Three-Dimensional Sensor Forward Modeling of Clouds and Precipitation in the Multi-Instrument Inverse Solver Testbed (MIIST)

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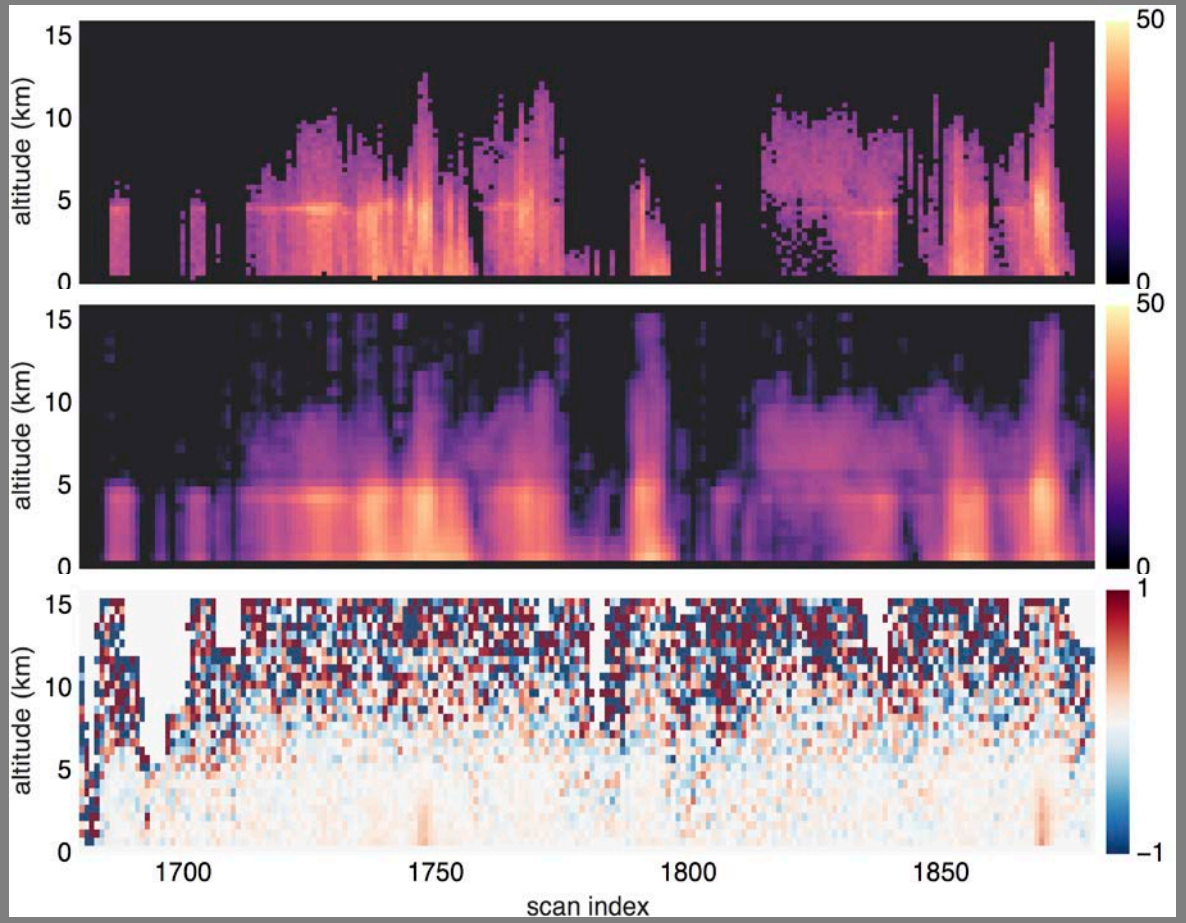
MIIST 3D Forward Model

The Multi-Instrument Inverse Solver Testbed (MIIST) uses the Atmospheric Radiative Transfer Simulator (ARTS) for solving the vector radiative transfer (RT) equation in up to three spatial dimensions within a spherical geometry

- Gas absorption
  - Line-by-line calculations
  - Fast transmittance tables
- Hydrometeor scattering solvers
  - Discrete ordinate
  - RT4 (Evans, 1D)
  - Radar Single Scattering (1D or 3D)
  - Monte Carlo (3D)

TRMM Overpass of Tropical Cyclone Asma

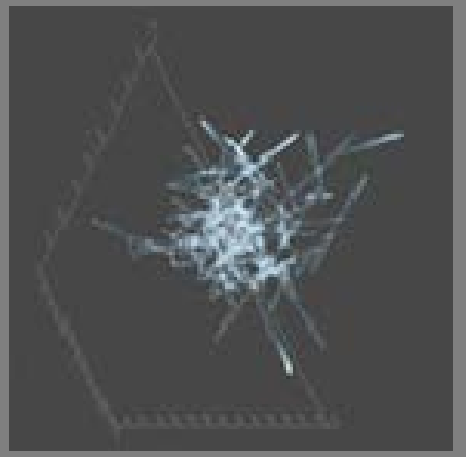


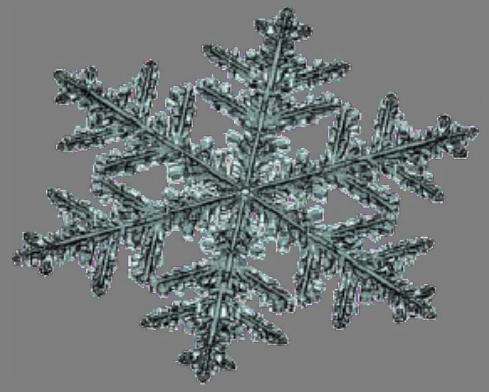
Scattering Tables

https://storm.pps.eosdis.nasa.gov/storm/OpenSSP.jsp

High-fidelity hydrometeor scattering tables are necessary for accurate and consistent forward modeling of multi-frequency observations

- Requires full Stokes matrices
  - And absorption vector
- Randomly oriented particles
  - Discrete Dipole Approximation
  - Characteristic Basis Function Method (coming soon)
- Horizontally-oriented plates
  - Invariant Imbedding T-matrix Method



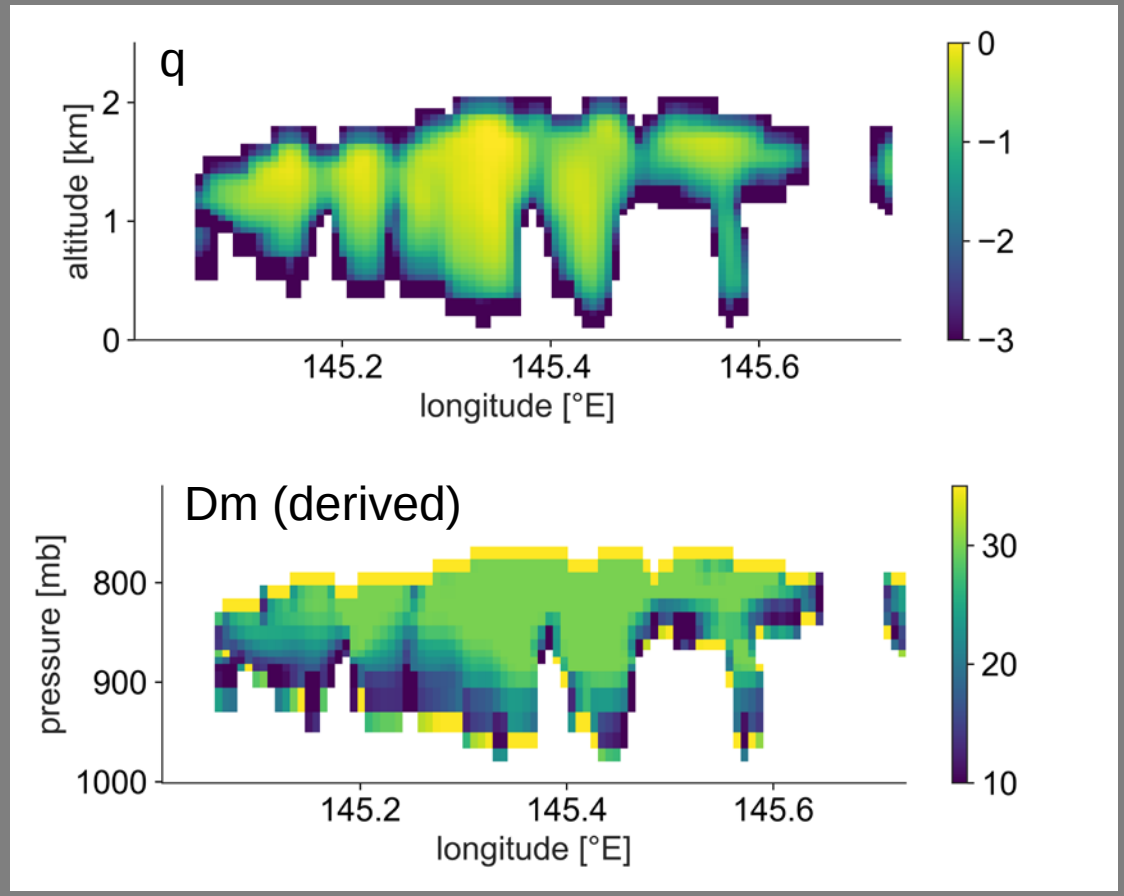


Cloud Resolving Simulations

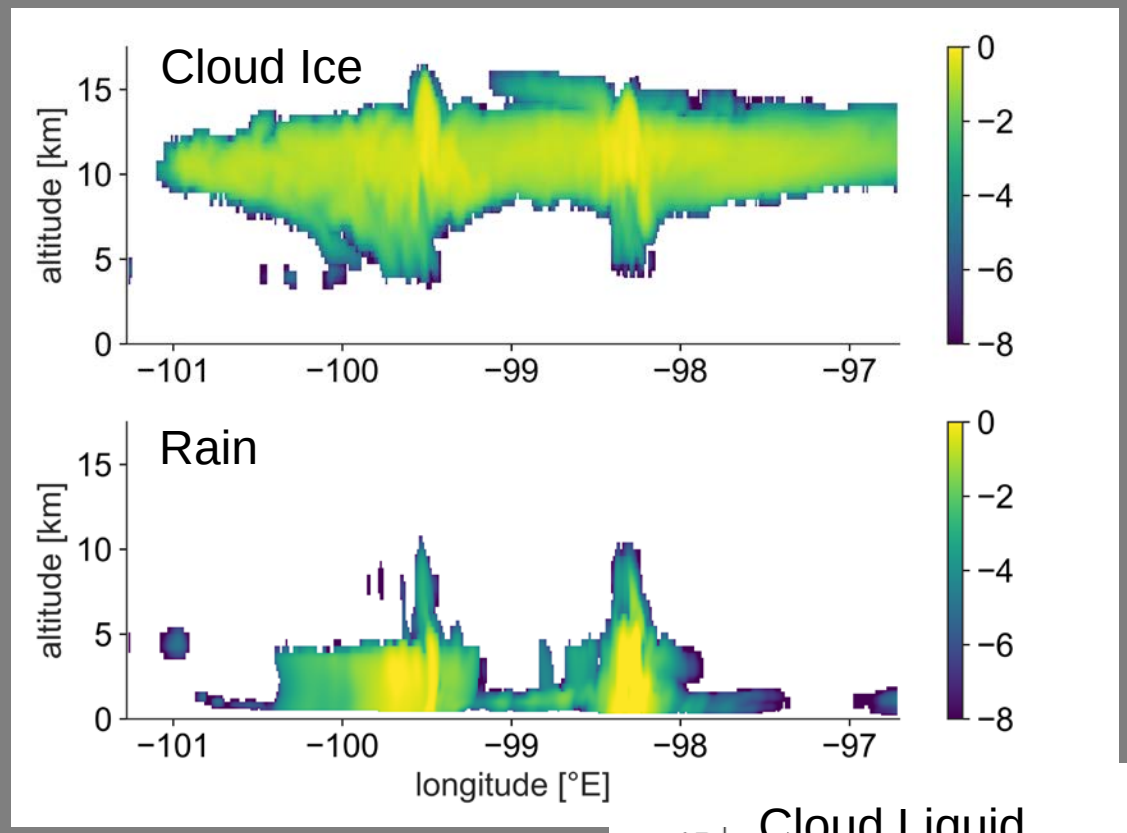
Cloud resolving simulations (e.g., NU-WRF) supply output consistent with ARTS needs

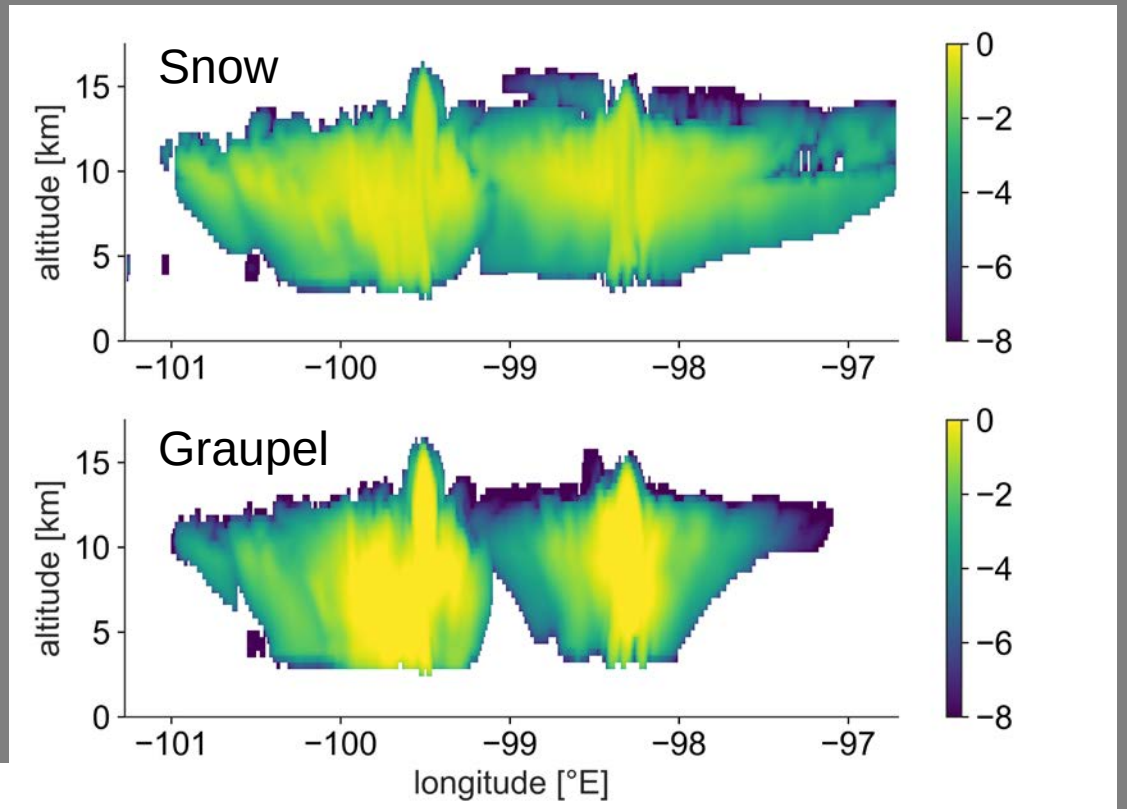
- Atmospheric Information
  - Temperature
  - Pressure / height
  - Water vapor
- Hydrometeor Profiles
  - ARTS architecture ripe for explicit bin microphysics
- Examples use Morrison 2M scheme

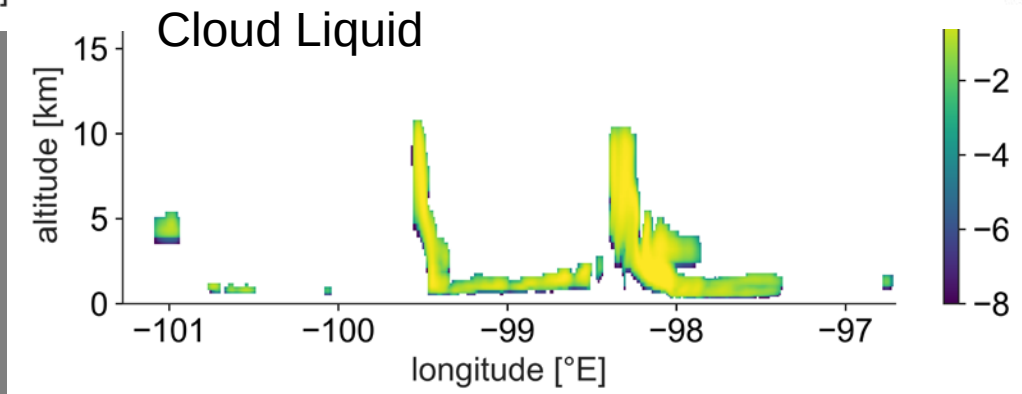
Cloud Liquid



Radar Simulations: MC3E (20 May 2011, 0600 UTC)

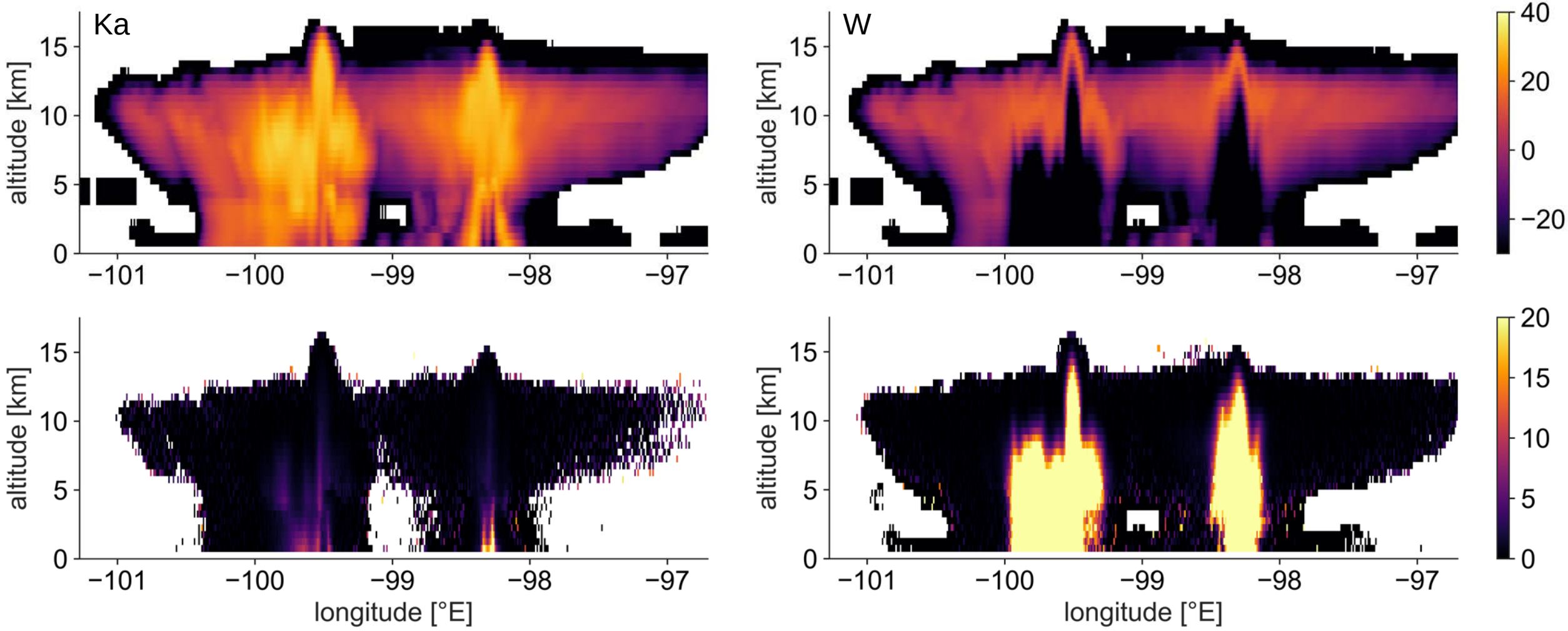




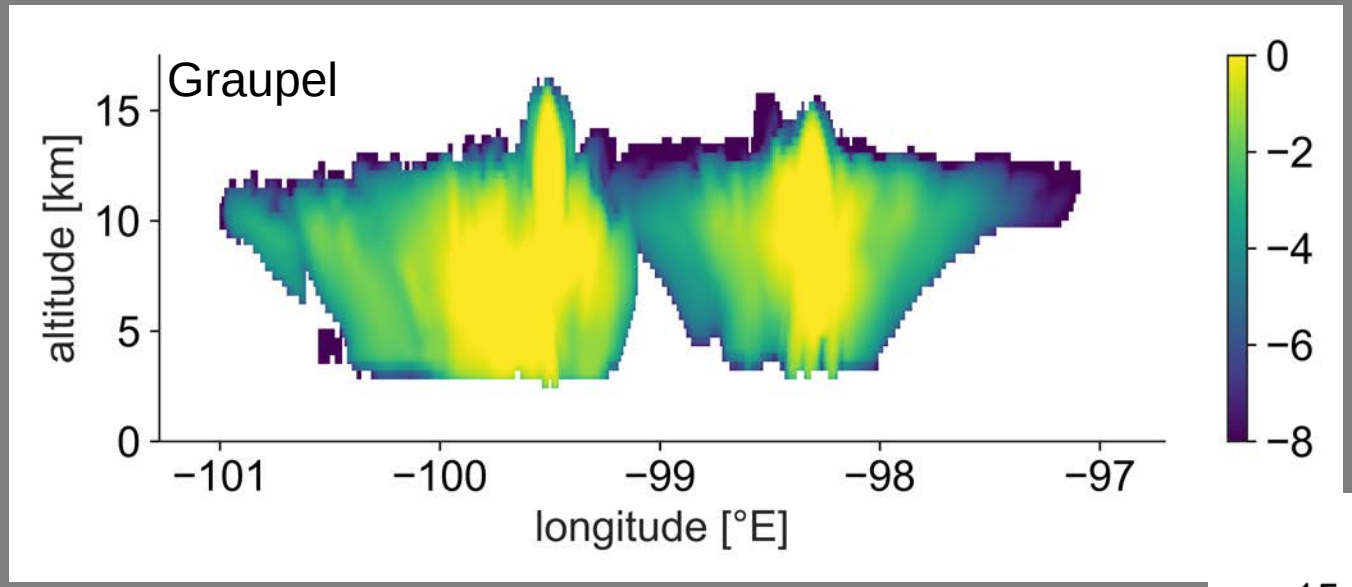


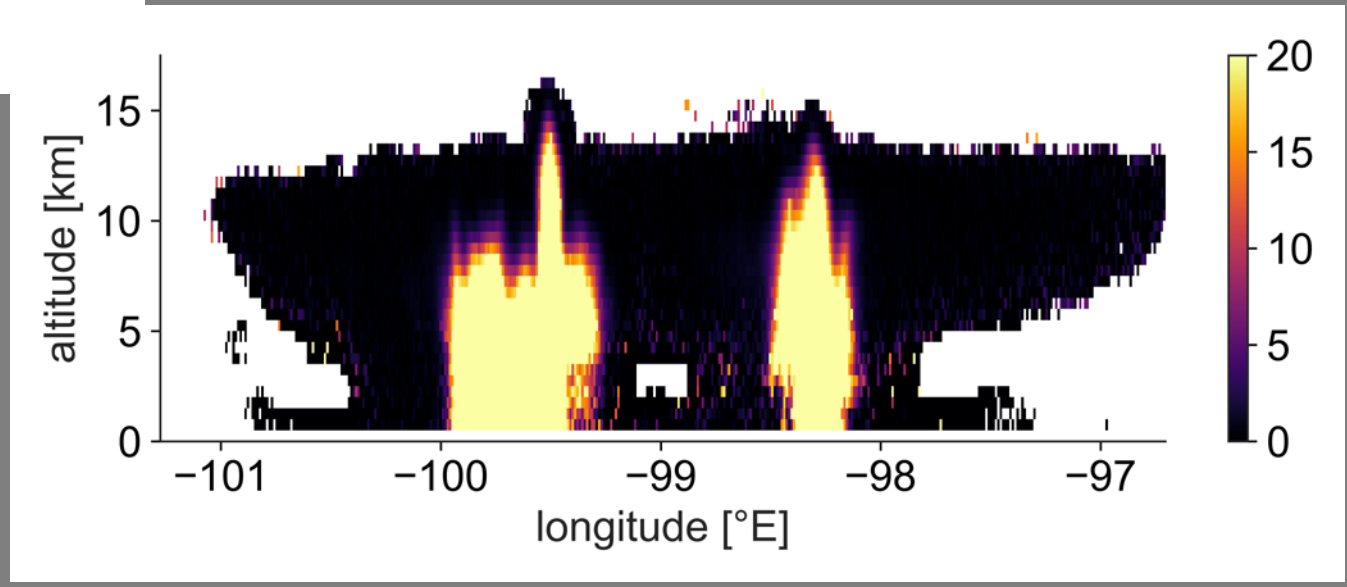
NU-WRF simulation provided by Xiaowen Li

Spaceborne Radar Simulations (CloudSat-Like Sensor)

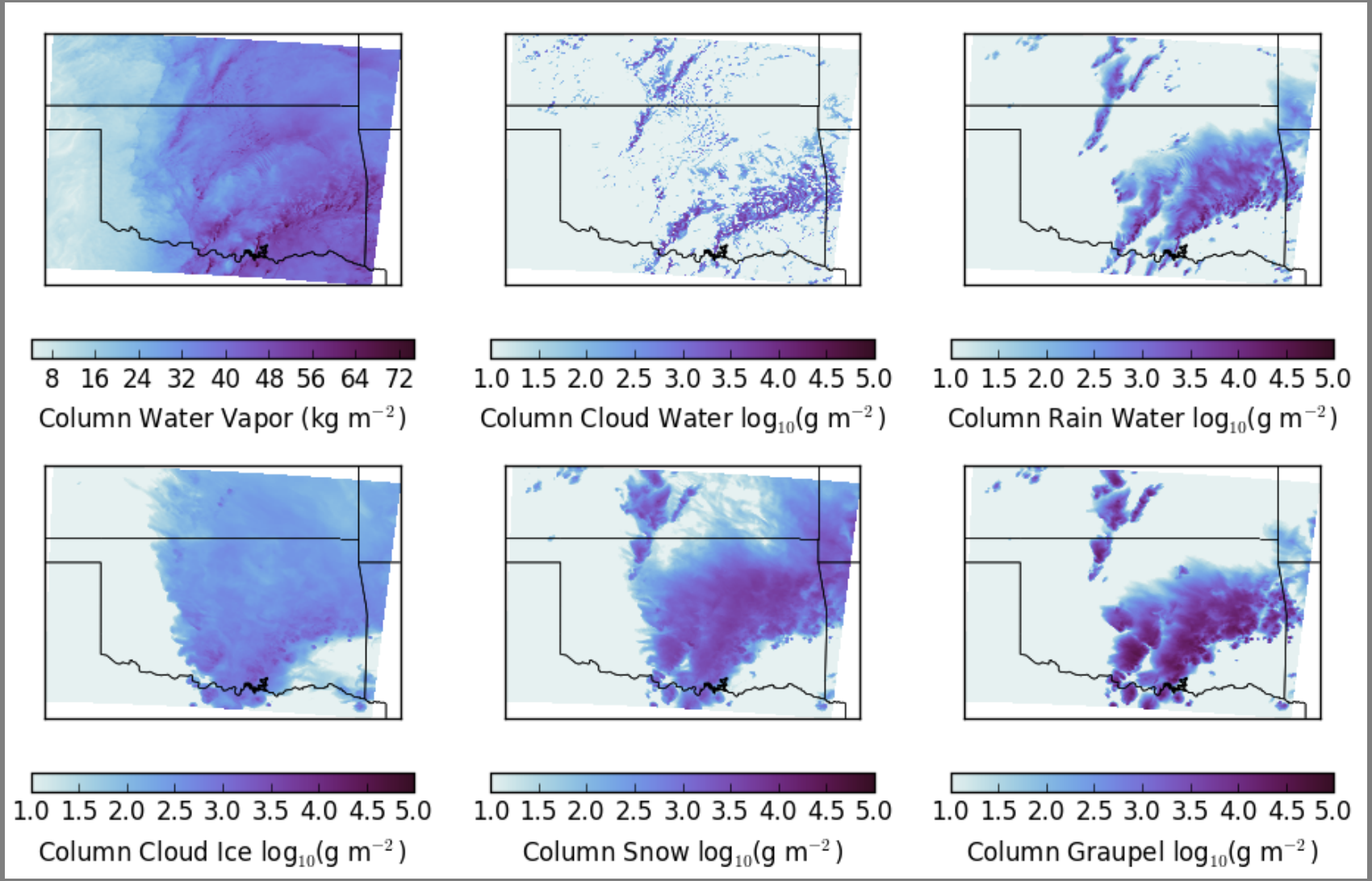


Multiple Scattering Corresponds to Graupel

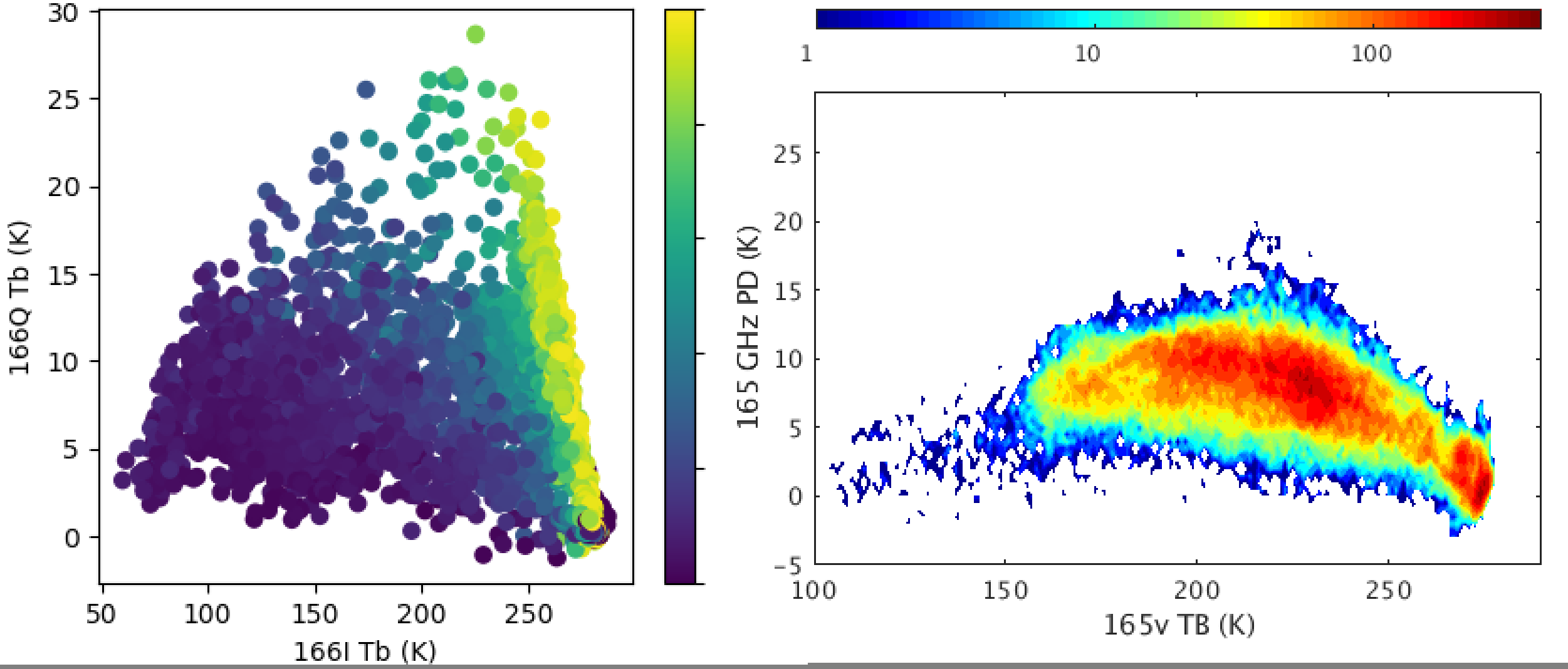




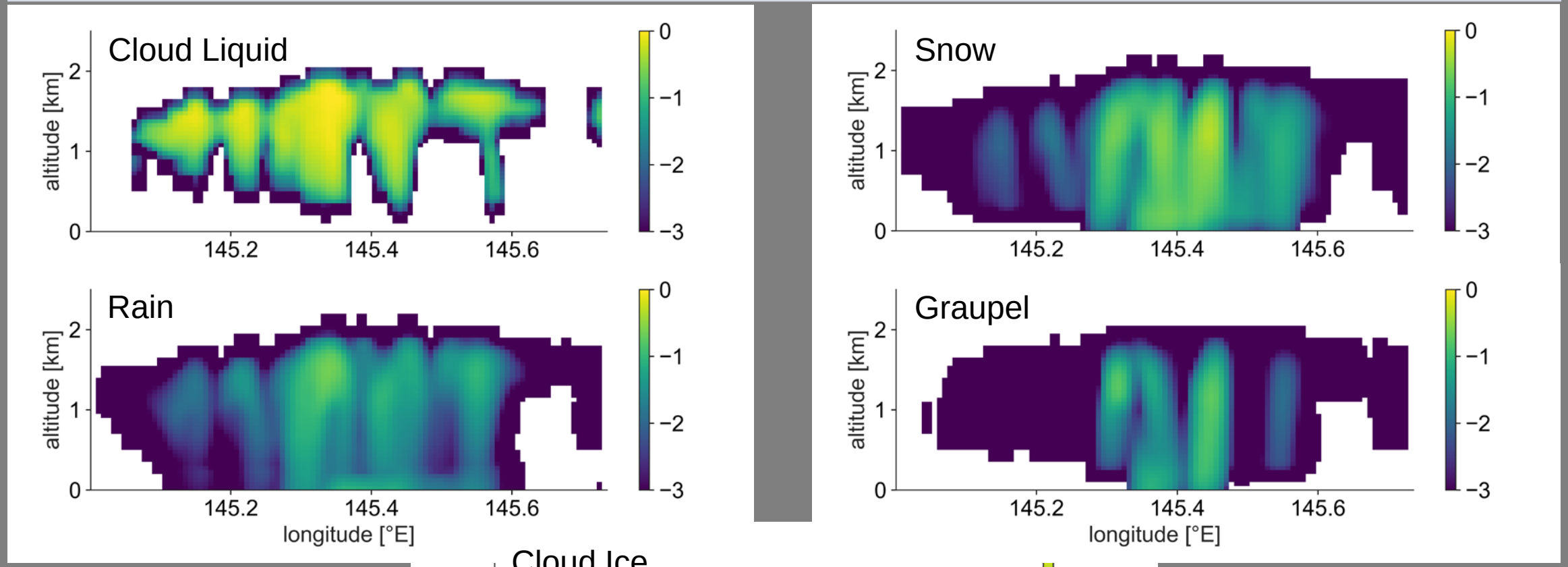
Radiometer Simulations: MC3E (20 May 2011, 2300 UTC)



GMI-Like 166 GHz Polarization Difference

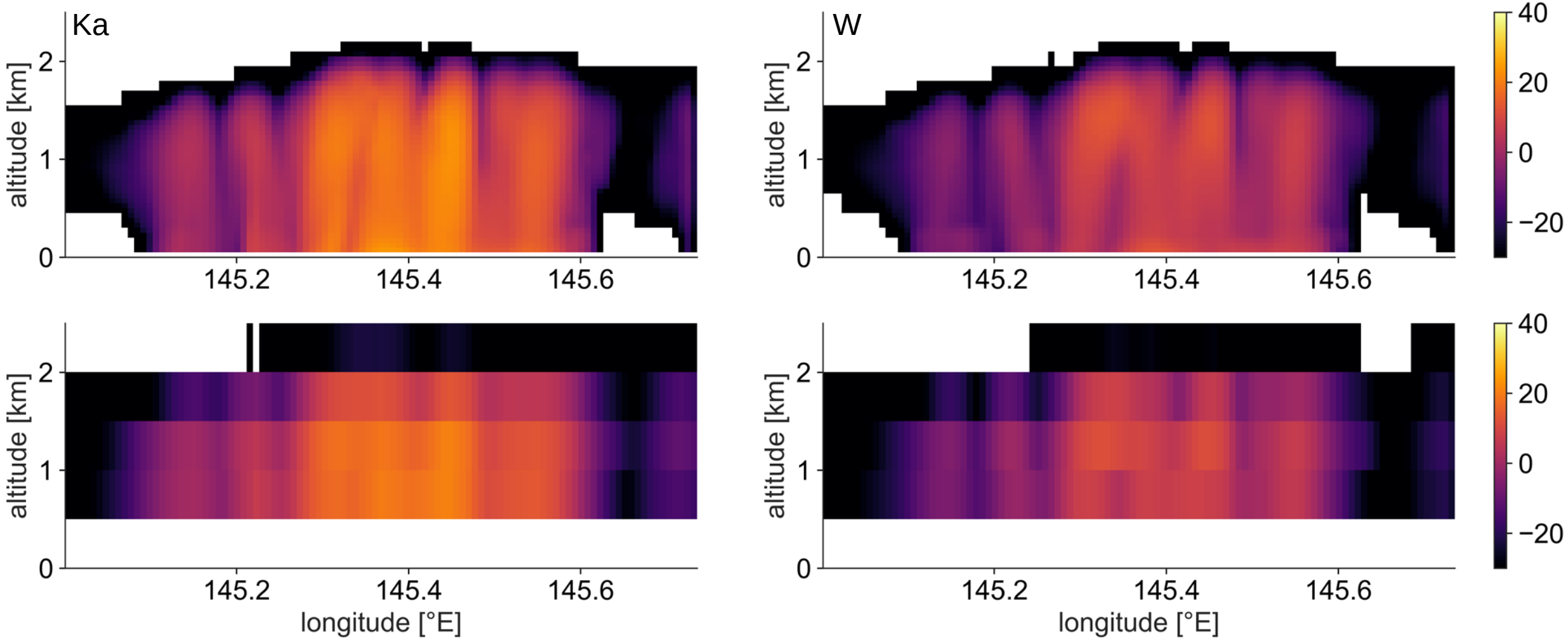


Shallow System: CAPRICORN (06 April 2016, 0200 UTC)



NU-WRF simulation provided by Adrian Loftus

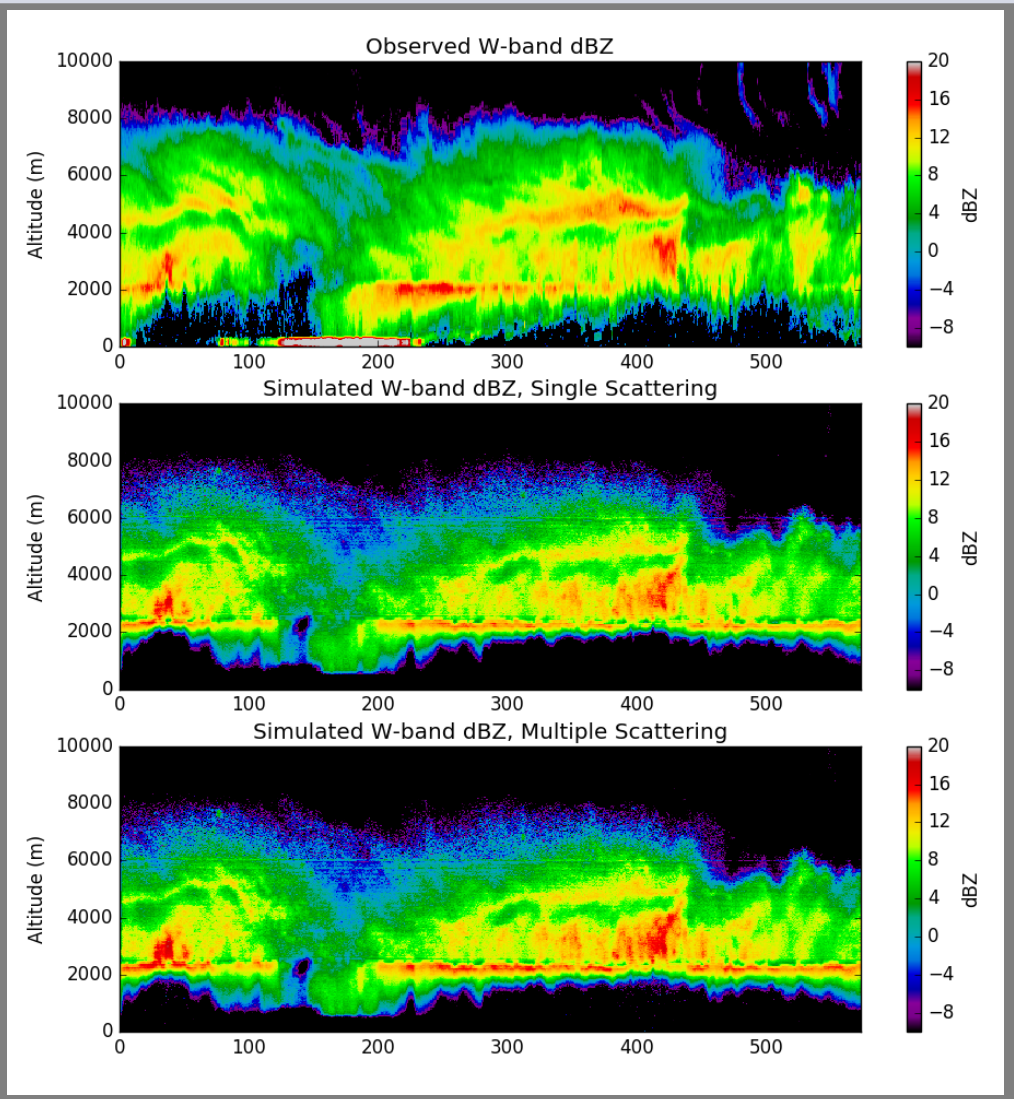
Airborne versus Spaceborne



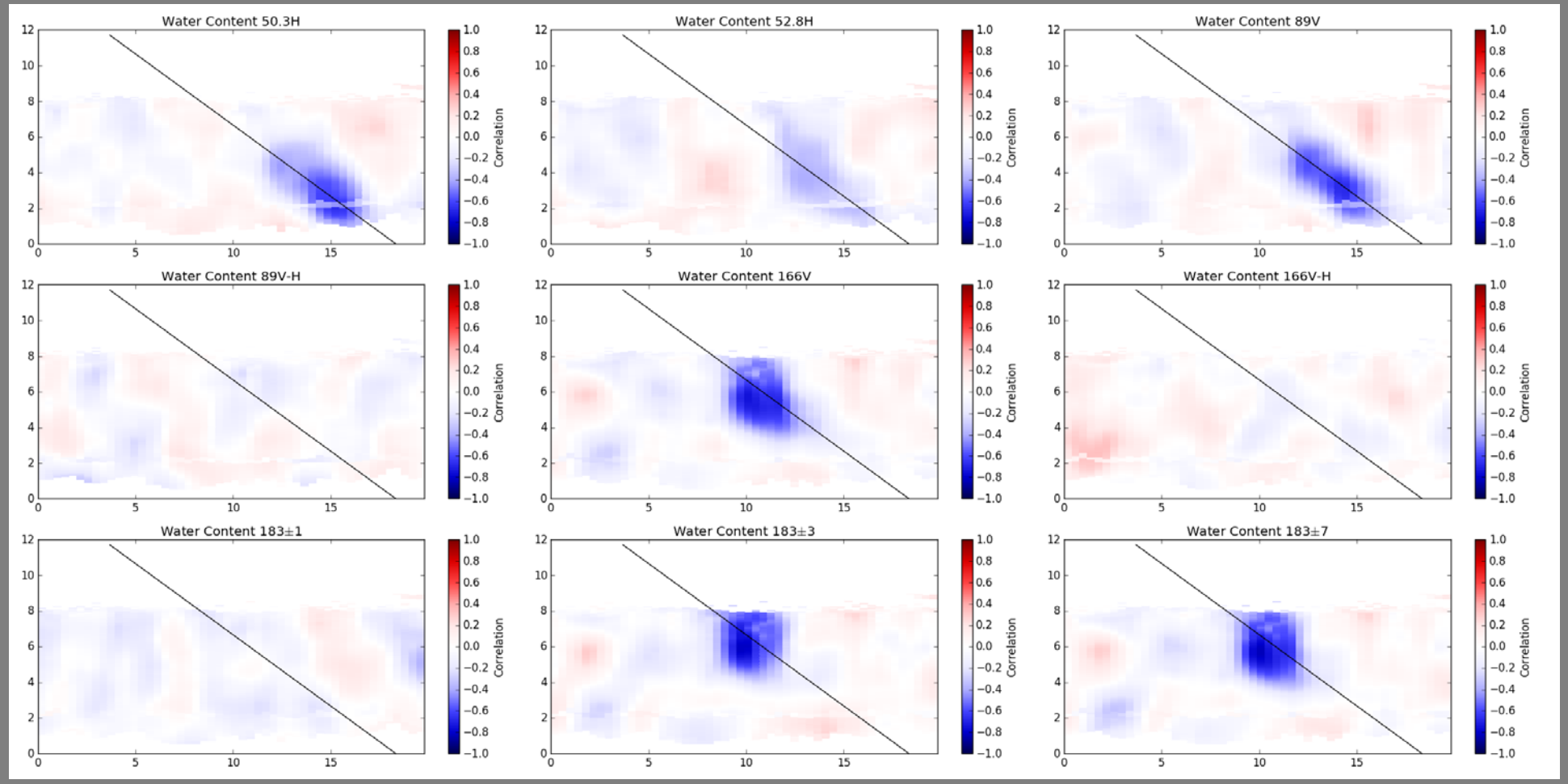
Simulations from Observations: OLYMPEX

Simulate sensor response using geophysical retrievals as input

- Single frequency radar retrievals
- Multiple scattering enhancement apparent at W band
- Spatially dependent phenomenon



Sensitivity Study (CoSMIR in OLYMPEX)



Future Work

- OLYMPEX cases
  - Interesting microphysics
    - Riming
    - Polycrystals
- Incorporate Inversions
  - 3D Estimation
- Melting particles
- More aligned ice
  - Scattering using IITM
- Other domains and campaigns
  - IPHEx
  - Arctic