Atmospheric Water Vapor Measurements with Fine Spatial and Temporal Resolution using 3D Tomographic Inversion of Passive Microwave Brightness Temperatures from a Ground-based Radiometer Network

Steven C. Reising[1*], Sharmila Padmanabhan[2], J. Vivekanandan[3] ,
Flavio Iturbide-Sanchez[4] and Swaroop Sahoo[1]

1. Department of Electrical and Computer Eng., Colorado State University, Fort Collins, CO 80523.
2. CalTech/NASA Jet Propulsion Laboratory, Pasadena, CA 91109.
3. National Center for Atmospheric Research, Boulder, CO 80301.
4. NOAA/NESDIS Center for Satellite Applications and Research, Camp Springs, MD 20746.

Quantitative precipitation forecasting is currently limited by the paucity of observations on sufficiently fine temporal and spatial scales. In particular, convective storms have been observed to develop in regions of strong and rapidly evolving moisture gradients that vary on sub-meso γ scales (<2-5 km). Therefore, measurements of water vapor aloft with fine temporal resolution and sufficient vertical and horizontal resolution have the potential to improve forecast skill for the initiation of convective storms. In addition, such measurements may be used for data assimilation into and validation of future, high-resolution numerical weather prediction (NWP) models.

Currently, water vapor density profiles are obtained using *in-situ* radiosonde sensors as well as remote sensors including lidars, GPS ground-based networks, GPS radio occultation from satellites and a relatively small number of space-borne microwave radiometers. *In-situ* radiosonde measurements have excellent vertical resolution but are severely limited in temporal and horizontal coverage. In addition, radiosondes take nearly one hour to rise from ground level to the tropopause and may be advected horizontally by upper-level winds up to tens of km. COSMIC (Constellation Observing System for Meteorology, Ionosphere and Climate) and CHAMP (CHAllenging Minisatellite Payload) satellites in low earth orbit (LEO) provide measurements with 0.1-0.5 km vertical resolution at 30-minute intervals but with only 200-600 km horizontal resolution, depending on the magnitude of the path-integrated refractivity. Microwave radiometers on polar-orbiting satellites measuring in the 183 GHz band provide reasonable vertical resolution (2 km) and mesoscale horizontal resolution (20 km), but with repeated times on the order of tens of hours.

However, prediction of both the location of convective initiation and the amount of precipitation require knowledge of water vapor variations on sub-meso γ scales (<2 km) with update times on the order of tens of minutes. Such measurements have typically been unavailable due to the relatively high cost of vertically-profiling commercially-available microwave radiometers as well as that of densely-spaced and/or frequent radiosonde launches. Similarly, Raman lidars have a demonstrated capability of high-resolution water vapor profiling in clear air and low-opacity clouds, but their extremely high cost, eye-safety of the lidar signal and background sunlight limit their deployment to very few locations.

To make such measurements possible, the low-cost Compact Microwave Radiometer for Humidity profiling (CMR-H) was developed and fabricated by the Microwave Systems Laboratory at Colorado State University. Component costs are reduced substantially through the implementation of monolithic microwave integrated circuit technology, yielding a radiometer that is also small (24 x 18 x 16 cm), lightweight (6 kg) and low in power consumption (25-50 W, depending on weather conditions). A number of CMR-Hs are deployed in a scanning network configuration. Algebraic reconstruction tomography is used to retrieve the 3-D water vapor field from simultaneous brightness temperatures using radiative transfer theory, optimal estimation and Kalman filtering. Recently, observation system simulation experiments as well as field measurements at the U.S. Department of Energy's Atmospheric Radiation Measurement (ARM) Southern Great Plains (SGP) site in Oklahoma have demonstrated the potential for a network of coordinated scanning microwave radiometers to provide 0.5-1 km resolution both vertically and horizontally with sampling times of 15 minutes or less. Additionally, three scanning CMR-Hs were deployed in a triangular network configuration in Rome, Italy, as part of the Mitigation of Electromagnetic Transmission errors induced by Atmospheric Water Vapor Effects (Metawave) campaign. Results of both OSSEs and field measurements from Oklahoma and Rome will be presented and discussed.