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OBSERVATIONS OF ATTENUATION AT 20.6, 31.65 AND 90.0 GHz -  
PRELIMINARY RESULTS FROM WALLOPS ISLAND, VAJ. B. Snider, M. D. Jacobson, and R. H. Beeler  
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Abstract - Ground-based radiometric observations of atmospheric attenuation at 20.6, 31.65 and 90.0 GHz were made at Wallops Island, VA during April and May 1989. Early results from the analysis of the data set are compared with previous observations from California and Colorado. The relative attenuation ratios observed at each frequency during clear, cloudy, and rainy conditions are shown. Plans for complete analysis of the data are described.

## 1. Introduction

During 1987 and 1988 the NOAA/ERL/Wave Propagation Laboratory (WPL) transportable three-channel ground-based radiometer measured atmospheric attenuation at 20.6, 31.65, and 90.0 GHz at San Nicolas Island, CA (July 1987) and Denver, CO (December 1987 and August 1988). From April 11 to May 8, 1989, additional measurements were made at Wallops Island, VA (hereafter referred to as Wallops for brevity). Because of the relatively short time between observations and the June 1989 NASA Propagation Experimenters (NAPEX) meeting, and because all supporting data have not yet been made available, the material presented in this paper is preliminary and incomplete. However, since both the quality and the variety of the data collected at Wallops were exceptional, it is desirable to present some early results.

## 2. Description of Experiment

The observations at Wallops were made in conjunction with an experiment designed to investigate the measurement of atmospheric moisture by an array of ground-based remote sensors and in situ balloon-borne humidity sensors. The experiment, ATmospheric Moisture Intercomparison Study (ATMIS), was conducted primarily during the nighttime hours from April 11 to April 18. The organizing agency for ATMIS was NASA/Goddard.

During ATMIS, joint observations of water vapor were made simultaneously by radiometers operated by Jet Propulsion Laboratory (JPL), NASA/Goddard, Pennsylvania State University (Penn State), and WPL, and by an ultraviolet lidar operated by NASA/Goddard. In addition, when clouds were present, simultaneous observations were made by the SPANDAR radar operated by the Applied Physics Laboratory of Johns Hopkins University. Supporting data consisted of several radiosondes daily, each equipped with three different types of humidity sensor, and a lidar ceilometer and multi-beam

Doppler acoustic sounder, both owned and operated by Penn State. During the week of the ATMIS, and for the following three weeks, the WPL radiometer operated mostly in the zenith direction providing both water vapor data and atmospheric attenuation data. However, on a few occasions the system was employed in an azimuthal scan mode to make joint observations with other radiometers having scan capability to determine the homogeneity of the water vapor field. Other brief interruptions of the attenuation measurements were necessary for instrument calibration. Approximately 570 hours of attenuation data were collected by the WPL system.

Procedures employed by the WPL microwave radiometer in the measurement of atmospheric attenuation have been described at previous NAPEX meetings and in the literature (Westwater et al., 1988; Westwater and Snider, 1989) and will not be presented here. However, whereas previous observations have employed either 60- or 120-sec averaging times, we used a 30-sec interval at Wallops in order to extend subsequent spectral analysis to higher temporal frequencies.

### 3. Preliminary Results

Weather at Wallops varied from clear and dry to four events in which the precipitation rate was perhaps the highest observed to date (inferred from the attenuation values as quantitative precipitation rates were not measured). Because of the high rainfall rates, radiometer saturation at all frequencies occurred on a few occasions. More typically, however, saturation was found to occur at 90 GHz but not at the two lower frequencies. Saturation events have been removed from the data set by limiting attenuation values derived from the radiometer data to less than 12 dB. A case where saturation occurs is indicated in the time series of Fig. 1.

Cumulative distributions of zenith attenuation are presented in Fig. 2, along with means and standard deviations. Note that at a relatively wet location such as Wallops, the atmospheric attenuation at 20.6 GHz generally exceeds that at 31.65 GHz. This is in contrast to the situation at Denver in December where attenuation at 31.65 GHz exceeds that at 20.6 GHz for about 65 percent of the time. The general shape of the distribution is similar for Denver and Wallops since some precipitation occurred. However, for SNI where no precipitation fell, the distributions are dissimilar. Table I contains a statistical comparison of our radiometrically-derived atmospheric attenuation at various locations.

In another useful type of comparison that deserves increasing attention, we examined the ratios of attenuation observed at the three frequencies for both combined clear-cloudy conditions and for

clear conditions at Wallops. Results for the former are in Fig. 3a, which shows how the ratios vary as conditions change from clear to cloudy to precipitating. In general, the attenuation ratios remain relatively constant on the right side of the distributions. This portion of the distribution is associated with clear weather and non-precipitating clouds. However, on the left side of the distribution, where precipitation and high liquid water contents are present, the ratios change rather dramatically, approaching a factor of 9 for the 90/20 GHz attenuation ratio.

Similar data for the clear weather case (Fig. 3b) show a much smaller variation, in general, although some non-linear effects occur during conditions of higher atmospheric moisture. Understanding these effects, of course, is critically important to the eventual extension of the satellite communication bands to 90 GHz and higher. During the next year, we plan to investigate attenuation ratios in greater detail and include the data sets collected earlier in the NAPEX program. Fig. 4 contains attenuation ratio data observed in Denver during August 1988 for clear, cloudy, and rainy conditions.

#### 4. Future Plans

Plans for future analysis of the Wallops data set include studies similar to those previously reported as well as new investigations:

- Comparisons of measured and calculated values of atmospheric absorption and attempts to improve present absorption models. The simultaneous observations of atmospheric humidity by three different types of sensor may help shed new light upon the modelling problem.
- Further study of regression relationships for prediction of attenuation between various frequencies.
- Refinement of liquid absorption models.
- Further studies of the attenuation ratios observed during the Wallops observations and extension of the study to the entire data set.

Table I - Comparison of 20.6/31.65/90.0 GHz Attenuation Statistics For Three Locations at Various Times of the Year. Clear and Cloudy Data Combined.

<u>Location</u>	<u>20.6 GHz</u>		<u>31.65 GHz</u>		<u>90.0 GHz</u>	
	<u>Mean</u>	<u>Std. Dev.</u>	<u>Mean</u>	<u>Std. Dev.</u>	<u>Mean</u>	<u>Std. Dev.</u>
(All values are in dB)						
San Nicolas (el 13 m) July 1987	0.398	0.113	0.321	0.096	1.128	0.498
Denver (el 1611 m) Dec. 1987	0.159	0.068	0.158	0.081	0.411	0.323
Denver (el 1611 m) August 1988	0.497	0.195	0.278	0.259	1.190	1.850
Wallops Is. (el 2 m) April/May 1989	0.428	0.291	0.398	0.407	1.239	1.323

#### References

- Westwater, E. R., J. B. Snider, and M. J. Falls, 1988: Observations of Atmospheric Emission and Attenuation at 20.6, 31.65, and 90.0 GHz by a Ground-based Radiometer, NOAA Technical Memorandum ERL WPL-156, November 1988, pp16.
- Westwater, E. R., and J. B. Snider, 1989: Ground-based Radiometric Observations of Atmospheric Emission at 20.6, 31.65, and 90.0 GHz, Proc. Sixth International Conference on Antennas and Propagation ICAP 89, Part 1: Antennas April 1989, pp 229-233.

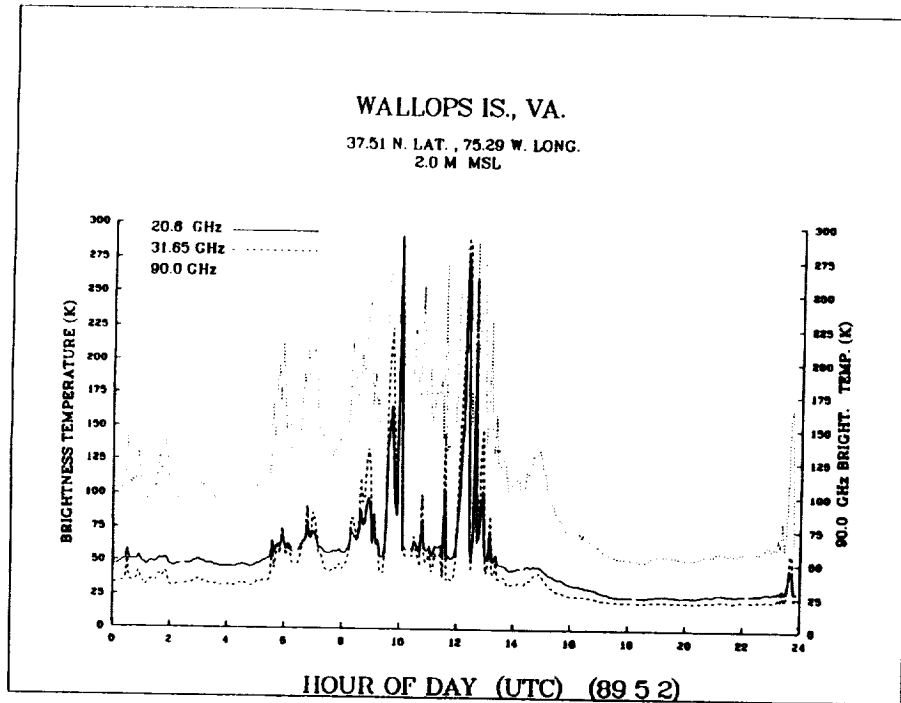


Figure 1. Time series of brightness temperatures at 20.6, 31.65, and 90.0 GHz during clouds and precipitation. Radiometer saturation at all frequencies occurs near 1000 and 1210 UTC.

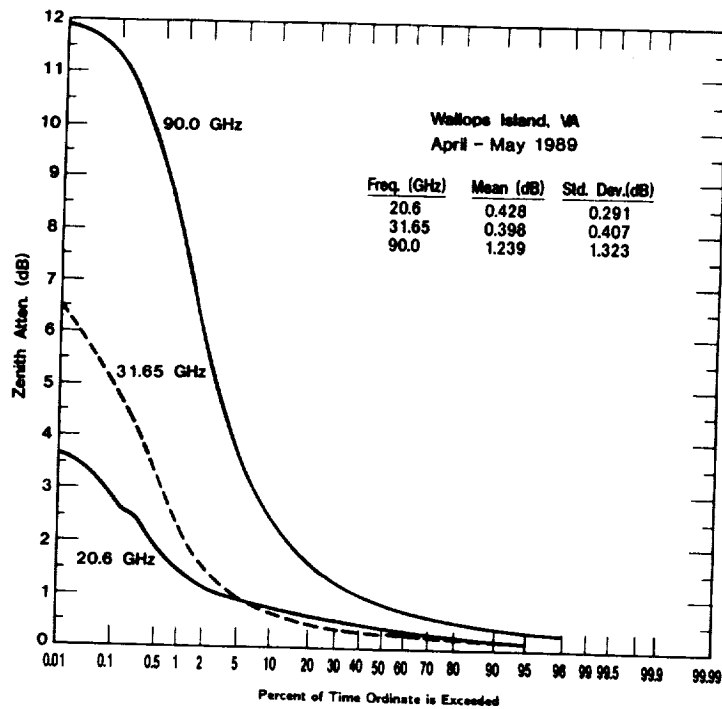


Figure 2. Cumulative distributions of zenith attenuation at Wallops Island, VA, for clear and cloudy conditions.

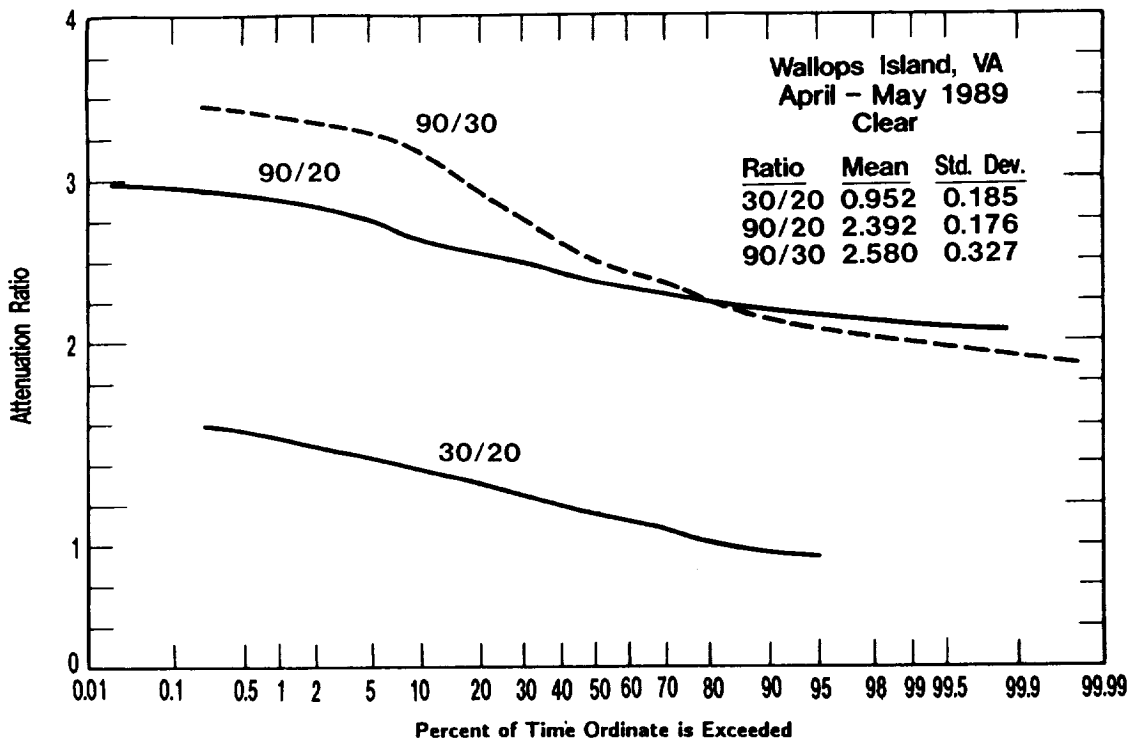
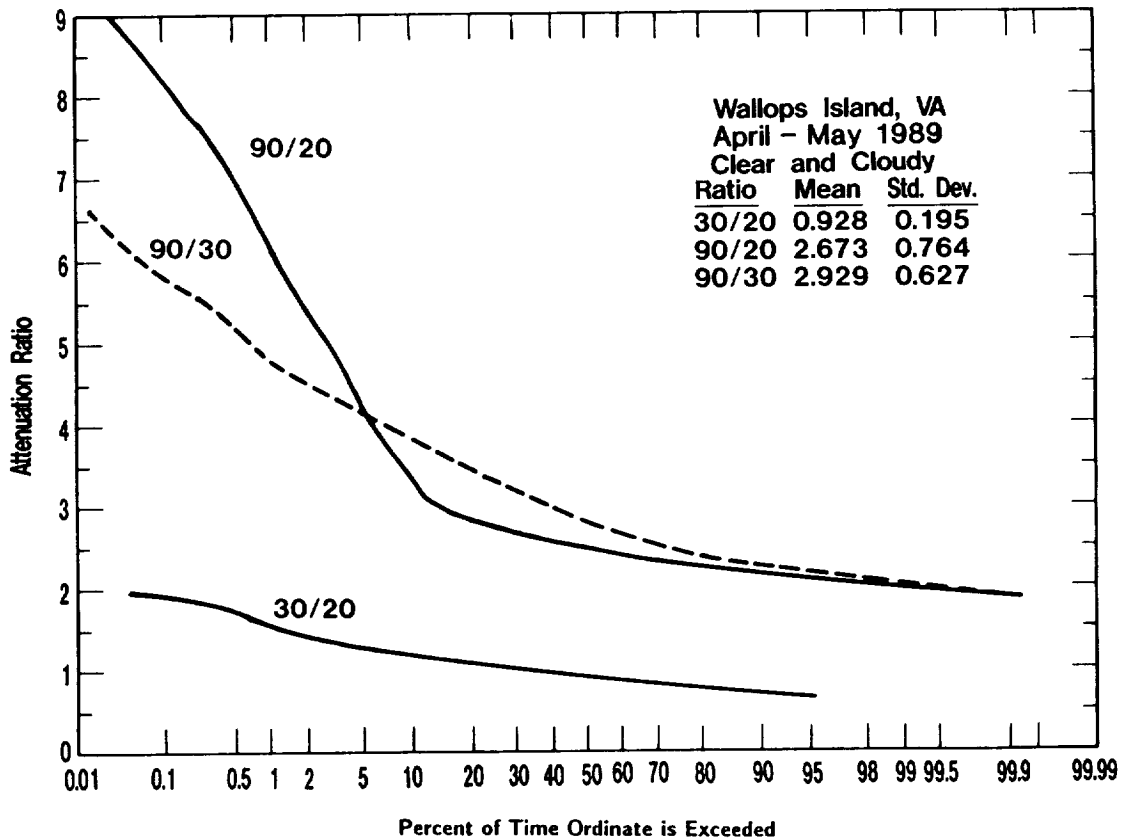


Figure 3. Cumulative distributions of attenuation ratios for (a) clear and cloudy conditions, and (b) clear conditions. Wallops Island, VA, April-May 1989.

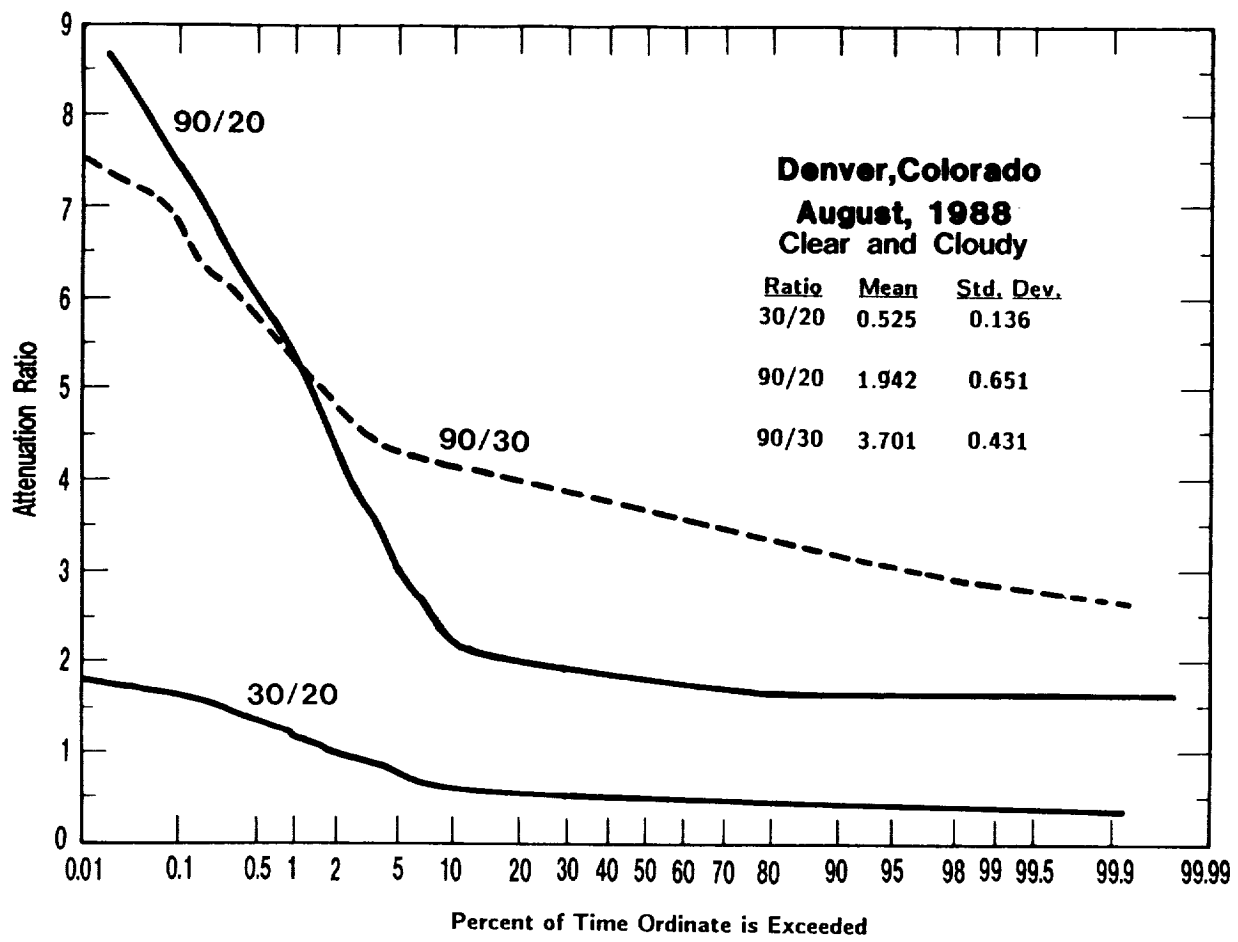


Figure 4. Cumulative distributions of attenuation ratios for clear, cloudy, and rainy conditions at Denver, CO, August 1988.