

# High resolution snow cover mapping using Sentinel 2

# The motivation

Karrat 2017 landslide





Kristian Svennevig  
@K\_Svennevig · Follow



# The motivation

Monitoring of landslide activity

What are the drivers?

Any change yet due to warming climate?



Edvard Paornáguaq Kruse

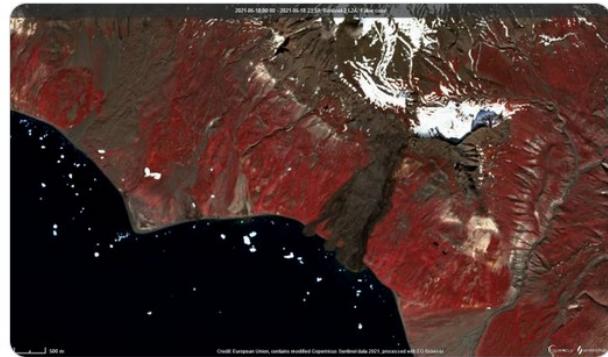
1 dag ·

Una qaarsimarpasittooq 😊



Fresh #sentinel2 of the June 15th #landslide in Greenland. Wow - just wow. Look at those lobes building out into Vaigat. See you in 1½ month!

Image credit #ESA and @sentinel\_hub



11:02 PM · Jun 18, 2021



# Thawing mountain project

15 thermistor strings

3 AWS

Complementary of 28 DTU  
sites along a transect

Sisimiut-Kangerlussuaq-Ice  
sheet margin



GEUS

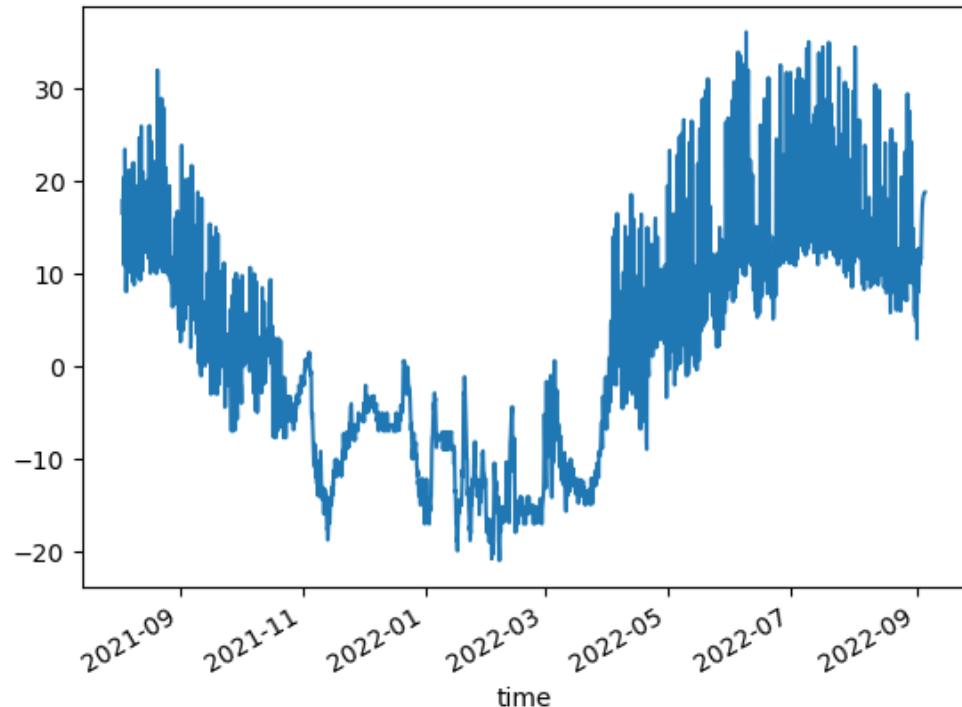


# Thawing mountain project

779BOB.csv

The key variable:

**Ground Surface Temperature  
(GST)**



# Thawing mountain project

The key variable:

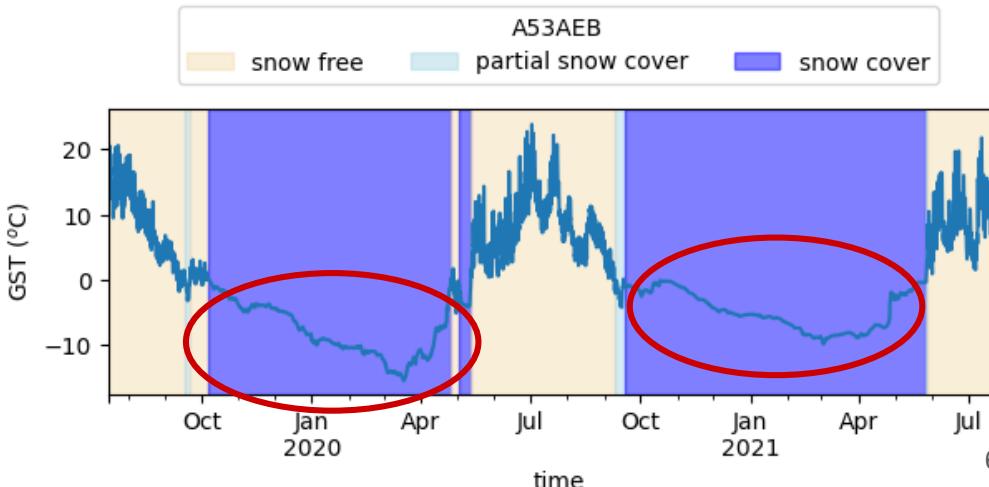
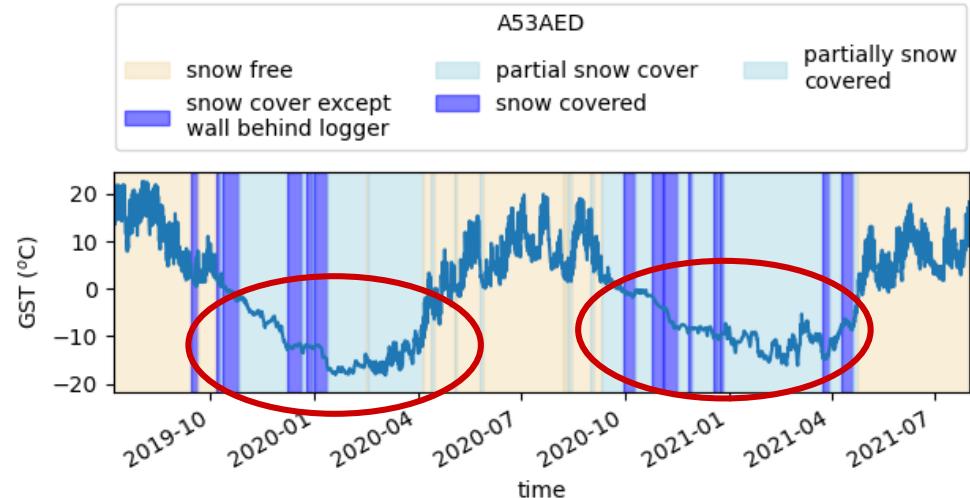
## Ground Surface Temperature (GST)

and its drivers:

local climate

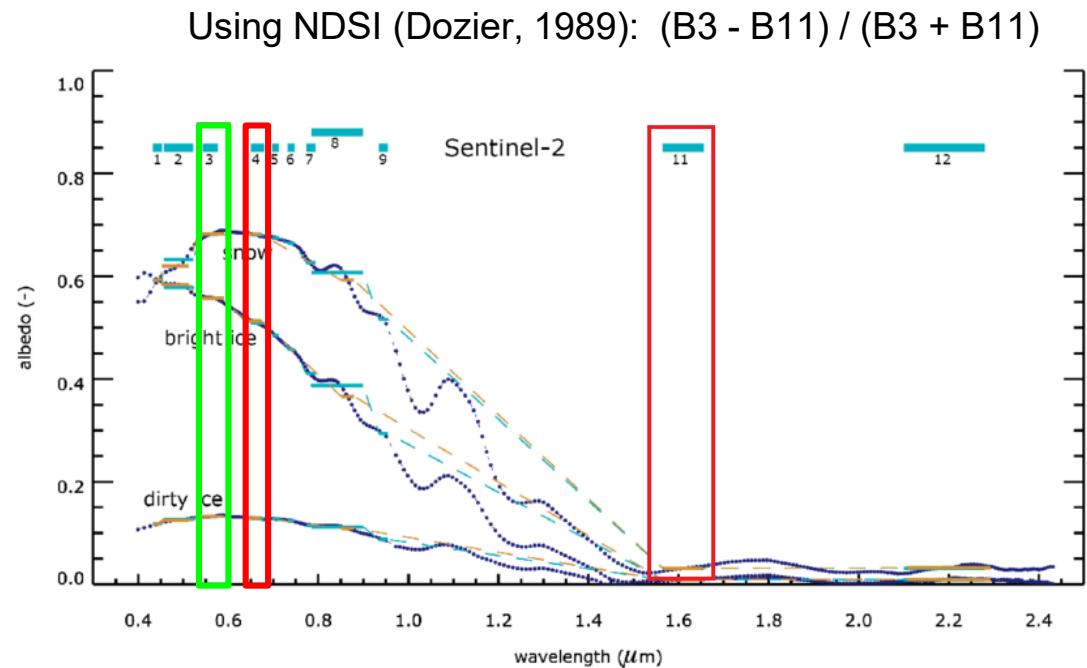
snow cover

**Mapping this effect  
at larger scale?**



# Mapping snow cover at high resolution

Sentinel-2 Multispectral Instrument (MSI) **10-20 m spatial resolution**



# Mapping snow cover at high resolution



Sentinel-2 Multispectral Instrument (MSI) **10-20 m spatial resolution**



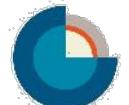
Let-It-Snow algorithm (Gascoin et al., 2019)

First pass:  $\text{NDSI} > n_1 \text{ & } \text{B04} > r_1$

↓  
Minimum elevation of snow cover  $z_s$

Second pass for areas  $>z_s$ :  $\text{NDSI} > n_2 \text{ & } \text{B04} > r_2$

Possible third pass to recover snow pixels under thin clouds



# Mapping snow cover at high resolution

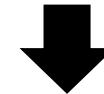


Sentinel-2 Multispectral Instrument (MSI) **10-20 m spatial resolution**



Available since 2017

5 days revisit time (minus days with clouds)



Not enough to study year to year changes

enough to build a  
**multi-year climatology of snow presence**

# Cloud masking over snow

S2cloudless:

Using the (slow) MAJA multi-temporal algorithm as a reference to train a  LightGBM tree-based algorithm on a set scenes considered representative.

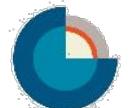
True Label	Fraction of classifications as clouds		
	Fmask	Sen2Cor	Sentinel Hub 
Cloud	89.0%	97.5%	99.4%
Cirrus	88.3%	87.7%	83.8%
Land	7.2%	5.7%	2.2%
Water	2.0%	0.0%	0.1%
<b>Snow</b>	<b>39.2%</b>	<b>30.7%</b>	<b>13.5%</b>
Shadow	3.9%	3.9%	5.8%

Cloud and cirrus cloud detection rates and land, water, snow and shadow misclassification rates as clouds as determined using 108 Sentinel-2 scenes hand labeled by Hollstein et al.



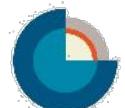
# Cloud masking over snow

S2cloudless:



# Cloud masking over snow

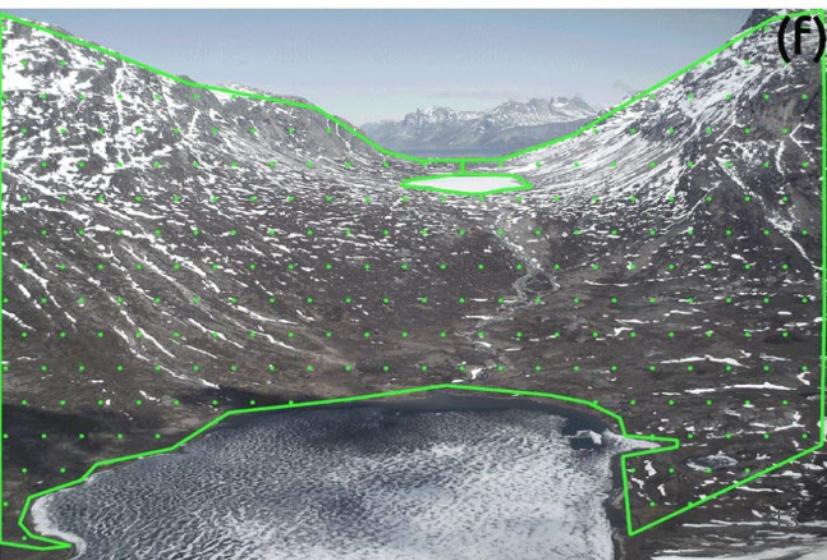
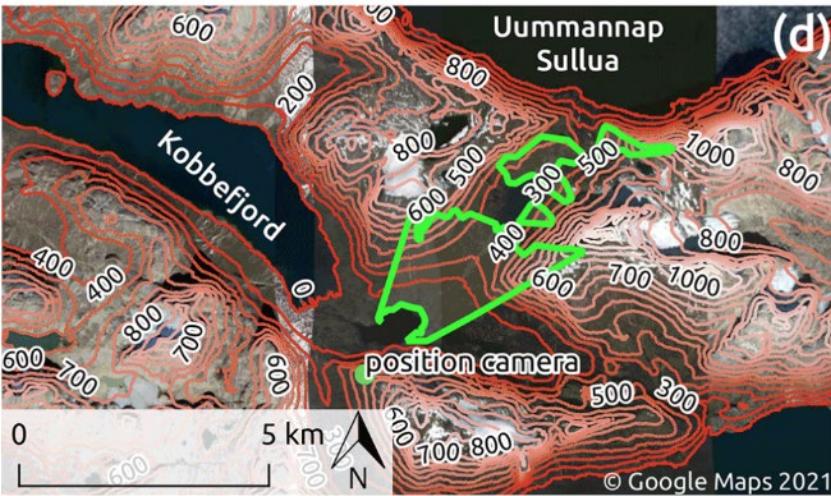
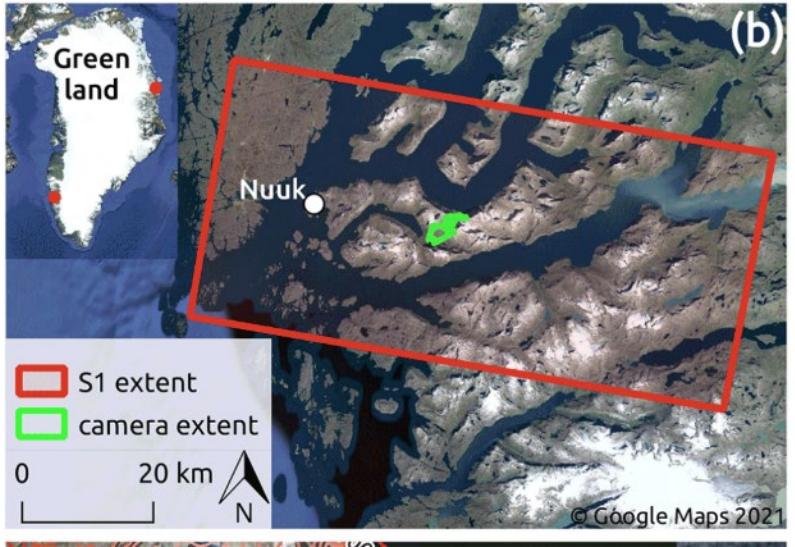
S2cloudless:



(Zupanc et al., 2017; Skakun et al. 2022)

# Evaluation dataset: Snow cover from time lapse camera at Kobbefjord (2m res)

Buchelt et al. (2022)

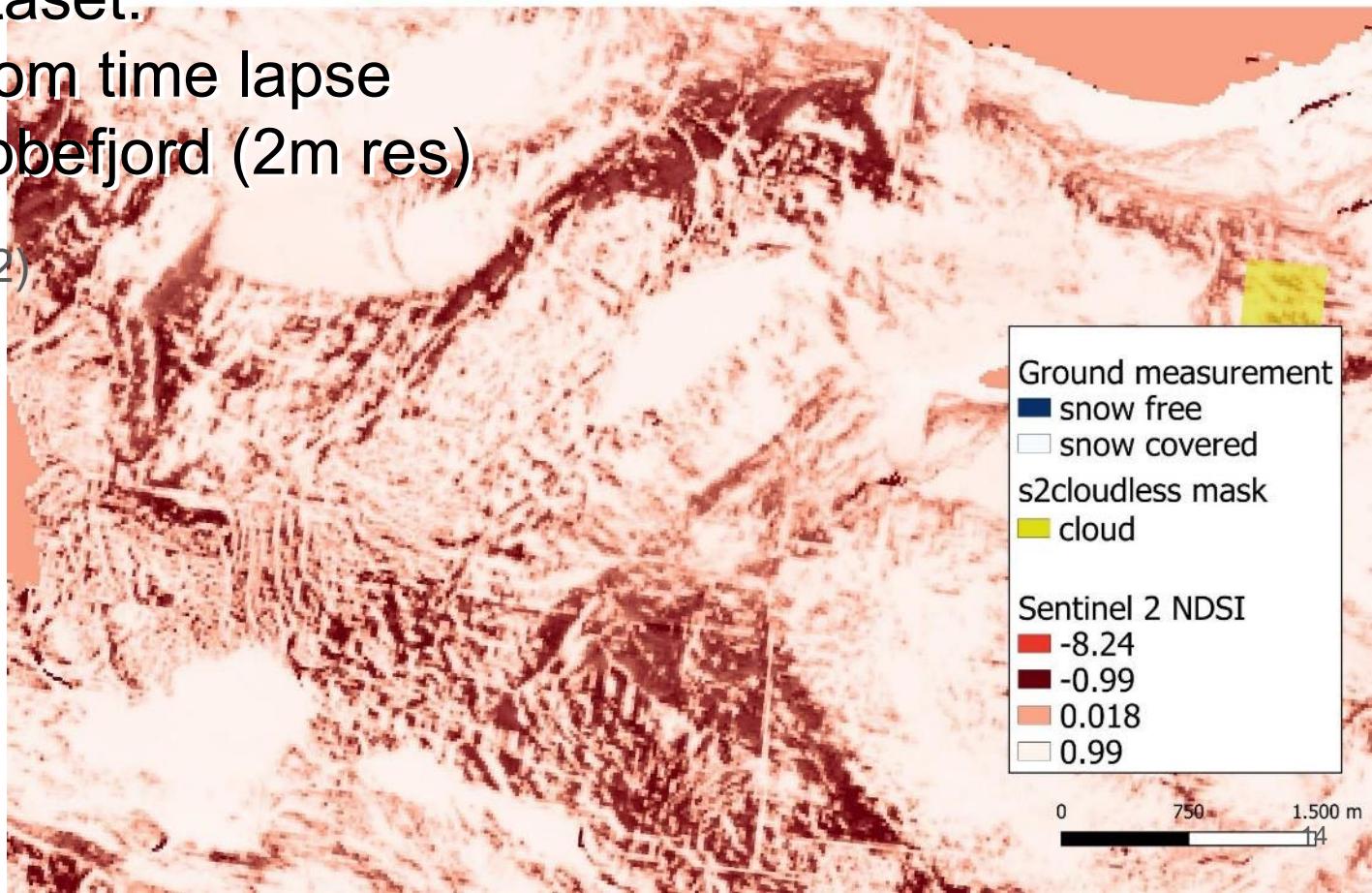


Evaluation dataset:

Snow cover from time lapse  
camera at Kobbefjord (2m res)

2017-05-31

Buchelt et al. (2022)

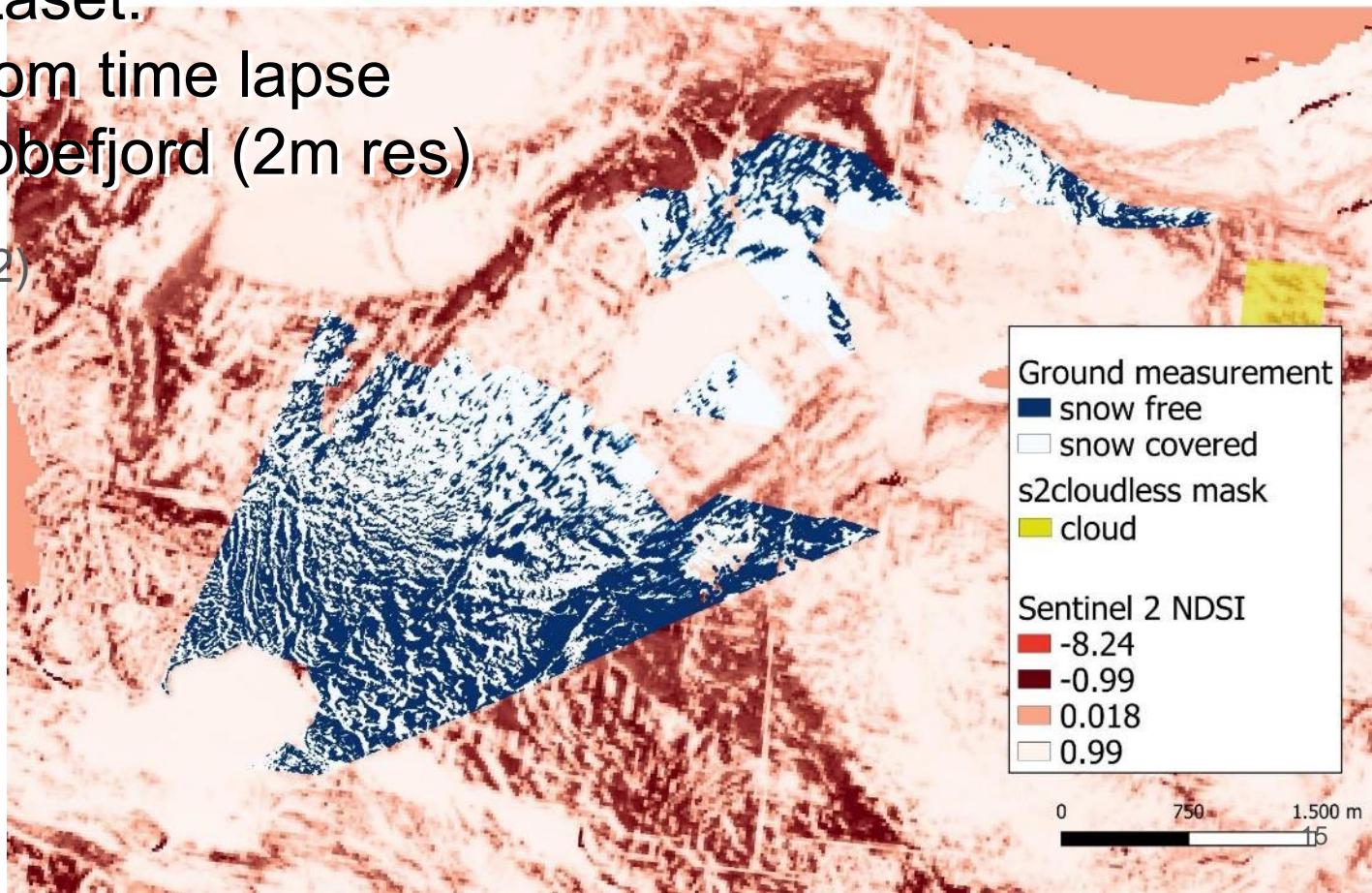


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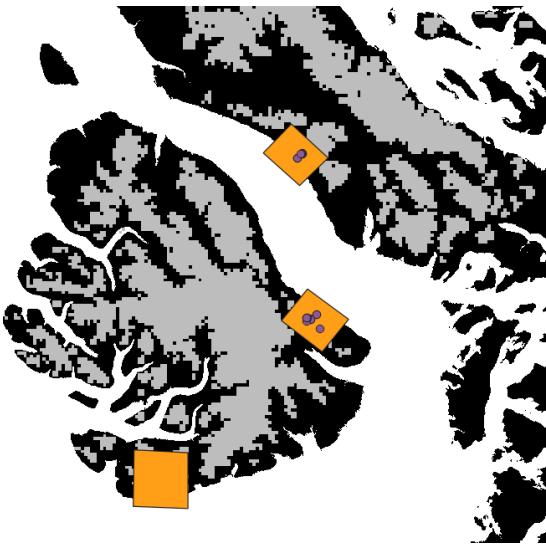
Snow cover from time lapse  
camera at Kobbefjord (2m res)

2017-05-31

Buchelt et al. (2022)

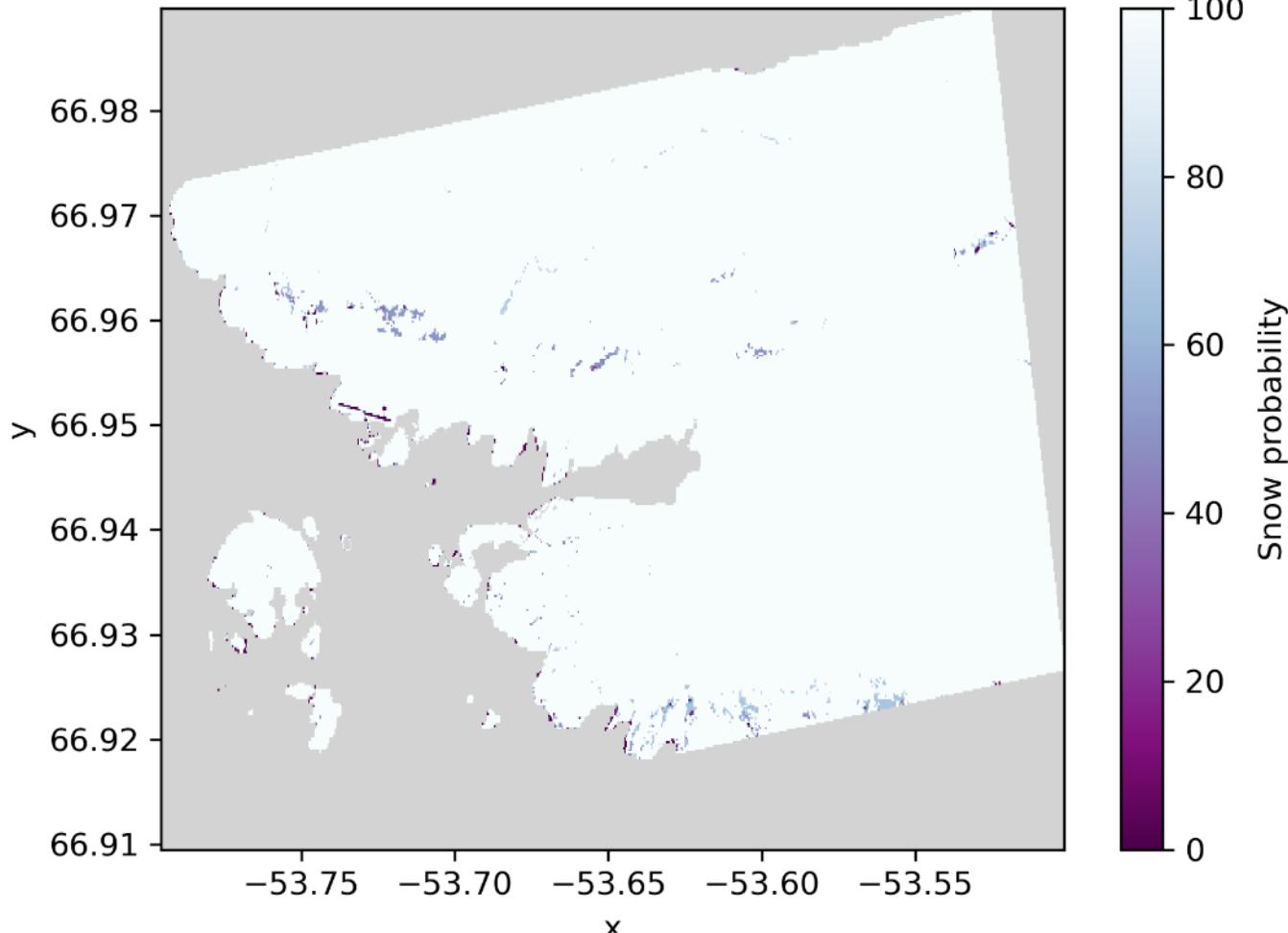


# Mapping snow climatology over the 8 target areas:



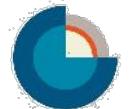
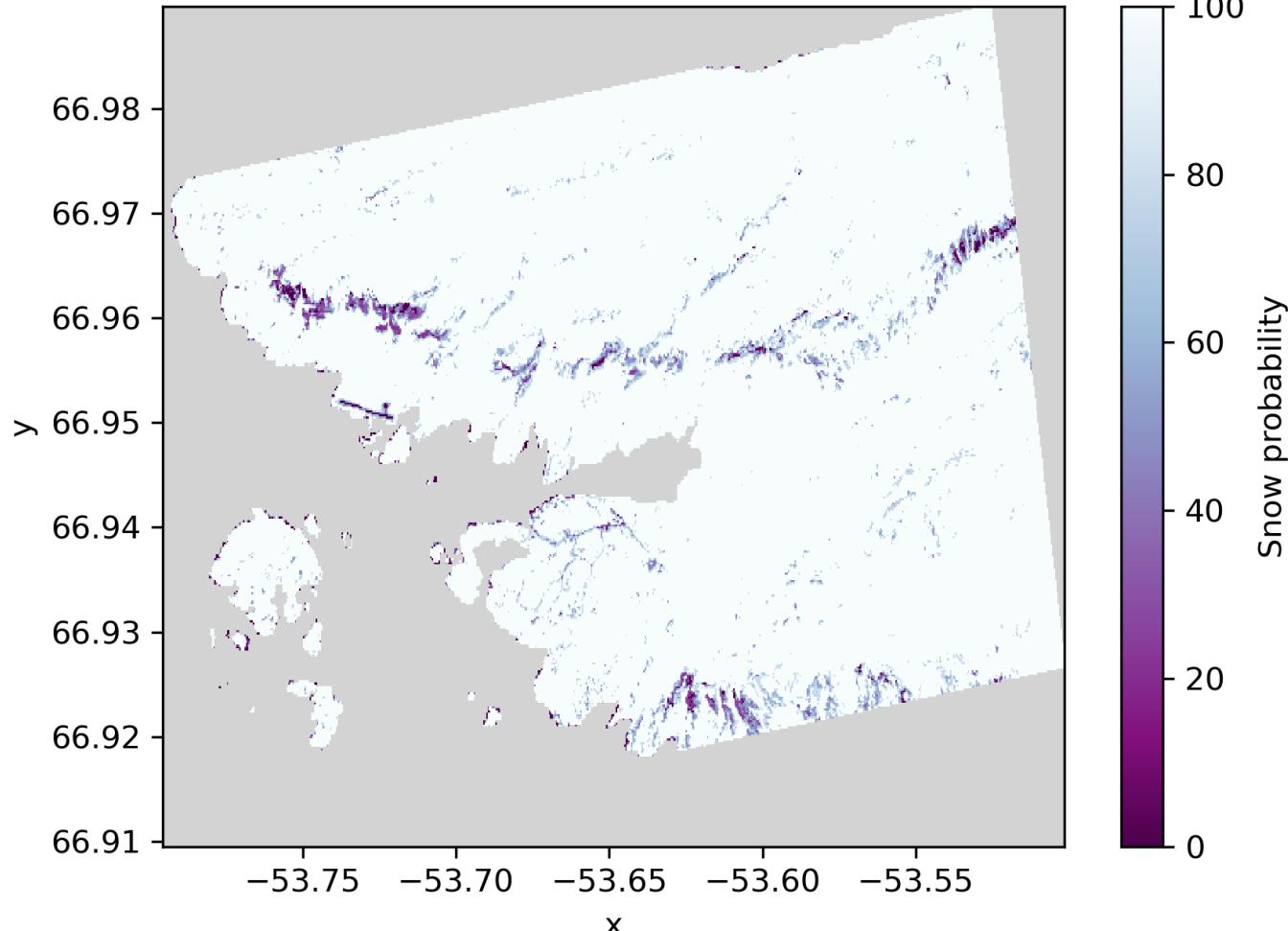
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DOY: 001



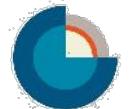
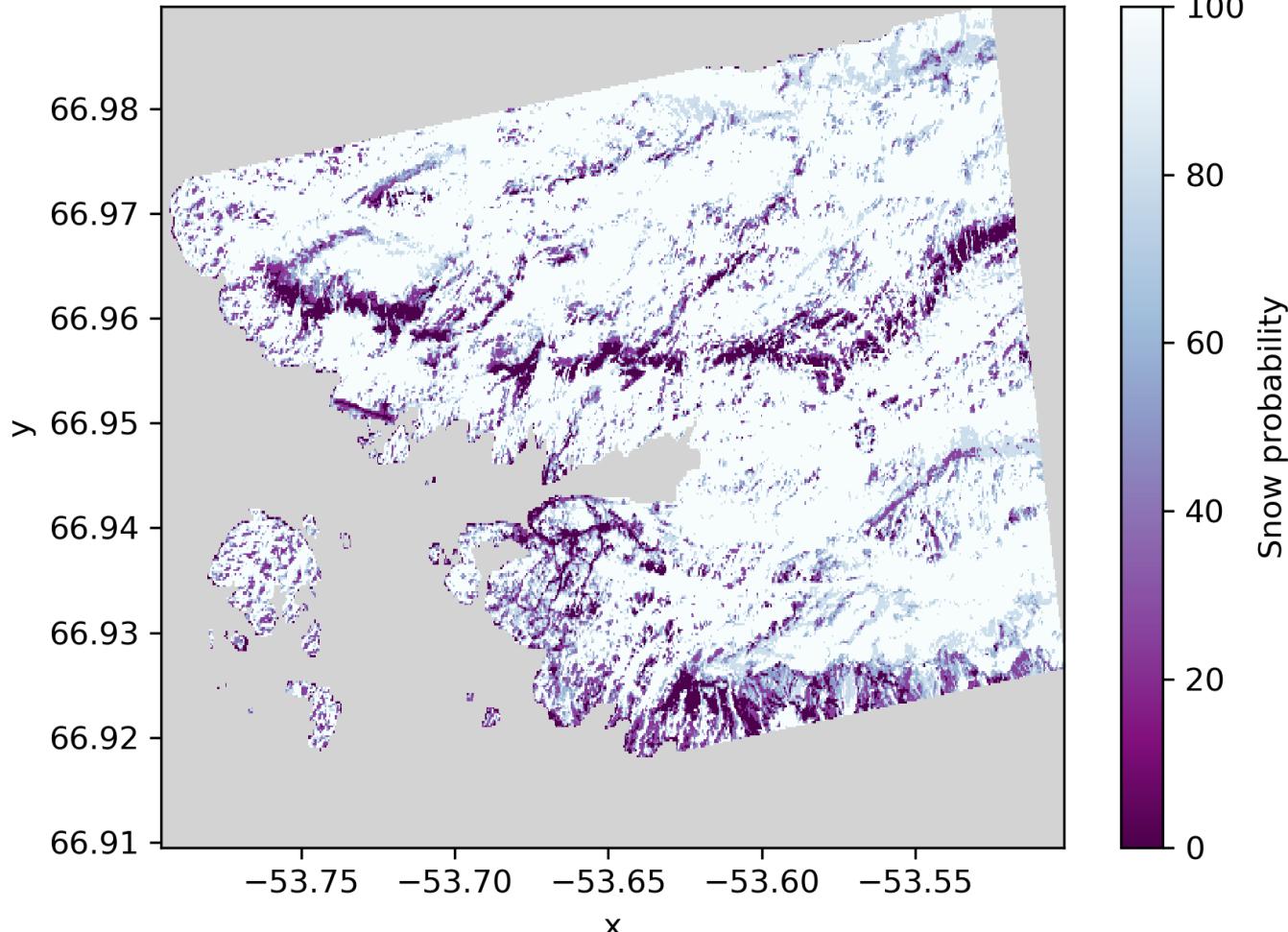
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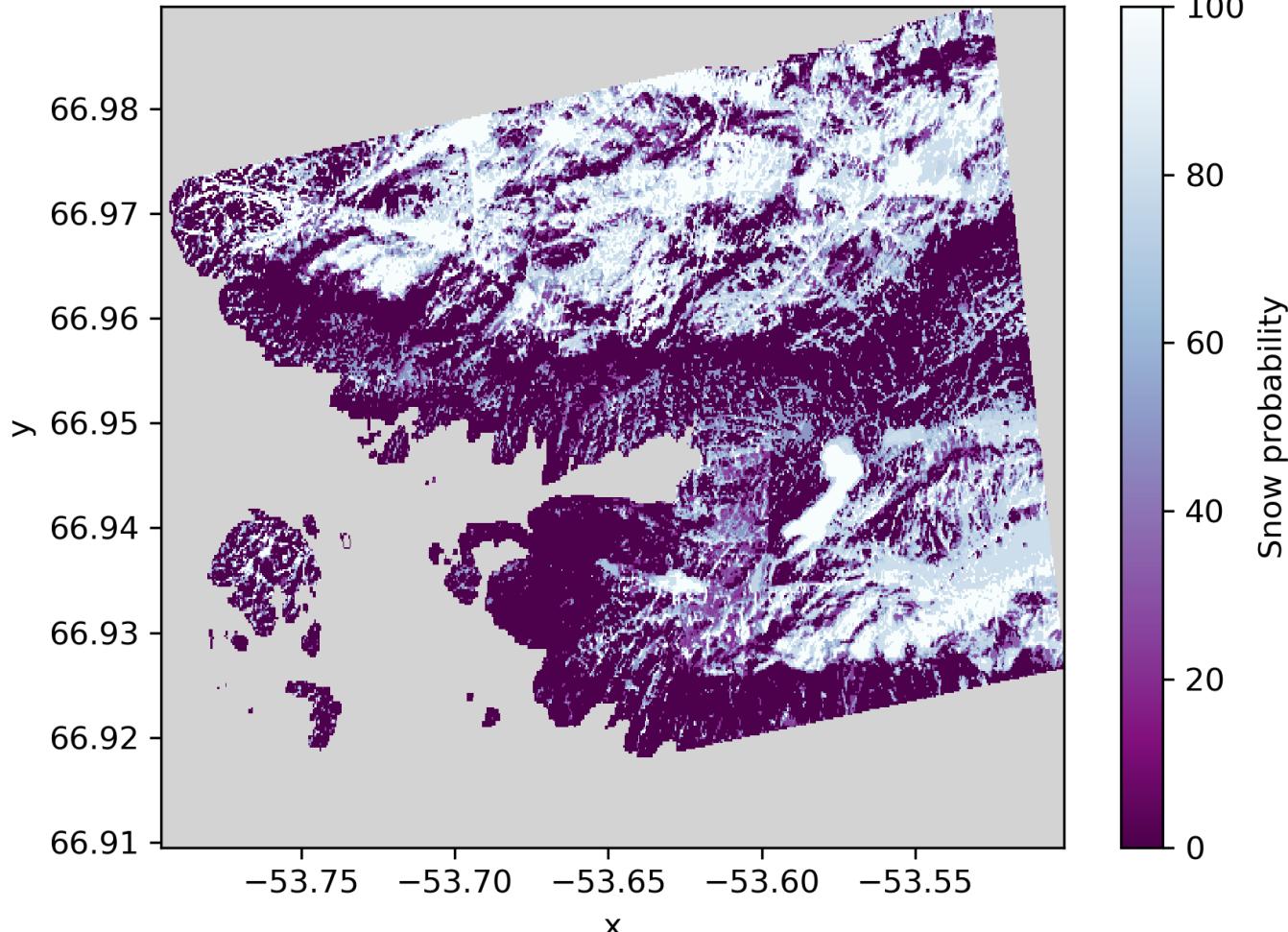
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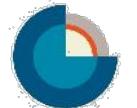
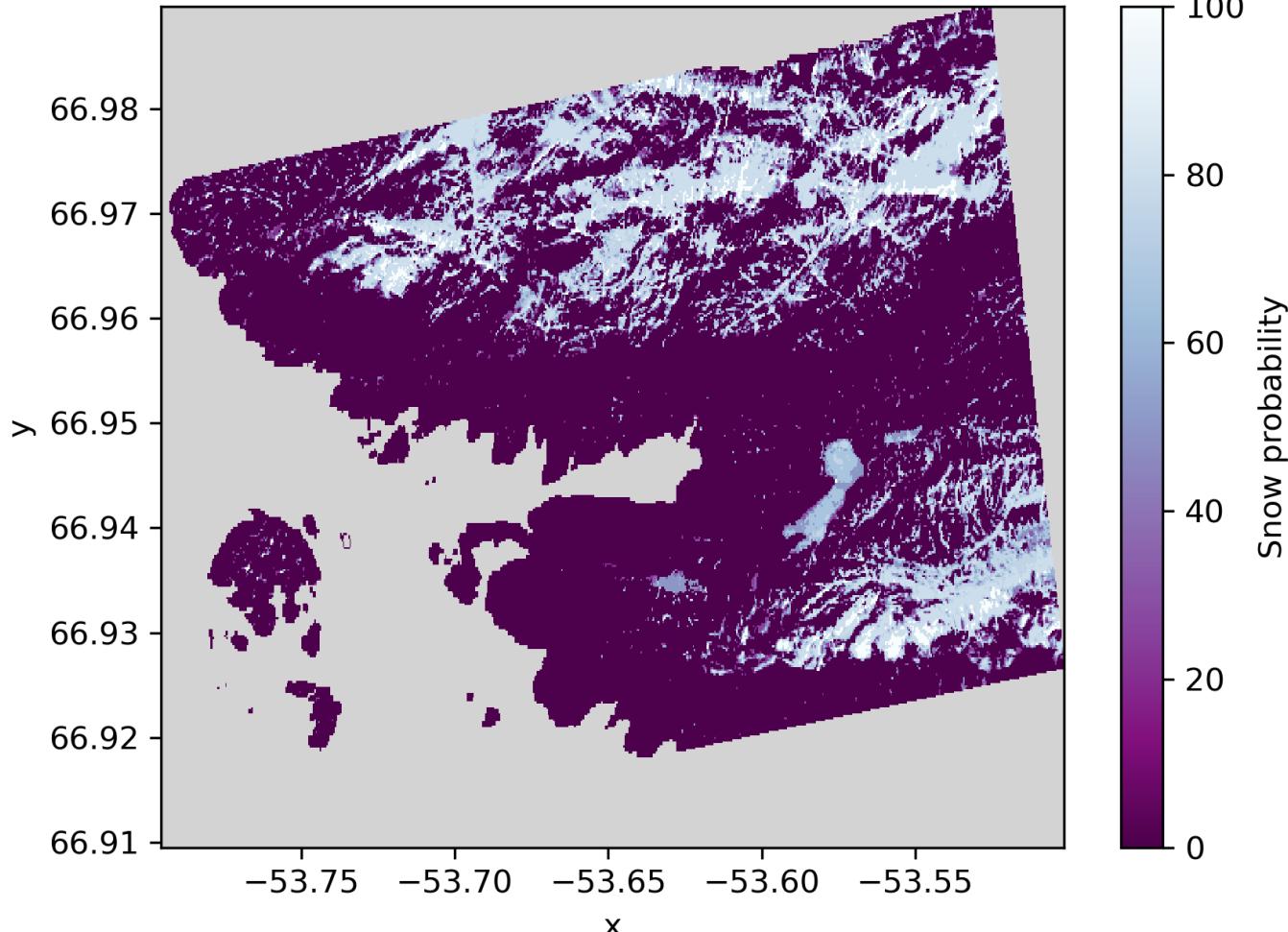
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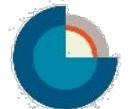
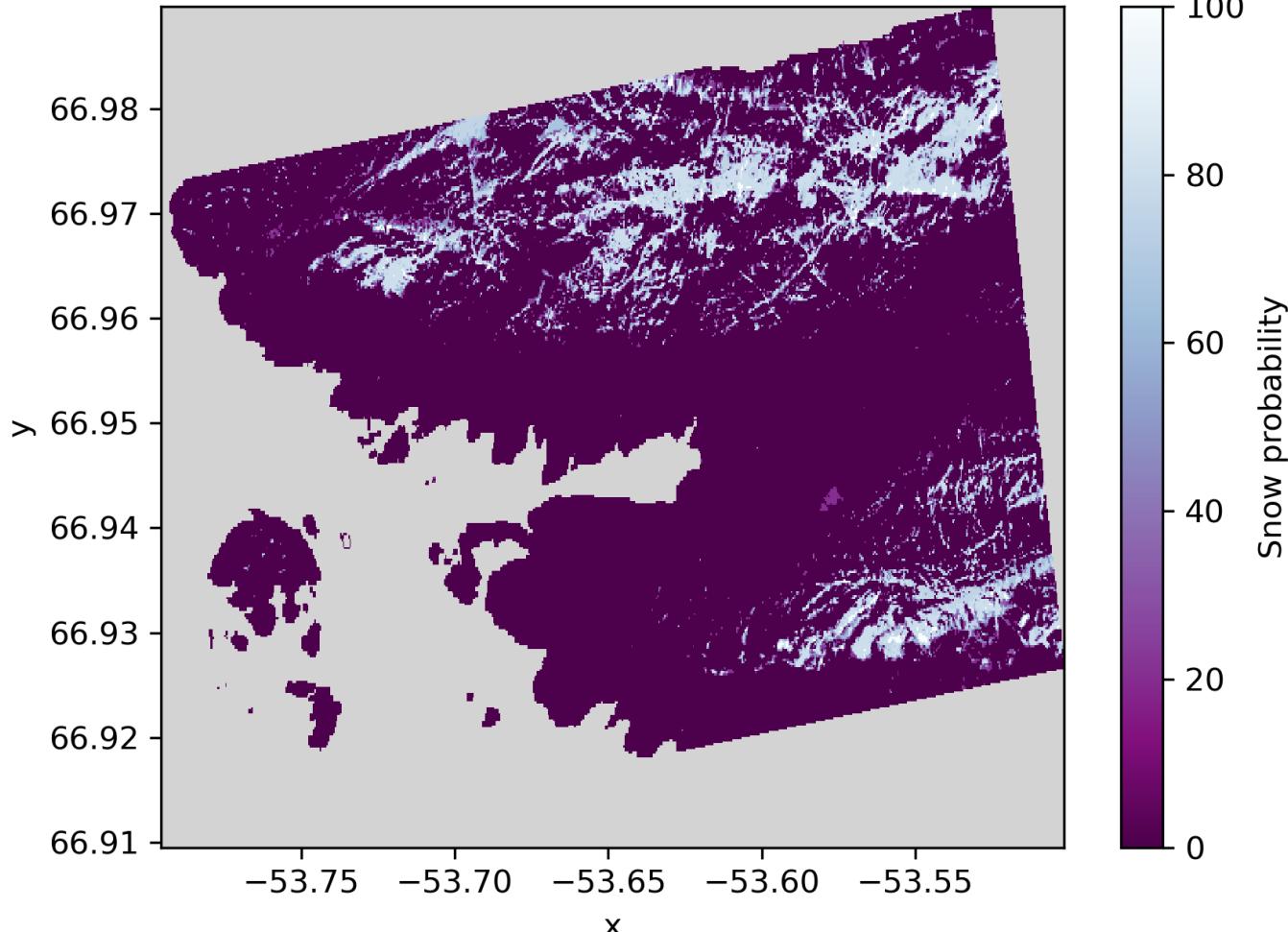
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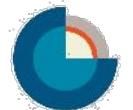
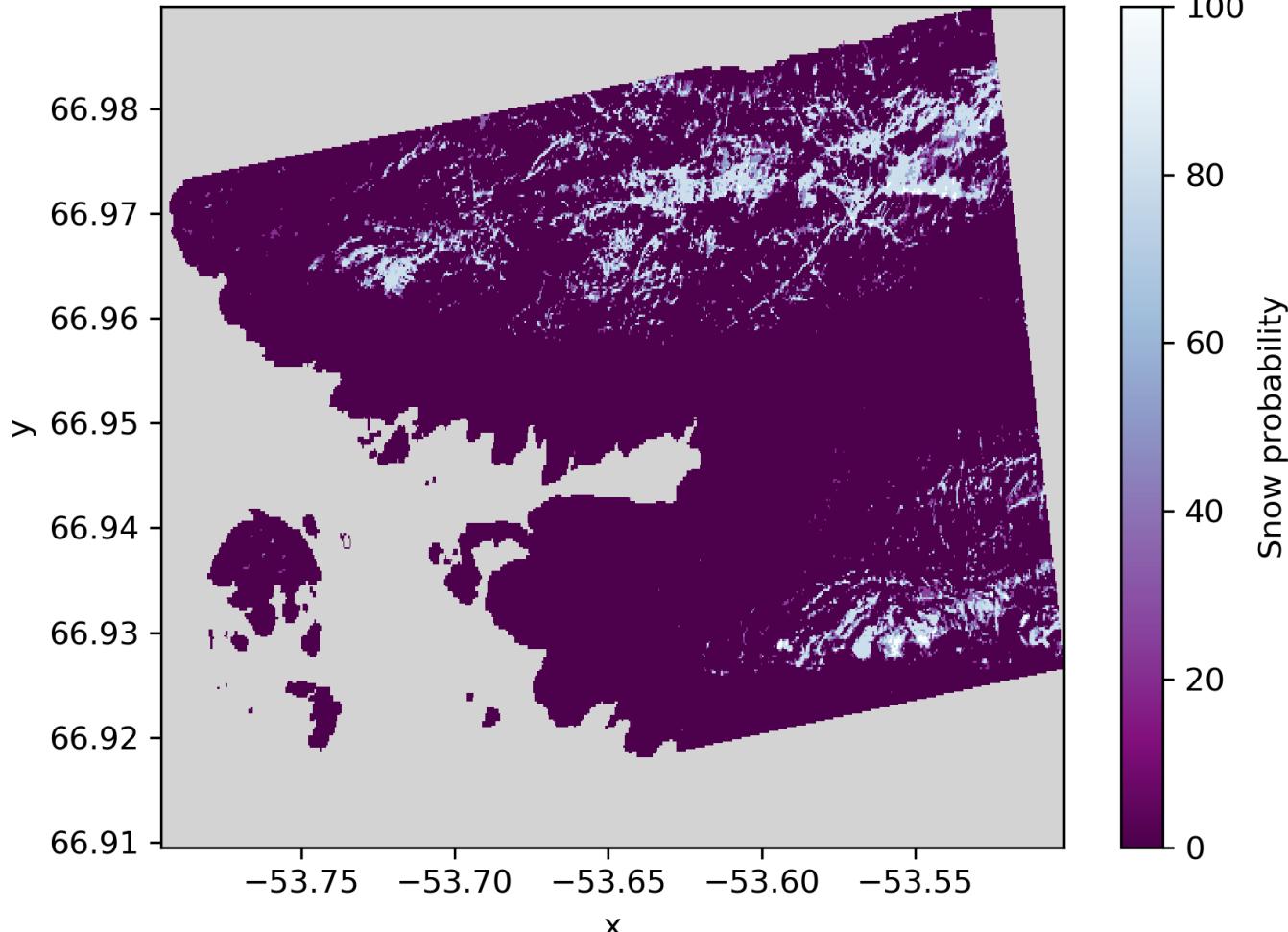
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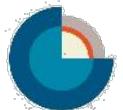
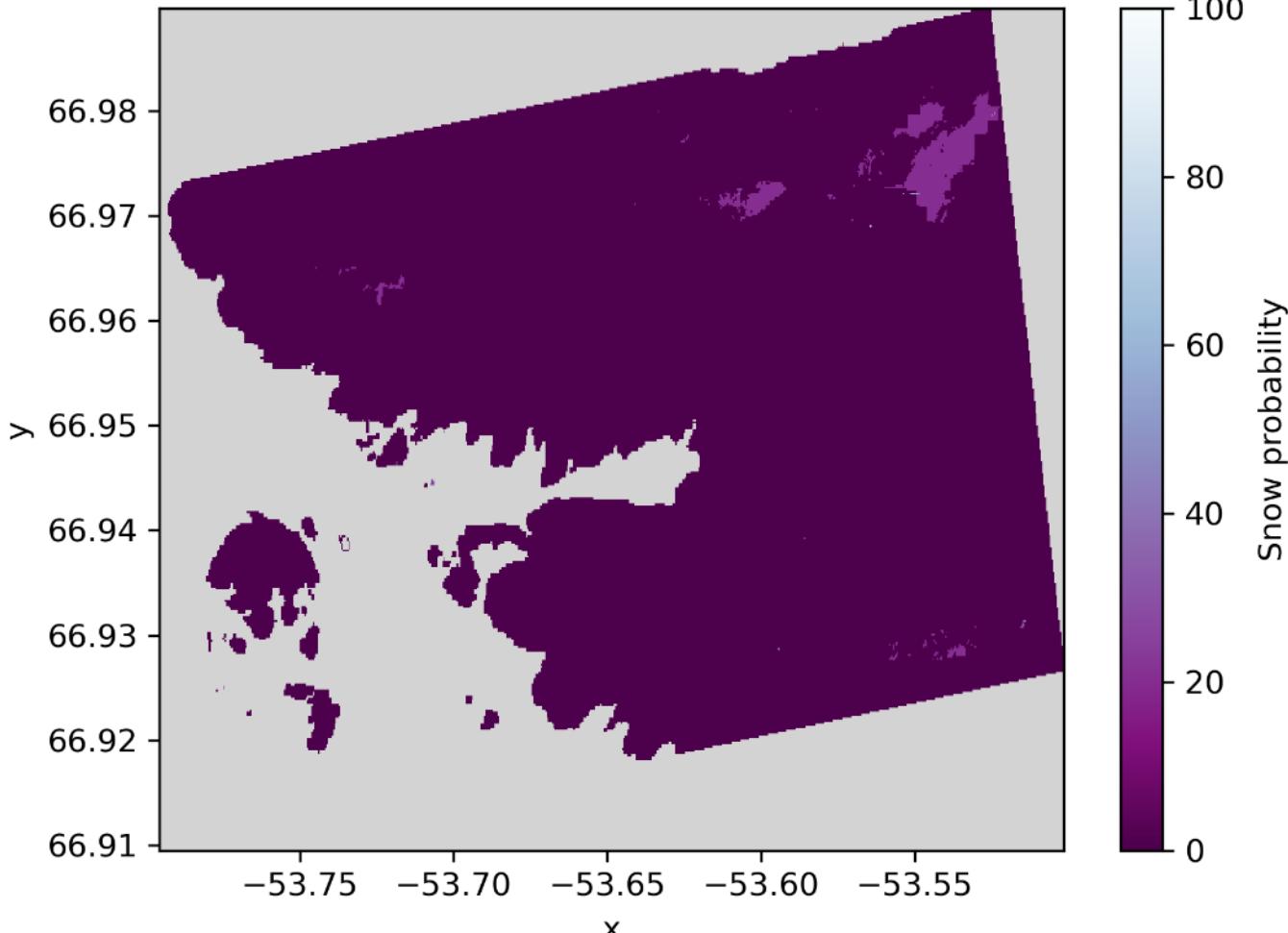
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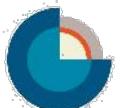
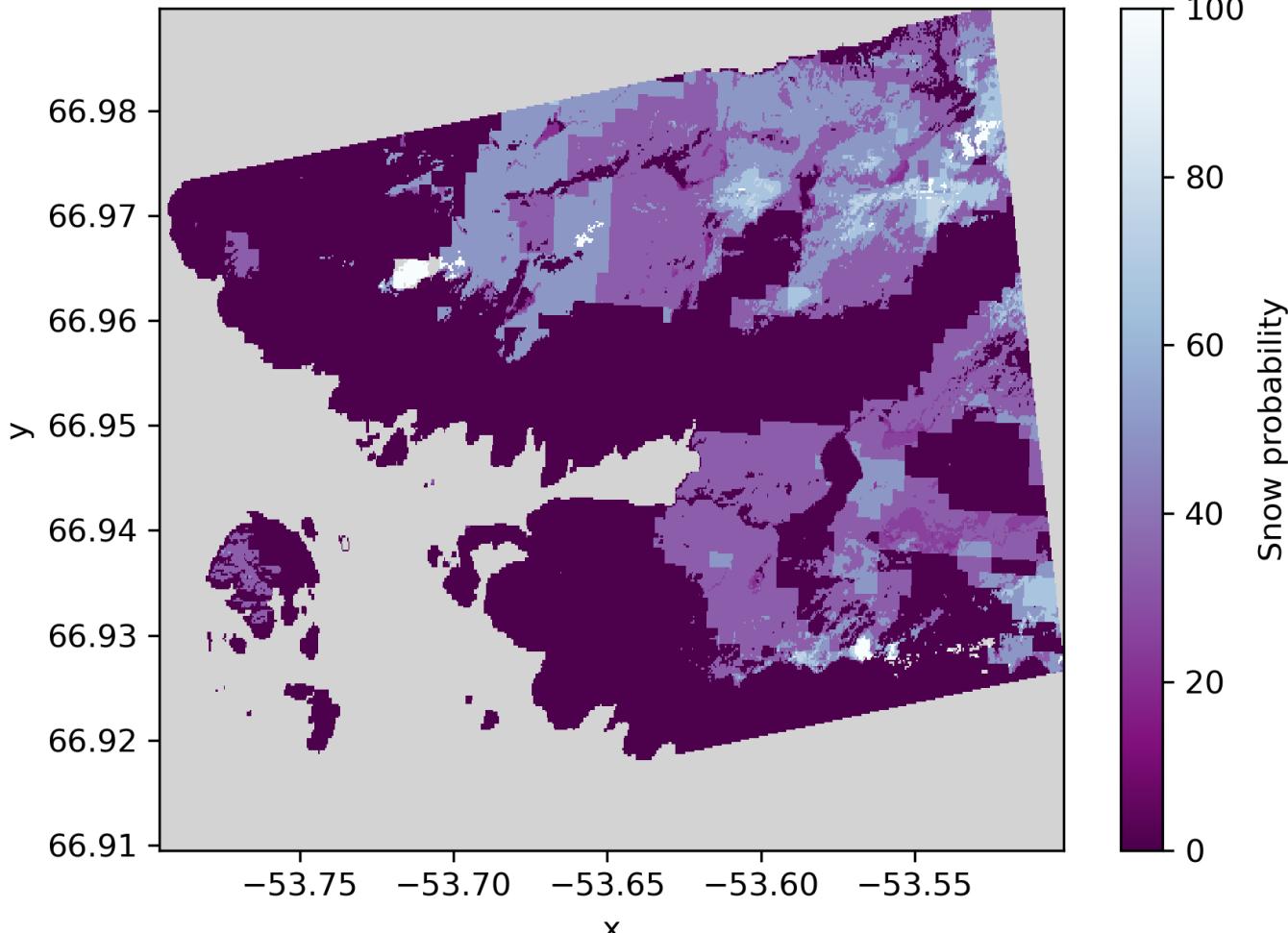
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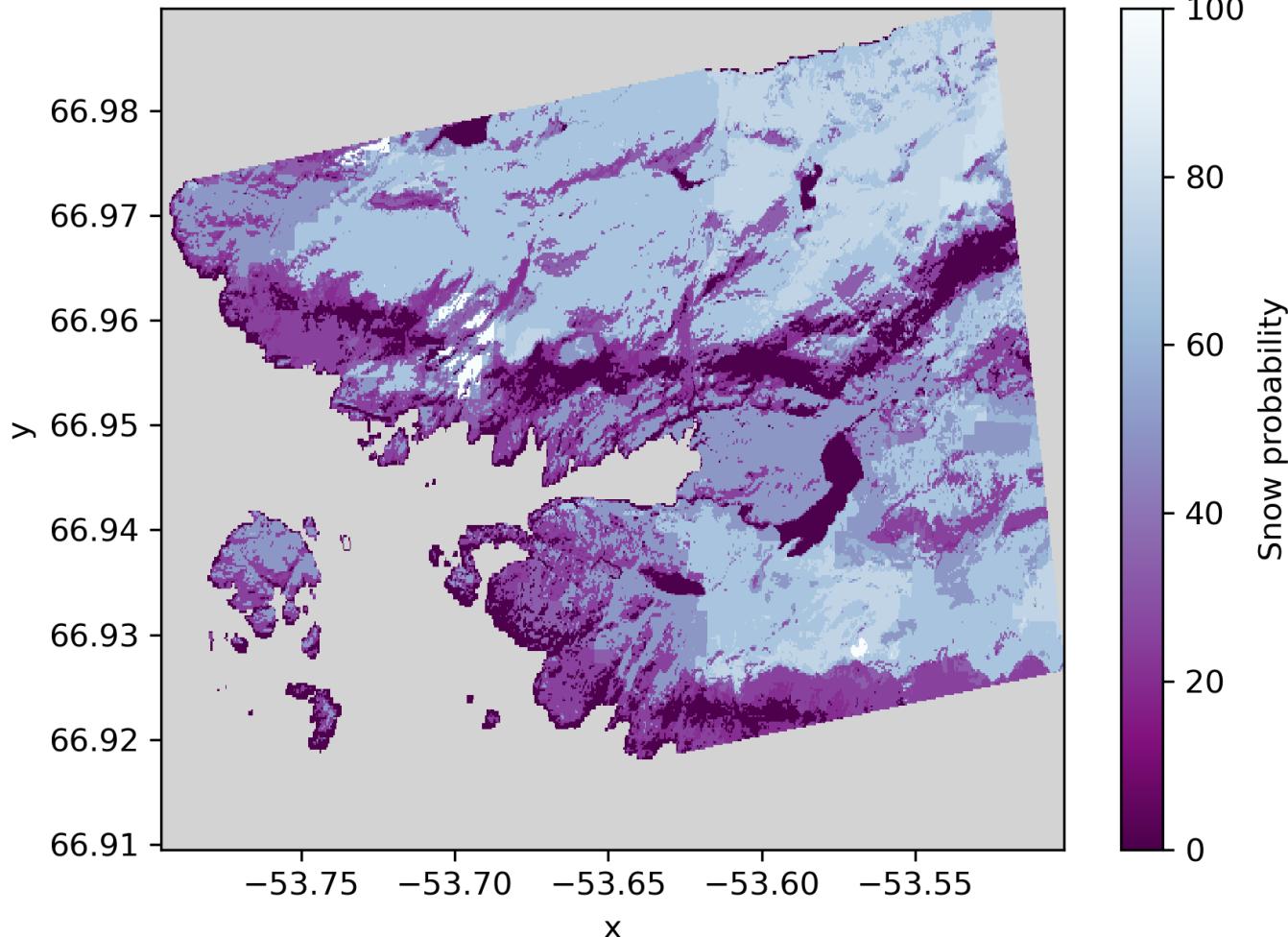
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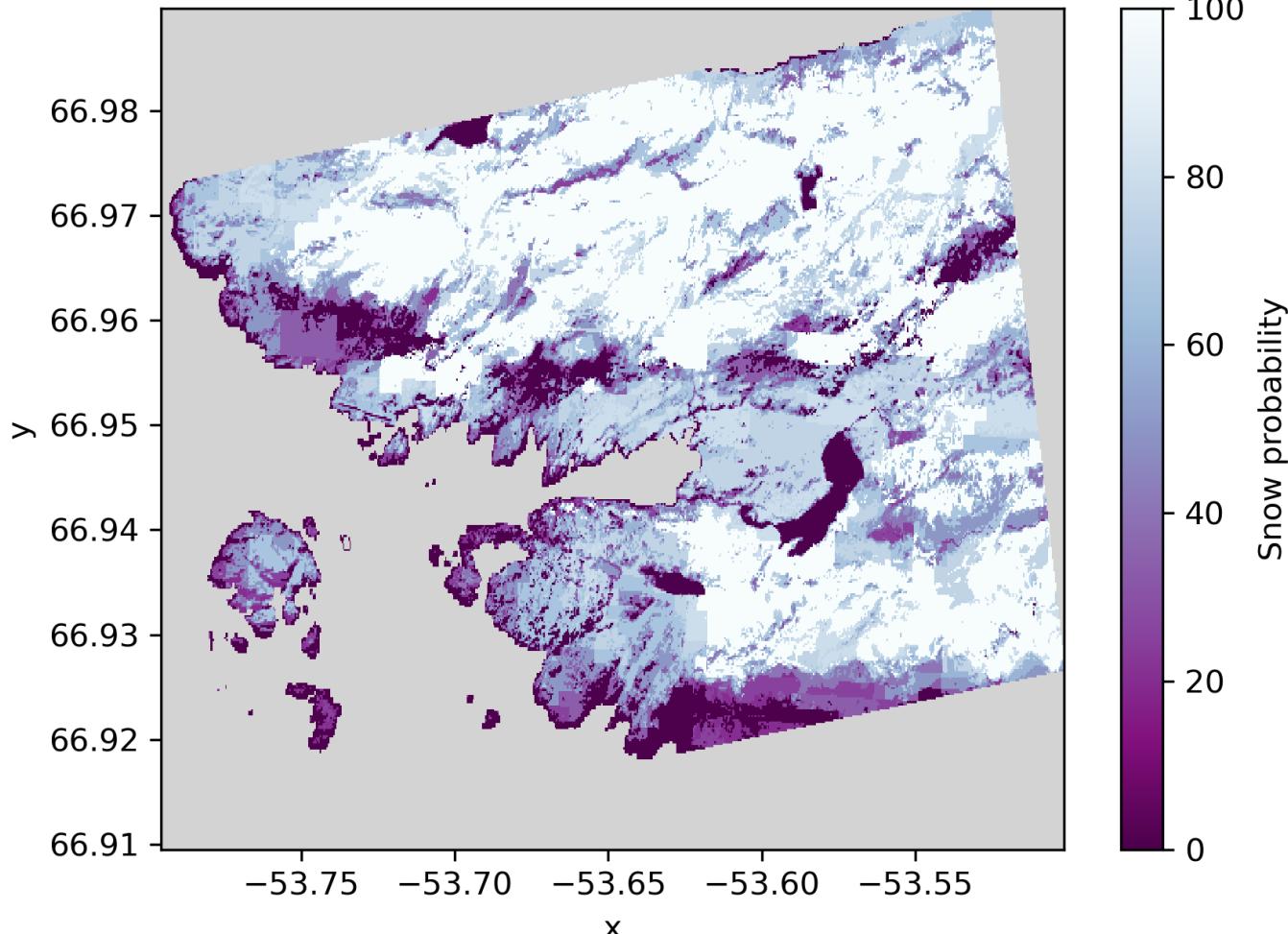
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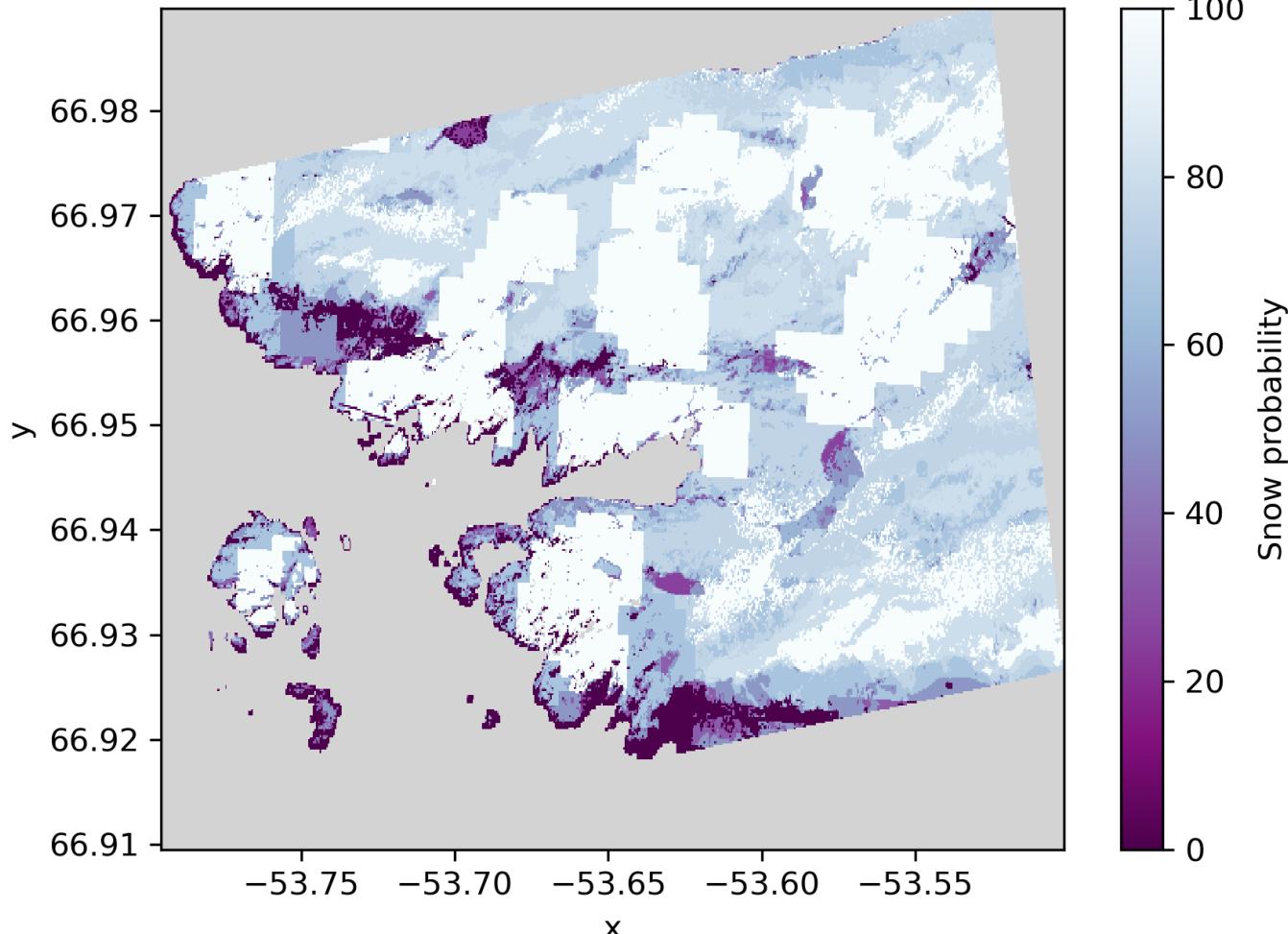
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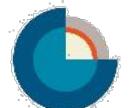
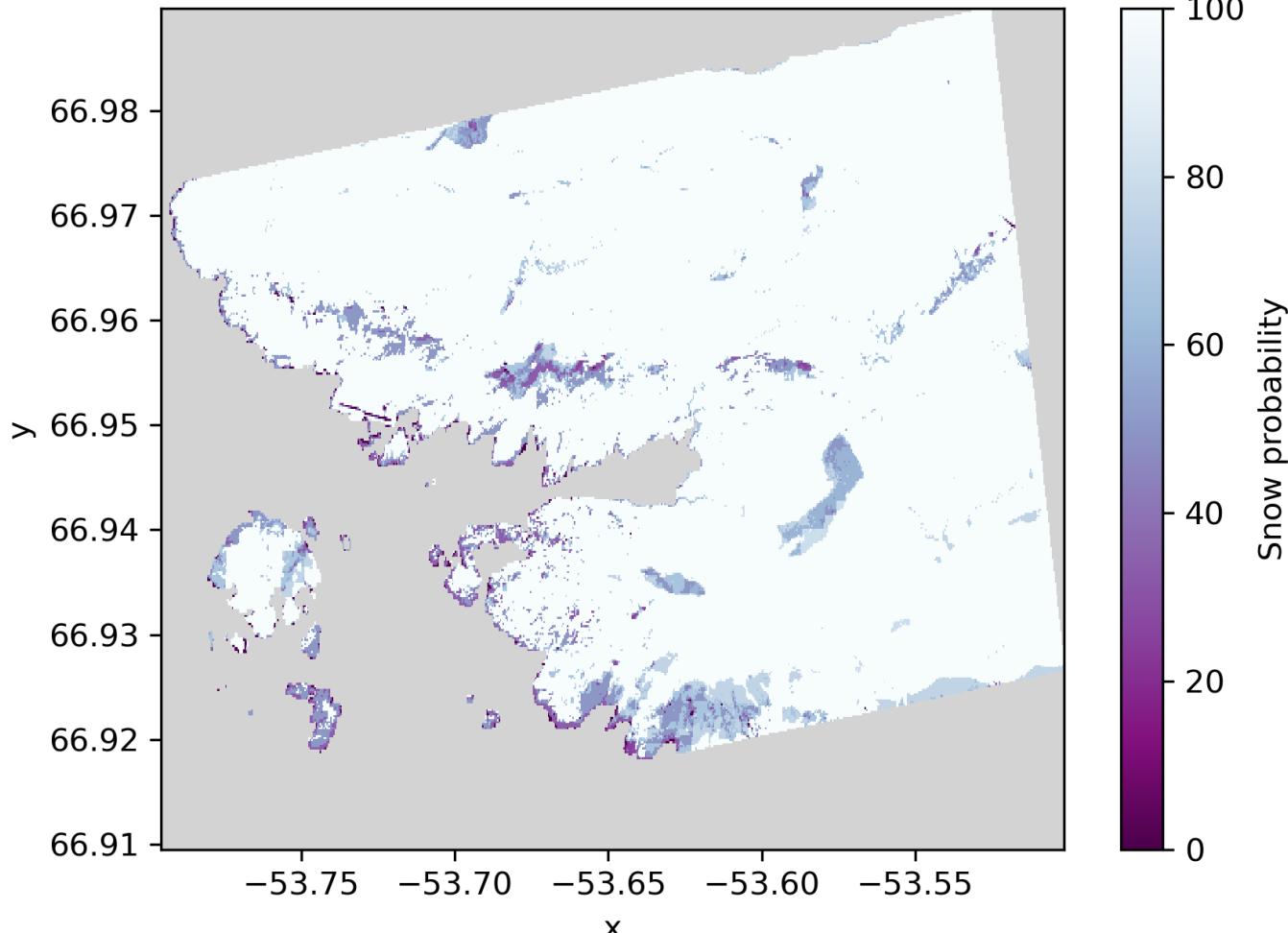
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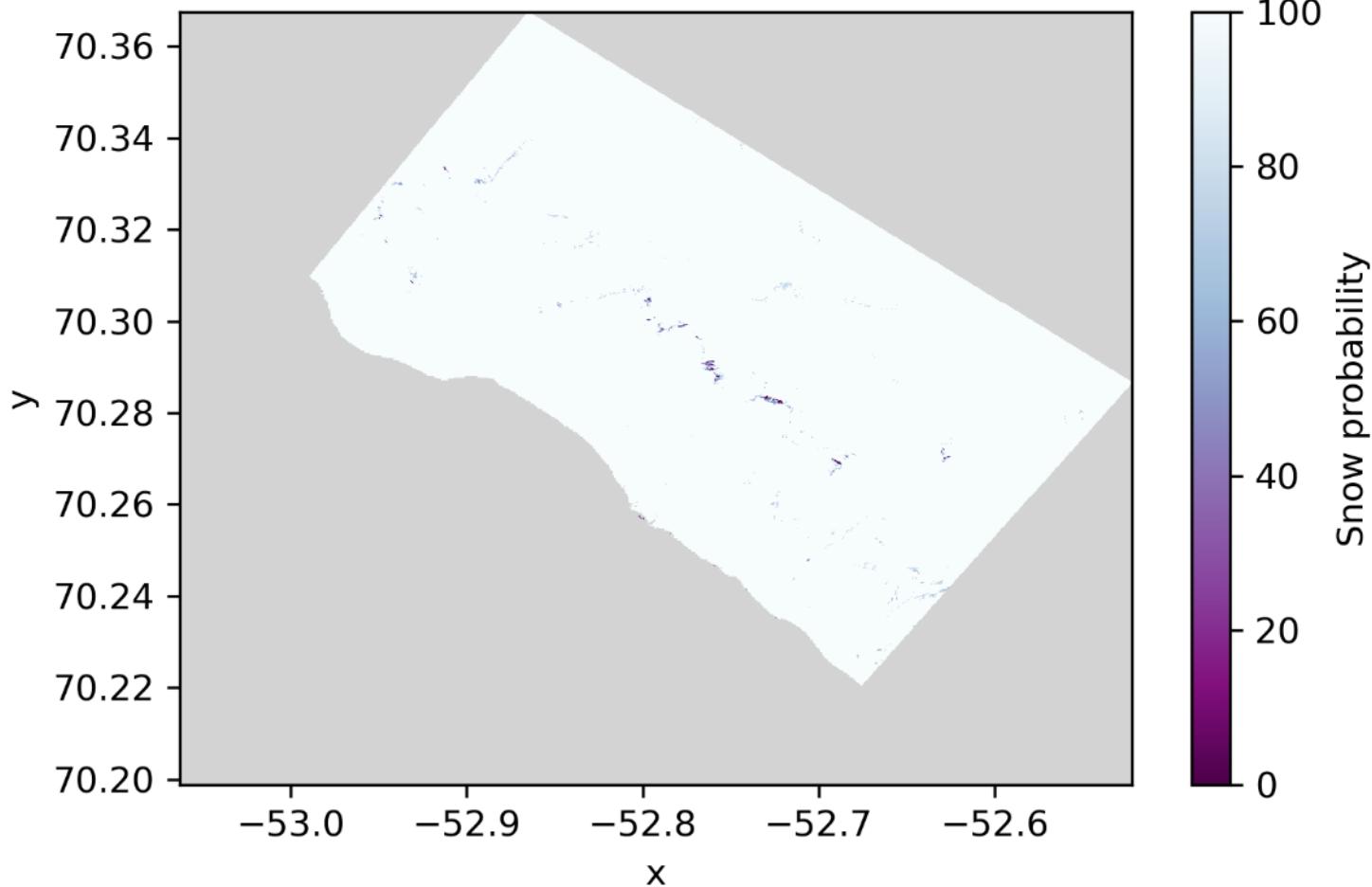
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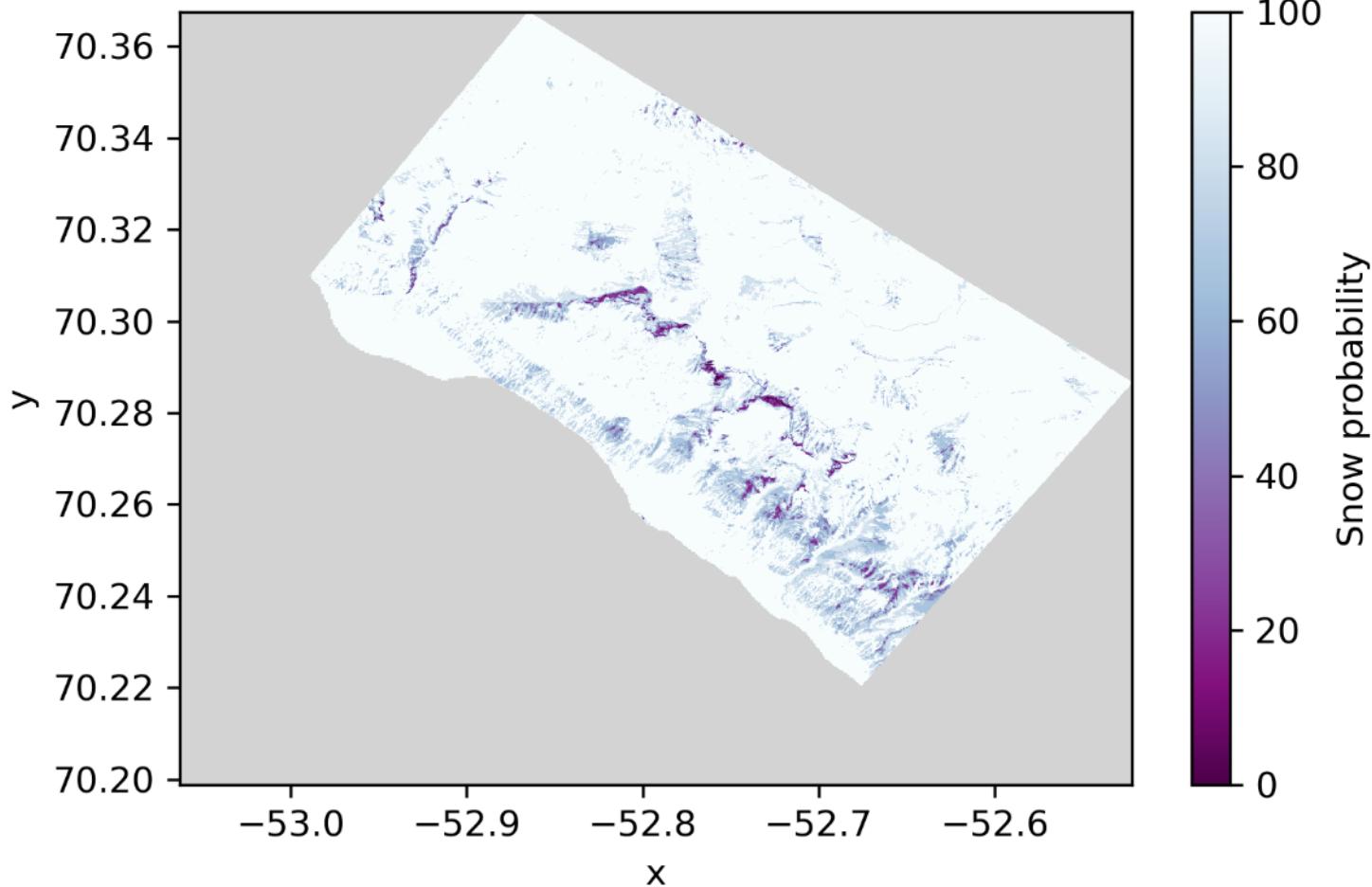
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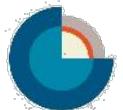
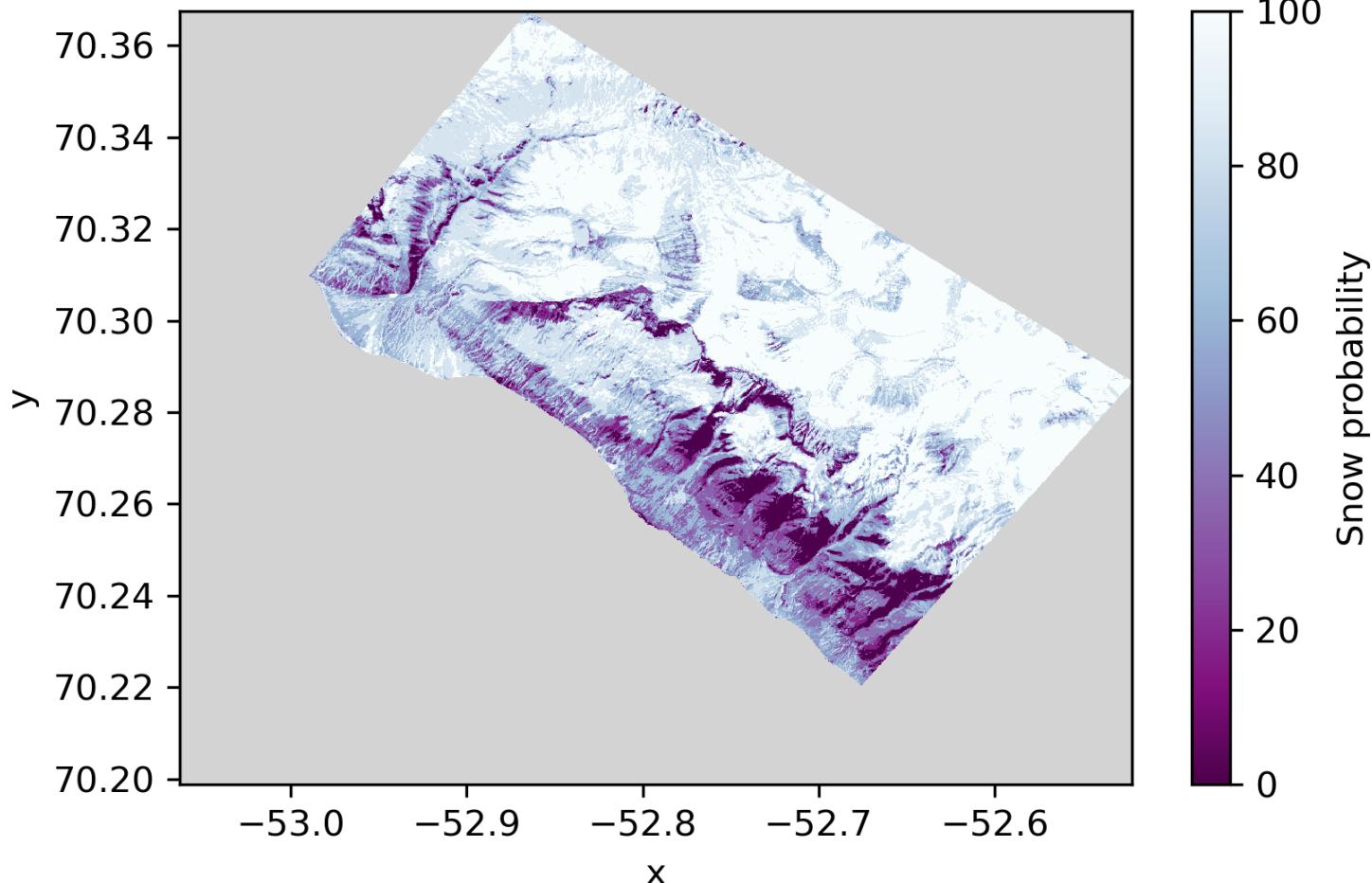
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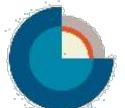
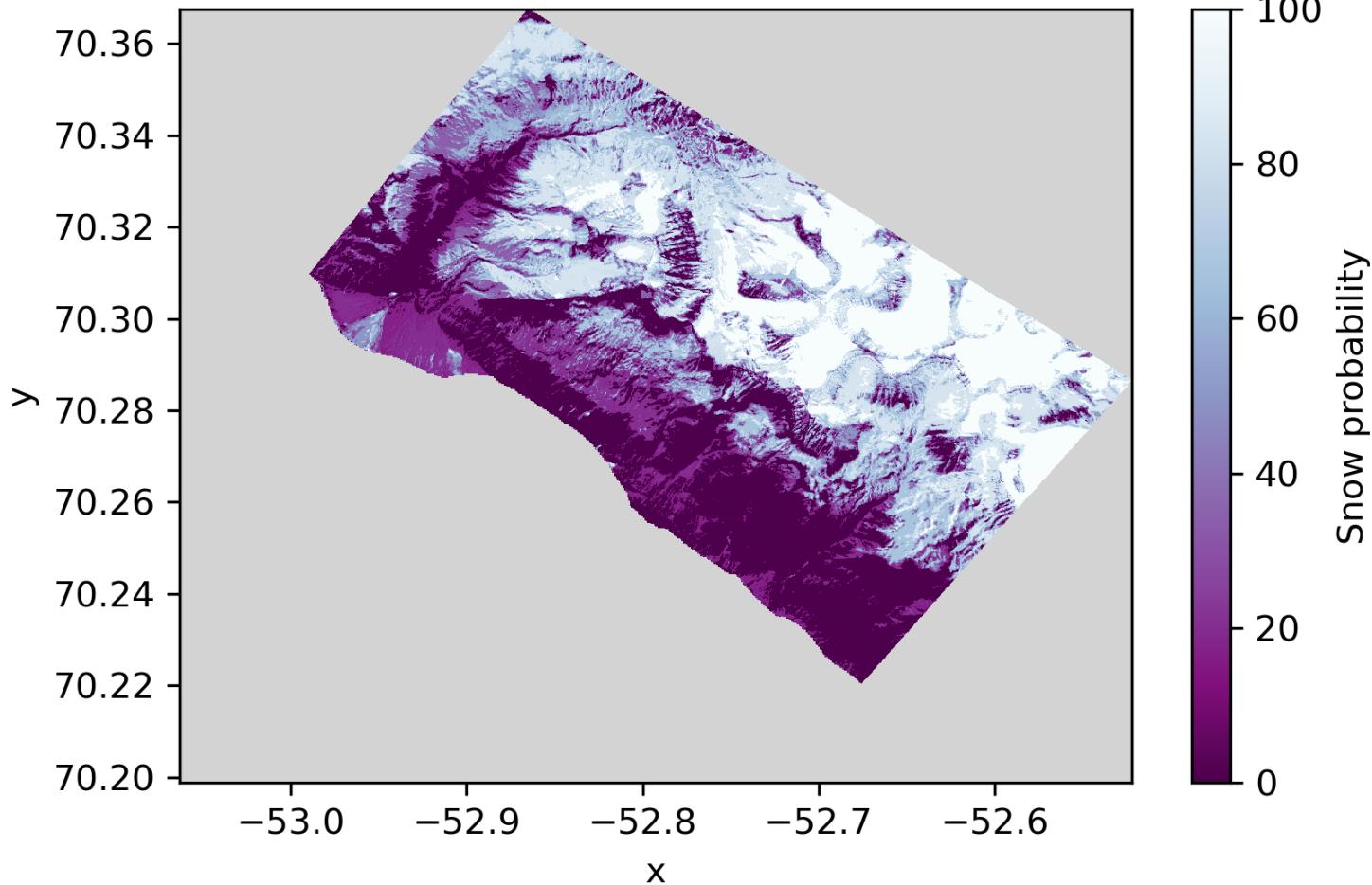
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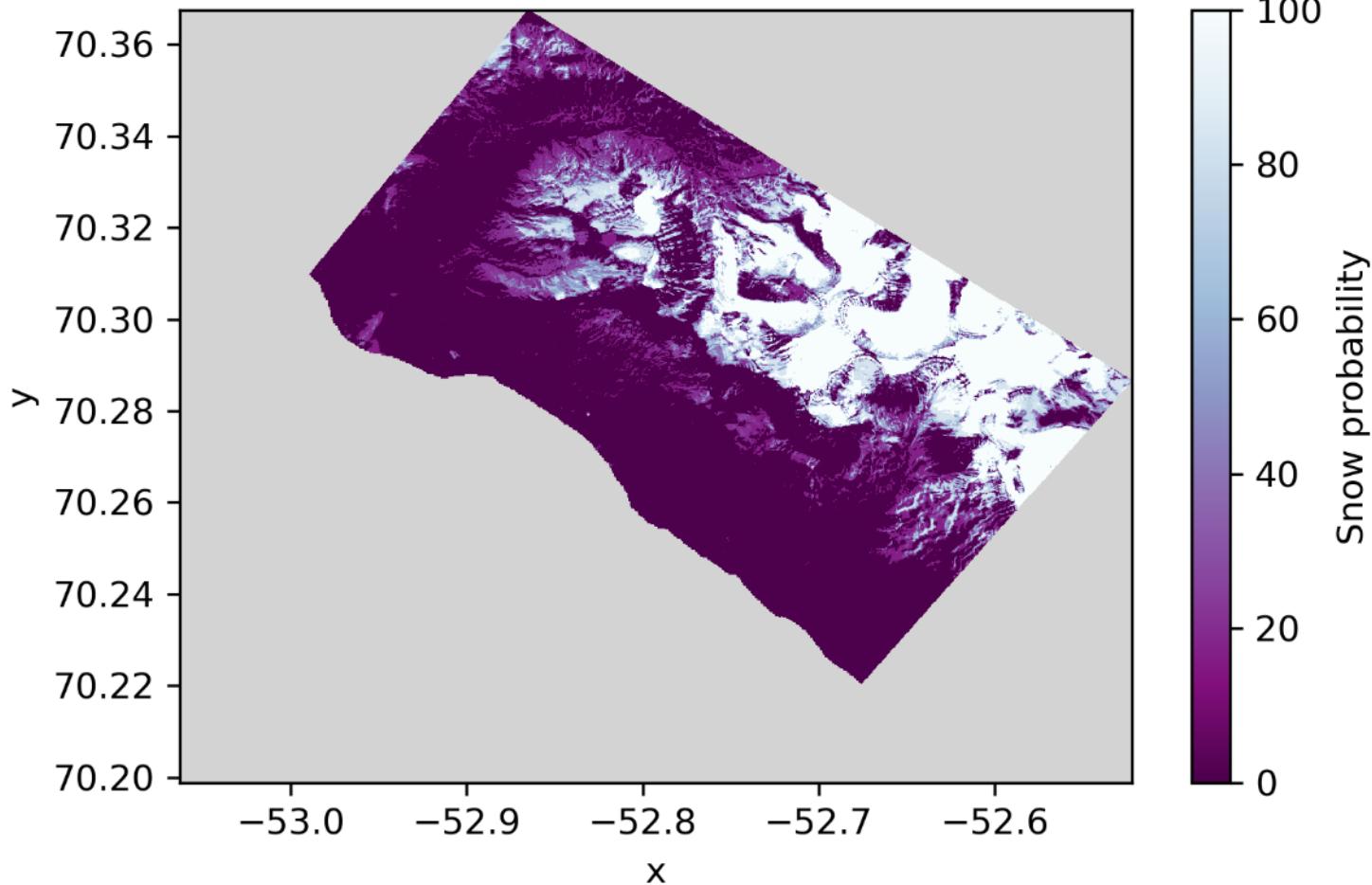
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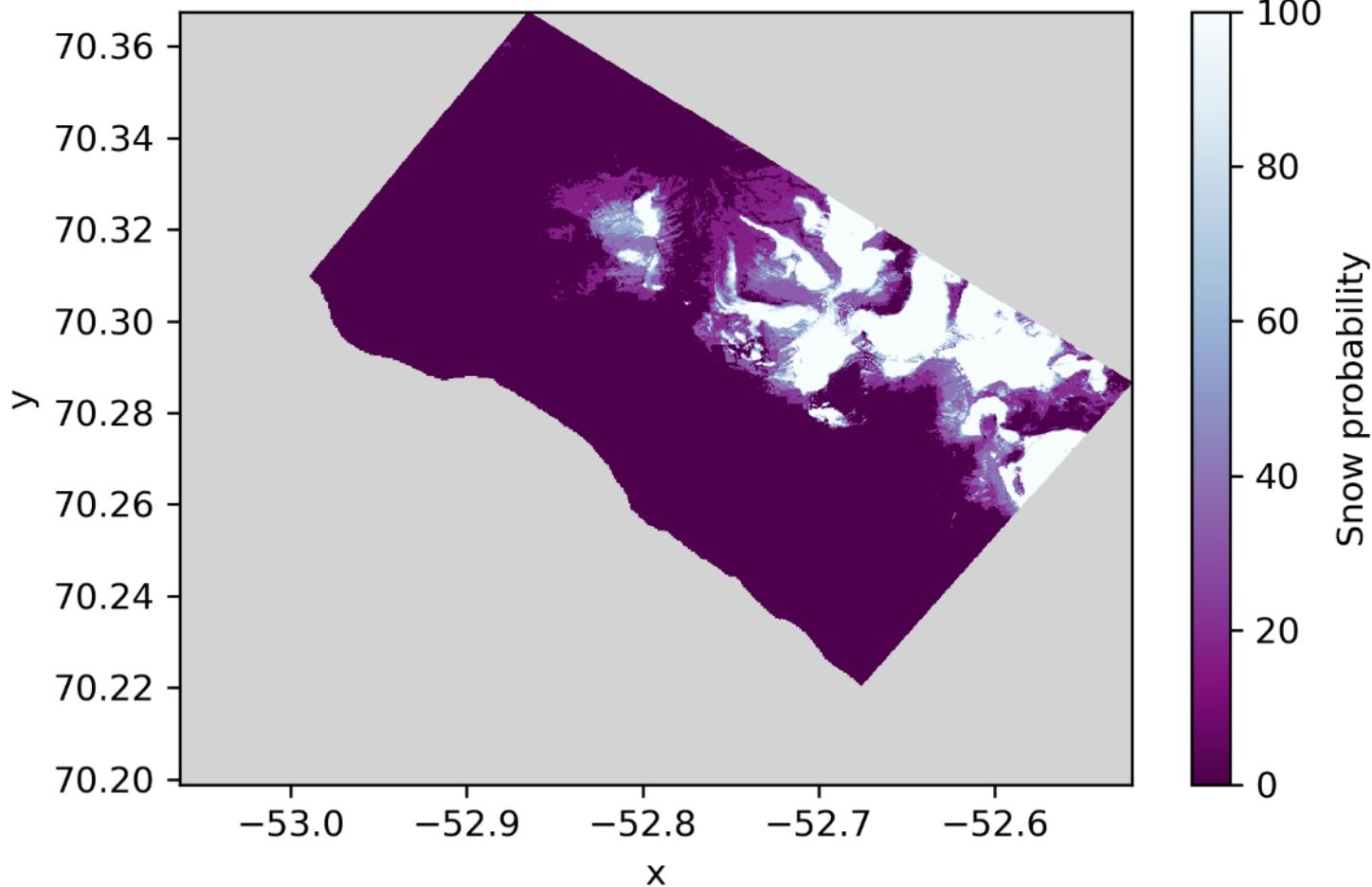
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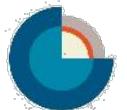
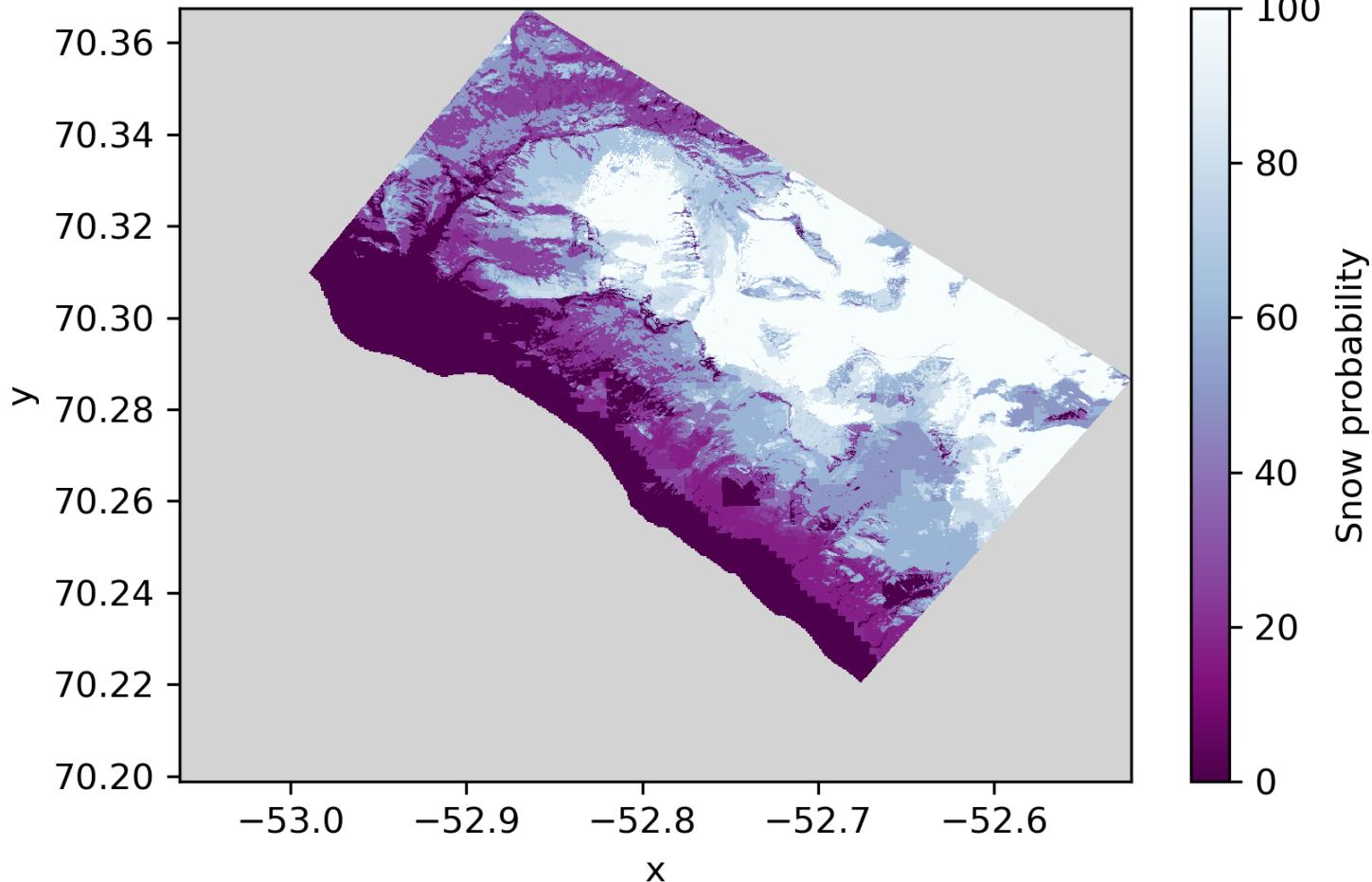
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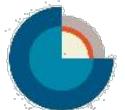
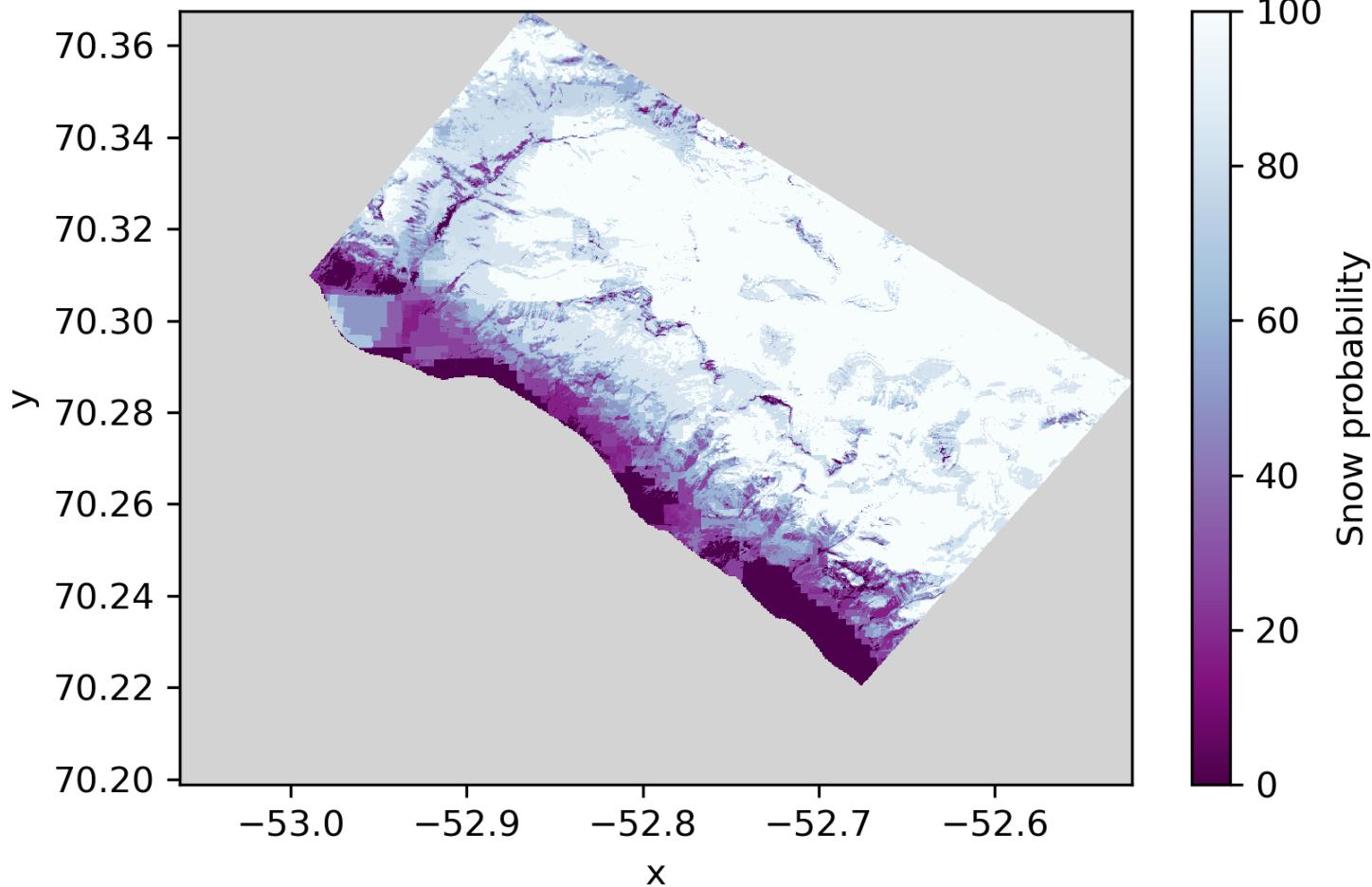
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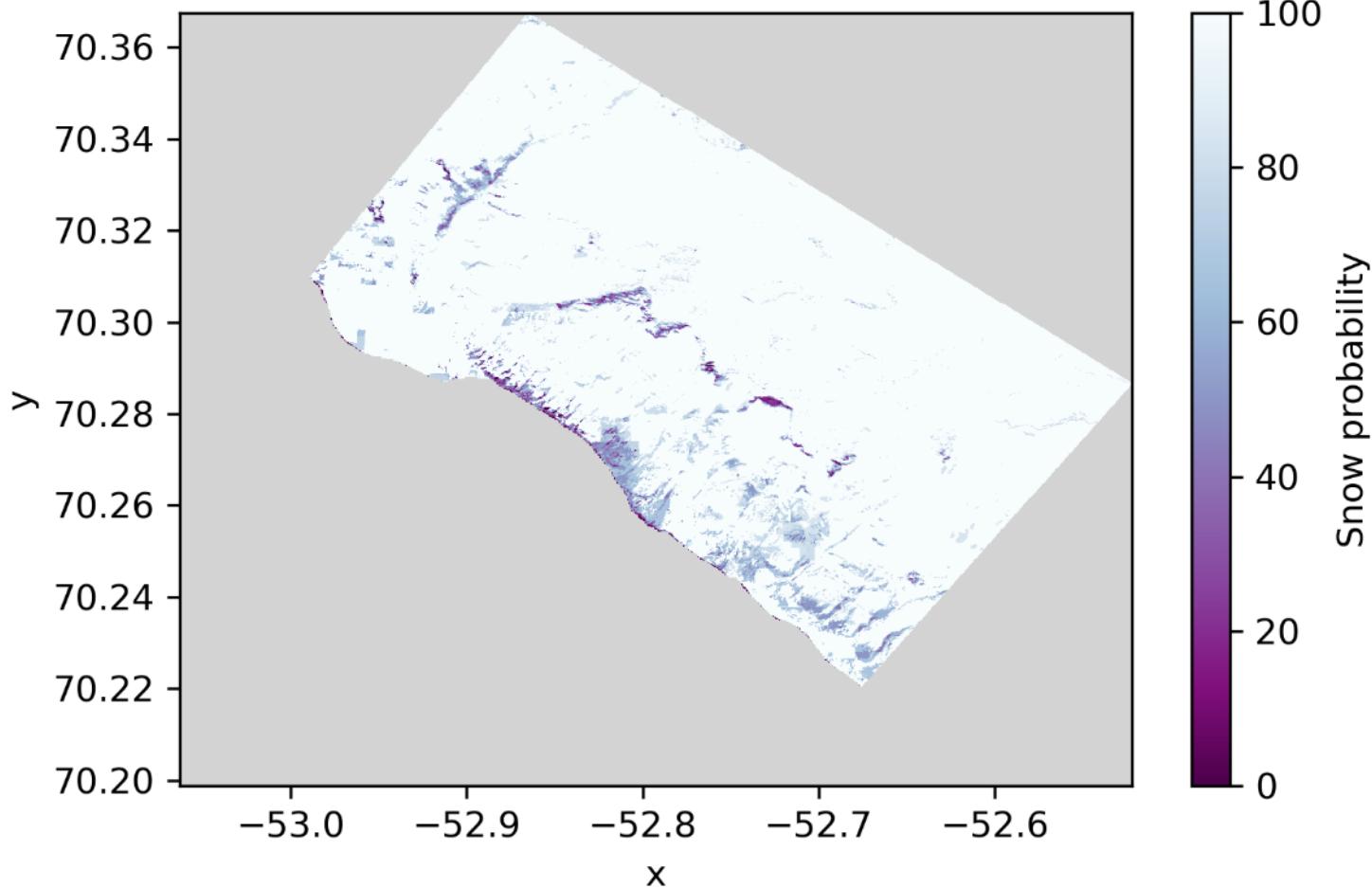
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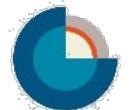
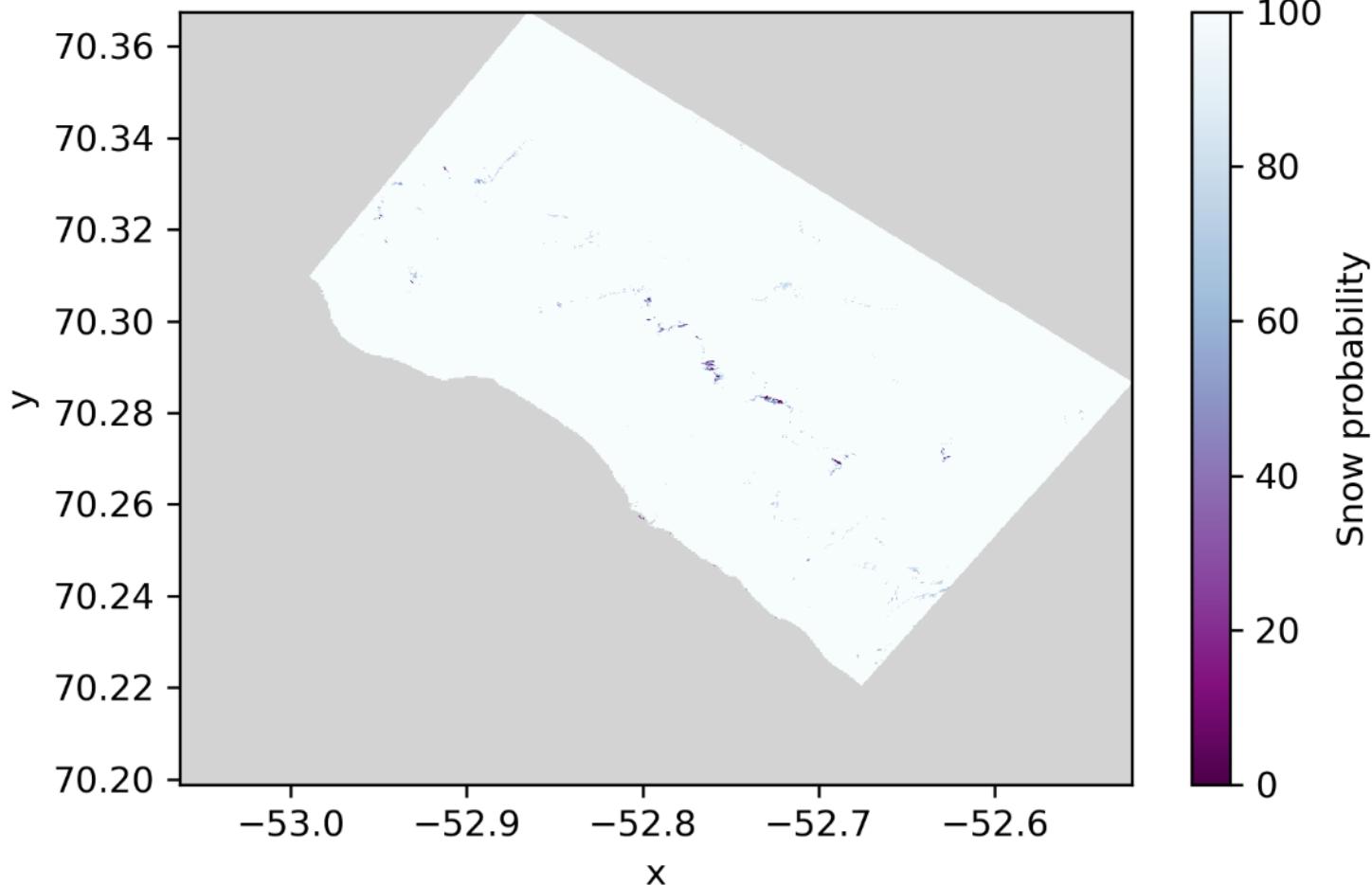
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# Ittutarfik

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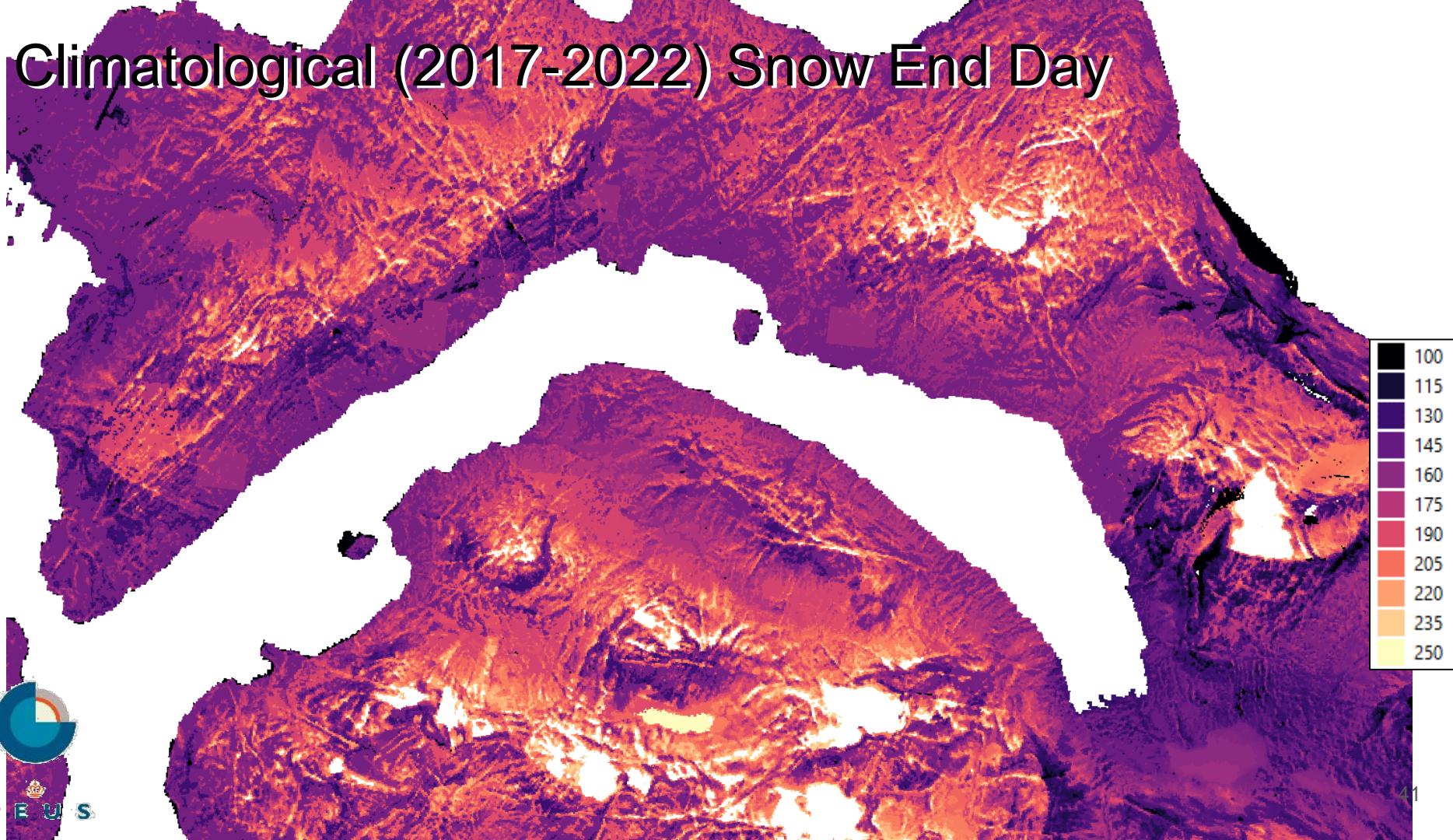


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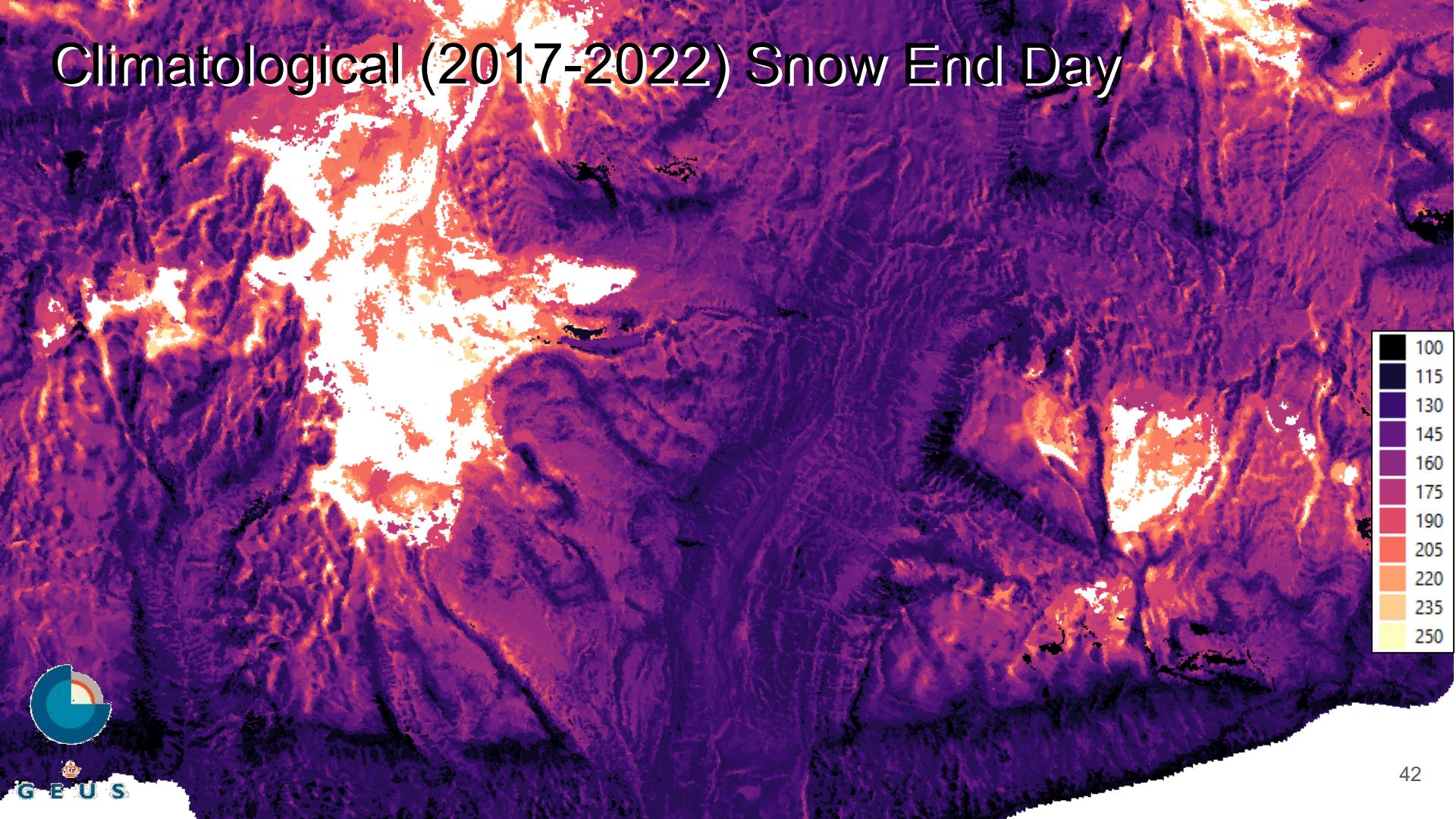
# Climatological (2017-2022) Snow End Day



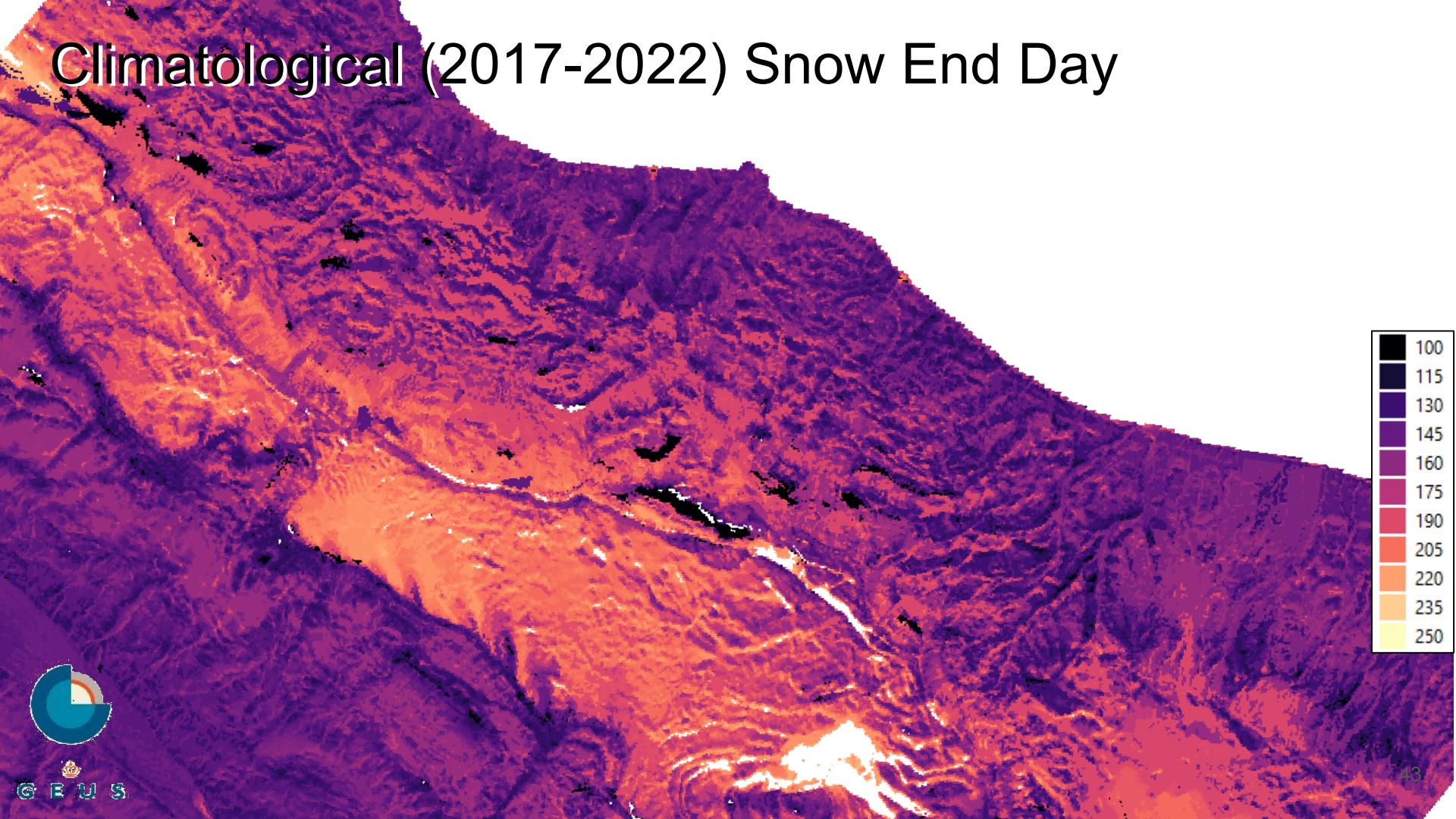
# Climatological (2017-2022) Snow End Day



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# Climatological (2017-2022) Snow End Day



# Future Development:

- Send SED maps to DTU for **inclusion in climate-permafrost model**  
(Long time scale, monthly resolution)
- **Landsat 8** for increased temporal resolution?
- Coupling with **Sentinel 1** for updates under cloud?
- Study of **snow impact on GST at daily time scale**:  
Possible at time-lapse sites but very local  
Still problem of cloud cover and polar night  
Downscaling of daily climate at high resolution (10-20 m)
- Is snow season/timing changing in Greenland ?
- Has this change impacted permafrost and slope stability?
- **A snow mapping service in Greenland ???**



# References

Buchelt, S., Skov, K., Rasmussen, K. K., and Ullmann, T.: Sentinel-1 time series for mapping snow cover depletion and timing of snowmelt in Arctic periglacial environments: case study from Zackenberg and Kobbefjord, Greenland, *The Cryosphere*, 16, 625–646, <https://doi.org/10.5194/tc-16-625-2022>, 2022.

Dozier, J., 1989. Spectral signature of alpine snow cover from the Landsat Thematic Mapper. *Remote sensing of environment*, 28, pp.9-22.

Gascoin, S., Grizonnet, M., Bouchet, M., Salgues, G., and Hagolle, O.: Theia Snow collection: high-resolution operational snow cover maps from Sentinel-2 and Landsat-8 data, *Earth Syst. Sci. Data*, 11, 493–514, <https://doi.org/10.5194/essd-11-493-2019>, 2019.

Skakun, S., Wevers, J., Brockmann, C., Doxani, G., Aleksandrov, M., Batič, M., Frantz, D., Gascon, F., Gómez-Chova, L., Hagolle, O. and López-Puigdollers, D., 2022. Cloud Mask Intercomparison eXercise (CMIX): An evaluation of cloud masking algorithms for Landsat 8 and Sentinel-2. *Remote Sensing of Environment*, 274, p.112990.

Zupanc, A., 2017. Improving Cloud Detection with Machine Learning. <https://medium.com/sentinel-hub/improving-cloud-detection-with-machine-learning-c09dc5d7cf13> (accessed 09 June 2021).