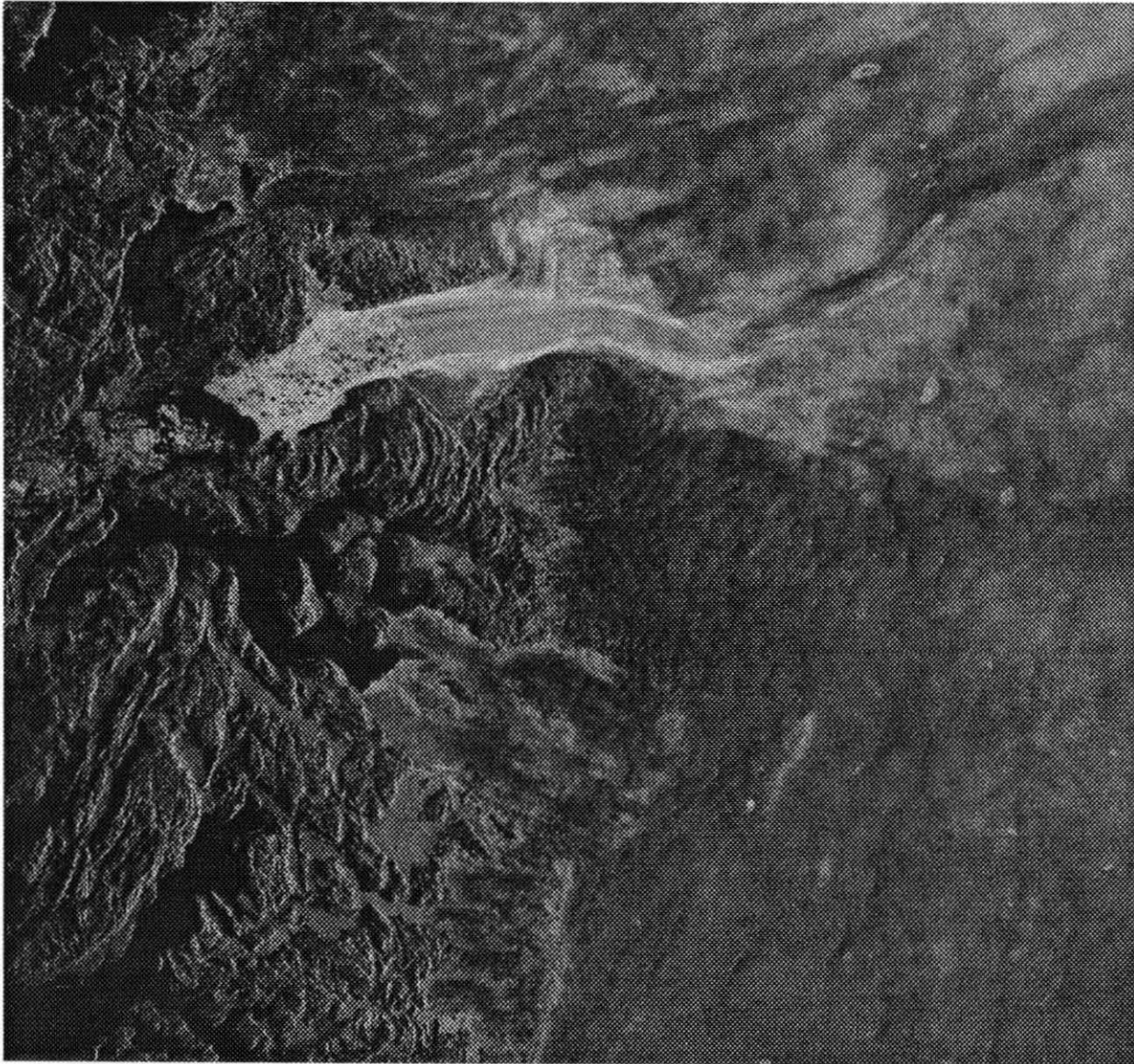


ERS-1 SAR Data Extraction Methodologies, and Procedures



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Byrd Polar Research Center
The Ohio State University
Columbus, Ohio 43210

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Cover art depicts a SAR scene over the Jakobshavn Glacier, Greenland. This image comes from the ERS-1 satellite and is referenced as Orbit 3304 Frame 2187.

Introduction

This paper discusses the procedures used to derive the products available from the ERS-1 SAR Precision Images (Herein called SAR images.) The products that are available are: raw image, 8x8 averaged image, tiling, simple tiling of percolation threshold classification, swath of dB values of across swath along row or column of images, filtered data of swaths. Each of these products have a distinct procedure for producing the result, and have a section of this paper dedicated to expressing it.

The purpose of the products can be expressed by the following: To understand seasonal and longer time variations in the dynamics & physical properties of polar ice on hemispheric scales. Remote sensing provides the tools for reaching that goal. A preliminary plan to meet this goal is 1) To visualize the data received, 2) Classify the different regimes, 3) Overlay different instruments data sets for comparison and enhancement, 4) Produce a model to use against other SAR data, and 5) To create an animated movie of changes with respect to temporal changes. At the date of publication, (1) and (2) have been attacked.

Extracting SAR data from tape

There are three facilities from which the Remote Sensing Laboratory (RSL) receives tapes of ERS-1 SAR data. These facilities are UK-PAF, D-PAF, and Alaskan SAR facility. The three facilities distribute the tapes with different formats. The primary difference between the formats is that size of the data cell. The UK-PAF and D-PAF uses two bytes for each data cell (pixel.) The Alaskan SAR uses one byte for each data cell (pixel.) This causes the size of the data file on the UK-PAK and D-PAF to be twice the size of the Alaskan SAR file. Another difference is that the UK-PAF and D-PAF has leaders for the file and for each row of data. However the UK-PAF and D-PAF have different size headers.

It is therefore necessary for two procedures to extract data off of a tape, being dependent upon the producing facility.

UK-PAK

On the tape there are four files. These files are named: header, leader, data, trailer. The header has information about the volume (tape) of data. The leader provides information about the data set including: location, sensor parameters, facility parameters, data set information, etc. The data file has the actual pixel values, and has a file header of 720 bytes, and a per line header of 192 bytes. The trailer has more information about the conditions of this image. Generally, there is only one image on a tape. It is referenced by the orbit and frame.

To extract type the following:

```
cp /dev/nrst17 <file_name>.header
dd if=/dev/nrst17 of=<file_name>.leader bs=8600
dd if=/dev/nrst17 of=<file_name>.data bs=16192
cp /dev/nrst17 <file_name>.trailer
```

This code can be executed by using the program *load_uk_ers1*¹ located in the `~jadkins/ers1` directory. This script is to be used with the 9" 6250 format tapes. This program The format is `load_uk_ers1 <tape_name>`. Replace `<tape_name>` with the file name that you wish to label the tape. For example, `load_uk_ers1 upc00186r` will load the current tape in `/dev/nrst17` (6250 tape drive) and store it under `upc00186r` with the appropriate suffixes. Table 1, "UK ERS1 PRI Suffixes meanings," on page 2, shows the file extensions meanings.

Table 1: UK ERS1 PRI Suffixes meanings

suffix	meaning
.az	Azimuth swath range
.data	PRI data file
.header	PRI header file
.leader	PRI leader file
.null	PRI null volume file
.sub	8x8 averaged data set
.1x1	1x1 averaged data set
.2x2	2x2 average data set

Alaskan SAR Facility (ASF)

The ASF tapes can have multiple images on a tape. Therefore it is easier to use a program specifically generated to extract the ASF data sets. The program is located in `/project/bin/ceos_reader`². Since the program handles the extraction, it is not necessary to discuss the format of the tape. To execute it one must first define the variable `CEOS_DEV`, and then execute the program. This is accomplished by the following commands

```
setenv CEOS_DEV /dev/nrst17
ceos_reader
```

Once inside the `ceos_reader` program, menu, as shown in appendix I, item select all of the images to be extracted, and select the extract option. The table below shows the information that is outputted from the `ceos_reader` program. With this program you may select which image you wish to extract, and what records you want to transfer. The program will create files with either a L, P or T prefix. This prefix will let you know which file the information came from. L is the leader file, P is the data file, and T is the trailer file.

Since no additional work has been done by the author on the ASF products, this

1. This script was written by Jeff Adkins at the Byrd Polar Research Center, Columbus, Ohio
 2. `Ceos_Reader` was created by Augustine Rosas, ASF, for the Alaska SAR Facility Archive and Operations system.

explanation is all that this report will include. The reader is encourage to look at *Science Plan for the Alaska SAR facility program - Phase 1: First European Remote Sensing Satellite, ERS-1*. This is cataloged as JPL 89-14.

Table 2: CEOS_READER File Extension Meanings

file extension	meaning
.ATT_1	Attitude Data Record
.DQL_1	Data Quality Record
.DSS_1	Data Set Summary Record
.HST_1	Data Histogram Record
.PLT_1	Platform Position Record
.RAD_1	Radiometric Data Record
.RAN_1	Range Spectra Data Record
.RDC_1	Radiometric Compensation Record
.CAL_1	Calibration Data record
.DTL_1	Detailed Processing Data Record
.FDR_1	Facility Data Record

D-PAF

The German data sets are constructed a little differently that the other facilities. Like the UK-PAF, the German data are in sixteen bit pixel cell. However, the format of the file itself is very different that the UK-PAF's file. The range of values are also different than the UK data.

The German data column width is not fixed from image to image. It is fixed within an image. This is a logical width where the physical width is standardize at 8000 cells. So when processing, the number of records within a line is constant at 8000, but the amount of non-zero information fluxuates between images. The D-PAF data also have 8270 rows as opposed to the 8192 rows found in the UK-PAF's data.

The German data seems to be in a range of 150 to 800 with a few spikes in the thousands. In contrast to the UK data, this range is significantly lower. Due to this reasons, the average routines used for the UK data need to be modified to work with the D-PAF data.

In both the UK and the German data sets, each row of data is preceded by a record that gives information about that particular line. The difference is that the header for the UK data is 192 bytes, whereas the header for the D-PAF data is 12 bytes. This causes more incompatibility between routines used to manipulate these two data sets because the locate functions within the programs need to be altered to account for the difference in record widths.

Averaging UK-PAK SAR.PRI data sets

Introduction

The UK-PAK SAR.PRI data sets are 8000 columns by 8192 rows. Each one of these cells are two bytes wide, and use twelve of the sixteen bits. This equals approximately 130 megabytes (Mb). The images at this resolution is very speckled, and difficult to manage due to the sixteen bit cell. Although the image only uses thirteen of the possible sixteen bits, it is necessary, and convent, due to hardware constraints, to reduce the width of the cell to 8 bits, and at the same time to reduce the speckle by averaging non-intersecting square data areas of a given size.

Sizes of data areas

Currently three sizes of averaging are being used. 8x8, 2x2, 1x1. The 1x1 simply changes the cell width to 8 bit, and removes all of the headers. The 8x8 produces a sharp image of the area by smoothing the data.

Location of programs

All of the programs to do averaging are located in ~jackson/ers1

Table 3: Averaging Routines^a

Size of average square	program name
1x1	avesub1
2x2	avesub2
8x8	avesub

a. Originally developed
by Mark Fagnstock, God-
dard Space Flight Center

There are reference pages to describe the use of these routines in the appendices.

Pseudo-Code used to generate average

```
for rows = 1 to 8192 step 8
  for columns = 1 to 8000 step 8
    for sub_row = 1 to 8
      for sub_col = 1 to 8
        total = data(row+sub_row, columns + sub_col);
      next sub_col
    next sub_row
  write(outfile, total/(64 * 5))
next columns
writeln(outfile)
next rows
```

The method of this code is to break up the code into 8x8 non-interloping segments. Each section is totalled, divided by 64 to produce the average, and divided by 5 to reduce the width from 13 bits used to 8 bits. There are some error checking within the program that is omitted for brevity and complexity problems. It has been the general standard to label the output of the files as .sub for an 8x8, .1x1 for a 1x1 average, .2x2 for a 2x2 average. This can be seen in "UK ERS1 PRI Suffixes meanings" on page 2.

Resulting Image from average

"Figure 1 - Jakobshavn Glacier" on page 7 shows the Jakobshavn Glacier during the month of March, 1992. This image has had the above algorithm applied. As it can be observed, the quality of the images can be quite spectacular.

Routine changes to account for D-PAF format

The first change to the Pseudo-Code shown above is the upper bound of the first for loop. This should be changed to 8270 since that is number of rows within the D-PAF data file.

The second change is to change the amount that total is divided by since the values of the D-PAF are significantly less. At the time of publication, a scalar has not been determined to reduce the scale so that the values can be stored in a byte.

The modified programs will have a suffix of '_d' to denote the characteristic of working exclusively on D-PAF data.

Producing Swaths of data across images along the column and row vectors.

Introduction

Since the amount of data within an image can be quite large, a technique is needed to quantize a segment to "see" a vector of data and how it changes in accordance with spacial distance. The vectors can be along the column (azimuth) or row (Pixel) direction. The algorithm to extract the vector of data is quite simplistic. The algorithm receives a column/row, width, and frame. For each row/column, the values of the given width around the column/row are averaged. This should reduce the speckle perpendicular to the direction of interest.

Analysis of algorithm for along and across image swath

The algorithm to extract for along swath can be described by the following pseudo-code:

```

for row/column = 1 to max row/column do {
  for column/row = selected - width / 2 to selected + width / 2 - 1 do
    total = (total + value[row,column])/ 2
  print (row + frame * 8192/8000, 10 * log10 (total2) - KdB)}

```

The method of this code is to take a *width* number of columns/rows and average them. The output is [row + frame * 8192/8000, σ°_{dB}]. The reason for frame is to create sequential frames, and keep the row value of the output unique throughout the sequence of frames. The output of the this algorithm should be labeled as .az or .range as specified by "UK ERS1 PRI Suffixes meanings" on page 2. These files are usually along the mid-swath.

The K_{dB} is a value that is dependent on the facility that processed the data. Table 4, "ERS-1.SAR.PRI Processed after 1st September 1992," on page 6 shows for the facilities

Table 4: ERS-1.SAR.PRI Processed after 1st September 1992^a

Facility	K	K _{dB}
ESRIN/EECF	666110	58.24
D-PAF	666110	58.24
UK-PAF	890107.2	59.49

a. as defined by LAUR92 p. 5

the values of K and K_{dB} .

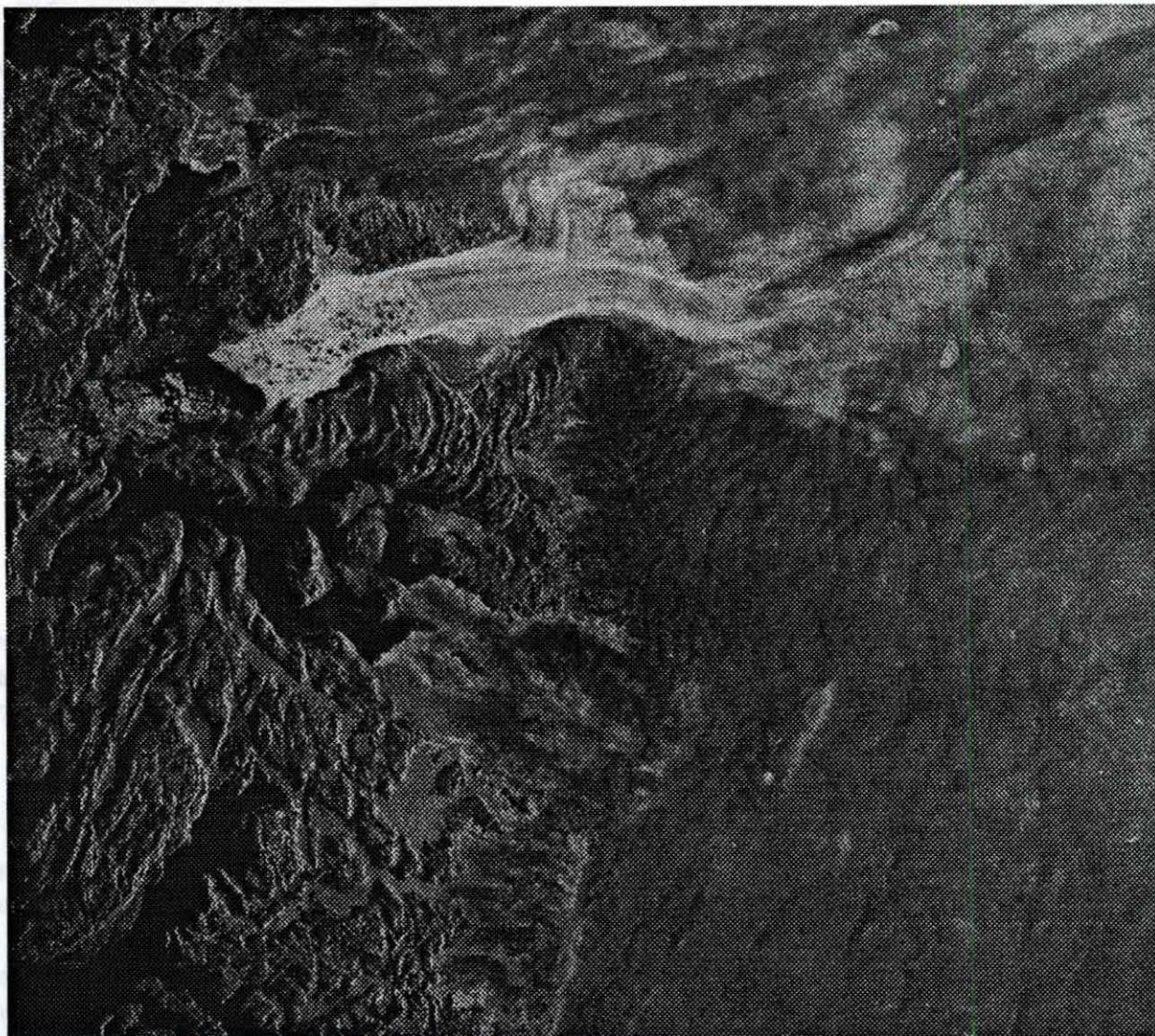


Figure 1 - Jakobshavn Glacier¹

The σ_{dB}° value is determined by the equation given by Laur [1992] as $\sigma_{dB}^{\circ} = 10 \times \log(I^2) - 10 \times \log(K) + 10 \times \log\beta$. The value of K is dependent on the facility that produced that image. For the UK-PRI images, as shown in Table 4, "ERS-1.SAR.PRI Processed after 1st September 1992," on page 6, the value of K is 890107.2. To reduce the amount of calculations required, the dB value of K has been calculated by the second term of the equation, and used as a decibel value rather than calculate it each time. The resulting value is 59.49 dB. When going along the azimuth direction, the β value does not change because of the incident angle will be the same throughout the entire image. However, when going along the range direction, the β value will change in accordance to the changing incident angle. According to Laur [1992], the α (incident angle) changes from 19.5° at near range to 26.6° at far range. This translates into a correction

1. This image was produced by the ERS-1 satellite and is referenced as Orbit 3304 Frame 2187

factor β that can vary from -0.7 dB to +0.6 dB within the image swath. The correction factor β can be calculated by $\beta = \sin \alpha / (\sin \alpha_{ref})$, and applied by adding β_{dB} . Since the across swath requires the correction factor β , another algorithm must be used. The pseudo-code of this algorithm to extract across swath is shown below. It is assumed that the incident angle (α) changes universally from 19.5 to 26.6 degrees. With this assumption, calculating the β correction factor becomes easy. We know that this change occurs within 8000 pixels which are assumed to have the same width. Since the difference is 7.1° then the $\Delta\alpha = 7.1/8000$ or 8.88×10^{-4} therefore $\alpha = 19.5 + \Delta\alpha \times row$. Since the reference angle is constant, there is no need to compute it's sin, and the denominator within Laur's equation is set at a constant for faster computation.

```

for column= 1 to maximum column do {
  for row = selected - width / 2 to selected + width / 2 - 1 do
    total = (total + value[row,column])/ 2
  print (row + frame * 8192/8000, 10 * log10 (total2) - KdB + 10 *
    log10(  $\frac{\sin (19.5 + 0.000888 \times column)}{0.45}$  )

```

Location of swath creating algorithms

To allow for swath creating along the azimuth as well as the pixel direction, two algorithms exist. They are located in */home/users/jadkins/ers1*, are called *logdata*, and *logdatarow*. Plans are in the works to consolidate these programs into one system. The man pages are shown in appendix II.

Calculating Latitude for Swaths of Data

Since each image of data only has the corner points indicated, an approximation was applied to get a latitude for each row along the azimuth. The orientation for an image is shown below.

In order to compute the latitude for the midswath, the average of the more southerly coordinates, and the more northerly coordinates were taken. Which resulted in 81.34° for the northern, and 80.65° for the southern ones. The difference is $.69^\circ$. Since there are 8192 rows, the $\Delta\lambda = 0.0000824229^\circ$. With $\Delta\lambda$ a latitude can be computed for each row by $row \times \Delta\lambda + latitude_{initial}$

Producing Plots of Swath Data

In order to visualize the data set produced by the swath, a line plot becomes a valuable tool. With the line plot, one can follow the trend by correlating the line plot with the image. This gives an initial impression of the trends of the data as it varies through different regimes.

Using MatLab to generate Plots

Using MatLab¹ or another mathematical manipulation system, one can produce line graphs that show the σ_{dB} vs. latitude/longitude. With this and an output of the image, a visual survey can detect varies regimes. To actually generate the plot (as shown below in Figure 2) sev-

1. MatLab is a trademark, and software package by The MathWorks, Inc.

eral steps must be performed. First the data file, as produced by the swath creating algorithm as described earlier, must be loaded. Latitude must be calculated by the method described in the section entitled "Calculating Latitude for swaths of data." on page 6. Using the MatLab command plot, figure 2 can be generated as a representation of the actual image.

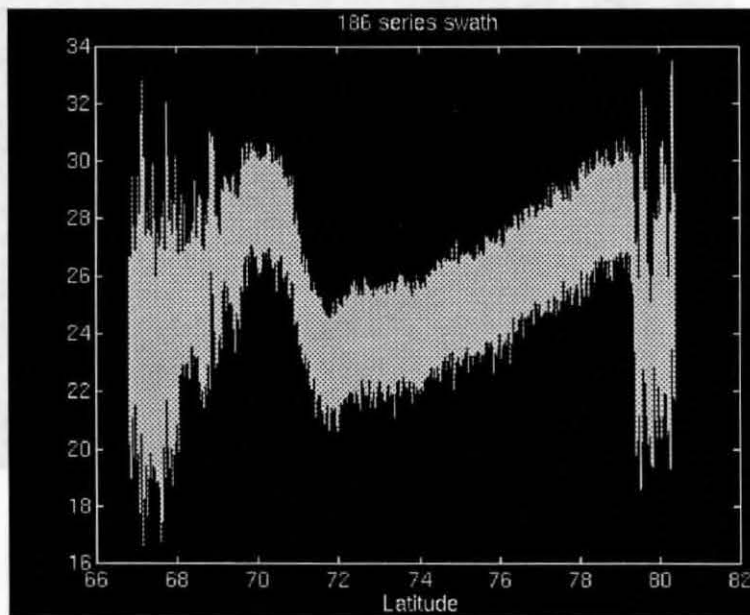


Figure 2 - 186 Swath Data

Using MatLab to filter the data

Due to the amount of data extracted, a filter was applied to the data. This filter was an order 4, lowpass butterworth filter with a cutoff frequency of $1/512$. To create this filter, the command $[b,a] = \text{butter}[4,1/512]$ was used within MatLab and returned the filter coefficients into the vectors b and a . These vectors are passed to a digital filter that filters data in both forward and reverse directions, which according to Little and Shure [1992] should eliminate any phase distortion. The command to accomplish this *filtfilt*.

The script below was used to produce the filtered data is shown in "Figure 3 - Filtered Data Set" on page 10, and was executed within MatLab.

```
[b,a] = butter[4,1/512];
load data_file.dat
x = data_file - mean(data_file);
y = filtfilt(b,a,x);
z = x + mean(data_file);
plot(latitude, z);
```

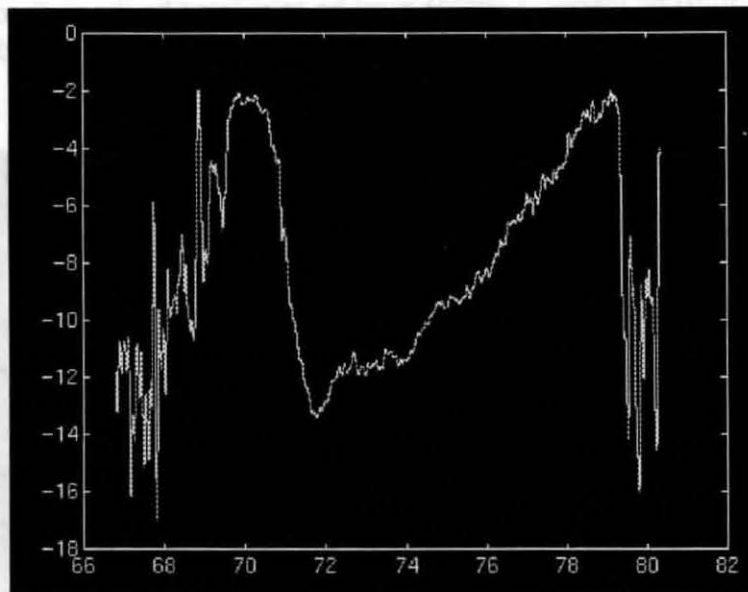


Figure 3 - Filtered Data Set

Threshold filter for Percolation zone

It was determined that -2.49 dB was the threshold for the percolation zone. We modified a color map to color anything that was above the -2.49 dB (90 on colortable) as blue, and anything below that as yellow. This coloring provides an intuitive feel for the fluctuation of the data. This mosaic, produced by Jet Propulsion Laboratories, is the combined data of several frames of SAR images. The mosaic pixel resolution has been degraded to one kilometer, and is placed on the SSM/I plane. The RSL applied a color map using Khoros¹, and figure 3 was produced. This color map is located in */home/users/jadkins/ers1/color*. It should be noted that the threshold filter produces incorrect results at the Jakobshavn Glacier.

Image Tiling at the Remote Sensing Laboratory

Image tiling has been produced on three areas of interest. 1) The Jakobshavn Glacier, 2) The Percolation Zone colored by threshold filter, 3) The Percolation Zone area in grayscale. These images were produced on the Apple Macintosh with Aldus PageMaker². These files are located on the Macintosh named *trouble* in the directory *UltraDrive100:Mosaic - Greenland*. output of these tiles can be seen in appendix X.

The tiles were created by matching up features such as lakes, outcrops, etc. This

1. Khoros is an image processing system produced by the University of New Mexico

2. Aldus PageMaker is a registered trademark of the Aldus corporation

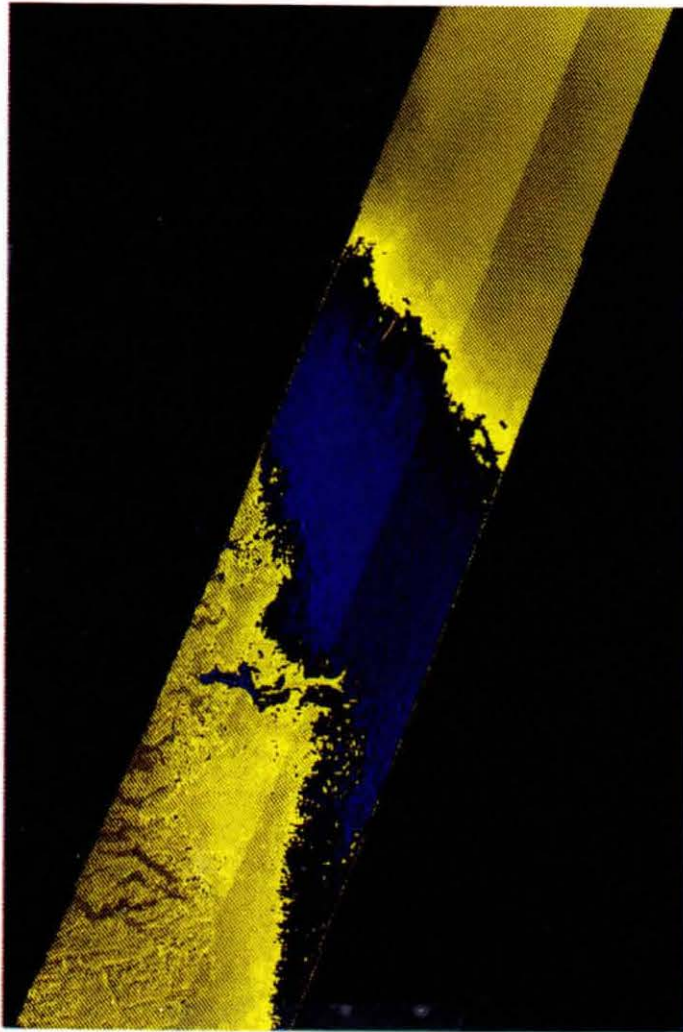


Figure 4 - Colored Mosaic of 186 and 322 swaths.¹

This method although requires very little in the area of tools, produces quite crude results. However, it does lead itself to a first look approach.

To create these tiles, the respective scenes are converted into tiffs by use of the Khoros program applying the color map, if appropriate. Afterwards, it is transferred to a macintosh, and imported into PageMaker. Common points of reference are found, and lined up.

1. Mosaic Produced at the Jet Propulsion Laboratories, Pasadena, California

Summary

Although the Sar Data Extraction is still in the early stages of development, considerable progress has been made in the areas of tool understanding, tool development, and general knowledge of the SAR data itself. With this groundwork established, the next phases of research should prove to be rewarding.

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Sar Data Extraction Methodologies and Procedures

Main Menu of the Ceos Reader Program

```
*****  
* CEOS SAR - DATA READER *  
*****
```

- L - List products on tape
- S - Select products to transfer
- T - Transfer selected products
- A - Transfer all products using defaults
- D - Display text information about products
- Q - Quit Program without further action

Enter letter of desired menu selection :

Status Line of the CEOS Reader program

```
PRODUCTPRODUCT PHYSICAL PHYSICAL # OF SELECTION  
SELECTION# NAME VOLUME START VOLUME END RECORDS STATUS  
-----
```

```
1 19523200 1 1 1025
```

- F - Scroll Forward
- B - Scroll Backward
- X - Return to main menu

AVEDATA(1L)

MISC. REFERENCE MANUAL PAGES

AVEDATA(1L)

NAME

avedata - creates a 2d data file of averaged data at given column and given width

SYNOPSIS

avedata input_file_name column width

DESCRIPTION

avedata will create a file *data_out* which will contain the averaged pixel values across the row. Width specifies the number of columns to be used.

SEE ALSO

logdata(1), *logdatarow(1)*

AUTHOR

Jeff Adkins, Byrd Polar Research Center

AVESUB(1)

USER COMMANDS

AVESUB(1)

NAME

avesub - creates a matrix file of 8x8 averaged data

SYNOPSIS

avesub2 input_file_name output_file_name

DESCRIPTION

avesub will create a file *output_file_name* which will contain a matrix 1/4 the size of the original matrix file. For each pixel value within the output file there is an 2x2 matrix of pixel values located within the input file. This 2x2 matrix is averaged and the corresponding value is written to the *output_file_name*.

SEE ALSO

avesub1(1), avesub2(1), avesubline(1)

BUGS

This program will only work with ERS-1.SAR.PRI images from ESRIN

AUTHOR

Mark Faughstock, Goddard Space Flight Center

modified by Jeff Adkins, Byrd Polar Research Center

AVESUBLINE(1) USER COMMANDS AVESUBLINE(1)

NAME

avesubline - creates a matrix file of 8x8 averaged data

SYNOPSIS

avesubline input_file_name output_file_name column width highlight

DESCRIPTION

avesubline will create a file *output_file_name* which will contain a matrix 1/64 the size of the original matrix file. The program will take for each point within the output file an 8x8 matrix of data within the input file. This 8x8 matrix will be averaged and the corresponding value will be written to *output_file_name*. There are no intersections of the 8x8 matrices within *input_file_name*.

This tool will highlight by adding highlight to all of the pixels that are within width/2 columns of column. This step is done prior

SEE ALSO

avesub(1), avesub1(1), avesub2(1)

BUGS

This program will only work with ERS-1.SAR.PRI images from esrin.

AUTHOR

Mark Faughstock, Goddard Space Flight Center

modified by Jeff Adkins, Byrd Polar Research Center

HIST(1)

USER COMMANDS

HIST(1)

NAME

hist produces a 2d histogram of sar data file

SYNOPSIS

hist input_file_name output_file_name

DESCRIPTION

hist will create a file output_file_name which will contain a 2d histogram of a sar data file. This program will produce output in the form of:

value number of occurances.

BUGS

This program will only work with ERS-1.SAR.PRI images from ESRIN

AUTHOR

Mark Fahnestock, Goddard Space Flight Center

LOGDATA(1)

USER COMMANDS

LOGDATA(1)

NAME

logdata - creates a 2d data file of the log of the data at given column and given width

SYNOPSIS

logdata input_file_name column width

DESCRIPTION

logdata will create a file *data_out* which will contain the log base 10 of the averaged pixel values across the row. Width specifies the number of columns to be used.

SEE ALSO

avedata(1), *logdatarow*(1)

BUGS

This tool only works with ERS-1.SAR.PRI data sets supplied by ESRIN.

AUTHOR

Jeff Adkins, Byrd Polar Research Center

LOGDATAROW(1L)

MISC. REFERENCE MANUAL PAGES

LOGDATAROW(1L)

NAME

logdata - creates a 2d data file of the log of the data at given column and given width

SYNOPSIS

logdatarow input_file_name row width

DESCRIPTION

logdatarow will create a file *data_out* which will contain the log base 10 of the averaged pixel values across the column. Width specifies the number of rows to be used.

SEE ALSO

avedata(1L), logdata(1L)

BUGS

This program only works on ERS-1.SAR.PRI supplied by ESRIN.

AUTHOR

Jeff Adkins, Byrd Polar Research Center