Evaluating Precipitation Observed in Complex Terrain During GPM Field Campaigns with the SIMBA Data-fusion Tool

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System for Integrating Multi-platform data to Build the Atmospheric column (SIMBA)

- GPM GV & field campaign datasets
- Surface-, ground-, satellite-based instruments → points, profiles, volumes of data

SIMBA:
- Available observations from all supported platforms on a single, 3D grid
- Platform-specific modules
- Interpolate only as required for grid
- NetCDF, Atmospheric Column files
- Attributes maintain sensor parameters
SIMBA Overview

**User Defines Column Grid:**
- center location, horiz. & vert. extent, spacing

**Platform-specific Modules:**
- Read native data, process only as needed to set coincident observations into column grid

**Atmospheric Column Data Product:**
- All available observations on common 3D grid in NetCDF format

**Ground-based Scanning Radars**
- NPOL, D3R, DOW6, NWS NEXRAD/88D: Doppler, polarimetric radar fields, GPM-GV DPQC
- Gridded via Radx

**Satellite-based Sensors**
- GPM GMI: L1C, L2AGPROF $T_B$s & retrieved precip
- GPM DPR: 2ADPR Ka/Ku-band obs & retrievals
- FOV locations

**Ground, Point Observations**
- Disdrometers, tip bucket & weighing gauges and derived parameters
- Exact locations preserved

**Soundings:**
- $T$, $T_d$, winds, LCL, LFC, EL, CAPE, CIN, TPW

**MRMS QPE Product**
- 0.01° x 0.01° over CONUS: Precip rate, precip type, RQI

**Atmospheric Column Data Product**
- Coincident data set into the requested column grid
- Attributes maintain: column grid set up, exact/original platform locations, modes, timestamps, algorithms, product versions, etc
- Inventory utility

**Ground-based Profiling Radars**
- MRR: Z, w, LWC, DSD parameters
- Vertical gate spacing

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**SIMBA enables more efficient precipitation science**
by fusing targeted GPM GV observations from several instruments to a common atmospheric column grid

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OLYMPEX Campaign: Winter 2015-2016

- Coast & terrain impacts on precipitation in Pacific frontal systems
- Effects on satellite measurements
- Remote and In-situ data collection
  - Ground-based:
    - NPOL, D3R, DOW, 88Ds
    - Disdrometers, gauges, particle imaging
  - Airborne sensors:
    - NASA DC-8, ER-2: dropsondes, GPM Core analog
    - UND Citation: In-situ cloud particle probes
  - Satellite: 2nd post-launch campaign for GPM Core Observatory

Houze et al. (2017)
OLYMPEX – 3 December 2015

- Evolving system with shortwave trough
- Southerly flow
- Early: Widespread stratiform, variability
- GPM Core OP @ 1523
- Ideal coordination
- Later: front-like shallow echo line with wind shift

UW WRF+GFS Analyses: 10 m winds & SLP

NPOL 1.5° Z

SIMBA Columns
6 locations
Ocean – Quinault River Valley
Along NPOL 50°/230° azimuth/DPR scan line

DPR & GMI swaths
Near perfect ground- & space-based scan alignment

NPOL RHI
DPR NS
DPR HS
DPR MS

1537
6 Columns along NPOL 50°/230°:

1) Ocean
   • Elev: 0 m
   • KLGX, NPOL, D3R

2) NPOL
   • Elev: 157 m
   • KLGX, NPOL, D3R
   • APU, tip gauges

3) Midpoint (N-AP)
   • Elev: 40 m
   • KLGX, NPOL, D3R, 1 MRR
   • APU, 2DVD, tipping bucket gauges

4) Amanda Park
   • Elev: 63 m
   • KLGX, NPOL, D3R, DOW6, 2 MRRs
   • APU, 2DVDs, Pluvio, tipping bucket gauges

5) Grave’s Creek
   • Elev: 358 m
   • KLGX, NPOL, DOW6
   • APU

6) Upper East Fork
   • Elev: 1120 m
   • KLGX, NPOL, DOW6
   • Pluvio gauge

Max time offset:
10 min (NPOL v. GMI)

RHIs Reveal Structure:
• Fallstreaks below brightband
• Upward VR shift over terrain; enhancement in Z, Z_{dr}, K_{dp} (e.g., Kingsmill et al. 2006, Medina et al. 2007, Kennedy and Rutledge 2011)
• Transient vertical Z_{dr} feature, max K_{dp} at base – but near 0°C (Tromel et al. 2013)
• DPR misses $D_M$ behavior below 0°C level: Decrease then grow; only decreases in higher terrain – SW flow...

• Precip rates: at modest elevation sites, GPROF & DPR PRs vs. sfc-based data w/in ~3 mm/h

• Higher Terrain: More variability; DPR limited - at worst no gates below 0°C level
OLYMPEX – 3 December 2015

DPR HS Lowest Clutter-Free Bin Height: ~3 km in highest terrain for this case

- DPR misses $D_M$ behavior below 0°C level: Decrease then grow; only decreases in higher terrain – SW flow...
- Precip rates: at modest elevation sites, GPROF & DPR PRs vs. sfc-based data w/in ~3 mm/h
- Higher Terrain: More variability; DPR limited - at worst no gates below 0°C level
OLYMPEX – 12 November 2015

UW WRF+GFS Analyses: 10 m winds & SLP
- Atmospheric river event
- Domain in warm sector
- Southwesterly flow

- GPM GMI OP @ 2115
- Up to 60 mm/24 h in QRV
- Leeward rain shadow

NPOL RHIs:
- Secondary peaks ~2km above 0°C
- VR shifts upward ahead of terrain
- BB, 2nd peaks bend down toward terrain
- Downslope flow

DPR & GMI swaths

- GPM GMI OP @ 2115
- Up to 60 mm/24 h in QRV
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NPOL RHIs:
- Secondary peaks ~2km above 0°C
- VR shifts upward ahead of terrain
- BB, 2nd peaks bend down toward terrain
- Downslope flow
• GMI only for this case
• Lower elev. Disdrometer-derived Rayleigh Z compares well to S-band obs

• Marked $D_M$ increase approaching ground, particularly from MRRs - flow more normal to terrain barrier

• Precipitation rates especially more challenging in higher terrain
OLYMPEX – 17 November 2015

- Atmospheric river event
- Westerly flow
- Prominent stratiform, some embedded cells
- 200 mm + /24 h in QRV (up to 60 mm leeward)
- GPM GMI OP @ 2001

 Later: FROPA with NCFR, into elongated sections as passed over land

NPOL RHIs:
- VR shifts upward ahead of terrain
- Secondary peaks
- BB bends less than seen in 12 Nov case
- Growth below 0°C
• Z profiles compare better at lower elevation sites
• Precip rates: satellite estimates underest. ground-based by 50%+ at higher elevation
• DPR shows \( D_M \) behavior more subtly than ground-based sensors
• \( D_M \) increases toward ground (westerly flow) – except at highest elevation sites
17 Nov 2015

As approach terrain:
- MRRs: $D_M$ increase more prominent
- NPOL/HID: more riming, big drops

- Topographically enhanced riming/aggregation leads to DSD changes resulting in more efficient collision-coalescence and larger drops at surface
- Dependent on flow orientation relative to terrain

DPR HS Lowest Clutter-Free Bin Height: ~3+ km in highest terrain for this case

- DPR can not see the whole story!
- DPR scan along NPOL 50° azimuth
- NPOL RHI composite filled in below DPR
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IPHEEx Campaign: Spring/Summer 2014

- Warm season orographic precipitation & complex terrain hydrologic processes
- Effects on satellite measurements, QPE
- Remote and In-situ data collection
  - Ground-based:
    - NPOL, D3R, 88Ds, NOXP
    - Disdrometers, gauges, particle imaging
  - Airborne sensors:
    - NASA ER-2: dropsondes, GPM Core analog
    - UND Citation: In-situ cloud particle probes
  - Satellite: 1st post-launch campaign for GPM Core Observatory

Barros et al. (2014), IPHEEx Sci Plan

IPHEEx GV focus domain (yellow) & river basins of interest
IPHEEx – 23 May 2014

- GPM “Check-out” period
- Early: MCS off Appalachians
- Approaching cold front
- GPM DPR OP @ 2316
- Convection with 1-2 in hail in NPOL coverage; ER-2 coordination
IPHEX – 23 May 2014

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- Early: MCS off Appalachians
- Approaching cold front
- GPM DPR OP @ 2316
- Convection with 1-2 in hail in NPOL coverage; ER-2 coordination
IPHEX – 23 May 2014

- DPR NS captures Z increase below 0°C better than HS, MS
- Satellite preip rates underestimate ground-based sensors

- Except in strongest Z core, satellite sfc precip rates underestimate MRMS
- DPR $D_M$ behavior below 0°C better than OLYMPEX – less terrain
Summary & Continuing Work

- SIMBA fuses targeted satellite- & ground-based observations to a user-specified 3D grid for more efficient precipitation investigations

OLYMPEX Cases:
- Demonstrate concerns with DPR in regions of complex terrain
- $D_M$ behavior below 0°C implies processes changes, dependent on orientation of cross-barrier flow

IPHEX Example:
- DPR NS better represents $Z$ in stronger convection
- Improved DPR $D_M$ in regions of less complex terrain

- $Z_{dr}$ signature, ML characteristics, DPR profiles/algorithms improvements
- Additional events, statistics
- Further SIMBA developments

Visualization for Integrated Satellite- Airborne- and Ground-based data Exploration (VISAGE):
NASA AIST effort to use SIMBA

IN41B-0031: Thursday 8a-12:20p
Poster Hall D-F

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