U.S. Department of the Interior
National Park Service

Glacier Extent of the Southwest Alaska Network
DRAFT Monitoring Protocol for the Southwest Alaska Network
Kenai Fjords National Park, Lake Clark National Park and Preserve, and Katmai National Park and Preserve

Draft Protocol Narrative

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Prepared for:

Southwest Alaska Network
Inventory and Monitoring Program
National Park Service
U.S. Department of the Interior

Version 1.00

May 8, 2009

Acknowledgements

This protocol was developed with the consultation of Guy Adema (Denali National Park and Preserve), John Reidel (North Cascades National Park), Ron Karpilo (Geologic Resources Division Contractor – Colorado State University) and Dorothy Hall (NASA – Goddard Space Flight Center).

Keywords:
Glacier Extent, Landsat, Satellite, Decadal

Suggested Citation:
Giffen, B. A.., 2009. Glacier Extent of the Southwest Alaska Network Monitoring Protocol for the Southwest Alaska Network
Kenai Fjords National Park, Lake Clark National Park and Preserve,
and Katmai National Park and Preserve

Monitoring Protocol for the Southwest Alaska I&M Network. National Park Service, Inventory & Monitoring Program, Southwest Alaska Network, Anchorage, Alaska. ?? pp.

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Glacier Extent Protocol
Monitoring Protocol for the Southwest Alaska Network
DRAFT

Version 1.0 (May, 2009)

Revision History Log:

Previous Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #

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Background and Objectives

Background and history
The National Park Service (NPS) has implemented a strategy through "vital signs monitoring" designed to observe and understand the status and long-term trends natural resources and ecosystem function in park units. The Southwest Alaska Network has identified glacier extent as an important vital sign to monitor (Bennett, 2006). This protocol describes the methods employed to monitor the change in glacier extent on a park-wide basis, identify where anomalous change is occurring and to recognize and identify where areas of landscape scale processes are actively changing.

The climate of SWAN parks is influenced by strong moist maritime inputs from the Northern Gulf of Alaska, extreme topography and strong continental inputs from interior Alaska. The interaction of both climate and topography result in large amounts of annual snow accumulations which in turn leads to over 6,300 sq km (1.5 million acres) of glacier ice within the SWAN parks, Figure 1, Location Map. Even modest changes to glacier extent in the SWAN may have dramatic affects to landscapes and aquatic systems. Monitoring glacier extent on a park-wide scale will allow scientists to quantify glacier change and study how these changes affect ecosystems in the SWAN. Change in glacier extent and volume also offer insight into climate change (Raup, et al, 2006). The public has a strong interest in the status of glaciers because of the recent public awareness of global warning.

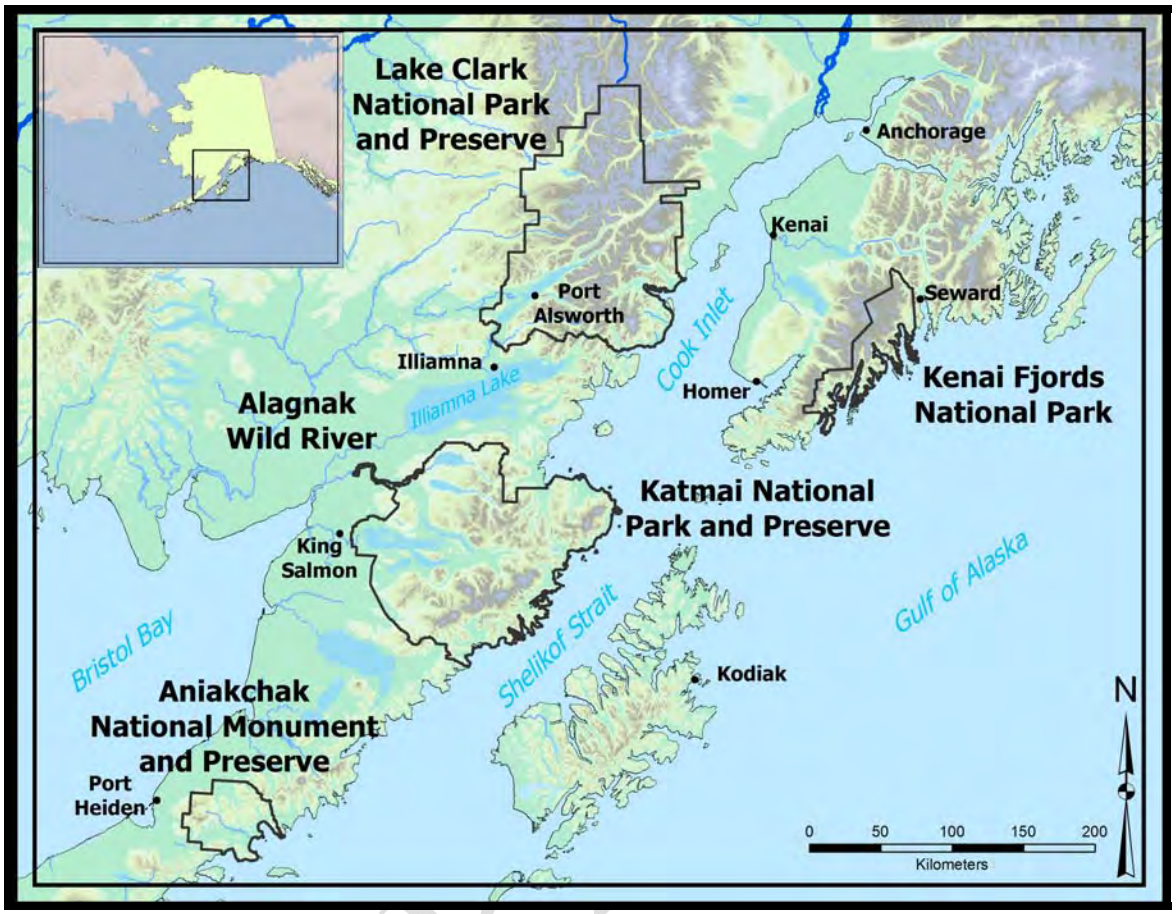

Figure 1. Southwest Alaska Network Location Map.

The SWAN is comprised of five park units (Aniakchak National Monument and Preserve, Alagnak Wild River, Katmai National Park and Preserve, Kenai Fjords National Park, Lake Clark National Park and Preserve) encompassing over 38,000 sq kilometers (9.4 million acres) of remote Alaskan wilderness. Glaciers occur in four of the five SWAN parks (Aniakchak National Monument and Preserve, Katmai National Park and Preserve, Kenai Fjords National Park, Lake Clark National Park and Preserve) and are a significant land cover type in three of the five SWAN park units (Katmai National Park and Preserve, Kenai Fjords National Park, Lake Clark National Park and Preserve), see Figure 2. The expanse and inaccessibility of much of the glacierized terrain in the SWAN preclude the use of ground-based glacier monitoring. Thus, remote sensing techniques will be employed to track the change in glacier extent in the SWAN on a decadal scale.

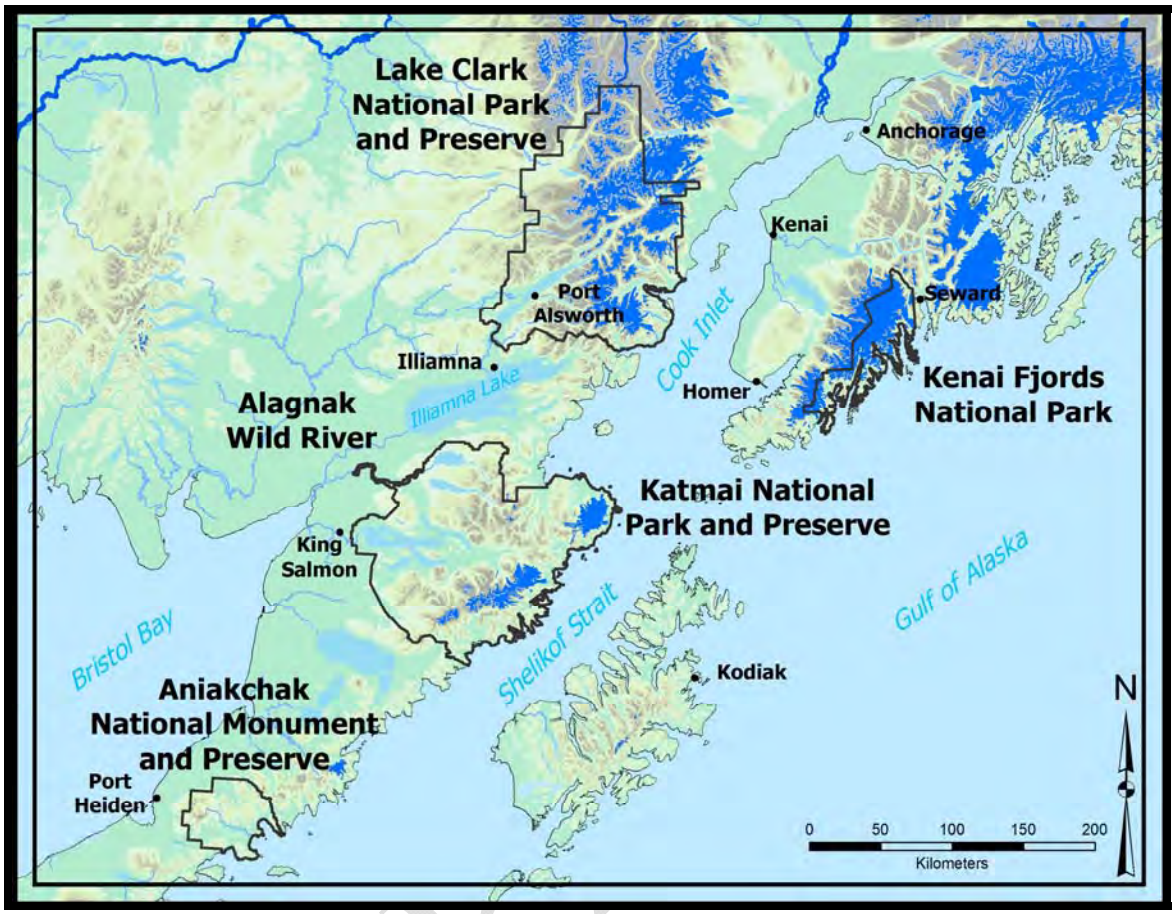

Figure 2. Glacierized areas of the SWAN parks.

Glacier ice extent (beginning in the 1970s) will be mapped on a park-wide basis repeated on a decadal scale using Landsat satellite imagery. Analysis of the data will quantify park-wide change in total area of glacier ice and identify trends and areas of anomalous change in glacier ice extent. Due to the large geographic extent of the SWAN parks, Landsat imagery has been chosen as the primary tool to map the glacier extent. A single Landsat scene covers a large area (160 km2), with a resolution of 30m. Other types of imagery were evaluated, but Landsat provided the best combination of imagery resolution, footprint, historic data availability, and economy.

Landsat data can be analyzed for glacier extent using a combination of algorithms followed by detailed manual editing (Raup, 2007).

Geographic/Topographic/Environmental Setting

The SWAN region is located between 57° to 61° north latitude and 149° and 158° west longitude. Located on the North American Plate, KATM, KEFJ and LACL are along a convergent tectonic plate boundary, with the Pacific Plate subducting beneath the North American Plate. The SWAN parks are coastal exhibiting extreme mountain topography adjacent to the North Pacific. Mountains rising abruptly from sea level approach 2,300 m in elevation in the SWAN region. KATM and LACL and the surrounding region contain at least 17 active volcanoes (Bennett et al., 2006) with elevations up to 2300 m. Though not volcanic in origin, the mountains in KEFJ rise up to >1800 m above sea level.

Climate

The SWAN parks are aligned along the northern coast of the Gulf of Alaska where the climate is dominated by strong moist maritime inputs. This region experiences a high frequency of marine cyclones making landfall in some of the most extreme and dramatic terrain in North America. Important features of the climate-hydrological cycle in these parks include the location of the Aleutian Low during the winter months (Davey et al., 2007) and the presence of mountains rising directly and steeply from the Gulf of Alaska (Davey et al., 2007; Bennett et al., 2006). Maritime influences interact with steep topography to create patterns of high precipitation on the windward side of the mountains, and rain shadows on the leeward side; regional winds have an easterly component (Davey et al., 2007), are predominant during the winter and common during the summer.

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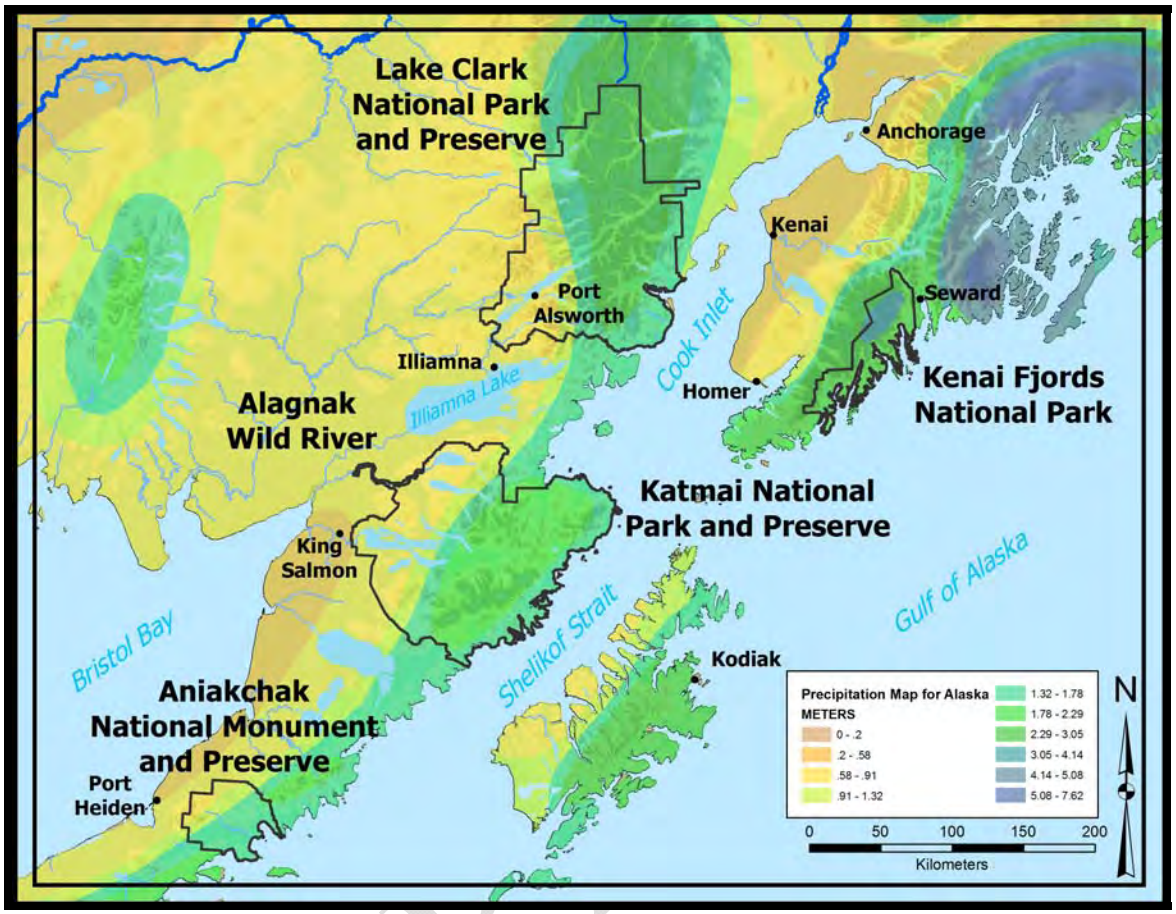

Figure 3. Generalized precipitation across Kenai Fjords NP and Katmai and Lake Clark NPs&P (Brabets, 1997).

Glacier Characteristics - Kenai Fjords National Park

There are over 2,200 km^2 (540,000 acres) of glacier ice/permanent snowfields in this park, comprising approximately 83% of the park area (Hydrography dataset, NPS - Alaska Regional Office).

The main body of the Harding Icefield (including the out-flow glaciers) is 1,786 sq km, (approximately 80 km x 30 km in area), about 2/3^{rds} of which occurs within the boundary of Kenai Fjords National Park. The bulk of the Harding Icefield occurs at elevations between 900 m and 1,300 m. Dozens of outlet glaciers flow down valleys and terminate on land, in lakes or in the Pacific Ocean.

A few kilometers to the southwest of the Harding Icefield is the Grewingk-Yalik Glacier Complex (approximately 35 km by 10 km in area) with elevations reaching 1400 m above sea level. This Icefield spawns several outlet valley

glaciers that terminate on land and in lakes. There are no tidewater glaciers issuing from the Grewingk-Yalik Glacier complex.

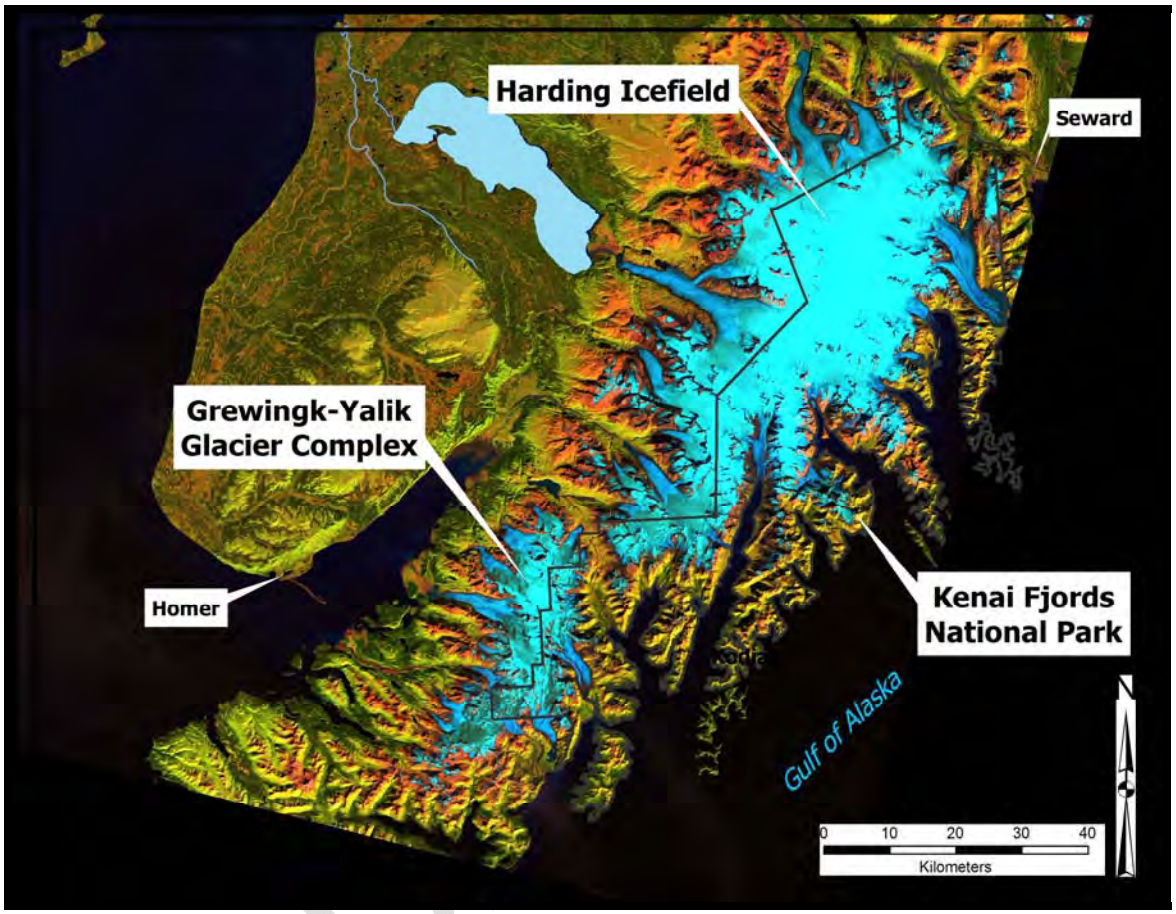

Figure 4. September 1986 Landsat image (Thematic Mapper 5) of Kenai Fjords National Park.

Glacier Characteristics - Katmai National Park and Preserve

Over a hundred glaciers originate from three primary areas in Katmai National Park and Preserve. Source areas for these glaciers are volcanic mountains (approaching 2,300 m above sea level) of the northern Alaska Peninsula. Valley glaciers are the most common glacier type in KATM and most of these glaciers terminate on land, though a few terminate in lakes and the flow from both simple and compound basins coalescing into larger valley glaciers. Beyond the three primary accumulation areas of glacier ice, there are small cirque glaciers and innumerable small isolated permanent snowfields. There are over 998 km^2 (246,000 acres) of glacier ice/permanent snowfields in this park, comprising approximately 6% of the park area (Hydrography dataset, NPS - Alaska Regional Office).

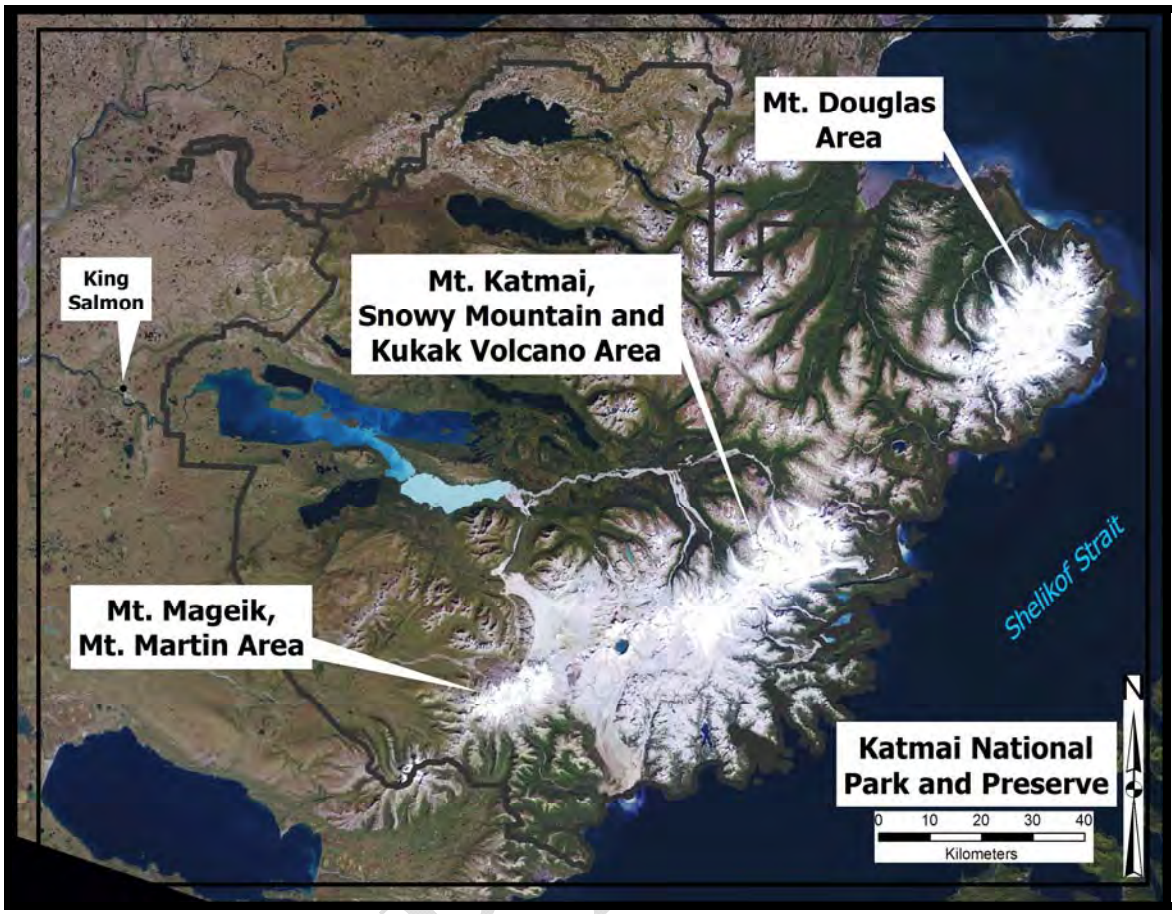

Figure 5. Landsat satellite image (composite image of August 30, 1991, September 3, 1995 and August 16, 2000) of Katmai National Park and Preserve.

Glacier Characteristics - Lake Clark National Park and Preserve

Lake Clark National Park and Preserve hosts the convergence of two major mountain ranges, the Aleutian and Alaska Ranges, resulting in broad expanses of rugged topography approaching 3,050 m (10,000 feet). Hundreds of glaciers and small icefields occur throughout the mountainous areas of the park. Valley glaciers terminate on land, with a few terminating in lakes. There are over 3,065 km^2 (750,000 acres) of glacier ice/permanent snowfields in this park, comprising approximately 19% of the park area (Hydrography dataset, NPS - Alaska Regional Office).

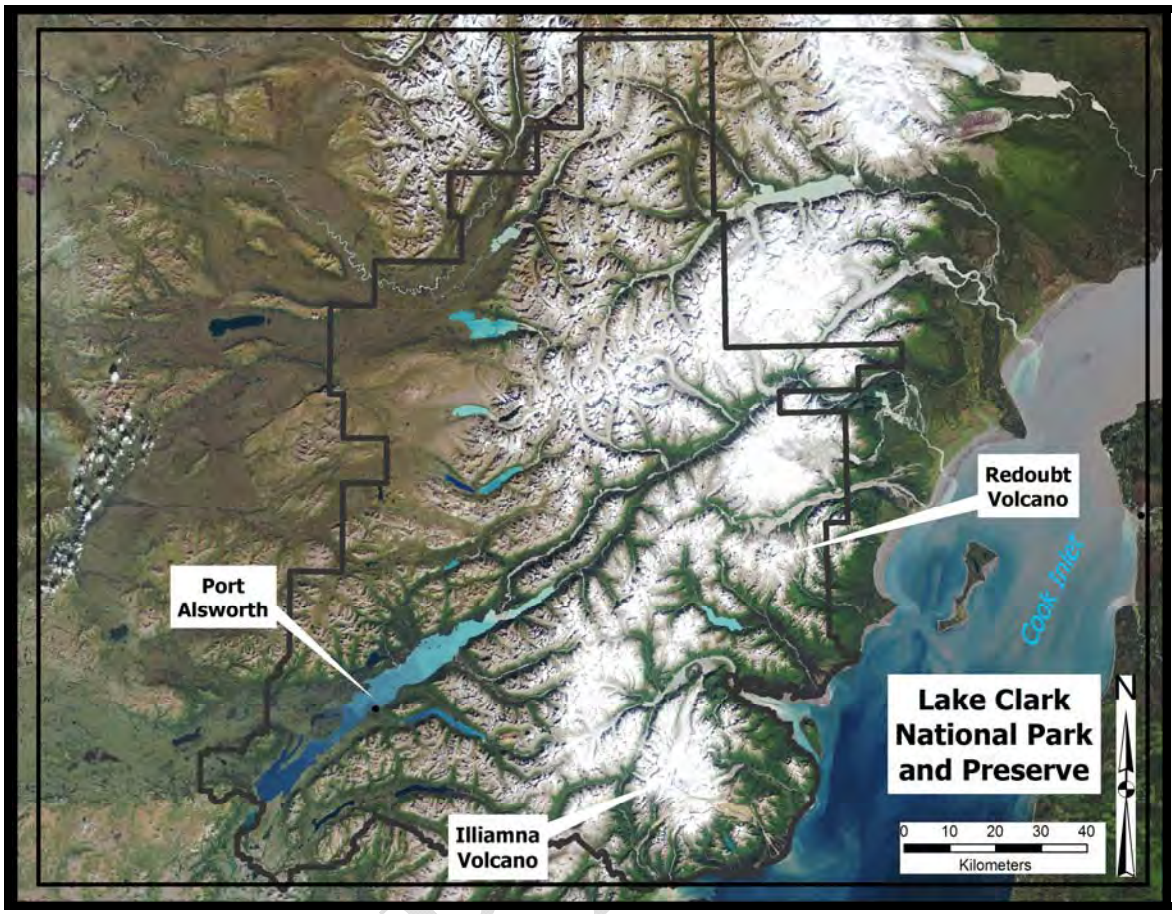

Figure 6. Landsat satellite image (composite image of August 30, 1991, September 3, 1995 and August 16, 2000) of Lake Clark National Park and Preserve.

Glacier Characteristics - Aniakchak National Monument and Preserve
Aniakchak National Monument and Preserve is home to a couple small hanging/cirque glaciers of very limited extent that occur inside the Aniakchak crater on the very steep north aspect of the southern portion of the crater. Glaciers of Aniakchak are not a significant feature of the landscape and will not be monitored through this protocol.

Glacier Terminus Characteristics
Glacier termini characteristics in these parks include vary from typical clean-ice boundaries of calving tidewater or lake-terminating glaciers to the debris covered termini of the many land-terminating glaciers covered in varying amounts of moraine material (a characteristic of glaciers in recession). Additionally the larger valley glaciers are striped with characteristic medial moraines as a result of coalescing valley glaciers; these valley glaciers also exhibit strong accumulations of lateral moraine material on the glacier surface. There are also isolated cirque

glaciers and many small valley glaciers throughout these parks. In addition, since the volcanic eruption of Novarupta in 1912, vast exposures of volcanic ash remain in KATM. Frequent wind events in the area entrain volcanic ash and redeposit this ash over the landscape. Many glaciers in this portion of KATM are completely blanketed with a thick layer of volcanic ash (Figure 3).

Rationale for monitoring glacier extent

Glacial systems are primary drivers of the park landscapes and ecosystems. Glaciers throughout Alaska and the SWAN have been in widespread retreat since the end of the Little Ice Age (late 1800s) (Larsen, et al, 2007) and recent rapid thinning (Arendt, et al, 2002, Larsen, et al, 2008). If this trend continues, dramatic reductions in glacial extent will occur and also impart significant changes in hydrologic processes and ecosystems across the SWAN region. A comparative analysis of glacier extent change can provide a direct measurement in the change of terrestrial and aquatic habitats in the SWAN parks. Long-term monitoring will indentify where and at what rate glacier extent is changing and will allow scientists, managers, and the public to understand and respond to the change through the availability of better information.

There are 90,000 square kilometers (22.2 million acres) of mountain glaciers located in Alaska and Canada - 13% of the mountain glaciers worldwide, approximately 75,000 square kilometers (18.5 million acres) occurring in Alaska (Arendt, et al, 2002, p. 382-384). Glaciers cover about 5% of Alaska today (Hamilton, 1994). Glaciation is most extensive in the southern portion of the Alaska due to the interaction of maritime climate and rugged topography, i.e. the Gulf of Alaska and the North Pacific Ocean (Hamilton, 1994, p. 813, 814, 837).

For a SWAN-wide glacier ice/permanent snowfield landscape cover type estimate, the Alaska-wide hydrography dataset created by the USGS and BLM from USGS DRGs (1:63,360, circa 1950s) and updated in some areas using the Alaska High Altitude Aerial Photography (circa 1980s), is the best data source. This dataset indicates that glaciers and permanent snow fields cover nearly 6,300 sq km (1.5 million acres) within the SWAN.

Glaciers are important indicators of climate fluctuations over time (Hall, 1992, p. 141, Raup, et al, 2006). Topography and geology are also factors that interact with glacier movement to influence glacier change (Reidel, 2005, p. 7). Measurement of glacier change can be used to correlate changes in regional climate in many glacierized areas of the Earth (Hall, 2000, p. 375, Hall, 2003, p. 576, Sapiano, 1998, p. 119). Valley and mountain glaciers change in response to changes in the regional climate on a decadal scale (Hall, 1992, p. 129, Hall,

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1995, p 271; Aoalgeirsdottir, 1997, p. 10). Generally, small glaciers have been losing mass globally on all continents except Antarctica (Hall, 2003, p 566) (insufficient data for Antarctica does not allow a conclusion to be made in this regard one way or the other). Small glaciers are sensitive indicators of local climate (Sapiano, J.J., 1998).

Trends in Alaska climate point towards increasing annual temperatures over the last 50 years, with winter temperature increasing about twice those observed for the summer (Larsen, et al, 2007). Based on Alaska temperature modeling (PRISM - The Climate Source), the mean annual temperature in the SWAN area is close to zero degrees centigrade (Redmond, et al, 2007). A positive temperature shift of only a degree or two will increase the mean annual temperature from near to below freezing, to one that is near to above freezing throughout the SWAN parks thus directly influencing glacierized areas (Redmond, et al, 2007).

Glaciers store an enormous amount of water in the form of ice and this feature alone makes any drainage basin containing glaciers both unique and complex (Brabets, 2004, p. 1). Changes in glacier coverage may also significantly change the fresh water flow and productivity throughout the large lake systems in the SWAN. One recent study explored glacier changes and runoff characteristics in the Tlikakila River Basin in the Lake Clark National Park and Preserve. The retreat of glaciers since the late 1950s has resulted in an increase of the salmon spawning and rearing habitat in the basin (Brabets, 2004, p. 1-5).

Anticipated changes to glacier extent will affect both terrestrial and aquatic ecosystems in the SWAN region. Monitoring changes in and tracking trends of the glacier extent will allow scientists to identify and focus on significant areas of change and study how these changes affect ecosystems in the SWAN. Public awareness and interest in glaciers has also been heightened as change in extent and volume offer insight into climate change (Raup, et al, 2006).

Understanding landscape-scale natural processes, how these processes are changing and interacting over time will further our knowledge of ecosystem function in the SWAN. Natural processes are largely outside the control of natural resource managers, understanding and anticipating these processes provides important ecological context for interpreting changes in park resources and is integral to the preservation and protection of public lands, and to determining the appropriate management strategies to employ (Reed, et al, 2006).

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Measurable Objectives

The objective of this protocol is to measure and document changes in the extent of glacier ice across the SWAN parks.

- Map the extent of glacier ice in the SWAN parks on a decadal scale beginning in the early 1970s and continuing through the early 2000s and decadally into the future.
- Quantify changes in glacier extent for the SWAN parks.
- Estimate trends in how the extent of glacier ice in the SWAN parks is changing.
- Identify glaciers and/or areas that appear to be changing rapidly and/or anomalously.
- Develop a regional perspective on expansion or shrinkage of glacier ice cover.
- Make reliable data (satellite imagery and data delineating glacier extent) available to parks, the scientific community and the public.
- Contribute data applicable to larger scale glacier monitoring efforts (GLIMS - Global Land Ice Measurements from Space program).
- Identify potential areas of resource concern within the SWAN parks based on an analysis of glacier change.

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Sample Design

Most glaciers are remotely studied by measuring glacier parameters such as length, width, elevation, ablation area, and accumulation area (Haeberli and Hoelzle, 1995) because detailed ground-based mass balance measurements are difficult and costly to obtain.

The SWAN parks are vast, remote wilderness parks. Access to most of the glacierized areas is expensive and difficult due to the terrain and ever-changing weather conditions. Thus, delineating glacier extent on a SWAN-wide basis necessarily requires the acquisition of vertical imagery from aircraft and/or satellites.

Mapping glacier boundaries using aerial photography, including the use of satellite imagery, is recognized as a simple and effective method for documenting change in glacier extent (Hall 2005). For glacier studies covering large remote glaciated areas, aerial photography and satellite imagery provide the most efficient means for monitoring regional glacier activity (Fountain, et al, 1997). Many time-series studies utilizing Landsat imagery produce very good results when repeated on approximately a decadal scale (Hall, 1995; Hall, 2003;

Hall, 2000; Li, 1998; Bayr, 1994). Remote sensing using satellite imagery and/or aerial photography, in combination with a Geographic Information System provides an effective means to analyze the state of glacier cover (Khalsa, et al, 2004), and as the dataset is built up over decades, trends in glacier change can be determined (Li, 1998, p. 258, 263-264).

Landsat, ASTER and IKONOS are three sources of satellite imagery which will meet the objectives of this protocol, although others were considered too (MODIS and SAR).

The first Landsat mission was launched in 1972. Landsat imagery has a large foot print (185 km X 185 km) with 15 to 30 m resolution in 7 spectral bands, with a repeating orbit every 16 days, recovering data continuously. Thirty meter data are collected in visible and near-infrared wavelengths. Fifteen meter data are collected in a panchromatic band in the visible green to near-infrared wavelengths. Landsat satellite imagery is available from 1972 (Landsat 1) to the present (Landsat 7). The next Landsat mission (Landsat Data Continuity Mission) is scheduled for launch in 2011.

ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer) is a sensor aboard the Terra satellite launched in 1999. One ASTER scene covers an area 60 km X 60 km. It takes nine ASTER images to cover same area of one Landsat image. ASTER has 15 to 90 m resolution in 14 spectral bands, with a repeating orbit every 16 days. The 15m data are collected in the visible and near-infrared wavelengths, 30m data in the shortwave infrared, and 90m data in the thermal infrared wavelengths. ASTER is an “on-demand” instrument and data will only be acquired if a request has been submitted by an authorized user (ASTER Science Team). Only the ASTER Science Team may request that the ASTER instrument acquire new data. Thus, ASTER data is not as readily available as other satellite data.

The commercial satellite IKONOS-2 was launched in 1999. IKONOS imagery has a foot print (13 km X 13 km). It takes over 200 IKONOS images to cover the same area of one Landsat image. IKONOS has 4 m resolution in 5 spectral bands. The 4 m data are collected in the visible and near-infrared wavelengths. A panchromatic ban collects 1m data in the visible blue to near-infrared wavelengths. IKONOS is an on-demand instrument, acquiring data over a location only if a request has been submitted to observe that area. The expense of acquiring IKONOS images over the glacier areas of the SWAN parks is high. The NPS has acquired Ikonos imagery for all of KEFJ and ANIA and portions of the remaining SWAN park units.

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SAR (Synthetic Aperture Radar) has a good resolution (30 meter) but the swath width is smaller (100 km) than Landsat. Landsat produces better contrasting data between the glacier and the surrounding debris than does SAR, though SAR is not affected by cloud cover (Hall, 1995, p. 272). Landsat is generally a better tool to measure glacier area than is SAR (Hall, 2000, p. 386). SAR is not considered further for this protocol.

MODIS (Moderate Resolution Imaging Spectroradiometer aboard the Terra satellite) has a minimum spectral resolution of 250 meters, which will not meet the objectives of the protocol. MODIS is not considered further because of its resolution.

Table 1 summarizes the data types evaluated for their ability to meet the objectives of this protocol.

Data Type	Satellite	Launch Date	Spectral Bands	Swath Width (km)	Resolution	Ground Track - Repeat Cycle	Georectified
Aerial Photography	N/A	N/A	N/A	varied	high	scheduled by misson	no
Landsat 1 (MSS) through Landsat 7 ETM+ Imagery	Landsat	1972	6	185	15 - 30 m	16 days	yes
ASTER	Terra	1999	14	60	15 m for visible	16 days/authorized users	yes
IKONOS	IKONOS	1999	4	11.3	1 m	3 days	yes
MODIS	Terra	1999	36	2,330	200, 500, 1000 m	2 days	yes
SAR	ERS-1	1991	1	100	30 m	35 days	yes
SAR	ERS-2	1995	1	100	30 m	35 days	yes

Table 1. Potential Data Acquisition Platforms

Currently, Landsat is the best fit for the objectives of this protocol. Landsat has good resolution in the visible spectral range (15 to 30 m) (see Table 2) and a large foot print (185 km X 185 km), which is important to cover the large glaciated areas of the SWAN parks. Even with the large foot print, multiple

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scenes will be required to cover the glacier areas on a SWAN-wide basis. Landsat imagery can also be used for retrospective studies as there is a Landsat data archive that dates back to 1972.

Satellite	Spectral Resolution (µm)	Band	Spatial Resolution
Landsat 1-3	MSS Band 4: 0.50 - 0.60	Green	(meters) 79
	Band 5: 0.60 – 0.70	Red	79
	Band 6: 0.70 – 0.80	Near IR	79
	Band 7: 0.80 – 1.10	Near IR	79
Landsat 4-5	TM		
	Band 1: 0.45 – 0.52	Blue	30
	Band 2: 0.52 – 0.60	Green	30
	Band 3: 0.63 – 0.69	Red	30
	Band 4: 0.76 – 0.90	Near IR	30
	Band 5: 1.55 – 1.75	Mid IR	30
	Band 6: 10.4 – 12.5	Thermal	120
	Band 7: 2.08 – 2.35	Mid IR	30
Landsat 7	ETM+		
	Band 1: 0.450 – 0.515	Blue	30
	Band 2: 0.525 – 0.605	Green	30
	Band 3: 0.630 – 0.690	Red	30
	Band 4: 0.760 – 0.900	Near IR	30
	Band 5: 1.550 – 1.750	Mid IR	30
	Band 6†: 10.40 – 12.5		
	Band 7: 2.080 – 2.35		
	Band 8: 0.52 – 0.92	Thermal	60

Table 2. Landsat bands and resolution.

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Satellite Imagery Data Interpretation Accuracy

Landsat scenes are composed of pixel data. Landsat MSS (Multi Spectral Scanner) resolution is 79 meters, one pixel representing the spectral reflectance of a piece of ground measuring 79 meters x 79 meters. Landsat TM (Thematic Mapper) or ETM+ (Enhanced Thematic Mapper +) resolution is 30 meters, one pixel representing an area 30 meters x 30 meters. The level of change that can be detected in a Landsat image is dependant on the resolution of the imagery plus any registration error. The spatial accuracy of Terrain Corrected TM or ETM+ Landsat data is 30 meters between images (EROS Data Center, personal comm., 2006)

If the glacier terminus is clean (i.e. not debris covered), changes of terminus positions can be determined to within +- 40 meters when analyzing Landsat TM and ETM+ scenes. The accuracy decreases to +- 113 meters when analyzing data between Landsat MSS and TM or ETM+ scenes (Hall, 2003, p. 569).

Site Selection

The area to be monitored is driven by the extent of glacier ice within each of the three major glacierized SWAN parks. Glacier extent and change in extent will be monitored on a park-wide basis, approximately every decade. The size of the area to be monitored is approximately 6,300 sq km (1.56 million acres).

Data Acquisition, Processing and Analysis

The following discussion identifies the methods of data acquisition, processing and analysis. The goal is to outline the procedures for the acquisition of appropriate Landsat data and that the data processing and analysis are repeatable and comparable.

Data processing and analysis requires the use of image processing software and geographic information system (GIS) software. Currently the SWAN is using RSI's ENVI and ESRI's ArcGIS software packages for image processing (classification) and manual editing of the classification. Excel is used for summarizing and reporting the trends and findings.

Data Acquisition and Archiving

Landsat data will be acquired on approximately a decadal scale. Landsat imagery (historic data or future data) will meet the following standards:

- Satellite imagery over glacier areas will be cloud-free or minimum cloud cover
- Satellite imagery will be acquired as late into the melt-season as possible, but prior to any seasonal snow. For the SWAN parks, this acquisition window is typically mid-August through mid-September, the later into the melt season the better. July scenes will not meet the requirements of this protocol due lingering of the prior season's snow fall.

A cloud-free, late-season Landsat image is difficult to capture over the SWAN parks. In the context of this protocol, decadal means 10 years, plus or minus several years, but is wholly is dependant on the availability of quality Landsat imagery.

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With the next generation of Landsat scheduled for launch in 2011, 2012 to 2015 will be the next target window to acquire the next set of satellite imagery in support of this protocol. There will likely be advances in satellite technologies and advancements in image classification methodologies in the next 10 to 15 years. This protocol will be updated to take advantage of future advancements satellite imagery and classification techniques.

Landsat data is available at no cost from the EROS Data Center (a branch of the USGS), downloaded directly over the world wide web and posted to the Alaska Regional Office GIS X drive.

Current Status – Landsat Program

Landsat 7 ETM+ stopped functioning as designed in May 2003 and currently collects data in Scan Line Corrector (SLC)-off mode. This malfunction causes an increasing amount of data loss as you move away from the scene center towards the sides of the scene. To meet the objectives of this protocol, all Landsat data acquisition subsequent May 2003 will necessarily revert to Landsat 5 imagery, which continues to operate as designed.

See SOP #1 for procedures for evaluating imagery for data quality and ordering imagery from the EROS Data Center and archiving.

Data Processing

All imagery ordered from EROS is Terrain Corrected (Level 1T) and includes radiometric, geometric, and precision correction, as well as the use of a digital elevation model (DEM) to correct parallax error due to local topographic relief (http://edc.usgs.gov/products/satellite/landsat7.html#l7status). The geotiff images are delivered to the NPS as describe in SOP #1. No addition data processing is required prior to the classification techniques detailed in SOP 3 and 3.

Data Analysis

Supervised classification of satellite imagery may be a reasonable method to employ to delineate some glacial facies (i.e. clean glacial ice boundaries). However, debris on glaciers cause the glacier to have a similar reflectance as the surrounding moraine and/or mountain material (Hall, 2003, p. 575; Hall, 2000, p. 382, Wowarth, 1986, p. 91, Jacobs, 1997, p. 100), thus, classification of ice that is completely covered in debris, is not possible because its spectral reflectance can't be distinguished from surrounding moraine/mountain material (Sidjak, 1999, p. 281). When a glacier is in recession, debris may become concentrated

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on the surface of part or all of the glacier tongue. Also, debris on the sides of valley glacier obscures the glacier boundaries. Supervised classification techniques utilized in combination with detailed review and manual editing will increase the accuracy of the glacier extent boundary. Manual interpretation remains the best tool in mapping glacier extent in many situations (Ruap, et al, 2007).

Another mapping challenge obscuring glacier boundaries are shadows. Sun angle and extreme topography are factors affecting the extent of shadowing across an image, resulting in-turn obscured glacier boundaries. Careful manual interpretation of these areas will be required to accurately map the glacier boundary. See SOP#4.

Another mapping challenge is eliminating permanent/seasonal snowfields not associated with any glacier from being included in the mapping. Snow lying on ground or on a glacier is not spectrally different, so these two feature types can't be distinguished from one another. Small snowfields not associated with a glacier are removed from the mapping effort. See SOP#3 and #4.

Another factor affecting the interpretation of glacier ice extent is the seasonal date of the satellite image. The amount of seasonal snowpack observed in an image is heavily dependant upon the date of the imagery. A mid-September image vs. a mid-August image may show significantly less seasonal snow cover, thus increasing the certainty of the delineation of the accumulation areas. Conversely, early season snowfall may render the mid-September image useless for accurately mapping the accumulation area.

Some of these factors can be resolved by viewing higher resolution imagery (if available) and/or local knowledge of the area. Comparing higher resolution imagery with Landsat data is beneficial in accurately interpreting Landsat data.

Attempts over the years to develop an automated classification technique to accurately define glacier ice extent have not proved entirely successful. Debris covered ice likely being the single largest obstacle to success because the reflectance of debris covered ice is the same as the surrounding moraine material. Human interpretation of the Landsat data will necessarily be a large part of the process in areas of debris cover.

For this protocol, mapping of glacier extent (classification of snow and ice) will be accomplished by using RSI's ENVI software to determine the most effective band math techniques and threshold values to apply to the Landsat data thus segregating all snow and glacier pixels from all other pixels in the Landsat data.

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Several band math techniques and corresponding threshold values have been studied for their suitability in segregating snow and glacier pixels. These techniques are fully described in SOP #2.

After identifying the most effective band math techniques and threshold values (SOP #2), the actual data processing, converting the resultant raster files to shapefiles and subsequent editing of the shapefiles is all carried out in the ArcGIS/ArcCatalog environment (SOP #3 and #4). Editing of shapefiles occurs with a Landsat color composite image in the background (bands 5, 4, 2 (TM and ETM+) and bands 4, 2, 1 (for MSS)).

Editing the automatically derived glacier boundary where glacier ice contacts ground is not as simple as may first appear. As the interpreter zooms in to an area of interest, the pixels representing the contact will trend from white/light (ice) to black/dark (ground/rock), and in many circumstances, a transition zone of grey pixels between. The spectral reflectance of the pixels represents surface conditions that contain varying proportions of ice, debris on the ice and ground. Mapping the glacier boundary in these situations is left up to the judgment of the image interpreter.

To help standardize glacier mapping, the definition of what falls into the category called "glacier extent" must be defined. Seems simple, but it is more complicated than first appears. With this in mind, the following is from the GLIMS definition of a glacier to better define a glacier for this protocol (Raup, 2007, GLIMS Analysis Tutorial):

> *A glacier or perennial snow mass consists of a body of ice and snow that is observed at the end of the melt season. This includes, at a minimum, all tributaries and connected feeders that contribute ice to the main glacier, plus all debris covered parts of it. Excluded is all exposed ground, including nunataks.*
>
> *The following circumstances will be considered when mapping glacier boundaries (Raup, 2007, GLIMS Analysis Tutorial):*
> *1. Bodies of ice above the bergschrund that are connected to the glacier shall be considered part of the glacier, because they contribute snow (through avalanches) and ice (through creep flow) to the glacier.*
> *2. Any steep rock walls that avalanche snow onto a glacier but do not retain snow themselves are NOT included as part of the glacier.*
> *3. A stagnant ice mass still in contact with a glacier is part of the glacier, even if it supports an old-growth forest.*
> *4. All debris covered parts of the glacier must be included.*

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5. Map only at the end of the ablation period to exclude seasonal snow. Map everything that is connected to the glacier.
6. Rock glaciers are not included in this protocol.

For each successive glacier extent mapping effort, a comparative analysis of how glacier extent is changing will be done with all previous mapping efforts. This analysis will identify change and trends in glacier extent. Changes and trends for selected glacier termini will also be quantified throughout the SWAN. Areas of anomalous change will be identified and quantified.

Currently, this protocol is designed to document change in glacier extent, identify areas which are changing anomalously and report on observed trends. This protocol doesn't provide for the measurement of glacier surface elevation and how the elevation of the glacier surface is changing though time. This is due to the expense of collecting this type of data over the vast, rugged, remote and inaccessible glacierized terrain presented by the SWAN parks. As technologies advance and data acquisition costs lesson, acquisition of high quality digital elevation models (on a repeating cycle) over glacierized regions of the SWAN may be considered in the future.

Opportunistic Data Harvest – Information Capture
Glaciers are comprised of an area of ablation (bare ice in the summer) and an area of accumulation, separated by the equilibrium line (Williams, 1991, p. 120; Sidjak, 1999, p. 273). The area of accumulation can be divided into three zones in the summer: wet snow, percolation, and dry snow facies. Some of these glacier features are identified as valuable features to monitor in "A Strategy for Monitoring Glaciers" (Fountain, 1997, p. 9-13). Some of the reflectance bands (TM bands 4, 5 and 6) on Landsat can be useful in detecting these facies (Hall, 1987, p. 104, Orheim, 1987, p. 110; Williams, 1991, p. 123; Jacobs, 1997, p. 100). If possible, these data will be harvested opportunistically from the acquired imagery. To increase the accuracy of these measurements, September imagery would be the best. By opportunistically harvesting some of these data, the NPS can contribute information to the scientific community.

Future Plans
As more is learned about the glaciers of the SWAN, NPS will encourage future glacier studies through partnerships with other agencies and universities. This listing is meant only to identify some of the possibilities.

- Link glacier observations with past and future climate changes

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- Regional and/or glacier specific ice elevation surveys (LIDAR and survey-grade GPS)
- Link change in glacier extent to mass balance studies at the Wolverine Glacier (USGS Benchmark Glacier)
- Mass balance studies (snow stakes) as described in (Riedel, 2004)
- Repeat Photography (aerial and/or surface locations)
- Monitor the equilibrium line altitude (ELA) through imagery (Khalsa, et al, 2004)
- Monitor accumulation area ratios

Data Management

There are two components to data management, operational and archival. Operational data management includes acquisition, processing and analysis of Landsat data. Archival data management includes the treatment of final data products generated from the data processing and analysis steps of this protocol and insuring final baseline data is archived and available for future analysis and study.

Operational Data
The primary objective is to create a procedure whereby final data products are transferred to the permanent data archive. To reach this goal, a procedure has been developed for handling original data (imagery), temporary working files (classification files, shapefiles, spreadsheets) and creating final data products.

This operational plan includes:
1) acquisition of data (Landsat imagery and aerial oblique photography)
2) data analysis and management of temporary work files,
3) production of final data products
4) removal of temporary work files

All data handling, processing, analysis and management is done with desktop computer. Details regarding folder structure and file naming is presented in detil in SOP #3, #4 and #5.

Briefly, a base folder is created for each glacier extent mapping effort. Several other folders, are located in the base folder. The folders within the base folder contain Landsat, digital elevation and hydrography data. The base folder will also contain a personal geodatabase and feature datasets where shapefiles are created and manually edited using ArcGIS/ArcCatalog. Detailed folder/file

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structure and naming conventions are thoroughly covered in SOP #3, #4 and #7.

Archival Data Management

The SWAN physical scientist is responsible for checking the accuracy of the glacier extent boundary and approving the final shapefiles. When shapefiles are final, they will be delivered to the SWAN Data Manager for archiving and placement into the Alaska Regional Office GIS Theme Manager.

The archive data for each park will consist of:

1) A color composite satellite image for which the editing of the glacier extent is based
2) A shapefile consisting of glacier ice and nunataks
3) A spreadsheet presenting a comparison analysis with previous mapping efforts

The imagery and final shapefiles will become part of the Alaska-NPS GIS dataset and available for analysis with many other related datasets maintained by the Alaska-NPS. The final shapefiles will be archived on the Alaska Regional Office central data file server. These files will be served on the ArcGIS Theme Manager maintained by the AKRO GIS Team.

Data backups at the AKRO are managed by the AKRO Information Technology team as detailed in the SWAN Data Management Plan, Section 11.5.

Documentation

Complete metadata records will be created for each satellite image and each shapefile in the archive data. Metadata will meet Federal Geographic Data Committee (FGDC) standards for Digital Geospatial Metadata (CSDGM). See SOP #8 for an example of a metadata file.

Quality Assurance/Quality Control and Validation

Quality assurance and control is imperative in creating high quality data that is comparable between mapping efforts. First, all Landsat imagery is acquired in standard format (see SOP #1) from the USGS EROS Data Center and QA/QC is a critical element in Landsat product. Image processing, and classification techniques are standardized (see SOP #3 and #4) and techniques employed for manual editing are detailed in SOP #4. By paying careful attention to processes outlined in these SOPs, baseline datasets created in support of this protocol will be of high quality.

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Analysis and Reporting

This section describes the analysis techniques and means of reporting and presenting the comparative analysis data. These data and reporting products will be useful in understanding glacier extent in the SWAN parks and how it is changing over time. These data and reporting products are intended to reach a wide audience including park management and staff, SWAN staff, outside scientists and the public.

Each successive glacier extent mapping effort increases the dataset's comparative analysis qualities. As with most scientific data, each successive data point adds reliability and credibility to analyses to be conducted. A decadal analysis of glacier extent can identify trends occurring across the SWAN parks.

Glacier Extent Mapping

An analysis of glacier extent between multiple points in time can be compared to identify trends in glacier cover and identify areas and/or regions of rapid and/or anomalous change of glacier extent in the SWAN parks (Figure 1). Changes in glacier extent can be quantified and trends established at various scales (park-wide, region-wide, watershed-wide, individual glacier). See SOP #8 for reporting.

Various band ratio techniques are useful [TM3/TM5, TM2/TM5, (TM3-TM5)/(TM3+TM5) and (TM2-TM5)/(TM2+TM5)] in classifying Landsat imagery (late-season, cloud-free) for glacier and snow cover. A threshold value is defined thus classifying pixels data as a glacier/snow or not. Some experimenting with the threshold value is required to achieve a glacier/snow classification that best represents glacier/snow and minimizes the amount of manual correction. The National Elevation Dataset is used to eliminate all water bodies below 200 feet elevation – this eliminates confusion of the classification with large bodies of water. Image classifications are converted to line shapefiles and these shape files are edited in an ArcGIS session to increase the accuracy of the glacier extent mapping. The final step in the process is to convert the line shapefile into a polygon shapefile. Details of the classification technique are further described in SOP #3

Reporting will be accomplished through annual reports and meetings with park staff and management. Reports will include a description of the current status and decadal trends of glacier extent. (SOP #8). Reports may include graphical representation (imagery, maps, charts and graphs) describing the change in and the observed trend of glacier extent (e.g., Fig. 5-6) detected, if any. Any

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observations that are made outside the ordinary trends observed will be highlighted in reports. Reporting and analysis will occur about every decade, though the actual reporting schedule will be driven by the availability of high quality late-season satellite imagery.

Reports will contain:

- Listing of the imagery used in the analysis (type of imagery, date of imagery, image identifier, projection, datum, pixel size, format, level of correction)
- A description of imagery enhancements/processing used (band ratioing, band composite, thresholds)
- Accuracy of the interpretation of glacier extents based in sensor resolution and imagery registration
- A listing of the terminus change of individual glaciers
- Overall glacier extent change and trends on a park-by-park basis
- Listing of particularly active areas that are candidates for site-specific studies

Glacier extent shapefiles will be provided to the Global Land Ice Measurement from Space Program (GLIMS) for inclusion into their database.

Glacier extent information will also be submitted for publication in peer-reviewed scientific journals.

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Personnel Requirements and Training

Carrying out of this protocol will require skills including expertise in remote sensing, image processing, geographic information systems and data management. Glacier extent mapping can be automated through supervised classification techniques, which will require expertise in the remote sensing and the use of image processing software. The results of the classification will require extensive manual editing in ArcGIS to improve the accuracy of the glacier extent boundary, requiring expertise in remote sensing and ArcGIS. A high level of expertise will be required of physical scientists and technicians for the duration of this protocol. The SWAN Data Manager plays a key role in data handling and archiving.

Experience and qualification of personnel are outlined in Tables 3 and 4.

Task	Personnel
Data Acquisition: • Review and order imagery	Physical Scientist/Technician
Data Processing - Image Processing • Satellite imagery classification • Convert classification to shapefiles files • Create color composites of satellite imagery ArcGIS Work Session • Using color composite satellite imagery as a base, edit the shapefiles/line features in AcrGIS. • Convert line feature class to polygons • Creating and updating metadata	Physical Scientist/Technician or Remote Sensing Specialist Physical Scientist/Technician or Remote Sensing Specialist
Data Analysis and Interpretation • Spatial analysis - determine park-wide/region-wide area of glacier extent • Trend analysis (glacier area, terminus position) • Data summaries	Physical Scientist/Technician or Remote Sensing Specialist
Reporting	Physical Scientist
Data Management • Manage directory structure and file naming convention • Move final shapefiles to archive • Data backups	Data Manager, Physical Scientist/Technician and Remote Sensing Specialist
Protocol revisions	Physical Scientist

Table 3. Work flow and tasks for achieving the goal of glacier extent mapping.

Satellite imagery acquisition will happen on approximately a decadal scale, depending on availability of late season, cloud-free imagery. As acceptable imagery is available, glacier extent mapping will take approximately .33 FTE per SWAN park. The work tasks will be shared among the physical scientist, GIS specialist and physical science technician.

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Personnel	Qualifications/Experience
Data Manager	Experience with data stewardship and developing applications for data analysis
Physical Scientist Physical Science Technician	Experience with image processing (using RSI's ENVI and ArcGIS software) • Classification techniques • Conversion to shapefiles • Creation of color composite Geotiffs Experience in using ESRI's ArcGIS Experience in remote sensing and manual interpretation of satellite imagery and derived products in glacierized regions Complete comparative analysis and develop reports, maps, posters to convey finding to management, staff, scientific community and the public
GIS Specialist/Analyst Physical Science Technician	Experience in using ArcGIS • Geodatabases, • Feature datasets • Feature classes • Editing • Various data types (raster, shapefiles and polygon) • Map projections • Preparation of interpretive maps Experience in remote sensing and manual interpretation of glacier features using satellite imagery Prepare comparative analysis and summary spreadsheets

Table 4. Personnel qualifications

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Training procedures.
Personnel performing tasks detailed in this protocol should receive update training in ESRI's ArcGIS and RSI's ENVI software on an as needed basis.

Operational Requirements

Workload and Data Acquisition
Workload associated with this protocol are on a reoccurring decadal cycle, but is dependant upon availability of late-season, cloud-free imagery. It is not realistic to think that cloud-free, late-season satellite imagery for all the SWAN parks will available in the year 2010, 2020, 2030 and so on. With this in mind, the search for acceptable imagery for a park should begin eight years after the last glacier extent analysis was completed and continue until acceptable late-season cloud-free imagery is acquired. Due to the fact that the next generation Landsat mission launch is scheduled for 2011, it is recommended that imagery acquisition in support of this protocol not occur until the new Landsat satellite data is available.

The workload associated with image preparation, supervised classification and manual interpretation of glacier extents and analysis will be approximately four work-months per park. Preparation of reports and accompanying graphics, will require another month. This will be a reoccurring workload approximately every ten years.

Field Investigation
The accuracy and interpretation of glacier boundaries from imagery will be enhanced by field investigations where debris cover, shadows and/or clouds obscure glacier ice. With this in mind, following the year of imagery acquisition, it is anticipated that approximately one week of fixed wing over-flights be conducted to gain time-relevant local-knowledge of identified areas within the SWAN parks where imagery interpretation is uncertain. However, for over-flights to be fully effective, the draft interpretation of the glacier boundaries on satellite imagery must be finished, thus identifying those areas where fixed wing over-flights will facilitate the mapping of glacier boundaries. See SOP #5 and #6.

Software
Currently there are three primary software packages which will be required to meet the goals of this protocol.

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- Standard internet browser for evaluating and ordering satellite imagery from the EROS Data Center website
- Satellite image processing software package, RSI's ENVI is the current package used by the SWAN
- Geographic Information System software package, ESRI's ArcGIS is the current package used by the NPS
- Microsoft Office (word processing, spreadsheet preparation, presentations preparation)

Hardware
The hardware requirements include a personal computer with a minimum of 2.0 GHZ processor and 2 GB or greater of memory - these are minimum requirements. To achieve maximum performance in processing and manipulation of imagery, more powerful processors and memory are preferred. A minimum hard drive capacity of 100 GB is recommended for imagery processing.

Procedures for Revising this Protocol

Over time, revisions to both the Protocol Narrative and to specific Standard Operating Procedures (SOPs) are to be expected. Careful documentation of changes to the protocol, and a library of previous protocol versions are essential for maintaining consistency in within the program. SOP #9 identifies the steps necessary for changing this protocol. Each SOP contains a revision history log that should be filled out when a SOP is revised. The new version of the SOP and/or protocol narrative should then be archived in the SWAN protocol library under the appropriate folder.

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Glacier Extent Protocol
Southwest Alaska Network

Standard Operating Procedure (SOP) # 1

Data Search - Landsat Imagery

Version 1.0 (May, 2009)

Revision History Log:

Previous Version #	*Revision Date*	*Author*	*Changes Made*	*Reason for Change*	*New Version #*

Explanation and Overview

This Standard Operating Procedure describes the procedures for searching the USGS National Center for Earth Resources Observation & Science (EROS) EarthExplorer website for Landsat images.

Cloud-free Landsat imagery will be acquired on a decadal scale for the glacierized regions of the SWAN. This is the primary dataset used to map glacier extent across the SWAN. A comparative analysis with previous mapping efforts will document change and trends in glacier ice cover in the SWAN parks. The seasonality of the Landsat imagery is critical. Imagery must be acquired late in the ablation season (mid August to late September) to maximize seasonal snow melt but also before the first winter snows appear across the landscape. Typically, sky conditions in the SWAN region tend to be cloudier in August and September; that combined with a 16 day repeating orbit of Landsat, it will not be uncommon to wait several years to acquire acceptable late-season, cloud-free imagery. The Landsat data will be archived at the NPS - Alaska Regional Office.

Landsat 7 ETM+ satellite had a hardware failure in May 2003 and is no longer operating as designed. The older Landsat 5 satellite continues operate as

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designed. The next generation Landsat vehicle (Landsat Data Continuity Mission) is scheduled for launch in 2011. This mission is designed to continue the acquisition, archival, and distribution of multi-spectral imagery affording global, synoptic, and repetitive coverage of the Earth's land surfaces at a scale where natural and human-induced changes can be detected, differentiated, characterized, and monitored over time. When the new Landsat satellite data becomes available, this SOP will be updated. But until then, any Landsat data acquired post May 2003 in support of this protocol must be Landsat 5 data.

1-1 Landsat Data Source

EROS Data Center is the depository and archival facility for all Landsat data acquired over the USA. Information about the Landsat program and products are found on the web at:
http://landsat.usgs.gov/products_productinformation.php

Current updates about the Landsat mission and data can be found at:
http://landsat.usgs.gov/

EROS Data Center - About the EROS

The Earth Resources Observation Systems (EROS) Data Center (EDC) is a data management, systems development, and research field center for the U.S. Geological Survey's (USGS) National Mapping Division. Organizationally, the USGS is a bureau of the U.S. Department of the Interior. The EDC opened in the early 1970's with a handful of employees and the largest mainframe computer in the State of South Dakota. Today the EDC has approximately 600 government and contractor employees, including employees at its Alaska Field Office in Anchorage, Alaska, and employees at the NASA Ames Research Center in Moffett Field, California. And now the EDC houses one of the largest computer complexes in the Department of the Interior.

Currently, the EROS Data Center provides all Landsat imagery free of charge to all users of the data. As significant changes occur to the EROS web site, this protocol will be updated.

1-2 EROS Data Center - Landsat Data

To order Landsat data visit:
http://edcsns17.cr.usgs.gov/EarthExplorer/

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Instructions to navigate the EROS web site are attached (EarthExplorer Tutorial) as an appendix to the SOP.

Below is a step-by-step procedure for searching and ordering imagery from EROS. To order or download data from the EROS website, you will need to "Sign in" if you are a registered user. If not, it is easy to register, creating your own username and password.

There are three active buttons on the top-left of the web page (Home, Help, EarthExplorer Tutorial). These links will give you the most recent guidance to acquiring Landsat data. Attached to this SOP is the most recent EarthExplorer Tutorial.

1-3 EROS Website - Landsat Data Search –

On-line search for Landsat imagery is conducted through the EROS website. Below are the step by step procedures to conduct a search for Landsat data specific to SWAN parks.

1) Access the EROS website through the following link:
http://edcsns17.cr.usgs.gov/EarthExplorer/

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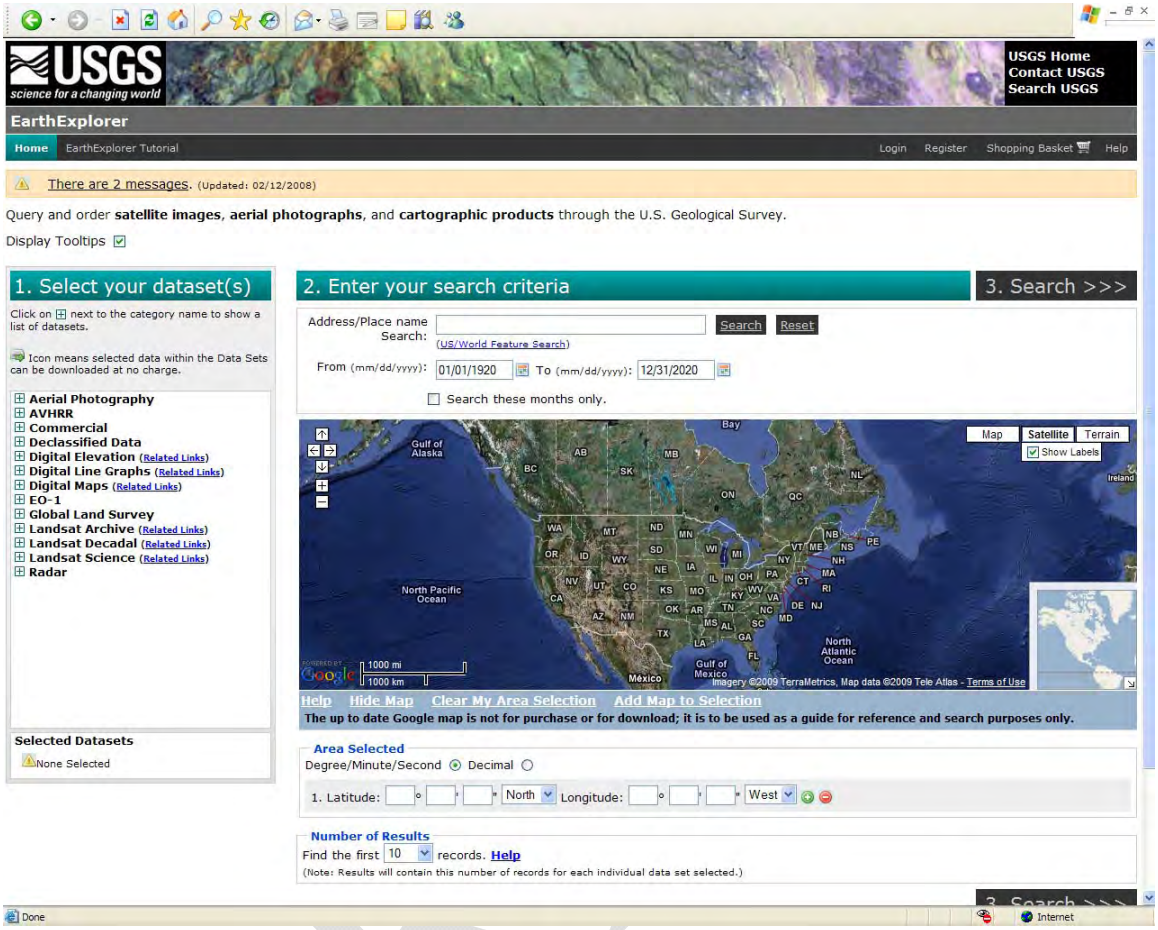

Figure 1. EROS website.

There are 3 steps to be completed in order to conduct a search for data.

1. Select your dataset(s)
2. Enter your search criteria
3. Search

<u>Select your dataset(s)</u>

In this window of the webpage, all datasets (both free and cost) severed by EROS are listed. Expand the Landsat Archive by clicking on the + symbol.

At this point all Landsat data options appear. Click on the box next to the desired imagery (i.e. Landsat 4-5 TM is selected in the example).

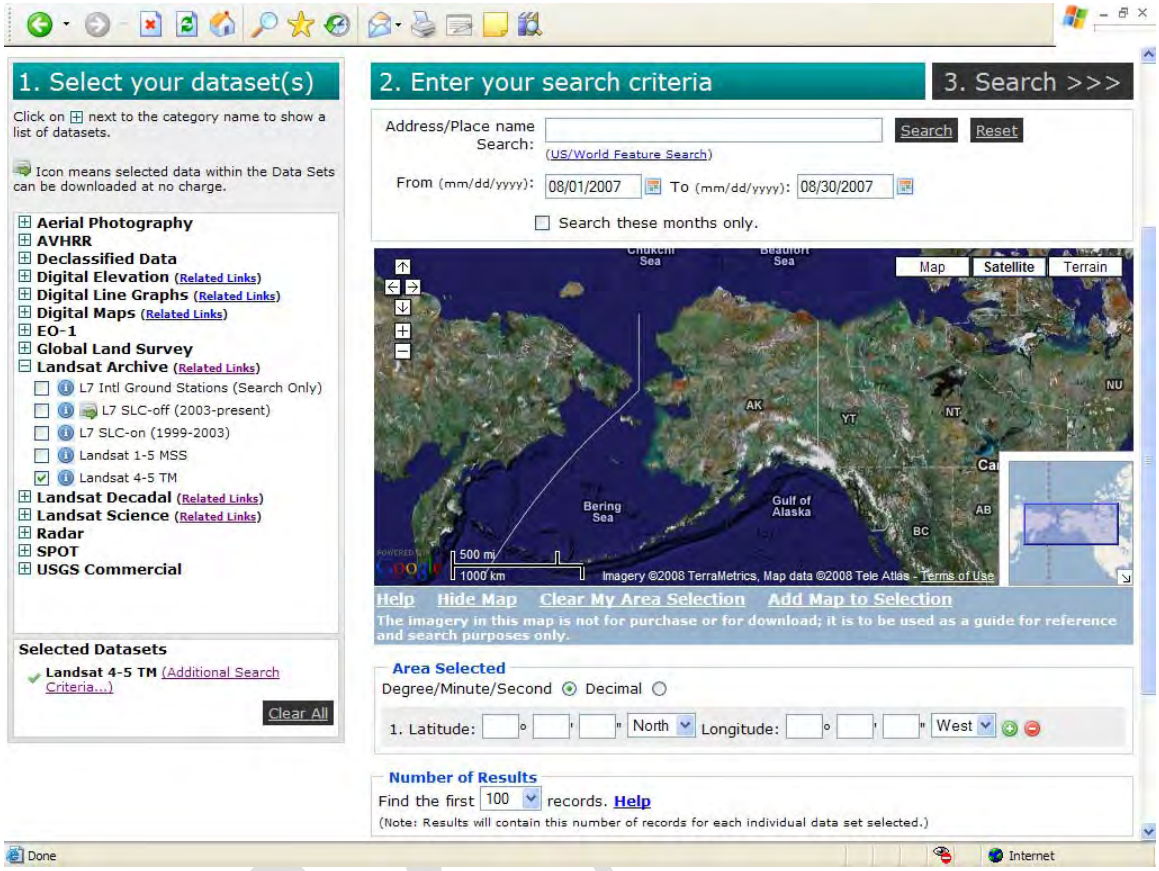

Figure 2. EROS website – selecting datasets.

To further refine the dataset search criteria, go to the "Selected Datasets" portion of the "Select your Dataset(s)" window and click on "Landsat 4-5 TM (Additional Search Criteria.....)."

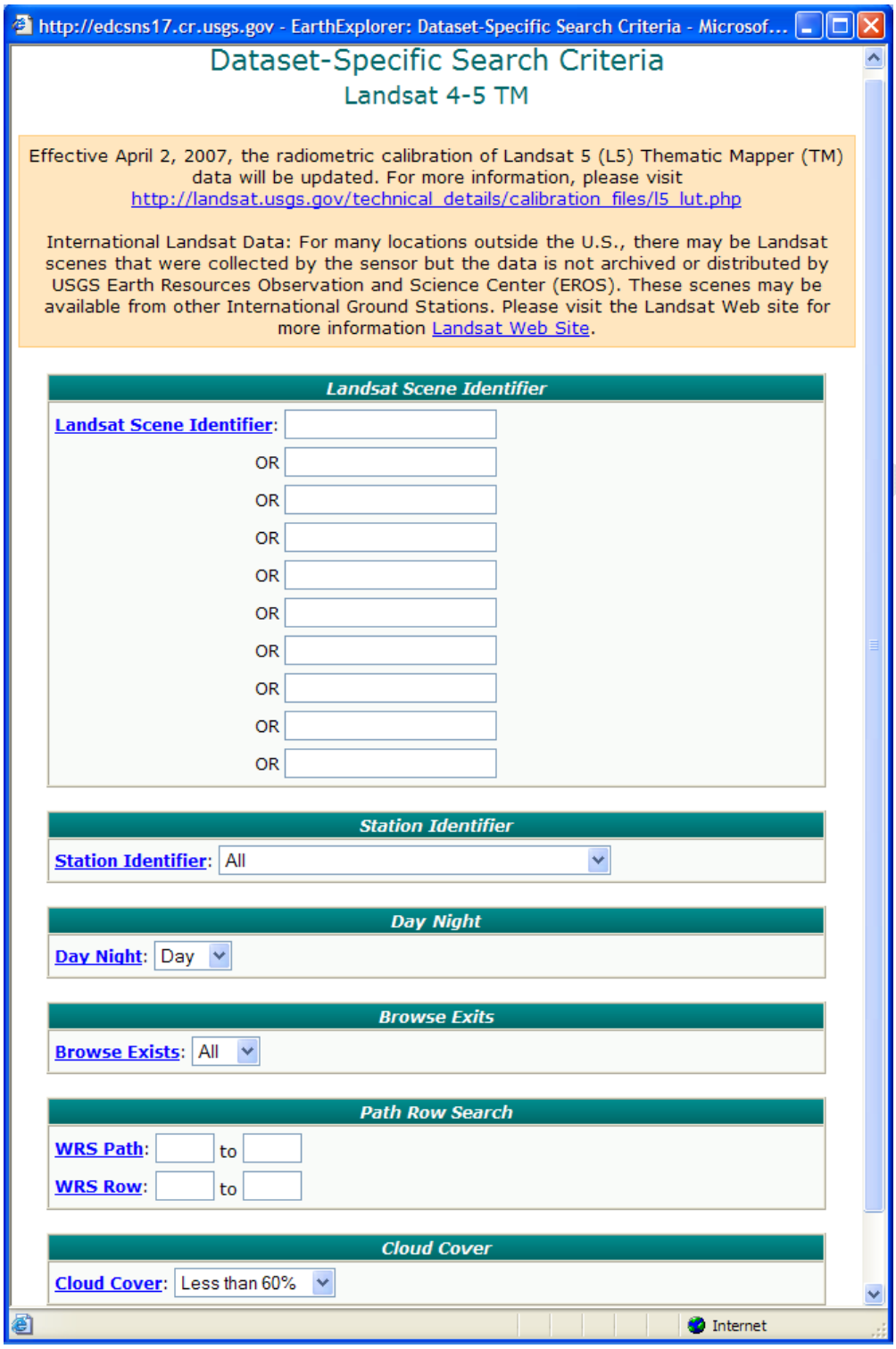

Figure 3. EROS website – selecting specific search criteria.

Created on 3/24/2009 10:15:00 AM
Created by bagiffen
Last saved by bagiffen on 8/18/2009

In the screen that appears, there are several criteria that can be selected to refine your search, such as: **Day Night**, **Cloud Cover** and several others. To eliminate unacceptable imagery from the search results, select a couple components in this window:

- **Day Night** – select "Day"
- **Cloud Cover** – select "Less than 60%"
- Select "OK"

Based on Landsat 5 flight path and swath width, the following is a tally of the minimum number of Landsat scenes required to cover the glacier bearing parks in the SWAN:

- KEFJ – 1 scene (path 69, row 18; path 69, row 19),
- LACL – 3 scenes (path 72 row 17, path 71, row 18, path 71, row 17),
- KATM – 1 scene (path 71, row 19).

Enter your search criteria

In this window of the webpage, you can identify the search dates (to and from), geographic location and you can limit the number of results returned in the search.

Search Dates (From and to in mm/dd/yyyy format). Mid-August through September imagery should be identified in the search. Check the box "Search these months only" and your search becomes a seasonal search over the span of years identified. This eliminates all imagery outside the August-September time-frame.

The next step is to toggle in the upper left of the map image to pan and zoom to the region of interest. To move the image around, click and drag. Once your region of interest is displayed, click with your mouse at the northeast corner of the region of interest and click again at the southwest corner of the region of interest. This defines the geographic limits of the search area. The glacierized region of LACL is used in the example.

The "Number of results" is the last item to fill out in this window. Limit the search to 100. This ensures that all available results will be identified.

The following example shows the EROS website with search criteria appropriate for Landsat 5 data from 1985 through 2009, seasonally for August 15 through September 30 only, returning 100 results.

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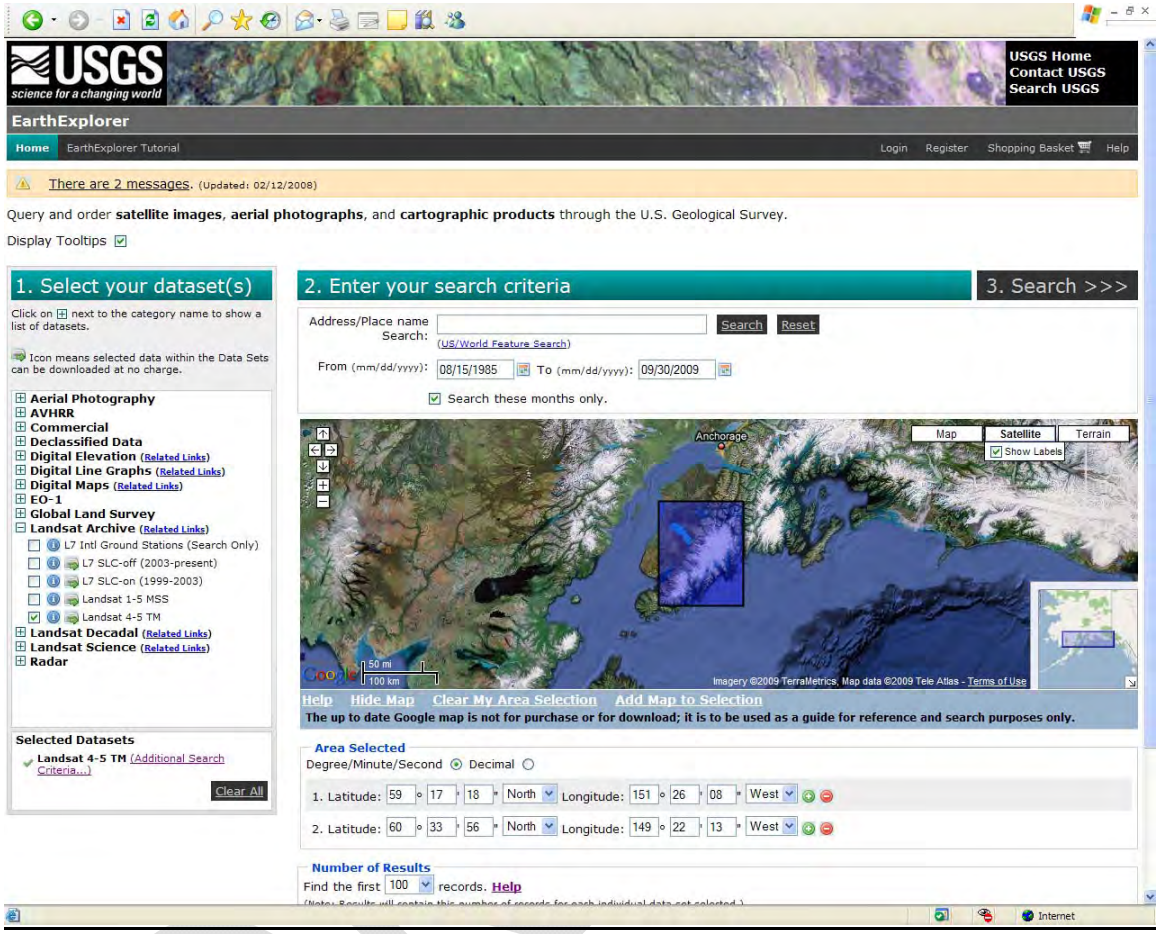


Figure 4. EROS website. Identifying date range, geographic extend and maximum possible or returns for meeting the search criteria.

Next, click on the “Search” button. The search may take several minutes to complete. The results screen:

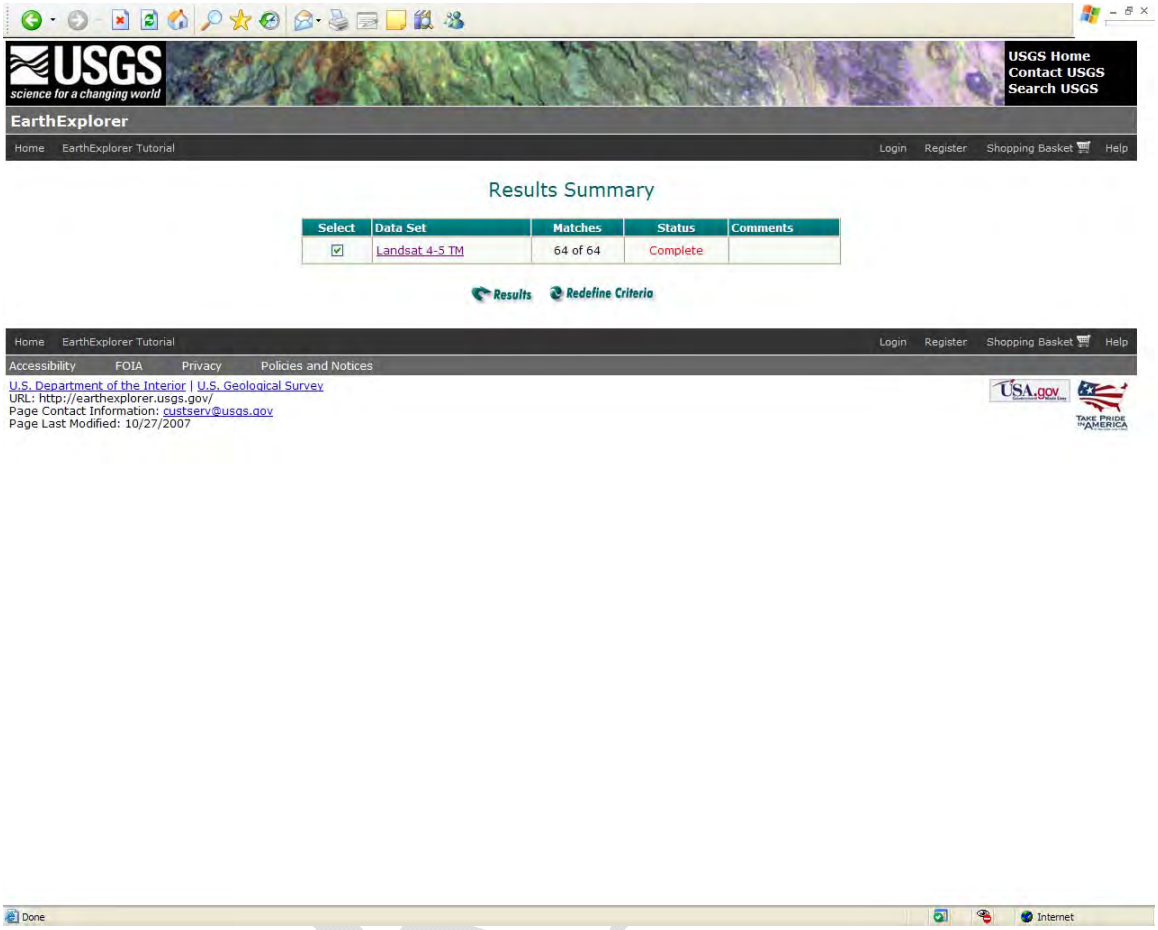
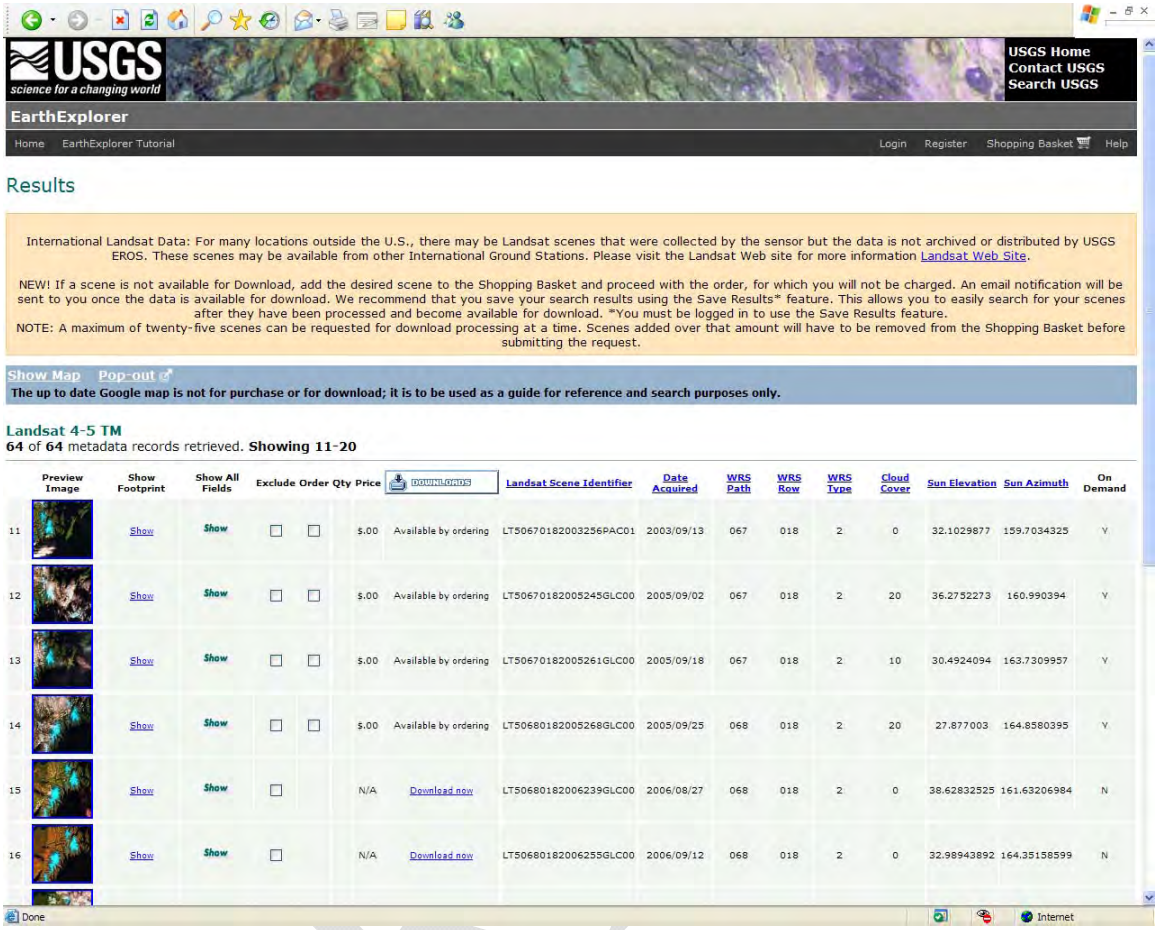


Figure 5. EROS website – Summary Results of the search criteria.

The data set and number of matches to the search criteria are displayed when the search is complete. Click on the data type identified under “Data Set” and the following screen appears.



	Preview Image	Show Footprint	Show All Fields	Exclude	Order Qty	Price	DOWNLOADS	Landsat Scene Identifier	Date Acquired	WRS Path	WRS Row	WRS Type	Cloud Cover	Sun Elevation	Sun Azimuth	On Demand
11		Show	Show			$.00	Available by ordering	LT50670182003256PAC01	2003/09/13	067	018	2	0	32.1029877	159.7034325	Y
12		Show	Show			$.00	Available by ordering	LT50670182005245GLC00	2005/09/02	067	018	2	20	36.2752273	160.990394	Y
13		Show	Show			$.00	Available by ordering	LT50670182005261GLC00	2005/09/18	067	018	2	10	30.4924094	163.7309957	Y
14		Show	Show			$.00	Available by ordering	LT50680182005268GLC00	2005/09/25	068	018	2	20	27.877003	164.8580395	Y
15		Show	Show			N/A	Download now	LT50680182006239GLC00	2006/08/27	068	018	2	0	38.62832525	161.63206984	N
16		Show	Show			N/A	Download now	LT50680182006255GLC00	2006/09/12	068	018	2	0	32.98943892	164.35158599	N

Figure 6. EROS website – thumbnails and details for each image meeting the search criteria.

A thumbnail of each image is displayed. Scroll through the results. Click on those thumbnail images that appear to be largely cloud free. This will display the image in greater detail. Evaluate these images for there acceptability in meeting the requirements of this protocol.

Note that the below image is approximately 30% cloudy, but this is acceptable because the glacier area is cloud-free.

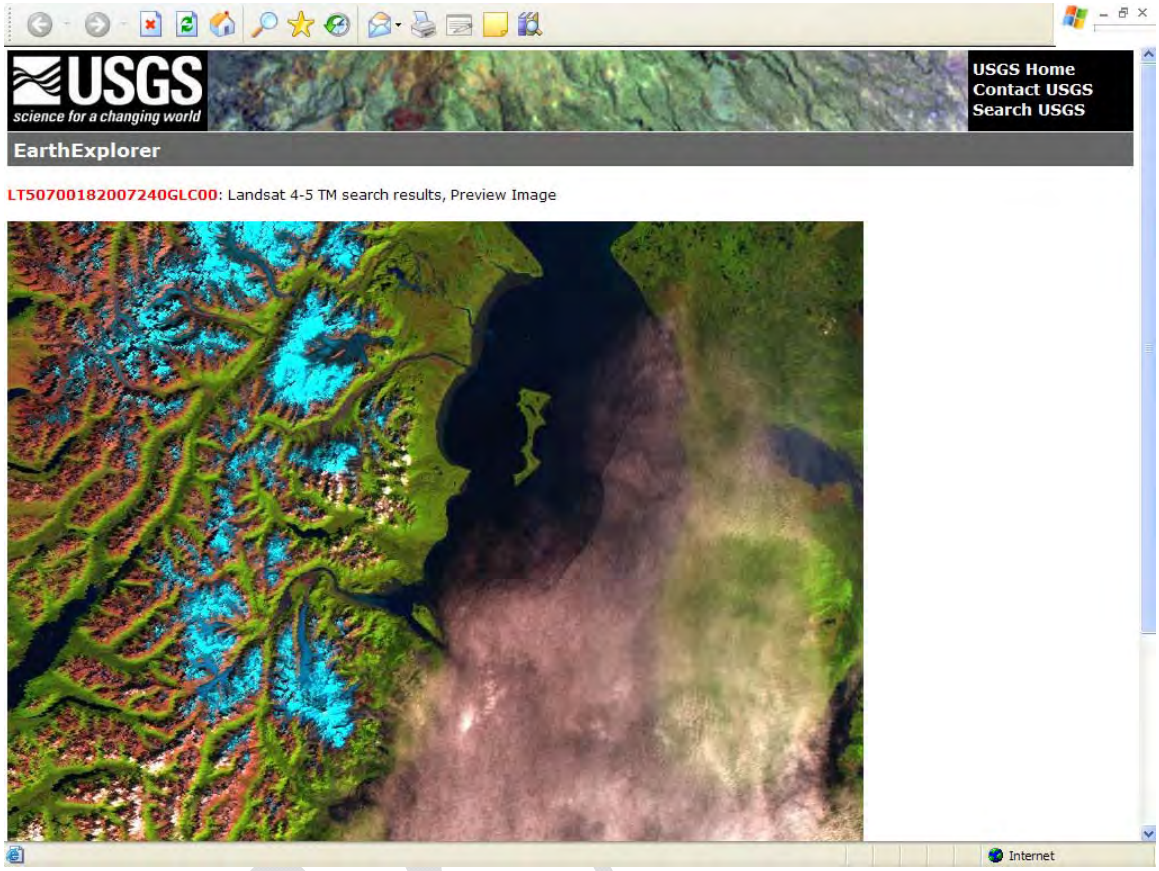


Figure 7. EROS website – Expanded thumbnail.

1-4 EROS Website - Landsat Data Order

When Landsat imagery is identified that meets the late-season, cloud-free requirements with little or no early-season snow requirements, it is time to order or download the image for free. If you are not "Signed in" on the EROS website, do so now.

From Figure 8, some data is available immediately if the "Download now" option is activated. Click on the "Download now" button and follow the instructions. Otherwise, select the box under the Column "Order" and then select "Add Selected Items to Shopping Basket" near the bottom of the page. Then select "View Shopping Basket."

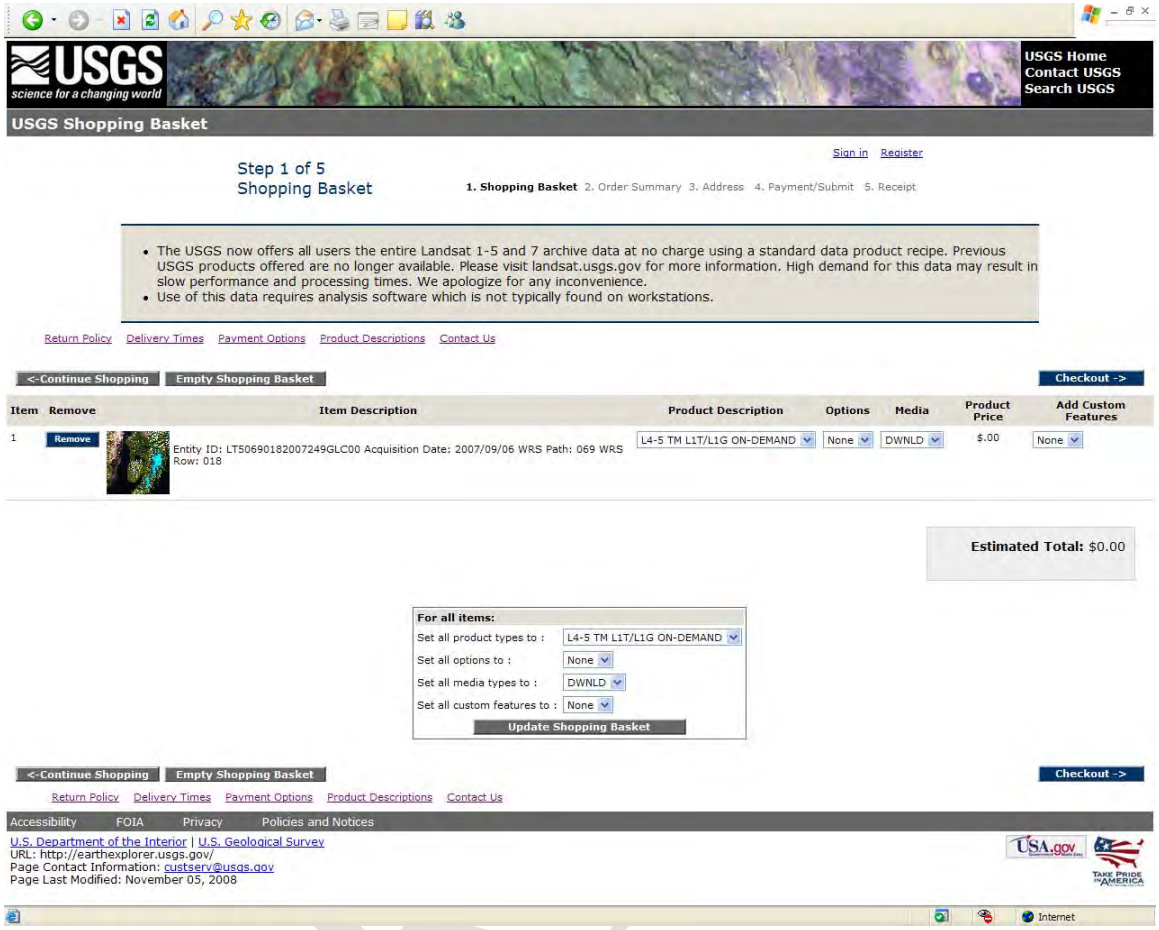


Figure 8. EROS website – shopping basket.

Verify that the images you need are identified in you “Shopping Basket” and select “Checkout” and the following screen appears verifying that the order is being processed.

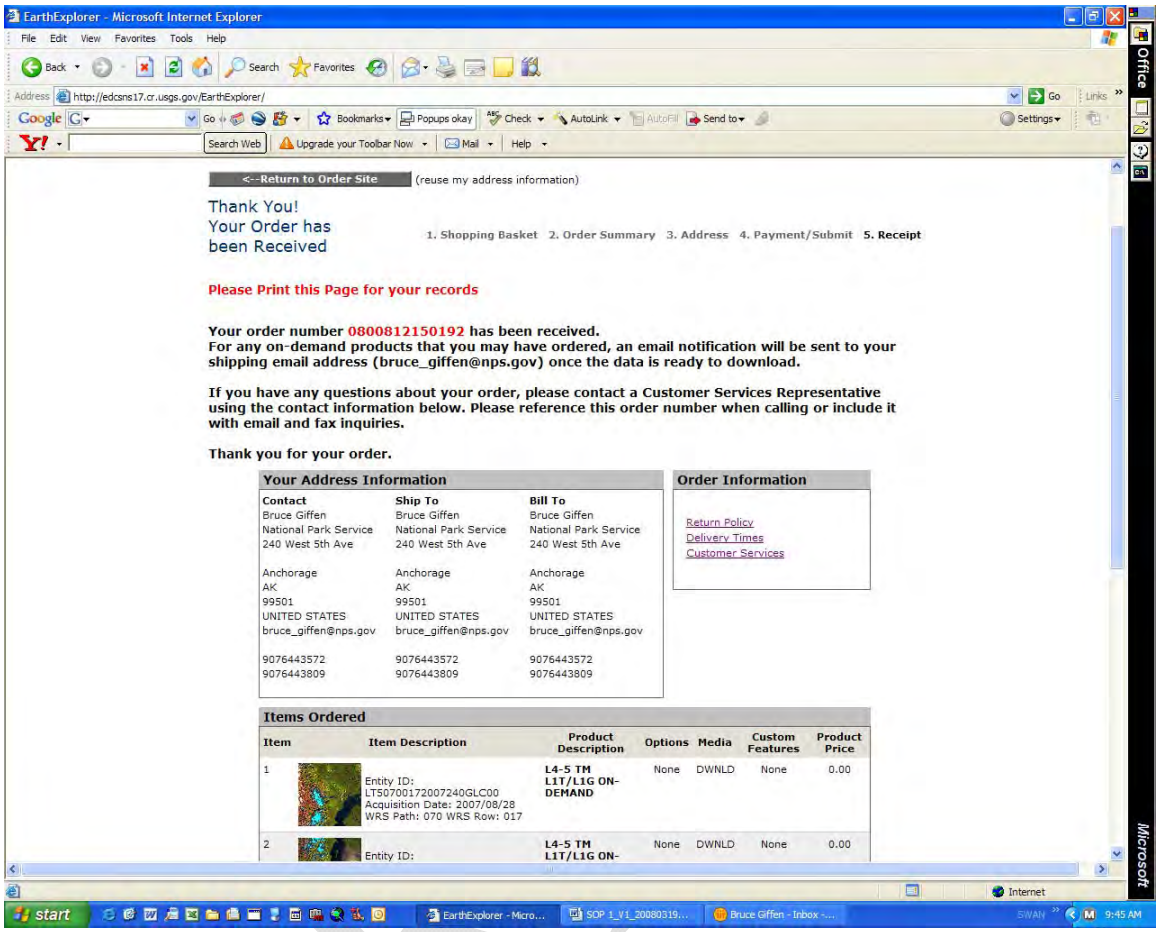


Figure 9. EROS website – order confirmation.

An email will be received verifying the order and when the order has been processed, another email will be received with downloading instructions.

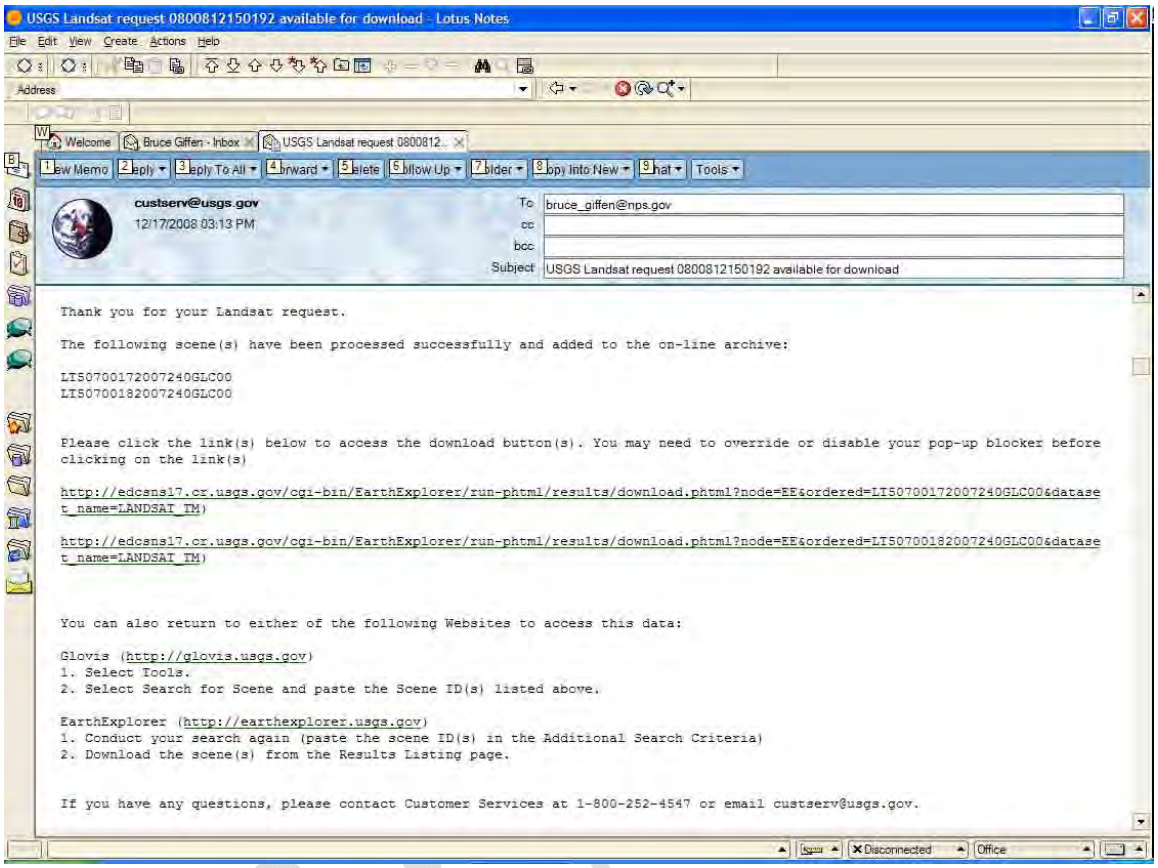


Figure 10. Email for the EROS Data Center – notification that ordered imagery is available for downloading.

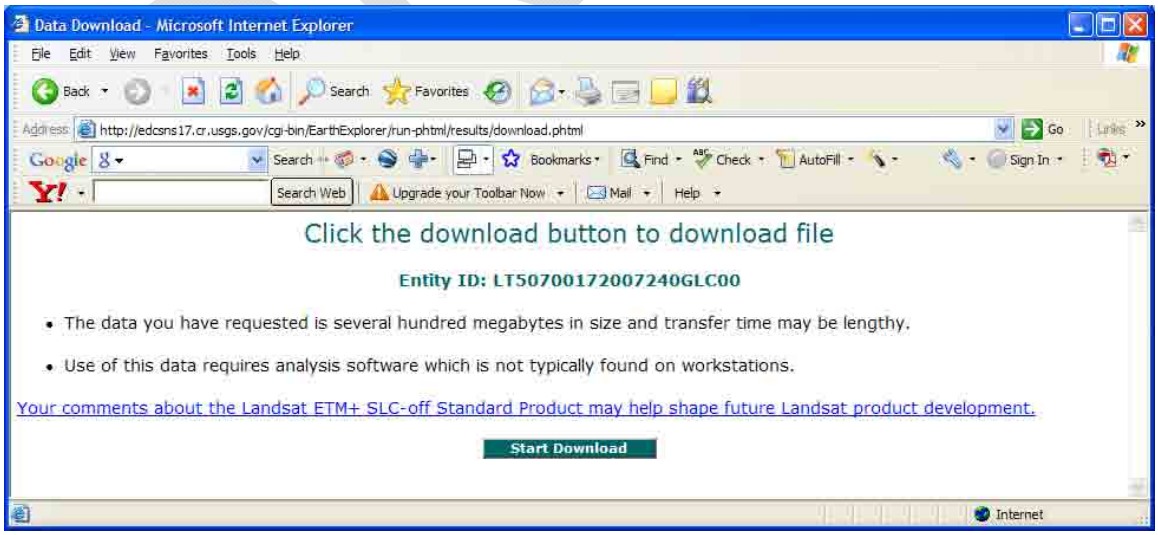


Figure 11. EROS website – web-link provided in email from EROS notifying that imagery is ready for download.

The downloading instructions in the email are clear. When you click the download button, a Windows message appears asking to “open” or “save” the file – select “save” and “ok.” Navigate to a previously created folder where the file should be saved. (See SOP 7 for folder/file naming convention). When the download is complete a Windows panel appears, select “open folder”.

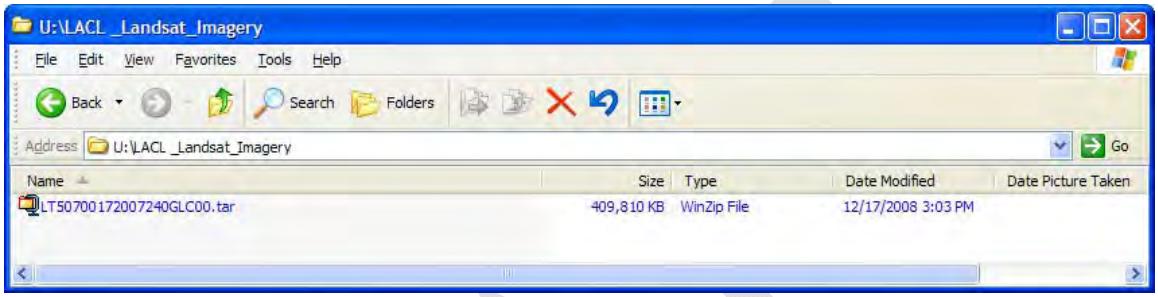


Figure 12. Landsat imagery lownload as a .tar file in appropriate folder.

There is a *.tar Winzip file in the folder with the standard naming convention for Landsat imagery. Winzip will not decompress this *.tar file.

Using 7-Zip, an open source software package, the *.tar file can be decompressed into the seven Landsat geotiff bands. Launch the 7-Zip software and navigate to the appropriate folder containing the *.tar file. Highlight the file and select the “Extract” button.

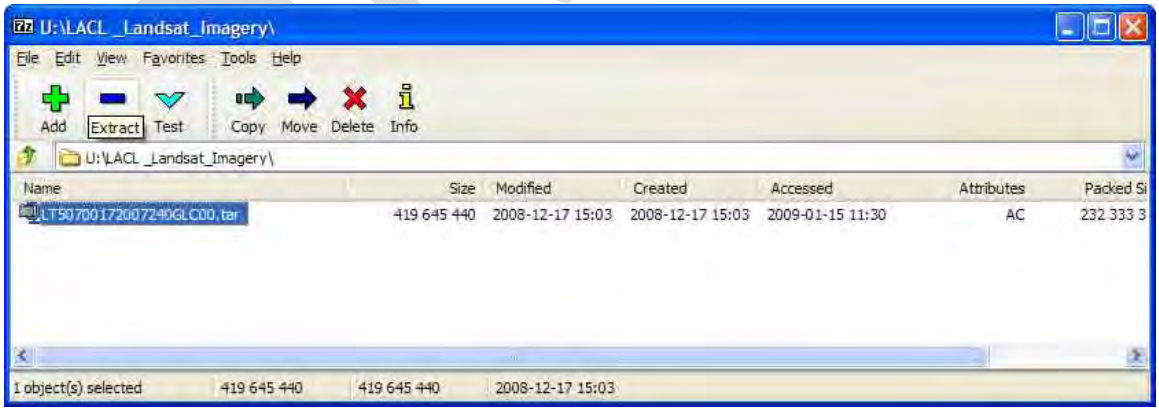


Figure 13a. 7-Zip software.

A window appears asking: “Extract To.” The default is the folder currently holding the *.tar file, select “ok.”

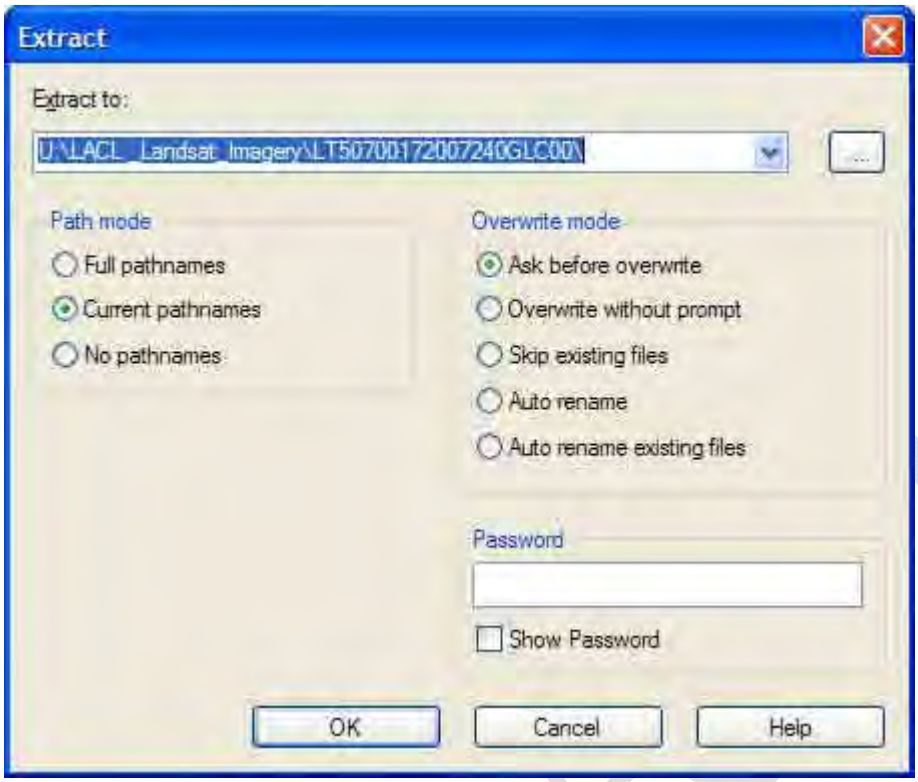


Figure 13b. 7-Zip software.

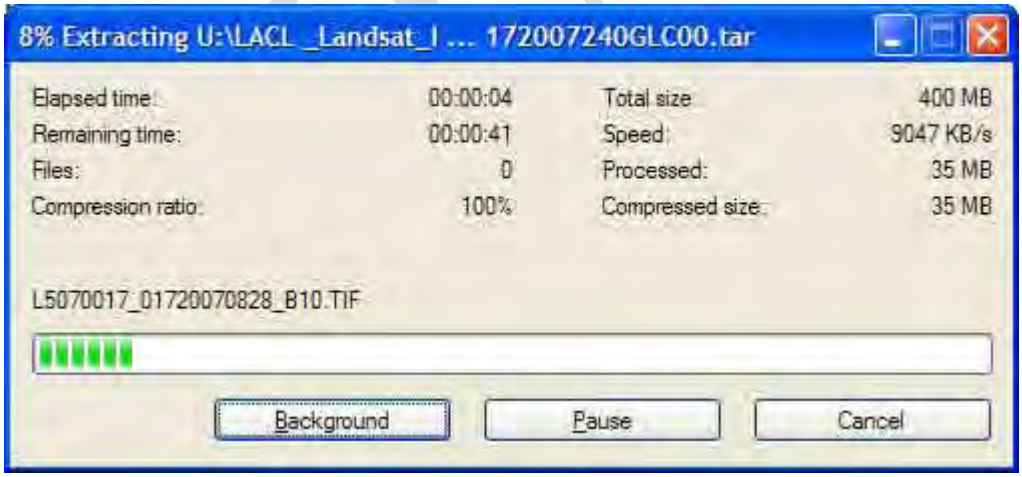


Figure 13c. 7-Zip software.

Close 7-Zip.

The Landsat geotiff bands are located in a folder named using the standard naming convention for Landsat imagery.

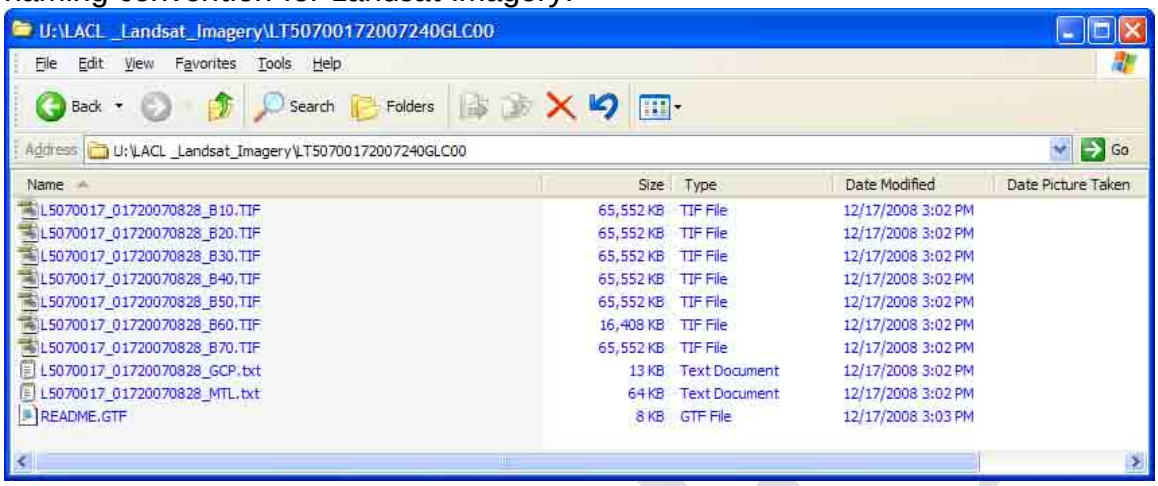


Figure 14. A look at the folder and the extracted Landsat geotif files.

The Landsat image is now ready to load into the image processing software.

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The Alaska Landsat data is delivered as with the following parameters:

Map projection: UTM, Zone 5 or Zone 6
Pixel: 30 meters
Datum: WSG84
Image orientation: Map (north up)
Correction (Level L1T/L1G)
Geotiff

<u>EROS Pricing Policy - Landsat</u>

Landsat Imagery:

Free

DRAFT

Glacier Extent Protocol
Southwest Alaska Network

Standard Operating Procedure (SOP) # 2

Analysis – RSI's ENVI
Image Processing Software

Version 1.0 (May, 2009)

Revision History Log:

Previous Version #	*Revision Date*	*Author*	*Changes Made*	*Reason for Change*	*New Version #*

Overview and Explanation

This Standard Operating Procedure explains the first few steps to take in initiating the glacier ice mapping using Landsat satellite imagery. This SOP describes the first steps employed in a process to automatically classify (separate) snow and glacier ice data from all other data in a Landsat satellite image.

Simple band math techniques are used to manipulate the Landsat data, which in-turn allows for the automated classification (separation) of snow and glacier ice pixels from all other pixels in the Landsat image.

Each Landsat image is unique. Sun angles, atmospheric conditions and cloudiness are some of the characteristics that vary between images. Due to this variation, one single classification technique does not produce an acceptable classification for all Landsat data. Thus, this SOP will introduce several band math techniques which can be tested and the result evaluated to determine which technique best classifies the data for snow and glacier ice.

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After the appropriate band math technique and threshold values are identified using the ENVI software, the remainder of the snow and glacier ice classification effort is carried out is a GIS work environment. The NPS currently uses ArcGIS.

As we gain experience in Landsat data enhancement processes and interpretation, this SOP will be modified and updated.

Attempts over the years to develop an automated classification technique to accurately define glacier ice extent have not proved entirely successful. Debris covered ice likely being the single largest obstacle to success because the reflectance of debris covered ice is the same as the surrounding moraine material. Human interpretation of the Landsat data will necessarily be a large part of the process in areas of debris cover.

Landsat imagery data quality, data standards and data acquisition is found in SOP #1.

The glacier extent will be mapped decadally with a comparative analysis conducted with previous mapping efforts to assess changes in extent and identify trends.

The goal of this protocol is to automate the classification as much as possible and remove as much of the human interpretation component as possible from the mapping effort. Not only will this enhance the non-biased repeatability of this protocol, but it will significantly reduce the workload burden for the SWAN parks. Accuracy and repeatability is the goal for this protocol and as such, this protocol relies on the following:

- Landsat satellite imagery must meet the criteria specified in SOP #1. Cloud-free, late-season imagery.
- Imagery classification techniques to automate as much of the glacier extent mapping effort as possible.
- Manual editing techniques of the automatically derived glacier extent boundary in an ArcGIS edit session (see SOP #3).

When careful attention is maintained throughout the mapping effort, accuracy and repeatability is substantially increased.

Procedures - Mapping Glacier Extent

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2-1 What is a Glacier?

To help standardize glacier mapping, the definition of what falls into the category called "glacier extent" must be clearly defined. The following is from the GLIMS definition of a glacier and is used for this protocol (Raup, 2007, GLIMS Analysis Tutorial):

> *A glacier or perennial snow mass consists of a body of ice and snow that is observed at the end of the melt season. This includes, at a minimum, all tributaries and connected feeders that contribute ice to the main glacier, plus all debris covered parts of it. Excluded is all exposed ground, including nunataks.*
>
> *The following circumstances will be considered when mapping glacier boundaries (Raup, 2007, GLIMS Analysis Tutorial):*
> *1. Bodies of ice above the bergschrund that are connected to the glacier shall be considered part of the glacier, because they contribute snow (through avalanches) and ice (through creep flow) to the glacier.*
> *2. Any steep rock walls that avalanche snow onto a glacier but do not retain snow themselves are NOT included as part of the glacier.*
> *3. A stagnant ice mass still in contact with a glacier is part of the glacier, even if it supports an old-growth forest.*
> *4. All debris covered parts of the glacier must be included.*
> *5. Map only at the end of the ablation period to exclude seasonal snow. Map everything that is connected to the glacier.*
> *6. Rock glaciers are not included in this protocol.*

2-1 Software Selection

There are several satellite image processing software packages that can be used to view, analyze, enhance and process Landsat imagery data: ERDAS, ENVI and PCI are just a few. The selection of a single product boils down to user preference. The SWAN I&M program currently uses ENVI for image processing. ENVI satellite imagery processing software will be utilized to meet the objectives of this glacier extent protocol.

2-2 Landsat Imagery Processing and Enhancement

A general overview of the satellite imagery processing steps is presented here and based on RSI's ENVI image processing software.

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2.2.1. Multi-spectral classification methods

As previously indicated, several classification techniques will be presented relying on simple band math and the identification of threshold values. For the most part, each of these techniques produce good results for clean glacier boundaries. Each of the techniques may produce varying results in areas of shadows and/or debris covered ice. Therefore, there is an effort needed to identify which technique will produce the best results given the Landsat dataset being used.

Four simple band math techniques have been tested:

- NDSI ((TM2-TM5)/(TM2+TM5))
- NDVI ((TM3-TM5)/(TM3+TM5))
- TM3/TM5
- TM2/TM5

(NDSI – Normalized Difference Snow Index, NDVI – Normalized Difference Vegetation Index).

(TM2 refers to Landsat band 2 and so forth)

These classification techniques are fast and accurate for clean glacier and snow boundaries, but require substantial manual editing for areas of debris covered boundaries. Each of these classifications are sensitive to the threshold values applied. A range of threshold values should be tested to identify the threshold value that best classifies the Landsat image for snow and glacier ice.

The following band math techniques appear to perform well in areas of extreme topography (shadowed glacier) and in areas of light debris cover:

- NDVI ((TM3-TM5)/(TM3+TM5))
- TM3/TM5

None of the techniques produce acceptable results in areas of heavily debris covered ice. These areas will require human interpretation to correct the glacier margin during an ArcGIS work session.

Time spent on the process of identifying the best band math technique and accompanying threshold value will result in an accurate automated mapping effort which will at the same time minimize the amount of manual editing required to complete the glacier mapping effort.

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For a starting point, threshold values for the four simple band math techniques used are:

- NDSI ((TM2-TM5)/(TM2+TM5)): >.2
- NDVI ((TM3-TM5)/(TM3+TM5)): >.5
- TM3/TM5: >1 (Andreassen, et el, 2008)
- TM2/TM5: >2.3

Outlining the steps and procedures of band math and applying threshold valuesn using RSI'S ENVI are presented here. The person performing these duties should be well versed in ENVI, as the good results are based on a series of trial and error efforts until a satisfactory result is achieved.

One the band math technique and threshold value is identified, this information is then used in an ArcGIS work session to classify the Landsat data and produce shapefiles based on the classification. These shapefiles are then edited in ArcGIS to correct areas of miss-classification.

General instructions below describe how to navigate through the ENVI software.

<u>Opening an Image File in ENVI</u>
From the File drop-down in ENVI, select Open External File, then select Landsat, then select Geotiff (or appropriate format). And then navigate to the folder where the imagery resides and select the imagery/bands of interest. See Figure 2-1.

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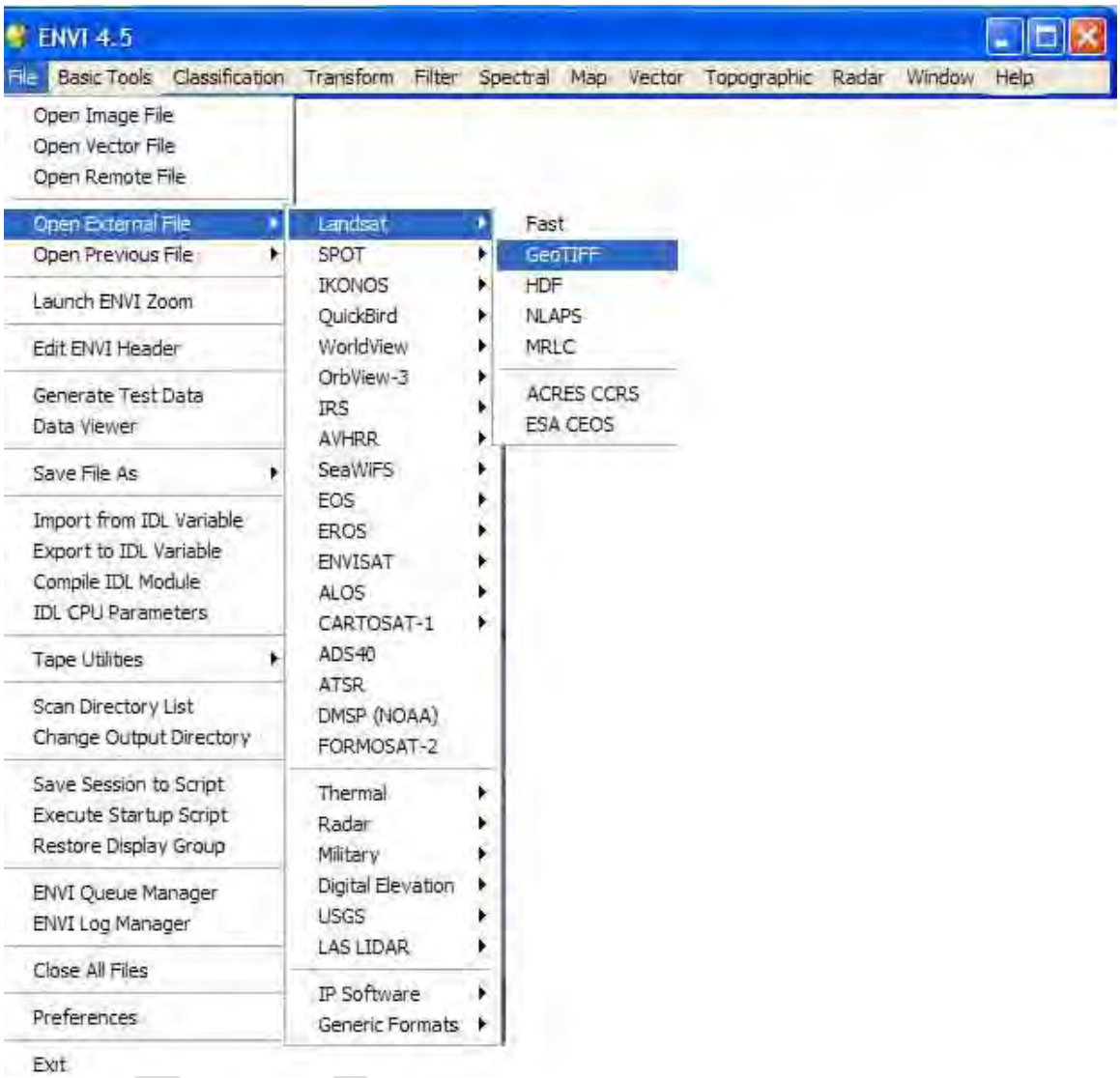

Figure 2-1. ENVI – opening a Landsat geotiff file.

After selecting the bands of interest, the Available Bands List dialog box appears, Figure 2-2.

Figure 2-2. ENVI avalable bands dialog box.

<u>Create a Color Composite Image in ENVI</u>

From the Available Bands List window, select the RGB button and then from the available bands list, select the “R” button and click on band 5, select the “G” button and click on band 4, select the “B” button and click on band 2. This band combination works well for glacier mapping. Now click on the button “Load RGB.” Figure 2-5. A color composite image will now load and display in three windows (display, scroll and zoom). Figure 2-6.

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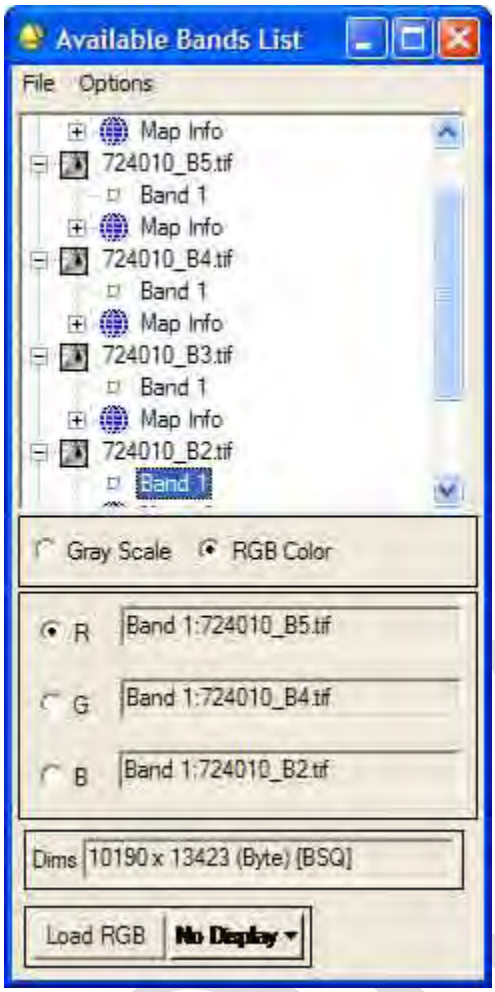

Figure 2-5.

DRAFT

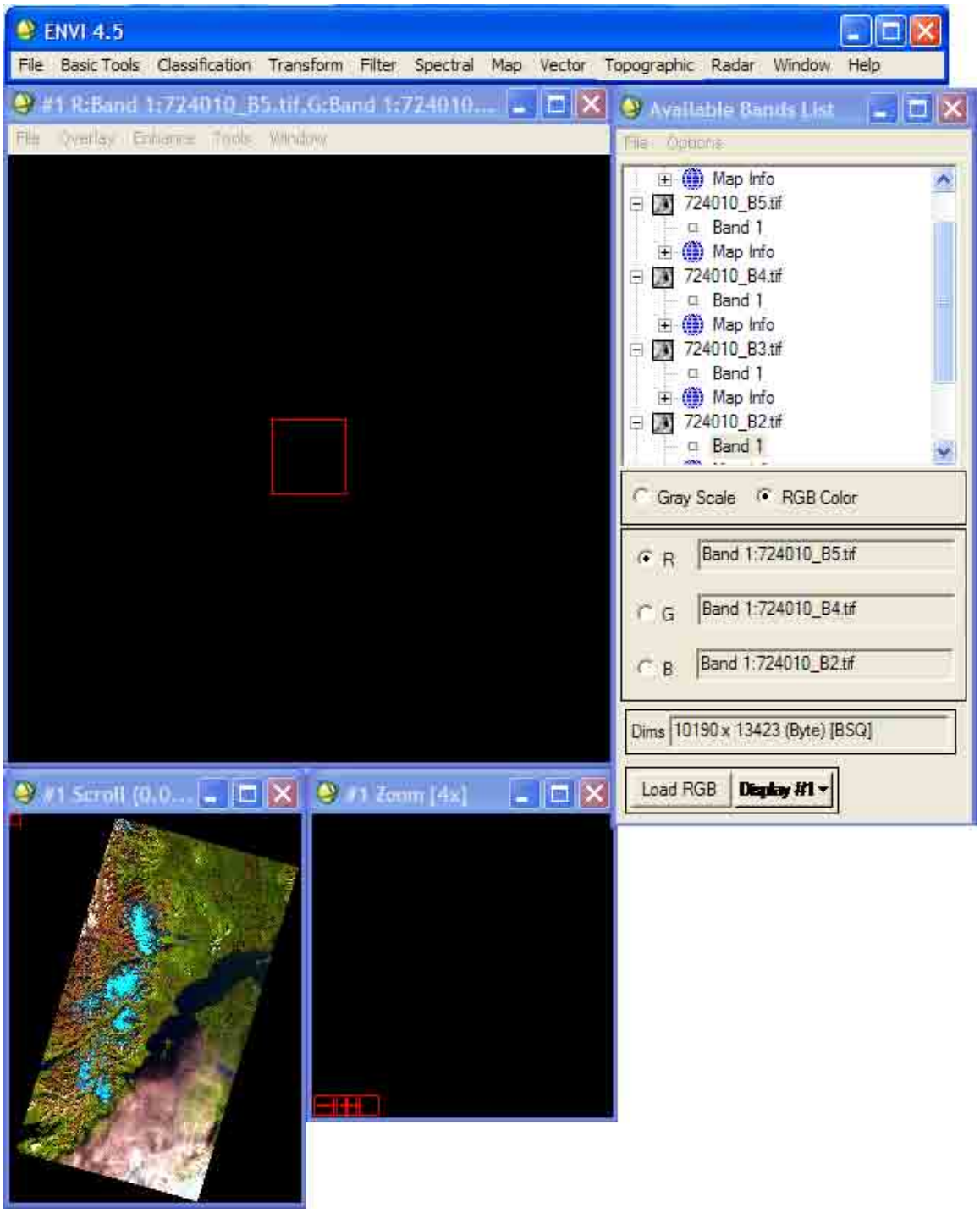
ENVI 4.5
File Basic Tools Classification Transform Filter Spectral Map Vector Topographic Radar Window Help
#1 R:Band 1:724010_B5.tif,G:Band 1:724010...
Available Bands List
Map Info
724010_B5.tif
Band 1
Map Info
724010_B4.tif
Band 1
Map Info
724010_B3.tif
Band 1
Map Info
724010_B2.tif
Band 1
Gray Scale
RGB Color
R
Band 1:724010_B5.tif
G
Band 1:724010_B4.tif
B
Band 1:724010_B2.tif
Dims
10190 x 13423 (Byte) [BSQ]
Load RGB
Display #1
#1 Scroll (0,0...
#1 Zoom [4x]

Figure 2-6.

Glacier and snow Classification

As stated earlier, automated classification techniques are capable of accurately mapping clean glacier margins. However, these techniques are less accurate in areas where there is debris covered ice, shadows and/or clouds. The automated classification effort in these areas will require extensive manual editing.

As classification techniques are developed, this SOP will be modified and updated.

As indicated earlier, simple band math techniques are robust in classifying clean glacier ice and snow. These techniques also produce very good results in areas of shadowed ice and where debris cover is not too heavy. Band B3/B5 ratio has produce very good results, especially in deep shadows.

ENVI is the software used here to perform simply band math and identify appropriate threshold values. The steps for performing band math and identifying appropriate threshold values are presented below.

Four different band math expressions have been identified as useful in snow and glacier ice classification.

- NDSI ((TM2-TM5)/(TM2+TM5)): >.2
- NDVI ((TM3-TM5)/(TM3+TM5)): >.5
- TM3/TM5: >1 (Andreassen, et el, 2008)
- TM2/TM5: >2.3

Detailed instructions follow below for one band math expression, though the steps are the same for the remaining three methods.

Instructions below direct you to the appropriate areas in the ENVI software where band math can be performed (See Figure 2-9 through 2-12).

Band Math

To perform band math in ENVI, select the Basic Tools drop down menu and click on Band Math.

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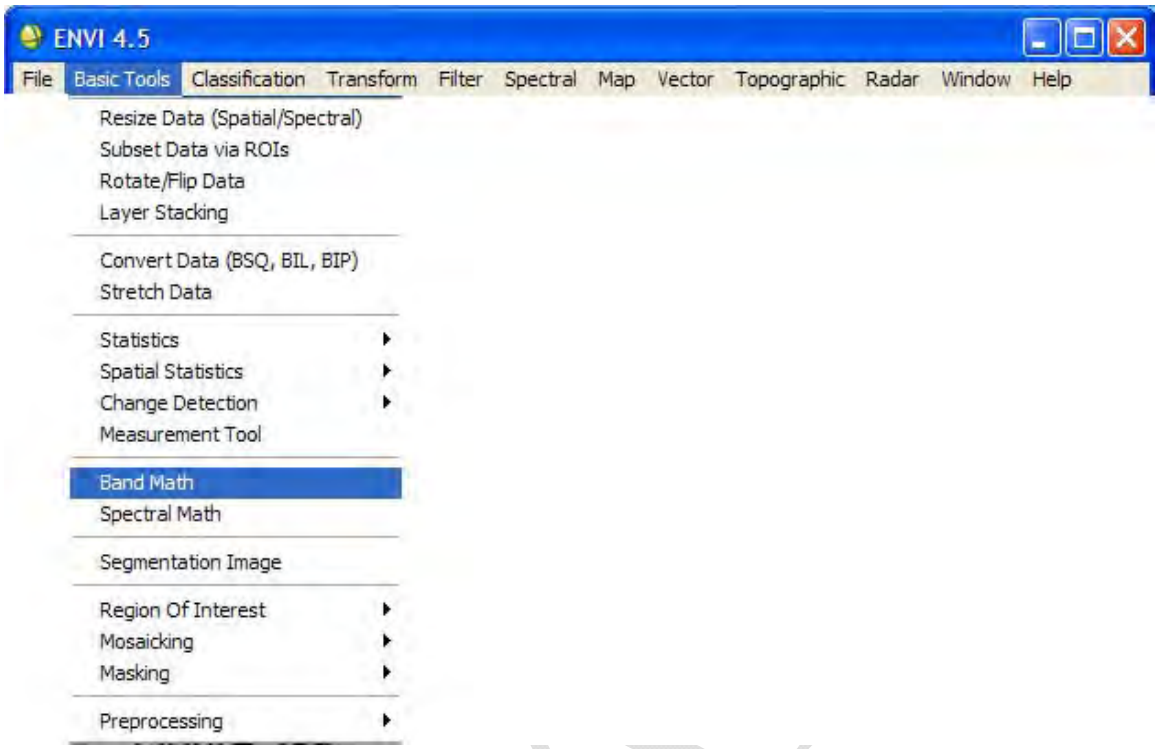


Figure 2-9.

A Band Math window appears. Enter your equation in the box labeled "Enter an expression." In this particular example the expression is:

- float(b3)/float(b5)

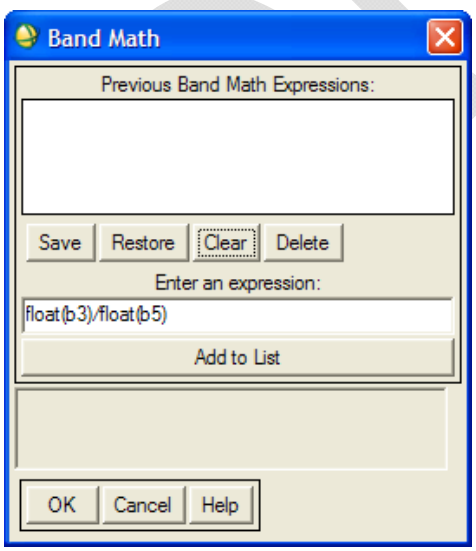


Figure 2-10.
Click OK and another window appears: the Variables to Bands Pairings dialog box.

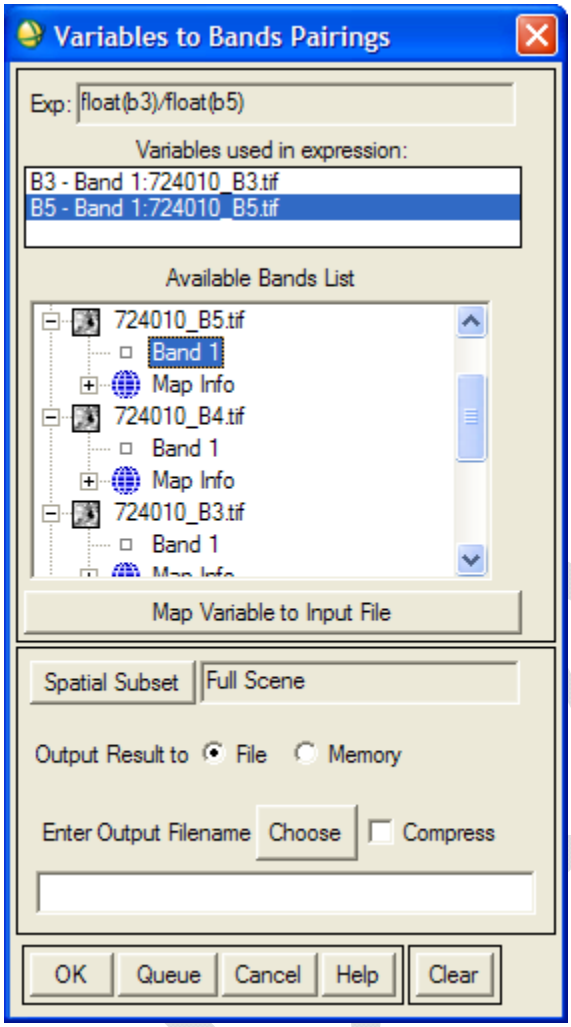


Figure 2-11.

Highlight one of the variables located in the box labeled “Variables Used in expression” and then click on the appropriate band in the “Available Bands List” and choose “File” or “Memory” for the output. If you choose “File” “Choose” an appropriate file name and folder location. Click “OK.” The following dialog appears to show you the progress of the operation.

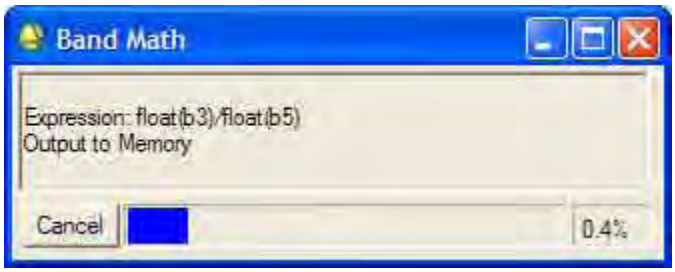


Figure 2-11.

A single band result appears in the Available Bands List window. Load the image in a “New Display” using the gray scale and inspect the results. You now have two images displayed, the color composite image (Display 1) and a grey scale image (Display 2) representing the results of the band math (float(b3)/float(b5)).

DRAFT

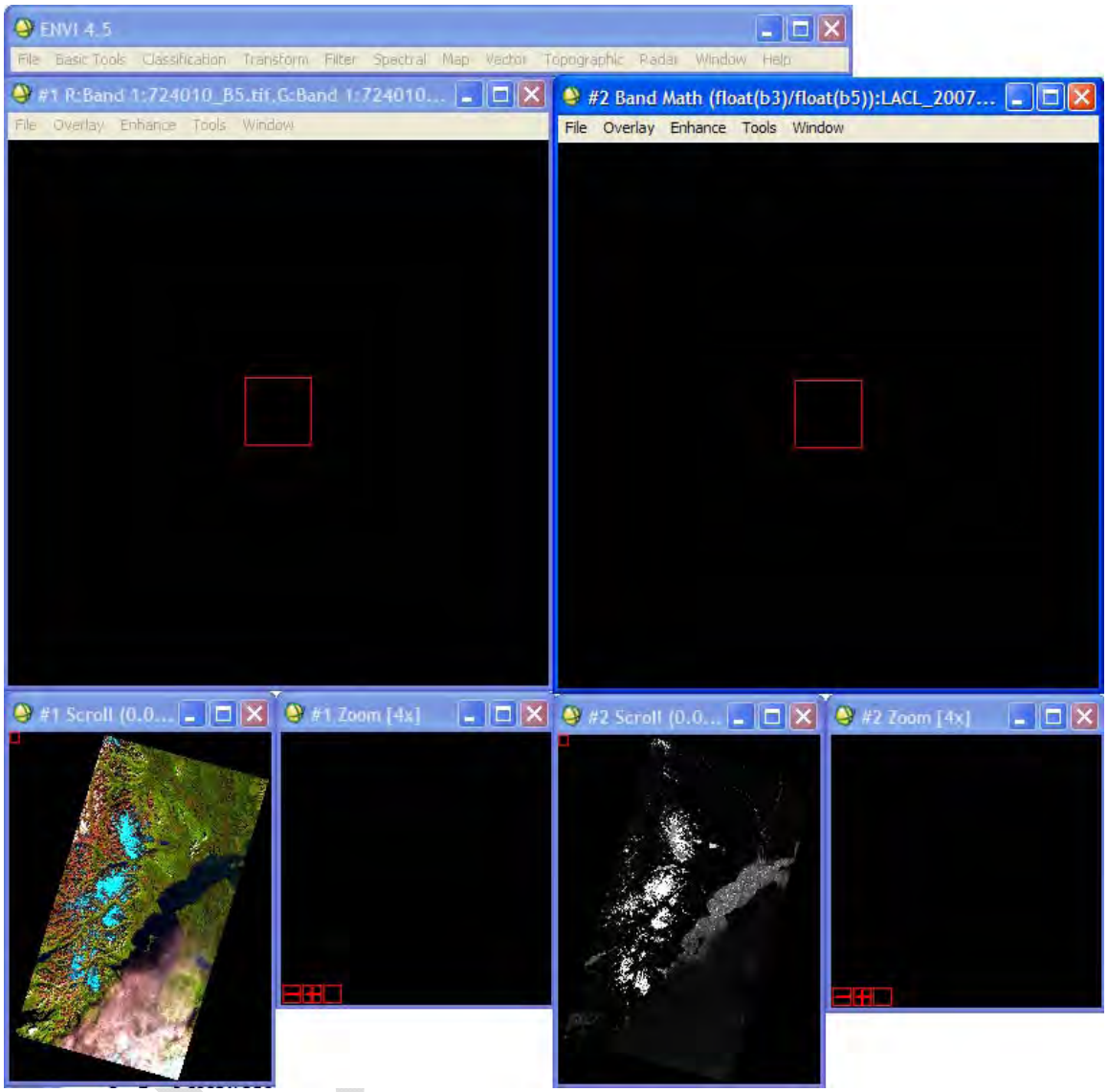
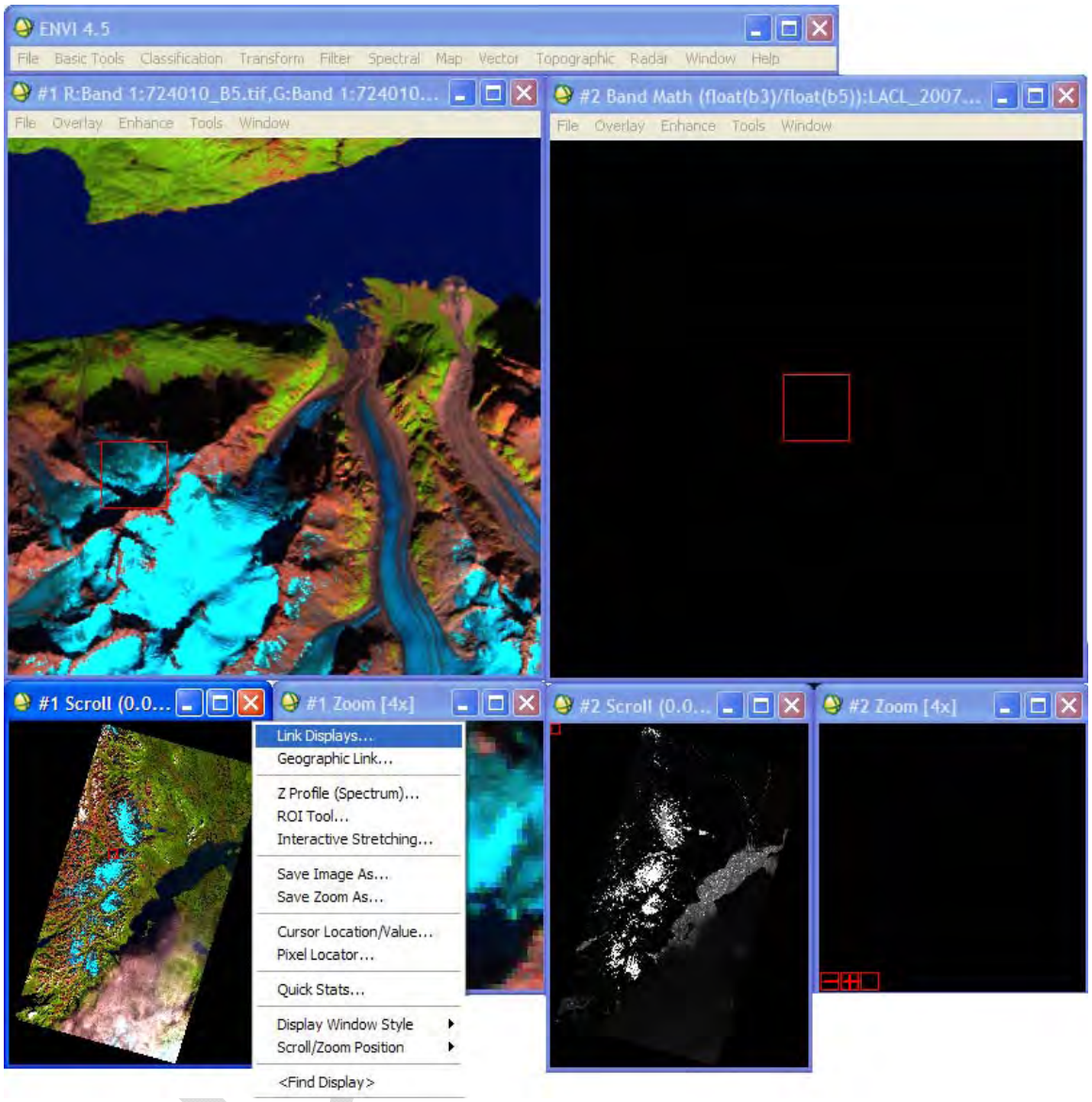
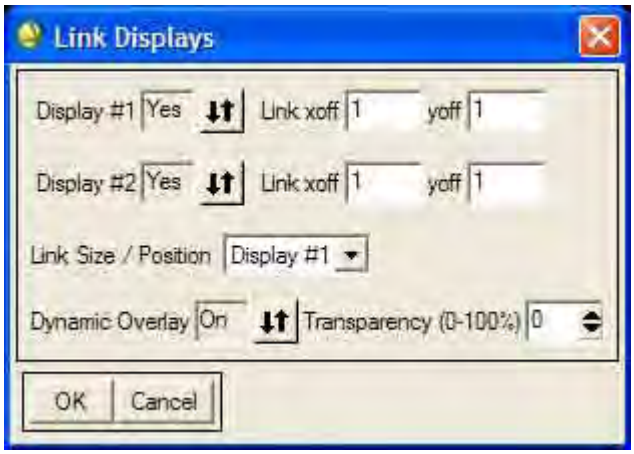


Figure 2-12.

One nice feature with ENVI is that the two displays can be linked together by right clicking on an image and select “Link Displays.”



The following dialog box appears:



The two displays are now linked. Turn on the cross-hairs for both the "Zoom" windows. There are three red boxes in the lower left of the "Zoom" window for each of the two images. Click on the furthest right red box in each of the two "Zoom" windows and the cross-hairs will appear in the window.

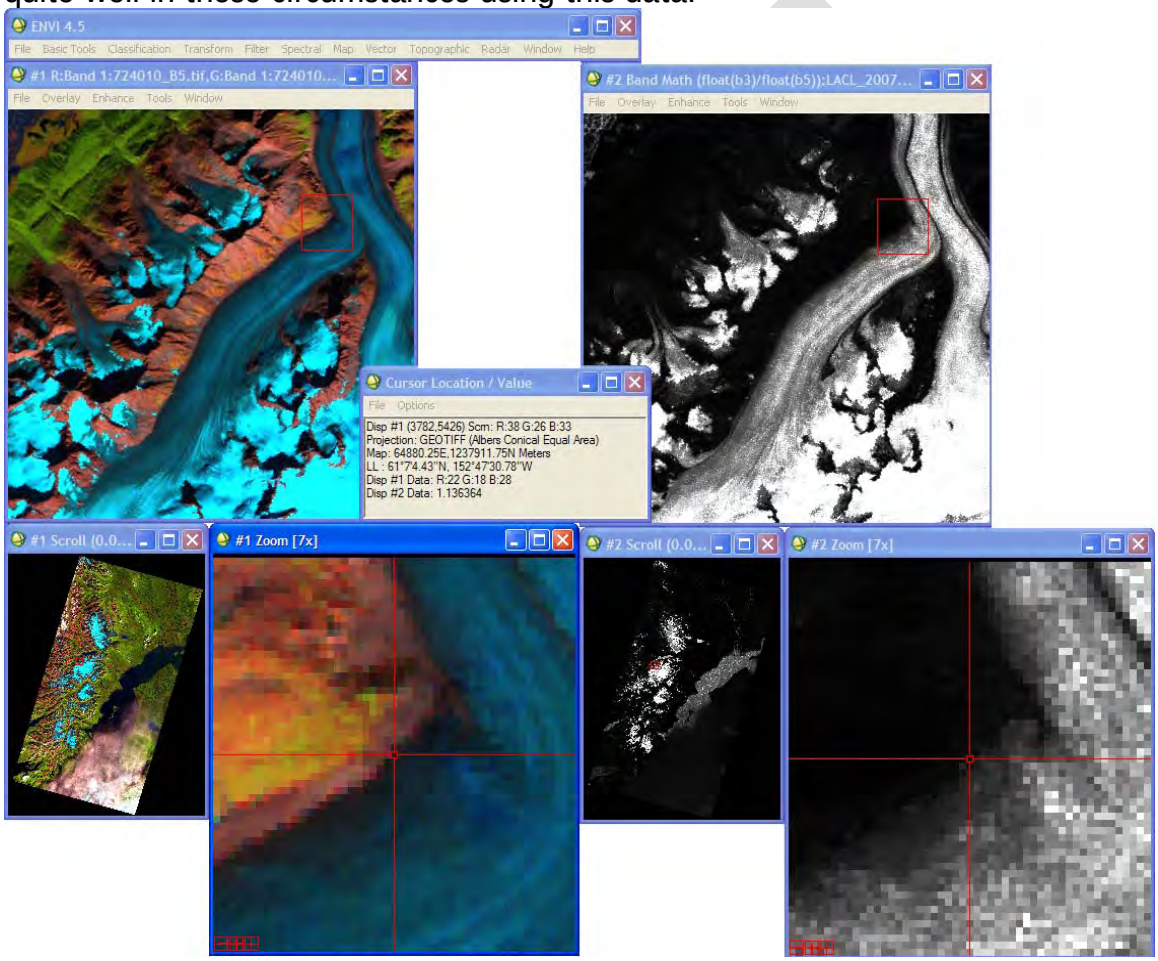
B3/b5 1.347

Now turn on the "Cursor Location/Value" tool by right clicking on any image window and selecting "Cursor Location/Value." The following dialog box appears:

This allows you to see the pixel values at the cross hairs as you move across the image.

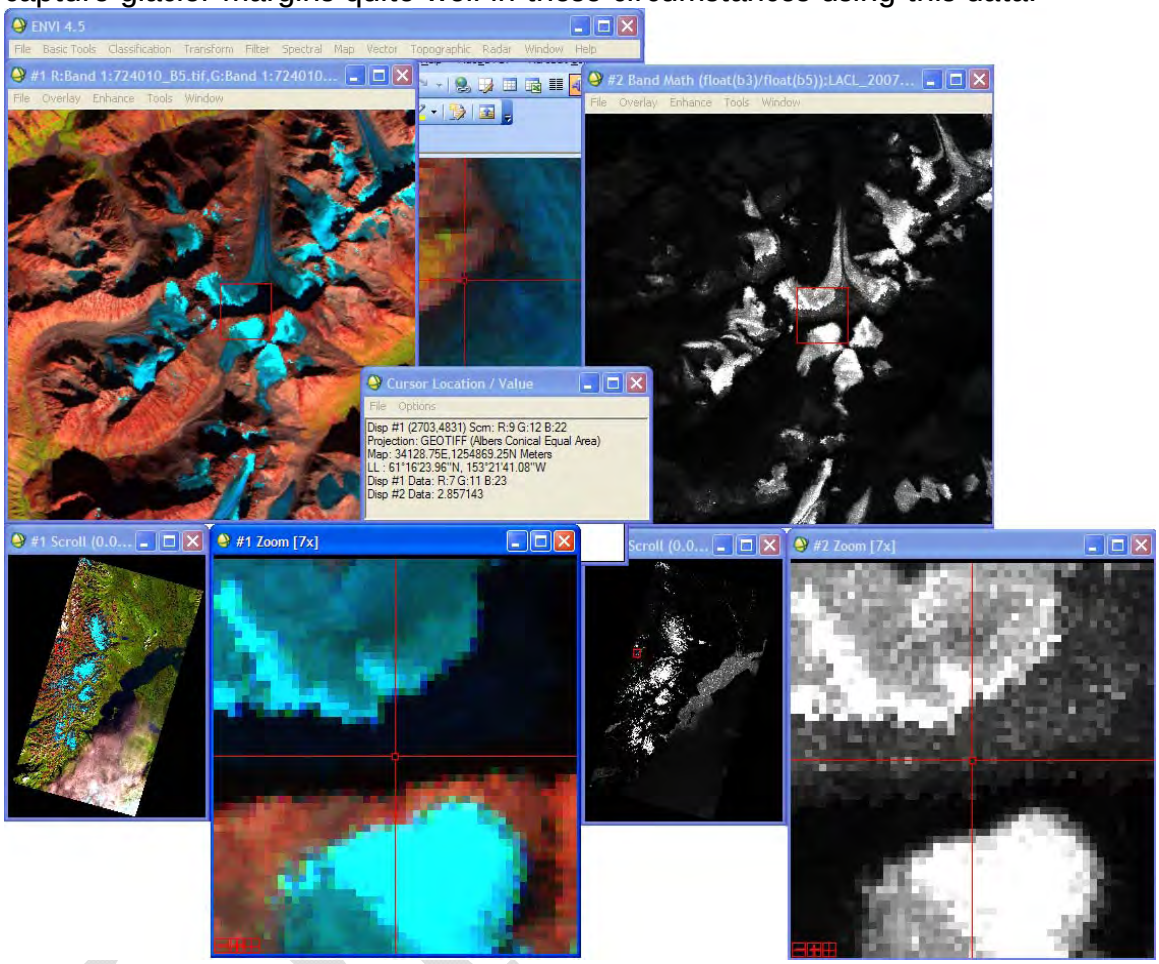
At this point you are ready to begin to identify the range of pixel values that represent snow and glacier ice. Two images are now displayed, the color composite and the single gray band (B3/B5) image. The images are linked together and the "Cursor Location/Value" dialog box is in view.

Move around the image to get a feel for what the range of pixel values are for snow and glacier ice in the single gray band (B3/B5) image. You will begin to see that pixel values for snow and glacier ice are well above 1. Now move to the glacier ice margins (lower reaches of valley glaciers) – you will begin to be able to identify the lower limit for pixel values representing snow and glacier ice. In the below example, a threshold value would be >1.136. A classification of the (B3/B5) image with a threshold value of >1.136 will capture glacier margins quite well in these circumstances using this data.



Move to another part of the image, an area of shadowed glacier ice and begin to identify the lower limit for pixel values representing snow and glacier ice in shadow conditions. In the below example, a threshold value would be >2.285.

A classification of the (B3/B5) image with a threshold value of >2.285 will capture glacier margins quite well in these circumstances using this data.



From the example above, ENVI was used to perform simple band math and identify threshold values that are effective in mapping glacier margins. With this information in hand, Landsat data will be classified for snow and glacier ice, shapefiles created and editing of the shapefiles completed in an ArcGIS work session as described in SOP#3 and SOP#4.

Glacier Extent Protocol
Southwest Alaska Network

Standard Operating Procedure (SOP) # 3

Analysis - ESRI's ArcGIS
GIS Software

Version 1.0 (May, 2009)

Revision History Log:

Previous Version #	*Revision Date*	*Author*	*Changes Made*	*Reason for Change*	*New Version #*

DRAFT

Overview and Explanation

This Standard Operating Procedure describes the process of classifying Landsat imagery for snow and glacier ice. This is a process by which all pixels in the image representing snow/glacier ice are segregated from all other pixels in the Landsat image. The great majority of the glacier margins are captured through the classification of the Landsat imagery described in this SOP. The classified raster files are converted to polygon shapefiles. Polygons representing snow/glacier ice and nunataks are segregated and small isolated snow fields that aren't connected to and/or associated with a glacier are eliminated. The steps outlined in this SOP are performed entirely in ArcCatalog and/or ArcGIS.

The final polygon shapefiles created in this SOP will require significant manual editing in an ArcGIS edit work session. Manual editing of the polygon shapefiles will be detailed in SOP #4 to more accurately capture glacier margins. Areas of misclassification are associated with:

- debris covered glacier ice (typically terminus areas),
- shadowed snow/glacier areas,

- water bodies exhibiting higher concentrations of suspended solids (glacier flour),
- clouds

This SOP is not an ESRI's ArcGIS users manual; a working knowledge of ArcGIS is expected. A current understanding and working knowledge of ArcGIS is essential.

3-1 Procedures - Mapping Glacier Extent using ArcGIS and ArcCatalog

The mapping the glacier extent requires several steps from creating a color composite image to spatial analysis using simple math, conditional statements using threshold values, conversion of these results to shapefiles, manipulation of shapefiles to extract the most accurate representation of glacier margins and finishing up with manual editing of the shapefiles (as described in SOP #4).

The procedures outlined in SOP #3 necessarily involve the creation of numerous folders and files. Care must be exercised in developing a rational folder and file naming structure/plan. SOP #7, Data Management, presents a thorough description of the recommended folder structure and file naming convention.

Step #1 Setup Folder and File Structure

Folder structure and naming convention, the creation and naming of Personal Geodatabases and Feature Datasets are presented in SOP#7. Detailed file naming convention is presented through out this SOP as appropriate.

C:\PARK. The PARK folder will be that of the four letter park acronym, in the case of the SWAN parks either: KEFJ or KATM, or LACL. In this PARK folder, set up the additional folders as follows: DEM, Hydro, Landsat_YYYY and a Personal Geodatabase with the following naming convention "PARK_YYYYMMDD", where YYYYMMDD is the year, month and day of the Landsat imagery for which the glacier mapping is based. Within the Personal Geodatabase are Feature Datasets named "PROCESSING_1375" and "PROCESSING_1200." See Figure 1. These Feature Datasets hold all the working shapefiles for the glacier extent mapping. The "1375" and "1200" represent the threshold value of the snow and ice pixels that was established in SOP #2 (i.e. 1.375 and 1.200). All data processing relevant to threshold value 1.375 occurs in the Feature Datasets named "PROCESSING_1375" and so forth.

In creating Feature Datasets in ArcCatalog, be sure to define the datum and projection consistent with the datum and projection of the Landsat imagery.

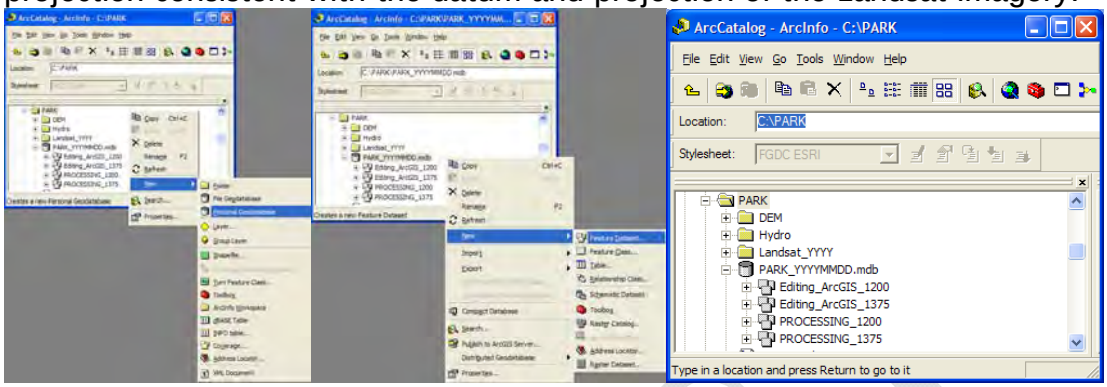


Figure 1. Creating a Personal Geodatabase (left), and a Feature Dataset (middle) using ArcCatalog. Basic folder structure for glacier extent mapping (right). Note that creating a new folder is also an option using ArcCatalog (left).

Step 2 Place Landsat Raster Data in the Landsat_YYYY Folder

Populate the Landsat_YYYY folder with the subject Landsat raster data necessary for the classification processes and composite image production. Naming convention should be consistent with the Landsat bands representing the Landsat data, (i.e. B2 is equivalent to Landsat band 2 and so forth). Variations in the naming of the various raster data in this folder identify the processes performed with the Landsat data and are further explained in the pages below.

In this example, the Landsat bands 2, 3 4 and 5 will be placed in the Landsat_YYYY folder. Note: In Figure 2 below, other raster files observed in the Landsat_YYYY folder and are the resultant raster files from processes (ArcGIS/ArcCatalog commands) yet to be explained.

DRAFT

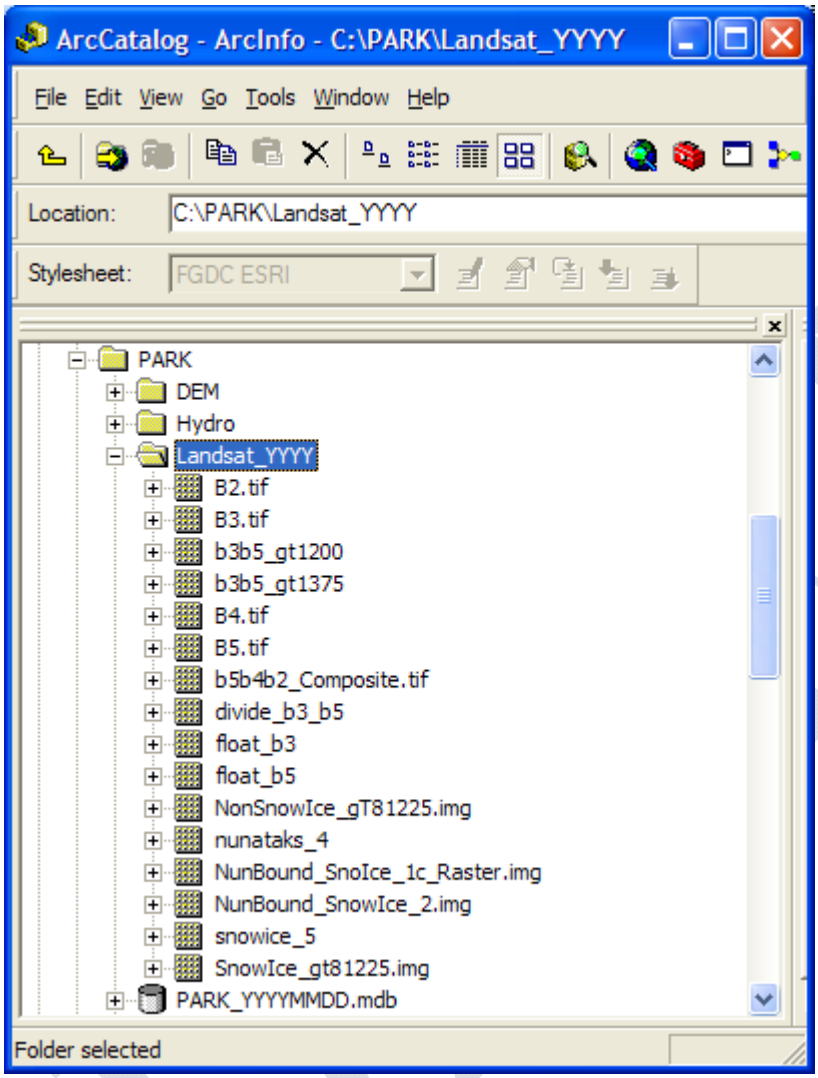


Figure 2. File naming convention within the Landsat_YYYY folder.

Step 3 Create a Color Composite Image

Create a color composite image using Landsat Band 5 (red), Landsat Band 4 (green), and Landsat Band 2 (blue). This Landsat band combination is very affective for glacier mapping purposes, see Figure 3.

- Composite Bands (management): Landsat Band 5 (b5), Landsat Band 4 (b4), Landsat Band 2 (b2).

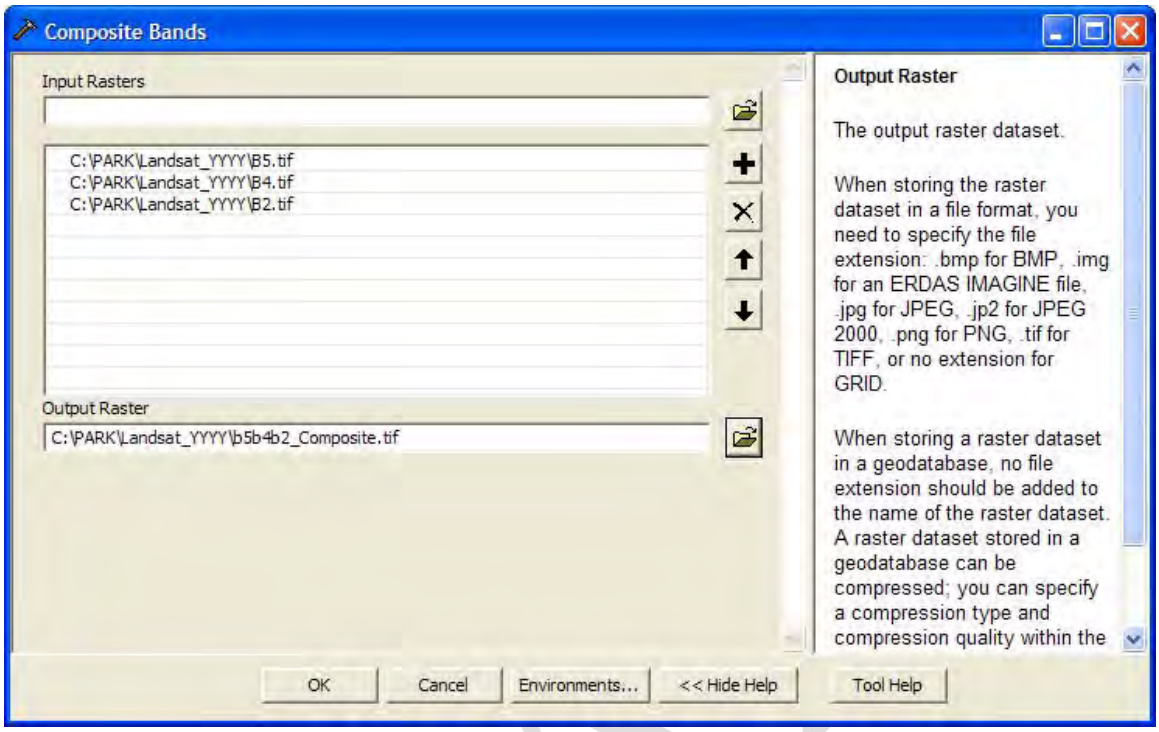


Figure 3. Creating a color composite Landsat image using the "Composite Bands" command in ArcCatalog.

Step 4 Band Ratio Technique and Threshold Value(s)

The band math and threshold information determined from SOP #2 are essential for successful implementation of SOP #3. From SOP #2, ENVI was used to determined the most appropriate band ratio technique(s) to apply to segregate snow/ice pixels from all else.

- NDVI (b3-b5)/(b3+b5)
- NDSI (b2-b5)/(b2+b5)
- b3/b5

There maybe more than one threshold value for the band ratio technique selected; one threshold may produce excellent results in areas of shadowed ice (but not so well outside shadows) and visa versa. However, it is recommended to define one threshold value that best segregates snow/glacier pixels from all else. The effort required to clean and edit classifications created using two threshold values is not justified when classifying imagery over large geographic areas.

The following steps will proceed with an example using b3/b5 ratio with a threshold of value 1.375 as determined using ENVI in SOP #2. Also note that a second set of files, a geodatabase and a feature dataset was created in this example fascilitating the processing of of the Landsat data using a threshold value of 1.200.

Step 5 Float Appropriate Landsat Bands

In this step, "float" **all** the appropriate Landsat bands to be used in the band math calculations, based on information derived from SOP #2, a band math expression was selected and a threshold value determined that best segregates snow and Ice pixels from all other pixels in the Landsat data. In this example, Landsat band 3 and band 5 are floated. The following example (Figure 4) shows the procedure to float Landsat band 3. Place the resultant bands in the Landsat_YYYY folder:

- Float (sa): Float Landsat band 3 and 4 and name the resultant raster files "float_b3" and "float_b5".

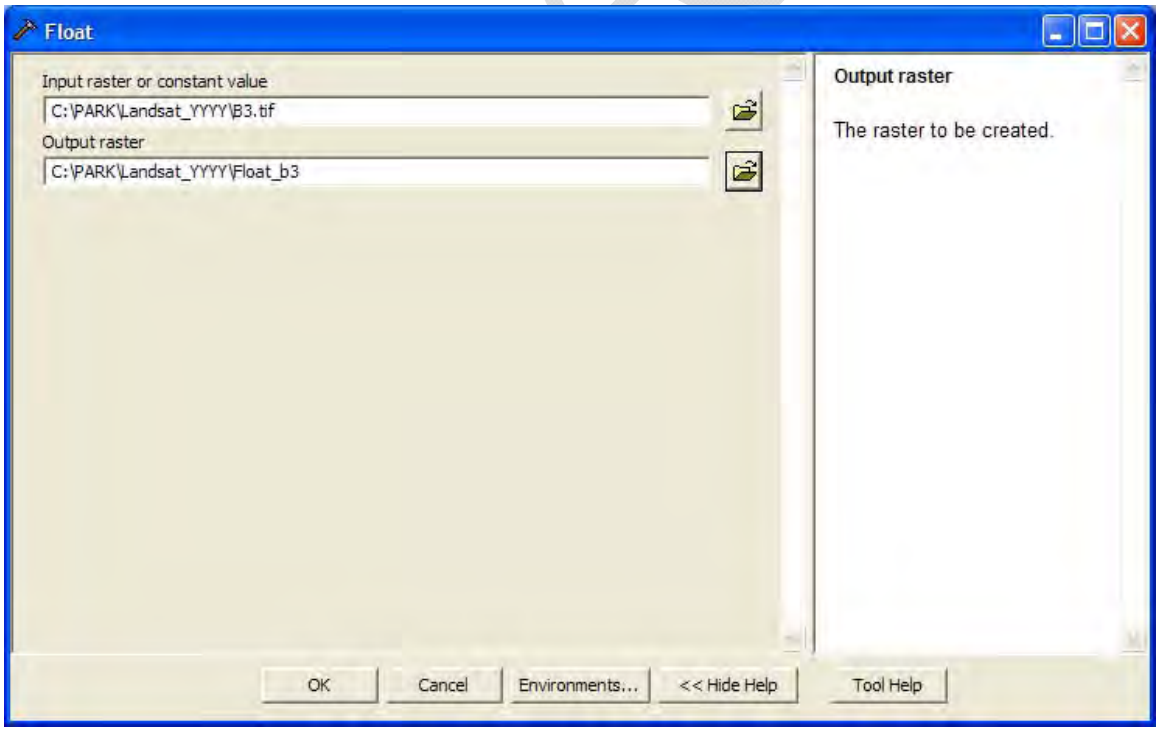


Figure 4. "Float" command in ArcCatalog.

Step 6 Band Math

Next, perform the math expression using the “Floated” bands created in Step 5 above (Figure 5).

- Divide (sa): Using the Spatial Analyst Tools>Math>Divide; divide the floated bands “float_b3” by “float_b5”. Name the output raster “divide_b3_b5”.

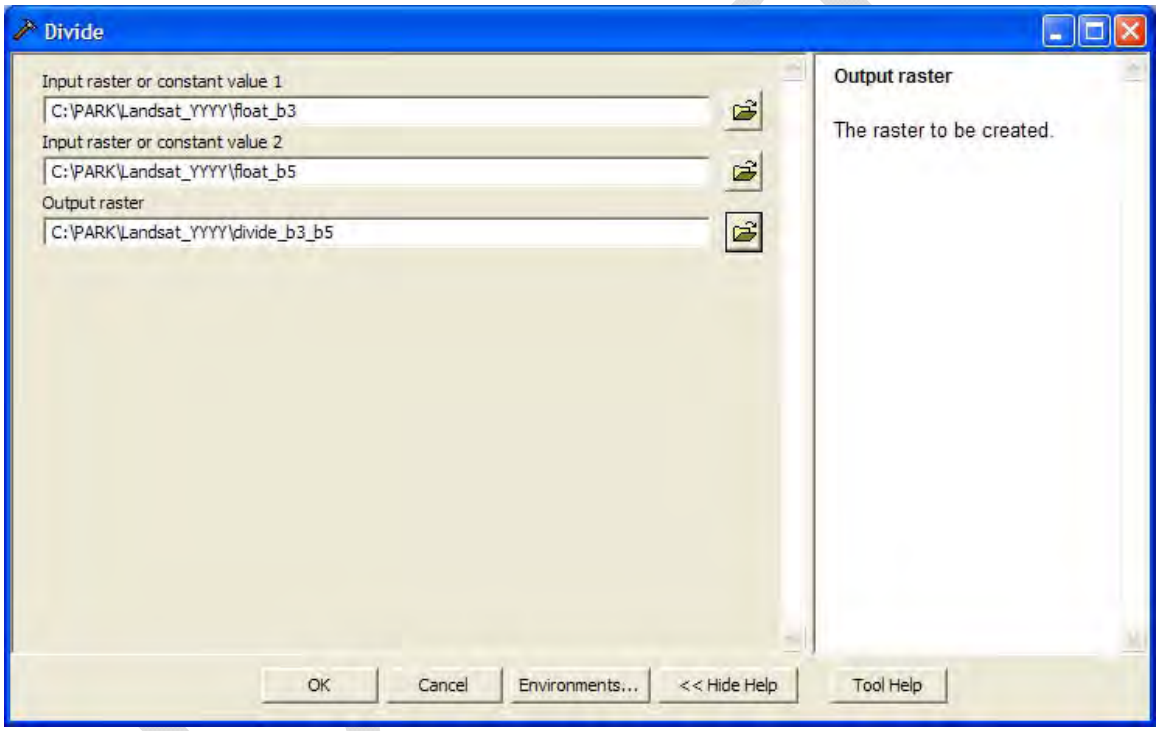


Figure 5. “Divide” command in ArcCatalog.

Step 7 Conditional Statement

Using the “divide_b3_b5” raster created in Step 6 above, apply the threshold value determined in SOP #2 that best segregates snow/glacier pixels from all else (Figure 6). In this case, the threshold value is 1.375.

- Con (sa): Use the Spatial Analyst Tools>Conditional>Con; Use “divide_b3_b5” as the input raster, the expression is the threshold

value determined in SOP1. True = 1 False = 2. And name the output raster: "b3b5_gt1375".

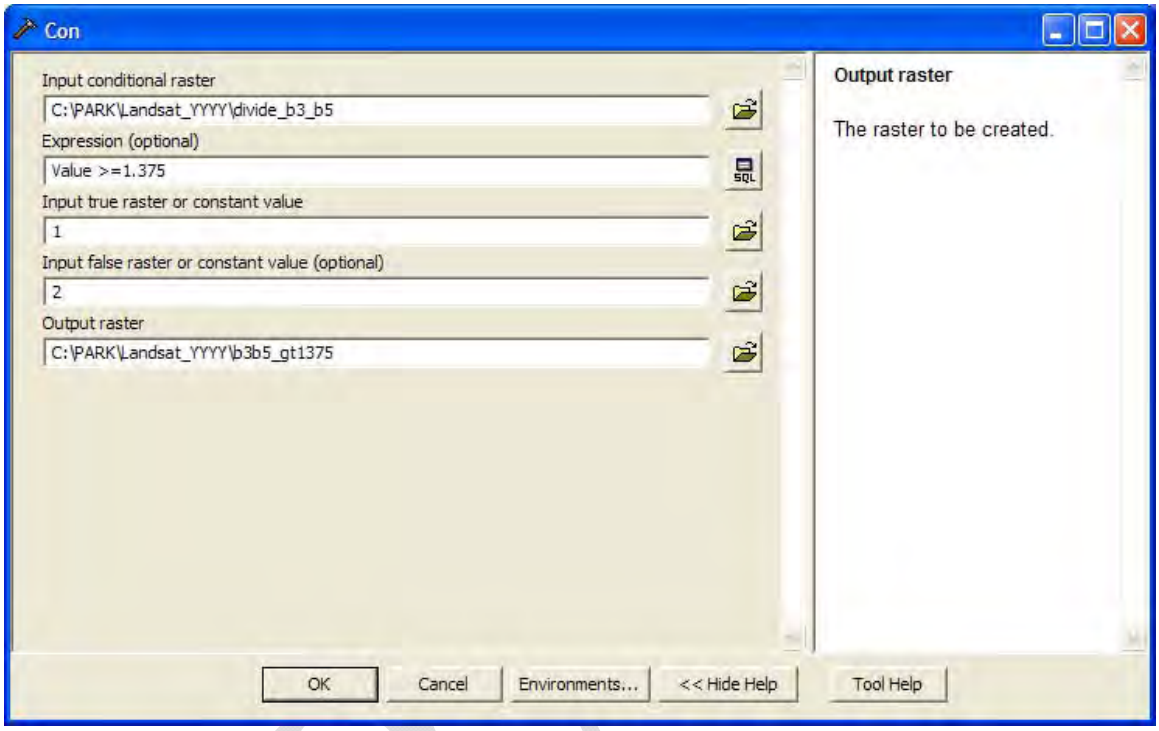


Figure 6. Creating a raster image using the "Con" command in ArcCatalog.

Step 8 Raster To Polygon Conversion

Convert the raster created in Step 7 to a polygon shapefile.

- Raster-To-Polygon: Convert raster "b3b5_gt1375" to a polygon shapefile: "RstrToPoly_b3b5_gt1375" and save to the PROCESSING_1375 feature dataset within the PARK_YYYYMMDD personal geodatabase. Make sure the "Simplify polygons" box in unchecked.

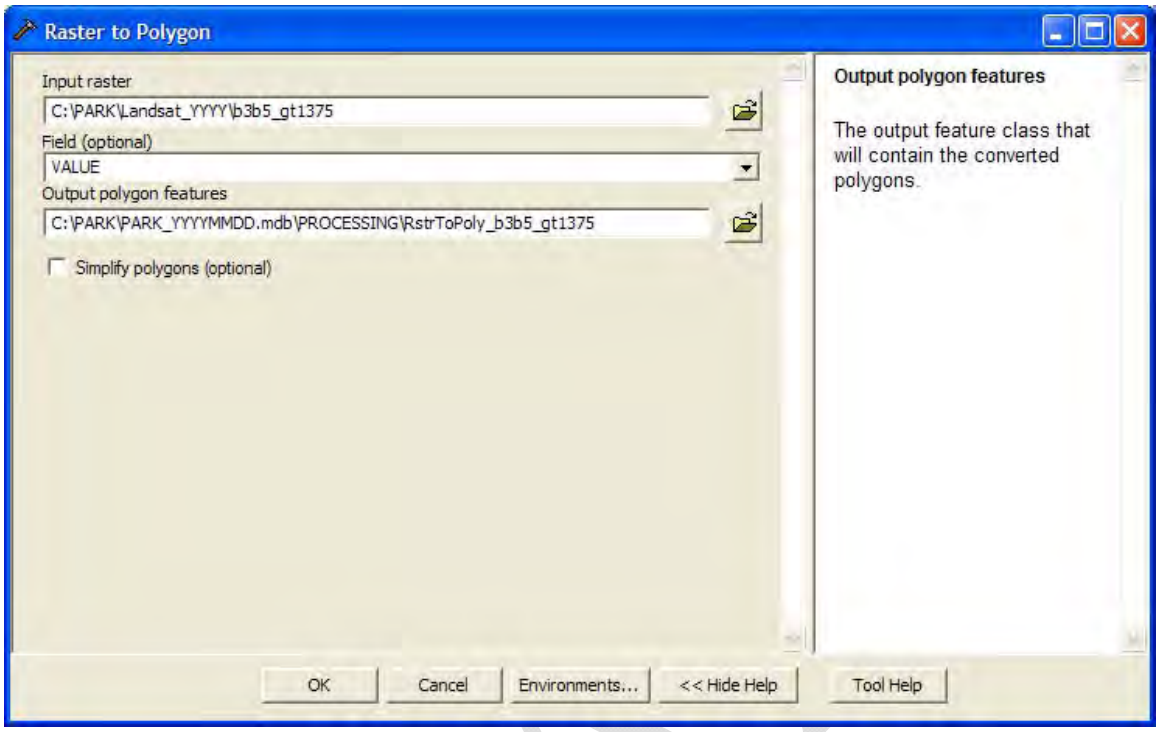


Figure 7. Converting the raster created in Step 7 to a polygon shapefile using the "Raster to Polygon" command in ArcCatalog.

Step 9 Analysis of the Polygon Shapefiles - SnowIce and NonSnowIce

The polygon shapefile created in Step 8 above "RstrToPoly_b3b5_gt1375" has two types of features, snow and/or glacier features (GRIDCODE=1) or all other features (GRIDCODE=2). Also, because the "RstrToPoly_b3b5_gt1375" was created in Feature Dataset within a Personal Geodatabase, a field labeled "Shape_Area" was created; the data is presented in square meters. Figure 8 shows a portion of the attribute table for the polygon shapefile:

Attributes of RstrToPoly_b3b5_gt1375

OBJECTID *	Shape *	ID	GRIDCODE	Shape_Length	Shape_Area
76011	Polygon	760	2	18450501	5055327036
59665	Polygon	596	1	4902627	1227225276
71405	Polygon	714	1	1117257	373490419.5
49991	Polygon	499	1	533634	98175845.25
14317	Polygon	143	1	227316	79010806.5
18477	Polygon	184	1	264309	35237029.5
57951	Polygon	579	1	217113	30942663.75
2387	Polygon	238	1	209019	25660602
75218	Polygon	752	1	147231	22920070.5
72643	Polygon	726	1	99921	17416264.5
64533	Polygon	645	1	114570	14796758.25
67196	Polygon	671	1	36423	14475919.5
24778	Polygon	247	1	115767	12658916.25
75529	Polygon	755	1	86811	11284589.25
28544	Polygon	285	1	149340	11031167.25
35815	Polygon	358	1	87495	10256280.75
53810	Polygon	538	1	120384	9705575.25
55662	Polygon	556	1	85842	9193857.75
45336	Polygon	453	2	77007	8093259
40142	Polygon	401	1	53352	7832526.75
61261	Polygon	612	1	34200	7789477.5
26306	Polygon	263	1	56715	7237959.75
75861	Polygon	758	1	66006	6894378
6528	Polygon	652	1	46512	6865137
17475	Polygon	174	1	53352	6291688.5
48017	Polygon	480	1	47025	5934298.5

Record: 0 Show: All Selected Records (1

Figure 8. Attribute table for “RstrToPoly_b3b5_gt1375” shapefile.

The goal in this step is to isolate larger snow and/or ice features from smaller snow and/or ice features. For this particular example, 8122.5 sq m is the threshold for size.

- Select (analysis): Using the Analyst Tools>Extract>Select; Using file “RstrToPoly_b3b5_gt1375” Select for GRIDCODE = 1 AND Shape_Area >= 8122.5 and save as “SnowIce_gt81225”. See Figure 9.

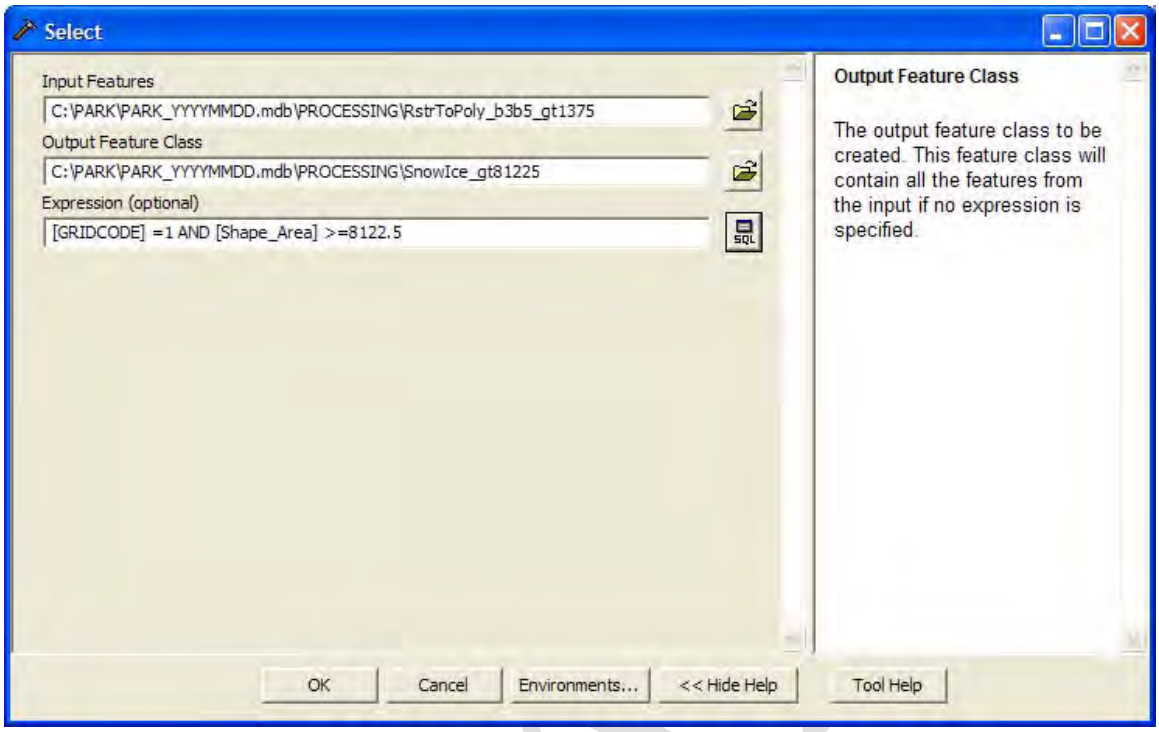


Figure 9. Selecting polygons within the "RstrToPoly_b3b5_gt1375" shapefile that represent snow and ice features (GRIDCODE = 1) and that are equal to or greater than 8,122.5 sq m (Shape_Area >= 8122.5) using the "Select" command in ArcCatalog.

Note: The threshold value for "Shape_Area" may seem low in this instance, however, in Lake Clark National Park and Preserve, a larger threshold value eliminates the ability to capture the many linear and narrow nunatak features in the region.

Repeat the previous "Select" command, except the target data is large non-snow and -ice features. The goal in this command is to isolate large non-snow and/or -ice features from all others, see Figure 10. For this particular example, 8122.5 sq m is the threshold for size.

- Select: Using the Analyst Tools>Extract>Select; Using file (RstrToPoly_b3b5_gt1375) Select for GRIDCODE = 2 AND Shape_Area >= 8122.5 and save as (NonSnowIce_gt81225).

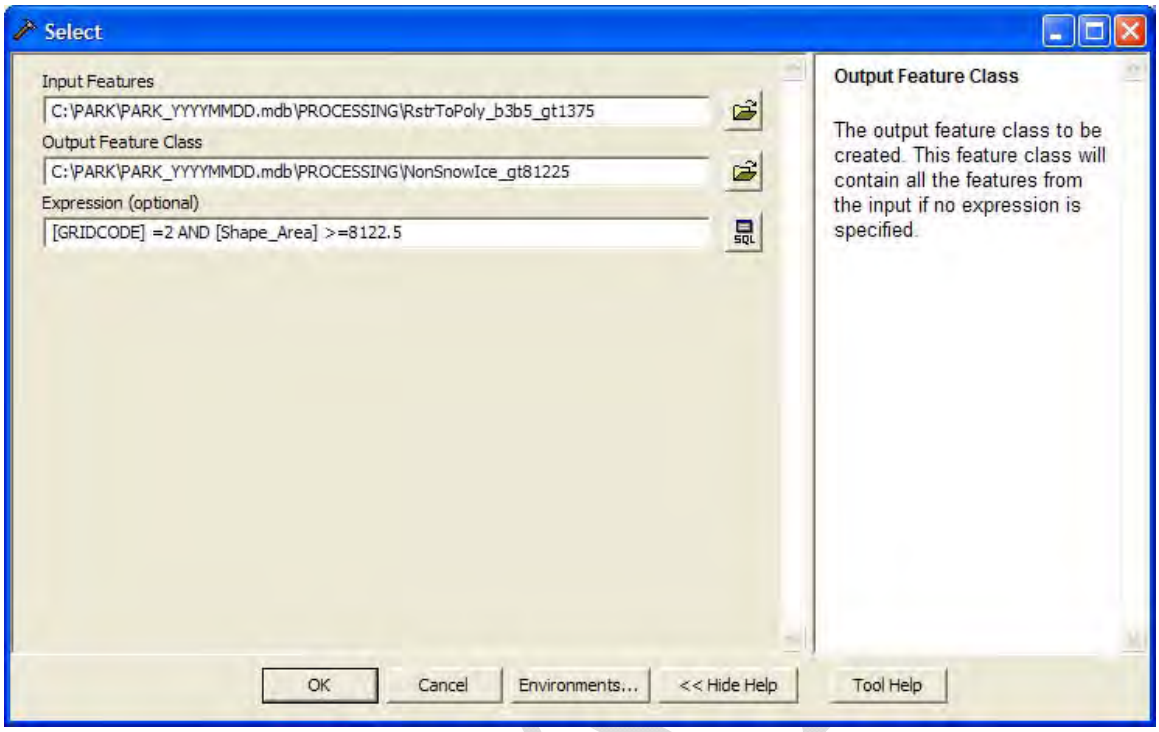


Figure 10. Selecting polygons within the "RstrToPoly_b3b5_gt1375" shapefile that represent non snow and ice features (GRIDCODE = 2) and that are equal to or greater than 8,122.5 sq m (Shape_Area >= 8122.5) using the "Select" command in ArcCatalog.

Note: 8,122.5 sq m is equivalent to 10 pixels or approximately 2 acres. So the goal of Steps 9 and 10 is to isolate all snow/ice polygons greater than 8,122.5 sq m (10 pixels) and isolate all non-snow and/or -ice polygons greater than 8,122.5 sq m.

Step 10 Cleaning Polygon Shapefiles - SnowIce

The next step is to clean the polygon shapefiles "SnowIce_gt81225" and "NonSnowIce_gt81225" through the following process. The next couple commands will remove small unwanted artifacts in the shapefiles:

- Feature-To-Line (management): Convert "SnowIce_gt81225" polygon shapefile to a line shapefile and name the resultant file "SnowIce_gt81225_Clean1a", see Figure 11.

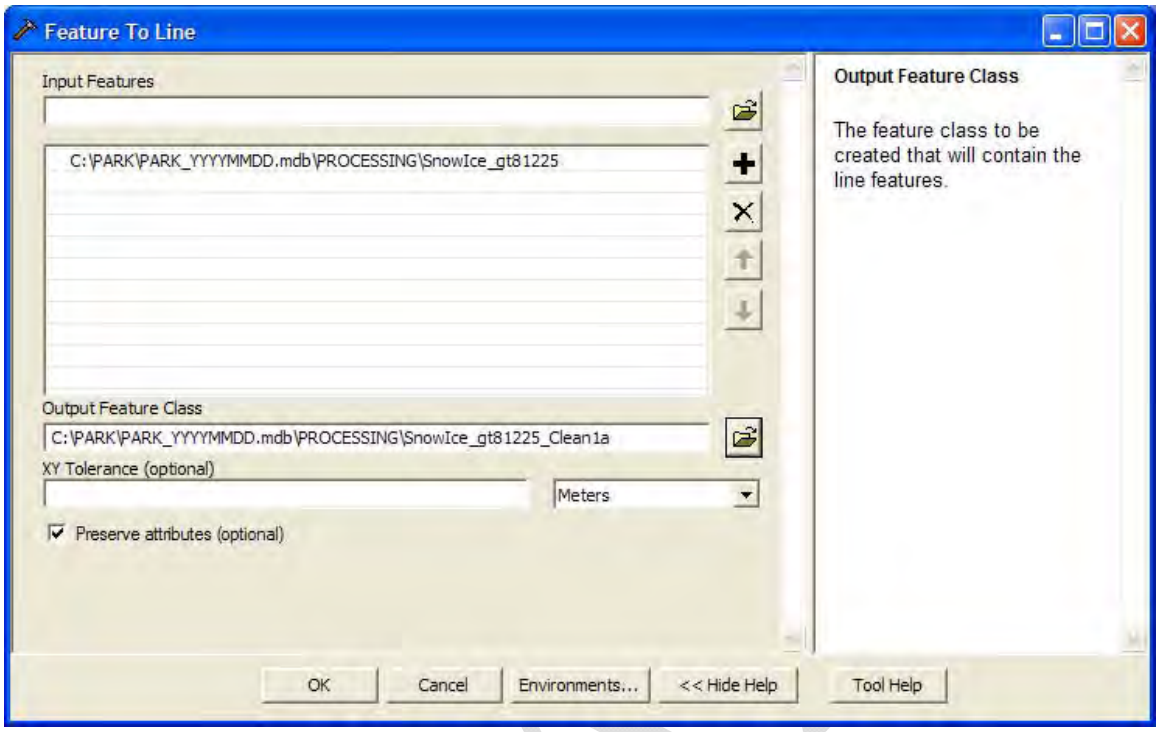


Figure 11. Convert "SnowIce_gt81225" polygon shapefile to a line shapefile using the "Feature to Line" command in ArcCatalog.

- Feature-To-Polygon (management): Convert "SnowIce_gt81225_Clean1a" line shapefile to a polygon shapefile and name it "SnowIce_gt81225_Clean1b", see Figure 12.

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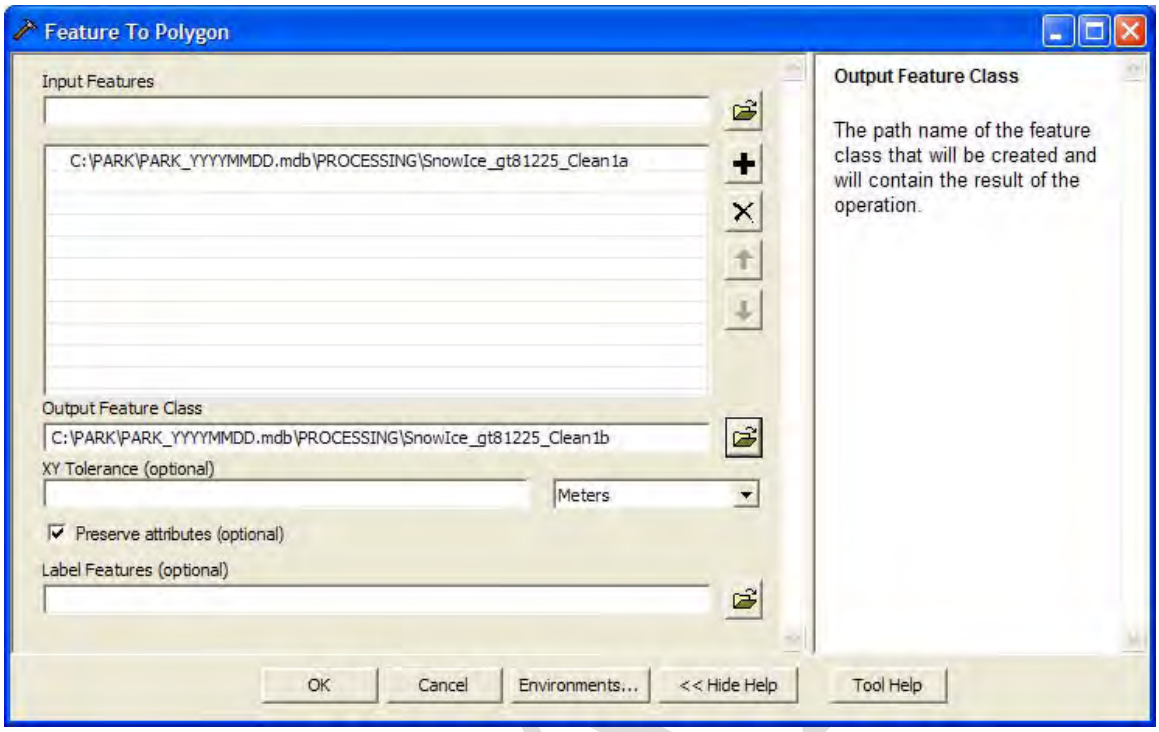

Figure 12. Convert "SnowIce_gt81225_Clean1a" line shapefile to a polygon shapefile using the "Feature to Polygon" command in ArcCatalog.

Step 11 Cleaning Polygon Shapefiles - NonSnowIce

Repeat the two commands outlined in Step 10, this time using "NonSnowIce_gt81225" polygon shapefile.

- Feature-To-Line (management): Convert "NonSnowIce_gt81225" polygon shapefile to a line shapefile and name the resultant file "NonSnowIce_gt81225_Clean1a".

- Feature-To-Polygon (management): Convert "NonSnowIce_gt81225_Clean1a" line shapefile to a polygon shapefile and name it "NonSnowIce_gt81225_Clean1b".

Step 12 Attribute Tables Management - SnowIce and NonSnowIce

Add a field to the attribute tables and calculate field values for the polygon shapefiles created in Step 10 “SnowIce_gt81225_Clean1b” and Step 11 “NonSnowIce_gt81225_Clean1b”, see Figure 13 and 14.

- Add Field (management): Add a “field” called RASTER to each of the polygon shapefiles:
  - “SnowIce_gt81225_Clean1b”
  - “NonSnowIce_gt81225_Clean1b”

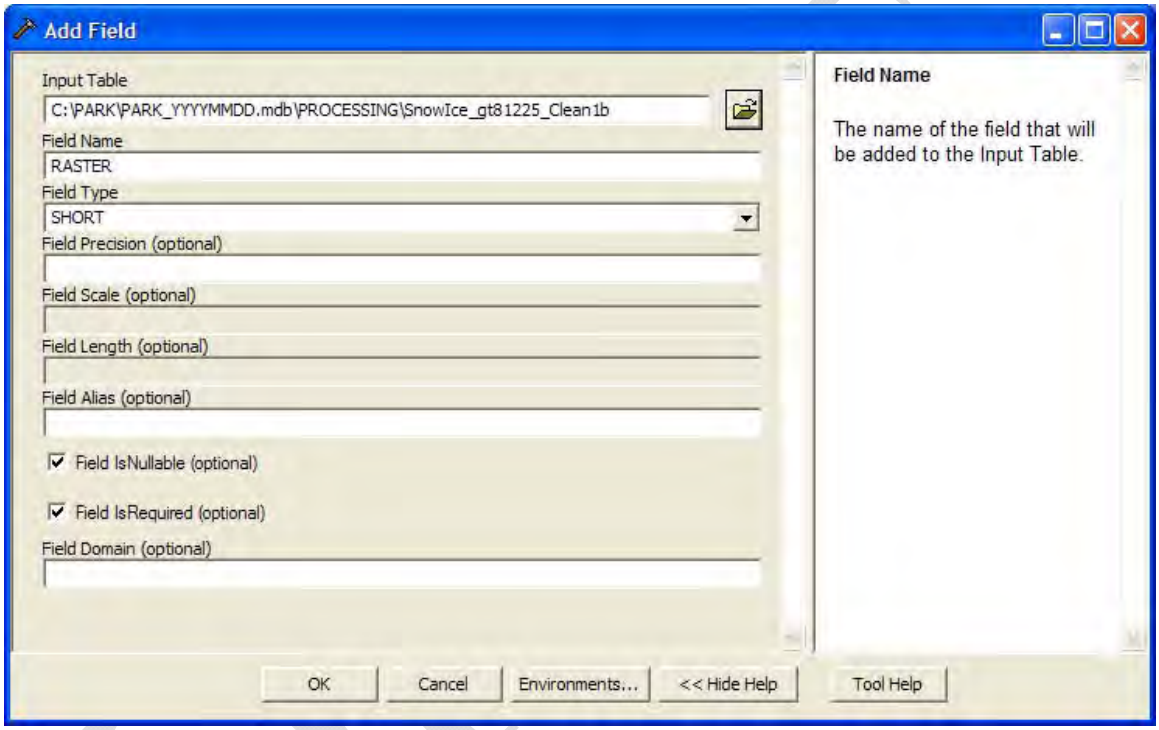

Figure 13. Add a “field” to the attribute table of “SnowIce_gt81225_Clean1b” polygon shapefile using the “Add Field” command in ArcCatalog.

- Calculate Field (management): Assign a value of “1” to the RASTER field for each of the polygon shapefiles created above:
  - “SnowIce_gt81225_Clean1b”
  - “NonSnowIce_gt81225_Clean1b”

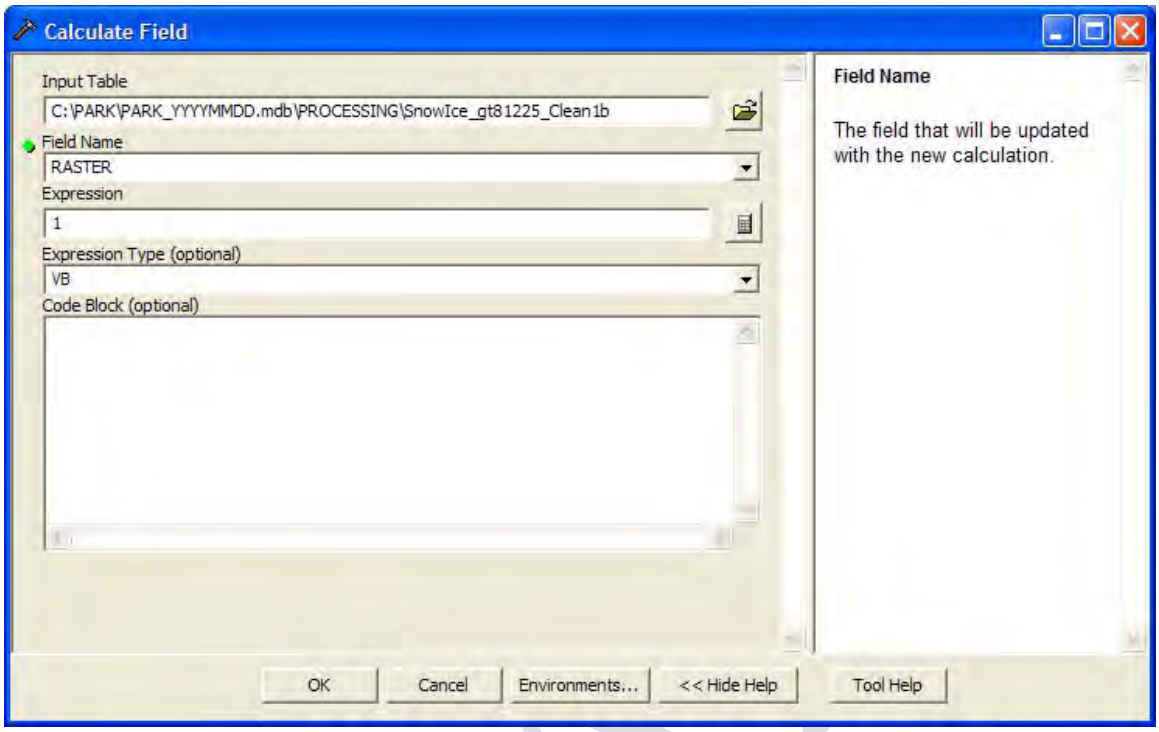

Figure 14. Calculate RASTER "field" value equal to "1" for all records "SnowIce_gt81225_Clean1b" polygon shapefile using the "Calculate Field" command in ArcCatalog.

Step 13 Polygon To Raster Conversion - SnowIce and NonSnowIce

Create raster files from the polygon shapefiles created in Step 12, see Figure 14 and 15. Set the "Cell Size" equivalent to the original resolution of the Landsat data, in this case, 28.5.

- Polygon-To-Raster (conversion): Convert Polygon to Raster for the two files:
  - "SnowIce_gt81225_Clean1b"
    a. resultant file - "SnowIce_gt81225.img" is located in the PARK/Landsat folder

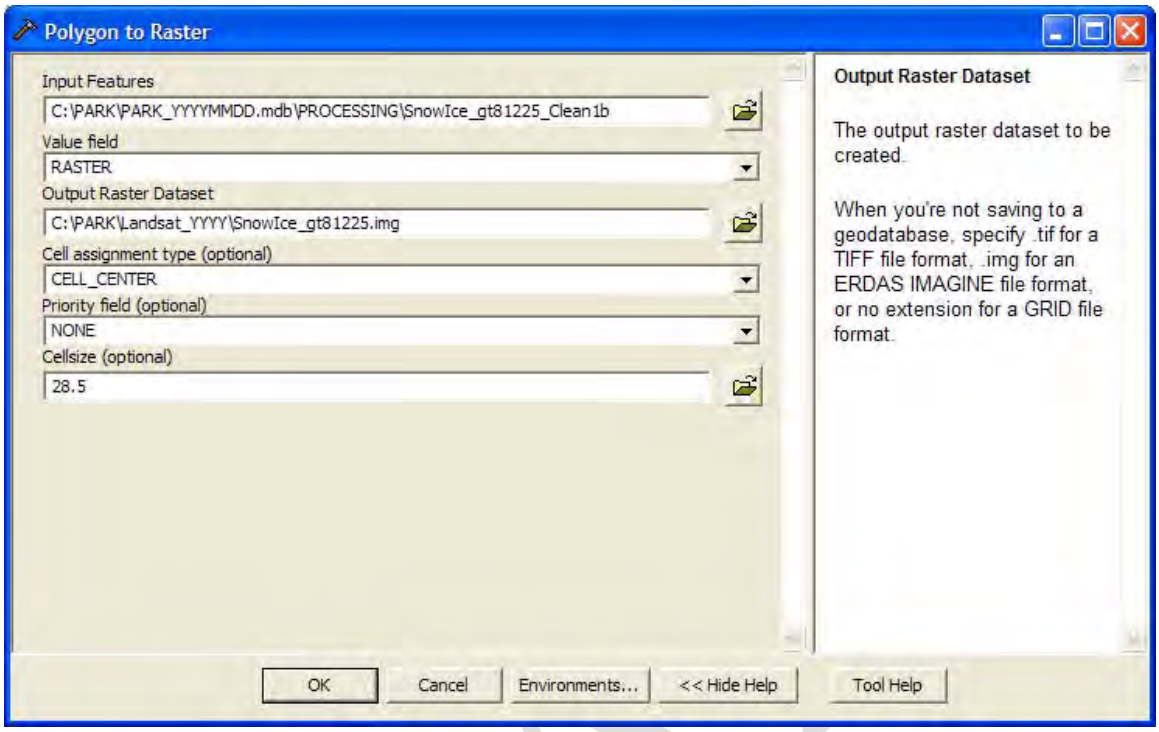

Figure 14. Convert "SnowIce_gt81225_Clean1b" polygon shapefile to a raster file using the "Polygon to Raster" command in ArcCatalog.

- "NonSnowIce_gt81225_Clean1b"
    a. resultant file - "NonSnowIce_gt81225.img" is located in the PARK/Landsat folder

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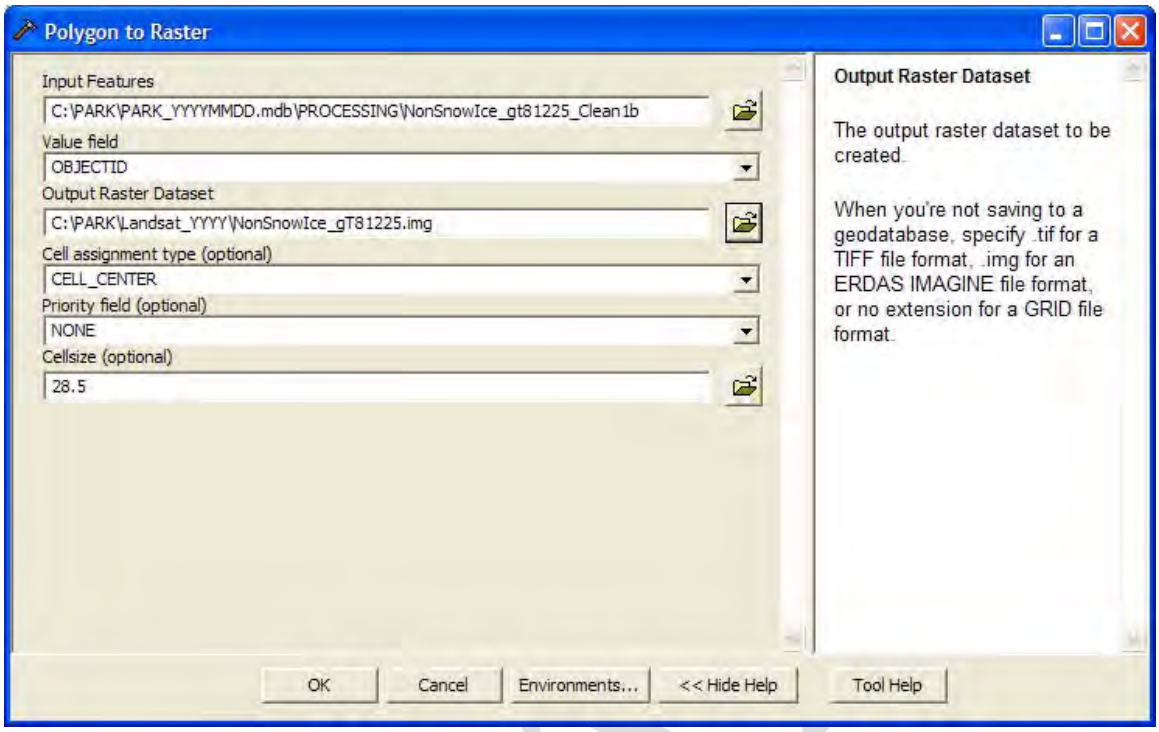

Figure 15. Convert "NonSnowIce_gt81225_Clean1b" polygon shapefile to a raster file using the "Polygon to Raster" command in ArcCatalog.

Step 14 Raster To Polygon Conversion – SnowIce and NonSnowIce

Create polygon shapefiles from the raster files created in Step 13, see Figures 16 and 17. Be sure that the "Simplify Polygons" box is not checked.

- Raster-To-Polygon (conversion): Convert Raster to Polygon for the two files:
  - "SnowIce_gt81225.img"
    a. resultant file - "**SnowIce_gt81225_Clean1c"**

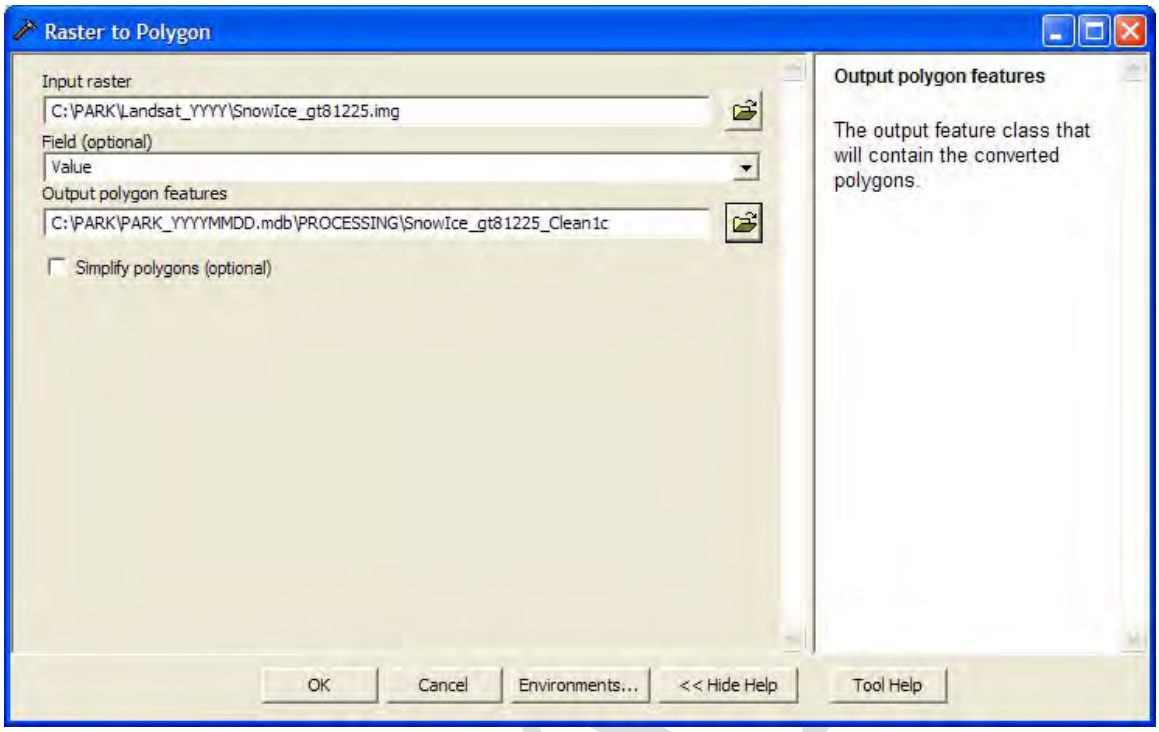

Figure 16. Convert "SnowIce_gt81225.img" raster file to a polygon shapefile using the "Raster to Polygon" command in ArcCatalog.

- "NonSnowIce_gt81225.img>
    a. resultant file - "NonSnowIce_gt81225_Clean1c"

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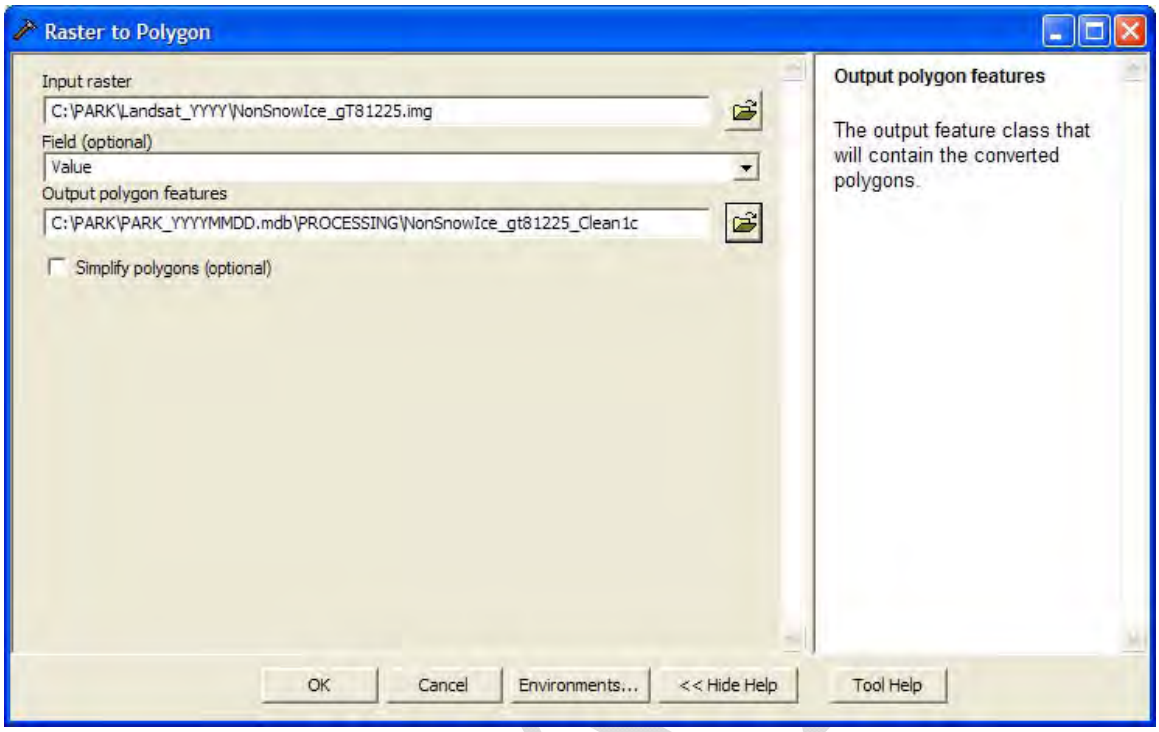

Figure 17. Convert "NonSnowIce_gt81225.img" raster file to a polygon shapefile using the "Raster to Polygon" command in ArcCatalog.

Step 15 Cleanup of Nunatak Boundaries

The purpose of the following steps is to cleanup nunatak boundaries, see Figure 18 and 19.

- Erase (analysis): "SnowIce_gt81225_Clean1c" minus "NonSnowIce_gt81225_Clean1c" = "NonSnowIce_gt81225_XX"

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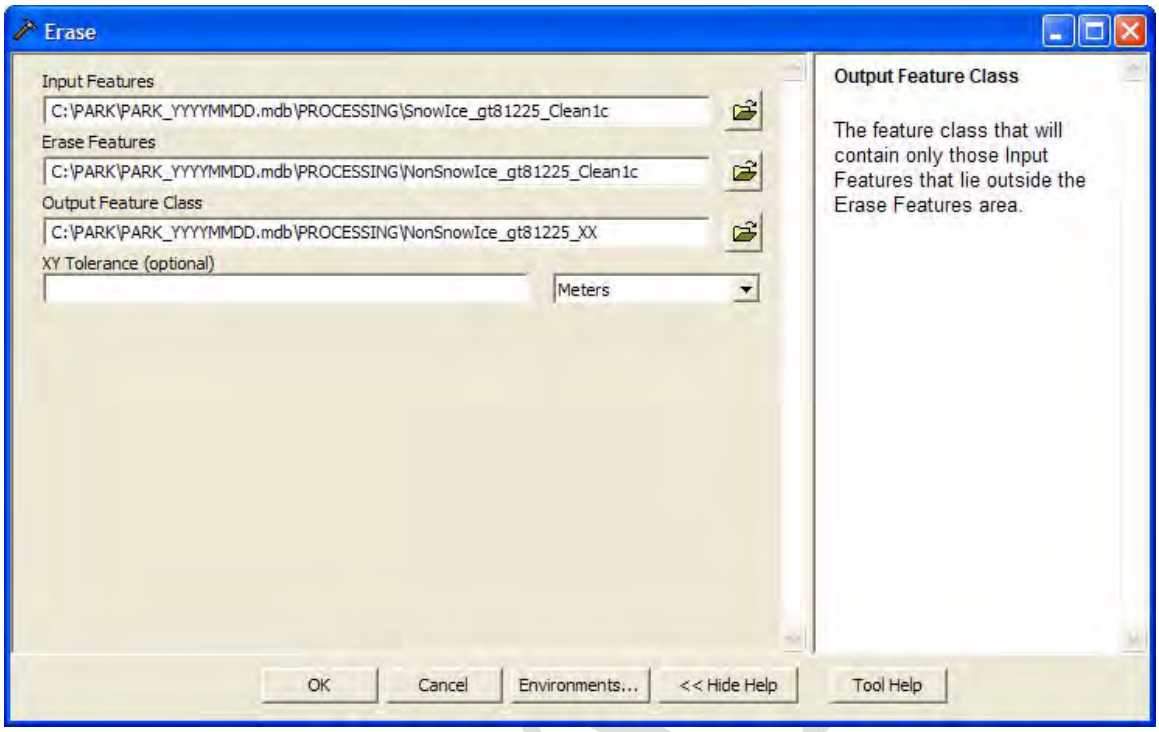

Figure 18. Erase polygons of the "NonSnowIce_gt81225_Clean1c" polygon shapefile from the "SnowIce_gt81225_Clean1c" polygon shapefile using the "Erase" command in ArcCatalog.

- Erase (analysis): "SnowIce_gt81225_Clean1c" minus "NonSnowIce_gt81225_XX" = "**NonSnowIce_gt81225_1d"**

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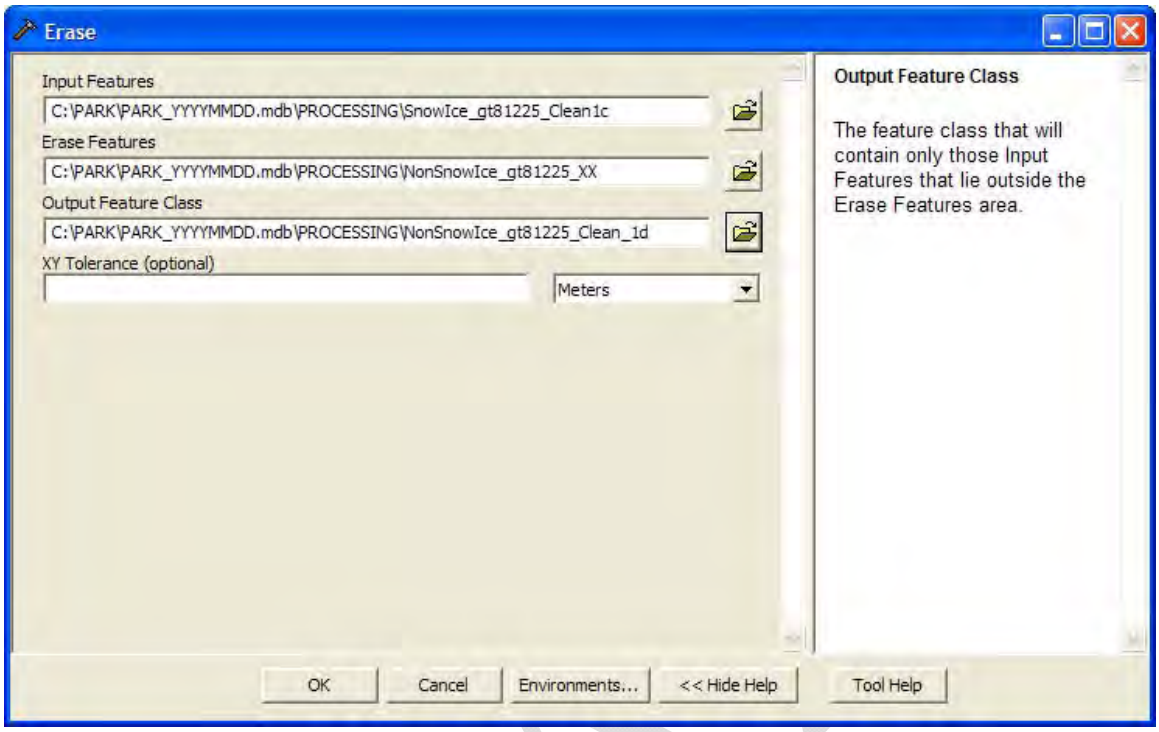

Figure 19. Erase polygons of the "NonSnowIce_gt81225_XX" polygon shapefile from the "SnowIce_gt81225_Clean1c" polygon shapefile using the "Erase" command in ArcCatalog.

Step 16 Cleanup of Nunatak-Bound Glacier Boundaries

The following commands are designed to cleanup the boundaries of nunatak-bound glaciers, see Figures 20 and 21. These are smaller glaciers occurring completely within the bounds of nunataks.

- Erase (analysis): NonSnowIce_gt81225_Clean1d minus SnowIce_gt81225 = NunBound_SnowIce_1a

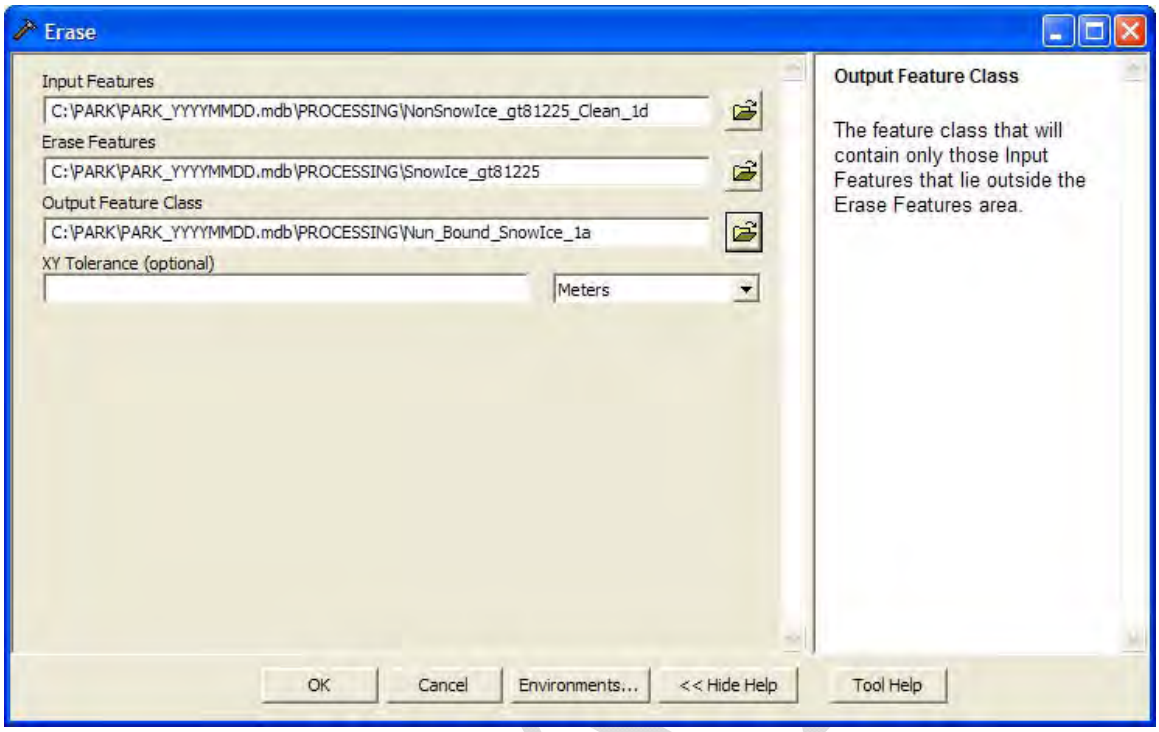

Figure 20. Erase polygons of the "SnowIce_gt81225" polygon shapefile from the NonSnowIce_gt81225_Clean1d polygon shapefile using the "Erase" command in ArcCatalog.

- Erase (analysis): NonSnowIce_gt81225_Clean1d - NunBound_SnowIce_1a = **NunBound_SnowIce_1b**

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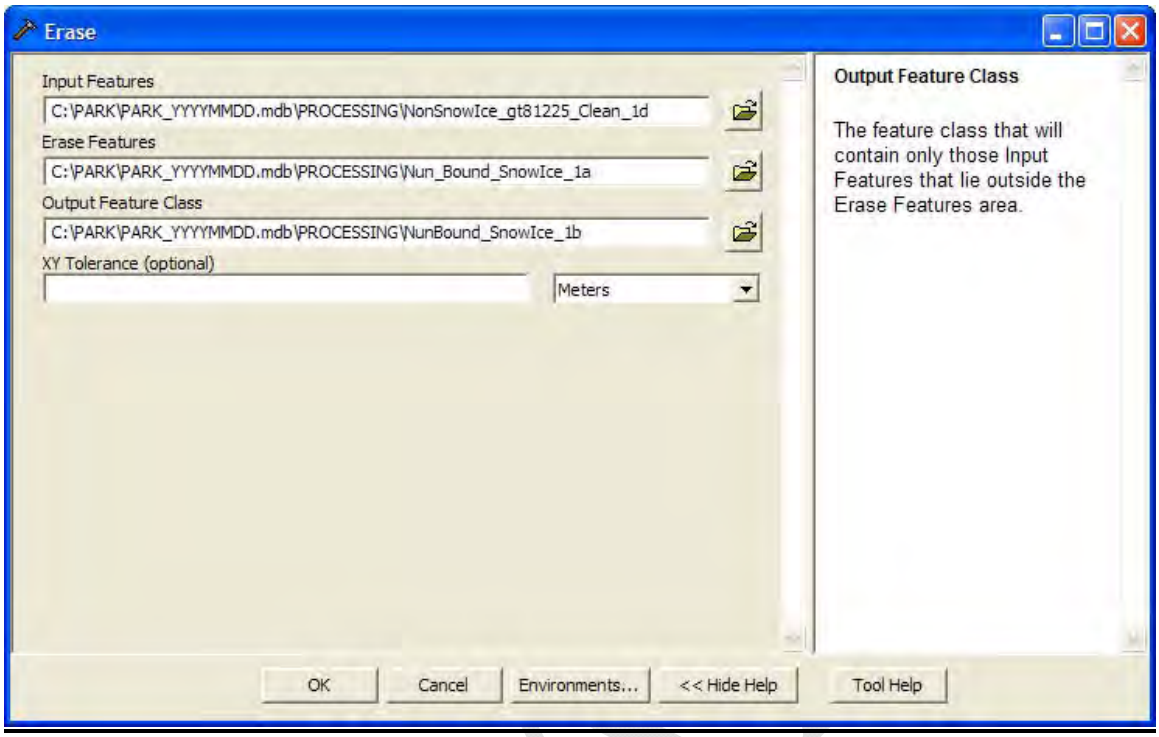

Figure 21. Erase polygons of the "NunBound_SnowIce_1a" polygon shapefile from the "NonSnowIce_gt81225_Clean1d" polygon shapefile using the "Erase" command in ArcCatalog.

- Feature-To-Line (management): NunBoundGlacier1b polygon shapefile = NunBound_SnowIce_1c to line shapefile.

DRAFT

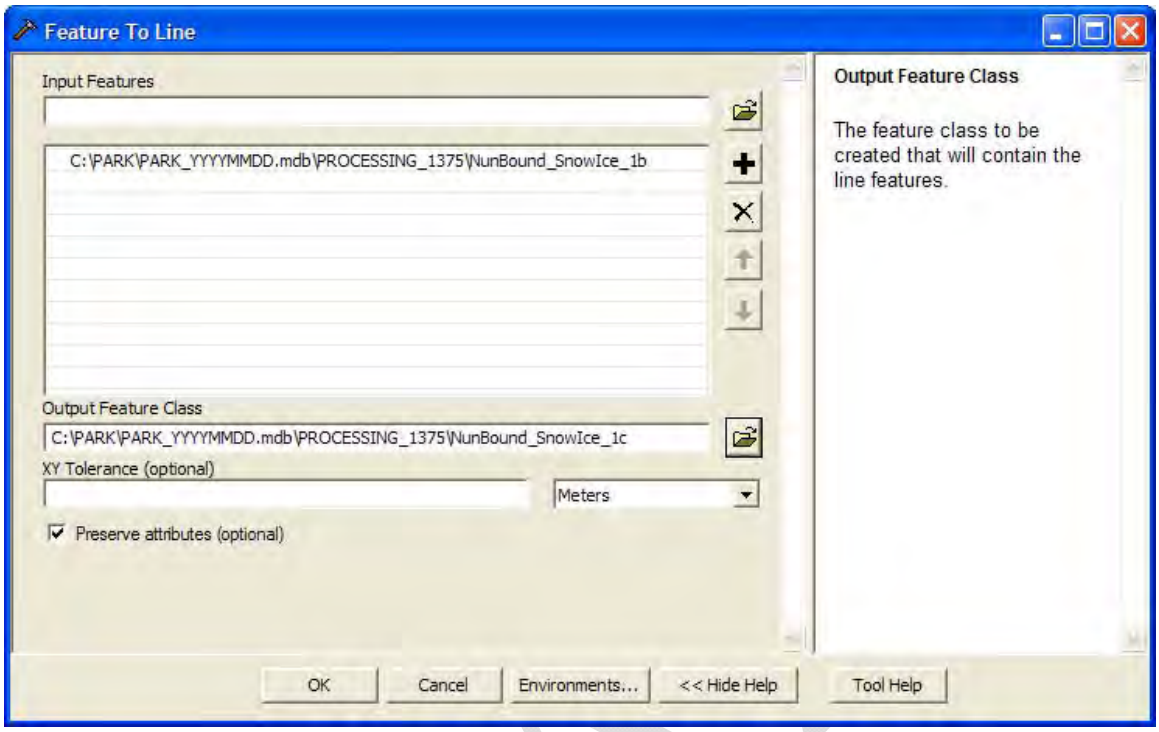

Figure 22. Convert "NunBoundGlacier1b" polygon shapefile to a line shapefile using the "Feature to Line" command in ArcCatalog.

- Feature-To-Polygon (management): NunBoundGlacier1c to polygon shapefile = **NunBound_SnowIce_1d**

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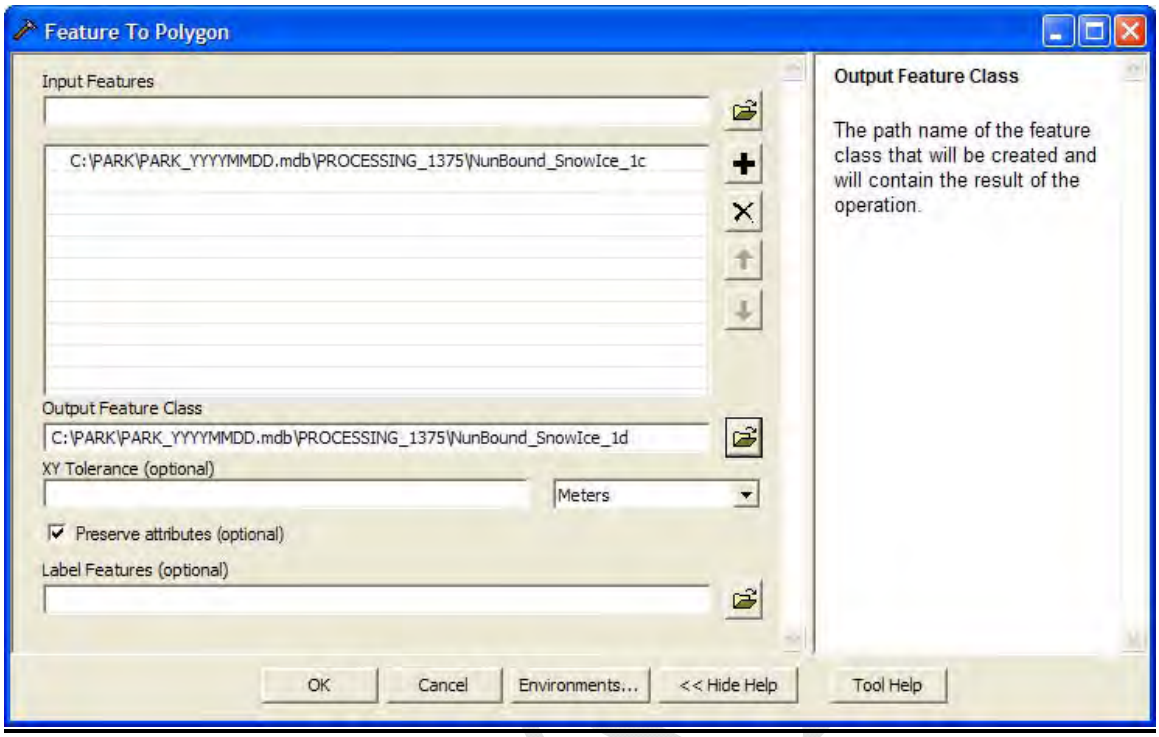

Figure 23. Convert "NunBoundGlacier1c" line shapefile to a polygon shapefile using the "Feature to Polygon" command in ArcCatalog.

- Add Field (management): Add a Field named RASTER to the attribute table of NunBound_SnowIce_1d

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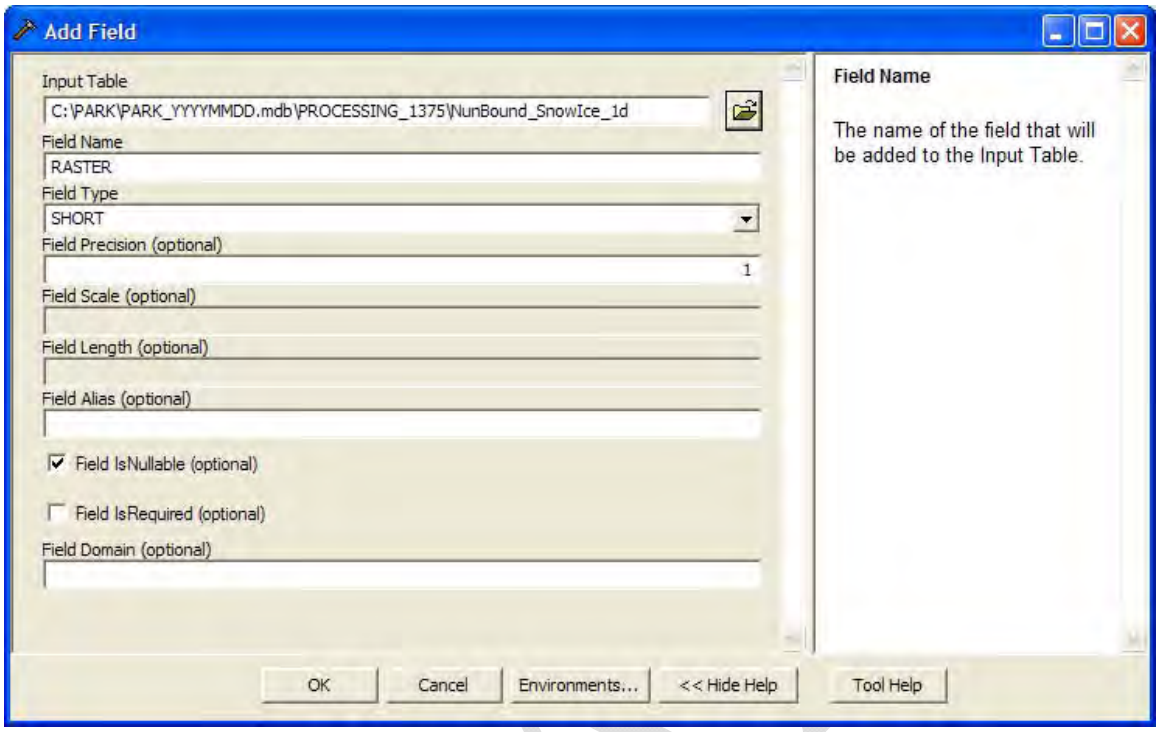

Figure 24. Add a "field" to the attribute table of "NunBound_SnowIce_1d" polygon shapefile using the "Add Field" command in ArcCatalog.

- Calculate Field (management): Calculate to "1" the RASTER field for the polygon shapefiles created above.

DRAFT

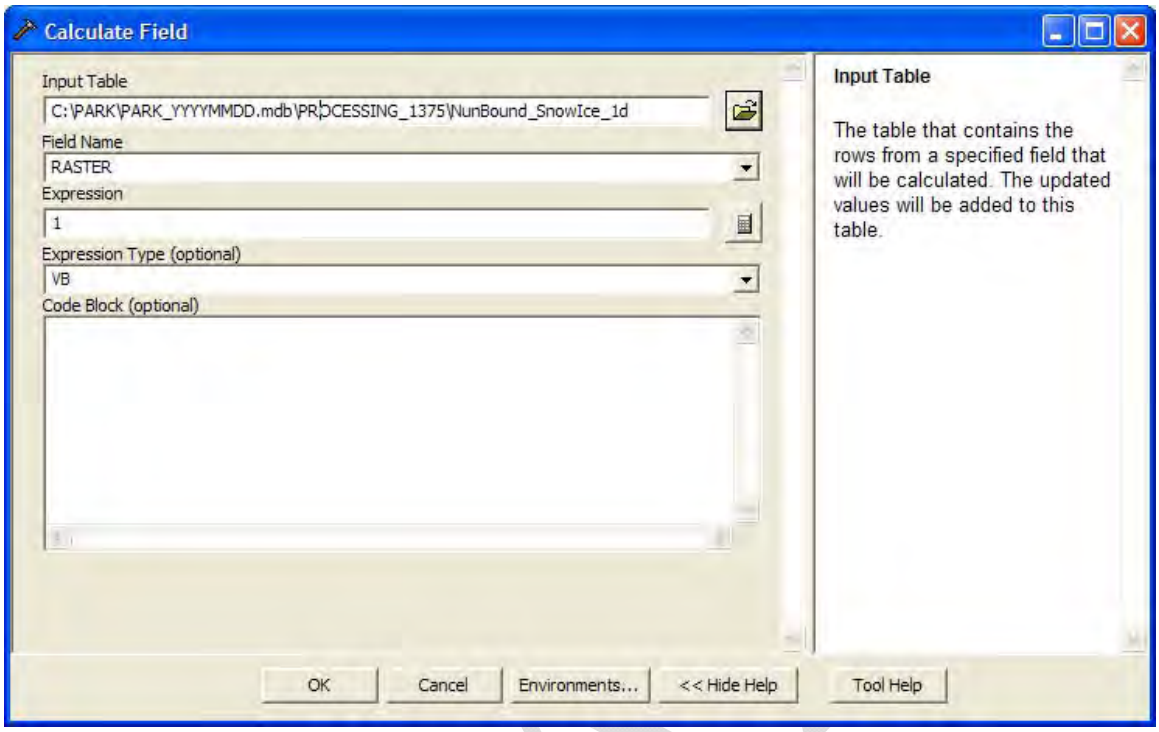

Figure 25. Calculate RASTER "field" value equal to "1" for all records "NunBound_SnowIce_1d" polygon shapefile using the "Calculate Field" command in ArcCatalog.

- Polygon-To-Raster (conversion): NunBound_SnowIce_1d to raster = NunBound_SnoIce_1d_Raster

DRAFT

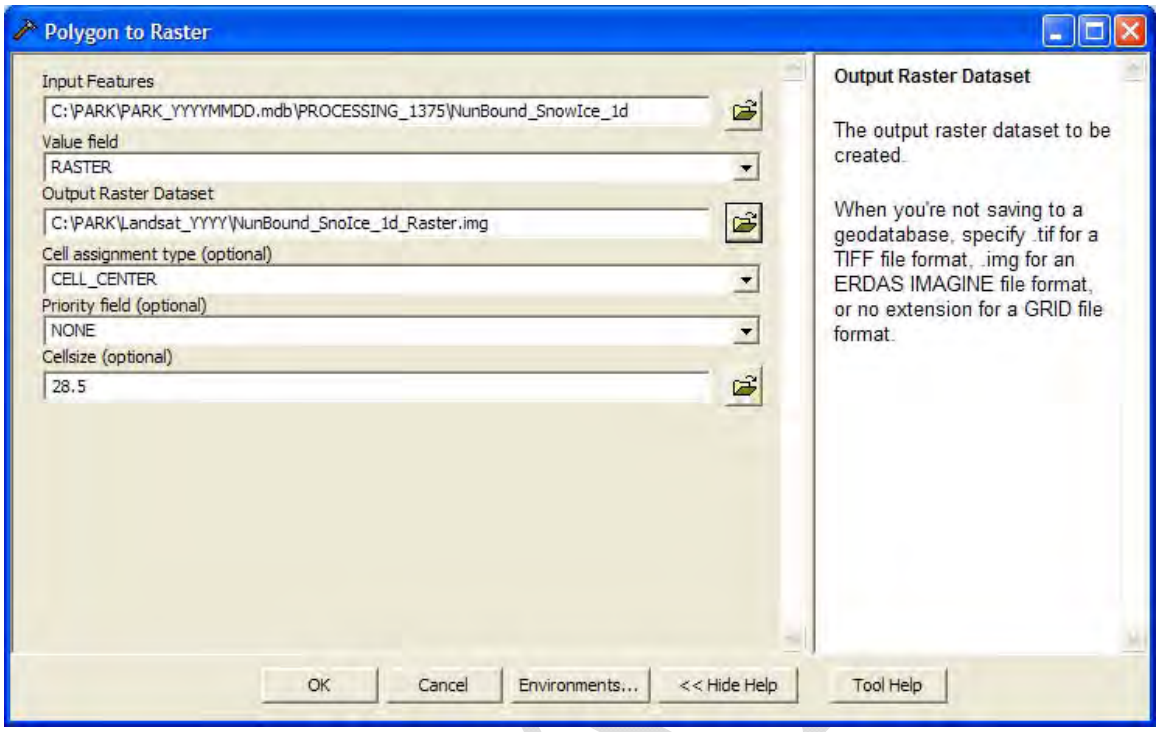

Figure 26. Converting "NunBound_SnowIce_1d" polygon shapefile to a raster file using the "Polygon to Raster" command in ArcCatalog.

- Raster-To-Polygon (conversion): NunBound_SnoIce_1d_Raster to Polygon shapefile = **NunBound**_SnowIce_**1e**

DRAFT

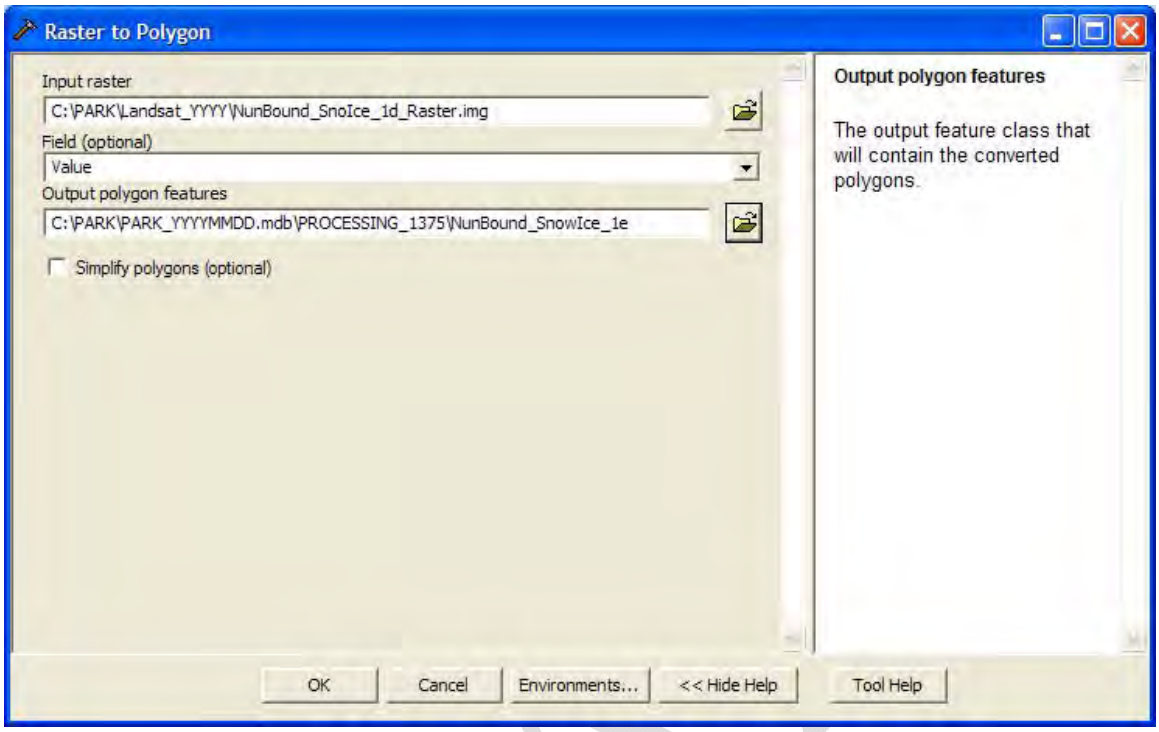

Figure 27. Convert "NunBound_SnoIce_1d_Raster" raster file to a polygon shapefile using the "Raster to Polygon" command in ArcCatalog.

Step 17 Using a DEM and Hydrologic Data to Cleanup of Polygon Shapefiles

The next two processes are optional and may or may not save time and could create additional editing work. The effort required to complete these steps is minimal, so a determination can be quickly made as to their added value or not.

<u>USGS Digital Elevation Model and Hydrologic Datasets (DEM)</u>

Acquire and trim the appropriate National Elevation Dataset for the region of interest. Depending on the elevation of your lowest glacier terminus, using USGS digital elevation model (DEM) is a quick and easy way to remove unwanted clutter from the classifications/shapefiles created in the above steps. Even if the mapping area includes tidewater glaciers, this step may still be useful.

The USGS DEM (National Elevation Dataset, NED) is a very large file. To make the file more manageable, clip the USGS DEM to the mapping area of interest taking the following ArcCatalog commands:

- Create a polygon shapefile (Figure 28) in the appropriate projection and name the file: PARK_DEM_CLIP and place it in the DEM folder. In an ArcGIS edit session, create a feature in the PARK_DEM_CLIP polygon shapefile that defines the boundary of the mapping region. This is a large feature with little detail in the boundary that completely surrounds the mapping area of interest. A four sided polygon will do.

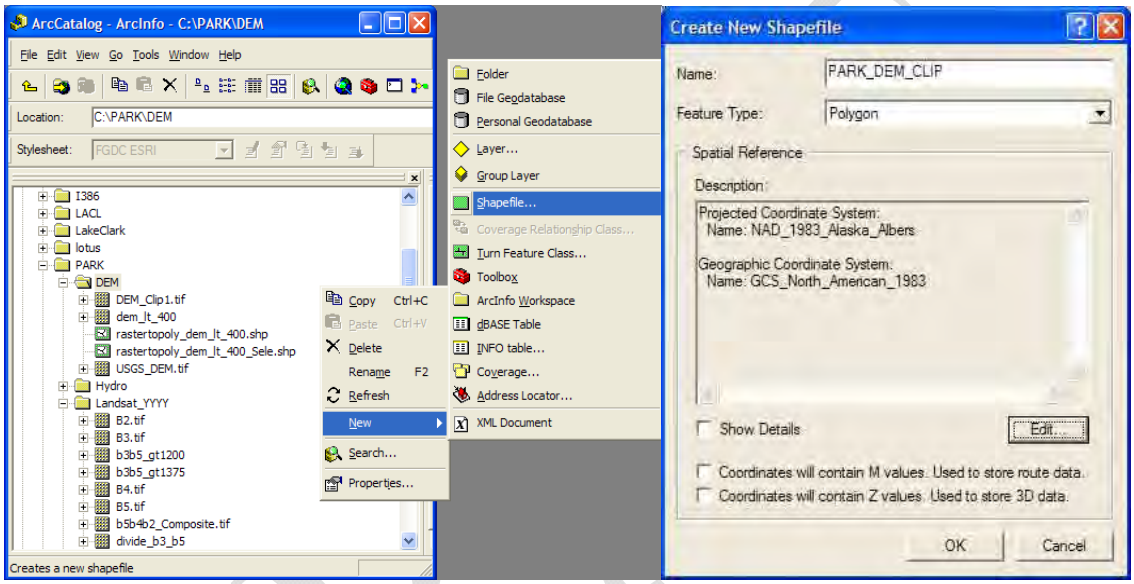

Figure 28. Create the "PARK_DEM_CLIP" polygon shapefile using ArcCatalog.

Clip the USGS DEM to just that of the mapping area. This removes unnecessary and unwanted DEM data from beyond the boundaries of the mapping area, see Figure 29.

- Clip the USGS DEM using the Clip (management) command: Clip the "USGS_DEM" raster file using the "PARK_DEM_CLIP" polygon shapefile created above. Be sure to check the box "Use Input Features for Clipping Geometry".

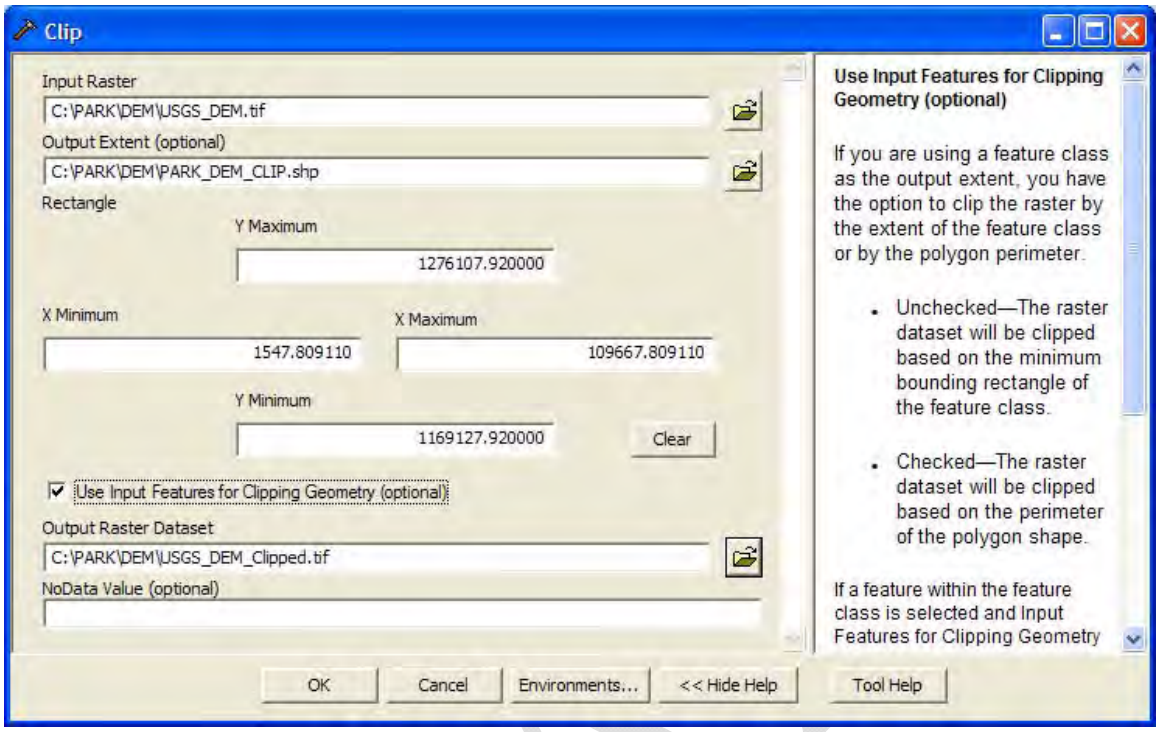

Figure 29. Clipp the USGS_DEM to the boundary of the "PARK_DEM_CLIP" polygon shapefile using the "Clip" command in ArcCatalog.

Identify the lowest elevation in the mapping area that glacier termini occur. Use a conditional statement to select all pixel data in the "USGS_DEM_Clipped" raster file that falls below the elevation desired, in the following example, 400 feet elevation is used, see Figure 30.

- Use command, Con (sa): "USGS_DEM_Clipped" 400; true = 1, false = 0

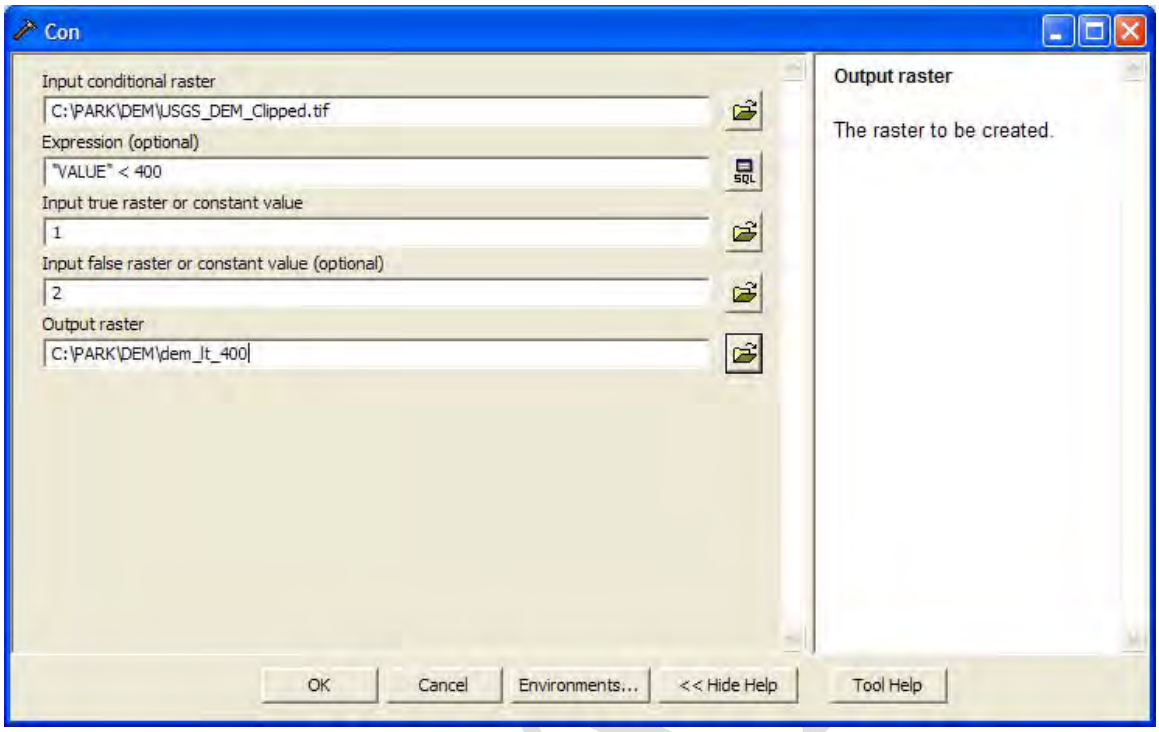

Figure 30. Creating a raster image using the "Con" command in ArcCatalog.

Convert the "dem_lt_400" raster file to a polygon shapefile created in the previous step, Figure 31.

- Raster to polygon GRIDECODE = 1, name file: "rastertopoly_dem_lt_400"

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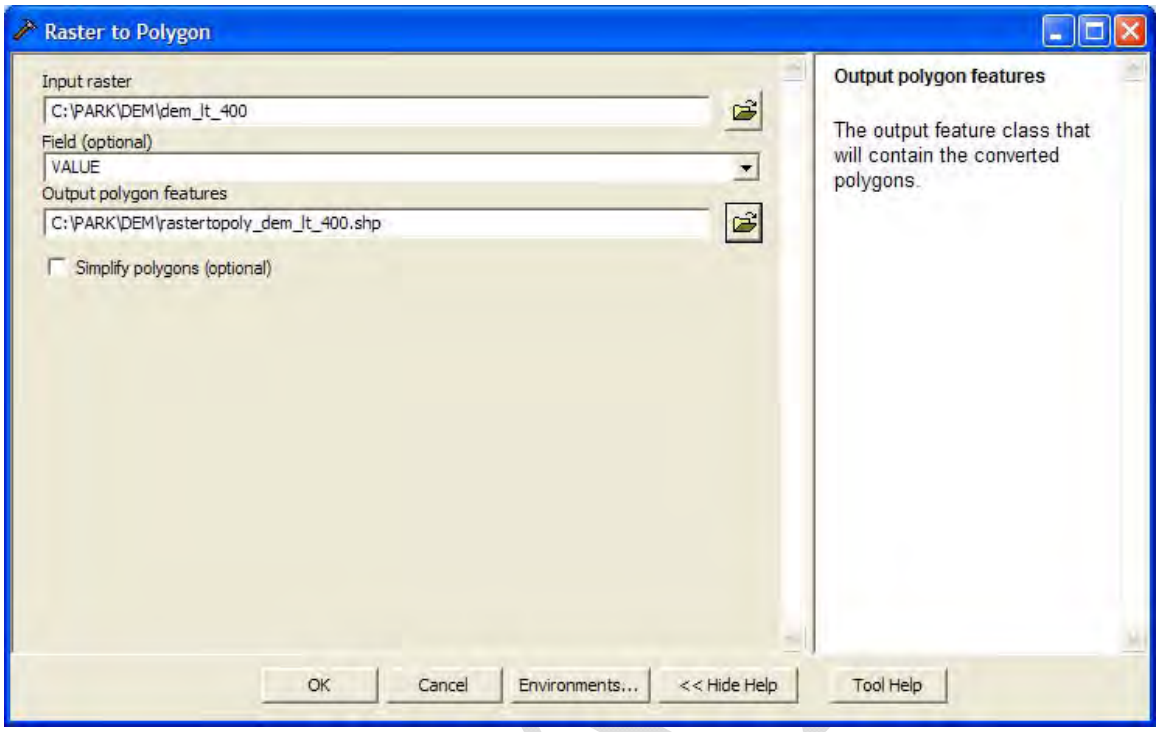

Figure 31. Convert the raster created in preceding step to a polygon shapefile using the "Raster to Polygon" command in ArcCatalog. "Simplify polygons" box is unchecked.

Using the polygon shapefile created above, "rastertopoly_dem_lt_400", select those polygons representing areas less than 400 feet elevation (GRIDCODE = 1).

- Select (analysis): Select "rastertopoly_dem_lt_400" for GRIDCODE = 1 and name the file "rastertopoly_dem_lt_400_sele"

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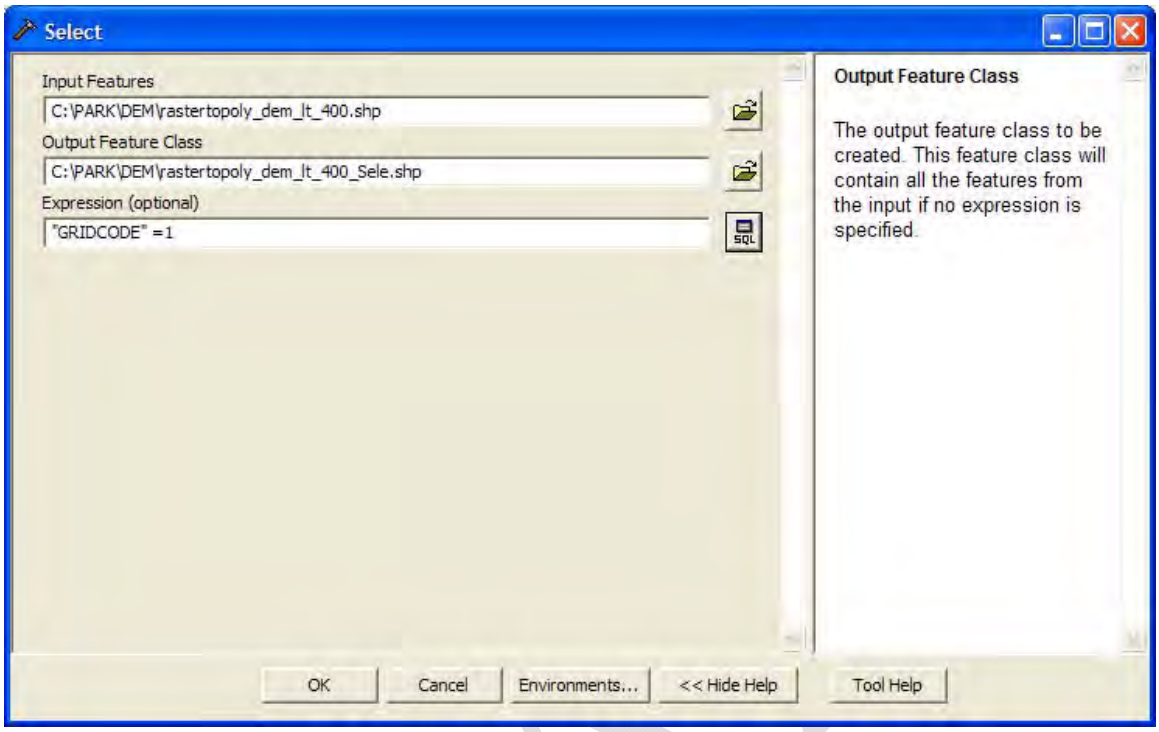

Figure 32. Select polygons within the "rastertopoly_dem_lt_400" polygon shapefile that represent elevations less than 400 feet (GRIDCODE = 1) using the "Select" command in ArcCatalog.

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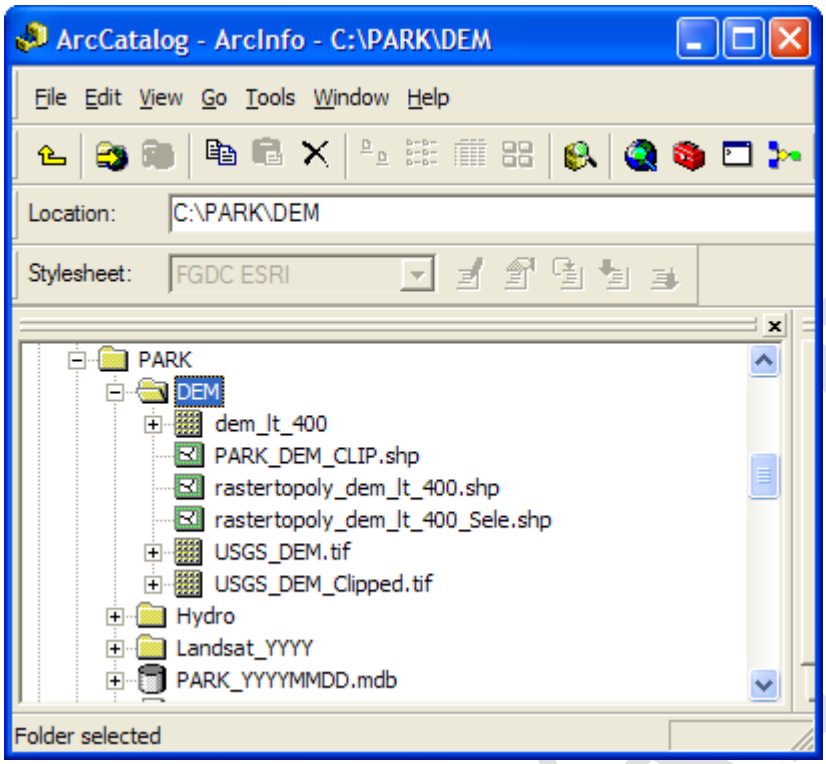

Figure 29. Files in the DEM folder. USGS DEM (National Elevation Dataset) data, clip shapefiles, clipped USGS DEM, etc.

Now that the low-elevation, glacier-free areas in the mapping project are represented by the "rastertopoly_dem_lt_400_sele" polygon shapefile, this file can be used to quickly eliminate areas of misclassification low elevation (<400 feet in this case) occurring in "**SnowIce_gt81225_Clean1c"** polygon shapefile.

- Erase (analysis): "SnowIce_gt81225_Clean1c" minus "rastertopoly_dem_lt_400_sele" = "SnowIce_gt81225_Clean1d"

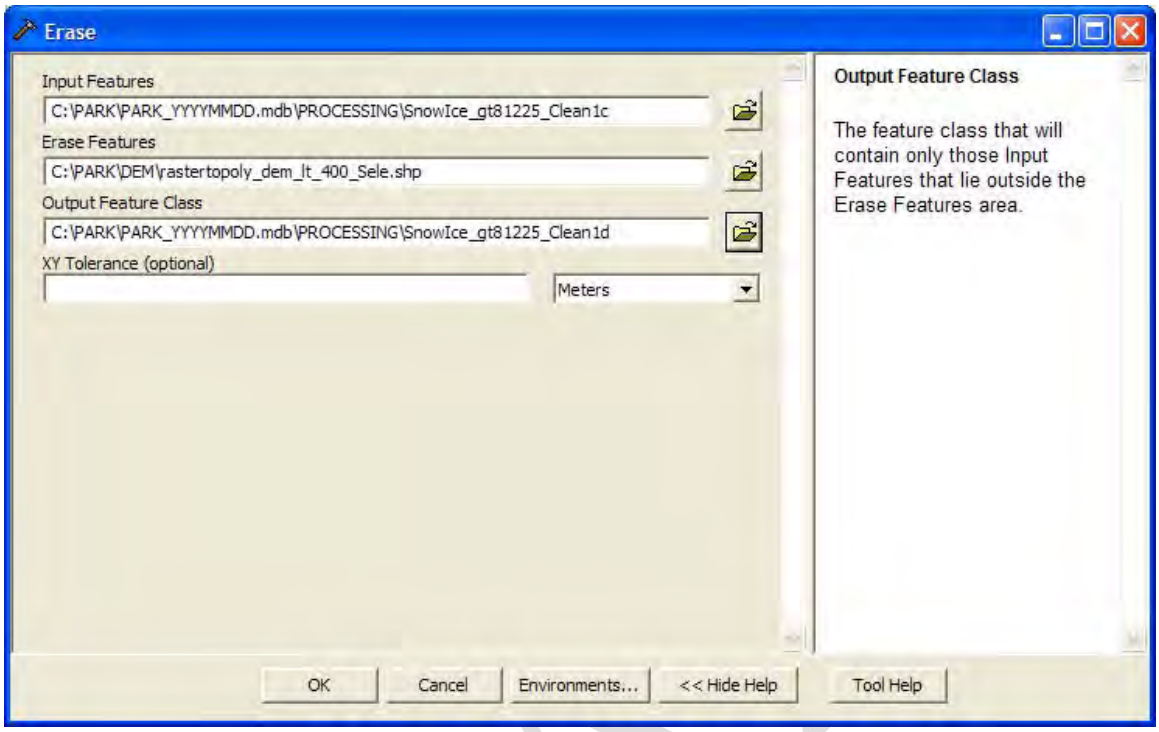

Figure 34. Erase polygons of the "rastertopoly_dem_lt_400_sele" polygon shapefile from the "SnowIce_gt81225_Clean1c" polygon shapefile using the "Erase" command in ArcCatalog.

Evaluate the resultant polygon shapefile "SnowIce_gt81225_Clean1d" and verify that no glacier polygons were erased/modified and that there isn't substantial additional artifacts created in the data that may require additional editing time. If the data is good, use it in the following steps which are designed to further remove misclassified data using a hydrology dataset.

Hydrology: Note: At this time, data features in the Hydro Poly Group dataset create unwanted results that may require addition and lengthy editing.

Though the specific steps aren't detailed below, the methodology is the same as many of the preceding steps using the USGS DEM. This procedure utilizes the Hydro Poly Group dataset in an attempt to remove data erroneously captured as snow/ice but are really water features (lakes or rivers or streams).

- Hydro LACL Poly Group
  - Quad by quad select for field Minor1 = 413 OR 421 and

- Merge: Merge all into one file;
  Note: Review the merged file and erase any errant polygons i.e. lake or river polygons which are obviously over glacier and/or nunataks regions.

- Erase: SnowIce_gt81225_Clean1d - "merged hydro coverage" = **SnowIce_gt81225_Clean1e**
  - A word of caution: these steps create many small fractional polygons that will require manual removal. Knowing this, it maybe just as quick to remove these miss mapped polygons manually from the start.

3-2 Conclusions

Phewf! If you are thinking that was fun, SOP #4 is even more fun!

Before moving on to SOP #4, identify the shapefiles created in SOP #3 that will be needed in SOP #4.

<u>Selecting shapefiles for final ArcGIS Editing</u>
The next step is to move to an ArcGIS edit session and complete the final editing of the polygon shapefiles created in SOP #3.

<u>Snow/Glacier Ice</u>
For snow/glacier ice extent, the following shapefile will be edited as outlined in SOP #4:

SnowIce_gt81225_Clean1c

If the steps outlined above that utilizing the USGS DEM and Hydro Poly Group dataset are successful in cleaning and eliminating errant data, then the shapefiles to be edited in SOP #4 may be:

SnowIce_gt81225_Clean1d, or
SnowIce_gt81225_Clean1e

<u>Nunataks</u>
For nunatak features, the following shapefile will be edited as outlined in SOP #4:

NonSnowIce_gt81225_1d

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Nunatak Bound Snow/Glacier

For snow/glacier features of limited extent and occurring only within the boundaries of nunataks, the following shapefile will be edited as outlined in SOP #4:

NunBoundGlacier1d

The resulting folder and file Structure is as follows:

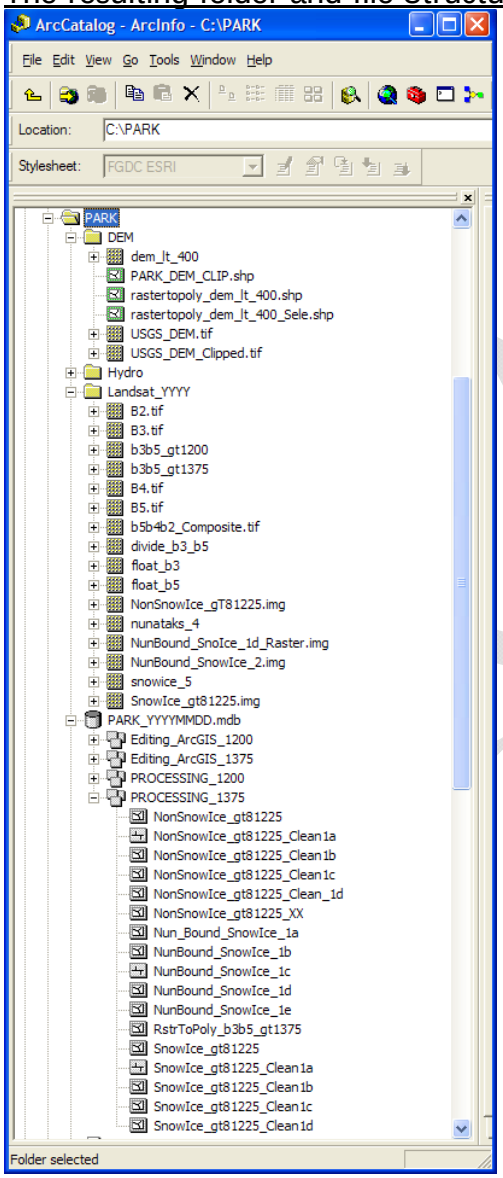

Figure 35. Folder and file structure and naming.

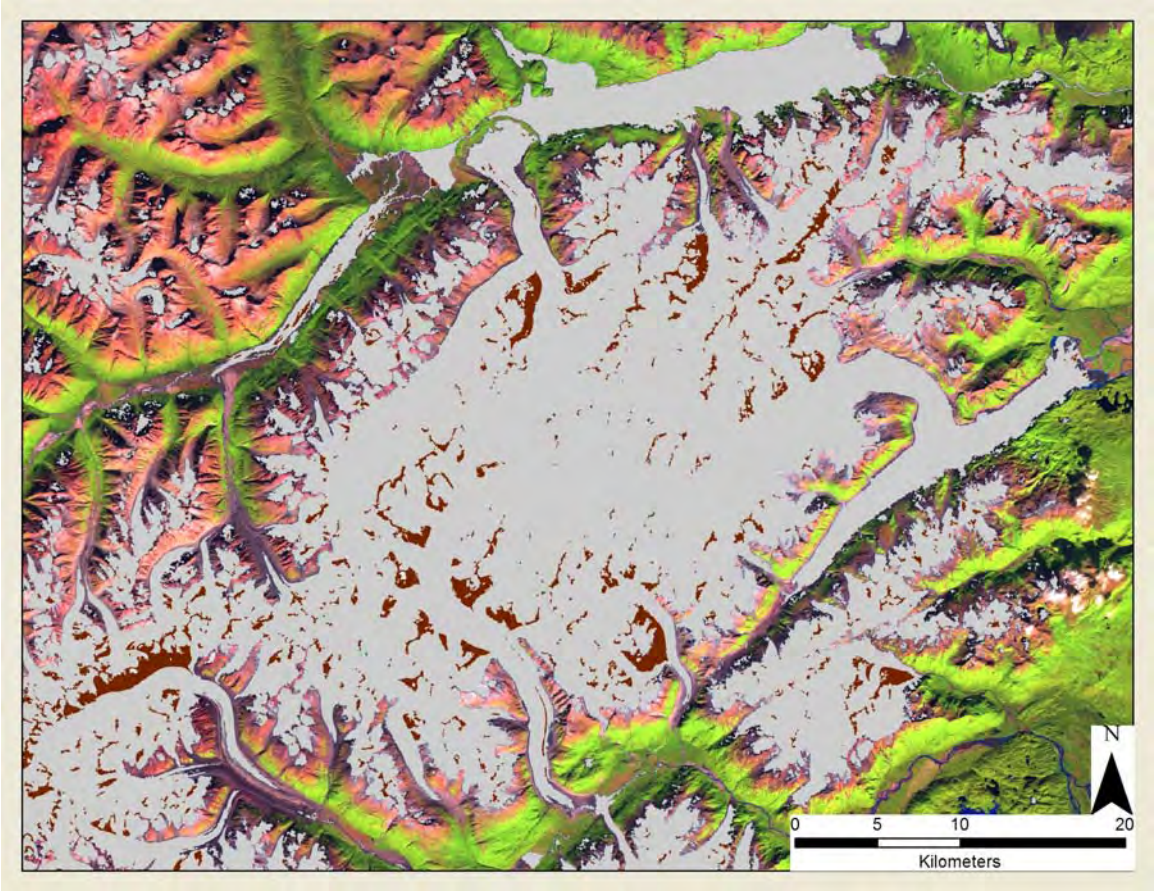

Figure 36. A portion of Lake Clark National Park and Preserve (and nearby areas). Final polygon shapefiles, before manual editing. Three classes of shapefiles are depicted here: glacier extent, nunataks and nunatak-bound glaciers. Note: obvious areas of misclassification in this figure include large lakes and rivers (over classification) and debris covered glacier termini (under classification). Landsat 5, Sept 28, 2007 in the background.

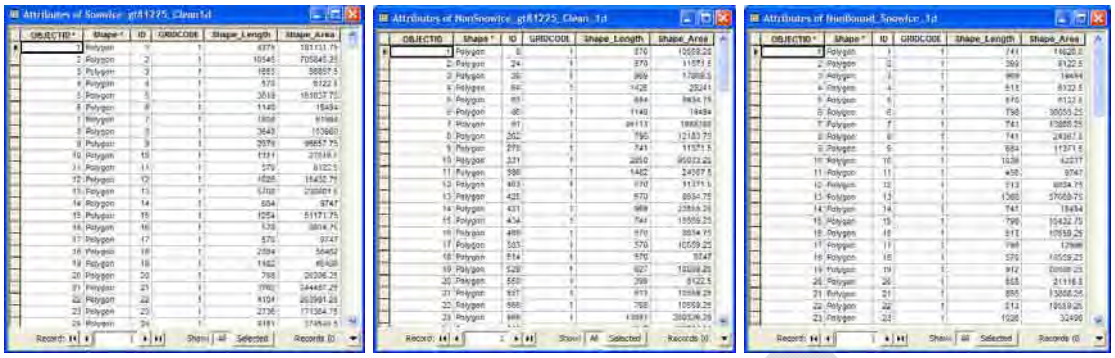

Figure 37. Attribute tables for the three final polygon shapefiles created using SOP #3, glacier extent, nunataks and nunatak-bound glaciers, respectively.

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Glacier Extent Protocol
Southwest Alaska Network

Standard Operating Procedure (SOP) # 4

Editing - ESRI's ArcGIS
GIS Software

Version 1.0 (May, 2009)

Revision History Log:

Previous Version #	*Revision Date*	*Author*	*Changes Made*	*Reason for Change*	*New Version #*

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Overview and Explanation

This Standard Operating Procedure describes the process of editing glacier extent classifications created in SOP #3 using ESRI's ArcGIS and ArcCatalog software, supplemented with higher resolution aerial photography, if available.

This SOP is not an ESRI's ArcGIS or ArcCatalog users manual; a working knowledge of ArcGIS is expected.

This SOP is an exercise in editing polygon shapefiles in GIS. Raster classifications were created and converted to polygon shapefiles via several processing steps as outlined in SOP #3. These shapefile accurately capture snow and glacier boundaries in all areas except in areas debris covered termini and these are the areas where glacier boundaries will be edited using the techniques outlined in this SOP.

A true-color composite satellite image (Landsat bands 5, 4, and 2) was created in SOP #3 using the same Landsat scene data from which the glacier extent classification is based. The polygon shapefiles and color-composite satellite

image will be loaded into an ArcGIS edit session where the shapefiles will be modified to correct areas of miss-classification.

Editing of the glacier extent polygon shapefiles will be accomplished with the aid of expert personal knowledge of the region's glaciology and higher resolution photography, if available. When careful attention is maintained throughout the mapping and editing effort, accuracy and repeatability is substantially increased, especially in areas of debris covered ice.

4-1 Editing Glacier Extent Boundaries - Overview

The polygon shapefiles created from the raster classification (from SOP #3) will be edited in ArcGIS to correct for areas of miss-classification. In order to create and maintain as much consistency in this glacier extent mapping effort, an understanding of what qualifies as a glacier must be defined.

Delineating the boundary where glacier ice contacts ground is not as simple as may first appear. As the interpreter zooms in to an area of interest, the pixels representing the contact will trend from white (ice) to black (ground), and in many circumstances, a transition zone of grey pixels between. The spectral reflectance of the pixels represents surface conditions that contain varying proportions of ice, debris on the ice and ground. Mapping the glacier boundary in these situations is left up to the judgment of the image interpreter.

To help standardize glacier mapping, the definition of what falls into the category called "glacier extent" must be defined. Seems simple, but it is more complicated than first appears. With this in mind, the following is from the GLIMS definition of a glacier to better define a glacier for this protocol (Raup, 2007, GLIMS Analysis Tutorial):

> *A glacier or perennial snow mass consists of a body of ice and snow that is observed at the end of the melt season. This includes, at a minimum, all tributaries and connected feeders that contribute ice to the main glacier, plus all debris covered parts of it. Excluded is all exposed ground, including nunataks.*
>
> *The following circumstances will be considered when mapping glacier boundaries (Raup, 2007, GLIMS Analysis Tutorial):*

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1. Bodies of ice above the bergschrund that are connected to the glacier shall be considered part of the glacier, because they contribute snow (through avalanches) and ice (through creep flow) to the glacier.
2. Any steep rock walls that avalanche snow onto a glacier but do not retain snow themselves are NOT included as part of the glacier.
3. A stagnant ice mass still in contact with a glacier is part of the glacier, even if it supports an old-growth forest.
4. All debris covered parts of the glacier must be included.
5. Map only at the end of the ablation period to exclude seasonal snow. Map everything that is connected to the glacier.
6. Rock glaciers are not included in this protocol.

4-2 ArcGIS/ArcCatalog – Editing Glacier and Nunatak Boundaries

A general overview of ESRI's ArcGIS/ArcCatalog commands and procedures is presented here. The steps described are general. A working knowledge of ArcGIS/ArcCatalog is expected.

4-2.1 ArcGIS/ArcCatalog – Folder and File Naming Convention and Data Handling

Folder structure and naming convention, the creation and naming of Personal Geodatabases and Feature Datasets are presented in SOP#7. Detailed file naming convention is presented through out this SOP as appropriate.

The first step will be to set up a folder and file naming system as identified in SOP #7 and already initiated in SOP #3. Within the "PARK" folder, a Personal Geodatabase (PARK_YYYYMMDD) was created in SOP #3. Within the Personal Geodatabase, create a new Feature Dataset and name it "Editing_ArcGIS_1375". This is where all the editing of the polygon shapefiles created in SOP #3 will occur.

The standard datum and projection for in NPS-Alaska is NAD83 – Alaska Albers.

The Datum and Projection of the Feature Datasets created will be equivalent to the Landsat data being processed. As indicated in SOP #1, Landsat imagery is currently delivered from EROS Data Center in WGS84, UTM zone 5 or 6, for the SWAN parks. If glacier mapping occurred in a different datum/projection from

the Alaska NPS standard, the re-projection of the data will occur upon completion of the glacier mapping when all shapefiles are final.

As outlined in SOP #7, frequent saves during this process is critically important. It will save time in the long run. Also be sure to backup you work files to a separate server.

4-3.2 Copy Polygon Shapefiles into Editing_ArcGIS_1375 Folder

The final polygon shapefiles created in SOP #3 are copied to the "Editing_ArcGIS_1375" Feature Dataset. Rename these files:

"Processing_1375"	→	"Editing_ArcGIS_1375"
SnowIce_gt81225_Clean1d	→	SnowIce
NonSnowIce_gt81225_Clean1d	→	Nunataks
Nun_Bound_SnowIce1d	→	NunatakBound_SnowIce

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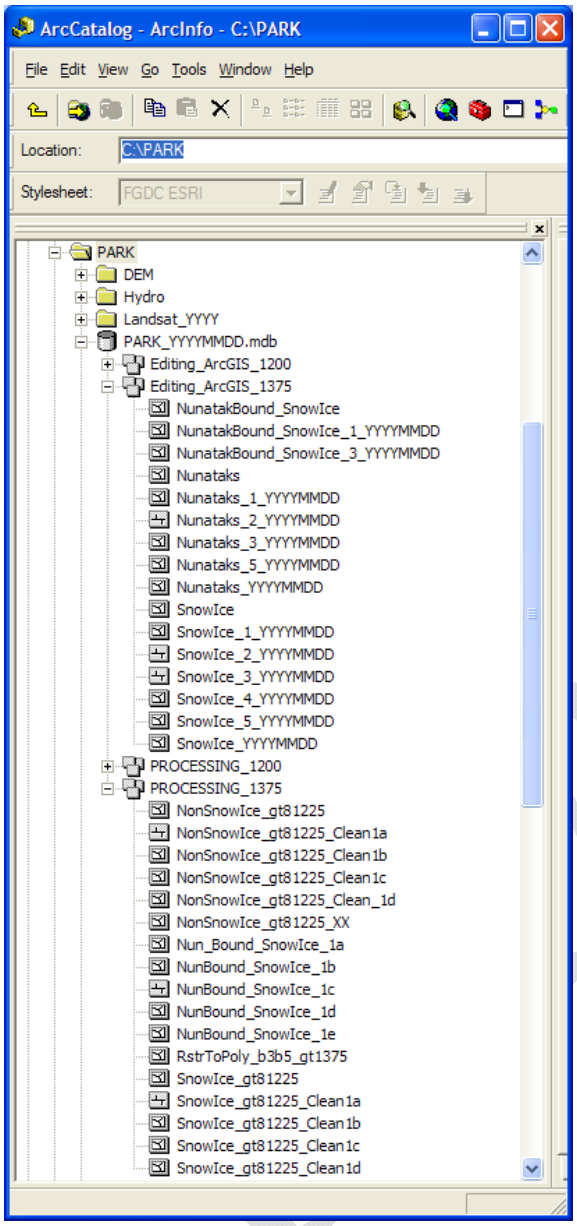

Figure 1. Folder, file personal geodatabase and feature dataset organization

4-3.3 Load Raster and Shapefiles into ArcGIS

ArcGIS and ArcCatalog are running:

- Load the color-composite Landsat image that was created in SOP #3 (which is located in the "Landsat" folder) into ArcMap. This is the Landsat scene data for which the glacier extent classification is based.

- Using ArcCatalog, make a copy of the “SnowIce” line shapefile and name it “SnowIce_X_YYYYMMDD” and place it in the “Editing_ArcGIS_1375” feature dataset. “YYYYMMDD” equates to the year-month-day the editing is taking place. “X” is a number progressing by one from “1” for each successive file produced. Load “SnowIce_1_YYYYMMDD” shapefile into ArcMap.

- Adjust the symbolization representing “SnowIce_1_YYYMMDD” shapefile. Select “Hollow” and then select the “Outline” color you prefer. This will enhance your ability to see the “SnowIce_1_YYYMMDD” shapefile on the base image.

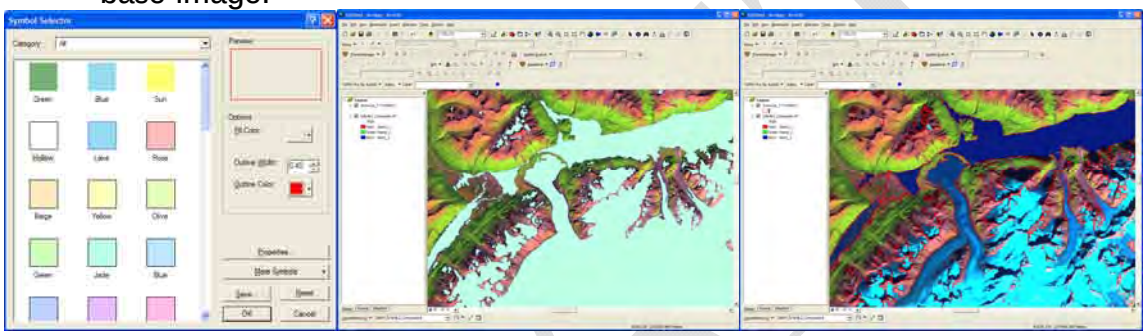

Figure 2. “SnowIce_1_YYYYMMDD” shapefile before and after “Symbol Selector” is modified.

4-3.3 Begin an Edit Session in ArcGIS

Begin an Edit Session in ArcMap. There are hundreds and possibly thousands of polygons in the “SnowIce_X_YYYYMMDD” shapefile that are a result of over-classification. Begin deleting the polygons that are obvious errors. These areas of over-classification are typically water bodies (lakes and rivers) and shadowed areas.

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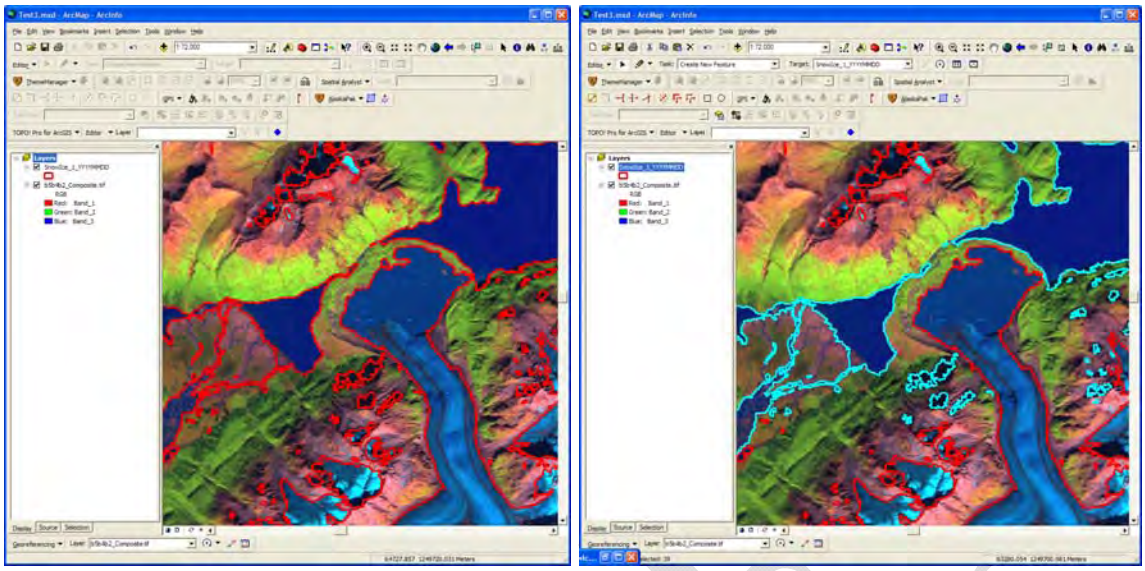

Figure 3. The original “SnowIce_1_YYYYMMDD” shapefile on the left with polygons representing areas of obvious over-classification (lakes, rivers, shadows). The image on the right shows the highlighted polygons to be deleted from the “SnowIce_1_YYYYMMDD” shapefile.

As the larger (easiest) polygons are identified and deleted from the “SnowIce_1_YYYYMMDD” shapefile, zoom in on the scene to a scale of not smaller the 1:24,000. At this point, systematically pan across the entire glacier mapping region deleting all polygons of over-classification (misclassification). If a polygon can’t be deleted in its entirety (i.e. there is snow/glacier ice within its boundary), leave it. Don’t’ begin polygon boundary modifications at this point.

This process of deleting polygons of misclassification will take a dedicated amount of time and effort and may span several days. Frequent “saves” of the editing work will reduce frustration and save time. The following screen capture illustrates this procedure. Create a new polygon shapefile at the beginning of each new day of editing from the most recent edited shapefile.

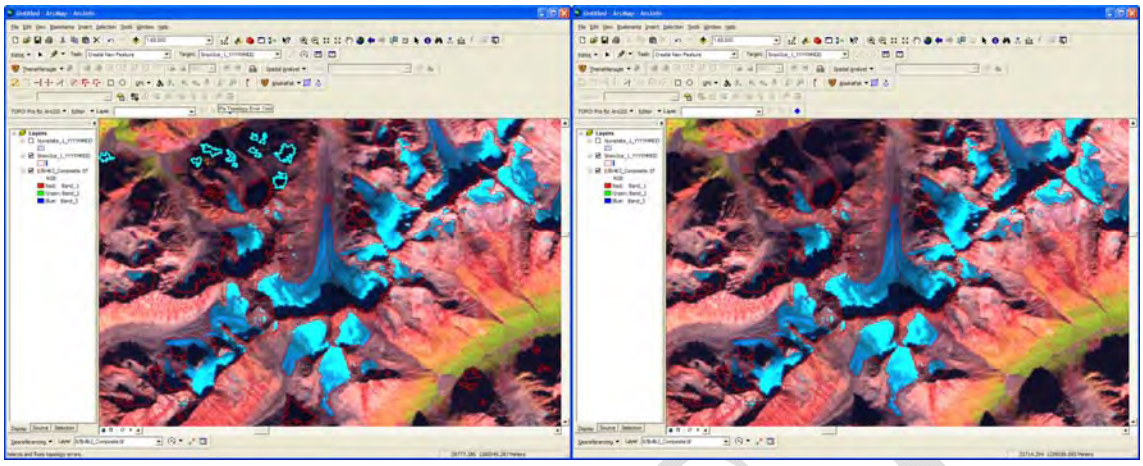

Figure 4. The highlighted polygons in the left image (SnowIce_X_YYYYMMDD shapefile) represent shadow, not snow or glacier ice. These polygons are deleted from the shapefile in the image on the right.

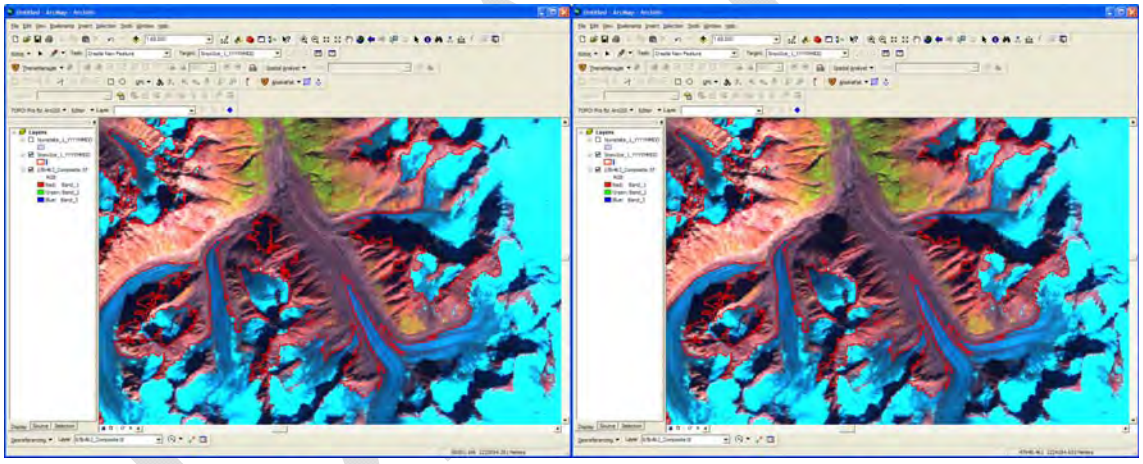

Figure 5. A couple shadow polygons are present in the center-left portion of the left image (SnowIce_X_YYYYMMDD shapefile). These polygons are deleted from the shapefile in the image on the right.

Continue systematically traversing the entire glacier mapping area deleting these polygons of misclassification. Zooming in and out and looking at higher resolution imagery (if available) will aid this editing process.

Repeat the process of removing polygons of misclassification with the Nunataks shapefile. Begin by creating the “Nunatak_1_YYYYMMDD” shapefile from the

“Nunataks” shapefile. Next, convert “Nunatak_1_YYYYMMDD” shapefile to a line file “Nunatak_2_YYYYMMDD” and then back to a polygon shapefile “Nunatak_3_YYYYMMDD.” Begin deleting misclassified polygons using the “Nunatak_3_YYYYMMDD” shapefile, eliminating all polygons captured erroneously as nunataks. Again, this process should also be carried out with the composite image and the most recent “SnowIce_X_YYYYMMDD” shapefile as a backdrop during the editing process. By definition, nunataks are bare ground are surrounded by glacier ice.

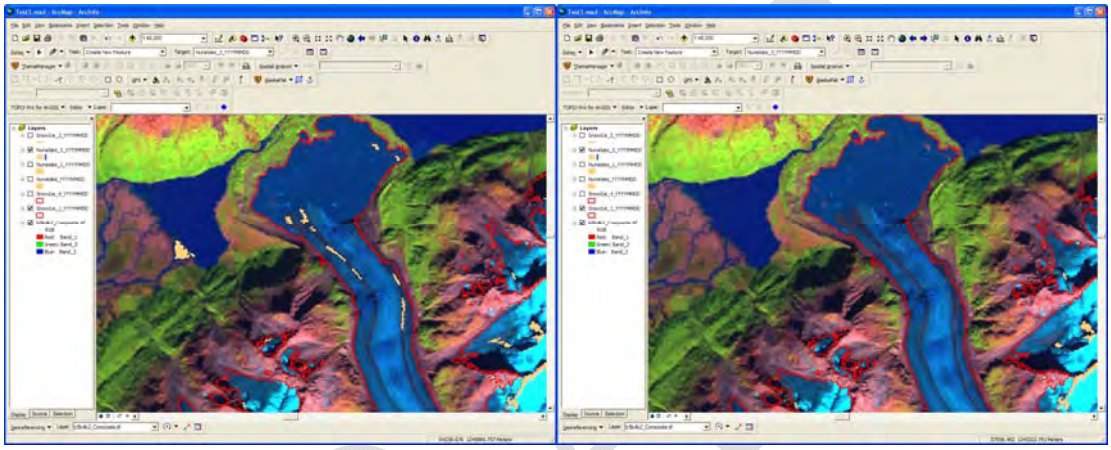

Figure 6. A few nunatak polygons (cream color) in the “Nunatak_3_YYYYMMDD” shapefile (left image) are clearly not nunataks but are moraine features on the glacier and deltaic feature (left of left image). These polygons are deleted from the “Nunatak_3_YYYYMMDD” shapefile in the image on the right.

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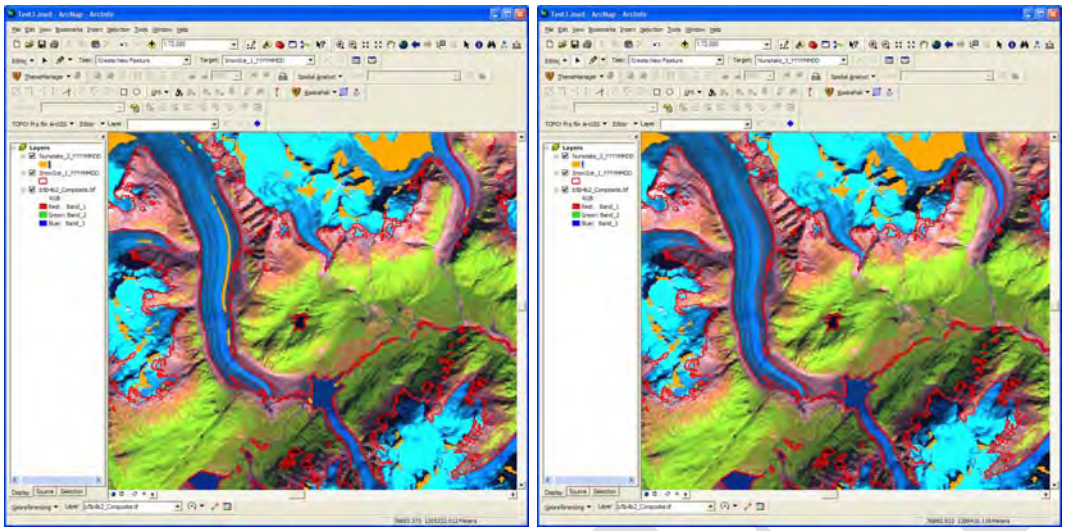

Figure 7. Again, a few nunatak polygons (orange color) in the "Nunatak_3_YYYYMMDD" shapefile (left image) are clearly not nunataks but are moraine features on the glacier. These polygons are deleted from the shapefile in the image on the right.

4-3.3 Editing Glacier Boundaries

When all extraneous polygons representing miss-classification (both "SnowIce_X_YYYYMMDD" and "Nunatak_X_YYYYMMDD" shapefiles) have been eliminated, it is time to begin to modifying polygon boundaries to capture areas of miss-classification; typically these are areas of under-classification. This step will be performed at a scale of not smaller than 1:24,000 and 1:15,000 is better. Frequently zooming in and out is a useful, though actual line modification should occur zoomed to at a scale of least 1:24,000.

For this step in the boundary modification process, there are essentially two classes of glaciers:

- Individual debris covered glacier termini
- Coalescing debris covered glacier termini (two or more coalescing glaciers)

4-3.4 Editing Glacier Boundaries - Individual Debris Covered Glacier Termini

For individual debris covered glaciers, this step is a simple editing task in ArcGIS. Some of the editing features that will be important are:

- Create Tasks

- Modify Tasks
- Snapping

In areas of coalescing debris covered glaciers, the process becomes more complicated, requiring several additional steps be accomplished to facilitate the editing process. This process will be described in the next section of this SOP.

Start with the polygon shapefiles that have been cleaned of all polygons representing misclassification/over-classification (SnowIce_X_YYYYMMDD, Nunatak_X_YYYYMMDD). Make a copy of these shapefiles prior to conducting the following steps in the editing process and name the file appropriately (next in the numbering sequence). This ensures that you can step back to the latest version shapefile if the work becomes corrupt.

ALSO NOTE: At this stage, the "SnowIce_X_YYYYMMDD" is the best representation of clean glacier ice boundaries created in the process.

The following process/example will be presented using the latest version of the "SnowIce_X_YYYYMMDD shapefile. This editing process will also necessarily create some new polygons representing nunataks and thus these new nunatak polygons will be added to the most recent nunatak shapefile.

<u>ArcGIS/ArcCatalog Commands</u>

- Feature To Line (management): Convert the "SnowIce_X_YYYYMMDD" shapefile to a line shapefile and name the file appropriately (next in the file naming sequence):

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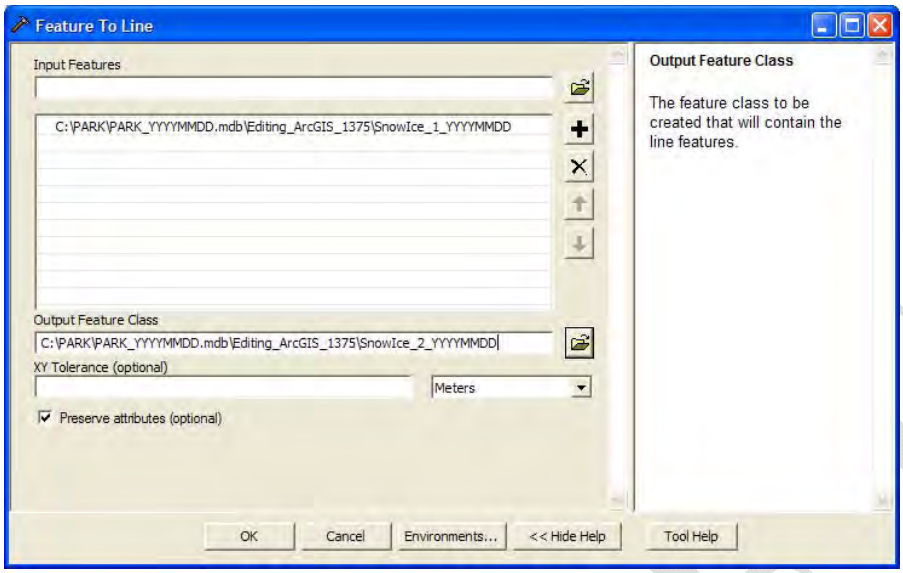
Feature To Line
Input Features
C:\PARK\PARK_YYYYMMDD.mdb\Editing_ArcGIS_1375\SnowIce_1_YYYYMMDD
Output Feature Class
C:\PARK\PARK_YYYYMMDD.mdb\Editing_ArcGIS_1375\SnowIce_2_YYYYMMDD
XY Tolerance (optional)
Meters
Preserve attributes (optional)
Output Feature Class
The feature class to be created that will contain the line features.
OK
Cancel
Environments...
<< Hide Help
Tool Help

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- Split Line At Vertices (management): Split the “SnowIce_X_YYYYMMDD” shapefile created above at the vertices and name the file appropriately (next in the file naming sequence).
- At this point begin editing of the newest “SnowIce_X_YYYYMMDD” line shapefile in a standard ArcGIS edit session. Start an Edit session in ArcGIS and select “Create New Feature” and indentify the “Target” as the “SnowIce_X_YYYYMMDD” line shapefile.
- Begin to capture areas of debris covered termini digitizing their boundaries using on-the-fly digitizing with your mouse. Be sure to use the snapping feature in the edit session to initiate and terminate the new feature at an appropriate vertex of the “SnowIce_X_YYYYMMDD” line shapefile. Using the “snapping” feature to initiate and terminate lines will ensure that the polygons will be created when this line shapefile is converted to a polygon shapefile.

  The following figures illustrate editing of individual glacier termini that are debris covered.

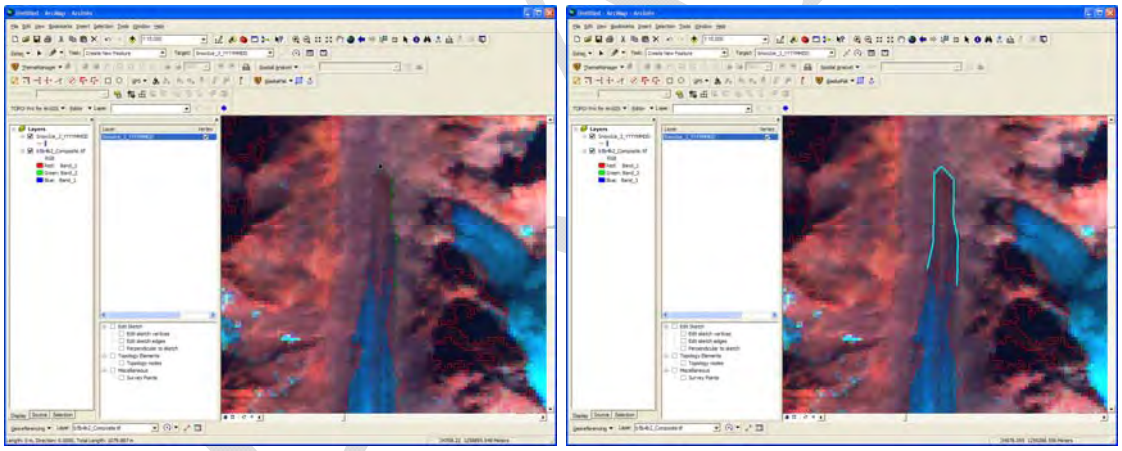

Figure 8. Simple glacier boundary extension in areas of one debris covered glacier terminus: initial classification and editing in progress (left) and the corrected classification (right).

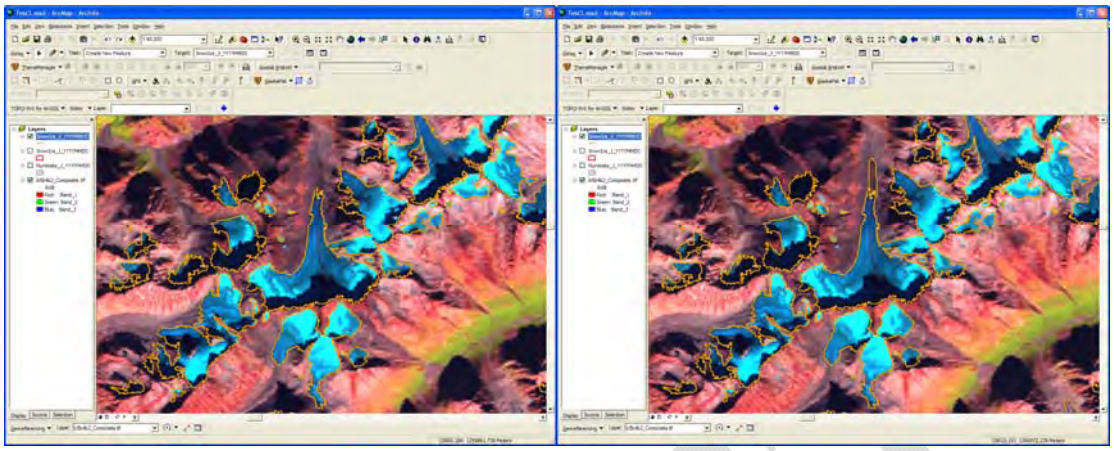

Figure 9. Landsat image and the initial classification (left) and the corrected classification (right).

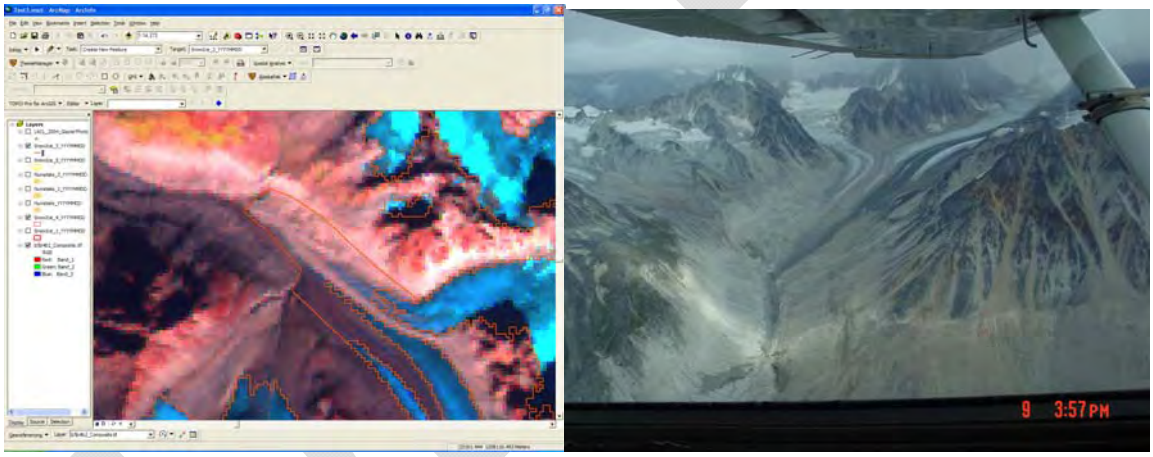

Figure 10. In this situation, an aerial oblique photo is available to aid in the glacier boundary modification. Landsat image (left), the initial classification and the corrected classification based on information gained from the aerial oblique photo of the glacier. The Landsat image and the aerial oblique photo were both captured in August 2007.

Figure 11. Another example of the initial classification and corrected classification based on aerial oblique photography. Correction shown in blue.

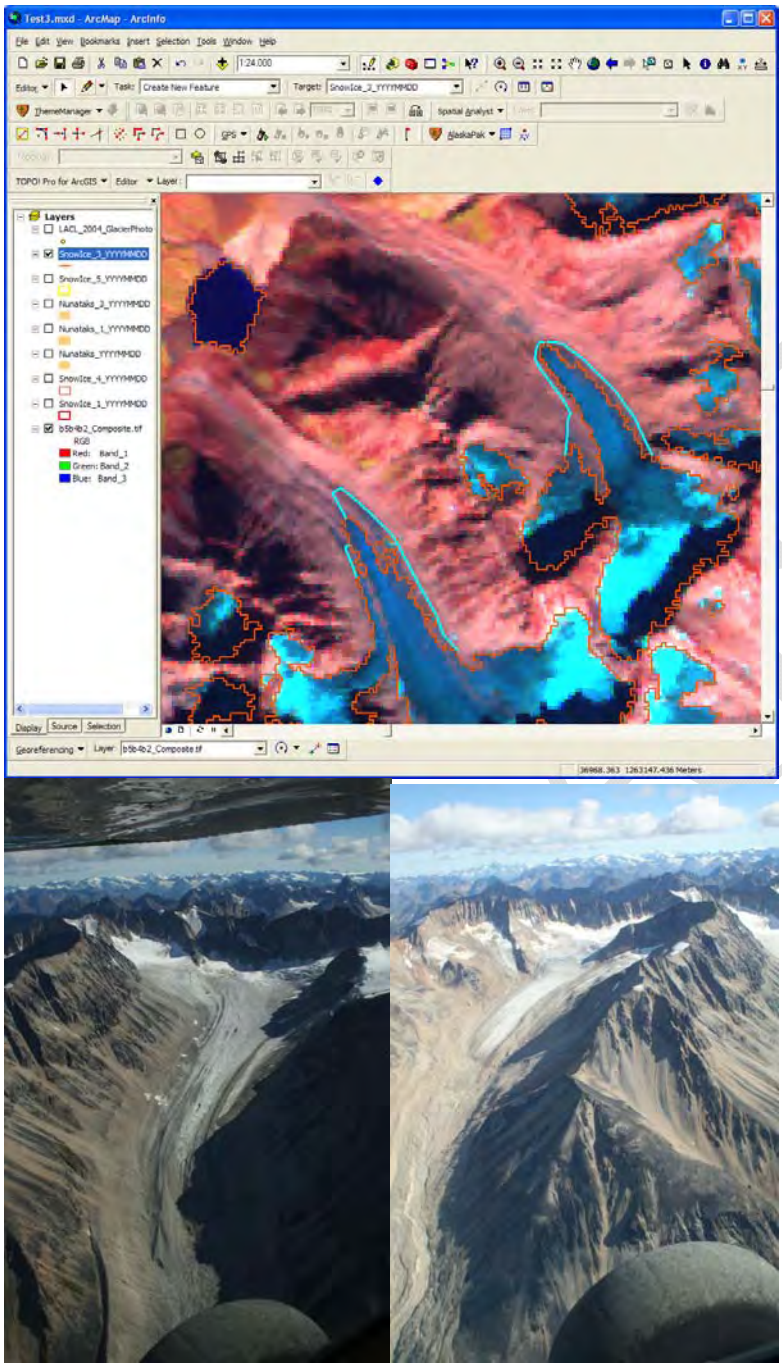

Figure 12. Another example of the initial classification and corrected classification based on aerial oblique photography. The aerial oblique on the left is of the glacier on the left of the Landsat image. The aerial oblique on the right is of the glacier on the right of the Landsat image. (Correction shown in blue)

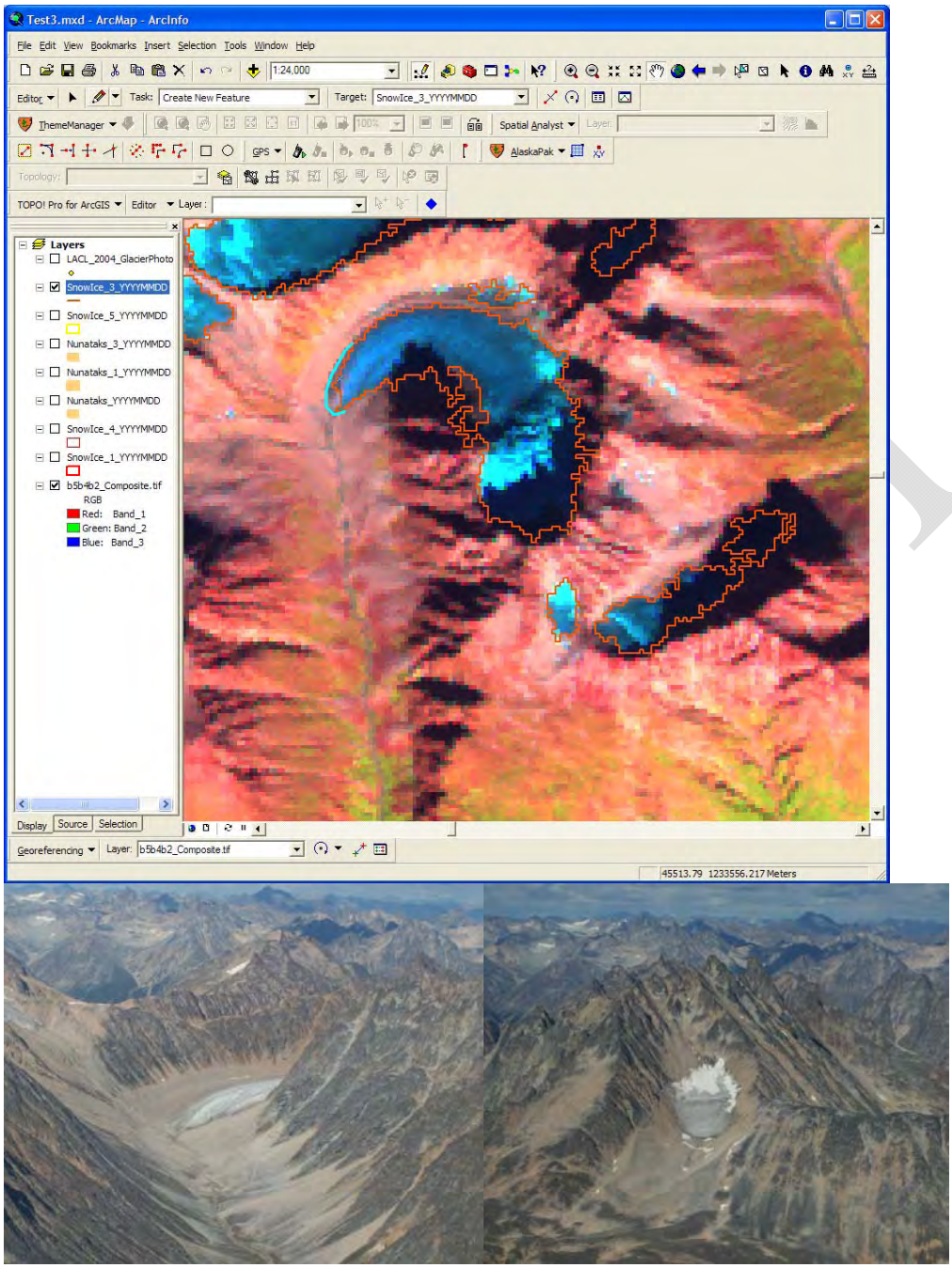

Figure 13. Another example of the initial classification and corrected classification based on aerial oblique photography. The aerial oblique on the left is of the glacier on the left of the Landsat image. The aerial oblique on the right is of the small glacier on the right of the Landsat image. (Correction shown in blue) Note no correction was made to the small glacier on the right.

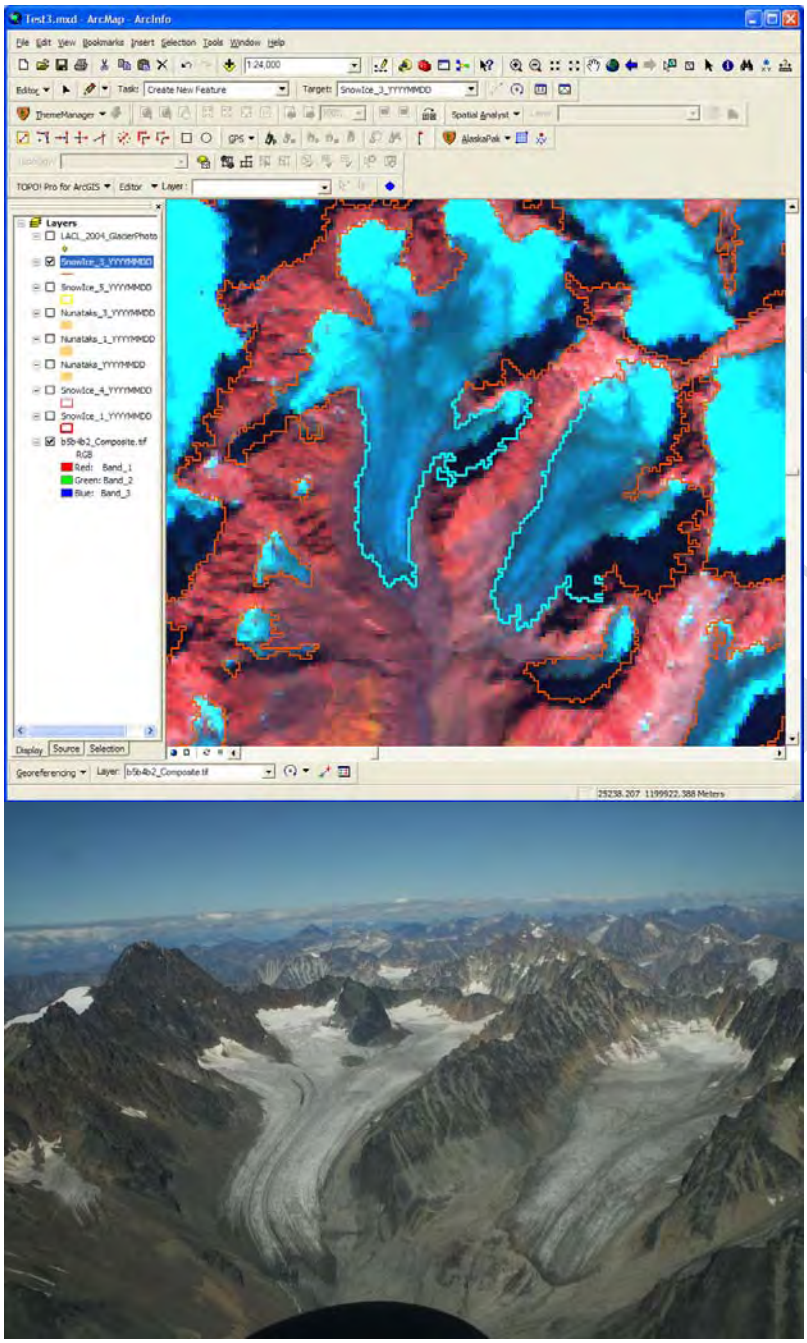

Figure 14. An example of the initial classification. No correction is required here. The glacier on the left of aerial oblique is on the on the left of the Landsat image and the glacier on the right of aerial oblique on the on the right of the Landsat image.

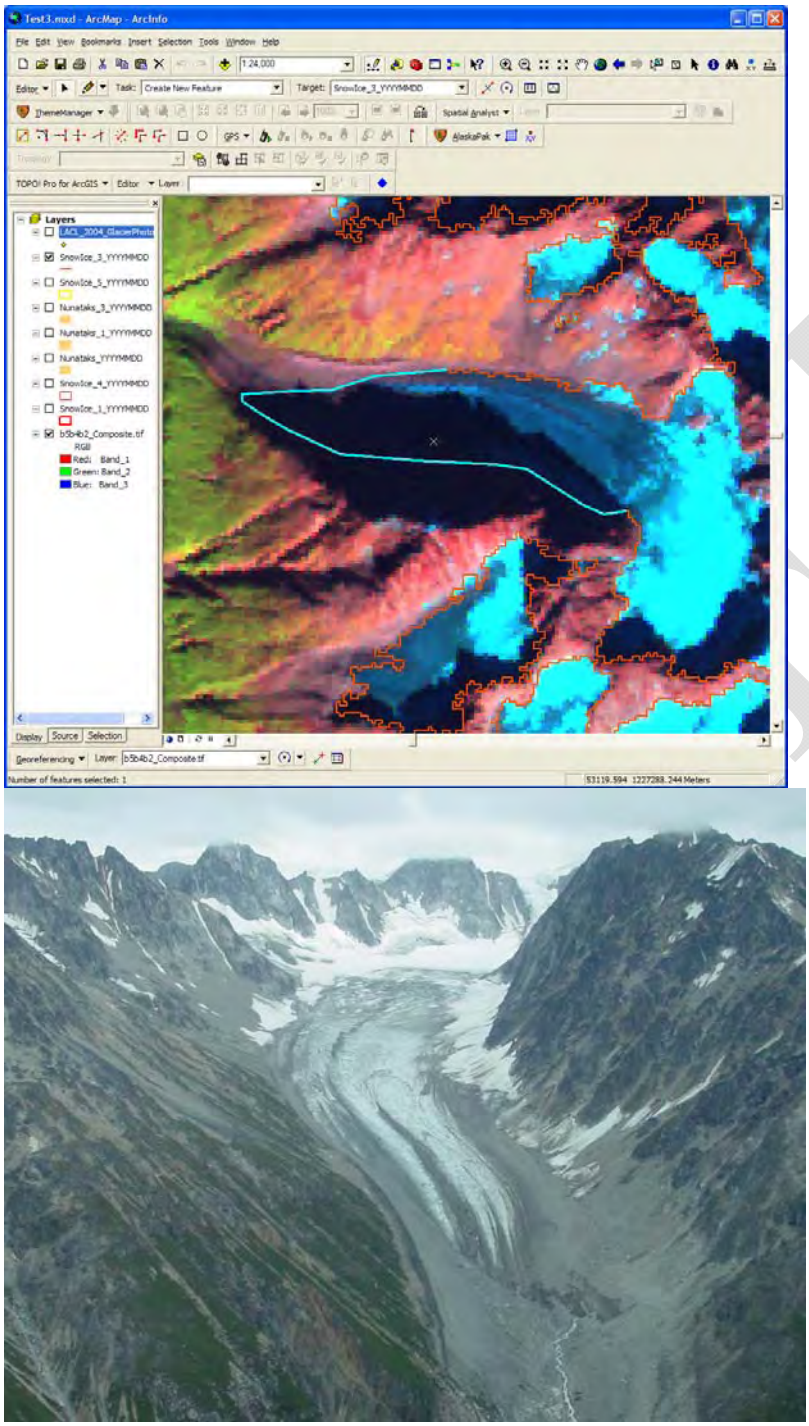

Figure 15. Another example of the initial classification and corrected classification based on aerial oblique photography. The initial classification is challenged by shadowed ice. (Correction shown in blue)

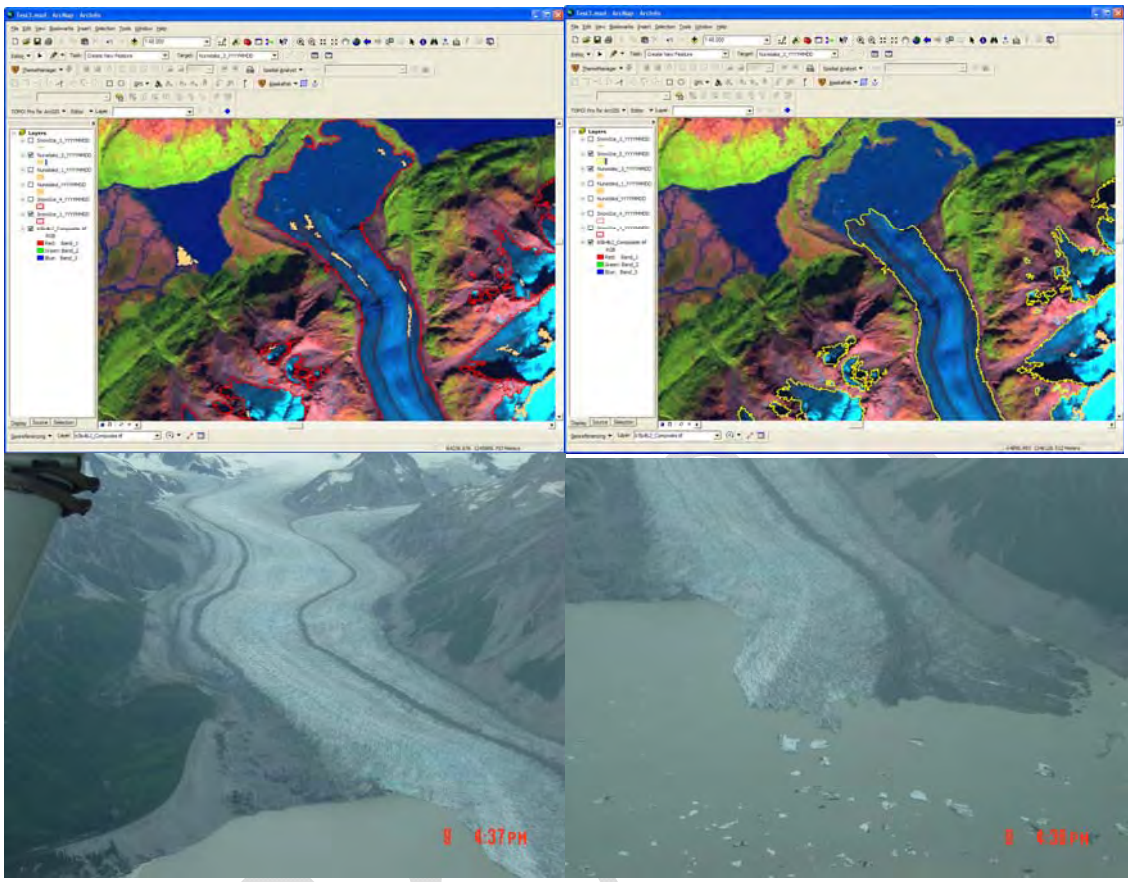

Figure 16. An example of the corrected classification based on aerial oblique photography. The aerial oblique imagery show both the terminus and the boundaries of the Shamrock Glacier. In this situation, aerial oblique imagery is helpful but not critical as the terminus position shows up very nicely in the Landsat imagery.

4-3.5 Editing Glacier Boundaries - Coalescing Debris Covered Glacier Termini

At this stage of the editing process, the boundaries of all the individual debris covered glaciers have been edited. Phewf! The next step is to edit glacier boundaries in areas of coalescing debris covered glaciers. In these circumstances, not only will glacier termini boundaries be adjusted to encompass a larger area but the process will create features representing ground (nunataks) that were not captured in the original Nunatak shapefile. Care must be taken to copy these “new” nunatak features to the current Nunatak shapefile. The process of editing glacier boundaries in these areas gets complex and confusing,

so each of these areas will be addressed one at a time as editing progresses through the mapping region. The processing/editing steps will be repeated in each of the coalescing glacier areas and will seem repetitive. However, it is best to proceed in this fashion, because as glacier boundaries are corrected through an area of coalescing glaciers, you will see that boundaries of features representing barren ground (nunataks) have also been delineated. These new bare-ground features will need to be added to the "NonSnowIce_X_YYYMMDD shapefile as editing progresses throughout the mapping region. Again, editing glacier margin boundaries will occur at a scale of not less that 1:24,000.

Start with the most recent "SnowIce_X_YYYYMMDD" line shapefile. The figure below shows an area of debris covered coalescing glaciers before editing and after new glacier boundaries were added to the "SnowIce_X_YYYYMMDD" shapefile (blue lines).

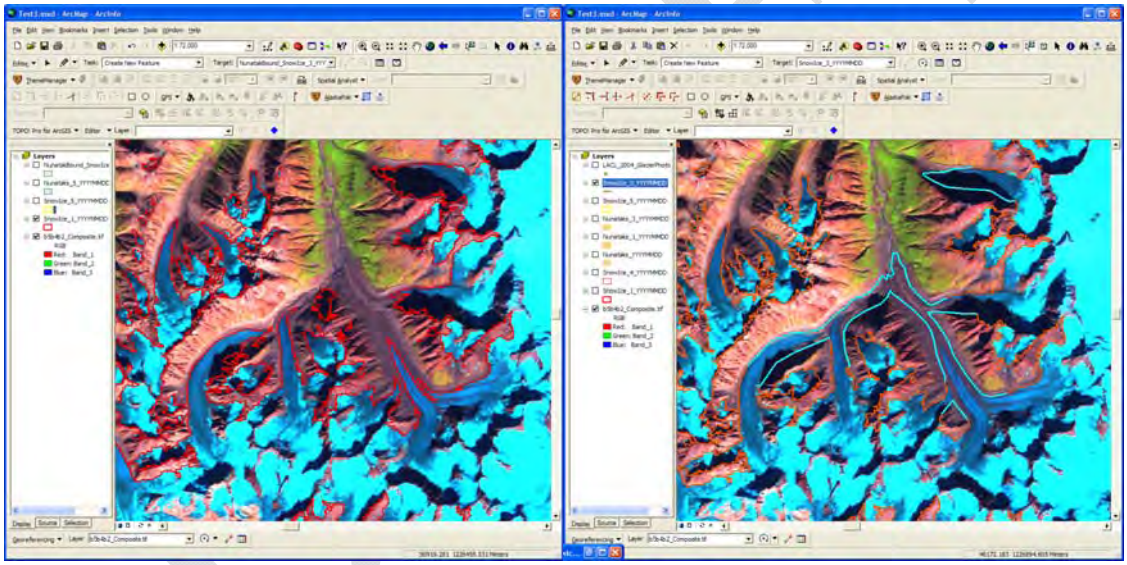

Figure 17. Landsat image and the initial classification of snow and glacier ice (left) and the corrected classification (right). Blue lines (left) indicate corrections. Note the addition of four nunatak (barren ground surrounded by ice) features that must be copied to the most current nunatak shape file.

Because the glaciers in the area are heavily debris covered, aerial oblique images were used as an aid in interpreting the Landsat data. Looking at the oblique images simultaneously with the Landsat image helps to more accurately interpret the Landsat imagery and thus create an accurate glacier boundary.

Figure 18a. A series of 6 aerial oblique images used in the process of modifying glacier boundaries in areas of debris covered coalescing glacier termini.

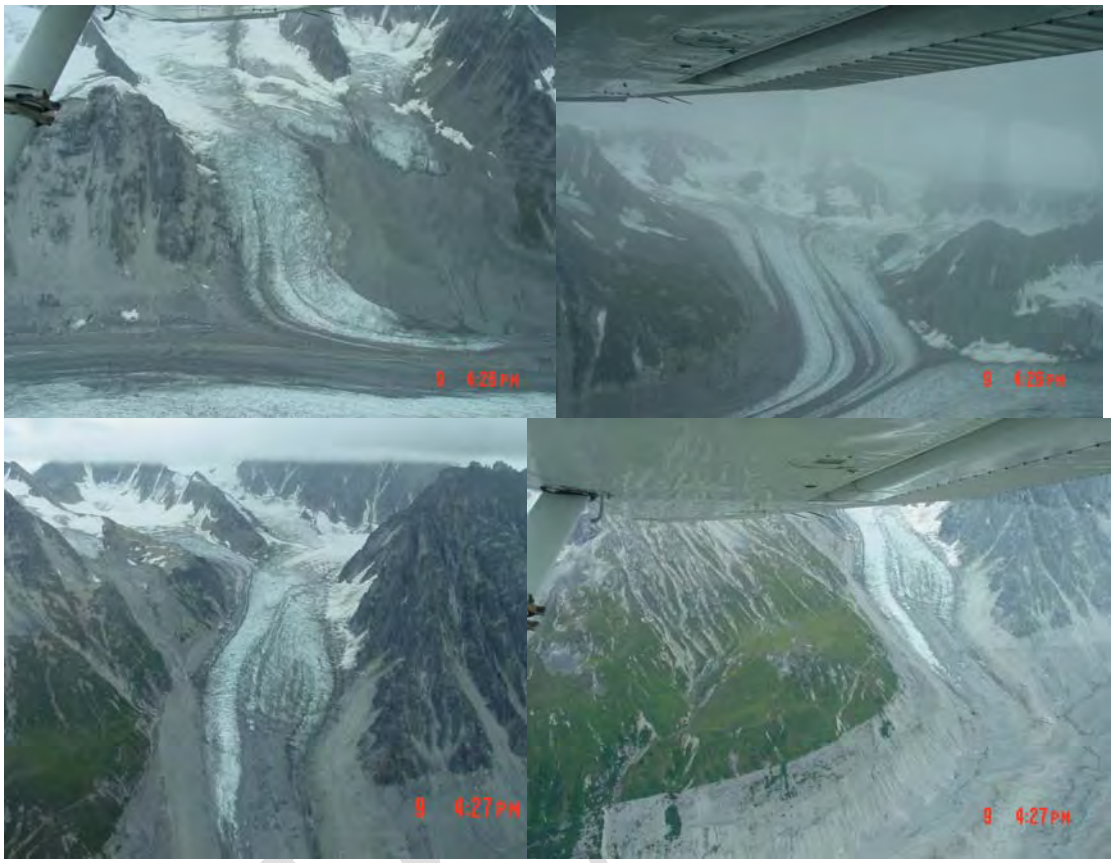

Figure 18b. A series of 4 aerial oblique images used in the process of modifying glacier boundaries in areas of debris covered coalescing glacier termini.

The below example illustrates the original snow/glacier and nunatak classification and the final snow/glacier and nunatak classification after modification of boundaries and the addition of several bare-ground (nunatak) polygons. These bare-ground (nunatak) features were added to the most recent "NonSnowIce_X_YYYYMMDD" shapefile.

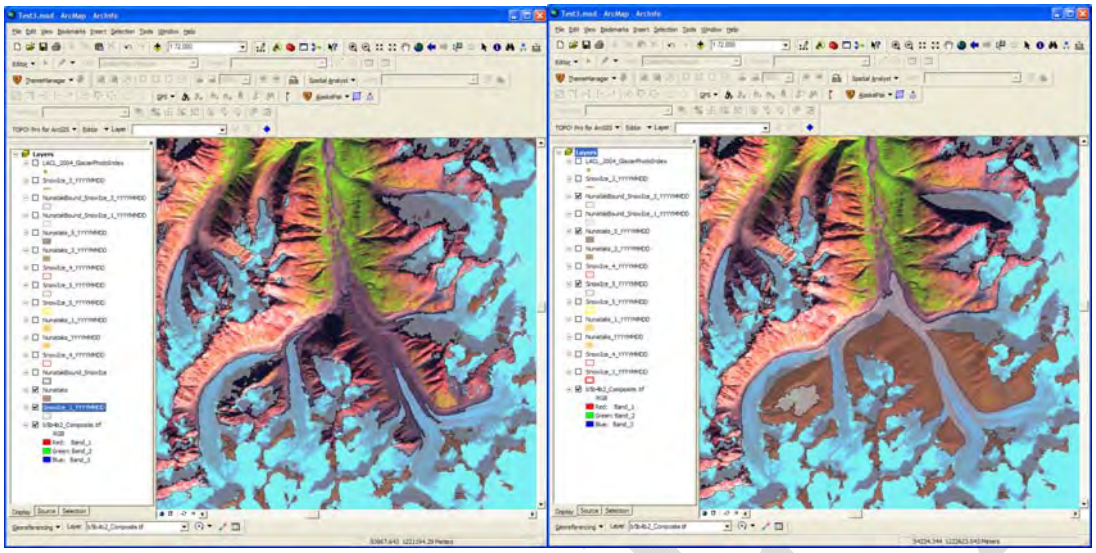

Figure 19. Landsat image and the initial classification of snow/glacier and nunataks (left) and the corrected classification (right). Note the expanded glacier boundaries (light blue) and the addition of four barren ground features (light brown).

Remember, all boundaries (snow/Ice and/or nunataks) being edited are being edited as line shapefiles. When you are satisfied that the glacier boundaries have been accurately captured in an area of debris covered coalescing glaciers the next few ArcGIS commands must be completed to properly update the "SnowIce_X_YYYYMMDD" and the "NonSnowIce_X_YYYYMMDD" shapefiles.

<u>ArcGIS/ArcCatalog Commands</u>

Beginning with the most recent "SnowIce_X_YYYYMMDD" shapefile (this should be a line shapefile), proceed with the following commands:

- Feature to Polygon:

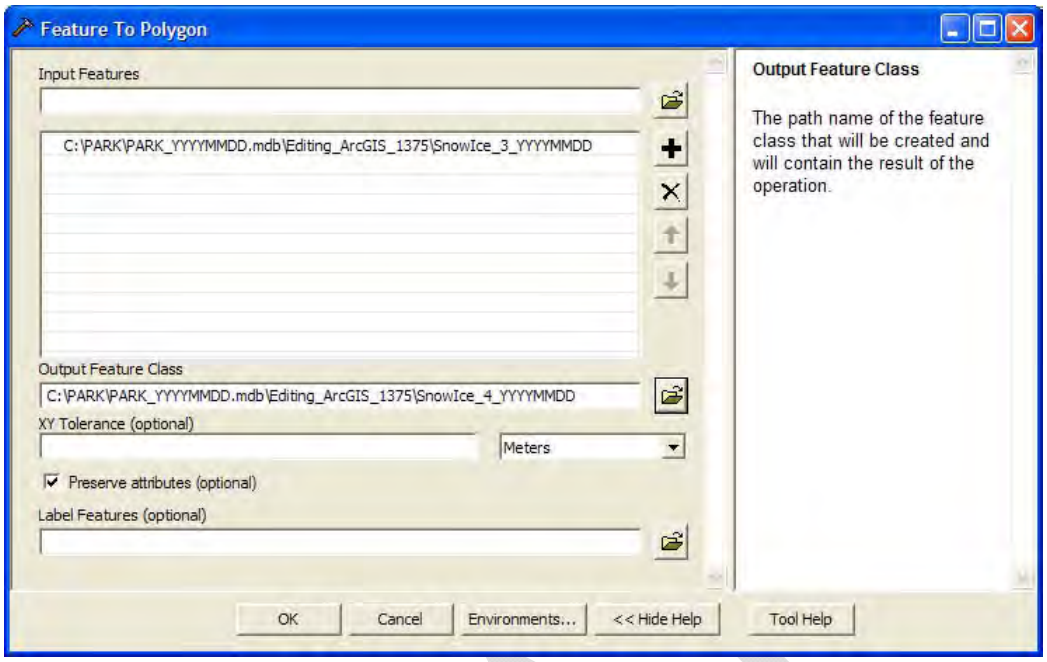

Figure 20. "Feature to Polygon" command in ArcCataolg.

- Load the new "SnowIce_X_YYYYMMDD" polygon shapefile into ArcGIS along with the most recent Nunatak_X_YYYYMMDD" shapefile (this should also be a polygon shapefile).
- Load the Landsat color composite image into ArcGIS.
- Verify that the modifications to the glacier boundaries have been accurately captured as polygons in the most recent "SnowIce_X_YYYYMMDD" polygon shapefile.
- Start an Edit session in ArcGIS and select "Create New Feature" and indentify the "Target" as the Nunatak_X_YYYYMMDD" shapefile.
- Select features in the new "SnowIce_X_YYYYMMDD" polygon shapefile that represent bare ground (nunataks) and copy these new features to the Nunatak _X_YYYYMMDD" polygon shapefile. Double check that the boundaries between the "SnowIce_X_YYYYMMDD" and the "Nunatak _X_YYYYMMDD" are coincident. Don't delete polygons from the "SnowIce_X_YYYYMMDD" polygon shapefile as you copy them the the Nunatak_X_YYYYMMDD" shapefile.
- Note: In some cases, you may also need to add polygon features to the NunatakBound_SnowIce_X_YYYYMMDD" shapefile from the "SnowIce_X_YYYYMMDD" polygon shapefile if these types of features were created in the editing process.

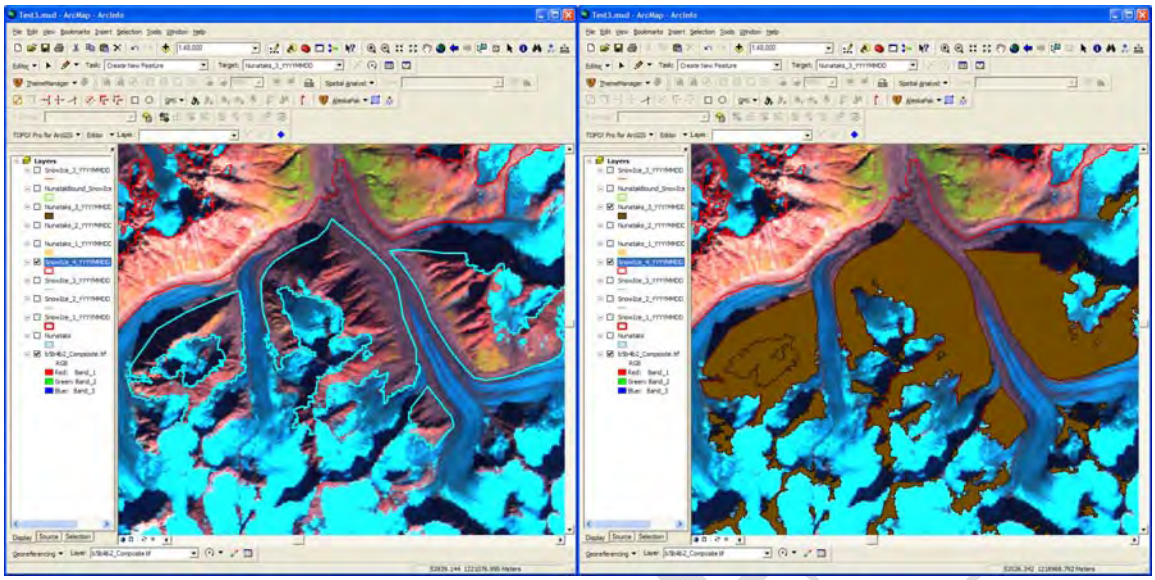

Figure 21. Selecting polygon features representing nunataks created in the editing process from the “SnowIce_X_YYYMMDD polygon shapefile (left) and copying those features to the Nunatak_X_YYYYMMDD” polygon shapefile (right).

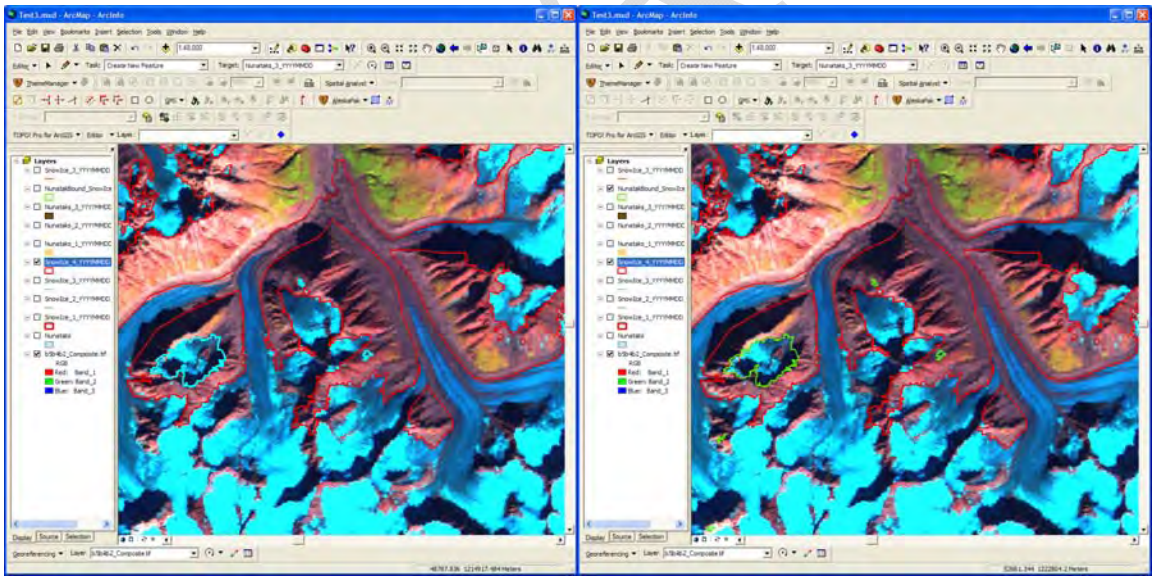

Figure 22. Selecting polygon features representing nunatak-bound glaciers created in the editing process from the “SnowIce_X_YYYMMDD polygon shapefile (left) and copying those features to the NunatakBound_SnowIce_X_YYYYMMDD” polygon shapefile (right).

Complete the task of updating the most recent “Nunatak_X_YYYYMMDD” polygon shapefile with the new features created from the process of modifying glacier boundaries of the “SnowIce_X_YYYYMMDD.” Be sure not to delete any polygons from the “SnowIce_X_YYYYMMDD” polygon shapefile in this process.

Complete the task of updating the most recent “NunatakBound_SnowIce_X_YYYYMMDD” polygon shapefile with the new features created from the process of modifying glacier boundaries of the “SnowIce_X_YYYYMMDD.” Be sure not to delete any polygons from the “SnowIce_X_YYYYMMDD” polygon shapefile in this process.

When the Nunatak and NunatakBound polygon shapefiles are updated convert the “SnowIce_X_YYYYMMDD” polygon shapefile to a raster file. First “Add Field” called RASTER to the Attribute table. Next, “Calculate Field” for RASTER equal to “1.”

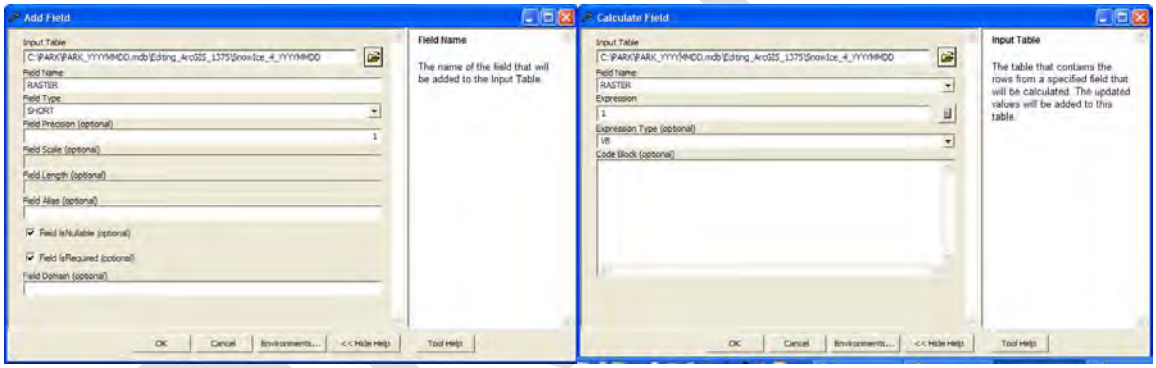

Figure 23. Adding a “Field” in an attribute table and “Calculating” a value for that “Field.”

The “SnowIce_X_YYYYMMDD” polygon shapefile is now ready to convert to a raster file. Be sure to define the “Cellsize” equivalent to the original Landsat data resolution, in this case, 28.5. Next, convert the raster back to a polygon shapefile and name it appropriately in the successively increasing sequence. Be sure the “Simplify polygons” box is not checked.

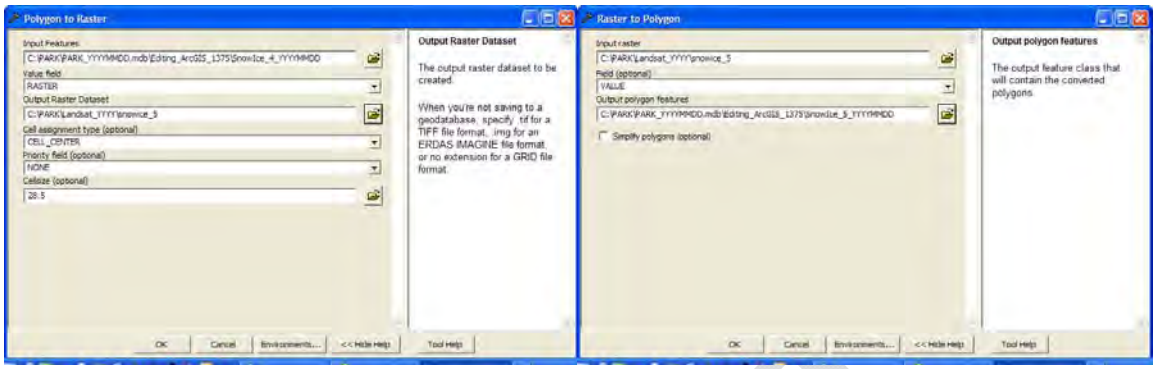

Figure 24. Converting a polygon shapefile to a Raster file (left) and converting a raster file to a polygon shapefile (right).

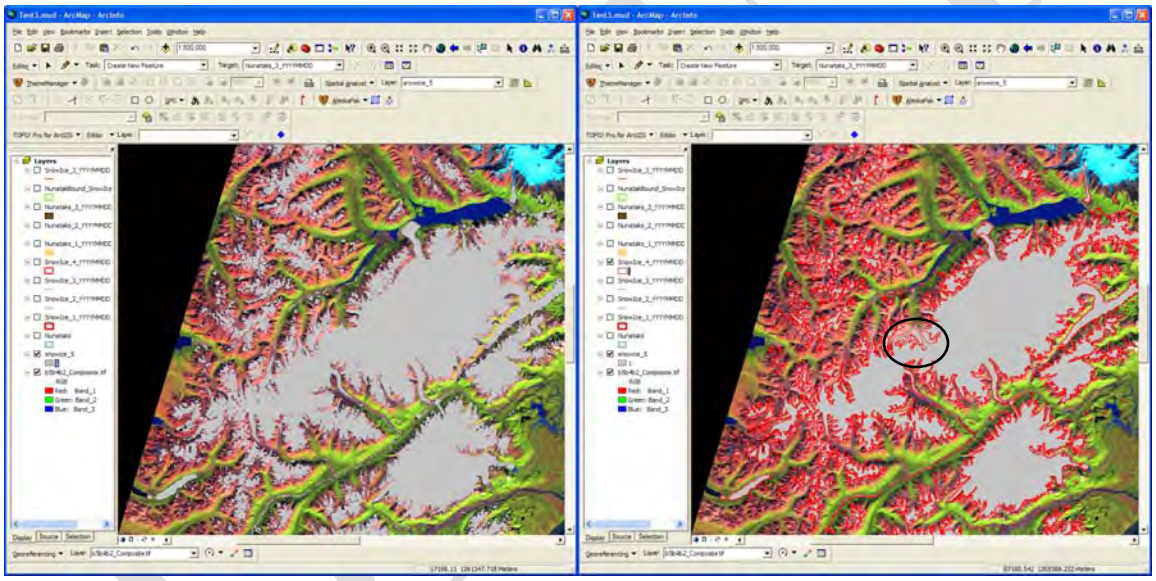

Figure 25. The left image is the raster file created from the most recent "SnowIce_X_YYYYMMDD" polygon shapefile. Note the detail of the polygon boundaries interior to the glacier extent boundary in the central part of the image on the right (circled). This is the area of the coalescing glaciers used in the preceding example.

Move to another area of the mapping region that contains coalescing debris covered glaciers and repeat the boundary editing steps outlined above. Repeat this process, one-by-one, for all areas of coalescing debris covered glaciers in the mapping region. This will seem repetitive, but is necessary to be sure all

nunatak features and nunatak-bound glacier features created during the editing process are capture timely to the “Nunatak_X_YYYYMMDD” and “NunatakBound_SnowIce_X_YYYYMMDD” shapefiles before too much time passes and memories fade.

Remember, frequent “saves” will save the day.

4-3.6 Creating Final Polygon Shapefiles

At the conclusion of the glacier boundary editing process (Phewf again! and Congratulations!), now create the final of the shapefiles and add “fields” to the attribute tables and calculate these “fields” as directed below.

One of the last commands (Erase) will create a near final Glacier Extent Shapefile. The process of creating the last in the sequence of the “SnowIce_X_YYYYMMDD” shapefiles represents glacier extent without accounting for nunataks or barren ground that occur within the glacier extent boundary. Now is the time to erase the most recent “Nunataks_X_YYYYMMDD” shapefile from the most recent “SnowIce_X_YYYYMMDD” shapefile.

- Erase (analysis): “SnowIce_X_YYYYMMDD” - “Nunataks_X_YYYYMMDD” = “Glacier_Extent_X_YYYYMMDD”.

One more command (Merge) will create the final Glacier Extent Shapefile. Merge “Glacier_Extent_X_YYYYMMDD” and “NunatakBound_SnowIce_YYYYMMDD” into the final shapefile representing glacier extent.

- Merge (management): “Glacier_Extent_X_YYYYMMDD” and “NunatakBound_SnowIce_YYYYMMDD” = “Glacier_Extent_YYYYMMDD_Final”

Now, create the final shapefiles for nunataks. This is a simple copy and name procedure in ArcCatalog. This final shapefile is created from the last file in the numerical sequence for of the nunatak shapefiles below:

“Nunataks_X_YYYYMMDD” - copy and name the file:
“Nunataks_YYYYMMDD_Final”

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For the “Final” shapefiles, the “YYYYMMDD” is the date (year, month, day) of the Landsat imagery used in this glacier mapping effort.

The final step is to add a “field” called “ICE” to the attribute tables of the final shapefiles using the command “Add Field.” Next, calculate the “ICE” field using the “Calculate Field” for ICE equal to “1” (glacier features) or “0” (nunataks/barren ground features) in the final two shapefiles.

4-3.7 Conclusions

Done, awesome! Folder and file structure is seen Figure 26.

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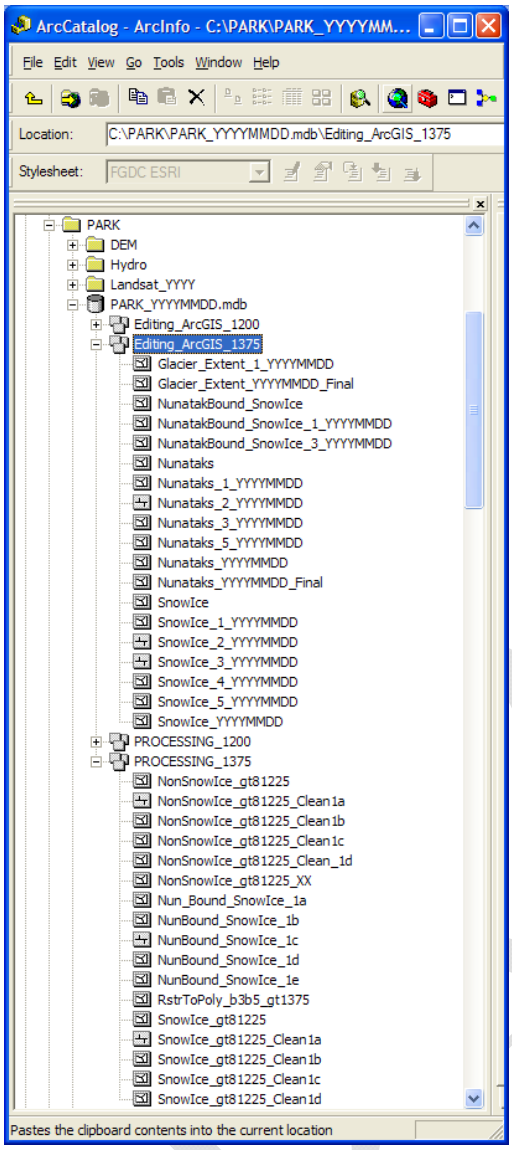

Figure 26. Glacier extent mapping folder and file structure.

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Glacier Extent Protocol
Southwest Alaska Network

Standard Operating Procedure (SOP) # 5

Field Investigation

Version 1.0 (May, 2009)

Revision History Log:

Previous Version #	*Revision Date*	*Author*	*Changes Made*	*Reason for Change*	*New Version #*

Background / Overview

This Standard Operating Procedure describes how "local expert" knowledge of glaciers margins is acquired and/or enhanced. It will be necessary to rely on or develop "local expert" knowledge in areas where the location of glacier margins is unclear from Landsat imagery interpretation alone. Areas that will present challenges to the interpretation of Landsat imagery will be primarily those areas of debris covered ice, areas obscured by clouds, and areas of extreme topography resulting in shadowed ice. Acquisition of this aerial oblique photography will facilitate the interpretation of Landsat imagery in these challenging areas.

After working through SOP #4, there is now a clear understanding of where developing "local expert" knowledge through the acquisition of oblique photography will facilitate the interpretation of Landsat imagery in areas where glacier margins are uncertain. Beyond identifying target areas, this SOP speak to mission planning (flight routes, aircraft selection, time of year, weather requirements).

Acquisition of aerial oblique photography in support of this SOP will necessarily require the acquisition of 100s if not 1000s of photographs. Organizing this

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amount of data is imperative. Refer to SOP #6, "Geotagging and Organizing Oblique Aerial Digital Photographs in a GIS" for guidance. SOP#6 explains the process for geotagging oblique aerial digital photographs and organizing large numbers of photographs in a Geographic Information System (GIS).

5-1.1 Identification of Areas for Further Investigation

From SOP #1, the repeat cycle for this protocol is on a decadal scale with the next series of Landsat imagery to be acquired in 2010+. Presuming that good quality Landsat imagery (late-season, cloud-free) is available in the target year, interpretation of that imagery will occur during the following winter months. By the following spring, the interpretation will have identified those areas where the interpretation of the Landsat imagery is questionable. Areas that will be identified will include:

- Debris cover glacier termini
- Side moraine areas of large glaciers
- Shadowed snow and ice
- Clouds

Prepare a map (1:250,000) with specific targets identified locating all features where aerial oblique photos should be acquired. Depending on the number of targets, it may be necessary to prioritize targets.

5-1.2 Developing a Flight Plan

The map prepared in 5-1.1 above, identifying and prioritizing target areas, will be used for navigation during a reconnaissance flight. Prioritized flight routes should be marked on the map. Weather conditions in the field will dictate actual flight paths.

Aerial oblique photography will be acquired of each of these priority target areas. Flights routes to and from the priority areas will be planned in such a way as to pass by other glaciers and glacier features where by aerial oblique photographs can be acquired opportunistically of these features of interest.

5-1.3 Preferred Aircraft and Flight Characteristics

<u>Aircraft</u>

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The preferred aircraft is a Cesnsa 185/206 or equivalent. This aircraft has a reasonable cruising speed and is capable of carrying up to several passengers. The Department of Interior - National Business Center (NBC) Aviation Management assign aircraft of this type to National Parks to be used in support of park operations. If available, this aircraft should be used to fulfill this SOP. If a park aircraft is not available, this type of aircraft is readily available in the private rental market in Alaska.

Scheduling

The purpose of this SOP is to enhance the accuracy of Landsat imagery interpretation acquired in the previous year. There are two primary considerations affecting the scheduling of the mission: weather and the desire to acquire late-season photography. Mid- to late- August would be the preferred scheduling window to conduct these flight operations to maximize the loss of seasonal snow across the landscape but acquire the oblique photos prior to any new snowfall.

Flight Conditions

It is best to conduct the flight under clear, sunny, smoke-free conditions. Contrast between the debris covered glacier surface and surrounding moraine material will be more evident under these conditions.

Flight Characteristics

A safe flight operation is the priority.

The preferred elevation above ground level is 2000 to 3000 feet. This flight elevation may vary depending on sun angle (morning, evening, mid-day), turbulence, and other factors at the time of the flight.

The elevation of the targets identified may range from a few hundred feet up to 5,000 feet. Capturing photography at targets at an elevation of 5,000 feet will require different flight conditions than those at lower elevations. For example, flights at low elevations could be conducted under cloudy conditions as long as the ceiling is high enough for safe flight operations.

5-1.4 GPS tracking of Aircraft Flight Path

All flights will be tracked by via the tracking feature on most hand-held GPS units. See Appendix 1 for a quick guide to collecting positional information using

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a Global Positioning System (GPS) while taking digital photographs from a small aircraft. This will insure that the GPS tracks and digital photographs can be geo-tagged properly with GPS PhotoLink software.

See SOP #6, "Geotagging and Organizing Oblique Aerial Digital Photographs in a GIS" for detailed guidance.

5-1.5 Digital Photography

High resolution digital photography will be used to capture images of all areas identified in 5-1.2 above. All digital photography will be linked to the GPS tracking feature. This will allow accurate geographic locations for each photograph.

See SOP #6, "Geotagging and Organizing Oblique Aerial Digital Photographs in a GIS" for detailed guidance.

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Quick Start Guide Using Any Digital Camera, Garmin and GPS PhotoLink

National Park Service - Alaska Regional Office - GIS Team – Updated 2/27/08

GPS –	Purchase a Garmin GPS. Applies to most modern Garmin handhelds.
Digital Camera –	Any modern camera. Target ruggedized, long battery life.
GPS PhotoLink software –	One of several software available. $229 software purchased from http://www.geospatialexperts.com
Cables:	Cable for GPS and Camera

Steps: Here are the bare minimum setups to accomplish the task

GPS: Set up as follows:

- Turn on GPS outside. Initialize - Let stand for 20 minutes to collect almanac if GPS is cold.
- Set Garmin time to local time – watch out for the switch to daylight savings time!
- Set Interface to Garmin Protocol.
- Clear all active tracks and waypoints. Prefer backing up to MapSource beforehand.
- Decide on linking to Tracklogs or Waypoints before hand – See Section on Waypoints or Tracklogs?
- Tracklog Setup: Set Tracklog to recording **Stop When Full**, Record Method to **Time** and Interval to **5 seconds**. Set to 1 second if flying. Most modern GPS store 10,000 trackpoints leaving 13 hours or 5 hours of collection depending on time interval.
- Waypoint Setup: Ensure waypoints are cleared.
- Turn GPS to the page where you can see the time and date.

Digital Camera: Set up as follows:

- Remove all old photos.
- Ensure date/ time is set to GPS time. Roll over to the exact minute on camera when the GPS rolls over. Given a little practice, you should be able to calibrate camera to GPS within 1 or 2 seconds.
- Turn date/time watermark **Off** so date is not watermarked onto photo in camera.
- Check batteries.
- Turn on camera and set resolution settings on camera as appropriate for job.

In the Field: General Settings

When GPS is sufficiently warmed up, take photo of GPS screen showing time. This is the most critical photo, so ensure you can clearly see time to nearest second. Hold GPS at arms length, and hold camera at face. Put sun at back and tilt screen away from you. Flash off. Turn backlight on in dull light conditions. Remain stationary. Do not use MACRO mode. Use cameras review mode. You DO not need to be collecting a tracklog or waypoint during this process.

- **TrackLog Collection Method**
- Ensure Tracklogs are being collected.
- Place GPS antenna on top of photo subject you want a location of. This works best with 2-person teams.
- Stand back and take photo of subject. Track must be collecting when collecting pictures. You can turn GPS off or camera off between collections, but the GPS must be collecting tracks when collecting photos.
- When done for the day, turn off GPS Tracklog before returning to inside. DO NOT SAVE ACTIVE TRACK, but turn off track.
- **Waypoint Collection Method** Remember this mantra: POINT BEFORE PHOTO.
- Place GPS antenna on top of photo subject you want a location of.
- Press and hold Mark. Average location until error is under 20 feet. Save waypoint.
- Stand back and take photo of subject.
- Repeat on all photo subjects. Take point, then take Photo.
- Some Garmins store waypoints to nearest minute, so ensure photos are collected at least 60 seconds apart.

Back in the Office NEVER ALTER PHOTOS – YOU RISK SCRAMBLING CAMERA TIME.

Software: Start GPS PhotoLink and Follow the Wizard

- Transfer Digital Images from Camera to PC – note where you put the images
- Connect GPS to PC with Cable. Select Data Source as Garmin Tracklog
- Make sure the time is set properly. Ensure “Auto Adjust for Daylight Savings” is active.
- Make sure you use the DATUM Tab and switch to NAD83 Worldwide and Lat/Long coordinate system.
- Time Sync step: Use photo of the GPS Receiver for time sync method. For Tracklogs use “Match to closest GPS Point”. If in aircraft use ”Interpolate Method”. When using waypoints, use “ Match to closest point BEFORE photo”
- Follow next steps entering the time correctly on the photo of the GPS receiver, then entering title/comments.
- Ensure Watermarks (include lat/long, date, time, datum, title, comment).On last step, be sure to select Create ESRI shapefiles and web output.

TIPS: Shapes generated will be GCS_North_American_83. Always manage all your photos with a database – NPS recommends ThumbsPlus.

There are two methods of GPS data collection on a Garmin when linking with camera – Waypoints or Tracklogs. This section helps you decide which method to use.

TrackLogs (The No-Brainer Choice)

Advantages:

1) Easy. Hard to screw up. Turn on and with 5 second interval you have 13 hours of data collection. You only need to keep GPS alive and tracklog running.
2) Thee method to use when photographing while moving. This allows Track course to be collected and picked up in GPS Photolink to determine look direction.

Disadvantages:

1) Multiple photos on same location will be associated with multiple coordinates. Though the coordinates may only be meters apart, the precision of the GPS will determine spread of data
2) You forget and leave the GPS running with antenna blocked, you may associate a very poor coordinate to a photo.

Applications:

Aircraft aerial obliques. This allows you to automate look direction in GPS PhotoLink.
Have too much things going on and a photo would be nice addition, but not a major driver of project.

Waypoints (The Point before Photo Choice)

Advantages:

1) A more accurate point will be constructed due to averaging, standing still and concentrating.
2) One waypoint can be associated with multiple photos using the same position.

Disadvantages:

1) Easy to forget to take point, then photo. If you screw this up, then association with wrong waypoints will occur. This method requires consistent, no screw up methods.

Applications:

Collect one waypoint at a building entrance. Then associate photos from inside building to that one point.
When photos are extremely important to the GPS mission. Taking time to collect with waypoints pay off in accuracy and consistency.

Revision	Description of Change	Author	Effective Date
2/7/05	Formatting, datum switch	j. cusick	2/7/05
5/12/05	Edits	j. cusick	6/10/05
5/17/06	Edits	j.cusick	6/1/06
3/17/07	Update	j.cusick	7/14/07
2/26/08	Update	J.cusick	2/27/08

Southwest Alaska Network

Standard Operating Procedure (SOP) #6

Geotagging and Organizing Oblique Aerial Digital Photographs in a GIS

Version 1.0 (March, 2009)

Revision History Log:

Previous Version #	*Revision Date*	*Author*	*Changes Made*	*Reason for Change*	*New Version #*
	03/02/2009	*C. Lindsay*	*Original*		*1.o*

Background / Overview

This Standard Operating Procedure explains the process for geotagging (adding geographic locations to media) oblique aerial digital photographs and organizing large numbers (100s-1000s) of these photographs in a Geographic Information System (GIS). Detailed procedures describe how to: 1) collect positional information using a Global Positioning System (GPS) while taking digital photographs from a small aircraft; 2) store the positional information within a digital photograph's metadata file (EXIF); 3) store, edit, and name photographs using SWAN digital photograph management strategy; 4) create a GIS shapefile with photograph locations and attributes; and 5) create a Google Earth file in Keyhole Markup Language (KML) with photograph locations and descriptions.

6-1.1 Equipment and Software Needed

Acquiring, geotagging, and managing digital photographs in a GIS requires the following equipment and software. The detailed procedures that follow are specific to the recommended equipment and software that are listed.

<u>Digital Camera</u>

A digital single-lens reflex (DSLR) camera is recommended for use in oblique aerial photography because it is faster than a digital point-and-shoot camera, uses precise optical viewfinders, and is very battery-efficient. Resolution should be 5 megapixels or better. Memory cards should be capable of holding approximately 400 images at >5 megapixels (2GB cards work well). A relatively wide-angle lens is recommended (24-35 mm).

Recommended Digital Camera

Cannon Digital Rebel XT (8.0 megapixel), 18-55 mm lens, and 2GB CompactFlash storage card.

GPS Receiver

A recreational-grade handheld GPS receiver is suitable for this work. The NPS Alaska Region GIS team recommends and supports Garmin handheld GPS receivers that allow waypoint averaging, external GPS antenna capability, and support with DNRGarmin software for downloading. Currently, these units include the GPSMap60 and GPSMap76 series. Although the GPS receiver can be placed on top of an aircraft instrument panel, use of an external antenna will improve accuracy.

Recommended GPS Receiver

Garmin GPSMap60Csx with magnetic external antenna (this unit stores time to the second, which improves positional accuracy of photographs taken in rapid succession).

GPS Software

Software is necessary to transfer data from the GPS receiver to a computer. The NPS Alaska Region GIS team recommends and supports both Garmin MapSource and DNRGarmin (Minnesota Dept. of Natural Resources). Garmin MapSource is necessary in order to download and archive GPS data. DNRGarmin is recommended to transfer GPS data into GIS.

Recommended GPS Software

Garmin MapSource v6.15.3 and DNRGarmin v5.4.0 (free).

File Renaming Software

Software is necessary to rename large numbers of digital photographs. File naming software must be capable of batch file renaming without changing the EXIF date/time. Many file naming programs are commercially available.

Recommended File Renaming Software

FineBytes Magic File Renamer (Professional Edition) v6.12 ($30).

Photograph Viewing and Editing Software

Software is necessary to view and edit large numbers of digital photographs. Photograph viewing software must be capable of lossless JPEG rotation (rotating and saving JPEG files without compressing image), batch photo resizing without changing EXIF date/time, and showing the EXIF information. Many photograph viewing and editing programs are commercially available.

Recommended Photograph Viewing and Editing Software

IrfanView v4.23 with Graphic Viewer PlugIns (free).

Geotagging Software

Software is necessary to store positional information from a GPS in the digital photograph's metadata file (EXIF). The software should be capable of geotagging using locations interpolated from a GPS track log, storing this information in the EXIF, and creating a GIS shapefile with photograph locations and attributes.

Recommended Geotagging Software

GeoSpatial Experts GPS-Photo Link Ricoh Edition v4.2 ($329)

GIS Software

Software is necessary to organize and index large numbers (100s-1000s) of geotagged photos. Photograph locations can be plotted on maps or satellite imagery using a GIS. Information about each photograph (location, orientation, subject matter, caption, etc.) can be stored in a spatially referenced database. This allows oblique aerial photographs to be searched based on location or subject (or combination thereof)

Recommended GIS Software

ESRI ArcGIS v9.3 (ArcInfo)

GIS to KML software extension

A software extension is necessary to export GIS data in a format that can be viewed by non-GIS users in Google Earth. This extension must be capable of exporting point, polyline, or polygon datasets in any defined projection into Keyhole Markup Language (KML). The extension should be able to incorporate GIS symbology, labeling, and database attributes into KML.

Recommended GIS to KML software extension

Export to KML v2.5.3 (free)

File compression software

A file compression utility is necessary in order to create a compressed KML archive, also known as a KMZ file for use in Google Earth. A number of open-source file compression utilities are freely available.

Recommended file compression utility

7-Zip v4.65 (free)

3D Geobrowser Software

Software is necessary so that non-GIS users can explore large numbers of geotagged photos. Geotagged photographs can be located and viewed using geobrowser software. Indexes in KML format can include information about each photograph (location, orientation, subject matter, caption, etc). A number of 3D geobrowser software programs are available.

Recommended 3D Geobrowser Software

Google Earth v5.0 (free)

6-1.2 Pre-Flight

The GPS and camera need to be prepared prior to flying and taking photographs. The pilot should be asked about cleaning aircraft windows or flying with side windows open. The photographer should verify that the GPS receiver is on, receiving adequate satellite information, and collecting an active tracklog before takeoff.

Digital Camera

Accurate camera date and time is critical because it is recorded in the EXIF and will be used for geotagging the photographs. The camera clock should be synchronized to an active GPS to within 1 or 2 seconds (use local time and pay attention to daylight saving time). Digital cameras name photos differently. Typically cameras will have several file naming options. The most useful setting is sequential numbering (00001-99999). In general, it is recommended that the sequential numbering be reset each day that photographs are taken. Most digital cameras can digitally imprint the date and time onto the photo image. In general, it is recommended that this feature not be used because this information will automatically be stored in each photograph's metadata (EXIF) file. Any existing photographs should be deleted from the camera. Make sure the batteries are new or freshly charged. Image resolution should be set to the highest setting.

GPS Receiver

Turn on the GPS outside and let it initialize for 20 minutes to collect current satellite almanac. Set GPS to local time zone (pay attention to daylight saving time). Clear all tracks and waypoints. Set up the track log to record at 1 second intervals and to stop recording when full. Make sure the batteries are new or freshly charged. GPS receiver or external antenna should be placed on top of the instrument panel close to the windshield. With pilot's approval and direction, a magnetic external GPS antenna can be placed outside (and on top) of the aircraft. The wire may need to be taped in place to reduce vibration and prevent

damage to the aircraft. Take a picture of the GPS screen showing local time before take off and collecting photographs. Hold the GPS at arm's length from the GPS and tilt the screen slightly. Verify that the time is visible in the photograph.

Aircraft

Ask the pilot if the windows (inside and outside) can be washed. The photographer can volunteer to do this with the pilot's approval and direction. If the windows are heavily scratched it may be possible to fly with the side window propped open (this will be very windy and cold).

Camera Orientation

The photographer should sit in the copilot's seat and photograph out of the side windows. Photographs taken straight ahead through the front windshield will be blurred by the propeller and should be avoided. In general, it is recommended that the camera angle relative to aircraft heading remain constant (45-135 degrees to the left or right of aircraft heading works well). Focal length (zoom) should not vary while photographs are taken (24-35 mm) works well. If there are two photographers and cameras, each should photograph from opposite sides of the aircraft (one GPS receiver will suffice, although a second GPS may be used for backup). Try not to photograph the aircraft's wings or wheels/floats/skis as much as possible.

6-1.3 Post-Flight

After the flight the GPS track log needs to be stopped (do not save the track log) and the GPS should be turned off. If possible, digital photographs and GPS data should be transferred to a computer as soon as possible (especially if multiple days of flying and photography will take place).

GPS Track Log

Stop the track log, but do not save it! A track log is made up of many points (one point stored each second). Saving a track log on a Garmin GPS receiver greatly simplifies the track log by deleting points. A saved track log will not work for geotagging oblique aerial photographs.

6-1.4 Transfer Photographs

Refer to Appendix A for a detailed description of the file management structure necessary for geotagging and managing oblique aerial photographs in a GIS.

Even if the files are first transferred to a field laptop or a computer that won't be used for managing the photographs and GIS the same file management structure should be used.

Transfer the photographs from the camera to a computer. Copy them to the folder:
/Oblique_Aerial_Photos/Original_Photos/pppp_yyyymmdd_iii/ **(here)**
Do not rename or alter these photographs in any way. Then copy the photographs to the folder:
/Oblique_Aerial_Photos/Working_Photos/pppp_yyyymmdd_iii/ **(here)**

6-1.5 Transfer GPS Data

Use Garmin MapSource to transfer the GPS track log. Open Garmin MapSource and connect to the GPS receiver. Select **Transfer** then **Receive from device** then **Tracks**. Then save the track log using three different file types: **Garmin GPS Database Version 3 (*.gdb)**, **GPS eXchange Format (*.gpx)**, and **Text (Tab delimited) (*.txt**. These files should be named as shown below (see Appendix A) and stored in the folder:
Oblique_Aerial_Photos/Original_GPS/pppp_yyyymmdd_iii/

pppp_yyyymmdd_iii.gdb
pppp_yyyymmdd_iii.gpx
pppp_yyyymmdd_iii.txt

6-1.6 Create Flight Line and Track Log Shapefile

Use DNRGarmin to create a line and point shapefile from the GPS data. Open DNRGarmin. Select **File** then **Set Projection** and make sure that the datum and projection listed are NAD83 and Alaska Albers Equal Area Conic. Make sure that the PRJ Definition is loaded and matches the datum and projection listed above. Connect to the GPS receiver and select **Track** then **Download**. This will take some time. Editing may be necessary if the GPS receiver was turned off or if more than one flight was captured by the track log. The **new_seg** field displays **True** anytime the track log was restarted. Double-click on that cell to modify the value and change it to **False** if the track log should be continuous but isn't. Convert the track log to a line shapefile that represents the flight line by saving the data as an **ArcView Shapefile (Projected) (*.shp)**. Name the file as shown below (see Appendix A) and select **Line** when prompted to define the output shape. Then convert the track log to a point shapefile that represents the flight line by saving the data as an **ArcView Shapefile (Projected) (*.shp)**.

Name the file as shown below (see Appendix A) and select **Point** when prompted to define the output shape. These files should be stored in the folder labeled:
/Oblique_Aerial_Photos/Working_GPS/pppp_yyyymmdd_iii
/pppp_yyyymmdd_iii_Flightline.xxx **(line)**
/pppp_yyyymmdd_iii_Tracklog.xxx **(point)**

6-1.7 Edit and Rotate Working Photographs

Make sure that you are not making changes to the original photographs. Make changes only to the photographs stored in the folder:
/Oblique_Aerial_Photos/Working_Photos/pppp_yyyymmdd_iii/ **(here)**

Look through each of the working photographs and carefully delete any photographs that are poor quality (blurred or out of focus), duplicate, or not relevant (people photos).

Use IrfanView to rotate photographs so that they are oriented correctly. This should be done so that when the file is overwritten the image quality and the file creation date/time stored in the EXIF are not changed. The Graphic Viewer PlugIns must be installed in IrfanView. Select **Options** then **JPG Lossless Rotation…(Plugin)**. Under **Transformation** select the correct rotation angle so that the photograph will be oriented correctly. Make sure to select **Apply original EXIF date/time to new file**. This will overwrite the existing image file.

6-1.8 Rename Working Photographs

Make sure that you are not making changes to the original photographs and that the renaming process does not change the file date/time stored in the EXIF (DateTimeOriginal) and that the sequential numbering in the file name (e.g. img_**00135**.jpg) is preserved. The sequential numbering in the working photograph's file name can be used to reference the original photograph if necessary. Use Magic File Renamer to batch rename all the photographs. Browse to the working photographs stored in the folder labeled:
/Oblique_Aerial_Photos/Working_Photos/pppp_yyyymmdd_iii/ **(here)**

Select the **#AddAll** button (it looks like this: **>>>**) to change the photograph's file names in that folder. The window at the bottom of the screen shows the original file name (**Full File Name** – black type**)** and the draft modified file

name **(Full File Name** – red type**)**. The file names aren't actually changed until the **#GO** button (the round button with a lightening bolt symbol) is selected. Make changes to the file names using the **Inserter** and **Replacer** filters. When the modified photograph file names match the example shown below (See Appendix A) select the **#GO** button **(**or **Ctrl+G)**.

Example: Rename **Img_0234.jpg** to **pppp_yyyymmdd_iii_00234.jpg**

6-1.9 Geotagging

GPS-Photo Link is used for geotagging. The software matches interpolated positions from the GPS track log to the file date/time saved in the photograph EXIF. Identify the photographs to be used for geotagging. Select the **Camera Folder** option under **Photo Source**. The **Camera Folder** under **Load Photographs from Camera Folder** should match the working photograph folder:
/Oblique_Aerial_Photos/Working_Photos/pppp_yyyymmdd_iii/

The **Photo Root Folder** under **Save Output To** should match the Geotagged Photographs folder:
/Oblique_Aerial_Photos/Geotagged_Photos/

Name the new folder under **New Folder to be created under Photo Root Folder**:
pppp_yyyymmdd_iii

Select **No action** under the **Original Photo Action** option.

Next, select the GPS data source. Select **Use GPS data in file** and select the GPS eXchange Format (*.gpx) file in the Original GPS data folder:
Oblique_Aerial_Photos/Original_GPS/pppp_yyyymmdd_iii/
pppp_yyyymmdd_iii.gpx

Select the **(GMT-09:00) Alaska** time zone and make sure that **Auto adjust for daylight saving time, if needed** is selected. Select **Lat /Lon** and **WGS 84** for the **Datum/Position Format**. Select **Next >**.

Next, select the method of time synchronization. Select **Use photo of GPS receiver**. Make sure that **Use GPS position only if within 60 seconds** is selected. Select **Interpolate between closest GPS points** under **Matching**.

In the “Time Offset Entry” window scroll to view the photo of the GPS screen showing GPS time. Select **Use this photo for time entry** and enter the date and time shown on the GPS screen. If the pre-flight setup was carefully done the calculated offset should only be a few seconds.

The photographs can be further edited and a title and comments can be added in the “Data Entry / Photo Edit” window. Although useful in other applications, these options are not used in this protocol. Scroll to the photograph of the GPS unit and select **Do not include photo in output**.

Next, the desired output formats are selected. Select **Watermarked Photo**, **Text File (CSV)**, **GPS Exchange (GPX)**, **and ESRI Shape File (SHP)** under **Select output formats**. Select the **Watermarks** tab. Make sure that **Resize photo** is not selected and that nothing is selected under the **Items to Show and Placement** options. Although useful in other applications, these options are not used in this protocol. Select **Best** under **JPEG Quality**. Select the **Heading / Distance** tab. Select **GPS Track** under **Heading (Picture Direction)**. Make sure that **Calculate new position from heading and distance** and **Adjust Heading** are not selected. (Note, this option is very useful if the camera orientation relative to aircraft heading was fixed). Select **None** under **Distance to Object**. Default settings under the **Misc** tab are acceptable because they only apply to the watermark and html settings, which are not used in this protocol. Batch geotagging and shapefile creation happens when **Finish** is selected. This process will take a while if a large number (100s) of photographs are being processed.

GPS-Photo Link creates five different output file-types in the folder:
/Oblique_Aerial_Photos/Geotagged_Photos/pppp_yyyymmdd_iii/

GPS-Photo Link.txt
: is the configuration settings used by GPS-Photo Link

pppp_yyyymmdd_iii_12345_**small.jpg**
: thumbnails of the photographs with Lat / Lon stored in EXIF

pppp_yyyymmdd_iii_12345_**tag.jpg**
: somewhat compressed photographs with Lat / Lon stored in EXIF

picture.xxx
: are shapefiles that will be used in the GIS

track.xxx
: are shapefiles containing all track log points

6-1.10 Create GIS Photograph Index

Copy the shapefile generated by GPS-Photo Link using ArcCatalog (ArcGIS)
Copy the shapefile from:
/Oblique_Aerial_Photos/Geotagged_Photos/pppp_yyyymmdd_iii/picture.shp
to:
/Oblique_Aerial_Photos/Working_GIS/pppp_yyyymmdd_iii/picture.shp

Define the shapefile's map projection using the **Project** tool in ArcToolbox (ArcGIS). Select:
/Oblique_Aerial_Photos/Working_GIS/pppp_yyyymmdd_iii/picture.shp
as the **Input dataset**. Define and rename the **Output Dataset**:
/Oblique_Aerial_Photos/Working_GIS/pppp_yyyymmdd_iii/
pppp_yyyymmdd_iii_Origin
Select the **Alaska Albers Equal Area Conic** projected coordinate system for the **Output Coordinate System**.

Copy the line shapefile generated by DNRGarmin using ArcCatalog (ArcGIS).
Copy the shapefile from:
/Oblique_Aerial_Photos/Working_GPS/pppp_yyyymmdd_iii/
pppp_yyyymmdd_iii_Flightline.xxx
to:
/Oblique_Aerial_Photos/Working_GIS/pppp_yyyymmdd_iii/
pppp_yyyymmdd_iii_Flightline.xxx

Verify that the line shapefile is in the **Alaska Albers Equal Area Conic** projected coordinate system using ArcCatalog (ArcGIS).

Open ArcMap (ArcGIS) and create a new map document. Name and save the map document:
/Oblique_Aerial_Photos/Working_GIS/pppp_yyyymmdd_iii/
pppp_yyyymmdd_Map.mxd

Load the corresponding digital raster graphic (DRG) mosaic of topographic maps at the 1:63,360 scale and the working point and line shapefiles:
/Oblique_Aerial_Photos/Working_GIS/pppp_yyyymmdd_iii/
pppp_yyyymmdd_iii_Origin.shp
and
/Oblique_Aerial_Photos/Working_GIS/pppp_yyyymmdd_iii/
pppp_yyyymmdd_iii_Flightline.shp

Open the attribute field for the Origin feature class. Delete (or turn off) the following attribute fields:

i. East
ii. North
iii. Zone
iv. Direction
v. Title
vi. Comment
vii. Internal
viii. Timestamp
ix. Webpage
x. Wptname
xi. Track
xii. DOP
xiii. FixType
xiv. GPSValid
xv. Camera
xvi. FOCLEN
xvii. FNumber
xviii. Exposure
xix. ISO
xx. FOV

These attribute fields are either not populated by GPS-Photo Link, also preserved in the digital photographs EXIF, or not useful for this application.

Add the following attribute fields to the Origin feature class using the field types and properties listed below:

i. PARK_CODE
    a. Text, Width=4
ii. DATE_
    b. Date, Width=8
iii. PHTO_DIR
    a. Short Integer, Precision=4
iv. PHTOGRAPHR
    a. Text, Width=25
v. LOC_1
    a. Text, Width=25
vi. LOC_2
    a. Text, Width=25

vii. GLAC_NAME
    a. Text, Width=25
viii. DIST_RSTR
    a. Text, Width=10
ix. ARCHIV_LOC
    a. Text, Width=50
x. COLL_NAME
    a. Text, Width=50
xi. PUBLISHER
    a. Text, Width=50
xii. GEOG_NAME
    a. Text, Width=50
xiii. CAPTION
    a. Text, Width=200
xiv. PICT_GE
    a. Text, Width=50
xv. KEYWORDS
    a. Text, Width=100

Populate the following attribute fields for all features within the Origin feature class with the same values using the attributes dialog box. Start editing, select all features within the Origin feature class, activate the **Attributes dialog box**, select the feature class name (not individual features), select the **Value** for a field, and enter the new value. This will change the value for all selected features within the feature class.

i. PARK_CODE
    a. Four-letter park code (ex. LACL)
ii. DATE_
    a. Date picture was taken (ex. mm/dd/yyyy)
iii. PHTOGRAPHR
    a. Photographer's name (first last)
iv. DIST_RSTR
    a. None (if taken by NPS or permission granted)
    b. Restricted (if otherwise)
v. ARCHIV_LOC
    a. NPS, SWAN Electronic Library
vi. COLL_NAME
    a. Last name, year (ex. Schmidt, 2009)
       or
    b. NPS, SWAN Glacier Photo Index

vii. PUBLISHER

a. NPS, SWAN Inventory and Monitoring Program

Populating the remaining attribute fields for features within the Origin feature class involves viewing the corresponding digital photograph, examining a topographic map (1:63,360 DRG), and editing the feature's attribute fields. It is helpful to have two computer screens – one showing ArcMap (ArcGIS) with feature class, topographic map (1:63,360 DRG), and attribute fields visible, the other showing the corresponding digital photograph using photograph viewing software (IrfanView) (Figure 1).

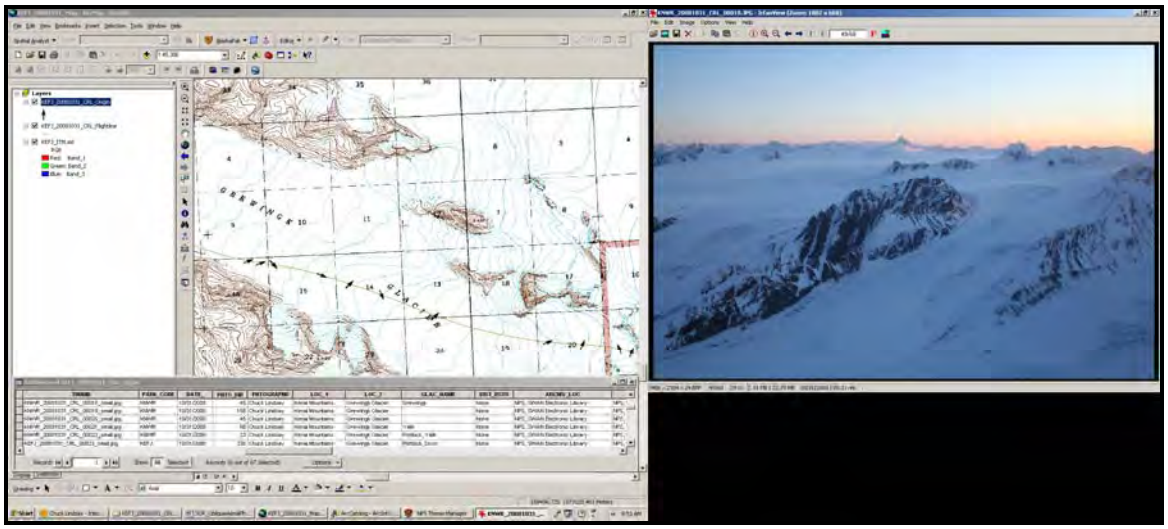


Figure 1. GIS and photograph viewing software running on two computer screens. The feature class, topographic map, attribute table, and corresponding digital photograph are viewed simultaneously.

Incrementally work through each feature and corresponding digital photograph, populating the remaining attribute fields for each feature. Select the first point in the feature class, pan to its location on the topographic map (1:63,360 DRG), and view the corresponding digital photograph. Use the photograph file name from [Original] (use of "[xxxx]" describes an attribute field name) and open the file from:

/Oblique_Aerial_Photos/Working_Photos/pppp_yyyymmdd_iii/

Start editing the target layer: /pppp_yyyymmdd_iii_Origin and enter values for the following attribute fields:

i. **PHTO_DIR** (Azimuth of photograph). This is the angle (from true north) from the location where the photograph was taken to the

a. Attribute field properties will need to be changed. Select **Field Properties** for the entire attribute field. Select the "**...**" button under **Display > Number Format**, select **Angle** under **Category**, select **Degrees** under both options.
b. The symbology can be changed to display camera azimuth if desired. To change the symbology for the Origin feature class, right-click the Origin feature class name in the **Table of Contents** and select **Properties**. Select the **Symbology** tab. Change the default symbol to **Cutting Plane Arrow** from the **Dimension Symbols** under **More Symbols**. Select symbology **Properties** and change the **Angle** to **180**. Select **Rotation** under the **Advanced** pull-down menu. Select **PHTO_DIR** under **Rotate Points by Angle in this field:** and select **Geographic** for the **Rotation Style:**.

ii. **LOC_1** (Primary Geographic Location). This is the name of the mountain range where the photograph was taken. Polygon shapefiles for each park identify values to be used for [LOC_1] and this attribute field can be populated by spatial relationship. Primary geographic locations are described in Appendix B. Note: values for [LOC_1] are the same primary geographic locations that are used in the modified photograph naming format for the SWAN Glacier Photo Index (e.g. pppp_yyyymmdd_xxxxxx_iii_12345.jpg where "xxxxxx" is the same as [LOC_1].

iii. **LOC_2** (Secondary Geographic Location). This is the name of closest water body (river, creek, lake) in the drainage from which the photograph was taken. If tributaries to the drainage are named, use the name for the corresponding lowest-order stream tributary (e.g. North Fork Tlikakila River in LACL). Sometimes it makes more sense to use a glacier name for [LOC_2] (this occurs when a large, named glacier melts into a relatively small, often unnamed drainage that's close to the ocean. Examples include Fourpeaked Glacier in KATM, and Bear Glacier in KEFJ.

iv. **GLAC_NAME** (Glacier Name). This is the formal or local name of a glacier(s) visible in the digital photograph. The word “glacier” is omitted.

v. **GEOG_NAME** (Named Geographic Features). This is the name of readily identified geographic features visible in the digital photograph. Use names published on USGS topographic maps (1:63,360 or smaller scale). Include glacier names (and the word “glacier”). Don’t use any geographic name if it’s already used for that feature in [LOC_2]. The reason for these nuances is because attribute fields are later concatenated (combined) to automatically generate photograph captions and keywords. If named geographic features are not visible in the digital photograph enter **Glaciated Landscape** if glacier ice is present and **Landscape** if no glacier ice is present.

vi. **PICT_GE** (Google Earth KML file name). This is the file name of the photograph used to generate Google Earth KML files. Entry should be the same as [ORIGINAL], except no underscores are used (because they create errors in the KML). Use the Field Calculator to automatically populate this field for all features.

   a. Start editing. Select (highlight) [PICT_GE] and activate the Field Calculator. Under **PICT_GE=** type in: **Replace([ORIGINAL],”_”,””)**
   b. If the primary geographic location is used in the photograph naming format (as in the case of the SWAN Glacier Photo Index, e.g. pppp_yyyymmdd_xxxxxx_iii_12345.jpg where xxxxxx is the same as the primary geographic location, select (or highlight) [PICT_GE] and activate the Field Calculator. Under **PICT_GE=** type in **REPLACE([PICT_GE],”xxxxxx”,””)** where **xxxxxx** is the geographic location.

vii. **CAPTION** (Photograph caption). This is the caption that will be used for the digital photographs in documents, reports, websites, and Google Earth KML. Use the Field Calculator to automatically populate this field for all features (once all the other attribute fields have been populated).

   a. Start editing. Select (highlight) [CAPTION] and activate the Field Calculator. Under **CAPTION=** type in **[GEOG_NAME]&”_from_”&[LOC_2]&”_Watershed”&”,_” &[LOC_1]&”,_”&”Full_Park_Name”** where “_” is a space.

viii. **KEYWORDS** (Photograph keywords). These are keywords that will be used to search any database that contains the digital photographs. Use

the Field Calculator to automatically populate this field for all features (once all other attribute fields have been populated).

a. Start editing. Select (highlight) [KEYWORDS] and activate the Field Calculator. Under **KEYWORDS=** type in **[LOC_1]&",_"&[LOC_2]&",_"&[GEOG_NAME]** where "_" is a space.

An example of completed attributes for a photograph from Lake Clark is shown in Figure 2.

Field	Value
ALTITUDE	7841.109
ARCHIV_LOC	NPS, SWAN Electronic Library
CAPTION	Neacola Glacier from Neacola River, Neacola Mountains, Lake Clark National Park and Pres...
COLL_NAME	NPS, SWAN Glacier Photo Index
DATE_	8/28/2007
DATUM	NAD 83
DIST_RSTR	None
FID	264
GEOG_NAME	Neacola Glacier
GLAC_NAME	Neacola
HEADING	172
KEYWORDS	Neacola Mountains, Neacola River, Neacola Glacier
LAT	60.87299
LOC_1	Neacola Mountains
LOC_2	Neacola River
LOCALTIME	28-Aug-2007 16:05:27
LON	-153.375754
ORIGINAL	LACL_20070828_Neacola_CRL_00268.JPG
PARK_CODE	LACL
PHTO_DIR	293
PHTOGRAPHR	Chuck Lindsay
PICT_GE	LACL20070828CRL00268.JPG
PICTURE	LACL_20070828_Neacola_CRL_00268_tag.jpg
PUBLISHER	NPS, SWAN Inventory and Monitoring Program
SPEED	154.4
THUMB	LACL_20070828_Neacola_CRL_00268_small.jpg

Figure 2. Completed attribute fields for photograph from Lake Clark.

6-1.11 Finalized Photographs

Copy photographs to the Final_Photos folder:
Copy the full-size photographs from:
/Oblique_Aerial_Photos/Working_Photos/pppp_yyyymmdd_iii/
To:
/Oblique_Aerial_Photos/Final_Photos/Full_Size/

Copy the geotagged photographs (files that end with "_tag") from:

/Oblique_Aerial_Photos/Geotagged_Photos/
To:
/Oblique_Aerial_Photos/Final_Photos/Geotagged/

Copy the thumbnail-sized photographs (files that end with "_small") from:
/Oblique_Aerial_Photos/Geotagged_Photos/
To:
/Oblique_Aerial_Photos/Final_Photos/Thumbnails/

6-1.12 Finalized GIS Photograph Index

After all attribute fields have been populated and feature editing is complete, use ArcCatalog (ArcGIS) to copy the shapefiles to the Final_GIS folder.

Copy the line feature class from:
/Oblique_Aerial_Photos/Working_GIS/pppp_yyyymmdd_iii/
pppp_yyyymmdd_iii_Flightline.xxx
to:
/Oblique_Aerial_Photos/Final_GIS/Shapefiles/pppp_yyyymmdd_iii_Flightline.xxx

Copy the point feature class from:
/Oblique_Aerial_Photos/Working_GIS/pppp_yyyymmdd_iii/
pppp_yyyymmdd_iii_Origin.xxx
to:
/Oblique_Aerial_Photos/Final_GIS/Shapefiles/pppp_yyyymmdd_iii_Origin.xxx

Create an ArcMap (ArcGIS) map document for each park with the following layers, symbology, and field-based hyperlinks:

i. **Layers** Add layers for the point feature class "Origin", the line feature class "Flightline", the USGS 1:63,360 topographic map (DRG) and the true-color Landsat image mosaic. Layers should be ordered: Origin, Flightline, Topography, and Landsat Image with the Origin layer at the top of the Table of Contents.
    a. Select **Layer Properties** for the Topography layer. Select the **Display** tab. Enter **50** under **Transparency**.
ii. **Symbology** Use rotated symbology for the "Origin" feature class (as described above). Symbol colors for the point and line feature classes should match.
iii. **Hyperlinks** Create field-based hyperlinks for the Origin layer:

a. Select **Layer Properties** for the Origin layer. Select the **Display** tab. Activate **Support Hyperlinks using field:** and select [PICTURE] in the pull-down menu.
b. Identify the hyperlink base. Click on **File** and select **Document Properties**. Copy and paste the complete pathname for the folder containing the geotagged photographs:
/Oblique_Aerial_Photos/Final_Photos/Geotagged/
This folder must contain digital photographs with file names which match the entries in the attribute field [PICTURE].

An example data frame view from a map document created following this procedure is shown in Figure 3.

Name and save the map document:
/Oblique_Aerial_Photos/Final_GIS/Photo_Index/
pppp_Oblique_Aerial_Photos.mxd

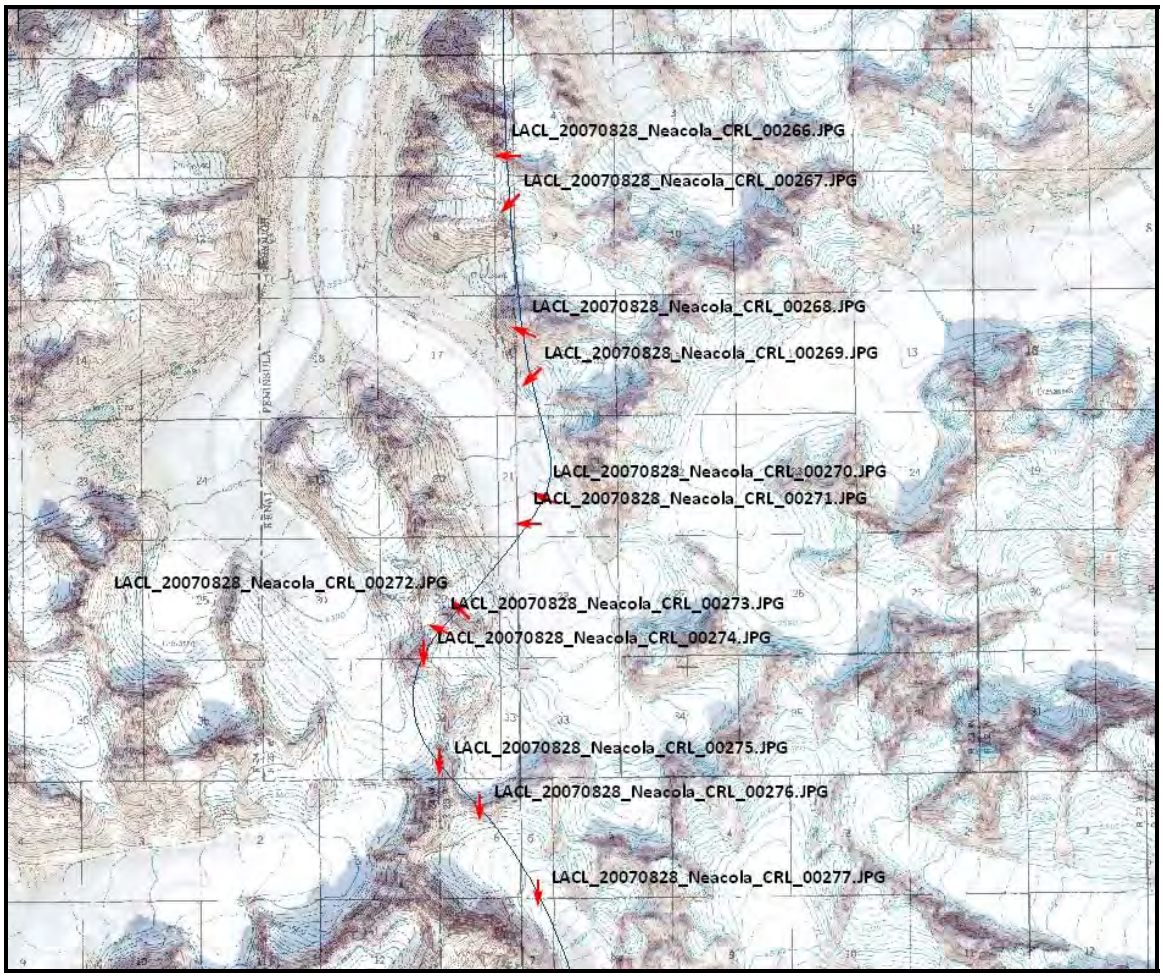


Figure 3. Data frame view of GIS photograph index for Lake Clark.

6-1.13 Batch process photographs for Google Earth KML

Copies of working photographs are resized and renamed for use in Google Earth KML. This procedure results in a folder of photographs that are sized 400 x 350 pixels with file names that follow the naming format: ppppyyyymmddiii.jpg.

Use IrfanView to batch resize photographs. Select **File > Batch Conversion/Rename**. Identify the folder with photographs to use: /Oblique_Aerial_Photos/Working_Photos/pppp_yyyymmdd_iii/
Click the **Add all** button to select all photographs for resizing.
Select **Batch Conversion – Rename result files** and **JPG/JPEG Format**.
Activate **Use advanced options**. Click the **Advanced** button and activate

Resize. Select **Set new size:** and **Set one or both sides to: 400 Width** by **350 Height** (pixels). Select **Preserve aspect ratio (proportional)**. Activate **Save files with original date/**time. Select OK. Click the **Options** button under **Batch rename settings**. Type **$N** for **Name pattern:** and type "_" after **Replace text (1):** and "" after **with**. Identify the **Output directory for result files**:
/Oblique_Aerial_Photos/Google_Earth/pppp_yyyymmdd_iii/files
Click **Start Batch**. Batch processing may take some time.

If primary geographic locations ([LOC_1]) are included in the photograph naming format (e.g. SWAN Glacier Photo Index) use file renaming software to remove this text from the file name. Refer to the section titled **Rename Working Photographs** above and use Magic File Renamer. The **Replacer** filter is used to delete text in a file name by replacing selected text with nothing.

6-1.14 Export GIS to KML

Download and install the Export to KML extension for ArcGIS from the ESRI Support Center. Detailed instructions for installation are included in the download package.

Open the final GIS map document. Make sure that the photograph directions ([PHTO_DIR]) in the attribute table are in numeric (not angle) format. Select **View > Toolbars** and activate the Export to KML toolbar. Click on the **Export to KML** button (it looks like the Google Earth program icon – a small blue globe with white stripes).

Select the layer to export. Select the point feature class by using the pull-down menu to select **pppp_yyyymmdd_iii_Origin**. Don't activate **Group and color features using the layer's symbology** (it doesn't recognize symbology based on field attributes like the rotated arrow used). Select **<None>** for both **Select an attribute for labeling features** and **Select an attribute that represents the height**. Browse to:
/Oblique_Aerial_Photos/Google_Earth/pppp_yyyymmdd_iii/
and name the output KML:
pppp_yyyymmdd_iii

Click the **Options** button. Select the **Export Options** tab. Type a description like: **Oblique aerial photographs taken in PARK on MONTH DAY, YEAR.** under **KML Layer Description**.

Click the **Labeling and Description Options** tab. Use the pull-down menu to select **Original** under **Select an attribute for naming each feature:**. Copy and paste the following HTML code under **Feature description expression:**

```
<b>[ORIGINAL]</b><br>
<img  src="files/[PICT_GE]"><br><b>[CAPTION]</b><br><br>Date:
[DATE_]<br>Taken from: Lat [LAT], Lon [LON], Alt [ALTITUDE] (ft)<br>Datum:
[DATUM]<br>Photo Orientation: [PHTO_DIR] deg<br>Aircraft heading: [HEADING]
deg<br>Aircraft speed: [SPEED] mph<br>Photographer:
[PHTOGRAPHR]<br>Collection name: [COLL_NAME]<br>Publisher:
[PUBLISHER]<br>Archive location: [ARCHIV_LOC]<br>Distribution restrictions:
[DIST_RSTR]<br>
```

Click **OK** twice to create the KML.

Now, export the line feature class. Click on the **Export to KML** button. Select the layer to export. Select the line feature class by using the pull-down menu to select **pppp_yyyymmdd_iii_Flightline**. Don't activate **Group and color features using the layer's symbology**. Select **<None>** for both **Select an attribute for labeling features** and **Select an attribute that represents the height**. Browse to:
/Oblique_Aerial_Photos/Google_Earth/pppp_yyyymmdd_iii/
and name the output KML:
pppp_yyyymmdd_Flightline

Click the **Options** button. Select the **Export Options** tab. Type a description like: **Flightline for oblique aerial photography in PARK on MONTH DAY, YEAR.** under **KML Layer Description**.

Click **OK** twice to create the KML.

An example of the Google Earth output files is shown in Figure 4.

The folder for Google Earth file must follow this file structure:
/pppp_yyyymmdd_iii/
    /.kml
    /.kml
    /files
        /resized, renamed photographs (400 x 350 pixel, no "_" in name)

It may be useful to create a compressed KMZ archive that contains the point feature class and the resized, renamed photographs. Use a file compression utility (e.g. WinZip) to create a file archive containing:

/pppp_yyyymmdd_iii_Origin.kml
/files

and rename the archive extension **.kmz**. Sometimes Google Earth doesn't recognize .kmz archives created with WinZip. The open source file compression utility 7-Zip works well.

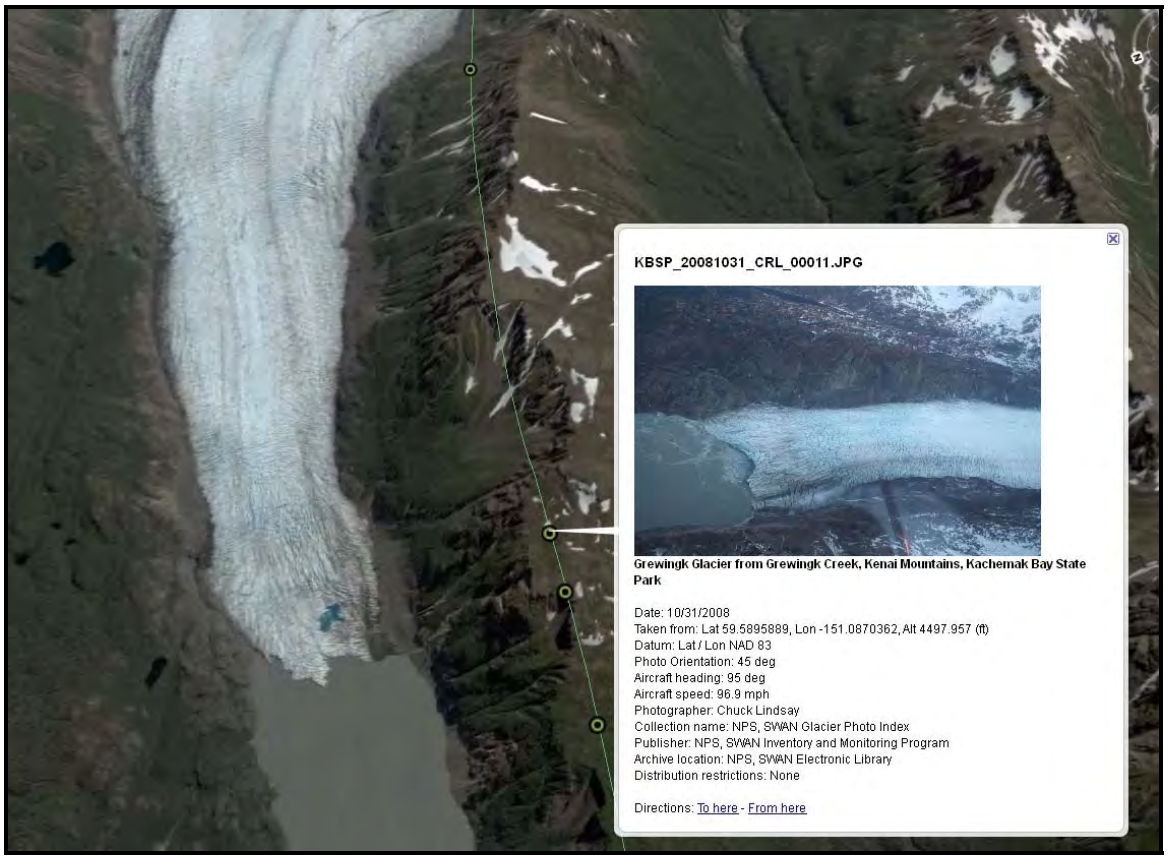


Figure 4. Screenshot from Google Earth showing point and line feature class and feature description with embedded photograph exported from ArcGIS.

Appendix A. File Organization

The following steps provide guidance on naming and organizing the large number of files that will be created during geotagging and managing oblique aerial photographs in a GIS. It is important to carefully organize these files and keep original, working, and final copies of the photographs, GPS data, and GIS data.

Explanation

/ = denotes directory, subfolder
pppp = four letter park code (e.g. KEFJ)
yyyymmdd = Year, Month, Day code
iii = photographers initials (first, middle, last)
xxx = various ArcGIS shapefile extensions
12345 = sequential numbering assigned to photograph by camera
example = KEFJ_20090212_CRL.shp (use underscore in file name)

Photograph Naming Format

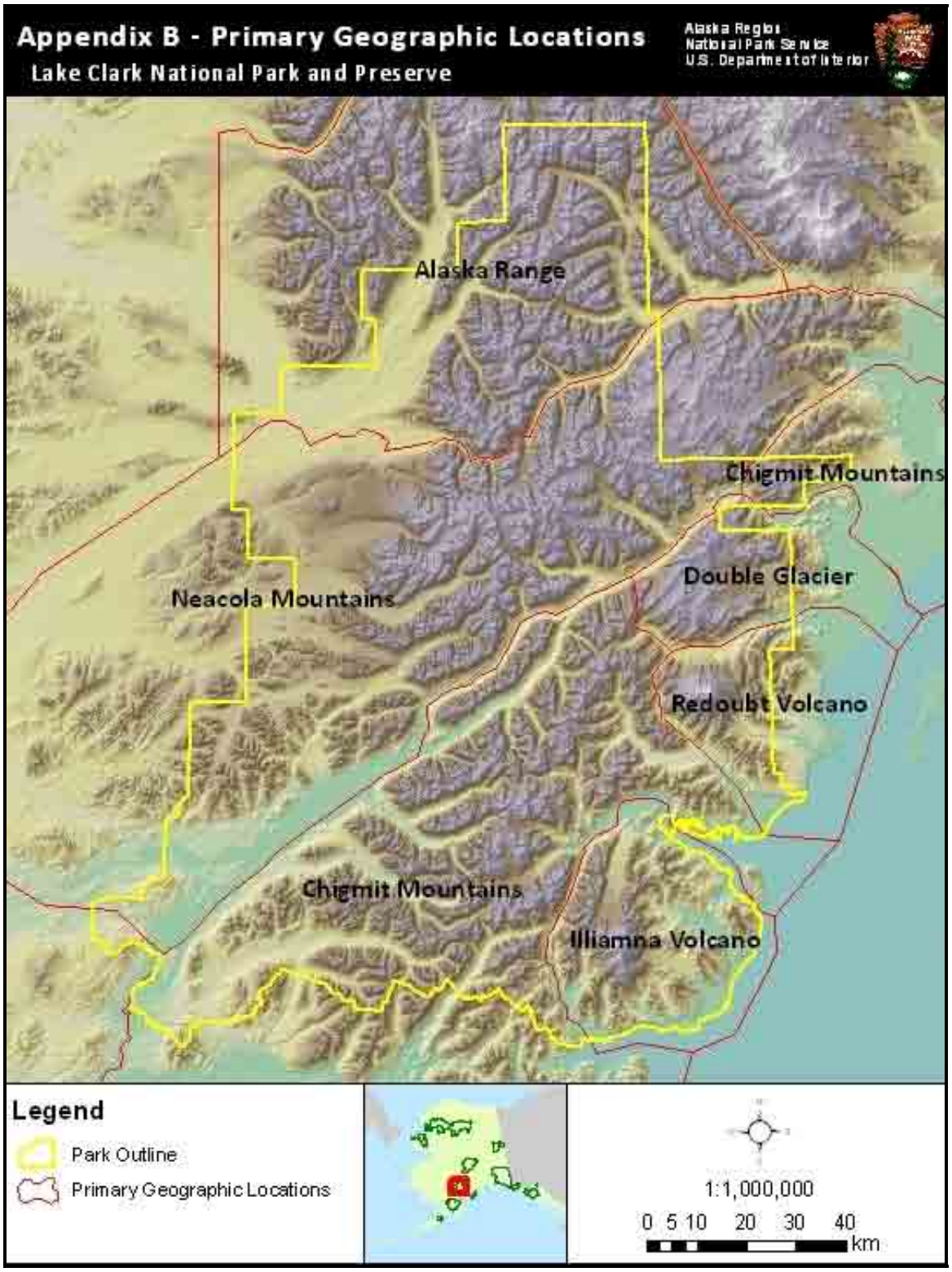
pppp_yyyymmdd_iii_12345.jpg
(example: KEFJ_20090212_CRL_0234.jpg)

Note: The SWAN Glacier Photo Index uses a modified photograph naming format: pppp_yyyymmdd_[LOC_1]_iii_12345.jpg where [LOC_1] is the primary geographic location where the photograph was taken from. This value is the same as the field attribute [LOC_1] used in the GIS shapefile (pppp_yyyymmdd_iii_Orgin.xxx) and these values are described in Appendix B. This naming format is somewhat redundant and not necessary, but it was specifically requested.

Example File Organization

```
/Oblique_Aerial_Photos
    /Geotagged_Photos
        /pppp_yyyymmdd_iii
    /Google_Earth
        /pppp_yyyymmdd_iii
            /files
            /pppp_yyyymmdd_iii_Flightline.kml
            /pppp_yyyymmdd_iii_Origin.kml
            /pppp_yyyymmdd_iii.kmz
    /Final_GIS
        /Photo_Index
            /pppp_Oblique_Aerial_Photos.mxd
        /Shapefiles
            /pppp_yyyymmdd_iii_Origin.xxx
            /pppp_yyyymmdd_iii_Flightline.xxx
    /Final_Photos
        /Full_Size
            /pppp_yyyymmdd_iii
        /Geotagged
            /pppp_yyyymmdd_iii_tag
        /Thumbnails
            /pppp_yyyymmdd_iii_small
    /Original_GPS
        /pppp_yyyymmdd_iii
            /pppp_yyyymmdd_iii.gdb
            /pppp_yyyymmdd_iii.gpx
            /pppp_yyyymmdd_iii.txt
    /Original_Photos
        /pppp_yyyymmdd_iii
    /Working_GIS
        /pppp_yyyymmdd_iii
            /pppp_yyyymmdd_iii_Flightline.xxx
            /pppp_yyyymmdd_iii_Origin.xxx
            /pppp_yyyymmdd_iii_Working.mxd
    /Working_GPS
        /pppp_yyyymmdd_iii
            /pppp_yyyymmdd_iii_Flightline.xxx
```

/pppp_yyyymmdd_iii_Tracklog.xxx
/Working_Photos
/pppp_yyyymmdd_iii


Appendix B - Primary Geographic Locations
Lake Clark National Park and Preserve
Alaska Region
National Park Service
U.S. Department of Interior
Alaska Range
Chigmit Mountains
Double Glacier
Neacola Mountains
Redoubt Volcano
Chigmit Mountains
Illiamna Volcano
Legend
Park Outline
Primary Geographic Locations
1:1,000,000
0 5 10 20 30 40
km

Glacier Extent Protocol
Southwest Alaska Network

Standard Operating Procedure (SOP) # 7

Data Management

Version 1.0 (May, 2009)

Revision History Log:

Previous Version #	*Revision Date*	*Author*	*Changes Made*	*Reason for Change*	*New Version #*

DRAFT

Data Management Procedures – Background

Mapping glacier extent as described in this protocol requires a significant effort and investment in personnel time spread out over a period of a couple months for each mapping effort. This being the case, significant attention to folder and file management (folder/file structure and naming convention) and backup procedures is critical to the efficient management of this glacier boundary mapping protocol.

7-1 Data Acquisition - Landsat

Acceptable Landsat imagery is ordered and received from the EROS Data Center (See SOP #1 for direction). This Landsat data is currently stored on the X drive (NPS Alaska Region GIS Data) maintained by the NPS, Alaska Regional Office – GIS group with the following directory structure and file naming convention.

X:\Source_Data\Satellite_Imagery\

The Landsat image file naming convention is:

Example: TM5_7118_03Sep1995_Albers_NAD27

Sensor: "TM5" means Landsat 5 Thematic Mapper

PathRow identifier: Path 71, Row 18
Date of Acquisition: 03Sep1995
Projection: Albers
Datum: NAD27

7-2 Directory Structure and File Naming

The following is the suggested folder and file naming convention. The SWAN Data Management Plan recommends that there be no periods (.) in the path or filename. Use the underline (_) in file and folder names. This is particularly important for ArcGIS and ArcCatalog software operations. All the data processing is completed in the ArcGIS/ArcCatalog environment, thus all folders, files, Personal Geodatabases and Feature Datasets will all be created using ArcCatalog. Figure 1 shows the primary folder structure where data processing occurs. From past experience, it seems that ArcGIS/ArcCatalog performs best when the folder location is located as close to the root of the "C" drive as possible.

The standard datum and projection for in NPS-Alaska is NAD83 – Alaska Albers.

The Datum and Projection of the Feature Datasets will be equivalent to the Landsat data being processed. As indicated in SOP #1, Landsat imagery is currently delivered from EROS Data Center in WGS84, UTM zone 5 or 6, for the SWAN parks. The standard datum and projection for Alaska NPS is NAD83, Alaska Albers. If glacier mapping occurred in a different datum/projection from the Alaska NPS standard, the re-projection of the data will occur upon completion of the mapping when all shapefiles are final.

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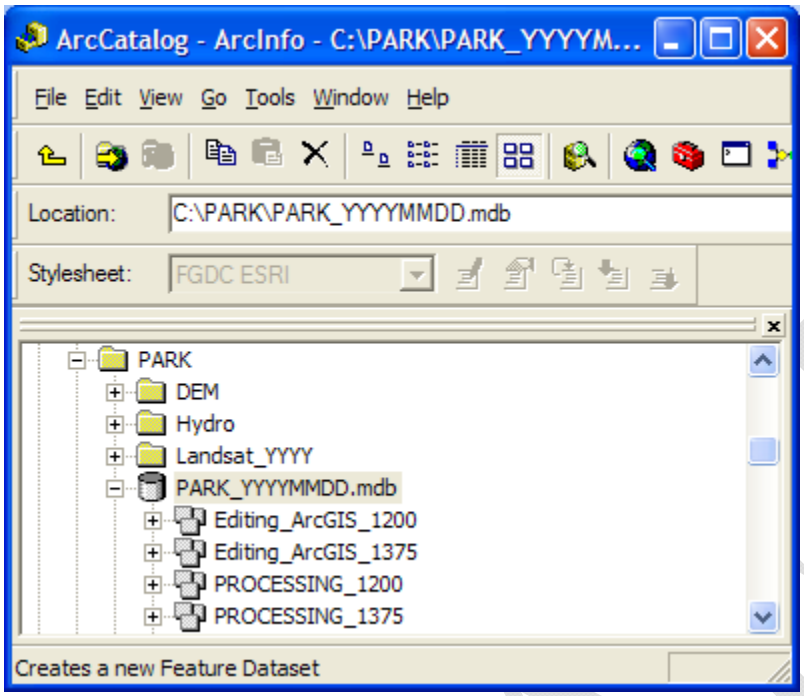

Figure 1. Primary folder structure.

A few definitions are in order:

"C" is the C drive on the computer

"PARK" is the primary folder in which all folders and files are located. The "PARK" acronym should name this folder, i.e. KATM, KEFJ, LACL.

"DEM" is a subordinate folder in the "PARK" folder that contains digital elevation model data of the mapping region.

"Hydro" is a subordinate folder in the "PARK" folder that contains hydrography data of the mapping region.

"Landsat_YYYY" is a subordinate folder in the "PARK" folder that contains Landsat data of the mapping region.
"PARK_YYYYMMDD.mdb" is a Personal Geodatabase created using ArcCatalog. Replace "PARK" with the appropriate park acronym. YYYYMMDD is the date of the Landsat imagery.

"Editing_ArcGIS_1200" is a Feature Dataset where shapefiles are edited in ArcGIS/ArcCatalog. The 1200 represents a threshold value

determined in SOP #2. In this case “1200” represents a threshold value of 1.200.

“Editing_ArcGIS_1375” is a Feature Dataset where shapefiles are edited in ArcGIS/ArcCatalog. The 1375 represents a threshold value determined in SOP #2. In this case “1375” represents a threshold value of 1.375.

“Processing_1200” is a Feature Dataset where all the processing occurs. The 1200 represents a threshold value determined in SOP #2. In this case “1200” represents a threshold value of 1.200.

“Processing_1375” is a Feature Dataset where all the processing occurs. The 1375 represents a threshold value determined in SOP #2. In this case “1375” represents a threshold value of 1.375.

Creating folders, Personal Geodatabases and Feature Datasets in ArcCatalog is simply done by right clicking the mouse button on the intended location. Figure 2 illustrates the process of creating a Personal Geodatabase within the PARK folder. Figure 3 illustrates the process of creating a Feature Dataset within the PARK_YYYYMMDD.mdb Personal Geodatabase.

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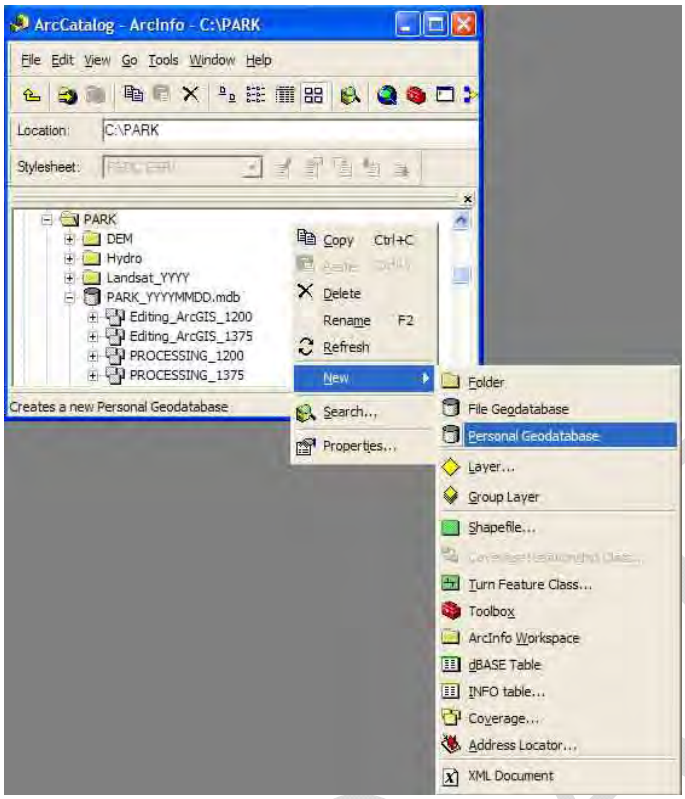

Figure 2. Creating a Personal Geodatabase using ArcCatalog.

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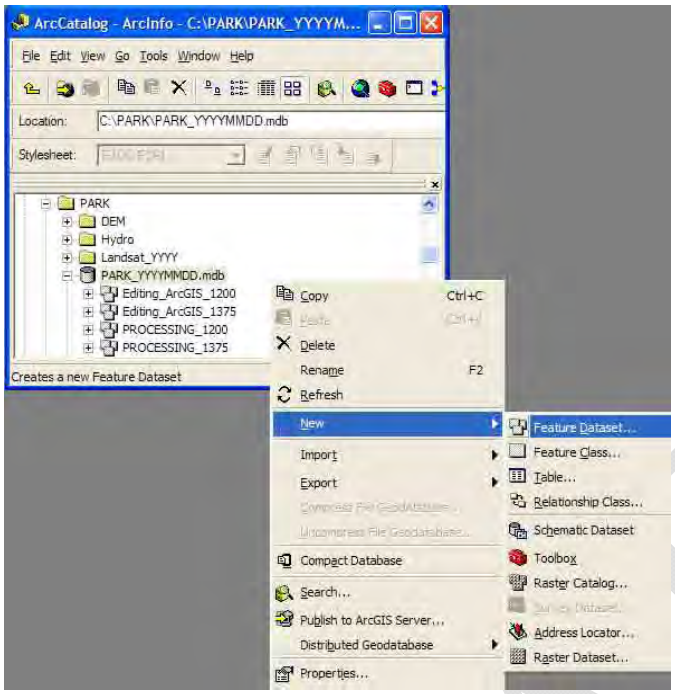

Figure 3. Creating a Feature Dataset within a Personal Geodatabase using ArcCatalog.

<u>DEM Folder Contents</u>

The "DEM" folder contains raster and shapefiles, Figure 4. Raster files include an appropriate USGS DEM (USGS_DEM), the USGS DEM clipped to the area of the glacier mapping (DEM_Clip1) and a resultant raster file after a conditional statement (Con(sa)) is applied to the clipped DEM (dem lt_400), Figure 5.

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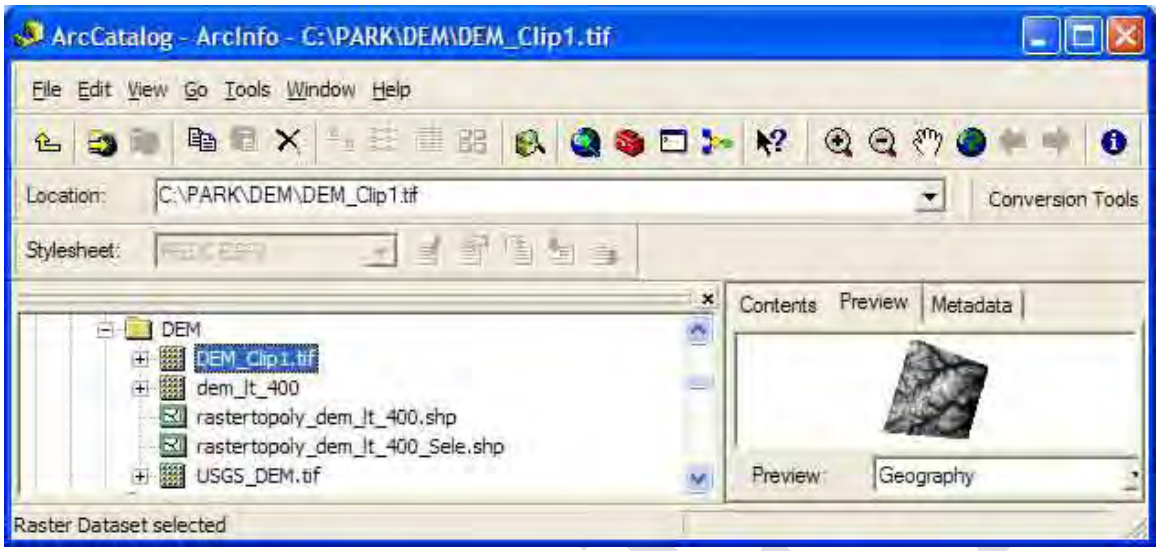

Figure 4. DEM folder contents.

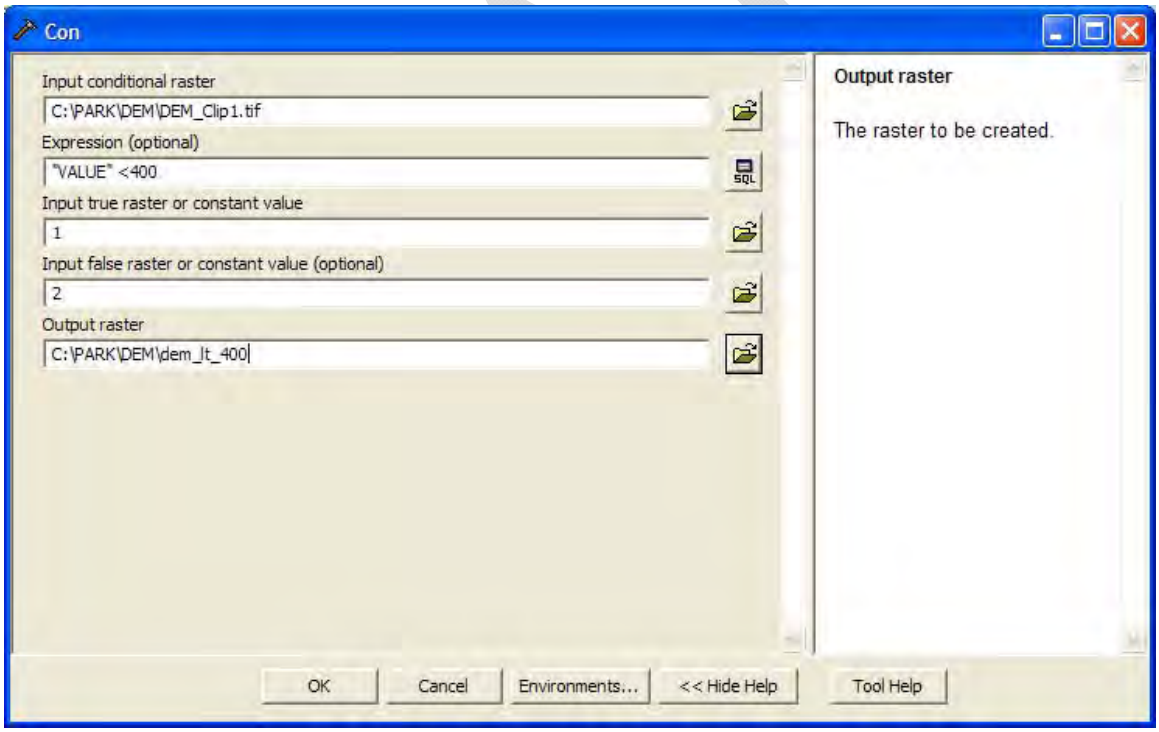

Figure 5. Conditional statement (Con (sa)) command in ArcCatalog.

Shapefiles are the result of a Raster-To-Polygon conversion (Figure 6) and a select (analysis) of the first polygon shapefile (Figure 7):

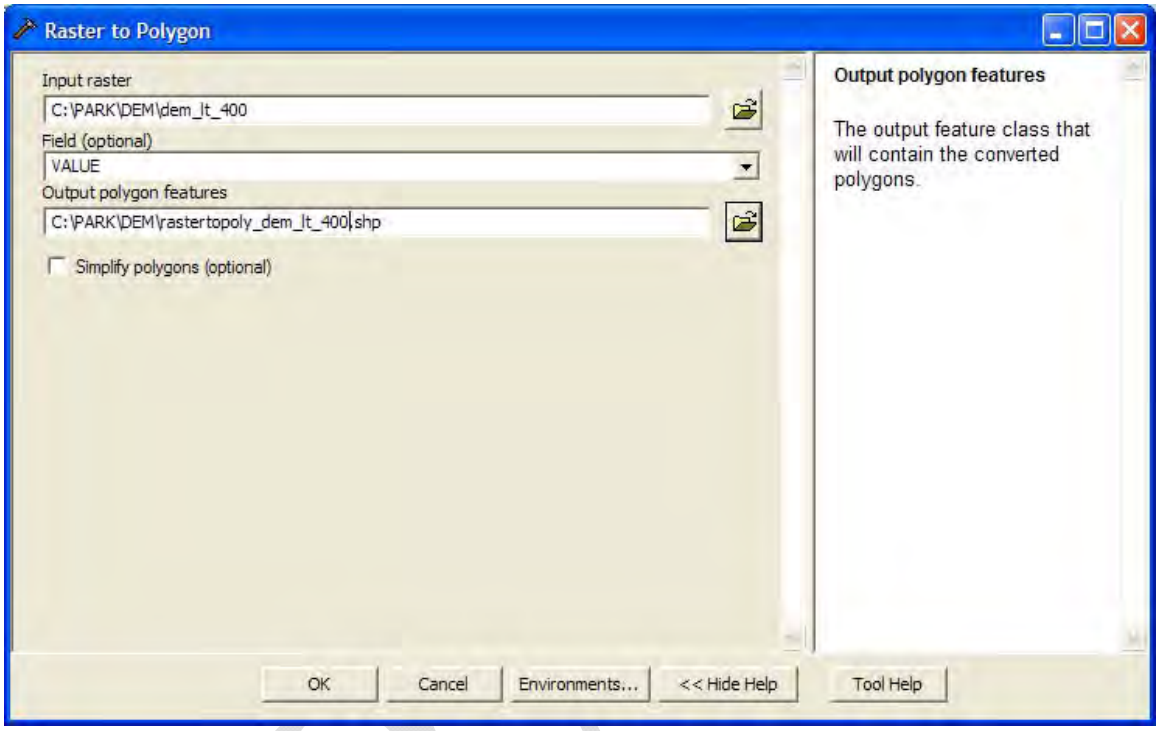

Figure 6. Raster to polygon conversion command in ArcCatalog.

DRAFT

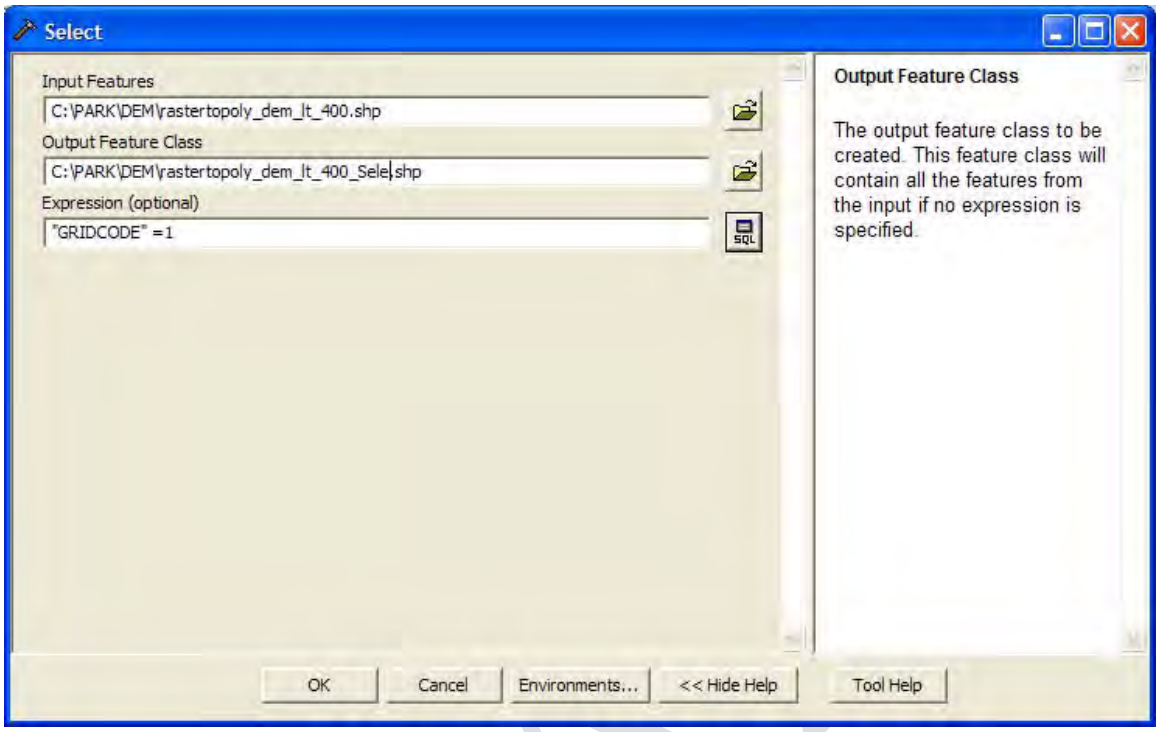

Figure 7. "Select" command in ArcCatalog.

<u>Landsat_YYYY Folder Contents</u>

The "Landsat_YYYY" folder contains raster files, Figure 8. Raster files include Landsat bands and resultant raster files after various processing steps. The raster files seen in Figure 8 have been fully described in SOP #4, so only a few explanations are offered here to reduce redundancy. For example:

B2 is the original Landsat Band 2
B3 is the original Landsat Band 3
B4 is the original Landsat Band 4
B5 is the original Landsat Band 5
float_b3 is the resultant band after applying the "Float" command
float_b5 is the resultant band after applying the "Float" command
divide_b3_b5 is the resultant raster after the dividing band 3 by band 5
b5b4b2_Composite is the color composite Landsat image

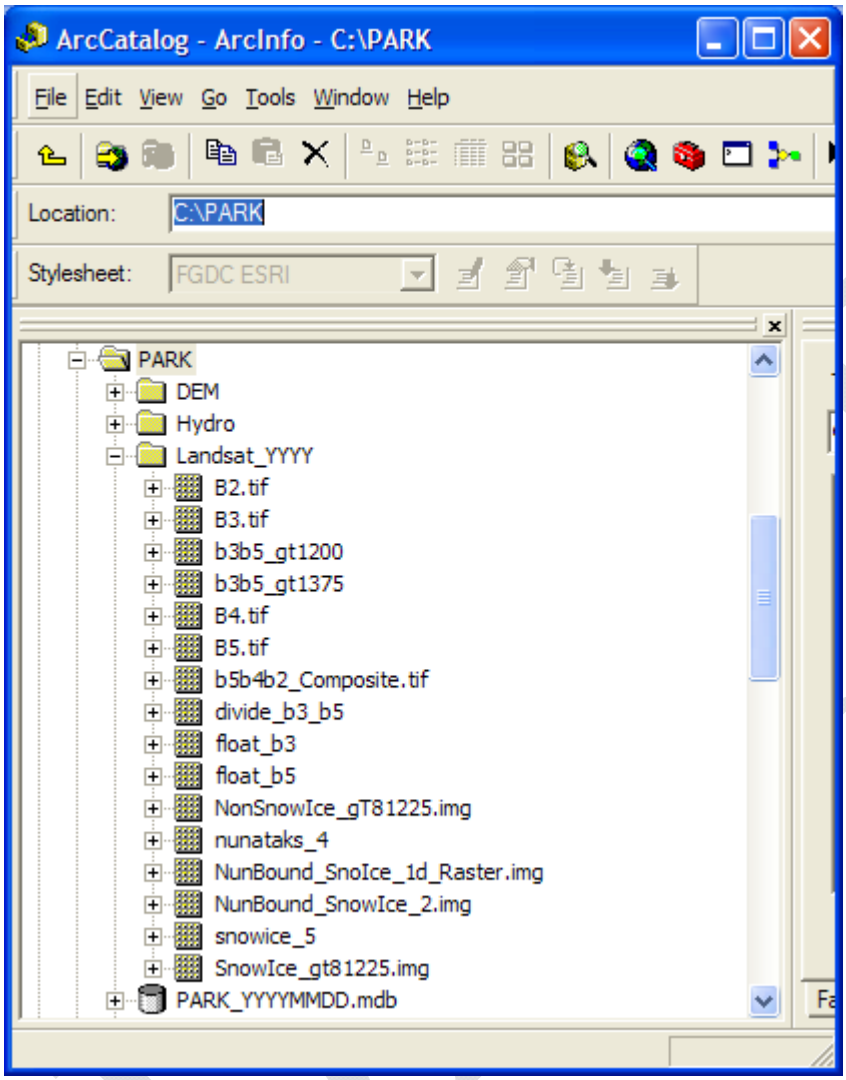

Figure 8. Landsat folder and file naming.

PARK_YYYYMMDD.mdb Personal Geodatabase

This Personal Geodatabase contains only Feature Datasets; no folders or files are found directly in this Personal Geodatabase. Figure 9 shows four Feature Datasets, two "Editing_" and two "Processing_". Each representing mapping efforts using different threshold values (threshold values are described in SOP #2, SOP #3 and SOP#4) where all data processing occurs.

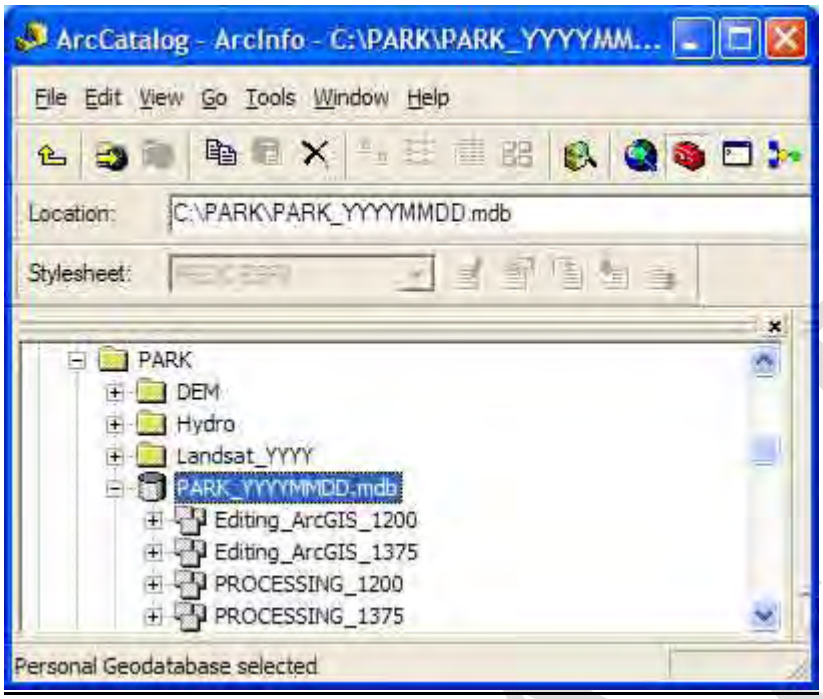

Figure 9. Personal Geodatabase and Feature Dataset structure.

<u>PROCESSING_1375 Feature Dataset</u>

Figure 10 illustrates the file naming convention used in this Feature Dataset. The file naming convention was already covered in SOP #3 and SOP #4.

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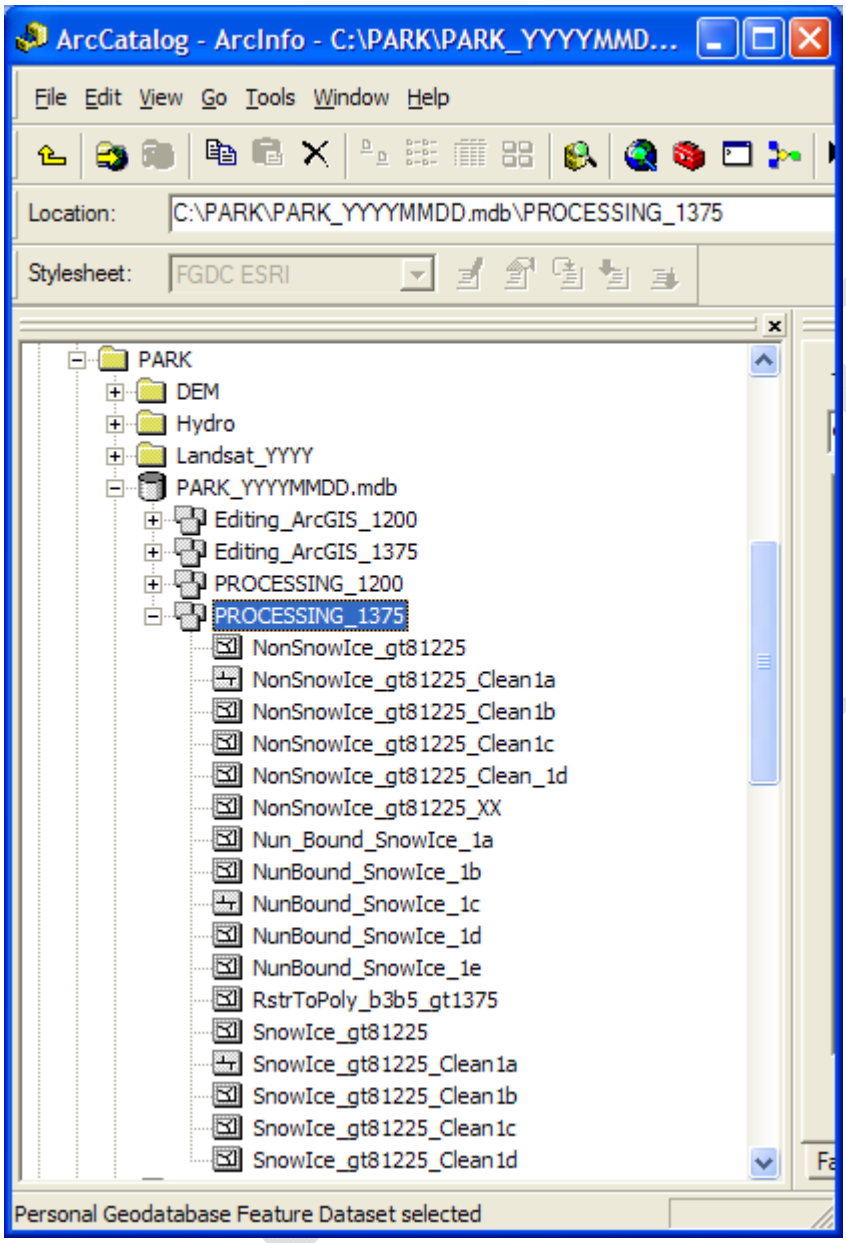

Figure 10. File naming convention for a “Processing_” Feature Dataset.

<u>Editing_ArcGIS_1375 Feature Dataset</u>
Figure 11 illustrates the file naming convention used in this Feature Dataset. The file naming convention was already covered in SOP #3 and SOP #4.

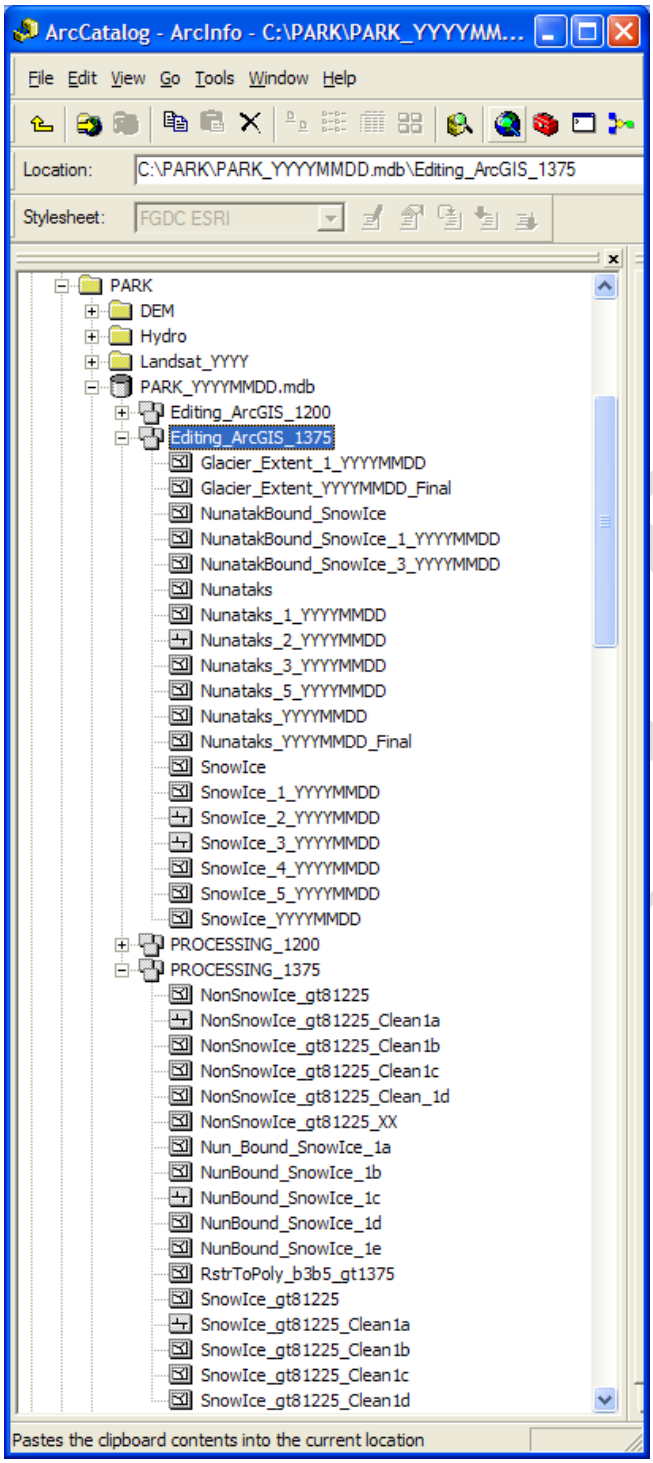

Figure 11. File naming convention for a “Editing_” and “PROCESSING_” Feature Dataset.

7-3 Metadata

Metadata will be FGDC (Federal Geographic Data Committee) compliant. A complete metadata file will be prepared for each of the final data products produced in support of this protocol. An example of an acceptable metadata file is attached as Appendix A.

Final Products for each glacier mapping effort:

Glacier_Extent
Nunataks

7-4 Operational and Archiving File Management

The data acquisition, processing and interpretation of LandSat data will be conducted on NPS desktop computers. This protocol has a repeat cycle of every ten years. Filenames will follow the conventions outlined in procedure 7-1, above. This naming convention will allow for easier transfer to the SWAN server. Upon final completion of imagery classification and generation of final shapefiles, the files will be transferred to the SWAN server and the Alaska Regional Office - GIS Theme Manager.

Data processing steps will require the creation of temporary working files that will not be needed for long-term monitoring of the SWAN. These temporary files will remain on the desktop computer until the glacier extent mapping is complete for the subject Landsat image. Upon acceptance of the glacier extent shapefiles into the Alaska Regional Office - GIS Theme Manager, all previous working files can be deleted, except for one file. This polygon shapefile is the most recent "SnowIce_X_YYYY" shapefile created after over-classification polygons are completely removed but before glacier boundary modifications are made. This shapefile is representative of clean-ice glacier extent in the mapping region. The name of the file should be: Glacier_Extent_CleanIce_Only.

Final glacier extent and nunatak shapefiles and the associated color composite Landsat images will be archived on the SWAN data file server in their appropriate product type directories.

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7-5 Backup Procedures

System backups are managed by the Alaska Regional Information Technology staff as described in the SWAN Data Management Plan, Section 11.5. Additional backups of working documents will be performed by SWAN staff. Interim and final work products are competed on a desktop PC and these products will be backed up to the SWAN server on a daily basis when mapping work is being accomplished.

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Appendix A. Metadata Example

KEFJ_GLACIER_EXTENT_ALL_2000

Metadata:

- Identification_Information
- Data_Quality_Information
- Spatial_Data_Organization_Information
- Spatial_Reference_Information
- Entity_and_Attribute_Information
- Distribution_Information
- Metadata_Reference_Information

Identification_Information:

Citation:
Citation_Information:
Originator: National Park Service, Alaska Regional Office
Publication_Date: 2008
Title:
KEFJ_GLACIER_EXTENT_ALL_2000
Geospatial_Data_Presentation_Form: vector digital data
Publication_Information:
Publication_Place: Anchorage, Alaska
Publisher: National Park Service, Alaska Regional Office
Online_Linkage: http://science.nature.nps.gov/nrdata/
Online_Linkage:
\\165.83.60.63\GisData\Albers\parks\swan\base\physical\statewid\GlacExtKEFJ.gdb
Description:
Abstract:
This dataset delineates glacial extents for Kenai Fjords National Park over a 30 year period. It contains polygon areas of Glacial and non-glacial areas (i.e. Nunataks) and Linear glacial terminus features for 3 time periods from the 1970s to 2000s.
Purpose:
The purpose of this effort was to map the glacier extent on a park-wide basis using Landsat imagery over a 30 year period, identifying changes in extent. This glacier extent data set was created through a joint effort between the NPS and NASA-Goddard Space Flight Center. This data set is the result of extensive

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manual editing of shapefiles created from supervised classification of the Landsat imagery. This mapping effort was repeated on a decadal scale to quantify trends and changes in glacial extent from the 1970s to 2000.
Time_Period_of_Content:
Time_Period_Information:
Single_Date/Time:
Calendar_Date: 2000
Currentness_Reference:
ground condition
Status:
Progress: Complete
Maintenance_and_Update_Frequency: As needed
Spatial_Domain:
Bounding_Coordinates:
West_Bounding_Coordinate: -151.137404
East_Bounding_Coordinate: -149.464285
North_Bounding_Coordinate: 60.308669
South_Bounding_Coordinate: 59.340381
Keywords:
Theme:
Theme_Keyword_Thesaurus: National Park Service Theme Category Thesaurus
Theme_Keyword: Landform
Theme_Keyword: Monitoring
Theme:
Theme_Keyword_Thesaurus: ISO 19115 Topic Category
Theme_Keyword: geoscientificInformation
Theme:
Theme_Keyword: glacier
Theme_Keyword: snow
Place:
Place_Keyword_Thesaurus: National Park System Unit Name Thesaurus
Place_Keyword: Kenai Fjords National Park
Place:
Place_Keyword_Thesaurus: National Park System Unit Code Thesaurus
Place_Keyword: KEFJ
Place:
Place_Keyword: Alaska
Access_Constraints: none
Use_Constraints:
none
Point_of_Contact:

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Contact_Information:
Contact_Organization_Primary:
Contact_Organization: National Park Service, Alaska Regional Office
Contact_Person: GIS Team
Contact_Position: GIS Specialist
Contact_Address:
Address_Type: mailing and physical address
Address:
240 W 5th Ave.
City: ANCHORAGE
State_or_Province: AK
Postal_Code: 99501
Country: USA
Contact_Voice_Telephone: Please contact us via email.
Contact_Electronic_Mail_Address: AKRO_Internet_Contact@nps.gov
Hours_of_Service: 8:00am- 5:00pm AST
Native_Data_Set_Environment:
Microsoft Windows XP Version 5.1 (Build 2600) Service Pack 3; ESRI ArcCatalog 9.2.5.1450

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Data_Quality_Information:
Attribute_Accuracy:
Attribute_Accuracy_Report:
All attributes were verified by visually comparing the attributes in the digital coverage against the original source material, but no formal tests were performed.
Logical_Consistency_Report:
Topologically clean as verified by ArcGIS version 8.x/9x
Completeness_Report:
Data set complete
Positional_Accuracy:
Horizontal_Positional_Accuracy:
Horizontal_Positional_Accuracy_Report:
Horizontal positional accuracy for the digital data is tested by visual comparison of the source with hard copy plots at intended scale.
Lineage:
Process_Step:
Process_Description:
Landsat imagery was acquired that met the following standards:
Cloud-free or minimal cloud cover;

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Late-season imagery (to maximize seasonal snow melt and minimize new seasonal snow (August and September).

Landsat imagery was classified for glacier ice and snow using PCI image-processing software where training sites were defined and a "maximum likelihood" algorithm was used to classify the imagery. The classification was converted to GIS shapefiles and edited in ArcGIS. If available, higher-resolution aerial photography was used as a tool to help interpret the Landsat data. Very small glaciers, and areas that appeared to be snowfields (not glacier ice) were generally not captured.

Complicating Issues

Several factors influence the accuracy of the initial supervised classification of glacier extent:

Debris-covered ice (moraine and/or volcanic ash)

Shadows

Seasonal snow cover and /or new snow cover

Permanent snowfields outside of the accumulation area

Each of these factors influence the spectral reflectance of the terrain which in-turn affects the accuracy of the supervised classification.

Manual Editing

The supervised classification was converted to a GIS shapefile. Areas that were misclassified in the original classification were captured manually (debris-covered ice, shadowed ice) or removed (isolated small snowfields) during an edit session in ArcGIS. Editing of the shapefile is based on the judgment of the person doing the satellite image interpretation. The human eye can perceive textural differences in debris-covered ice that were typically missed in the original supervised classification. In addition, local knowledge and the use of high-resolution imagery can aid in the interpretation of Landsat data. Careful manual interpretation of these areas is required to optimize the accuracy of the mapping effort.

SATELLITE IMAGERY INTERPRETATION ACCURACY

The amount of change that can be detected in a Landsat image is dependent on the resolution of the imagery plus any registration error. The spatial accuracy of Terrain Corrected TM or ETM+ Landsat data is 30 meters between images (EROS Data Center, personal comm., 2006). If the registration between images is perfect, changes of terminus positions can be determined to within +- 42.4 meters when analyzing Landsat TM and ETM+ scenes; the accuracy decreases to +- 113 meters when analyzing data between Landsat MSS and TM or ETM+ scenes (Hall et al., 2003).

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BRUCE A. GIFFEN, Alaska Regional Office, National Park Service, 240 West 5th Ave., Anchorage, Alaska 99501,
USA, bruce_giffen@nps.gov.
Source_Used_Citation_Abbreviation:
Landsat scene 17-Aug-73 MSS LM1074018007322990
Source_Used_Citation_Abbreviation:
Landsat Scene 12-Sep-86 TM LT5069018008625510
Source_Used_Citation_Abbreviation:
Landsat Scene 9-Aug-00 ETM+ NZT070690180809200000
Source_Produced_Citation_Abbreviation:
Bruce Giffen
Process_Contact:
Contact_Information:
Contact_Organization_Primary:
Contact_Organization: National Park Service, Alaska Regional Office
Contact_Person: GIS Team
Contact_Position: GIS Specialist
Contact_Address:
Address_Type: mailing and physical address
Address:
240 W 5th Ave.
City: ANCHORAGE
State_or_Province: AK
Postal_Code: 99501
Country: USA
Contact_Voice_Telephone: Please contact us via email.
Contact_Electronic_Mail_Address: AKRO_Internet_Contact@nps.gov
Hours_of_Service: 8:00am- 5:00pm AST

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Spatial_Data_Organization_Information:

Created by bagiffen
Created on 5/6/2009 12:15:00 PM
Last saved by bagiffen on 8/18/2009

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Direct_Spatial_Reference_Method: Vector
Point_and_Vector_Object_Information:
SDTS_Terms_Description:
SDTS_Point_and_Vector_Object_Type: G-polygon
Point_and_Vector_Object_Count: 350

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Spatial_Reference_Information:
Horizontal_Coordinate_System_Definition:
Planar:
Map_Projection:
Map_Projection_Name: Albers Conical Equal Area
Albers_Conical_Equal_Area:
Standard_Parallel: 55.000000
Standard_Parallel: 65.000000
Longitude_of_Central_Meridian: -154.000000
Latitude_of_Projection_Origin: 50.000000
False_Easting: 0.000000
False_Northing: 0.000000
Planar_Coordinate_Information:
Planar_Coordinate_Encoding_Method: coordinate pair
Coordinate_Representation:
Abscissa_Resolution: 0.000100
Ordinate_Resolution: 0.000100
Planar_Distance_Units: meters
Geodetic_Model:
Horizontal_Datum_Name: North American Datum of 1983
Ellipsoid_Name: Geodetic Reference System 80
Semi-major_Axis: 6378137.000000
Denominator_of_Flattening_Ratio: 298.257222
Vertical_Coordinate_System_Definition:
Altitude_System_Definition:
Altitude_Resolution: 0.000003
Altitude_Encoding_Method: Explicit elevation coordinate included with horizontal coordinates

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Entity_and_Attribute_Information:
Detailed_Description:
Entity_Type:
Entity_Type_Label: KEFJ_GLACIER_EXTENT_ALL_2000

Created by bagiffen
Created on 5/6/2009 12:15:00 PM
Last saved by bagiffen on 8/18/2009

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Attribute:
Attribute_Label: OBJECTID
Attribute_Definition:
Internal feature number.
Attribute_Definition_Source:
ESRI
Attribute_Domain_Values:
Unrepresentable_Domain:
Sequential unique whole numbers that are automatically generated.
Attribute:
Attribute_Label: Shape
Attribute_Definition:
Feature geometry.
Attribute_Definition_Source:
ESRI
Attribute_Domain_Values:
Unrepresentable_Domain:
Coordinates defining the features.
Attribute:
Attribute_Label: ACRES
Attribute:
Attribute_Label: SQ_KILOMETERS
Attribute:
Attribute_Label: ICE
Attribute_Definition:
Contains Ice
Attribute_Domain_Values:
Enumerated_Domain:
Enumerated_Domain_Value: 0
Enumerated_Domain_Value_Definition:
No Ice i.e. Nunataks
Enumerated_Domain:
Enumerated_Domain_Value: 1
Enumerated_Domain_Value_Definition:
Ice - i.e. Glacier
Attribute:
Attribute_Label: Shape_Length
Attribute_Definition:
Length of feature in internal units.
Attribute_Definition_Source:
ESRI

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Attribute_Domain_Values:
Unrepresentable_Domain:
Positive real numbers that are automatically generated.
Attribute:
Attribute_Label: Shape_Area
Attribute_Definition:
Area of feature in internal units squared.
Attribute_Definition_Source:
ESRI
Attribute_Domain_Values:
Unrepresentable_Domain:
Positive real numbers that are automatically generated.

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Distribution_Information:
Distributor:
Contact_Information:
Contact_Organization_Primary:
Contact_Organization: National Park Service, Alaska Regional Office
Contact_Person: GIS Team
Contact_Position: GIS Specialist
Contact_Address:
Address_Type: mailing and physical address
Address:
240 W 5th Ave.
City: ANCHORAGE
State_or_Province: AK
Postal_Code: 99501
Country: USA
Contact_Voice_Telephone: Please contact us via email.
Contact_Electronic_Mail_Address: AKRO_Internet_Contact@nps.gov
Hours_of_Service: 8:00am- 5:00pm AST
Resource_Description: GlacExtKEFJ.gdb
Distribution_Liability:
The National Park Service shall not be held liable for improper or incorrect use of the data described and/or contained herein. These data and related graphics (i.e. GIF or JPG format files) are not legal documents and are not intended to be used as such. The information contained in these data is dynamic and may change over time. The data are not better than the original sources from which they were derived. It is the responsibility of the data user to use the data appropriately and consistent within the limitations of geospatial data in general and these data in

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particular. The related graphics are intended to aid the data user in acquiring relevant data; it is not appropriate to use the related graphics as data. The National Park Service gives no warranty, expressed or implied, as to the accuracy, reliability, or completeness of these data. It is strongly recommended that these data are directly acquired from an NPS server and not indirectly through other sources which may have changed the data in some way. Although these data have been processed successfully on computer systems at the National Park Service , no warranty expressed or implied is made regarding the utility of the data on other systems for general or scientific purposes, nor shall the act of distribution constitute any such warranty. This disclaimer applies both to individual use of the data and aggregate use with other data.
Standard_Order_Process:
Fees: none

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Metadata_Reference_Information:
Metadata_Date: 20080512
Metadata_Contact:
Contact_Information:
Contact_Organization_Primary:
Contact_Organization: National Park Service, Alaska Regional Office
Contact_Person: GIS Team
Contact_Position: GIS Specialist
Contact_Address:
Address_Type: mailing and physical address
Address:
240 W 5th Ave.
City: ANCHORAGE
State_or_Province: AK
Postal_Code: 99501
Country: USA
Contact_Voice_Telephone: Please contact us via email.
Contact_Electronic_Mail_Address: AKRO_Internet_Contact@nps.gov
Hours_of_Service: 8:00am- 5:00pm AST
Metadata_Standard_Name: FGDC Content Standards for Digital Geospatial Metadata
Metadata_Standard_Version: FGDC-STD-001-1998
Metadata_Time_Convention: local time
Metadata_Extensions:
Online_Linkage: http://www.esri.com/metadata/esriprof80.html
Profile_Name: ESRI Metadata Profile

Created by bagiffen
Created on 5/6/2009 12:15:00 PM
Last saved by bagiffen on 8/18/2009

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Glacier Extent Protocol
Southwest Alaska Network

Standard Operating Procedure (SOP) # 8

Reporting

Version 1.0 (May, 2009)

Revision History Log:

Previous Version #	*Revision Date*	*Author*	*Changes Made*	*Reason for Change*	*New Version #*

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Overview and Explanation

Glacier extent mapping efforts are repeated approximately every decade for each of the glacier-bearing SWAN parks. Reporting and updates will occur as glacier mapping efforts are initiated and completed. Reporting will be completed through annual SWAN reporting requirements, annual updates to the SWAN Technical Committee and through public presentations.

The subject of glaciers and glacier change is currently very much in the public eye. It is the intent of the SWAN to share these data and information about these glacier mapping efforts with other government agencies, universities and the general public by presenting formal talks/presentations, through casual communications and sharing of data with colleagues and the public.

6-1 Generating Statistical Information and Decadal Comparisons

GIS shape files are created delineating the glacier extent occurring within each glacier-bearing SWAN park. Using GIS, these shape files are analyzed to determine where, how much and identify trends about how glacier extent is

changing. Glacier ice extent will be described by total-area (sq units) and change in total-area (sq units) from the previous temporal data points. Further analysis can be carried out on a watershed-by-watershed basis, thus identifying specific areas within SWAN parks that are experiencing change beyond the park- and SWAN-wide averages. Areas of unusually rapid change will be identified as potential areas for site specific studies.

6-2 Reports

Reporting is relatively simple and can be achieved by presenting metrics in table form identifying SWAN- or Park-wide glacier extent (sq km), change and trends. As the glacier extent data is built up over several decades, rates of change and trends can be identified (Attachment 1 and 2).

Another measurement being captured, beyond that of SWAN- and Park-wide glacier extent, is change in glacier terminus position. A suite of representative glaciers has is selected in each of the SWAN parks and measurements documenting change in terminus position over time are determined. Glacier terminus change measurement techniques and table presenting the data are presented in Attachment 3.

6-3 Data Sharing

Glacier extent data created as a result of this protocol will be shared with the GLIMS (Global Land Ice Measurements from Space) program, a project designed to monitor the world's glaciers primarily using data from optical satellite instruments. Data will also be hosted on the NPS Alaska Regional Office GIS Datastack available to NPS employees. This data will also be available to anyone upon request.

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Attachment 1

Glacier Extent Change - Sample Table

Katmai National Park and Preserve																
	Glacier Extent, sq km			Change in Glacier Extent, sq km (total | annual rate)						% Change in Glacier Extent (total | annual rate)					
Glacier Area	1974	1987	2000	1974 to 1987		1987 to 2000		1974 to 2000		1974 to 1987		1987 to 2000		1974 to 2000	
Mt Douglas Area	377	348	330	-30	-2.3	-17.6	-1.4	-47.2	-1.8	-7.8%	-0.6%	-5.1%	-0.4%	-12.5%	-0.5%
Mt Katmai Area	543	563	510	21	1.6	-53.6	-4.1	-32.9	-1.3	3.8%	0.3%	-9.5%	-0.7%	-6.1%	-0.2%
Mt Mageik Area	72	74	70	2	0.2	-4.6	-0.4	-2.5	-0.1	2.9%	0.2%	-6.2%	-0.5%	-3.5%	-0.1%
Katmai NPP	992	985	910	-7	-0.5	-75.8	-5.8	-82.6	-3.2	-0.7%	-0.1%	-7.7%	-0.6%	-8.3%	-0.3%

Kenai Fjords National Park																
	Glacier Extent, sq km			Change in Glacier Extent, sq km (total | annual rate)						% Change in Glacier Extent (total | annual rate)					
Glacier Area	1974	1987	2000	1974 to 1986		1986 to 2000		1974 to 2000		1974 to 1986		1986 to 2000		1974 to 2000	
Harding Icefield and surrounding glaciers	2043	1935	1903	-108	-9.0	-32.3	-2.3	-140.7	-5.4	-5.3%	-0.4%	-1.7%	-0.1%	-6.9%	-0.3%
Grewingk Yalik Glacier Complex	514	445	424	-69	-5.8	-20.5	-1.5	-89.5	-3.4	-13.4%	-1.1%	-4.6%	-0.3%	-17.4%	-0.7%
	2557	2380	2327	-177	-14.8	-52.8	-3.8	-230.2	-8.9	-6.9%	-0.6%	-2.2%	-0.2%	-9.0%	-0.3%

Attachment 2

Glacier Terminus Change - Sample Table

Glacier Terminus Movement in Katmai NP&P						
	Average Change (in m) from 1951-1987; Second number is average annual rate of change (m/yr)		Average Change (in m) from 1987-2000; Second number is average annual rate of change (m/yr)		Average Change (in m) from 1951-2000; Second number is average annual rate of change (m/yr)	
North and west flowing (Interior) *	-647	-18	-243	-19	-890	-18
South and East Flowing (Coastal) **	-706	-20	-116	-9	-822	-17

* data based on 9 northwest flowing glacier; ** data based on 11 southeast flowing glaciers

Kenai Fjords National Park															
	Glacier Extent, sq km			Change in Glacier Extent, sq km (total | annual rate)						% Change in Glacier Extent (total | annual rate)					
Glacier Area	1974	1987	2000	1974 to 1986		1986 to 2000		1974 to 2000		1974 to 1986		1986 to 2000		1974 to 2000	
Harding Icefield and surrounding glaciers	2043	1935	1903	-108	-9.0	-32.3	-2.3	-140.7	-5.4	-5.3%	-0.4%	-1.7%	-0.1%	-6.9%	-0.3%
Grewingk Yalik Glacier Complex	514	445	424	-69	-5.8	-20.5	-1.5	-89.5	-3.4	-13.4%	-1.1%	-4.6%	-0.3%	-17.4%	-0.7%
	2557	2380	2327	-177	-14.8	-52.8	-3.8	-230.2	-8.9	-6.9%	-0.6%	-2.2%	-0.2%	-9.0%	-0.3%

ATTACHMENT 3

TERMINUS POSITION MEASUREMENTS

Methodology

The terminus "position" can be measured at various points along the terminus of the glacier. Changes in the terminus positions and rates of recession are approximate because they are highly dependent on the exact spot on the terminus that was selected to make the measurement. For this protocol, a standard method was developed to select a point on a glacier terminus for each terminus measurement. First, a down-valley vector parallel to the direction of glacier flow was determined for each glacier terminus to be measured. Then the farthest down-valley point on the terminus was identified and a line was projected from this point, and then a line projected normal to the down-valley flow vector was drawn. The result is a series of parallel lines intersecting the down-valley flow vector, see Figure 1. The distance between these parallel lines is the distance assigned to the terminus movement. Change in terminus position was determined using ArcGIS software.

This analysis shows rates and trends of glacier terminus movement, and also identifies which glaciers are most active. The 1951/1952 terminus positions were determined from the USGS 1:63,360 quadrangle maps produced from high quality aerial photography (approximately 1:40,000). Terminus positions were determined using Landsat imagery from 1986, 1987, 2000 and 2006. A 2005 Ikonos image was used to map 2005 terminus positions (KEFJ only).

Kenai Fjords National Park

The terminus positions were mapped for 27 glaciers emanating from the Harding Icefield and the Grewingk-Yalik Glacier Complex, Figure 2; 10 of these glaciers terminate within the KEFJ. Figure 2 identifies these glaciers on a Landsat image (2000) by name (or alpha code) which corresponds with Table 1.

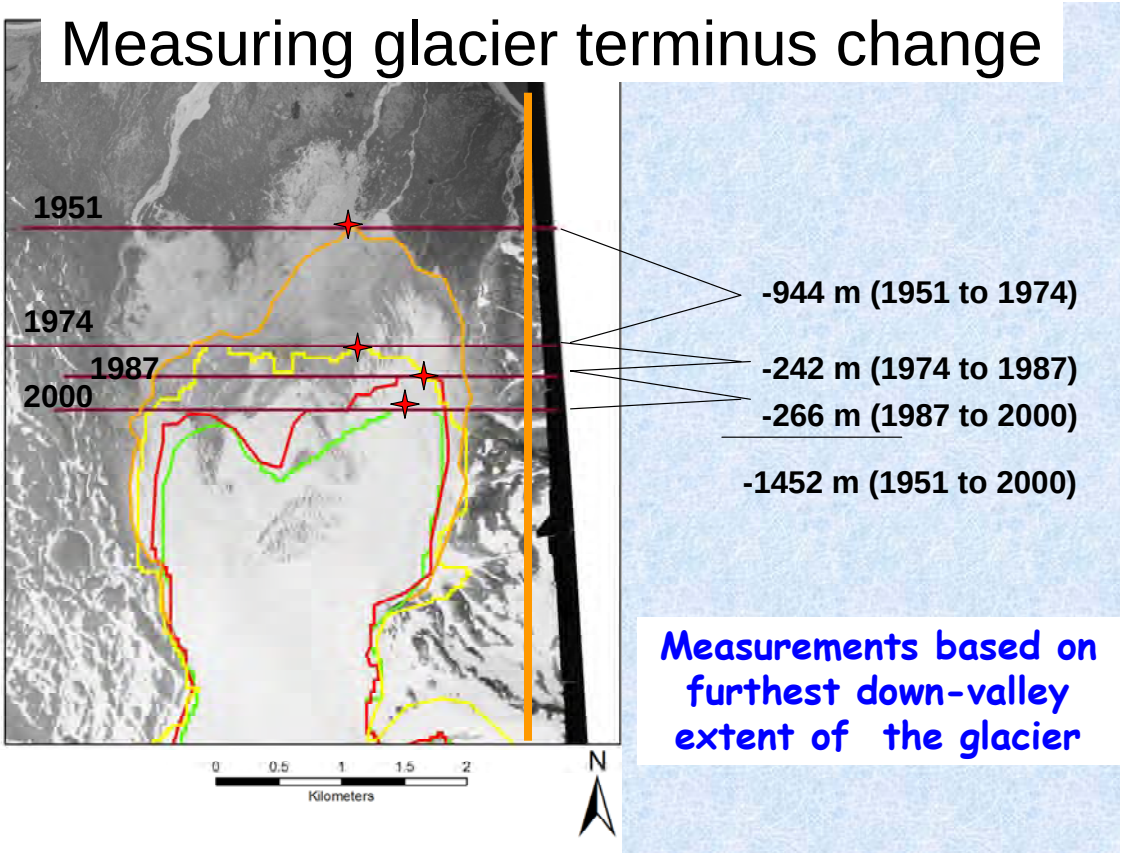

Figure 2. Measurement of glacier terminus position. Vertical orange line is parallel to the direction of glacier flow.

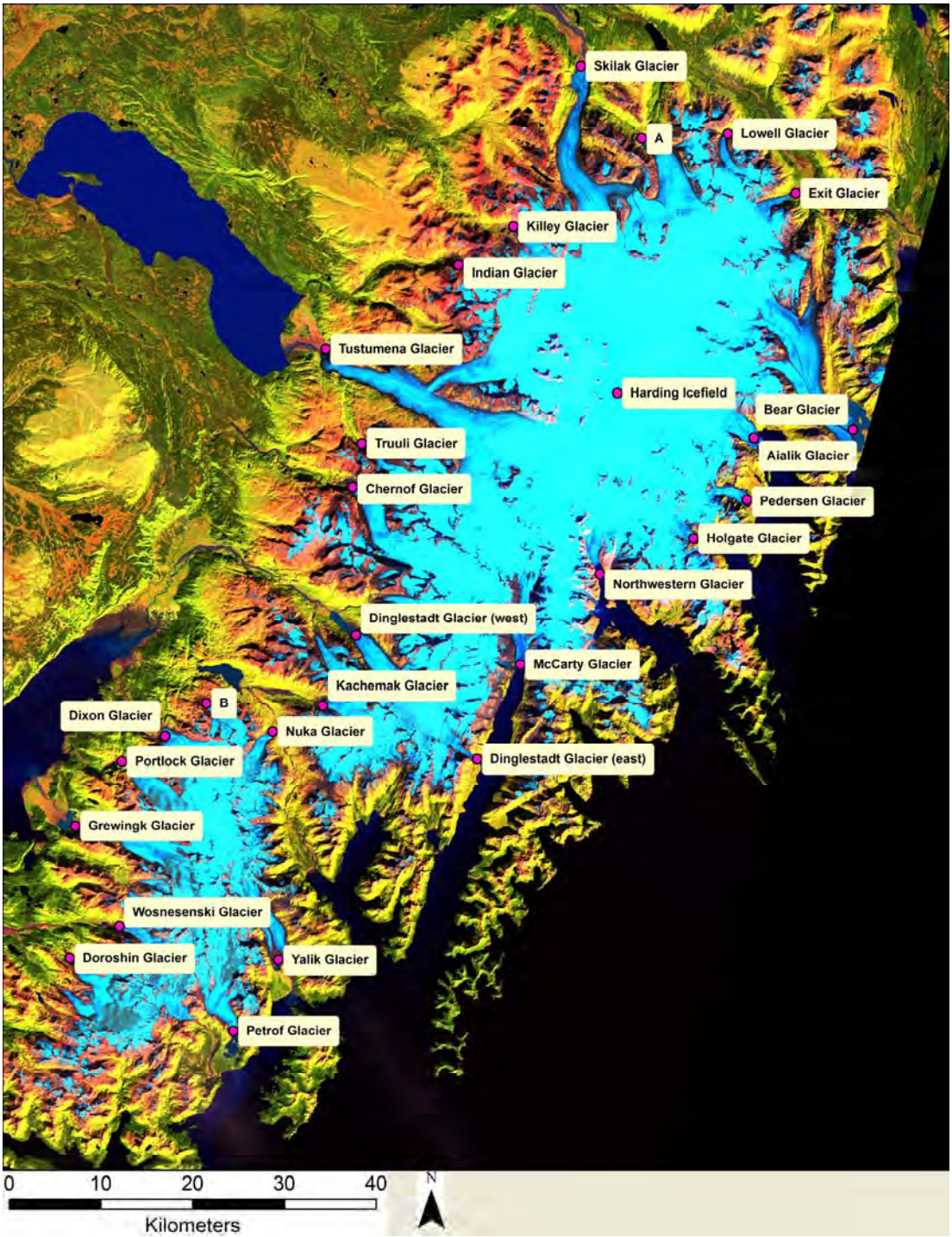

Figure 2. This is a true-color September 12, 1986, TM Landsat-5 image of the glaciated portion of KEFJ. The glacier names in this Figure 1 identify which glacier termini were measured and correspond to data presented in Table 1.

Glacier Terminus Movement in KEFJ - Sample Table

Glacier Name	Change (in m) from 1950(51) - 1986; Second number is average annual rate of change (in m/yr)		Change (in m) from 1950(51) - 2000; Second number is average annual rate of change (in m/yr)		Change (in m) from 1950(51) - 2005(06); Second number is average annual rate of change (in m/yr)		Change (in m) from 1986 - 2000; Second number is average annual rate of change (in m/yr)		Change (in m) from 1986 - 2005(06); Second number is average annual rate of change (in m/yr)		Change (in m) from 2000 - 2005(06); Second number is average annual rate of change (in m/yr)	
Lowell	-741	-21	-1375	-28	-1505	-28	-634	-45	-764	-40	-130	-26
A	-586	-17	-906	-18	-1055	-19	-320	-23	-469	-23	-149	-25
Skilak	-2267	-65	-4053	-83	-4032	-73	-1786	-128	-1765	-88	21	4
Killey	-798	-23	-1229	-25	-1589	-29	-431	-31	-791	-40	-360	-60
Indian	-692	-20	-973	-20	-1257	-23	-281	-20	-565	-28	-284	-47
Tustumena	-324	-9	-712	-15	-744	-14	-388	-28	-420	-21	-32	-5
Truuli	-1065	-30	-971	-20	-1118	-20	94	7	-53	-3	-147	-25
Chernof	-1366	-39	-1461	-30	-1914	-35	-95	-7	-548	-27	-453	-76
Dinglestadt (West)	-2823	-81	-3052	-62	-3408	-62	-229	-16	-585	-29	-356	-59
Kachemak	-801	-23	-989	-20	-1145	-21	-188	-13	-344	-17	-156	-26
Nuka	-226	-6	-189	-4	-342	-6	37	3	-116	-6	-153	-26
B	-728	-21	-997	-20	-1115	-20	-269	-19	-387	-19	-118	-20
Dixon	-422	-12	-589	-12	-746	-14	-167	-12	-324	-16	-157	-26
Portlock	-1188	-34	-1322	-27	-1563	-28	-134	-10	-375	-19	-241	-40
Grewingk	-1350	-39	-2298	-47	-2502	-45	-948	-68	-1152	-58	-204	-34
Wosnesenski	-1268	-36	-1436	-29	-1982	-36	-168	-12	-714	-36	-546	-91
Doroshin	-751	-21	-1495	-31	-1644	-30	-744	-53	-893	-45	-149	-25
Petrof	-1261	-36	-1576	-32	-1696	-31	-315	-23	-435	-22	-120	-20
Yalik	-1057	-30	-1854	-38	-2160	-40	-797	-57	-1103	-58	-306	-61
Dinglestadt (East)	-347	-10	-446	-9	-521	-10	-99	-7	-174	-9	-75	-15
McCarty	-1599	-46	-1730	-35	-2248	-42	-131	-9	-649	-34	-518	-104
Northwestern	-5198	-149	-6553	-134	-6367	-118	-1355	-97	-1169	-62	186	37
Holgate	-245	-7	-349	-7	-359	-7	-104	-7	-114	-6	-10	-2
Pederson	-706	-20	-860	-18	-1140	-21	-154	-11	-434	-23	-280	-56
Aialik	186	5	183	4	-105	-2	-3	0	-291	-15	-288	-58
Bear	-158	-5	-1123	-23	-2968	-55	-965	-69	-2810	-148	-1845	-369
Exit	-488	-14	-481	-10	-621	-12	7	1	-133	-7	-140	-28
Average Rate of Terminus Change (m/yr)	**-1047.0**	**-29.9**	**-1438.4**	**-29.4**	**-1698.0**	**-31.1**	**-391.4**	**-28.0**	**-651.0**	**-33.3**	**-259.6**	**-47.5**
North and West flowing (Interior)	-993.6	-28.4	-1362.7	-27.8	-1571.2	-28.6	-369.1	-26.4	-577.7	-29.0	-208.6	-35.3
South and East Flowing (Coastal)	-1153.9	-33.0	-1589.8	-32.4	-1951.6	-36.1	-435.9	-31.1	-797.7	-41.9	-361.8	-71.9

Table 1. Glacier Terminus Movement in KEFJ.

Glacier Extent Protocol
Southwest Alaska Network

Standard Operating Procedure (SOP) # 9

Changes to SOP

Version 1.0 (May, 2009)

Revision History Log:

Previous Version #	*Revision Date*	*Author*	*Changes Made*	*Reason for Change*	*New Version #*

This Standard Operating Procedure outlines the documentation of changes to the protocol narrative and accompanying SOPs. Anyone editing the protocol narrative or any one of the SOPs must follow these procedures, as indicated by Oakley et al. (2003).

Revision Procedures:

1. All edits will require review for clarity and technical soundness. Small changes or additions to existing methods will be reviewed by SWAN staff. However, if a complete change in methods becomes necessary, an outside review will be required. Regional and National staff of the National Park Service with expertise in remote sensing and data analysis, and/or external specialists, will be utilized as reviewers.

2. Edits to the protocol will be tracked in the Revision History Log that accompanies the protocol narrative and each SOP. Version numbers assigned to each edited draft should reflect the magnitude of changes therein: major changes will be designated by whole number increases (e.g., Version 1.0 to Version 2.0, etc.) and minor changes by tenths (e.g., Version 1.1 to Version 1.2, etc.). With each round of changes to the protocol narrative or SOPs, the

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following information should be recorded in the associated Revision History Log: the previous version number, new version number, date of revision, author of the revision, paragraph(s) and page(s) where changes appear, and the rationale for each change.

3. The Data Manager must be informed regarding changes to the protocol narrative or SOP so that the new version number can be incorporated in the metadata of the project database. The database may have to be edited by the Data Manager to accompany changes in the protocol narrative and SOPs.

4. The Data Manager will post new versions of the protocol on the internet and forward copies to all individuals known to have a previous version.

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