

# **Ice Sheet Sensing - Information Technology support and development**

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## Table of Contents

Ice Sheet Sensing - Information Technology support and development.....	i
1. Abstract .....	1
2. Introduction .....	1
3. Geospatial Data Processing .....	1
4. GIS Server and Geospatial Distribution Service .....	3
4.1. GIS Server.....	3
4.2. On-Line Data Browser .....	4
4.3. CReSIS Toolbox Support.....	5
5. Application Development .....	5
5.1. 3D Visualization .....	5
5.1.1. 3D Greenland Ice Sheet Model.....	5
5.1.2. Flight Path Visualization .....	6
5.2. Flight Path Crossover Analysis .....	7
5.3. Picker Tool Development .....	8
6. Conclusion and Remarks.....	9
8. Appendix: Ice Sheet Research GIS Software and Data Package List.....	10

## Table of Tables

Table 2 Comparison of geospatial data access methods in Matlab .....	5
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## Table of Figures

Figure 4-1 Overview of Greenland Flight Path Data.....	2
Figure 4-3 Overview of Antarctica Flight Path Data.....	2
Figure 5-1 Components of PolarGrid GIS Server .....	3
Figure 5-2 Web Service API example: Imaging Service: WMS (top) and Spatial Operations: Buffer and Clip (bottom) .....	4
Figure 5-3 Examples on on-line data browser .....	4
Figure 6-1 Greenland ice sheet surface and bed model.....	5
Figure 6-2 Greenland ice bed structure on high resolution display wall.....	6
Figure 6-3 Examples of flight path visualization .....	7
Figure 6-4 Visualization of 480 intersection points .....	8
Figure 6-5 Screenshot of Python Picker tool.....	9

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## 1. Abstract

This report provides a summary of the PolarGrid geospatial support activities carried out by Jun Wang from July 2010 to June 2012 while working in the Digital Science Center of the Pervasive Technology Institute and later in the Science Gateway Group of Research Technology.

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## 2. Introduction

The Center for Research in Ice Sheet Sensing (<https://www.cresis.ku.edu/>) has produced large amount of geospatial data in various formats. Currently, all radar products, mainly in plain text format or Matlab format, are distributed through CReSIS data portal (<https://data.cresis.ku.edu/data/>). The PolarGrid project (<http://www.polargrid.org/polargrid>) was funded by the National Science Foundation to aid in the analysis of ice sheet data.

Indiana University and the IU Pervasive Technology Institute have set the following aims in supporting ice sheet research:

- Organizing polar ice sheet data files by its spatial attributes and provide standard-compliant geospatial data products.
- Supporting data access through multiple protocols for different user groups, such as via WMS (web map service), KML (keyhole markup language), and direct geospatial database access.
- Supporting efficient data access methods in different computing and network environments.
- Supporting high level geospatial operations powered by geospatial database.

Section 3 summaries the processing of radar depth sounder (RDS) data sets. PolarGrid GIS server and geospatial distribution services are introduced in Section 4. Applications supported by PolarGrid GIS server, such as 3D visualizations and the development of a Python version of the Picker tool, are covered in Section 5. Available software packages for downloading are listed in the Appendix.

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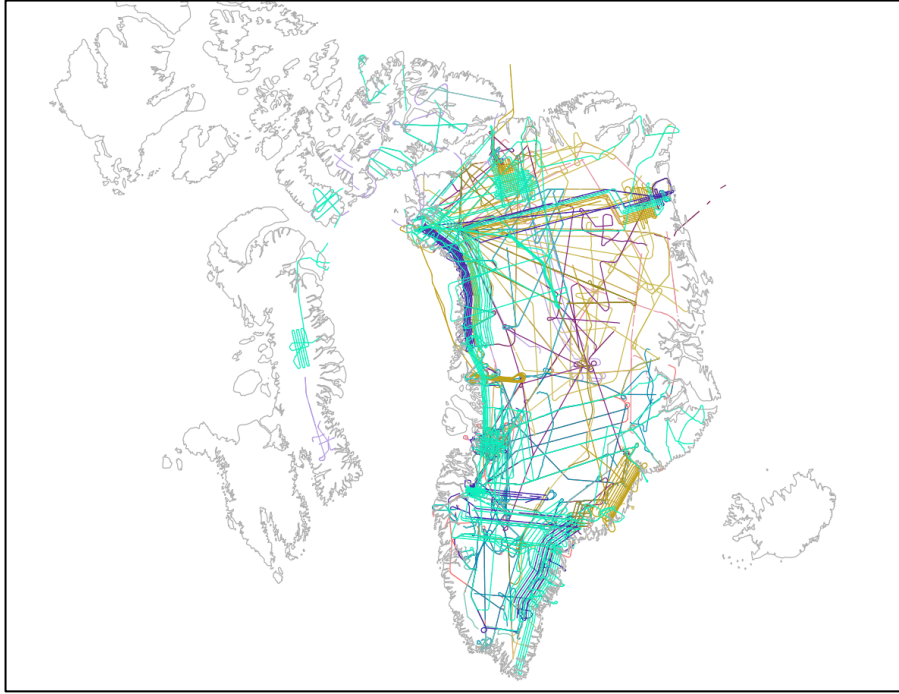
## 3. Geospatial Data Processing

Radar Depth Sounder (RDS) data set contains L1B Geolocated Radar Echo Strength Profile Images, L2 Ice Thickness, Ice Surface, and Ice Bottom elevations, and L3 Gridded Ice Thickness, Ice Surface, and Ice Bottom elevations over Greenland, Canada, and Antarctica taken with the CReSIS radar depth sounders since 1993.

The following flight path data (L2 products) with the information on corresponding L1B echograms (data source: <ftp://data.cresis.ku.edu/data/rds/>) have been processed and imported into geospatial database.

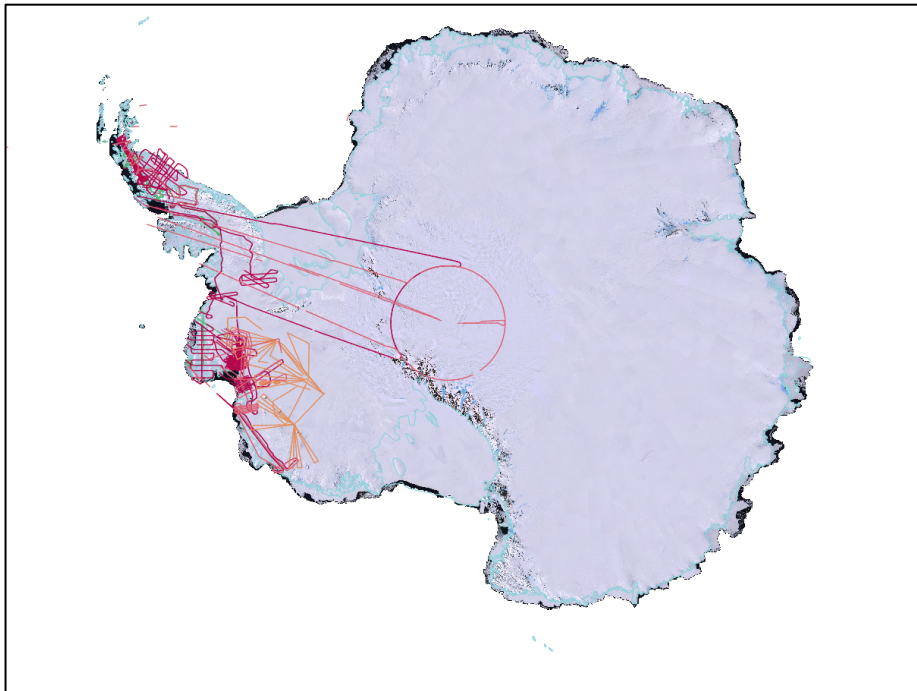
**Greenland:** 1993\_Greenland\_P3, 1995\_Greenland\_P3, 1996\_Greenland\_P3, 1997\_Greenland\_P3, 1998\_Greenland\_P3, 1999\_Greenland\_P3, 2001\_Greenland\_P3, 2002\_Greenland\_P3, 2003\_Greenland\_P3, 2005\_Greenland\_TO, 2006\_Greenland\_TO, 2007\_Greenland\_P3, 2010\_Greenland\_DC8, 2010\_Greenland\_P3, 2011\_Greenland\_P3

Note: As the time of this reported is produced, the latest data posted on CReSIS data portal are not processed: 2001\_Greenland\_TO, 2012\_Greenland\_P3.



**Figure 3-1 Overview of Greenland Flight Path Data**

**Antarctica:** 2002\_Antarctica\_P3chile, 2004\_Antarctica\_P3chile, 2009\_Antarctica\_DC8, 2009\_Antarctica\_TO, 2010\_Antarctica\_DC8, 2011\_Antarctica\_DC8



**Figure 3-2 Overview of Antarctica Flight Path Data**

The flight path data are stored as two types of spatial objects: line and point in both the original (longitude, latitude) coordinates and the proper local projections for high-latitude region: EPSG: 32624 -

WGS 84 / UTM zone 24N for Greenland, EPSG: 3031 - WGS 84 / Antarctic Polar Stereographic for Antarctica.

Python scripts to load L2 products from CSV format into geospatial database are available for downloading (see Appendix).

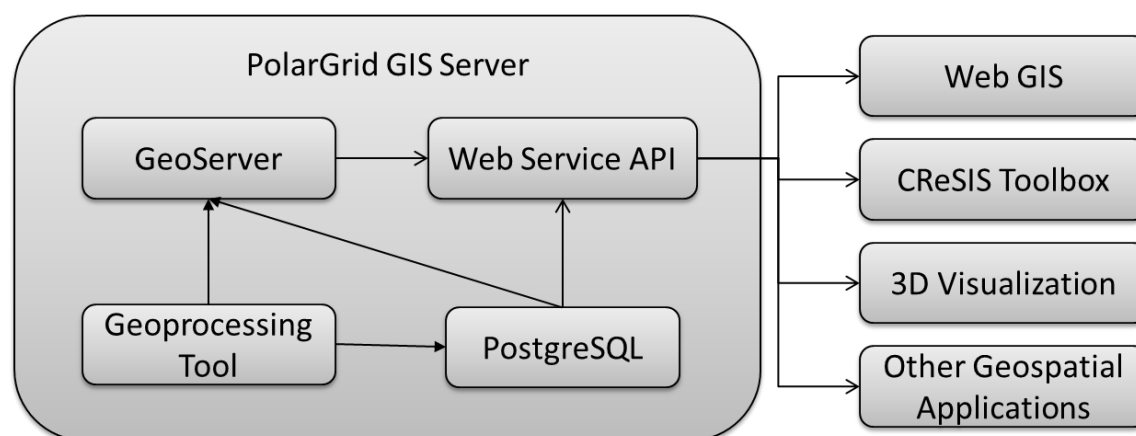
Geospatial data can be accessed through on-line data browser, Matlab, GIS software, Google Earth and other software which supports OGC (Open Geospatial Consortium, <http://www.opengeospatial.org/>) standards. Raw data in ESRI shapefiles and Spatialite are also available (see Appendix).

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## 4. GIS Server and Geospatial Distribution Service

### 4.1. GIS Server

GIS Server is the centerpiece of software packages for ice sheet research geospatial support. Figure 4-1 shows the components of the current GIS Server.



**Figure 4-1 Components of PolarGrid GIS Server**

GeoServer (<http://geoserver.org>) provides core GIS capabilities. GeoServer is a community-maintained open source GIS server that allows users to share and edit geospatial data. It publishes data from any major spatial data source using the OGC standards (<http://www.opengeospatial.org/standards>), which includes WMS (Web Mapping Service), WFS (Web Feature Service), WCS (Web Coverage Service) and WPS (Web Processing Service).

PostgreSQL (<http://www.postgresql.org/>) provides the data storage for GeoServer and direct geospatial database support through spatial SQL. Geoprocessing tools include Python scripts and web services to import/output the flight path data in various formats.

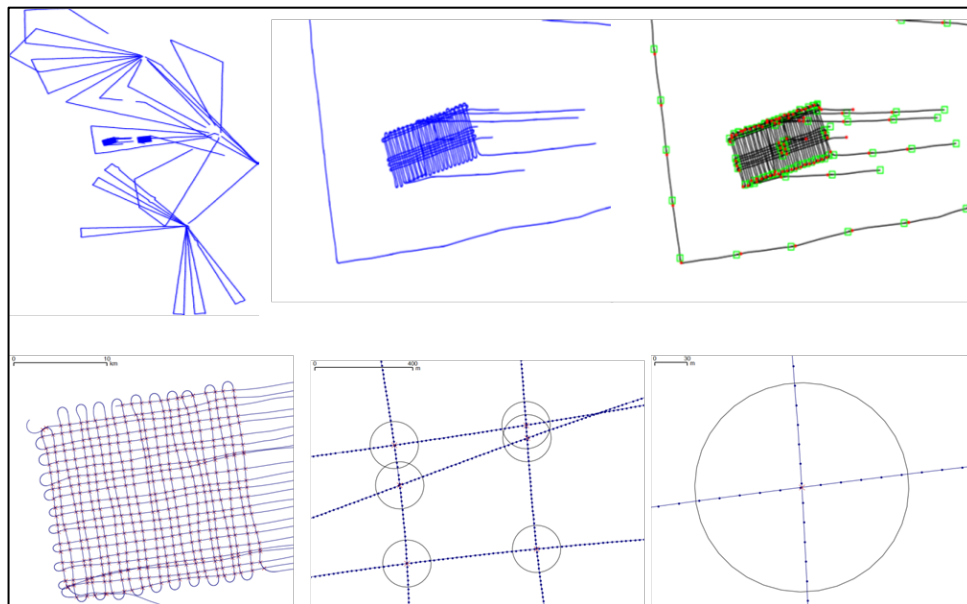
Geoprocessing tools include Python scripts to import/output the flight path data in various formats.

Web Service Layer provides easy-to-use network service (typically REST-based) API for various specialized tasks. It can be both used in web applications and standalone desktop applications that enable users to use the processing power of GIS server without the requirement of knowing complex GIS operation syntax. API is implemented with Python web.py framework (<http://webpy.org/>).

The GIS server software package has been released on Jan 8, 2012. The virtual machine packed with server software and flight path data is available for downloading: <http://polargrid.org/polargrid/software-release>. This release is mainly designed for PolarGrid developers to explore the potentials to integrate GIS services into CReSIS processing toolbox, also services as a platform for on-line PolarGrid application

development. The GIS server is built on Ubuntu virtual machine (<http://www.ubuntu.com/>) with very low memory (256 M) requirement; it can be carried on the USB drive and efficiently run on common laptop computer for field crew. We have successfully deployed the GIS server on Amazon EC2 cloud service with minor adjustments to the configuration, and test results were positive.

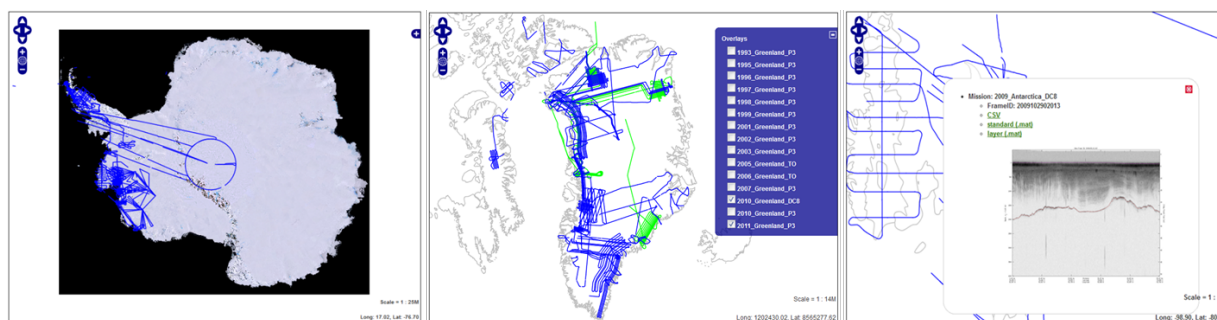
The latest development focuses on Web Service Layer for the integration with Python Picker tool (see Section 5 for the information on Picker tool). A single consistent access interface to various geospatial services is under planning with KU development team.



**Figure 4-2 Web Service API example: Imaging Service: WMS (top) and Spatial Operations: Buffer and Clip (bottom)**

#### 4.2. On-Line Data Browser

Most popular on-line map systems, such as Google Maps and Microsoft Bing Maps, are based on Mercator projection, which has two problems in high-latitude regions: it produces huge distortion on the size and shape of larger objects; and it doesn't work on the region with the latitude higher than 85 degree. The data browser is developed to supports the special projections for high latitude area (Antarctic Polar Stereographic and UTM zone 24N); it also serves as the simple interface for data downloading from KU ftp site. In the next step, third-party data sources will be incorporated into the data browser interface. The online demo is running at <http://gf2.ucs.indiana.edu>



**Figure 4-3 Examples on on-line data browser**

### 4.3. CReSIS Toolbox Support

CReSIS toolbox is a Matlab Application. There are three ways to access the flight path data and geospatial operations in Matlab application. One is through WMS (web mapping service) with Matlab Mapping Toolbox; it is mainly useful for quickly displaying thematic maps. The second method is direct geospatial database access, which allows Matlab application access the original data through spatial SQL query. PostgreSQL is supported through Matlab Database Toolbox; Spatialite database (<http://www.gaia-gis.it/spatialite/>) is accessible with the modified third party Matlab package. The third access method, using Web Service API from GIS server, was developed as a proof of concept but was not deployed in the analysis environments.

**Table 1 Comparison of geospatial data access methods in Matlab**

	GeoServer	PostgreSQL	Spatialite	Web API
<b>Data location</b>	Remote	Remote	Local	Remote
<b>Server requirement</b>	Yes	Yes	No	Yes
<b>Software requirement</b>	Mapping Toolbox	Database Toolbox	Third Party	No
<b>Spatial query</b>	Yes	Yes	Yes	Yes
<b>Attributes query</b>	Yes	Yes	Yes	Yes
<b>Advance GIS function</b>	Limited	Yes	Yes	Yes
<b>Access Interface</b>	WFS, WMS	Spatial SQL	Spatial SQL	REST
<b>Syntax</b>	Complex	Complex	Complex	Simple
<b>Modify the data</b>	Possible	Yes	Yes	Yes
<b>Add new data</b>	Possible	Yes	Yes	Yes

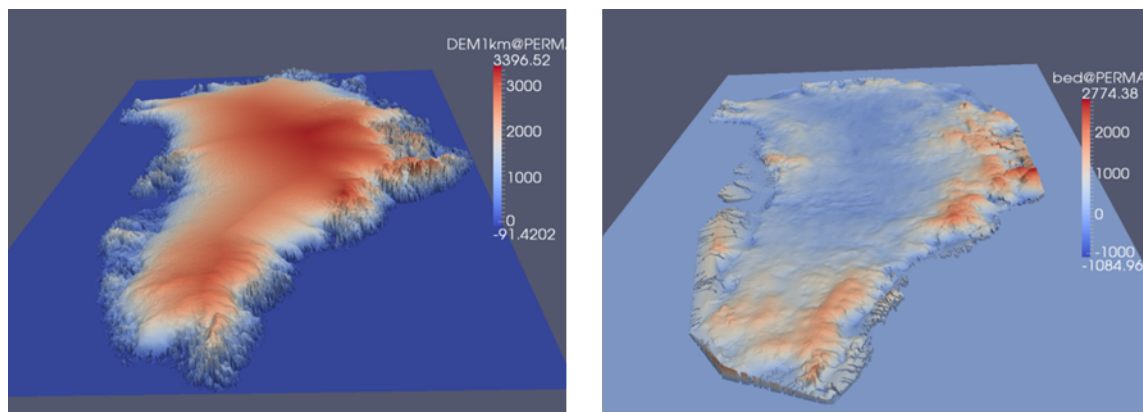
## 5. Application Development

### 5.1. 3D Visualization

PolarGrid has produced a significant amount of high-resolution geospatial data which are best analyzed with three-dimensional (3D) visualization techniques.

#### 5.1.1. 3D Greenland Ice Sheet Model

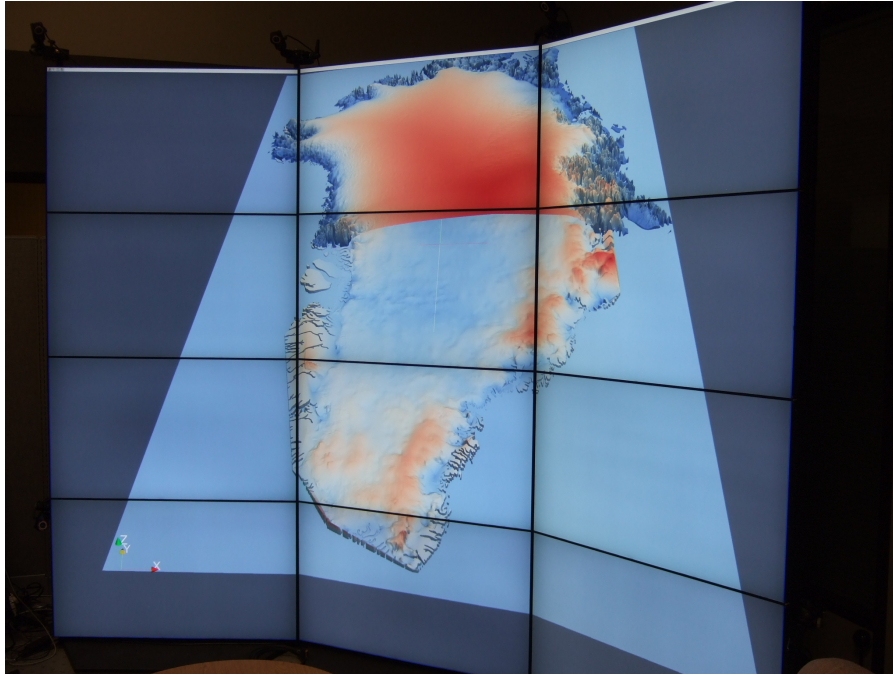
3D Greenland ice sheet model is created from CReSIS L3 gridded ice thickness data products (<ftp://data.cresis.ku.edu/data/grids/>), and has 1km spatial resolution for surface and ice bed DEM, and 2km resolution for volume model.



**Figure 5-1 Greenland ice sheet surface and bed model**



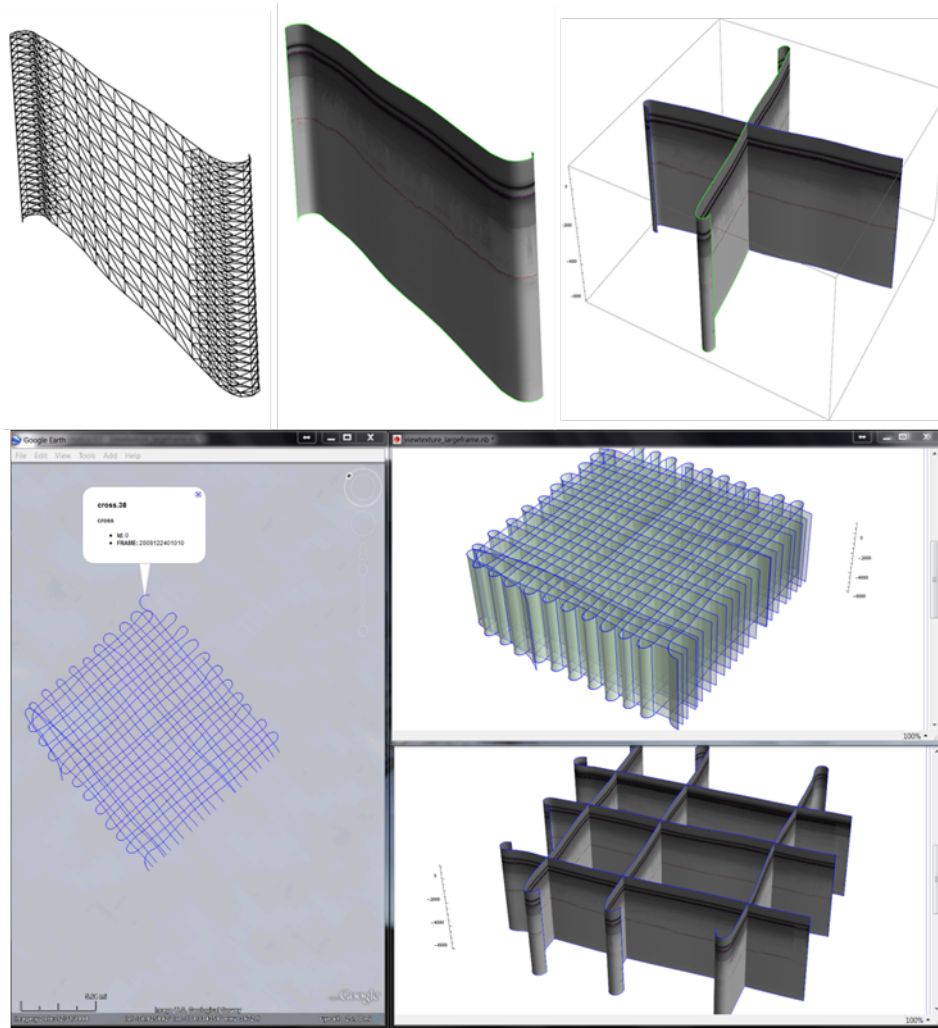
The 3D surfaces are interpolated and resampled in GIS software and exported as VTK format with in-house Python scripts. The VTK model is visualized with ParaView (<http://www.paraview.org/>) which is one of most popular 3-D scientific visualization applications, and is capable of analyzing extremely large datasets on supercomputers. Figure 5-2 shows the example of displaying the Greenland ice bed 3-D structure in IU's high-resolution display wall. Each panel has a resolution of 1366x768 pixels, with over 12 million pixels on the wall. Users can also carry out 3D analysis, such as extracting cross-section and measuring ice sheet volume through ParaView. A short movie is shown on PolarGrid Multimedia Gallery (<http://www.polargrid.org/polargrid/gallery>)



**Figure 5-2 Greenland ice bed structure on high resolution display wall**

#### 5.1.2. *Flight Path Visualization*

The latest development supports 3D visualizations of flight paths and associated radar images. A spline surface is constructed from flight path, and its radar image is used as the texture mapping. This service utilizes GIS server, and all the necessary data including both vector and raster are directly pulled from GIS Server through WFS and CReSIS data portal. 3D model of flight paths also can serve as the initial step for quality check with crossover analysis (see Section 5.2 for details).

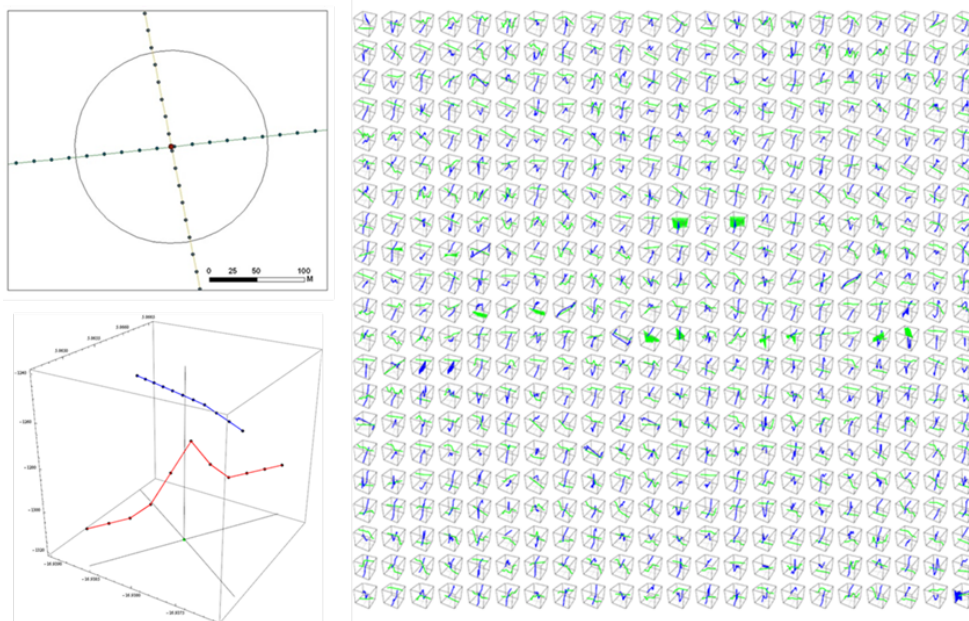


**Figure 5-3 Examples of flight path visualization**

## **5.2. Flight Path Crossover Analysis**

The crossover analysis is a step in the data processing for quality control to check if ice bed elevations at the intersection of two flight lines match or not. Prototype tools are developed in Mathematica, and the flight path data are pulled from GIS server through WFS. The main GIS functions are also supported by GIS server with WPS.

The initial test used three flight paths from 2009 Antarctica data set ([ftp://data.cresis.ku.edu/data/rds/2009\\_Antarctica\\_TO/csv\\_good/](ftp://data.cresis.ku.edu/data/rds/2009_Antarctica_TO/csv_good/)). The results showed high consistency among the crossover flight paths. The last development focused on automating the spatial analysis procedure with web service API across the data sets from multiple seasons.



**Figure 5-4 Visualization of 480 intersection points**

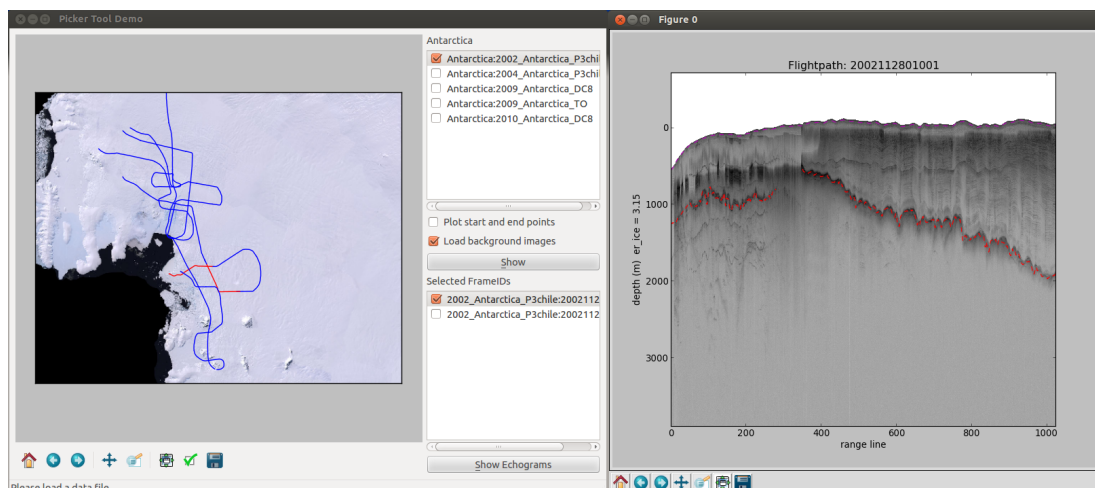
### **5.3. Picker Tool Development**

CReSIS Picker tool is the Matlab application that uses the manual picker to pick layers for ice thickness estimation in 2-D depth sounder data. However, Matlab application is not efficient enough to handle large amount of geospatial data, it is difficult to build complex spatial analysis tools within the current Matlab Picker framework. The cost of Matlab licenses is also an issue for some CReSIS user groups.

The new Picker tool is developed in Python, and built on open-source software packages (see Appendix). The deep integration with PolarGrid GIS server is the major improvement over the Matlab version. GIS server not only provides geospatial data and spatial analysis functions, but also serves as the platform for collaboration among different user groups.

The first developer preview version of Python picker tool is released on May 18, 2012. It has the following features:

1. Cross-platform Qt GUI framework
2. Automatically downloading seasonal flight path data from GIS server
3. Automatically pulling radar data from KU ftp data site, and plotting the echogram with the layer tracing results if available.



**Figure 5-5 Screenshot of Python Picker tool**

## 6. Conclusion and Remarks

In the past two years, we have made great efforts to develop geospatial support applications and demonstrate the potentials of using open-source geospatial technology to make PolarGrid products more accessible for general users. We have processed large amount of flight path data (Radar Depth Sounder L2 products), and built on-line distribution interface with PolarGrid GIS server. Various projects, including 3D visualization, flight path crossover analysis and Python Picker tool have utilized the data service and spatial operations provided by GIS server.

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## 8. Appendix: Ice Sheet Research GIS Software and Data Package List

Download URL: <http://gf2.ucs.indiana.edu/software/> (login username: polargrid, password: polargrid)

### GIS Server:

Release package: <http://polargrid.org/polargrid/software-release>

Download: [http://gf2.ucs.indiana.edu/software/GISServerVM\\_08Jan2012.7z](http://gf2.ucs.indiana.edu/software/GISServerVM_08Jan2012.7z)

### Pickertool Python Preview Version:

Download: [http://gf2.ucs.indiana.edu/software/pickertool\\_pythondevelopment.zip](http://gf2.ucs.indiana.edu/software/pickertool_pythondevelopment.zip)

### Geoprocessing Tools:

Python scripts to load L2 products into geospatial database

Download: <http://gf2.ucs.indiana.edu/software/geoprocessing.zip>

### GIS Data:

Flightpath in ESRI Shapefile format:

Download: [http://gf2.ucs.indiana.edu/software/flightpath\\_shapefile.zip](http://gf2.ucs.indiana.edu/software/flightpath_shapefile.zip)

Flightpath in Geodatabase (Spatialite) format:

Download: [http://gf2.ucs.indiana.edu/software/flightpath\\_geodatabase.zip](http://gf2.ucs.indiana.edu/software/flightpath_geodatabase.zip)

L2 products (points) in Geodatabase (Spatialite) format:

Download: [http://gf2.ucs.indiana.edu/software/L2\\_point\\_geodatabase.zip](http://gf2.ucs.indiana.edu/software/L2_point_geodatabase.zip)

### Media:

Short movie and screenshots

Download: <http://gf2.ucs.indiana.edu/software/Media.zip>