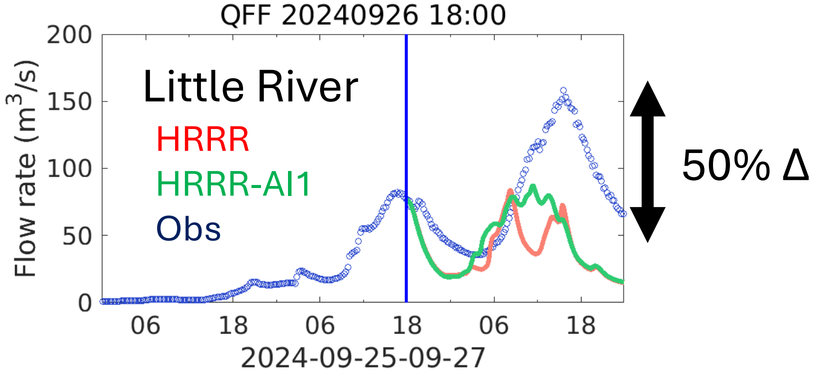
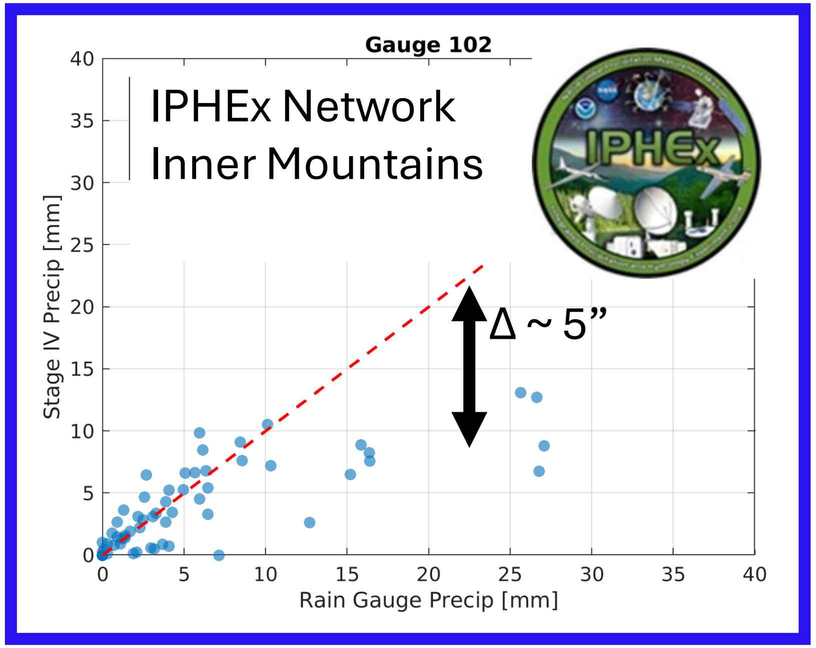
# Challenges for Modeling Extreme Rainfall from Tropical Cyclones in the Appalachians

## Microphysics and the Vertical Structure of Precipitation

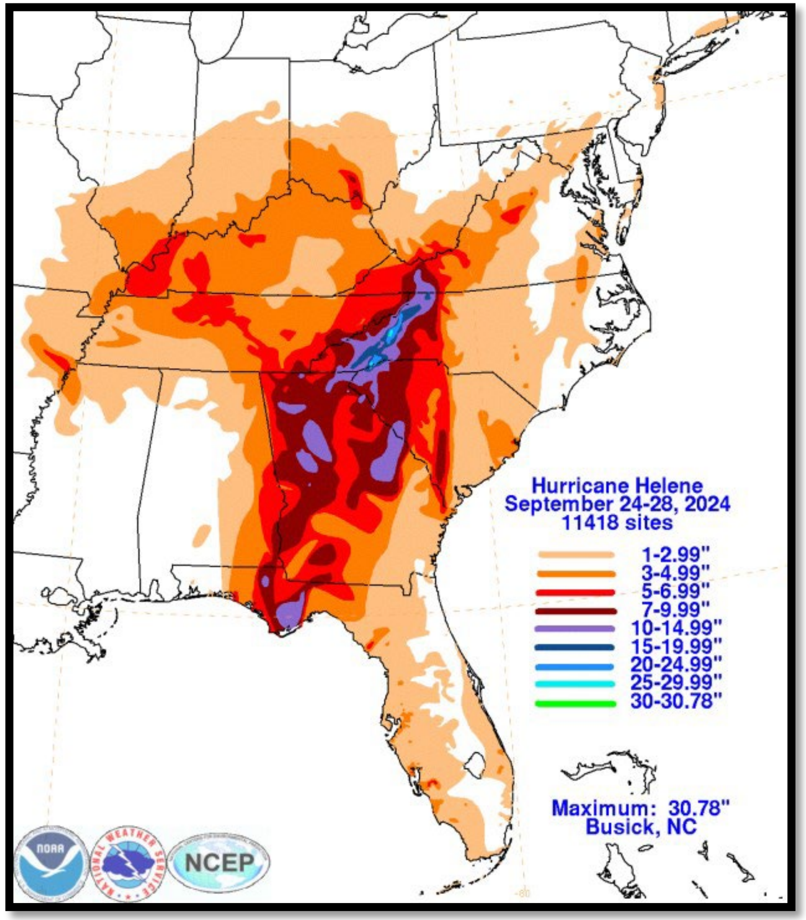
### Tropical Storm Helene

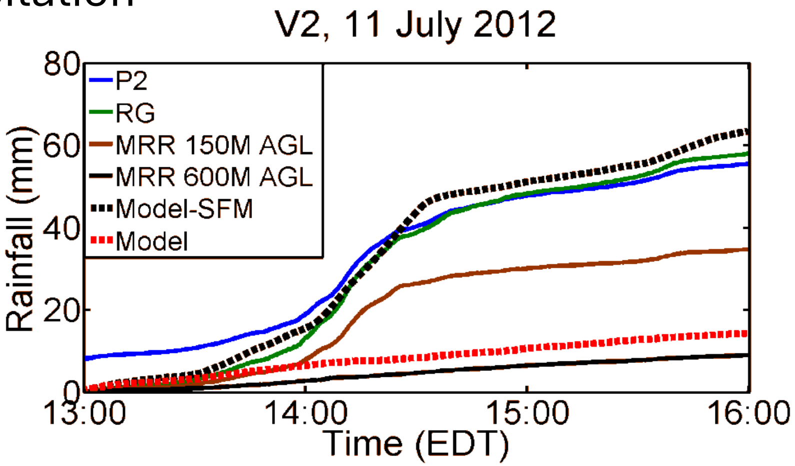
in the valleys, when it rains it pours



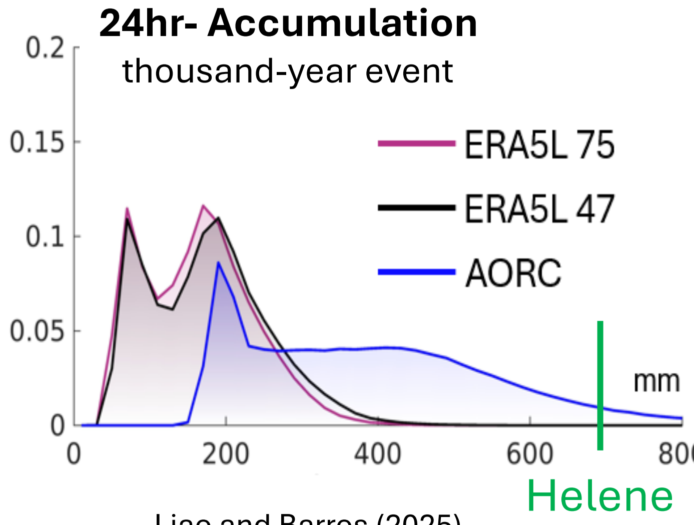




Barros et al. (2014)




Wilson and Barros (2014)




Liao and Barros (2025)

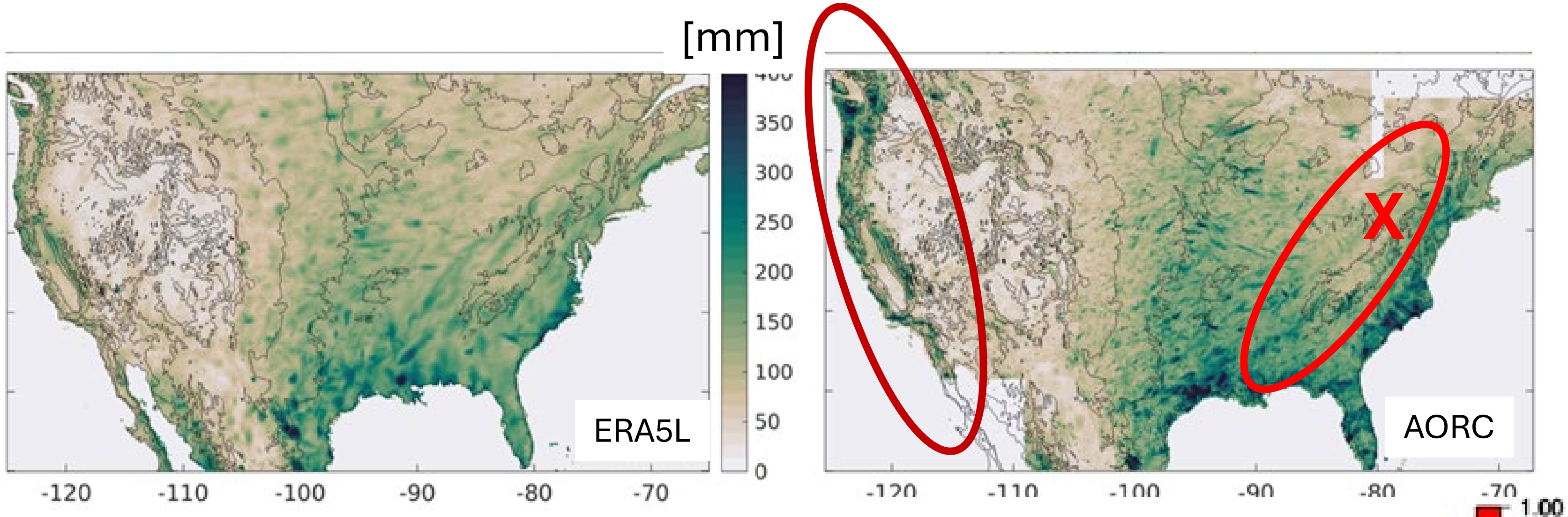
center for secure water

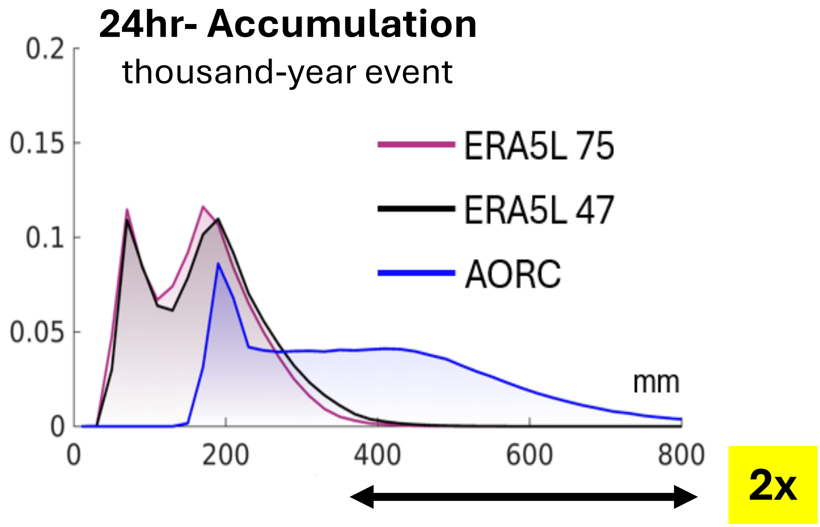
Ana P. Barros - November 4, 2025

NASEM Workshop Extreme Rainfall in Mountainous Terrain:
- Modeling and observational challenges for warm-season precipitation -

# **Extreme Rainfall in Mountainous Terrain:** Models vs Observations

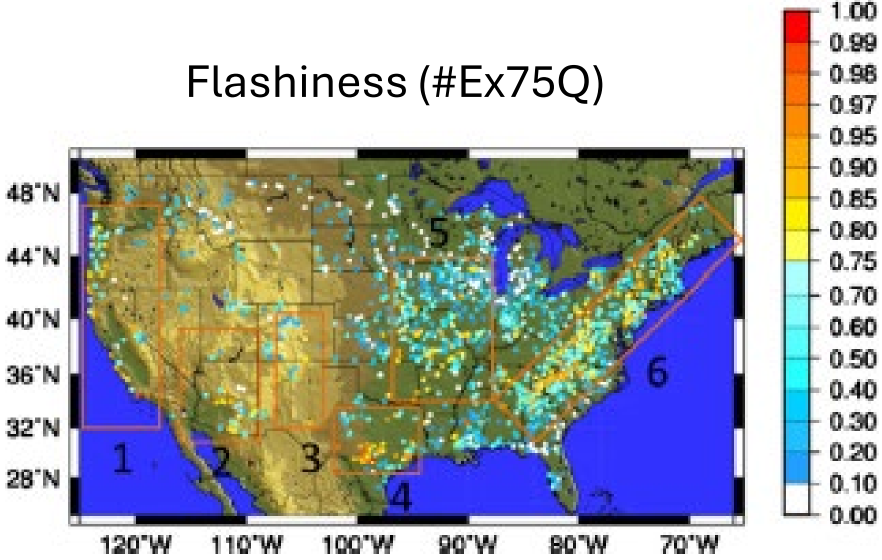
1000 year 24hr Maximum Precipitation

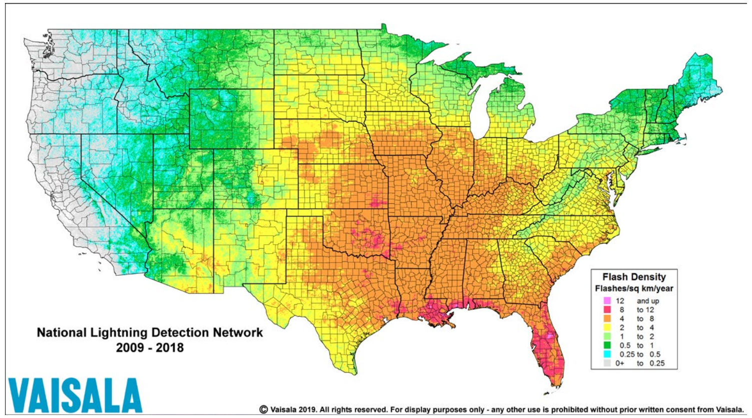


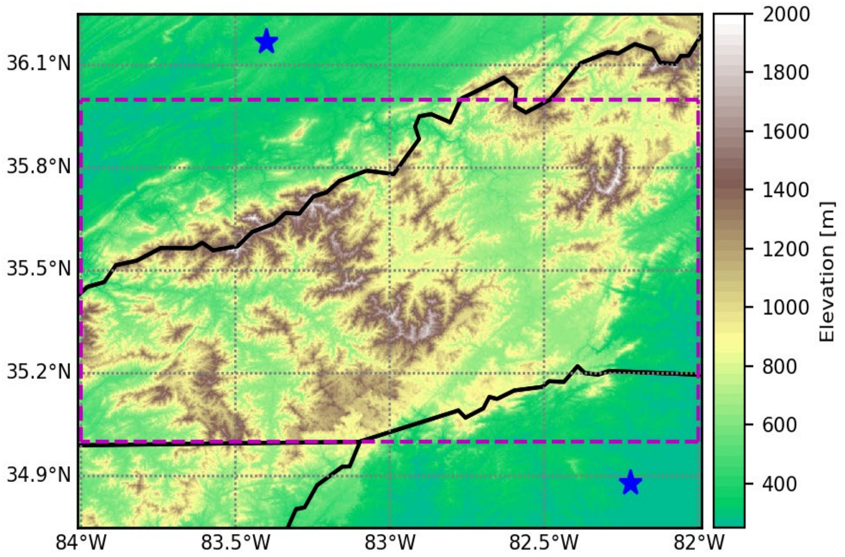

Liao and Barros (2025)

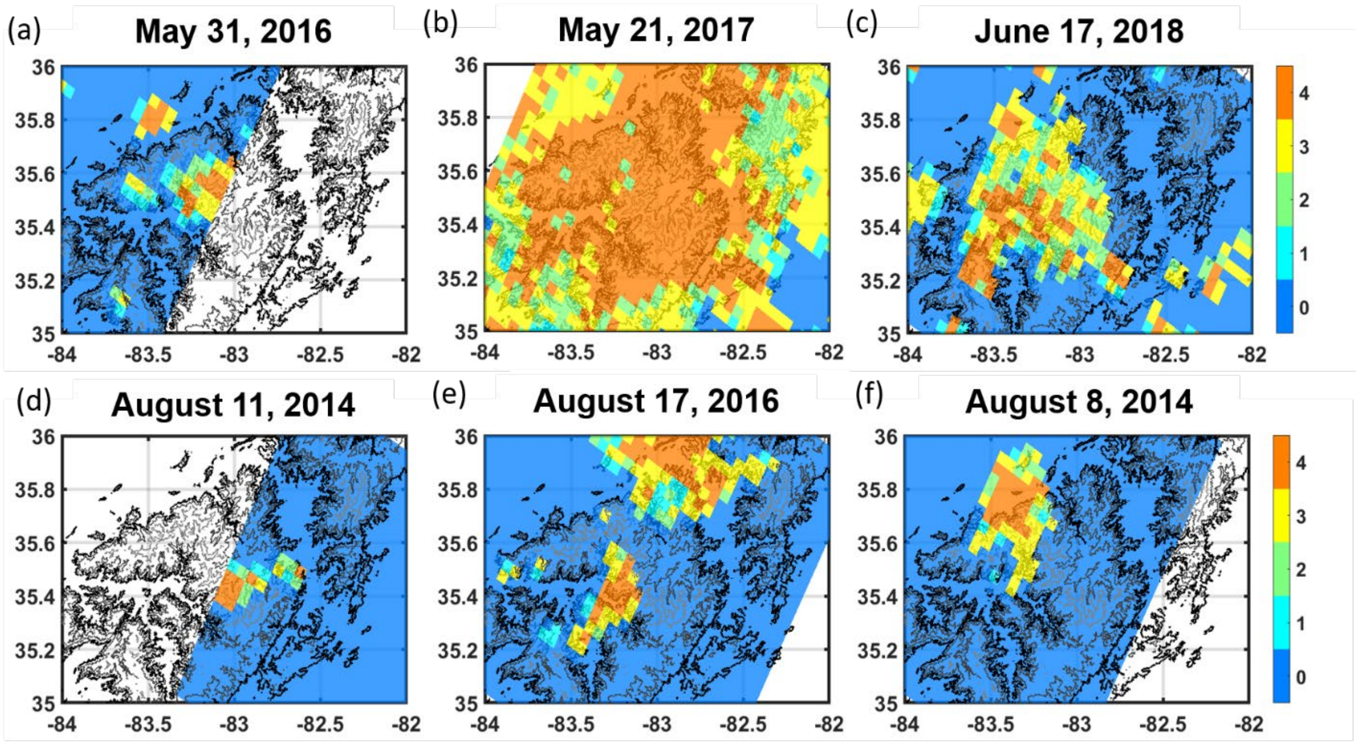

Flashiness (#Ex75Q)

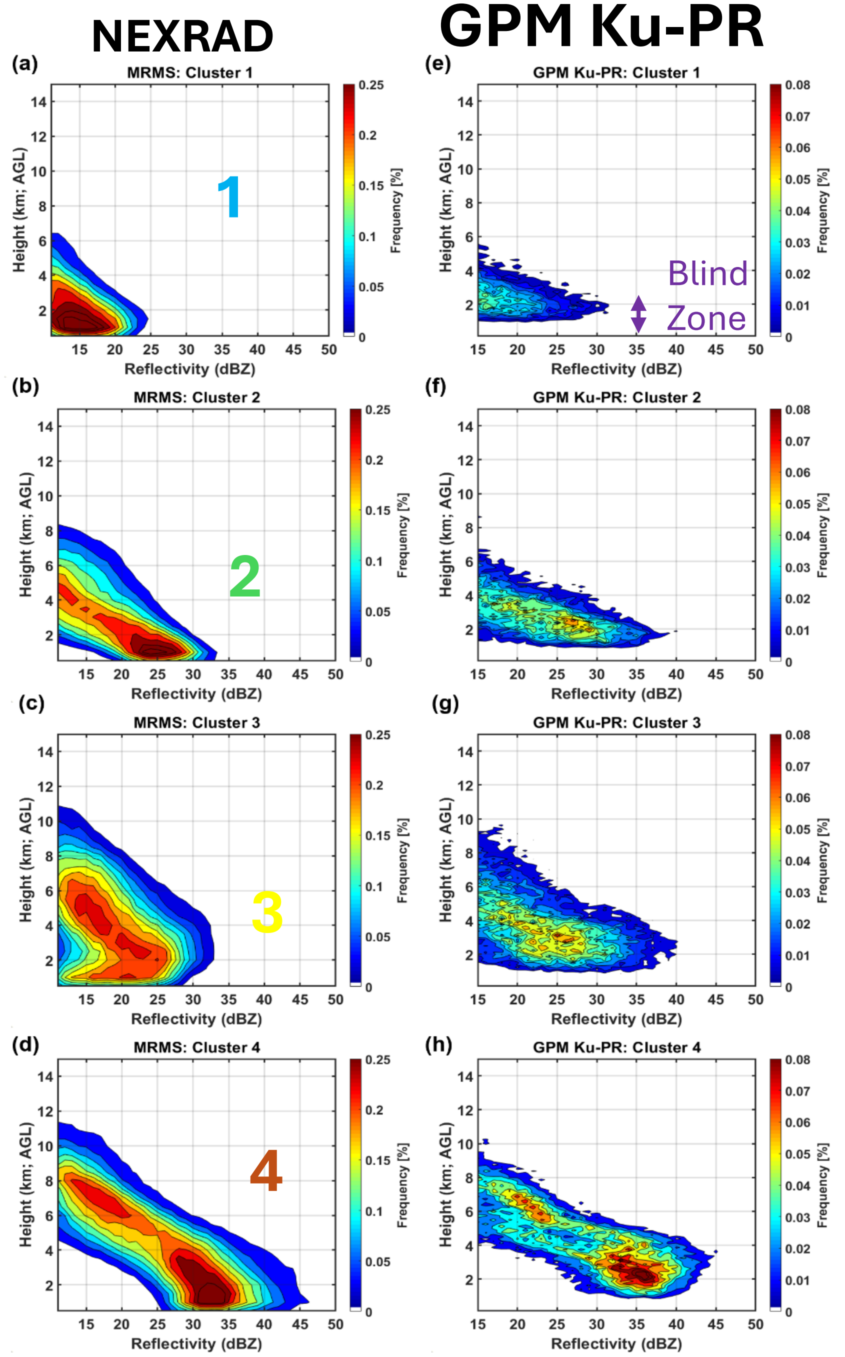


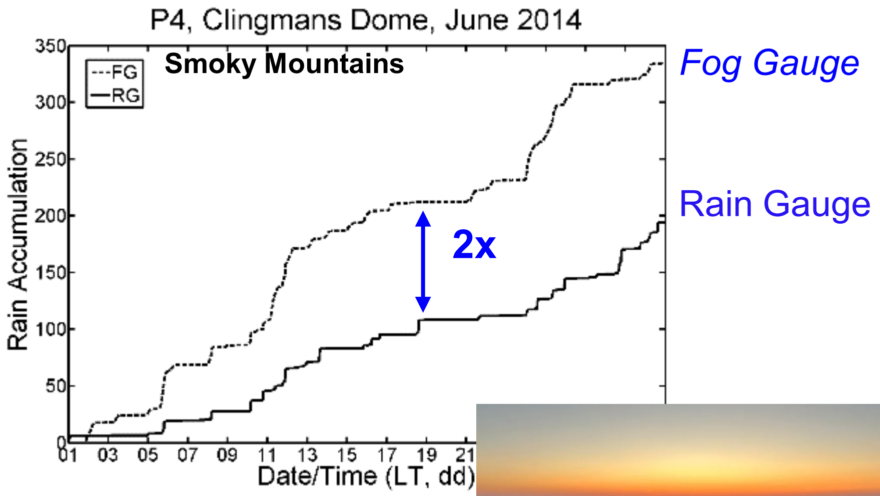

Saharia et al. 2017

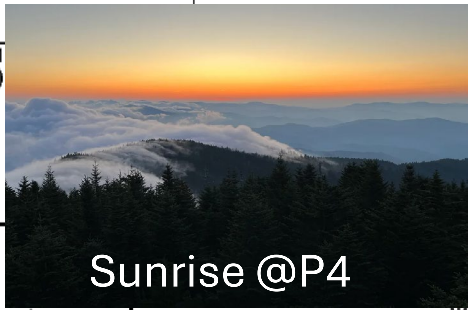


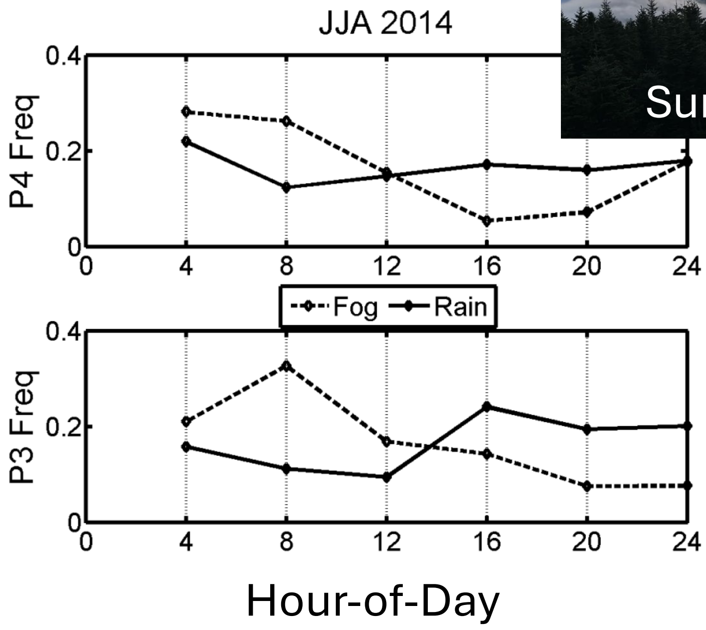



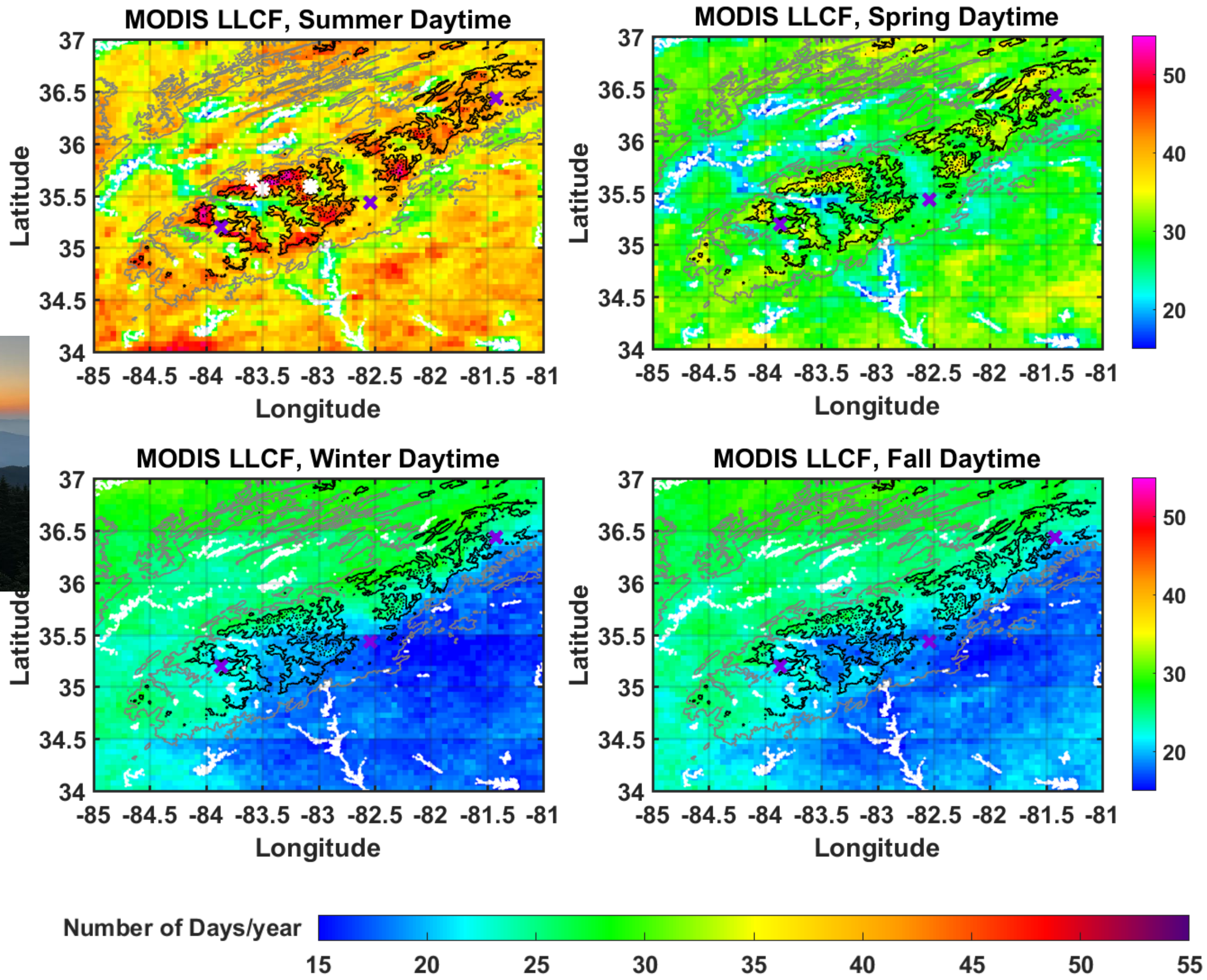

Arulraj and Barros (2021)



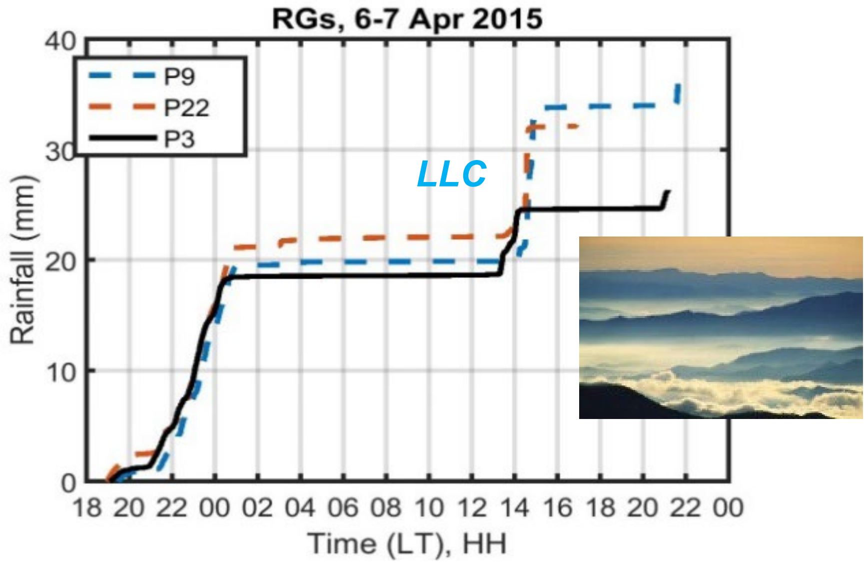



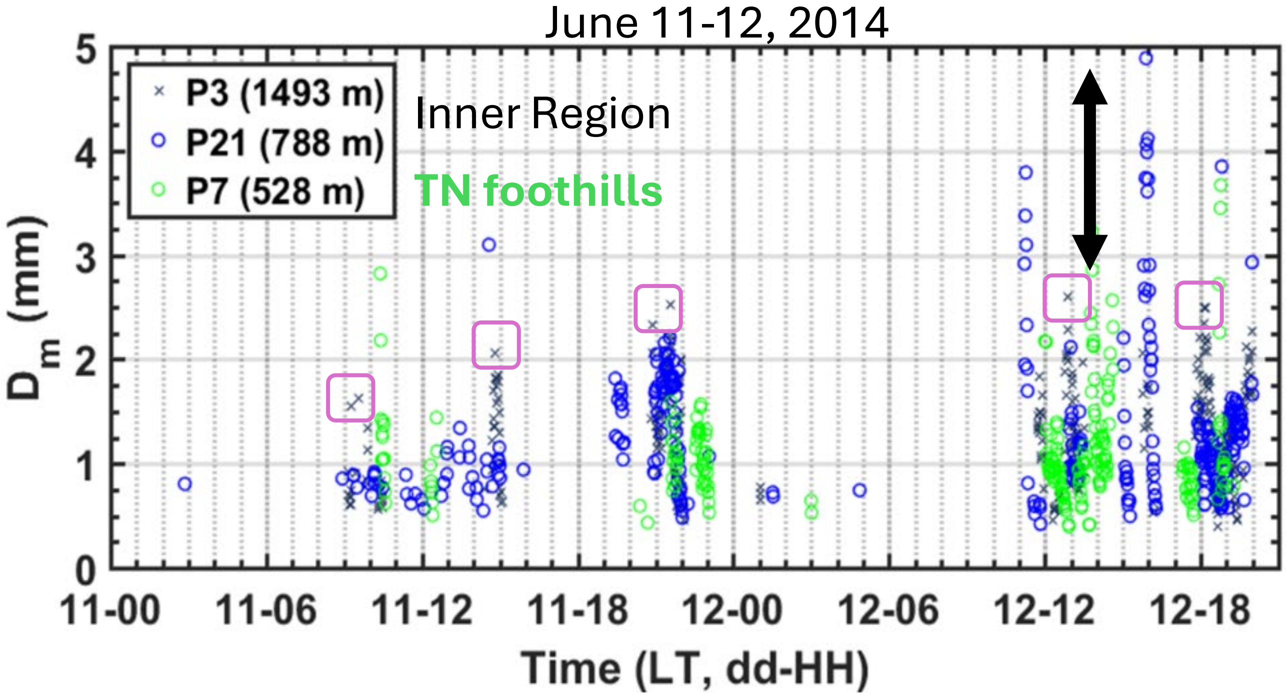



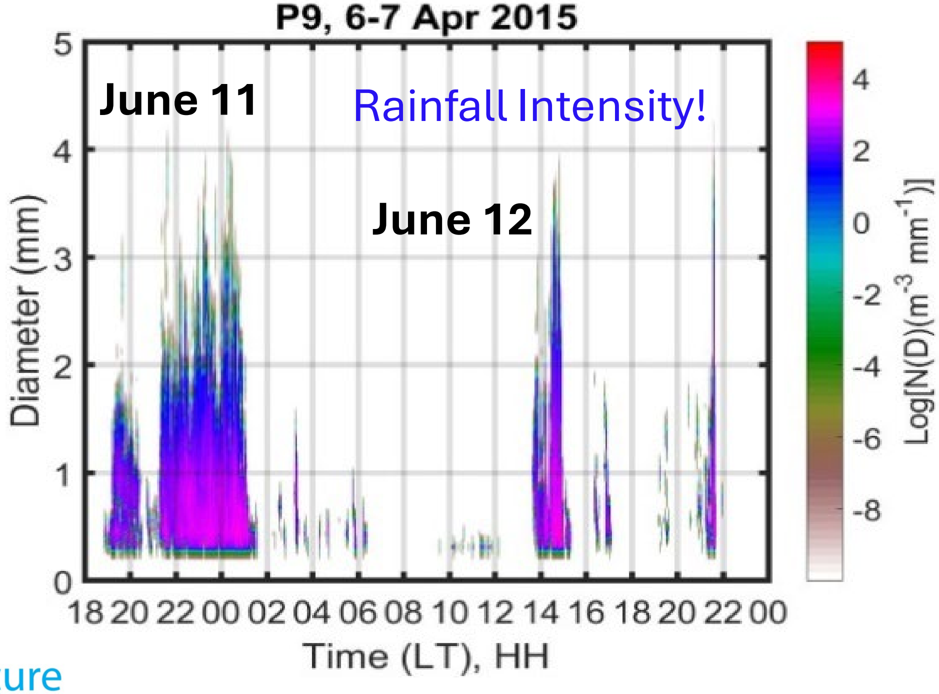

Wilson and Barros (2014, 2015, 2017)

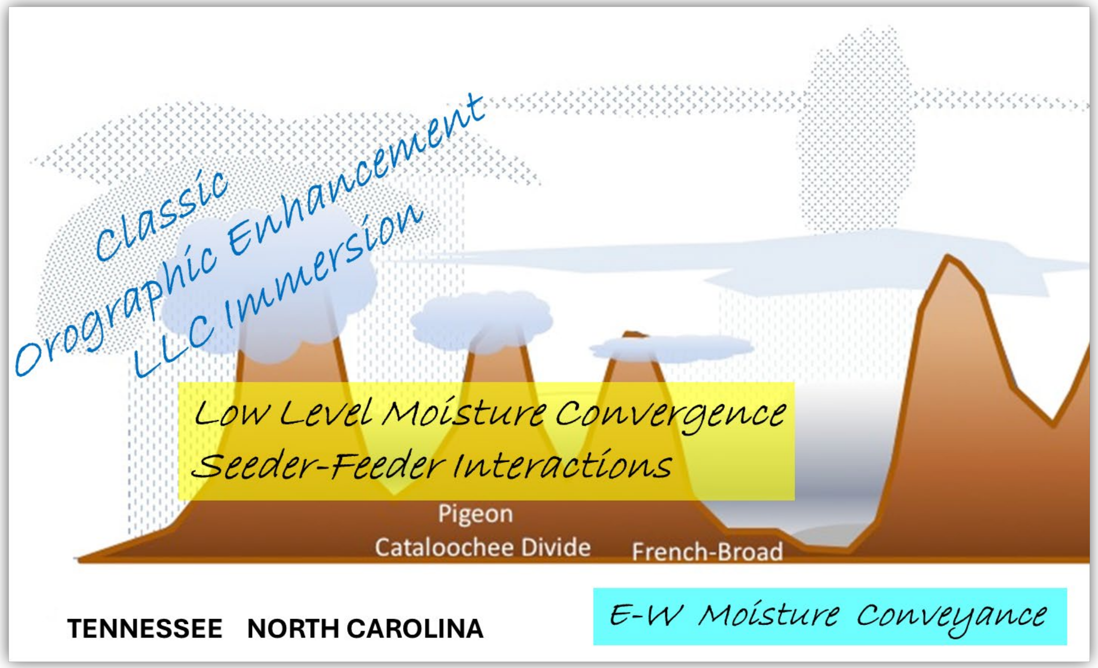



Duan and Barros (2017)

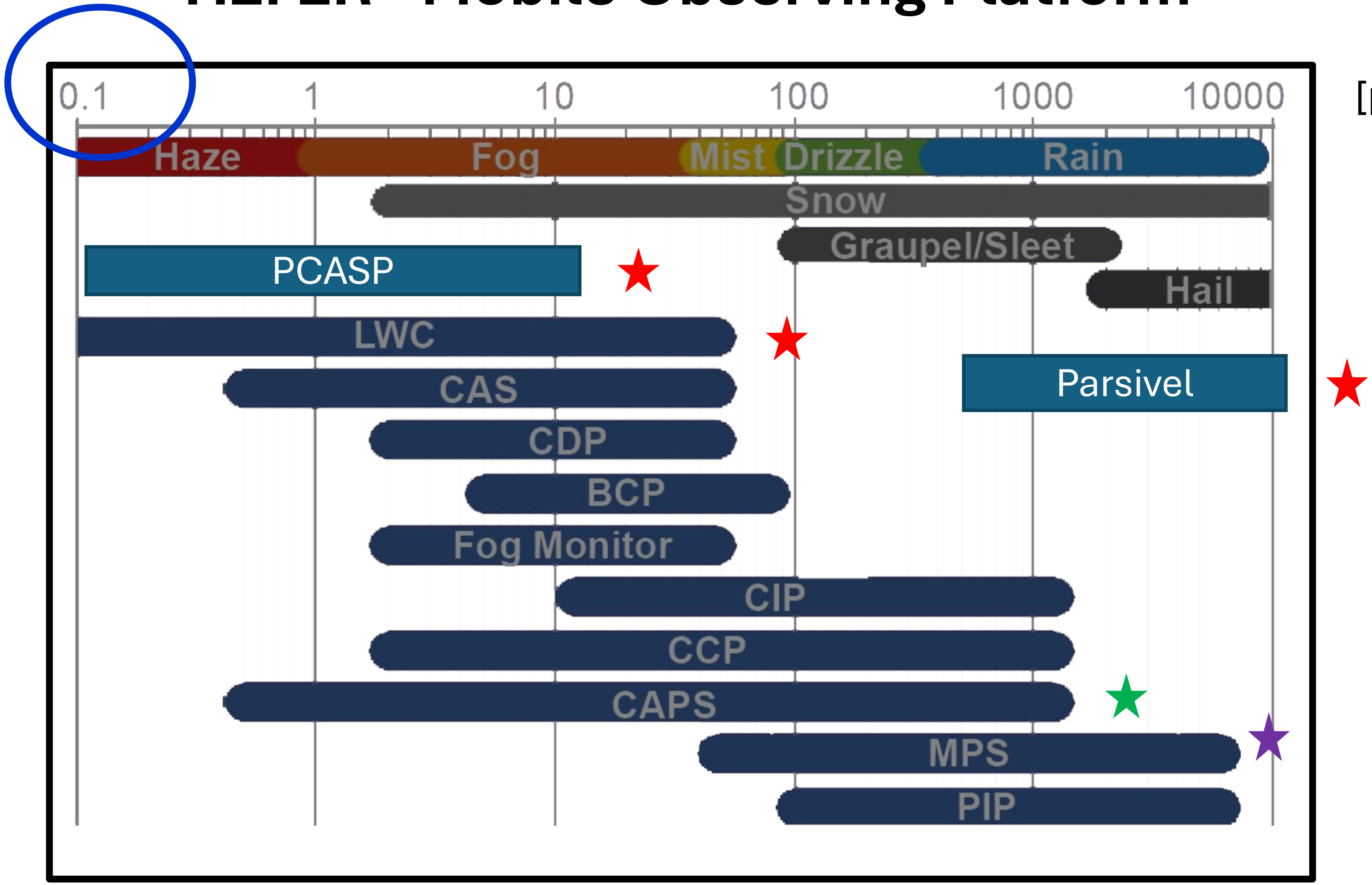

RGs, 6-7 Apr 2015
P9
P22
P3
LLC
Rainfall (mm)
Time (LT), HH
0
10
20
30
40
18 20 22 00 02 04 06 08 10 12 14 16 18 20 22 00


June 11-12, 2014
P3 (1493 m)
P21 (788 m)
P7 (528 m)
Inner Region
TN foothills
$D_m$ (mm)
0
1
2
3
4
5
11-00 11-06 11-12 11-18 12-00 12-06 12-12 12-18
Time (LT, dd-HH)


P9, 6-7 Apr 2015
June 11
Rainfall Intensity!
June 12
Diameter (mm)
0
1
2
3
4
5
18 20 22 00 02 04 06 08 10 12 14 16 18 20 22 00
Time (LT), HH
4
2
0
-2
-4
-6
-8
Log[N(D)(m$^{-3}$ mm$^{-1}$)]

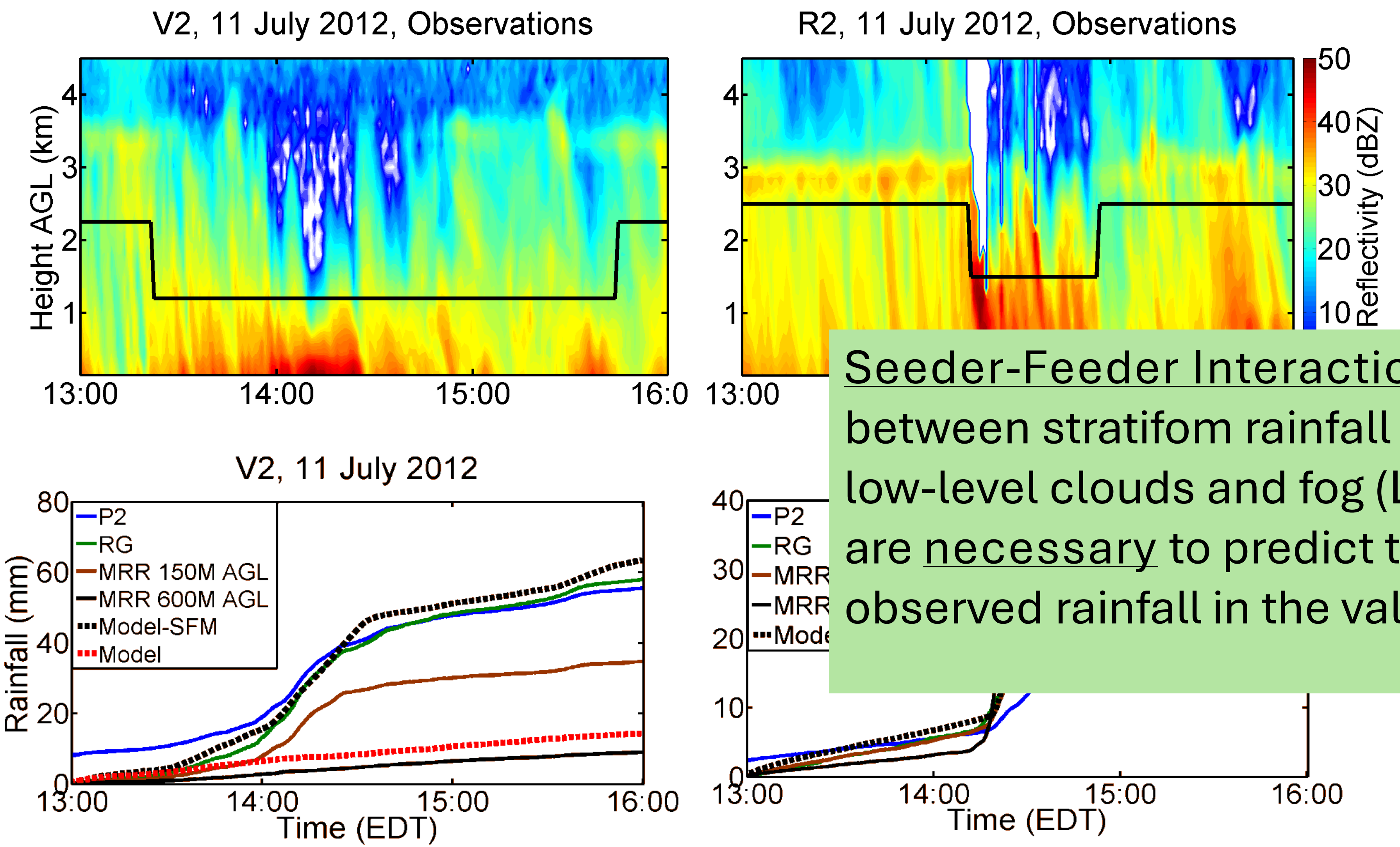

Classic
Orographic Enhancement
LLC Immersion
Low Level Moisture Convergence
Seeder-Feeder Interactions
Pigeon
Cataloochee Divide
French-Broad
TENNESSEE
NORTH CAROLINA
E-W Moisture Conveyance

# H2F2R - Mobile Observing Platform




Weather Station
MRR
Raingauges
Pluvio
Fog Gauges
Web Cam
Tethersonde

# Seeder-Feeder Interactions

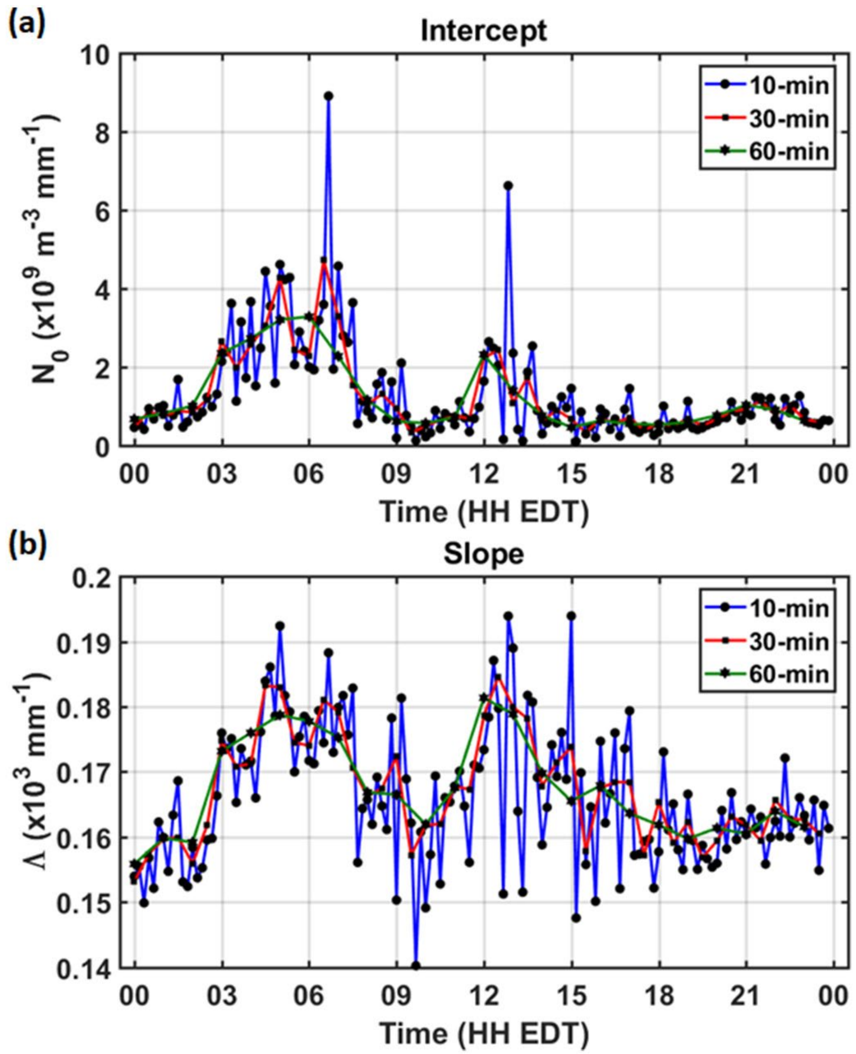




<u>Seeder-Feeder Interactions</u> between stratifom rainfall and low-level clouds and fog (LLCF) are <u>necessary</u> to predict the observed rainfall in the valley.

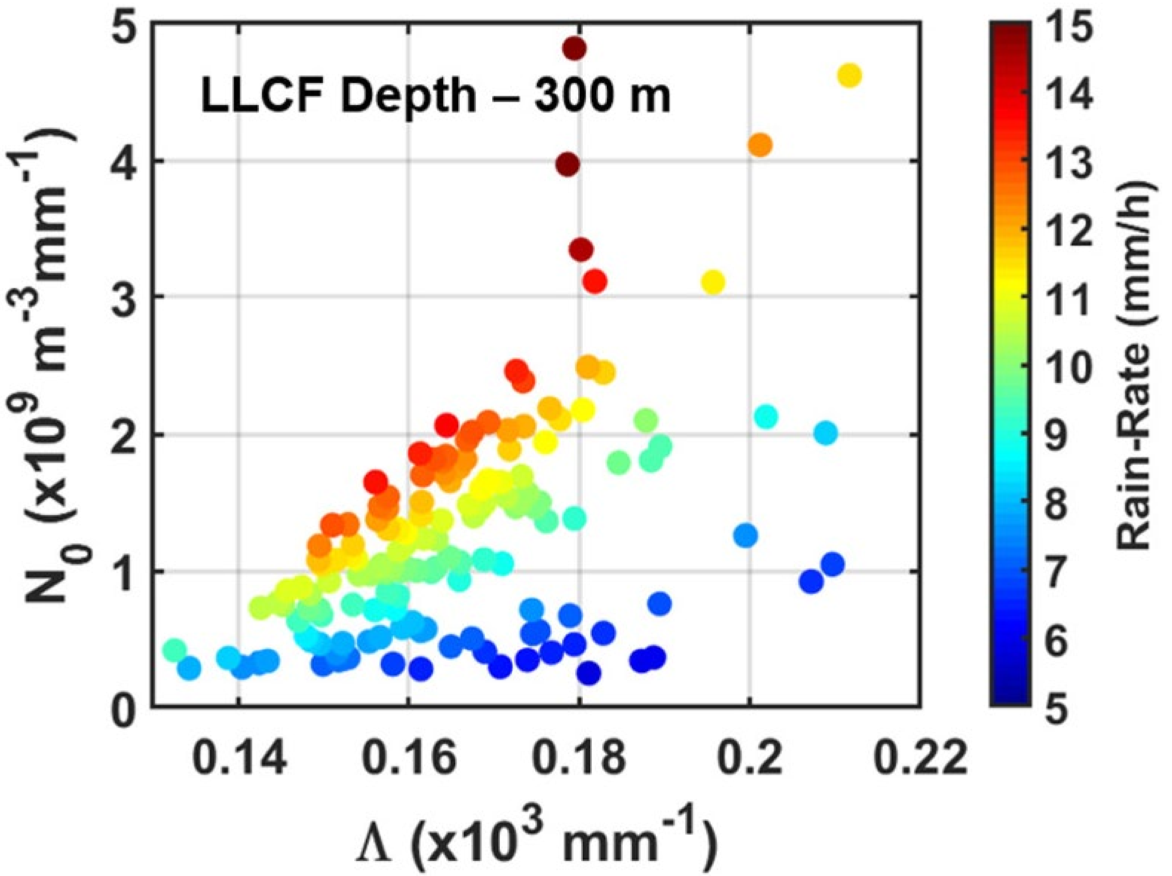
Wilson and Barros (2014)

# Diurnal Cycle of Microphysics

$N(D) = N_o \exp(-\Lambda D)$




## Nonlinear DSD Dynamics



# Impact of Aerosols on the Vertical Structure of Precipitation

## Scattered Convection

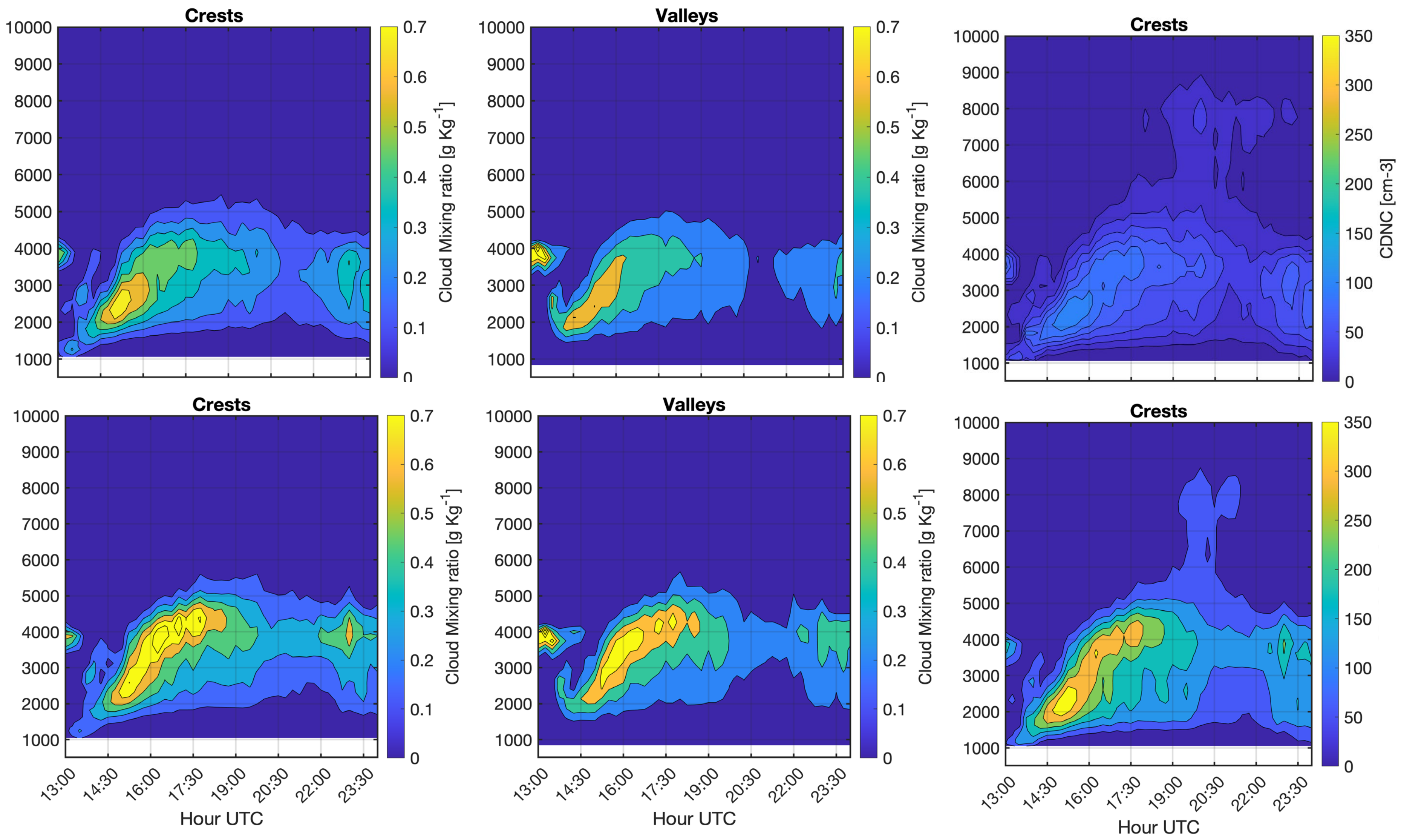
WRF simulations (1 km)

Cloud Mixing Ratio

Drop Number Concentration

**CONT**
( Mix,HH)

**IPHEx**
(Org, LH)




elevation < 1000 m
Main ridges: elevation > 1000 m

Chavez and Barros (2023)
Duan et al. 2019

center for secure water

# Impact of Aerosols on the Vertical Structure of Precipitation

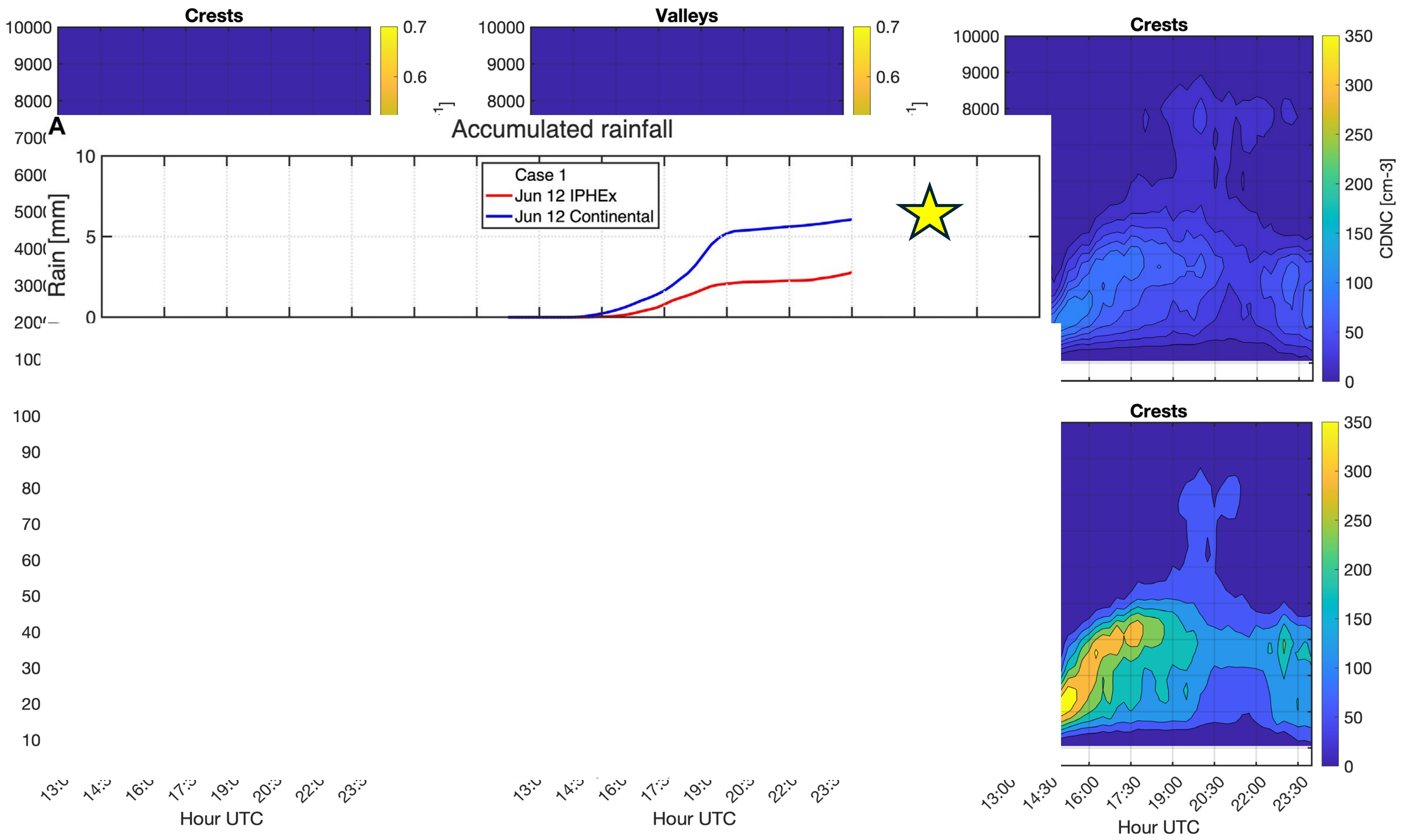
## Cloud Mixing Ratio

## Drop Number Concentration

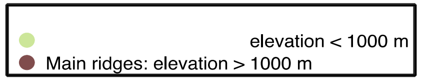
**Scattered Convection**

WRF simulations (1 km)

**CONT**
( Mix,HH)

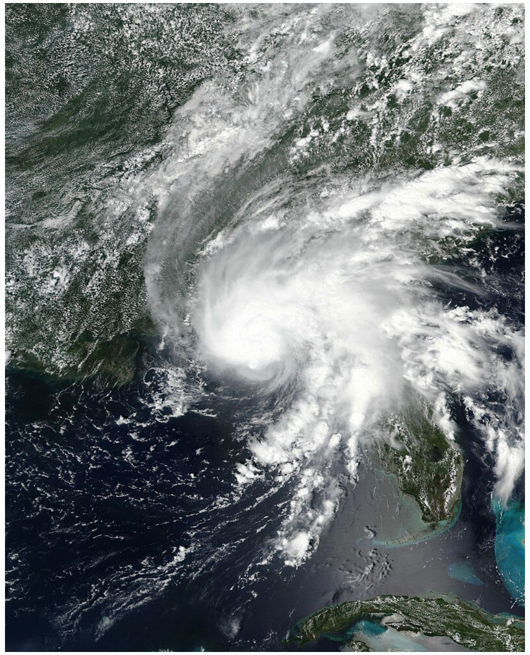


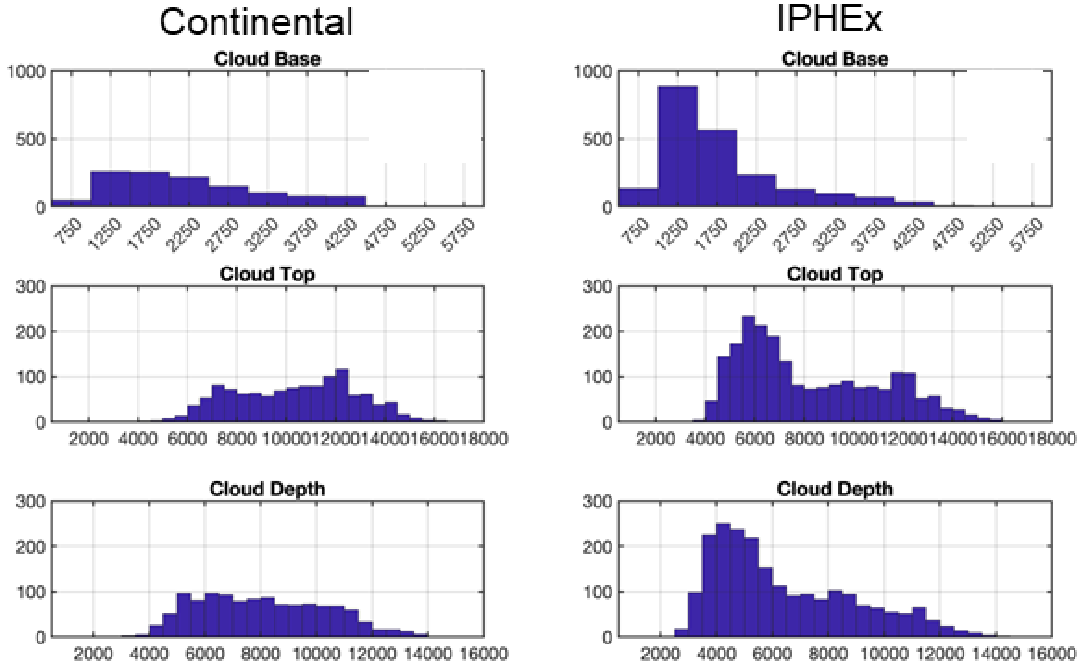

**IPHEx**
(Org, LH)

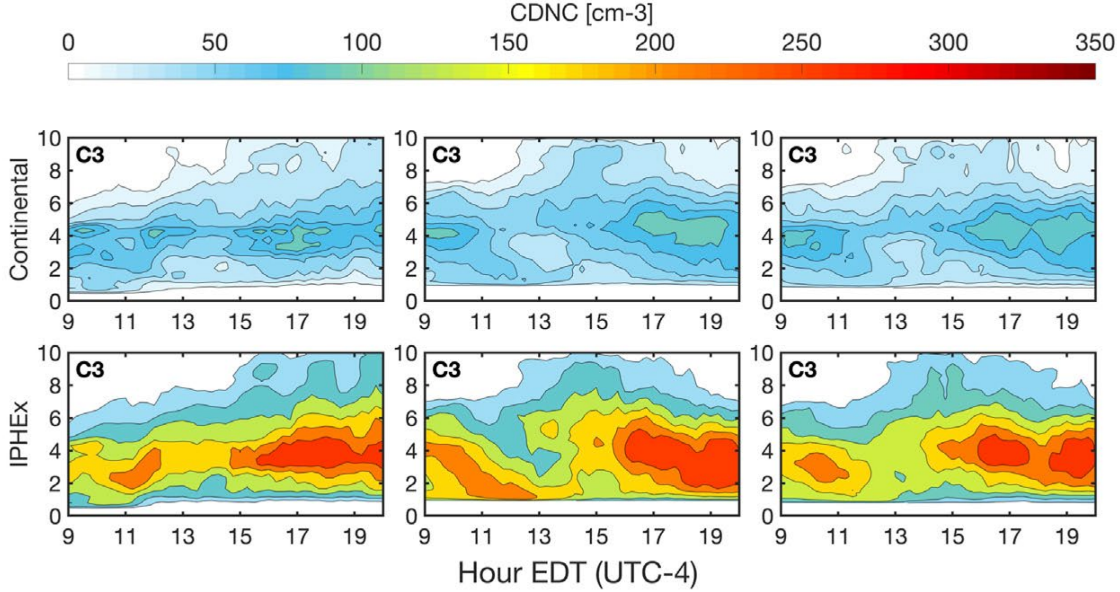



Chavez and Barros (2023)
Duan et al. 2019

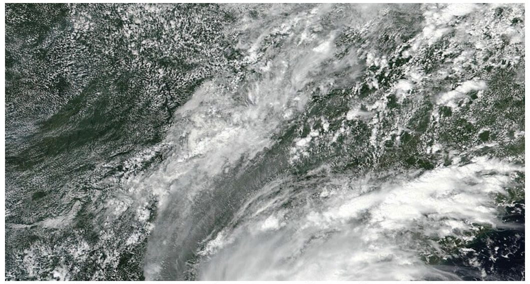
# Tropical Storm Fred

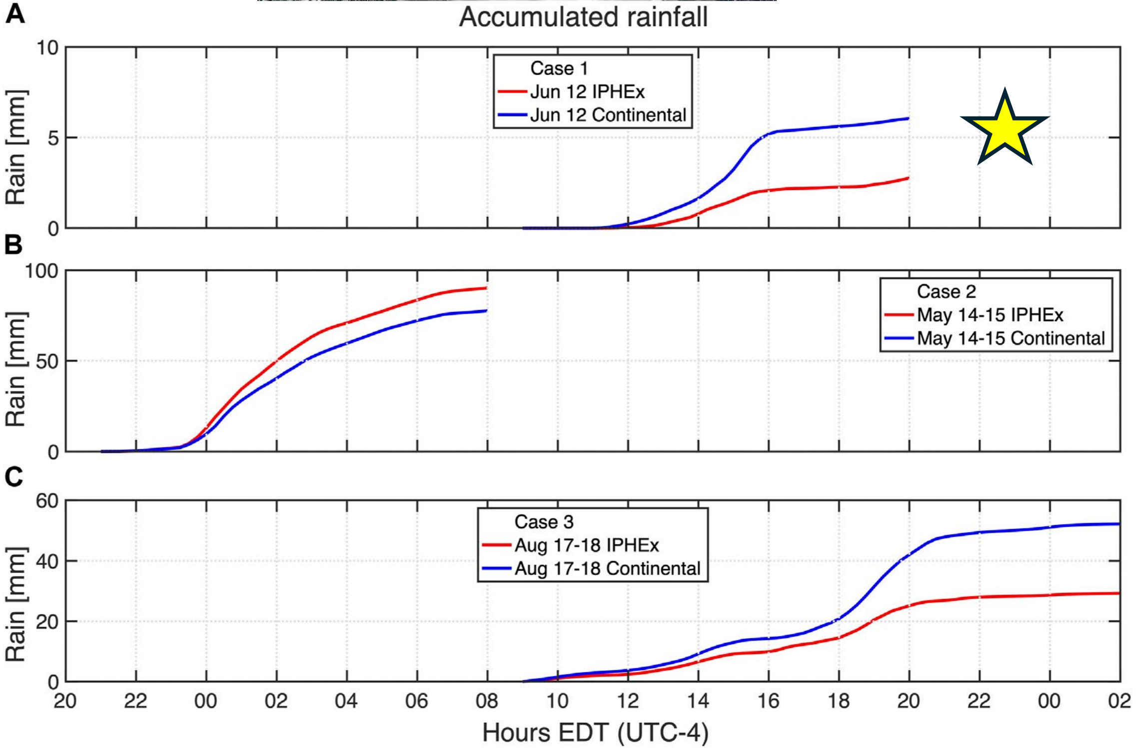




# Tropical Storm Fred



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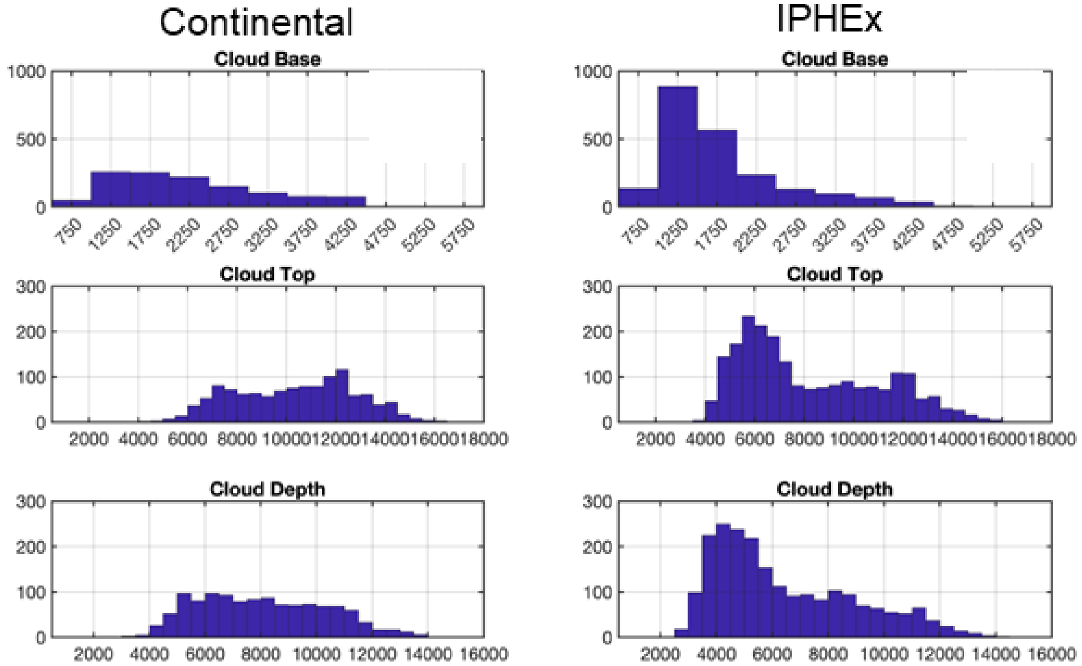
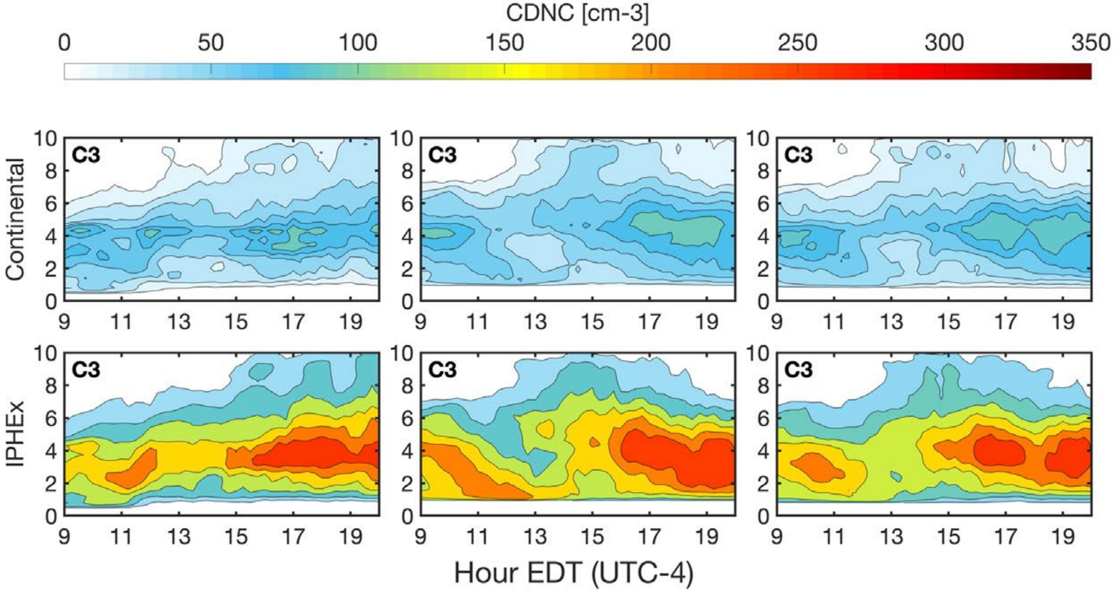
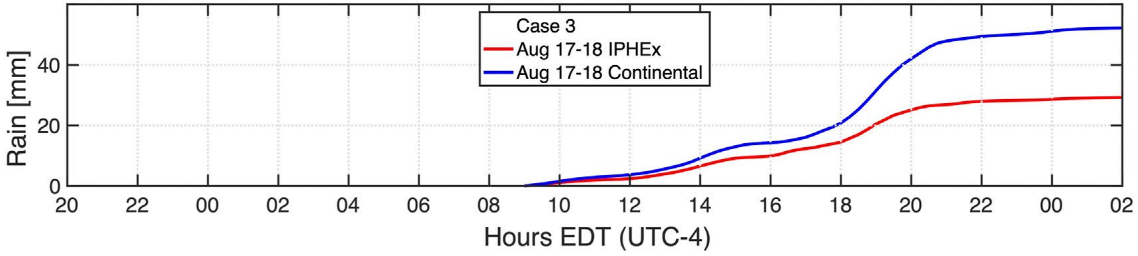
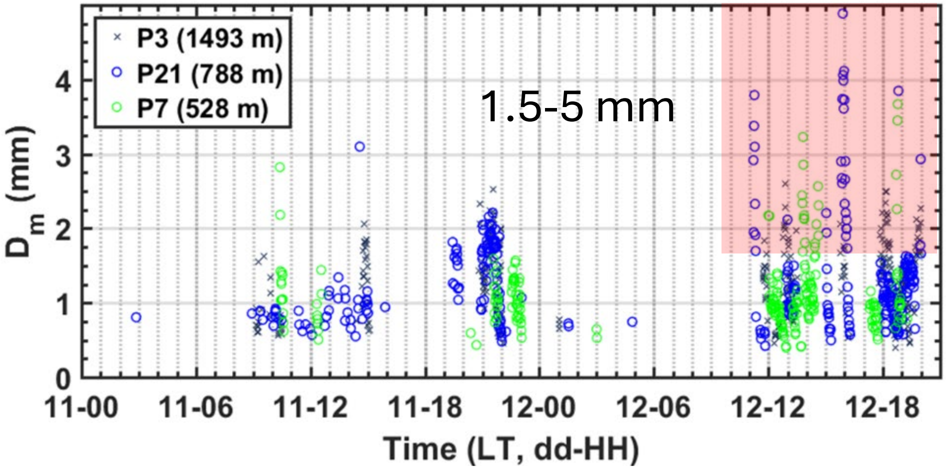
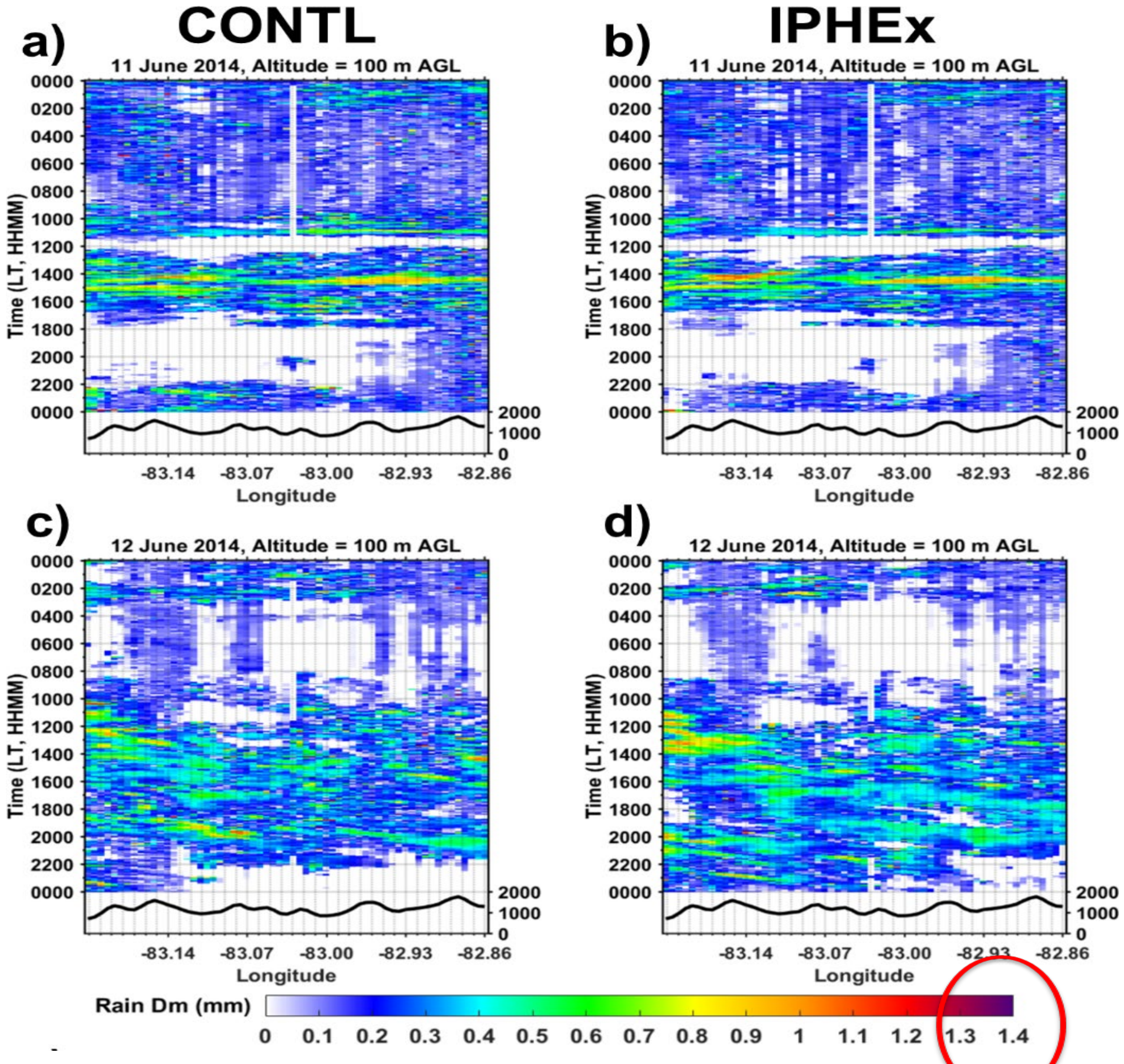



Lack of DSD dynamics and SFI in the model to accelerate hydrometeors removal before they are advected out




Strong Synoptic Forcing

Weak Synoptic Forcing

- ❑Models Strongly Underestimate Heavy Rain
- ❑Resolution is not enough
- ❑Model Structural Uncertainty (not addressed by ensembles)
- ❑Must Represent Vertical Structure & Space-Time Microphysics

- ❑**Integrated Science-Grade Observations**

**Thank you!**

# References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