Validated Maturity Science Review For Microwave Integrated Retrieval System (MiRS):

Land Surface Emissivity, Land Surface Temperature, Cloud Liquid Water, Sea Ice Concentration, Snow Water Equivalent and Snow Cover

Presented by

Chris Grassotti, Junye Chen, Shuyan Liu, and Quanhua Liu

Date: 04/20/2017

Outline

- Algorithm Cal/Val Team Members
- Product Requirements
- Evaluation of algorithm performance to specification requirements
  - Evaluation of the effect of required algorithm inputs
  - Quality flag analysis/validation
  - Error Budget
- Identification of Processing Environment
- Users & User Feedback
- Documentation (Science Maturity Check List)
- Conclusion
- Path Forward

MiRS Cal/Val Team

Algorithm Cal/Val Team Members

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

Evaluation of algorithm performance to specification requirements

- MiRS initial operational processing at NDE was v9.2 in June 2013. Updated DAP v11.1 implemented in operations in October 2015. All validation results shown here reflect v11.1 (v11.2 for all other satellites delivered to OSPO I in August 2016)
  - Algorithm Improvements in v11.1: updated CRTM (v2.1.1), dynamic climatology background for T and WV (variable with location, season, time of day), plus other changes.
- Cal/Val Activities for evaluating algorithm performance:
  - Daily comparisons to both ECMWF and GDAS: global maps and statistics. Results automatically posted to MiRS website each day (T, WV, TPW, Tskin, LSE).
  - Land Surface Emissivity: Daily comparisons with analytic emissivities derived from ECMWF/GDAS+CRTM.
  - Land Surface Temperature: Daily comparisons ECMWF and GDAS analyses. (Collocation with SURFRAD for 3-month period in 2012.)
  - CLW: Regular comparisons with GPROF GMI CLW globally. Qualitative comparisons with ECMWF CLW.
  - Sea Ice Concentration: Regular comparisons with NASA SSMIS (F17/F18) NRT 25-km product (NASA Team Algorithm), supplemented with 4-km NIC/IMS analyses.
  - SWE/SC: Regular comparisons with JAXA Algorithm (AMSR2) 25-km product, supplemented with NIC/IMS analyses.
  - External Users: provide feedback, identify issues, algorithm team has issued several bug fixes/patches in past 3 years.

- Required Algorithm Inputs
  - Primary Sensor Data: MiRS requires (1) TDRs (for retrieval), (2) SDRs (for NEDTs), and (3) geolocation
  - Ancillary Data: No real-time ancillary data required.
  - Upstream algorithms: None
  - Static tables/files needed for: CRTM sensor coefficients, snow/ice retrieval, radiometric bias corrections, EOFs, background mean/covariance
- Evaluation of the effect of required algorithm inputs
  - None needed since only dynamic inputs are the TDR/SDR/GEO data. All other required data is static.
  - MiRS tools in STAR available to evaluate as needed to rapidly assess impacts of turning select channels on/off (e.g. if sensor shows signs of degradation, drift). This has been done for other operational satellites/sensors that MIRS runs on. To date, not required for ATMS.

Quality flag analysis/validation

- MiRS Quality Flags
  - Top level QC: 0=good, 1="some event", 2=bad
  - Lower level QC: bitwise packed for multiple conditions (e.g. precipitation, RH saturation, T inversion, etc.)
  - Normally sufficient to utilize top level QC flag, along with geophysical situation for filtering (i.e. for valid T and WV in non-rainy conditions select all points where QC< 2 .and. RR=0)
- Quality flag analysis/validation
  - Daily maps indicate extremely low rate of QC=2 (bad), < 1%, normally caused by high chi-square (non-convergence), or extremely heavy precipitation
  - See maps and time series later in presentation

MiRS QC Flag Information

• Numerous checks made at various steps in retrieval process: TB values, chi-square, rain intensity, physical ranges, inversions, supersaturation, etc.

• Stored in 4-byte Integer array len=4.

• Individual QC checks are stored bitwise in QC(2-4). QC(1) contains top level summary QC: 0=good, 1=probably good, but some event triggered (e.g. rain, do not use T and WV), use with more caution, 2=bad

	Bit 0	Bit 1	Bit 2	Bit 3	Bit 4	Bit 5	Bit 6	Bit 7	Bit 8	Bit 9	Bit 10	Bit 11	Bit 12	Bit 13	Bit 14	Bit 15
QC (1)	0 = GOOD, 1= SOME PROBLEM, 2=BAD															
QC (2)	CONVERGENCE I (ChiSq >= 10)	CONVERGENCE II (5<=ChiSq <10)	PRECIPITATION (YES/NO)	TYPE OF PRECIPITATION			OUT-OF-BOUND FLAGS								MEAS. QC	
				LIGHT	MEDIUM	HEAVY	TSKIN	TEMP	Q	EMISS	TPW	ICLW	RWP	GWP		
QC (3)	TEMPERATURE LAPSE RATE	TEMPERATURE INVERSION (Range:Psfc-200mb to Psfc)	SUPERSATURATION (RH > 99.9 %)	SUPERSATURATION 3 CONTIGUOUS LAYERS (RH > 99.9 %)	HUMIDITY INVERSION	CLOUD	VALIDITY FLAGS									
							TSKIN	TEMP	Q	EMISS	TPW	ICLW	RWP	GWP		
QC (4)	ALLOCATED FOR EACH ELEMENT OF MEASUREMENT QC												OCEAN	LAND		Calibration

Requirements and Validation Results: Land Surface Emissivity

Attribute	Threshold	Validated
Geographic coverage	Global land(non-frozen surfaces)	See table/figs
Vertical Coverage	Surface	
Horizontal Cell Size	15 km at nadir	
Mapping Uncertainty	N/A (reflects SDR characteristics)	
Measurement Range	0.00001 – 1.0	
Measurement Accuracy	See table	
Measurement Precision	See table	

Meets threshold

Meets objective

- Daily, Global Collocations with Analytic emissivity
- Analytic emissivity = See below
- Requirements from JPSS-REQ-1004
- Maturity Level: Validated, Stage 3

"Analytic" Emissivity Calculation

- Assume Simplified RT equation:

$$Tb(f) = [\epsilon(f) * B(Tskin) * \tau(f)] + T\uparrow(f) + [T\downarrow(f) * (1 - \varepsilon(f)) * \tau(f)]$$

- Analytic emissivity:

$$\epsilon(f) = \left[\left(\frac{Tb(f) - T\uparrow(f)}{\tau(f)}\right) - T\downarrow(f)\right] / (B(Tskin) - T\downarrow(f))$$

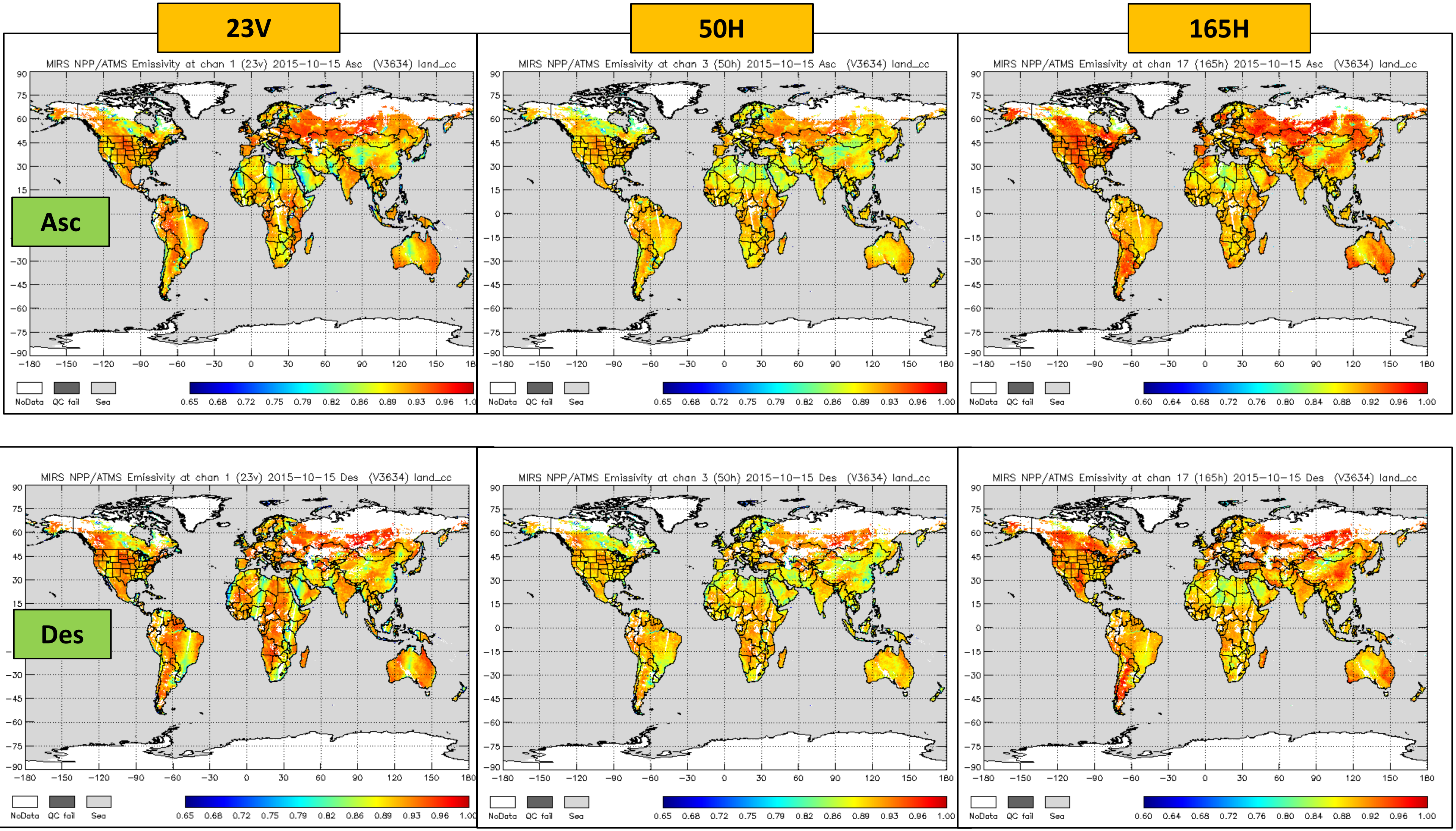
- Tb= measured radiance (corrected Tb), at frequency f
- Tskin=LST
- ε = emissivity
- τ = total transmittance (top of atmosphere)
- $T\uparrow$ = upwelling radiance
- $T\downarrow$ = downwelling radiance
- $Tskin, T(p), q(p)$ from ECMWF; B the Planck function
- $\tau, T\uparrow, T\downarrow$ from CRTM using ECMWF inputs

Note: R-J approximation is used here and will be changed by using radiance.

Product	Sfc	Condition	Freq (GHz)	Bias (%) (Accuracy)			StDv (%) (Precision)		
				MiRS	Thresh	Obj	MiRS	Thresh	Obj
Emissivity	Land	Clear+ Cloudy	23.8	**[0.000 - 0.004]**	**0.020**	**0.013**	**[0.020 - 0.023]**	**0.030**	**0.020**
			50.3	**[0.001 - 0.006]**	**0.015**	**0.010**	**[0.027 - 0.030]**	**0.030**	**0.020**
			165.5	**[0.001 - 0.007]**	**0.015**	**0.010**	**[0.030 - 0.038]**	**0.040**	**0.030**

Validation Results: Land Surface Emssivity

2015-10-15

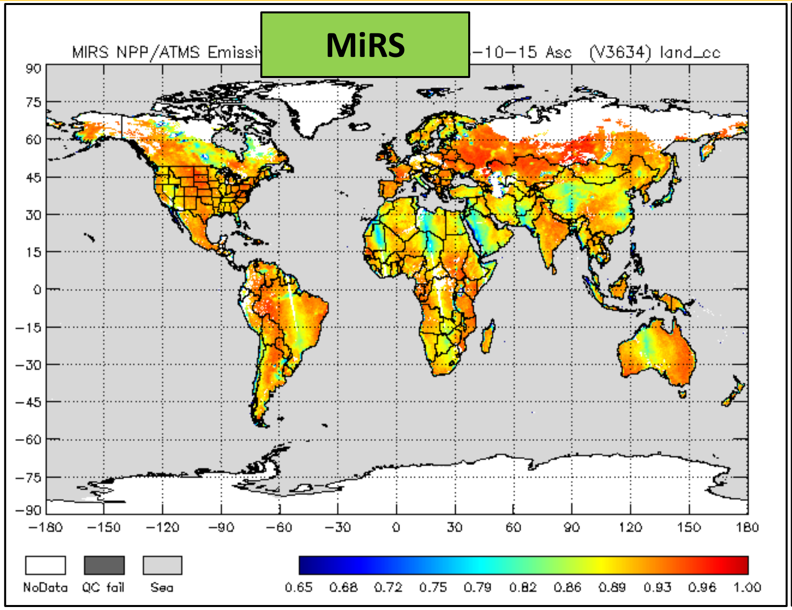


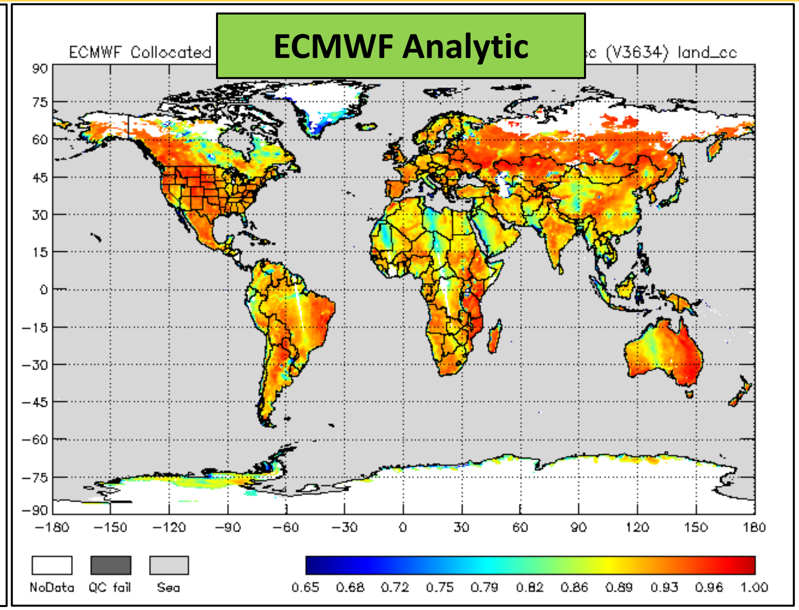
Validation Results: Land Surface Emssivity

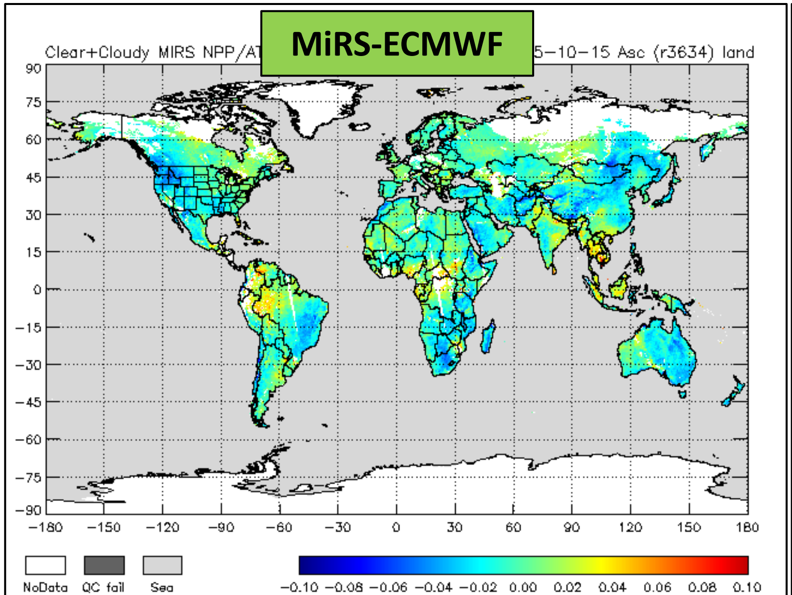
2015-10-15

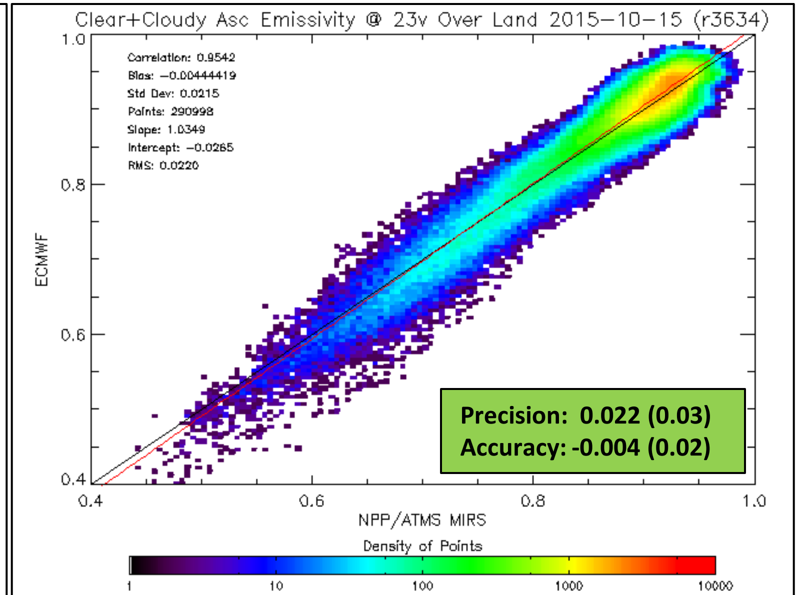
23V

Asc









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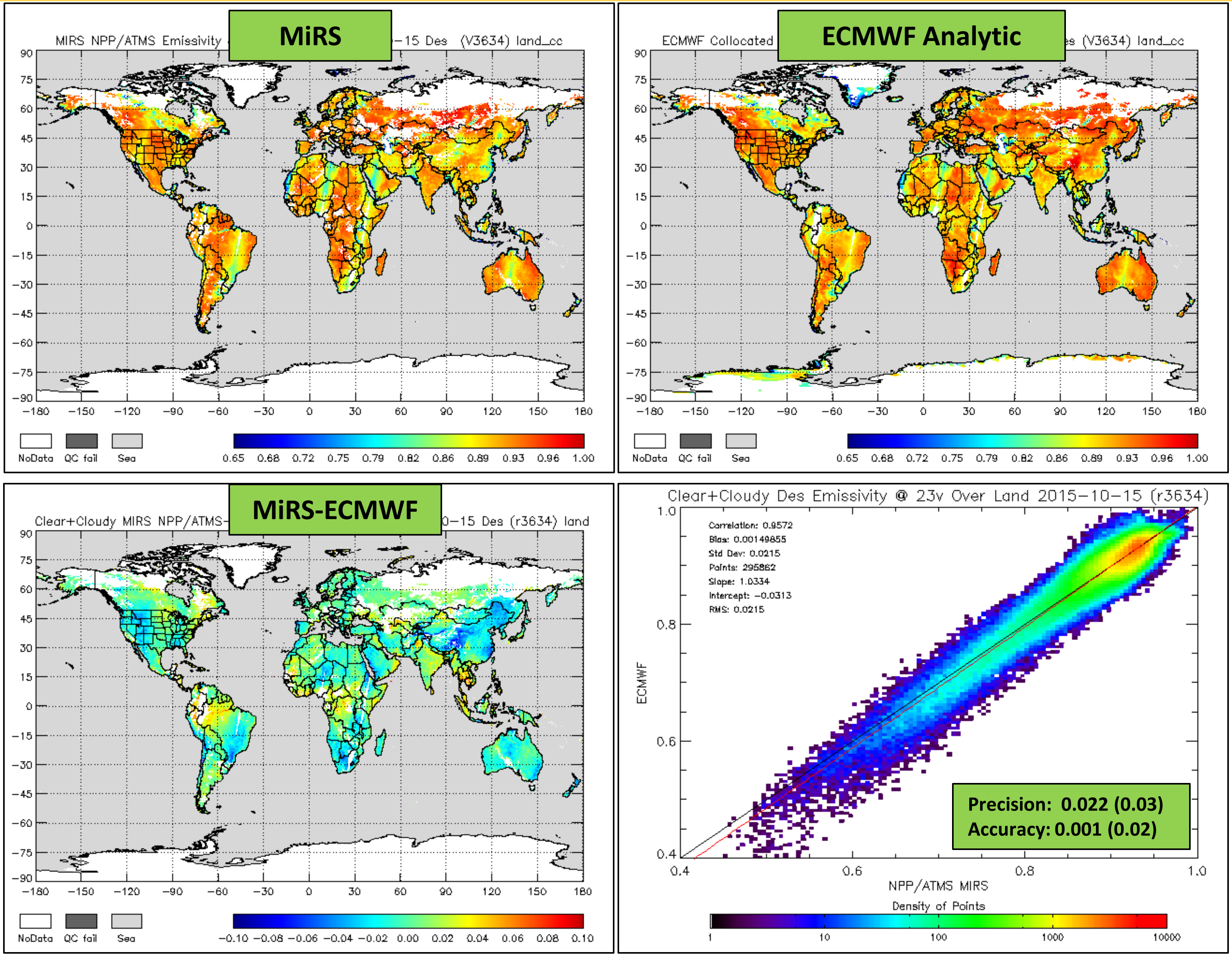


2015-10-15

23V

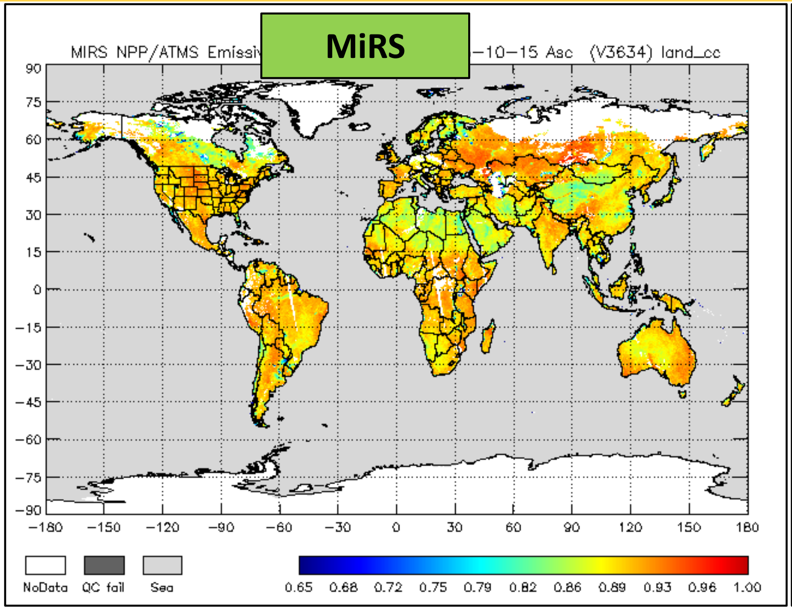
Des

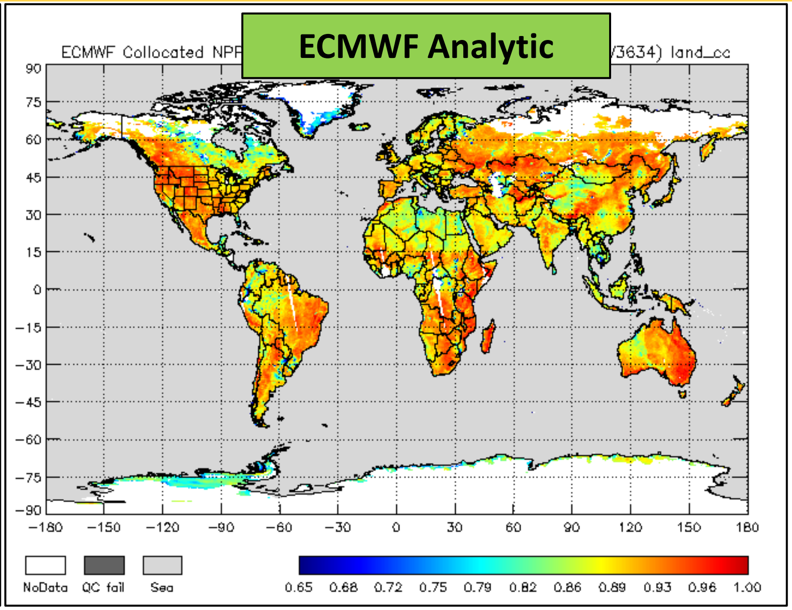
Validation Results: Land Surface Emssivity

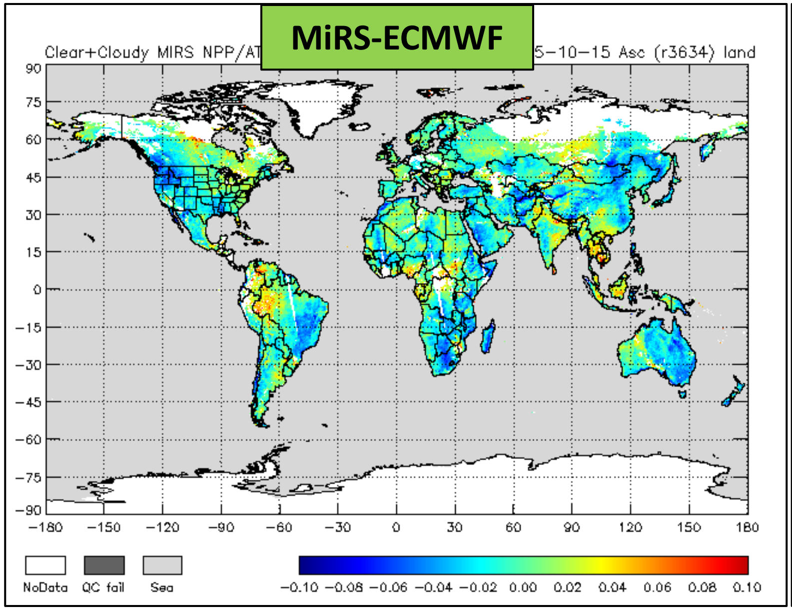
2015-10-15

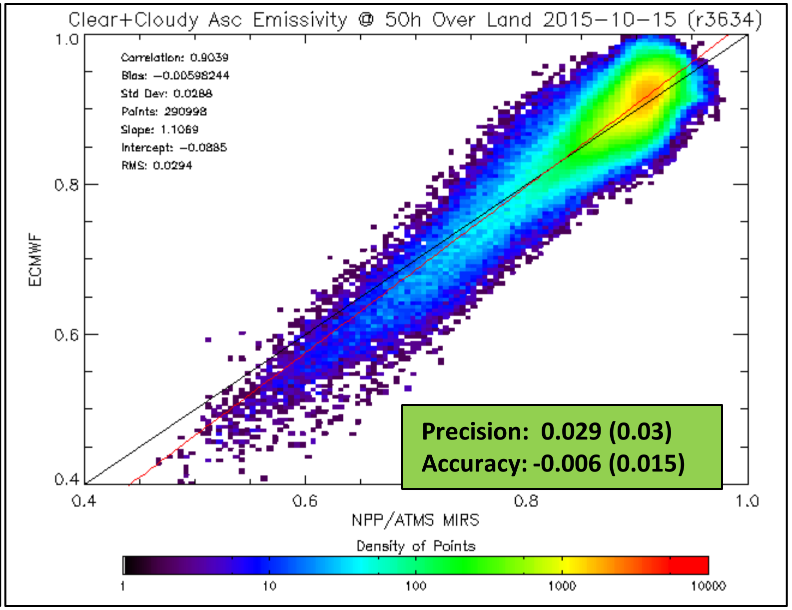
50H

Asc







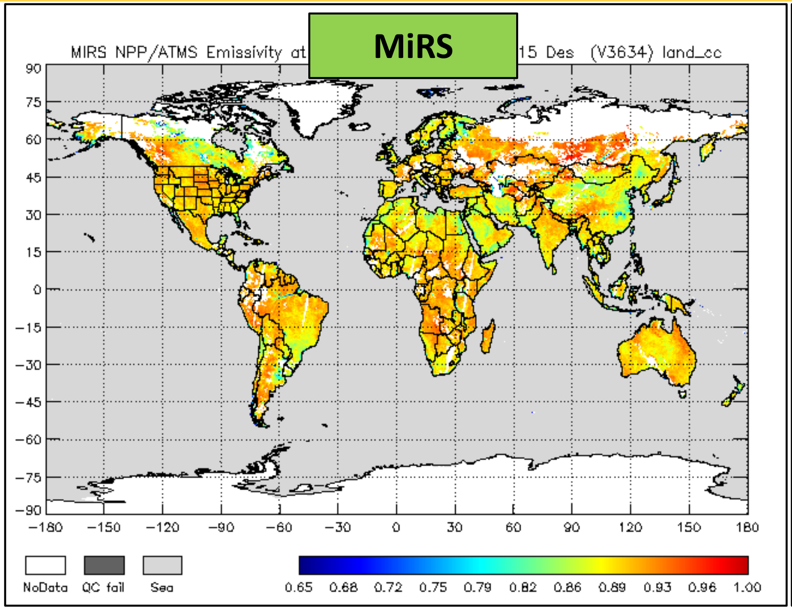


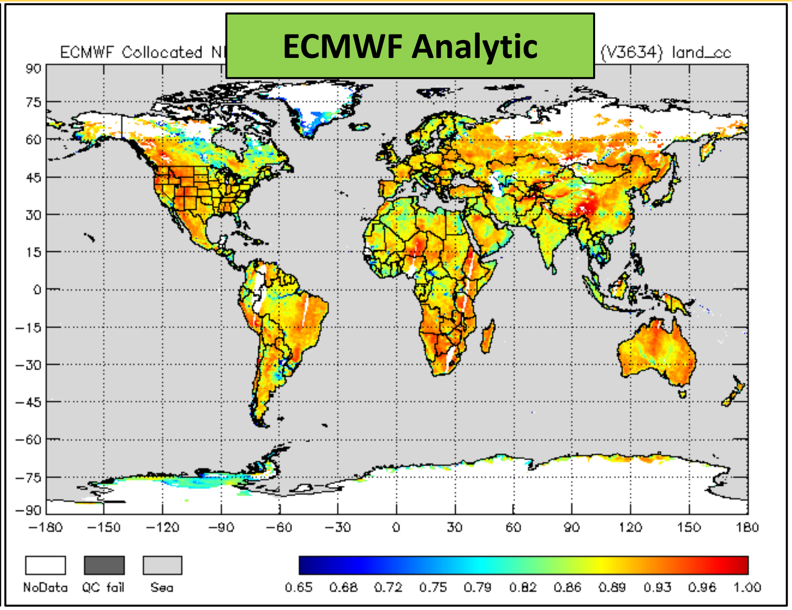
Validation Results: Land Surface Emssivity

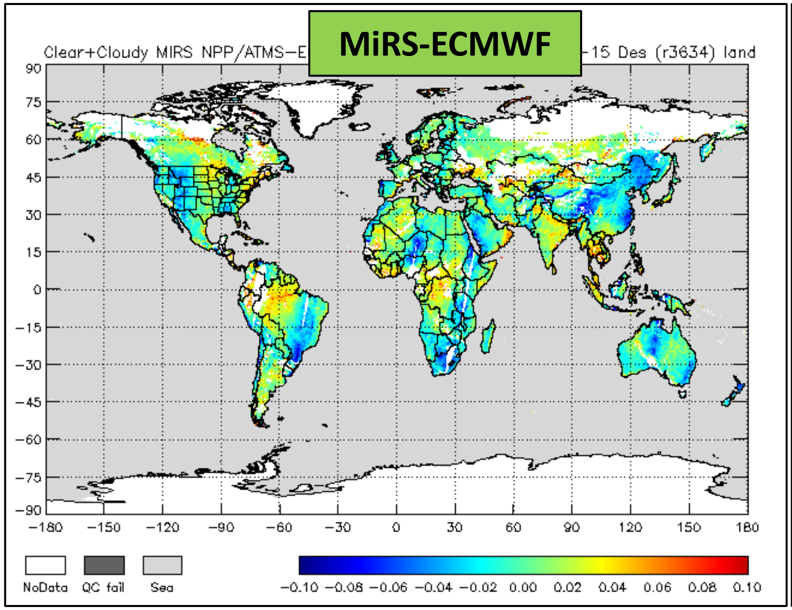
2015-10-15

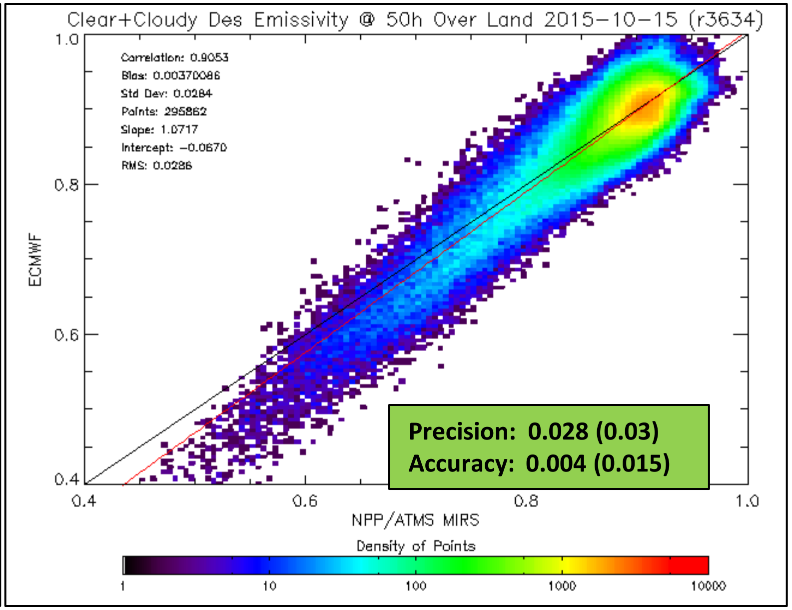
50H

Des









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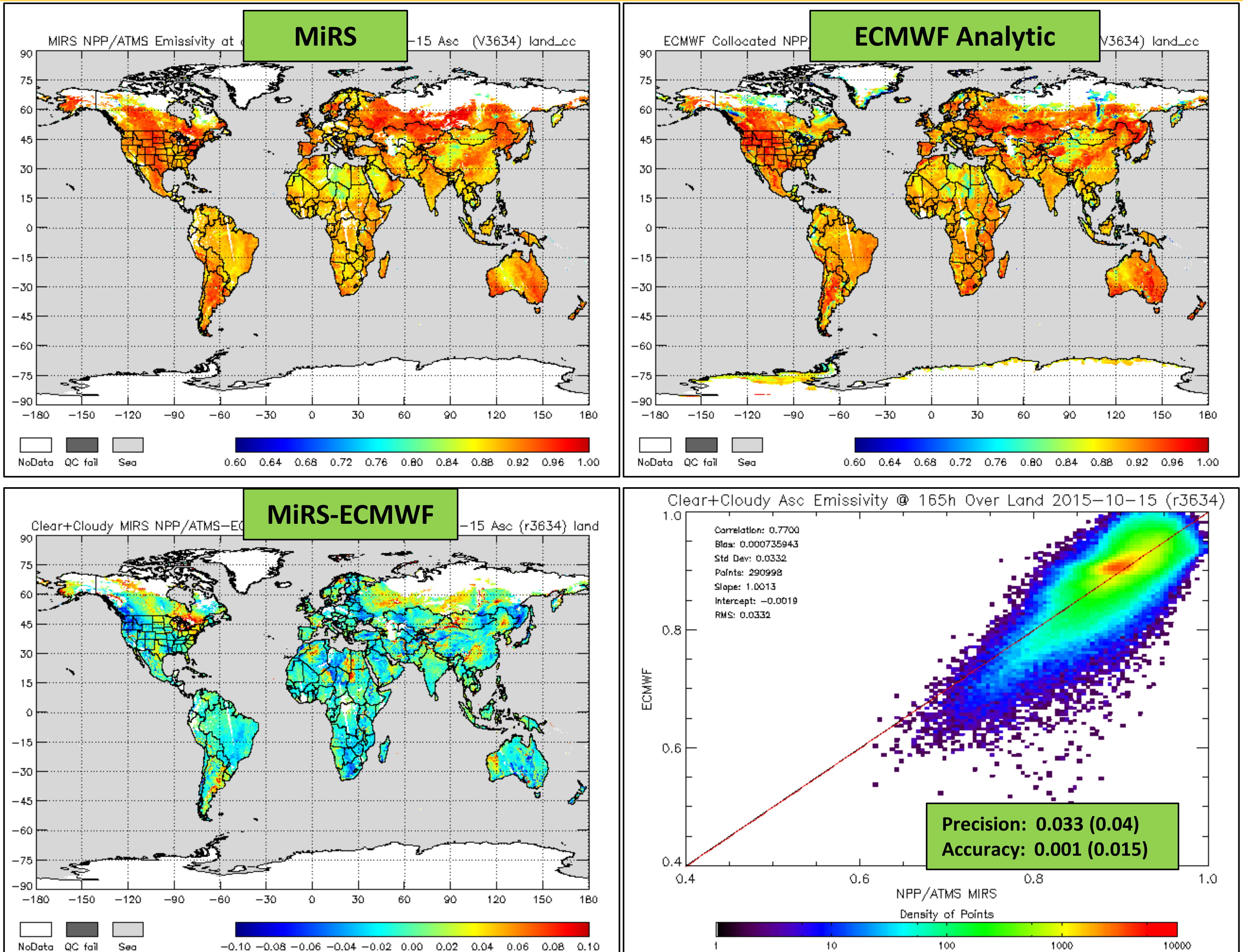


2015-10-15

165H

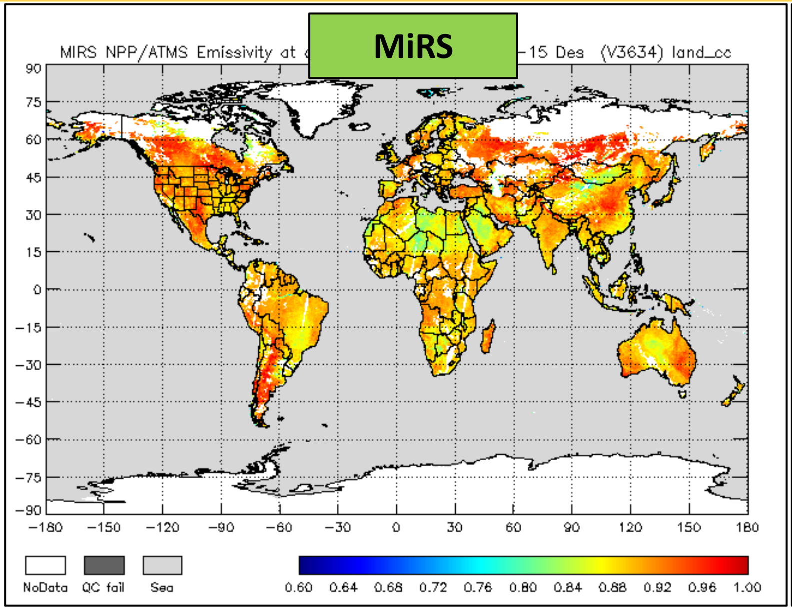
Asc

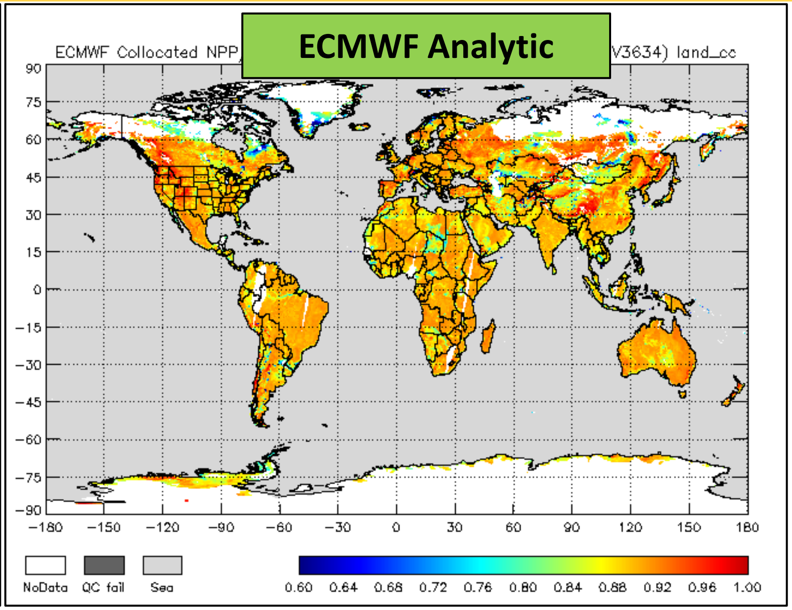
Validation Results: Land Surface Emssivity

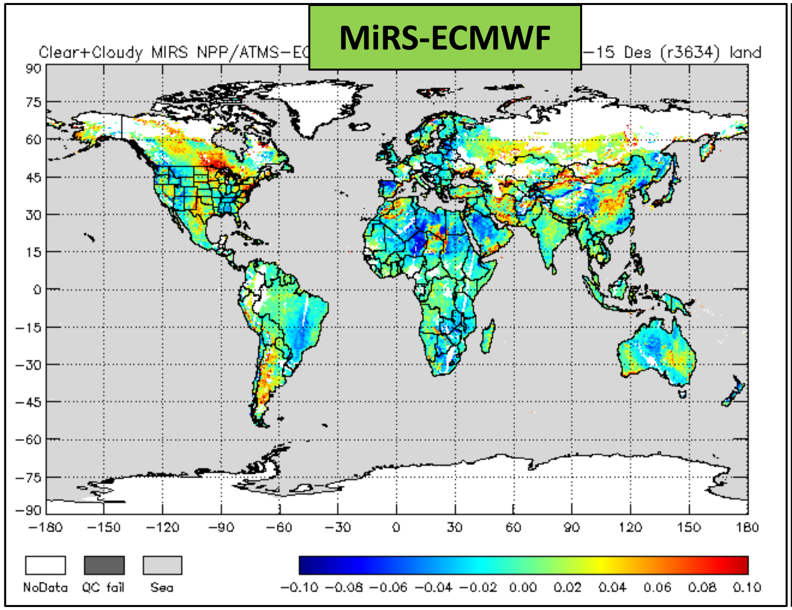
2015-10-15

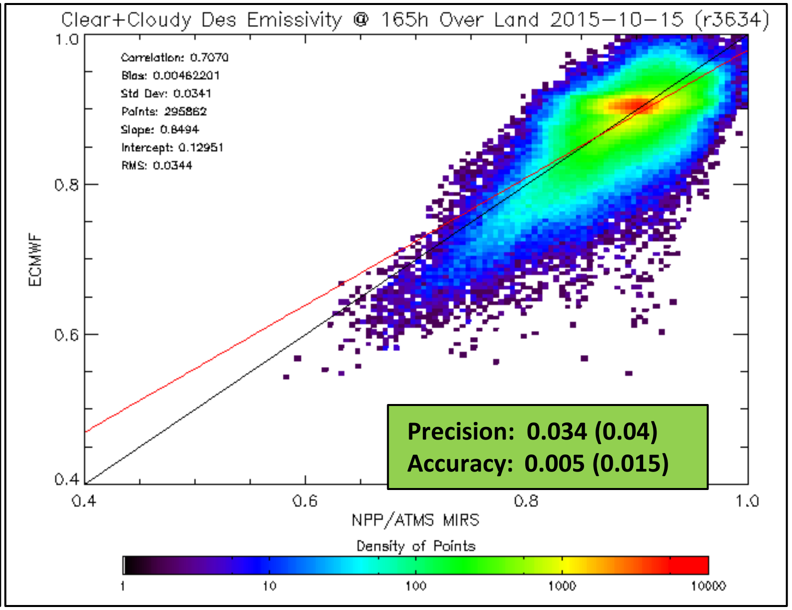
165H

Des





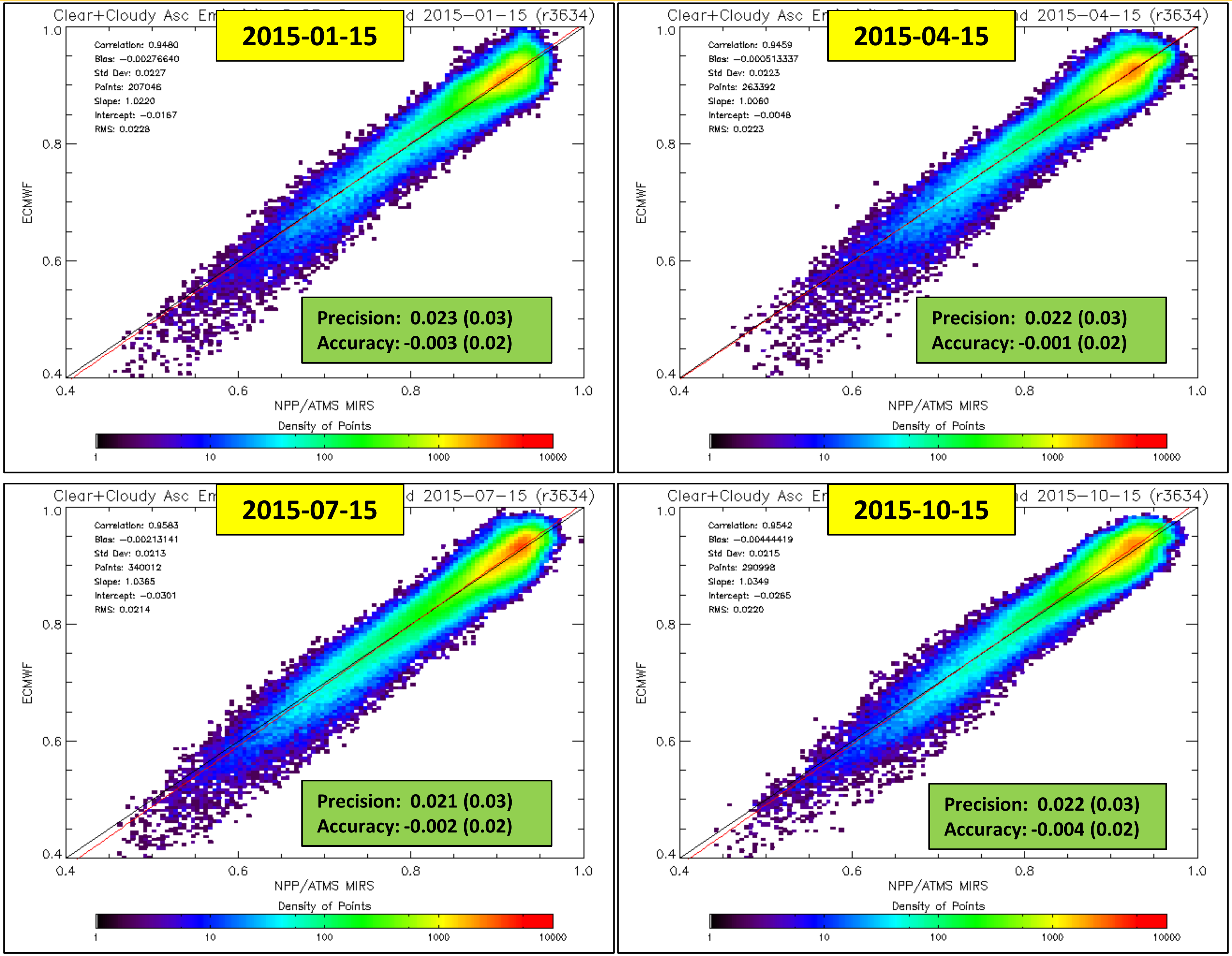




Validation Results: Land Surface Emssivity

23V

Asc



Validation Results: Land Surface Emssivity

23V

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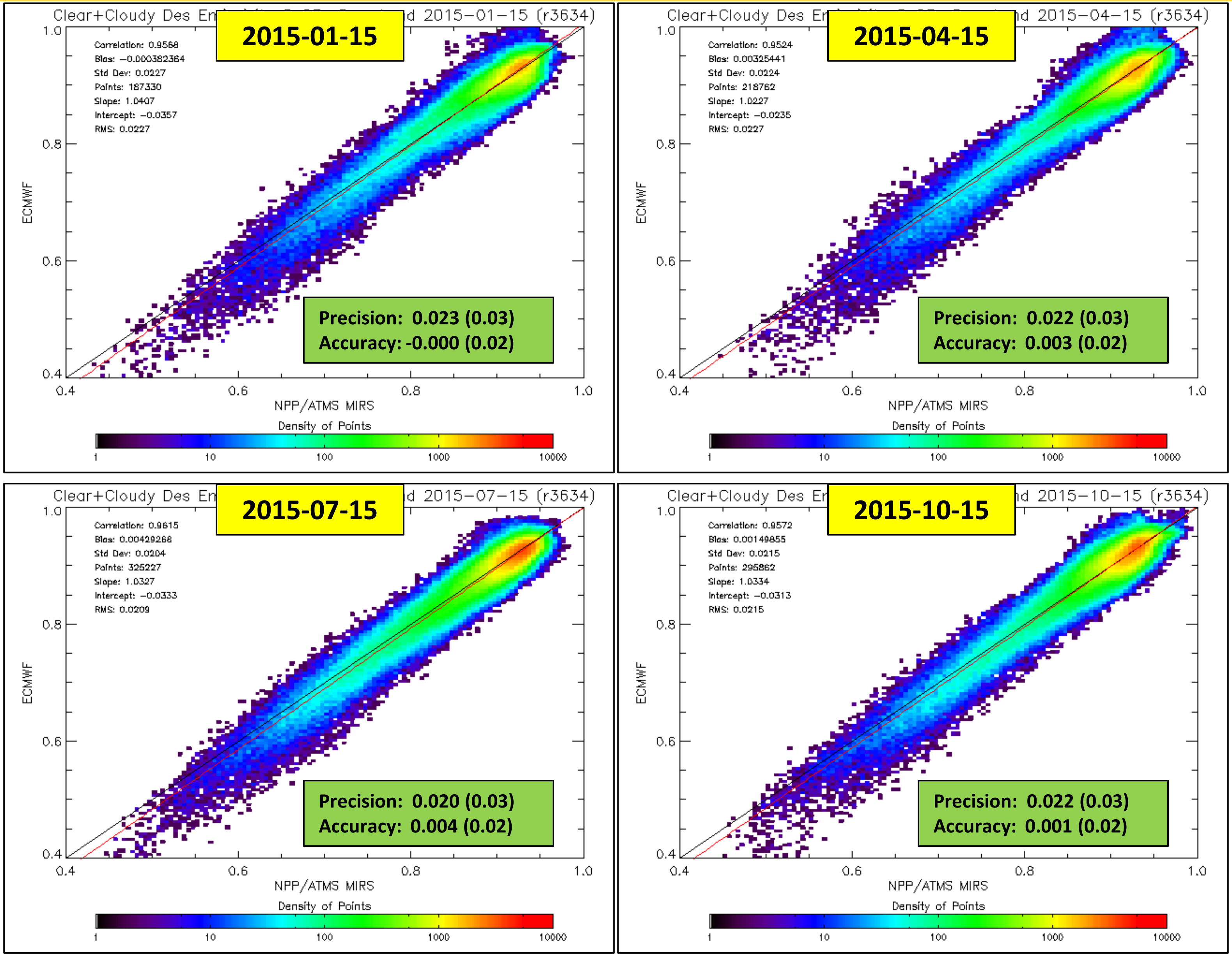

Validation Results: Land Surface Emssivity

50H

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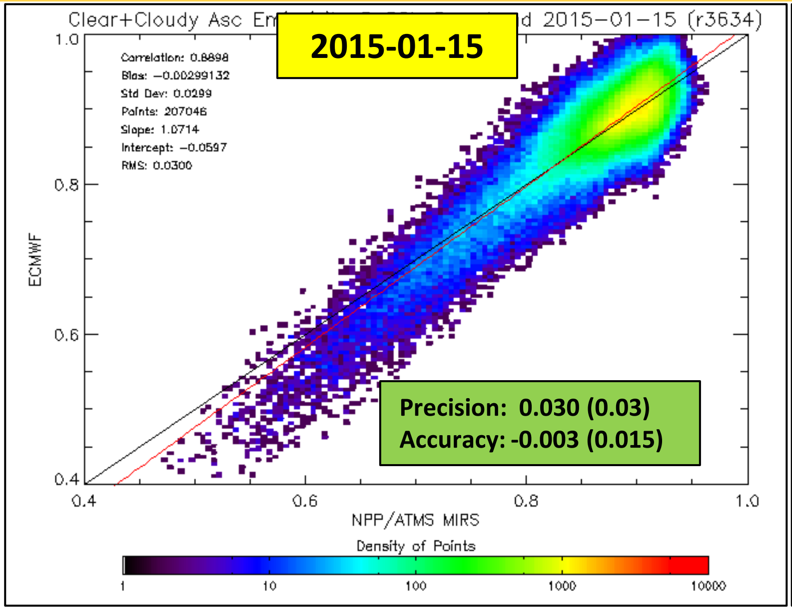

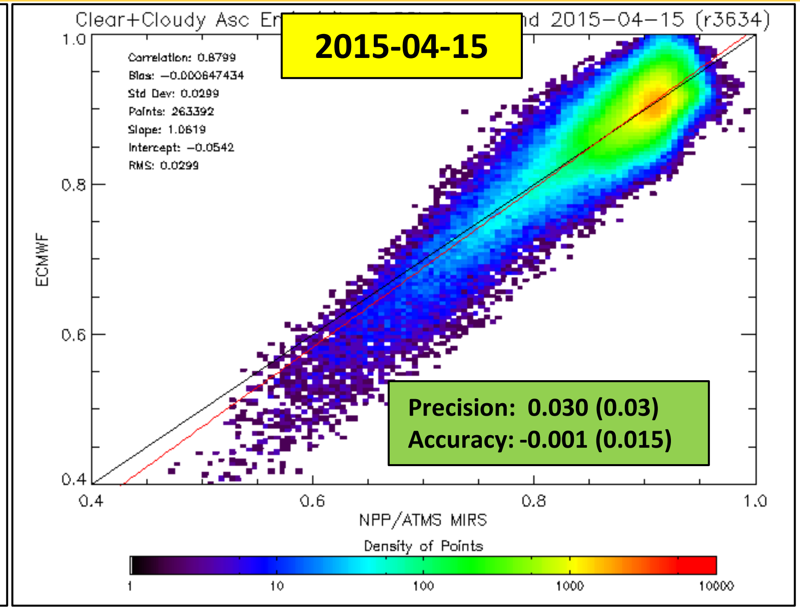

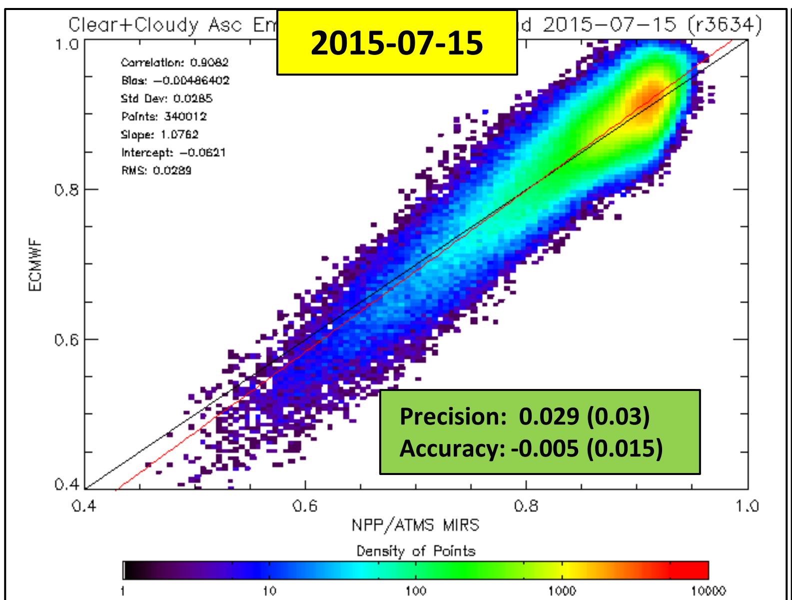

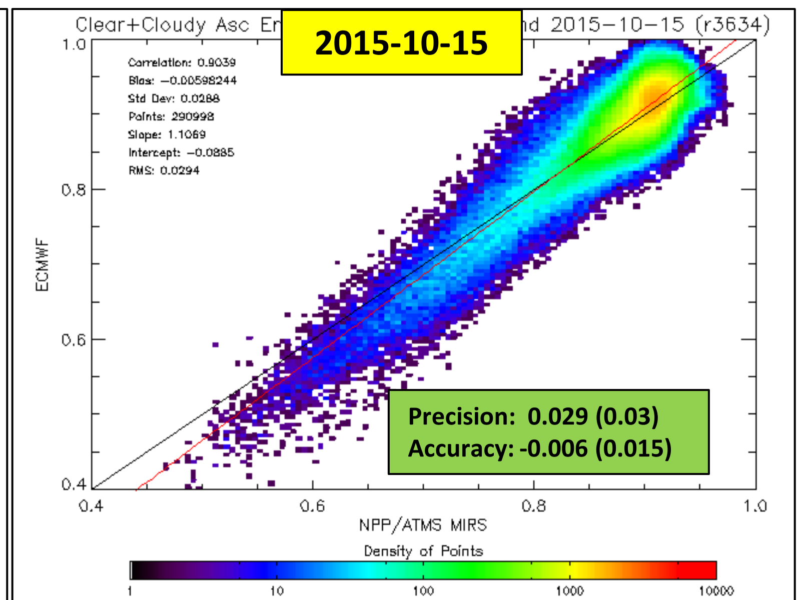

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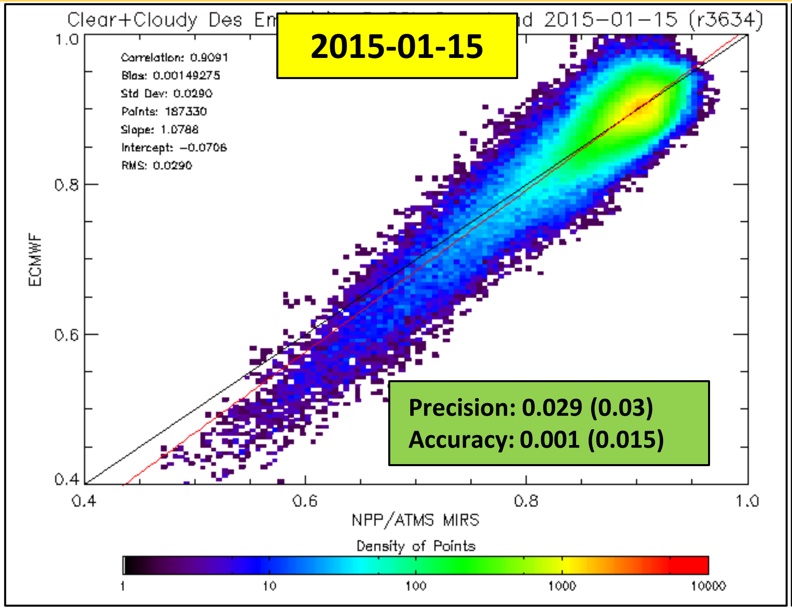
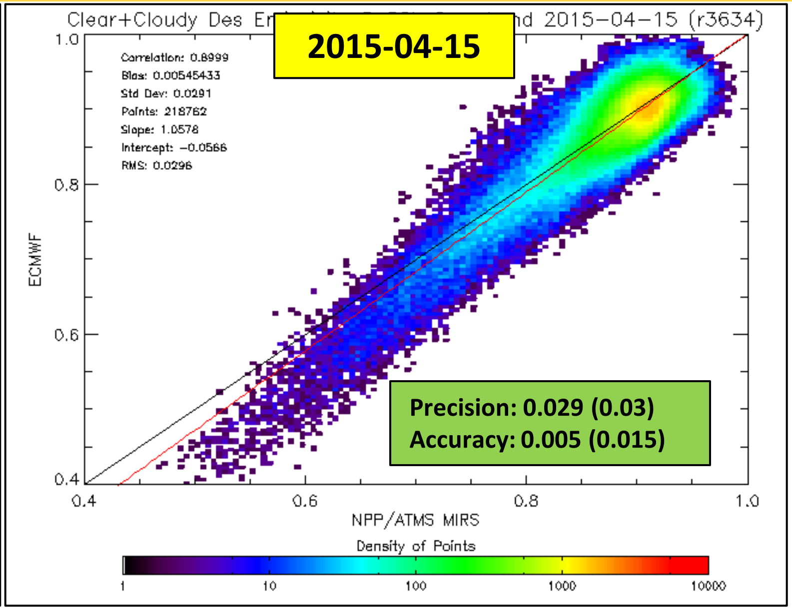
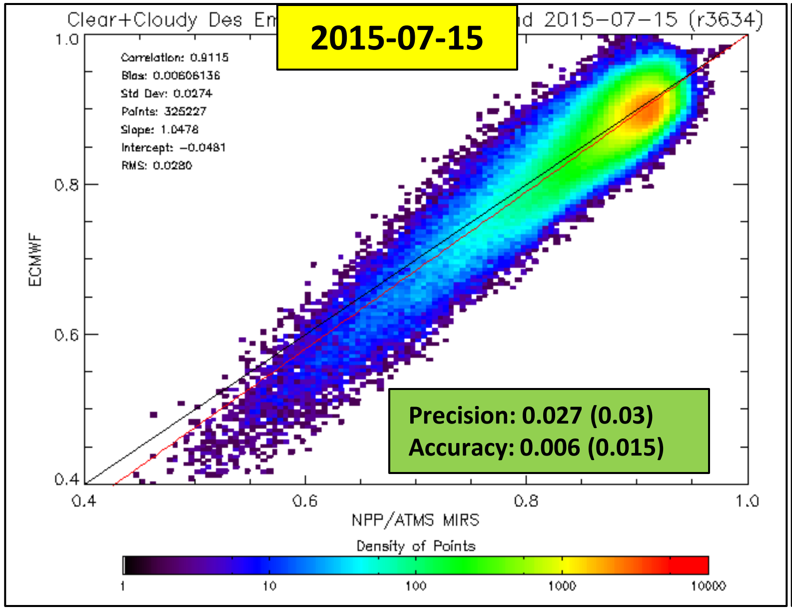
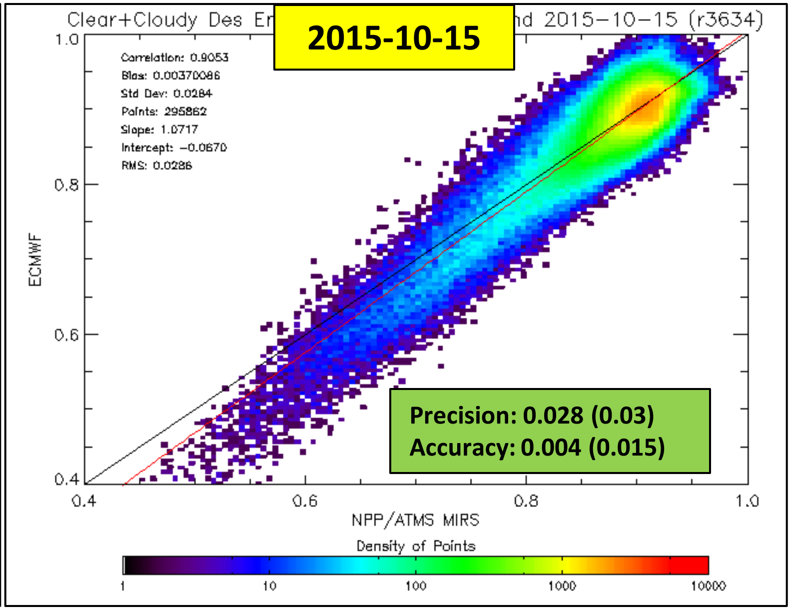








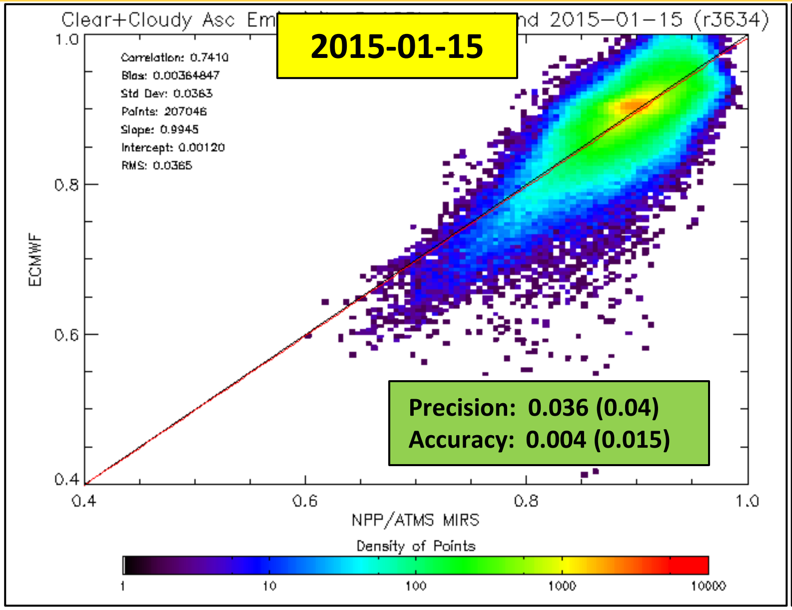
50H

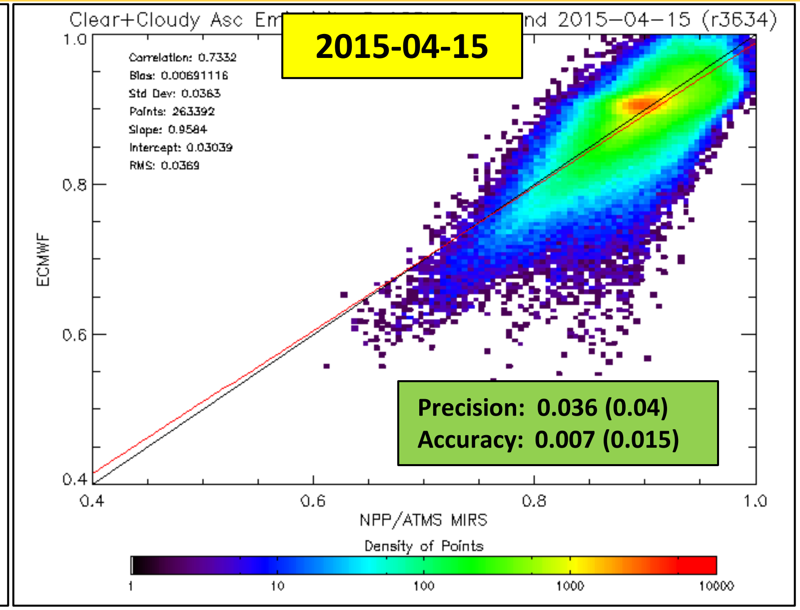
Des

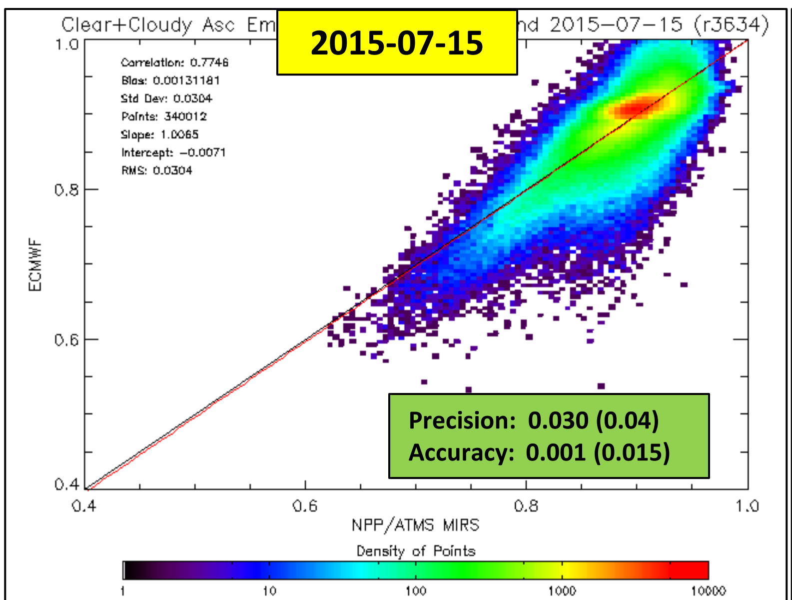
Validation Results: Land Surface Emssivity

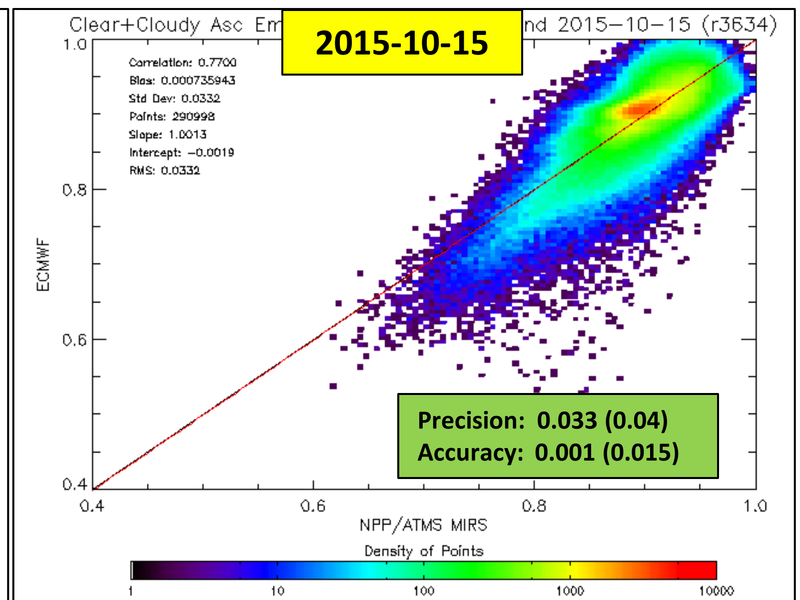
165H

Asc





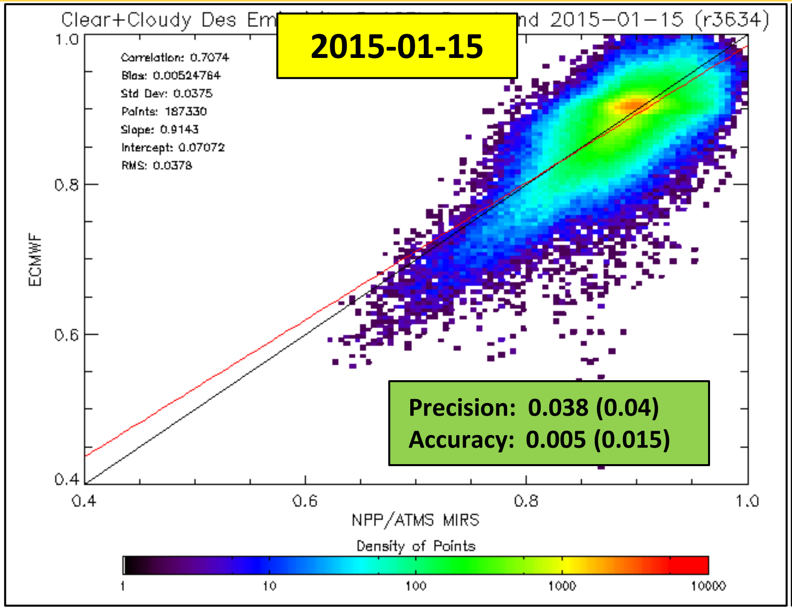


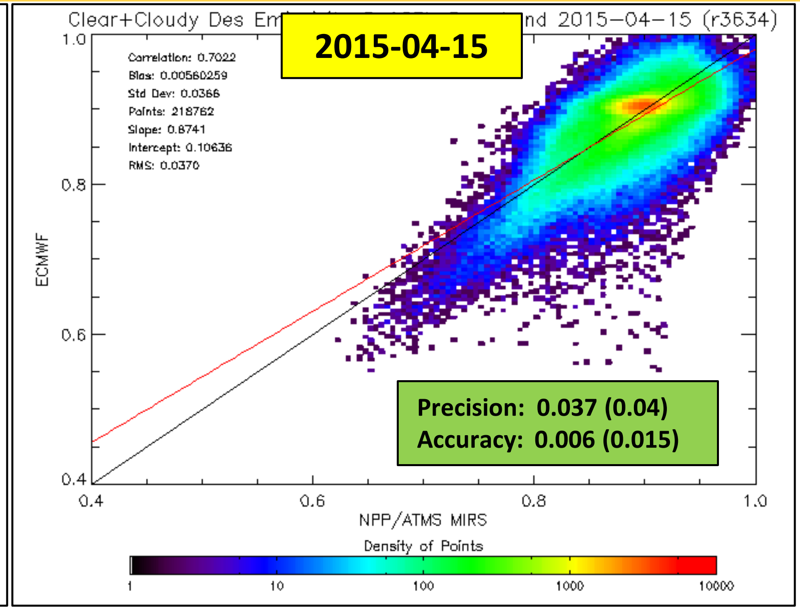


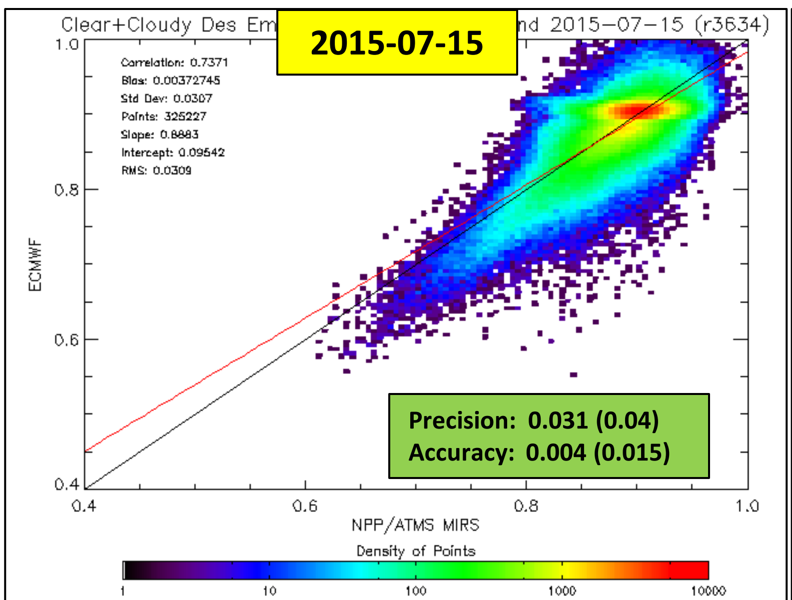
Validation Results: Land Surface Emssivity

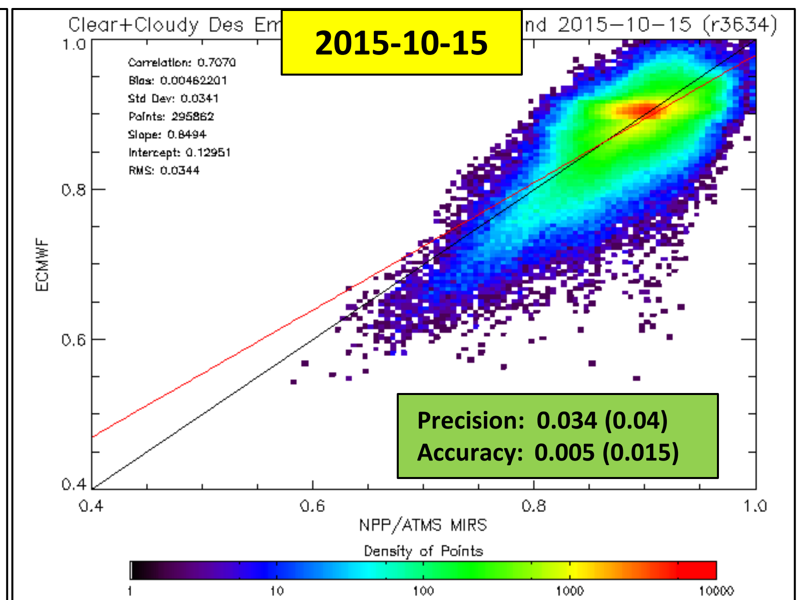
165H

Des









Validation Results Summary: Land Surface Emissivity

Date	Sfc	Condition	Freq (GHz)	Bias (%) (Accuracy)			StDv (%) (Precision)		
				MiRS	Thresh	Obj	MiRS	Thresh	Obj
2015-01-15	Land	Clear+ Cloudy	23.8	**0.002**	**0.020**	**0.013**	**0.023**	**0.030**	**0.020**
			50.3	**0.002**	**0.015**	**0.010**	**0.030**	**0.030**	**0.020**
			165.5	**0.005**	**0.015**	**0.010**	**0.037**	**0.040**	**0.030**
2015-04-15	Land	Clear+ Cloudy	23.8	**0.002**	**0.020**	**0.013**	**0.022**	**0.030**	**0.020**
			50.3	**0.003**	**0.015**	**0.010**	**0.030**	**0.030**	**0.020**
			165.5	**0.007**	**0.015**	**0.010**	**0.037**	**0.040**	**0.030**
2015-07-15	Land	Clear+ Cloudy	23.8	**0.003**	**0.020**	**0.013**	**0.021**	**0.030**	**0.020**
			50.3	**0.006**	**0.015**	**0.010**	**0.028**	**0.030**	**0.020**
			165.5	**0.003**	**0.015**	**0.010**	**0.031**	**0.040**	**0.030**
2015-10-15	Land	Clear+ Cloudy	23.8	**0.003**	**0.020**	**0.013**	**0.022**	**0.030**	**0.020**
			50.3	**0.005**	**0.015**	**0.010**	**0.029**	**0.030**	**0.020**
			165.5	**0.003**	**0.015**	**0.010**	**0.034**	**0.040**	**0.030**

Meets threshold

Meets objective

MiRS LSE Performance relative to ECMWF Analytic emissivity
- Stable performance in different months/seasons.
- All threshold requirements met for all 3 channels; Accuracy objective requirements met.

Requirements and Validation Results: Land Surface Temperature

- Regular daily collocations with ECMWF and GDAS analyses
- Requirements from JPSS-REQ-1002
- Maturity Level: Validated, Stage 3

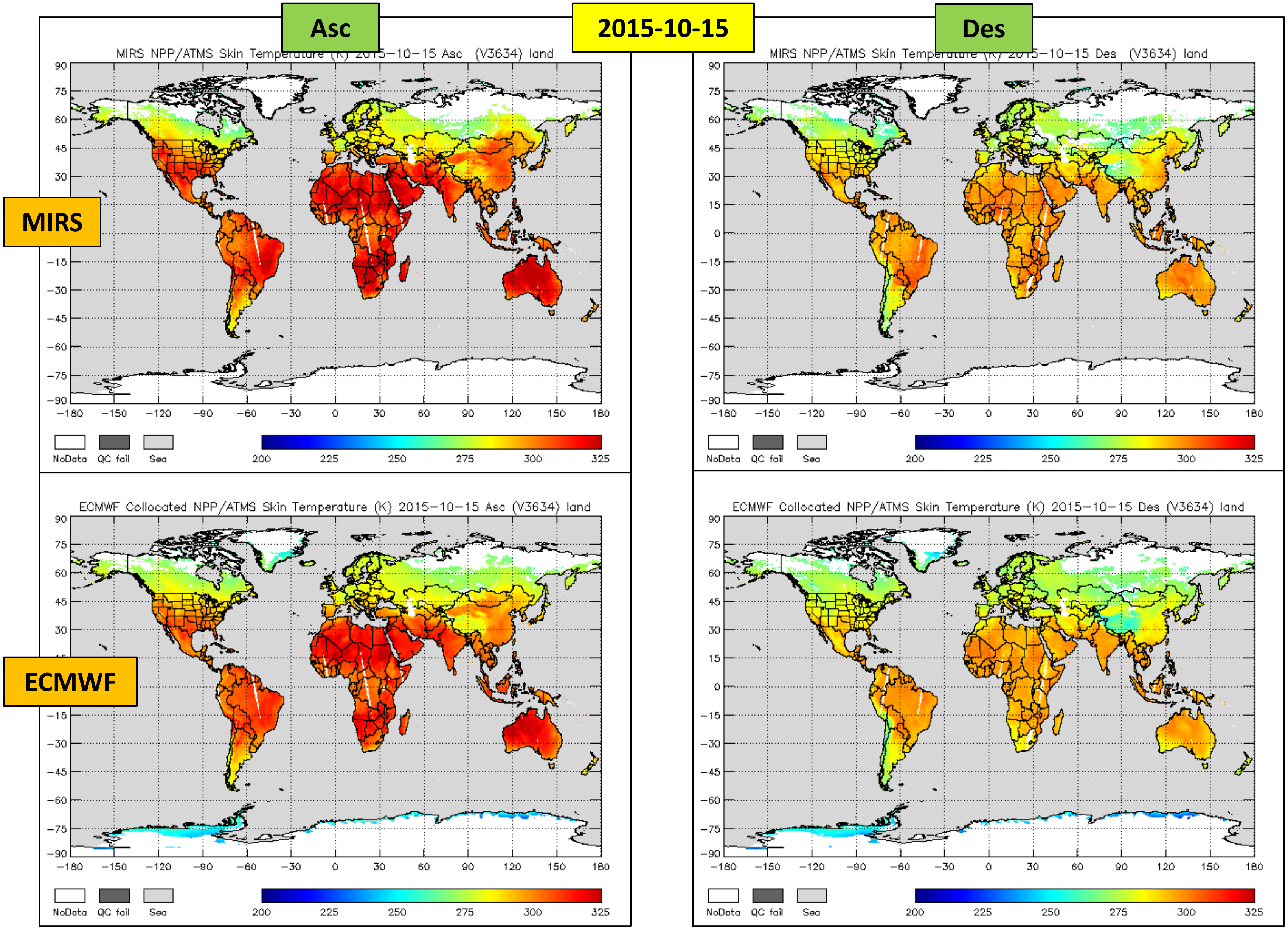
Product	SFC	EDR Attribute	MiRS	Threshold	Objective
LST (K)	Land	Bias/Accuracy (K)	**[0.3 - 1.5]**	**4.0**	**3.4**
		STDV/Precision (K)	**[5.0 - 5.7]**	**7.0**	**6.3**
		RMS/Uncertainty (K)	**[5.1 - 6.1]**	**8.0**	**7.1**

Meets threshold

Meets objective

Attribute	Threshold	Validated
Geographic coverage	Global (clear/cloudy)	See table/figs
Vertical Coverage	Surface	
Horizontal Cell Size	15 km at nadir	
Mapping Uncertainty	N/A (reflects SDR characteristics)	
Measurement Range	150-350K	
Measurement Accuracy	See table	
Measurement Precision	See table	

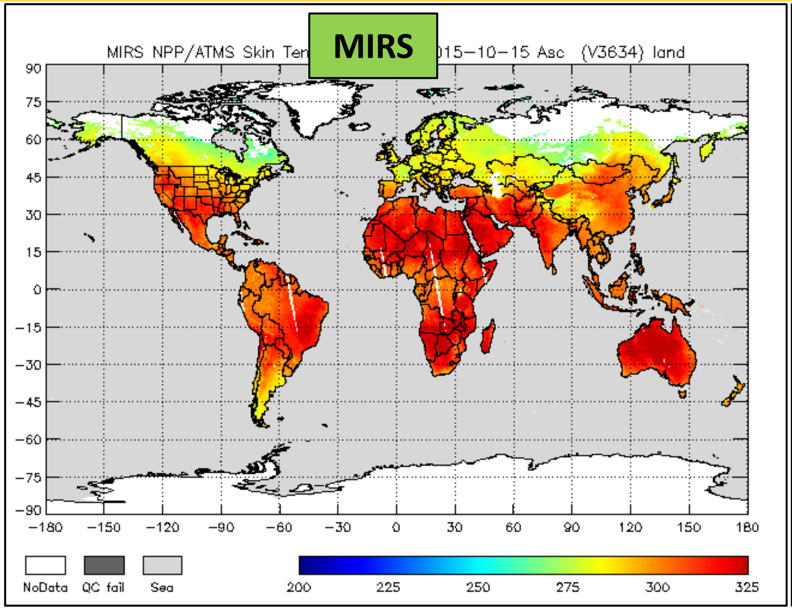
Validation Results: Land Surface Temperature

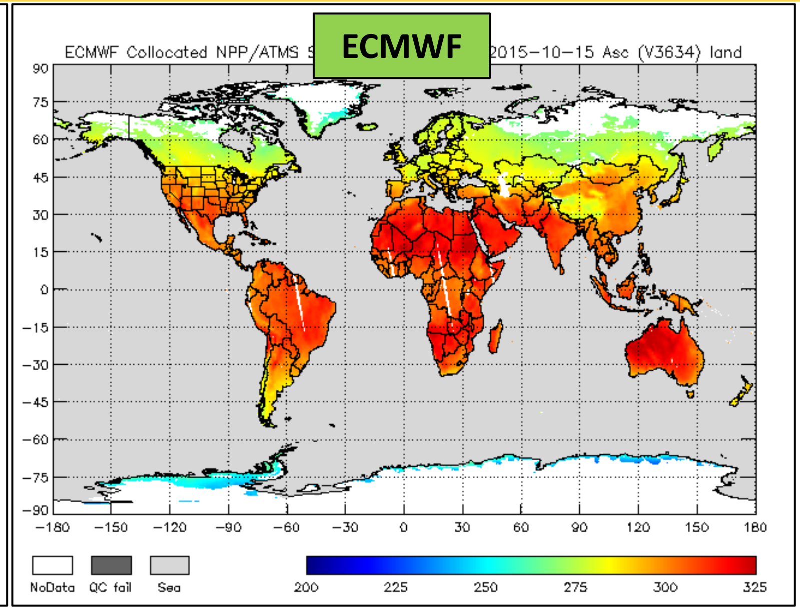


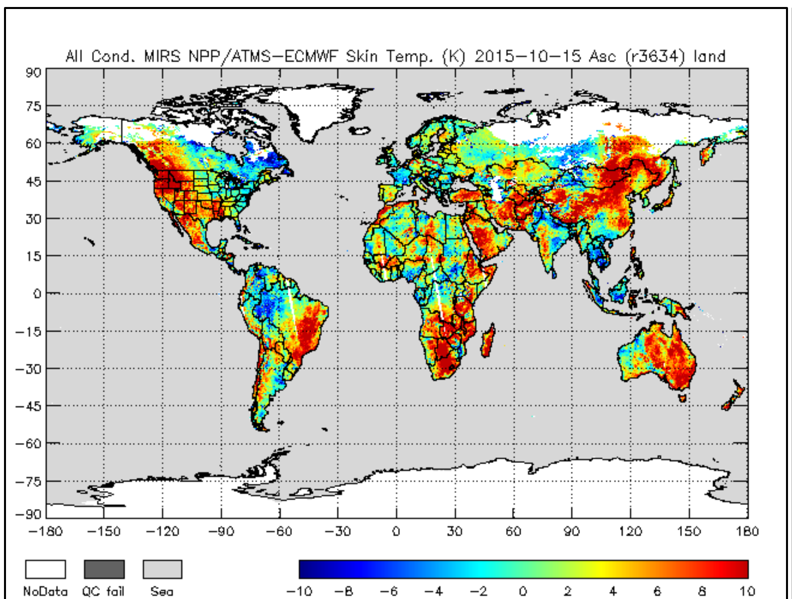
Validation Results: Land Surface Temperature

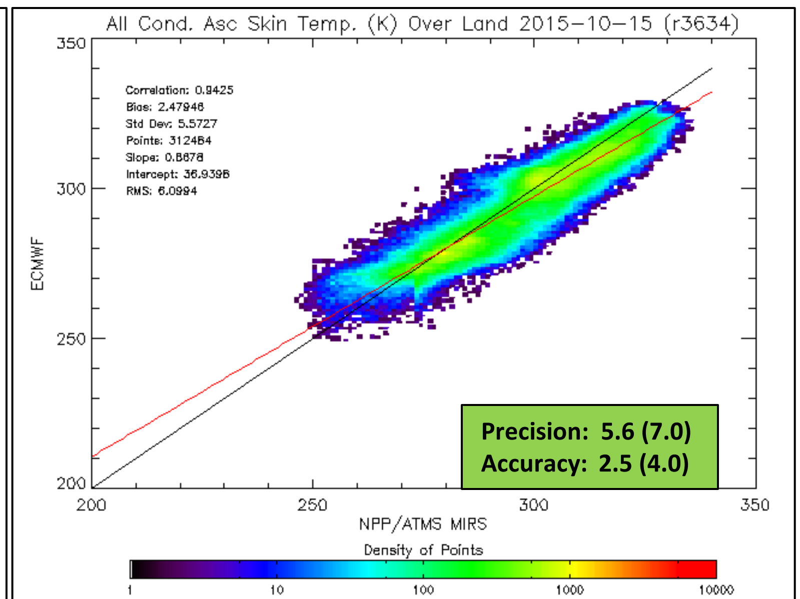
2015-10-15

Asc





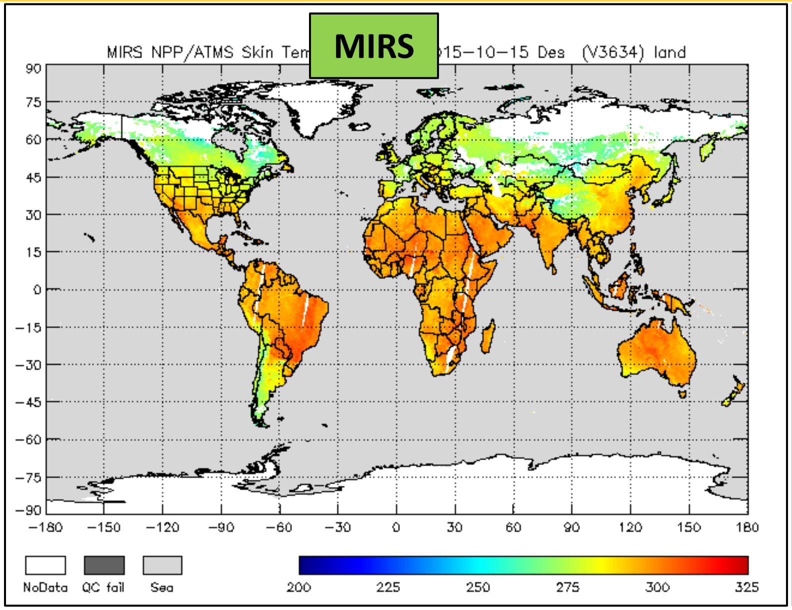


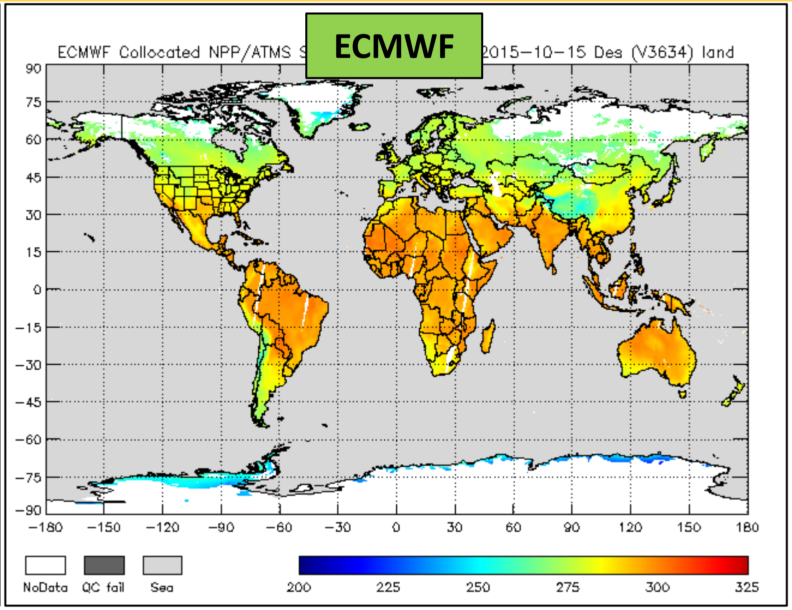


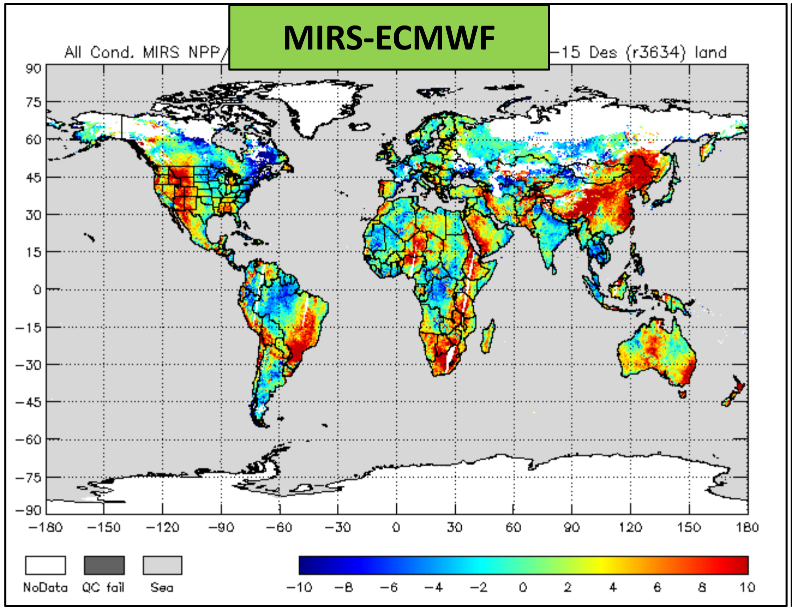
Requirements and Validation Results: Land Surface Temperature

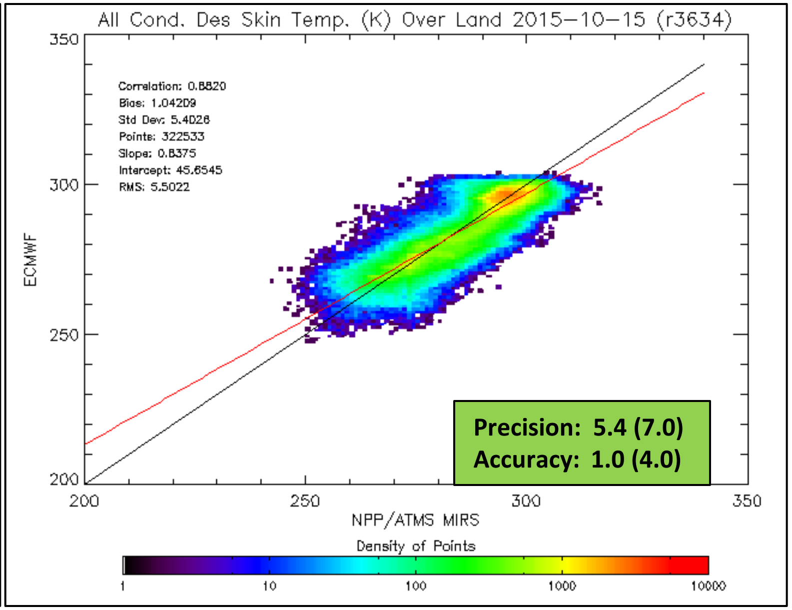
2015-10-15

Des



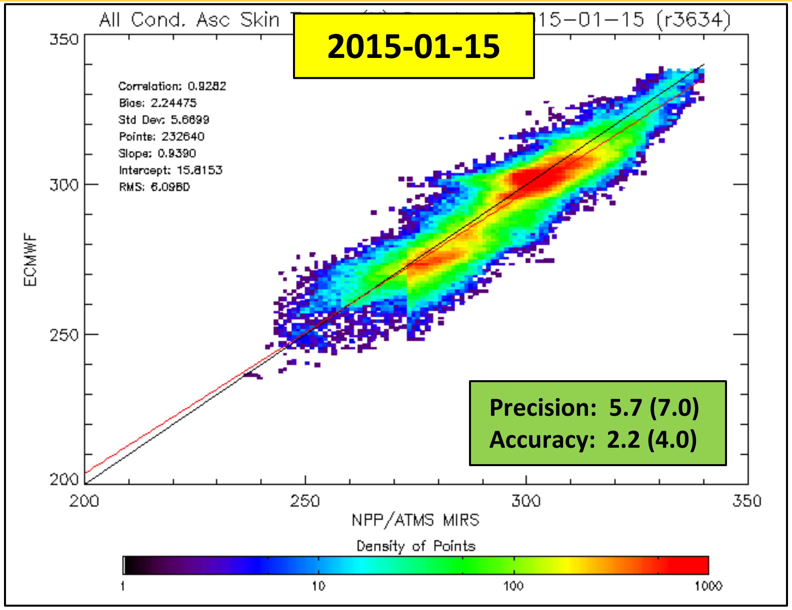


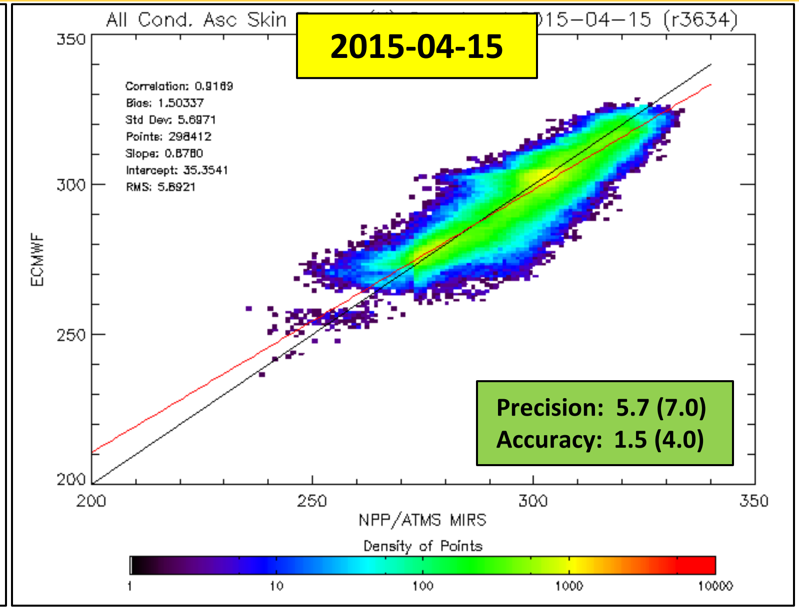


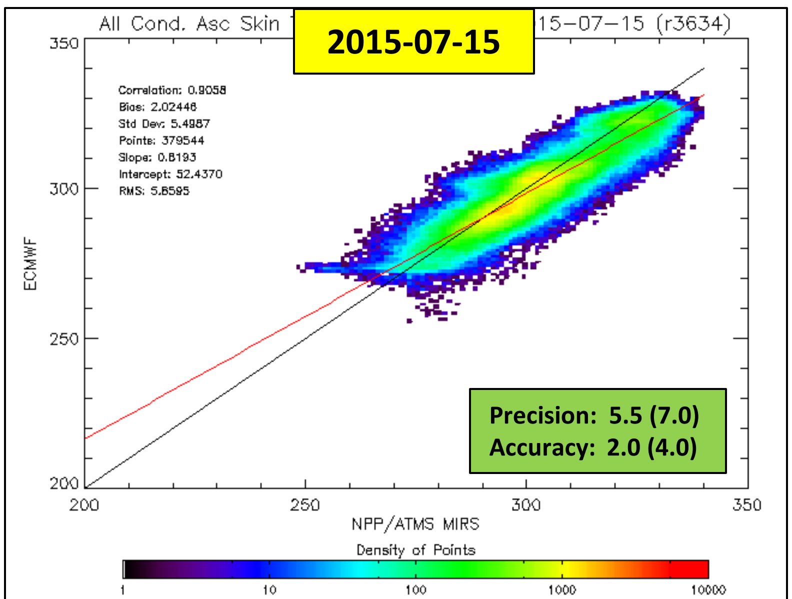


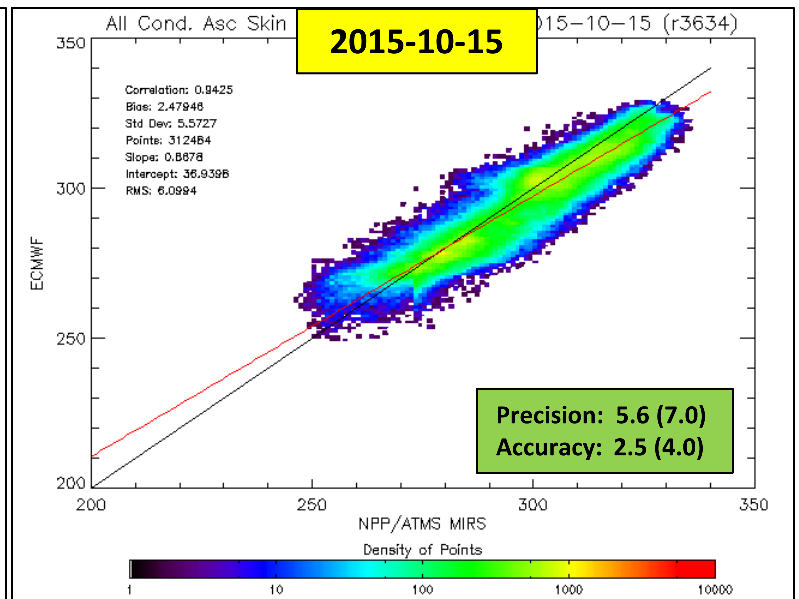
Validation Results: Land Surface Temperature

Asc

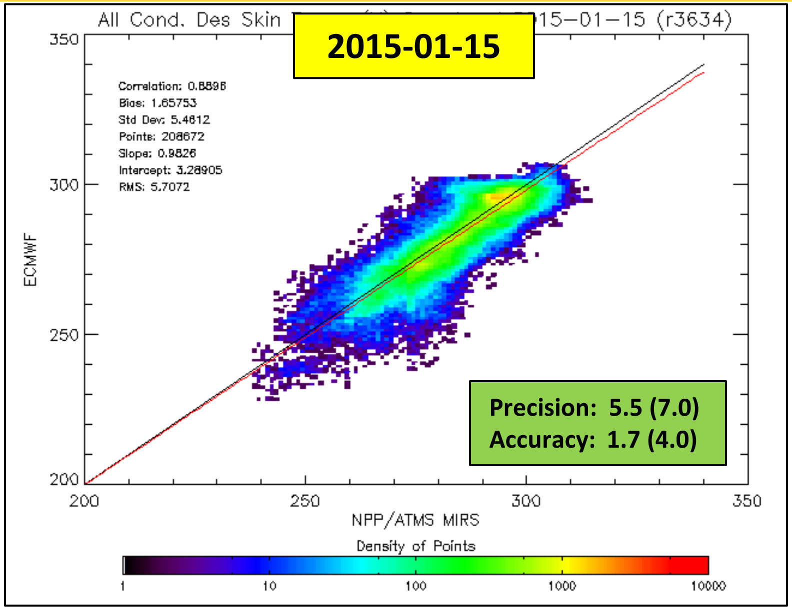


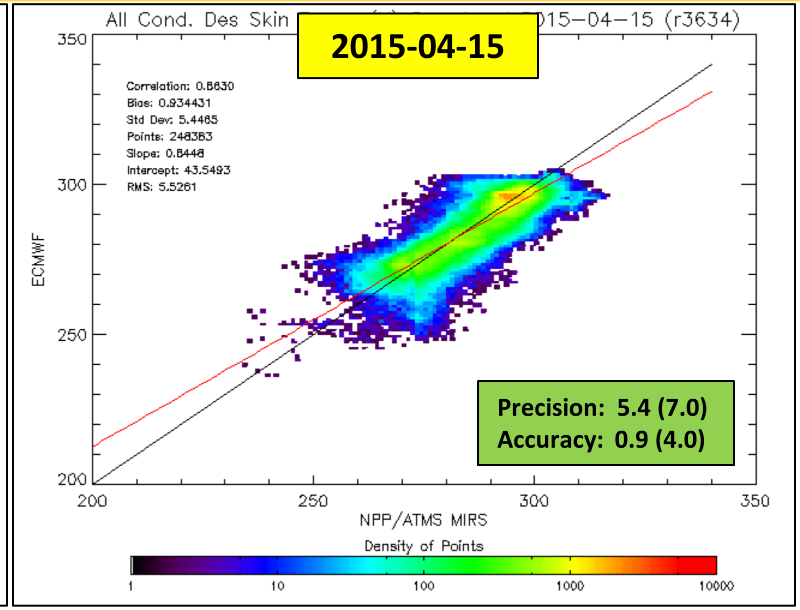


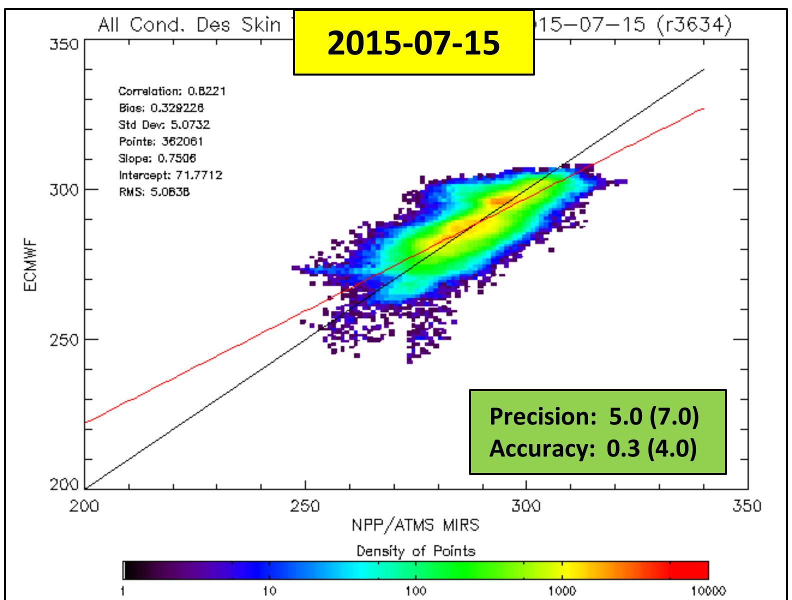


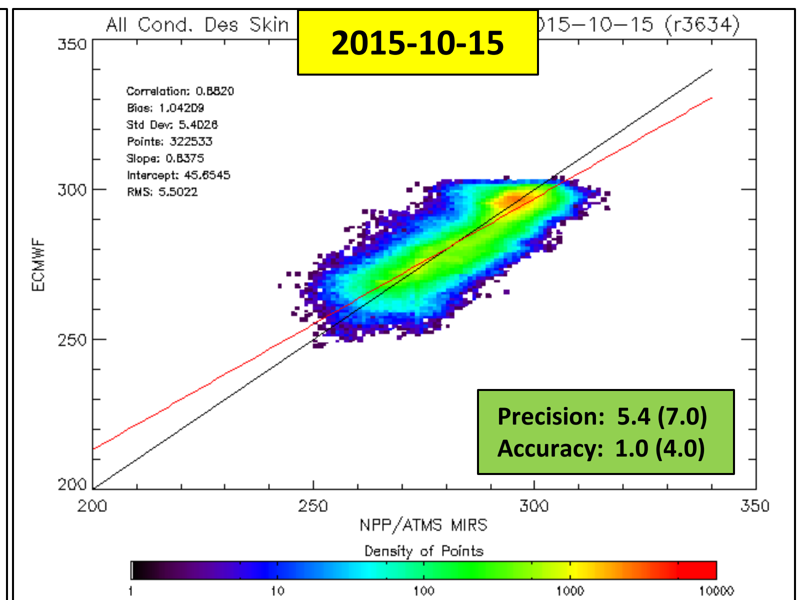


Validation Results: Land Surface Temperature









Des

Validation Results Summary: Land Surface Temperature

Date(s)	Bias/ Accuracy (K)	StDev/ Precision (K)	RMS/ Uncertainty (K)	Reference
Threshold Requirement	**4.0**	**7.0**	**8.0**	
Objective	**3.4**	**6.3**	**7.1**	
2015-01-15	2.0	5.6	5.9	ECMWF
2015-04-15	1.2	5.6	5.7	ECMWF
2015-07-15	1.2	5.3	5.5	ECMWF
2015-10-15	1.8	5.5	5.8	ECMWF

Meets threshold

Meets objective

MiRS LST Performance Relative to ECMWF

- Globally, all threshold and objective requirements for both accuracy and precision are met
- Accuracy and precision slightly better in descending node retrievals (night time)

Requirements and Validation Results: Cloud Liquid Water

- Regular collocations with GPROF V04 GPM CLW
- 3 full months of collocations: Jul 2016, Oct 2016, Feb 2016
- Requirements from JPSS-REQ-1002
- Maturity Level: Validated, Stage 3

Attribute	Threshold	Validated
Geographic coverage	Ocean	See table/figs
Vertical Coverage	Single Layer	
Horizontal Cell Size	15 km at nadir	
Mapping Uncertainty	N/A (reflects SDR characteristics)	
Measurement Range	0.0 - 2.0 mm	
Measurement Accuracy	See table	
Measurement Precision	See table	

Product	SFC	EDR Attribute	MiRS	Threshold	Objective
CLW (mm)	Ocean	Bias/ Accuracy (mm)	**[0.003 - 0.009]**	**0.03**	**0.02**
		STDV/ Precision (mm)	**0.07**	**0.08**	**0.06**

Meets threshold

Meets objective

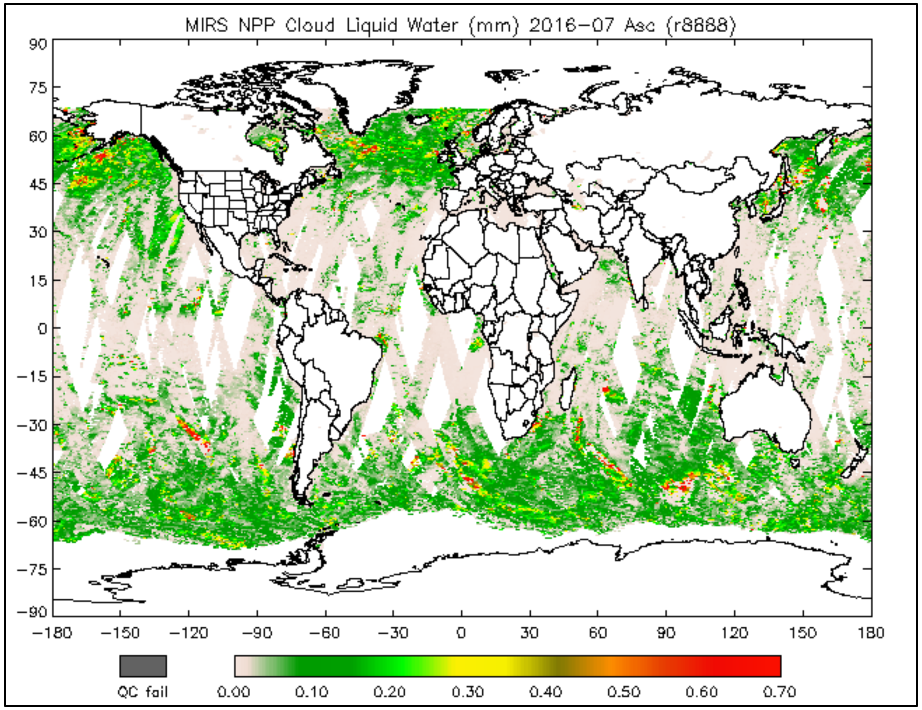
Validation Results: Cloud Liquid Water (CLW) Comparison with GPROF GPM

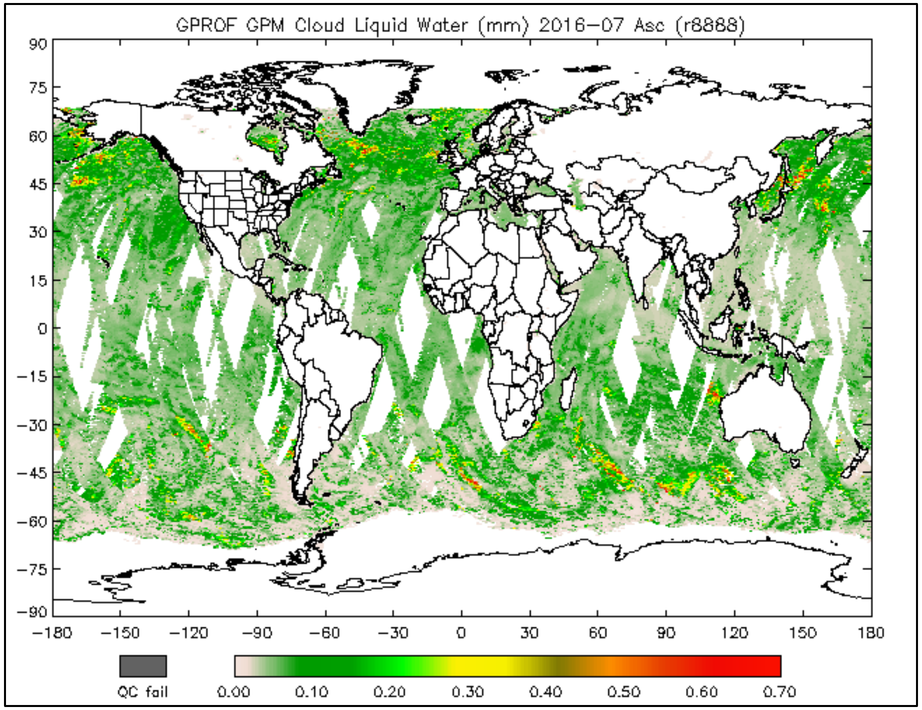
- Full month aggregation of collocations with GPROF GPM CLW

July 2016

MiRS SNPP

GPROF GPM





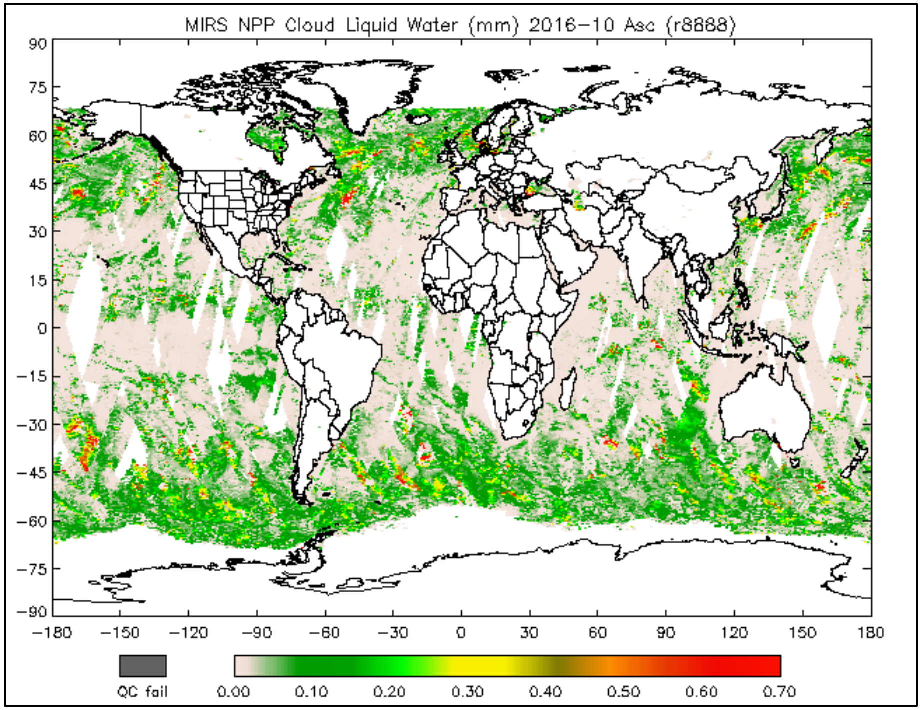
- Mid, High latitudes: good qualitative agreement with GPROF
- Low latitudes: GPROF more coverage of CLW ~ 0.03 mm

Validation Results: Cloud Liquid Water (CLW) Comparison with GPROF GPM

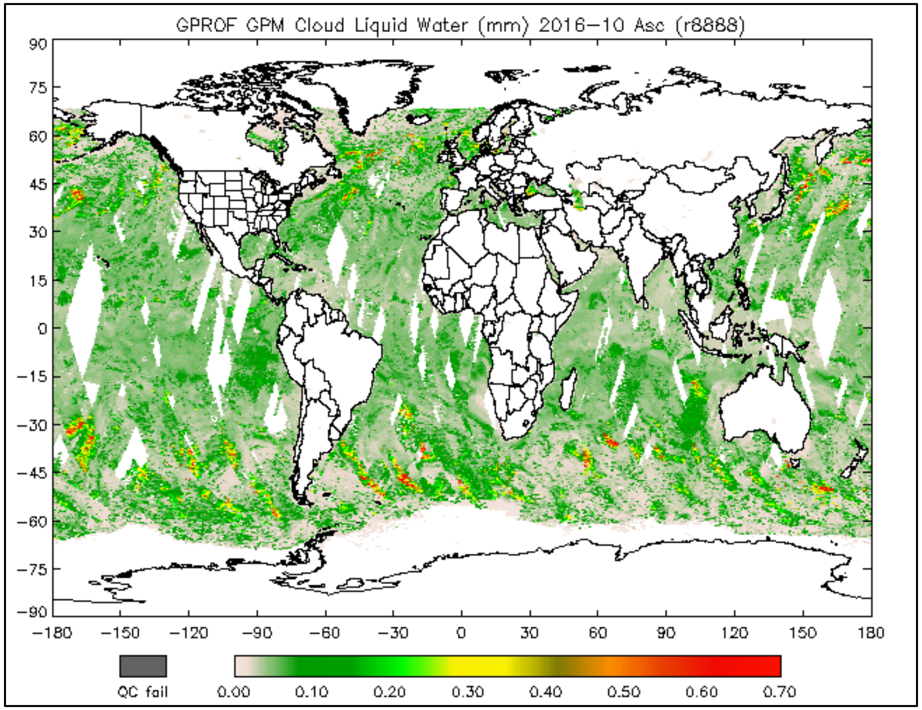
• Full month aggregation of collocations with GPROF GPM CLW

October 2016

MiRS SNPP



GPROF GPM



• Mid, High latitudes: good qualitative agreement with GPROF
• Low latitudes: GPROF more coverage of CLW ~ 0.03 mm

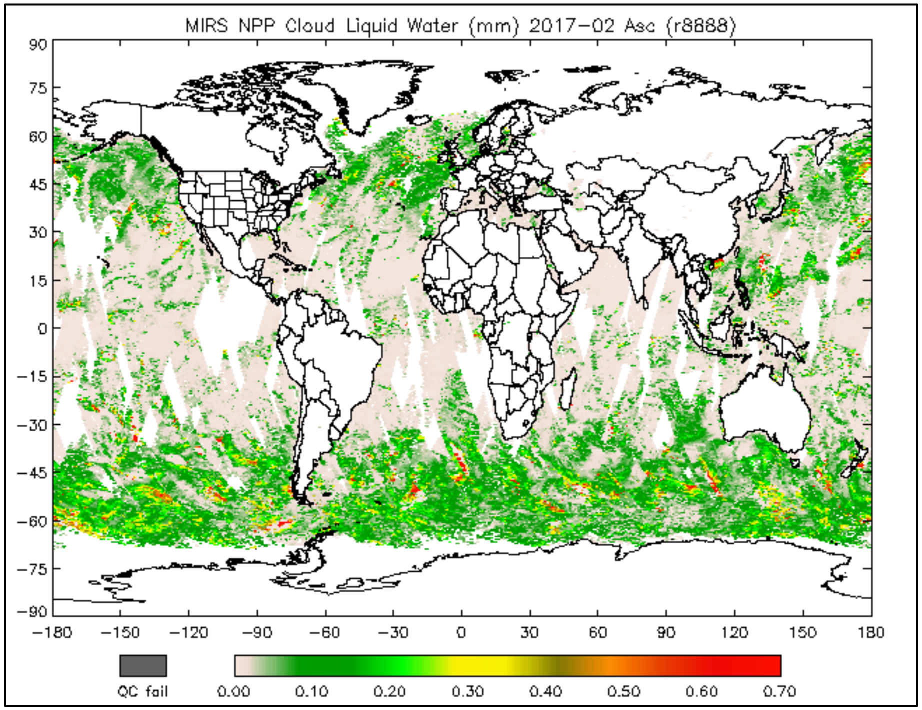
Validation Results: Cloud Liquid Water (CLW) Comparison with GPROF GPM

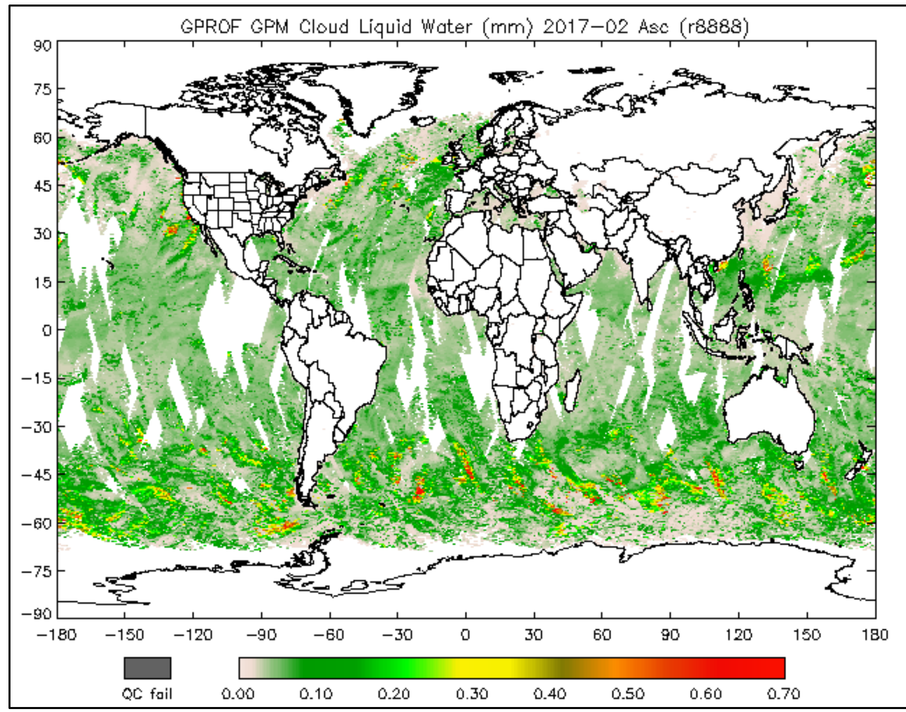
• Full month aggregation of collocations with GPROF GPM CLW

February 2017

MiRS SNPP

GPROF GPM





• Mid, High latitudes: good qualitative agreement with GPROF
• Low latitudes: GPROF more coverage of CLW ~ 0.03 mm

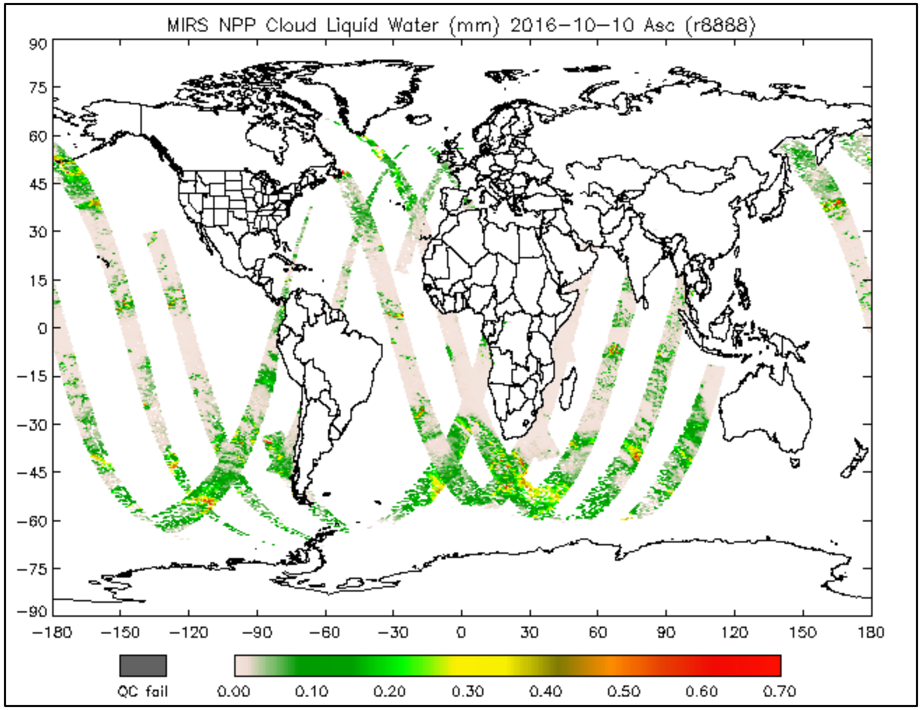
Validation Results: Cloud Liquid Water (CLW) Comparison with GPROF GPM

- Because of the differences in SNPP and GPM orbital characteristics, the number of daily collocations vary with a ~2-week cycle (see time series plots in later slides)

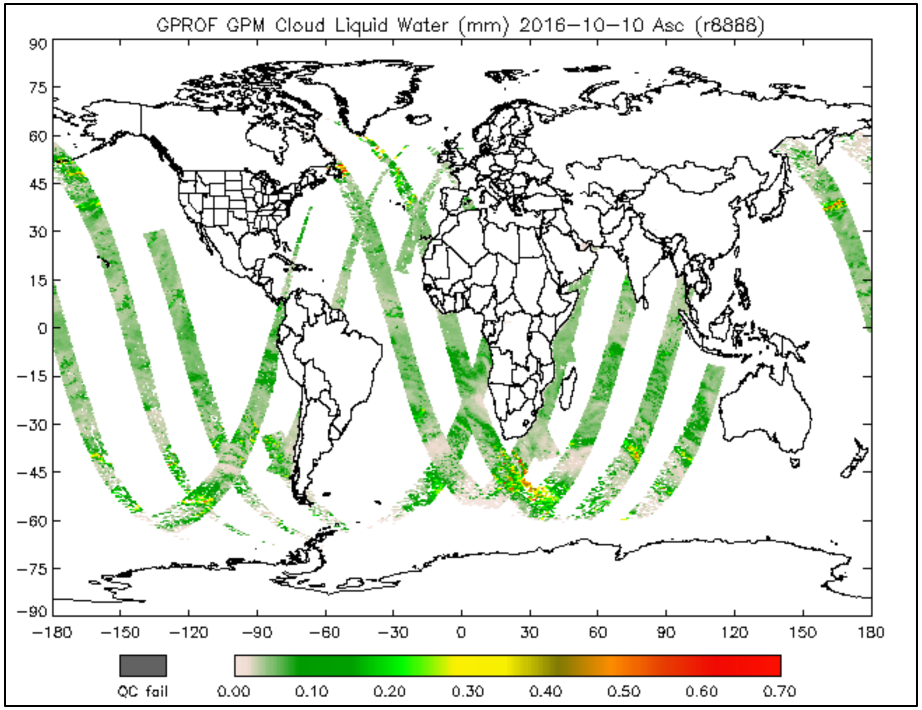
- Single day of collocations with GPROF GPM CLW (maximum during the month)

10 October 2016

MiRS SNPP



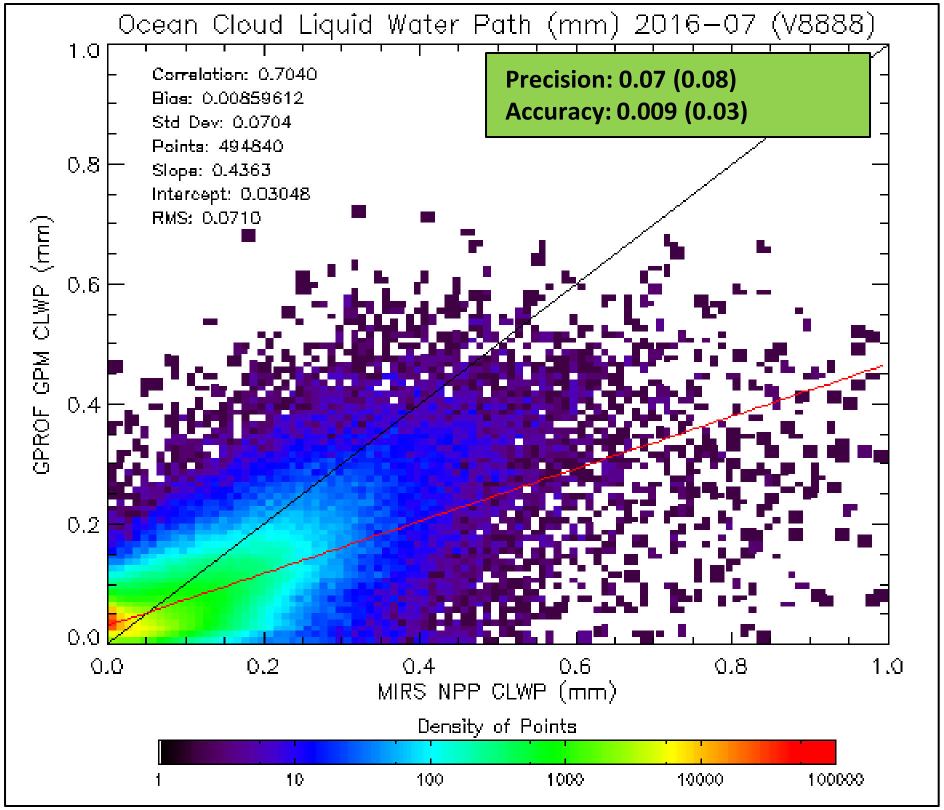
GPROF GPM

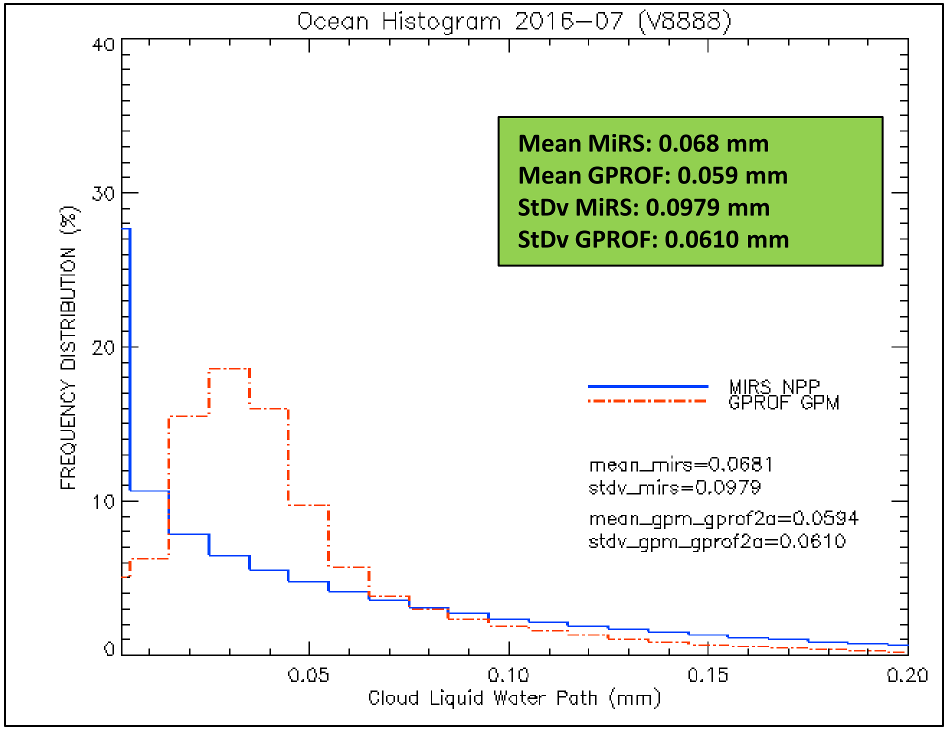


Validation Results: Cloud Liquid Water (CLW) Comparison with GPROF GPM

- Full month aggregation of collocations with GPROF GPM CLW

July 2016

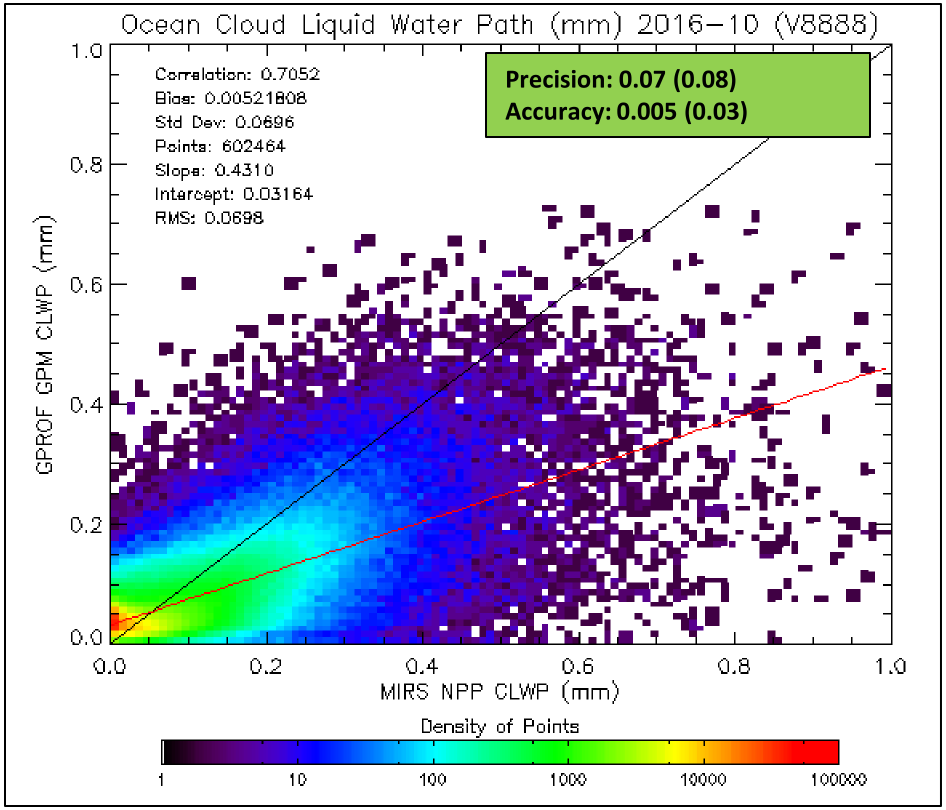


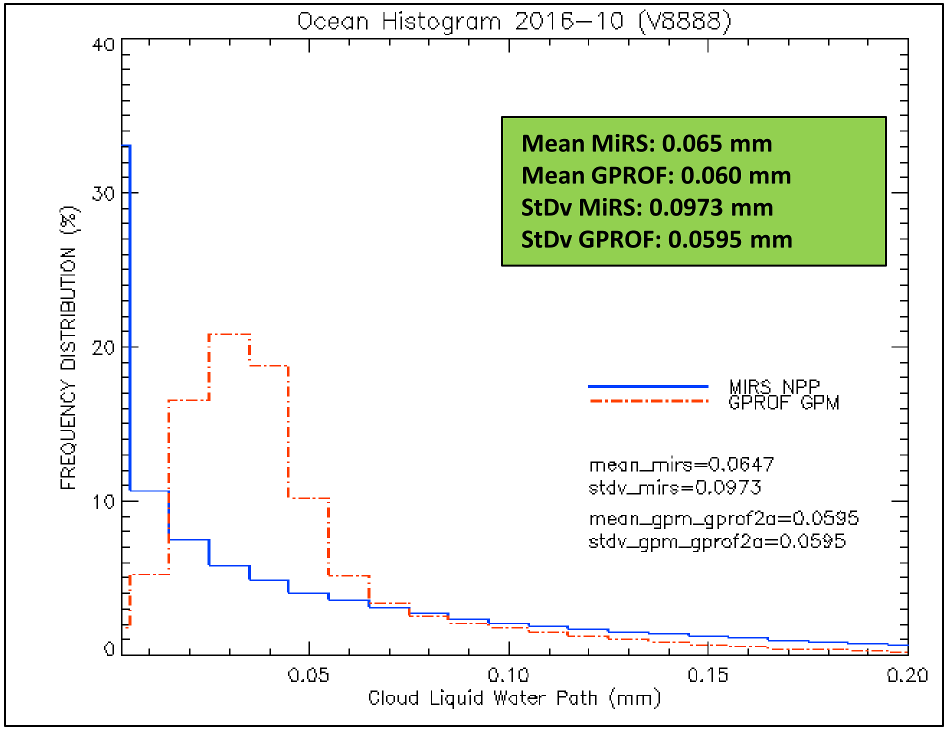


Validation Results: Cloud Liquid Water (CLW) Comparison with GPROF GPM

• Full month aggregation of collocations with GPROF GPM CLW

October 2016

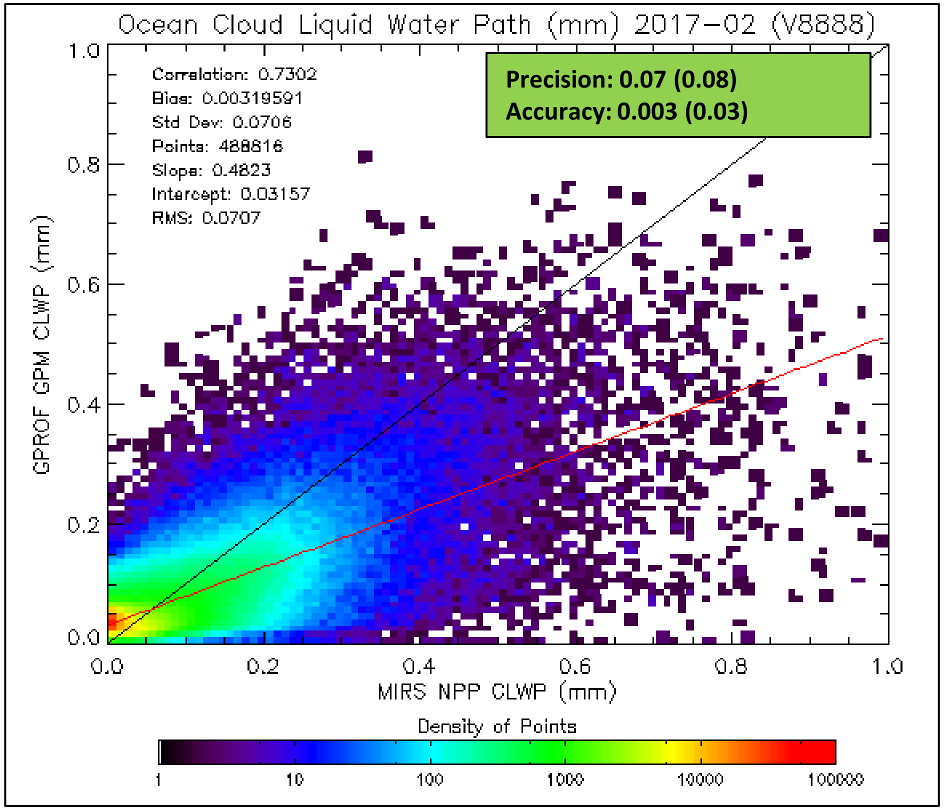


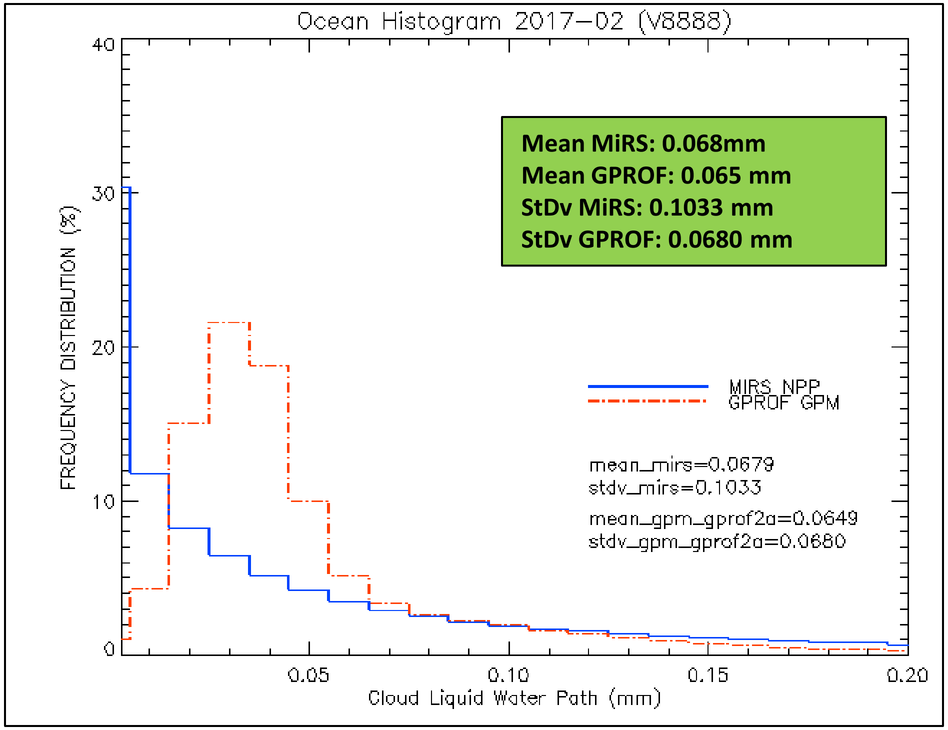


Validation Results: Cloud Liquid Water (CLW) Comparison with GPROF GPM

- Full month aggregation of collocations with GPROF GPM CLW

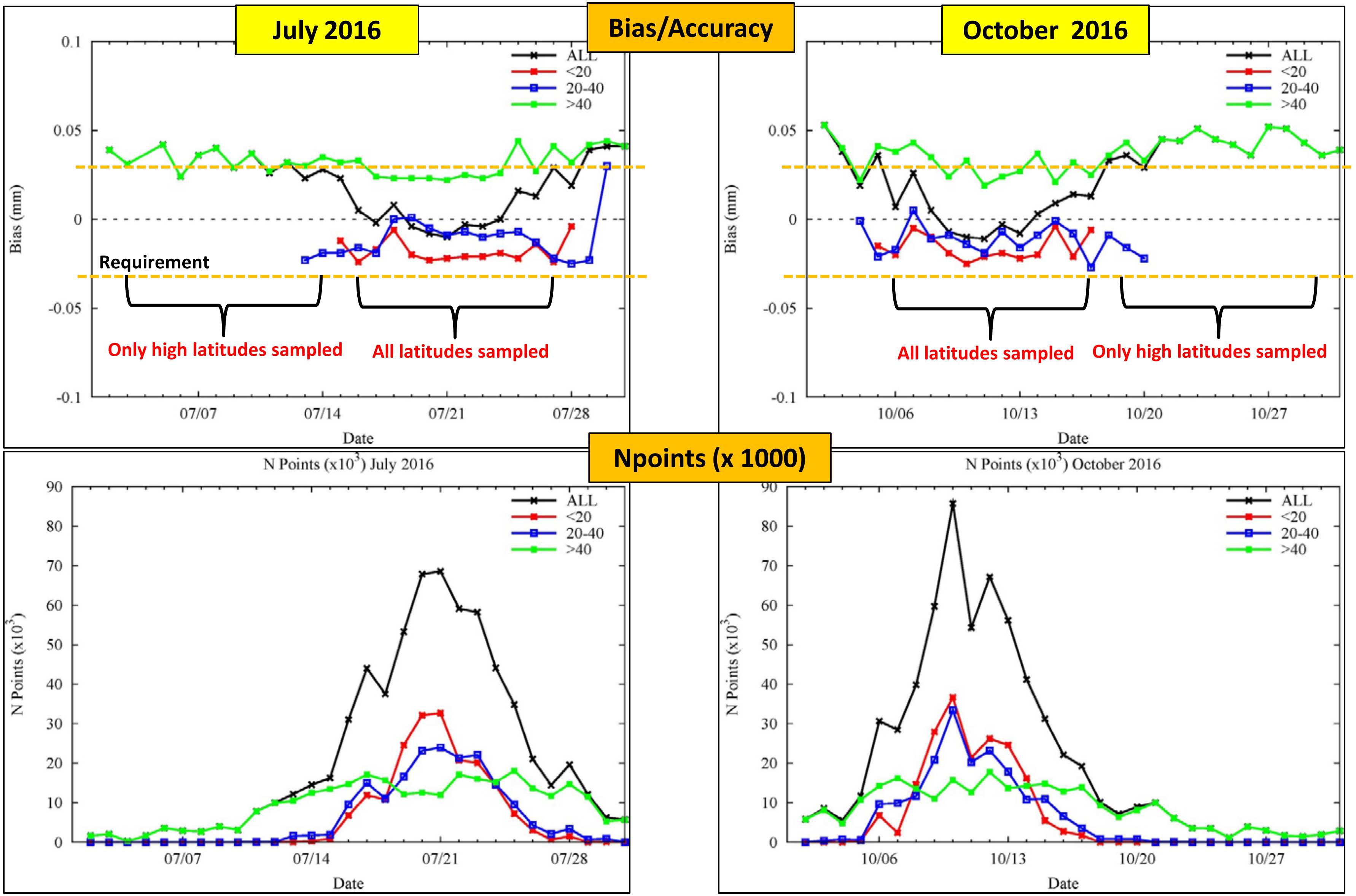
February 2017



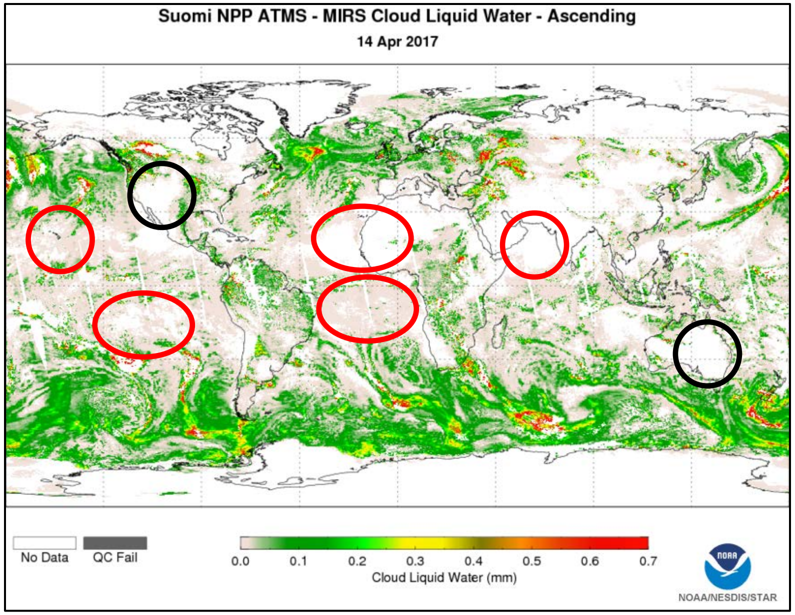


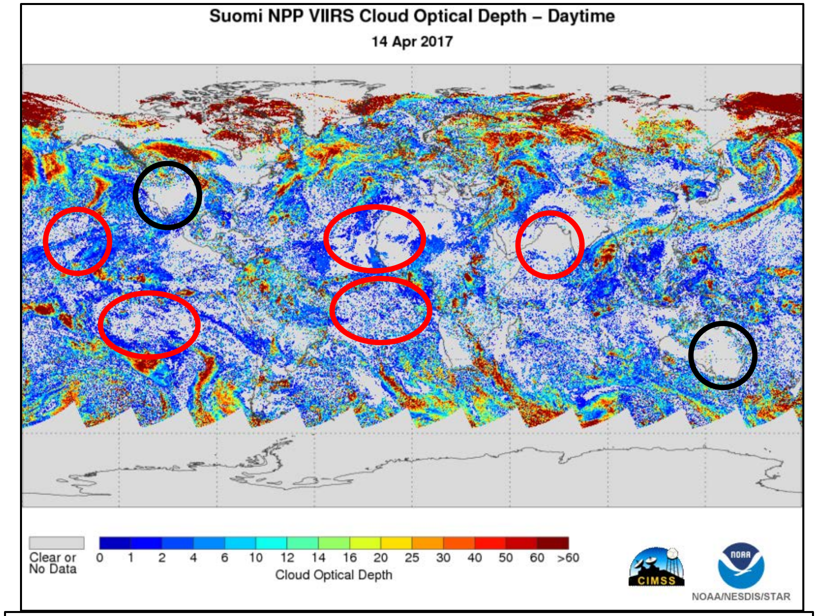
Validation Results: Cloud Liquid Water (CLW) Comparison with GPROF GPM

- Daily collocation statistics, with latitude dependence



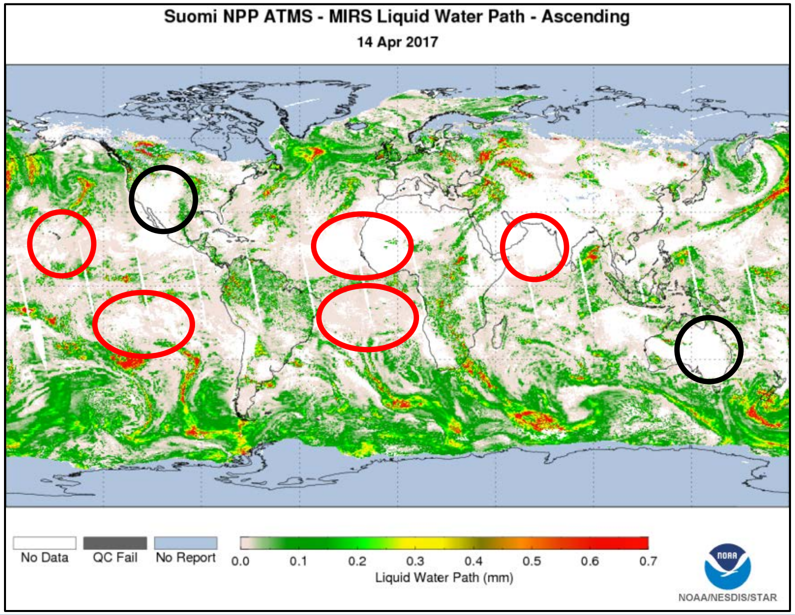
MiRS ATMS CLW, LWP and VIIRS Cloud Optical Depth

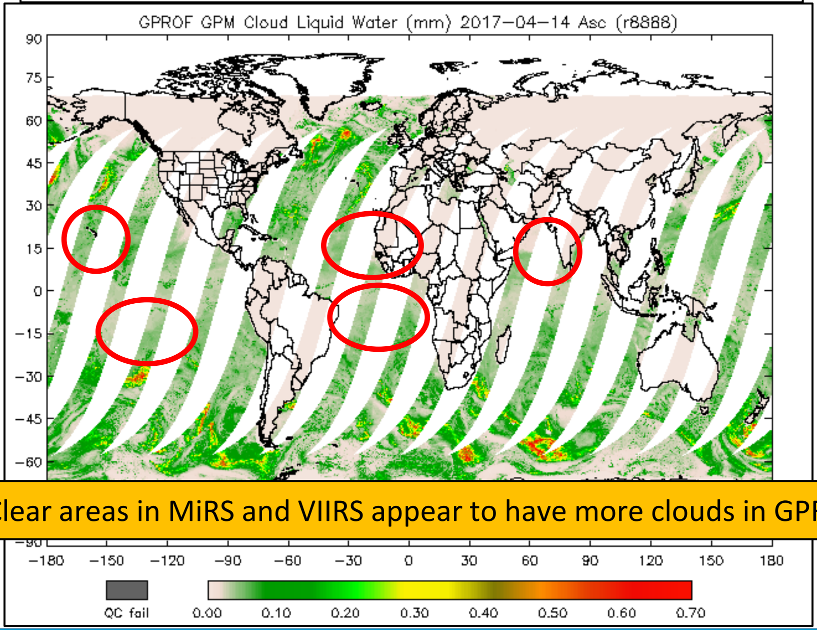




Clear Land

Clear Sea





Clear areas in MiRS and VIIRS appear to have more clouds in GPROF

Validation Results Summary: Cloud Liquid Water

Date(s)	Bias/ Accuracy (mm)	StDev/ Precision (mm)	Reference	Comment
Threshold Requirement	**0.03**	**0.08**		
Objective	**0.02**	**0.06**		
July 2016	0.009	0.07	GPROF V04 GMI	
October 2016	0.005	0.07	GPROF V04 GMI	
February 2017	0.003	0.07	GPROF V04 GMI	Some missing orbits due to SCDR issues

Meets threshold
Meets objective

MiRS CLW Performance relative to GPROF GPM

- Globally, all threshold requirements, and objective requirements for accuracy also are met
- Some latitudinal dependence, requirements met at all latitudes (< 65 deg)
- 2-week cycle in collocations due to orbital differences
- GPROF reference has inherent uncertainties (e.g. is maximum occurrence at 0.03 mm real?)

Requirements and Validation Results: Sea Ice Concentration

- Regular collocations with SSMIS NRT (F17/F18), NASA Team algorithm (also comparisons with NIC IMS analyses)
- Official reference is SSMIS NASA Team
- Requirements from JPSS-REQ-1002
- Maturity Level: Validated, Stage 3

Product	SFC	EDR Attribute	MiRS	Threshold	Objective
SIC (%)	Ocean /Ice	Bias/Accuracy (%)	**[2.0 - 10.0]**	**10.0**	**5.0**
		STDV/Precision (%)	**[10.0 - 20.0]**	**25.0**	**18.0**

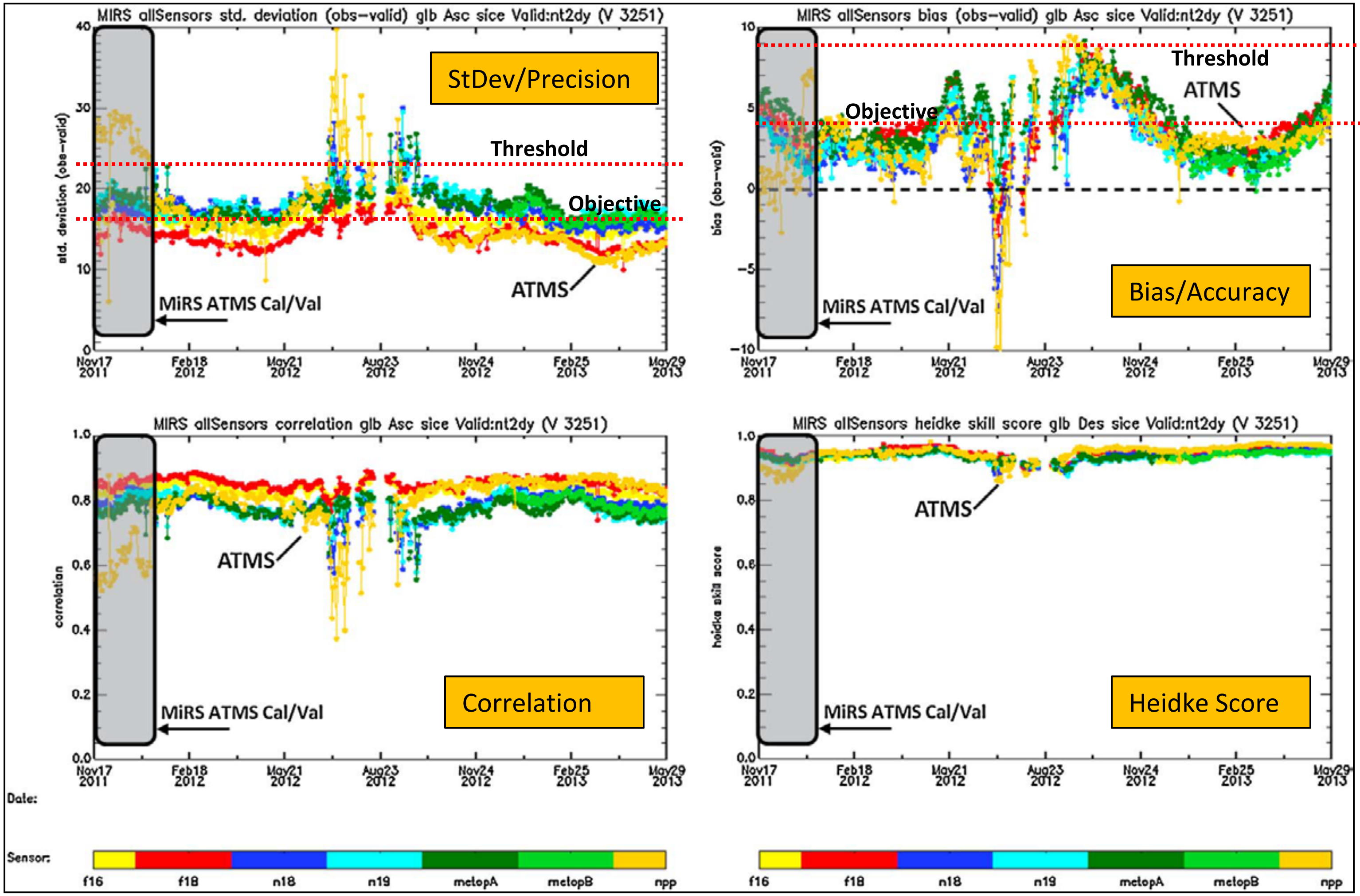
Meets threshold

Meets objective

Attribute	Threshold	Validated
Geographic coverage	Global (Oct-May)	See table/figs
Vertical Coverage	Surface	
Horizontal Cell Size	15 km at nadir	
Mapping Uncertainty	N/A (reflects SDR characteristics)	
Measurement Range	20 – 100 %	
Measurement Accuracy	See tables	
Measurement Precision	See tables	

Sea Ice Concentration Performance (2012-2013): Comparison with NASA Team NRT SSMIS (F17)

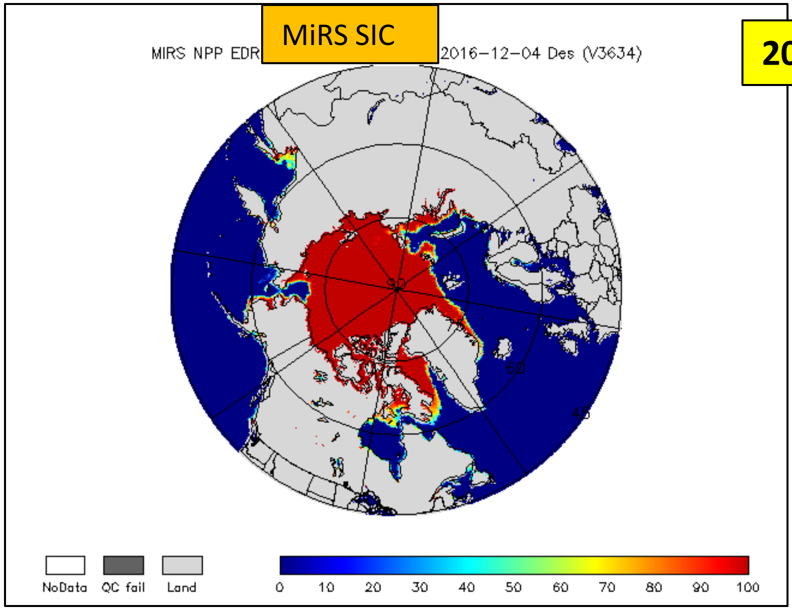
- From Boukabara et al. (2013): J. Geophys. Res. Atmos., 118, 12,600–12,619
- Collocation Period: January 2012 - May 2013
- Global Collocation with NRT SSMIS (F17), NASA Team
- Maturity Level: Validated, Stage 3



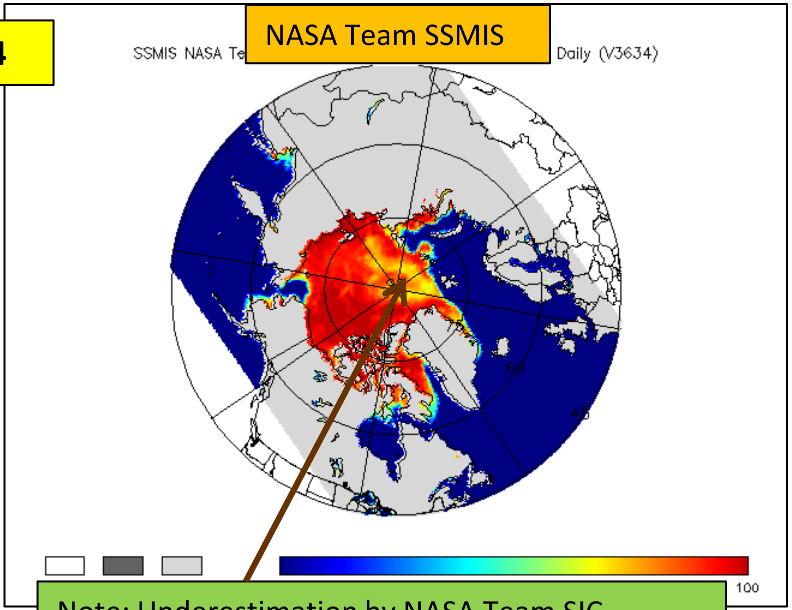
Sea Ice Concentration Performance: Comparison with NASA Team NRT SSMIS (F18)

2016-12-04

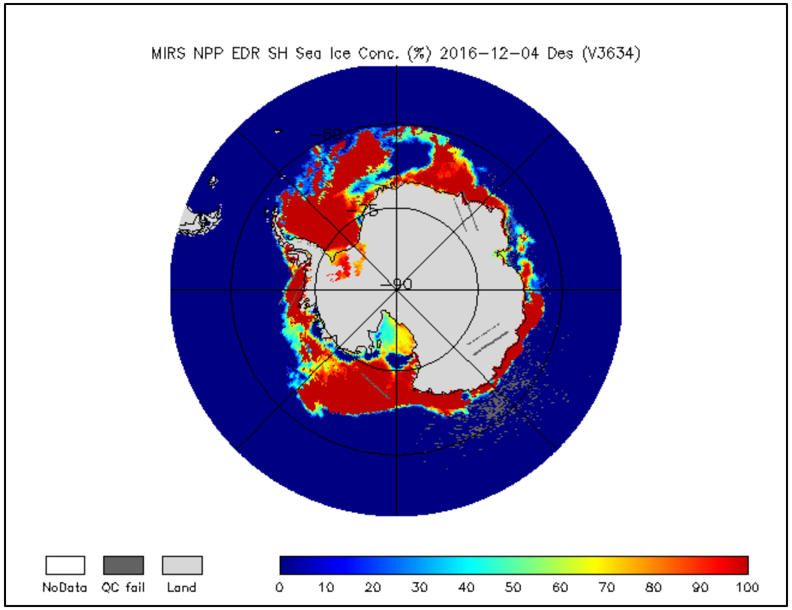
MiRS SIC

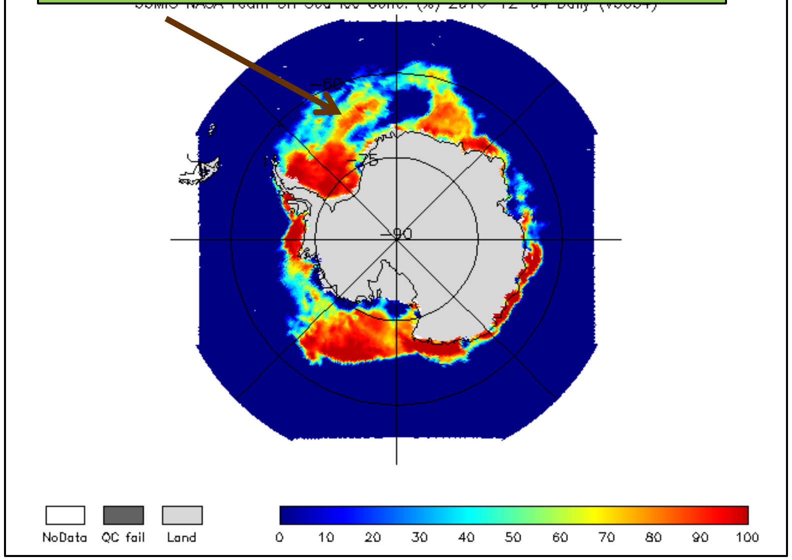


NASA Team SSMIS

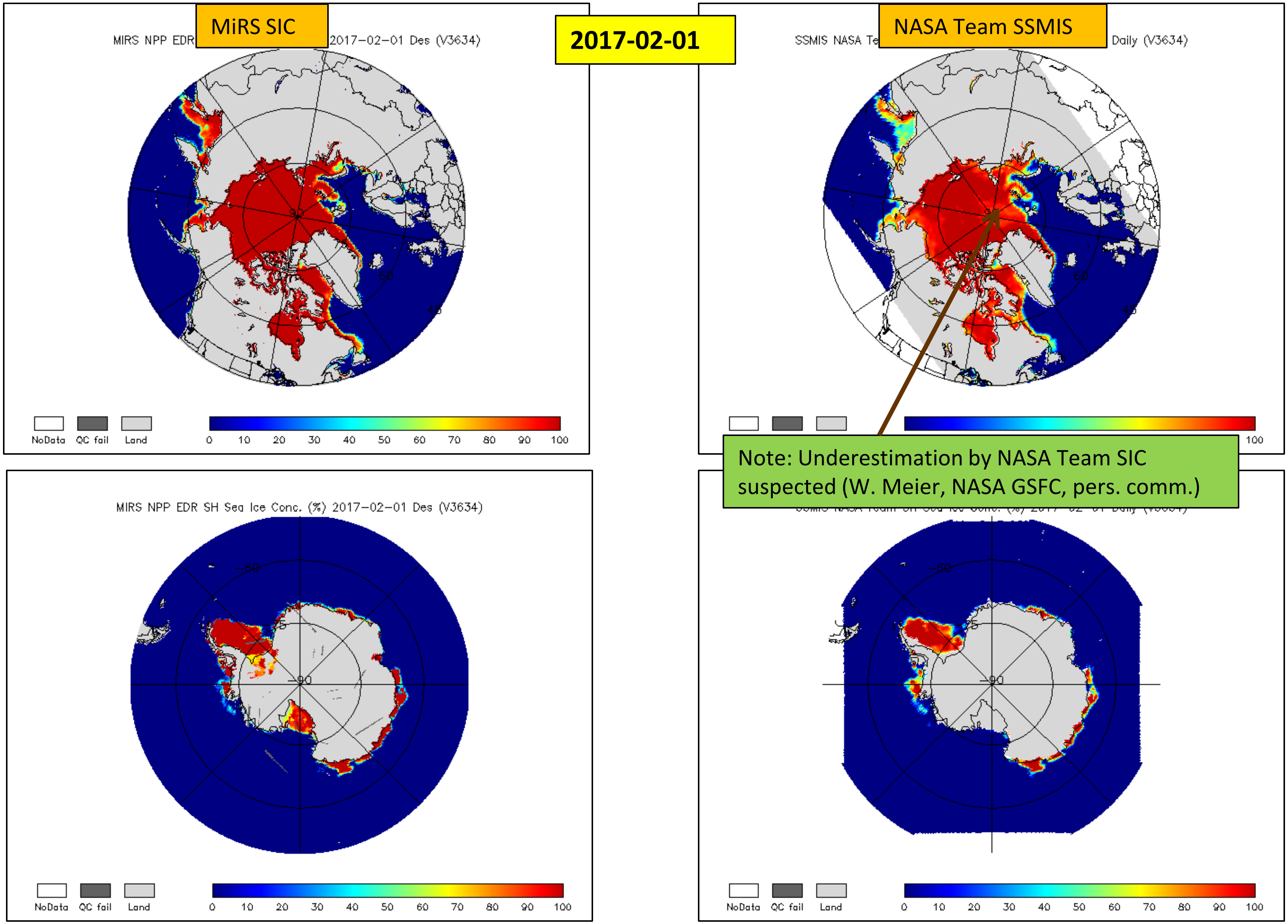


Note: Underestimation by NASA Team SIC suspected (W. Meier, NASA GSFC, pers. comm.)

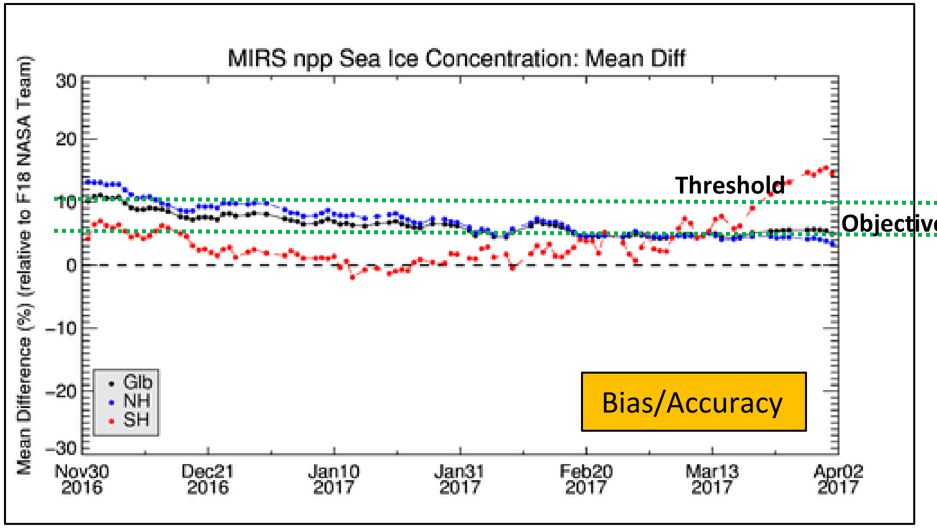


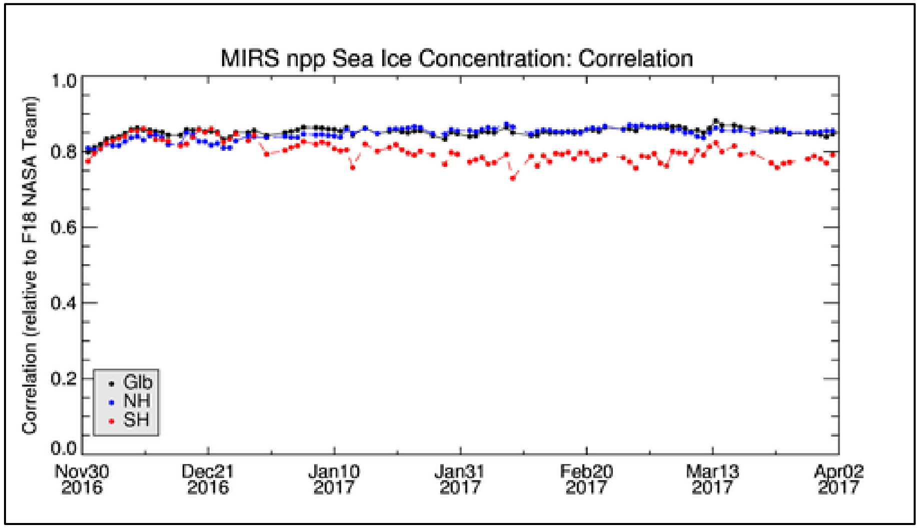


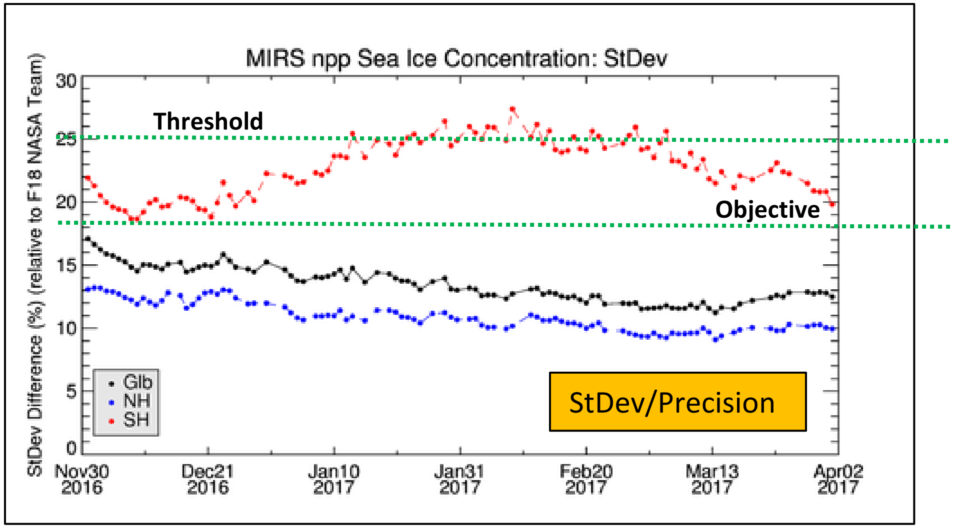
Sea Ice Concentration Performance: Comparison with NASA Team NRT SSMIS (F18)

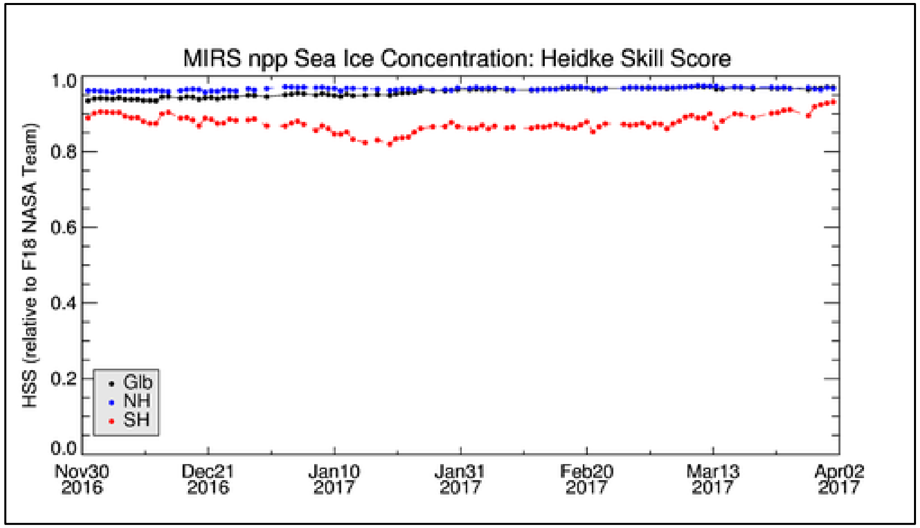


Sea Ice Concentration Performance (Dec 2016-Apr 2017): Daily Comparison with NASA Team NRT SSMIS (F18)

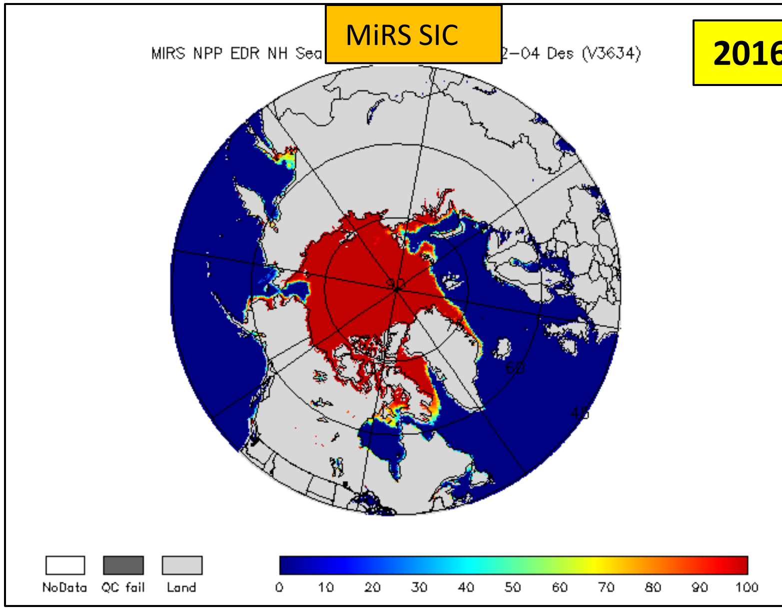


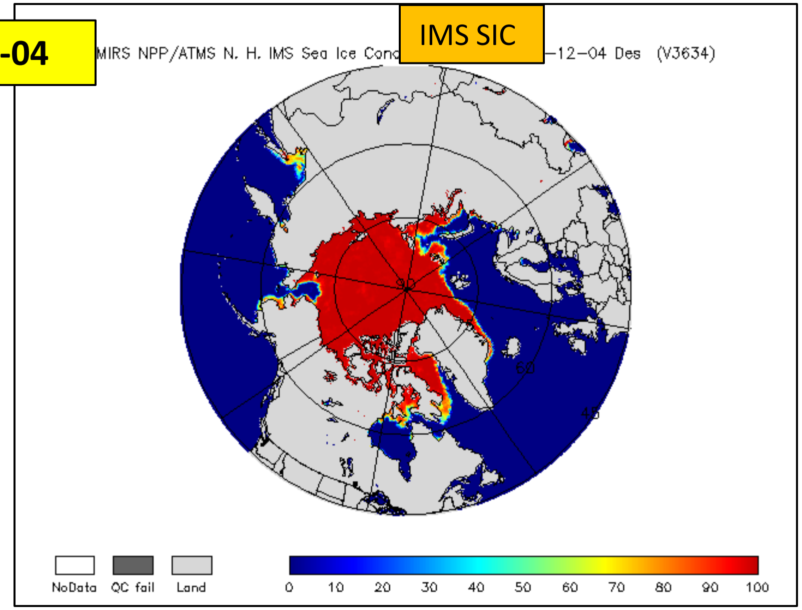


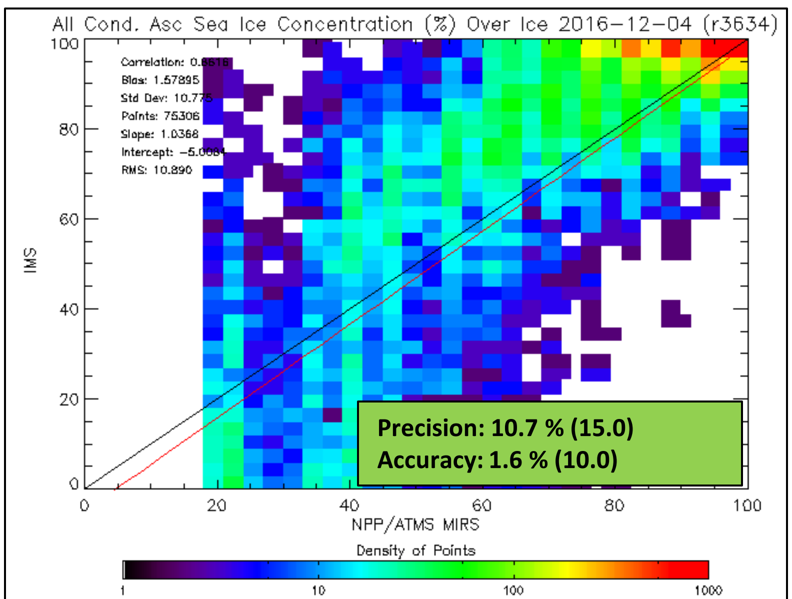


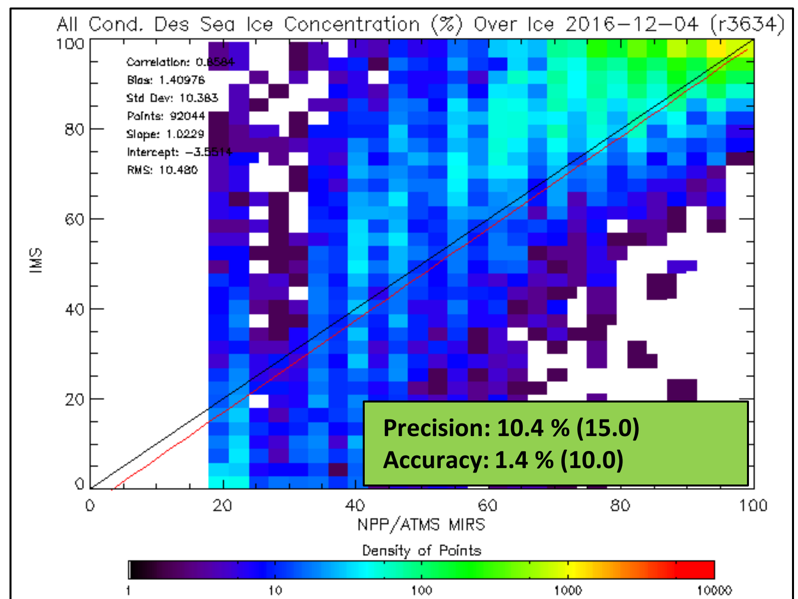


Sea Ice Concentration Performance: Comparison with IMS 4-km Analysis



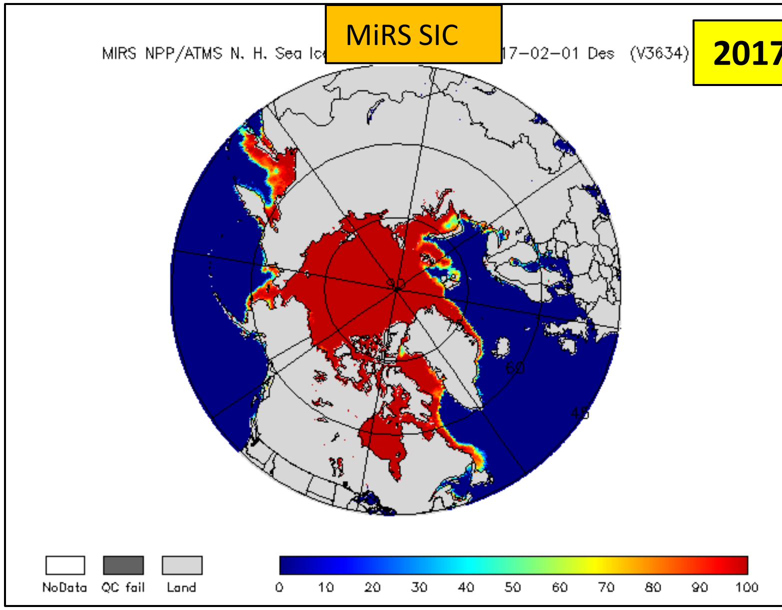


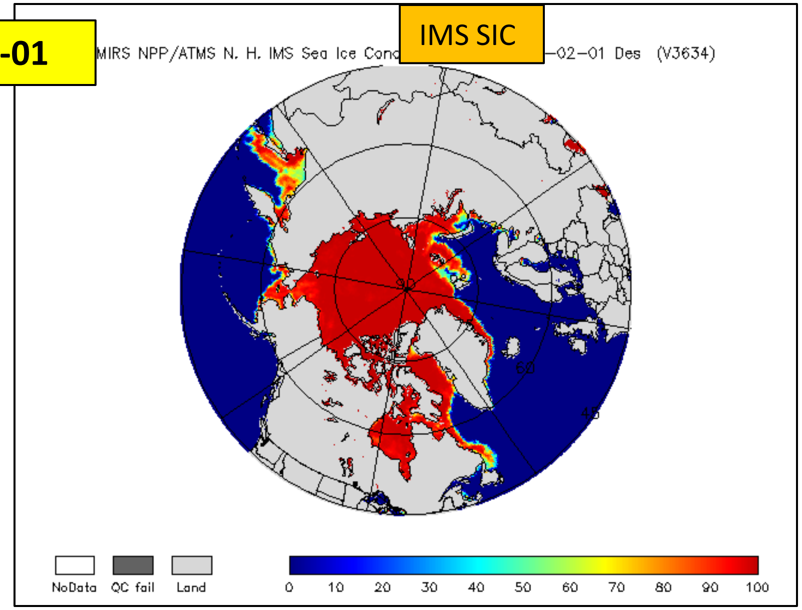


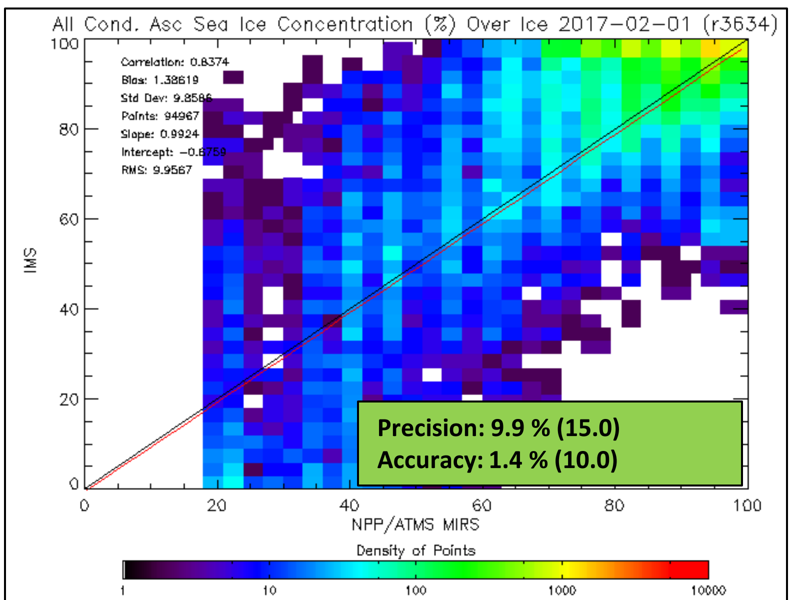


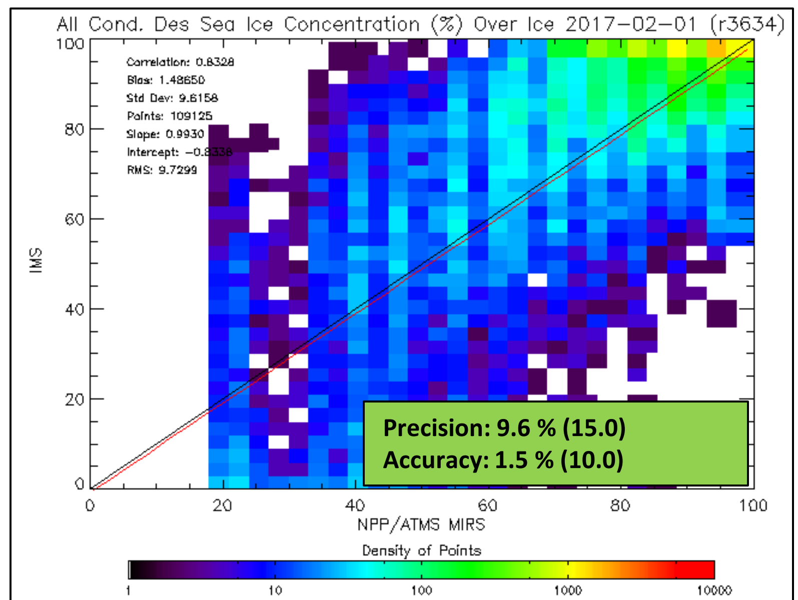
Sea Ice Concentration Performance: Comparison with IMS 4-km Analysis

2017-02-01









Validation Results Summary: Sea Ice Concentration

Date(s)	Bias/ Accuracy (%)	StDev/ Precision (%)	Reference	Comment
Threshold Requirement	**10.0**	**25.0**		
Objective	**5.0**	**18.0**		
Jan 2012-Nov 2013 (Glb)	[2.0 - 9.0]	[12.0 - 22.0]	F17 SSMIS NASA Team (NRT)	Performance degraded June-Sept (NH ice melt)
Dec 2016-Mar 2017 (Glb)	[5.0 - 10.0]	[12.0 - 17.0]	F18 SSMIS NASA Team (NRT)	
Dec 2016-Mar 2017 (NH)	[5.0 - 13.0]	[10.0 - 13.0]	F18 SSMIS NASA Team (NRT)	Exceeds bias thresh requirement in Fall season
Dec 2016-Mar 2017 (SH)	[0.0 - 8.0]	[19.0 - 27.0]	F18 SSMIS NASA Team (NRT)	SH warm season performance degraded (ice melt)
2016-12-04 (NH)	1.5	10.5	NIC IMS	
2017-02-01 (NH)	1.5	9.8	NIC IMS	

Meets threshold

Meets objective

MiRS SIC Performance vs. SSMIS NASA Team and NIC IMS
- Official reference is SSMIS NASA Team
- Most threshold requirements, and many objective requirements are met (degraded performance in warm season due to ice melt)

Requirements and Validation Results: Snow Water Equivalent/Snow Cover

- Periodic collocations with JAXA AMSR2 (also comparisons with NIC IMS analyses)
- Official reference is JAXA AMSR2
- Requirements from JPSS-REQ-1002
- Maturity Level: Validated, Stage 3

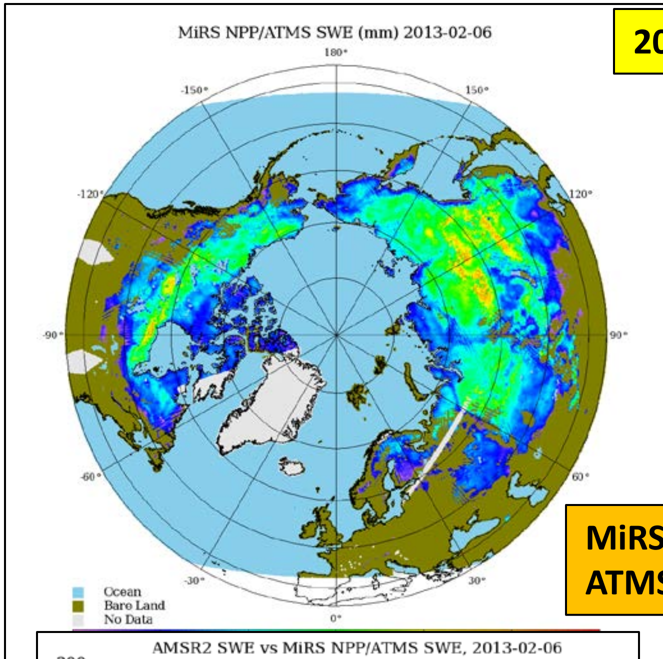
Product	SFC	EDR Attribute	MiRS	Threshold	Objective
SWE/SC (cm)	Land/ Snow	Bias/Accuracy (cm)	**[-1.2 - 2.0]**	**3.0**	**2.0**
		STDV/Precision (cm)	**[2.1 - 4.2]**	**6.0**	**5.0**
		Probability of Detection (%)	**[0.77 - 0.89]**	**0.80**	**0.90**
		False Alarm Rate (%)	**[0.04 - 0.14]**	**0.10**	**0.05**
		Heidke Skill Score	**[0.60 - 0.87]**	**0.55**	**0.65**

Meets threshold
Meets objective

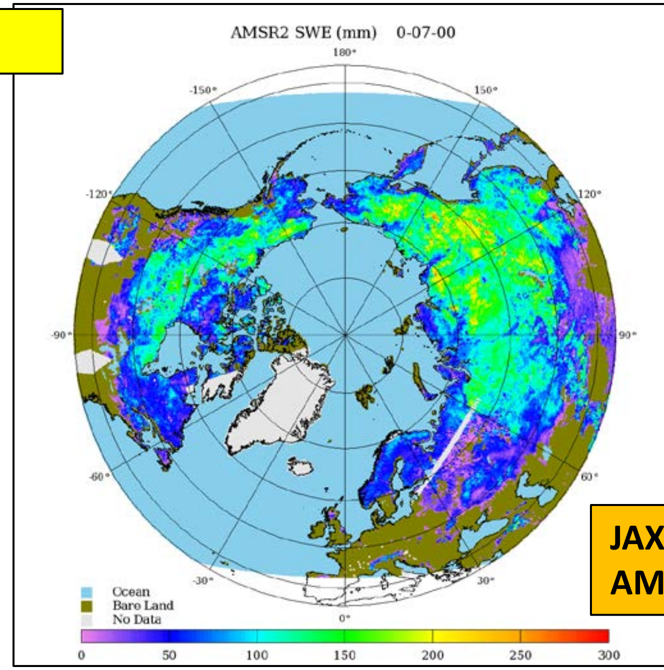
Attribute	Threshold	Validated
Geographic coverage	N. Hemisphere (cold season, Nov-Mar)	See table/figs
Vertical Coverage	Surface	
Horizontal Cell Size	15 km at nadir	
Mapping Uncertainty	N/A (reflects SDR characteristics)	
Measurement Range	1.2 – 26.5 cm	
Measurement Accuracy	See tables	
Measurement Precision	See tables	

Snow Water Equivalent Performance: Comparison with JAXA AMSR2

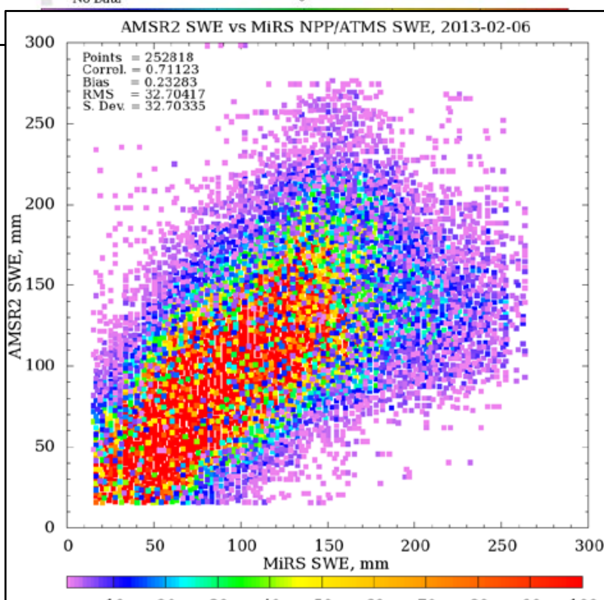
2013-02-06



MiRS ATMS



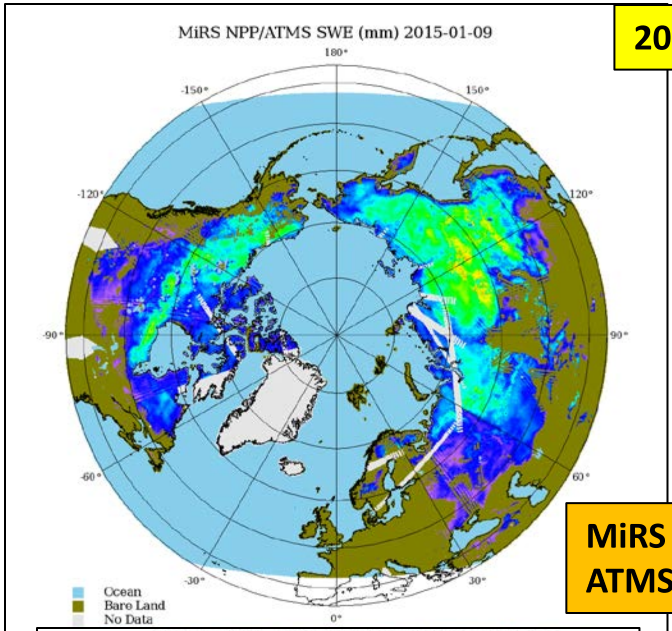
JAXA AMSR2



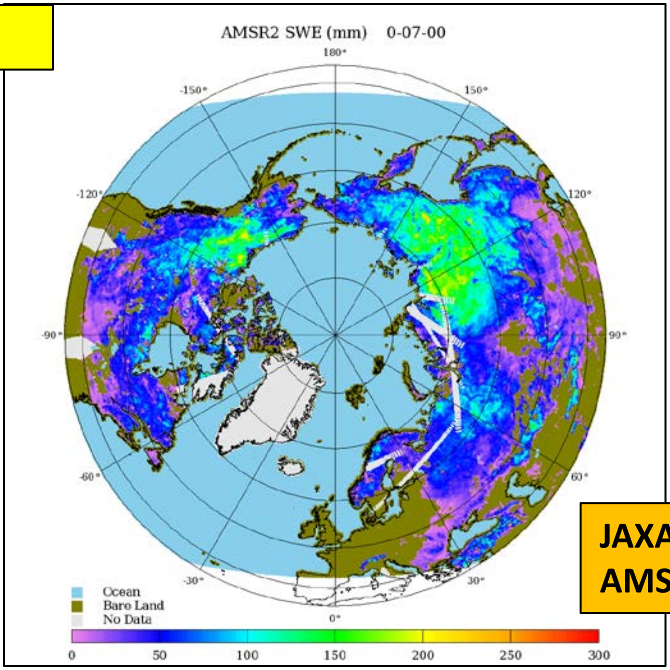
Precision: 3.3 cm (6.0)
Accuracy: 0.0 cm (3.0)
Prob. Detection: 0.84 (0.80)
False Alarm Ratio: 0.04 (0.10)
Heidke Skill Score: 0.60 (0.55)

Snow Water Equivalent Performance: Comparison with JAXA AMSR2

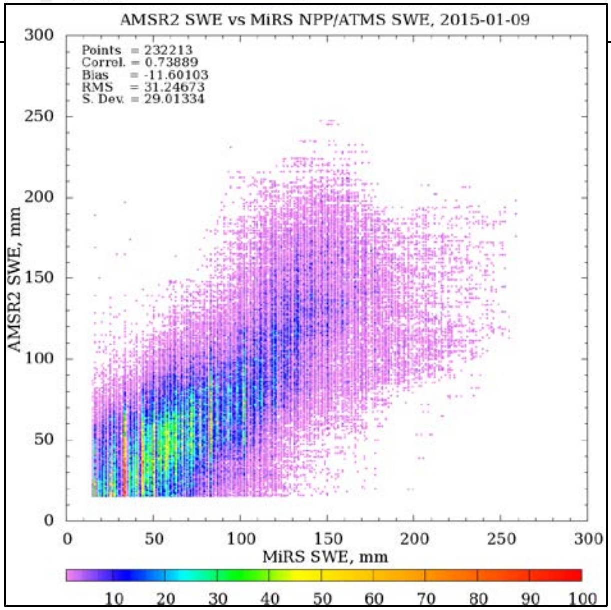
2015-01-09



MiRS ATMS



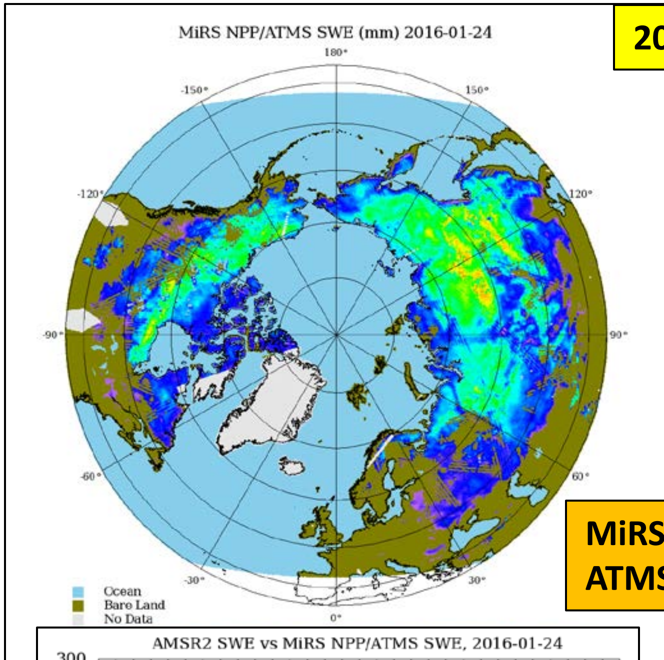
JAXA AMSR2



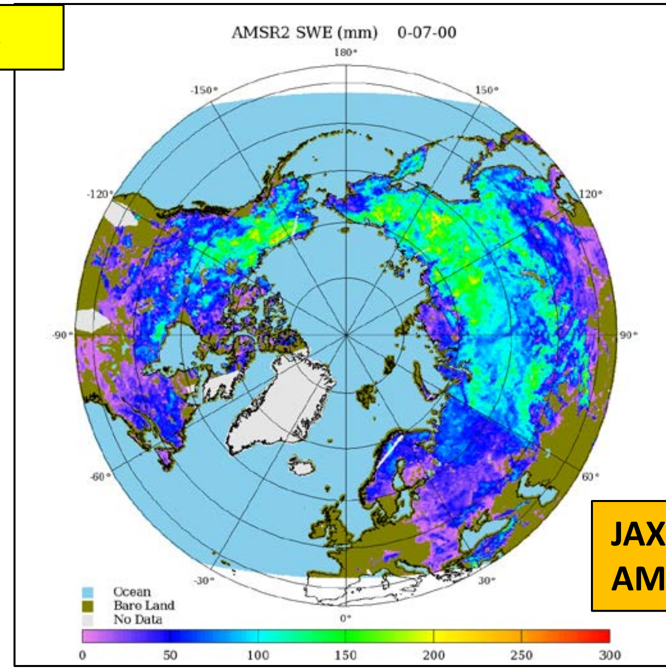
Precision: 2.9 cm (6.0)
Accuracy: -1.2 cm (3.0)
Prob. Detection: 0.85 (0.80)
False Alarm Ratio: 0.06 (0.10)
Heidke Skill Score: 0.62 (0.55)

Snow Water Equivalent Performance: Comparison with JAXA AMSR2

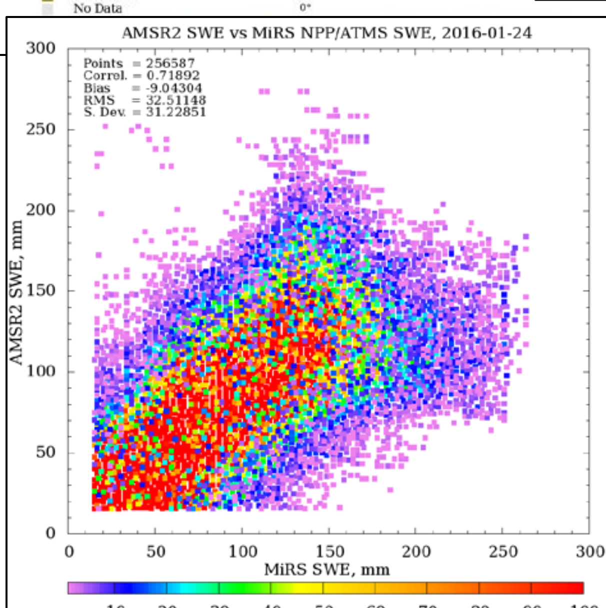
2016-01-24



MiRS ATMS



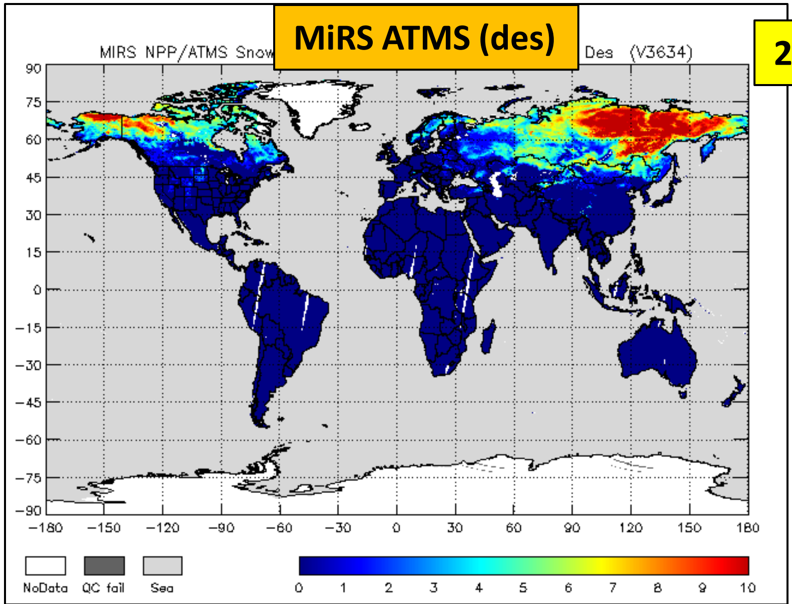
JAXA AMSR2

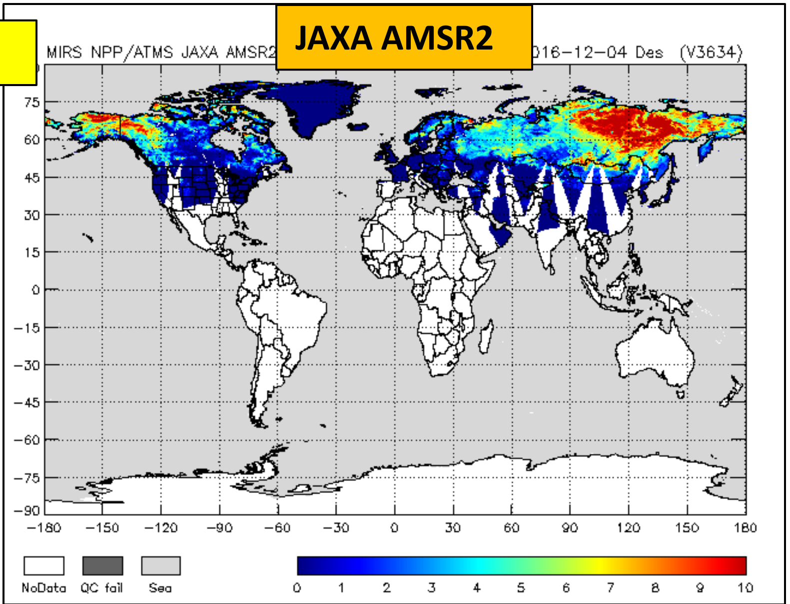


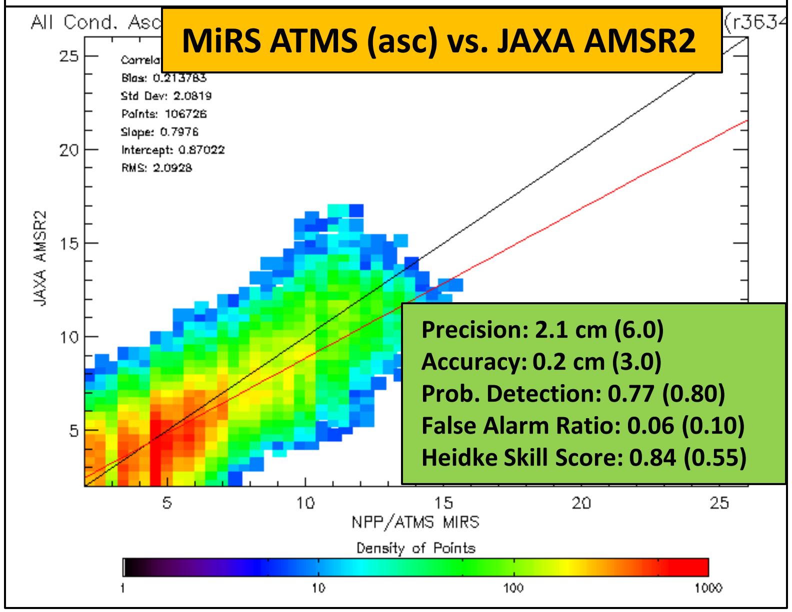
Precision: 3.1 cm (6.0)
Accuracy: -0.9 cm (3.0)
Prob. Detection: 0.86 (0.80)
False Alarm Ratio: 0.05 (0.10)
Heidke Skill Score: 0.61 (0.55)

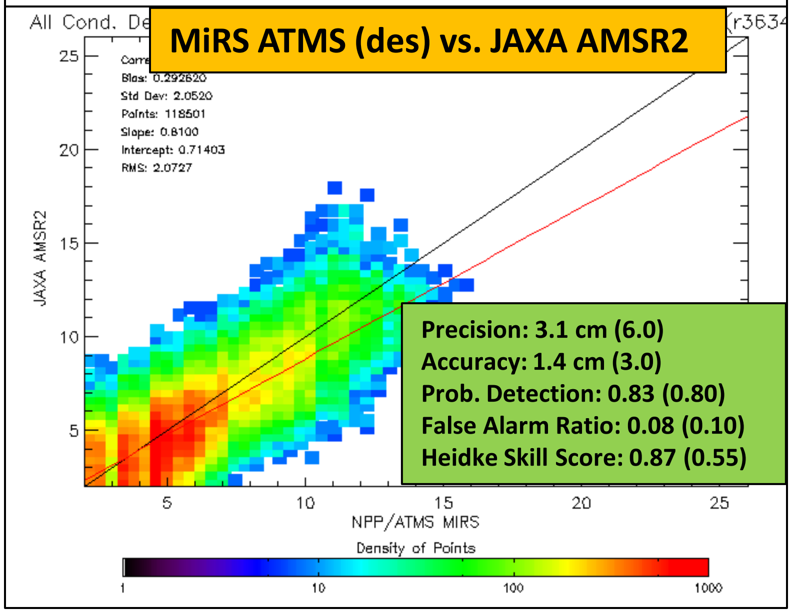
Snow Water Equivalent Performance: Comparison with JAXA AMSR2

2016-12-04





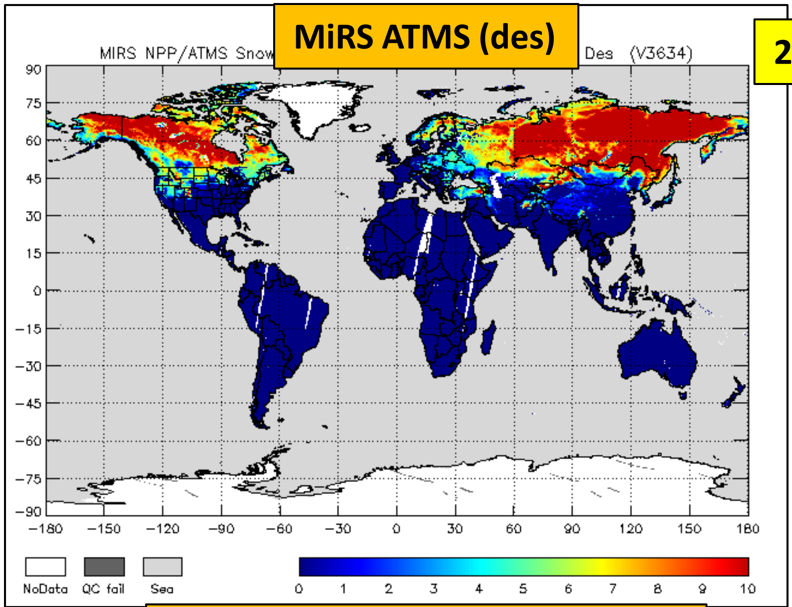




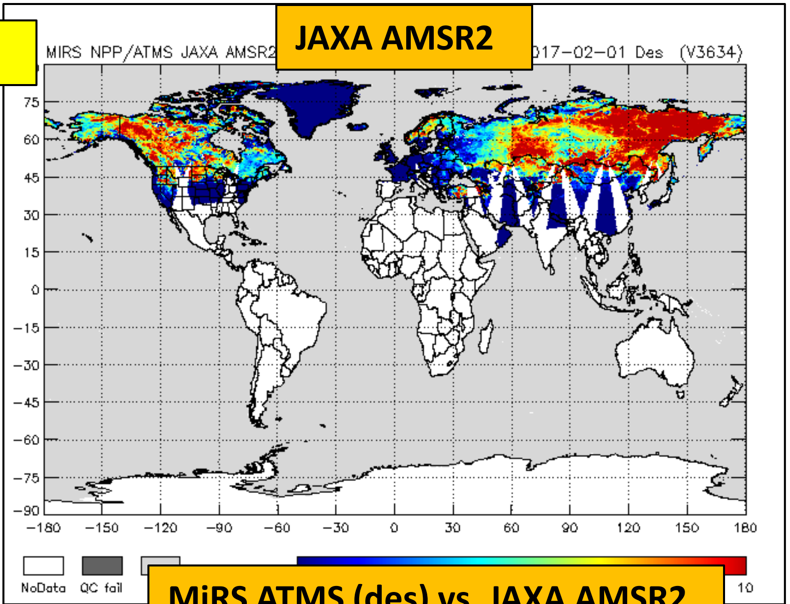
Snow Water Equivalent Performance: Comparison with JAXA AMSR2

2017-02-01

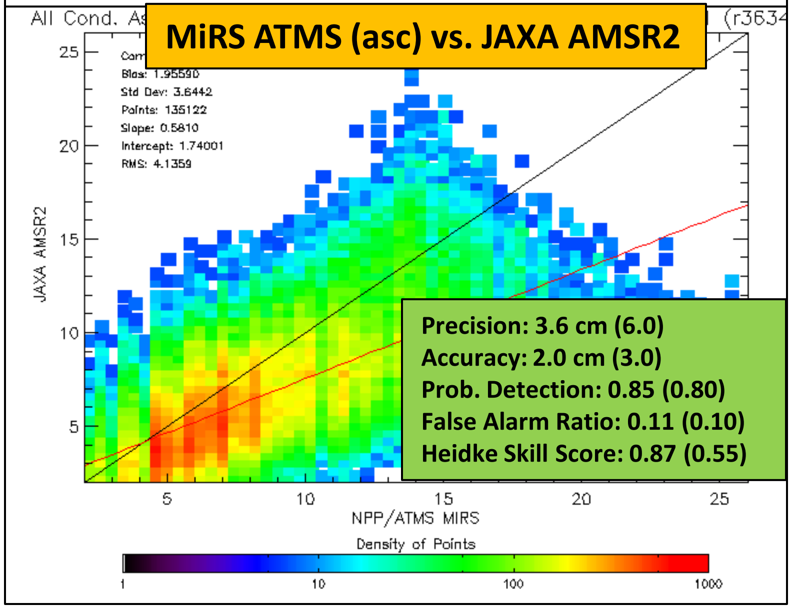
MiRS ATMS (des)



JAXA AMSR2

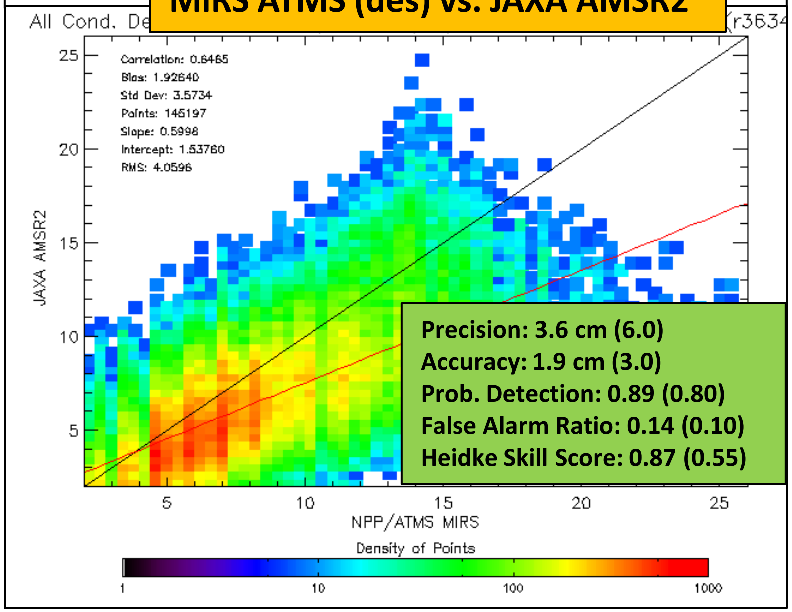


MiRS ATMS (asc) vs. JAXA AMSR2



Precision: 3.6 cm (6.0)
Accuracy: 2.0 cm (3.0)
Prob. Detection: 0.85 (0.80)
False Alarm Ratio: 0.11 (0.10)
Heidke Skill Score: 0.87 (0.55)

MiRS ATMS (des) vs. JAXA AMSR2



Precision: 3.6 cm (6.0)
Accuracy: 1.9 cm (3.0)
Prob. Detection: 0.89 (0.80)
False Alarm Ratio: 0.14 (0.10)
Heidke Skill Score: 0.87 (0.55)

Validation Results Summary: Snow Water Equivalent/Snow Cover

Date	Bias/ Accuracy	StDev/ Precision	POD	FAR	HSS	Reference
Threshold Requirement	**3.0**	**6.0**	**0.80**	**0.10**	**0.55**	
Objective	**2.0**	**5.0**	**0.90**	**0.05**	**0.65**	
2013-02-06	0.0	3.3	0.84	0.04	0.60	JAXA AMSR2
2015-01-09	-1.2	2.9	0.85	0.06	0.62	JAXA AMSR2
2016-01-24	-0.9	3.1	0.86	0.05	0.61	JAXA AMSR2
2016-12-04	[0.2 - 1.4]	[2.1 - 3.1]	[0.77 - 0.83]	[0.06 - 0.08]	[0.84 - 0.87]	JAXA AMSR2
2017-02-01	[1.9 - 2.0]	3.6	[0.85 - 0.89]	[0.11 - 0.14]	[0.87 - 0.87]	JAXA AMSR2

Meets threshold

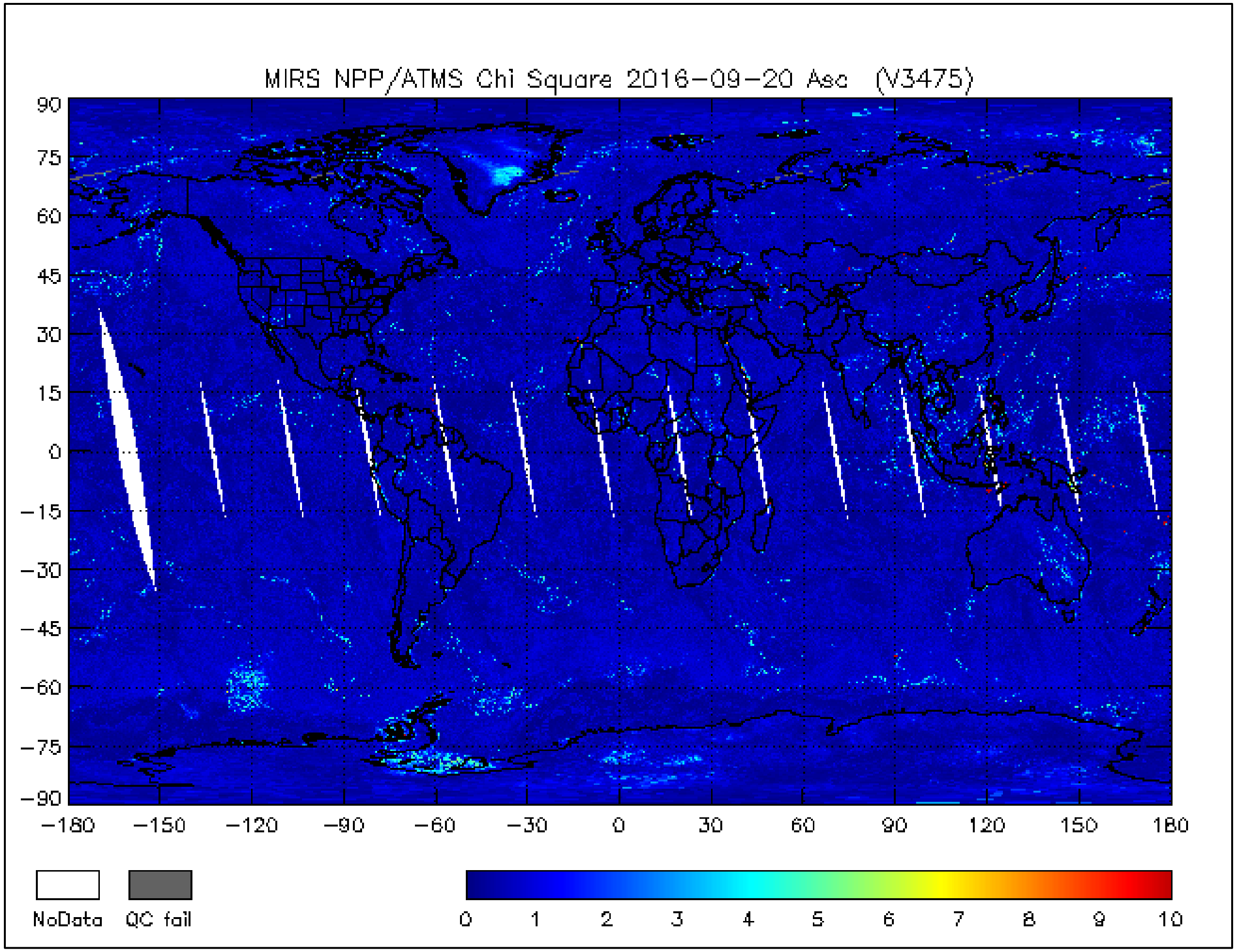
Meets objective

MiRS SWE/Snow cover Performance vs. JAXA/AMSR2 and NIC IMS

- Official reference is JAXA/AMSR2
- Most threshold requirements, and many objective requirements are met (except FAR for select cases)

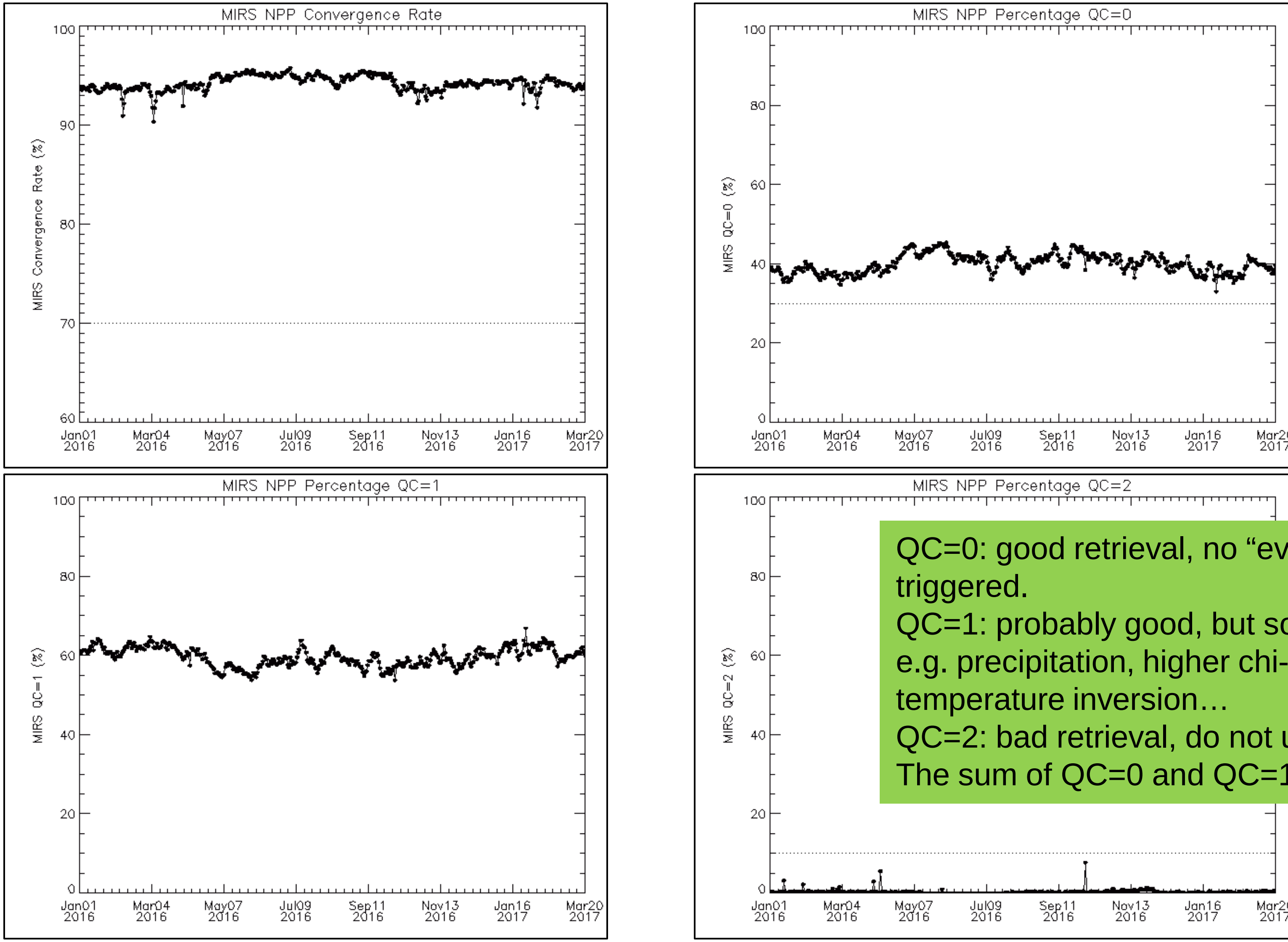
Validation Results: Chi-Square Convergence Metric

- MiRS SNPP/ATMS Chi-square (convergence) for 20 September 2016



Validation Results: QC flagging

MiRS SNPP/ATMS Convergence and QC flags: 1 Jan 2016 – 20 March 2017



QC=0: good retrieval, no “events” triggered.
QC=1: probably good, but some event, e.g. precipitation, higher chi-square, temperature inversion…
QC=2: bad retrieval, do not use.
The sum of QC=0 and QC=1 is > 90%

Error Budget: LSE, LST, CLW, SIC, SWE/SCE

Compare analysis/validation results against requirements, present as a table. Error budget limitations should be explained. Describe prospects for overcoming error budget limitations with future improvement of the algorithm, test data, and error analysis methodology.

Attribute Analyzed	L1RD Threshold Accuracy/Precision	Analysis/Validation Result	Error Summary	Support Artifacts
LSE	See Slide 22	Meets all requirements	See Slide 22	
LST	See Slide 29	Meets all requirements	See Slide 29	
CLW	See Slide 40	Meets all requirements	See Slide 40	
SIC	See Slide 48	Meets all requirements	See Slide 48	
SWE/SCE	See Slide 55	Meets all requirements	See Slide 55	

Identification of Processing Environment

- Algorithm version: v11.1 (delivered to NDE September 2015; v11.2 delivered to OSPO for all other satellites August 2016)
- All static ancillary files needed by algorithm are contained within the DAP
- All validation conducted in STAR:
  - Linux servers running f90, IDL, bash, C/C++, libraries (hdf5 and netCDF4)
  - Many codes are run every day as part of regular validation and assessment

Users and User Feedback

- MIRS is mature algorithm. In operations since 2007, now running 4 AMSUA-MHS, 2 SSMIS, GPM/GMI, MT/SAPHIR, and since 2013 for SNPP/ATMS. Performance is very stable. Many users in research and operations:
  - NOAA NWS: CPC, NHC, TPC, SPC, WFOs
  - + more than 30 users (e.g. NASA/MSFC, JPL, CSU/CIRA, JMA, UKMO, UW/SSEC (e.g. MIMIC TPW), UMD, CMA, Taiwan Weather Bureau, CPTEC/Brazil, Max Planck Inst./Hamburg, U.Wisc/SSEC, ISRO,...)
- Users:
  - CLW, LWP, T and WV: CIRA TC group for operational TC intensity algorithm
  - SWE: currently used in IMS snow/ice analyses at the National Ice Center
  - SWE: potential use by NCAR in JPSS-PG project with National Water Model
  - SIC: Naval Oceanographic Office evaluation found JAXA AMSR2 product better fit due to higher spatial resolution compared to ATMS.
- Feedback from users
  - provide feedback, identify issues, algorithm team has issued several bug fixes/patches in past 3 years

- Downstream product list: e.g. Tailored products (OSPO can provide details), TC Intensity Estimates (sent to NHC)

- No known issues in data dependencies for downstream products

MiRS CLW: Use in TC Intensity Algorithm (CIRA and NHC)

- From Galina Chirokova (CIRA):

Chris,

our TC intensity and structure algorithm is using CLW in several ways:

1. if CLW > 0.3 a correction is applied to T retrieval

2. CLW was used to derive that correction

3. CLW is also used for ice correction

4. CLW is a predictor to estimate final vmax, pmin, r30,r50, and r64.

I attached 2 papers that describe that algorithm. The papers were written about the original algorithm developed for the statistical retrievals, but the CLW is used in a similar way in the updated algorithm that uses MIRS retrievals. The use of CLW for (1) CLW correction and (2) ice correction is described in the 2004 paper in the Appendix (starts on page 294)

Also, I am writing a paper about the verification of the MIRS and NUCAPS soundings in the TC environment, and I might look at the additional uses of CLW, LWP, and other integrated quantities.

MiRS SWE: Use within NIC IMS

- Poster presented by S. Helfrich (NOAA) at Eastern Snow Conference, 2016:

Evaluation of Algorithm Alternatives for Blended Snow Depth in the IMS

Sean R. Helfrich[1], Cezar Kongoli, Lawrence Vulis[3], Milton Martinez[4], Christopher Grassotti[2], and Naresh Devineni[3]

[1]NOAA/NESDIS/OSPO/NIC—NOAA NSOF Building, 4231 Suitland Road, Suitland, MD 20746, USA
[2]NOAA/NESDIS/STAR 5830 University Research Court, College Park, MD 20740, USA
[3]Environmental Engineering, City College of New York, New York, NY 10031, USA
[4]University of Puerto Rico, Mayaguez Campus, Mayaguez, PR 00680

Since December 2014, the Interactive Multisensor Snow and Ice Mapping System (IMS) has generated snow depth estimates over the Northern Hemisphere at a 4 km resolution. The algorithm applies optimal interpolation with an elevation nudging technique to generate a snow depth over locations within 800 km of the snow observing site. This data is further blended using a weighting schema with passive microwave based estimates from the Advanced Technology Microwave Sounder (ATMS) instrument and a snow depth elevation climatology. Improvements in the blended snow depth were sought to improve performance. Several methods were tested to improve snow depth estimates by refining microwave estimate of snow depth, promoting application of prior day estimates, developing regional snow depth/elevation relationships, altering the source of snow depth in-situ observations, and adjusting the weighting schema based on elevation ranges. Testing of these algorithm enhancements are presented in this poster to demonstrate the methodology of the enhancements and provide an evaluation of algorithm performance compared to the current algorithm baseline.

Documentation

Science Maturity Check List	Yes ?
Readme for Data Product Users	Yes
Algorithm Theoretical Basis Document (ATBD)	Yes
Algorithm Calibration/Validation Plan	Yes
(External/Internal) Users Manual	Yes
System Maintenance Manual (for ESPC products)	Yes
Peer Reviewed Publications (Demonstrates algorithm is independently reviewed)	Yes Boukabara et al. (2011, 2013): All EDRs Iturbide-Sanchez et al. (2011): Rain rate Ferraro et al. (2017): Rain rate Wang et al. (2017): Emissivity
Regular Validation Reports (at least annually) (Demonstrates long-term performance of the algorithm)	In progress

ATBD, External/Internal Users Manual, System Maintenance Manual available upon request, on Google Drive, and as part of DAP

Conclusion

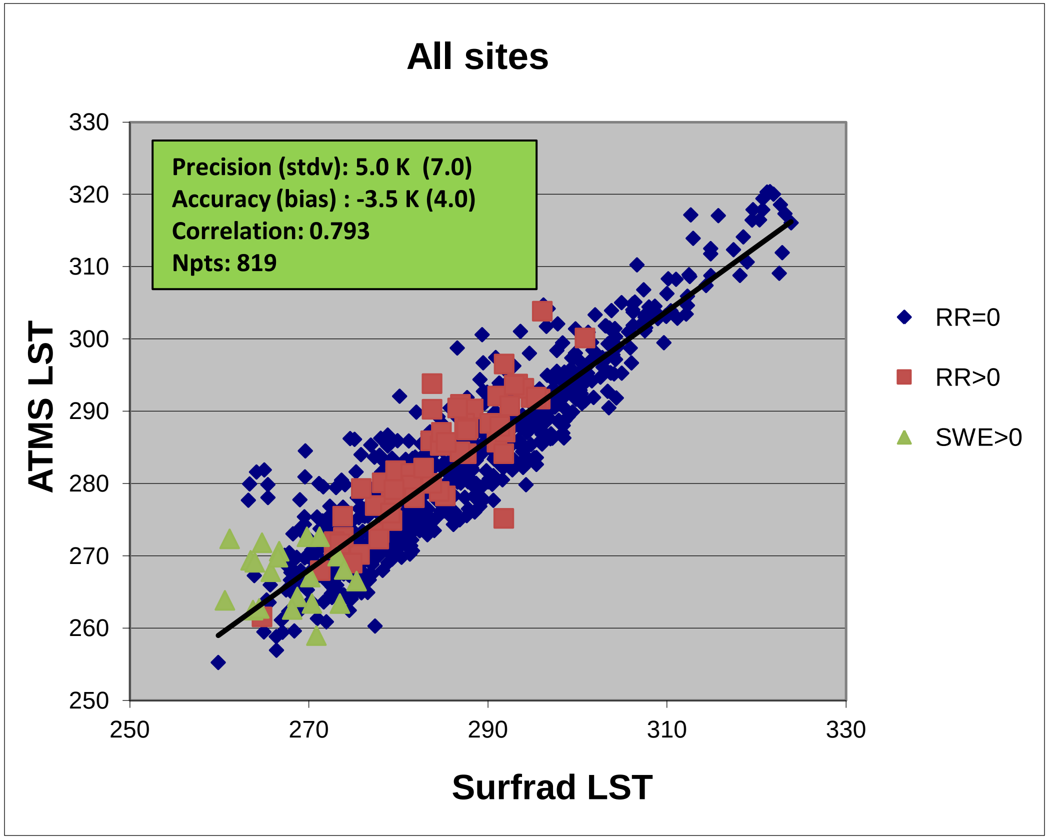
- Cal/Val results summary:
  - LSE, LST, SIC, SWE/SC, CLW are considered to be Validated, Level 3 Maturity
  - Performance in operations has been evaluated in STAR over more than one annual cycle, globally, over land and ocean, and in clear and cloudy conditions.
    - LSE: lack of direct measurement for reference; must be derived with assumptions; indirect validation also useful (i.e. do other surface/atmospheric parameters improve when LSE is changed?)
    - LST: both model and surface-based estimates have uncertainties; spatial representativeness an issue
    - CLW: direct global-scale measurements of CLW limited; comparisons with other satellite estimates (e.g. GPROF) include uncertainty
    - SIC: Meeting requirements globally, seasonal dependence (e.g. warm season performance degradation)
    - SWE/SC: only satellites provide regular global coverage; increased uncertainty for products if SD->SWE is required (e.g. NIC IMS).

Path Forward

- Planned further improvements
  - Next 3-6 months: Extension to JPSS-1/ATMS and preliminary delivery prior to Fall 2017 launch (v11.3)
  - Future Improvements:
    - **Snowfall rate integration (pending approval)**
    - **Hydrometeors (CLW over land for light rain detection)**
    - **Snow cover/amount (vegetation correction)**
    - Air mass-dependent bias corrections
    - Rainy condition sounding (update a priori constraints)
    - Hydrometeors (precharacterization of precip type, improvements to CRTM i.e. scattering, particle size/shape distribution in CRTM)
    - ATMS Imagery product
    - Work with EMC and/or JCSDA on LSE assimilation
    - Applications/user feedback
- Planned Cal/Val activities
  - All cronjobs that perform daily monitoring for SNPP are being extended to JPSS-1
  - Additional tools being developed for SIC/SC and SWE.

Backup Slides

Land Surface Temperature Performance: Comparison with SURFRAD measurements



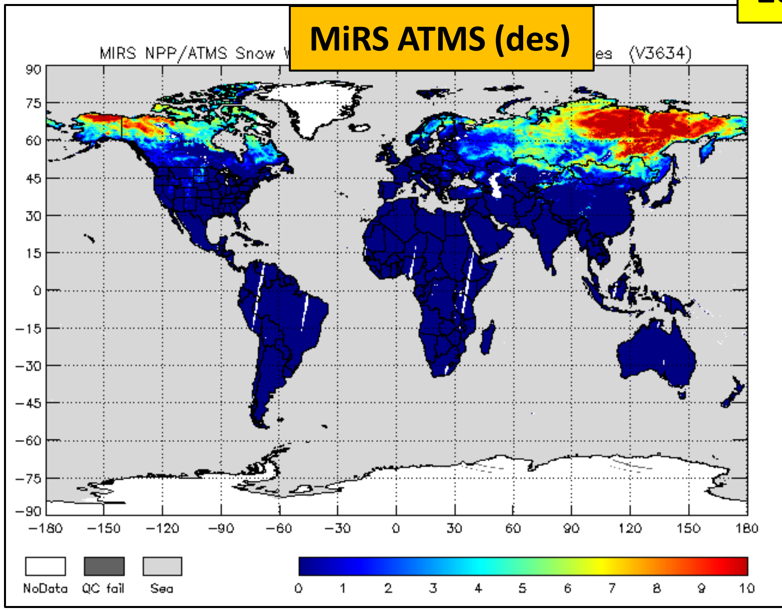
GEOLOCATION AND SURFACE TYPE OF THE SIX SURFRAD STATIONS

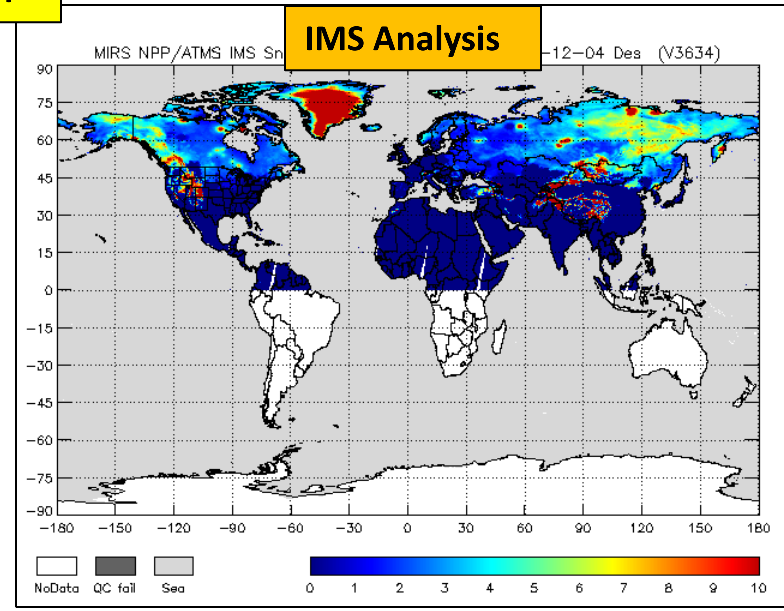
No.	Site Location	Lat(N)/Lon(W)	Surface Type*
1	Bondville, IL	40.05/88.37	Crop Land
2	Fort Peck, MT	48.31/105.10	Grass Land
3	Goodwin Creek, MS	34.25/89.87	Deciduous Forest
4	Table Mountain, CO	40.13/105.24	Crop Land
5	Desert Rock, NV	36.63/116.02	Open Shrub Land
6	Pennsylvania State University, PA	40.72/77.93	Mixed Forest

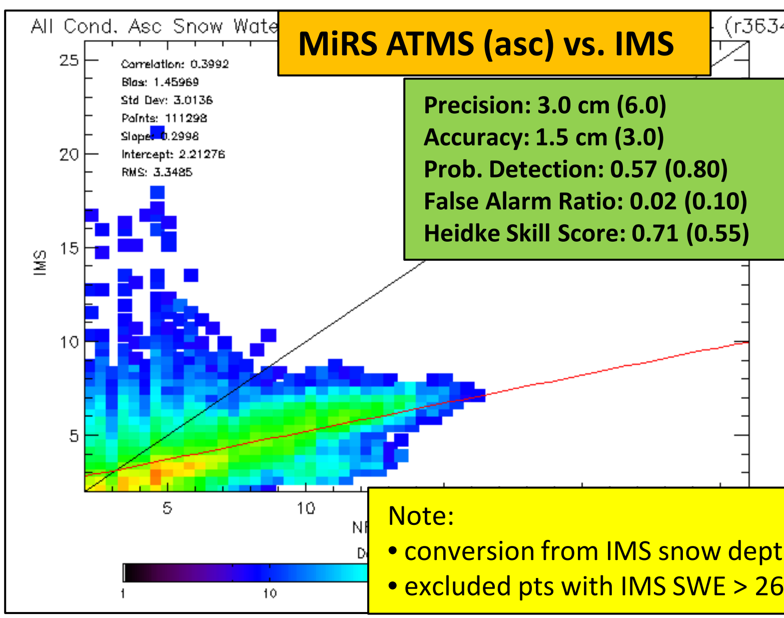
- Daily collocations at 6 sites between Sept-Dec 2012.
- SURFRAD surface IR radiometer based estimates
- Performance stratified by weather/surface conditions
- Uncertainty: not exactly the same as MW-based LST (e.g. IR vs. MW emissivity, penetration depth, IR conversion from flux to Tskin estimate, spatial representativeness)

Snow Water Equivalent: Comparison with IMS Analysis

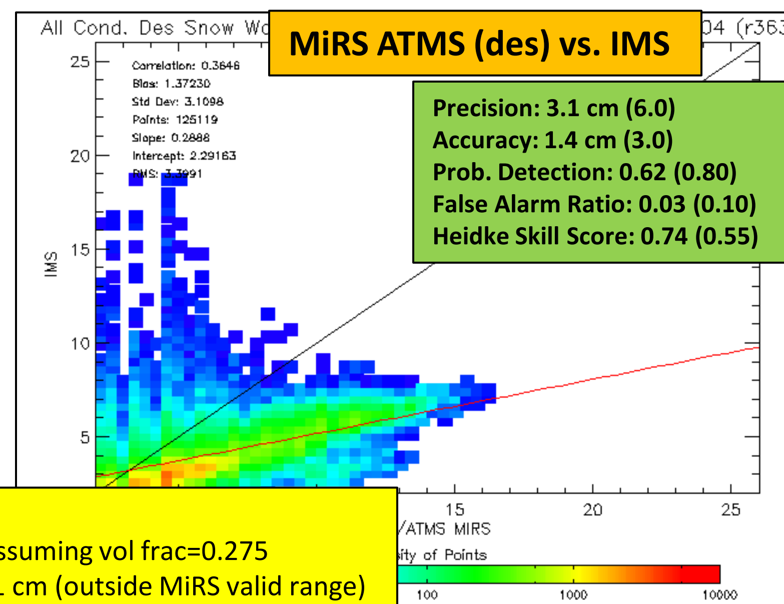
2016-12-04







Precision: 3.0 cm (6.0)
Accuracy: 1.5 cm (3.0)
Prob. Detection: 0.57 (0.80)
False Alarm Ratio: 0.02 (0.10)
Heidke Skill Score: 0.71 (0.55)



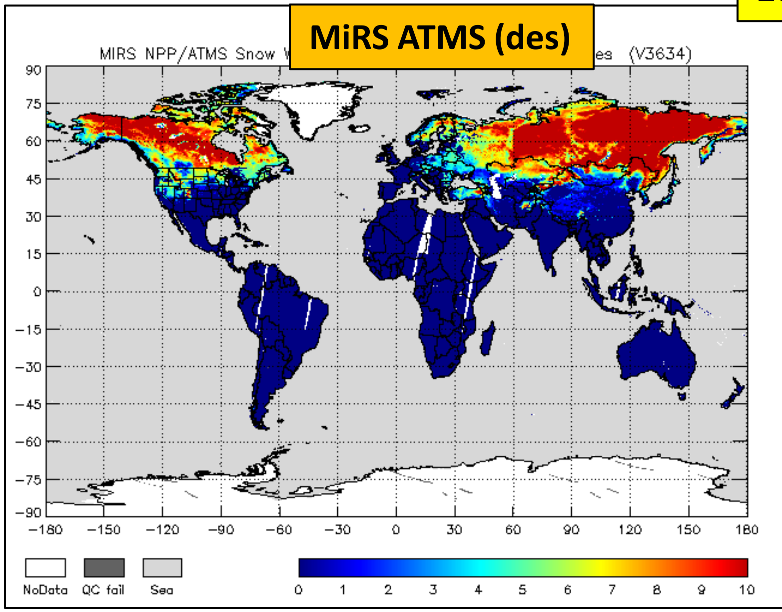
Precision: 3.1 cm (6.0)
Accuracy: 1.4 cm (3.0)
Prob. Detection: 0.62 (0.80)
False Alarm Ratio: 0.03 (0.10)
Heidke Skill Score: 0.74 (0.55)

Note:
- conversion from IMS snow depth to SWE assuming vol frac=0.275
- excluded pts with IMS SWE > 26 cm and < 1 cm (outside MiRS valid range)

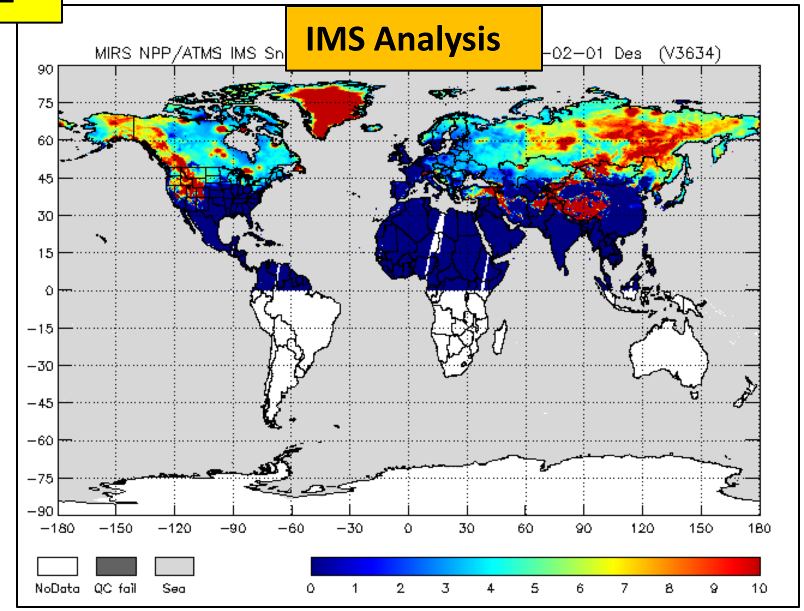
Snow Water Equivalent: Comparison with IMS Analysis

2017-02-01

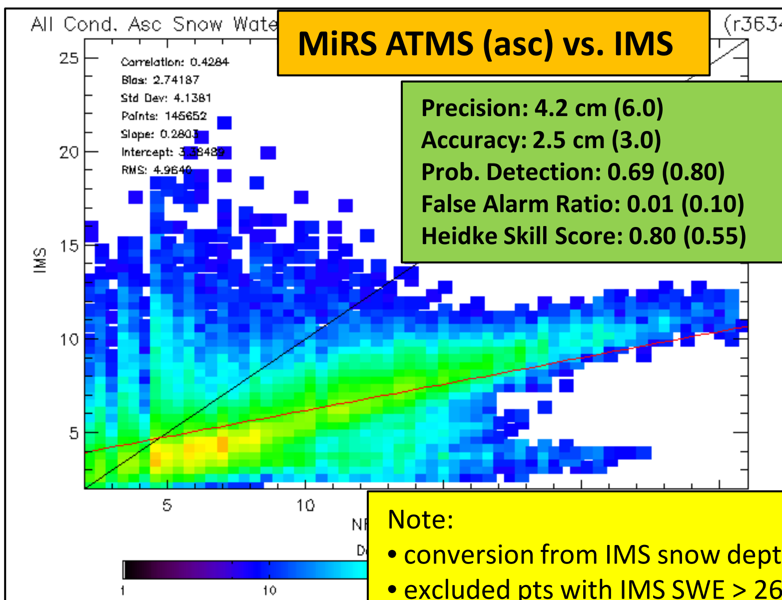
MiRS ATMS (des)



IMS Analysis

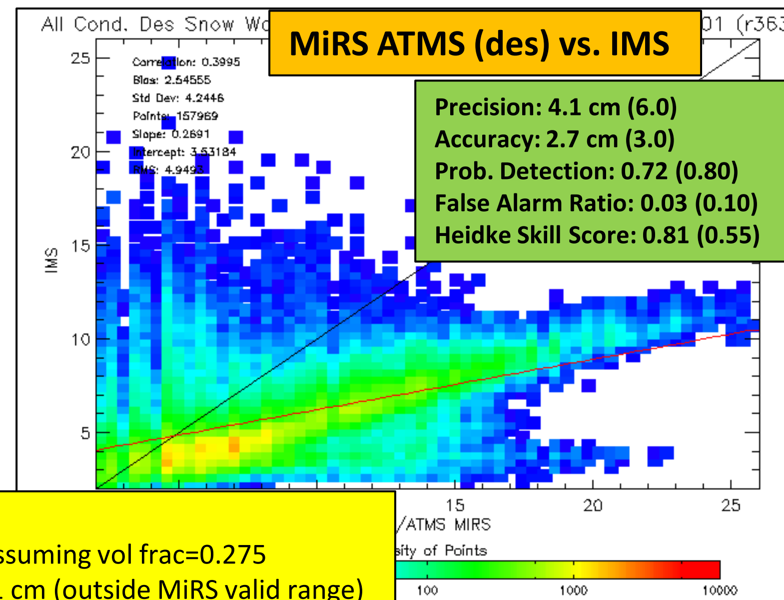


MiRS ATMS (asc) vs. IMS



Precision: 4.2 cm (6.0)
Accuracy: 2.5 cm (3.0)
Prob. Detection: 0.69 (0.80)
False Alarm Ratio: 0.01 (0.10)
Heidke Skill Score: 0.80 (0.55)

MiRS ATMS (des) vs. IMS



Precision: 4.1 cm (6.0)
Accuracy: 2.7 cm (3.0)
Prob. Detection: 0.72 (0.80)
False Alarm Ratio: 0.03 (0.10)
Heidke Skill Score: 0.81 (0.55)

Note:
- conversion from IMS snow depth to SWE assuming vol frac=0.275
- excluded pts with IMS SWE > 26 cm and < 1 cm (outside MiRS valid range)

Validation Results Summary: Snow Water Equivalent/Snow Cover

Date	Bias/ Accuracy	StDev/ Precision	POD	FAR	HSS	Reference
Threshold Requirement	**3.0**	**6.0**	**0.80**	**0.10**	**0.55**	
Objective	**2.0**	**5.0**	**0.90**	**0.05**	**0.65**	
2013-02-06	0.0	3.3	0.84	0.04	0.60	JAXA AMSR2
2015-01-09	-1.2	2.9	0.85	0.06	0.62	JAXA AMSR2
2016-01-24	-0.9	3.1	0.86	0.05	0.61	JAXA AMSR2
2016-12-04	[0.2-1.4]	[2.1-3.1]	[0.77-0.83]	[0.06-0.08]	[0.84-0.87]	JAXA AMSR2
2017-02-01	[1.9-2.0]	3.6	[0.85-0.89]	[0.11-0.14]	[0.87-0.87]	JAXA AMSR2
2016-12-04	[1.4-1.5]	[3.0-3.1]	[0.57-0.62]	[0.02-0.03]	[0.71-0.74]	NIC IMS
2017-02-01	[2.5-2.7]	[4.1-4.2]	[0.85-0.89]	[0.11-0.14]	[0.87-0.87]	NIC IMS

Meets threshold
Meets objective

MiRS SWE/Snow cover Performance vs. JAXA/AMSR2 and NIC IMS

- Official reference is JAXA/AMSR2
- Most threshold requirements, and many objective requirements are met (except POD and FAR for select cases)