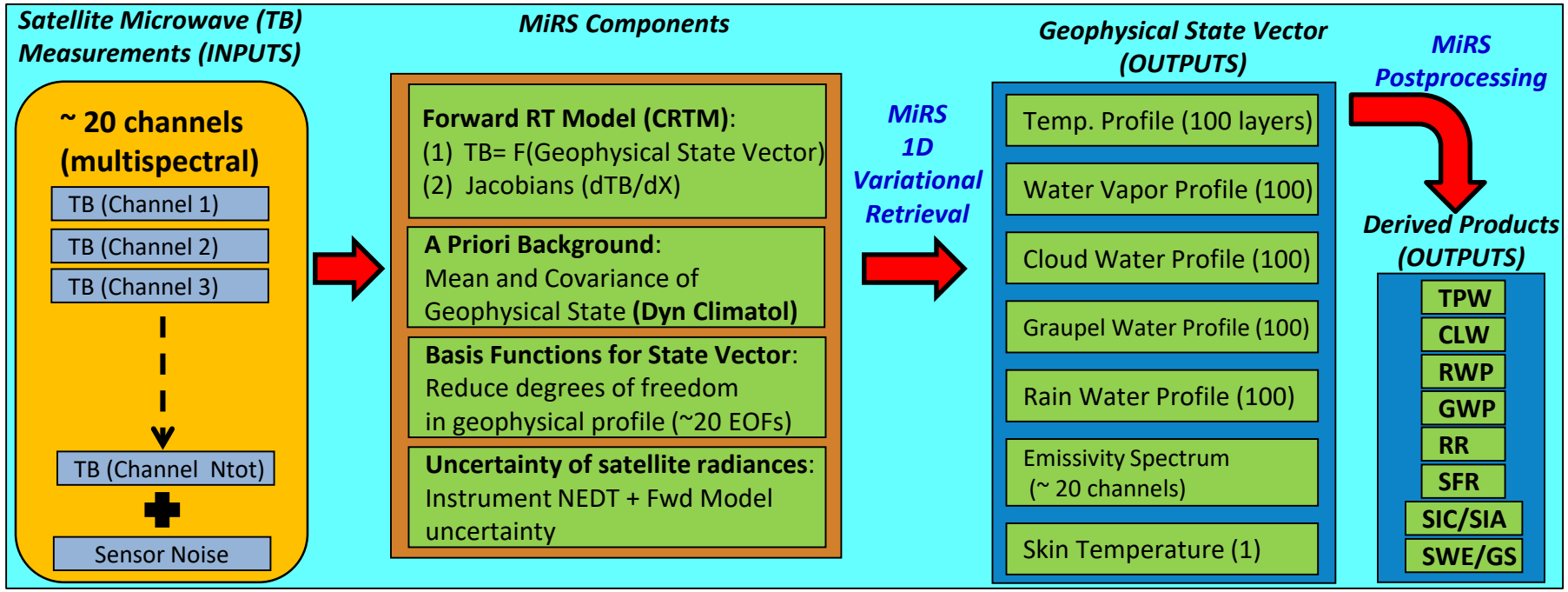
The NOAA Microwave Integrated Retrieval System (MiRS) Validation Update and Applications

Yong-Keun Lee (U.MD ESSIC/CISESS)
Christopher Grassotti (U.MD ESSIC/CISESS)
Shuyan Liu (CSU/CIRA)
Yan Zhou (U.MD ESSIC/CISESS)
Quanhua (Mark) Liu (NOAA/STAR)
Ming Fang (IMSG)

Topics

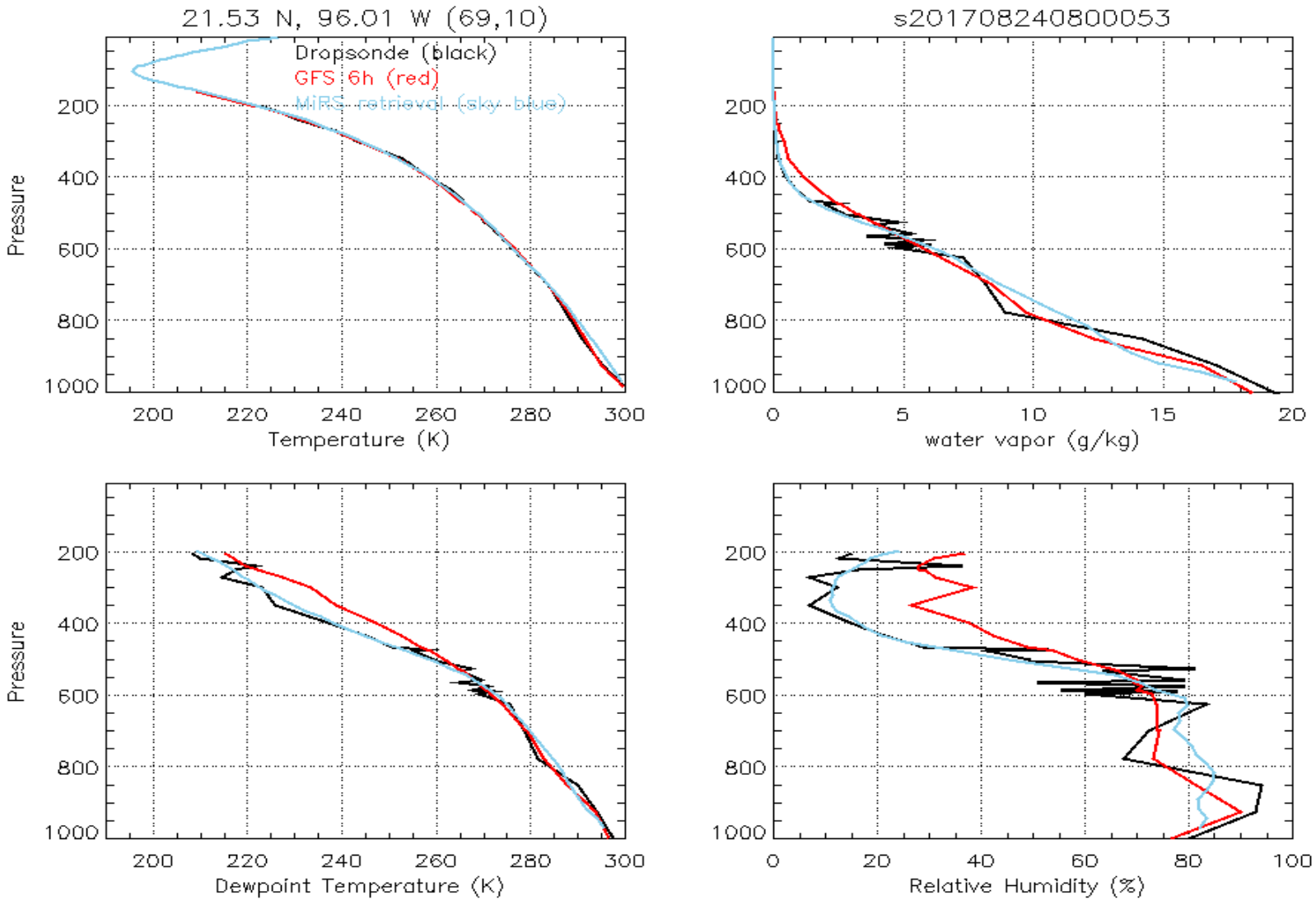
- **Introduction of MiRS**
- **Evaluation of MiRS algorithm performance (NOAA-20 ATMS)**
  : T and WV
- **MiRS Users and applications**
- **Improvements in MiRS**
- **Future plan**
- **Path Forward**

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…)
- Transition of v11.3 (extended to NOAA-20/ATMS) to operations in **March 2019**.
- V11.4 to operations in July 2019.
- External Users/Applications: TC Analysis/Forecasting at NHC, Blended Total/Layer PW Animations at NHC and WPC Animations (CSU/CIRA, U. Wisconsin/CIMSS), CSPP Direct Broadcast (U. Wisconsin), NFLUX model (NRL, Stennis), Global blended precipitation analysis at NOAA/CPC (CMORPH).

Dropsonde, GFS 6h Forecast, and MiRS Retrieval



Within 30 minute ranges between Dropsonde, GFS, and Mirs retrieval

Topics

- **Introduction of MiRS**
- **Evaluation of MiRS algorithm performance (NOAA-20 ATMS and sometimes with NPP ATMS)**
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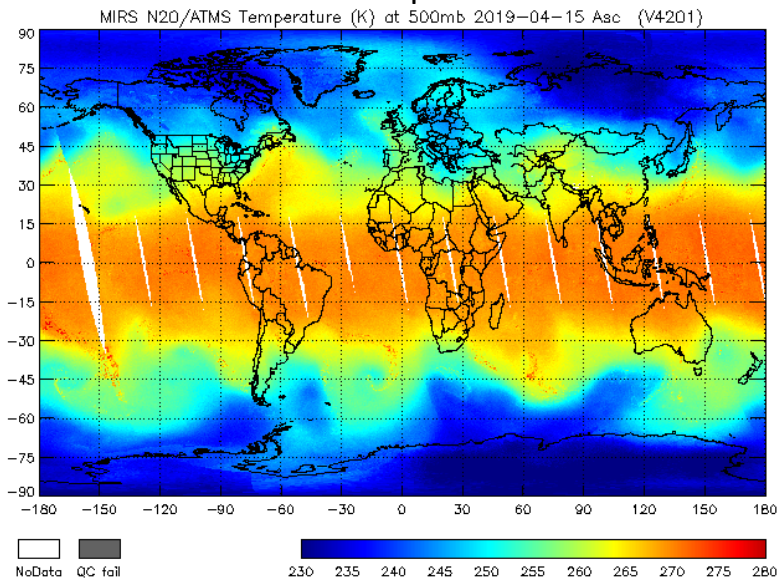
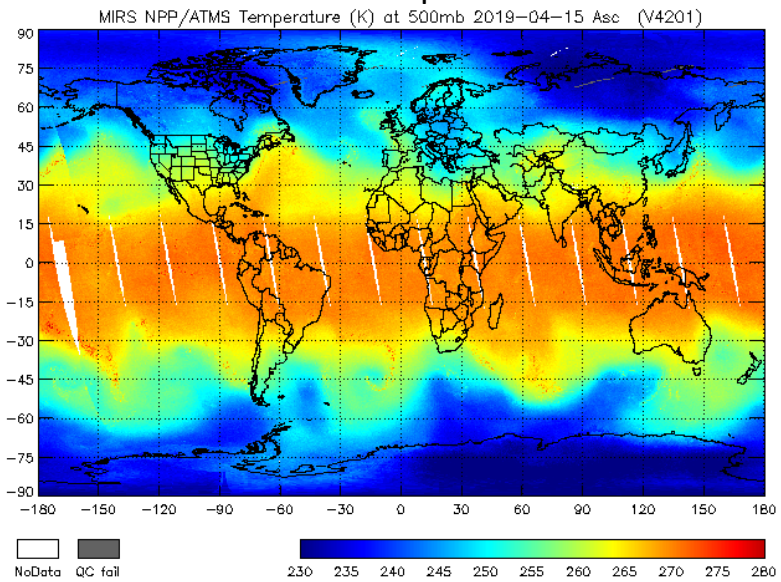
Temperature Profile Validation based on ECMWF data

N20 500hPa Temperature

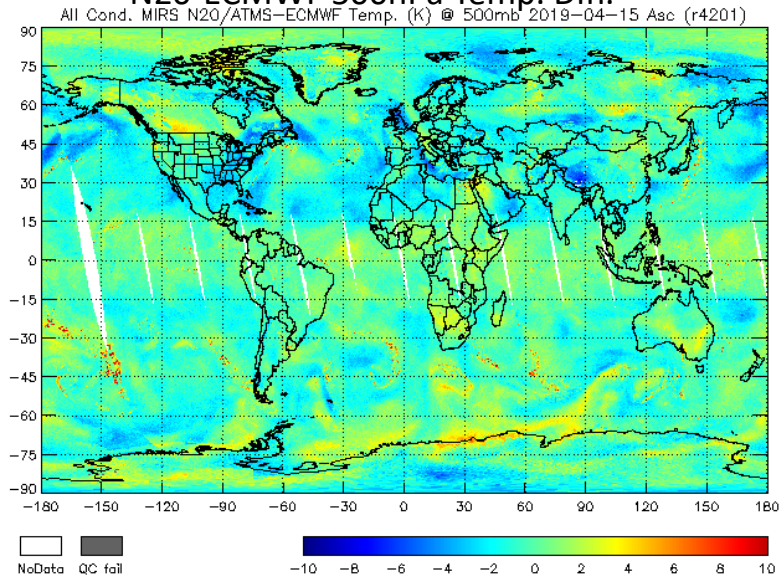


NPP 500hPa Temperature

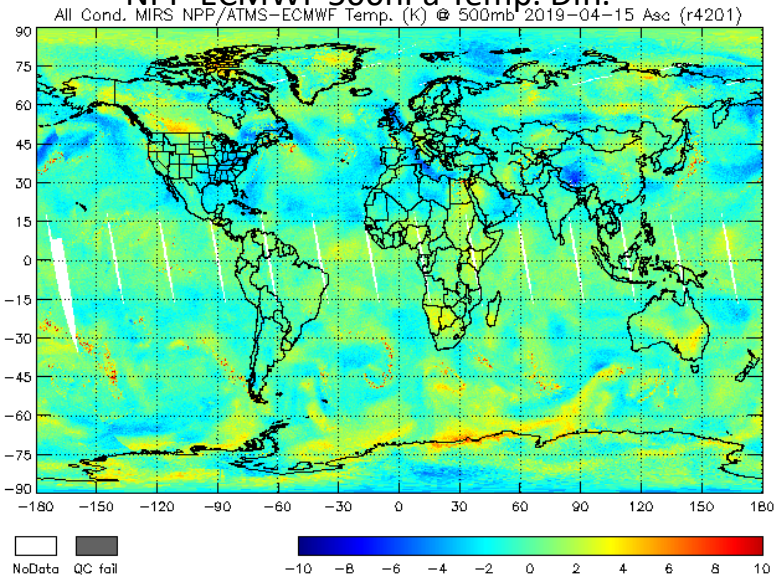


Same instrument: ATMS
Only 50 minute apart

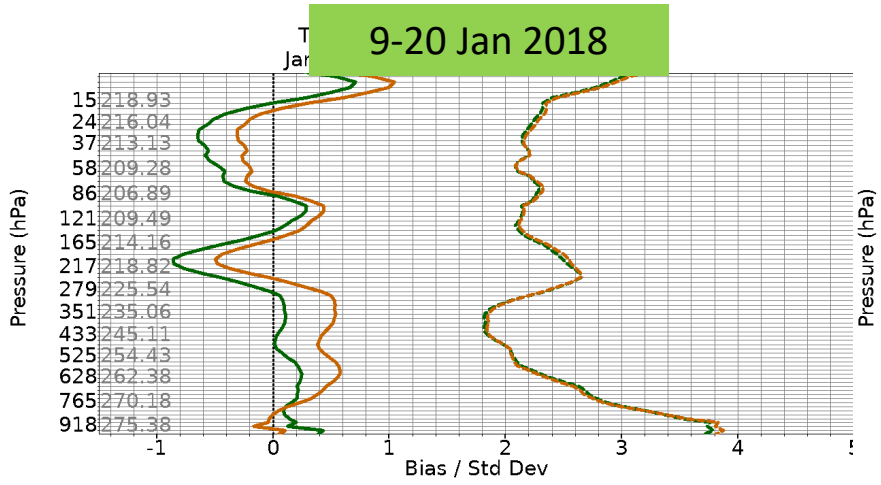
N20-ECMWF 500hPa Temp. Diff.

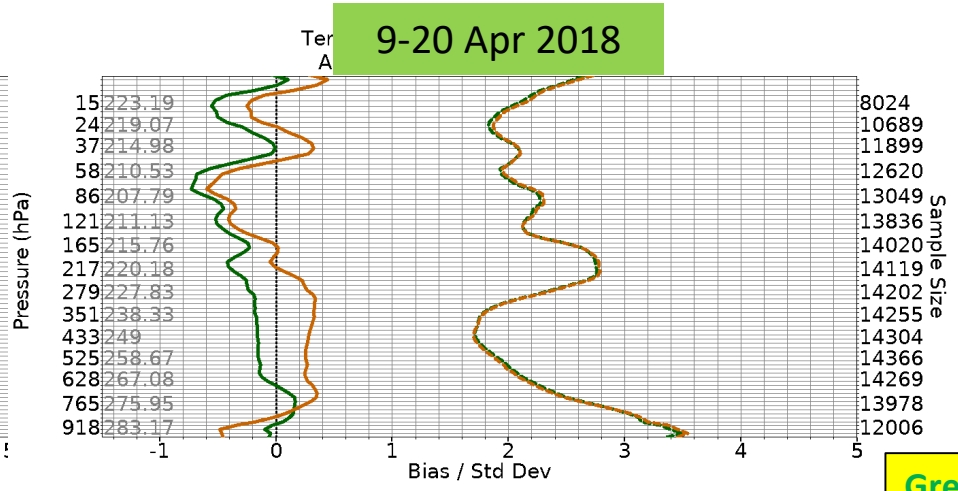


NPP-ECMWF 500hPa Temp. Diff.



Temperature Profile Validation based on sonde data





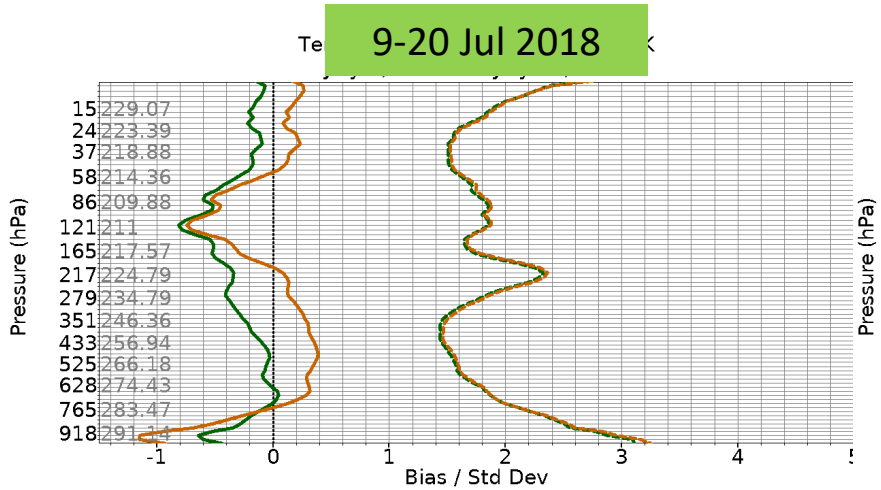
Baseline: SONDE

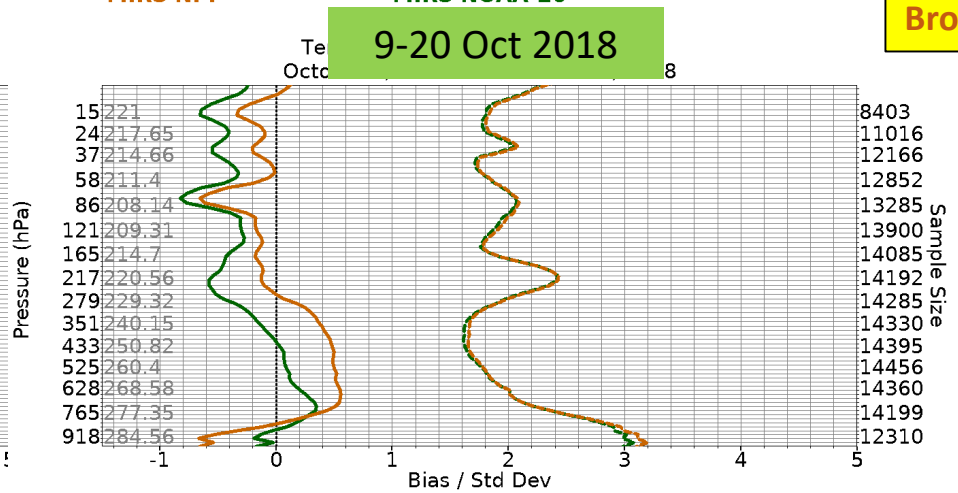
MIRS NPP **MIRS NOAA-20**

Baseline: SONDE

MIRS NPP **MIRS NOAA-20**

Green thick: N20 bias
Brown thick: NPP bias
Green dotted: N20 std
Brown dotted: NPP std





Baseline: SONDE

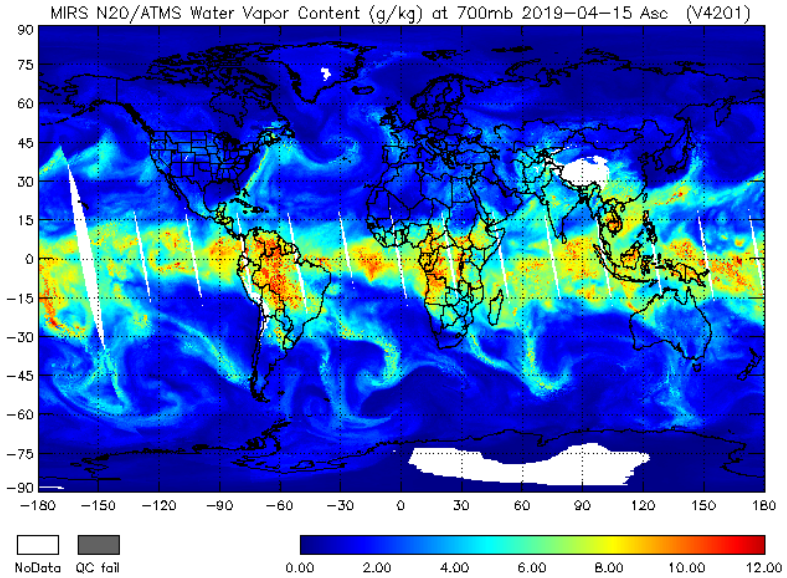
MIRS NPP **MIRS NOAA-20**

Baseline: SONDE

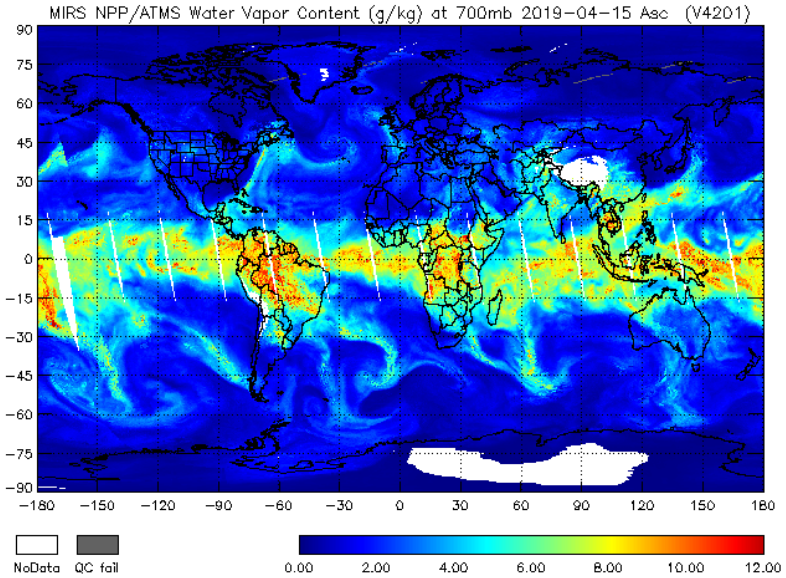
MIRS NPP **MIRS NOAA-20**

Water Vapor Profile (g/kg) Validation based on ECMWF data

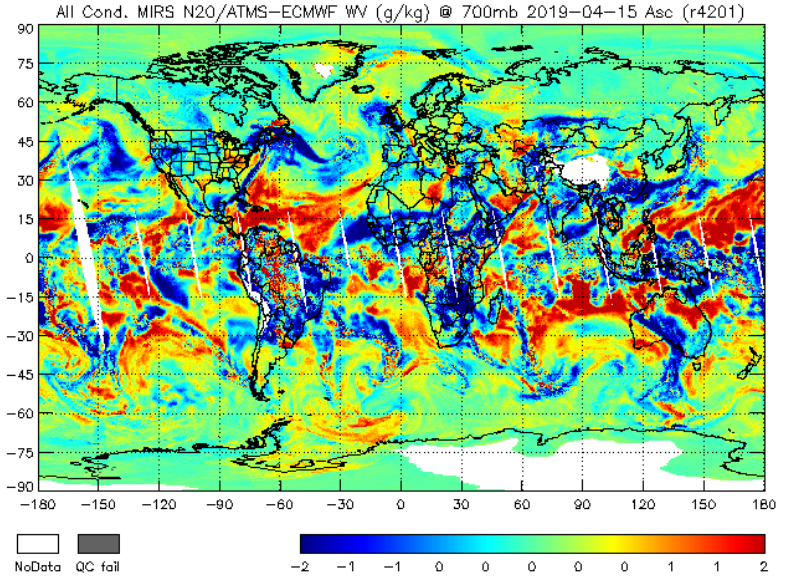
N20 700hPa Water Vapor



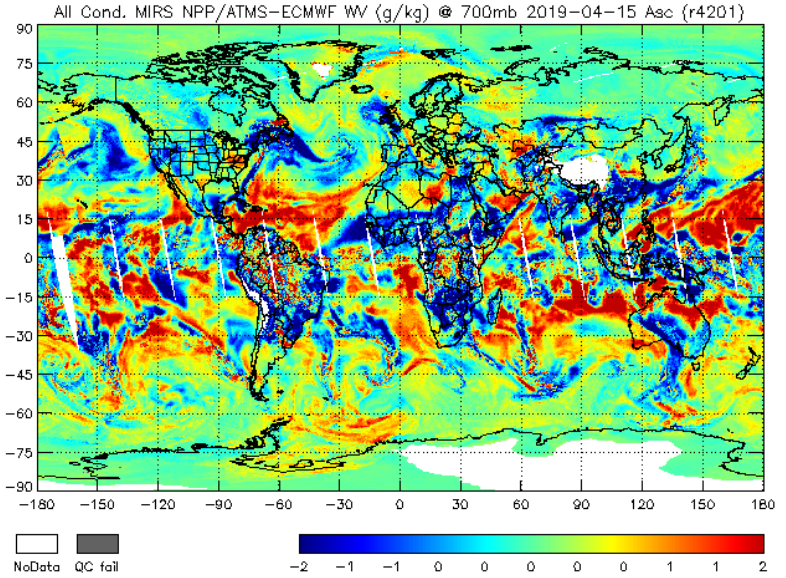
NPP 700hPa Water Vapor



N20-ECMWF 700hPa WV Diff.



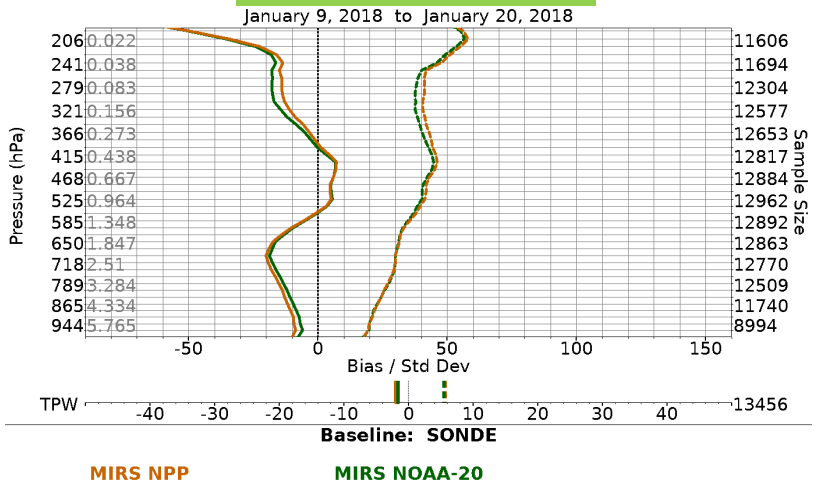
NPP-ECMWF 700hPa WV Diff.



Water Vapor Profile (%) Validation based on sonde data

All conditions and surface types

9-20 Jan 2018



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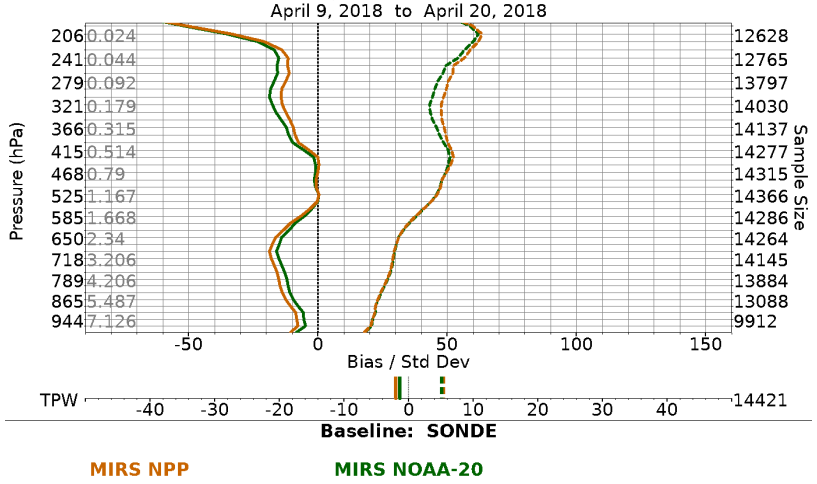

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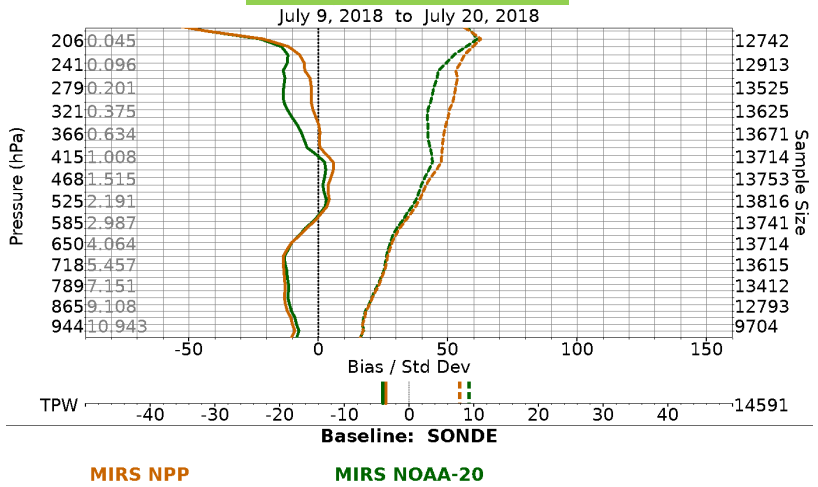

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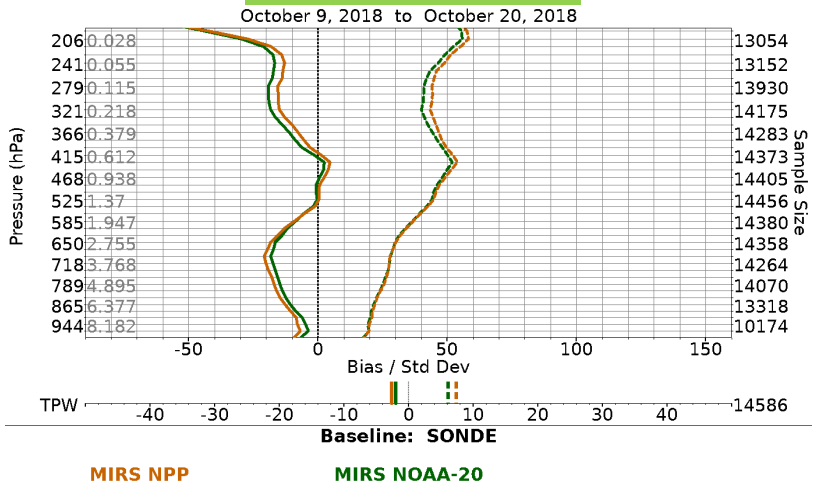

Green thick: N20 bias
Brown thick: NPP bias
Green dotted: N20 std
Brown dotted: NPP std

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MiRS Users

- Many users use MiRS products for operational applications and research.
- Operational users, who have subscriptions on PDA, are:
  - NWS NHC, NESDIS_VIZLAB, CLASS, STAR, NASA GPM, NAVO, FNMOC, 557TH, NASA JPL, GNC-A, NWC, CHINA CMA, NWS AWIPS, NWS NCO, CIRA, NASA SPORT, SSEC/CIMSS, NESDIS operational applications: eTRaP, blended TPW, blended RR, IMS and TC,
  - NHC TC intensity (POC: Galina Chirokova (CIRA))
  - International Arctic Research Center, Alaska (POC: Carl Dierking, NOAA Liaison)
  - NOAA Climate Prediction Center (POC: Pingping Xie)
  - National Ice Center
  - NWS Weather Forecast Offices
- CSPP generates MiRS products for direct broadcasting
- Users also download MiRS from CSPP and generate MiRS products at their own machines

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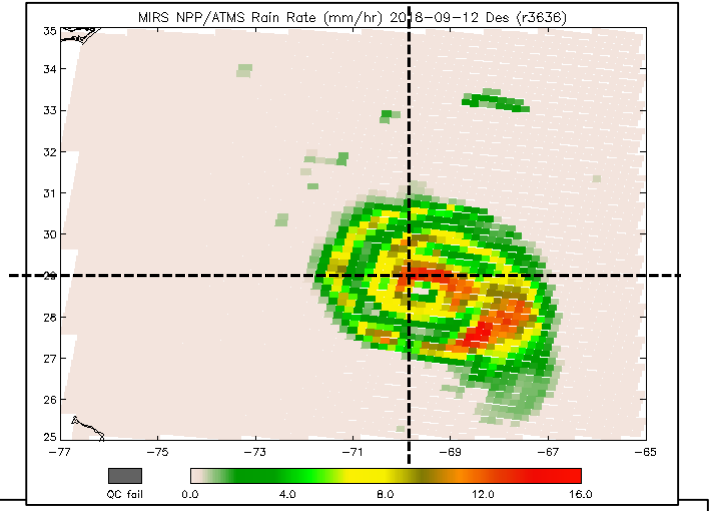
Developing a TC-Specific Version of MiRS

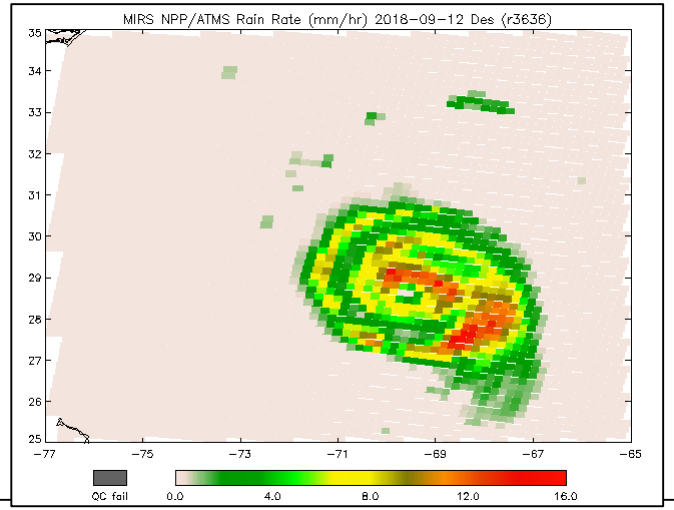
- Motivation:
  - MiRS data currently used in the operational TC Intensity Algorithm (HISA, developed at CIRA). Utilizes T and WV sounding to estimate warm core structure combined with statistical/dynamic model to predict future intensification.
  - Challenge: (1) retrieval of warm core structure complicated 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.
- Development of a MiRS-TC, a version of MiRS optimized for tropical cyclones, adapting several components:
  - Modify use of higher frequency channels in scenes likely to have large amounts of scattering
  - Test varying sources of First Guess/Background constraints (developing updated background mean/covariance based on observed TCs
  - Vary number of EOF basis functions for T and WV profiles:
- Testing ongoing with multiple TC cases
  - Dorian (2019), Florence (2018), Joaquin (2016), Matthew (2015), Edouard (2014)
  - Planned collaboration with CIRA to determine impact on TC intensity estimates

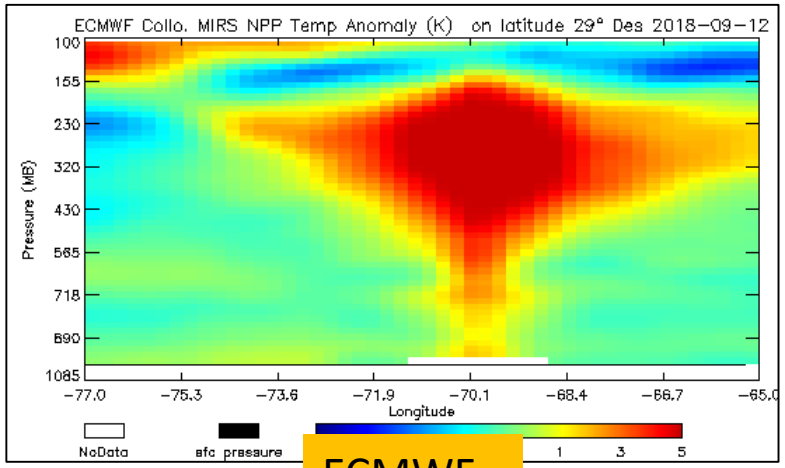
Rain rate and Temperature Anomaly Cross-sections

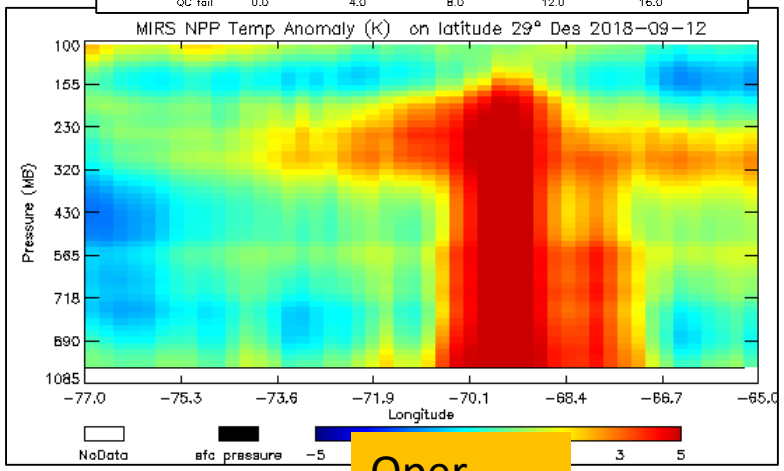
Florence: 2018-09-12

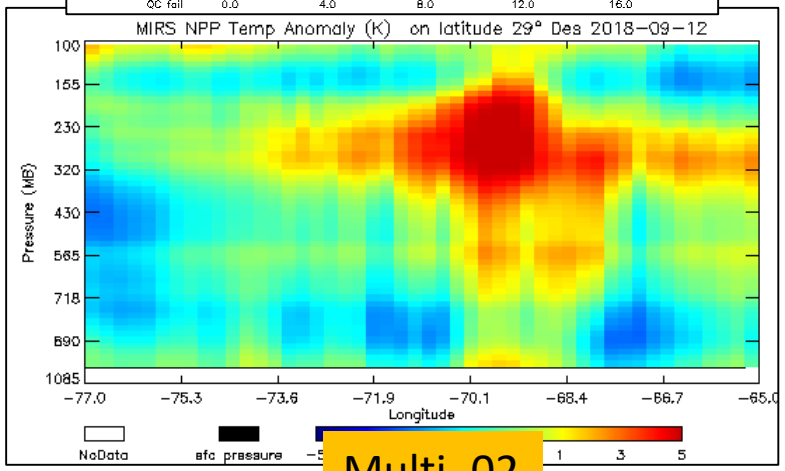
NPP Des







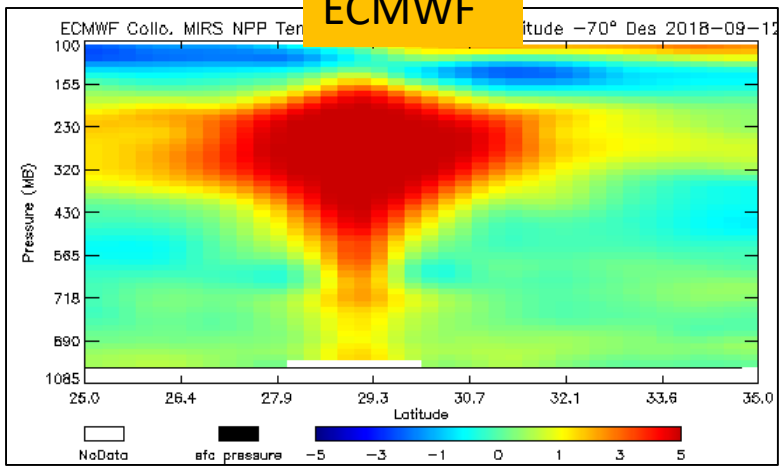


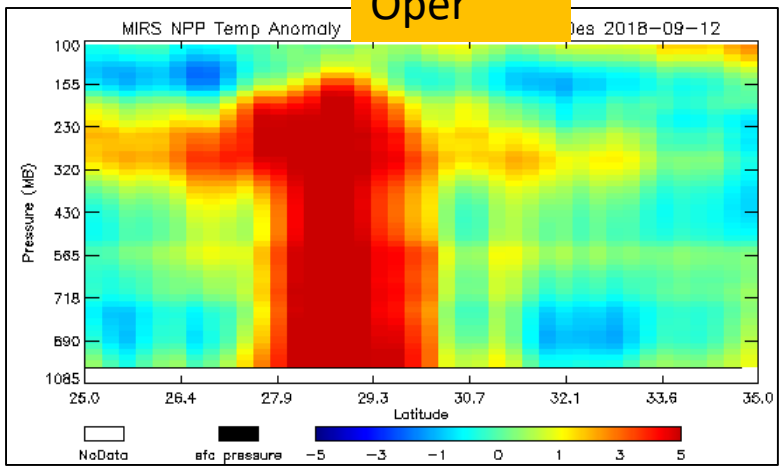


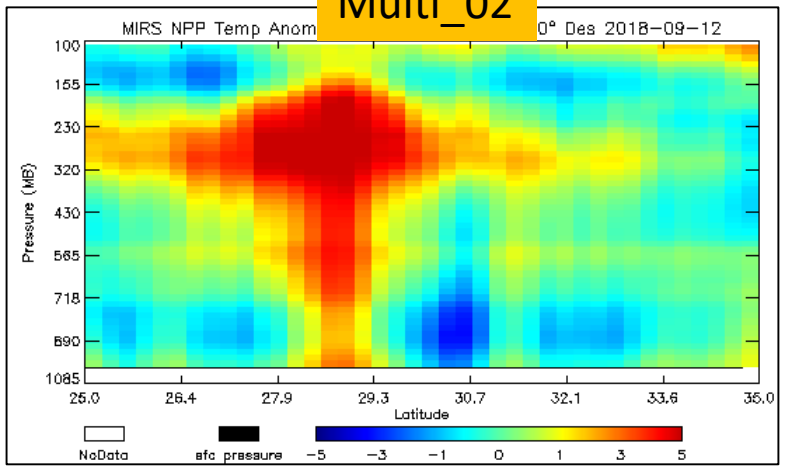
ECMWF

Oper

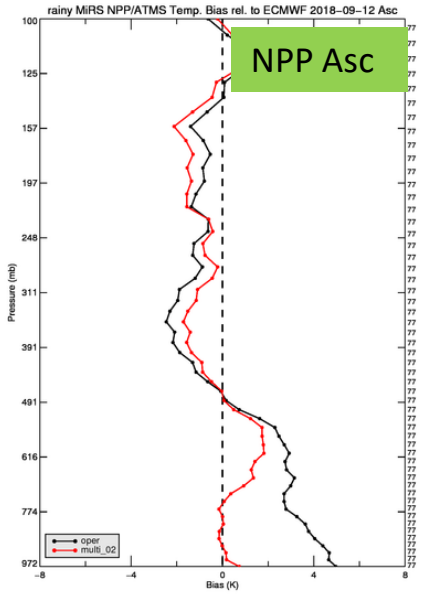
Multi_02

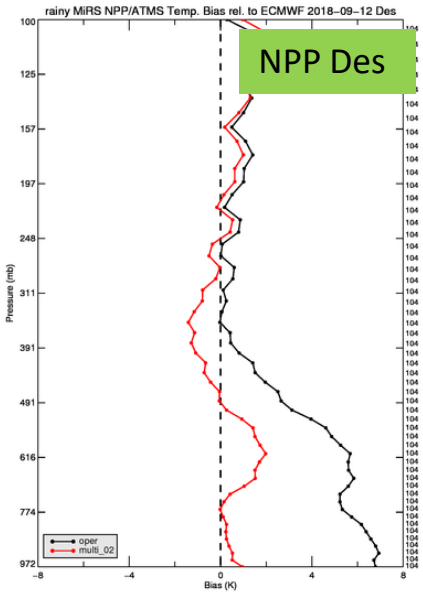




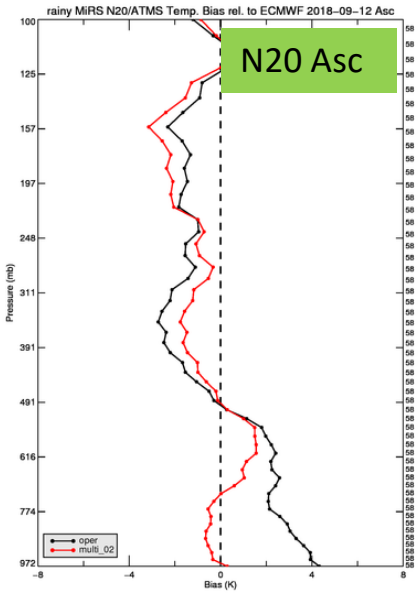


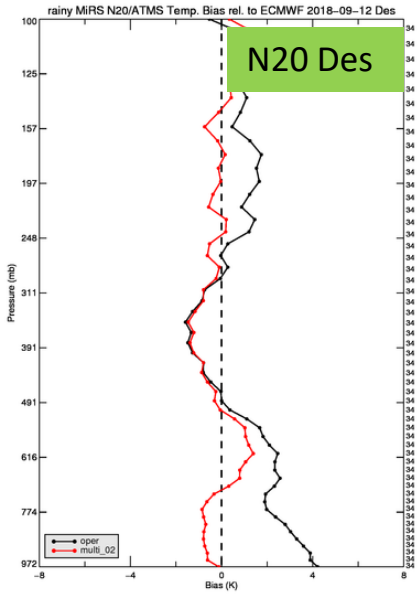
TC Florence and Dorian NPP and N20 Temperature Bias: MiRS-ECMWF (Rainy, dist <= 100km)

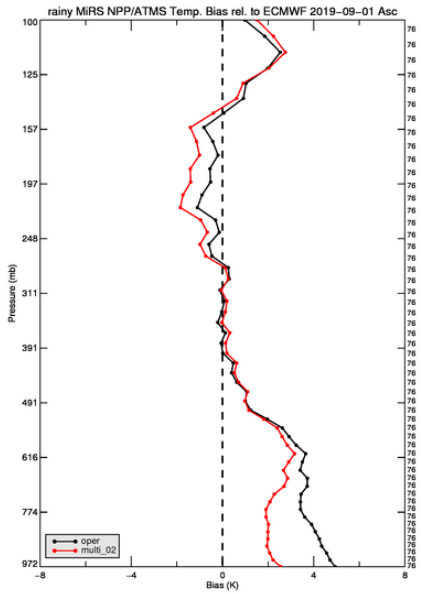


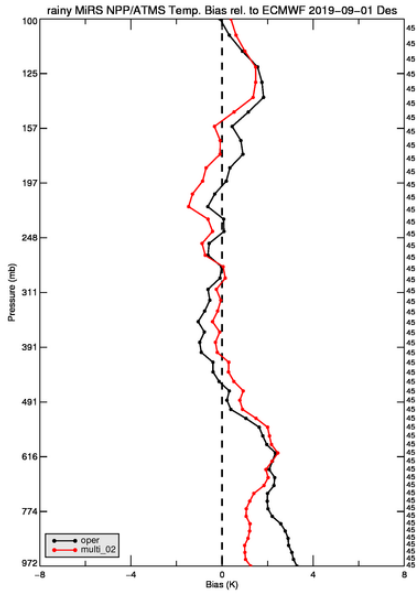


TC Florence

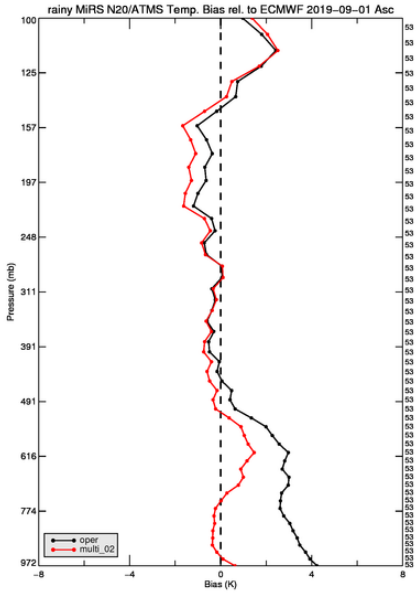


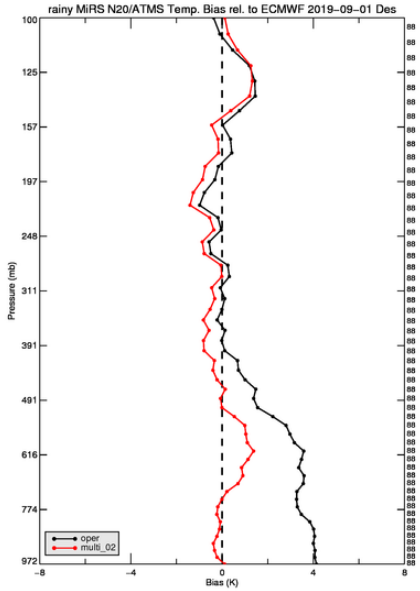






TC Dorian

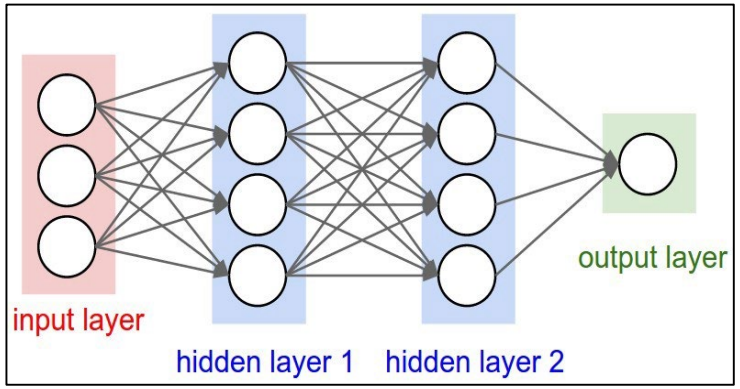


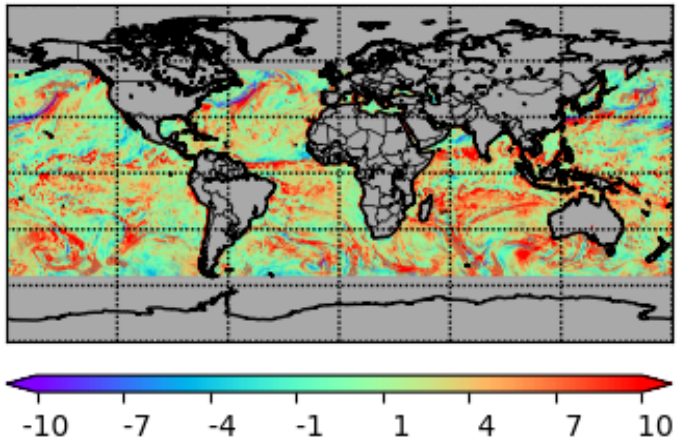


Development of a Neural Network for MiRS Radiometric Bias Correction

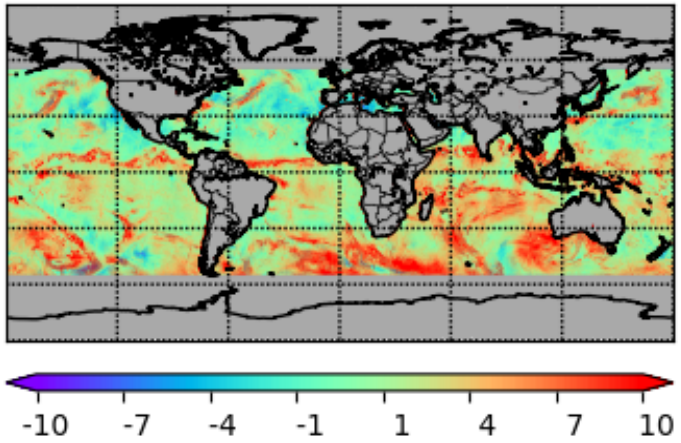
- **Why bias correction?**
  - To remove potential systematic bias between the measurements and the CRTM simulations.
- **Current bias correction (static):**
  - statistics of bias over oceanic and clear scenes. The bias is channel and scan position dependent. Local variations are not accounted for.
- **A machine learning-based bias correction: Neural Network (NN)**
  - NN was trained to learn the bias structure. Inputs are:
    - ➢ Brightness temperature (TB) of the measurements,
    - ➢ Satellite viewing angle
    - ➢ latitude,
    - ➢ other geophysical parameters like cloud liquid water (CLW), total precipitable water (TPW), Tskin, Psfc, emissivity, etc.

Neural Network Schematic

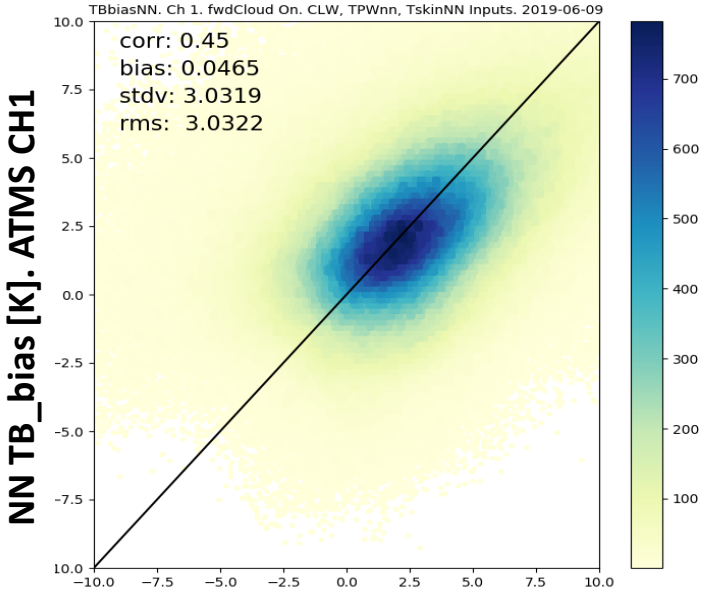




True TB_bias [K] . ATMS CH1

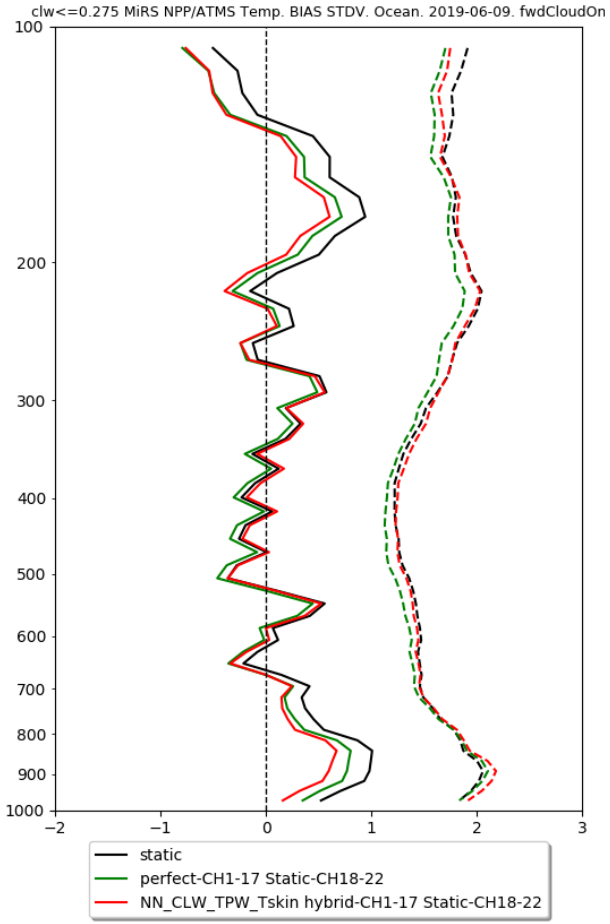


NN TB_bias [K]. ATMS CH1

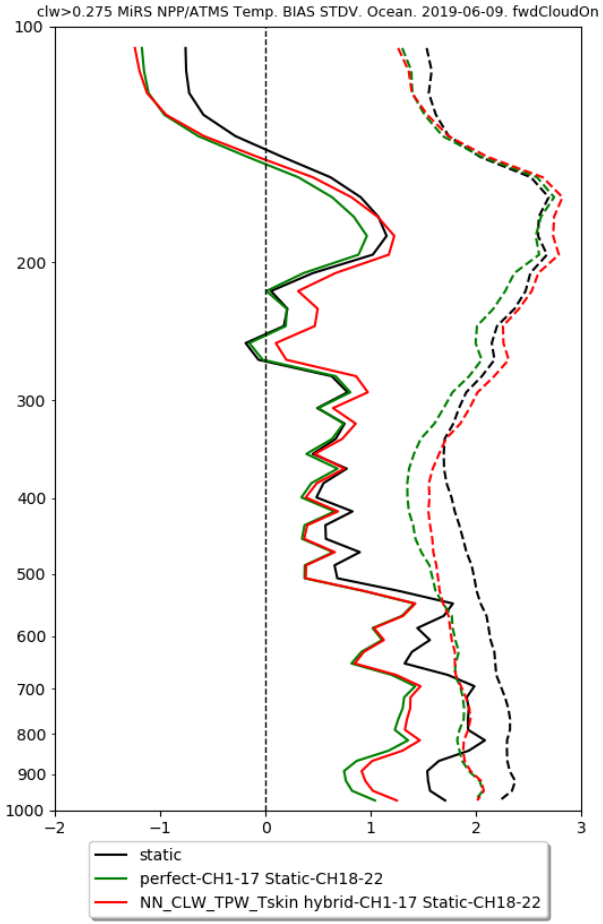


NN TB_bias applied in MiRS

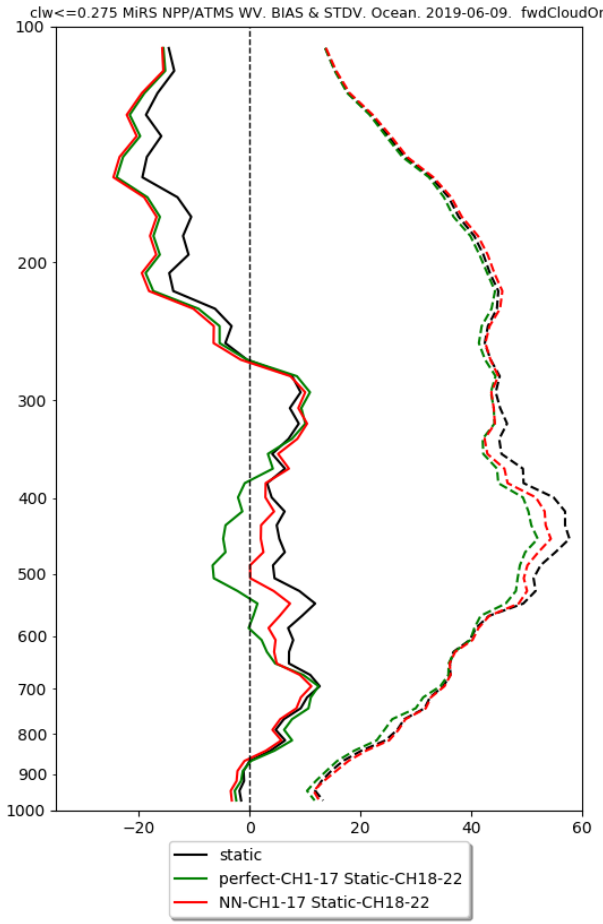
T (CLW<=0.275)



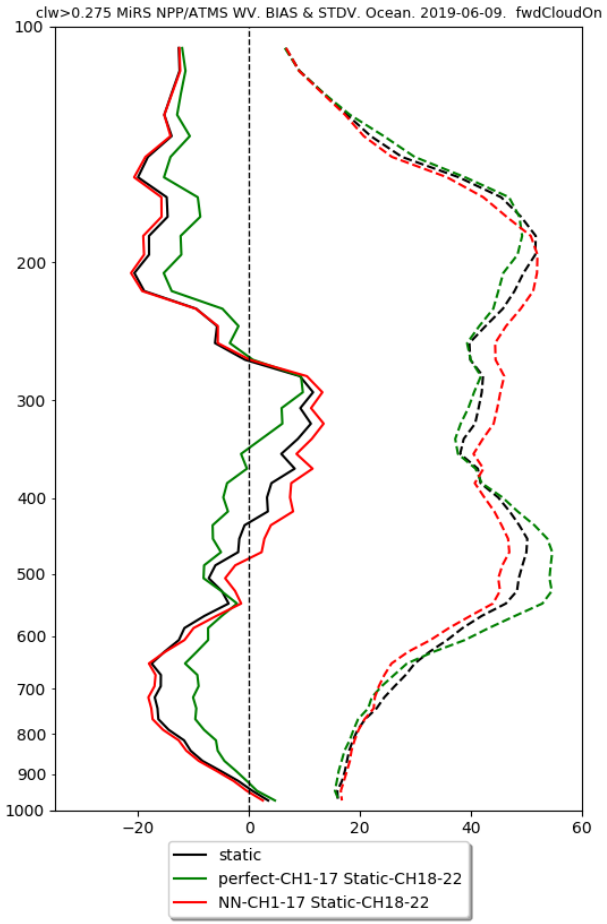
T (CLW>0.275)



WV (CLW<=0.275)



WV (CLW>0.275)



Yan Zhou et al. “Development of a Machine Learning-Based Radiometric Bias Correction for NOAA’s Microwave Integrated Retrieval System (MiRS)” in poster session

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JPSS/MetOp-SG sensor intercomparison (ATMS vs. MWS): Channel Selection

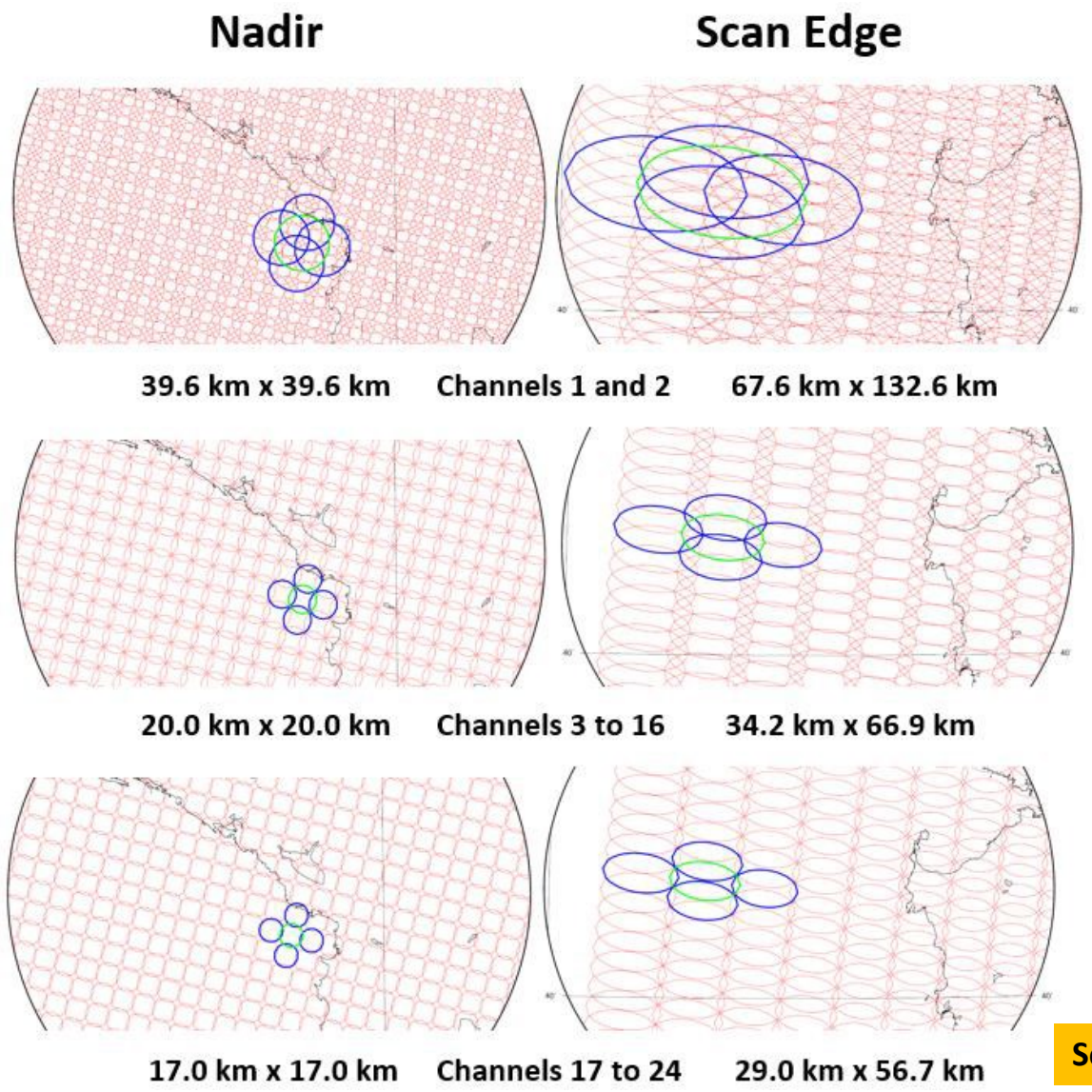
- MWS has similar channel set to ATMS, but with different polarizations for some frequencies.
- Will require updating several MiRS ancillary files (e.g. emissivity background means/covariances, ice/snow emissivity catalogs).
- Additional channel (24) at 229 GHz should help with ice detection and removal of impact on WV channels 19-23.
- Will need updated CRTM coefficients for MWS. UPDATE: coefficients now generated.

Source: MWS L1B ATBD

AMSU/MHS			ATMS			MWS		
Ch.	*GHz*	*Pol.*	*Ch.*	*GHz*	*Pol.*	*Ch.*	*GHz*	*Pol.*
1	23.8	QV	1	23.8	QV	1	23.8	QH
2	31.4	QV	2	31.4	QV	2	31.4	QH
3	50.3	QV	3	50.3	QH	3	50.3	QH
			4	51.76	QH			
4	52.8	QV	5	52.8	QH	4	52.8	QH
						5	53.246 ± 0.08	QH
5	53.595±0.115	QH	6	53.596±0.115	QH	6	53.596±0.115	QH
						7	53.948 ± 0.081	QH
6	54.4	QH	7	54.4	QH	8	54.4	QH
7	54.94	QV	8	54.94	QH	9	54.94	QH
8	55.50	QH	9	55.50	QH	10	55.50	QH
9	57.290344	QH	10	57.290344	QH	11	57.290344	QH
10	57.290344±0.217	QH	11	57.290344±0.217	QH	12	57.290344±0.21	QH
11	57.290344 ±0.3222±0.048	QH	12	57.290344 ±0.3222±0.048	QH	13	57.290344	QH
12	57.290344±0.3222±0.022	QH	13	57.290344±0.3222±0.022	QH	14	57.290344±0.32	QH
13	57.290344±0.3222±0.010	QH	14	57.290344±0.3222±0.010	QH	15	57.290344±0.32	QH
14	57.290344±0.3222±0.0045	QH	15	57.290344±0.3222±0.0045	QH	16	57.290344±0.32	QH
15	89.0	QV						
16	89.0	QV	16	88.2	QV	17	89.0	QV
17	157.0	QV	17	165.5	QH	18	164-167	QH
18	183.311±1.0	QH	22	183.311±1.0	QH	23	183.311±1.0	QV
			21	183.31 ± 1.8	QH	22	183.311±1.8	QV
19	183.311±3.0	QH	20	183.311±3.0	QH	21	183.311±3.0	QV
			19	183.311±4.5	QH	20	183.311±4.5	QV
20	191.31	QV	18	183.311±7.0	QH	19	183.311±7.0	QV
						24	229	QV

Matched	Pol. is Different	Unique Passband	Pol. is Different and Unique Passband	New channel

JPSS/MetOp-SG sensor intercomparison (ATMS vs. MWS): Scan Geometry



- Both MWS and ATMS are cross-track scanning
- Scan positions: MWS=95, ATMS=96
- Scan angle range: MWS = ±49.31, ATMS = ±52.73
- MWS channels 1 and 2 FOVs are significantly smaller than ATMS; this may preclude the need for resampling/footprint matching

Channels (MWS)	Nadir resolution (km)		Edge of scan resolution (km)	
	MWS	ATMS	MWS	ATMS
1-2	39.6 x 39.6	74.8 x 74.8	67.6 x132.6	141.8 x 323.1
3-16	20.0 x 20.0	31.6 x 31.6	34.2 x 66.9	60.0 x 136.7
17-24	17.0 x 17.0	15.8 x 15.8	29.0 x 56.7	30.0 x 68.4

Source: MWS L1B ATBD

Path Forward

- Improvements implemented
  - Snowfall rate integration for N20
  - Hydrometeors (CLW over land for light rain detection)
  - Snow cover/amount (vegetation correction)
  - Updated sea ice climatology mask (finer temporal/spatial resolution) ➔ Great Lakes ice detection
- Planned further improvements
  - Air mass-dependent bias corrections (machine learning)
  - Rainy condition sounding (update a priori constraints)
  - Experimenting with MiRS version adapted for tropical cyclones (MiRS-TC)
  - Hydrometeors: precharacterization of precip type, improvements to CRTM i.e. scattering, particle size/shape distribution in CRTM)
  - Applications/user feedback
- Planned/ongoing activities
  - N20/ATMS validation: Continued daily assessments (as posted to MiRS website) including comparisons with radiosondes, and other in situ data (e.g. for rain rate and land surface temperature)
  - Reprocessing of NPP and N20 mission data (Spring/Summer 2020)
  - Plan for JPSS-2 (2020-2021), and EPS-SG (2019-2022)

Yan Zhou et al. “Development of a Machine Learning-Based Radiometric Bias Correction for NOAA’s Microwave Integrated Retrieval System (MiRS)” in poster session

3-D Visualization with NOAA-20/ATMS: Super Typhoon Yutu, 2018-10-24