SPATIAL RESOLUTION ENHANCEMENT OF AMSR TB IMAGES BASED ON MEASUREMENT LOCAL TIME OF DAY

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ABSTRACT

Advanced Microwave Scanning Radiometer (AMSR) brightness temperature (Tb) data are typically organized into daily average images characterized by compromised temporal resolution. An alternate approach considers the location-dependent measurement time of each sample and organizes data by local time-of-day (LTOD), producing bi-daily images with high temporal locality and reduced noise. These LTOD images show greater improvement and fewer artifacts than daily images when spatial resolution enhancement algorithms are applied. LTOD ice edges are on average 8 km closer to MODIS ice edges than daily ice edges.

***Index Terms*—** Remote Sensing, Polar Studies, Ice Edges, Ice Concentrations, Temporal Resolution, Spatial Resoluton Enhancement

1. INTRODUCTION

Data collected by satellite-based Earth-scanning radiometers are used in a variety of important studies, which include estimating sea and ice surface temperatures, ice edges, ice concentrations, sea ice migrations, ocean winds, rain rates, soil moistures, and snow depths.

With a swath width of 1445 km and a near-polar sun-synchronous orbit, the AMSR scans areas in extreme latitudes 2–7 times a day, and is therefore particularly valuable over polar regions for studies involving transient phenomena. Since its orbit is sun-synchronous, the AMSR makes measurements at nearly the same local time each day. Daily Tb images can be produced by (1) using only the most recent values for a given pixel or by (2) combining all daily values. The first method creates images with higher noise levels, and will not be considered further in this paper. Although the second method can produce images characterized by high spatial resolution through applying resolution enhancement algorithms to overlapping swaths, its temporal resolution—and thus its accuracy and value for studies involving transient phenomena—may be compromised.

The measurement local times-of-day for locations above 60° latitude are separated by less than 12 hours. The precise sampling time is location-dependent, based on the longitude-offset UTC time. Local time-of-day calculations allow us to produce two LTOD Tb images with narrow, disjoint temporal windows each day.

Table 1. The corner coordinates for each study region.

Region	LL Lat/Lon		UR Lat/Lon	
1	-60	60	-50	70
2	-40	60	-30	70
3	-20	65	-10	75

Throughout the day there may be large Tb variations for a given location; therefore, the daily average—which combinines Tb data differing by up to 24 hours—may produce processing artifacts, particularly when used with resolution enhancement algorithms such as the radiometer version of the Scatterometer Image Reconstruction (SIR) algorithm. In an LTOD data set, however, the maximum temporal variation for spatially overlapping data is less than 7 hours. Because of this narrow time window, LTOD has less Tb variation between spatially overlapping passes. When used with SIR, LTOD Tb images have fewer artifacts and give more accurate Tb values than daily average images.

For this paper we define custom regions with 2.225 km pixel resolution for SIR processing. We compare and present data using the Equal-Area Lambert projection. We define in Table 1 the study regions, which contain both areas of high and areas of low sea ice concentration. We select days from the winter season to minimize complications associated with dramatic day/night temperature variations.

Our study cases compare non-enhanced (GRD) images and images enhanced by a single (AVE) and multiple (SIR) iterations of the radiometer version of the Scatterometer Image Reconstruction resolution enhancement algorithm [2]. Ice features derived from resolution-enhanced AMSR LTOD images using the Bootstrap algorithm (Section 2.1) are validated using MODIS data.

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2. ICE AND CLOUD MOVEMENT

2.1. Bootstrap Ice Concentration Estimate

The Bootstrap algorithm is a method of obtaining ice concentration estimates (ICE) from Tb measurements [1], and is defined by:

$$ICE = \sqrt{\frac{(Tb_1 - Tb_{1o})^2 + (Tb_2 - Tb_{2o})^2}{(Tb_{1i} - Tb_{1o})^2 + (Tb_{2i} - Tb_{2o})^2}}$$

where Tb_1 and Tb_2 are the measured Tb values for two different radiometer channels, Tb_{1o} and Tb_{2o} are the open ocean Tb values, and Tb_{1i} and Tb_{2i} are the 100% ice Tb values for those channels. This method has been previously applied to the Special Sensor Microwave Imager (SSMI) using finely-tuned parameterized Tb_o and Tb_i values. Though the Tb_o and Tb_i values are frequency-dependent, we use the values suggested for the dual-pol 37 GHz SSMI channels for the 36 GHz AMSR channels. We consider regions of less than 15% ice concentration to be open water and those above 15% to be ice-covered.

2.2. Ice Migration

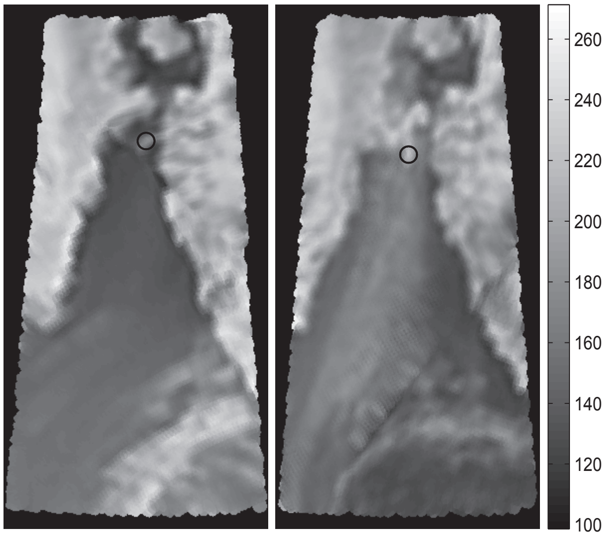
For our initial comparison of LTOD and daily images, we track a parcel of ice which broke free from the main pack ice for a period of four days (Fig. 1). Using the Bootstrap ice concentration method we obtain ICE from AMSR and estimate the location of the parcel for each image using a ICE-weighted pixel location average. The daily data have only one location estimate per day, while LTOD produces two. From Fig. 1(c) and 1(d) we note that the daily location estimates fall near the interpolated path between the LTOD values which reveal movement on scales finer than a day.

Though not identical, the GRD and SIR position estimates are very similar. Linearly interpolating each gives us an average of 1.7 km (GRD) and 2.1 km (SIR) difference from the daily values.

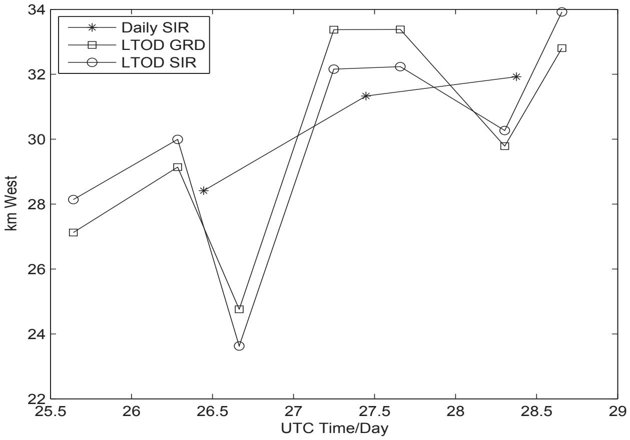
2.3. Clouds

While clouds affect AMSR Tb values less than they do optical or IR sensors, AMSR cloud contamination is non-negligible, especially for higher frequency channels. Clouds move quickly and demand high temporal resolution for atmospheric-related studies or image masks.

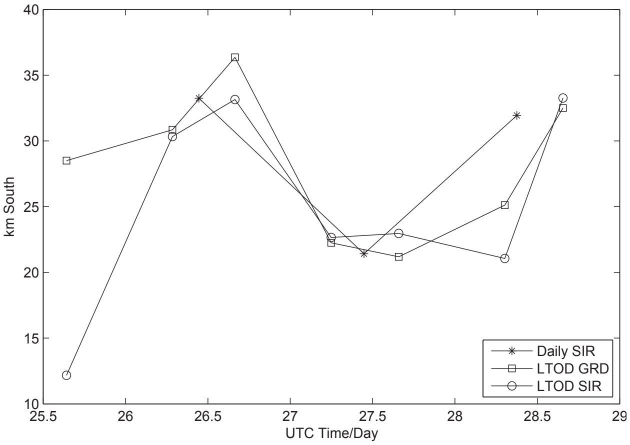
Fig. 2 shows ice in the upper half and cloud contamination and open water in the lower half of each image. The most apparent difference between these daily and LTOD images is LTOD's ability to resolve cloud detail. The morning and evening images show cloud cover to the south and to the east, respectively, but the daily image has no defined cloud cover; it instead presents processing artifacts in those regions. The sharp brightness gradients in the lower portion of the



(a) (b)

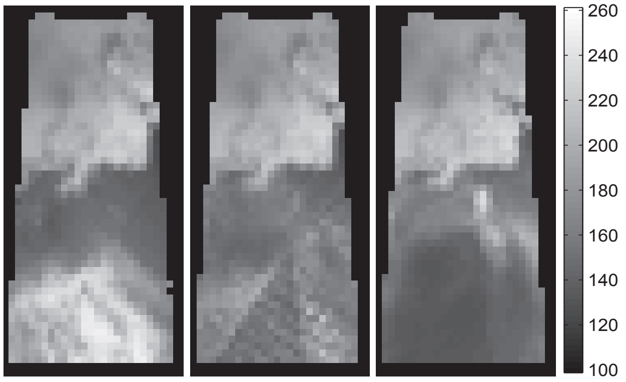


(c) Western Displacement

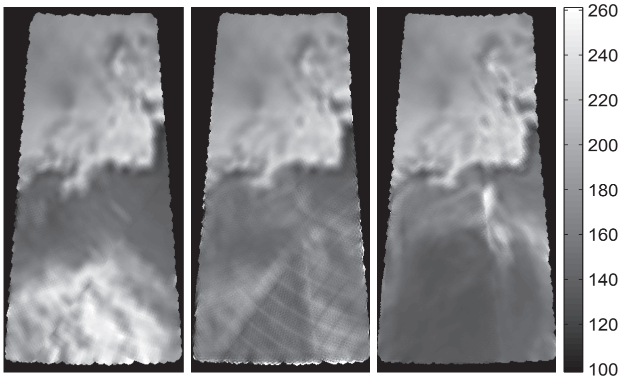


(d) Southern Displacement

Fig. 1. H-pol 36 GHz LTOD SIR images of Region 1 for Julian day 25 (a) and 28 (b) of 2007 with the ice patch of interest circled. (c) and (d), displacements in the western and southern direction versus time for daily and LTOD images.

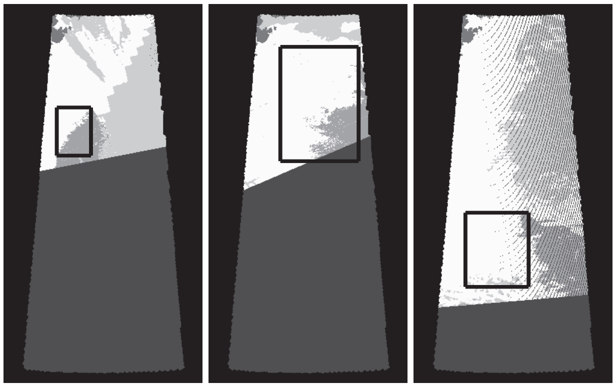


(a) Morning (b) Daily (c) Evening

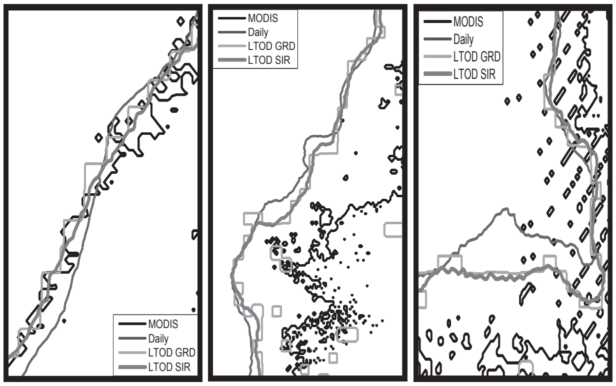


(d) Morning (e) Daily (f) Evening

Fig. 2. AMSR 36 h-pol GHz Tb images from Region 2, Julian day 44, 2005. (a)-(c) are GRD and (d)-(f) are SIR. Note that the high spatial frequency components introduced by the pixelation in the GRD images create an false illusion of higher resolution than actually exists.



(a) MODIS Images



(b) Ice Edges

Fig. 3. Region 3 ice edge comparisons for Julian day 339 of 2004 (left) and days 53 (center) and 55 (right) of 2005 for (a) MODIS and (b) AMSR and MODIS. The boxed regions in (a) are used for the ice edge comparisions shown in (b). The speckle apparent in the rightmost MODIS images is an artifact of MODIS sampling.

daily images correspond to swath edges. The gradients partially represent the change in Tb between two time-separated swaths. The curving texture corresponds to the scan pattern of the scanning pencil-beam antenna. These artifacts are less prominent in the LTOD images.

The GRD images are notably coarser than the SIR, which reveals finer detail of the ice features and their time-variation. There are small changes between the ice Tb values of the morning and evening images for some locations. A slight change in the form and location of the foot-shaped ice extrusion can also be seen by comparing the morning and evening images.

LTOD's improvements in temporal resolution from daily images are evident in LTOD's additional detail and reduced artifact for time-changing features. These improvements directly affect the performance of analyst methods in studies requiring high temporal resolution, of which one is demonstrated in the next section.

3. AMSR AND MODIS ICE EDGES

Here we compare Moderate Resolution Imaging Spectrometer (MODIS) ice edges with ice edges derived from the Bootstrap algorithm applied to AMSR. Pixel values for MODIS *Sea Ice by Surface Temperature* images map regions of ice, cloud, water, land, or unknown. Due to MODIS' high sensitivity to clouds, the MODIS comparison data set with cloudless ice edges is small. Samples were selected at Julian day 339 of 2004 and days 53 and 55 of 2005 for Region 3 (Fig. 3).

For each MODIS image we choose spatially congruent daily and LTOD AMSR images which most closely match the MODIS sampling time. We then apply the Bootstrap algorithm to find the ICE for the AMSR images. In Fig. 3 we compare contours representing the MODIS ice edge and the AMSR 15% ice concentration threshold. In Table 2, differences in inferred ice edge are compared using an area metric.

Table 2. Approximate distances between the AMSR- and MODIS-derived ice edges, calculated by summing the area of AMSR ICE below 15% within the MODIS ice region with the area of AMSR ICE above 15% in the MODIS water region and dividing it by the approximate length of the ice edge.

Ice Edge Difference (km)				
	I	II	III	Average
AMSR GRD Daily	11.3	82.0	68.0	63.7
AMSR AVE Daily	10.2	82.8	66.7	63.3
AMSR SIR Daily	11.2	85.6	68.0	65.2
AMSR GRD LTOD	8.05	76.9	58.6	57.2
AMSR AVE LTOD	7.38	74.5	55.7	54.9
AMSR SIR LTOD	7.73	73.7	56.9	55.1

The clear atmospheric conditions over the ice edge imply that the weather is relatively calm. With calm weather, we expect the ice edge to change very little. Although this decreases the advantage of using LTOD images, there is still improvement from the daily to the LTOD ice edges. Greater difference would be expected for more dynamic cases.

We make two observations from Fig. 3 and Table 2. First, the improvement from daily to LTOD is on average 6.5 km (GRD), 8.4 km (AVE), or 10.1 km (SIR), or on the order of the antenna footprint size. Secondly, upon applying the SIR algorithm the LTOD ice edge improves by 2.3 km (AVE) and 2.1 km (SIR). The daily ice edge improves by 0.4 km for AVE but increases in average distance to the MODIS ice edge by 1.5 km for SIR. We conclude that the LTOD images are more accurate than daily images for measuring ice edges and that the SIR algorithm improves the LTOD ice edge more than it improves the daily ice edge.

4. CONCLUSION

Resolution enhancement algorithms combine multiple swaths over a region to estimate Tb at higher spatial resolution. Although several swaths contribute to daily data in the polar regions, the separation in their measurement time allows for temporal Tb variation. This Tb variation between swaths in the daily data decreases the effectiveness of the SIR algorithm. Because LTOD data sets are constrained to a narrower time window, the Tb variation is diminished, and the effectiveness of the SIR algorithm increased. This paper demonstrates this improvement through studies of weather and ice, showing LTOD to have less processing artifact, more accurate ice edge estimates, and a greater increase in these qualities upon applying SIR than daily images.

Future studies include comparing average midday or midnight ice extents over different seasons.

5. REFERENCES

[1] J.C. Comiso "SSM/I Sea Ice Concentrations Using the Bootstrap Algorithm" *NASA Reference Publication*, Vol. 1380, pp. 49, 1995.

[2] D.G. Long and D.L. Daum "Spatial Resolution Enhancement of SSM/I Data" *IEEE Transactions on Geoscience and Remote Sensing,*, Vol. 36, No. 2, pp. 407-417, Mar. 1998.

[3] W.N. Meier and J. Stroeve "Comparison of Sea Ice Extent and Ice Edge Location Estimates from Passive Microwave and Enhanced-Resolution Scatterometer Data," in *Annals of Glaciology,* Vol. 48. July, 2007.