NOAA's Hydrology Studies Under the Earth Resources Survey Program

by

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INTRODUCTION

The long-range objective of NOAA's program of hydrology studies is to develop, in-house and through contracts, techniques for comprehensive, repeated, and timely satellite and aircraft information on the areal distribution of hydrologic factors on a local and regional basis, and to assist in the development of applications of this data to operational and research problems in hydrology and meteorology. Most of this research is being performed or technically monitored by researchers in the Environmental Sciences Group (ESG) of NOAA's National Environmental Satellite Service (NESS).

Among the short-range objective of these studies carried out with the support of NASA's Earth Resources Survey Program are:

(1) Obtain more data with a multifrequency (5) microwave system so that the range of soil moisture amounts and types can be extended. Secondly, if data permit, to establish instrument and data specifications for microwave sensing of soil moisture from satellite and aircraft.

(2) Refine the procedures for mapping snow cover that have been developed using satellite and aircraft remote sensor data in the visible spectrum. To begin the evaluation of satellite and aircraft infrared observations for determining their information content with respect to snow cover, ice cover, and water temperature over large lakes (e.g., Lake Ontario).

A few recent results from some of these studies are discussed briefly in the following sections.

SOIL MOISTURE STUDIES

From 10-24 July 1970 measurements of the microwave emission of soil as a function of moisture content were performed under contract with Aerojet General Corporation at the United States Water Conservation Laboratory near Phoenix, Arizona. Measurements of the microwave emission, soil moisture content and soil temperature were acquired along with micrometeorological data as a soil plot was allowed to dry from a flooded condition to as low a moisture content as feasible.

The purpose of these efforts was to perform a systematic study of microwave emission at 21, 6, 2.2 and 0.81 cm wavelengths of soil over a range of moisture conditions. Toward this end, microwave measurements were performed as a function of observational wavelength, antenna viewing angle, and polarization.

All radiometric data have been initially reduced and appear satisfactory in answering some basic hydrologic questions. The warmest radiometric temperatures at all wavelengths occurred for the first and driest test plot. Similarly, the coldest radiometric temperatures occurred for the wettest soil moisture conditions. Temperatures steadily decreased by about 5 deg. K for each percentage point increase in water content of the soil by weight (see Fig. 1).

SNOW COVER STUDIES

Under an earlier contract for developing methods of mapping snow boundaries in mountainous terrain scientists at Allied Research Associates concluded that mountain snow can be reliably identified in satellite photography and that mapping accuracy is as good as, or better, than in flat terrain (Barnes & Bowley, 1969). In an extension of this work, ESSA 3, 5, 7, 9 AVCS pictures, Nimbus III daytime HRIR and IDCS imagery, and Apollo 9 color photographs (hand held camera) over the western mountain states were used to map mountain snow distribution onto working base maps for comparison with aerial snow cover surveys. Climatological and ground survey data summaries were used in evaluating mapping accuracy.

The results of these investigations (Barnes & Bowley, 1970) indicate that of the three regions tested, satellite imagery provided the most reliable measurements of snow extent in the southern Sierras. For typical river basins in this region, snow extent in terms of percentage of basin covered can be determined from satellite photographs to within ± 5% of the aerial-survey measurement (see Fig. 2). In the Kings River Basin, the satellite snow-line elevation was within 500 feet of the aerial-survey snow-line elevation, with the satellite value being higher in 10 of 11 cases analyzed.

In the Upper Columbia Basin satellite snow mapping was less reliable because the region consists of more densely forested mountain ranges, each with a relatively small horizontal snow-cover extent. Furthermore, springtime cloudiness is more prevalent in this region. In the Arizona mountains considerably lesser snow depths than in the other two regions can be mapped because of the sparse vegetation.

In-house, development of the five-day composite minimum brightness (CMB) chart (McClain & Baker, 1969) for delineating major snow boundaries has been extended by examining quantitative CMB values. The CMB technique has proven effective in removing or suppressing the effects of cloudiness on the brightness of the scene. Using brightness data taken over the Greenland ice cap and over cloudfree ocean areas as calibration references at the bright and dark ends of the range, respectively, the CMB values were adjusted to obtain an internally consistent data set. Adjusted brightness averages over areas about 40 km on a side were obtained for all available five-day periods in two Spring/Summer periods of 1969 and 1970 in several areas of Canada. Preliminary results of this study are shown in Fig. 3. The brightest areas, as expected, correspond to snow-covered frozen lakes and tundra. Snow-covered, dense coniferous forests are substantially less bright. Brightness drops to minimum values as the snow and ice cover melts and evaporates.

LAKE TEMPERATURE STUDIES

On several occasions during 1970, ITOS-1 satellite infrared (10.5 - 12.5μm) data were obtained of the Great Lakes. These have been corrected for atmospheric "limb darkening" and nominally mapped for comparison with aircraft infrared spot measurements along selected tracks. Furthermore, comparison has been made with ship and buoy in *situ* surface-water temperature measurements. The satellite's Direct Readout InfraRed (DRIR) mode provides a signal that, during cloud-free conditions, enables a synoptic view of all the Great Lakes. Aircraft coverage of the same area would require several hours or even days.

Using this ground-air-space sensor system, confirmation was made of all the large-scale (10-20 n. miles) thermal features. In some instances features were present in the satellite imagery that were missed by the aircraft. Satellite imagery was obtained that closely correlated with monthly aircraft monitoring flights made by the Canadian's Department of Transport. One such comparison is shown in Figure 4. In November 1970, an unusual cooling was noted in the deeper, more central portion of Lake Ontario. The more typical cooling pattern is closely depth dependent and progresses from shallow near-shore waters toward the middle of the lake.

CONCLUDING REMARKS

The world's natural water supply is perhaps our single most essential earth resource, and man's ever increasing use of this vital commodity demands optimal management of it. Improved measurement or estimates of hydrologic factors on an areal basis are needed to improve forecasts of stream flow and water storage, for these in turn strongly affect power generation, irrigation, water quality (pollution), flood control and forecasting, shipping, manufacturing, and recreation. Thus, there exists an economic and scientific requirement for comprehensive and timely mapping of hydrologic parameters, expecially over watersheds where hydrologic data are inadequate for proper conservation, management, and forecasting of the water resources of the region. Collecting this amount of hydrologic information by means of surface-based observation systems would be time-consuming and costly at best, hazardous at worst, because of the large areas involved and, frequently, because of their inaccessibility. Spot observations at ground-level can be supplemented by aircraft surveys, but these also are costly if large areas and/or repeated surveys are required. A polar-orbiting satellite, however, could provide a practical means for getting hydrologic observations for operational and research purposes, although a synergistic approach wherein ground-based and aircraft observations were employed in conjunction with satellites would be the most powerful.

The work described briefly above contributed to the Earth Resources Survey Program because the experience and knowledge gained in validation, interpretation, handling, and applications of available satellite and/or aircraft data can be brought to bear directly on refining requirements and specifications for analogous data acquisition and usage from the future Earth resources satellites. This research relates to stated NOAA requirements for data from ERTS A and B, as well as to later satellites or manned spacecraft (e.g. SKYLAB) that are likely to carry microwave sensors, in the area of hydrology.

REFERENCES

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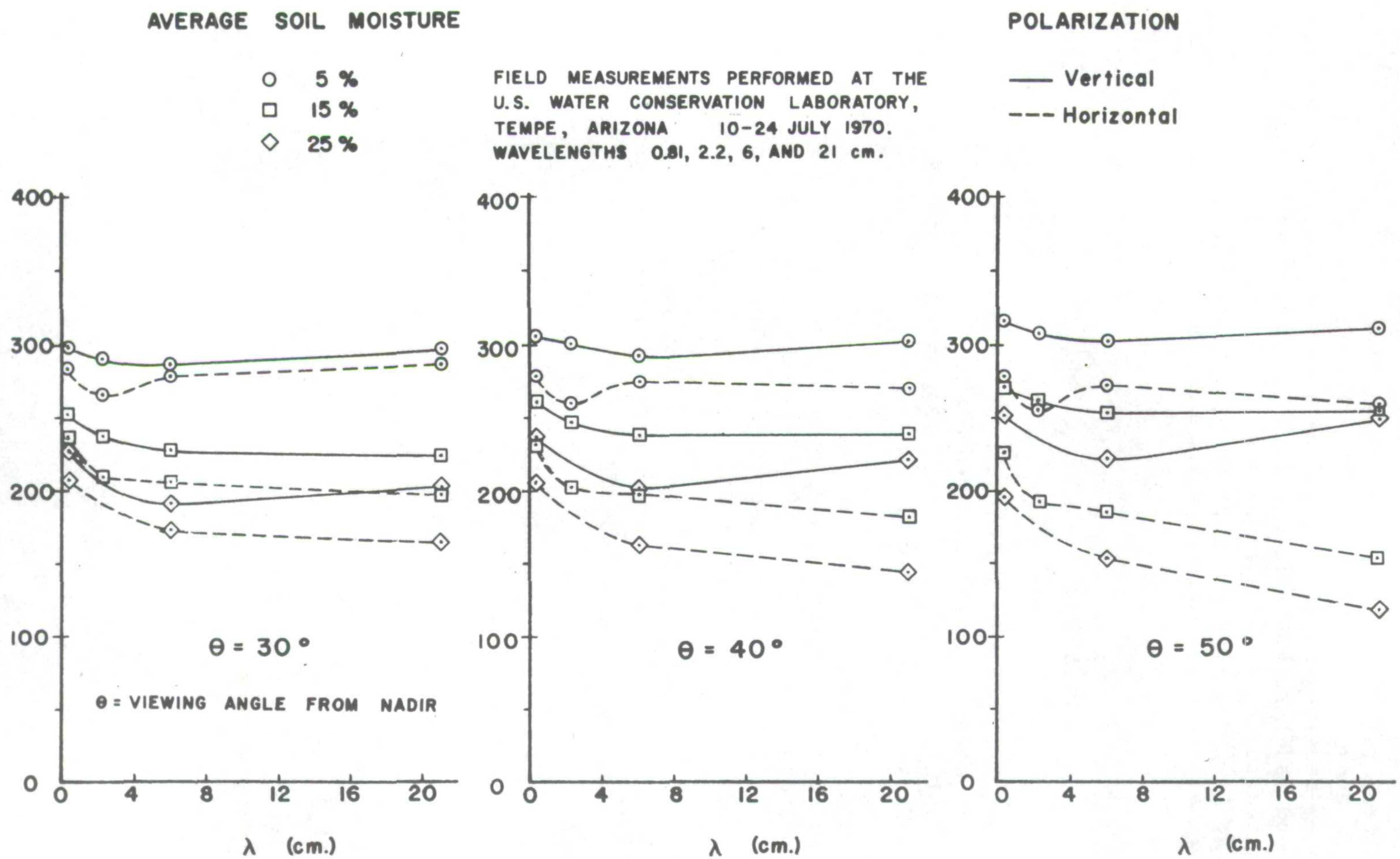

RADIOMETRIC TEMPERATURE vs. MICROWAVE WAVELENGTHS

DATA OBTAINED FROM AEROJET-GENERAL CORP. — MONTHLY REPORT NO. 1684M-1
18 AUGUST 1970

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Figure 1.- Results of field measurements of microwave brightness temperature at three levels of soil moisture. Measurements are shown for three viewing angles, four wavelengths, and at vertical and horizontal polarization.

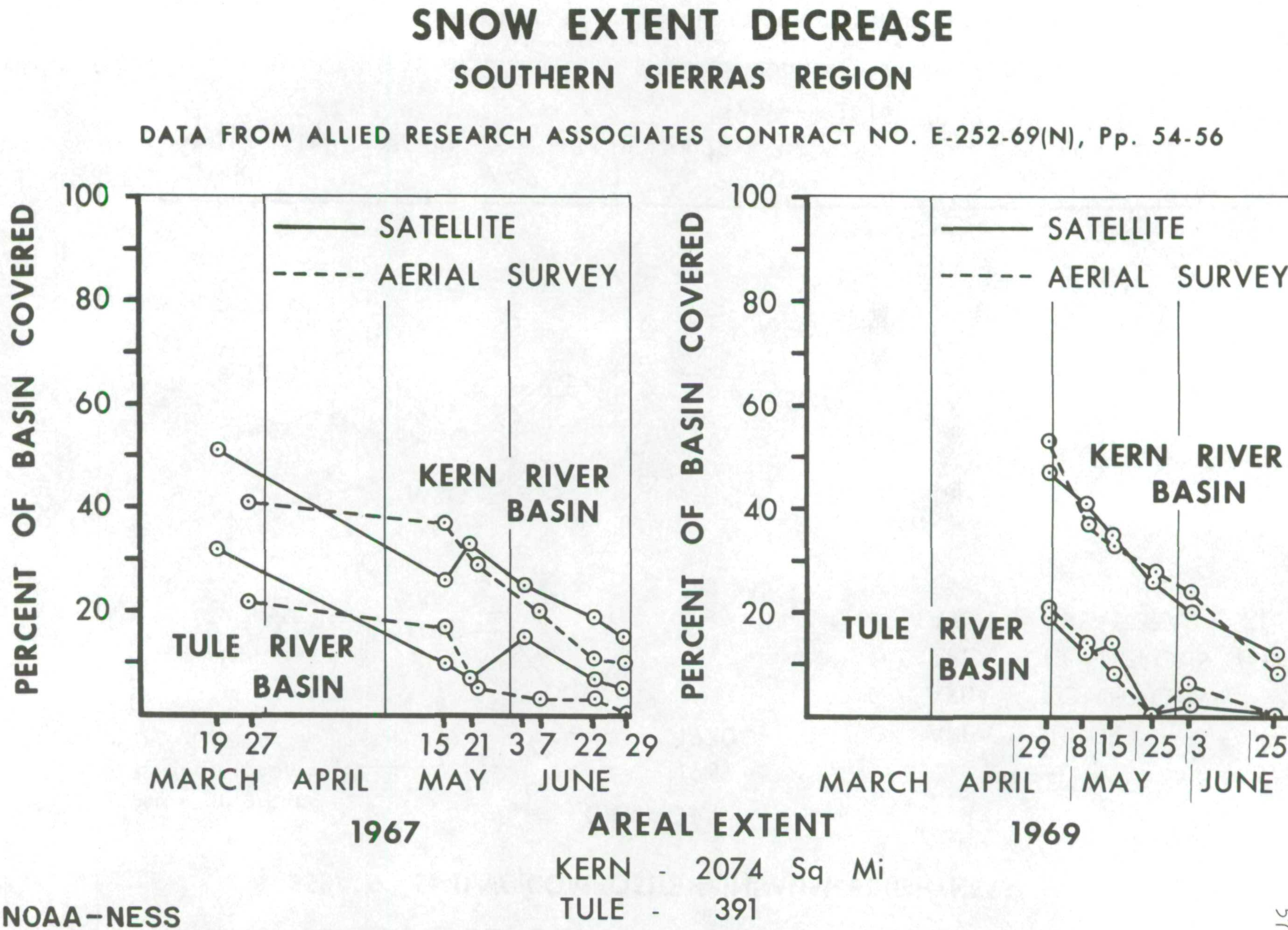
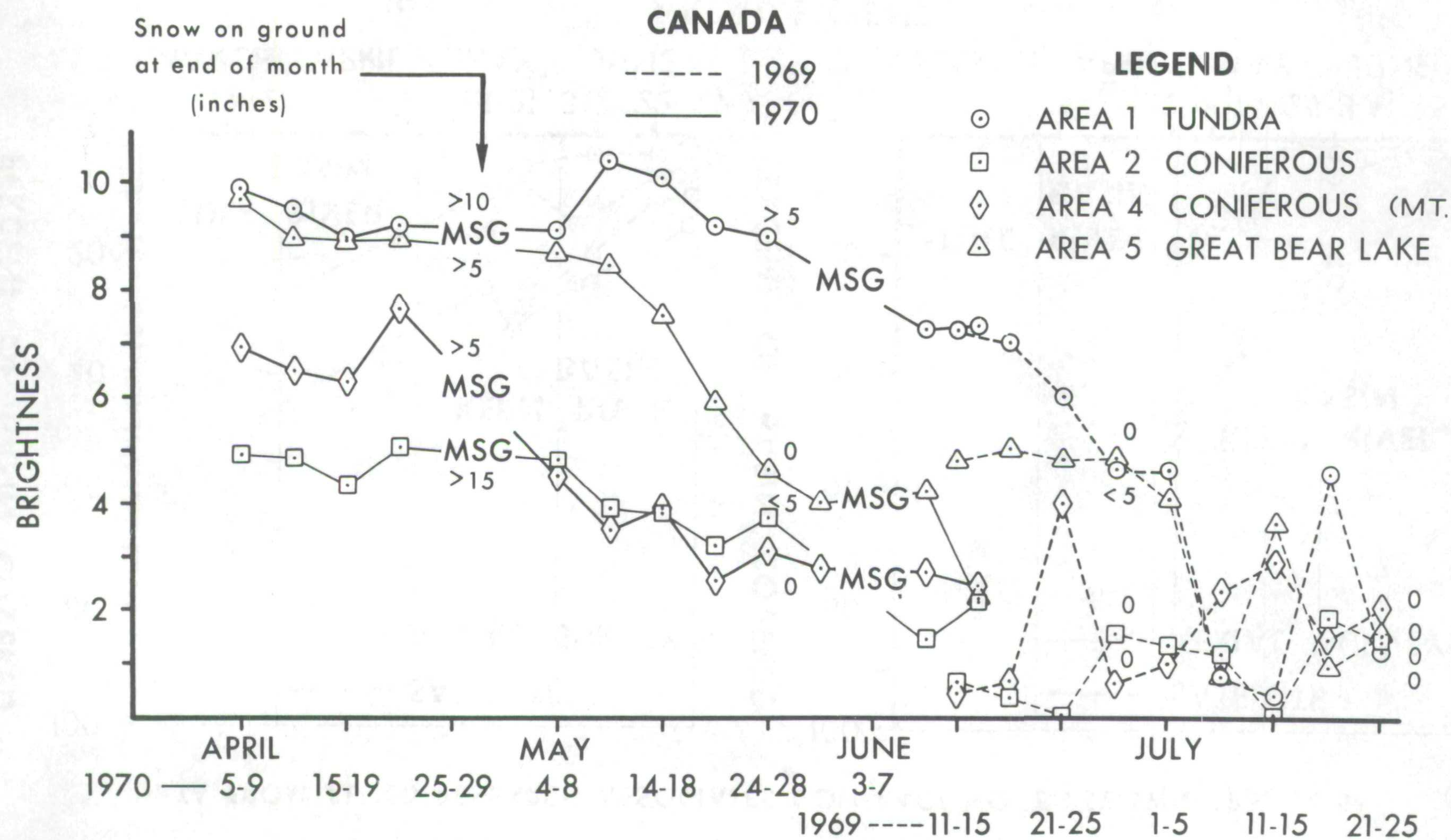


Figure 2.- Comparison of satellite and aerial survey measurements of Spring decrease in snow extent (percent of basin covered).

ADJUSTED BRIGHTNESS AVERAGES

ESSA 9 5–DAY COMPOSITE MINIMUM BRIGHTNESS



NOAA-NESS

Figure 3.- Seasonal variation of Composite Minimum Brightness (CMB) values for snowy areas in northern Canada having different vegetative cover or topography. CMB values are routinely derived for 5-day periods from digitized and mapped vidicon data obtained by ESSA operational satellites. The notation "MSG" means "missing data."

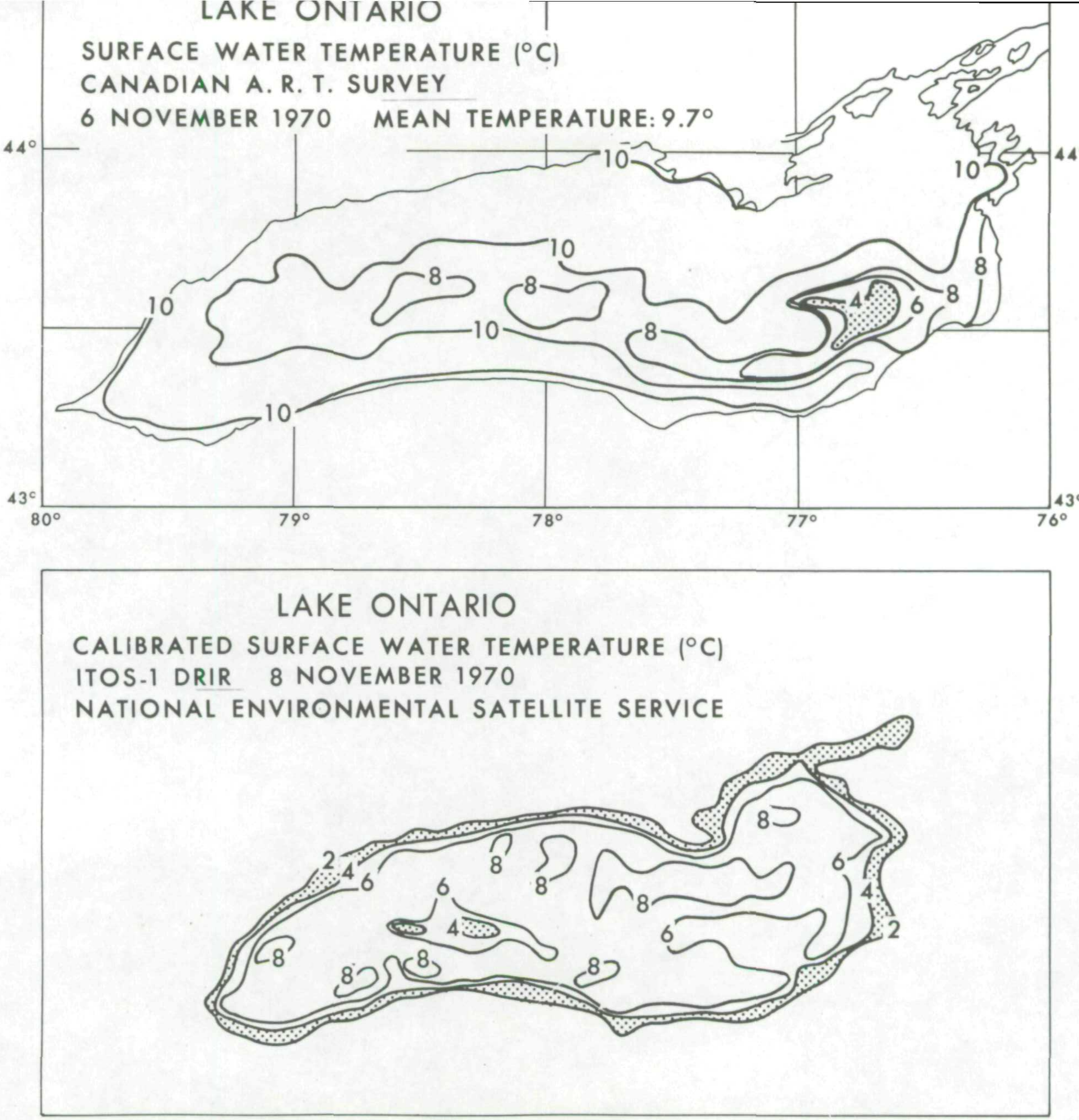


Figure 4.- Comparison of aircraft (ART) and satellite (DRIR) surveys of surface water temperature. The satellite analysis is based on unrectified scan-spot listings. The lake boundary is grossly defined by the thermal gradient between the warmer lake and the cooler land.