MICROWAVE INTEGRATED RETRIEVAL SYSTEM (MIRS):

RECENT ACTIVITIES AND SCIENCE IMPROVEMENTS

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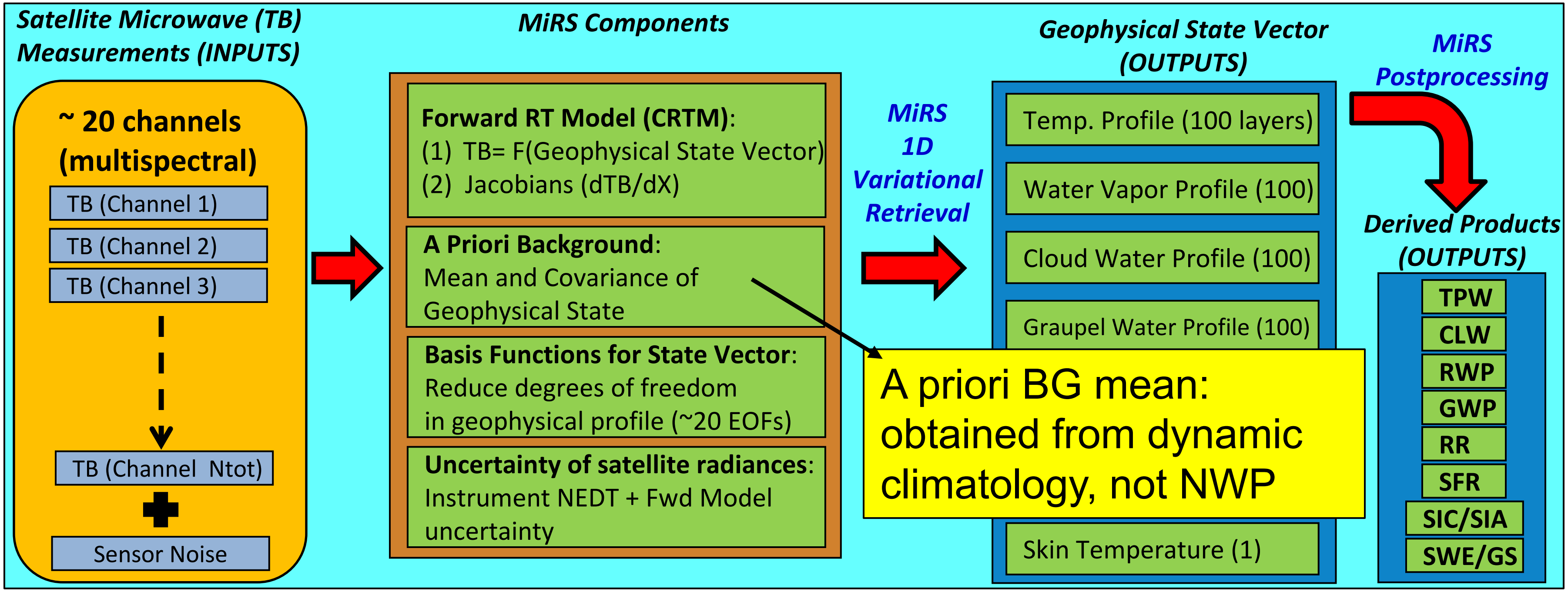
Outline

- Algorithm Overview
- S-NPP Product(s) Overview
  - Standard validation: global performance for T, WV Sounding
  - Targeted validation:
    - in situ reference data (SURFRAD) for LST
    - ARM ground-based radiometers for CLW
- Applications/Example
  - Blended Layer Water Vapor
  - Hurricane Harvey example
- New Activities/Science Improvements
  - Air mass-dependent radiometric bias correction
  - Tropical Cyclone Adaptation (MiRS-TC)
- Summary and Path Forward

Algorithm Overview

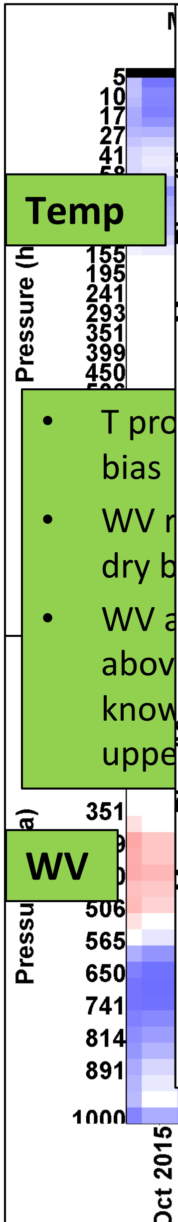


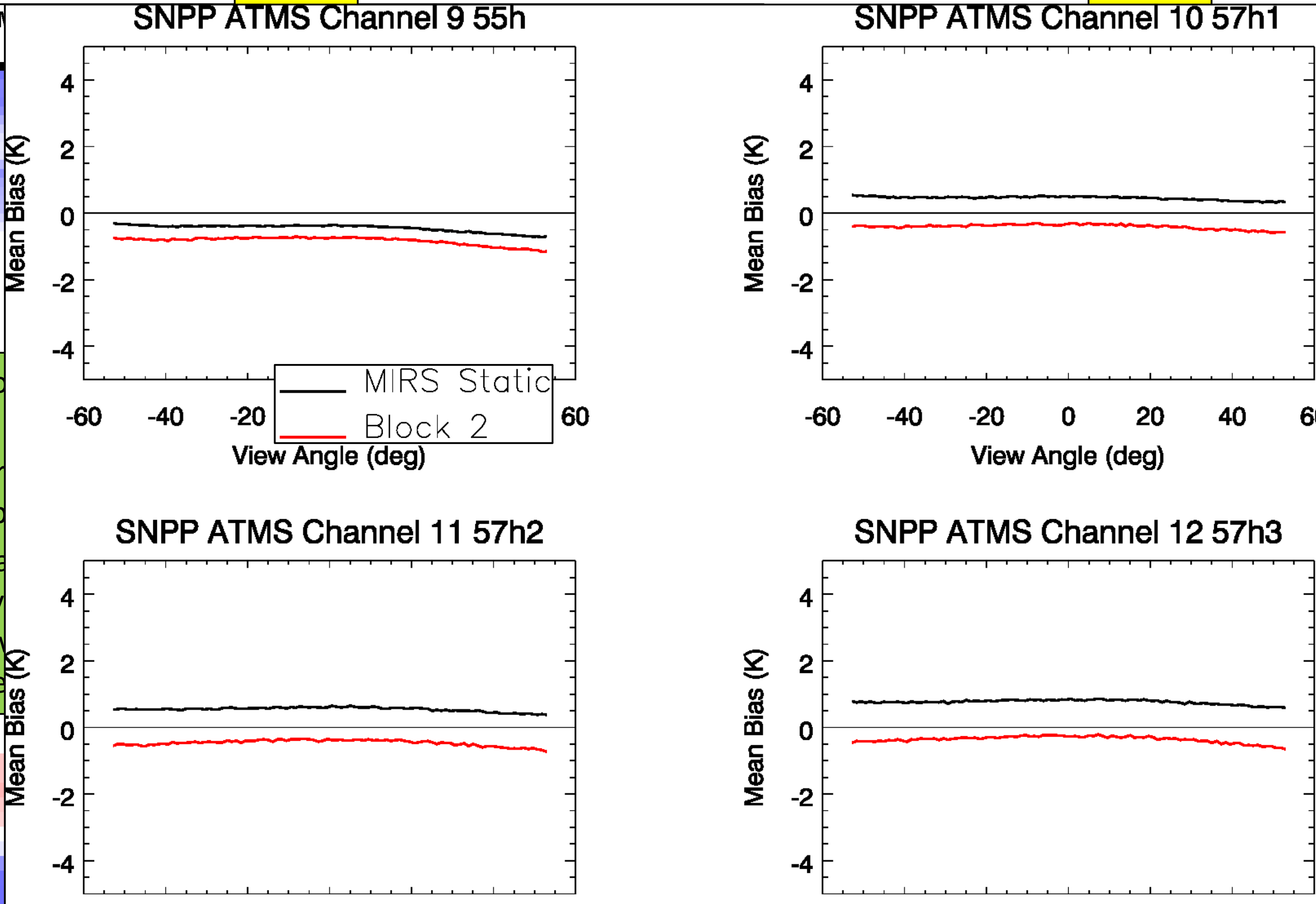
- MW Only, Variational Approach: Find the "most likely" atm/sfc state that: (1) best matches the satellite measurements, and (2) is still close to an a priori estimate of the atm/sfc conditions.
- **"Enterprise" Algorithm: Same core software runs on all satellites/sensors; facilitates science improvements and extension to new sensors.**
- Initial capability delivered in 2007. Running v11.2 since Jan 2017 on SNPP/ATMS, N18, N19, MetopA, MetopB, F17, F18, GPM/GMI, Megha-Tropiques/SAPHIR. (eventually MetopC…)
- Delivery of J1/ATMS (v11.3) capability in early 2018, assuming 10 Nov launch.
- External Users/Applications: TC Analysis/Forecasting at NHC, **Blended Total/Layer PW** at NHC and WPC, MIMIC TPW Animations (U. Wisconsin), CSPP Direct Broadcast (U. Wisconsin), NFLUX model (NRL, Stennis), Global blended precipitation analysis at NOAA/CPC (CMPORPH),…

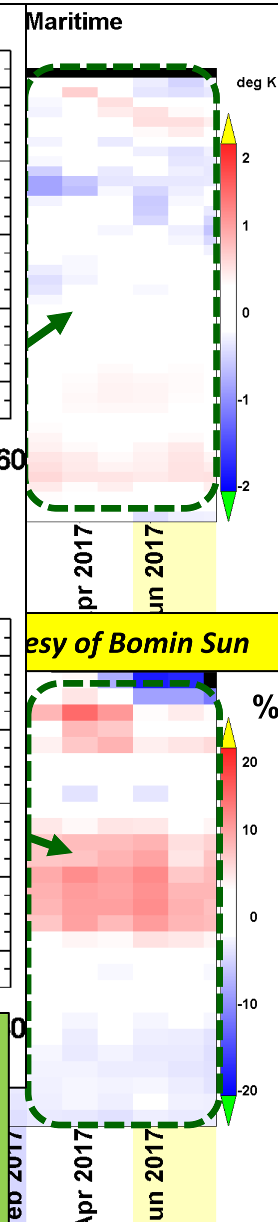
MiRS SNPP/ATMS Temperature and WV Bias vs. Raobs (NPROVS): Sept 2015 – August 2017

Land

Sea







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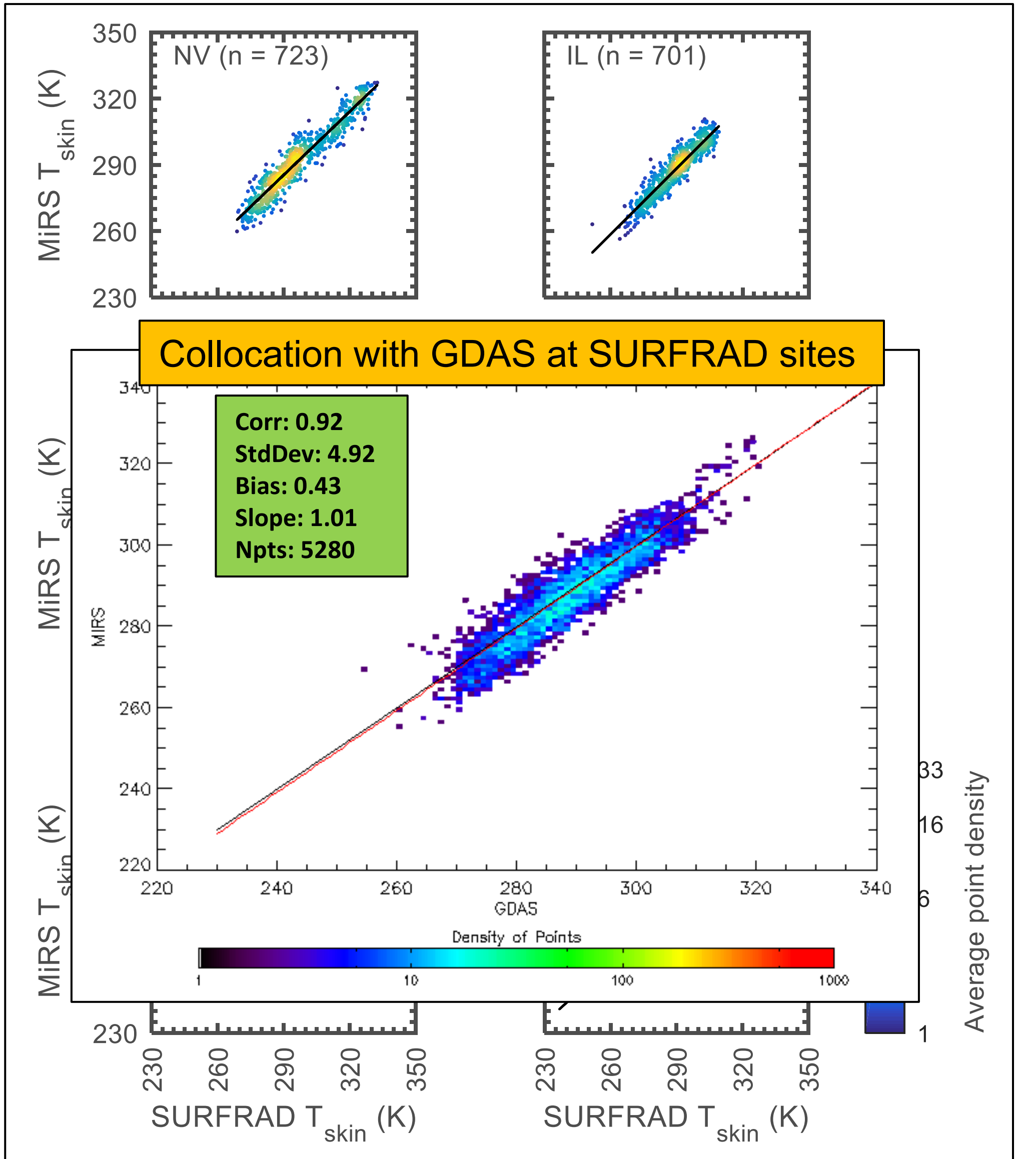
- MiRS radiometric bias corrections for T sounding channels (5-12): Block 1 (Static) and Block 2, OBS-SIMULATED
  - These corrections are subtracted from observed TBs prior to retrieval (i.e. negative means correction increases TB)
  - Block 2 corrections generally ~0.5 to 1 K lower than Block 1

Validation of Land Sfc Temperature

- Daily Comparisons:
  - Automated global comparisons with both ECMWF and GDAS; results posted daily
  - Advantage: Global coverage, all sfc and weather conditions, large sample sizes
  - Disadvantage: LST from NWP analyses may have large errors depending on obs available and land surface assimilation model.
- Targeted collocations with in situ data:
  - Collocations with SURFRAD LST (IR Flux Based): May 2016-May 2017, 6 stations over the CONUS
  - Advantage: in situ, direct measurement (need to convert from flux to LST using Stefan-Boltzmann law), IR emissivity assumed=0.97
  - Disadvantage: IR LST, not same as MW LST (vertical penetration/emission depth), representiveness error (point vs. IFOV average)
  - SURFRAD stations used:

Station name	Surface	Latitude (N)/longitude (W)	Elevation (m)	U.S. state	ID
Desert Rock	Open shrub land	36.63˚/116.02˚	1007	NV	DRA
Bondville	Cropland	40.06˚/88.37˚	230	IL	BON
Fort Peck	Grassland	48.31˚/105.10˚	634	MT	FPK
Goodwin Creek	Deciduous forest	34.25˚/89.87˚	98	MS	GWN
Penn State	Mixed forest	40.72˚/77.93˚	376	PA	PSU
Sioux Falls	Grassland	43.73 ˚/96.62 ˚	473	SD	SXF

Validation of Land Sfc Temperature: Collocation with SURFRAD, May 2016-May 2017



Validation Parameter	All SURFRAD stations and overpasses				
	Spring	Summer	Autumn	Winter	13 months
R	0.91	0.90	0.90	0.81	0.92
Bias (K)	-2.21	-2.55	-0.58	-2.05	-1.84
Std. dev. (K)	5.21	4.66	5.25	5.98	5.26
RMSE (K)	5.65	5.31	5.28	6.32	5.58
Slope	0.96	0.74	0.92	0.89	0.92

Requirements	Bias/ Accuracy (K)	StDev/ Precision (K)	RMS/ Uncertainty (K)
Threshold	4.0	7.0	8.0
Objective	3.4	6.3	7.1

Meets threshold

Meets objective

Courtesy of Carlos Perez-Diaz (CUNY/CREST)

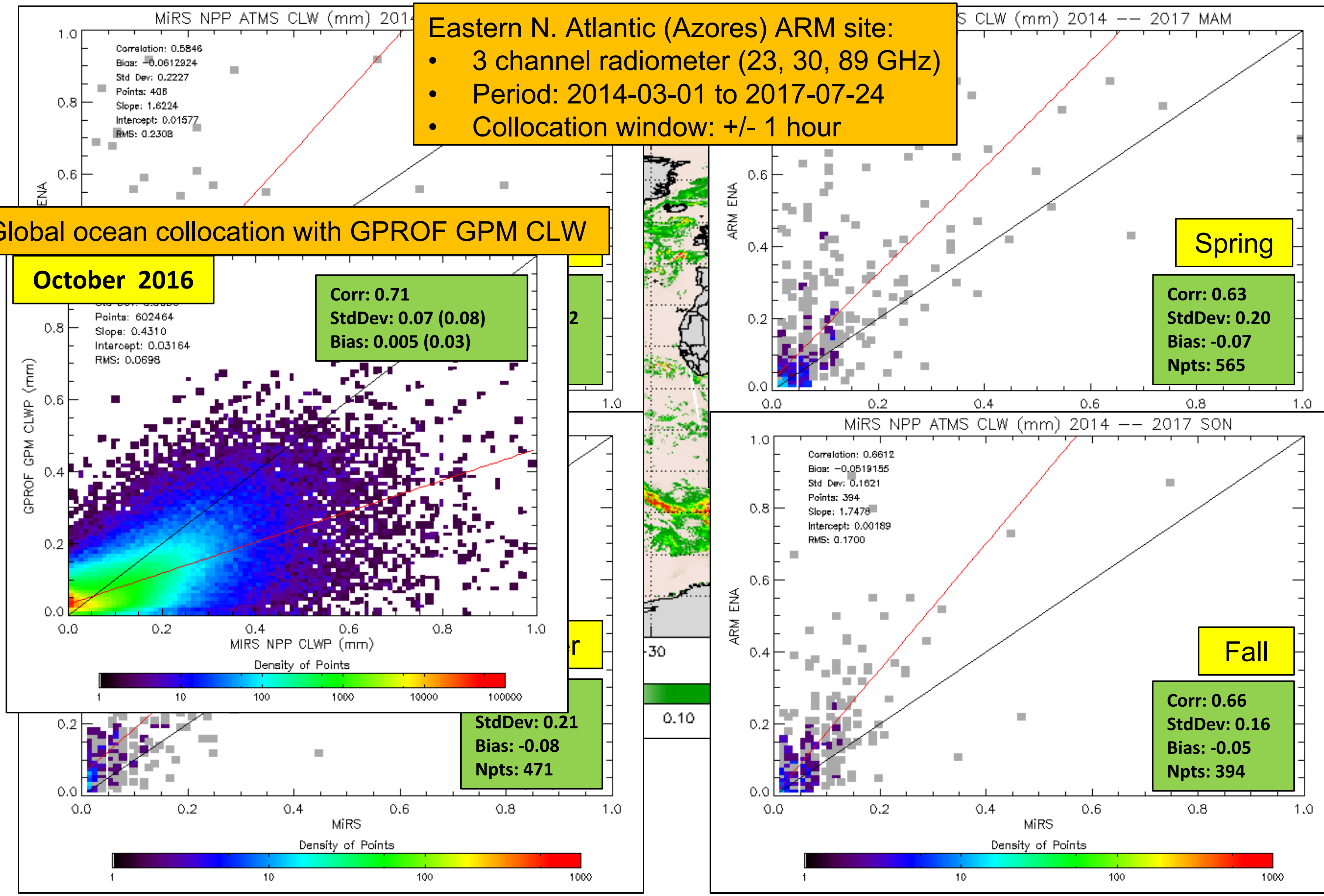
Manuscript submitted to GRL

Validation of Oceanic Cloud Liquid Water: Collocation with ARM Ground-based Measurements

Eastern N. Atlantic (Azores) ARM site:

- 3 channel radiometer (23, 30, 89 GHz)
- Period: 2014-03-01 to 2017-07-24
- Collocation window: +/- 1 hour

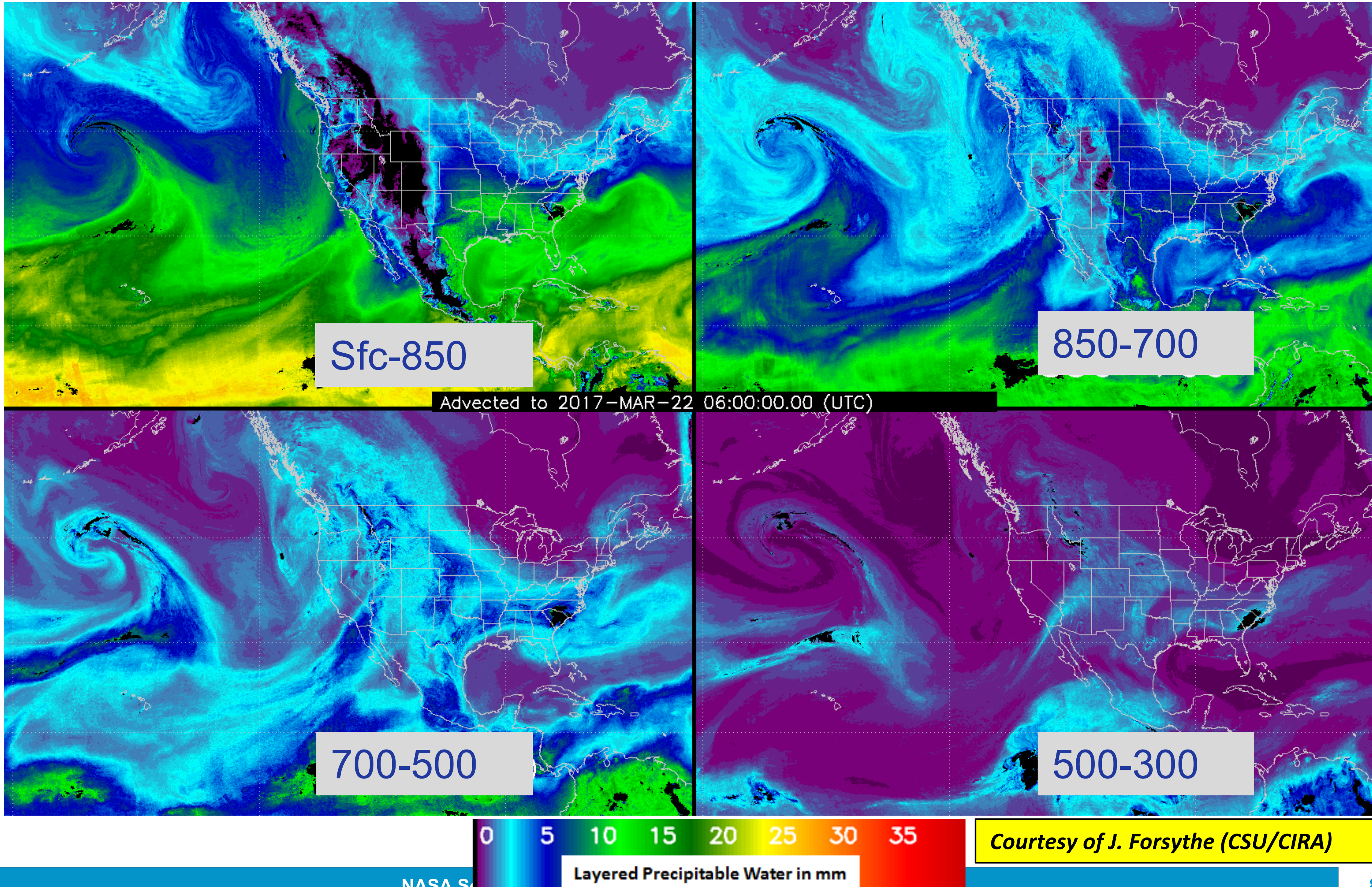
Global ocean collocation with GPROF GPM CLW



Application: Blended Layer Precipitable Water

Combines MiRS WV from up to 7 Polar Satellites for Rapid Refresh and Advection (NWP-based winds)

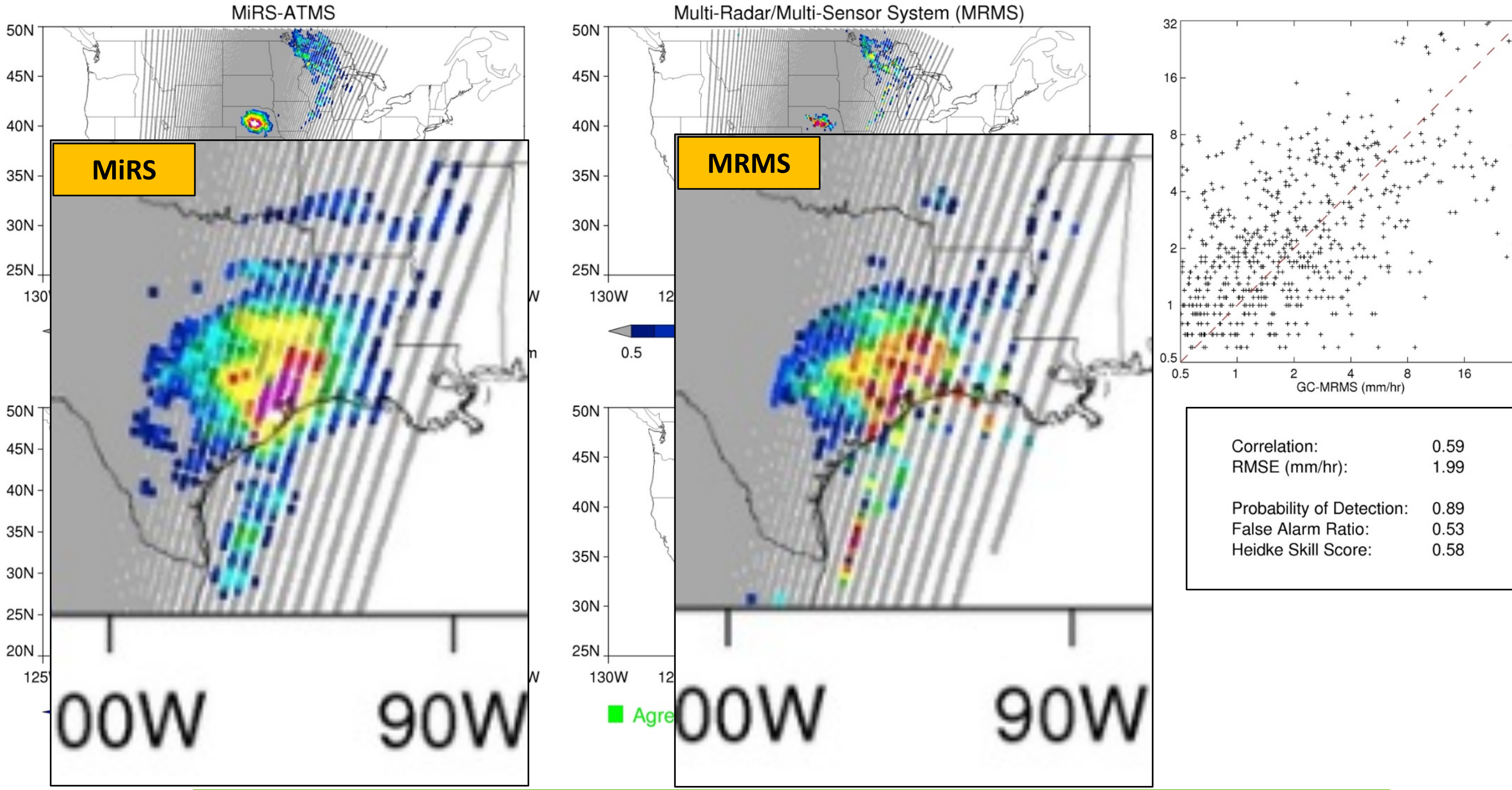
To be implemented at NHC and WPC in next 1-2 months



Courtesy of J. Forsythe (CSU/CIRA)

Case Study: Hurricane Harvey
27 August, Day of Extreme Flooding

ATMS & MRMS Precipitation Rate @ 20170827-1018UTC



- MRMS: Operational Blended Radar-Gauge Analysis, 1 km resolution
- Both satellite and MRMS detected rainfall rates > 25 mm/h

Development of an Air Mass-Based Radiometric Bias Correction

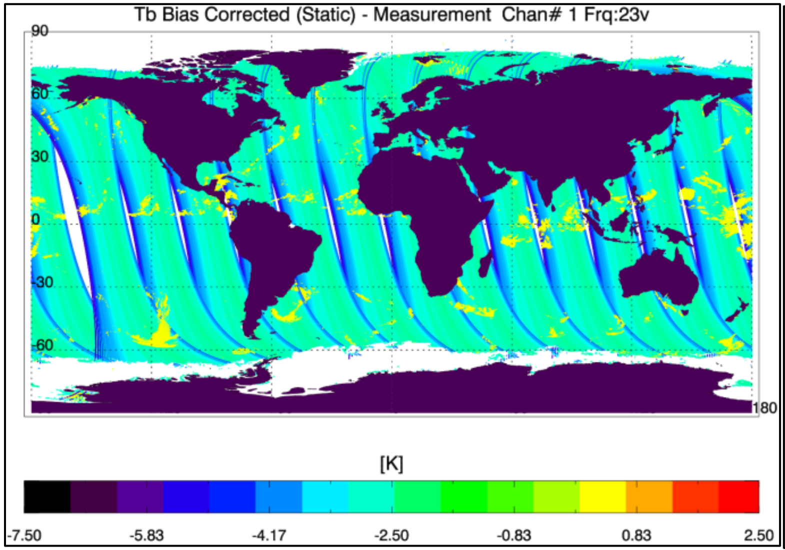
- Motivation:
  - Current operational MiRS uses Histogram Adjustment Method. Derived over oceanic/clear scenes. Bias specified as function of channel and scan position.
  - Advantages: Stable, reduces impact of outliers/cloud/rain contamination, good at characterizing the average global differences between measurements and model.
  - Disadvantages: Systematic errors in forward model due to over/underestimation of absorber effects (e.g. water vapor, non-precip cloud) not accounted for. (also assumes atmospheric and ocean emissivity models are accurate).
- Testing air mass dependent bias correction (ocean only)
  - Regression-based, 2-steps
    - **Step 1: CLW and TPW using uncorrected TBs**
    - **Step 2: dTB(iChan, iscanpos)=f(CLW, TPW, Tskin, TB(iChan)); Tskin from operational "Dynamic Background" (f(lat,lon,time,month)). Scan position dependent.**
    - **Applied to all channels except T sounding channels 4-15 (static bias correction used)**
  - Applied over ocean only, using ATMS Block 2 SDRs (operational switch in March 2017)
    - **Quantify impact on retrieved parameters (e.g. T, WV, ocean emissivity, CLW, TPW, chi-square, iterations)**
  - Analogous to variational bias correction used in direct radiance assimilation for NWP

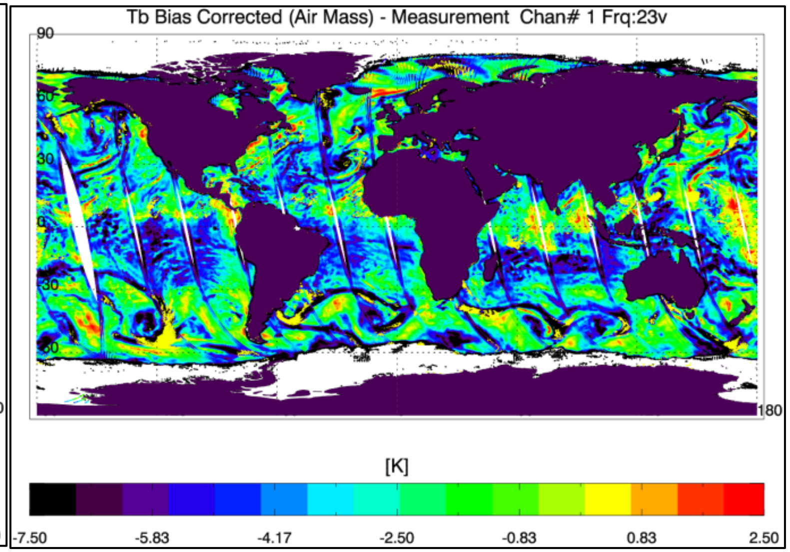
Testing an Air Mass-Based Radiometric Bias Correction

Static Correction (operational)

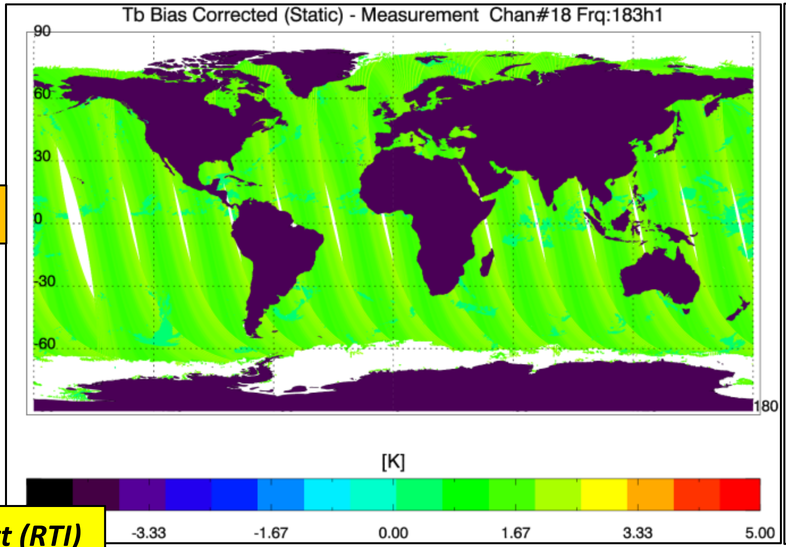
Air-mass Correction

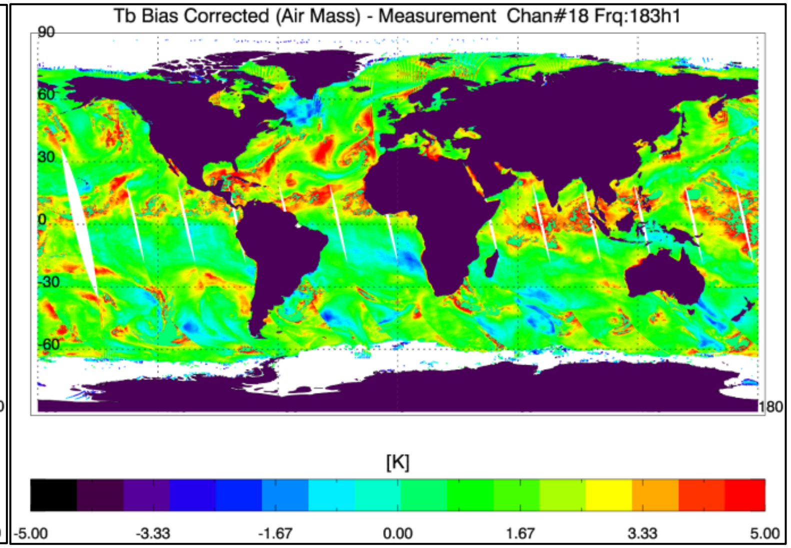
Ch 1 (23 GHz)





Ch 18 (183+/- 7 GHz)

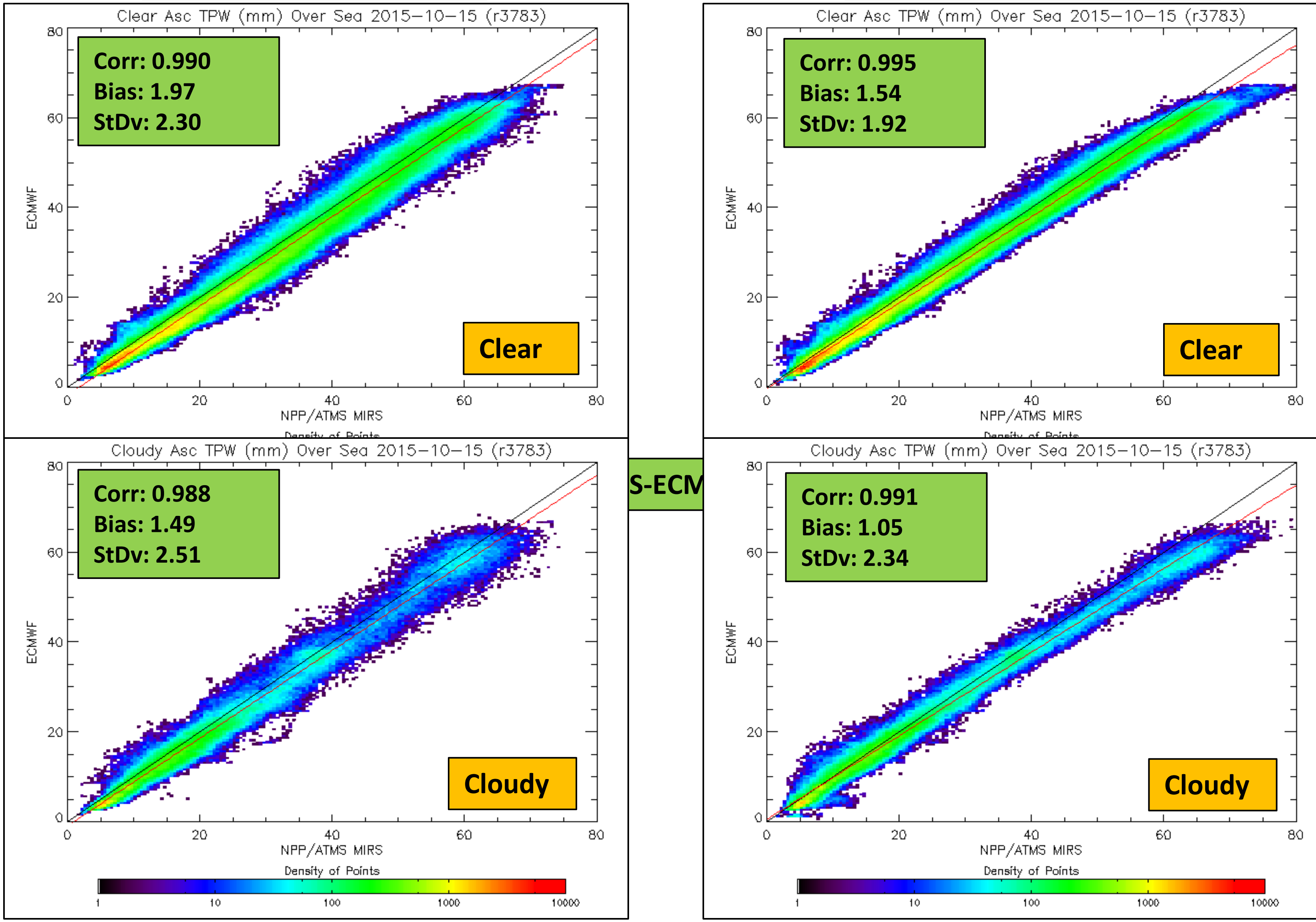




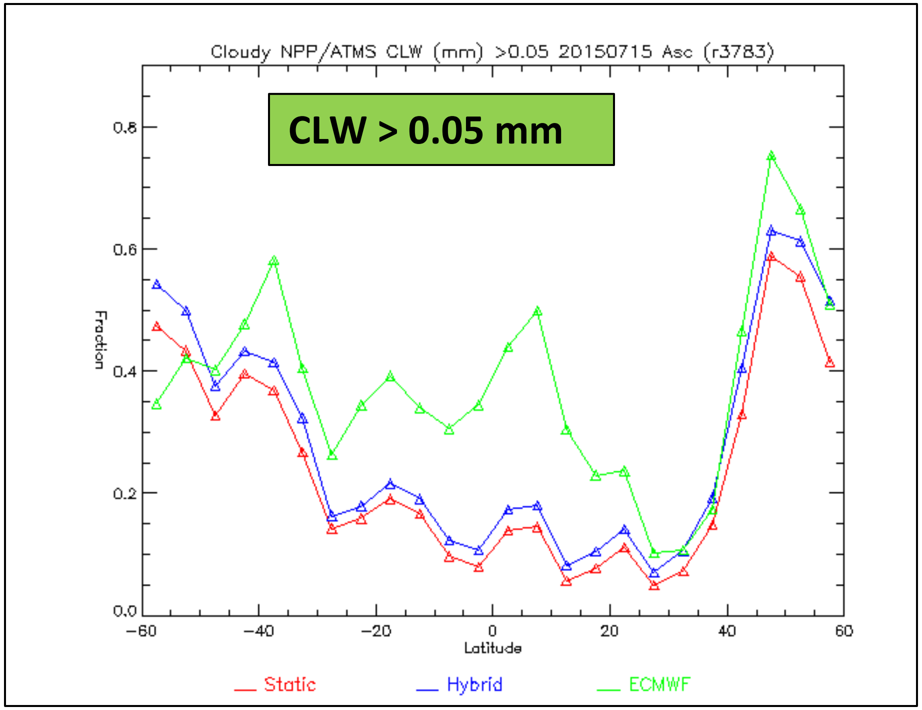
Courtesy of K. Garrett (RTI) and P. Liang (AER)

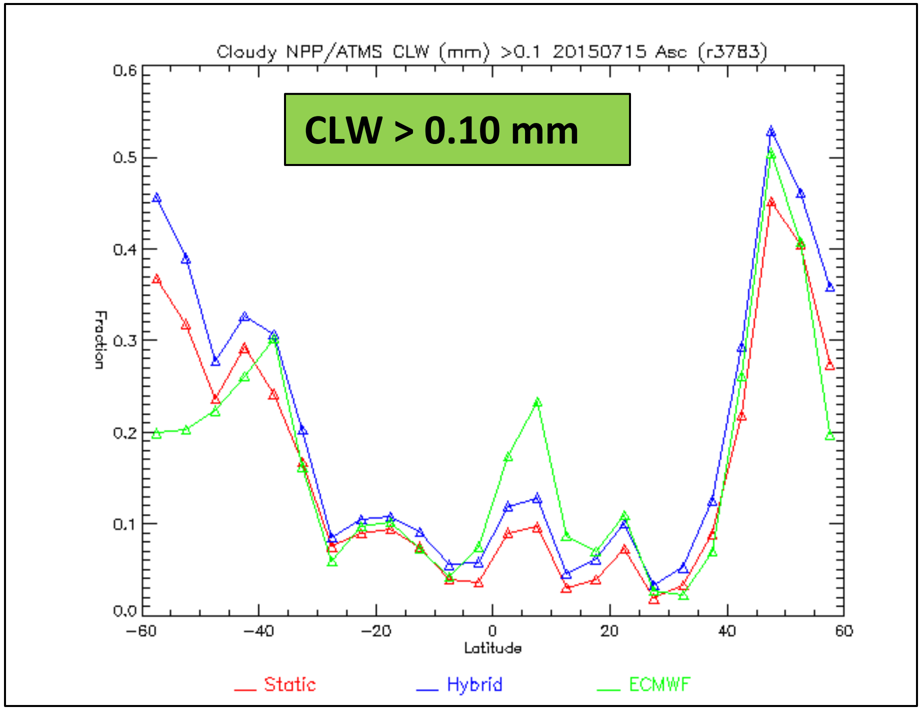
Testing an Air Mass-Based Radiometric Bias Correction: Ocean TPW vs. ECMWF

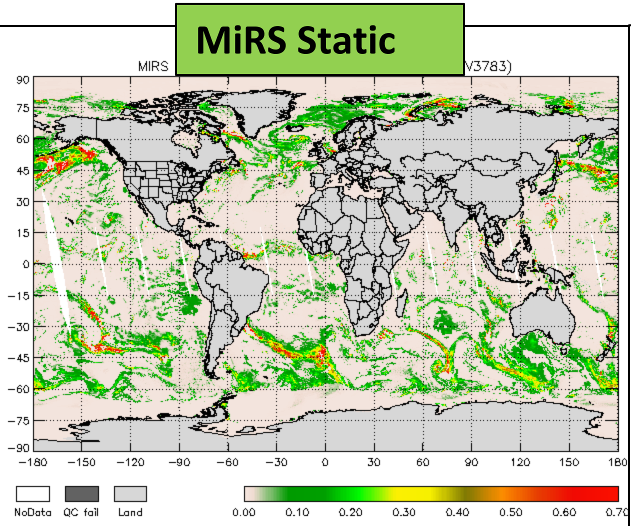
TPW (Static Correction) | **TPW (Air-mass Correction)**

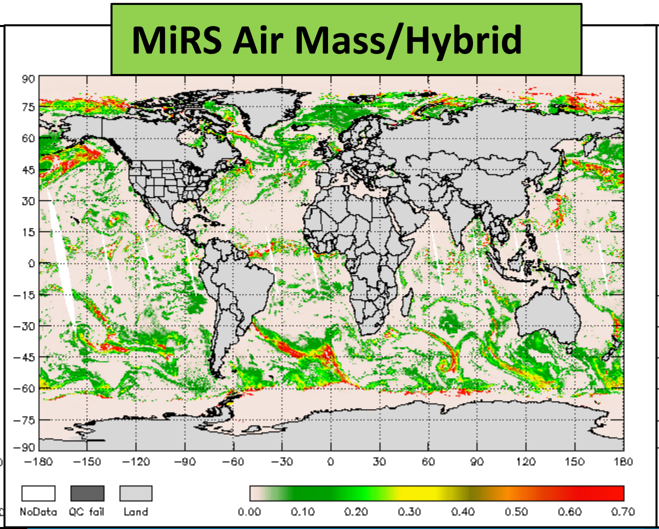


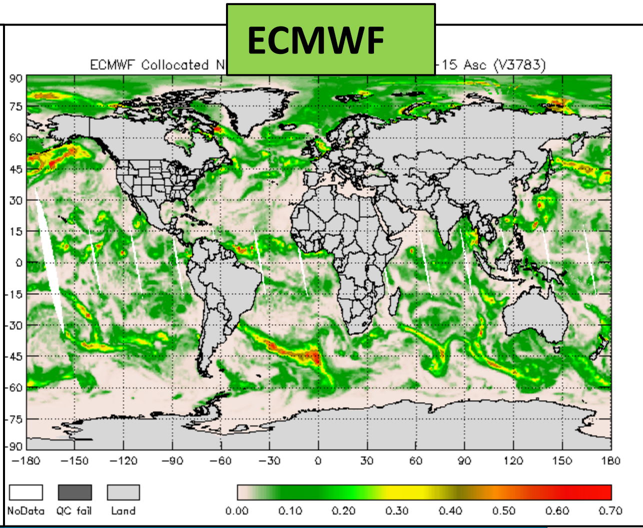
Testing an Air Mass-Based Radiometric Bias Correction: Ocean Cloud Liquid Water







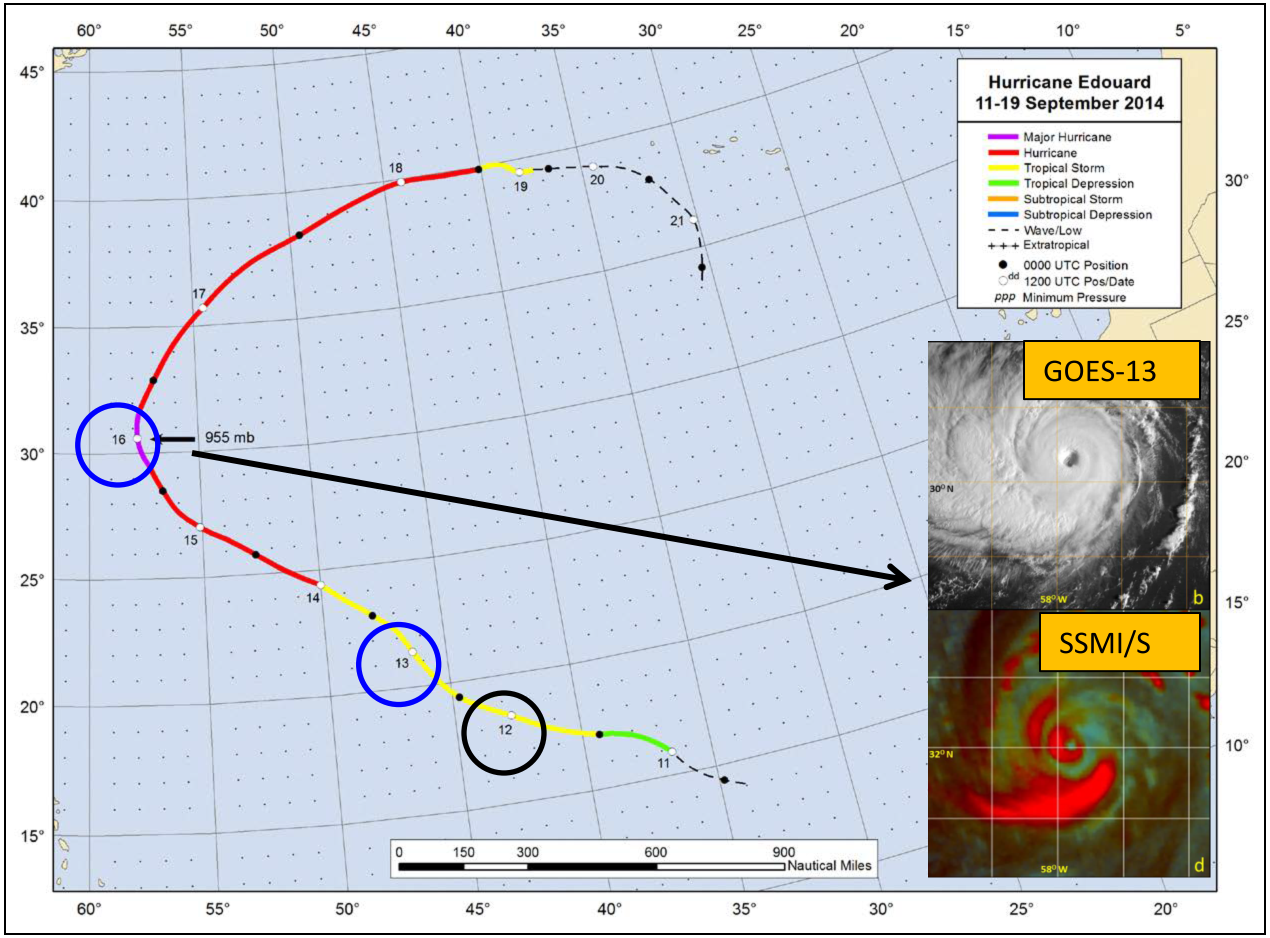




Developing a TC-Specific Version of MiRS

- Motivation:
  - MiRS data currently used in the operational TC Intensity Algorithm (developed at CIRA). Utilizes T and WV sounding to estimate warm core structure combined with statistical/dynamic model to estimate TC intensity.
  - Challenge: (1) retrieval of warm core structure complicated due to presence of hydrometeors; scattering signal in TBs can interfere with retrievals (2) hurricane warm core structure is anomalous relative to "global climatology" currently used as a priori constraint in MIRS.
- Experiments with SNPP/ATMS (3 control parameters)
  - Modify use of higher frequency channels in scenes likely to have large amounts of scattering
    - **(A) Oper: Use all 22 channels, (B) Turn off WV channels (18-22) when rain detected, (C) Turn off all high-frequency channels when rain detected (16-22).**
  - Test varying sources of First Guess/Background constraints:
    - **(A) Oper: Climatology f(lat,lon,time,month), (B) TC-Climatology based on COSMIC RO data (from CIRA)**
  - Vary number of EOF basis functions for T and WV profiles:
    - **(A) Oper: nEOFT=7, nEOFWV=5, (B) nEOFT=9, nEOFWV=4 when rain detected**

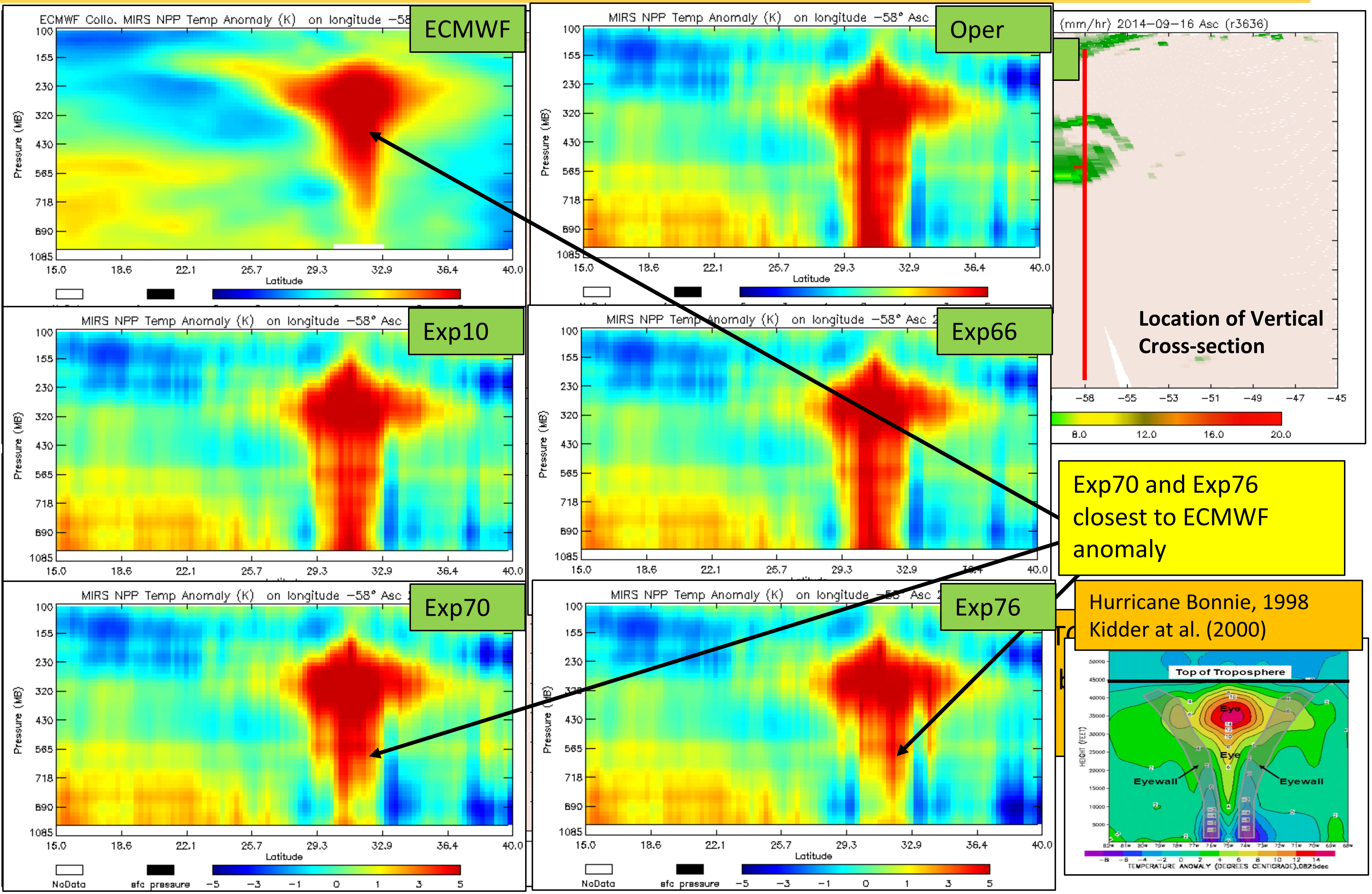
Case Study: Hurricane Edouard, Sept 2014



- 11-19 Sept 2014
- Maximum strength: 105 knots, 955 mb (16 Sept)
- Retrievals performed:
  - 12 Sept
  - **13 Sept**
  - **16 Sept**

Experiment	2nd att BG T	2nd att BG WV	WV Chans 18-22 On/Off	Chans 16-17 On/Off	2nd att nEOF T and WV
OPER	Oper	Oper	ON	ON	Oper
Exp 10	Oper	Oper	OFF	ON	Oper
Exp 66	Oper	TC	OFF	ON	Oper
Exp 70	Oper	TC	OFF	ON	nEOFT=9,nEOFWV=4
Exp 76	Oper	TC	OFF	OFF	nEOFT=9,nEOFWV=4

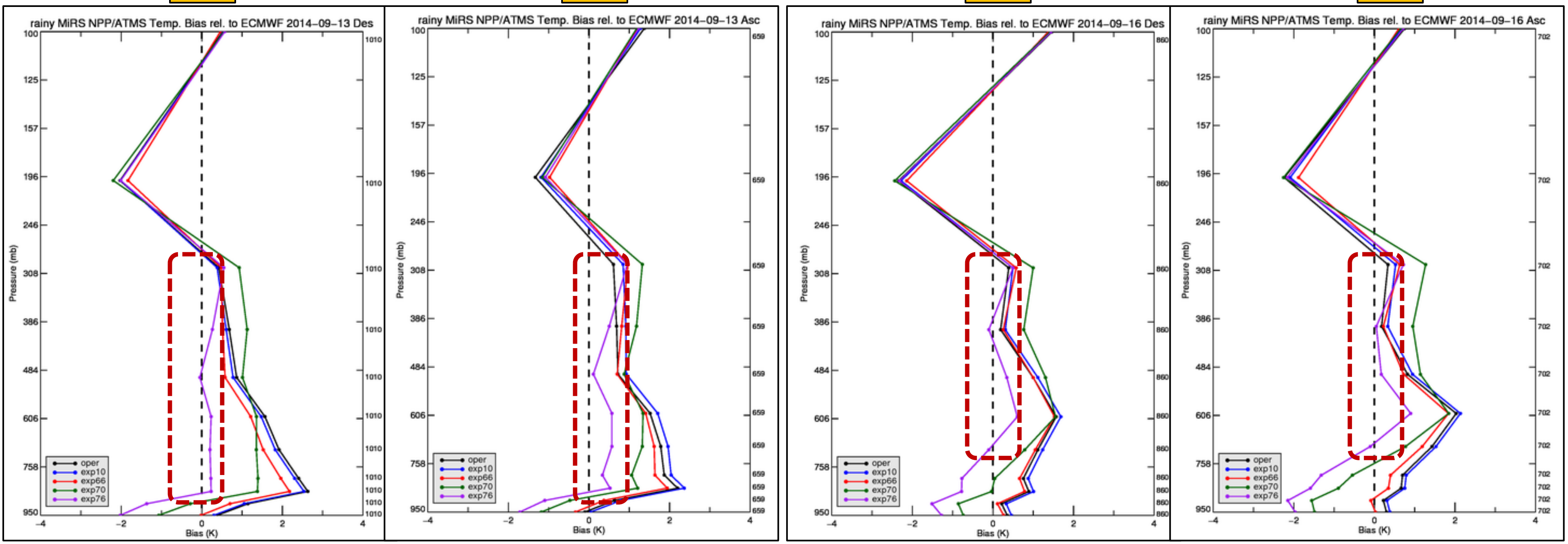
Temperature Anomaly Along -58 deg Lon: 2014-09-16



Temperature Bias Statistics in Rainy Conditions (wrt ECMWF)

2014-09-13: Des, Asc

2014-09-16: Des, Asc



- **Best result mid,upper-trop**: TC climatology for WV BG + chans 16-22 off (cold bias below 800-850 hPa); but ECMWF may also have errors
- Use of TC-specific WV BG critical when all WV sounding channels turned off
- **Future:** FG/BG from forecast, TC-specific covariance/EOFs, additional TCs (Joaquin 2015, Matthew 2016), validation w/dropsondes, continue collaboration with CIRA

Exp	2nd att BG T	2nd att BG WV	WV Ch 18-22 On/Off	Ch 16-17 On/Off	2nd att nEOF T and WV
OPER	Oper	Oper	ON	ON	Oper
Exp 10	Oper	Oper	OFF	ON	Oper
Exp 66	Oper	TC	OFF	ON	Oper
Exp 70	Oper	TC	OFF	ON	nEOFT=9,nEOFWV=4
Exp 76	Oper	TC	OFF	OFF	nEOFT=9,nEOFWV=4

Summary

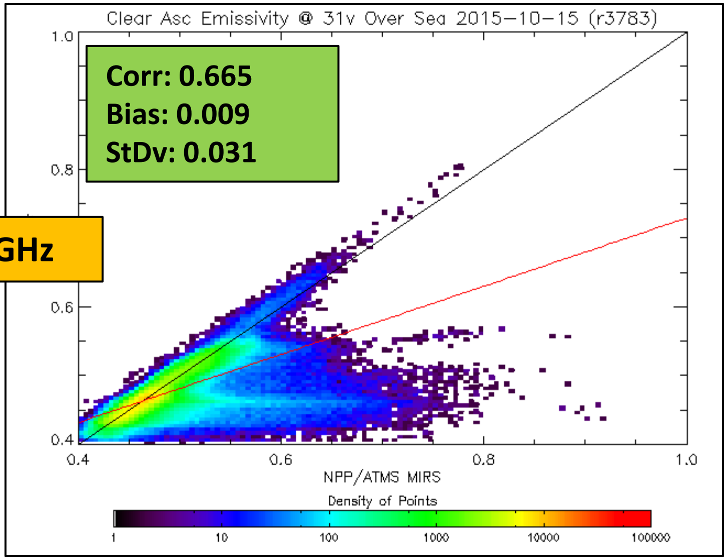
- MiRS is relatively mature algorithm; evolution and improvement since SNPP launch (v9.2 -> v11.2); additional improvements in progress.
- Next version (v11.3): Will include extension to J01/N20 ATMS processing
- Path Forward
  - FY18 Milestones: (1) preDAP delivery in Feb/Mar 2018 (initial cal/val), (2) official DAP ~L+12 months.
  - Future Improvements:
    - **Snowfall Rate, included in v11.3**
    - **Snow (vegetation correction to emissivity), included in v11.3**
    - **CLW over land to improve light rain detection, included in v11.3**
    - Air mass-dependent bias corrections
    - TC-specific applications (FG/BG a priori based on TC climo or 6-h fcst)
    - Rainy condition sounding (update a priori constraints)
    - Stakeholders/user needs…

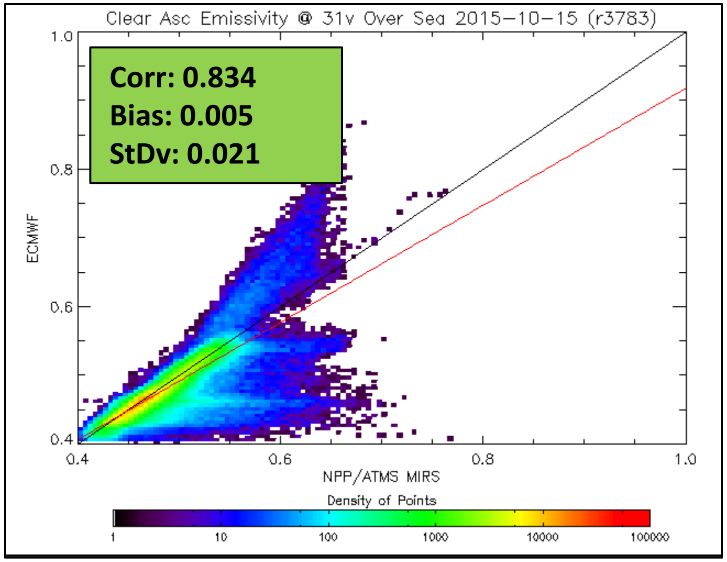
Backup

Testing an Air Mass-Based Radiometric Bias Correction: Ocean Emissivity

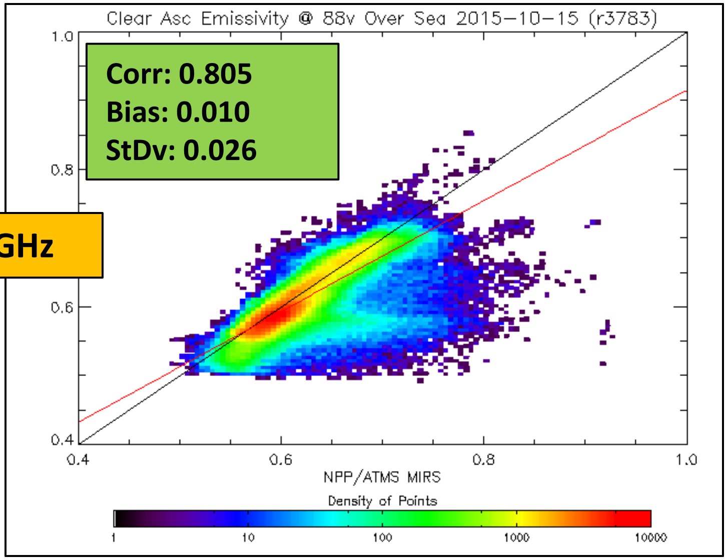
MIRS-FASTEM (Static Correction) | MiRS-FASTEM (Air-mass Correction)

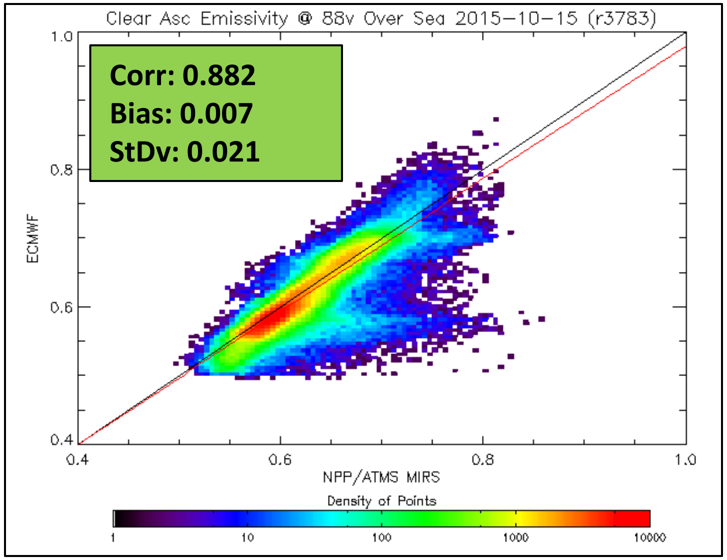
31 GHz





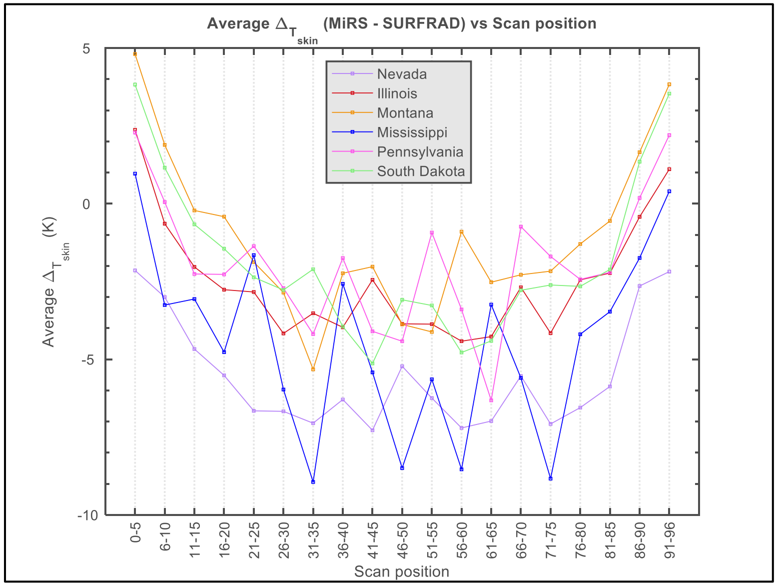
88 GHz

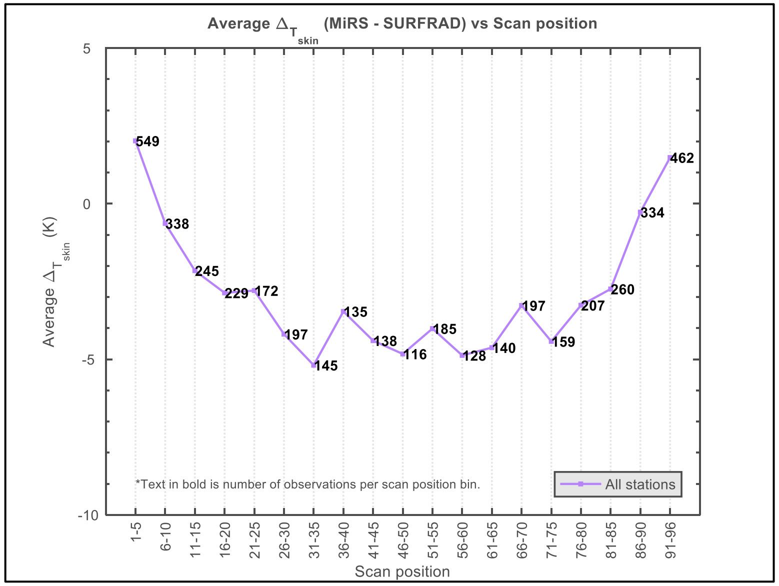




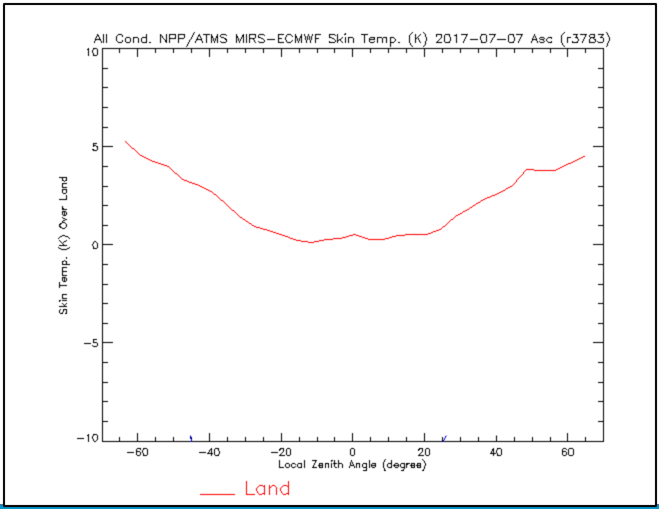
Validation of Land Sfc Temperature: Scan Dependence wrt SURFRAD and ECMWF

Scan Dependence wrt SURFRAD





Scan Dependence wrt ECMWF



- Relative scan dependence seen wrt both SURFRAD and ECMWF
- Absolute biases different
- Likely due to radiometric bias correction (trained over ocean)

Block1 and Block 2 Bias corrections