The Use of Open Source Software in the Global Land Ice Measurements From Space (GLIMS) Project, and the Relevance to Institutional Cooperation

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Abstract—*GLIMS is a NASA funded project that utilizes Open-Source Software to achieve its goal of creating a globally complete inventory of glaciers. The participation of many international institutions and the development of on-line mapping applications to provide access to glacial data have both been enhanced by Open-Source GIS capabilities and play a crucial role in the success of the project.*

Thousands of the world's glaciers have seen a steady reduction in size over the past several decades, a trend that is representative of the recent warming temperatures of the world's climate (fig. 1). Because of this strong correlation between the health of glacial systems and corresponding weather patterns, glaciers can provide a great amount of understanding towards the world's changing environments (Kargel and others 2002). Though we cannot change these current patterns, we can strive for a better understanding of the causes behind the increases in glacial melting, hoping that we may become more thoroughly prepared for the changes we face in the future. Because of these reasons it is of great importance that there be created a global inventory of glacial ice that contains the current extent and present location of all the world's numerous glacial resources. The creation of such a database would help us to clearly understand current

Figure 1. ASTER image showing the receding terminus of the Gangotri Glacier in central Asia (Image by Jesse Allen, Earth Observatory).

glacial behaviors, and provide a stronger foundation for the future monitoring and studying of glacial activities.

The Global Land Ice Measurements from Space (GLIMS) project was founded by a group of researchers in the United States, most namely are Hugh H. Keiffer, who first conceived the project, the Principal Investigator, and Coordinator, Jeffrey S. Kargel of the USGS Astrogeology Research Program in Flagstaff, Arizona, and Bruce H. Raup of the National Snow and Ice Data Center in Boulder, Colorado. Bruce is the lead technical coordinator of the data archiving processes needed to build the foundation of the GLIMS database and serve the data to the public. The NASA funded project's primary goal is to provide the world with a complete inventory of glaciers, making the data available to the public through the collaboration of a host of international institutions and new developments in the use of Open-Source Software (www.glims.org). Open-Source GIS tools are a free, cross-platform, and efficient method of ensuring that GLIMS completes the objective of obtaining the first-ever global glacier database. The utilization of this technology is a fundamental aspect in the success of a project that has grown to encompass the participation and coordination of sixty-seven different institutions from twenty-three countries.

Each institution that is participating in the project is referred to as a GLIMS Regional Center (RC) and is responsible for the creation and analysis of glacial data for its associated region, a region that contain amounts of glacial ice and of which the RC has particular knowledge. The GLIMS Coordination Center at the USGS in Flagstaff has developed and distributed to each RC an application called GLIMSView, a specifically designed, free, and cross-platform digitizing application. GLIMSView was developed specifically for GLIMS, and for the purpose
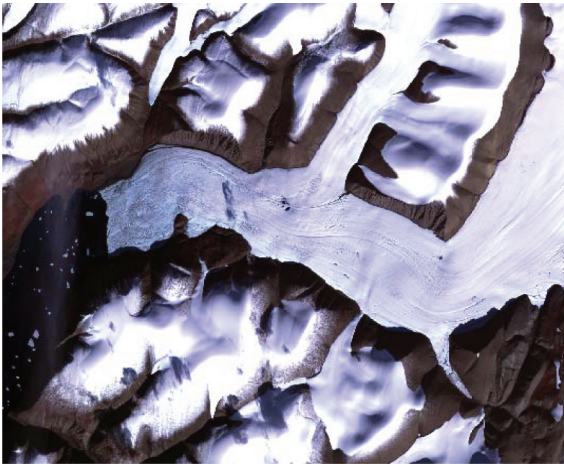
Figure 2. Example of an ASTER Image showing clearly defined glacial extents (Image courtesy of NSIDC).

of viewing Advanced Space-borne Thermal Emission and Reflection radiometer (ASTER) images (fig. 2) as well as other types of satellite imagery. Each ASTER image covers a sixty square kilometer region at a fifteen meter resolution. The ASTER Science Team, a division within GLIMS, has received over two-thousand ASTER images covering the world's approximate 170,000 glaciers (Raup, B. H. and others 2000). It is expected that GLIMS will receive updated ASTER images on a yearly basis to be distributed for analysis by the RCs. GLIMSView allows the RCs to easily view ASTER images, from which the RCs digitize glacier outlines, attach GLIMS specific attributes, and prepare data to be exported and ingested to the GLIMS database. Though it is not required of the RCs to use GLIMSView, the software ensures that the creation of data is based on the same set of standards. However, an RC can choose to use which ever type of software it desires for the production of its data as long as the data is submitted in the proper GLIMS format. More information about ASTER images, GLIMSVIEW, GLIMS data attribution standards, and the GLIMS data submission format are available at http://www.glims.org.

The glacial data created by each RC is submitted to NSIDC where it's ingested into the existing database of information. The database, also a form Open-Source Software (PostgreSQL and its spatial extension PostGIS) has been structured to organize incoming data into several tables comprising of two major types of information, dynamic and static. This makes it possible for data pertaining to changes in the shape and extent of the same glacier to be stored chronologically. Meaning that as a glacier changes, the database becomes updated with a new analyses of dynamic information, using the static attributes to link different sets of data with information that always remain the same, such as a glacier's name and a glacier's ID. The monitoring of changes in glacial

extents on a global basis enhances the ability to study glacial activity in different regions on an annual basis. It provides a stable ground for studying the relationships between glaciers that are changing at different rates and helps to identify the reasons why these change are occurring. The data stored in the database contains a variety of glaciological data and contains attributes that are spatial in nature, in other words each record in the database can be visually represented by the outline of its glacier's extent in the real world. A unique aspect of this database is that the Open-Source database package PostGIS allows spatial data types to be stored in the form of geometries (points, lines, and polygons), and also allows a number geo-processing functions to be applied to this type of data. These capabilities allow the GLIMS data to be integrated into existing GIS projects and analysis in a number of different ways. The functionality of GLIMS data being GIS compatible, is being accomplished through the use of the University of Minnesota's MapServer, an Open-Source, on-line mapping utility.

MapServer is an Open-Source GIS tool that is distributed free of charge by the University of Minnesota. It is an interoperable and innovative GIS package, providing the capability for large amounts and types of spatial data to be interactively mapped over the Internet. Using MapServer, GLIMS will be able to export its data to the public, making the data easily viewed and retrieved by anyone who wishes to use it. MapServer operates based on a set of Open-Specifications designed by the Open GIS Consortium that detail the requirements for the creation of Web Feature Services (WFS). In other words, a WFS is a new type of interface that utilizes the Internet to serve GIS compatible features to the public. NSIDC, who is in charge of maintaining the database, is also designing the interface for the WFS to serve out the glacial data created from GLIMS. The construction of the WFS is currently under development and it will continue to grow as more data is received and the GLIMS database becomes more complete.

A total of three Open-Source GIS utilities are being used to fulfill GLIMS' goals of a geographically complete glacier inventory. Currently the project is in the stage of receiving data from the different RCs and will continue to move toward a complete database in the coming months. The use of Open-Source Software is what makes the cooperation and participation of the GLIMS RCs possible. Without such software and capabilities the goals of GLIMS would not be as easily accomplished. It is the hope of GLIMS that glacial data will continue to be received and updated for many years into the future, creating a greater wealth of information and increasing our knowledge about the ways in which glaciers interact with the world's climate and the effects they have on local

environments. For a more in depth discussion of threats of glacier melting and the history of the GLIMS project please visit the GLIMS website (www.glims.org).

References

Hathaway, James. 2001. Melting Glaciers Signal Global Warming. Earth Observatory, Media Alerts Archive, May 29, 2001.

Kargel, Jeffrey S., Keiffer, Hugh H., Wessels, R., Mingus, D., Rosenborough, K. 2002. Satellite Remote Sensing of Glaciers and Ice-dammed Lakes: Pragmatic Issues and Case Studies. June 2002.

Pellikka. P., Kajuutti, K., Koskinen, R., Jackson, M., Stotter, H., Haggren, H., Luukkonen, K. M., Guneriussen, T., Sharov, A., 2001. Development of an Operational Monitoring System for Glaciers - Synthesis of Earth Observation Data of the Past, Present and Future. Proceedings, International workshop on geo-spatial knowledge processing on natural resource management, 28 - 29 June 2001, Varese, Italy, pp. 283 - 288.

Perens, Bruce. 2004. Open Source Definition. Open Source Initiative, 2004.

Raup, Bruce H.; Keiffer, Hugh H.; Hare, Trent M.; Kargel, Jeffrey S. 2000. Generation of Data Acquisition Requests for the ASTER Satellite Instrument for Monitoring a Globally Distributed Target: Glaciers. IEEE Transactions on Geoscience And Remote Sensing, Vol. 38, No. 2, pp. 1105-1112, March 2000.