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# Temporal Resolution Enhancement for AMSR Images

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**Abstract**

Some techniques which average multiple AMSR satellite data passes into daily sets create images with diminished temporal resolution. This results from averaging data of multiple overlapping passes separated by many hours. Overlap can be reduced by instead grouping data according to local time of day. This new method[1] maximizes temporal resolution by decreasing both the number and the temporal variation of overlapping data sets, especially at extreme latitudes, and results in two images per day separated by approximately 12 hours.

## 1 Introduction

The Advanced Microwave Scanning Radiometer (AMSR) is a spaceborne radiometer in a near-polar sun-synchronous orbit. Because of its orbit geometry and wide swath, this instrument scans areas near the poles multiple times a day. This high sampling frequency is valuable in studies over regions of extreme latitudes, especially those involving transient phenomena such as weather or ice.

Current satellite image-creating techniques combine data from several satellite passes by averaging the measurement from each pass for overlapping swaths. A daily image includes all data collected over the day and area to which it corresponds. Although useful in some contexts, the number and extreme temporal variation of overlapping passes in the resulting images make this method less than ideal for use in studying transients.

A new method improves upon this by separating data instead by local time of day. This method preserves all collected satellite data while minimizing the overlap and time gap between distinct swaths in an image and results in two images per day.

Before evaluating this new method, we first introduce the SIR **p** image as a useful evaluation tool, after which we further discuss and evaluate daily images. Following this discussion, the local time of day (L-TOD) method is presented.

[1]This method has also been applied to QuickSCAT [1].

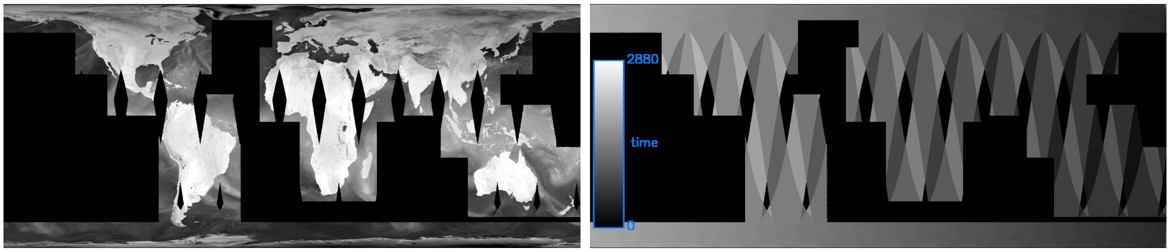


Figure 1: Continental daily **a** and **p** images, respectively. The equatorial nodes are at 8:00 am/pm local time. Data from oceanic areas are removed to decrease processing time. The satellite track moves to the left for both ascending and descending swaths.

## 2 The SIR p Image as a Useful Tool

The simplest method for creating AMSR satellite images averages all corresponding normalized TB measurements for each pixel. While the gridded images produced by this method have a high signal-to-noise ratio, their spatial resolution is limited by the footprint of the antenna pattern. Scatterometer Image Reconstruction (SIR) is an alternate technique which improves spatial resolution[2] [3].

The SIR process creates several auxiliary images, one of which estimates the time at which the value for each pixel was measured.

The pixel brightness for this image is the weighted time average of the brightness temperature measurement, given by the equation

$$P_{pixel} = \frac{\sum_{i=1}^{n} \frac{t_i}{\hat{\sigma^o}}}{\sum_{i=1}^{n} \frac{t_i}{\hat{\sigma^o}}}$$

where $t_i$ is the universal time of day in minutes and $\hat{\sigma^o}$ is the $\beta$ corrected $\sigma^o$ brightness temperature[4] corresponding to the $i^{th}$ measurement over that pixel. This image type, referred to as the **p** image, is our primary tool in the analysis of temporal resolution processes.

## 3 Daily Images

Having a near-polar sun-synchronous orbit, the satellite maintains a constant angle relative to the sun and completes 14.2 orbital cycles every 24 hours. Therefore, while the satellite crosses the equator on its descending pass at approximately 8:00 pm local time of day and on its ascending pass at approximately 8:00 am local time of day, only 50 minutes elapse between the equatorial crossings. Above 60 and below -60 degrees latitude, twice-daily coverage is guaranteed—once during both the ascending and the descending passes of the satellite.

Daily images as in Fig. 1 have several qualities which make them preferable in some contexts. First, the data processing algorithm is simpler than others due to the loosely-defined boundaries between data of consecutive images. Second, these images maximize daily coverage by including all data possible in each image. Third, image-generating techniques such as SIR combine the many overlapping swaths of the daily images so as to improve spatial resolution.

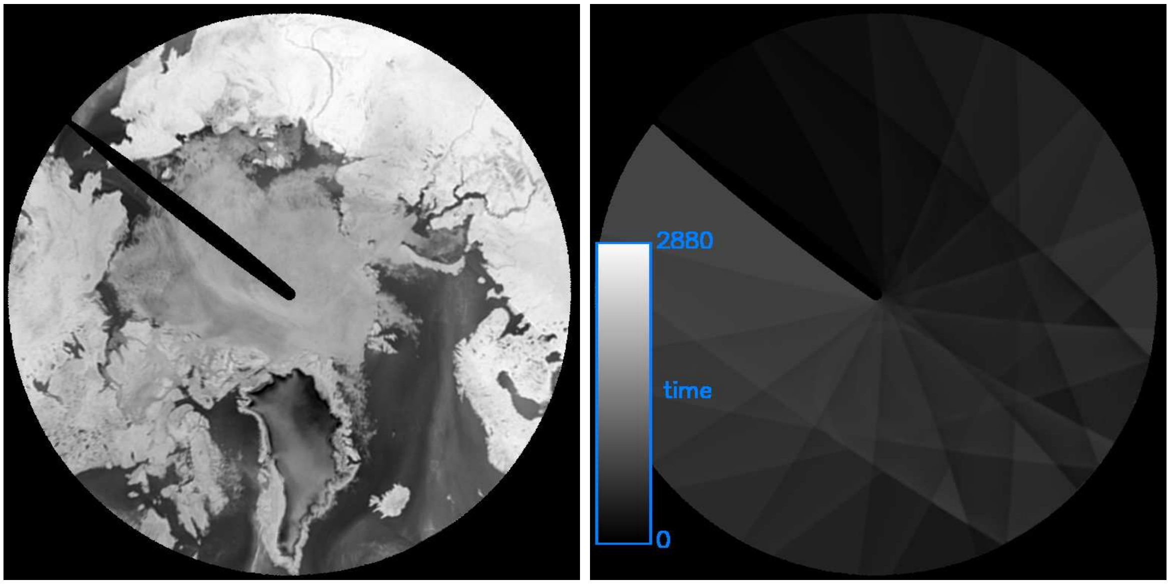


Figure 2: Arctic **a** and **p** images, with data contribution limited to 8 passes (about 800 min) to illustrate the relationship between elapsed time and coverage. The time scale colorbar to the left of the **p** image is in units of minutes from start of day.

Although some studies prefer the spatial coverage and resolution of the daily images, studies dealing with rapidly moving or changing phenomena require higher temporal resolution. An image's temporal resolution is evaluated by considering the maximum number of overlapping swaths and the time separation between them.

Daily images have three types of swath overlap: low-latitude, nearly-consecutive, and day boundary. Each type is considered in the following subsections.

## 3.1 Low-Latitude Overlap

Fig. 1 shows the overlap of the ascending and descending swaths at low latitudes. Lighter shades correspond to more time elapsed since the start of the day. Swaths descend and ascend to the left. Approximately 12 hours elapse between overlapping swaths.

This overlap causes the temporal resolution to decrease. The variation in brightness temperatures between morning and evening measurements over these regions is lost. Details of tropical storms (which are often tracked using satellite data) can be corrupted or de-emphasized. For use in these studies, much improvement is needed over daily images.

## 3.2 Nearly-Consecutive Pass Overlap

Nearly-consecutive pass overlap degrades temporal resolution near the poles. Of the three overlap types characteristic of daily images, this type occurs with swaths of most varied temporal gaps. One orbit period occurs between each consecutive pass, and with 14.2 cycles each day and 1440 minutes per day we have a temporal gap of about 100 minutes between consecutive swaths. From Fig. 2, all 8 consecutive swaths overlap, making a maximum temporal variation of 800 minutes for this overlap type.

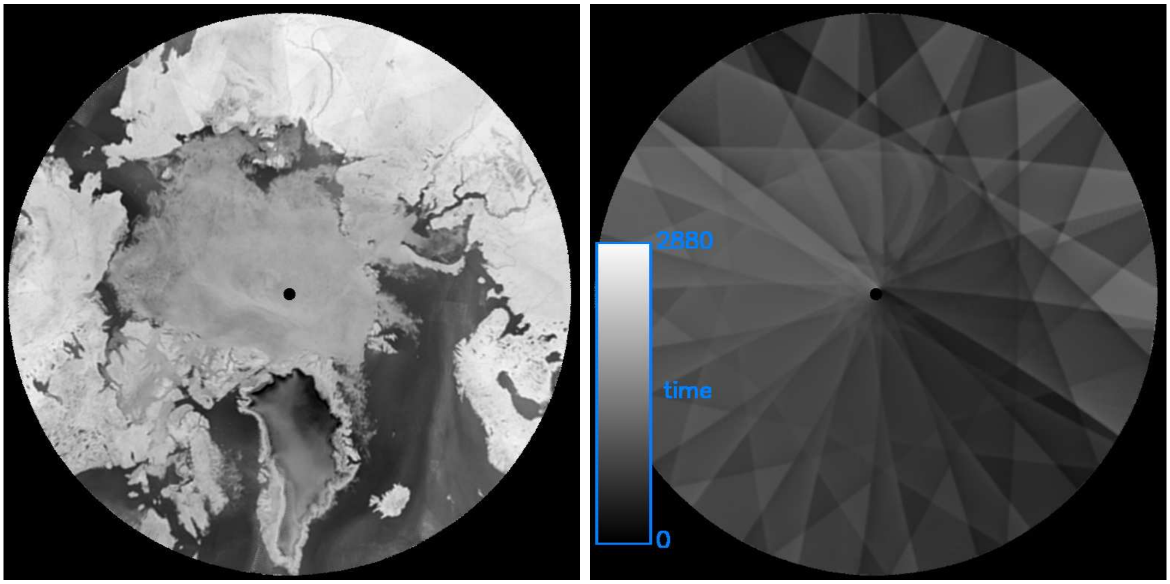


Figure 3: Full arctic daily **a** and **p** images. Note the swath edge artifacts in the **a** image and the extreme temporal variation in the **p** image, particularly along the dateline towards the upper right.

The degradation in temporal resolution for this case is due to the high temporal gap and the high number of overlapping swaths. The multiple daily passes over the polar regions encourages studies with temporal variations in the satellite measurements, but this overlap type degrades the detail that would be useful in such an investigation.

### 3.3 Day Boundary Overlap

The day boundary overlap of daily images as seen in Fig. 3 causes greater deterioration in temporal resolution than either of the other overlap types. While low-latitude and near-consecutive swath overlaps have temporal variations of 12 hours and between 1.5–12.5 hours, respectively, the overlap at the day boundary occurs between swaths which are 12 to 24 hours apart. For a full-daily image, the seven final swaths overlap completely with the first seven of the day. From the upper right side of Fig. 3 one can easily see the artifacts of the overlapping swaths which evidences the corruption of the data for use in transient studies. The large time difference of these passes degrades temporal resolution.

## 4 Separation by Local Time of Day

Instead of organizing data by day, the L-TOD method creates bi-daily images. While some satellite image processing techniques have done this by separating ascending and descending path [1], the L-TOD method separates data according to local time of day instead of by satellite time and direction. We first discuss the process, then the subsequent implications for temporal resolution.

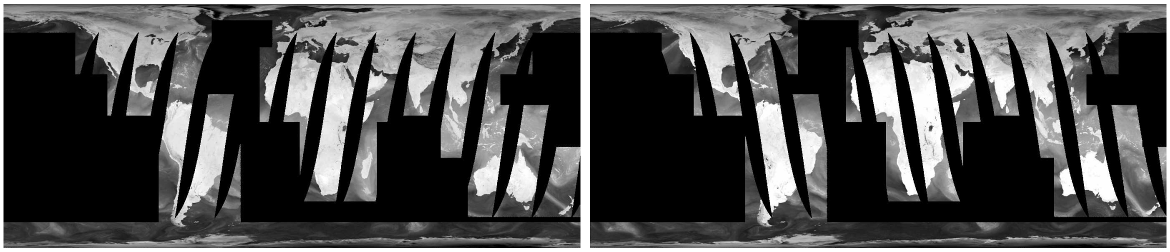

Figure 4: L-TOD **a** images, showing the evening/midnight and morning/noon images, respectively. Overlapping swaths are in effect averaged in the SIR algorighm.

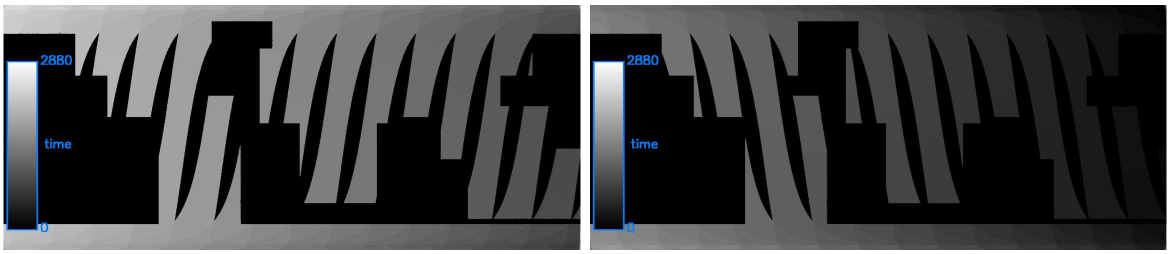


Figure 5: L-TOD **p** images, showing the evening/midnight and morning/noon images, respectively.

## 4.1 Process

A discussion of terminology is in order before introducing the process. The *location* of a data sample refers to the location on Earth's surface to which it corresponds. The *longitude* of a data sample is measured easternly from the International Date Line. The *Universal Time* is the time of the first time zone west of the International Date Line. Thus the *local time* for a data sample is approximated by subtracting from the Universal Time four minutes times its longitude. The effectiveness of this calculation results from the Earth's rotation of 360 longitudinal degrees every 1440 minutes per day or 1 degree every 4 minutes.

After calculating the local time of day for a data sample, the process uses polar nodes of 2:00 am and pm to separate the data into noon/morning (**n**) images and midnight/evening (**m**) images.

## 4.2 L-TOD

As seen in Fig. 4, separating the data by local time of day eliminates the low-latitude overlap completely. This provides a great increase in the utility of the data images in studying lower latitude transient phenomena, such as tropical storms.

In Fig. 6 the improvement in the near-consecutive swath overlap from the daily image is obvious. L-TOD has only 4 consecutive swaths ovelapping with a maximum temporal variation of 7 hours. This may seem to be a small improvement from the 8 overlapping swaths in the daily case. However, by comparing Fig. 6 with Fig. 2 we see that both the total overlap area and the area for which the maximum temporal variation is present are decreased dramatically. This is synonymous to increasing the temporal resolution.

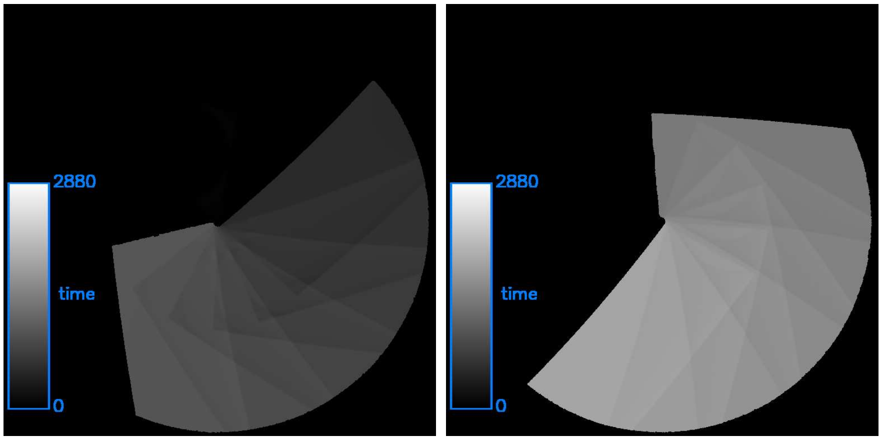


Figure 6: L-TOD **p** noon and midnight images, respectively, showing swath features of the L-TOD method.

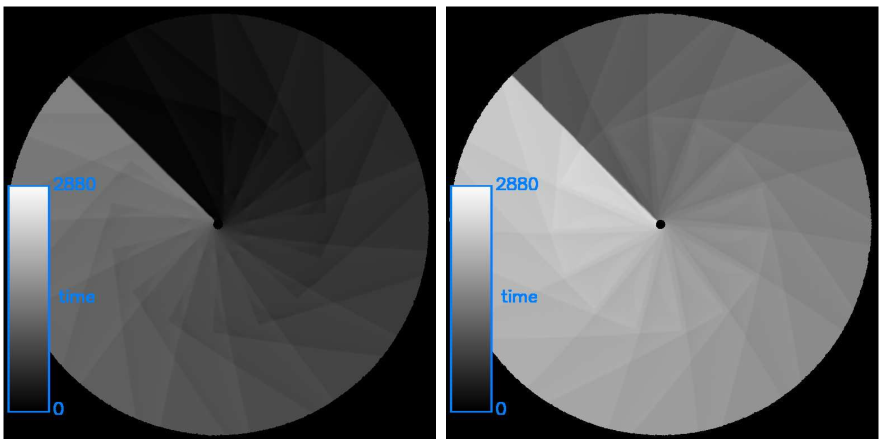


Figure 7: Complete L-TOD **p** images for noon and midnight images, respectively.

As seen in Fig. 7, the L-TOD separation algorithm creates a well-defined day boundary at the International Date Line. Due to the nature of the algorithm, data that is collected to the east of the Date Line is not used for the first few swaths of the day, and data that is collected to its west is not used for the last few swaths. This boundary results in virtually no overlap and thus no degradation of the temporal resolution at the day boundary. This is a improvement over the overlapping swaths from the daily case, whose maximum temporal gap is nearly 24 hours.

There are some drawbacks associated with the day boundary as defined by L-TOD. First, it becomes necessary to include data contributed by 2-3 swaths from both the preceding and following days in order to complete the image. This slightly increases processing time, but is acceptable due to the exclusion of that data from the previous and following days' images. Secondly, it creates a visible discontinuity in the image along the boundary, as seen in Fig. 8. While this may decrease the aesthetic value of the image, the inherent detriment is justified by its increased temporal resolution.

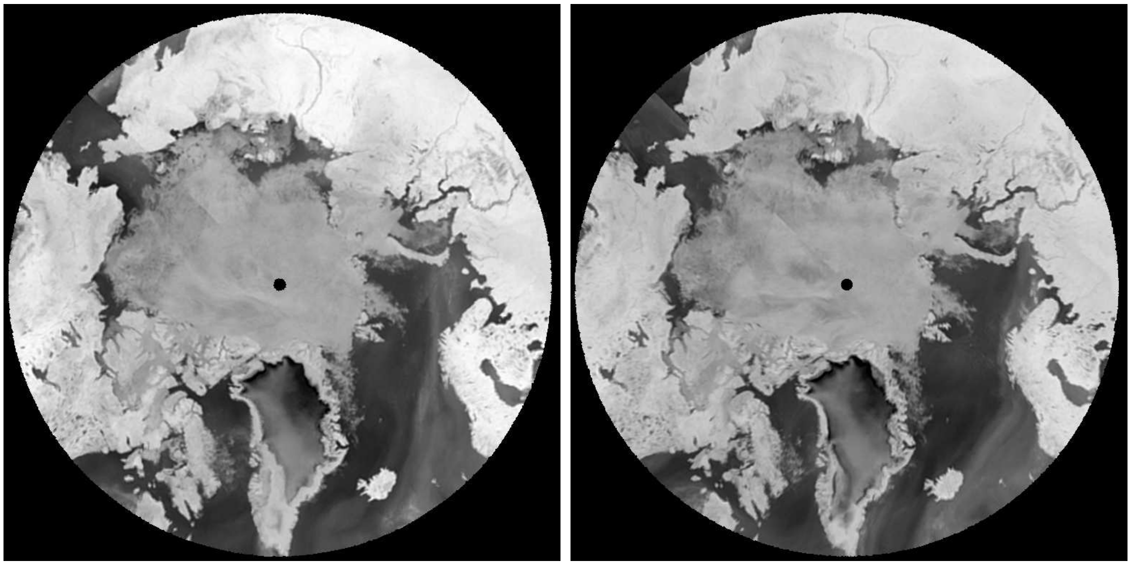

Figure 8: Complete L-TOD images for noon and midnight images, respectively, for Julian day 197 of the year 2003. The day boundary is visible in the upper-left quadrant of each image.

# 5 Conclusion

While the ascending/descending method of data separation in the creation of AMSR polar images is simple to implement and requires minimal processing, the resulting images suffer from decreased temporal resolution due to consecutive-swath overlap and the loosely-defined day boundary. Separation by local time of day, while requiring some additional processing, returns images with maximized temporal resolution. These L-TOD images are especially valuable in studies treating transient phenomena, where temporal resolution is critical.

# References


[1] Hicks, Brandon R., and Long, David G., *Improving Temporal Resolution of SIR Images for QuickSCAT in the Polar Regions*, Brigham Young University MERS Report 05-02, 25 March 2005.

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[4] Watt, Gardner, and Long, David G., *Temporal Average Estimate Algorithm for ERS-1/2*, Brigham Young University MERS Report 97-07, 5 August 1997.