

Observations of Integrated Water Vapor and Cloud Liquid Water at SHEBA

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Introduction

In the arctic, water vapor and clouds influence the surface radiation balance to a greater extent than at lower latitudes. Because the integrated water vapor (IWV) is often less than 5 mm, substantial radiative cooling occurs in the 20- μ m infrared region, whereas this region is normally opaque at lower latitudes having greater water vapor amounts. Thin liquid water clouds also significantly affect the surface radiation balance.

IWV and cloud liquid water at the Surface Heat Budget of the Arctic (SHEBA) ice station were measured continuously over a 12-month period with a Microwave Radiometer (MWR; see Figure 1) that was among the suite of instruments deployed at SHEBA by the Atmospheric Radiation Measurement (ARM) Program.



Figure 1. The ARM MWR deployed at SHEBA.

Calibration

Beginning in December 1997, the radiometer was operated in a continuous elevation angle-scanning mode in order to permit calibration updates whenever the sky was clear. The algorithms applied *a posteriori* to the SHEBA MWR data to derive a continuous calibration from the angular scans were essentially identical to those developed for continuous real-time calibration of the other ARM MWRs. (See Liljegren [1999] for details of the calibration algorithms.)

General Results

Figure 2 presents the record of IWV, integrated liquid water (ILW), and surface air temperature at the SHEBA ice station for the period from December 1997 through September 1998. The wide range of IWV, from 0.1 cm to over 2.0 cm, is evident. Note also the marked changes that occur once the temperature reaches 0 °C.

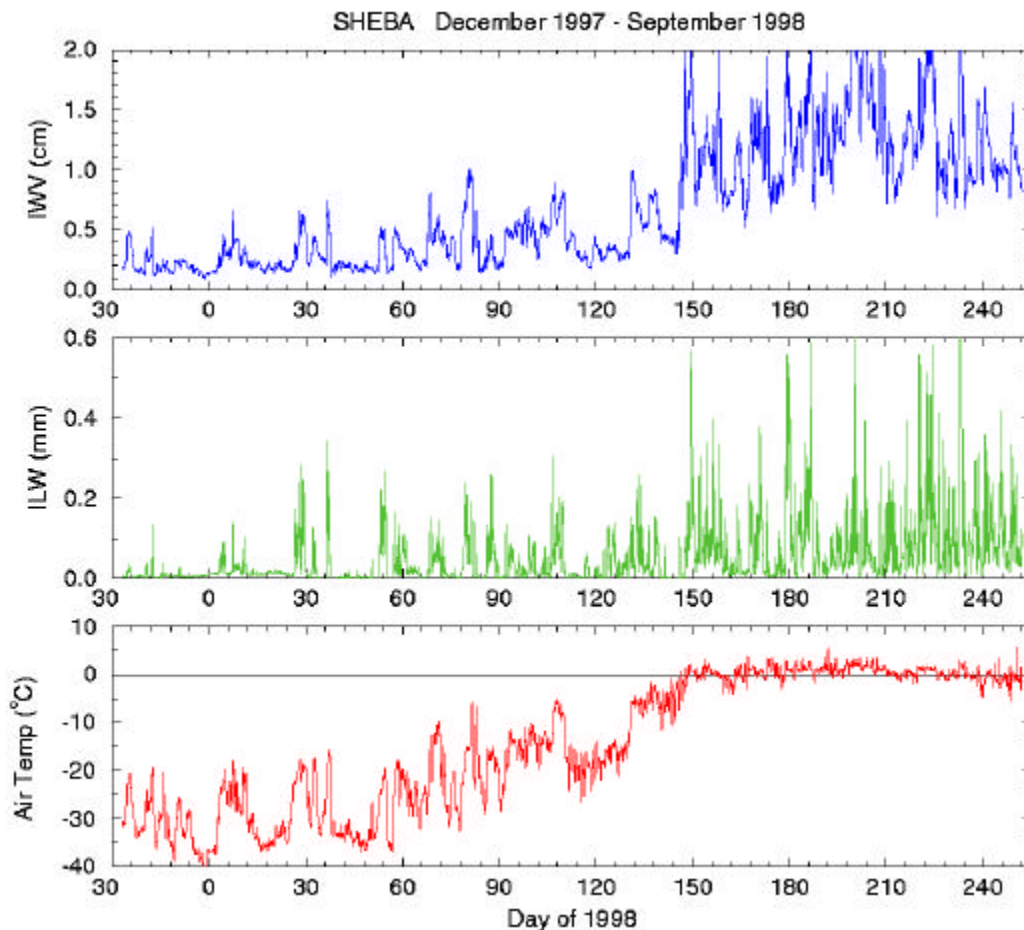


Figure 2. The hourly record of IWV, ILW, and surface air temperature at the SHEBA ice station.

Below freezing, the IWV and ILW are generally small and variations in IWV correlate well with variations in the surface air temperature as warmer (and moister) air masses move through the region. However, once the surface air temperature reaches 0° C, the net radiation no longer goes to heating the air but rather to melting snow and evaporating water. Once this happens and melt ponds develop, the IWV (and ILW) dramatically increase and are no longer well correlated with the surface air temperature.

Water Vapor Comparisons

Radiosondes were launched twice per day, except during the FIRE (First ISCCP [International Satellite Cloud Climatology Program] Regional Experiment) Intensive Field Observation (IFO) when they were launched four times per day. These provide an opportunity for comparing IWV with the MWR. The comparison of IWV derived from radiosondes with that from the MWR is presented in Figure 3 for clear-sky conditions.

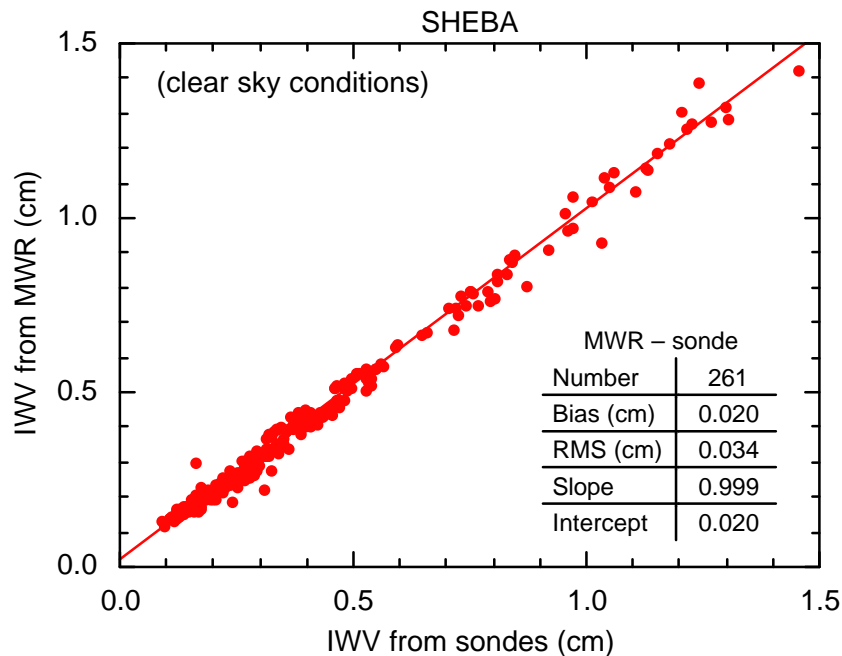


Figure 3. Comparison of IWV derived from radiosondes and the MWR.

The agreement between the MWR and the radiosondes is very good, down to 1 mm. (The calibration correction recently developed by Vaisala for the sonde relative humidity sensor was not applied. For such low water vapor amounts, the correction would not be significant. See the accompanying papers by Liljegren and Lesht for more about the effect of this correction at the SGP [Southern Great Plains].)

In Figure 4, radiometric brightness temperatures measured with the MWR are compared with calculations based on the Liebe 87 absorption model in order to examine the model performance in the limit of low water vapor where the microwave signal is dominated by oxygen emission. The similar values for the slope indicate that the water vapor absorption model appears correct. The 0.7 K difference in the intercepts suggests the oxygen absorption model may be too low.

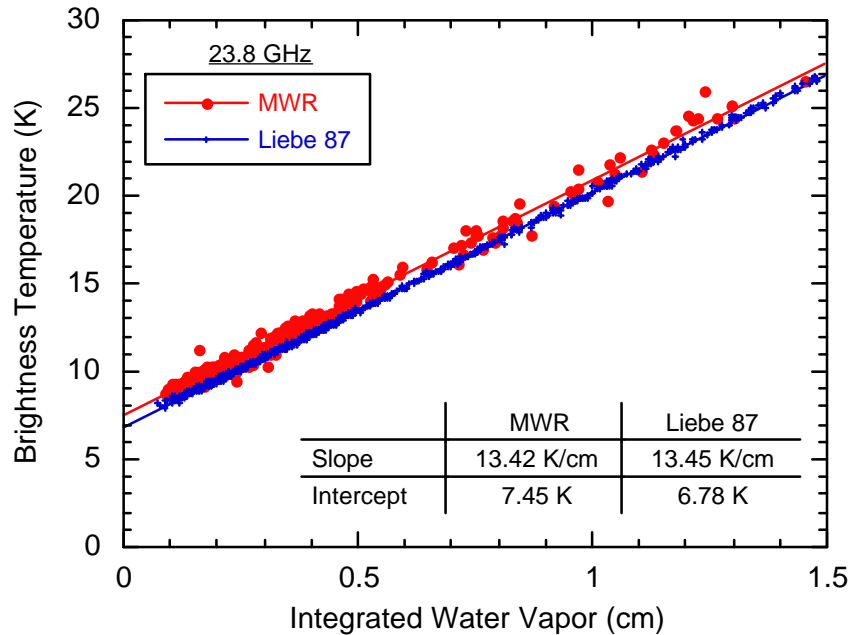


Figure 4. Comparison of brightness temperatures measured with the MWR and calculated using the Liebe 87 model. The IWV along the abscissa is derived from the radiosondes.

Liquid Water Comparisons

During the FIRE IFO periods, the SHEBA ice camp was over flown by several research aircraft, including the National Center for Atmospheric Research (NCAR) C-130, which was equipped with a Gerber PVM liquid water content probe. As shown in Figures 5a and 5b, comparison of the ILW from the MWR with ILW from the Gerber PVM probe generally exhibit good agreement, although it appears that on May 15 the cloud sampled by the aircraft did not always pass over the radiometer.

Continuously scanning the sky between $\pm 45^\circ$ of zenith at 5° intervals permitted the time-varying spatial structure of cloud liquid water to be observed. Figures 6 and 7 represent the ILW distribution from $+45^\circ$ to -45° about zenith. The values have been adjusted to zenith (measured opacities were divided by the sine of the elevation angle before applying the retrieval). These figures reveal significant spatial variations in the ILW that contribute to spatial variations in the solar and thermal radiation fields that would not be observed by either zenith-only or hemispherically-integrating sensors.

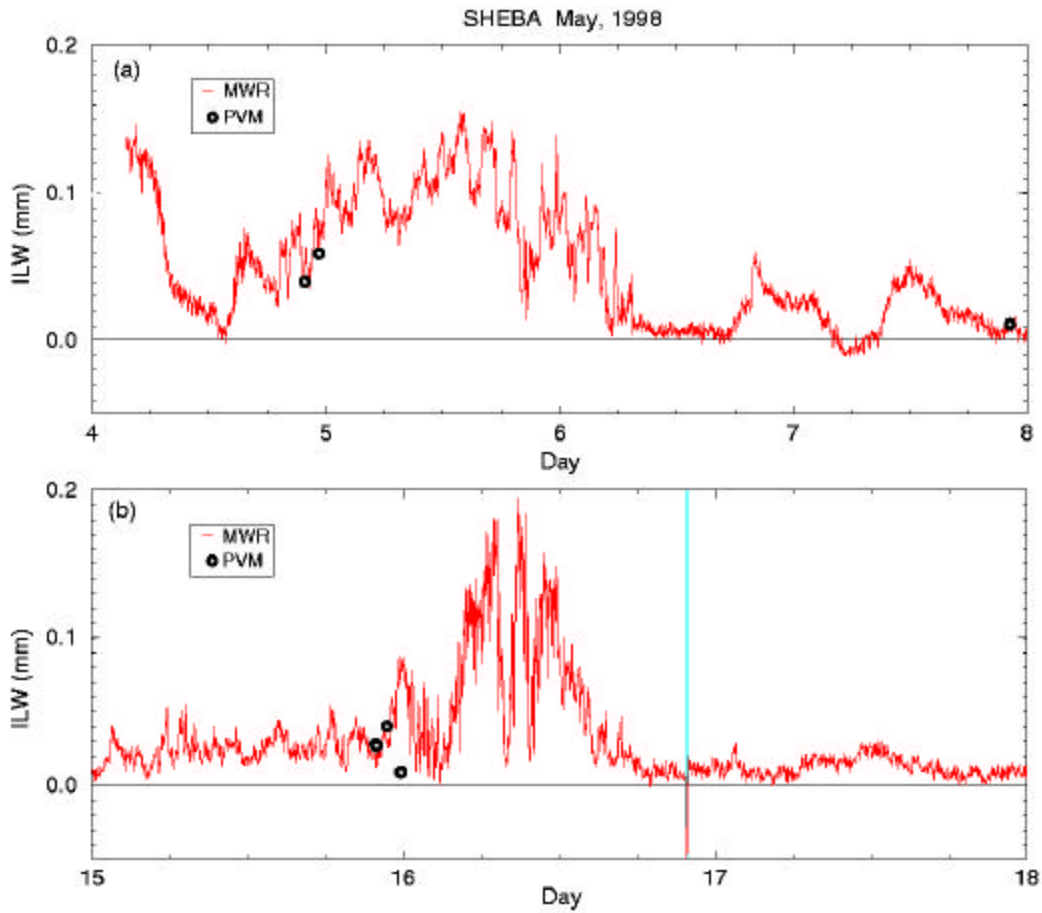


Figure 5. ILW from the MWR and Gerber PVM. a) May 4-7; b) May 15-17. The light blue vertical bar in b) indicates an anomaly in the ILW from the MWR detected by the quality control processing.

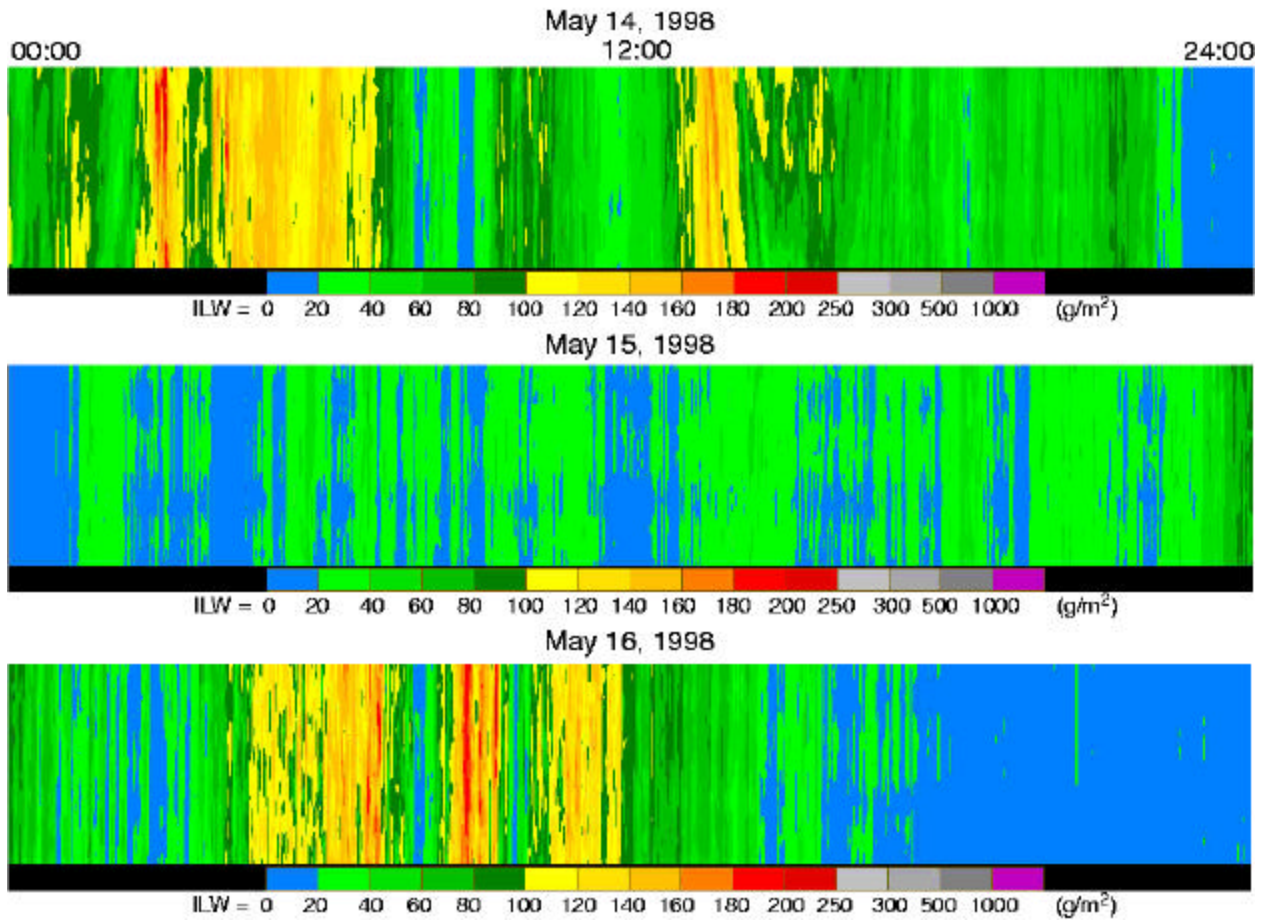


Figure 6. Spatial distribution of ILW (adjusted to zenith) for May 14-17, 1998 ($1000 \text{ g/m}^2 = 1 \text{ mm}$). The top of each plot is $+45^\circ$ from zenith; the bottom is -45° from zenith.

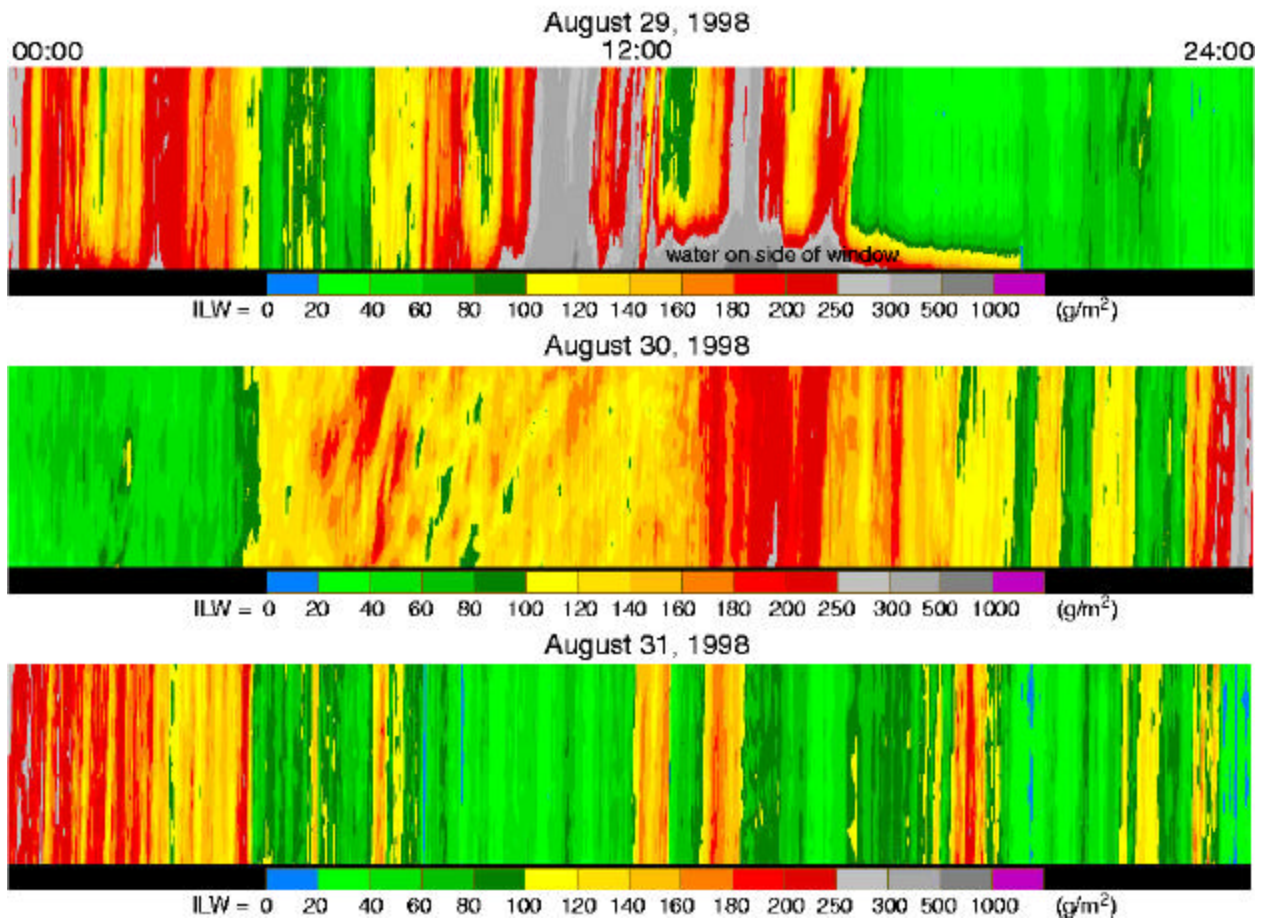


Figure 7. Spatial distribution of ILW (adjusted to zenith) for August 29-31, 1998 ($1000 \text{ g/m}^2 = 1 \text{ mm}$). The occurrence of water on the radiometer window is evident on August 29.

Conclusions

The ARM MWR provided a continuous record of IWV and ILW at the SHEBA ice station. The water vapor measurements (down to 1 mm) exhibited very good agreement with radiosondes. Measured brightness temperatures were in agreement with the Liebe 87 water vapor absorption model. ILW measurements generally agreed very well with the Gerber PVM on the NCAR C-130 aircraft.

Reference

Liljegren, J. C., 1999: Automatic self-calibration of ARM microwave radiometers. This proceedings.