Monitoring Melting at Antarctic Peninsula with Landsat 8 Data and NDWI Analysis

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Introduction

Severe sea ice melting is observed at the Antarctic Peninsula. Previous study [1] and observations show that seasonal melts at the Antarctic is mainly caused by Southern Annular Mode (SAM, or known as Antarctic Oscillation). SAM is a north-south wind belt movement that causes temperature oscillate and drives melting during its positive phase (Figure 2). Goosse et al., 2023 (Figure 1) shows the SAM-coupled simulation result of monthly change in ice melt at the Antarctic area [1].

This projects aims to analyze satellite imagery data, investigate SAM's effects on the ice melt situation at the Antarctic Peninsula, and compared to the simulated result from Goosse et al., 2023. The locations of interest are at Worldwide Reference System 2 (Path,Row) = (214,109) and (215,107) as shown in Figure 3. Landsat 8 satellite images data with cloud cover less than 10% are selected with the observation time ranges from October 2018 to January 2023 with one image per month.

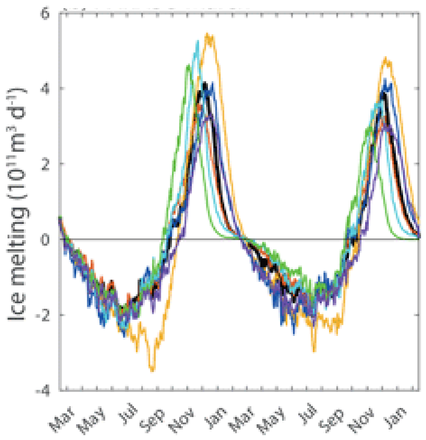


Figure 1. Simulation of ice mass flux of a year presented by Goosse et al., 2023. [1]

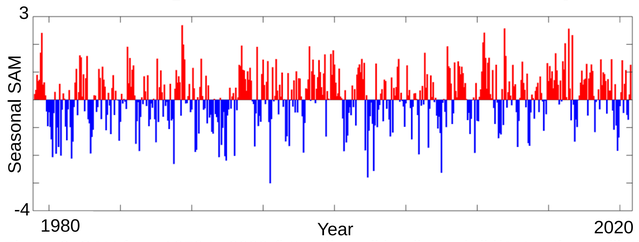
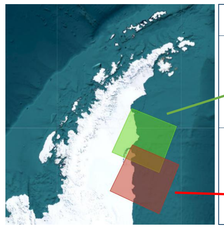


Figure 2. SAM from 1979 to 2020 (https://en.wikipedia.org/wiki/Antarctic_oscillation).



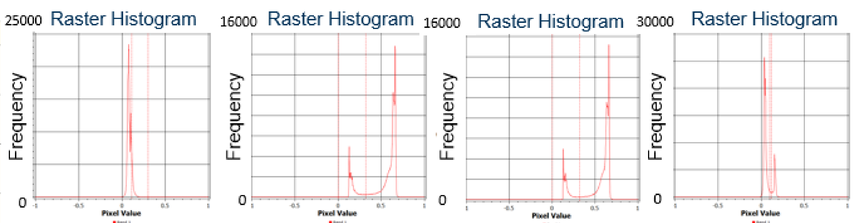
Location	The months of imagery data
(215, 107)	Oct 2018, Oct 2019, Sep 2020, Mar 2021, Jan 2022, Apr 2022, Oct 2022, Nov 2022, Jan 2023
(214, 108)	Oct 2018, Dec 2018, Mar 2019, Mar 2020, Sep 2020, Nov 2020, Feb 2021, Sep 2022, Nov 2022, Dec 2022

Figure 3. Location of the Landsat 8 data used in this projects.

Methods

(1) NDWI Selection (Acharya et al., 2018; Yang et al., 2012)

NDWI	Equation
NDWI$_{NIR}$	$\frac{Green - NIR}{Green + NIR}$
MNDWI$_1$	$\frac{Green - SWIR1}{Green + SWIR1}$
MNDWI$_2$	$\frac{Green - SWIR2}{Green + SWIR2}$
NDWI$_{ice}$	$\frac{Blue - Red}{Blue + Red}$

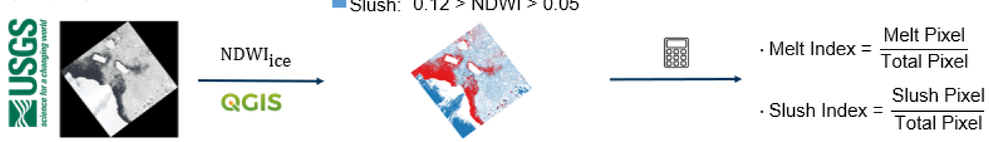


→*NDWI$_{ice}$ has the highest frequency and could better identify melt.*

(2) Melt Index Calculation

(214,108) – 6 data
(215,107) – 10 data

Melt: NDWI > 0.12
Slush: 0.12 > NDWI > 0.05

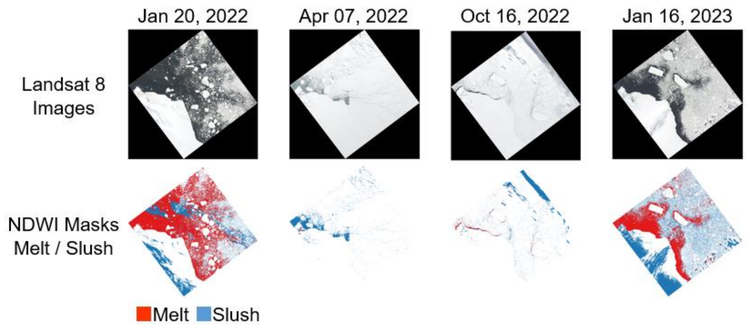


· Melt Index = $\frac{\text{Melt Pixel}}{\text{Total Pixel}}$

· Slush Index = $\frac{\text{Slush Pixel}}{\text{Total Pixel}}$

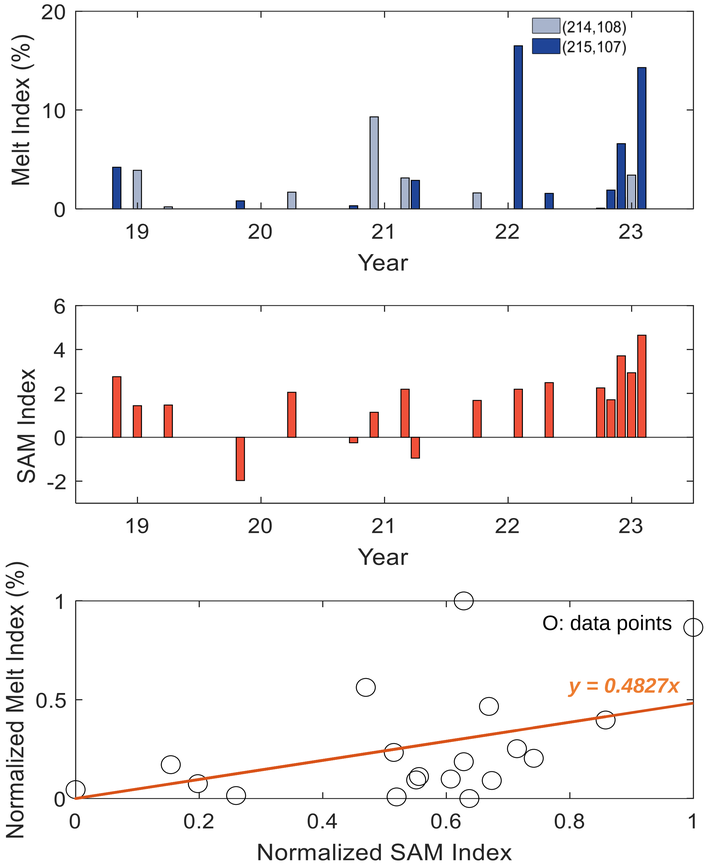
Results

(1) Seasonal melt analysis from Jan. 2022 to Jan. 2023



- The melt area at location (215,107) peaked at January and have the lowest melt in the middle of the year at April. This result corresponds the simulated melting trend presented by Goosse et al., 2023.
- By examining the slush classification, we can see that the existed NDWI threshold is able to classifying both cloud and slush apart from melt, but can barely tell the different of slush and cloud.

(2) Melt index, SAM index, and the analysis of their relationship



2a) Melt index analysis of the dataset

- Each year, the maximum melts index happen during November ~ January, which is the same as the simulated melting trend presented by Goosse et al., 2023.
- The value of maximum melt index also increase during the most recent two years, indicating the acceleration of global warming.

2b) The monthly SAM index of the data points

- The values of the monthly SAM index that correspond to the data of data points are extracted from https://legacy.bas.ac.uk/met/gjma/sam.html.
- Overall, the larger the SAM index is, the more of the melt occur.
- The SAM index of the selected data of 2022 and 2023 are all positive, which might be cause more melt during the recent years.

2c) The quantification of SAM's effect on ice melt

- Melt and SAM index of the selected data points are normalized to the range [0,1] to have the result best represent the current dataset. Each data points is represent by its normalized SAM index (x) and normalized melt index (y).
- Linear regression is performed to quantitatively determine the relationship between melt and SAM index of the selected data points.
- The plot shows a positive relationship between SAM index and ice melt, indicating positive SAM to be a factor causing more melt.

Future Directions

1. Perform research on more ways to calculate NDWI for a better classification not only slush and melt ponds, but also clouds and other glacier hydrology features
2. Include more data for analyzing different regions of the Peninsula area to see if the current Melt vs SAM trend still remains true.

References

1. Goosse, Hugues, et al. "Modulation of the seasonal cycle of the Antarctic sea ice extent by sea ice processes and feedbacks with the ocean and the atmosphere." The Cryosphere 17.1 (2023): 407-425.
2. Acharya, Tri Dev, Anoj Subedi, and Dong Ha Lee. "Evaluation of water indices for surface water extraction in a Landsat 8 scene of Nepal." Sensors 18.8 (2018): 2580.
3. Yang, Kang, and Laurence C. Smith. "Supraglacial streams on the Greenland Ice Sheet delineated from combined spectral–shape information in high-resolution satellite imagery." *IEEE Geoscience and Remote Sensing Letters* 10.4 (2012): 801-805.