The Vapor In-cloud Profiling Radar (VIPR): Field deployment and validation of in-cloud humidity profiles retrieved using a 170 GHz differential absorption cloud radar

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Remote sensing of water vapor profiles inside of cloudy and precipitating volumes with high spatial resolution remains an important measurement gap for the existing set of spaceborne observing systems. The Vapor In-cloud Profiling Radar (VIPR) is a proof-of-concept instrument being developed under NASA's Instrument Incubator Program (IIP) at the Jet Propulsion Laboratory (JPL) with the aim of filling this observational gap. VIPR is a first-of-its-kind instrument, both as an all solid-state G-band cloud radar and as a differential absorption radar (DAR), which targets water vapor profiling inside of boundary layer clouds and precipitation with high vertical resolution (< 200 m). By switching between different transmission frequencies on the low-frequency flank of the 183 GHz water vapor absorption line, VIPR utilizes the differentially attenuated cloud reflectivity profiles to retrieve range-resolved maps of humidity. The radar is operated between 167 and 174.8 GHz in frequency-modulated, continuous-wave (FMCW) mode and features a state-of-the-art transceiver that utilizes GaAs Schottky diode frequency multipliers and power-combining techniques to realize 0.3 W of CW output power, as well as a G-band InP low-noise amplifier with a noise figure of 8 dB. As a result of the small wavelength (1.8 mm) and high receiver sensitivity, VIPR can detect extremely weak cloud signals, with a signal-to-noise ratio (SNR) of unity for a cloud reflectivity of -40 dBZ at 1 km range.

The instrument was recently deployed on the ground at the Department of Energy's Southern Great Plains Atmospheric Radiation Measurement (ARM) site for an intensive observation period to validate VIPR's retrieved in-cloud humidity profiles with coincident measurements from active, passive, and in-situ sensors. In this talk, we will present these validation results and an improved retrieval algorithm that includes comprehensive statistical and systematic uncertainty quantification. Furthermore, we will discuss important realistic technical limitations for any DAR system, including effects from dynamics of the observed scene (e.g. fast advection of spatially heterogeneous clouds and rain) and realistic frequency-dependent scattering by hydrometeors over the relatively small transmission bandwidth (~5%). The system will be deployed in the fall of 2019 on a Twin Otter aircraft to demonstrate its airborne profiling capabilities, as well as for measurements of total column water vapor in clear sky regions using radar returns from the surface.

Keywords: Cloud radar, Differential absorption radar, Humidity profiling, G-band radar, Millimeter-wave radar, Boundary layer