Empirical corrections and quality control of ocean surface winds from scatterometers due to contamination from sea-ice, rain, and other sources

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ABSTRACT: While working on neural network methods to correct ScatSAT and QuikSCAT scatterometer data for rain as part of an OVWST funded task, we found artifacts in the Arctic and Antarctic that limit the usefulness of the Ku-band scatterometer winds. We also found serendipitously that the method we were using for rain correction shows promise for achieving better quality control and data correction ability for ocean surface winds in polar regions.

A neural network was trained to output the expected difference between C-band and Ku-band scatterometer wind speed given network inputs of Ku-band backscatter, Ku-band brightness temperature, and instrument geometry. Because Ku-band data is much more sensitive to rain than C-band, C-band winds are used as a proxy for winds without rain contamination so that the difference between the two wind retrievals serves as both an estimate of the amount of rain contamination for use in flagging and the correction to apply to the Ku-band wind speed.

Neural network weights were tuned using C-band ASCAT-B and ScatSat data collocated within 30 minutes. The rain correction was then applied autonomously to ScatSat and QuikSCAT data for which co-located C-band wind speeds were not available. The neural network rain correction was serendipitously found to also improve wind speeds near sea-ice edges and to remove wind speed biases due to unflagged backscatter artifacts in one of the four azimuth looks.

For our newly funded OVWST task, we plan to sort scatterometer data into three categories: data that does not need sea-ice correction; data that is too extensively contaminated by sea-ice to offer the possibility of correction; and data that needs correction but is correctable. We will then design two neural networks: one to correct sea-ice contamination in C-band scatterometer data and one to correct sea-ice contamination in Ku-band scatterometer data. The design process will, of necessity, be iterative as we will need to attempt correction to better understand what is and is not correctable.

ScatSAT-ASCAT

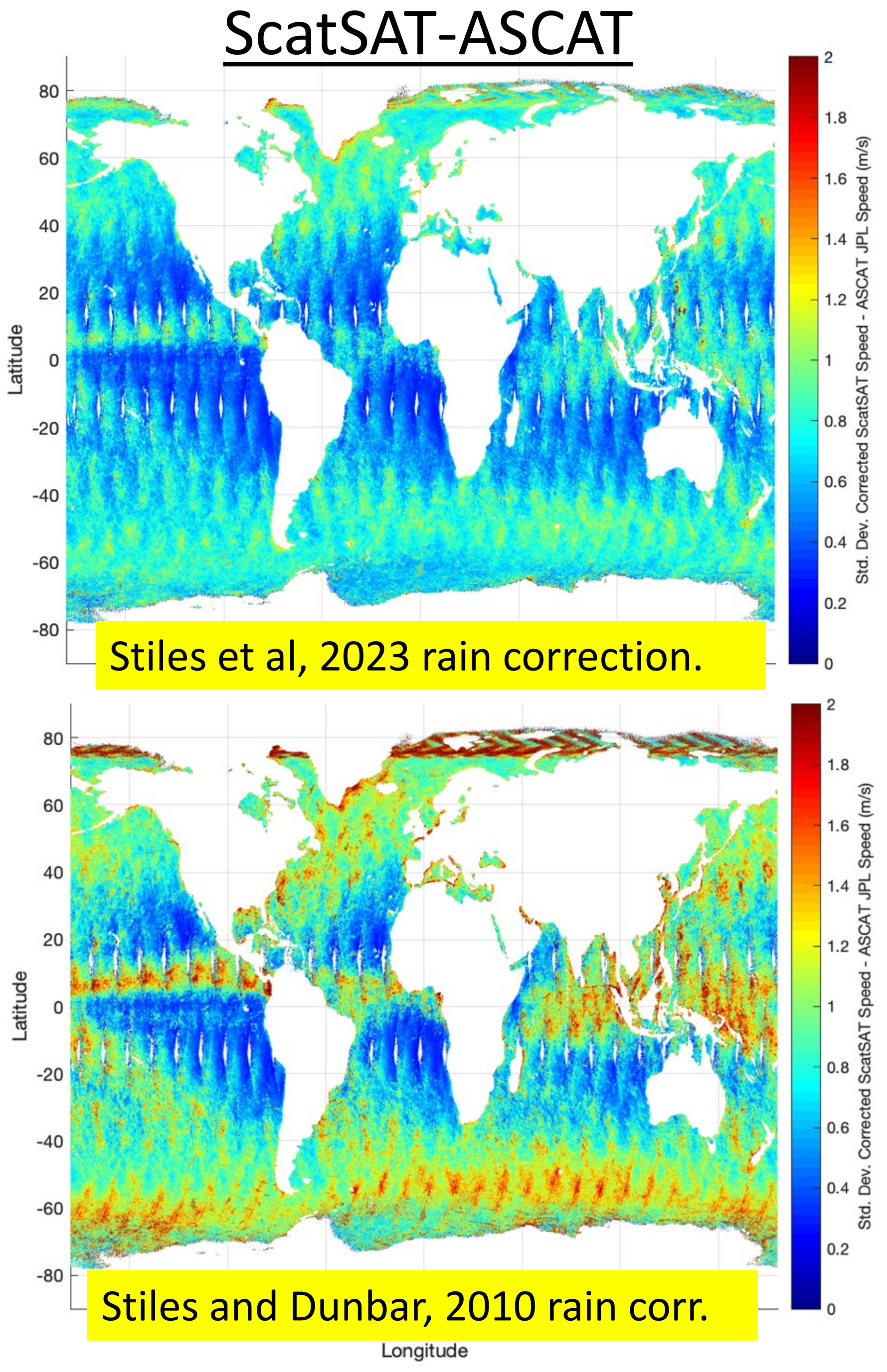

Figure 1. *Root Mean Square Difference between ASCAT and ScatSCAT speeds over one year, Top panel: Using new neural network correction tuned using ASCAT and ScatSAT colocations. Bottom panel: Using neural network rain corrections from Stiles and Dunbar, 2010. In both panels all winds are shown including those flagged as rain contaminated. Note that the new correction also serendipitously improves the RMS differences in the polar regions by removing artifacts in ScatSAT data near the poles, but residual ice contamination remains as evidenced by red halos near the Northern and Southern edges of the valid data region. Sea-ice flagging for scatterometers is performed autonomously to avoid time-varying errors associated with publicly available ice masks, but how strict that flagging is done varies among platforms and data producers.*

QuikSCAT

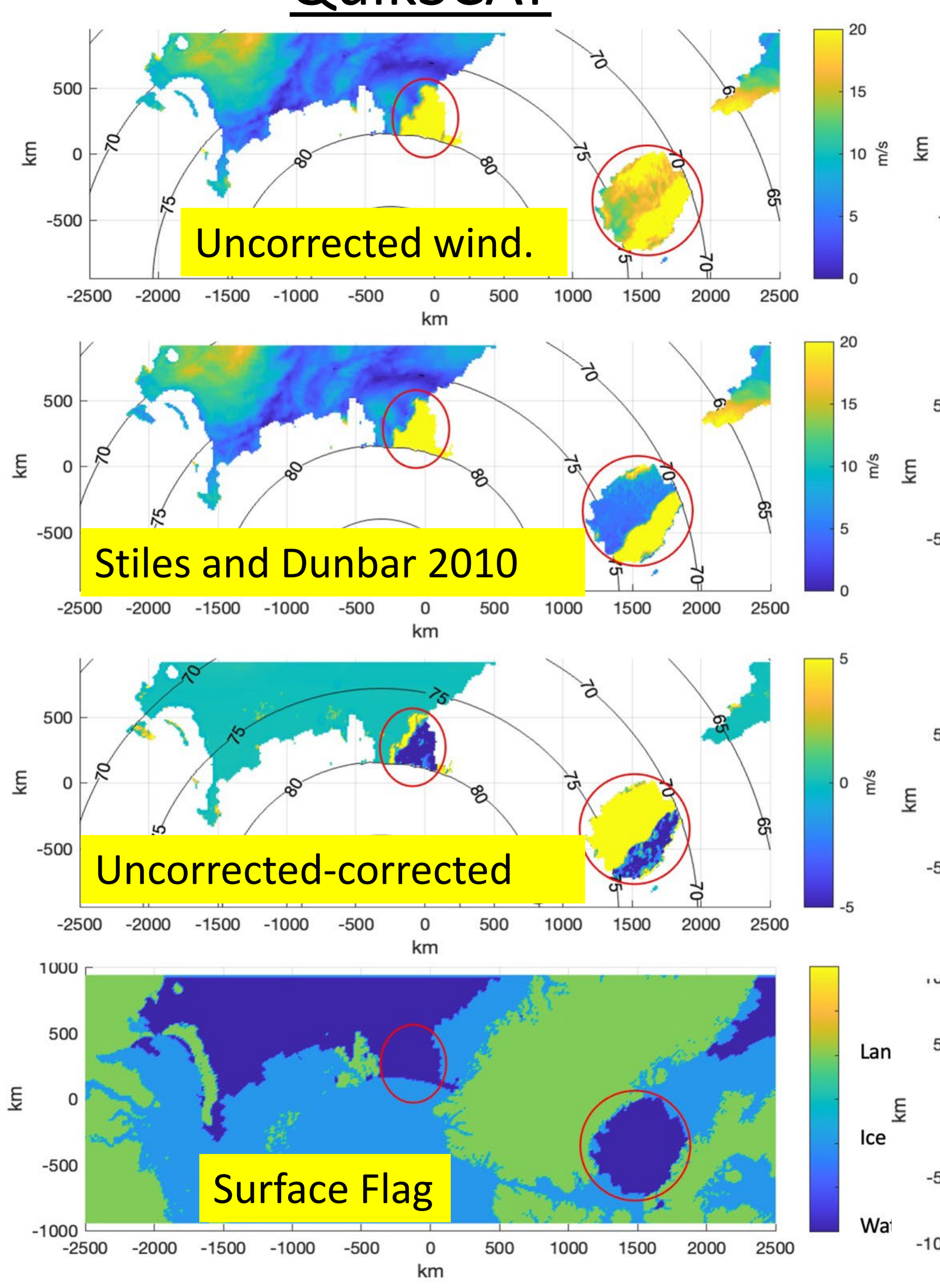

Figure 2. *Single orbit example of poor QuikSCAT sea ice flag from orbit #44514 acquired from 22:40 UTC January 5, 2008 to 00:21 UTC January 6, 2008. From top to bottom: QuikSCAT wind speed without neural network rain correction; QuikSCAT wind speed with neural network rain correction (Stiles and Dunbar 2010); the difference of the uncorrected and corrected QuikSCAT speeds; QuikSCAT land, sea-ice, and open water masks. Circled regions are sea-ice that was erroneously treated as open water in QuikSCAT processing. These regions are indicated by unphysically abrupt transitions to high QuikSCAT wind speeds, and large magnitude neural network speed corrections. Contours are latitude in degrees.*

ASCAT-B

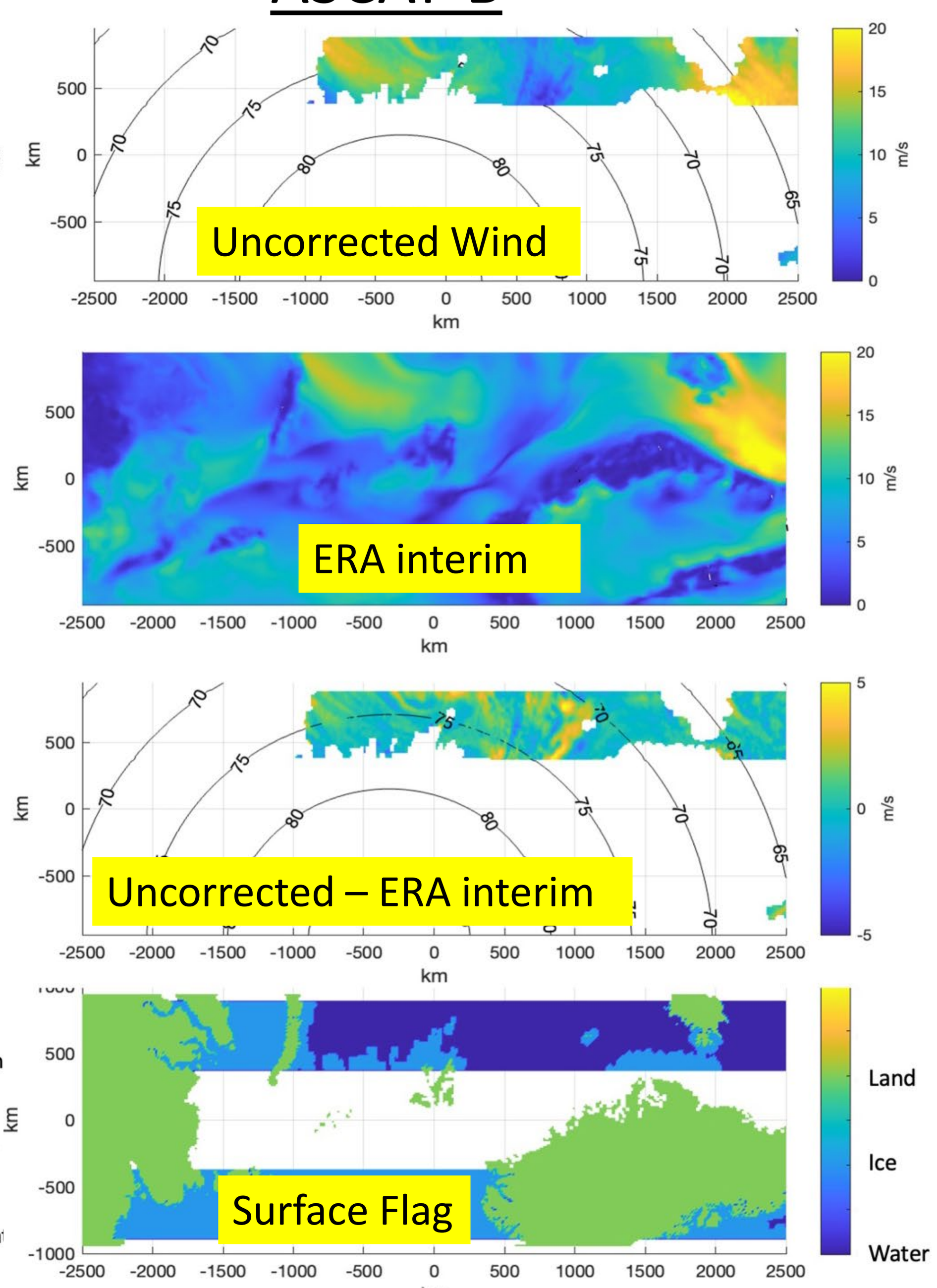

Figure 3. Single orbit example of ASCAT-B data for orbit #33143 acquired from 12:23 to 14:04 UTC on February 6, 2019. From top to bottom, panels are ASCAT wind speed; ERA Interim wind speed; difference between ASCAT and ERA Interim speeds; ASCAT land, sea-ice, and open water masks. This is a typical example with the median RMS difference between ASCAT and ERA-Interim. There is no indication of sea-ice contamination. Quality control appears to be good. White area in bottom panel is the gap in the center of the ASCAT swath where winds cannot be retrieved due to poor viewing geometry.

ScatSAT

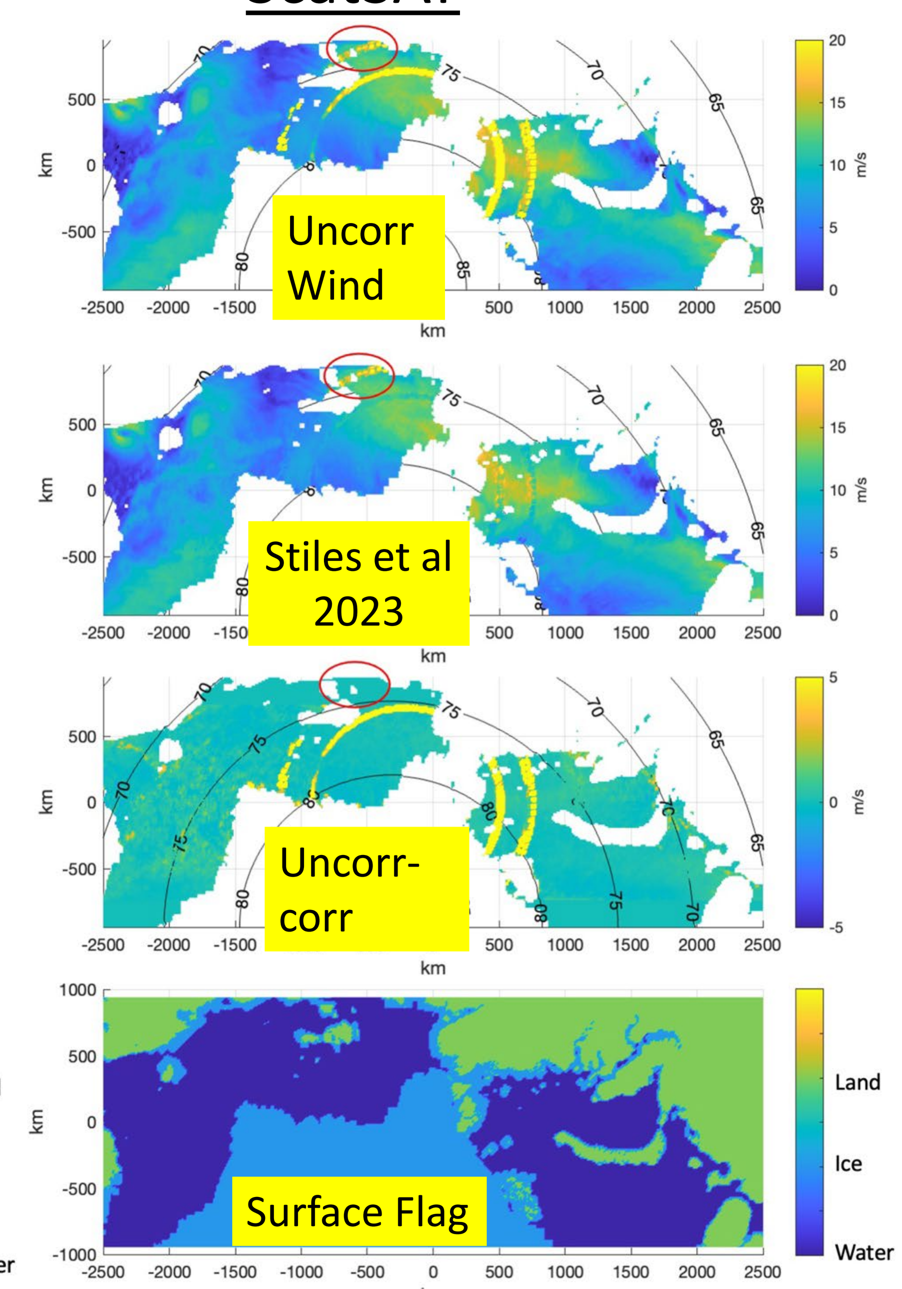

Figure 4. *Single orbit example of SCATSAT artifact from orbit #15820 acquired from 05:12 to 06:52 UTC on September 22, 2019. From top to bottom: ScatSAT wind speed without neural network rain correction; ScatSAT wind speed with neural network rain correction (new neural network trained using ASCAT/ScatSAT colocations); the difference of the uncorrected and corrected ScatSAT speeds; ScatSAT land, sea-ice, and open water masks. The artifact is characterized by erroneously high wind speeds along two circles (inner and outer beam) which correspond to a single rotation of the dual beam antenna. Note that the neural network rain correction tends to remove the artifact except for regions (red circle) in the outer single-beam portion of the Swath where the neural network correction is not applied due to lack of information. The neural network corrects speeds using information from 4 azimuth looks (fore and aft measurements from both inner and outer beams). Its performance with respect to the single rotation artifact suggests it is robust to large backscatter error from a single azimuth look. A single bad rotation contributes at most one bad azimuth look to each wind vector cell.*

Platform	Year	Rain Corrected?	RMS Q1	RMS Q2	RMS Q3	RSF Q1	RSF Q2	RSF Q3
QuikSCAT	2008	Yes, 2010	2.41	14.7	22.24	0.676	0.878	0.924
QuikSCAT	2008	No	2.42	17.32	31.96	0.676	0.878	0.924
ASCAT A	2008	No	1.96	2.16	2.47	0.511	0.615	0.665
ASCAT B	2019	No	1.66	1.76	1.95	0.487	0.599	0.664
ScatSat	2019	Yes, 2023	1.84	2.38	2.51	0.703	0.901	1
ScatSat	2019	No	1.96	3.21	25.05	0.703	0.901	1

Table 1. One-Year Scatterometer Wind Speed Statistics with respect to ERA Interim for latitudes poleward of 60 degrees, Current Flagging, RMS=Root mean square difference (m/s), RSF = Relative Sampling Frequency, Q1 = High Quality, Q2=Medium quality, Q3=All retrieved winds

The relative sampling frequency (RSF) reported in Tables 1 and 2 is proportional to the area of retrieved winds per orbit for each instrument and QC method. The value is scaled so that RSF=1 corresponds to the instrument/QC combination with the greatest frequency of coverage.

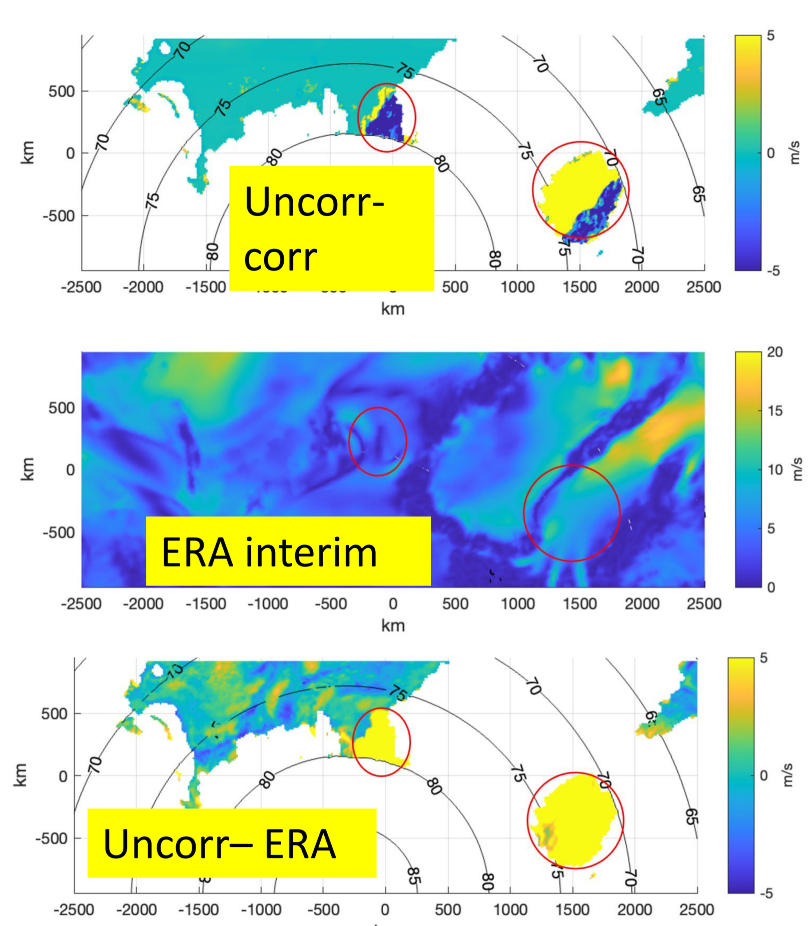

Figure 5. Comparison with ERA Interim neutral equivalent wind speeds for QuikSCAT orbit shown in Figure 2. Top panel is the difference between the uncorrected and neural network corrected QuikSCAT speeds. Middle panel is ERA Interim winds. Bottom panel is the difference between the uncorrected QuikSCAT speeds and the ERA Interim wind speeds. Note that the circled regions also have large positive speed biases with respect to ERA Interim winds as one would expect if they are actually sea-ice rather than open ocean.

Platform	Year	Rain Corrected?	Speed RMS Diff< 1.0 m/s	Speed RMS Diff<20 m/s	Direction RMS Diff< 1.0 m/s	Direction RMS Diff<20 m/s	RSF Diff< 1.0 m/s	RSF Diff<20 m/s
QuikSCAT	2008	Yes, 2010	2.39 m/s	4.45 m/s	22.7 deg	25.1 deg	0.794	0.862
QuikSCAT	2008	No	2.40 m/s	4.88 m/s	22.7 deg	25.1 deg	0.794	0.862
ScatSat	2019	Yes, 2023	1.53 m/s	1.59 m/s	19.3 deg	21.0 deg	0.868	0.919
ScatSat	2019	No	1.56 m/s	1.96 m/s	19.3 deg	21.0 deg	0.868	0.919

Table 2. One-Year Scatterometer Wind Speed Statistics with respect to ERAInterim for latitudes poleward of 60 degrees, Flagging using difference between corrected and uncorrected speeds

Related Papers:

Fore, A.G.; Stiles, B.W.; Strub, P.T.; West, R.D. “QuikSCAT Climatological Data Record: Land Contamination Flagging and Correction.” Remote Sens. 2022, 14, 2487. https://doi.org/10.3390/rs14102487

Stiles, B. W., Danielson, R.E, et al, "Optimized Tropical Cyclone Winds From QuikSCAT: A Neural Network Approach," Geoscience and Remote Sensing, IEEE Transactions on , vol.52, no.11, pp.7418,7434, Nov. 2014 doi: 10.1109/TGRS.2014.2312333

Stiles, B. W. and R. S. Dunbar, "A Neural Network Technique for Improving the Accuracy of Scatterometer Winds in Rainy Conditions," in *IEEE Transactions on Geoscience and Remote Sensing*, vol. 48, no. 8, pp. 3114-3122, Aug. 2010. doi: 10.1109/TGRS.2010.2049362

Paper in preparation:

Stiles, B.W., Fore, A.G, Wineteer, A.G. et al, “A neural network technique for estimating C-band winds from Ku-band data in rainy conditions” 2023.