Geophysical Retrievals During OLYMPEX/RADEX Using the Advanced Microwave Precipitation Radiometer

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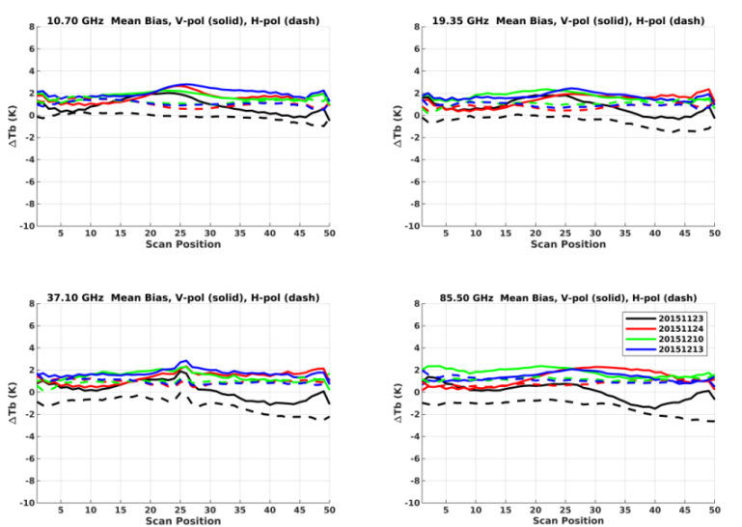
Introduction & Background

- The Olympic Mountains Experiment and Radar Definition Experiment (OLYMPEX/RADEX) took place Fall 2015 – Spring 2016 in Washington, United States (Houze et al. 2017)
- The Advanced Microwave Precipitation Radiometer (AMPR) was flown on NASA ER-2 aircraft during science flights
- This poster summarizes advancements in geophysical retrievals using AMPR data from OLYMPEX/RADEX
- Calm ocean has low emissivity at microwave frequencies; wind creates foam – increases emissivity (Wilheit and Chang 1980)
- Liquid hydrometeors in atmosphere generally yield higher brightness temperature (T_b) due to their higher reflectance
- Effect of liquid hydrometeors depends highly on frequency – Mie (1908) resonance increases with increasing frequency, as does absorption (e.g., due to water vapor) (Wilheit and Chang 1980)
- Retrieve cloud liquid water (**CLW**), water vapor (**WV**), and 10-m wind speed (**WS**) using multiple T_b (e.g., Spencer et al. 1994)

AMPR System

- Total power, cross-track scanning microwave radiometer
- Four frequencies: 10.7, 19.35, 37.1, 85.5 GHz; orthogonal receivers for each channel = dual-polarization deconvolution
- 20-km altitude; data sampled at 0.6 km cross-scan intervals
- Hot and cold calibration targets = raw radiometer count to T_b



- Corrected for error caused by receiver gain & offset estimations, antenna pattern, polarization mixing geometry, and cross-polarization fraction (Biswas et al. 2017; Lang et al. 2019)

Source for Figures: Biswas et al. (2017)

Data & Methods

- 523,176 globally distributed atmos. profiles from Global Data Assimilation System (GDAS; NCEP 2000) – get T_b dataset, randomly vary SST from 0 – 30°C and WS from 0 – 20 m s^{-1}
- Simulate AMPR-viewed T_b data using RTM (Meissner and Wentz 2012; Liebe et al. 1991; Rosenkranz 1993; Rosenkranz 1998); derive multiple-linear regression equations for CLW, WV, and WS
- Compare AMPR-calculated CLW, WV, and WS with GDAS profiles; evaluate retrieval and crosstalk errors
- Test new equations on four OLYMPEX/RADEX cases after removing rain- or land-contaminated data and plane roll > 1°
- Compare new retrievals with one-dimensional variational inversion algorithm (1DVAR; Duncan and Kummerow 2016) results, provided by Colorado State University, for same AMPR dataset; examine median absolute deviation (MedAD)
- Compare WV and WS with Advanced Vertical Atmospheric Profiling System (AVAPS; Hock and Young 2017) sondes; calculate WS only if data present below 500 or 150 m (Uhlhorn et al. 2007):

$$WS_{10} = 0.8 \cdot \overline{WS_{0,\,500}}$$

$$WS_{10} = \overline{WS_{0,\,150}} \cdot \left[1.0314 - 4.071 \times 10^{-3}(z) + 2.465 \times 10^{-5}\left(z^2\right) - 5.445 \times 10^{-8}\left(z^3\right)\right]$$

New Geophysical Retrieval Equations

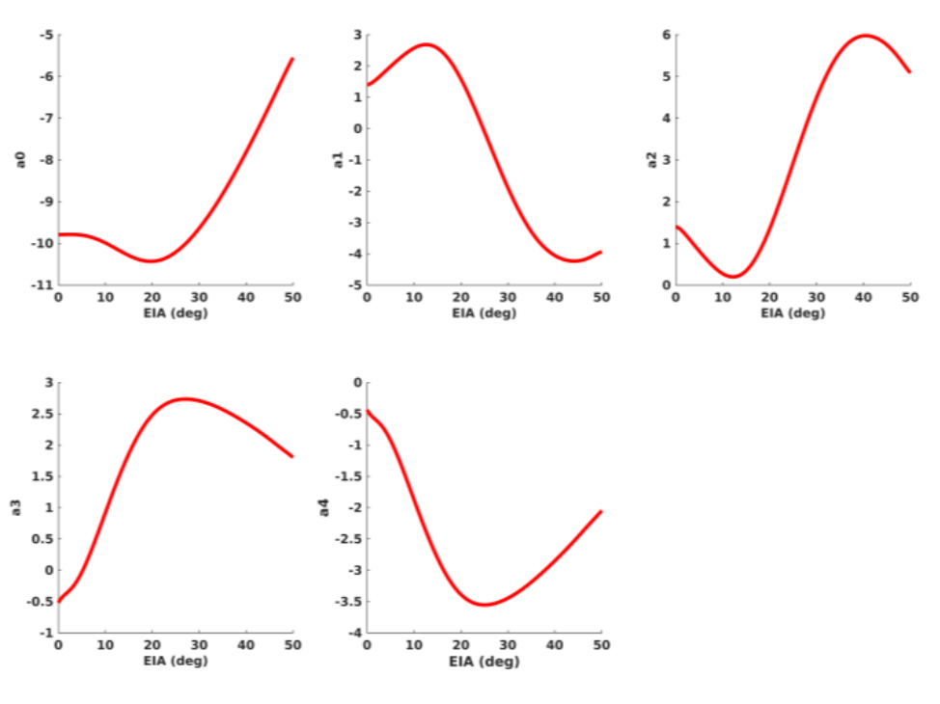
$$\text{CLW (mm)} = a_0 + [a_1{*}\ln(290-T_{B19v}) + a_2{*}\ln(290-T_{B19h})] + [a_3{*}\ln(295-T_{B85v}) + a_4{*}\ln(295-T_{B85h})]$$

$$\text{WV (mm)} = a_0 + [a_1{*}T_{B10v} + a_2{*}T_{B10h}] + [a_3{*}\ln(290-T_{B19v}) + a_4{*}\ln(290-T_{B19h})] + [a_5{*}\ln(290-T_{B37v}) + a_6{*}\ln(290-T_{B37h})] + a_7{*}(\text{SST})$$

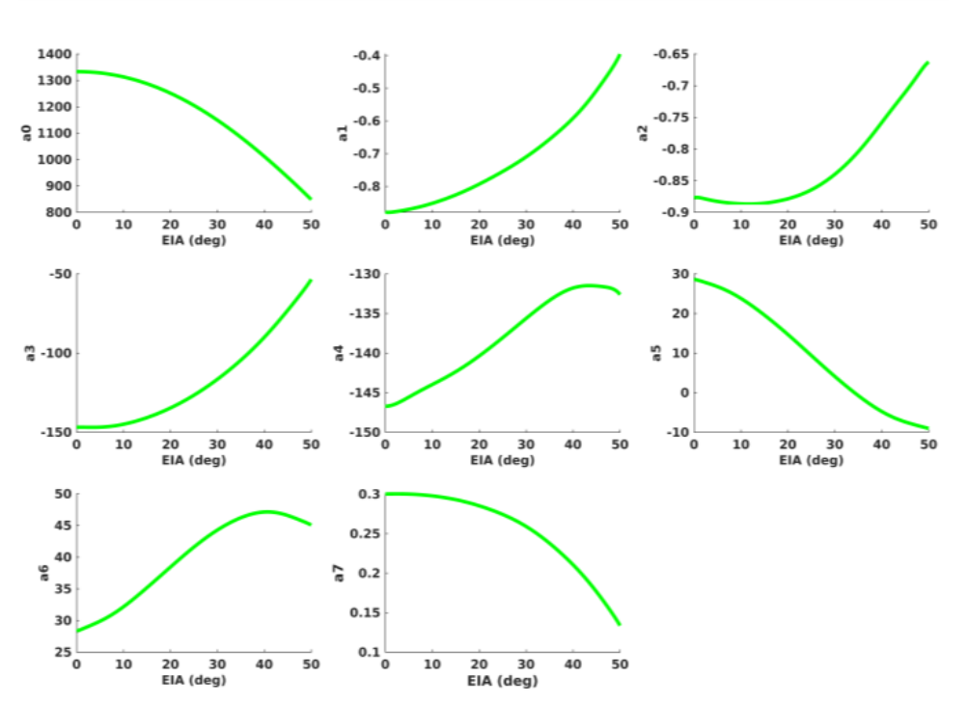
$$\text{WS (m s}^{-1}) = a_0 + [a_1{*}\ln(285-T_{B10v}) + a_2{*}\ln(285-T_{B10h}) + a_3{*}T_{B10v}^2 + a_4{*}T_{B10h}^2 + a_5{*}(T_{B10v}{*}\,T_{B10h})] + [a_6{*}T_{B19v} + a_7{*}T_{B19h} + a_8{*}T_{B19v}^2 + a_9{*}T_{B19h}^2 + a_{10}{*}(T_{B19v}{*}\,T_{B19h})] + [a_{11}{*}T_{B37v} + a_{12}{*}T_{B37h} + a_{13}{*}T_{B37v}^2 + a_{14}{*}T_{B37h}^2 + a_{15}{*}(T_{B37v}{*}\,T_{B37h})] + a_{16}{*}(\text{SST})$$

$T_{Bxxh,v}$ = T_b at xx-GHz frequency and h, v polarization; SST = *a priori* sea-surface temperature (K);
a_n = regression coefficients (function of AMPR Earth-incidence angle) – see figures below

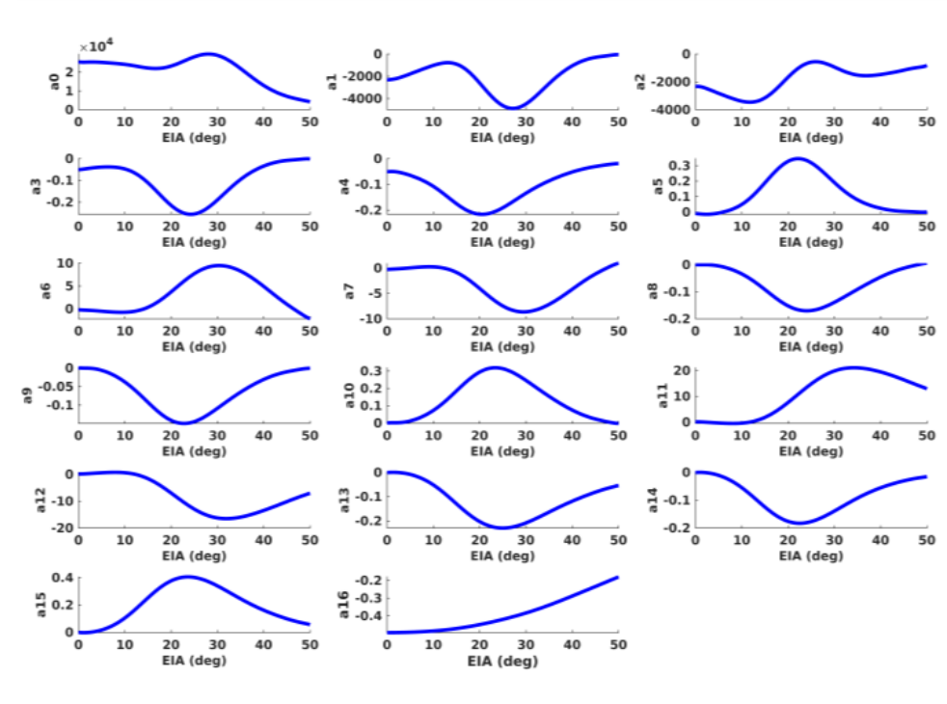
a_n for CLW



a_n for WV

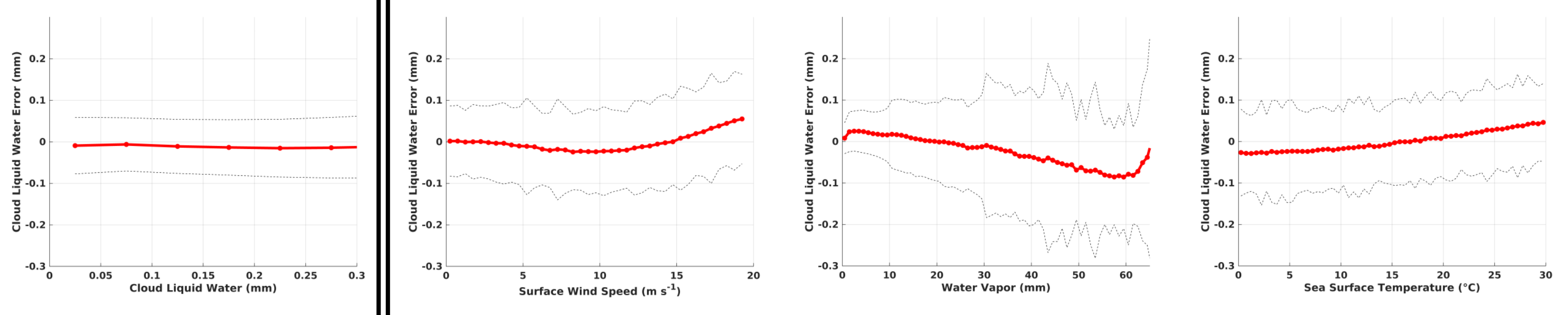


a_n for WS

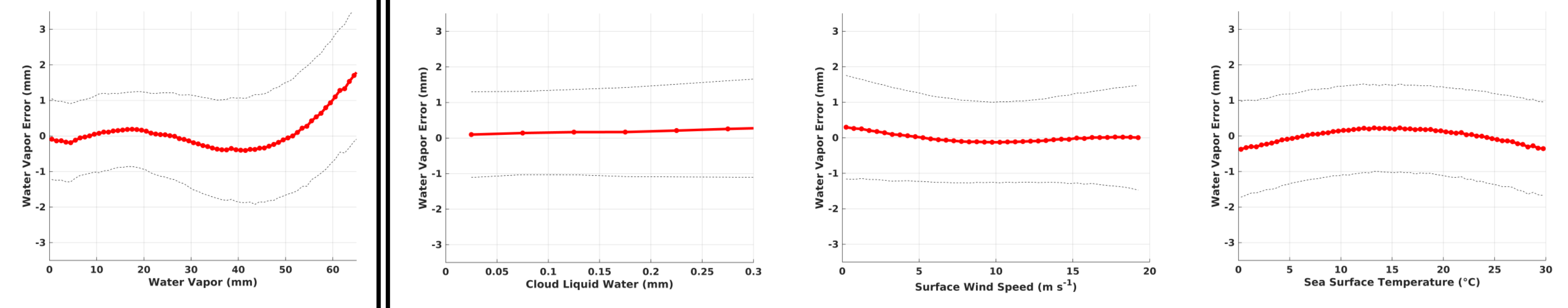


Simulation Results Using New Equations

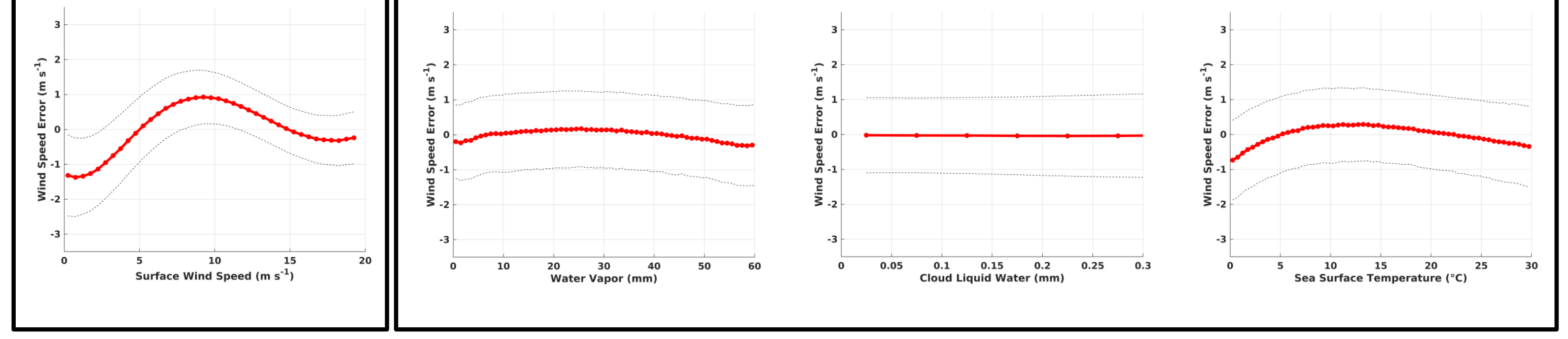
Cloud Liquid Water (CLW)



Atmospheric Water Vapor (WV)



10-m Wind Speed over Ocean (WS)

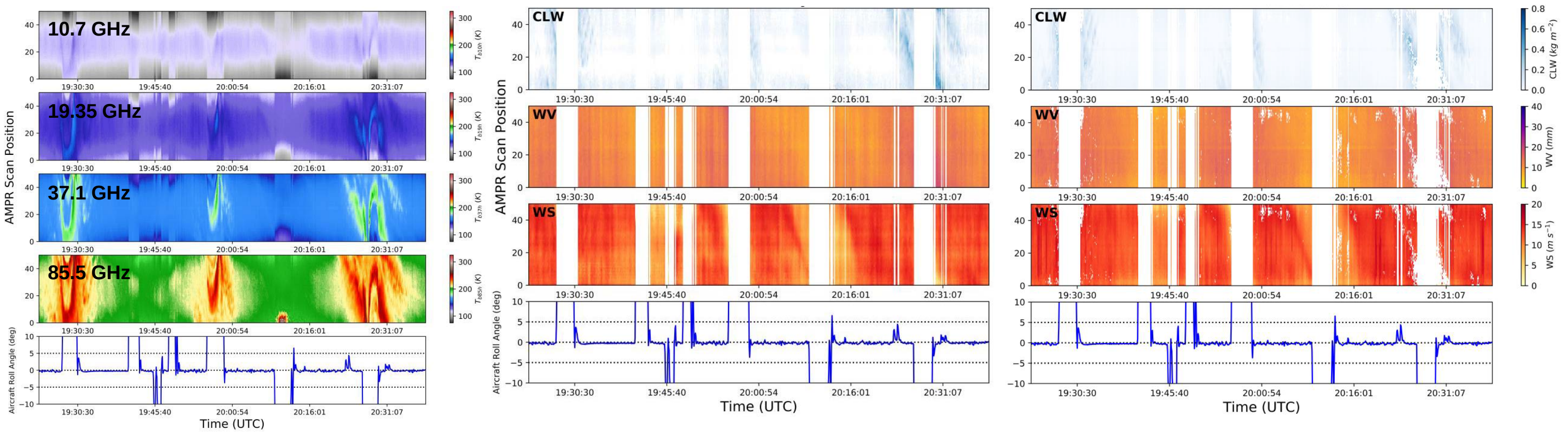


Retrieval Errors **Crosstalk Errors**

Retrieval Root-Mean-Square Deviations:	Retrieval MedAD values:
CLW: 0.11 mm	CLW: 2.26 x 10^{-2} mm
WV: 1.28 mm	WV: 0.22 mm
WS: 1.11 m s^{-1}	WS: 0.55 m s^{-1}

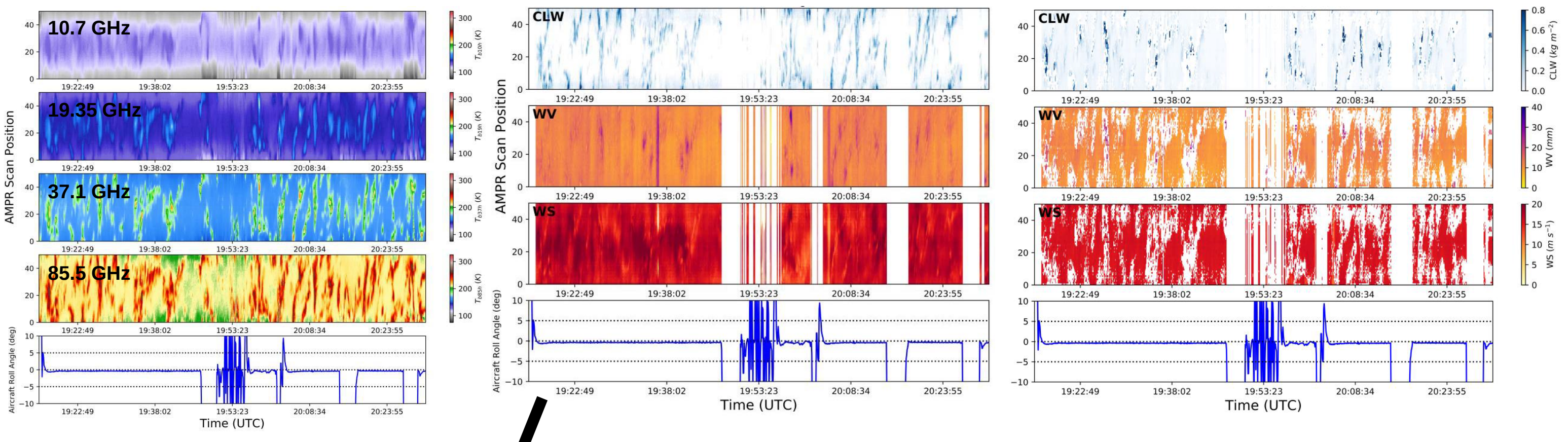
New Equations Compared with 1DVAR

24 November 2015: mostly clear-air and light precipitation overpasses



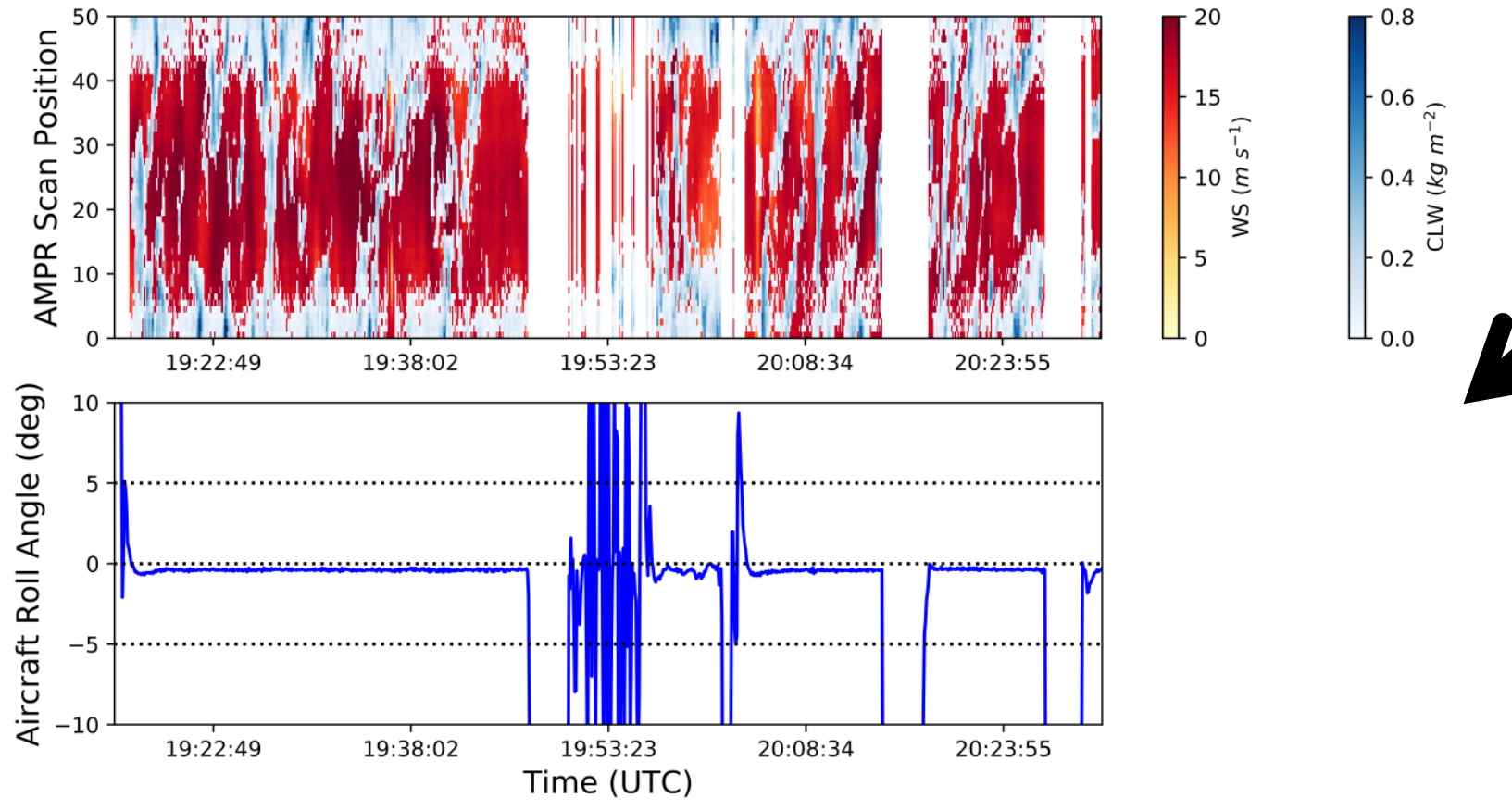
H-polarized AMPR T_b (K) New Equation Results 1DVAR Results

13 December 2015: stronger convection; gust fronts observed in new WS Eq.



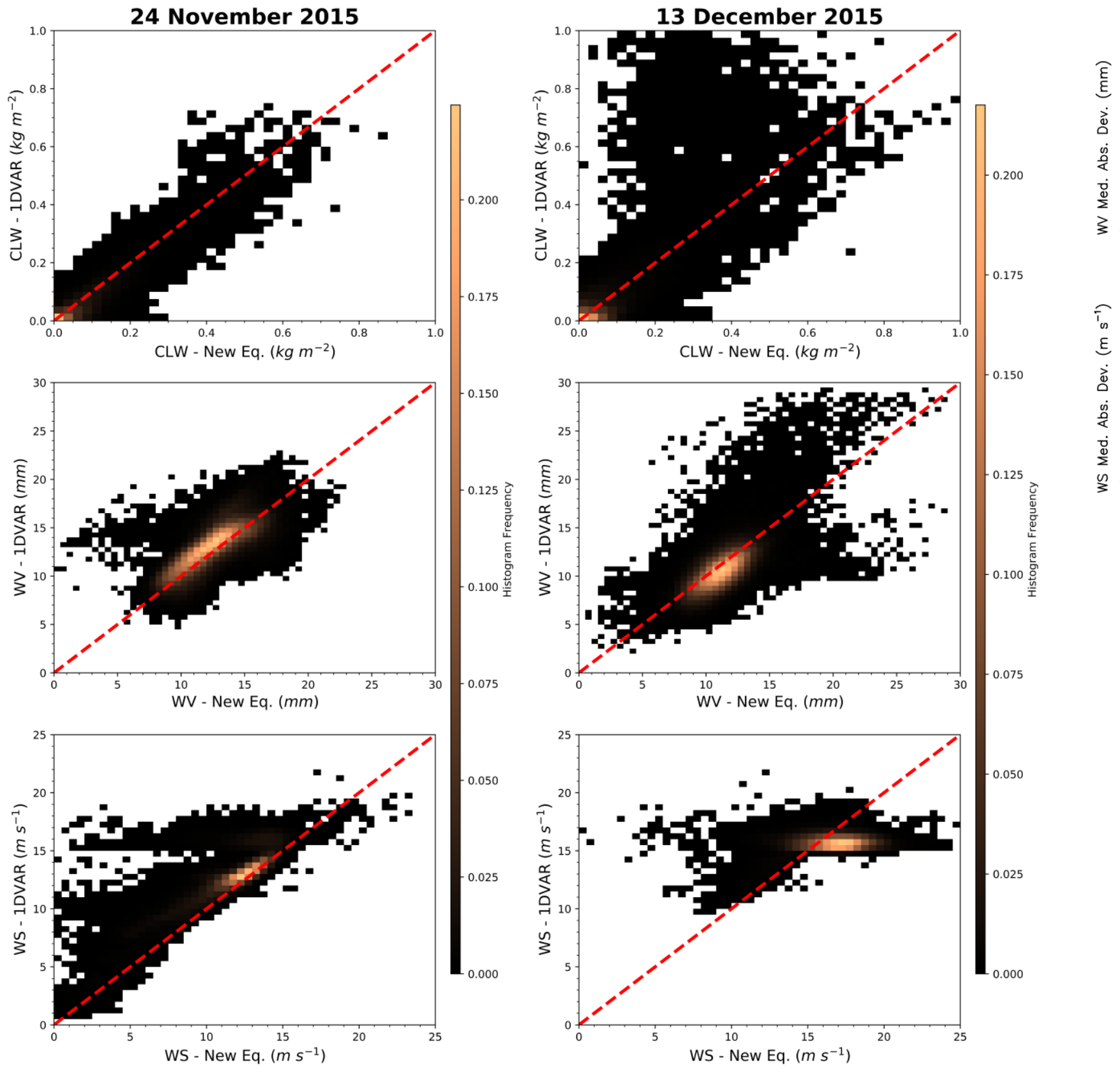
H-polarized AMPR T_b (K) New Equation Results 1DVAR Results

Gust Fronts, Post-Frontal Convection

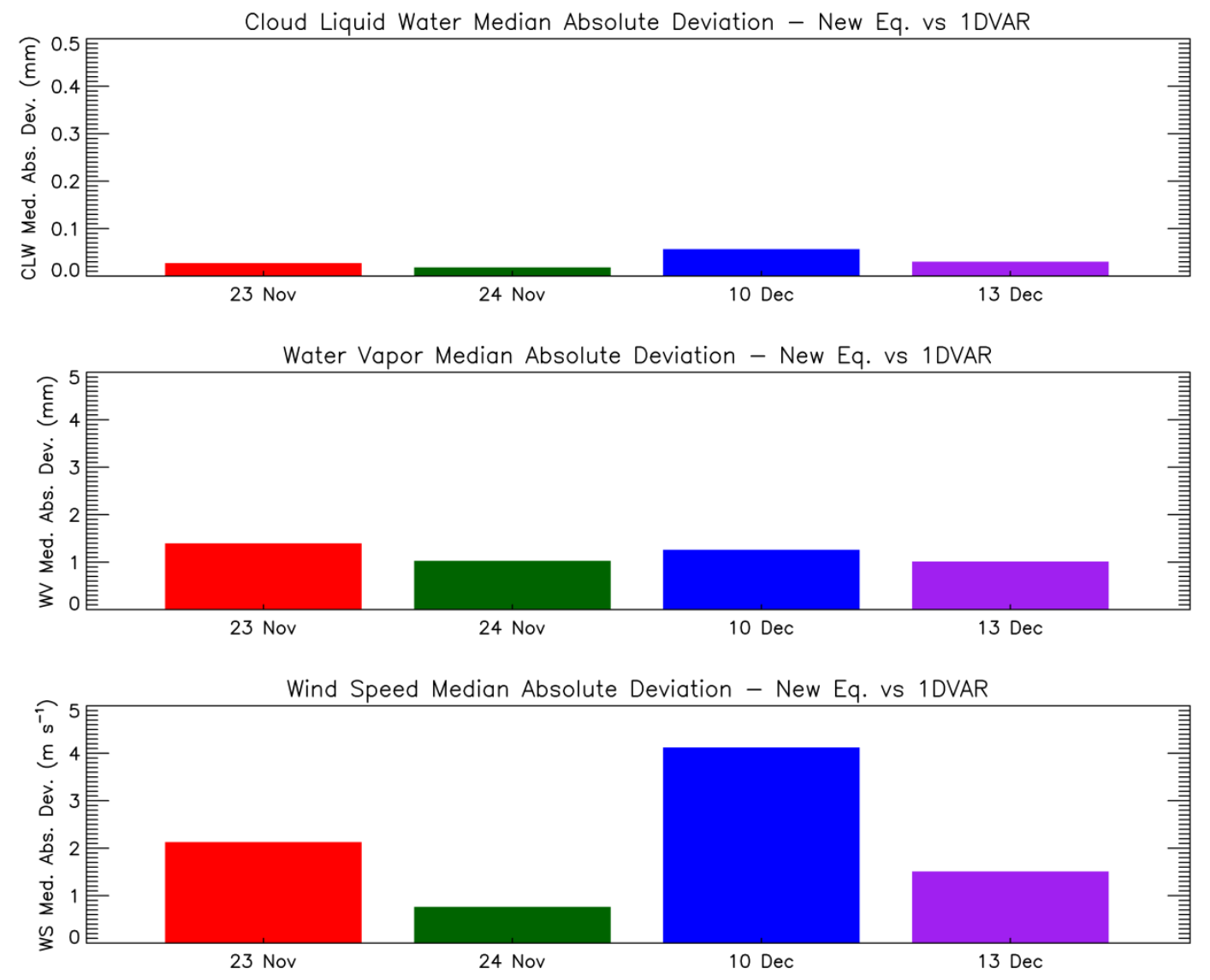


- Masked AMPR pixels where CLW > 0.01 kg m^{-2}; plotted these relatively high CLW values (blue colorbar)
- Plotted WS where CLW ≤ 0.01 kg m^{-2} (red colorbar)
- WS maxima fall outside of CLW maxima (i.e., are not an effect of rain impact on T_b signal)
- Spatial offset from higher CLW values suggests presence of gust fronts resulting from post-frontal convection

2-D Histograms: New Eqs. vs 1DVAR



Median Absolute Deviation (MedAD)



Overall MedAD values:

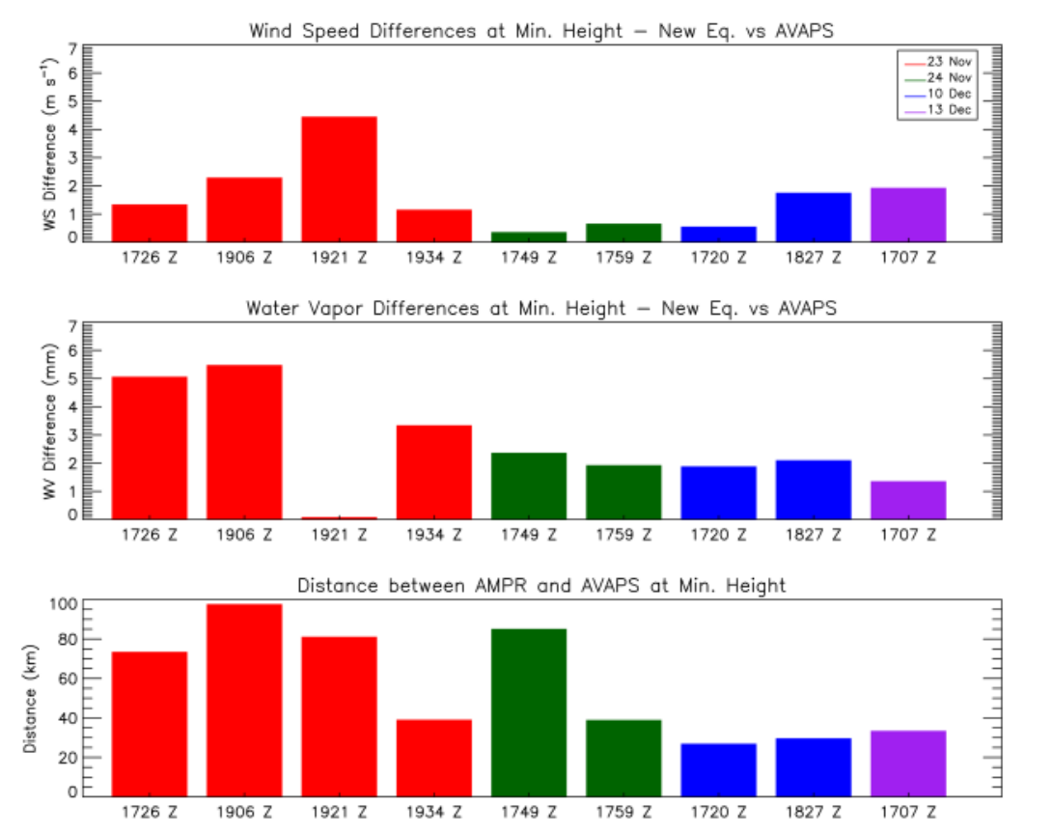
CLW: 2.88 x 10^{-2} mm
WV: 1.14 mm
WS: 1.82 m s^{-1}

Generally good agreement between New Equations and 1DVAR; differences in methods and masking

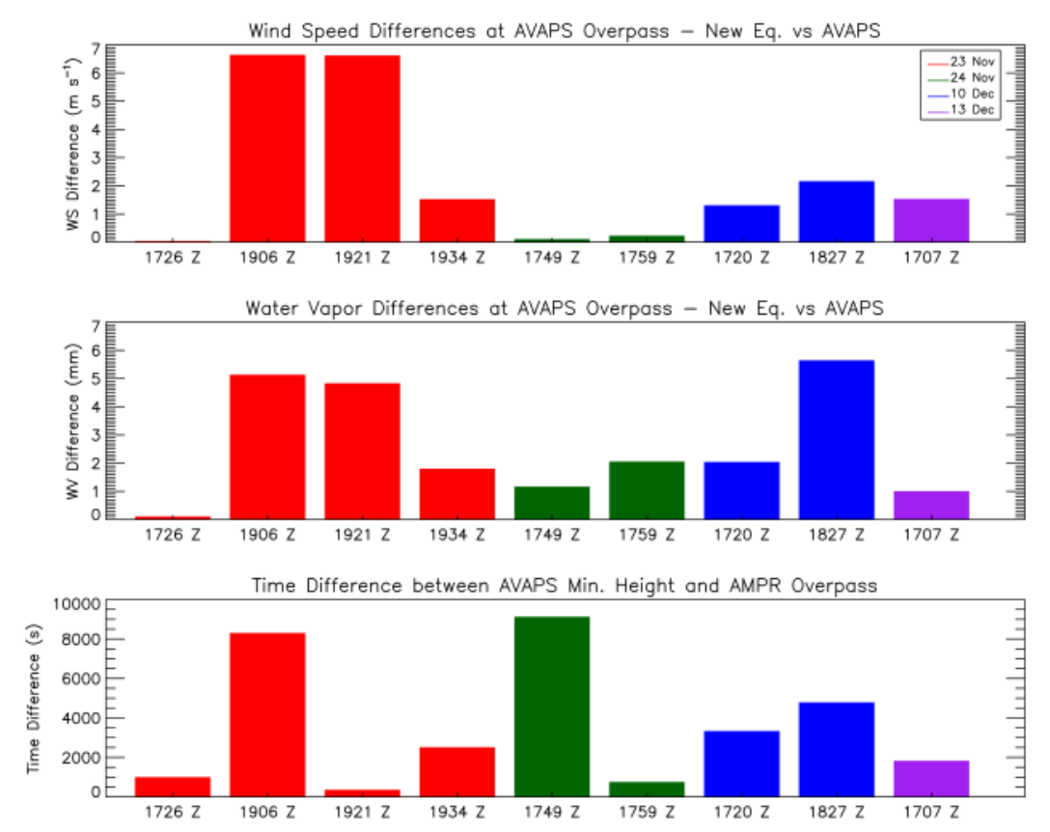
AVAPS In Situ Comparisons

- AMPR and AVAPS flown on separate aircraft during OLYMPEX/RADEX, so **spatial offset** between the instruments when AVAPS reached its min. height
- Also **temporal offset** between AVAPS reaching min. height and when AMPR passed over that location

Differences with **Spatial Offset**



Differences with **Temporal Offset**



Overall MedAD – Spatial:	Overall MedAD – Temporal:
WV: 2.10 mm	WV: 1.80 mm
WS: 1.15 m s^{-1}	WS: 1.53 m s^{-1}

Summary & Future Work

- New equations have been developed and tested for retrieving **cloud liquid water**, **water vapor**, and **10-m wind speed** over the ocean using AMPR data
- Minimal retrieval and crosstalk errors in simulations
- New equations compared well with 1DVAR and were able to detect finer-scale features (e.g., gust fronts)
- Fairly strong agreement between new WV and WS equations compared to AVAPS in situ values
- Reductions in retrieval error, crosstalk error, and data artifacts compared to past methods using AMPR data

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- **Future work** will include: analysis of additional cases from OLYMPEX/RADEX, testing the new equations in other climate regions (e.g., $CAMP^2Ex$ data from the Philippines), and developing additional retrieval equations (e.g., rainfall rate retrievals)

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