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EVALUATE ERTS IMAGERY FOR MAPPING AND DETECTION OF CHANGES OF  
SNOWCOVER ON LAND AND ON GLACIERS

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16. Abstract  A new procedure to determine snowcovered areas has been devised, <del>using the SRI ESIAC</del> . Aside from problems in heavily forested areas this method shows promise in predicting snowmelt runoff from mountain areas and will also assist in energy balance modeling of large snowfields. Snowcover results in this study compare favorably with measurements made by high-altitude aircraft photography.  Changes in snowcover in areas as small as 3 x 5 km can be determined from ERTS images by both optical and electronic methods. Snowcover changes determined by these two methods in the experimental South Cascade Glacier Basin were verified by field mapping.  Image enhancement techniques on ERTS images of large Alaskan glaciers (i.e., the Hubbard, Yentna, and Kahiltna) have given new insights into the large-scale structures and flow dynamics of these potentially hazardous glaciers. The Hubbard Glacier, in particular, is one which poses a threat to man and should be monitored for future changes.			
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Type II Progress Report  
ERTS-1

a. Title: Evaluate ERTS Imagery for Mapping and Detection of Changes of Snowcover on Land and on Glaciers.

ERTS-A Proposal No.: SR 342-7

b. GSFC ID No. of P.I.: IN 045

c. Statement and explanation of any problems that are impeding the progress of the investigation:

No major problems. Minor problems include long delays in receiving data following Data Requests, some imagery too dark for analysis, difficulty with radiometric calibration of images, and no word yet received on status of Data Analysis Plan.

Snowlines were drawn for South Cascade Glacier Basin (3 x 5 km) for three cycles using greatly enlarged ERTS images. This basin was chosen because a large amount of ground truth and aircraft data exist. This was a productive study of the relation of ERTS imagery to ground truth, especially in areas of partial snowcover with patches smaller than those resolvable from ERTS imagery.

Robert M. Krimmel spent three days at Stanford Research Institute working with William E. Evans and others on the Electronic Image Analysis Console (ESIAC). The purpose of this visit was to give another member of our group direct experience with the ESIAC, to attempt several new experiments, and to clear up some questions between the investigators of Project 342-7 and Project 342-B.

The most promising experiment was to directly compare sequential frames of snowline data. This was tried using color transparencies of an oblique, ground-based time-lapse sequence. By playing a positive of one date against a negative of another date, areas that were first snow-covered and later free of snow are highlighted. The highlighted areas are easily masked, and the area measured. Since using the ground views SRI personnel were asked to use ERTS images of Mount Rainier in this way to measure changes in snowcovered (and shadowed) area which could then be compared with differences between direct measurements of snow-covered area on different dates.

The ESIAC was also used to form a binary mask of the snowlines in the South Cascade Glacier Basin as a direct comparison of results using optical methods versus electronic methods.

Frames of Mount Rainier and Thunder Creek areas, previously analyzed by SRI, were recalled and Krimmel (an experienced glaciologist) formed video masks independently of SRI influence confirming the negligible operator-bias in the techniques evolved by SRI.

Electronic image enhancement techniques were tried by Krimmel on several glacier images to investigate certain problems in our current understanding of glacier flow, glacier surges, and the potentially hazardous advance of Hubbard Glacier.

Considerable effort was devoted by SRI personnel to generating curves of apparent snowcovered area versus gray scale value for specific drainage basins. These curves were then studied by comparison with results from planimetering snowlines on high-altitude aircraft images. Aircraft snowline data were also transferred to enlarged ERTS images for study. As a result the discrepancies between aircraft and ERTS data have been largely resolved and standardized analysis techniques have been evolved.

Average snowline altitudes were measured over about 800 5-km squares of 27 September images in the Anchorage area and the results contoured. The concept of an equivalent snowline altitude (ESA) was developed and many examples calculated. A hydrologic analysis was made of the changing snowcover of the Thunder Creek drainage basin. Papers were prepared for the 5-9 March ERTS-1 Symposium and for the 23-25 May Symposium on Approaches to Earth Survey Problems Through the Use of Space Techniques, COSPAR, Konstanz, Germany.

Attention next period will be concentrated on analysis of the 1973 melt season data, utilizing high-altitude aircraft flights scheduled to coincide with clear weather ERTS passes, and comparison of results from this abnormally low snow year with results from the 1972 abnormally high snow year. Special attention will be given to the problem of locating the snowline in forested terrain. Quantitative results will be produced more rapidly now that analysis procedures have been developed. The date-to-date differencing technique will be further studied and the accuracy of this method evaluated. Also, glacier surges and other features of interest will be monitored and studied.

e. Discussion of significant scientific results and their relationship to practical applications or operational problems including estimates of the cost benefits of any significant results:

A procedure to derive snowcovered area values for specific drainage basins has been devised using the SRI ESIAC. This technique has been repeatedly checked and calibrated with independent data; however, problems still exist when snowcover exists in forested terrain. Sample results for basins in the North Cascades, Washington, are given in Table 1.

Table 1.--Area of snow in specific drainage basins, North Cascades, Washington, 1972

No.	Drainage basin Name	Snowcovered area, in km <sup>2</sup> , on given date			
		29 July	2 Sept.	8 Oct.	14 Nov.
1755	Thunder Cr.	105	59	40	--
1825	Cascade R.	139	66	42	--
1434	South Fork Snoqualmie R.	--	.7	.4	12*
1413+	North plus Middle Fork	--	27	14	29
1420	Snoqualmie R.	--	27	18	52
1330	South Fork Skykomish R.	--	27	18	52

\*Value slightly uncertain because of partial cloud cover.

These results supersede some preliminary uncalibrated values reported previously. In addition, the snowcover of the Mount Rainier areas has been measured over a longer sequence, using several different techniques, as given in Table 2.

Table 2.--Area of snowcover, Mount Rainier, Washington, 2 June 1972 to 11 February 1973.

Date	Snowcovered area, in km <sup>2</sup> , on given date		
	From aircraft	From ERTS	
		By direct measurement	By date-to-date subtraction*
2 June	760		
29 July		339+ **	293
10 August	147		
2 September	120	119+ **	168
8 October		108	96
14 November		184	182
2 December		206	232
6 January		305	
21 January		302	
11 February		431	

\* Date-to-date differences added to 29 July and 2 September direct measurement values and then averaged to obtain a total area value.

\*\* Shadowed areas, believed to be mostly snowcovered, not evaluated.

Results such as these should prove to be very useful in predicting inflow to reservoirs (using the snow depletion curve method) and to determine energy balance and snowmelt over regional areas for both water management and scientific purposes.

A new concept was developed which has proven to be useful in interpolating, extrapolating, or generalizing mountain snowcover data: the equivalent snowline altitude (ESA). The area/altitude function of most drainage basins or mountain massifs is known or can be easily measured. The ESA is then defined as that altitude above which the area of a basin or mountain is equal to the area of snowcover. Snowcovered area can be measured quickly and easily, and from this the ESA is determined. The ESA can be used directly in numerical modelling of regional heat balances, or it can be used to derive snowcovered area data from nearby basins which are cloud covered or not imaged. First introduced at the ERTS-1 Symposium in March 1973, it is already in use by several other ERTS investigators.

In spite of the rather crude resolution of ERTS imagery, it was found that snowcovered area could be measured in very small, experimental drainage basins. For instance, snowcover data have been obtained for several dates both optically (zoom-transfer scope) and electronically (ESIAC) for the South Cascade Glacier Basin, 3 km wide by 5 km long. These results were verified by field mapping.

Study of time-sequence and individual ERTS images of nine glaciers using image enhancement techniques has revealed much new information. A large medial "structure" in the accumulation area of Hubbard Glacier was discovered for the first time in spite of detailed maps and abundant aerial photography. Knowledge of this structure adds to our understanding of the drainage basin and dynamics of this huge glacier which threatens to close off Russell Fiord and endanger the salmon canning industry near Yakutat, Alaska.

Documentation of the motion of the surging Yentna Glacier was continued during the 1972-73 winter using ERTS imagery. Perhaps the most interesting discovery of this project is that of a periodically repeating series of steps or waves on the nearby Kahiltna Glacier, which had been thought to be a nonsurging glacier. These enigmatic features were first discovered by image enhancement procedures using the ESIAC.

f. A listing of published articles and/or papers, pre-prints, in-house reports, abstracts of talks, that were released during the reporting period:

Paper "Evaluation of ERTS imagery for mapping and detection of changes of snowcover on land and on glaciers," was read at ERTS-1 Symposium, Greenbelt, Maryland, 5-8 March.

Papers "New ways to monitor the mass and areal extent of snowcover" and "Applications of ERTS imagery to snow and glacier hydrology" were invited for Symposium on Approaches to Earth Survey Problems Through the Use of Space Techniques, COSPAR, Konstanz, Germany, 23-25 May; papers have been submitted for publication in the proceedings.

g. Recommendation concerning practical changes in operations, additional investigative effort, correlation of effort and/or results as related to a maximum utilization of the ERTS system:

Urgently need additional U-2 overflights and ERTS imagery during summer of 1973 in order to have useful time sequence through a complete melt season.

h. A listing by date of any changes in Standing Order Forms:

7 November 1972.

i. ERTS Image Description forms:

In preparation.

j. Listing by date of any changed Data Request forms submitted to Goddard Space Flight Center/NDPF during the reporting period:

16 January 1973  
23 February 1973  
18 April 1973

k. Status of Data Collection Platforms:

N/A