

Science Motivation

The MWR Precipitation Challenge

- MWRs are the most commonly used and accurate instruments ARM has to retrieve cloud Liquid Water Path (LWP).
- MWR data are frequently combined with measurements from radar and other instruments for cloud microphysical retrievals.
 - Nominally this improves the retrieval of LWP and other cloud microphysical quantities (such as effective radius or number concentration), but this also means that when MWR data is poor other cloud microphysical quantities are negatively affected.
- The Challenges
 1. Water on the Radome : Standing water on the MWR radome frequently makes a substantial contribution to the measured downwelling radiance and is a large source of error in MWR retrievals.
 2. Non-Rayleigh Scattering : Drizzle and rain particles are large enough to be in the Mie scattering regime (and one should include scattering effects). Nonetheless scattering is not presently considered in any widely used MWR retrieval (including the ARM “Gold” standard MWRRET).



Water on the Radome



- A. Leads to an artificially large retrieval of liquid and vapor amount.
- B. Periods with water on the radome account for a significant fraction of all measurements when a cloud is present.
 - The standard ARM MWRs have a resistance-based sensor which nominally detects when the MWR is wet, and this data is flagged. However, it is difficult to set the resistance threshold such that it is stable and sensitive to light precipitation without generating copious false detections.
 - Experience with the data suggest that this measurement of rain on the radome under-detects the presence of rain on the radome (except perhaps at NSA where cold temperatures have been a problem).
 - Nonetheless, as is, the wet window sensor suggests that the radome was wet 13% of the time at SGP (between 2002-2013) when there was more than 50 g/m² of water present, 8% of the time at Darwin, and more than 25% of the time at NSA.
- C. While it is obvious when the contamination is large, much of the time it is difficult to know with confidence that there is no contamination.
- D. Presently, there is no attempt to estimate or correct for water on the radome.
 - Tests with the latest blowers and “tilting” have shown that these simple solutions do not keep the radome dry, and water on the radome continues to be a problem.
 - While the new MWR-3ch systems “recover” faster than the old MWR-2ch systems, wet radome contamination is nonetheless common.

A Proposed Path Forward:

A two radiometer test : “Covered” and “Uncovered”

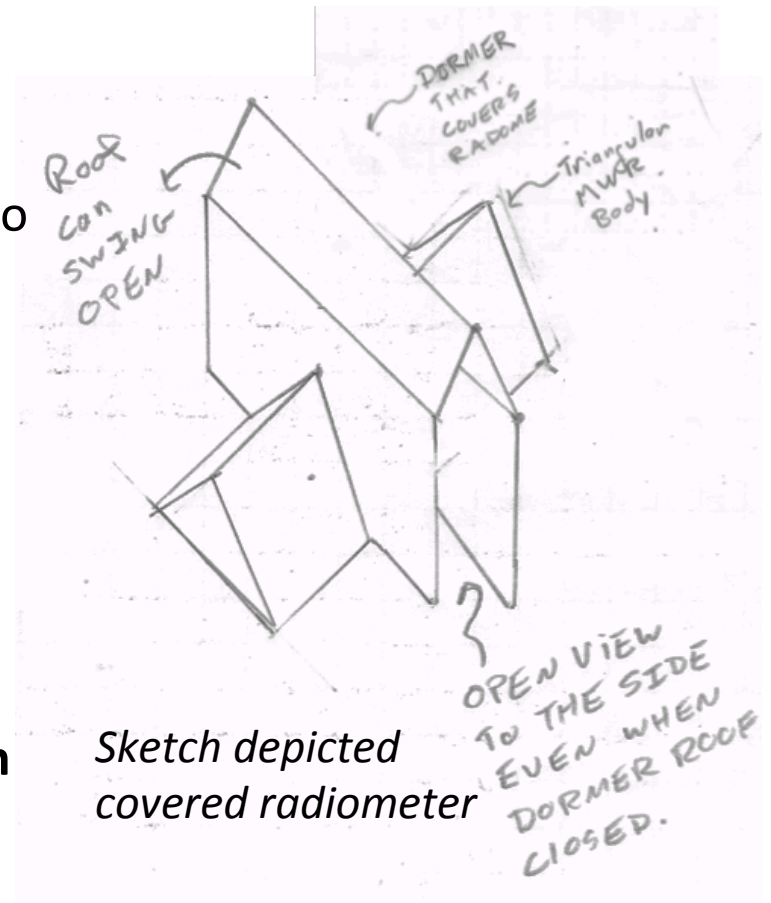
Two radiometers will be placed side-by-side.

One with the radome covered (or shielded) and one open to the sky, as usual.

The covered radome will allow one radiometer to take measurements away from zenith while preventing radiative cooling and droplets from reaching that radome.

This will provide :

- A) Off zenith **liquid water “slant” path in all conditions.**
- B) Comparison of covered and uncovered measurements off-zenith to **determine when rain contamination is present.**
- C) Data that could be used to develop/test corrections for the uncovered measurements.



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HighTech Prototype

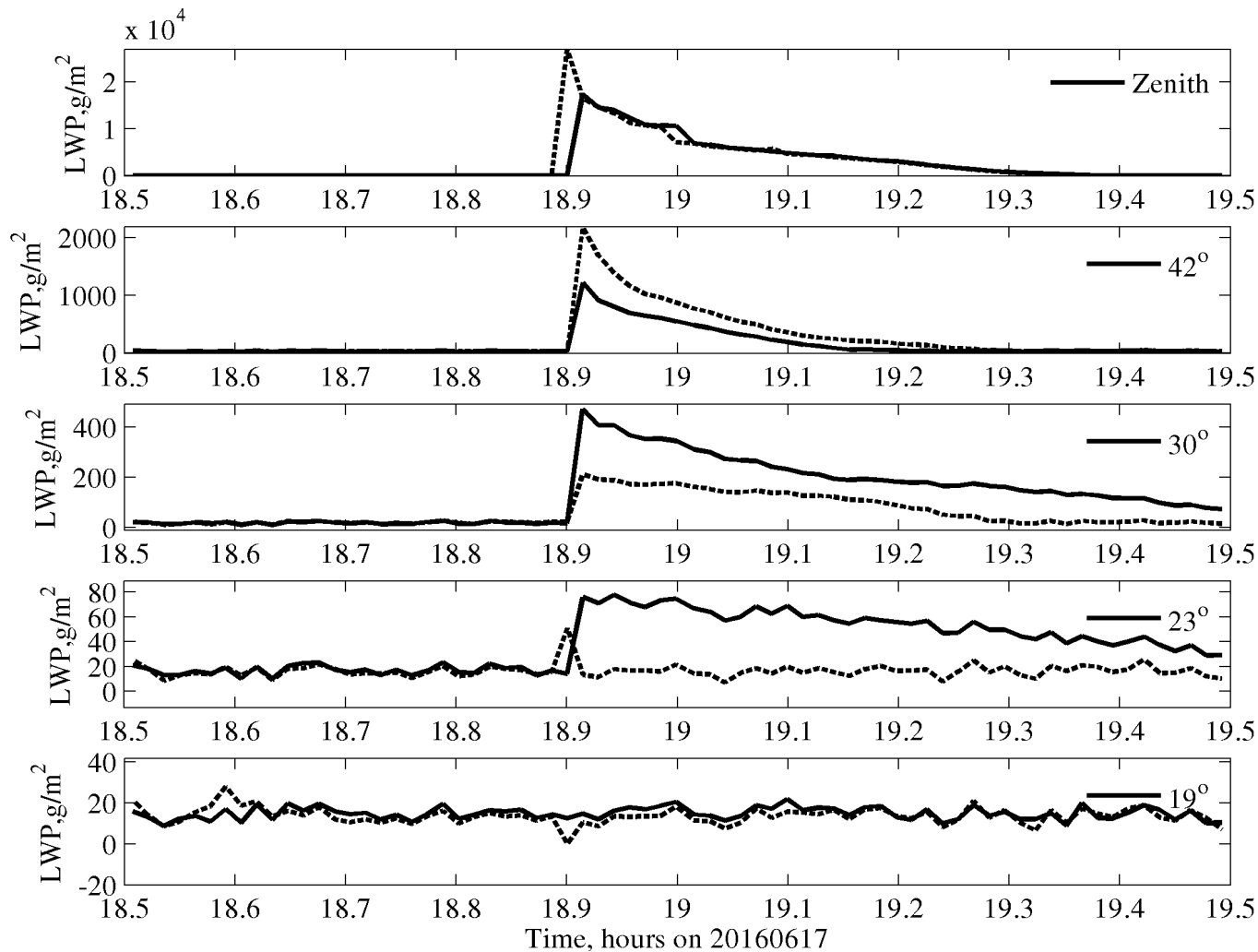


Current Enclosure



Example - "False Rain Test". Impact on LWP.

- We started using the simple approach of using a garden watering-can to simulate rainfall - results from the prototype are shown here.
- As expected, retrievals of LWP based on MWR measurements at the largest elevations angles ($\sim 19^\circ$) are unaffected.



Left : physical-Iterative retrievals of vertical-LWP using MWR 23.8 and 31 GHz radiances.

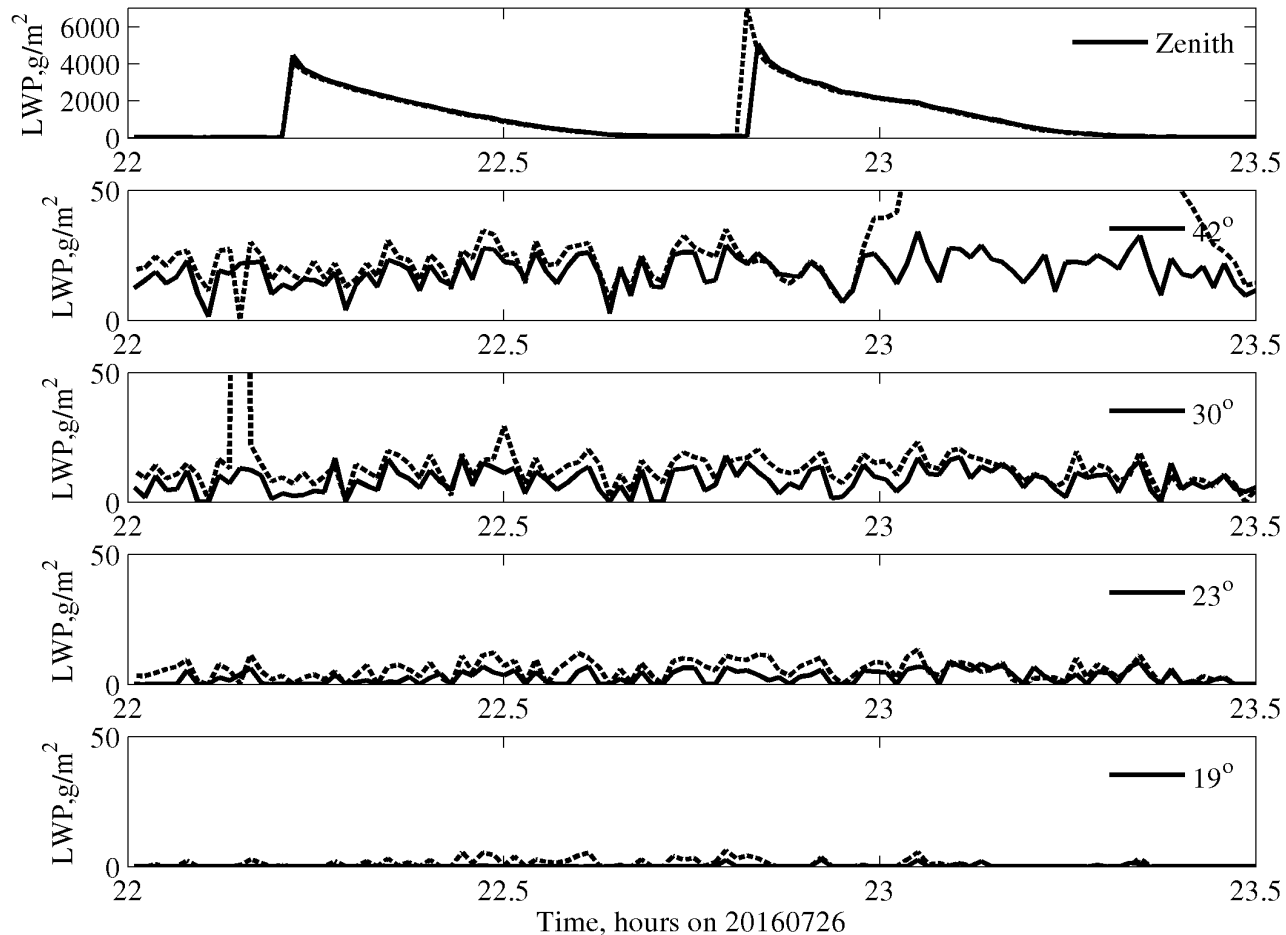
The MWR takes two measurements looking at zenith during its tip curve sequence.

For other angles, dashed lines is westward-looking, solid is eastward-looking.

23° east still showed some LWP response (the cover was raised on this side after this test).

Example - "False Rain Test". Impact on LWP.

- Second enclosure.
- **No LWP changes observed at any angle, other than Zenith.**



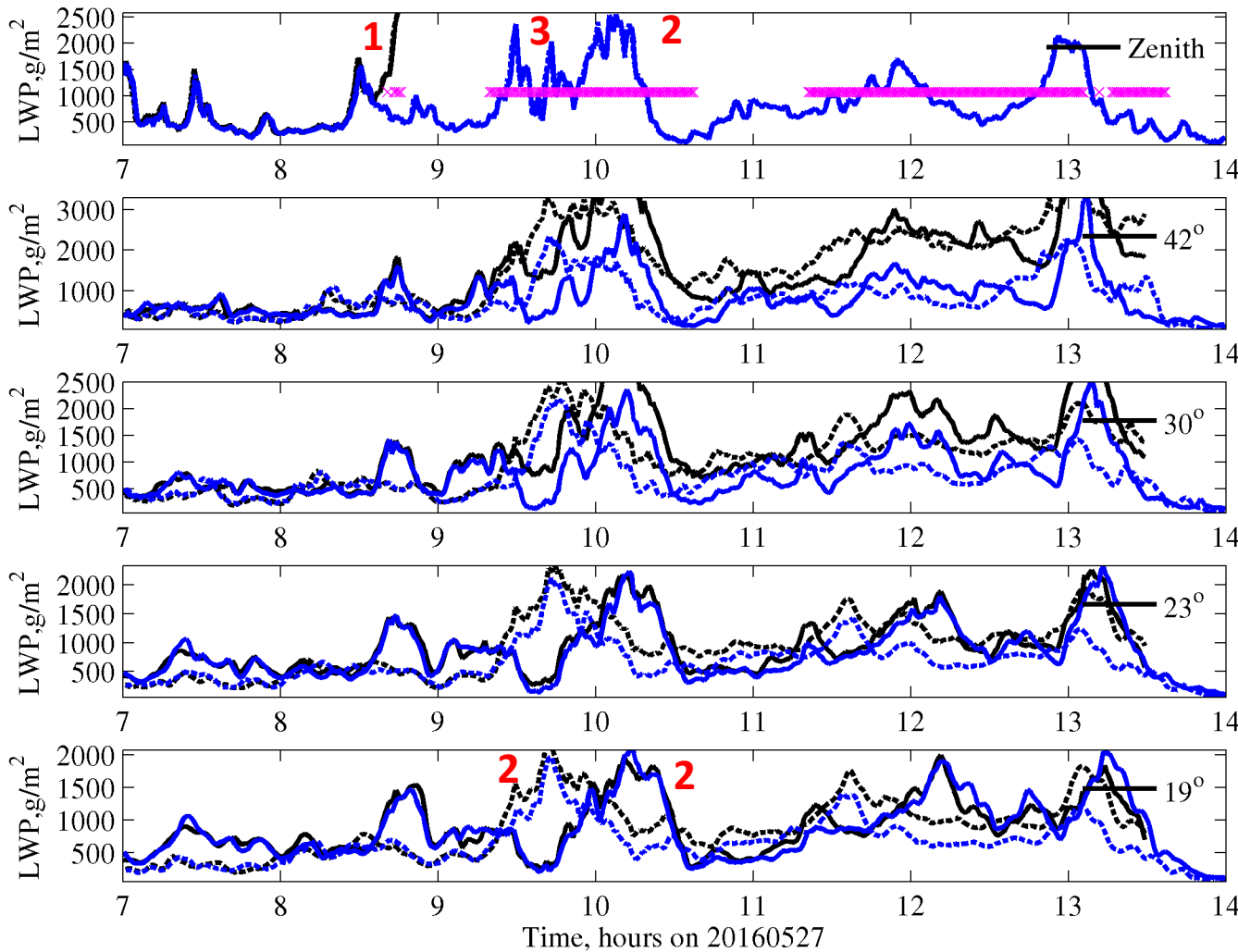
Left : physical-Iterative retrievals of vertical-LWP using MWR 23.8 and 31 GHz radiances.

The MWR takes two measurements looking at zenith during its tip curve sequence.

For other angles, dashed lines is westward-looking, solid is eastward-looking.

Example - “Real Drizzle/Light Rain Event 5/27 - prototype”

- Light rain or drizzle fell about 8:45 UTC, and then again after 9:15 UTC.
- ARM would typically avoid using MWR data when wet window flag is active, but blower might have done well, with zenith values (peak near 2500 g/m²) compare well with results at 19° and 23° (peak near 2000 g/m²).

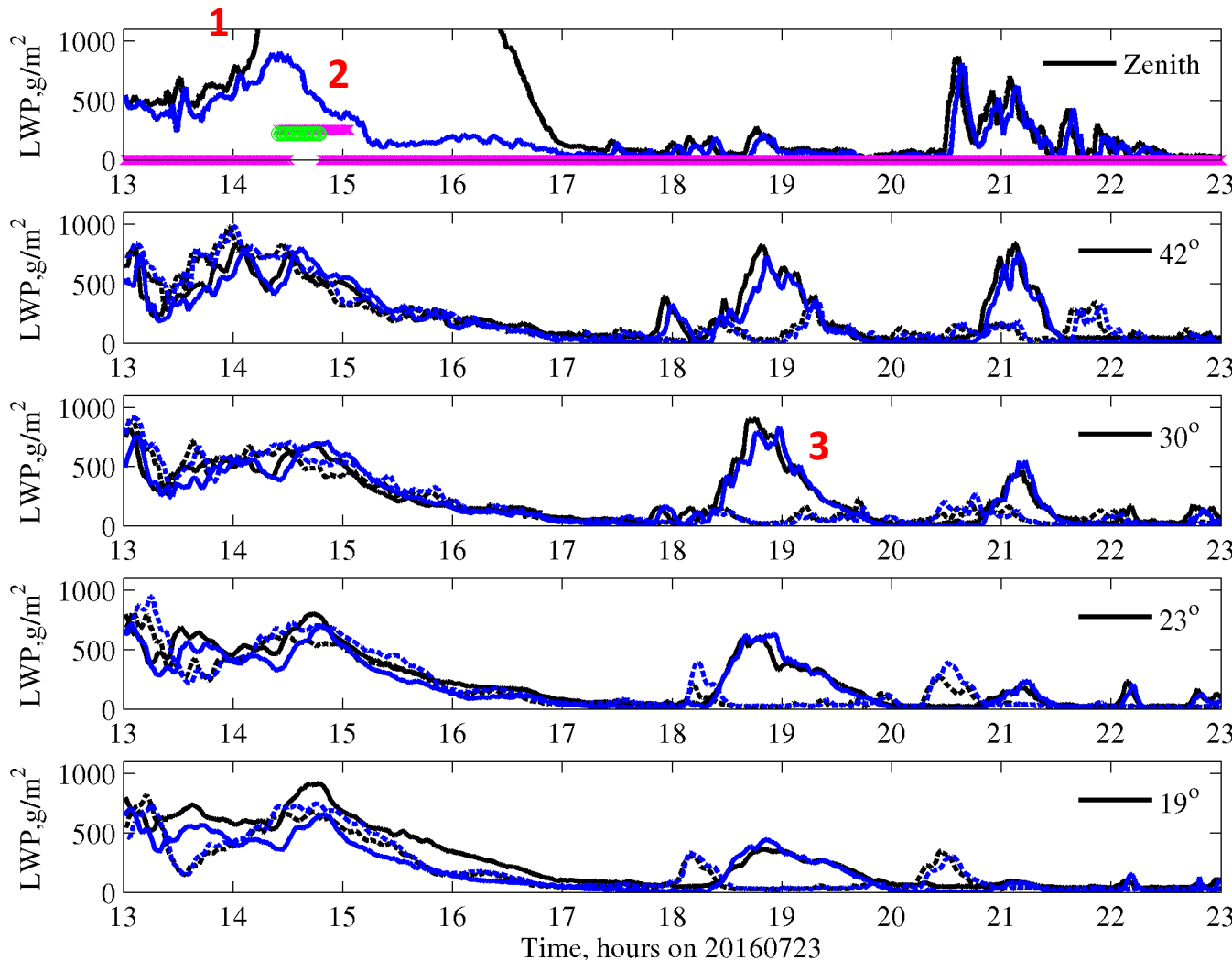


Left : vLWP from uncovered (blue) and covered (black) MWRs. Purple x's indicate wet-window flag from uncovered radiometer.

- 1** The covered radiometer has no blower/heater and shows large change even with light precip.
- 2** Feature appears to be captured by west, zenith, and east looking measurements in order.
- 3** Two peaks here are not seen at low elevation angles. Why?

Example - “Real Drizzle/Light Rain Event 7/23”

- Light rain or drizzle started about 14 UTC but did not trigger wet window sensors until about 14:30 UTC.
- LWP retrieval for uncovered MWR compares reasonably (same range of LWP values) with off-zenith values from the covered radiometer.

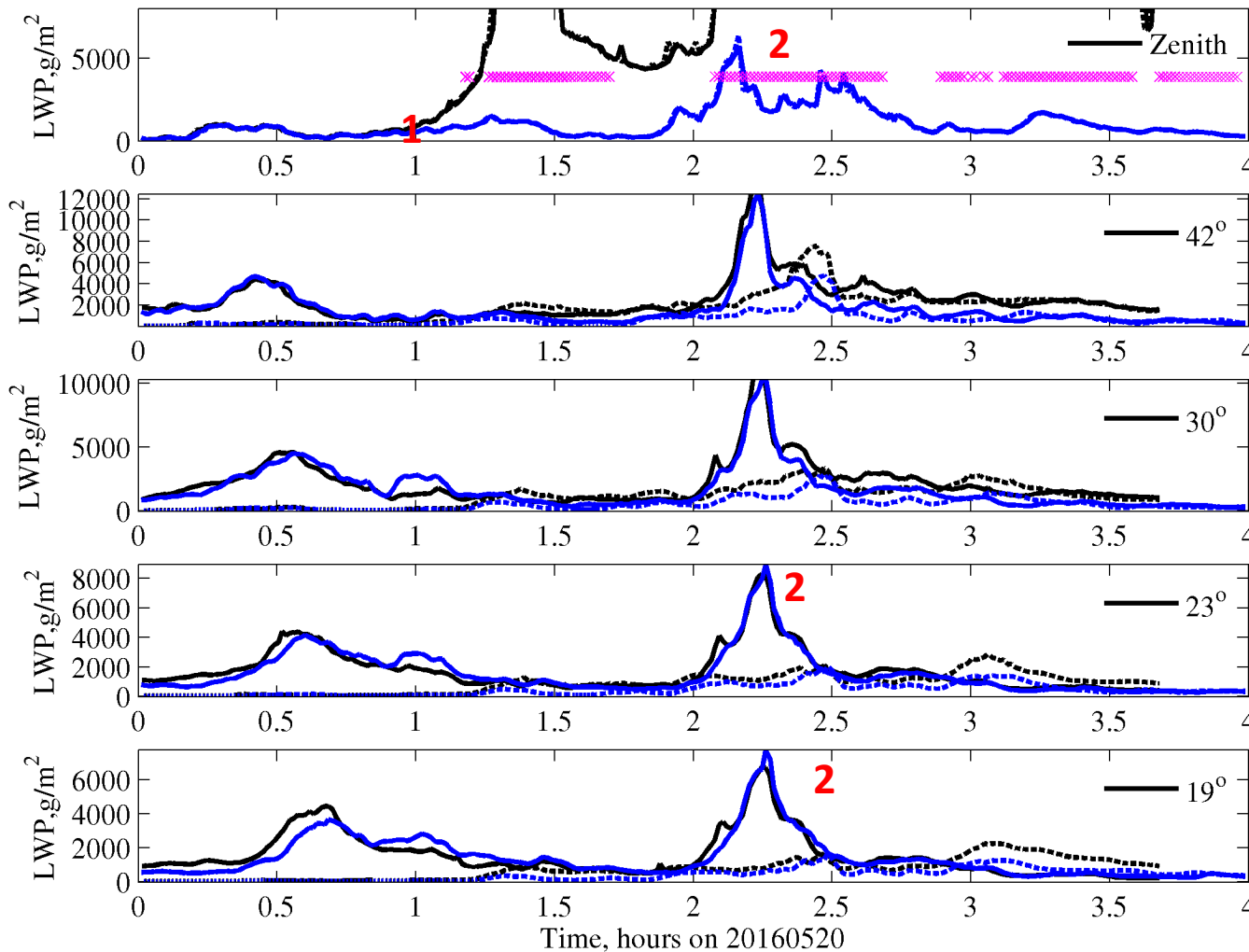


Left : vLWP from uncovered (blue) and covered (black) MWRs. Purple x's and green o's are wet-window flags.

- 1** The covered radiometer has no blower/heater and shows large change even with light precip.
- 2** Feature in zenith similar to off-zenith view.
- 3** Clear asymmetry between west and east

Example - "Heavier Precip. 5/20 - prototype"

- Large values of LWP at Zenith AND off-zenith (but only to the west).
- Is a value near 5000 g/m² reasonable ? ... or is scattering an issue here ?
- Very few of these events ... MWRs seems to be crashing during these events.



Left : vLWP from uncovered (blue) and covered (black) MWRs. Purple x's indicate wet-window flag from uncovered radiometer.

1 The covered radiometer has no blower/heater and shows large change even with light precip.

2 Feature with large LWP appears in 23 and 19 degree elevation angles. Therefore is NOT due to a wet radome.

Thoughts – slide 1 : The Good

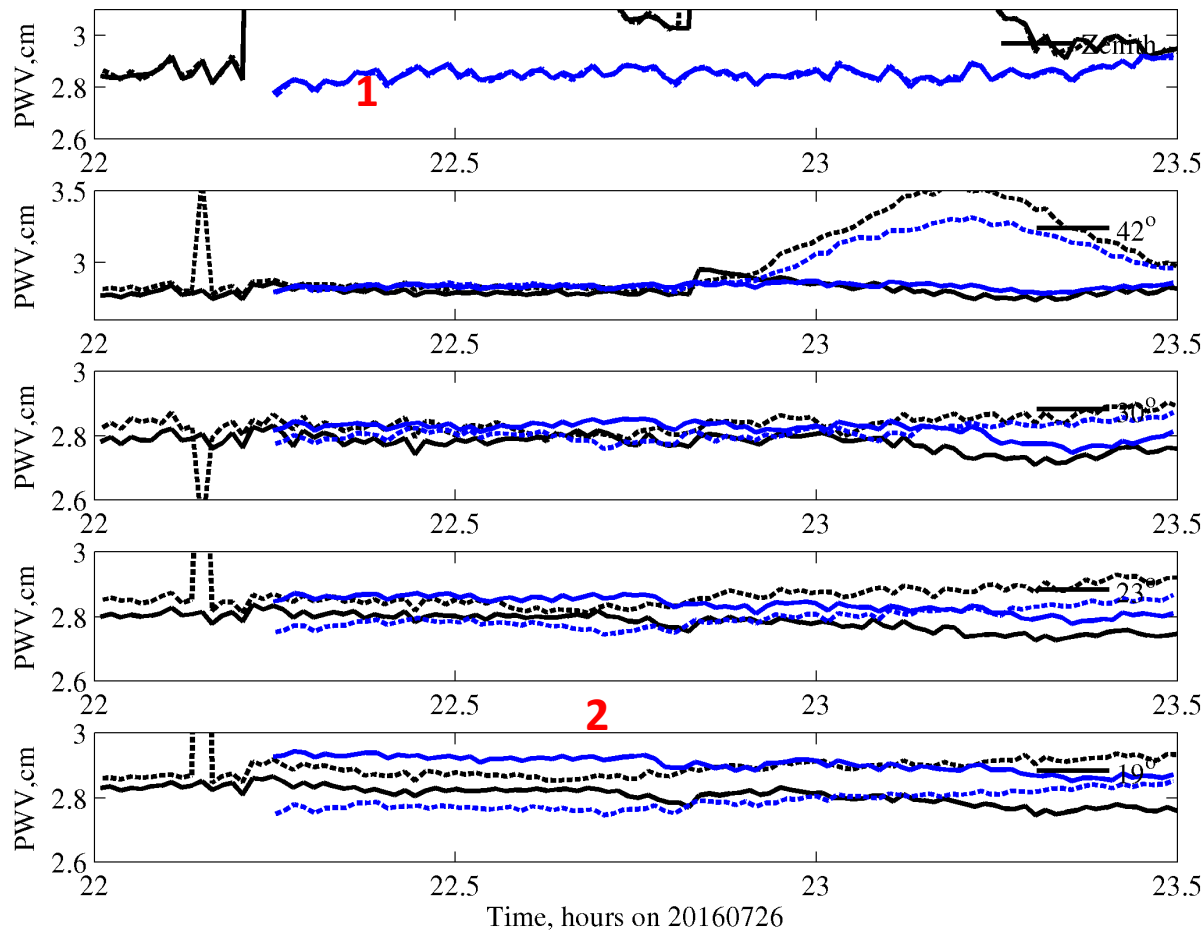
- The basic idea of covering the radiometer to get good off-zenith measurements seems to work. While these measurements need to be coupled with a better understanding and inclusion of scattering effects, it seems clear to me that getting slant-path LWP using this approach is worth pursuing.
- The covered data also appears potentially useful in identifying when the zenith measurements are contaminated by water on the radome, but (not surprisingly) spatial variability is going to make any detection (or correction) difficult unless the contamination is large ($>$ few hundred g/m^2).
- The handful of good cases to date suggest that in drizzle or very light rain conditions, the blower is doing a better job than I realized, and we are likely throwing out a lot of good data.

Thoughts – slide 2: The Bad

- I've had lots of problems collecting good data which has implications for trying this “in the field”.
- In particular, the covered MWR data software often crashes (with a variety of error messages) when “heavier” rains are falling.
 - I am guessing that the very large brightness temperatures near nadir (which don't occur so much with a blower and smaller effective radome area) are causing one or more part of the code that analyzes the measurements to fail.
 - We need a path forward here !!!
- Another problem is that there appear to be noteworthy differences in the mirrored off-zenith data that drive significant PWV differences (and some LWP difference).
 - My thinking was to use PWV field would be “less” variable than LWP and could be used as basis for correction ...

Example - “clear-sky PWV 7/26”

- This data is from the “faux rain” test on 7/26. So nadir PWV for nadir should be wrong. But all other angles should be okay.
- The PWV bias is due to bias in brightness temperatures (next two slides)
- Suggest to me, there is a pointing angle issue (that seems to vary over time) and will need to be address/corrected for ...



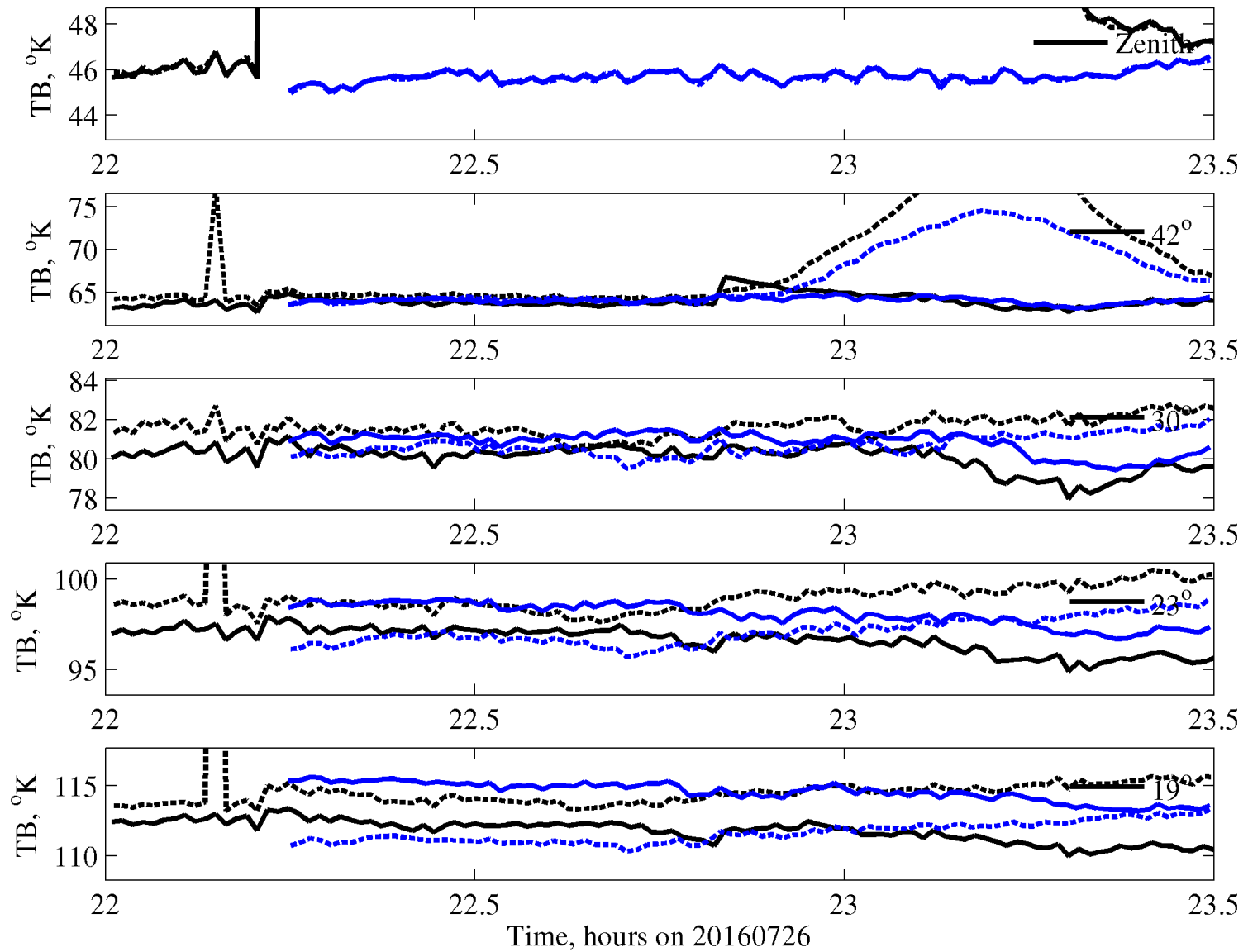
Left : vPWV from
uncovered (blue) and
covered (black) MWRs.
uncovered radiometer.

1 Water on top of covered
radiometer

2 Notice uncovered MWR
(#12) say much higher
PWV to west.

But covered MWR (#38)
says higher to the east.

Example - "clear-sky Tb 23 GHz 7/26"



Example - "clear-sky Tb 31 GHz 7/26"

