# *The RAL Seminar Series*

## NCAR

# MICROWAVE REMOTE SENSING OF HIGHER LATITUDE PRECIPITATION USING COMBINED ACTIVE AND PASSIVE SPACEBORNE INSTRUMENTS

by

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**Friday, November 12, 2010**
**Foothills Lab Building 2,**
**Room 1022, 11:00 a.m.**

Abstract

Spaceborne microwave remote sensing of precipitation at higher latitudes is investigated using an integrated observational and modeling approach. An ice particle model database containing microwave properties of twenty-five ice habits is developed and serves as the centerpiece of both a radar-based snowfall retrieval scheme and a combined active/passive modeling system. Equivalent radar reflectivity factor ($Z_e$) – snowfall rate (S) and ice water content (IWC) relationships are first derived, and their sensitivity to ice model, size distribution, and temperature are demonstrated. Next, a combined active/passive modeling system that converts CloudSat Cloud Profiling Radar (CPR) observations to simulated microwave brightness temperatures ($T_B$) is utilized to physically assess the ice particle models under precipitating conditions. Simulation results indicate certain ice models (e.g., low-density spheres) produce excessive scattering and implausibly low simulated $T_B$'s for stratiform precipitation events due to the combined effects of excessive derived ice water paths (IWP) and extinction. An ensemble of non-spherical ice particle models, however, consistently produces more physically realistic results under most circumstances and adequately captures the radiative properties of frozen hydrometeors associated with precipitation – with the possible exception of very high IWP events. Large derived IWP uncertainties are also noted and may indicate IWP retrieval accuracy limitations using passive microwave observations. Simulated brightness temperature uncertainties due to the ice particle model can approach 9 (5) K at 89 (157) GHz for high IWP conditions associated with mid-latitude synoptic snowfall cases and ~2-3 (~1-2) K under typical mid-latitude stratiform rain conditions. These uncertainties – and sample error correlations and covariances for select microwave frequencies - display distinct variability due to IWP, precipitation type, satellite zenith angle, and frequency. Active-only snowfall retrievals using CPR near-surface reflectivity histograms indicate the dominant mode of global snowfall has extremely light reflectivity values. The average retrieved near-surface global snowfall rate is ~0.3 mm $h^{-1}$, but shows regional variability with large uncertainties. Future multi-frequency space-borne radars are also evaluated using proxy $K_a/K_u$ reflectivities, and potential snowfall detection shortcomings are noted. Finally, the sensitivity of the $K_a/K_u$ dual-frequency radar signature of snowfall is explored to further highlight uncertainties due to ice model scattering properties and particle size distribution.