Lead detection with Sentinel-1 in the Beaufort Gyre using Google Earth Engine.

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Abstract

Sea ice leads are produced from deformational forces, which break apart the ice surface and expose open water areas or leads. Leads are the primary regulators of heat in Arctic sea ice during the polar night. Partially-frozen and re-frozen leads produce smaller heat exchanges than open leads due to the absence of a warm water surface. Thus detecting leads is important because they may be used as an indirect way of estimating air-sea heat fluxes. To quantify winter-time leads, we utilize Sentinel-1 C-Band Synthetic Aperture Radar (SAR) data to examine sea ice images through heavy cloud cover. We employ a support vector machine learning technique in a cloud computation environment (Google Earth Engine) to detect and quantify lead areas. With the use of dual-polarization data, we improve the separation of leads from other elongated features (e.g., ridges) in the Sentinel-1 dataset by adding altimetry information from ICESat-2. In addition to typical texture analysis to assess surface roughness, the ICESat-2 ATL-10 data allows us to train the algorithm by discretizing leads and ridges by their freeboard values. Performing this method in a cloud environment allows processing of a large volume of satellite data and converting it into a time series of leads properties. Overall, our method improves lead detection with dual-polarization SAR data while simultaneously providing a big data solution for SAR image processing. The interannual variability of leads and newly formed ice fractions were found for the winters of 2017-2020. Finally, we compare the results from previous studies to validate our cloud-derived sea ice lead detection maps.

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Introduction

Motivation & Objectives

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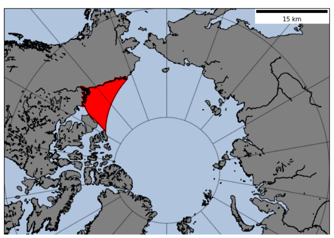
Plate 1: NASA/Goddard Space flight center courtesy of Stockli, R. "Annual Arctic Sea Ice minimum 1979-2020."

1. Create a cloud computation algorithm for sea ice classification.
2. Estimate lead fractions and dynamics during polar night-time in the Beaufort Sea.

Study Area



Data and Methodology

Sentinel-1: Synthetic Aperture Radar

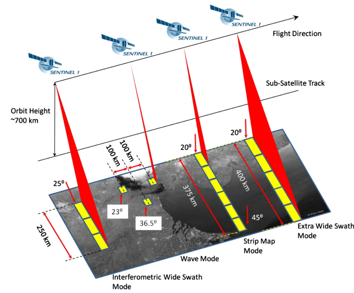
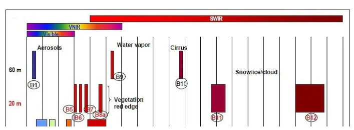


Figure 2: Sentinel-1 SAR acquisition.

- Frequency: C-band (4-8 Ghz, 7.5 - 3.75 cm).
- S1 A and S1B: 6-day revisit period; 12-day crossover.
- S1A & S1B: launched 2014 and 2016 respectively.
- Right looking.

Sentinel-2: Multi-spectral Imager



Results and Discussion

GEE Sea ice lead extraction

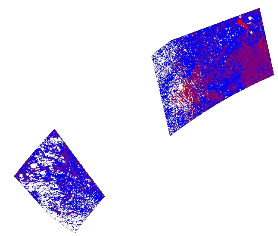
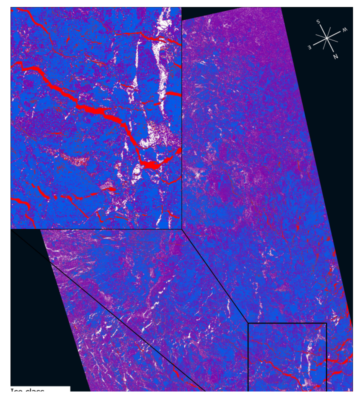


Figure 7: Daily mosaic classification output.



Conclusions

Leads can be geometrically and spectrally defined.

1. Leads can be characterized by their lenticular shape and spectral properties.
2. Ice ridges are similar in shape and (sometimes) brightness in SAR scenes. However, they have no preferred orientation.
3. SAR is ambiguous; the more polarizations, the better.
4. Image variance (GLCM) supported by ice thickness and visual inspection information can improve class accuracy.
5. The Beaufort Sea contains negligible open water coverage.

Thick ice cover in the Arctic continues to decline.

1. Maximum thick ice coverage has reduced by 12% between 2017 and 2020.
2. Sea ice production and dynamics are controlled by the circulation of the basin.
3. Weekly ice fractions throughout the frost minimum and maximum generally increase in thin ice lead production.
4. Leads display a westerly preferred orientation.
5. The Beaufort Gyre's efficiency in producing new ice is declining.

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