1994011572

N94-16045

BRIGHTNESS TEMPERATURE AND ATTENUATION STATISTICS AT 20.6 AND 31.65 GHz

E. R. Westwater and M. J. Falls
NOAA/ERL/Wave Propagation Laboratory
Boulder, CO

Abstract--Attenuation and brightness temperature statistics at 20.6 and 31.65 GHz are analyzed for a year's data that were collected in 1988 at Denver, and Platteville, Colorado. The locations are separated by 49 km. Single-station statistics are derived for the entire year. Quality control procedures are discussed and examples of their application are given.

I. Introduction

In previous NAPEX meetings, we have presented attenuation and attenuation diversity statistics for a limited number of station months (Westwater et al., 1988; Westwater et al., 1989; Snider et al., 1989). Because of an extensive data base of radiometric observations at 20.6 and 31.65 GHz in the front range of eastern Colorado, we are currently developing monthly and yearly statistics at these frequencies. Our goal is to develop statistics representing each of four locations, as well as appropriate diversity statistics for pairs of stations for the year 1988. This paper is a status report in which 1988 data from Denver and Platteville, stations 49 km apart, are analyzed. Details of the characteristics of our radiometers and our calibration procedures are reported in Westwater et al. (1990).

II. Quality Control

The radiometric data were taken by radiometers that operated in an unattended mode, although bimonthly on-site calibrations were done. For the most part, the data were of high quality, although occasional outliers had to be removed from the data. Such outliers can arise from liquid and ice buildup on the antennas, spurious signals of electromagnetic origin, calibration drifts in the receivers, and data transmission errors. To eliminate obvious erroneous data, we plotted and inspected daily time series of the following quantities: brightness temperature T_b at 20.6 and 31.65 GHz; derived attenuation τ at 20.6 and 31.65 GHz; and precipitable water vapor and cloud liquid. If a record had an obvious error at either or both frequencies, data from the entire record were removed. Next, scatter plots of T_bs at both frequencies were constructed; usually, suspicious points were easily identified from these plots. We show in Fig. 1 scatter plots showing both (A) original data and (B) data with outliers removed. During cold conditions, the total range of T_b is much less than 300 K. Therefore, for these cold conditions, we also constructed scatter plots over a 15 K range. In Fig. 2, obvious

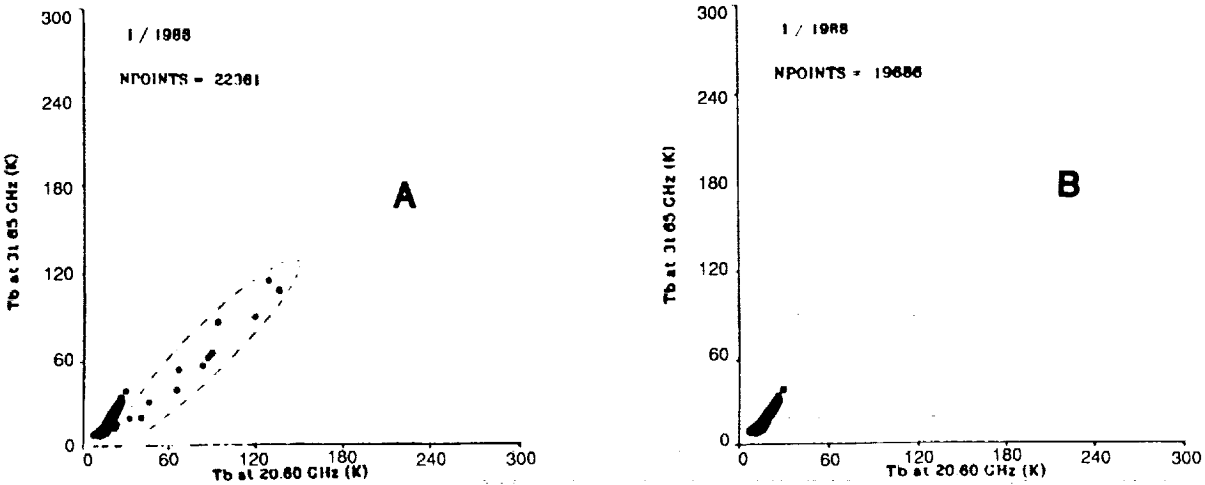


Fig. 1. Examples of brightness temperature scatter plots for quality control. (A) scatter plots with encircled outliers; (B) scatter plots with outliers removed. Denver, CO, 1/88.

outliers with 31.65 GHz T_bs less than ~ 8.5 K are shown. Finally, in Fig. 3, we show scatter plots of quality-controlled T_bs for a year's data taken at Denver and Platteville. The potential of using these plots for quality control is apparent. The general behavior of the scatter plots may be explained as follows: due to far wing absorption from O_2 and for clear, dry conditions, T_b (31.65 GHz) may be larger than T_b (20.6). For increasing water vapor concentration, T_b (20.6) rapidly becomes the larger of the two. Finally, since cloud attenuation is greater at 31.65 GHz than at 20.6 GHz, during many cloudy situations T_b (31.65) will again be the larger of the two.

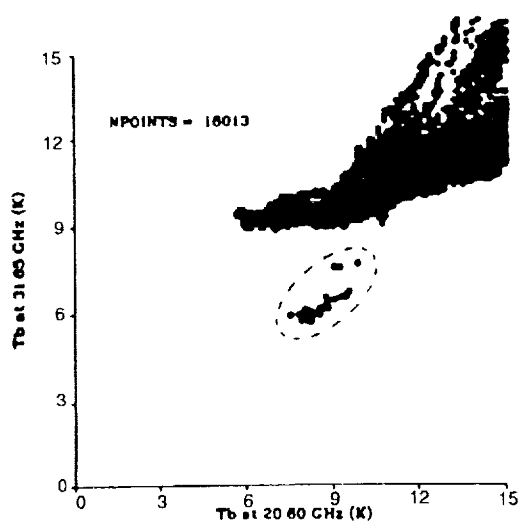


Fig. 2. Scatter plots of brightness temperatures for T_b < 15 K. Note the approximately 6 K and 9 K minimum T_bs at 20.6 and 31.65 GHz. Outliers are encircled. Platteville, CO, 1/1 - 12/31/88.

III. Brightness Temperature Statistics

The first paper in which the climatological variations of brightness temperatures were considered was given by Slobin (1982), who constructed statistics of T_b at a variety of locations and frequencies. His work was based on climatological radiosonde data. Since conventional radiosondes do not measure cloud liquid, modeling of this component requires additional assumptions: Slobin assumed a modified adiabatic cloud liquid distribution. We will compare later his results with ours.

For a given location, the dominant variable in determining the range of T_b is cloud liquid.

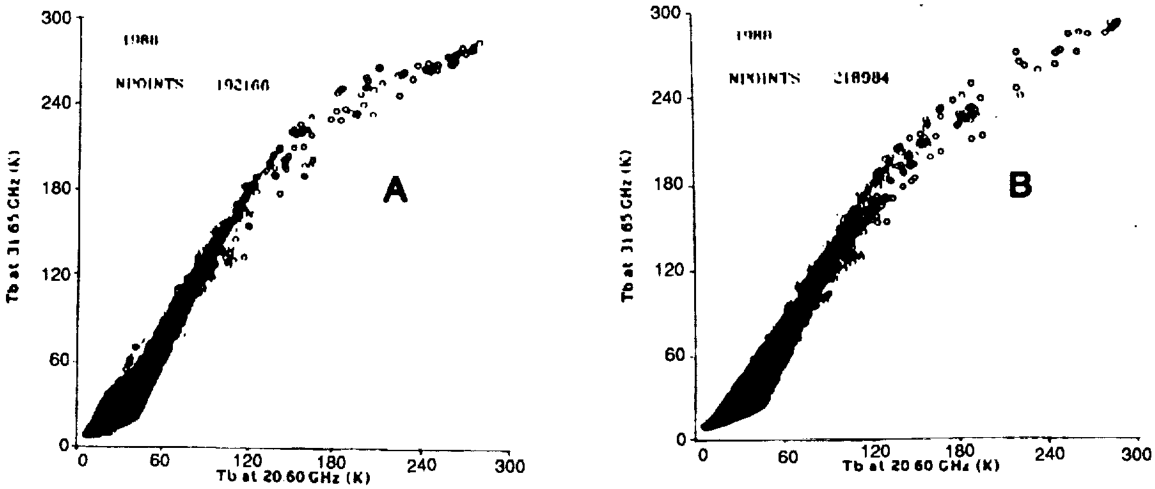


Fig. 3. Scatter plots of T_b at 20.6 and 31.65 GHz for (A) Denver, and (B) Platteville, CO for 1/1 - 12/31/88.

At Denver, in the winter, cold temperatures limit the amount of liquid that clouds can hold; hence, in the winter months, T_b values are limited to a range of less than ~75 K. During warmer months, cloud liquid greatly increases as does the range of T_b. Figs. 4 and 5 show scatter plots of T_b for each month of 1988 at Denver; similar results were obtained for Platteville.

The cumulative T_b statistics at 20.6 and 31.65 GHz for Denver and Platteville are shown in Fig. 6. For percentages of time greater than 0.1%, the probability distributions are almost identical. We also show in Fig. 6 (B) Slobin's estimated probability distribution for Denver. Given the uncertainties in modeling cloud liquid statistics from radiosonde data, the agreement is remarkable.

IV. Attenuation Statistics

We also derived attenuation τ(dB) from brightness temperature by using the well-known formula (Westwater et al., 1990)

$$\tau(\text{dB}) = 4.34 \ln\{(T_m - T_c)/(T_m - T_b)\} \quad , \qquad (1)$$

where

T_m = medium temperature (K),

and

T_c = cosmic background temperature = 2.75 K.

In deriving τ, we used monthly mean values of T_m that were calculated from our radiative transfer and cloud models. Yearly cumulative probability distributions of τ are shown in Fig. 7. Since water vapor attenuation at 20 GHz is larger than 31.65 GHz

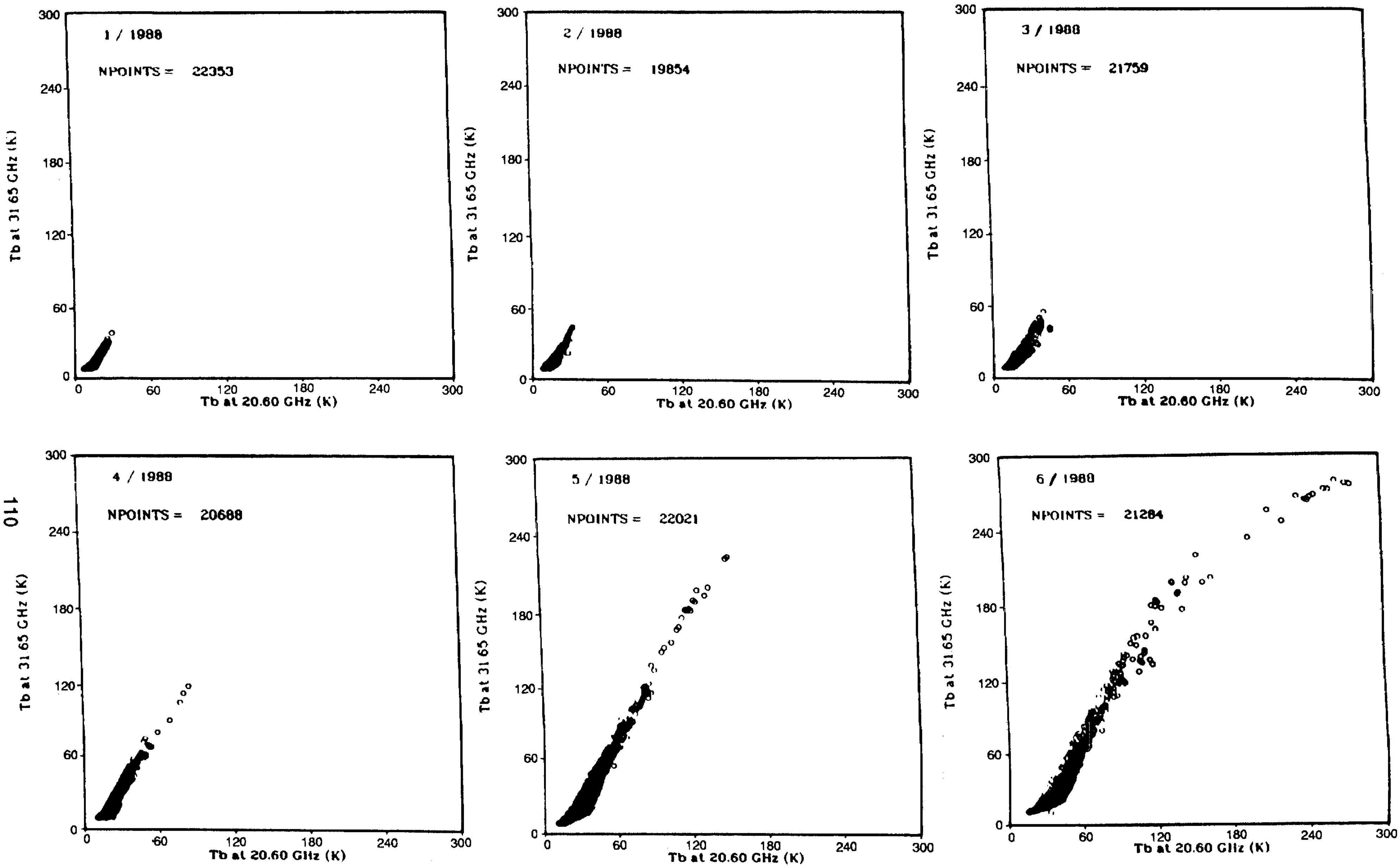


Fig. 4. Monthly scatter plots of 20.6 and 31.65 GHz T_bs for Denver, CO, for the first six months of 1988.

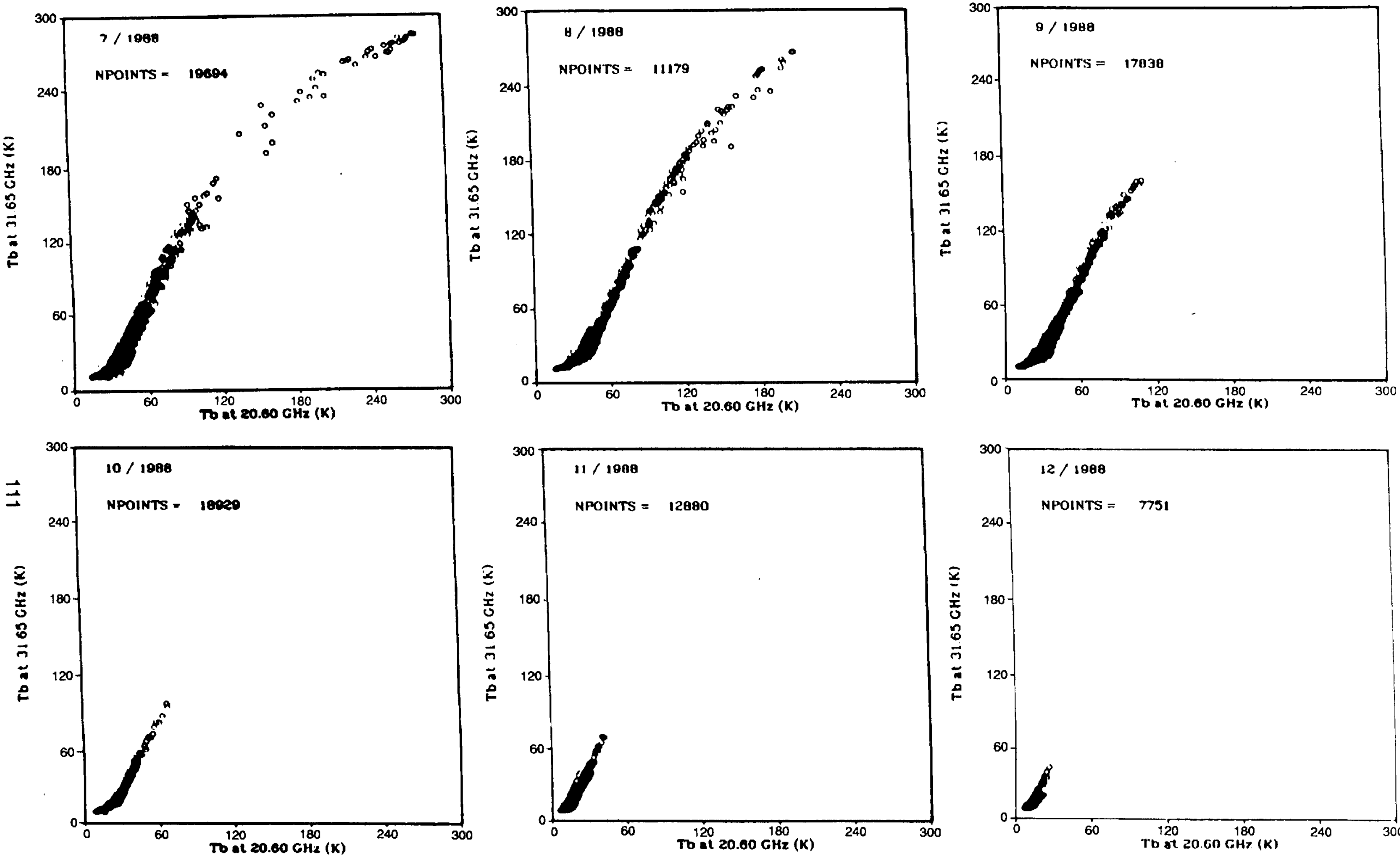
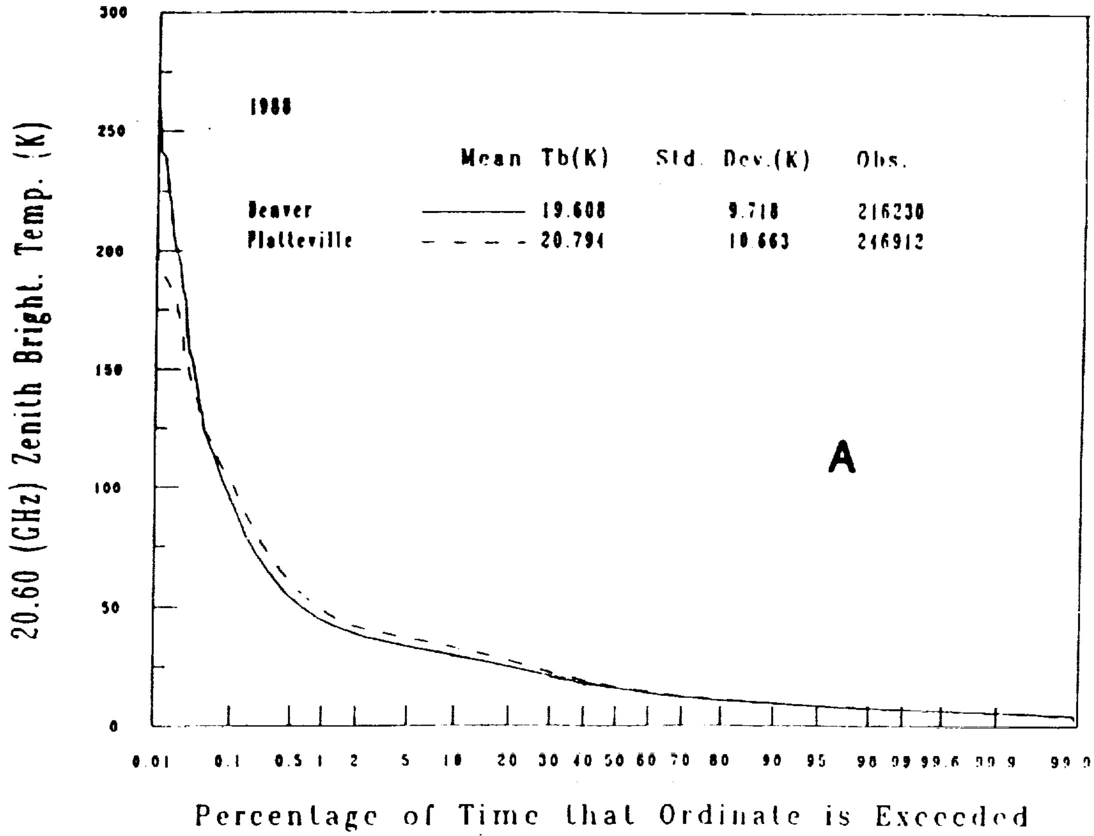


Fig. 5. Monthly scatter plots of 20.6 and 31.65 GHz for Denver, CO, for the last six months of 1988.



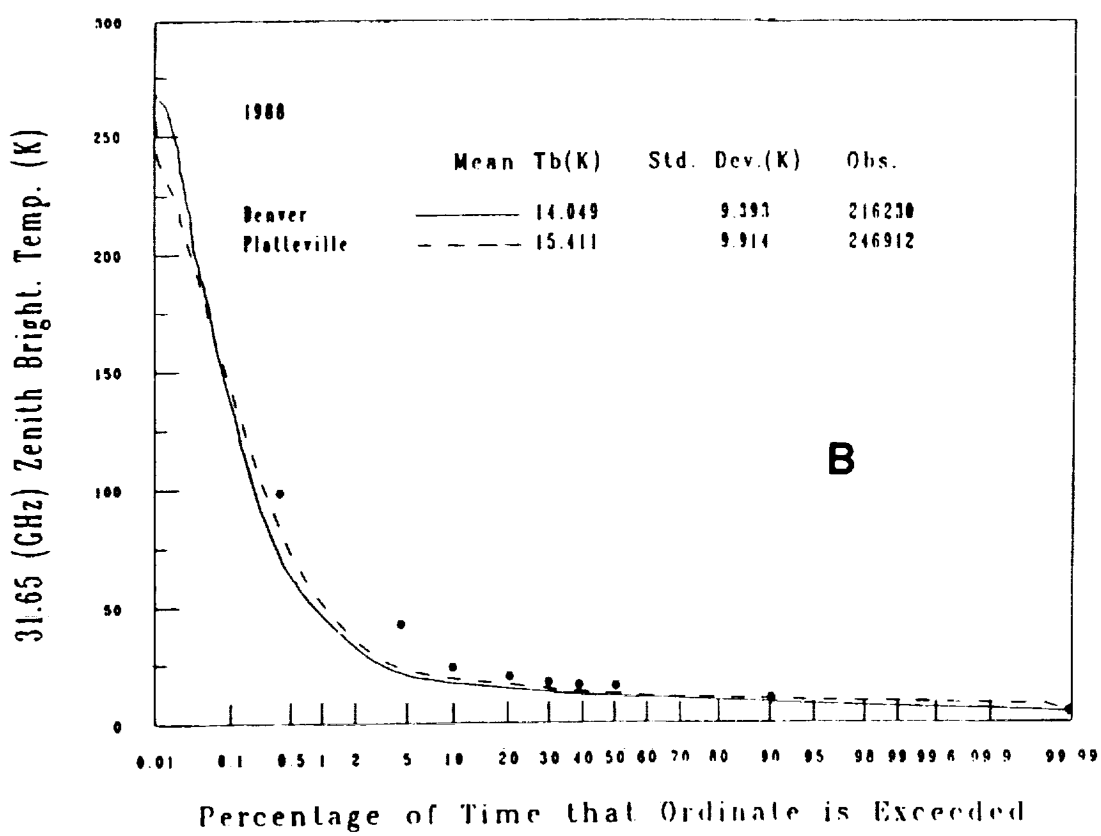
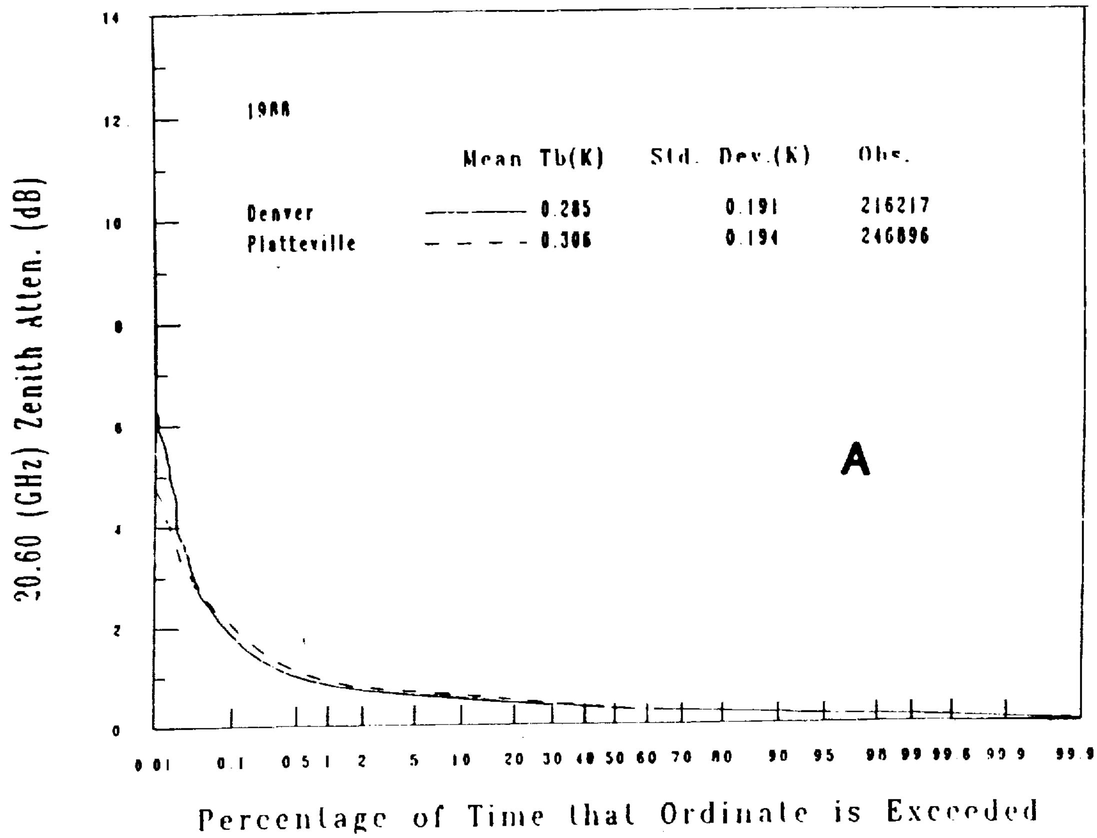


Fig. 6. Percentage of time that brightness temperature levels are exceeded at (A) 20.6, and (B) 31.65 GHz. Data represent measurements taken during 1/1 - 12/31/88, at Denver, and Platteville, CO. Comparisons with the estimates of Slobin (1982) are shown by dots in (B).



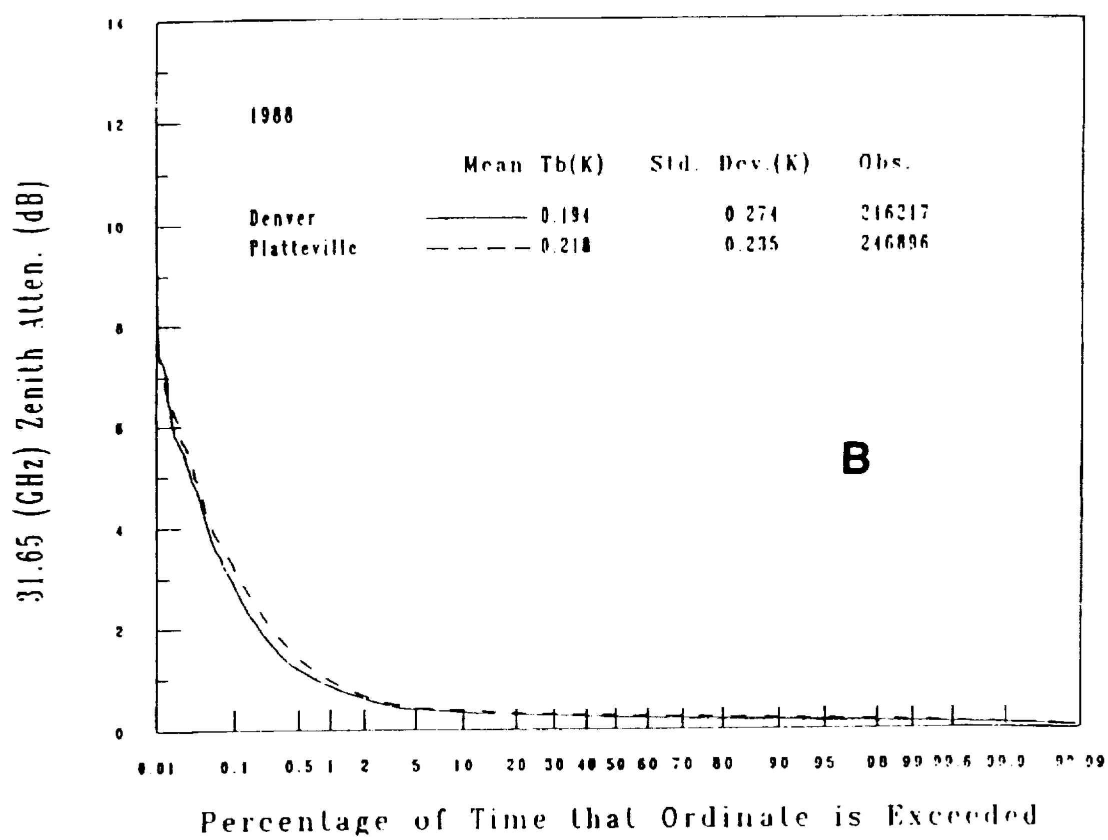


Fig. 7. Percentage of time that attenuation levels are exceeded at (A) 20.6, and (B) 31.65 GHz. Data represent measurements taken 1/1 - 12/31/88, at Denver, and Platteville, CO.

and since the situation is reversed for cloud liquid attenuation, there are crossovers in the cumulative probability distributions.

Another crossover occurs for the very low attenuations that occur during dry, cold conditions when 31.65 GHz is again larger than 20. We note that 8 dB is exceeded at the 0.01% level for the 31.65 GHz channel.

V. Summary and Plans

For the first time, we derived yearly brightness temperature and attenuation statistics at 20.6 and 31.65 GHz for Denver and Platteville, two Colorado locations separated by 49 km. A strong seasonal variation in attenuation was observed and maximum values in the summer months exceeded those in the winter by a factor of three or four. In our NAPEX XIV report, we reported on attenuation diversity between Denver and Platteville for three summer months. We are currently developing single station statistics and joint-station diversity statistics for all four stations of the Colorado Research Network for the 1988 data.

We have also shown the utility of using 20 vs. 31.65 GHz scatter plots for quality control. We plan to extend the procedure by developing confidence intervals as a function of attenuation and brightness values. Strict confidence intervals are required when precipitable water vapor and cloud liquid are derived from the radiometric data.

VI. Acknowledgements

The authors thank Joseph Shaw for reviewing the manuscript and for his help in preparing the figures.

References

Slobin, S. D., 'Microwave noise temperature and attenuation of clouds: Statistics of these effects at various sites in the United States, Alaska, and Hawaii,' Radio Science, **17:6**, pp 1443-1454, 1982.

Snider, J.B., M.D. Jacobson, and R.H. Beeler, "Observations of Attenuation at 20.6, 31.65 and 90.0 GHz - Preliminary Results from Wallops Island, VA," Proc. XIII NAPEX, San Jose, California, pp 138 - 144, 1989.

Westwater, E.R. and J.B. Snider, 'Microwave Radiometer Facilities at the Wave Propagation Laboratory,' Proc. of NAPEX XI, Virginia Polytechnic Institute and State University, Blacksburg, Virginia, pp 24-27, 1987.

Westwater, E.R., J.B. Snider, and M.J. Falls, 'Ground-Based Radiometric Observations of Emission and Attenuation at 20.6, 31.65, and 90.0 GHz,' Proc. of NAPEX XII, Syracuse, New York, pp 114-125, 1988.

Westwater, E.R., M. Falls, E. Fionda and J. Snider, 'Radiometric Observations at 20.6, 31.65 and 90.0 GHz: Continuing Studies,' Proc. XIII NAPEX, San Jose, California, pp 145-151, 1989.

Westwater, E.R., J.B. Snider, M.J. Falls and E. Fionda, 'Attenuation statistics derived from emission measurements by a network of ground-based microwave radiometers,' Proc. NAPEX XIV, Austin, Texas, pp 102-109, 1990.