VALIDATION OF THE 2003 ANTARCTIC GROUNDING LINE THROUGH THE USE OF ENVI®

Joyce Bevins, Robyn Evans, Ryan Lawrence, and Michael Jefferson
Mentor: Dr. Malcolm LeCompte Principal Investigator: Dr. Linda B. Hayden
1704 Weeksville Rd, Box 672
Elizabeth City, North Carolina 27909

Abstract— **The extent of the ice sheet and its dynamics or mass balance can be determined by making an accurate measurement of its area. To measure the area of the continent's ice sheet, the grounding line must first be accurately determined. The grounding line is the boundary between the grounded ice resting on land and the floating ice constituting the ice shelf perimeter of the continent. In a project entitled Antarctic Surface Accumulation and Ice Discharge (ASAID), Dr. Robert Bindschadler, lead an international team of glaciologists and computer scientists, including students from Elizabeth City State University (ECSU), obtained a more accurate measure of the area of the Antarctic ice sheet in order to determine its mass balance. That is, whether the amount of ice is growing or diminishing over long time intervals. Bindschadler's team determined the grounding line using methods of photoclinometry with LANDSAT Enhanced Thematic Mapper (ETM) image brightness and surface elevation data from the Geoscience Laser Altimeter System (GLAS) aboard NASA's Ice, Land and Cloud Elevation Satellite (ICESat) polar orbiting earth observatory. The ASAID grounding line (GL) was established using LANDSAT 7 and GLAS data obtained in 2003. However its accuracy had not been tested.**

With the current ASAID 2003 Grounding Line, the CERSER GL Validation Team was tasked by Dr. Bindschadler with determining its accuracy in two coastal regions and whether changes have occurred over long time intervals. The team overlayed the 2003 GL on LANDSAT Seven ETM imagery temporally proximate to 2003. This modified image was then compared to decades older LANDSAT 4 & 5 Thematic Mapper (TM) imagery. GL validation and change determination were planned for two geographic areas known to exhibit rapid changes potentially due to climate warming: Pine Island Glacier (PIG) and Larsen Ice Shelf. However, due to time constraints, the team was only able to work with a limited portion of the PIG. The GL was tested along a portion of the Antarctic coast near the PIG. To accomplish the validation, LANDSAT 7 images from 2003 used in creating the GL, were obtained from the USGS archive (lima.usgs.gov). Other LANDSAT images were obtained from the USGS glovis on-line archive (glovis.usgs.gov). The oldest possible, cloud-free LANDSAT 4 and 5 TM images were obtained for the regions of interest. To facilitate data manipulation and image comparisons, the extremely large GL vector file, obtained from Dr. Bindschadler. was truncated to include only the geographic regions of interest. Truncation and image comparisons were accomplished using ITT Visualization Information Solutions ENVI® image processing software. Using the 2003 image as a reference and then warping the older image to conform to the common fixed control points visible on both images corrected any departure from perfect geographic pixel registration. The grounding line overlying the 2003 image was then examined and compared to the older image. The geographic coordinates and extent of any departures from coincidence were recorded and reported. A possible deviation in the GL was found while comparing a 2001 LANDSAT 7 image to a 1986 LANDSAT 5 image, near a small glacier feeding into Pine Island Bay. Comparison with a 2003 image of the same area revealed no GL inaccuracy; however, a small ice shelf appeared to have progressively diminished over time until it disappeared in 2003. *(Abstract)*

Keywords— ENVI® , GloVis, ground control points, groundlingline, hinge point, Landsat 7 ETM+, LIMA, PIG

I. NATURE AND BACKGROUND OF THE STUDY

A. Introduction

For decades, scientists have debated on whether or not global warming really exists. In recent years, many scientists have come to an agreement that global warming is already affecting the earth's atmosphere with significant temperature and climate changes (Vergano). The Grounding Line Validation team focused on validating the grounding line of Antarctica's ice sheet, as a resource for determining temporal changes along the Antarctica coastline.

B. Statement and Background of the Problem

The team's ultimate goal was to determine if the groundling line could be used as a tool to determine temporal changes to the coastline. To answer this question, two objectives were created: 1. Determine the accuracy of the 2003 groundling line in two coastal regions—the Pine Island Glacier (PIG) and the Larsen Ice Shelf; and 2. Determine whether changes had occurred in its location over the course of ten plus years.

The first step was to validate the grounding line. To do this, the grounding line was overlaid onto the landsat image that was used to create it. The team then searched GLOVIS for Landsat images from 1986/1989 that corresponded to the image used to create the grounding line.

The two images were then evaluated and compared for any changes.

C. *Hypothesis*

The team hypothesized that there were only three possible outcomes: 1. The grounding line was moving inward and the sea level was rising due to a warming climate; 2. The grounding line was moving seaward and the sea level was decreasing due to a cooling climate; or 3. There was no change in the grounding line, thus there was no change in the sea level.

D. *Definition of Terms*

- **ENVI®** – a software application used to process and analyze geospatial imagery
- **GloVis (Global Visualization Viewer)** - USGS online archive used to store Landsat imagery
- **Ground Control Points** - a system of distinct geographic features that is recognizable on images and used to facilitate image-to-image pixel registration
- **Groundling line** - the last portion of an ice sheet that is supported by land before it becomes a floating ice shelf (Figure 1)
- **Hinge point** - the inflection point between ice shelf and ice sheet
- **Landsat 7 Enhanced Thematic Mapper Plus (Landsat 7 ETM+) -** the satellite used to collect data used in the team's research
- **Landsat Image Mosaic of the Antarctic (LIMA**) – provided the 2003 images used to define the GL
- **Pine Island Glacier (PIG) -** the are of interest for the grounding line investigation

II. REVIEW F LITERATURE

A. *Prior Research*

In 2003, Dr. Robert Bindschadler at NASA Goddard in Greenbelt, Maryland, lead a team of international glaciologists and computer scientists, including a group of students from Elizabeth City State University, and obtained a more accurate measure of the Antarctic ice sheet. The team was able to determine the grounding line by combining LANDSAT (ETM) image brightness with surface elevation data obtained by the GLAS aboard NASA's Ice, Land and Cloud elevation Satellite or ICESat, polar orbiting earth observatory. The ASAID GL was established using LANDSAT 7 and GLAS data obtained in 2003.

III. METHODOLOGY

A. *Definition of the Population*

The team used the GL established by Bindschalder and his team, along with Landsat 7 images collected from the LIMA website as an aid for validating the GL. The areas of interest were PIG and the Larsen Ice Shelf, though only PIG was examined. (Figure 2)

B. *Procedure*

Throughout the course of the research multiple ENVI® tutorials were utlized to get the team familiarized with the software.

After becoming familiarized with ENVI®, the team began to validate the GL. To do this, the GL vector file was obtained from Dr. Bindshadler and overlaid onto the 2003 images that were downloaded from LIMA. It was determined that the GL fit perfectly to the coastal line of the continent, therefore it was indeed valid.

The next step was to check to see if the GL could be used as a tool to determine temporal changes to the coastline—that is, does it cause a direct change to the sea level. To do this, the team searched GloVis for older Landsat images with the same path/row as the 2003 images used to create the GL. The team soon discovered that there were no old images in the GloVis archive with the same path/row and that a mosaic of multiple images was required to view PIG.

The team also found that the best path/row image that contained the area of interest had not been used in the creation of the grounding line, but they had older images from 1986 and 1989; however, the latest of these images was in 2001.

The team soon discovered that the grounding line was too large and took far to long to load; therefore it needed to be truncated.

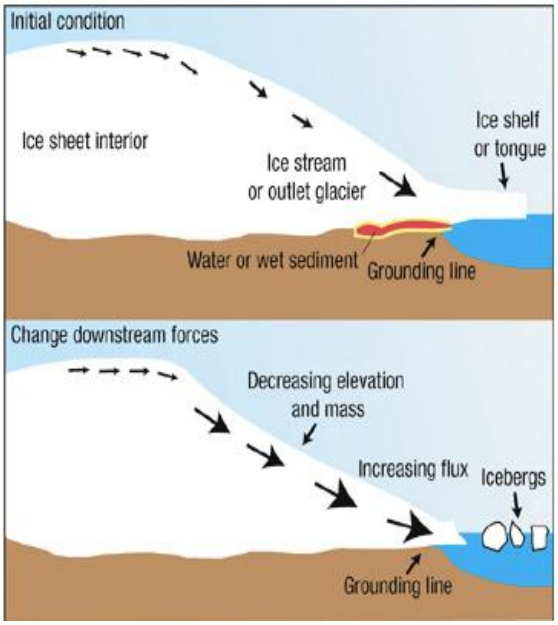


Figure 1: Visual representation of the grounding line

To truncate the GL, an ENVI® tutorial was utilized in the creation of a new polygon file. The team wanted to get as accurate as possible to the GL, so the original GL was overlaid onto the area of interest and points were then tediously picked out along the line. A new file, that was much smaller and could be opened in a timely manner, was created.

The next step was to link the 2001 LANDSAT7 and the 1986 LANDSAT 5 images so they would be properly geo-referenced. To due this, the team started by selecting the 2001 image as the geographic reference. Five common geographic points [the ground control points] were selected in both the reference image and in the 1986 image. (Figure 3) ENVI® provided the image-to-image registration process that co-registers the image pixels at common geographic points in each image. The team then compared the 2001, the 1986 images (Figure 4), the 2003 and the 2001 images (Figure 5).

Upon finding the appropriate images, ENVI® was used to view old and new Landsat images with the GL overlaid onto them; the images were then linked.

C. Statistical Methods and Tests that were used to Analyze the Data

ENVI® is a software application that is marketed by ITT Visual Information Solutions (ITT VIS), formerly known as Research Systems Inc. (RIS). The software is used for processing and analyzing geospatial imagery. The group specifically used the software to display, geo-rectify, and compare multiple images in order to determine if variations in the grounding line had occurred.

IV. ANALYSIS OF DATA

A. Results of the Visual Analysis of Data

After examining the two images side by side, the team concluded that a change had not occurred with the GL.

B. Shortcomings

First, the team discovered that the LIMA website had no single image that covered the entire area of interest. The only images available for PIG were mosaics of path/row (latitude delimiter/longitude delimiter): 233/113 and 233/114.

This led to another problem; the images did not have early Landsat counterparts. The team then looked to GloVis to obtain Landsat images with the correct row/path combination (001/113) from 2001 images that were available.

The team soon discovered that the grounding line was too large. Due to the large capacity of the GL vector file, the GL took to long to load images. The computer would often freeze and crash, resulting in the team having to start over. This led to slow image-to-image comparisons. The GL needed to be truncated.

The next problem revealed that the linking of the 2001 LANDSAT7 and the 1986 LANDSAT 5 images had not been properly geo-referenced.

Ultimately, the team's biggest set back was time. There was not enough time to examine the rest of PIG nor was there enough time to start looking at the Larsen Ice Shelf.

C. Tables, figures, etc. use for Data Analysis

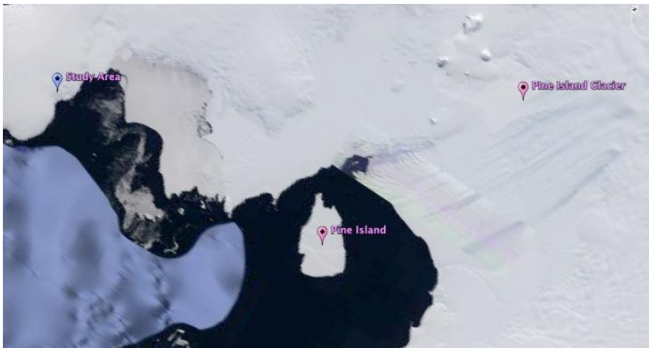
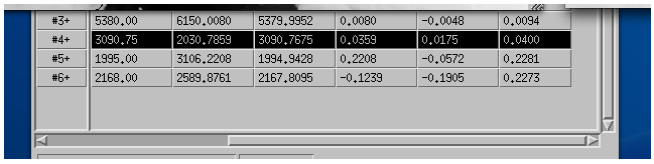


Figure 2. Close up of the area of interest, the Pine Island Glacier



#3+	5380.00	6150.0080	5379.9952	0.0080	-0.0048	0.0094
#4+	3090.75	2030.7859	3090.7675	0.0359	0.0175	0.0400
#5+	1995.00	3106.2208	1994.9428	0.2208	-0.0572	0.2281
#6+	2168.00	2589.8761	2167.8095	-0.1239	-0.1905	0.2273

Figure 3. The ground control points that allow the images to be georeferenced

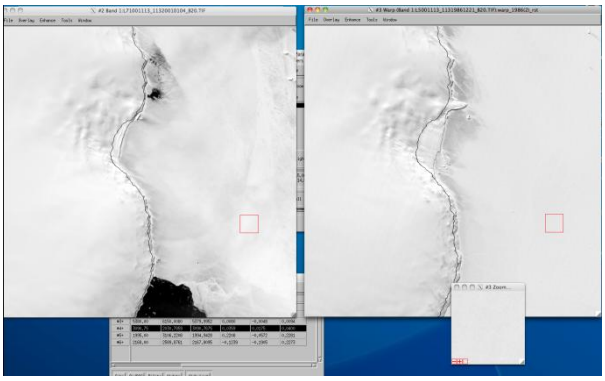


Figure 4. Shows the comparison between the 2001(LANDSAT7 image from LIMA archive) and the 1986 (LANDSAT 5 image from USGS GLOVIS) wrapped images. The 2001 image is from LANDSAT 7

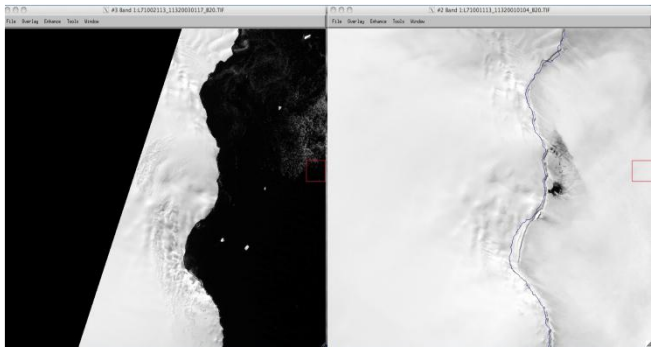


Figure 5. Comparison between the 2003 and 2001 images (LANDSAT7 images from LIMA archive)

V. SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

A. *Conclusions resulting from Visual Analysis of the Data*

In conclusion, a change had not occurred with GL; therefore it was an accurate depiction of the 2003 coastline. However, the team discovered that from 1986 -1989 - 2001 there was an ice shelf retreat until its dissipation in 2003. Bindshadler confirmed that our research uncovered a retreating ice shelf.

VI. FUTURE WORKS

Due to time constraints, the team was only able to focus on a small region of the PIG. Future investigation of the unexamined potion of the PIG coastline might show variations in the retaining ice shelf or changes in the GL itself. Also the Larson Ice Shelf also needs to be investigated. The team would also like to implement new software beta test using new NASA Goddard software to investigate the GL.

ACKNOWLEDGMENT

The team would like to acknowledge Dr. Linda B. Hayden, Dr. Robert Bindshadler, and Dr. LeCompte for guiding us.

REFERENCES

[1] Alley, R. B. & Bindschadler, R. A. 2001 The West Antarctic ice sheet and sea-level change. In The West Antartic ice sheet: behavior and ENVI® ronment (ed. R. B. Alley & R. A. Bindschadler). Antarctic Research Series, vol. 77, pp. 1–11. Washington, DC: American Geophysical Union.

[2] Baltrop, Jamika, MyAsia Reid, and Malcolm LeCompte. *Determining the Antarctic Ice Sheet Grounding Line with Photoclinometry using LANDSAT Imagery and ICESat Laser Altimetry*. Elizabeth City, North Carolina: 2009. Print.

[3] Bindschadler, R., Choi, H., Wichlacz, A., Bingham, R., Bohlander, J., Brunt, K., Corr, H., Drews, R., Fricker, H., Hall, M., Hindmarsh, R., Kohler, J., Padman, L., Rack, W., Rotschky, G., Urbini, S., Vornberger, P., and Young, N.: Getting around Antarctica: new high-resolution mappings of the grounded and freely-floating boundaries of the Antarctic ice sheet created for the International Polar Year, The Cryosphere Discuss., 5, 183-227, doi:10.5194/tcd-5-183-2011, 2011.

[4] Bindscahler, Robert. "The ENVI® ronment and evolution of the West Antartic ice sheet: setting the stage." *Philosophical Transactions of the Royal Society A* 364.1844 (2006): 1-23. Web. 05 Mar 2001. <http://rsta.royalsocietypublishing.org/content/364/1844/1583.full#ref-list-1>.

[5] Bird, Michael I., William E.N. Austin, Christopher M. Wurster, L. Keith Fifield, Meryem Mojtahid, and Sargeant, Chris. "Punctuated eustatic sea-level rise in the early mid-Holocene." *Geology* 39.9 (2010): 803-806. Web. 09 Feb 2011.

[6] Conway, H., B. L. Hall, G. h. Denton, and A. M. Gades. "Past and Future Groundin-Line Retreat of the West Antartic Ice Sheet." *Science Magazine* 286.5438 (280-283): 1999. Web. 05 Mar 2011.

[7] "ENVI® Online Tutorials from ITTVIS." *ENVI®* . N.p., 2011. Web. 26 Apr 2011. <http://www.ittvis.com/language/en-us/productsservices/ENVI® /tutorials.aspx>.

[8] *GloVis*. Web. 6 Apr 2011. < Glovis.usgs.gov>.

[9] Shepherd, Andrew, Duncan J. Wingham, Justin A.D. Mansley, and Hugh F. J. Corr. "In;and Thinning of Pine Island Glacier, West Anartica." *Science Magazine* 291.5505 (2001): 862-864. Web. 11 Mar 2011.

[10] "U.S. Geological Survey: Landsat Image Mosaic of Antarctica (LIMA)" , http://lima.usgs.gov.

[11] Vergano, Dan. "The debate's over: Globe is warming." *USA TODAY*. (2005): Print.

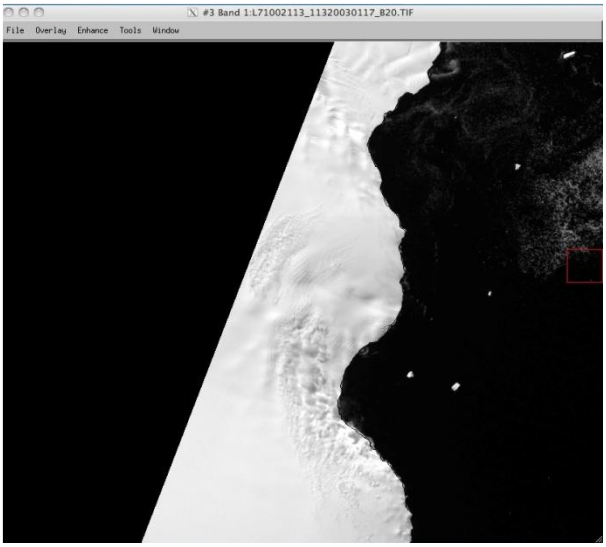


Figure 6 : Grounding line image overlaid onto the 2003 LANDSAT7 Image from LIMA archive