Validation Measurements of Humidity Profiling in Rain Using a 170 GHz Differential Absorption Radar

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A tunable 167-174.8 GHz differential absorption radar has been developed as a remote sensing tool for measuring range-resolved absolute humidity inside of clouds and rain [1]. This new capability complements the established humidity profiling technique of passive radiometric remote sensing, since the latter suffers from biases induced by scattering by cloud and precipitation droplets [2].

The VIPR (Vapor In-Cloud Profiling Radar) system, shown in Fig. 1a, has been designed based on prior short-range, low-power radar systems that the Jet Propulsion Laboratory has developed at 95, 340, and 680 GHz. Its salient features are a Schottky diode frequency-doubler source with nearly 500 mW of continuous-wave transmit power [3]; ultra-high-isolation quasioptical transmit/receive duplexing; digital chirp generation and FFT-based range compression; and a 60 cm diameter primary aperture with nearly 58 dB antenna gain.

To validate VIPR's ability to measure absolute water vapor concentration, relative-humidity and temperature sensors were deployed on the ground during light rain at a distance of 820 m from the radar. VIPR's beam was pointed into the sky just above the sensors. Absolute humidity averaged over a 60 m wide swath centered over the sensors' range was retrieved from VIPR's differential absorption signal using the methods previously described in [1]. Fig. 1b shows a comparison of the radar measurements (blue) and the mean value of the in situ results (black) over approximately three hours of observation in moderate rain.

The data of Fig. 1b show that the radar measurements provide an accurate measure of the local water vapor content with a mean value within ~10-20% of the sensor value. However, the significant scatter in the radar measurements, which is approximately ten times higher than the theoretical expectation from [1], is not fully understood yet. One possible contribution to this uncertainty is poorly decorrelated speckle arising from a too-short (1 ms) pulse repetition interval with respect to the beam width and rainfall rate. Another is and frequency-dependent dispersion in the rain drop scattering cross-section that competes with the magnitude of change in water vapor absorption over the radar bandwidth. Additional measurements and analysis of these effects will be presented at the ISSTT meeting, including a discussion of how they will affect an upcoming airborne deployment of VIPR in late 2019.

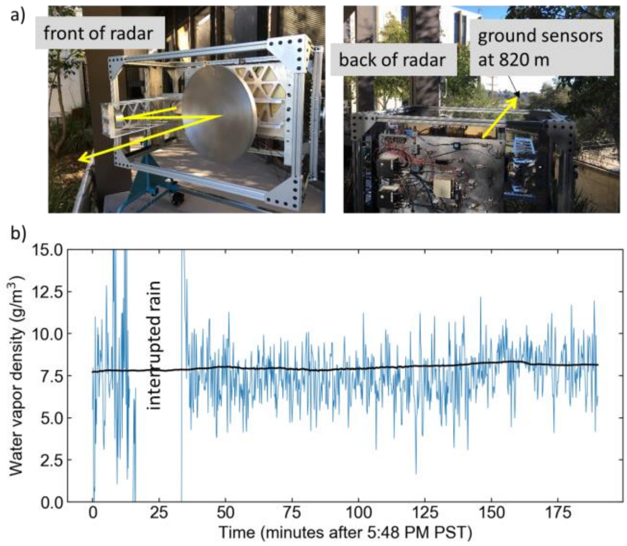

Fig. 1. a) VIPR system hardware showing how its 167-174.8 GHz beam is pointed above a distant hillside. b) Retrieved absolute water vapor content over ground sensors at 820 m (blue) are in good agreements with in situ measurements (black), but with higher than anticipated levels of measurement scatter.

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References

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