FINAL REPORT

INVESTIGATING LONG-TERM BEHAVIOR OF OUTLET GLACIERS IN GREENLAND

NASA - NAG5 - 13614

Reporting Period: September 1, 2003 – August 31, 2004

submitted by

Beata Csatho, Principal Investigator
The Ohio State University
Byrd Polar Research Center
108 Scott Hall, 1090 Carmack Road
Columbus Ohio 43210-1002
(614) 292-6641

28 March 2005

INVESTIGATING LONG-TERM BEHAVIOR OF OUTLET GLACIERS IN GREENLAND

NASA/GSFC, NAG5-13614, $ 66,630,

September 1, 2003 – August 31, 2004

OVERVIEW OF PROJECT:

Repeat surveys by airborne laser altimetry in the 1990s have revealed significant thinning of outlet glaciers draining the interior of the Greenland Ice Sheet, with thinning rates up to several meters per year. To fully appreciate the significance of these recent glacier changes, the magnitude of retreat and surface lowering must be placed within the broader context of the retreat since the Last Glacial Maximum and, more significantly, of the retreat following the temporary glacier advance during the Little Ice Age (LIA). The LIA maximum stand is marked by trimlines, sharp boundaries between recently deglaciated unvegetated rocks, and vegetated surfaces at higher elevations. The objective of this project was to demonstrate the use of remote sensing data to map these trimlines and other glacial geomorphologic features.

PROJECT PARTICIPANTS:

Beata Csatho: PI, coordination of project, interpretation of satellite imagery

Kees van der Veen: co-PI, spectral measurements, glaciological interpretation

Toni Schenk: co-PI, measurements from aerial photographs, measurement of iceberg velocities

Valerij Gataullin: quaternary geologist, field work for geomorphologic mapping and dating with lichenometry

Catherine Tremper: consultant, image processing

Kyung In Huh: GRA, image processing

MAJOR RESEARCH ACTIVITIES:

To evaluate whether multispectral satellite images can be used to map trimlines and to distinguish different surface types, we acquired a Landsat ETM+ image of Jakobshavn Isbræ and vicinity. Applying supervised classification, thirteen different surface types

were identified, ranging from bare ice, debris-covered ice and open water, to different types of vegetative cover. Each surface type is characterized by its spectral reflectance curve. To support the interpretation of the various surface classes and to provide much needed ground truth for the processing of Landsat and ASTER imagery, we conducted field measurements during July, 2003, at three camps near the ice margin. The spectra of typical landcovers (mosses, lichen, sand and gravel, freshly-deposited sediments, etc.) were measured using a Fieldspec FR spectroradiometer on loan from Analytical Spectral Devices, Inc. at individual stations as well as along transects crossing trimlines and moraines, The instrument covers the spectral range from 350 to 2500 nm, thus including the six Landsat spectral bands. Spectra, measured in the field, were compared to spectra of the thirteen classified surfaces to validate our interpretation of these classes. Two manuscripts, describing the image classification and reporting about the spectral measurements of lichens, have been submitted to *Géographie Physique et Quaternaire.*

While in the field, we also conducted moraine mapping with the intent to evaluate whether geomorphological landforms can be identified on satellite images. Unexpectedly, at the camp on the northern margin of the ice fjord, inspection of the surface below the trimline revealed a succession of lateral moraines consisting of boulders, gravel, and sand. These moraines were most likely formed at times when the ice margin was stationary or slowly changing and thus, each moraine signifies a period since the LIA during which the general trend of glacier thinning was interrupted. To accurately map these moraines, a profile line extending from the trimline to the margin of the fjord ice was established for geomorphological mapping and surveyed using Global Positioning System and optical leveling to obtain accurate elevations. Also, along this profile, sizes of various lichen species were measured in an attempt to establish a dating curve. To assign ages to lichens of given size, a calibration curve was derived by measuring lichen sizes on surfaces of known exposure date in the town of Ilulisat. The interpretation of these data suggests that thinning of Jakobshavn Isbræ since the LIA occurred intermittently. Interestingly, periods of thinning do not correlate in a simple way with retreat of the calving.

During the field work rock and vegetation samples were collected for laboratory spectral measurements and absolute dating. And finally we also conducted a terrestrial survey for measuring calving rates and iceberg velocity of Jakobshavn Glacier.

MAJOR FINDINGS:

Multispectral Landsat ETM+ imagery was used to study the ice-marginal region in the vicinity of Jakobshavns Isfjord, west Greenland. In particular, the trimline indicating margin retreat since the maximum stand attained during the Little Ice Age maximum was reconstructed. and compared with earlier maps based on aerial photogrammetry and ground surveys. Applying supervised classification, thirteen different surface types are identified, ranging from bare ice, debris-covered ice and open water, to different types of vegetative landcover. Field measurements of surface reflectance spectra support the interpretation of the various surface classes. By merging three spectral bands with the panchromatic band, a pan-sharpened image with a spatial resolution of 15 m is obtained that clearly shows morphological features on the ice surface.

In terms of global sea level change, Greenland ice loss since the Little Ice Age maximum is likely to be small. Weidick (1968) estimates an average loss over the last century of 200 km^3/yr for the entire ice sheet, which would correspond to a total contribution of ~0.05 m over one century. The more important question is whether observed recent changes are unusual, perhaps the result of recent warming trends, or if these changes are part of a longer-term trend, perhaps interrupted periodically. This study proved that the location of LIA trimlines can be mapped from satellite imagery with sufficient resolution and accuracy, enabling us to investigate volume changes over large areas or even for the whole ice sheet. Such a study will be an important contribution to the overall understanding of the future changes in ice sheet mass balance and dynamics and the consequent changes in sea level.

PUBLICATIONS AND PRODUCTS

Publications and presentations related to the project:

van der Veen, C.J. and B. Csatho, submitted. Spectral characteristics of Greenland lichens. *Geographie et Physique Quaternaire*

Csatho, B., C.J. van der Veen and C. Tremper, submitted. Trimline mapping from multispectral Landsat ETM+ imagery. *Geographie et Physique Quaternaire*

Schenk, T., C.J. van der Veen and B. Csatho, submitted. Velocity measurements in Jakobshavn Isfjord. *Polar Geography*

Data sets collected and created:

Field and laboratory spectra of different vegetation and rock types were measured with a Fieldspec FR spectroradiometer and a spectral library was created from these measurements using ENVI software (RSI, Inc.)

Atmospherically corrected Landsat imagery were created and processed by various techniques, including supervised and unsupervised classification, ratioing and object-based segmentation.

Educational component, outreach:

A graduate student started her training in the application of remote sensing in glaciology and glacial geomorphologic mapping. Results from the project were presented in several seminars at OSU and at the University of Illinois, Chicago. The classified Landsat imagery was displayed at the *Viewing the Invisible* exhibition of the Ohio State University. The exhibition showcased images that were created as by-products of research in such disciplines as cognitive science, chemistry, physics and geosciences.