Enhancing the NSIDC sea ice motion and age products for an improved long-term climate record of sea ice change

Walter N. Meier[1,2], J. Scott Stewart[1,2], Mark A. Tschudi[2], and Chuck Fowler[2]
[1]National Snow and Ice Data Center, Cooperative Institute for Research in Environmental Sciences; [2]University of Colorado Boulder

Why do we estimate sea ice motion?

- Sea ice motion is an essential climate variable (Lavergne et al., doi:10.1175/BAMS-D-21-0227.1).
- Along with thermodynamic processes, motion plays an important role in the seasonal and interannual evolution of the sea ice.
- Sea ice speed has been increasing in the Arctic, indicating a thinner and younger ice cover.
- A regime shift has been observed that includes a shorter sea ice residence time in the Arctic, in part due to faster ice motion (Sumata et al., 2023, doi:10.1038/s41586-022-05686-x).

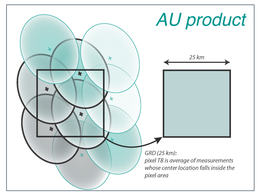
How do we estimate sea ice motion?

- Motion can be tracked from satellite imagery via feature tracking algorithms, and from buoy position data.
- The NSIDC product, using the Maximum Cross-Correlation (MCC) method for satellite imagery, was originally established in May 2003. Various improvements have been made over time.
- The product primarily employs passive microwave imagery (using MCC), augmented by visible imagery, reanalysis wind-forcing, and IAPB buoys.
- All sources are interpolated into a combined field via a optimal interpolation method.

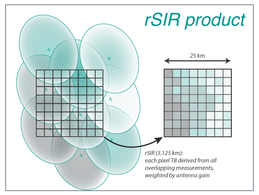
How are we improving estimates of sea ice motion?

- Passive microwave imagery provides complete daily coverage in all-sky conditions, but has low spatial resolution, which limits the accuracy and precision of the retrieve motion estimates.
- The rSIR method uses overlapping sensor footprints and signal processing techniques to synthesize a higher spatial resolution, improving the effective resolution 30 to 50% over the standard gridded resolution.
- Here we demonstrate that using enhanced resolution imagery from the rSIR method yields substantially improved motion estimates and a denser motion field.

STANDARD RESOLUTION



ENHANCED RESOLUTION



AMSR2 Frequency	Native Sensor Footprint	Standard Gridded Resolution	rSIR Enhanced Resolution
18.7 GHz	22 x 14 km	12.5 km	6.25 km
36.5 GHz	12 x 7 km	12.5 km	3.125 km
89.0 GHz	5 x 3 km	6.25 km	3.125 km

How will we further improve the sea ice motion product?

- AMSR2 will be added to the current product and rSIR TBs will be used for all passive microwave sources.
- New correlation length scales and weightings will be calculated for all sources.
- Buoy and wind-forcing sources will be better integrated with each other and with other sources.
- The optimal interpolation method will be rewritten using standard (e.g., python) toolkits.
- The product will be produced on the standard polar EASE2 grids instead of modified EASE1 grids.
- Source code will be documented and published.

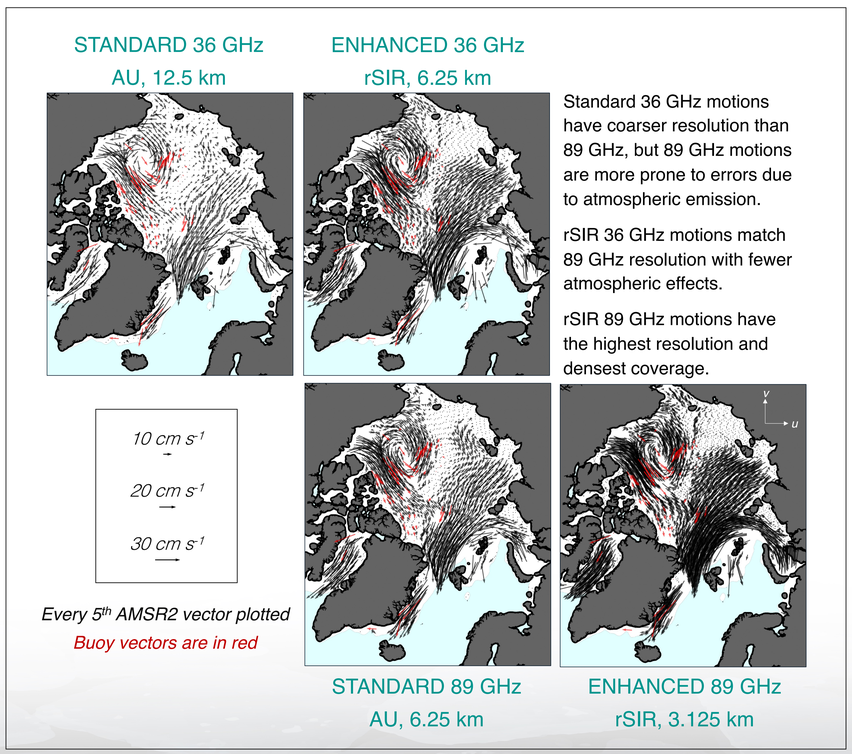
The Yada-Yada (Methodology)

- Motions were derived JAXA Advanced Microwave Scanning Radiometer 2 (AMSR2) gridded brightness temperature fields.
- Two data products were used, both gridded on EASE2:
  - NASA AMSR2 (AU) – standard resolution
  - rSIR AMSR2 – enhanced resolution
- The Maximum Cross-Correlation method was run on the following AMSR2 TBs (horizontal polarization) inputs [grid resolution]:
  - 36 GHz AU_SI12 [12.5 km]
  - 36 GHz rSIR [6.25 km, upscaled from 3.125 km]
  - 89 GHz AU_SI6 [6.25 km]
  - 89 GHz rSIR [3.125 km]
- Motions were derived where sea ice concentration >15% and at locations that are at least two grid cells from land.
- Correlation threshold and neighborhood vector filters were applied.
- Daily motion fields created for 1 November 2022 – 30 April 2023/
- IABP buoys were used for validation. Each buoy was compared to the closest AMSR2 estimate, with a maximum distance of 50 km.

The Bottom Line (Conclusions)

- The enhanced resolution rSIR TBs improve sea ice motion estimates over standard resolution AU TBs:
  - RMS errors relative to buoys are reduced ~25-30%
  - Biases are reduced as well
  - 36 GHz motion errors reduced more than 89 GHz
- rSIR yields a denser vector field, potentially obtaining more fine-scale motions.
- There is also the potential to use rSIR at 18 GHz for summer motions, which will improve estimates during the melt season.

Comparison of Standard vs. Enhanced: Example visualization of motion, 8 March 2023



Standard 36 GHz motions have coarser resolution than 89 GHz, but 89 GHz motions are more prone to errors due to atmospheric emission.

rSIR 36 GHz motions match 89 GHz resolution with fewer atmospheric effects.

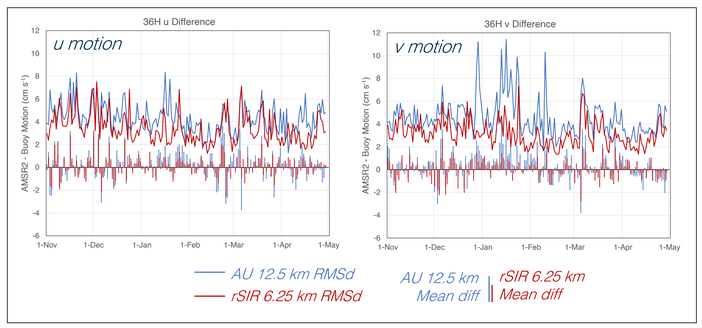
rSIR 89 GHz motions have the highest resolution and densest coverage.

Every 5th AMSR2 vector plotted

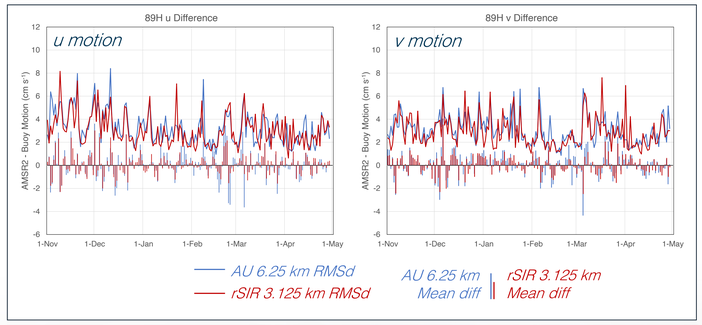
Buoy vectors are in red

Comparison of Standard vs. Enhanced: Error Statistics, November 2022 to April 2023

36 GHz difference with buoys



89 GHz difference with buoys



Units: cm s-1		36 GHz 12.5km AU_SI12	36 GHz 6.25 km rSIR	89 GHz 6.25 km AU_SI6	89 GHz 3.125 km rSIR	36 GHz rSIR-AU	89 GHz rSIR-AU
Mean Difference	u	0.21	0.11	0.05	0.07	-0.10	+0.02
	v	0.33	0.01	0.08	0.01	-0.32	-0.07
RMS Difference	u	4.34	3.41	3.28	3.05	-0.93	-0.23
	v	4.59	3.13	3.07	2.87	-1.46	-0.20

Data References

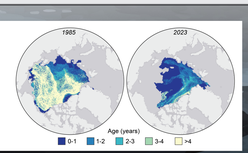
- NSIDC Sea Ice Motion Product: Tschudi et al., 2019, doi:10.5067/INAWUWO7QH7B
- rSIR TBs: Brodzik et al., 2016, doi:10.5067/MEASURES/CRYOSPHERE/NSIDC-0630.001
- NASA AMSR2 12.5 km TBs (AU_SI12): Meier et al., 2018, doi:10.5067/RA1MIJOYPK3P
- NASA AMSR2 6.25 km TBs (AU_SI6): Meier et al., 2018, doi:10.5067/NX1R09ORNOZN
- IABP buoy positions: International Arctic Buoy Programme, https://iabp.apl.uw.edu

In memory of Chuck Fowler, 1946 - 2023

Chuck developed the original MCC software and was instrumental in producing the original NSIDC sea ice motion product. He was a proficient programmer who was always able to find innovative solutions to challenges that arose. He is missed by NSIDC and the current sea ice motion project team.

Did you know?

We also have a sea ice age product! It was also created by Chuck, derived from the ice motions and will also be updated from the enhanced motion product.



CIRES Rendezvous, 16 May 2024

Acknowledgments

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