SAGE: A TOOL FOR EXPLORATION OF REMOTE SENSING DATA RELATING GREENLAND'S ICE SHEET AND GLACIERS

D. Gallaher, S. Khalsa and R. Duerr

National Snow and Ice Data Center, University of Colorado, Boulder, Colorado, 80303, USA

1. INTRODUCTION

There are many are impediments inhibiting the science community's use of Earth science data. One of the lessons learned from NASA's EOSDIS program is that one size does not fit all [1] and that systems attempting to satisfy the needs of all users end up satisfying none. What users desire is to obtain data they want, in the format they want it in, when they need it. While completely fulfilling this need may not yet be fully possible, it is certainly possible to produce data in a few of the ways most useful to large segments of the user community.

We have attempted address this problem by creating an application that helps with discovery and real-time analysis of highly heterogeneous data sets. This application is designed to meet Greenland-specific science needs by allowing the comparison of data and simplifying data access and delivery through the use of modular Web Services including a map server portal to the data. Visualization and analysis processes allow the user to explore the available data through the use of overlays, time series, and plots; and with user-specified aggregation, averaging, and sampling intervals. A workflow manager sequences the processes needed to fulfill user requests. The Application is known as **SAGE, S**ervices for **A**nalysis of the **G**reenland **E**nvironment.

2. OVERVIEW

Working with time-series data is particularly difficult as most products are organized as a series of files containing data acquired over a short period of time. This type of data organization facilitates investigations of spatial variability at the expense of investigations of temporal change, as it is often necessary to order the complete data set, and then extract just the region of interest from each file in order to obtain a time series-for a specific location.

The goal of this NASA ACCESS-funded project is to create easy to use, multi-faceted web services for access, browse, online analysis and delivery of data sets important for understanding the processes that control the mass balance of Greenland's ice sheet. SAGE exemplifies a new direction at NSIDC where specific cryospheric science needs are addressed through in-place data analysis and simplified data access and delivery. SAGE incorporates many of NSIDC's existing subsetting, gridding, projection, and visualization tools into modular services, invoked

through a web-hosted geospatial data management system. The desired goal is enabling scientists to devote more time to research and less time to locating and processing data. The new NSIDC infrastructure, know as the Searchlight Engine, aims to provide users with data discovery interfaces, collaboration tools and mapping services. It will ultimately be expanded to cover most of NSIDC's cryospheric data. We also plan to expose as Web services much of the functionality described, thereby extending the options available to scientists for accessing data and analysis tools.

3. GREENLAND-SPECIFIC SCIENCE

For several years, satellite observations have shown enhanced melting of the Greenland ice [2], and rapid thinning along the ice sheet margins [3]. Over the last five years, several large outlet glaciers have doubled their discharge rates. Currently, Greenland contributes about 0.5 mm to the annual (3 mm) rise in global sea level, of which approximately 0.33 mm appears to be a direct result from glacier speed-up and the rest a result of enhanced runoff minus accumulation [4]. Although studies point to the loss of ice at the margins of the ice sheet, there appears to be a corresponding buildup of ice in Greenland's interior that may partially compensate for this ice loss [5]. In order for scientists to better understand the role of melting at the surface and increased runoff versus enhanced glacier flow to Greenland's contribution to global sea level, the ability to integrate and analyze a variety of datasets from multiple sources and in vastly different formats is required. For example, if a scientist wants to examine the role of surface albedo to changes in surface melt and corresponding changes in surface elevation, they need access to several surface variables, such as albedo, temperature, melt and elevation.

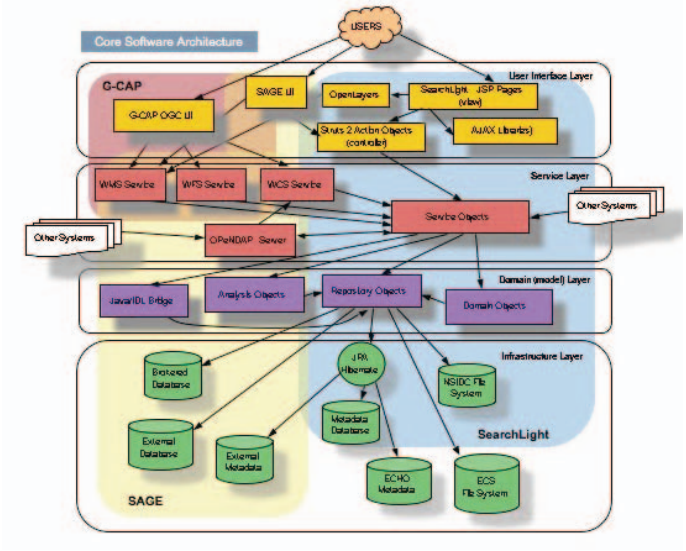

Figure 1. General SAGE architecture

4. SAGE PROJECT STATUS

We have built an infrastructure that is easier to maintain but more importantly is easier to expand to cover new datasets as well as new geographic areas beyond Greenland. By building on the work of the Searchlight Engine we have accomplished the goal of component reuse. Our foundation utilizes a best practice approach that makes use of the following: Java Persistence API, Java Server Pages, OpenLayers, WMS, MVC architecture, loose coupling of components, SOA, Agile development, Struts2, Spring, Scrum, Hibernate, version control and continuous builds. Project status and eventual applications links are available (http://nsidc.org/data/parca/sage.html). The foundation uses a layered architecture. Any layer or component can be replaced without application impact, as the layers are only dependent on components in the same or lower layers. The foundation infrastructure is shown in Figure 1.

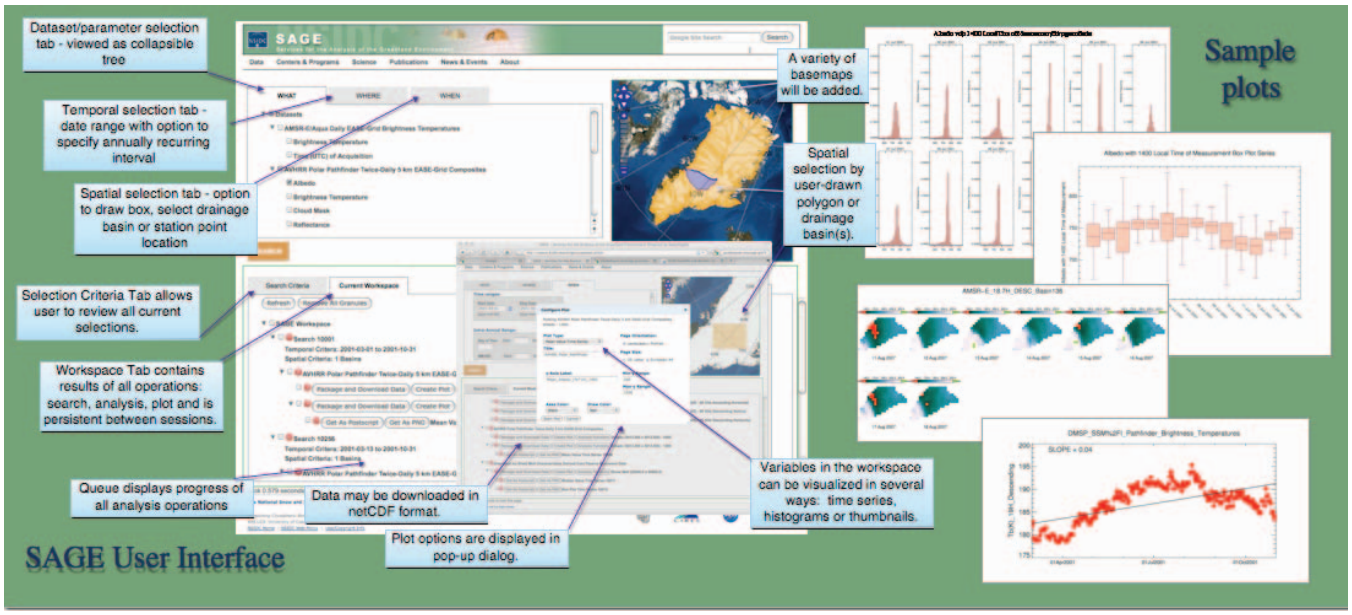

Figure 2. SAGE user interface and plot examples

The SAGE user interface allow the user to select *what* data they want, *where* on Greenland it is located, and *when*, i.e. the time period, the data apply to. This interface is depicted in figure 2. Once a query has been performed many forms of plots and analysis are available, including multivariate analysis. The system incorporates a user workspace that contains the results of any queries performed (i.e., search definitions and search results), and any analysis data or graphics plots that were generated and have not been explicitly deleted. The workspace appears as a web page with associated disk storage that persists between visits.

The data sets currently available through SAGE include microwave Brightness Temperatures from SSM/I and AMSR-E, AVHRR Polar Pathfinder products, and surface melt from SSM/I. We are planning to add data sets from MODIS, QuikSCAT, CERES, GLAS, ATM and meteorological data from GC-Net automatic weather stations. We have created web services that non-NSIDC search clients can use to query our data. This service supports both time and space searches. At this point the service is unique only to NSIDC data schemas. We need to begin defining additional web services, specifically RESTful web services.

5. CONCLUSION

SAGE exemplifies a new direction at NSIDC where specific science needs are addressed through in-place data analysis and simplified, near real-time data access and delivery. Visualization and analysis options allow data exploration with user-specified aggregation, averaging, or sampling intervals. The underlying services of SAGE are being made accessible through standardized service protocols. Additional data and analysis services will be added in the future. The production release is scheduled for August, 2010.

6. REFERENCES

[1] NOAA Research Council (NRC), Committee on Climate Data Records from NOAA Operational Satellites. Climate Data Records from Environmental Satellites: Interim Report. *The National Academies Press*. 2004.

[2] Abdalati, W., and K. Steffen, 2001. Greenland ice sheet melt extent: 1979-1999, *J. Geophys. Res.,*106(D24), 33,570-33,582.

[3] Krabill, W., W. Abdalati, E. Frederick, S. Manizade, C. Martin, J. Sonntag, R. Swift, R. Thomas, W. Wright, and J. Yungel, 2000. Greenland ice sheet: high-elevation balance and peripheral thinning, *Science,* 289, 428-430.

[4] Rignot, E. and P. Kanagaratnam, 2006. Changes in the velocity structure of the Greenland ice sheet, *Science*, 311, 986-990.

[5] Zwally, H.J., 2002, Surface melt-induced acceleration of Greenland ice-sheet flow, *Science*, 297, 218.