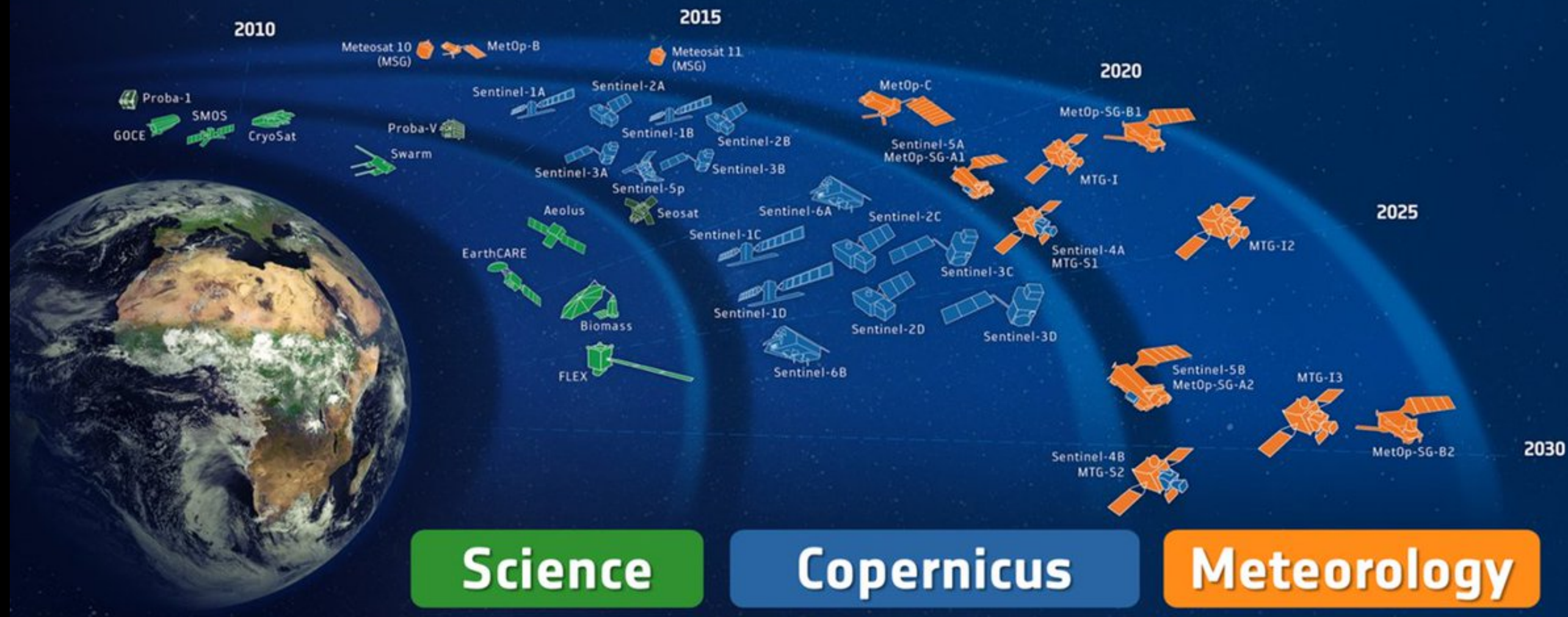
<sup>2</sup> LMU München

# Into the future with earth observation satellites



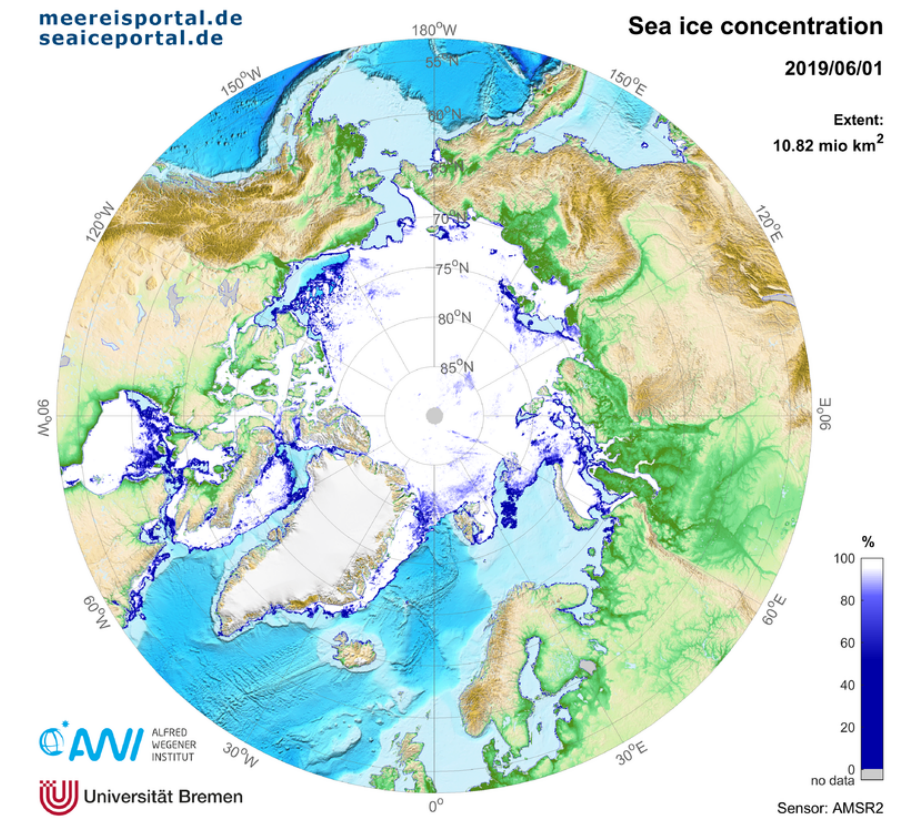
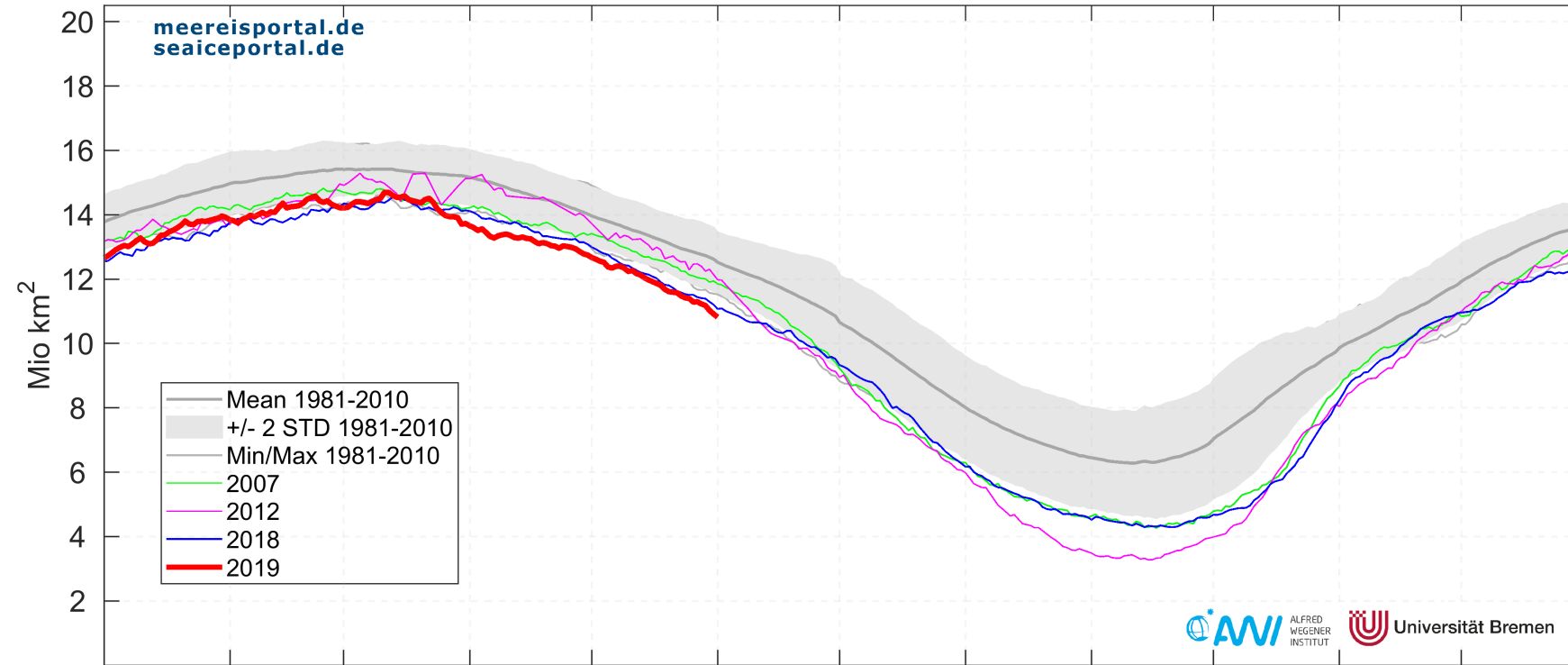
Currently, ESA's Earth observation activities include 14 satellites in operation and 26 satellites in development (September 2018)

## ESA-DEVELOPED EARTH OBSERVATION MISSIONS

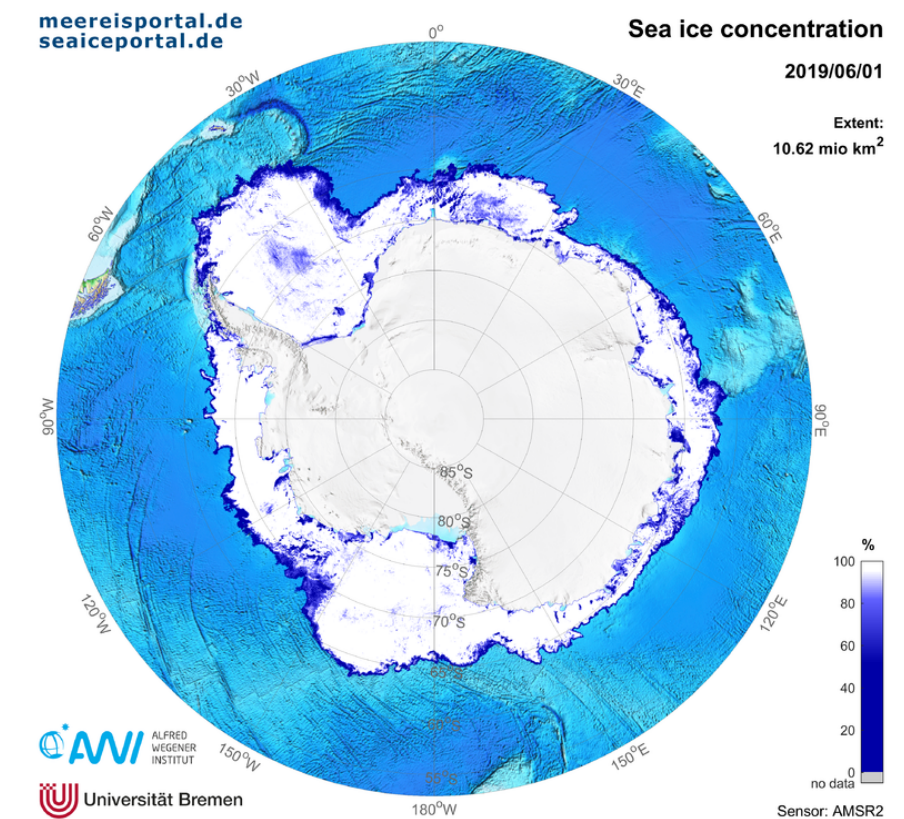
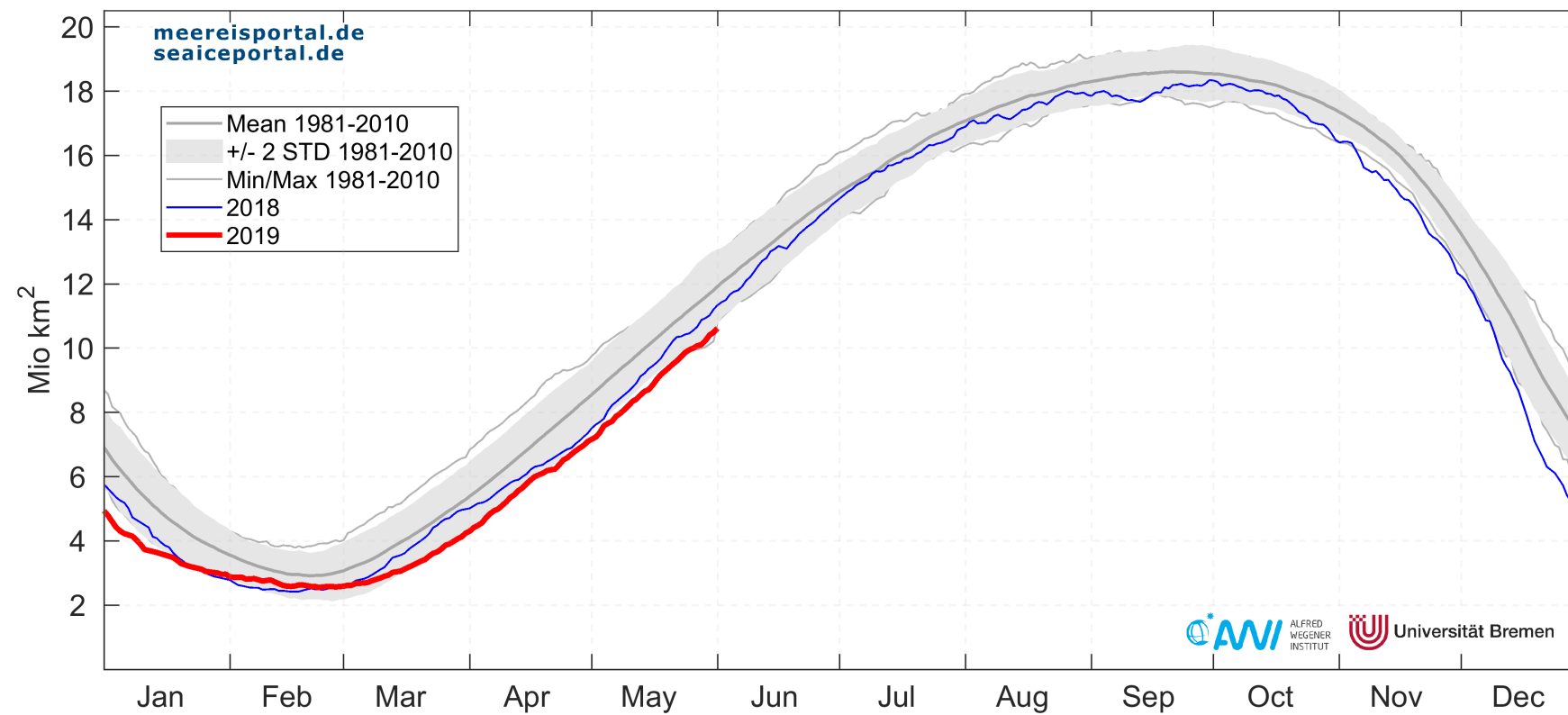


# Sea ice extent

Arctic sea ice extent (Sea ice concentration >15%) 2019/06/01: 10.82 mio km<sup>2</sup>



Antarctic sea ice extent (Sea ice concentration >15%) 2019/06/01: 10.62 mio km<sup>2</sup>

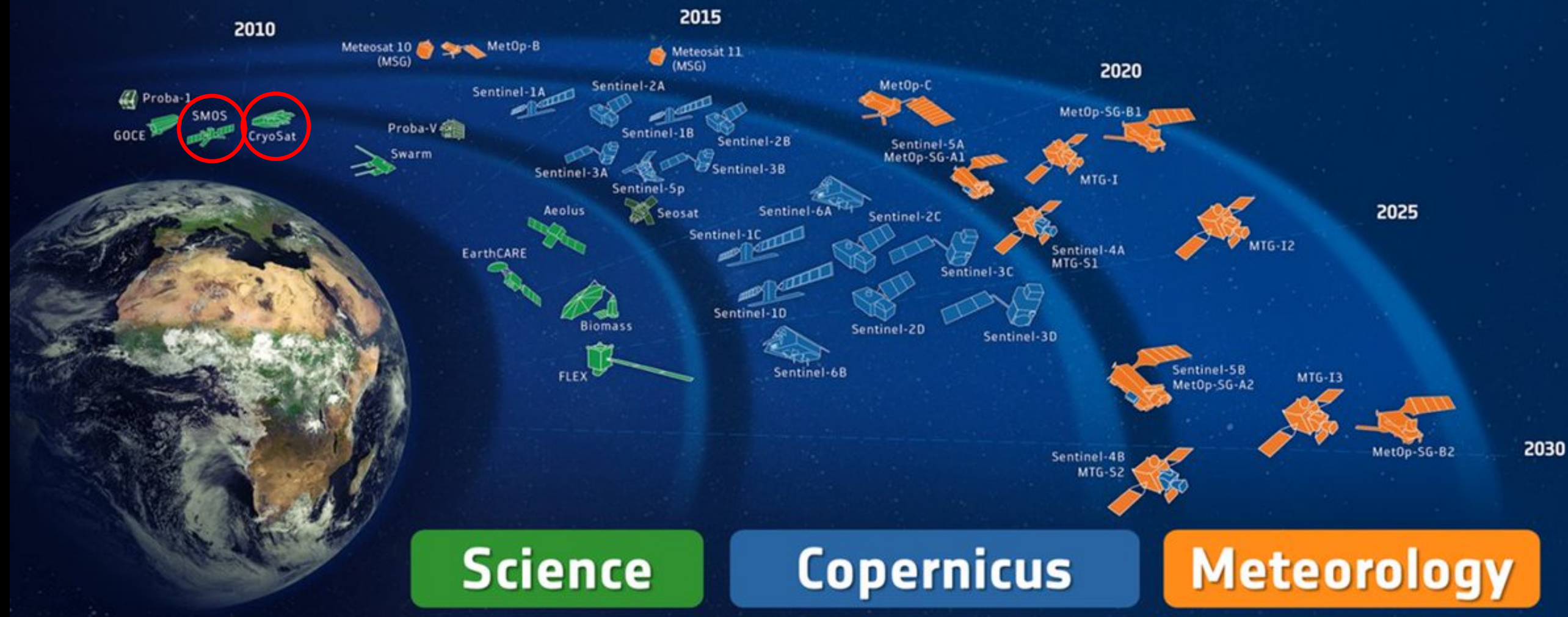


# Into the future with earth observation satellites



Currently, ESA's Earth observation activities include 14 satellites in operation and 26 satellites in development (September 2018)

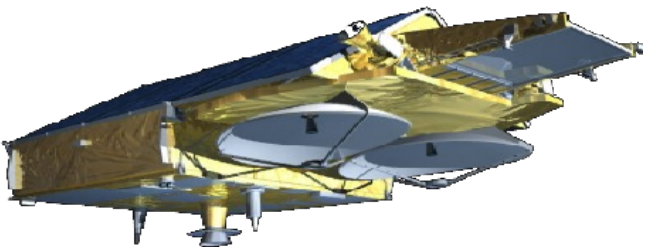
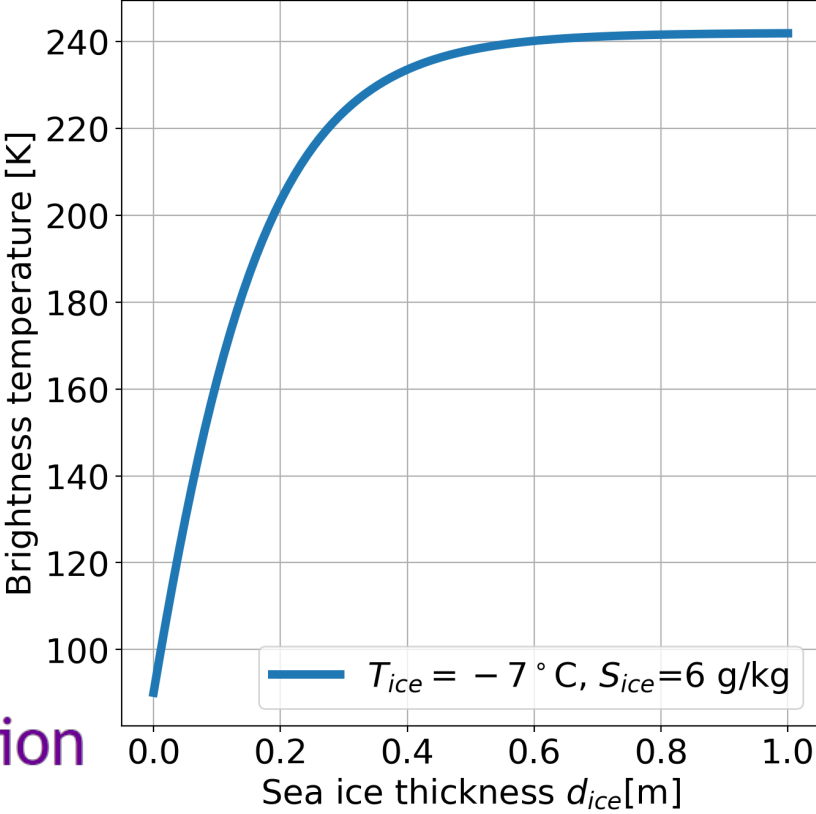
## ESA-DEVELOPED EARTH OBSERVATION MISSIONS



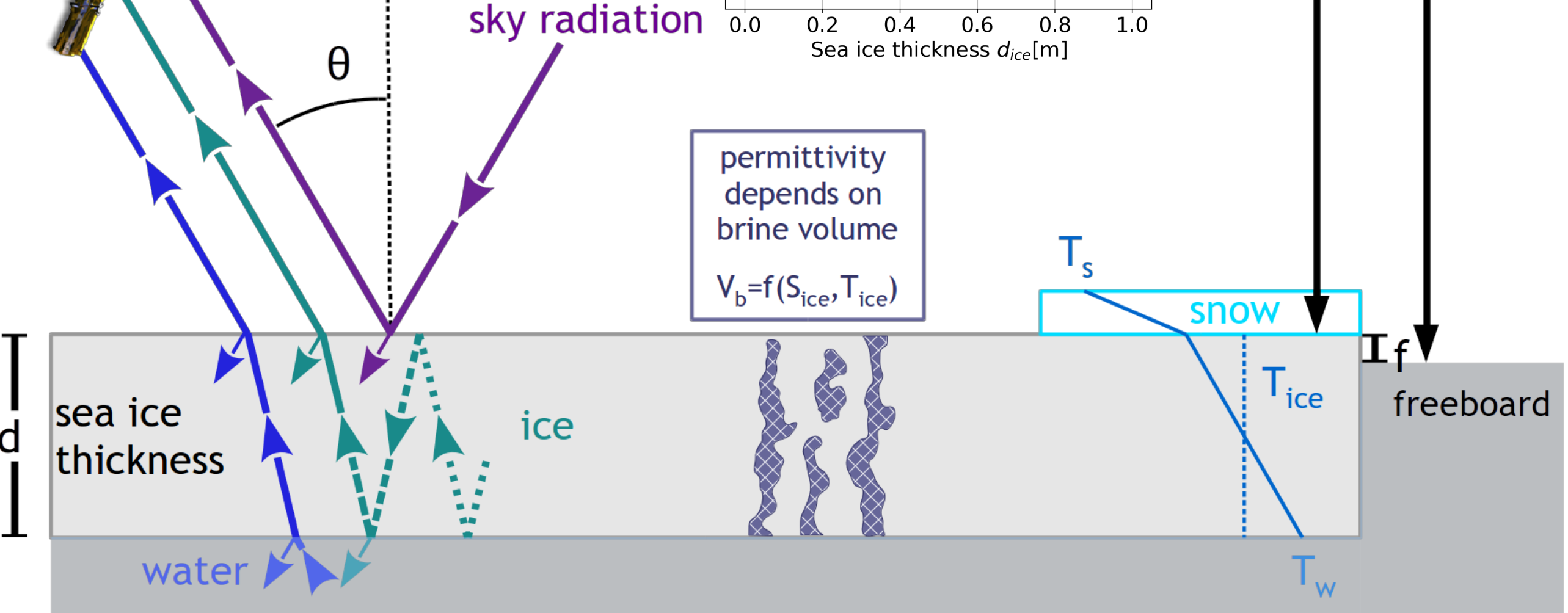
# How to measure sea ice thickness from space?



SMOS



CryoSat-2



# Sea ice altimetry vs. radiometry



Method

Footprint

Full coverage period

Max. Latitude

Thickness Range

## CryoSat-2

Altimetry (Ku-band)

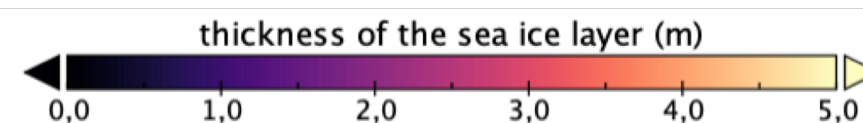
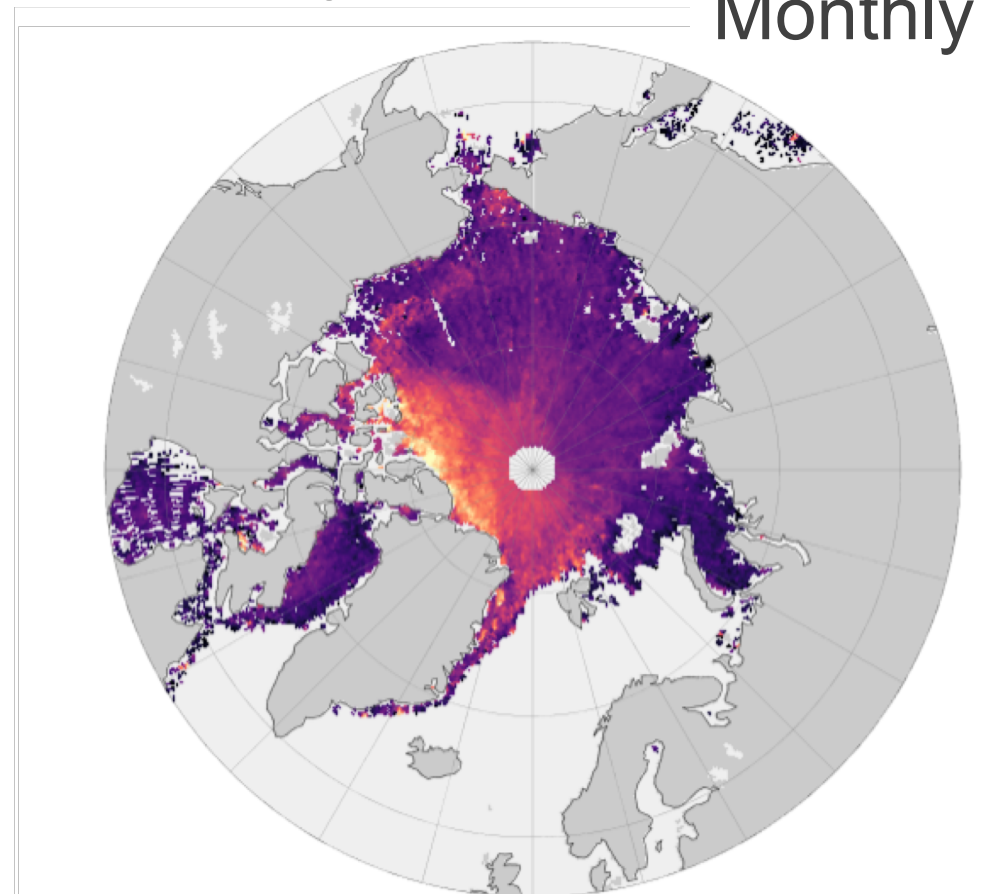
300 m x 1650 m

monthly

88°

Full

Monthly (Mar 2019)



## SMOS

Radiometry (L-Band)

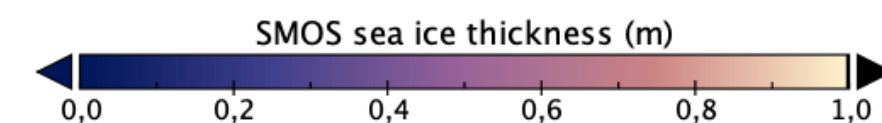
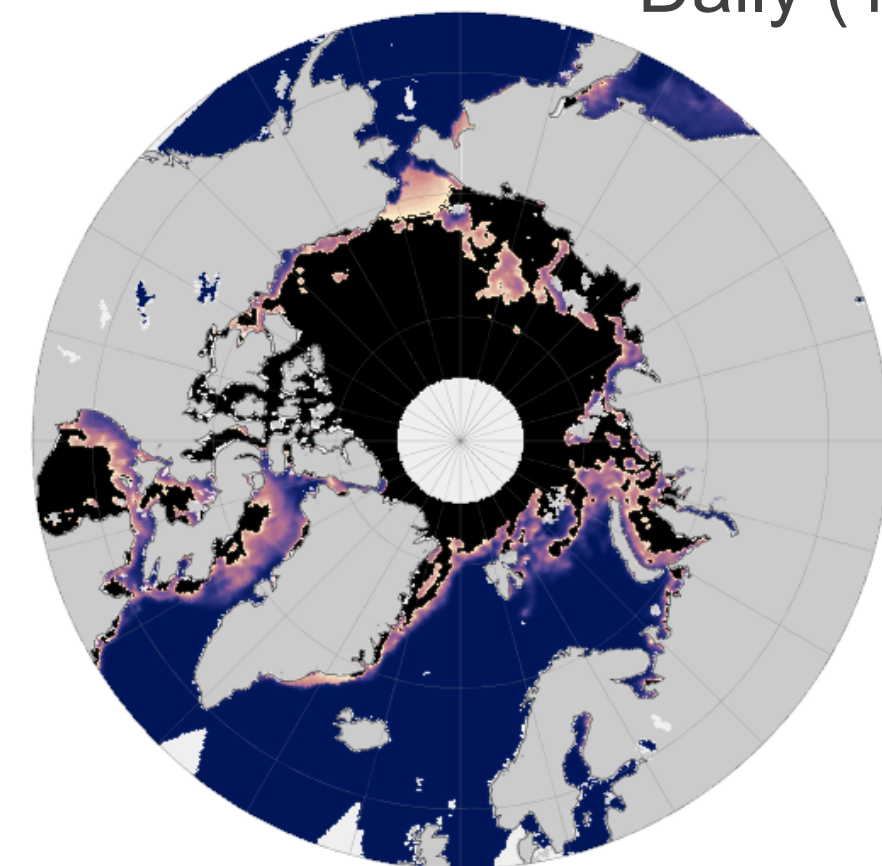
~40 km

daily

81.35

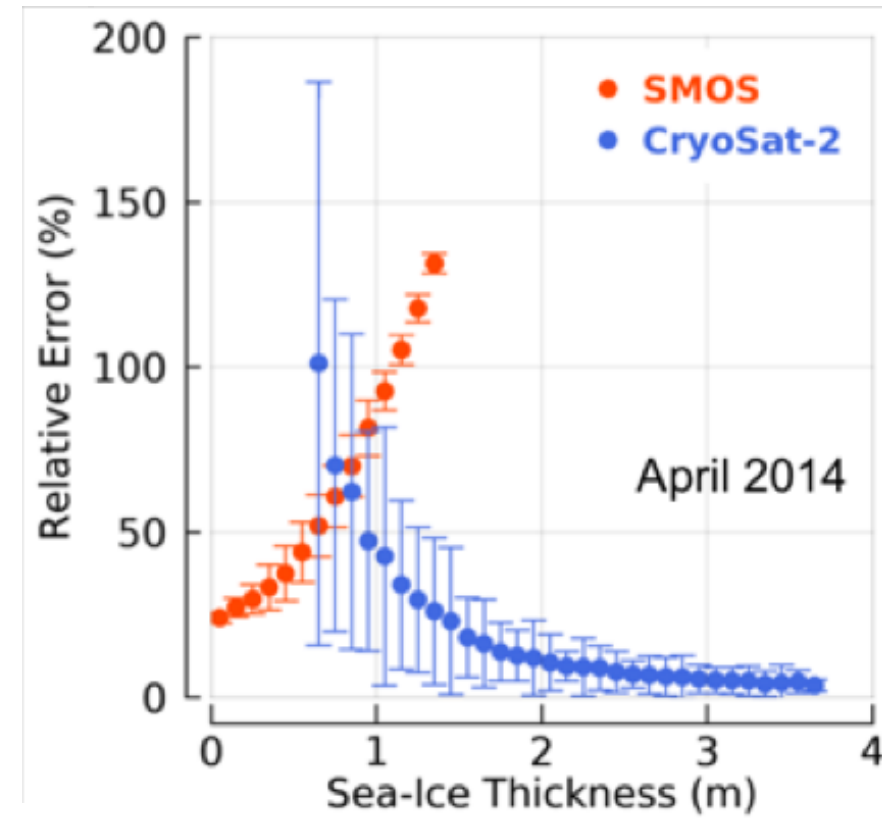
< 1 m

Daily (1.3.2019)

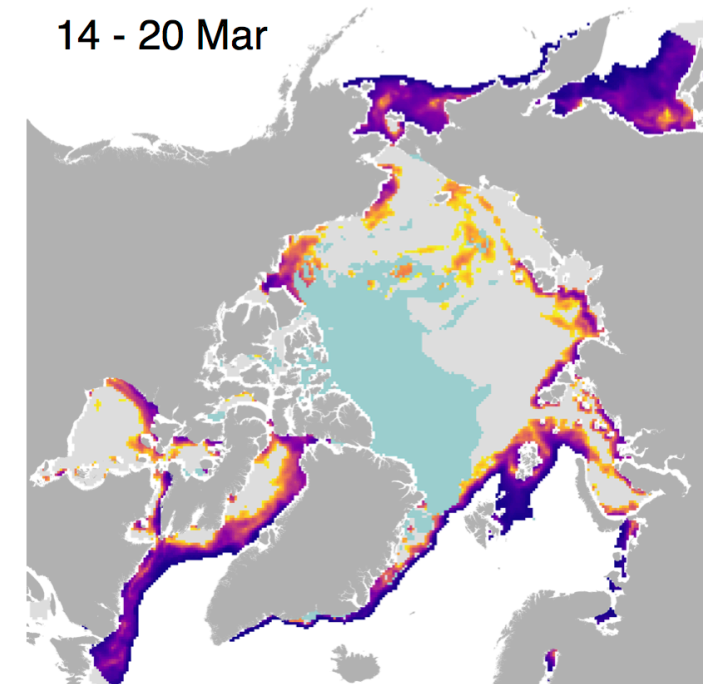


# Reducing uncertainties by data fusion

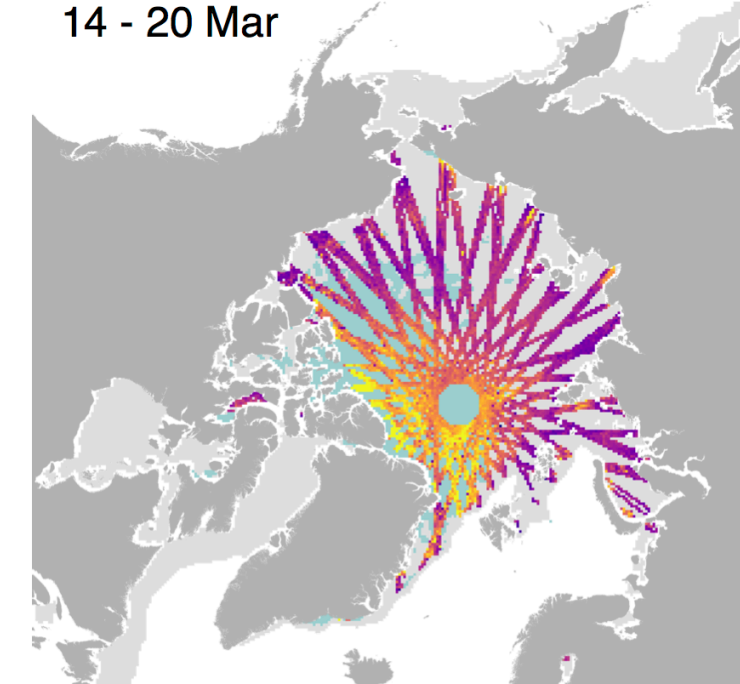
- Taking advantage of the complementary thickness retrievals, derived from the CS2 altimeter and the SMOS radiometer
- Weekly Arctic-wide sea-ice thickness fields with reduced relative uncertainties



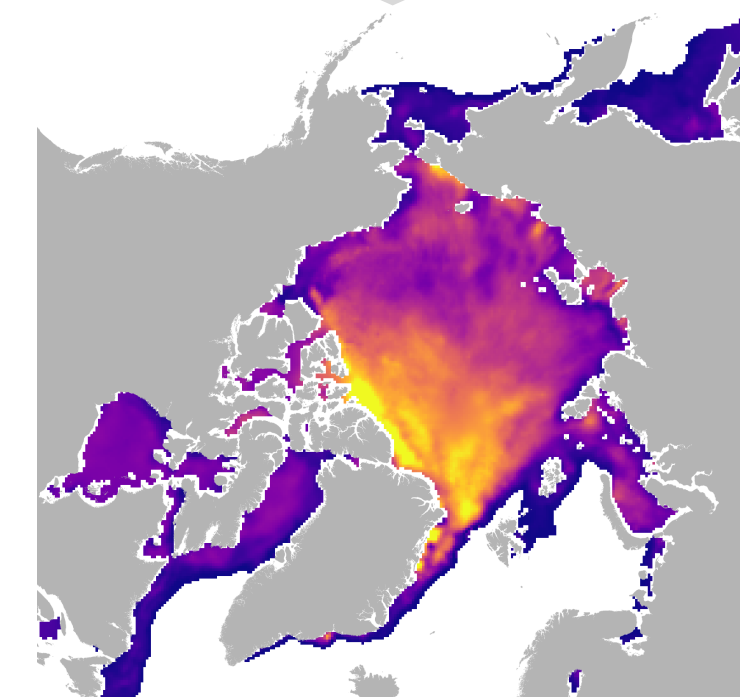
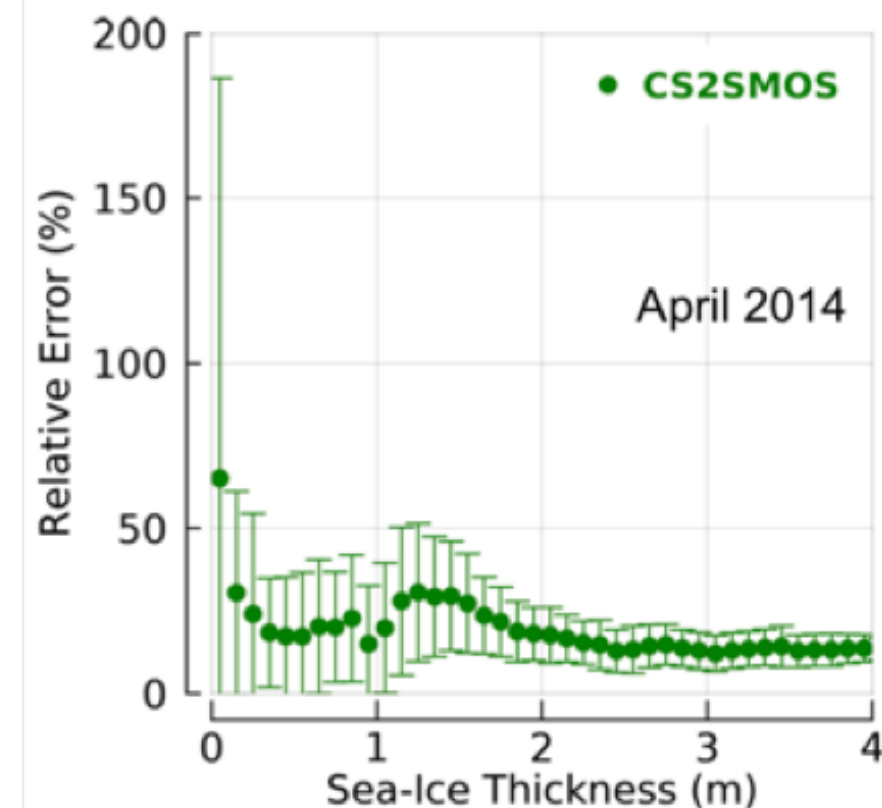
SMOS ice thickness retrievals  
14 - 20 Mar



CryoSat-2 weekly means  
14 - 20 Mar



■ First-Year Ice  
■ Multiyear Ice



# Sea ice thickness and volume time series

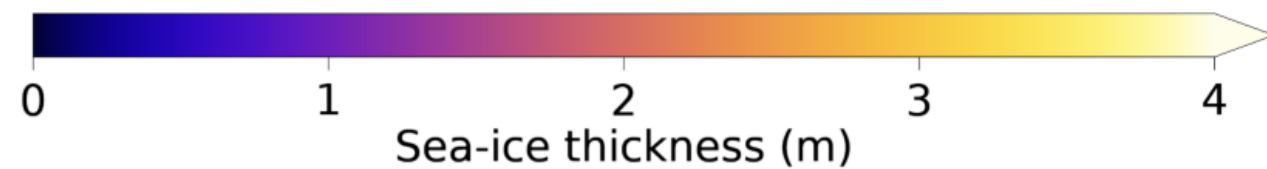
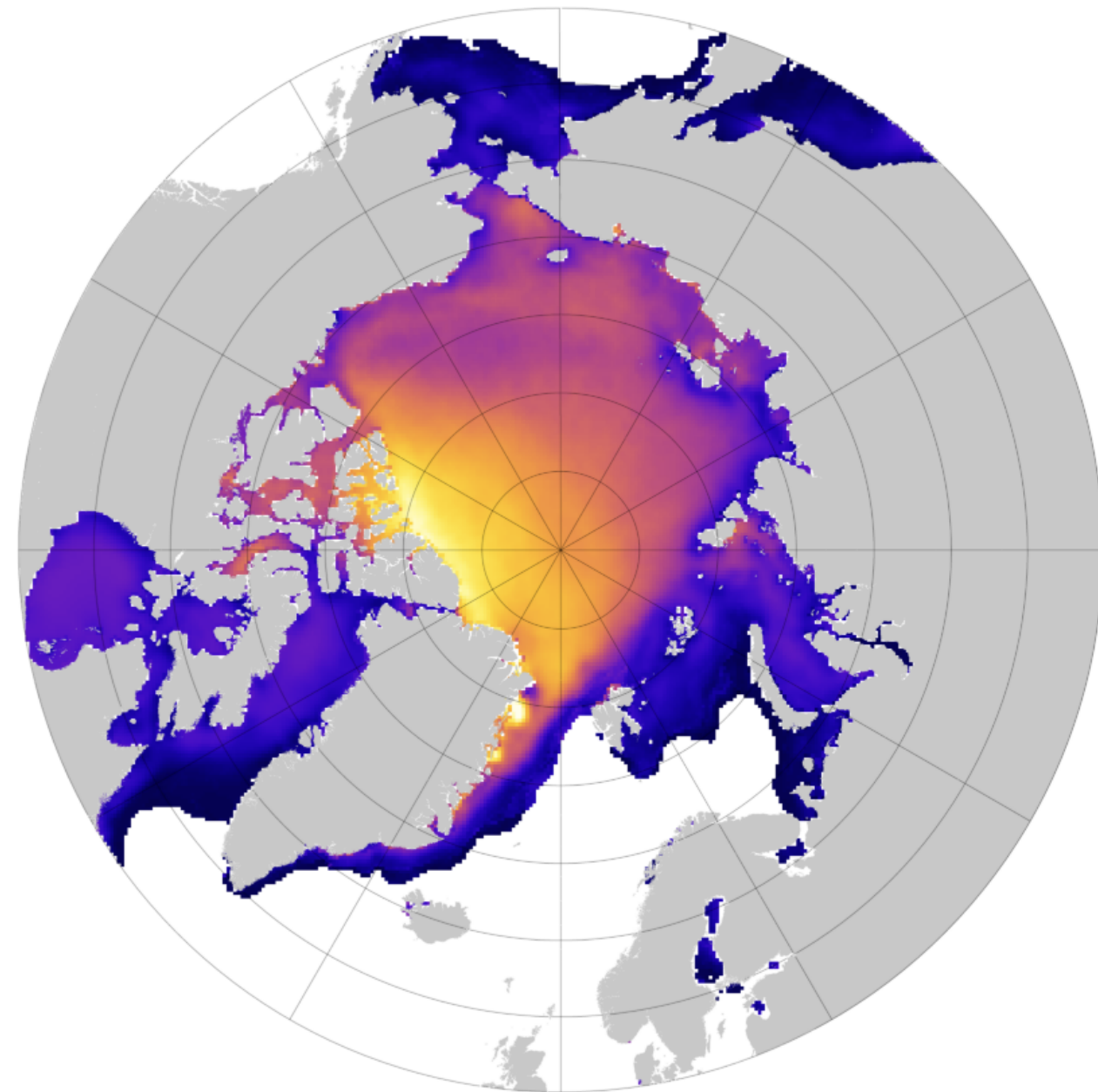




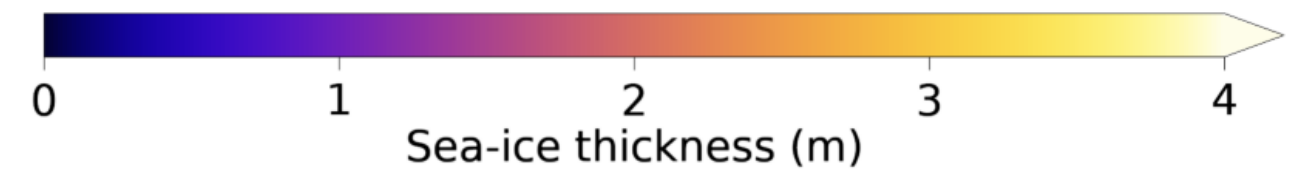
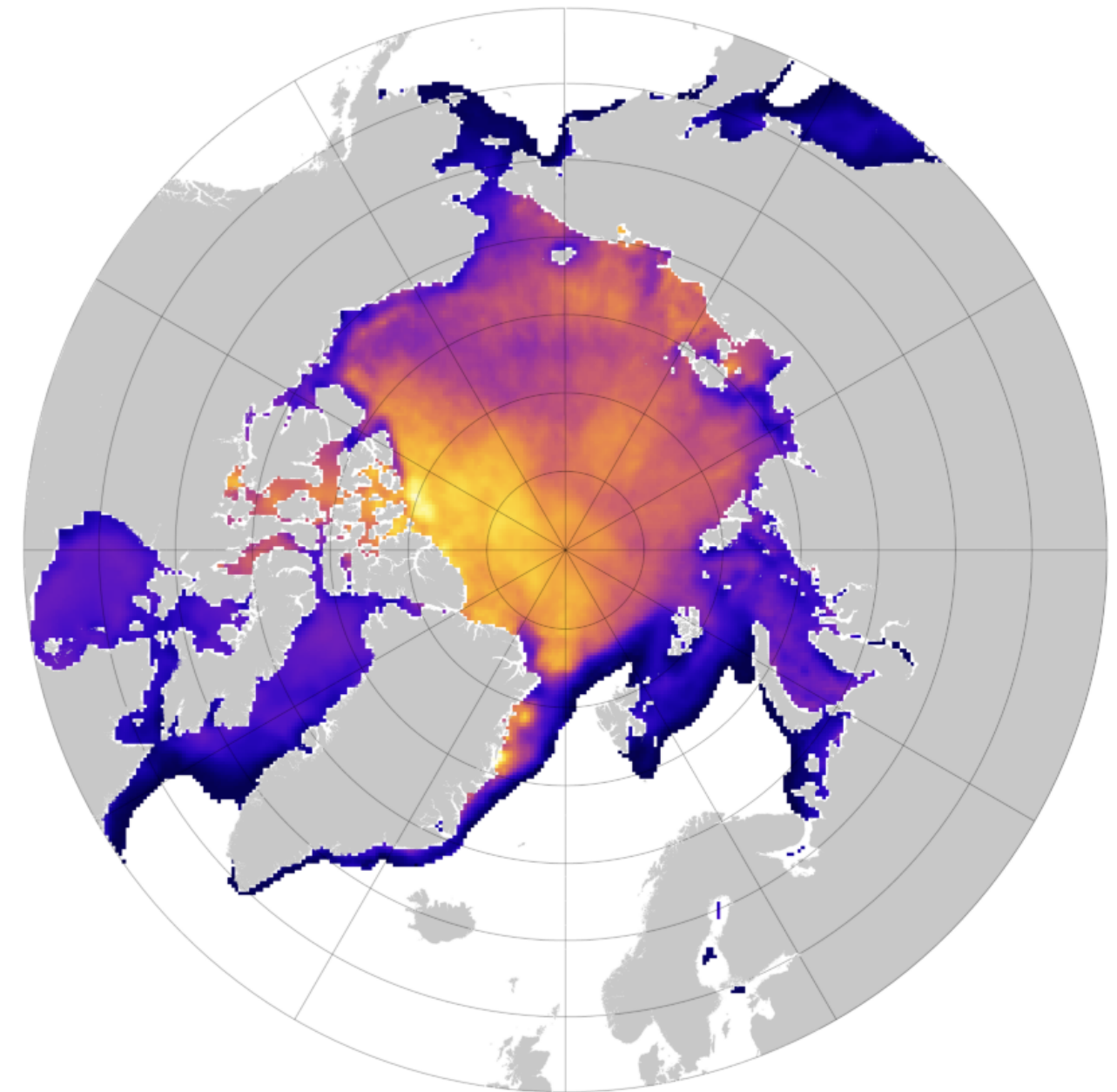
# Arctic sea ice thickness last winter (March 2018)



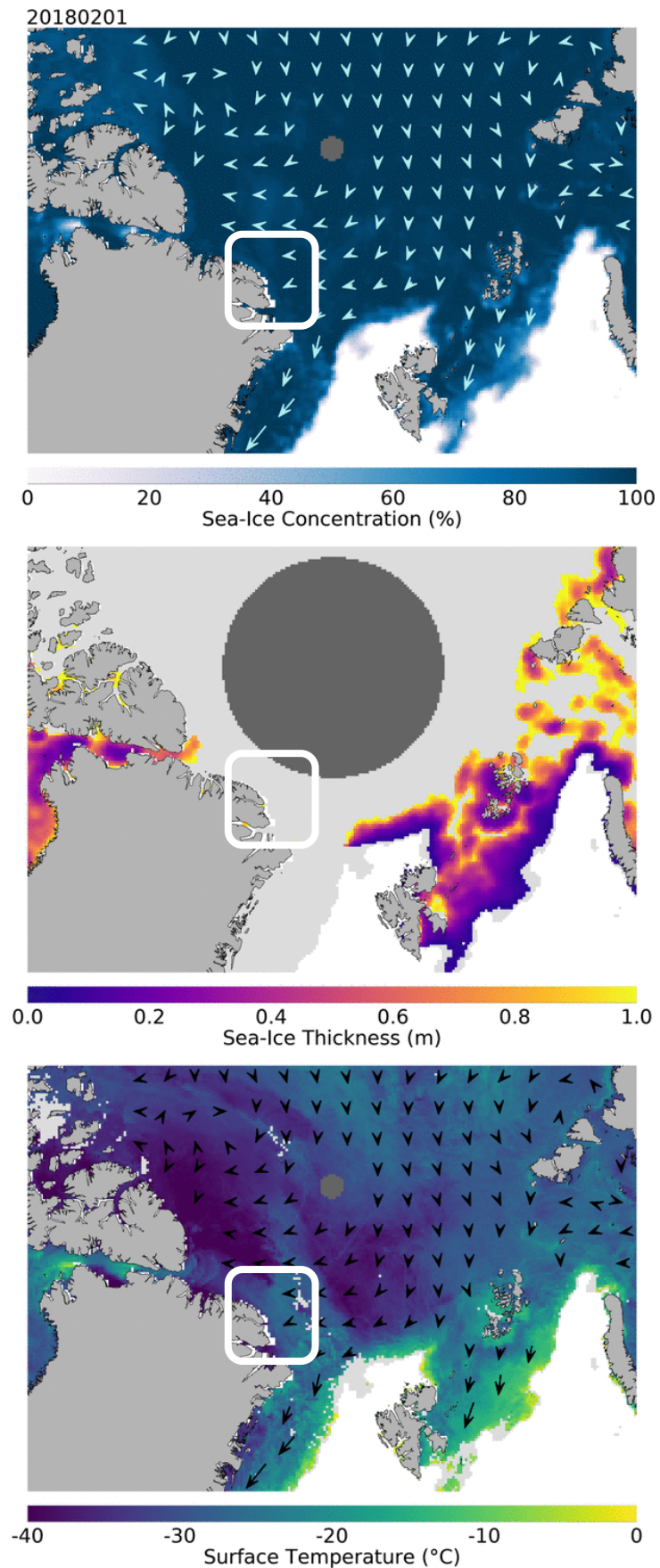
March mean sea-ice thickness  
(2011-2018)



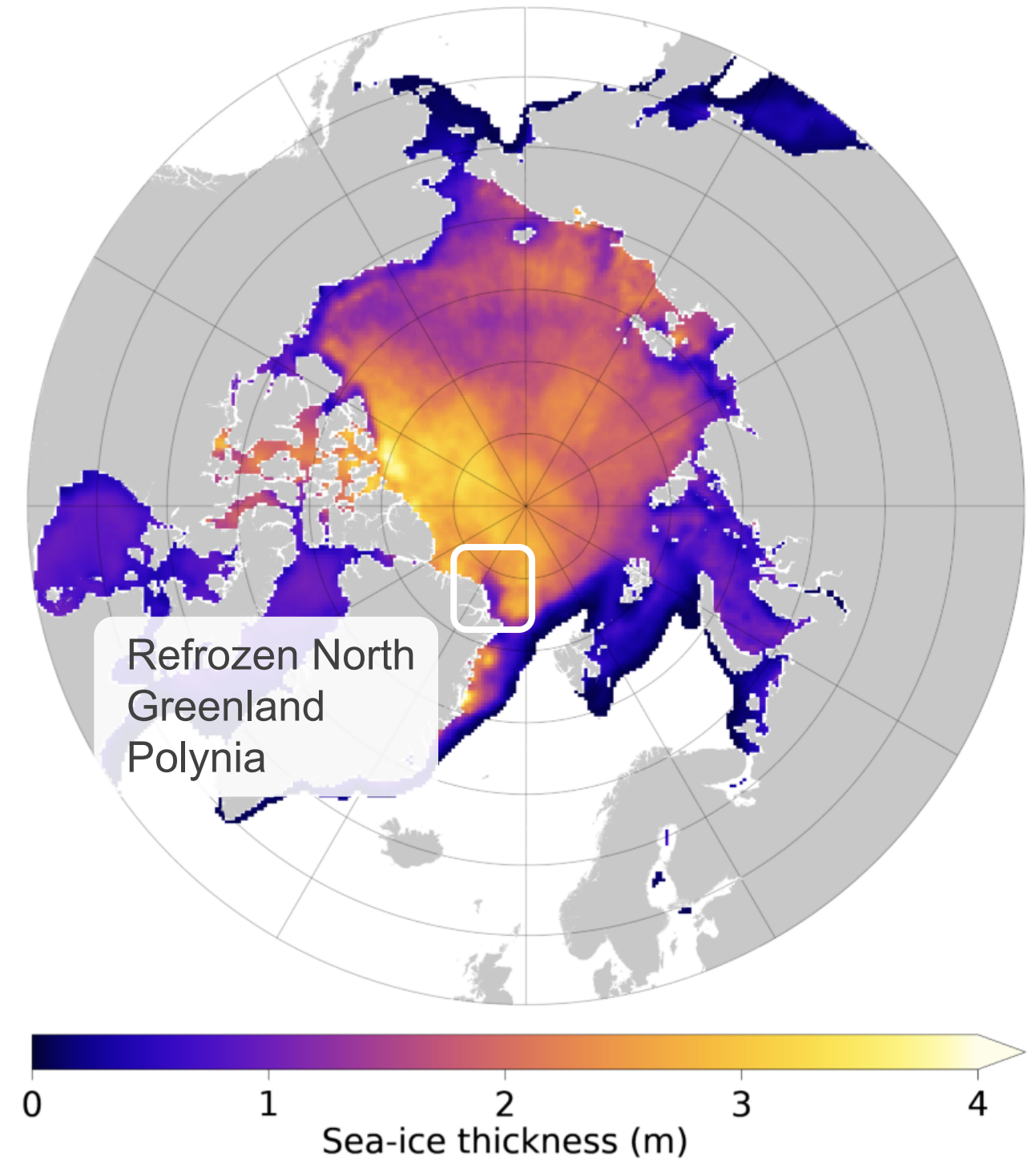
March 2018 sea ice thickness



# Arctic sea ice thickness last winter (March 2018)



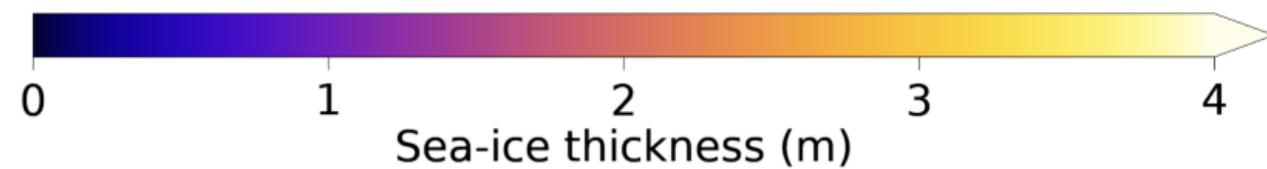
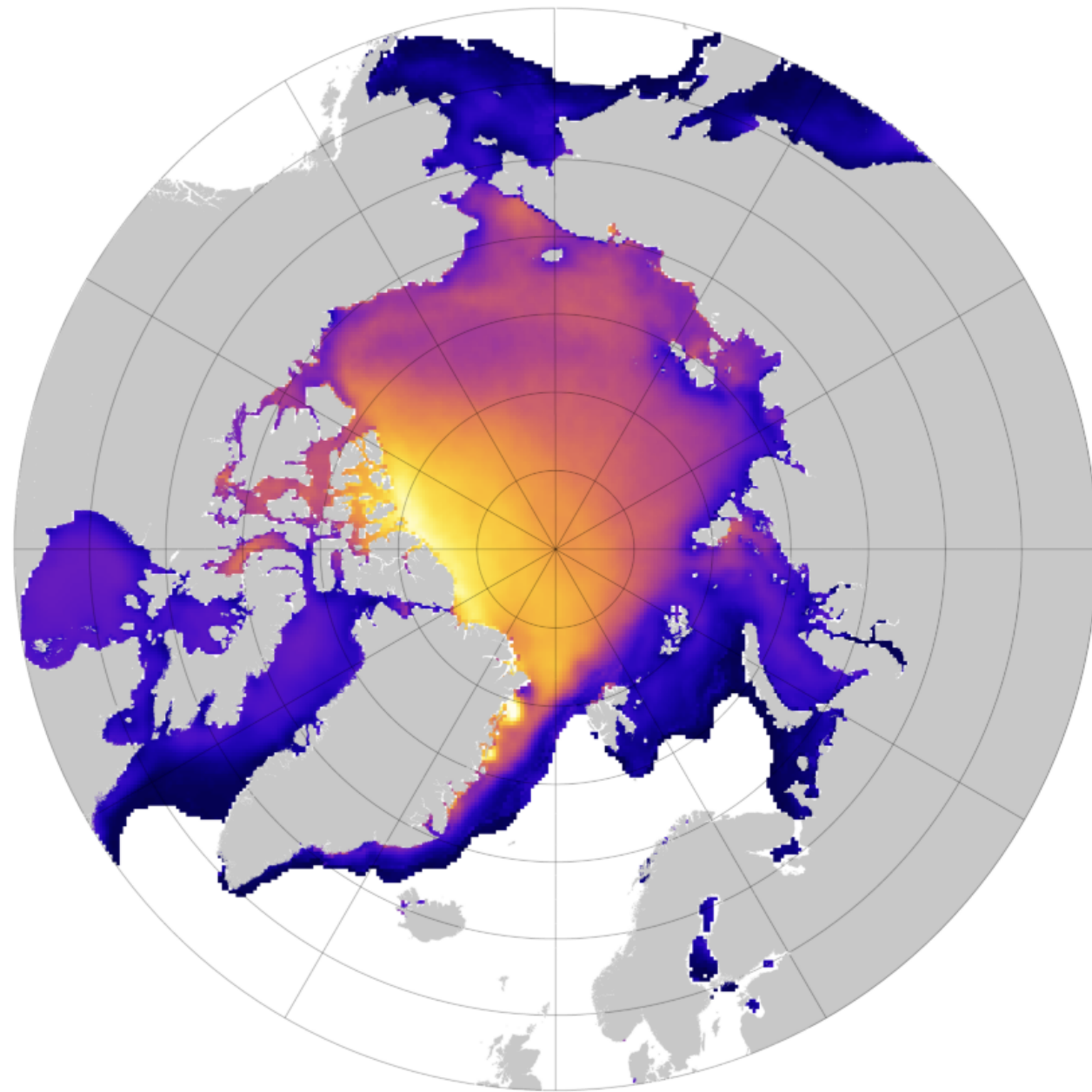
March 2018 sea ice thickness



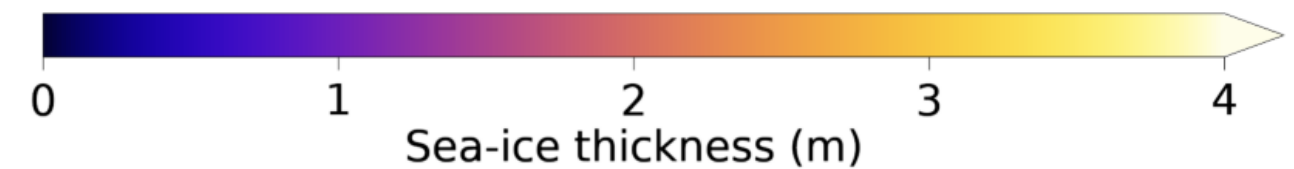
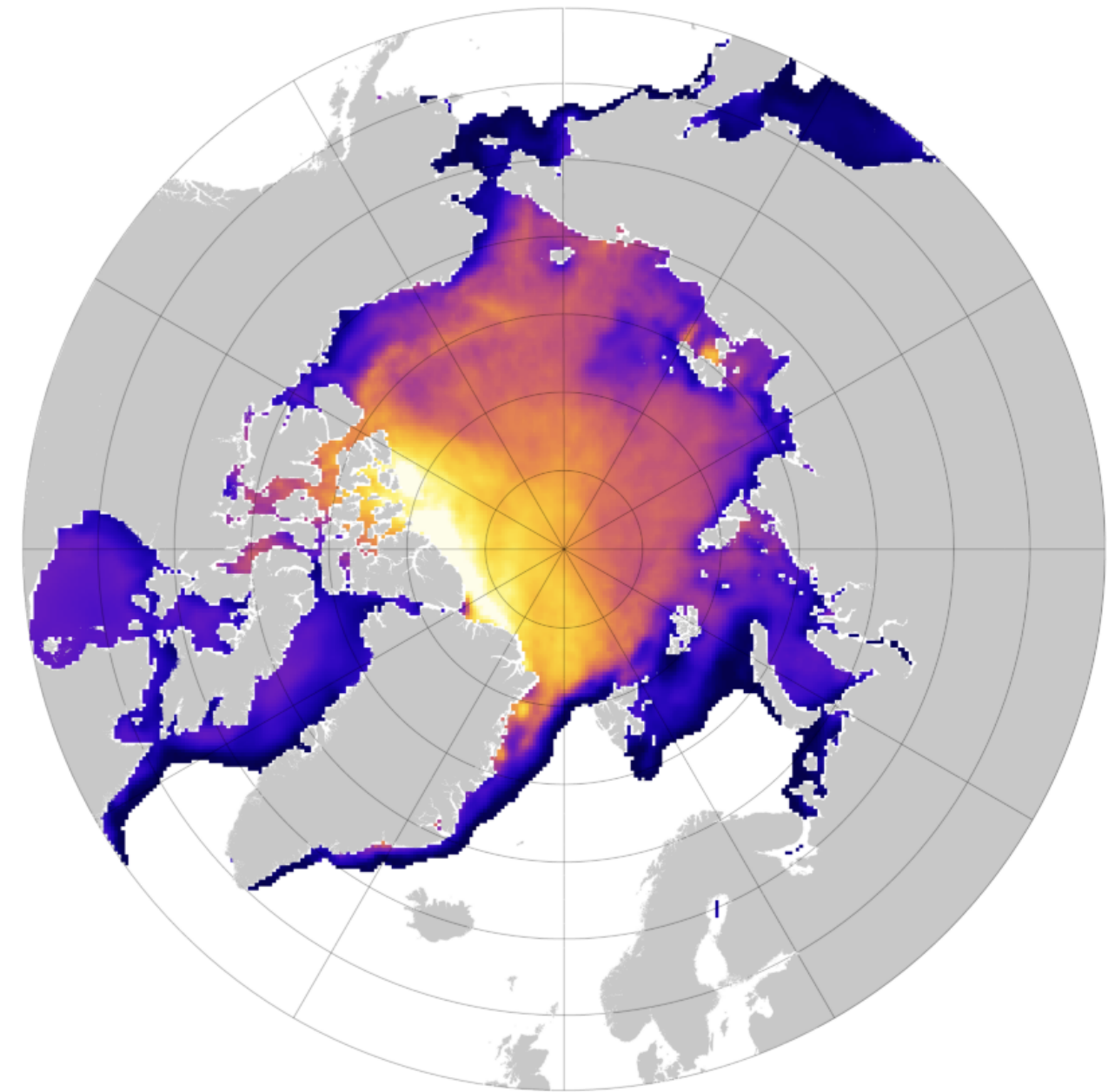
# Arctic sea ice thickness this winter (March 2019)



March mean sea-ice thickness  
(2011-2018)



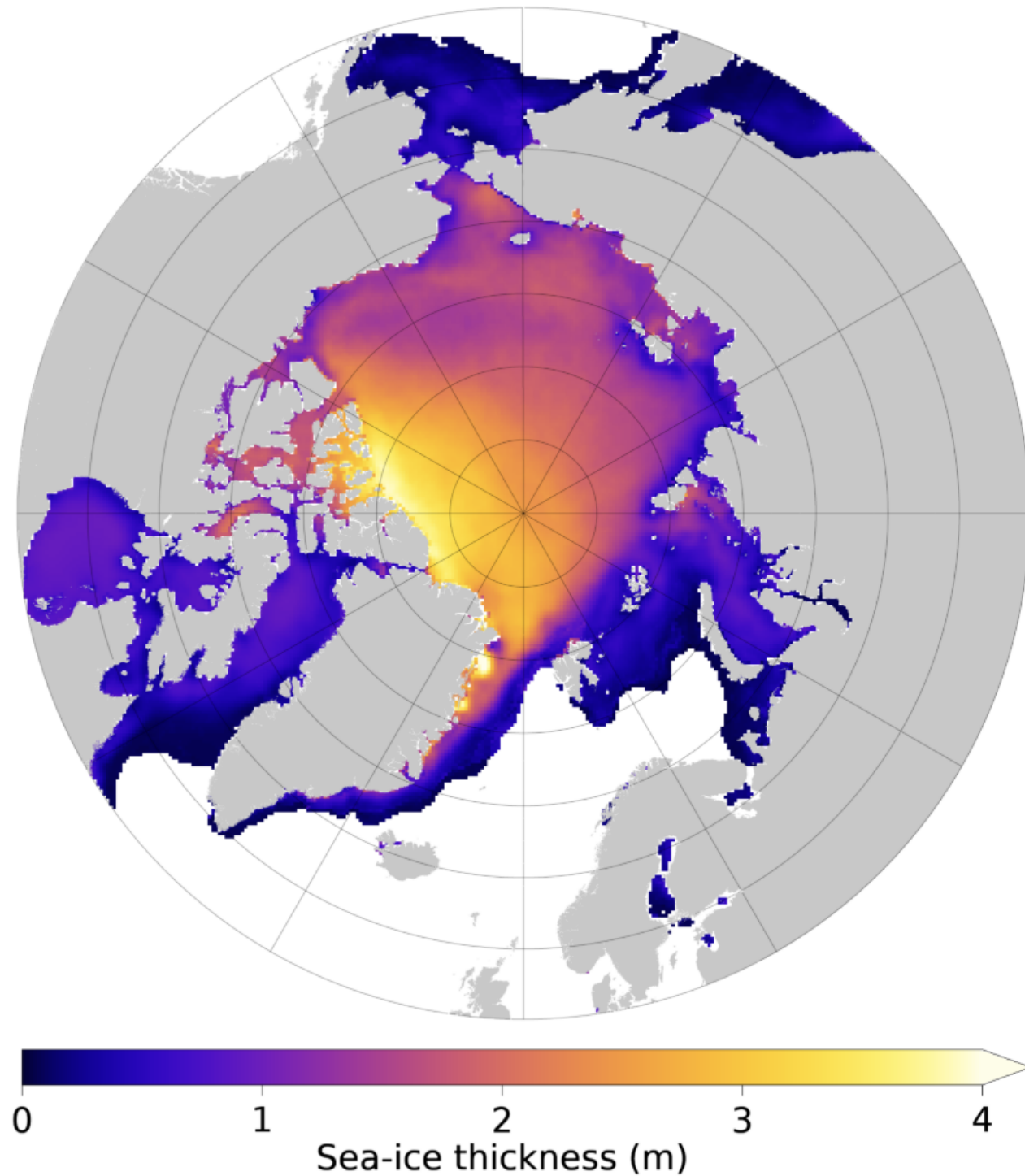
March 2019 sea ice thickness



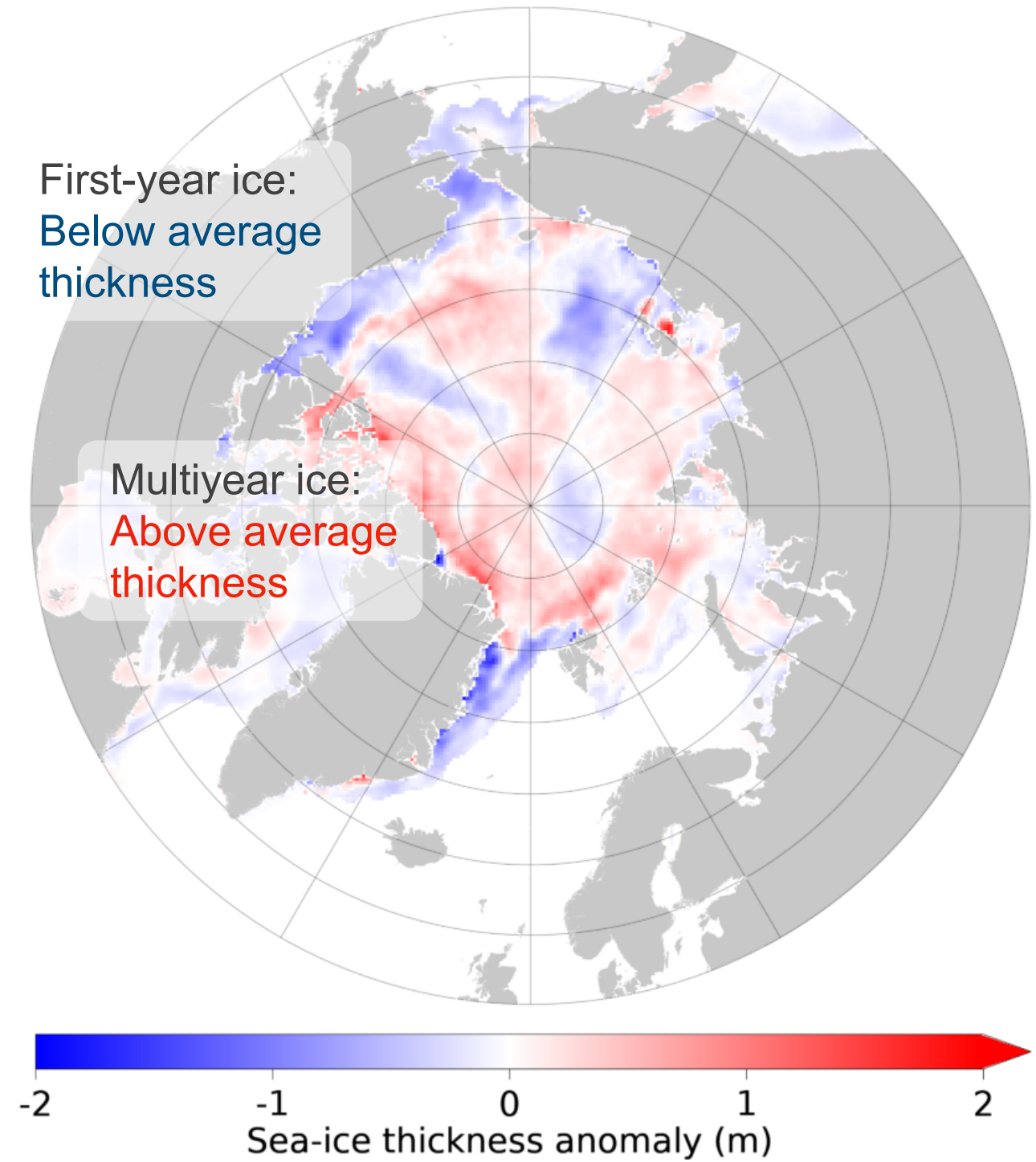
# Arctic sea ice thickness this winter (March 2019)



March mean sea-ice thickness  
(2011-2018)



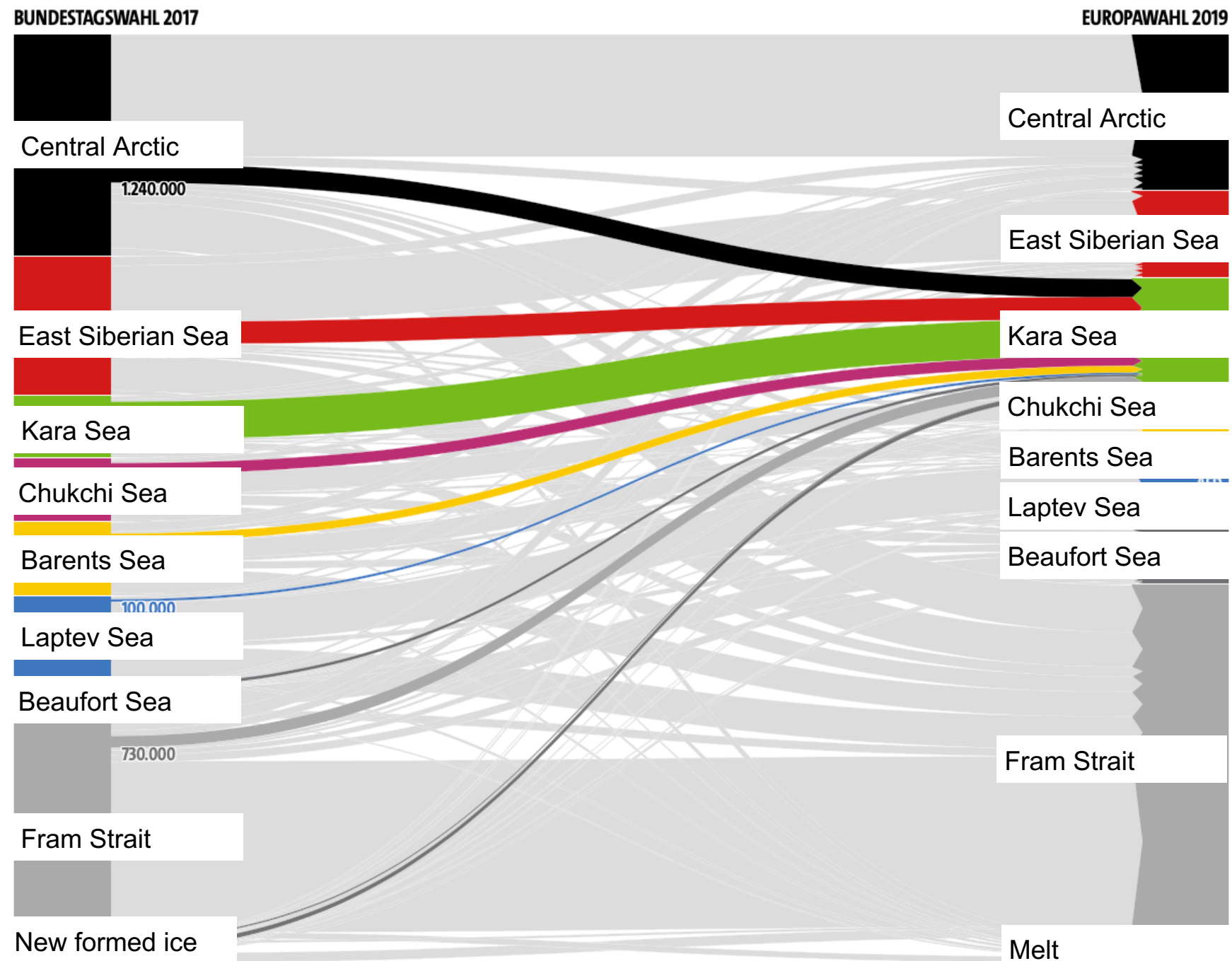
March 2019 sea ice thickness anomaly  
(March 2019 – March 2011 - 2018)



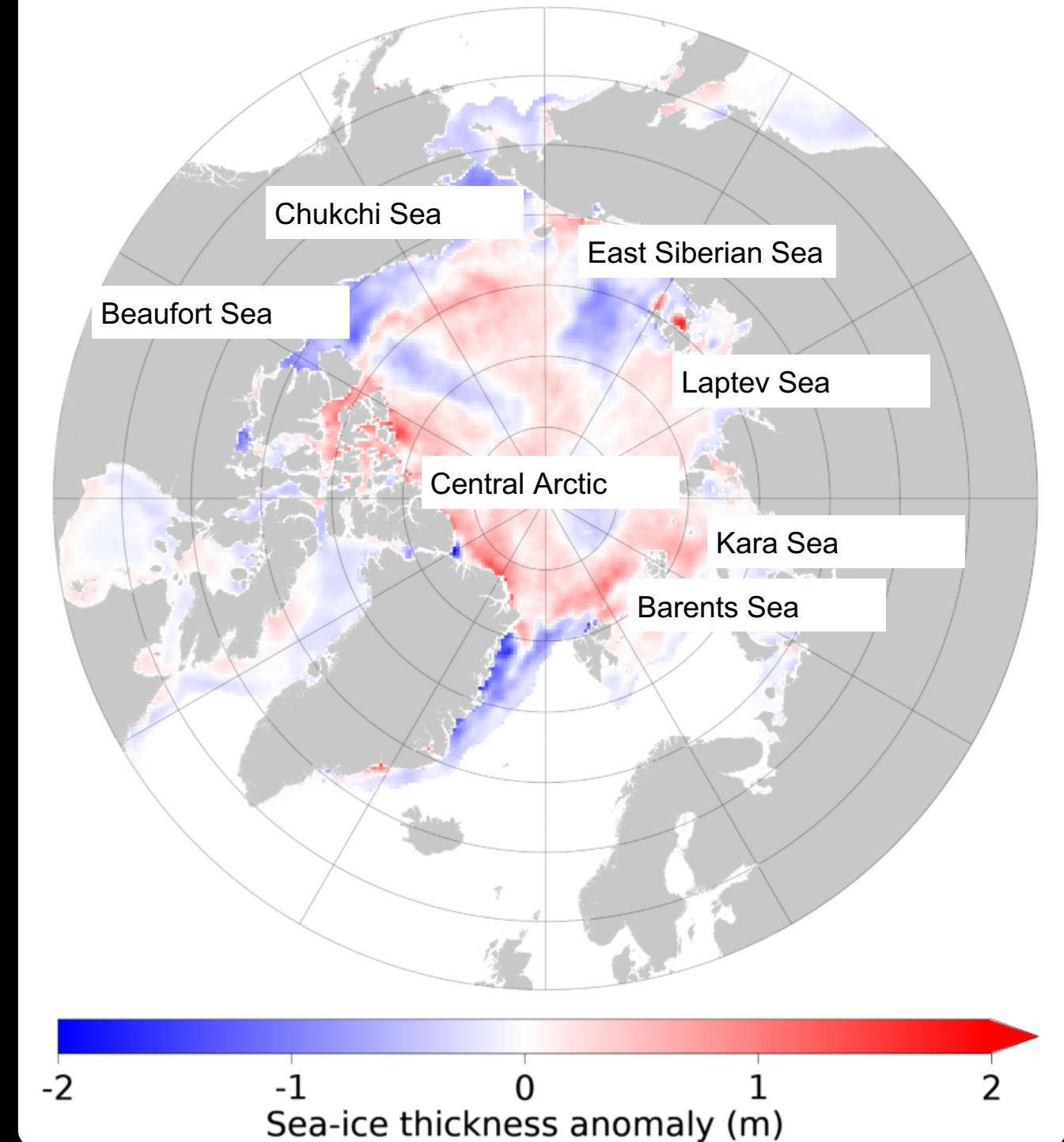
# Separation betw. dynamics and thermodynamics



## Voter migration at EU elections in Germany



## What drives the anomaly?



# Sea ice volume flux

Satellite Observation (*Ricker et al, 2018, The Cryosphere*)

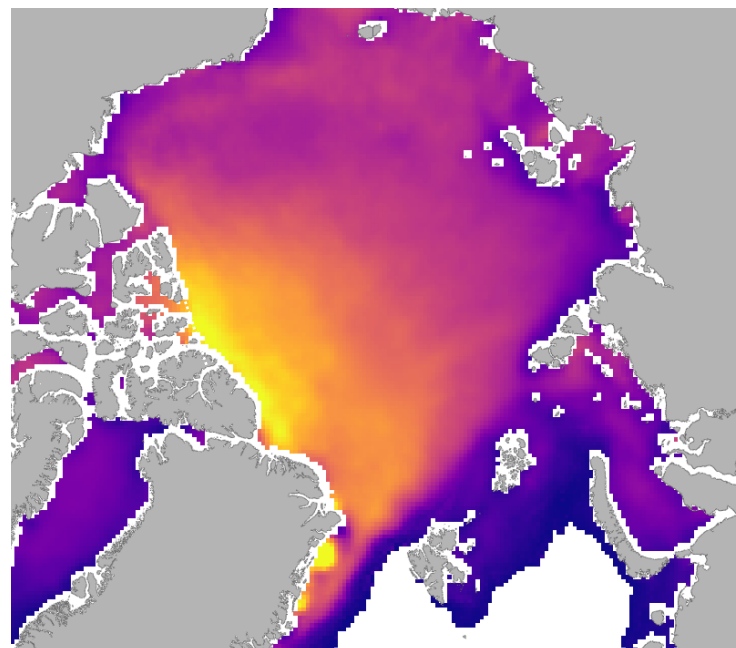
Model Simulations

Arctic-wide volume Flux ( $V$ ) is derived by  $V = G H D C$

Grid cell length ( $G=25$  km)

## Sea ice thickness ( $H$ )

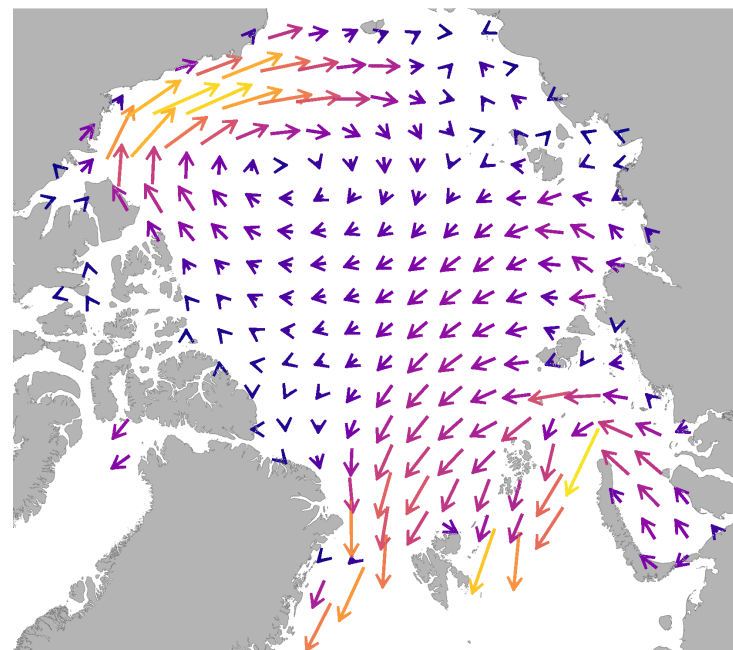
- monthly AWI CryoSat-2 + SMOS retrievals



0 1 2 3 4  
Sea-Ice Thickness (m)

## Sea ice drift ( $D$ )

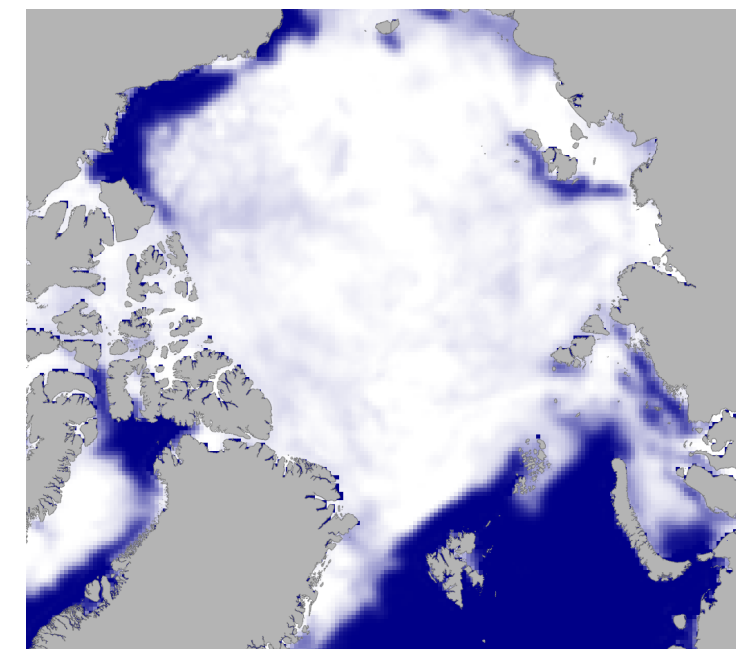
- low resolution ice drift products IFREMER, OSISAF, NSIDC



0 100 200 300 400  
Ice Drift (km/month)

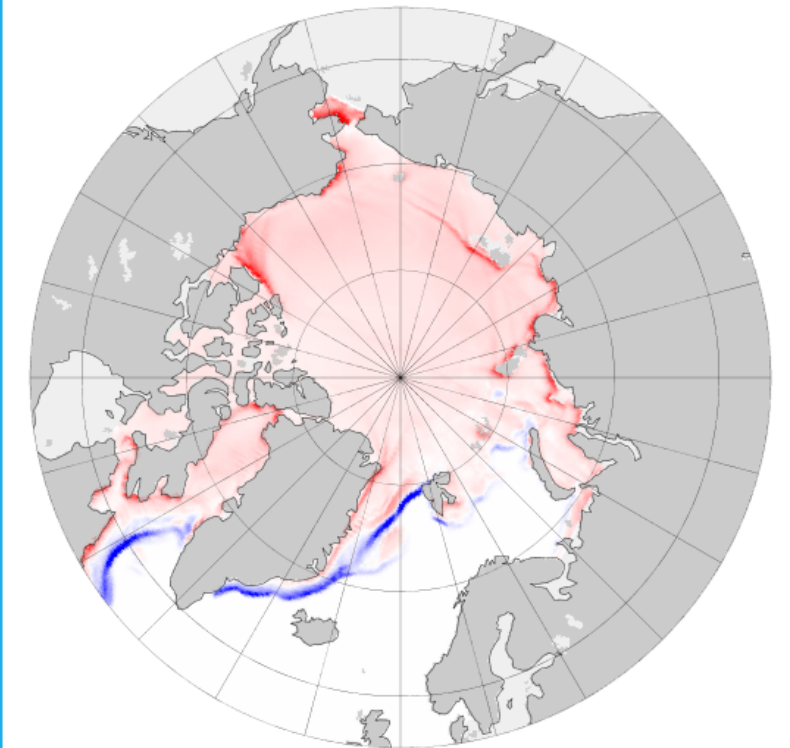
## Sea ice concentration ( $C$ )

- OSISAF

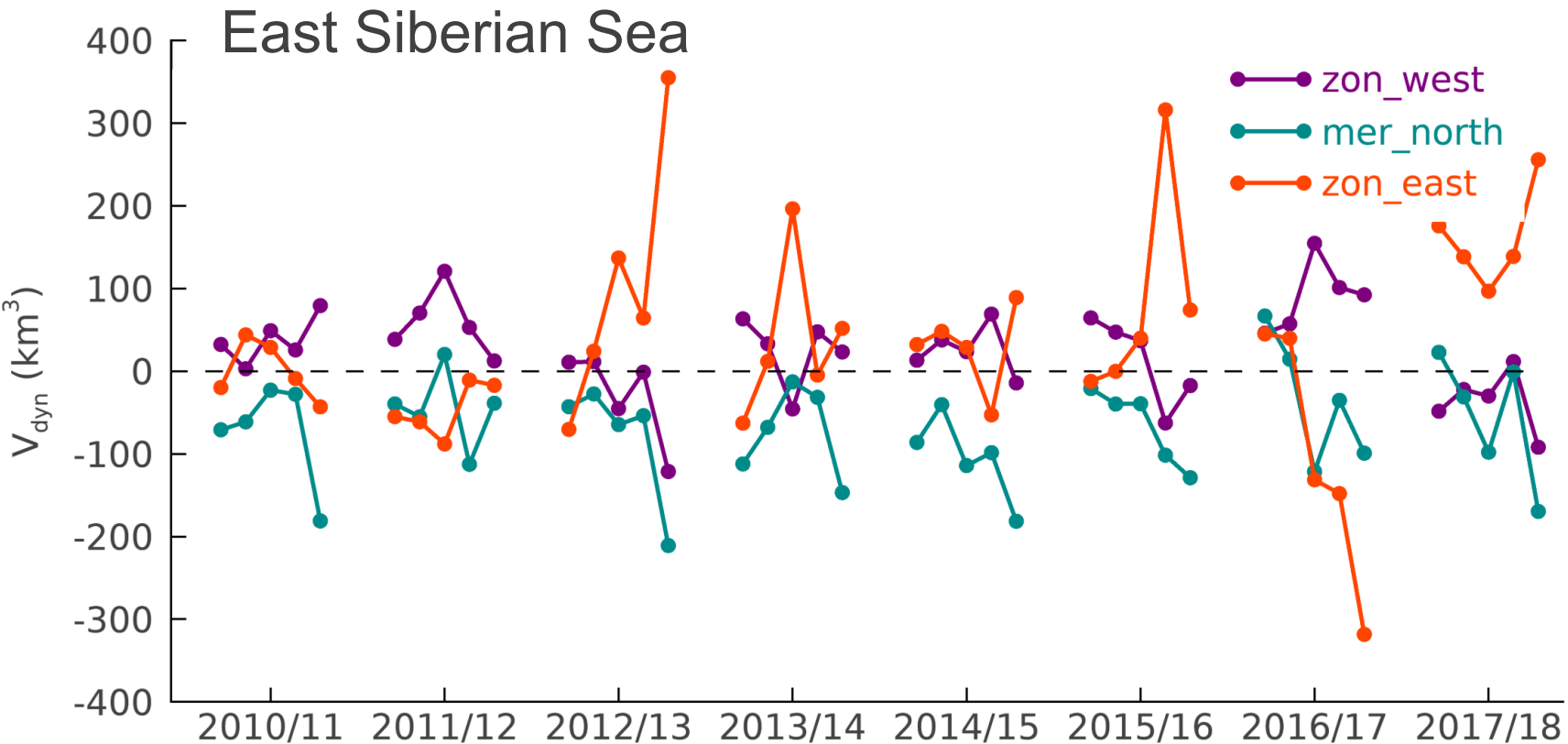
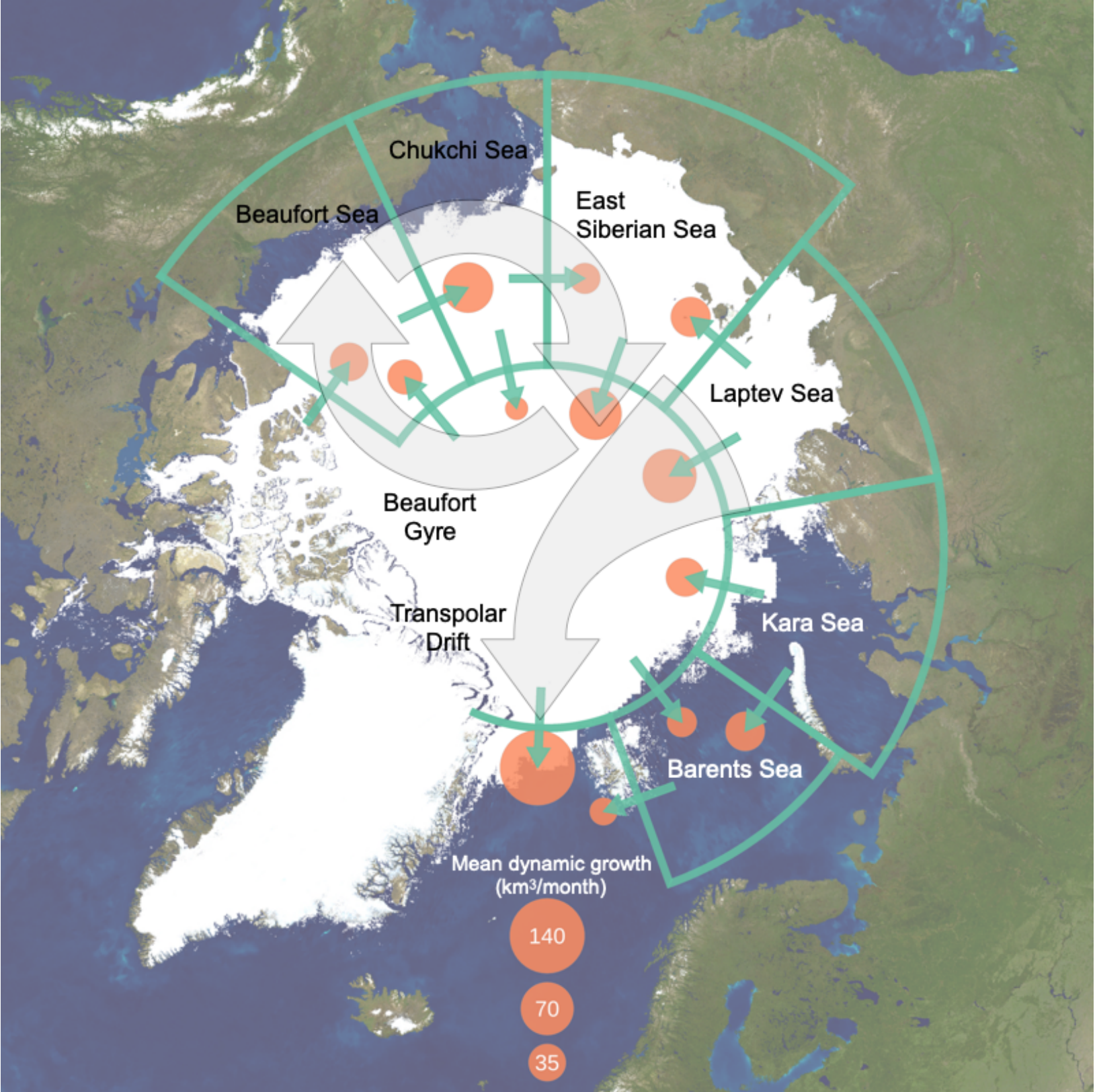


0 20 40 60 80 100  
Ice Concentration (%)

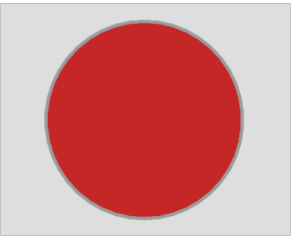
- ## Dynamic and thermodynamic ice growth
- NAOSIM



# Dynamic volume growth (2010-2018)



Zonal (west)



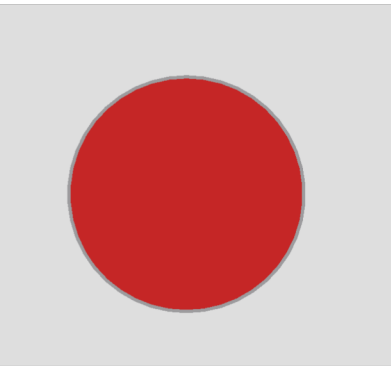
+23 km<sup>3</sup>/month

Meridional (North)



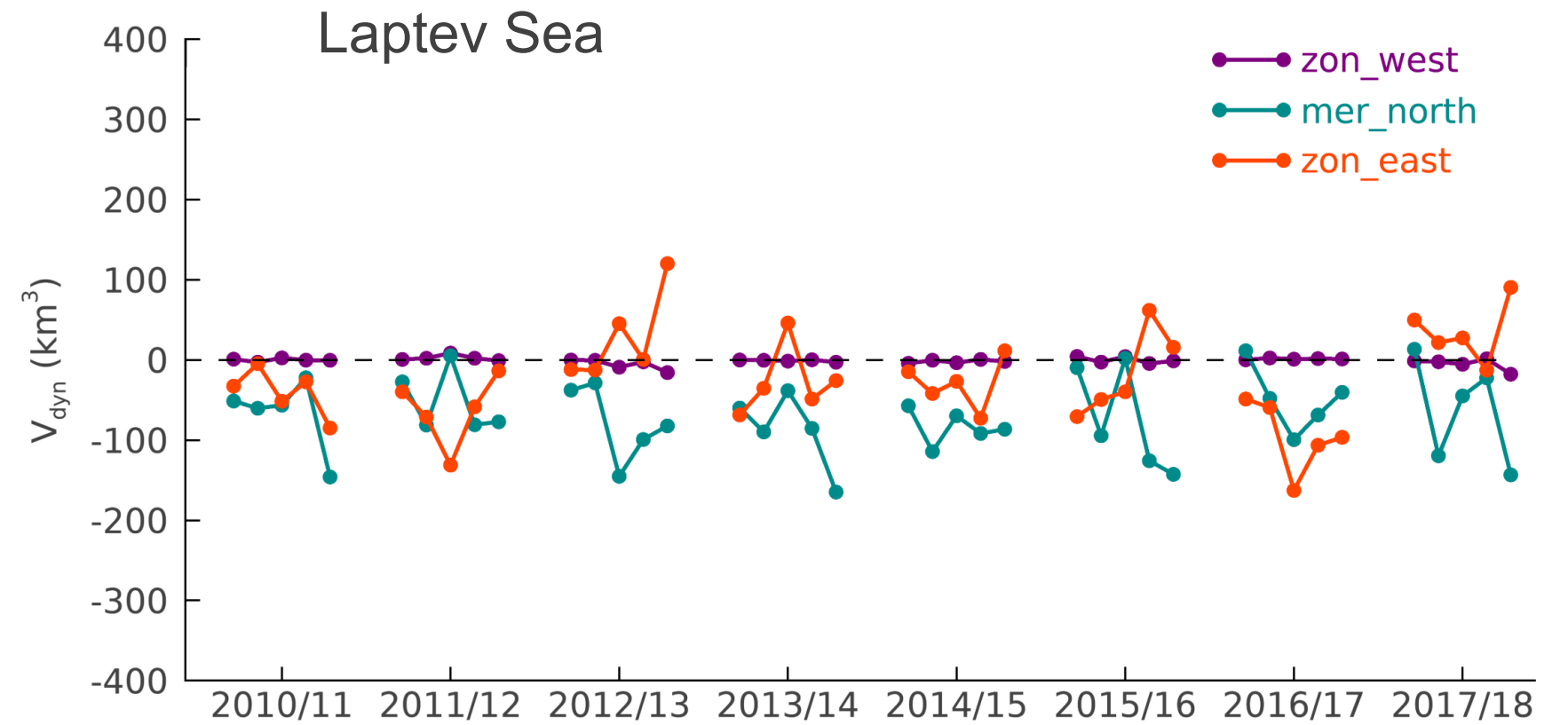
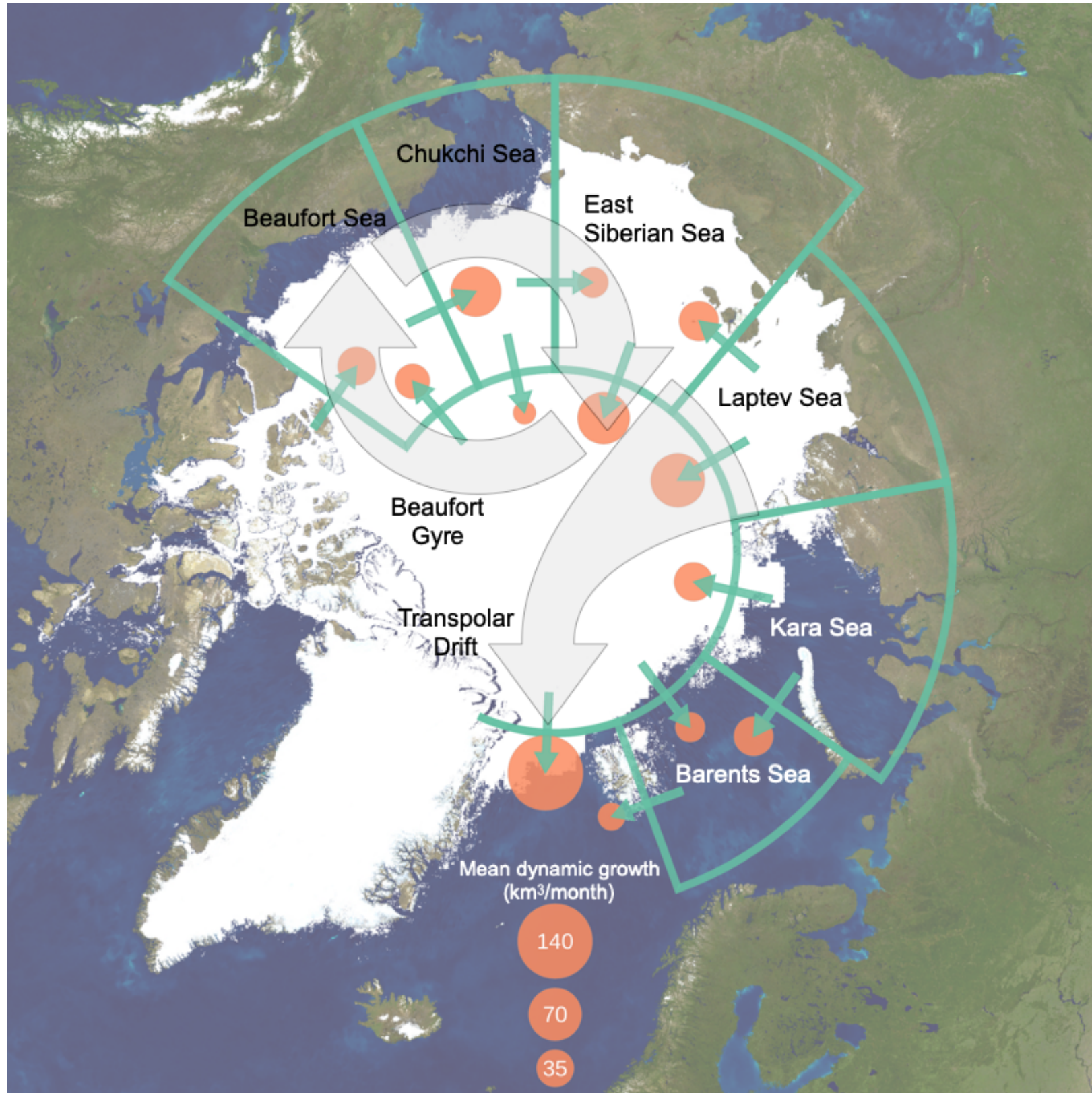
-67 km<sup>3</sup>/month

Zonal (East)

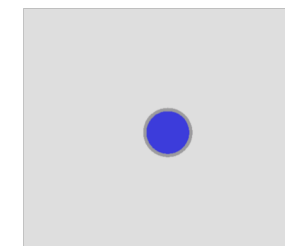


+33 km<sup>3</sup>/month

# Dynamic volume growth (2010-2018)

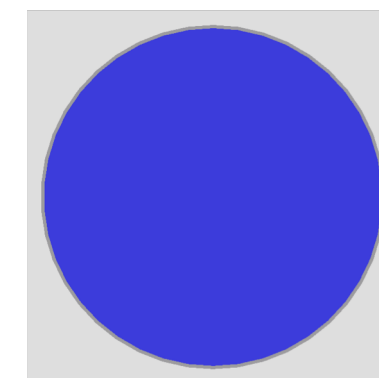


Zonal (west)



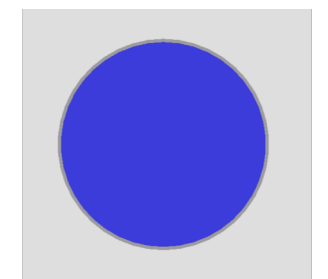
-1  $\text{km}^3/\text{month}$

Meridional (North)



-70  $\text{km}^3/\text{month}$

Zonal (East)



-26  $\text{km}^3/\text{month}$



# Dynamics vs. Thermodynamics

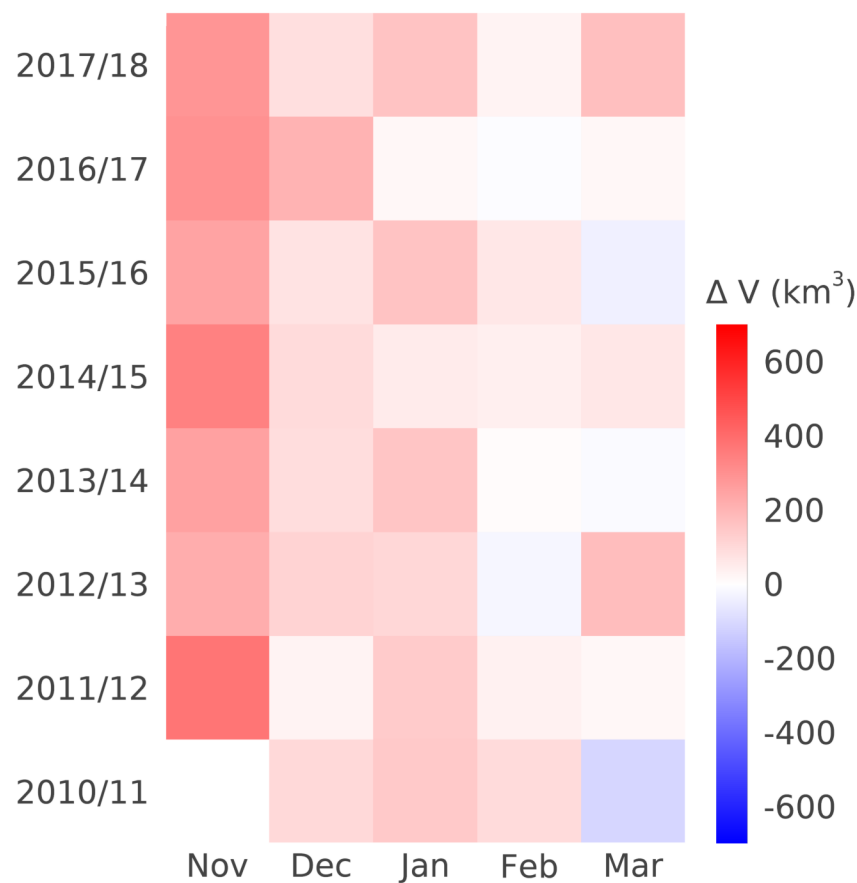


$$dV = dV_{\text{dyn}} + dV_{\text{thd}}$$

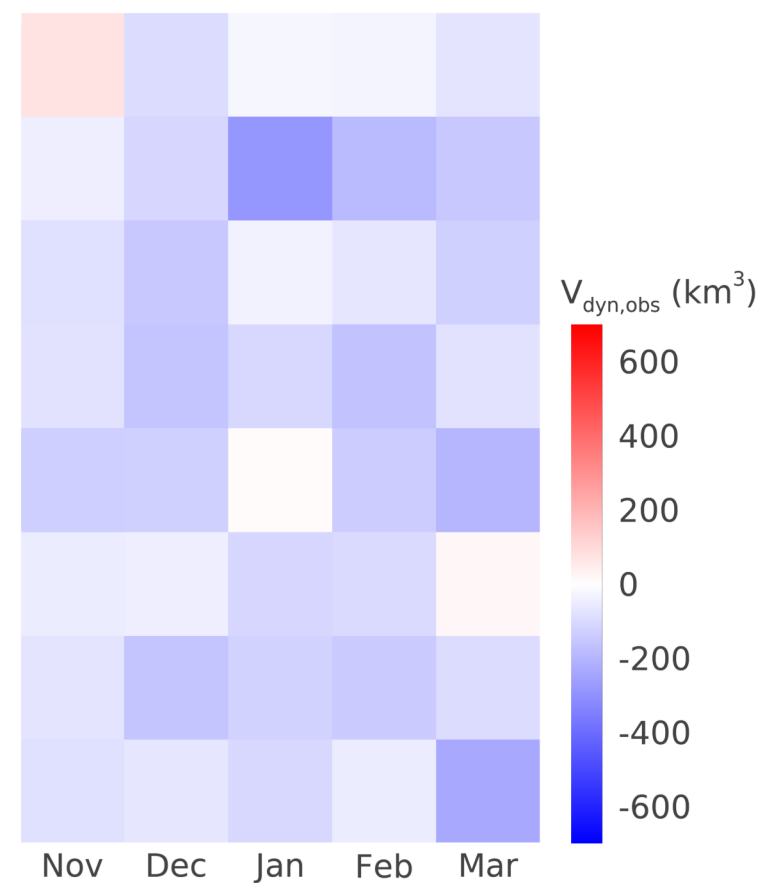
Volume Change = Dynamic Volume Growth + Thermodynamic Volume Growth

## Laptev Sea

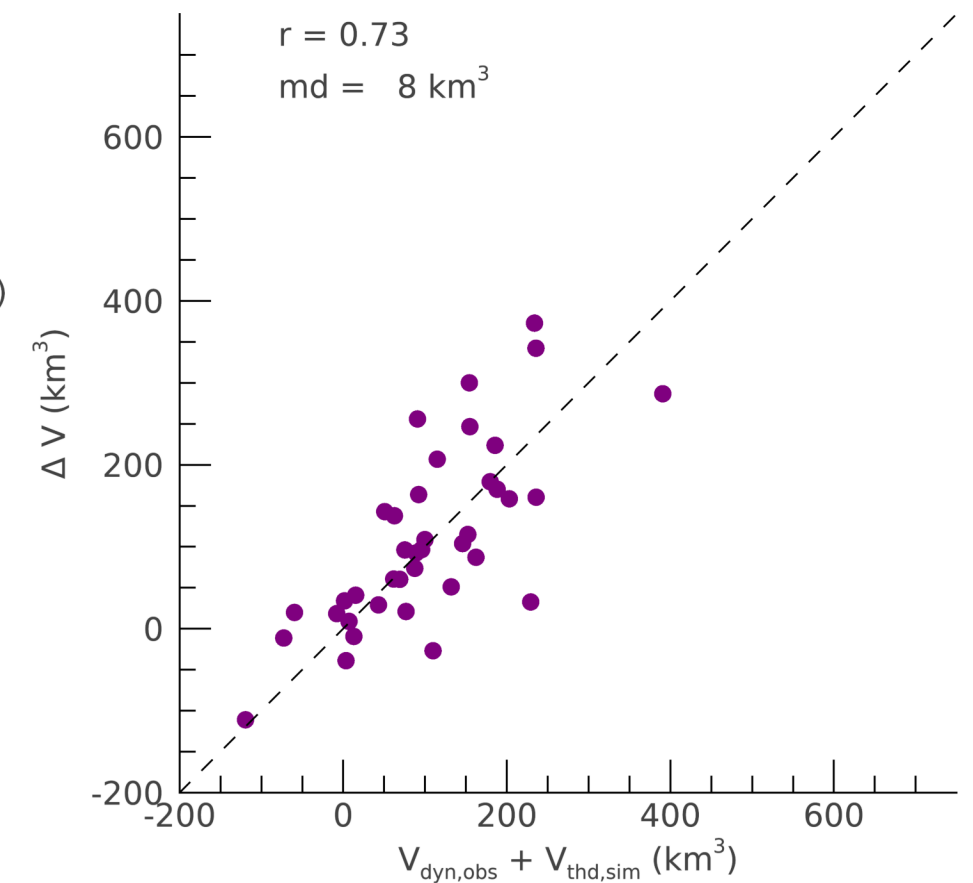
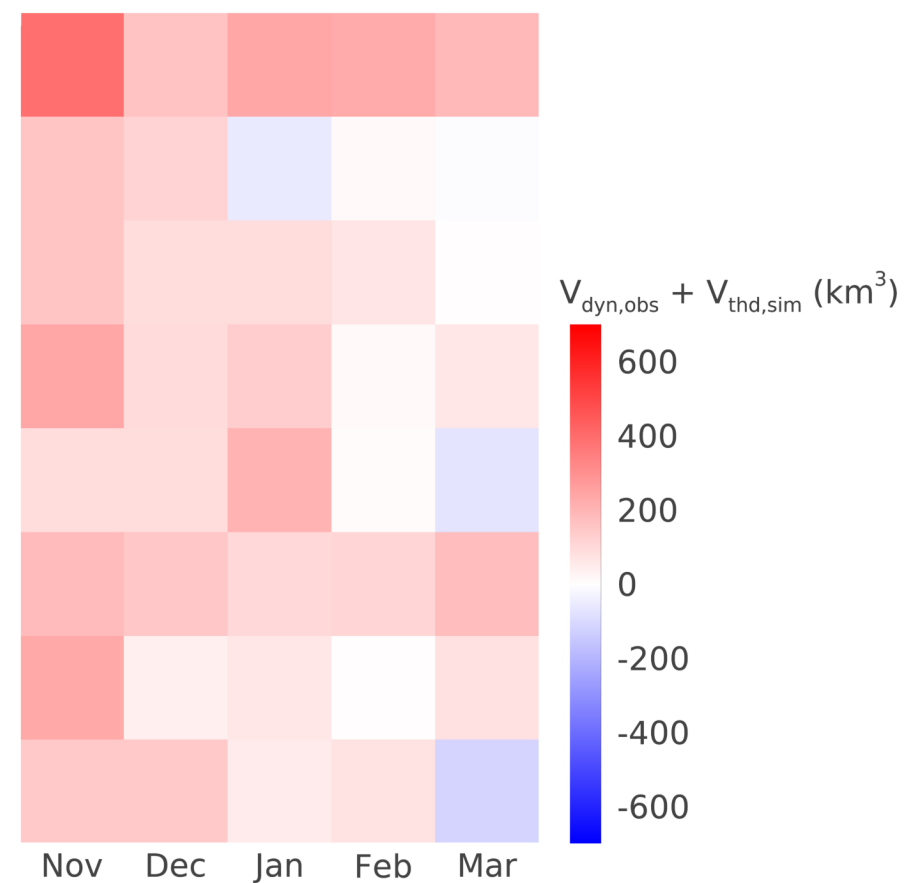
dV



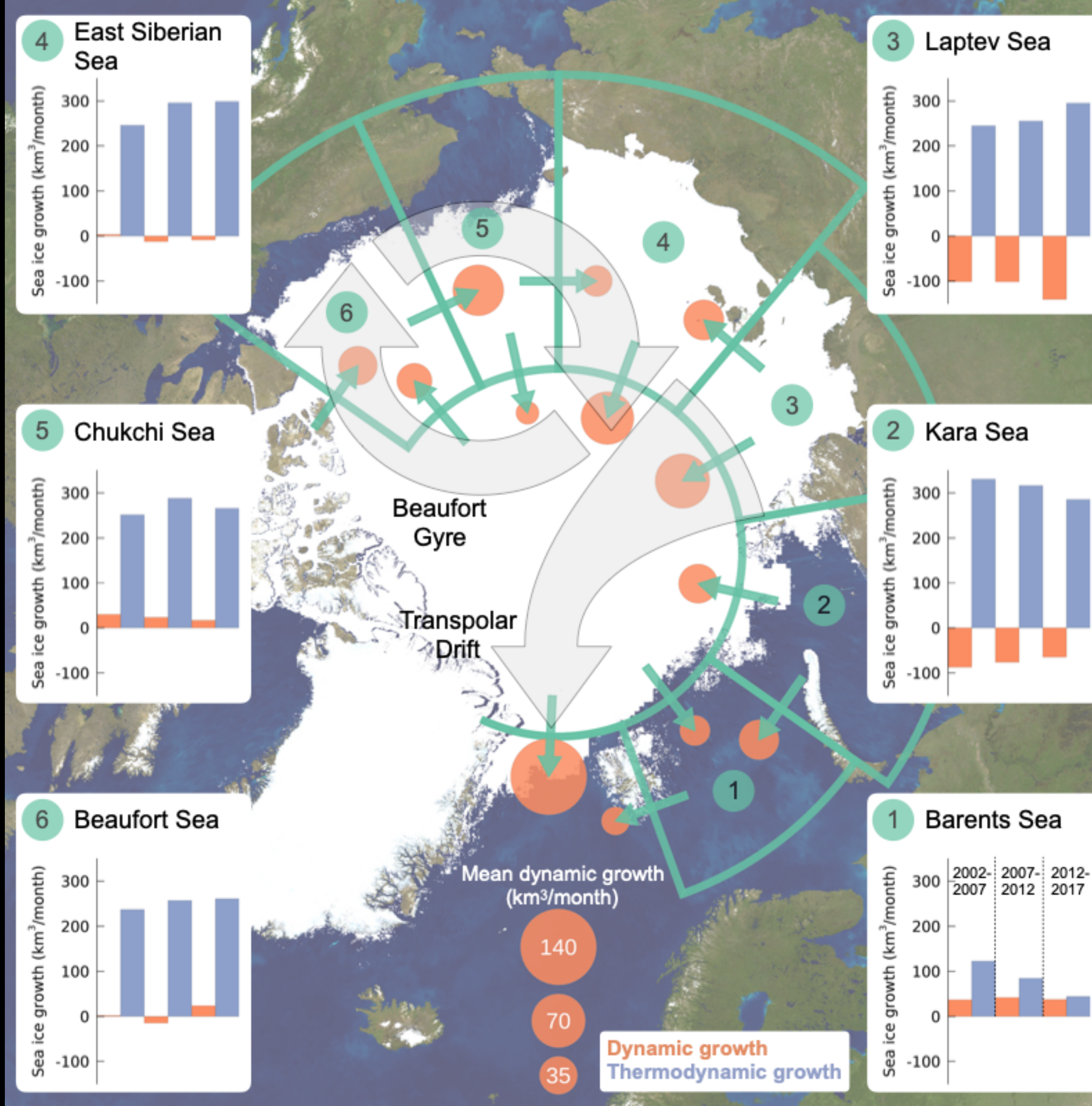
$dV_{\text{dyn}}$



$dV_{\text{dyn}} + dV_{\text{thd,sim}}$



- Dynamic and thermodynamic ice volume growth using the ESA CCI sea ice thickness data record (2002-2017)



# Data access



 [spaces.awi.de/confluence/display/CS2SMOS/SIRAL](https://spaces.awi.de/confluence/display/CS2SMOS/SIRAL)

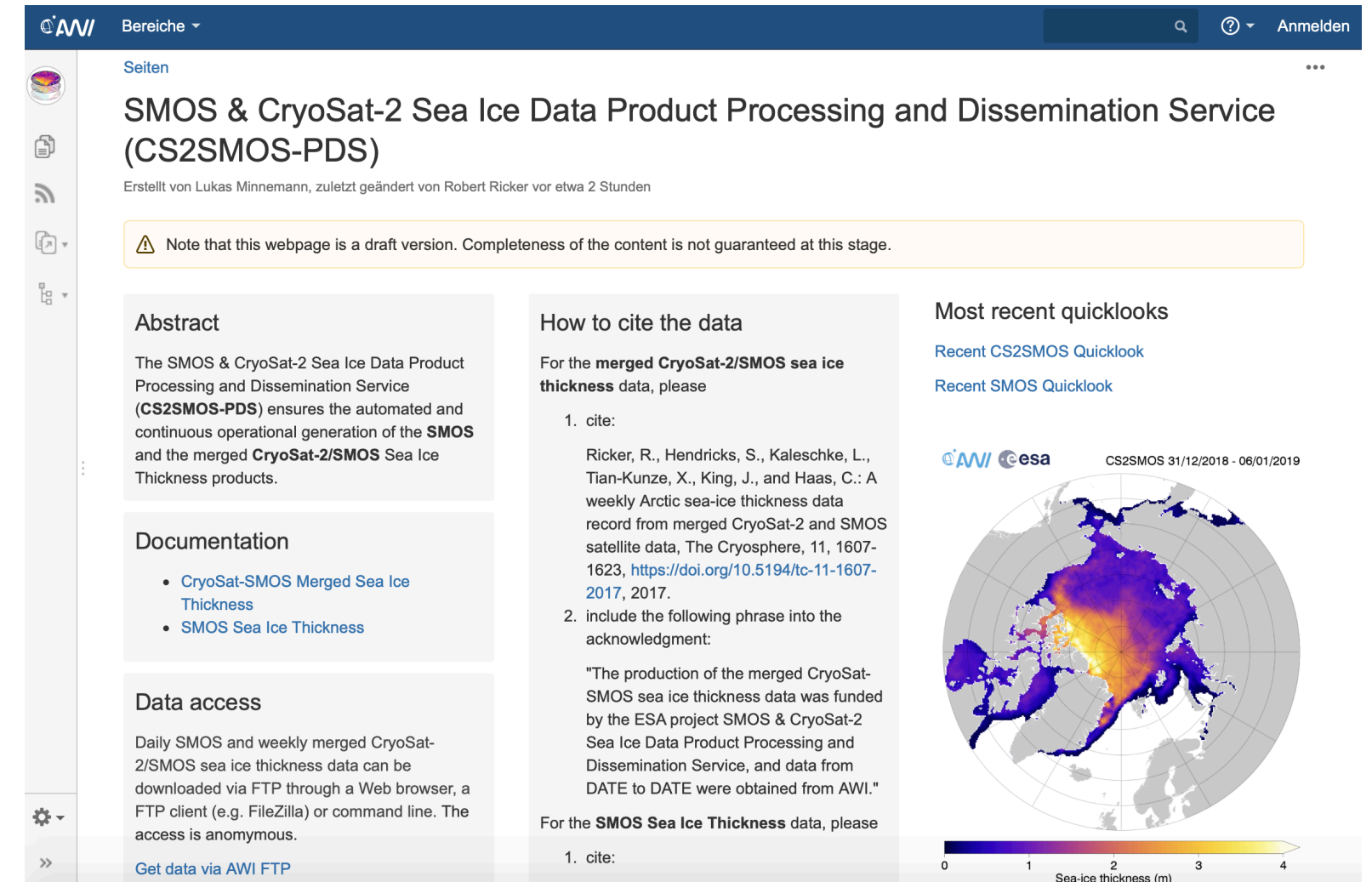
 [ftp.awi.de/sea\\_ice](ftp://ftp.awi.de/sea_ice)

Product timeliness **2 Days**

Data format **NetCDF**

Temporal resolution **Daily (SMOS)**  
**Weekly (CryoSat-2, CS2SMOS)**  
**Monthly (CryoSat-2)**

Spatial resolution of the product **12.5 km (SMOS)**  
**25 km (CryoSat-2, CS2SMOS)**



The screenshot shows the 'SMOS & CryoSat-2 Sea Ice Data Product Processing and Dissemination Service (CS2SMOS-PDS)' webpage. It includes a draft notice, an abstract, documentation links, data access instructions, and citation guidelines. A map of the Arctic region displays sea ice thickness data with a color scale from 0 to 4 meters.

**Abstract**  
The SMOS & CryoSat-2 Sea Ice Data Product Processing and Dissemination Service (CS2SMOS-PDS) ensures the automated and continuous operational generation of the SMOS and the merged CryoSat-2/SMOS Sea Ice Thickness products.

**Documentation**

- [CryoSat-SMOS Merged Sea Ice Thickness](#)
- [SMOS Sea Ice Thickness](#)

**Data access**  
Daily SMOS and weekly merged CryoSat-2/SMOS sea ice thickness data can be downloaded via FTP through a Web browser, a FTP client (e.g. FileZilla) or command line. The access is anonymous.  
[Get data via AWI FTP](#)

**How to cite the data**  
For the merged CryoSat-2/SMOS sea ice thickness data, please

1. cite:  
Ricker, R., Hendricks, S., Kaleschke, L., Tian-Kunze, X., King, J., and Haas, C.: A weekly Arctic sea-ice thickness data record from merged CryoSat-2 and SMOS satellite data, The Cryosphere, 11, 1607-1623, <https://doi.org/10.5194/tc-11-1607-2017>, 2017.
2. include the following phrase into the acknowledgment:  
"The production of the merged CryoSat-SMOS sea ice thickness data was funded by the ESA project SMOS & CryoSat-2 Sea Ice Data Product Processing and Dissemination Service, and data from DATE to DATE were obtained from AWI."

For the SMOS Sea Ice Thickness data, please

1. cite:

**Most recent quicklooks**  
[Recent CS2SMOS Quicklook](#)  
[Recent SMOS Quicklook](#)

CS2SMOS 31/12/2018 - 06/01/2019

Sea-ice thickness (m)

# Validation: MOSAiC (Sep 2019 – Sep 2020)

- Remote Sensing Ground Truthing
- Microwave interaction: Multi-frequency scatterometers and radiometers
- Radar penetration: Multi-frequency radar
- Helicopter based lidar, EM-Bird
- Spring & Summer support airborne campaigns (Polar-5 & Polar-6)

