Continuous Improvements to Calibrated, Enhanced-Resolution Brightness Temperatures (CETBs) for Near Real-Time Cryospheric Applications

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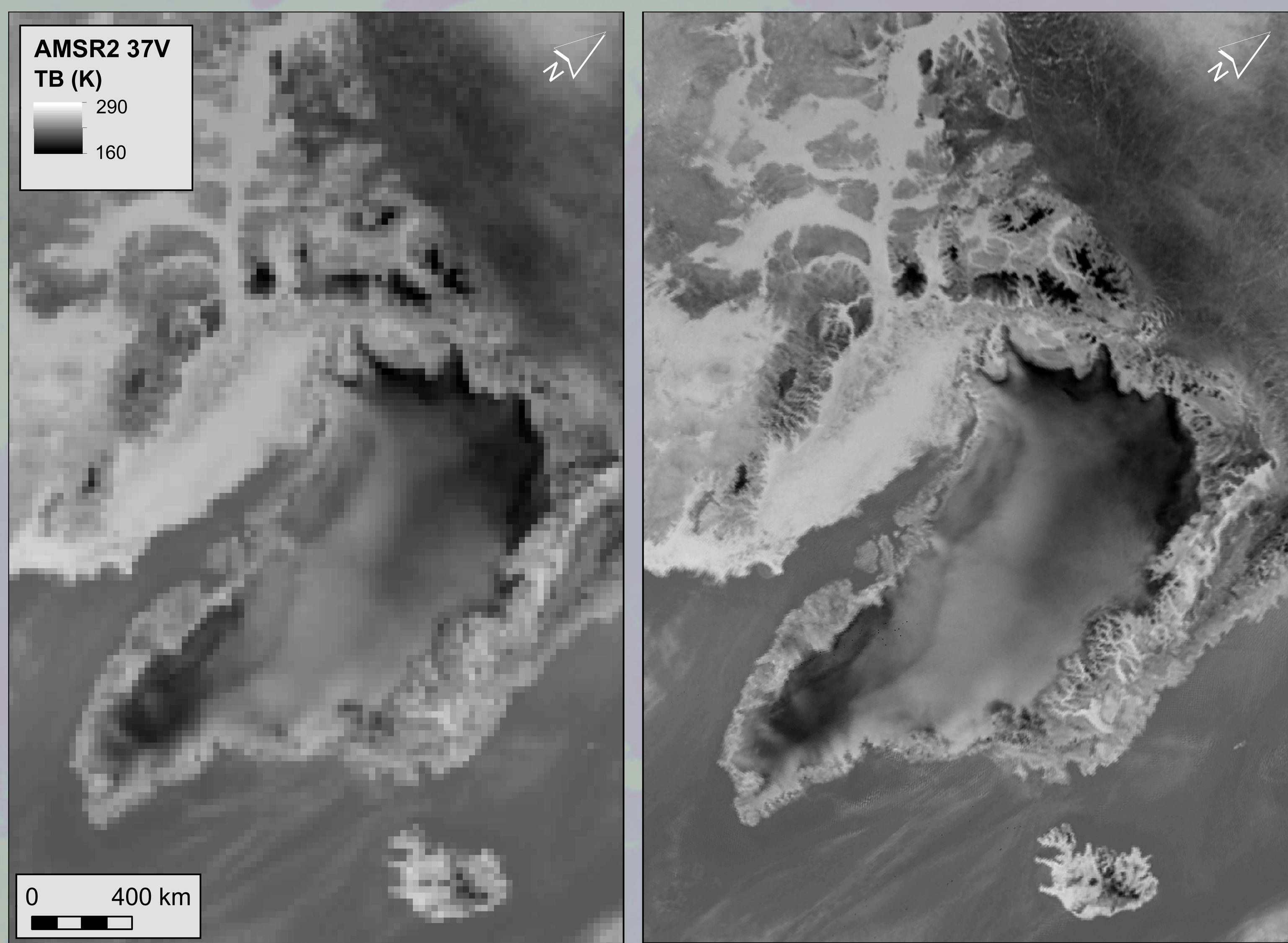
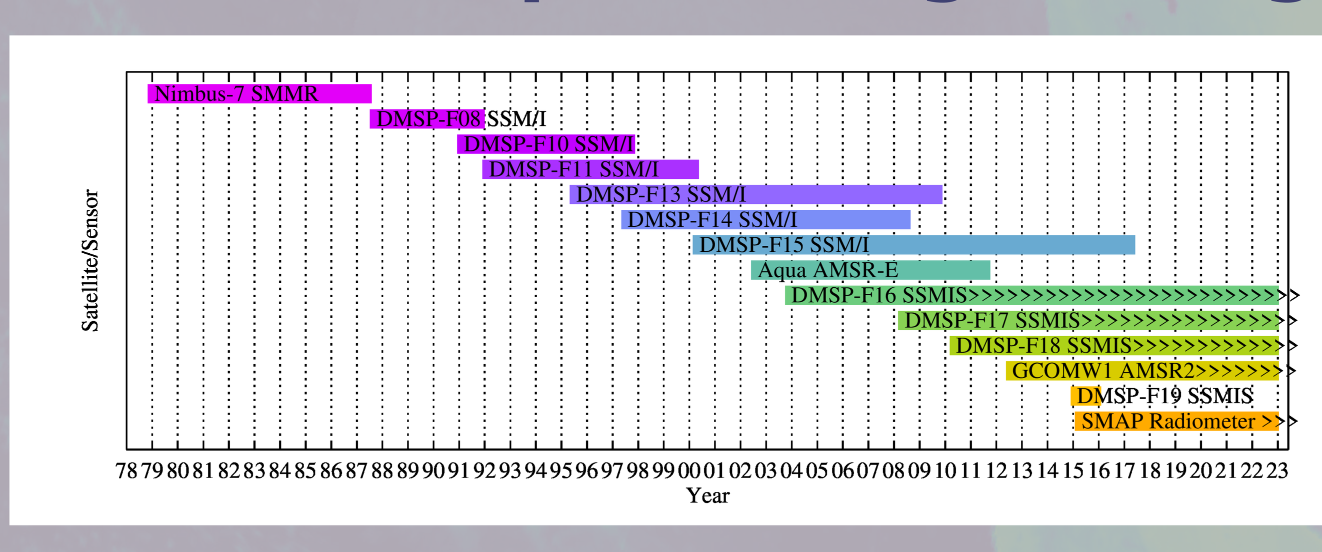
Objective



CETB data at conventional vs. enhanced-resolutions: AMSR2 37 GHz, vertically-polarized CETB low-noise, 25 km GRD (left) vs. enhanced-resolution, 3.125 km rSIR (right) Greenland, 04 Dec 2022. Note how rSIR enhanced resolution image reconstruction is resolving variability at sea ice edges and coastal fjords.

Since the release of the Calibrated, Enhanced-Resolution Brightness Temperature (CETB) Earth System Data Record (Brodzik *et al.*, 2016, updated 2022), the cryospheric research community has been using this long-term data record to improve and update derived geophysical parameters. This global, gridded data set is a fundamental tool in studying surprisingly rapid cryospheric change in the satellite era. *EASE-Grid 2.0* CETBs use an innovative computational algorithm, the radiometer version of Scatterometer Image Reconstruction (rSIR), to improve spatial resolution to 3 km, an effective improvement of 30-60% over conventional gridding techniques (Long and Brodzik, 2016). With data beginning in 1978, CETBs provide a 40+ year record of Earth's passive microwave emissions from multiple, often overlapping, polar orbiting sensors. In this presentation we highlight successful recent applications of the CETBs to advance understanding of the cryosphere for the benefit of human society.

CETBs in Near Real-time: Complete Version 2 Reprocessing Coming Soon

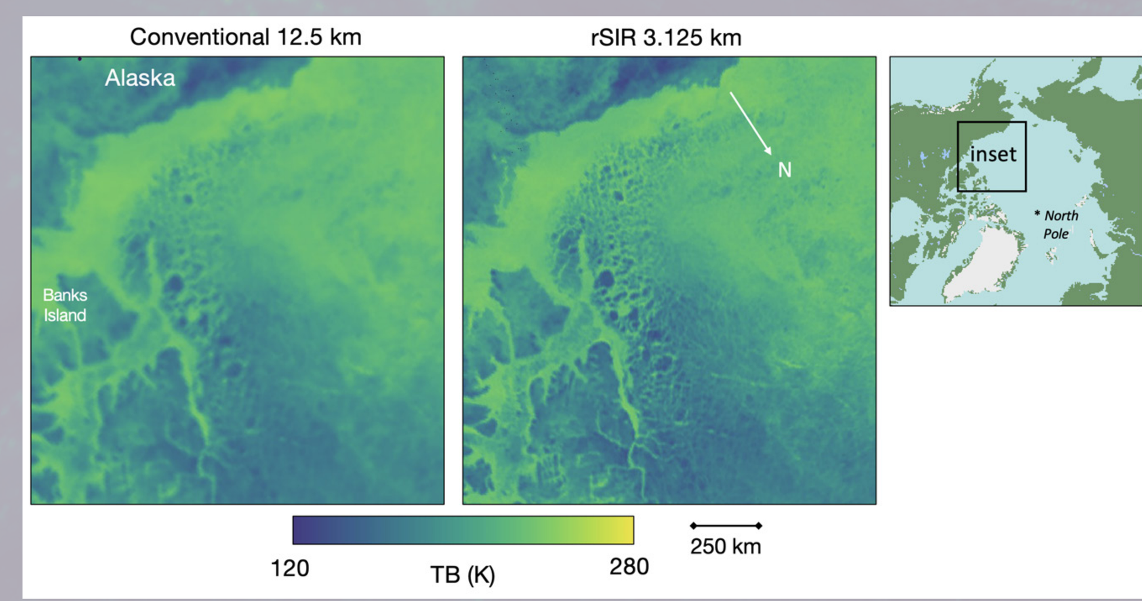


CETB passive microwave sensor timelines. Labels ending with ">>" indicate that sensor operation is ongoing in daily, near real-time, as of December 2022.

Recent sensor additions to CETBs include Advanced Microwave Scanning Radiometer 2 (AMSR2) and Soil Moisture Active Passive (SMAP) radiometer (Brodzik *et al.*, 2021, updated 2022). We now produce daily CETBs in near real-time for current operational sensors (3 SSMIS, SMAP radiometer and AMSR2). In 2023, we plan a complete CETB reprocessing as Version 2, using inputs from newly available L1C inputs (Berg *et al.*, 2018). Please contact *brodzik@colorado.edu* for advanced access to L1C-derived CETBs.

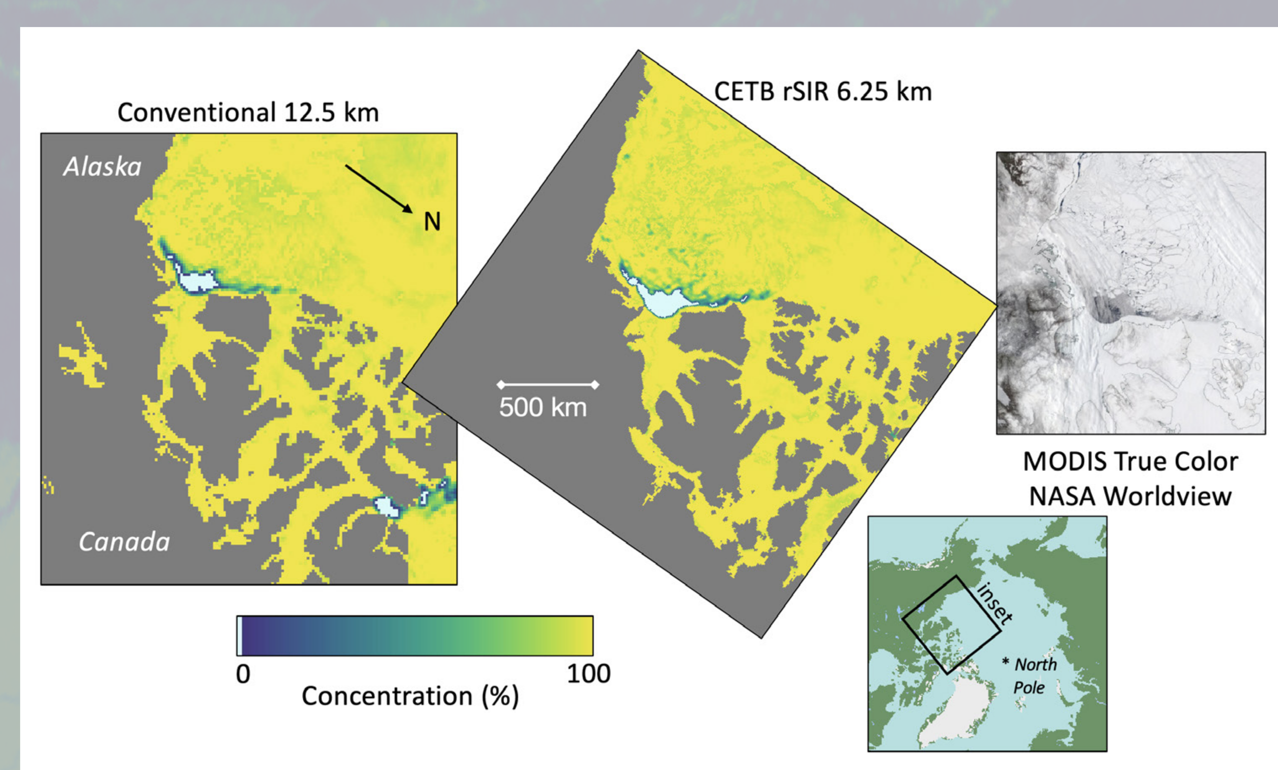
Freely distributed by the NASA NSIDC DAAC (nsidc.org), these reliable, high-quality, enhanced-resolution ESDRs are advancing our understanding of both spatial and temporal variability in cryospheric phenomena.

Improving Sea Ice Climate Records



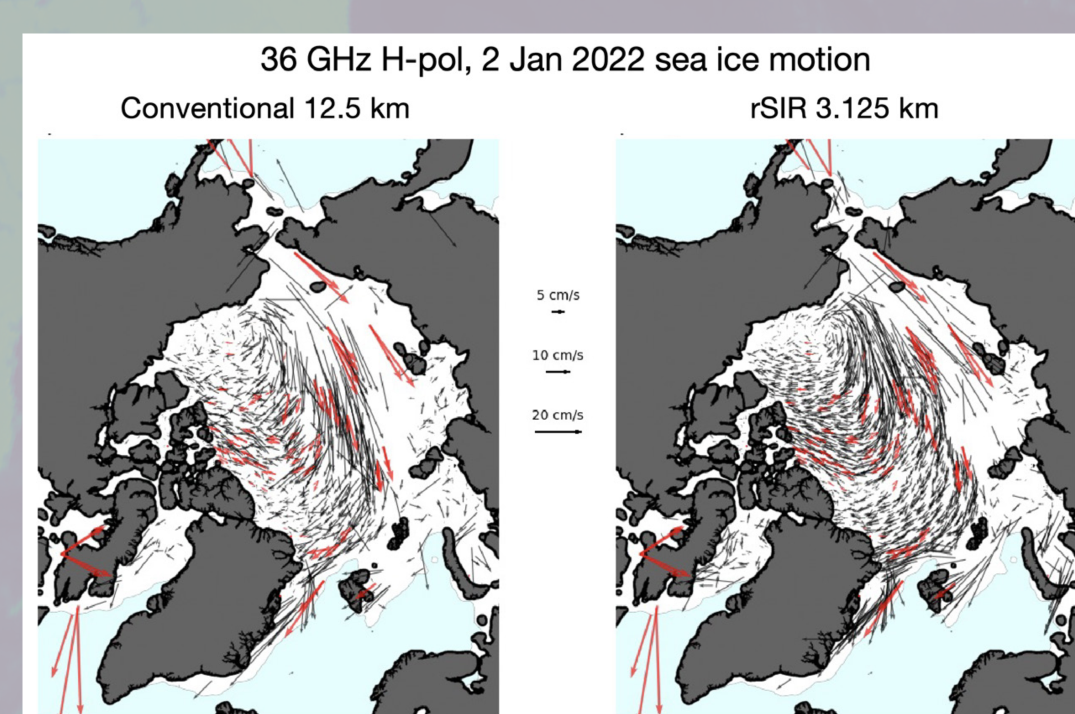
Improvement in spatial resolution for rSIR AMSR2 36 GHz TBs over sea ice in the Beaufort Sea, 02 Jan 2022. The multiyear sea ice floes (darker shades, lower TB values) are much sharper in the rSIR image than in the conventionally-gridded (drop-in-the-bucket) image at 12.5 km. The Alaska coastline detail is also sharper.

CETBs are improving our critical climate records of sea ice concentrations and ice motion. Conventional passive microwave grids at 12.5 km resolution are too coarse to map detail and variability in sea ice concentrations, and tend to "smear out" the ice edge. Enhanced-resolution CETB rSIR grids are improving our ability to detect small-scale details (ice floes, leads, polynyas) and to more accurately detect ice edge location (Meier and Stewart, 2020). Operational users at the National Weather Service Alaska Sea Ice Program are reporting positive feedback on rSIR spatial resolution improvements over currently-available products (Avila, 2022).



AMSR2 Bootstrap sea ice concentrations showing a polynya in the Beaufort Sea, 15 May 2022. The rSIR image (6.25 km) produces sharper ice edges and finer-scale features. Note the smeared ice edge and some thin open water areas that are missed in the conventional resolution. Although the MODIS image includes clouds, the it confirms the open water area and the sharp ice edge that is seen in the CETB image.

Our NOAA Climate Data Record (CDR) project (Meier *et al.*, 2021) is planning to use CETBs for the SMMR-SSMI-SSMIS time series together with AMSR-E and AMSR2 to create an improved, consistent long-term sea ice concentration CDR that will be extended into the future with ongoing AMSR2. We are currently quantifying the improvements to sea ice concentrations.



AMSR2 sea ice motion vectors (black, every 10th AMSR2 motion plotted) in the Arctic Ocean, 02 Jan 2022, demonstrating improvements by using CETB rSIR, compared with International Arctic Buoy Programme (IABP) buoy-derived motion vectors (red). The rSIR image yields a denser motion field (higher resolution) and less noise than the conventional (12.5 km) resolution fields.

We are also assessing improvements to sea ice motion fields, with plans to integrate CETBs to improve the NSIDC sea ice motion product (Tschudi *et al.*, 2019).

For a "look back" into the history of the passive microwave sea ice record, see tomorrow's poster by Meier and Parkinson (C22A-41).

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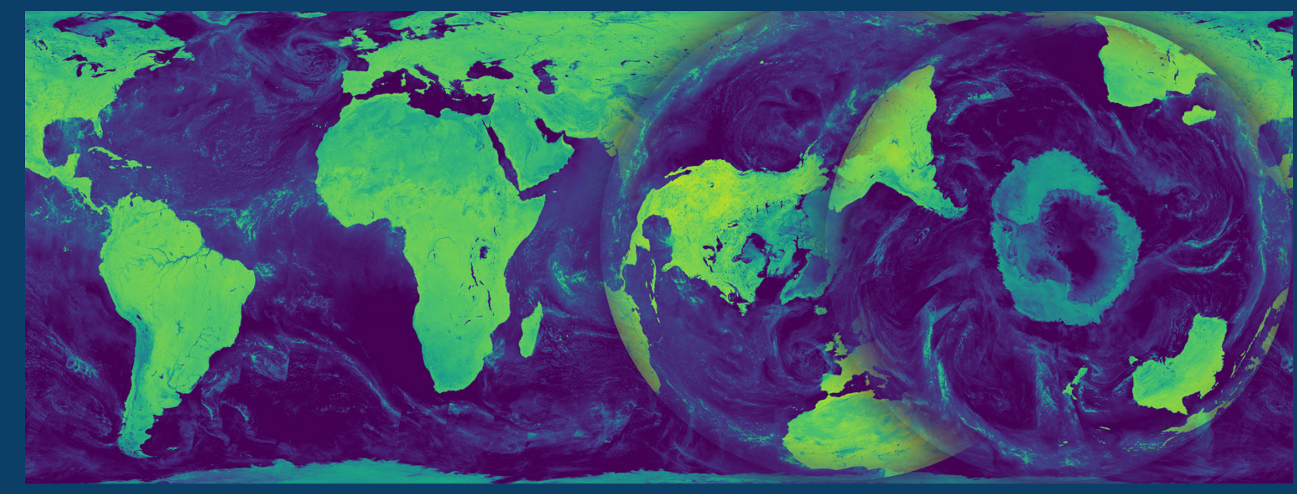
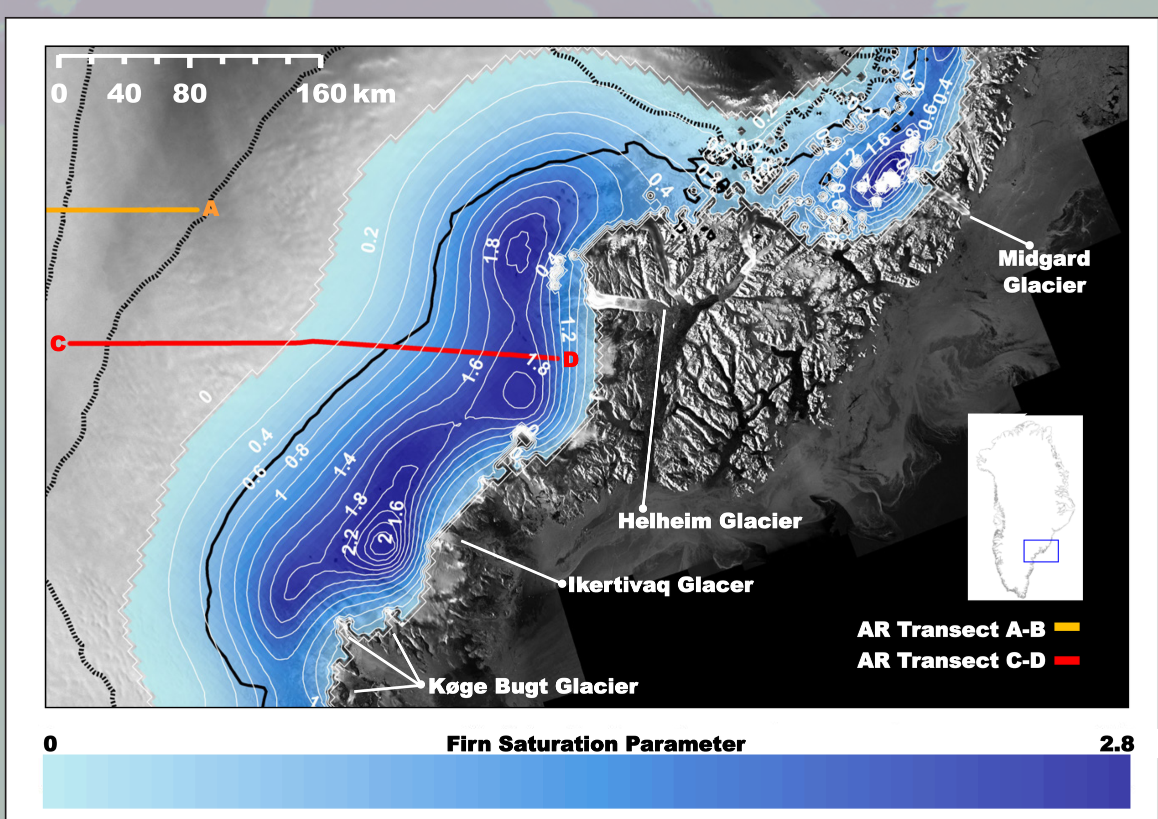
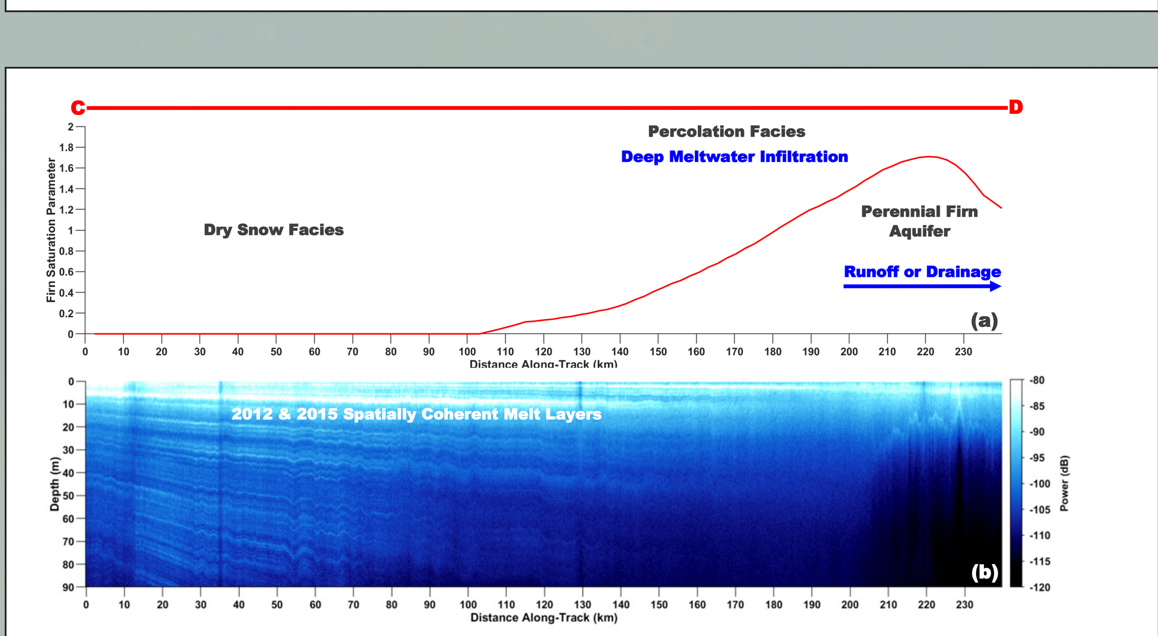
http://nsidc.org/pmesdr



Mapping Firn Saturation Location and Extent on the Greenland Ice Sheet



Firn saturation parameter (blues) and contour lines (white) derived from 1.4 GHz, vertically-polarized, SMAP radiometer rSIR CETBs, for glaciers in southeast Greenland, 2015-2019, overlaid on 2009-2010 winter season ALOS-PALSAR radar backscatter mosaic (grays).



Firn saturation parameter along transect C-D in direction of peripheral meltwater runoff, derived from 1.4 GHz vertically-polarized SMAP TBs and the two-layer L-band model, 2015-2019 (top), with CReSIS Accumulation Radar profile, 05 May 2017 (bottom).

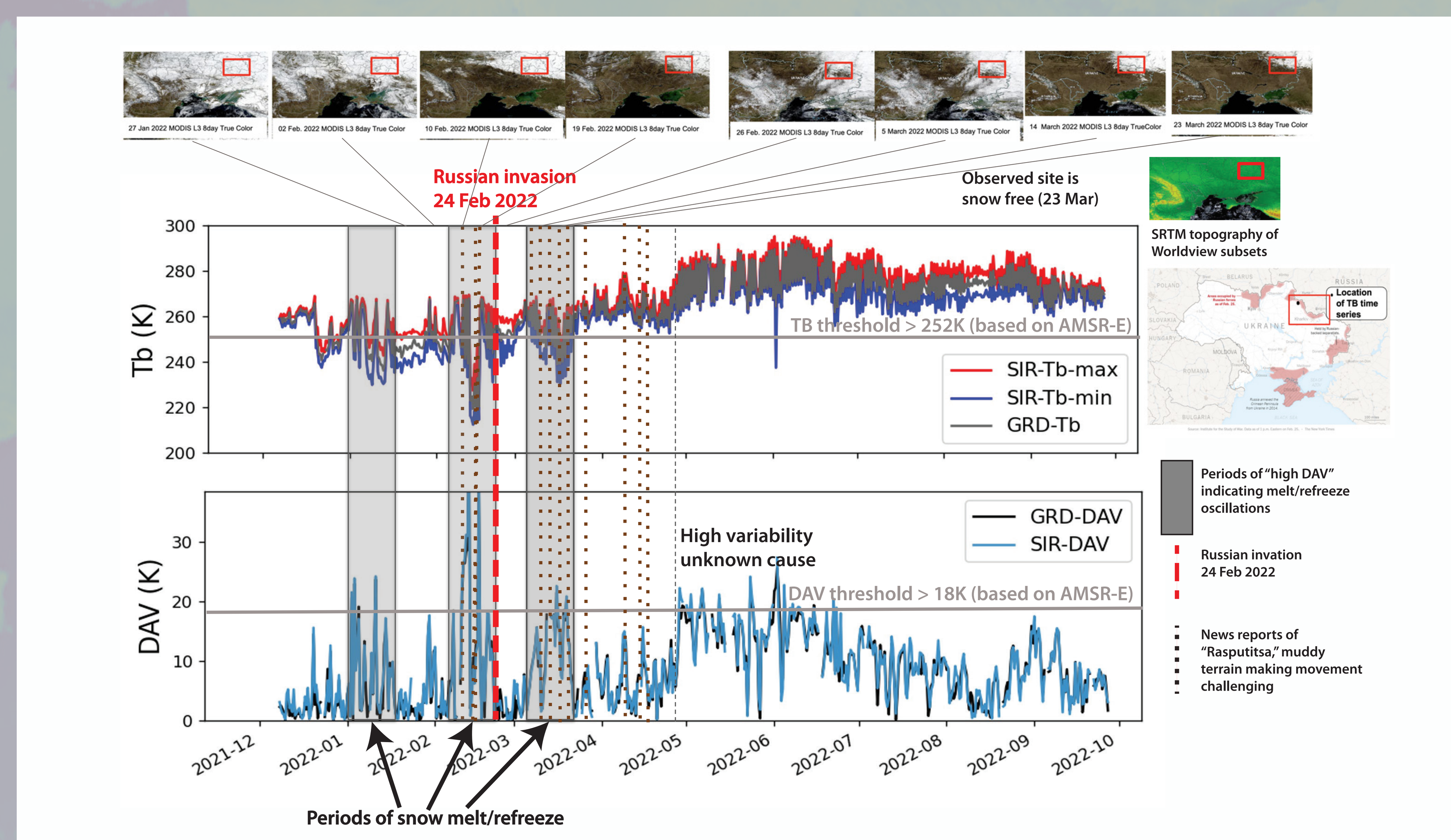
Using SMAP CETB rSIR brightness temperatures and a two-layer L-band brightness temperature model, we are mapping a *firn saturation* parameter that indicates spatial variability in thickness and volumetric fraction of seasonal meltwater stored within firn pore space at depth (Miller *et al.*, 2022). The firn saturation parameter identifies expansive englacial reservoirs that store significant volumes of meltwater year-round. Especially interesting are the perennial firn aquifer locations mapped above the fast-flowing (>100 m yr^{-1}) Helheim and Køge Bugt glaciers in southeastern Greenland. These large marine-terminating outlet glaciers were the second and fourth largest contributors of ice discharge from the Greenland Ice Sheet to the ocean between 1986 and 2020, respectively. Recent modeling studies suggest that if perennial firn aquifers intersect with crevasse fields and contain a sufficient volume of meltwater, they are capable of initiating meltwater-induced hydrofracturing through the full thickness (~1000 m) of the Greenland Ice Sheet. Meltwater-induced hydrofracturing is capable of delivering meltwater stored in englacial reservoirs to the subglacial hydrological system, which may lead to the localized acceleration of outlet glaciers, peripheral ice discharge and mass loss to the ocean.

For more details on related firn aquifer research, see this afternoon's poster by Scambos et al. (C15D-0609) & tomorrow's talk by Miller et al. (C22B-05).

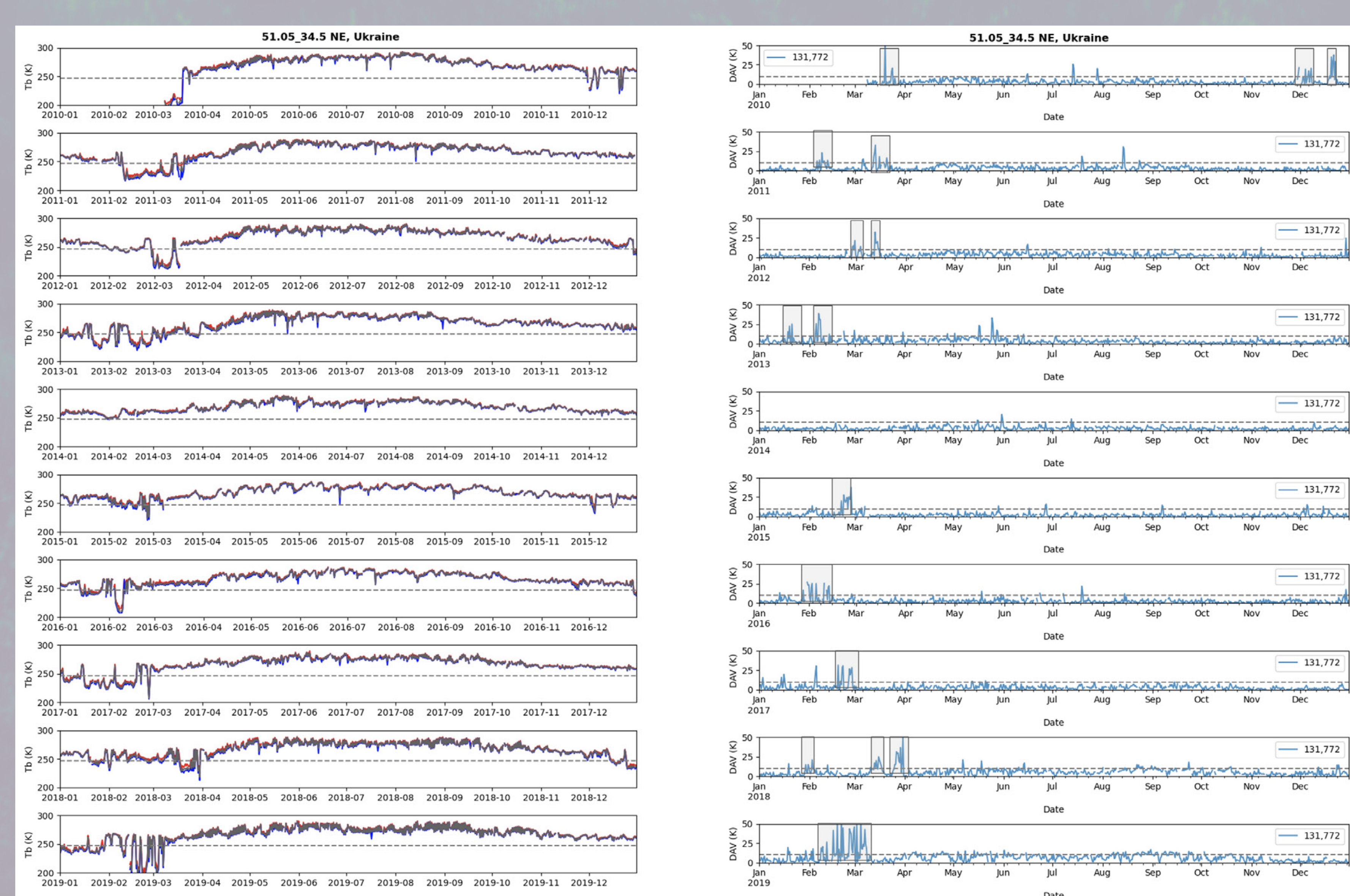
For more details on related melt onset research, see nearby poster in this session: Jagdeo et al. (C12B-0576).

Detecting Melt Onset to Inform Military Mobility

CETBs have improved our ability to detect snow melt timing at finer spatial resolutions and in heterogeneous terrain. Strategic military planners in cold regions need to monitor both the surface state and potentially fast transitions between frozen and thawed snow and soil. Preliminary work at a mid-latitude site in Eastern Ukraine is correlating snow melt timing with popular news accounts of *Rasputitsa*, or "muddy, impassable terrain."



Time series of AMSR2 36 GHz, vertically-polarized CETBs, Dec 2021 - Oct 2022, at agricultural site northwest of Kharkiv, Ukraine, near inital Russian invasion operations. MODIS Worldview 8-day composites, 27 Jan - 23 Mar 2022 (top row) provide snow-covered area context, indicating the CETB site location was snow covered until about 23 Mar. Diurnal Amplitude Variation (DAV), the absolute value of adjacent day-night CETB differences, (bottom) represents snow melt/refreeze or soil freeze/thaw. Melt windows (gray boxes) indicate when TB and DAV thresholds are exceeded (thresholds from AMSR-E, Johnson *et al.*, 2020). News reports of *Rasputitsa* (dotted brown lines) tended to coincide with melt/refreeze events.



To assess typical snow melt timing (and likelihood of rasputitsa), we plot time series of SSMIS 36 GHz vertically-polarized CETB (left) and DAV (right), for the same agricultural site northwest of Kharkiv, 2010-2019. The DAV plots include periods of potential melt (gray boxes), showing high interannual variability, with typical melt periods occurring from December to April. No potential melt period was detected in 2014.

This research is ongoing. Next steps include algorithm tuning by geographical region and further investigation of spatial and temporal variability of melt/refreeze cycles in cold regions, as potential decision support for mobility operations.

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