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RADIOMETRIC OBSERVATIONS AT 20.6, 31.65, AND 90.0 GHZ: CONTINUING STUDIES

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Abstract -- Ground-based radiometer measurements at 20.6, 31.65, and 90.0 GHz have been analyzed to provide attenuation statistics, thus extending the data base of previous NAPEX studies. Using data from colocated radiosondes, comparisons of measurements and calculations of brightness temperatures are presented. The oxygen absorption model of Rosenkranz (1988) and the water vapor absorption models of Liebe (1989) and of Waters (1976) are used in the study. Data from July 1987 at San Nicolas Island, California, and from December 1987, August 1988, and November 1988 at Denver, Colorado, are included in the study. Joint-attenuation statistics at 20.6 and 31.65 GHz are presented for two locations of the Colorado Research Network (Denver and Platteville) for December 1987 and August 1988.

1. Introduction

In the work reported in the Proceedings of NAPEX XII (Davarian, 1988), Westwater et al. (1988) presented attenuation statistics derived from radiometric data taken at 20.6, 31.65, and 90.0 GHz. These data were taken with the NOAA steerable-beam three-channel radiometer. Statistics were presented for San Nicolas Island, California, July 1987, and for Denver, Colorado, December 1987. In this paper we present single-station attenuation statistics for the same three frequencies at Denver, August 1988; in the companion paper by Snider et al.(1989), an extended set of statistics is presented for Wallops Island, Virginia, April 1989. We also present a summary of our results in modeling clear air absorption. Finally, we use data from the Colorado Research Network of dual-channel radiometers to derive joint-station attenuation statistics for Denver and Platteville.

2. Clear Air Thermal Emission: A Comparison of Theory and Experiments

As discussed by Westwater et al. (1988), the NOAA steerable-beam radiometer is calibrated by the "tipping curve" method. If independent measurements are available of the atmospheric variables describing the thermal emission, i.e., the vertical distributions of temperature, pressure, water vapor, and cloud liquid, then measurements and calculations can be compared to study absorption models. In particular, various absorption models for oxygen and for water vapor can be compared in this way. Our procedure (Westwater et al., 1989) is to calculate, for each height level at which meteorological data are available, the absorption coefficient. Brightness temperatures are then calculated by numerically integrating the radiative transfer equation. Since the rawinsonde data that we used to provide meteorological data do not measure cloud liquid, we restricted our comparison set for this section to clear sky conditions.

During 1987 and 1988, ground-based zenith-viewing observations of atmospheric thermal emission were made at the frequencies of 20.6, 31.65, and 90.0 GHz. At the locations of the experiments, San Nicolas Island, California, and Denver, Colorado, rawinsonde observations of temperature and humidity were also available. Two types of rawinsonde observations were available: standard soundings taken by the National Weather Service and those from a relatively new rawinsonde package, the Cross-chain Loran-C Atmospheric Sounding System (CLASS). The meteorological data were then used with radiative transfer computer programs that calculated brightness temperature and total attenuation. The resulting brightness temperatures could then be directly compared with measurements. Absorption algorithms of Liebe (1989), Waters (1976), and Rosenkranz (1988) were used in the comparison study. Composite results comparing theory and measurements are shown in Figs. 1–3. Somewhat surprisingly, at 20.6 and 31.65 GHz, the relatively old model of Waters is in better agreement with the measurements than that of Liebe; however, at 90.0 GHz, the model of Liebe is clearly superior. We intend to continue this analysis as more data become available.

3. Single-station Attenuation Statistics

The methods used in deriving attenuation from emission, as well as our procedures for editing of data, were described by Westwater et al. (1988). We continued the Denver, Colorado, analysis by deriving statistics at 20.6, 31.65, and 90.0 GHz for the month of August 1988; these results are shown in Fig. 4. Primarily because of the influence of liquid-bearing cumulus clouds, much higher attenuations were encountered than during December in Denver, or July in San Nicolas Island. The analysis of the new Wallops Island data is given by Snider et al. (1989).

4. Joint-station Attenuation Statistics

As described by Westwater and Snider (1987), the Wave Propagation Laboratory operated a research network of dual-frequency radiometers in the front range of eastern Colorado. We chose to analyze joint-station attenuation statistics (at 20.6 and 31.65 GHz) for Denver and Platteville, located about 40 km apart. Two months were chosen: 1987 December and 1988 August.

As was discussed previously, all data represent 2-min averages. Since the clocks at the two sites were not synchronized, we first ran the time series through a time matching algorithm: data were paired such that the maximum time difference associated with a pair was 1 min. Then, statistics were derived for each station, both individually and jointly, for the paired data. Thus, data for which there were gaps at at least one station, were not included in the statistics. Plots of the individual attenuation statistics are in Figs. 5 and 6. Although the cumulative distributions are somewhat different, both the means and the standard deviations are statistically indistinguishable.

We also developed joint statistics in the following manner: let $(\tau_D)_i$ and $(\tau_P)_i$ be the ith data pair for Denver and Platteville. For the ith pair, we calculated the corresponding quantities – maximum (τ_{Di}, τ_{Pi}) and minimum (τ_{Di}, τ_{Pi}). Then we computed the cumulative distribution from the time series of both the minimum and maximum of the two-station distributions. These joint statistics, for 20.6 and 31.65 GHz, are shown in Figs. 7 and 8. Note that for the August statistics, a difference in maximum to minimum of about 6 dB is achieved at 31.65 GHz.

5. Plans

We will continue the analysis of the Wallops Island data to compare clear air calculations of brightness temperature with measurements. This comparison will be broadened to include all of our existing data including data with clouds. We will also examine the newest cloud models. Some of our existing 6-channel data at Stapleton Airport will support this effort. In addition, at least one 3-day period of rain will be analyzed.

In the near future, WPL will have at least four dual-channel radiometers available. We propose to deploy these radiometers at various spacings in the Denver area to develop a reasonable set of space and time diversity statistics.

We plan to extend the diversity analysis of existing dual-channel radiometer data of Denver and Platteville to cover a time period of at least 2 years.

We propose to make joint observations of slant-path attenuation in conjunction with the microwave radiometers and receivers being built by Virginia Tech in support of the OLYMPUS project. For this collaboration, we would operate the three- channel steerable radiometer at the Blacksburg, Virginia, receiver site. A tentative time for the joint experiments would be summer 1990.

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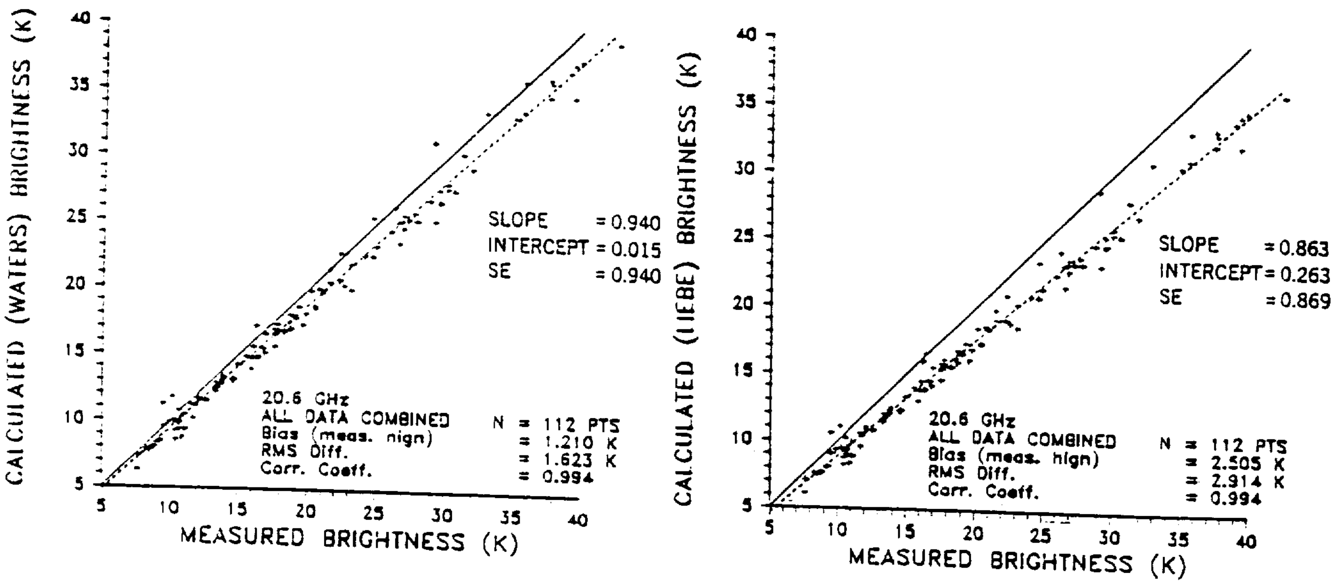

Figure 1. Comparison of measured and calculated brightness temperatures at 20.6 GHz. Data included in the comparison are from San Nicolas Island, California, July 1987, and from Denver, Colorado, December 1987, August 1988, and November, 1988. Oxygen attenuation calculated from the model of Rosenkranz (1988).

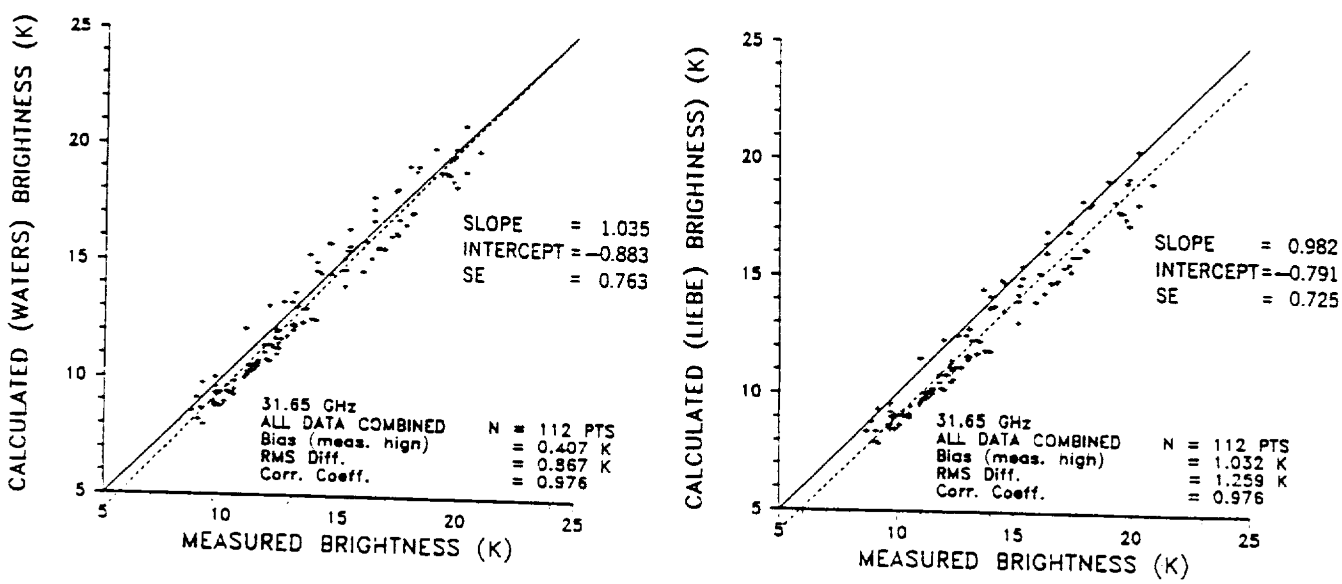

Figure 2. Comparison of measured and calculated brightness temperatures at 31.65 GHz. See Figure 1 caption for details.

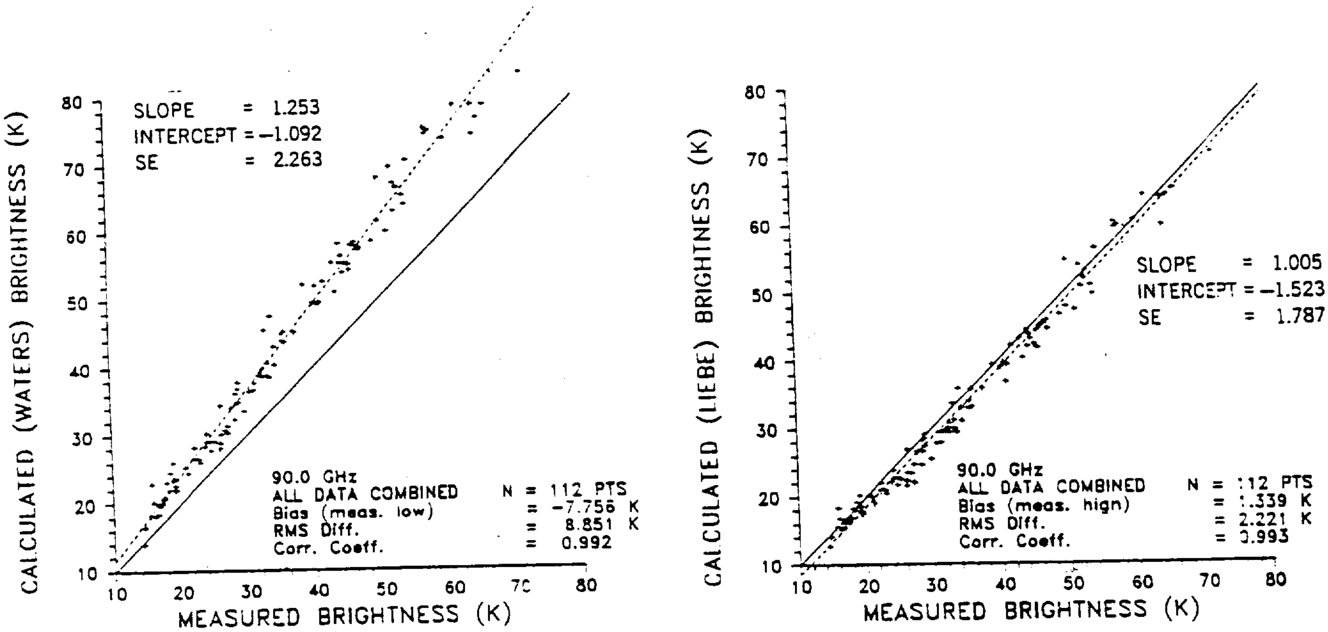

Figure 3. Comparison of measured and calculated brightness temperatures at 90.0 GHz. See Figure 1 caption for details.

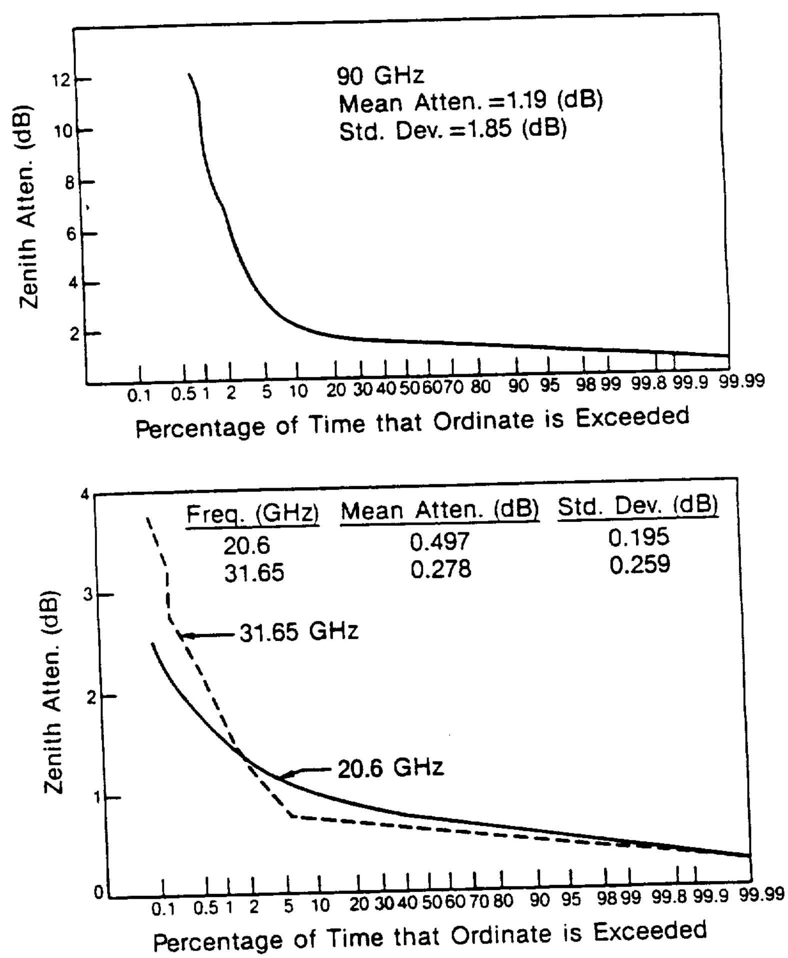

Figure 4. Cumulative distribution of zenith attenuation measured by a 3-channel radiometer at Denver, Colorado, August 1988. Data consisted of 17,792 2-min averages.

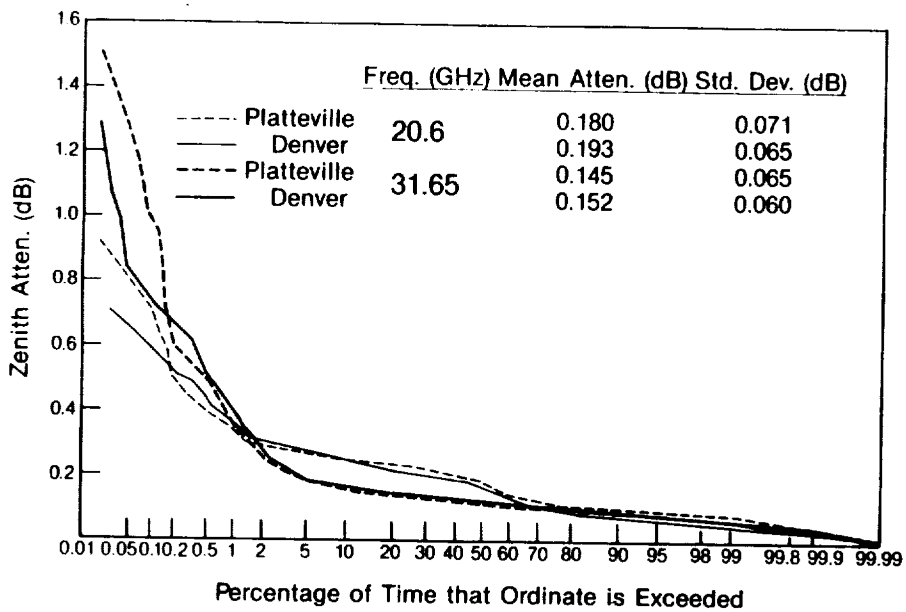

Figure 5. Cumulative distribution of zenith attenuation measured at 20.6 and 31.65 GHz at Denver and Platteville, Colorado, December 1987. Data consisted of matched pairs of 10780 2-min averages.

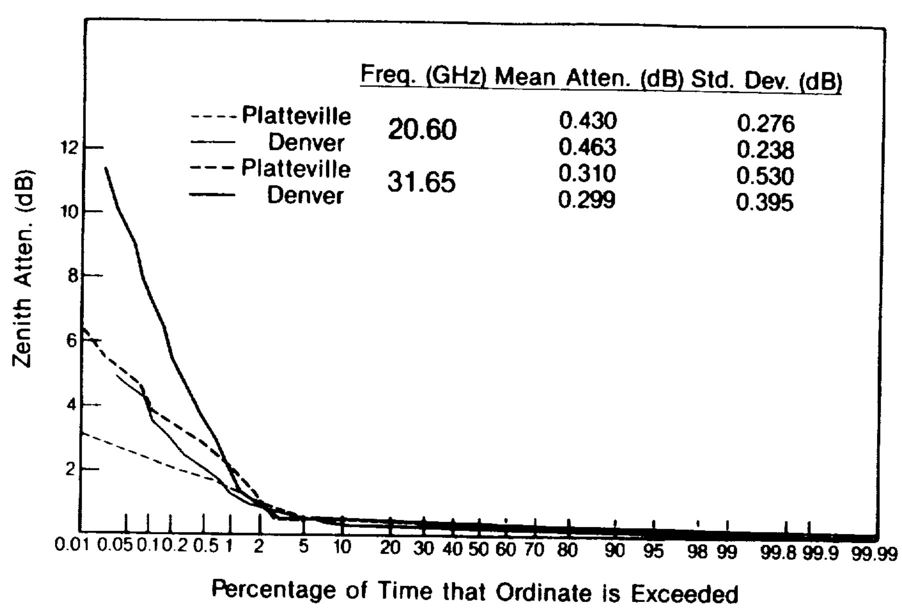

Figure 6. Cumulative distribution of zenith attenuation measured at 20.6 and 31.65 GHz at Denver and Platteville, Colorado, August 1988. Data consisted of matched pairs of 9175 2-min averages.

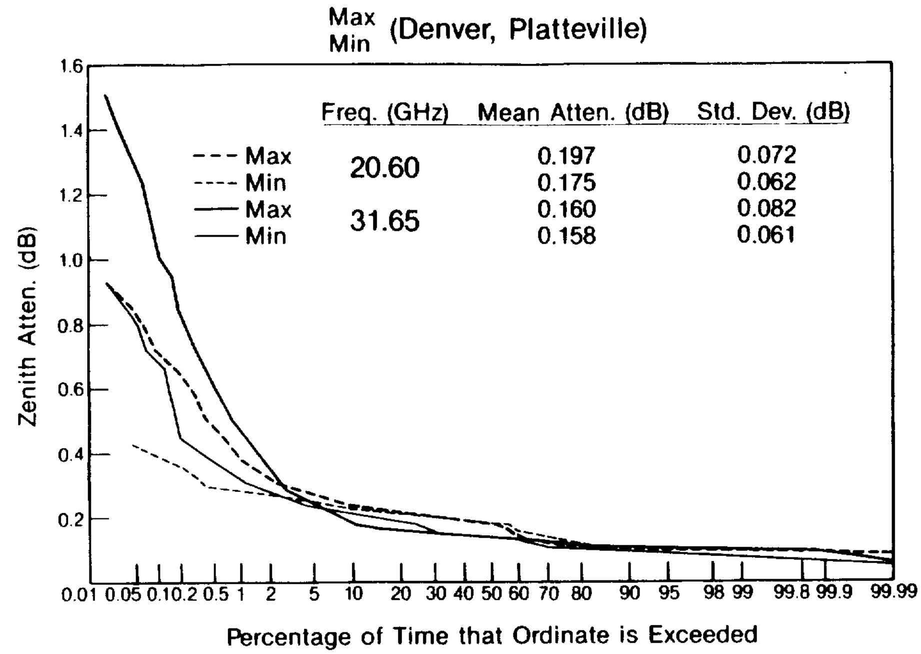

Figure 7. Joint cumulative distribution of minimum and maximum zenith attenuation at 20.6 and 31.65 GHz for Denver and Platteville, Colorado, December 1987. Distributions were derived from 10780 matched pairs of 2-min averages.

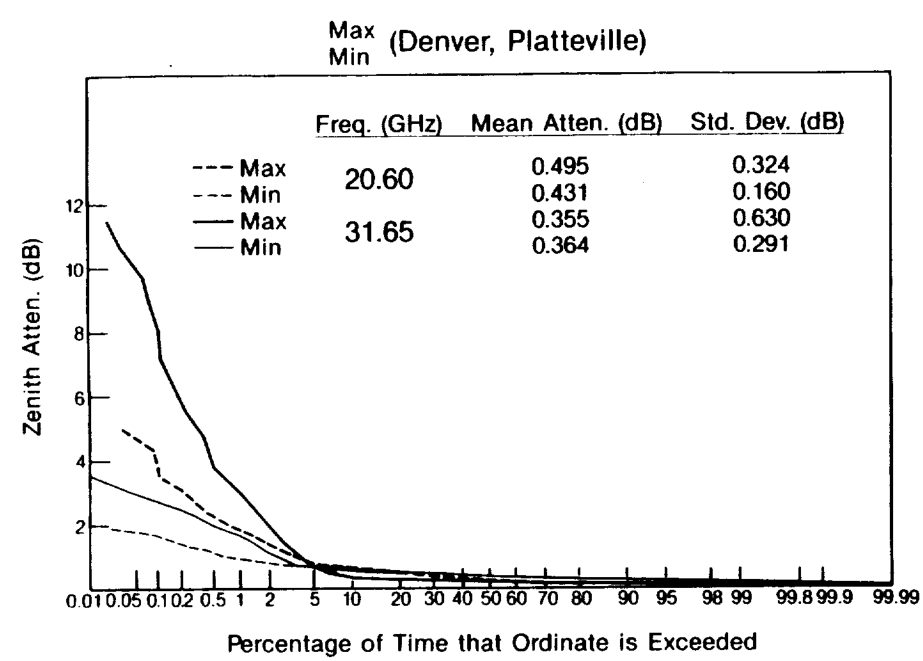

Figure 8. Joint cumulative distribution of minimum and maximum zenith attenuation at 20.6 and 31.65 GHz for Denver and Platteville, Colorado, August 1988. Distributions were derived from 9175 matched pairs of 2-min averages.