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

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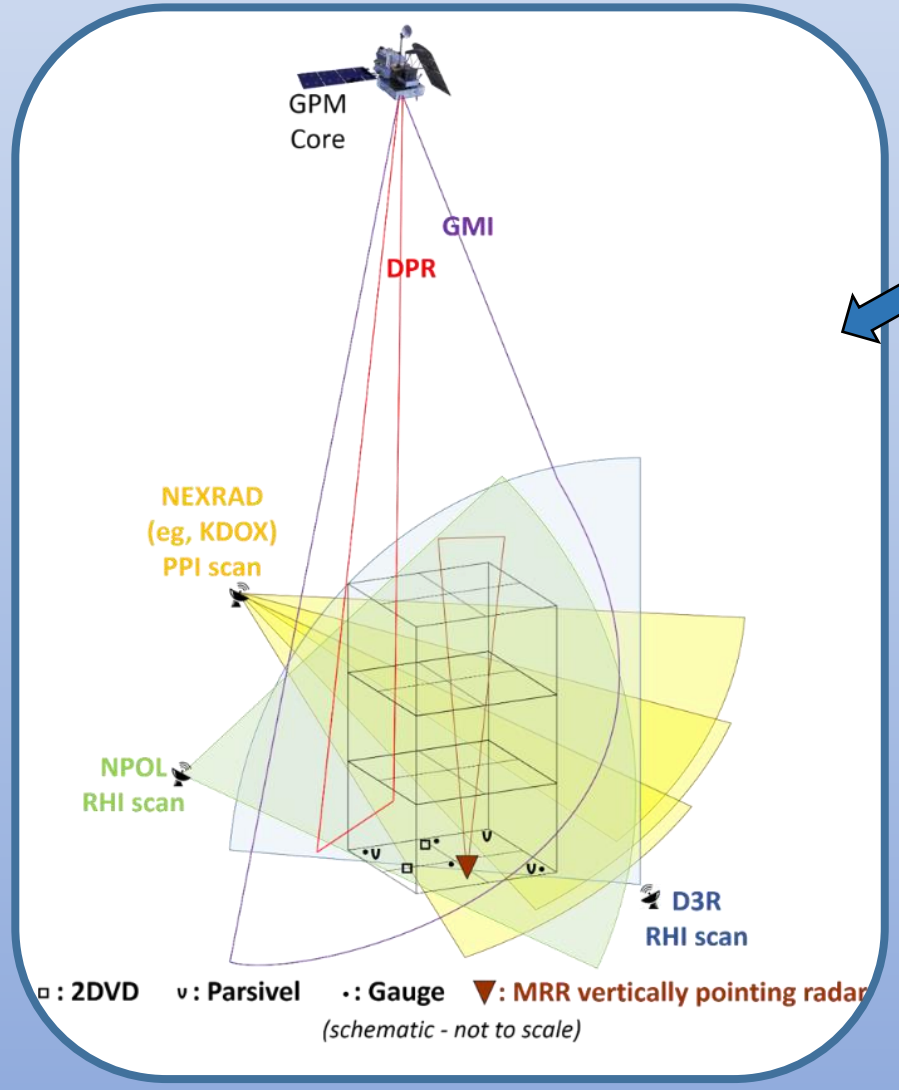
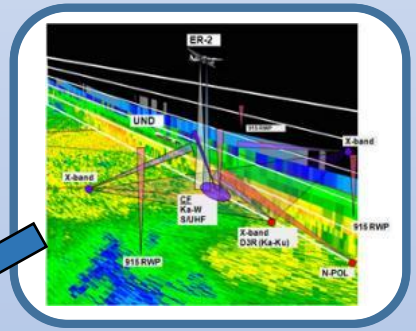
American Geophysical Union • 2017 Fall Meeting • New Orleans • H32C-05

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





Targeted observations collected in various formats & coordinate systems

Wingo et al. – in review (JTECH)

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

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

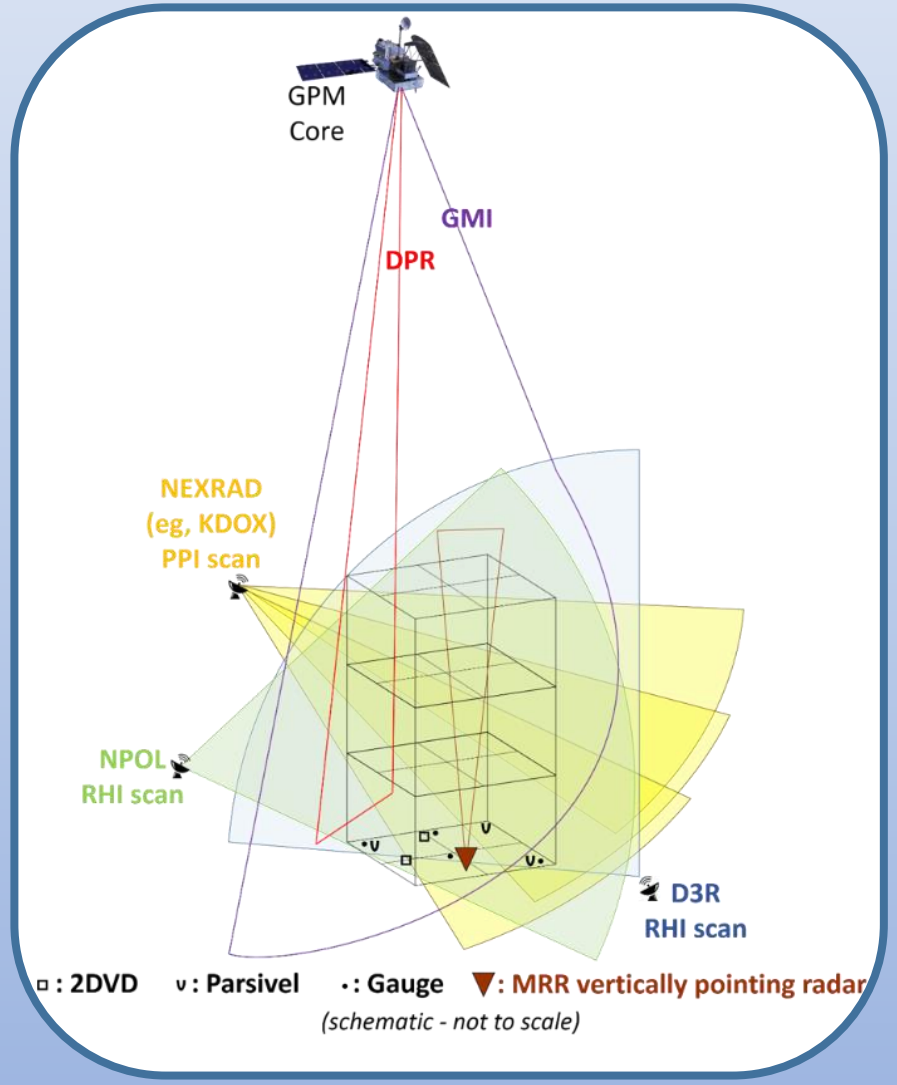
Soundings:
- T, T_d, winds, LCL, LFC, EL, CAPE, CIN, TPW

Satellite-based Sensors
- GPM GMI: L1C, L2AGPROF T_Bs & retrieved precip
- GPM DPR: 2ADPR Ka/Ku-band obs & retrievlas
- FOV locations

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

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

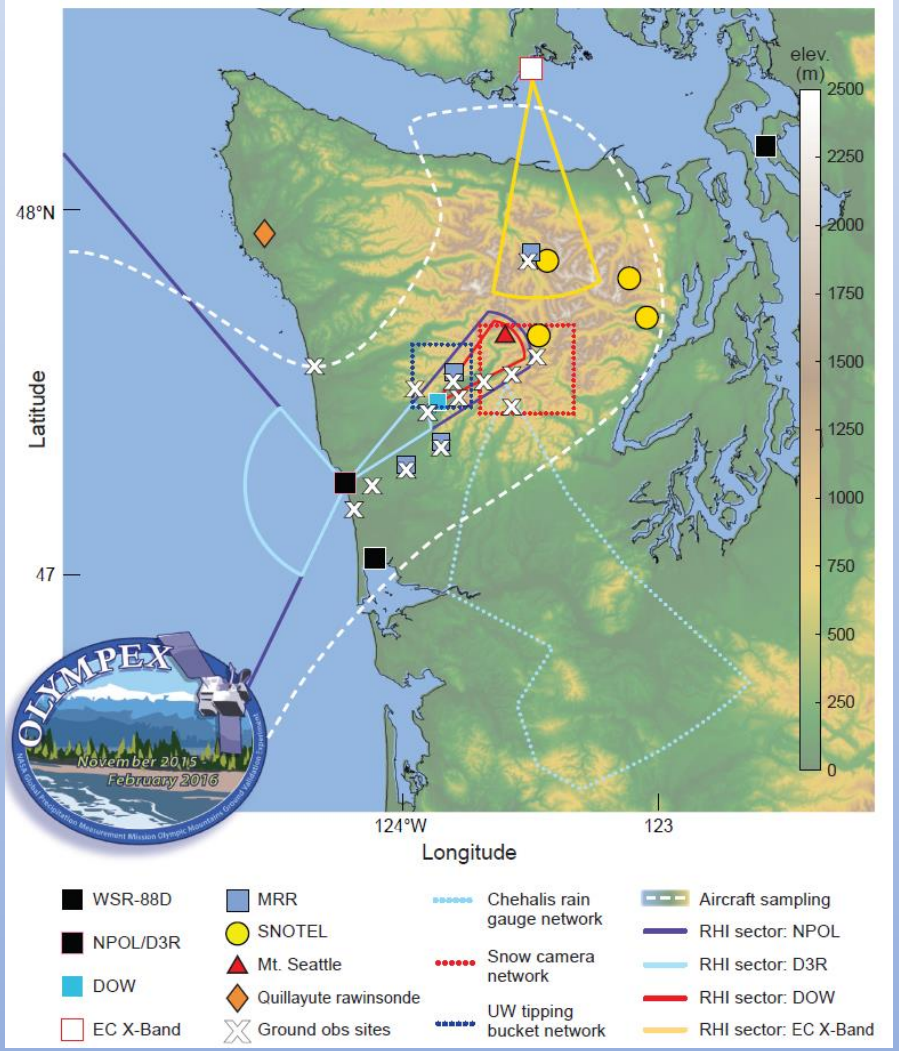
- Coincident data set into the requested column grid
- **Attributes maintain:** column grid set up, exact/original platform locations, modes, timestamps, algorithms, product versions, etc
- Inventory utility



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

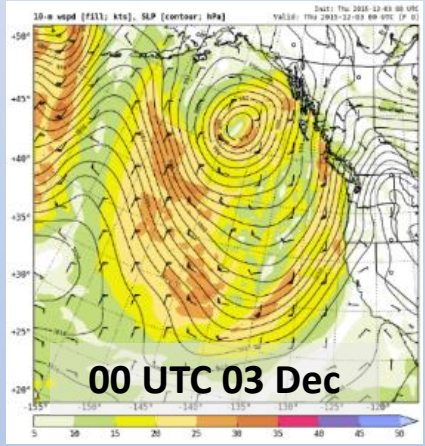
OLYMPEX Campaign: Winter 2015-2016

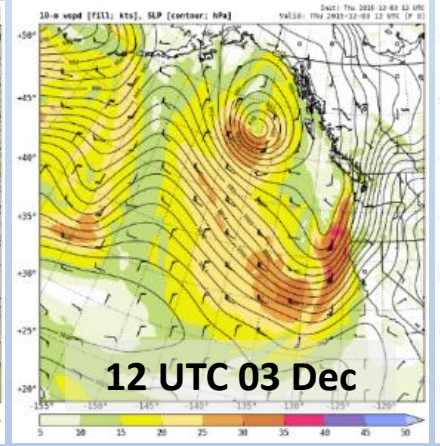
- Coast & terrain impacts on precipitation in Pacific frontal systems
- Effects on satellite measurements
- Remote and In-situ data collection
  - Ground-based:
    - NPOL, D3R, DOW, 88Ds
    - Disdrometers, gauges, particle imaging
  - Airborne sensors:
    - NASA DC-8, ER-2: dropsondes, GPM Core analog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

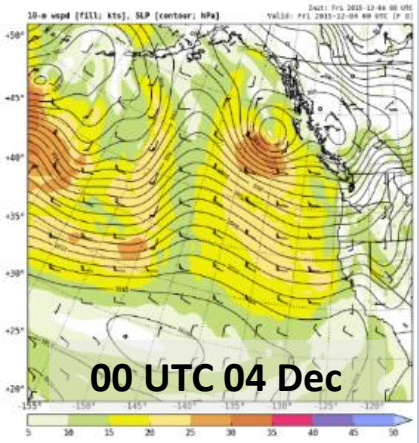


Houze et al. (2017)

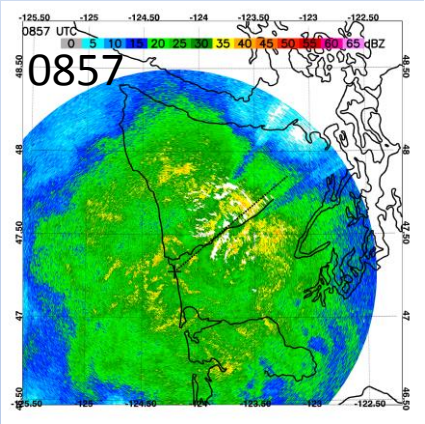
OLYMPEX – 3 December 2015

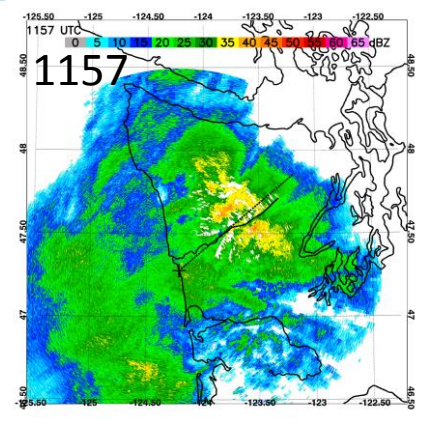


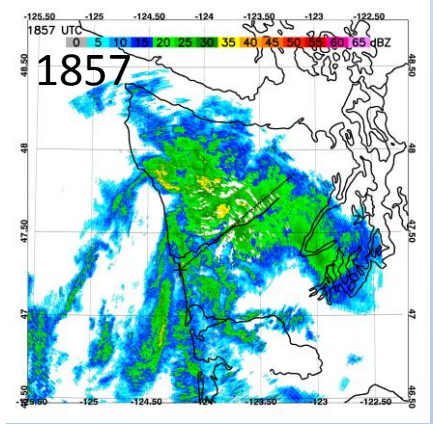




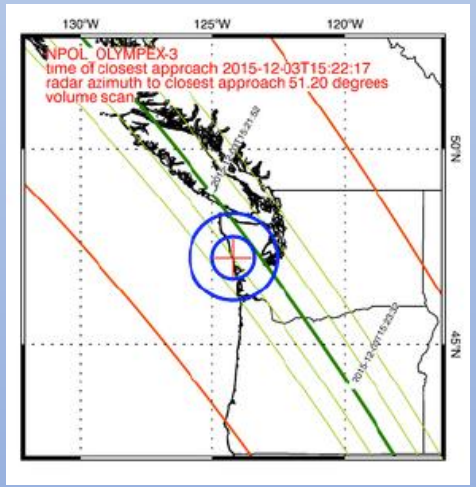
UW WRF+GFS Analyses: 10 m winds & SLP







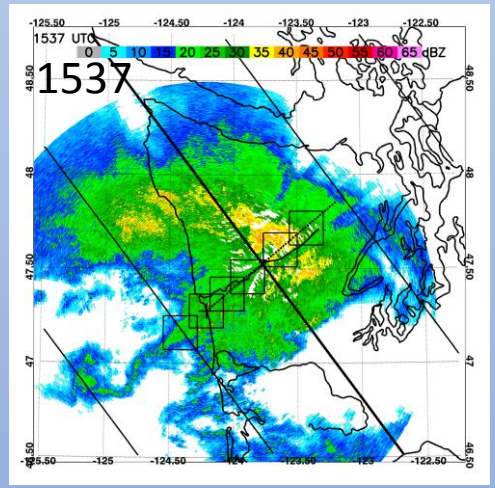
NPOL 1.5° Z



DPR & **GMI** swaths

Near perfect ground- & space-based scan alignment

- 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



NPOL w/ GPM swaths

SIMBA Columns

6 locations Ocean – Quinault River Valley

Along NPOL 50°/230° azimuth/DPR scan line

OLYMPEX – 3 December 2015

6 Columns along NPOL 50°/230°:

1) <u>Ocean</u>
- Elev: 0 m
- KLGX, NPOL, D3R

2) <u>NPOL</u>
- Elev: 157 m
- KLGX, NPOL, D3R
- APUs, tip gauges

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

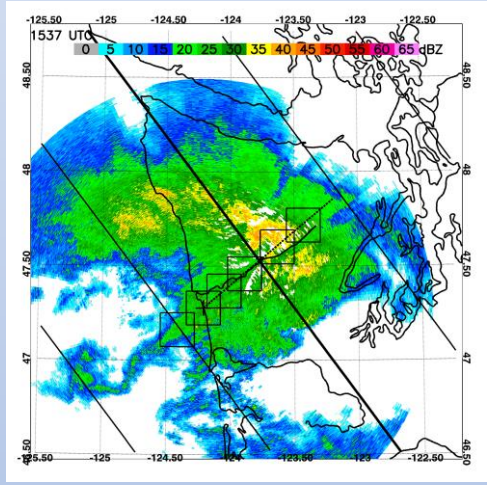
4) <u>Amanda Park</u>
- Elev: 63 m
- KLGX, NPOL, D3R, DOW6, 2 MRRs
- APUs, 2DVDs, Pluvio, tipping bucket gauges

5) <u>Grave's Creek</u>
- Elev: 358 m
- KLGX, NPOL, DOW6
- APUs

6) <u>Upper East Fork</u>
- Elev: 1120 m
- KLGX, NPOL, DOW6
- Pluvio gauge

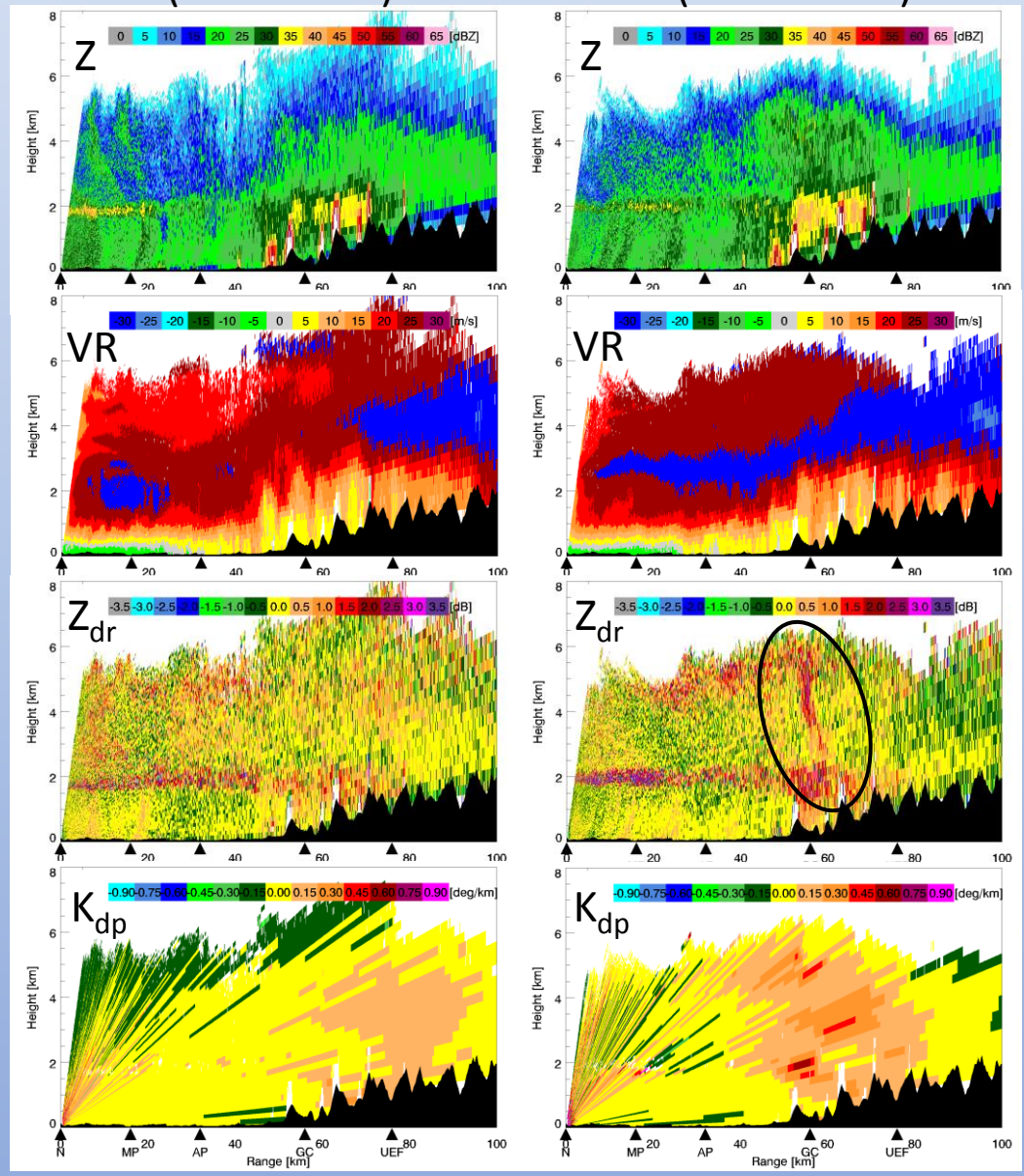
<u>All Columns:</u>
20 x 20 x 6 km
500 m spacing

<u>Max time offset:</u>
10 min (NPOL v. GMI)

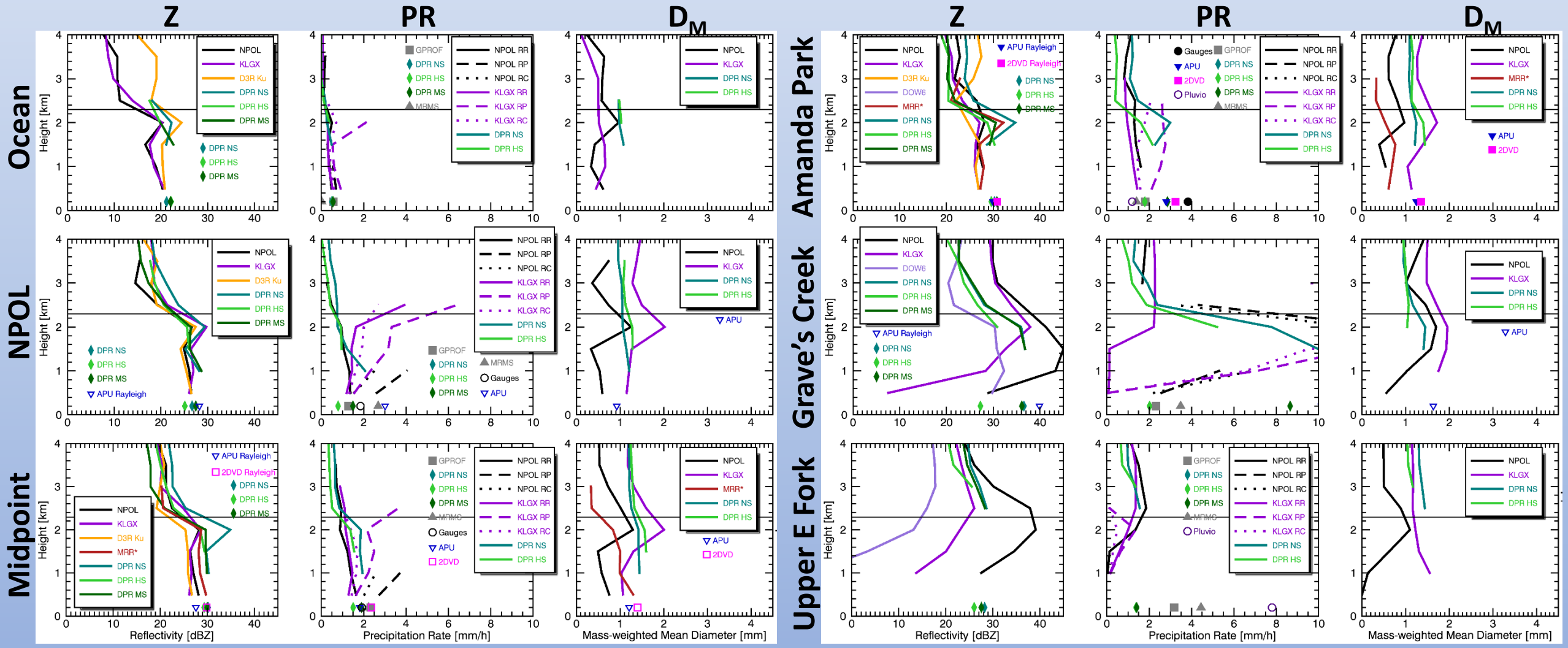


RHIs Reveal Structure:
- Fallstreaks below brightband
- Upward VR shift over terrain; enhancement in Z, Z_{dr}, K_{dp} (e.g., Kingsmill et al. 2006, Medina et al. 2007, Kennedy and Rutledge 2011)
- Transient vertical Z_{dr} feature, max K_{dp} at base – but near 0°C (Tromel et al. 2013)

(OP-10 min) (OP+10 min)

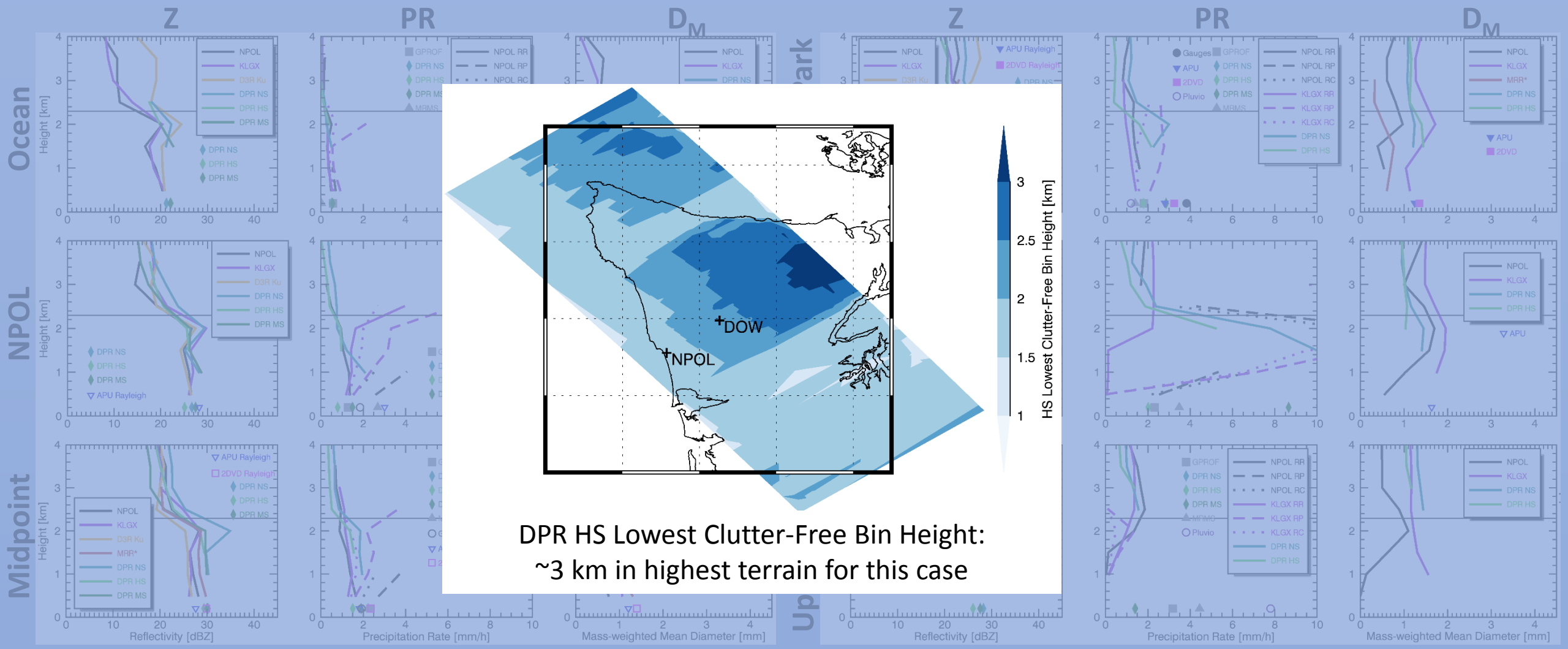


OLYMPEX – 3 December 2015



- **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

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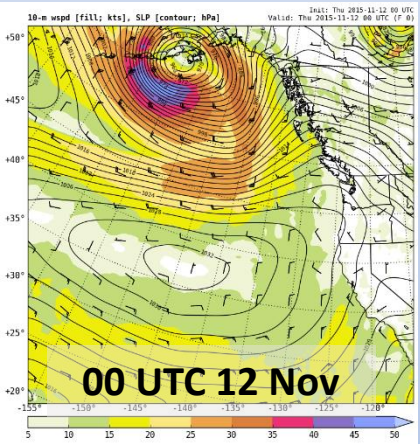
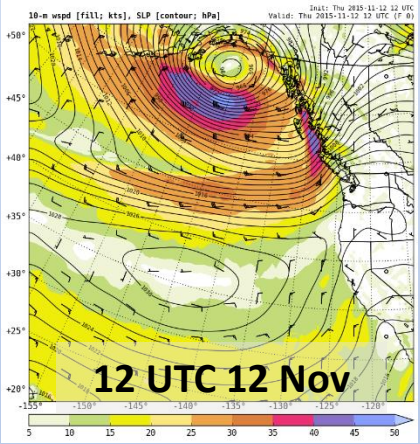
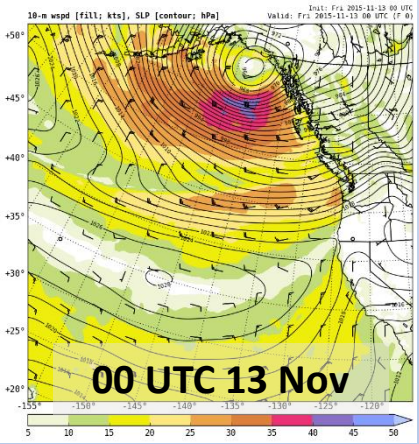
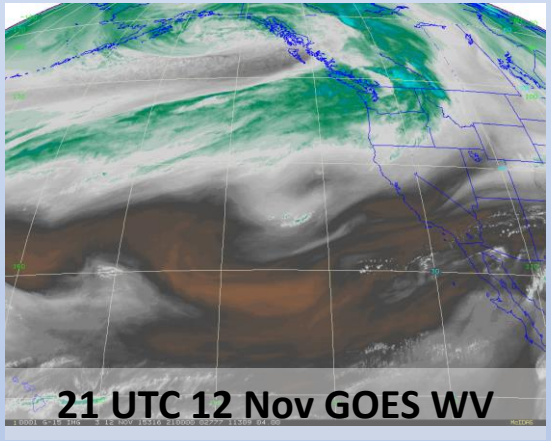
OLYMPEX – 12 November 2015

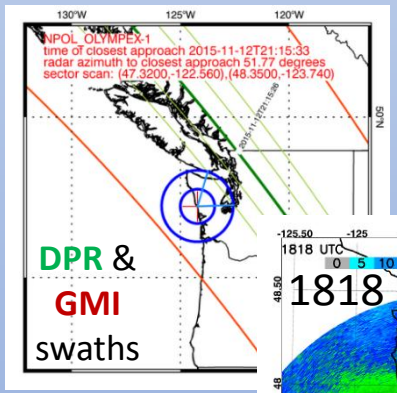




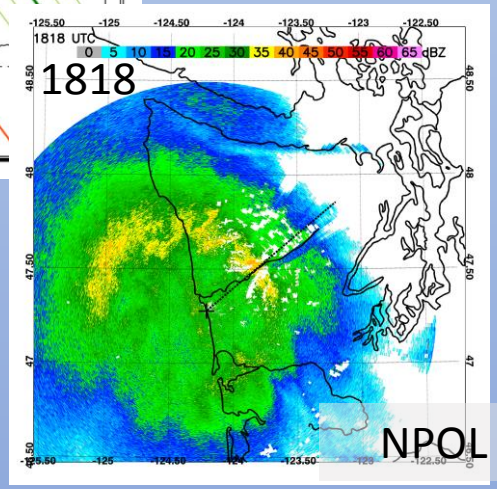


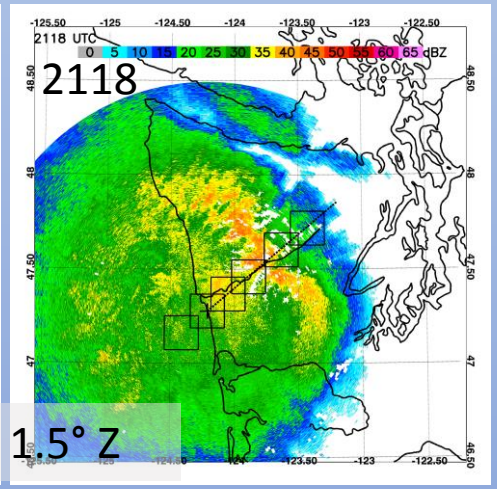


UW WRF+GFS Analyses: 10 m winds & SLP



- Atmospheric river event
- Domain in warm sector
- Southwesterly flow





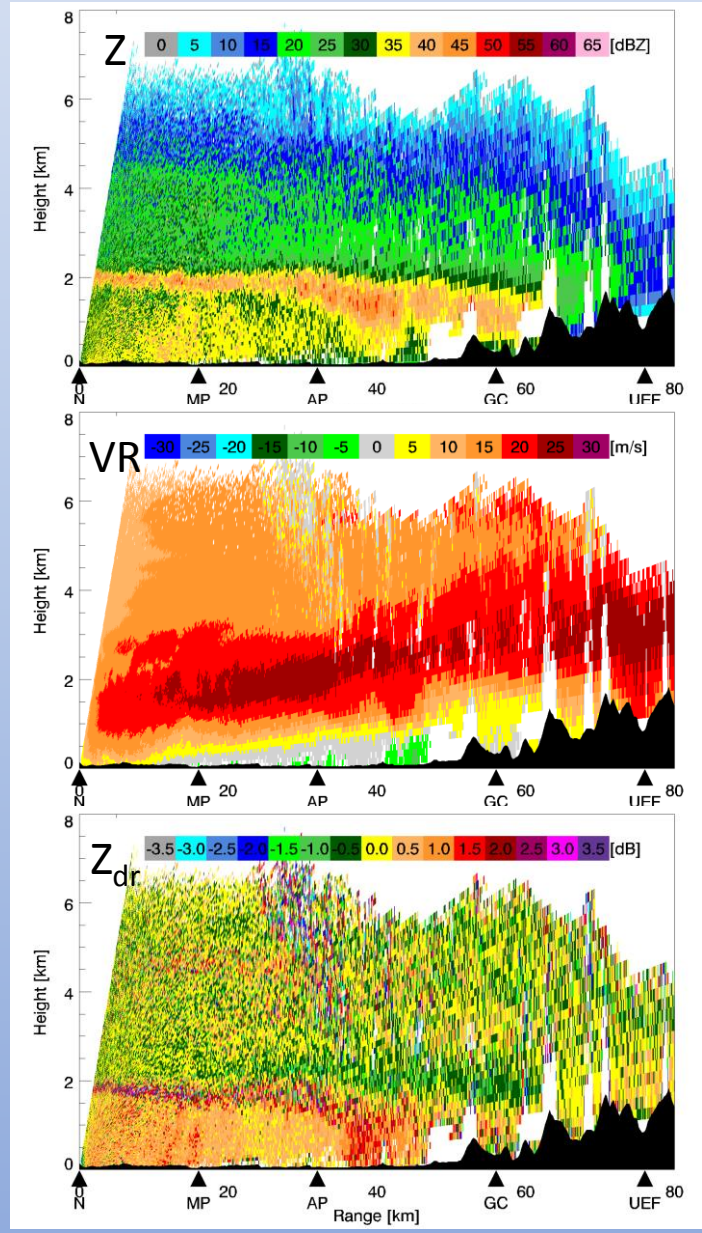
NPOL 1.5° Z

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

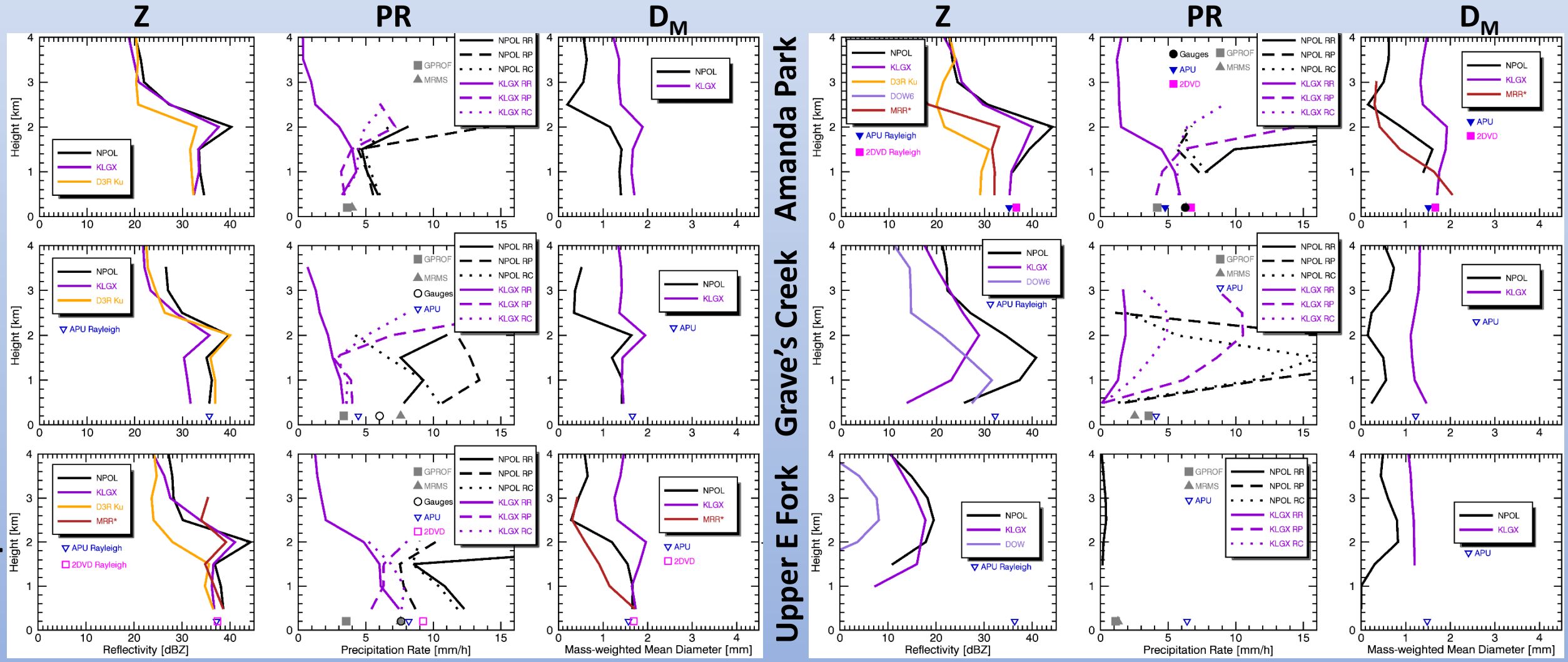
NPOL RHIs:

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

2112 UTC NPOL 50° RHI

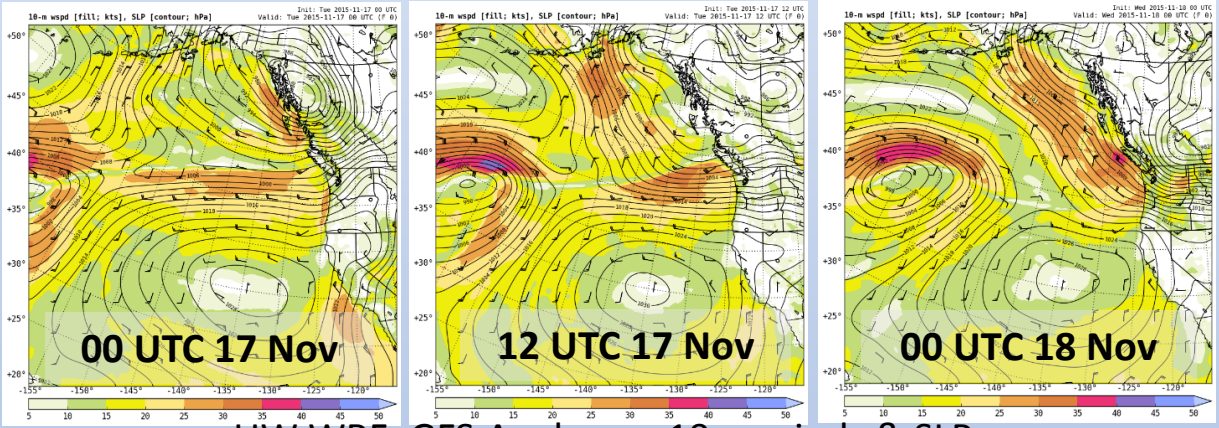


OLYMPEX – 12 November 2015



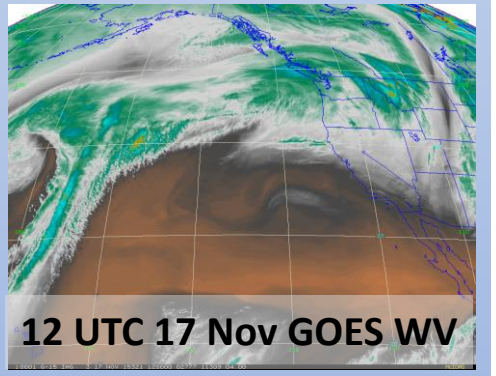
- GMI only for this case
- Lower elev. Disdrometer-derived Rayleigh Z compares well to S-band obs
- Marked ***D_M increase*** approaching ground, particularly from MRRs - ***flow more normal to terrain barrier***
- Precipitation rates especially more challenging in higher terrain

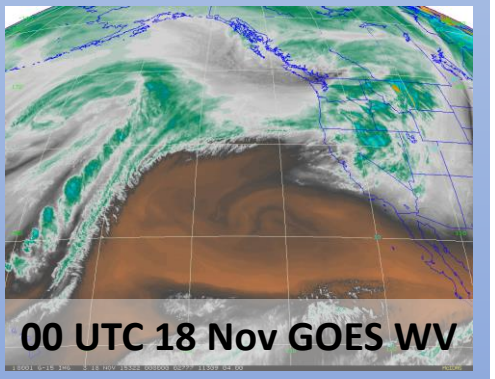
OLYMPEX – 17 November 2015

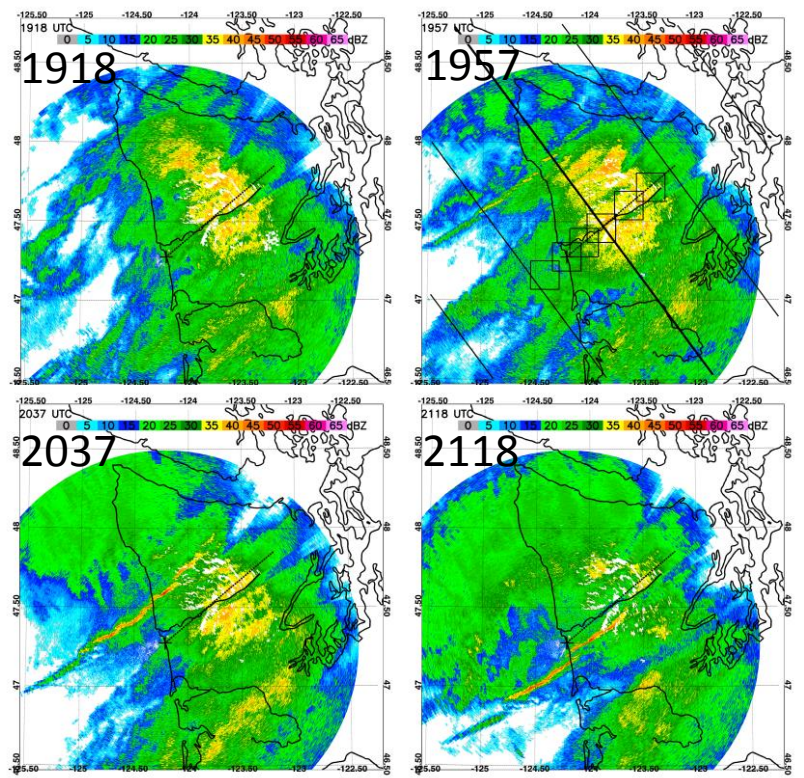


UW WRF+GFS Analyses: 10 m winds & SLP

- 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





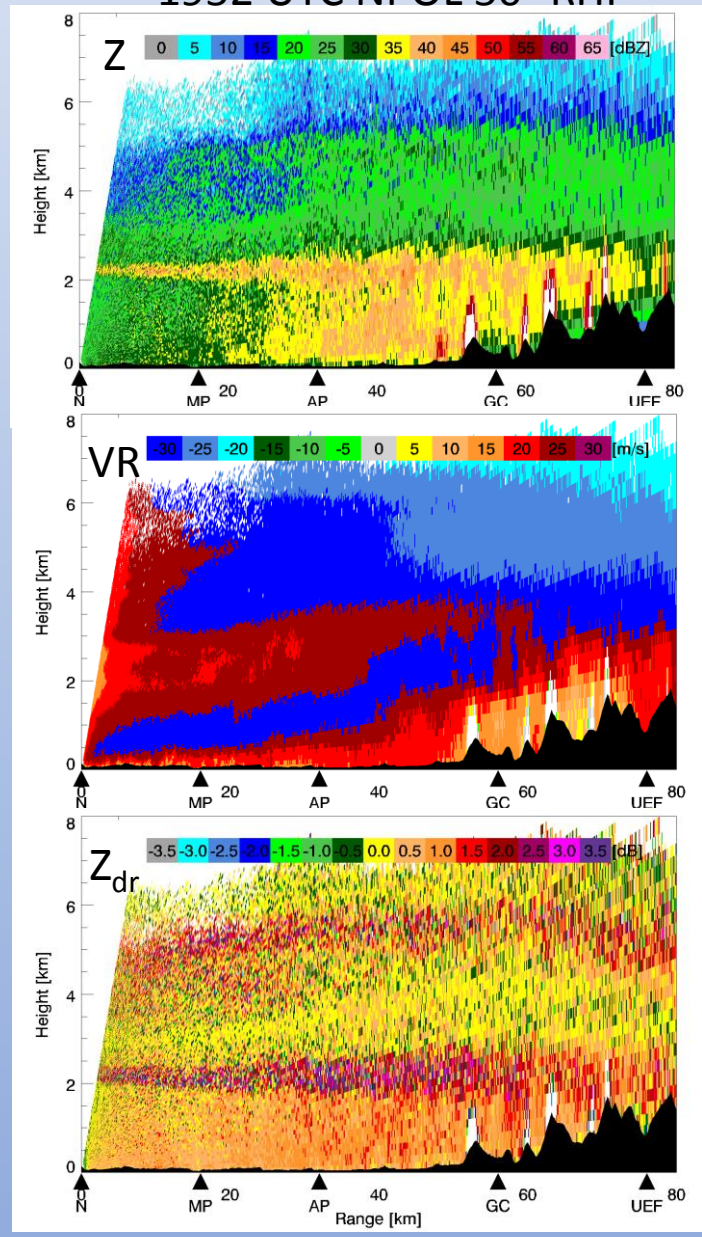


- Later: FROPA with NCFR, into elongated sections as passed over land

NPOL RHIs:

- VR shifts upward ahead of terrain
- Secondary peaks
- BB bends less than seen in 12 Nov case
- Growth below 0°C

1952 UTC NPOL 50° RHI



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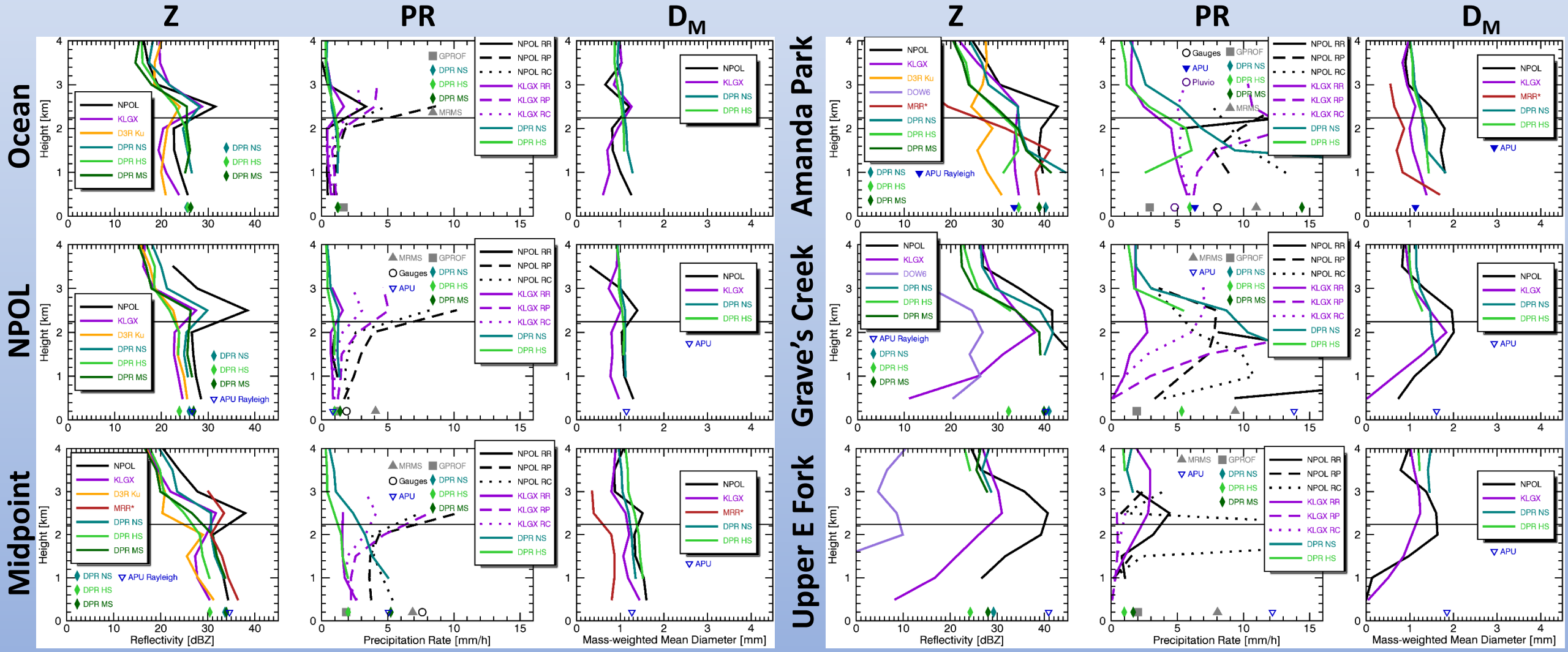
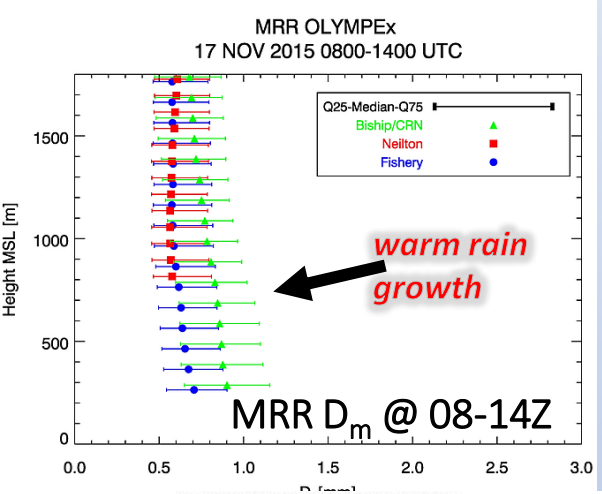


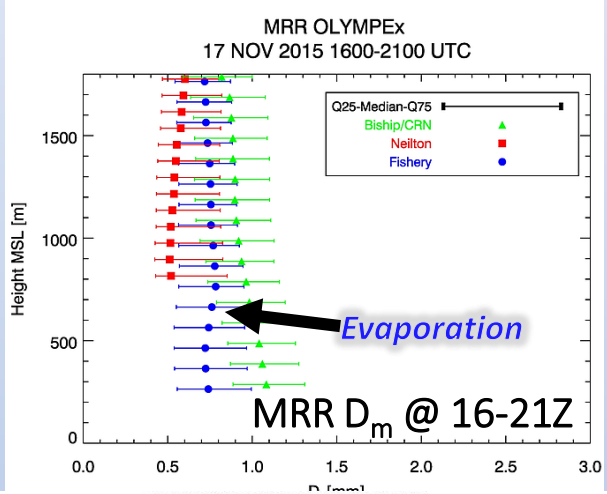
- Z profiles compare better at lower elevation sites
- Precip rates: satellite estimates underest. ground-based by 50%+ at higher elevation
- DPR shows D_M behavior more subtly than ground-based sensors
- ***D_M increases*** toward ground (***westerly flow***) – except at highest elevation sites

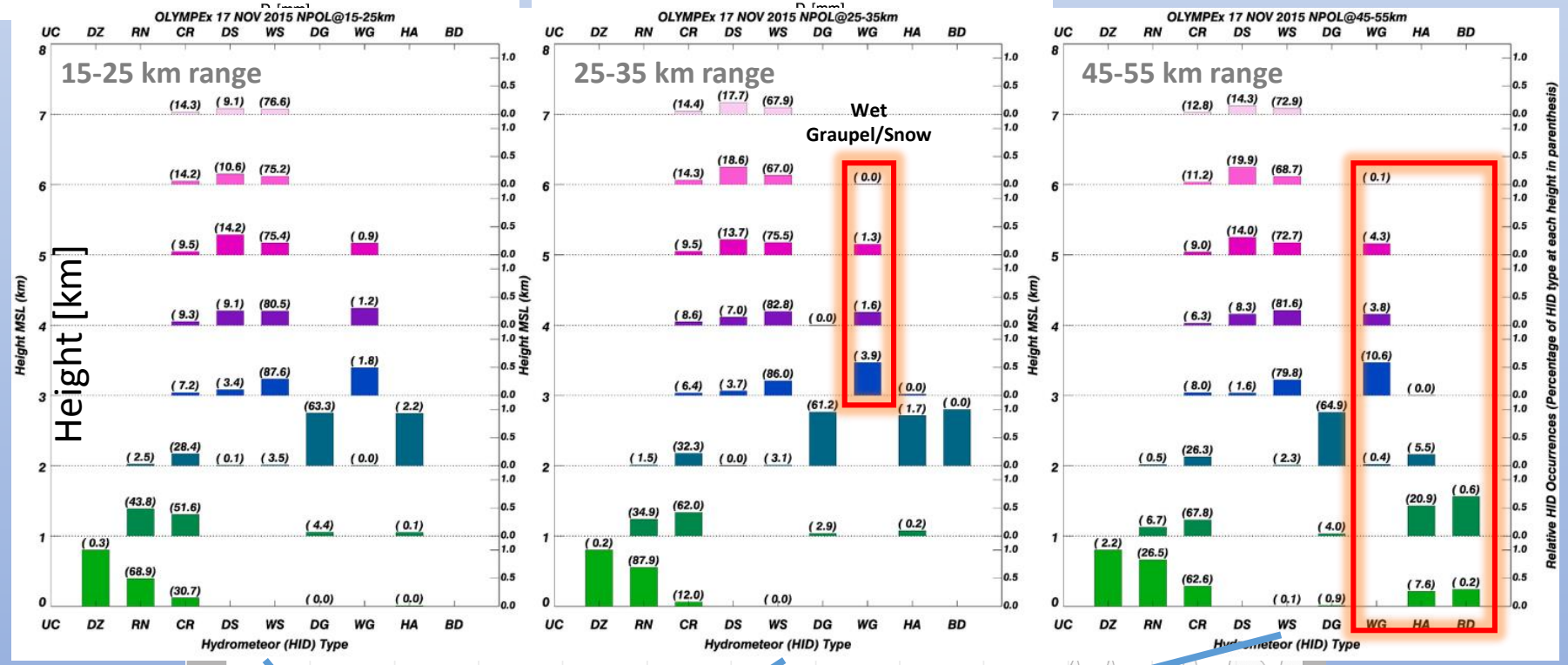
17 Nov 2015

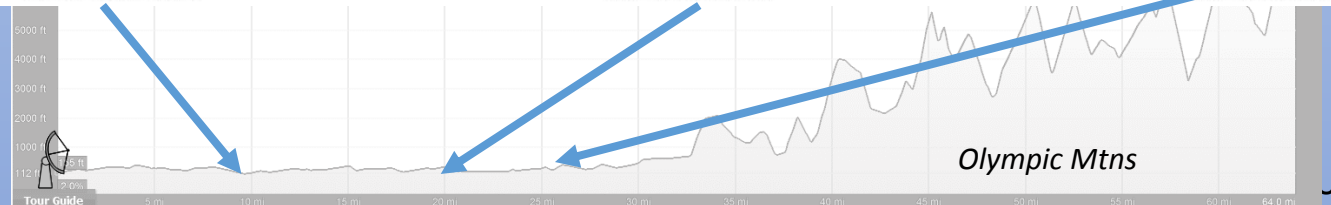
As approach terrain:

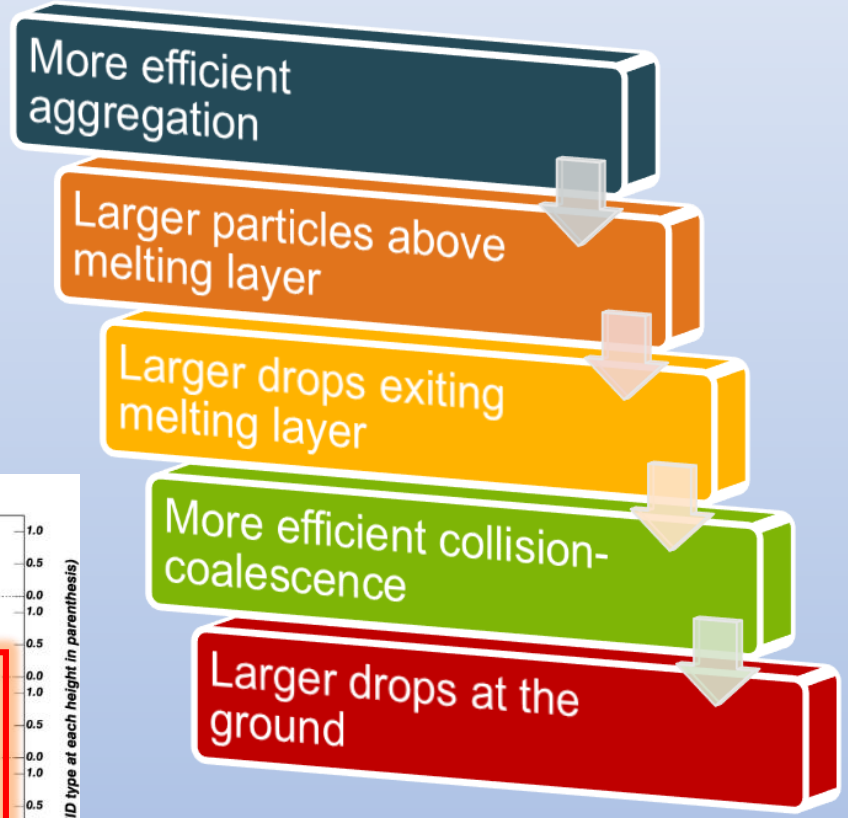
- MRRs: D_M increase more prominent
- NPOL/HID: more riming, big drops







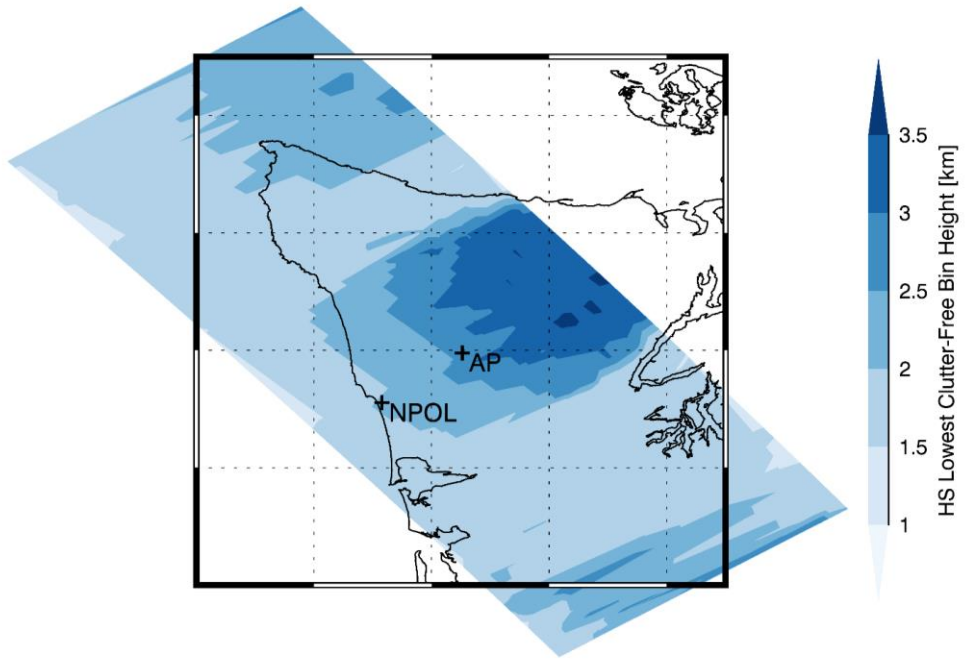




- Topographically enhanced riming/aggregation leads to DSD changes resulting in more efficient collision-coalescence and larger drops at surface
- Dependent on flow orientation relative to terrain

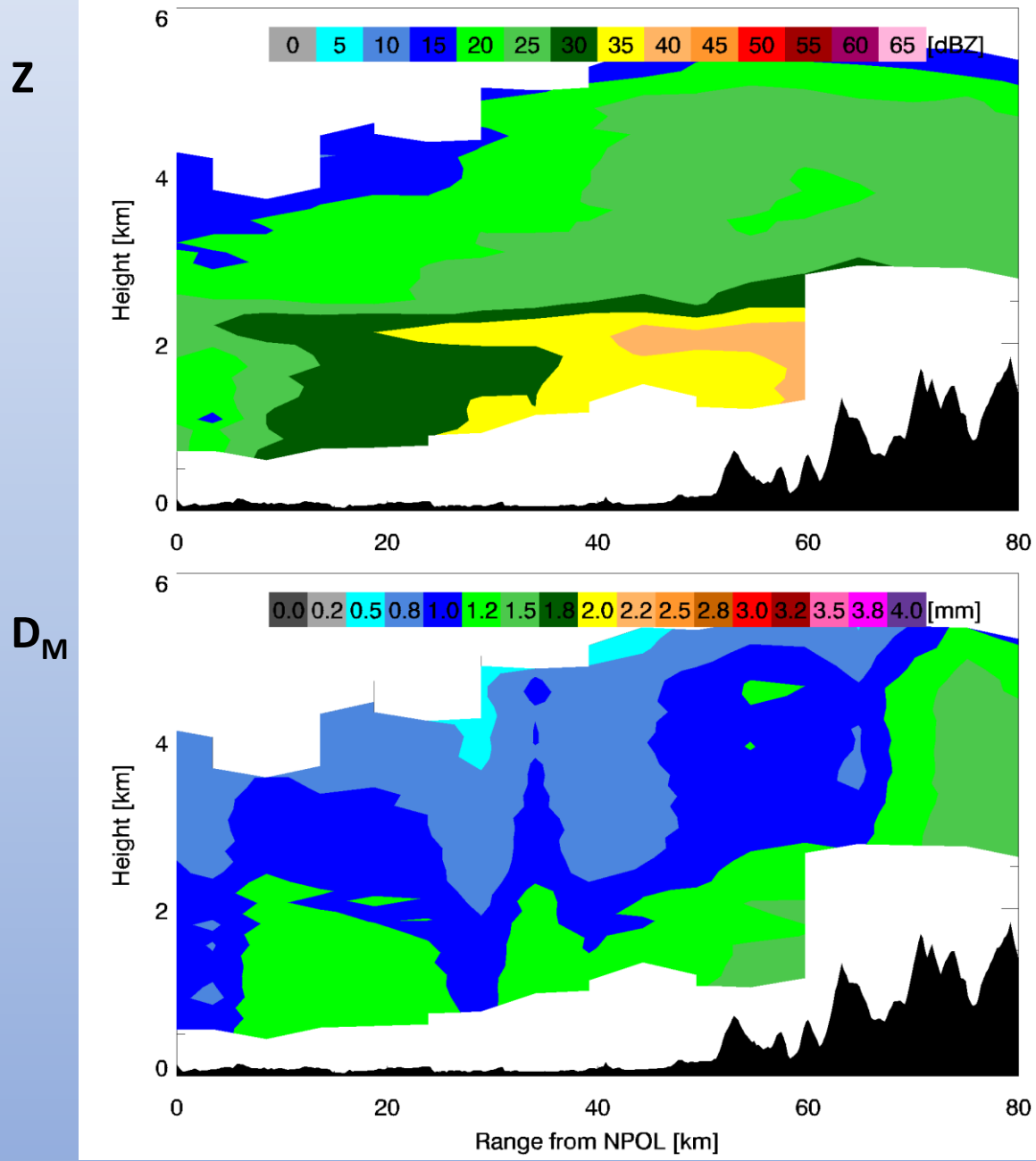
Gatlin et al. (2017) – AMS Radar Conf.

OLYMPEX – 17 November 2015

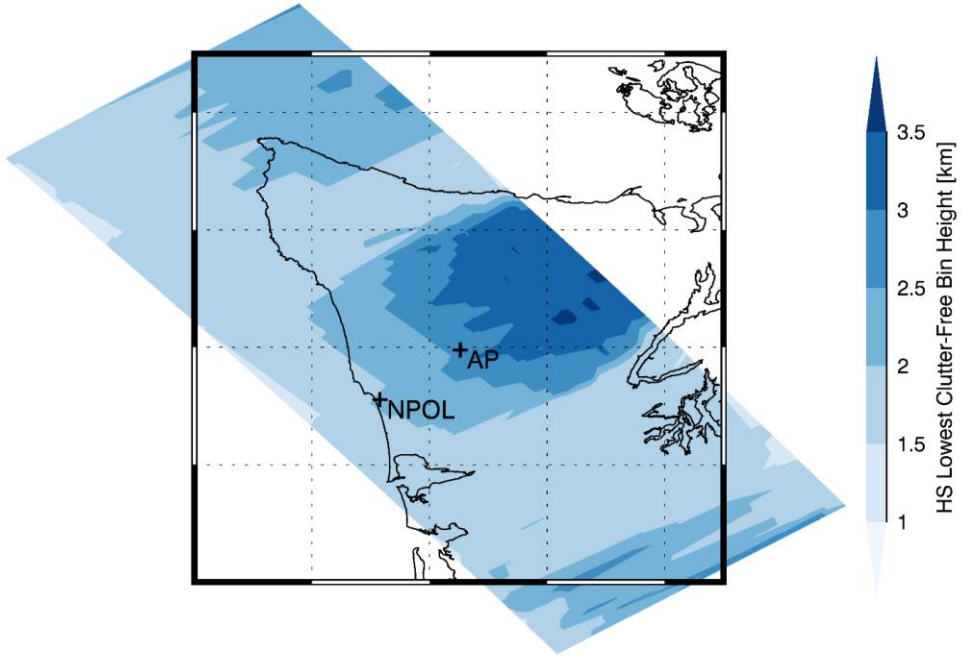


DPR HS Lowest Clutter-Free Bin Height:
~3+ km in highest terrain for this case

- DPR can not see the whole story!
- DPR scan along NPOL 50° azimuth
- NPOL RHI composite filled in below DPR



OLYMPEX – 17 November 2015



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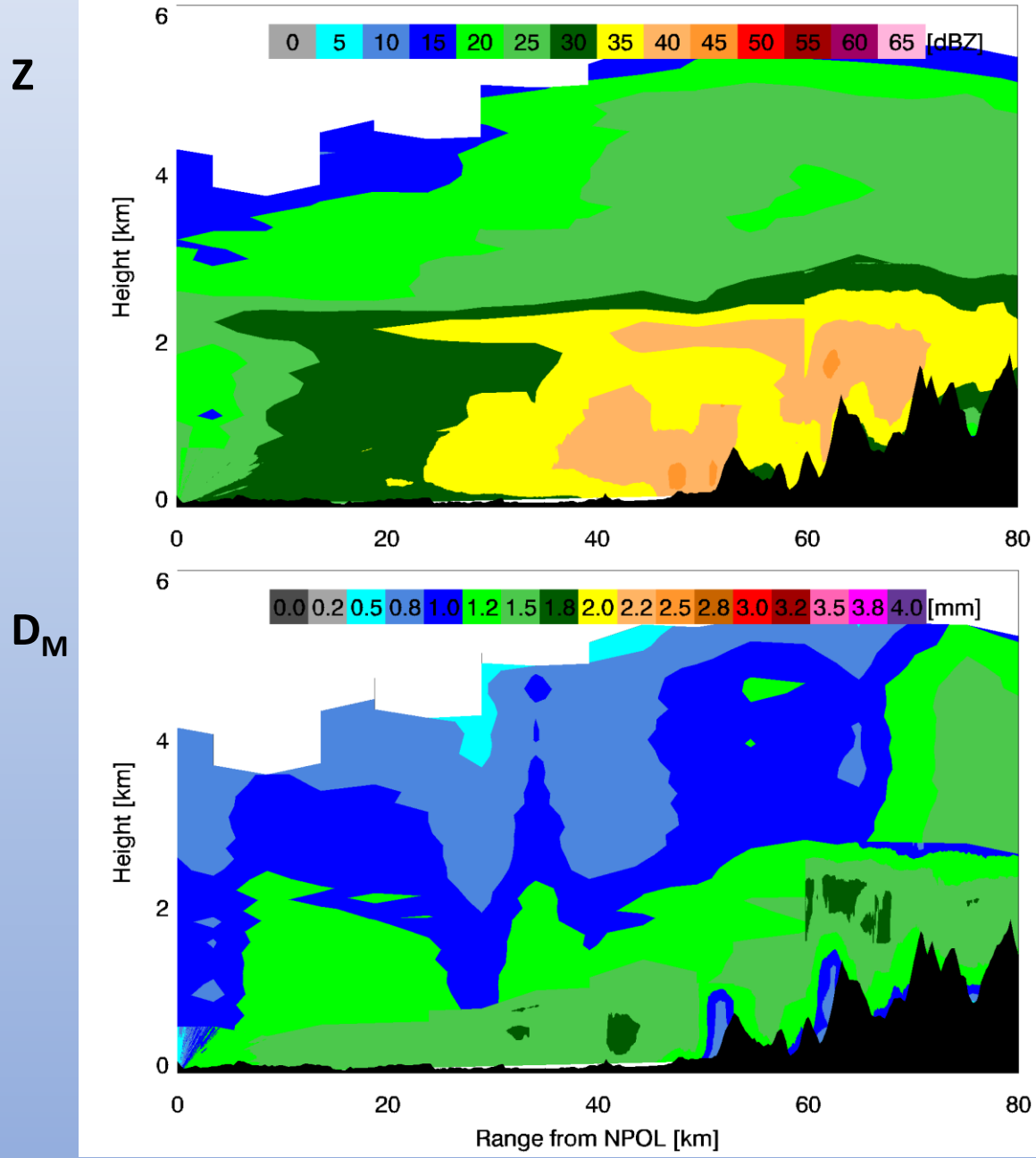
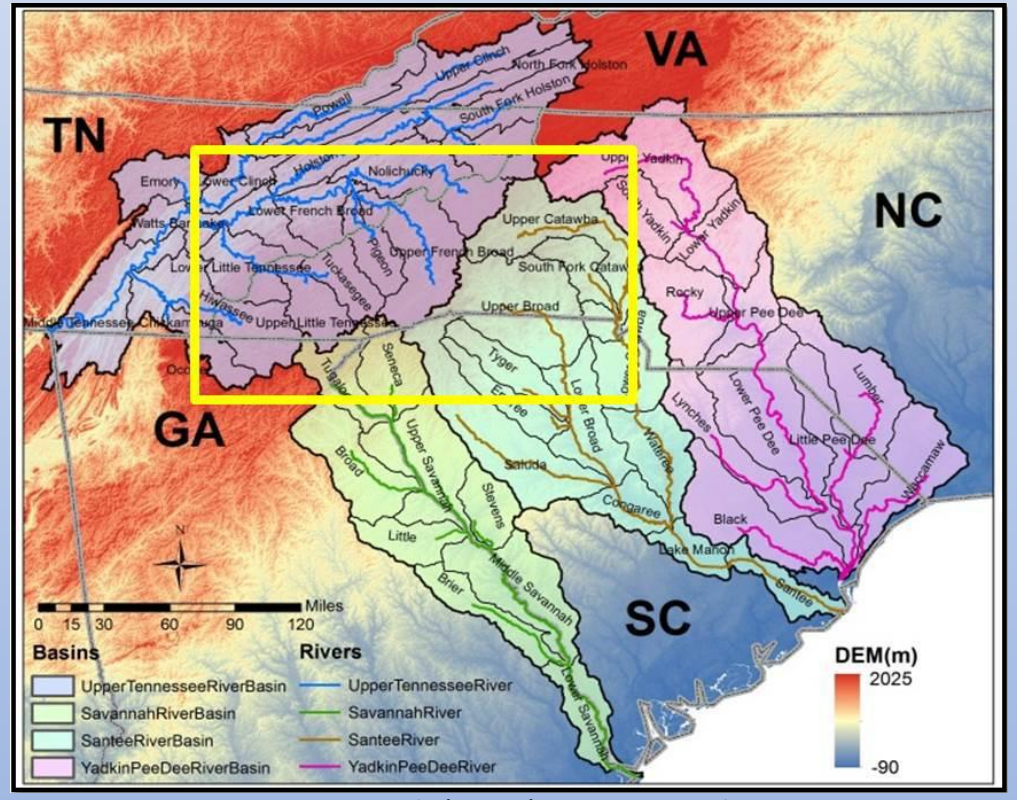


IPHEx Campaign: Spring/Summer 2014

- 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

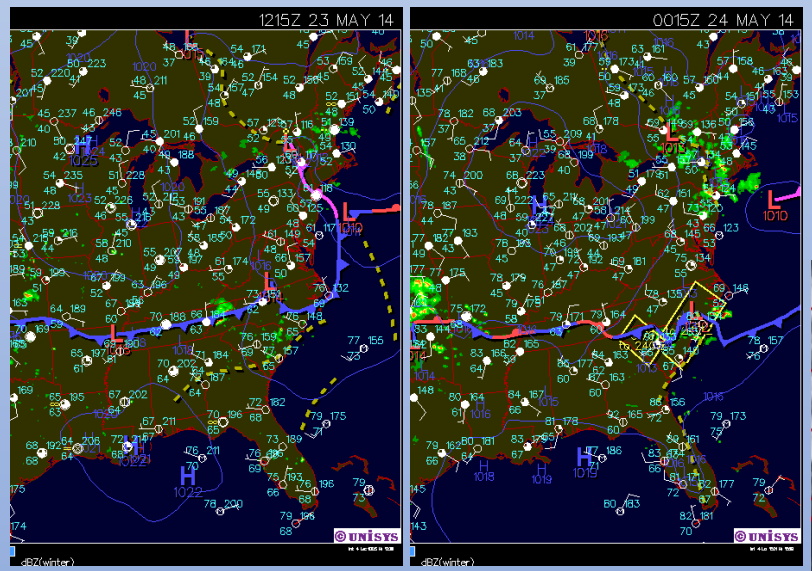


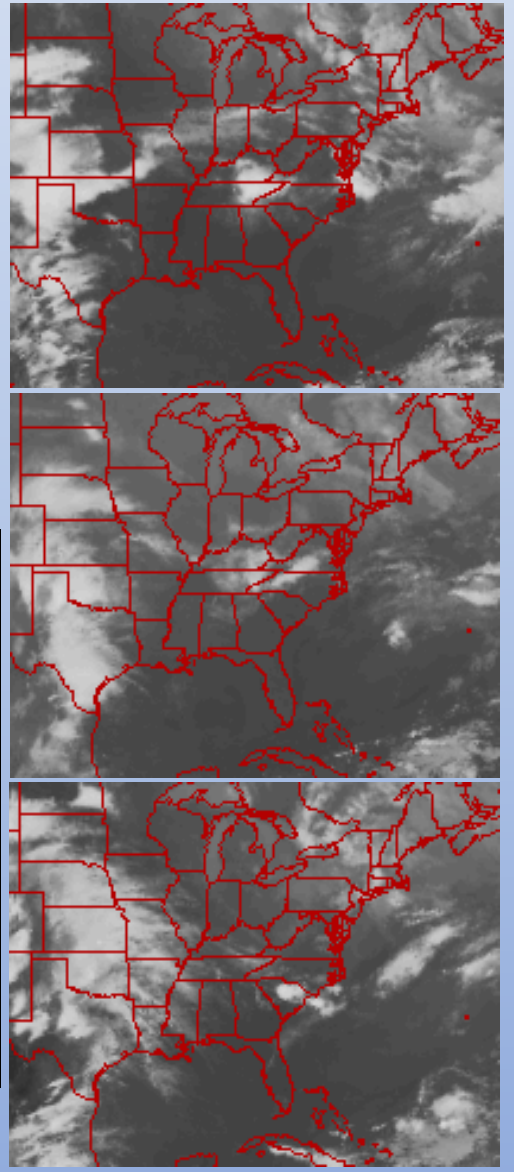
Barros et al. (2014), IPHEx Sci Plan

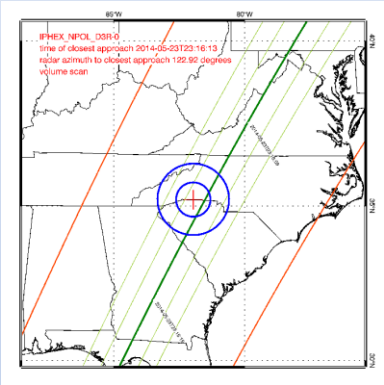
IPHEx GV focus domain (yellow) & river basins of interest

IPHEx – 23 May 2014

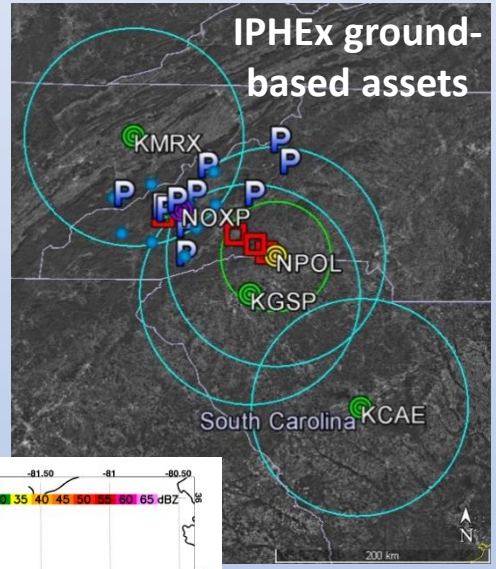
- GPM “Check-out” period
- Early: MCS off Appalachians
- Approaching cold front
- GPM DPR OP @ 2316
- Convection with 1-2 in hail in NPOL coverage; ER-2 coordination

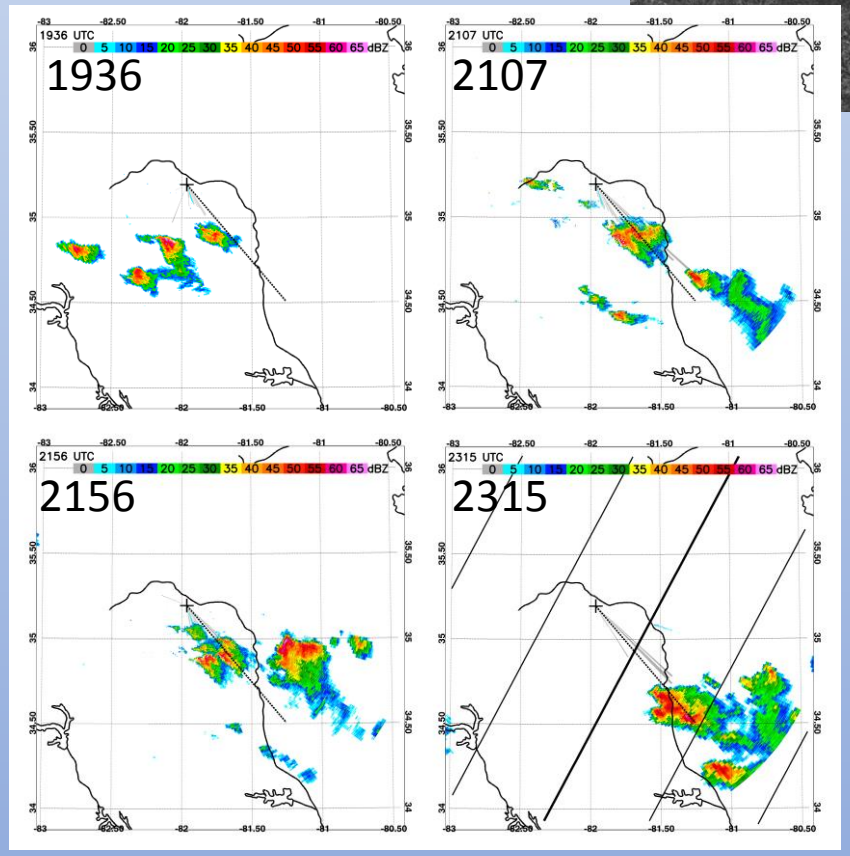






DPR & **GMI** swaths

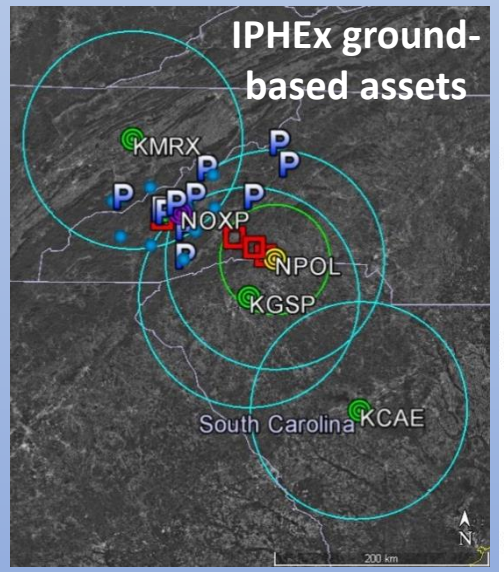


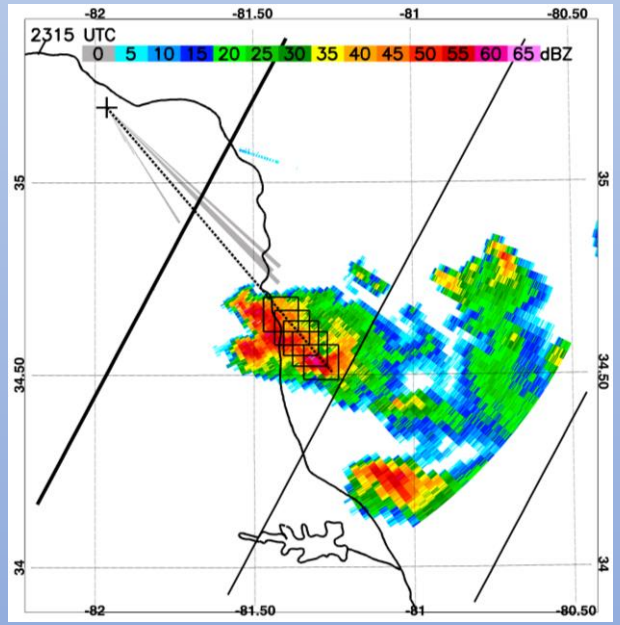


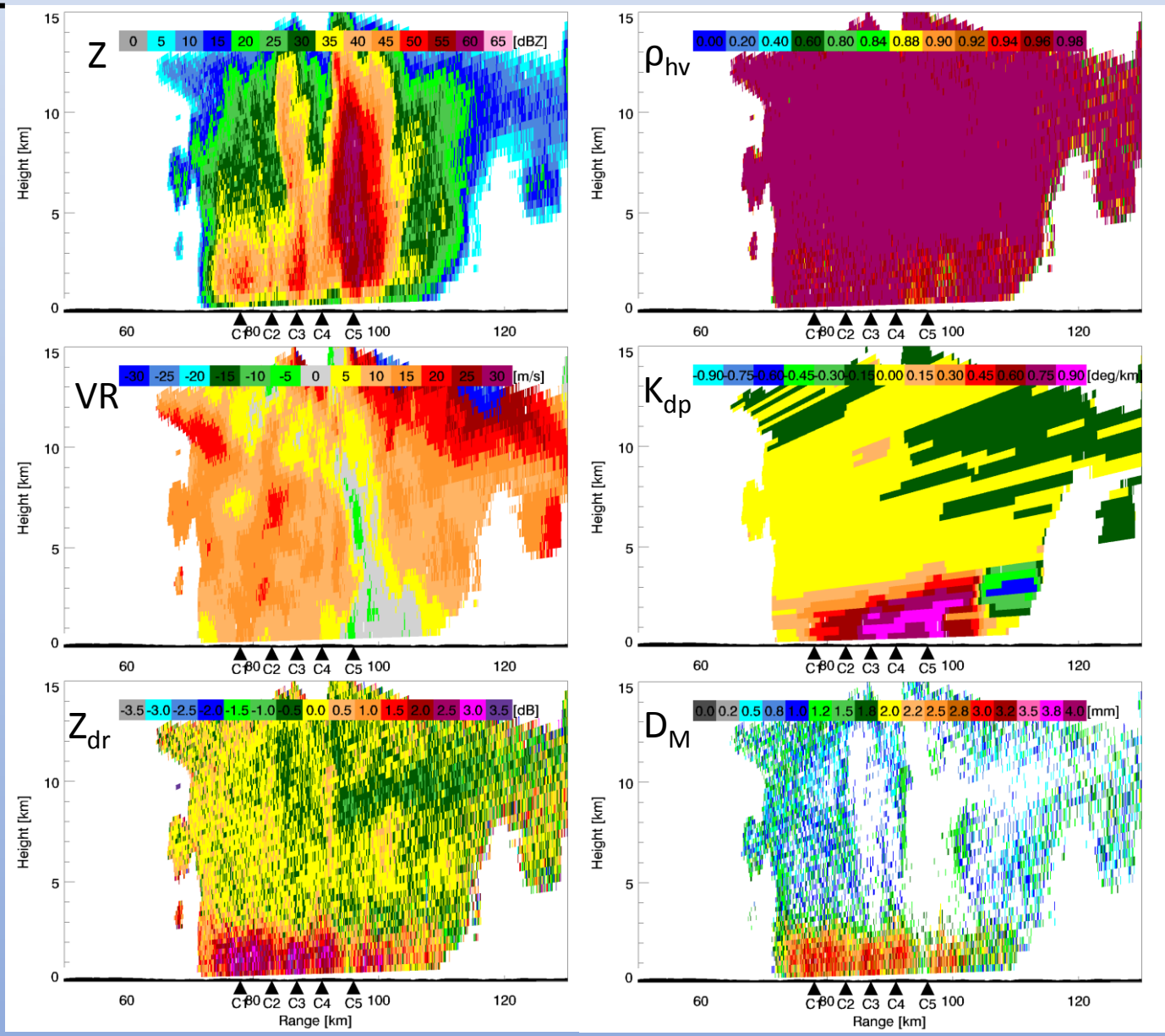
NPOL
1.5° Z

IPHEx – 23 May 2014

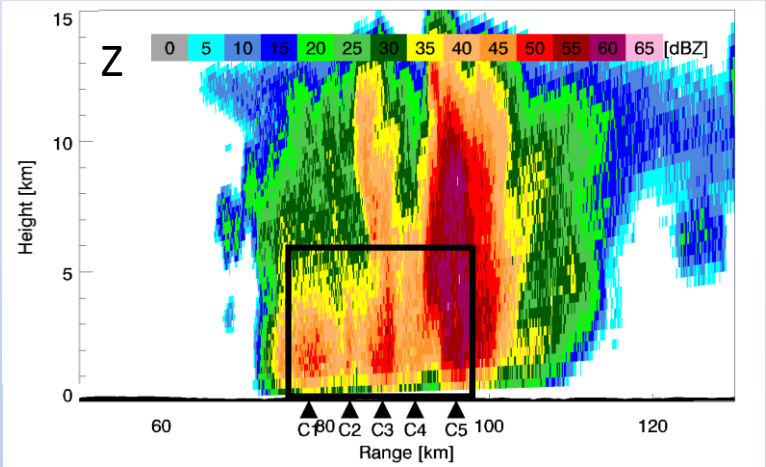
- GPM "Check-out" period
- Early: MCS off Appalachians
- Approaching cold front
- GPM DPR OP @ 2316
- Convection with 1-2 in hail in NPOL coverage; ER-2 coordination

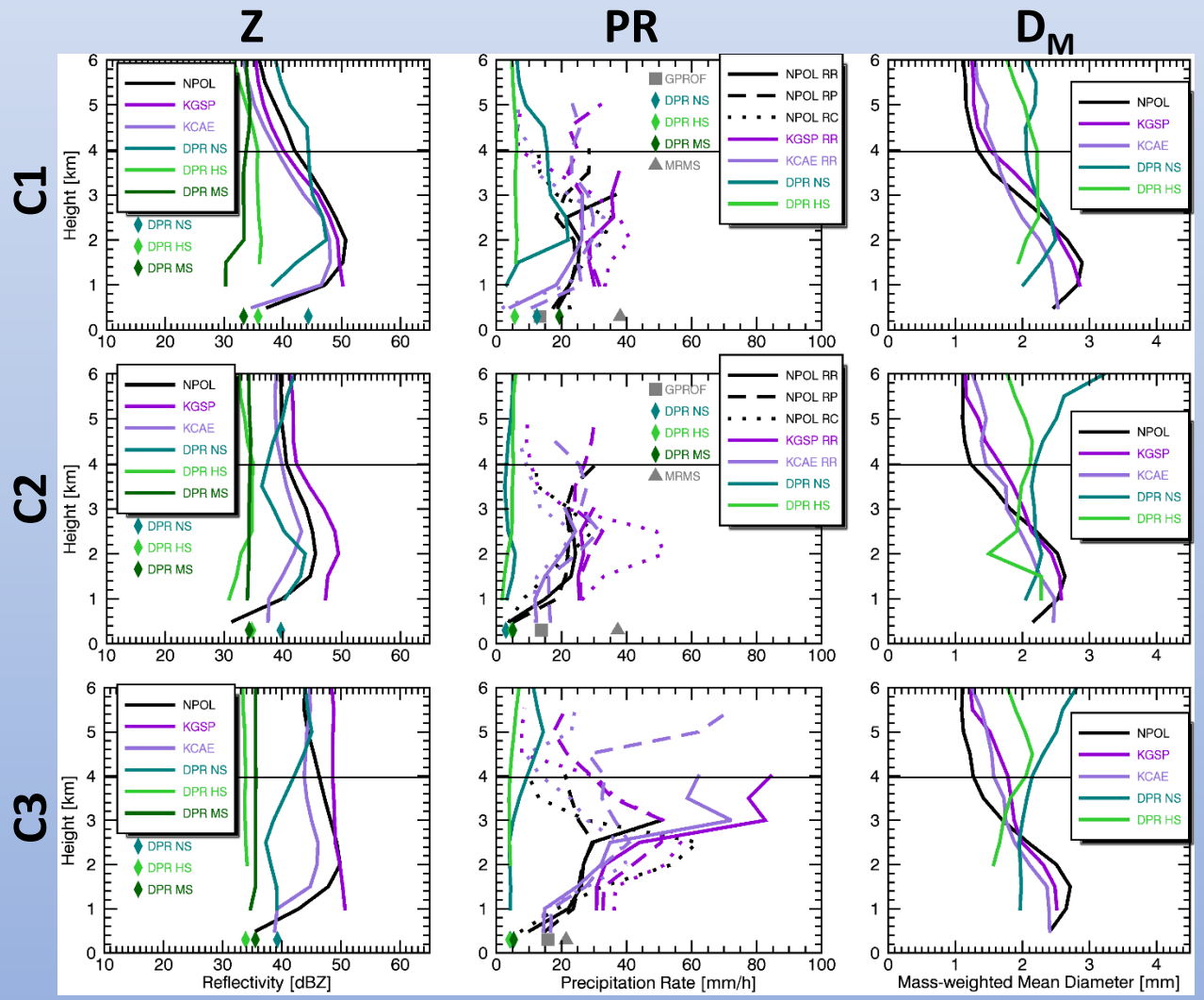


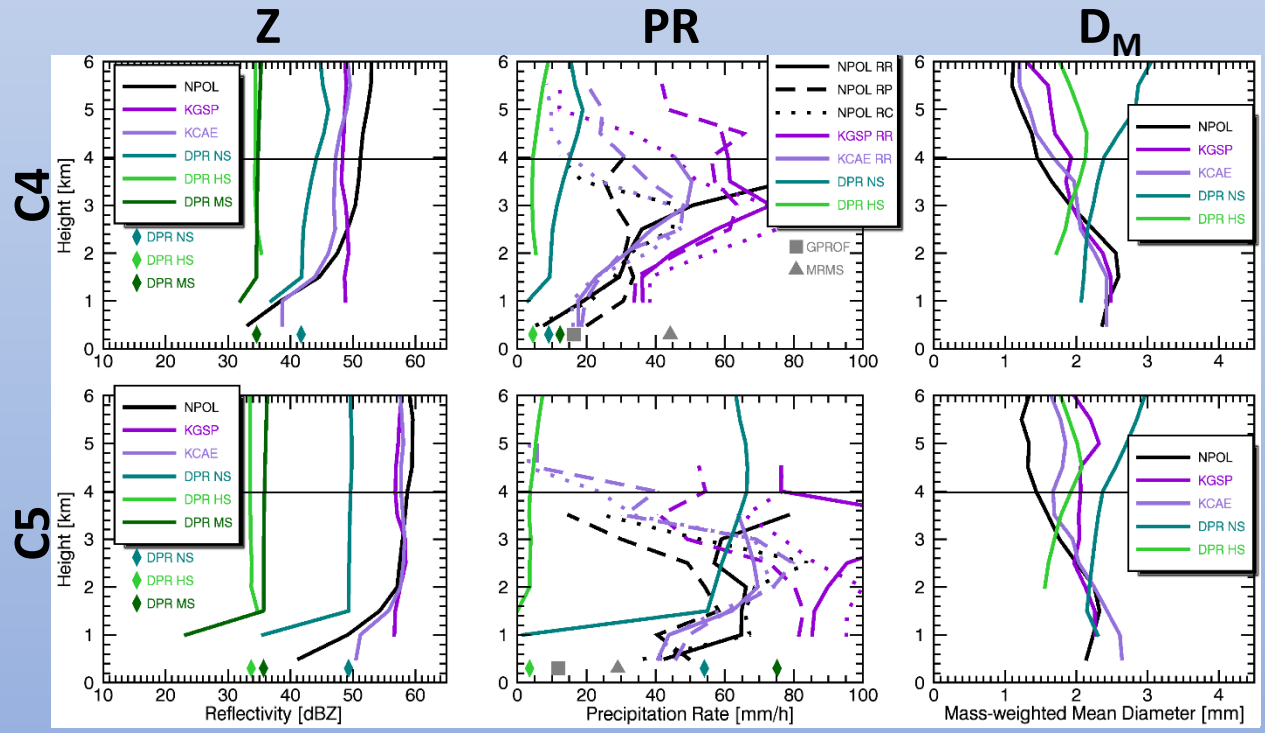




IPHEx – 23 May 2014



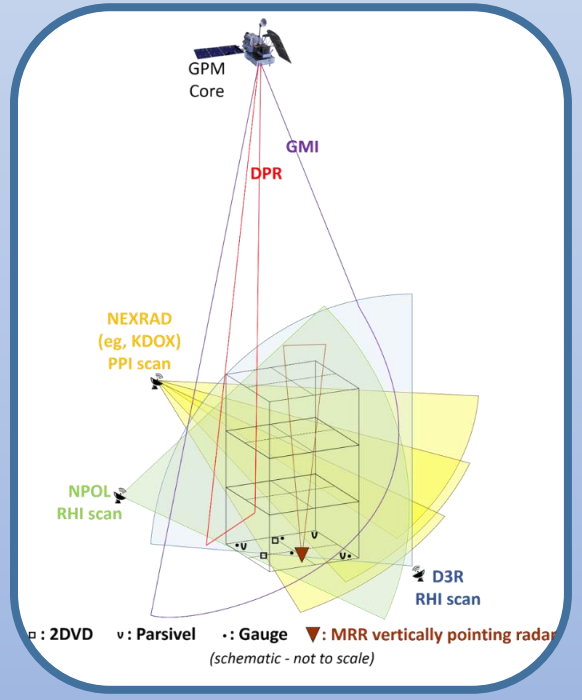




- DPR NS captures Z increase below 0°C better than HS, MS
- Satellite preip rates underestimate ground-based sensors
- Except in strongest Z core, satellite sfc precip rates underestimate MRMS
- DPR D_M behavior below 0°C better than OLYMPEX – less terrain

Summary & Continuing Work

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



OLYMPEX Cases:

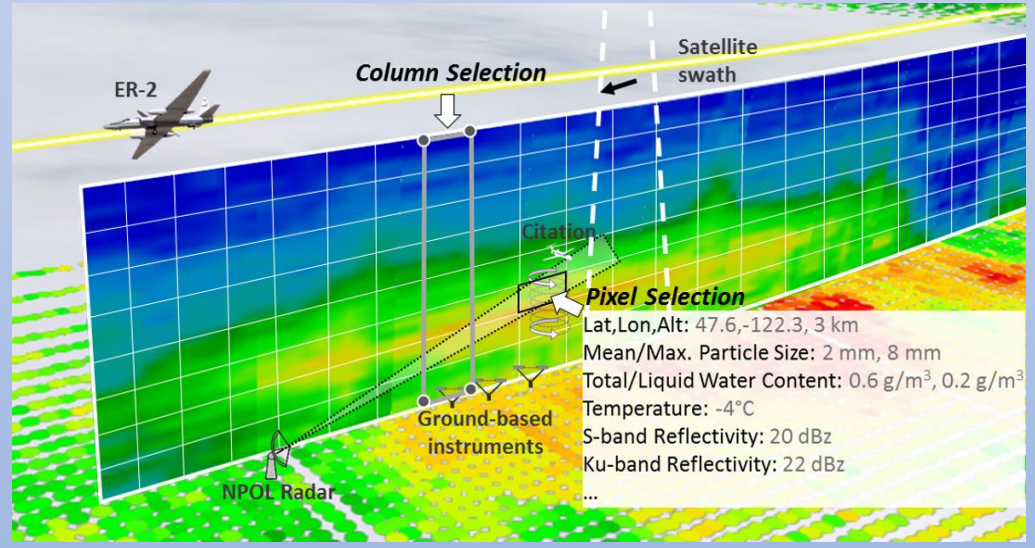
- Demonstrate concerns with DPR in regions of complex terrain
- D_M behavior below 0°C implies processes changes, dependent on orientation of cross-barrier flow

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/algorithm 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

This work is supported by an appointment to the NASA Postdoctoral Program at Marshall Space Flight Center, administered by Universities Space Research Association through a contract with NASA.