Advanced Microwave Precipitation Radiometer (AMPR) Calibration and Geophysical Retrievals

- Plus Initial Results from CAMP^{2}Ex!

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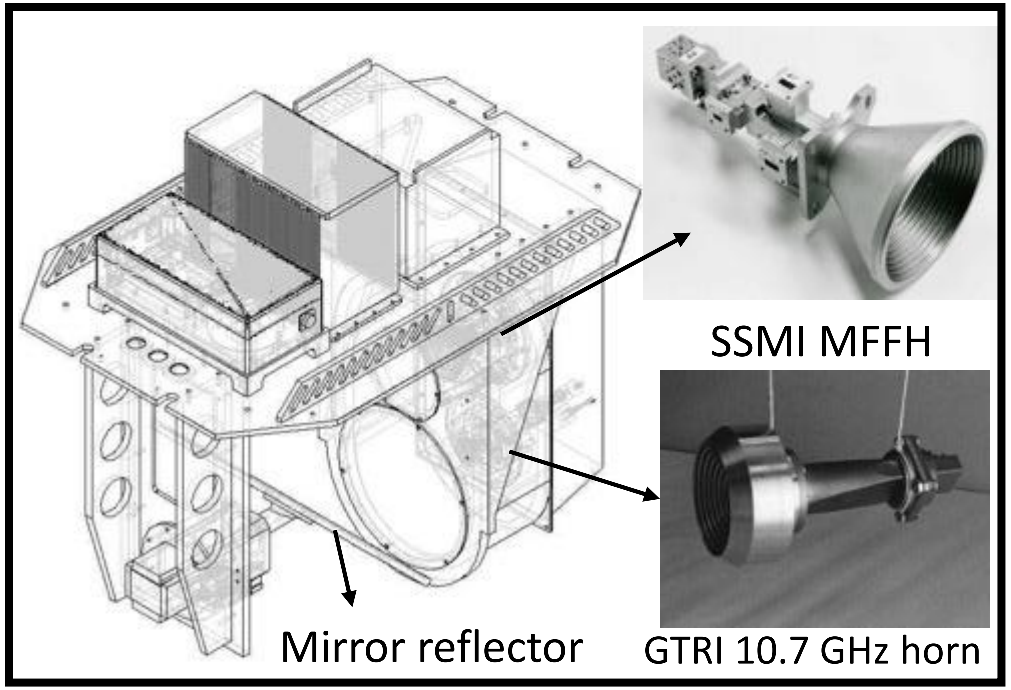
Talk Outline

- Overview of Instrument
- Calibration Methodology
- Geophysical Retrieval Methodology
- Results from OLYMPEX/RADEX campaign
- Initial Look at AMPR in CAMP^{2}Ex
- Conclusions



- Cross-track scanning microwave radiometer
- Four frequencies: 10.7, 19.35, 37.1, & 85.5 GHz
- Sensitive to precipitation, CLW, WV, ocean wind speed

Channel Center Frequency	85.5GHz	37.1GHz	19.35GHz	10.7GHz
Polarization	A/B	A/B	A/B	A/B
Pre Detection Bandwidth (MHz)	1400	900	240	100
Integration Time (ms)	50	50	50	50
Horn Type	SSM/I	SSM/I	SSM/I	GTRI
Lens Diameter (inches)	5.3	5.3	5.3	9.7
Beam width (degrees)	1.8	4.2	8.0	8.0
Footprint (km) [@20 km ER-2 alt. 500kts]	0.64	1.48	2.78	2.78

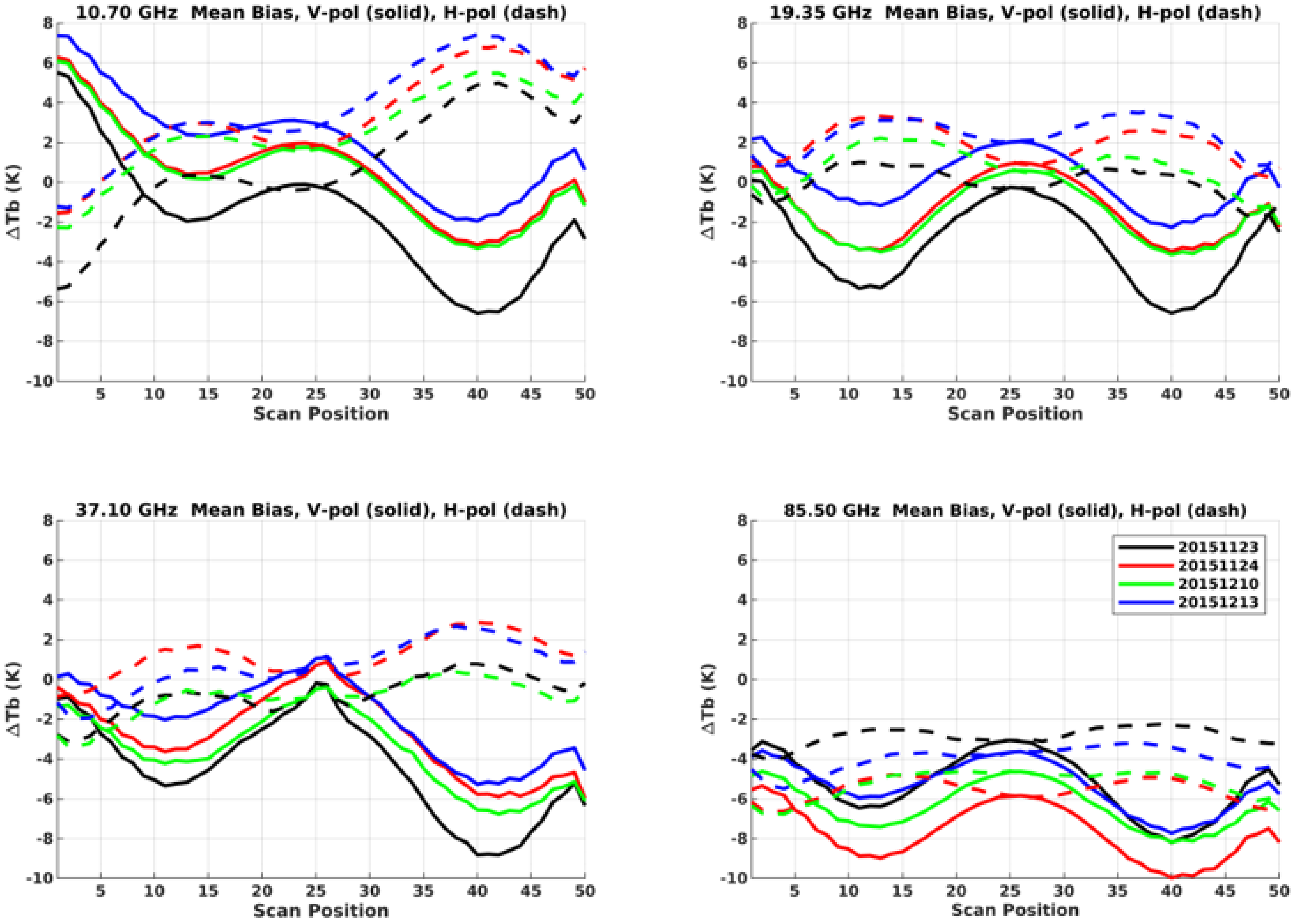
Feed horn polarization basis (A/B) rotates with respect to the scene polarization basis (V/H) as a function of scan angle.

Calibration Approach

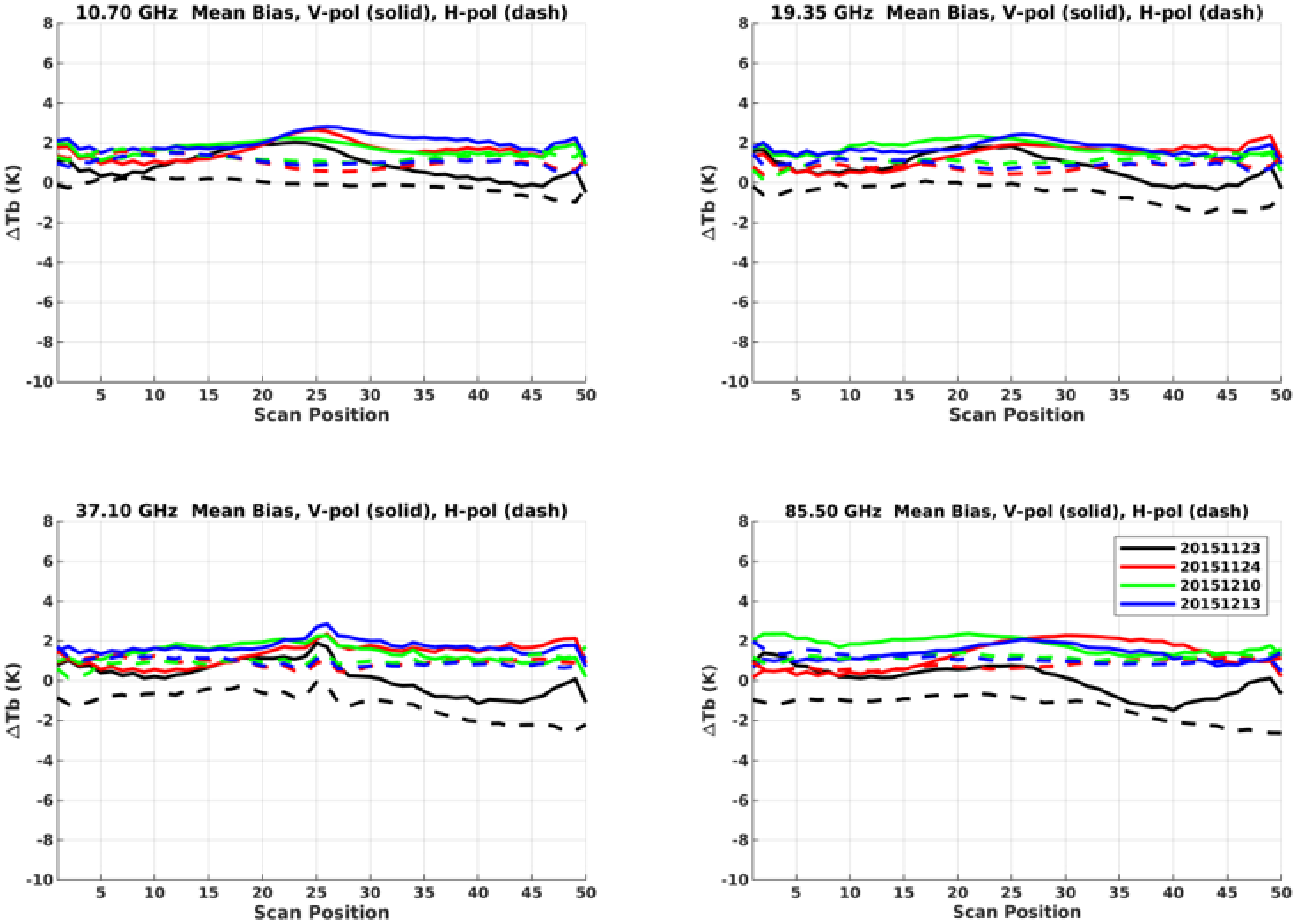
- The relationship between Tb measured in instrument polarization basis (A,B) and the scene polarization basis (V,H) is given by,

$$\begin{bmatrix} T_V \\ T_H \end{bmatrix} = \begin{bmatrix} \sin^2(45-\phi) & \cos^2(45-\phi) \\ \cos^2(45-\phi) & \sin^2(45-\phi) \end{bmatrix} \begin{bmatrix} T_A \\ T_B \end{bmatrix} \quad (1)$$

- Equation (1) is used to created observed V,H –pol Tb data from AMPR measurements.
- Standard two-blackbody approach does not help with biases related to different scan angles
- Tb Bias = Tb (Observed) – Tb (Simulated)
- GDAS profiles and SST information was used to simulate V,H –pol TB for several OLYMPEX flights with data over ocean.



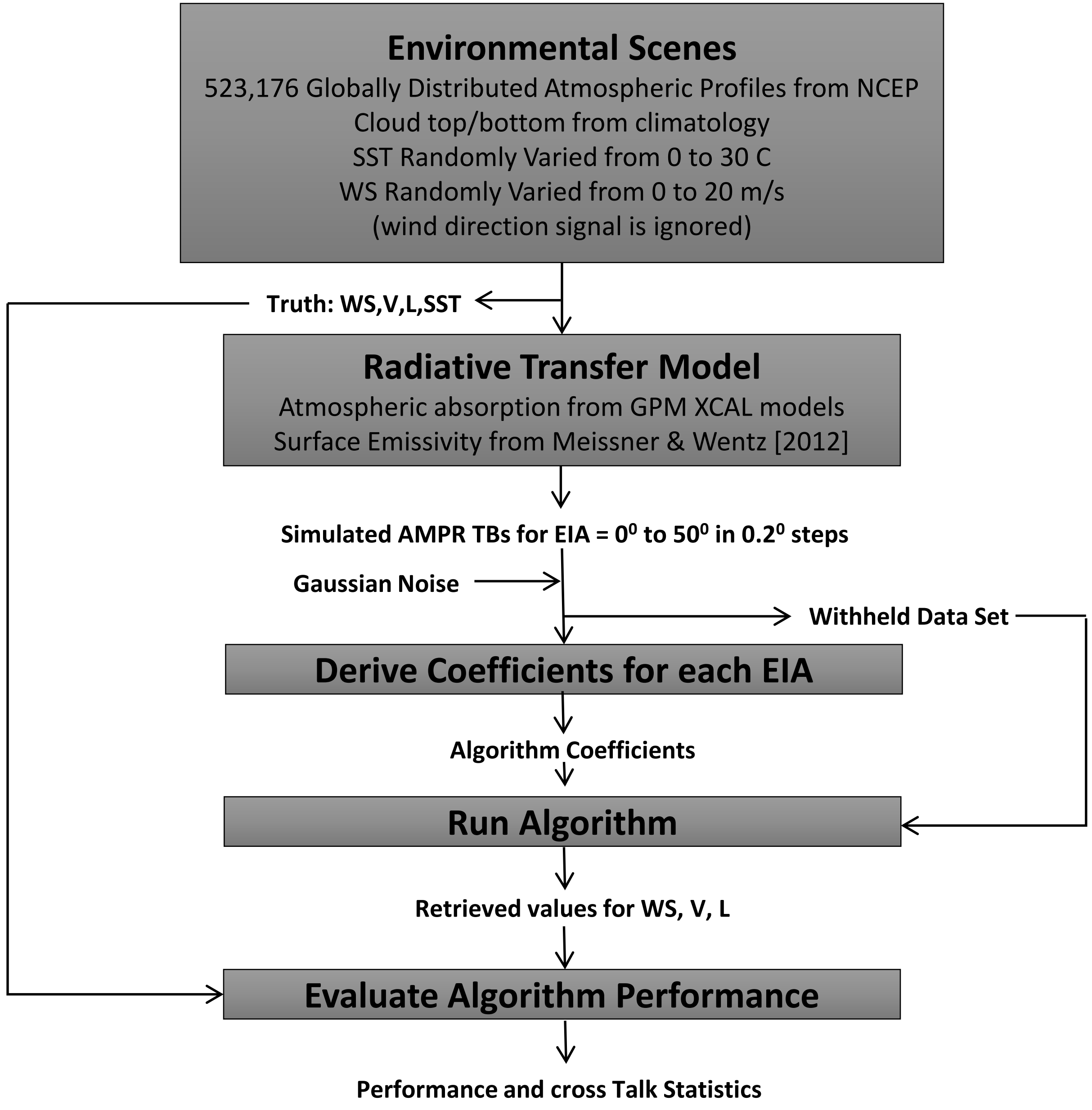
- AMPR flights for Olympic Mountain Experiment / Radar Definition Experiment (OLYMPEX/RADEX) occurred in late 2015 in Western WA
- Case study dates: 11/23, 11/24, 12/10, 12/13
- All AMPR channels available
- Available AVAPS dropsondes
- Need to adjust cross-track biases separately for each date



Mean T_b biases after corrections:

- Cross-polarization fraction
- Polarization mixing geometry
- Antenna pattern
- Error in estimation of receiver gain and offset

Coefficient Derivation & Testing



Geophysical Retrieval Equations

Cloud Liquid Water

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

Water Vapor

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

Ocean-surface Wind Speed (at 10 m AGL)

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

$T_{Bxxh,v}$ = deconvolved T_b for xx-GHz channel at h,v polarization, SST is sea-surface temperature in Kelvin, and a_n values are regression coefficients as a function of AMPR EIA

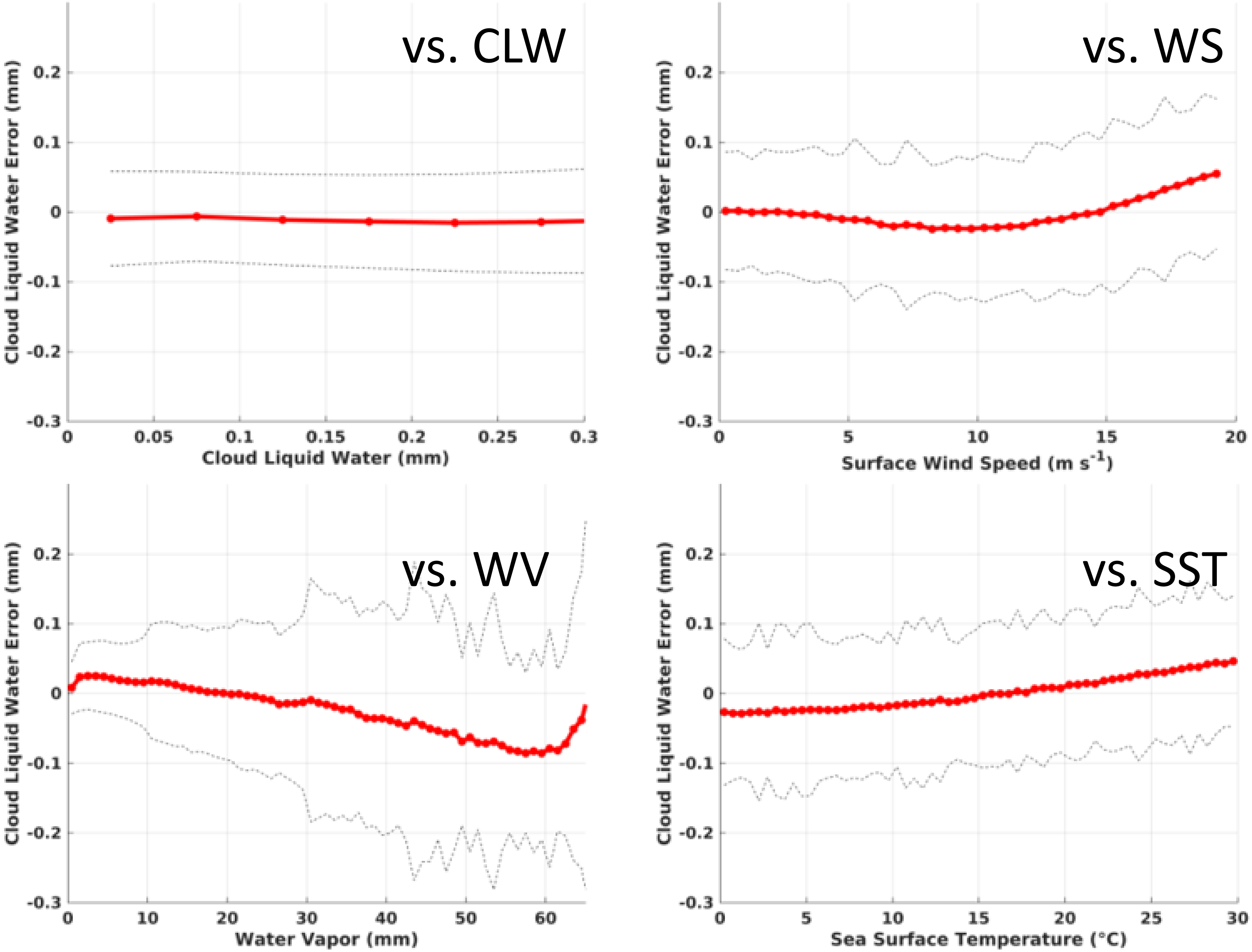
SST used in the WS and WV equations is the <u>median</u> SST observed during the ER-2 flight on the date being analyzed

Sensitivity test (not shown herein) indicated slightly lower error / deviation when using median SST compared to mean SST or a single assumed SST value

Cloud Liquid Water

Retrieval / Crosstalk Errors

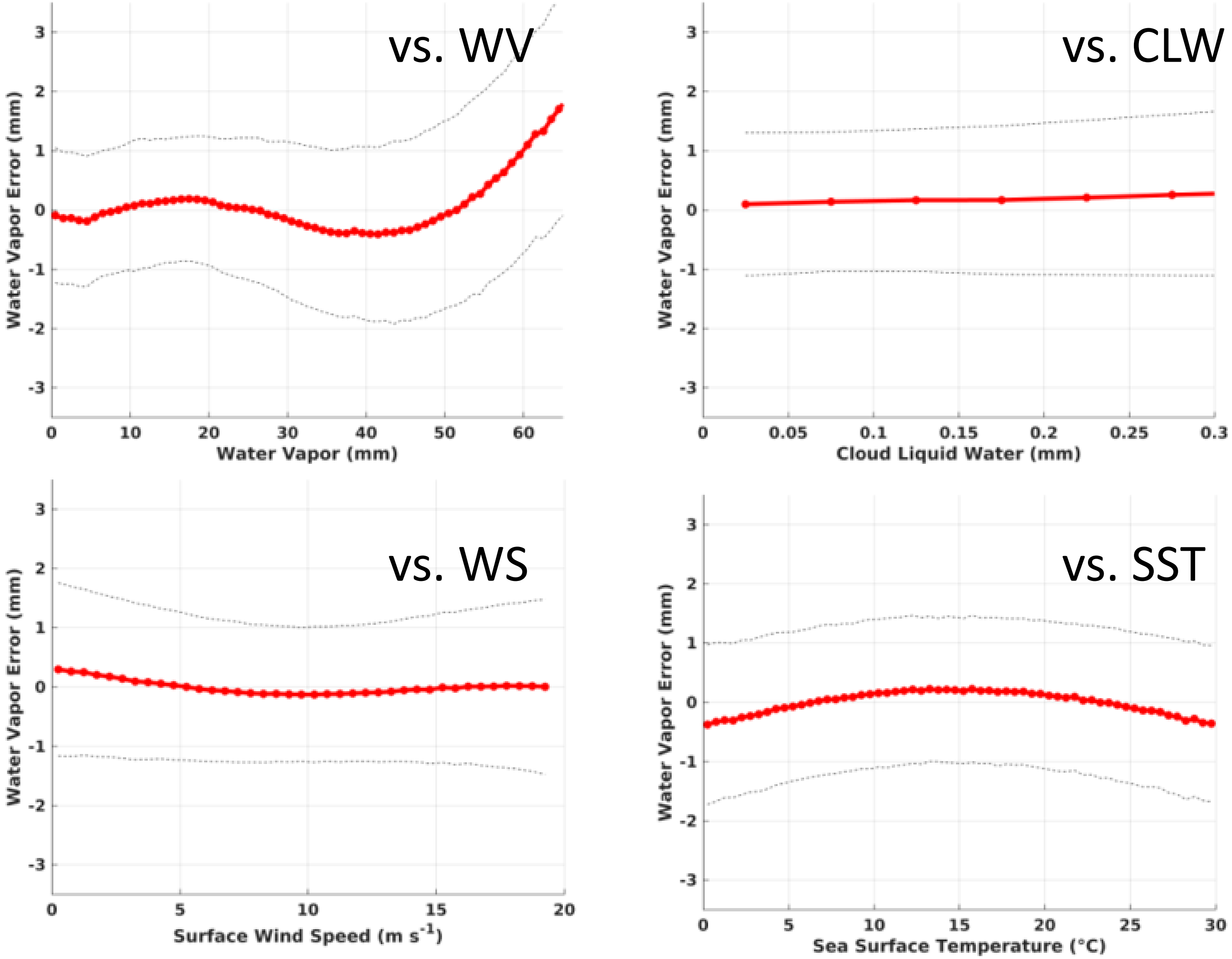
Median Absolute Deviation = **2.3 x 10^{-2} mm**



Water Vapor

Retrieval / Crosstalk Errors

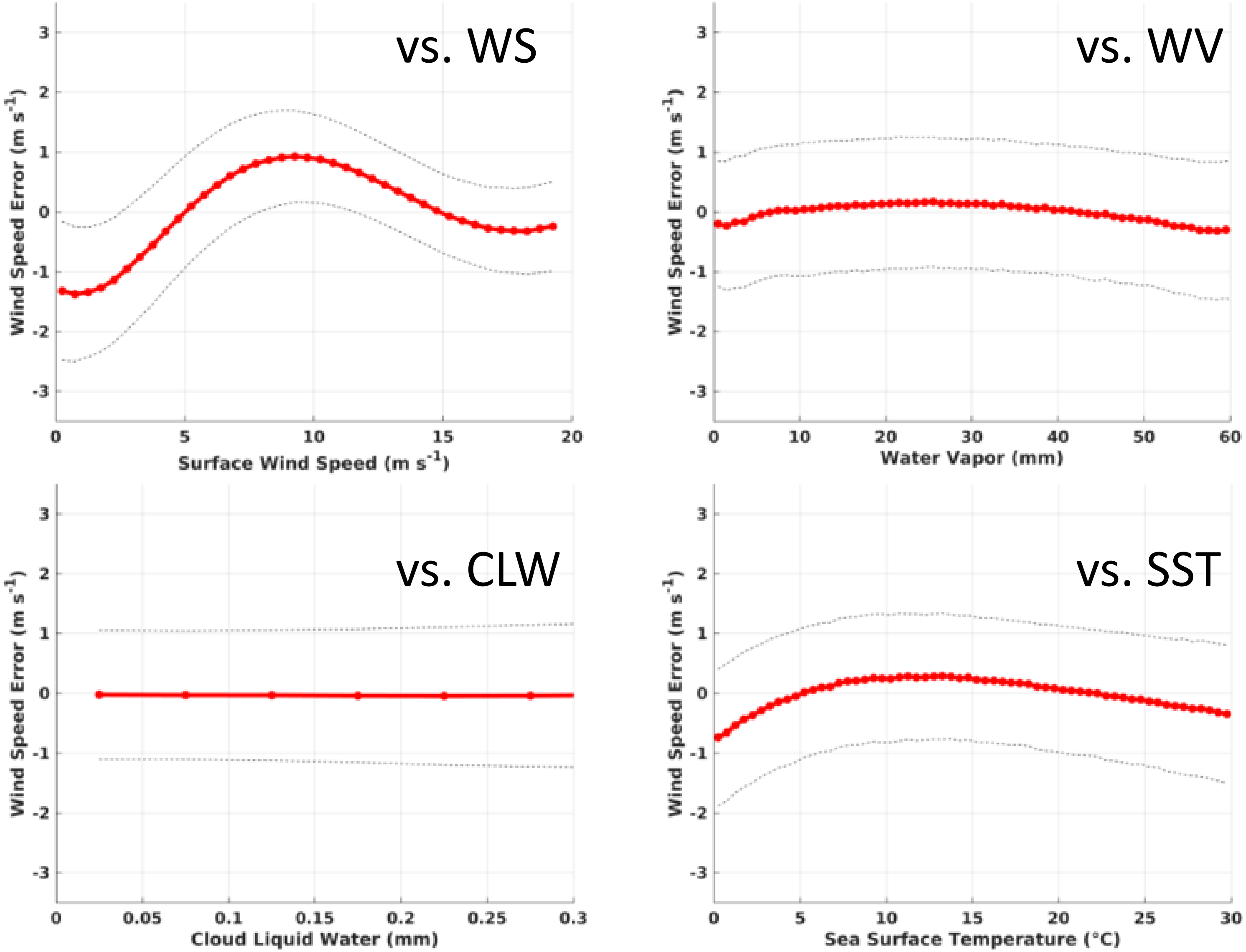
Median Absolute Deviation = **0.2 mm**



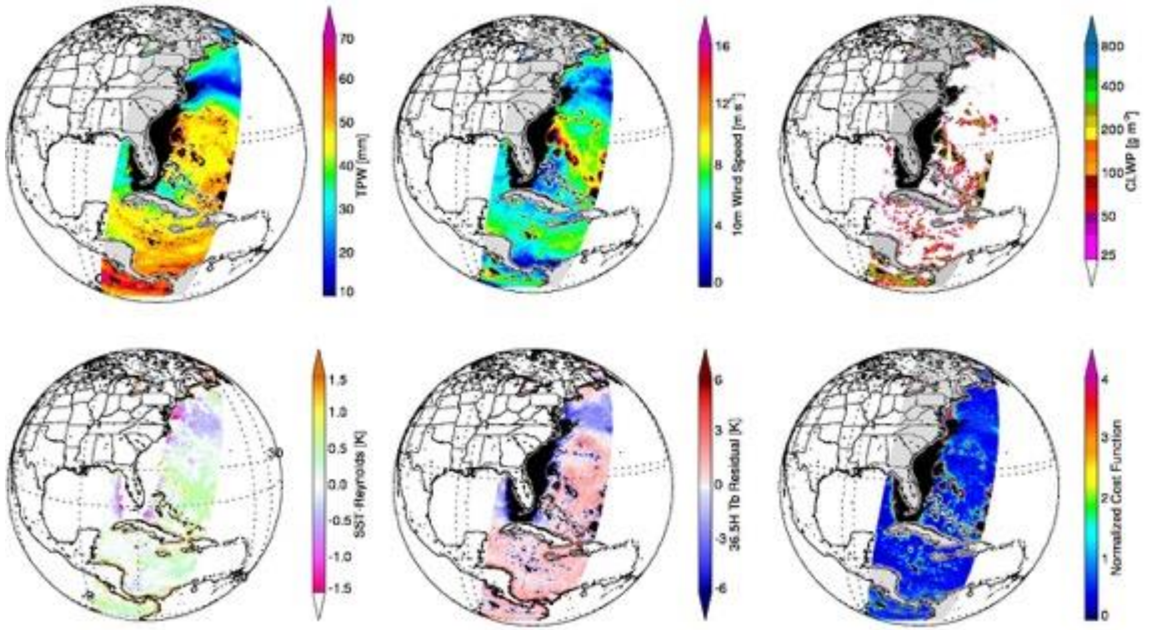
Wind Speed

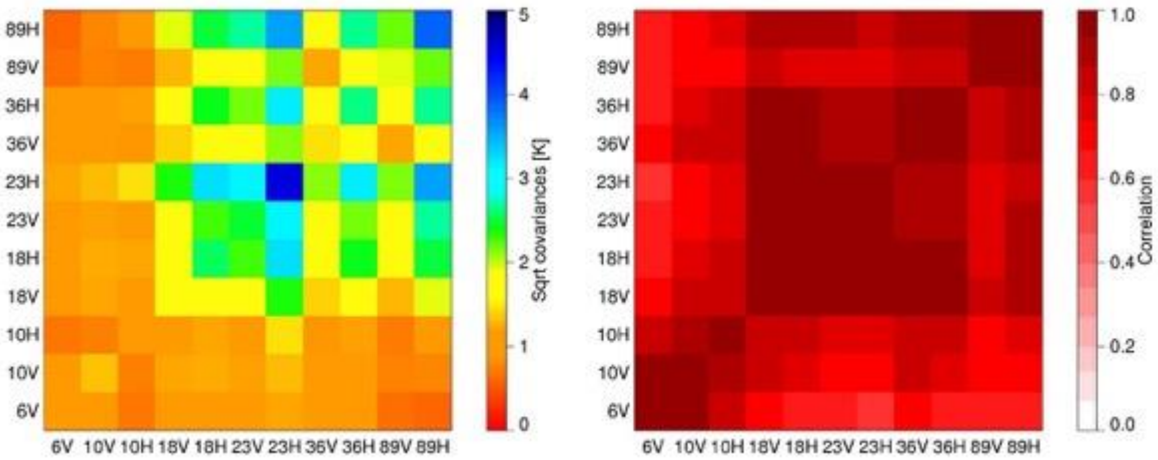
Retrieval / Crosstalk Errors

Median Absolute Deviation = **0.6 m/s**



CSU 1DVAR



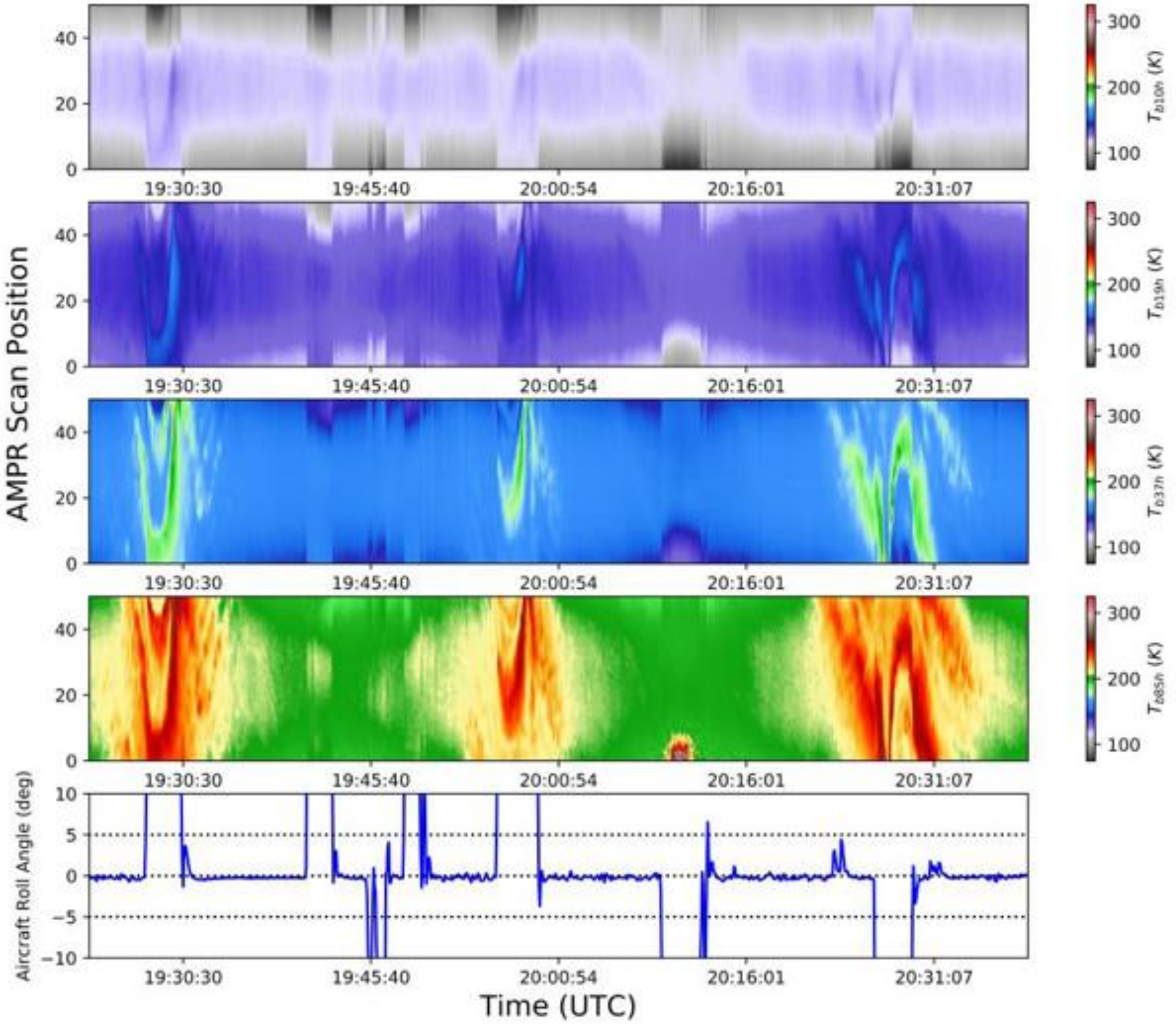


- Optimal estimation retrieval for microwave imagers over ocean
- Simultaneously solve for wind speed, SST, liquid water path, and water vapor profile
- CRTM with FASTEM6 in forward model
- Water vapor profile decomposed into principal components
- Novel observation error covariance matrix accounts for co-varying forward model errors
- Applicable to any imager platform due to physical forward model
- See Duncan and Kummerow (2016) for additional details

Case study example: 11/24/2015

TB_H for
(top to bottom):

- 10.7 GHz
- 19.35 GHz
- 37.1 GHz
- 85.5 GHz

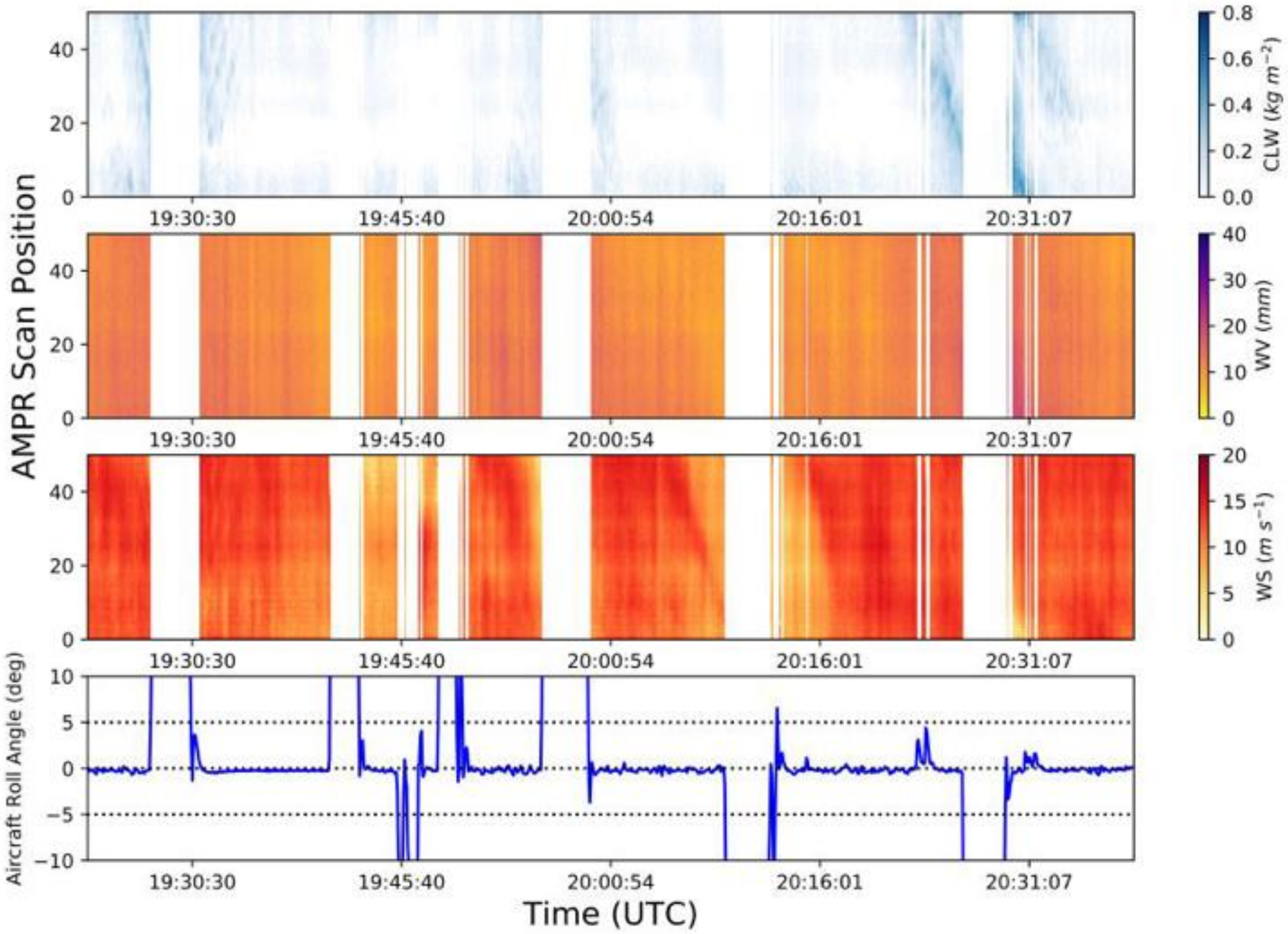


Cloud Liquid Water

Empirical Retrievals

Water Vapor

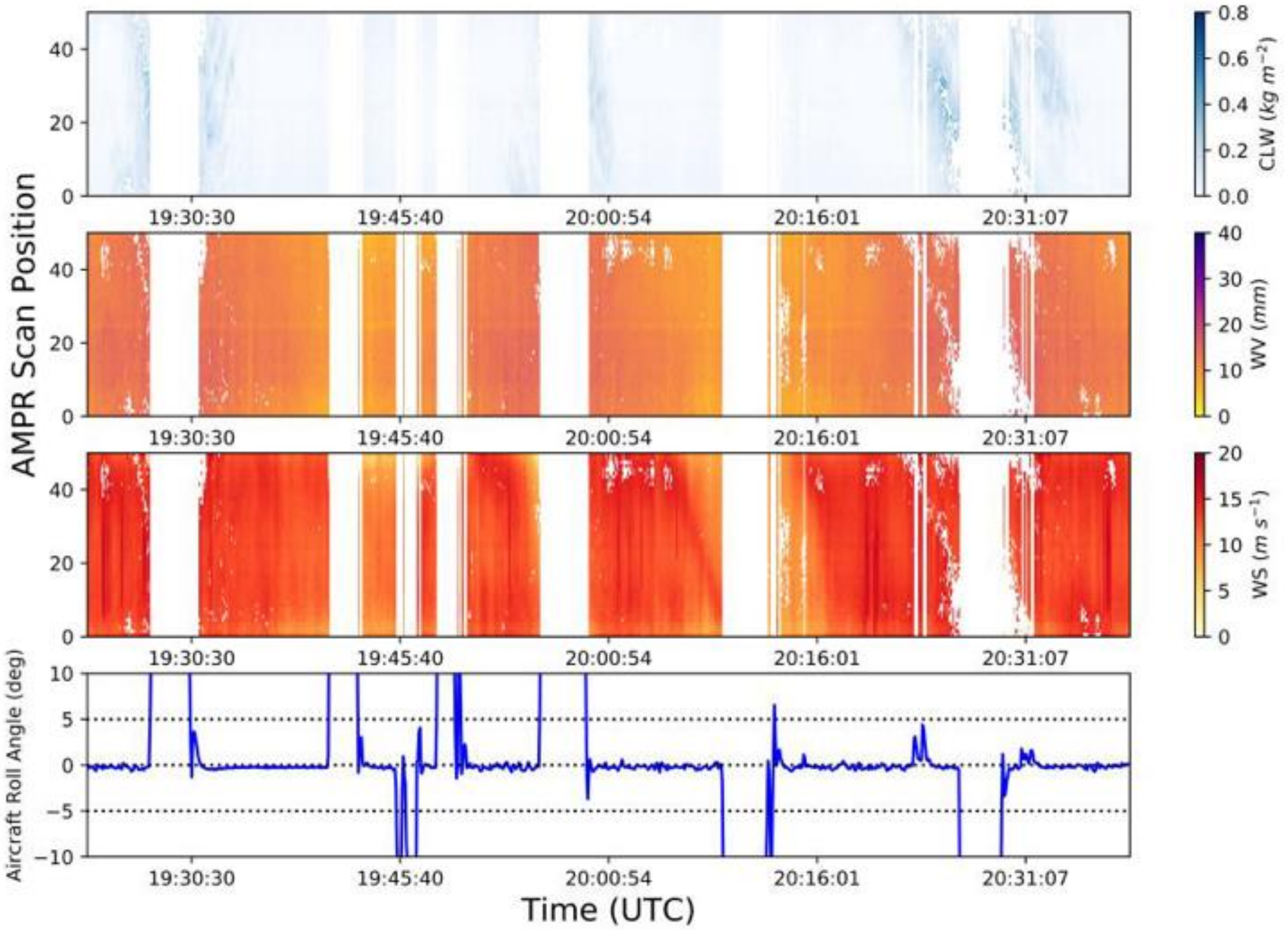
Wind Speed



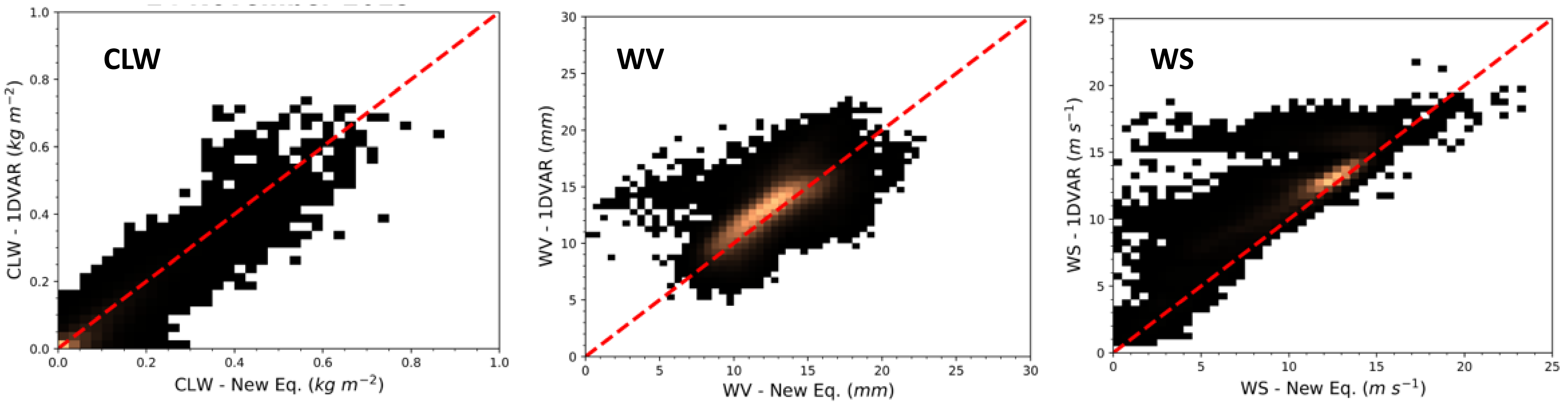
Cloud Liquid Water

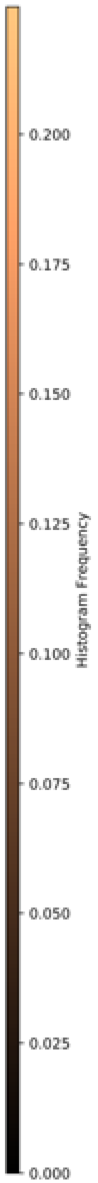
Water Vapor

Wind Speed



1DVAR Retrievals



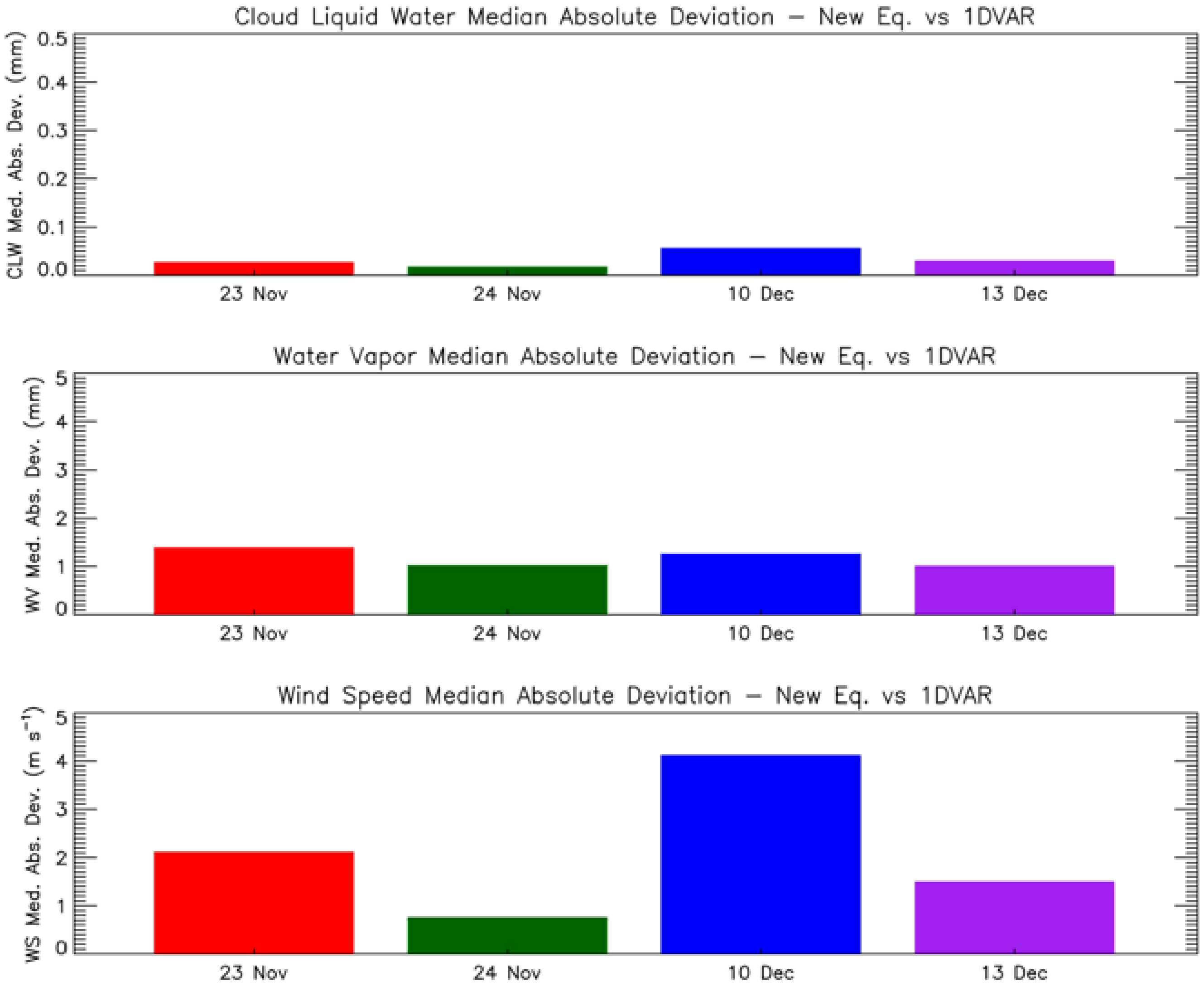


- 2-D histograms of Empirical vs. 1DVAR retrievals for 24 November 2015
- Generally good agreement for CLW and WV
- Artifacts in WS comparison appears to be related to selection of a priori GEOS-5 model input for 1DVAR

Median absolute deviations between the Empirical and 1DVAR retrievals for CLW (top), WV (middle), and WS (bottom) on the four case study dates

Overall median values (calculated across all four case dates):

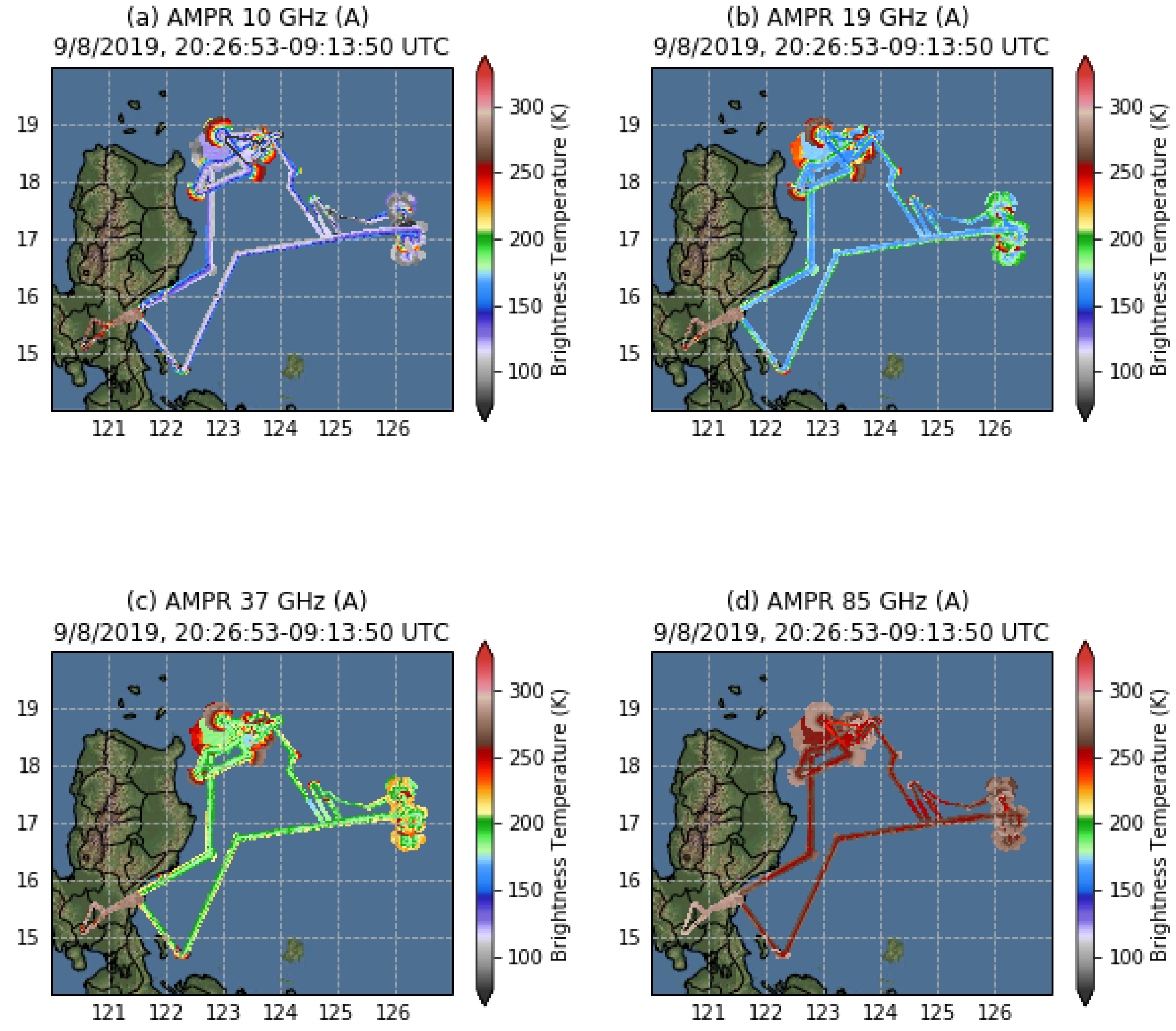
- CLW: 3.0×10^{-2} mm
- WV: 1.3 mm
- WS: 2.1 m s^{-1}



Comparison with AVAPS Dropsondes

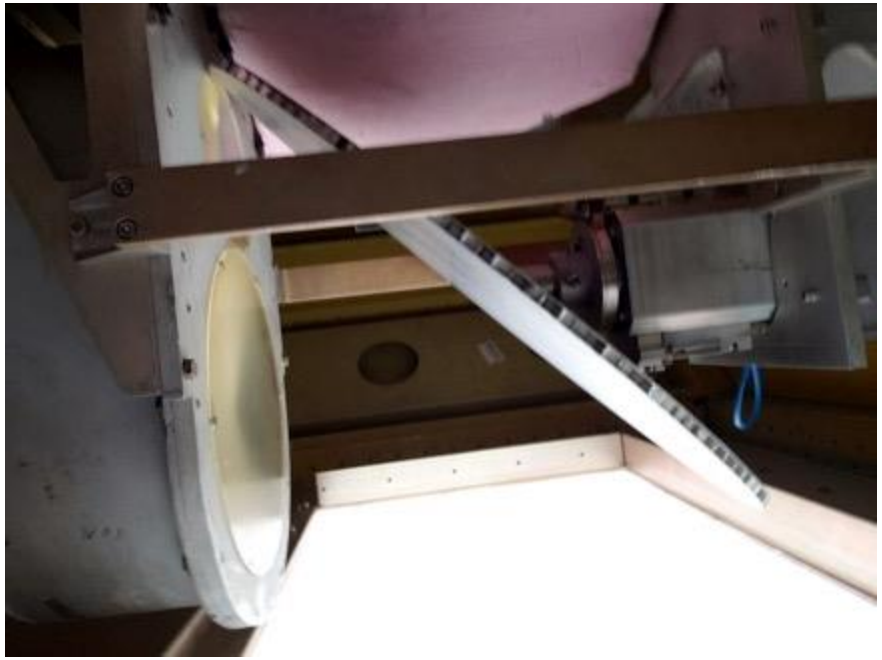
- AVAPS on DC-8, AMPR on ER-2
- Significant temporal and spatial offsets (10s of km / minutes)
- Nine dropsondes total over the four case days
- Median absolute deviation for water vapor and wind speed examined

	Water Vapor (mm)	Wind Speed (m/s)
Time of AVAPS Minimum Height (Spatial Offset)	2.1	1.2
Location of AVAPS Minimum Height (Temporal Offset)	1.8	1.5



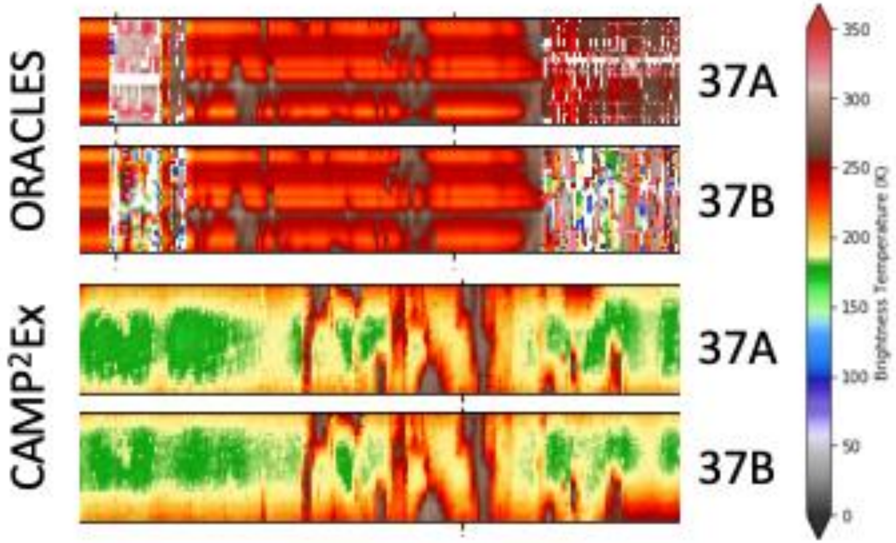
AMPR in the Cloud, Aerosol and Monsoon Processes Philippines Experiment (CAMP^{2}Ex)

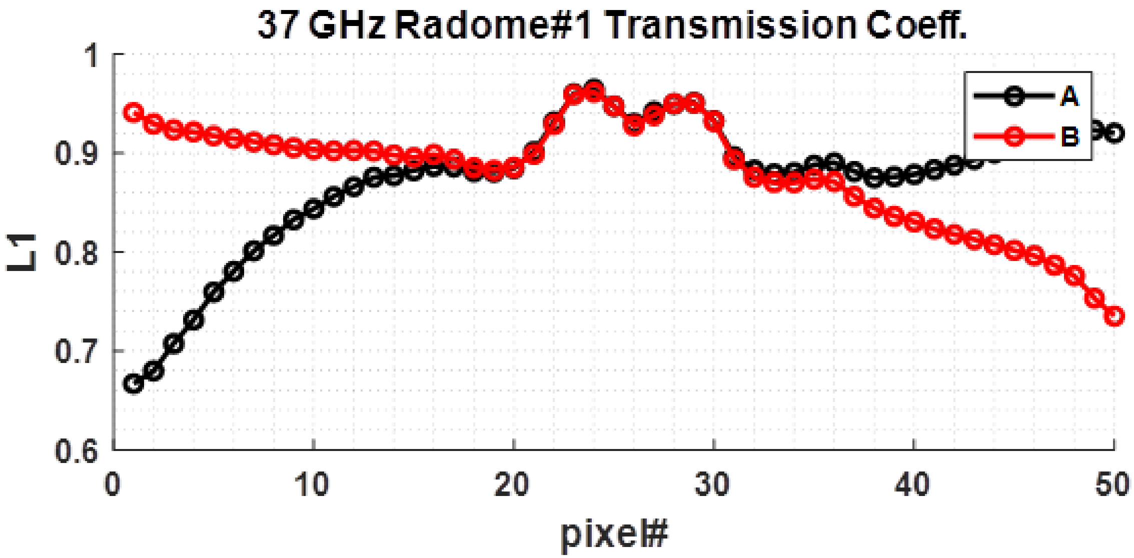
- Integrated on NASA P-3B
- ~140 science flight hours
- Sampled at variety of altitudes
- Combined microwave active-passive remote sensing system with APR-3



New Custom Multifrequency Radome

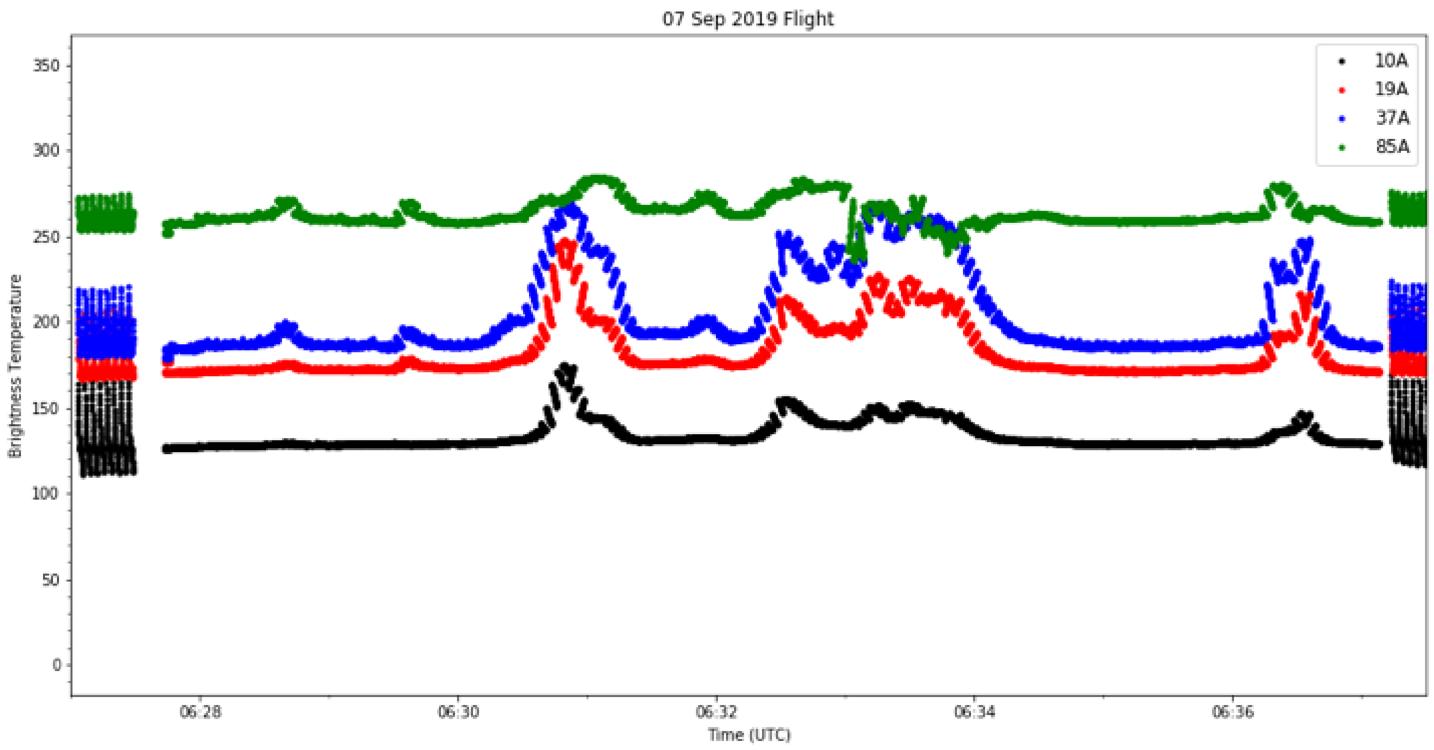
- Built and tested for flight by ProSensing
- Sky tests to determine transmissivity as function of scan angle
- Coupled with new filters for APR-3 Ka-band, Initial data quality vastly improved from ORACLES 2016 deployment



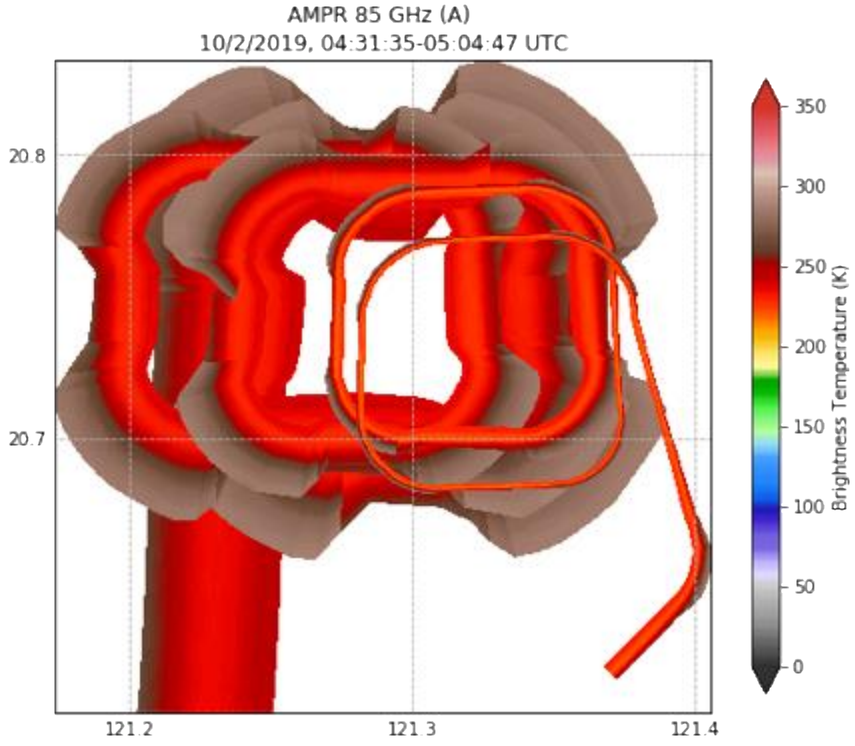


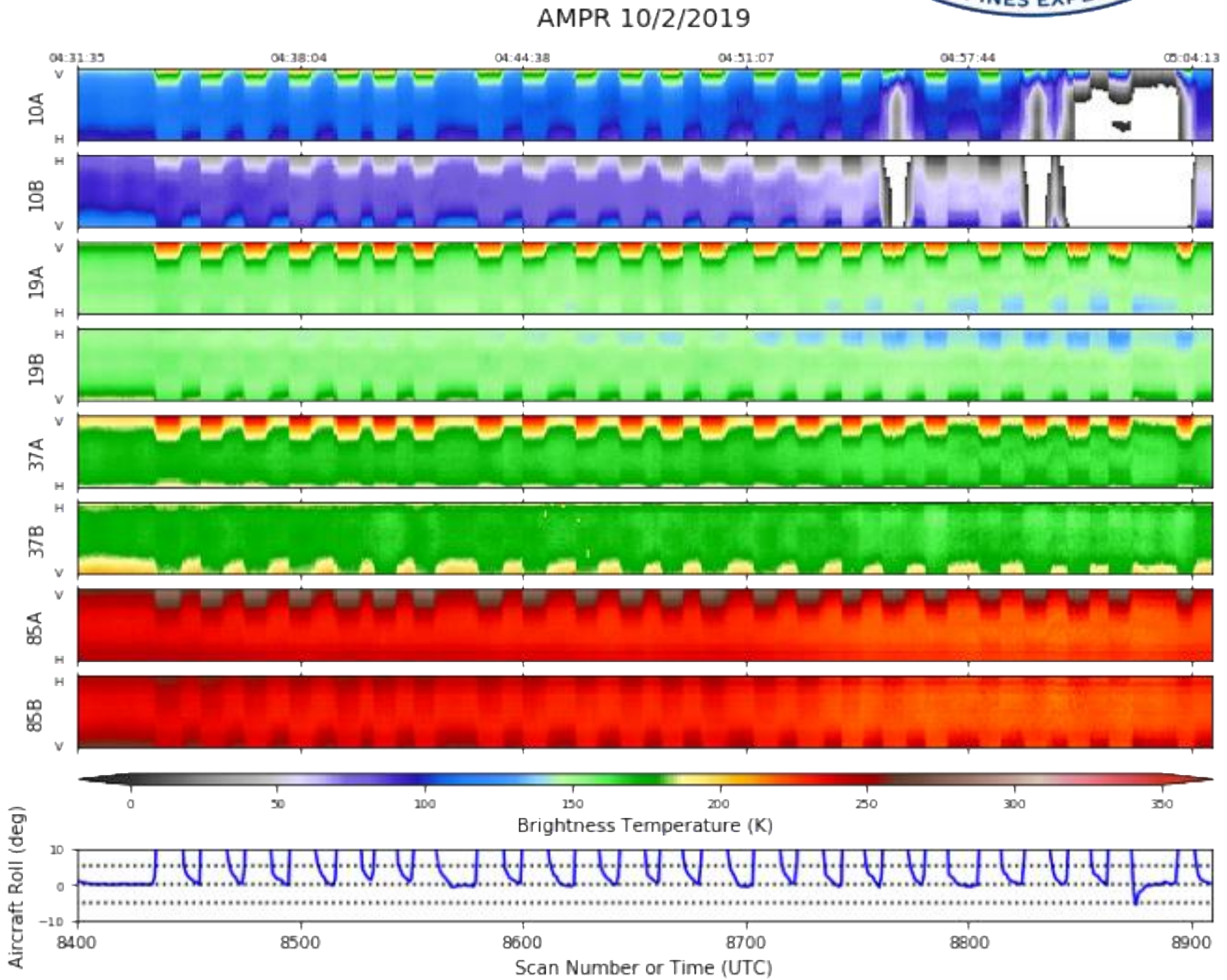
Nadir Staring

- AMPR normally samples a pixel every 50 ms, completes 50-pixel scan in 2.5 seconds
- What if we just made the mirror stare downward and sample the nadir pixel every 50 ms instead?
- Performed multiple times per flight, during select cloud overflights
- When coupled with APR-3, provide ultra-high-resolution microphysical retrievals along a nadir curtain in clouds



- Box spiral descents - Opportunity for water vapor profile retrievals
- Often coupled with AVAPS drops
- Also enable evaluation/improvement of calibration using air-cooled cold load





Conclusions

- AMPR is polarimetric cross-track scanning microwave radiometer
- Developed polarization deconvolution approach to provide improved calibration for brightness temperatures at V and H polarizations
- Developed and validated empirical retrieval approach for cloud liquid water, water vapor, and ocean surface wind speed
- CAMP^{2}Ex dataset will provide new geophysical retrieval opportunities