MONITORING CHANGE IN GLACIER EXTENT AT KENAI FJORDS NP AND KATMAI NPP USING SATELLITE IMAGERY

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Abstract

Glaciers have experienced measurable recession in Katmai National Park and Preserve and Kenai Fjords National Park largely in response to regional climate warming. Glacier-extent mapping using Landsat satellite imagery indicates a glacier ice loss of 75 sq km (7.7%) in Katmai NPP and a loss of 52 sq km (2.2%) in Kenai Fjords NP and the adjacent Kenai National Wildlife Refuge and Kachemak Bay State Park between 1986/87 and 2000.

Introduction

Glaciers dominate the landscape in Katmai NPP and Kenai Fjords NP. Most of Alaska's glaciers have been experiencing net recession and thinning since the end of the Little Ice Age (~1850). Because glaciers cover many hundreds of sq km in these parks, even modest changes to this landcover type will influence terrestrial and aquatic plant and animal communities.

Aside from the USGS topographic maps (circa 1950s), very little if any glacier mapping had occurred in these parks until the National Park Service, in partnership with NASA-Goddard Space Flight Center, initiated a project to map glacier extent on a park-wide basis for Katmai NPP, Kenai Fjords NP and Lake Clark NPP using Landsat satellite imagery on a decadal time frame.

Using Landsat Multispectral Scanner (MSS), Thematic Mapper (TM) and Enhanced Thematic Mapper Plus (ETM+) imagery, mapping of glacier margins has been completed in Katmai NPP and Kenai Fjords NP for the years 1974, 1986/87 and 2000. Mapping efforts in Lake Clark NPP are ongoing.

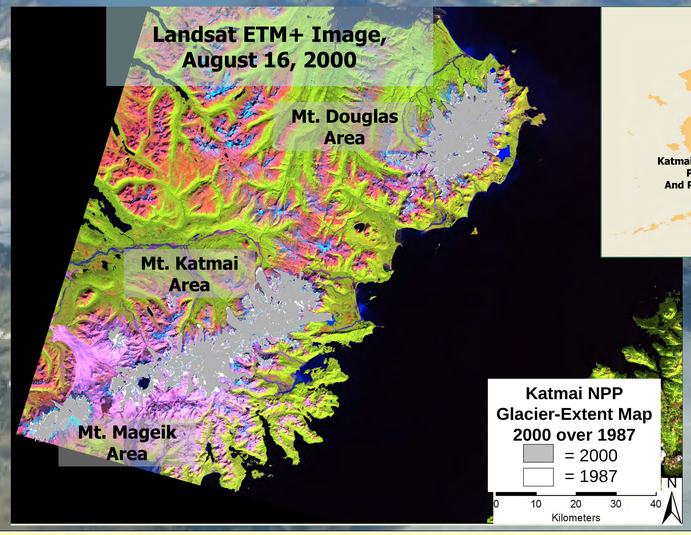
We also used USGS black and white aerial photographs from the 1950s to map glacier terminus positions of selected glaciers in Katmai NPP and Kenai Fjords NP. This allows us to evaluate how individual termini have changed since the 1950s when compared with more recent satellite-derived measurements.

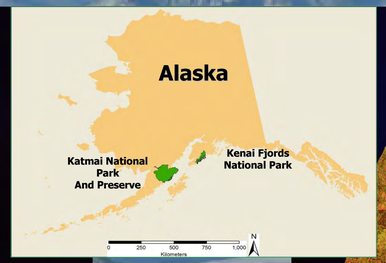
Methodology

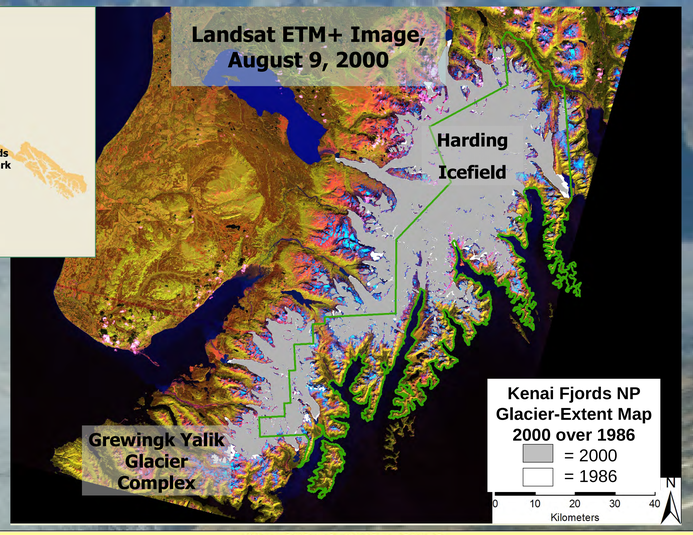
Cloud-free, late-season Landsat imagery was obtained from the EROS Data Center in Sioux Falls, South Dakota. The orthorectified satellite imagery was classified to separate snow and glacier ice from surrounding terrain features using image processing software as described in detail in Giffen, et al., in press. Two different band ratios were used with varying success in the classification process: Normalized Difference Snow Index or NDSI = (TM2-TM5)/(TM2+TM5), and TM3/TM5. Threshold values were defined for classifying the image. The classification was further refined in a sieving process to remove small, isolated snowfields that were confused with glacier ice. The resultant raster classifications were exported as polygon shapefiles.

Automated classification techniques resulted in many areas of misclassification, particularly in areas where moraine and/or volcanic ash cover the ice. Thus, shapefiles produced in the classification process required extensive editing in a GIS edit session to increase the accuracy of the glacier-extent mapping.

Clean glacier margins can be mapped to an accuracy of ±40 m when using TM or ETM+ (Hall et al., 2003). Landsat image registration error (±1 pixel or 30 meters for TM and ETM+) in combination with the imagery resolution contributes to this error.





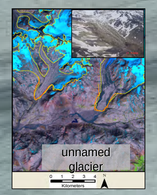


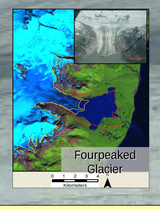
Katmai National Park and Preserve

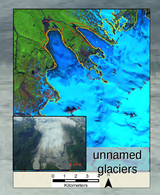
Glacier Area	Glacier Extent, sq km 1974	1987	2000	Change in Glacier Extent, sq km (total | annual rate) 1974 to 1987		1987 to 2000		1974 to 2000		% Change in Glacier Extent (total | annual rate) 1974 to 1987		1987 to 2000		1974 to 2000	
Mt Douglas Area	377	348	330	-30	-2.3	-17.6	-1.4	-47.2	-1.8	-7.8%	-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

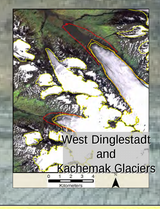
Glacier Area	Glacier Extent, sq km 1974	1987	2000	Change in Glacier Extent, sq km (total | annual rate) 1974 to 1986		1986 to 2000		1974 to 2000		% Change in Glacier Extent (total | annual rate) 1974 to 1986		1986 to 2000		1974 to 2000	
Harding Icefield and surrounding glaciers	2043	1935	1903	-108	-9.0	-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%

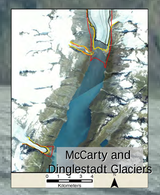






Red = 1950
Orange = 1986/87
Yellow = 2000
Black = 2005





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

Glacier Terminus Movement in Kenai Fjords NP and Surrounding Glaciers

	Average Change (in m) from 1950(51) - 1986; Second number is average annual rate of change (in m/yr)		Average Change (in m) from 1986 - 2000; Second number is average annual rate of change (in m/yr)		Average Change (in m) from 1986 - 2005(06); Second number is average annual rate of change (in m/yr)		Average Change (in m) from 2000 - 2005(06); Second number is average annual rate of change (in m/yr)		Average Change (in m) from 1950(51) - 2000; Second number is average annual rate of change (in m/yr)		Average Change (in m) from 1950(51) - 2005(06); Second number is average annual rate of change (in m/yr)	
North and West flowing (Interior)**	-994	-28	-369	-26	-578	-29	-209	-35	-1363	-28	-1571	-29
South and East Flowing (Coastal)***	-1154	-33	-436	-31	-798	-42	-362	-72	-1590	-32	-1952	-36

** data based on 18 northwest flowing glacier; *** data based on 9 southeast flowing glaciers

Challenges to Automated Classification Techniques

To enhance the accuracy and repeatability of the glacier mapping effort, late-season, cloud-free imagery is essential to minimize the amount of snow in the imagery. For Katmai NPP and Kenai Fjords NP, this means using mid-August to mid-September imagery when available, however fresh snow can fall anytime of the year in these parks, especially at higher elevations. If possible, imagery with large amounts of persistent snowpack and/or fresh snowfall should be avoided.

There are several substantial challenges to automated classification of snow and ice. These are: the existence of numerous small, isolated snowfields that have a spectral signature identical to glacier ice; shadows in areas of extreme topography; moraine debris and volcanic ash on the glacier surface, lingering snowpack, early snowfall and differences in imagery resolution. Each of these characteristics causes errors in the automated classification process.

Conclusions

Glacier-extent mapping clearly shows a net reduction of glacier extent in both Kenai Fjords NP and Katmai NPP over the study period (1974 through 2000) (Giffen et al., in press). On a percentage basis, glacier extent in Katmai NPP shows higher losses than observed at Kenai Fjords NP. This is due, in part, to a persistent lingering snowpack observed in the 1974 and 1987 Landsat imagey of Katmai NPP as compared to more extensive snowmelt observed in the 2000 image. In comparison, Landsat images used in the Kenai Fjords NP study (1974, 1986 and 2000) show more advanced snowmelt across the images. This verifies the absolute necessity of using only late season imagery for glacier-extent mapping.

Most glacier termini in Kenai Fjords NP and Katmai NPP exhibited recession between 1986 and 2000, some more dramatic than others. The majority of glaciers in these parks can be described as northwest flowing or southeast flowing glaciers. Southeast flowing glaciers in Kenai Fjords NP display markedly higher rates of recession than do southeast flowing glaciers in Katmai NPP over the study period. Northwest flowing glaciers in Kenai Fjords NP also exhibit higher rates of recession than do northwest flowing glaciers in Katmai NPP over the study period.

The result of this careful mapping study is that glacier extent changes in Kenai Fjords NP and Katmai NPP have been documented to the greatest extent possible given the limitations of the satellite mapping techniques. As a result, it will be possible to conduct future studies of glacier ice extent in these parks with the highest level of accuracy possible. The shapefiles developed for this mapping effort will be provided to the Global Land Ice Measurements from Space (GLIMS) mapping project which is a NASA-funded project that is compiling a database of global glacier ice extent.

References

Giffen, B.A., D.K. Hall and J.Y.L. Chien, in press: Glaciers of Kenai Fjords National Park and Katmai National Park and Preserve, J. Kargel (ed.) Title of book has not yet been decided. Praxis-Springer

Hall, D.K., K.J. Bayr, W. Schöner, R.A. Bindschadler and J.Y.L. Chien, 2003:Consideration of the errors inherent in mapping historical glacier positions in Austria from the ground and space (1893-2001), *Remote Sensing of Environment*, 86:566-577.

Background Image: Unnamed glacier in the Chigmit Mountains, Lake Clark National Park and Preserve