Survey to Detect Long-term Variability in Pine Island Bay Coastal Ice Morphology Using Archived Landsat Imagery

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Abstract— In the 2003 Antarctic Surface Accumulation and Ice Discharge project, the Pine Island Bay Region was identified as an area to exhibit rapid changes potentially due to climate warming.

Utilizing the 2003 Antarctic Surface Accumulation and Ice Discharge basal stress boundary vector file, the team surveyed the Pine Island Bay region from 100° West longitude to 112° West longitude to determine the accuracy of the grounding line and detect significant changes over multi-decadal time intervals.

Exelis Visualization Information Solutions' (ENVI) image processing software was used to co-register Landsat Muti-Spectral Scanner and Thematic Mapper images. Images prior to 2003 were co-registered with circa 2003 Landsat Enhanced Thematic Mapper used to create the 2003 Antarctic Surface Accumulation and Ice Discharge basal stress boundary. The survey yielded the possibility of one significant change in the placement of the basal stress boundary and instances of relatively minor basal stress boundary misplacement (or retreat) and evolutionary coastal ice retreat.

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

I. NATURE AND BACKGROUND OF THE STUDY

A. Introduction

The investigation of Antarctica's basal stress boundary (BSB) is an ongoing research project that was surveyed by the 2012 Antarctic Team. The team surveyed a section of Antarctica in the proximity of the previously discovered ECSU Bay. Research was to re-examine the basal stress boundary in the proximity where recent variability has been observed as well as the differences that have occurred over the years.

B. Statement and Background of the Problem

The team's goal was to determine if there are ongoing changes to the basal stress boundary of Antarctica in the specified area of Pine Island Bay.

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

C. Definition of Terms

- **ENVI** – a software application used to process and analyze geospatial imagery
- **Ground Control Points** - a system of distinct geographic features that is recognizable on images and used to facilitate image to image pixel registration
- **Basal Stress Boundary** - (Previously known as GL) 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**) is the first true-color, high-spatial-resolution image of the seventh continent
- **Pine Island Bay (PIB) -** the latitude and longitude for the basal stress boundary investigation

- **Geoscience Laser Altimeter System (GLAS)** - A laser altimeter is an instrument that is used to learn about the topography, or the shape of the surface, of a planet.

- **Landsat Image Mosaic of Antarctica (LIMA) -** the first true-color, high-spatial-resolution image of the seventh continent.

II. INTRODUCTION

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 basal stress boundary by combining LANDSAT (ETM) image brightness with surface elevation data obtained by the Geoscience Laser Altimeter System (GLAS) aboard NASA's Ice, Land and Cloud elevation Satellite or ICESat, polar orbiting earth observatory. The ASAID BSB was established using LANDSAT 7 and GLAS data obtained in 2003. However the BSB had not been tested.

III. METHODOLOGY

A. Definition of the Study Area

The team used the BSB 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 PI and the Larsen Ice Shelf; although only PIB was examined. (Figure 2)

B. Procedure

ENVI, a software application created by ITT Visual Information Solutions, was used to determine if any changes had occurred. Archived images from the years: 1973 to 2012 were downloaded from United States Geological Survey Global Visualization Viewer (GLoVis) and the Landsat Image Mosaic of the Antarctic, and earth Explorer. Path and row identifier combinations defined by the Landsat global coverage grid locates the geographic area captured in each scene. Thus, path and row numbers define the location and area covered by a specific image. Ice shelf area was measured in each of selected pre-2003 Landsat archived images with respect to the ASAID circa-2003 grounding line vector. Ice shelf area was identified and measured as equal to the area of ice lying seaward of the grounding line. Pixel and geographic coordinates were not well registered in Landsat images recorded prior to 2003.

The BSB is based on the pixel to geographic coordinate correlation of the 2003 Landsat 7 Images used to define it. However, the 2003 Landsat 7 Images do not have the same pixel-to coordinate registration as the older Landsat archived imagery. Therefore, an image-to-image registration had to be performed. Landsat 7 images from 2003 were used as reference images to accomplish this co-registration. Pixel to pixel image registration involves warping, stretching or shifting of an archived image to achieve a pixel-to-pixel geographic correspondence with one of the circa-2003 reference images. The reference image was defined as the base image and the archived image was selected for warping. Five geographic points in each image were selected as ground control points to from which to create the new (warped or co- registered) image. Once the points are selected, there is a tool on ENVI that will warp the images.

Once the new co-registered image is created, the BSB line is overlaid upon it. A vector bounding line was created to encompass the border of the ice shelf that included the BSB as one component.

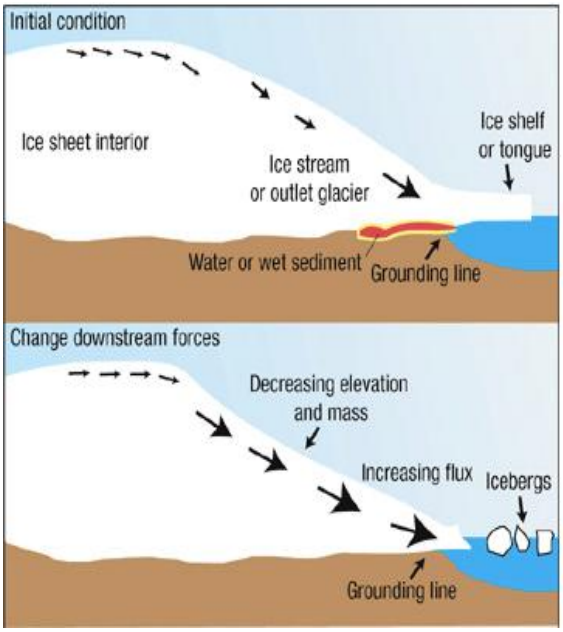


Figure 1: Visual representation of the basal stress boundary

Results of the Statistical Analysis of Data

After examining images throughout the years the three images side by side by side, the team concluded that there were missplacements of the GL along the study that was mainly due to evolutionary coastal ice erosion.

D. *Tables, figures, etc. use for Data Analysis*

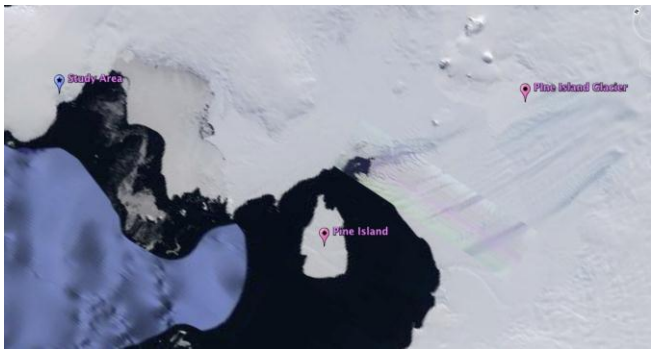
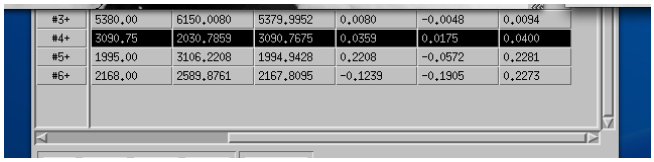


Figure 2. Close up of the area of interest, the Pine Island Glacier



#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

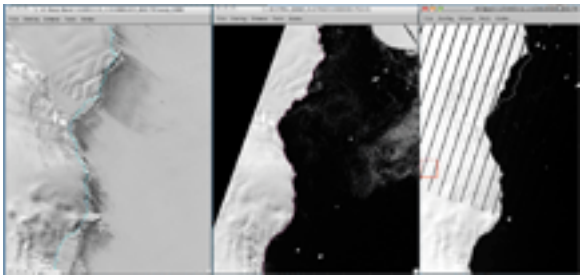


Figure 4. Shows the comparison between three images 1986 (LANDSAT 5 image from USGS GLOVIS), 2003 (LANDSAT7 image from LIMA archive), and 2012(LANDSAT7 image from LIMA archive) respectively.

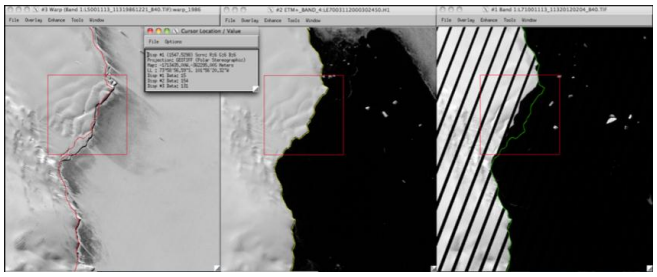


Figure 5. Comparison between the 1986, 2003, and 2012 clearly shows misplacement in the basal stress boundary as well as an evolutionary coastal ice retreat. (LANDSAT7 images from LIMA archive)

IV. Summary, Conclusions, and Recommendations

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

The survey yielded the possibility of one significant change in the placement of the BSB and instances of relatively minor BSB misplacement (or retreat) and evolutionary coastal ice retreat.

V. Future Works

The future research that will be conducted is the measurements for the survey areas that resulted in an apparent ice-shelf reduction as well as the investigation of more parts of the Antarctic Peninsula in the vicinity of Larsen Ice-Shelf. The investigation of Larsen Ice will also be researched with the new NASA Goddard software.

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