An Empirical Sea Ice Correction Algorithm for SMAP SSS Retrieval in the Arctic Ocean

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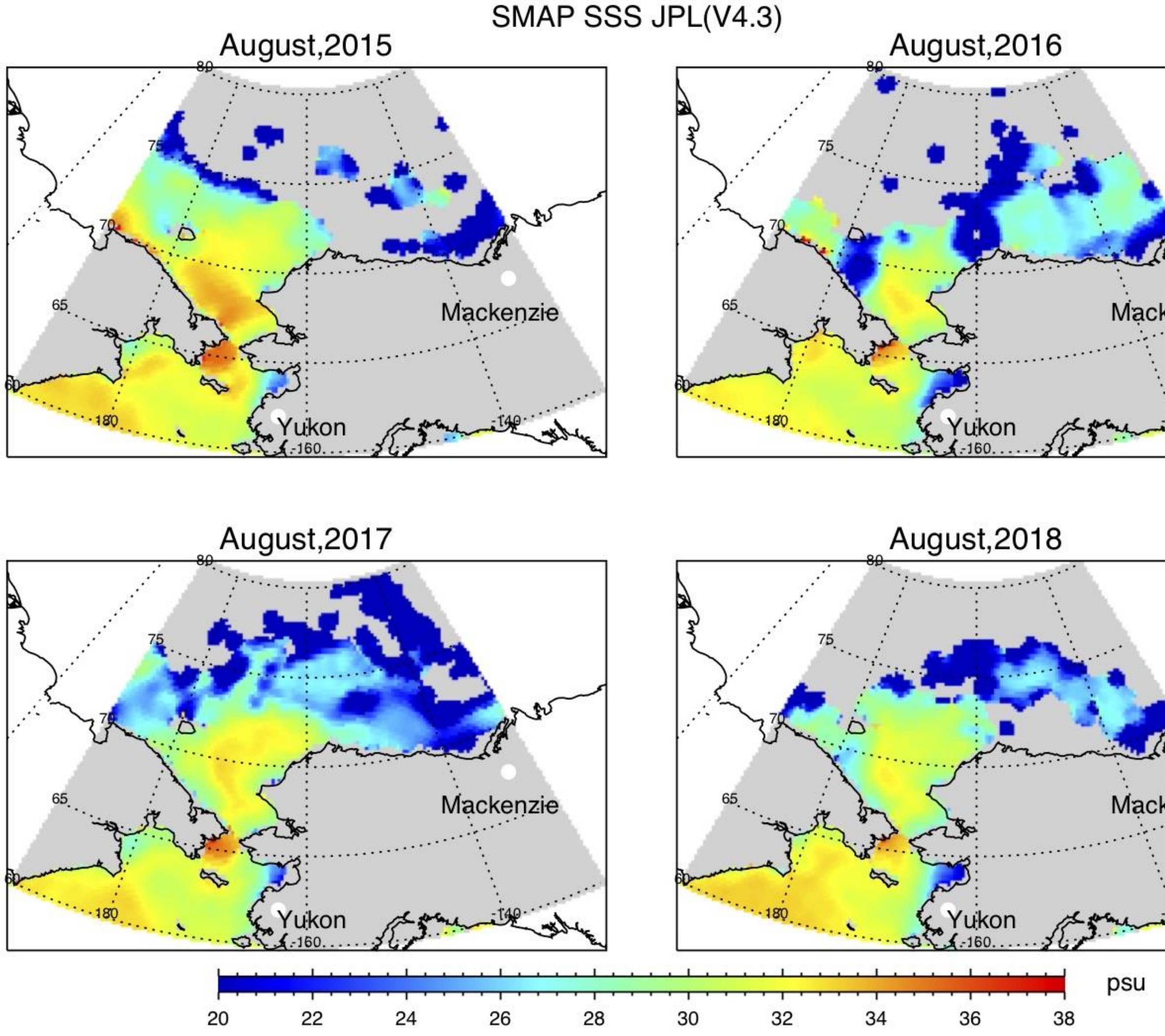
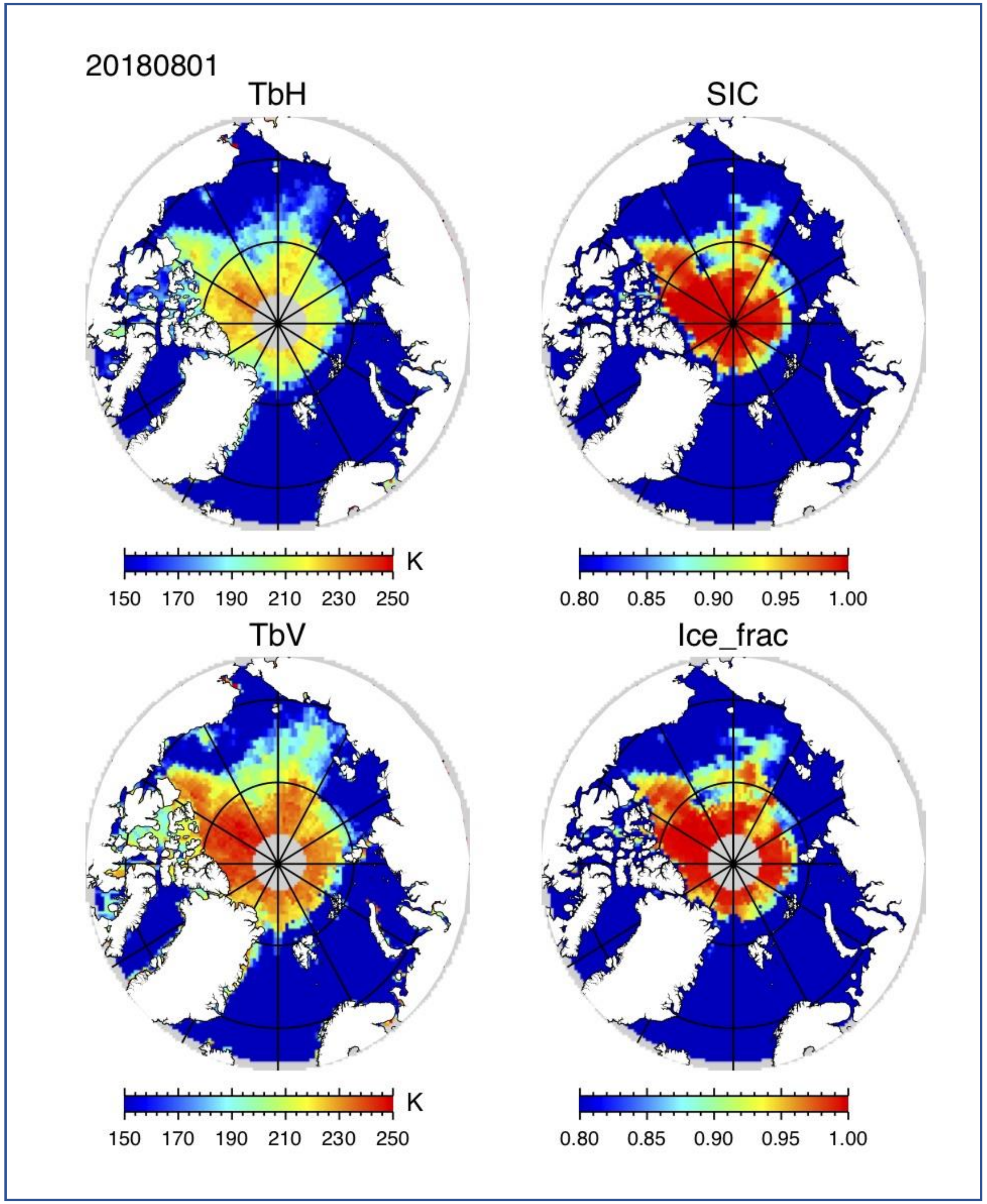
Motivation: develop a data-driven approach for sea ice correction to improve SMAP SSS retrieval in the Arctic Ocean



To explore the potential of SMAP SSS in monitoring the Arctic Ocean, JPL SMAP algorithm (V4.3) experimentally allows SSS retrieval in Level 2 cells with matchup SIC up to 3% (without any sea ice correction), instead of 0.5% SIC previously used.

Qualitatively, the locations of relatively low SSS are consistent with the patterns of sea ice as seen in SIC data.

But, quantitatively, the magnitude of the low SSS near the ice edge may contain error due to uncorrected sea ice contamination in scene mixed with ice and water.



Data

SMAP TB (V,H)

L1B_TB version 4 (~40km res.)

Sea ice concentration (SIC):

NCEP daily 1/12° x 1/12° grid

Ice fraction (ice_frac):

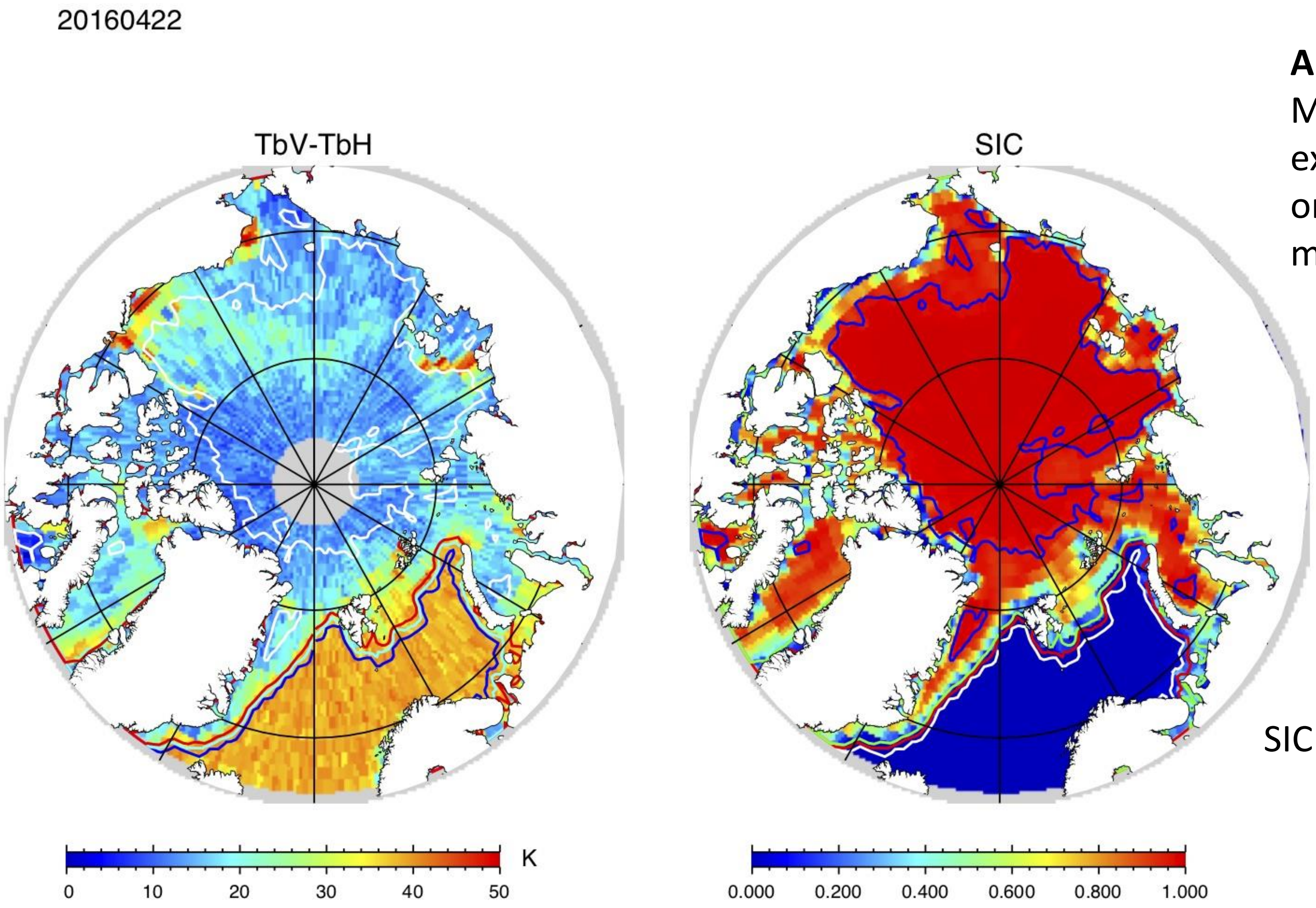
Ice fraction at SMAP footprint, obtained by integrating SIC weighted by antenna gain

EUMETSAT/OSISAF provides sea ice type and edge Classification products based on SIC derived from SSMIS, AMSR2, ASCAT using ECMWF for atmospheric correction

Sea Ice type distinguish between no ice (1) first-year sea ice (2) and multi-year sea ice (3).

Sea Ice edge distinguish between open water (1), open sea ice (2) and closed sea ice (3)

Coherence between the spatial patterns of SIC and TB polarization difference (TbV-TbH)



April 22, 2016
Maximum sea ice extend before the onset of the sea ice melting season

SIC contours over TbV-TbH:
- 3% blue
- 15% cyan
- 30% red
- 98% white

SIC contours over SIC:
- 3% white
- 15% red
- 30% cyan
- 98% blue

Coherence between the spatial patterns of SIC and TB polarization difference (TbV-TbH)

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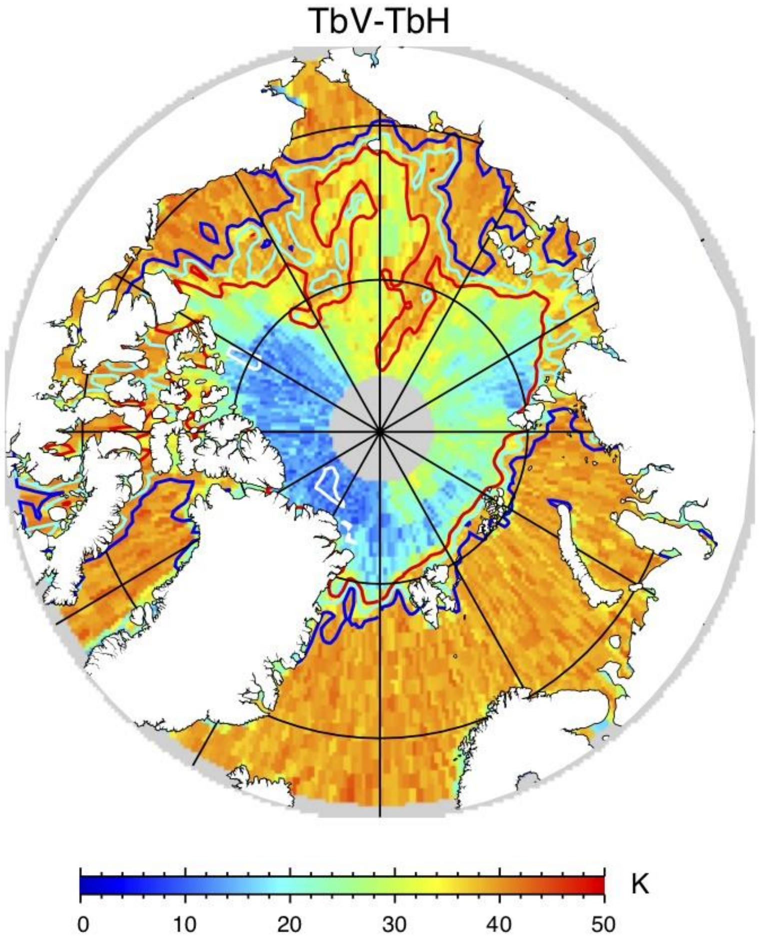
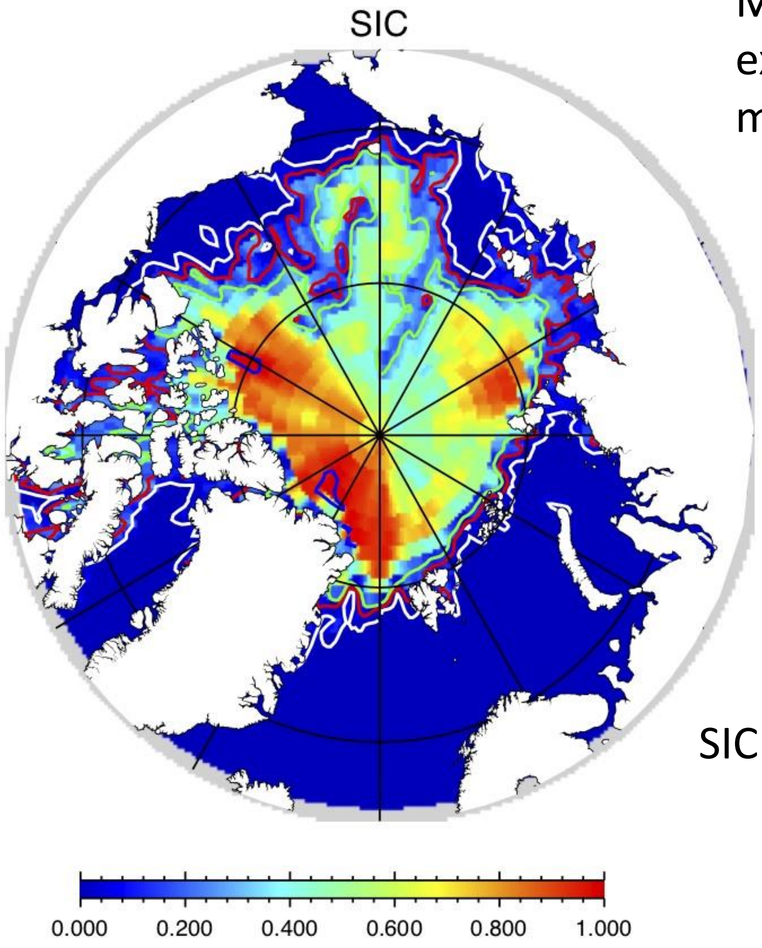
August 26, 2016
Minimum sea ice extend at the end of melting season





SIC contours over TbV-TbH:

- 3% blue
- 15% cyan
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- 98% white

SIC contours over SIC:

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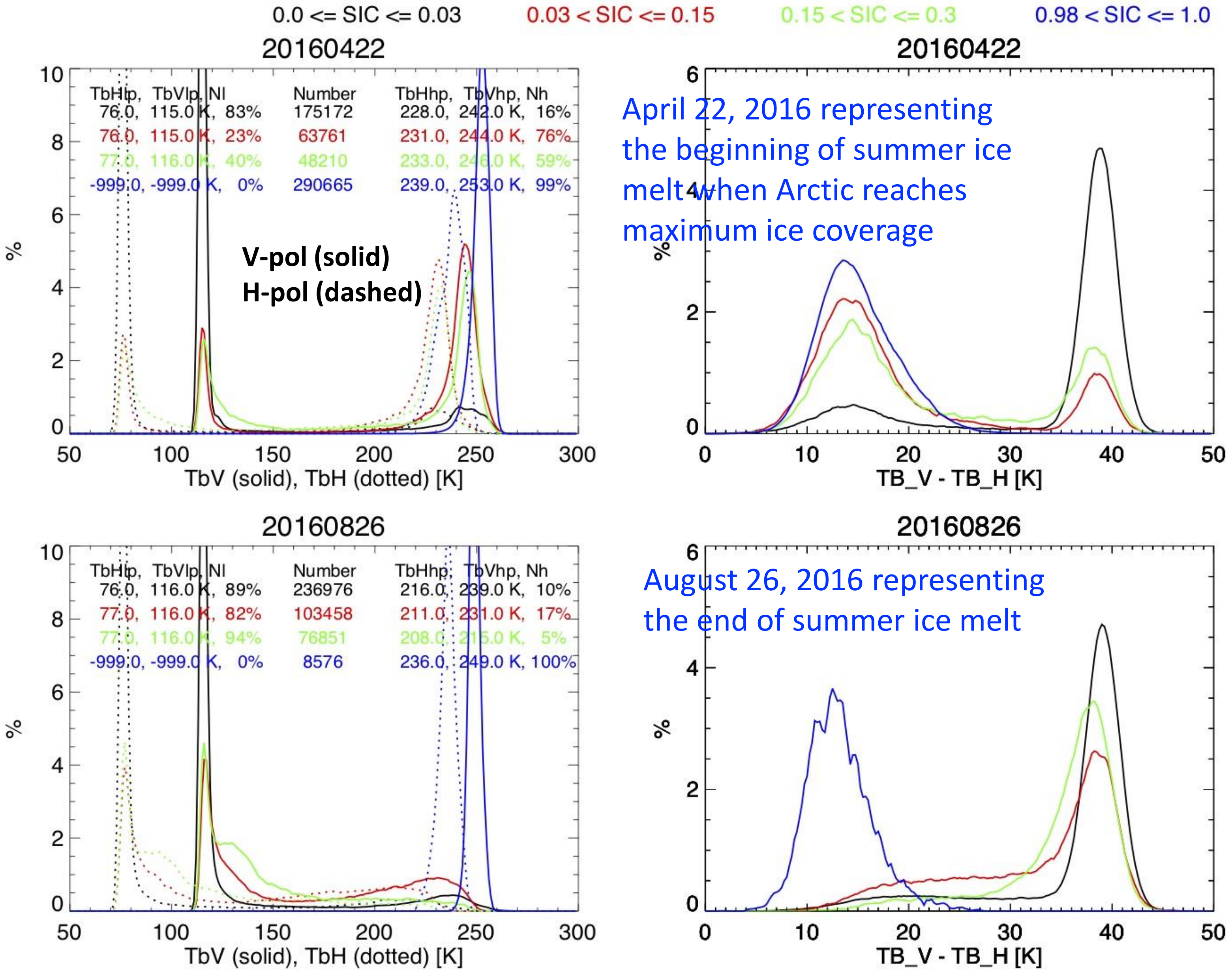
TB distribution in different sea ice categories



Plots are normalized distribution, i.e. the number of a TB bin divided by the total number of data within the category.

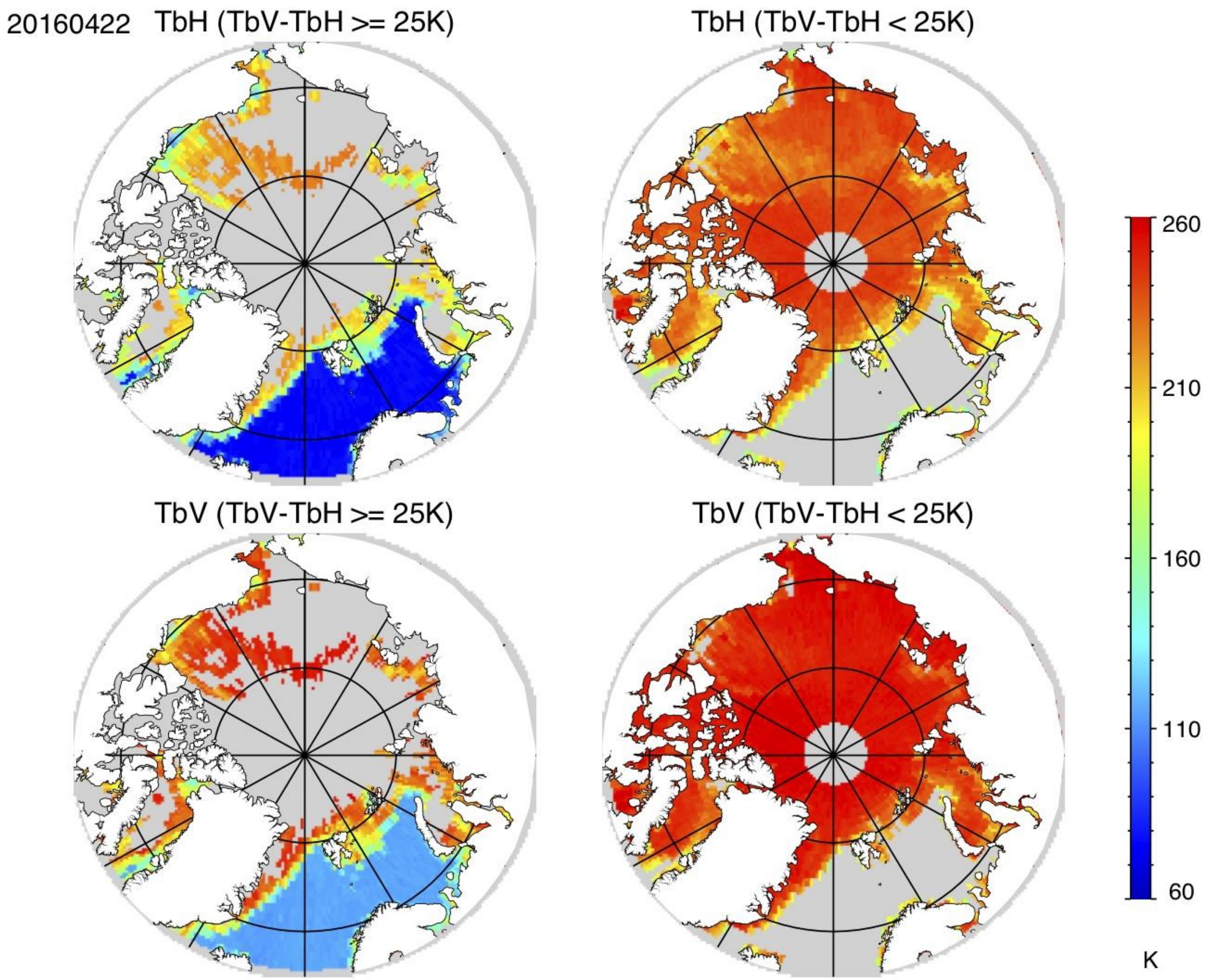
SMAP TBs collected north of 50°N are segregated into categories corresponding to the specific range of SIC. We consider 4 categories:
SIC < 3% (black): representing nearly open water condition;
3-15% (red) and **15-30%** (green): representing conditions at ice edge;
SIC > 98% (blue) for closed ice.

Closed ice category has one peak in TB distribution; while other three categories two distinct groups named low-end and high-end TB groups.

We hypothesize that the existence of this high-end TB group even at very low SIC (e.g. < 3%) suggests possible mis-match between SMAP observation and ancillary SIC, likely caused by in-sufficient resolution and accuracy of SIC product.

TB polarization difference as an observation-driven filter for sea ice?

TB polarization difference as an observation-based filter for sea ice



April 22, 2016 the beginning of summer ice melt when Arctic reaches maximum ice coverage

The polarization difference (dTB=TbV-TbH) for the high-end TB group is much smaller than the low-end group

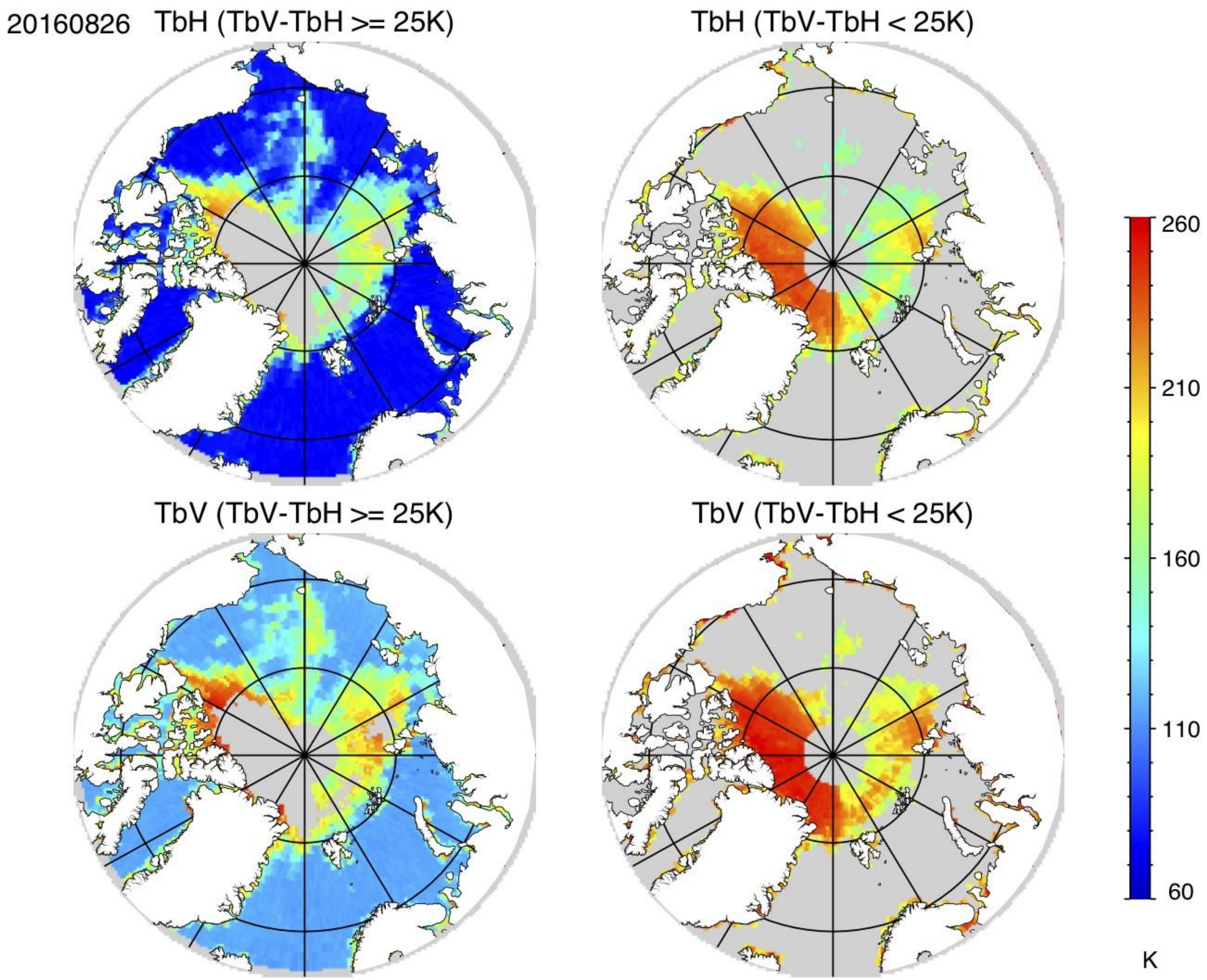
The reduction in polarization difference could be due to contribution by sea ice in sea ice dominated scenes

This suggests dTB can be a potentially useful observation-driven filter, in complimentary to ancillary SIC, for identifying scene dominated by sea ice

The daily TB maps averaged over data for dTB less/larger than a threshold (chosen to be 25K here).

The areas of closed ice (reddish color) and open water (blueish color) are effectively separated.

TB polarization difference as an observation-based filter for sea ice

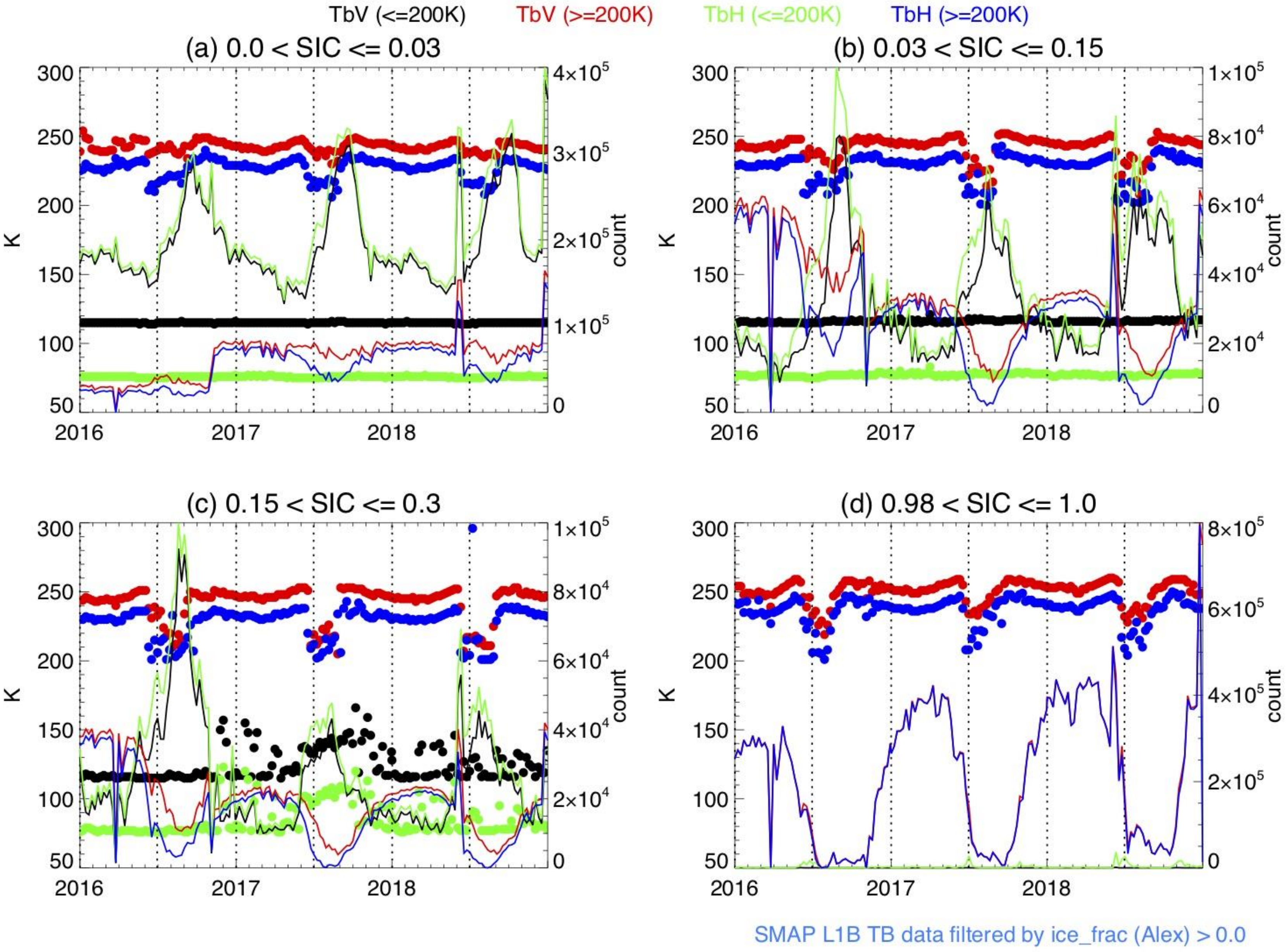


The areas of closed ice (reddish color) and open water (blueish color) are effectively separated.

In areas near ice edge, i.e. adjacent to SIC contours of 3% (white) and 30% (black), the observation-driven filter probably also separates the TB measurements from which SSS are retrievable (left) and those "uncorrectable" (right).

August 26, 2016 representing the end of summer ice melt

Seasonal Variation of low-end and high-end groups TBs



We performed the analysis using 3 years SMAP data from Jan. 2016 to Dec. 2018. The peaks of TB for the low-end and high-end groups, i.e. TB^{peak}_V and TB^{peak}_H are derived using data north of 50°N collected in one day, every 7 days.

Time series of TB^{Peak}_V and TB^{Peak}_H (dot symbols, left axis) of high-end (red for V and blue for H-pol) and low-end (black for V and green for H-pol) groups for 4 categories of SIC. TB^{Peak}s are derived using one day's of data north of 50°N every 7 days, wherever ice fraction of SMAP footprint is larger than zero. Thin lines (right axis) are the number of data points of each category.

An Empirical algorithm of sea ice correction (1)

The brightness temperature measured in a scene mixed with sea ice and water is represented by

$$TB^{mea.} = (1 - f_{ice})TB^{water} + f_{ice}TB^{ice}$$

where f_{ice} is the fraction of sea ice in the radiometer field of view (FOV), estimated on each SMAP L1B pixel by integrating SIC weighted by SMAP antenna gain G , i.e.

$$f_{ice}(x, y) = \int_{FOV} SIC(x, y)G(\Omega)d\Omega$$

We propose to use the single pixel algorithm (SPA), similar to [Chaubell et al., 2019] which was used to improve TB measurements near coastal areas for SMAP, with modification considering the characteristics of sea ice.

An Empirical algorithm of sea ice correction (2)

For a pixel (i,j) in the SMAP swath, with matchup SIC less than the retrieval threshold and *dTB=TBV-TBH >= 25K*,

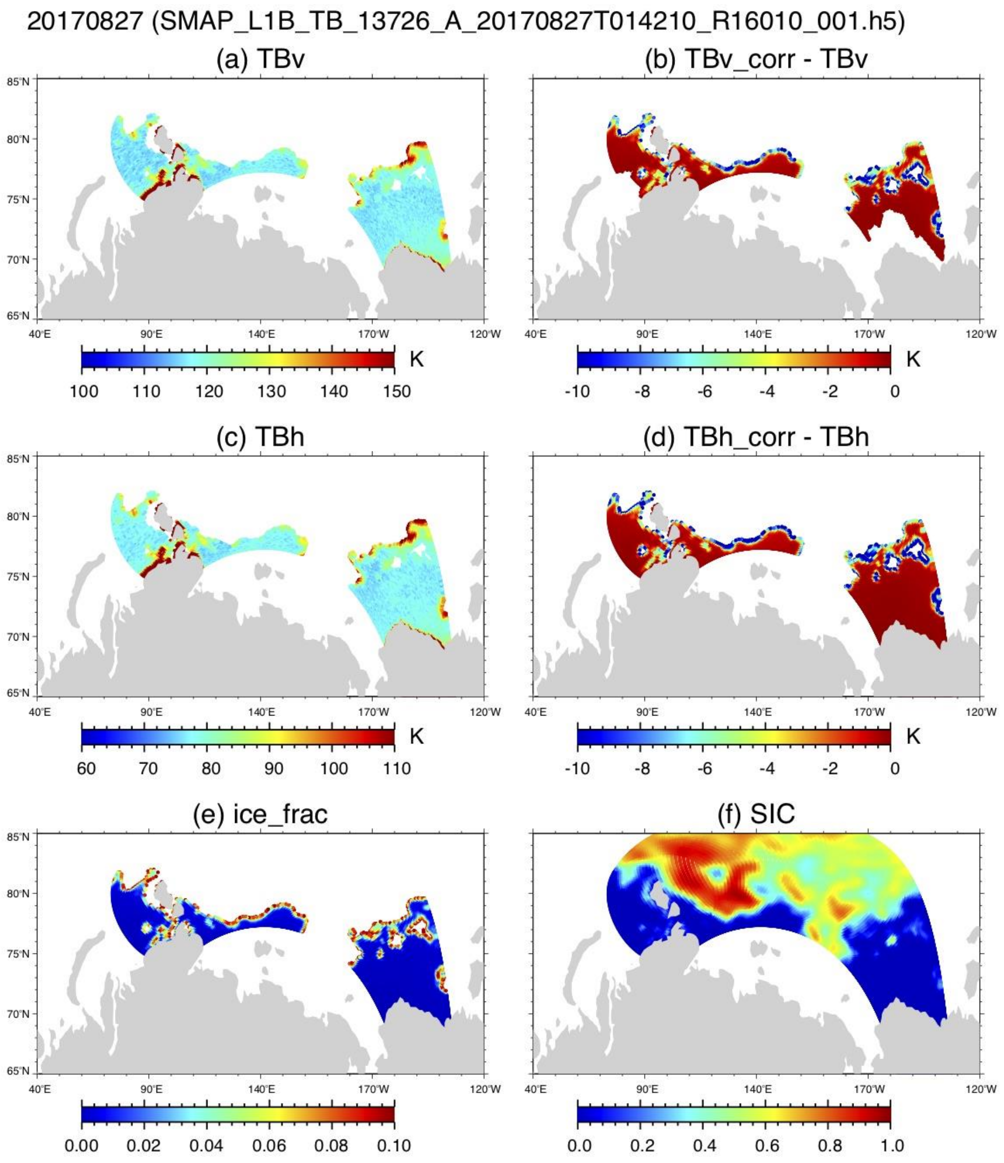
(1) Find all sea ice pixels (N) surrounding point (i.j) within 5 grid spaces (~200 km distance). Note how to define "sea ice pixel" is tricky and critical, because SIC data are not as reliable as land mask. We apply an additional observation-driven filter, based on dTB=TBV-TBH < 25K;

(2) Calculate $TB^{ice}(i,j)$ by averaging TBs of all sea ice pixel found in (1). If there is not enough sea ice pixels was found, TB from closed ice category is used as default TB^{ice}.

(3) Remove the sea ice contribution from measured TB, i.e.

$$TB_{water}(i.j) = \frac{TB^{meas.}(i,j) - f_{ice}(i,j)TB^{ice}(i,j)}{1 - f_{ice}(i,j)}$$

An Empirical algorithm of sea ice correction - example



We applied the empirical correction algorithm on SMAP L1B data in the satellite swath wherever the ice fraction is greater than zero but less than 10%.

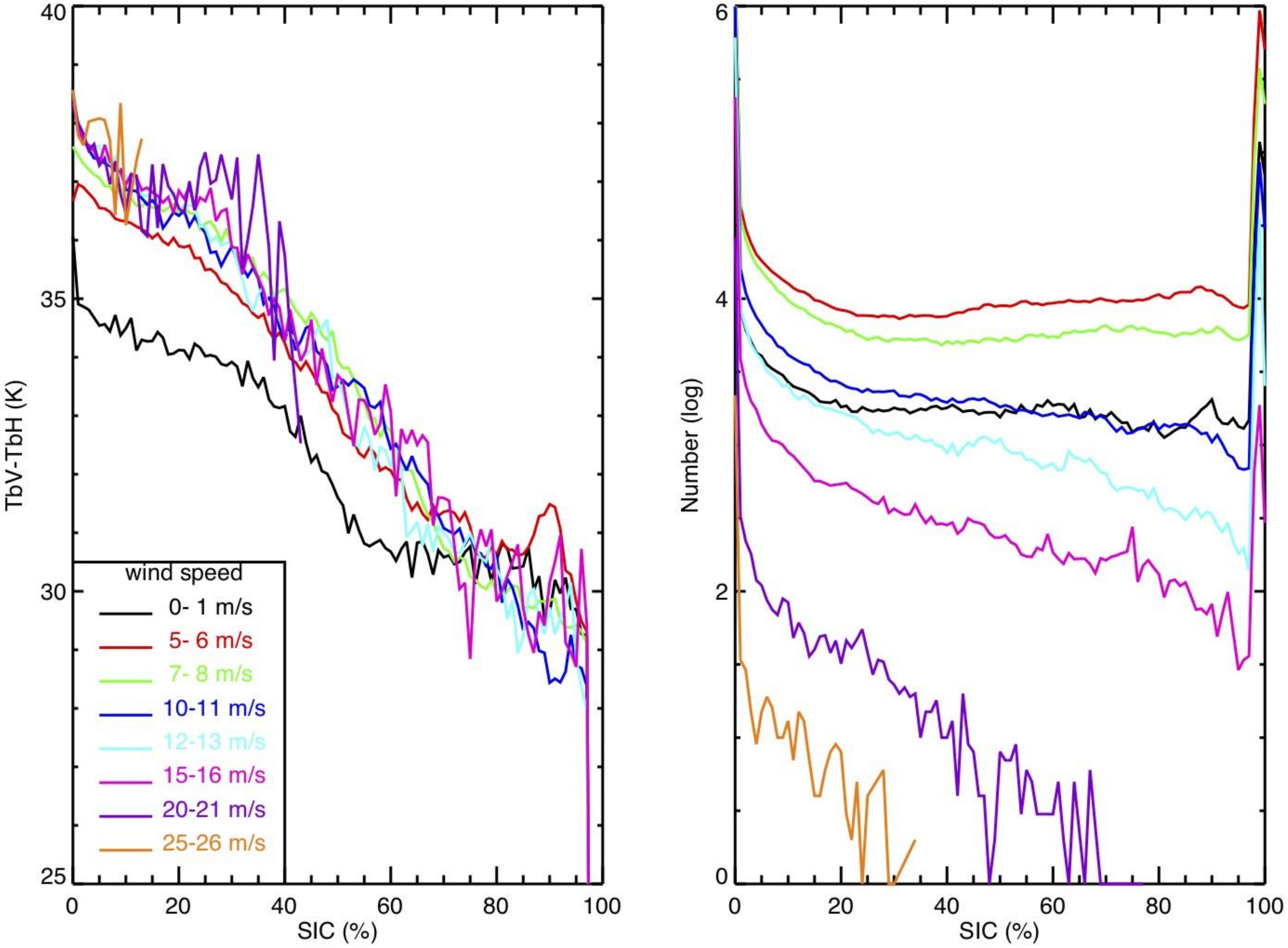
Example shows high $TB^{meas.}$ close to the ice edge (yellowish to reddish color, left top two panel) at the southern extend of Arctic ice, which is reduced by as much as 10K by the correction (blueish color, right top two panel).

We note the sea ice correction along the west coast of the northern tip of Canadian land is not as large as at the northern ice edge, which probably results from the combination of land and ice correction.

Summary and future work

- Key elements of the proposed empirical sea ice correction algorithm
  - Use observed TbV-TbH additional filter, in complimentary to ancillary SIC
  - Observation based Single Pixel Algorithm for correction
  - Consider seasonal variation of sea ice TB
- We plan to implement the sea ice correction as a pre-processor for routine L2B SSS retrieval. The specific parameters used in the algorithm will be fine-tuned through further development and validation, including
  - the search domain for sea ice pixels,
  - the dTB threshold for observation-driven filter,
  - the default for Tb^{ice}
- Understand the physics of polarization difference in scenes mixed with seawater and ice

The polarization difference (TbV-TbH) dependence on wind speed and SIC



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