A QuikScat/SeaWinds Sigma-0 Browse Product

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Abstract

Following up on the successful NSCAT mission, the QuikScat/SeaWinds scatterometer (Qscat) provides normalized radar cross section (σ^o) measurements of the Earth's surface at unprecedented coverage and resolution. While originally designed for wind observation, scatterometers have proven useful in a variety of land and ice studies. To aid in the selection of regions and time periods for study, a global σ^o browse product is produced by Brigham Young University. This product consists of spatial and temporal averages of Qscat L1B σ^o values over a one-day period. This report briefly describes this σ^o browse product.

1 Introduction

Though the mission was cut short by the loss of the host spacecraft, NSCAT was an unqualified success. In addition to advances from its primary wind observation mission. NSCAT data has also had an impact on a variety of polar ice [1] and tropical vegetation [2] studies. In particular, NSCAT data is very effective in mapping the extent of sea ice [3, 4]. It is clear that scatterometers can continue to play an increasingly important role in monitoring tropical vegetation and polar ice in the future.

As a follow-up/replacement for the NSCAT mission, the QuikScat/SeaWinds scatterometer (Qscat) provides measurements of the near-surface ocean wind field with unprecedented coverage and resolution. Qscat makes dual polarization measurements of the normalized radar cross section (σ^o) at both vertical and horizontal polarization. The σ^o measurements are finding application in land, ice, and ocean studies. As an aid to the selection of data to support such studies, Brigham Young University is producing a simple global σ^o browse product. This report describes this product.

2 Qscat σ^o Browse Product

Unlike NSCAT which made σ^o measurements over a broad range of incidence angles, Qscat makes σ^o measurements at each of two nominal incidence angles, 46° and 54.1°, corresponding to the inner and outer beams. The inner beam measurement is horizontal-polarization while the outer beam is vertical-polarization. Since it is undesirable to combine measurements from different polarizations, measurements from each beam are kept separate. We note that the variation in incidence angle over an orbit is small, typically less than a few tenths of a degree. For this reason, the incidence angle variation is not considered in this browse product.

Qscat σ^o measurements are reported in two forms: termed 'eggs' and 'slices' in the Qscat L1B files. These differ in their spatial sizes and shapes. The nominal instantaneous Qscat antenna footprint is an ellipse. However, the on-board range-doppler processing incorporated in the instruments improves the resolution. Using the on-board processor, twelve individual σ^o measurements are obtained for each footprint, though only 8 are reported in the L1B data product. These individual measurements are termed 'slices'. The slices are typically 6 km long (depending on the instrument mode and antenna beam) by 25 km wide. The summed measurements of the 8 center slices are known as 'egg' measurements and are reported in the standard L1B product. The effective resolution of the egg measurement nearly matches the elliptical 3 dB antenna footprint (approximately 15 km by 25 km depending on the antenna beam and instrument mode). Although lower resolution, the egg measurements have smaller measurement variance (K_p^2) than slice measurements and are also less sensitive to calibration errors. For this reason the σ^o browse product defined here is based on the egg measurements.

The σ^o browse product consists of a suite of images produced for three areas: (see Table 1) 1) a global rectangular lat/lon grid, 2) a southern hemisphere polar stereographic projection, and 3) a northern hemisphere polar stereographic projection. The grid resolution for the global projection is 5 pixels/deg, or about 22.5 km/pixel at the equator. The polar stereographic projections use a 70° reference latitude with a nominal grid size of about 22.5 km. The global projection product is best suited for equatorial and mid-latitude views, while the polar stereographic projections are best suited for high-latitude views. While the global browse product includes the entire globe, the projection distortion results in sampling problems in the polar regions; hence the production of separate polar products. The polar stereographic views include only measurements above a high latitude cutoff of 52°.

Region Name	Region Abreviation	Lower-Left Corner Latitude	Lower-Left Corner Longitude	Upper-Right Corner Latitude	Upper-Right Corner Longitude	Region Code Number
Southern Hemisphere	S	-90.0	-180.0	-52.0	180.0	100
Northern Hemisphere	N	52.0	-180.0	90.0	180.0	111
Global	G	-90.0	-180.0	90.0	180.0	500

Table 1: Browse product regions. The Northern and Southern hemisphere images (code 100 and 111) are produced in polar stereographic form while a rectangular projection in lat/long is used for the global image (code 500).

In producing the browse σ^o images, the center of each L1B egg σ^o measurement is located. The measurement is averaged into the image grid element (pixel) in which the center of the measurement falls, i.e., the measurements are gridded into earth-located pixels based on their location. The effective resolution of the image products is less than the pixel resolution, or approximately 55-60 km at the equator. The resulting images are temporal averages over a one day period of all the σ^o measurements whose centers fall within each image pixel area. We note that using slice σ^o measurements rather than egg σ^o would improve the effective resolution somewhat, though not significantly. The resulting browse image product is stored in the BYU Microwave Earth Remote Sensing (MERS) **SIR** file format described in Section 4. The file format includes a header which contains location transformation information.

Viewer and reader programs for the BYU MERS **SIR** file format are available on line from the

BYU MERS web and anonymous ftp sites at URLs `http://www.mers.byu.edu/` and `ftp://ftp.cers.byu.edu/`, respectively. A standard file naming convention for Qscat products (described below) is used.

The σ^o browse products are produced from L1B data. Only measurements flagged as 'usable' in the L1B file are included in the browse product. One set of image products is produced per mission Julian day. For each of the three projections, three separate image products are produced: the mean σ^o value in each pixel, the normalized standard deviation of the measurement in each pixel, and the count of the number of measurements used in each pixel. Each image browse product is stored in a separate file. Overlapping swaths are averaged.

3 Product file name format

The standardized data file naming scheme is:

$$QS\_Xb\mathbf{pTR}3C\mathbf{YEARDAY}.date$$

where **p** is the one character polarization ('h' or 'v') designator, **T** is the one character image type code ('a', 'C', or 'V'), **R** is the one character region ('G'=Global, 'N'=Northern Hemisphere, and 'S'=Southern Hemisphere), **YEAR** is a four digit year code, **DAY** is a three digit Julian day code, and *date* file extension is an 11 character string containing the file production date.

In the file name the product type is denoted by a one character type designator (see Table 2).

a: Mean σ^o value expressed in dB of the absolute value. Negative σ^o values are denoted by setting the corresponding pixel of the count image to a negative. The σ^o values are clipped to ± 32.5 dB with -33 used to denote no available data. For QuikScat/SeaWinds, the reference incidence angles are approximately H-pol (inner beam) 46° and V-pol (outer beam) 54.1°.

C: counts. The absolute value indicates the number of σ^o measurements which hit the pixel during the imaging interval. Negative values indicate that the corresponding mean σ^o value is negative. Zero denotes no data.

V: The normalized standard deviation (K_p) image defined as the standard deviation of the σ^o measurements hitting each grid element divided by the mean σ^o value. No estimate is made if the mean σ^o is negative and zero is returned. A negative V value indicates no data.

x: Longitude image (0° to 360°). This product contains an 'image' whose data is the longitude of the center of the image pixel and is provided for convenience of the user. Since only a single image is needed for the full image, the naming convention for this product is somewhat different than data products.

y: Latitude image (−90° to 90°). This product contains an 'image' whose data is the longitude of the center of the image pixel and is provided for convenience of the user. Since only a single image is needed for the full image, the naming convention for this product is somewhat different than data products.

A sample product listing is available in Appendix A. Table 3 gives the approximate file sizes for the BYU `SIR format` σ^o browse product files for each region.

Two auxiliary image files are available for each region. These files contain the longitude and latitude for the center of each pixel, respectively. The files are in the same format as the product

T (type)	Code Number	Description
a	1	σ^o (in dB)
C	8	counts or hits (measurements) per pixel
V	23	standard deviation image (unitless)
x	3	longitude image (deg)
y	31	latitude image (deg)

Table 2: Standard internal type codes for products

Region Name	File size (MB)	Pixel Size (X×Y)	Region Code Number
Southern Hemisphere	0.3	388 × 388	100
Northern Hemisphere	0.3	388 × 388	111
Global	3.2	1800 × 900	500

Table 3: Approximate σ^o browse product file sizes for each region.

but have a latitude value or longitude value instead of a σ^o value stored in the image. The naming scheme for the auxilary files is:

$$QS\_Xbl\mathbf{TR}3C.date$$

where **T** is the one character image type code ('x', or 'y'), **R** is the one character region ('G'=Global, 'N'=Northern Hemisphere, and 'S'=Southern Hemisphere), and *date* file extension is an 11 character string containing the date of the file's creation. This file is not expected to change over the life of the mission so only one file of each type per region is created.

4 User Notes

The σ^o browse products described herein are intended to help users to identify features of interest directly in the Qscat σ^o measurements by providing a spatial and temporal (over one day) average view of the Qscat σ^o measurements. Note that in producing the mean σ^o product, all σ^o measurements (from a single beam) falling within a single pixel are averaged. Thus, the forward-looking and aft-looking measurements are averaged and the resulting average is over the various azimuth angles of the measurements. The azimuth angles of the measurements hitting a given location vary with the pixel location and with time and may be further affected by missing or low-quality data. Discontinuities and artifacts can occur at swath edges and in areas where the surface shows significant azimuth dependence (e.g., over the ocean). The normalized standard deviation (K_p) images can be useful in evaluating temporal and azimuth variation in the σ^o measurements.

Computation of the average σ^o value is done in normal space (not in dB) with negative values included. If the resulting average is negative, the sign of the corresponding count image pixel is set to negative. Thus, count images can have both postive and negative values. In practice, negative averages occur primarily over the ocean in low wind speed regions. The count images are also useful for creating multi-day averages and as a quality control. Note that due to the rotation of the antenna, the cross-track density of σ^o measurements varies with more measurements at the outer edges of the swath than at the swath center. As a result, swath edges are clearly visible in the count images. Some areas of the Earth's surface are not covered in a single day, resulting in diamond shaped regions of no coverage in mid-latitude and equatorial averages. These no coverage regions are larger in the h-pol images than in the v-pol images due to the narrower swath of the h-pol measurements.

5 The BYU `SIR` File Format

The BYU-MERS **SIR** image format was developed by the Brigham Young University (BYU) Microwave Earth Remote Sensing (MERS) laboratory to store a variety of image types along with the information required to Earth-locate the image pixels.

A **SIR** format file consists of one or more 512 byte headers followed by the image data and additional zero padding to insure that the file is a multiple of 512 bytes long[1]. The file header record contains all of the information required to read the remainder of the file and the map projection information required to map pixels to lat/long on the Earth surface. The image pixel values generally represent floating point values and may be stored in one of three ways. The primary way is as 2 byte integers (with the high order byte first), though the pixels may be stored as single bytes or IEEE floating point values. Scale factors are stored in the header to convert the integer or byte pixel values to native floating point units. The image is stored in row-scanned (left to right) order from the lower left corner (the origin of the image) up through the upper right corner. By default, the location of a pixel is identified with its lower-left corner. The origin pixel (1,1) is the lower left corner of the image. The array index n of the $(i,j)^{th}$ pixel where i is horizontal and j is vertical is given by $n = (j-1) * N_x + i$ where N_x is the horizontal dimension of the image. The last pixel stored in the file is at (N_x, N_y).

The sir file header contains various numerical values and strings which describe the image contents. For example, a no-data flag value is set in the header as well as a nominal display range and the minimum and maximum representable value. Optional secondary header records (512 bytes) can be used to store additional, non-standard information.

The standard **SIR** file format supports a variety of image projections including:

1. Rectangular array (no projection)
2. Rectangular lat/lon array
3. Two different types of Lambert equal-area projections which can be used in either non-polar or polar projections
4. Polar stereographic projections
5. EASE grid polar projection with various resolutions
6. EASE global projection with various resolutions

For the Qscat global σ^o browse products, only the rectangular array and polar stereographic projections are used. Also, the browse product naming scheme is not SIR-standard.

Readers for the **SIR** file format are available in C, FORTRAN, Matlab, and IDL/PVWAVE. A customized version of the unix **xv** program which can read, display, and print **SIR** format files is also available. Viewer and reader programs are available on line from the BYU MERS web and anonymous ftp sites at URLs `http://www.mers.byu.edu/` and `ftp://ftp.cers.byu.edu/pub/sir`, respectively[2]. Documentation for these readers are located there. Sample files and various utility and display routines are also available. (Be sure to use binary ftp to transfer `.sir` files!) Adobe Photoshop can display the image data `.sir` file stored as two-byte integers. Read the file as 'raw', specify a 512 header and 16 bit data, and enter the pixel size.

[1] This ensures that images can be transferred to and from all platforms without loss using binary ftp.

[2] The reader code may be copied and modified and freely distributed so long as (1) original or modified code is not redistributed for profit and (2) acknowledgment is made that the original code was obtained from the Microwave Earth Remote Sensing Laboratory at Brigham Young University, Provo, UT.

References

[1] D.G. Long and M.R. Drinkwater, "Cryosphere Applications of NSCAT Data," *IEEE Trans. Geosci. Remote Sens.*, Vol. 37, No. 3, pp. 1671-1684, 1999.

[2] D.G. Long, "NSCAT Views Land and Ice," *Proc. Int. Geosci. Rem. Sens. Sym.*, pp. 1973-1975, Seattle, Washington, 6-10 July, 1998.

[3] Q.P. Remund and D.G. Long, "Polar Sea Ice Extent Mapping Using Ku-Band Scatterometer Data," *J. Geophys. Res.*, Vol. 104, No. C5, pp. 11515-11527, 1999.

[4] Q.P. Remund and D.G. Long, "Sea Ice Mapping Algorithm for QuikSCAT and SeaWinds," *Proc. Int. Geosci. Rem. Sens. Sym.*, pp. 1686-1688, Seattle, Washington, 6-10 July, 1998.

Appendix

A Sample Product Listing

The following is a sample listing of the browse product files for data corresponding to JD001, 1999. See Section 3 for information on how to read the BYU `SIR` file format.

Browse Products

```
QS_XbhaG3C1999001.19990020101
QS_XbhVG3C1999001.19990020101
QS_XbhKG3C1999001.19990020101
QS_XbvaG3C1999001.19990020101
QS_XbvVG3C1999001.19990020101
QS_XbvKG3C1999001.19990020101
QS_XbhaG3C1999001.19990020101
QS_XbhVN3C1999001.19990020101
QS_XbhKN3C1999001.19990020101
QS_XbvaN3C1999001.19990020101
QS_XbvVN3C1999001.19990020101
QS_XbvKN3C1999001.19990020101
QS_XbhaS3C1999001.19990020101
QS_XbhVS3C1999001.19990020101
QS_XbhKS3C1999001.19990020101
QS_XbvaS3C1999001.19990020101
QS_XbvVS3C1999001.19990020101
QS_XbvKS3C1999001.19990020101
```

Auxiliary Products

```
QS_XbxG3C.19990020101
QS_XbyG3C.19990020101
QS_XbxN3C.19990020101
QS_XbyN3C.19990020101
QS_XbxS3C.19990020101
QS_XbyS3C.19990020101
```

B Sample Images

Samples of selected Qscat σ^o browse images from JD 250, 2000 are presented in the following. Note that the images have been reduced in size for printing.

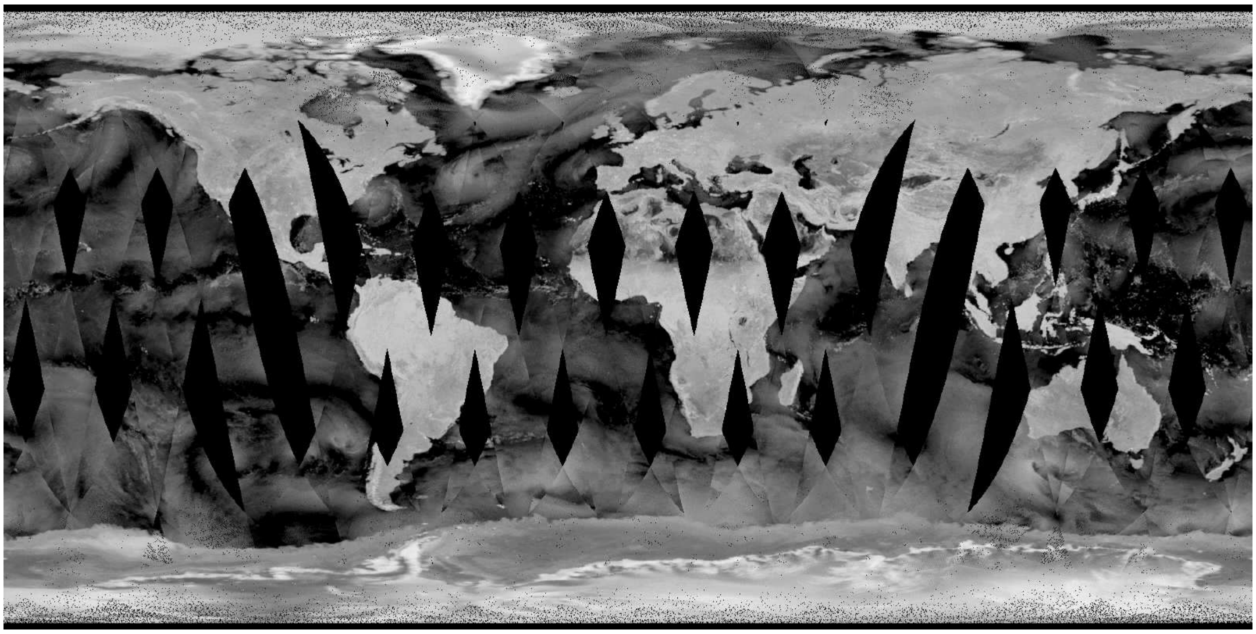

Figure 1: QS_XbhaG3C1999245.19992491643 (H-pol Global σ^o browse image). Grey scale extends from -32 dB to 0 dB.

Figure 2: QS_XbvaG3C1999245.19992491643 (V-pol Global σ^o browse image). Grey scale extends from -32 dB to 0 dB.

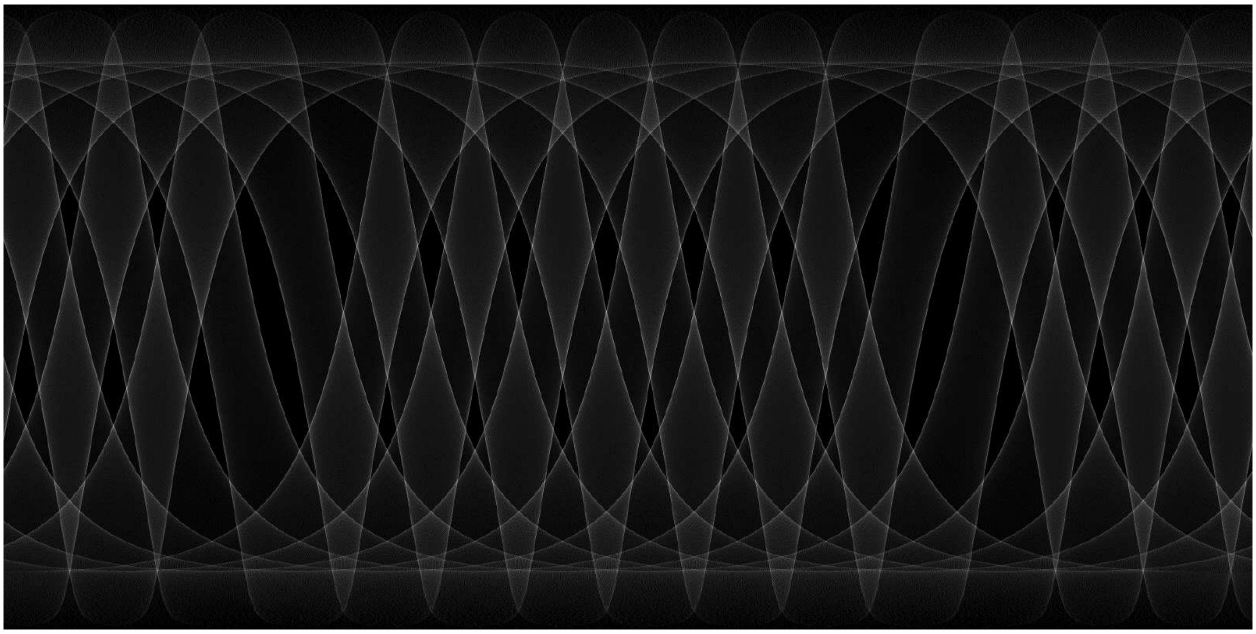

Figure 3: QS_XbvCG3C1999245.19992491643 (V-pol Global count image). Grey scale extends from 0 to 50.

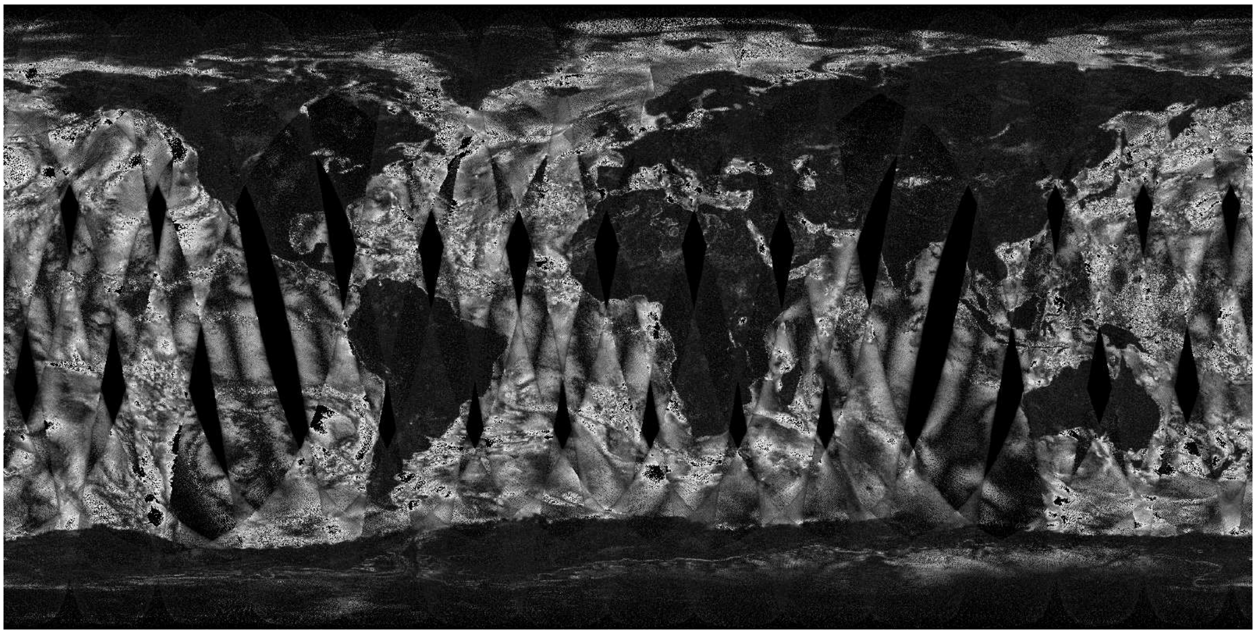

Figure 4: QS_XbvVG3C1999245.19992491643 (V-pol Global standard deviation (K_p) image). Grey scale extends from 0.0 to 1.0.

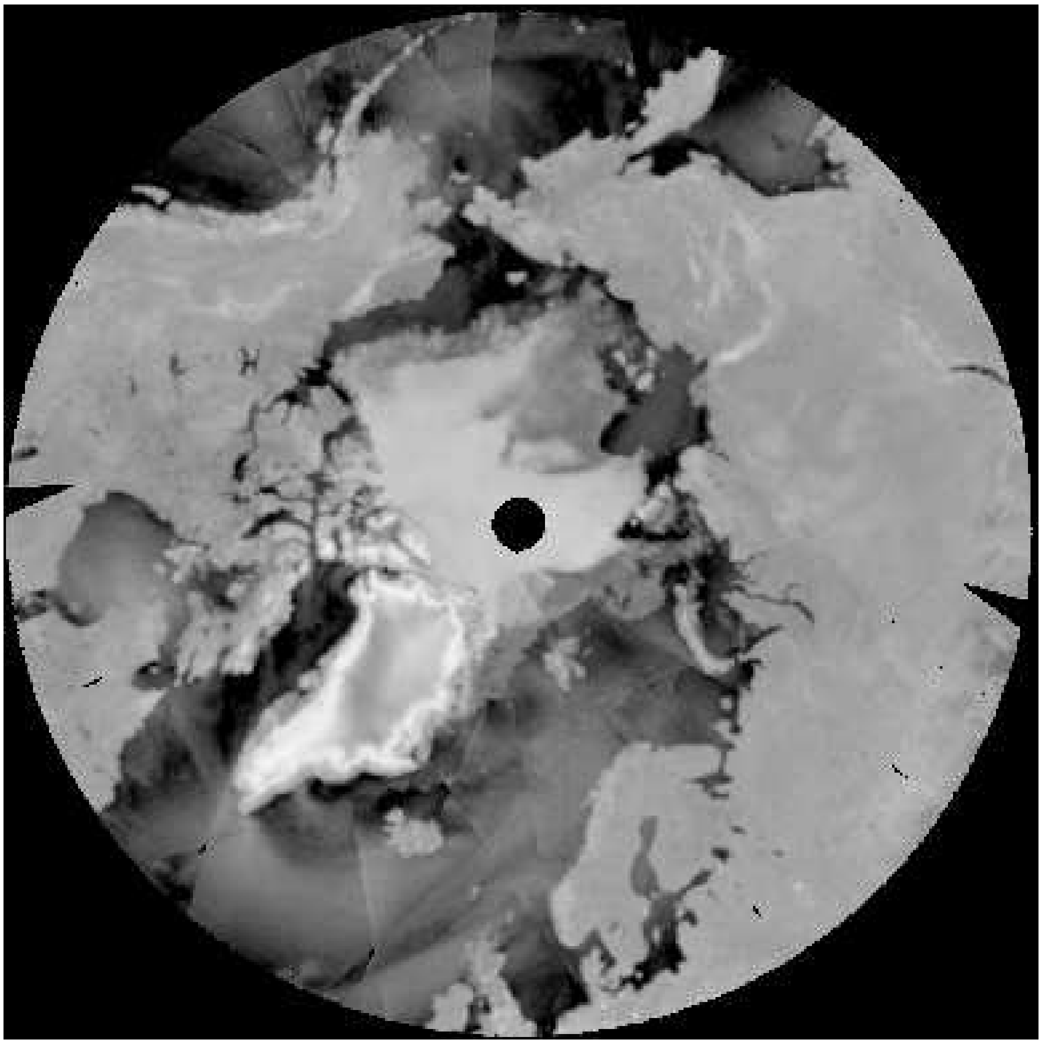

Figure 5: QS_XbhaN3C1999245.19992491643 (H-pol Northern Hemisphere σ^o browse image). Grey scale extends from -32 to 0 dB.

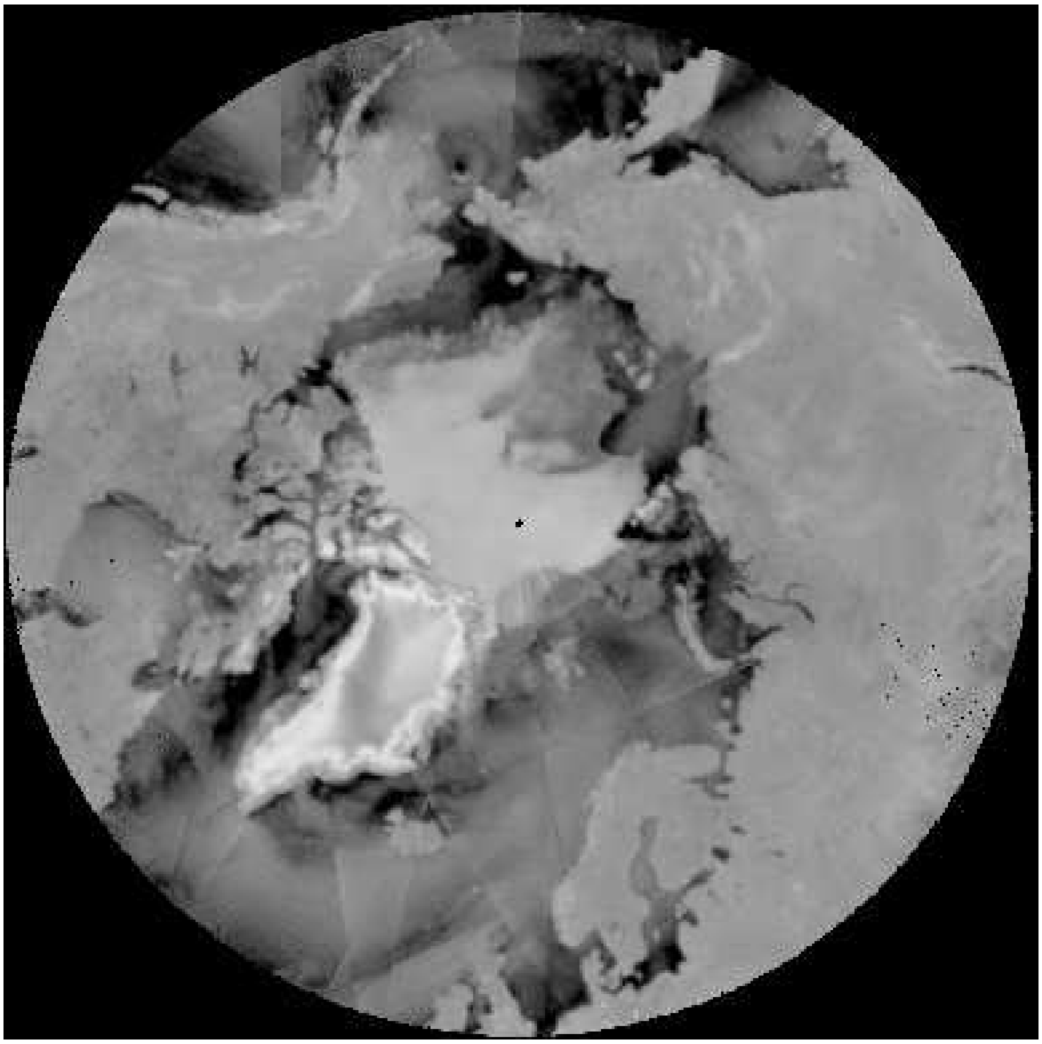

Figure 6: QS_XbvaN3C1999245.19992491643 (V-pol Northern Hemisphere σ^o browse image). Grey scale extends from -32 to 0 dB.

Figure 7: QS_XbhaS3C1999245.19992491643 (H-pol Southern Hemisphere σ^o browse image). Grey scale extends from -32 to 0 dB.

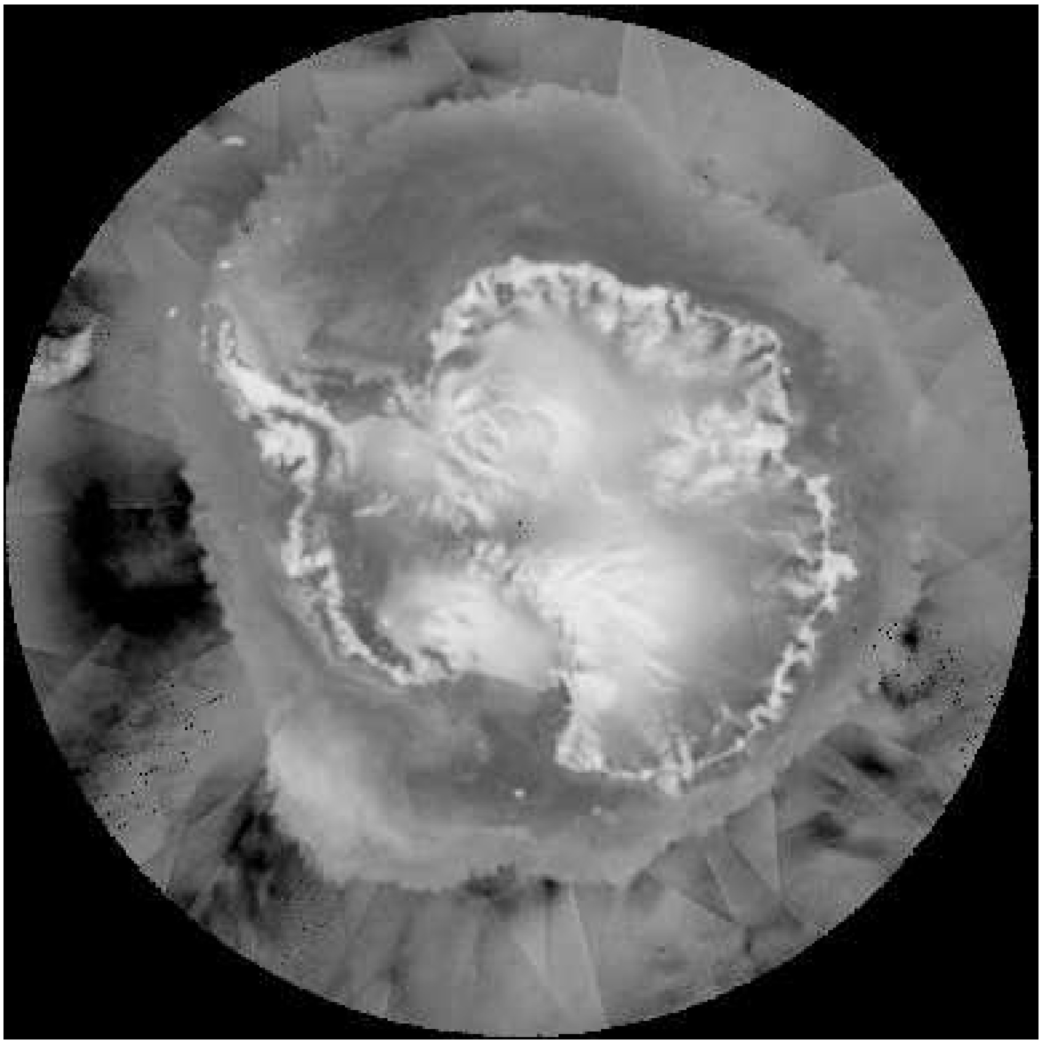

Figure 8: QS_XbvaS3C1999245.19992491643 (V-pol Southern Hemisphere σ^o browse image). Grey scale extends from -32 to 0 dB.

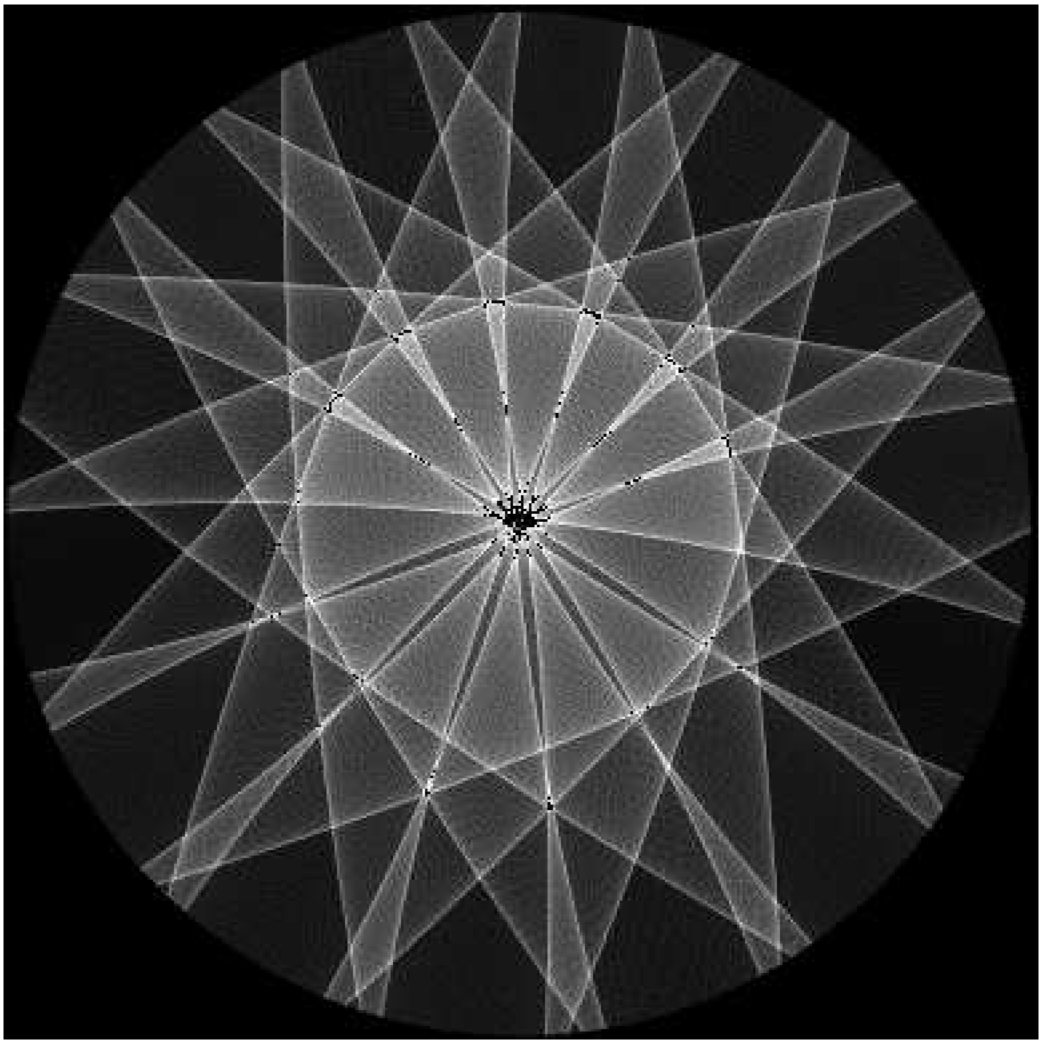

Figure 9: QS_XbvCN3C1999245.19992491643 (V-pol Northern Hemisphere count image). Grey scale extends from 0 to 50.

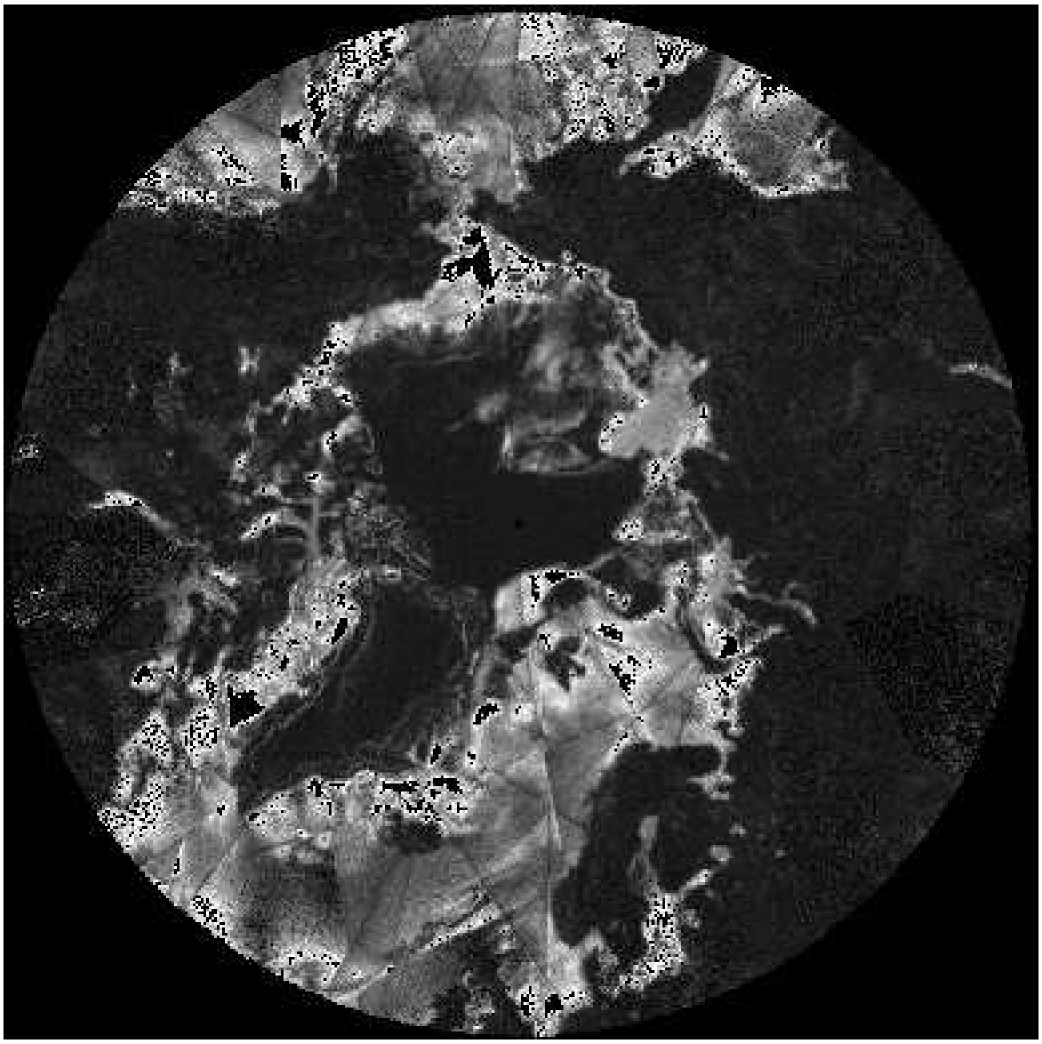

Figure 10: QS_XbvVN3C1999245.19992491643 (V-pol Northern Hemisphere standard deviation (K_p) image). Grey scale extends from 0.0 to 1.0.

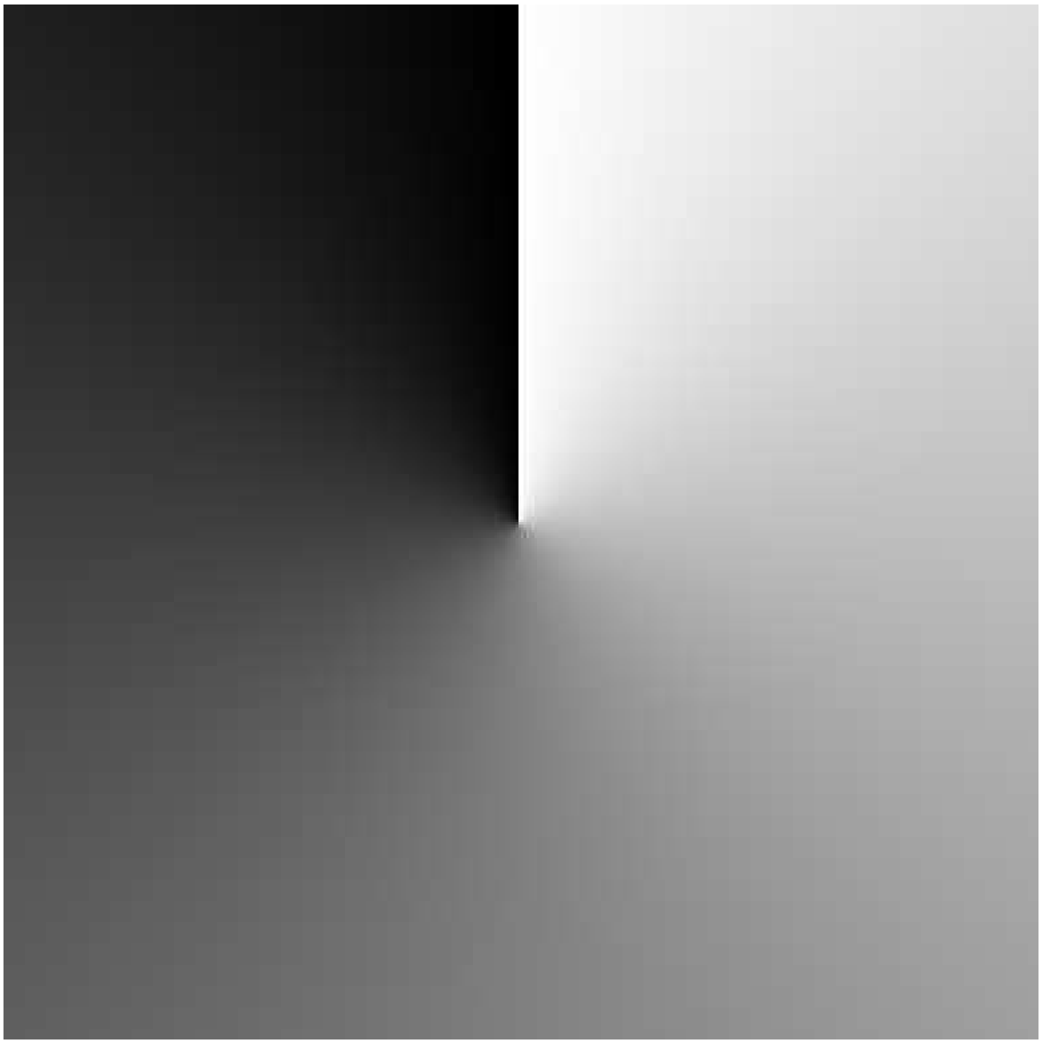

Figure 11: QS_XbxN3C.2000047.eps (Northern Hemisphere longitude image). Grey scale extends from 0 to 360 deg.

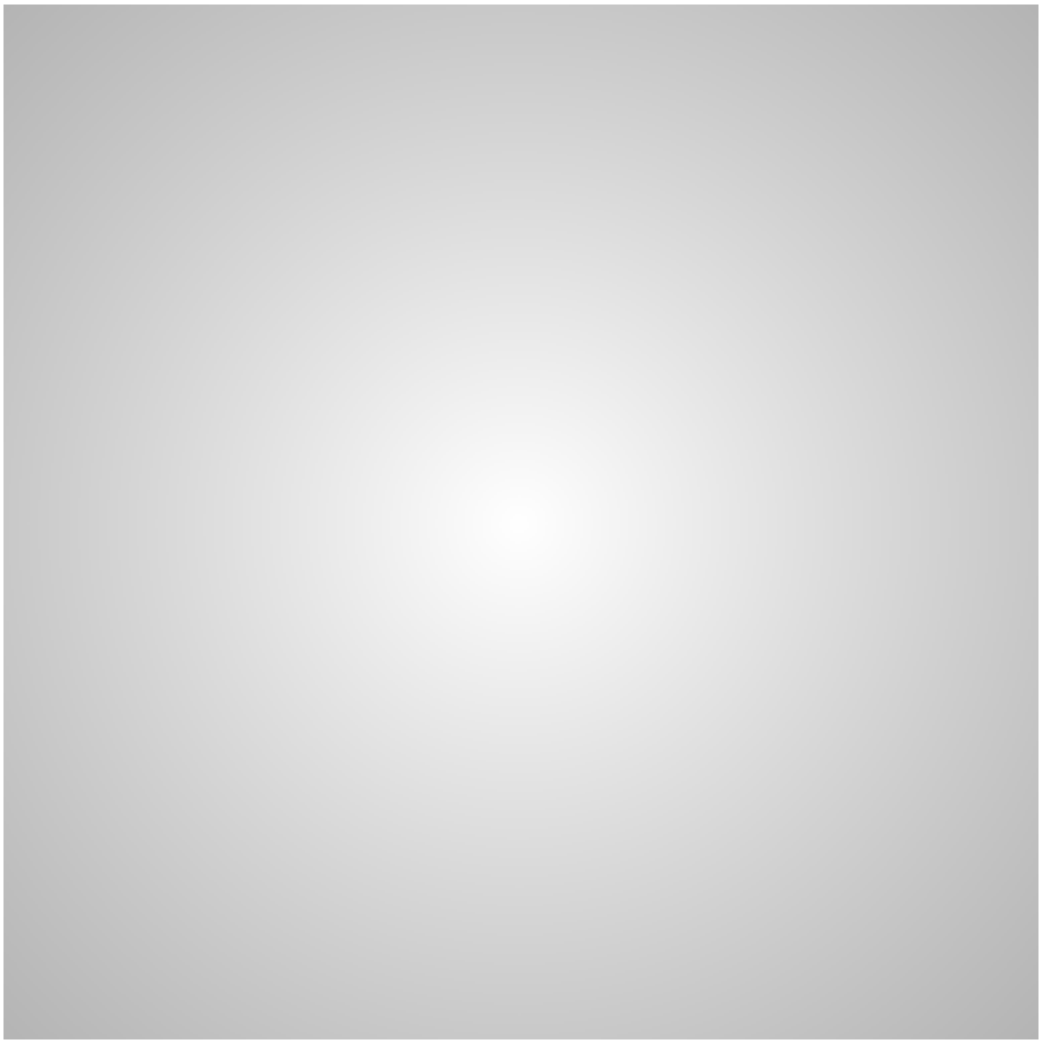

Figure 12: QS_XbyN3C.2000047.eps (Northern Hemisphere latitude image). Grey scale extends from -90 to 90 deg.