Multi-Frequency Microwave Radiometer Simulations of GCPEx Surface Snowfall Events Using In-Situ Microphysics Observations

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I. Introduction

Goal: Simulate Conically Scanning Millimeter-Wave Imaging Radiometer (CoSMIR) high-frequency microwave channels for surface snowfall events during GCPEx.

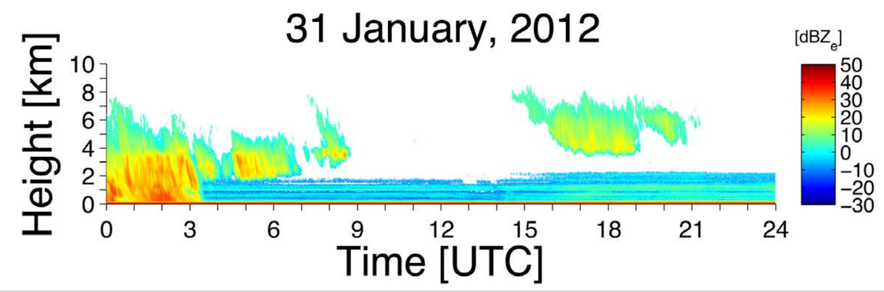
Tools: GCPEx airborne and surface observations as radiative transfer (RT) model input.

Focus: Simulated microwave brightness temperature sensitivities to key RT input parameters.

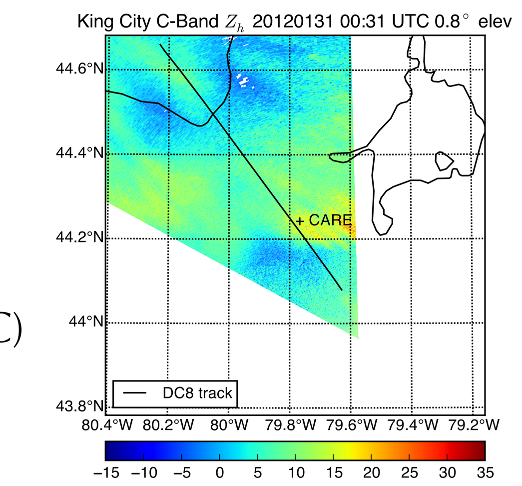
II. Case Study: 30-31 January 2012

The 20 UTC 30 Jan - 04 UTC 31 Jan2012 Global Precipitation Measurement Cold season Precipitation Experiment (GCPEx) snowfall event was chosen for initial testing purposes. Highlights of this snowfall event include:

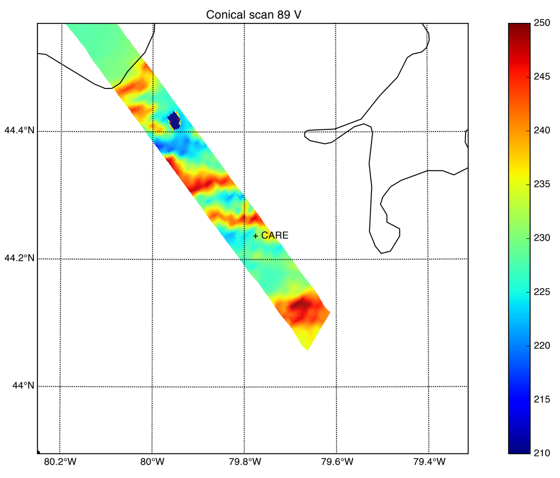
- Synoptic snowfall event driven by upper level forcing.
- Cloud top heights ~6-8 km
- Light to moderate snowfall
- 2-3 cm accumulated surface snowfall at CARE site
- Extensive ground-based observations at numerous sites
- DC-8 overflights (APR-2 radar + CoSMIR)
- Citation in-cloud spiral over CARE site (2315-2343 UTC)
- Observations used to create RT input (see below)



Vertically-pointing X-band radar reflectivity for last segment of snowfall event.

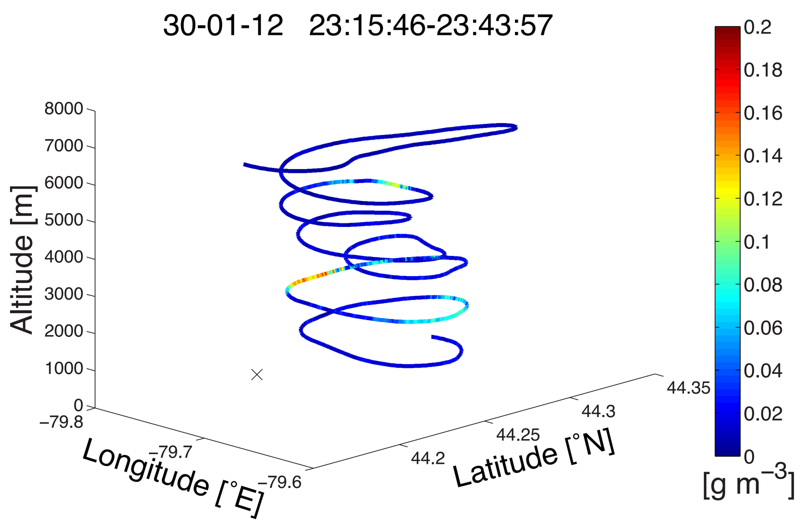


King City radar PPI scan with DC-8 track.

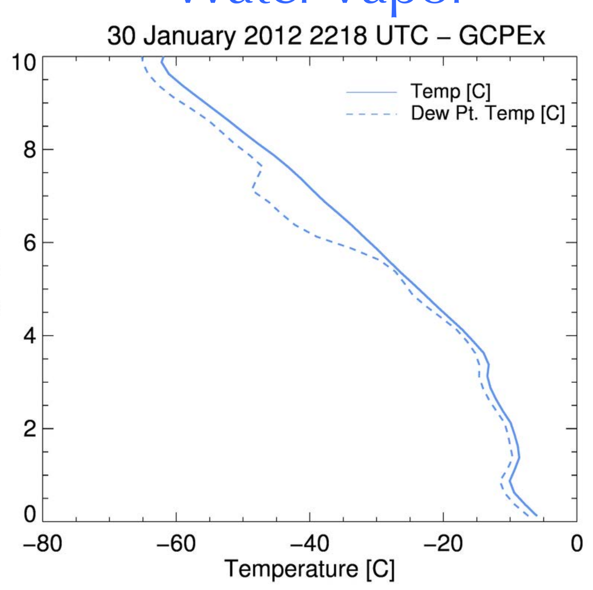


CoSMIR v89 GHz swath over CARE site.

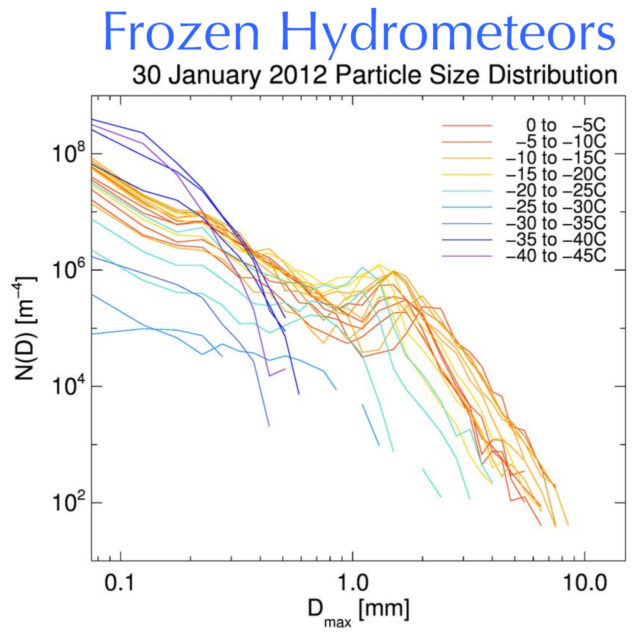
Cloud Liquid Water

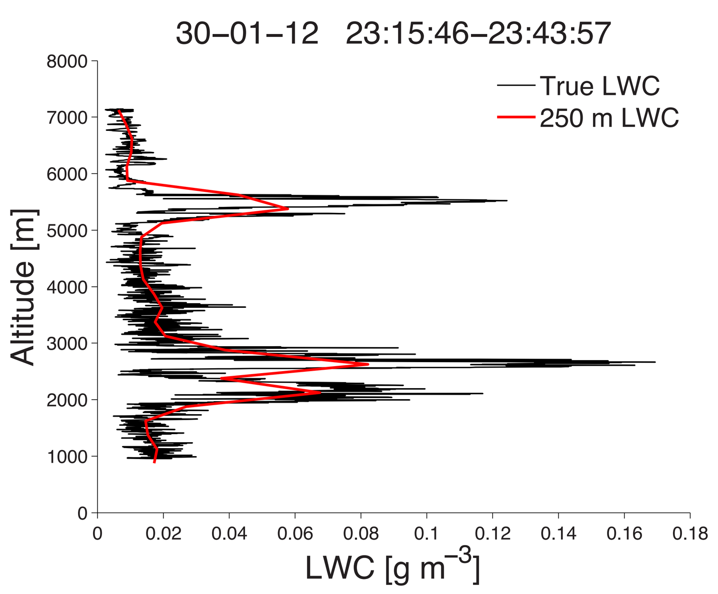


Water Vapor



Frozen Hydrometeors



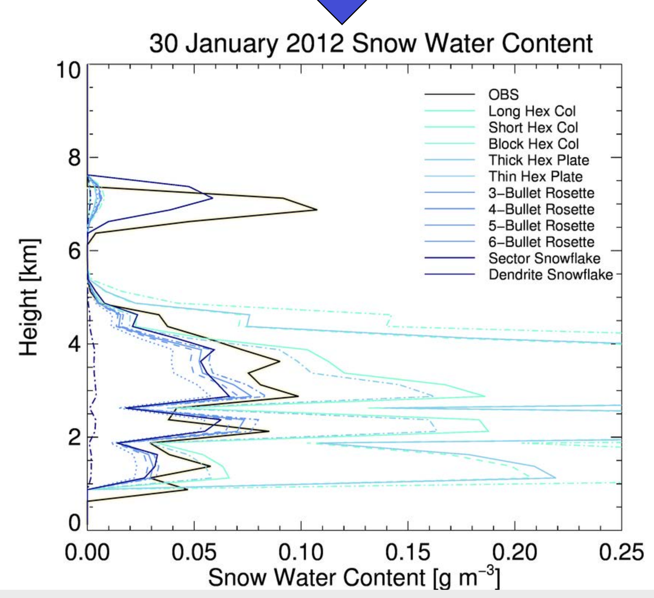


Cloud liquid water profiles from King probe on the Citation are averaged into 250 m bins.

RT Simulations performed using two different RT models:

1. Successive Order of Interaction (SOI; Heidinger et al. 2006; O'dell et al. 2006)
2. MWRT (Liu 1998)

PSD-averaged scattering properties are obtained by integrating single-scattering properties from Liu (2008) ice model database over the observed PSD's.



Frozen hydrometeor particle size distribution (PSD) profiles constructed from various probes are averaged into 250 m bins. Modeled snow water content is calculated by using mass-diameter relationships for each respective ice model from the Liu (2008) database and integrating over the observed PSD.

III. RT Results: Sensitivity to Cloud Liquid Water, Ice Habit, PSD

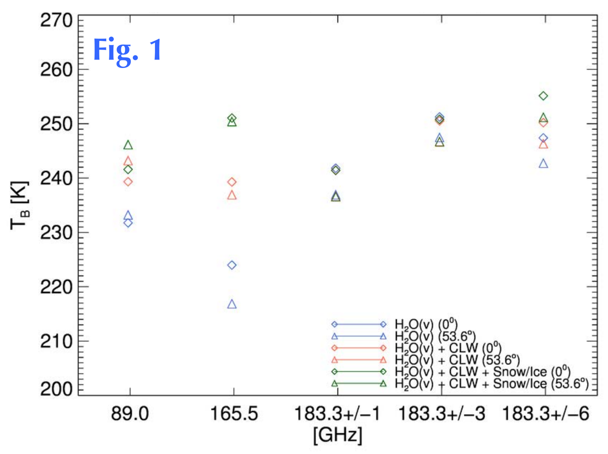


Fig. 1: Water vapor-only (blue), water vapor + observed cloud liquid water (CLW; red), and water vapor + CLW + ice microphysics (green) at 0° (diamond) and 53.6° viewing angle. Sector snowflake model is used for the ice microphysics simulation.

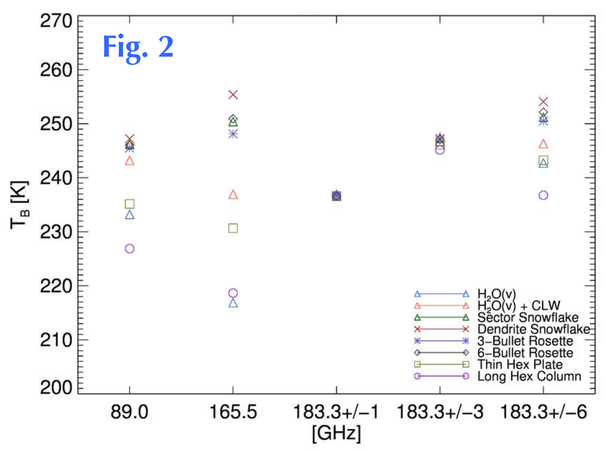


Fig. 2: Water vapor-only (blue), water vapor + observed CLW (red), and water vapor + CLW + sector snowflake ice microphysics (green) at 53.6° viewing angle. Different ice models are also indicated in the legend by other colors/ symbols to illustrate ice habit sensitivity.

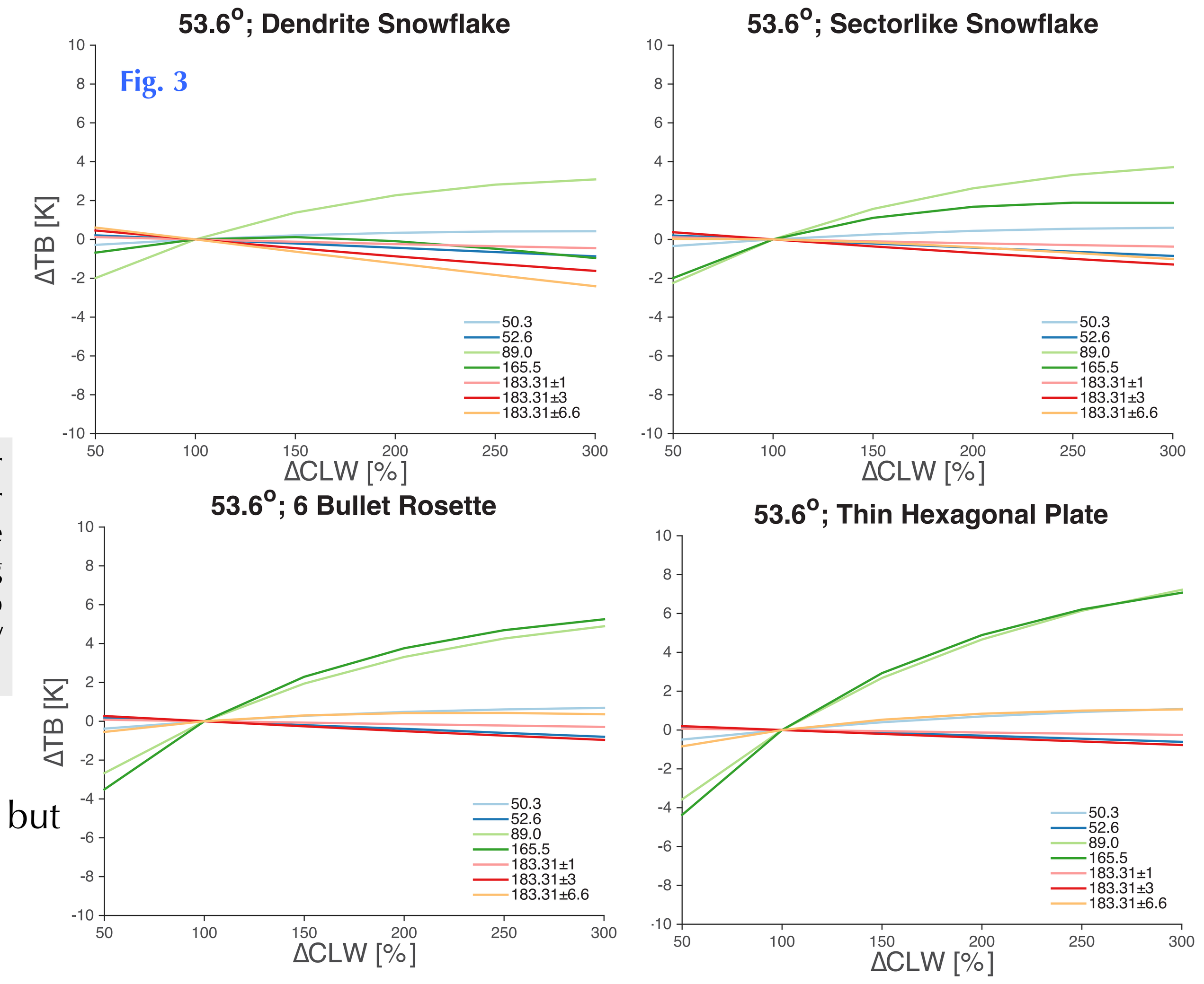
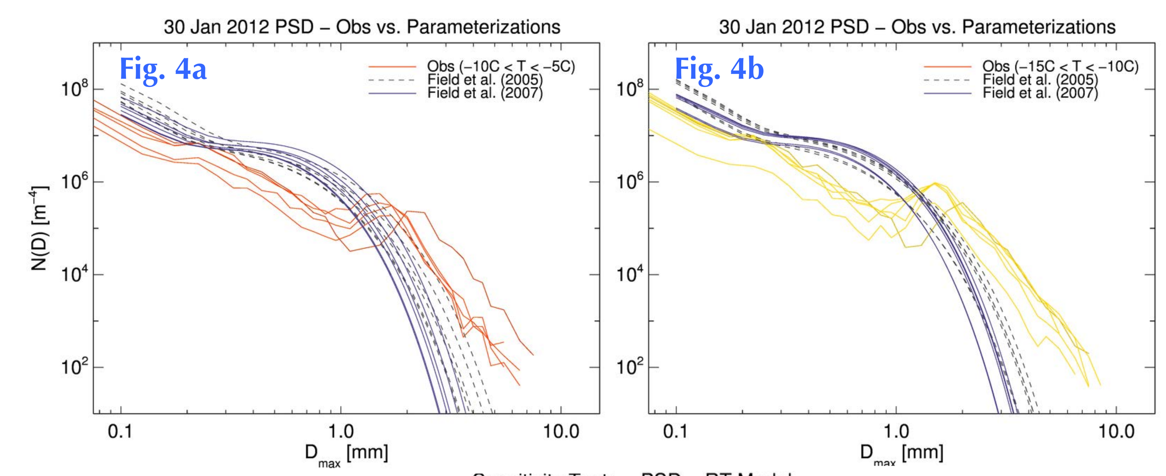


Fig. 3: T_B changes due to changes in CLW. CLW profile shown in Section II is altered by percentages indicated on abscissa to simulate environments with more/less CLW than observed CLW on 30 Jan 2012.

Summary of RT sensitivity tests (Figs. 1-3)

- 165.5 GHz T_B increases significantly when ice initially included (Fig. 1), but different ice models can significantly depress T_B (Fig. 2).
- 89 and 165.5 GHz responsive to CLW and ice habit, but effects of CLW inflation modulated differently by respective ice habits (Fig. 3).
- Some ice models produce high snow water content when integrated over observed PSD (Section II), producing excessive scattering (Fig. 2).
- 183.3+/-6 responsive to ice habit for this case study profile, but less than other scattering sensitive channels.



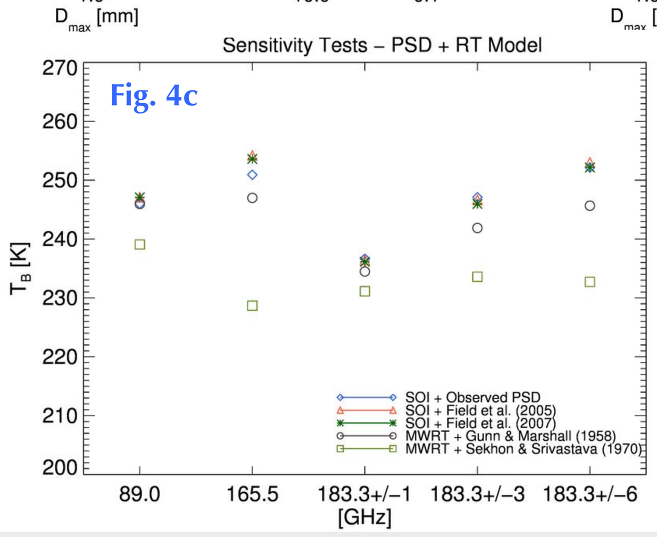


Fig. 4a: Observed (red), Field et al (2005; dash), and Field et al. (2007; solid) PSD's for temperatures between -5 and -10 C. Fig 4b: Same as Fig. 4a, but for temperatures between -10 and -15 C. Fig. 4c: TB simulations using SOI model + observed PSD (blue), SOI + Field et al. (2005) PSD (red), SOI + Field et al. (2007) PSD (dark green), MWRT + Gunn and Marshall (1958) PSD (gray), and MWRT + Sekhon and Srivastava (1970) PSD (light green).

Summary of RT sensitivity tests (Fig. 4)

- Temperature-dependent Field et al. (2005, 2007) PSD parameterizations produce systematically higher (lower) particle concentrations for D_{max} < 1 mm (D_{max} > 2 mm) compared to observed PSDs. However, *simulated TB's not very sensitive to these PSD differences in scattering-sensitive channels* (~ 2-3 K at 165.5 GHz).
- Much larger TB differences exist between SOI and MWRT simulations. MWRT+Sekhon-Srivastava (1970;SS) produces extremely low TB depressions compared to other RT Model/PSD combinations. MWRT +Gunn-Marshall (1958;GM) also much lower at 165.5 and 183.3+/-6.
- NOTE: 6-bullet rosette ice model used in all Fig. 4 simulations.
- Water-vapor only simulations are very similar between SOI and MWRT (not shown; both use similar water vapor absorption models), but microphysics induces differences depending on RT Model and PSD.
- Lingering Questions:
  - Can temp-dependent Field et al. PSD parameterizations be universally applied without inducing significant biases?
  - Differences in RT solvers? Need to apply SS and GM PSD's to compare SOI and MWRT using full microphysics.
  - How to effectively simulate 183.3+/-XX channels (scattering properties and simulation methodology)?

IV. Future Work

- Further sensitivity testing for 30 Jan 2012 case (surface emissivity, over-water, etc.).
- Simulate other GCPEx cases using in-situ microphysics observation (e.g., 27 Jan 2012 case – elevated supercooled water layer reduces scattering?).
- Spatially expand simulations using APR-2 microphysics retrievals? Compare directly to CoSMIR observations?
- Link airborne observations to surface observation (significant biases from ignoring microphysics in lowest few bins?).
- Do scattering models work when used with in-situ microphysics + CoSMIR + APR-2 simulations?