Progress Report for NASA grant NAG5-6275
The Role of Land-Cover Change in the High Latitude Ecosystems: Implications for the Global Carbon Cycle

(April 1998)

Principal Investigator: A. David McGuire

Address: Institute of Arctic Biology
216 Irving I Building
University of Alaska Fairbanks
Fairbanks, AK 99775

Voice Phone: 907-474-6242
Fax Phone: 907-474-6716
Email: ffadm@aurora.alaska.edu

Statement of Proposed Research and Scope of Progress Report

The land cover of northern boreal regions is likely to change substantially during the next century because of disturbances related to climate change, fire, logging, and insects. Changes in land cover of high latitude regions may potentially affect the earth's climate system by influencing the global carbon cycle. In our proposal (LCLUC-0016) we proposed a study focused on Alaska to develop a prototype spatially explicit modeling framework capable of using satellite-derived data to estimate how changes in land cover cause changes in ecosystem carbon storage at high latitudes. Our strategy for this study involves four tasks: (1) development of spatially explicit contemporary land-cover data sets in Alaska; (2) development of transient spatially explicit land-cover data sets for the historical satellite record in Alaska; (3) development of a successional biogeochemical model; and (4) application of the modeling framework for estimating the consequences of land-cover change on terrestrial metabolism in retrospective, contemporary, and prognostic analyses. This report summarizes progress between 15 August 1997, the start date of the study, and 15 April 1998. We focus separately on progress related to recruitment of project personnel, development of contemporary and historic land-cover data sets, and development and application of the successional biogeochemical model.

Recruitment of Project Personnel

We have recruited four individuals who are partially or fully funded under this project: Dr. Rose Meier, Mr. Qianlai Zhuang, Mr. Matt Macander, and Ms. Karen Clyde. Dr. Rose Meier, who is the laboratory manager of the Spatial Ecology Laboratory (supervised by McGuire), is the GIS specialist on the project and is primarily responsible for acquisition of data sets, archival of data sets, organization of model inputs, model application, and processing/archival of model output. Mr. Qianlai Zhuang, a Ph.D. graduate student on the project supervised by McGuire, is primarily responsible for developing a successional biogeochemical model for high latitude ecosystems. Mr. Matt Macander, a M.S. graduate student supervised by Verbyla, is primarily responsible for development of change-detection algorithms relevant to detection of disturbance in high latitudes from satellite imagery. Ms. Karen Clyde, a M.S. graduate student supervised by Verbyla, is primarily responsible for land-cover classifyication of satellite imagery.

Development of contemporary and historic land-cover data sets

The development of contemporary and historic land-cover data sets are needed to link with the biogeochemical model for understanding how these landscape changes influence the carbon budget of high latitude ecosystems. To investigate different types of disturbance, we are focusing the development of land-cover data sets on four regions of Alaska (see Figure 1): Tanana River Valley (fire and logging), Copper River Valley (insect infestation), North Slope (climate change), and Seward Peninsula (climate change). For each of these regions, we have identified and acquired a number of spatially explicit data sets and imagery that span the time period from the 1950's to the present (Tables 1-4). Important data sets and imagery acquired include (1) a GIS data set of fire polygons, (2) GIS data sets of insect infestation, logging, and tree inventory, (3) "contemporary" vegetation classifications funded by agencies, (4) aerial photography, and (5) MSS and TM imagery.

To obtain spatially explicit data sets we met with a number of agencies to explain our project. The USGS Alaska Field Office of the EROS Data Center agreed to collaborate with us and help us acquire imagery and other data sets for Alaska. We also met with the Regional Office of the National Park Service (NPS) to indicate our interest in a project funded by the NPS to create a "contemporary" vegetation map of the Copper River Valley region based on TM imagery. This has led to the development of a no-cost proposal by McGuire and Verbyla to the NPS to share information between the NPS project and our LCLUC project. We also met with the Bureau of Land Management regional personnel, who agreed to share their "contemporary" vegetation maps based on TM imagery (see Figure 2) as well as their ground truth data. We also met with personnel of the Alaska Department of Natural Resources, who agreed to share GIS data sets of insect infestation, logging, and tree inventory with our project. Finally, Dr. Eric Kasischke, who is a principal investigator on another high latitude LCLUC project, has generously shared his GIS data set of fire timing and extent for Alaska. This data set, which has annual temporal resolution and approximately 1-km spatial resolution, was developed in collaboration with the Alaska Fire Service of the Bureau of Land Management.

Presently, we are classifying two TM scenes from Interior Alaska that range from the north slope of the Alaska range to the Yukon River (Figure 3). We compared these scenes with the fire extent and timing data set provided by Dr. Kasischke (Figure 4). This comparison verified that the fire data set was quite accurate and the substantial fire disturbance has occurred in these scenes during the last five decades (Figure 3). To develop contemporary land-cover data sets for the two scenes, we are using TM scenes acquired on 22 June 1991. We have finished classifying the vegetation from the southern scene (Figure 5) and are in the process of classifying the vegetation in the northern scene. To classify the vegetation, each TM scene is rectified to the UTM projection using nearest neighbor resampling. The rectification model is an affine transformation based on at least 30 well distributed control points and a RMS error of less than 1 pixel. Rectified images are then stratified prior to classification. The stratification process is hierarchical. The rational is to control for spectral response variation due to highly reflective pixels such as snow, clouds, sand and due to topography. Once this variation has been reduced via stratification, each strata is separately classifed. The classified strata are then combined to produce the land cover classification for the entire scene. For additional details of the classification please see our project web page (http://alces.sel.uaf.edu/spatial.html). Once we have developed contemporay land-cover classifications, we will use historic TM/MSS imagery and aerial photography to develop historic land-cover data.

Development and application of the successional biogeochemical model

The successional biogeochemical model, which is based on a transient version of the Terrestrial Ecosystem Model (TEM), is being designed so that it can operate in either a diagnostic or prognostic mode. In the diagnostic mode the model uses the timing of disturbance identified in the transient land-cover data sets to model ecosystem recovery from disturbance. Retrospective analyses with the diagnostic mode of the model are necessary for testing the dynamics of ecosystem recovery in the model. This testing will be important for establishing confidence in applying the prognostic mode of the model, which will predict simultaneous responses of land-cover and ecosystem function to global change. The prognostic mode of the model will consider land-cover change driven by ecological process and land-cover change driven by human land use. The development of a capability to predict the pattern of ecological land-cover change will build on an ongoing collaboration that is using TEM to develop a dynamic ecosystem/vegetation model.

Most of our efforts have focused on development of a successional biogeochemical model that operates in diagnostic mode (TEM version 4.3 TEM). Briefly, this version of the model prescribes initial ecosystem losses of carbon and nitrogen associated with disturbance and then simulates subsequent changes in ecosystem carbon and nitrogen. Prescriptions of initial losses depend on disturbance type and are based on literature estimates. For global ecosystems, we have parameterized the model for disturbance associated with the conversion of land for agricultural purposes in 18 upland vegetation types. We are presently using this parameterization to simulate historical carbon dynamics associated with changes in historical CO_2, climate, and agricultural land use for the time period 1860 to present in the Carbon Cycle Model Linkage Project (CCMLP); McGuire is the leader of the CCMLP task comparing simulations of the terrestrial biosphere models under this protocol.

In our LCLUC project, we have parameterized the diagnostic successional biogeochemical model for fire and logging disturbance in boreal forest. We are presently organizing data from a literature survey of changes in carbon storage that are associated with disturbance in boreal forest. These data will be used in additional model development and testing. Because changes in the thermal regime are substantial when boreal forest is disturbed, we have also focused attention on modeling the thermal regime based on the properties of moss cover, organic matter, mineral soil, and snow depth/density. Because the successional biogeochemical model operates at the monthly scale, we have first focused our attention on modification of a thermal model that uses daily temperature so that it operates on monthly data. We are collaborating with Dr. Vladimir Romanovsky, an expert on thermal modeling of permafrost-dominated soils in this temporal aggregation study. Preliminary results are promising (see Figure 6).

We are presently organizing a simulation to model changes in carbon storage associated with fire disturbance in the two TM scenes of focus in the Tanana River Valley. To conduct a simulation for these scenes requires organization of temporally explicit climate and disturbance data sets at 1-km resolution. In these simulations, we will conduct sensitivity analyses of different parameterizations, formulations, and conceptualizations to identify the most important issues that need to be addressed for reducing uncertainties. Our focus during the next year will be to reduce uncertainties in the diagnostic mode of the successional biogeochemical model before turning our attention to the prognostic mode of the model.

Figure 1

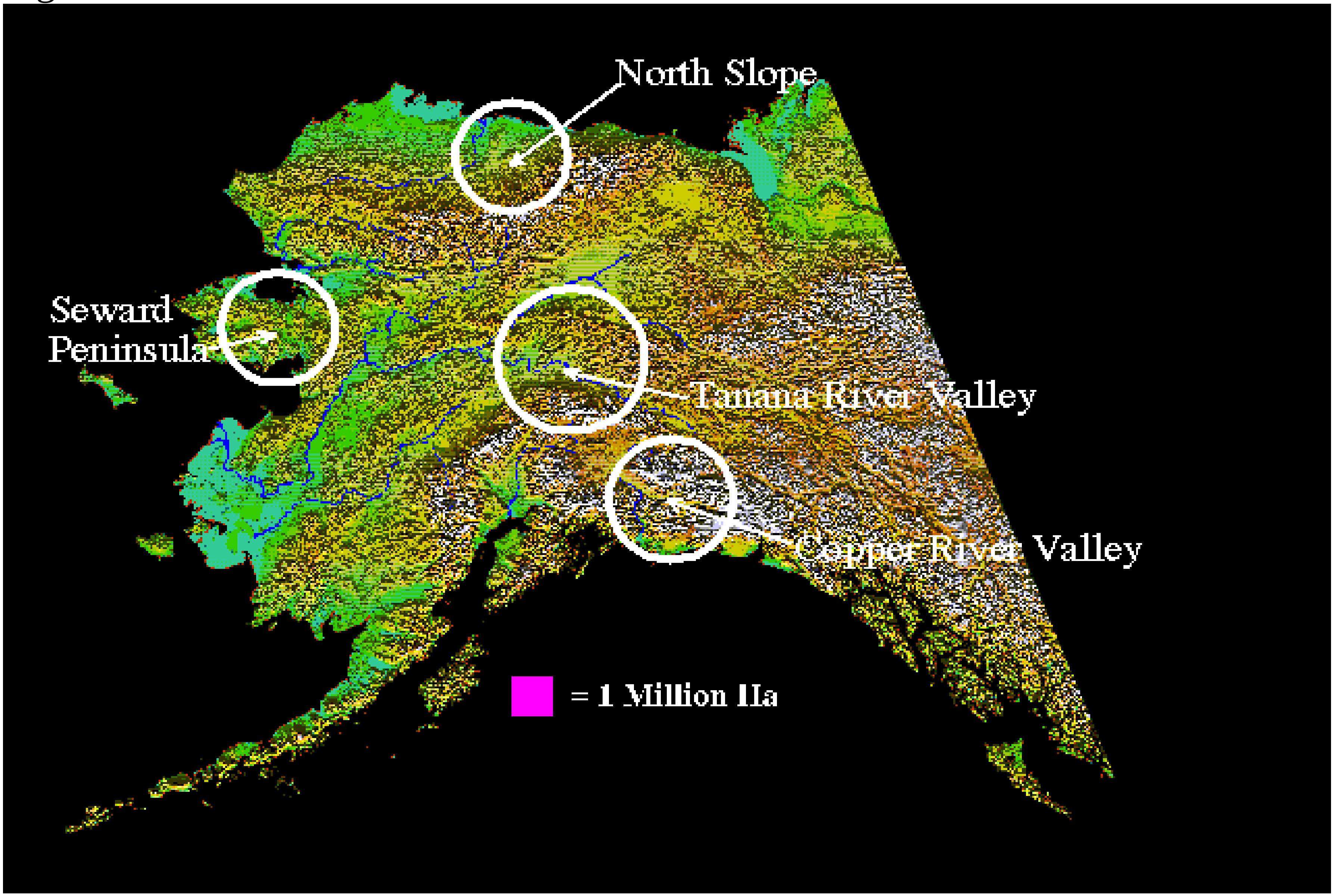

North Slope
Seward Peninsula
Tanana River Valley
Copper River Valley
= 1 Million Ha

Figure 2

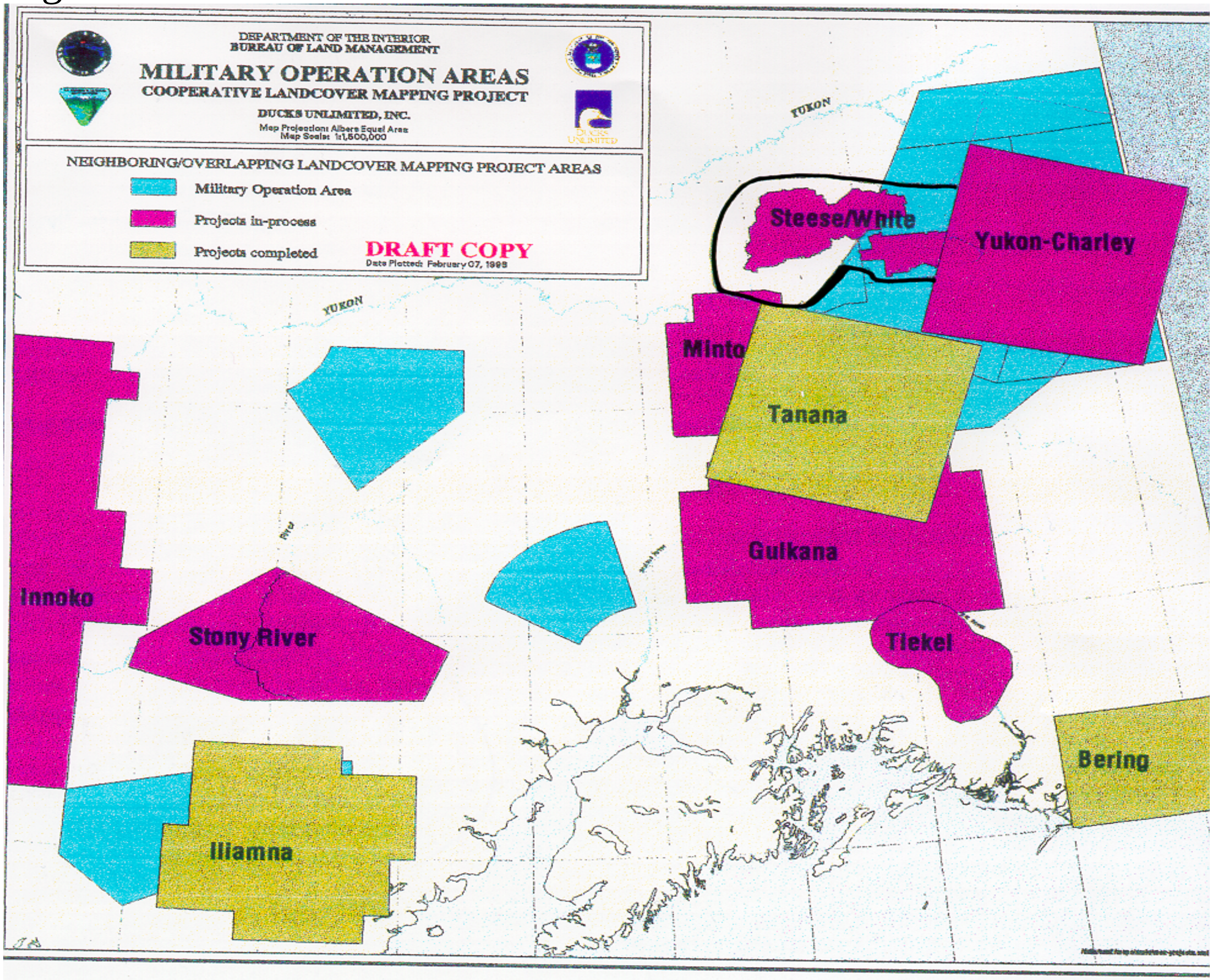

DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT
MILITARY OPERATION AREAS
COOPERATIVE LANDCOVER MAPPING PROJECT
DUCKS UNLIMITED, INC.
Map Projection: Albers Equal Area
Map Scale: 1:1,500,000
DUCKS UNLIMITED
NEIGHBORING/OVERLAPPING LANDCOVER MAPPING PROJECT AREAS
Military Operation Area
Projects in-process
Projects completed
DRAFT COPY
Date Plotted: February 07, 1998
YUKON
YUKON
Steese/White
Yukon-Charley
Minto
Tanana
Gulkana
Tiekel
Innoko
Stony River
Bering
Iliamna

Figure 3: Interior Alaska Boreal Forest Study Area

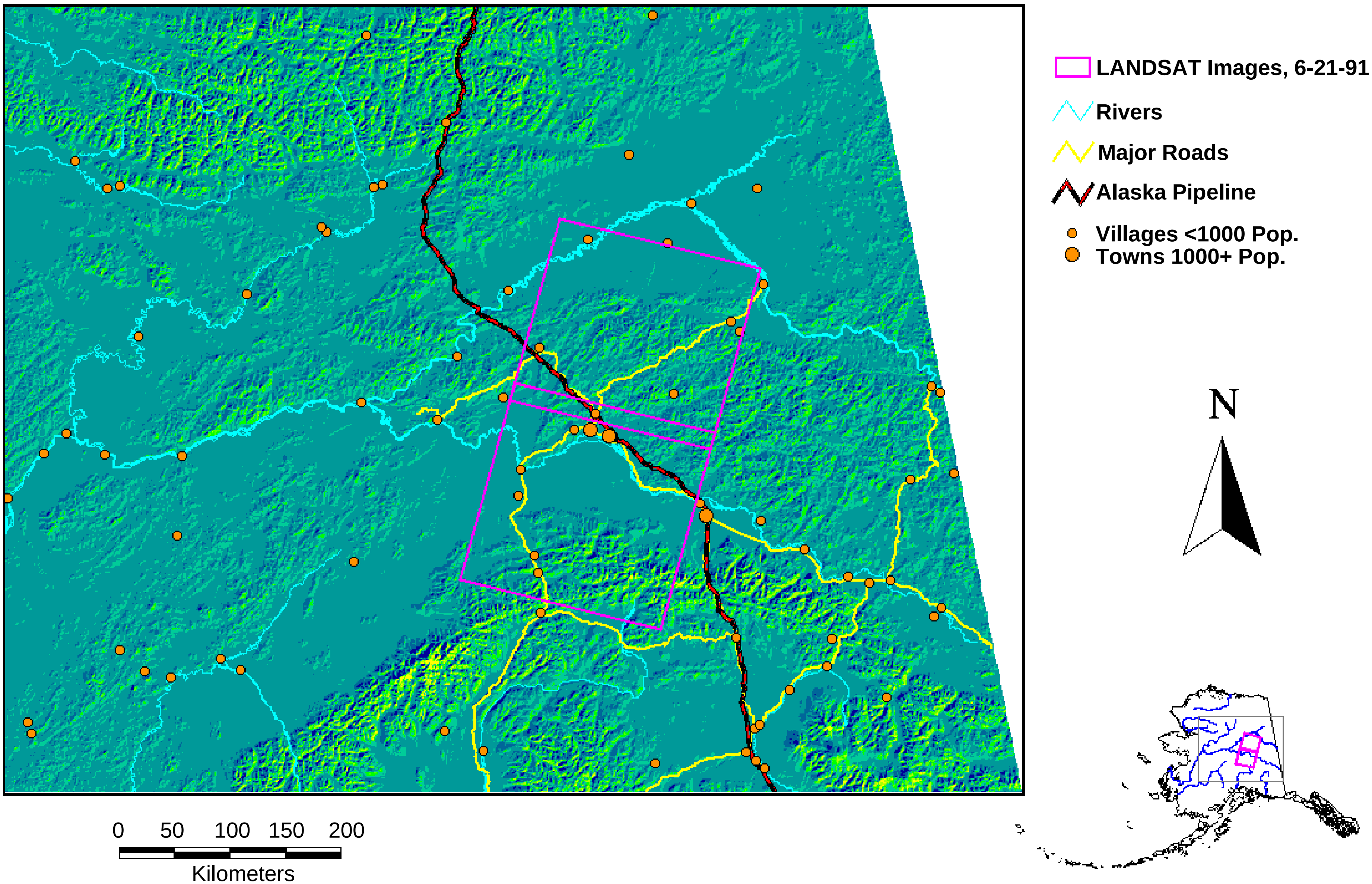


Figure 4

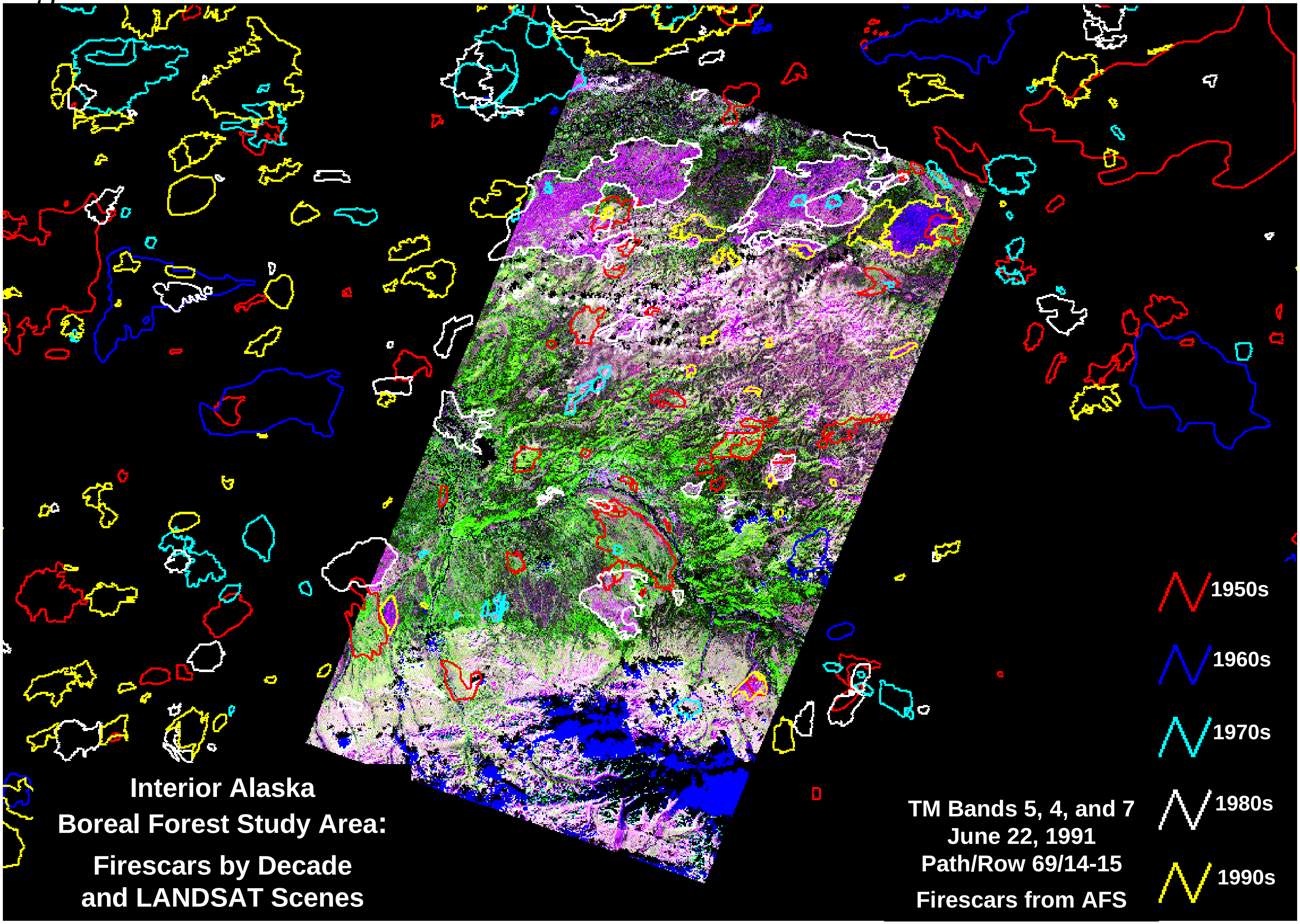
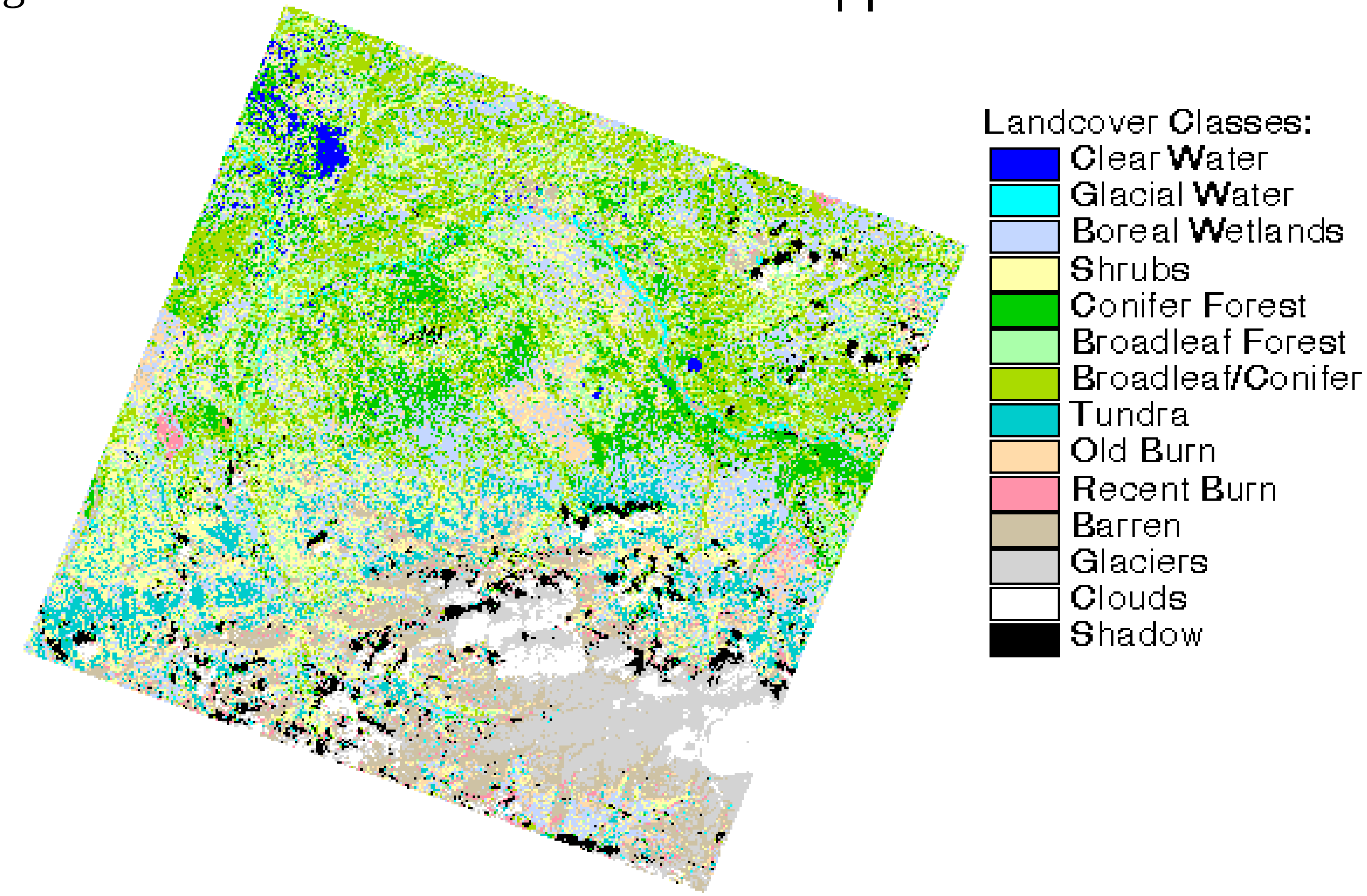

Interior Alaska
Boreal Forest Study Area:
Firescars by Decade
and LANDSAT Scenes
1950s
1960s
1970s
1980s
1990s
TM Bands 5, 4, and 7
June 22, 1991
Path/Row 69/14-15
Firescars from AFS

Figure 5: 1991 Landsat Thematic Mapper Classification



Land cover classification of path 69/row 15, Alaska Range north to Tanana Uplands in Interior Alaska

Figure 6 Soil Temperature (0.24m)

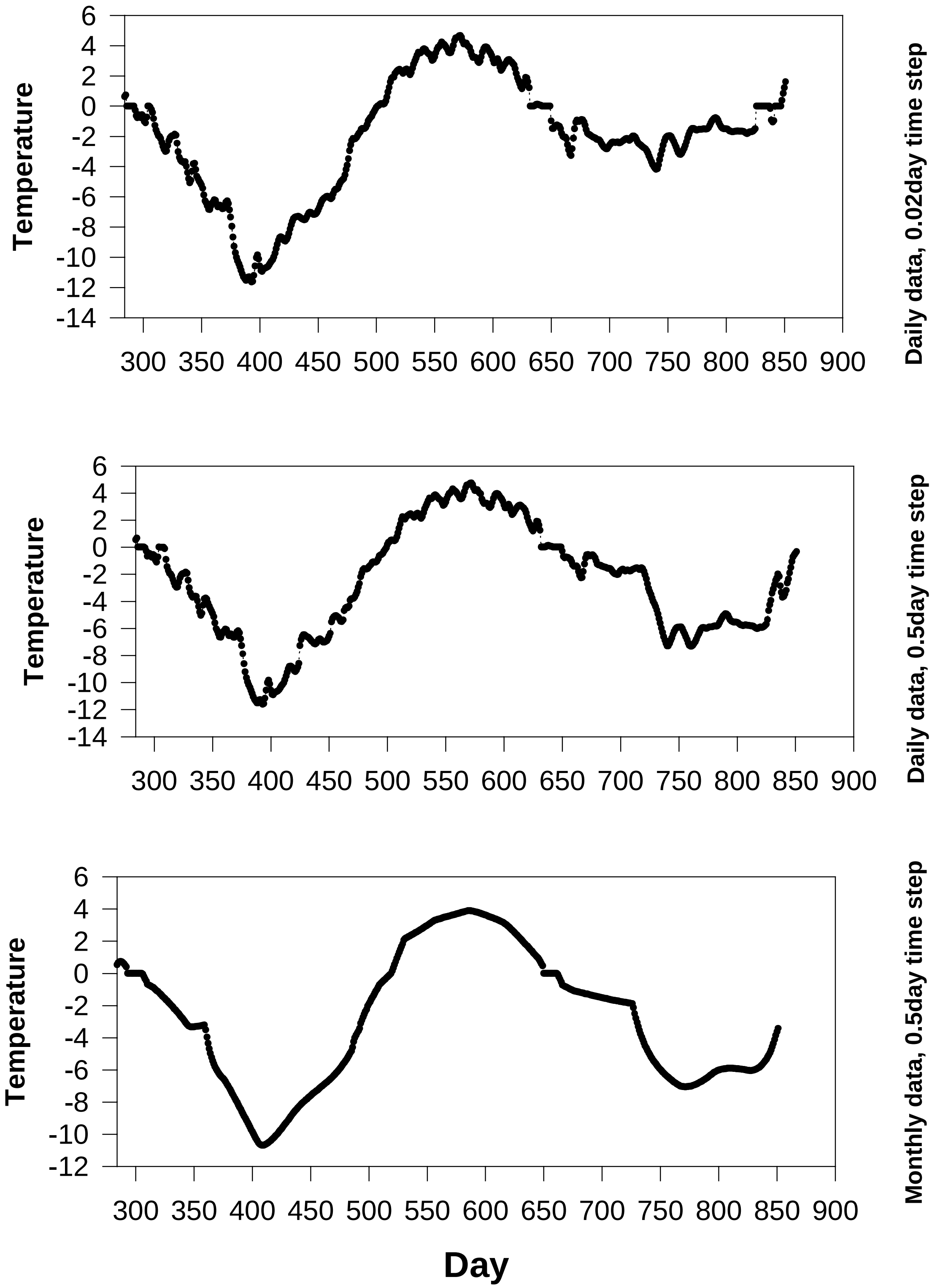


Table 1

Data Sets for Land-Cover Change in High Latitude Ecosystems: Interior Region - Tanana Valley, Alaska

Decade	*Data*	*Dates*	*Source*
1950's to 1990's	**Fire polygons: GIS**	**---**	**BLM /AFS/EK**
	Aerial photos	**---**	**USGS /GI – UAF**
1970's	**MSS Landsat 1-3**	**6/20/74, 7/6/76, 8/24/77, 7/27/74, 8/11/78, 7/1/79**	**EDC**
1980's	**TM Landsat 4,5**	**5/23/86, 6/5/86, 5/23/86, 6/8/86, 7/1/86, 6/15/86, 6/15/86, 7/1/86**	**EDC**
	Insect infestation: GIS	**1987 to present**	**Alaska DNR**
1990's	**TM Landsat 4,5**	**6/22/91, 6/29/91, 8/10/92, 8/19/92, 9/9/94**	**EDC**
	TM Landsat 4,5 Vegetation: GIS	**---**	**BLM**
	MSS/TM Landsat 4,5, Vegetation	**6/22/91, 9/9/94**	**Verbyla, Co-PI, UAF**
	Logging: GIS, Tree inventory: GIS	**1991-1994**	**Alaska DNR**

Table 2

Data Sets for Land-Cover Change in High Latitude Ecosystems: Southcentral Region - Copper River Basin, Alaska

Decade	*Data*	*Date*	*Source*
1950's to 1990's	**Fire polygons: GIS**	**---**	**BLM /AFS/EK**
	Aerial photos	**---**	**USGS /GI – UAF**
1970's	**MSS Landsat 1-3**	**7/8/73, 7/19/76, 7/20/76, /23/78**	**EDC**
1980's	**TM Landsat 4,5**	**6/28/86, 7/30/86**	**EDC**
	MSS Landsat 4,5	**7/27/85, 7/30/86**	**EDC**
1990's	**TM Landsat 4,5**	**8/8/95, 8/20/91, 9/8/92,**	**EDC**
	TM Landsat 4,5		
	Insect infestation: GIS	**8/8/95**	**NPS**

Table 3

Data Sets for Land-Cover Change in High Latitude Ecosystems: North Slope Region - Toolik Lake, Alaska

Decade	*Data*	*Date of Scene*	*Source*
1950's to 1990's	Fire polygons: GIS	---	BLM /AFS/EK
	Aerial photos	---	USGS /GI – UAF
1970's	MSS Landsat 1-3	8/15/78, 7/14/79	EDC
1980's	TM Landsat 4,5	8/4/85, 7/6/86	EDC
1990's	TM Landsat 4,5	7/4/91	NASA Landsat Data Collection
		6/28/92, 7/14/92	EDC

Table 4

Data Sets for Land-Cover Change in High Latitude Ecosystems: Northwest Region – Seward Peninsula, Alaska

Decade	*Data*	*Date*	*Source*
1950's to 1990's	Fire polygons: GIS	---	BLM /AFS/EK
	Aerial photos	---	USGS /GI – UAF
1970's	MSS Landsat 1-3	6/17/73, 7/4/75, 6/28/76, 7/11/77	EDC
1980's	TM Landsat 4,5	7/13/85, 6/30/86	EDC
1990's	TM Landsat 4,5	6/6/92	EDC