Overview of ER-2 Radar Observations, WRF, and Radar Retrievals from IPHEX and OLYMPEX

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Overall Goals

- Cross-validate microphysical characteristics and physical properties of orographic precipitation from GPM algorithm retrievals, aircraft, GPM GV, and WRF
- Quantify how terrain modifies and impacts orographically modified precipitation - intensity, timing, coverage, etc.
- Utilize GPM field assets to evaluate the capabilities of WRF and DPR radar retrievals to characterize ice and liquid hydrometeor properties
- Create lookup tables from WRF to augment DPR profiles in the ground clutter region.
Motivation

Low-level data missed by GPM DPR can be significant over terrain

GPM Ku, Ka-band DPR cross section over the Alps, which shows significant clutter related problems. The lowest ~1 km of data above the surface is missed; blue line is 0°C isotherm from JMA Global Analysis (GANAL).

One scan of DPR Ku-band from a cold season cyclone. Ground clutter causes missed data up to 2 km above the surface at the left and right scan edges, and ~500 meters at nadir (Ray 25).
Motivation
Terrain in IPHEx And OLYMPEX – ER-2 Radars

Dashed lines: At 0.5 km and 2 km above surface representing clutter region of DPR
Motivation
Impact of Orography on Amount and Profiles of Reflectivity in Low Levels
OLYMPEX: WRF simulations showing effect of terrain.

Figure 3.2. Capping the Olympic Mountains at its average height (640 m) reduces simulated snow mixing ratios, vertical velocities, and mountain wave generation. Model output is at 1-km, with (top) original and (bottom) modified terrain for the OLYMPEX case. Gray shading denotes region within 2 km of the surface that may be missed by DPR. Black line indicates 0°C isotherm.
Extending Precipitation Estimates through Terrain-related Ground Clutter Using Simulation Profiles to Fill in Missing DPR profiles
FIELD CAMPAIGNS

OBSERVATIONS
- Aircraft radars, radiometers, polarimetric radars

USAGE
- Retrieve profiles and particle properties in ground clutter region
- Validation of WRF hydrometeor statistics
- Evaluate WRF microphysics and DPR retrieval algorithms

GPM
- Vertical dBZs above clutter layer
- Terrain Height/Gradient
- Conv/Strat precip., Echo tops
- Profile shape above clutter layer
- Ambient RH, Temp, Flow
- 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

- Look up table development
  - Low-level rain/precipitation profiles
  - Low-level precipitation characteristics
  - (e.g., DSDs, Dm, etc.)
<table>
<thead>
<tr>
<th>Date</th>
<th>Case Description</th>
<th>Special Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>23/24 May 2014</td>
<td>Convective storms initiated over the mountains</td>
<td>ER-2; GPM overpass.</td>
</tr>
<tr>
<td>5 June 2014</td>
<td>Stratiform region of an MCS</td>
<td>ER-2, Citation coordination; TRMM overpass.</td>
</tr>
<tr>
<td>11 June 2014</td>
<td>Widespread precipitation over NC mountains</td>
<td>ER-2, Citation coordination; GPM overpass.</td>
</tr>
<tr>
<td>12 June 2014</td>
<td>Post frontal passage with widely scattered convection over NC mountains</td>
<td>DC-8 data availability, MRMS data missing</td>
</tr>
<tr>
<td>3 Dec 2015</td>
<td>Complex baroclinic system with orographically enhanced rain</td>
<td>ER-2, DC-8, Citation coordination during GPM overpass</td>
</tr>
<tr>
<td>4 Dec 2015</td>
<td>Post frontal convection over the ocean and mountains</td>
<td>ER-2, DC-8, Citation coordination</td>
</tr>
<tr>
<td>5 Dec 2015</td>
<td>Broad frontal cloud system with strong wind shear</td>
<td>ER-2, DC-8, Citation coordination</td>
</tr>
<tr>
<td>10 Dec 2015</td>
<td>Occluded front and post frontal convection</td>
<td>ER-2, DC-8, Citation coordination</td>
</tr>
<tr>
<td>12 Dec 2015</td>
<td>Precipitation associated with and occluded front and warm sector</td>
<td>ER-2, DC-8, Citation coordination</td>
</tr>
</tbody>
</table>
Model Configuration and Available Data Products

1. **Weather Research and Forecasting model (WRF)**
   - 4-model domains (13.5, 4.5, 1.5, 0.5 km)
   - ECMWF reanalysis (ERA5) initialization and boundary conditions
   - Morrison, P3, Goddard 4-ice
   - 12/4 minute output interval
   - Satellite data simulator (G-SDSU) [T. Matsui]

2. **Aircraft and Surface Obs.**
   - **Radars**: HIWRAP Ka- and Ku-band, CRS W-band, and EXRAD X-band
   - **Radiometers**: AMPR (10-85 GHz), CoSMIR (89-103 GHz)
   - **Polarmetric radars**: NPOL, D3R, WSR-88D

3. **Radar Retrieval for Ice (Grecu, 2018)**
   - Possible inclusion for GPM
   - Applied to ER-2 radar data (Ka-, Ku-, W-bands)
   - Provides: Drop size distribution, Ice water content, Attenuation corrected radar data
Bulk particle properties highlight the utility of G-SDSU simulations utilizing WRF model output for microphysical processes and property investigations.

Goddard Satellite Data Simulator Unit (G-SDSU, Matsui et al. 2013, 2014)

Black line is 0°C isotherm.
Retrieved ice water content (g/m³) and mean drop diameter (mm) above the freezing level – from ER-2

WRF-derived water content (ice + liquid) and combined (ice + liquid) drop diameter (mm).

WRF figures are simulated by G-SDSU and includes the 0°C and -40°C isotherms. Grey shading denotes the topography.
Added value of aircraft observations: LDR, vertical velocity, fallspeeds, etc.
Summary & Future Work

• IPHEx and OLYMPEX aircraft and ground radar observations provide rich data sets to validate WRF microphysics parameterizations and radar/radiometer retrievals in orographic regions.

• Include additional IPHEx and OLYMPEX cases.

• Under development: high-spatiotemporal resolution (0.5 km horizontal; avg. 200 m (30 m in clutter region) vertical; 4 min output) WRF simulations to construct lookup tables for profiles in clutter region.

• Goal: physically based look up table to address current limitations of DPR in ground clutter region.