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BREAK-UP CHARACTERISTICS OF THE CHENA RIVER WATERSHED, CENTRAL ALASKA

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ABSTRACT

The snow melt for a small watershed (5130 km^2) in Central Alaska was successfully monitored with ERTS imagery. Aerial photography was used as supporting data for periods without satellite coverage. Comparison both with actual measurements and with a computer model showed good agreement.

INTRODUCTION

Of the many water resource problems faced by the State of Alaska, floods are the most widespread; the damage is large in small population centers, and statewide the floods cause annually a great amount of damage. The art of the prediction of floods, either on a day-to-day operational basis or as a part of a long term study, has advanced to a rather high state of knowledge. There are available a wide number of computer oriented, graphical, analytical, and empirical methods which are used successfully with experience.

However, regardless of the degree of knowledge, the engineer or forecaster is limited by the completeness of the measured input. In the case of rainfall, the provision of adequate input data, although not always easy, is quite straightforward. Snowmelt, on the other hand, provides an input, to the runoff system which is, in itself, the output of a rather complex process as the snowmelt depends on a variety of factors; some of a permanent physiographic nature and others of a more transient environmental nature, (Wendler, 1967). Because of the complexity of the process, snowmelt measurement on a pointwise basis and extrapolation of point measurements to even a relatively small basin become very difficult. This is especially true of the Chena River in particular and Alaska in general, where precipitation gauge densities are extremely small (Searby, 1968).

Because of Alaska's rather severe cold climate the surface hydrology in most areas of the state is only active during four to six months. As a result, the spring snow and ice break-up dominate the cycle and the resulting snowmelt runoff contributes most of the stream flow and causes many of the floods.

Major floods have occurred in the Fairbanks area in 1930, 1937, 1948, 1960, and 1967.

To overcome the shortcomings of conventional point measurements (Snow Surveys, 1973), satellite imagery has been applied (Barnes and Bowley, 1968a,b, 1969; McClain and Baker, 1969). However, up till now the resolution of the satellite imagery was insufficient for small watersheds. The launch of ERTS 1, having a resolution of 100m together with supporting aerial photography has made it possible to monitor the snow melt for much smaller basins such as that of the Chena River (5130 km^2).

DESCRIPTION OF THE CHENA RIVER BASIN

The Chena River Basin lies in the interior of Alaska, about 100 miles (160 km) south of the Arctic Circle. The climate is continental sub-polar, with cold winters and relatively warm summers; the precipitation is relatively low with a long-term annual mean of 11.3 inches (287 mm) (Searby, 1968). The elevation of the basin ranges from very small areas in excess of 5000 ft (1525 m) to 440 ft (134 m), at the confluence of the Chena with the Tanana River (Figure 1). The area is hilly, mostly lying below 2500 ft (760 m) and less

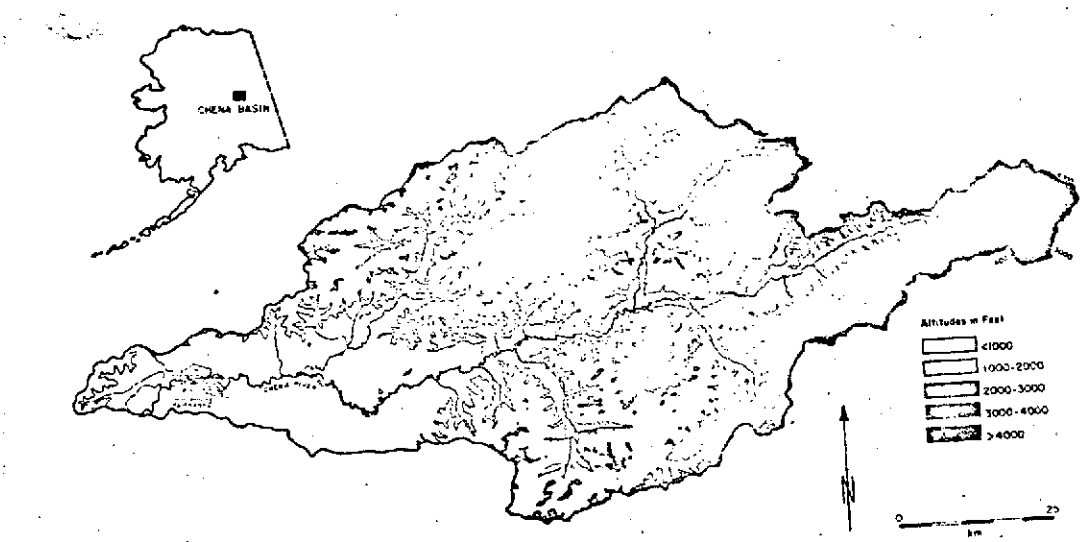

Figure 1. Topographic map with Chena River Basin Boundary outlined.

than 20% has an elevation above this level (Figure 2). The basin has a size of 1980 sq. miles (5130 km^2). Major tributaries of the Chena are the Little Chena River, West, East, and South Forks and Munson Creek. The precipitation increases with altitude, as can be seen from the snow course data (Snow Survey, 1970).

METEOROLOGICAL CONDITIONS DURING BREAK-UP

The climatological data for Fairbanks, the lowest point in the basin, are shown in Figure 3 (NOAA, 1973). On 28 March 1973 the average daily temperature rose above the freezing point for the first time in the season. However, positive temperatures of any longer duration were observed only after 6 April 1973. During 16-27 April a cold spell occurred, with temperatures around the freezing point. After this period the temperature remained above freezing, and most of the melting occurred. The dew point remained below the saturation point for water until 7 May 1973, thus indicating that evap-

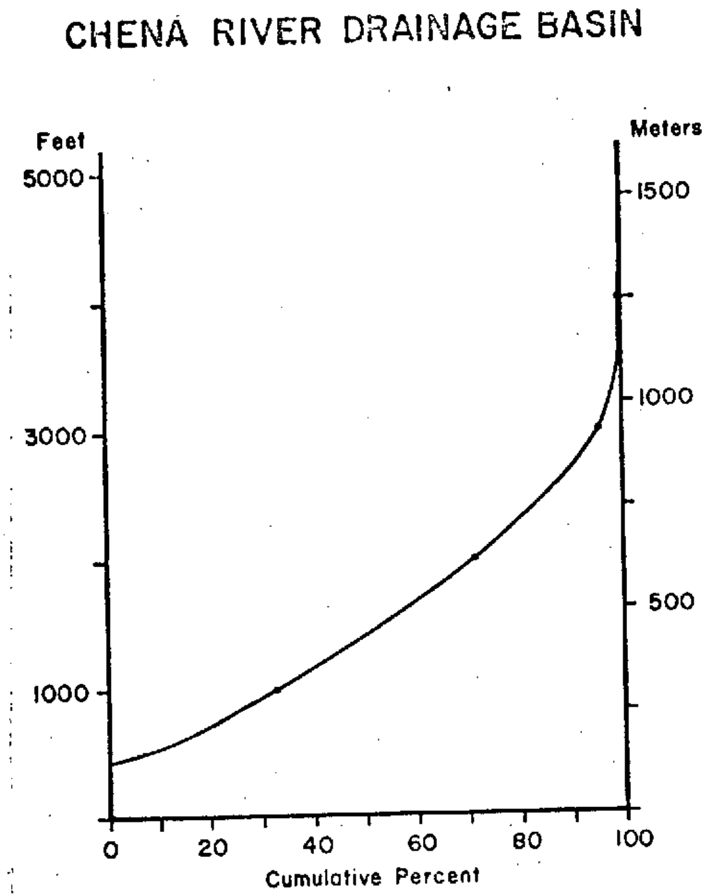

Figure 2. Elevation distribution for the Chena River Basin.

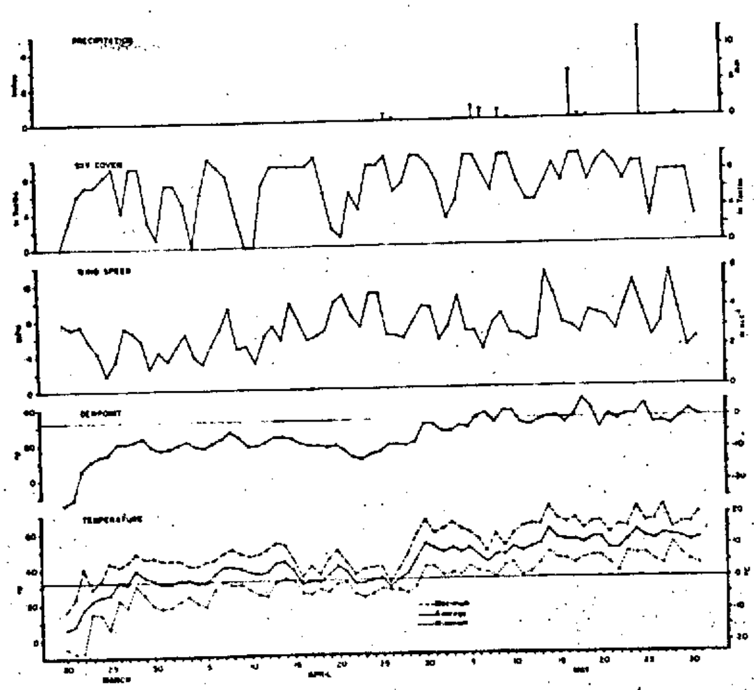

Figure 3. Climatological conditions at Fairbanks (temperature, dew point, wind speed, cloud cover and precipitation) during break-up (20 March to 31 May 1973) on the Chena River.

oration occurred, which is typical for the early part of the break-up (Wendler, 1967). Thereafter, values around the saturation value for melting snow were observed, showing that the condensation balanced the evaporation. The wind speeds were relatively low (around 3 m sec^{-1}), which is typical for the interior of Alaska (Searby, 1968). The cloudiness with a mean of 6/10 was average for the spring period. No appreciable precipitation was observed during the break-up until the latter part of May 1973.

SNOW MELT MODEL

Because of the difficulties of comparing satellite imagery with spot measurements of the snow cover, a snow melt model which had been developed by Carlson and Norton (1973) was used. This model is based on calculation of energy fluxes at the surface and within the snowpack. Cloudiness is used to estimate the radiative fluxes, temperature and wind speed to estimate the sensible heat flux, and dew point and wind speed to calculate the latent heat flux. Also the process of melting at the surface and refreezing at deeper layers in the snow pack is considered. This model is tested against actual measurements for the spring of 1973 (Figure 4). It can be seen that

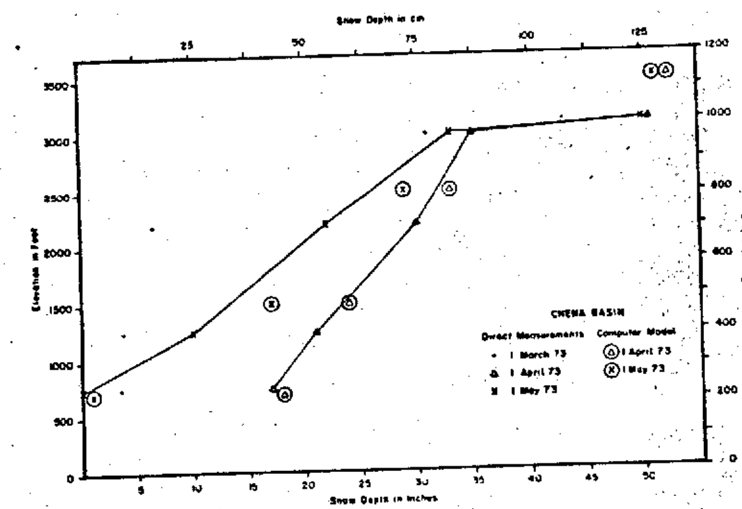

Figure 4. Snow depth - actual measurements and model calculations in relation to altitude for particular times during break-up on the Chena Basin, 1973.

the agreement is very good, especially if one considers the variability of the snow pack for point measurements. Hence, data obtained from this model might be compared directly with the snow cover extent of the basin.

ERTS IMAGERY AND AERIAL PHOTOGRAPHY

Cloudfree ERTS imagery during break-up was obtained on 12 and 30 April and 2 May 1973. Later in May, it was cloudy at the time the satellite passed. Therefore, two aerial flights (height about 12000 ft (3660 m), stereo photography) were carried out on 11 May and 20 May over part of the basin. Altitude lines were transferred from topographic maps onto the photographs with a zoom transfer scope (Bausch and Lomb), and areas were obtained with a planimeter. Patches of snow were found down to the lowest lying areas on north slopes on 11 May, while no snow was found on a slope with southerly exposure below 1250 ft (380 m) (Figure 5). The percentage of snow-covered area

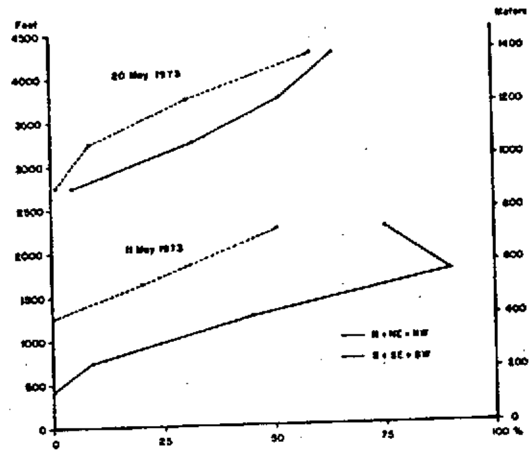

Figure 5. The amount of snow cover in percent as function of altitude for northerly and southerly exposure on two occasions during break-up.

increased with height. A similar percentage cover was attained at heights some 750 ft (230 m) higher on the south slopes than on the north slopes on 11 May and 400 ft higher (120 m) on 20 May. The decrease in snow cover for the greatest altitude range on 11 May 1973 is at first sight astonishing. However, when the photographs are analysed, it can be seen, that it is real. The area photographed did not exceed 2500 ft (780 m), and hence this area represented the top of the hills. As no forest is present on these hill tops and they are thus more freely exposed to the wind, some of the areas were snow free even before the melting started. An example is given in Figure 6. Further, it can be seen from Figure 5, that the snow line ascended about 2000 ft (610 m) in the 9 days from 11 to 20 May 1973. This rapid ascent of the snow line was caused by the high temperature (see Figure 3) during this period.

The Chena Basin was outlined on the ERTS imagery for the three dates, at which pictures were obtained. It was found, that channel 5 (0.5 - 0.6 μm) was the best suited to distinguish the snow cover from snow free areas. An example is given in Figure 7, showing the Chena Basin at two times during break-up. It can be seen, that at the later data, most of the snow in the lower lying areas (compare with Figure 1) has melted. A VP-8 analyser was used to obtain quantitative results. This instrument displays a grey scale in color, which makes it easier for the eye to distinguish different levels. Also, an automatic built in planimeter makes it possible to rapidly measure areas with different snow coverage. Such a task using a hand planimeter is a very time consuming task. Using this instrument the

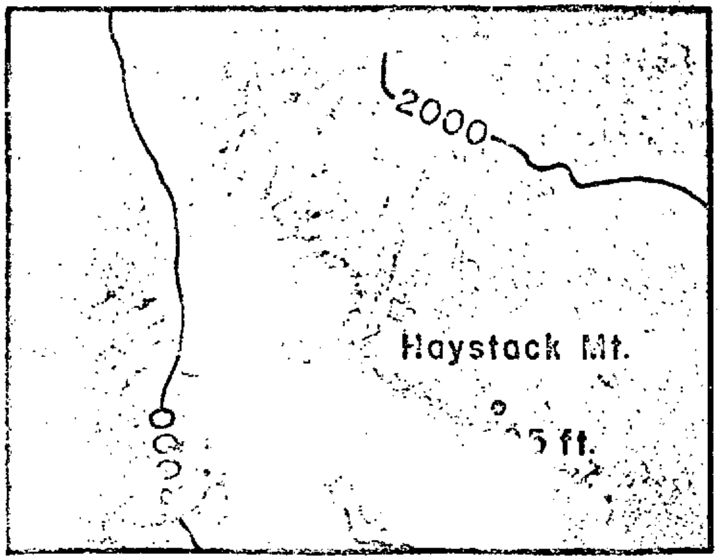

Figure 6. Aerial photography of an area north of Fairbanks. (Note that the southerly and westerly slopes of Haystack Mountain (2525 ft or 770 m) are snow free, but at altitudes below 2000 ft (610 m) snow is observed.

following values were obtained:

Percent of Snow Cover Determined from ERTS Imagery
Chena River Basin
(1980 sq. mi.)

	<50% snowfree or snow patches	>50% broken or continuous snow	
12 April 1973	18	82	%
30 April 1973	28	72	%
2 May 1973	46	54	%

COMPARISON OF THE STAGE OF BREAK-UP

The areal percentage of the basin, which was snow free, could be obtained from both the ERTS imagery and aerial photography. These values are compared with data from the snow melt model, from which the melt could be calculated for various altitude intervals, and by knowing the altitude distribution (Figure 2), the percentage of the area, which was snow free, could be calculated. One can see (Figure 8), that the agreement is very good. To appreciate such an agreement, one should notice, that a snow melt model never reflects nature in every detail, and further, that measurements of the snow cover by satellite or aircraft are hindered by vegetation and the shadowing effects of mountains.

In addition, the amount of discharge, measured in Fairbanks, is shown in Figure 8. This curve is not totally comparable with the other ones, as there is a lag between the time of melting, and the time at which this water arrives in Fairbanks. A lag time of about a week was found, which is probably somewhat longer than might be expected.

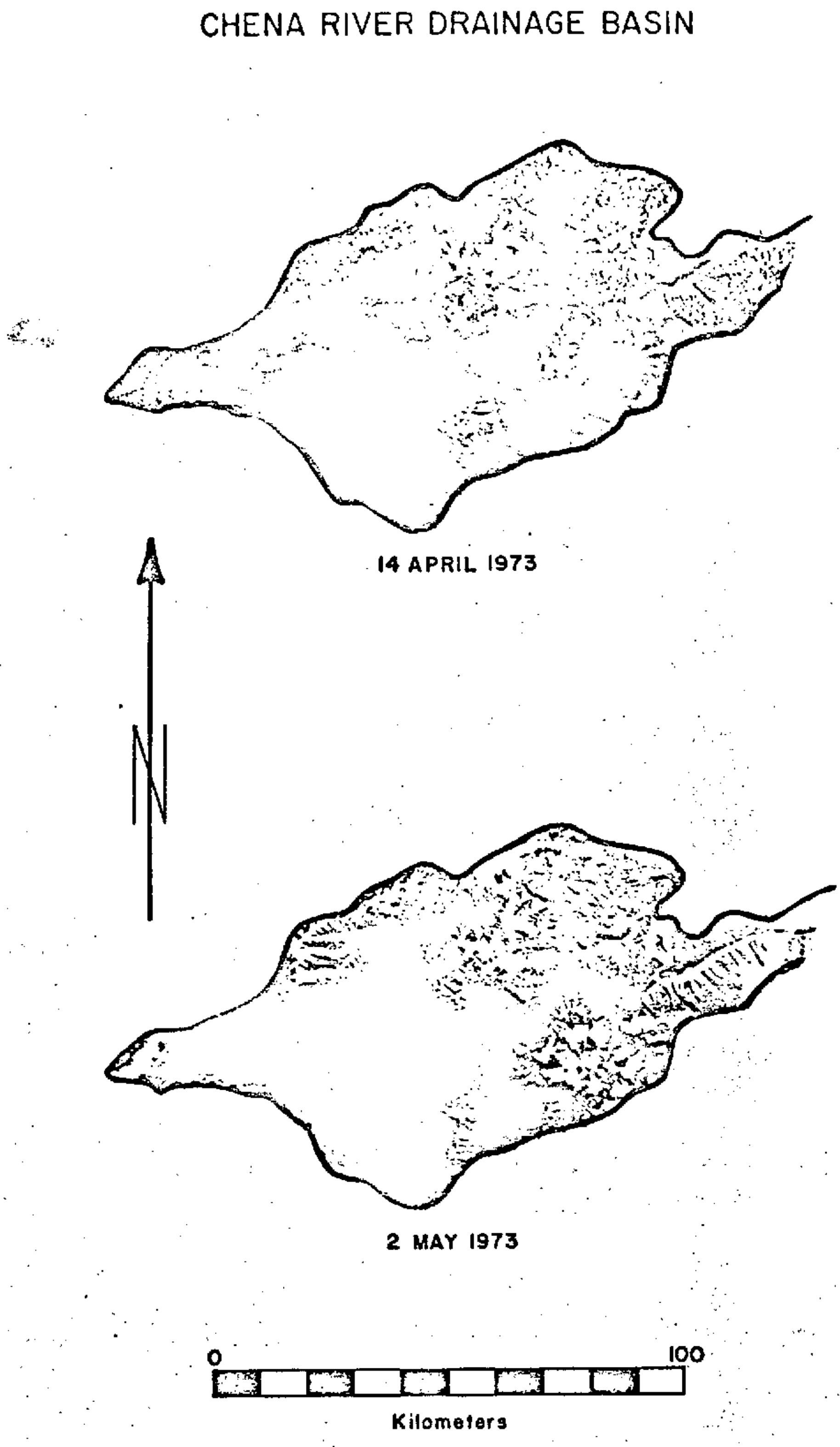

Figure 7. Imagery of the Chena River Basin as seen from ERTS.
7a. 14 April 1973 (Note that most of the area is snow covered.)
7b. 2 May 1973 (Note that the lower lying areas are snow free.)

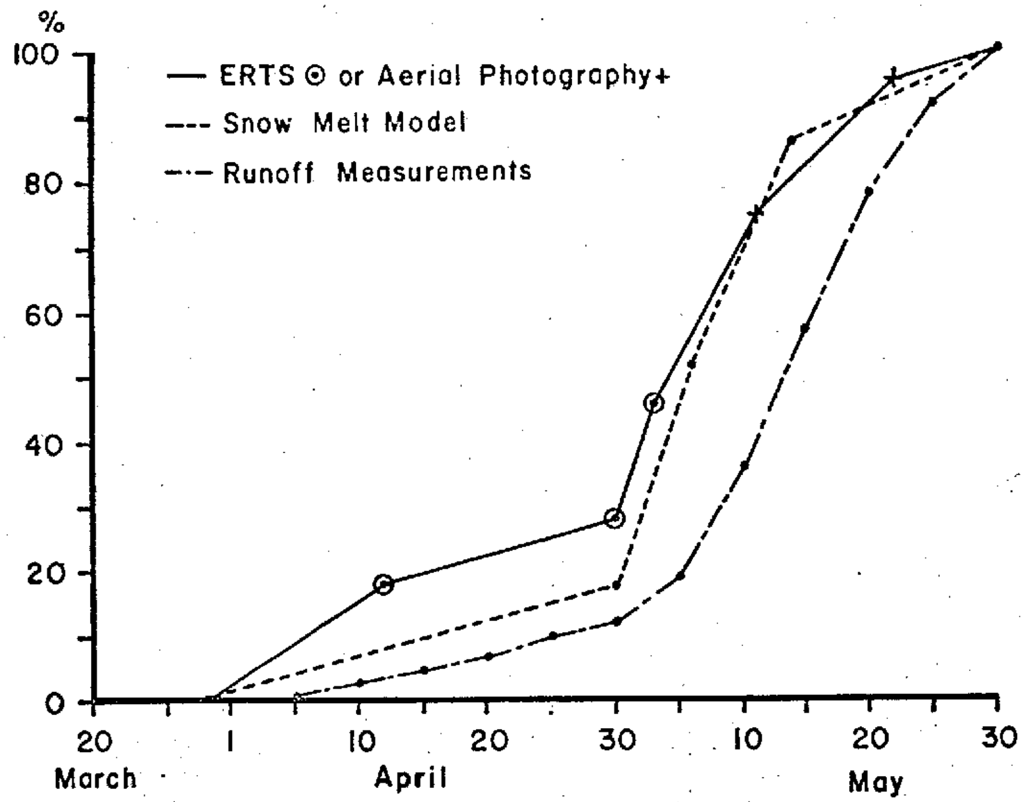

Figure 8. Variation in snow free area with time for the Chena Basin during the break-up of 1973. Values obtained from ERTS and aerial photography, the snow melt model, and direct run off measurements.

CONCLUSION

It has been shown that ERTS imagery can successfully be used to monitor the snow melt in a relatively small watershed. Comparison with actual measurements as well as with a computer model showed good agreement. These same techniques can therefore be used to study the snow melt behavior in watersheds where little or no hydrological or climatological data are presently being collected. Such information will make it possible to draw preliminary conclusions about the most dynamic portion of the hydrologic cycle in the Arctic, namely the spring break-up.

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