CRH SSD
NOVEMBER 1987

CENTRAL REGION TECHNICAL MEMORANDUM 87-27

REMOTE SENSING OF SNOW

J. L. Foster, D. K. Hall, and A. T. C. Chang
Laboratory for Terrestrial Physics
NASA/Goddard Space Flight Center
Greenbelt, Maryland
(Reprinted from August 11, 1987 Issue of EOS)

Detection of natural gamma radiation emissions from the Earth has been used to measure the water equivalent of snow. Gamma ray detection must be carried out from aircraft at low altitudes (about 150 m) because of the significant atmospheric attenuation of the radiation. Background gamma radiation of the soil is obtained before the snow falls, and subsequent flights are flown to measure the gamma radiation through the attenuating snow cover. The degree of attenuation is related to the snow water equivalent through various calibration curves. The National Oceanic and Atmospheric Administration (NOAA) National Weather Service has an operational program to obtain such data on the shallow snowpacks of the high plains of the upper Midwest United States (Carroll and Voss, 1984). Although results have been encouraging, there are drawbacks to this method. Deep mountainous snowpacks may drastically attenuate the gamma radiation, thus limiting its usefulness, and mountainous terrain presents obvious safety problems for aircraft. In addition, interpretation of the data becomes more confusing when the soil moisture level changes significantly between the calibration flight made before the snow and the snow season flights. Because of the low altitude of the flights and narrow width of the data swath that is obtained, the gamma radiation method is confined to measurements of limited index lines (Rango, 1985).

The gamma radiation flux near the ground originates primarily from the natural potassium (^{40}K), uranium (^{238}U) and thallium (^{208}TI) radioisotopes in the soil. In a typical soil, 96% of the gamma radiation is emitted from the top 20 cm. After the background (i.e., no snow cover) radiation and soil moisture are measured over a specific flight line, the attenuation of the radiation signal due to the snow pack overburden is used to calculate the amount of water in the snow. These snow water equivalent values are calculated by measuring the attenuation of the gamma radiation flux with data from the K window (1.36-1.56 MeV), the TI window (2.41-2.81 MeV), and the ground count (GC) energy spectrum (0.41-3.0 MeV). The potassium "photopeak," the K window, is consistently the strongest in the energy spectrum. It has been used successfully to measure snow water equivalent in the prairie areas of Canada and in the United States (Carroll and Voss, 1984).

Flight line networks have recently been established in the Lake Superior basin and in the Saint John River basin in northern Maine, New Brunswick (Canada), and Quebec (Canada) to assess the capability of the airborne measurement technique over forested regions. Approximately 200 depth and density samples are collected on each of 72 calibration flight lines in both research basins and compared with the associated airborne snow water equivalent measurements (Figure 1). Results from the last several snow seasons indicate that airborne snow water equivalent measurements can be made in a forested environment with a root mean square error of 2.3 cm (Carroll and Voss, 1984). Flight lines are now being set up in the Colorado River basin of Utah, Wyoming, and Colorado to determine whether gamma ray remote sensing can be accomplished over mountainous terrain and deep snowpacks (deeper than 1 m).

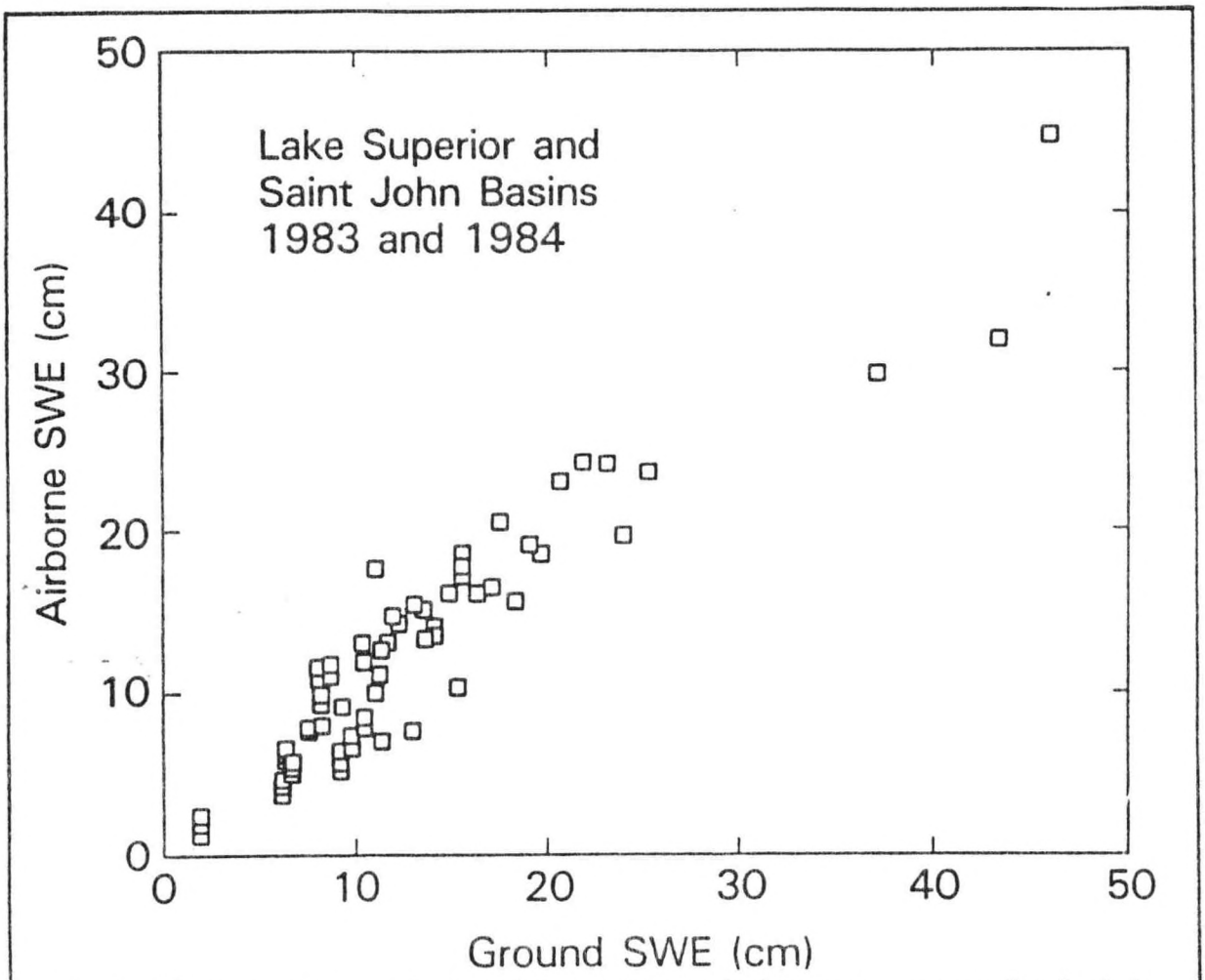

Fig. 1 Airborne gamma and ground snow water equivalent measurements for the Lake Superior and Saint John River basins [from *Carroll and Voss*, 1984].