

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

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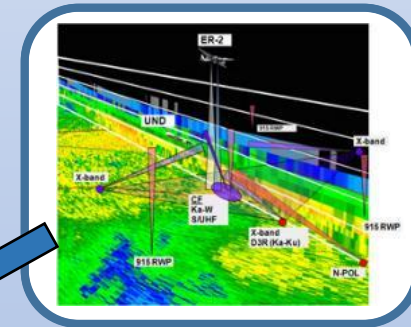
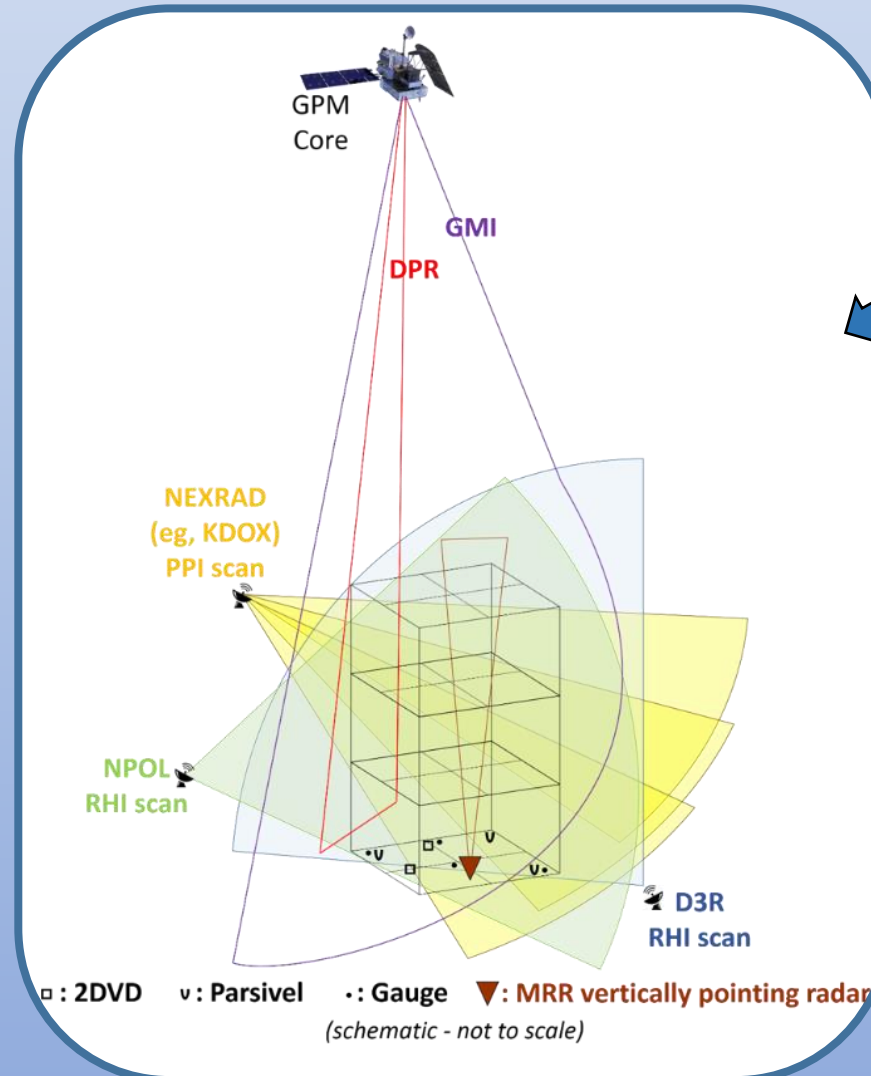
And Colleagues:

Jason Pippitt<sup>4</sup>, Ali Tokay<sup>5</sup>, Pierre Kirstetter<sup>6</sup>, Jianxin Wang<sup>4</sup>, V. Chandrasekar<sup>7</sup>, Shashank Joshil<sup>7</sup>

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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



Targeted observations collected in various formats & coordinate systems

# 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<sub>d</sub>, winds, LCL, LFC, EL, CAPE, CIN, TPW

## Satellite-based Sensors

- GPM GMI: L1C, L2AGPROF T<sub>B</sub>s & retrieved precip
- GPM DPR: 2ADPR
- Ka/Ku-band obs & retrievals
- FOV locations

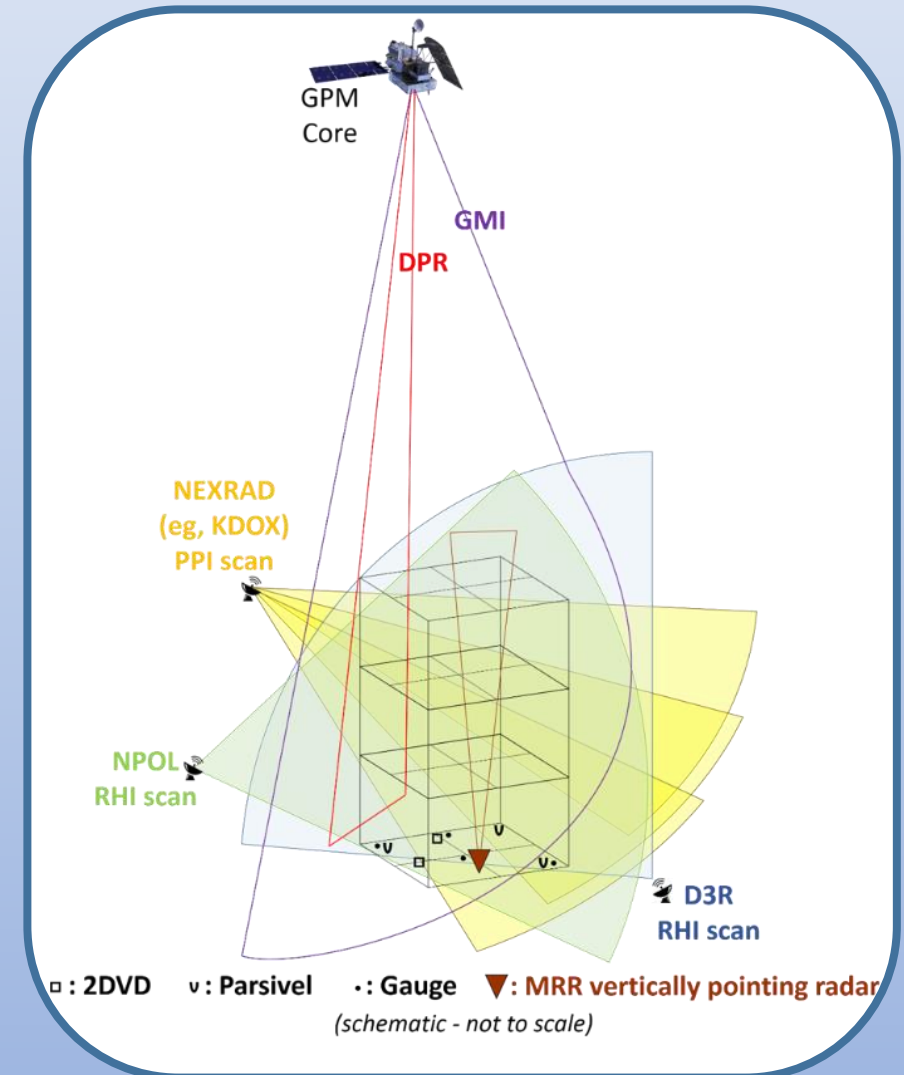
## Ground, Point Observations

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

## MRMS QPE Product

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

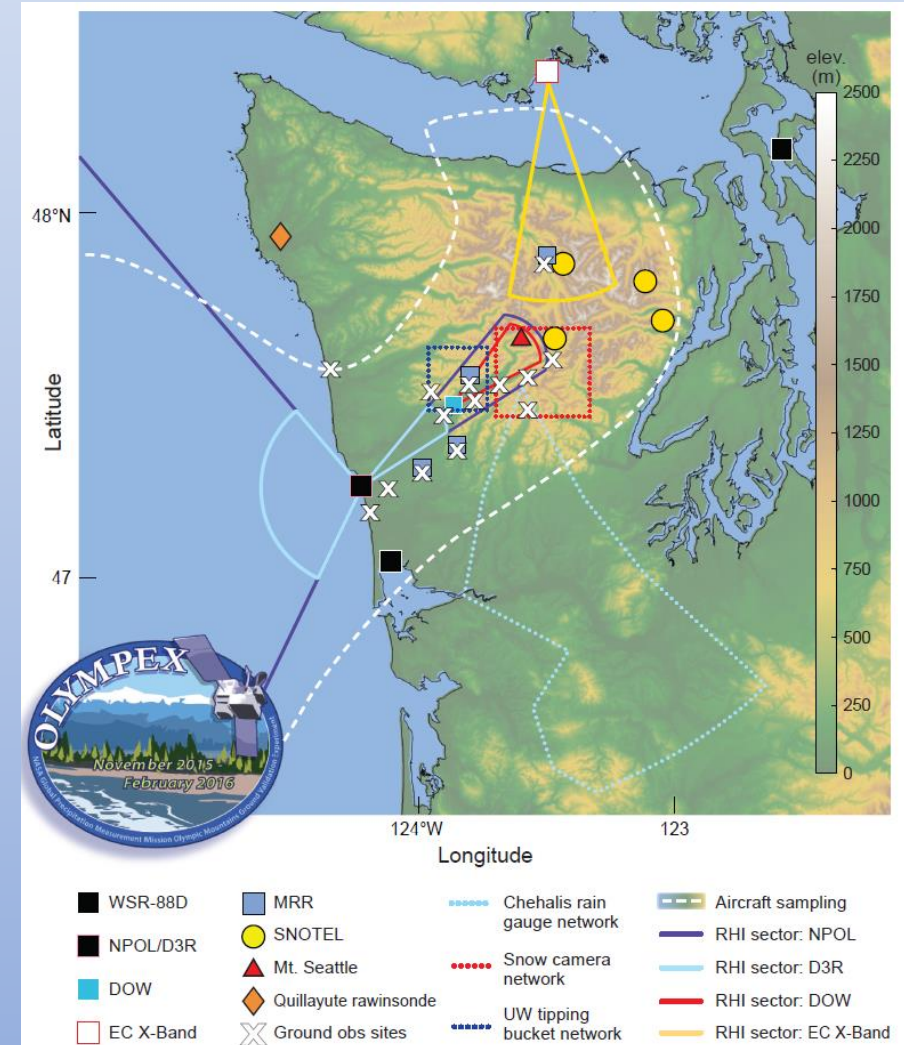
- Coincident data set into the requested column grid
- **Attributes maintain:** column grid set up, exact/original platform locations, modes, timestamps, algorithms, product versions, etc
- Inventory utility



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

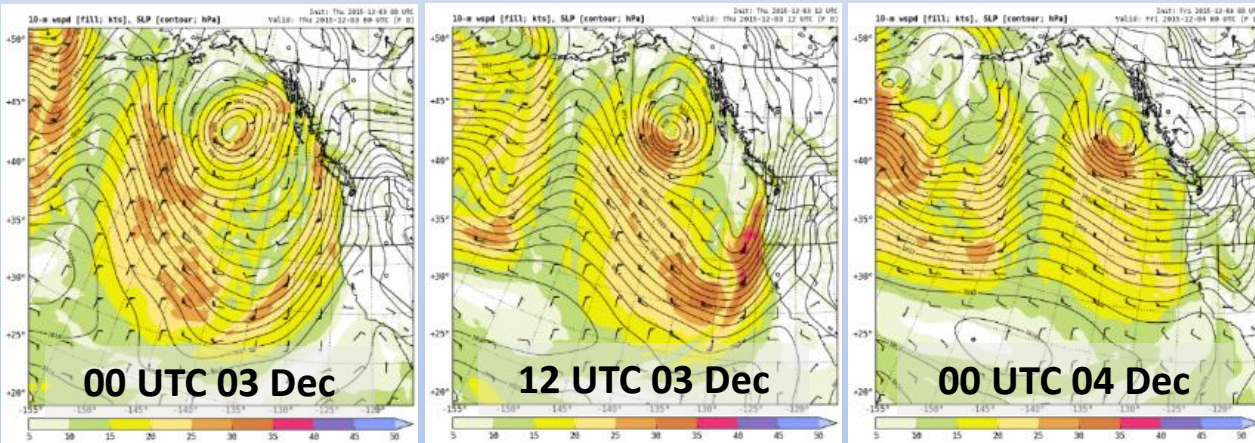
# OLYMPEX Campaign: Winter 2015-2016

- 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: 2<sup>nd</sup> post-launch campaign for GPM Core Observatory

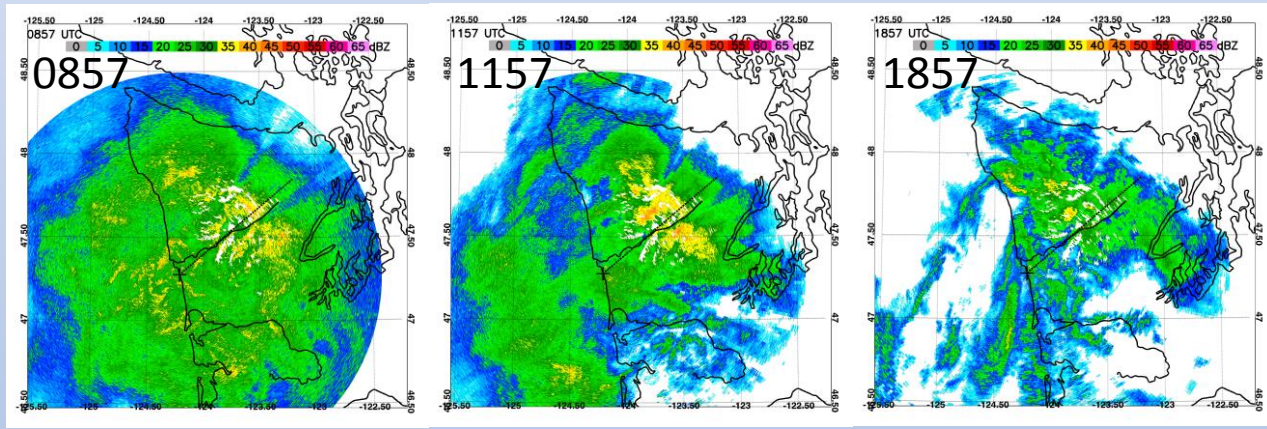


Houze et al. (2017)

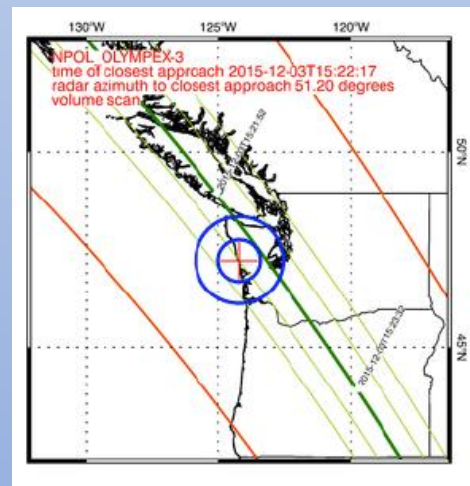
# OLYMPEX – 3 December 2015



UW WRF+GFS Analyses: 10 m winds & SLP



NPOL 1.5° Z

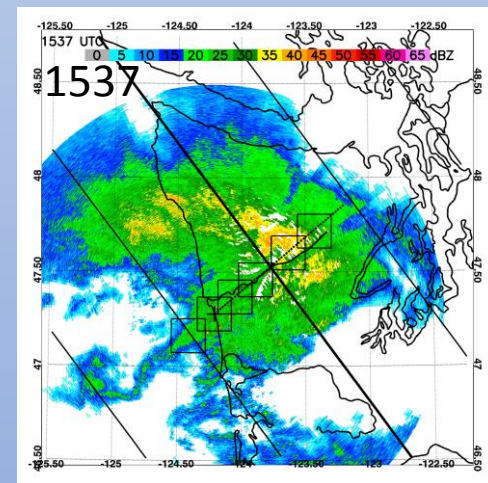


DPR & GMI swaths



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) Ocean

- Elev: 0 m
- KLGX, NPOL, D3R

### 2) NPOL

- Elev: 157 m
- KLGX, NPOL, D3R
- APUs, tip gauges

### 3) Midpoint (N-AP)

- Elev: 40 m
- KLGX, NPOL, D3R, 1 MRR
- APU, 2DVD, tipping bucket gauges

All Columns:  
20 x 20 x 6 km  
500 m spacing

### 4) Amanda Park

- Elev: 63 m
- KLGX, NPOL, D3R, DOW6, 2 MRRs
- APUs, 2DVDs, Pluvio, tipping bucket gauges

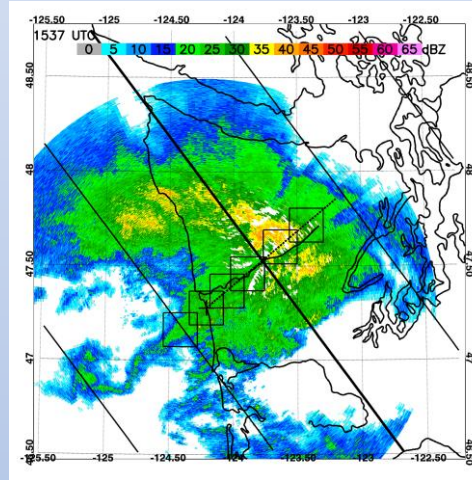
### 5) Grave's Creek

- Elev: 358 m
- KLGX, NPOL, DOW6
- APUs

### 6) Upper East Fork

- Elev: 1120 m
- KLGX, NPOL, DOW6
- Pluvio gauge

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

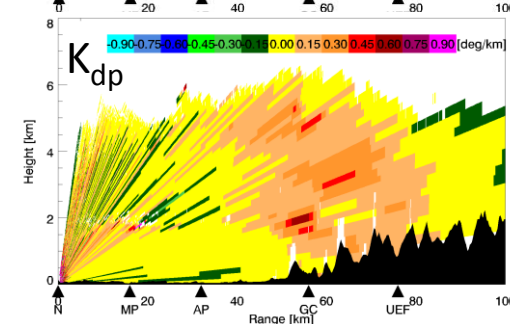
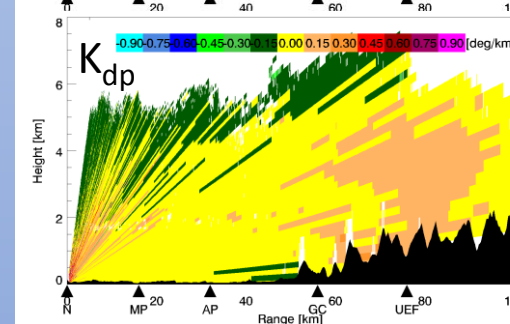
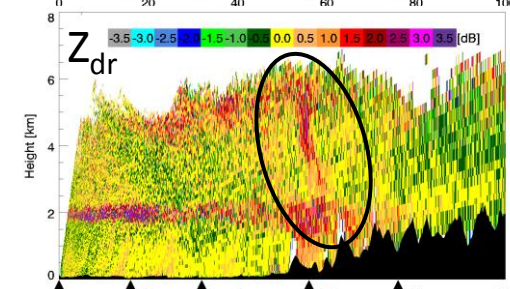
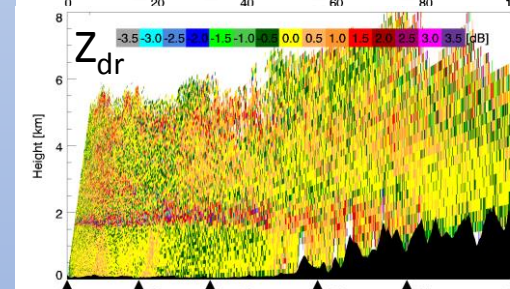
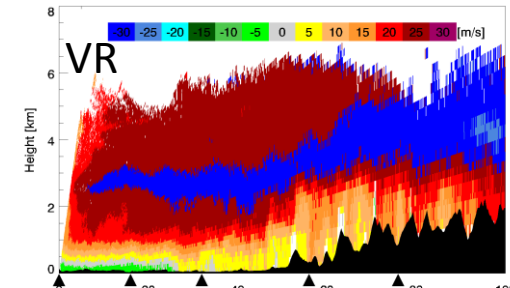
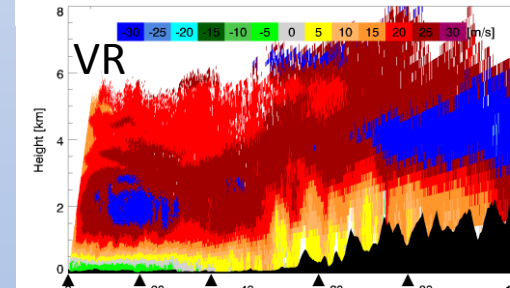
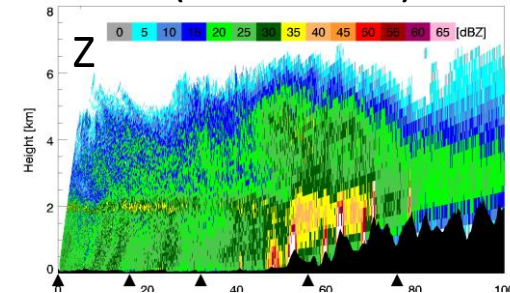
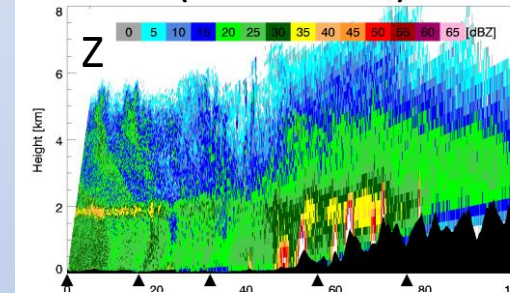


## RHIs Reveal Structure:

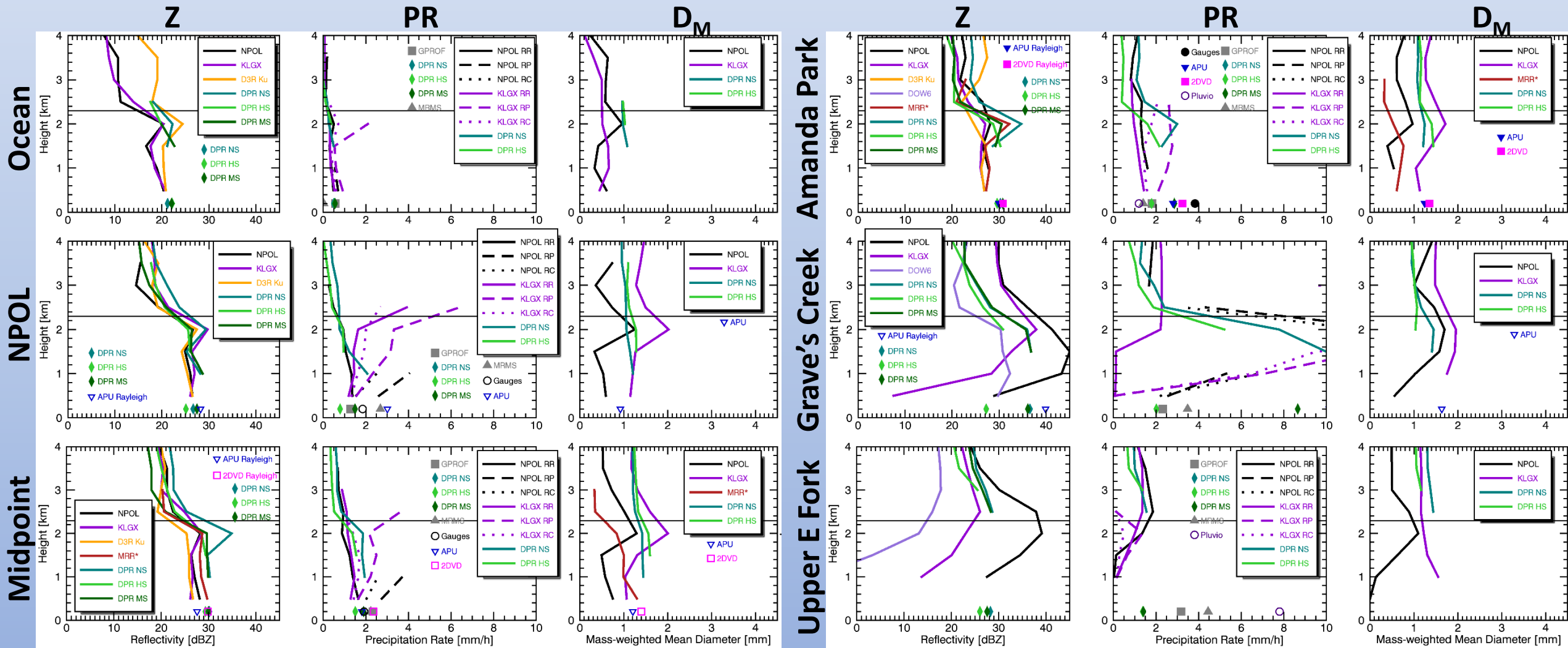
- Fallstreaks below brightband
- Upward VR shift over terrain; enhancement in Z,  $Z_{dr}$ ,  $K_{dp}$  (e.g., Kingsmill et al. 2006, Medina et al. 2007, Kennedy and Rutledge 2011)
- Transient vertical  $Z_{dr}$  feature, max  $K_{dp}$  at base – but near 0°C (Tromel et al. 2013)

(OP-10 min)

(OP+10 min)



# OLYMPEX – 3 December 2015

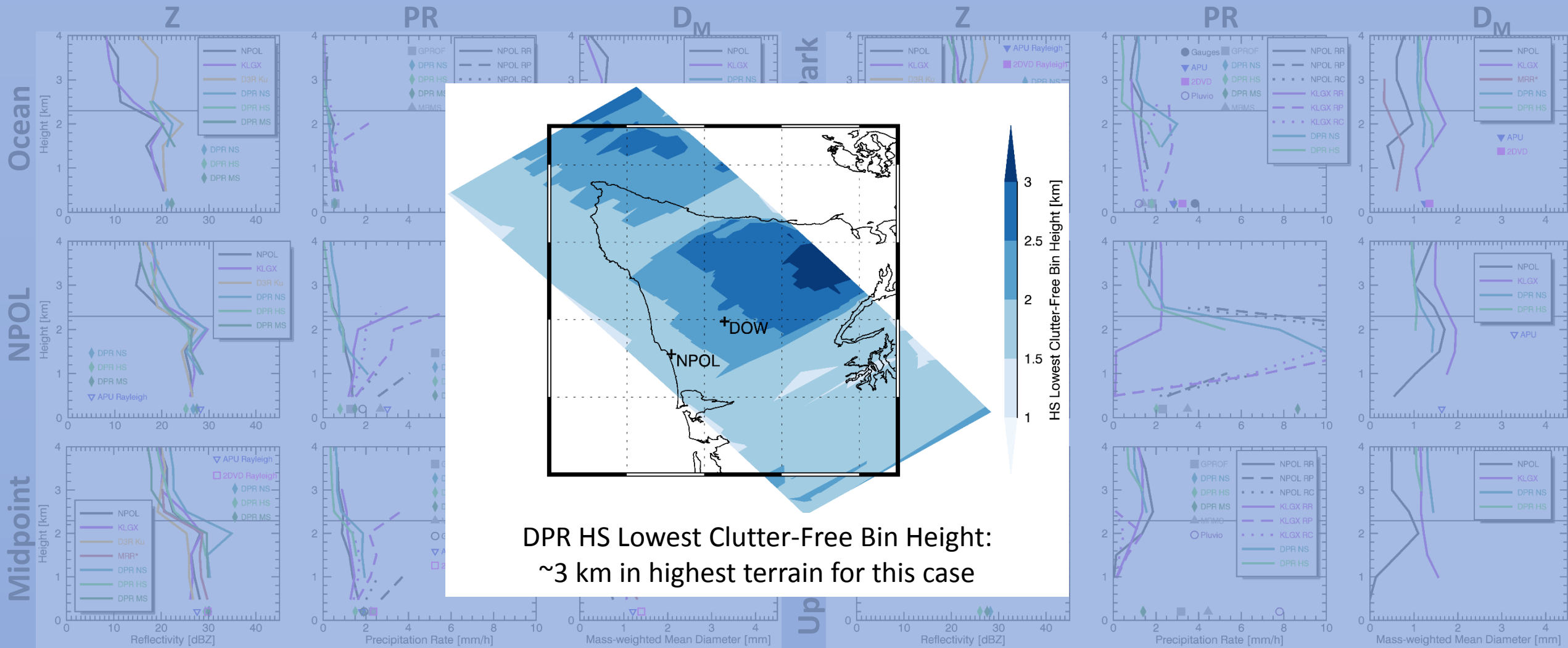


- DPR misses  $D_M$  behavior below  $0^\circ\text{C}$  level: Decrease then grow; only decreases in higher terrain – **SW flow...**

- Precip rates: at modest elevation sites, GPROF & DPR PRs vs. sfc-based data **w/in  $\sim 3 \text{ mm/h}$**

- Higher Terrain: More variability; **DPR limited** - at worst no gates below  $0^\circ\text{C}$  level

# OLYMPEX – 3 December 2015

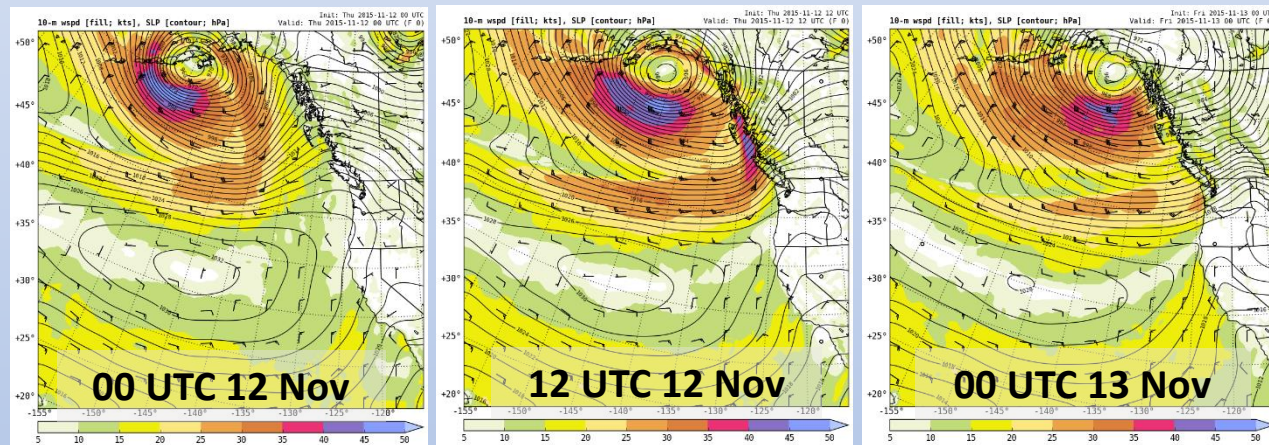


DPR HS Lowest Clutter-Free Bin Height:  
~3 km in highest terrain for this case

- DPR misses  $D_M$  behavior below  $0^\circ\text{C}$  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  $\sim 3 \text{ mm/h}$
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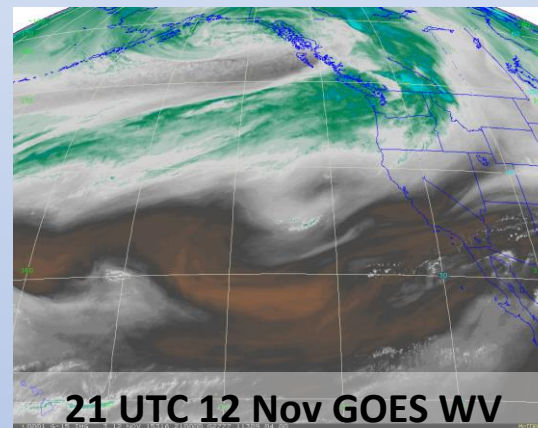
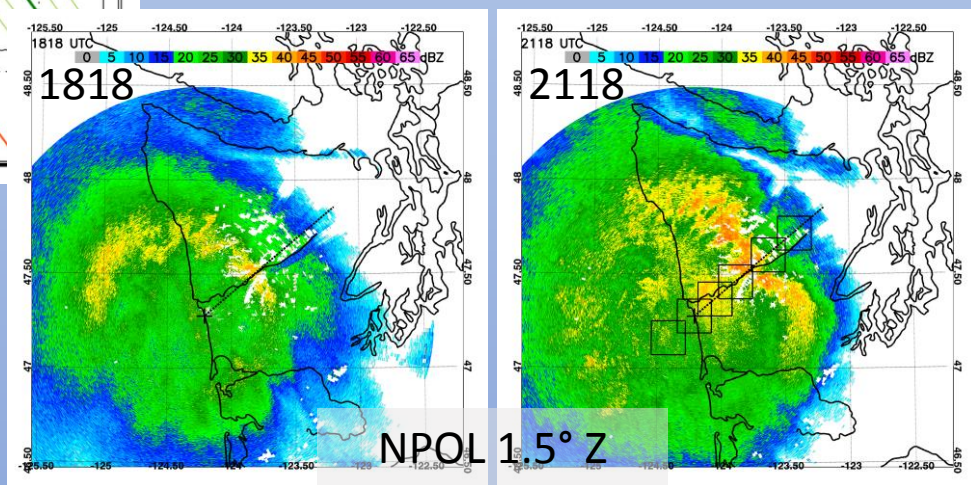
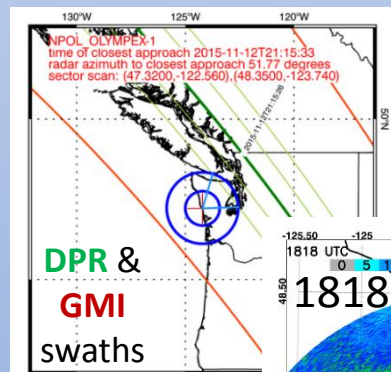


# OLYMPEX – 12 November 2015



UW WRF+GFS Analyses: 10 m winds & SLP

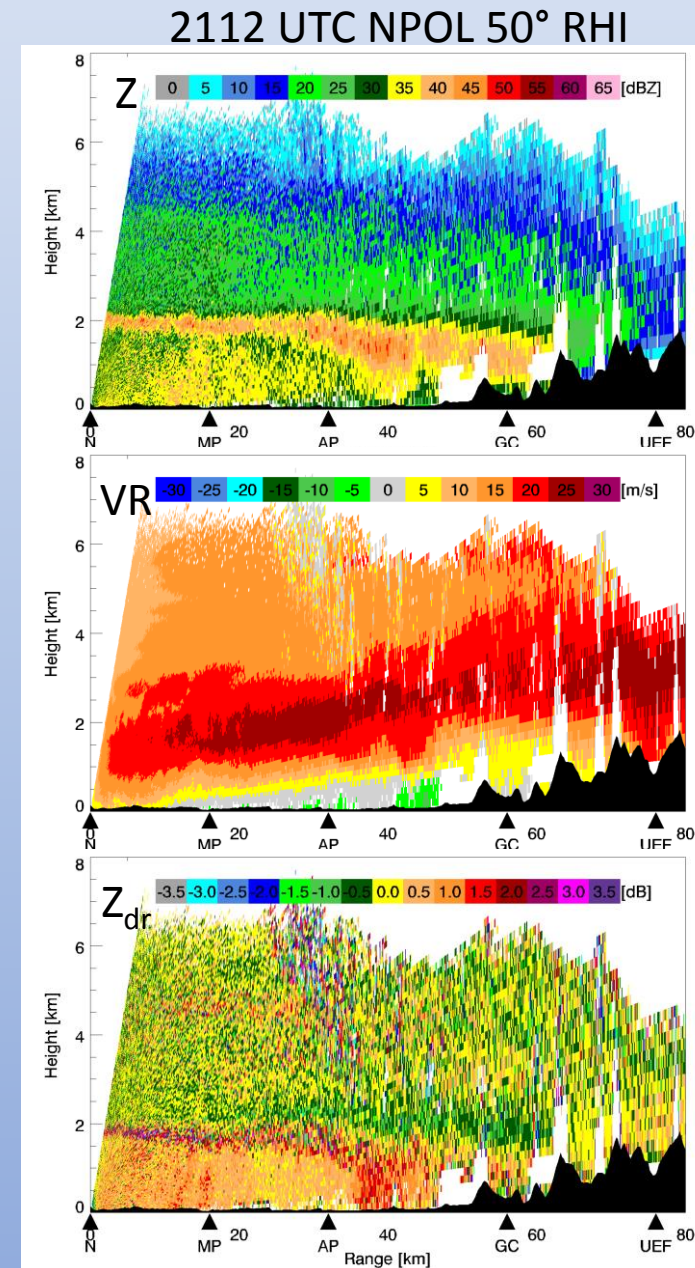
- Atmospheric river event
- Domain in warm sector
- Southwesterly flow



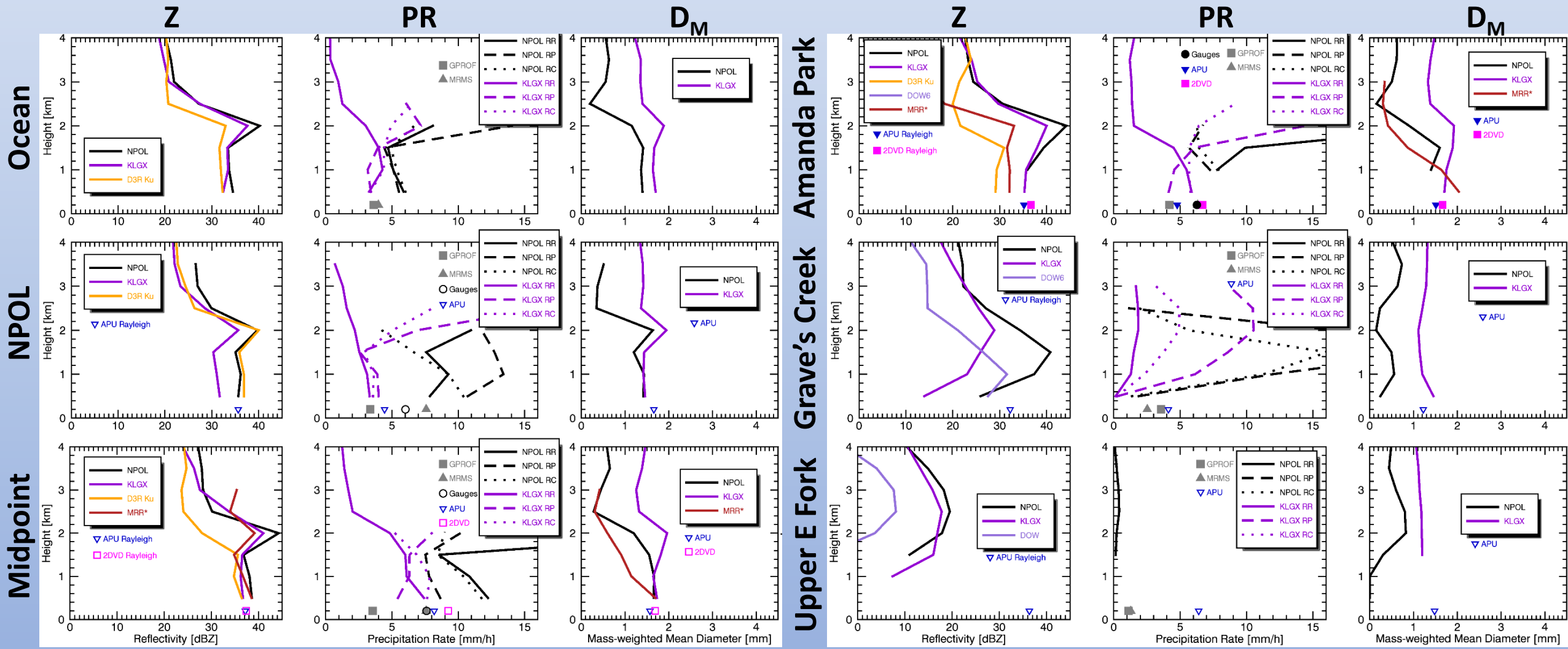
- GPM GMI OP @ 2115
- Up to 60 mm/24 h in QRV
- Leeward rain shadow

NPOL RHIs:

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



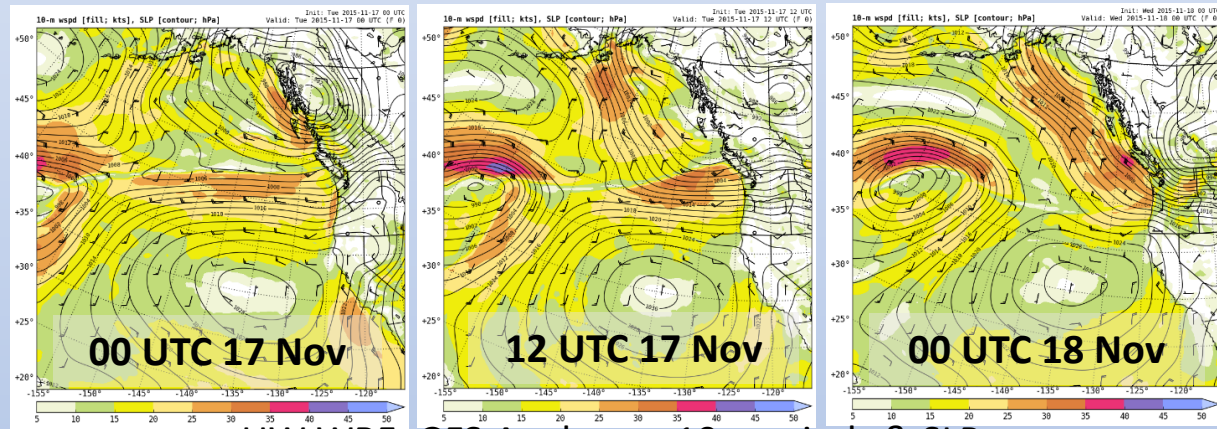
# OLYMPEX – 12 November 2015



Amanda Park  
Grave's Creek  
Upper E Fork

- 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

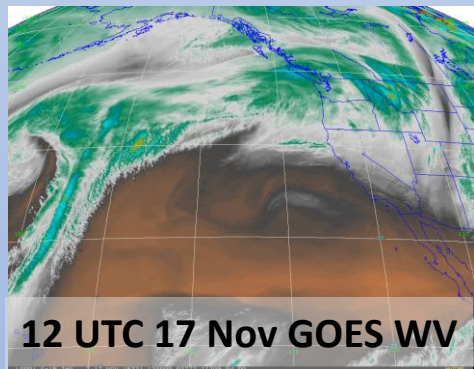
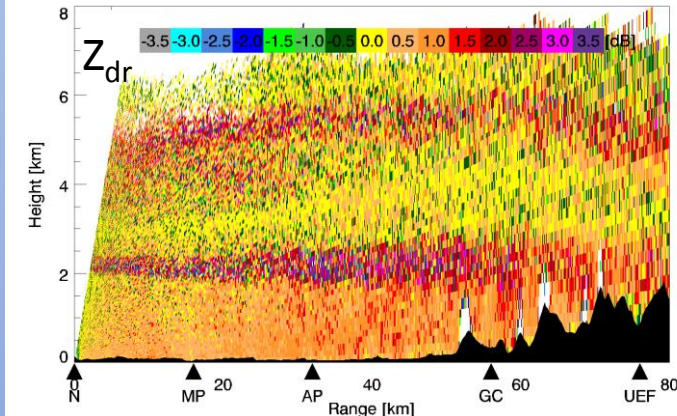
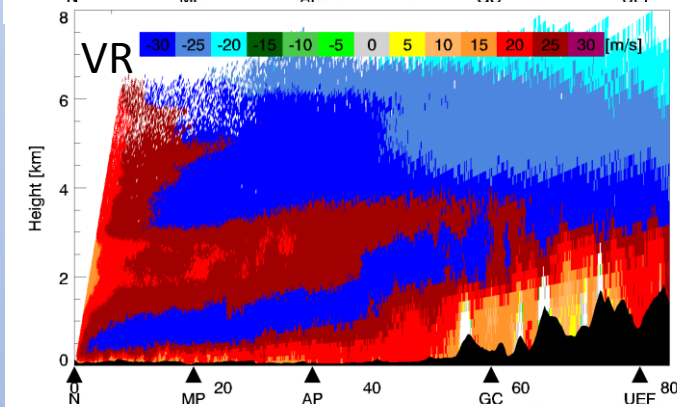
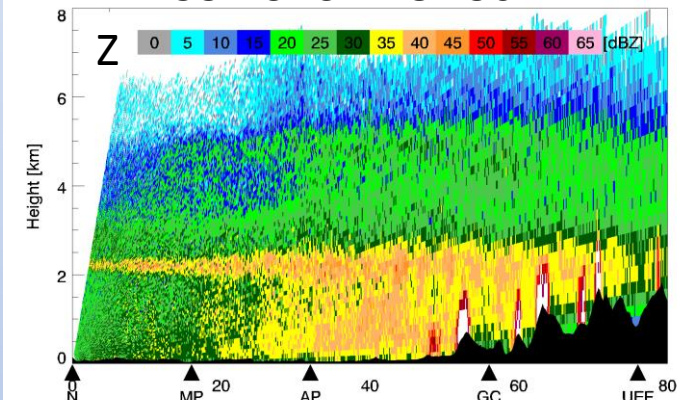
- Atmospheric river event
- Westerly flow
- Prominent stratiform, some embedded cells
- 200 mm + /24 h in QRV (up to 60 mm leeward)
- GPM GMI OP @ 2001

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

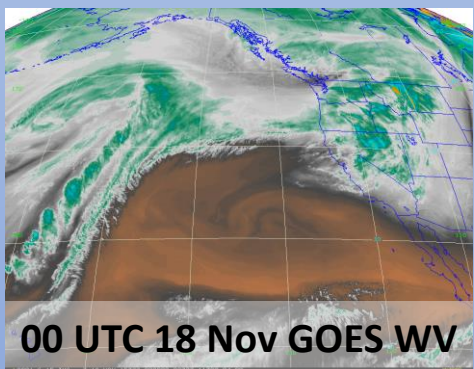
## NPOL RHIs:

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

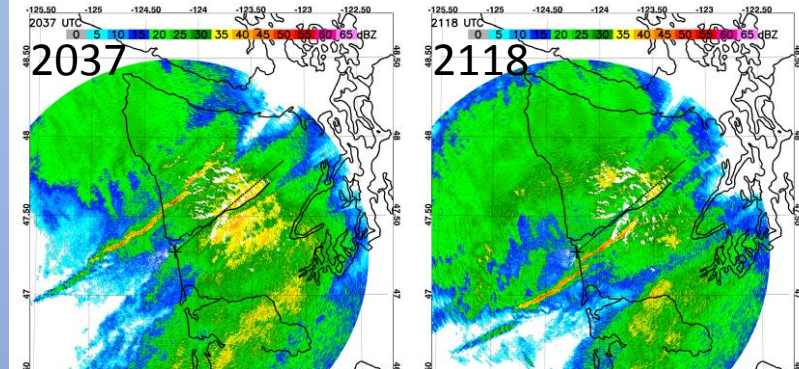
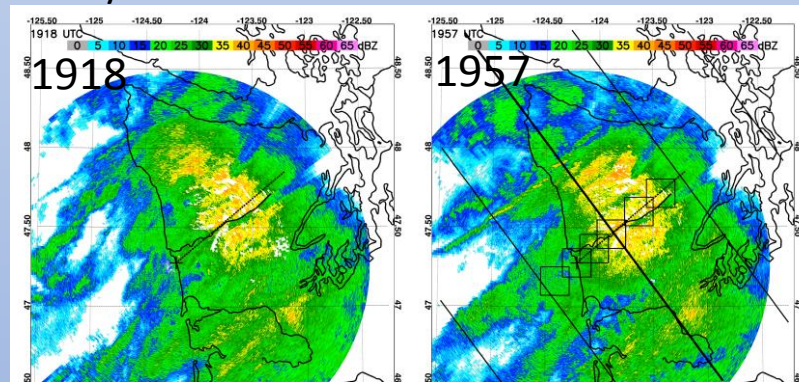
1952 UTC NPOL 50° RHI



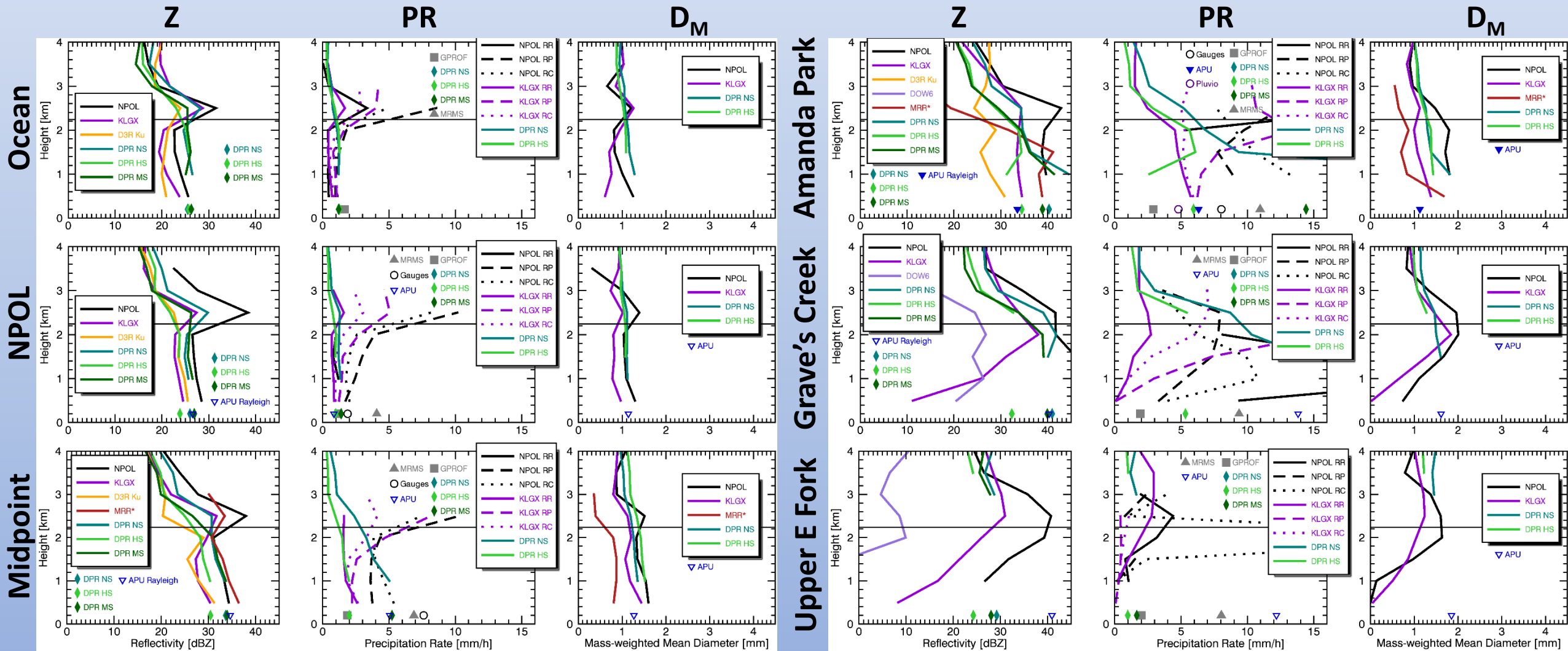
12 UTC 17 Nov GOES WV



00 UTC 18 Nov GOES WV



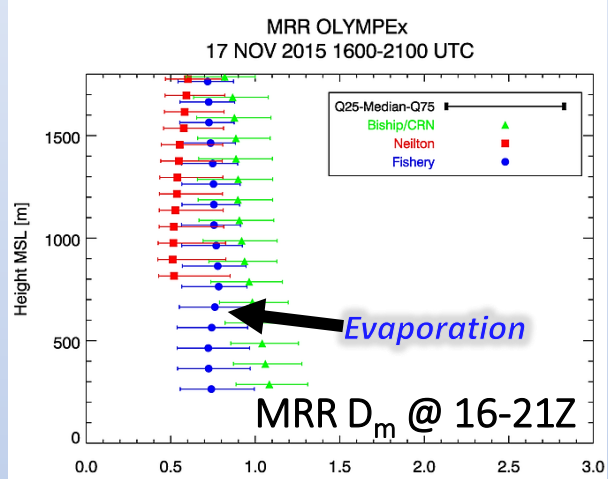
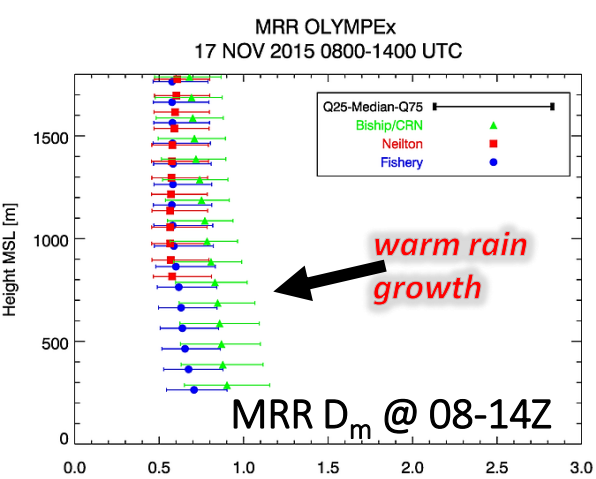
# OLYMPEX – 17 November 2015



- 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

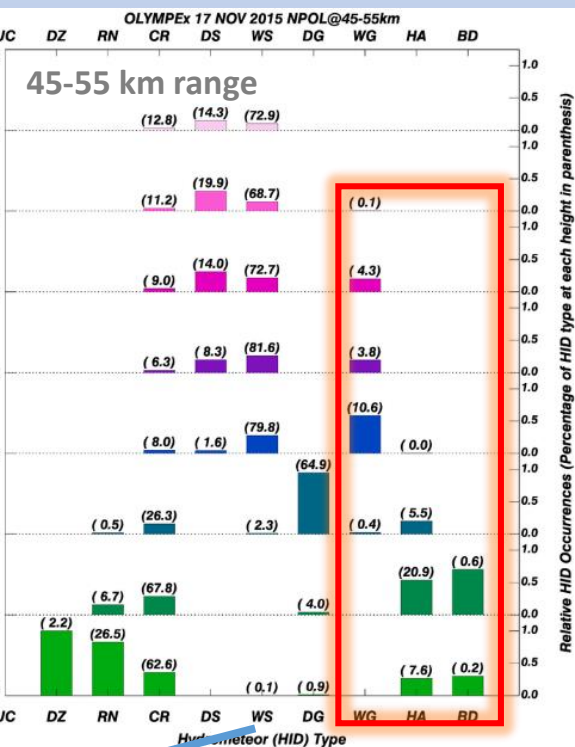
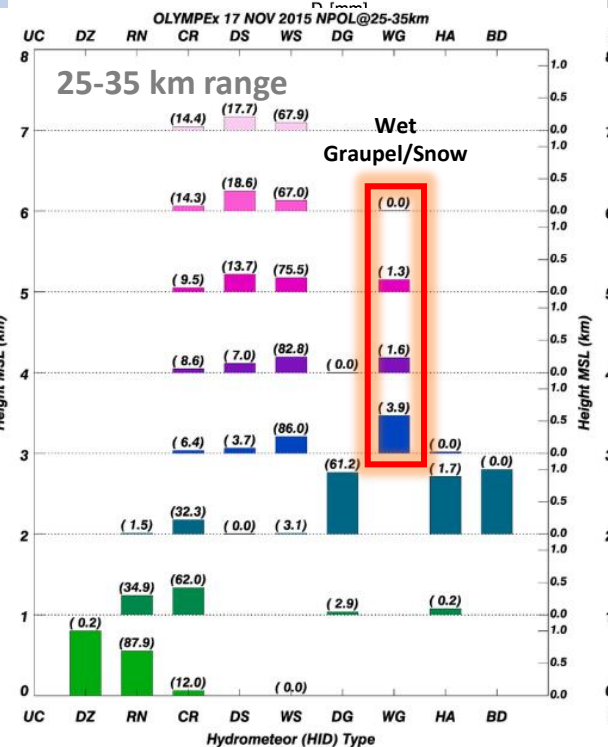
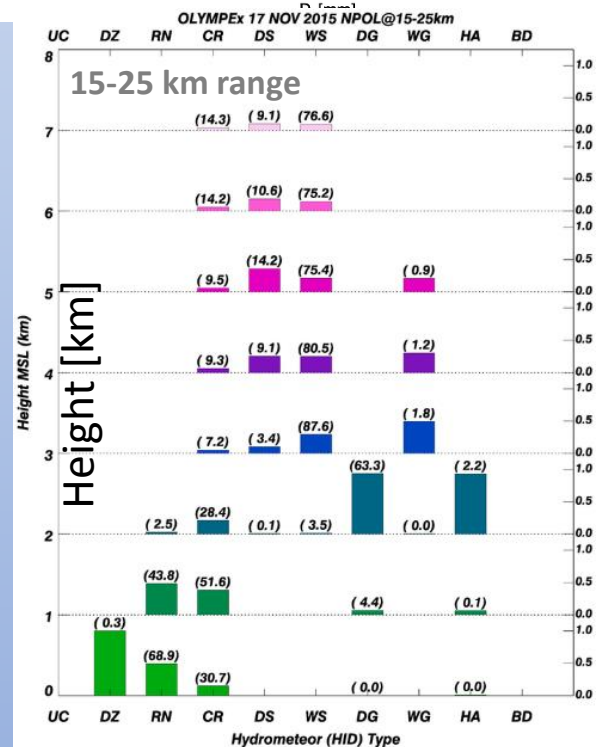
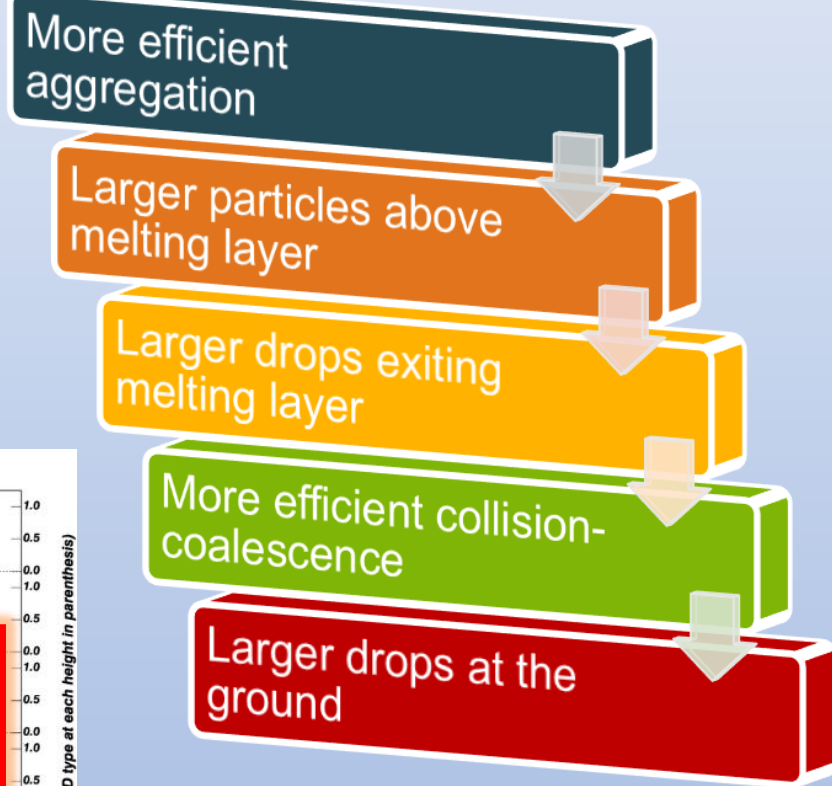
- $D_M$  increases toward ground (*westerly flow*) – except at highest elevation sites



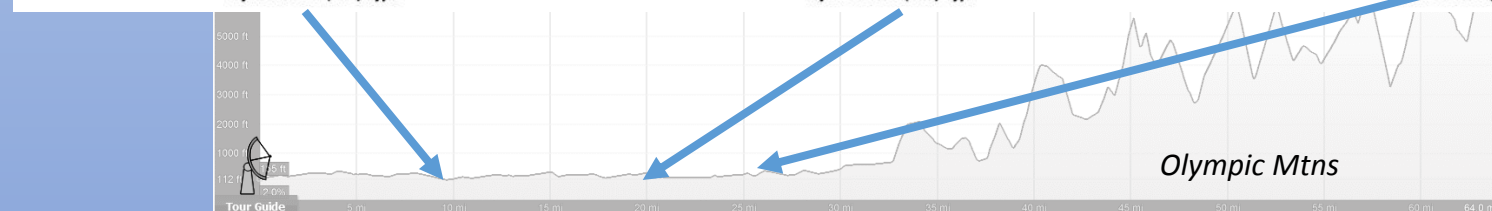
# 17 Nov 2015

As approach terrain:

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

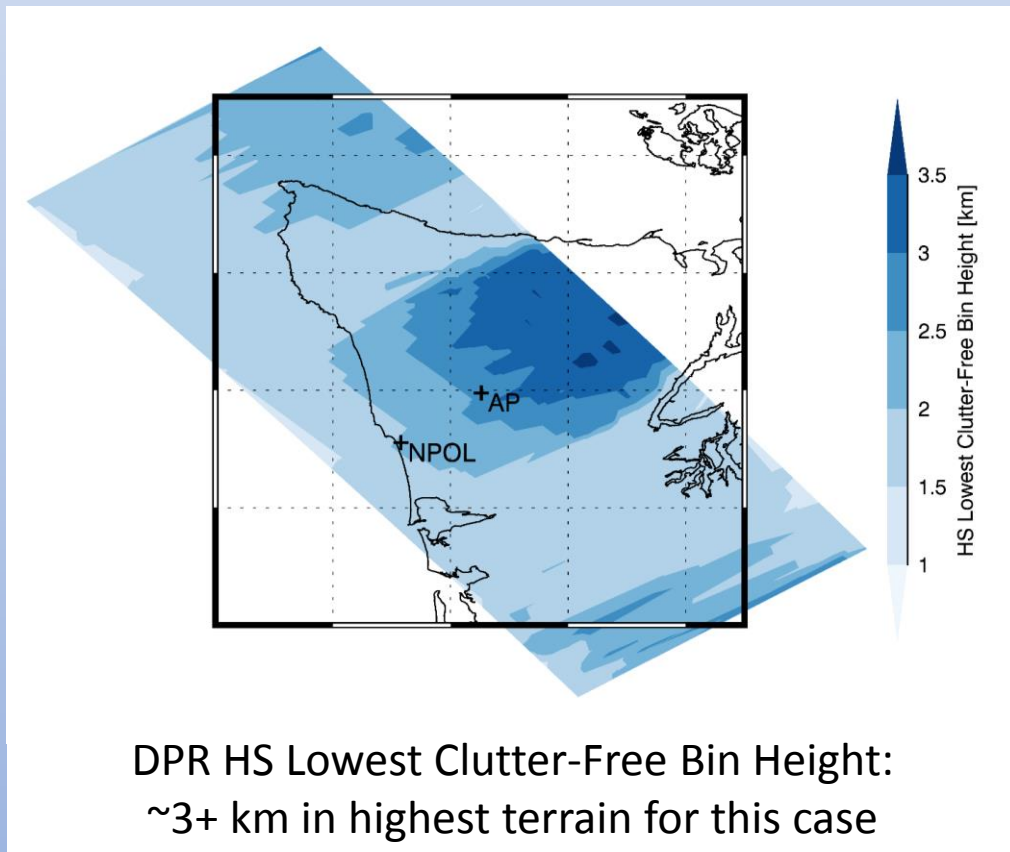


- Topographically enhanced riming/aggregation leads to DSD changes resulting in more efficient collision-coalescence and larger drops at surface
- Dependent on flow orientation relative to terrain



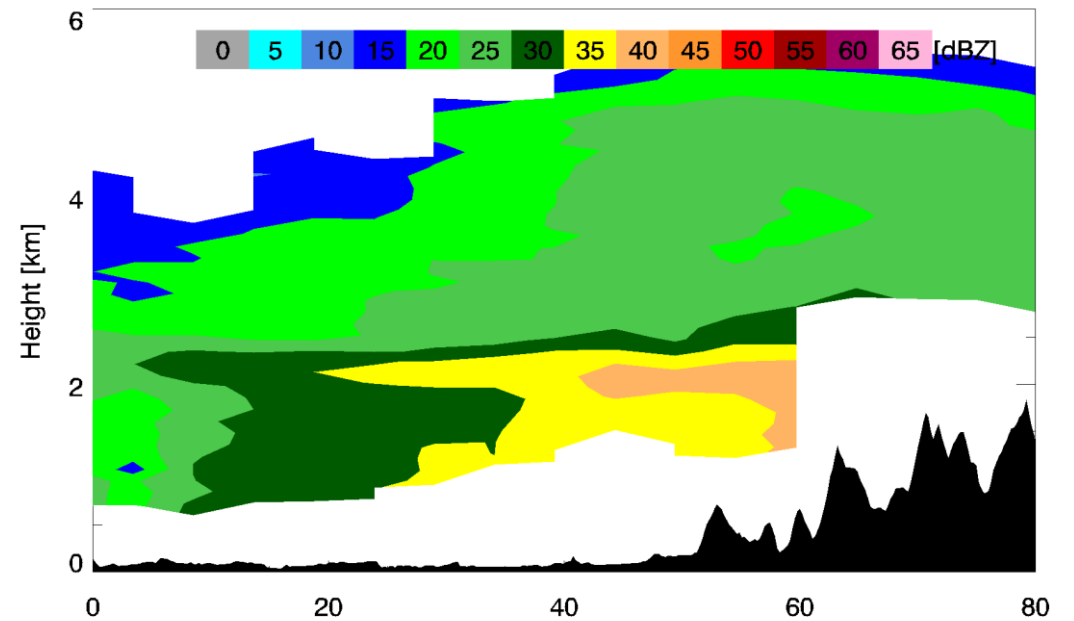
Gatlin et al. (2017) – AMS Radar Conf.

# OLYMPEX – 17 November 2015

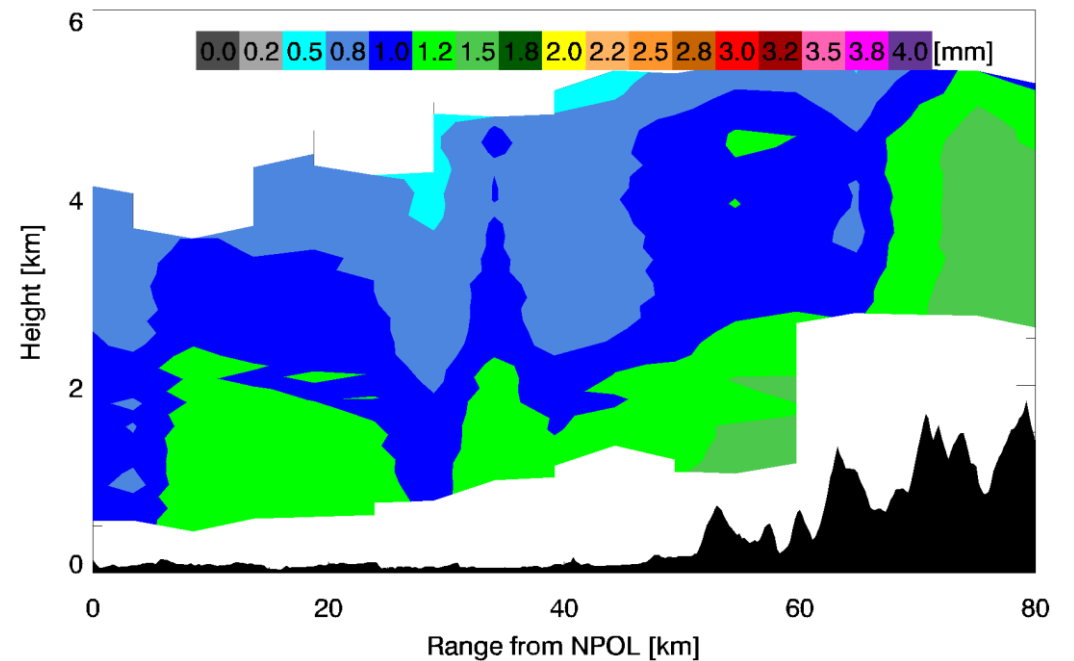


- DPR can not see the whole story!
- DPR scan along NPOL 50° azimuth
- NPOL RHI composite filled in below DPR

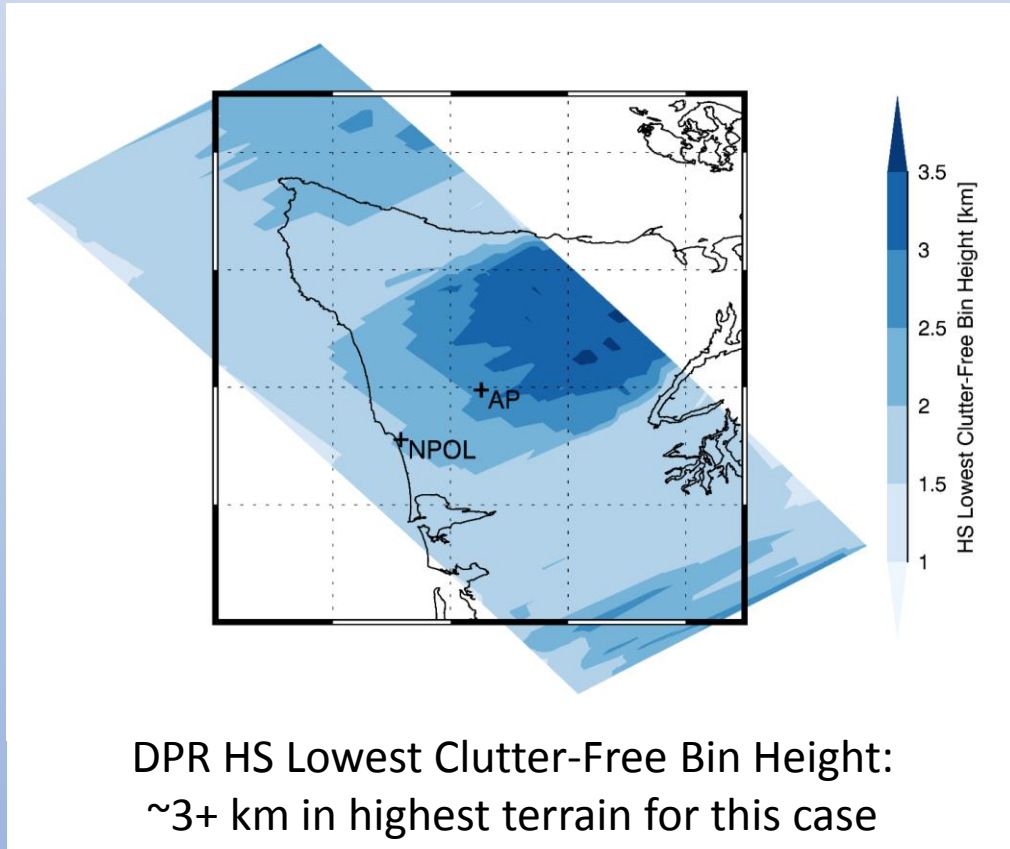
Z



$D_M$

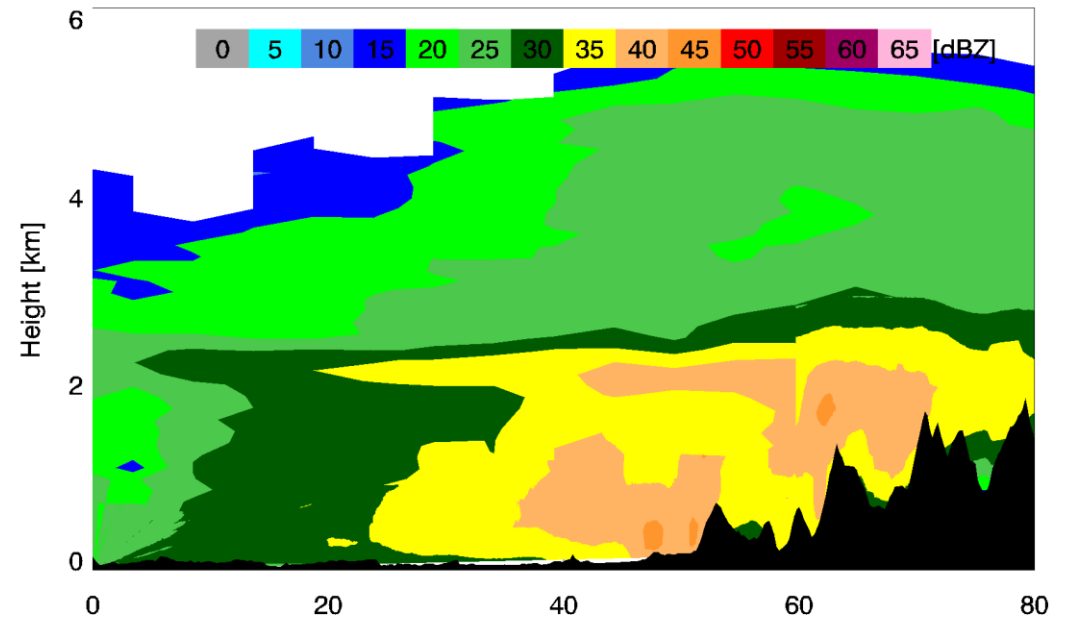


# OLYMPEX – 17 November 2015

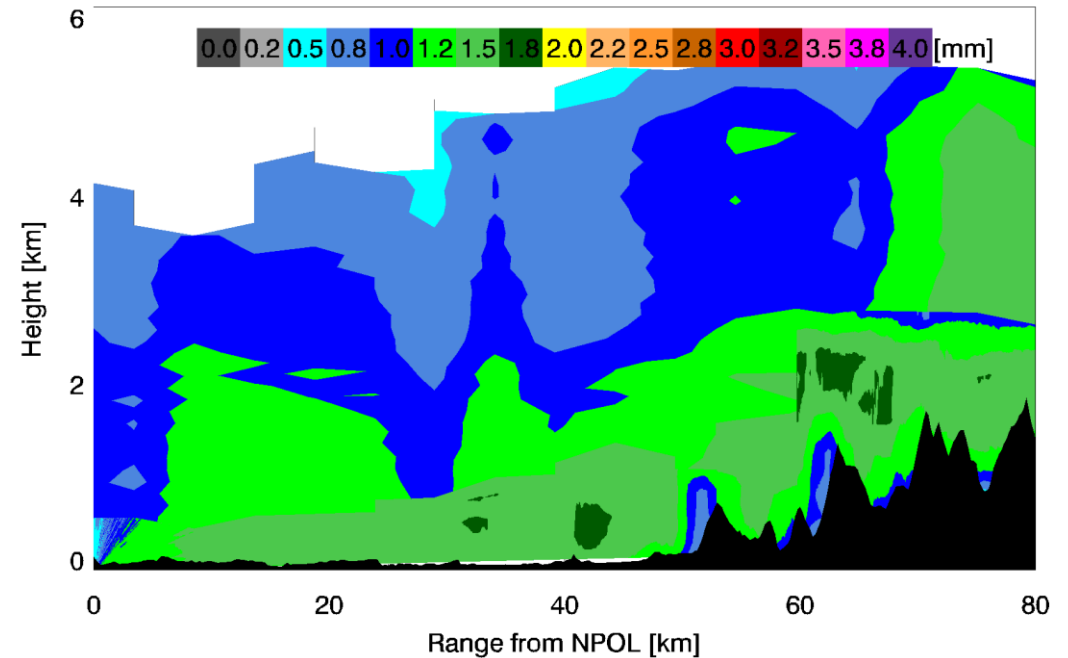


- DPR can not see the whole story!
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Z

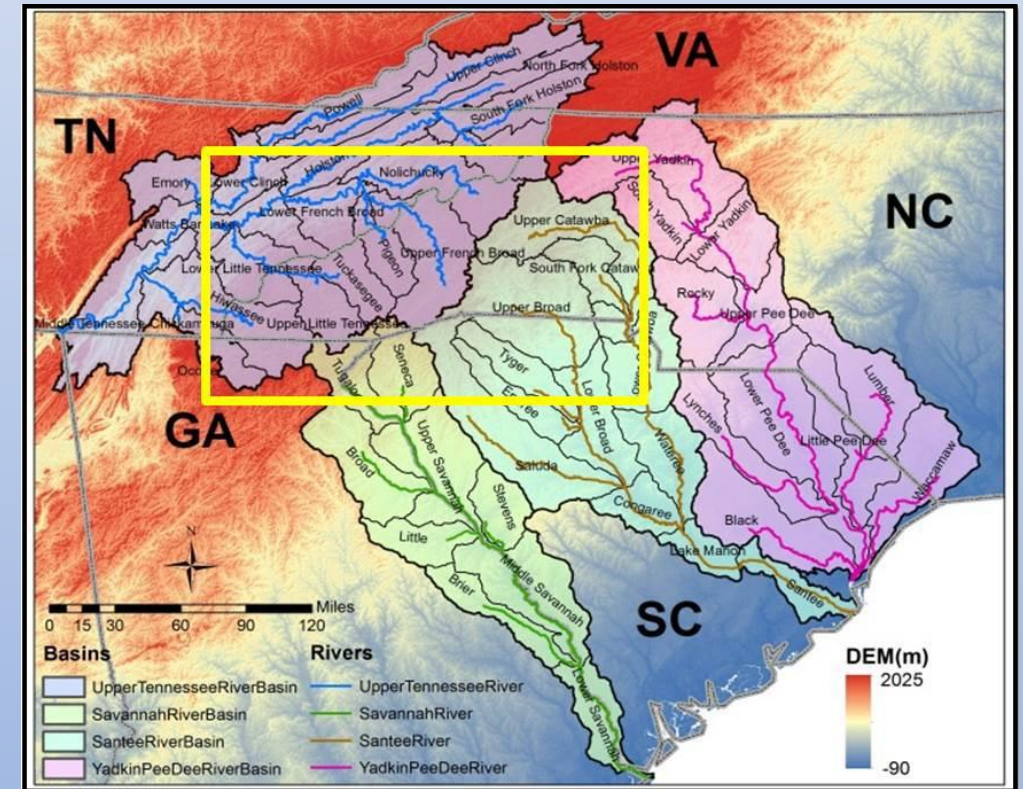


$D_M$



# 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: 1<sup>st</sup> post-launch campaign for GPM Core Observatory



Barros et al. (2014), IPHEX Sci Plan

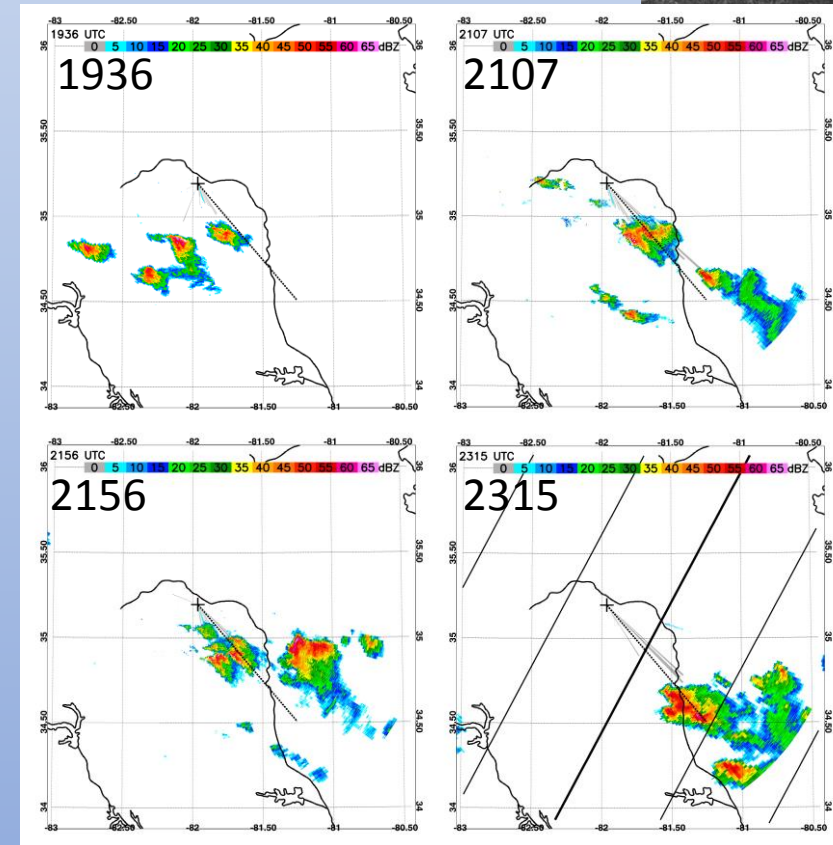
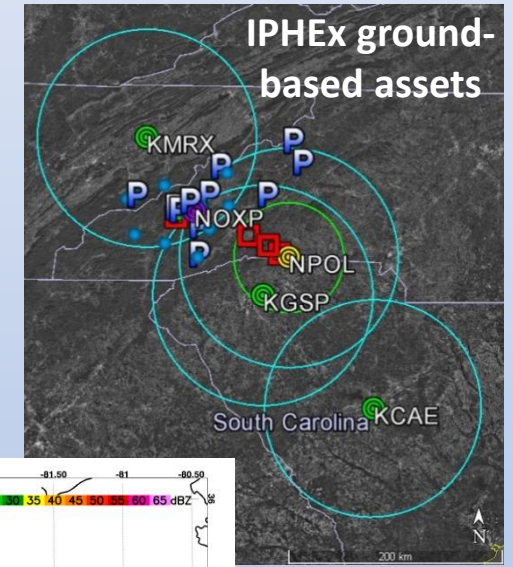
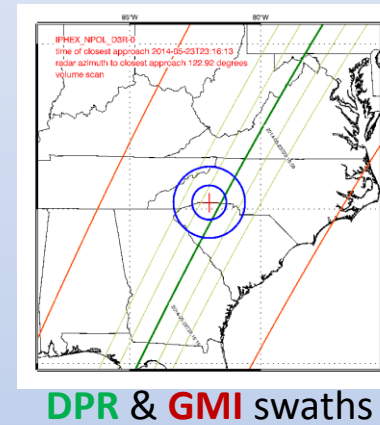
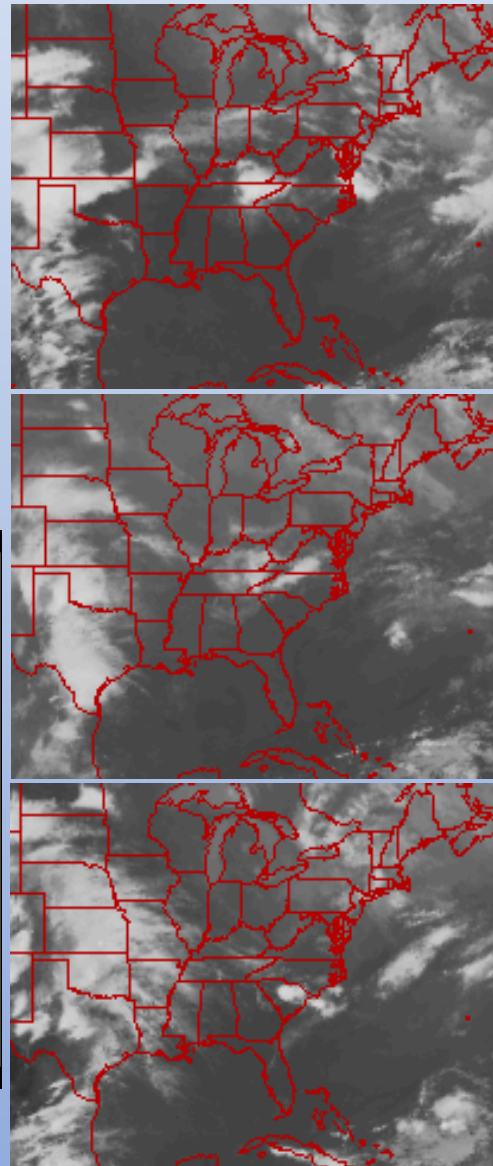


IPHEX GV focus domain (**yellow**)  
& river basins of interest



# IPHEX – 23 May 2014

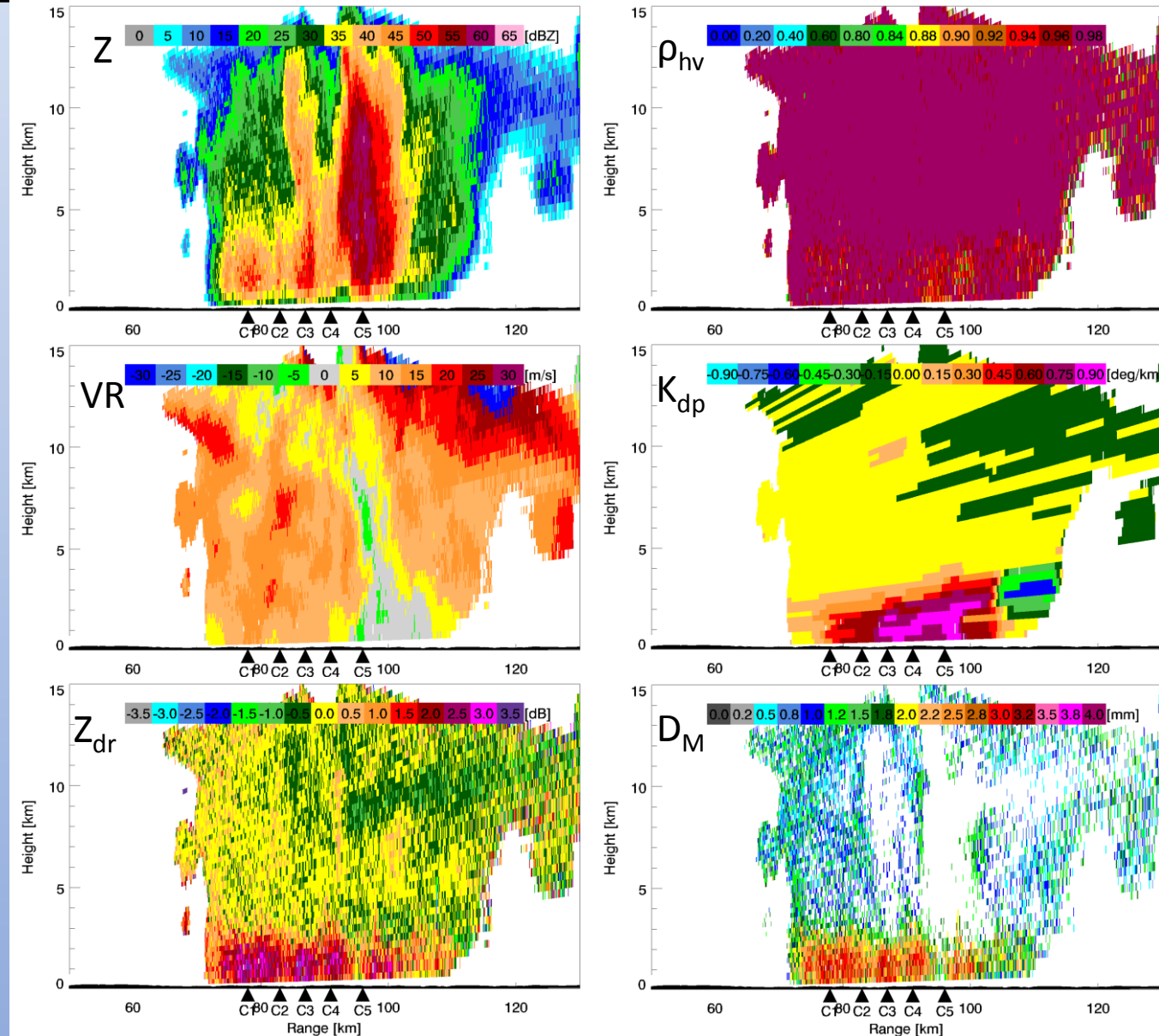
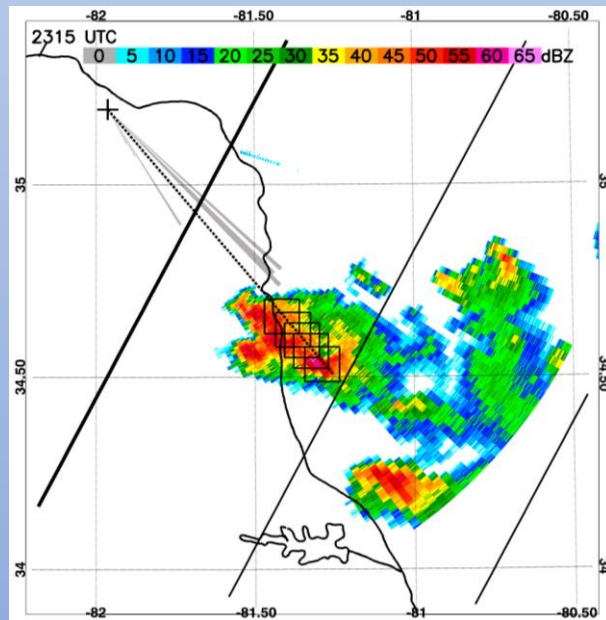
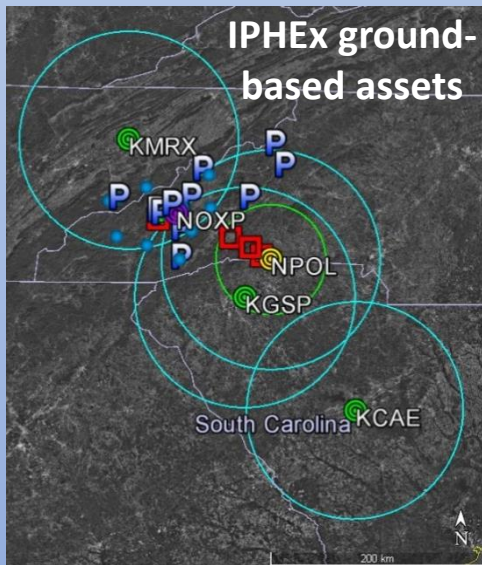
- GPM “Check-out” period
- Early: MCS off Appalachians
- Approaching cold front
- GPM DPR OP @ 2316
- Convection with 1-2 in hail in NPOL coverage; ER-2 coordination



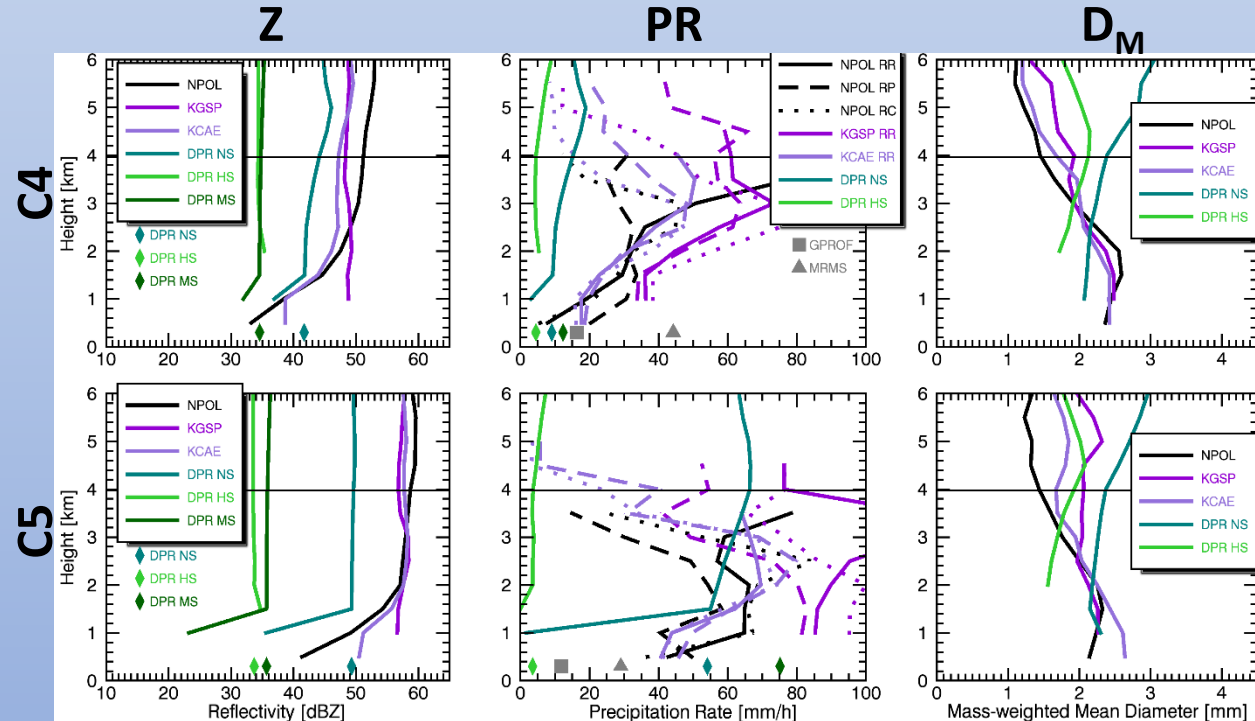
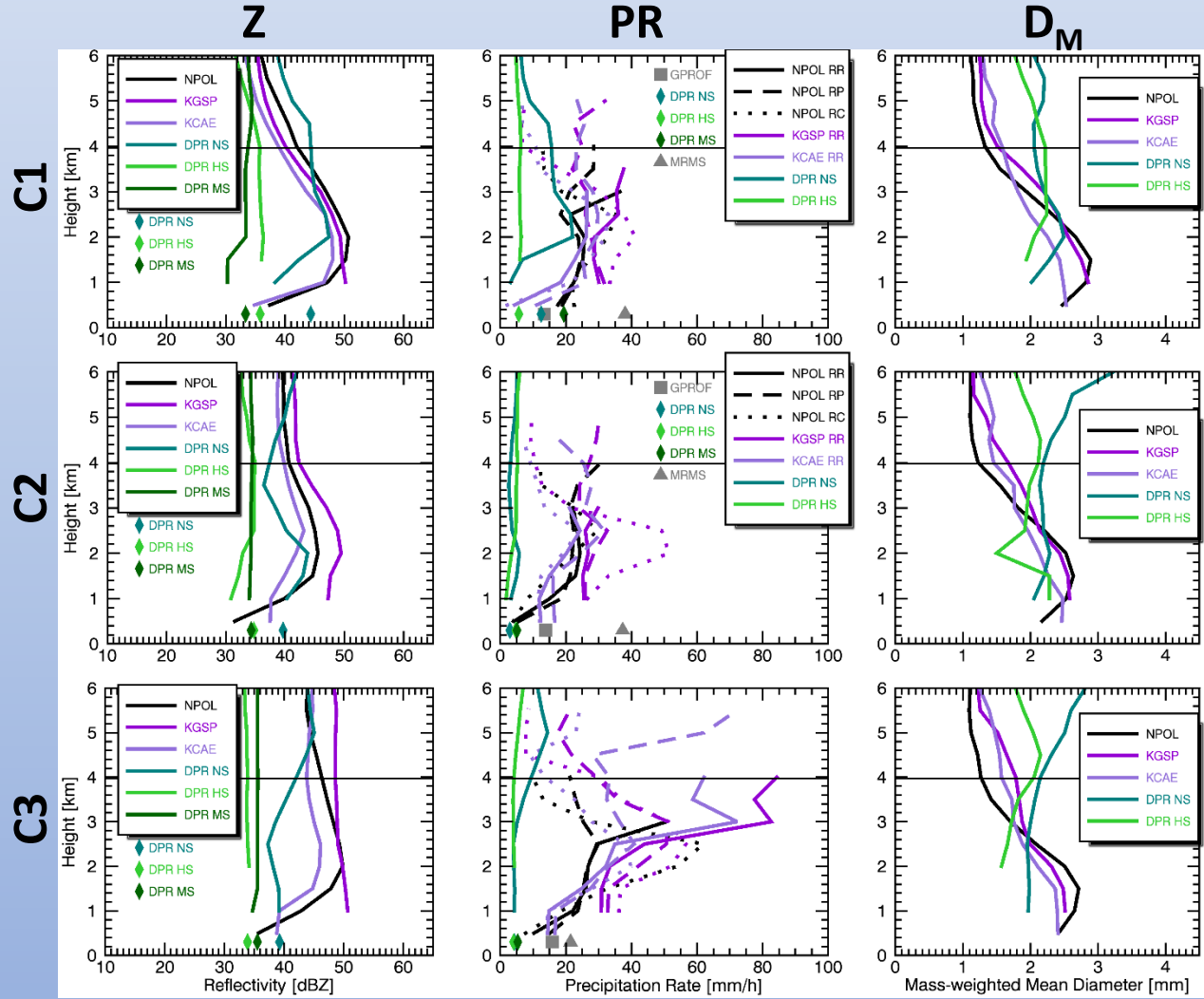
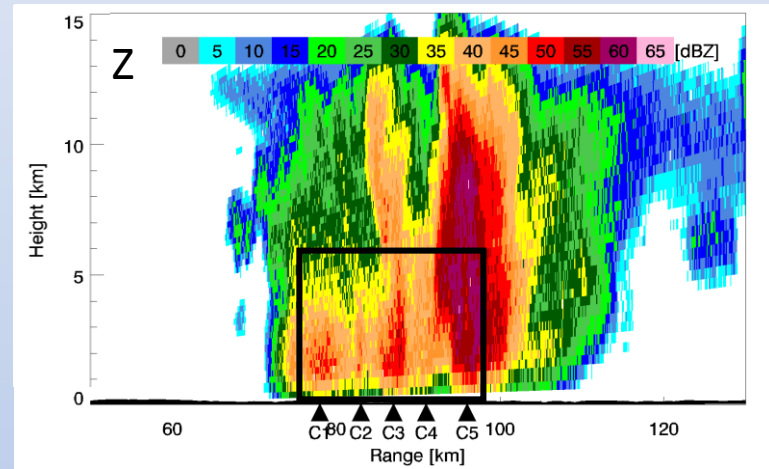
NPOL  
1.5° Z

# 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



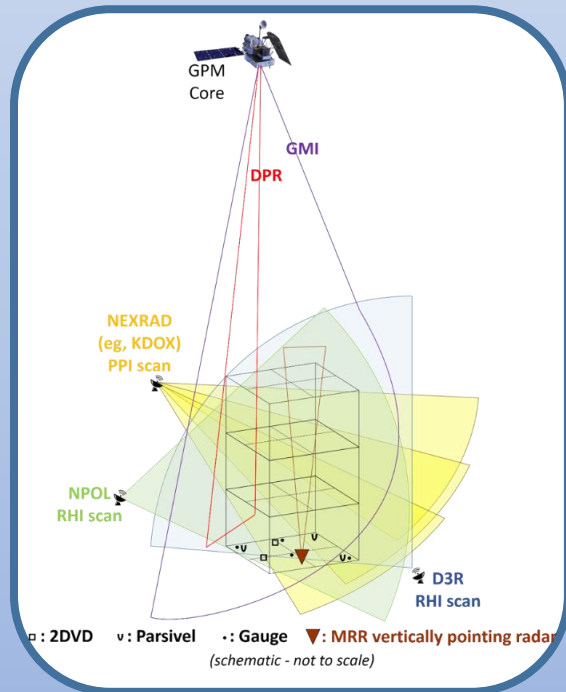
- DPR NS captures Z increase below 0°C better than HS, MS
- Satellite preip rates underestimate ground-based sensors

- 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:

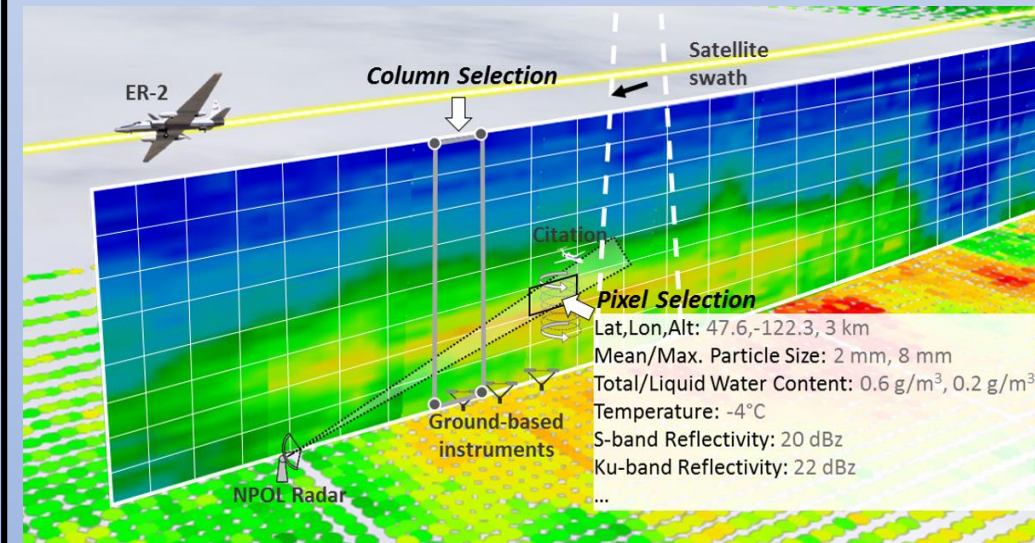
- Demonstrate concerns with DPR in regions of complex terrain
- $D_M$  behavior below  $0^\circ\text{C}$  implies processes changes, dependent on orientation of cross-barrier flow

## 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

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