MICROWAVE INTEGRATED RETRIEVAL SYSTEM (MIRS): PRODUCTS OVERVIEW AND POTENTIAL IMPROVEMENTS
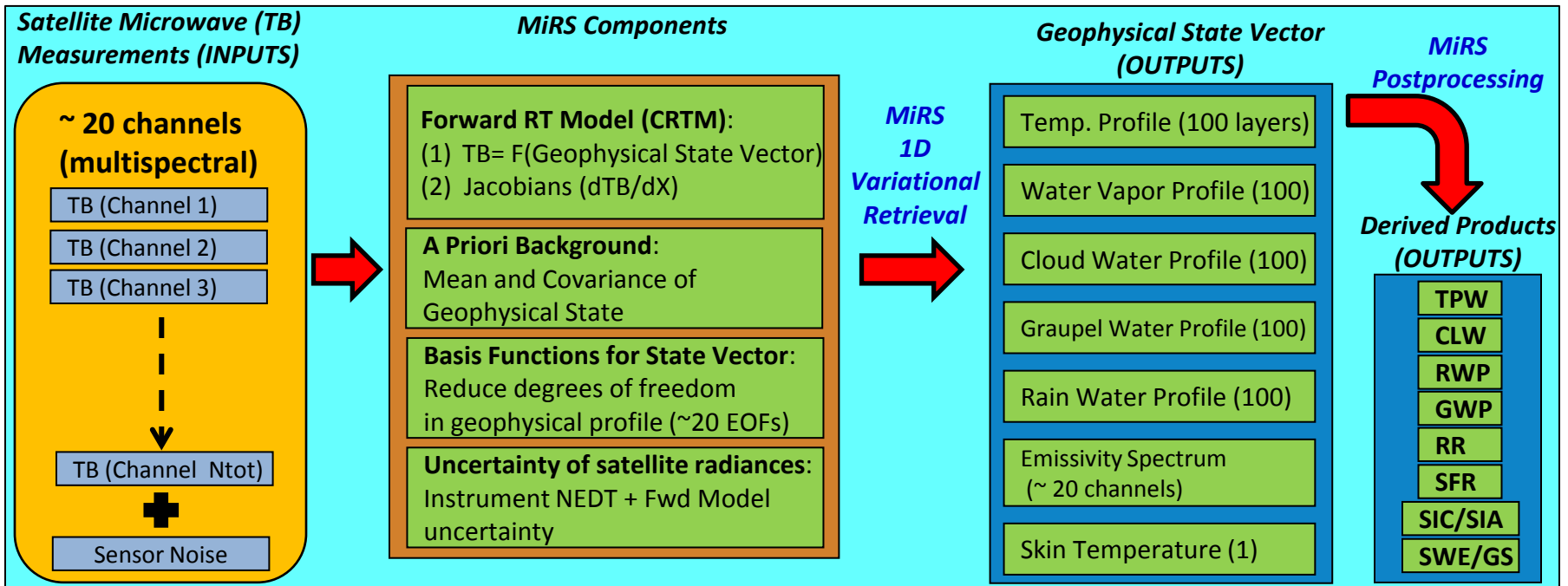
Chris Grassotti
NOAA/NESDIS/STAR
301-683-3573
christopher.grassotti@noaa.gov
MiRS Team
10 August 2016

Outline

- Team Members

- Algorithm Overview

- S-NPP Product(s) Overview
  - T, WV Sounding (+ rainy condition sounding improvement)
  - Hydrometeors
  - Snow Water Equivalent Potential Improvements

- JPSS-1 Readiness
  - Algorithm changes
  - Pre-launch activities
  - Post-launch cal/val

- Summary and Path Forward

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/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

Algorithm Overview

Satellite Microwave (TB) Measurements (INPUTS)

~ 20 channels (multispectral)
- TB (Channel 1)
- TB (Channel 2)
- TB (Channel 3)
- ⋮
- TB (Channel Ntot)
- **+**
- Sensor Noise

MiRS Components

Forward RT Model (CRTM):
(1) TB= F(Geophysical State Vector)
(2) Jacobians (dTB/dX)

A Priori Background:
Mean and Covariance of Geophysical State

Basis Functions for State Vector:
Reduce degrees of freedom in geophysical profile (~20 EOFs)

Uncertainty of satellite radiances:
Instrument NEDT + Fwd Model uncertainty

MiRS 1D Variational Retrieval

Geophysical State Vector (OUTPUTS)
- Temp. Profile (100 layers)
- Water Vapor Profile (100)
- Cloud Water Profile (100)
- Graupel Water Profile (100)
- Rain Water Profile (100)
- Emissivity Spectrum (~ 20 channels)
- Skin Temperature (1)

MiRS Postprocessing

Derived Products (OUTPUTS)
- TPW
- CLW
- RWP
- GWP
- RR
- SFR
- SIC/SIA
- SWE/GS

- 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 in 2017.
- At OSPO: Initial capability delivered in 2007. Running on N18, N19, MetopA, MetopB, F17, F18, Megha-Tropiques/SAPHIR.
- Recently extended to GPM/GMI [and F19] -> V11.2
- Experimental versions for: TRMM/TMI, Aqua/AMSRE, GCOM-W/AMSR2
- Ancillary data: Currently not required for ATMS (V11.2). But addition of SFR in V11.3 will require GFS
- External Users/Applications: **(1) CIRA TC Analysis/Forecasting (G. Chirokova), (2) MIMIC TPW Animations (T. Wimmers), (3) Blended, Layered PW (J. Forsythe)**, CSPP (Direct Broadcast), others…

MiRS Version History/Product List

Version	Feature	Delivery Date(s)
8.0	SNPP/ATMS to NDE	November 2012
9.0	Extension to Metop-B High Resolution	January 2013
9.1	Added QC DAP capability; netCDF metadata modifications	May 2013
9.2	**Minor netCDF filename convention changes; bug fixes, changes to metadata conventions**	**June 2013 – May 2014**
10.0	Extension to Megha-Tropiques/SAPHIR	March 2014
11.0	HR Extension for AMSUA/MHS, SSMIS; CRTM 2.1.1 implementation, dynamic background, etc.	September 2014
11.1*	**HR Extension for F18, addition of new operational product: SFR for AMSU/MHS (experimental products SGS and SIA); new DAP to NDE for SNPP/ATMS**	**June/July 2015**
11.2	**HR Extension for GPM/GMI**	**~ August 2016**
11.3	**Extension to J1/ATMS; SFR integration**	**~ Late 2016**

Images of many of these products now available on both MiRS (http://mirs.nesdis.noaa.gov/), and long-term monitoring website (http://www.star.nesdis.noaa.gov/jpss/EDRs/products_MiRS.php)

V9.2/V11.0

Atmospheric Temp.profile
Atmospheric WV profile
Total Precipitable Water
Land Surface Temperature
Surface Emissivity Spectrum
Sea-Ice Concentration
Snow Cover Extent
Snow-Water Equivalent
Integrated Cloud Liquid Water
Integrated Ice Water Path
Integrated Rain Water Path
Rainfall Rate

Added V11.1

Snowfall Rate (MSPPS, AMSU/MHS currently, ATMS integration in V11.3)
Sea Ice Age (FY, MY)
Snow Grain Size

* For SNPP/ATMS: V11.1 is operational at NDE since October 2015

MiRS S-NPP Products: T and WV Profile

- Daily, Global, collocations with radiosondes (NPROVS)
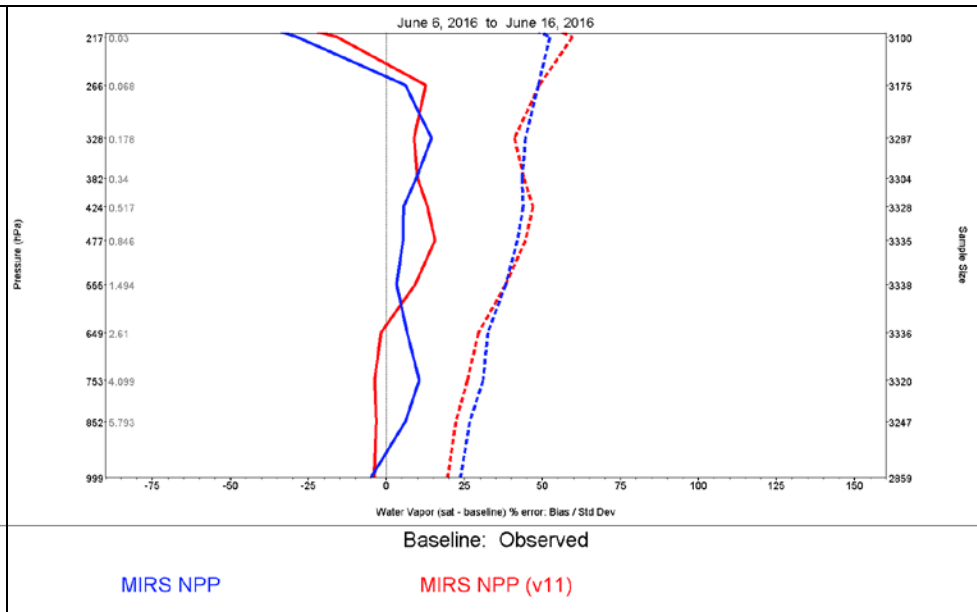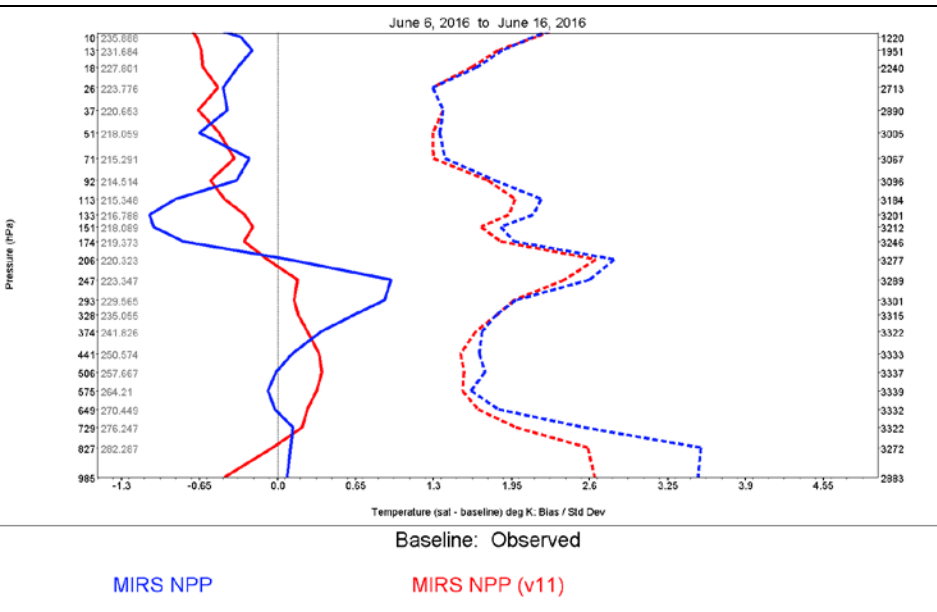- Comparison of MiRS **v9.2** and **v11.1 at 918 hPa from May 2015 – May 2016**
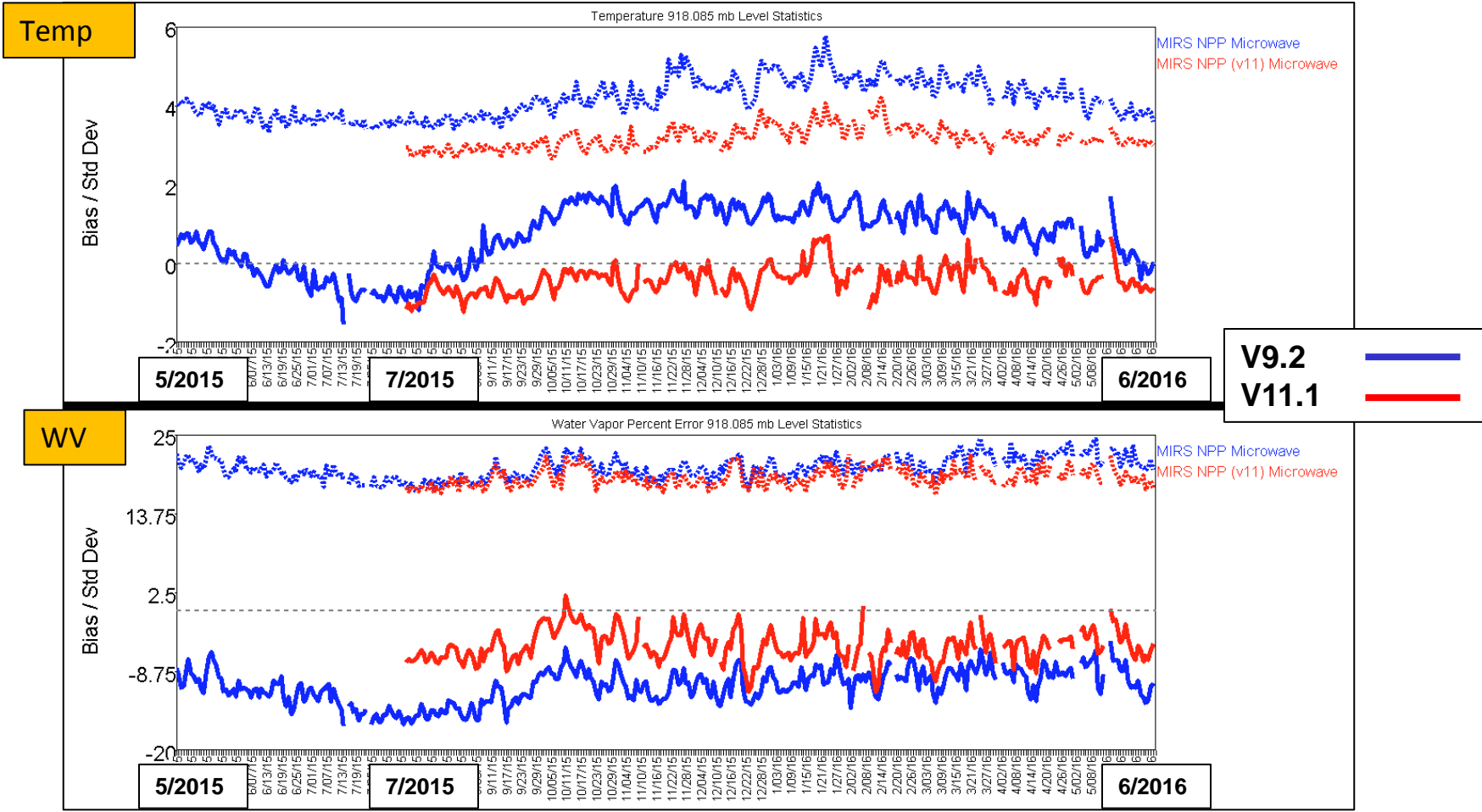
Courtesy of Bomin Sun

MiRS S-NPP Products: T and WV Profile

- Daily, Global, collocations with radiosondes (NPROVS)
- Comparison of MiRS **v9.2** and **v11.1** for 10-Day Period, 6-16 June 2016

Temp

WV

| V9.2 | |
| V11.1 | |

Courtesy of Bomin Sun

MiRS S-NPP Products: T and WV Profile

- Daily, Global Collocations with ECMWF and GDAS.
- Periodic Global, collocations with radiosondes (NPROVS)
- Stratified by clear/cloudy, and surface type
- Maturity Level: Validated, Stage 3

Product	Sfc	Condition	Layer (hPa)	Bias (K) (Accuracy)		StDv (K) (Precision)	
				MiRS	Req	MiRS	Req
Temperature	Sea	Clear	100	-0.5	0.5	1.7	2.0
			300	+0.5	0.5	2.0	2.0
			500	-0.5	0.5	1.4	2.0
			900	+0.5	1.5	1.8	3.0
		Cloudy	100	0.0	0.8	1.8	2.0
			300	+0.5	0.8	2.0	2.5
			500	-0.7	0.8	1.5	2.0
			900	+1.0	2.0	2.0	3.0
	Land	Clear+Cloudy	100	-0.5	1.0	1.5	2.0
			300	+0.8	0.8	1.5	2.0
			500	0.0	0.5	1.2	2.5
			900	-1.0	2.5	2.5	5.5

Product	Sfc	Condition	Layer (hPa)	Bias (%) (Accuracy)		StDv (%) (Precision)	
				MiRS	Req	MiRS	Req
Water Vapor	Sea	Clear	400	-5.	30.	50.	60.
			500	0.	20.	40.	60.
			700	-5.	20.	30.	50.
			900	+5.	20.	15.	30.
		Cloudy	400	+5.	30.	60.	70.
			500	0.	20.	50.	65.
			700	+5.	10.	40.	60.
			900	0.	20.	20.	30.
	Land	Clear+Cloudy	400	+10	30.	50.	60.
			500	0.	20.	40.	60.
			700	-10.	20.	30.	50.
			900	-10.	20.	20.	50.

- Developed new T and WV Covariance Matrices based on EC137 data set, stratified by atmospheric conditions.
- TEST: Replace current global covariances with rainy covariances when MiRS detects rain.
- One day global ATMS retrievals, comparison with ECMWF on 2015-11-13

Bias: OPER v11.1

StDv: OPER v11.1

Bias: TEST

StDv: TEST

Improved performance over ocean
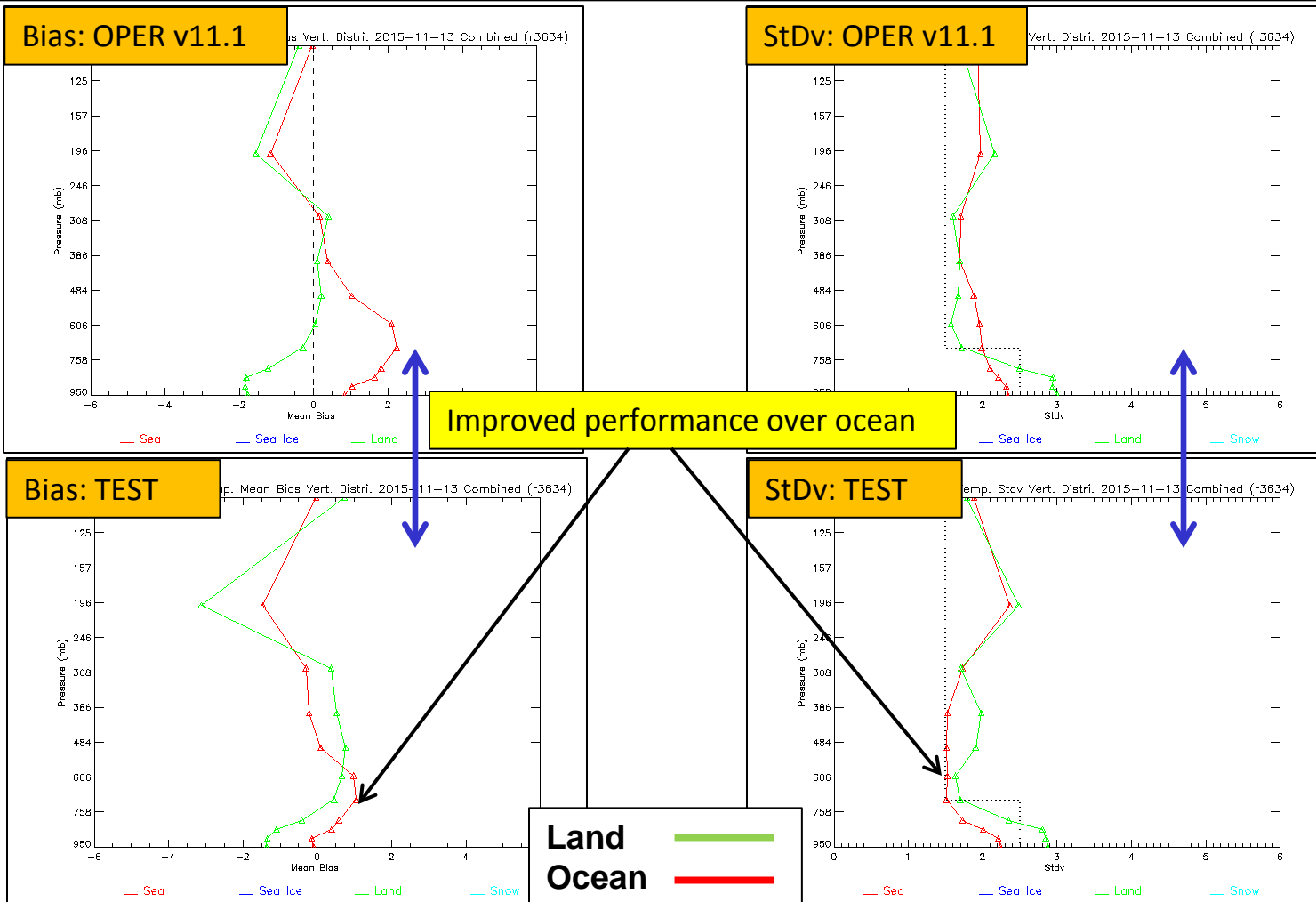
Land ————
Ocean ————

MiRS S-NPP Products: Hydrometeors

8 Month Collocation Period: August 2015- March 2016
- Rain Rate: MiRS ATMS collocation with Stage IV (CONUS and coastal ocean)
- Rain Rate: MiRS ATMS collocation with GPM GPROF 2A (global land and ocean)
- CLW: MiRS ATMS collocation with GPM GPROF 2A over ocean
- Maturity Level: Validated, Stage 3

CLW: MiRS and GPROF Ocean
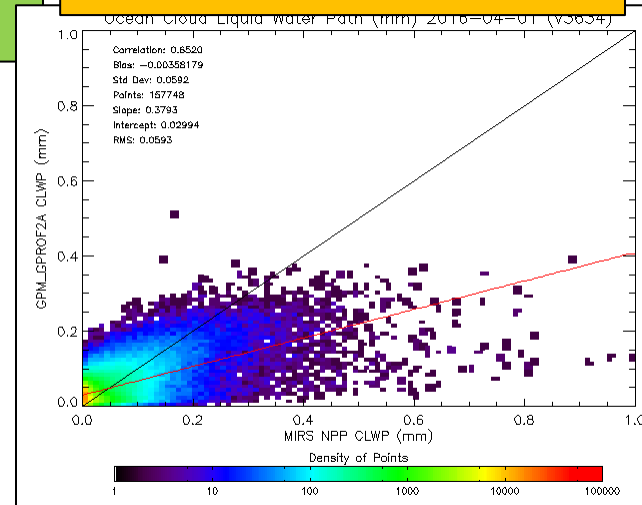
Product	Units	Bias (Accuracy)		StDv (Precision)		Npts
		MiRS	Req	MiRS	Req	
Rain Rate (land, Stage IV)	mm/h	0.01	0.05	0.8	1.5	8.7E+06
Rain Rate (ocean, Stage IV)	mm/h	0.08	0.10	1.0	1.0	1.8E+06
Rain Rate (land, GPROF)	mm/h	-0.01	0.05	0.4	1.5	8.1E+04
Rain Rate (ocean, GPROF)	mm/h	-0.01	0.10	0.8	1.0	1.8E+05
CLW (ocean, GPROF)	mm	-0.00	0.03	0.06	0.08	1.6E+05

RR: MiRS and Stage IV

Land

Ocean

RR: MiRS and GPROF

Land

Ocean
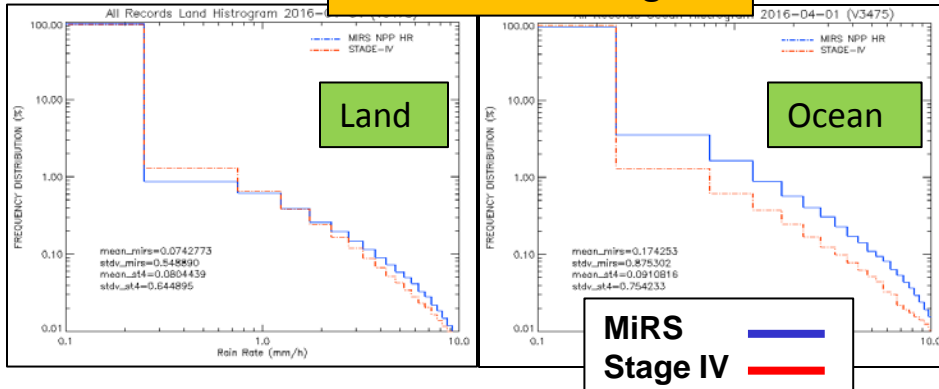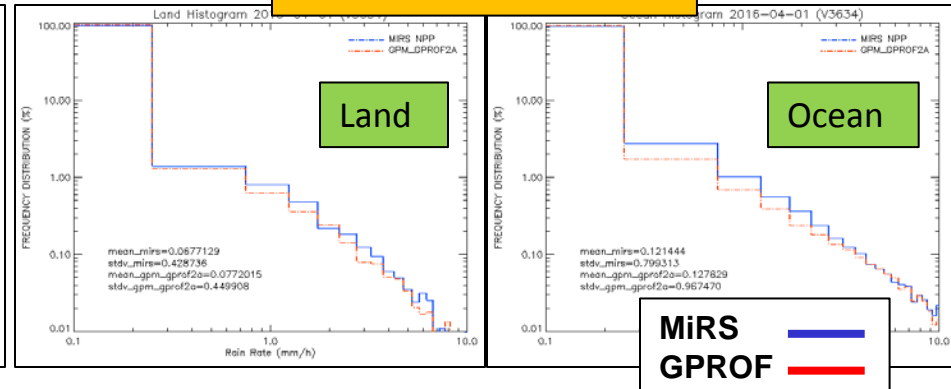
MiRS S-NPP Products: Snow Water Equivalent

AMSR2 SWE vs MiRS NPP/ATMS SWE, 2015-01-09

Points = 232213
Correl. = 0.73889
Bias = -11.60103
RMS = 31.24673
S. Dev. = 29.01334
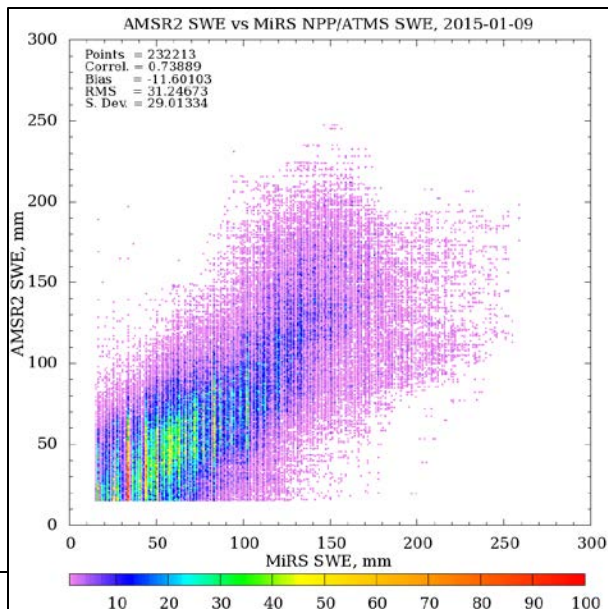
MiRS (v11.1) SWE/Snow cover Performance vs. JAXA/AMSR2
- **JPSS requirement in parentheses**
- **Maturity Level: Validated**

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)
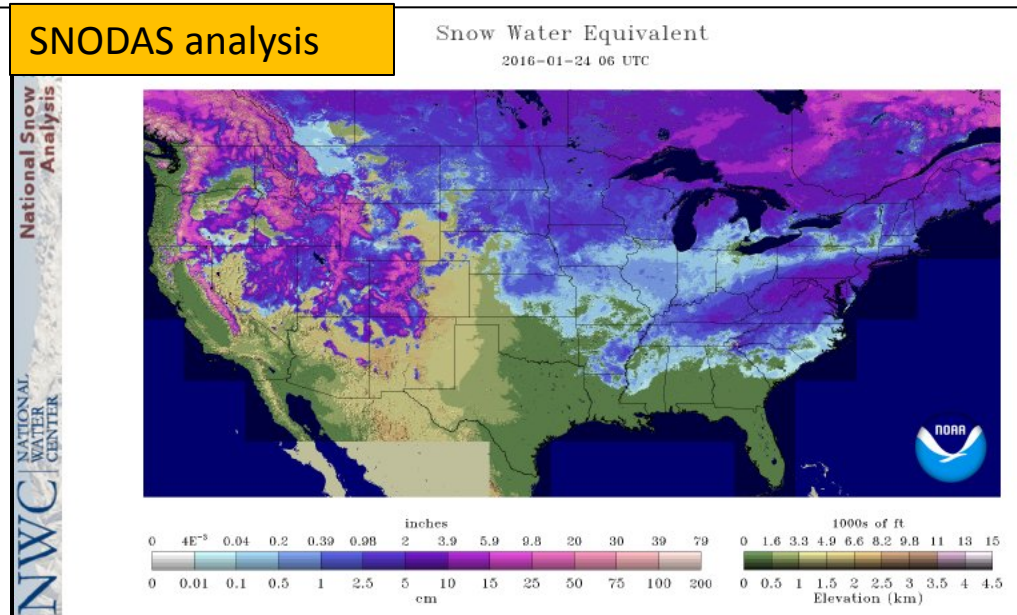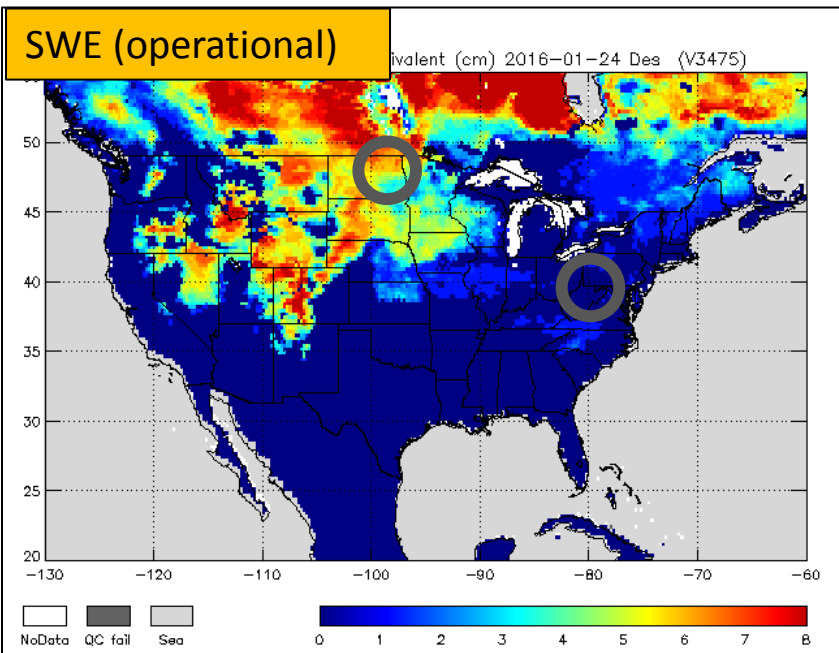**Heidke Skill Score: 0.62 (0.55)**

MiRS ATMS

AMSR2 SWE (mm)   0-07-00

JAXA AMSR2

Snow Water Equivalent: Potential Improvements
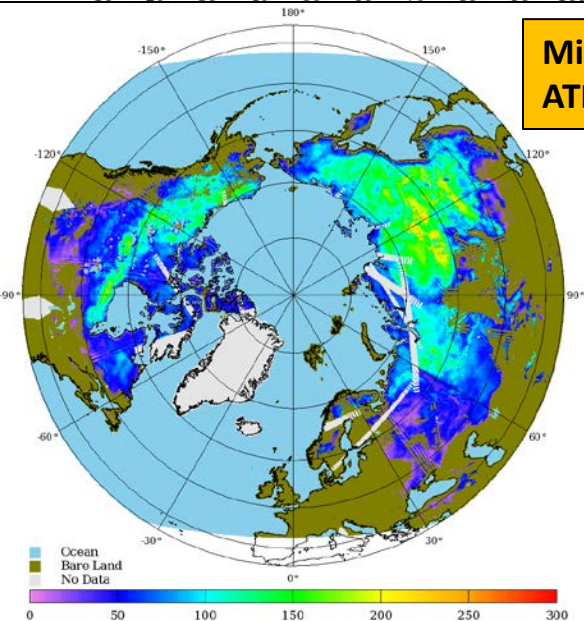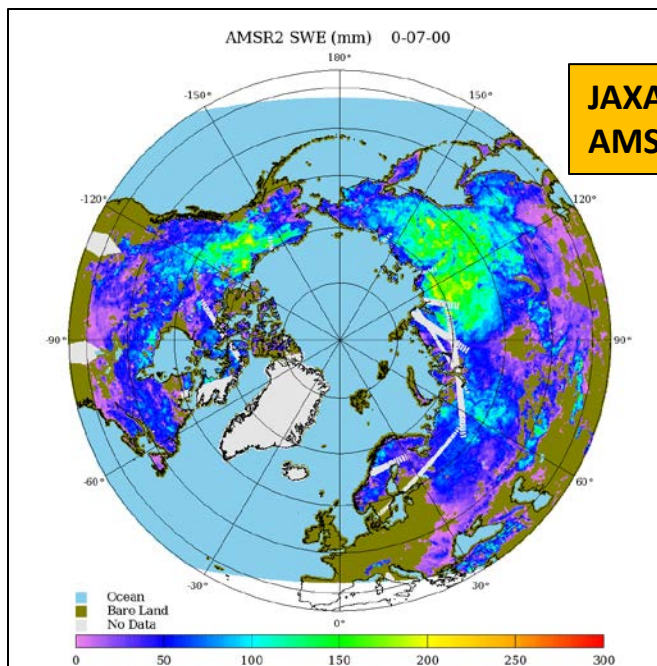
January 23-24, 2016 East Coast Blizzard ("Snowzilla")
- 1-2+ feet in many locations
- MiRS operational SWE greatly underestimated
- Investigating possible causes/improvements
- Focus on vegetation cover (forest) as contributing factor
- Other factors: snow wetness, emissivity model (lookup table)
- **See poster on Thursday by Carlos Perez on emissivity model assessment**
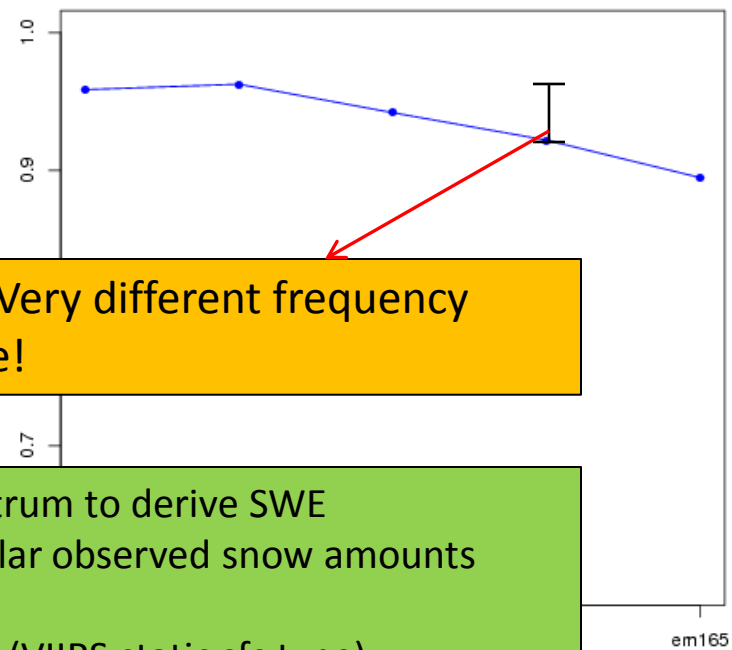

SWE (operational)

SNODAS analysis

Snow Water Equivalent: Potential Improvements

MIRS NPP/ATMS Snow Water Equivalent (cm) 2016-01-24 Des (V3475)
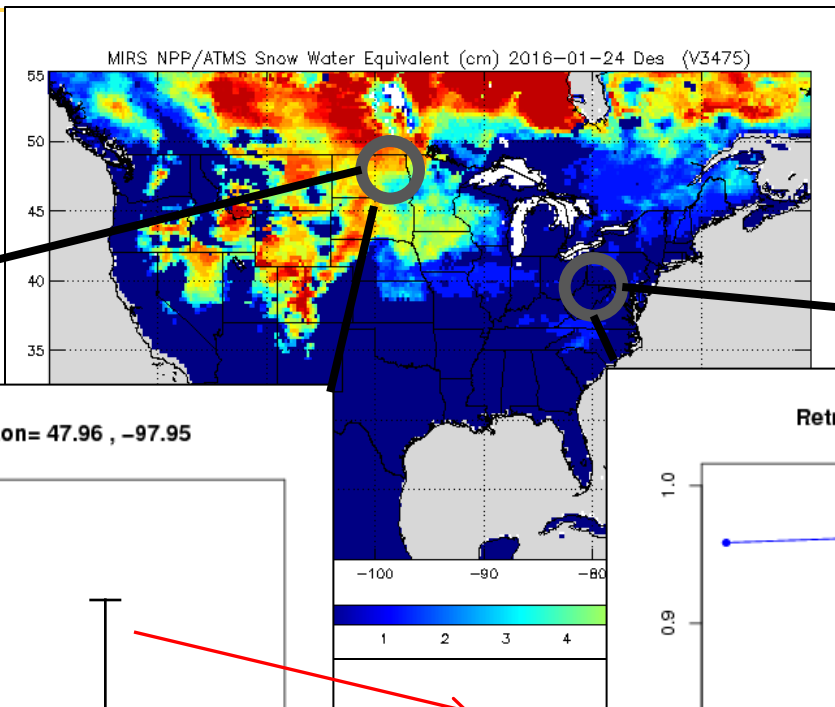
Retrieved Emissivity: Lat,Lon= 47.96 , −97.95
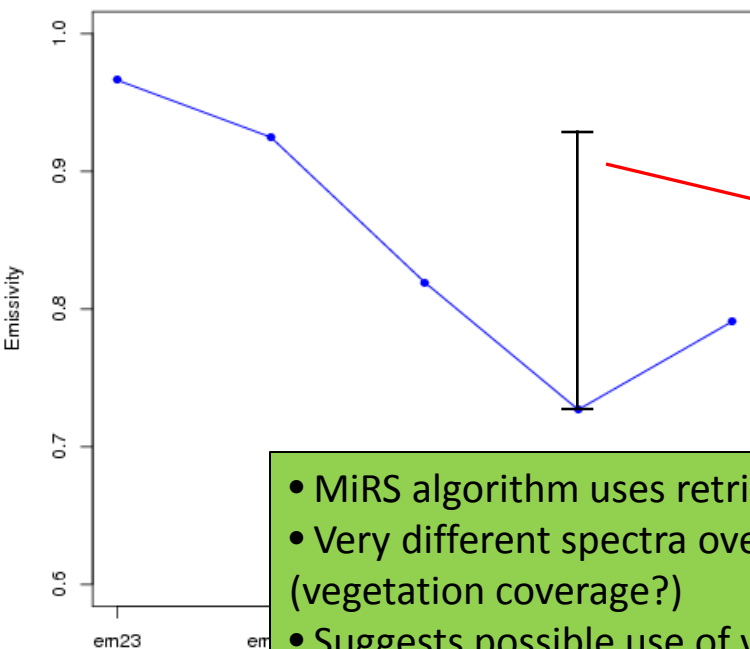
Retrieved Emissivity: Lat,Lon= 39.58 , −80.41

31-89 GHz: Very different frequency dependence!

- MiRS algorithm uses retrieved emissivity spectrum to derive SWE
- Very different spectra over 2 regions with similar observed snow amounts (vegetation coverage?)
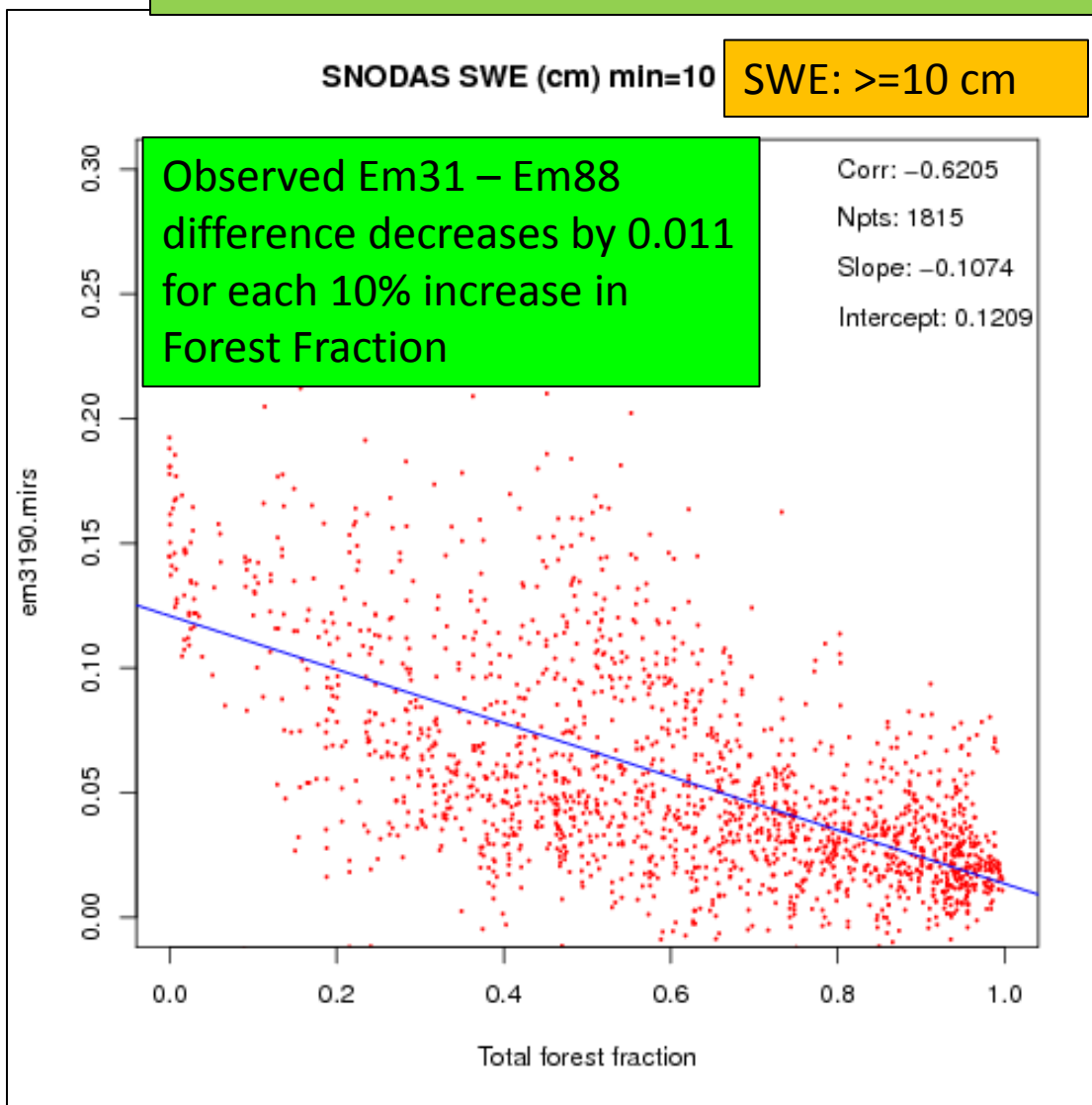- Suggests possible use of vegetation correction (VIIRS static sfc type)

Snow Water Equivalent: Potential Improvements

VIIRS Sfc Type

Total Forest Fraction (Global)

VIIRS Total Forest Fraction
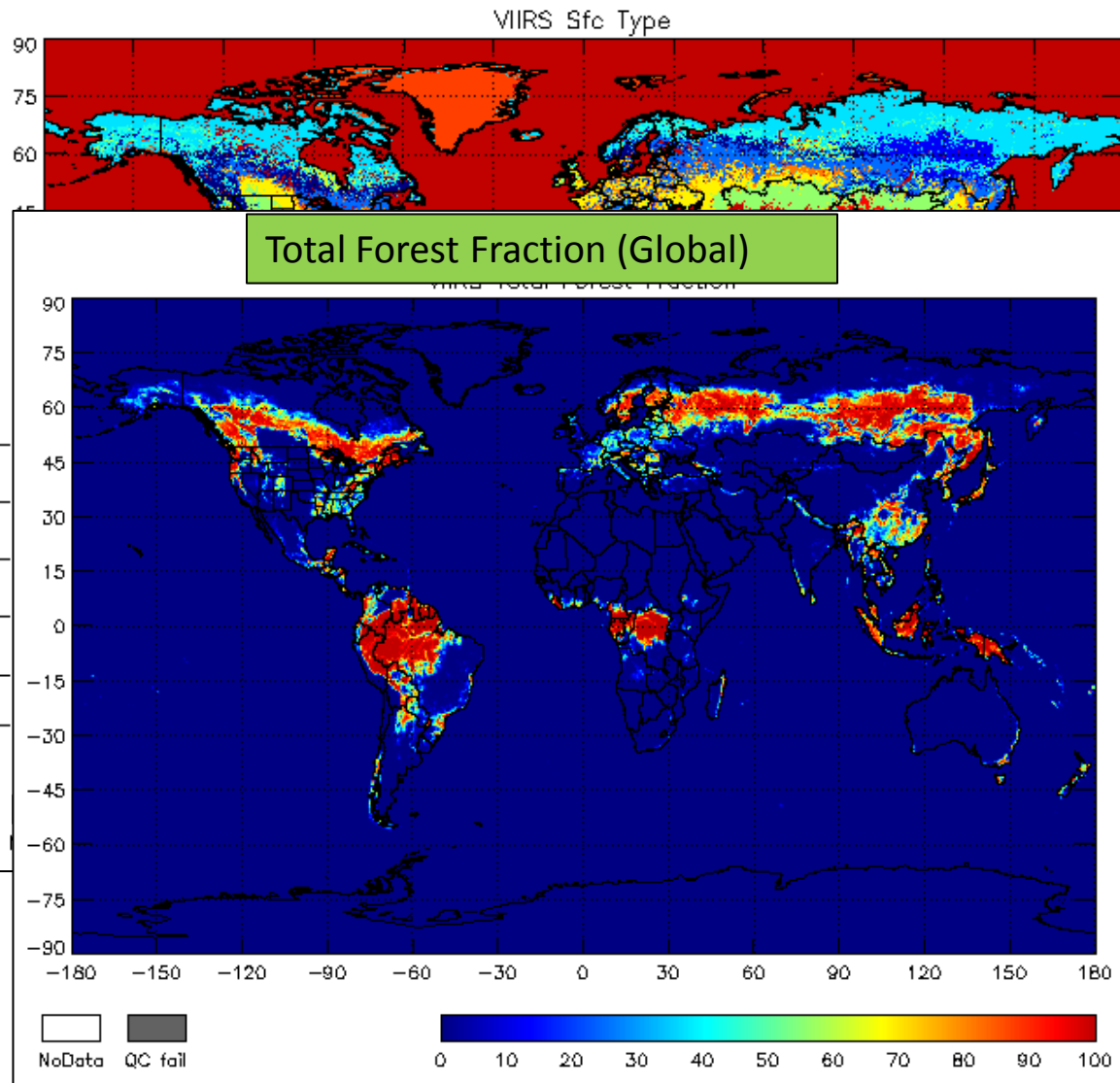
VIIRS Sfc Type database:
- 30 arc second (~ 1 km)
- based on one year of VIIRS data
- 19 potential types:

0= Unclassified
1= Evergreen Needleleaf Forests
2= Evergreen Broadleaf Forests
3= Deciduous Needleleaf Forests
4= Deciduous Broadleaf Forest
5= Mixed Forests
6= Closed Shrublands
7= Open Shrublands
8= Woody Savannas
9= Savannas
10= Grasslands
11= Permanent Wetlands
12= Croplands
13= Urban and Built-up Lands
14= Cropland/Natural Vegetation Mosaics
15= Snow and Ice
16= Barren
17= Water Bodies
18 =No data

Snow Water Equivalent: Potential Improvements

Difference in EM at 31 and 88 GHz as function of Forest Fraction

SNODAS SWE (cm) min=10

SWE: >=10 cm

Observed Em31 – Em88 difference decreases by 0.011 for each 10% increase in Forest Fraction
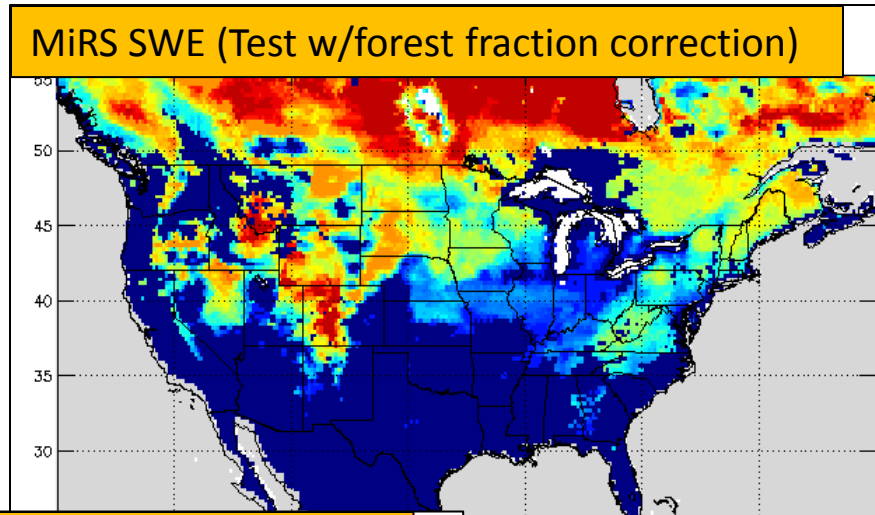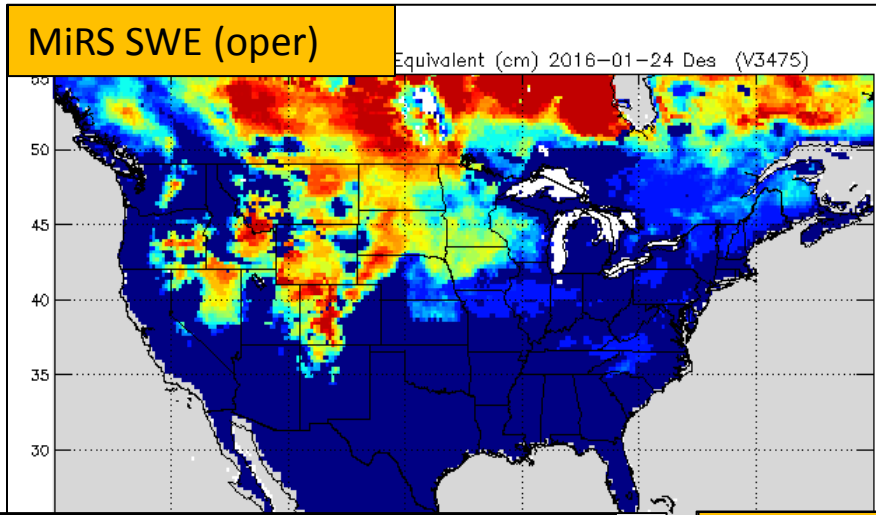
Corr: −0.6205
Npts: 1815
Slope: −0.1074
Intercept: 0.1209

- Based on the regression slopes, can we apply a correction to the Em31-90 gradient of the form: Em3188(cor)=Em3188(ret)+a1*(FF-FF0) ?
- Use corrected Em3188 in lookup table search
- Slope nearly independent of SWE amounts (0 < SWE <= 20)
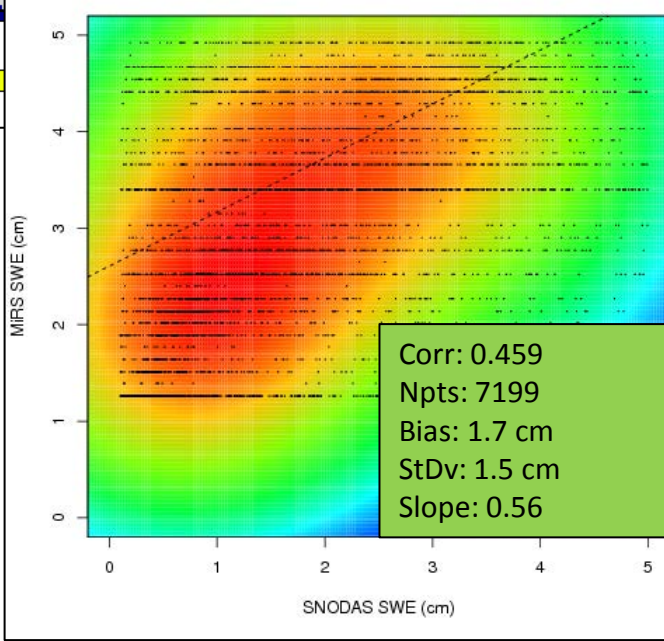
Snow Water Equivalent: Potential Improvements
Case 1, 2016-01-24

MiRS SWE (oper)

Equivalent (cm) 2016-01-24 Des (V3475)

MiRS SWE (Test w/forest fraction correction)

OPER: SNODAS > 0. <=5. and MIRS >0.

Corr: 0.225
Npts: 5390
Bias: 1.7 cm
StDv: 2.0 cm
Slope: 0.34

TEST: SNODAS > 0. <=5. and MIRS >0.

Corr: 0.459
Npts: 7199
Bias: 1.7 cm
StDv: 1.5 cm
Slope: 0.56
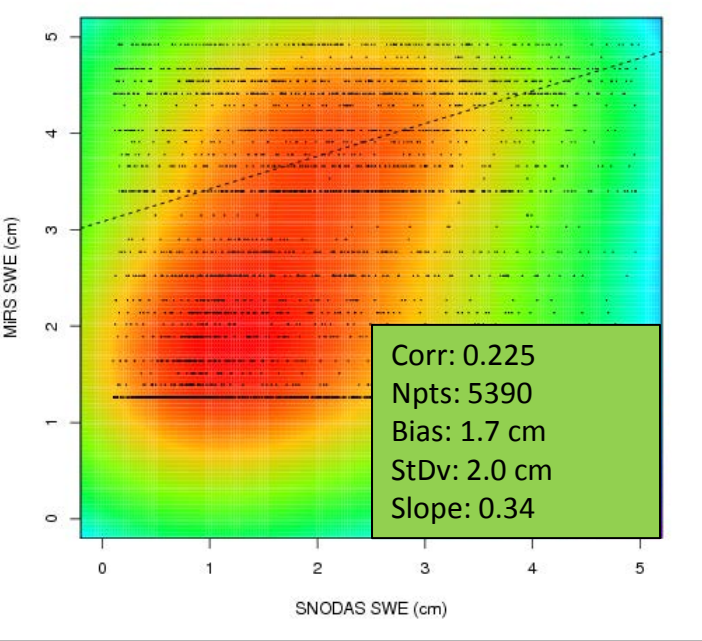
• Test version has higher correlation, smaller StDv, and regression fit has slope closer to 1
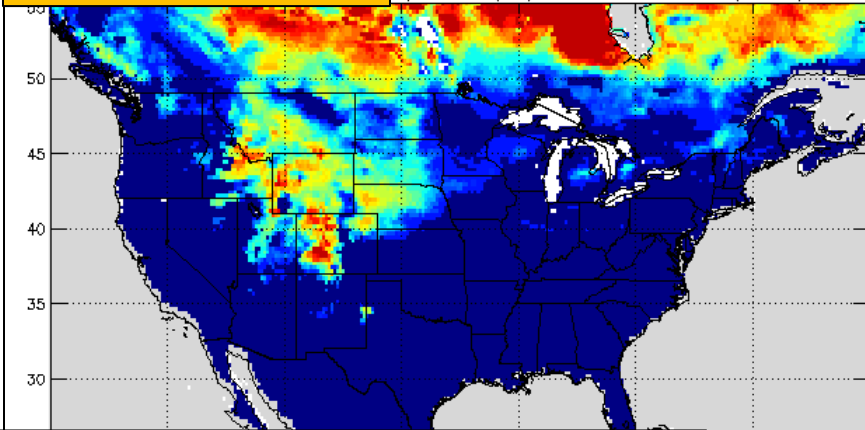• Note increase in Npts with SWE> 0 in Test version
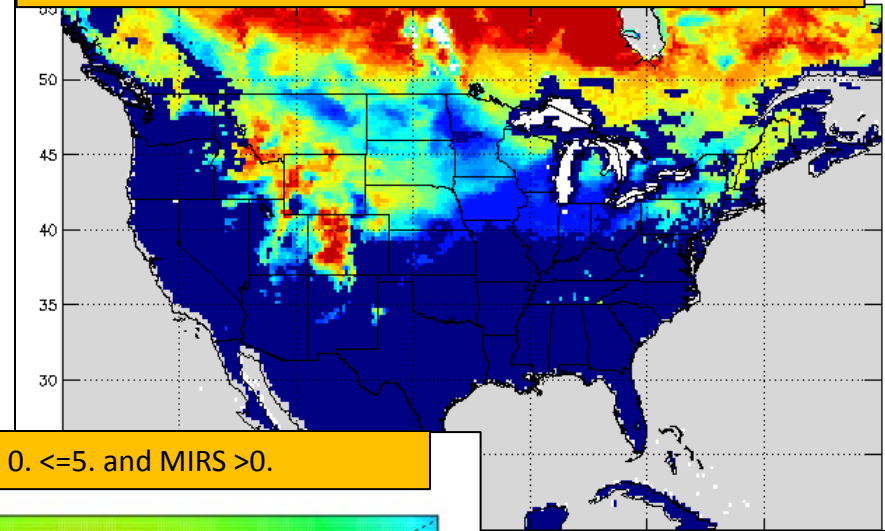
Snow Water Equivalent: Potential Improvements
Case 2, 2015-01-09

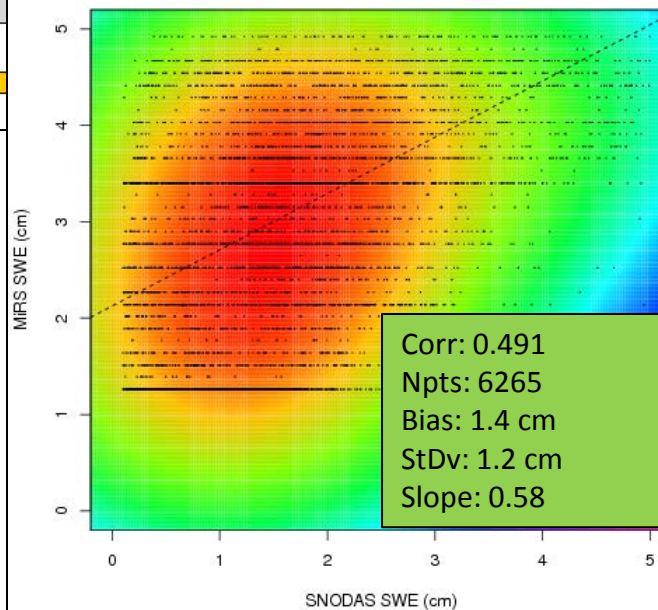**MiRS SWE (oper)**

Equivalent (cm) 2015-01-09 Des (V3636)

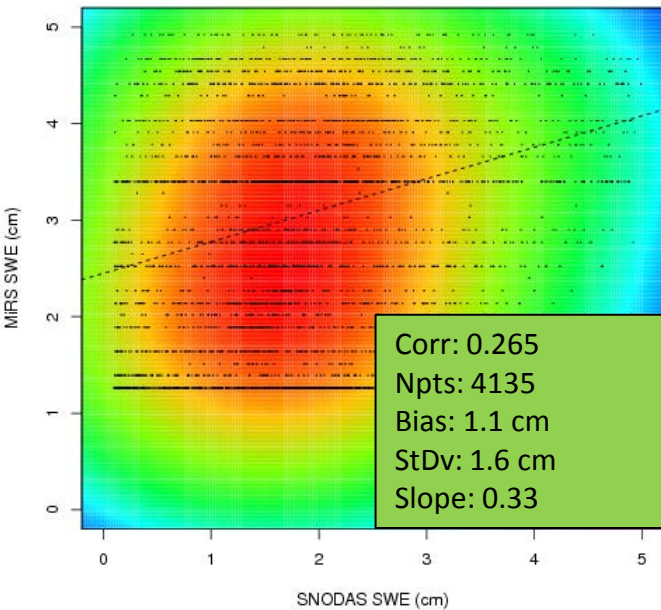**MiRS SWE (Test w/forest fraction correction)**

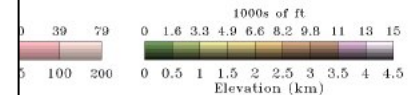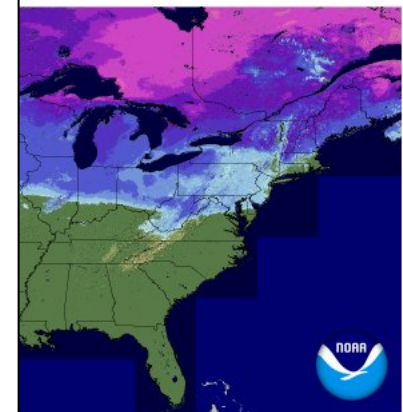**OPER: SNODAS > 0. <=5. and MIRS >0.**

Corr: 0.265
Npts: 4135
Bias: 1.1 cm
StDv: 1.6 cm
Slope: 0.33

TEST: SNODAS > 0. <=5. and MIRS >0.

Corr: 0.491
Npts: 6265
Bias: 1.4 cm
StDv: 1.2 cm
Slope: 0.58

JPSS-1 Readiness

- Significant Algorithm changes from S-NPP to JPSS-1:
  - **Addition of SFR**: will require access to GFS forecasts (will work with NDE during integration and testing; already done for AMSU/MHS). **Already integrated for AMSU/MHS.** Huan Meng's presentation next.

- Pre-launch Characterization
  - Currently extending software to J1: completion planned in Fall 2016, with end to end testing on proxy data. CDR in late 2016. STAR: Daily processing set up prior to launch.

- Post-Launch Cal/Val Plans
  - Data Sets: Update radiometric bias corrections, T and WV sounding (ECMWF, GDAS, raobs), rain rate (Stage IV, NMQ, GPROF), CLW (GPROF, CloudSat), snow (SNODAS, AMSR2, IMS), ice (IMS, OSI-SAF, VIIRS)
  - Milestones: (1) CDR in late 2016, (2) prelaunch preDAP delivery in early 2017, (3) official DAP ~L+6 months (initial cal/val, validated maturity stage 1 (T, WV), or provisional maturity (RR, cryosphere, hydrometeors)).

- Risks and Mitigation: None major, awaiting outcome of chan 17 tests to determine potential impact. (clouds, precipitation)

- Collaboration with Stake Holders: Feedback from OSPO, NDE to identify bugs/issues, other external users/applications.

Summary & Path Forward

- MiRS is relatively mature algorithm; evolution and improvement since SNPP launch (v9.2 -> v11.1)

- Next version: Biggest change from data flow/dependence perspective is integration of SFR requiring GFS data; one focus of pre-launch integration and testing.

- Path Forward
  - FY17 Milestones: (1) CDR in late 2016, (2) prelaunch preDAP delivery in early 2017, (3) official DAP ~L+6 months (initial cal/val).
  - Future Improvements:
    - Snow (vegetation correction)
    - Rainy condition sounding (update a priori constraints)
    - Hydrometeors (improvements to CRTM i.e. scattering, precharacterization of precip type, particle size/shape distribution in CRTM, CLW over land for light rain detection)
    - Air mass-dependent bias corrections
    - Stakeholders/user needs…