ESTIMATED ACCURACY OF GROUND-BASED LIQUID WATER MEASUREMENTS DURING FIRE

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Remote measurements of path-integrated liquid water and precipitable water vapor were made continuously during the Marine Stratocumulus Intensive Field Observations (IFO) from 1 - 19 July 1987. Observations were made with a three-channel (20.6, 31.65 and 90.0 GHz) microwave radiometer whose antenna was directed toward the zenith. As a result, the radiometer provided a continuous record of the total vertical moisture substance, i. e. both liquid and vapor, passing overhead. Fig. 1a shows hourly averages of the vapor and liquid amounts passing over the radiometer during the three week experiment. As expected, amounts of vertically-integrated liquid water contained in the marine stratocumulus were relatively small but highly variable (see table I). An example of the typical variation observed during a day's time is shown in figure 1b.

Since one goal of the FIRE project is to improve our understanding of the relationships between cloud microphysics and cloud reflectivity, it is important that the accuracy of remote liquid measurements by microwave radiometry be thoroughly understood. The question is particularly relevant since the uncertainty in the absolute value of the radiometric liquid measurement is greatest at low liquid water contents (<0.1 mm). However, it should be stressed that although uncertainty exists in the absolute value of liquid, it is well known that the observed radiometric signal is proportional to the amount of liquid in the antenna beam. As a result, changes in amounts of liquid are known to greater accuracy than the absolute value, which may contain a bias. In this paper, an assessment of the liquid measurement accuracy attained at San Nicolas Island (SNI) is presented.

The vapor and liquid water data shown in Fig. 1 were computed from the radiometric brightness temperatures using statistical retrieval algorithms (Hogg et al.,1983). The regression coefficients in the algorithms are customarily derived from a priori radiosonde data for the area where the measurements are performed. However, for the data reported here, the retrieval coefficients were derived from the 69 soundings made by Colorado State University during the SNI observations. Sources of error in the vapor and liquid measurements include cross-talk in the retrieval algorithm (not a factor at low liquid contents), uncertainties in the brightness temperature measurement, and uncertainties in the vapor and liquid attenuation coefficients. The relative importance of these errors is discussed. For the retrieval of path-integrated liquid water, the greatest uncertainty is caused by the temperature dependence of the absorption at microwave frequencies. As a result, the accuracy of statistical retrieval of liquid depends to large measure upon how representative the a priori radiosonde data are of the conditions prevailing during the measurements.

In an attempt to clarify this question, the microwave radiometer measurements at SNI were supplemented by an infrared (IR) radiometer modified for measurement of cloud-base temperature. Thus, the IR system provides the means to incorporate continuous measurements of the liquid temperature into the retrieval process. The method involves separation of the contributions to the total absorption due to water vapor and liquid water through an empirical relationship between absorption by vapor and the integrated water vapor obtained at SNI during clear weather. The excess attenuation caused by the liquid water is converted to the amount of path-integrated liquid using recent formulations for dielectric constant (Liebe, 1988) at the liquid temperature indicated by the IR radiometer. Table II presents calculations of amounts of liquid water calculated by (1) statistical inversion, and (2) taking into account the temperature of the liquid. Although comparative liquid amounts do not differ greatly, values obtained using the liquid temperature are about 5 percent higher. In the remainder of this paper, the trend for the entire data set is examined.

Acknowledgement:

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References:

Hogg, D. C., F. O Guiraud, J. B. Snider, M. T. Decker, and E. R. Westwater, 1983: A steerable dual-channel microwave radiometer for measurement of water vapor and liquid in the troposphere. J. Climate Appl. Meteor., 22, 789-806.

Liebe, Hans J., 1988: private communication.

Table I - Statistical Summary of Precipitable Water Vapor and Vertical Integrated Liquid Water Recorded at San Nicolas Island, 1-19 July 1987

Quantity	Mean	Std. Dev.	Coeff. of Var.
Water Vapor	1.903 cm	0.538 cm	28.84 %
Liquid Water	0.077 mm	0.108 mm	114.30 %

Table II Comparison of Integrated Liquid Water Calculated by Statistical Inversion and by Taking Liquid Temperature into Account

Date	Time(UTC)	Integrated Liquid (mm) Stat. Inversion	Temp. Dependence
870703	0400	0.051	0.060
870709	1000	0.319	0.320
870714	1800	0.201	0.215
870715	1700	0.217	0.231
870715	2200	0.060	0.068
870717	1200	0.487	0.490

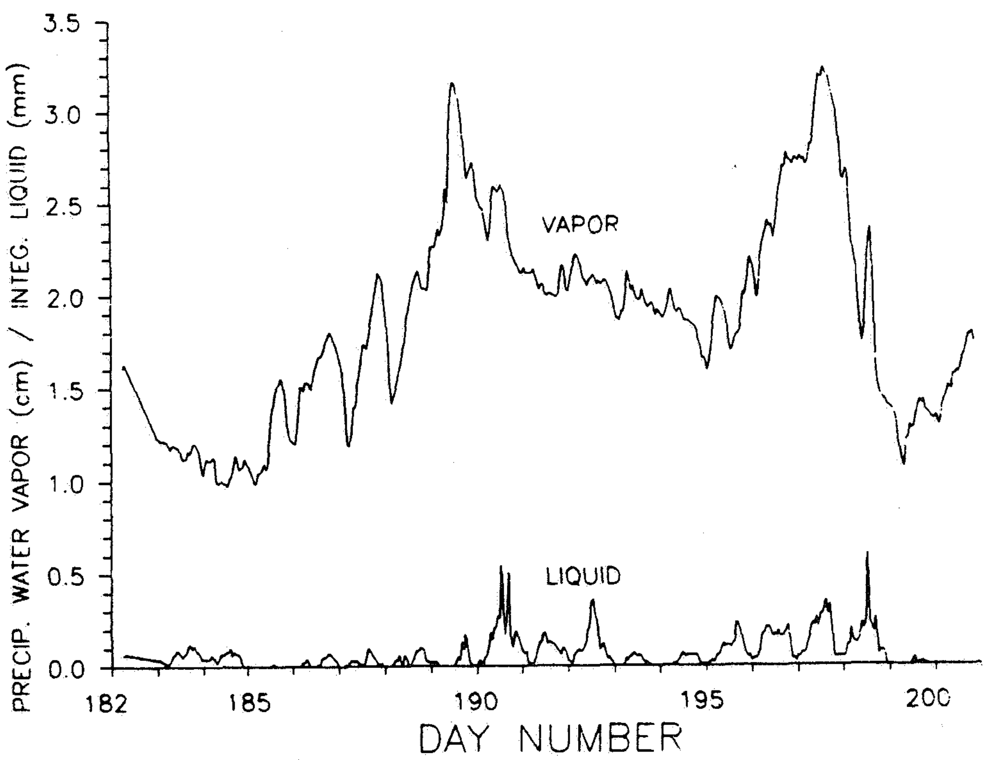

Figure 1a. Hourly averages of precipitable water vapor and vertical integrated liquid water measured at San Nicolas Island, 1-19 July 1987.

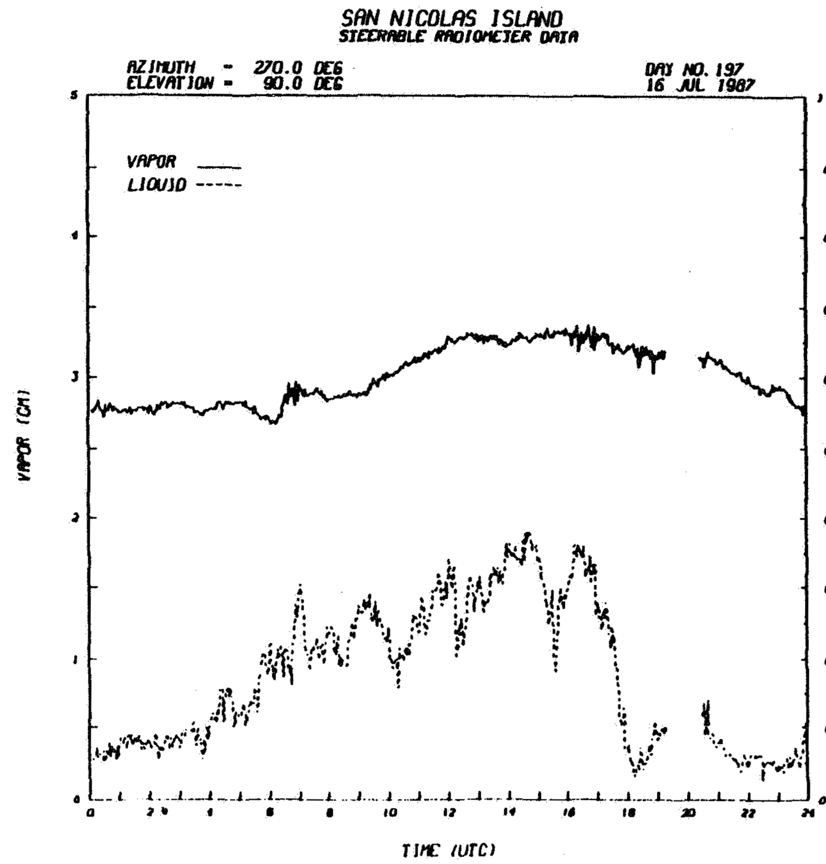

Figure 1b. Variation of precipitable water vapor and liquid water for 16 July 1987. Data values are one minute averages.