A Combined Aircraft, Model, and Algorithm Analysis of the Organization and Structural Characteristics of an Orographically-forced Organized Convective System

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Objectives

- Cross-evaluate microphysical characteristics and physical properties of orographic precipitation from GPM algorithm retrievals, GPM GV, and WRF
- Quantify how terrain modifies and impacts orographic precipitation properties
- Assess the capability of WRF and an aircraft-based experimental radar retrieval for ice to characterize cloud tops and associated particle properties
- Quantify particle growth and drop size distributions within the GPM ground clutter zone
- Create characteristic precipitation processes in GPM ground clutter regions

Datasets

1. **Weather Research and Forecasting model (WRF)**
   - 4-model domains (13.5, 4.5, 1.5, 0.5 km) 2x's last year
   - 12 minute (4 minute subset)
   - ECMWF Reanalysis Version 5 (ERA5) input and BCs
   - Goddard 4-ice, Morrison, P-3
   - Initialized 24-hour before ER-2
   - Satellite data simulator (G-SDSU)
2. **Aircraft and Surface Obs.**
   - Ka-band – HIWRAP (35.5 GHz)
   - Ku-band – HIWRAP (13.6 GHz)
   - W-band – CRS (94 GHz)
   - X-band – EXRAD (9.4 GHz)
   - Radiometers
     - AMPR (10-85 GHz)
     - CoSMIR (89-103 GHz)
   - Polarmetric radars
     - NPOL, D3R, WSR-88D
3. **Experimental Radar Retrieval for Ice (ERRI; Grecu, 2018)**
   - Proposed for inclusion in GPM
   - Applied to ER-2 radar data (Ka-, Ku-, W-bands)
   - Provided data
     - Drop size distribution
     - Ice water content
     - Attenuation corrected radar

FIELD CAMPAIGN

A) Project Overview

IPHEX and OLYMPEX Cases

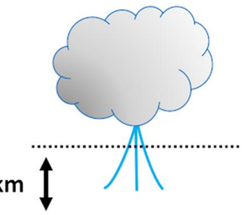
Date	Case Description	Special Notes
IPHEx		
23/24 May 2014	Convective storms initiated over the mountains	Limited ER-2/Citation coordination; GPM overpass.
5 June 2014	Stratiform region of an MCS	ER-2, Citation coordination;, TRMM overpass.
11 June 2014	Widespread precipitation over NC mountains	ER-2, Citation coordination; GPM overpass.
12 June 2014	Post frontal passage with widely scattered convection over NC mountains	DC-8 data availability, MRMS data missing
OLYMPEX		
3 Dec 2015	Complex baroclinic system with orographically enhanced rain	ER-2, DC-8, Citation coordination during GPM overpass
4 Dec 2015	Post frontal convection over the ocean and mountains	ER-2, DC-8, Citation coordination
5 Dec 2015	Broad frontal cloud system with strong wind shear	ER-2, DC-8, Citation coordination
10 Dec 2015	Occluded front and post frontal convection	ER-2, DC-8, Citation coordination
12 Dec 2015	Precipitation associated with and occluded front and warm sector	ER-2, DC-8, Citation coordination

OBSERVATIONS
- Aircraft radars: (HIWRAP, CRS, EXRAD)
- Radiometers: (AMPR, CoSMIR)
- Polarmetric Radars: (NPOL, D3R, WSR-88D)

USAGE
- Capable of retrieving particle properties in ground clutter region
- Validation of WRF hydrometeor statistics
- Evaluate upgrades to WRF microphysics and ERRI

GPM

- Vertical dBZs above clutter layer
- Terrain Height/Gradient
- Conv/Strat, Echo tops
- Profile shape above clutter layer
- Ambient RH, Temp, Flow (profiles, etc.)
- Flow relative to terrain

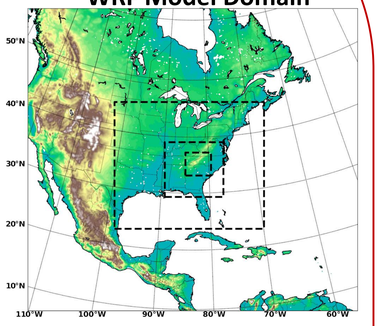


WRF

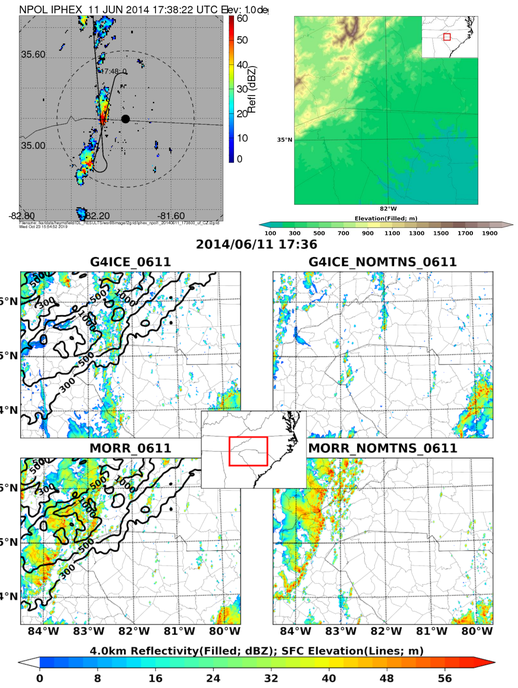
- Vertical dBZs above clutter layer
- Terrain Height/Gradient
- Conv/Strat, Echo tops
- Profile shape above clutter layer
- Ambient RH, Temp, Flow (profiles, etc.)
- Flow relative to terrain

- Low-level rain/precipitation profiles
- Low-level precipitation characteristics (e.g., DSDs, Dm, etc.)

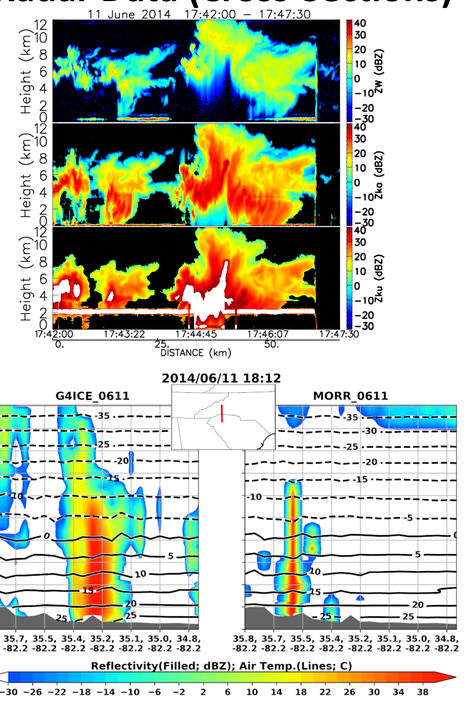
WRF Model Domain



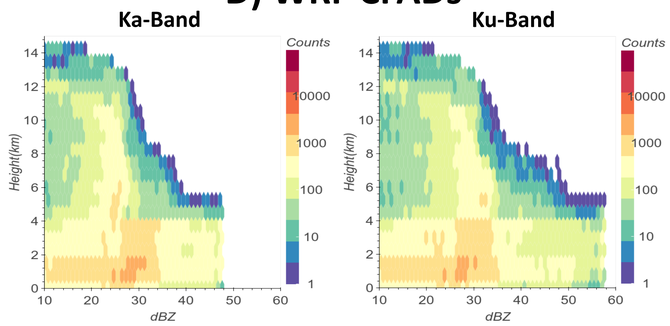
B) Radar Data (Planar)



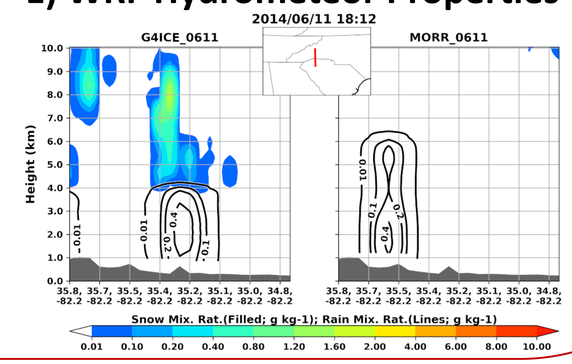
C) Radar Data (Cross-Sections)



D) WRF CFADs



E) WRF Hydrometeor Properties



Discussion of Figures

A) This project utilizes a combined model (WRF), GPM, and field campaign data approach with the aim to improve GPM algorithm retrievals within the ground clutter region (with 2 kms of the surface) particularly over orographic regions.
- This investigation targets the periods of the IPHEX (2014), and OLYMPEX (2015) field campaigns with ER-2 observations.
- Aircraft and ground validation data will be used to evaluate updated GPM retrievals and test updates to Goddard 4-ice microphysics

B) WRF model simulations using the Goddard 4-ice (G4ICE) and Morrison (MORR) microphysics show considerable variability. Although only a single-moment scheme, G4ICE matches more closely to radar observations than MORR, but WRF lags the NPOL ground truth.
- Comparing WRF model simulations with and without terrain (NOMTNS) reveal that orography tends to supplement synoptic scale forcing by inducing stronger, faster moving convection

C) Compared along HIWRAP radar retrievals, WRF tends to underestimate convective system intensity, but MORR tended to develop convective cores that were considerably narrower than G4ICE, which is also reflected in simulated hydrometer properties (Section E)

D) Analysis of WRF model output along a June 11th GPM overpass shows an abrupt transition in Ka- and Ku-band CFADs from the G4ICE simulations when transitioning through the melting level. Likely a result of either model microphysics or model vertical resolution.

Summary

- The project team has commenced its efforts to improve GPM radar retrievals within the ground clutter region using a combined model, GPM, and GPM ground validation approach, particularly in orographic regions.
- Since last year, we have doubled the WRF model resolution (1km vs 500 m), significantly increased the WRF model vertical resolution (61 vs 101 vertical levels) and applied the recently released ERA5 reanalysis for model input and BCs.
  - This has resulted in more accurate simulations than before, but as illustrated by Panel B and C, these simulations remain imperfect and vary considerably in response to different bulk microphysics schemes.
- Our initial simulations show a sharp discontinuity around the melting level (Panel D), which is not commensurate with GPM or NPOL retrievals and may be associated with microphysics scheme assumptions or model vertical resolution
- We will attempt to resolve the freezing level challenge by refining our model configuration and grid configuration (particularly in the vertical) and by introducing WRF simulations using the P3 microphysics scheme.
- We will also start the construction and testing of our radar reflectivity lookup tables (WRF-based) to investigate how they may augment GPM retrievals provide much needed data in the ground clutter region.