Towards a Web-based Arctic Geographic Information System:

A hierarchic GIS geobotanical atlas for the Toolik Lake-Kuparuk River region

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University of Alaska Fairbanks
UAF: One node in a global Arctic Network
The University of Alaska Fairbanks: a treasurehouse of arctic geospatial information

- International Arctic Research Center (IARC)
- Institute of Arctic Biology (IAB)
- Geophysical Institute (GI)
- Water and Environmental Research Center (WERC)
- Toolik Field Station (TFS)
We are proposing:

- Develop a web-based geobotanical atlas focused on the Toolik Lake Field Station and the North Slope.
- Link GIS facilities at UAF to support and manage research at the Toolik Field Station.
- A prototype Arctic GIS network node based at the University of Alaska Fairbanks (UAF).
Focus on the geobotanical data sets

- Vegetation
- Soils
- Landforms
- Geology
- Hydrology
- Remote sensing data

Bundy Fiord, Axel Heiberg Island

Critical information for research and...
science support at the Toolik Field Station and Kuparuk River region
Why Toolik Lake and Kuparuk River region?

- Long history of research associated with Arctic LTER, Imnavait Creek site, and many sites along the Dalton Highway.
- Prudhoe Bay and the Trans-Alaska Pipeline are within the Kuparuk River region, enhancing the applied aspects of the GIS.
- Availability of many types of spatial data not available elsewhere.
- Existing hierarchical geobotanical atlas of the region.

Photo: Rich Flanders
Four UAF subnodes interacting to serve North Slope geospatial information

**Geographic Information Network of Alaska (GINA)**
Central node for northern Alaska spatial data

**Arctic Region Supercomputing Center (ARSC)**
High performance computational research for the Arctic

**Toolik Lake Field Station GIS**
Research Support and Management for the Toolik Lake region

**Alaska Geobotany Center (AGC)**
Arctic Hierarchic Geobotanical Atlas
Components of a UAF node

Northern Alaska GIS Network

- ARSC
- GINA
- Toolik GIS Facility
- AGC
- Other UAF nodes
- Other North Slope nodes
Part of an ARCSS and Circum-Arctic GIS Network
Part of GINA’s goals are to:

- Integrate geospatial information and satellite image data into the university’s mission of providing high-quality education and basic research opportunities.
- Expand the use of satellite remote sensing and geospatial information systems (GIS) applications within government agencies and the private sector.
- Create new capability for serving Alaska’s needs to monitor natural resources, natural hazards, and the effects of climate change.

GINA’s role in the proposed node:

- Gateway to Toolik Lake, Geobotanical Atlas, and other North Slope geospatial databases with links to other statewide, national, and circum-arctic clearinghouses.
- Provide Internet Map Server (IMS) consultation to the develop the Geobotanical Atlas web site.
Arctic Region Supercomputing Center (ARSC)

Part of ARSC’s goals are to:

• Support high performance computational research in science and engineering with an emphasis on high latitudes and the Arctic.

• Provide high performance computational, visualization, networking and data storage resources for researchers within the Department of Defense, the University of Alaska (UA), other academic and scientific institutions, and government agencies.

• Make significant contributions to science on state, national and international levels using ARSC resources and talent.

ARSC’s role in the proposed node:

• Provide to GINA the high speed computational, networking, and data storage resources necessary for handling massive amounts of spatial information.
Toolik Field Station GIS Facility

Part of the facility’s goals are to:
• Support the science mission of the Station by providing high quality maps, GIS-based products, and analysis to users.
• Support management of the Toolik Lake natural resources.
• Provide a rich spatial database for projects, logistical support, planning, consultation and historical documentation.

The facility’s role in the proposed node:
• Provide the link between users in the field and the geobotanical GIS.
• Fully develop the Toolik Natural Resource Tool and other tools for application of the Geobotanical GIS.
Alaska Geobotany Center (AGC)

AGC’s goals are to:

- Explore and understand global northern regions through GIS, remote sensing, and ecosystem analysis.
- Address land-use and conservation issues in northern regions.
- Educate students and the public about northern systems and issues.

AGC’s role in the proposed node:

- Develop and manage data within the Atlas.
- Fully document the Atlas information through publications and digital metadata.
- Develop a web-based IMS interface for the Atlas.
A web-based Circumpolar Arctic Geobotanical Atlas

- Collection of geobotanical maps and supporting documentation for the Arctic.
- Fusion of three large GIS efforts:
  - Circumpolar Arctic Vegetation Mapping project,
  - Kuparuk River basin geobotanical atlas,
  - Prudhoe Bay geobotanical atlas and cumulative impact studies.
- Maps are currently in PDF format.
Processes of Arctic change operate across spatial scales that differ by 15 orders of magnitude.

- Documenting and predicting change requires a broad range of map scales.
- The hierarchy of map in the Atlas cover scales spanning 11 orders of magnitude.
The 4-Dimensional Framework of the Arctic Geobotanical Atlas
The horizontal dimension: Location
Vertical dimension: scale of maps

(Delcourt and Delcourt, 1988)  (Walker and Walker, 1991)
Depth dimension: Map themes or attributes

Toolik Lake Grid
Time dimension: Historic changes

- 1:6000-scale mapping of the Prudhoe Bay Oil Field
- Cumulative impacts of oil field development

Predevelopment vegetation

History of area covered by four disturbance types
• Planet to plant scales: 8 scales in all for some areas of the Kuparuk River basin.
Global-scale: the CAVM
Vegetation plus 8 ancillary data sets
Information available from the CAVM for northern Alaska
Hierarchy of Databases for the Kuparuk River basin
The regional scale: Some Kuparuk River Basin databases

- Current data bases include:
  - Topography
  - Hydrology
  - Vegetation
  - NDVI
  - Active layer depth
  - Methane flux

- Most are derived from remote-sensing data, Landsat MSS.

- Geobotanical maps are needed at this scale.

- Maps at the this scale and all other scales within the basin need to be co-registered to a common high-resolution topographic base map.
Upper Kuparuk River Basin databases
Recent application of 1:25,000-scale database
Kuparuk River basin: hierarchy of map scales
Landscape scale: Geobotanical maps of the Toolik and Innnavait Creek regions

- Databases include:
  - Vegetation (primary, secondary, tertiary)
  - Landform
  - Surface geomorphology
  - Glacial geology
  - Percent water cover
  - Topography
  - Hydrology
  - NDVI

- Information registered to an orthophoto topographic map.

- Legend terminology and color schemes are compatible and hierarchical at all scales.
1 x 1 km grids with 100-m grid point spacing, registered to orthophoto topographic maps and CIR aerial photographs.

Similar CALM grids exist at Toolik, Innnavait Creek, Prudhoe Bay West Dock, Betty Pingo, Barrow, Atqasuk, Council, Quartz Creek and other international sites.

Additional grids are needed at Franklin Bluffs and Sagwon to examine the full bioclimate gradient in northern Alaska.
Geobotanical maps of the ARCSS/CALM grids

- Geobotanical data sets include vegetation and 8 ancillary data sets.
- Currently, geobotanical maps available for the grids at Innnavait Creek and Toolik Lake.
Photo Dictionary: links to map legends

- Photos and descriptions of legend units.
- Plans call for similar links to PDF files of critical literature, and Excel files for the supporting plot information (vegetation, soils, site factors).
**Plot-scale:** 1x1-m plots at grid points

**Microtopography of Toolik Lake Grid**

1989 Microsite Topography and Canopy Structure

Explanation: This matrix of plots shows the microtopography and vegetation structure at the 72 1 x 1-m plots at the gridpoints of the Imnavait Creek Grid. The lower layer in each pair of plots shows microtopography of the ground surface. The upper layer shows the height of the vegetation canopy at each of the 100 points in the plots. The colors portray the microtopography height classes according to the legend below.

- **Sample point**
  - 30-40
  - 20-30
  - 10-20
  - 5-10
  - 2-5
  - 0-2
Plant species within 1-m plots

- 10-cm intervals, top and bottom of the plant canopy.

- Plots are permanently located so individual points can be resampled over time.

- Toolik and Innnavait Creek grids have been resampled at 6 year intervals to record changes in plant canopy structure and species composition.
Detail of species maps

- Colors represent plant functional types.
- Shape and color represent plant species.
Map legend also has links to the Photo Dictionary for species photos.
Thorough documentation of mapped information in peer-reviewed literature. (For example, Hamilton’s description of glacial geology units, IAB Biological Papers Series No. 26)

Documentation of GIS files to National Standards (Content Standard for Digital Geospatial Metadata, CSDGM).
Consultation with ESRI…

Help with:
- IMS interface,
- System architecture,
- Hardware.
Vision for Web-based Toolik-Kuparuk River GIS Atlas

- Link GINA, ARSC, Toolik GIS facility, and AGC to form a highly interactive, high-speed, fully functional web-based hierarchic geobotanical GIS to serve the research needs of the Toolik Field Station and others working within the Kuparuk River Basin.

- Convert the existing maps from PDF files into ArcIMS files so the data are available and fully functional over the Web. A major task to accomplish this is to co-register all maps to a common high-resolution topographic base map.

- Develop the research tools, applications and analyses needed by the researchers to access and use data. Fully develop the Toolik Natural Resource Tool.

- Fully document the data within the Atlas through publications and Federal metadata standards.
Possible prototype for GISs at other Arctic locations...

Emphasis on the nodes.
GIS: A means to bring the pieces together
GIS is key tool for answering scientific and societal questions

For example:

- Is there a relationship between vegetation, water cover, topography and caribou calving success?

- Is the distribution of atmospherically-transported contaminants controlled by the Arctic Front? And are levels of contaminants related to phytogeographic subzones?

- Is there any danger from contaminants in eating caribou hunted during the migration of the Central Arctic Herd?