Towards a Web-based Arctic Geographic Information System:

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

D.A. Walker, A.W. Balser, H.A. Maier, V. Sharpton

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:

• A prototype Arctic GIS network node based at the University of Alaska Fairbanks (UAF).

• Develop a web-based geobotanical atlas focused on the Toolik Lake Field Station and the North Slope.
Focus on the geobotanical data sets

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

Critical information for research and...

Bundy Fiord, Axel Heiberg Island
...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
Five UAF subnodes interacting to serve North Slope geospatial information

- Geographic Information Network of Alaska (GINA)
- A Region Supercomputing Center (ARSC)
- Toolik Lake Field Station GIS
- Alaska Geobotany Center (AGC)
- Water and Environmental Research Center (WERC)
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.
- 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 GIS, the Geobotanical Atlas, and other North Slope geospatial databases with links to other statewide, national, and circum-arctic clearinghouses.
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 University of Alaska (UA), other academic and scientific institutions, and government agencies.

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.

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.
• Educate students and the public about northern systems and issues.

AGC’s role in the proposed node:

• Develop and manage data within the Arctic Geobotanical Atlas.
• Fully document the Atlas information through publications and digital metadata.
• Develop a web-based IMS interface for the Atlas.
WERC’s role in the proposed node:

- Help develop the visualization products of the geobotanical atlas.
- Provide the high resolution DEM for the Kuparuk River basin.
Components of a UAF node

Northern Alaska GIS Network

- ARSC
- GINA
- Toolik GIS Facility
- AGC
- WERC
- Other UAF nodes
- Other North Slope nodes
Part of an ARCSS and Circum-Arctic GIS Network

For example:

- ARCSS US Arctic GIS Network
  - VECO/ADCC/JOSS

Northern Alaska GIS Network

- ARSC
- Toolik GIS Facility
- AGC
- WERC
- Other UAF nodes
- Other North Slope nodes

Other national GIS networks

Circum-Arctic GIS Network
- UNESCO/Grid-Arendal

AGDC

Other Alaska GIS Nodes
A web-based Circumpolar Arctic Geobotanical Atlas

• Collection of geobotanical maps and supporting documentation for the Arctic.
• Current collection is a 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 maps in the Atlas cover scales spanning 11 orders of magnitude.
The 4-Dimensional Framework of the Arctic Geobotanical Atlas
Hierarchy of map scales

- Planet to plant scales: 8 scales in all for some areas of the Kuparuk River basin.
Vegetation plus 8 ancillary data sets

Making the Circumpolar Arctic Vegetation Map

The Circumpolar Arctic Vegetation Map (CAVM) was developed as the Arctic component of the Global Biodiversity Information Facility (EML-BIOT). This effort is part of a larger initiative to compile and provide access to global vegetation maps, including the Tree Cover Maps of the United Nations Framework Convention on Climate Change (UNFCCC) and the Terrestrial Ecosystems of the World (TEWS) project. The CAVM project, supported by the Arctic Council’s Working Group on Biodiversity and Ecosystem Services (WG-BES), is a collaborative effort involving scientists and organizations from around the world, with a focus on the circumpolar Arctic region.

Key components of the CAVM include:
- High-resolution satellite imagery
- Ancillary data sets from various sources
- Natural vegetation types
- Human land use
- Topography
- Soil and substrate chemistry
- Climatic conditions
- Historical vegetation

The CAVM was created using a combination of remote sensing data and in situ field observations, with a focus on the following vegetation types:
- Tundra
- Forest
- Grassland
- Wetland

The map provides a comprehensive view of the vegetation distribution across the circumpolar Arctic region, enabling researchers and policymakers to better understand and manage the region's biodiversity and ecosystem services.

Acknowledgements

The development of the Circumpolar Arctic Vegetation Map was supported by the Arctic Council’s Working Group on Biodiversity and Ecosystem Services (WG-BES) and the Global Biodiversity Information Facility (EML-BIOT). Special thanks to the following organizations and institutions for their contributions:
- University of Alaska Fairbanks
- Norwegian Polar Institute
- Canadian Centre for Remote Sensing
- Russian Academy of Sciences

References

[Insert list of references related to the Circumpolar Arctic Vegetation Map]

For more information, visit the CAVM website: [CAVM Website]
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

Vegetation of the Upper Kuparuk River Region in relationship to glacial geology and surficial geomorphology

A Research Experience for Undergraduates (REU) project
C.A. Munger and D.A. Walker, Alaska Geobotany Center, Institute of Arctic Biology, University of Alaska Fairbanks
Poster presented at the 54th Arctic Science Conference Fairbanks, AK, September 22-24, 2003

Introduction: The main factors controlling mesoscale vegetation patterns in the Upper Kuparuk River Region are landscape age and surficial geology. The complex topography of the region is the result of glacial deposition from two major glaciations: the Sagavanirktok (Hdb. Puersiluhen) and the抓获 III (late Pleistocene). Surficial geomorphological features are created through fluviation, colluviation, and periglacial processes. This poster examines the relationship between vegetation, glacial geology, and surficial geomorphology in the Upper Kuparuk River Region through area analyses of the three maps.

Vegetation Complexes

Vegetation

The vegetation of the upper Kuparuk River Region is divided into eleven vegetation complexes, which are characterized by 30 to 40 species of grasses and forbs. The upper Kuparuk River region is a relationship forsted by willow, and a relationship forsted by birch. The upper Kuparuk River region is dominated by willow, and a relationship forsted by birch. The upper Kuparuk River region is dominated by willow, and a relationship forsted by birch.

Vegetation and Glacial Geology

The Upper Kuparuk River Region is divided into eleven vegetation complexes, which are characterized by 30 to 40 species of grasses and forbs. The upper Kuparuk River region is dominated by willow, and a relationship forsted by birch. The upper Kuparuk River region is dominated by willow, and a relationship forsted by birch. The upper Kuparuk River region is dominated by willow, and a relationship forsted by birch.

Vegetation, Glacial Geology, and Surficial Geomorphology

Sagavanirktok III,抓获 III, and抓获 II glacial deposits. Each have characteristic surficial geomorphological features. The vegetation of the upper Kuparuk River Region is divided into eleven vegetation complexes, which are characterized by 30 to 40 species of grasses and forbs. The upper Kuparuk River region is dominated by willow, and a relationship forsted by birch. The upper Kuparuk River region is dominated by willow, and a relationship forsted by birch.

Conclusions

Acknowledgments:

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Literature cited:


Kuparuk River basin: hierarchy of map scales
Landscape scale: Geobotanical maps of the Toolik and Imnavait 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.
ARCSS/ CALM Grids

- 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, Imnavait 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 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
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 Imnavait 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 a Web-based Toolik-Kuparuk River Geobotanical Atlas

• Link GINA, ARSC, Toolik GIS facility, and AGC to form a northern Alaska node of the Arctic GIS.

• Develop 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 researchers to access and use data. Fully develop the Toolik Natural Resource Tool.

• Develop visualization products and user friendly interfaces for the public and schools to access and use the Atlas.

• 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.
The horizontal dimension: Location
Vertical dimension: scale of maps

Macroscale Megascale
Macroregion

Mesoscale Microregion Mesoregion

Microscale... Mesosite Macrosite

...Microscale Microsite

Linking Elements

Scale, Locations, and Example Research Topics

Circumpolar Arctic (10,000,000 sq km)
- Extension of Flux Study findings to the circumpolar Arctic
- Global flux estimates for trace gases, water and energy

Regions (10 - 10,000 sq km)
- Regional patterns of vegetation, NDVI, and fluxes related to climate and large-scale geologic features
- Regional measures of CO$_2$ flux (aircraft)
- Hydrology of major rivers

Landscapes (0.1 to 10 sq km)
- Landscape controls on vegetation, NDVI, soil carbon, and active layer
- Tower measurements of CO$_2$, ET, and soil heat flux
- Linkages between terrestrial and freshwater systems

Plots (0.1 - 100 sq m)
- Influence of site factors on species, vegetation communities, NDVI, and soils
- Spatial and temporal variation of trace-gas (CO$_2$, CH$_4$) energy and H$_2$O flux

Integration, Modeling

Arctic Land-Atmosphere Ecosystem Model (ALATEM)
- Regional permafrost model
- Hydrologic model

Hierarchic GS
- General Ecosystem Model (GEM)
- Land Surface model
- Canopy light/NDVI model

Vertical dimension: scale of maps

(Walker and Walker, 1991)

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

Toolik Lake Grid
Time dimension: Historic changes

- History of disturbance
- 1:6000-scale mapping of the Prudhoe Bay Oil Field
- Predevelopment vegetation
- History of area covered by four disturbance types
- Cumulative impacts of oil field development
GIS: A means to bring the pieces together
GIS is key tool for answering scientific and societal questions

Societal concerns regarding caribou

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?