

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

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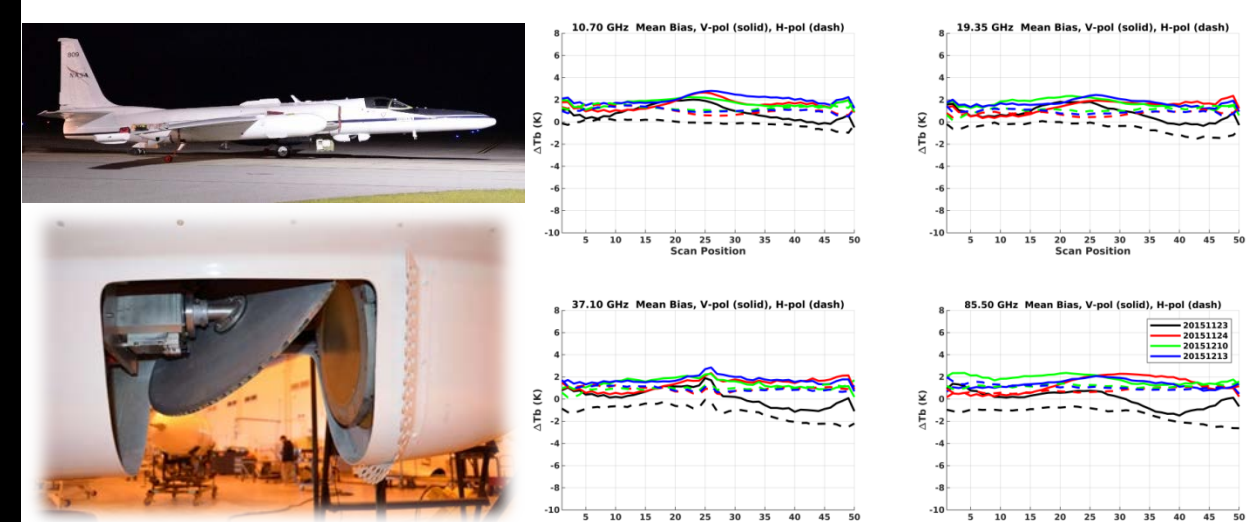
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Introduction & Background

- 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



Source for Figures: Biswas et al. (2017)

- 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)

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):

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

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

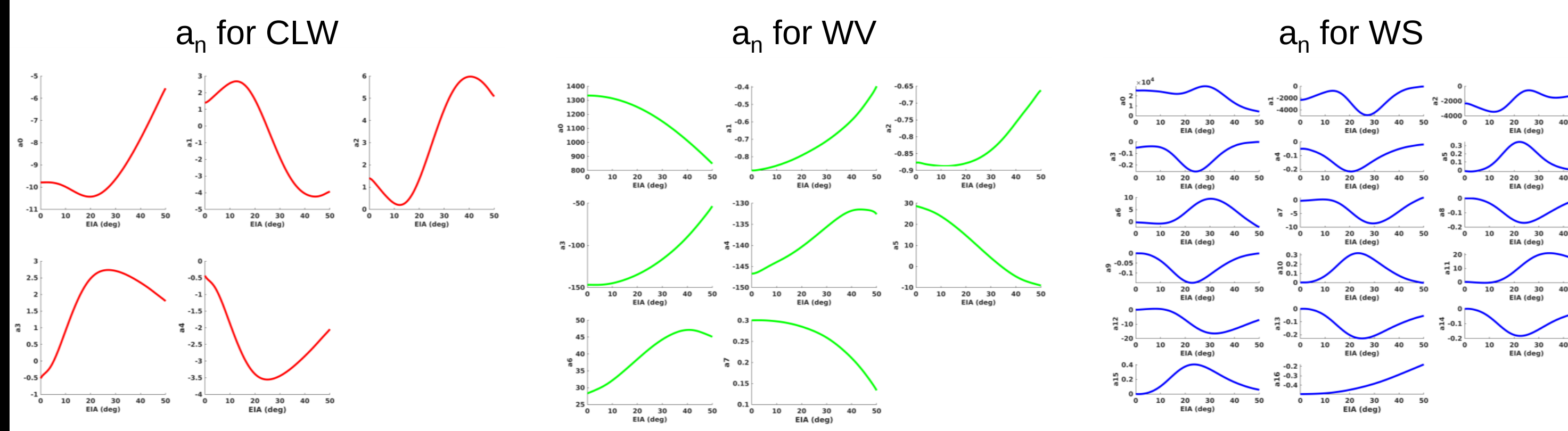
New Geophysical Retrieval Equations

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

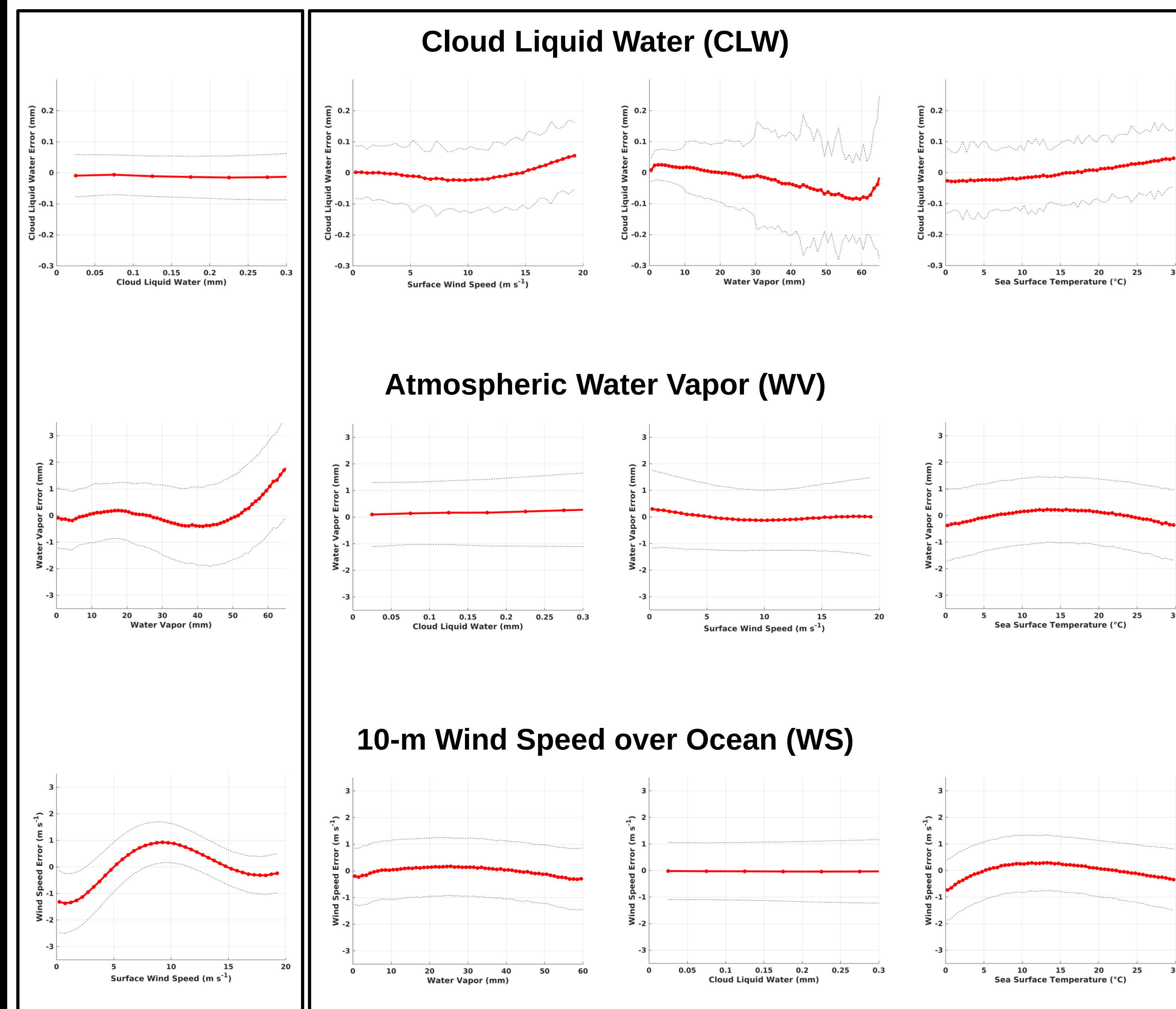
$$WV \text{ (mm)} = a_0 + [a_1 \cdot T_{B10v} + a_2 \cdot T_{B10h}] + [a_3 \cdot \ln(290 - T_{B19v}) + a_4 \cdot \ln(290 - T_{B19h})] + [a_5 \cdot \ln(290 - T_{B37v}) + a_6 \cdot \ln(290 - T_{B37h})] + a_7 \cdot (SST)$$

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

$T_{Bxxh,v} = T_b$ 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



Simulation Results Using New Equations



Retrieval Errors

Retrieval Root-Mean-Square Deviations:

CLW: 0.11 mm
WV: 1.28 mm
WS: 1.11 m s⁻¹

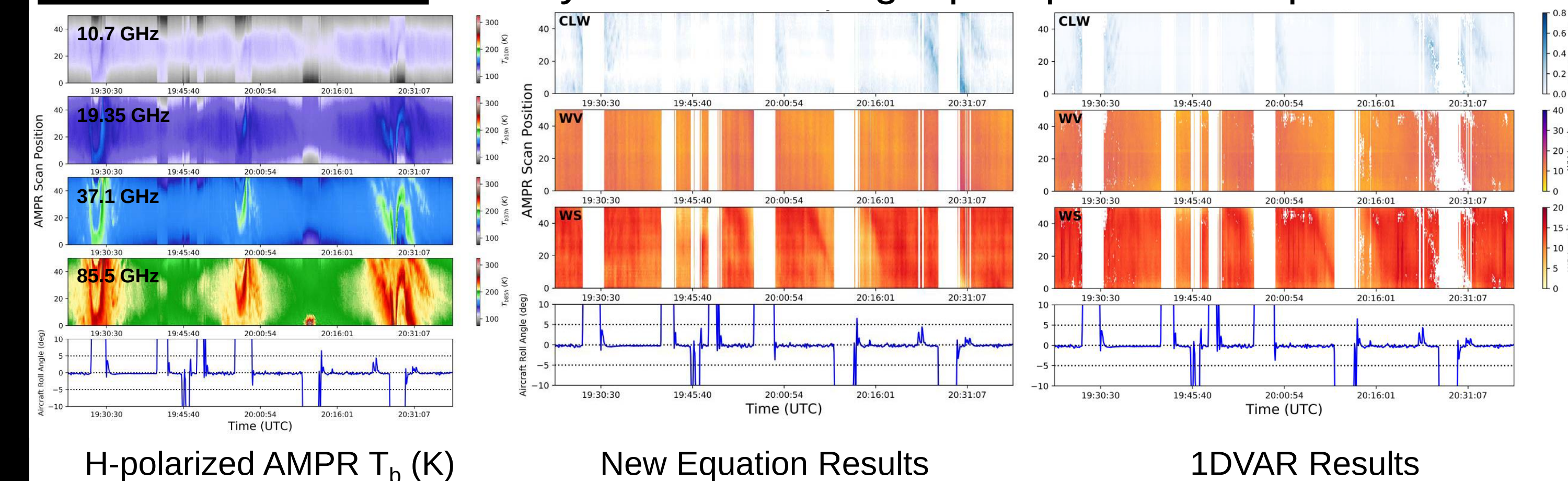
Crosstalk Errors

Retrieval MedAD values:

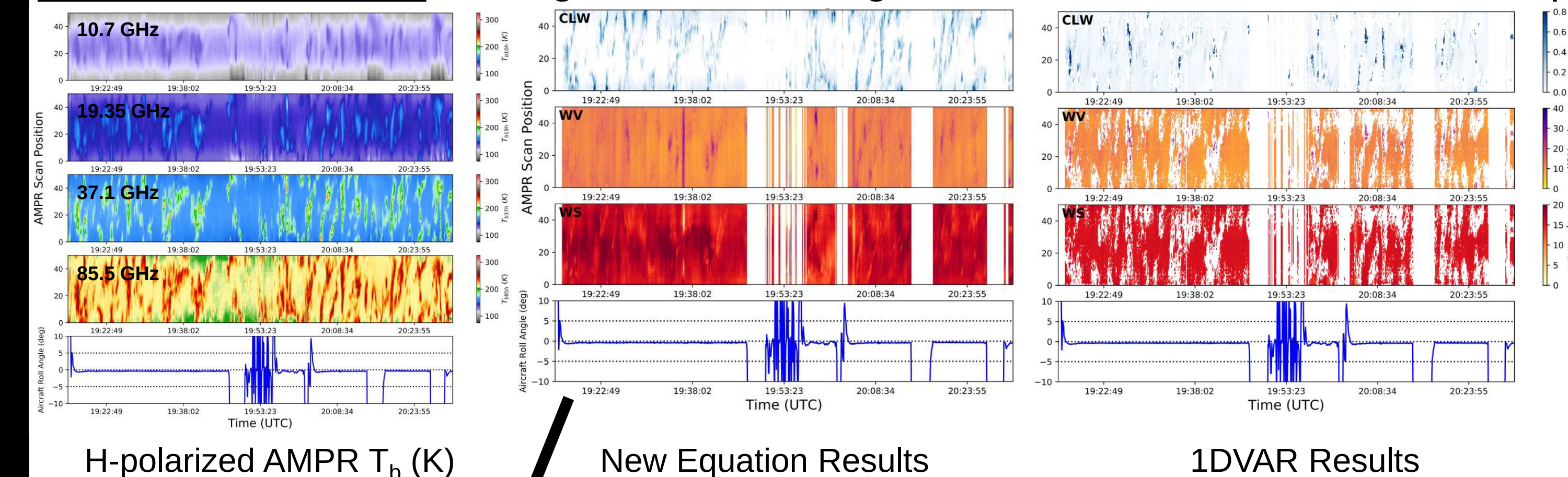
CLW: 2.26 x 10⁻² mm
WV: 0.22 mm
WS: 0.55 m s⁻¹

New Equations Compared with 1DVAR

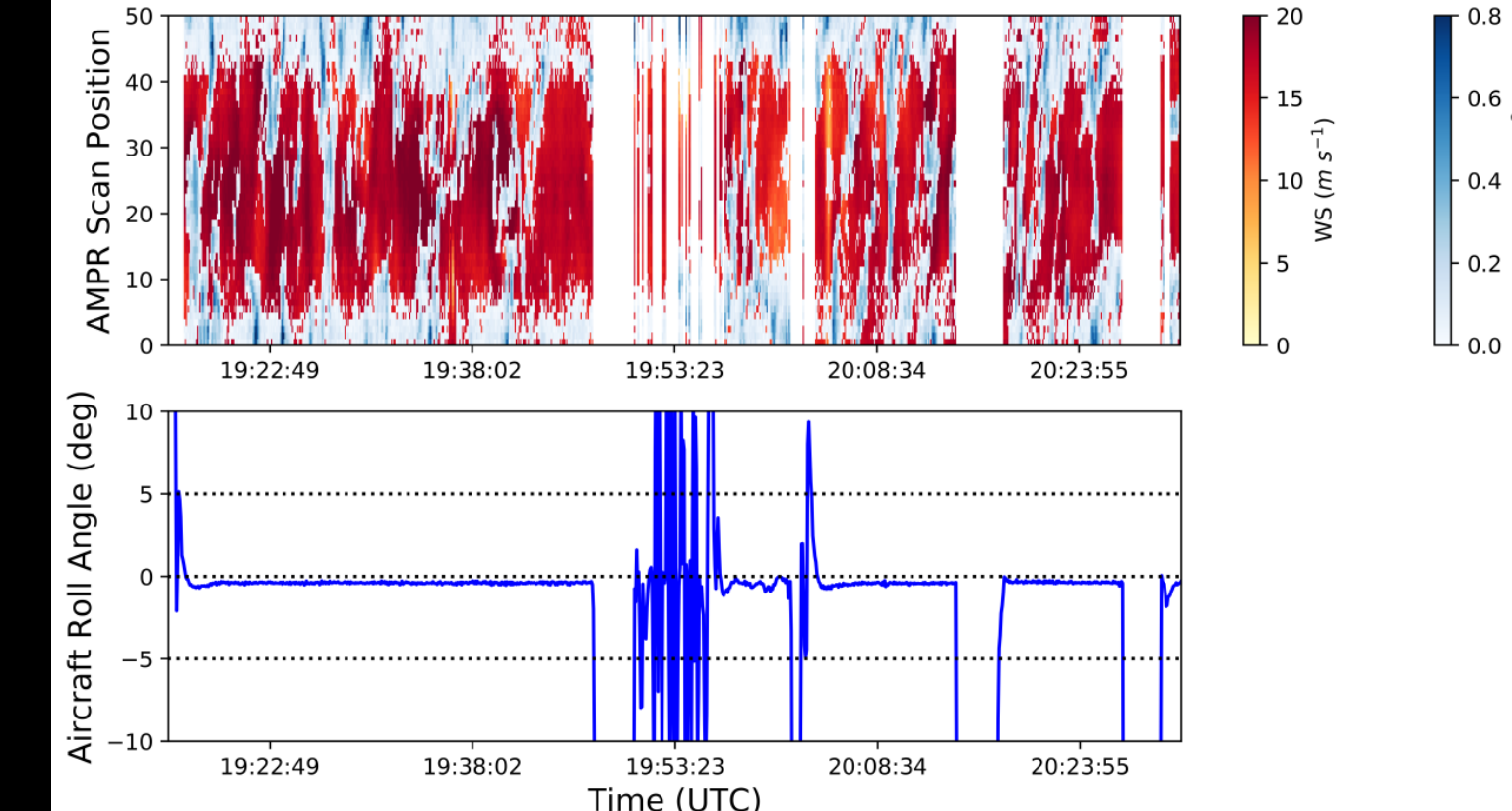
24 November 2015: mostly clear-air and light precipitation overpasses



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

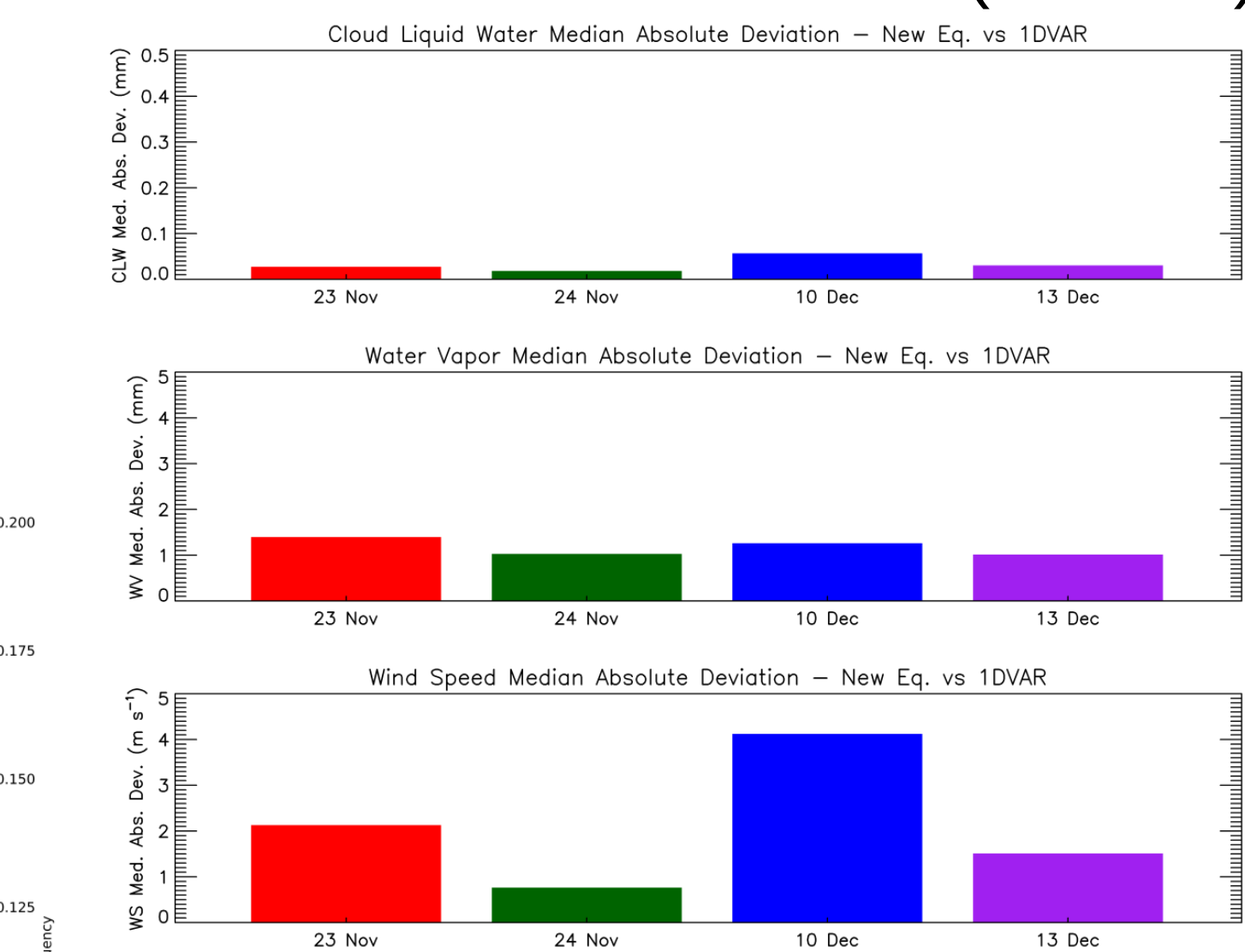


Gust Fronts, Post-Frontal Convection



- 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

Median Absolute Deviation (MedAD)



Overall MedAD values:

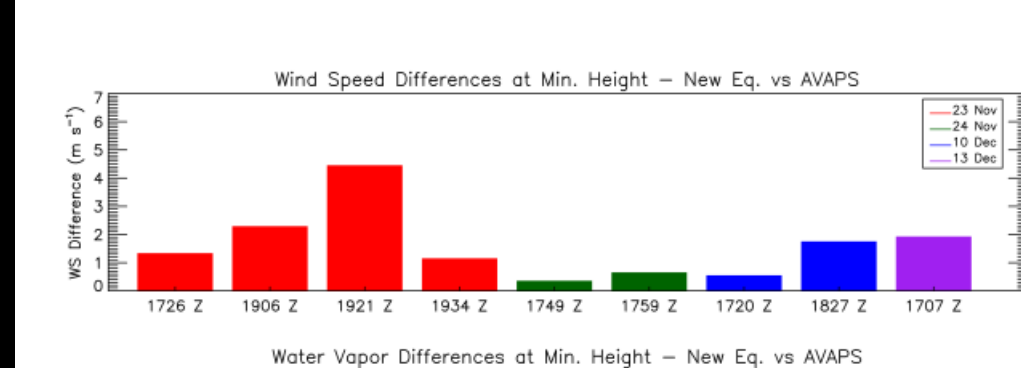
CLW: 2.88 x 10⁻² mm
WV: 1.14 mm
WS: 1.82 m s⁻¹

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

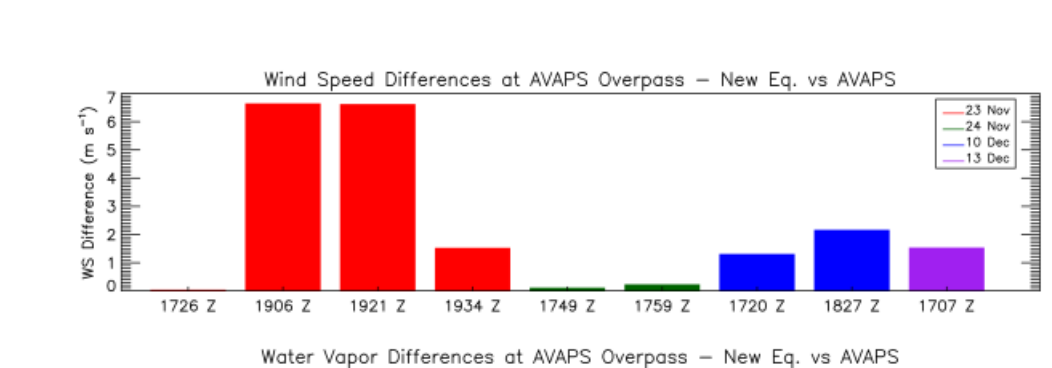
AVAPS In Situ Comparisons

- 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:

WV: 2.10 mm
WS: 1.15 m s⁻¹

Overall MedAD – Temporal:

WV: 1.80 mm
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
- Future work** will include: analysis of additional cases from OLYMPEX/RADEX, testing the new equations in other climate regions (e.g., CAMP²Ex data from the Philippines), and developing additional retrieval equations (e.g., rainfall rate retrievals)

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