Update and Discussion on recommended priorities in cloud and precipitation science and measurements

Christine Chiu, Scott Giangrande, Adam Theisen, Christopher Williams

Goal and approach

To provide recommendations for improving the performance and science impact of ARM's measurements of clouds and precipitation

By

- Identifying **science needs** from the broader research community, and **measurements gaps** in instrumentations, products, and retrieval techniques
- Helping to set **the priorities**
- Providing ARM with **clear pathways** to address those needs and gaps

Past Focuses of CPMSG

- Collect input and **we will continue collecting input!!**
- Input and discussions are documented using the science traceability matrix, showing a pathway from roadblocks to improved understanding and modeling.
- **Science traceability matrices can be found via the QR code.**
- These matrices will serve as an important document for the future strategic planning workshop.

ARM Decadal Vision

well as for precipitation. ARM will pursue advancing measurement capabilities in these areas and will continue to engage the science community to identify measurement priorities and new technologies that improve the characterization of these and other cloud- and precipitation-related parameters.

- *Cloud droplet number concentration:* ARM has implemented data products that provide droplet number concentrations through in situ measurements as well as through remote-sensing retrievals; however, work is needed to improve the accuracy of remotely sensed values.
- *Liquid water path in the presence of precipitation:* There has been much work on providing high-quality liquid water path measurements, primarily using microwave radiometers. In recent years, this work has included improved measurements for low liquid water paths; however, providing this measurement in the presence of precipitation remains a significant challenge and calls for development of modified measurements that minimize the collection of water on the radiometer and possibly modified retrievals.
- *Cloud hydrometeor phase and ice properties:* There has been a great deal of progress in this area using multi-frequency radars, radar spectra, and combinations of active and passive remote sensors, but there remains significant work to do, particularly with regard to deriving detailed properties of ice.
- *Frozen precipitation properties:* ARM has recently deployed several instrument systems on the North Slope of Alaska that provide measurements of ice particle shape, snowfall rate and snow depth, and auxiliary measurements that help distinguish falling snow from blowing snow. However, work is required to fully apply these measurements to obtaining a quantitative snowfall rate and spatial variability, especially near the coast, is an issue that is beginning to be explored.
- *Vertical air motion: Measurements of vertical air motion are critical for studying cloud processes.* A variety of instruments and techniques are being used to obtain vertical air motion in various domains (e.g., below cloud base and within clouds); however, significant challenges remain, including measurement of vertical motion above clouds and developing an integrated view of vertical motion.

(1) Improving the capability of measuring liquid water path in the presence of precipitation

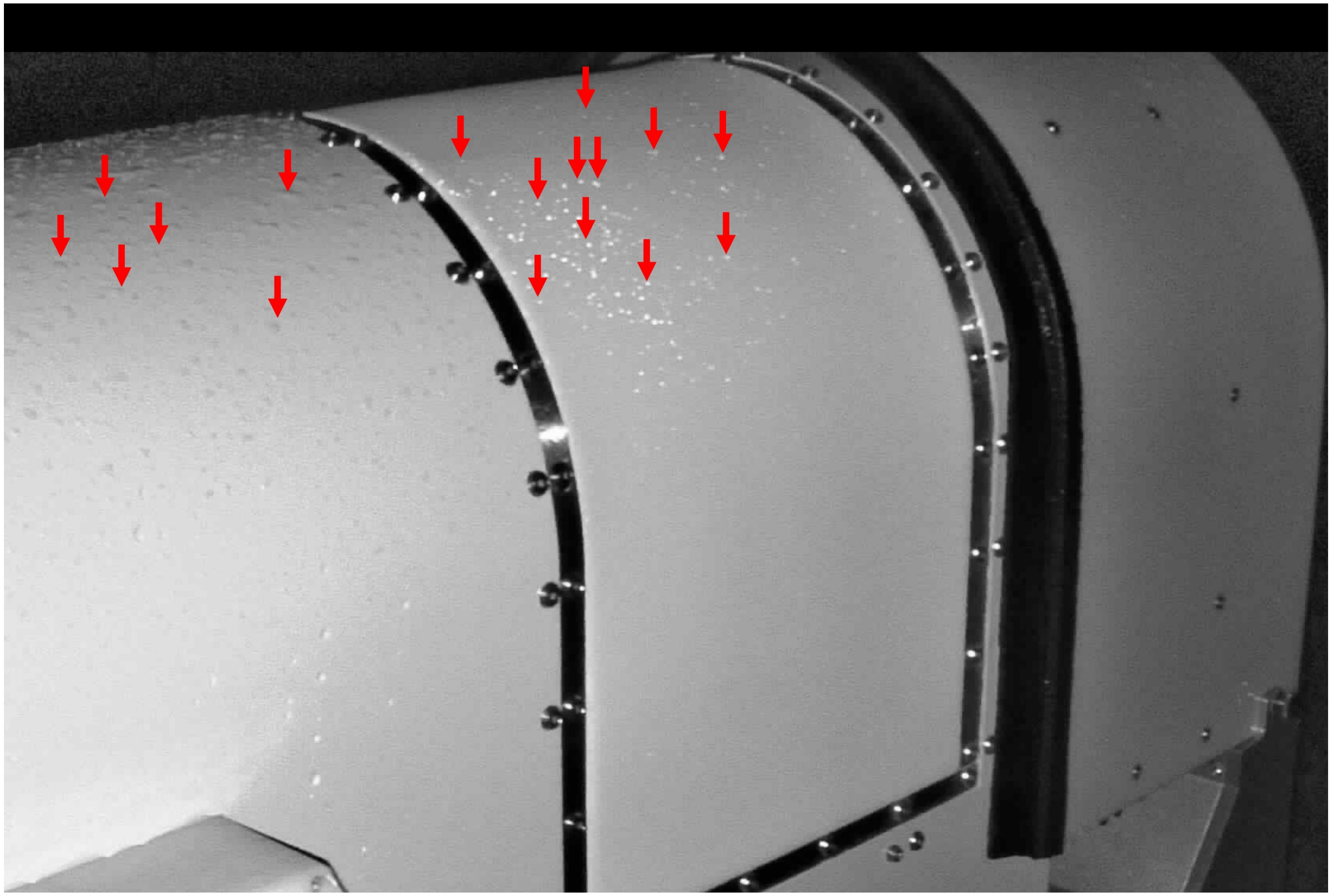
- **For cases with light and moderately drizzling (not reaching the ground)**
  - Retrieval methods exist and have been evaluated (Fielding et al., 2015; Mace et al., 2016; Rusli et al., 2017; Wu et al., 2019; Cadeddu et al., 2017; and perhaps more)
- **For cases with the presence of surface precipitation** – Not quite there yet.

- **Maria Cadeddu**: Background and status of liquid water path retrievals
- **Roger Marchand:** Past efforts that have been made but put aside
- **Open Discussion:** other potential approaches, any new ideas?

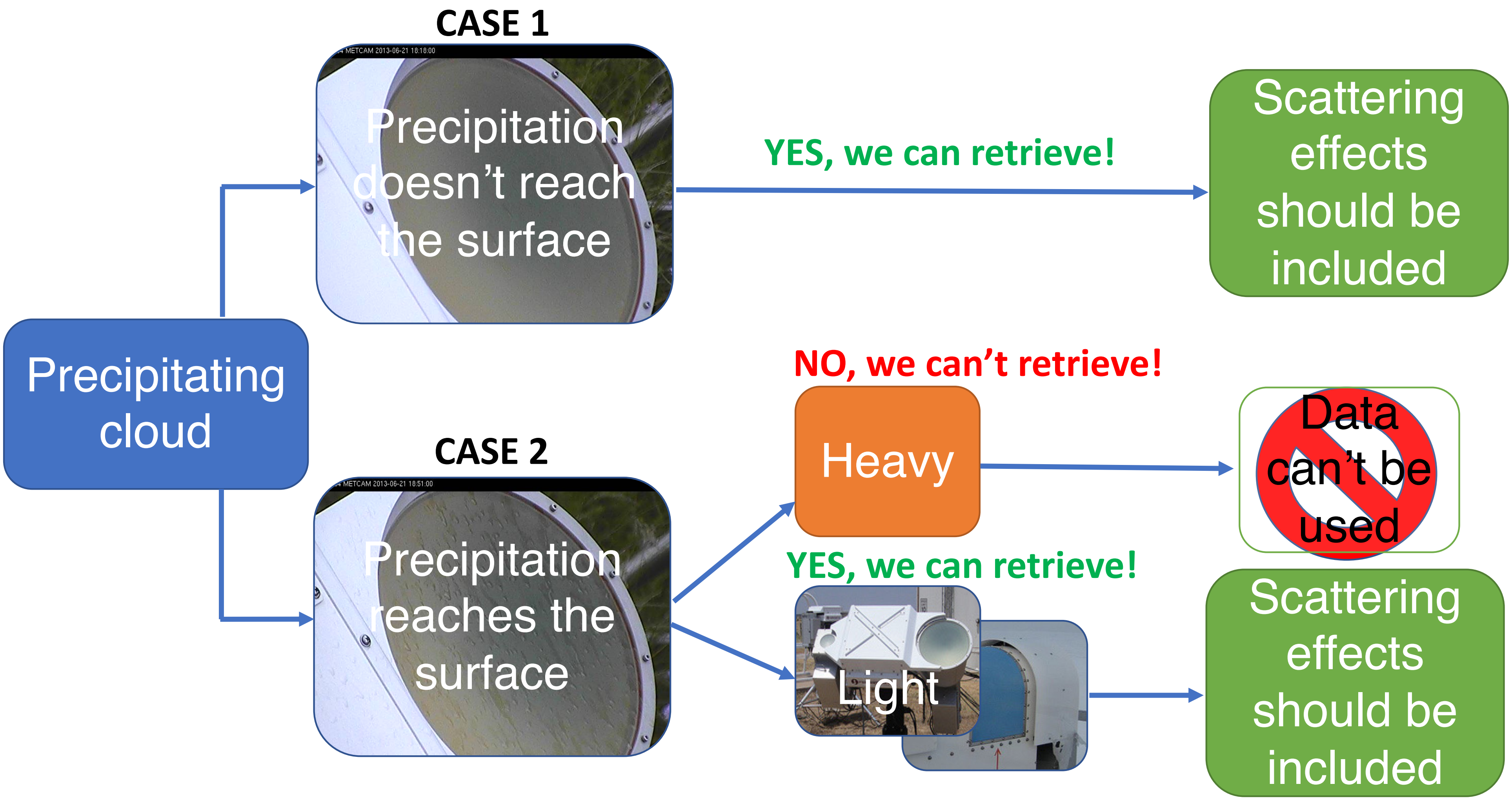
Background and status of liquid water path retrievals

Maria Cadeddu
Argonne National Laboratory

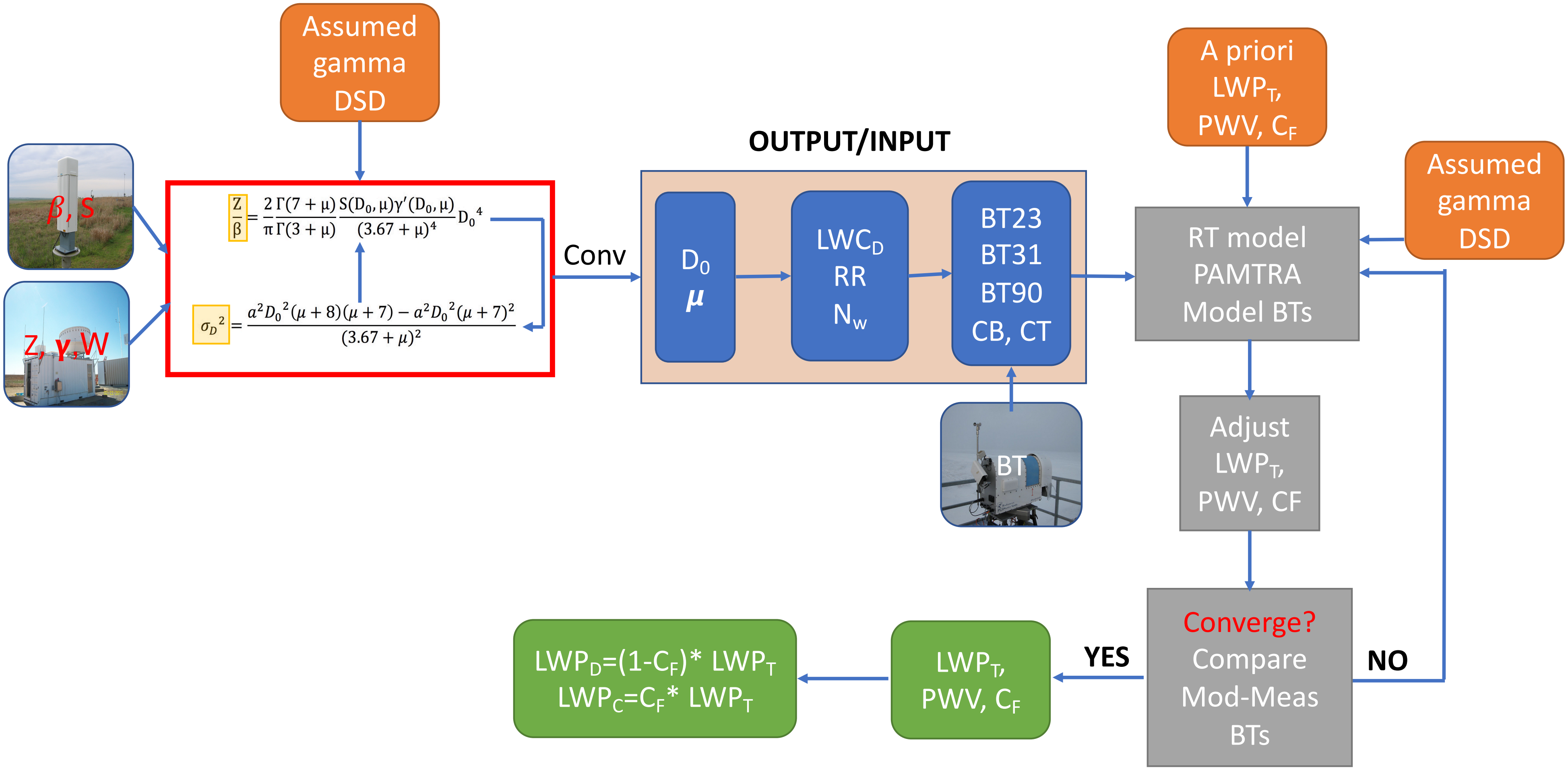
Measuring LWP during precipitation: Where we are and where do we go from here?



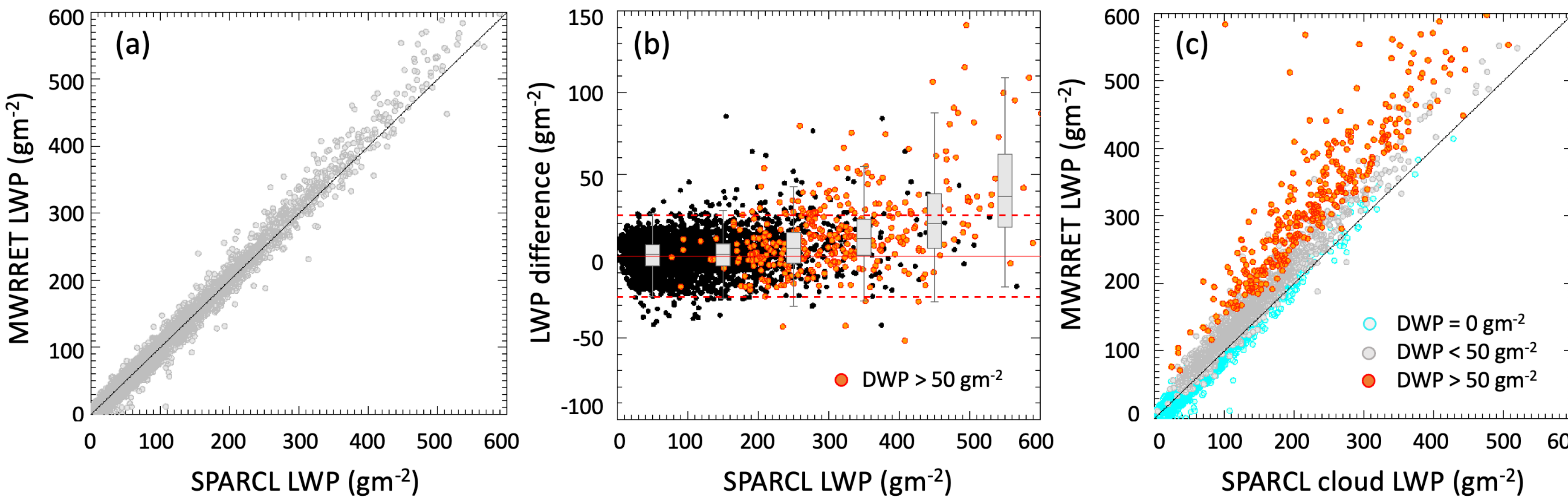
Possible scenarios



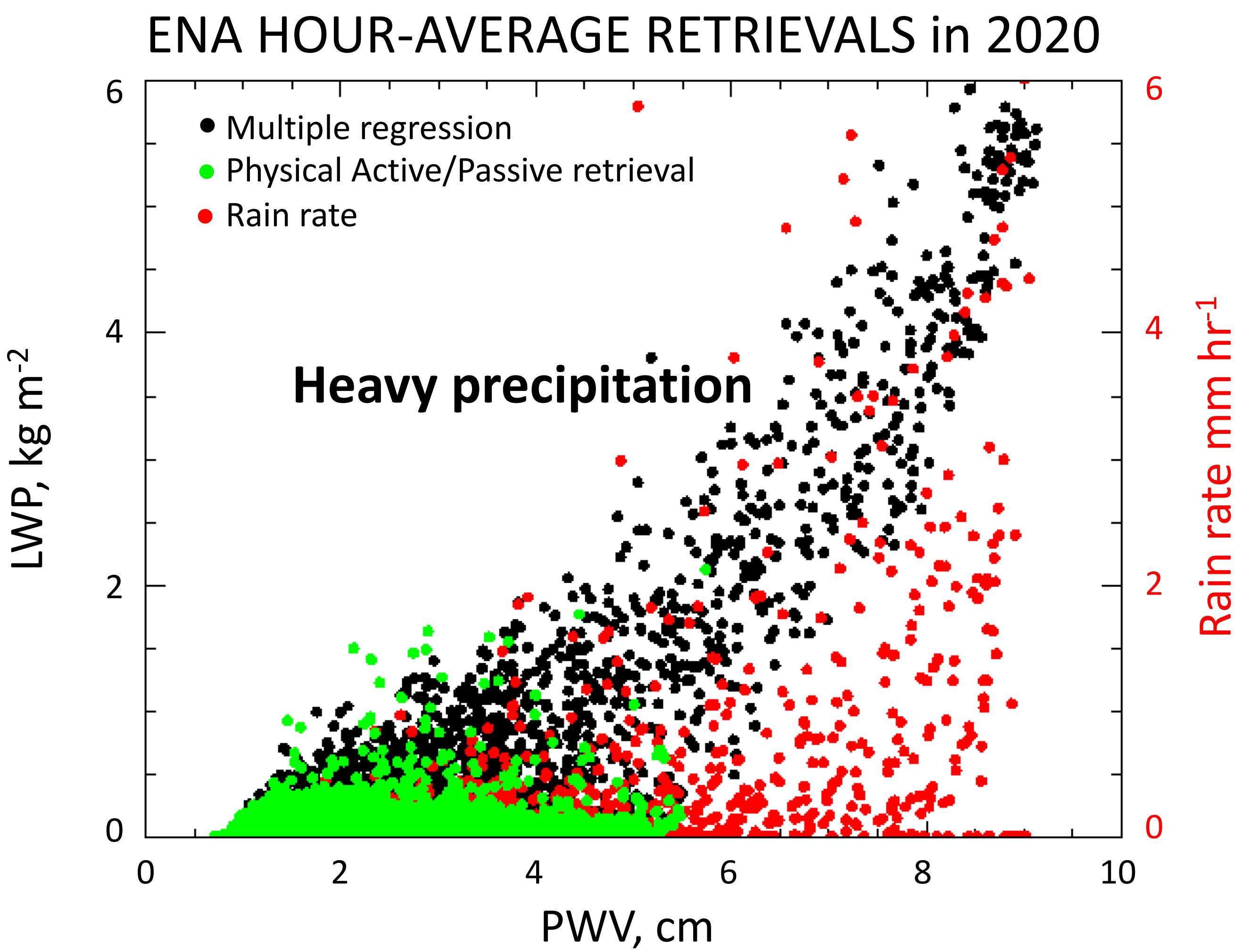
Light precipitation: Partition of cloud and drizzle water path using active and passive sensors-SPARCL algorithm



Light precipitation: Comparison with MWRRET

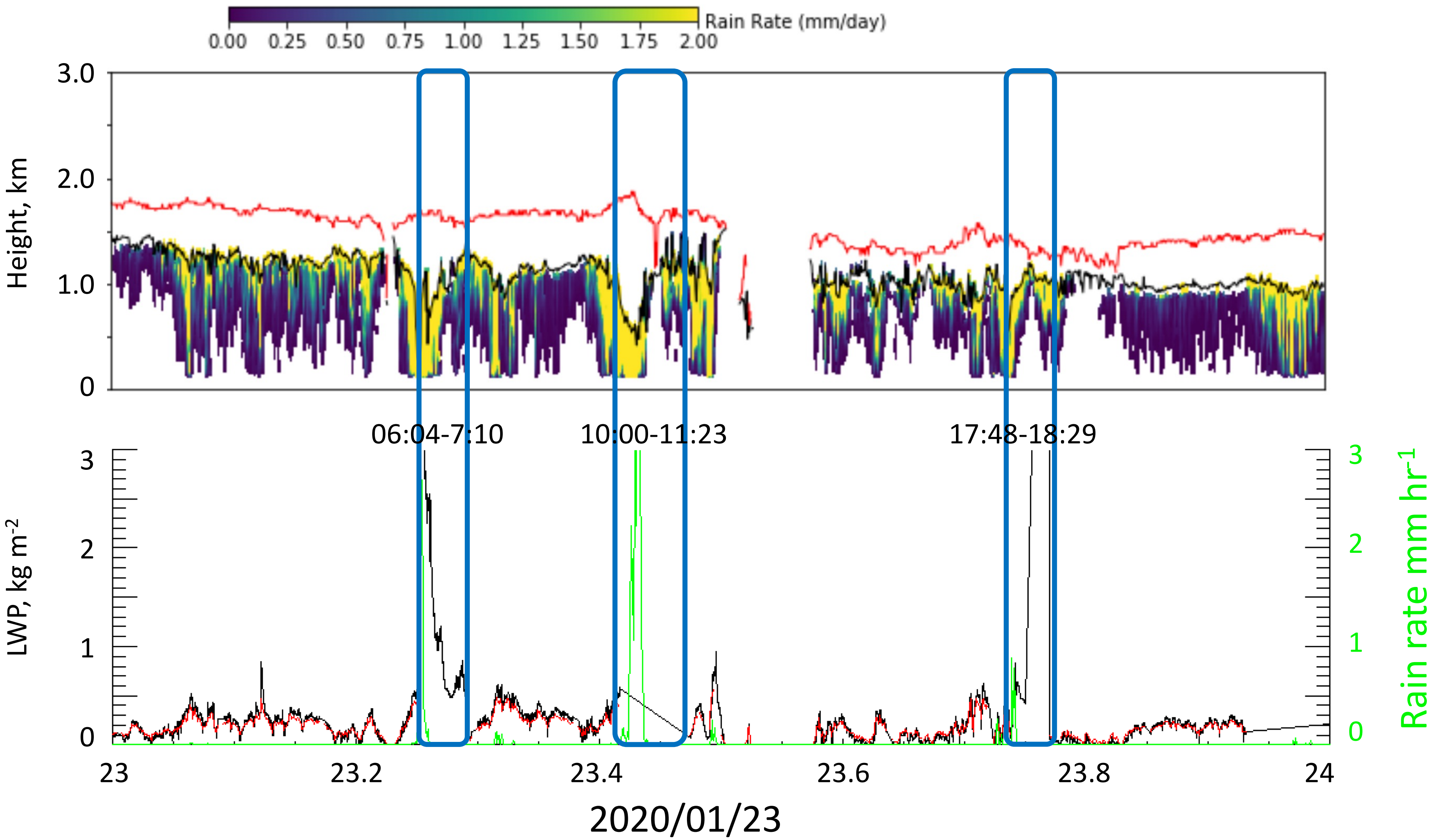


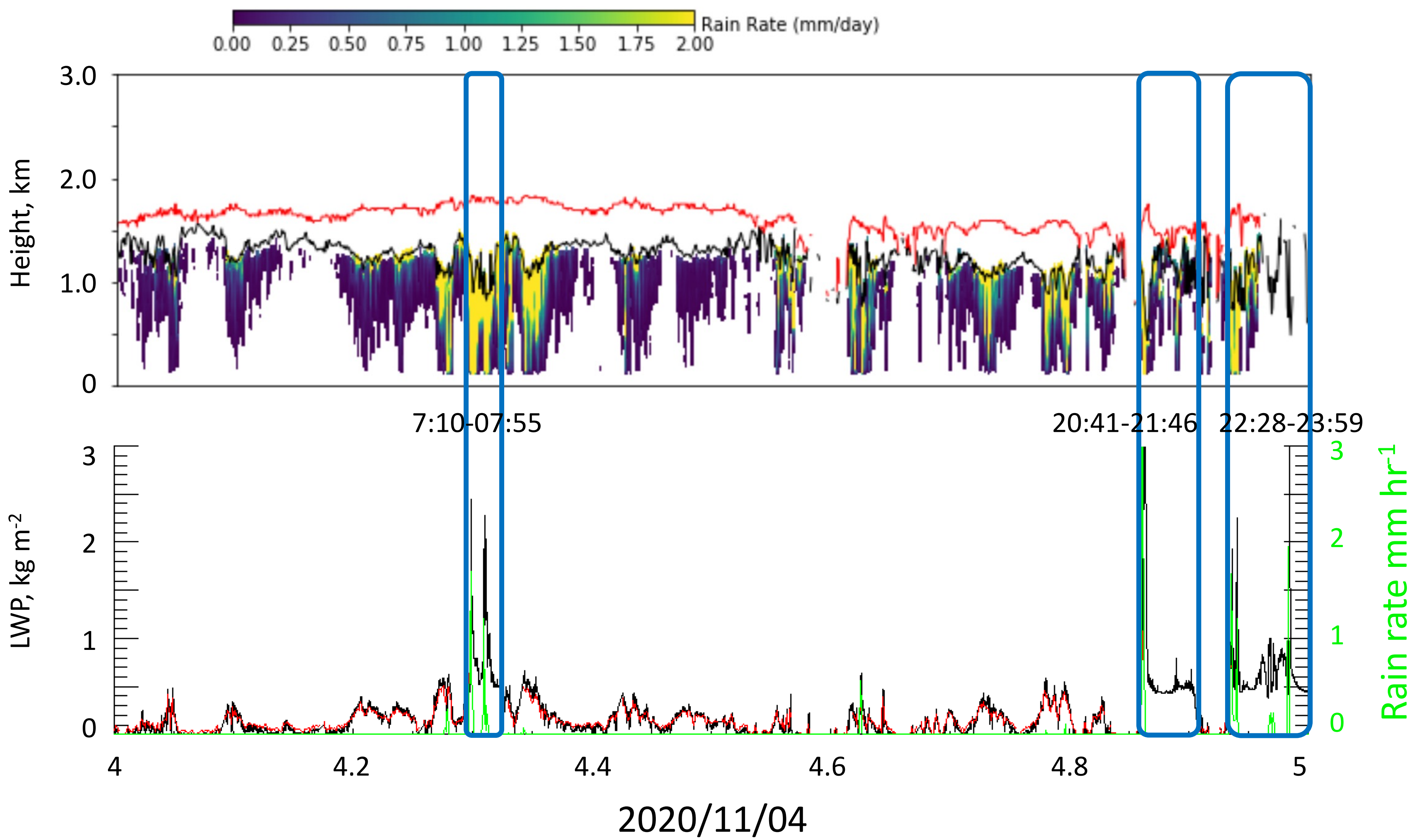
(a) Scatterplot between total LWP and physical retrieval (MWRRET) LWP. (b) Difference between the two retrievals (MWRRET minus SPARCL) for all samples (black) and samples with below cloud drizzle water path greater than 50 g m^{-2} (orange). The orange dashed horizontal lines indicate ± 25 g m^{-2}. (c) Scatterplot between SPARCL cloud water path and MWRRET total LWP. Colors represent cases with no drizzle (cyan), drizzle water path below cloud base less than 50 g m^{-2} (grey), and drizzle water path below cloud base greater than 50 g m^{-2}.



From 5-year statistics about 75% of retrievals converge at the ENA (green) imposing a strict convergence acceptance.

Specific example in next slides: We retrieve during rain all the time except for a few hours of heavier precipitation.


Rain Rate (mm/day)
0.00 0.25 0.50 0.75 1.00 1.25 1.50 1.75 2.00
Height, km
3.0
2.0
1.0
0
06:04-7:10
10:00-11:23
17:48-18:29
LWP, kg m-2
3
2
1
0
Rain rate mm hr-1
23
23.2
23.4
23.6
23.8
24
2020/01/23


Rain Rate (mm/day)
0.00 0.25 0.50 0.75 1.00 1.25 1.50 1.75 2.00
Height, km
3.0
2.0
1.0
0
7:10-07:55
20:41-21:46
22:28-23:59
LWP, kg m-2
3
2
1
0
Rain rate mm hr-1
4
4.2
4.4
4.6
4.8
5
2020/11/04

Heavier precipitation possible topics for discussion:

Site-specific analysis and mitigation-On demand?

- Analyze *each site* to understand site-specific behavior
- Where possible develop *more instrument synergy* for the missing data, for example using passive information immediately before and after gap + active wavelengths retrieval during the hours of missing data
- Possible tradeoff accuracy-convergence for physical retrievals?

Operations and Hardware design

- Off-zenith view: Objective difficulties
- Identify *target sites* for special observation strategies
- Instrument design: Long term, costly – no results guaranteed

Past efforts on measuring large LWP

Roger Marchand
University of Washington

Other potential approaches

- Dual-frequency – Hogan et al. (2005),… Zhu et al. (2019); drizzling case; "Sometimes our retrieval approaches would work and sometimes they would not work so well, and we could never figure out how to predict the times when they would fail".
- Dual Polarisation Rain Radiometer (DP-RR) for thick cloud and rain LWP
- 3D Cloud Tomography – Huang et al. (2008) but has not been tried for precipitating clouds.
- Mounting microwave radiometer with scanning radar
- **Maximize the synergy between lidar, radar and microwave radiometer**
- Your thought?