From Snowflake to Snowpack:

How do Cloud Microphysical Representations Influence Hydrologic Response?

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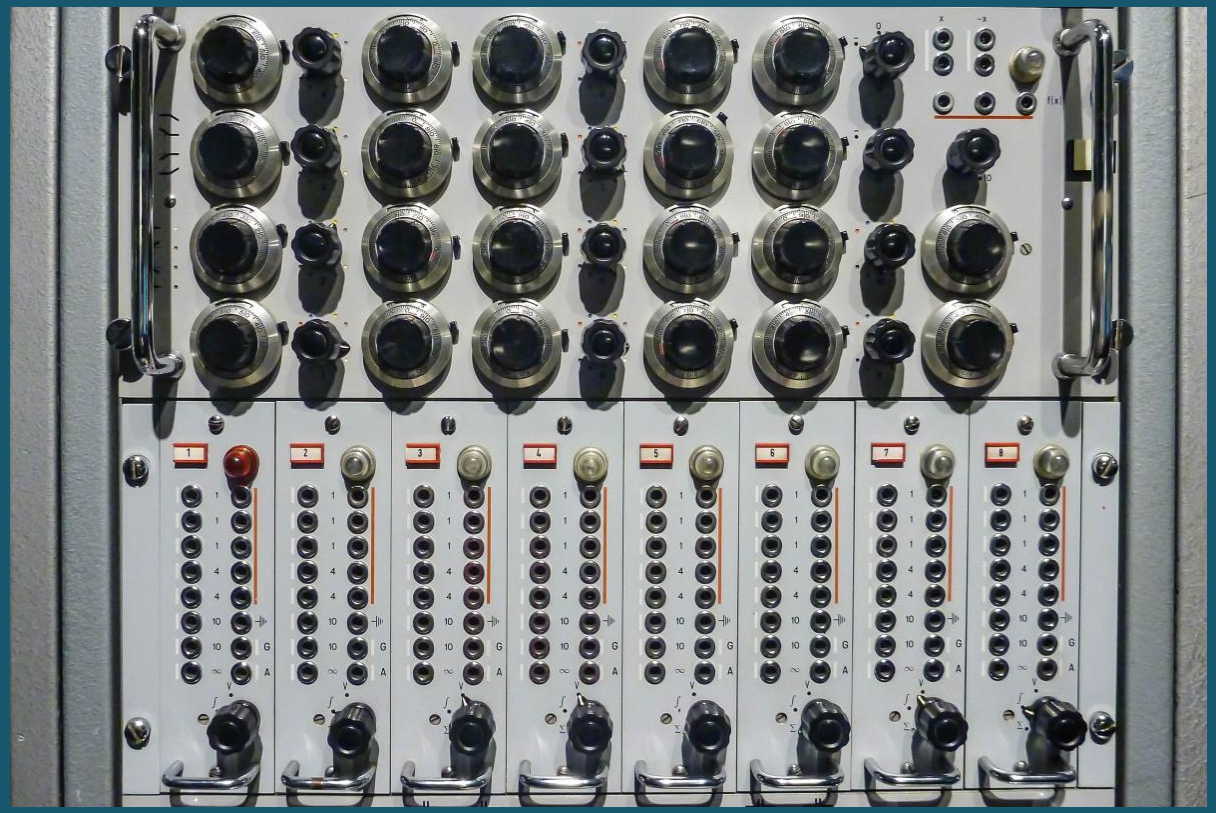
Motivating Issues and Questions

- Hydrologic models and process studies require forcings
- Climate models run at convection-permitting resolutions can produce reasonable-looking precipitation at O(km)
- Commonly used models aren’t so much models as much as modeling frameworks requiring choices
- Evaluating model outputs is challenging: benchmark datasets are often not entirely independent
- How can we evaluate precipitation from convection-permitting climate models from a hydrologic context?

The Modeler's Dilemma

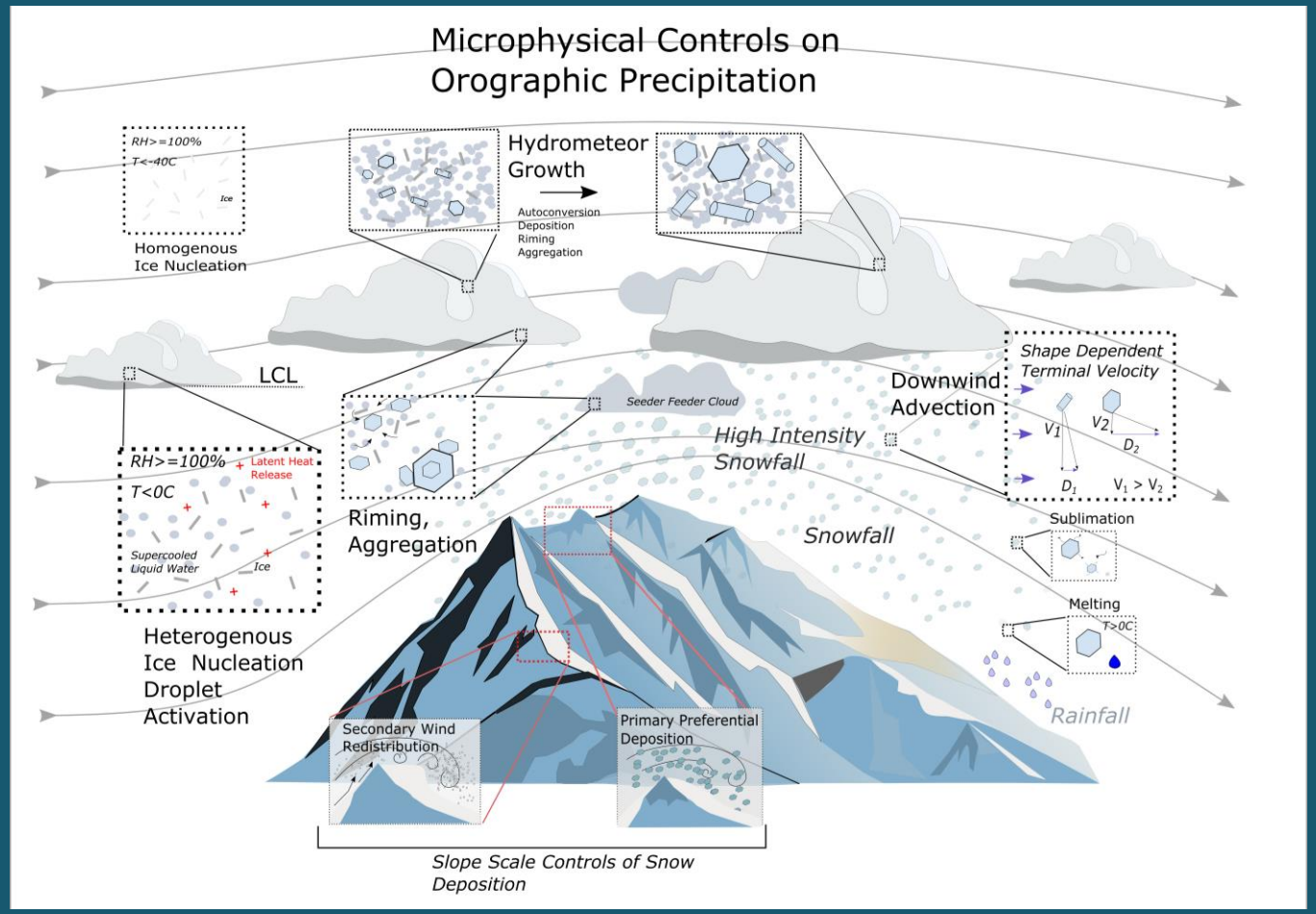


From: https://pxhere.com/en/photo/874919 [CC0]

When choosing model options, we often ask:

- Which option is most physically realistic?
- Which options produces better results?
- The answer is often not the same!

Microphysics Control Precipitation



Rudisill et al., in review

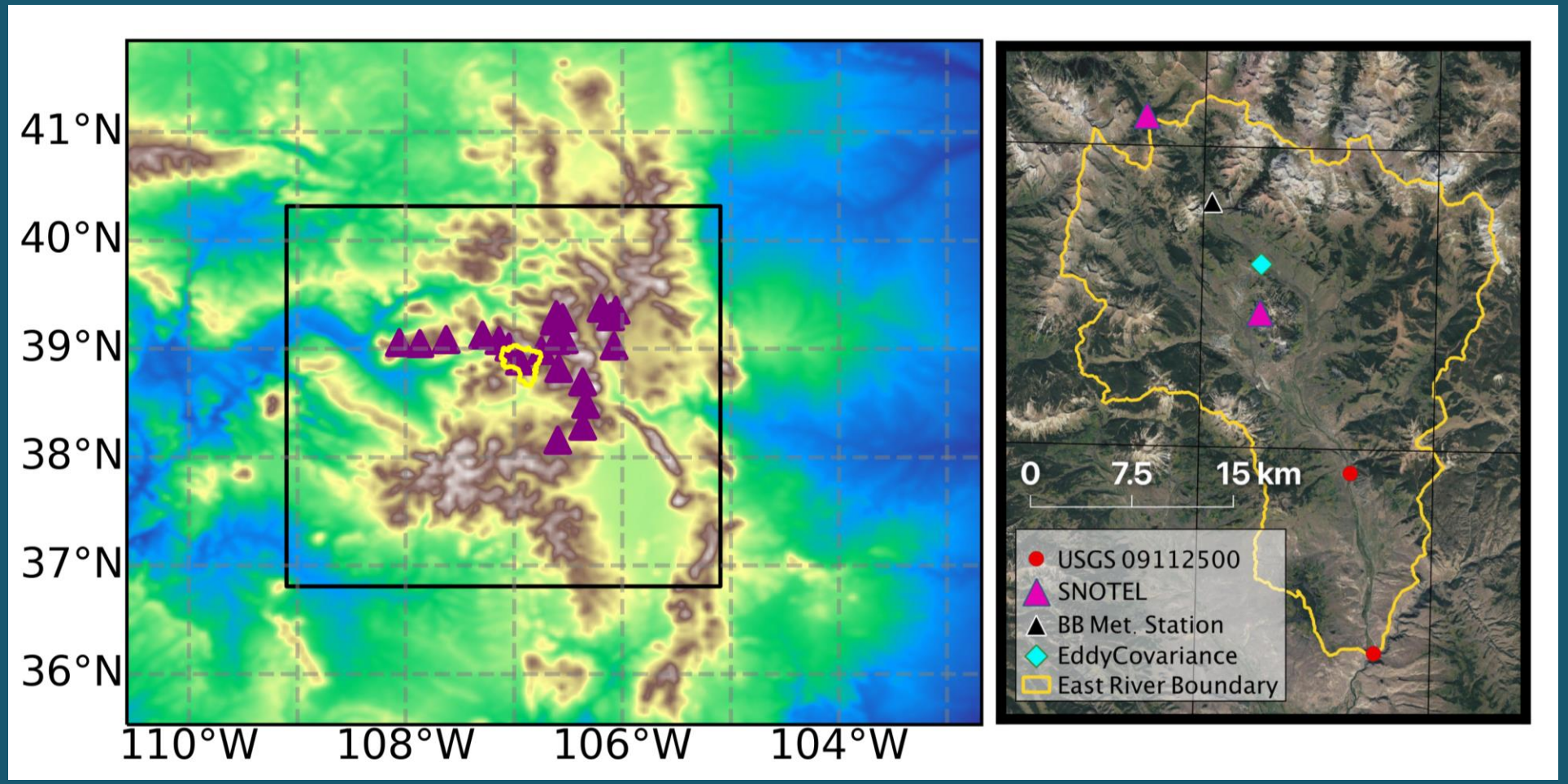
Full WRF Configurations

Physics Parameterization	Option	Reference
Convection	None	N/A
Microphysics	Thompson (MP08)	Thompson et al. (2008)
	Morrison (MP10)	Morrison et al. (2005)
	Ismael (MP55)	Jensen et al. (2017)
LSM	Noah-MP	Niu et al. (2011)
Surface Layer	Monin-Obukhov (Option 2)	Monin and Obukhov (1954)
Planetary Boundary Layer	Mellor-Yamada-Janjic (Eta/NMM) PBL	Janić (2001)
Longwave Radiation	Community Atmosphere Model (CAM)	Neale et al. (2010)
Shortwave Radiation	Community Atmosphere Model (CAM)	Neale et al. (2010)

WRF Numerical Experiments

- Nested 3 and 1 km grids centered on central CO Rockies
- WY2018 and WY2019 runs (Oct.-May) forced by CFSv2:
  - Thompson et al. (2008) [MP08]
  - Morrison et al. (2005) [MP10]
  - Jensen et al. (2017) [MP55]
- Offline model runs with Noah-MP
- East and Taylor River Watersheds
  - DOE SC Watershed Function Scientific Focus Area
  - DOE ARM Surface Atmosphere Integrated field Laboratory (SAIL)
- Airborne Snow Observatory snow depth and SWE retrievals

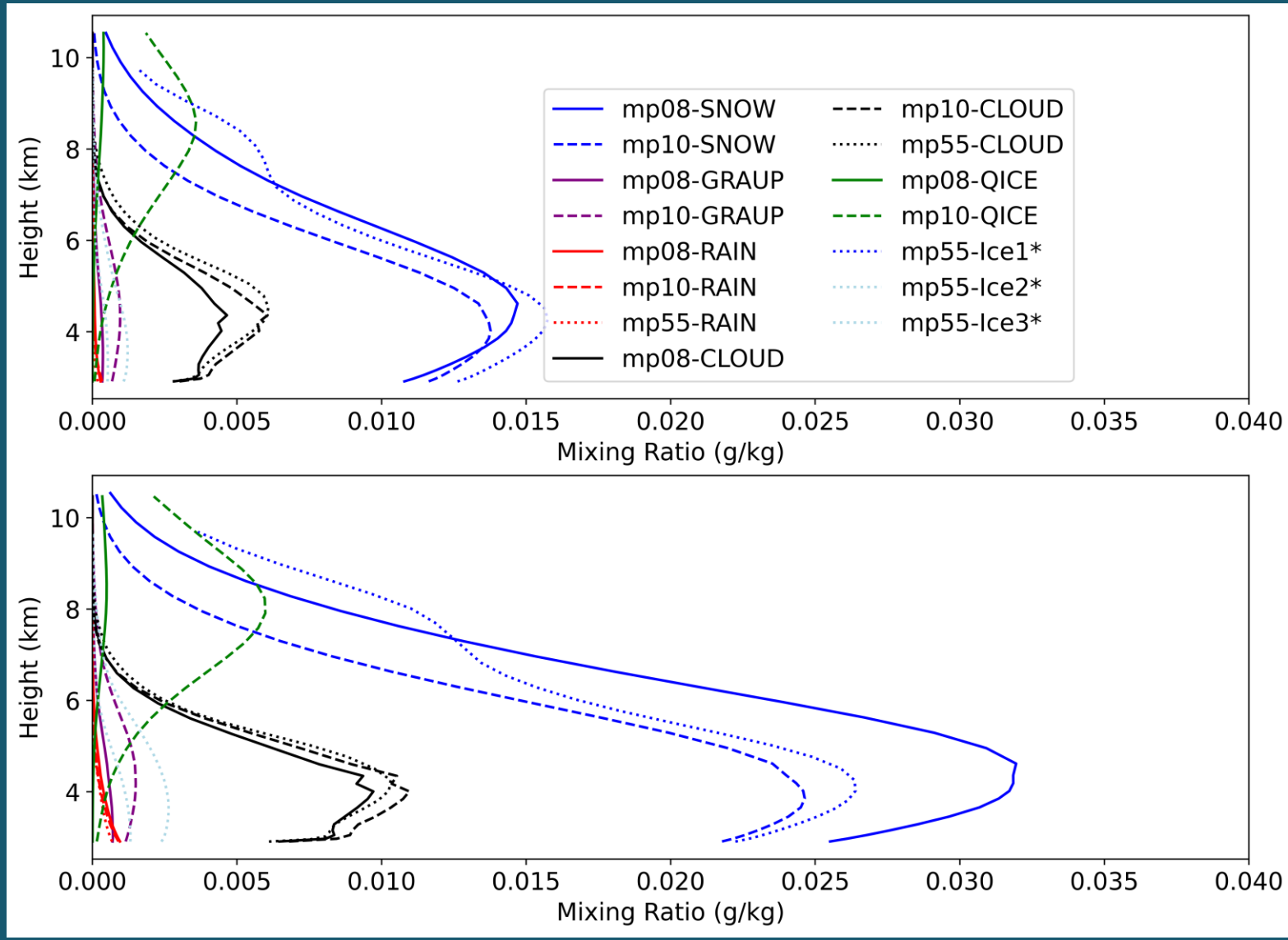
Full WRF Domain



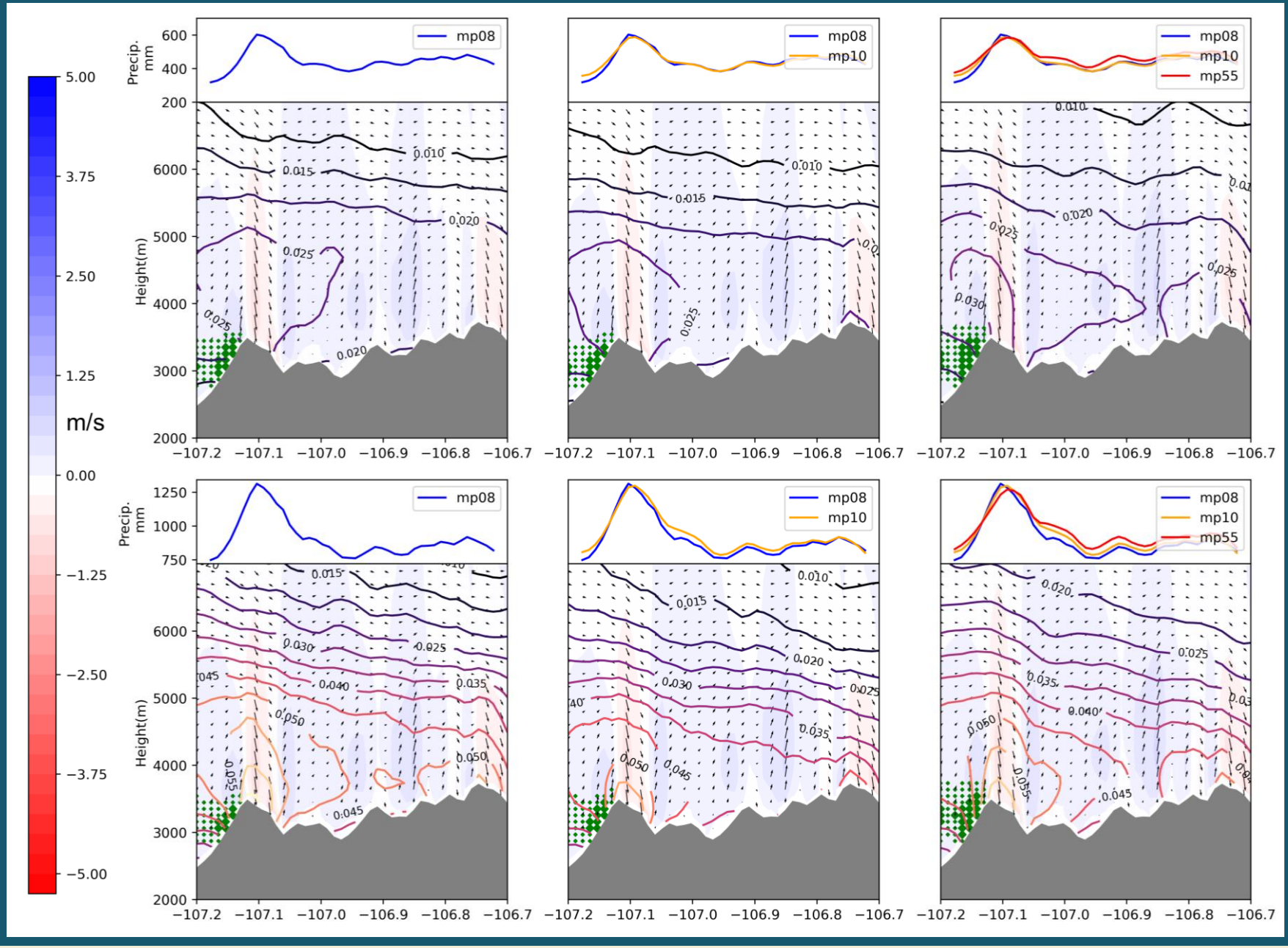
Somewhat of an Apples::Oranges Comparison

Schemes differ in:

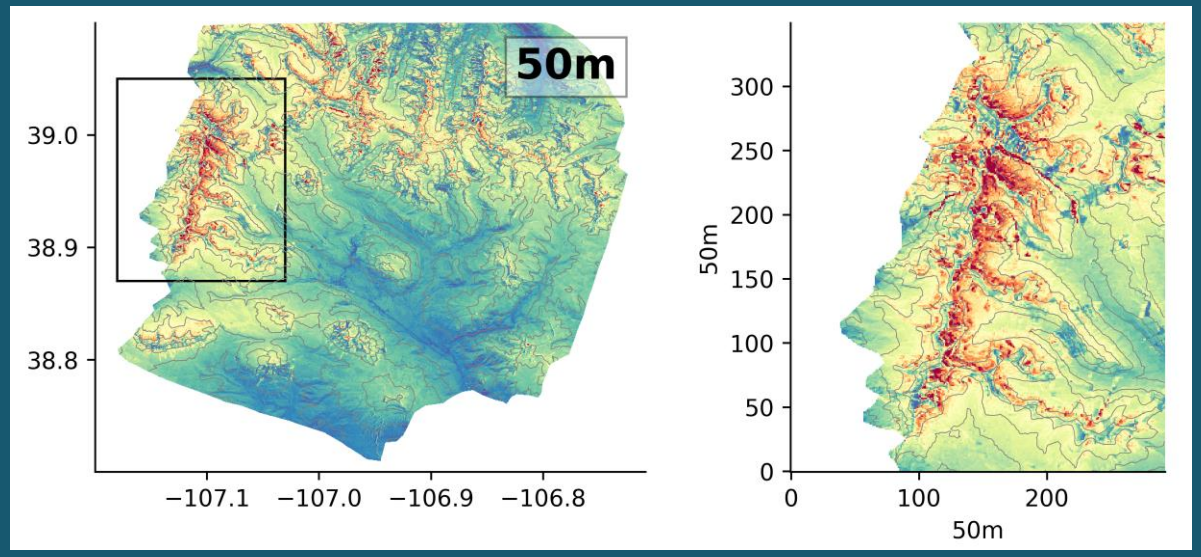
- # of hydrometeor classes
- Shape and orientation

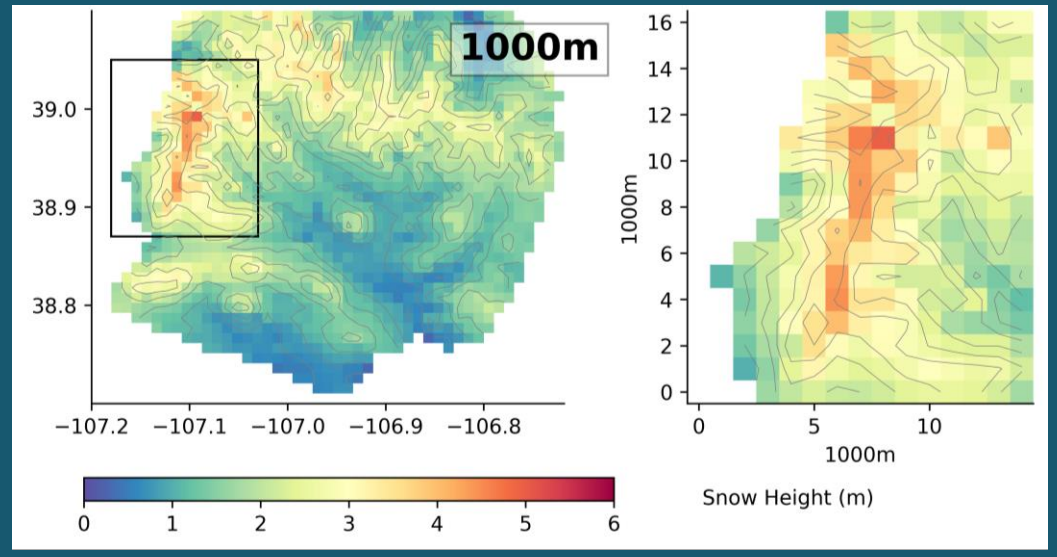


Rudisill et al., in review


mp08
mp10
mp55
Precip. mm
Height(m)
m/s
5.00
3.75
2.50
1.25
0.00
−1.25
−2.50
−3.75
−5.00
−107.2
−107.1
−107.0
−106.9
−106.8
−106.7

Airborne Snow Observatory Data

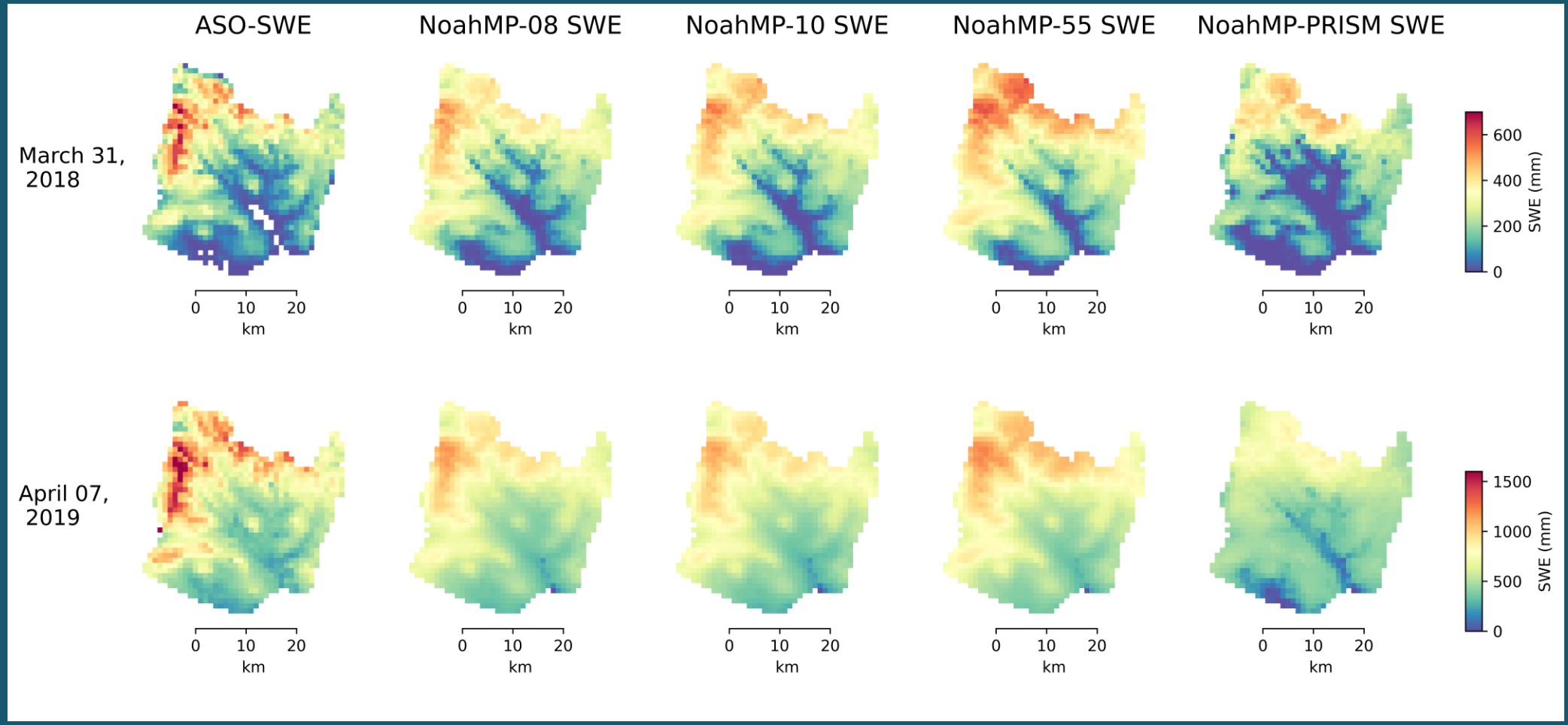




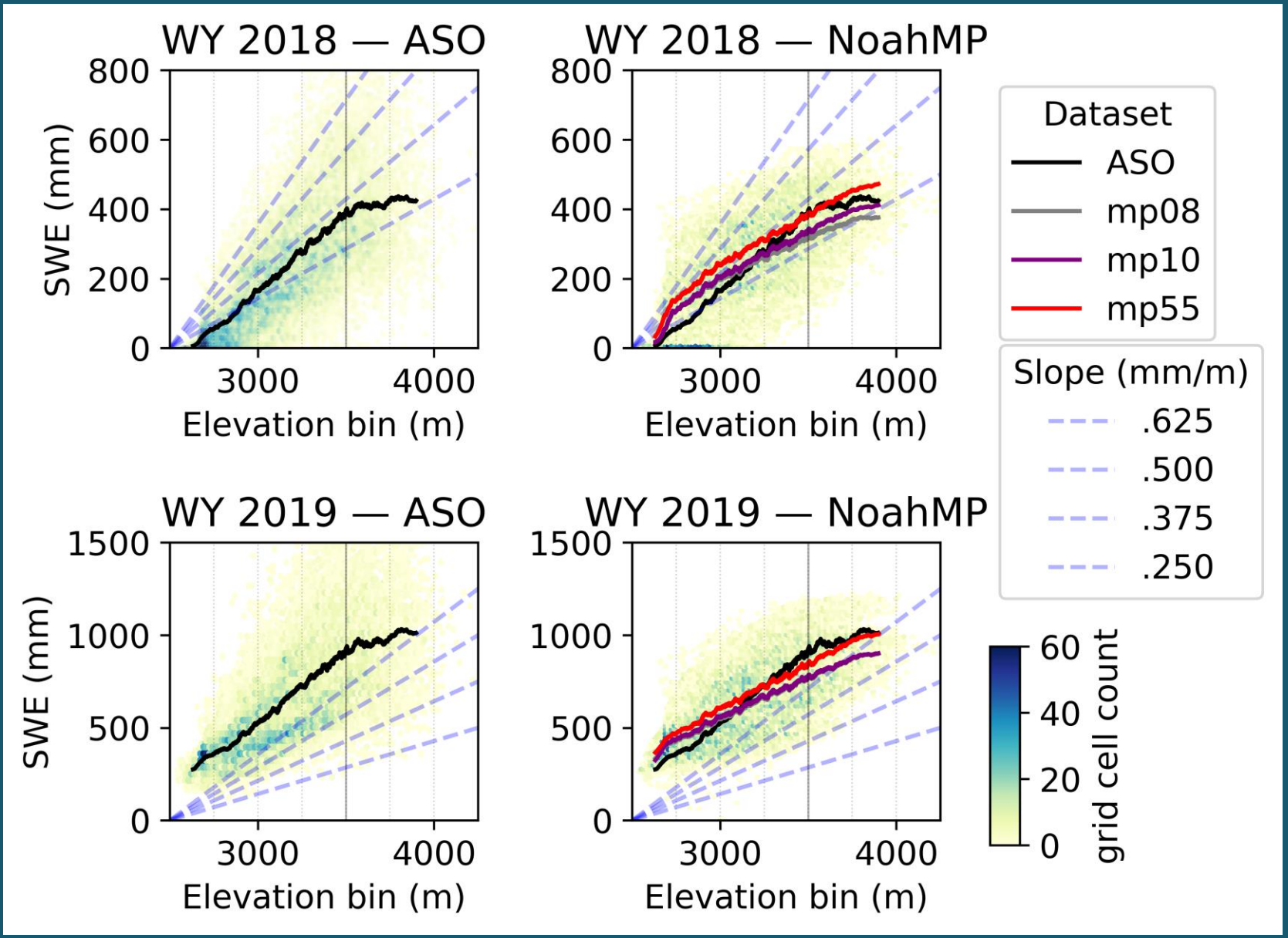
Rudisill et al., in review

Thanks to Jeff Deems, the ASO team, and the Watershed Function SFA!

Comparisons at Peak SWE

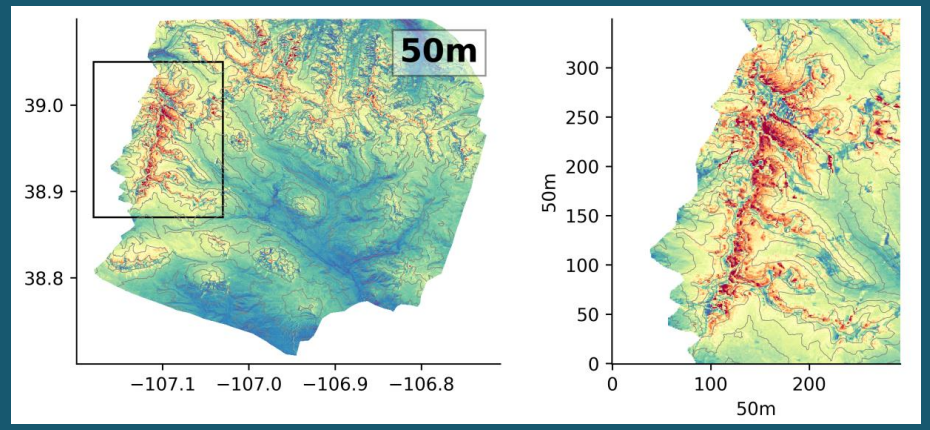


Rudisill et al., in review


WY 2018 — ASO
WY 2018 — NoahMP
WY 2019 — ASO
WY 2019 — NoahMP
SWE (mm)
Elevation bin (m)
800
600
400
200
0
1500
1000
500
3000
4000
Dataset
ASO
mp08
mp10
mp55
Slope (mm/m)
.625
.500
.375
.250
60
40
20
0
grid cell count

Coordinated Field Campaigns

- Does the snowpack record microphysics?
- Does the microphysics set the stage for runoff and streamflow?



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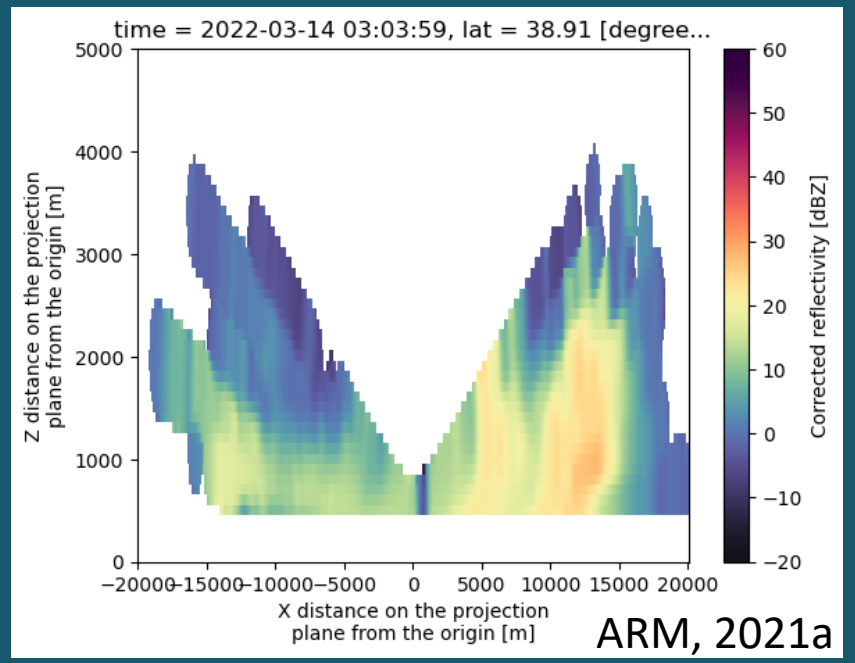
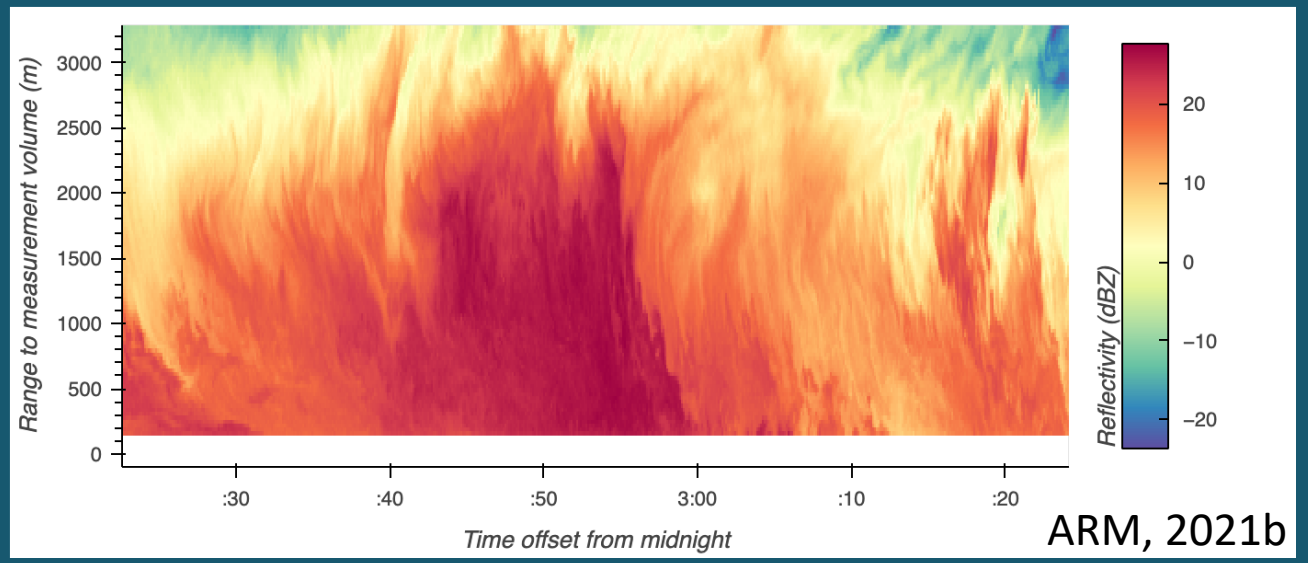


ARM, 2021a



ARM, 2021b

Figures created with PyART, Helmus, J.J. & Collis (2016)

Summary

- Cloud microphysics schemes control:
  - Evolution of the hydrometeor,
  - Interactions of the hydrometeor and topography, and
  - Ultimately precipitation
- This sets conditions for snowpack development and water delivery to the critical zone
- Coordinated atmosphere-to-bedrock field campaigns in mountain watersheds are essential!

Thank you!

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