MICROWAVE INTEGRATED RETRIEVAL SYSTEM (MIRS): RECENT VALIDATION, FUTURE ENHANCEMENTS, AND PLANS FOR JPSS-1/ATMS

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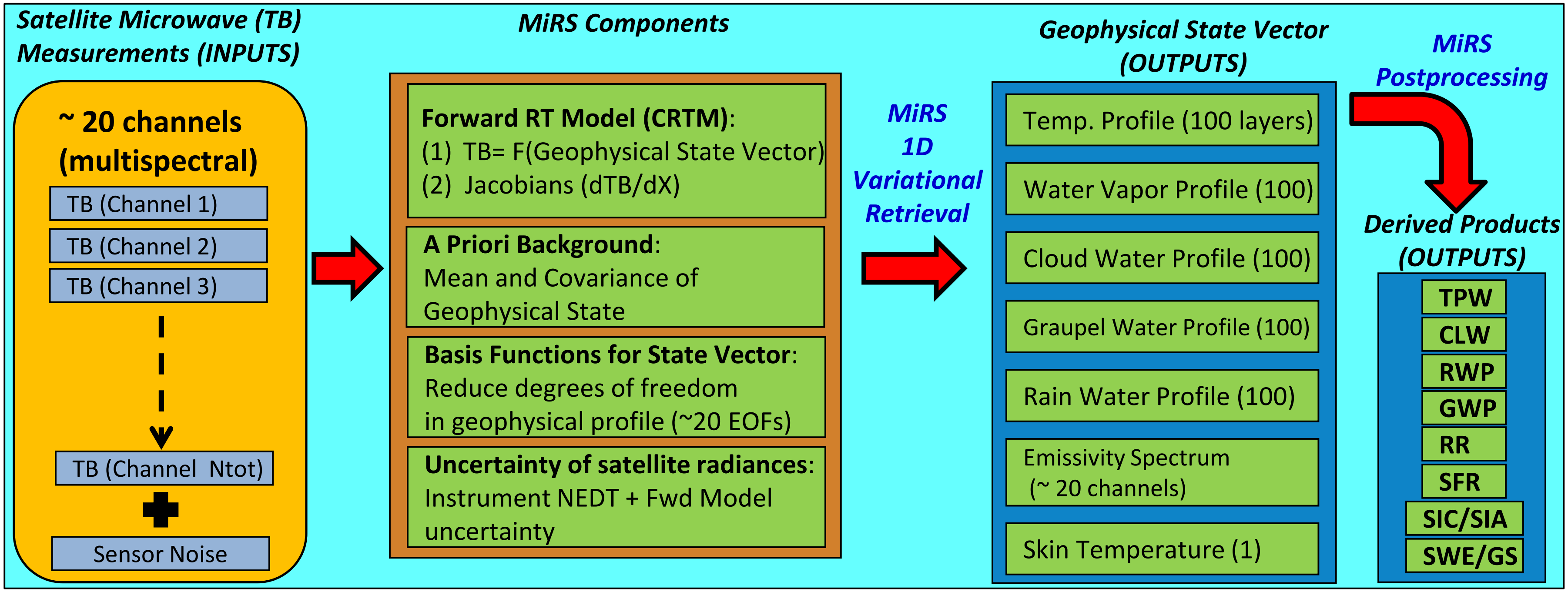
Outline

- Algorithm Overview
- S-NPP Product(s) Overview
  - Standard validation: global performance for T, WV Sounding
  - Validation maturity status/plans
  - Targeted validation: in situ reference data (SURFRAD) for LST
- New Activities/Science Improvements
  - Precipitation: Rain rate and Snowfall Rate
  - Air mass-dependent radiometric bias correction
  - Tropical Cyclone Adaptation (MiRS-TC)
- JPSS-1 Readiness
  - Algorithm changes
  - Pre-launch activities
  - Post-launch cal/val
- Summary and Path Forward

Algorithm Overview

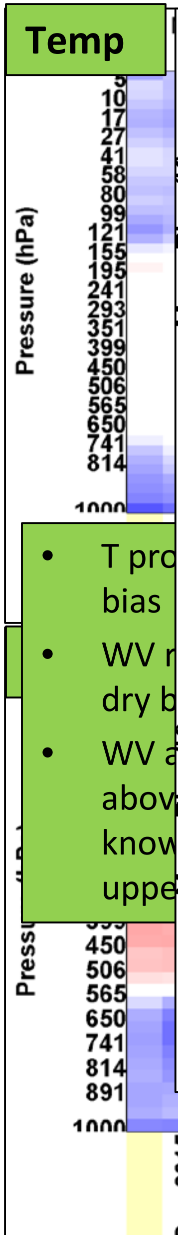


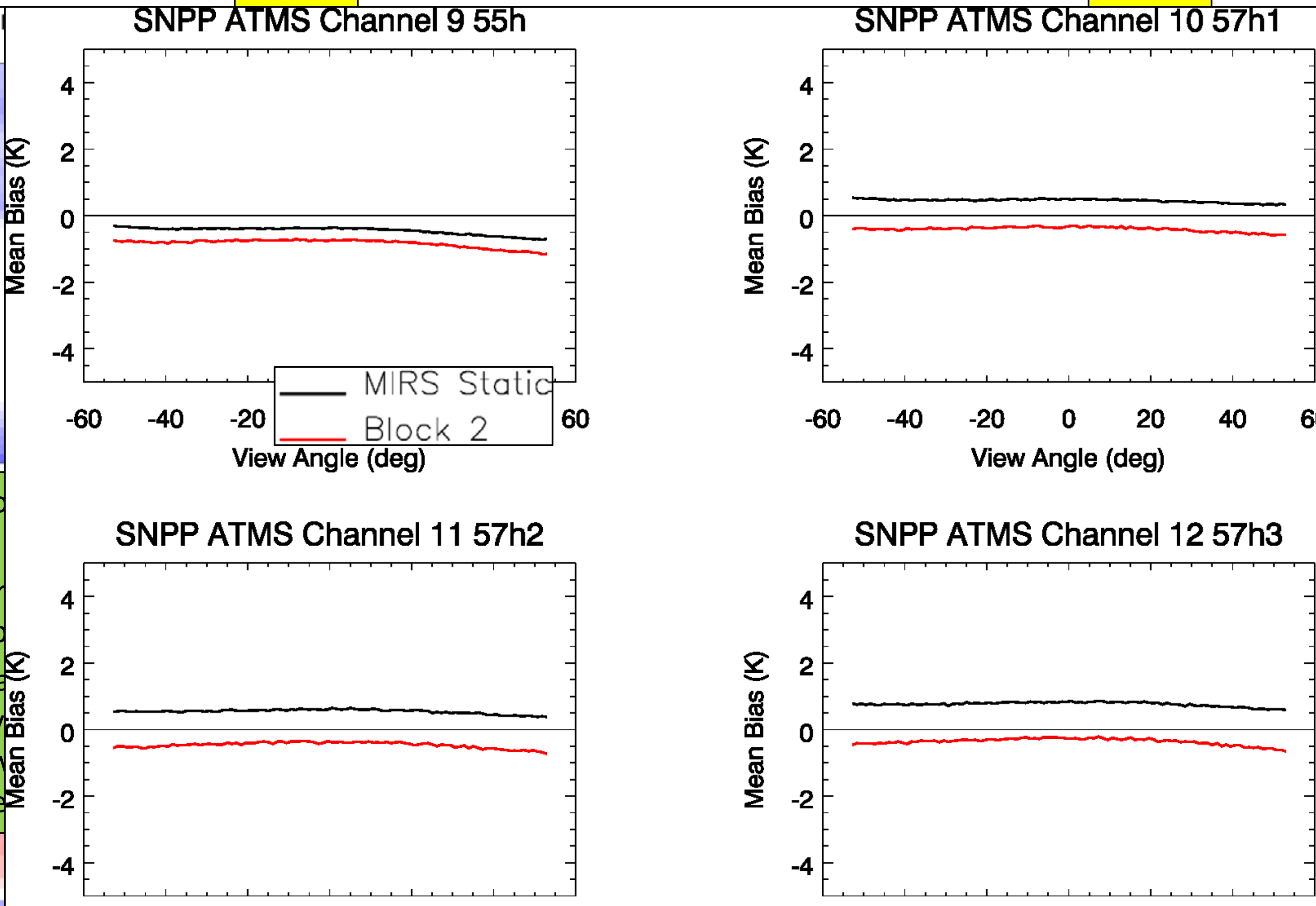
- MW Only, Variational Approach: Find the “most likely” atm/sfc state that: (1) best matches the satellite measurements, and (2) is still close to an a priori estimate of the atm/sfc conditions
- At NDE: Currently running v11.1 on SNPP/ATMS data, on J1/ATMS (v11.3) in early 2018.
- At OSPO: Initial capability delivered in 2007. Running v11.2 since Jan 2017 on N18, N19, MetopA, MetopB, F17, F18, GPM/GMI, Megha-Tropiques/SAPHIR. (eventually MetopC…)
- External Users/Applications: **(1) CIRA TC Analysis/Forecasting (G. Chirokova), (2) Layer PW (J. Forsythe), (3) MIMIC TPW Animations (T. Wimmers)**, CSPP (Direct Broadcast), NFLUX model (NRL, Stennis), CMORPH (CPC, precipitation), …

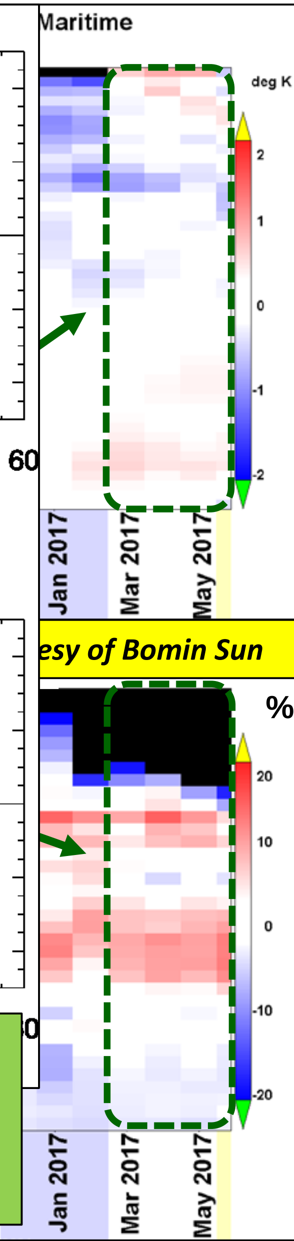
MiRS SNPP/ATMS Temperature and WV Bias vs. Raobs (NPROVS): Aug 2015 – June 2017

Land **Sea**

Temp







- T pro… bias
- WV r… dry b…
- WV a… abov… know… uppe…

- 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

MiRS SNPP Validation Status/Plans

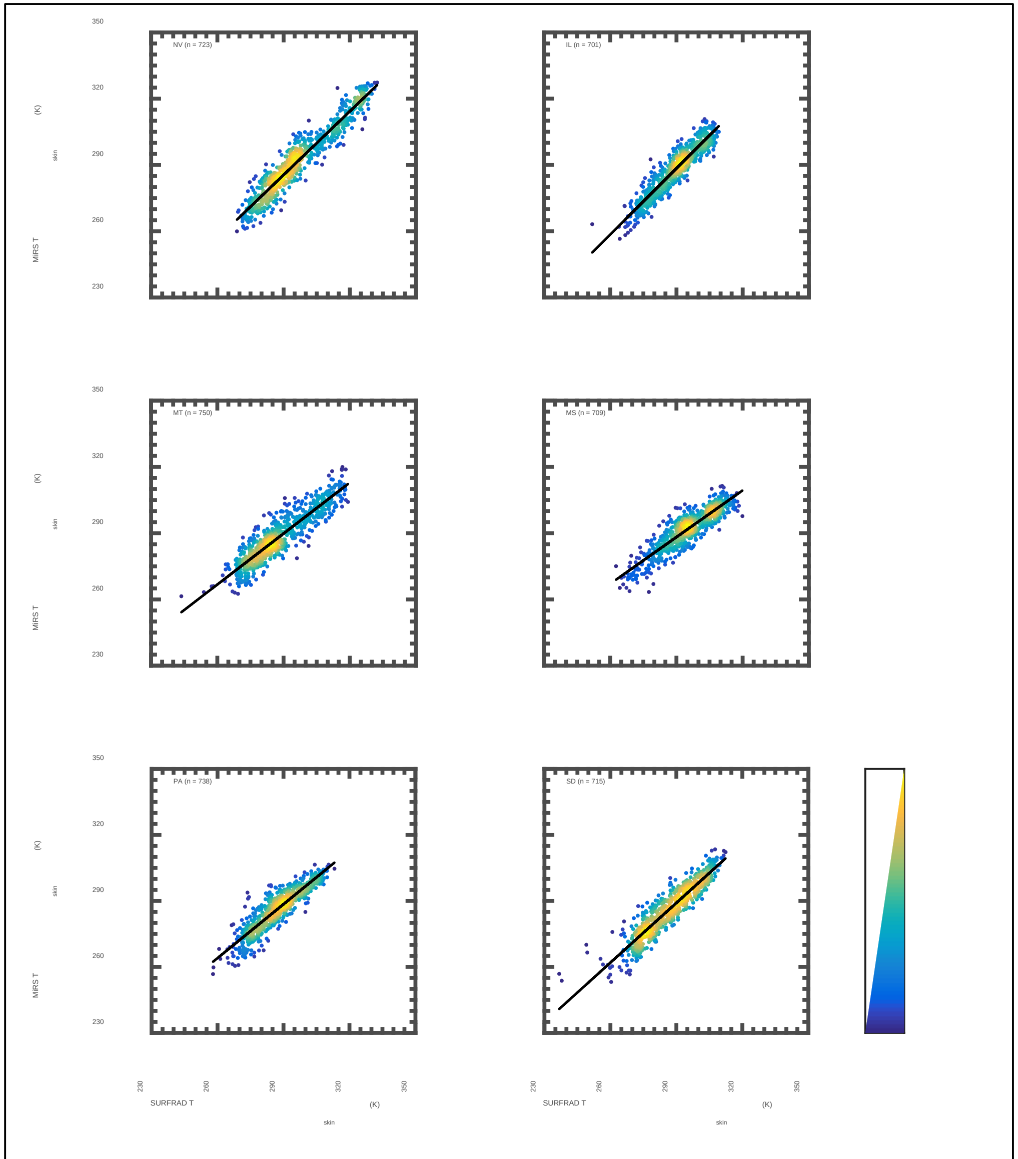
- Validated Maturity Reviews:
  - Two reviews in last 12 months:
    - October 2016 (T, WV, TPW, RR)
    - April 2017 (SIC, SWE, SCE, LST, LSE, CLW)
  - Status: All products validated maturity, except LST, LSE, CLW provisional maturity, with recommendations to utilize additional reference data, both in situ and satellite-based.
- Current Validation Activity Status for LST, LSE, CLW:

EDR	Plans/Activity	Status
LST	(1) 13-month collocation with in situ SURFRAD data (7 sites over CONUS). Performance characterized by location, season, day/night, scan position. (2) global collocation with VIIRS LST for single day (more days planned). **See next slides, and poster by C. Perez-Diaz et al.**	Nearly complete.
LSE	Global collocation with analytic emissivities derived from VIIRS LST+ECMWF atmosphere. One day complete, additional days planned (seasonal cycle). **(J. Chen)**	Ongoing. Expected completion Nov 2017.
CLW	Collocation with ARM surface-based MW radiometers in Tropical Western Pacific (3+ years), and Eastern N. Atlantic (10 months to date). Plan to process entire record of ENA (4+ years). Challenge to find non-tropical ocean sites. **(S. Liu)**	Ongoing. Expected completion Nov 2017.

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-May2017, 7 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 depth), representiveness error (point vs. IFOV average)
  - SURFRAD stations used:
    - Desert Rock, NV
    - Bondville, IL
    - Fort Peck, MT
    - Goodwin Creek, MS
    - Penn State, PA
    - Sioux Falls, SD
    - Boulder, CO

Validation of Land Sfc Temperature: Collocation with SURFRAD



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

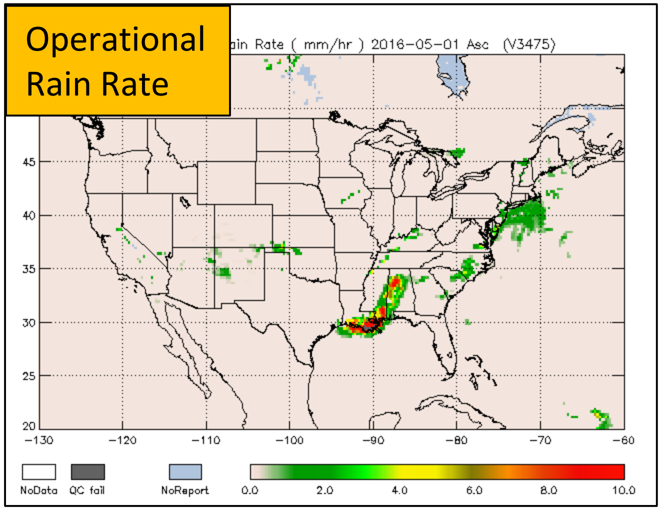
Requirements	Bias/ Accuracy (K)	StDev/ Precision (K)	RMS/ Uncertainty (K)
Threshold	**4.0**	**7.0**	**8.0**
Objective	**3.4**	**6.3**	**7.1**

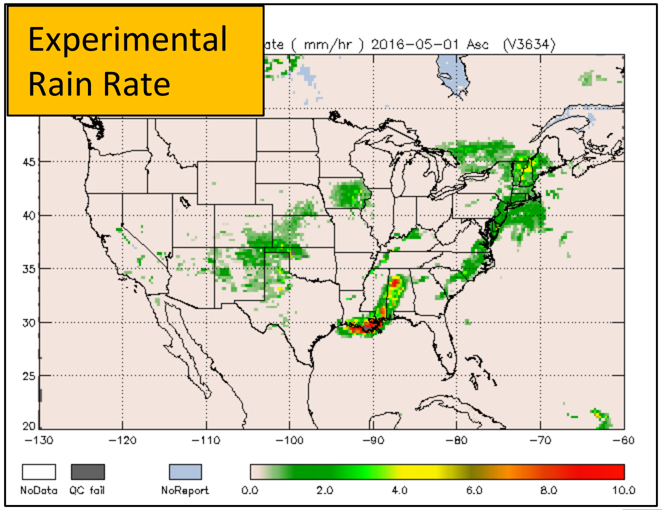
Meets threshold

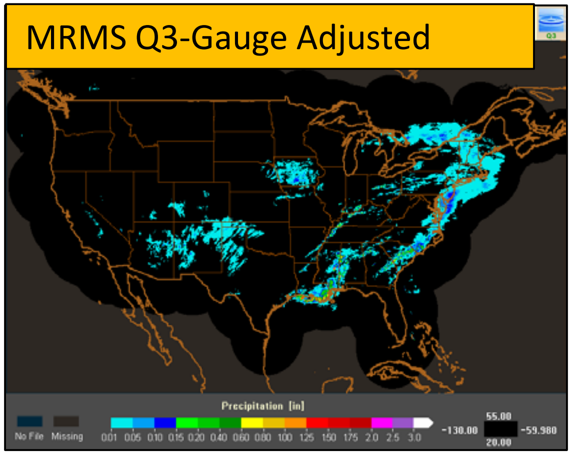
Meets objective

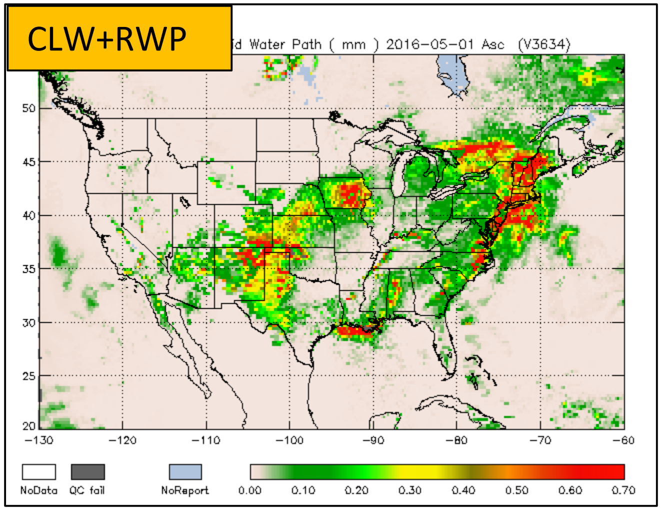
Many more results in poster by C. Perez-Diaz et al.

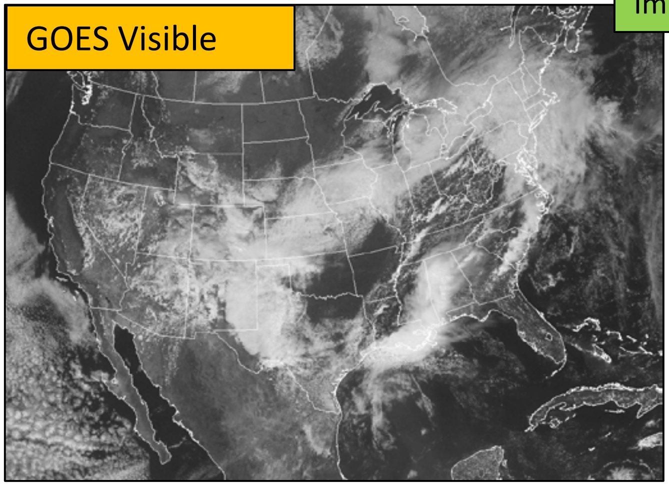
Path Forward: Rainfall Rate, Incorporating CLW over Land







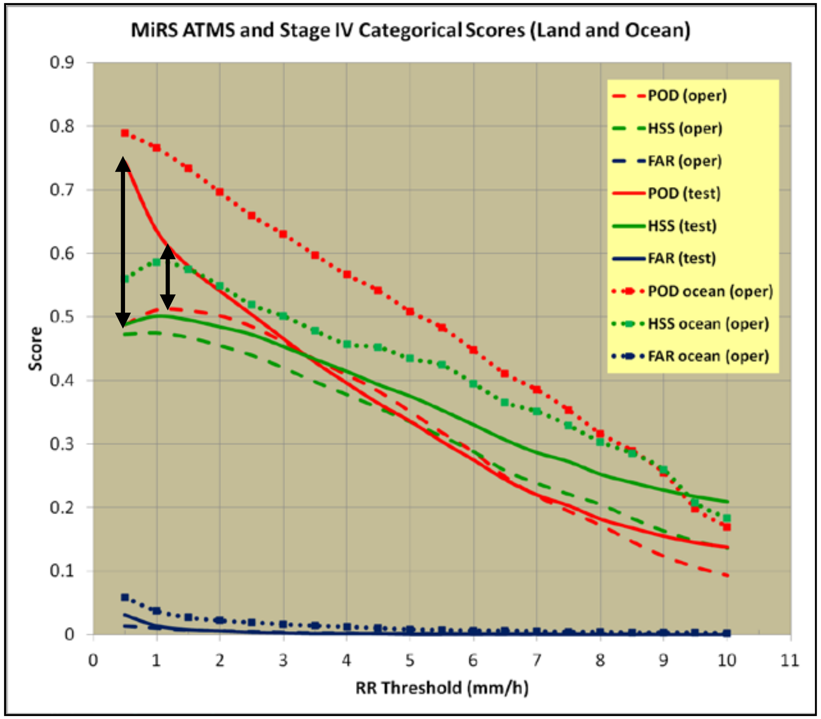


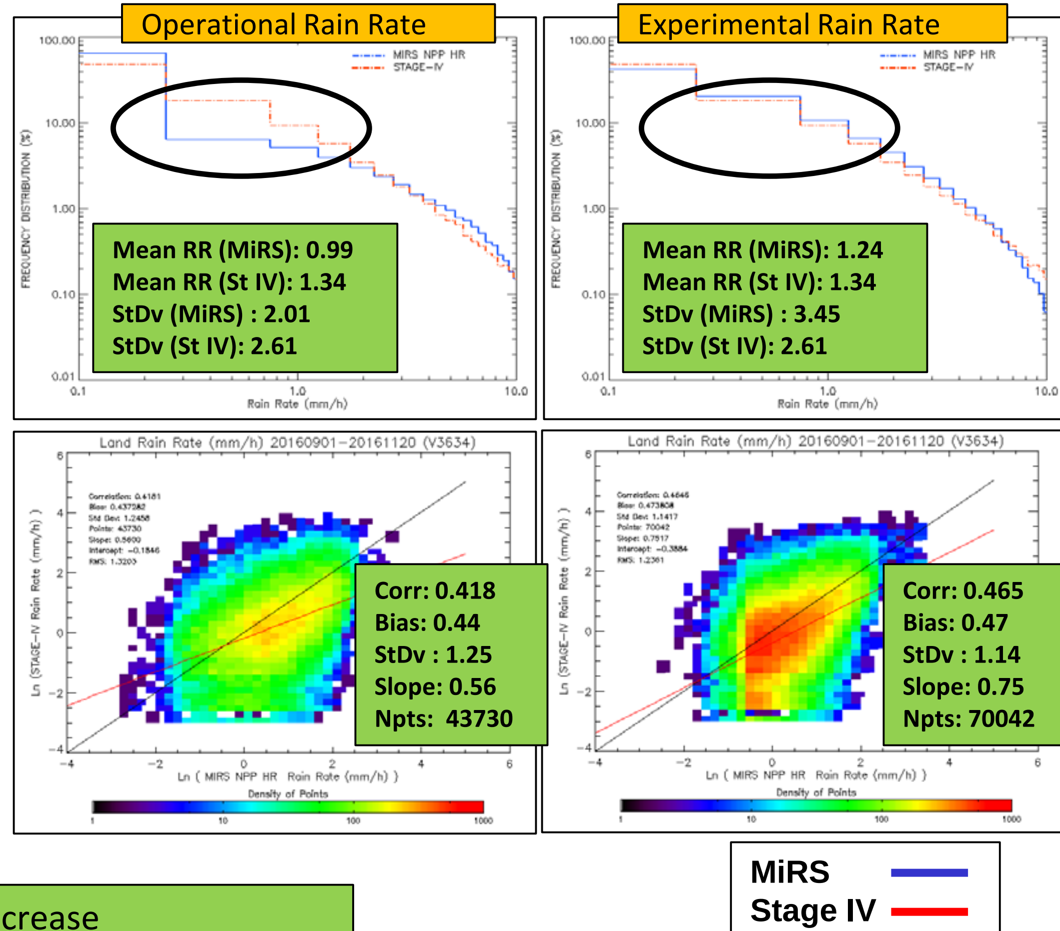


Improved detection of light rain (< 2 mm/h)

Path Forward: Rainfall Rate, Incorporating CLW over Land

MiRS ATMS RR Performance Relative to Stage IV: 1 Sept-20 Nov 2016





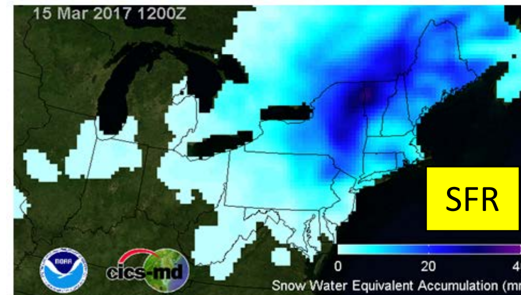
- Over land POD and Heidke Score significant increase
- Better PDF match with Stage IV for both low and high rain rates
- Increased correlation and slope closer to 1
- Plan to incorporate in next version of MIRS (v11.3)

ATMS Snowfall Rate (SFR)

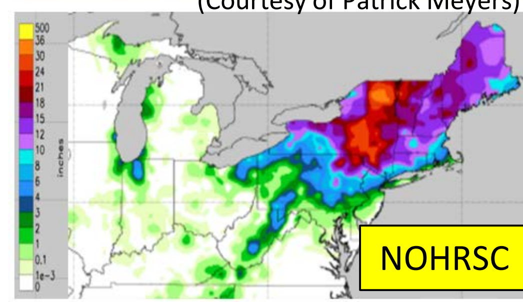
- POES and Metop AMSU/MHS SFR product is operationally produced inside MiRS
- SNPP ATMS SFR algorithm developed with the JPSS PGRR support; to be integrated into MiRS in FY18 pending PSDI support
- ATMS SFR initial cal/val indicates ATMS SFR outperforms AMSU/MHS SFR
- Development of SFR algorithms for DMSP SSMIS and NASA GMI with the JPSS PGRR support; significantly improves temporal coverage and enhances product utility with four additional satellites (nine in total)
- Applications: hydrology and weather forecasting

ATMS and MHS SFR from the intense Nor'easter on March 14-15, 2017

24-hour snowfall accumulation ending March 15, 2017 12 UTC



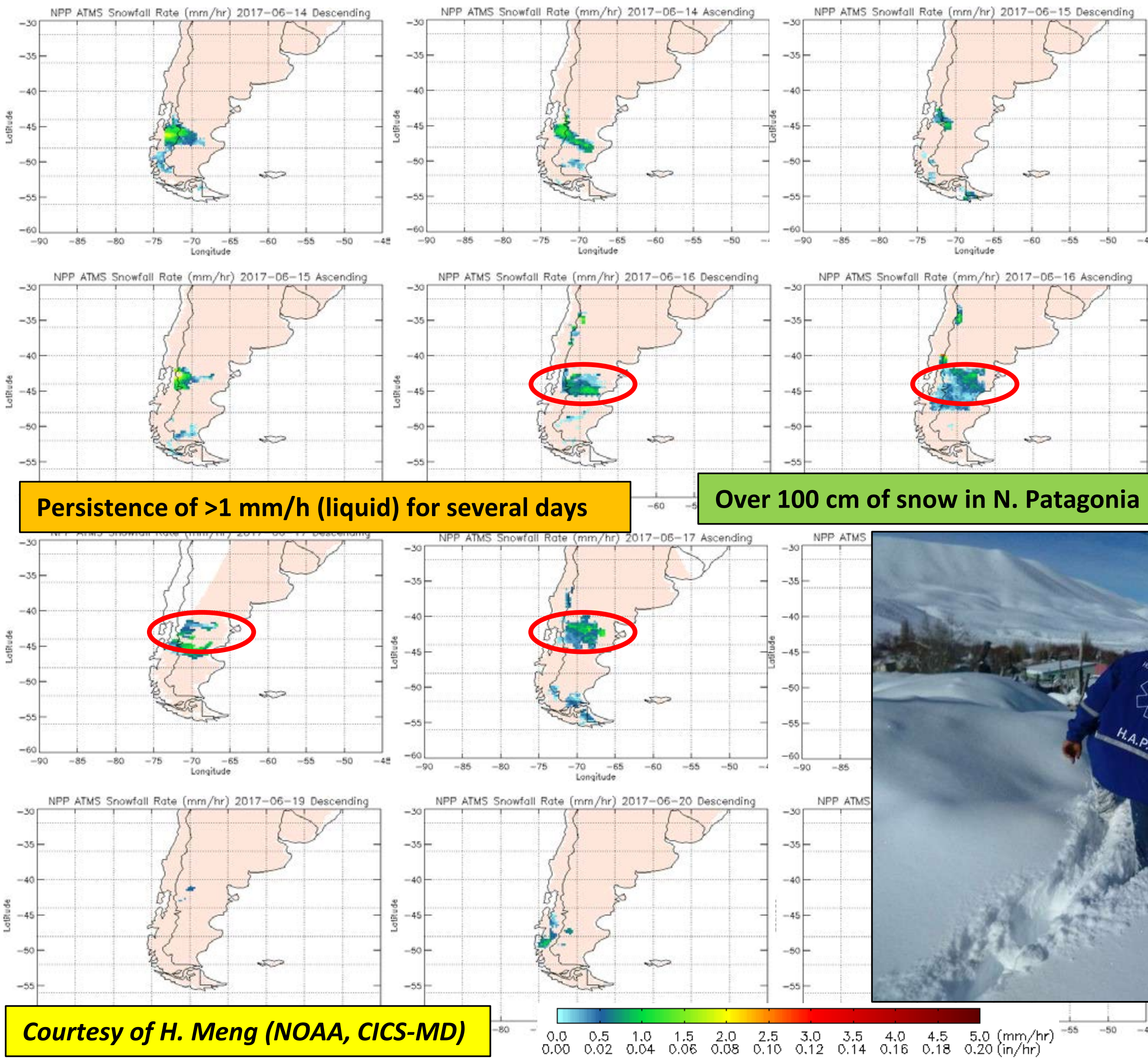
(Courtesy of Patrick Meyers)



- Entering Intensive Calibration/Validation (ICV) phase
  - ✓ Snowfall Detection (SD) cal/val with gauge observations and potentially radar snowfall detection data
  - ✓ Snowfall Rate cal/val with radar estimates (MRMS) and gauge snowfall accumulations (SNOTEL, USCRN)

Courtesy of H. Meng (NOAA, CICS-MD)

ATMS SFR Captures Record South American Snowfall (14-21 June 2017)



Persistence of >1 mm/h (liquid) for several days

VIIRS Snow Cover Fraction

Over 100 cm of snow in N. Patagonia

Courtesy of H. Meng (NOAA, CICS-MD)

Development of an Air Mass-Based Radiometric Bias Correction

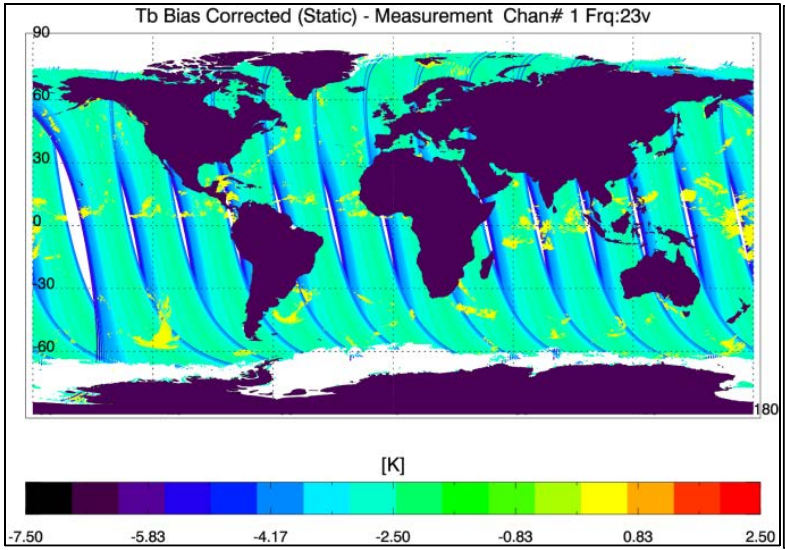
- Motivation:
  - Current operational MiRS uses Histogram Adjustment Method. Derived over oceanic/clear scenes. Bias specified as function of channel and scan position.
  - Advantages: Stable, reduces impact of outliers/cloud/rain contamination, good at characterizing the average global differences between 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 using uncorrected TBs**
    - **Step 2: dTB(iChan, iscanpos)=f(CLW, TPW, Tskin, TB(iChan)), TPW and 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 Block 2 SDRs
    - **Quantify impact on retrieved parameters (e.g. T, WV, ocean emissivity, CLW, TPW, chi-square, iterations)**

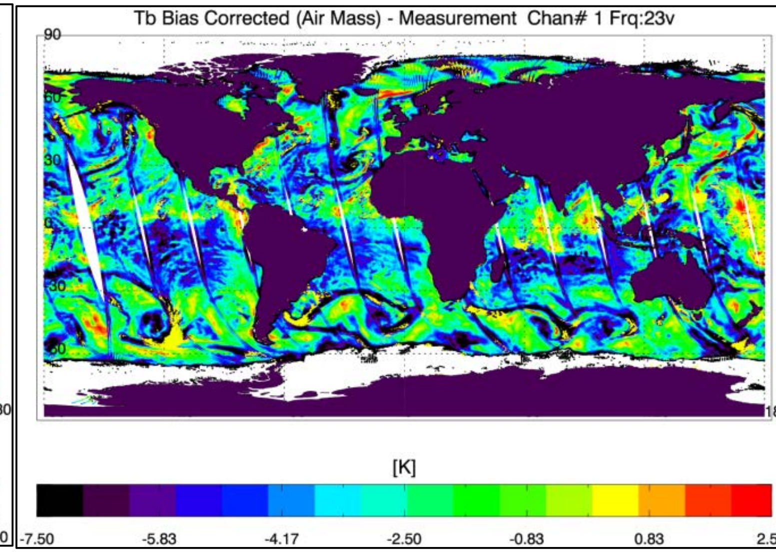
Testing an Air Mass-Based Radiometric Bias Correction

Static Correction (operational)

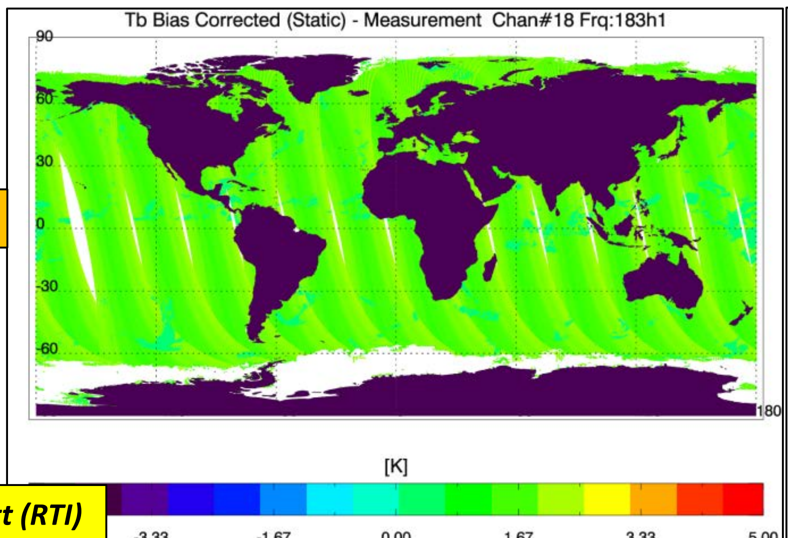
Air-mass Correction

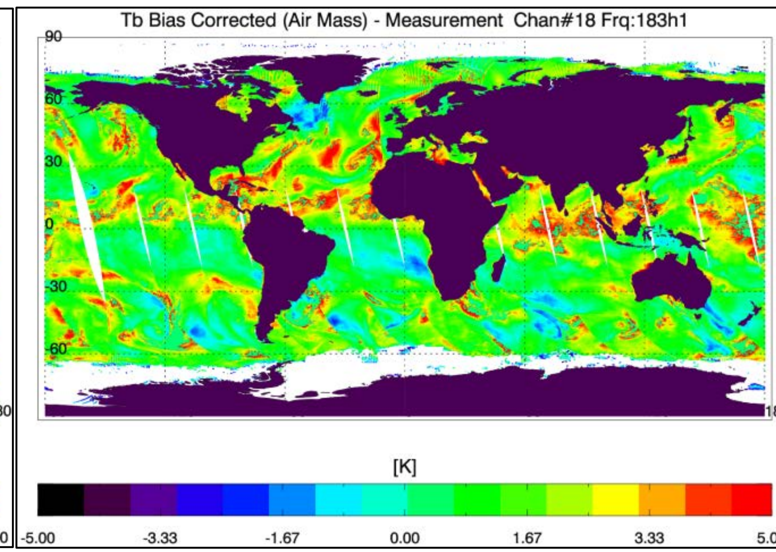
Ch 1 (23 GHz)





Ch 18 (183+/- 7 GHz)

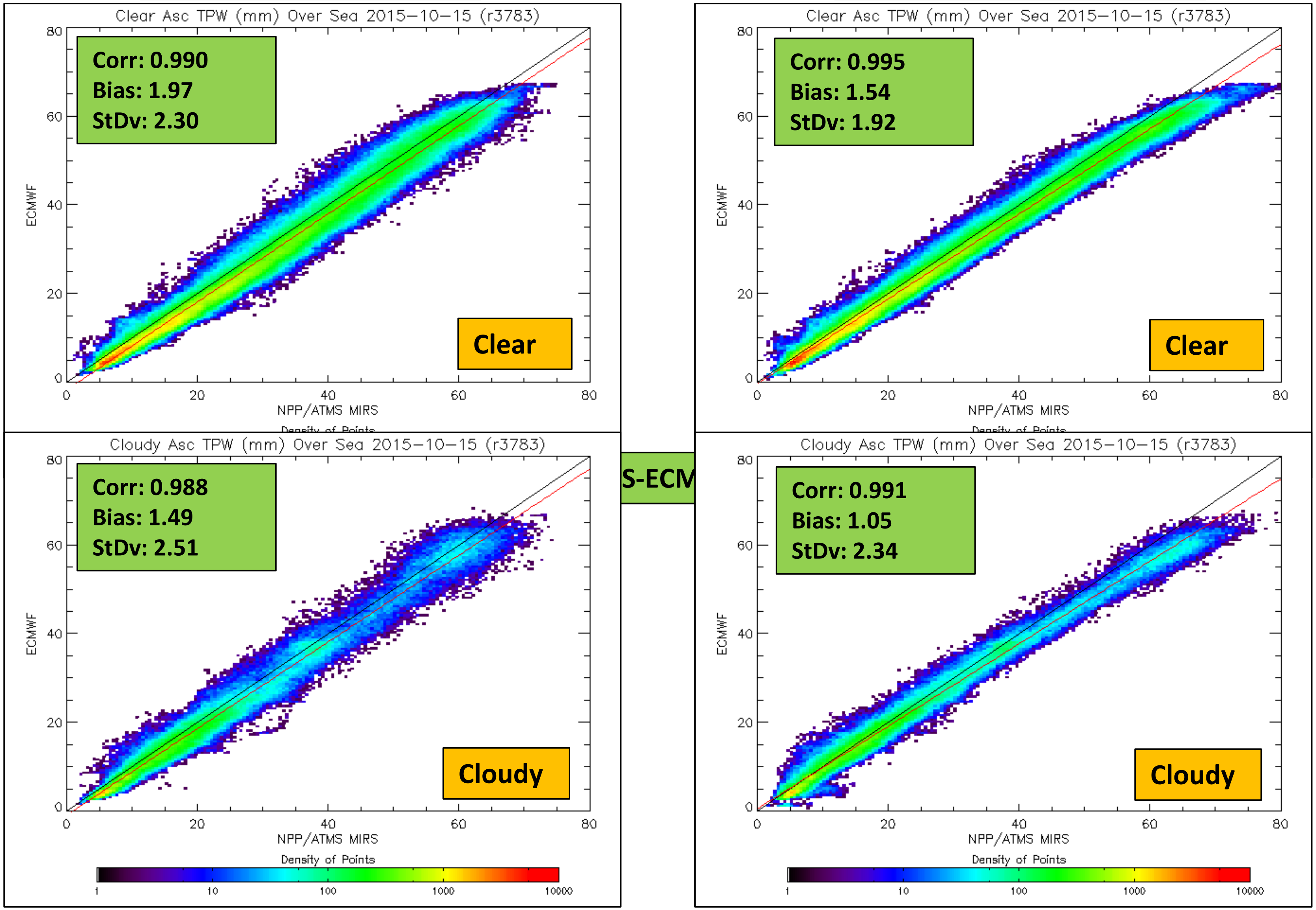




Courtesy of K. Garrett (RTI) and P. Liang (AER)

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

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

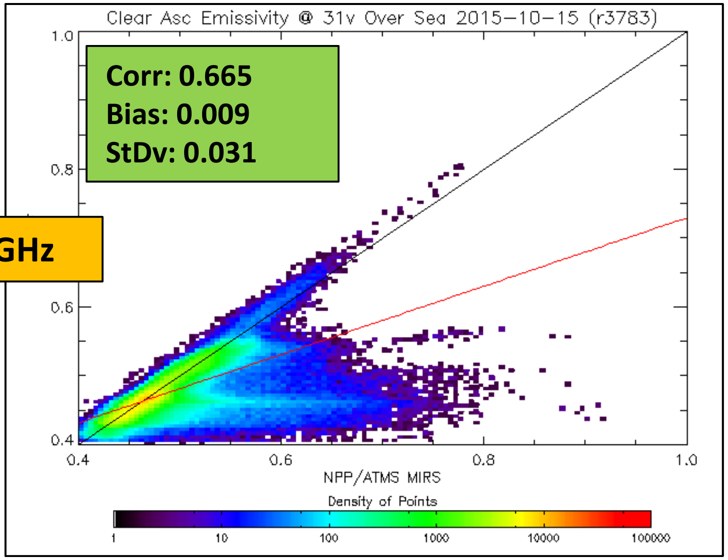


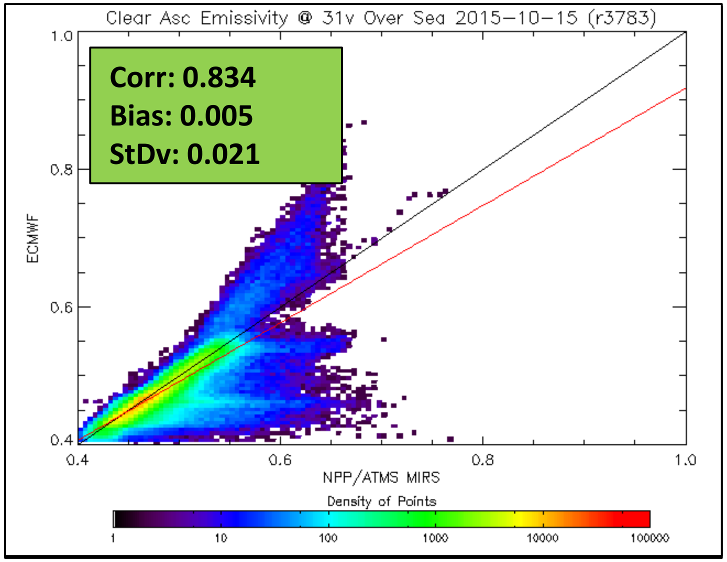
Testing an Air Mass-Based Radiometric Bias Correction: Ocean Emissivity

MIRS-FASTEM (Static Correction)

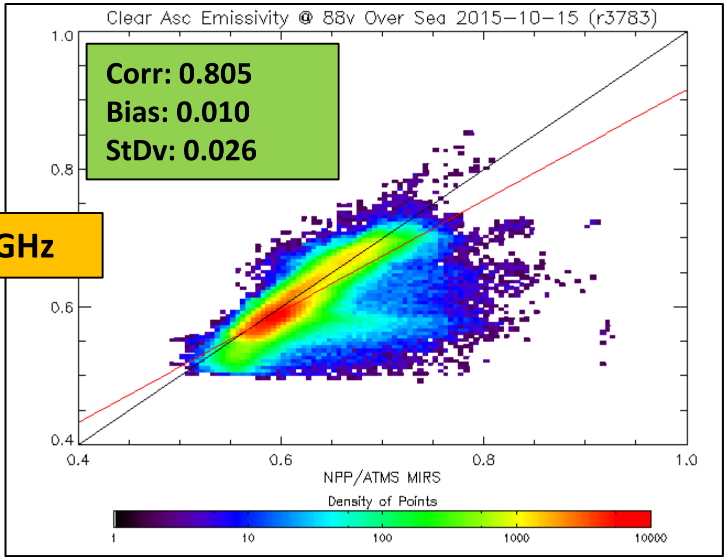
MiRS-FASTEM (Air-mass Correction)

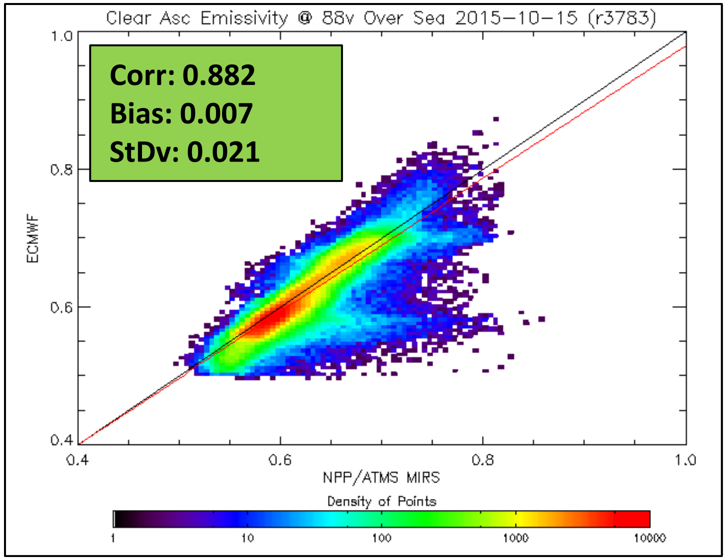
31 GHz





88 GHz

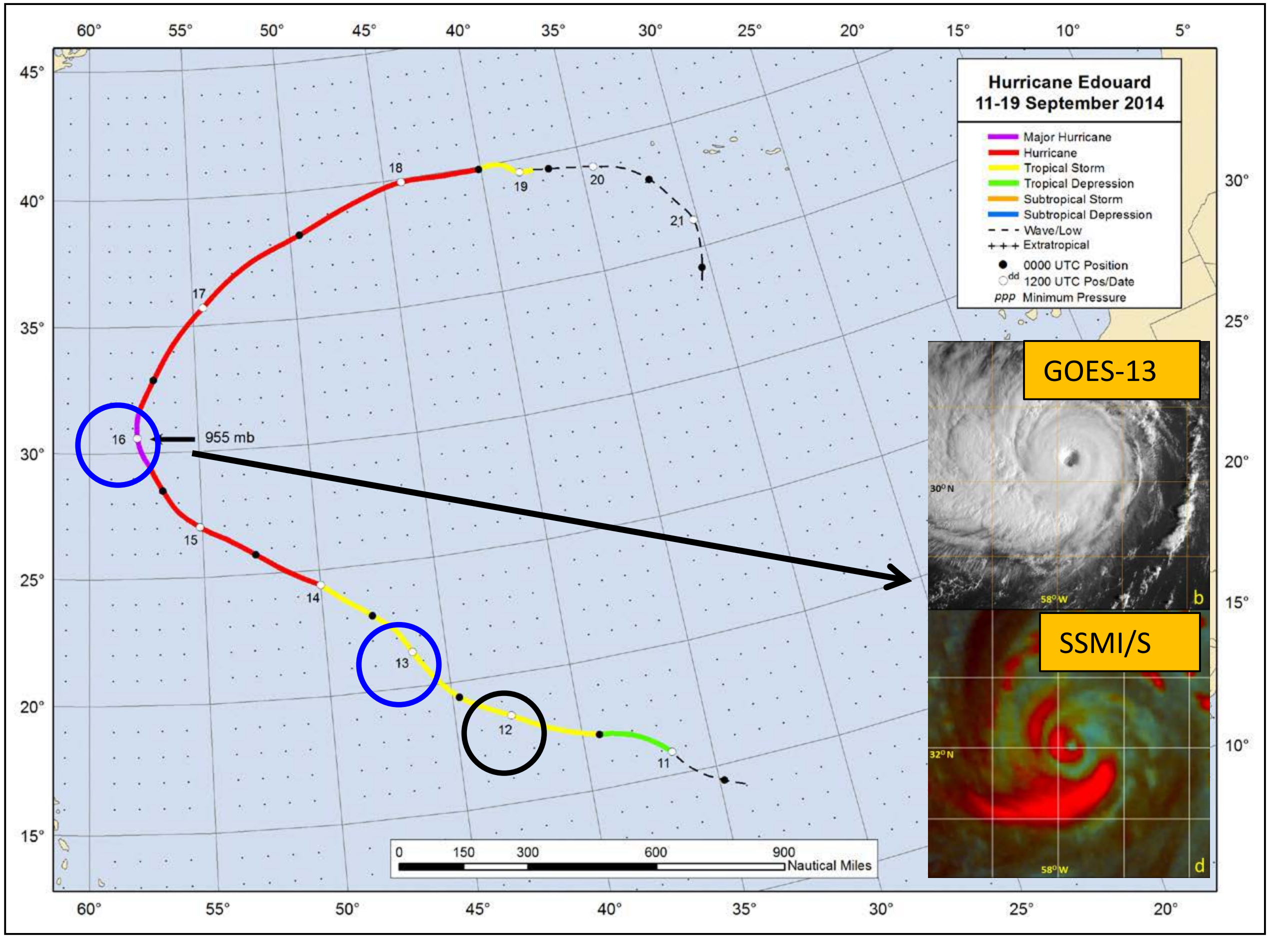




Developing a TC-Specific Version of MiRS

- 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 predict future intensification.
  - 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**

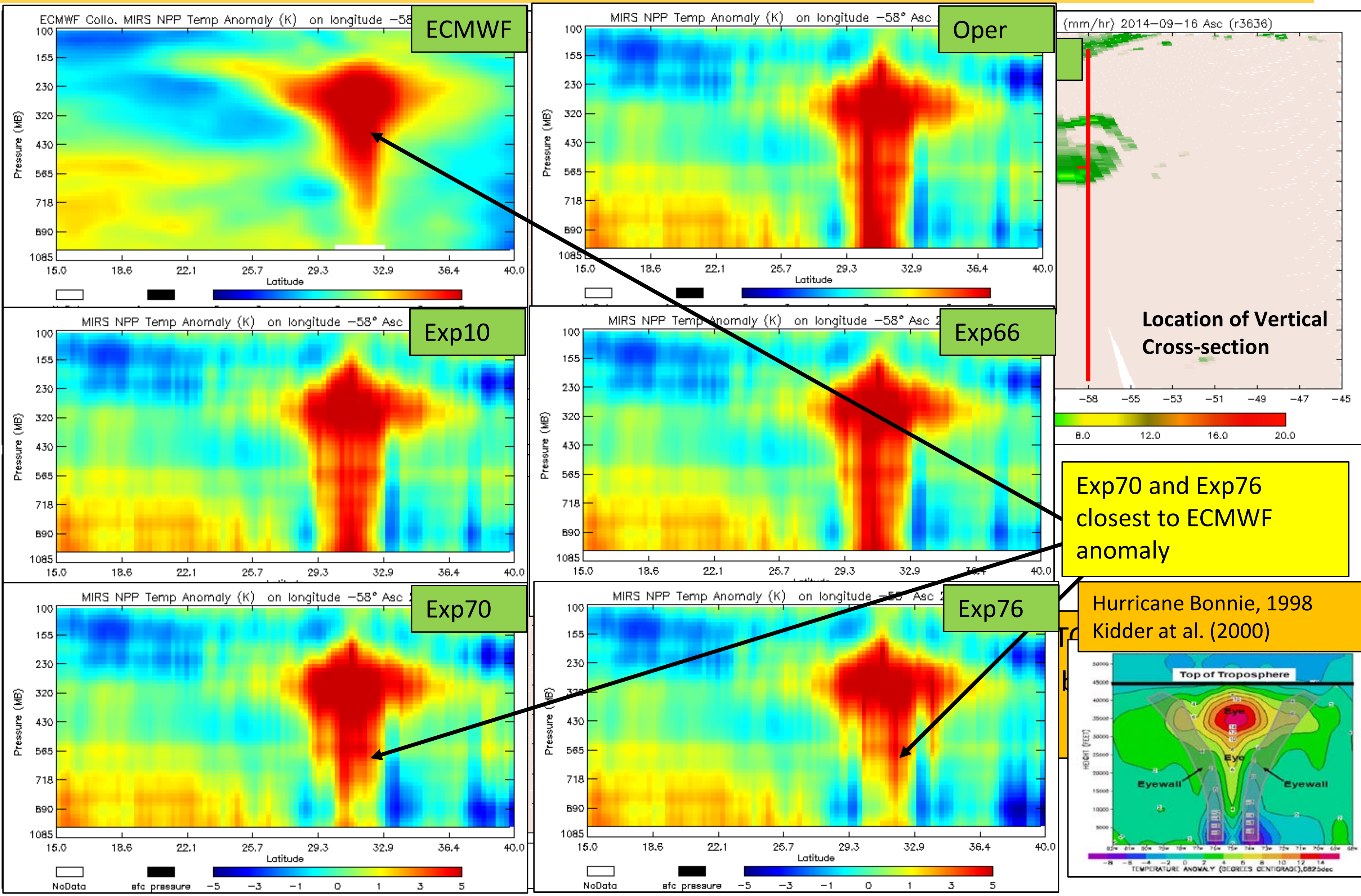
Case Study: Hurricane Edouard, Sept 2014



- 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

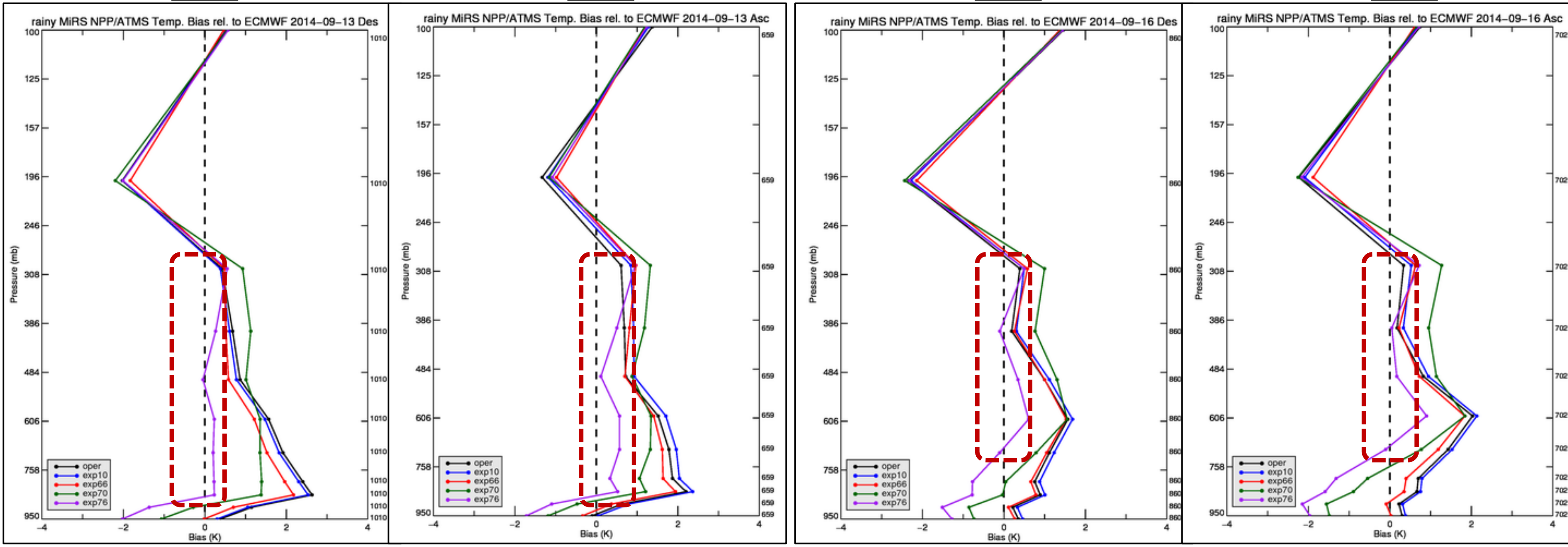
Temperature Anomaly Along -58 deg Lon: 2014-09-16



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

JPSS-1 Readiness

- Significant Algorithm changes from V11.2 to V11.3:
  - **Addition of SFR for ATMS**: will require access to GFS forecasts (will work with NDE during integration and testing; already done for AMSU/MHS).
  - Vegetation correction for SWE (improved estimation over forested regions).
  - CLW retrieved over land (improved light rain detection)
- Pre-launch Characterization
  - **All software now extended to J1**: End to end testing on previous proxy data completed, also plan to process 8-day data. Daily processing codes in STAR now complete and ready for near real-time data after launch.
- Post-Launch Cal/Val Plans
  - Data Sets: Radiometric bias characterization (ECMWF), T and WV sounding (ECMWF, GDAS, raobs), rain rate (Stage IV, MRMS, GPROF), CLW (GPROF, ARM), snow (SNODAS, AMSR2, IMS), ice (IMS, OSI-SAF, VIIRS), LSE/LST (ECMWF, SURFRAD, VIIRS),
  - Milestones: (1) preDAP delivery in Feb 2018, ~L+6 months (initial cal/val for T, WV and TPW) (2) official DAP ~L+12 months. Possible delivery to CSPP/DB after preDAP complete.
- Risks and Mitigation: None at this time.
- Collaboration with Stake Holders: Feedback from OSPO, NDE to identify bugs/issues, other external users/applications. Explore pathway to AWIPS2.
- Science improvements in testing: Air-mass bias correction, TC-specific applications. Website: www.star.nesdis.noaa.gov/mirs

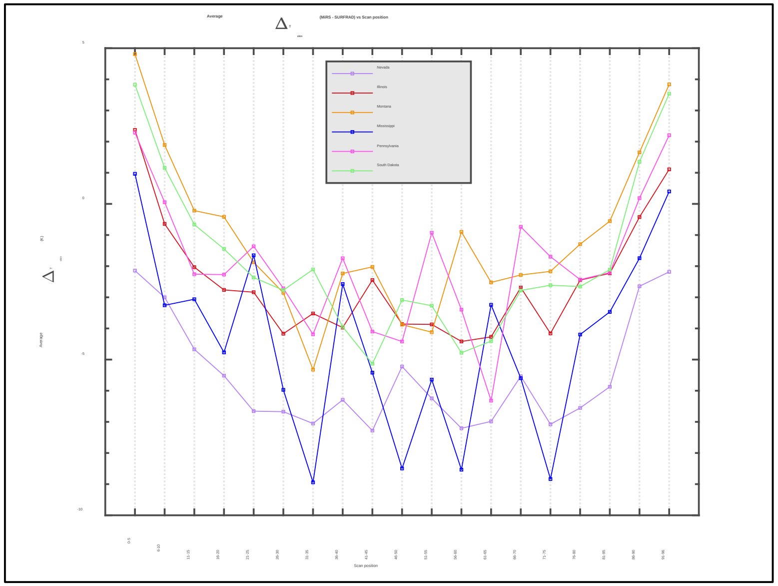
Summary & Path Forward

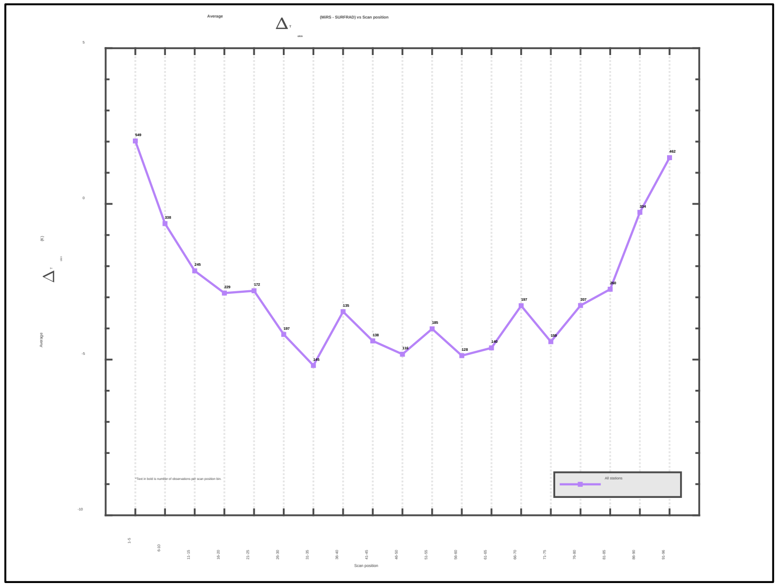
- MiRS is relatively mature algorithm; evolution and improvement since SNPP launch (v9.2 -> v11.2); more improvements possible!
- Next version (v11.3): Biggest change from data flow/dependence perspective is integration of SFR requiring GFS data.
- Path Forward
  - FY18 Milestones: (2) preDAP delivery in Feb 2018, (3) official DAP ~L+6 months (initial cal/val).
  - Future Improvements:
    - **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
    - Rainy condition sounding (update a priori constraints)
    - TC-specific applications (FG/BG a priori based on TC climo or 6-h fcst)
    - Stakeholders/user needs…

Backup

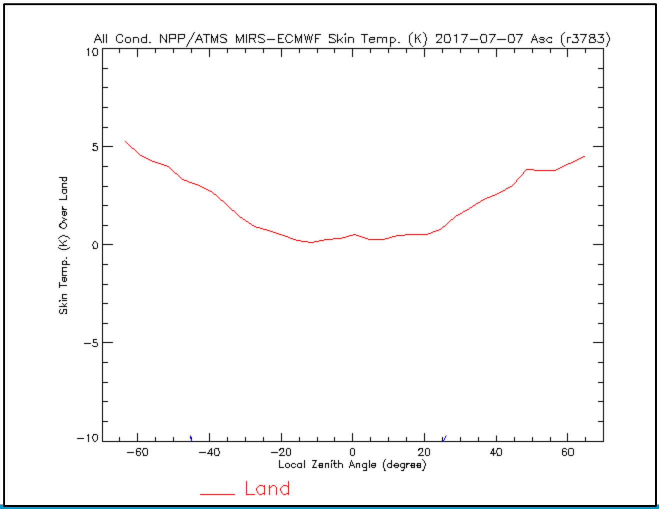
Validation of Land Sfc Temperature: Scan Dependence wrt SURFRAD and ECMWF

Scan Dependence wrt SURFRAD



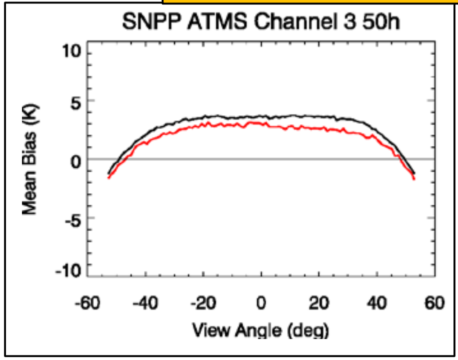


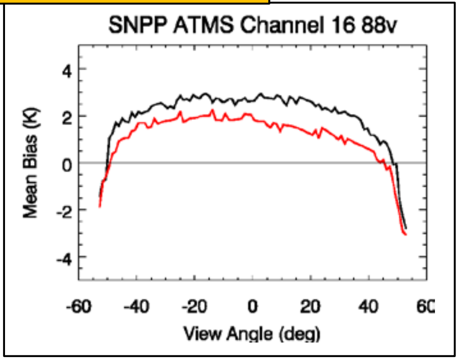
Scan Dependence wrt ECMWF



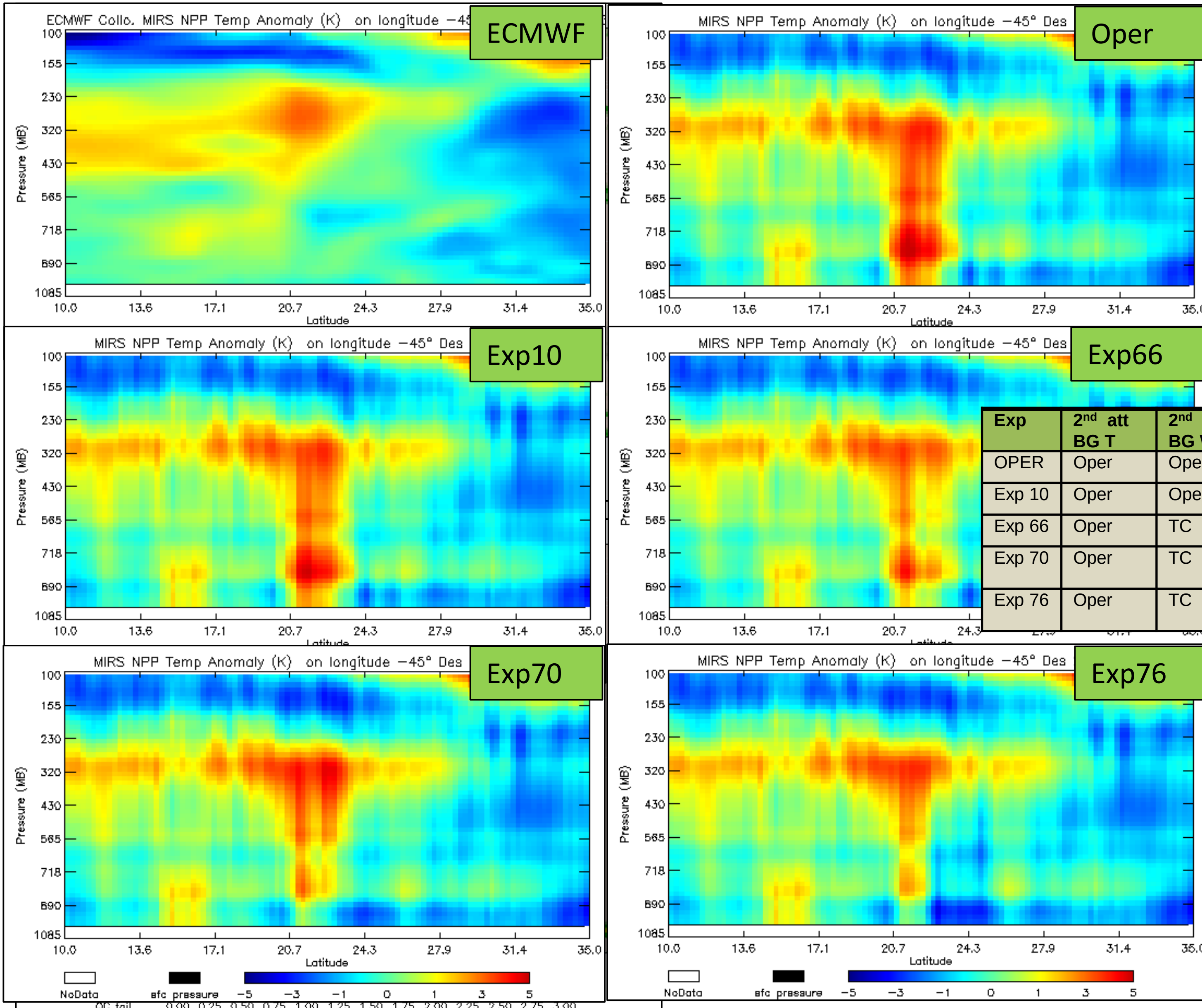
- Relative scan dependence seen wrt both SURFRAD and ECMWF
- Absolute biases different
- Likely due to radiometric bias correction (trained over ocean)

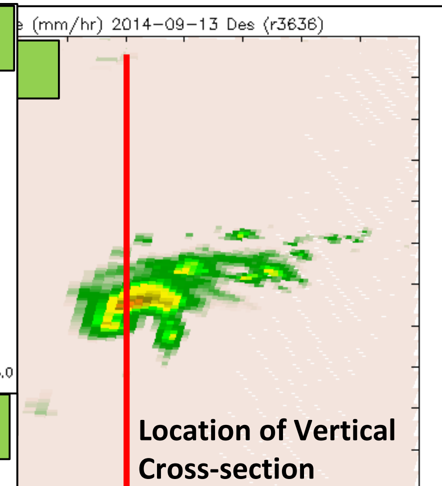
Block1 and Block 2 Bias corrections





Temperature Anomaly Along -45 deg Lon: 2014-09-13





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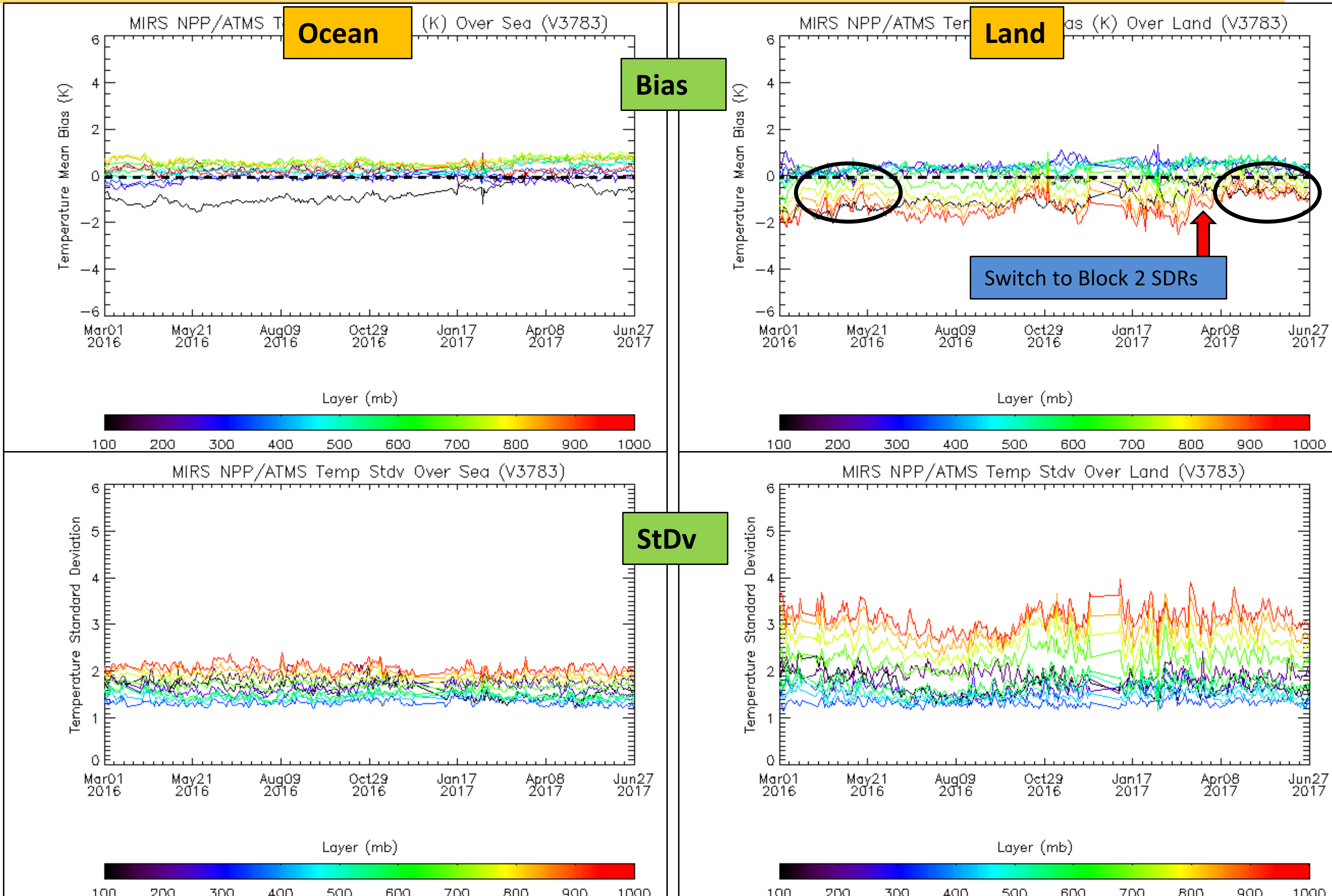
OPER	Oper	Oper	ON	ON	Oper
Exp 10	Oper	Oper	OFF	ON	Oper
Exp 66	Oper	TC	OFF	ON	Oper
Exp 70	Oper	TC	OFF	ON	nEOFT=9,nEOFWV=4
Exp 76	Oper	TC	OFF	OFF	nEOFT=9,nEOFWV=4

MiRS SNPP/ATMS Temperature Bias and Std Dev vs. GDAS: 1 March 2016 – 1 July 2017



MiRS Cal/Val Team Members

Team Member	Organization	Roles and Responsibilities
Q. Liu (Project Manager)	NESDIS/STAR/SMCD	Project management
C. Grassotti (Technical Lead)	NESDIS/STAR/SMCD (U. MD./ESSIC)	Coordination of technical activities; review/deliverable planning
S. Liu	NESDIS/STAR/SMCD (CIRA/CSU)	Precipitation cal/val, SFR integration, DAP preparation
J. Chen	NESDIS/STAR/SMCD (U. MD./ESSIC)	Sounding and emissivity cal/val, J1 extension, Sounding improvements