Sentinel-3 snow and ice optical products (SICE)

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Kenneth D. Mankoff[1], Alexander Kokhanovsky[2],
Carsten Brockmann[3], Olaf Danne[3], A. Fleming[4],
Ghislain Picard[5], Kristian Pagh Nielsen[6]

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[2] Telespazio.be, Darmstadt, Germany
[3] Brockmann Consult, Geesthacht, Germany
[4] PolarTEP, UK
[5] IGE, Grenoble, FR
[6] Danmarks Meteorologiske Institut (DMI), Copenhagen, Denmark

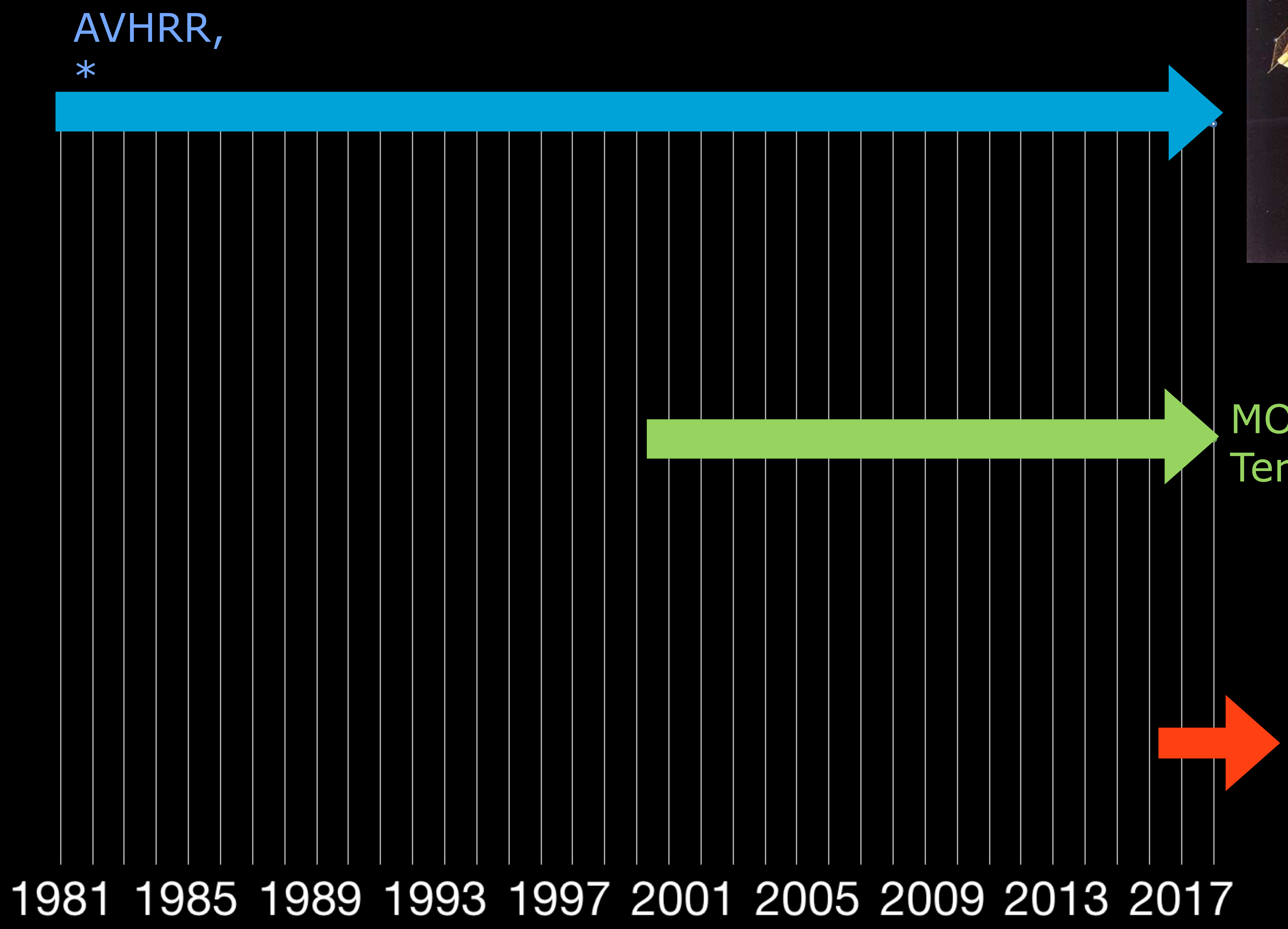
ESA support
SEOM S34SciSnow, 2016-2019, M. Kern
EO Sci for Society, 2018-2020, M. Kern
PRODEX, 2019-present, T. Ridder

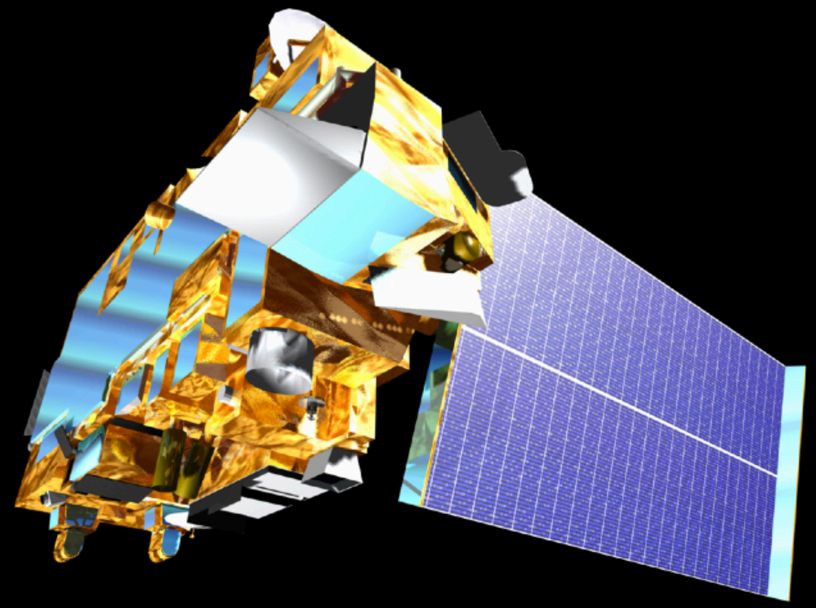
Sentinel-3A,B

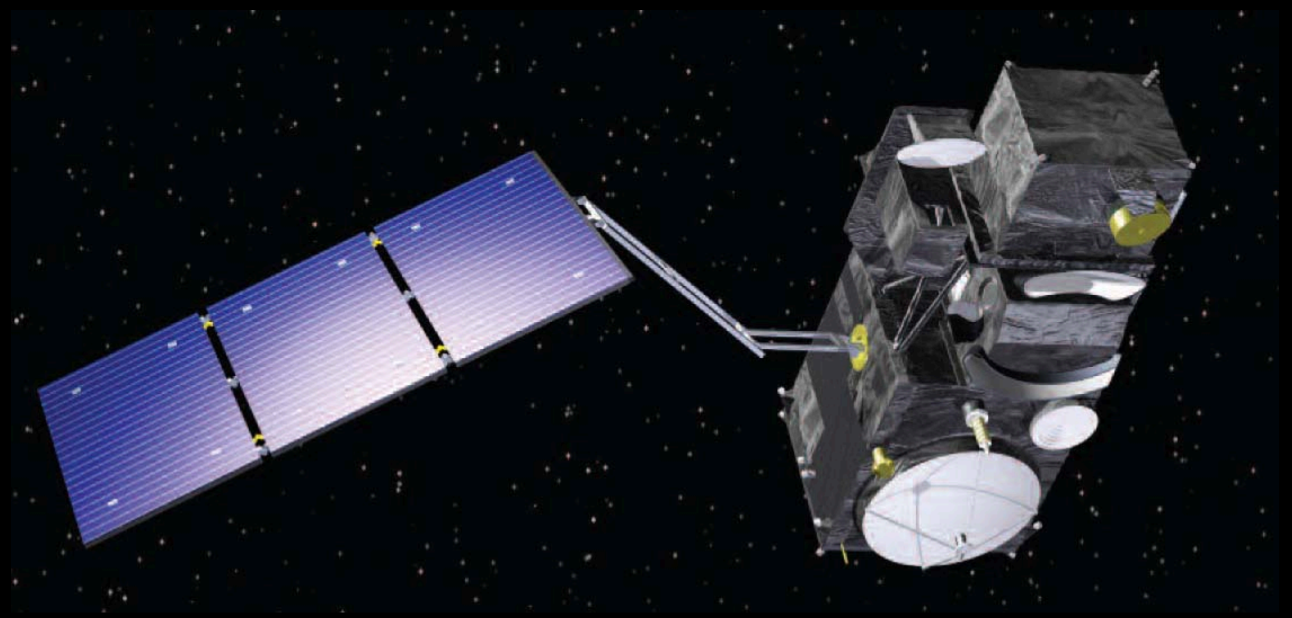
Ocean Land Colour Instrument (OLCI)

Sea and Land Surface Temperature Radiometer (SLSTR)

Toward constructing a global snow (& ice) albedo ECV record 1981-present





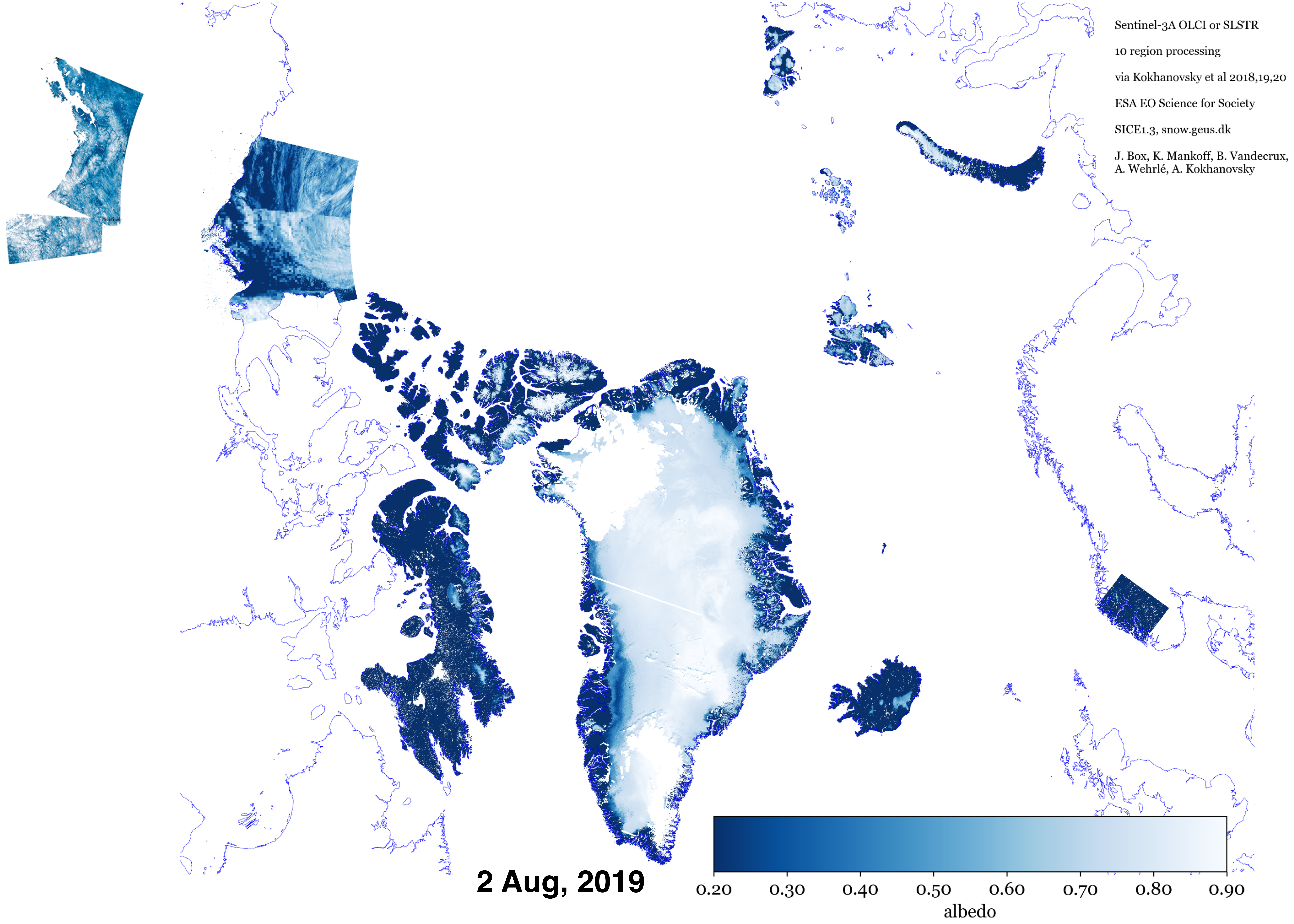


*NOAA-7 .. 14, NOAA-15 .. 19, MetOp-A, MetOp-B

Snow and ICE optical (SICE) project

- NRT automated, open source processing chain
- Sentinel-3A,B OLCI and SLSTR inputs
- snow and bare ice spectral and broadband optical products
  - snow and bare ice extent
  - albedo
    - snow and ice spectral and broadband
  - snow specific surface area
  - pollution concentration
- daily product for user-defined area

regional processing



cloud/snow discrimination

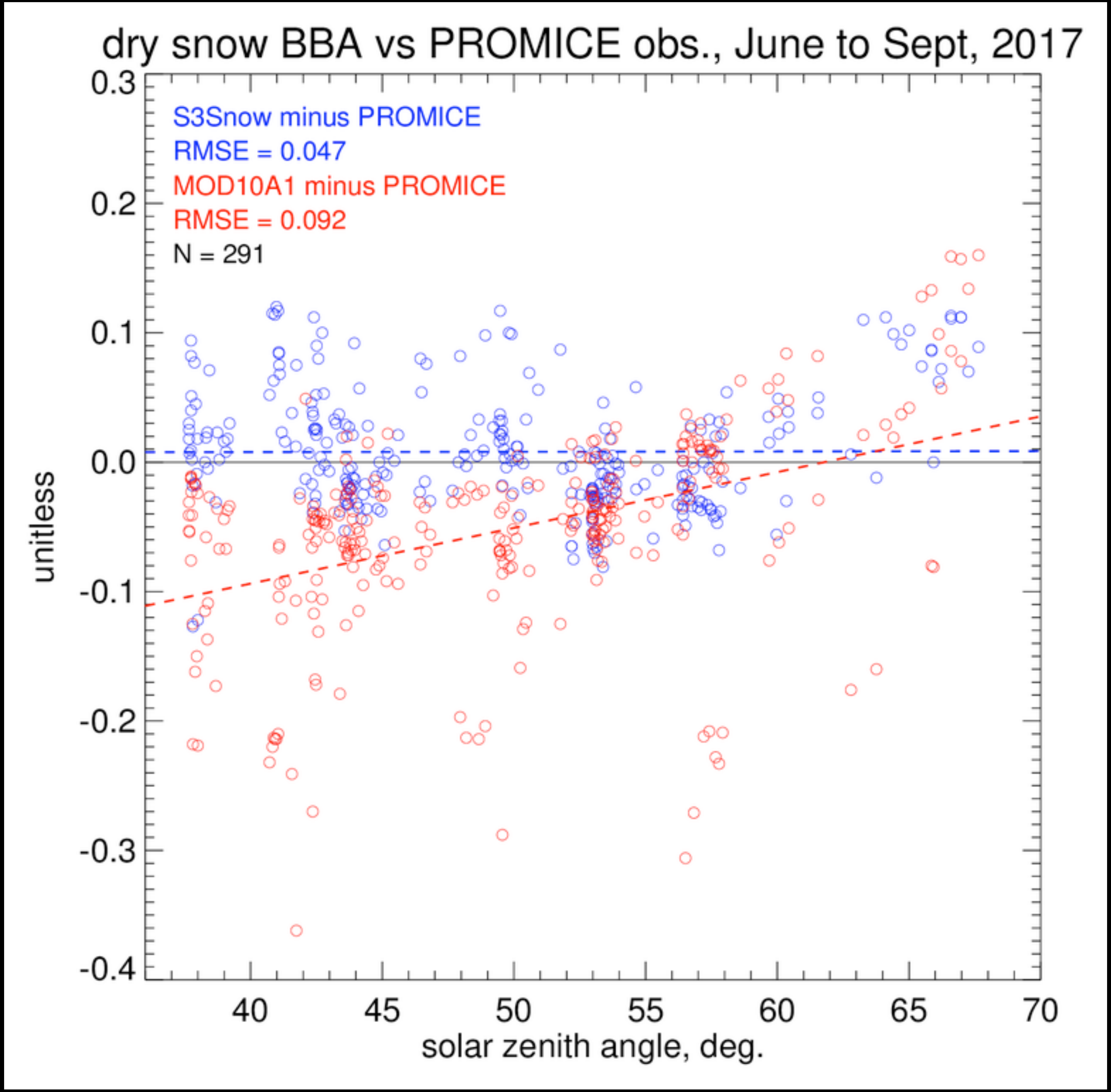
Simple Cloud Detection Algorithm (SCDA)

- SLSTR
- 6 tests using
  - R 0.55 μm
  - NDSI
  - BT 11 μm, 12 μm, 3.7 μm

Metsämäki, Sari, Pulliainen, Jouni, Salminen, Miia, et al. Introduction to GlobSnow Snow Extent products with considerations for accuracy assessment. Remote Sensing of Environment, 2015, vol. 156, p. 96-108. link

snow albedo
SICE vs MODIS MOD10A1

- latitude varying bias
- 61% cases error is less than 0.05 accuracy target



GEUS

SICE publications

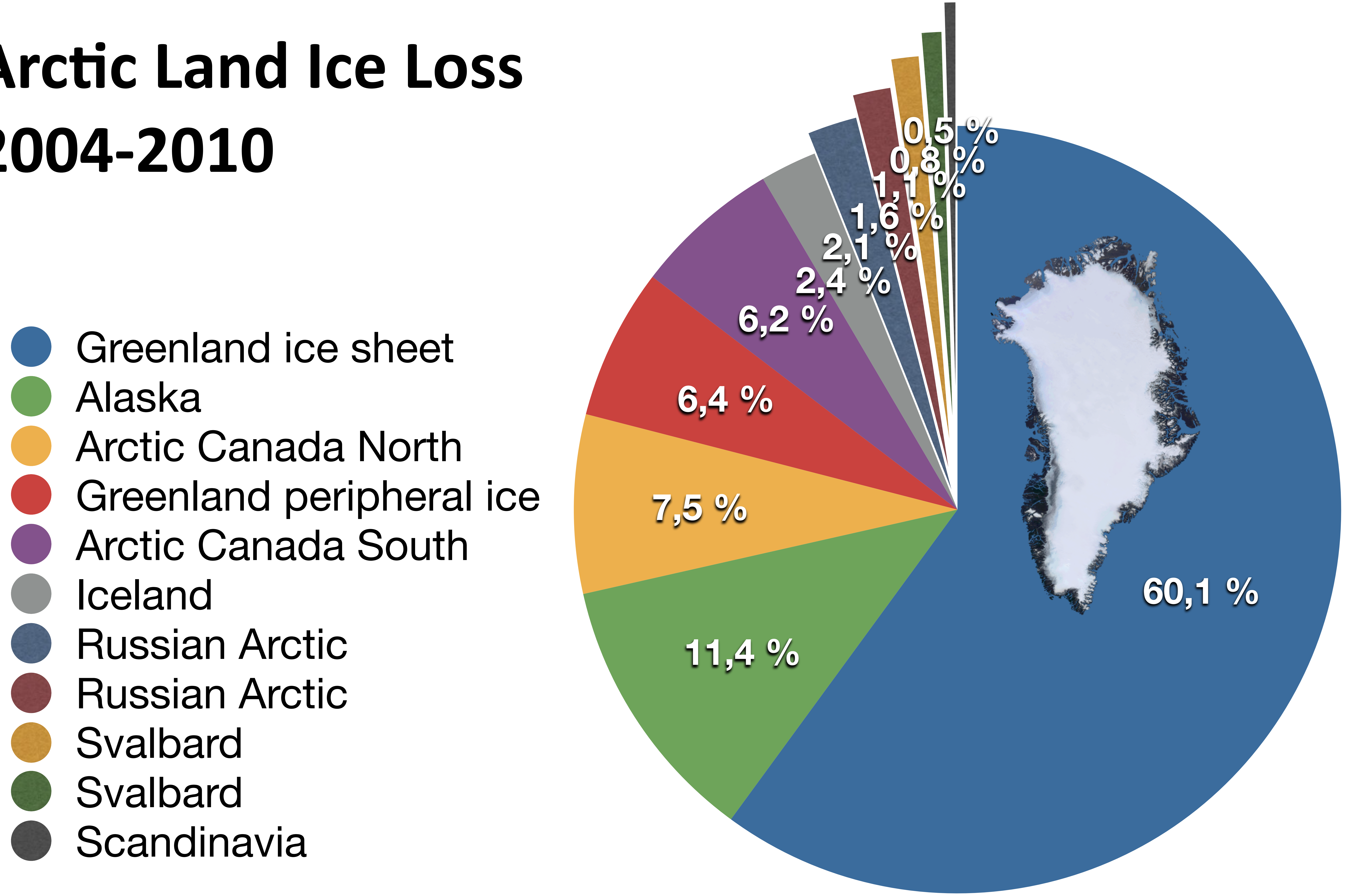
1. Kokhanovsky, A., Lamare, M., Di Mauro, B., Picard, G., Arnaud, L., Dumont, M., Tuzet, F., Brockmann, C., and Box, J. E.: **On the reflectance spectroscopy of snow**, The Cryosphere, 12, 2371-2382, https://doi.org/10.5194/tc-12-2371-2018, 2018.

2. Kokhanovsky, A., M. Lamare, O. Danne, C. Brockmann, M. Dumont, G. Picard, L. Arnaud, V. Favier, B. Jourdain, E. Lemeur, B. Di Mauro, T Aoki, M. Niwano, V. Rozanov, S. Korkin, S. Kipfstuhl, J. Freitag, M. Hoerhold, A. Zuhr, D. Vladimirova, A.-K. Faber, H.C. Steen-Larsen, S. Wahl, J.K. Andersen, B. Vandecrux, D. van As, K.D. Mankoff, M. Kern, E. Zege, and J.E. Box, **Retrieval of snow and ice properties from the Sentinel-3 Ocean and Land Colour Instrument**, Remote Sens. 2019, 11(19), 2280; https://doi.org/10.3390/rs11192280

3. Kokhanovsky, A., Box, J.E., Vandecrux, B., Mankoff, K.D., Lamare, M., Smirnov, A., Kern, M. **The Determination of Snow Albedo from Satellite Measurements Using Fast Atmospheric Correction Technique**. Remote Sens. 2020, 12, 234.

4. Wehrlé, A., Box, J. E., Niwano, M., Anesio, A. M., & Fausto, R. S. (2021). **Greenland bare-ice albedo from PROMICE automatic weather station measurements and Sentinel-3 satellite observations**. GEUS Bulletin, 47. https://doi.org/10.34194/geusb.v47.5284

Arctic Land Ice Loss
2004-2010



Non-Greenland GRACE data *after Wouters et al. (2008)*
Barletta et al. (2014) for Greenland
Greenland peripheral contribution after Bolch et al. (2013)

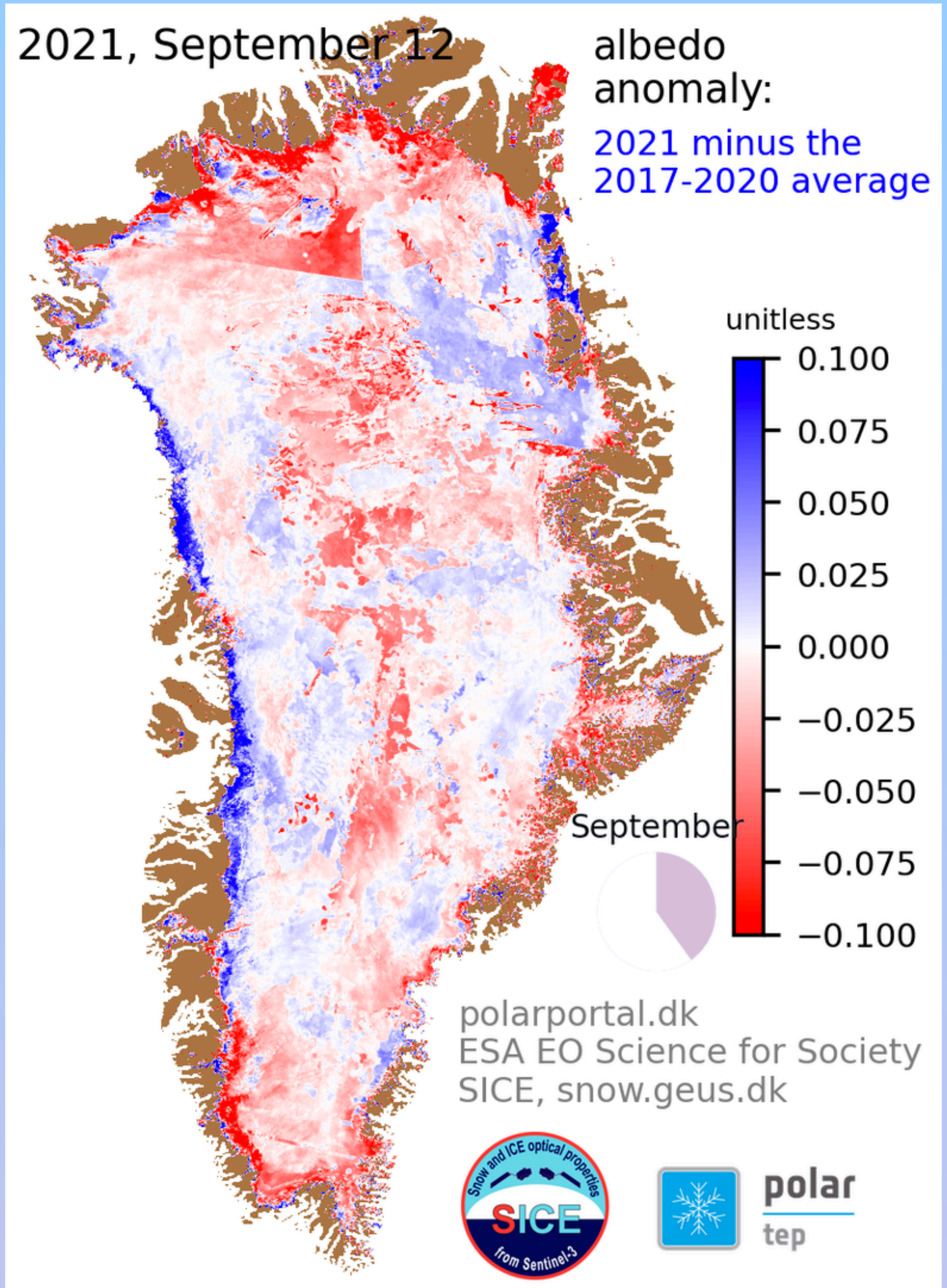
Arctic Monitoring and Assessment Program (AMAP)

SWIPA 2017

societal service

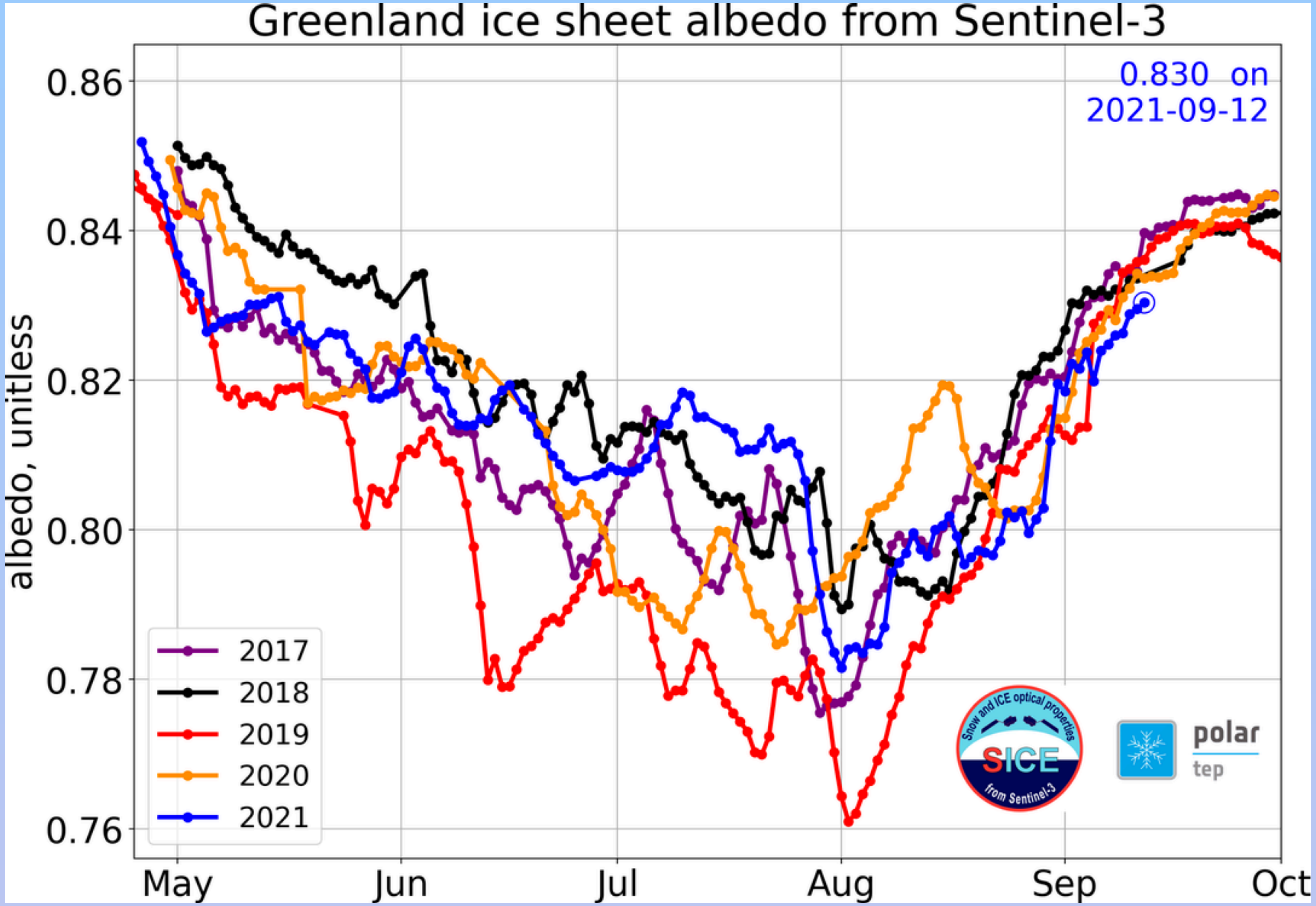
societal service
element 1: NRT climate monitoring

NRT albedo anomaly



http://snow.geus.dk/
https://dataverse01.geus.dk/dataverse/sice
https://github.com/GEUS-SICE/SICE
https://github.com/GEUS-SICE/dataverse-io

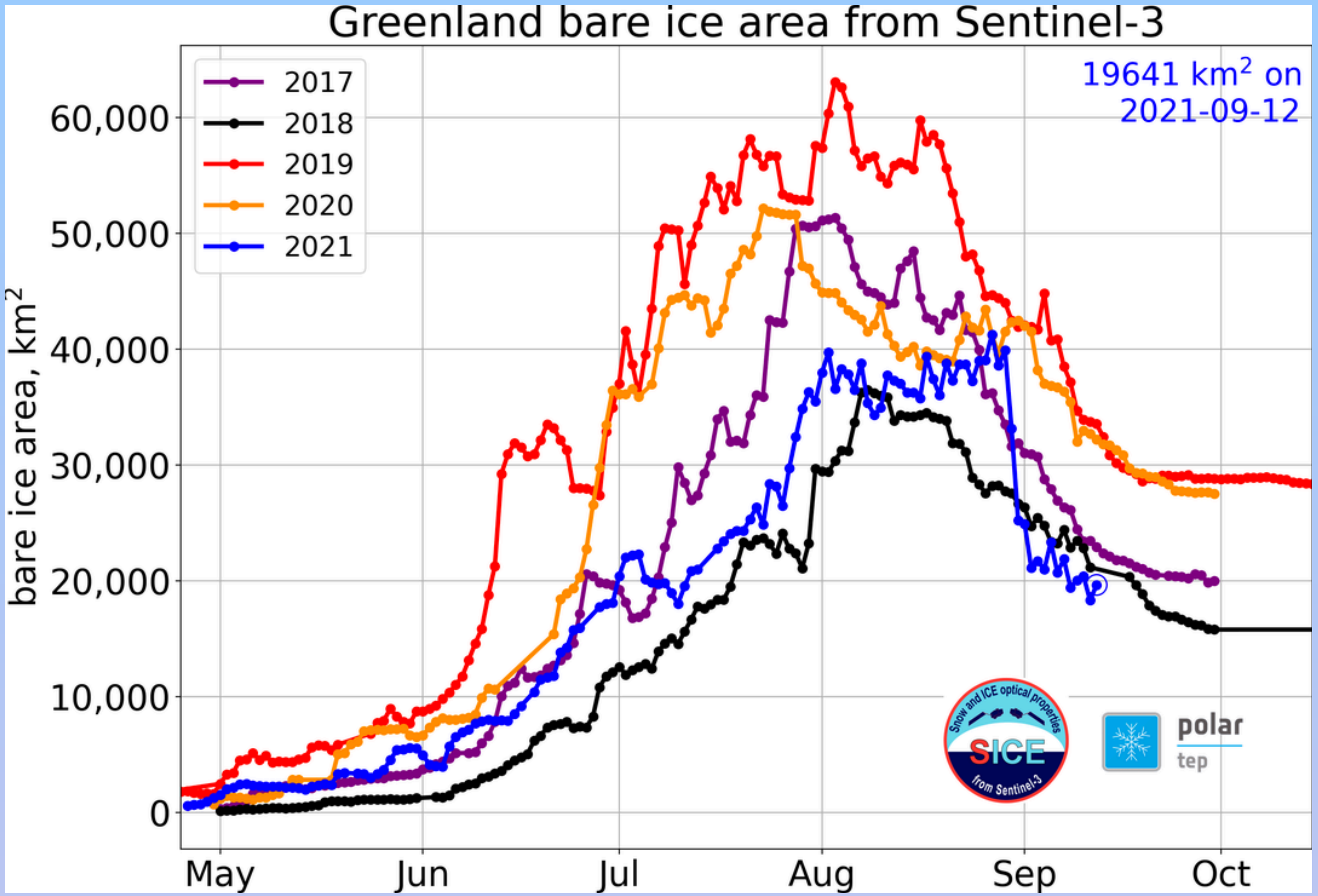
NRT albedo



http://nsidc.org/greenland-today/2021/08/large-melt-event-changes-the-story-of-2021/

http://snow.geus.dk/
https://dataverse01.geus.dk/dataverse/sice
https://github.com/GEUS-SICE/SICE
https://github.com/GEUS-SICE/dataverse-io

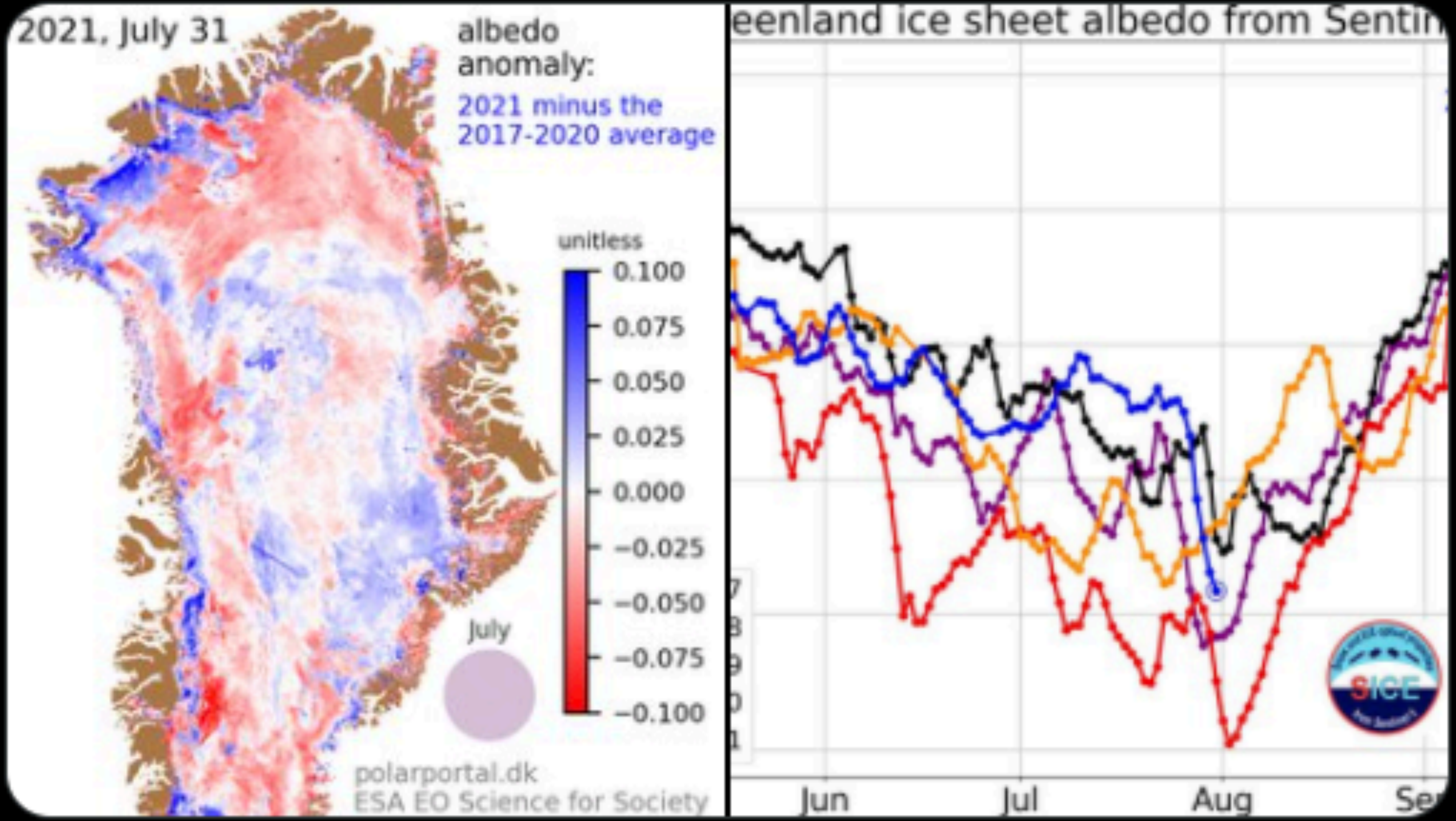
NRT bare ice area



http://snow.geus.dk/
https://dataverse01.geus.dk/dataverse/sice
https://github.com/GEUS-SICE/SICE
https://github.com/GEUS-SICE/dataverse-io

Prof. Jason Box @climate_ice · Aug 1

recent Greenland heat wave has given the ice sheet's snow and ice a darker hue (red areas). Yet, this melt season has only recently approached abnormal darkness. So, the ice sheet THIS YEAR is mostly spared from amplified ice loss. HT #Sentinel3

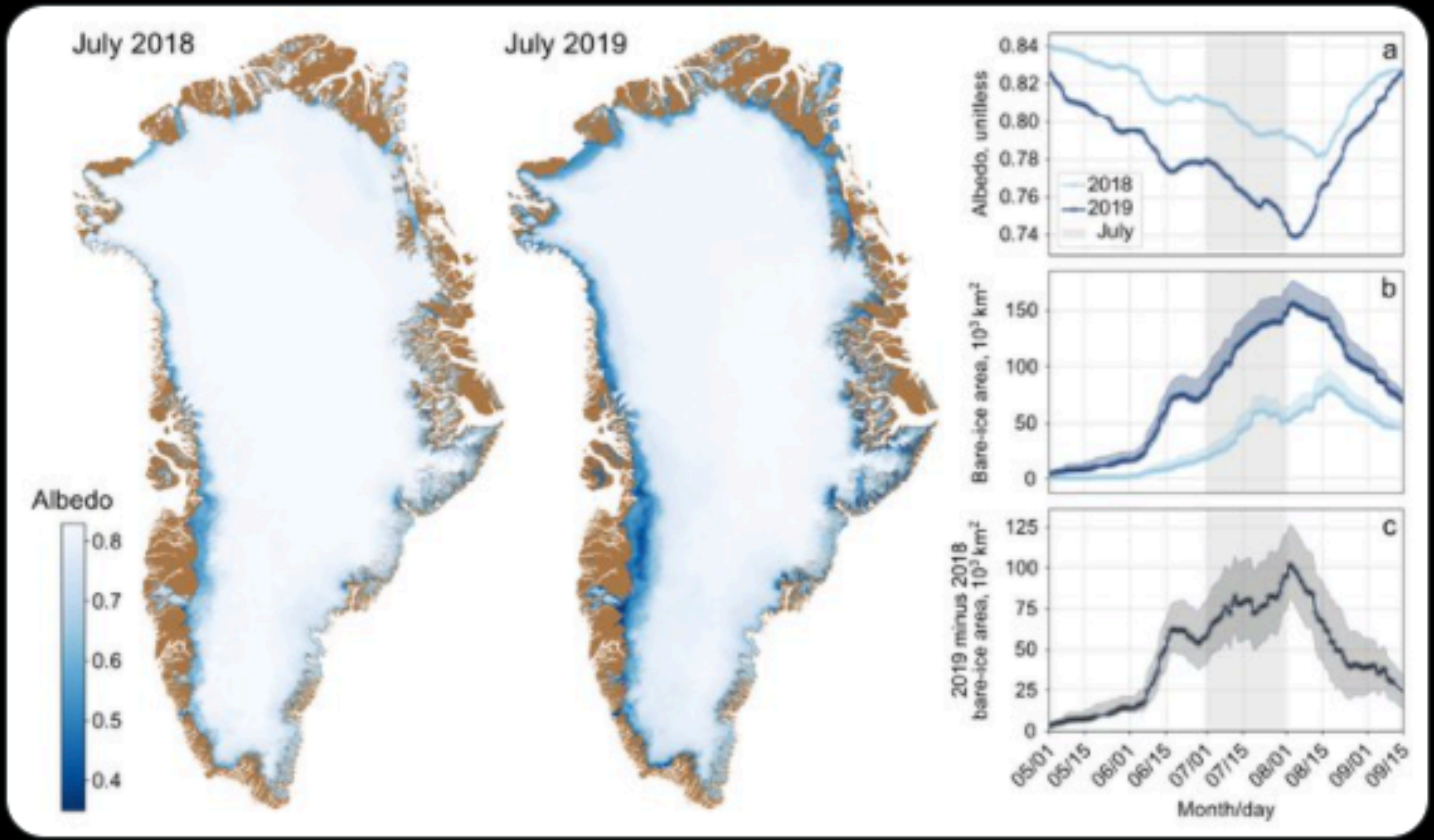


Adrien Wehrlé and polarview

2 31 62

Adrien Wehrlé
@AdrienWehrle

Our new publication on Greenland bare-ice albedo is finally out! Here, we summarize our main findings through a short thread! @climate_ice @MasashiNiwano @AlexAnesio #vEGU21 #Sentinel3 geusbulletin.org/index.php/geus... 1/n

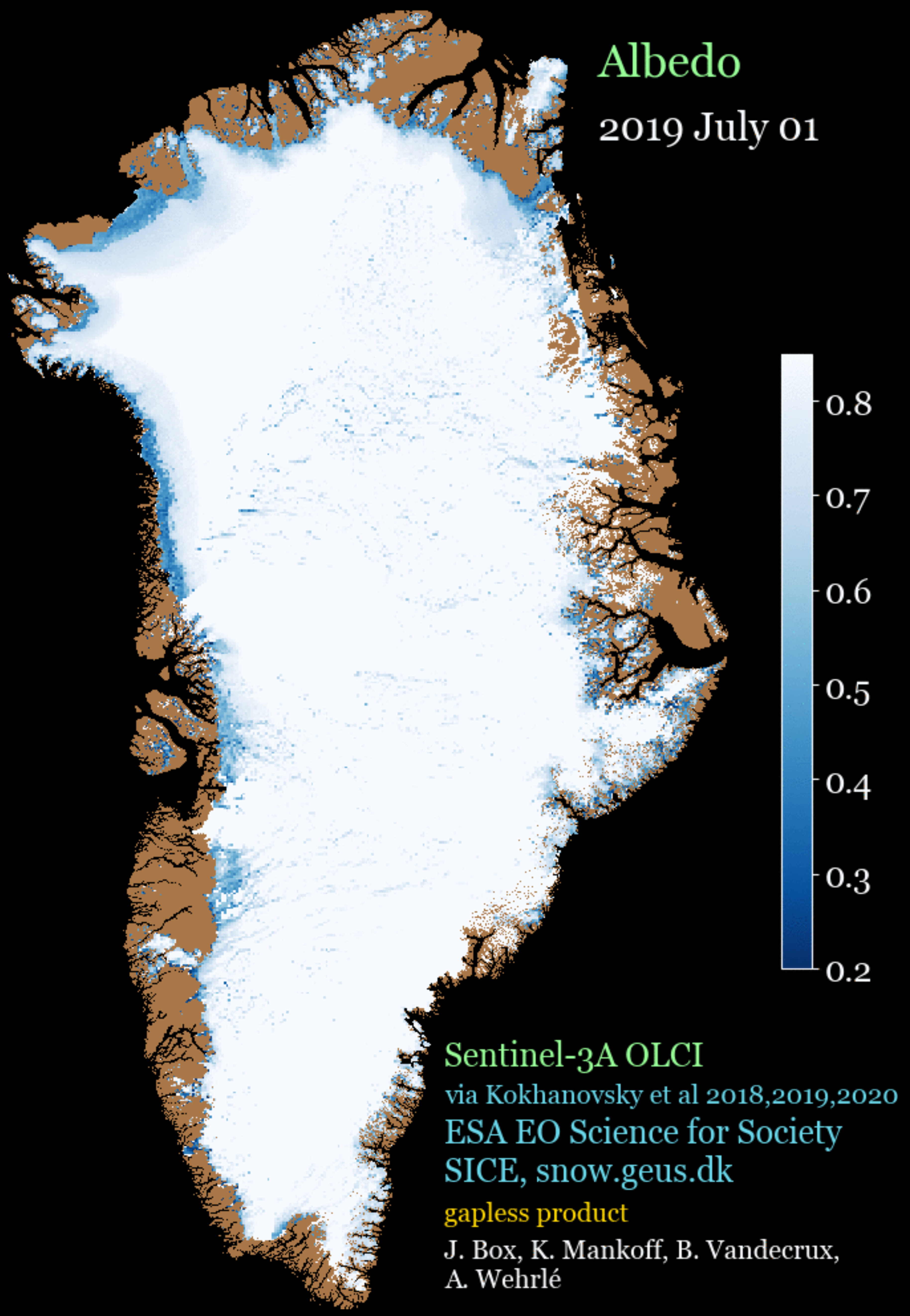


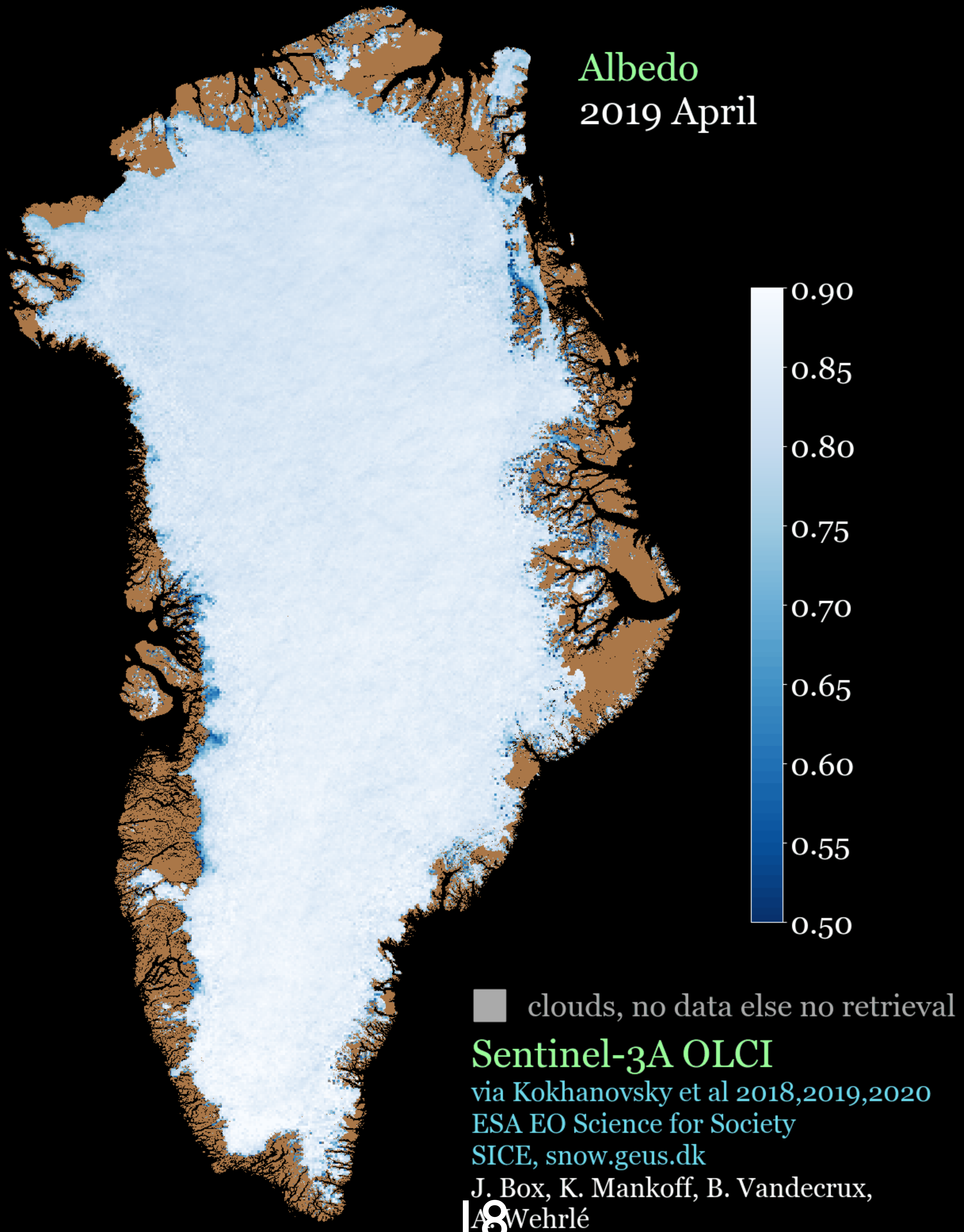
PROMICE and 9 others

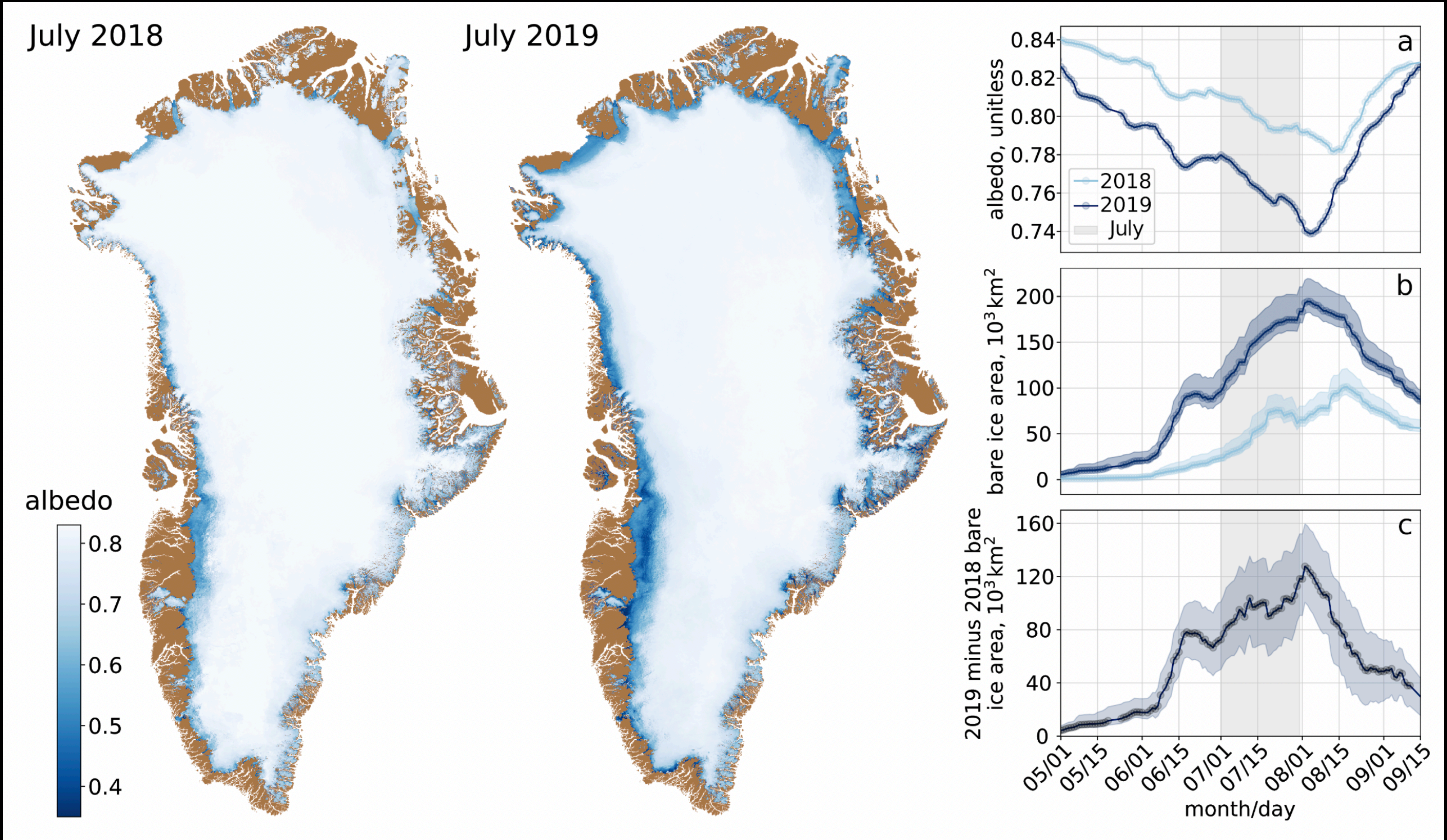
5:23 PM · Apr 20, 2021 · Twitter Web App

17 Retweets **3** Quote Tweets **60** Likes

societal service
element 2: climate assessment

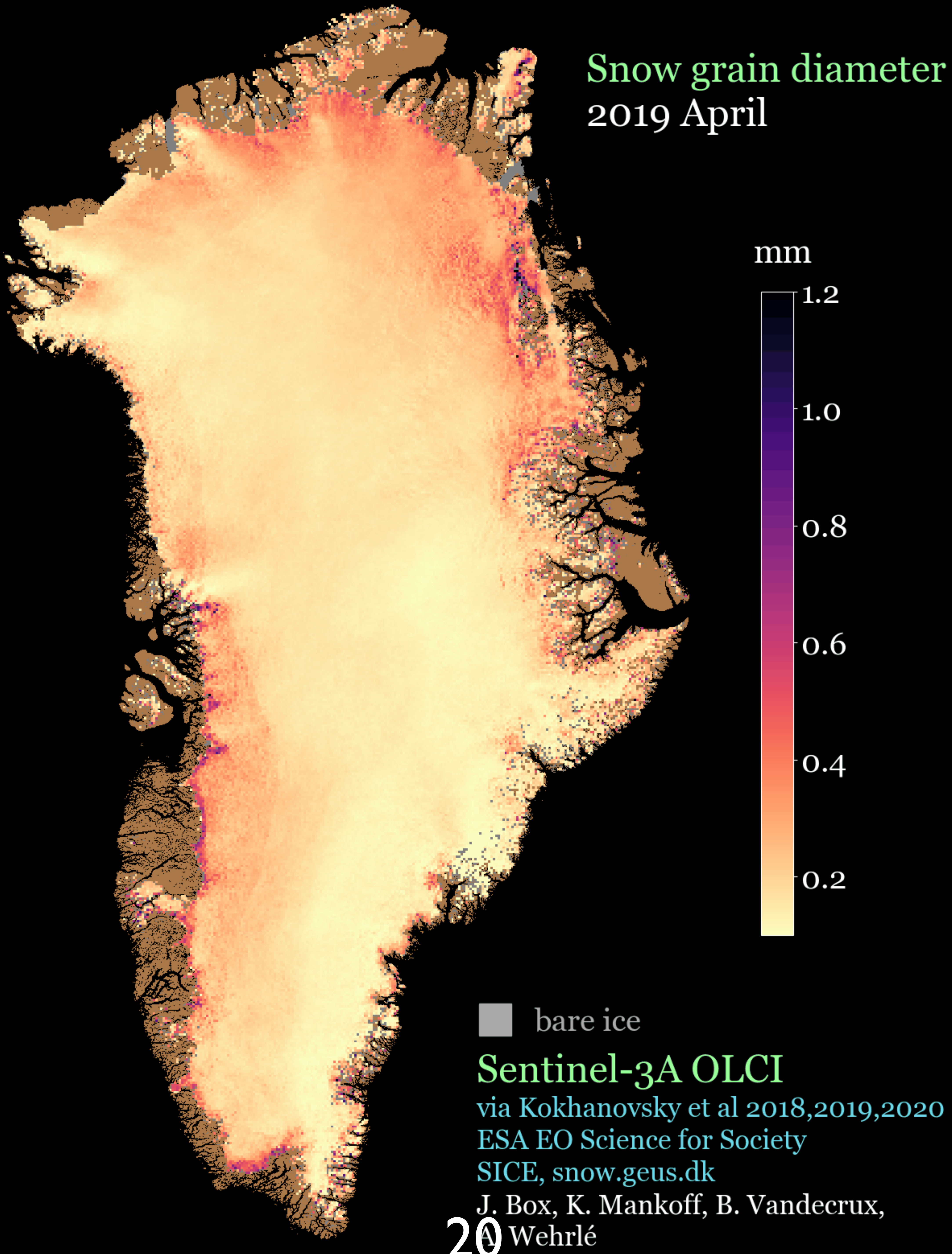

Albedo
2019 July 01
0.8
0.7
0.6
0.5
0.4
0.3
0.2
Sentinel-3A OLCI
via Kokhanovsky et al 2018,2019,2020
ESA EO Science for Society
SICE, snow.geus.dk
gapless product
J. Box, K. Mankoff, B. Vandecrux,
A. Wehrlé


Albedo
2019 April
0.90
0.85
0.80
0.75
0.70
0.65
0.60
0.55
0.50
clouds, no data else no retrieval
Sentinel-3A OLCI
via Kokhanovsky et al 2018,2019,2020
ESA EO Science for Society
SICE, snow.geus.dk
J. Box, K. Mankoff, B. Vandecrux,
A. Wehrlé



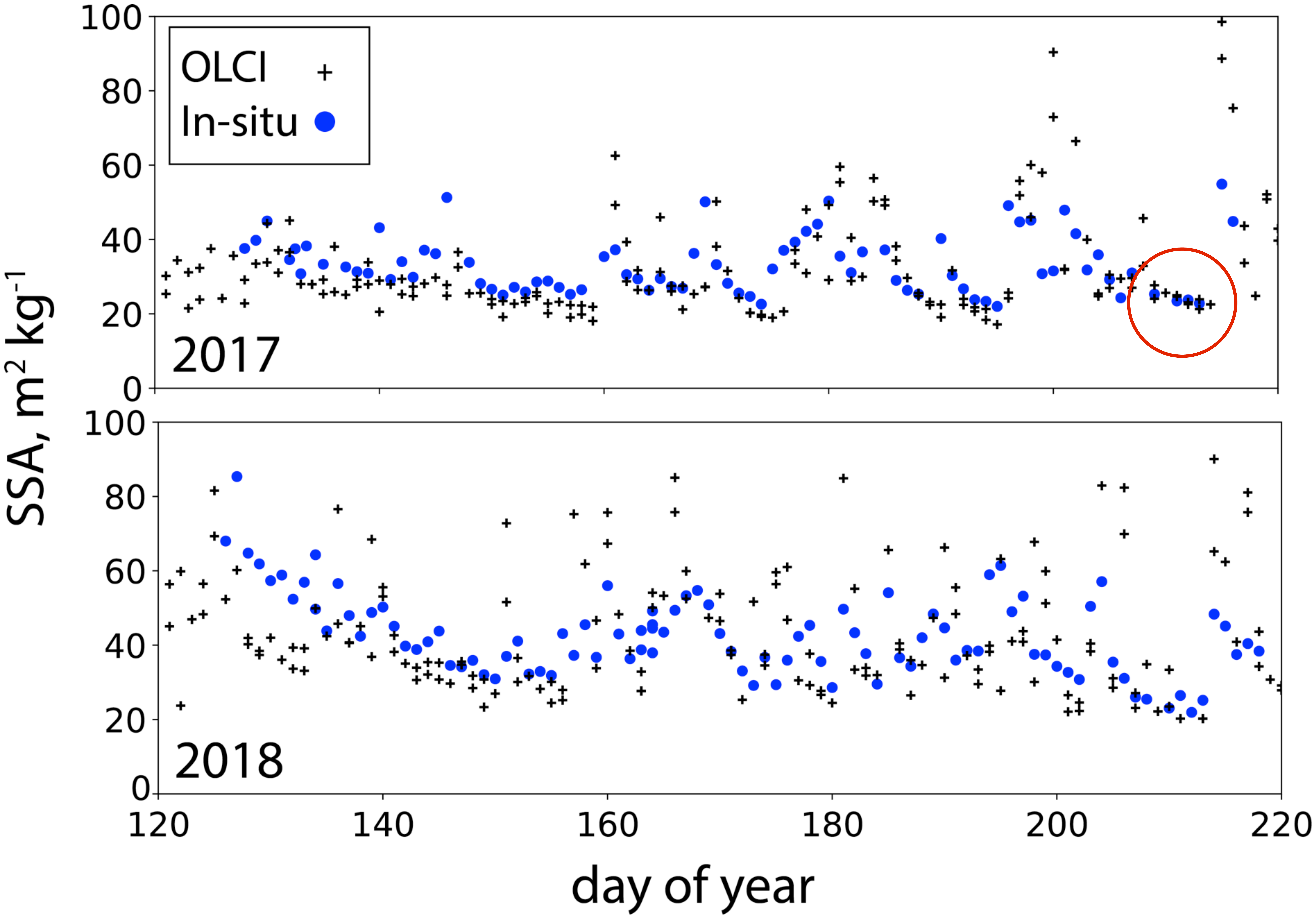
From 1 May to 15 September, 2019 bare ice area was 50,750 km² or 4.3x larger than in 2018 …reaching a maximum difference of 126,685 km² or 3.0 times larger on peak melt day 2 August, 2019

Fig. 3 Wehrlé et al. (2020) Maps of 2018 and 2019 July average Greenland snow and ice albedo from Sentinel-3. Inset Figures feature a) area averaged albedo and b) bare ice area for the low melt 2018 and high melt 2019 melt seasons. Inset Figure c) illustrates the 2018 and 2019 Greenland bare ice area variations. Shaded areas in b) correspond to the range of bare ice areas computed from bare ice albedo threshold values of 0.585 and 0.554 according to respective ice ablation thresholds of 4 and 12 cm.

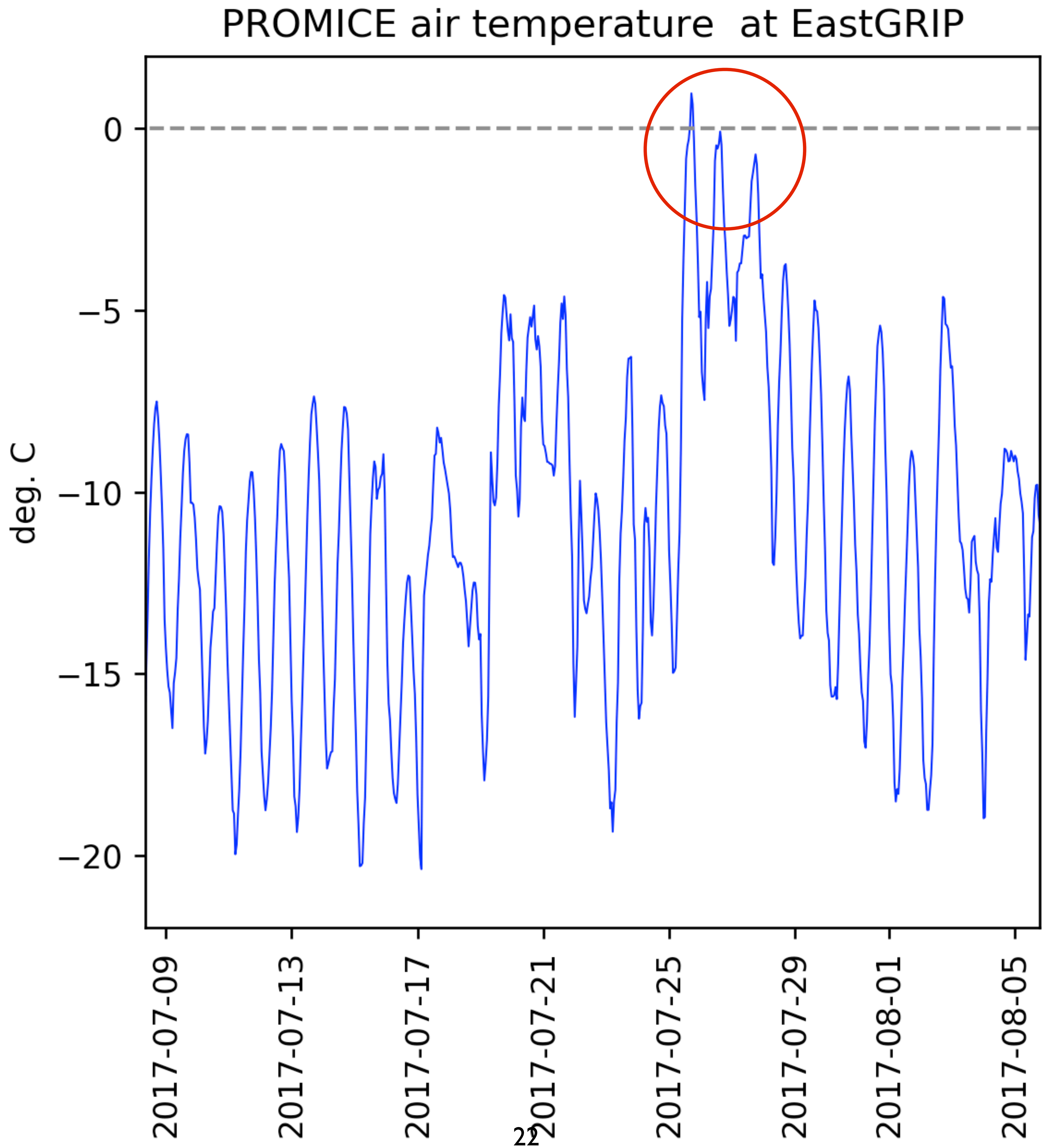

Snow grain diameter
2019 April
mm
1.2
1.0
0.8
0.6
0.4
0.2
bare ice
Sentinel-3A OLCI
via Kokhanovsky et al 2018,2019,2020
ESA EO Science for Society
SICE, snow.geus.dk
J. Box, K. Mankoff, B. Vandecrux,
A. Wehrlé

$$s = \frac{6}{\rho d}$$

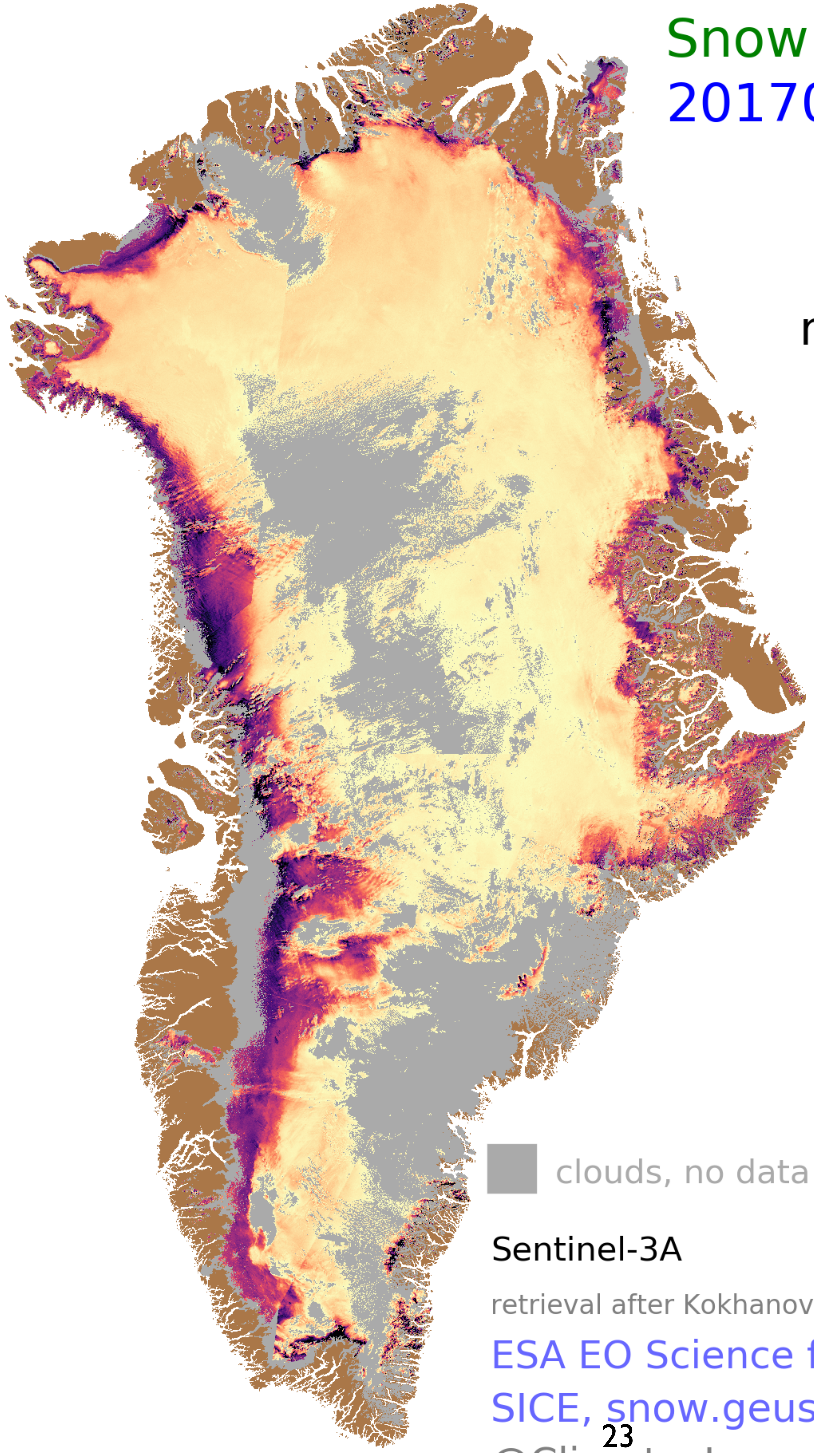
$d = 6/SSA\rho$

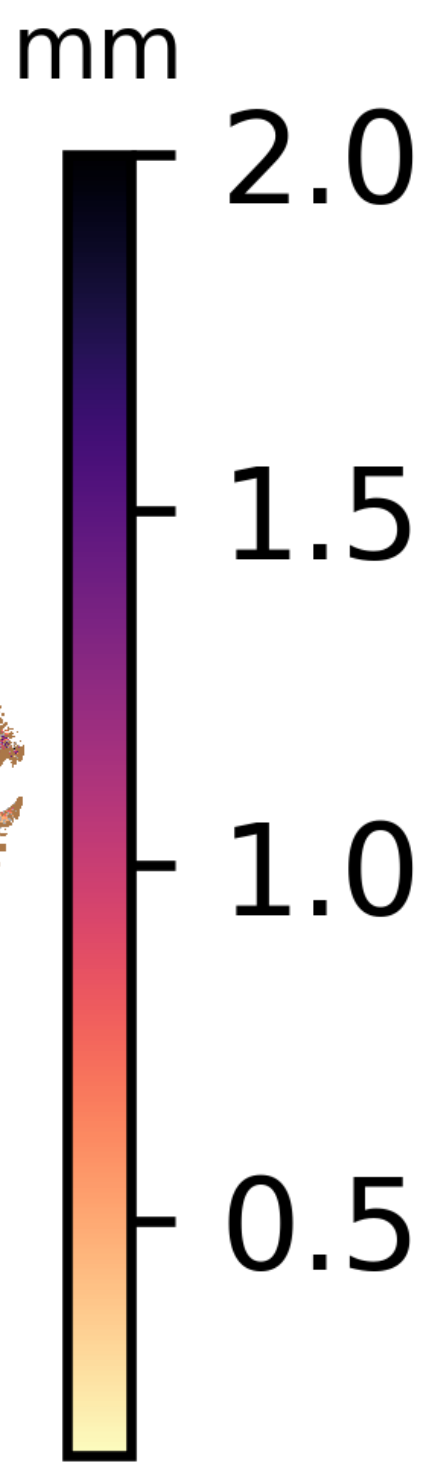


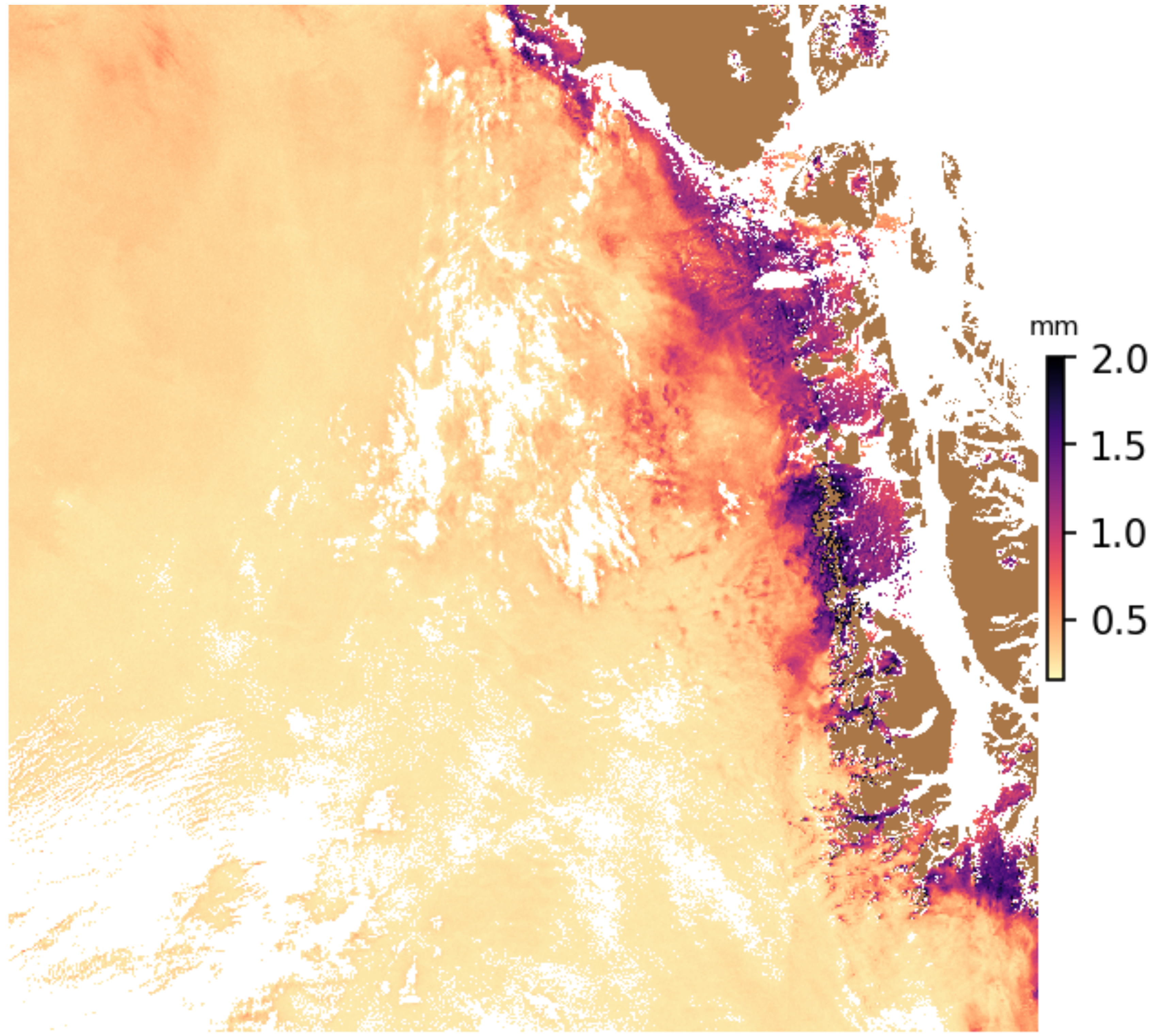
Kokhanovsky, A.; Lamare, M.; Danne, O.; Dumont, M.; Brockmann, C.; Picard, G.; Arnaud, L.; Favier, V.; Jourdain, B.; Lemeur, E.; Di Mauro, B.; Aoki, T.; Niwano, M.; Rozanov, V.; Korkin, S.; Kipfstuhl, S.; Freitag, J.; Hoerhold, M.; Zuh, A.; Vladimirova, D.; Faber, A.; Steen-Larsen, H.; Wahl, S.; Andresen, J.; Vandecrux, B.; van As, D.; Mankoff, K.; Kern, M.; Zege, E.; Box, J. **Retrieval of snow properties from the Sentinel-3 Ocean and Land Colour Instrument**. 2019, *Remote Sens.* **2019**, *11*(19), 2280; https://doi.org/10.3390/rs11192280


PROMICE air temperature at EastGRIP
deg. C
0
−5
−10
−15
−20
2017-07-09
2017-07-13
2017-07-17
2017-07-21
2017-07-25
2017-07-29
2017-08-01
2017-08-05

Snow Grain Diameter
20170725







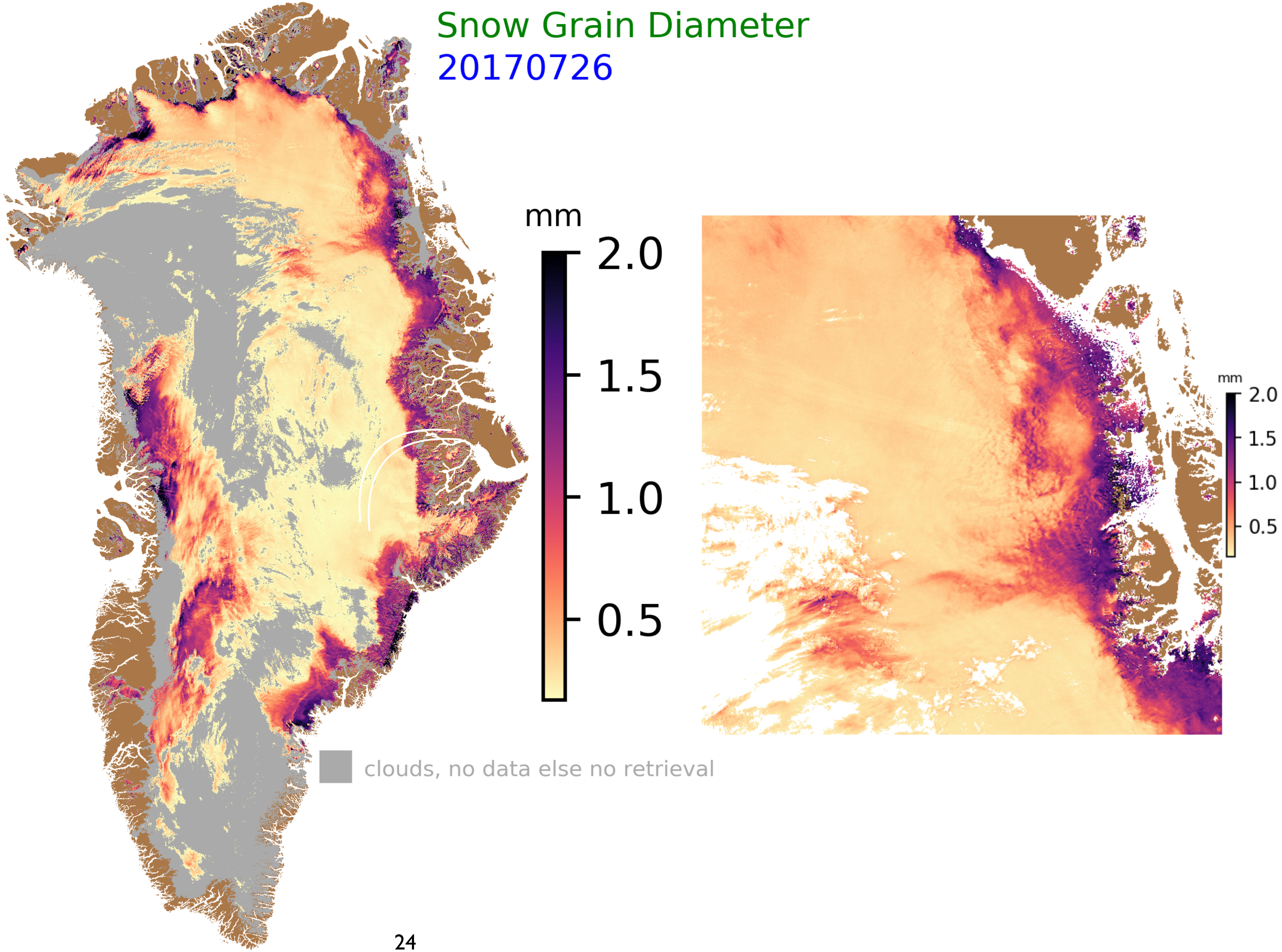
clouds, no data else no retrieval

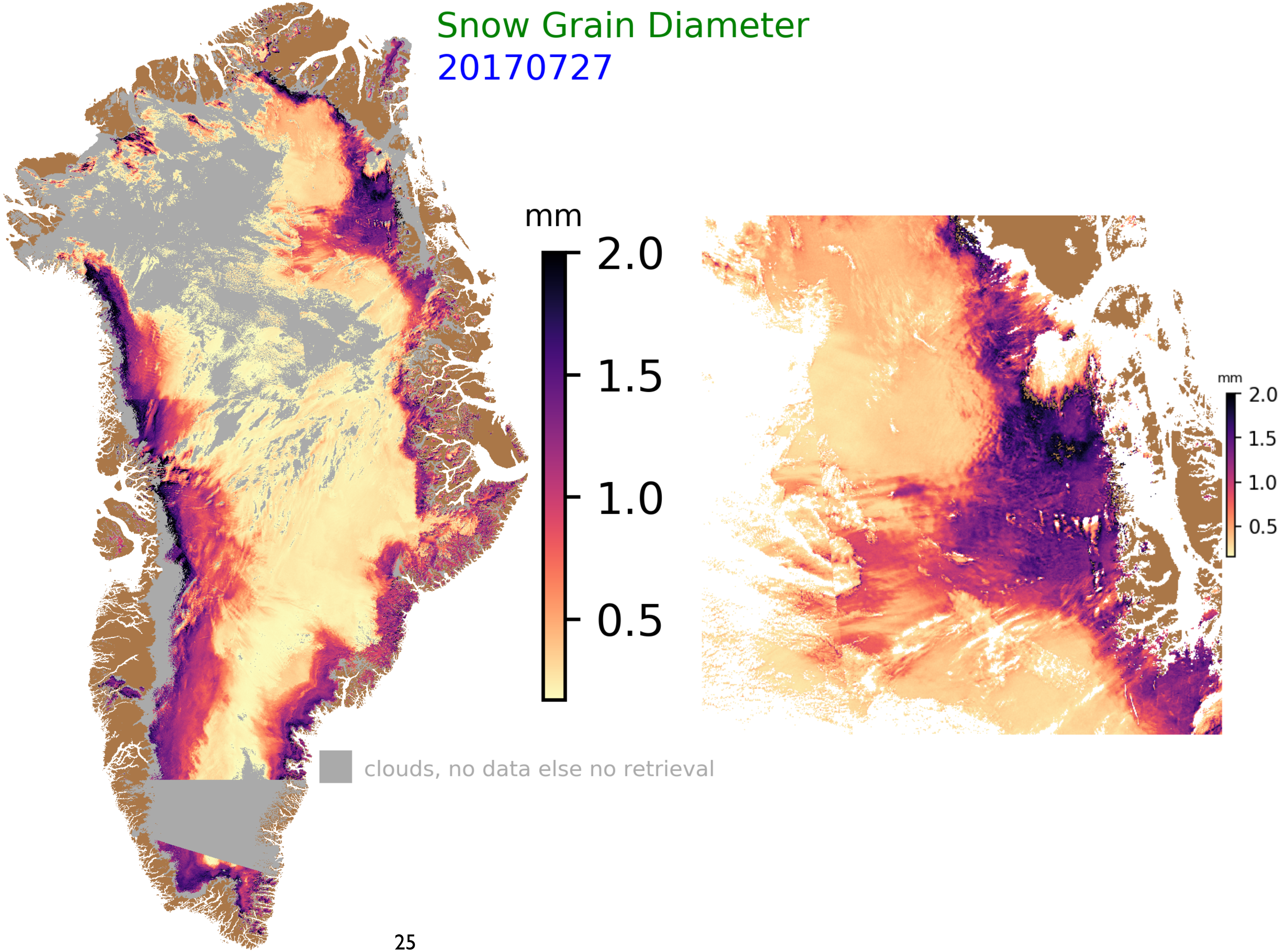
Sentinel-3A

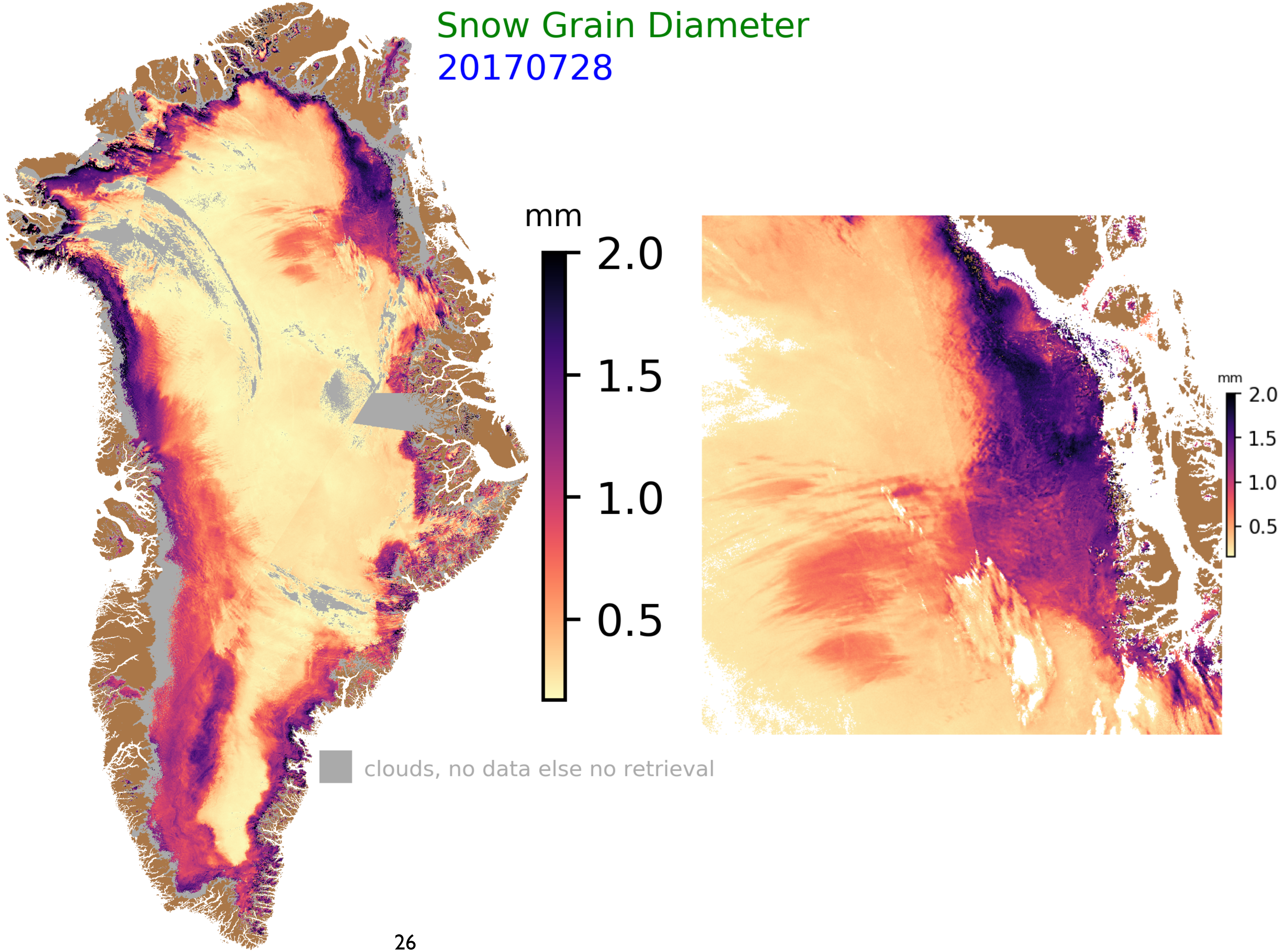
retrieval after Kokhanovsky et al 2018

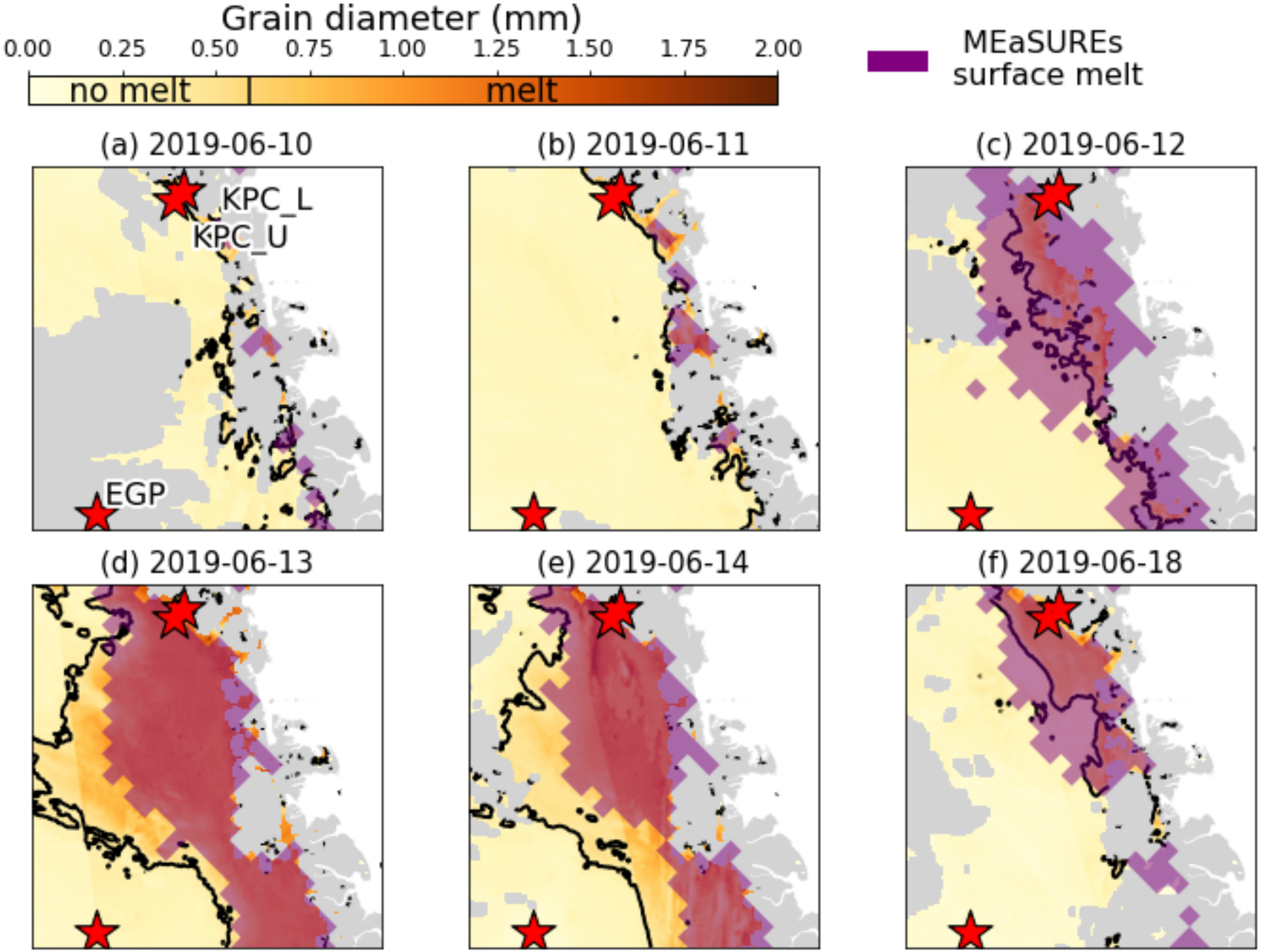
ESA EO Science for Society

SICE, snow.geus.dk


Snow Grain Diameter
20170726
mm
2.0
1.5
1.0
0.5
mm
2.0
1.5
1.0
0.5
clouds, no data else no retrieval


Snow Grain Diameter
20170727
mm
2.0
1.5
1.0
0.5
clouds, no data else no retrieval
mm
2.0
1.5
1.0
0.5

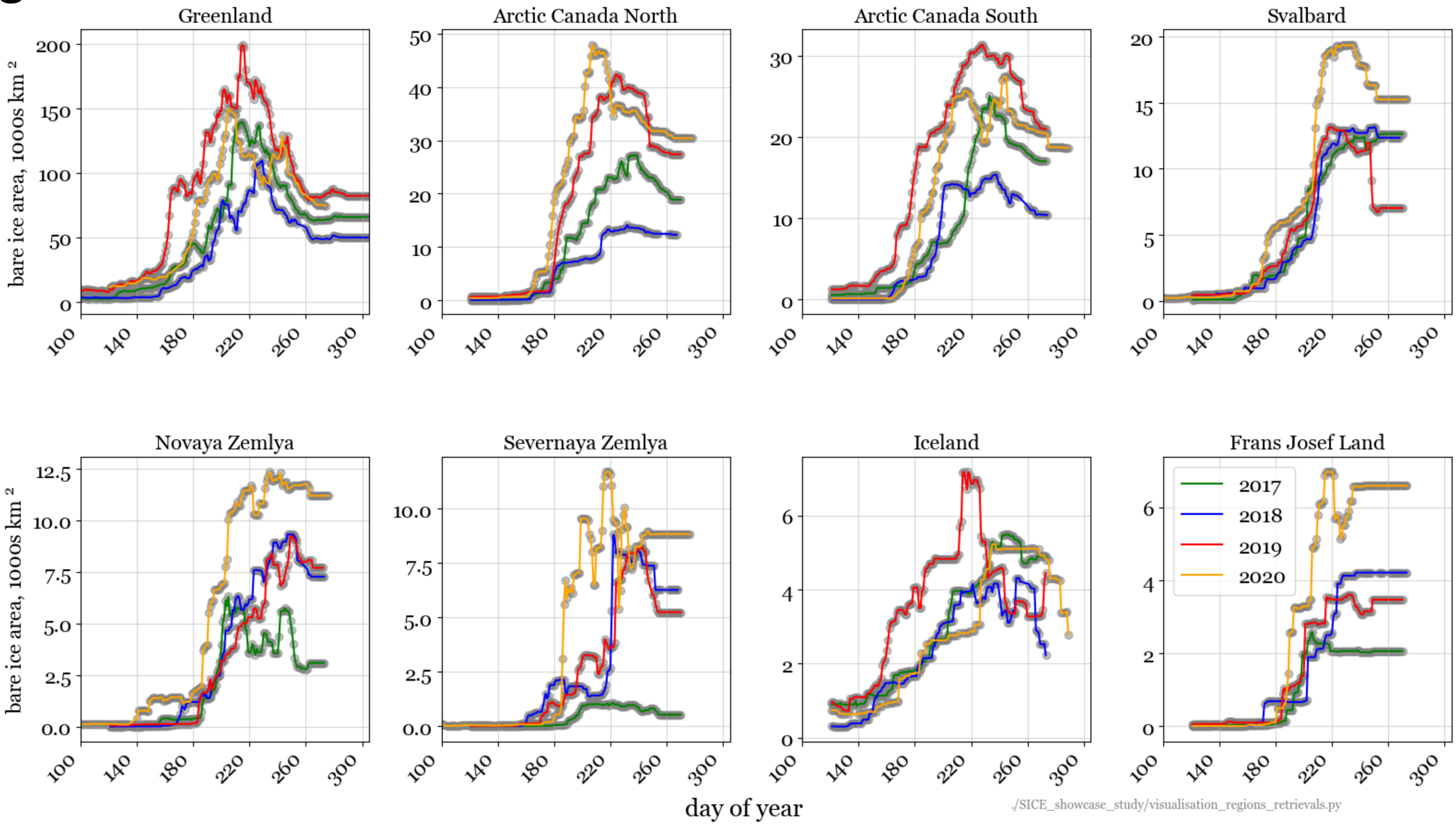

Snow Grain Diameter
20170728
mm
2.0
1.5
1.0
0.5
mm
2.0
1.5
1.0
0.5
clouds, no data else no retrieval



Grain diameter (SSA) vs melt

Vandecrux et al. in prep

regional bare ice area



societal service
element 3: data assimilation

Seamless Integration of Sentinel-3 Albedos in a Weather-modelling System (SISAWS)

GEUS

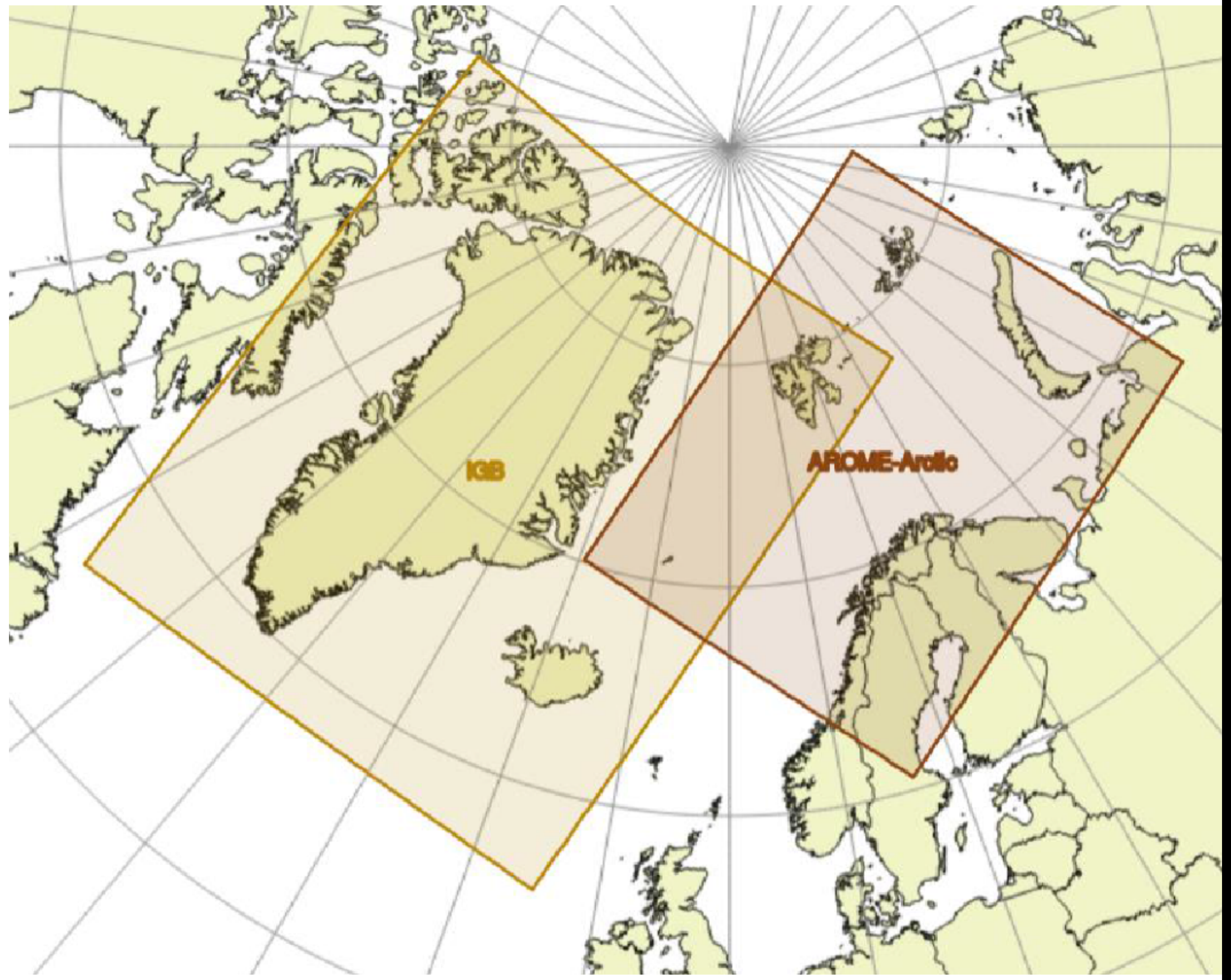
Danmarks Meteorologiske Institut

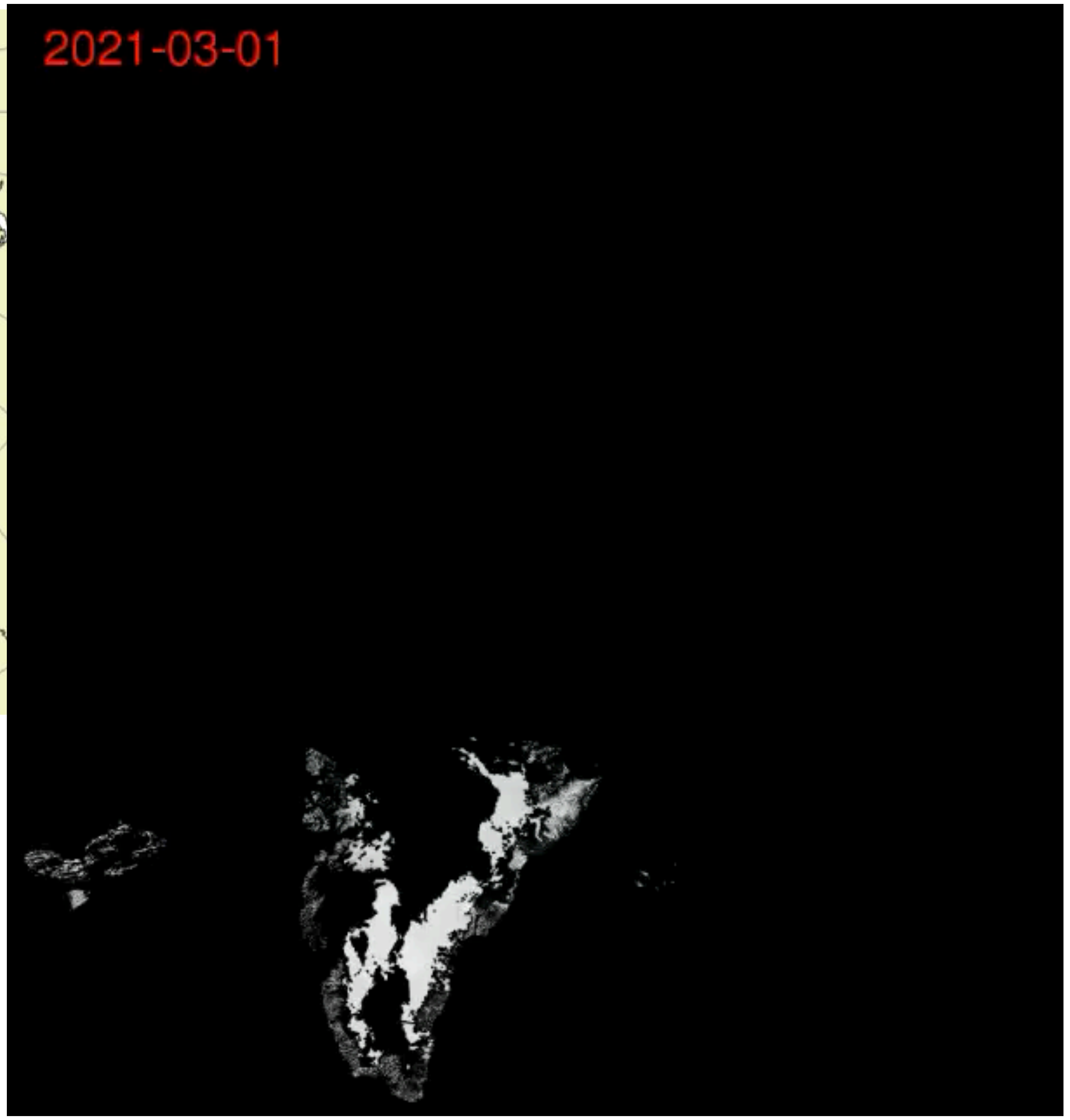
PROgramme de Développement d'EXpériences scientifiques (PRODEX) 2021-2023

Seamless Integration of Sentinel-3 Albedos in a Weather-modelling System (SISAWS)

C3S - Copernicus Arctic Regional Reanalysis

- Very high resolution regional model Harmonie-AROME (2.5 km, 65 layers)
- 3D-VAR with extensive use of local surface observation collected from the national weather services in North Europe and Russia.
- Special emphasis on NWP schemes and observations for the handling of "*cold surfaces*": Snow, sea ice, glaciers





Copernicus Climate Change Service

SICE data users

Category	User	Nation
climate monitoring	Program for the Monitoring of the Greenland Ice Sheet	Denmark
	polarportal.dk	Denmark
climate assessment	1.) Arctic Report Card 2.) American Meteorological Society, State of the Climate	USA
	National Snow and Ice Data Center	USA
climate data assimilation	Japanese Meteorological Acency	Japan
	C3S - Copernicus Arctic Regional Reanalysis	EU

Frontier topics


Ice Algae

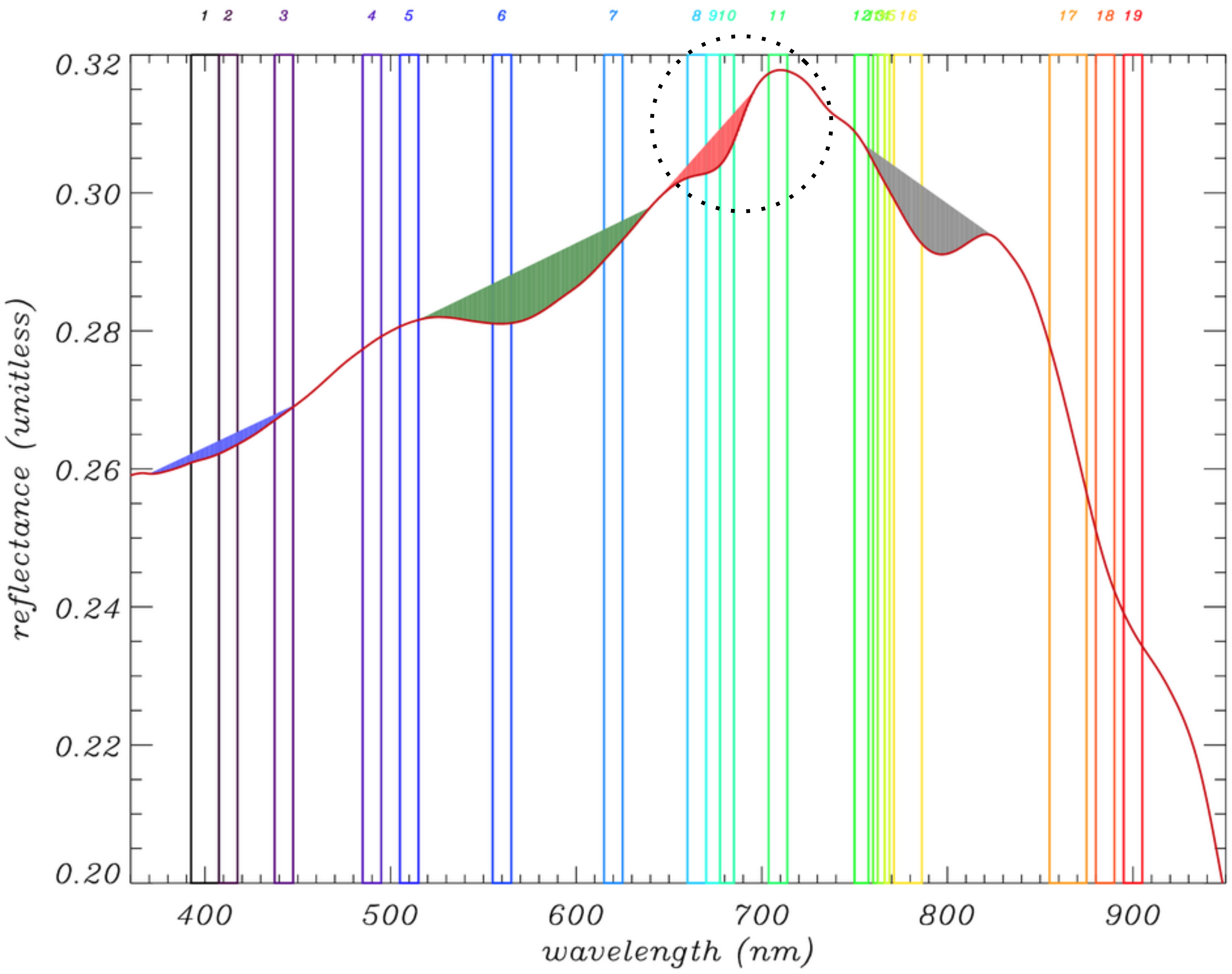

Photo Alex Anesio, Deep Purple ERC

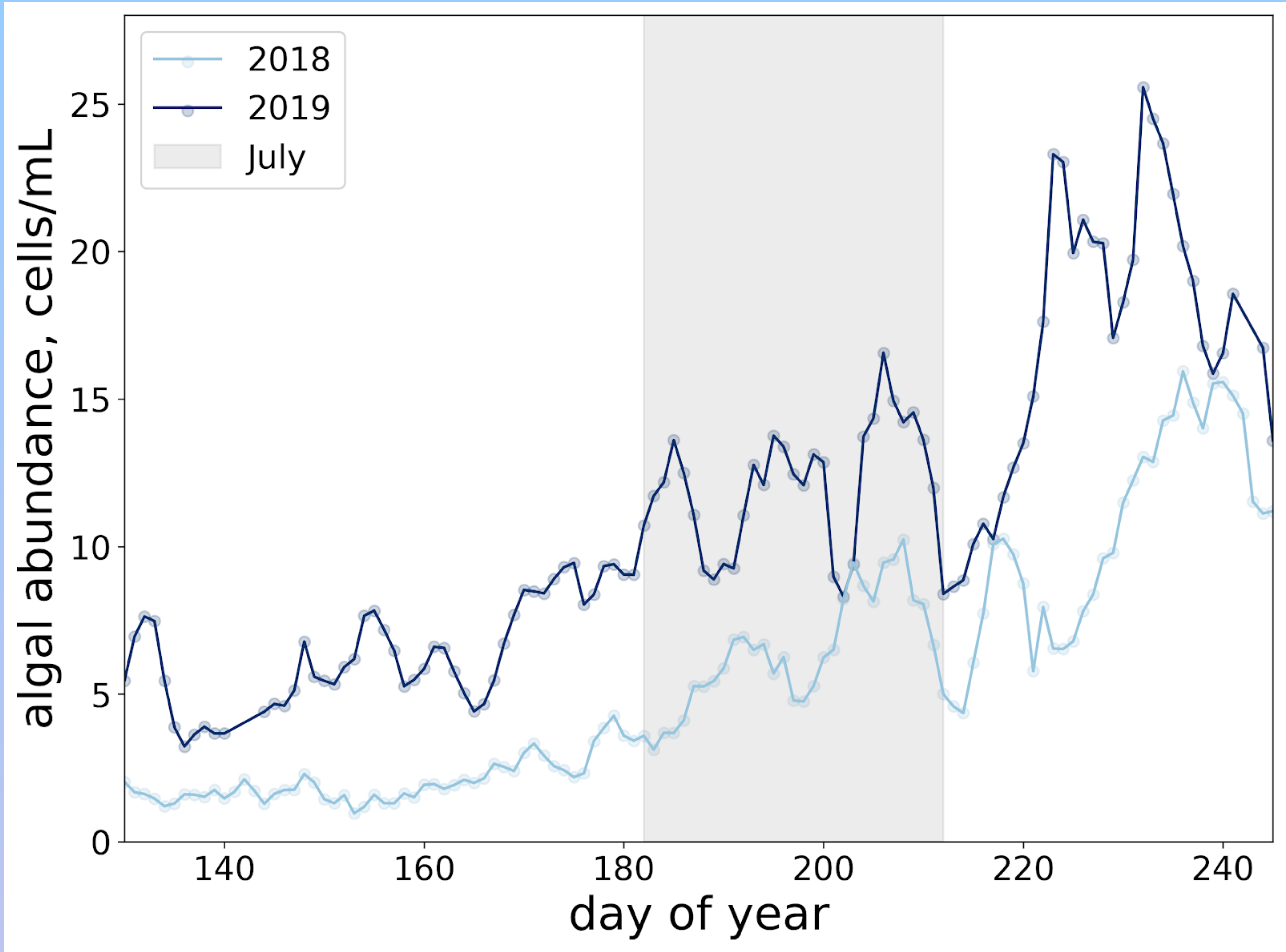
Ice Algae chlorophyll signal

r_TOA_11/r_TOA_10

$R_{709\ nm} / R_{681\ nm}$

Should be > 1

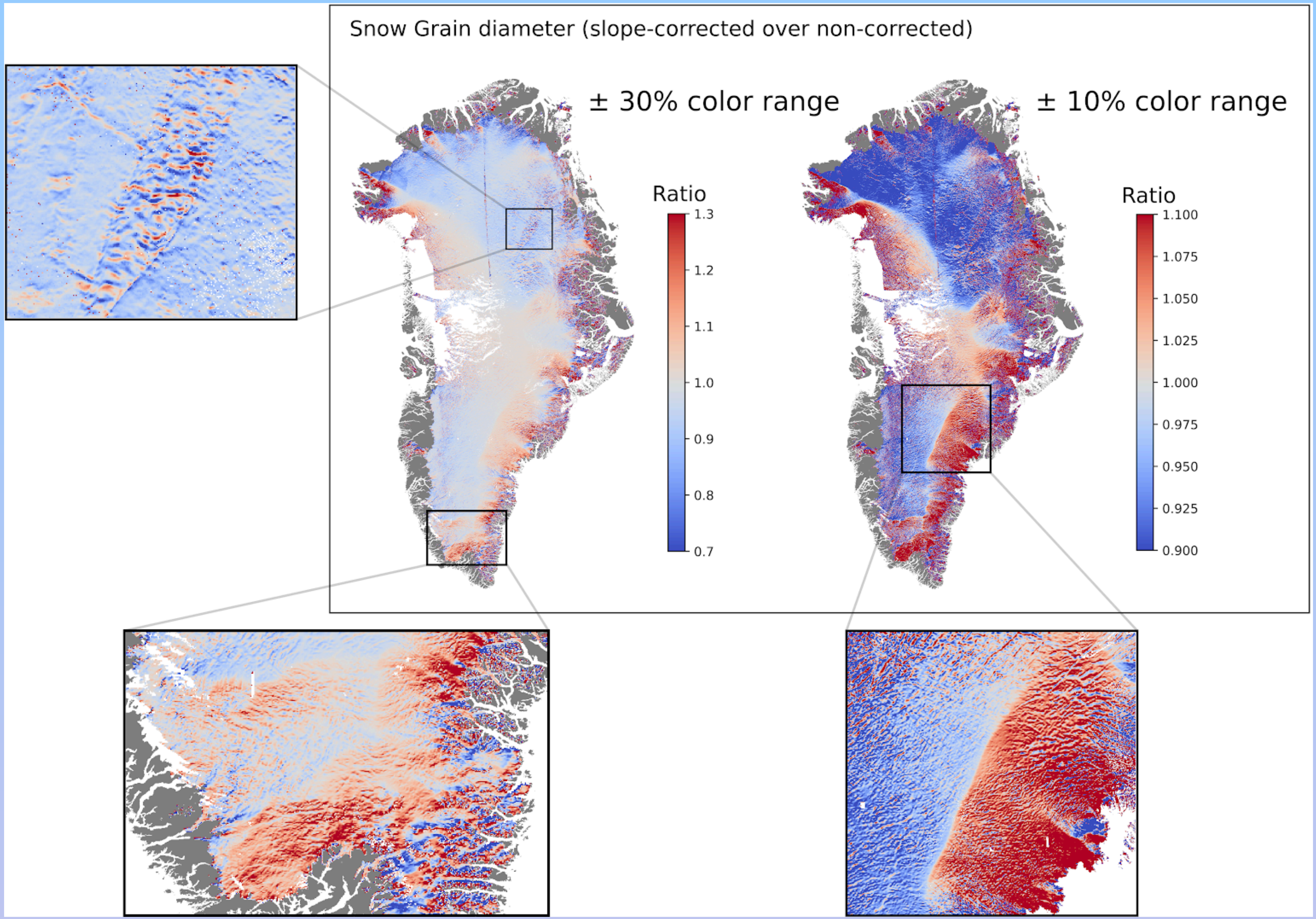




2018
2019
July
algal abundance, cells/mL
day of year
0
5
10
15
20
25
140
160
180
200
220
240

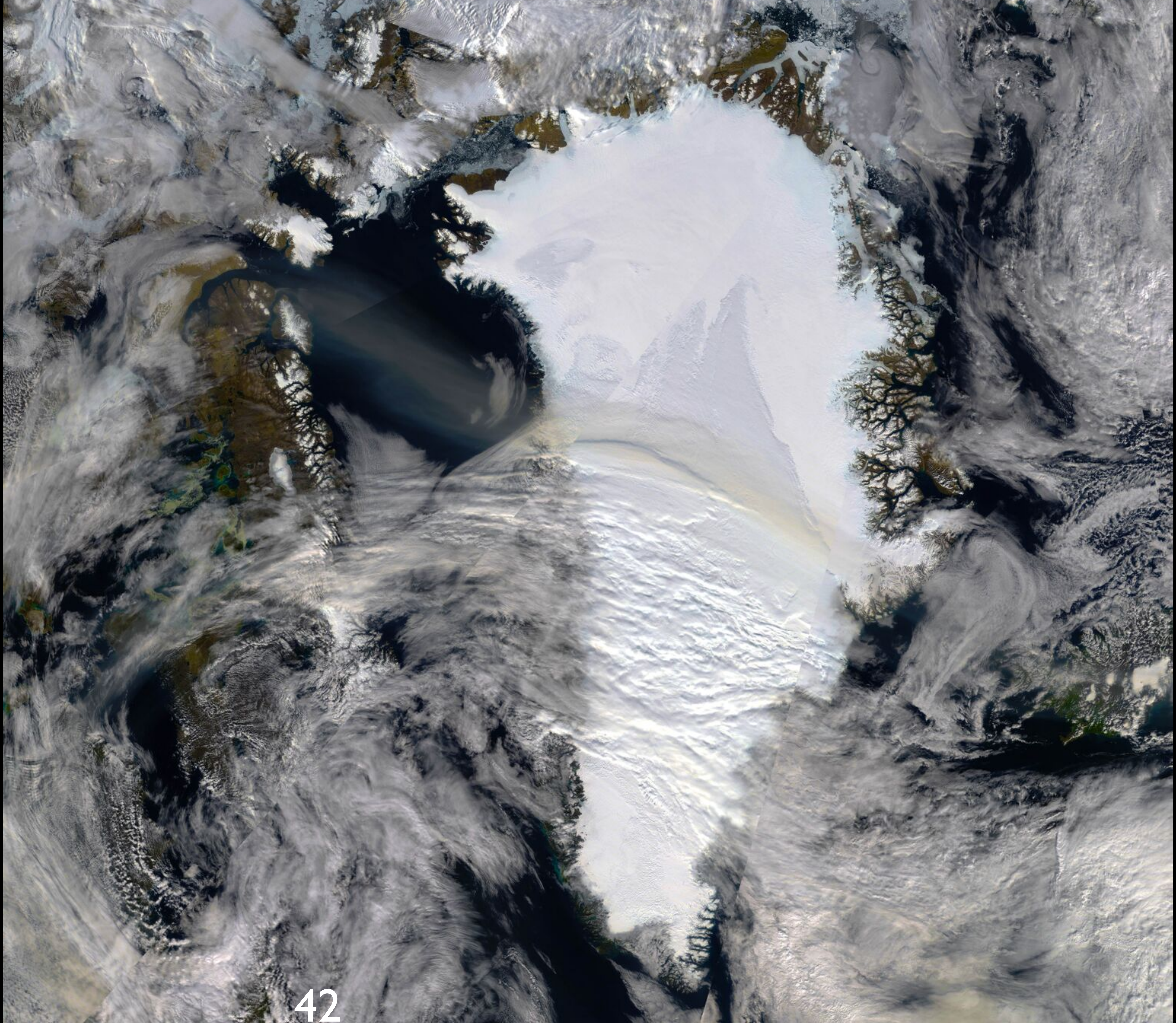
Surface slope

Slope Effects



wildfire impacts

Wildfire smoke over Greenland



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