Towards an Arctic Geographic Information Network:
A WEB-BASED PLANT-TO-PLANET-SCALE GEOBOTANICAL ATLAS CENTERED ON THE TOOLIK LAKE FIELD STATION, ALASKA

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A PROJECT SUMMARY

The central goal of this project is to develop a web-based multi-scale Arctic Geobotanical Atlas (AGA) for the Toolik Lake Field Station, the North Slope of Alaska, and circumpolar region. The Arctic Geobotanical Atlas (AGA) will include a framework set of geobotanical map themes (vegetation, soils, landforms, surface geomorphology, geology, hydrology, and topography). The maps span *plant to planet scales,* seven scales in all. The map themes, map legends, and map colors are consistent across map scales. The great bulk of the maps in the Atlas have already been made, but are currently only available as hard copy maps or by ftp of data files. An internet-map server (IMS) will make all the maps available in a variety of formats for display, query, and on-line analysis. The Atlas will be part of a regional GIS node at the University of Alaska Fairbanks (UAF) and an envisioned circum-Arctic GIS network. A major effort will be devoted to metadata for the Atlas using national metadata standards and peer-reviewed publications. Links will provide access to key supporting publications, photo glossaries, and other information relevant to the maps. We will develop the research tools, applications, and analyses needed by researchers, land managers, educators, and the public to access and use the data. *We are requesting funds to complete the following tasks: (1) Create the IMS interface for the atlas, (2) design a user-friendly web site to make the data easily comprehensible and accessible to users from a variety of backgrounds, (3) develop a educational package that will include a visualization tool that allows users to "fly" over the maps at multiple scales, (4) co-register the maps to a common high-resolution base map, (5) develop a photo gallery and literature library, (6) write standardized metadata files necessary to fully document the contents of the database, (7) write key chapters and a hard-copy of the Atlas to document the major map themes (vegetation, soils, landforms, glacial geology, etc.), and (8) develop tools for on-line spatial analysis and manipulation of the maps.*

Intellectual merit of the project: Vegetation maps, digital elevation models and other mapped geobotanical information are key datasets for a wide variety of ecological and geophysical studies. The materials in the AGA have been under development for over 20 years. The proposed work will make this information readily available to a wide diversity of users and greatly enhance the use of these key data sets. The data have been used by many research projects in northern Alaska, and have resulted in many publications that are reviewed in this proposal. Future use of the maps and data products are key to several ongoing and proposed ARCSS and other NSF projects, including the International Tundra Experiment (ITEX), the Circumpolar Active Layer Monitoring (CALM) project, two arctic Biocomplexity in Environment (BE) projects, the Arctic Long-Term Ecological Research (LTER) project, the Study of Environmental Arctic Change (SEARCH), and Pan-Arctic Cycles, Transitions, and Sustainability (PACTS).

Broader impacts resulting from the project: A major effort will be made to make the information accessible to non-technical users, including students at high schools and universities. The atlas will be integrated into a new Geoinformatics course at UAF. The project is particularly important for science and site management at the Toolik Lake Field Station and Imnavait Creek. It is anticipated that many government and private agencies working within the Kuparuk River region and the Dalton Highway corridor will use the information in the Atlas. The project will be closely coordinated with other proposed Arctic GIS efforts including the Arctic Logistics Tool, the Barrow Area Information Database (BAID), and the Circumpolar Environmental Observatory Network (CEON).

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C PROJECT DESCRIPTION

C.1 INTRODUCTION

New technologies now allow very complex spatial data sets contained in Geographic Information Systems (GIS) to be accessed, queried, and analyzed directly over the Internet (Dangermond 2002, 2003). Participants at a recent NSF-sponsored Arctic GIS workshop recognized that enhanced internet-based GIS would benefit nearly all Arctic scientific disciplines, and would improve management of field sites where NSF and other organizations conduct research. The final report from the workshop pointed out that:

> *Tremendous assemblages of geospatial data are being developed by agency and academic researchers, often in consultation with technical experts in private industry. Typically, these data are only available for use by small groups of collaborators. Recent technological advances in GIS software, computer hardware, and the Internet are making it possible for researchers to electronically share datasets once thought to be impossibly large. To do this, however, data must be documented and maintained in standard format that allows cross-platform, interdisciplinary, and international data sharing (Sorenson et al. 2001).*

The report made five suggestions for implementation of an Arctic GIS web-based network. One recommendation was to fund demonstration projects that focus on specific geographic regions or user communities that represent the broadest possible sets of natural and human environmental questions. These prototype GIS databases could serve as examples for nodes in other areas of the Arctic.

The Toolik Lake and Kuparuk River region in northern Alaska is an ideal area for such a demonstration. The region has a long history of GIS-based research associated with the Toolik Lake Field Station and nearby research sites along the Dalton Highway and at Prudhoe Bay. Furthermore, ongoing resource development at Prudhoe Bay and the nearby oil and gas fields enhance the applied aspects of GIS in the region. Because of the oil fields and intense scientific and government interest in the region, there are many types of spatial data that are not available elsewhere. One of the most notable is an existing hierarchical geobotanical GIS database for the region (Walker et al. 1996). *This proposal is to convert this database into a prototype Web-based GIS Geobotanical Atlas for the Toolik Lake and North Slope region.*

C.2 HISTORY OF GEOBOTANICAL AND GIS RESEARCH IN THE TOOLIK LAKE REGION

This proposal focuses on *geobotanical* information, including vegetation, soils, landforms, topography, hydrology, and geology. These are critical framework data for a wide variety of scientific and management GIS applications. The geobotanical mapping method was developed at Prudhoe Bay in the early 1970s (Everett et al. 1978), and has been applied at many scales in northern Alaska (Walker and Walker 1991), Colorado (Walker et al. 1993), and the circumpolar Arctic (CAVM Team 2003). The method is similar to the landscape-guided mapping methods developed by the International Training Centre for Aerial Survey (ITC, now called the Institute of Aerospace Survey and Earth Sciences) in the Netherlands (Zonneveld 1988). The method unifies information from many sources into a single map coverage, similar to the Integrated Terrain Unit Mapping (ITUM) approach developed at the Environmental System Research Institute (ESRI) (Dangermond and Harnden 1990), and the "landschaft" approach used by the Earth Cryosphere Institute in Moscow (Melnikov 1988, 1998). The approach is based on the philosophy that physiographic landscape features (topography and landforms) control hydrological, soil, and vegetation boundaries. Geobotanical maps have a wide variety of biological and geophysical attributes coded for each map polygon. This eliminates the need for separate overlays for all geobotanical variables and greatly simplifies the GIS procedures and analysis of the maps (Walker 1999).

During the past 30 years, northern Alaska, and particularly the Kuparuk River basin, has been a focus of resource mapping and GIS applications at multiple scales (Walker et al. 1980, Jorgenson et al. 1997, Muller et al. 1998, Muller et al. 1999). The Prudhoe Bay region saw one of the first applications of GIS to analyze the cumulative impacts of industrial development (Walker et al. 1987b). Since then, GIS-based scientific research has been conducted at the Toolik Field Station (TFS) (Walker and Walker 1991), and nearby Imnavait Creek (Reynolds and Tenhunen 1996). The Dalton Highway (Brown and Berg 1980), the Prudhoe Bay oil fields (Walker et al. 1980), and the Arctic National Wildlife Refuge (Jorgenson et al. 1994) have also been subjects of vegetation mapping efforts. The region will continue to see a great deal of scientific research that will benefit from accurate, well-documented, easily accessible, user-friendly, geographic information.

C.3 THE ARCTIC GEOBOTANICAL ATLAS (AGA)

The majority of geobotanical data for the Toolik Lake, Imnavait Creek and Kuparuk River region has been assembled into a hierarchic Arctic Geobotanical Atlas that can be viewed on the Web at http://www.geobotany.uaf.edu/arcticgeobot/. The site has recently been recognized in *Science* magazine's Netwatch section as a notable science web site (*Science 303:*21, http://www.sciencemag.org/cgi/content/summary/303/5654/21d). The maps and GIS databases in the atlas have been assembled from three primary sources: (1) Geobotancial mapping and cumulative impact analysis of the Prudhoe Bay Oil Field (Walker et al. 1986b); (2) mapping conducted as part of DOE and NSF funded projects in the Toolik Lake and Imnavait Creek regions (Walker and Walker 1996); and (3) the Circumpolar Arctic Vegetation Map (CAVM Team 2003). These data are a unique resource that spans seven spatial scales from individual plants to the circumpolar region. The atlas has a unified system of scales, map legends, map colors, and methodology that makes them particularly useful in efforts to scale plot-based research to regional and circumpolar scales. A wide variety of supplementary information is also in the Atlas, including links to key data sets, photographs, and publications. A summary below shows the current structure and contents of the atlas (see Section C.5). The AGA maps can be downloaded as PDF files, or the GIS data files can be ordered from the AGC or the ARCSS Arctic Data Coordination Center (ADCC), but this can be a time-consuming process, particularly for non-GIS experts.

The vision for the AGA is to develop a highly flexible multi-scale geobotanical GIS database that will be useful to scientists, land managers, educators, students, and the public. The goal is to provide users with the capability to download and manipulate digital map files and GIS data via Internet Map Server (IMS) software so that the maps can be easily displayed, analyzed, and used in a variety of formats directly over the Web.

C.3.1 Intellectual merit

The database contributes to several areas of ARCSS terrestrial research programs. Historically, the database has been used to inventory the geobotanical resources at the Imnavait Creek research site (Walker and Walker 1996), the glacial geology of the Toolik Lake region (Hamilton 2003), the Kuparuk River basin (Muller et al. 1998), the Prudhoe Bay region (Walker et al. 1980), the North Slope of Alaska (Muller et al. 1999), and the circumpolar Arctic (CAVM Team 2003). Components of the AGA were used to analyze the relationship between snow cover, terrain, and vegetation at Imnavait Creek (Evans et al. 1989a) and the Kuparuk River basin (Liston 1999). The AGA was critical to unraveling the relationship between terrain age and key vegetation characteristics, including biomass, leaf-area index, and the normalized difference vegetation index (Shippert et al. 1995). It has been particularly useful at the Arctic LTER site, where understanding the spatial relationships between soil pH and ecosystem processes has affected a wide variety of studies including those of plant diversity (Gough et al. 2000), and the effect of substrate on Holocene pollen records (Oswald et al. 2003). The database has been used to develop spatially explicit models of trace-gas fluxes (Ostendorf et al. 1996, Oechel et al. 2000), active-layer relationships (Nelson et al. 1997), and the effects of road-related disturbances (Leadly et al. 1996). Time-series data in the AGA have also been used to determine the cumulative effects of resource development (Walker et al. 1986a), long-term trends in tundra greenness patterns (Jia et al. 2003), and long-term changes to the plant species composition of the tundra (M. Walker, personal communication).

The role of the AGA will expand as the data become more accessible, and more sites are mapped using the same methods. For example:

(1) The Circumpolar Active Layer Monitoring (CALM) is taking advantage of AGA databases for the 1-km grids at Toolik Lake and Imnavait Creek to examine thaw layer-geobotany relationships. The CALM project would like to develop geobotanical databases for other CALM grids in northern Alaska and elsewhere in the Arctic. Additional CALM grids will be proposed in the future for sites at Happy Valley, Franklin Bluffs, Sagwon, and sites in Canada in order to examine active layer and geobotanical relationships along the full Arctic climate gradient.

(2) A new Biocomplexity in the Environment (BE) project at Imnavait Creek is taking advantage of the geobotanical information for that site to examine land-water interfaces at the catchment scale to link biogeochemistry and hydrology (Marc Stieglitz, pers. comm.). Another BE project is using data from the existing grids to examine frost-boil-terrain relationships (Walker et al. 2003 submitted). Data from this project will also be used to develop databases for 10x10-m grids, which is very useful for examining small-scale periglacial features.

(3) The International Tundra Experiment (ITEX) is using the detailed plant-level information from the CALM grids to examine long-term changes to plant canopy structure and species composition (M. Walker, pers. comm.). These data will be even more valuable as time goes on and if the same sort of databases are constructed at other sites to examine, for example, along the Arctic bioclimate gradient, or gradients of terrain age.

(4) The data may prove most useful for issues related to scaling information from plot-level research to the circumpolar region. A recent scaling workshop at the Open Science Meeting for the Study of Environmental Arctic Change (SEARCH) discussed applications of the AGA for this purpose. The recently published Circumpolar Arctic Vegetation Map will be a key tool here. The map has been recently used for making a new phytomass map for the Arctic based on the NDVI information in the database (Walker et al. 2003). On-going and proposed research will examine biomass/LAI/NDVI relationships along the full Arctic bioclimate gradient to develop models of tundra response to changes in temperature, and how this varies across substrate types. The Atlas data should also be useful for examining the vegetation-hydrology relationships across the Arctic and developing models of water, carbon, and nutrient inputs from the land to the Arctic Ocean.

C.3.2 Broader impacts

The AGA data are also useful for a wide variety of management, planning and educational issues. The information is an essential component of science support and management of the Toolik Lake Research Natural Area (Balsar 2002). The Toolik Field Station GIS uses the information extensively for site selection for science projects, landscape-scale analyses, and graphic support for publications. The data are also useful for other management agencies. For example, The Nature Conservancy recently used the vegetation map of the Arctic Slope to develop a more detailed Ecosystems of Northern Alaska map (TNC 2003, in progress). The Bureau of Land Management has expressed interest in the database as part of the North Slope Science Initiative (NSSI). The USGS is interested in the data for improving its land-cover mapping of the Arctic. The circumpolar data are particularly useful to vegetation and climate modelers. The AGA presents a unified view of the Arctic, compared to a previously disjointed picture that resulted from many maps of small pieces of the Arctic with different legend approaches. From an international perspective, other countries will find the information useful for selecting protected areas and planning cross-border conservation efforts.

The data will also be a useful tool for high-school and university education, and for informing the public about the nature of the Arctic. For example, students in Kaktovik can use the map to see how their environment is similar to or different from other Arctic environments. It gives them a chance to see where they fit into the bigger picture. The data will help students understand geography, maps and GIS, and how to use these in science. Toward this end, we are proposing to use the AGA as a component of a new Geoinformatics course at UAF. (See attached letter from Anupma Prakesh). Students will use the data to develop their own research projects. We will make the information accessible to students and the public with user-friendly interfaces. One of the exciting features will be a visualization tool, that will allow users to "fly" around in the topographic databases and view the landscape as from a jet aircraft.

C.4 AGA: PART OF AN ARCTIC GIS NETWORK

The AGA will be a framework dataset for a new GIS node at UAF and an important component of an Arctic GIS Network. The AGA will require input from five subnodes (Figure 1):

(1) *The Alaska Geobotany Center (AGC)* is housed at the Institute of Arctic Biology (IAB). The details of AGC's role in the AGA are described in this proposal.

(2) The *Toolik GIS facility (TGIS)* is also housed at IAB. TGIS is funded through an NSF-UAF cooperative agreement for management of the Toolik Lake Field Station. The facility provides logistic, management, and research support through GIS to the Toolik Field Station and its user community. TGIS and AGC closely cooperate in developing maps and analyses related to the Toolik Lake. The cooperative agreement for the TGIS is up for renewal in 2004. Part of the renewal proposal requests funds for additional support to include development of application tools for site management. One example is the Toolik Natural Resource Tool, which is among other things, a zoning tool to help researchers select new sites and manage the Toolik Lake Research Natural Area. This tool uses geobotanical information in the AGA to help in this process.

(3) The *Water and Environmental Research Center (WERC)* performs basic and applied research related to water and environmental resources. WERC has developed high-resolution digital elevation models (DEMs) for northern Alaska using SAR imagery. A high-resolution DEM for the Kuparuk River Basin will be used to register databases at several scales to a common base map. Additionally, the Center will help in the development of visualization tools In a separate proposal, WERC is proposing to expand the high-resolution DEMs to cover the Arctic National Wildlife Refuge, and to develop visualization tools for the circumpolar databases.

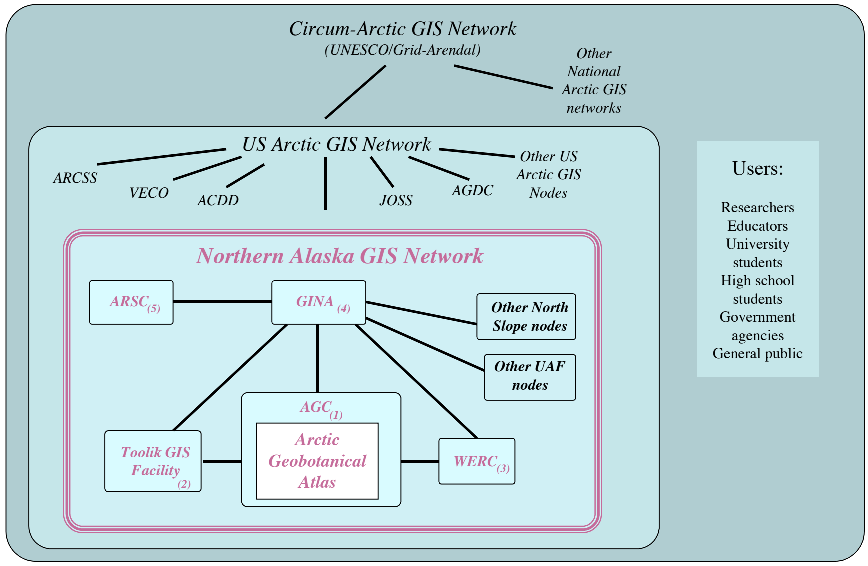


Figure 1. The Arctic Geobotanical Atlas (AGA) within the Alaska Geobotany Center (AGC) and GIS networks encompassing Northern Alaska, US Arctic, and the circum-Arctic. The red box shows the Northern Alaska network. The red numbered nodes provide support for the AGA (see Sectioin C-4 for description).

(4) The *Geographic Information Network of Alaska (GINA)* is housed in the Geophysical Institute (GI) and the International Arctic Research Center (IARC) at UAF. It is the University's organization for sharing its diverse data and technological capabilities among the Alaska, Arctic, and world communities. It serves Alaska's needs to monitor natural resources, natural hazards, and the effects of climate change through remote sensing and geospatial information systems. In the proposed network, GINA would be the gateway to the AGA and provide linkage to many subnodes at UAF and elsewhere that have spatial datasets in northern Alaska. GINA has massive computing capabilities that will allow all datasets to be continuously spinning and available over the Internet.

(5) The *Alaska Regional Super-computing Center (ARSC)* supports high performance computational research in science and engineering at UAF with emphasis on high latitudes and the Arctic. It provide high performance computational, visualization, networking and data storage resources for researchers at UAF and other government agencies. ARSC will provide GINA and the Northern Alaska GIS network with additional high-speed computational, networking and data storage resources necessary for handling massive amounts of spatial information and provide an ultra-high speed link to the national internet backbone through the Pacific Northwest Gigapop system and the Internet 2 consortium.

C.5 CONTENT AND ORGANIZATION OF THE AGA

The Atlas has a four dimensional framework that allows users to select maps according to the following criteria: (1) the region of interest (horizontal dimension), (2) scale of interest (vertical dimension), (3) topic or theme of interest (depth dimension), or (4) the year of interest (time dimension) (Figure 2). Maps and information in the Atlas can be accessed through clickable index maps or through menus containing a complete list of maps by region, scale, topic, or year.

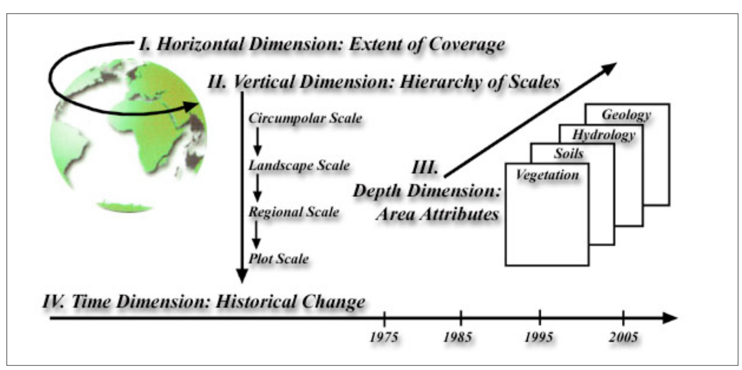


Figure 2. Four-dimensional framework of the AGA.

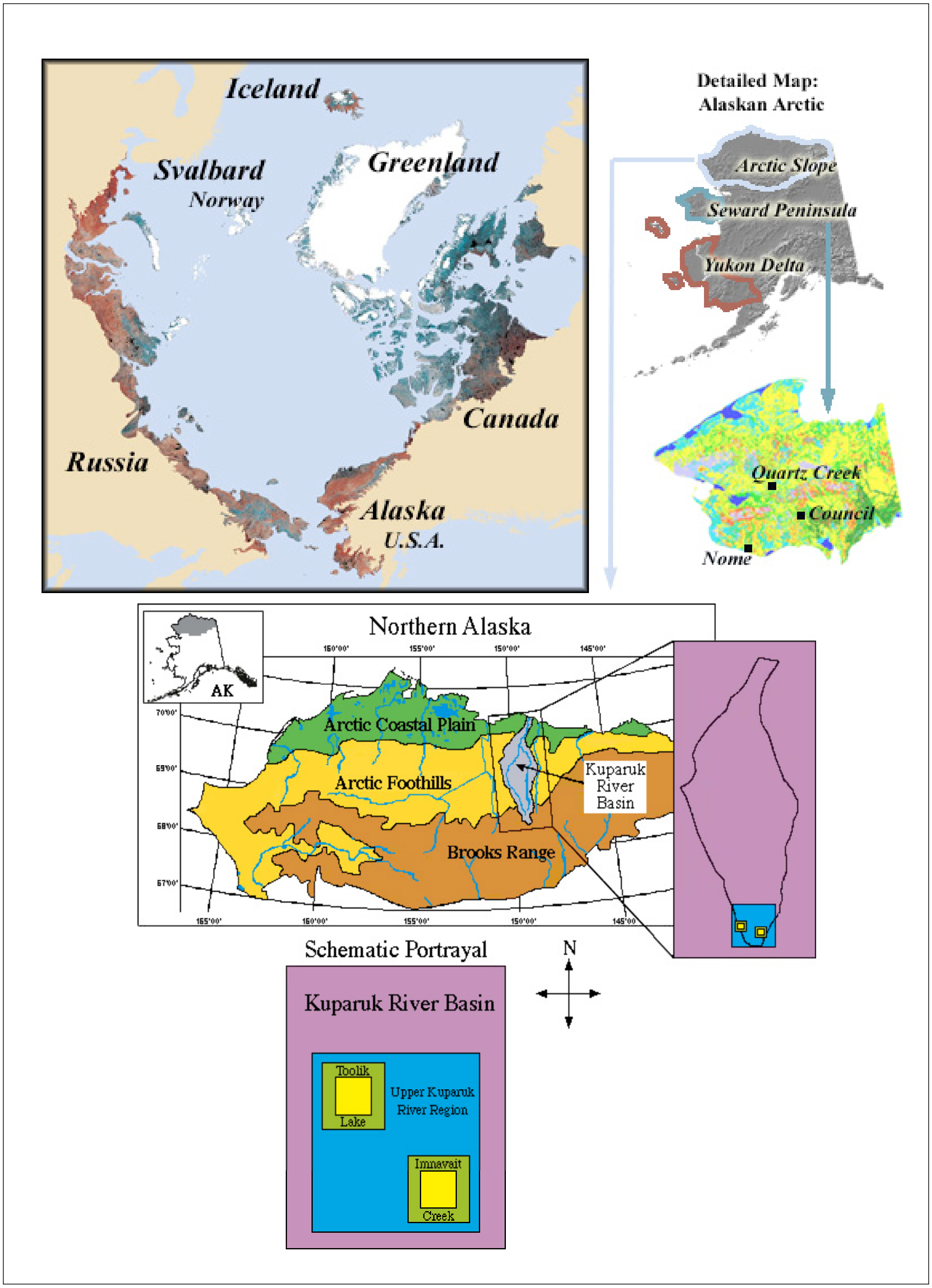


Figure 3. Extent of coverae of the AGA. Regional maps at 1:4 million scale are available for all areas of the Circumpolar Arctic (area north of tree line in upper left map). Finer scale maps cover northern Alaska and the Seward Peninsula (upper right). The databases focuses in northern Alaska and the Kuparuk River basin (center map). A complete hierarchy of seven map scales is available for the Toolik Lake and Imnavait Creek sites (lower diargram.

C.5.1 Extent of coverage (horizontal dimension)

The AGA covers the entire circumpolar region (Figure 3, upper left). with a focus on Arctic Alaska (upper right) Clicking on any arctic country will access pages with more detailed visual indices, or it is also possible to access data via outlines of available information for each country.

The majority of the information in the atlas is from the Kuparuk River region with a focus on the Toolik Lake and Imnavait Creek research sites in the upper Kuparuk River basin (Figure 3, lower diagrams, and Figure 5).

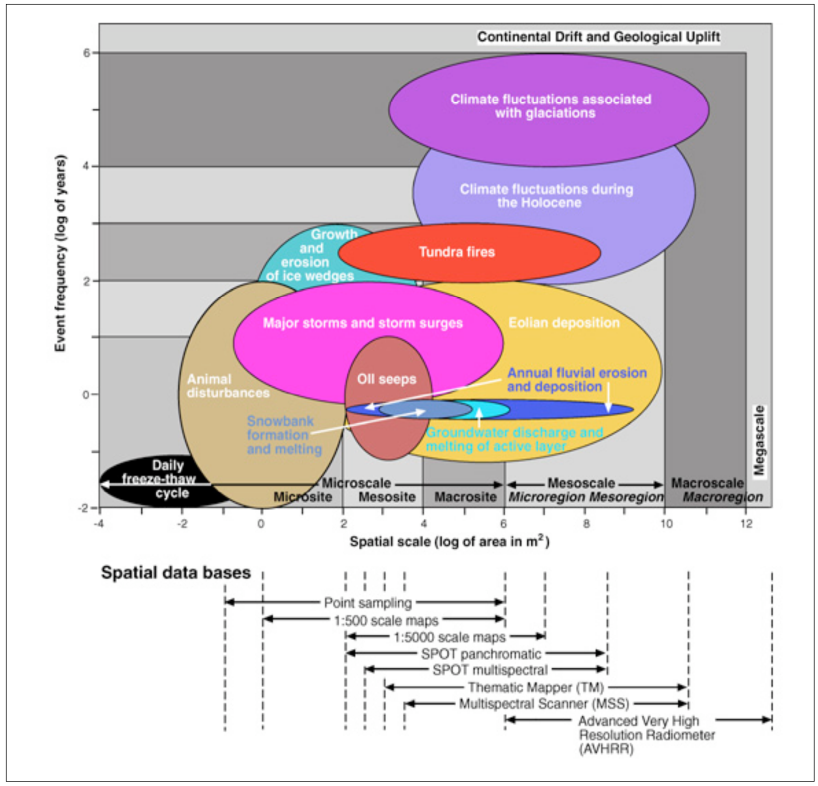


Figure 4. Ranges of spatial and temporal scales for change in the Arctic. Appropriate databases for examining the different scales are shown at the bottom of the figure.

C.5.2 Hierarchy of scales (vertical dimenson)

Processes of change in the Arctic operate across spatial scales that differ by 15 orders of magnitude (Figure 4). Monitoring and predicting change across this vast range of spatial domains requires maps at many scales. The current map scales include (Figure 5): (1) plot- level maps of plant species (1:10 scale, see example in Fig. 10); (2) grid-level maps (1:500 scale; Fig. 11); (3) landscape level maps of the Imnavait Creek and Toolik Lake areas at 1:5000 scale, (4) landscape-level maps of the Upper Kuparuk River region at 1:25,000 scale (Fig. 8), (5) regional maps of the Kuparuk River basin (1:250,000 scale; not shown), (6) regional maps of the North Slope (1:4,000,000 scale, Fig. 7), and (7) maps of the circumpolar

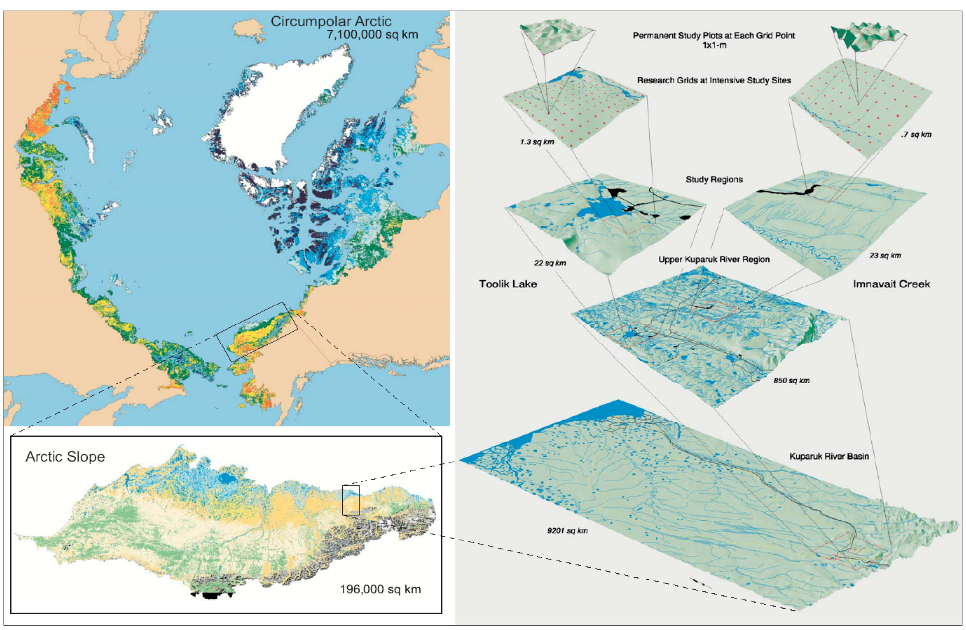


Figure 5. Hierarchy of map scales in the AGA.

Arctic (1:7,500,000; Fig. 9). The heart of the database is a hierarchy of maps centered on 1-km research grids at Toolik Lake and Imnavait Creek.

The maps were originally developed for scaling plot-level measurements of trace-gas fluxes and the active layer to larger regions (Figure 6). They also have potential for a wide variety of other studies including scaling of hydrological processes, biodiversity, and modeling processes of landscape evolution. The maps developed for Toolik Lake and Imnavait Creek could also serve as prototypes for making maps at other research sites. For example, numerous 1x1-km grids in northern Alaska and elsewhere in the Arctic are part of the Circumpolar Active Layer Monitoring (CALM) project (Brown et al. 2000). Toolik and Imnavait Creek are part of this network of CALM sites, and are currently the only sites to have detailed geobotanical maps. It would be highly desirable to have detailed maps of these characteristics at most if not all of the CALM grids (planned future proposals).

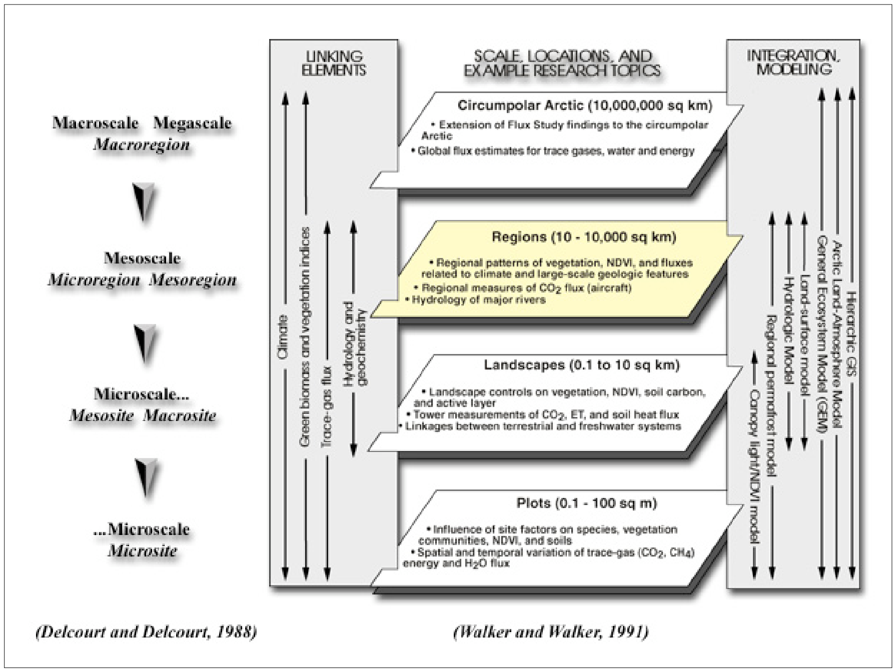


Figure 6. Application of the map hierarchy to scaling fluxes of trace gases, water, and energy, showing the range of scales for several linking elements and models.

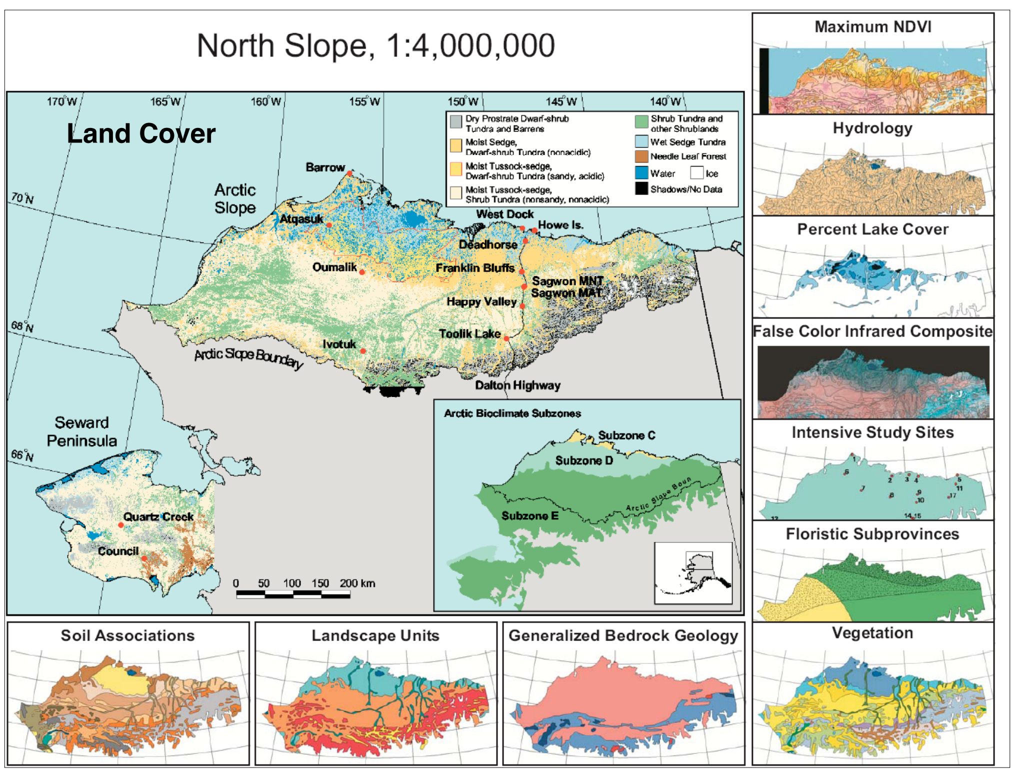


Figure 7. Map themes for the Alaska North Slope at 1:4 million scale.

C.5.3 Map themes (depth dimension)

A wide variety of map themes are available at all map scales. The themes available for northern Alaska at 1:4 million scale are shown in Figure 7. These same themes are available for most parts of the circumpolar Arctic. At most scales, integrated geobotanical mapping methods were used to construct databases that include the following variables: vegetation (primary, secondary, and tertiary), landform, surficial geology, surface geomorphology (primary and secondary), and lake cover. Other layers in the databases include digital elevation models, hydrological networks, satellite imagery, aerial photography, road and infrastructure networks, locations of study plots, and land-cover classifications derived from satellite imagery. For the most part, legends and map colors are compatible between map scales so that users can move between scales and regions using the same legend systems. This compatibility will be improved as the atlas is developed further. It is not possible to fully illustrate the range of map themes available at all the map scales within this proposal, but Figures 8, 9, 10 and 11 give some idea of the available products. Figure 8 shows some of the map themes for the upper Kuparuk River region at 1:25,000 scale. These illustrate some of the high quality cartographic products that are produced by Andrew Balsar, Toolik Lake GIS manager. These sorts of products will be available for all the maps at all scales.

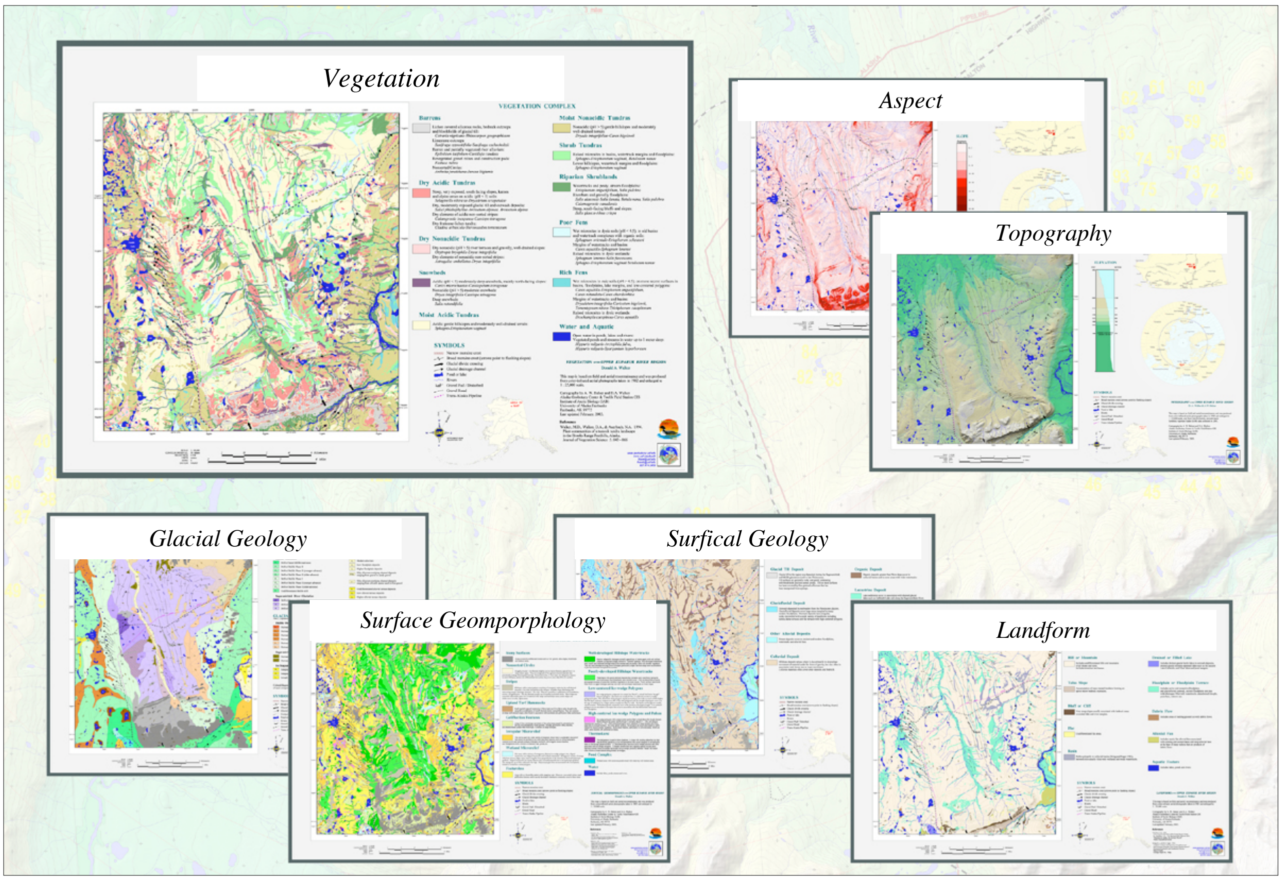
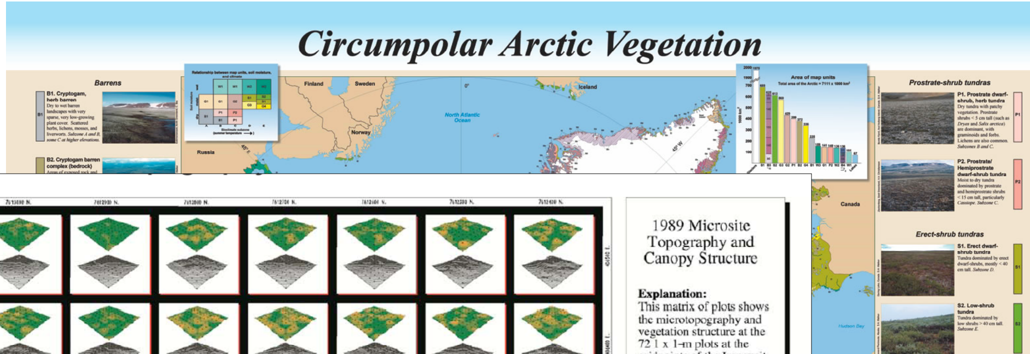


Figure 8. Some map themes available for the upper Kuparuk River basin at 1:25,0000 scale.

Figure 9 shows the Circumpolar Arctic Vegetation Map, a much-reduced version of the recently published 36 x 48-inch map (CAVM Team 2003). This map and the associated database were developed over a period of 10 years in collaboration with vegetation scientists from all the circumpolar countries. The reverse side of the map has nine ancillary data sets that cover the same region north of the Arctic tree line (false-color AVHRR image, bioclimate subzones, floristic provinces, topography, lake cover, landscape units, substrate pH, phytomass, NDVI).

Figures 10 shows a database at the other end of the spectrum of map scales. This map portrays topography of soil surface and the plant canopy within 1-m plots at the grid points of the 1-km grids at Imnavait Creek. Another map (not shown) provides the details of plant species at each 10-cm grid point in the plots. These maps are being used to examine long-term changes in plant canopy structure and composition (M.D. Walker, in prep.)



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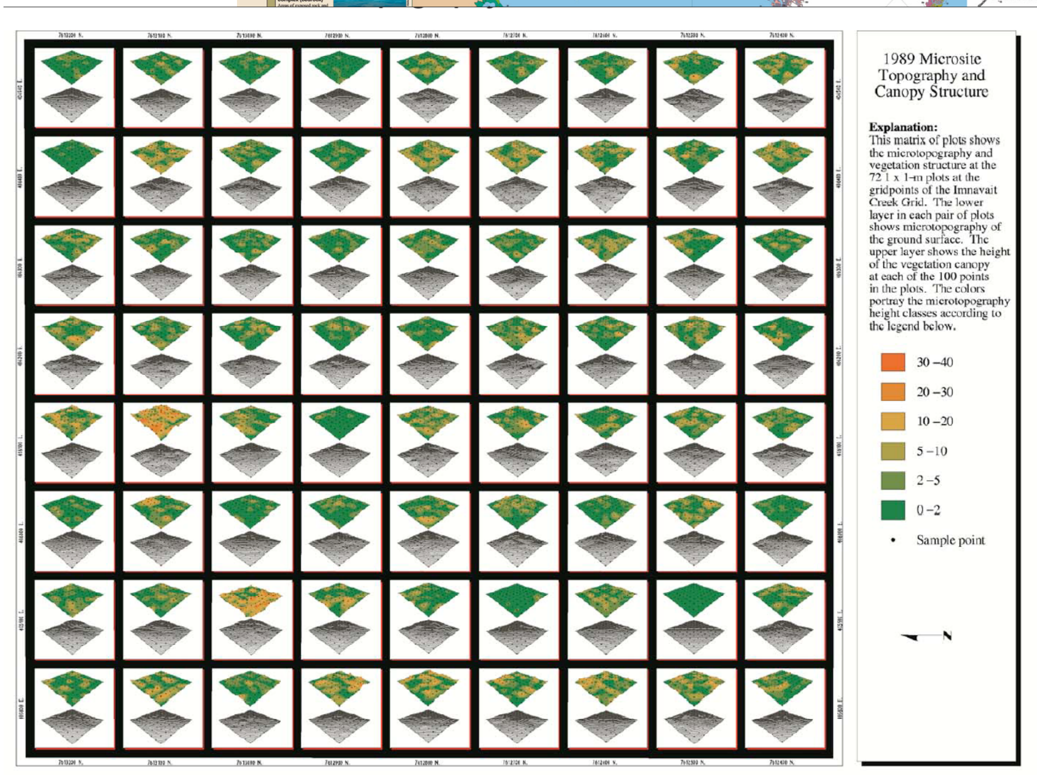


igure 10. Microtopography and plant canopy height of the 1-m plots at grid points of the Toolik ake CALM grid. The plots are spaced at 100 m. The sample points within the plots are spaced at 10-n intervals. Other data layers contain species at each 10-cm sample point for the top and bottom of ıe plant canopy.

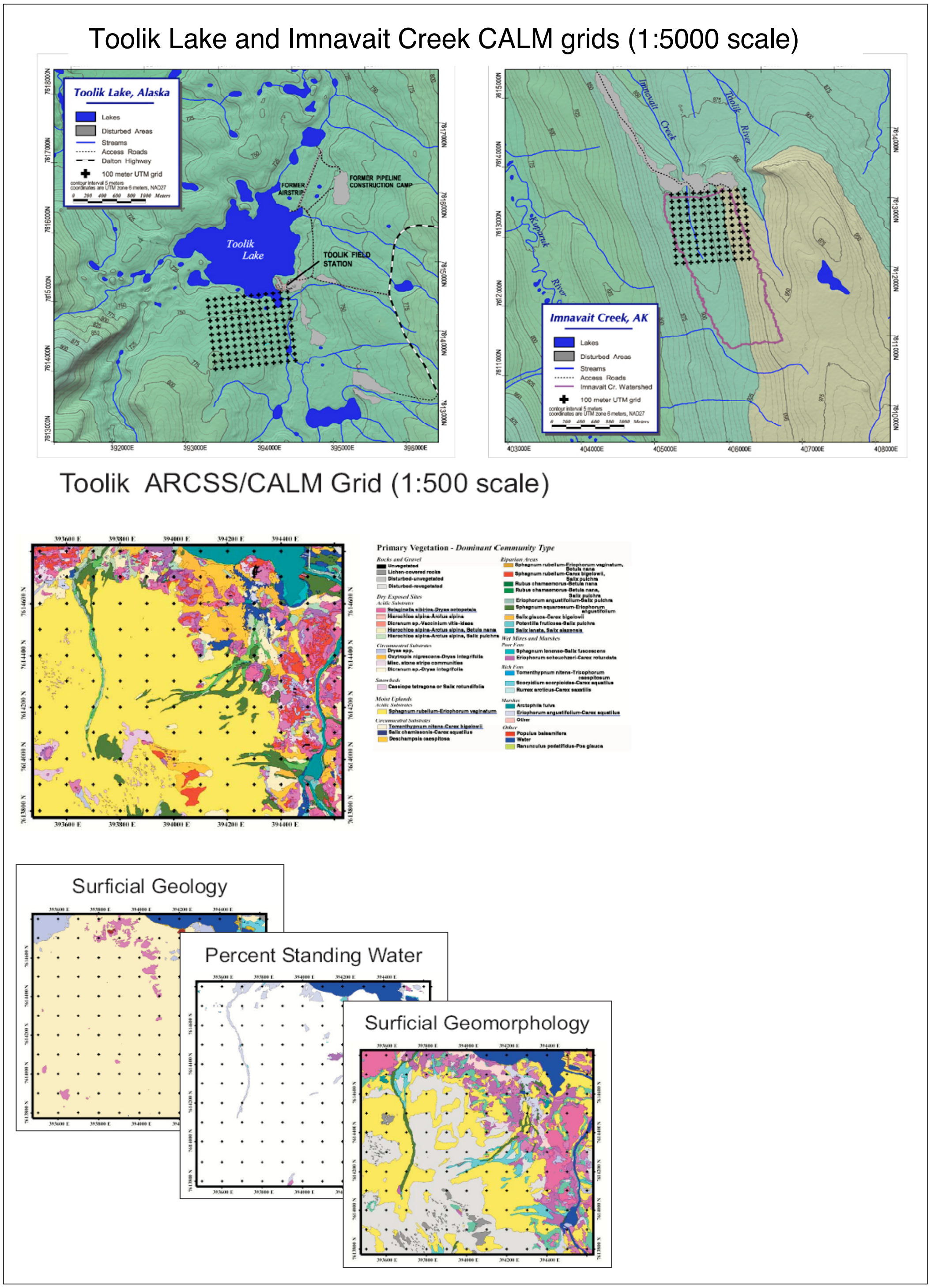


Figure 11. CALM grids at Toolik Lake and Imnavait Creek (upper diagrams). See Figure 5 for location with th Kuparuk River basin. Geobotanical maps have been made of both areas at 1:5000 scale. The lower part of the diagram shows four representative map themes for the Toolik Lake grid at 1:500 scale. Not shown are the high-resolution DEM, landform, NDVI, LAI and biomass maps of the same area.

Figure 11 shows two intermediate scales (1:5000 and 1:500 scale) from the CALM grids. These maps are important for numerous landscape studies at both sites. Snow, active layer depth, soil variables, and vegetation variables are monitored regularly at each grid point in the 1-km grids. Detailed maps of plant-species composition and plant-canopy structure have been made at each grid point.

Over the next few years, we would like to make several additions to the databases. These additions are not part of this proposal, but give some idea of the changes that we are planning: (1) Add a soils attribute to the maps at all scales. Dr. Kaye Everett (deceased, formerly at Ohio State University) helped develop the soils component of the geobotanical maps. Since he passed away in 1995, this component has been missing in the databases. We would like collaborate with Drs. Jim Bockheim and Chein Lu Ping, who now have the longest experience with northern Alaska soils, to fill these holes. (2) Develop a hierarchical database for Happy Valley and other CALM grids, as discussed earlier (Section C.3.1). (3) Develop a geobotanical database for the entire Kuparuk River basin. Currently, this scale of mapping (1:250,000 scale) has only a digital elevation map, and products derived from a Landsat-derived land-cover classification of the basin. (4) Incorporate maps of 10x10-m grids that are part of a biocomplexity-of-frost-boil-ecosystems project (Walker et al. 2003 accepted). This scale of mapping (1:50) is essential for examining the fine details of many periglacial landscapes.

C.5.4 Multiple-year databases (time dimension)

Some of the databases have multi-temporal coverage. Examples include maps of the oil-field infrastructure and related impacts at Prudhoe Bay (Figure 11) and the 1-m plots at Imnavait Creek and Toolik Lake (Figure 10). We are planning to expand the multi-temporal coverage by including satellite-derived AVHRR multi-spectral images of the Arctic Slope for the past 20 years.

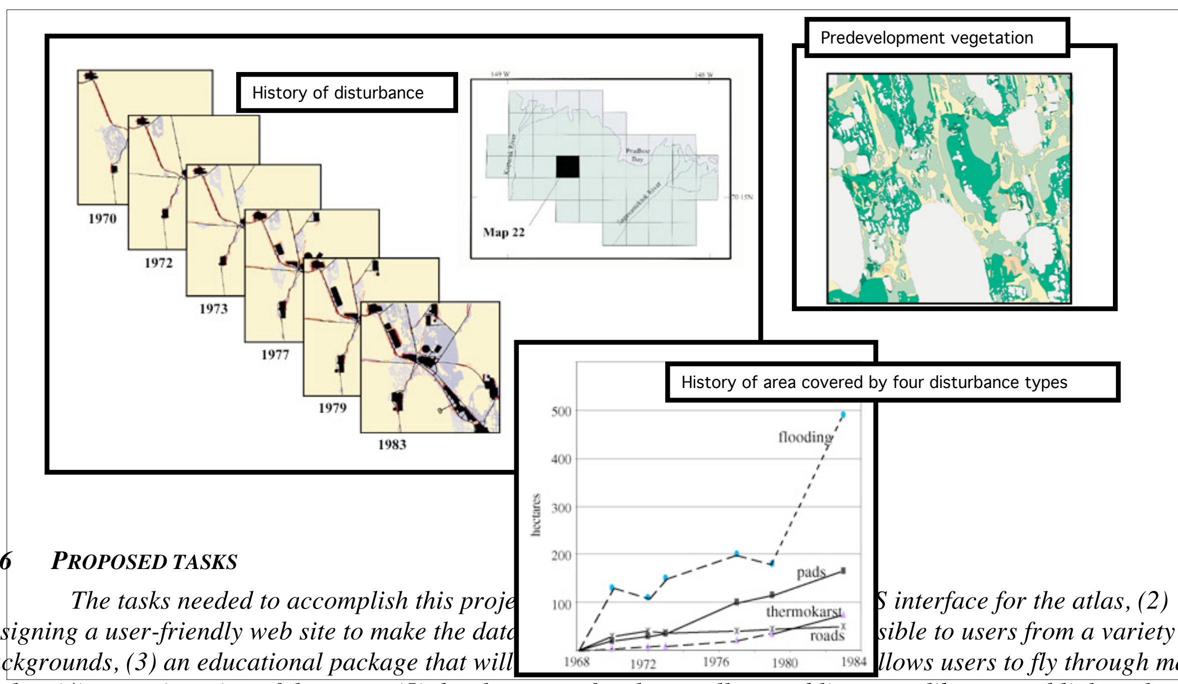


Figure 12. Growth of the industrial infrastructure for a portion of the Prudhoe Bay oil field, 1970-1983. Baseline geobotanical maps were made from aerial photographs taken prior to development (upper right). Trends of several disturbance types are shown in the lower diagram (derived from Walker et al. 1987b).

C.6 PROPOSED TASKS

The tasks needed to accomplish this proje[illegible]S interface for the atlas, (2) designing a user-friendly web site to make the data[illegible]sible to users from a variety of backgrounds, (3) an educational package that will[illegible]llows users to fly through many scales, (4) co-registration of the maps, (5) development of a photo gallery and literature library, and links to key databases such as soils and vegetation data from study plots, (6) writing standardized metadata files necessary to fully document the contents of the database, (7) writing key publications to document the major map themes (vegetation, soils, landforms, glacial geology, etc.), (8) incorporation of spatial analytical tools, and (9) miscellaneous logistical issues, including a high-speed connection to GINA and training and consultation with the Environmental Systems Research Institute (ESRI).

C.6.1 Task 1: IMS programming

Internet Map Server (IMS) technology provides the foundation for distributing high-end GIS and mapping services via the Internet (Dangermond 2002, 2003). It has revolutionized the way users can access and interact with GIS data. Users can integrate data obtained from many sources over the Internet and perform display, query, and analysis functions on line with an easy-to-use Web browser.

The maps in the AGA are in an Arc/Info format. Currently, they are only available over the web in a PDF format, or the raw data can be obtained through a request to the Alaska Geobotany Center or to the Arctic Data Coordination Center (ADCC). This can often take some time, and analysis of the data is not straight forward, especially for users not trained in GIS analysis.

Conversion of the AGA into an IMS format will greatly enhance the use of the maps and spatial data, but the conversion will take considerable effort. We will first need to train our personnel in the use of the software (Task 9), install and configure the software, adapt it to AGA map data, develop appropriate analytical tools for display and analysis of the data, and develop the web-site interface (Task 2). The first two years of the project will focus on developing the Oracle database necessary for the web-based GIS. Other IMS-related activities will stretch over the 4-year length of the project.

C.6.2 Task 2: Web site

We will redesign the current static AGA web site to a dynamic site that will incorporate the IMS interface and the user to interact with the data.. The site will be designed as an educational tool as well as a site where sophisticated GIS analyses can be conducted. The layperson will be able to browse the atlas and learn about the geobotany of the region through maps and photos and a full motion flight simulator (see Task 3). Students may want to use the information in the database to develop their own GIS projects. They will be able to download maps, and do simple queries and GIS analyses. More sophisticated users, who may only be interested in the data, will be able to obtain the ArcInfo files directly over the Internet.

The website framework will be developed mostly during the first two years of the project. The second two years will focus mostly on incorporating information for the photo glossaries, literature libraries, and links to key data sets.

C.6.3 Task 3: Educational package

The AGA will be used in a new Geoinformatics course at UAF (GEOS F378). The course introduces students to geospatial information and analysis. Students will be shown the methods of GPS data acquisition, mapping and field data acquisition, use of remote sensing images, cartographic principles, and concepts of GIS to analyze data. Students will use the AGA web site to develop projects of their own. One of the tools developed for students and the public will be a method to navigate through the various digital elevation models using a 3D "full motion flight" simulator. The DEMs will be overlaid with shape files simulating vegetation and major infrastructure features. Using TerraExplorer software developed by Skyline Software Corp students will be able to enter the Arctic from outer space and view the Arctic Slope and the Upper Kuparuk River region from several elevations. They will be able to fly along prescribed routes to important points of interest, or navigate on their own as in a jet aircraft (or helicopter). Once the educational aspects have been tested at UAF, we will work with high schools in the Fairbanks area and villages to bring this system into a variety of classroom settings. Students in remote villages will be able to look at maps and photographs and data and compare their environment with that of students in other villages. They will also be able to use the AGA data and incorporate local information to develop science projects with the GIS.

C.6.4 Task 4: Co-registration of the maps

Currently, there is a problem moving between scales in the AGA. The same features do not always align well on maps at different scales. This is a particular problem along streams and lakes where geobotanical boundaries at different scales should correspond. At the time the maps were made, high-resolution digital elevation models for the region did not exist. The fine-scale maps at 1:500, 1:5000, and 1:25,000 scales required special DEMs made from aerial photographs taken at low-elevation. Because of the sparse number of ground-control benchmarks in the region, the resulting topographic base maps did not align well in some instances. We are proposing to co-register the data at all scales in the Kuparuk River basin to a high-resolution digital elevation model (DEM) prepared from airborne SAR imagery by Intermap Tecnologies Corp using the Star3i system. These maps have an absolute horizonal accuracy of about 5-m, which is much better resolution than the USGS DEM products. Dr. Matt Nolan, at the UAF Water and Environmental Research Center has worked extensively with these products. We would employ Peter Prokin in Dr. Nolan's lab to help with registration of five of the AGA digital elevation models.

C.6.5 Task 5: Metadata

GIS metadata are a set of strictly defined data field names and field values that provide a common vocabulary for documenting digital geospatial data. Strict field definitions are critical if a dataset is to be properly indexed and located by automated searches performed through data clearinghouses. This is especially critical for IMS applications where the data are shared extensively over the Internet. In recent years, metadata standards have been developed for various types of GIS data. Metadata typically include the data format, the geographic extent, the data quality, the spatial reference and the attribute descriptions. Two major metadata standards exit. The US federal government is required to use the "Content Standard for Digital Geospatial Metadata (version 2.0)", FGDC-STD-001-1998, developed by the Federal Geographic Data Committee (FGDC). The International Organization for Standardization (ISO) recently published standard ISO 19115, Geographic information – Metadata in May 2003. Metadata will be written for all files to satisfy the national GIS metadata standards (Content Standard for Digital Geospatial Metadata, CSDGM). Additional data standards exist for biological data and soils data (FGDC-STD-001.1-1999). Although all of the data sets in the AGA have metadata in some form, most of these files were created before the national standards. We will bring all of the data in the AGA up to federal and international metadata standards and go further with detailed descriptions of the mapped information with links to publications, literature, photographs, and other data sets that fully describe the mapped information (see Tasks 6 and 7).

C.6.6 Task 6: Photo gallery and literature library

A photo gallery has been started for the atlas. This will be expanded with photographs of all the various map units (plant species, vegetation types, landforms, soil units, periglacial features, etc.) The legends on the maps will be linked to photographs of the units, full descriptions of each of the map unit, and PDF files of key literature. Maps of the plot locations for key studies will also be included. For example, a map of the vegetation study plots at Toolik and Imnavait Creek will be linked to photographs of the plots and soils, and complete data regarding site factors, soil analyses, and plant species composition.

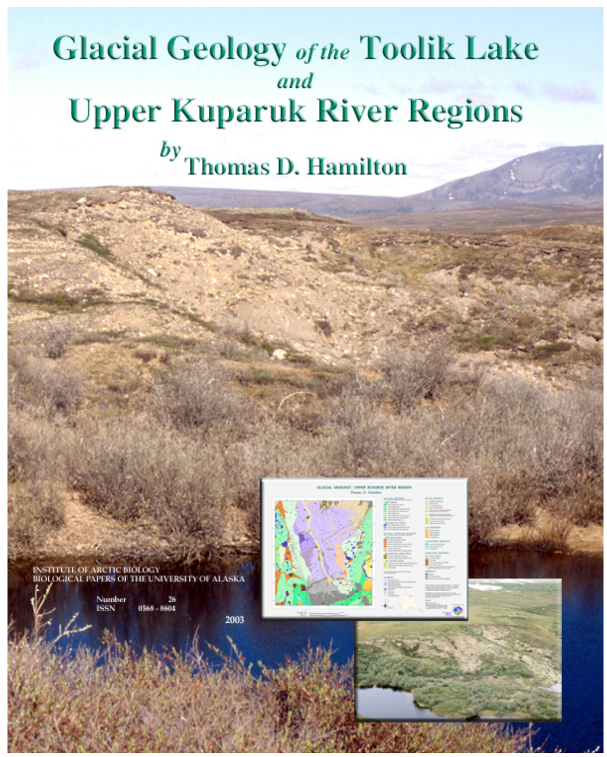


Figure 13. Example of the IAB Biological Paper of the University of Alaska, which will be one outlet for other hard-copy peer-reviewed documentation of the descriptions of the major themes in the Atlas.

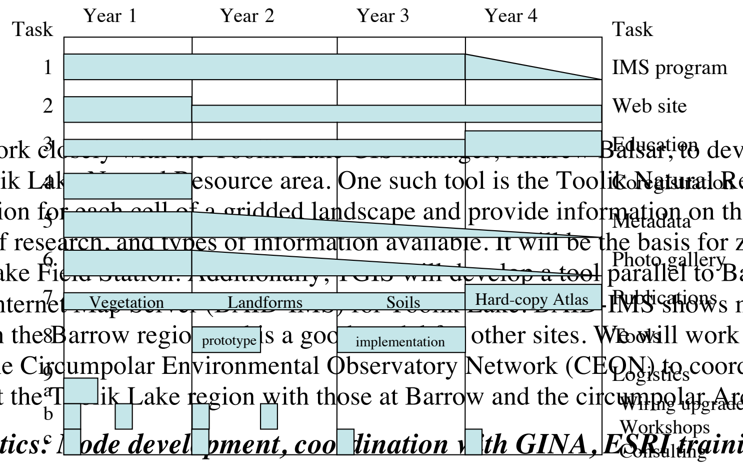
C.6.7 Task 7: Publications of map themes and hard-copy Geobotanical Atlas of the Toolik Lake Region

The documentation of the maps will include peer-reviewed publication of maps and descriptions of the information in the database. One avenue of publication will be through the Institute of Arctic Biology's Biological Papers of the University of Alaska (BPUA) series (Figure 13). Each year a different map theme will be published, vegetation in year 1, landforms and surficial geology in year 2, soils in year 3, and climate and hydrology in year 4. Additional chapters in the atlas will include history of the research in the region, and applications of the various map themes.

A hard-copy *Geobotanical Atlas of the Toolik Lake Region* will be published in year 4. This will include chapters describing the four dimensional framework of the atlas, history of the region, chapters on each of the map themes, with maps at each scale, and example applications and derived products. Appendices in the atlas will contains maps of plot locations, and key data sets for vegetation, and soils.

C.6.8 Task 8: Spatial analysis and management tools

The functionality of the AGA will be improved with incorporation of numerous tools for geostatisitical analysis and modeling. Examples include graphic packages to perform summary statistics, frequency distributions, nearest neighbor analyses, semivariograms, and kriging routines. Some of these tools are available in Arc/Info and will be enhanced with easy-to-use web interfaces. Some modeling tools include viewshed analyses, hill-shading routines for analytical graphical purposes, calculating cut and fill, and cost-weighted disance analysis.



We will also work closely with the Toolik Lake GIS manager, Andrew Balsar, to develop tools for the management of the Toolik Lake Natural Resource area. One such tool is the Toolik Natural Resource Tool, which will synthesize information for each cell of a gridded landscape and provide information on the geobotanical characteristics, history of research, and types of information available. It will be the basis for zoning and tracking research at the Toolik Lake Field Station. Additionally, TGIS will develop a tool parallel to Barrow Area Information Database–Internet Map Server (BAID-IMS) for Toolik Lake. BAID-IMS shows much promise as a tool for managing research in the Barrow region and is a good model for other sites. We will work closely with the BAID-IMS group and the Circumpolar Environmental Observatory Network (CEON) to coordinate GIS site management activities at the Toolik Lake region with those at Barrow and the circumpolar Arctic.

C.6.9 Task 9: Logistics: Node development, coordination with GINA, ESRI training, and consultation

We are requesting funds for help with several logistical items, including linking AGA to GINA, training for AGA personnel, and consulting with ESRI for help in developing our IMS site. AGA is housed in the Arctic Health Building at UAF with a 10 mbps Ethernet connection to the internet. We are proposing to upgrade this to a high-speed 1000 mbps link (estimated cost $10,000).

We are also requesting funds for consultation with the IMS experts at the Environmental Systems Research Institute (ESRI) for help in implementing the AGA. We will involve ESRI early in the project to assure that Oracle database is properly designed to interface with the IMS software. Oracle is used in the ArcSDE (spatial data engine) that interfaces with ArrcIMS for serving the GIS data over the internet. Will periodically consult with ESRI to assure that the web site takes advantage ESRI's knowledge of recent advances in IMS software and applications.

We are also requesting funds to train our current GIS manager, Hilmar Maier, in the techniques of IMS programming, system optimization, and visual basic, four courses are offered by ESRI.

C.7 SCHEDULE

Task 1 (IMS programming and system administration) will span all four years with most of the effort coming in the first three years with installation (year 1), interface development (year 2), and development of the analytical tools (year 3). This task also includes system administration and maintenance, which will be done by Hilmar Maier. Task 2 (web-site development) will be spread over four years, with most of the effort coming in the first 1.5 years. Task 3 (education) will be developed in conjunction with the Geoinformatics course over the first three years, and then introduced to high schools in Fairbanks area and villages. Task 4 (coregistration of the DEMs) will be done in the first year, and will be combined with GPS location of all the study sites in the region and development of the plot location maps. Task 5 (metadata) and Task 6 (photo gallery and literature library) will require most effort in Year 1 and will require less effort in successive years. Task 7 (publications) will be a large task that will span all four years with the most effort coming in Year 4 with writing a hard-copy geobotanical atlas. Task 8 (spatial analysis and visualization tools) will occur mostly after all the maps have been finalized. A prototype flying visualization tool will be developed in Year 2 and implemented in Year 3. Task 9 (logistics) will occur during several workshops throughout the period. The wiring upgrade will occur in Year 1.

D RESULTS OF PRIOR NSF SUPPORT

The maps in the AGA developed over many years during projects funded by NSF, the US Army (CRREL), DOE, USGS, and FWS. The most relevant NSF-funded projects were part of the ARCSS LAII FLUX and ATLAS studies (OPP-9908829 and OPP-9415554) and a subcontract from the Arctic LTER project. The atlas of the upper

Kuparuk River region began during a DOE-funded project called R4D (Walker and Walker 1991). The research grid at Toolik Lake was funded by the LTER project. Publication of this work is in progress and will be part of a book describing research at the Arctic LTER site (Hobbie et al., in prep.) Additional ARCSS 1-km grids were created at Barrow, Atkasuk, Betty Pingo, West Dock, and Happy Valley. These were later incorporated into the CALM network for examining long-term changes to the active layer (Brown et al. 2000, Hinkel et al. 2000). Geobotanical mapping was done at 1:500, 1:5000, and 1:25,000 scales at Toolik Lake and Imnavait Creek and the Upper Kuparuk River region. Landsat-MSS-derived land-cover maps were made for the Kuparuk River basin, (Muller et al. 1998) and northern Alaska (Muller et al. 1999). These maps and associated field studies provided fundamental framework information for the NSF FLUX studies (Fahnestock et al. 1998, Hinzman et al. 1998, Nelson et al. 1998, Reeburgh et al. 1998, Walker et al. 1998, Walker 2000, Walker et al. 2003). The Circumpolar Arctic Vegetation Map was also a component of the ARCSS/LAII ATLAS project (CAVM Team 2003). Numerous publications are related to the CAVM (Walker et al. 1995, 2000, 2002; Walker and Talbot 1997; Gould et al. 2000, 2003; Walker 1995, 1999, 2000). Ground-based vegetation sampling accompanied all the mapping work. Some of these data have been published (Walker et al. 1994; Hamilton, 2003; Walker et al, 2003), but much remains in unpublished data reports (e.g. Walker et al. 1987a, Raynolds et al. 2002). One of the objectives of the proposed work is to incorporate this information into peer –reviewed publications and provide internet links to the data. Many publications resulted from these mapping studies at all scales including analysis of terrain evolution (Evans et al. 1989b); snow-terrain relationships (Evans et al. 1989a), analysis of trace-gas fluxes (Walker et al. 1998, Reeburgh et al. 1998, Fahnstock et al 1998), classification of the foothills tundra vegetation (M.D. Walker et al. 1994), analysis of thaw layer patterns, (Nelson et al. 1997, 1998; Hinkle 2000), analysis of the relationship of vegetation and wildlife to soil pH (Walker et al. 2001) and other publications cited in section C. Starred publications in the references are those resulting from previous NSF funding to D.A. Walker. Six REU students have contributed extensively to these studies resulting in one major publication, one in preparation, and several posters presented at conferences (Muller et al. 1998; Thayer-Snyder, 2000; Wirth and Walker. 2000; Cushing et al. 2002; Munger and Walker 2003; Raynolds et al. 2004 in prep.).

E REFERENCES

Balsar, A. 2002. Toolik Field Station GIS, Annual Report 2002. Institute of Arctic Biology, University of Alaska Fairbanks, Fairbanks, AK.

Brown, J., and R. L. Berg. 1980. Environmental engineering and ecological baseline investigations along the Yukon River-Prudhoe Bay Haul Road. Report 80-19, CRREL, Hanover, NH.

Brown, J., K. M. Hinkel, and F. E. Nelson. 2000. The circumpolar active layer monitoring (CALM) program: research designs and initial results. Polar Geography **24**:165-258.

* CAVM Team. 2003. Circumpolar Arctic Vegetation Map (Scale 1:7,500,000). Conservation of Arctic Flora and Fauna (CAFF) Map No. 1. U.S. Fish and Wildlife Service, Anchorage, AK.

* Cushing, E. E., D. A. Walekr, A. N. Kade, and A. M. Kelley. 2002. Differences in vegetation and thaw depths of frost boils and interboils in acidic and nonaciduc tundra. Pages pp. 88 *in* 53rd Alaska Science Conference: Connectivity in northern waters, University of Alaska, Fairbanks.

Dangermond, J. 2002. Web services and GIS. Geospatial Solutions 12:56.

Dangermond, J. 2003. Serving our world with GIS. ARCNews 25(3):1-6.

Dangermond, J., and E. Harnden. 1990. Map data standardization: a methodology for integrating thematic cartographic data before automation. ARC News 12:16-19.

Evans, B. M., D. A. Walker, C. S. Benson, E. A. Nordstrand, and G. W. Petersen. 1989a. Spatial interrelationships between terrain, snow distribution and vegetation patterns at an arctic foothills site in Alaska. Holarctic Ecology **12**:270-278.

Evans, B. M., D. A. Walker, E. Binnian, N. D. Lederer, E. Nordstrand, and P. J. Webber. 1989b. Terrain, vegetation, and landscape evolution of the R4D research site, Brooks Range foothills, Alaska. Holarctic Ecology **12**:238-261.

Everett, K. R., P. J. Webber, D. A. Walker, R. J. Parkinson, and J. Brown. 1978. A geoecological mapping scheme for Alaskan coastal tundra. Pages 359-365 *in* Proceedings of the Third International Conference on Permafrost. National Research Council of Canada, Edmonton, Alberta, Canada.

* Fahnestock, J. T., M. H. Jones, P. D. Brooks, D. A. Walker, and J. M. Welker. 1998. Winter and early spring CO2 efflux from tundra communities of northern Alaska. Journal of Geophysical Research **103**:29023-29027.

Gough, L., G. R. Shaver, J. Carroll, D. L. Royer, and J. A. Laundre. 2000. Vascular plant species richness in Alaskan arctic tundra: the importance of soil pH. Journal of Ecology **88**:54-66.

* Hamilton, T. D., editor. 2003. Glacial Geology of Toolik Lake and the Upper Kuparuk River Region. University of Alaska Printing Services, Fairbanks, AK.
Hinkel, K. M., F. E. Nelson, J. G. Bockheim, L. L. Miller, and R. F. Paetzold. 2000. Spatial and temporal patterns of soil moisture and depth of thaw at proximal acidic and nonacidic tundra sites, North-central Alaska, U.S. Pages 197-209 *in* R. Lal, J. M. Kimble, and B. A. Stewart, editors. Global Climate Change and Cold Regions Ecosystems. Lewis Publishers, Boca Raton.
Hinzman, L. D., D. J. Goering, and D. L. Kane. 1998. A distributed thermal model for calculating soil temperature profiles and depth of thaw in permafrost regions. Journal of Geophysical Research **103**:28975-28992.
* Jia, G. J., H. E. Epstein, and D. A. Walker. 2003. Greening of arctic Alaska, 1981-2001. Geophysical Research Letters 30, 2067, doi: 10.1029/2003GL1018268.
Jorgenson, J. C., P. E. Joria, T. R. McCabe, B. E. Reitz, M. K. Raynolds, M. Emers, and M. A. Williams. 1994. User's Guide for the land-cover map of the coastal plain of the Arctic National Wildlife Refuge. US Dept. of the Interior, US Fish and Wildlife Service Region 7, Anchorage, AK.
Jorgenson, M. T., J. E. Roth, E. R. Pullman, R. M. Burgess, M. K. Raynolds, A. A. Stickney, M. D. Smith, and T. M. Zimmer. 1997. An ecological land survey for the Colville River Delta, Alaska, 1996. Final Report ABR, Inc., Fairbanks, AK.
Leadly, P. W., H. Li, B. Ostendorf, and J. F. Reynolds. 1996. Road-related disturbances in an arctic watershed: analyses by a spatially-explicit model of vegetation and ecosystem processes. Pages 387-415` *in* J. F. Reynolds and J. D. Tenhunan, editors. Landscape Function and Disturbance in Arctic Tundra. Springer-Verlag, New York.
Liston, G. E. 1999. Interrelationships among snow distribution, snowmelt, and snow cover depletion: implications for atmospheric, hydrologic, and ecologic modeling. Journal of Applied Meteorology **38**:1474-1487.
Melnikov, E. S. 1988. Natural geosystems of the plain cryolithozones. Pages 208-212 *in* Permafrost Proceeding of the Fifth International Permafrost Conference, Trondheim, Norway.
Melnikov, E. S. 1998. Uniting basis for creation of ecological maps for the Russian cryolithozone. Pages 719-722 *in* Proccedings of the Seventh International Conference on Permafrost, Yellowknife, Canada.
* Muller, S. V., A. E. Racoviteanu, and D. A. Walker. 1999. Landsat MSS-derived land-cover map of northern Alaska: extrapolation methods and a comparison with photo-interpreted and AVHRR-derived maps. International Journal of Remote Sensing **20**:2921-2946.
* Muller, S. V., D. A. Walker, F. Nelson, N. Auerbach, J. Bockheim, S. Guyer, and D. Sherba. 1998. Accuracy assessment of a land-cover map of the Kuparuk River basin, Alaska: considerations for remote regions. Photogrammetric Engineering & Remote Sensing **64**:619-628.
* Munger, C. A., and D. A. Walker. 2003. Vegetation of the upper Kuparuk River region in relationship to glacial geology and surficial geomorphology. Poster presented at the 54th Arctic Science Conference, Fairbanks, AK, 22-24 Sep 2003.
* Nelson, F. E., K. M. Hinkel, N. I. Shiklomanov, G. R. Mueller, L. L. Miller, and D. A. Walker. 1998. Active-layer thickness in north-central Alaska: systematic sampling, scale, and spatial autocorrelation. Journal of Geophysical Research **103**:28963-28973.
* Nelson, F. E., N. I. Shiklomanov, G. R. Mueller, K. M. Hinkel, D. A. Walker, and J. G. Bockheim. 1997. Estimating active-layer thickness over a large region: Kuparuk River Basin, Alaska. Arctic and Alpine Research **29**:367-378.
Oechel, W. C., G. L. Vourlitis, J. Verfaillie Jr., T. Crawford, S. Brooks, E. Dumas, A. Hope, D. Stow, B. Boynton, V. Nosov, and R. Zulueta. 2000. A scaling approach for quantifying the net CO2 flux of the Kuparuk River Basin, Alaska. Climate Change Biology **6**:160-173.
Ostendorf, B., P. Quinn, K. Bevan, and J. D. Tenhunen. 1996. Hydrological controls on ecosystem gas exchange in an Arctic landscape. *in* J. F. Reynolds and J. D. Tenhunen, editors. Landscape Function and Disturbance in Arctic Tundra. Springer-Verlag, New York.
Oswald, W. W., L. Brubaker, F. S. Hu, and G. W. Kling. 2003. Holocene pollen records from the central Arctic Foothills, northern Alaska: testing the role of substrate in the response of tundra to climate change. Journal of Ecology **91**:1034-1048.
* Raynolds, M. K., C. R. Martin, D. A. Walker, A. Moody, D. Wirth, and C. Thayer-Snyder. 2002. ATLAS Vegetation Studies: Seward Peninsula, Alaska, 2000: Vegeation, Soil, and Site Information, with Seward Vegetation Map. Alaska Geobotany Center, Institute of Arctic Biology, University of Alaska Fairbanks, ARCSS-ATLAS-AGC Data Report, Fairbanks, AK.
* Reeburgh, W. S., J. Y. King, S. K. Regli, G. W. Kling, N. A. Auerbach, and D. A. Walker. 1998. A CH4 emission estimate for the Kuparuk River basin, Alaska. Journal of Geophysical Research **103**:29005-29014.

* Raynolds, M. A., H. A. Maier, D. A. Walker, and J. Burian. 2004 in prep. Analysis of the distribution of vegetation types in the circumpolar Arctic. Journal of Vegetation Science.
Reynolds, J. F., and J. D. Tenhunen, editors. 1996. Landscape Function and Disturbance in Arctic Tundra. Springer-Verlag, New York.
* Shippert, M. M., D. A. Walker, N. A. Auerbach, and B. E. Lewis. 1995. Biomass and leaf-area index maps derived from SPOT images for Toolik Lake and Imnavait Creek areas, Alaska. Polar Record **31**:147-154.
Sorenson, M., W. Manley, R. D. Crain, and W. K. Warnick, editors. 2001. Recommendations for a Geographic Information Infrastructure to Support Arctic Research: Outcomes of the Arctic GIS Workshop, 22-24 January 2001, Seattle, Washington. The Arctic Research Consortium of the U.S. (ARCUS), Fairbanks, AK.
* Thayer-Snyder, C. 2000. A preliminary Landsat MSS-derived land-cover map of the Seward Peninsula, Alaska: Classification methods, and comparison with existing data sets. Poster presented at the ARCSS LAII Science Workshop, Seattle, WA, 23-26 Feb 2000.
TNC (The Nature Conservancy). 2003, in progress. Ecosystems of Northern Alaska. *in*. Alaska Biological Research, Fairbanks, AK.
* Walker, D. A. 1995. Toward a new circumpolar arctic vegetation map. Arctic and Alpine Research **31**:169-178.
* Walker, D. A. 1999. An integrated vegetation mapping approach for northern Alaska (1: 4 M scale). International Journal of Remote Sensing **20**:2895-2920.
* Walker, D. A. 2000. Hierarchical subdivision of arctic tundra based on vegetation response to climate, parent material, and topography. Global Change Biology **6**:19-34.
* Walker, D. A., N. A. Auerbach, J. G. Bockheim, F. S. I. Chapin, W. Eugster, J. Y. King, J. P. McFadden, G. J. Michaelson, F. E. Nelson, W. C. Oechel, C. L. Ping, W. S. Reeburg, S. Regli, N. I. Shiklomanov, and G. L. Vourlitis. 1998. Energy and trace-gas fluxes across a soil pH boundary in the Arctic. Nature **394**:469-472.
* Walker, D. A., N. A. Auerbach, L. R. Lestak, S. V. Muller, and M. D. Walker. 1996. A hierarchic GIS for studies of process, pattern, and scale in arctic ecosystems: the Arctic System Science Flux Study, Kuparuk River Basin, Alaska. *in* Poster presented at the Second Circumpolar Arctic Vegetation Mapping Workshop, Arendal, Norway, May 20-23, 1996.
* Walker, D. A., C. Bay, F. J. A. Daniëls, E. Einarsson, A. Elvebakk, B. E. Johansen, A. Kapitsa, S. S. Kholod, D. F. Murray, S. S. Talbot, B. A. Yurtsev, and S. C. Zoltai. 1995. Toward a new arctic vegetation map: a review of existing maps. Journal of Vegetation Science **6**:427-436.
Walker, D. A., E. F. Binnian, N. D. Lederer, E. A. Nordstrand, M. D. Walker, and P. J. Webber. 1986a. Cumulative landscape impacts in the Prudhoe Bay Oil Field 1949-1983. Final report Habitat Resources Section, Anchorage, AK.
* Walker, D. A., J. G. Bockheim, F. S. I. Chapin, W. Eugster, F. E. Nelson, and C. L. Ping. 2001. Calcium-rich tundra, wildlife, and the "Mammoth Steppe". Quaternary Science Reviews **20**:149-163.
* Walker, D. A., H. E. Epstein, W. A. Gould, J. A. Knudson, W. B. Krantz, R. A. Peterson, C. L. Ping, M. A. Raynolds, and V. E. Romanovsky. 2003 accepted. Biocomplexity of frost-boil ecosystems: a conceptual model of morphology in relation to vegetation along a bioclimate gradient. Permafrost and Periglacial Processes.
* Walker, D. A., H. E. Epstein, J. G. Jia, C. Copass, E. J. Edwards, W. A. Gould, J. Hollingsworth, J. Knudson, H. Maier, A. Moody, and M. A. Raynolds. 2003. Phytomass, LAI, and NDVI in northern Alaska: relationships to summer warmth, soil pH, plant functional types and extrapolation to the circumpolar Arctic. Journal of Geophysical Research - Atmospheres **108**:8169, doi:8110.1029/2001d00986.
Walker, D. A., K. R. Everett, P. J. Webber, and J. Brown. 1980. Geobotanical atlas of the Prudhoe Bay Region, Alaska. CRREL Report 80-14, U.S. Army Cold Regions Research and Engineering Laboratory.
* Walker, D. A., W. A. Gould, H. A. Maier, and M. K. Raynolds. 2002. The Circumpolar Arctic Vegetation Map: AVHRR-derived base maps, environmental controls, and integrated mapping procedures. Int. J. Remote Sensing **23**:2552-2570.
* Walker, D. A., J. C. Halfpenny, M. D. Walker, and C. Wessman. 1993. Long-term studies of snow-vegetation interactions. Bioscience **43**:287-301.
* Walker, D. A., G. J. Jia, H. E. Epstein, M. K. Raynolds, F. S. Chapin , III, C. D. Copass, L. D. Hinzman, D. Kane, H. Maier, G. J. Michaelson, F. Nelson, C. L. Ping, V. E. Romanovsky, N. Shiklomanov, and Y. Shur. 2003 submitted. Vegetation-soil-thaw-depth relationships along a Low-Arctic bioclimate gradient, Alaska: synthesis of information from the ATLAS studies. Permafrost and Periglacial Processes.
Walker, D. A., N. D. Lederer, and M. D. Walker. 1987a. Permanent vegetation plots: site factors, soil physical and chemical properties, and plant species cover. Data report for R4D Program U.S. Department of Energy.

*Walker, D. A., and S. S. Talbot. 1997. Toward a new circumpolar arctic vegetation map. Arctic Research of the United States **11**:80-81.
Walker, D. A., and M. D. Walker. 1991. History and pattern of disturbance in Alaskan arctic terrestrial ecosystems: a hierarchical approach to analysing landscape change. Journal of Applied Ecology **28**:244-276.
Walker, D. A., and M. D. Walker. 1996. Terrain and vegetation of the Imnavait Creek Watershed. Pages 73-108 *in* J. F. Reynolds and J. D. Tenhunen, editors. Landscape Function: Implications for Ecosystem Disturbance, a Case Study in Arctic Tundra. Springer-Verlag, New York.
Walker, D. A., P. J. Webber, E. F. Binnian, K. R. Everett, N. D. Lederer, E. A. Nordstrand, and M. D. Walker. 1987b. Cumulative impacts of oil fields on northern Alaskan landscapes. Science **238**:757-761.
Walker, D. A., P. J. Webber, M. D. Walker, N. D. Lederer, R. H. Meehan, and E. A. Nordstrand. 1986b. Use of geobotanical maps and automated mapping techniques to examine cumulative impacts in the Prudhoe Bay Oilfield, Alaska. Environmental Conservation **13**:149-160.
*Walker, M. D., D. A. Walker, and N. A. Auerbach. 1994. Plant communities of a tussock tundra landscape in the Brooks Range Foothills, Alaska. Journal of Vegetation Science **5**:843-866.
* Wirth, D., and D. A. Walker. 2000. A comparison of forest composition and structure of old and new growth *Picea glauca* forests of Council, AK. Poster presented at the ARCSS LAII Science Workshop, Seattle, WA, 23-26 Feb 2000.
Zonneveld, I. S. 1988. The ITC method of mapping natural and semi-natural vegetation. Pages 401-426 *in* A. W. Küchler and I. S. Zonneveld, editors. Vegetation mapping. Kluwer Academic Publishers, Boston.

F BIOGRAPHICAL SKETCHES

F.1 DONALD A.(SKIP) WALKER

University of Alaska, Institute of Arctic Biology and Department of Biology and Wildlife, University of Alaska Fairbanks, Fairbanks, AK, USA 99707, Present Telephone: 907 474 2460, Facsimile: 907 474 2459, Email : ffdaw@uaf.edu.

Personal Data

Date of Birth: 16 April 1945, Denver, Colorado
Military Experience: U.S. Air Force, 1963-1969
Social security number: 522-60-7573

Education

1964-1967 U.S. Air Force Academy - Mechanical Engineering, Astronautics
1972 B.A. Environmental Biology, University of Colorado, Boulder
1977 M.A. Environmental Biology, University of Colorado, Boulder
1981 Ph.D. Environmental Biology, University of Colorado, Boulder

Areas of Specialization

Geobotany, Tundra Ecology, Vegetation Mapping, Quantitative Ecology Methods, Vegetation of Northern Alaska, Geographic Information Systems and Remote Sensing, Snow Ecology, Soil-Vegetation Interactions, Disturbance Ecology, Paleo-vegetation of northern Alaska

Positions

Professor, Department of Biology and Wildlife, University of Alaska Fairbanks 1999-
Fellow, Institute of Arctic and Alpine Research, University of Colorado 1986-1999
Co-Director, Tundra Ecosystem Analysis and Mapping Laboratoryn 1986-1999
Assistant Professor (1986-1994), Associate Professor (1994-1998), and Professor (1998-1999) Attendant-Rank, Department of Environmental Population and Organismic Biology, University of Colorado

10 most relevant publications: (Total list includes 1 edited book, 7 book chapters, 52 journal articles, 38 other publications including refereed government reports, 8 book reviews, 47 conference papers and lectures (14 invited), 39 conference posters, 49 reports and maps to government agencies and consulting firms, 2 theses..

CAVM Team. 2003. Circumpolar Arctic Vegetation Map (Scale 1:7,500,000). US Fish and Wildlife Service, Anchorage, AK, Conservation of Arctic Flora and Fauna (CAFF) Map No. 1.

Gould, W. A., M. A. Raynolds, and D. A. Walker. 2003. Vegetation, plant biomass, and net primarty productivity patterns in the Canadian Arctic. Journal of Geophysical Research 108:ALT 8-1 to 8-14.

Gould, W. A., D. A. Walker, and D. Biesboer. 2003. Combining research and education: Bioclimate zonation along a Canadian Arctic transect. Arctic 56:45-54.

Jia, G. J., H. E. Epstein, and D. A. Walker. 2002. Spatial characteristics of AVHRR-NDVI along latitudinal transects in northern Alaska. Journal of Vegetation Science 13:315-326.

Jia, G. J., H. E. Epstein, and D. A. Walker. 2003. Greening of arctic Alaska, 1981-2001. Geophysical Research Letters 30, 2067, doi: 10.1029/2003GL1018268.

Walker, D. A. 2000. Hierarchical subdivision of arctic tundra based on vegetation response to climate, parent material, and topography. Global Change Biology 6:19-34.

Walker, D. A., H. E. Epstein, J. G. Jia, C. Copass, E. J. Edwards, W. A. Gould, J. Hollingsworth, J. Knudson, H. Maier, A. Moody, and M. A. Raynolds. 2003. Phytomass, LAI, and NDVI in northern Alaska: relationships to summer warmth, soil pH, plant functional types and extrapolation to the circumpolar Arctic. Journal of Geophysical Research - Atmospheres 108:8169, doi:8110.1029/2001d00986.

Walker, D. A., G. J. Jia, H. E. Epstein, M. A. Raynolds, F. S. Chapin , III, C. D. Copass, L. Hinzman, J. A. Knudson, H. Maier, G. J. Michaelson, F. Nelson, C. L. Ping, V. E. Romanovsky, and N. Shiklomanov. 2003. Vegetation-soil-thaw-depth relationships along a low-arctic bioclimate gradient, Alaska: Synthesis of Information from the ATLAS Studies. Permafrost and Periglacial Processes 14:103 - 123.

Walker, D. A., W. A. Gould, H. A. Maier, and M. K. Raynolds. 2002. The Circumpolar Arctic Vegetation Map: AVHRR-derived base maps, environmental controls, and integrated mapping procedures. Int. J. Remote Sensing 23:2552-2570.

Walker, D. A., J. G. Bockheim, F. S. I. Chapin, W. Eugster, F. E. Nelson, and C. L. Ping. 2001. Calcium-rich tundra, wildlife, and the "Mammoth Steppe". Quaternary Science Reviews 20:149-163.

U.S. collaborators in the past two years: Chien-Lu Ping, University of Alaska; Dr. Vlad Romanovsky, University of Alaska; Dr. William Krantz, University of Cincinnati; Dr. Howard Epstein, University of Virginia; Dr. Stephen Talbot, USFWS, Anchorage; Dr. Jiong Gia, Colorado State University; Dr. Gennadiy Tipenko, University of Alaska; Dr. Yuri Shur, University of Alaska.

G SUMMARY PROPOSAL BUDGET

G.1 BUDGET JUSTIFICATION

G.1.1 Personnel and salaries

Dr. D.A. Walker will be the project's principal investigator. He has 34 years experience in Arctic Alaska vegetation, soils, remote sensing, and geographic information systems. He is on a 50% FTE and is requesting 3 mo salary support per year. He is also funded for 3 mo/yr from an NSF Biocomplexity award.

Hilmar Meier (10 mo/yr) is the GIS technical expert and system manager. Hilmar has 14 years experience working with GIS in several jobs including BLM, USFWS, Alaska Department of Fish and Game, and has worked in the Alaska Geobotanical Center for four years. He will assist with many of the GIS and mapping aspects of the project. He is currently funded for 2 mo/yr from an NSF Biocomplexity award. He will develop the ArcIMS interface, and do all of the GIS and remote sensing work involved with the project, help in the development of the web site, and perform the system management duties.

Christine Martin (6 mo/yr) will develop the web site with help from Chris Shock at IAB, who is an expert at web-site design, and Peter Prokin in the UAF Water and Environmental Research Center, who will help adapt the Skyline Software "flight simulator" tool for the web site. Chris is budgeted for 3 months in Year 1 and 1 month in the following years. Peter is budgeted for 2 mo/yr.

G.1.2 Permanent equipment

No permanent equipment is requested.

G.1.3 Travel

Travel is requested for two people to attend and present papers at two ESRI conferences in years 2 and 4 of the project. Four round-trip plane fares are budgeted at $700 each. Hotel and per diem expenses are budgeted at $200/day/person. Conference registration is budgeted at $300 per person per conference.

G.1.4 Participant support

We are requesting funds for Hilmar Maier to attend four ESRI training sessions. The workshops include Introduction to ArcIMS, ArcIMS Administration, Customizing ArcIMS using ArcXML, and Customizing ArcIMS Using HTML and Javascript. Tuition for the workshops averages about $1300/workshop. Air fare ($700 RT per workshop), hotel and per diem (4 days @$200 per day) are also requested.

G.1.5 Other direct costs

Supplies/Instrumentation:

We are requesting some supplies for the production of the maps including ink cartridges for the plotter ($600/yr), paper ($1000/ year), Other miscellaneous supplies related to plotter and workstation maintenance are budgeted at $1000 year based on previous years experience.

Consulting Services

We are requesting a total of $25,000 for consulting services from ESRI to help in various aspects of the project. Most critical are the design of the Oracle databases required for the Arc Spatial Data Engine that will link with ArcIMS for serving the Atlas data over the web.

G.1.6 Indirect costs

An agreed **modified total direct cost (F&A)** rate is set at 51.3% by the University of Alaska Fairbanks. All professional and technician salaries are increased 3% annually. All materials and service costs are estimates based on current information available at the time of the writing.

H CURRENT AND PENDING SUPPORT

	Source	Title	Amount	Period	Commitment	Location
D.A. Walker	NSF	Arctic climate change, substrate, and vegetation	$375,000	1998-2003 (with one year extenstion in progress)	0 mo	University of Alaska
	Ecosystem Center	GIS support for Arctic LTER project	$15,000/y	1999-2005	0 mo	University of Alaska
	NSF	Biocomplexity associated with beigeochemical cycles in arctic frost-boil ecosystems	$2,725,127	2001-2006	3 mo/yr	University of Alaska

I FACILITIES, EQUIPMENT, AND OTHER RESOURCES

I.1 ALASKA GEOBOTANY LAB, UNIVERSITY OF ALASKA FAIRBANKS

The mission of AGC is to explore and understand global tundra ecosystems and to foster responsible land use and conservation of these systems. The Center is dedicated to excellence in field research, teaching and making our teaching and research relevant to societal issues and concerns. Interdisciplinary geobotanical research involves the cooperation among vegetation scientists, soil scientists, hydrolgists, geologists, geographers, permafrost specialists, and other involved in Earth system research. Our primary areas of interest are climate change, paleoecology, vegetation classification and analysis, geobotanical mapping, snow ecology, and disturbance ecology in northern regions.

NEAML's lab facilities include equipment to support vegetation and soil field research and computer equipment to support GIS and remote-sensing work. AGC's current computing resources include a total of 14 GIS workstations, personal workstations, portable notebook computers, file servers and web servers. The AGC maintains a full complement of high-end software and peripheral devices to support our GIS and remote-sensing environment, allowing us to perform advanced GIS analysis, image processing and graphic layout on the Unix, Macintosh and Intel platforms. The major software packages currently used at AGC include ARC/Info Workstation, ArcView and ArcGIS (Environmental Research Systems, Inc.) for geographic information system analysis and cartographic design, ENVI (Research Systems, Inc.) and Land Analysis System (USGS) for manipulation and analysis of multi-spectral remote sensing data, Photoshop (Adobe Systems, Inc.) for editing graphic images and Studio MX (Macromedia, Inc.) for website development and graphic production.

For supporting plant research, AGC is equipped with a plant-canopy analyzer, an LAI meter, a line-quantum sensor, and spectrometers. AGC also maintains a plant/soils lab complete with dryers and freezers. To support field research in Alaska and other remote locations, NEAML is equipped with camping gear, field gear. AGC is located in the Institute of Arctic Biology (IAB) at the University of Alaska Fairbanks. The facilities of the Institute include a well-staffed administrative office, and a library specializing in northern topics.