SECTION 92

COMPARISON OF REMOTE SENSORS FOR SOIL MOISTURE AND OTHER HYDROLOGIC STUDIES

by

Donald R. Wiesnet
National Oceanic and Atmospheric Administration
Washington, D. C. 20031

INTRODUCTION

NOAA's interest in aircraft and satellite hydrology is centered on, but not restricted to NOAA's statutory obligations, some of which include:

1. Flood Forecasting (NWS)
   - (a) Snow mapping
   - (b) Soil moisture
   - (c) Precipitation patterns
2. Limnology, (NOS, IFYGL, NMFS, EFL, EDS)
   - (a) Great Lakes
   - (b) Lake Ice
   - (c) Fisheries
3. Coastal Zone Hydrology (NOS, NGS, NMFS, ERL)
   - (a) Currents
   - (b) Shoreline change

In NOAA we expect that the use of satellite data and imagery will lead to improved flood and low-flow forecasts, improved water-level and ice reports for the Great Lakes, and better and faster coastal-zone storm damage assessment.

The purpose of this paper is to point out progress in lake-temperature and soil-moisture remote sensing during the past year.

MICROWAVE STUDIES OF SOIL MOISTURE

It has long been recognized that passive microwave radiation theoretically provides a means of measuring soil moisture. Inadequate microwave theory, surface scattering, the heterogeneous nature of the soil, and the unpredictability of soil-moisture distribution, are four of the many difficulties that impede progress toward this goal. A contractual study by Aerojet General funded by NOAA/NESS/ESG has moved us a step closer to that goal.

In February and March 1971, multifrequency microwave brightness temperatures of an unvegetated area near Phoenix, Arizona, were taken on the ground and by aircraft at 3000-foot and 10,000-foot altitudes. A low-level gamma-ray survey, the Aerial Radiological Measuring System (ARMS), monitored the test site at 300 and 500 feet, and a large number of ground samples were collected along the flight path. These samples were subsequently measured gravimetrically for soil moisture content.

NOAA's past efforts in the area of soil moisture studies using passive microwave techniques were aimed at carefully studying microwave emission from ground level and slightly above ground level in order to achieve a sound empirical basis for developing a theory of microwave emission that would allow a better understanding of the role played by such factors as surface and soil temperature, dielectric constant of the soil, surface roughness, soil type, and vegetation. As a result of this work, comparison of measured brightness temperatures with those computed from the recent theory of vertically structured media indicate that we now have achieved a partial understanding of the microwave emission properties of soils (Poe, Stogryn and Edgerton, 1971). Excellent agreement of computed and measured total volumes of water per unit area were obtained for all but the dry soil conditions.

Present efforts extend the previous work into aircraft levels over unvegetated fields near Phoenix, Arizona, with the simultaneous collection of ground-truth data. Briefly, 1.42 and 4.99 GH_z measured brightness temperatures along the flight lines consistently responded to measured soil moisture changes along the flight lines. Further details of this experiment are described elsewhere in this volume by A. T. Edgerton (Soil Moisture Mapping by Ground and Airborne Microwave Radiometry).

The next step in this project plan is to now move into an instrumented, vegetated test area to obtain additional aircraft microwave measurements. The Rock River Test Site in SW Minnesota is one well suited for this purpose, as a computerized hydrologic model has already been established for it, and it is monitored by special recording instruments already installed and operating.

GAMMA RAY SURVEY

One of the methods of remote sensing of areal snowpack conditions currently being investigated by the NWS Office of Hydrology in cooperation with EG&G, Inc., is the airborne measurement of passive terrestrial gamma radiation. The NWS Office of Hydrology wishes to determine the feasibility of evaluating average water equivalent of snow along selected courses. (Peck et al., 1971). Research on this subject has been conducted for several years in the Soviet Union and Norway (Kogan et al, 1965; Zotimov, 1968; Dahl and Odegaard, 1970).

Briefly, in the lowest few hundred meters of the atmosphere the gamma radiation field is largely the result of radiation from natural radioactive isotopes, normally present in the soil. Water and (or) snow attenuates the gamma radiation. This attenuation depends only on the total mass of water (Dmitriev et al., 1971) and not on the physical state of the water (snow or ice).

THE ARMS SYSTEM

The aerial radiological measuring system (ARMS) is designed and operated by EG&G, Inc. for the U. S. Atomic Energy Commission. The system is installed in a Beachcraft Twin Bonanza together with an accurate aircraft positioning system. The detector consists of 4 sodium iodide (NaI(Tl) scintillation crystals, thermally insulated and shock mounted. Its gamma-ray sensitivity is several thousand times greater than that of a common geiger counter.

PRELIMINARY RESULTS

Two legs of the survey flown minutes apart provided a measure of reliability of the system, (Fig. 1). The excellent reproducibility is readily apparent. The surveys a week apart (Fig. 2) also track well but are separated by almost a constant. This separation is caused by airborne radon daughter contributions (Fritzsche, Burson, and Burge 1971).

Figure 3 shows a relationship between the normalized net count and a moving mean of 100 soil moisture samples. Note the suppressant effect of the soil moisture on the gamma-ray emissions. These preliminary results are encouraging, and the analysis will continue. Base line flights over the Rock River test site have been completed.

It is believed that the ARMS surveys can be perfected to act as soil-moisture ground truth for the microwave overflights, by providing a kind of bulk soil moisture. If this proves to be feasible, it will greatly aid the interpretation and evaluation of airborne passive microwave data.

LAKE ONTARIO SURFACE TEMPERATURES

In spring 1970, an aerial survey of western and central Lake Ontario was flown by Bendix Aerospace Systems Division using the Bendix Thermal Mapper. The results of that survey are now available (Marshall, Hanson and Shah, 1971) and a brief synopsis of their findings follows.

Daytime infrared imagery in the 8-14 micron range was collected on May 28-29, 1970, using the Bendix LN-3 with an internal blackbody reference for temperature calibration. Altitude ranged from 11,000 ft. to 12,500 ft. during the flights. The stated ground resolution of the system is given as 30 ft. The gain was adjusted to span the 0° - 15°C range.

Marshall, Hanson and Shah, (1971) have interpreted major and minor hydrologic surface features from the mosaicked imagery. Large-scale features include:

1. The cold central zone 2.5 to 4°C
2. The Niagara River plumes, 6° - 0°C at the base, 3.5° - 4°C at the tip.
3. The midlake tongue, 4.5 to 10°C

Small-scale features described are:

1. The Toronto eddy
2. Cold shore water
3. Shear features
4. Creek plumes
5. Ships' wakes
6. Harbor features

Comparison of this aircraft survey with Canadian Dept. Transport ART surveys and ITOS HRIR data is being undertaken by NOAA/NESS in cooperation with the Canadians and with Bendix Corp. A report by Strong and others is in preparation. Additional data collection by aircraft and satellite is planned for the IFYGL data collection period.

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7. Fritzsche, A.E., Burson, Z. G., Burge, D. L., 1971, Water Equivalent of Snow Measurements Using Natural Terrain Radiation, EGG Tech. Rept. L-1047, 53 p.

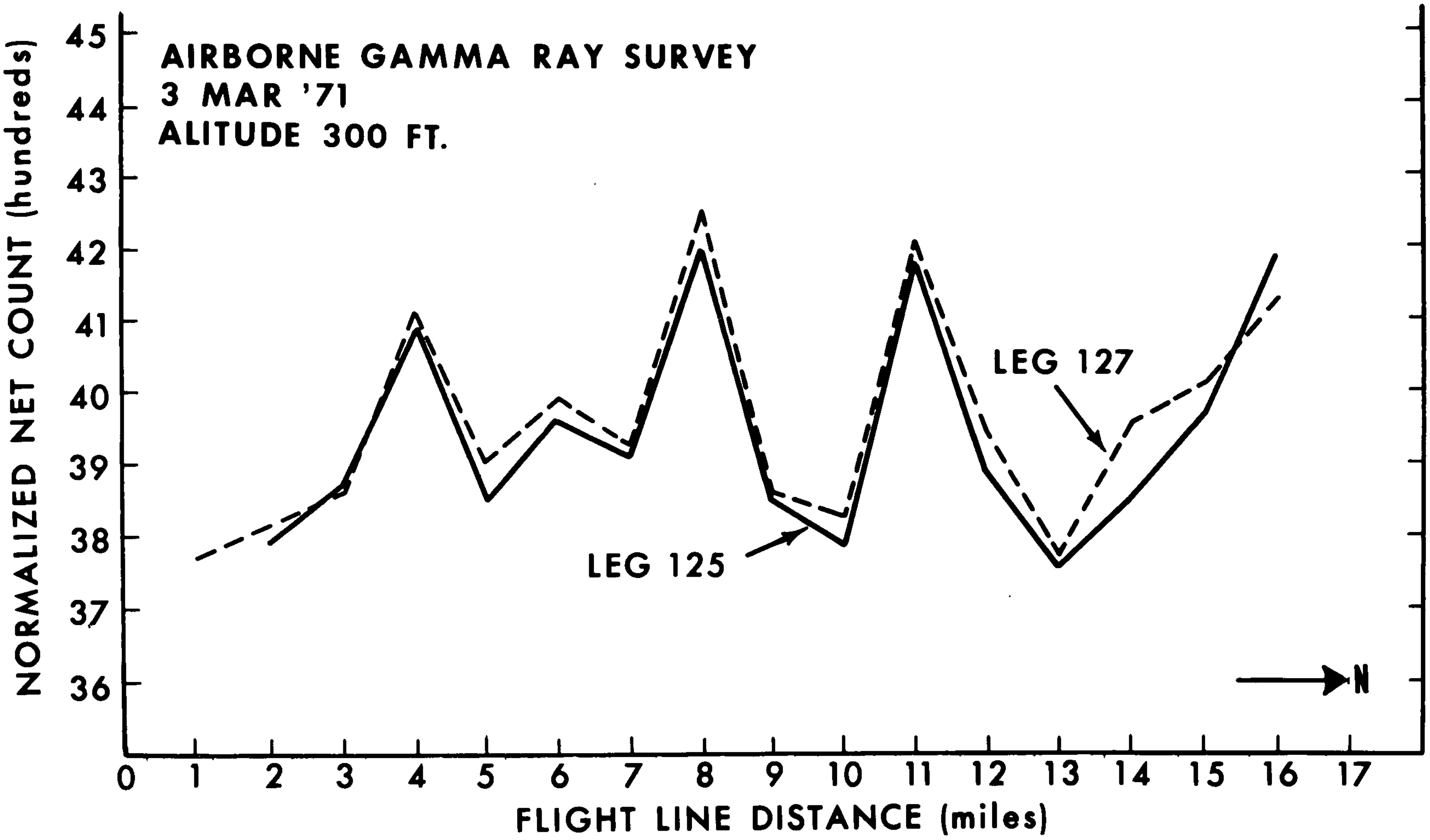


Figure 1. Comparative plot of gamma radiation vs. flight line distance shows excellent repeatibility in two legs flown only minutes apart.

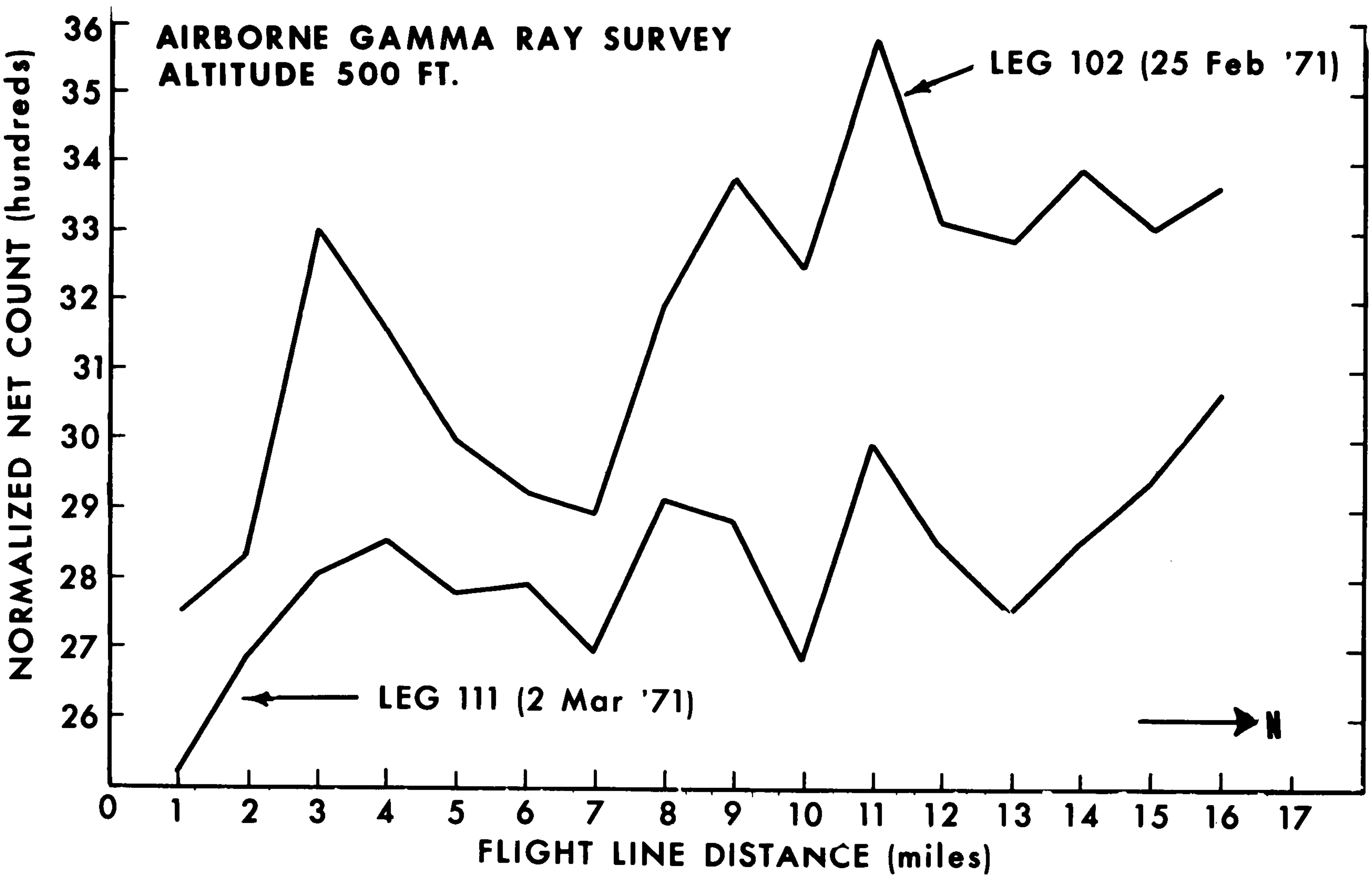


Figure 2. Plots of two aerial surveys of gamma radiation flown a week apart over the same flight line have similar trends and are separated by almost a constant.

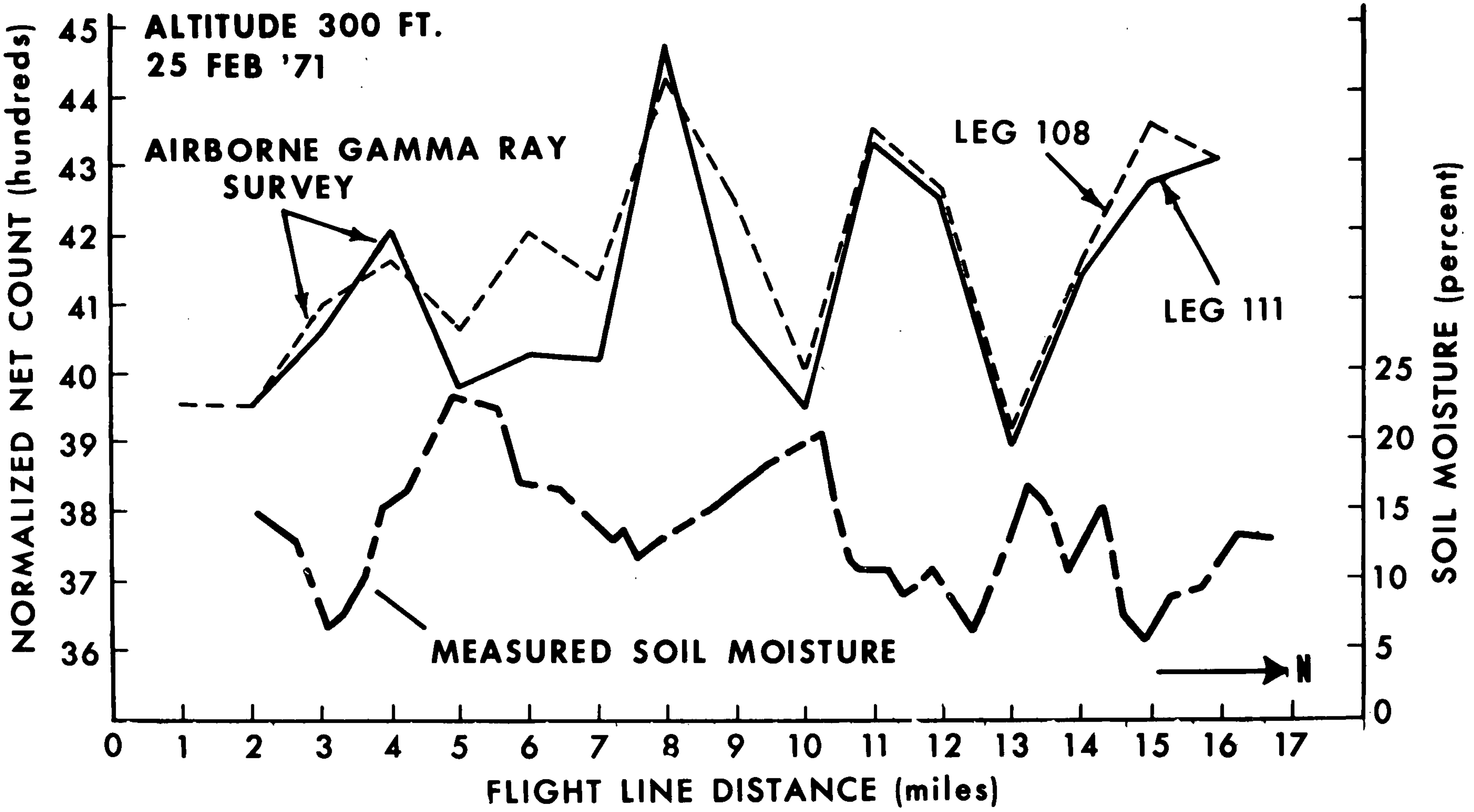
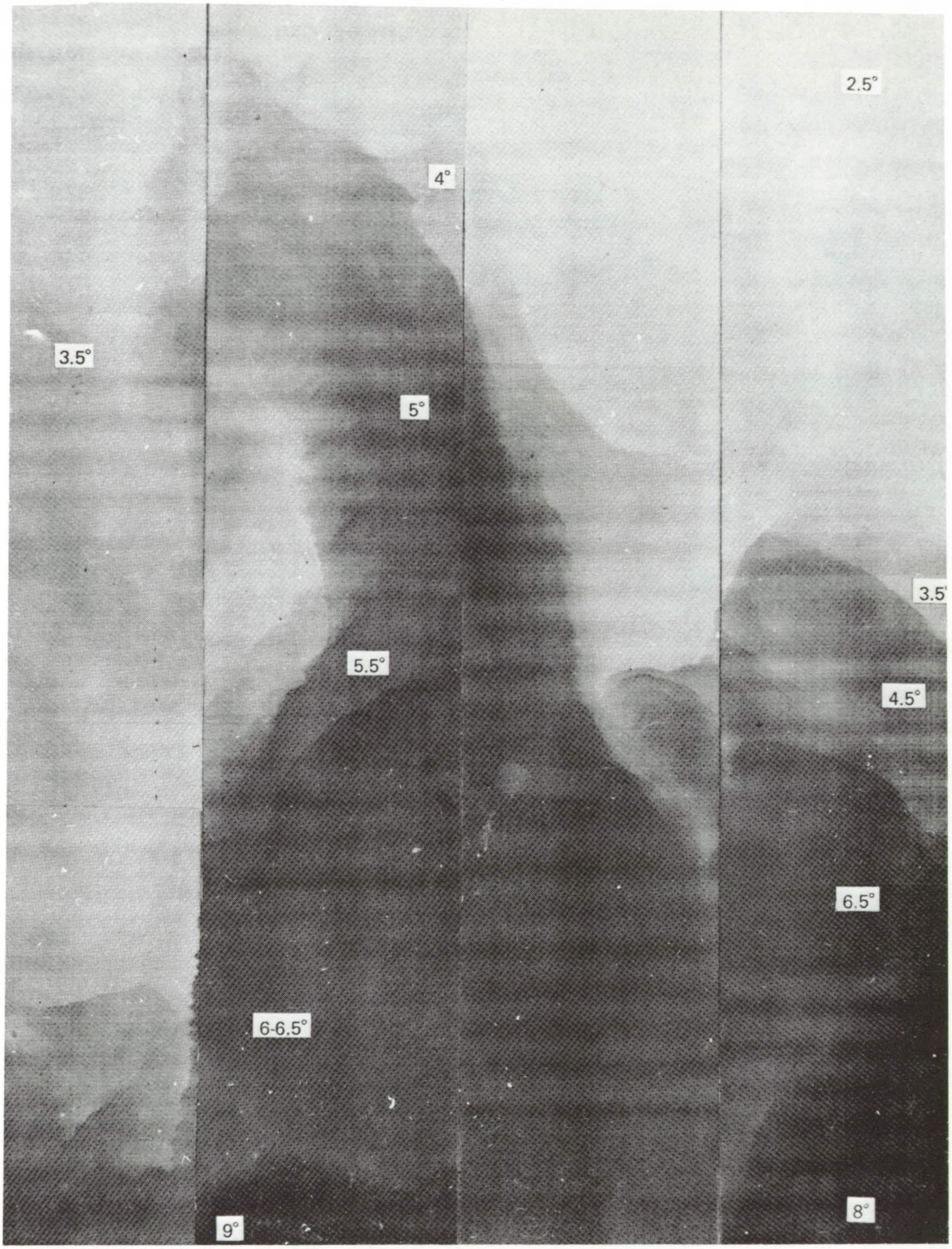
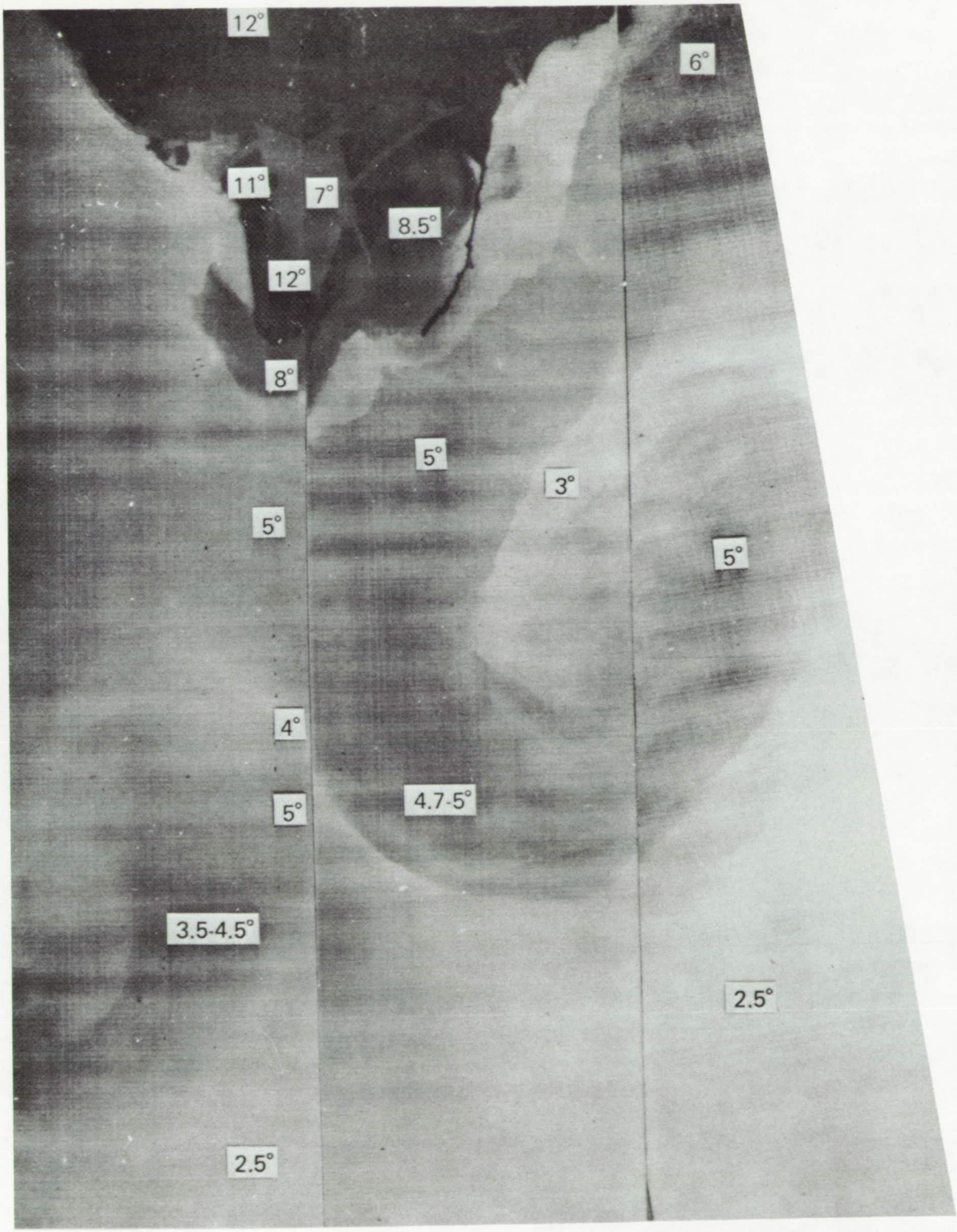


Figure 3. Running 3-point mean of measured soil moisture of 100 samples compared with ARMS gamma-ray survey. Note good repeatibility of the data and inverse relationship of soil moisture to gamma radiation.



ALL TEMPERATURES ARE IN °C.

Figure 4. Aircraft infrared daytime imagery mosaic of the Niagara River plume in Lake Ontario, 28 May 1970. Dark areas are warm.



ALL TEMPERATURES ARE IN C.

Figure 5. Aircraft infrared daytime imagery mosaic of the Toronto Eddy along north shore of Lake Ontario, 28 May 1970. Dark areas are warm.