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TOMOGRAPHIC RETRIEVAL OF CLOUD WATER DISTRIBUTIONS USING AN AIR-BORNE SCANNING MICROWAVE RADIOMETER

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ABSTRACT

Microwave radiometers have been used to retrieve the integrated water content of the atmosphere for many decades. Their use in imaging three-dimensional cloud structure was made possible in 1980s after Warner et al.'s pioneering work on cloud tomography, but neither the microwave technology nor the cloud models were mature enough for practical application. In this paper we show the feasibility and caveats of the tomographic method with a single air-borne scanning microwave radiometer by using computer simulations from a tomography simulator along with data from an imaging microwave radiometer observed during the 2003 Wakasa Bay field campaign.

We developed the Tomography Simulator with simulated clouds and simulated microwave radiometers to enables investigation into the effects of tomographic system specifications on retrievals. Sensitivity simulations based on our Tomography Simulator show that retrieval accuracy is determined by several factors, including radiometer characteristics (e.g., noise level, beam width, channel selection), uncertainty in ancillary data (e.g., background brightness temperature, water vapor mixing ratio), and platform motion (fixed or airborne). For a typical configuration of 0.5 K radiometer noise, 1.0 K uncertainty in the background brightness temperature data, and 60 m/s airspeed our simulations suggests a reconstruction accuracy of ~10% of the maximum cloud water content within the clouds.

To verify the tomographic method we used along-track scanning data from the CU Center for Environmental Technology's Polarimetric Scanning Radiometer (PSR) observed on January 28, 2003 during the Wakasa Bay campaign. The multi-band PSR was aboard the NASA P-3 aircraft along with several other instruments, including two millimeter-wave cloud radars. PSR observations over a range of angles up to 70 degrees off nadir were used to reconstruct the cloud fields underneath the aircraft. The tomographic reconstruction appeared to be reasonable from the climatological point of view, providing plausible magnitude and distribution of cloud content. The reconstruction also captured the locations of the cloud top boundary well compared with that from the radar. Unfortunately, a quantitative validation of the retrieved lower boundary and cloud water distribution was not feasible since the cloud radar could not provide a useful estimation of these quantities for the precipitating clouds.

The Wakasa Bay campaign was initially designed to validate AMSR-E shallow rainfall and snowfall retrieval capabilities. As a result, many conditions were not ideal for the tomographic study. For example, the aircraft flew at 144 m/s resulting in insufficient overlap between each scan cycle, and the wind speed was about 20 m/s causing more than 3 K uncertainty in the background (sea surface) brightness temperature. Nevertheless, this research demonstrates the feasibility of tomographically retrieving cloud structure using current scanning microwave radiometer technology and provides guidelines by which to improve future field-based studies of cloud tomography.

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