Blended VIIRS and AMSR2 Sea Ice Concentration

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Introduction

This work aims at improving Sea Ice Concentration (SIC) estimates from space, providing a new product that gives SIC under all-weather conditions through optimal blending of high spatial resolution Visible Infrared Imaging Radiometer Suite (VIIRS) ice concentration with ice concentration from passive microwave observation from Advanced Microwave Scanning Radiometer-2 (AMSR2).

Validation of VIIRS and passive microwave-derived SIC has been done using high-resolution Landsat data from the U.S. Geological Survey (USGS). In each scene there is a visible and thermal channel observation at 30 meter spatial resolution form the Operational Land Imager (OLI) and the Thermal Infrared Sensor (TIRS) onboard Landsat-8. Each pixel at the original spatial resolution is identified as either snow/ice or water under clear conditions based on the visible channel reflectance and the derived Normalized-Difference Snow Index (NDSI). SIC at lower spatial resolutions of 1 and 10 km are calculated as the ratio of the number of snow/ice pixels to the number of all pixels inside a grid cell. For each of the Landsat scenes a corresponding granule of the Suomi NPP VIIRS SIC with a spatial resolution of 750 m is located with a time difference of less than 1 hour. A daily mean SIC product is also obtained from AMSR2 at 10 km. Bias and RMSE of SICs form VIIRS and AMSR2 are calculated with regard to SIC from Landsat.

Method

After both VIIRS and AMSR-2 SICs are remapped into 1-KM EASE-Grid, the Best Linear Unbiased Estimator (BLUE) is then applied to derive the final ice concentration under clear sky conditions.

$$ICE_{CONC} = (\sigma_1^2/\sigma_1^2+\sigma_2^2)\times(ICE\_CON_1-D_1) + (\sigma_2^2/\sigma_1^2+\sigma_2^2)\times(ICE\_CON_2-D_2)$$

where ICE_CONC_1 and ICE_CONC_2 are the optimized ice concentrations from the two products; D_1 and D_2 are measurement biases; σ_1 and σ_2 are the measurement precisions. For the pixels under cloudy conditions, the resulting SIC is determined as the ice concentration form the microwave observations with bias correction. Furthermore, ice cover is defined by pixels with SIC larger than 15%. The final product will have the same spatial resolution as VIIRS (1 km) with ice product from microwave observations interpolated to the VIIRS spatial resolution.

Example Sea Ice Concentrations

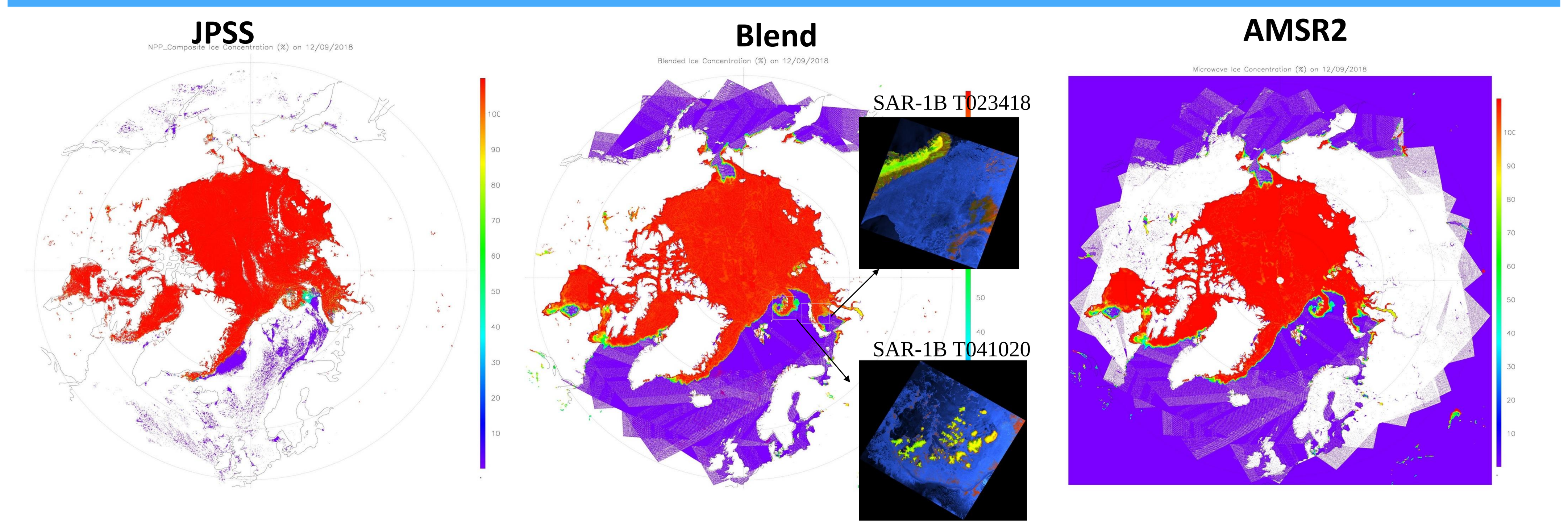

Figure 1: Examples of Daily Sea Ice Concentration Composite over Arctic on 09 Dec 2018. Left: SNPP-VIIRS, Middle: blended VIIRS and AMSR2, Right: AMSR2. SAR-1B images in boxed region over Franz Josef Land and Barents Sea

Validation Results:

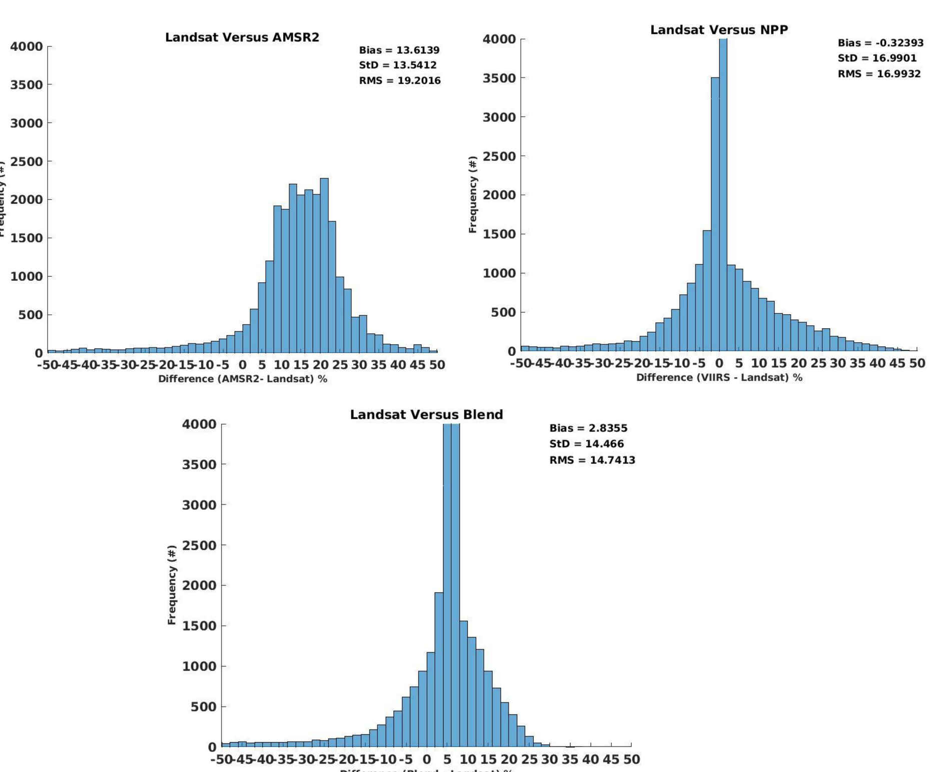

Figure 2: Histogram comparisons to Landsat from 12 Sea Ice Concentration scenes over Arctic from June 2019. Upper left is AMSR2, upper right S-NPP and lower middle is the Blended product.

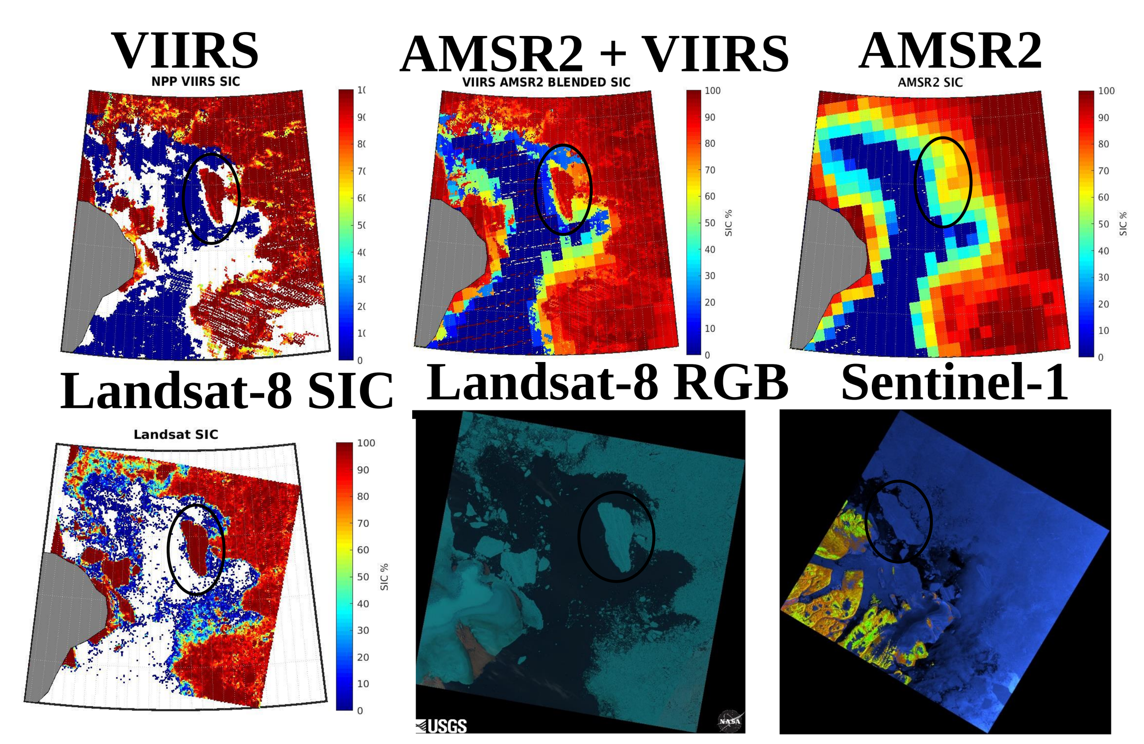

Figure 3: On August 1, 2019 in Greenland Sea off Greenland NE Coast. Top: VIIRS, Blended and AMSR2 SIC. Bottom: SIC, OLI/TIRS RGB from Landsat-8 and Sentinel-1 SAR image.

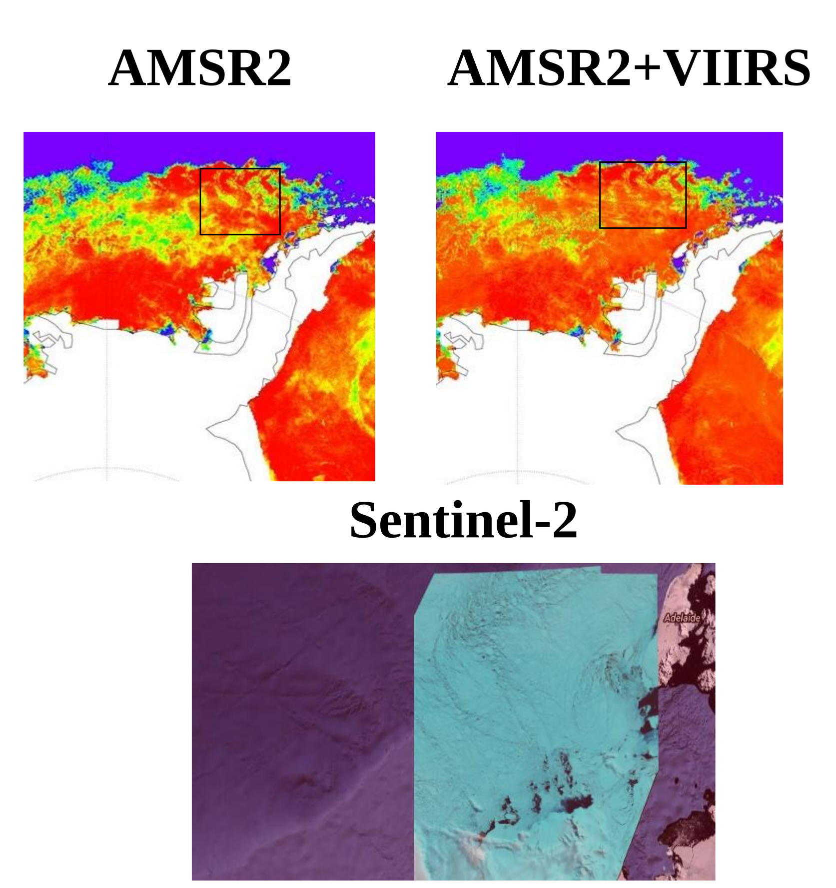

Figure 4: On 15 Oct 2017 over Bellingshausen Sea. Top: AMSR2 and Blended SIC; Bottom: Sentinel-2 RGB from the same day.

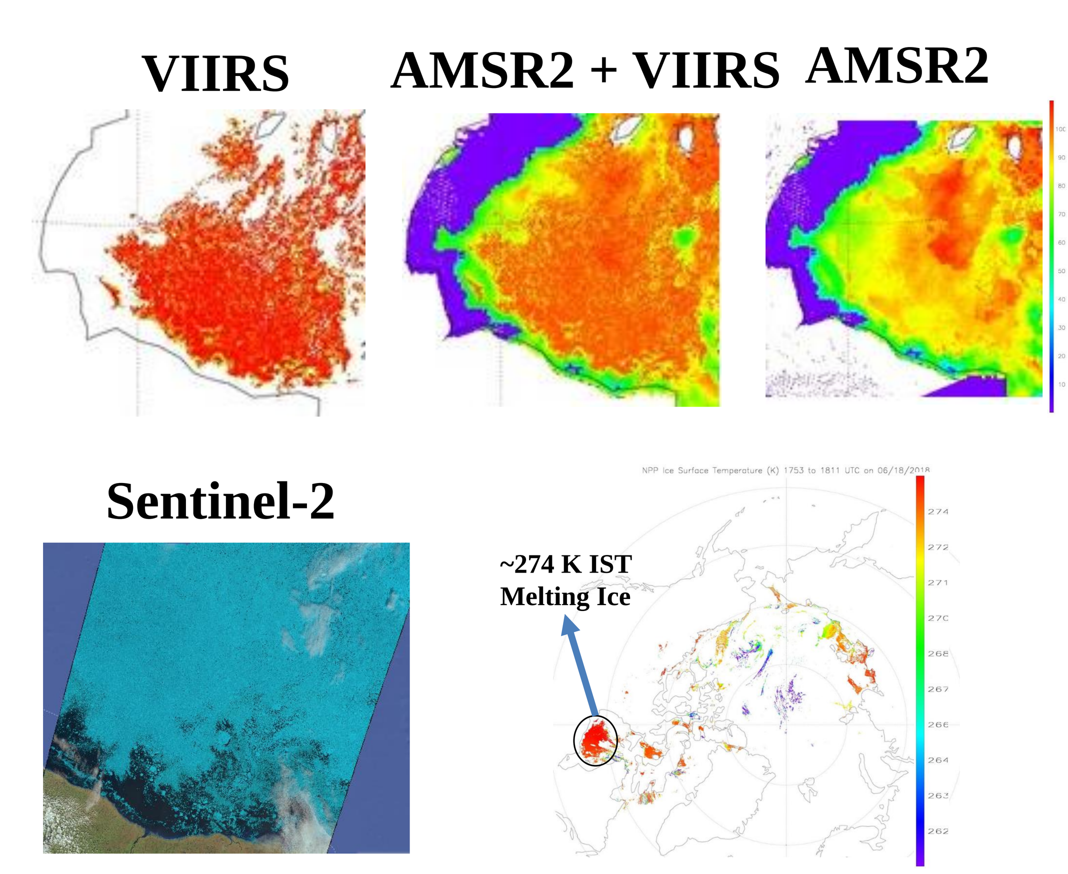

Figure 5: On 18 Jun 2018 over Southeast Hudson Bay. Top: VIIRS, Blended and AMSR2 SIC . Bottom: Sentinel-2 RGB from same day ~17 UTC , and NPP VIIRS IST at 260-275 K scale for same day ~18 UTC.

To the left is an example blending of the VIIRS and AMSR2 SIC from 09 December 2018. Notice the resultant SIC in Barents Sea, near Franz Josef Land and Canadian inland lakes. Next, validation results are shown from a dozen ice scenes analyzed from June 2019 with resultant statistics and histograms from cases (Figure 2). Overall, the blended SIC product reduces overall RMS error compared to VIIRS and AMSR2. A summer season case from 01 August 2019 over Greenland Sea (Figure 3) is shown where there were coinciding Landsat-8 and Synthetic Aperture Radar (SAR) imagery from Sentinel-1. Qualitative analysis indicates improvement when a blend of VIIRS plus AMSR2 SIC is utilized, with the AMSR2 SIC product noticeably missing a sea ice feature (circled). For this particular case both Standard Deviation and RMS errors (not shown) are reduced in blended product compared to VIIRS and AMSR2 SIC. Another case in the Antarctic region over the Bellingshausen Sea compared to Sentinel-2 RGB shown in Figure 4 gives further indication of AMSR2 SIC underestimation. A summer case on 18 June 2018 over Hudson Bay (Figure 5) gives additional indication that the AMSR2 retrieval has an underestimation of SIC when compared to Sentinel-2 RGB. Sensitivity in warm ice surface temperature environments, such as shown in southern Hudson Bay is a likely reason for the discernible underestimation of SIC in AMSR2.

Finally, Landsat and Sentinel 1-A and B SAR imagery that coincide with differences between the Blend and AMSR2 SIC during the 2017 March through June period were analyzed to see how often the NPP SIC improves upon the AMSR2 SIC in the Blend. These scenes where observed to have SICs that were anywhere from 25-75% difference in value. For Landsat a total of 117 images, of which only 11 occur in the Antarctic region. In total it was found to have a 75% success rate in having Blend improving the overall SIC field. For SAR comparisons, they are partitioned into Arctic and Antarctic, with 205 Arctic and 132 Antarctic scenes being analyzed, with Blend having a different SIC than AMSR2. It was found that the Blend had a success rate 85% over the Arctic and 82% over the Antarctic.

However, one caveat is that VIIRS still has some issues with ice cloud leakage. This is expected to be improved with the release of updated JPSS/VIIRS cloud products that provide cloud probabilities.

Conclusions

In summary, it has been shown that the higher resolution VIIRS data provides beneficial information to improve upon microwave (AMSR2) SIC under clear sky conditions. It was found that the AMSR2 retrieval suffers from low SIC bias in especially summer-time warmer ice conditions and the inclusion of VIIRS SIC mitigates that specific problem. For future work, to improve upon this product, we will include seasonally adjusted bias corrections.

Acknowledgements

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