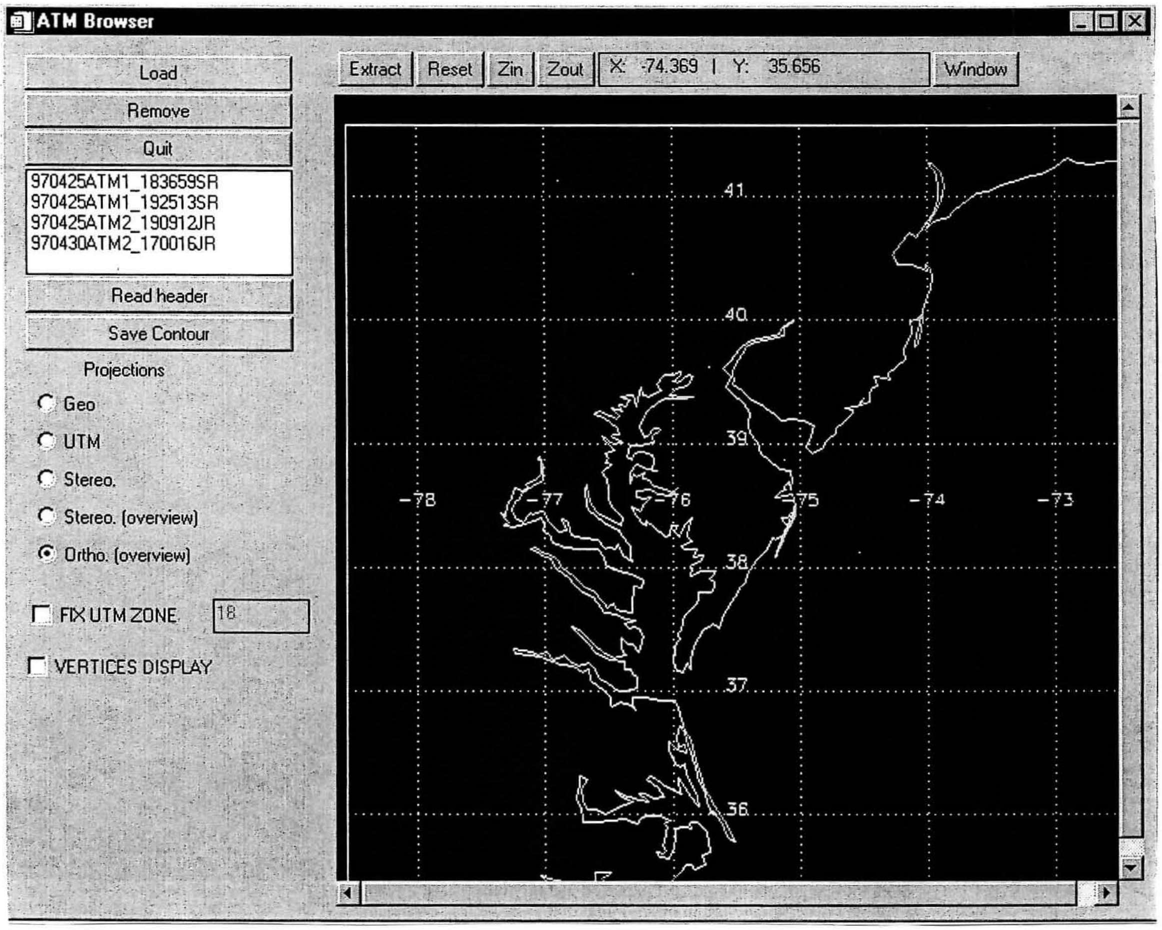
AN ALGORITHM AND APPLICATION FOR VISUALIZATION AND ANALYSIS OF SCANNING LASER ALTIMETER DATA



970425ATM1_183659SR
970425ATM1_192513SR
970425ATM2_190912JR
970430ATM2_170016JR

X: -74.369 | Y: 35.656

Projections
○ Geo
○ UTM
○ Stereo.
○ Stereo. (overview)
● Ortho. (overview)

☐ FIX UTM ZONE 18

☐ VERTICES DISPLAY

BYRD POLAR RESEARCH CENTER
THE OHIO STATE UNIVERSITY

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THE OHIO STATE UNIVERSITY
COLUMBUS, OHIO 43210-1002

An Algorithm And Application For Visualization And Analysis Of Scanning Laser Altimeter Data

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1. Introduction

Ice sheet elevation changes have been measured by repeat airborne laser altimetery in Greenland since 1991. The Airborne Topographic Mapper (ATM) system, which has been mounted in a NASA P-3 aircraft, includes a scanning laser altimeter, INS and differential GPS. During the post-processing the measured data are converted into measurements of ice sheet elevation relative to the Earth ellipsoid (Krabill et al., 1995). Since laser scanner data sets are composed of a huge amount of points, obtaining the swath contour and locating overlapping areas between different swaths in an efficient way is not a simple task. To make this task more feasible a thinned data set called ICESS has been created from the laser data collected over the Greenland ice sheet (Martin, 1997). Since the surface is reasonably smooth, the laser swath was modeled as a series of planes, each characterized by a center elevation, a north-south slope, and an east-west slope. However, for many applications such as mapping the rough surface of outlet glaciers or surveying urban areas, the original dense laser points are needed. Our major goal is to develop software to access, display, and manipulate the original binary data files. By using a single application the user should be able to determine the overlap between several surveys, compute elevation changes, and create DEMs and contour maps. So far we were mainly focusing on the first part of the job, namely, providing tools for locating the laser swaths and their overlapping areas.

In this report we present the algorithm that we recommend for an efficient contour extraction from laser swaths data and the application that was developed for this purpose. The report is organized as follows. First the major objectives of the development of the algorithm are presented and then the algorithm itself is described. The fourth chapter describes the application functionality, and it is followed by a documentation of the software modules and the installation guide.

2. Objectives

The lack of visualization tools for laser altimetery swaths poses difficulties in performing advanced processing with the data. The main problem is that preliminary tasks, such as analysis of the shape of swaths, location, extent and relation to other data sets, are difficult to accomplish interactively without a visualization tool. As a result, successive processes, including merging of overlapping swaths, and analysis of elevation changes, become increasingly difficult to perform. Due to the huge amount of data within each swath, no straightforward, simple solution such as plotting all points in a data set, exists due to the long running time it consumes. In addition, the data format poses a non-trivial problem. The large volume of data dictated storage of the data records in a binary format to reduce the size of the data files. Binary format, however, is difficult to handle, especially for an unskillful programmer. Moreover, binary number representation is not unique and may be represented differently on different machines. A common procedure for processing the data prior to the implementation of the 'ATM_browser' was to convert and save the data in an ASCII file and then use it as input for further processing. This conversion replicated the data in an increased data volume, but did not provide any direct information about the shape of the swath, and its geographic location.

Our main motivation was therefore to develop an application that would enable an efficient visualization of the data without the necessity to convert the data first. It should also provide basic analysis and processing tools. Since these tasks are steps prior to analyzing the data, the application should be simple and easy to operate. Moreover, it should be easy to extend or modify the application either by us or by other users. These aspects have led us to draw the following objectives:

- **Simplicity** - We consider the 'ATM_browser' a tool for analyzing the data. Therefore our aim is to develop an application that will not require much effort in operating, i.e., be as self-explanatory as possible.
- **Efficiency** –The large number of points in typical data files requires an efficient algorithm for the extraction of the contour of the laser altimetry swath or extraction of a subset of the data in a given geographic window.

- **Machine independent** –The ATM data is being provided in binary format. This format in notorious for problems arising during data transfer from one machine to another. Therefore our motivation was to develop an application that would run on any machine, without being specific for a given operating system and that would be able to read the binary data regardless of the machine and without involving the user in this process.
- **Open architecture** – The application was designed bearing in mind easy maintenance and the possibility of extension either by us or by other users
- **User friendly** – A Graphical User Interface (GUI) was implemented to enable the user to extract data and use other applications in an intuitive way.

Based on these criteria we decided to develop the application in an IDL (Interactive Data Language) environment by using IDL programming language. There were several reasons for preferring IDL. Firstly, IDL is commonly used software in the current environment as well as at NASA. Secondly it runs on most platforms, thus the application will not be system dependent. IDL provides a GUI development toolkit so incorporating graphics does not require external packages. Running IDL applications does not require complicated compilation before executing. In addition, IDL includes advanced graphical analysis tools that can be used to develop further applications. Finally, although not less important, IDL provides a low cost student version product. The application was developed to fit this version, therefore it does not require costly software to run it.

The application supports the following procedures:

- **Extraction and graphical display of the laser data swath** – The preliminary graphical overview of the swath trajectory is an important tool for deciding whether the current file is of any interest or not before extracting the whole data file. The extraction supports 10 and 14 records file format and also the extraction of profiler data.

- **Extraction and display of the laser data header** – Since the header may hold some significant information about the acquisition and the preprocessing of the data, the header can be displayed and written into an ASCII file.

- **Manipulation of several laser files simultaneously** –This tool allows the user to compute and display the boundaries of two or more laser swaths and to locate overlapping areas. Laser points extracted from the overlapping area can then be used as input for the computation of surface elevation changes.

- **Swath contour display over a background map** – The geographic location of the swath is illustrated by using a continent outline map in the background.

- **Multiple coordinate system representation** – The application supports the representation of the data in different coordinate systems, namely a geographic coordinate system, Universal Transverse Mercator (UTM) and Polar Stereographic projection systems. The laser points are represented in a geographic coordinate system in the input binary files.

- **Flexible graphical display of the data –** Although the length of the laser swaths is usually of the order of several hundred kilometers, the overlap between the swaths may be limited to a much smaller region. In order to provide details over a small region zooming options were implemented, and a coordinate readout field that follows the cursor position was also provided.

- **Conversion from binary to ASCII format and coordinate conversion** – An ASCII to binary conversion, independent of operating system, has been implemented with an option to transform the geographic positions (latitude, longitude) into a user selected projection system. Currently (UTM) and Polar Stereographic projection systems are supported.

- **Conversion according to user specified criteria** - For extraction of the area of interest only, the application enables the user to define a window either graphically or manually (in all the projections specified above). In addition, either full or partial records can be extracted. The full record includes 10 or 14 parameters for each laser shot, while the partial record includes the Easting, Northing, Height, and the time (either GPS or GMT). For a list of the parameters in the full records see Appendix 1.

3. Details of the algorithms and techniques

Data extraction

First, data is converted from binary format to ASCII. Besides the technical aspect of data conversion, the main obstacle is that each machine has its way to represent numerical data, namely, the position of the most significant bit can differ from one machine to another. This is tackled by first identifying the representation method and then choosing the appropriate data conversion strategy.

Detection of the data acquisition pattern (conical scanning vs. profiling)

The 'ATM_browser' can process both conical scanner and profiler data. The identification of the data acquisition type was implemented to be transparent to the end user.

There are two tests that are applied for this purpose. The first one is the verification that the azimuth field in the extracted records is fixed. Constant value should indicate that no conical scanning was performed for the given data. In the second test, the co-alignment of the extracted points is evaluated by performing a line regression using least square adjustment. A relatively small standard deviation of the laser points relative to the fitted line indicates that the extracted data is co-aligned and therefore form a profile. A large standard deviation indicates that the data were acquired by conical scanner.

Determination of the laser swath contour

We define the swath contour as the polygon that bounds all laser points within a given data file. However, extracting the perimeter from a large data file (files are often larger than 80 MB) may result in an unacceptably long processing time. Moreover, the well known algorithms for detecting the bounding polygon relates to the convex hull, and their running time is of the order of O(n log(n)). Since the trajectory of a real swath does not always lie on a straight line, the contour is not necessarily convex. Therefore, the main two design issues here are the definition of swath contour and the development of an algorithm for its efficient extraction.

The algorithm utilizes the shape of the scanning pattern. The laser data footprints form a set of overlapping spirals on the ground (Figure 1). The scan pattern can be estimated by an ellipse quite well, although the actual pattern is a function of the laser scanning mechanism and the aircraft's motion.

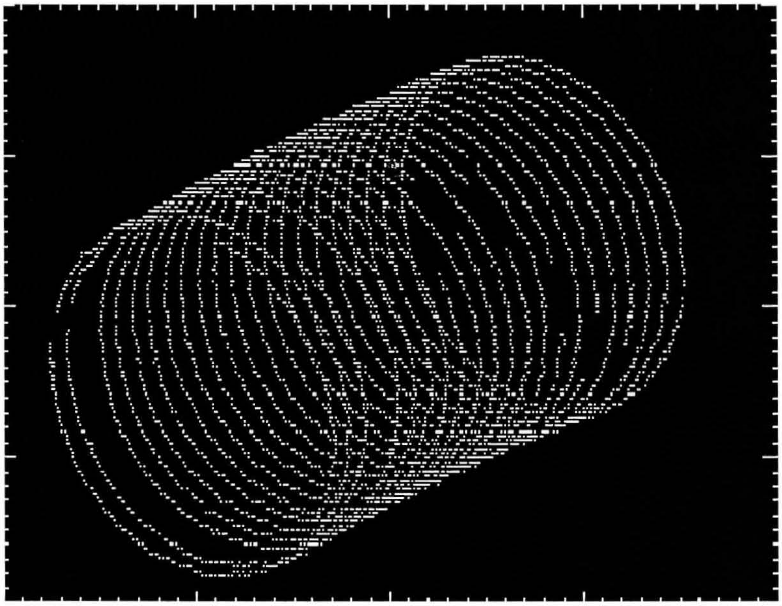


Figure 1. The data pattern for the conical laser altimetery scanner.

Such a pattern implies that the two extreme points of each scanning cycle with respect to the flight direction define the swath contour. Therefore a basic algorithm can first identify a complete cycle, then compute its extreme points, and augment them into the constructed contour of the swath. This algorithm already reduces the computation complexity from O(n log(n)) into linear time, i.e., O(n). However, the aircraft motion is relatively simple and it is only necessary to use one cycle every few seconds to accurately depict the contour of the swath. Since the scanning frequency is usually 10-20 [Hz], the number of cycles necessary to form the swath's contour is negligible compared with the overall number of cycles within the flight. The computational complexity is therefore further reduced to O(m * s) where 'm' is the number of cycles from which extreme points are computed and 's' is a constant representing the number of points per cycle. The contour can be computed by selecting an equally distributed subset of the cycles and by connecting their bounding points. This approach promises a reliable description of the contour, in contrast to other common contour extraction algorithms, and reduces the computational load to a feasible running time.

Since the scanning is an ongoing process it is not important from which point one should consider the beginning of a new cycle. The scanning cycle is determined by using the scan azimuth field attached to each laser point record. A cycle is determined when the azimuth value of the current point again crosses the initial azimuth value (see Figure 2). The skip interval is given as a fixed number of points that is equivalent to a selected time interval. After computing the bounding points of the first scan, a certain number of records are skipped, then the next scan cycle is processed in the same fashion, and so forth. This process continues until the end of file is reached.

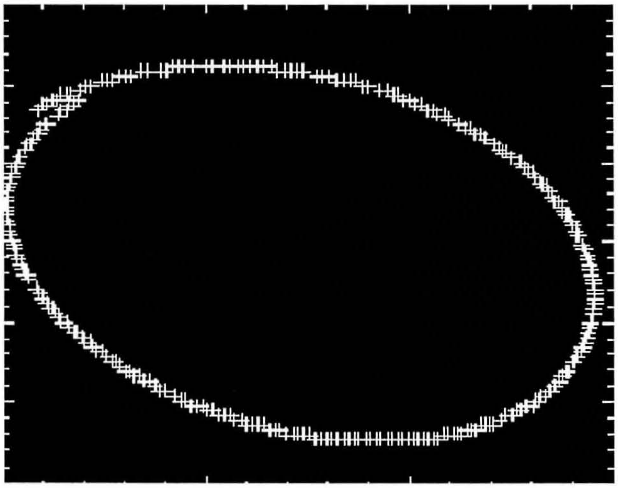


Figure 2. An extracted scanning-cycle.

Several methods were considered for computing the extreme points, for example, a rigorous solution using the mathematical description of the shape of the spirals. The two candidate solutions that were analyzed in details are fitting an ellipse to the points and detecting its extreme points, and detecting extreme points in terms of their distance from the center of the cycle.

The ellipse fitting solution is based on least square adjustment and on the analysis of the eigenvalues and eigenvectors for the detection of the extreme points. An ellipse is a conic and is characterized by six parameters: three relate to the quadratic term, two for the shift, and an additional one which is a constant. By shifting the ellipse to the origin the number of parameters can be reduced to the three quadratic terms (the constant is just a scaler) that can be written in the following form:

$$\begin{bmatrix} x & y \end{bmatrix} \begin{bmatrix} a & b \\ b & c \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} = 1 \quad \textit{The quadratic form}$$

that leads to the following matrix form:

$$\begin{bmatrix} x_i^2 & 2x_i y_i & y_i^2 \end{bmatrix}_{m*3} \begin{bmatrix} a \\ b \\ c \end{bmatrix}_{3*1} - \begin{bmatrix} e_i \end{bmatrix}_m = \begin{bmatrix} 1 \end{bmatrix}_m \quad \textit{where } a,b,c \textit{ are the unknowns}$$

The three unknowns can be computed by a least square adjustment and by that define the ellipse equation. The eigenvectors of the 2*2 symmetric matrix represent the major and minor axes of the ellipse where the eigenvalues are the coefficients. The major axis relates to the smaller eigenvalue (the extreme points are the reciprocal of the square root of the eigenvalues - $x = 1/\sqrt{\lambda_i}$) and the cycle-scan extreme points can be either computed by the ellipse extreme points or by the closest laser points to the major axis. Figure 3 presents the result of this algorithm.

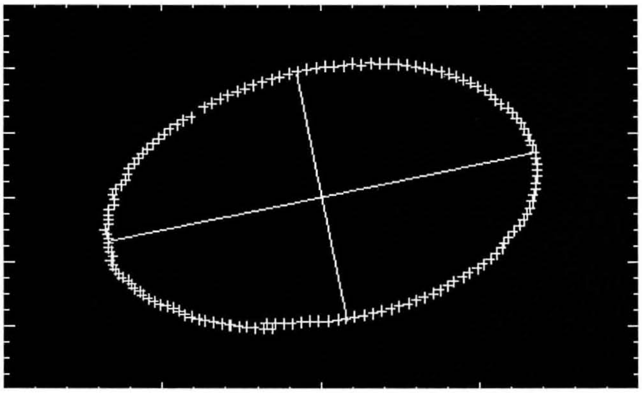


Figure 3. Detection of the extreme points by eigenvalue eigenvector analysis

This method is rigorous and less sensitive to noise or absence of points in a cycle. However, it involves matrix manipulations that, although supposed to be efficient in environments like IDL, may slow the running time. Therefore a method based on the determination of the centroids of the scan cycles was selected. The algorithm first computes the centroid of a single scan-cycle, then searches for the two farthest points in opposite directions. The centroid is computed as the weighted mean of the planimetric positions of the laser points in the scan cycle, and the distances between the consecutive laser points serve as weights.

$$\overline{x} = \frac{\sum_i (d_{i-i-1} + d_{i-i+1}) * x_i}{\sum_i (d_{i-i-1} + d_{i-i+1})} \qquad \overline{y} = \frac{\sum_i (d_{i-i-1} + d_{i-i+1}) * y_i}{\sum_i (d_{i-i-1} + d_{i-i+1})}$$

where:

x_i, y_i - the planimetric coordinates of a laser point

d_{i-i-1} - the distance between two consecutive points

The distance to the two neighboring points gives a better measure for the isolation of the point, and therefore for its significance in the computation of the centroid position. A weighted average is used since simple averaging did not work well in areas with gaps in the laser data sets. Data are usually missing because of the scattering of the laser energy from clouds, fog, water, etc. By using the distance between the consecutive points as a weight, the lower density of the laser data is compensated by their higher weights. Figure 4 presents the points detected by the process:

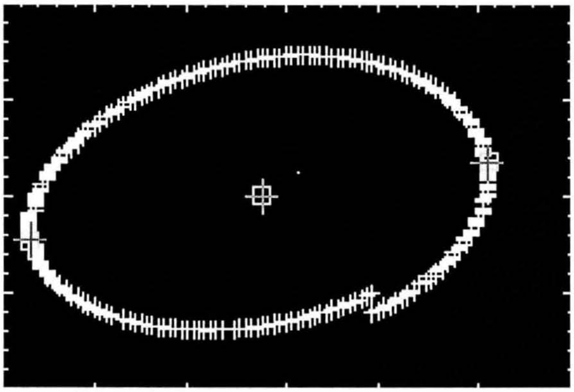


Figure 4. A cycle of laser points with the detected centroid and extreme points overlaid.

The size of the gaps mentioned above are sometimes non-negligible, as can be seen in Figure 5, and therefore can affect the detection of the extreme points. The incomplete cycles presented in the figure show that cases can occur in which some of the extreme points will be either missing or not reliable due to big gaps in data. Therefore as a preparatory step, prior to the detection of the extreme points, the cycle scans should be analyzed to detect big gaps in the cycle (for example one gap bigger the 20 degrees or more then 2 holes of 10 degree size each).

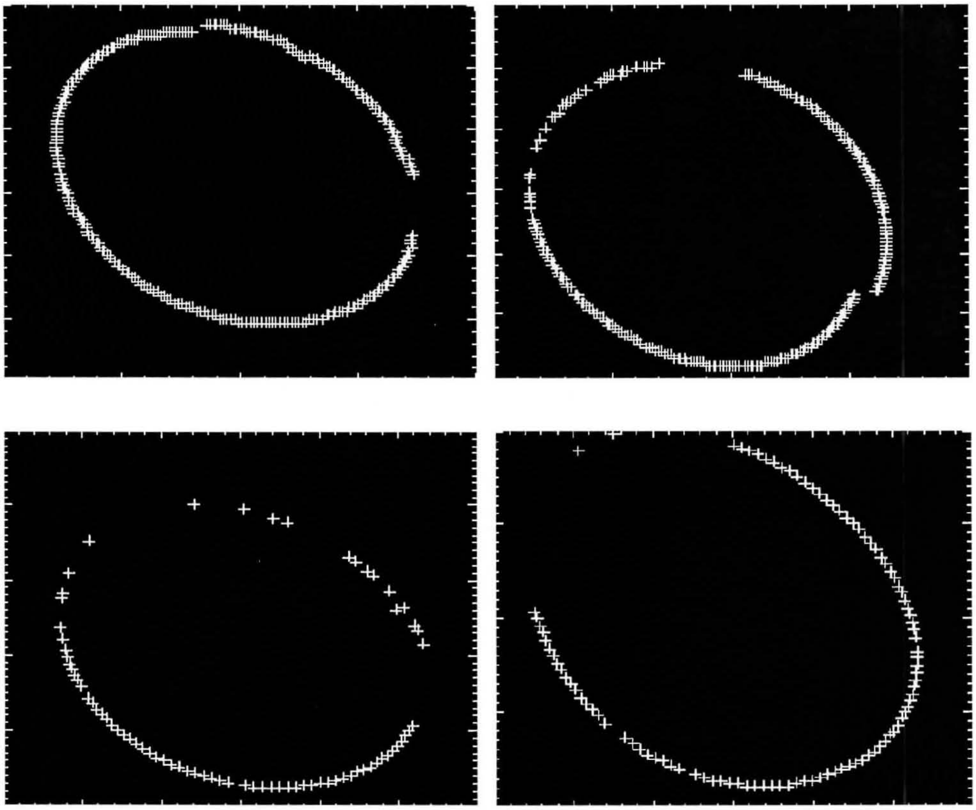


Figure 5. Examples of incomplete cycles.

In cases where a gap was detected the cycle was disqualified. In order to detect a nearby complete cycle the skip size of number of records was reduced until a complete cycle was detected.

Figure 6 depicts the product of the complete processing for a laser swath. The contour has been extracted from the original binary data files that contain the positions in a geographic coordinate system (latitude and longitude). The flight segment is about 40 km long, and size of approximately 50 Mb. The total processing time was about 6 seconds (PC with Pentium 133 MHz processor). The time interval between consecutive samples on the boundary was 10 seconds.

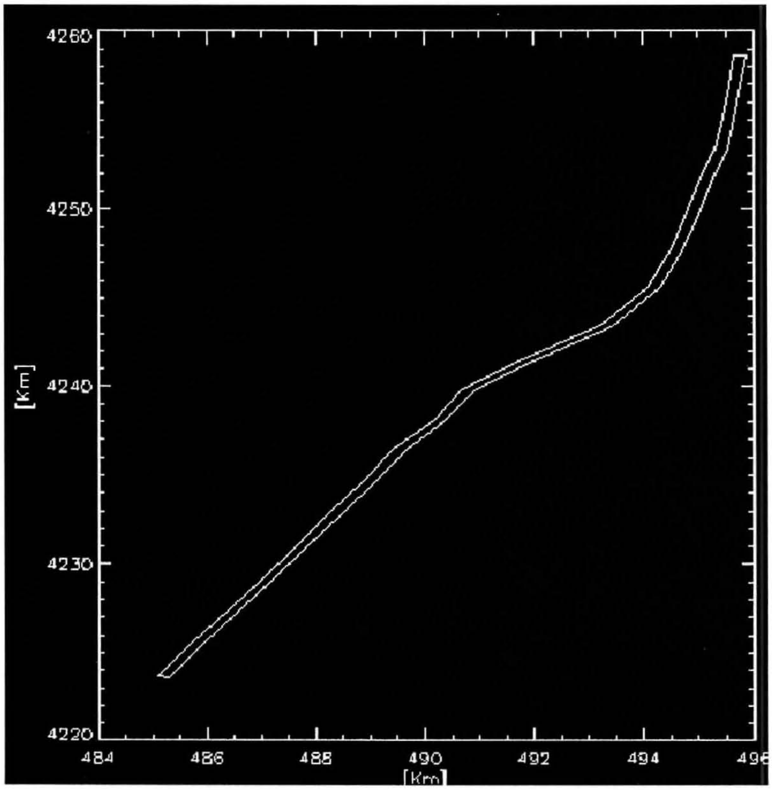


Figure 6. A contour of a laser swath.

The plot is made in UTM coordinate system (units are in km). As can be seen the contour maintains the almost uniform size of the laser swath and adheres to the actual trajectory of the flight.

4. Functionality

The 'ATM_browser' panel

Most of the operations in the system are activated from the main panel of the application presented in Figure 7.

Figure 7. The ATM browser application main panel.

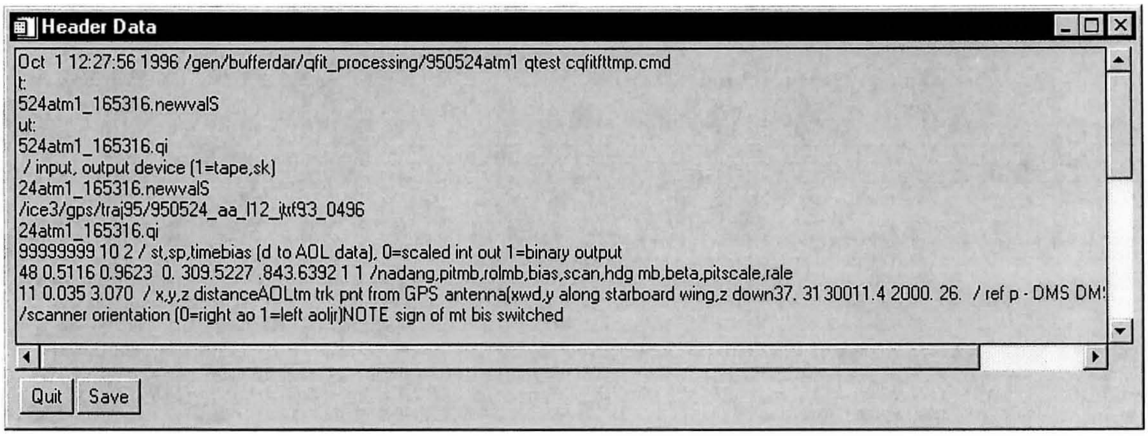
The functionality of the 'ATM_browser' includes:

- **Load** – Enables loading a new laser swath into the application. Laser swaths can either be in a scanner format or in a profiler format (there is no need to specify the data type). The loaded laser swath is then displayed in the graphical window (see Figure 8).

- **Remove** - Removes an existing laser swath from the application.

- **Quit** - Quits the application.

- **Display Header** – Opens a new dialog box (see Figure 8) in which the header information <u>of the selected swath</u> is presented. Within the header display dialog box the user can either save the information into an ASCII file or quit and return to the main panel.



```
Oct  1 12:27:56 1996 /gen/bufferdar/qfit_processing/950524atm1 qtest cqfitfttmp.cmd
t:
524atm1_165316.newvalS
ut:
524atm1_165316.qi
 / input, output device (1=tape,sk)
24atm1_165316.newvalS
/ice3/gps/traj95/950524_aa_l12_jtrf93_0496
24atm1_165316.qi
99999999 10 2 / st,sp,timebias (d to AOL data), 0=scaled int out 1=binary output
48 0.5116 0.9623  0. 309.5227 .843.6392 1 1 /nadang,pitmb,rolmb,bias,scan,hdg mb,beta,pitscale,rale
11 0.035 3.070  / x,y,z distanceAOLtm trk pnt from GPS antenna(xwd,y along starboard wing,z down37. 31 30011.4 2000. 26.  / ref p - DMS DM
/scanner orientation (0=right ao 1=left aoljr)NOTE sign of mt bis switched
```

Figure 8. The header readout dialog box.

- **Save contour** - Exports the coordinates of the vertices of a selected swath into an ASCII file. The exported contour coordinates are in a geographic coordinate system (latitude, longitude).

- **Projection** – This option includes a set of exclusive buttons that enables controlling the projection in which the swaths will be displayed. The swaths can be displayed in Orthometric (geographic coordinates), UTM and Polar Stereographic projections, or in an overview mode (either Orthometric or Polar Stereographic). The overview mode presents a skeleton continent boundary map at the background of the swath contours for better geographic orientation. The main difference between the projection and the overview mode is that the projection mode displays the swaths in the projection coordinate system whereas the overview mode (either orthographic or Polar Stereographic) presents the data in geographic (latitude, longitude) coordinates.

- **Fix UTM zone** – Enables changing the UTM zone manually. The UTM zone is automatically determined by the geographic coordinates of the laser swaths contours. However, for cases in which it is be preferred to view them in coordinates associated with a different zone, the 'Fix UTM Zone' enables changing the default zone to the preferred one.
  While the 'Fix UTM Zone' button is not checked, this option will be insensitive. In this mode the automatically computed UTM zone will be displayed grayed (i.e., cannot be edited). Once the button is checked the text field becomes sensitive and the zone can be changed.
  Note: the graphical display will not be changed unless the UTM button in the 'Projection' menu will then be checked (or rechecked).

- **Vertices Display** - This option enables changing the polylines drawing mode from continuous solid line to a display of the polylines vertices only. As was mentioned above, scanner cycles may be incomplete and therefore skipped or some files have non-documented gaps in the data. The 'vertices drawing' mode provides some insight into these problems by viewing the continuity of the vertices defining the swath contour.

- **Extract** - The extract button opens the data extraction dialog box (see the 'extraction dialog box' chapter) for the export of data from the selected swath into an ASCII file.

- **Reset** - Resets the display into the basic display mode, which is the display of the contours in geographic coordinates fitted to the graphic display window. No individual swath is selected.

- **Zoom in \ Zoom out** - These two buttons enable zooming in and out. Both actions take place after clicking in the graphical display window. The 'Zoom in' is centered on the clicked point. The zoom out is being performed by taking the current displayed range and increasing it (i.e., not with respect to the cursor position).

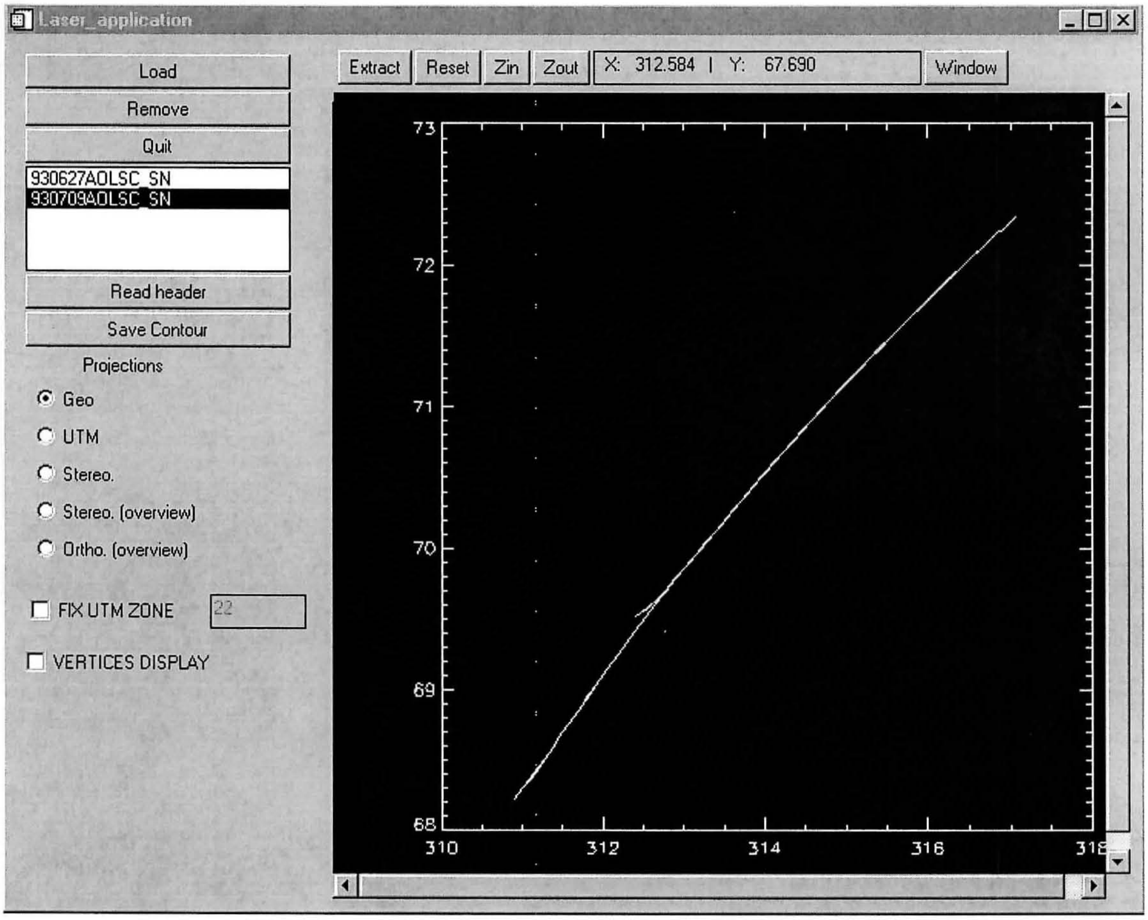
- **Window** - The 'window' button enables the user to graphically define a range (a bounding box) on the graphical window (Figure 9). The window can then determine the range of data extracted from the laser file in the extraction module.

  Note: When a new laser swath is loaded, the application will reset the display window.

- **Swaths list box** - The list box (between the 'Quit' and the 'Display header' buttons) presents the IDs (the file names) of the laser swaths. A selected swath (clicking on it in the list box) will be highlighted (see Figure 8). All operations that relate to a specific swath will be performed on the selected swath. No selection is needed in a case where only one swath is displayed.

  Note: Clicking on a swath in the graphical display will not highlight a swath.

- **Coordinate readout field** - The coordinate readout field displays the coordinates of the cursor location whenever the cursor is in the graphical window and at least one swath is loaded. The coordinates are given according to the current selected projection.



X: 312.584 | Y: 67.690

930627AOLSC_SN
930709AOLSC_SN

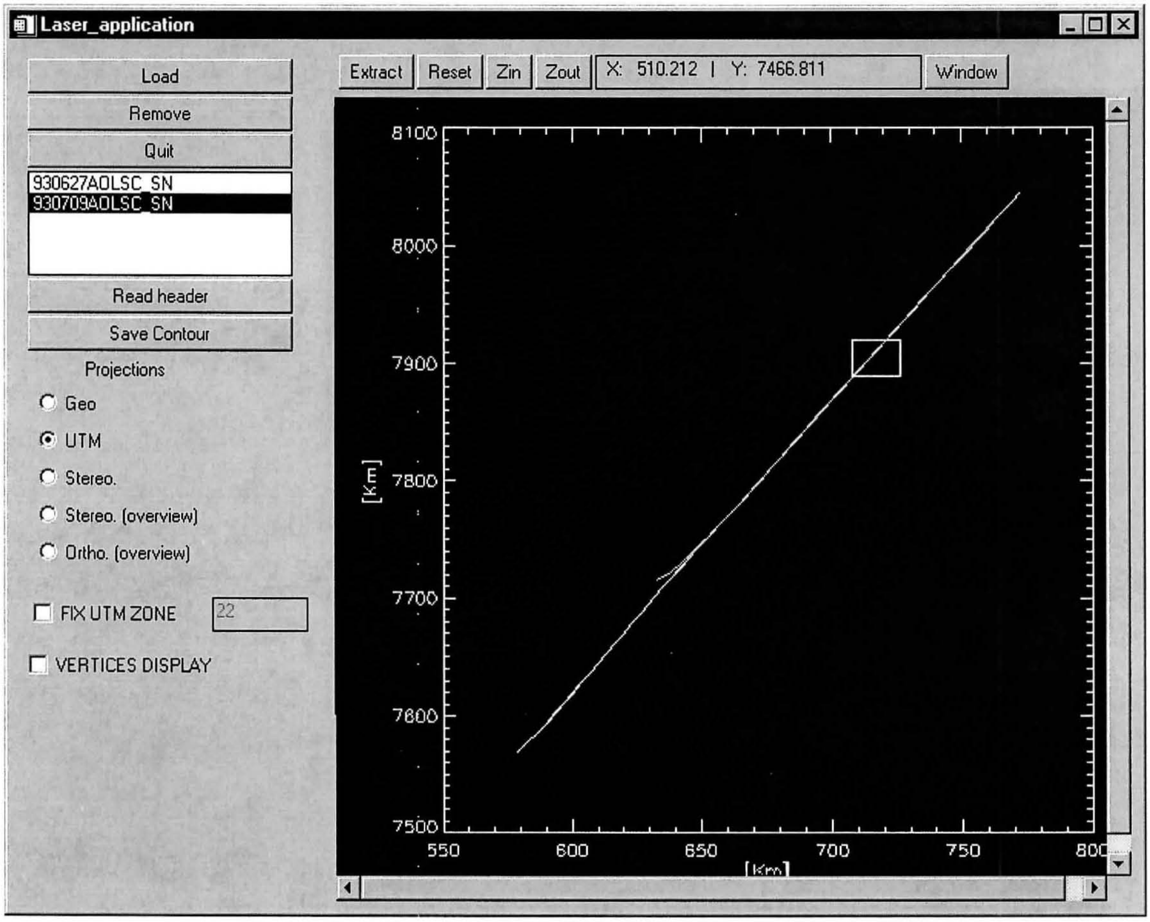
Projections
● Geo
○ UTM
○ Stereo.
○ Stereo. (overview)
○ Ortho. (overview)

☐ FIX UTM ZONE 22

☐ VERTICES DISPLAY

Figure 9. The 'ATM_browser' application with two laser swaths displayed.

In Figure 9 the two swaths are displayed in geographic coordinates. The coordinate readout field displays the geographic coordinates of the cursor location. The selected swath (marked in the list box) appears highlighted in the graphic window. Note that the UTM zone is automatically displayed, but since the 'FIX UTM ZONE' box is not checked the text filed is insensitive.



930627AOLSC_SN
930709AOLSC_SN

X: 510.212 | Y: 7466.811

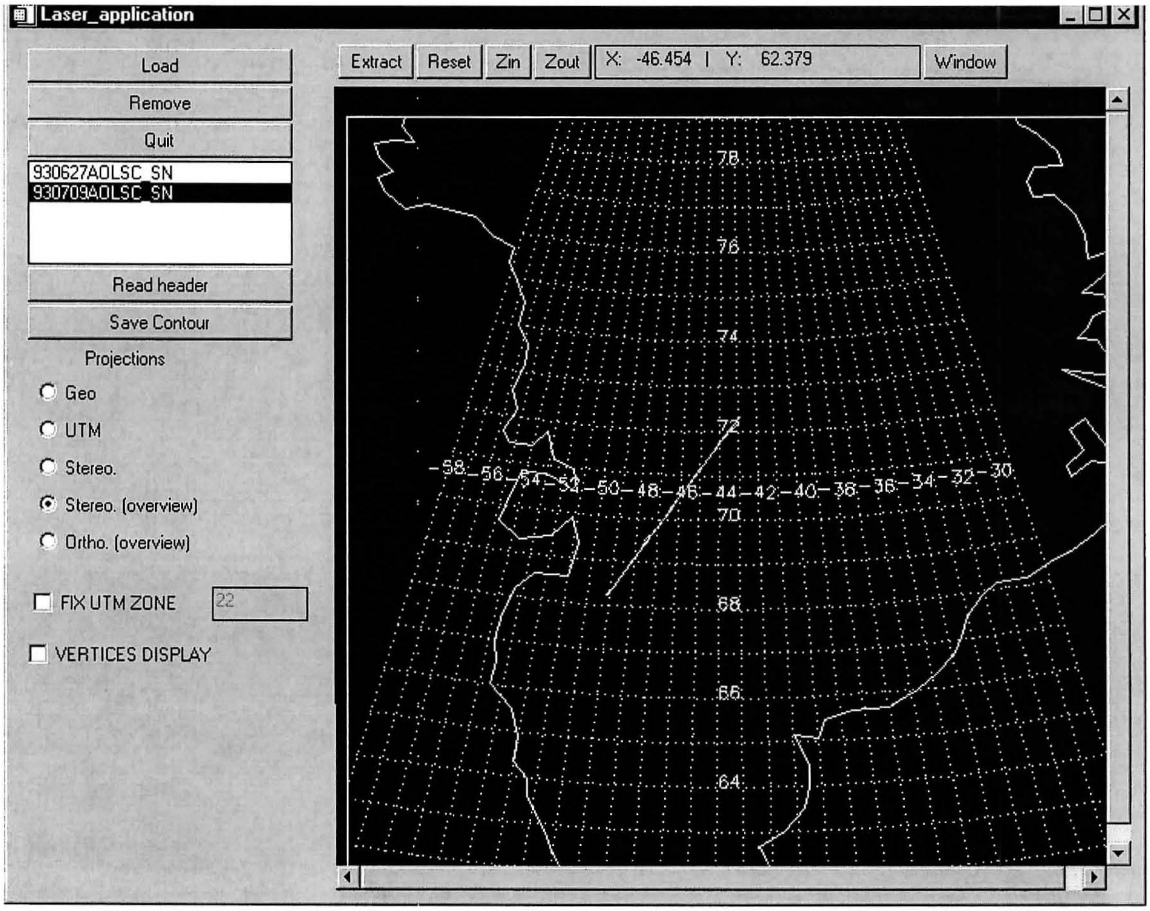
Projections
○ Geo
● UTM
○ Stereo.
○ Stereo. (overview)
○ Ortho. (overview)

☐ FIX UTM ZONE 22

☐ VERTICES DISPLAY

Figure 10. The 'ATM_browser' application with two laser swaths displayed in UTM coordinates and a user defined window.

In Figure 10 the two swaths displayed here are in UTM coordinates (in km resolution). The coordinate readout field displays the UTM coordinates. The selected swath (marked in the list box) appears highlighted in the graphic window. The box drawn on the top of the swaths defines the region from which data can be extracted.



X: -46.454 | Y: 62.379

○ Geo
○ UTM
○ Stereo.
● Stereo. (overview)
○ Ortho. (overview)

☐ FIX UTM ZONE 22

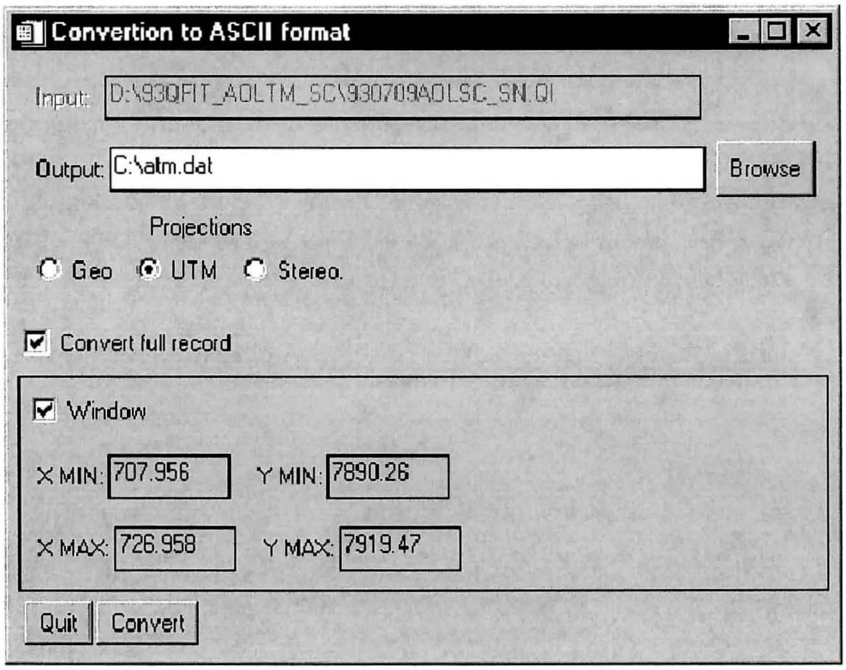
☐ VERTICES DISPLAY

Figure 11. The 'ATM_browser' application with two laser swaths displayed in a stereographic overview display mode.

Figure 11 presents the two swaths displayed in the overview mode, over a background map. Note that the projection is Setereographic, however the coordinates themselves are in geographic coordinate system (Latitude\Longitude).

The extraction dialog box

The extraction dialog box presented in Figure 12 controls the extraction options for a selected laser swath.



Convertion to ASCII format

Input: D:\93QFIT_AOLTM_SC\930709AOLSC_SN.QI

Output: C:\atm.dat

Projections

○ Geo ● UTM ○ Stereo.

☑ Convert full record

☑ Window

X MIN: 707.956 Y MIN: 7890.26

X MAX: 726.958 Y MAX: 7919.47

Figure 12. The data extraction dialog box.

These options include the following:

- **Input file name** - The input file name appears in an insensitive (grayed) text field without the option to change it from this dialog box.
  If the extraction application is run independently (see in the description of modules) this field status is changed to active.

- **Output file name** - The text field enables the user to type the output file name. Unless a full path is given the directory will be the default directory specified in IDL configuration. The 'Browse' button enables browsing the directory system and set the output directory and file name for the desired location.

- **Projection** - The application enables selecting the coordinate system in which the data will be written. The three options are Geographic coordinates, UTM, and Polar

Stereographic projection systems. The default projection will be the current selected one in the 'ATM_browser' panel, whereas the overview display is considered as geographic coordinate system. The zone for the UTM projection is the one appearing in the 'UTM zone' field in the main panel of the 'ATM_browser'. If the extraction application is run independently the zone will be automatically computed.

- **Convert full record** - The data can be exported to the ASCII file in two forms, either full record (10 or 14 fields) or skimmed record (containing the Easting, Northing, Elevation and GPS time fields) formats. A checked box implies that a full record will be converted.

- **The Window dialog** - The window dialog is composed of a check box indicating whether only a region from the overall swath (when button is checked) or the whole swath (unchecked button) is going to be extracted. The coordinates in the text fields present the range and enable the user to either type them or edit them. If a range is defined graphically in the 'ATM_browser' panel, these coordinates will be transferred to the dialog box in the same coordinate system in which they were taken.
  Note: The application does not convert the window coordinates according to the change of projection, therefore a change of projection may cause unexpected results in the output data. If a projection is changed while a geographic window is defined, the application will alert on possible implications but will not prevent the user from continuing with the conversion.

- **Convert** - Activate the conversion procedure.
  Note: The 14 fields data include both active laser ranging and passive sensing. In case of no return from the laser altimeter the relating fields have the value of 0 (that is the way the data appears in the binary files). Therefore, when the extraction by window mode is activated these records will be excluded, when not, these records will be included with 0 values for these fields (as in the original file).

- **Quit** - Quit the without converting the data.

5. Description of Modules

The software is composed of several modules each of them is dedicated to a specific task within the overall application. Such modules include the main module that creates and manages the main interface of the application, the swath contour extraction module, the profile trajectory extraction, the data translation into ASCII format etc. The current chapter is aimed at providing a general description of the modules within the application and a brief description of the main functions in each of them.

'Atm_browser' (atm_browser.pro)

The 'atm_browser' module is the core of the application. Its main task is to create and manage the events arriving from the graphic user interface (GUI) of the main panel in the application. Beside several utility functions the module is composed of two major procedures and another block of functions dedicated to plotting the laser swaths contours. The two major procedures are, the 'atm_browser' that initializes data structures and parameters and creates and displays the main panel and the 'atm_browser_event' that handles the events (i.e., the user actions) that arrive from the main panel. The block of graphical display functions (identified by the 'plot_' preface) handles the drawing into the graphical window according to the selected projection.

Data type analysis (check_data_type.pro)

This module handles the analysis of the type of laser altimetery data - scanner data or profiler. The analysis is based on evaluating certain fields within a laser point record, and on the analysis of the geometric shape of the point pattern.

Contour extraction (lsr_bin2poly.pro)

This module handles the swath contour generation including the input of the binary data, scanning the file and creating the laser swath contour according to the algorithm introduced above. The main two functions in this module are 'lsr_bin2poly' that scans the file, extracts scanner cycles, and gathers data for the creation of the polygon, and 'spiral_ex_pts' that performs the completeness analysis of the extracted scanner cycle and the extraction of the extreme points.

Profile extraction (lsr_prf2poly.pro)

This module handles the extraction of a profile's trajectory. This includes handling the binary format of the data, scanning the file, and creating the trajectory.

Data extraction user interface (extr_dbox.pro)

This module handles the user interface for the data extraction (the dialog box) but not the data extraction itself. The module is composed of two procedures, 'extr_dbox' that create the dialog box and initializes parameters and data structures, and 'extr_dbox_event' that handles the coming events and validates the consistency of the operations.

Note: This module was designed to run also separately without the need to be accessed from the 'atm_browser' application. Thus data can be extracted by running this application independently. To work in this mode run 'extr_dbox' from the command line (by simply typing it). In this configuration, however, the bounding window cannot be drawn graphically.

Conversion of records to an ASCII format (lsr1_bin2asc.pro)

This module handles the data extraction from the binary format and its output into an ASCII file. The major function in this module is 'lsr1_bin2asc' that supports the extraction of data, conversion into the specified coordinate system, truncation according to a geographic window, and the output according to the defined format (long format or a short one).

Header display (lsr_hdr.pro)

This module handles the dialog box that presents the laser file header. The module is composed of two main procedures: 'lsr_hdr', which reads the header information, creates the dialog box and displays the header content, and 'lsr_hdr_event', which handles the events and validates the consistency of the operations.

Conversion from geographic coordinates to UTM (geo2utm.pro)

This module (composed of one function) handles the conversion of an array of latitude and longitude coordinates into Universal Transverse Mercator (UTM) coordinates upon a given UTM zone (adopted from Snyder 1987).

Conversion from Latitude\Longitude to Polar Stereographic projection (geo2stereo.pro)

This module handles the forward and backward conversion of geographic coordinates into Polar Stereographic ones (adopted from Snyder).

Other Utility Modules:

extract_file_name.pro - Extraction of the ATM ID (to appear in the list box) from the overall file name.

p2l_pos.pro - Computation of the position of point with respect to a line. Aimed to organize swath contour points in a manner that will prevent self-intersection of the contour.

calc_ellips_const.pro - Computation of geodetic constants used for the coordinates transformations.

Important Data Structures

There are several data structures worth reviewing in some level of detail, for an easy understanding of the data flow within the application:

Geographic windows - Geographic windows are defined by the Lower Left (LL) and Upper Right (UR) coordinates. Geographic window is represented as a structure (defined as 'Range_type' and declared in the 'atm_browser' procedure). There are two major geographic windows in the application, the first one defines the range of all the presented laser swaths and stores data in geographic coordinates. The second one holds the window position that was extracted from the graphical display and is used for zooming manipulations, this range will hold coordinates in the displayed coordinate system as it is presented.

Laser swath information - The information for a specific laser swath is stored in a structure. The structure holds the swath file name, the swath ID and three pointers to arrays that store the swath central line, the swath contour and a position of the cycle in the file (in cases where fast access will be needed). The swaths are stored together in an array of structures.

Auxiliary data necessary to handle events is stored in structures created in the main functions (such as the structure 'all_data' in the 'atm_browser' procedure) and are attached as user value (see 'Building IDL Applications') to the base object.

Common Blocks - There are two common blocks in the 'atm_browser' module. The first one 'share1' holds miscellaneous data (projection constants, central meridian, range and plot symbol) that are required by many functions. The second one, 'share2', holds the display window coordinates that are required solely for the event handler.

6. Installation

Installation of the application is simple. The recommended way is to create a new directory (or sub-directory) specified for the application and to store all the IDL (.pro) files in this directory.

Then a path should be defined in IDL to this directory. This can be done in two ways. The convenient one is using the graphical user interface (the default in PC's and activated by 'idl –autow' in UNIX machines) select the 'Path | preference ...' option and then include the directory in the 'Path' sub-folder. In the Alphanumeric environment the path can be extended in the following set of commands:

```
tmp = !path
tmp = tmp + 'new path'
!path = tmp
```

However, IDL does not save the new path in the permanent path definition. Information about that can be found in the online help (or reference manual) under '!Path'.

Downloading the application can be done from our web site - http://puka.mps.ohio-state.edu/annete/atm_browser.html

7. Appendix 1 – Description of the data records in output file

The 10 records data

Word	Actual value	Description
1	2231.353	Seconds since start of file.
2	69.976091	Latitude (degrees)
3	313.177422	Longitude (degrees)
4	2132.819	Elevation (m)
5	1017.000	Laser Transmit Power (relative units)
6	1978.000	Surface Return Energy (relative units)
7	359.977	Scan Azimuth (degrees)
8	2.109	Pitch (degrees)
9	3.295	Roll (degrees)
10	132136.797	Time (GPS in HHMMSS.ss)

The 14 records data

Word	Actual value	Description
1	2231.353	Relative Time (sec from start of data file).
2	69.976091	Laser Spot Latitude (degrees)
3	313.177422	Laser Spot Longitude (degrees)
4	2132.819	Elevation (m)
5	1017.000	Laser Transmit Power (relative units)
6	1978.000	Surface Return Energy (relative units)
7	359.977	Scan Azimuth (degrees)
8	2.109	Pitch (degrees)
9	3.295	Roll (degrees)
10	275.00	Passive Signal (relative)
11	69.976089	Passive Footprint Latitude (degrees)
12	313.177420	Passive Footprint Longitude (degrees)
13	2312.189311	Passive Footprint Synthesized Elevation (m)
14	132136.797	GPS Time in (HHMMSS.sss)

8. References:

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Martin, C., 1997. Airborne laser data smoothing, compression, and glaciological parameter extraction. In *PARCA Contributed Reports*, Greenland Science and Planning Meeting, October 15-16,1997, Tucson, AZ, 71-76.

Snyder J. P., 1987, *Map Projection A Working Manual*, U.S. Geological Survey Professional Paper 1395, Washington D.C.

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