Brigham Young University
Department of Electrical and
Computer Engineering

459 Clyde Building
Provo, Utah 84602

Effects of Time Sampling on QuikSCAT Near Real Time Polar Images

Brandon R. Hicks

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Effects of Time Sampling on QuikSCAT Near Real Time Polar Images

Brandon R. Hicks
Microwave Earth Remote Sensing Laboratory, Brigham Young University
Provo, Utah

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Abstract

Daily near real-time images of the northern hemisphere are created using 38 hours of data. Using more than 24 hours of data to create these images allows complete coverage, but also causes some interesting temporal sampling effects to occur. When combined with the sampling geometry of the SeaWinds instrument aboard QuikSCAT, this has the effect of making the effective sample time to oscillate on a 4-day period. This report explains the effect and gives qualitative as well as quantitative measures that these effects have on the available images.

1 Introduction

The SeaWinds instruments aboard QuikSCAT is a spaceborne scatterometer in a near-polar sun-synchronous orbit. Because of its wide swath width and orbit geometry this satellite covers many areas in the polar regions multiple times a day. The backscatter data collected is processed into daily near real-time images of the northern hemisphere. These images are used operationally by many organizations for various reasons including the tracking of sea ice.

Because full coverage northern hemisphere images are desired, the images produced for the near real-time (NRT) image set include some data from the previous day. As a result of including more than 24 hours of data in each images, and the time sampling characteristics of QuikSCAT, many ares in these images have effective sample times which change from day to day, making the time separation between images of adjacent days to oscillate. When computing ice velocities by measuring displacement, this oscillation may cause spurious velocity estimates if not accounted for.

This report first discusses the creation process for the NRT images, then the result of QuikSCAT's orbital and measurement geometry effect on the images is shown. Finally, the result of these combined effects on the effective pixel time is considered.

2 Background on QuikSCAT NRT Images

QuikSCAT data is continuously collected and processed into both scientific and near real-time (NRT) image sets. The NRT images are produced shortly after the data has been acquired, and are made available daily using data from the past 38 hours of collected data. 38 hours of data is used in the NRT images, as opposed to the normal 24 hour period used

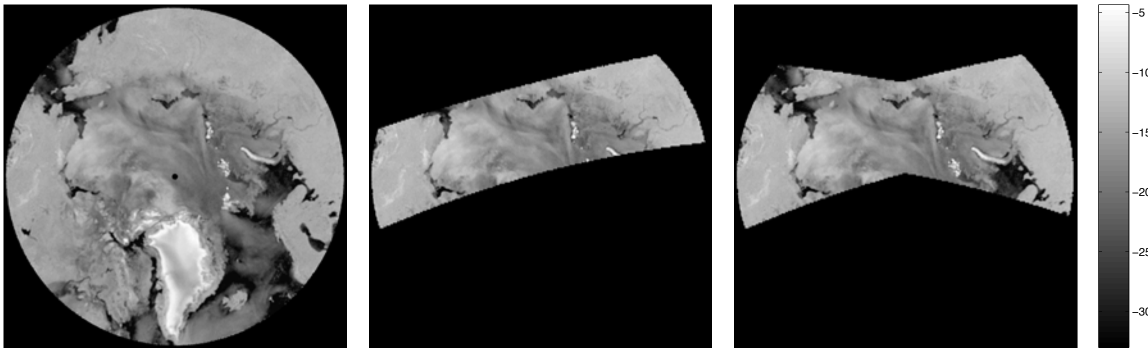


Figure 1: A QuikSCAT v-pol image showing a) an image of the Arctic (Arc) region of the earth, b) the same image masked to show the structure of a single pass, and c) the same image masked to show the structure of two consecutive passes. NHe images are similar to Arc images only with additional coverage extending to 45 degrees N.

in the scientific images, to increase the coverage of data and to make full coverage images of the northern hemisphere (NHe) region possible.

In the production of the NRT NHe images, the algorithm that combines the data and produces the images is run at roughly 0:00 UTC every day. When run, the processing code takes whatever data is available from the past 38 hours (or after roughly 10:00 UTC the previous day), combines and processes them into the image. Because of random variations of the precise starting and running times of the processing code, and random variations in the satellite pass data available, the number of passes and the actual starting and ending times of each image vary from image to image.

The images themselves are produced by the AVE algorithm. For each pixel, this algorithm averages all the normalized radar cross section, σ_0, measurements which cover that pixel. The NRT images produced by QuikSCAT have a pixel resolution of approximately 2.25 km, however, the effective resolution limited by the measurement geometry, is estimated to be around 6–10 km.

3 QuikSCAT orbit and its Effect on Time Sampling

Because QuikSCAT is in a near-polar sun-synchronous orbit, it passes near the poles many times a day. With an approximately 101 min orbit period, in a 24 hour period the satellite makes 14.25 orbits a day, thus repeating coverage every 4 days. For NRT images which include nearly 38 hours of data, 21–23 passes are included in each image. Figure 1a shows an Arctic QuikSCAT SIR image from the scientific image set. This same image is masked in Figure 1b to exclude all but one pass of the satellite. Figure 1c is also masked to exclude all but two consecutive passes. These figures illustrate the general shape and pattern of passes that QuikSCAT makes viewed from a polar stereographic projection that Arctic (Arc) and NHe images share. Note that because the earth rotates beneath the syn-synchronous orbit the pattern made by the second pass in Figure 1c is a rotated version of the first about north pole located at the center of the image.

In the course of the 38 hours of data used to make NRT images, the satellite covers every point in the NHe region at least once. However, for many areas of this region, pixel

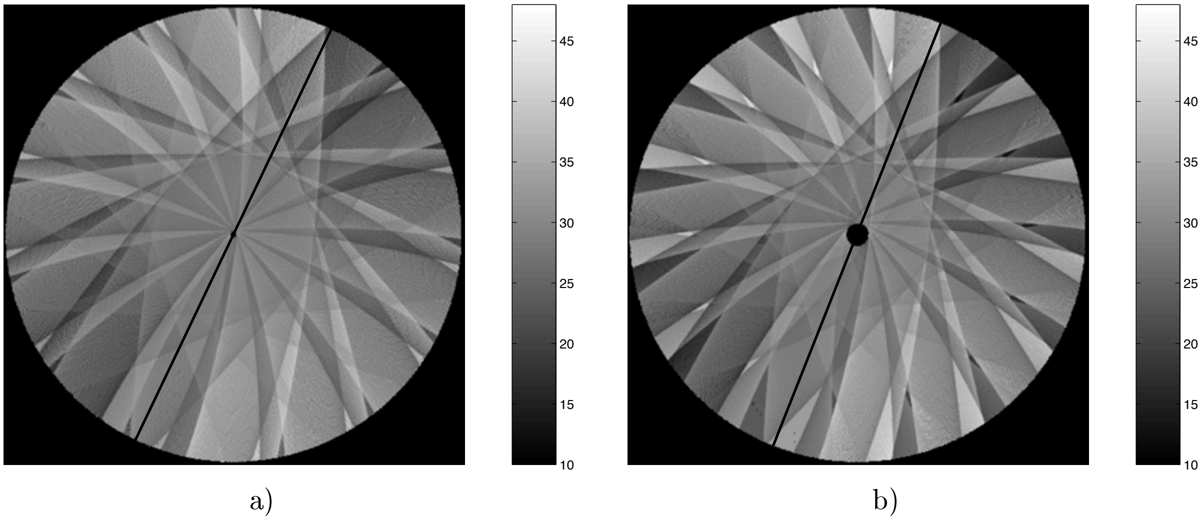


Figure 2: A typical NHe pixel time image in hours from 0:00 UTC of the images' starting day for a) v-pol, and b) h-pol (which has a narrower swath than v-pol). The black lines placed at a diagonal through the center of the images shows an apparent line of anti-symmetry. Note the bands of light (later) and dark (earlier) that radiate out from the center and tangental to the outer edge of each swath.

values are the average of measurements from many passes. Due to its sun-synchronous orbit, QuikSCAT makes one pass every 12 hours on average for any particular location along the southern most boundary of the NHe images, 45 degrees North. Although the satellite passes twice daily, its limited swath width leaves small regions unmeasured in a 24 hour period. By using 38 hours of data to make the daily images, these missed coverage regions are filled.

Filling in these regions comes at a cost: the effective pixel time becomes more variable. The "effective pixel time" is defined as the average time of all the measurements covering the pixel. For areas with only one pass, each pixel's time is exactly determined by the time of that particular pass. At the lower latitudes in the images, there is the possibility of having either one or two passes at any given pixel, each separated by nearly 24 hours. Because some areas have these widely spread samples, and others are purely determined by a single pass, there maybe wide variations in effective pixel time at lower latitudes in these images. Because of these variations, the effective pixel time is dependent on the location of the pixel and time of each pass.

Figures 3a and 3b are images showing the effective pixel time in hours starting from 0:00 UTC of the first day included in the image for v-pol and h-pol respectively. The line through the center of the images is added to show that there is anti-symmetry in the images. The light and dark bands, representing areas of later and earlier than average sample times, are the result of more than 24 hours of data being included in each image. The small triangular regions on the outer edge of the image are areas where only one pass during the 38 hour period are included in the images.

Figure 3 shows the time separation in hours between two consecutive daily h-pol NRT images, and illustrates the effect that the coverage pattern rotation has on image time separation. The alternating bands of red and blue show how the daily coverage pattern shift affects the time separation. Because these bands alternate, and shift from day to day,

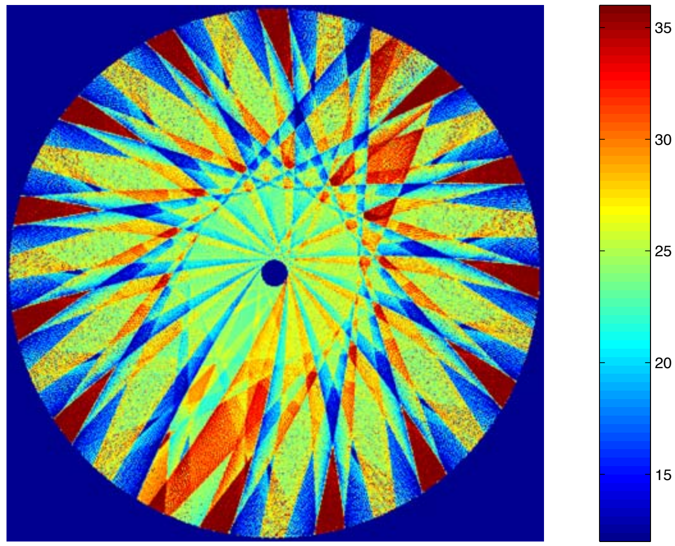
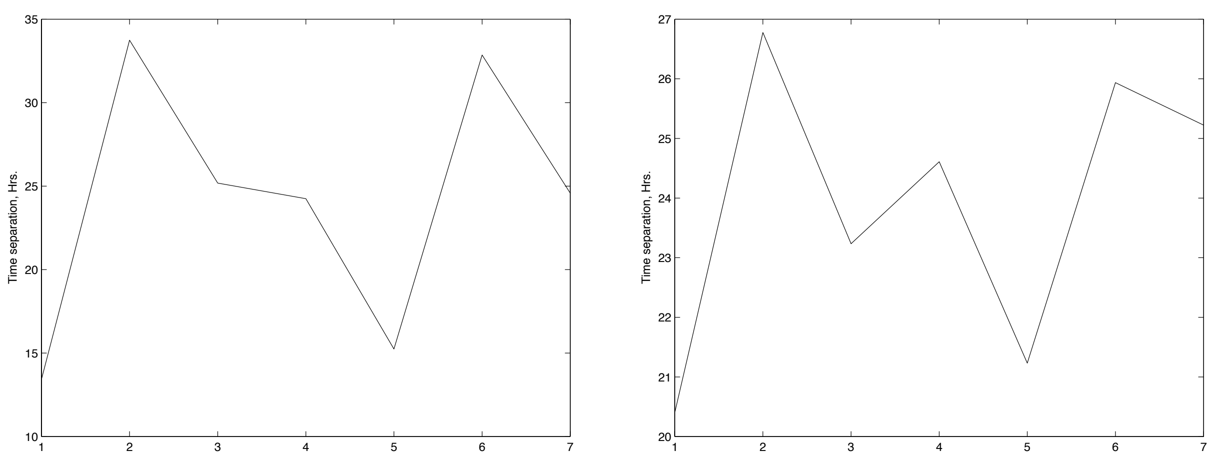


Figure 3: Time separation in hours from between two consecutive h-pol NRT images. The alternating pattern of red and blue is a result of the coverage pattern shifting. This pattern rotates from day-to-day resulting in alternating pixel times. This alternating from red to blue causes the effective time separation between images at a particular pixel to oscillate.

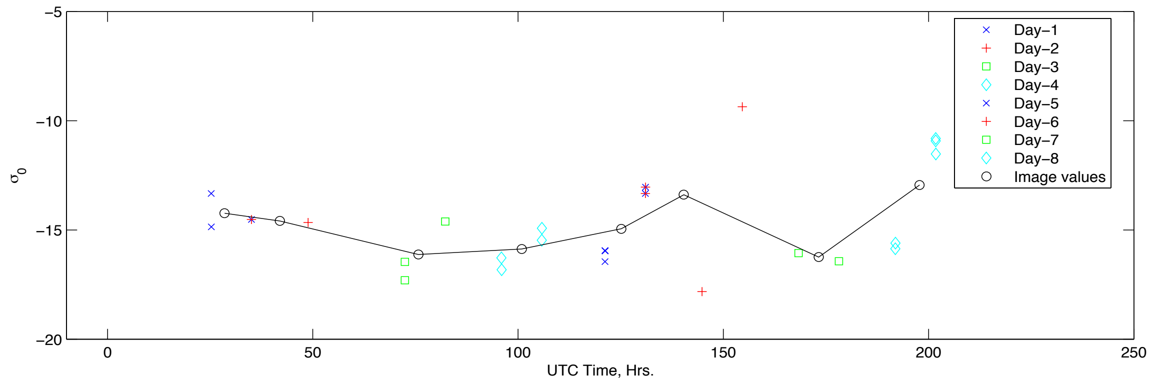
the time separation for pixels in these bands tends to oscillate: This means that on one day the image time for a particular pixel is later than normal, and the next day it may be earlier.

Figures 4a, and 4b show the time separation for two specific pixels located in the Hudson Bay, and the Beaufort Sea respectively. The pattern seen in these figures illustrates the day to day variability of the pixel time in these regions. In addition to the 4 day pattern

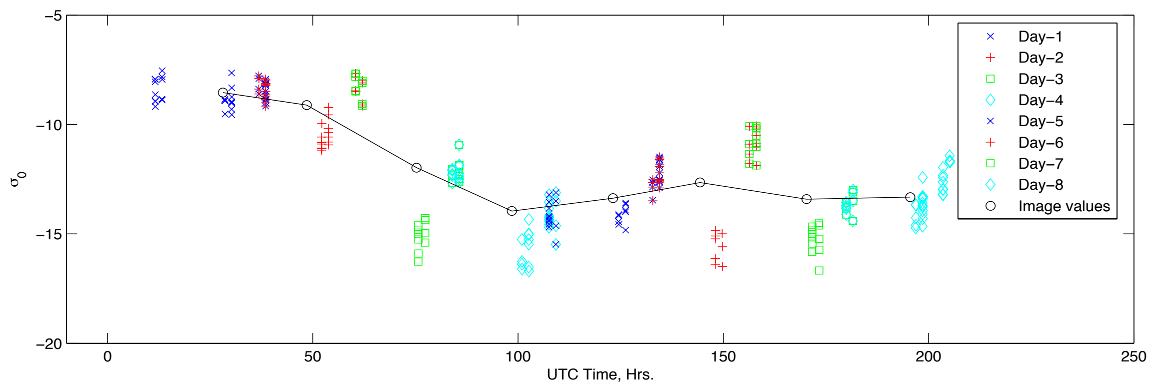


a) b)

Figure 4: Separation time between consecutive days in an 8 day series in a) the Hudson Bay (60.0009 N, 85.0024 W), and b) the Beaufort Sea (72.0035 N, 135.9032 W). Note the 4 day repeating cycle.



a)



b)

Figure 5: The QuikSCAT measurements starting in JD 163, 2003, that make up NRT NHe pixels in a) the Hudson Bay (60.0009 N, 85.0024 W), and b) the Beaufort Sea (72.0035 N, 135.9032 W). Some of the measurements are shared between consecutive days, indicated with composite markers (e.g. star is the composite of the 'x' and the '+' markers). The 4 day variations and the source of additional temporal noise is apparent in these graphs; note that passes appear as columns of measurements, daily pass count depends on the day in the 4 day cycle, and the number of measurements per swath varies depending on the particular orbit and measurement geometry of the particular pass.

apparent in these figures, there is some additional variability. This additional noise is due to a changing number of measurements per pass in each pixel from day-to-day. The number of measurements covering each pixel is partially determined by the location of that pixel in the swath, thus the number of pixels per pass follows the 4-day pattern as well. However, the actual number of measurements per pass is random and may vary from the mean number from day-to-day.

Figures 5a and 5b the individual measurements averaged to create the image pixel values for the same pixels used in Figures 4a and 4b. Both sources of time separation variation are visible in these scatter-plots: 4-day cycle variations, and random measurement count variations. Individual passes appear as columns of measurements because they are taken within a few minutes of each other, and passes are separated by 100 min. The number of passes on any particular day in the 4-day cycle has direct influence on the time separation. Whether a pass is shared by consecutive images also plays a large role. Directing attention to the first three image values in Figure 5a, one can see that the sharing of a pass by the first image, and the second image draws the two image times closer together. Because these image times are so close together, it forces the third image value to be farther separated from the second. The rest of the days in the cycle are near the mean 24 hour separation time, causing the oscillating pattern in Figure 4a.

In Figure 5b there is more consistency in the number of shared passes in each day in the cycle, resulting in smaller variations. There is a 4-day variation clearly visible in 4b, which results from the number of measurements per pass having some dependency on where in the swath the pixel is located, which location depends on the day in the 4-day cycle. The additional temporal noise is also somewhat visible with the number of measurements in each pass varying between two days in the same cycle phase (i.e., day 1, and day 5, or day 3, and day 7).

4 Conclusion

In this report we have explained how data is used to create the NHe images in the NRT image set. Namely, the last 38 hours of available data is combined to create each daily image. This is done to create full coverage images of this region. Using 38 hours of data does have some repercussions on the time sampling that occurs in the image. When combined with the sampling geometry of QuikSCAT, this has the effect of causing the daily sample time to change from day to day. This effect closely follows the 4-day coverage cycle that QuikSCAT employs.

Because the effective sample time oscillates on a 4-day period, velocity estimates of sea ice from these images will suffer from periodic errors unless compensated for. All satellite systems that create composite images will suffer similar effects to greater or lesser extent. The best means of compensating for these effects, an approximate sample time image, is not available for NRT images currently produced. NRT Pixel time images, similar to the scientific **p** images available at [1], are not available, however, these images might be made available if sufficient demand exists.

References

[1] *Scatterometer Climate Record Pathfinder*, *http://scp.byu.edu/data.html*, Center for Remote Sensing, Brigham Young University. (Note NHe images are produced only for NRT and are not in the scientific data set.)