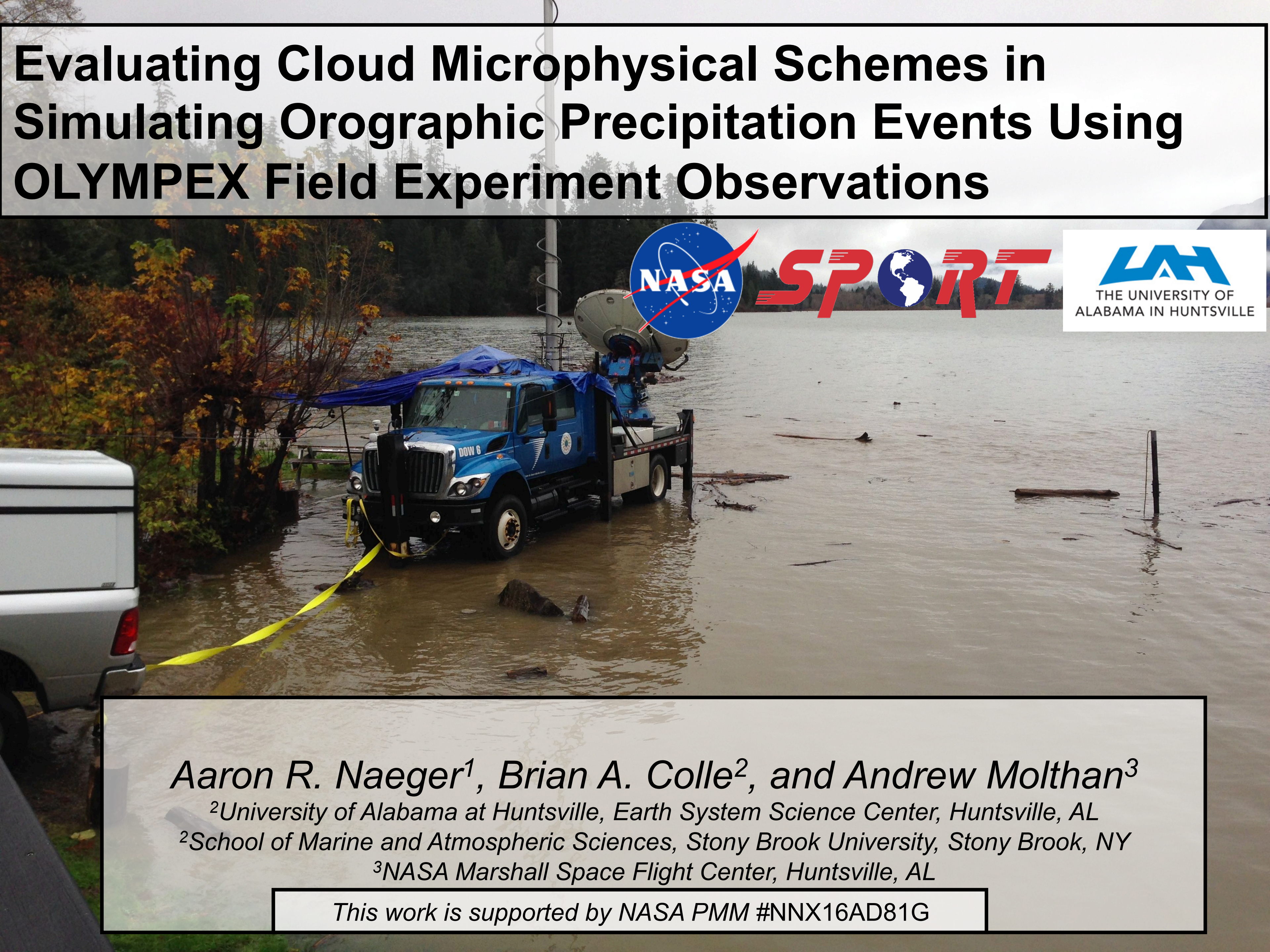
Evaluating Cloud Microphysical Schemes in Simulating Orographic Precipitation Events Using OLYMPEX Field Experiment Observations



Aaron R. Naeger[1], Brian A. Colle[2], and Andrew Molthan[3]

[2]University of Alabama at Huntsville, Earth System Science Center, Huntsville, AL

[2]School of Marine and Atmospheric Sciences, Stony Brook University, Stony Brook, NY

[3]NASA Marshall Space Flight Center, Huntsville, AL

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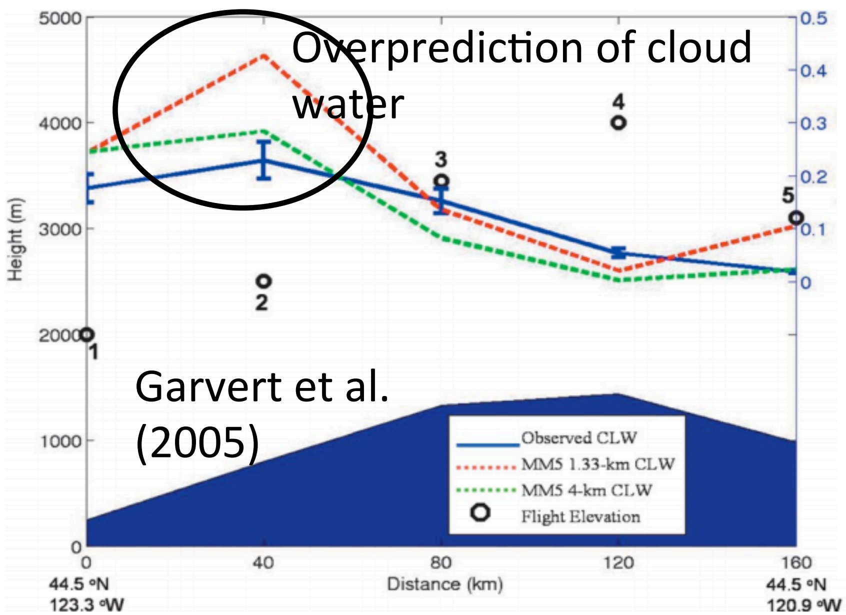
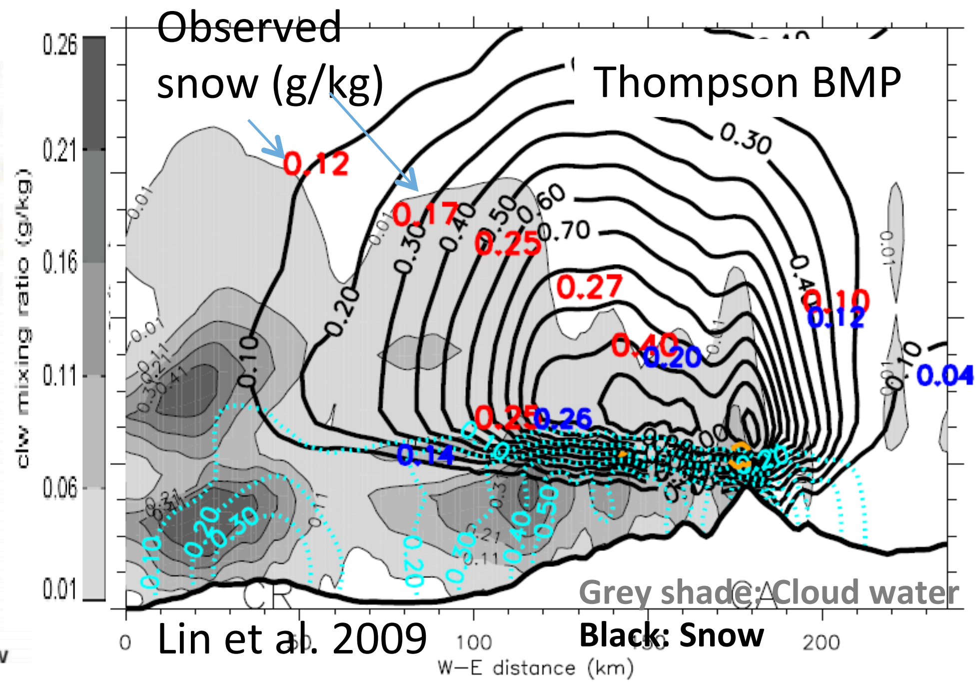
Motivation and Goals

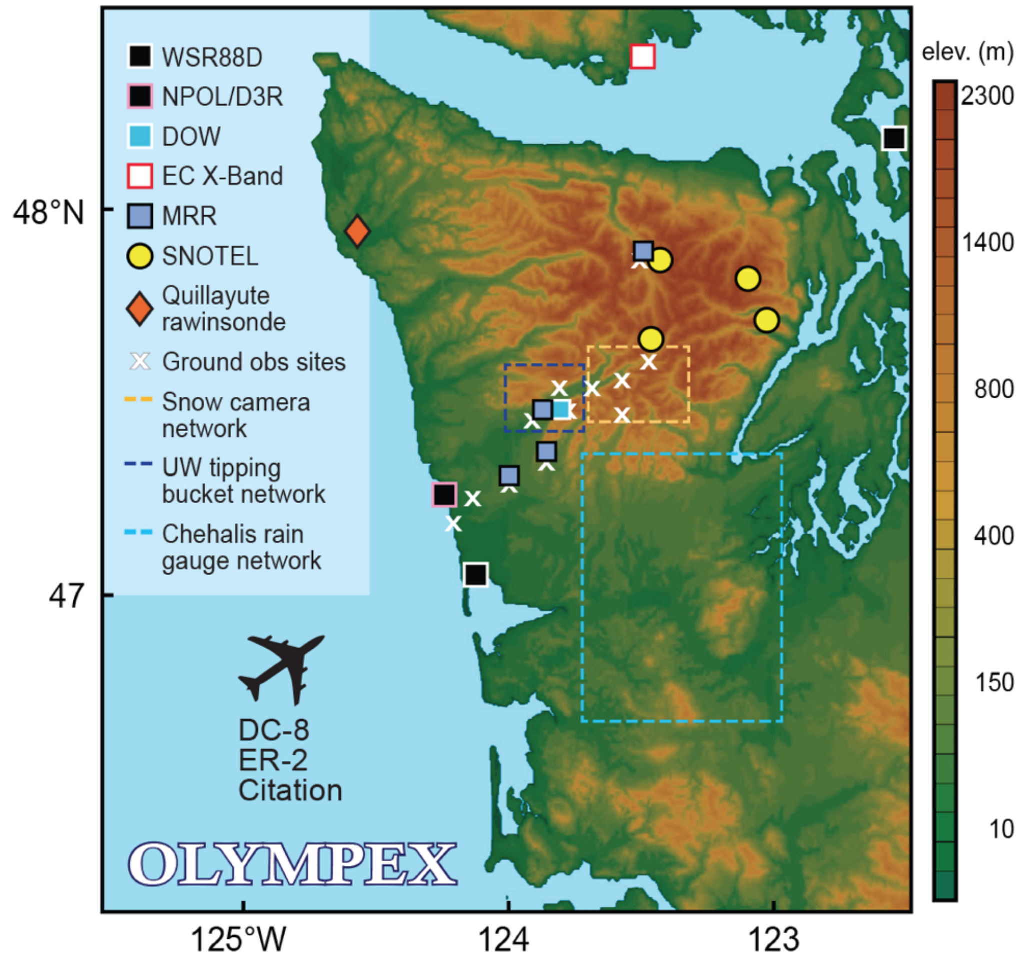
- Previous studies over the Pacific Northwest (e.g., IMPROVE-2; Garvert et al. 2005; Colle et al. 2005, Lin et al. 2009, …) showed many bulk micro schemes over-predict windward precipitation and snow aloft (too much cloud water lower windward slope and too little near crest).
- There are large bulk microphysical parameter (BMP) uncertainties to riming and other ice characteristics (habit, size distribution, density, etc…).
- Orographic precipitation is also highly sensitive to the upstream cross barrier flow, moisture, and stability.
- There has been limited verification of orographic flooding events (high freezing levels) over the PNW.

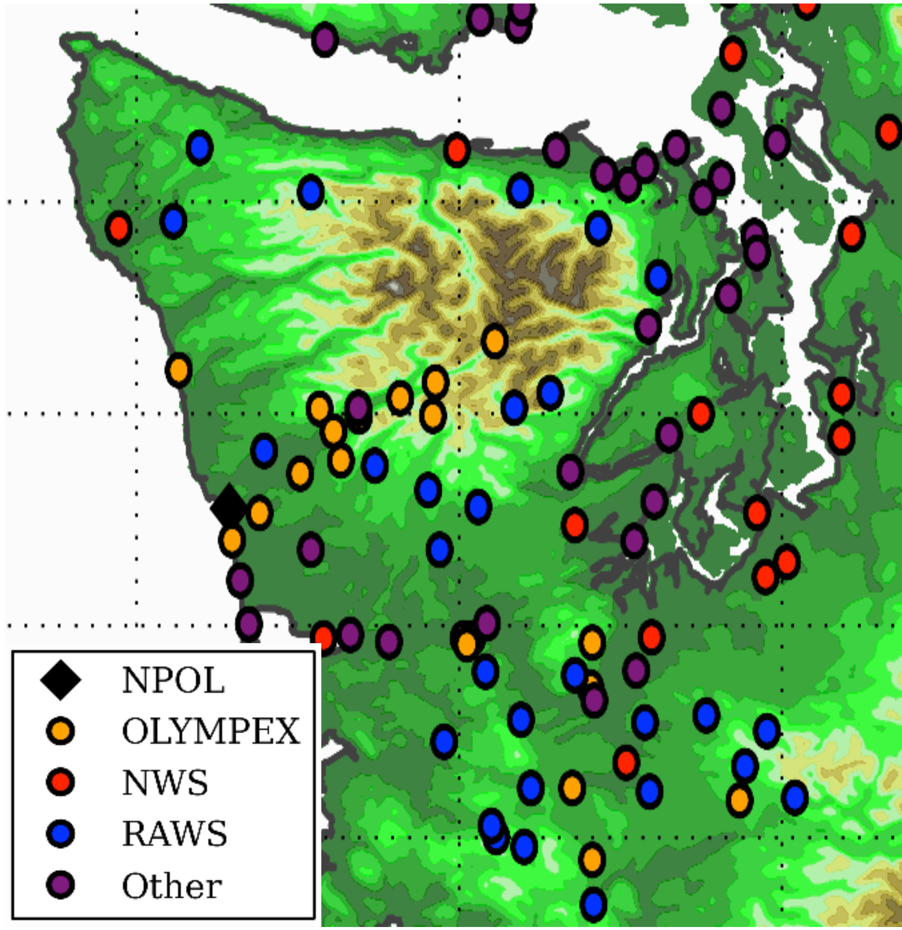




OLYMPEX Field Experiment

- Coastal soundings: Upstream flow, moisture, and stability
- WSR-88D/NPOL: Precipitation evolution around barrier
- DOW/ MRR: Detailed precipitation structures over windward slope/valley
- Gauges/Citation Aircraft: Spatial precipitation amounts and microphysics verification



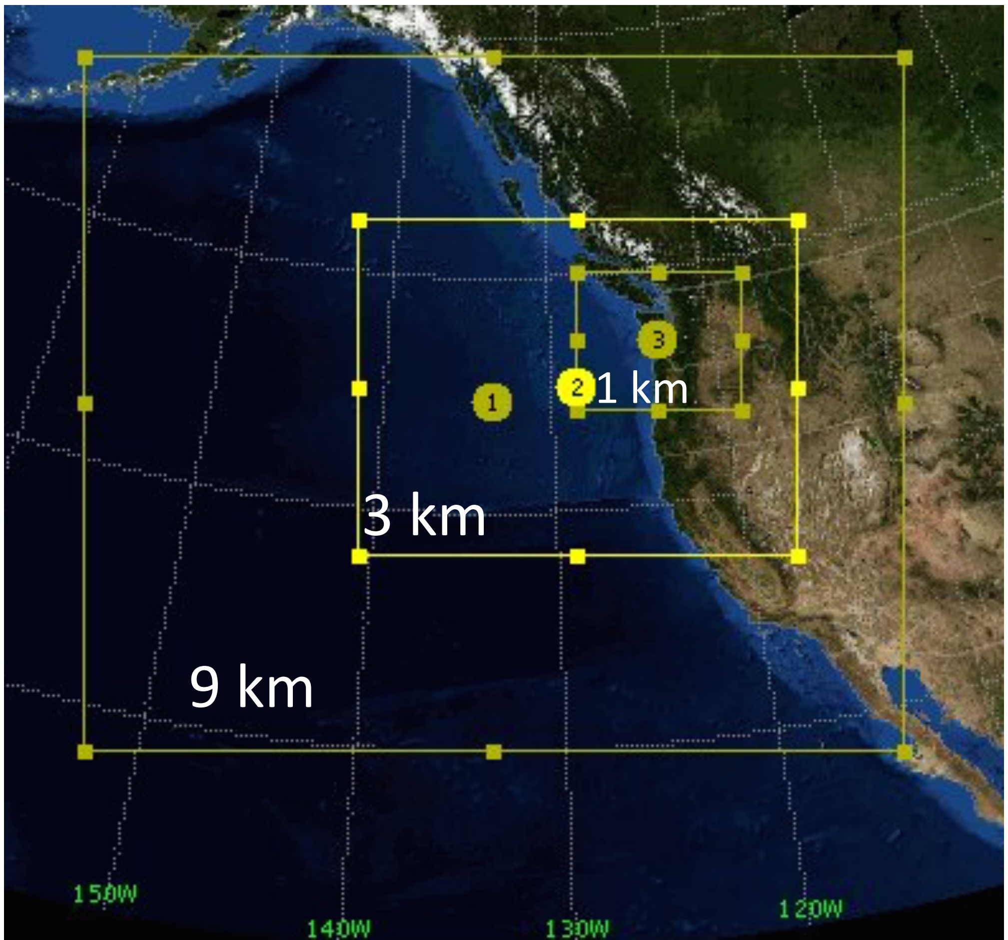


Motivational Questions

- How do the orographic precipitation structures evolve for these flooding cases (focus on 12-13 Nov 2015 event)?
- How well do the various bulk microphysical schemes (BMPs) in WRF predict these precipitation structures and amounts?
- Are there any microphysical differences aloft between the BMPs?

WRF Model Setup

- Three heavy precipitation cases simulated (12-13 Nov 2015, 17-18 Nov 2015, and 8-9 Dec)
- WRF V3.7.1 at 9, 3, and 1 km grid spacing (50 vertical levels).
- IC/BCs: (GFS analyses and NARR – so far)
- MYJ PBL, Grell-Freitas (9 km), RRTMG
- 36-h runs starting (11/12/12z, 11/16/12z, and 12/08/00z). First 9-h spin-up.

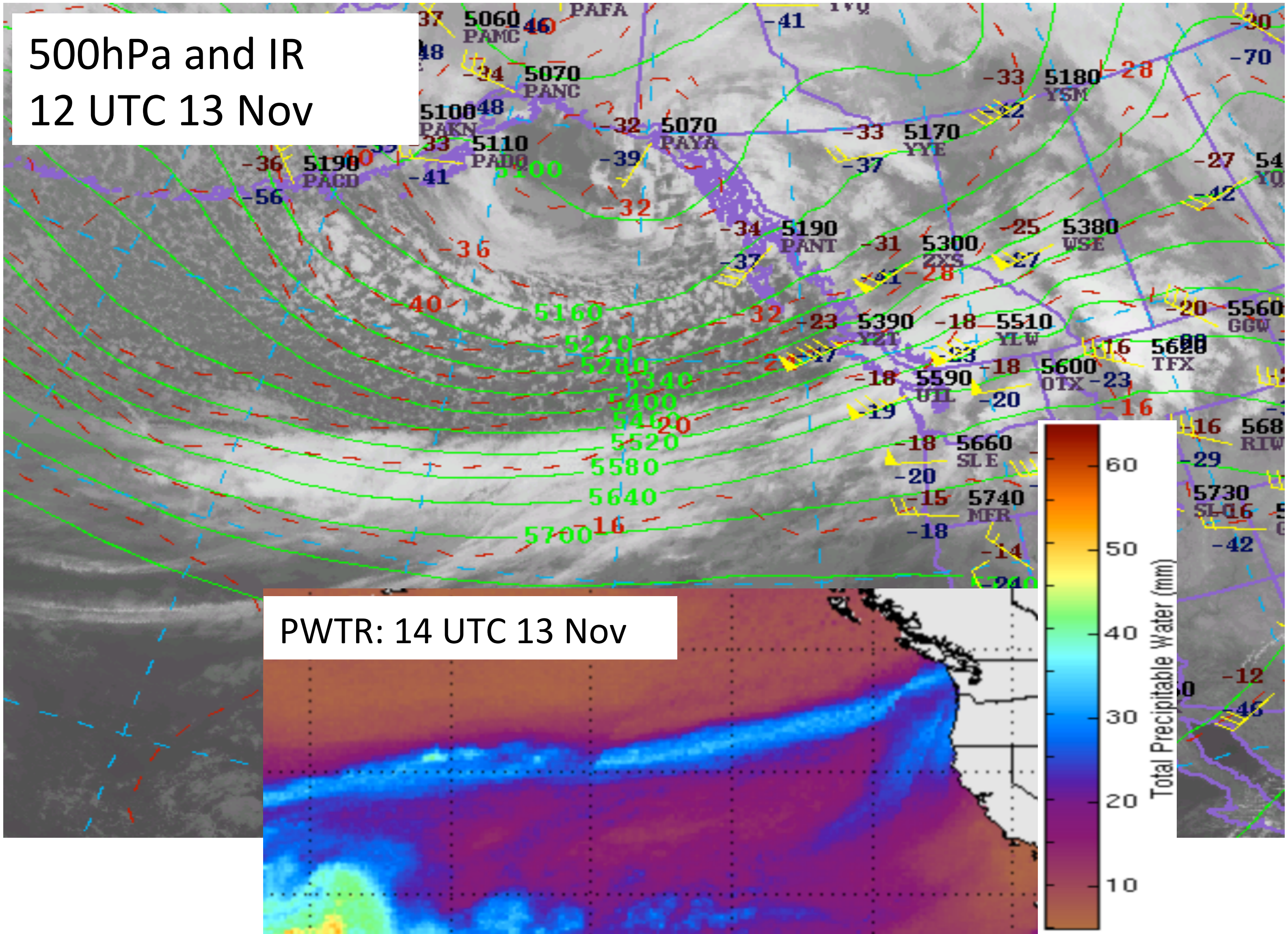


Bulk Microphysical Schemes (BMPs)

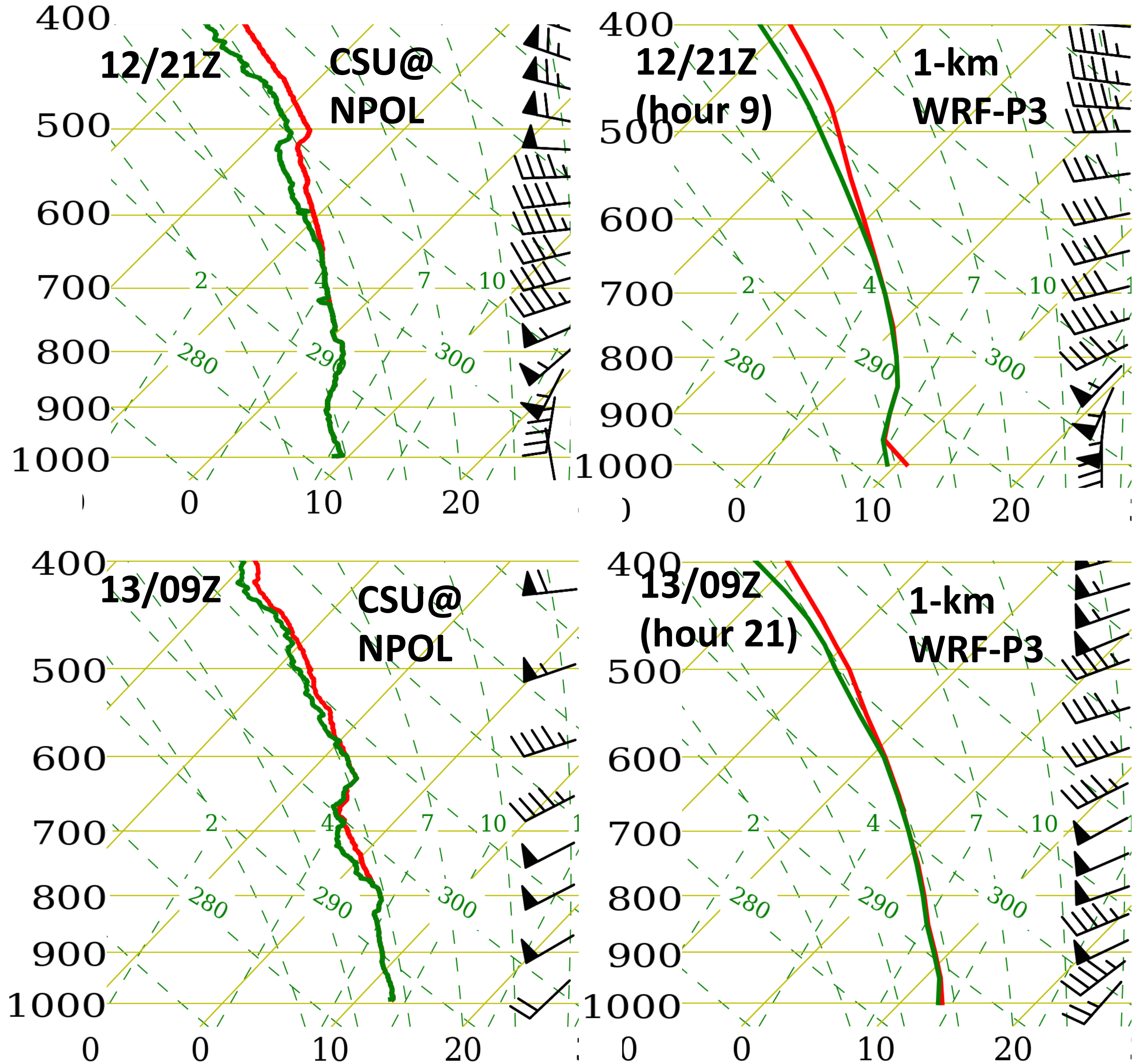
- **Thompson** – (2008) ~2D ice, ice size distribution from Field et al. (2005), variable riming efficiency.
- **Morrison (MORR**, 2-moment -2009) predicts number concentration (Nx) to get snow/ice size distribution (l) and intercept (Nos). Spherical ice/snow.
- **Stony Brook** (**SBU**, 2011) Uses Nos(T), ~2-D ice/snow, combines snow and graupel into one category, and a degree of riming is estimated and variations in snow density (T). Snow/rime properties not advected horizontally.
- **P3** (2015) **(Control Run)** Four prognostic mixing ratio variables (total ice mass, rime ice mass, rime volume, and total number) predict the bulk particle properties of a single ice-phase. Advects ice/rime properties.

12-13 November 2015 Event

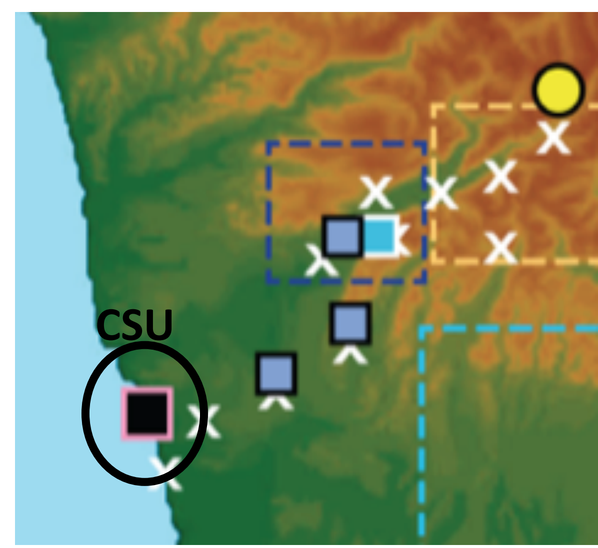
- Significant atmospheric river (~30 mm PWTR: obs and in WRF)



Stability/Flow Evolution (Obs-CSU vs WRF)

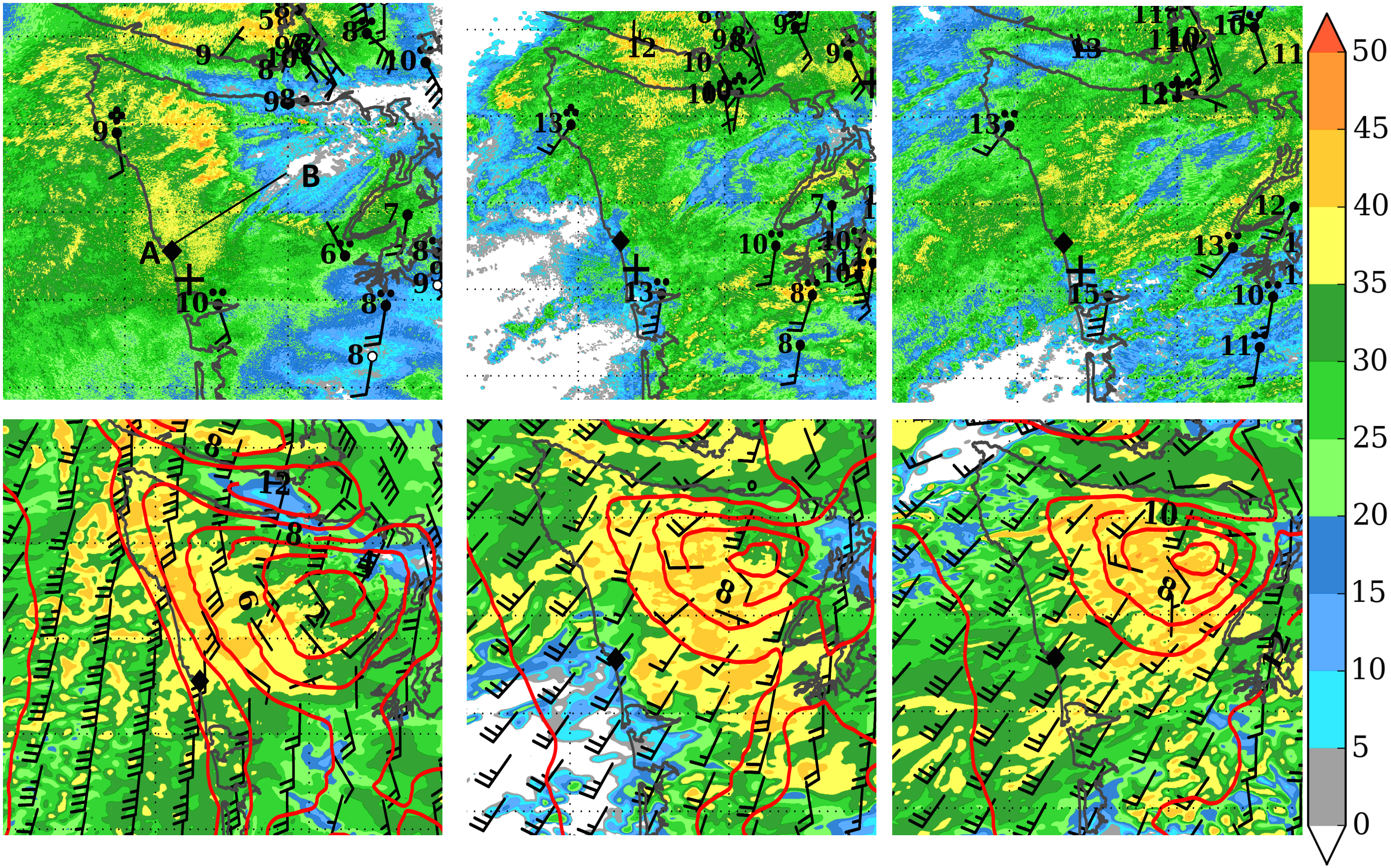


- Before 0300 UTC 13 November – Stable layer between 950 and 800 hPa
- Closer to moist neutral after 0600 UTC 13 November
- Freezing level slowly rising from 2.3 to 2.7 km AMSL.

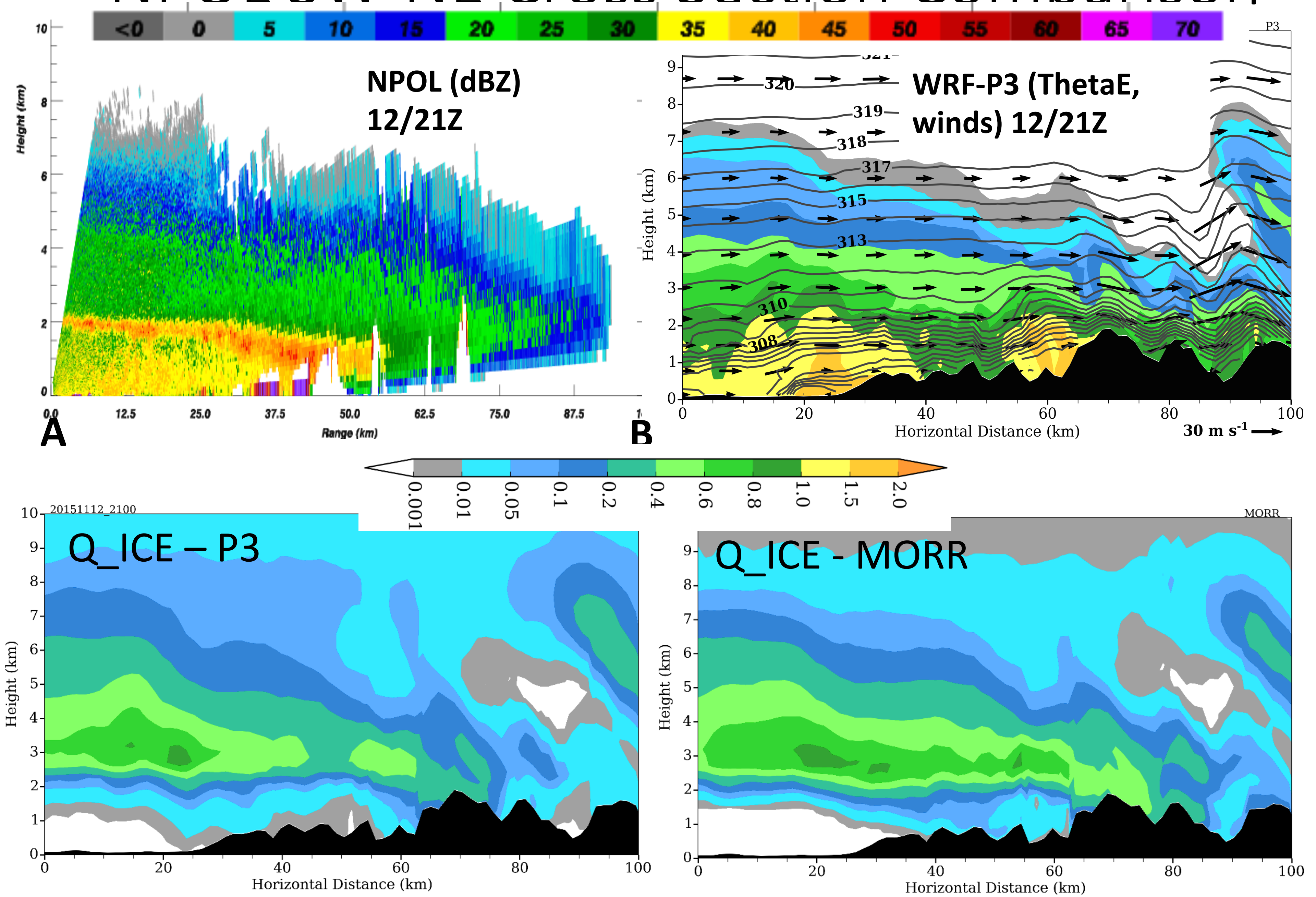


Surface Obs and WSR-88D (dBZ; 0.5 deg) and 1-km WRF-P3 (dBZ and sfc V/Temp)

2100 UTC 12 Nov 2015 | 0600 UTC 13 Nov 2015 | 1200 UTC 13 Nov 2015



NPOL SW-NE Cross Section Comparison



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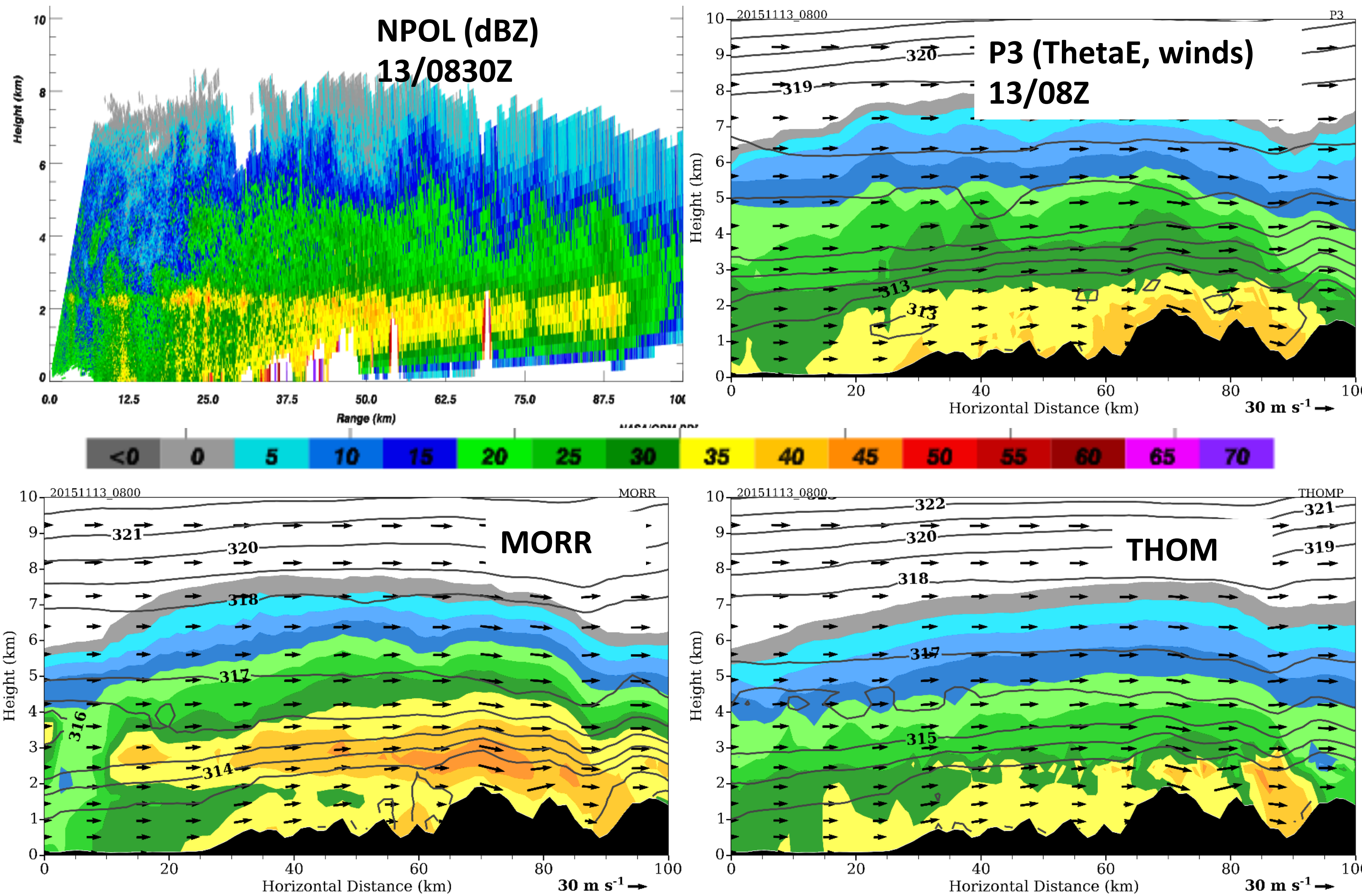
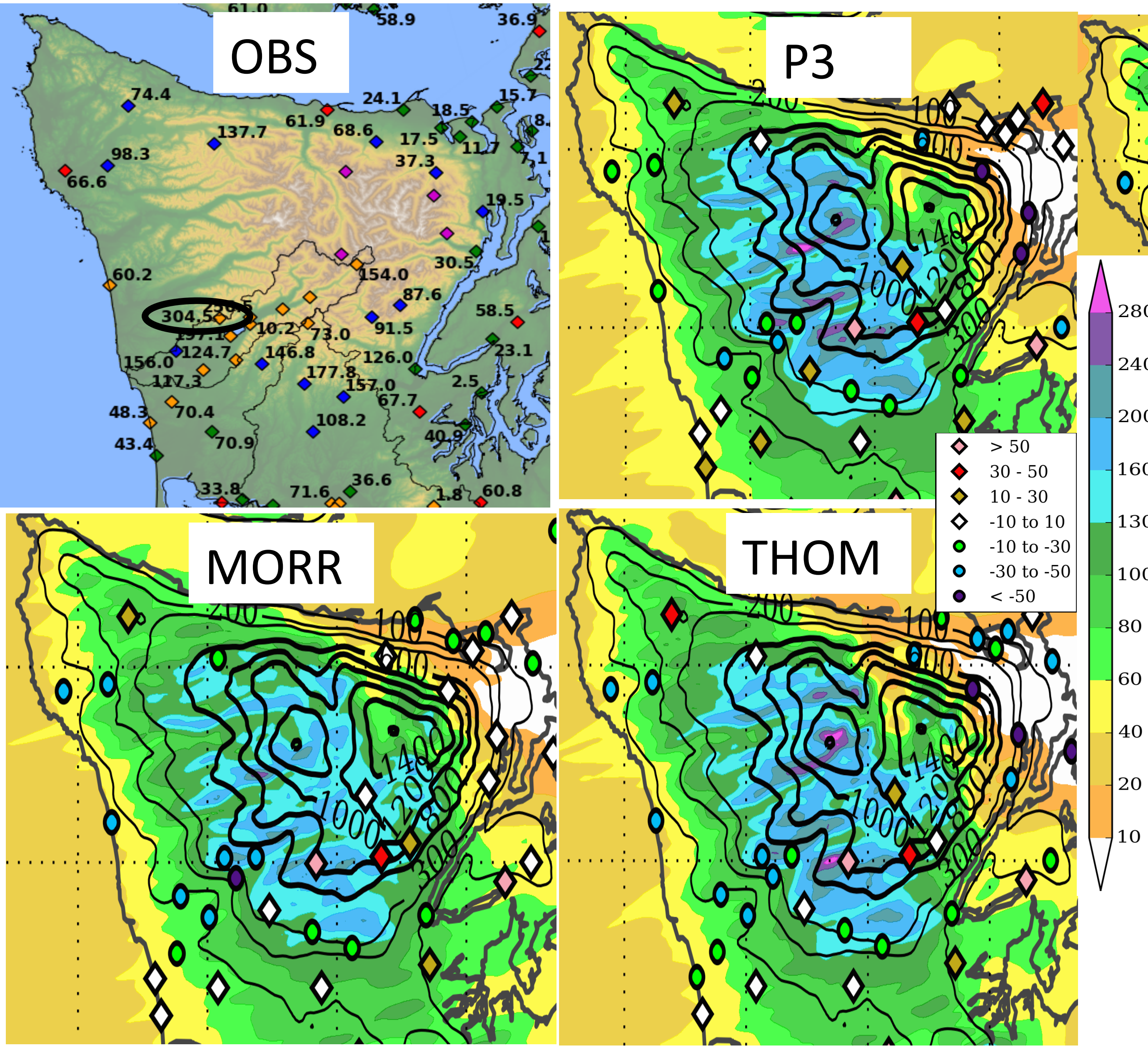
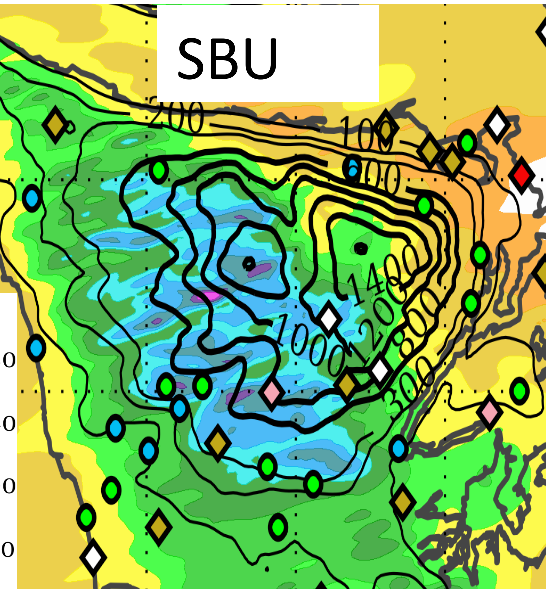


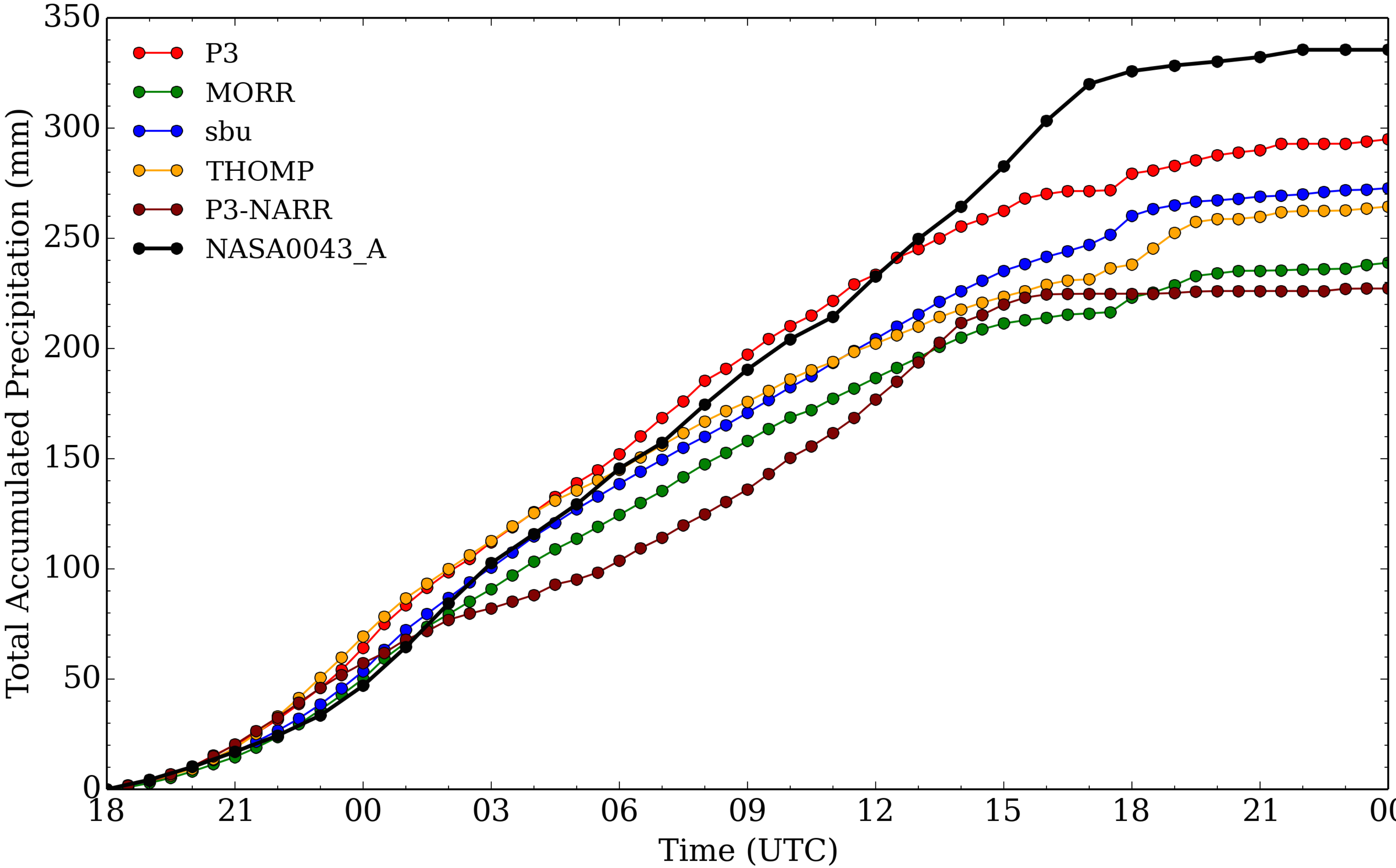
13 Nov 2015 Precipitation Total (in mm) and 1-km WRF % of Obs



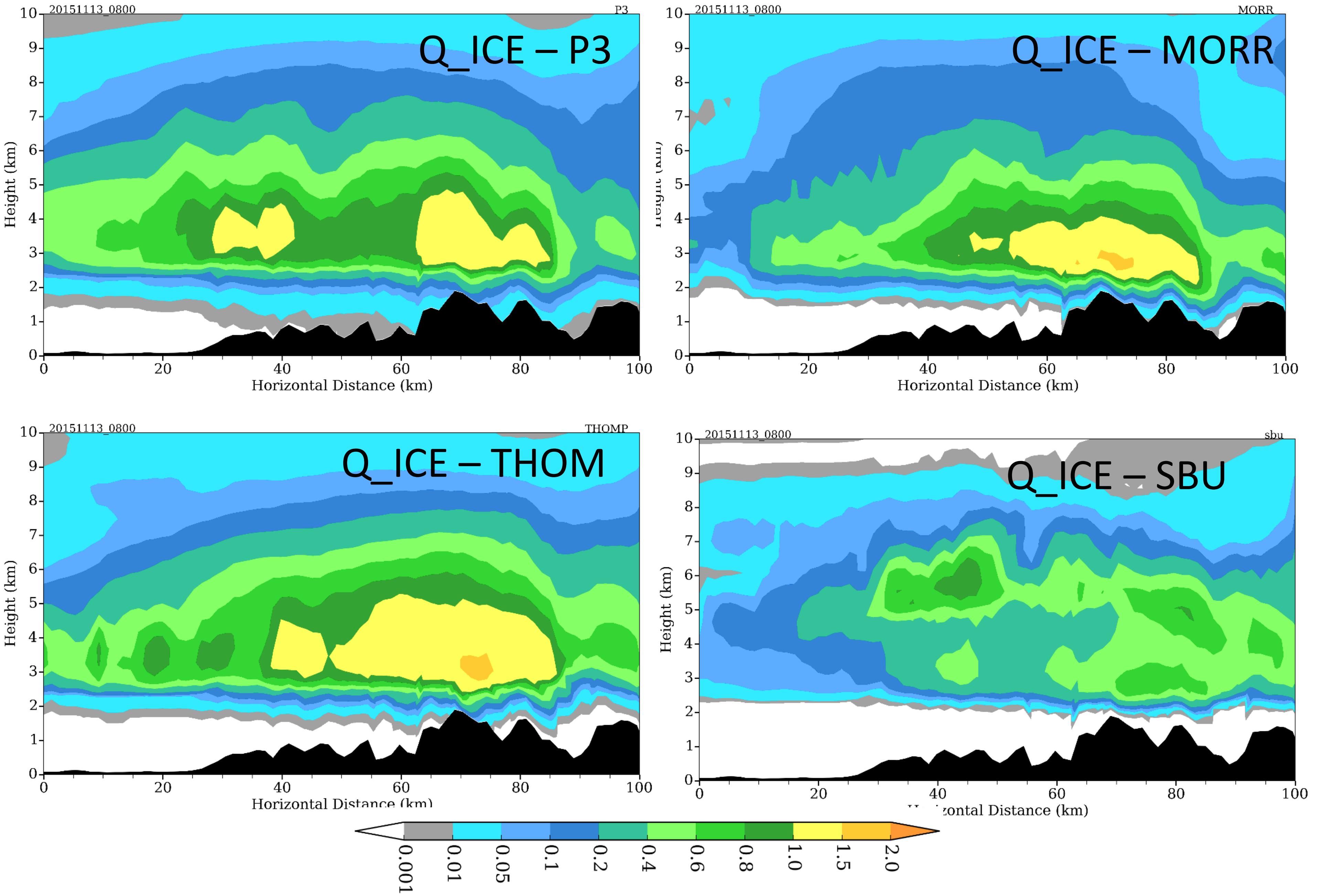


- 250-300 mm was observed over SW lower windward slopes
- WRF schemes underpredicted windward precip by 10-30%, especially MORR.

12-13 Nov Precipitation Time Series (Prairie Creek)



WRF Micro Along NPOL Section (08 UTC 13 Nov)



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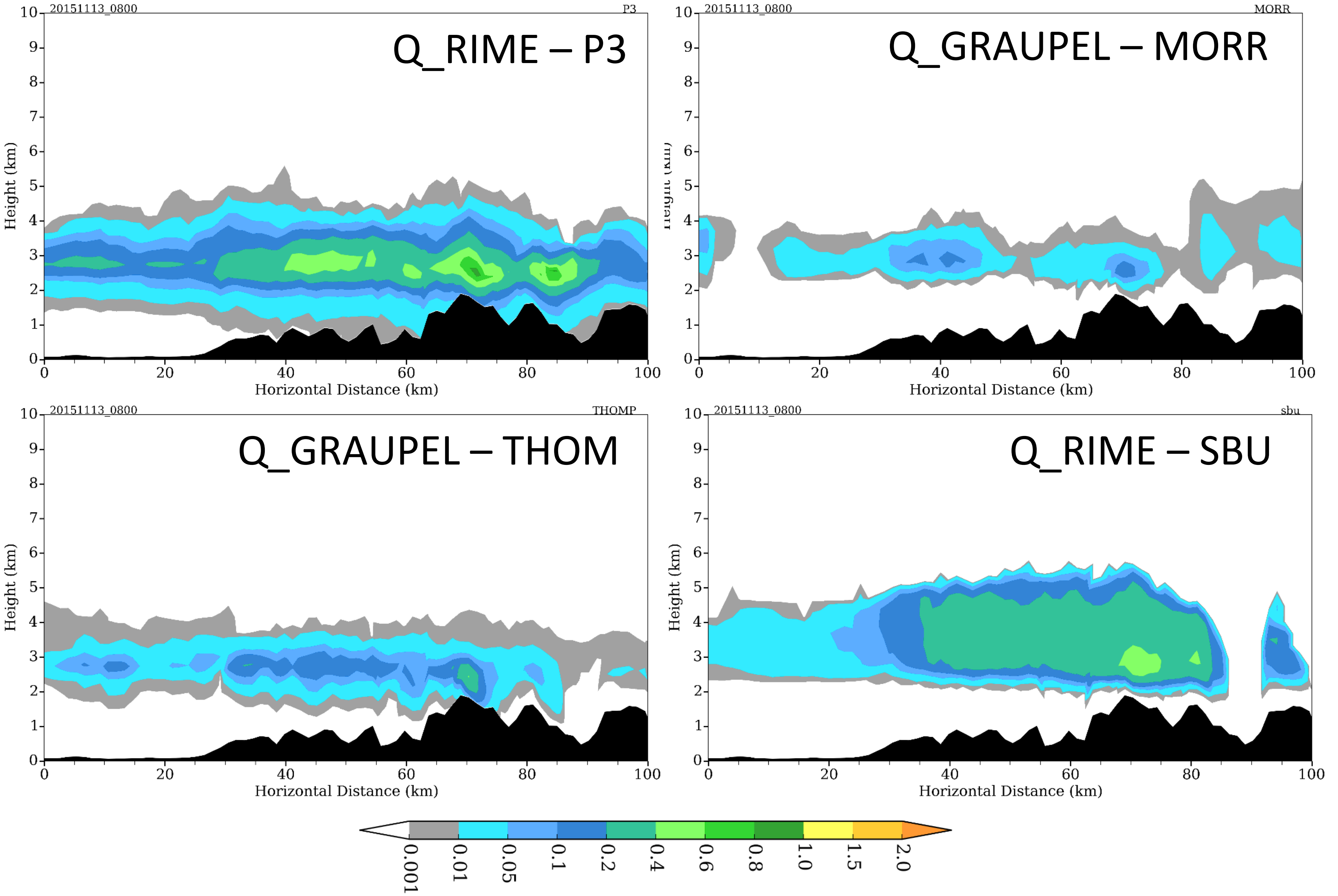
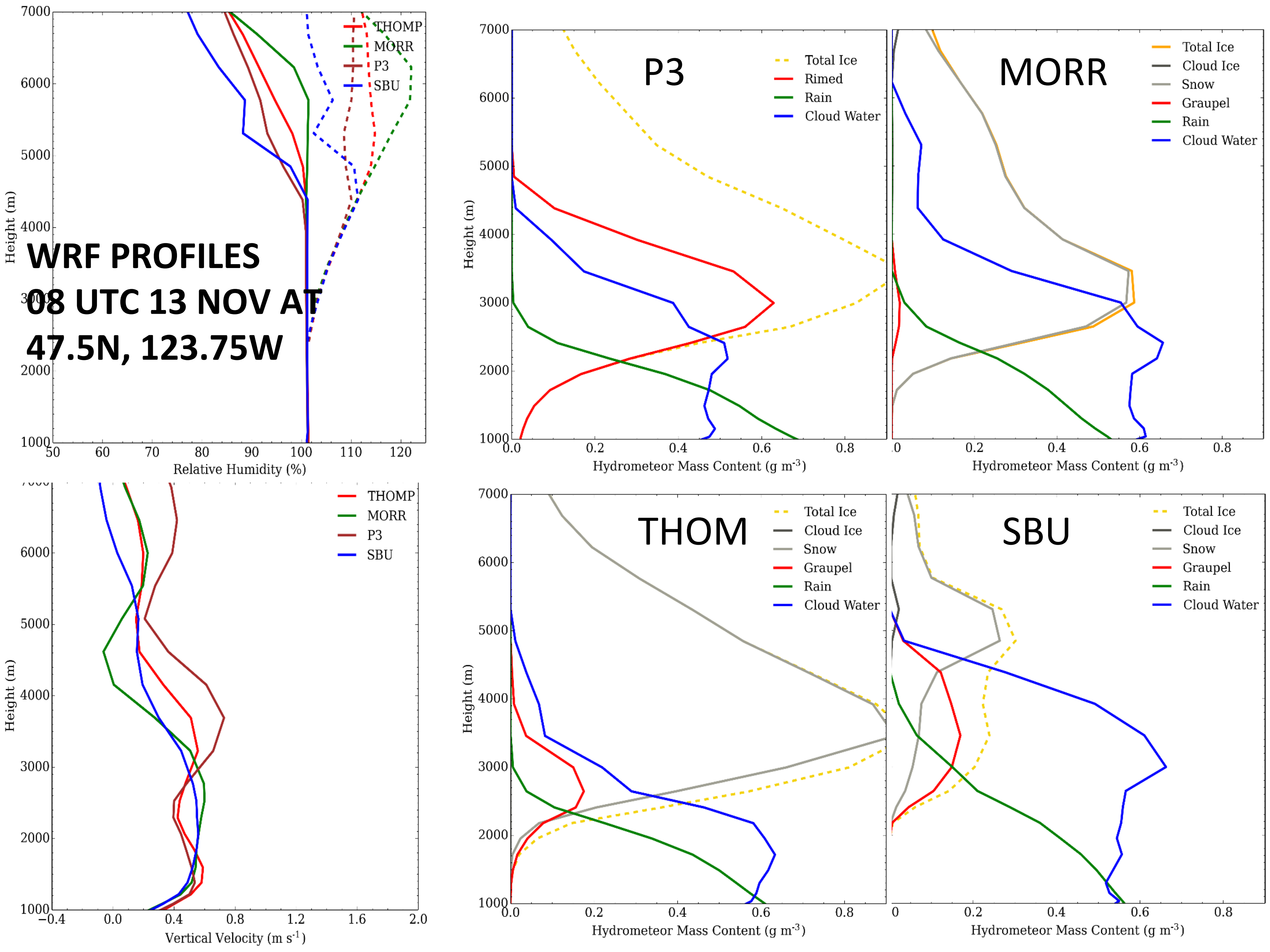
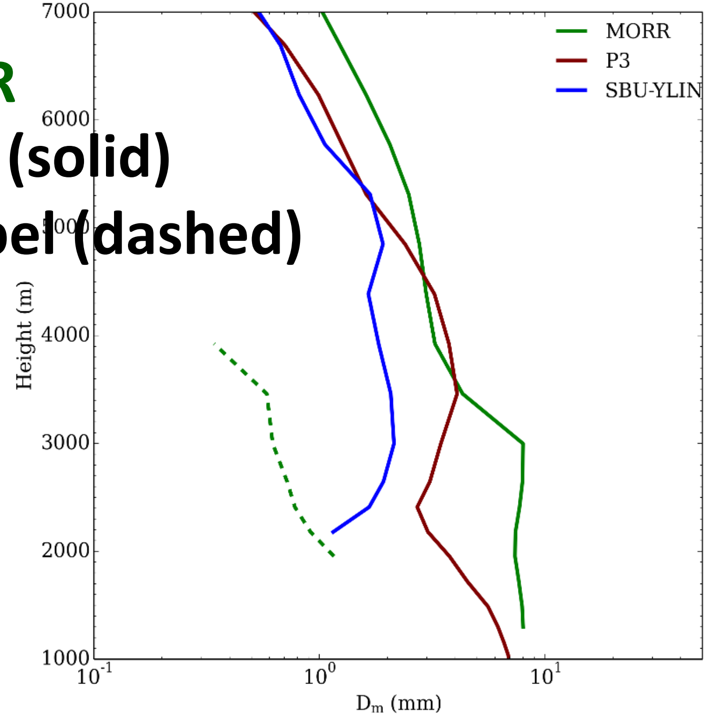
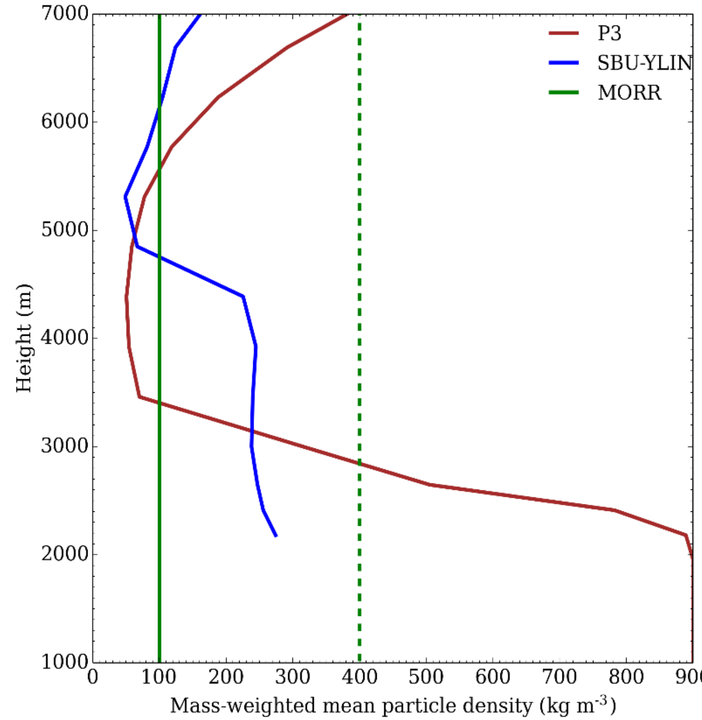




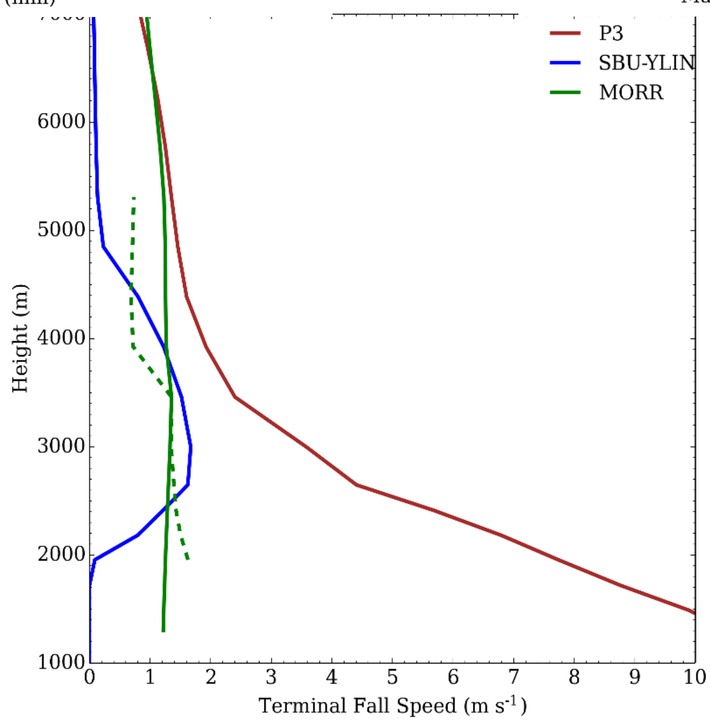
WRF PROFILES
08 UTC 13 NOV AT
47.5N, 123.75W
THOMP
MORR
P3
SBU
Height (m)
Relative Humidity (%)
Vertical Velocity (m s-1)
P3
Total Ice
Rimed
Rain
Cloud Water
MORR
Total Ice
Cloud Ice
Snow
Graupel
Rain
Cloud Water
THOM
Total Ice
Cloud Ice
Snow
Graupel
Rain
Cloud Water
SBU
Total Ice
Cloud Ice
Snow
Graupel
Rain
Cloud Water
Hydrometeor Mass Content (g m-3)

MORR
Snow (solid)
Graupel (dashed)



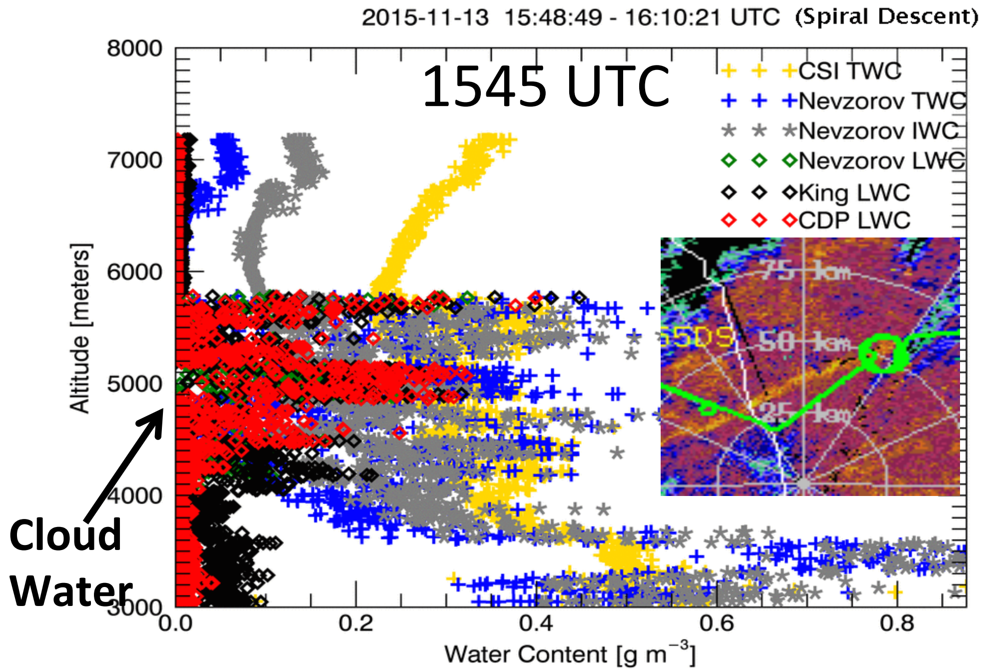


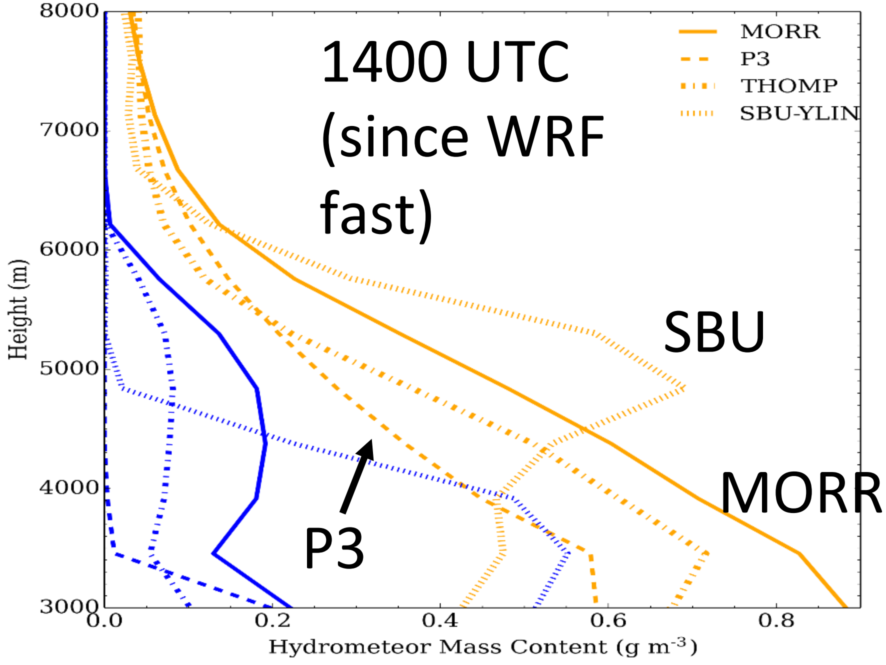
WRF PROFILES 08 UTC 13 NOV AT 47.5N, 123.75W



- P3 predicts larger ice particle sizes than SBU and MORR (graupel)
- P3 particle density and fall speed increases dramatically below 3 km.

Citation Aircraft Micro Comparisons with WRF BMPs

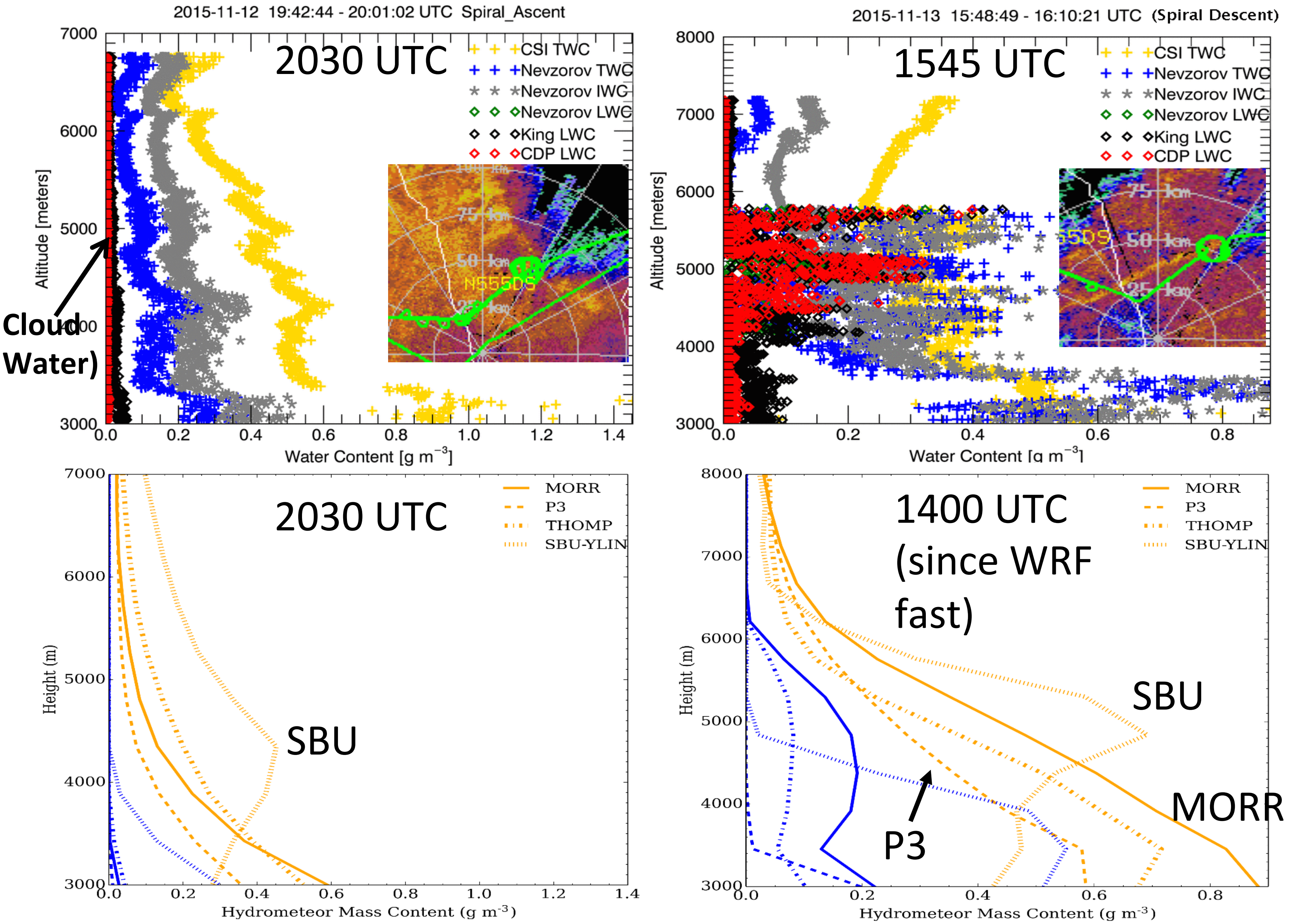




Conclusions

- For the 12-13 November 2015 event, relatively large low-level stability early in the event resulted in flow splitting and maximum precipitation immediately west of the lower windward slope.
- As the stability decreased the maximum precipitation shifted over the Olympics higher terrain.
- WRF BMPs underpredicted precipitation over the lower windward slope by 10-30%. Some of this was the result of the precipitation ending too soon.
- WRF P3 scheme more realistically predicted the amounts and precipitation rate which is partially (mostly?) attributed to more riming and precipitation fallout.
- Morrison (2009) scheme showed largest underprediction in precipitation likely due to minimal graupel "riming" production and reduced precipitation fallout.

Citation Aircraft Micro Comparisons with WRF (P3 and MORR)



WRF Micro Along NPOL Section (08 UTC 13 Nov)