Analysis of Passive Microwave and Enhanced-Resolution Scatterometer Sea Ice Estimates

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Introduction

The SeaWinds scatterometer on NASA's QuikScat satellite now provides routine daily coverage of Arctic and Antarctic sea ice. Scatterometer data is an important complement to the long-running SSM/I passive microwave (PM) sea ice timeseries. While scatterometers and PM radiometers both operate in the microwave frequencies, scatterometers are active instruments and can potentially provide improved or additional information on sea ice conditions. The nominal spatial resolution (25-50 km) and coverage of both QuikScat and SSM/I is similar. However, techniques have been developed to use multiple swaths to enhance spatial resolution. Effective resolutions of 8-10 km have been achieved, though there is a cost of longer time averaging and higher noise the fields. Here, enhanced-resolution QuikScat extents are compared to non-enhanced SSM/I ice concentrations from the NASA Team (NT) algorithm produced at NASA Goddard and archived online at NSIDC (http://nsidc.org/data/seaice/). The ice edge from each is evaluated and compared to visible and infrared imagery from AVHRR.

QuikScat Data

QuikScat raw backscatter data is obtained in two modes. "Slices" have a footprint 4-6 km along-track and 20 km cross-track. "Slices" are summed into "eggs" ~20x30 km. Resolution of QuikScat raw imagery is enhanced using the Scatterometer Image Reconstruction with Filtering (SIRF) algorithm (*Early and Long*, 2001). The SIRF algorithm yields sea ice "slice" fields with an effective resolution of ~4 km, gridded onto a 2.225 km polar stereographic projection; "egg" fields have an effective resolution of ~8-10 km and a gridded resolution of 4.45 km. Sea ice extent is computed from backscatter based on polarization ratio, incidence angle, backscatter standard deviation, and filtering techniques (*Remund and Long*, 1999). Egg and slice fields are processed slightly differently to obtain consistent extents from both. QuikScat extent fields are archived at NSIDC and are also available through the NASA Scatterometer Climate Record Pathfinder and Brigham Young University.

Issues with QuikScat Extents

The enhanced-resolution QuikScat fields provide useful information on sea ice extent. However, the current fields have some limitations. First, the spatial coverage in the Arctic is limited to poleward of 60°N. Thus, in winter, many ice-covered areas are not included, such as the southern Sea of Okhotsk, Bering Sea, and Hudson Bay – up to 4×10^6 km^2 of ice during the winter maximum extent. Also, the resolution-enhancement results in a noisier field. Usually, this amounts to minor variability along the ice edge, but occasionally can be significant. A 5-day centered running mean was implemented for the timeseries comparison with the SSM/I fields.

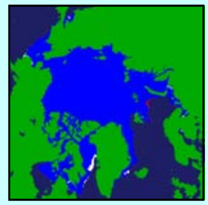

Figure 1. QuikScat egg field for 23 Jan 2000. In light blue are areas where ice occurred on all 5 days of the running mean (i.e., 21-25 Jan). White represents areas where ice was found on the surrounding four days, but not the 23rd. Red represents area where ice was found on the 23rd but not on any of the other four days. Note also the coverage extending only 60°N.

Comparison of QuikScat and SSM/I Sea Ice Extent

In previous studies, the 15% SSM/I ice concentration threshold has been found to be most consistent with the actual ice edge. However, scatterometer data has been found to compare best with the SSM/I 30% contour. Here, comparisons between QuikScat and SSM/I extents are done for both concentration thresholds. SSM/I extent was subset poleward of 60°N, compatible with QuikScat. The comparisons show some distinct differences (Figure 2). QuikScat extents are lower than SSM/I 15% in winter in both hemispheres. There is reasonable agreement in the Arctic summer, but in the Antarctic summer QuikScat indicates more ice. There is better agreement between QuikScat and SSM/I 30% during winter, but the difference was larger in summer compared to the SSM/I 15% concentration. QuikScat slices are in better agreement with SSM/I than eggs, but the difference between slices and eggs is small. Figure 3 demonstrates the spatial distribution of QuikScat-SSM/I differences in the Arctic for winter and summer.

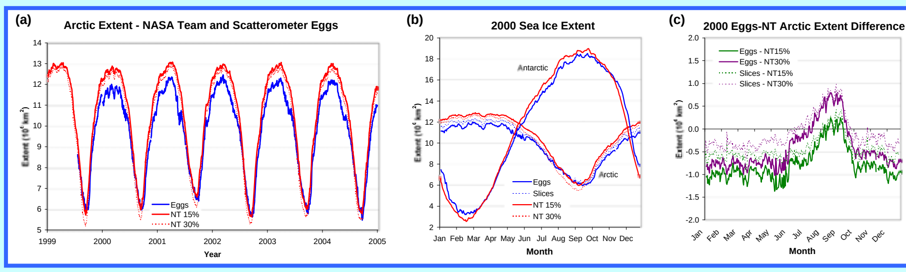

Figure 2. Timeseries of QuikScat and SSM/I sea ice extent N of 60° for (a) the Arctic 1999-2004, (b) the 2000 Arctic for Eggs and Slices (middle), and (c) the 2000 QuikScat-SSM/I extent difference.

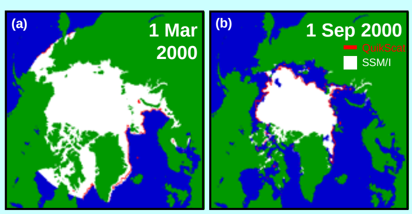

Figure 3. QuikScat (eggs) and SSM/I (15%) sea ice extent for (a) Arctic maximum in March and (b) Arctic minimum in September.

Evaluation of QuikScat and SSM/I Ice Edge Location with AVHRR Imagery

The location of the ice edge from QuikScat eggs and SSM/I (15% concentration) is evaluated through comparison with AVHRR visible and infrared imagery. The AVHRR imagery covers regions in the Barents Sea, East Greenland Sea, and Baffin Bay (Figure 4, map) for summer 2001 through winter 2002. The imagery is gridded to a 2.5 km spatial resolution, comparable to the gridded QuikScat eggs. The AVHRR ice edge location was calculated manually through visual interpretation. There are several potential sources of error, including the manual AVHRR ice selection, geo-referencing errors, and the fact that 'snapshot' AVHRR images are being compared to daily average QuikScat and SSM/I fields. Despite these potential errors, the AVHRR fields provide a useful evaluation of the differences between the QuikScat and SSM/I.

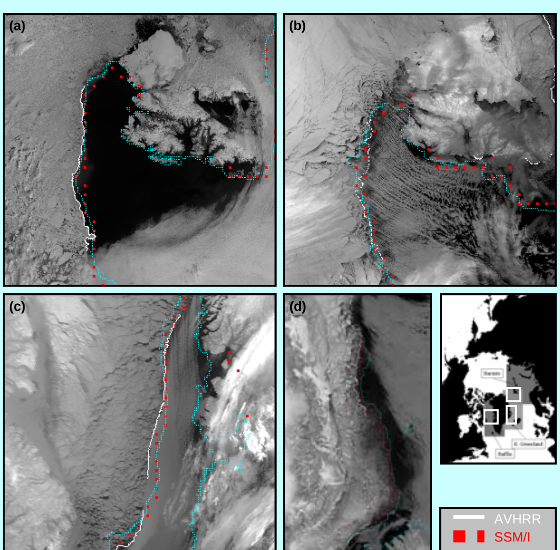

Figure 4. AVHRR imagery overlaid with AVHRR, SSM/I, and QuikScat ice edge location for (a) Barents winter [28 Feb 2002], (b) Barents summer [16 Jun 2001], (c) Baffin winter [17 Dec 2001], and (d) Greenland winter [19 Mar 2002]. The specific regions of the images in the figure are indicated with white boxes in the inset map.

	Winter			Summer		
	Baffin	*Barents*	*Greenland*	*Baffin*	*Barents*	*Greenland*
Date	17 Dec	28 Feb	19 Mar	15 Jun	16 Jun	27 Jun
Edge	Diffuse	Compact	Diffuse	Compact	Compact	Diffuse
# pixels	285	292	424	251	232	461
Mean Absolute Difference (km)						
NT15%	14.0	32.4	16.1	13.7	16.1	25.0
NT30%	19.9	30.0	14.3	20.4	12.0	18.6
Eggs	15.9	27.7	24.6	7.9	10.4	32.0
Slices	14.2	31.5	20.5	13.0	11.4	29.4
Standard Deviation of Difference (km)						
NT15%	6.8	25.0	10.3	6.0	7.0	16.0
NT30%	9.1	17.8	7.8	8.5	5.4	9.8
Eggs	8.3	25.6	16.7	6.6	5.0	27.5
Slices	9.7	26.9	16.0	6.6	5.2	27.6

Table 1. Statistics of QuikScat & SSM/I vs. AVHRR ice edge.

In theory, with higher resolution, QuikScat should provide a more precise edge than SSM/I. This is the case in the Barents summer, but in general the results are mixed with QuikScat not clearly better than SSM/I (Table 1). This may be related to the higher noise in QuikScat as well as the temporal variability of the ice edge.

References

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This research funded by NASA Grant. No. NNG-04GG72A.