Radar Mosaics

We produced several image mosaics each covering the majority of Greenland. For RADARSAT we produce both calibrated and uncalibrated mosaics for the winters of 2000/1, 2005/6, 2006/7, 2007/8, 2008/9, 2012/13 and multi-year nearly complete mosaic. For ALOS we produced mosaics for the winters of 2008/9 and 2009/10. These mosaics were assembled from overlapping images, with a feathered average in the regions of overlap. Hence, areas with fast-moving ice in regions of overlap may appear slightly blurred due to motion between the acquisition of the overlapping images.

RADARSAT Mosaics

These mosaics were created using collected by the Canadian Space Agency's RADARSAT Synthetic Aperture Radar (SAR). The original-source data were all delivered by ASF (the Alaska Satellite Facility) as level-0 data, which includes digitized voltage values, calibration constants, satellite timing, attitude and position information, which together give all the information necessary to generate an uncalibrated SAR image of ground targets.

All data were collected using the FN1 (Fine-1) beam, which has a single-look resolution of around 4.6 m in the range direction and 5.6 m in the azimuth direction, at incidence angles between 33 and 35 degrees.

Level-0 data are processed into SLC (Single-Look Complex) images using the GAMMA software MSP package, assuming a flat, constant 0-dB antenna-sensitivity pattern, which determines the scaling between recorded DN (digital numbers, the output of the RADARSAT digitizer) and power returned from the ground, as a function of antenna angle.

For the 20-m mosaics, data were multi-looked by incoherently averaging by 3 looks in range by 4-looks in azimuth. This degree of averaging translates into a nominal ground resolution of 22-m by 22-m. For the 100-m mosaics, we multi-looked the data using 12 pixels in range and 18 pixels in azimuth, which yields a nominal ground resolution of 89x99 meters.

Geometric Calibration

Errors in the satellite time produce along track errors of up to several 10s of meters. For the 2000/1 mosaics we cross-correlated from adjacent overlapping tracks to compute the relative timing offset. We then calculated a mean offset, which we subtracted to determine an offset for each track. Comparison with other geolocated imagery indicates there are no substantial absolute offsets. For the mosaics from subsequent years, we determined the timing offsets by cross-correlating with the original 2000/1 mosaic. We also applied a range correction of 66 to 70 to the data from each year (a single value in this range was used for each year). As a result, the mosaics are internally consistent with relative displacement error between mosaics that generally are less than 1-pixel (20 m), where the topography is fixed (see next paragraph).

The image mosaics have all been terrain corrected using the GIMP DEM. Any errors in the elevation used at a given point translates in a horizontal displacement error in the across-track (range) direction of ~ dz/tan(38.5^o). In areas of unchanging topography, this yields a common elevation-error dependent location error at each pixel. Where glaciers are thinning rapidly, there is a time varying error that is depends on the change in elevation relative to the GIMP DEM used for terrain correction. So for example, the location of point on a glacier that has thinned by 100-m relative to the GIMP dem will have a horizontal location error of ~125 meters.

Uncalibrated Mosaics

We used a non-linear stretch on the uncalibrated byte mosaics to provide good visual discrimination of features within the images. The stretched data were also threshold to discard extreme values. As result, the pixel values for each year are not directly comparable. For inter-annual comparison of backscatter value the calibrated image mosaics should be used.

Calibrated SAR mosaics from RADARSAT C-band SAR data.

This product provides calibrated σ_0 images, which show spatial patterns in both the surface slope and the surface reflectance for C-band (5.3 GHz) radiation. These maps show the ratio between power incident on the surface and reflected power per unit area for a fictitious flat earth, in which the surface height varies from place to place, but the surface slope is always zero. This imagery is thus calibrated with respect to instrumental parameters and the range between the satellite and the target while preserving information that gives visual clues to the shape of the surface topography. Further correction for the surface slope to produce a γ_0 image depending only on surface properties is beyond the scope of this project.

Because the GAMMA processor did not provide calibrated outputs, it was necessary to derive radiometric calibration coefficients. These images are in arbitrary DN units, proportional to the sum of the received power and the receiver noise power. We apply two calibration constants and an assumed antenna sensitivity pattern to these images to calibrate the images:

$$\sigma_0 = (a \cdot DN - b) / G(\theta)$$

The antenna pattern $G(\theta)$ was provided by ASF and gives an estimate of the ratio between the power incident on the RADARSAT antenna and the recorded DN value, as a function of antenna angle θ, relative to the ratio at $\theta=0$.

The values of the *a* and *b* parameters depend on the SAR processor used to generate the images, so establishing their values for our imagery required comparing our uncalibrated to calibrated σ_0 imagery. We chose the RAMP (RADARSAT Antarctic Mapping Project) mosaic of Antarctica (cite Jezek) for this purpose, because it includes large numbers of calibrated images over polar snow and ice targets whose surface properties should be similar to those of Greenland targets. For seventeen areas around Antarctica, we generated uncalibrated images that were multi-looked 4 pixels in range by 6 pixels in azimuth, and calculated θ and $G(\theta)$ for each pixel. We extracted the same area from the RAMP mosaics at 100-meter resolution, and subsampled the RAMP imagery to the same resolution as the raw images. We smoothed both images to 400 m by convolving the values with a Gaussian kernel. We then used a grid-search algorithm to find *a* and *b* values that minimized the pixel-wise log misfit between the smoothed images:

$$R = \left(\frac{1}{\sum_{pixels} w_i} \sum_{pixels} w_i \left(10 \log \sigma_s(a', b') - 10 \log \sigma_{s,RAMP}\right)^2 \right)^{1/2}$$

here $\sigma_s(a', b')$ is the smoothed, calibrated image value for trial values *a'* and *b'*, and $\sigma_{s,}$ RAMP is the corresponding smoothed RAMP mosaic value, and w_i is a weighting factor that is 1 for pixel misfit values that are in the central 95% of the distribution, and zero for pixel misfit values that are not. We performed this optimization both for each area independently and for pooled values from all seventeen areas. The individual scenes give scale values that vary by around 10%, while the noise values are all small, are scattered by about 30% around the median value of 0.057. Figure 1 shows a scatter plot of the combined corrected scene powers against the mosaic powers; the misfit between the two data sets is around 0.72 dB, or around a factor of 18%. Because the RAMP mosaic is a mosaicked product, the images in the mosaic may or may not correspond the images that we used in our calibration. Thus, some of the difference may reflect natural variability (i.e., time varying cross-section) or differing speckle patterns (i.e., noise).

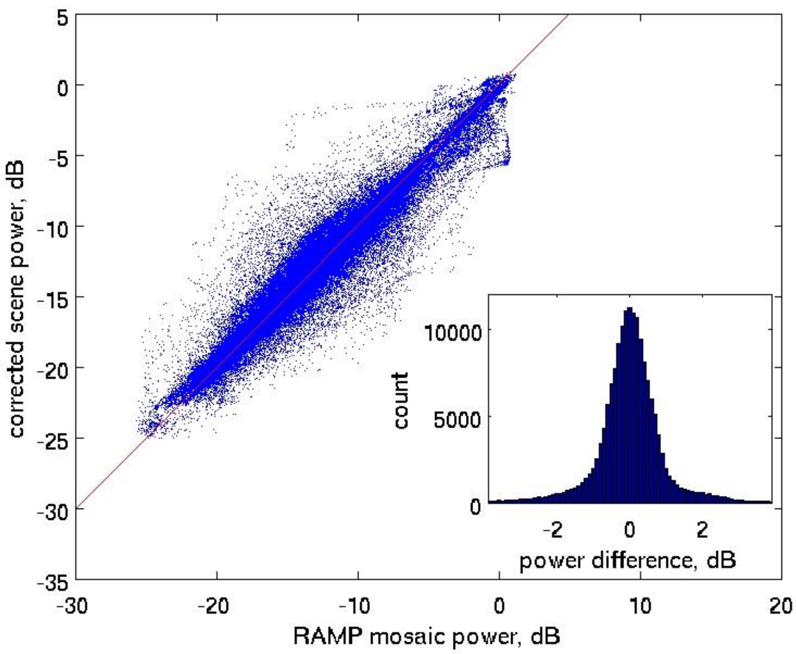

Figure 1. Scatter plot of corrected power estimated using the Gamma processor against the corresponding pixels from the RAMP mosaic. Inset shows the histogram of power differences (gamma minus RAMP), which have a zero mean and a misfit value of around 0.7 dB.

segment	A/D	scale	Noise(DN)	R (dB)
25351_21	A	28.5	0.0034	0.72
25232_31	D	26.4	0.0089	0.83
25361_51	D	27.5	0.0062	0.53
25918_31	D	26.6	0.0076	0.83
25469_11	D	39	-0.005	0.79
25784_101	D	27	0.0073	0.35
25326_11	D	30.1	0.0057	0.56
25898_111	D	28.9	0.0045	0.3
25584_151	A	24	0.0074	1.08
25602_61	D	28.7	0.0054	0.38
25573_101	D	28.7	0.0058	0.42
25716_91	D	29.2	0.0006	0.53
25802_61	D	27	0.0052	0.45
25612_91	A	25.7	0.0063	1.27
25802_61	D	27	0.0052	0.45
25612_91	A	25.7	0.0063	1.27
25913_121	A	29.2	0.0053	0.36
combined		1/a=27.3	b=0.0058	0.72

Table 1. Recovered scale and noise values for seventeen SAR images, and their residuals with respect to the RAMP mosaic. The last line gives the values for the aggregate of all the segments (1/a, and b) that were used to produce the final calibrated mosaics.

ALOS PALSAR Mosaics

We created a set of uncalibrated ALOS PALSAR L-band image mosaics using a similar set of procedures to those described for the RADARSAT mosaics. All images were collected in Fine-Beam Single-Polarization mode from ascending orbits.

The 20-m mosaics were produced from images multi-looked 3 pixels in range by 6 pixels in azimuth, which yields a nominal ground resolution of 22 by 19 meters.

Geometric Calibration

We found that a constant along track timing offset of 0.062 seconds applied to all images yielded locations consistent with other geolocated data. No range correction was applied.

Uncalibrated Mosaics

A similar non-linear stretch was applied to the L-band mosaics to enhance features.

Calibrated Mosaics

We have not produce a calibrated mosaic product.

Image Format

All mosaics are in polar stereographic project with the following parameters

```
GEOGCS["WGS 84",
    DATUM["WGS_1984",
      SPHEROID["WGS 84",6378137,298.257223563,
        AUTHORITY["EPSG","7030"]],
      AUTHORITY["EPSG","6326"]],
    PRIMEM["Greenwich",0],
    UNIT["degree",0.0174532925199433],
    AUTHORITY["EPSG","4326"]],
  PROJECTION["Polar_Stereographic"],
  PARAMETER["latitude_of_origin",70],
  PARAMETER["central_meridian",-45],
  PARAMETER["scale_factor",1],
  PARAMETER["false_easting",0],
  PARAMETER["false_northing",0],
```

High Resolution Mosaics

All mosaics are provided as set of 25 geotiff tiles with 20-m posting, which is comparable to the true resolution of the source images. These tiles are distribted with a GDAL ".vrt" file, which allows the mosaic to be opened as a single file in ARCGIS and QGIS and other GIS programs. There is also a ".vrt.ovr" file that contains image pyramids at several postings for rapid viewing.

The 100-m mosaics are produced as a single geotiff with pyramids embedded in the tif file.

The uncalibrated image mosaics use byte values (0-255) are LZW compressed. The calibrated mosaics use floating point values rounded to the nearest sixteenth of a dB and also are LZW compressed. To keep the ".vrt.ovr" file from exceeding 4GB, the first pyramid level (i.e., half resolution) is embedded in each geotiff tile.

Each mosaic is distributed with a shape file that gives the nominal outline for the image used in the mosaic along with date, sensor, and orbit number. Because of the irregular boundaries of the images after terrain correction and feathering at the edges, images do not conform exactly to these boundaries.