MICROWAVE RADIOMETER OBSERVATIONS OF SNOWPACK PROPERTIES AND COMPARISON OF U.S. JAPANESE RESULTS

A. T. C. Chang
Laboratory for Earth Sciences
NASA/Goddard Space Flight Center
Greenbelt, MD 20771

INTRODUCTION

Recent studies using the Nimbus-5 and Nimbus-6 electrically scanning microwave radiometer (ESMR) have demonstrated the potential of passive microwave sensors in monitoring interested snow properties such as snow covered area, snow depth/water equivalent and wetness. This capability is primarily due to the strong scattering effect of large snow grains and dielectric contrasts between water and ice in the microwave region. The use of dual polarization, multifrequency scanning multichannel microwave radiometer (SMMR) offers an even greater potential to delineate snow properties.

Field experimental data collected in Vermont during the winter of 1981-1982 and data collected in Hokkaido are studied. The Nimbus-7 SMMR data over the U.S. test site (North Dakota) and the Japanese test site (Hokkaido) during February and March for 1979, 1980 and 1981 are studied. Results from these data sets are encouraging for future snowpack study using passive microwave data.

OBSERVATIONS OF MICROWAVE FIELD EXPERIMENT DATA

During the winter of 1981-1982, a field experiment with microwave radiometers was conducted in Vermont. The radiometer system (SMMR Engineering Model) consisted of four frequencies (6.6, 10.7, 18 and 37 GHz) and dual polarization (H and V) and mounted on a steerable hydraulic boom. The antenna was an offset parabola with 80 cm diameter. The normal 3-dB beamwidth were 4.2, 2.6, 1.6 and 0.8 degree for these four frequencies. The radiometers were comparison or Dicke types with square wave modulation and synchronous detection. The noise equivalent brightness temperatures for each channel are 0.6, 0.7, 0.8 and 1.2 K respectively.

Most brightness temperature data were obtained by scanning the instrument unit. In order to remove the potential field inhomogeneity effect, the radiometer antenna was scanned such that it always viewed the same spot on the snowpack while the incidence angle changed. In addition to the scanning measurement, several time sequence measurements and snow removal experiments were made to study the diurnal effect and layering effect on microwave snow signatures.

The general snow conditions for the test sites were dry snow with depth ranged from 0 to 120 cm. Snowpacks typically layered with several ice or crust layers and the grain size was very fine, 0.5 to 1 mm in diameter, throughout the packs except in the ice layers. The air temperatures varied from $-3\,°C$ to $-25\,°C$ during the observation period. Physical characterizations of the snowpack were made along with the microwave measurement. The truck unit performed microwave measurements at three separated fields with different snow depth and layering effects.

The data collected during this experiment generally fall into the envelope of brightness temperature with averaged grain radius 0.25 to 0.5 mm (Figure 1). Figure 2 shows the results for a three week study of snow at the Townline test site. The observed brightnesses are following closely with the brightness-snow depth curve for snow grain with 0.25 mm radius. The small grain sizes at the top 50 cm of the snowpack that contributed the major portions of the brightness at 37 GHz dominated the observed brightness.

To study the layering effect, ice layers were removed to measure the changes of microwave responses. Figure 3 shows the variation of the 37 GHz brightness as layers were removed. No significant effect was observed during the experiment. However, in another location (Figure 4) the 6.6 GHz show strong effects due to the ice layers.

The experimental data for Sapporo microwave tower experiment was fitted with 2 layer scattering model and the results are shown in Figure 5. The snow density used for this calculation was based on the averaged ground truth information and the mean radius for each layer was assumed to be 0.2 and 0.35 mm respectively.

OBSERVATIONS OF THE NIMBUS-7 SMMR DATA ON SNOWFIELDS

Two test sites, one in North Dakota and one in Hokkaido, were selected for this study. A total of five time periods of SMMR data were acquired. They were, February and March, 1979, February and March, 1980 and February of 1981. Due to the smooth terrain in the North Dakota site, SMMR data could provide useful information both the snow cover area and snow depth. For the Hokkaido site, the results were different. Since the resolution of SMMR is approximately 25 km for the 0.8 cm radiometer, it is rather difficult to separate out the small geographical features. Mixed pixels are much more difficult to interpret than a uniformed footprint.

Under this condition, the snow cover area could be delineated marginally. Figures 6 and 7 show the 37 GHz brightness as a function of snow depth. They generally fall within the envelope between 0.25 and 0.35 mm radius. However, due to different snow conditions in 1979 and 1980 winter season, different responses were observed. The SMMR data show some potential for studying the snow properties in Hokkaido. If the spatial resolution can be reduced to ~ 5 km, then the snowfield can be delineated much more accurately.

CONCLUSIONS

Microwave data collected by field experiments over Vermont and Hokkaido and Nimbus-7 SMMR over North Dakota and Hokkaido were studied under the Joint U.S.-Japan snowpack property study project. The measured 37 GHz brightness temperatures showed considerable effect of volume scattering by the snow grain. The 37 GHz brightness for a new snowpack with average grain radius of 0.25 mm is generally about 40K higher than the naturally compacted pack with average grain radius of 0.4 mm. The scattering effect is much less distinct for the 6.6 GHz. However, the layering effect is much stronger at the longer wavelength. For 10.7 and 18 GHz, the effect of layering and scattering vary due to different combinations of internal snow grain distribution and layering structures.

Both the microwave observations taken by field experiment and satellite-borne instruments shown that snow properties may be inferred from these observations. In the open area such as North Dakota site, resolutions of 25 km is adequate for snow properties determination. However, over the Hokkaido test site, the SMMR data is too coarse for the snow field. A better spatial resolution is required to study these snow fields.

The challenge in the analysis of the microwave response to snowpack properties lies in the fact that snowpack conditions are complex and their interaction with microwave radiation is not completely understood. The fact that snowpack character can change so rapidly, and, is in fact, constantly changing, adds a complicating factor to data analysis. It is believed that with additional measurements in the coming years, a more quantitative relationship between brightness temperatures and snow depth will be possible for snowpacks of known wetness condition. The near-term goal is to understand the microwave emission from snow so that a system for improved snowpack monitoring from a remote platform can be defined.

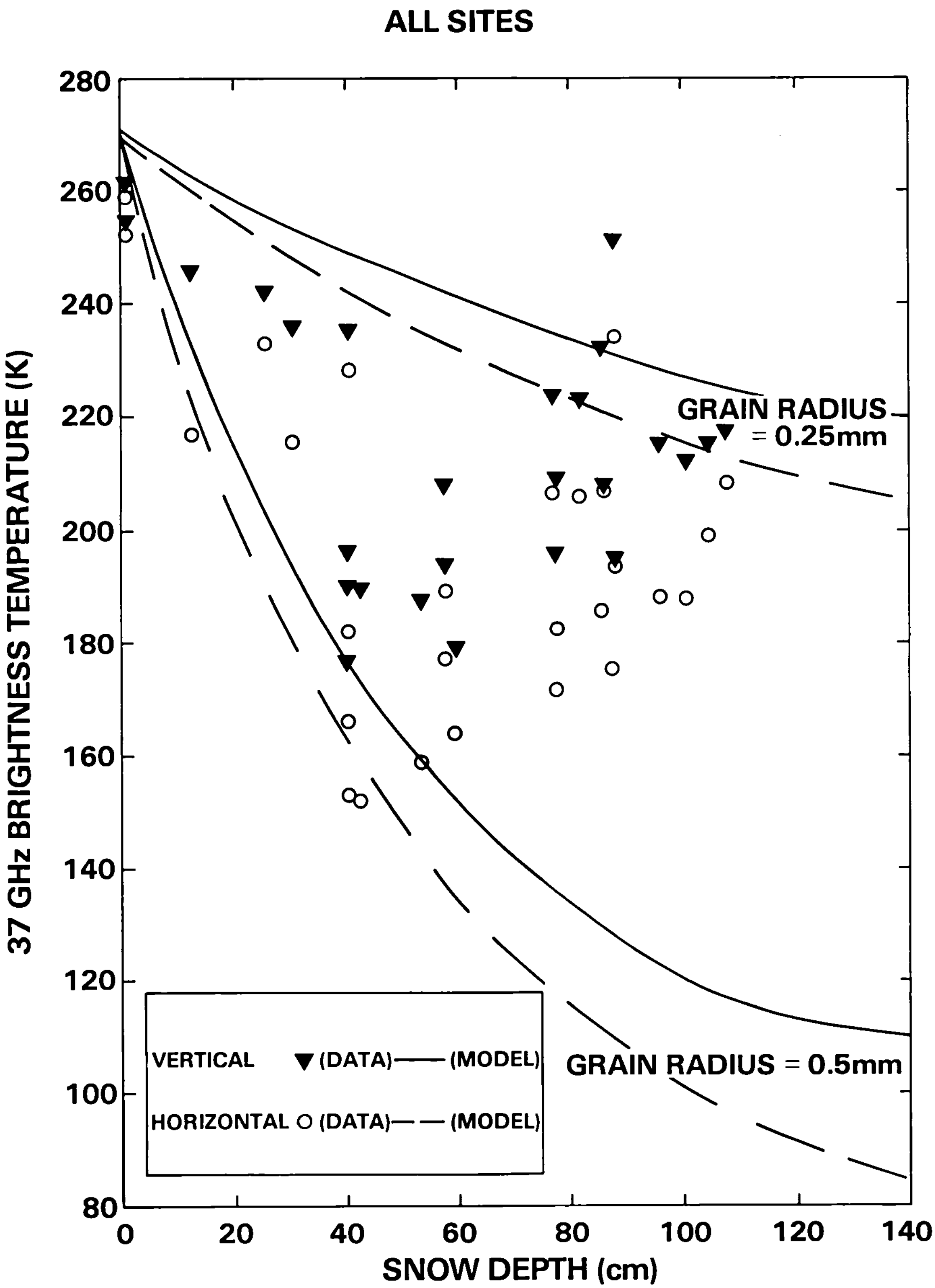

Figure 1. 37 GHz emission vs. snow depth with 50° look angle, Vermont, 1982.

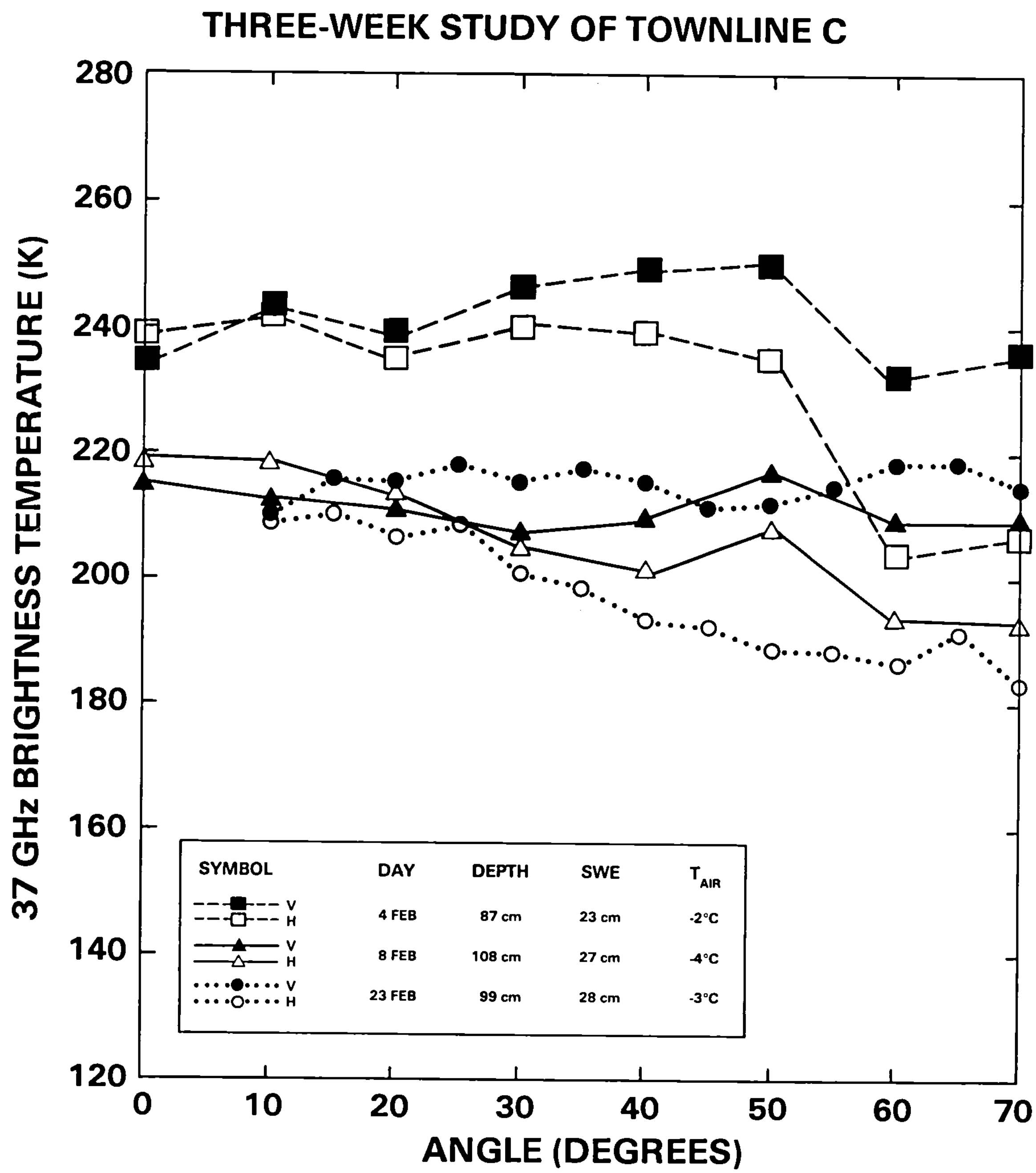

Figure 2. 37 GHz emission from a natural snowpack, Townline, Vermont.

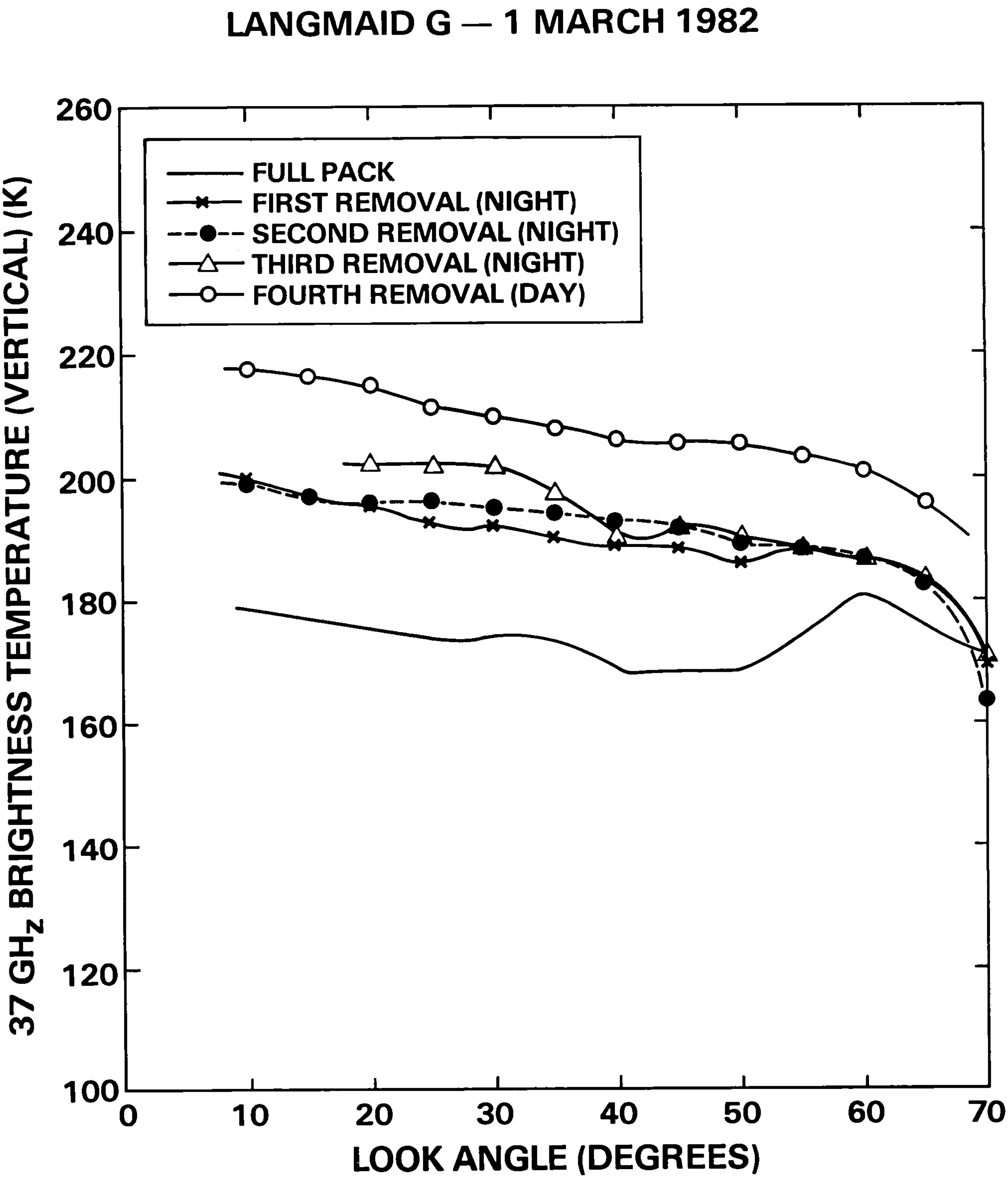

Figure 3. 37 GHz emission from a snow removal experiment, Vermont, 1982.

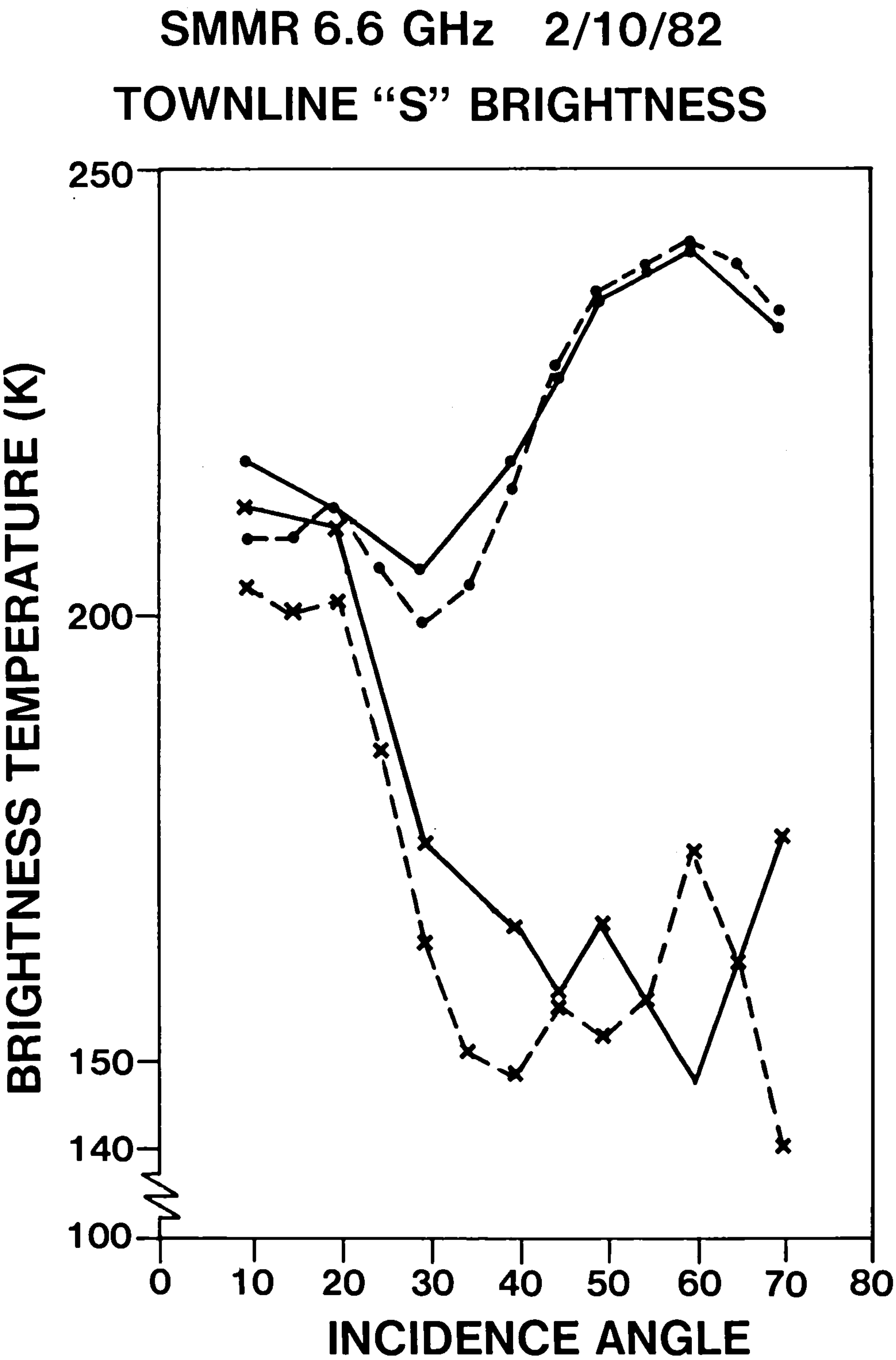

Figure 4. 6.6 GHz emission from a snow removal experiment, Vermont, 1982.

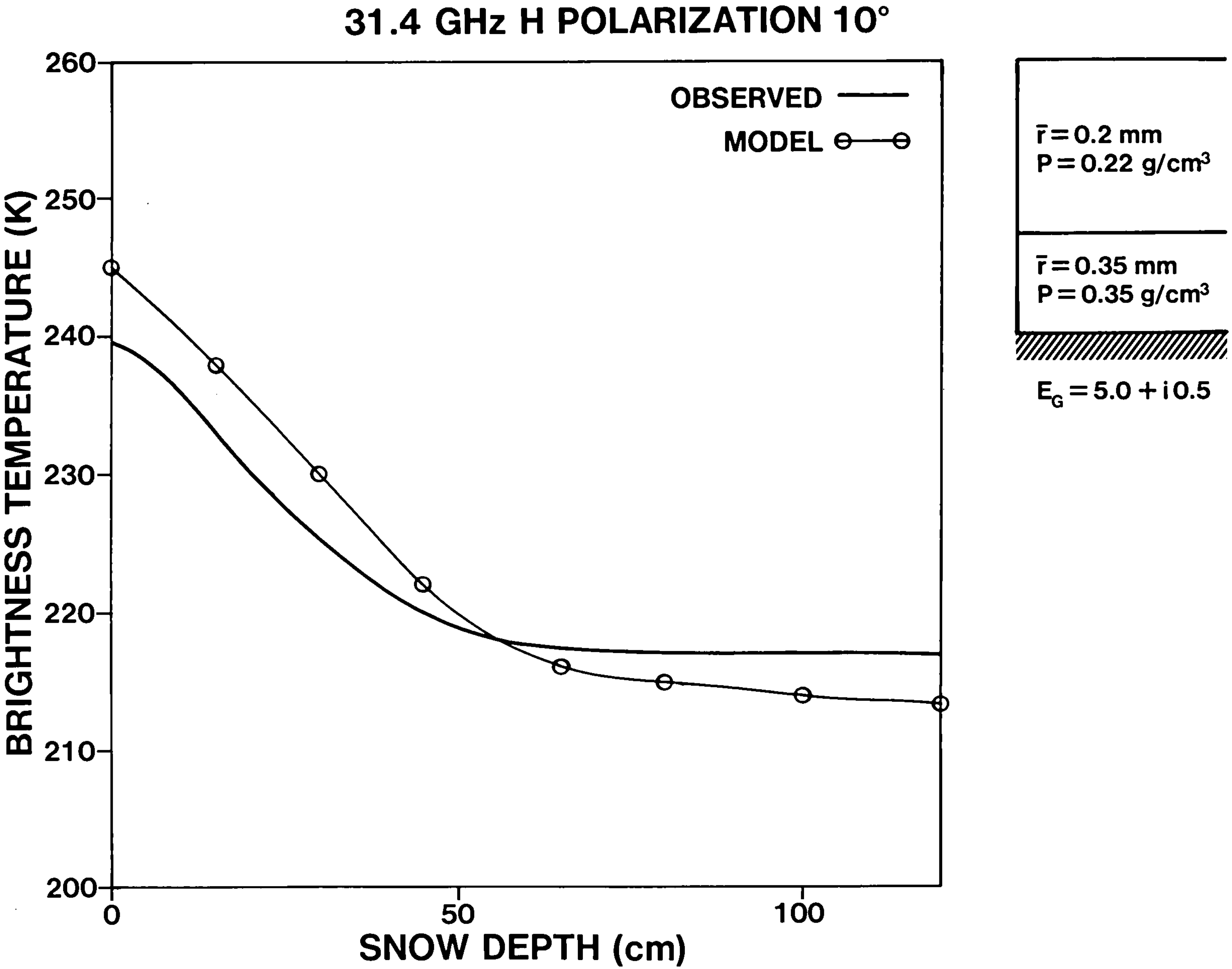

Figure 5. Comparison of calculated and observed 31.4 GHz brightness, Sapporo, 1981.

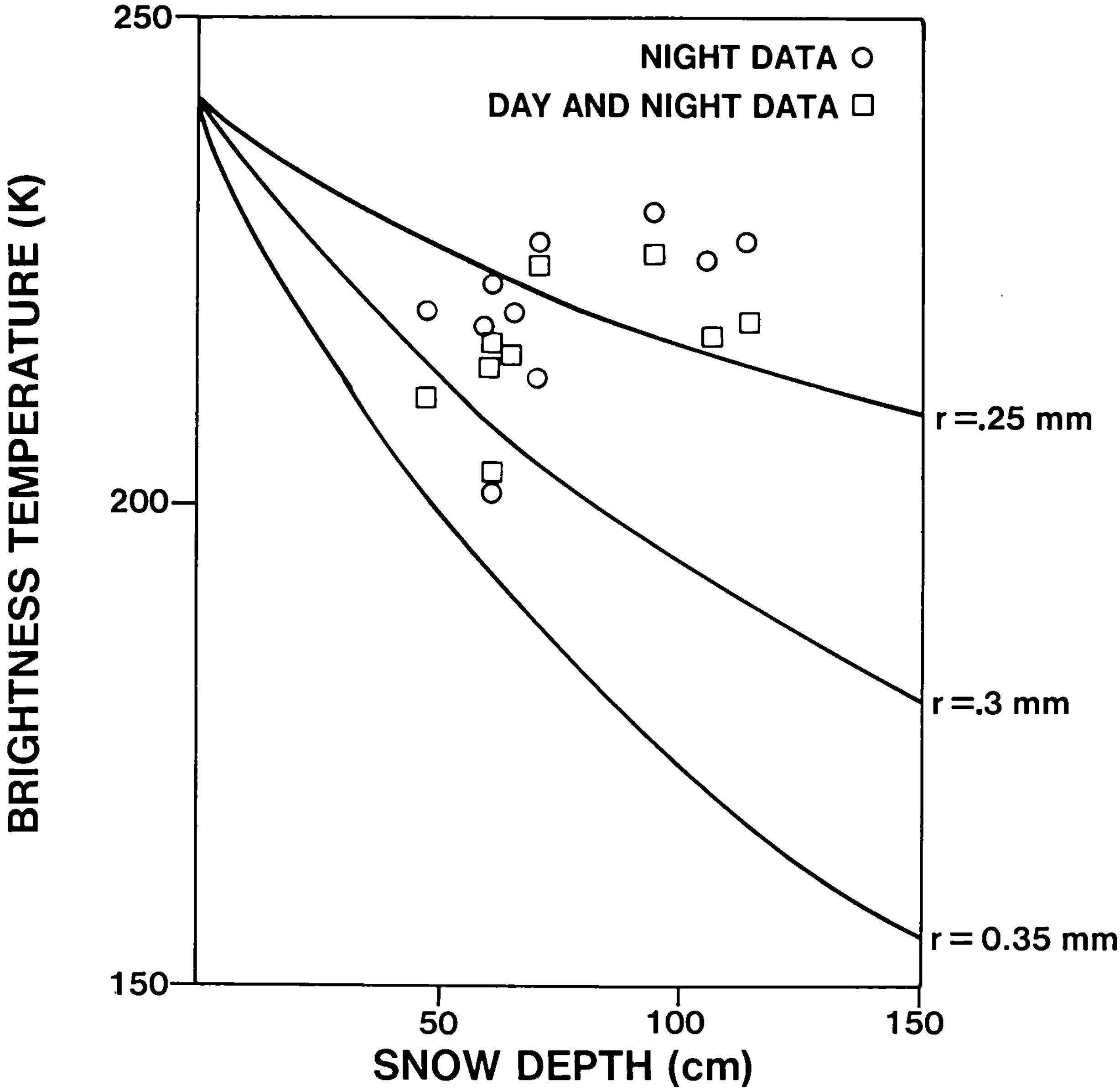

Figure 6. Nimbus-7 SMMR 37 GHz brightness over Hokkaido, Japan, February, 1979.

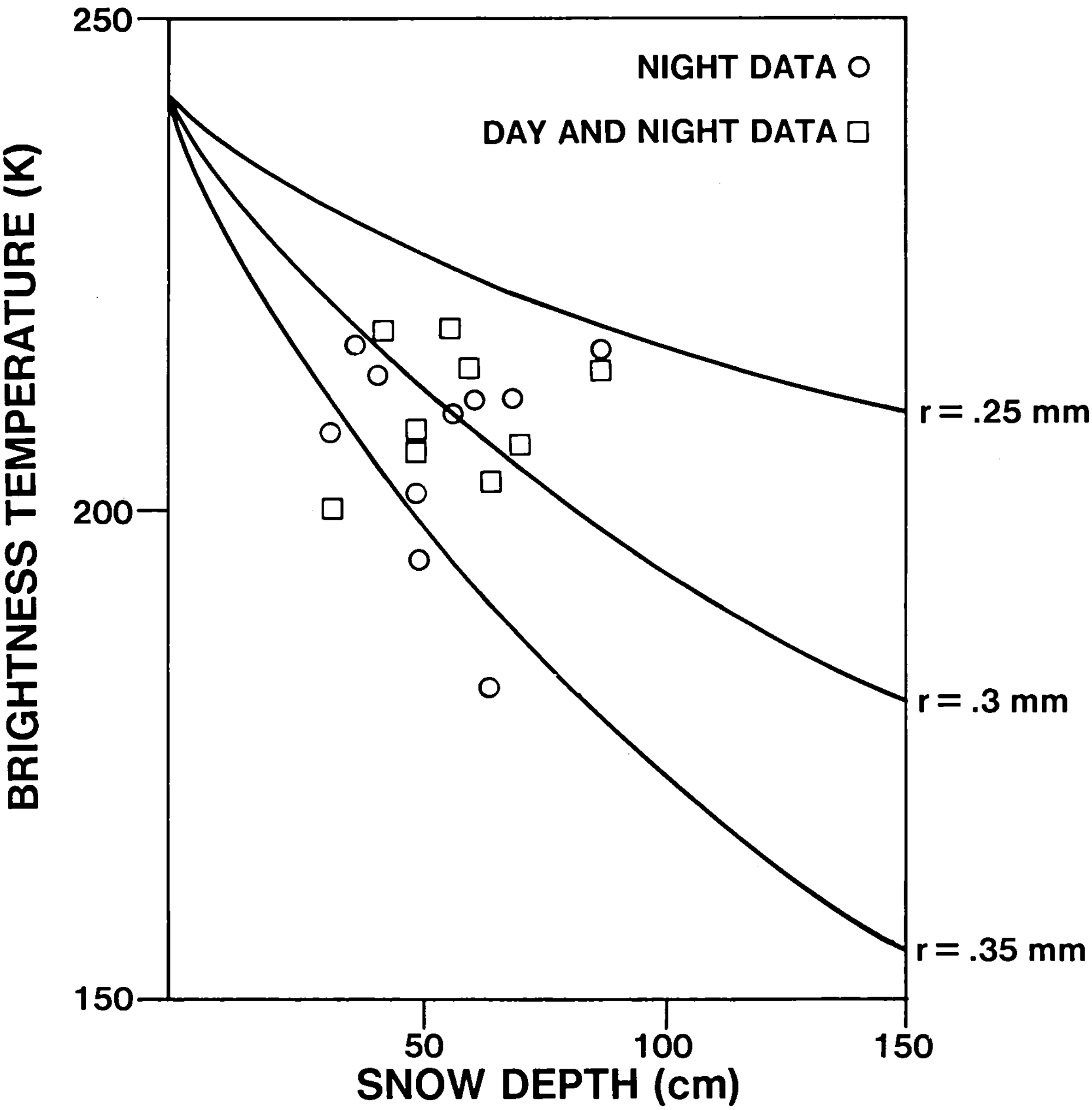

Figure 7. Nimbus-7 SMMR 37 GHz brightness over Hokkaido, Japan, February, 1980.