76. Toward more direct evaluation of cloud resolving models with polarimetric, Doppler radar observations

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Introduction

Radar observations of kinematics and microphysics are critical for evaluating the performance of cloud resolving models (CRMs). However, evaluation of model microphysical fields remains challenging due to observational errors and a mismatch between simulation parameters and observational quantities. To this end, we describe a new framework for comparing model simulations and radar bulk microphysics, as well as methodologies for improving radar-derived kinematics and microphysics.

Herein we analyze data from two DoE field projects with polarimetric and Doppler observations, allowing for retrievals of the 3-D wind field and hydrometeor categories. The Tropical Warm Pool – International Cloud Experiment (TWP-ICE) took place near Darwin, Australia in January – March 2006. The Mid-latitude Continental Convective Clouds Experiment (MC3E), took place in the spring of 2011 at the Southern Great Plains Central Facility. Several cases were selected from each project to represent a variety of convective regimes. From MC3E, a wide spread stratiform case (01 May), a classic squall line (20 May), and a deep convection (24 May) case are analyzed. Two periods from TWP-ICE, corresponding to the monsoon (21-26 January) and break (15-20 February) periods, are studied.

Observations

Although radar observations are considered “ground truth” when validating CRMs, it is important to understand observations are imperfect and have sources of error. Here we try to understand and quantify errors associated with dual-Doppler radar retrievals of the vertical winds using the CPOL – Berrima C-band radar pair in Darwin, Australia during the 22 January 2006 monsoon case by examining two different methods for deriving the 3D wind field.

- **CED**: Mohr and Miller (1983)
  - Horizontal divergence from vector decomposition, then integrate anelastic mass-continuity from top-to-bottom, then redistribute residual errors
  - Z-Vt relationship for 3 categories following Giangrande et al. (2013)
- **COST**: Collis et al. (2013)
  - Minimize cost function including terms for radial velocity disparity, retrieval noise, and anelastic continuity equation disparity
  - Z-Vt from Caya 2001

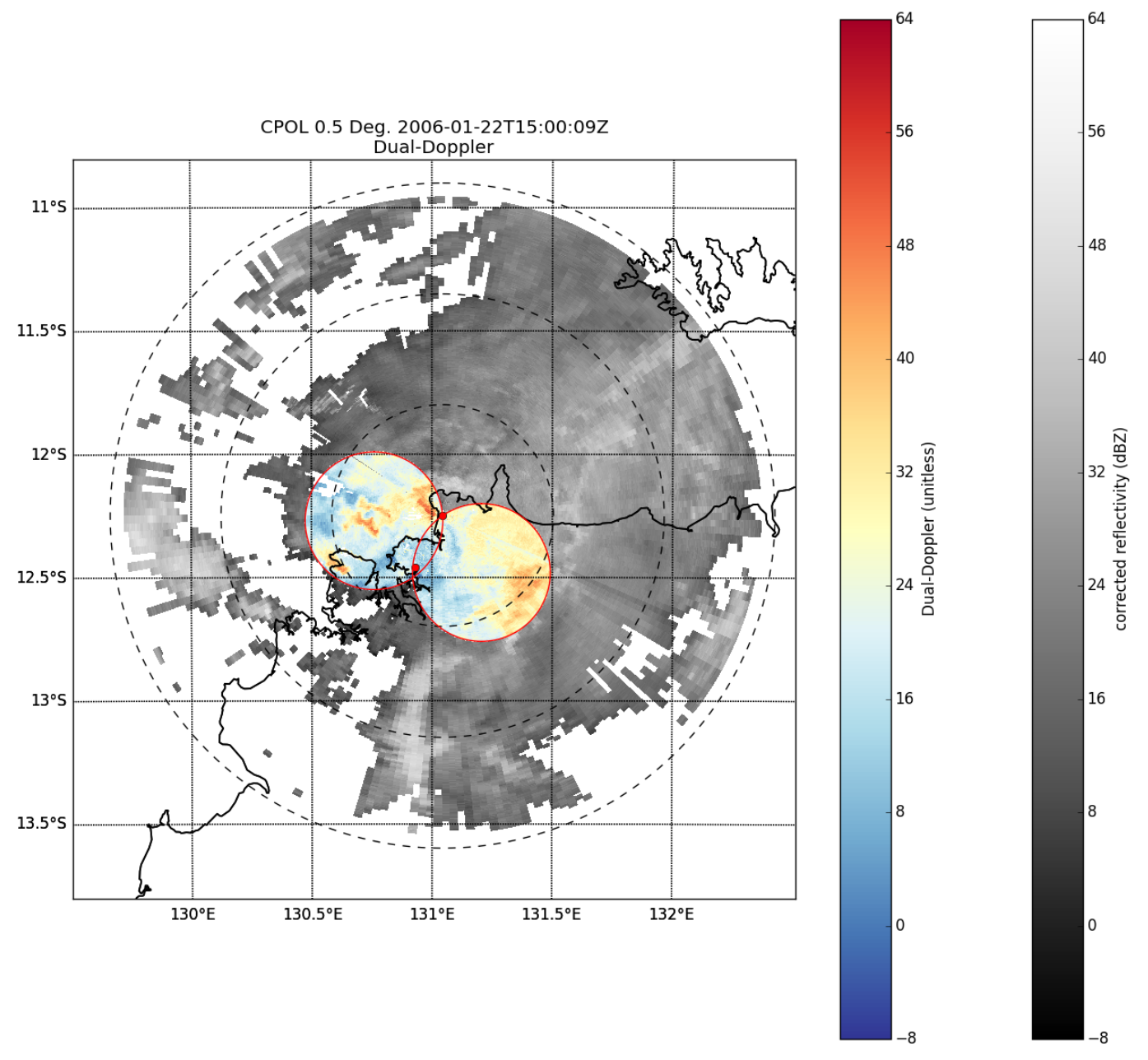


Fig. 1: CPOL – Berrima dual-Doppler coverage area at 15 Z on 22 January 2006.

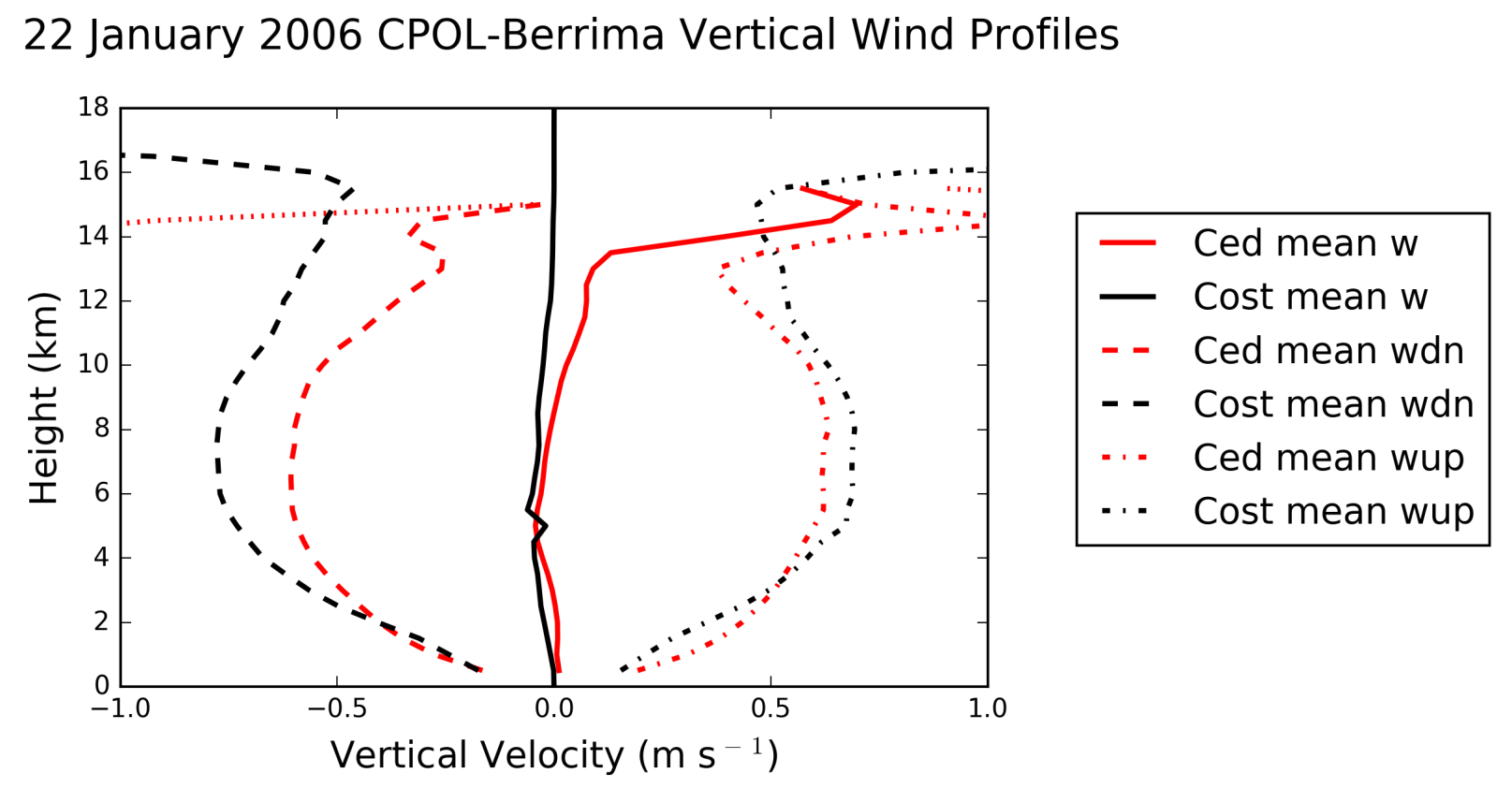


Fig. 2: Mean vertical winds for CED and COST. Wdn is all w < 0, Wup is all w >0

- Means similar; CED tends toward slightly higher values
- Means of both up and down are larger for COST in mid-levels
- Means of up and down are smaller for COST in upper levels

Acknowledgements

This research is supported by the DOE ASR grant DE-0000000SC14371. We wish to thank Scott Collis, Jonathan Helmus, Paul Hein, and Mike Dixon for their assistance with acquisition and processing of radar data.

POLARRIS: Polarimetric Radar Retrieval and Instrument Simulator

POLARRIS will be composed of CRM IO module, T-Matrix module, Mueller-Matrix modules, and the CSU HID radar algorithm module. T-matrix computes the single scattering matrix of axis-symmetric oblate hydrometeors, while Mueller-Matrix uses the properties derived from the T-Matrix, and estimates polarimetric radar observables.

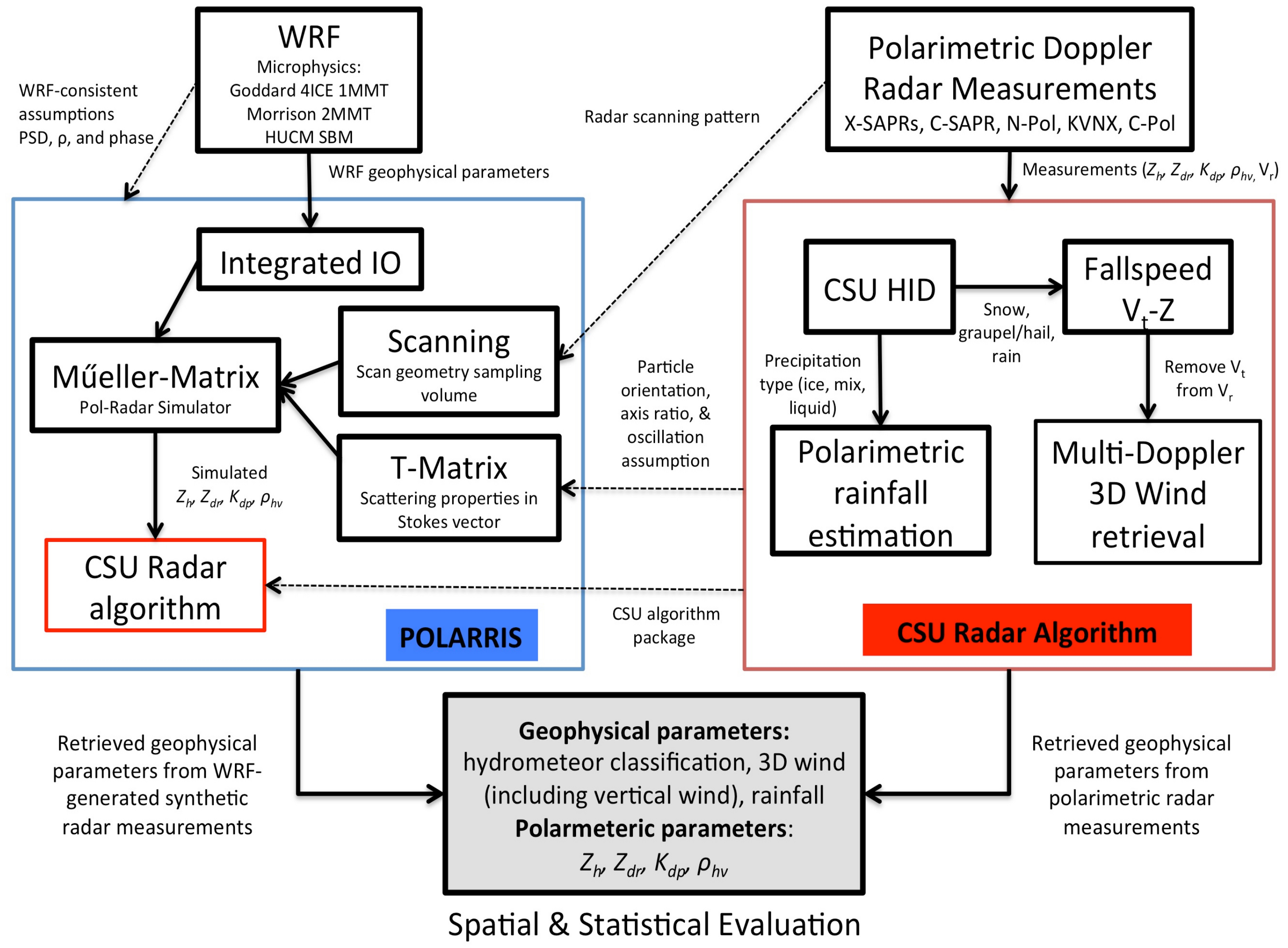


Fig. 3: POLARRIS Framework

Linking Model to Observations

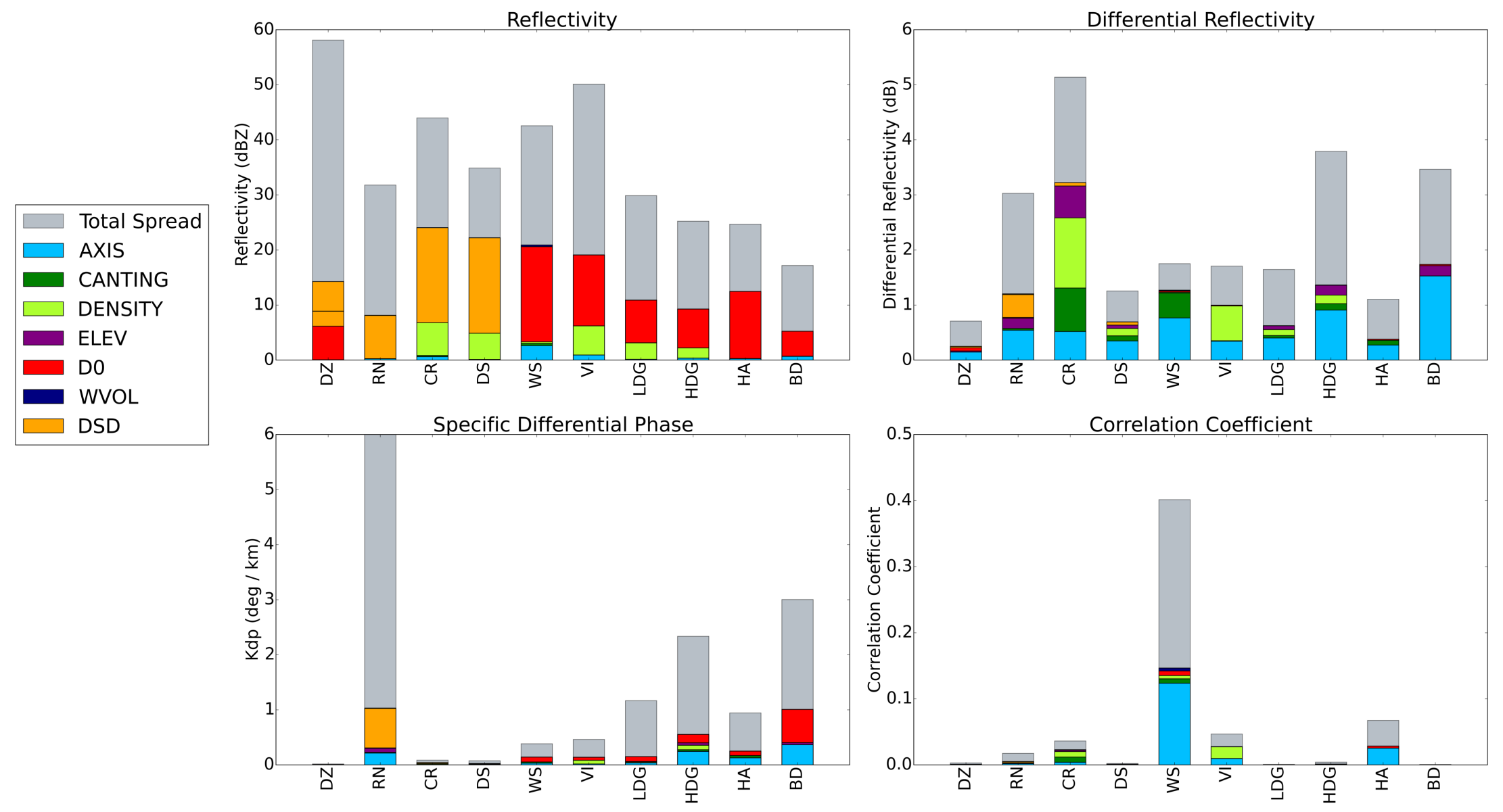


Fig. 4: Contribution to uncertainty of each assumption relative to the overall spread of each radar variable in Dolan and Rutledge (2009) and Dolan et al. (2013) T-matrix simulations at S-band. Contributions are stacked.3

Dolan and Rutledge 2009 hydrometeor identification (HID) development made assumptions about microphysical variability for each hydrometeor type in order to simulate a range for each variable.

- **Size distribution** largest influence on reflectivity
- **Axis ratio** has a large impact on all variables, particularly Z_{dr}
- **Density** has a large impact on Z_{dr} and reflectivity
- **Temperature** and standard deviation of the **canting angle** have minor effects on Z_{dr}, ρ_{hv}

Ensemble Approach

- Model will prescribe size distribution, density, and temperature
- Ensemble simulations of axis ratios, elevation angles, and standard deviation of canting angles will be run
- Ensemble members will be run through hydrometeor identification and degree of agreement in hydrometeor type will be used to asses uncertainty in final categorization

NU-WRF

The NASA-Unified Weather and Research Forecasting (NU-WRF) model is employed as a cloud resolving model (CRM) for simulations of intensive observation periods (IOPs) of MC3E and TWP-ICE. We conducted preliminary simulations to investigate the effects of different cloud microphysics and forcing data before determining base-line simulations for further sensitivity experiments including spectral bin microphysics. The simulation results were compared with on-site radar measurements through Goddard Satellite Simulator Unit (G-SDSU)

MC3E: Microphysics scheme

- Different bulk microphysics schemes (Goddard 3-ice, Goddard 4-ice and Morrison) tested
- Large sensitivities to distribution of ice mixing ratios, contributing to different reflectivity structures
- Overall, bulk microphysics able to reproduce timing and locations of MC3E cases

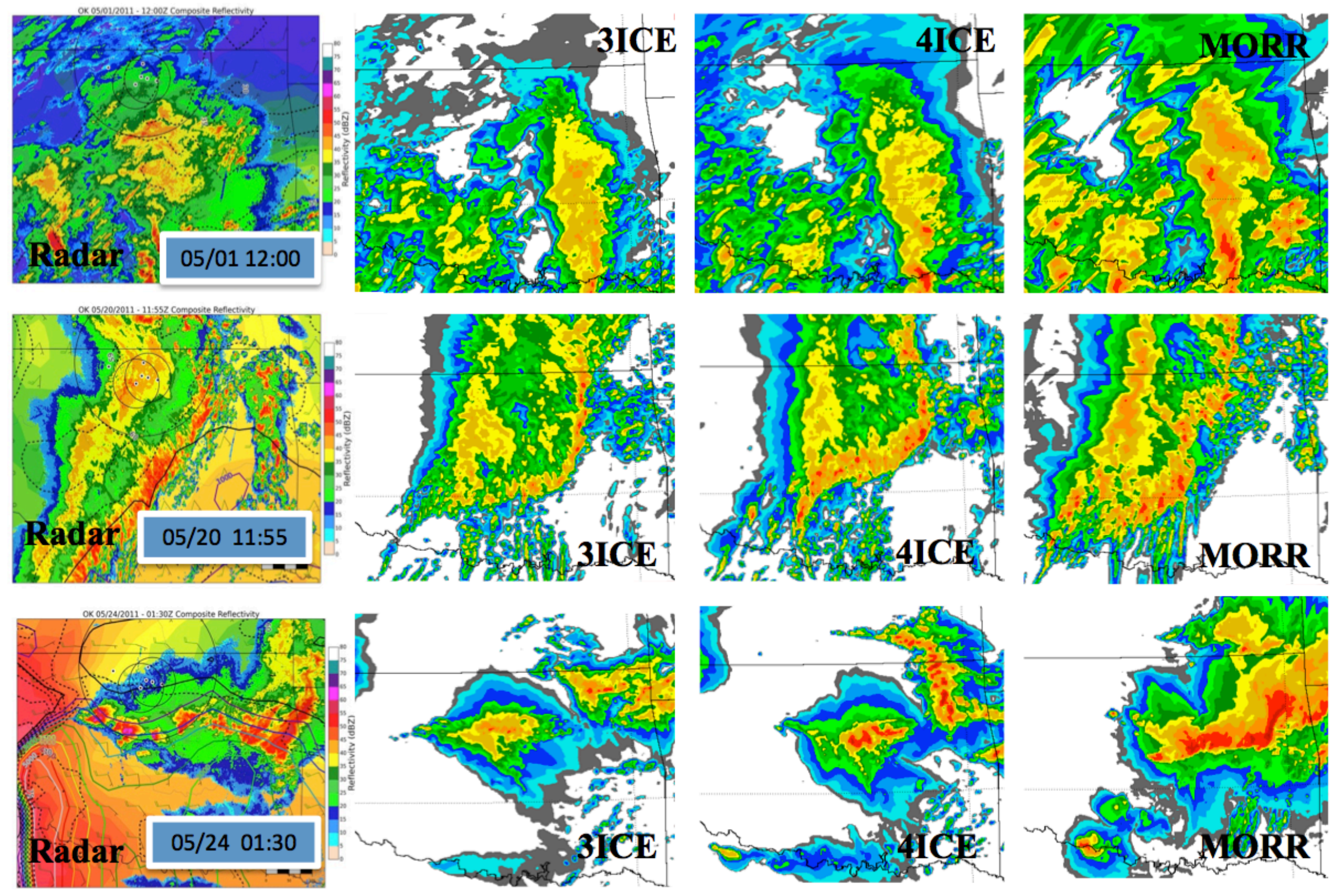
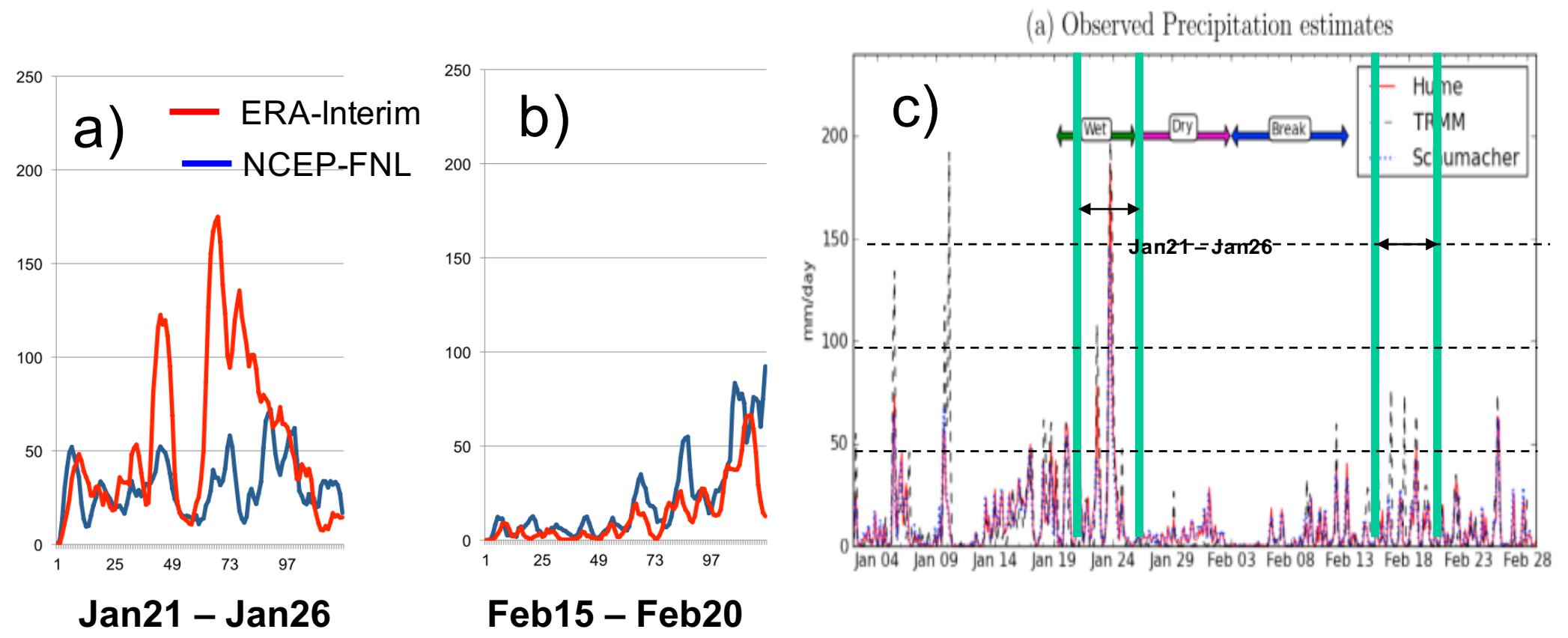


Fig. 5: Composited radar reflectivities from the observations, NU-WRF simulations with Goddard 3-ice, 4-ice, and Morrison microphysics schemes for cases on 1 May, 20 May, and 24 May.

TWP-ICE: Forcing Sensitivity

- NCEP-FNL and ERA-Interim forcings with GCE-4ICE scheme
- NCEP-FNL underrepresents observed large rain rates during the monsoon case (Jan 21-26) but ERA-Interim and NCEP-FNL similar for break case (Fig. 6)
- Structure of convection is similar to observations but much more widespread stratiform coverage in model(Fig. 7)



Jan21 – Jan26

Feb15 – Feb20

Fig. 6: a-b) WRF rainfall for the domain 3 (mm/day). C) Observed Precipitation during TWP-ICE. Green bars indicate the Jan and Feb cases in a-b.

24 January Monsoon

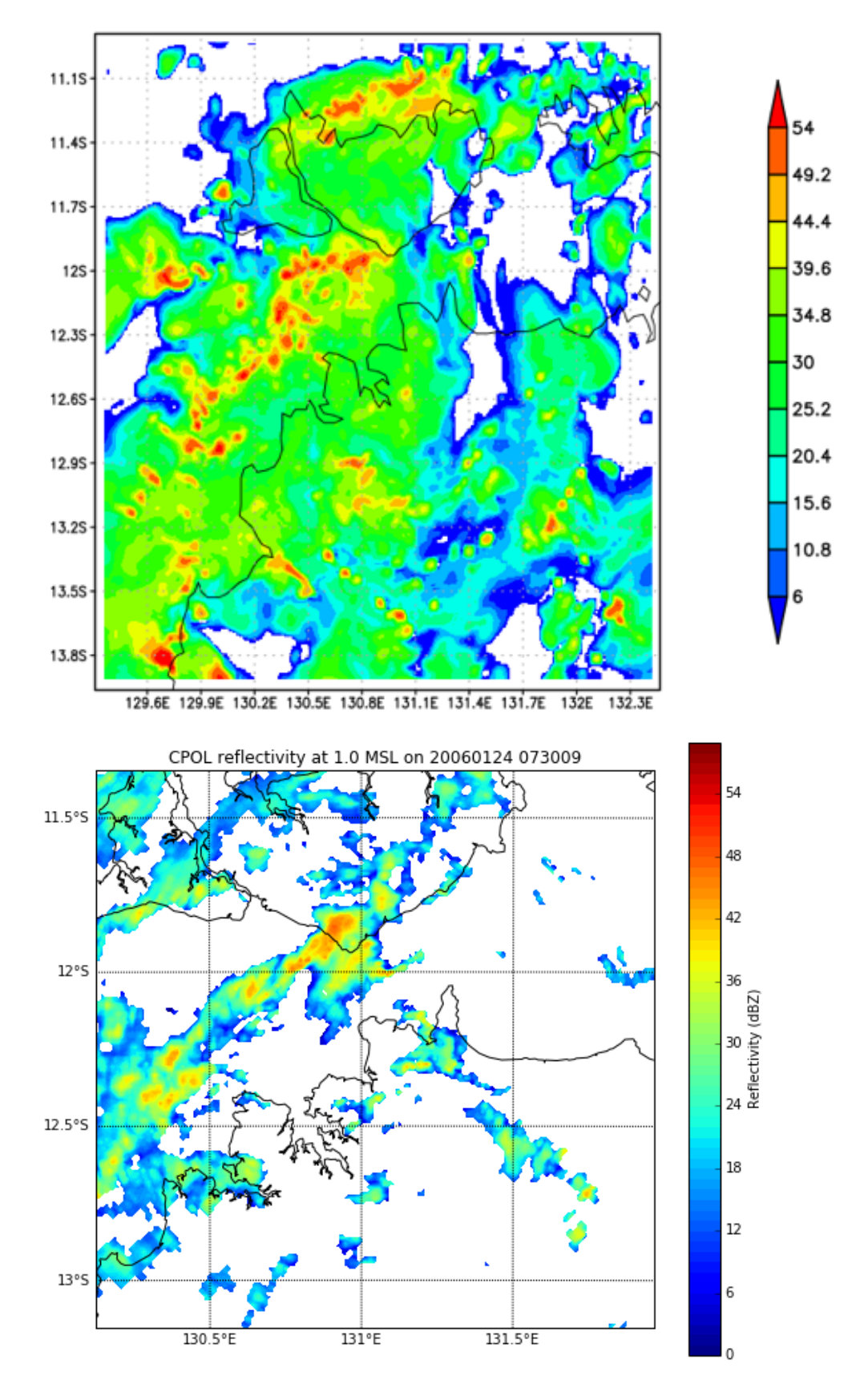


Fig. 7: WRF C-band (dBZ) from ERA-Interim 24 Jan 2006 at 0700 UTC and CPOL reflectivity at 0730 UTC.