Atlas of the Cryosphere: Mapping the Earth's Frozen Regions on the Internet

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ABSTRACT

The National Snow and Ice Data Center (NSIDC) "Atlas of the Cryosphere" Web site (http://nsidc.org/data/atlas) allows visitors to explore and dynamically map the Earth's frozen regions. Viewed from a polar perspective, the available data sources include snow cover, sea ice extent and concentration, glaciers, permafrost, ice sheets, and other critical components of the Earth's cryosphere. Users can zoom in to a specific region on the Earth as well as overlay country borders, major cities, and other geographic information. This site should act as a useful tool in science and education efforts surrounding the International Polar Year (IPY) (2007-2008) and beyond by providing a geographic tool for viewing snow and ice on the planet. In addition to providing an interactive Web interface, maps and data sources contained in the Atlas of the Cryosphere are also accessible via the Open Geospatial Consortium (OGC) Web Map Service (WMS), Web Feature Service (WFS), and Web Coverage Service (WCS). These international specifications provide a framework for sharing maps and geospatial data over the Internet.

This paper will provide an overview of the Atlas of the Cryosphere, describe its interoperability with other OGC-compatible software applications, as well as outline some of the "lessons learned" in developing an OGC-enabled map server from disparate geospatial data sources.

The development of this application was supported by NASA's Earth Observing System (EOS) Program and was developed using MapServer, an Open Source development environment for building spatially-enabled Internet applications.

Keywords: atlas, cryosphere, Open Geospatial Consortium (OGC), Web Map Service (WMS), map server

1. Introduction

The National Snow and Ice Data Center (NSIDC) "Atlas of the Cryosphere" Web site (http://nsidc.org/data/atlas) allows visitors to explore and dynamically map the Earth's frozen regions. Viewed from a polar perspective (Figure 1 and Figure 2), the available data sources include snow cover, sea ice extent and concentration, glaciers, permafrost, ice sheets, and other critical components of the Earth's cryosphere. Users can zoom in to a specific region on the Earth as well as overlay country borders, major cities, and other geographic information to help provide spatial context. This site should act as a useful tool in science and education efforts surrounding the International Polar Year (IPY) (2007-2008) and beyond by providing a user-friendly geographic tool for viewing snow and ice on the planet. Maps that the user generates can be saved as images for inclusion in reports and other documents.

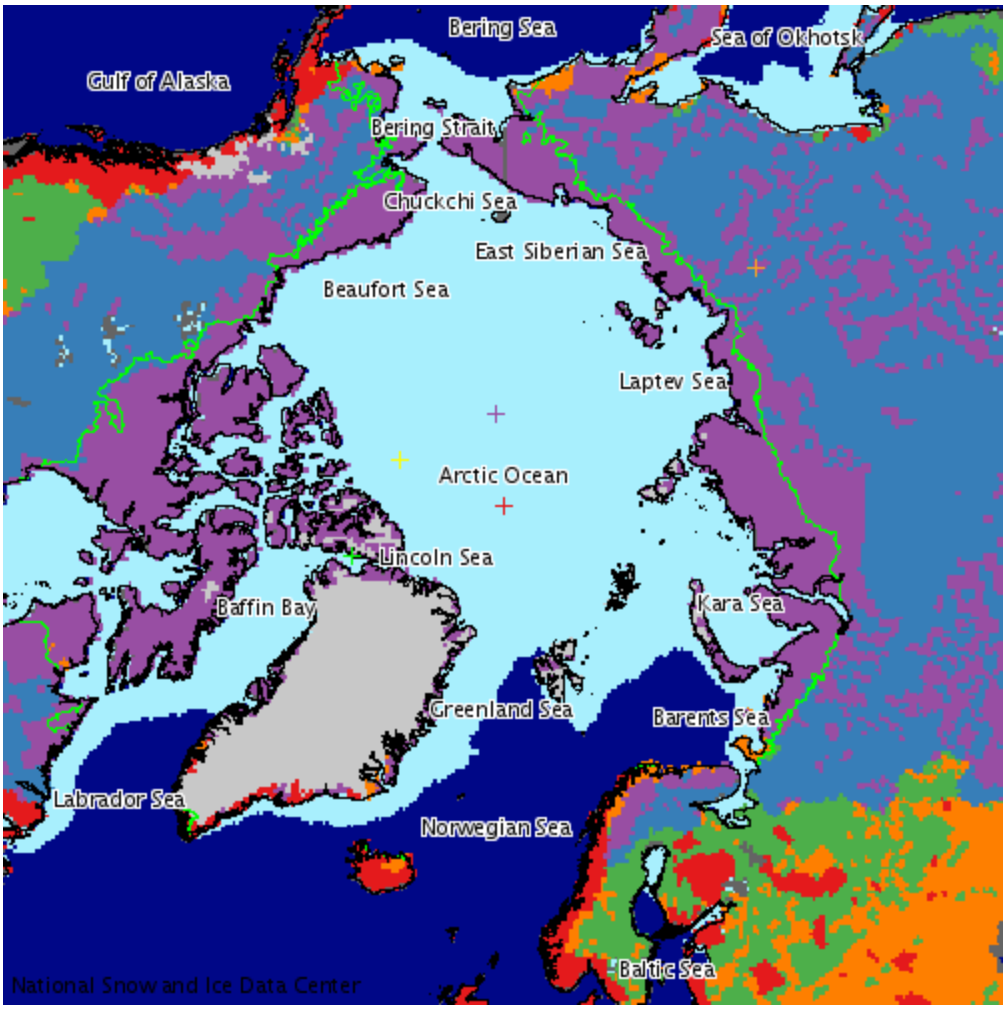

Figure 1. Arctic view of January sea ice climatology (1979-2005); seasonal snow classification on land; northern limit of forests (green line); and various types of North Poles referenced (crosses): geographic (red), geomagnetic (green), magnetic (yellow), cold pole (orange), and pole of inaccessibility (purple).

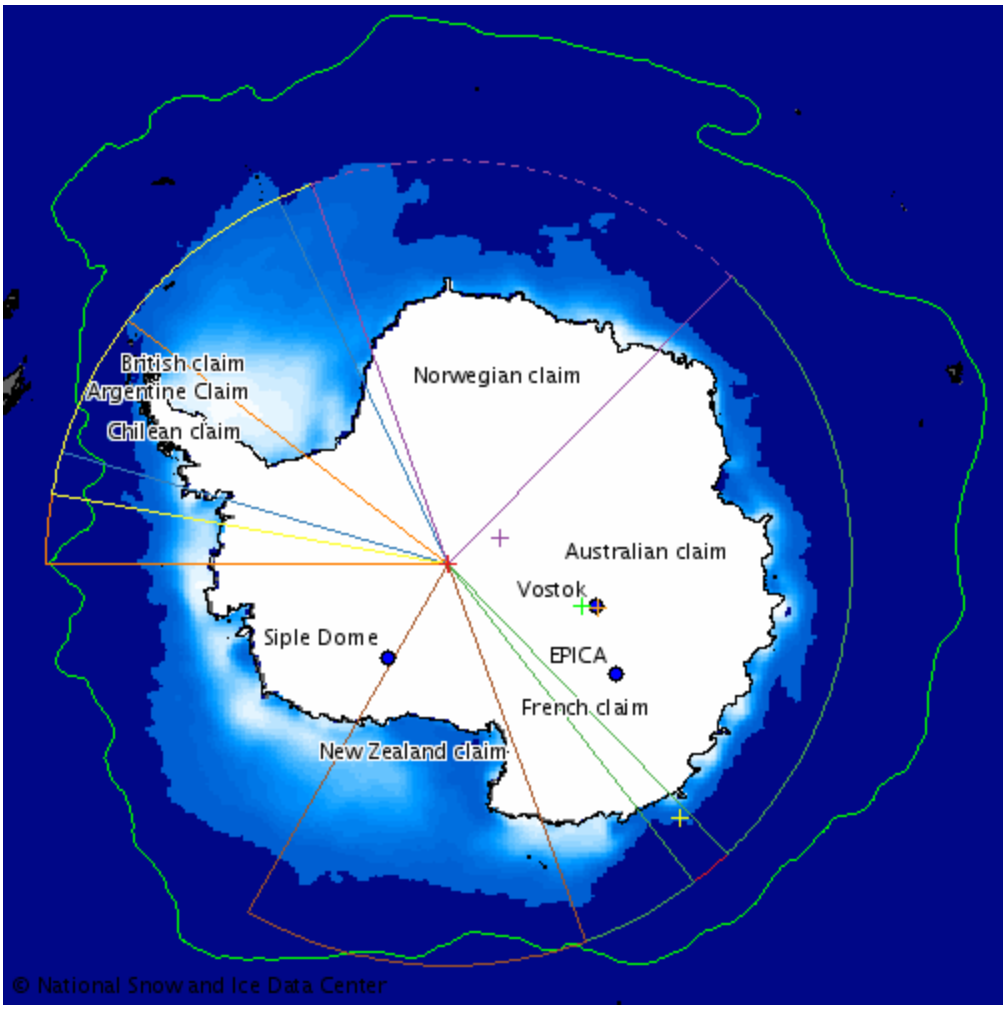

Figure 2. Antarctic view of January sea ice concentration climatology (1979-2003); Polar Front (green line); Antarctic territorial claims; deep ice core locations (blue dots); and various types of South Poles referenced (crosses): geographic (red), geomagnetic (green), magnetic (yellow), cold pole (orange), pole of inaccessibility (purple).

In addition to providing an interactive Web interface, maps and data sources contained in the Atlas of the Cryosphere are also accessible remotely via the Open Geospatial Consortium (OGC) Web Map Service (WMS), Web Feature Service (WFS), and Web Coverage Service (WCS). These international specifications provide a framework for sharing maps and geospatial data over the Internet. WMS provides custom access to map images in JPEG, GIF, or PNG formats; WFS provides access to vector data sources (points, lines, and polygons) in Geography Markup Language (GML) format; and WCS provides custom access to raster data sources (rectangular grids of data values) in GeoTIFF format. All of these services can be called through your Web browser via the construction of a URL or through OGC-compatible applications.

This paper will provide an overview of the Atlas of the Cryosphere, describe its interoperability with other OGC-compatible software applications, as well as outline some of the "lessons learned" in developing an OGC-enabled map server from disparate geospatial data sources.

2. Atlas Features

- Dynamically visualize Earth's snow and ice
- Explore the planet from a polar perspective for both the Northern and Southern Hemispheres
- Customize maps by zooming in and out and selecting from a variety of basemaps and overlays

- Save custom maps as images for use in other documents
- View monthly climatologies of snow and sea ice to see how and where the cryosphere shrinks and grows over the course of a year
- Look up definitions for unfamiliar cryospheric terms
- Access maps and source data through WMS, WFS, and WCS
- RSS feed for keeping informed about Atlas additions and modifications

3. Selectable Parameters

3.1. Cryosphere-Related

- glacier locations
- glacier outlines
- ice core locations
- ice sheet accumulation
- ice sheet elevation
- permafrost classification
- permafrost extent
- sea ice concentration
- sea ice extent
- seasonal snow classification
- snow extent
- snow water equivalent
- treeline (northern limit of forests)
- and more...

3.2. Other

- Antarctic Circle
- Arctic Circle
- cities
- countries
- Equator
- geographic features (land, sea, and ice)
- International Date Line
- latitude and longitude
- North Pole
- South Pole
- Tropic of Cancer
- Tropic of Capricorn
- U.S. states
- and more...

4. Open Source GIS

NSIDC has leveraged use of the following Open Source software packages for the development of the Atlas and for manipulation of its diverse data sources, such as reformatting and reprojecting:

- MapServer: a development environment for building spatially-enabled internet applications (http://mapserver.gis.umn.edu)
- Geospatial Data Abstraction Library (GDAL): a data translation and processing library for raster geospatial data formats (http://www.gdal.org)

- OGR Simple Features Library: a data translation and processing library for vector geospatial data formats (http://www.gdal.org/ogr/)
- PROJ.4: a cartographic projections library for enabling reprojections (http://proj.maptools.org)
- libgeotiff: a GeoTIFF library for reading and writing GeoTIFF information tags (http://www.remotesensing.org/geotiff/geotiff.html)
- libtiff: a TIFF library for reading, writing, and manipulating TIFF images (http://remotesensing.org/libtiff/)
- FWTools (Frank Warmerdam Tools): a package which includes the latest version of all of the above (http://fwtools.maptools.org)

5. Interoperability

Maps can be generated through the provided Atlas of the Cryosphere Web interface. Alternatively, interoperable and customizable data access to Atlas maps and source data are enabled via the following Open Geospatial Consortium, Inc. (OGC) (http://www.opengeospatial.org) specifications:

- Web Map Service (WMS): provides map and legend images of selected data layers and basemaps
- Web Feature Service (WFS): provides vector source data in Geographic Markup Language (GML) format
- Web Coverage Service (WCS): provides raster source data in GeoTIFF format

Using these services, maps and data can be accessed for the user's spatial region of interest and desired resolution or output size. These services are accessible through the construction of a URL string that contains certain required and optional parameters for customizing output. Several OGC-compatible clients are also available for handling these interactions through point-and-click graphical user interfaces (GUIs), such as MapServer, ArcGIS 9 Service Pack 2, ENVI Zoom 4.3.1, Google Earth 4, uDig, QGIS, and GRASS, to name just a few. Client support for OGC services is constantly improving and expanding as popularity for these specifications increases.

Remote access through a client is normally obtained via an OGC “GetCapabilities” URL, as in the following examples for the Northern and Southern Hemispheres of the Atlas of the Cryosphere, where the “service” parameter can be either WMS, WFS, or WCS:

- http://nsidc.org/cgi-bin/atlas_north?service=WMS&request=GetCapabilities
- http://nsidc.org/cgi-bin/atlas_south?service=WMS&request=GetCapabilities

Other possible OGC requests include:

- GetMap: get an image of selected data layers
- GetLegendGraphic: get a map legend for selected data layers
- GetFeature: get vector source data in Geography Markup Language (GML) format
- GetCoverage: get raster source data in GeoTIFF format

These requests can include various standardized options for customizing output, including the ability to limit results to a particular spatial region. For more information, visit http://opengeospatial.org. A summary for applying these requests to the Atlas of the Cryosphere is also available at http://nsidc.org/data/atlas/ogc_services.html.

6. Lessons Learned

6.1. EPSG Codes

In order for users to access maps and source data remotely via OGC Web Services (OWS), the application must list the available map projections for these services. These map projections must be specified as EPSG Codes. These codes are developed and maintained by the European Petroleum Survey Group (EPSG)—now known as the International Association of Oil and Gas Producers (OGP)—and are a shorthand way of specifying a map projection and other coordinate parameters. Unfortunately, requiring the use of EPSG codes limits your OWS to the map projections that are already defined in the EPSG Geodetic Parameter Dataset. This can be especially limiting for polar projections, very few of which are currently available. As a result of this limitation, NSIDC submitted a

request to have several new polar projections added to the EPSG Geodetic Parameter Dataset. This request was granted and eventually incorporated into the latest release (version 6.12; see EPSG Codes 3408-3413), however these new codes can take several months to be incorporated into the various Open Source applications and OWS clients that use them. ESRI has informed us that these codes will be incorporated in the next release of ArcGIS (9.3).

6.2. Custom Ellipsoids and Datums

Several of NSIDC's data sets are projected on two somewhat unconventional datums, neither of which is available in popular image processing or GIS packages such as ENVI and ArcGIS, often leading the georeferencing information to be ignored when opening GeoTIFFs that are in coordinate systems using these datums. This is something to consider when attempting to distribute geospatial data that will be easily readable for users without extra configuration to be handled on their end. If there is not a strong justification for using an unconventional datum, one should consider reprojecting onto something like WGS84 prior to distribution, which is especially popular and appropriate for global- or large-scale earth science applications. As stated above in 6.1., these datums have been included in version 6.12 of the EPSG Geodetic Parameter Dataset (e.g. see EPSG Ellipsoid Code 7058) and should be incorporated into the next release of ArcGIS (9.3).

6.3. Wrap-Around and Overlapping the Pole

There are particular issues that need to be addressed when attempting to display global data in polar projections. If you have a data set that is in a latlong (Plate Carrée) projection or other such global projections, there can be problems when attempting to display these data in a polar projection on the fly. Namely, if you have data that overlap the +/-180 degree latitude line, they will likely be distorted in a polar projection because of wrap-around at this boundary (Figure 3). In addition, data that overlap the pole will also likely be distorted, and an annulus will likely prevent data from being viewed directly at or near the pole itself. A work-around is to reproject and store your global source data in a common polar projection prior to displaying them in a polar-projected MapServer application so that the reprojection is not done on the fly.

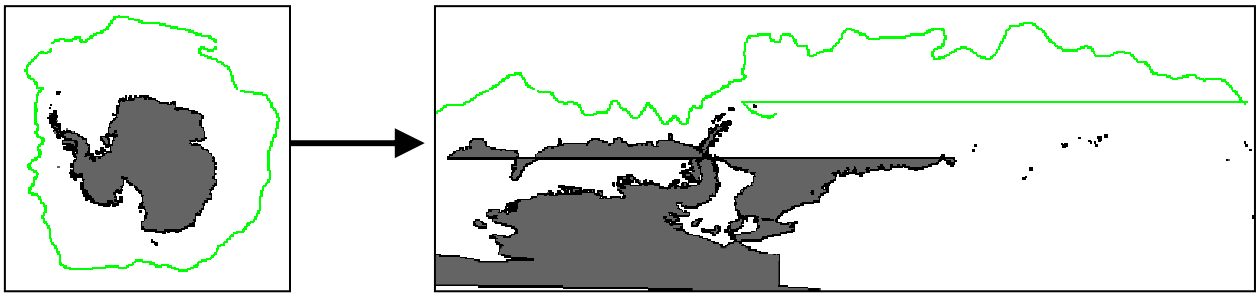

Figure 3. Illustration of adverse wrap-around effect when displaying polar data (left) in a global projection (right). This map shows the Antarctic Polar Front oceanic boundary (green) surrounding the Antarctic continent (grey).

6.4. Optimizing MapServer Performance

For improved speed and to avoid unexpected artifacts such as those mentioned in 6.3., reproject all data sources into identical or very similar projections ahead of time rather than relying on MapServer to do this on the fly. Also, when accessing large raster data files, use a tiling scheme to improve access speed, as was done for NSIDC's 250-m resolution MODIS Mosaic of Antarctica (MOA) product. This enables the map server to access smaller subsets of the larger file at any given time rather than always needing to access the entire file. Lastly, while incorporating external OWS services into your application promotes interoperability, it can noticeably slow performance depending on the remote server and how greatly their projections differ from that of your own application.

7. Conclusions

Between the public release of the Atlas of the Cryosphere on February 2, 2007 and the end of May, 2007, there have been 2,682 unique visitors to the site, already demonstrating its popularity. This project has been an attempt to bring

together the important, large-scale, climatological features of the cryosphere into a single, user-friendly, and Web-accessible interface that not only provides dynamic visualization but also a flexible and interoperable means for obtaining the source data for these features as well, thereby going beyond the criticism that many scientists have about applications that merely provide "pretty pictures." Also, by providing a simple Web interface, this and other map server applications are more broadly accessible to the general public compared to other geospatial applications that may require special software to download and/or broadband internet access such as Google Earth. Additional cryospheric data sets, supported polar EPSG Codes, and interface features will be developed according to time and demand. If you have questions, comments, or suggestions, please contact NSIDC User Services at nsidc@nsidc.org.

8. Acknowledgements

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9. List Of Acronyms

- ENVI: Environment for Visualizing Images
- EPSG: European Petroleum Survey Group
- EOS: NASA Earth Observing System
- GDAL: Geospatial Data Abstraction Library
- GIF: Graphics Interchange Format
- GIS: Geographic Information System
- GML: Geography Markup Language
- GRASS: Geographic Resources Analysis Support System
- GUI: Graphical User Interface
- IPY: International Polar Year
- JPEG: Joint Photographic Experts Group
- MOA: MODIS Mosaic of Antarctica
- MODIS: Moderate Resolution Imaging Spectroradiometer
- NASA: U.S. National Aeronautics and Space Administration
- NSIDC: National Snow and Ice Data Center
- OGC: Open Geospatial Consortium, Inc.
- OGP: International Association of Oil and Gas Producers
- OWS: OGC Web Services
- PNG: Portable Network Graphics
- QGIS: Quantum GIS
- RSS: Really Simple Syndication
- TIFF: Tagged Image File Format
- uDig: User-friendly Desktop Internet GIS
- URL: Uniform Resource Locator
- WCS: Web Coverage Service
- WFS: Web Feature Service
- WMS: Web Map Service