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Abstract

Like other polar-orbiting sun-synchronous platforms, ASCAT collects many observations of the polar regions each day. Multiple scatterometer measurements of a single area are desirable for image reconstruction such as SIR (Scatterometer Image Reconstruction). Using measurements of the region with differing local time results in decreased temporal resolution due to the potentially large time difference between different measurements of the same location. This drawback is ameliorated by using only measurements that are in the same neighborhood of local time. The local time measurements for the polar regions fall into two distinct groups for each 24-hour period. Image reconstruction can then be performed separately on these two groups of data. In this report, we show that the QuikSCAT LTD (local time of day) window definitions can be used for ASCAT after compensating for the 15.5 hour difference in time of ascending node. We introduce multi-day LTD images to increase spatial coverage while maintaining the benefits of LTD. The resulting images are presented and discussed.

1 Introduction

A trait common to satellites in a sun-synchronous polar orbit is a high number of observations near the poles each day. Multiple overlapping passes is desirable for the SIR algorithm, which uses the dense sampling to perform image reconstruction. However, observations that are averaged together (using SIR) that differ widely in time local to the observed location result in a coarse temporal resolution that is ill-suited to track diurnal polar features such as sea ice extent, melting patterns, icebergs, and other variations. Separately processing observations with similar local

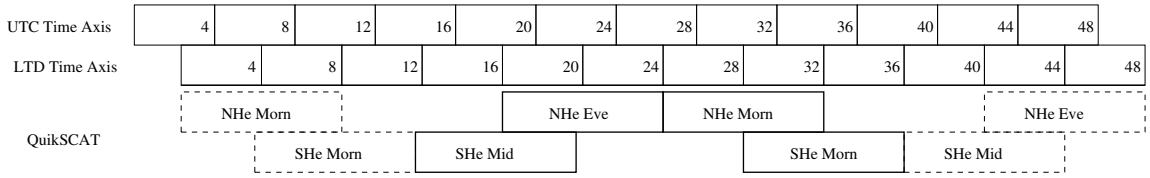

Figure 1: Using two days of data, two LTD time divisions are defined for each hemisphere. The dashed boxes indicate where LTD processing covers for the adjacent overlapping two days of data.

time results in SIR images with a finer temporal resolution to better track these diurnal polar features.

For a σ^0 measurement from a scatterometer at a given longitude and UTC time, the local time of the measurement is given by

$$\text{Local Time [minutes]} = \text{UTC [minutes]} + 4\left[\frac{\text{minutes}}{\text{degree}}\right] * \text{longitude [degrees]}. \quad (1)$$

Local time of day processing has previously been implemented using the AMSR radiometer [2] and the QuikSCAT scatterometer [3]. In this report, we review local time of day processing (LTD) for QuikSCAT and then discuss LTD processing with ASCAT SIR data.

2 Local time of day with QuikSCAT

The orbit of QuikSCAT has an ascending node at (on average) 6:00 am. Using Eq. (1), two images of each hemisphere (northern and southern) can be made from each day's worth of data. This is done by starting with 48 hours of data and only extracting data that falls within the local time window defined by Fig. 1 for a specific region.

The time intervals in Fig. 1 are 8-hour windows, so that for an arbitrary polar location, QuikSCAT observes it in a morning or midday window, an evening window, or not at all. Note the lower time axis given in Fig. 1 represents not the absolute UTC time but the local time of some polar location. Applying Eq. (1) for a given longitude results in a UTC time axis offset from the local time axis directly proportional to the longitude of the location. This is represented by the upper time axis in Fig. 1.

Only 8 hours of data are used for each LTD window (NHe Morn, NHe Eve, SHe Morn, SHe Mid). As shown in Fig. 1, only 24 hours of data are used to make the four LTD images. These 24 hours of data are in local time, so they shift relative

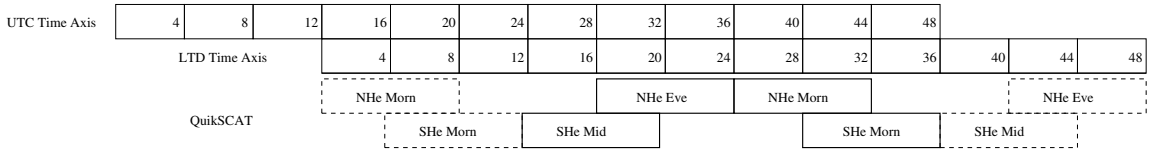

Figure 2: For a location with longitude 180°, the local time axis is offset relative to UTC by 12 hours. Because the LTD region windows were chosen to be near the middle of the 48 hour UTC window, all LTD windows are still contained within the 48-hour data window.

to UTC depending on the longitude of the location. We illustrate this by using the two extremes: for locations at 0° longitude, there is no offset between local time and UTC, so data from 1200Z of one day to 1200Z of the next day is used. For locations at 180° longitude, there is a 12 hour offset between local time and UTC, so data in the second day only from 0000Z to 2400Z is used. This case is illustrated in Fig 2. The LTD windows shift a maximum of 12 hours in either direction. To accommodate the maximum shift we define the LTD windows to be near the center of 48 hours of UTC data. With LTD, each longitude uses a different 24-hour subset of the 48-hour UTC interval.

3 Local time of day with ASCAT

The motivation for local time of day (LTD) processing for ASCAT is similar to that of QuikSCAT and other polar-orbiting satellites. Namely, rather than combining all measurements from 24 hours of polar coverage, they can be split into two groups of coverage with each group having a much smaller time variance between measurements–and therefore greater temporal resolution.

3.1 ASCAT and QuikSCAT comparison

Although QuikSCAT and ASCAT both operate on platforms in a near-polar sun-synchronous orbit, their orbit periods differ. ASCAT operates on an orbit with a 29-day exact-repeat and a 5-day near-repeat [1], while QuikSCAT operates on an orbit with a 4-day near-repeat period. Notwithstanding the differences in orbital period, the QuikSCAT LTD processing techniques can be applied very similarly to ASCAT.

ASCAT has a mean ascending node at 9:30 pm, whereas the mean ascending node of QuikSCAT is 6:00 am. We investigate shifting the time division periods of

QuikSCAT LTD processing by 15.5 hours to accommodate the different ascending node of ASCAT.

3.2 Validating LTD efficacy with ASCAT

We validate a shift in LTD window definitions for ASCAT by collecting ASCAT data for a region and calculating the local time using Eq. (1). We use a region for either hemisphere high in latitude and wide in longitude: a strip defined by 82–83° N, −80–100° E for the northern hemisphere, and 82–83° S, −80–100° W for the southern hemisphere. Figure 3 shows a normalized histogram of the local time for each measurement falling within the two regions for an 11-day time period. The vertical lines indicate a 15.5 hour shift of the QuikSCAT LTD time divisions.

The histograms from the test regions show that shifting QuikSCAT LTD time divisions in order to match the time of ascending node for ASCAT is a good fit. Figure 4 shows the LTD time divisions for QuikSCAT and ASCAT. As before, the lower time axis is the local time for an arbitrary longitude east of the Prime Meridian, and the upper time axis is UTC. As with QuikSCAT, the LTD regions are defined for the middle of the data period to accommodate locations far from the prime meridian (a large offset between the time axes).

We test LTD processing on ASCAT by processing the Antarctic and Arctic regions for a two-day period. Figures 5 and 6 show the resulting $\mathcal{A}$ and p-SIR images. Each pixel in a p-type SIR is the weighted average UTC value of all measurements covering that pixel. Figure 7 shows the corresponding $\mathcal{A}$ SIR images without LTD processing and the p-type SIR images. By comparing P images for LTD and non-LTD images, the daily cycles are easier to resolve.

3.3 Multi-day LTD images

A side-effect of the LTD processing is a loss of spatial coverage. The LTD images shown in Figs. 5 and 6 have good coverage for latitudes very near the poles, but there are many gaps at lower latitudes. Because many regions of interest lie in these gaps, we combine multiple LTD windows to increase the spatial coverage.

Fig. 8 defines LTD time intervals for 2-day LTD processing. Here, a region such as "NHe Evening" uses data from two separate windows separated by 24 hours. As before, the dashed boxes indicate where the LTD windows of adjacent time periods fit. Horizontal bars have been added to the figure to indicate possible shifts of the windows depending on local longitude. Although the 2-day LTD processing only requires 48 consecutive hours of data, 76 hours of data starting from midnight UTC

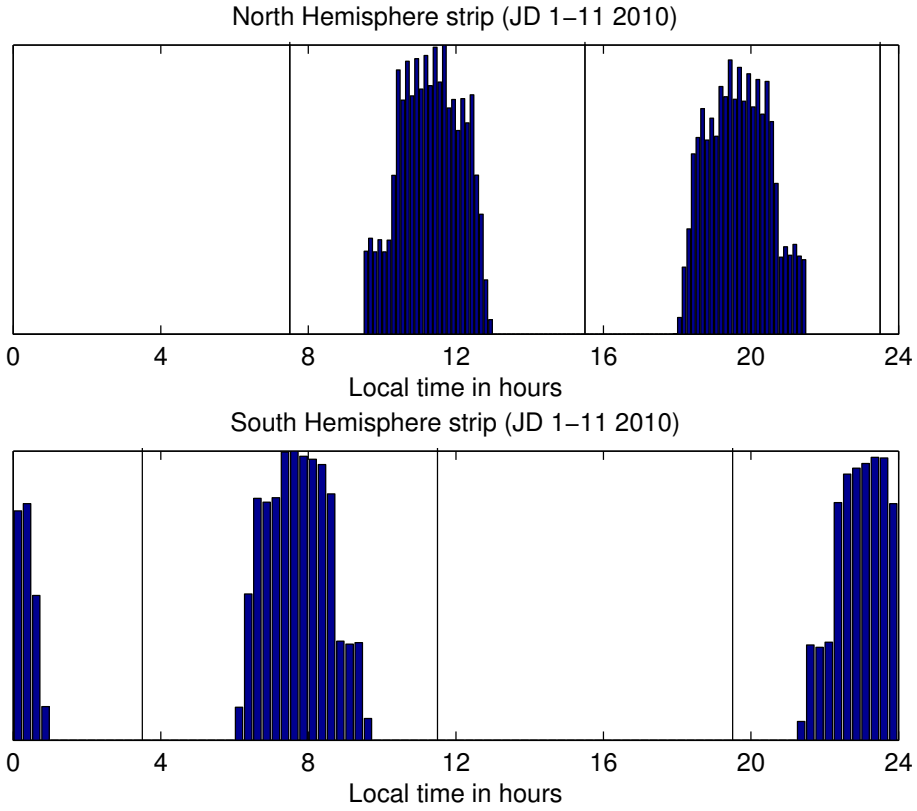

Figure 3: For regions defined in the north and south hemispheres, this normalized histogram shows the local time of day for each measurement falling within the region for an 11-day time period. The vertical lines are the QuikSCAT LTD window boundaries shifted by 15.5 hours (the difference between the ascending nodes for QuikSCAT and ASCAT).

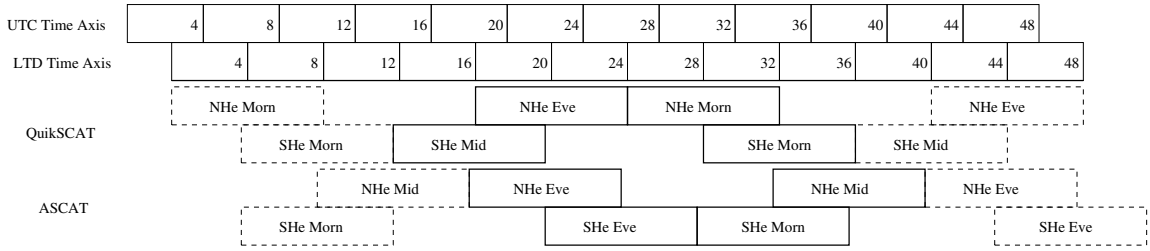

Figure 4: Using two days of data, two LTD time divisions are defined for either hemisphere. The dashed boxes indicate where LTD processing would cover for the adjacent overlapping two days' of data.

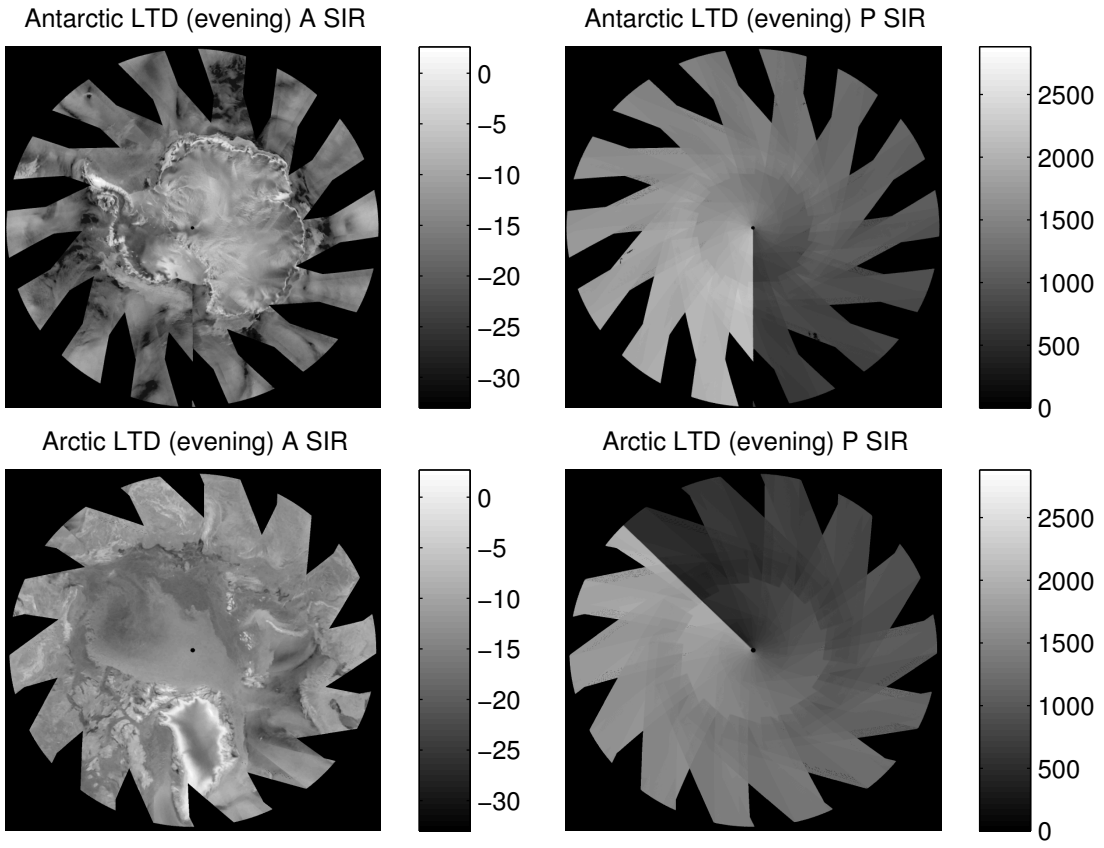

Figure 5: The evening LTD ASCAT $\mathcal{A}$ and P SIR images for the Antarctic and Arctic regions for JD 21–22 2010. The $\mathcal{A}$ images are measured in dB and the P images are measured in minutes from UTC midnight of JD 21 2010.

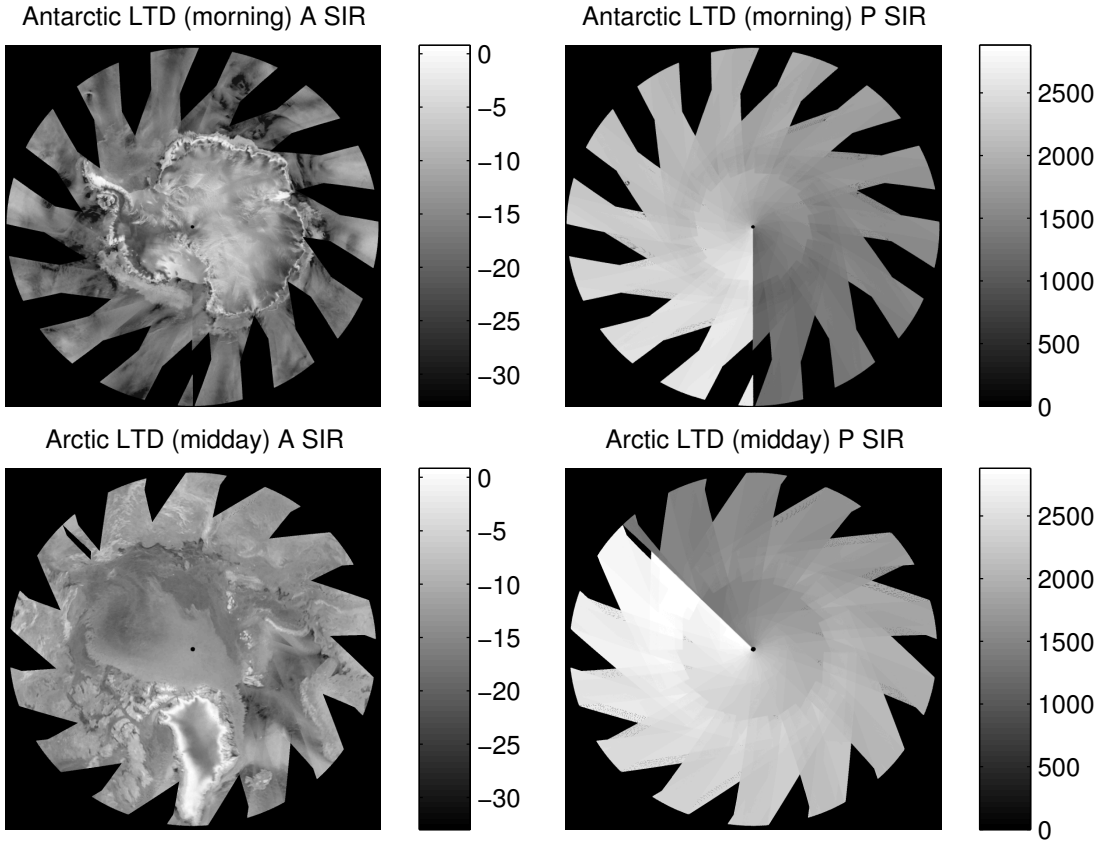

Figure 6: The morning/midday LTD ASCAT $\mathcal{A}$ and P SIR images for the Antarctic and Arctic regions for JD 21–22 2010. The $\mathcal{A}$ images are measured in dB and the P images are measured in minutes from UTC midnight of JD 21 2010.

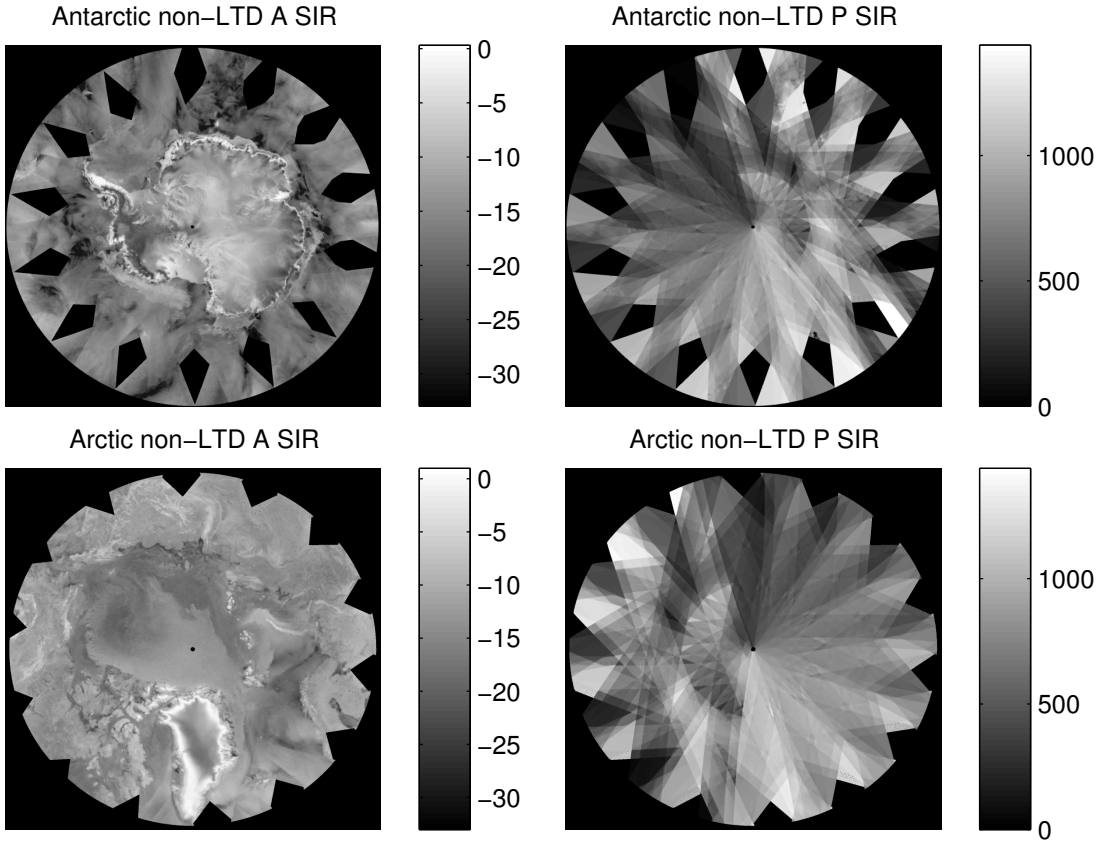

Figure 7: The non-LTD ASCAT $\mathcal{A}$ and P SIR images for the Antarctic and Arctic regions for JD 21 2010. The $\mathcal{A}$ images are measured in dB and the P images are measured in minutes from UTC midnight of JD 21 2010.

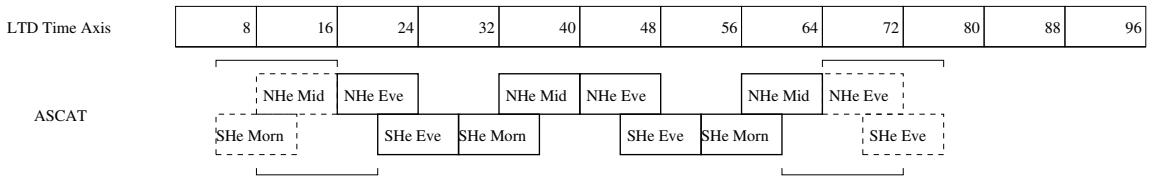

Figure 8: 4 days of UTC data is needed to cover the worst-case location for 2-day LTD ASCAT images. The horizontal bars indicate the maximum shift of 12 hours (at 180° longitude) relative to UTC. The dashed boxes indicate LTD windows from adjacent date ranges.

is needed for locations in the northern hemisphere with a longitude of 180°.

Using 2-day LTD images leads to greater spatial coverage, as shown in Fig. 9. Unfortunately this scheme uses σ^0 measurements that are separated by at most 32 hours (8-hour window width + 24-hour spacing between windows). We deem this drawback acceptable because rather than average measurements made, for example, during local morning and local evening (non-LTD processing), measurements are averaged for a local morning and the local morning of the following day. This is beneficial to track features that differ in morning versus evening.

Figure 10 is an example of 2-day LTD processing. The middle column contains 1-day $\mathcal{A}$ SIR LTD images of Greenland in chronological order. The leftmost and rightmost columns contain 2-day midday and evening images, respectively. Each 2-day image corresponds to the 1-day image diagonally above and below it. In the 1-day LTD images, some melting near the west coast of Greenland occurs in the evening images, but refreezes in the midday images. The 2-day LTD midday images show the area with a greater σ^0 value (frozen), whereas the 2-day evening image shows the area with a lower σ^0 value (melting). As the season progresses, melting becomes obvious in both morning and evening images (not shown). The 2-day LTD images provide greater spatial coverage while retaining this diurnal feature.

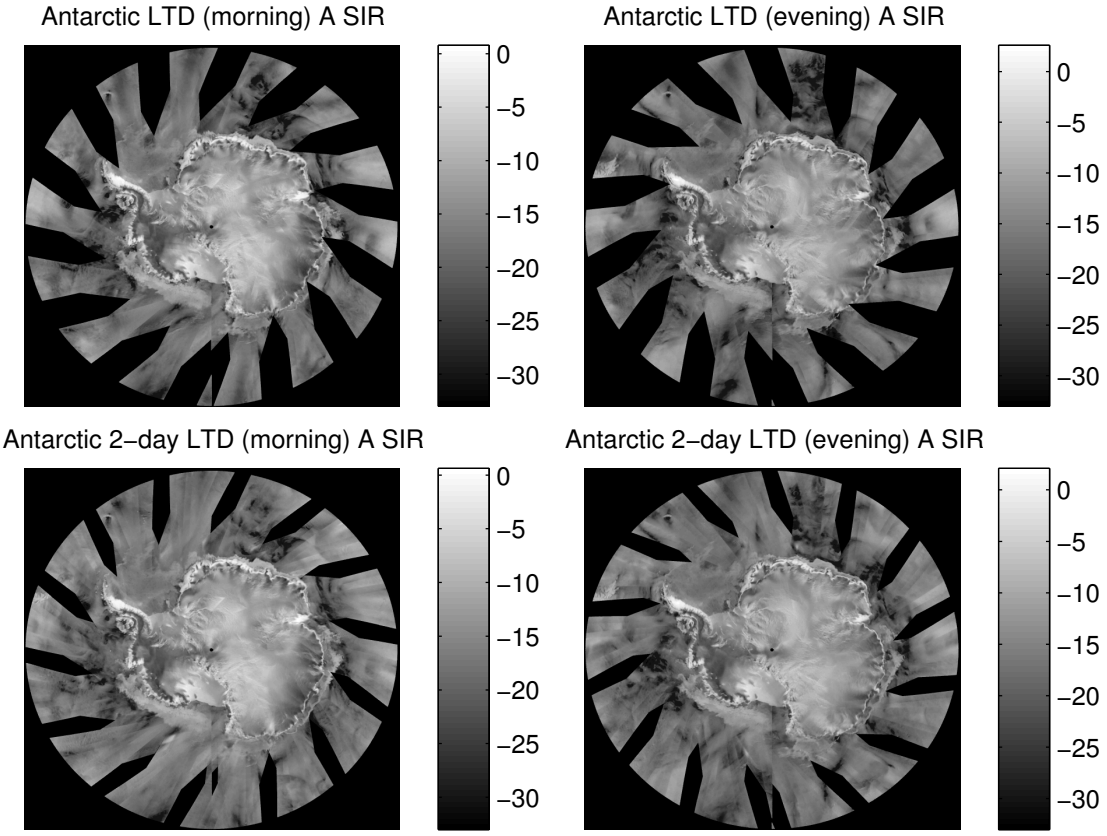

Figure 9: The 1-day and 2-day LTD ASCAT $\mathcal{A}$ SIR images for the Antarctic region for JD 21-22 2010 and JD 21-24 2010, respectively. $\mathcal{A}$ is in dB. The 2-day LTD images have greater spatial coverage.

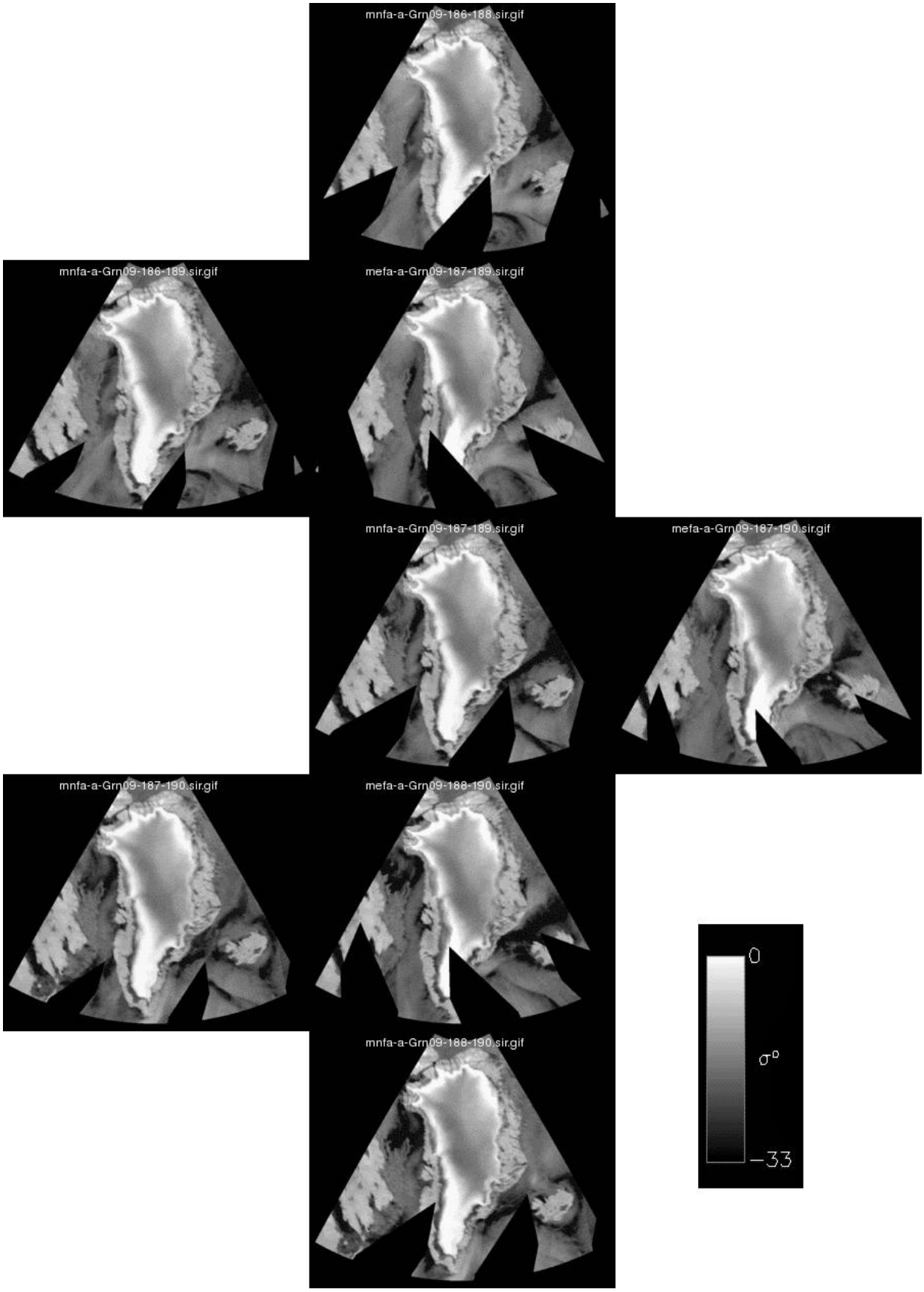

Figure 10: A sequence of 1-day and 2-day LTD ASCAT $\mathcal{A}$ SIR images for Greenland during the summer melt season (JD 186-190 2009). The middle column is a chronological sequence of 1-day images, alternating between evening and midday. The left column is 2-day midday images, the right column is 2-day evening images.

4 Discussion and Conclusions

Each 8-hour window is defined in terms of the local time. Because the conversion to UTC is longitude-dependent, each window needs to fit on the two-day UTC range for every possible longitude. The maximum offset between the local and UTC time axes is 12 hours (at 180° longitude, roughly the International Date Line), so each LTD 8-hour window +/- a 12 hour offset must still fall within the UTC 2-day interval. Because the QuikSCAT ascending node is 6:00 am, all LTD windows +/- a 12 hour offset stay within the 2-day UTC interval. Three of the four ASCAT LTD windows also stay within the 2-day UTC interval, but the NHe Mid window requires data beyond the 2-day UTC interval for values of longitude close to 180°. For this reason, 3 days of ASCAT UTC data are used to extract the 8-hour NHe Mid LTD window. 2-day LTD images similarly require 4 days of UTC data for NHe Mid LTD images and 3 days for the other regions.

A consequence of the multi-day orbital period of ASCAT can be seen in the LTD images in Figs 5 and 6. The pattern of "spokes" going to the edges of the image are a result of less than 100% spatial coverage for the number of measurements used to produce the images. The spokes don't exactly line up because there is not an integer number of orbits per 24-hour period. The discontinuity is evident at 180° longitude for both Arctic and Antarctic images. If ASCAT measurements covering an integer number of orbits were used, discontinuities would be less evident.

ASCAT exhibits similar behavior to other polar-orbiting sun-synchronous satellites: the local time of the measurements fall into two 8-hour (local time) windows each day. The measurements from the 8-hour windows can be processed separately to increase temporal resolution. Accounting for the difference in time of ascending node between QuikSCAT and ASCAT has led to similar results for ASCAT as has been previously done on QuikSCAT. We have validated the choice of window for ASCAT and confirmed its efficacy. The final LTD window divisions for ASCAT and for QuikSCAT (for comparison) are given in Tab. 1.

We use 2-day LTD images to increase the spatial coverage of LTD images. There is some loss of temporal resolution, but as shown in Fig. 10, combining the LTD data from multiple days retains many diurnal features. The advantages of greater spatial coverage and resolution of diurnal effects convince us to regularly process 2-day LTD images for ASCAT in the future.

Table 1: The LTD window definition for regions in the north and south hemispheres. The ASCAT definitions are the QuikSCAT divisions shifted by 15.5 hours.

	QuikSCAT		ASCAT	
NHe	12:00a–8:00a qmsh,qmsv	4:00p–12:00a qesh,qesv	7:30a–3:30p mnfa	3:30p–11:30p mefa
SHe	4:00a–12:00p qmsh,qmsv	12:00p–8:00p qnsh,qnsv	3:30a–11:30a mmfa	7:30p–3:30a mefa

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