ASCAT UHR Sea Ice Extent Record Extension

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Overview

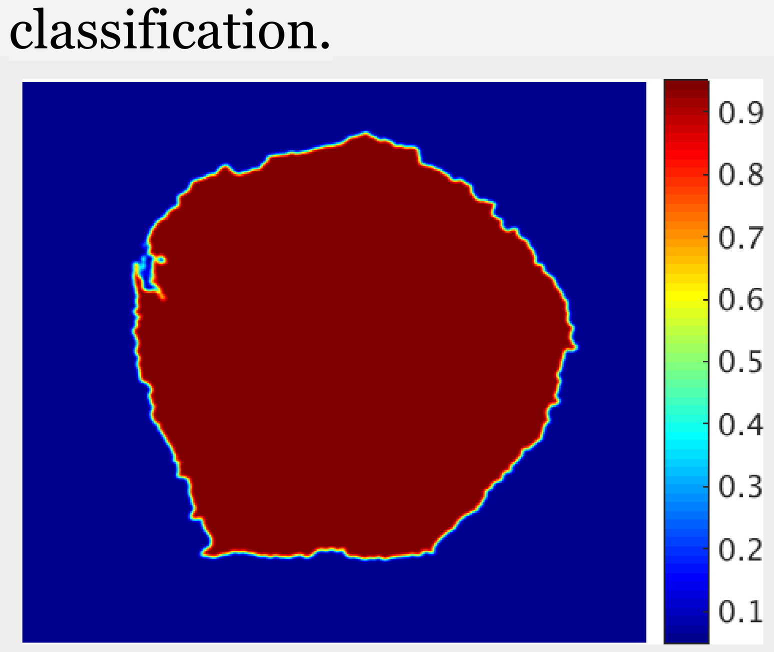
Though originally designed for vector wind measurement, scatterometers have shown sensitivity to indicators of sea ice. Various methods have been employed to create sea ice extent maps from scatterometer data. It is desired to generate such estimates at high resolutions so as to enable the study of fine features on the ice sheet, including polynyas. One method for estimating sea ice extent with C-band ASCAT data uses ultra-high resolution (UHR) imagery to perform a Bayesian classification and generate near real time ice extent maps. We are applying this method and modernizing it with new tools created for ASCAT analysis since the method's initial development. We are then extending this dataset throughout the ASCAT instrument lifespan to enable multi-decadal analysis of polar sea ice extent at UHR resolution.

$$\phi(\mathbf{x}) = \begin{cases} \text{sea ice}, & \text{if } p(\mathbf{x}|\omega_1)P(\omega_1) > p(\mathbf{x}|\omega_0)P(\omega_0), \\ \text{ocean}, & \text{otherwise}, \end{cases}$$

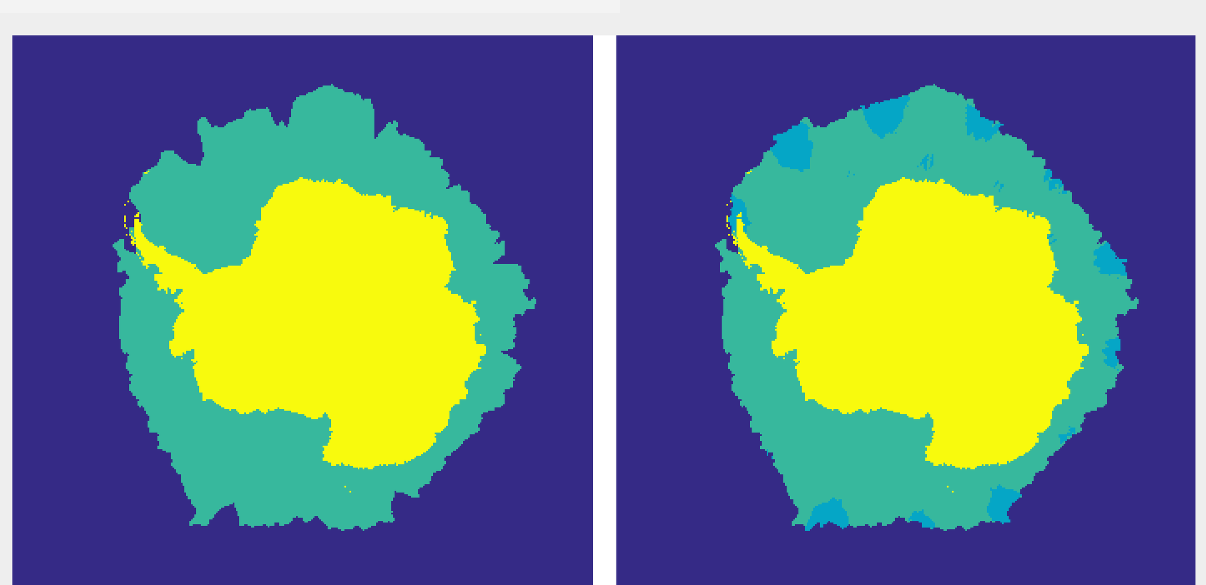
Decision rule for Bayesian classification

Method

Initial classification between ice and ocean is done via a Bayesian Classifier. The classifier relies upon a previous-day ice mask for two purposes. First, to generate a map of *a priori* values and conditional pdfs necessary for Bayesian classification. Second, to fill holes caused by coverage gaps in the ASCAT 2-day SIR image. As observation vector elements, the classifier uses the SIR A image (σ°), the B image (incidence angle dependence), the V image (spatial standard deviation), and the D image (normalized difference between beams). Image classification techniques (i.e., region growing) are then used to create a clean ice extent mask from the initial classification.



PPM used for Bayesian classification, drawn from previous day ice mask. Previous ice pixels assigned 0.95 probability ice, sea pixels are assigned 0.05. Map then smoothed with a 2D gaussian.

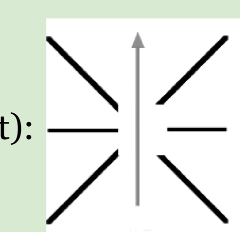


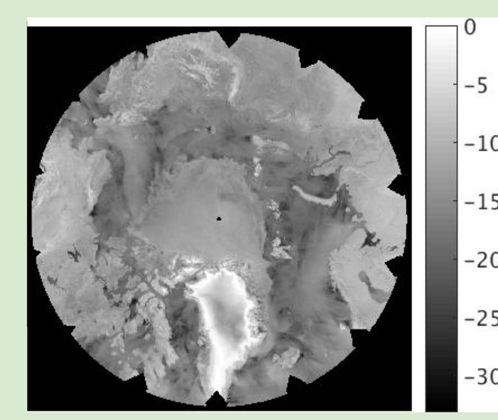
Raw ice mask on left. Several "bites" missing due to insufficient ASCAT coverage on 2-day span. Coverage gaps are filled with previous day range ice mask data in light blue.

Normalized Difference Image

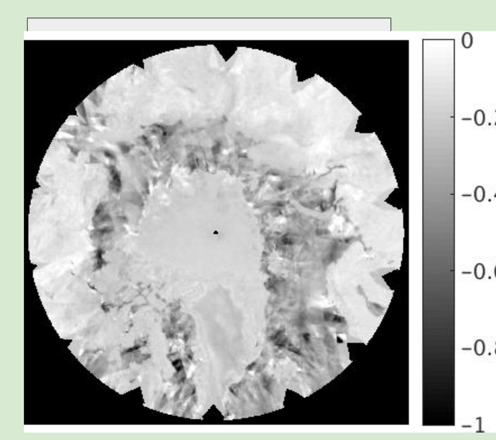
The ocean exhibits a high degree of azimuth modulation, whereas sea ice is generally isotropic and has little azimuth modulation. ASCAT's beam geometry provides three azimuth angles to compare, (fore, mid, and aft beams) to estimate azimuth modulation. We create three-antenna normalized difference images and process them at UHR resolution for use as an ocean/ice classification parameter. This difference image is calculated using the maximum difference between any two beams.

ASCAT beam geometry (fore, mid, aft):

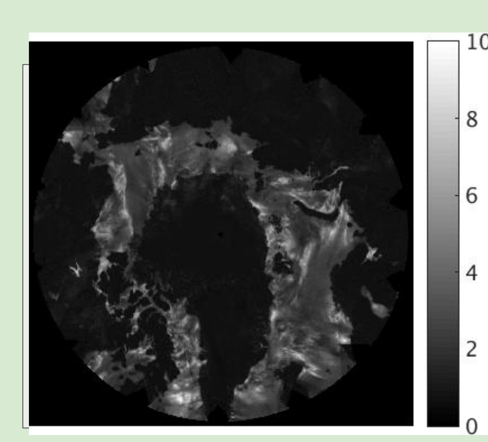




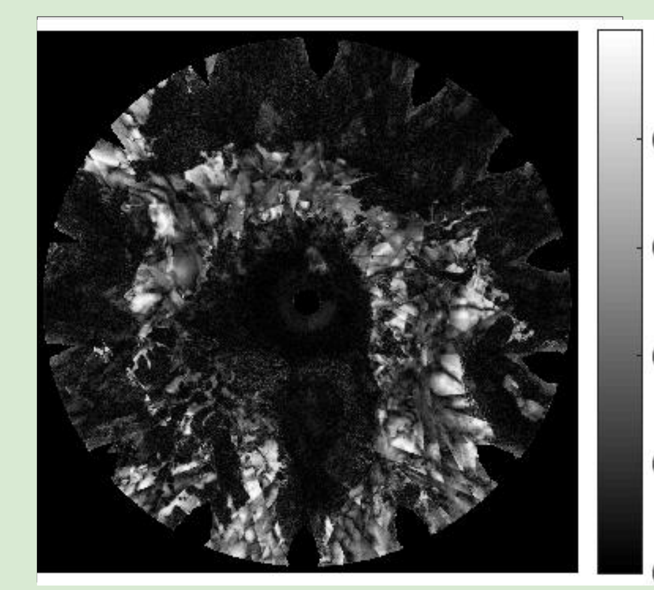
The A SIR image contains SIR-enhanced σ° in dB at 40 deg incidence angle values. It is brighter over rough and conductive surfaces. Ice generally appears brighter than ocean.



The B SIR image contains the slope of the incidence angle dependence in dB/degrees.

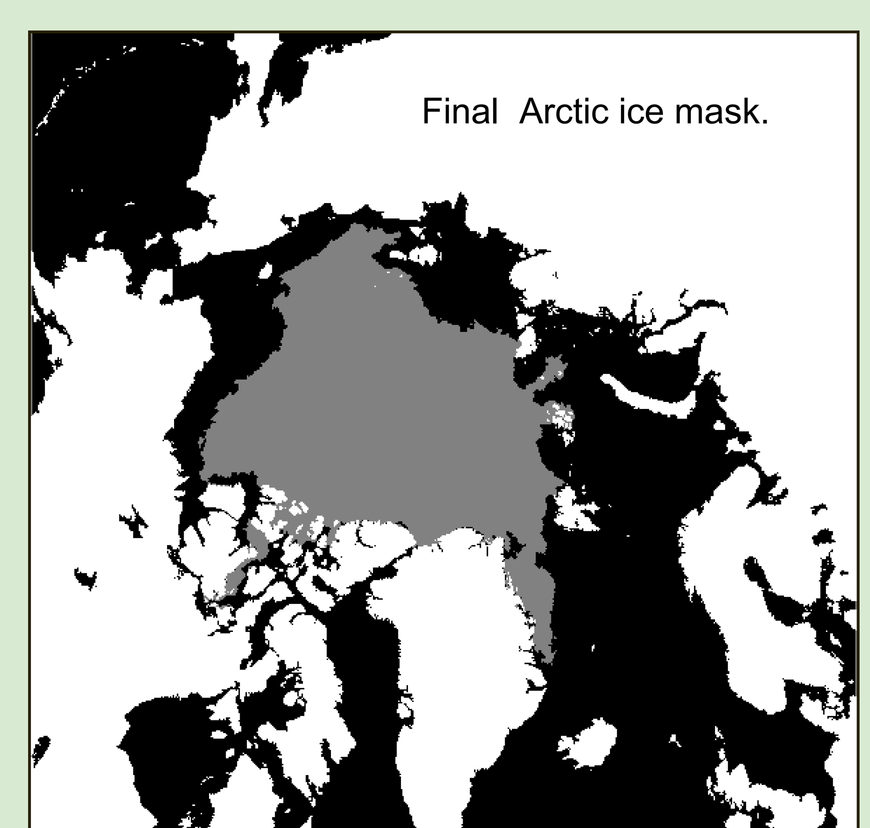


The V image contains the spatial standard deviation of σ° in each pixel (from its forward projection given surrounding pixels).



The d SIR image is the normalized difference image between ASCAT's beams, defined so as to describe the anisotropy of the surface. The maximum possible difference between ASCAT'S three beams is chosen, and has shown to better discriminate sea ice than any fixed two-beam difference scheme [2].

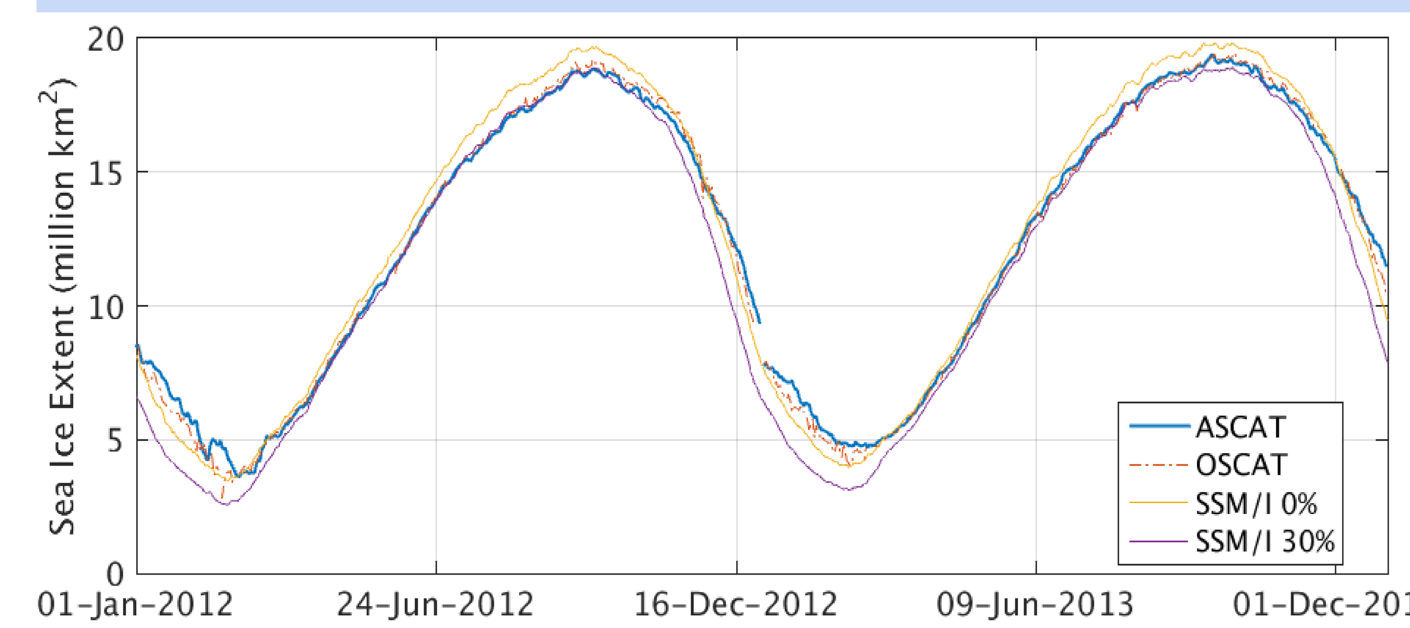
$$d = \max \frac{|\sigma_i^o - \sigma_j^o|}{|\sigma_i^o + \sigma_j^o|}, \text{ where } i \neq j$$



Production of the final mask includes binary image operation such as erosion and dilation,

Developments

The extended ASCAT UHR ice mask dataset incorporates improvements to ASCAT data processing [3] and the modern CETB-standard [4] image regions. ASCAT processing is enhanced with the incorporation of R. Lindsley's improved parameterized spatial response function [3]. This improves the resolution and accuracy of the sigma-0 images. Adopting the standard EASE-2 grid map projection for the ice masks ensures future compatibility with other UHR microwave remote sensing products.



ASCAT UHR ice extent algorithm estimate of total sea ice extent compared with the Ku-Band Reemund-Long algorithm (adapted for OSCAT) and the NASA Team pass microwave sea ice concentration algorithm with 0% and 30% thresholds. Both active sensors tend towards lower estimates in Antarctic summer and higher in Antarctic winter [2] compared to radiometer estimates.

Applications

Due to the longevity of the ASCAT mission, an extended UHR ice masking dataset for the instrument will enable long-term studies of the polar sea ice edge with active microwave remote sensing data at high resolution and bridges the gaps between Ku-band sensor products of this type. Daily UHR ice maps are used to prevent ice-contamination of ocean vector wind measurements and open the door to studies of fine ice features like polynyas, whose large number and wide geographical distribution complicate other methods of regular comprehensive survey.

References

[1] S. Reeves, "Sea Ice Mapping Using Enhanced Resolution Advanced Scatterometer Images", Master's Thesis, Brigham Young University, Utah, 2012.

[2] J.C. Hill and D.G. Long, Extension of the QuikSCAT Sea Ice Extent Dataset with OSCAT Data, IEEE Geosci. Rem. Sens. Lett., Vol. 14, No.1, pp. 92-96, 2017.

[3] R. D. Lindsley, C. Anderson, J. Figa-Saldaña and D. G. Long, A Parameterized ASCAT Measurement Spatial Response Function, IEEE Trans. Geosci. Rem. Sens., Vol. 54, no. 8, pp. 4570-4579, 2016.

[4] M.J. Brodzik, D.G. Long, M.A. Hardman, A. Paget, and R. Armstrong, "MEaSUREs Calibrated Enhanced-Resolution Passive Microwave Daily EASE-Grid 2.0 Brightness Temperature ESDR, Version 2." Boulder, Colorado USA. NASA National Snow and Ice Data Center Distributed Active Archive Center. NSIDC-0630, doi:10.5067/MEASURES/CRYOSPHERE/NSIDC-0630.002, 2016.