MiRS Extension to High Resolution for N18, N19, MetopA, F17, and Algorithm Updates

System Readiness Review (SRR)

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Review Agenda

1. Introduction	9:30 – 9:40	**J. Zhan/C. Grassotti**
• Background, Objectives, Plan		
2. MiRS DAP 11.0 Highlights	9:40 – 9:50	**C. Grassotti**
• Transition to High-Resolution • Science Improvements • Requirements		
3. Algorithm/System Readiness	9:50 – 11:30	**C.Grassotti/T. Islam/ C. Smith**
• Algorithm Description: Mathematical Basis, Process Flow, Internal Interfaces		
• MiRS Science and Algorithm Improvements: CRTM 2.1.1, dynamic background		
• Footprint Matching, F17 Calibration, Product Assessment, QC (AMSUA/MHS, SSMIS)		
• IT Resource Requirements		
4. Risks/Actions	11:30 – 11:40	**C. Grassotti**
5. Summary and Conclusions	11:40 – 11:45	**C. Grassotti**
Discussion	11:45 – 12:00	**All**

- **INTRODUCTION**
  - » Background, Objectives, Plan
- DAP 11.0 Highlights
  - » High-Resolution Processing
  - » Science Improvements
  - » Requirements
- Algorithm Readiness
  - » Algorithm Description: Mathematical Basis, Process Flow, Internal Interfaces
  - » Algorithm/Science Improvements : a priori background mean and covariance, CRTM
  - » Algorithm Test Results: Product Assessment, MiRS STAR IT requirements
- Risks/Actions
- Summary and Conclusions
- Discussion

Section 1 – Introduction

Presented by

C. Grassotti/J. Zhan

Milestones (from MiRS project plan)

DAP New Sensor Capability	Initial Delivery Date(s)	Resolution	Delivered or Planned
N18, MetopA, N19, F16, F18	2007 - 2012	LR	✓
NPP/ATMS	**November, 2012**	**HR**	✓
MetopB/AMSU-MHS	**January, 2013**	**HR**	✓
Megha-Tropiques/SAPHIR	**March, 2014**	**HR**	✓
N18, N19, MetopA, F17	**August, 2014**	**HR**	✓
N18, N19, MetopA, MetopB: SFR product	**December, 2014**	**HR**	
F18	**January, 2015**	**HR**	
All sensors: SIA and SGS product	**March, 2015**	**HR**	
F19	**Aug-Dec, 2015**	**HR**	

Project Objectives

- Overarching Science Objectives (general)
  - » Improved temperature and moisture profile retrievals in all-weather conditions (clear, cloudy, precipitating) and over non-standard surfaces (snow, sea ice); improved precipitation retrievals
  - » An improved set of retrieved surface properties whose derivation is based on the retrieved emissivities instead of directly from the brightness temperatures
- Technical Objectives (this review)
  - » **Extension of MiRS to high-resolution: N18, N19, MetopA AMSUA-MHS (existing LR capability in operations)**
  - » **Extension of MiRS to high-resolution: F17 SSMIS (not currently in operations)**
- Science Objectives (this review)
  - » **Extension to latest version of CRTM forward model (v 2.1.1)**
  - » **Enhancement of the background mean constraint in 1dvar (temporally/spatially variable "dynamic" background)**

SRR Objectives

- Objectives of the Review
  - » Goal #1: Gather all MiRS stakeholders to review the extension of MiRS to high-resolution
  - » Goal #2: Review of algorithm requirements and science enhancements
  - » Goal #3: Review of MiRS software package readiness (incl. EDR performance assessments, IT benchmarking)
  - » Goal #4: Identify new or outstanding risks w/mitigation strategies
- Follow the STAR EPL Guidelines

MiRS Stakeholders

- Development Team
  - » J. Zhan, C. Grassotti, T. Islam, C. Smith, P.Liang
- OSPO Partners
  - » L. Zhao, J. Wang, Z. Cheng, C. Davenport, H. Uhlenhake
- MiRS Oversight Board
  - » R. Ferraro (STAR), L. Zhao (OSPO), S. Boukabara (Chair), T. Schott (OSD)
- MiRS Users
  - » **NOAA NWS:** CPC, NHC, TPC, SPC, WFOs (AWIPS)
  - » **DoD:** NRL, AFWA
  - » **Joint Typhoon Warning Ctr.**
  - » **NOAA/NESDIS:** JCSDA, NCDC, OSPO, STAR
  - » + more than 30 users (e.g. NASA/MSFC, JPL, CSU/CIRA, JMA, UKMO, UW/SSEC, UMD, CMA, Taiwan Weather Bureau, CPTEC/Brazil, Max Planck Inst./Hamburg, U.Wisc/SSEC, ISRO,...)

MiRS High-Resolution SRR Entry Criteria

- Entry # 1 – Review of the ARR/SRR for MiRS High-Resolution
  - » Science and technical improvements
  - » High-resolution extension
  - » Algorithm Readiness: Product assessments, IT requirements
  - » Risks/Actions

MiRS High-Resolution SRR Exit Criteria

- Exit # 1 – System Readiness Review Report
  - » SRR Report will be compiled and delivered after SRR
  - » SRR Report to contain:
    - – SRR Presentation
    - – Actions
    - – Comments

- Introduction
  - » Background, Objectives, Plan
- **DAP 11.0 HIGHLIGHTS**
  - » High-Resolution Processing
  - » Science Improvements
  - » Requirements
- Algorithm Readiness
  - » Algorithm Description: Mathematical Basis, Process Flow, Internal Interfaces
  - » Algorithm/Science Improvements : a priori background mean, CRTM 2.1.1
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Section 2 –

Highlights of Upcoming DAP (MiRS 11.0)

Presented by

C. Grassotti

Context: MiRS Recent DAP Deliveries

MiRS DAP 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.**	**Sept/Oct, based on SRR Feedback**

- Review will focus on intercomparisons of v9.2 and v11.0
- v10.0 for SAPHIR only (future DAP will fully integrate with other sensors)

Upcoming MiRS DAP 11.0: Highlights

- HR Deliverable
- Science Improvement

Description	Satellites/Sensors Affected	Benefit
Extension to high (MHS) resolution for AMSUA-MHS (LR=30 FOVs/scan, HR=90FOVs/scan)	N18, N19, MetopA/AMSUA-MHS, (MetopB, SNPP/ATMS already high-res)	Improved depiction of small-scale features: CLW, RR, WV, ice edge
Extension to high (ENV) resolution for SSMIS (+extension to F17) (LR=30 FOVs/scan, HR=90FOVs/scan)	F17/SSMIS (and F18, to be delivered early 2015)	Better depiction of small-scale features: CLW, RR, WV, ice edge
Integration of CRTM 2.1.1 (previously using pCRTM)	All: N18, N19, MetopA, MetopB/AMSUA-MHS, SNPP/ATMS, F17, F18//SSMIS (MT/SAPHIR already using CRTM 2.1.1)	Better sync with CRTM development cycle; more realistic ice water retrievals (Jacobians)
New bias corrections for all sensors	All	Needed for consistency with CRTM 2.1.1
Integration of new dynamic a priori atmospheric background	All	Large improvement in T, WV sounding; reduction in average number of iterations; increase in conv rate
Updated hydrometeor/rain rate relationships	All	Improved RR over land and ocean
Updated hydrometeor a priori background profiles	All	Improved RR over land and ocean; improved sounding products in rainy conditions
Dynamic channel selection near sea ice boundary	N18, N19, MetopA, MetopB/AMSUA-MHS, SNPP/ATMS	Better convergence behavior for cross-track instruments
Updated surface type preclassifier	F17, F18 SSMIS	Improved snow detection for conical scan instruments
Miscellaneous changes to improve code efficiency, bug fixes	All	Matrix preparation time reduced from 40% to 5% of 1dvar computation time

Requirements

- **Satisfy User Requests**
  - » Rainfall product from all sensors at high-resolution
  - » Previously followed the NPOESS IORD; Now following JPSS/L1RD as it evolves for EDR performances
- **Follow SPSRB Guidelines for DAP Deliveries**
  - » Documentation, test data, pcf, scs scripts
- **NESDIS/STAR Coding Standards**
  - » F90, C/C++, Linux bash, ifort, gfortran, gcc compilers
  - » Documented, error trapping, memory leak checking
- **Science Products Quality Assessments:**
  - » Temp, WV, TPW, LST, Emissivity, RR, SIC, SWE, SCE
  - » IT Benchmarking (timeliness, latency, memory, file sizes)

- Introduction
  - » Background, Objectives, Plan
- DAP 11.0 Highlights
  - » High-Resolution Processing
  - » Science Improvements
  - » Requirements
- **ALGORITHM READINESS**
  - » Algorithm Description: Mathematical Basis, Process Flow, Internal Interfaces
  - » Algorithm/Science Improvements : a priori background mean, CRTM 2.1.1
  - » Algorithm Test Results: Product Assessment, MiRS STAR IT requirements
- Risks/Actions
- Summary and Conclusions
- Discussion

Section 3 –
Algorithm Readiness

Presented by

C. Grassotti, T. Islam, C. Smith

MiRS Algorithm Readiness

- MiRS Algorithm Description (*C. Grassotti*)
  - » Mathematical Basis/1DVAR/VIPP
  - » Flow diagrams
- MiRS Algorithm/Science Improvements (*C. Grassotti*)
  - » CRTM 2.1.1
  - » Dynamic A Priori Background
- MiRS Algorithm Test Results/ Product Assessments (*All*)
  - » Footprint matching for AMSUA/MHS and SSMIS (*C. Smith*)
  - » F17: calibration, bias corrections (*C. Smith*)
  - » AMSUA/MHS, SSMIS EDR assessments: T, WV, Hydrometeors, LST, Emissivity (*T. Islam*)
  - » Cryospheric Products (*C. Grassotti*)
  - » IT Requirements (*C. Grassotti*)

MiRS Algorithm Description and Improvements

Presented by

C. Grassotti

MiRS Algorithm: Mathematical Basis

- Cost Function to minimize:

$$J(X)=\left[\underbrace{\frac{1}{2}(X-X_0)^T\times B^{-1}\times(X-X_0)}_{\text{Bkg-departure normalized by Bkg Error}}\right]+\left[\underbrace{\frac{1}{2}\left(Y^m-Y(X)\right)^T\times E^{-1}\times\left(Y^m-Y(X)\right)}_{\text{Measurements-departure normalized by Measurements+Modeling Errors}}\right]$$

Updates to MiRS algorithm

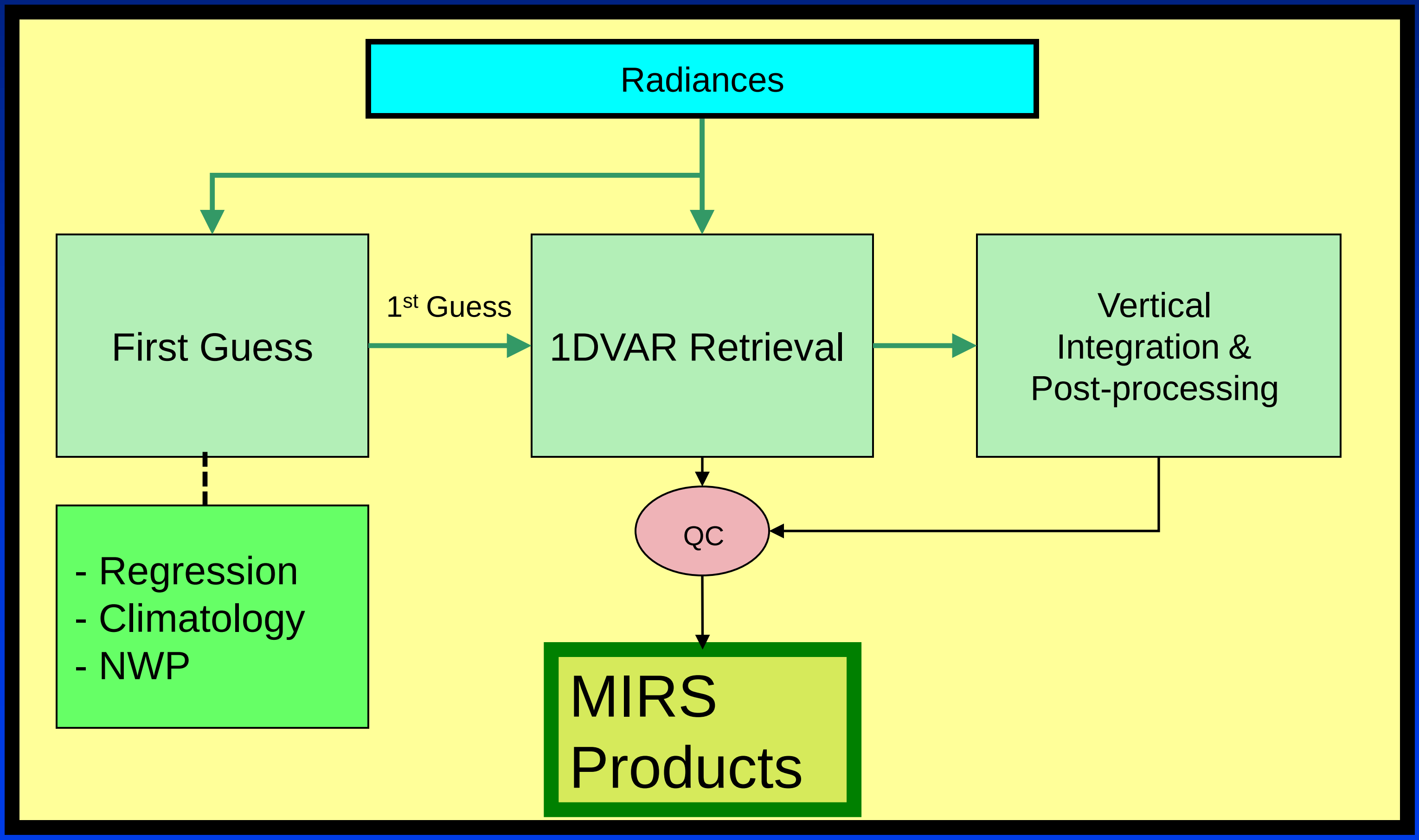
- To find the optimal solution, solve for: $\frac{\partial J(X)}{\partial X}=J'(X)=0$

- Assuming local Linearity: $y(x)=y(x_0)+K\left[x-x_0\right]$

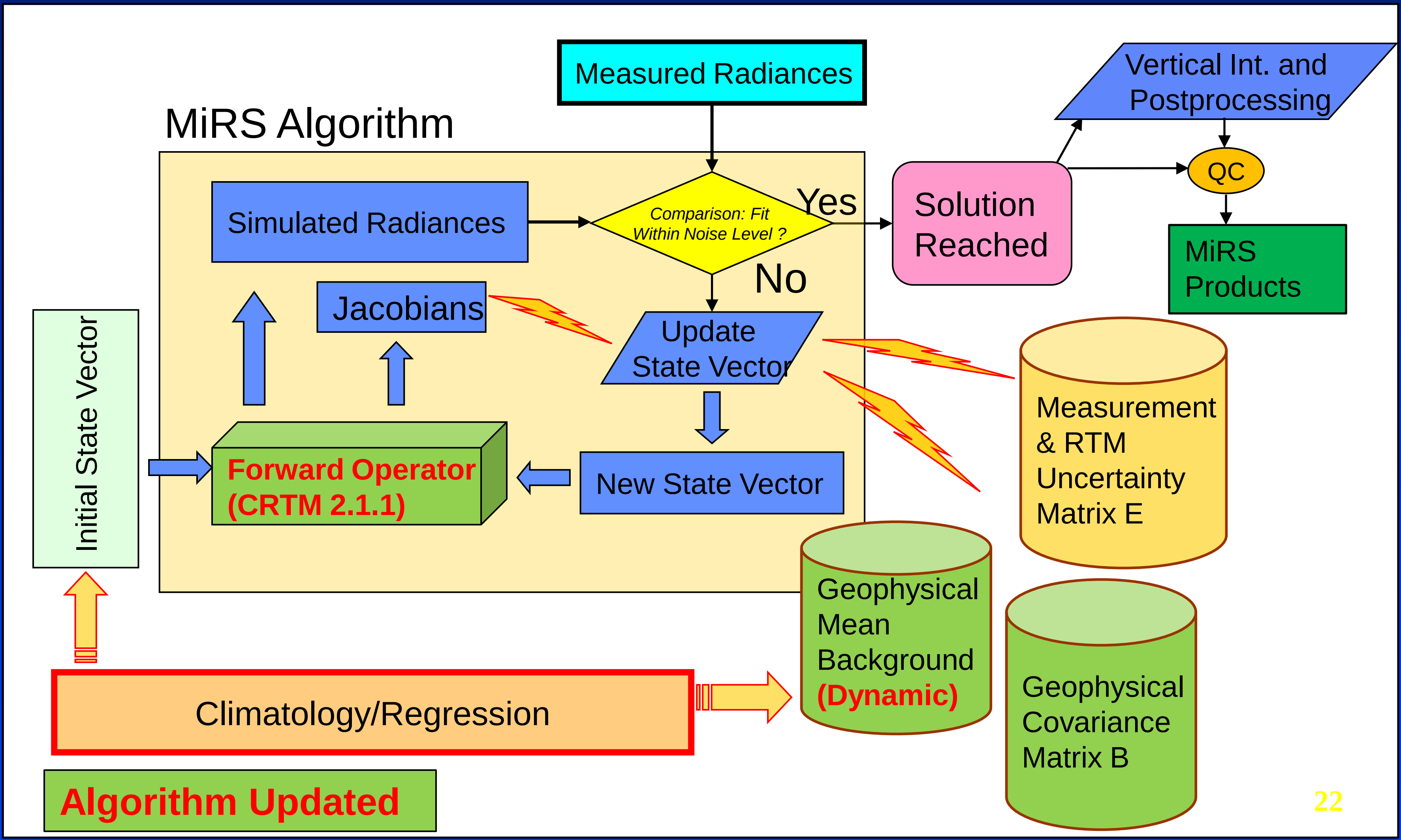
- This leads to iterative solution:

$$\boxed{\Delta X_{n+1}=\left\{BK_n^T\left(K_nBK_n^T+E\right)^{-1}\right\}\left[\left(Y^m-Y(X_n)\right)+K_n\Delta X_n\right]}$$

MiRS Algorithm: General Overview (1DVar)

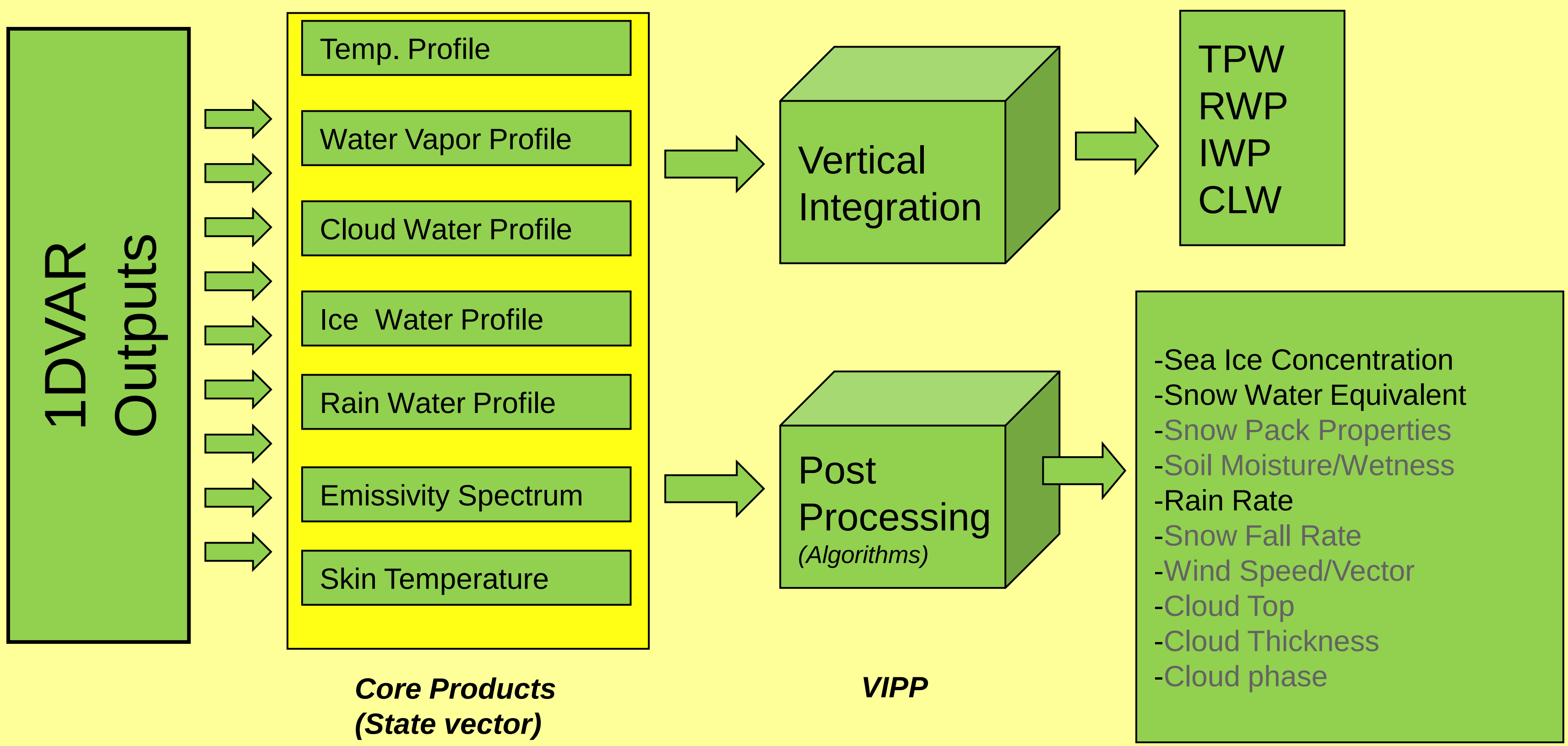


MiRS Algorithm: Detailed Overview (1DVar)

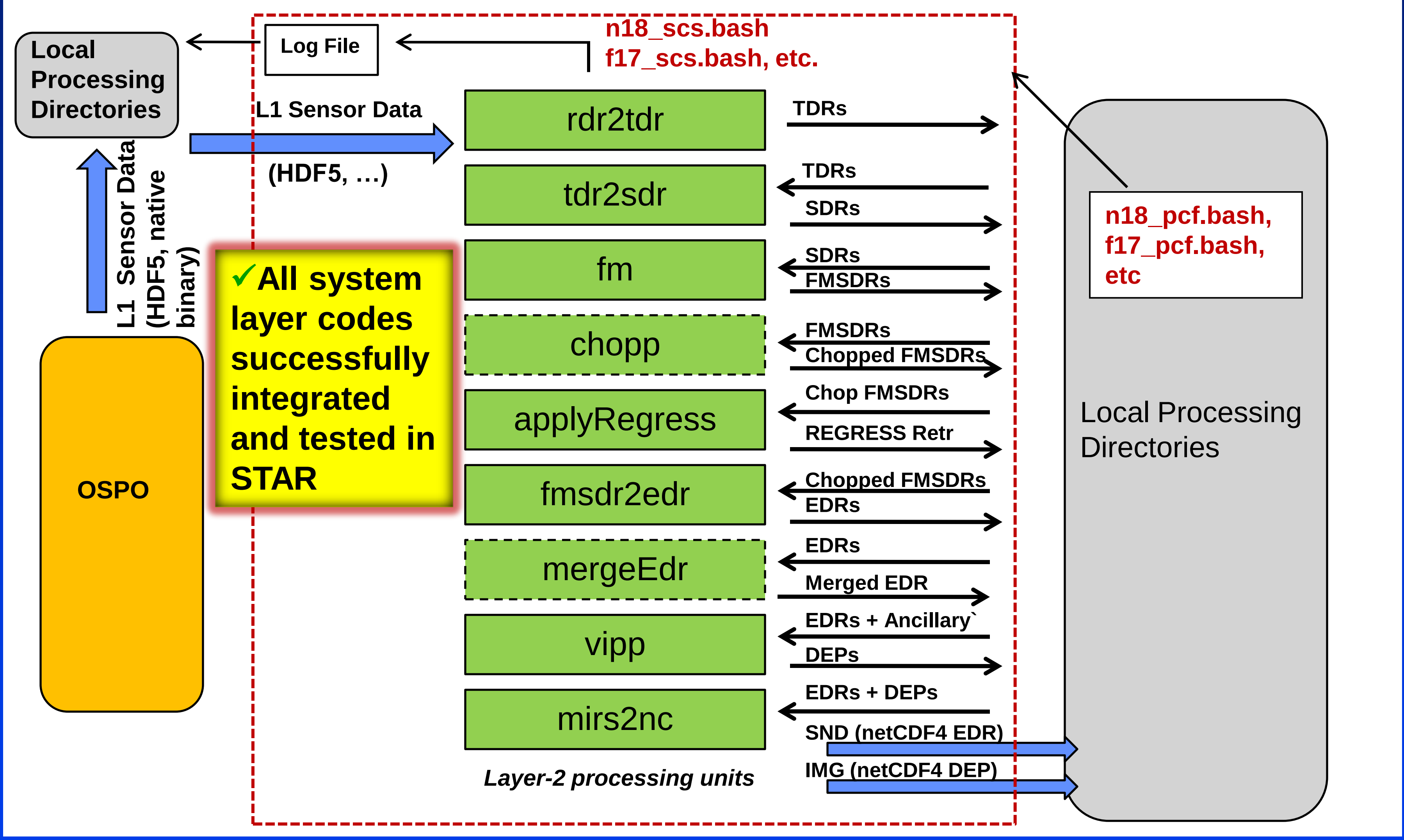


MiRS Algorithm: Post-Processing Flow

Vertical Integration and Post-Processing (VIPP)



MiRS System-Layer Process Flow: General Algorithm



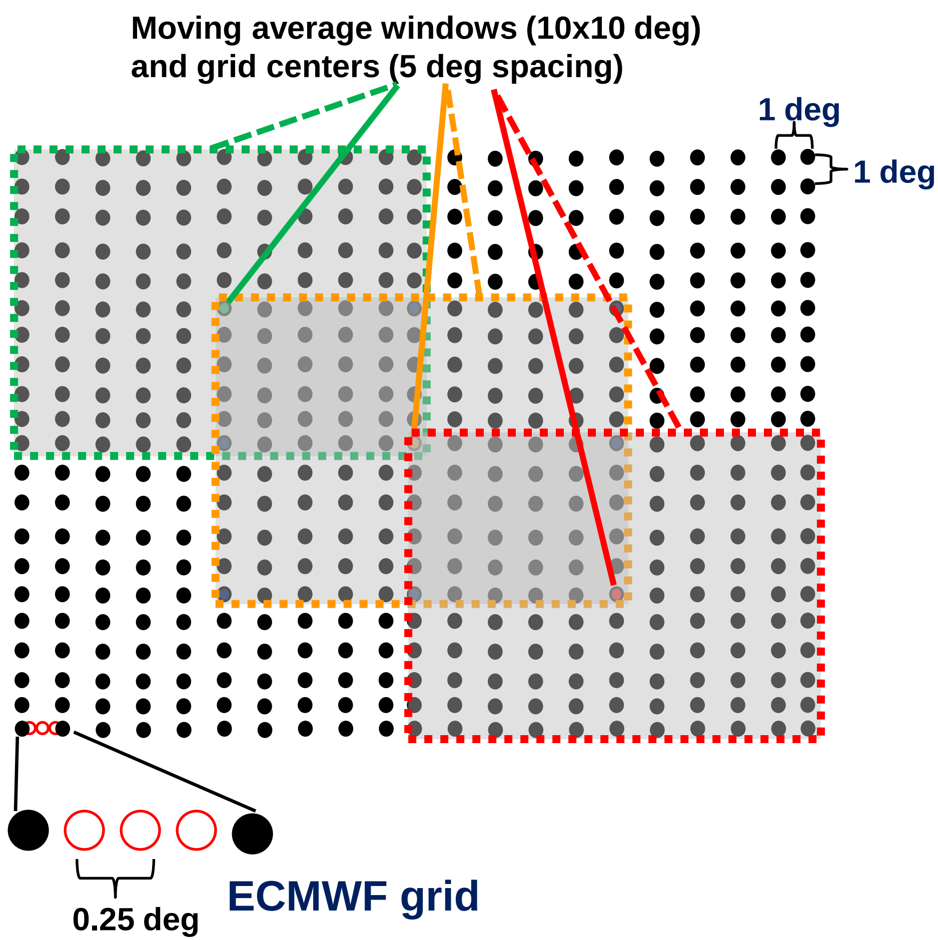
MiRS Tests: STAR Environment
MiRS DAP

- **No substantial software architecture changes from previous DAPs**
- Run on standard Linux machine (e.g. orbit272L, rhw1016)
- **Codes:** (F95, C++) precompiled using Linux compiler (ifort, g++, HDF5, netCDF4)
- **Required:** Installation dependent. In STAR, standard directory structure used for all operational sensors is used: file input/output takes place in the appropriate subdirectories. OSPO also follows this structure.
- **MiRS DAP**
  - » Single granule or orbit file: (*.h5, or native binary)
  - » PCF: contains directory, variable specifications, flags to control execution of MiRS script (e.g. npp_scs.bash, f17_scs.bash, etc.) which steps to run, where file I/O takes place, etc.
  - » Total Memory Used (per orbit, sub-orbit, or granule): 350 MB (MiRS 9.2 was 60 MB)
  - » README and test data included

MiRS Algorithm Improvements

- **New a priori background**
  - » A priori mean is spatially and temporally varying (seasonally, diurnally)
  - » Previous v9.2 used global mean values
- **New Forward Model : CRTM 2.1.1**
  - » Primary impact is in scattering (rainy) atmospheres

Improved MiRS *a Priori* State: Dynamic Mean Profile, Methodology (using ECMWF 6-hr analyses from 2012)



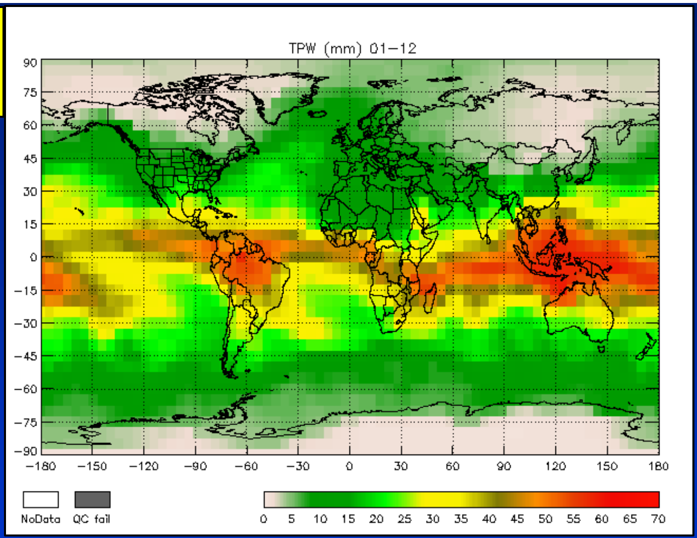
Spatial sampling
- output: 5 deg lat/lon averaging grid: averaged data output to 5 x 5 deg grid
- based on 10 degree moving average window (smoothness)
- Global Grid 72 x 37 x 100 (NX x NY x NZ)

Temporal sampling:
- Unique background for each month and time of day (0, 6 12 18 UTC); based on 5 days evenly spaced within month
- Temporal grid 12 x 4 (Nmonth x Nhr)

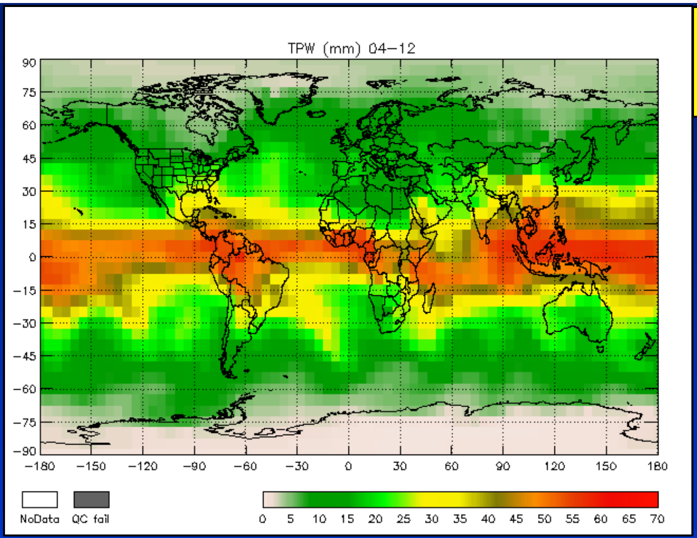
- Additional smoothness within MiRS due to interpolation in space and time to obs location
- Variables stored: T, WV, Tskin, CLW

Improved MiRS *a Priori* State: Dynamic Mean Profile, Examples TPW

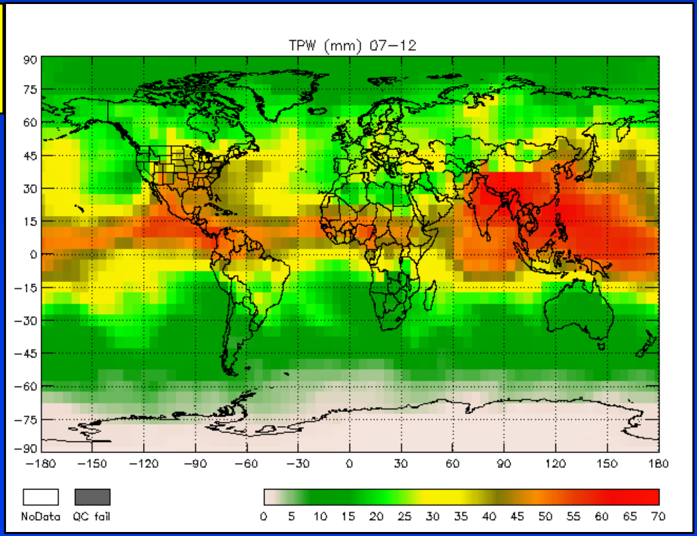
January:
12 UTC



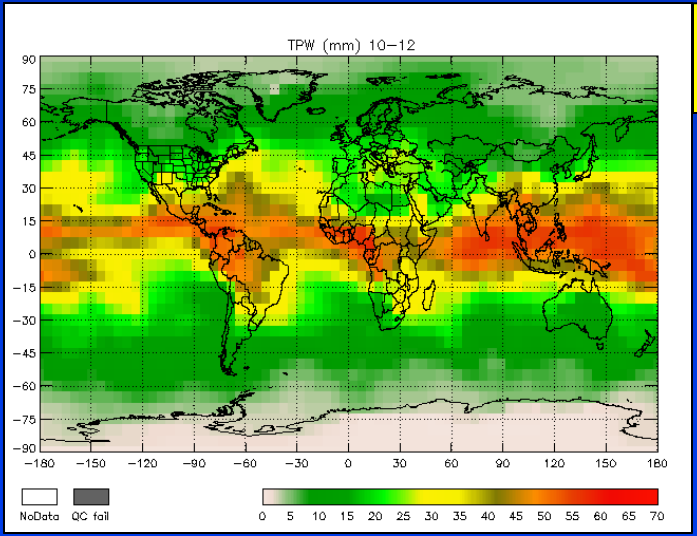
April:
12 UTC



July:
12 UTC

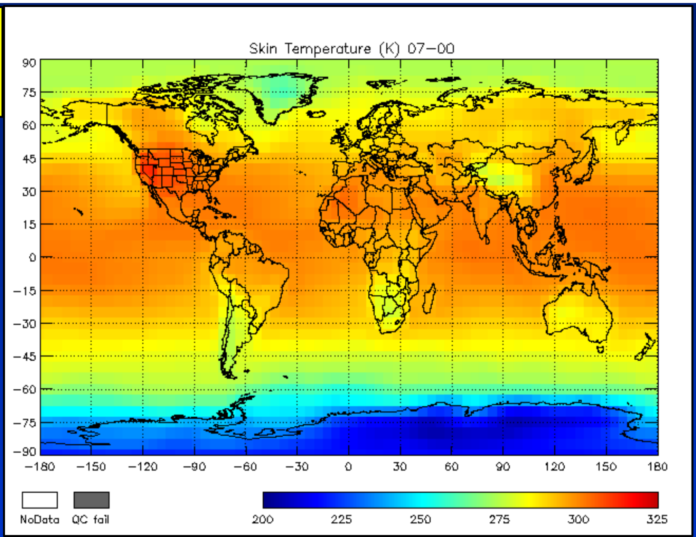


October:
12 UTC

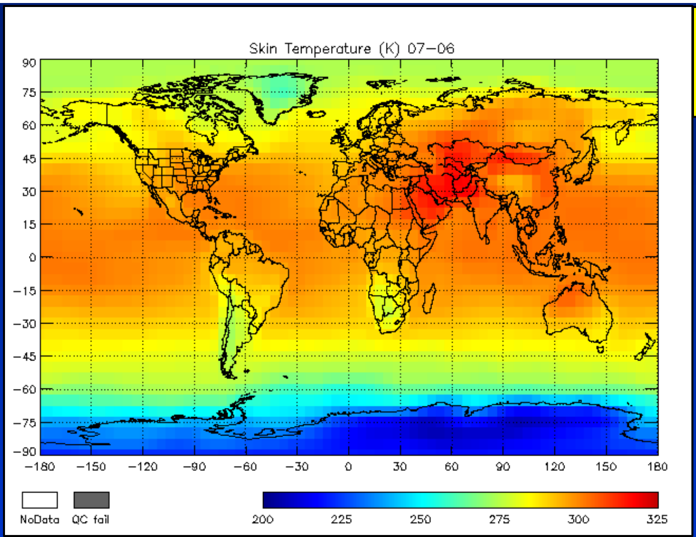


Improved MiRS *a Priori* State: Dynamic Mean Profile, Examples Tskin, July diurnal cycle

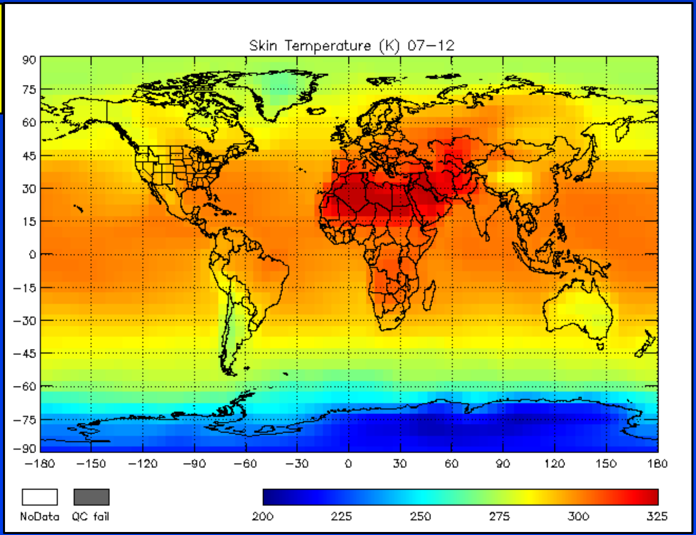
July:
00 UTC



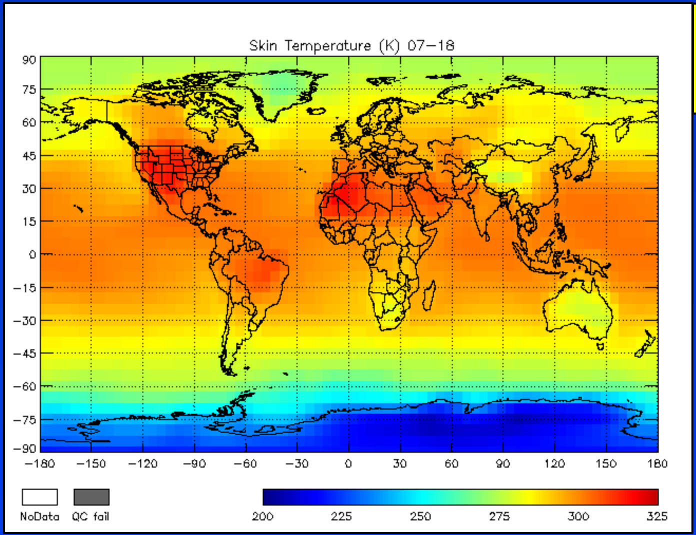
July:
06 UTC



July:
12 UTC



July:
18 UTC



MiRS Algorithm Update: Implementation of new CRTM

- All prior MiRS DAPs used an early version of CRTM (pCRTM)
- Good performance generally, but
  - » Extension to new sensors was cumbersome (coefficient file format differences)
  - » Leveraging improvements and fixes to CRTM difficult
- New CRTM (2.1.1) implemented in MiRS for all sensors
- CRTM 2.1.x:
  - » Complete overhaul of interface
  - » More sophisticated representation of hydrometeor data structures (rain, ice, graupel, snow) and in the simulation of scattering effects
- Going forward, incorporating improvements, fixes, new sensors within MiRS will be much simpler
- Increase in computational time (scattering scenes)
  - » Will be discussed in section on IT requirements

MiRS Product Assessment

- Products Assessed
  - » T, WV sounding, TPW, Hydrometeors, LST, Emissivity, Cryospheric products (SIC, SWE)
  - » QC metrics (convergence rate, QC flags)

- MIRS Science Quality Assessment
  - » Footprint matching issues (C. Smith)
  - » F17 HR Calibration and Bias Corrections (C. Smith)
  - » AMSUA-MHS and SSMIS Sounding and Sfc Products (T. Islam)
  - » Cryospheric Products (C. Grassotti)
  - » IT Requirements (C. Grassotti)

MiRS Product Assessments: Footprint Matching

Presented by

C. Smith

- SSMIS
- AMSUA/MHS

SSMIS Footprint Sizes on Earth

		After On-Board Averaging				
Channel Group Name	Freqs (GHz)	Number Averaged Along-scan	EFOV Along-scan (km)	EFOV Cross-scan (km)	Spacing Along-scan (km)	FOVs/Scan
IMG	91,150,183	1	13.2	15.5	12.5	180
ENV1	19,22	2	46.5	73.6	25	90
ENV2	37	2	31.2	45	25	90
LAS	50-60	3	37.7	27.3	37.5	60
UAS	60-63	6	75.2	27.3	75	30

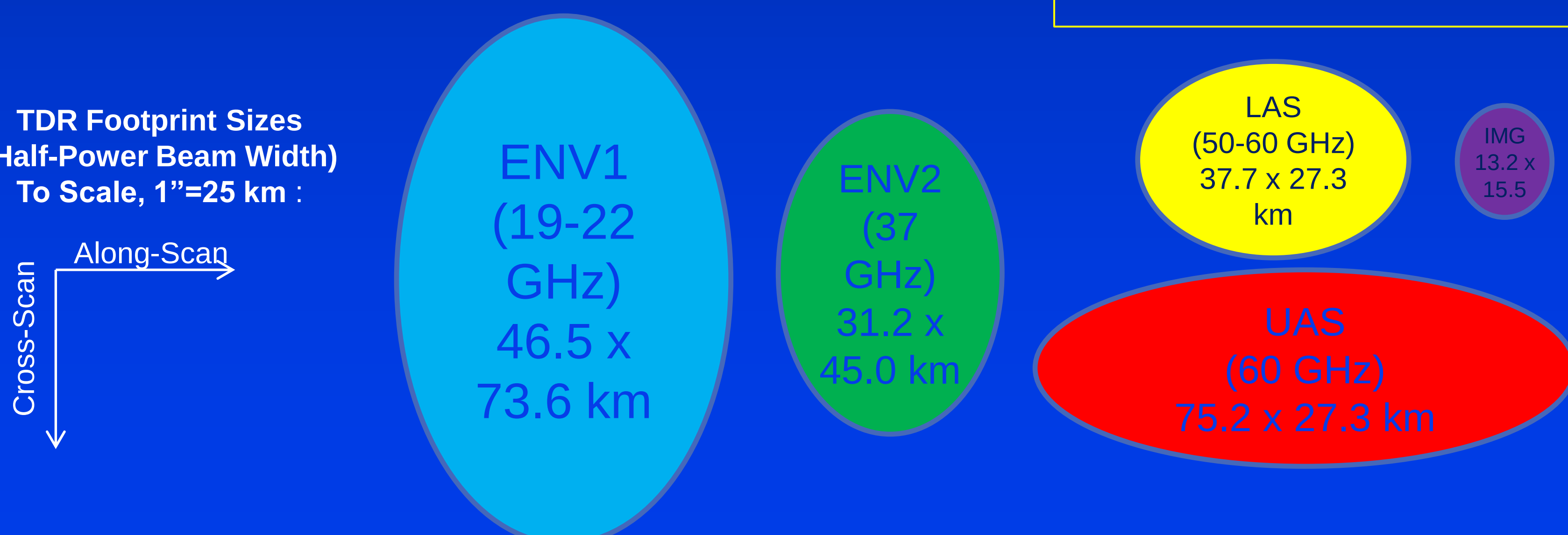
12.5 km spacing of scans along-track

MiRS F17 High Resolution Preview

Horizontal Sample Spacing:
- **25 km along-scan**
- **12.5 km along-track**

Resolution:
- **Defined by the native footprint sizes listed in the table, and below.**
- **Not equivalent to the Horizontal Sample Spacing (resolution generally larger).**

TDR Footprint Sizes (Half-Power Beam Width) To Scale, 1”=25 km :



SSMIS Low Resolution FOV (30 FOVs/scan, Current F18 Operational)

Footprint Matching Scheme:
Average 6 basic footprints (6 IMG, 3 ENV, 2 LAS, 1 UAS) along-scan. Then average 6 scans.

FOV Spacing:
75 km along-scan
75 km along-track

This is the footprint matching used for the current MIRS F18 operational product

Drawing is to scale
(1” = 25 km)

FOV Size:

IMG/ENV2/LAS/UAS:
75 km x 75 km

ENV1:
77km x 92 km

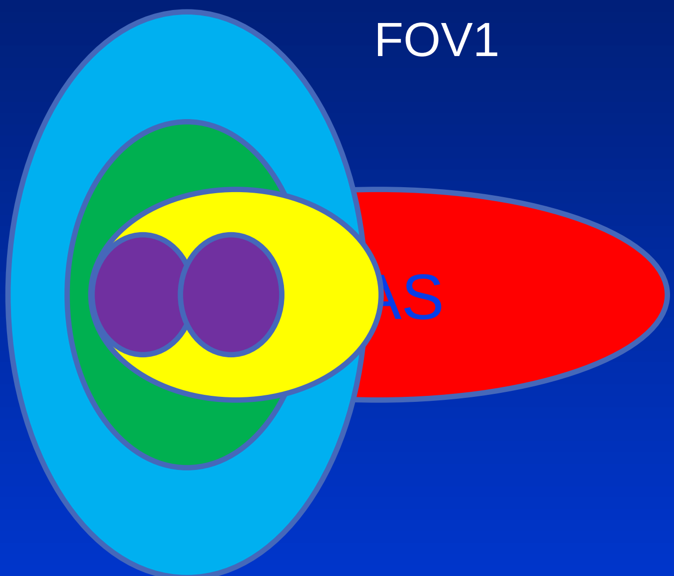
Spatial Error between channels is low.

But this is a large FOV: not optimal for representing EDRs that vary on small spatial scales (clouds, rain).

Operational Constraints for SSMIS High-Resolution Retrievals

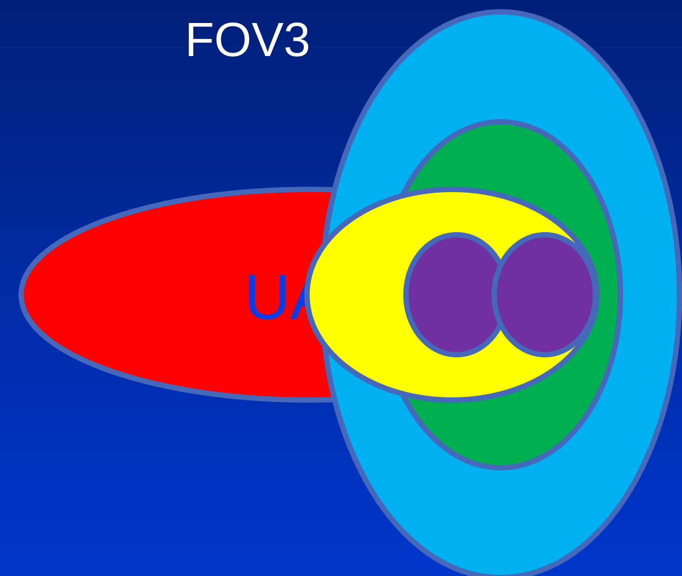
- Matching each IMG measurement to nearest ENV/LAS/UAS would result in 180 FOVs/scan
  - » 36 times more data than Low Resolution (6x along-track, 6x along-scan)
- OSPO has informed us that processing 180 FOVs/scan for every scan line exceeds current IT resources
- However 90 FOVs/scan is within IT capability
- Approach: Average 2 IMG measurements together, and select nearest neighbor ENV/LAS/UAS measurements
- Advantages:
  - » Less likely to miss isolated rain cells than subsampling IMG measurements
  - » Also provides factor of sqrt(2) NEDT reduction in IMG channels
    - – Minor improvement in WV 200-600 mb performance (land, ocean, all conditions)
    - – Minor improvement in Temp 600-950 mb performance (over ocean)

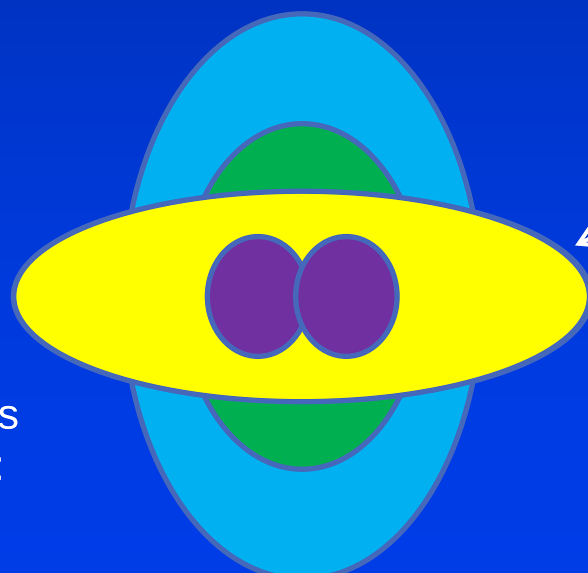
Hi-Res Baseline Footprint Matchup (90 FOVs/scan)



<u>Scheme</u>: Average 2 IMG, choose nearest neighbor single ENV/LAS/UAS

FOV Spacing:
25 km along-scan
12.5 km along-track





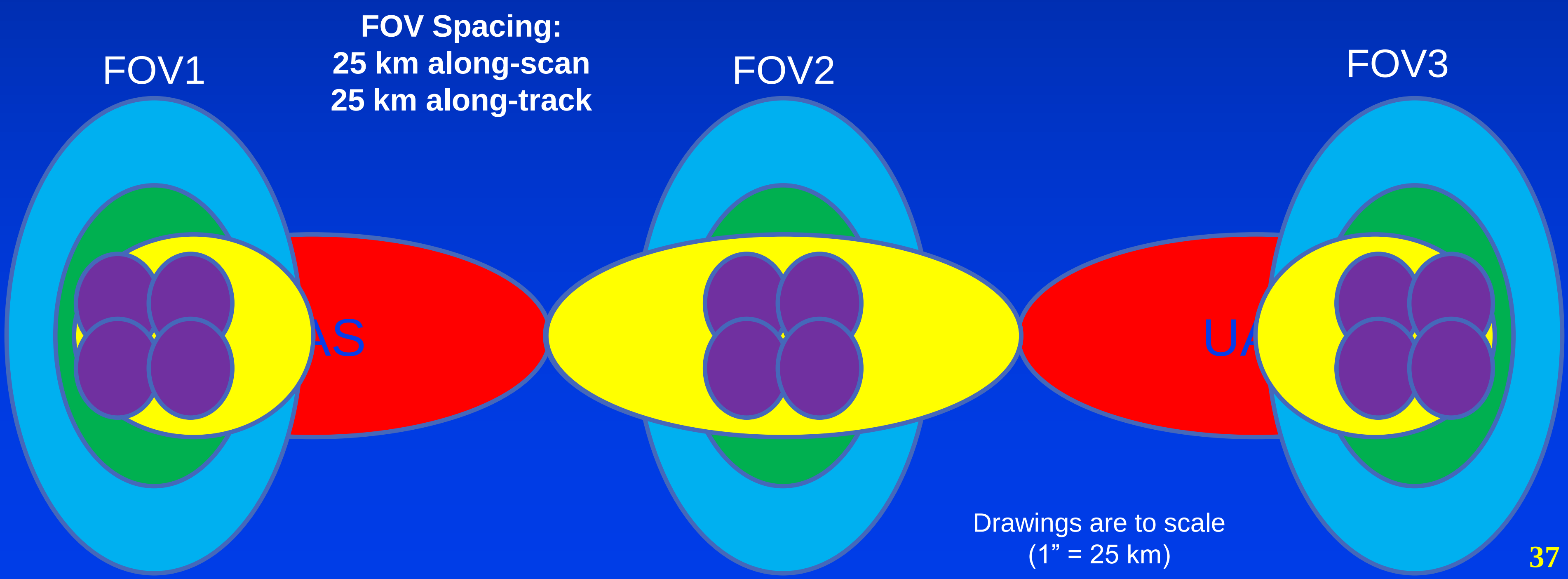
For every 3rd FOV, average two LAS to improve spatial match (maximum power) with IMG

No IMG/ENV/LAS measurements are replicated for different FOVs: no chance of “blocky” retrievals!

Drawings are to scale
(1” = 25 km)

Hi-Res Alternate Option: Average Two Scans (90 FOVs/scan)

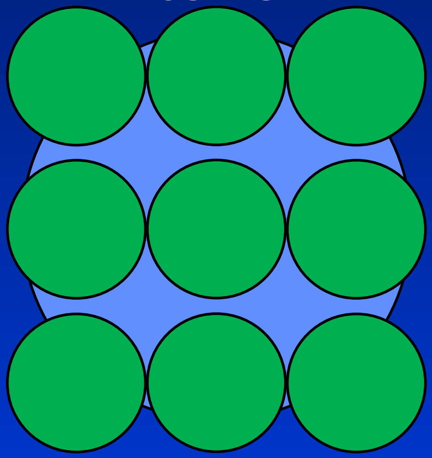
- Same as HR baseline, except that footprints from 2 scan lines are averaged for each FOV
  - » Reduces number of scenes to process by 50%
  - » Slight improvement in WV & Temp Profile, TPW performance
  - » Misses a very few light rain pixels (isolated or around edges of large storms)
- We will keep this option as a backup in case OSPO decides they need a reduction in processing time

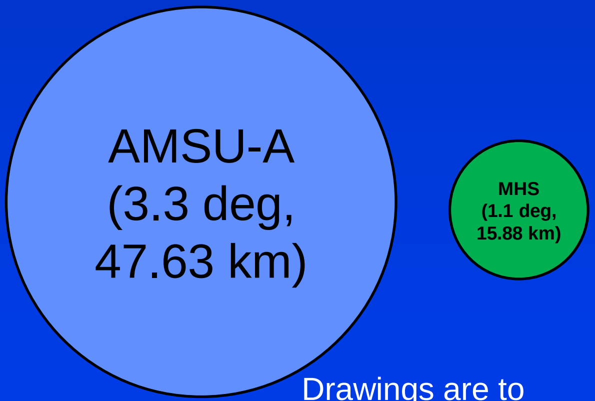


AMSU/MHS Low Resolution Footprint Matching (30 FOVs/scan)

- For each AMSU measurement, 9 MHS nearest neighbor measurements are averaged, and matched with that AMSU footprint to form a single FOV
- 1 FOV per AMSU footprint
- 30 FOVs/scan
- Geometry is shown at center of scan
  - » Identical pattern is simply stretched in both dimensions away from the center of scan
  - » Relative arrangement of AMSU & MHS footprints remains constant

A Single Low Res FOV



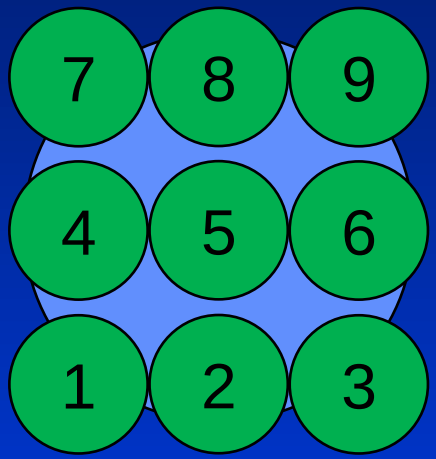


Drawings are to scale at Nadir (1” = 22 km))

AMSU/MHS High Resolution Footprint Matching (90 FOVs/scan)

- Measurement from a single MHS footprint is matched with its nearest neighbor AMSU footprint to form a single FOV
- 1 FOV per MHS footprint
  - 9 FOVs per AMSU footprint
  - The same AMSU footprint is reused over 3x3 FOVs
- 90 FOVs/scan
- Since AMSU has all the temperature sounding and imaging channels, one expects the temperature profile (and to some extent, TPW) retrievals to be very similar over the 3x3 FOVs

9 Hi Res FOVs



There will be some "3x3 blockiness" to the Temp profile and TPW retrievals.

One could interpolate AMSU measurements to MHS, but this increases the effective size of the AMSU footprint and leads to greater spatial mismatch error, i.e. greater noise.

NB: MiRS team will investigate interpolation options for HR that will reduce "blockiness".

MiRS Product Assessments: F17 Calibration and Radiometric Biases

Presented by

C. Smith

- F17 Radiometer Calibration Issues
- Impact on EDRs
- Development of high-resolution bias correction

F17 Calibration Anomalies: Dominant Dynamic Effects

- F17 (like F16) has numerous hardware related calibration issues that lead to both static and dynamic errors in the measured brightness temperatures (TBs)
  - » The most significant dynamic calibration errors are highly dependent on orbital phase (latitude, ascending/descending), and time of year

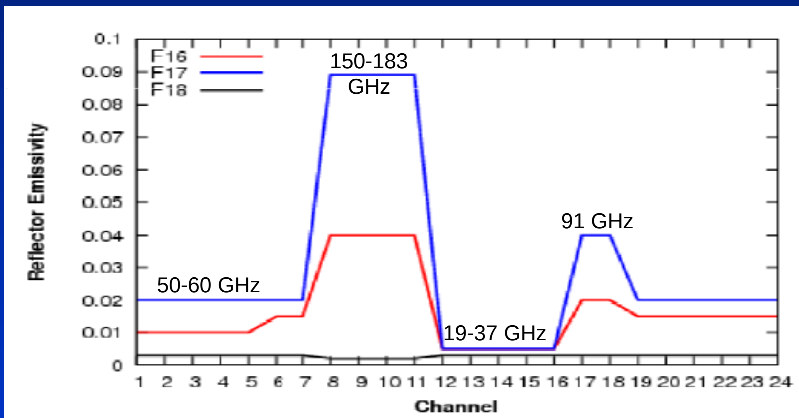
1. Emissivity of the main reflector—the dominant dynamic effect
   - » 1.5-2 K bias for temperature sounding channels
   - » 5-7 K bias for moisture profiling channels (150 - 183 GHz)
2. Solar intrusions into the warm load (reflection off canister deck)
   - » Increases warm calibration counts before corresponding rise in measured physical temperature
   - » Produces short duration (minutes) 0.5-1.5K depression in measured TBs

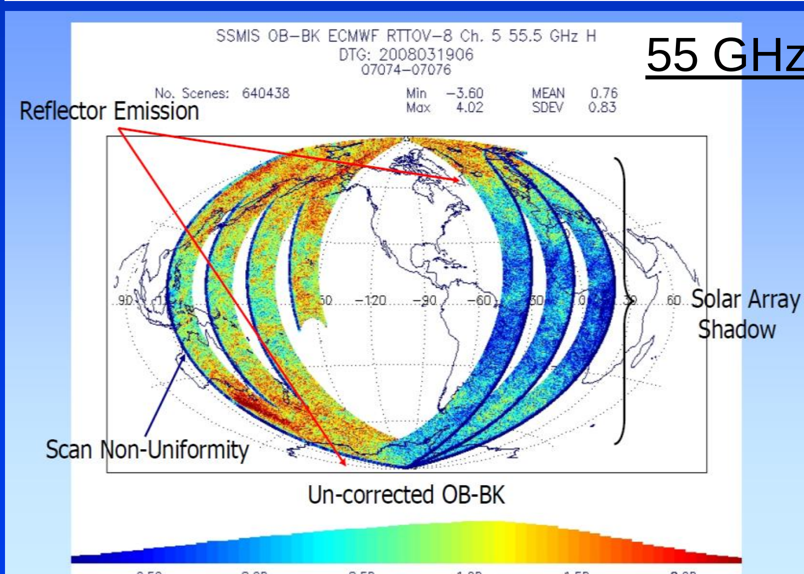
F17 Calibration Error includes Significant Dynamic Components

TB Bias due to Reflector Emissivity

$$T_{B,Meas} = (1-\varepsilon_{Rflct})T_{B,Scene} + \varepsilon_{Rflct}T_{Phys,Rflct}$$

$$\Delta T_{Bias} = T_{B,Meas} - T_{B,Scene} = \varepsilon_{Rflct}(T_{Phys,Rflct} - T_{B,Scene})$$

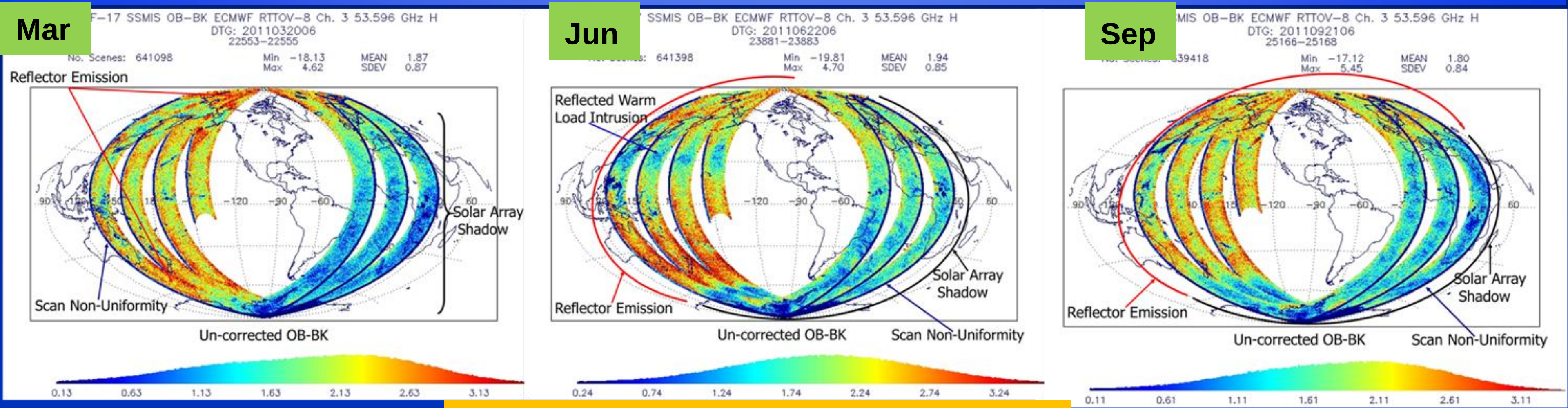




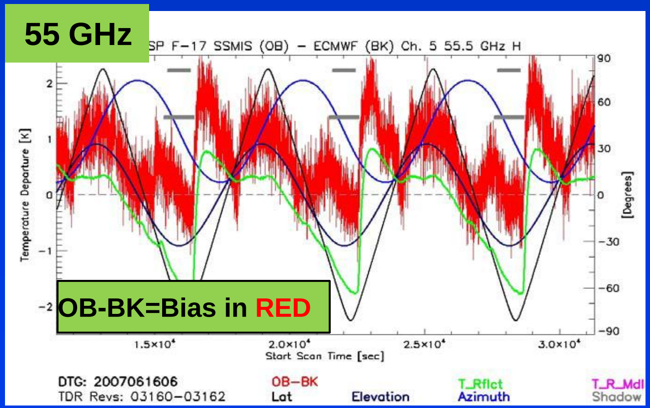
- Emissivity of the main reflector is significant
  - Should be ε_{Rflct}<<1%, but is actually much higher
- F17 bias variation dominated by Solar array shadowing of the reflector for most of the year
  - Some Earth and spacecraft shadowing for part of the year
  - Minor warm load solar intrusion bias at high elevation angles in spring and summer
- Positive TB bias when reflector in sunlight ($T_{Phys,Rflct} > T_{B,Scene}$)
  - 1-2 K for Temperature sounding channels
  - 5-7K for Water Vapor profiling channels
- Near zero or negative bias when reflector is shadowed ($T_{Phys,Rflct} \le T_{B,Scene}$)
  - Near zero/slightly negative for Temp channels
  - Negative 5-7 K for WV profiling channels

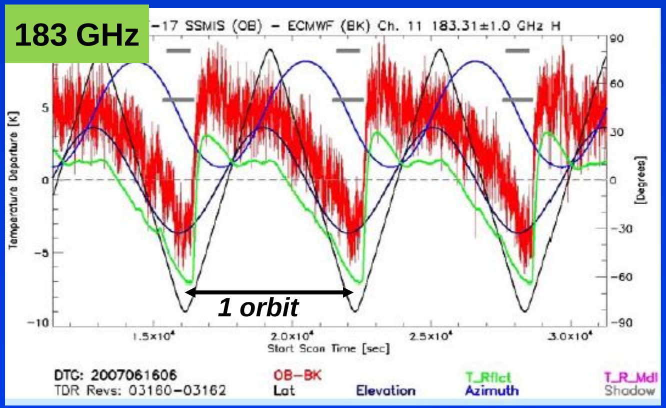
From Swadley et al. 2008

Seasonal Dependence in F17 Reflector Emissivity Induced Bias



Courtesy of Steve Swadley, Naval Research Laboratory





Variation in the amplitude of the bias w/ frequency: WV profile channels take the largest hit.

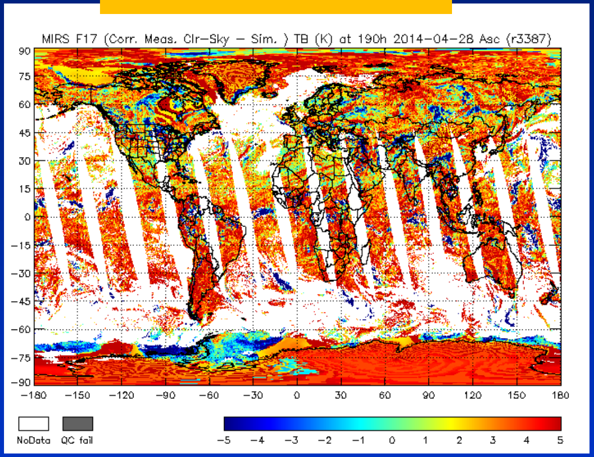
As different solar azimuth/elevation angles are sampled over the year, the latitudinal and ascending/descending pattern of F17 bias changes significantly!

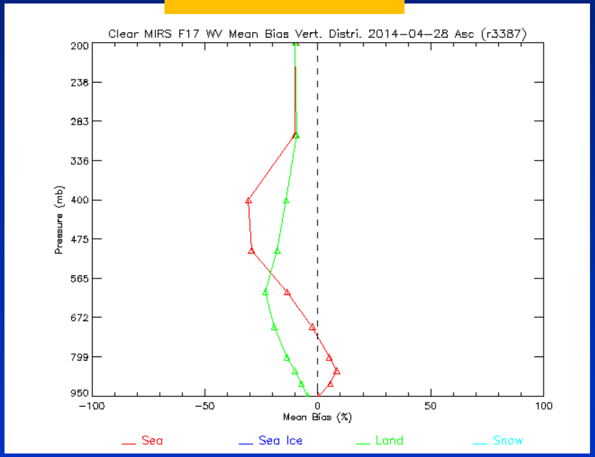
F17 Bias Pattern due to Reflector Emissivity Corresponds to EDR Biases

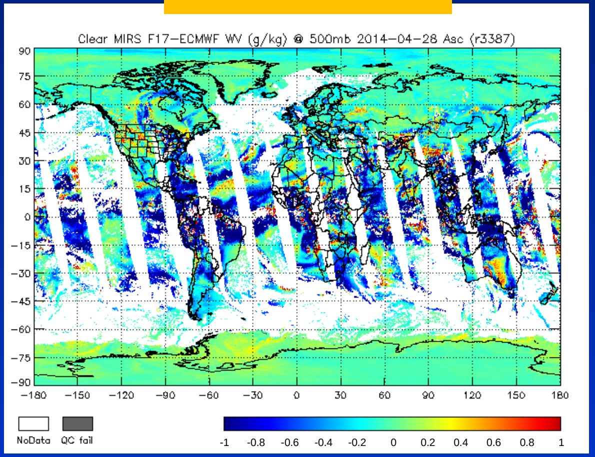
Example: Apr 28 190H TB Bias vs Water Vapor Profile Bias

183±6 GHz TB Bias | **WV Prof Bias** | **WV 500mb Bias**

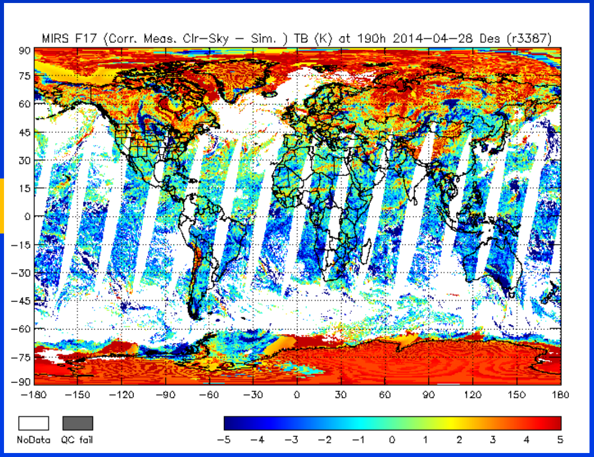
Ascend

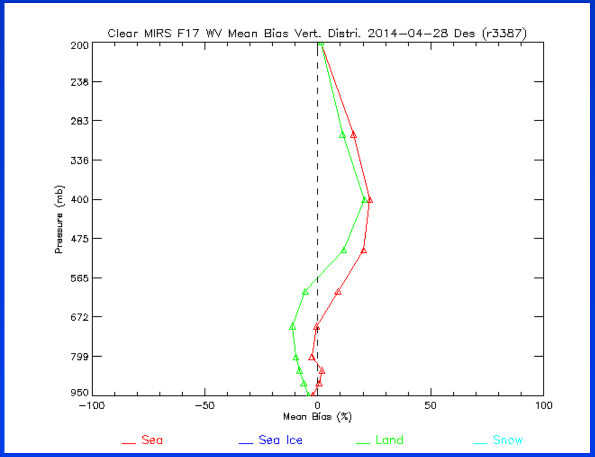


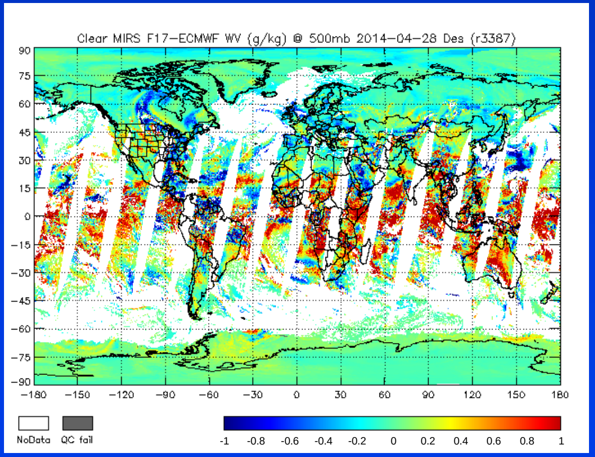




Descend







F17 Bias Pattern due to Reflector Emissivity Corresponds to EDR Biases

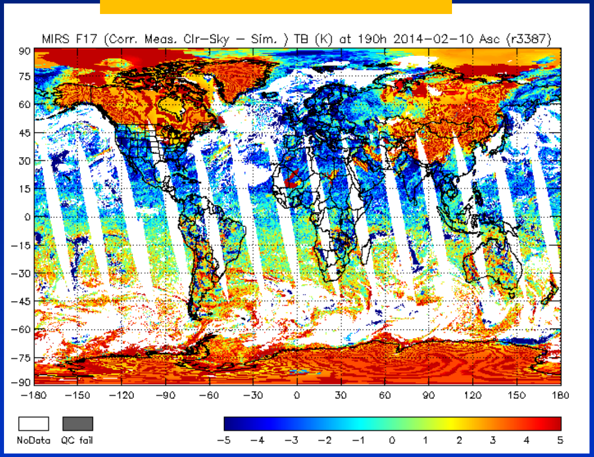
Example: Feb 10 190H TB Bias vs Water Vapor Profile Bias

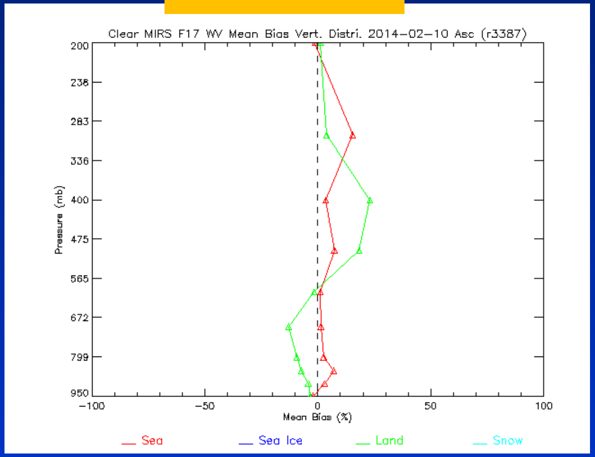
183±6 GHz TB Bias

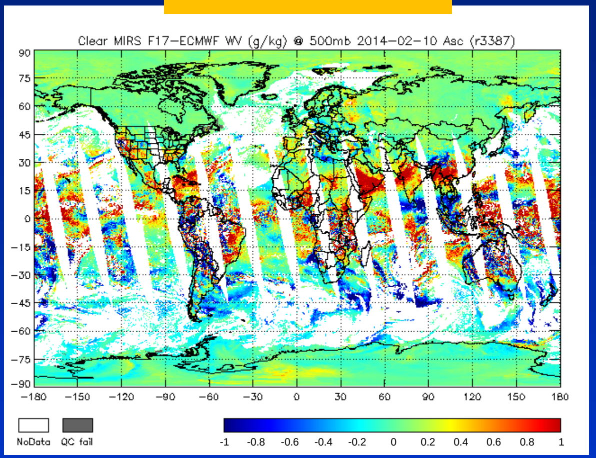
WV Prof Bias

WV 500mb Bias

Ascend







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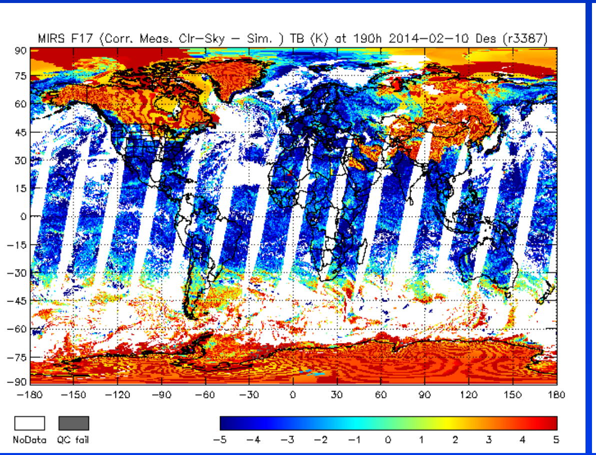
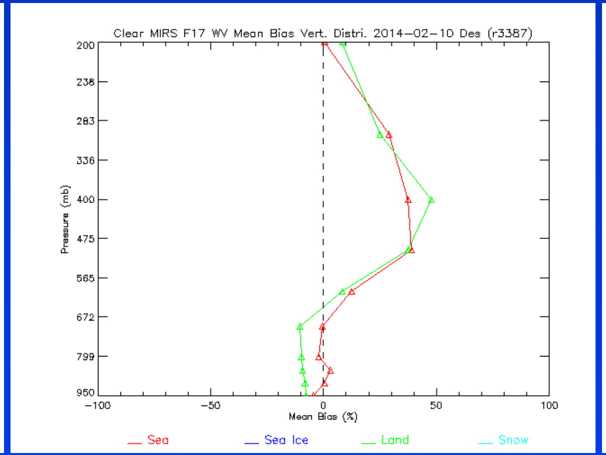
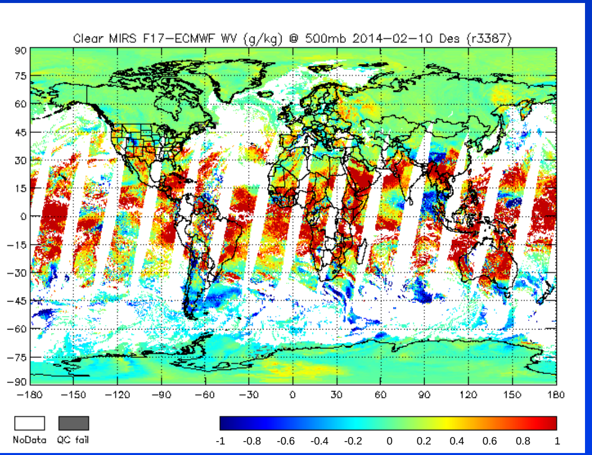
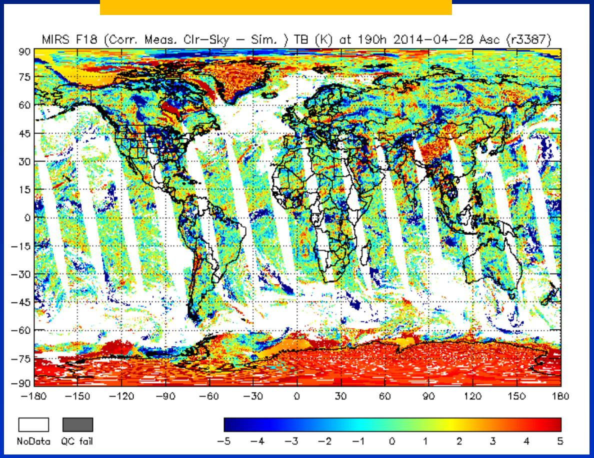
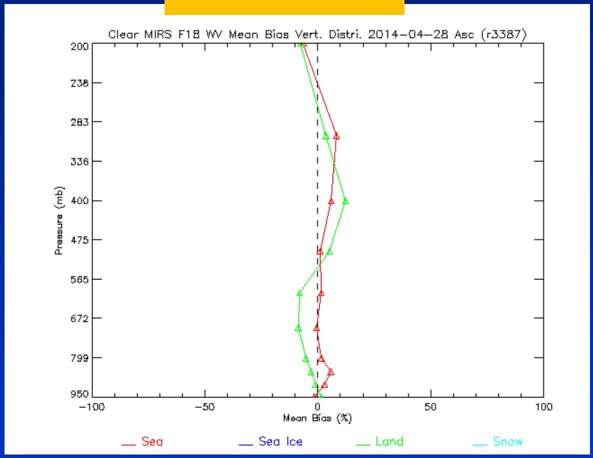
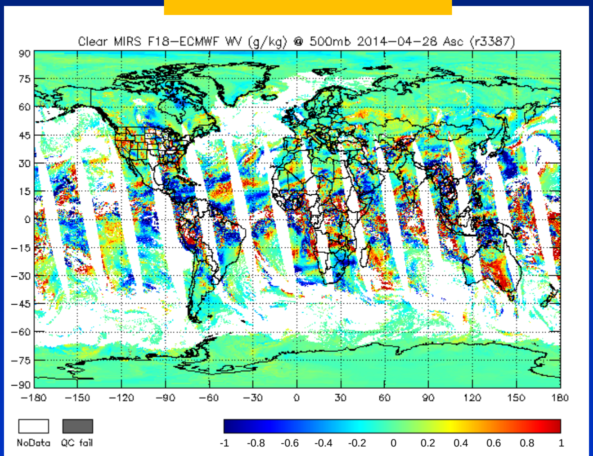
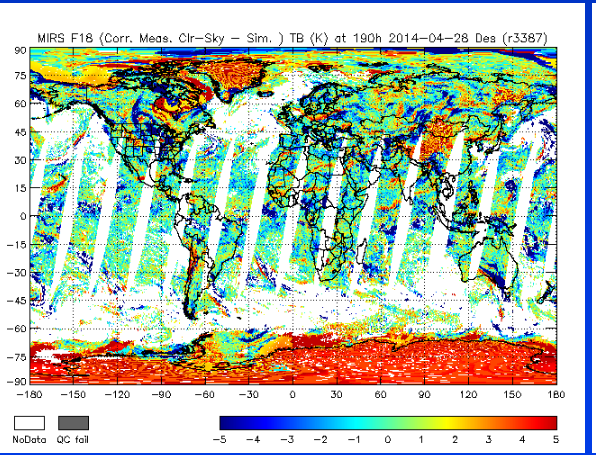
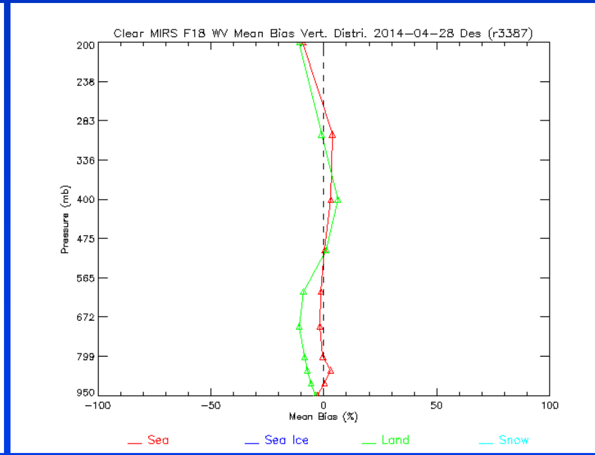
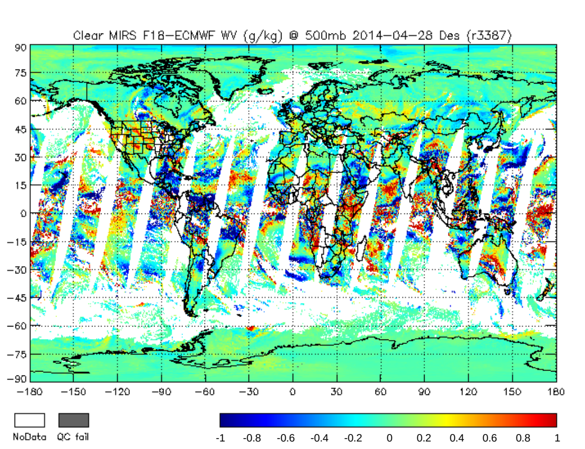






F18 Bias Pattern due to Reflector Emissivity Is Small; Little Effect on WV Bias

Example: Apr 28 190H TB Bias vs Water Vapor Profile Bias

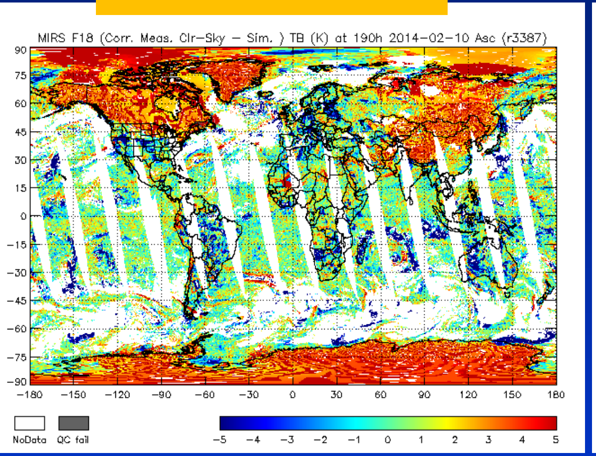
	183±6 GHz TB Bias	WV Prof Bias	WV 500mb Bias
Ascend			
Descend			

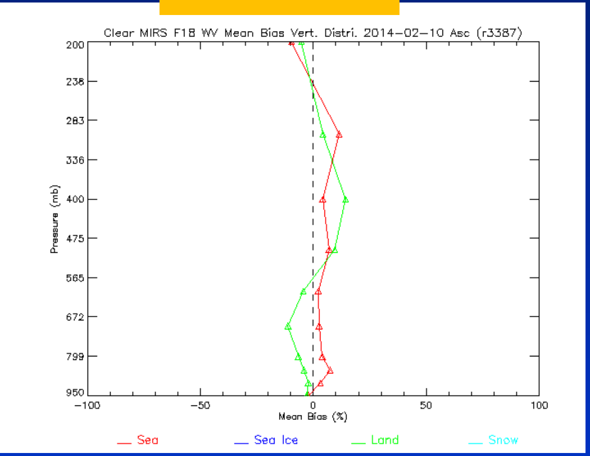
F18 Bias Pattern due to Reflector Emissivity Is Small; Little Effect on WV Bias

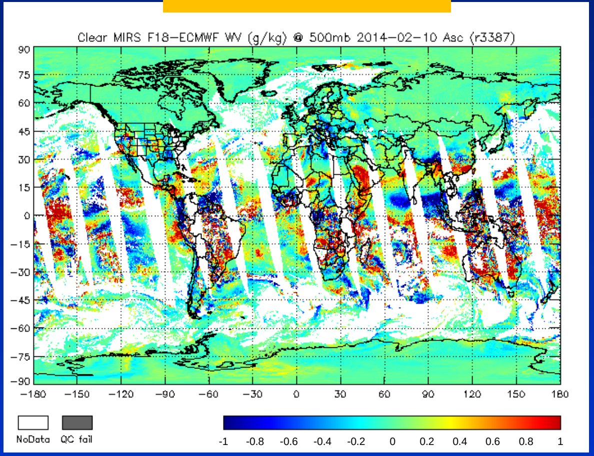
Example: Feb 10 190H TB Bias vs Water Vapor Profile Bias

	183±6 GHz TB Bias	WV Prof Bias	WV 500mb Bias

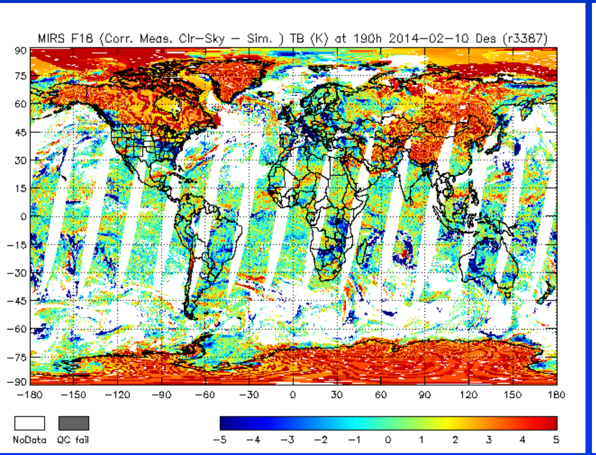
Ascend

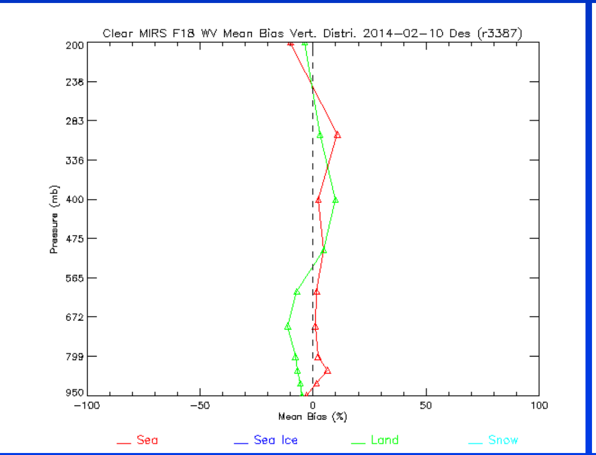


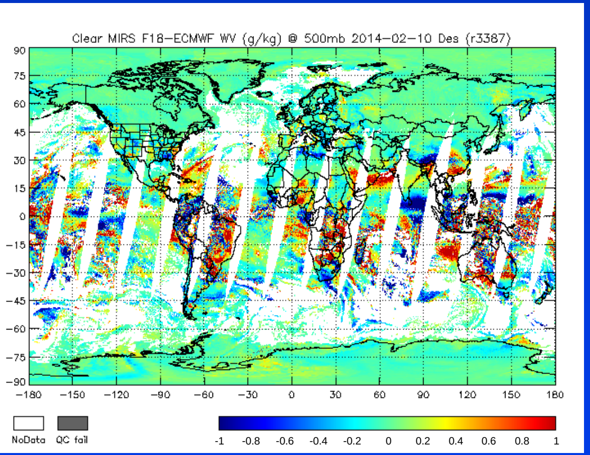




Descend







Variability of F17 EDR Performance

- Dynamic F17 Calibration Issues--specifically the Main Reflector emissivity problem—are a strong driver of both TB biases and the resulting EDR biases
  - » Both vary with orbital phase (latitude and ascending/descending) on a given day
  - » The orbital pattern of TB biases and EDR biases roughly repeats on an annual cycle

- F17 retrievals are very usable, but degraded relative to F18
  - » The reflector emissivity issue has largely been fixed for F18

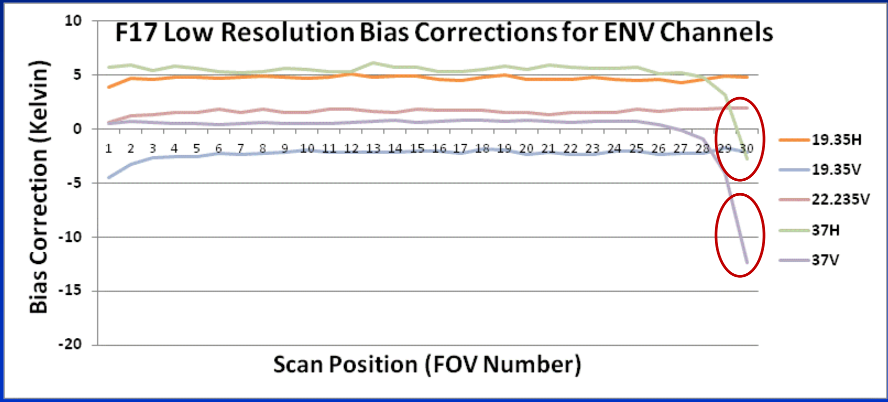
- MiRS F17 global performance will vary (and roughly repeat) on an annual cycle
  - » Similarly, performance varies geographically within a day
    - – Ascending vs descending, and latitude within each orbital node

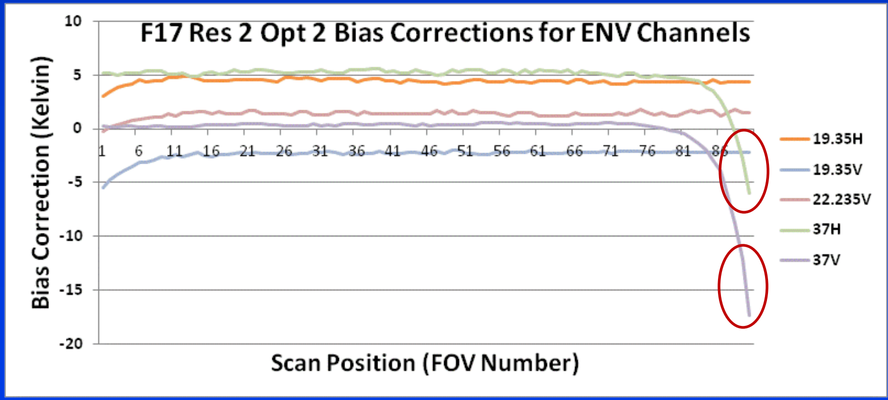
- MiRS F17 single, global bias correction designed to minimize variation in performance
  - » While mitigating static calibration issues, such as scan non-uniformity

High Resolution TB Bias Corrections

- F17 TB measurements for some ENV and LAS channels show a significant "roll-off" at the beginning and/or end of scan
  - » Feedhorn's view of the main reflector gets occluded by edges of the calibration loads
- TB bias corrections attempt to mitigate this issue
  - » As well as other instrument and CRTM biases
- Low resolution bias corrections (30 FOVs/scan)
  - » Can be used by MIRS for Hi-Res retrievals (duplicate x3)
  - » However, low resolution averages 6 IMG, 3 ENV, and 2 LAS measurements along-scan for each FOV
  - » This was averaging down the extent of the drop-off seen at high resolution.
  - » Applying low-res bias corrections to high-res retrievals resulted in significant residual TB bias at end of scan
  - » Results in end-of-scan bias in EDRs: striping in along-track direction in EDR bias maps & along-scan bias plots
- We derived new bias corrections for F17 high resolution

MIRS ENV Channel Bias Corrections
(Subtracted from TDR TBs before retrieval)



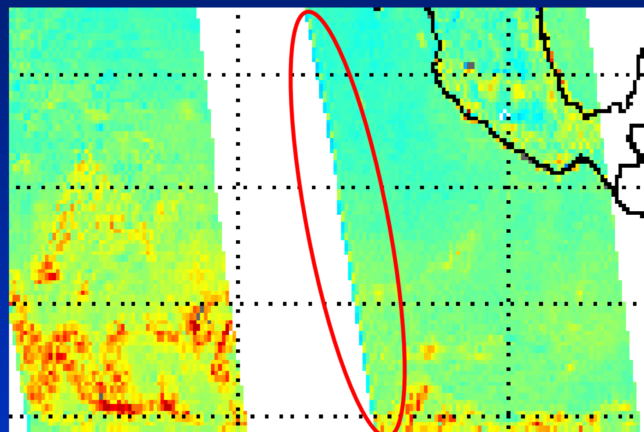


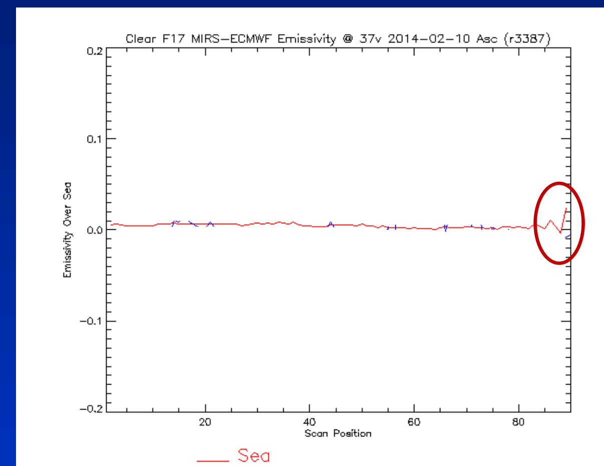
F17 Hi-Res Bias Correction: Mitigation of End of Scan EDR Biases

Example: Feb 10 37V Emissivity

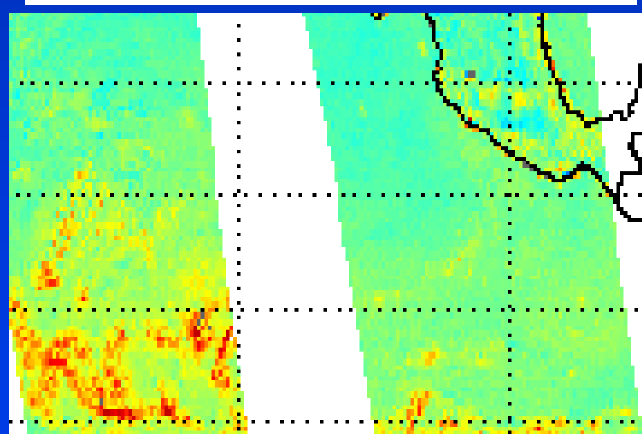
High-Res Retrievals Using:

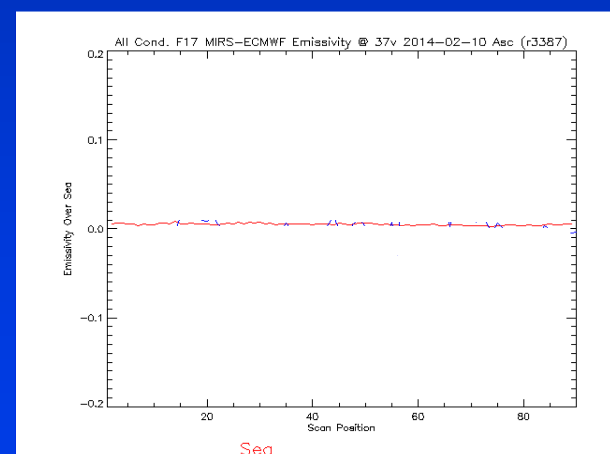
Low Res Bias Correct.





High Res Bias Correct.



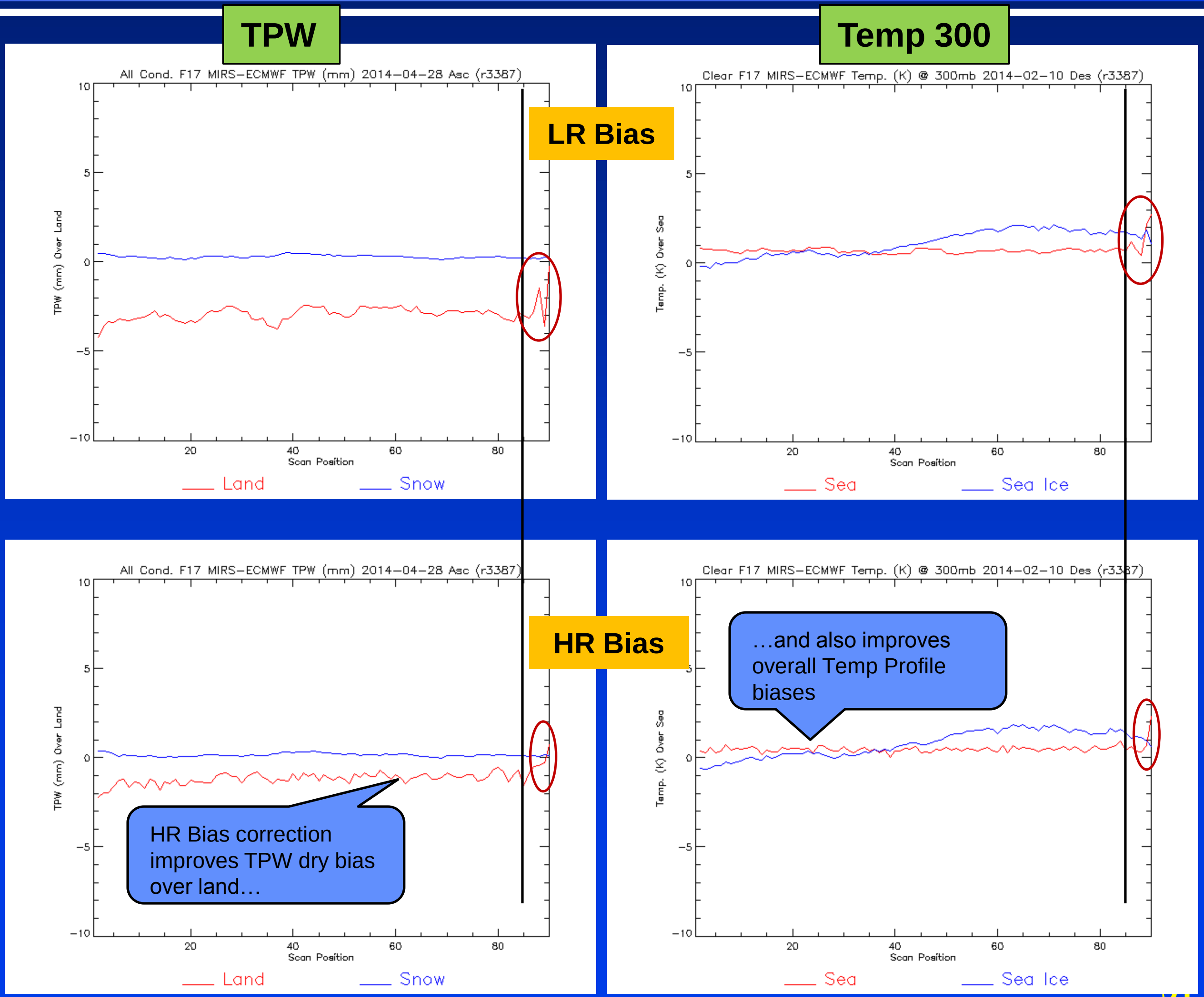


High Resolution Bias Corrections Largely Mitigate End-of-Scan EDR Biases

F17 Residual EDR End-of-Scan Bias

Example: Feb 10 TPW and Temp 300 mb

- High Res Bias Correction mitigates EDR End-of-Scan Bias, but does not remove it completely for a few EDRs
- For TPW over land & Temp Profile over ocean, it moves the onset of the bias from Scan Position 82-86 to scan position 89
  - » Is a result of modeling end-of-scan TB bias as additive, when it is really a multiplicative effect
- If the users desire, we can flag scan positions 89 and 90 as lower quality retrievals



F17 Global Bias Correction

- F17 calibration bias contains significant dynamic components that depend on orbital phase (latitude, ascending/descending) with a roughly annual cycle

- In order to produce an optimal global/yearly estimate, the Hi-Res bias correction was derived by sampling the bias data uniformly over the globe and over time of year

- Relative to low-res, use of the high-res bias corrections result in:
  - » A 3-4% improvement in convergence rate (up from 86-87% to 90%)
  - » An 8-12% reduction in execution time for each day of data (less iterations to reach convergence)
  - » Improved Temperature Profile Bias Errors
  - » Generally improved Water Vapor Bias Errors

- F17 results presented by T. Islam in next section will summarize single day performances; may differ from performance at other times

Improvement in Temp/WV Profile Biases Using HR Bias Corrections

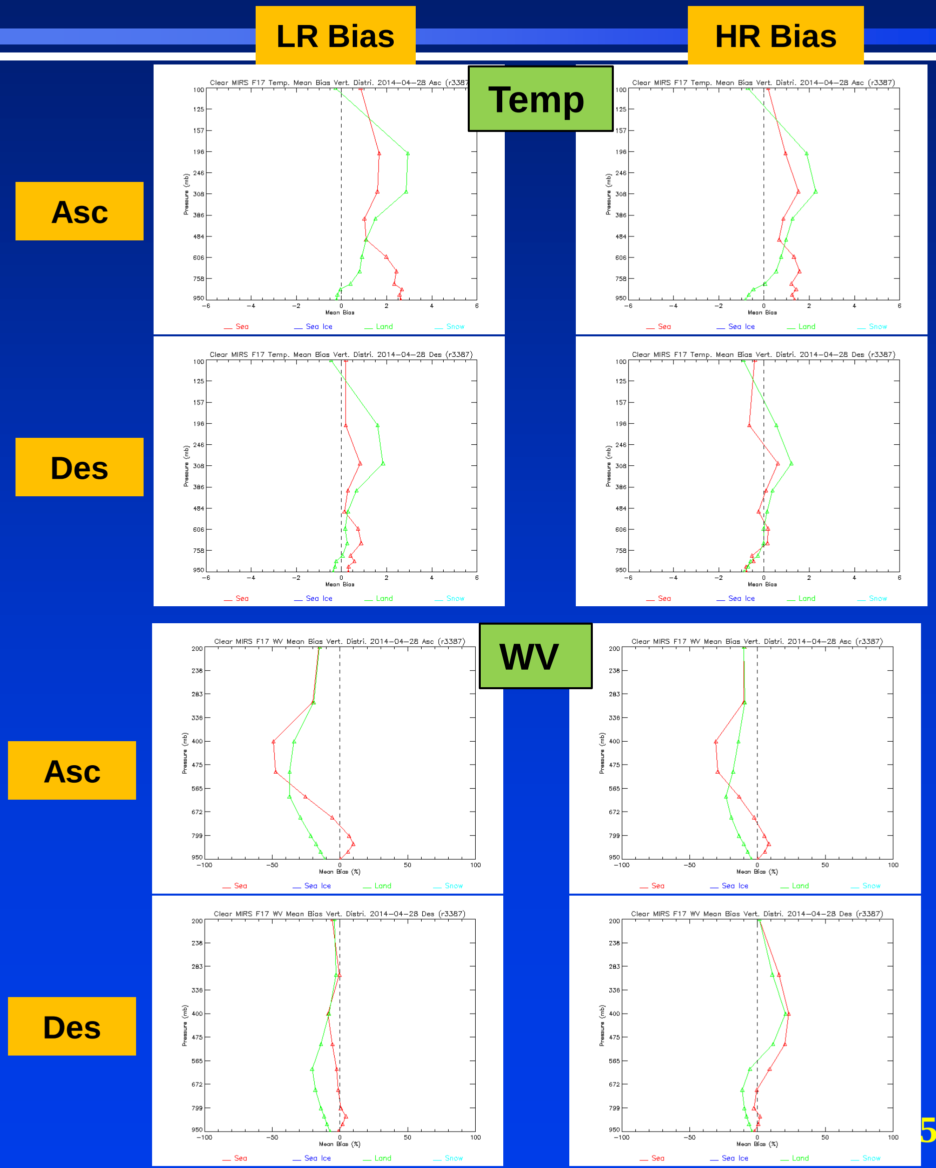
- Performed retrievals using LR and HR bias corrections over several days across the year (Jan 27, Feb 10, April 28, several days in August)

- HR biases seem to improve Temp Profile global bias errors in both clear and cloudy conditions

- WV profile bias errors are often improved, but not always

- Results from Apr 28 shown
  - » T: A day with a warm bias (due to reflector emissivity) in the ascending orbits, and a cold bias in the descending orbits.
  - » WV: A day with mixed improvement and degradation in WV profile bias errors

- Temp and WV profile std. dev. errors show slight improvement (not shown)



MiRS Product Assessments: Sounding Products: N18, N19, MetopA (MetopB), F17 (F18)

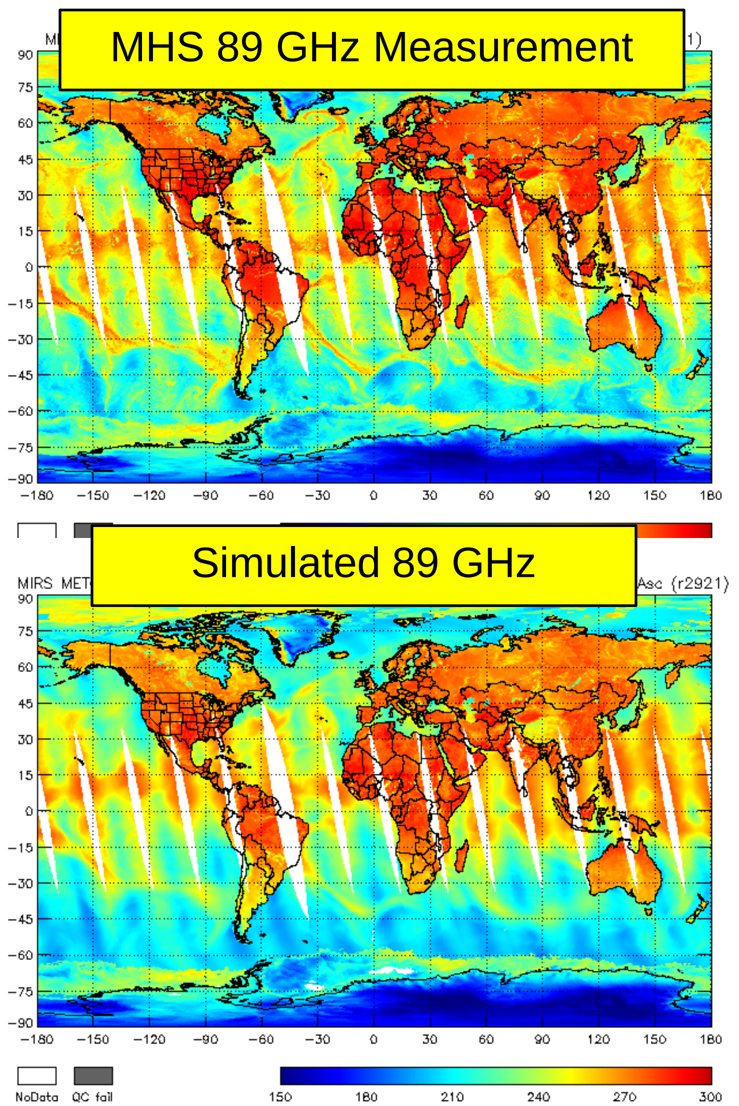
Presented by

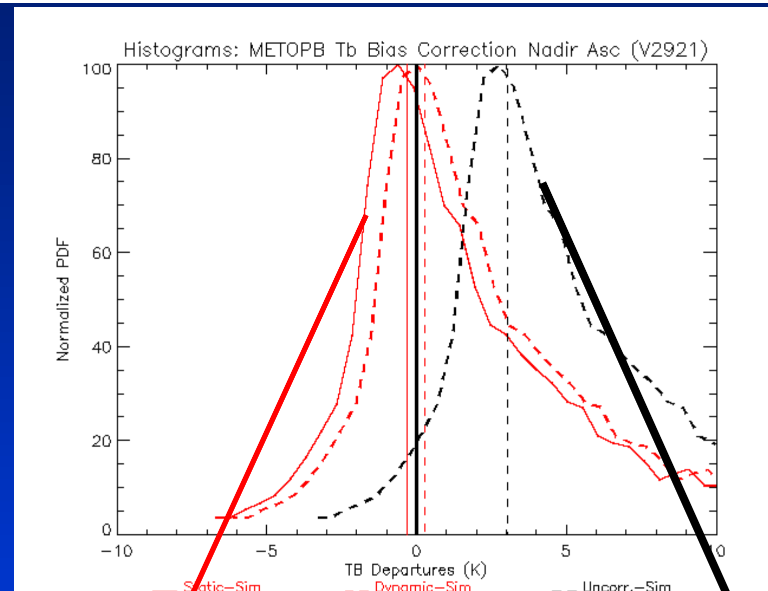
T. Islam

MiRS Product Assessments: Sounding Products: N18, N19, MetopA (MetopB), F17 (F18)

- Bias Correction (general)
- Sounding Products
  - » Temp profile
  - » WV Profile
  - » TPW
  - » LST
  - » Surface Emissivity
- MetopB (already HR) and F18 (fewer calibration issues) used as benchmarks to separate impacts of resolution from algorithm and sensor differences
- Overall performance assessments based on multiple days, but single days will be shown here; F17 SSMIS performances higher variability from one time of year to another than AMSUA/MHS

MiRS Product Assessments: Bias Correction





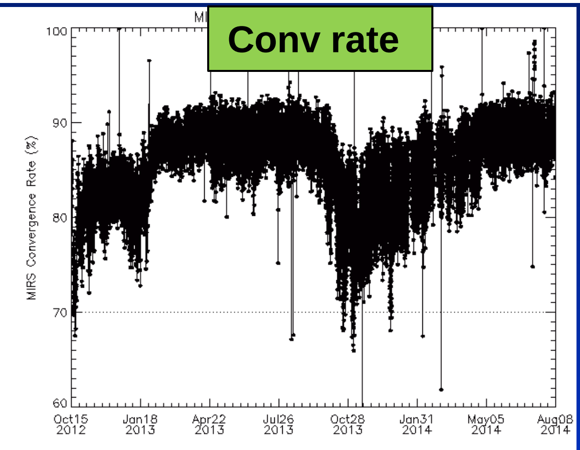
Residual after correction applied

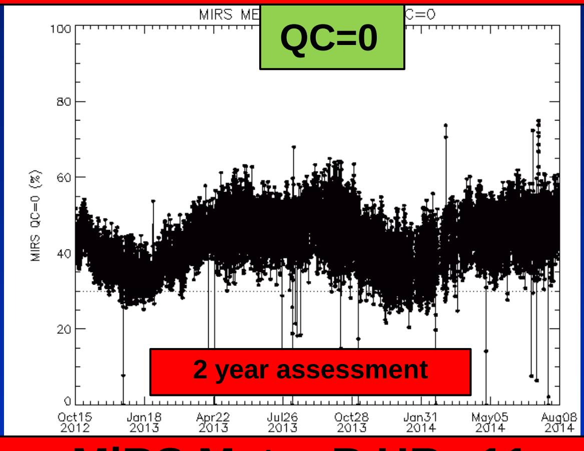
TDR
89 GHz bias
(Obs-Sim)

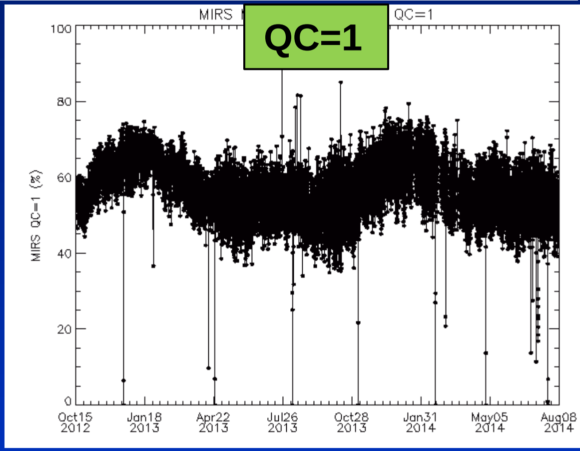
- **New bias correction is implemented for all operational sensors in MiRS v11.**

MiRS Product Assessments: Convergence Rate and QC flags

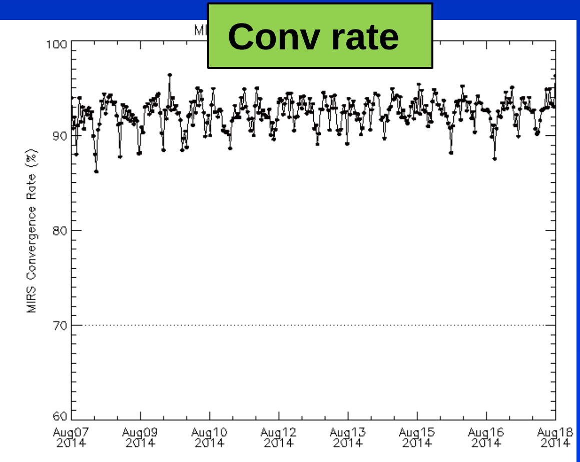
MiRS MetopB HR v9.2

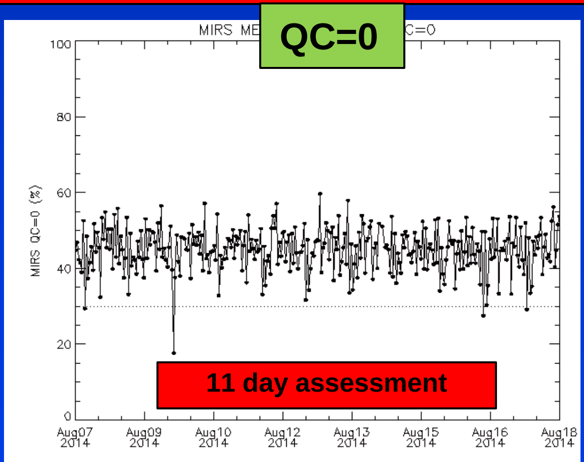


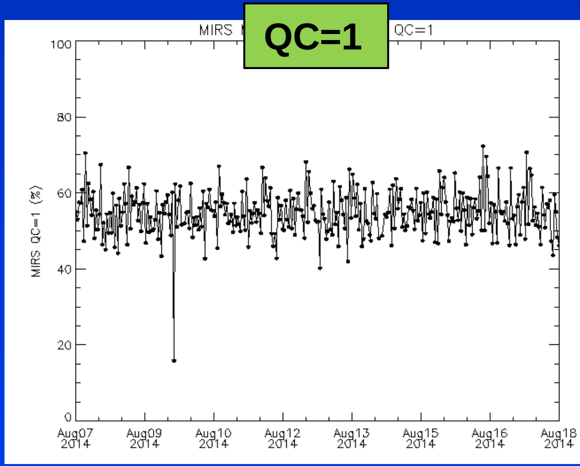




MiRS MetopB HR v11







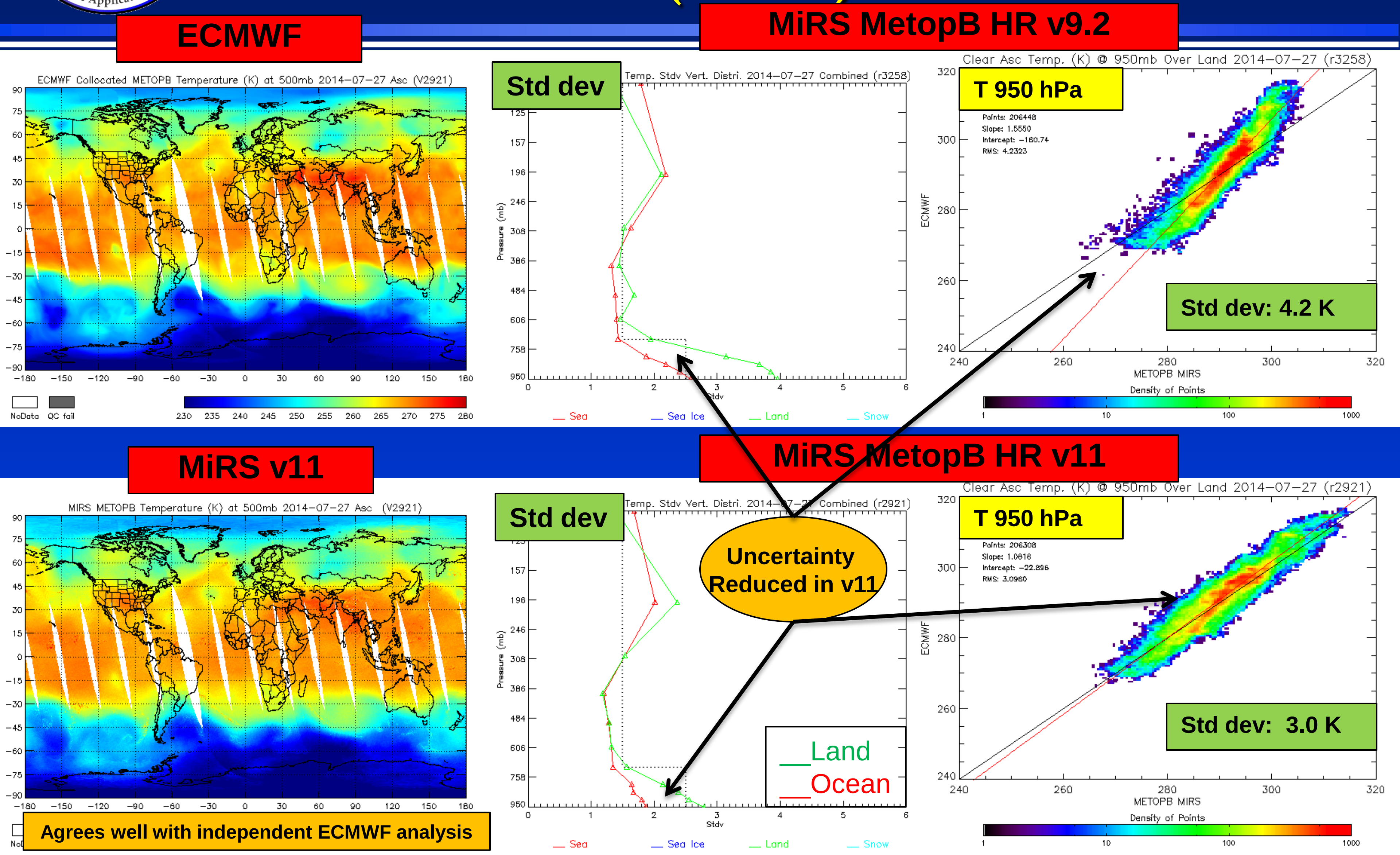
- **MiRS v11 convergence rate and QC flags are very similar to v9.2.**
- **Typically, Convergence rate>90%, usable retrievals (QC=0 and QC=1)>95%.**

MiRS Official Products: SND and IMG files

Observational Parameter	Imagery Product	Sounding Product
Atmospheric Temperature profile		X
Atmospheric Water Vapor profile		X
Total Precipitable Water	X	
Land Surface Temperature	X	
Surface Emissivity Spectrum	X	
Sea-ice Concentration	X	
Snow Cover Extent	X	
Snow-Water Equivalent	X	
Integrated Cloud Liquid Water	X	
Integrated Ice Water Path	X	
Integrated Rain Water Path	X	
Rainfall Rate	X	

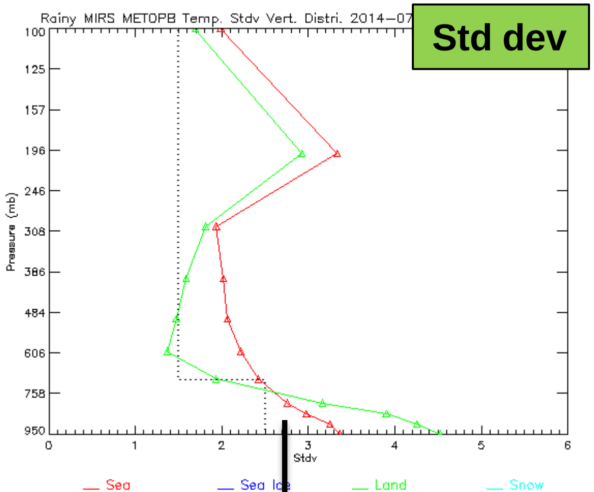
NB: IMG and SND products stored in netCDF4 files

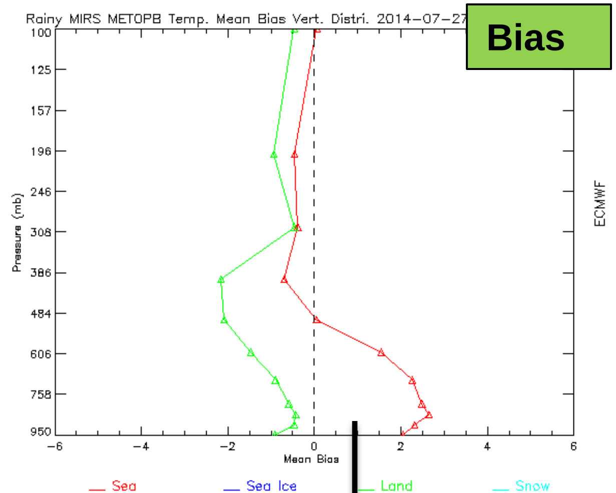
MiRS Product Assessments: AMSUA/MHS Temperature Sounding (Clear)

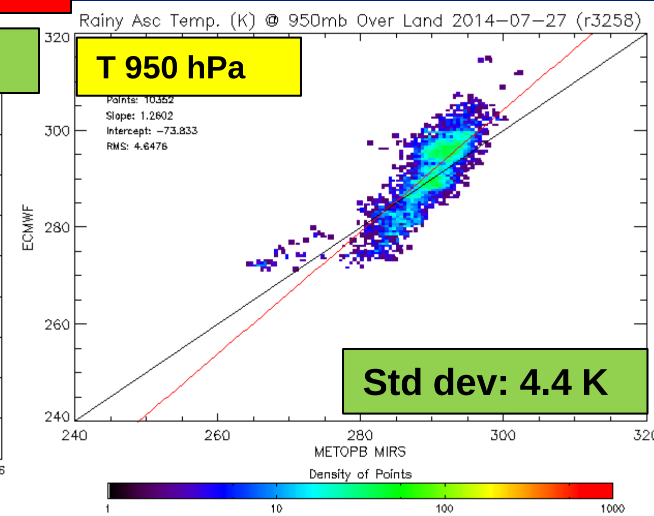


MiRS Product Assessments: AMSUA/MHS Temperature Sounding (Rainy)

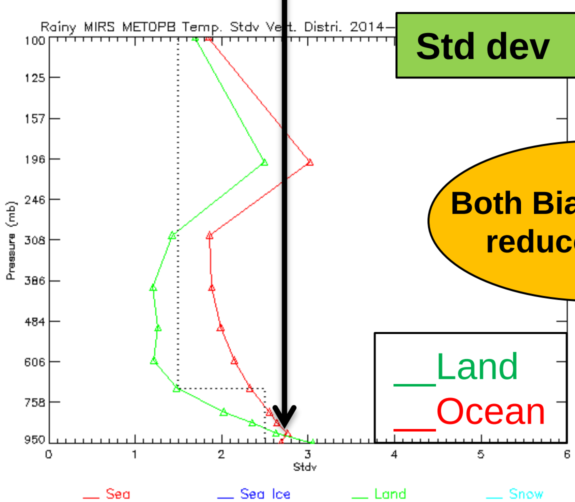
MiRS MetopB HR v9.2



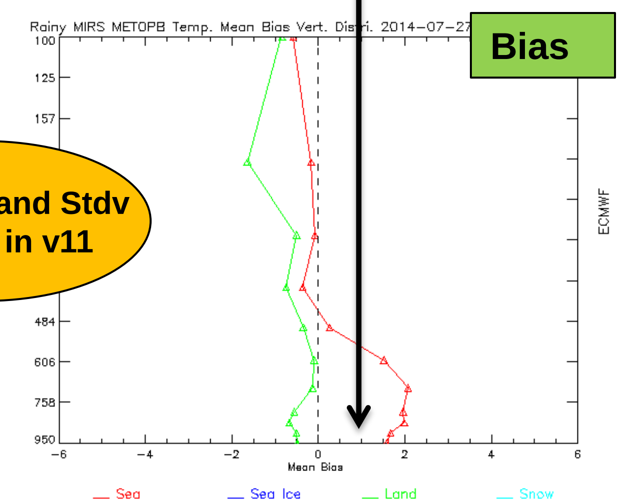


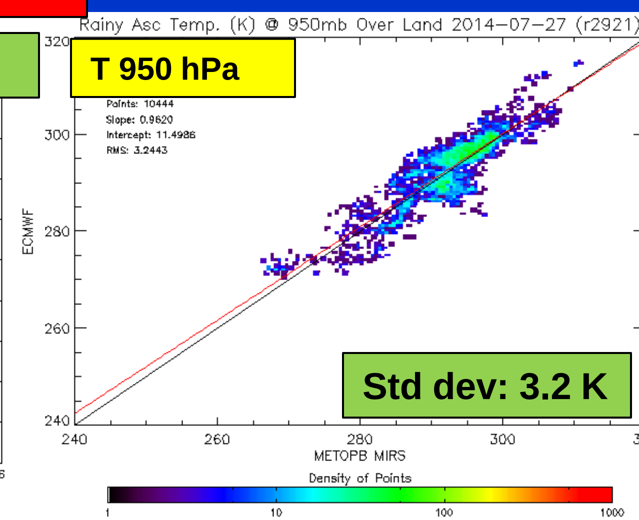


MiRS MetopB HR v11



Both Bias and Stdv reduced in v11





MiRS Product Assessments: AMSUA/MHS Temperature Sounding (Summary, all weather/all surface)

	N18					
	v9.2 LR			V11 HR		
Layer	Cor	Bias	Std	Cor	Bias	Std
200	0.96	-0.15	2.28	0.96	0.53	2.34
400	0.99	-0.38	1.48	0.99	-0.45	1.37
600	0.98	0.06	1.88	0.99	0.17	1.65
800	0.97	0.67	2.89	0.98	0.39	2.17
900	0.96	0.95	3.37	0.98	0.38	2.48
950	0.96	1.44	2.69	0.98	0.49	2.57

	MetopA					
	v9.2 LR			v11 HR		
Layer	Cor	Bias	Std	Cor	Bias	Std
200	0.95	-0.47	2.53	0.95	0.37	2.52
400	0.99	-0.29	1.58	0.99	-0.37	1.45
600	0.98	0.22	1.93	0.99	0.24	1.71
800	0.97	0.68	2.91	0.98	0.38	2.15
900	0.96	0.87	3.40	0.98	0.37	2.43
950	0.96	0.98	3.49	0.98	0.49	2.54

	N19					
	v9.2 LR			v11 HR		
Layer	Cor	Bias	Std	Cor	Bias	Std
200	0.94	-0.15	2.69	0.95	0.32	2.62
400	0.99	-0.33	1.70	0.99	-0.32	1.52
600	0.98	0.18	2.00	0.99	0.31	1.75
800	0.97	0.84	2.81	0.98	0.40	2.17
900	0.96	1.16	3.23	0.98	0.30	2.46
950	0.96	1.24	3.40	0.98	0.37	2.55

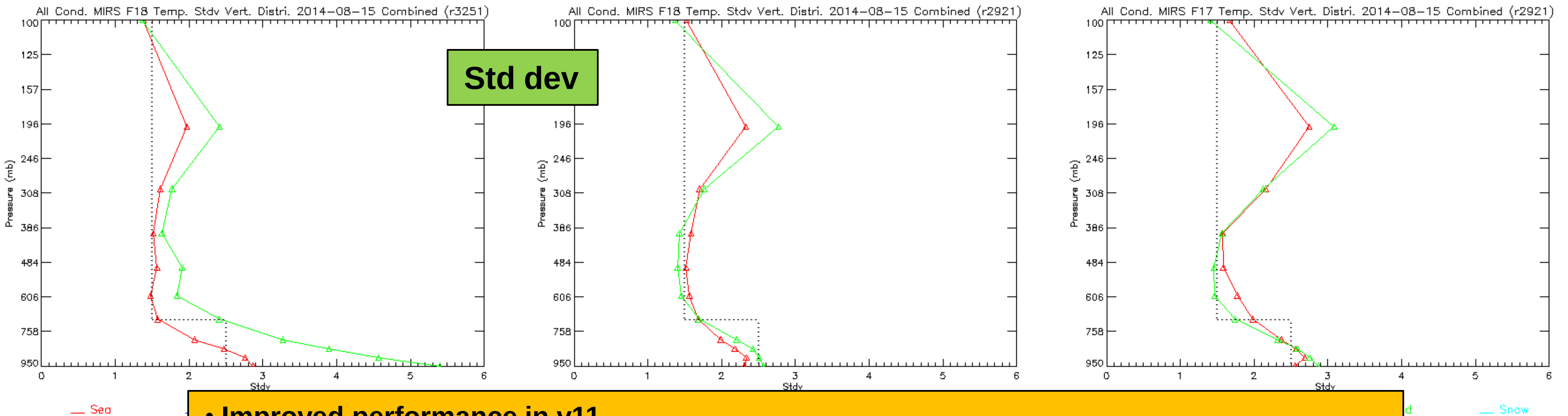
	MetopB					
	v9.2 HR			v11 HR		
Layer	Cor	Bias	Std	Cor	Bias	Std
200	0.96	-0.10	2.21	0.96	0.63	2.17
400	0.99	-0.62	1.50	0.99	-0.49	1.32
600	0.98	-0.14	1.95	0.99	0.17	1.63
800	0.97	0.38	2.96	0.98	0.35	2.11
900	0.96	0.71	3.50	0.98	0.42	2.47
950	0.96	0.90	3.59	0.98	0.56	2.58

- **Green box highlights the improvements from v9.2 to v11.**
- **Performance improvements noticeable for all sensors in v11, especially in lower troposphere.**

MiRS Product Assessments: F17 Temperature Sounding

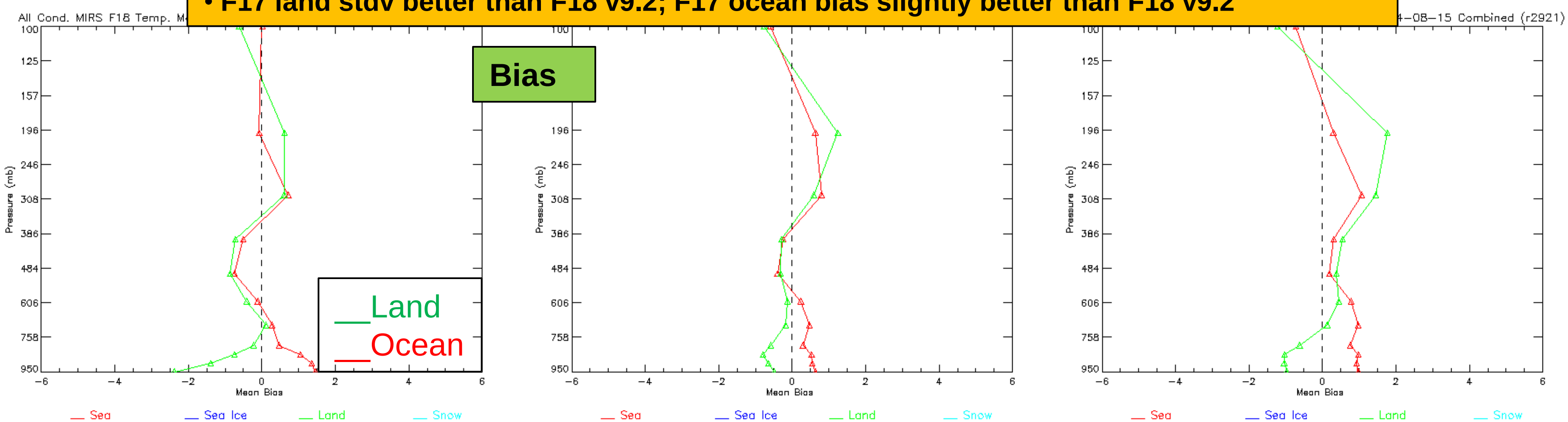
MiRS F18 LR v9.2	MiRS F18 HR v11	MiRS F17 HR v11

Std dev

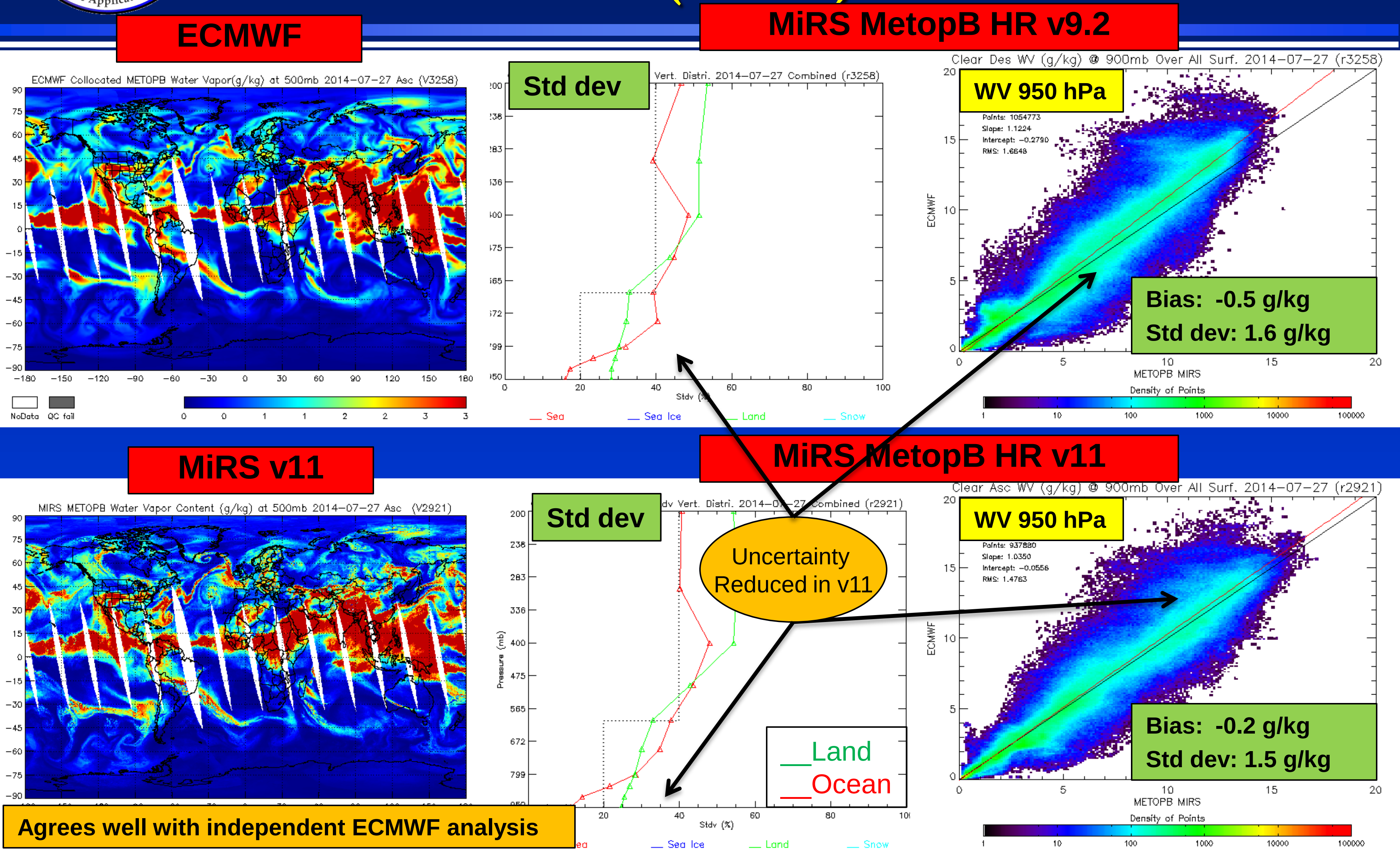


- Improved performance in v11
- F17 v11 performance is somewhat lower than F18 v11 due to F17 calibration issues
- F17 land stdv better than F18 v9.2; F17 ocean bias slightly better than F18 v9.2

Bias

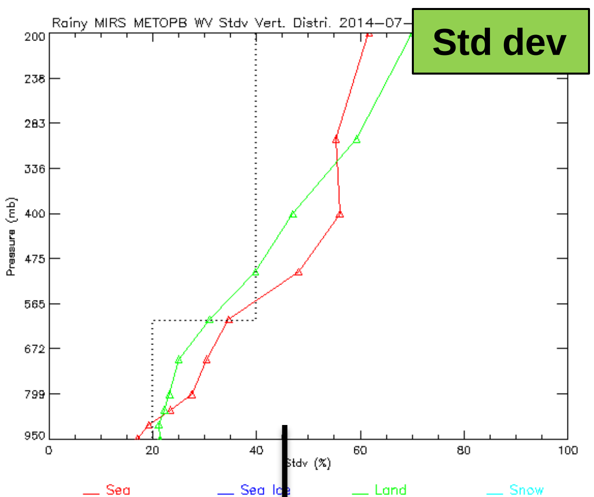


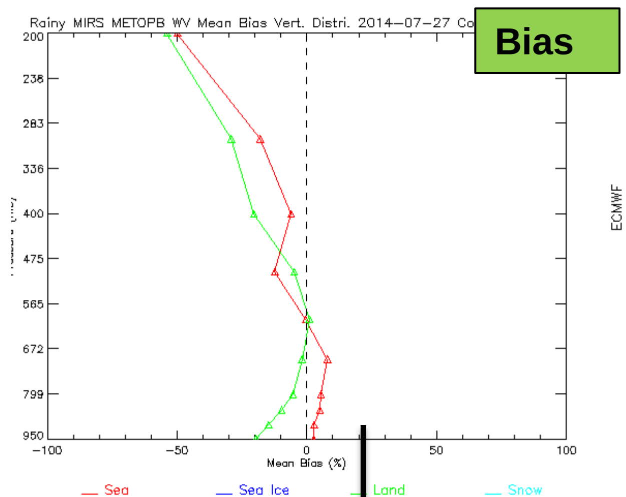
MiRS Product Assessments: AMSUA/MHS Water Vapor Sounding (Clear)

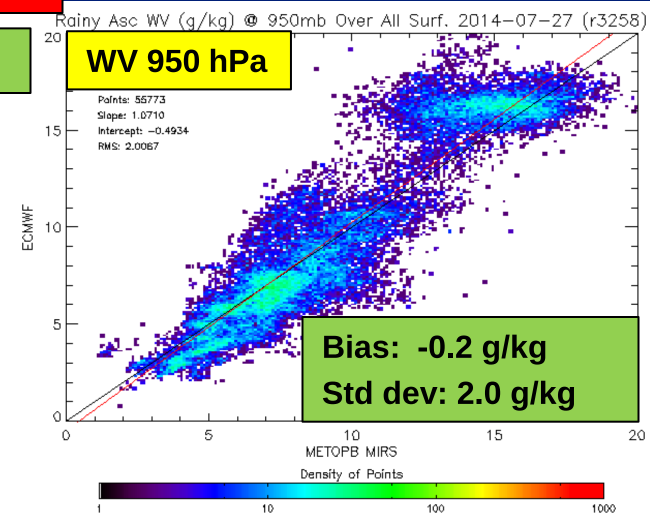


MiRS Product Assessments: AMSUA/MHS Water Vapor Sounding (Rainy)

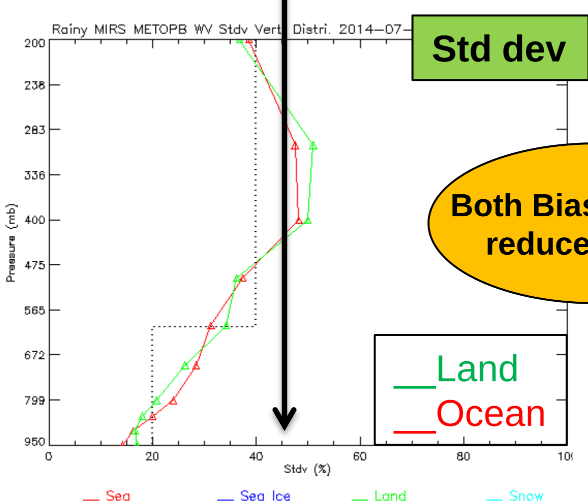
MiRS MetopB HR v9.2



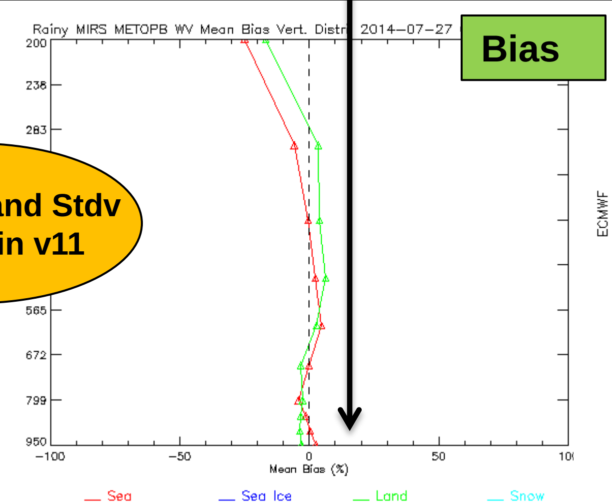


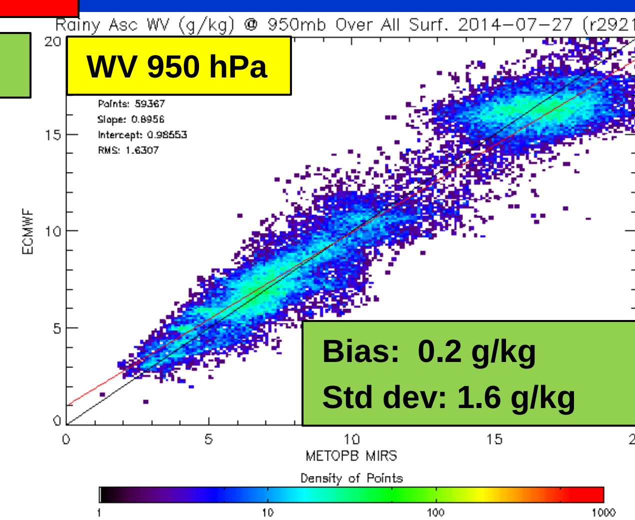


MiRS MetopB HR v11



Both Bias and Stdv reduced in v11





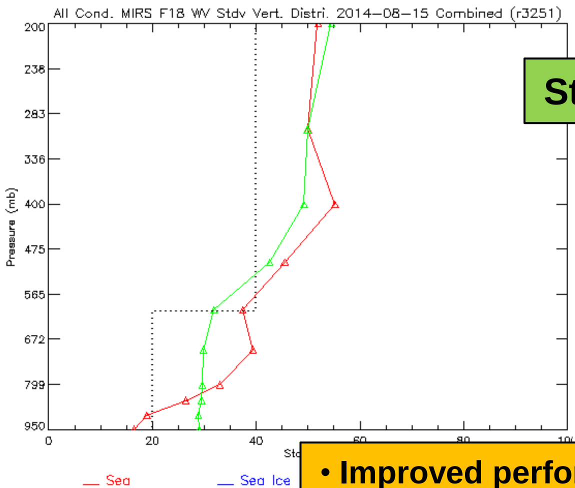
MiRS Product Assessments: AMSUA/MHS Water Vapor Sounding (Summary, all weather/all surface)

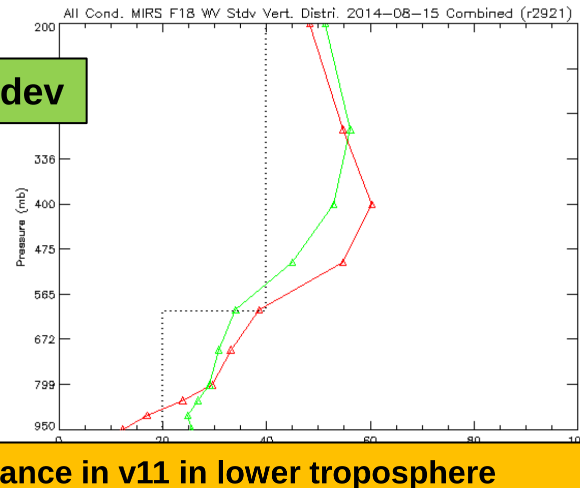
	N18								MetopA					
	v9.2 LR			v11 HR					v9.2 LR			v11 HR		
Layer	Cor	Bias	Std	Cor	Bias	Std		Layer	Cor	Bias	Std	Cor	Bias	Std
200	0.84	0.00	0.01	0.87	0.00	0.01		200	0.85	0.00	0.01	0.87	0.00	0.01
400	0.89	0.03	0.29	0.89	0.02	0.29		400	0.89	0.03	0.29	0.89	0.03	0.29
600	0.91	0.13	0.79	0.91	0.01	0.78		600	0.91	0.18	0.80	0.92	0.06	0.76
800	0.89	0.32	1.53	0.91	-0.08	1.43		800	0.89	0.42	1.53	0.92	-0.06	1.36
900	0.94	-0.21	1.47	0.94	-0.01	1.37		900	0.94	-0.17	1.45	0.95	-0.10	1.30
950	0.95	-0.46	1.61	0.96	-0.15	1.33		950	0.95	-0.51	1.63	0.96	-0.16	1.29
	N19								MetopB					
	v9.2 LR			v11 HR					v9.2 HR			v11 HR		
Layer	Cor	Bias	Std	Cor	Bias	Std		Layer	Cor	Bias	Std	Cor	Bias	Std
200	0.79	0.00	0.01	0.87	0.00	0.01		200	0.85	0.00	0.01	0.88	0.00	0.01
400	0.88	0.01	0.29	0.89	0.03	0.29		400	0.89	0.00	0.26	0.90	0.02	0.27
600	0.91	0.21	0.82	0.91	0.03	0.78		600	0.91	0.07	0.78	0.91	0.01	0.76
800	0.89	0.31	1.50	0.91	-0.11	1.36		800	0.88	0.20	1.59	0.91	-0.13	1.41
900	0.94	-0.33	1.48	0.94	-0.14	1.33		900	0.93	-0.39	1.56	0.94	-0.17	1.38
950	0.95	-0.63	1.60	0.96	-0.16	1.28		950	0.94	-0.74	1.73	0.96	-0.24	1.36

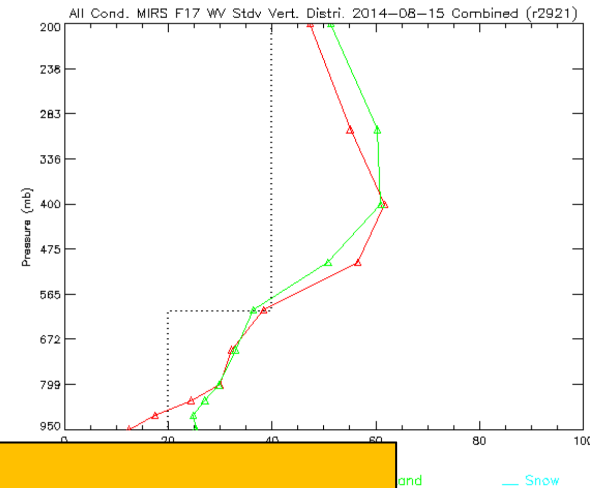
- Green box highlights the improvements from v9.2 to v11.
- Performance improvements noticeable for all sensors in v11, especially in lower troposphere.

MiRS Product Assessments: F17 Water Vapor Sounding

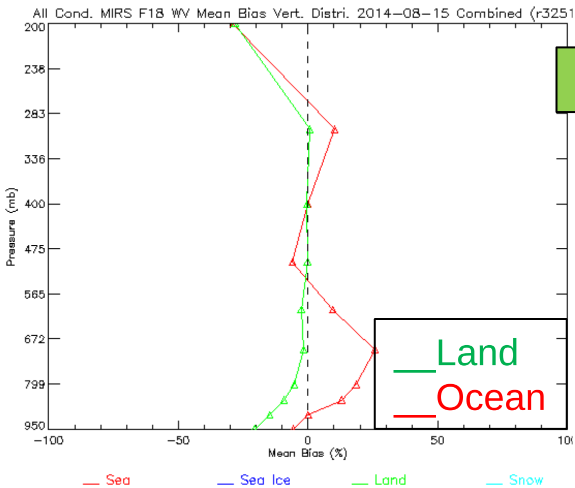
MiRS F18 LR v9.2	MiRS F18 HR v11	MiRS F17 HR v11

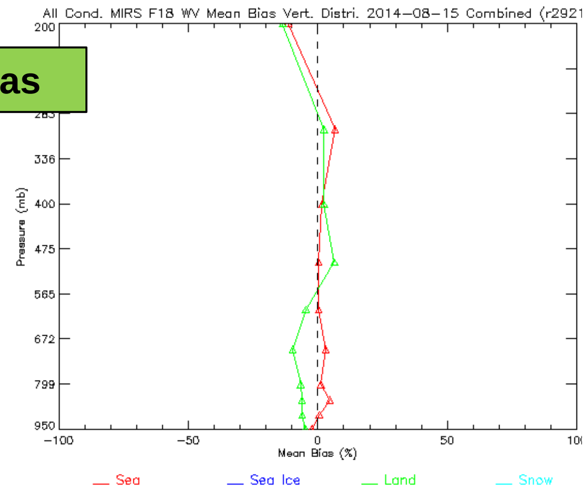


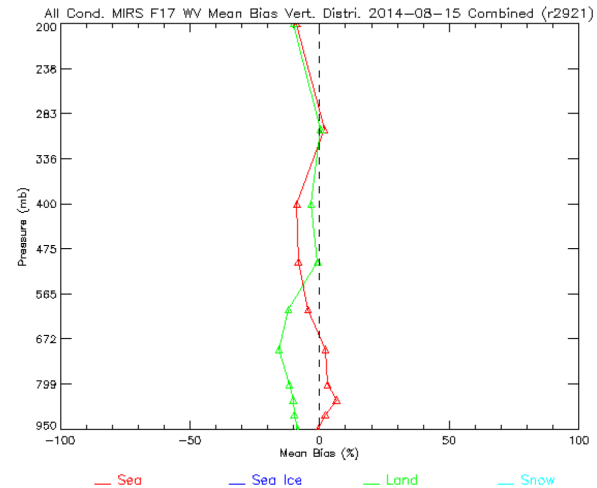




- Improved performance in v11 in lower troposphere
- F17 v11 performance is somewhat lower than F18 v11 due to F17 calibration issues

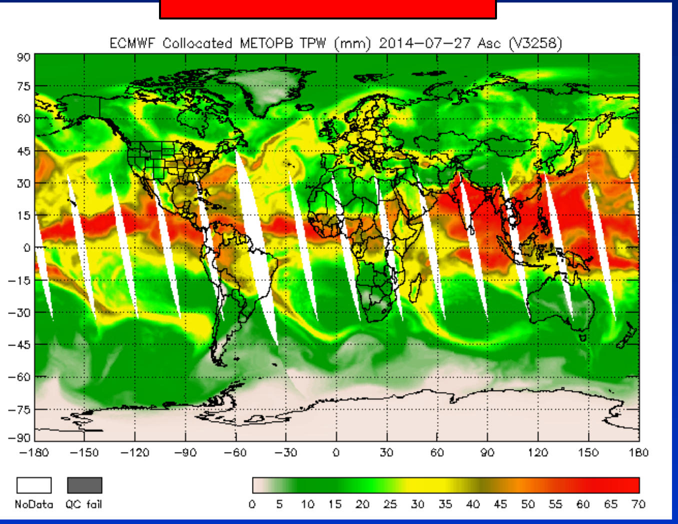






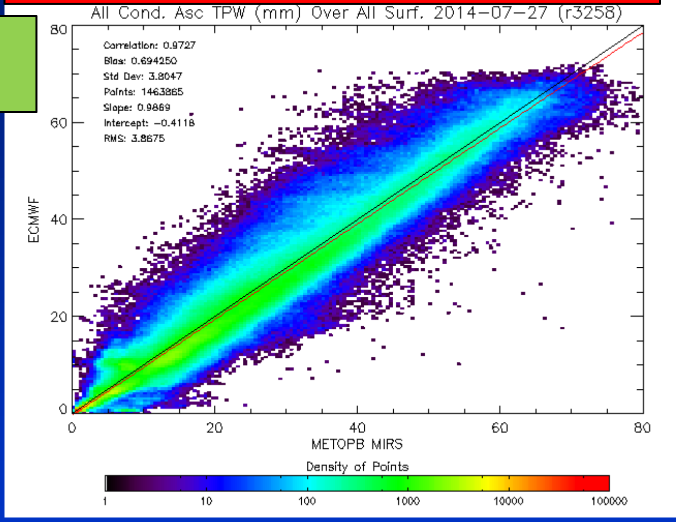
MiRS Product Assessments: AMSUA/MHS TPW

ECMWF



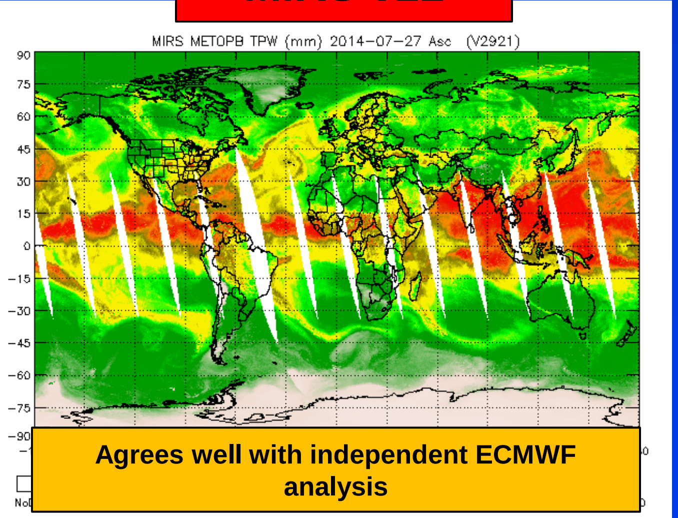
MiRS MetopB HR v9.2

Bias: 0.69
Std dev: 3.80



Both Bias and Std Dev reduced in v11

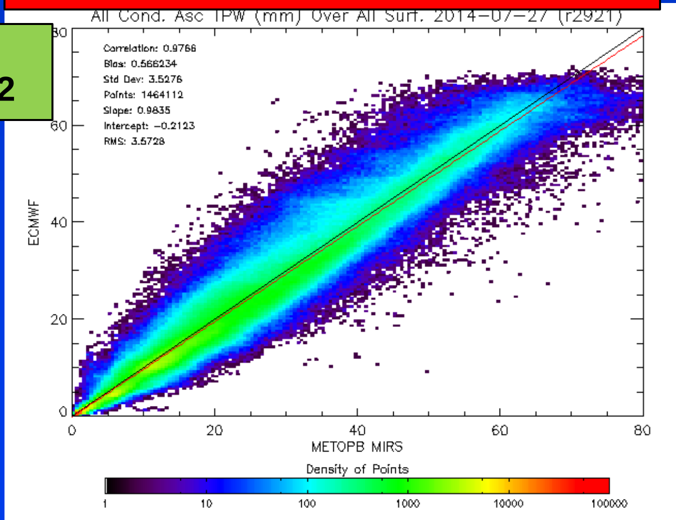
MiRS v11



Agrees well with independent ECMWF analysis

MiRS MetopB HR v11

Bias: 0.56
Std dev: 3.52



MiRS Product Assessments: AMSUA/MHS TPW (Summary, all weather/all surface)

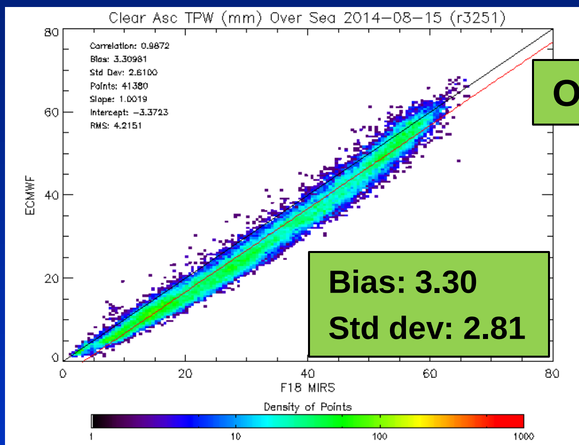
N18								MetopA					
v9.2 LR			v11 HR					v9.2 LR			v11 HR		
Cor	Bias	Std	Cor	Bias	Std			Cor	Bias	Std	Cor	Bias	Std
0.97	1.42	3.64	0.97	0.78	3.74			0.97	1.60	3.75	0.97	0.89	3.47
N19								MetopB					
v9.2 LR			v11 HR					v9.2 HR			v11 HR		
Cor	Bias	Std	Cor	Bias	Std			Cor	Bias	Std	Cor	Bias	Std
0.97	1.29	3.74	0.97	0.77	3.69			0.97	0.69	3.80	0.97	0.56	3.52

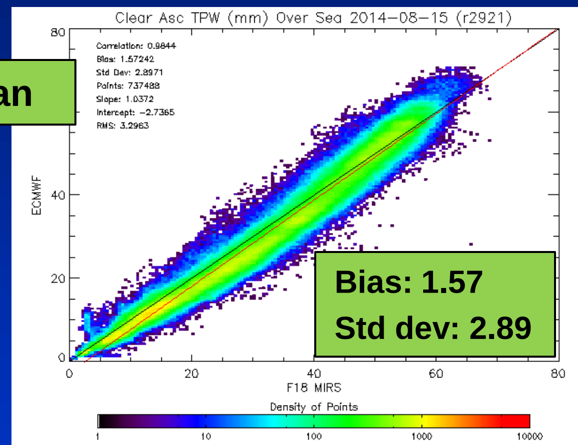
- Green box highlights the improvements from v9.2 to v11.
- Performance improvements noticeable for all sensors in v11.

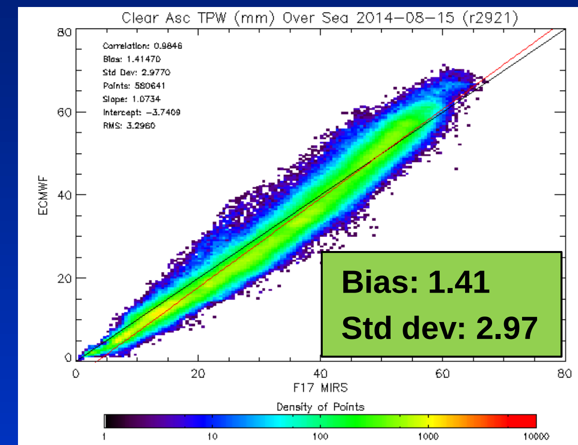
MiRS Product Assessments: F17 TPW

MiRS F18 LR v9.2	MiRS F18 HR v11	MiRS F17 HR v11

Ocean

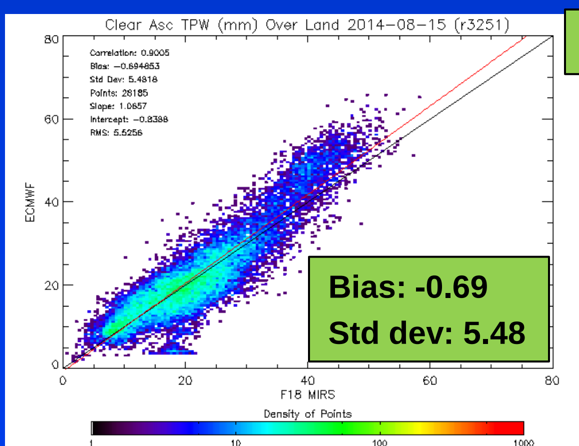


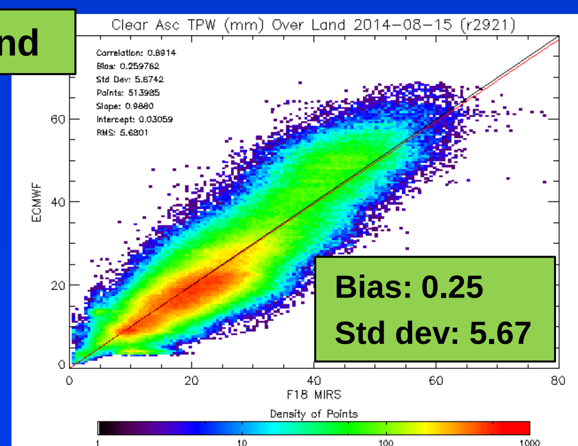


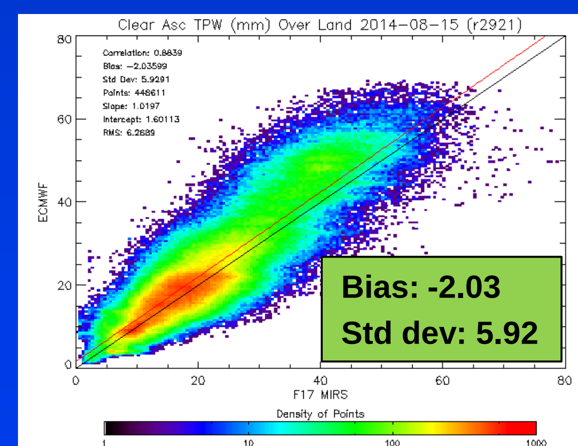


- **Reduced bias in v11 (Ocean)**
- **Dry bias in F17 partly related to calibration issue in water vapor sounding channels (Land)**

Land

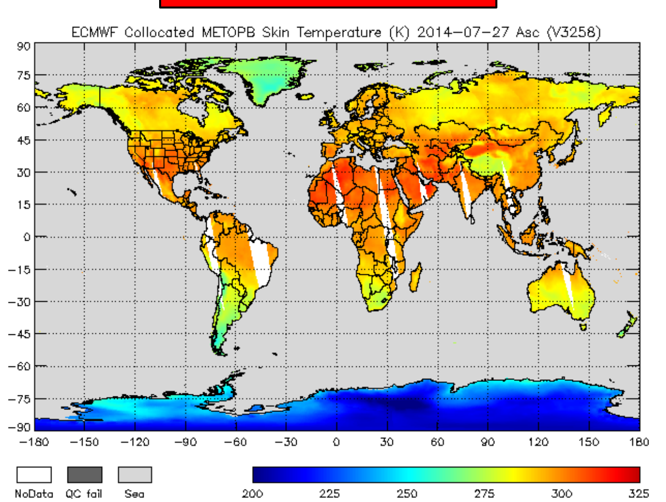






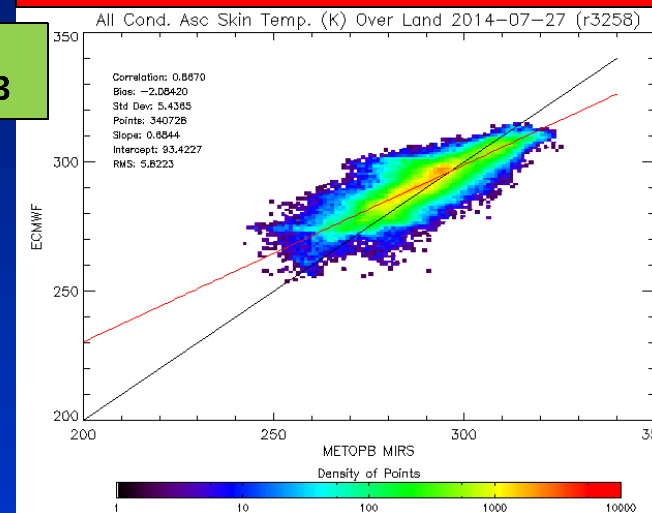
MiRS Product Assessments: AMSUA/MHS LST

ECMWF



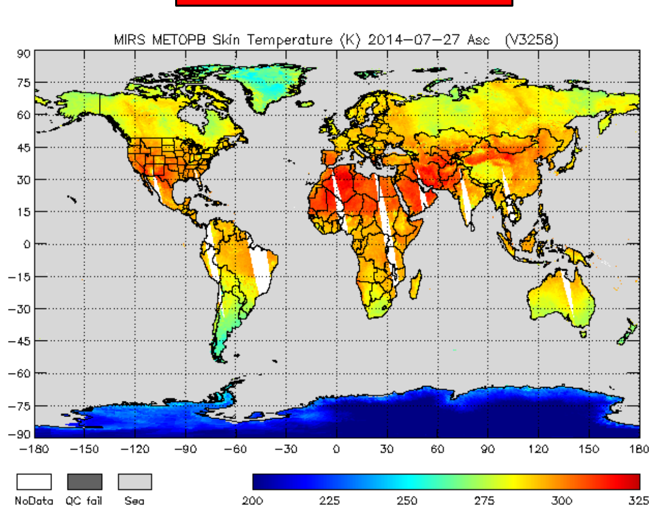
MiRS MetopB HR v9.2

Bias: -2.08
Std dev: 5.43



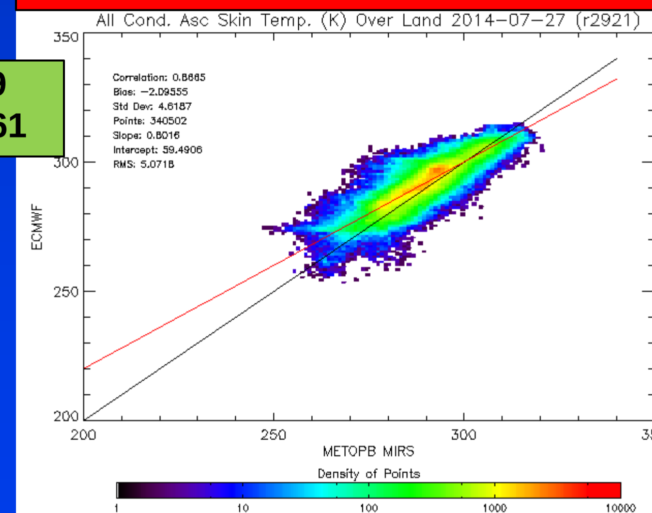
Improved performance in v11

MiRS v11



MiRS MetopB HR v11

Bias: -2.09
Std dev: 4.61



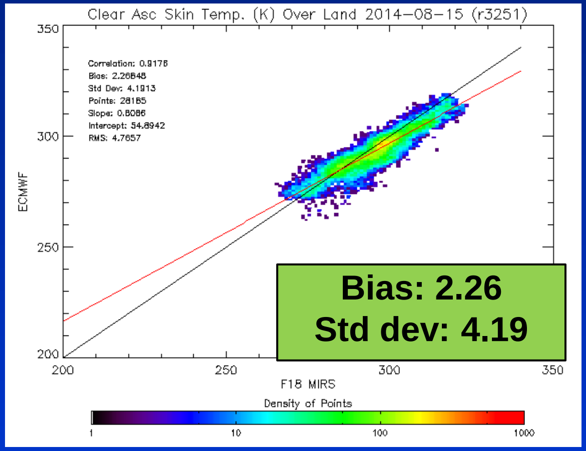
MiRS Product Assessments: AMSUA/MHS LST (Summary, all weather)

N18								MetopA					
v9.2 LR			v11 HR					v9.2 LR			v11 HR		
Cor	Bias	Std	Cor	Bias	Std			Cor	Bias	Std	Cor	Bias	Std
0.91	-2.73	5.71	0.90	-1.46	5.05			0.87	-2.51	5.21	0.87	-2.29	4.60
N19								MetopB					
v9.2 LR			v11 HR					v9.2 HR			v11 HR		
Cor	Bias	Std	Cor	Bias	Std			Cor	Bias	Std	Cor	Bias	Std
0.91	-3.41	5.59	0.91	-1.76	5.13			0.86	-2.08	5.43	0.86	-2.09	4.61

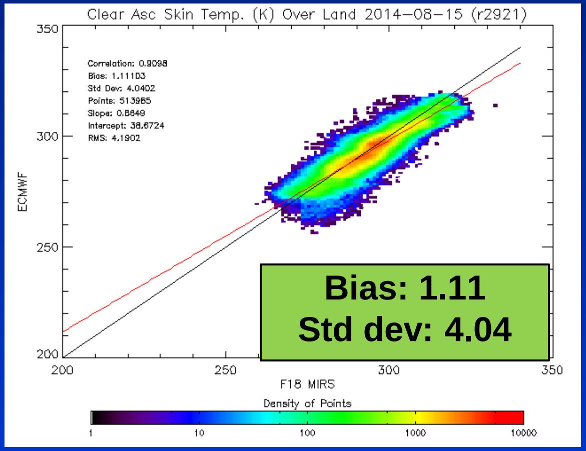
- Green box highlights the improvements from v9.2 to v11.
- Performance improvements noticeable for all sensors in v11.

MiRS Product Assessments: F17 LST

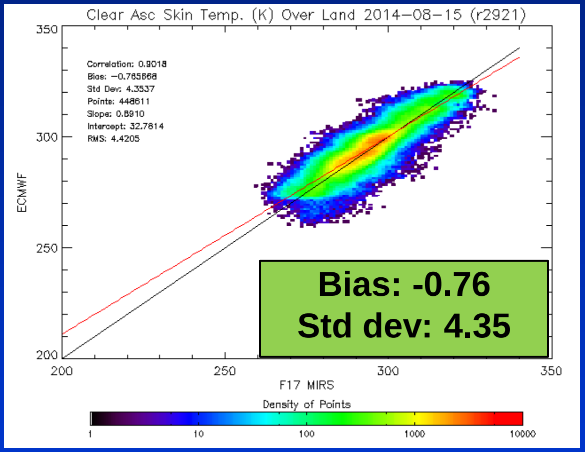
MiRS F18 LR v9.2



MiRS F18 HR v11



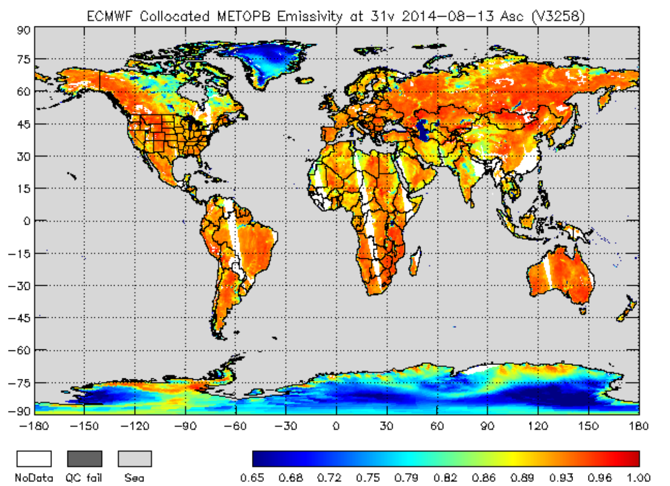
MiRS F17 HR v11



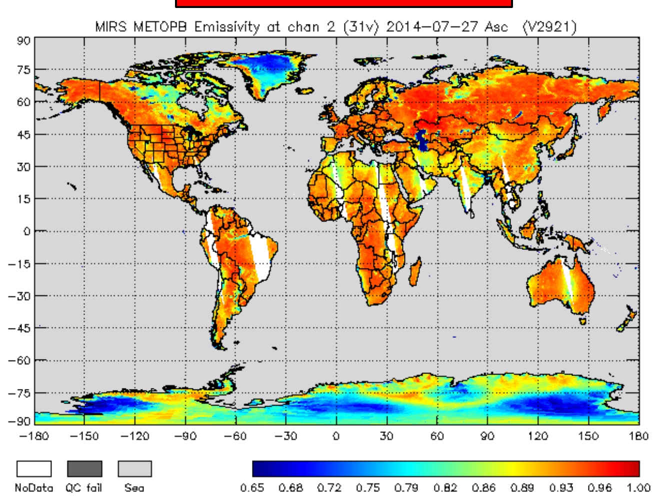
- v11 slightly smaller bias for both F17 and F18
- Std dev similar performance in v9.2 and v11

MiRS Product Assessments: ASMUA/MHS Emissivity

ECMWF



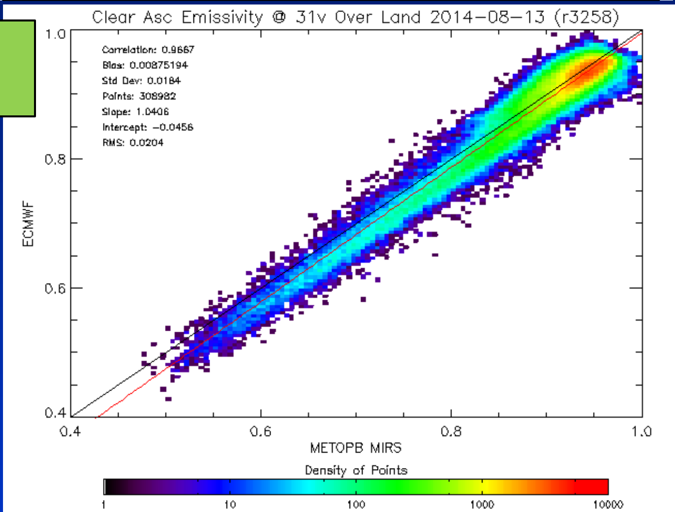
MiRS v11



Similar performance Between v9.2 & v11

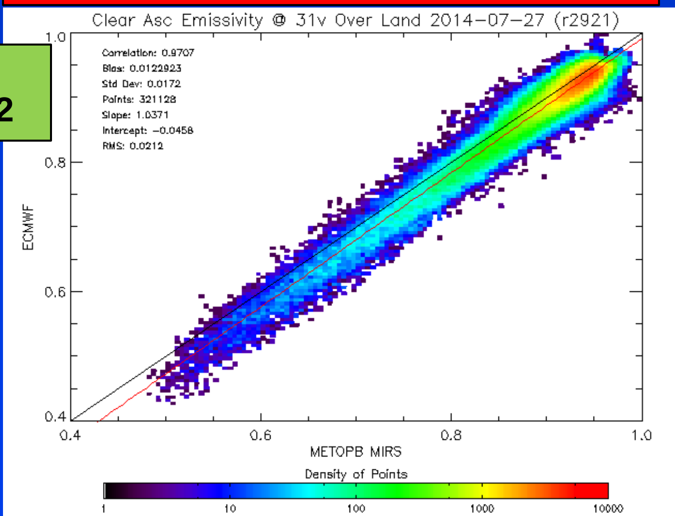
MiRS MetopB HR v9.2

Bias: 0.008
Std dev: 0.02



MiRS MetopB HR v11

Bias: 0.012
Std dev: 0.02



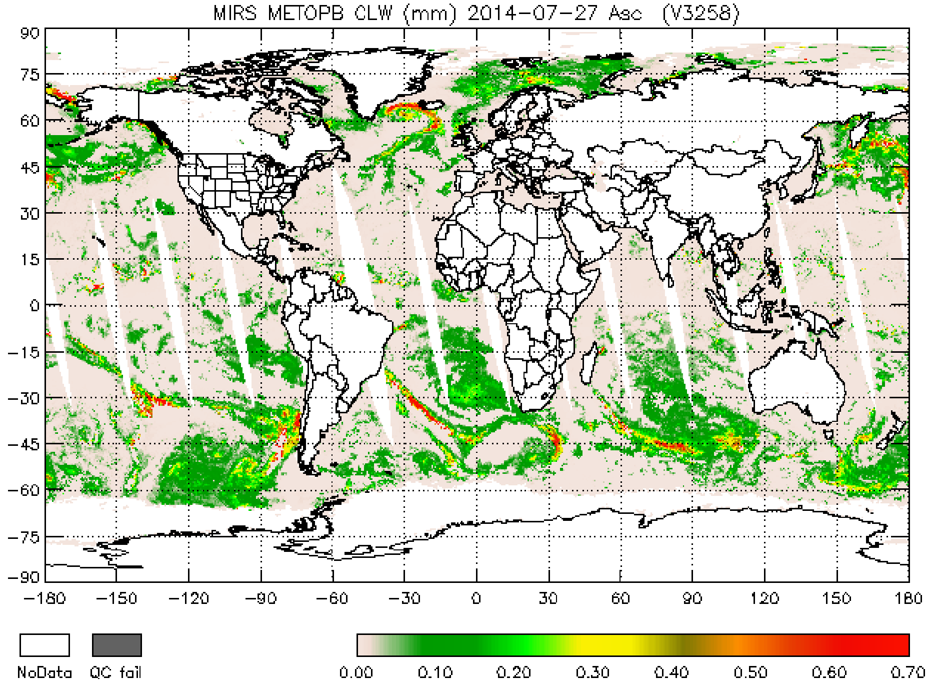
MiRS Product Assessments: Hydrometeors: N18, N19, MetopA (MetopB), F17 (F18)

Presented by T. Islam

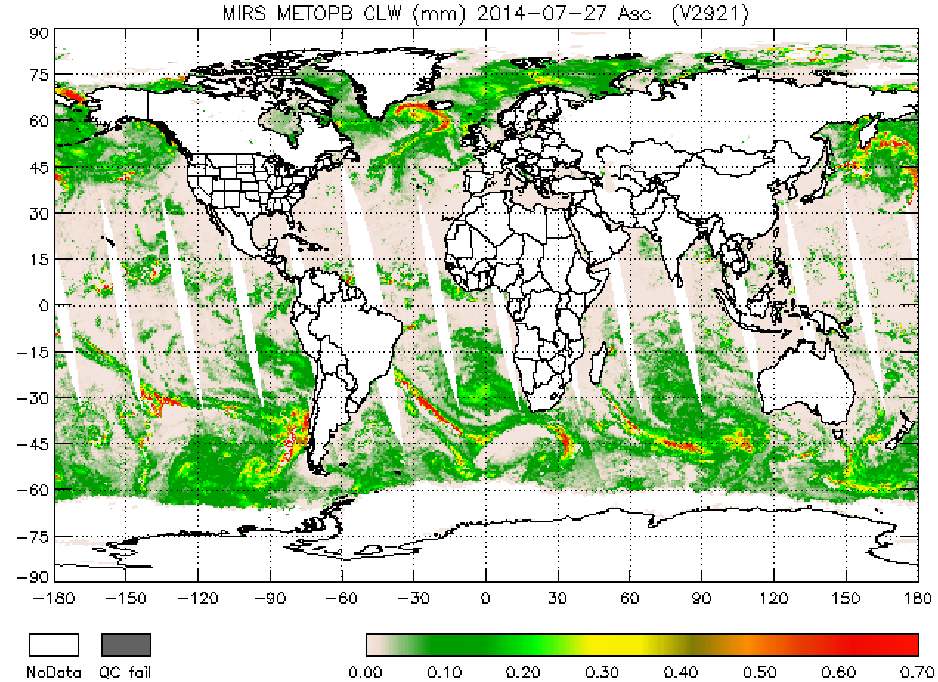
- CLWP
- IWP
- RWP
- Rain Rate (also an indirect assessment of CLWP, IWP, RWP)
- MetopB (already HR) and F18 (fewer calibration issues) used as benchmarks to separate impacts of resolution from algorithm and sensor differences

MiRS Product Assessments: Cloud Liquid Water

MiRS MetopB HR v9.2



MiRS MetopB HR v11



- Very similar patterns
- Better depiction of ITCZ
- Slightly more low CLW values in v11

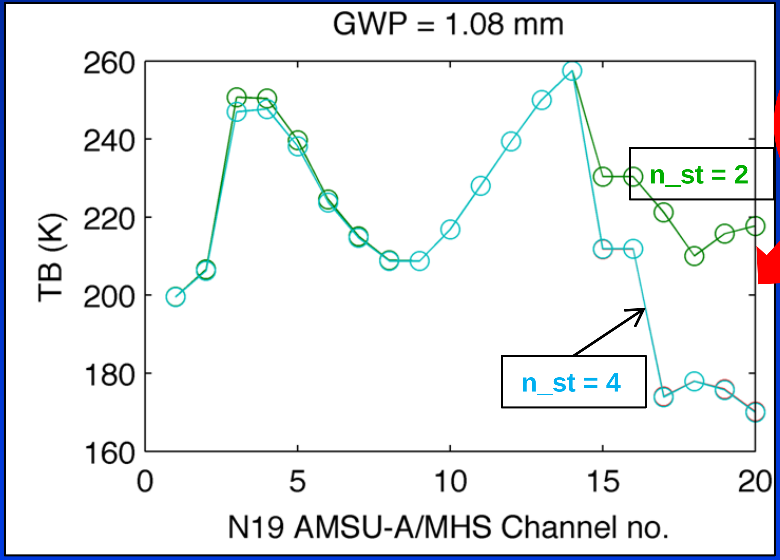
MiRS Product Assessments: Ice Water Path

CRTM n_stream sensitivity (impact on IWP)

MiRS v9.2 uses n_stream=2
MiRS v11 uses n_stream=4

- n_stream=2 and n_stream=4 have significant differences in TB simulation for high-freq channels (where scattering is larger)
- use of n_stream = 2 is not accurate enough with CRTM 2.1.1
- **less iterations**, lower chisq, and **better fit to TBs** in v11 using n_streams = 4 (only slight increase in overall computational cost.

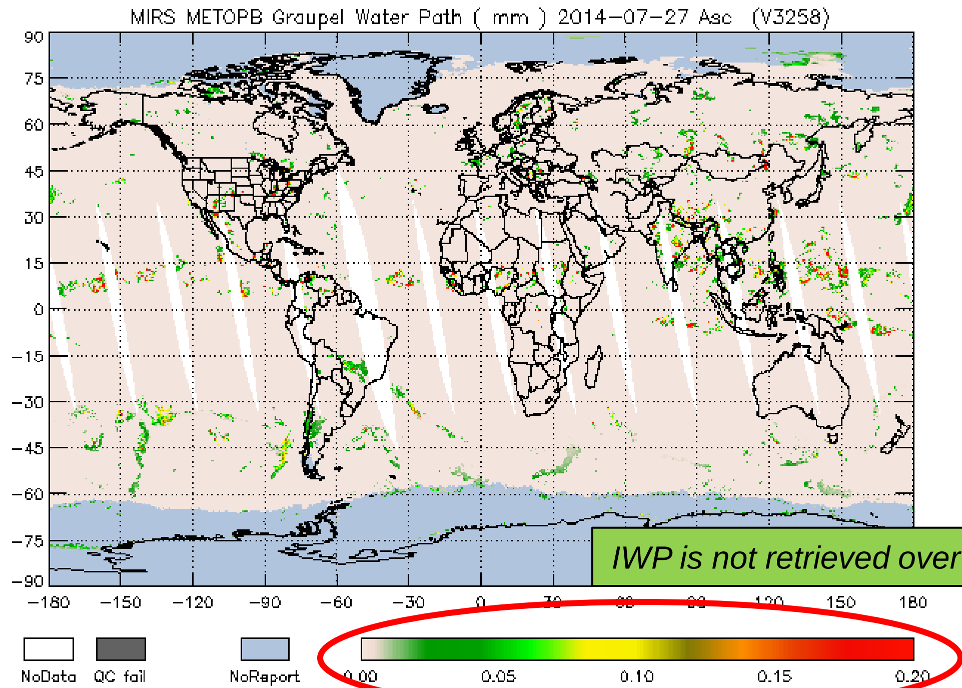
TB simulation for different AMSU/MHS channels using n_streams 2 and 4 in CRTM 2.1.1



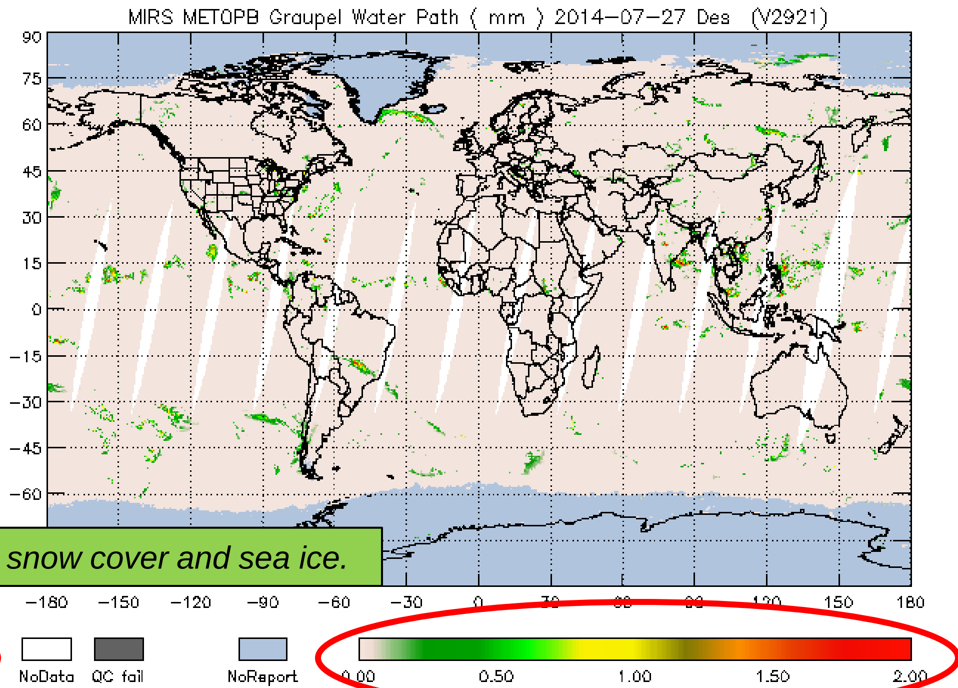
50K difference between n_stream 2 and 4/6 At 190 GHz

MiRS Product Assessments: Ice Water Path

MiRS MetopB HR V9.2



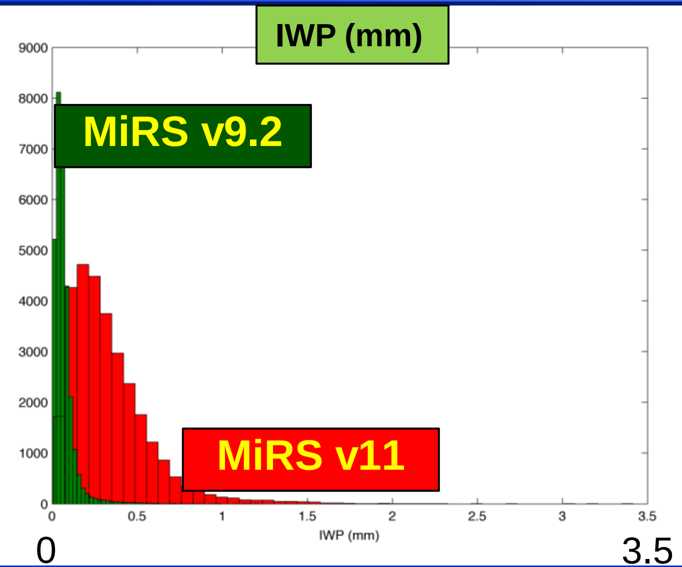
MiRS MetopB HR V11

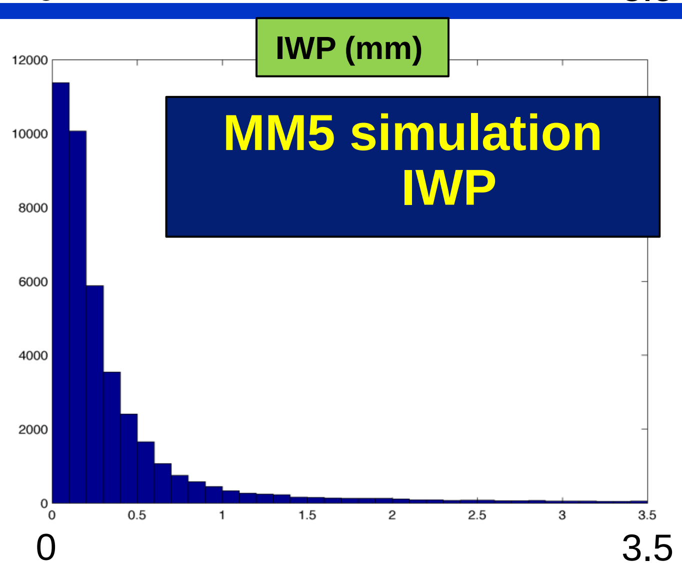


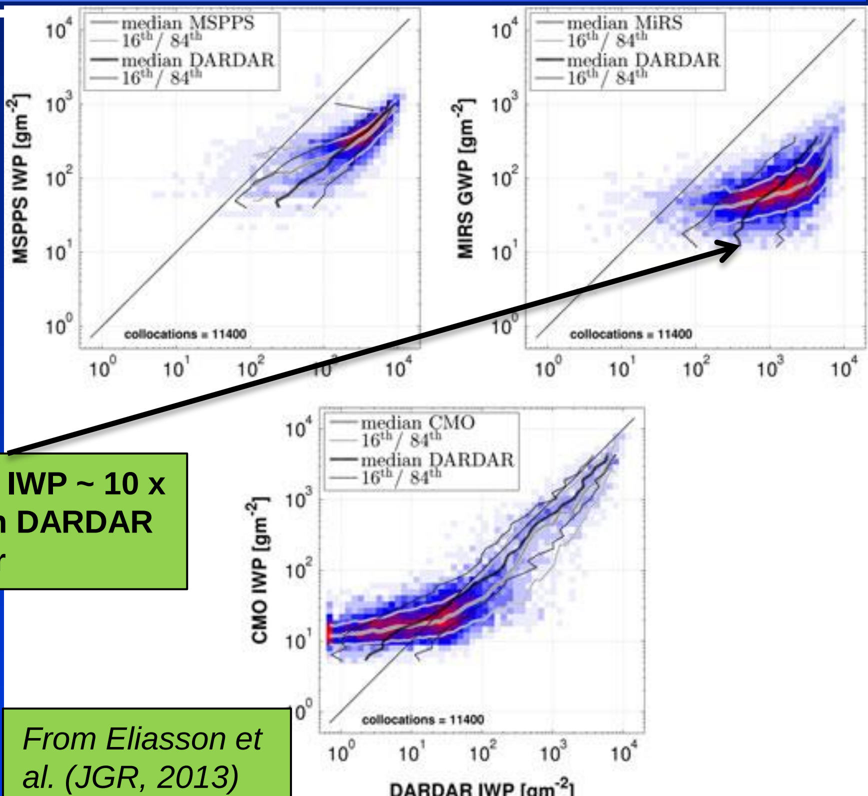
IWP is not retrieved over snow cover and sea ice.

- Improved ice water path retrieval
- Higher amounts in v11 than v9.2 (note scale change)
- 7-8 times increase, magnitudes more realistic (following slide)

MiRS Product Assessments: Ice Water Path







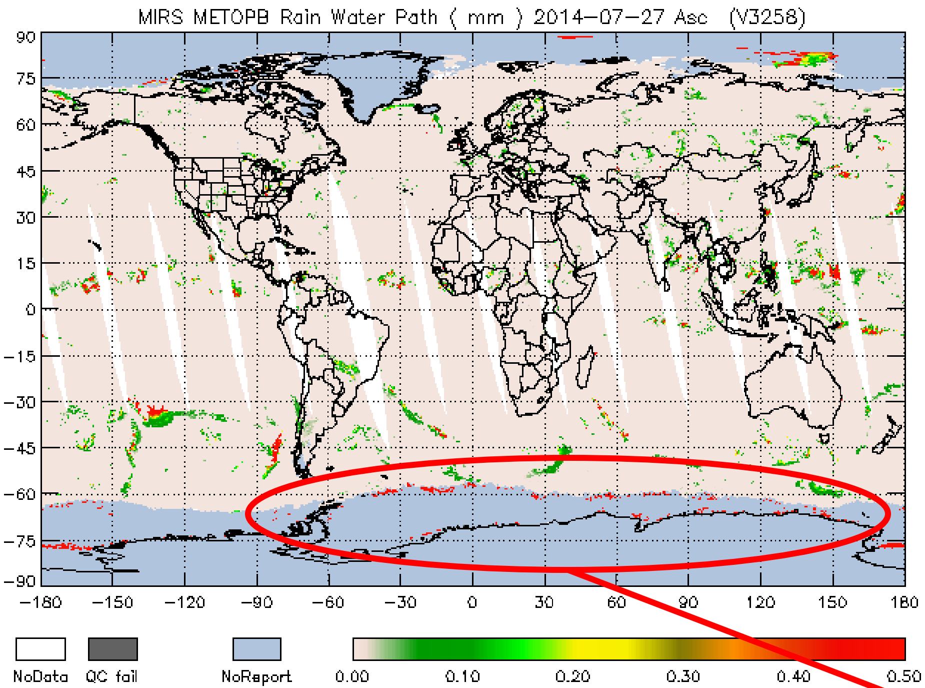
MiRS v9.2 IWP ~ 10 x lower than DARDAR radar-lidar

From Eliasson et al. (JGR, 2013)

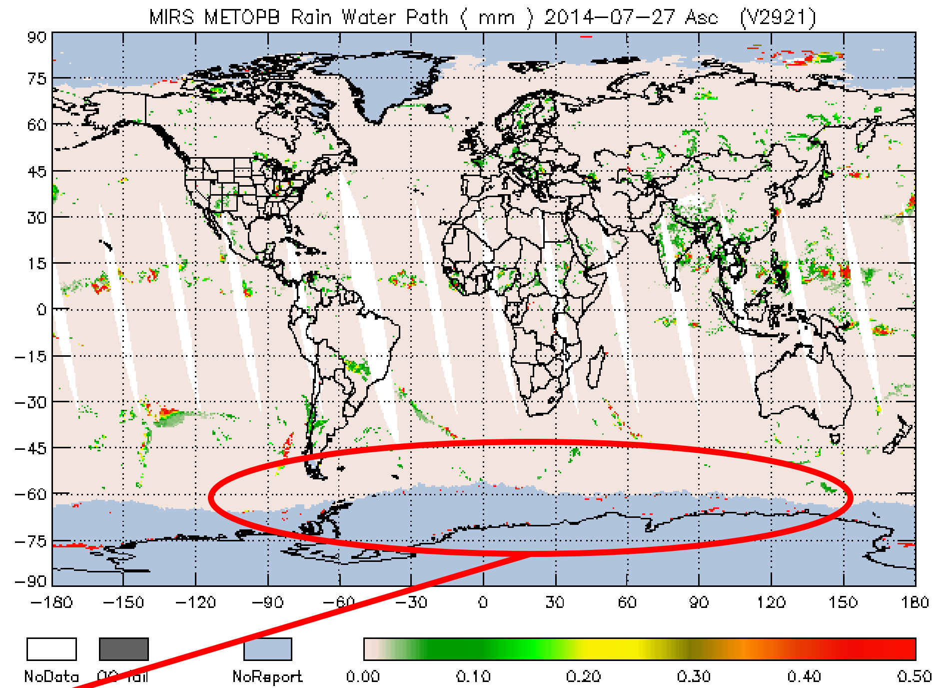
- MiRS v9.2 underestimated IWP quantities relative to ground-based measurements
- MiRS v11 IWP magnitudes now more physically realistic, and agrees well with MM5 simulation

MiRS Product Assessments: Rain Water Path

MiRS MetopB HR v9.2



MiRS MetopB HR v11



- Very similar patterns (slightly better coverage)
- Better retrieval behavior at sea ice edge (false alarms reduced due to algorithm update)

MiRS Product Assessments: Rain Rate

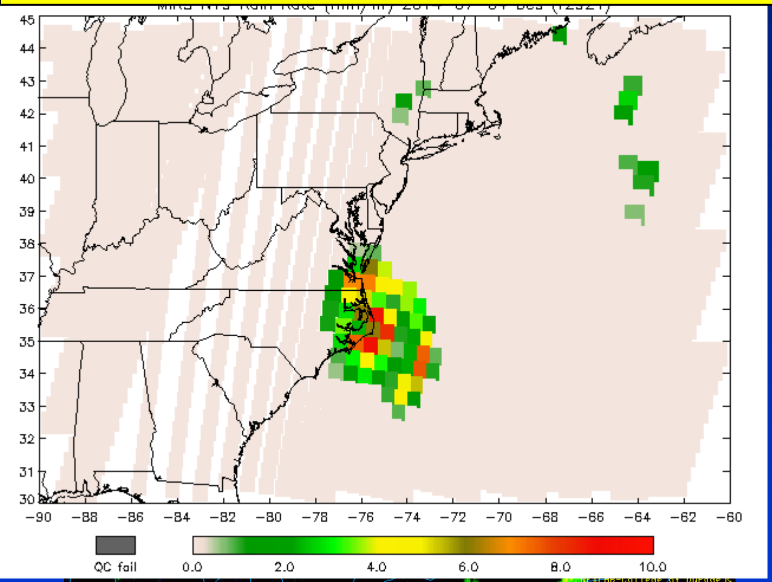
MiRS v9.2	MiRS v11
Ocean (MM5-trained): $RR = a_0 + a_1 x CLWP + a_2 x RWP + a_3 x IWP$ **Land (MSPPS-trained):** $RR = a_0 + a_1 x RWP + a_2 x IWP$	**Ocean (MM5-trained):** $RR = a_1 x CLWP^{b1} + a_2 x (RWP+IWP)^{b2}$ **Land (MM5-trained):** $RR = a_1 x IWP^{b1}$

- Rain rate algorithm is now improved, uses physically based relationship over both ocean and land
- Sensor-independent (assuming sufficient information content in measurements)

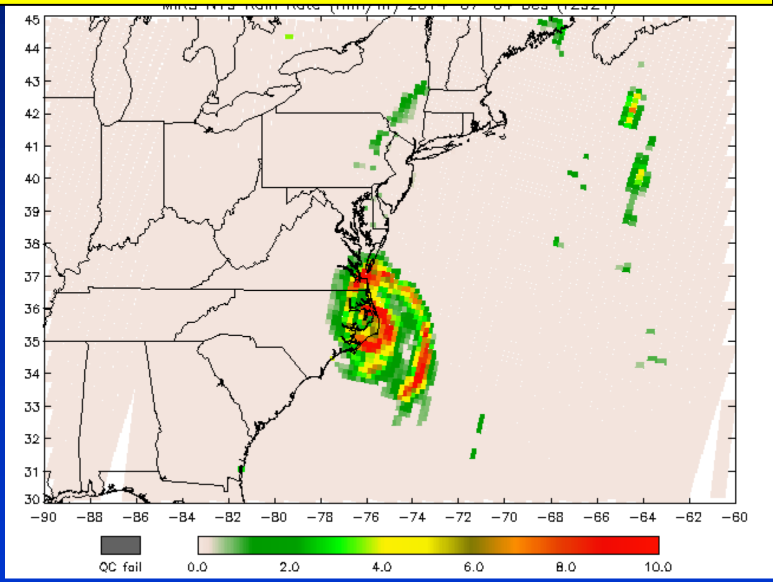
MiRS Product Assessments: N19 LR vs. HR Rain Rate (Hurricane Arthur)

MiRS N19 LR v11

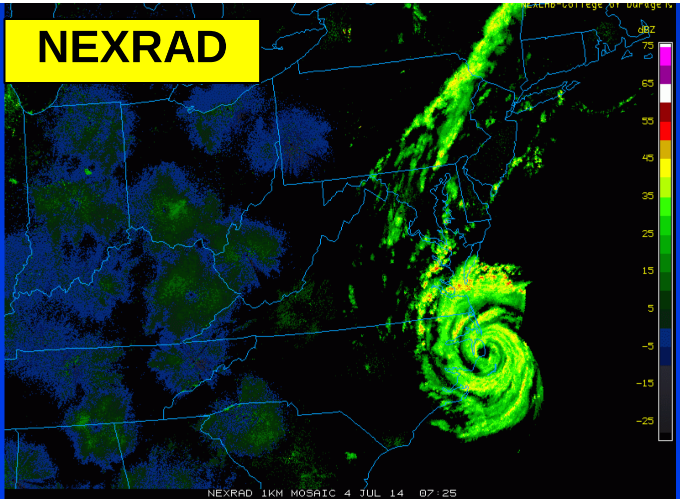
MiRS N19 HR v11



2014-07-04



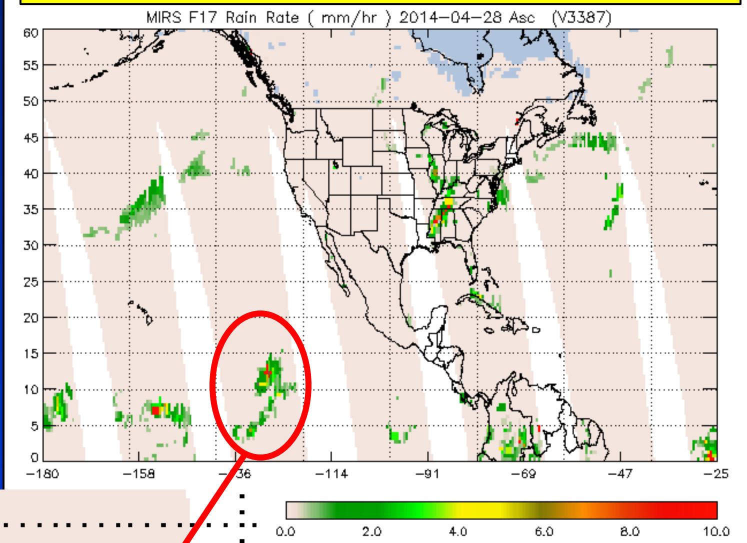
NEXRAD

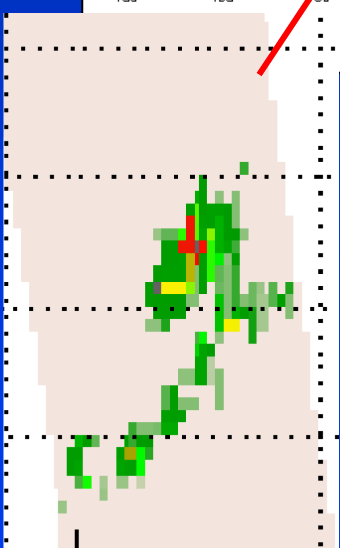


- Small-scale precipitation features are now captured in HR with increased dynamic range
- Smooth transition of rain across coastlines
- Generally, in agreement with NEXRAD radar

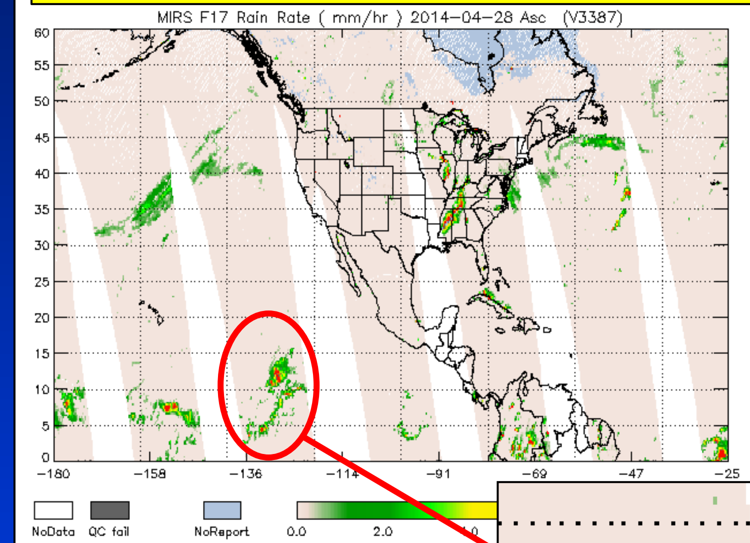
MiRS Product Assessments: F17 LR vs. HR Rain Rate

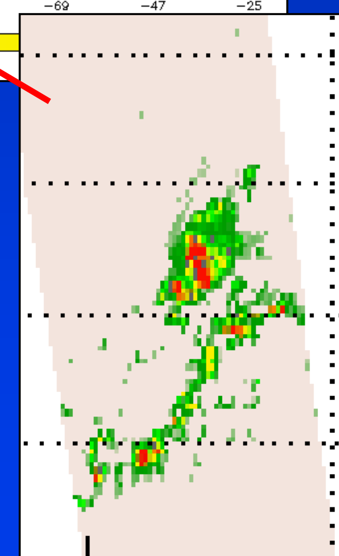
MiRS F17 LR v11





MiRS F17 HR v11

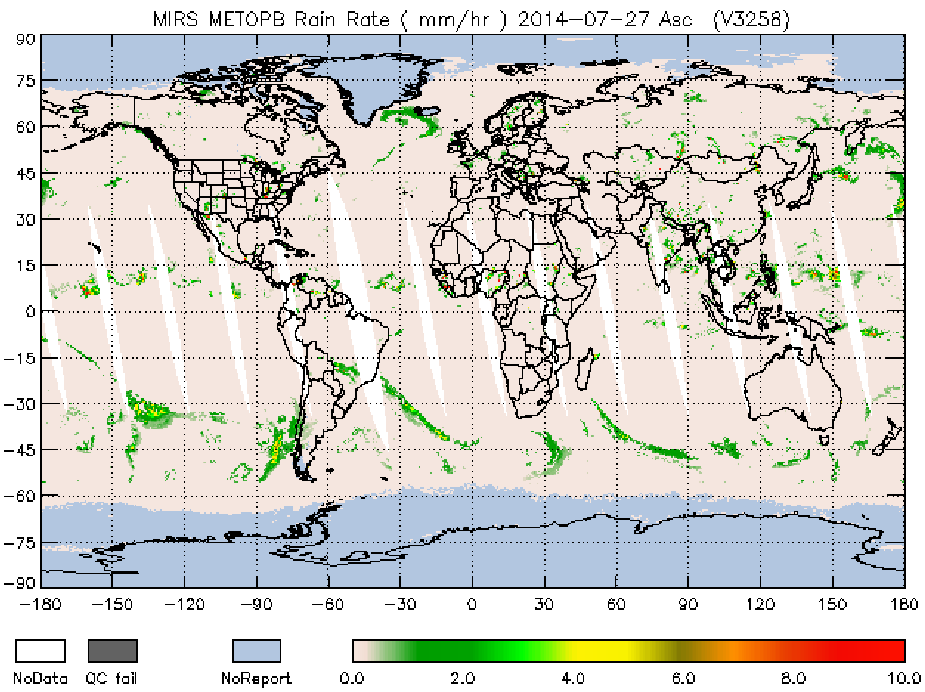




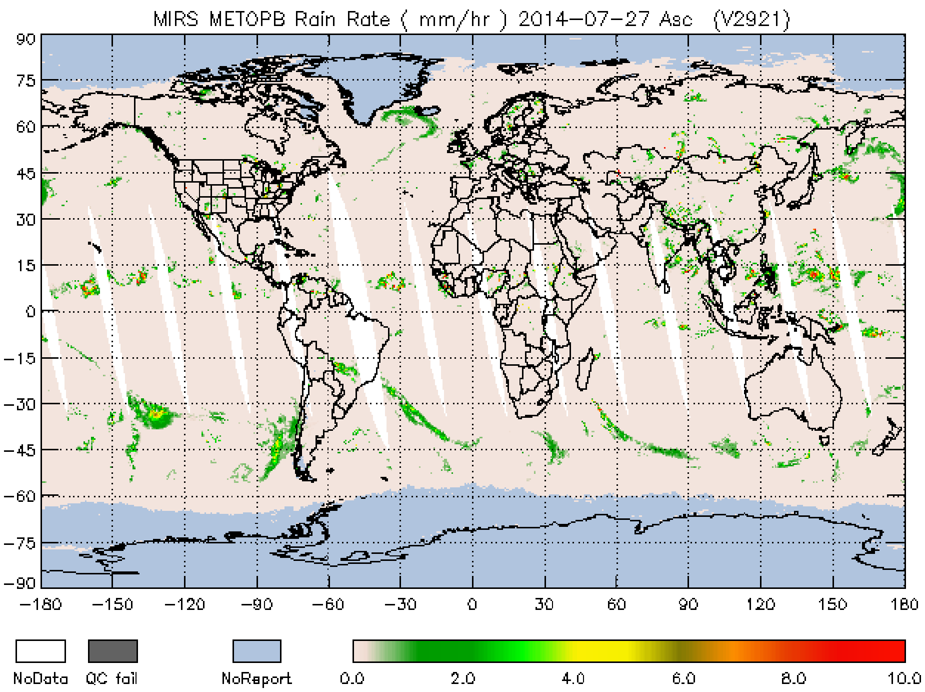
HR contains much more structure and increased dynamic range

MiRS Product Assessments: MetopB Rain Rate

MiRS MetopB HR v9.2



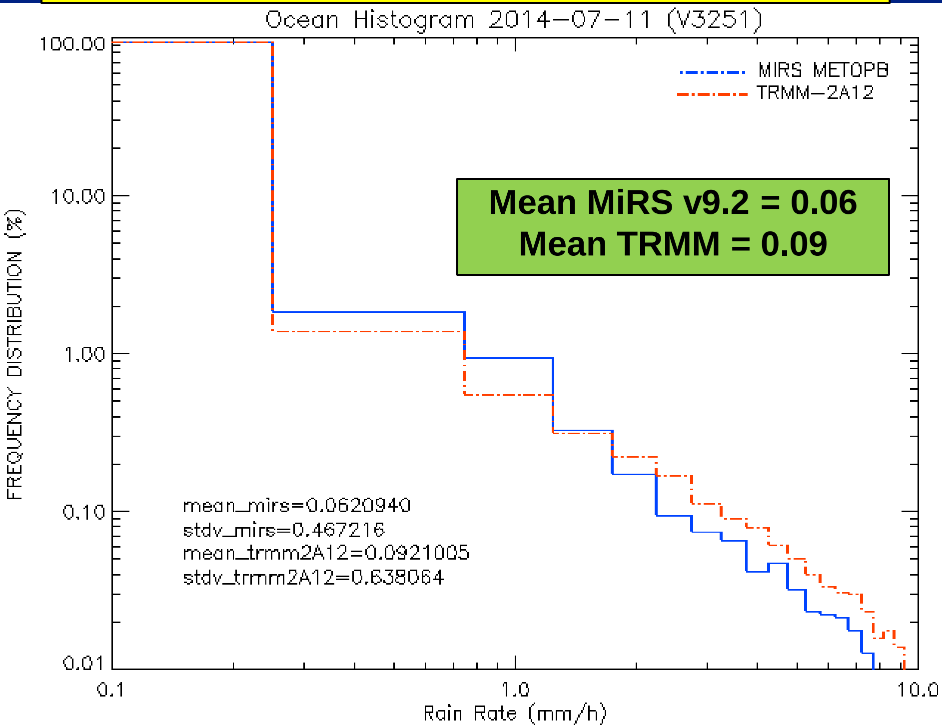
MiRS MetopB HR v11

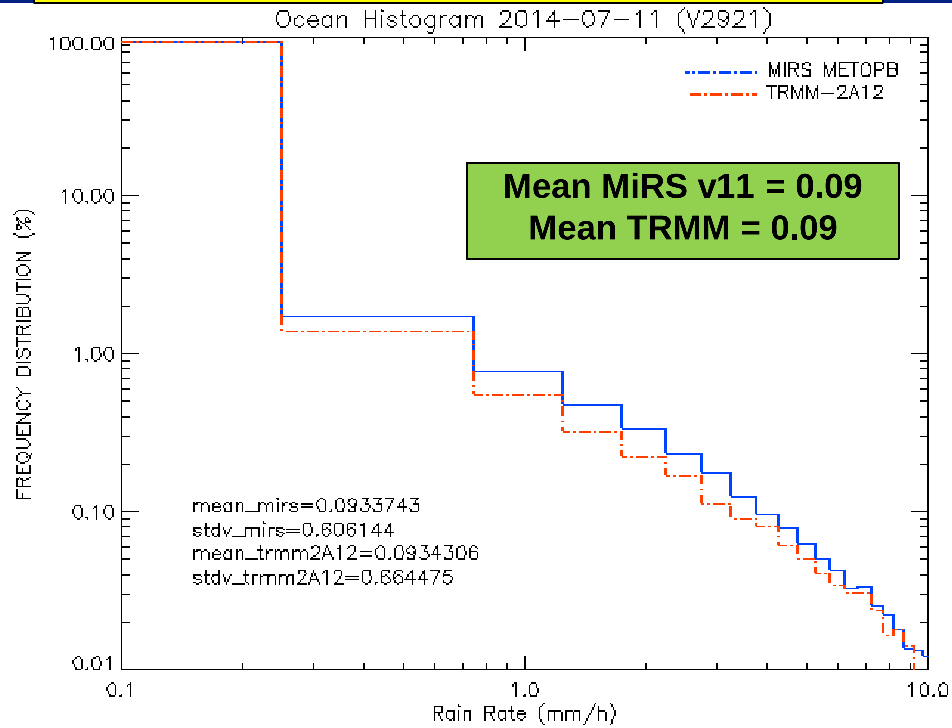


Qualitatively similar, but, quantitatively, there is improvement in MiRS v11 (following slides)

MiRS Product Assessments: MetopB Rain Rate (vs. TRMM 2A12)

MiRS MetopB HR v9.2	MiRS MetopB HR v11



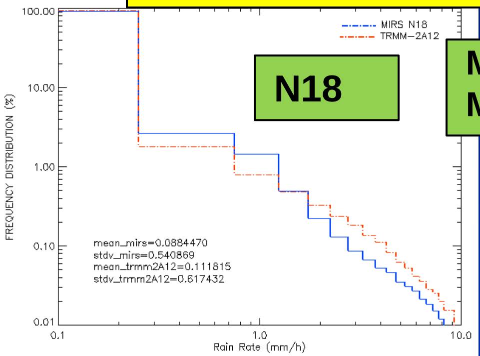


- MiRS v11 rain rate retrieval is now in better agreement with TRMM 2A12 as compared to v9.2 retrieval.
- Sample mean and std dev between MiRS and TRMM 2A12 also in better agreement in v11 than in v9.2

2 year assessment period (2009-2014)

MiRS Product Assessments: AMSUA/MHS Rain Rate (vs. TRMM 2A12)

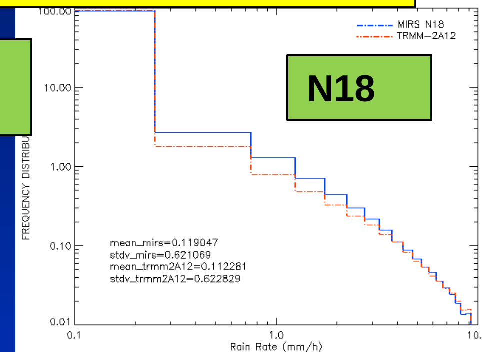
MiRS v9.2	MiRS v11



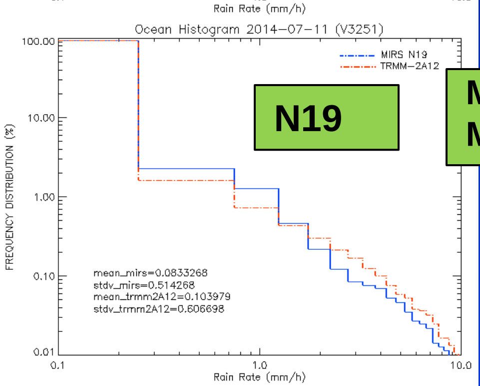
N18

Mean MiRS v9.2 = 0.08
Mean TRMM = 0.11

Mean MiRS v11 = 0.12
Mean TRMM = 0.11



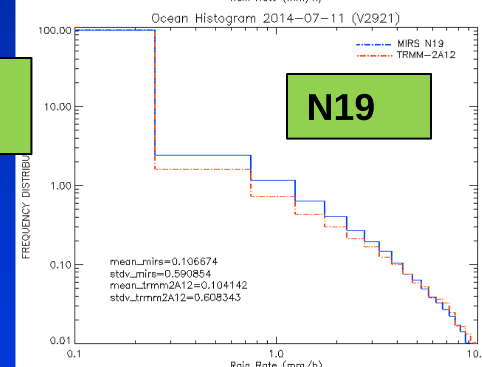
N18



N19

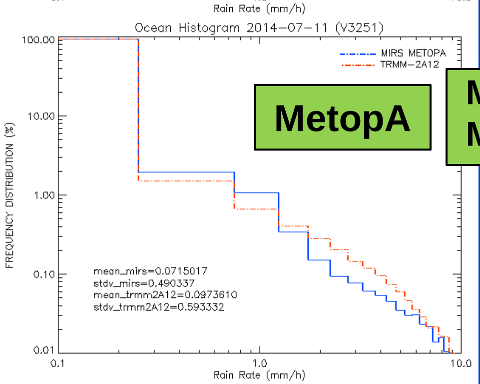
Mean MiRS v9.2 = 0.08
Mean TRMM = 0.10

Mean MiRS v11 = 0.11
Mean TRMM = 0.10



N19

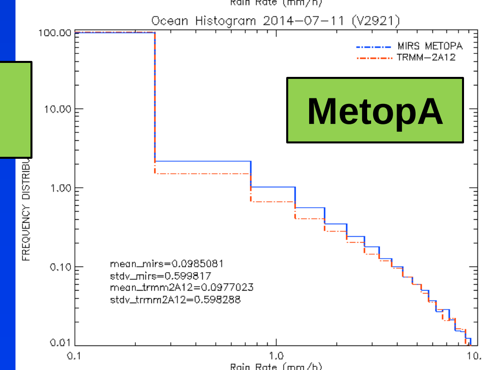
5 year assessment period (2009-2014)



MetopA

Mean MiRS v9.2 = 0.07
Mean TRMM = 0.11

Mean MiRS v11 = 0.10
Mean TRMM = 0.10

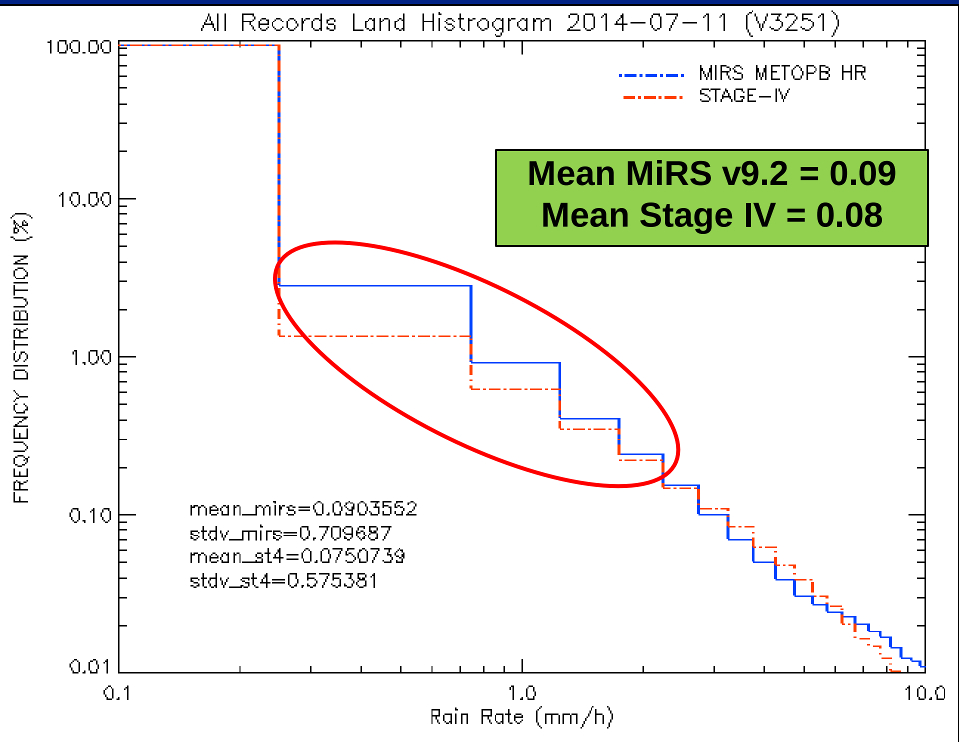


MetopA

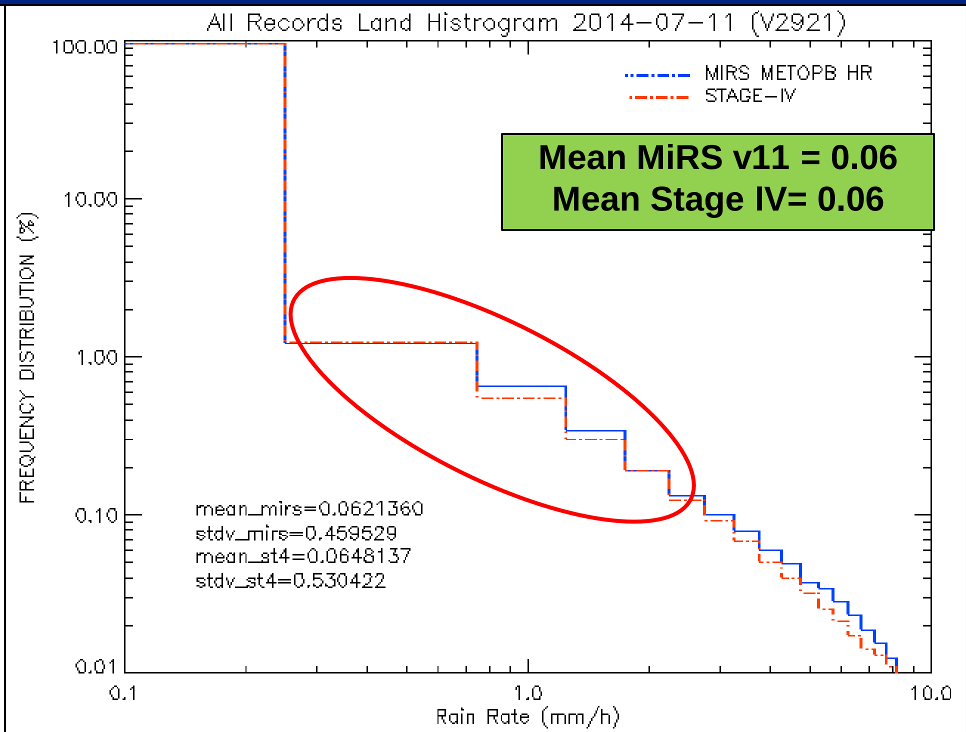
- N18, N19, and MetopA all show better agreement with TRMM using MiRS v11.0

MiRS Product Assessments: Rain Rate (vs. Stage-IV gauge-radar)

MiRS MetopB HR V9.2



MiRS MetopB HR V11

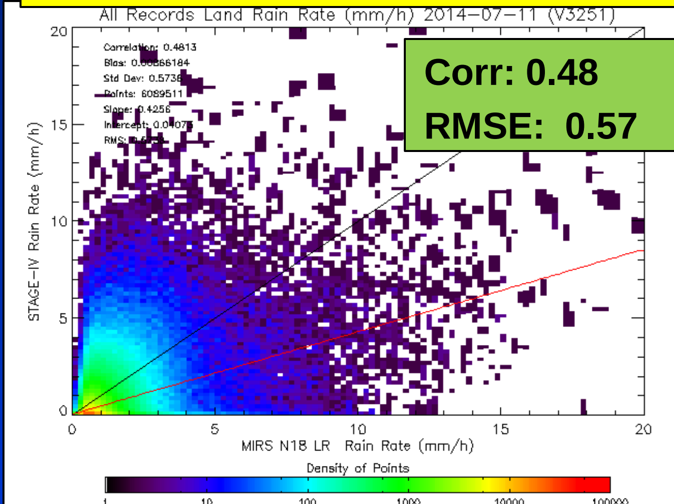


2 year assessment period (2009-2014)

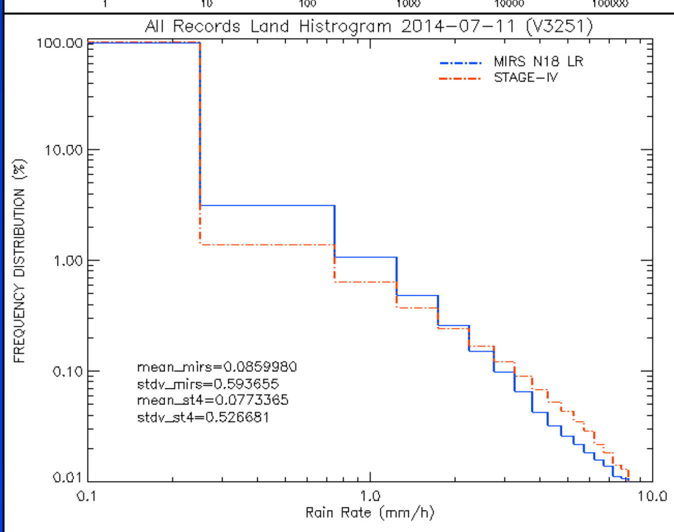
- Better agreement in low intensities
- Slightly more consistent at higher intensities (> 3 mm/h)

MiRS Product Assessments: Rain Rate (vs. Stage-IV gauge-radar)

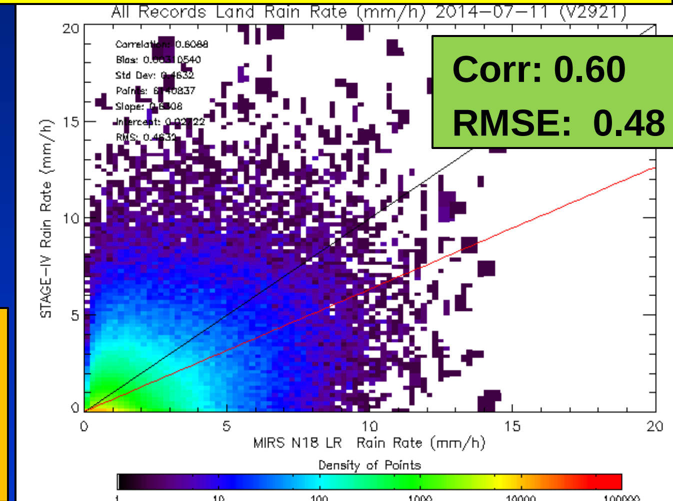
MiRS N18 LR v9.2



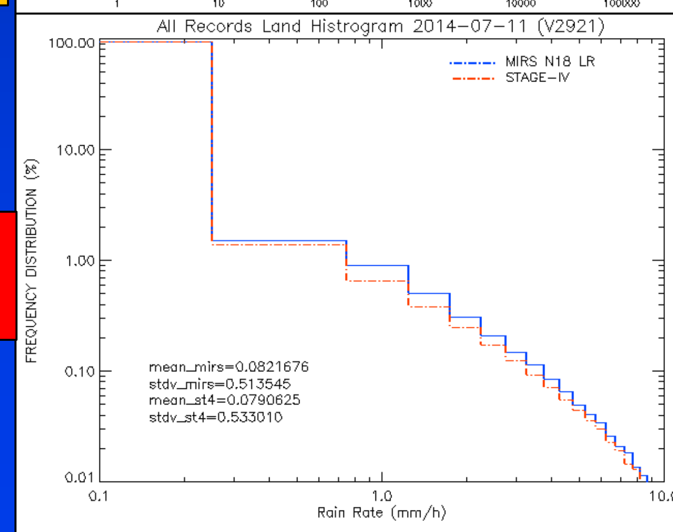
Corr: 0.48
RMSE: 0.57



MiRS N18 LR v11



Corr: 0.60
RMSE: 0.48

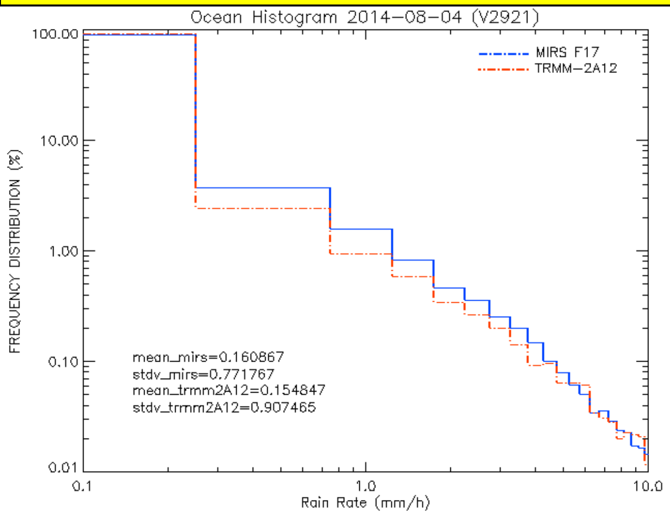


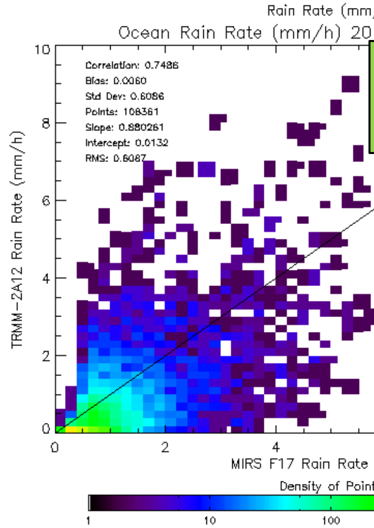
- **Significantly improved RR in MiRS v11**

5 year assessment period (2009-2014)

MiRS Product Assessments: Rain Rate (vs. TRMM 2A12)

MiRS F17 HR v11

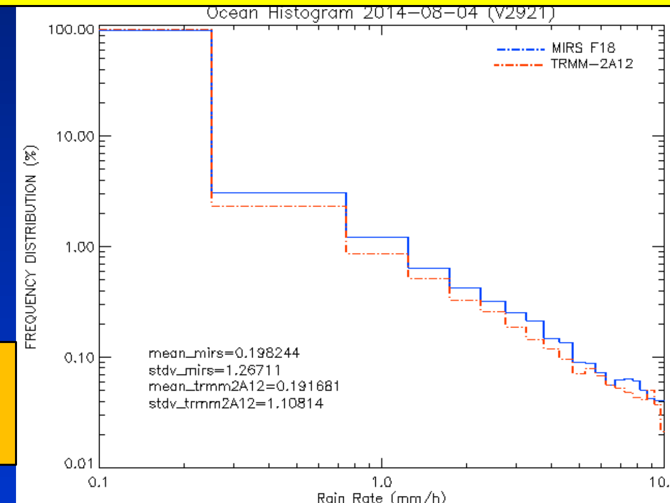


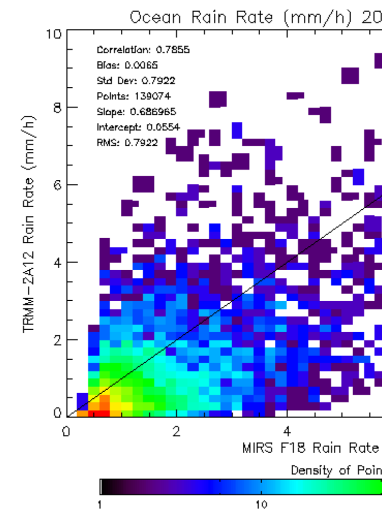


Cor: 0.74

RMSE: 0.60

MiRS F18 HR v11





Cor: 0.78

RMSE: 0.79

- F17 and F18 performances comparable

3 week assessment period (2014)

MiRS Product Assessments: Cryosphere

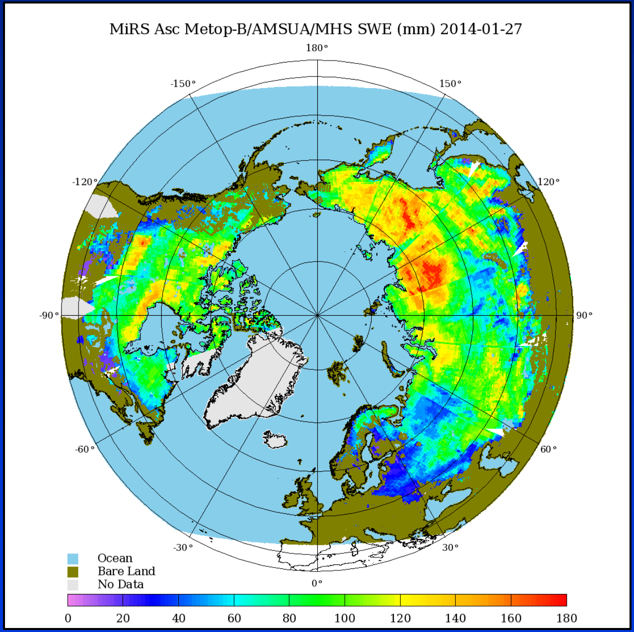
Presented by C. Grassotti

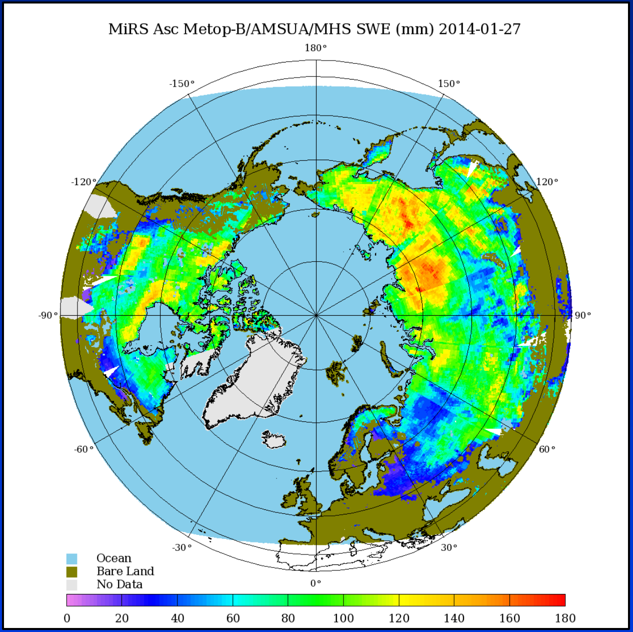
- » Snow Water Equivalent
- » Sea Ice Concentration

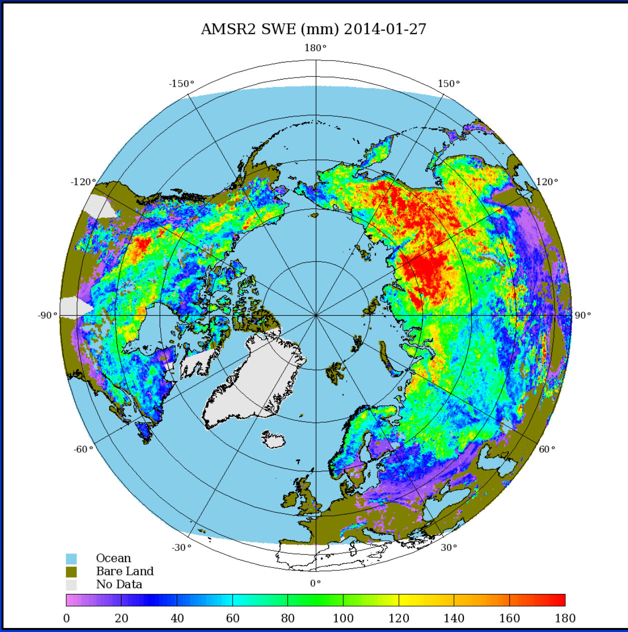
MiRS Snow Water Equivalent: MiRS v9.2 and v11.0

MetopB HR: 2014-01-27

MIRS v9.2 (operational)	MIRS v11.0	JAXA AMSR2





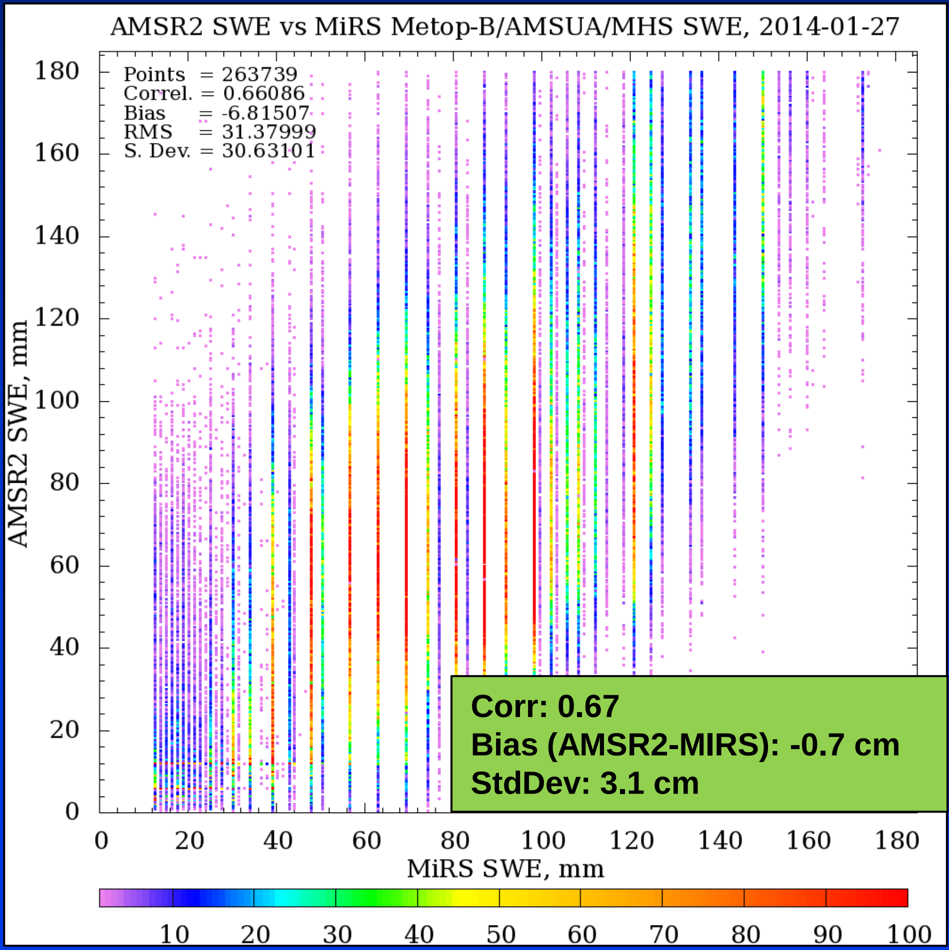


- v9.2 and v11.0 similar patterns of SWE
- v11.0 SWE maxima slightly reduced, but higher amounts close to southern snow cover edge over N. America
- JAXA AMSR2 SWE maxima over Siberia higher than MiRS
- No changes made to SWE algorithm from v9.2 to v11.0
  - Change related to retrieved emissivities: <u>cryospheric products will be focus for upcoming DAPs</u>

MiRS Snow Water Equivalent: MiRS v9.2 and v11.0

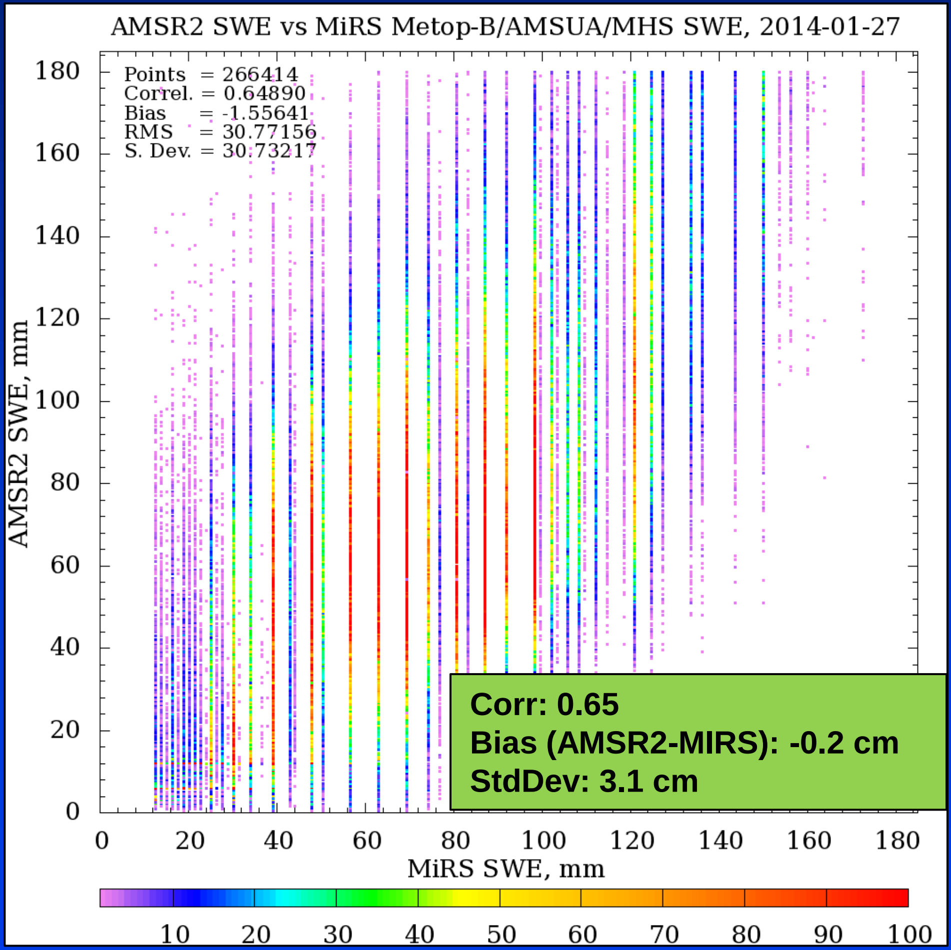
MetopB HR: 2014-01-27

MIRS v9.2 (operational)



Corr: 0.67
Bias (AMSR2-MIRS): -0.7 cm
StdDev: 3.1 cm

MIRS v11.0

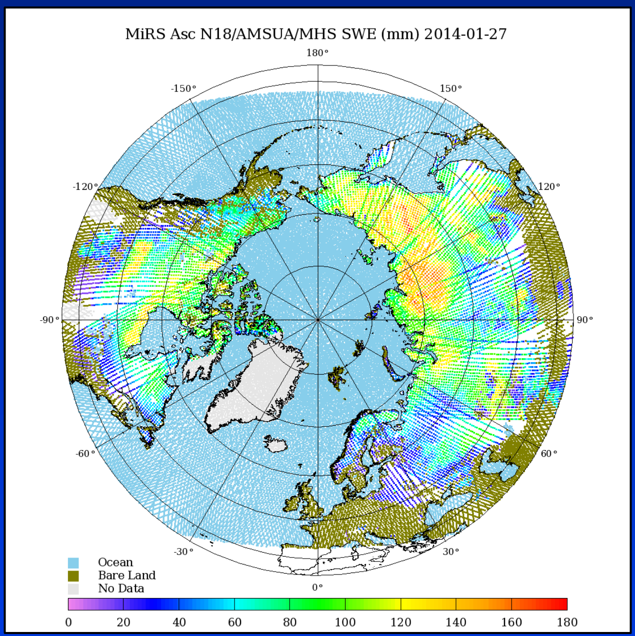


Corr: 0.65
Bias (AMSR2-MIRS): -0.2 cm
StdDev: 3.1 cm

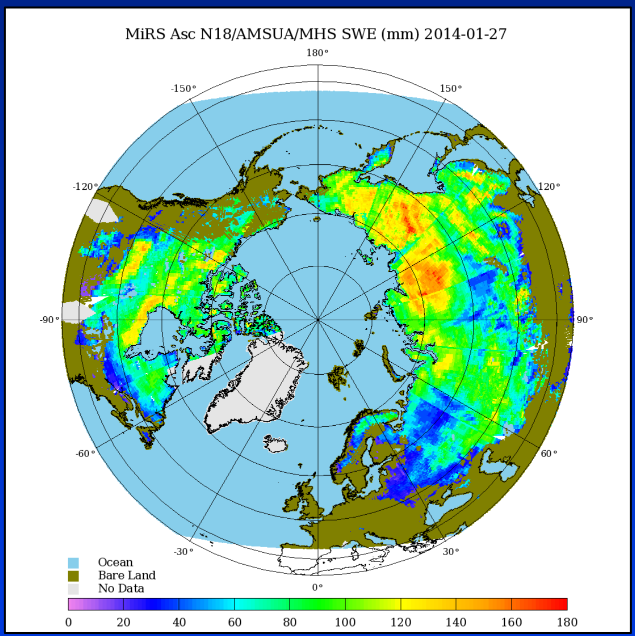
MiRS Snow Water Equivalent: Low vs. High Resolution

N18 LR and HR: 2014-01-27

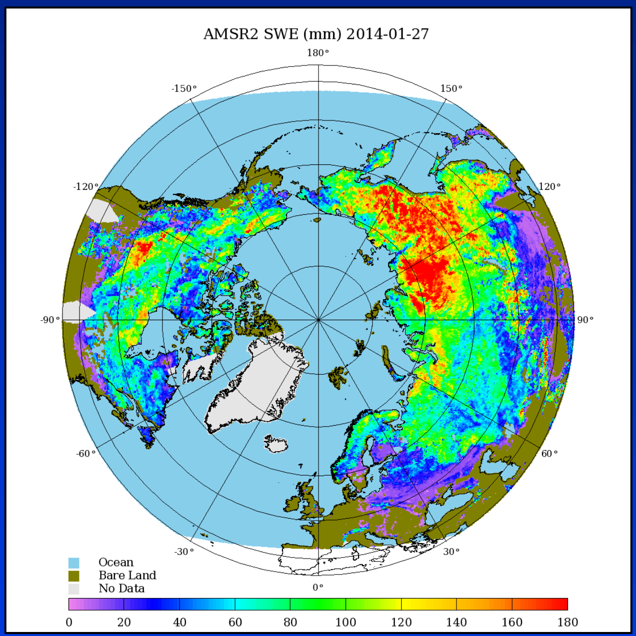
MIRS 11.0 LR



MIRS v11.0 HR



JAXA AMSR2

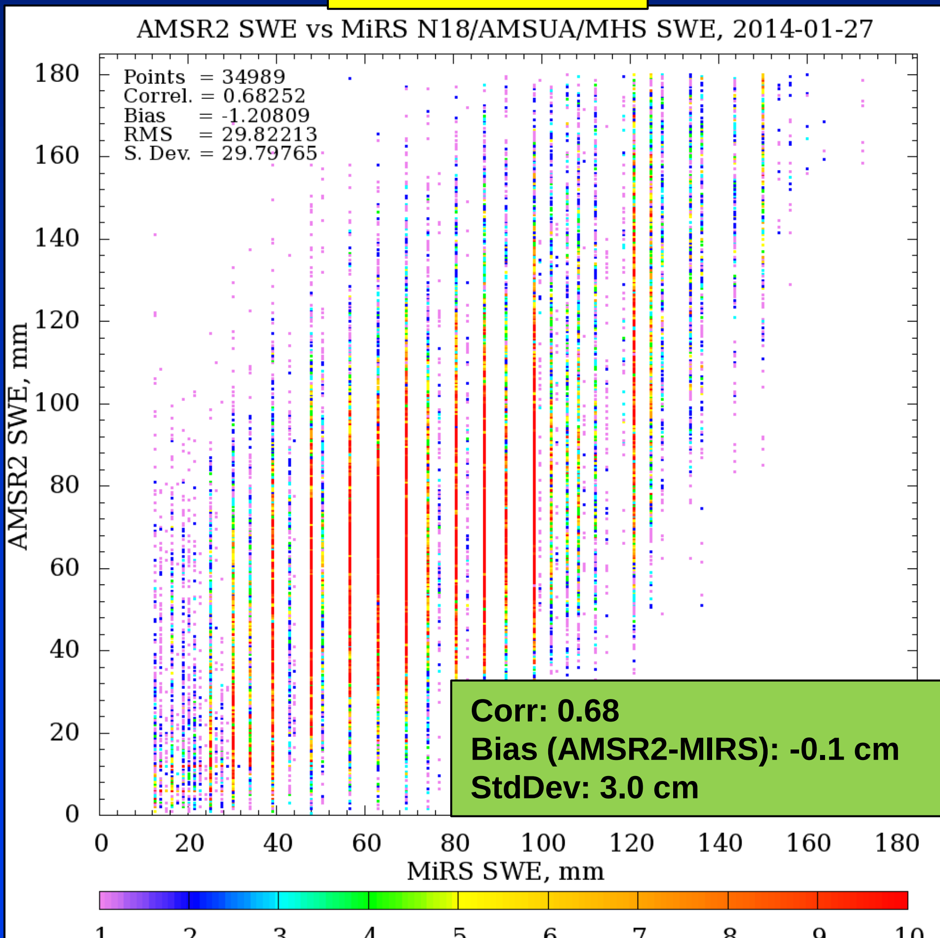


- HR better depiction of SWE spatial patterns than LR

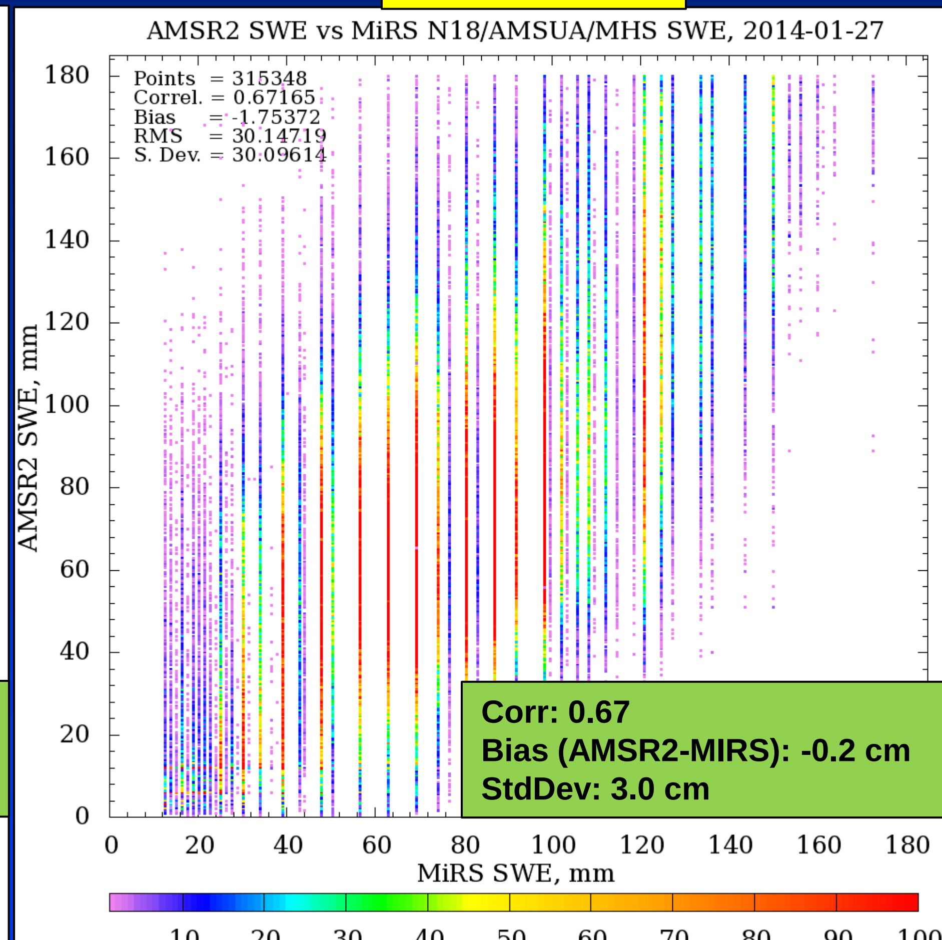
MiRS Snow Water Equivalent: Low vs. High Resolution

N18 LR and HR: 2014-01-27

MIRS 11.0 LR

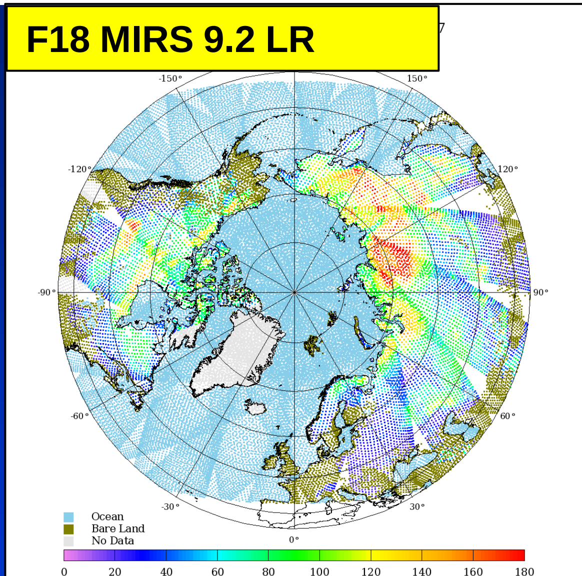


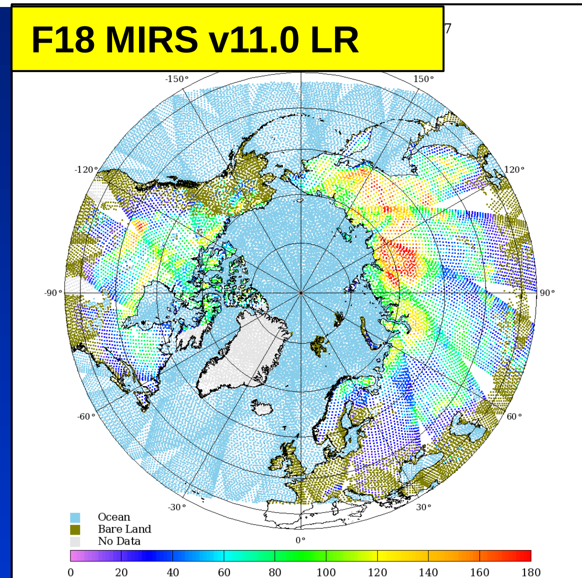
MIRS v11.0 HR

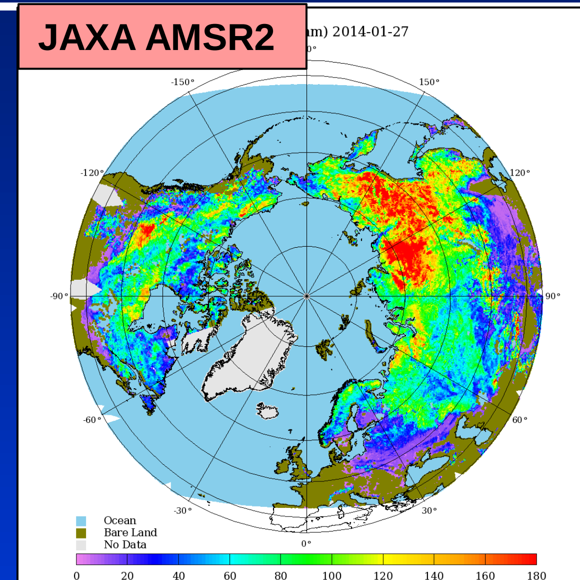


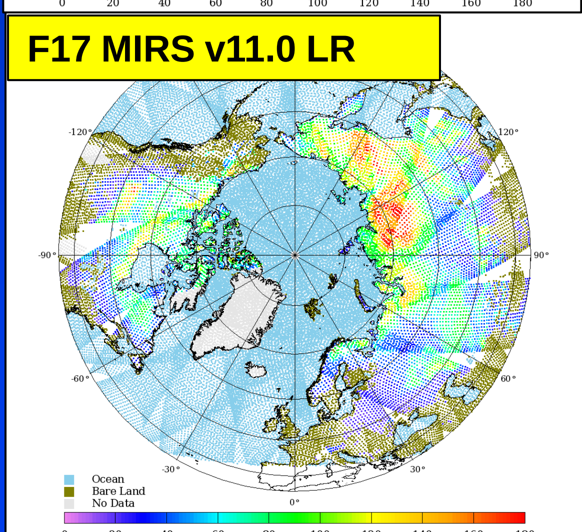
- HR and LR performance similar (vs. JAXA AMSR2)

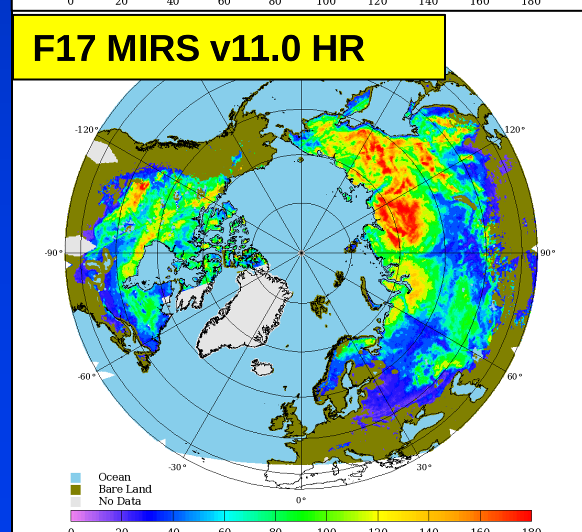
MiRS Snow Water Equivalent: F17 and F18 SSMIS





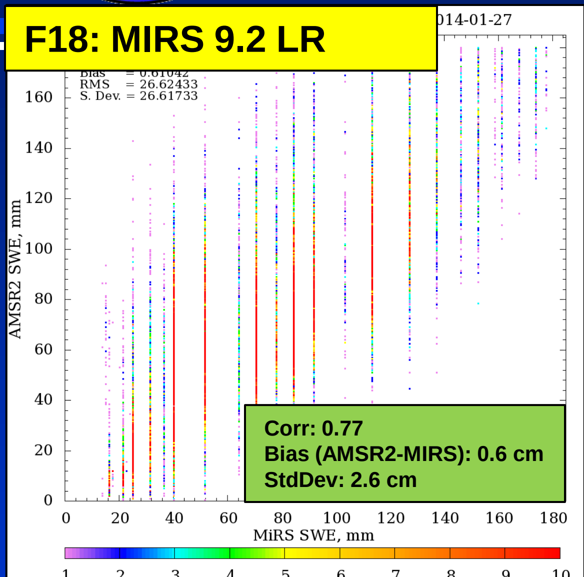


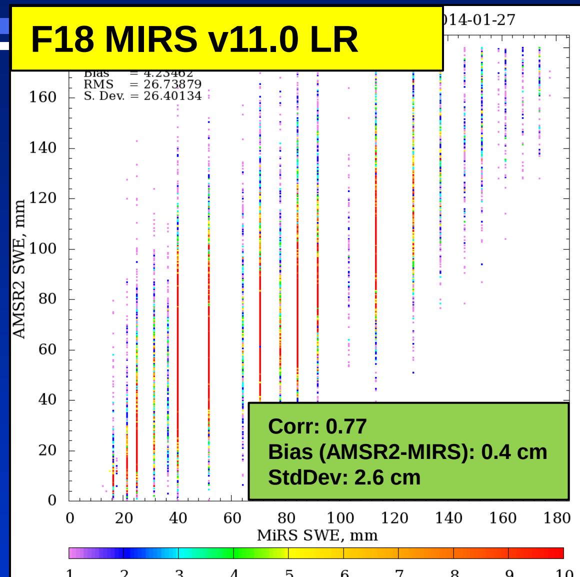


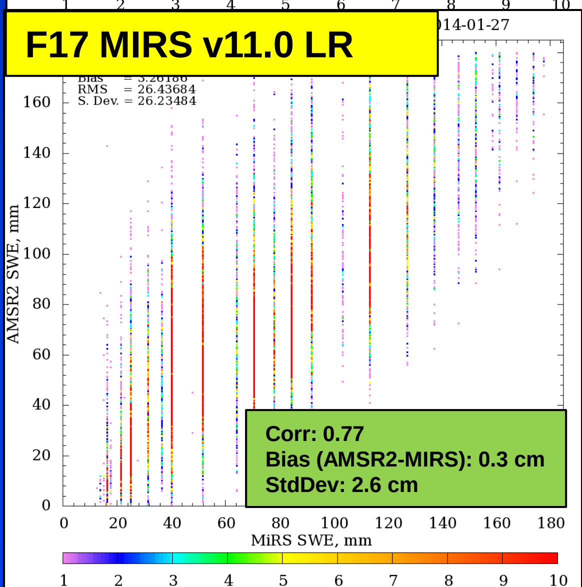


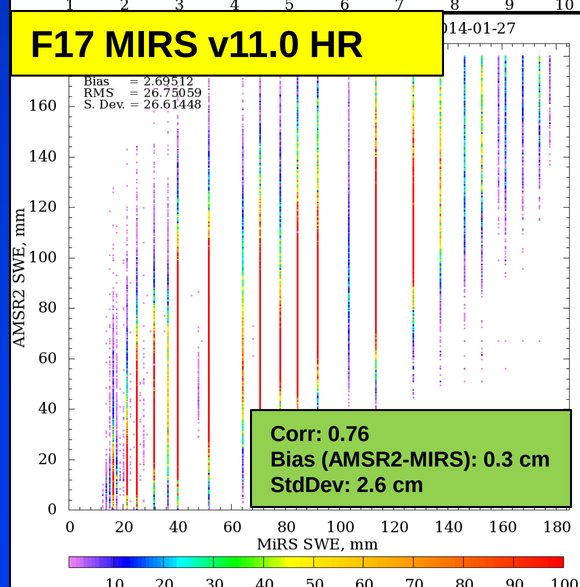
- Minor differences in retrieved SWE maps performance from:
  - v9.2 to v11.0
  - LR to HR

MiRS Snow Water Equivalent: F17 and F18 SSMIS







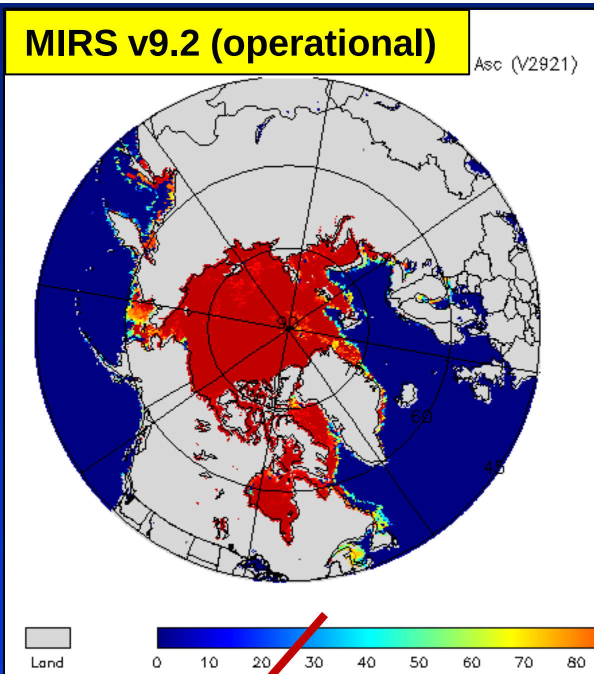


- No change in retrieval performance from:
  - v9.2 to v11.0
  - LR to HR
- F17 and F18 performances comparable

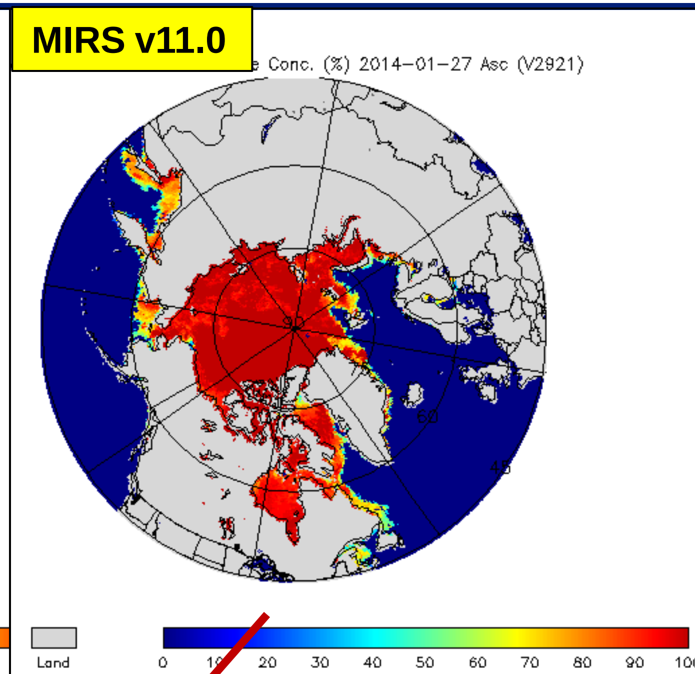
MiRS Sea Ice Concentration: MiRS v9.2 and v11.0 (N. Hem.)

MetopB HR: 2014-01-27

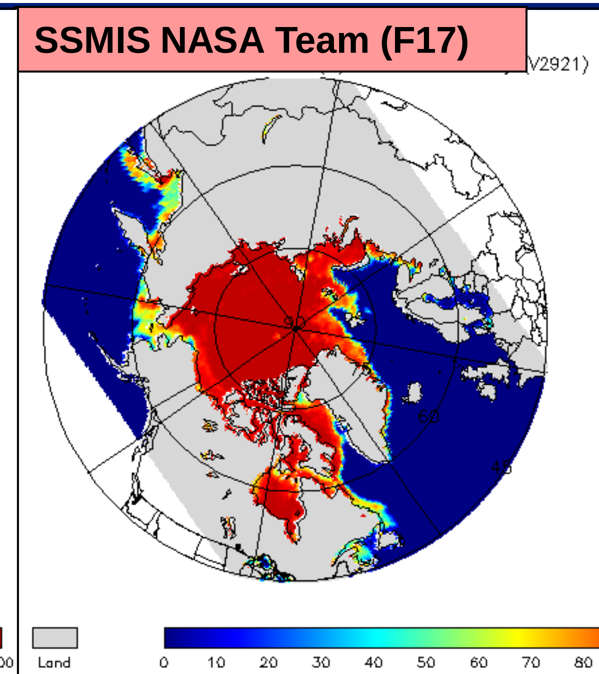
MIRS v9.2 (operational)

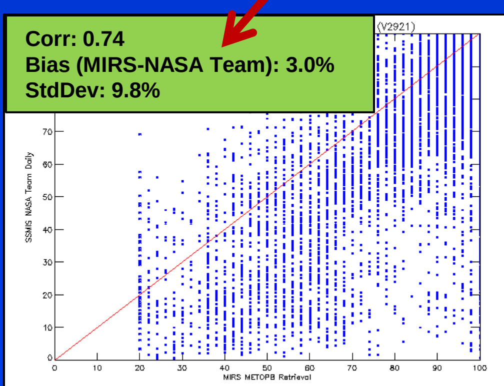


MIRS v11.0

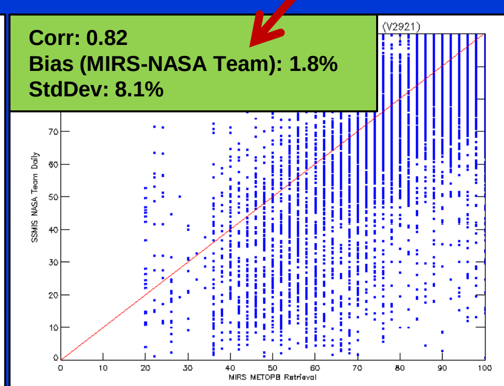


SSMIS NASA Team (F17)





Corr: 0.74
Bias (MIRS-NASA Team): 3.0%
StdDev: 9.8%



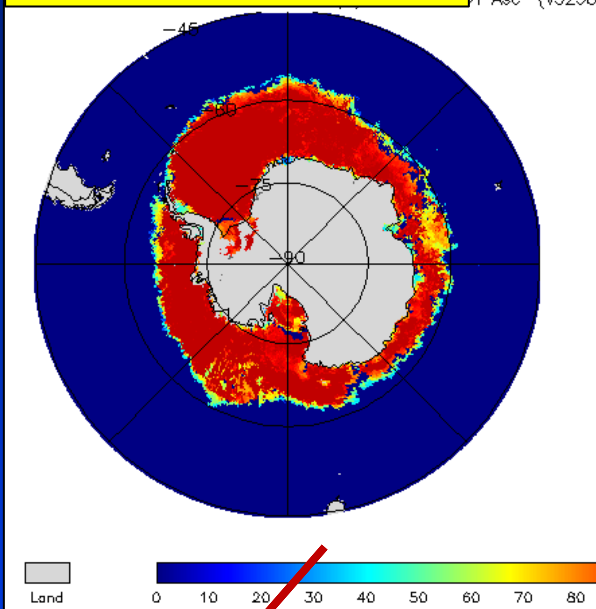
Corr: 0.82
Bias (MIRS-NASA Team): 1.8%
StdDev: 8.1%

- v11.0 better correlation, smaller bias and std dev
- v11.0 better detection near ice edge (e.g. Pacific coast of Asia, Labrador)
- Smoother transition at ice edge.
- Some differences due to gridding and visualization

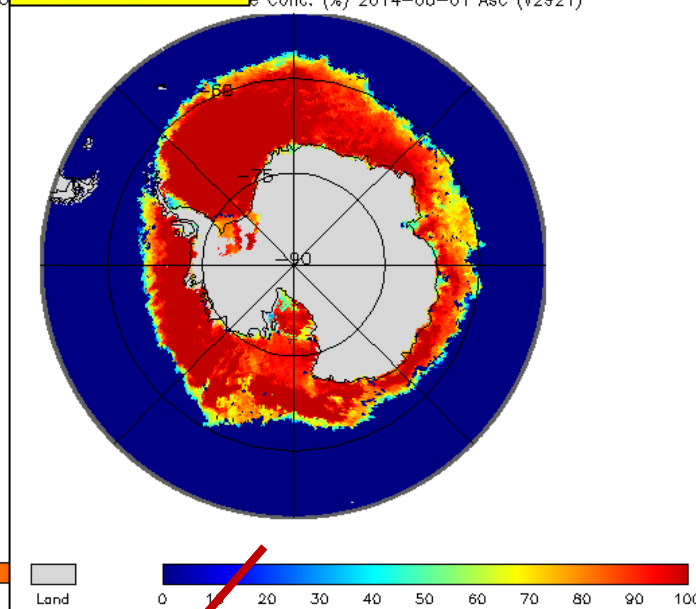
MiRS Sea Ice Concentration: MiRS v9.2 and v11.0 (S. Hem.)

MetopB HR: 2014-08-01

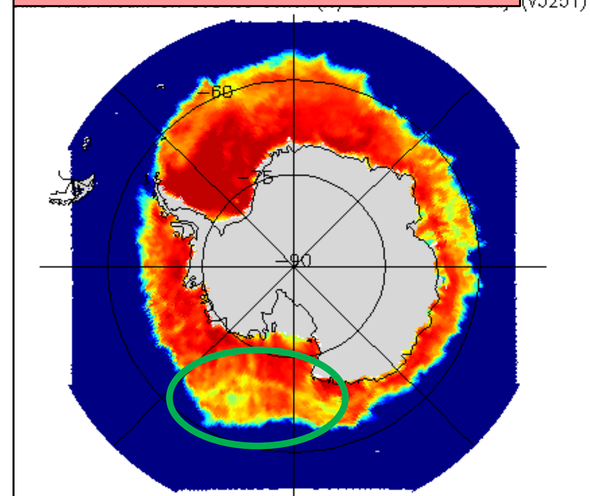
MIRS v9.2 (operational)



MIRS v11.0

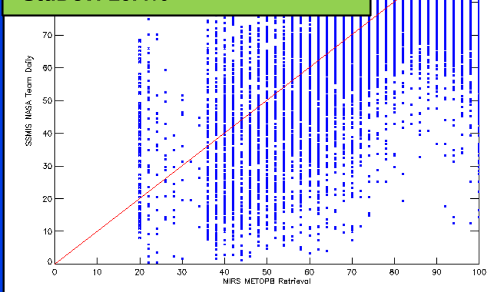


SSMIS NASA Team (F17)

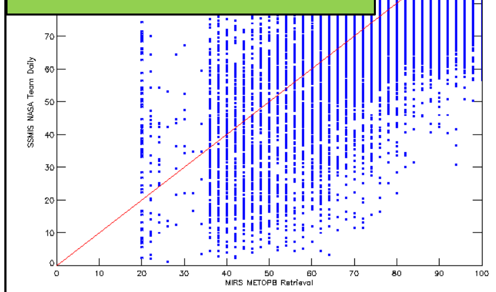


- NASA Team likely underestimating SICs < 100 % in SH Winter (W. Meier, GSFC, pers. comm.)

Corr: 0.76
Bias (MIRS-NASA Team): 9.7%
StdDev: 10.4%



Corr: 0.78
Bias (MIRS-NASA Team): 6.9%
StdDev: 9.9%

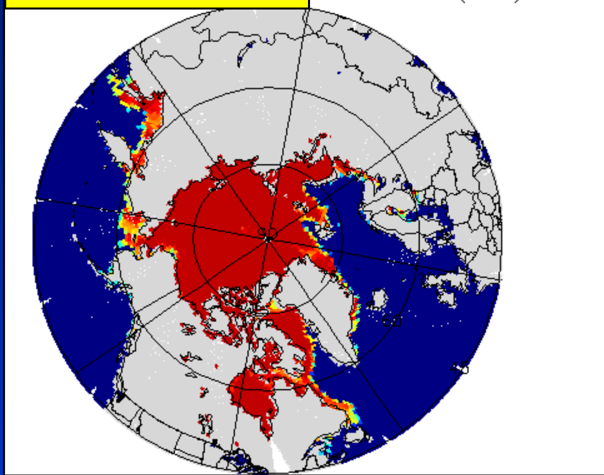


- v11.0 smaller bias and std dev
- v11.0 increased ice coverage; more consistent with NASA Team
- Smoother transition at ice edge

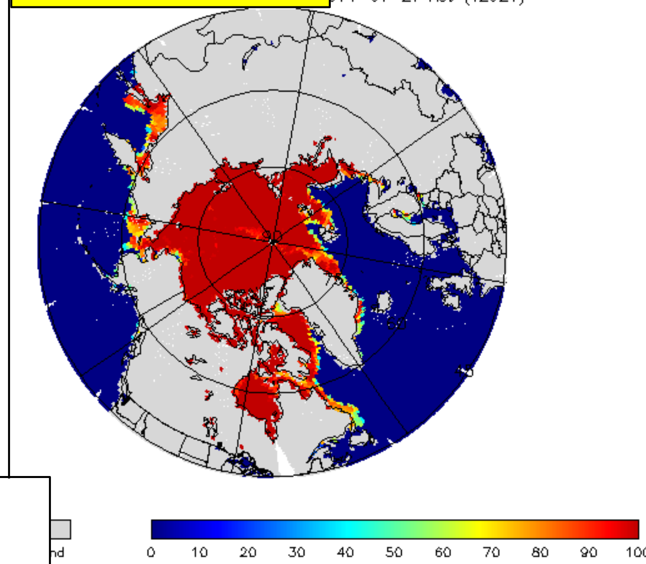
MiRS Sea Ice Concentration: F17 and F18 SSMIS (N. Hem.)

2014-01-27

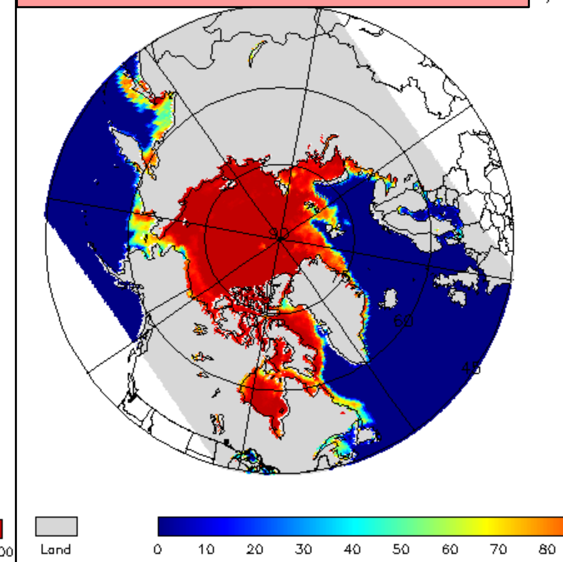
F18 v9.2 LR



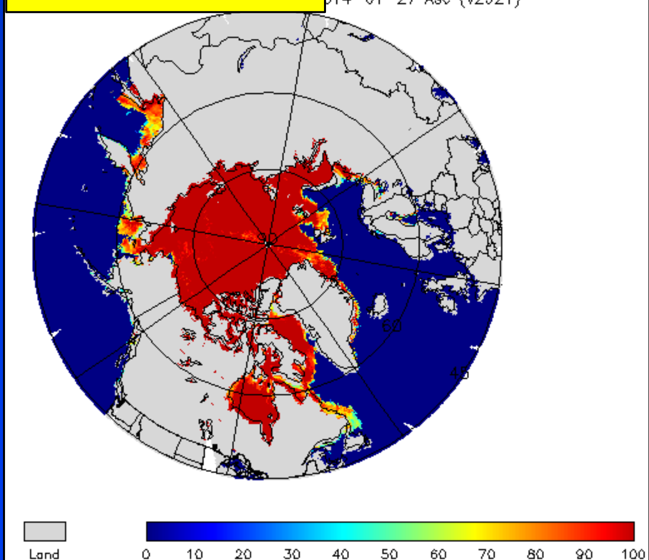
F18 v11.0 LR



SSMIS NASA Team (F17)



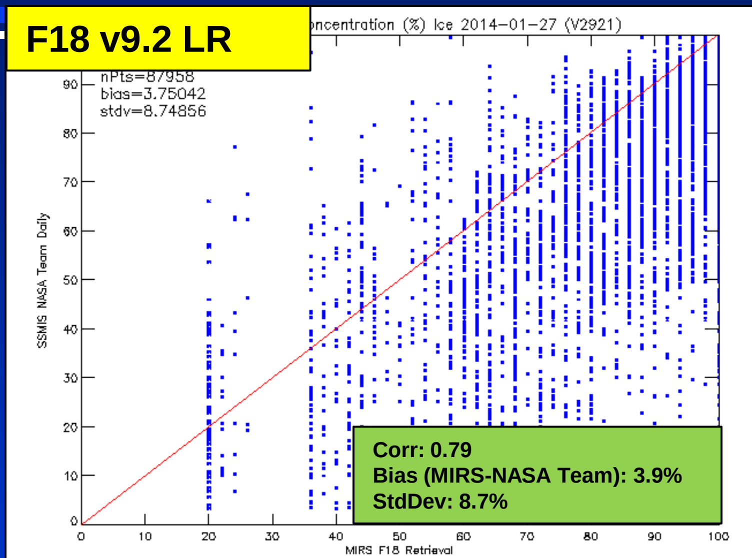
F17 v11.0 HR

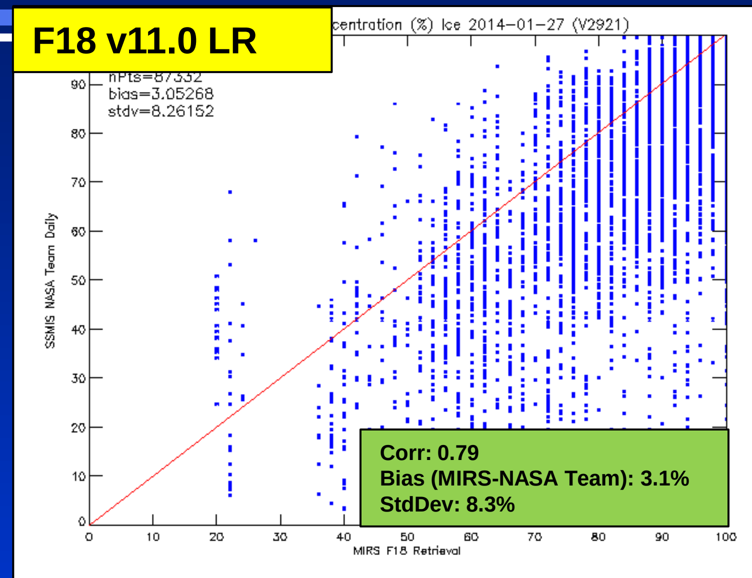


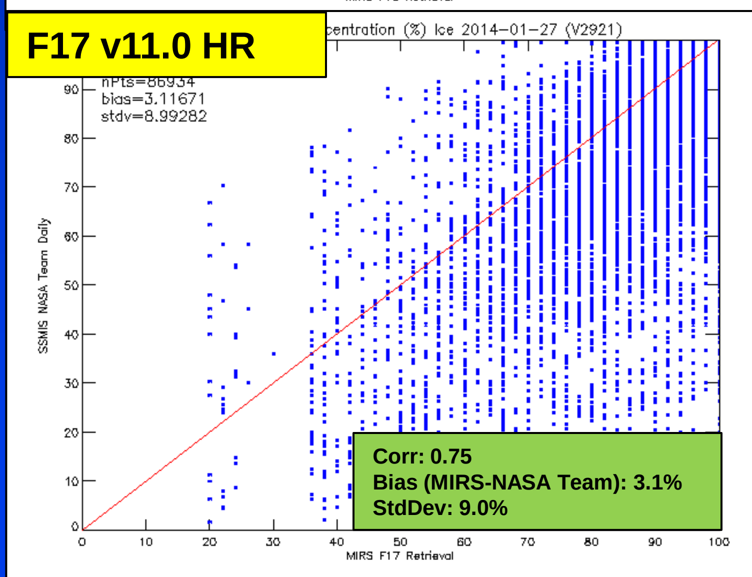
- F18 v9.2 and v11.0 similar SIC
- F17 v11.0 consistent with F18 SIC
- Both F17 and F18 higher ice amounts than NASA Team near ice edge

MiRS Sea Ice Concentration: F17 and F18 SSMIS (N. Hem.)

2014-01-27







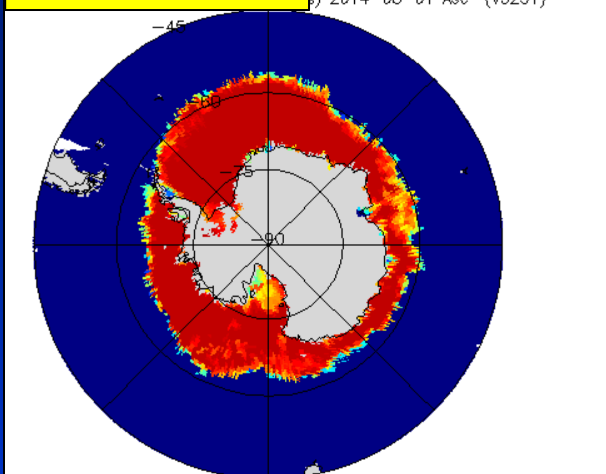
- F18 v11.0 slight reduction in bias and std dev vs. v9.2
- F17 v11.0 slightly lower correlation and higher std dev than F18 v11.0 (expected noise increase at HR)

- Focus on updating cryospheric products in upcoming DAPs

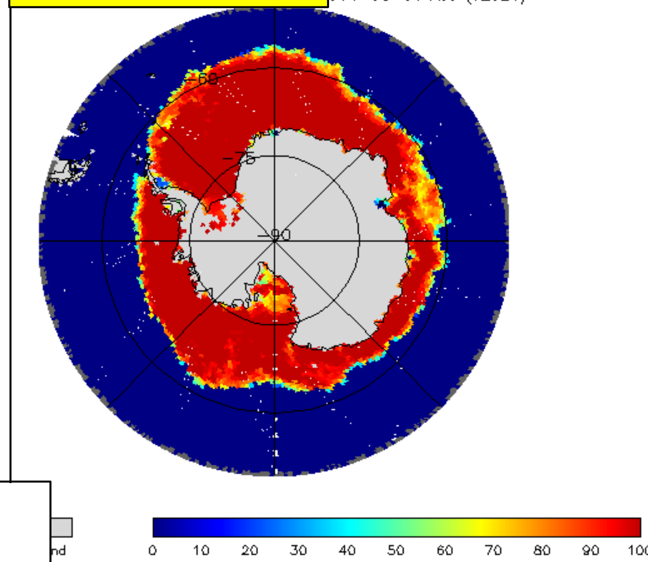
MiRS Sea Ice Concentration: F17 and F18 SSMIS (S. Hem.)

2014-08-01

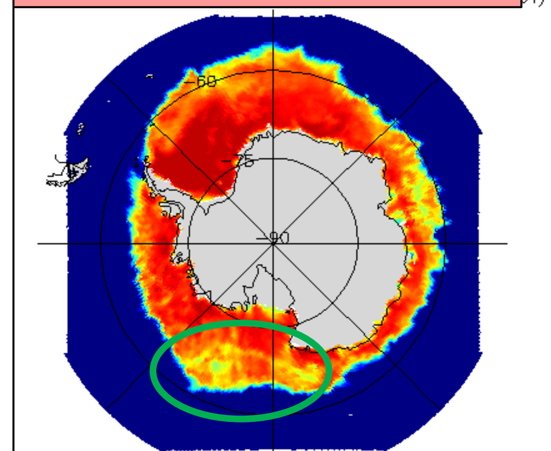
F18 v9.2 LR



F18 v11.0 LR

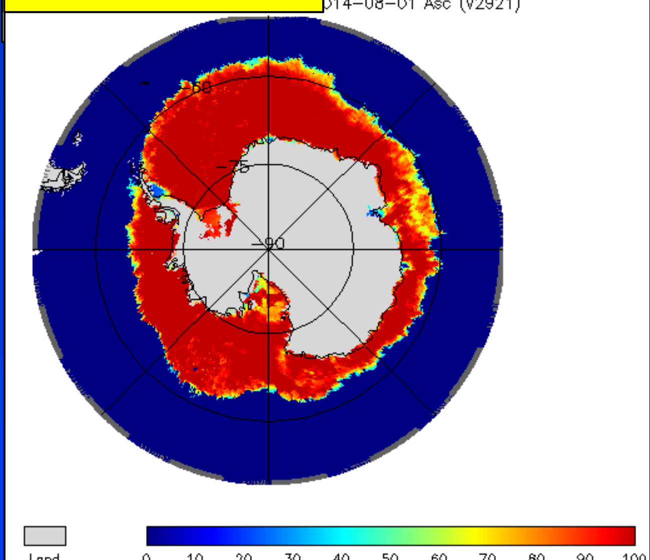


SSMIS NASA Team (F17)



- NASA Team likely underestimating SICs < 100 % in SH Winter (W. Meier, GSFC, pers. comm.)

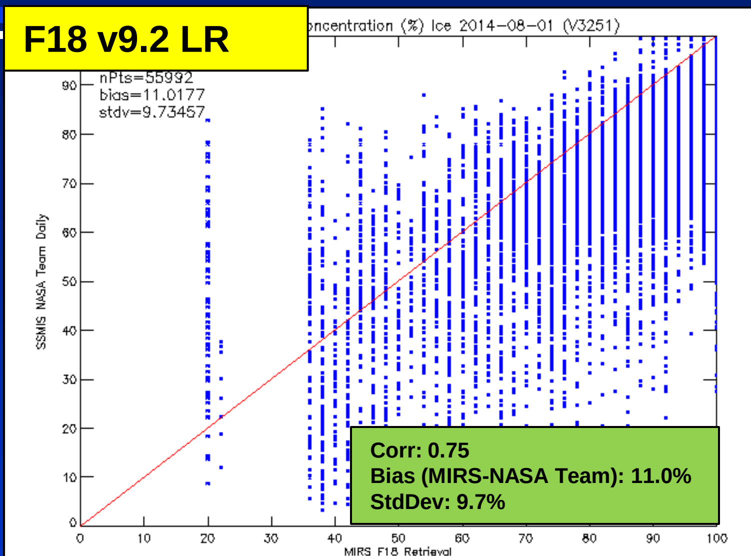
F17 v11.0 HR

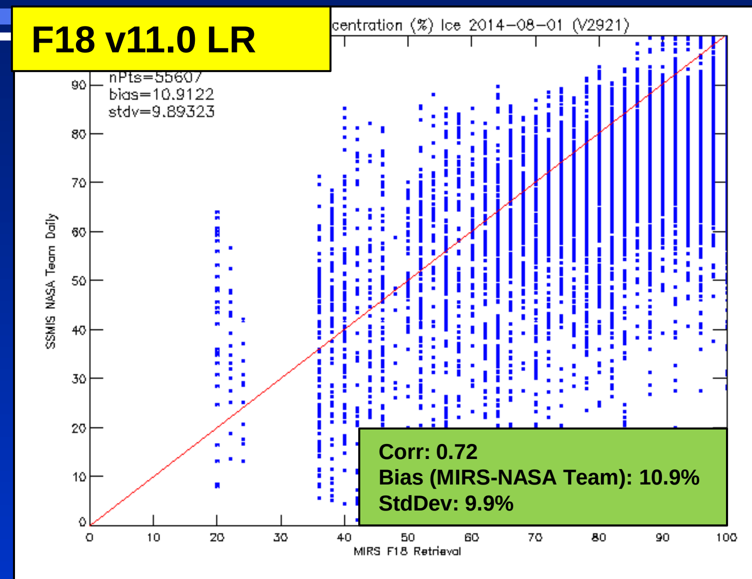


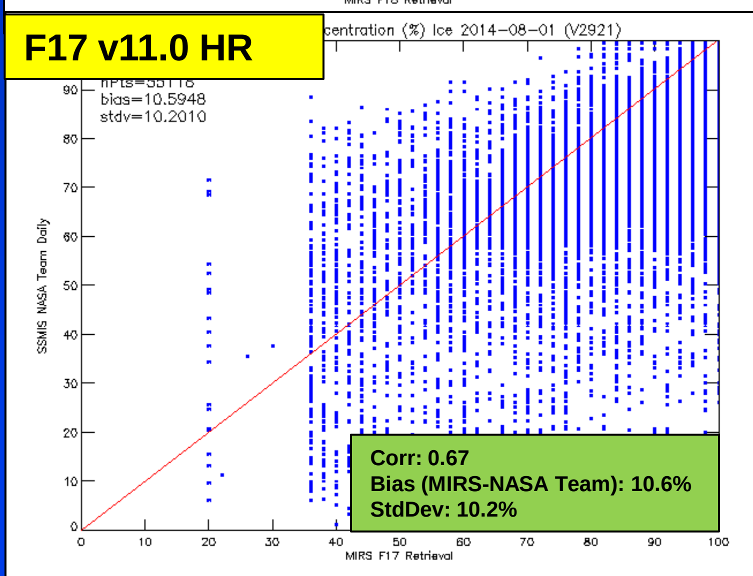
- F17 and F18 v11.0 increased area of ice cover wrt v9.2; closer to NASA Team
- F17 v11.0 consistent with F18 SIC
- Smoother transition at ice edge
- Both F17 and F18 higher ice amounts than NASA Team near ice edge

MiRS Sea Ice Concentration: F17 and F18 SSMIS (S. Hem.)

2014-08-01







- F18 v11.0 similar performance to v9.2
- F17 v11.0 slightly lower correlation and higher std dev than F18 v11.0 (expected noise increase at HR)

- Focus on updating cryospheric products in upcoming DAPs

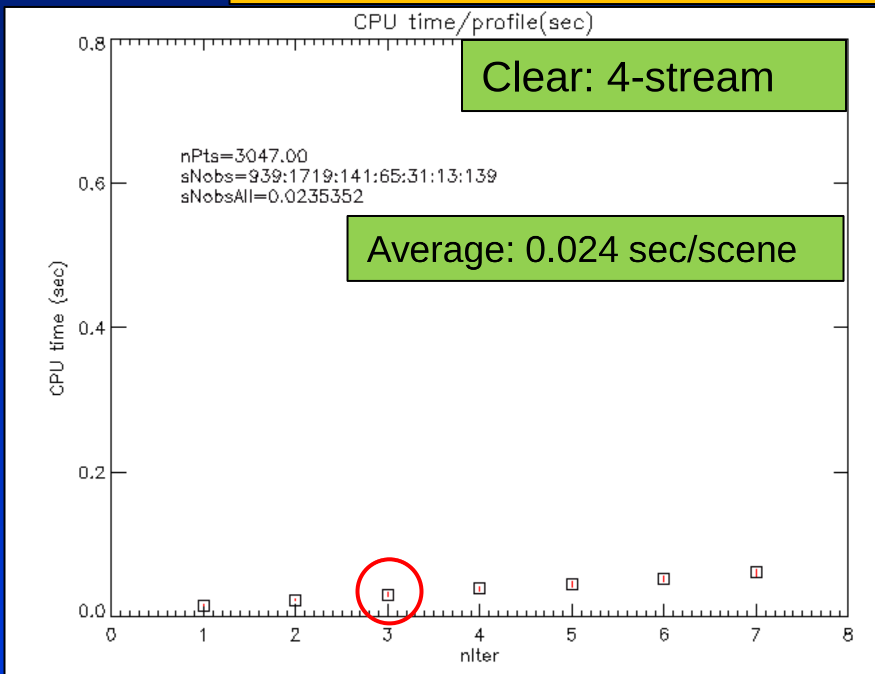
MiRS 11.0 IT Requirements

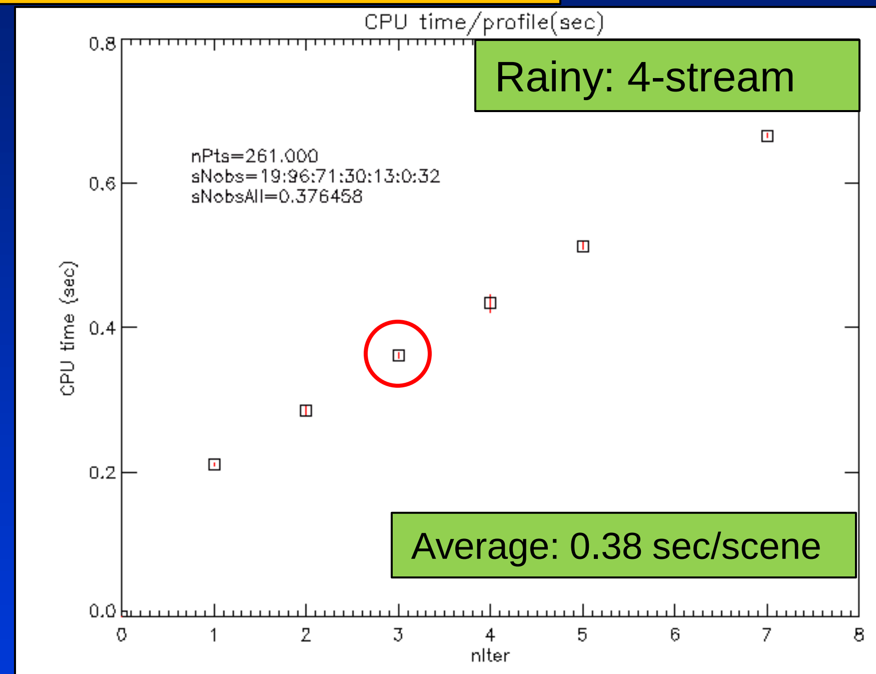
Presented by C. Grassotti

- Run at High-Resolution
  - » AMSUA-MHS: 90 FOVs/scan (single orbit)
  - » SSMIS: 90 FOVs/scan (single orbit)
- Input data processed with and without chopping (subfiles)
- Real (wall clock) and CPU time recorded
- Current operational MiRS (9.2) also run as benchmark for comparison
- Sensitivity to clear/rainy scenes (CRTM scattering slowdown)
- CRTM scattering time mitigation approaches

CRTM 2.1.1 Timing Tests: MiRS N18 AMSUA/MHS

1DVAR: CPU time per scene stratified by iteration number





- CRTM 2.1.1: On average, rainy scenes required more than 10x CPU time in 1dvar relative to clear scenes. Total time proportional to number of iterations.
- Scenes with scattering conditions comprise ~ 10% of total scenes globally (fortunately!)
- Previously not a focus since other users may explicitly QC rainy scenes (e.g. data assimilation)

MiRS IT Requirements: AMSUA-MHS High-Resolution

N18 AMSUA/MHS High-Res (90 Meas/scan)
- 1 orbit ~ 231390 profiles
- 1 day= 14 orbits
- 102 minute orbital period

Machine	Single CPU (core)	Number of CPUs	Total Avail Memory
rhw1016	3.33 GHz	24	66 GB

N18 AMSUA/MHS Single Orbit	Oper MiRS (pCRTM) nChopp=10	New MiRS (CRTM 2.1.1) nChopp=10
Real Time (min:sec)	13:59	39:37
CPU Time (min:sec)	119:38	223:04
Memory	60 MB	350 MB
Output IMG+SND (MB)	720 MB	720 MB

AMSU/MHS: Although 3 times slower than MIRS v9.2, clock time with MiRS v11 still **less than** elapsed time of orbit (102 min). **Processing speed sufficient to keep up with data flow (assuming additional latency < 50 min)**

- Additional speedup possible by increasing chop factor
- OSPO feedback required

MiRS IT Requirements: SSMIS High-Resolution (90 fovs/scan, baseline option)

F17 SSMIS High-Res (90 meas/scan)
- 1 orbit ~ 300600 profiles
- 1 day= 14 orbits
- 104 minute orbital period

Machine	Single CPU (core)	Number of CPUs	Total Avail Memory
rhw1016	3.33 GHz	24	66 GB

F17 SSMIS Single Orbit	Oper MiRS (pCRTM) nChopp=10	New MiRS (CRTM 2.1.1) nChopp=10
Real Time (min:sec)	N/A	54:34
CPU Time (min:sec)	N/A	287:53
Memory	60 MB	350 MB
Output IMG+SND (MB)	892 MB	892 MB

SSMIS: Clock time with MiRS v11 **less than** elapsed time of orbit (104 min). **Processing speed sufficient to keep up with data flow (assuming additional latency < 30 min)**

- Additional speedup possible by increasing chop factor
- OSPO feedback required

MiRS IT Requirements: SSMIS High-Resolution (90 fovs/scan, alternate option w/scan line averaging)

F17 SSMIS High-Res (90 meas/scan)
- 1 orbit ~ 150300 profiles
- 1 day= 14 orbits
- 104 minute orbital period

Machine	Single CPU (core)	Number of CPUs	Total Avail Memory
rhw1016	3.33 GHz	24	66 GB

F17 SSMIS Single Orbit	Oper MiRS (pCRTM) nChopp=10	New MiRS (CRTM 2.1.1) nChopp=10
Real Time (min:sec)	N/A	31:40
CPU Time (min:sec)	N/A	156:55
Memory	60 MB	350 MB
Output IMG+SND (MB)	446 MB	446 MB

SSMIS: Clock time with MiRS v11 **less than** elapsed time of orbit (104 min). **Processing speed sufficient to keep up with data flow**

- Additional speedup possible by increasing chop factor
- OSPO feedback required

CRTM 2.1.1 Slowdown in Scattering Scenes: Mitigation Approach

- Independent analysis by both MiRS and CRTM teams indicates that CRTM2.x scattering scene simulations require factor 10x more CPU time than non-scattering (absorbing only).
  - » Operational MiRS v9.2 using pCRTM shows timing of scattering scene simulations approximately same as non-scattering.
- Close cooperation with CRTM Team (i.e. P. van Delst, Q. Liu, D. Groff, Y. Chen)
  - » CRTM team actively investigating source(s) and will provide a code update ASAP.
  - » Focus: (1) a new RT solver for 2 and 4 streams, (2) optimizing interpolation of cloud scattering coefficients, (3) DDA (discrete dipole approximation) scattering coefficients for non-spherical scatters (currently using Mie theory).
  - » DDA scattering coefficients may achieve better accuracy and reduce computation time (under testing).
  - » MiRS team will work collaboratively with CRTM team to test any potential updates

MIRS Science Product Assessment Summary (1/2)

- **Sounding Products**
  - **T, WV profiles:** v11 significant improvement over v9.2 esp in lower troposphere; performance in rainy conditions much improved; F17 sounding performances generally worse than F18 due to sensor calibration issues – **but products still usable (F17 v11 performance better than operational v9.2 F18 in some cases)**.
- **Hydrometeors**
  - **RR:** v11 improved rain rates; updated RR relationship is now purely based on independent model (MM5) simulations
  - **IWP:** v11 more realistic IWP amounts (magnitudes increased by 7-10 times relative to v9.2, more consistent with independent obs)
- **Cryosphere**
  - **SWE:** v11 only small differences with v9.2 (slightly reduced maxima in v11)
  - **SIC:** v11 significant improvement for AMSUA-MHS (better estimation near ice edge); F17/F18 SSMIS v11 and v9.2 performances roughly equivalent.
- **QC Monitoring**
  - Convergence rates, QC Flags satisfactory, consistent with previous versions

MIRS Science Product Assessment Summary (2/2)

- **IT Benchmarks**
  - **AMSUA-MHS, SSMIS:** All integration and testing results (STAR) show adequate resources for operations (although slower than current MiRS v9.2 due to CRTM scattering); will engage with OSPO to identify any potential issues.
  - **SSMIS HR:** if baseline HR FM algorithm exceeds resources, alternate approach is a simple fall-back, and would not incur EDR performance degradation. (feedback from OSPO required)
- **Remaining tuning and testing:**
  - Minimal; valgrind to profile code for memory leaks

System Readiness for Users, Operations and Maintenance

- MIRS Algorithm in STAR
  - Updated v11.0 algorithm run in STAR on selected days (e.g. daily cronjobs processing up to 4 sensors each night); stable performance
  - All operational satellites/sensors tested in high-resolution
  - Plan is to migrate all daily cronjobs to v11 in near future; will be available on MiRS website.
- Algorithm is ready for integration at OSPO. Official DAP delivery planned September 2014.

- Introduction
  - Background, Objectives, Plan
- DAP 11.0 Highlights
  - High-Resolution Processing
  - Science Improvements
  - Requirements
- Algorithm Readiness
  - Algorithm Description: Mathematical Basis, Process Flow, Internal Interfaces
  - Algorithm/Science Improvements : a priori background mean, CRTM 2.1.1
  - Algorithm Test Results: Product Assessment, MiRS STAR IT requirements
- **RISKS/ACTIONS**
- Summary and Conclusions
- Discussion

Section 4 –
Risks and Actions

Presented by

C. Grassotti

SRR Risks

- **Risk #1:** CRTM 2.1.1 Computation time exceeds operational requirements for F17 high-resolution
  - **Risk Likelihood:** Low
  - **Risk Impact:** High.
  - **Risk Mitigation:** 1) Working actively with CRTM team on code mods for a speedup, 2) For F17, implement HR, alternate option to reduce processing time by ~50%
  - **Status:** CLOSED (STAR), OPEN (OSPO)

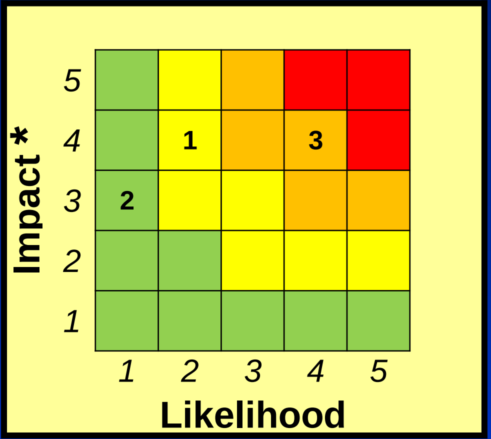
- **Risk #2:** Increased memory requirements exceeds operational resources
  - **Risk Likelihood:** Very Low
  - **Risk Impact:** Moderate
  - **Risk Mitigation:** Increase machine memory, or number of servers (requires OSPO effort)
  - **Status:** CLOSED (STAR), OPEN (OSPO)

SRR Risks

- **Risk #3: Delayed Operational Implementation Schedule due to OSPO SMOMS Contract Transition**
  - » **Risk Likelihood:** High
  - » **Risk Impact:** High
  - » **Risk Mitigation:** TBS – currently no contract support resource provided for the MiRS high resolution products implementation. The schedule is pending for SMOMS contract support resource allocation that is uncertain at this point.
  - » **Status:** OPEN (OSPO)

MiRS SRR Risk Summary

Risk No. (Rank)	Risk	*Risk Likelihood*	*Risk Impact*	*Risk Index*
1	CRTM 2.1.1 computation time	2	4	8
2	MiRS increased memory requirement	1	3	3
3	Delayed Operational Implementation Schedule due to OSPO SMOMS Contract Transition	4	4	16



***Risk Impact may be on schedule, cost, and/or science product quality and availability.**

Risk Level		*Likelihood*
1	Very Low	P < 10%
2	Low	10% ≤ P < 30%
3	Moderate	30% ≤ P < 70%
4	High	70% ≤ P < 90%
5	Very High	P ≥ 90%

Risk Impact		*Description*
1	Very Low	Negligible
2	Low	Minor
3	Moderate	Major
4	High	Critical
5	Very High	Catastrophic

Review Items Summary

- 3 SRR Risk Items were identified

- Introduction
  - Background, Objectives, Plan
- DAP 11.0 Highlights
  - High-Resolution Processing
  - Science Improvements
  - Requirements
- Algorithm Readiness
  - Algorithm Description: Mathematical Basis, Process Flow, Internal Interfaces
  - Algorithm/Science Improvements : a priori background mean, CRTM 2.1.1
  - Algorithm Test Results: Product Assessment, MiRS STAR IT requirements
- Risks/Actions
- **SUMMARY AND CONCLUSIONS**
- Discussion

Section 5
Summary and Conclusions

Presented by

C. Grassotti

Summary and Conclusions

- Following have been reviewed:
  - » Entry/Exit Criteria
  - » Highlights of the new MiRS version 11.0 (high-res, F17, science improvements)
  - » Algorithm Readiness
  - » Risks and Actions
- Based on all testing and integration results:
  - » **MIRS high-resolution processing ready for operations** (pending response to any Action Items from SRR)

Next Steps

- Prepare SRR/ARR Report (including action items)
- Update Documentation following SPSRB Guidelines
- Build MiRS DAP (e.g. documentation, software, test data)
- Address action items identified in SRR

- Introduction
  - » Background, Objectives, Plan
- DAP 11.0 Highlights
  - » High-Resolution Processing
  - » Science Improvements
  - » Requirements
- Algorithm Readiness
  - » Algorithm Description: Mathematical Basis, Process Flow, Internal Interfaces
  - » Algorithm/Science Improvements : a priori background mean, CRTM 2.1.1
  - » Algorithm Test Results: Product Assessment, MiRS STAR IT requirements
- Risks/Actions
- Summary and Conclusions
- **DISCUSSION**

Open Discussion

- The review is now open for discussion

Action Items

- The following slides contain action items and associated responses that were generated during and after the review. Each response, along with support material, was sent to the author of the action item for feedback and with the agreement of the author, the item was closed.

SRR for MiRS HR for AMSUA/MHS, SSMIS Action Items

Action Item	Description	Responder(s)	Status
1	Discussion of Beam Filling for RR in AMSUA/MHS	C. Smith	Closed
2	Use of Independent Reference Data for Performance Assessment	T. Islam	Closed
3	Show performance of FNMOC/NRL RR Algorithm and compare with MiRS	T. Islam	Open
4	Provide information/documentation on CRTM 2.1.1	C. Grassotti	Closed
5	Impact of Dynamic Background in Anomalous Weather Events	C. Grassotti	Closed

Action Item # 1: Discussion of Beam Filling for RR in AMSUA/MHS (1)

Submitted by: A.K. Sharma

Description: Discussion of the beam filling problem for RR should have been included. There should be some analysis for AMSUA vs. MHS FOVs in terms of beam filling aspect.

Responder: C. Smith

Response: The beam filling effect occurs when the FOV is not filled with a uniform rain rate (including cases where rain is present over only a fraction of the FOV). Due to the non-linear dependence of measured TBs on rain rate (RR), this results in a systematic bias in the measured rain rate (through retrieval). For retrievals using only low frequency channels and moderate rain rates (no scattering), the bias is negative, i.e. the retrieval is an underestimation of the true average rain rate over the FOV (computed as the average of the true RR over the FOV, weighted by the effective antenna pattern of the FOV). However, for higher rain rates or retrievals using 89-183 GHz channels (scattering present), the rain rate bias can be positive or negative (see final slide).The assumptions and methods necessary for a theoretical treatment of the beam-filling effect, and their drawbacks, are discussed over the following 3 slides. Further difficulties would be involved in performing an empirical analysis using MiRS data, including the changes in relative FOV shapes and sizes across scan, differences in AMSUA and MHS FOV sizes and centroid locations, and effects of cloud 3-d geometry given cross-track scanning.

The primary conclusion is that with respect to MiRS, the beam filling effect is just one important component of the overall RR retrieval error budget. The best assessment of the overall impact of transitioning the algorithm from low to high resolution, and of using both AMSUA and MHS measurements simultaneously is via the performance statistics obtained by collocating MiRS RR with other high-quality ground and satellite-based references such as radar-gauge Stage IV, TRMM 2A12, etc.

Status: CLOSED

Action Item # 1: Discussion of Beam Filling for RR in AMSUA/MHS (2)

In order to estimate the magnitude of the beam filling effect, one needs to assume:

(1) A simplified functional form of the dependence of brightness temperature (TB) on rain rate. This dependence is different for lower frequency channels (≤37 GHz)--where scattering does not occur for moderate rain rates (TB increases with rain)--and for higher frequency channels (89-183 GHz), where scattering can occur, and the TB dependence can be increasing or decreasing with RR. (The one-to-one relationship between TB and RR at low frequencies does not exist at high frequencies). Furthermore, the coefficients of these functional forms are highly dependent upon polarization, and frequency of the channels. Heuristic diagrams are shown in slide 4.

(2) A functional form for the effective antenna pattern of the FOV.

(3) A functional or statistical form for the fraction of the FOV containing rain rates between R and R+dR, including the contribution of zero rain areas to the FOV.

For an ensemble of rainy scenes simulated using(3): one can compute the TBs at grid points over the FOV using (1), obtain the FOV TB by integrating gridded TBs over the FOV using (2), and then use the inverse of the relationship in (1) on the FOV TB to obtain an estimate of the “effective”” (retrieved) rain rate, R_E.

- » This is then compared to the average RR over the FOV, R_{avg} obtained by integrating the RR in the simulated scene over the effective antenna pattern.
- » See for example, C.E Graves, Journal of Atmospheric and Oceanic Technology, Feb 1993
  - – $R_E \leq R_{avg}$ for low frequency channels (equality holding only when the rain rate is uniform)

Action Item # 1: Discussion of Beam Filling for RR in AMSUA/MHS (3)

However, this theoretical treatment is exceptionally difficult to formulate, and unlikely to yield realistic results, for MIRS retrievals, for the following reasons:

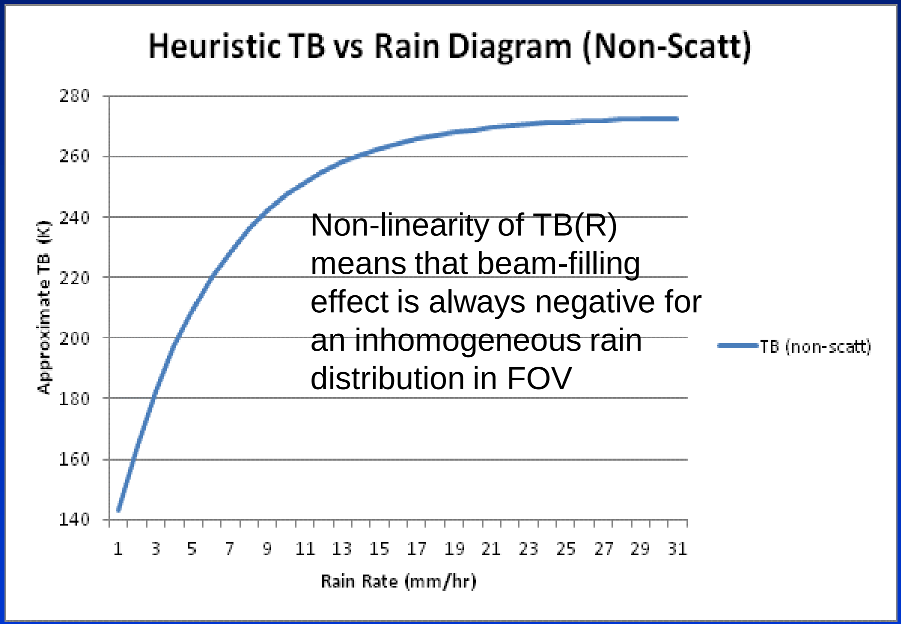
(a) The method just described assumes a single channel rain rate retrieval, although it has been applied to estimate the beam-filling effect for retrievals where a single channel dominates in sensitivity to rain. However, MIRS is a unified retrieval, i.e. uses all AMSU (23.8-89 GHz) channels and MHS 157-190 GHz channels simultaneously, to retrieve temperature, ice and rain water profiles, plus surface emissivity and temperature simultaneously. One could perform the theoretical analysis to obtain and estimate of R_E for each channel separately (one would first need to derive coefficients in (1) for each channel sensitive to rain), and then compute a weighted average of the R_E's across the channel set to derive a final R_E. But then it is unclear what weighting to use when combining the R_E results.

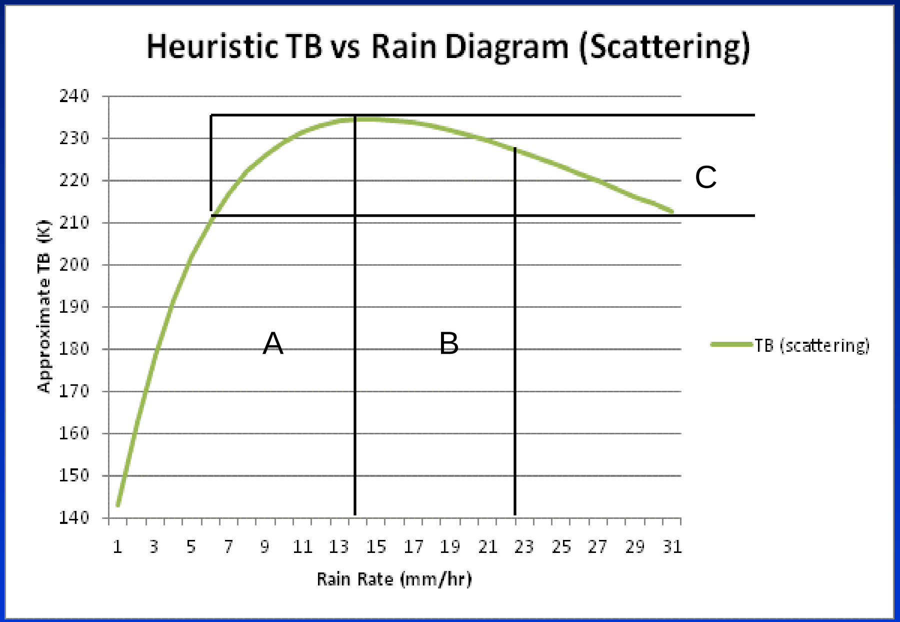
(b) MIRS does not actually retrieve rain rate directly. It retrieves cloud or ice and rain water profiles. In a post processing step, these are integrated to yield CLWP or IWP and RWP, which are then used in an MM5 derived non-linear relationship to compute rain rate. Therefore, the final retrieved rain rate will contain an additional uncertainty (and possible bias) due to the use of a NWP-derived hydrometeor-to-rain rate relationship, valid at the scale of the NWP model resolution.

(c) In the case of AMUS/MHS high resolution, there are two FOVs with considerably different (factor of 3) spatial extents, and the relative positions of the centroids of the 9 MHS footprints relative to the AMSU footprint involves 3 separate cases (center, side, diagonal).

(d) AMSU/MHS are <u>cross-track scanners</u>. While a non-scattering form of the TB(R) equation might be applicable for many channels at nadir, as one goes further out in the scan (to higher incidence angles) it is likely that there will be a cross-over to scattering for different channels at different points in the scan, for a given rain rate.

Action Item # 1: Discussion of Beam Filling for RR in AMSUA/MHS (4)





Region A (Low to Moderate Rain Rate): Bean Filling Effect yields negative bias on rain rate
Region B (Moderate to high rain rate): Beam Filling Effect yields small positive bias in rain rate
Region C (Low-moderate to very high rain rates): Inverse of TB(R) is multi-valued (unclear which solution to use in theoretical analysis without referring back to average of true rain rate over FOV

Action Item # 2: Use of Independent Reference Data for Retrieval Performance

Submitted by: A.K. Sharma

Description: Why were radiosonde data not used for comparison. The ECMWF data has already been used in the MiRS retrievals. For comparison purposes an independent source should be used.

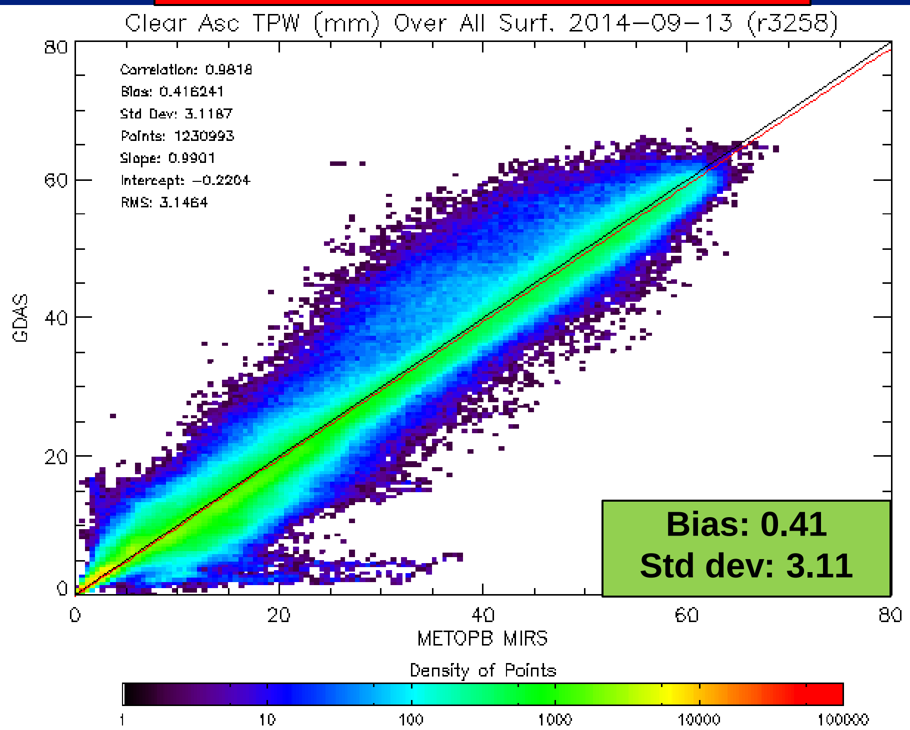
Responder: T. Islam

Response: Thanks for pointing out the matter. An effort is now made to demonstrate the retrieval performance using independent reference data. First three following slides demonstrate the MiRS sounding retrieval performance in comparison with GDAS independent analysis data (shown for MetopB example case). Similar to the comparison against ECMWF, as we have shown earlier, it is evident that MiRS v11 outperforms the v9 retrieval. In particular, the retrieval performance is now significantly improved in lower-troposphere. The next two following slides demonstrate the comparison against radiosonde data (prepared using few days NPP collocated data). Overall, MiRS v11 has a better retrieval behavior. We conclude that v11 is expected to perform well than v9.2. We will consider this Action Item closed unless we hear otherwise from the AI author.

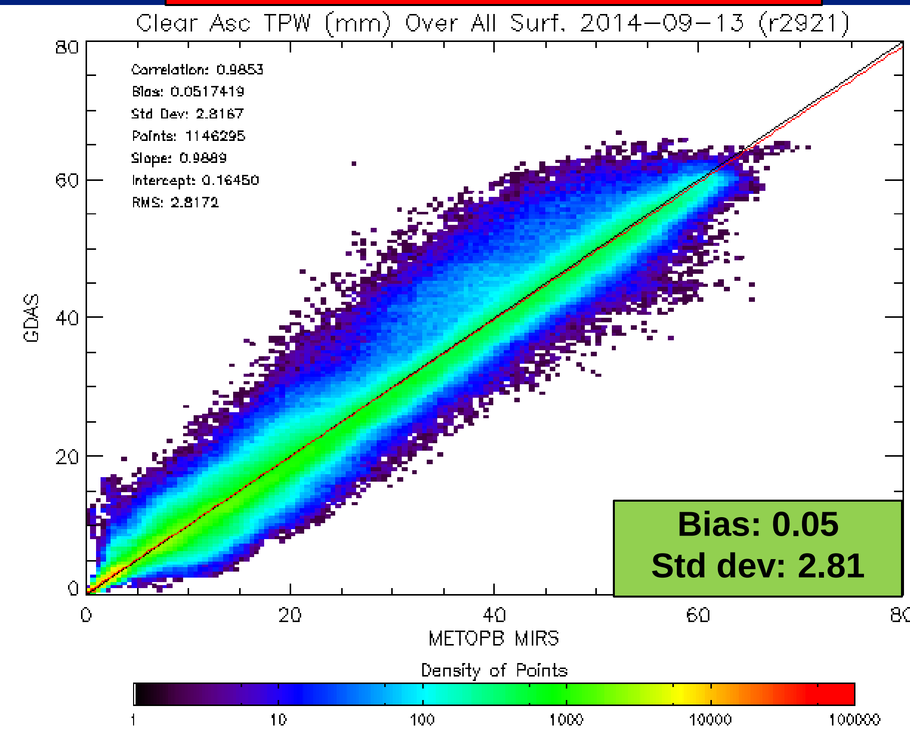
Status: CLOSED

Action Item # 2: Use of Independent Reference Data for Retrieval Performance (TPW performance against GDAS)

MiRS MetopB HR v9.2

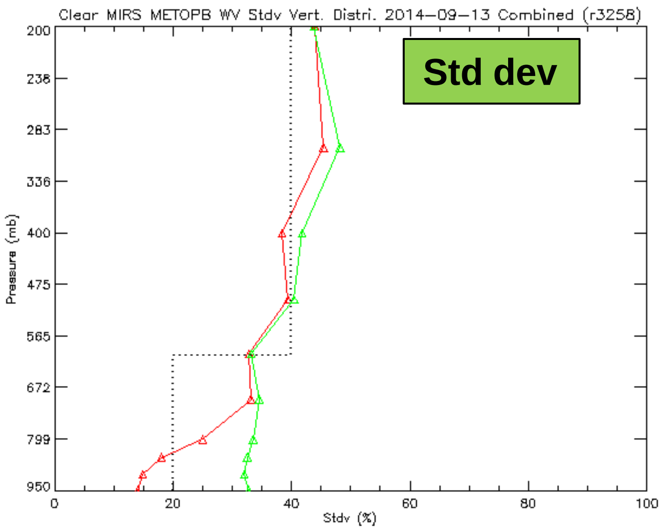


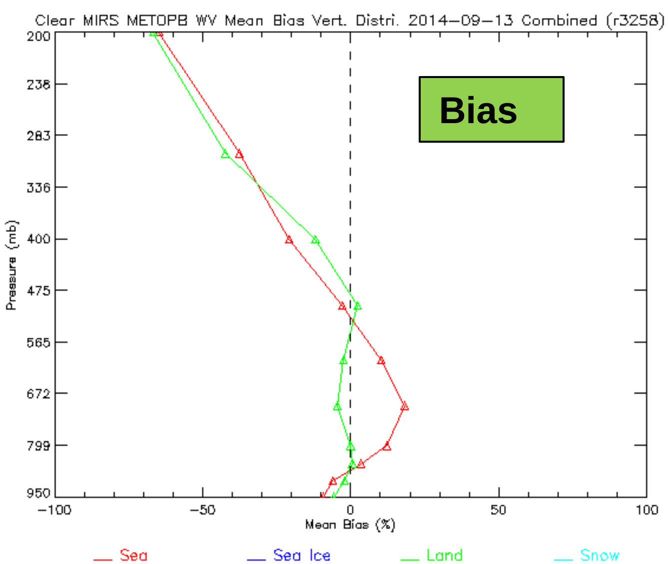
MiRS MetopB HR v11



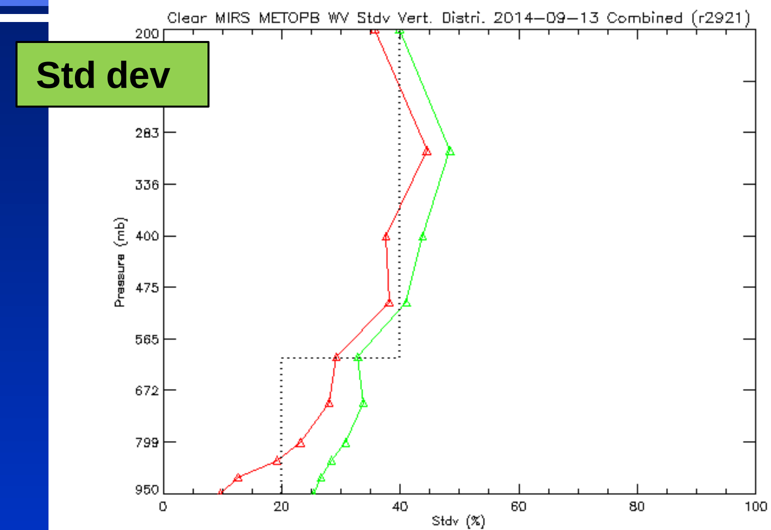
Action Item # 2: Use of Independent Reference Data for Retrieval Performance (Water vapor sounding performance against GDAS)

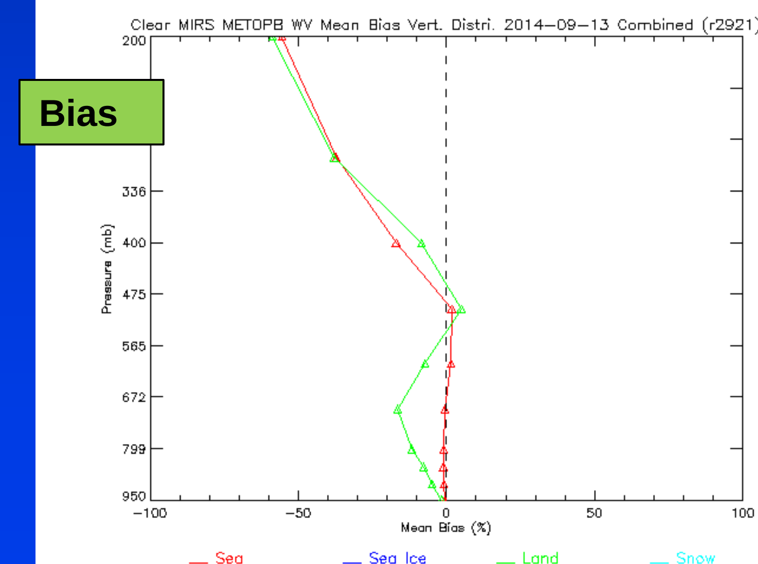
MiRS MetopB HR v9.2





MiRS MetopB HR v11

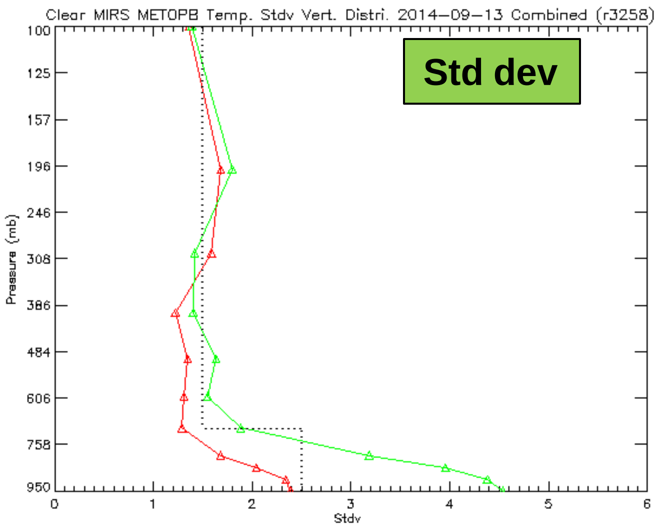


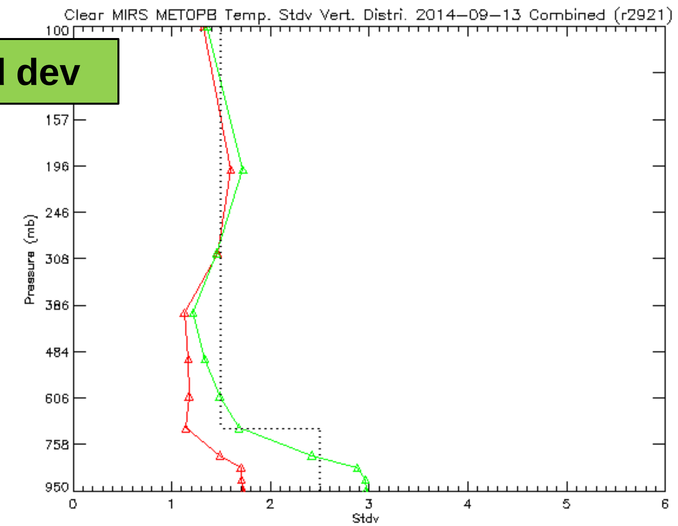


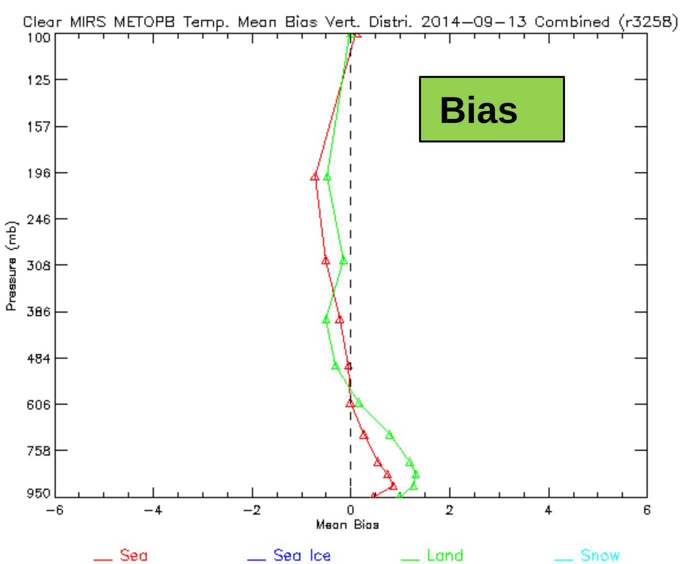
Action Item # 2: Use of Independent Reference Data for Retrieval Performance (Temperature sounding performance against GDAS)

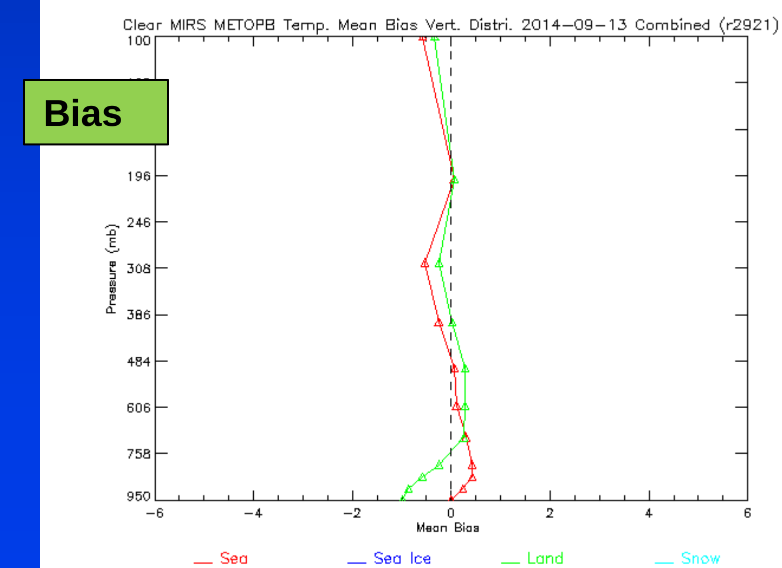
MiRS MetopB HR v9.2

MiRS MetopB HR v11





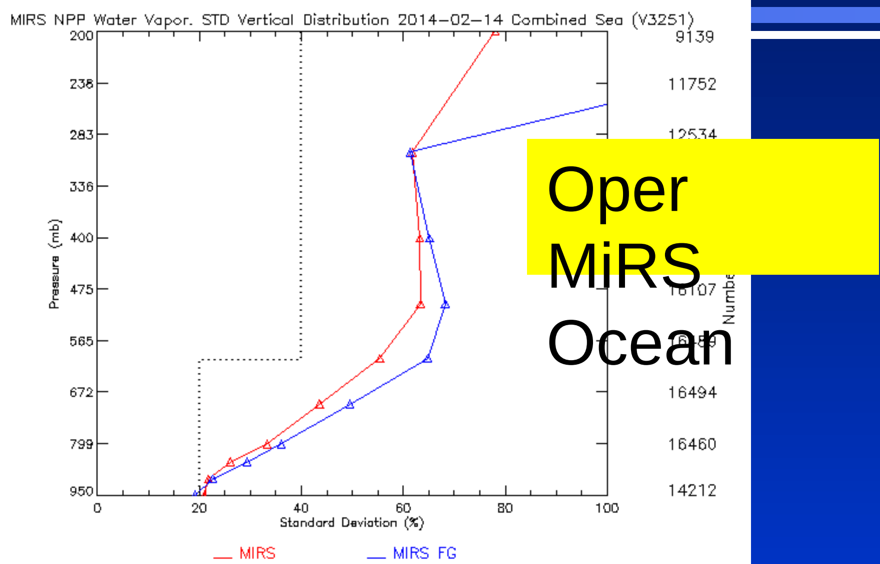


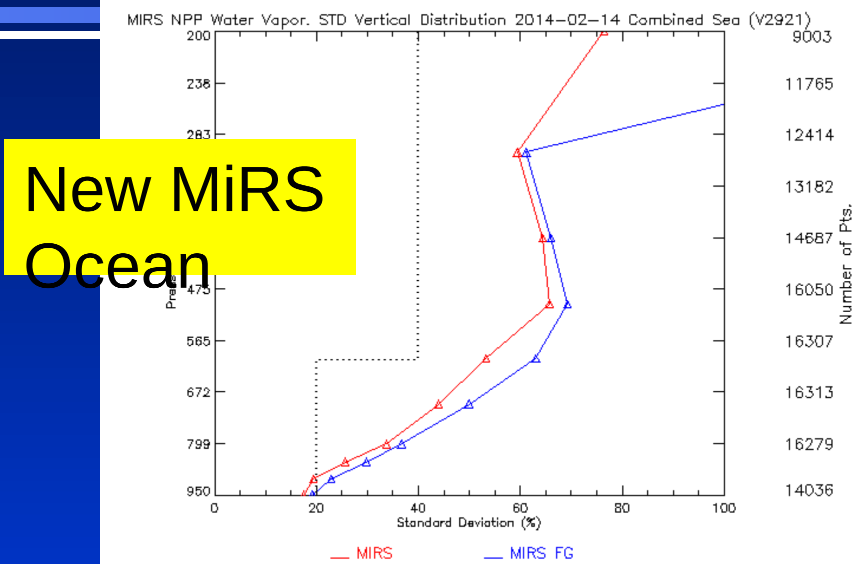


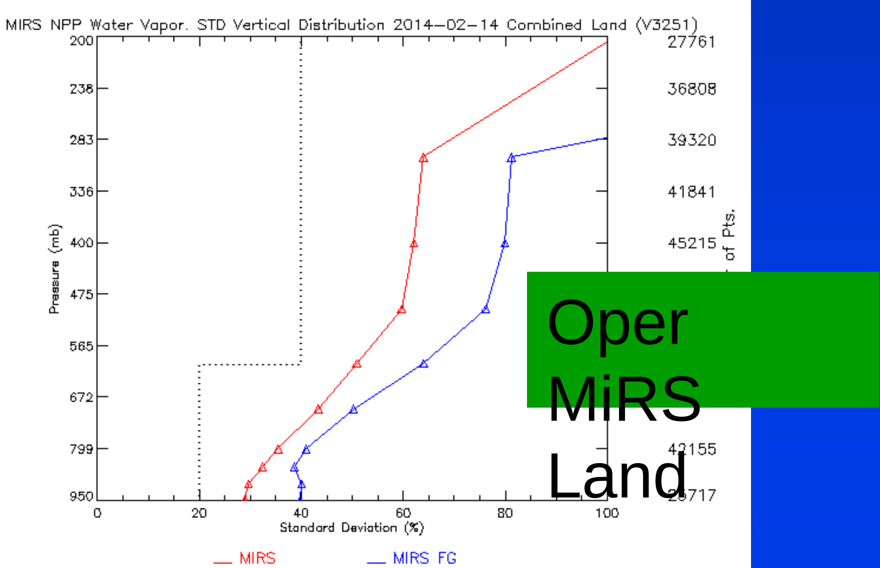
Action Item # 2: Use of Independent Reference Data for Retrieval Performance (Water vapor sounding performance against Radiosonde)

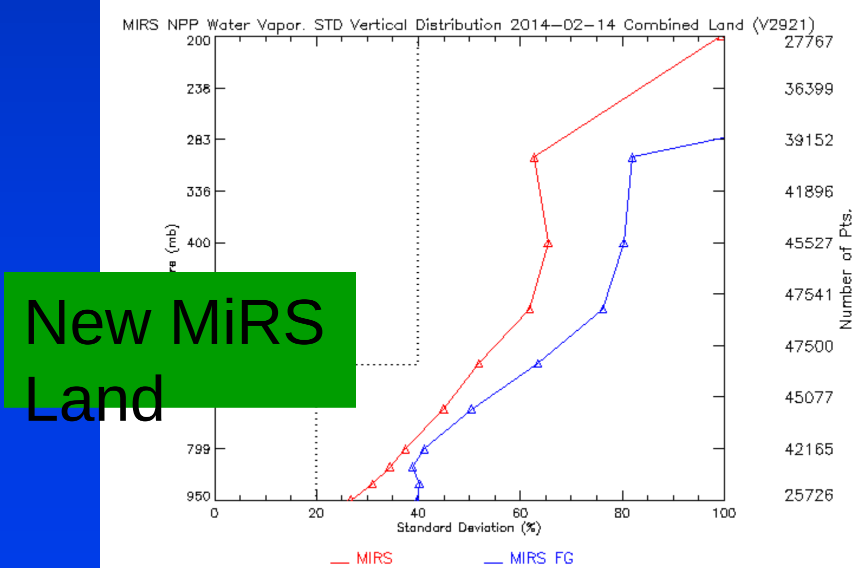
MiRS NPP HR v9.2

MiRS NPP HR v11



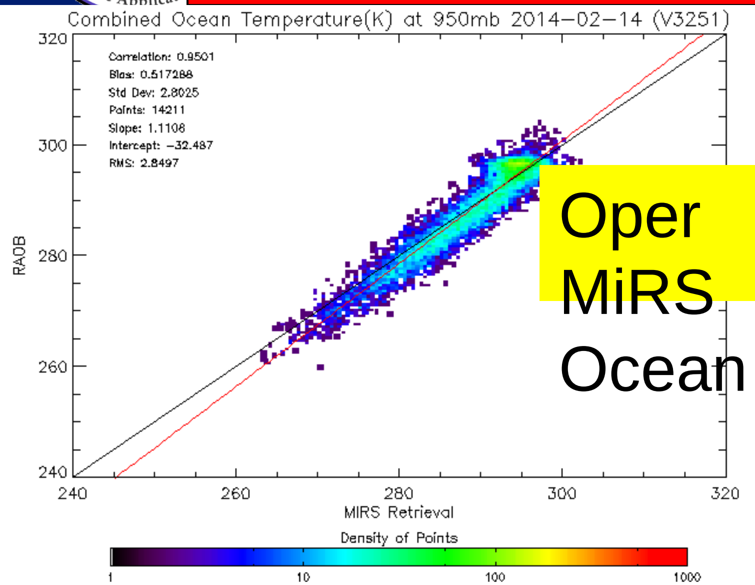






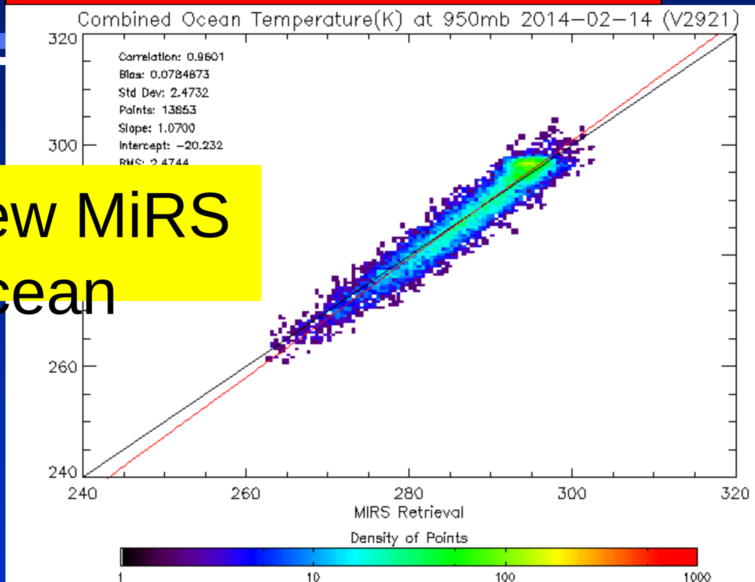
Action Item # 2: Use of Independent Reference Data for Retrieval Performance (Temp sounding performance against Radiosonde)

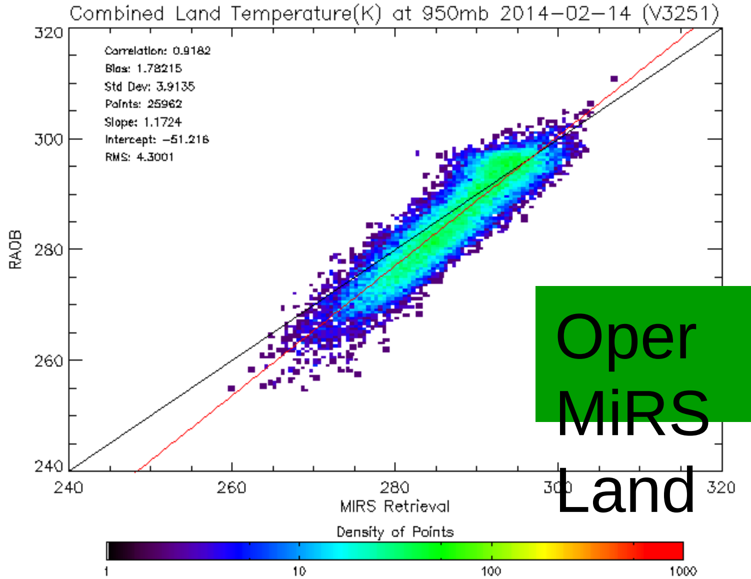
MiRS NPP HR v9.2 | **MiRS NPP HR v11**



Oper MiRS Ocean

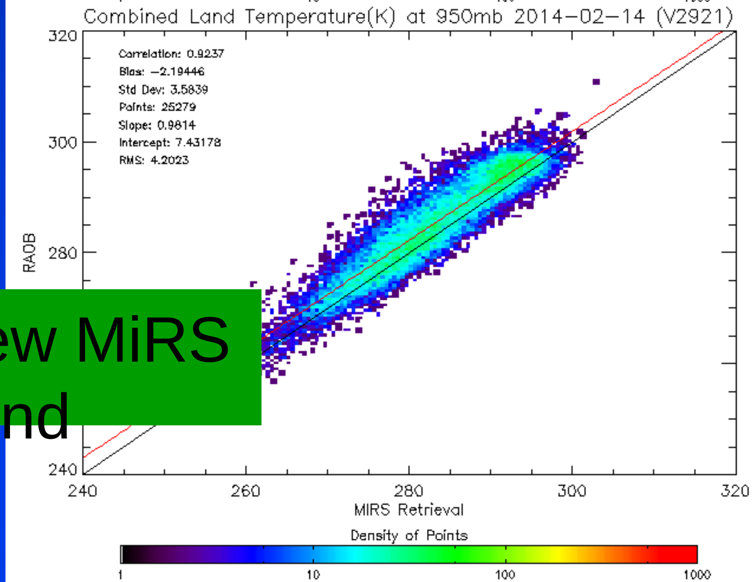
New MiRS Ocean





Oper MiRS Land

New MiRS Land



Action Item # 3: Show performance of FNMOC/NRL RR and TPW Algorithm and compare with MiRS

Submitted by: L. Zhao

Description: It would be very helpful to show a comparison between MiRS and FNMOC products quality (RR, TPW), and are looking better from MiRS. We need to demonstrate that the MiRS retrievals meet the requirements.

Responder: T. Islam

Response: TBD

Status: OPEN

Action Item # 4: Provide information/documentation on CRTM 2.1.1

Submitted by: R. Ferraro

Description: Could more information be provided on the accuracy of CRTM 2.1.1 scattering model? A publication or conference paper?

Responder: C. Grassotti

Response: The official website for CRTM releases and documentation is `http://ftp.emc.ncep.noaa.gov/jcsda/CRTM/` Additional information on the accuracy of CRTM, including the scattering processes is contained in an attached journal article by Y. Chen et al. (2008); doi:10.1029/2007JD009561. Comparisons of MHS based IWP and LWP with collocated CloudSat data showed good agreement.

Status: CLOSED

Action Item # 5: Impact of Dynamic Background in Anomalous Weather Events

Submitted by: R. Ferraro

Description: What is the impact of the dynamic background on anomalous weather events (e.g. polar vortex)? Are there any changes to convergence rate or accuracy?

Responder: C. Grassotti

Response: See following slides. A case from mid-winter 2014 with a significant polar vortex event was selected and retrievals from both operational (v9.2) and the new v11 versions of MiRS were examined. Results show that v11 retrievals are smoother, more horizontally consistent and generally show smaller differences with the ECMWF analysis. Additionally, chi-squared and number if iterations for v11 show smaller values than v9.2, indicating no difficulty in convergence with the new version of the algorithm. We conclude that v11 is expected to perform well in anomalous conditions, in part, due to the use of a spatially and temporally varying a priori background specification.

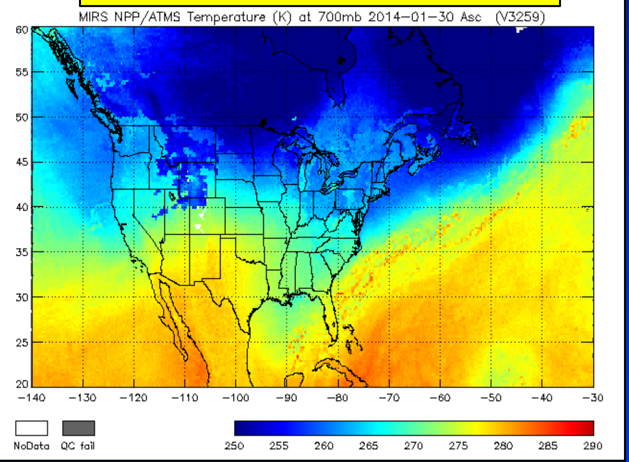
Status: CLOSED

MiRS High-Res Action Item # 5: Performance in Anomalous Conditions

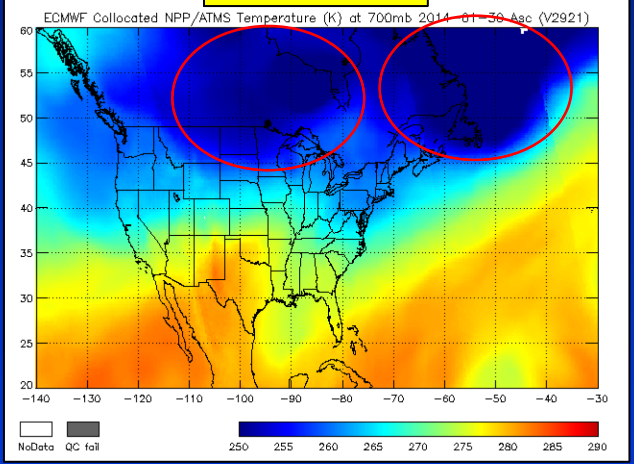
Polar Vortex Extension Located over Southern Canada

2014-01-30: T(700 hPa)

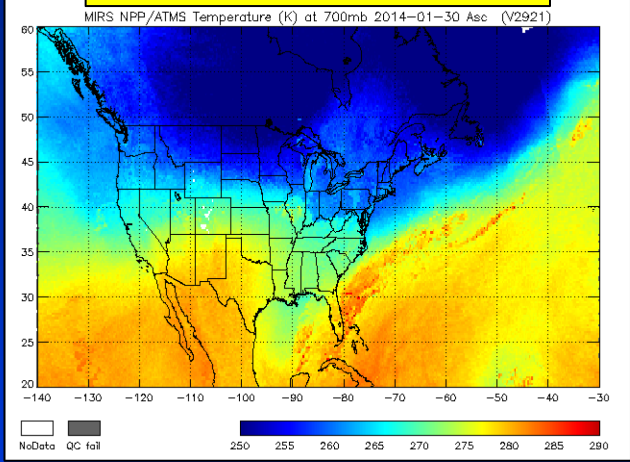
MiRS SNPP/ATMS v9.2

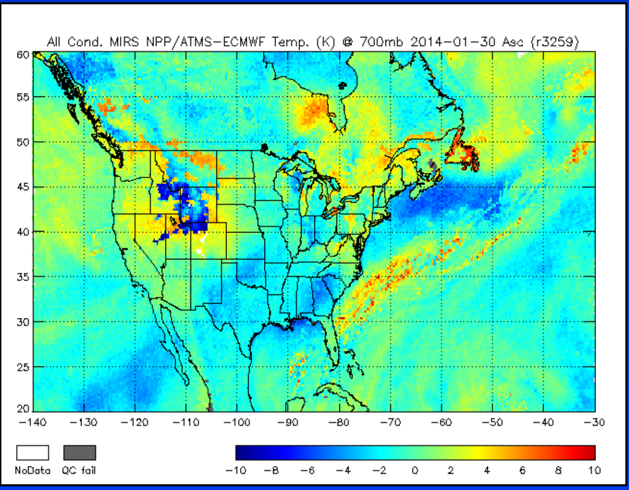


ECMWF

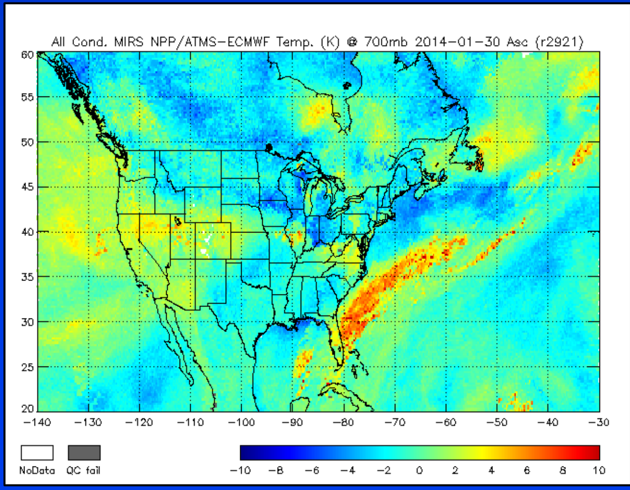


MiRS SNPP/ATMS v11



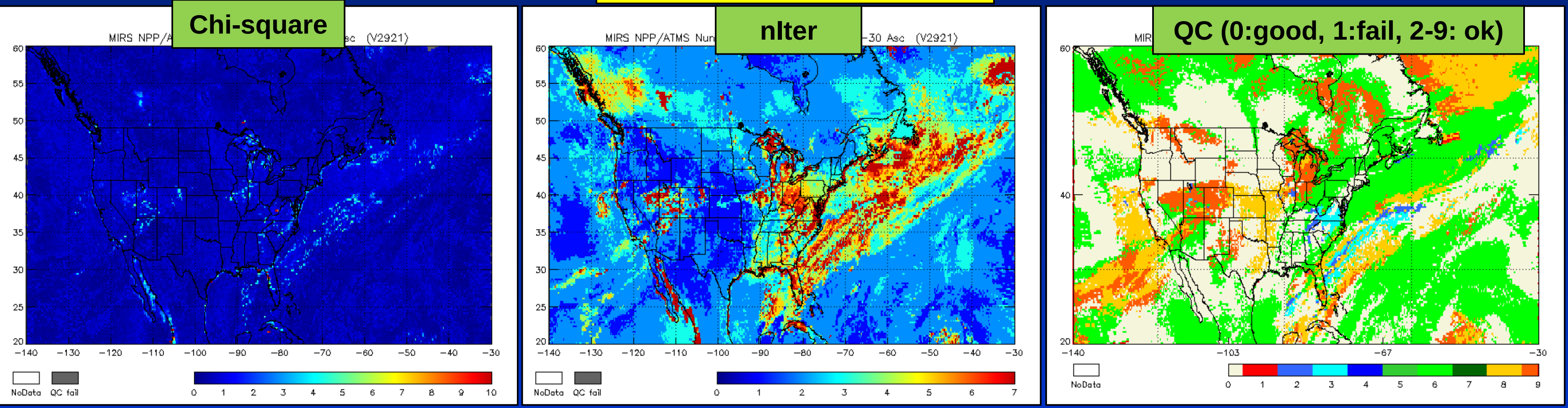


- MiRS v11 temperature field more horizontally consistent, smoother
- MiRS v11 differences with ECMWF are generally smaller than v9.2
- No evidence of polar vortex retrieval artifacts

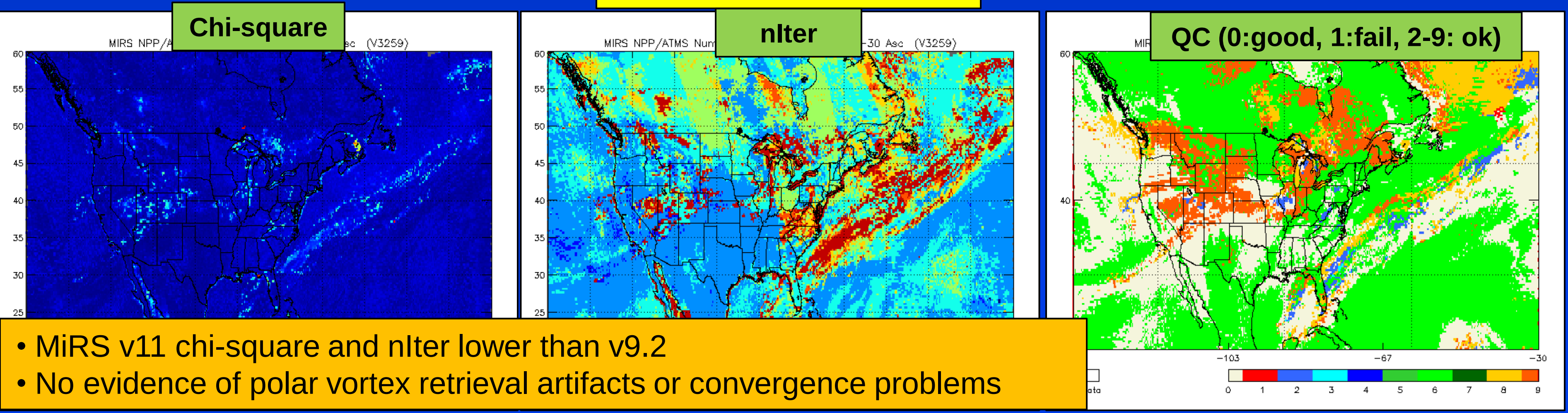


MiRS High-Res Action Item # 5: Performance in Anomalous Conditions

MiRS SNPP/ATMS v11



MiRS SNPP/ATMS v9.2



- MiRS v11 chi-square and nIter lower than v9.2
- No evidence of polar vortex retrieval artifacts or convergence problems

MiRS High-Res Action Item # 5: Performance in Anomalous Conditions

- Case from mid-winter 2014 with polar vortex (2014-01-30) shows that MiRS v11 produces smoother, more horizontally consistent T(700 hPa) retrievals. Other levels similar.
- Differences with ECMWF are generally smaller in v11, and the areas near polar vortex do not show significant warm bias in an anomalously cold situation (which would have been the case if there was a strong climatology influence in the retrieval).
- V11 shows smaller chi-square (fit to measurements), and generally fewer iterations than v9.2, indicating no convergence difficulty.

Back-up Slides

MIRS Future Science/Algorithm Improvements

- **Planned:**
  - » Sea ice age (early 2015)
  - » Snow grain size (early 2015)
  - » Snow fall rate (late 2014)
  - » Extension to GPM/GMI (2015)

- **Potential:**
  - » Updated HR footprint matching for AMSUA/MHS
  - » Air mass-based bias corrections
  - » Dynamic emissivity a priori background (spatio-temporally variable)
  - » Precipitation regime-based hydrometeor background
  - » A priori atmospheric background for precipitating conditions
  - » Variable hydrometeor particle size
  - » Improved preclassification
  - » Increase tuning files (currently only 2: non-scattering and scattering scenes)

MiRS Processing Units

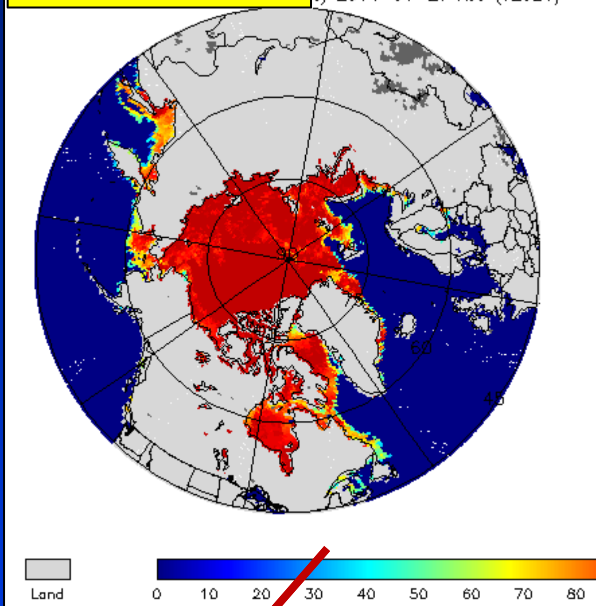
- Each major step in the MiRS processing is a stand-alone bash script and a corresponding Fortran 95 or C++ executable and namelist file and constitutes a Layer-2 Test Unit

Code Unit	Purpose	Ready
rdr2tdr	**Convert raw data records to temperature data records (decodes sensor-specific L1 data file) in MiRS format**	✓
tdr2sdr	**Convert temperature data record to sensor data record (TBs or radiances)**	✓
fm	**Footprint matching**	✓
chopp	**Chop fm files into sub-files (optional)**	✓
applyRegress	**First guess generation using TB-based regression (applied on fm files)**	✓
fmsdr2edr	**1dvar: converts footprint matched SDRs to EDRs**	✓
mergeEdr	**Merge EDR files into 1 file (optional)**	✓
vipp	**Postprocessing converts EDRs to derived environmental parameters (DEPs)**	✓
convertMirs2nc	**Converts files from MiRS binary to netCDF4**	✓

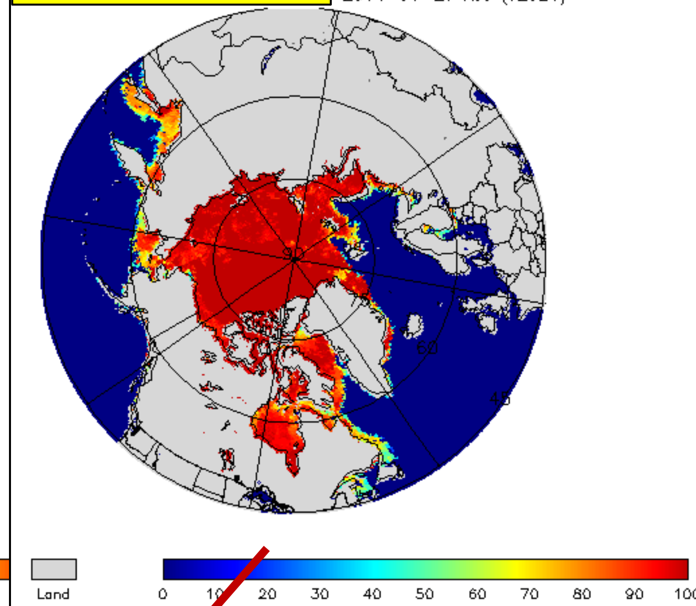
MiRS Sea Ice Concentration: Low vs. High Resolution

N18 LR and HR: 2014-01-27

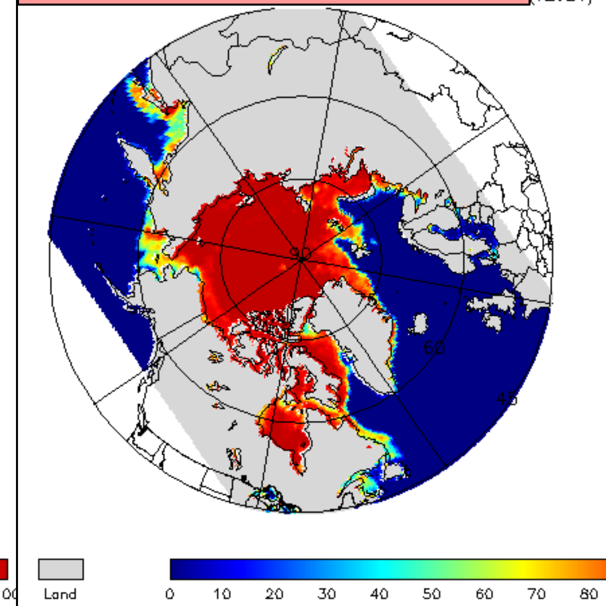
MIRS v11.0 LR



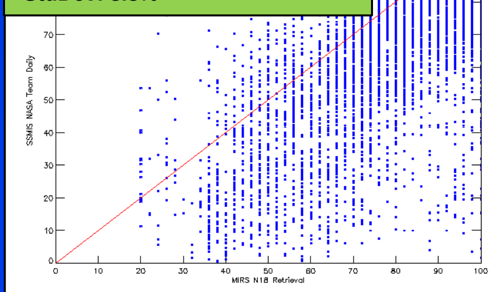
MIRS v11.0 HR



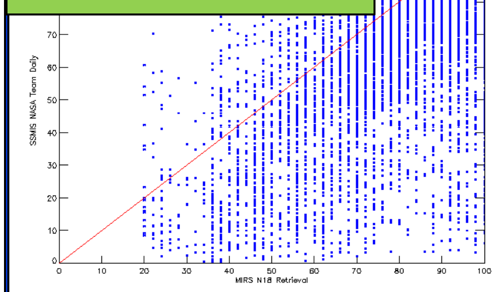
SSMIS NASA Team (F17)



Corr: 0.78
Bias (MIRS-NASA Team): 1.9%
StdDev: 8.8%



Corr: 0.75
Bias (MIRS-NASA Team): 2.4%
StdDev: 9.9%



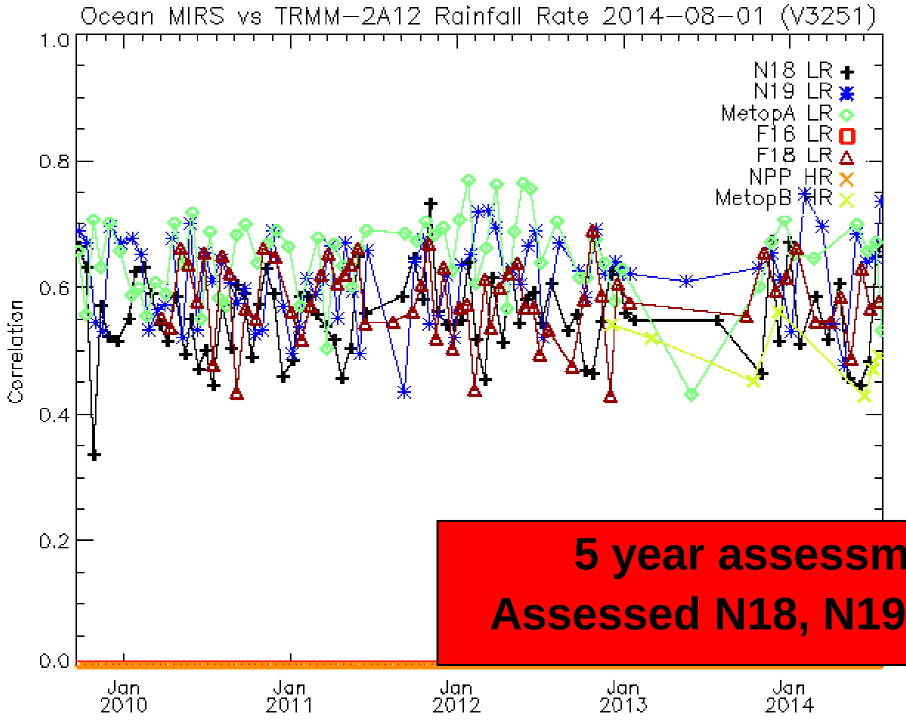
- v11.0 HR bias and std dev slightly larger than LR (expected due to mismatch of AMSU and MHS HR FOVs)
- Smoother transition at ice edge

Backup Slides

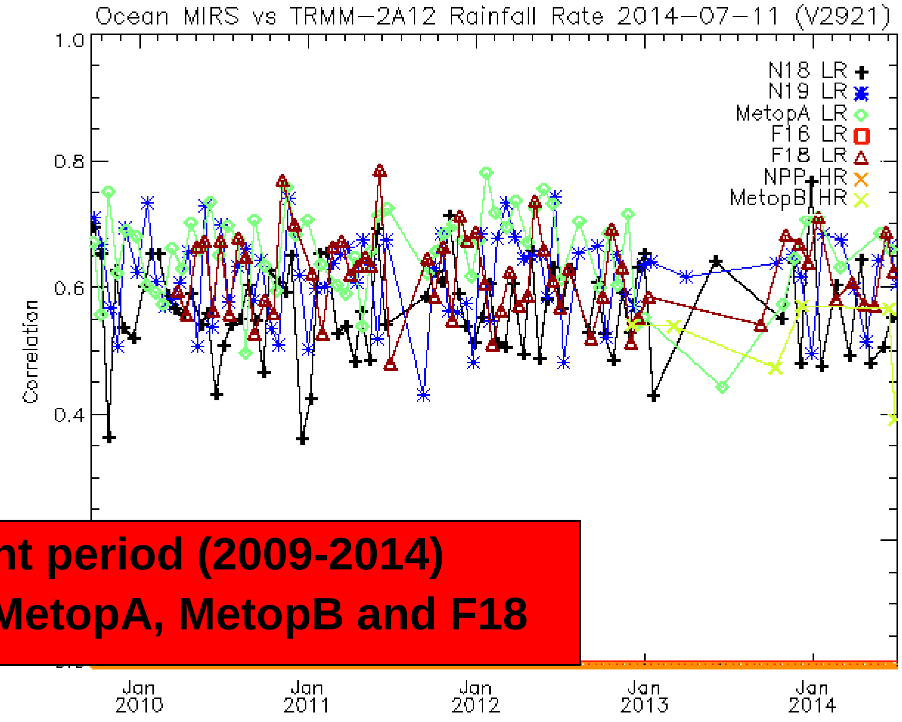
Hydrometeors

MiRS Product Assessments: Rain Rate (against TRMM 2A12)

MiRS v9.2



MiRS v11



5 year assessment period (2009-2014)
Assessed N18, N19, MetopA, MetopB and F18

- Time series of correlation coefficients from 2009-2014 (N18, N19, MetopA, MetopB and F18).
- Slightly higher correlation in v11

Backup Slides

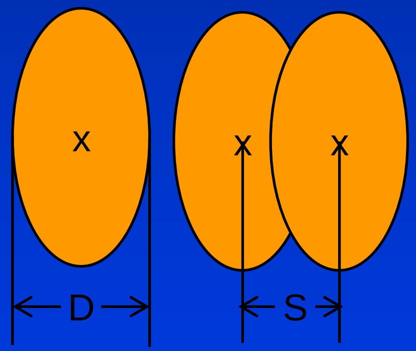
SSMIS Footprint Matching

Introduction to Footprint Matching

- Last generation of operational microwave sensors (e.g. SSMIS, AMSU-A/MHS) were not intended (or optimized) for simultaneous retrieval of all EDRs from the surface through multiple layers of the atmosphere
  - » Designed in the days when subsets of the full channel set were used separately to retrieve different types of EDRs
- Optimizing such "unified retrievals" requires the measurements, over the entire set of channels, to have (1) common centroid locations and (2) similar "footprint" sizes for each Field of View (FOV) at which retrievals are to be done
  - » Even when (1) is true, (2) is rarely fulfilled, for the "native observations"
    - – Factor of 10 range of frequencies implies large range of footprint sizes on the earth (size inversely proportional to frequency)
- Therefore "resampling" must be used to obtain measurements with a common centroid and similar resolution
  - » Generally this is not a problem for the lowest resolution—just average enough higher frequency measurements together so that the effective footprint on the ground matches the lowest resolution channels.
- The difficulty arises when one wants to obtain higher resolution retrievals
  - » FOVs that are more closely spaced, and of smaller footprints, than footprints for some of the channels

High Resolution Footprint Matching

- Accurate resampling to smaller footprint sizes and/or smaller FOV spacing requires both:
  1. Backus-Gilbert or other sophisticated resampling algorithms
     - Generally a large development/adaptation effort on the scale of retrieval algorithm work
  2. That the observations be at least Nyquist sampled on the ground
     - Often thought to be a sampling ratio of 2.0 (strictly true only for Gaussian antenna patterns)
     - Ruf (U. Mich) and I showed for NPOESS MIS that, due to high frequency components in realistic antenna patterns, a sampling ratio of 2.2-2.6 is required
       - Even then, one is limited in how much image enhancement one can do
- AMSU/MHS and SSMIS do not meet this second requirement
  - » They have sampling ratios close to 1.0 along-scan, rarely >2.0 along-track
- This severely limits the techniques for High-Res FM to:
  - » Averaging neighboring footprints (smallest footprints)
    - Useful if the FOV sampling interval is greater than the footprint size
      - We do this for 91-183 GHz
  - » Choosing nearest neighbors
    - Means that measurements from the largest footprints may be “reused” in several FOVs
      - This occurs out of necessity for both AMSU/MHS

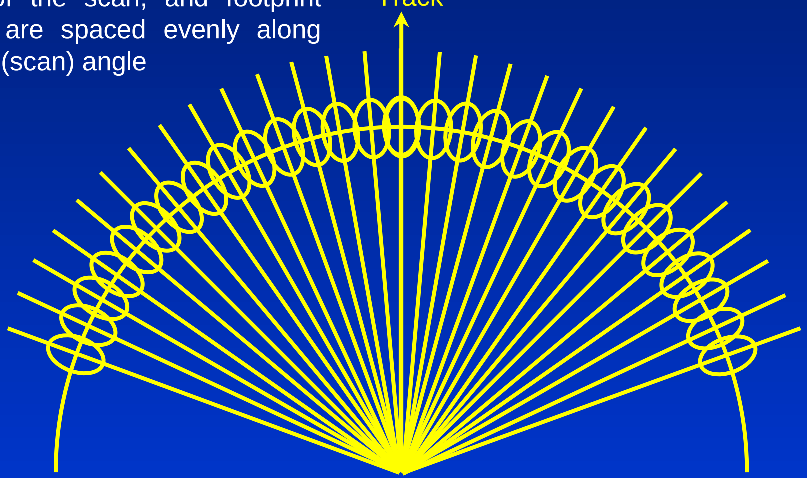


Sampling ratio = D/S

(Interpolating only increases effective footprint size)

Intro to SSMIS Scan Geometry: Conical Scanning

Footprint Orientation (long or “cross-scan” dimension) is aligned with the azimuth of the scan, and footprint centroids are spaced evenly along azimuthal (scan) angle



Four types of SSMIS Channels:
IMG—Imaging (91, 150 and 183 GHz)
ENV—Environmental (19, 23, and 37 GHz)
LAS—Lower Air Sounding (50-60 GHz)
UAS—Upper Air Sounding (60-63 GHz)

- SSMIS is a conical scanner
  - Footprints arranged on a circle on the earth (circle is slightly distorted by along-track motion)
  - Footprint sizes (IFOV) invariant over the scan (constant nadir & Earth incidence angles)
- All channels are sampled with a 4.22 ms integration time (0.8 deg=12.5 km along scan)
  - Starting at the same azimuth angle: footprints from different channel types are nearly co-centered
- <u>180 “basic beam positions” measured for all channels, footprints co-centered for all channels</u>
  - 179*0.8deg=143.2 deg active scan
  - First beam position at 143.2 deg / 2 = -71.6 deg, last beam position at +71.6 deg

Intro to SSMIS Scan Geometry: On-Board Averaging

- SSMIS does on-board averaging of measurements (along-scan only)
  - » To reduce NEDTs, but also to reduce the data rate to the ground
  - » Defines the spatial characteristics of the measurements as transmitted to ground
  - » Averaging begins at beginning of scan (basic beam position 1)
  - » <u>IMG channels undergo no averaging</u>—numbers show basic beam positions
  - » <u>ENV channels are averaged over 2 basic beam positions</u>
    - – Centroids are halfway between centroids of basic beam positions
  - » <u>LAS Channels are averaged over 3 basic beam positions</u>
    - – Centroids line up with IMG samples 2,5,8,etc
    - – Poor match with IMG (1,3), (4,6),… and ENV 2,5,8, …centroids
  - » <u>UAS channels are averaged over 6 basic beam positions</u>
    - – Poor match with 2/3 of IMG & ENV centroids and all LAS centroids

Pattern repeats every 6 basic beam positions

IMG	1		2		3		4		5		6		7		8		9		10		11		12	
ENV		1				2				3				4				5				6		
LAS			1						2						3						4			
UAS						1												2						

IMG	13		14		15		16		17		18		19		20		21		22		23		24	
ENV		7				8				9				10				11				12		
LAS			5						6						7						8			
UAS						3												4						

Schematic Diagram of on-board, along-scan averaging

Each cell represents 6.25 km along-scan (half of basic beam position spacing)

Zero is in the center of the first box on the left
Number in IMG row indicate basic beam position centroids
Extent of colors indicate averaging of native footprints, and not size of footprints
Placement of numbers in each row shows where the resulting centroids lie, along-scan

MIRS SSMIS Low Resolution Footprint Matching (current operational)

- Averages measurements within the along-scan space of the UAS on-board averaging
  - » For one FOV, average 6 IMG, 2 ENV, 3 LAS TDR measurements along-scan
  - » Equivalent to averaging 6 basic beam positions
  - » 30 FOVs/scan

IMG	1		2		3		4		5		6
ENV		1				2				3	
LAS			1						2		
UAS						1					

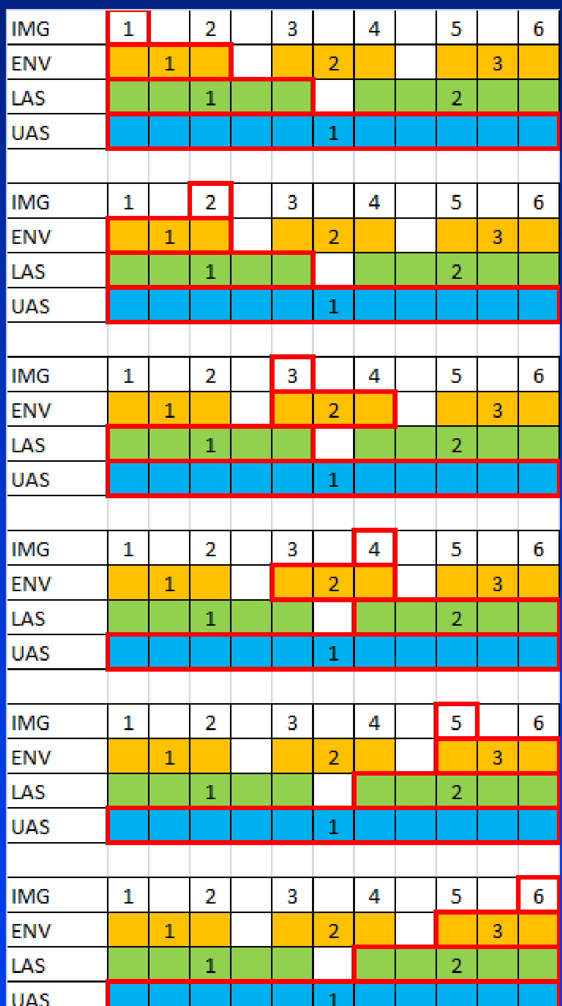
Is effectively a 6 x 6 average of basic beam positions

Red boxes indicate extent of averaging

- Then average 6 scans of the corresponding measurement to form one FOV
  - » Attempts to equalize the resolution of all IMG, ENV, LAS, and UAS channels

- Advantages we have had retrieving at this resolution:
  - » All IMG/ENV/LAS/UAS centroids are well matched
  - » All channels are fairly well-matched in footprint size: (outlier is ENV1)
    - – The more one averages along-scan and along-track, the more the 5 footprint sizes move closer to each other.
  - » Very low NEDTs
    - – Reduced by sqrt(36,12,18, 6) from on-board averaged IMG, ENV, LAS, UAS measurements

MIRS Highest Resolution ("IMG" or "Res 3")



- No footprint averaging along-scan or along-track
  - » To preserve the smallest possible footprint sizes
- Footprint matching consists entirely of selecting "nearest neighbors" for each IMG footprint (1-180)
  - » As shown in red highlighting in diagrams at left
  - » Along-scan and along-track FOV spacing is 12.5 km
  - » A single ENV, LAS, or UAS measurement is reused (replicated) in 2, 3, or 6 FOVs, respectively

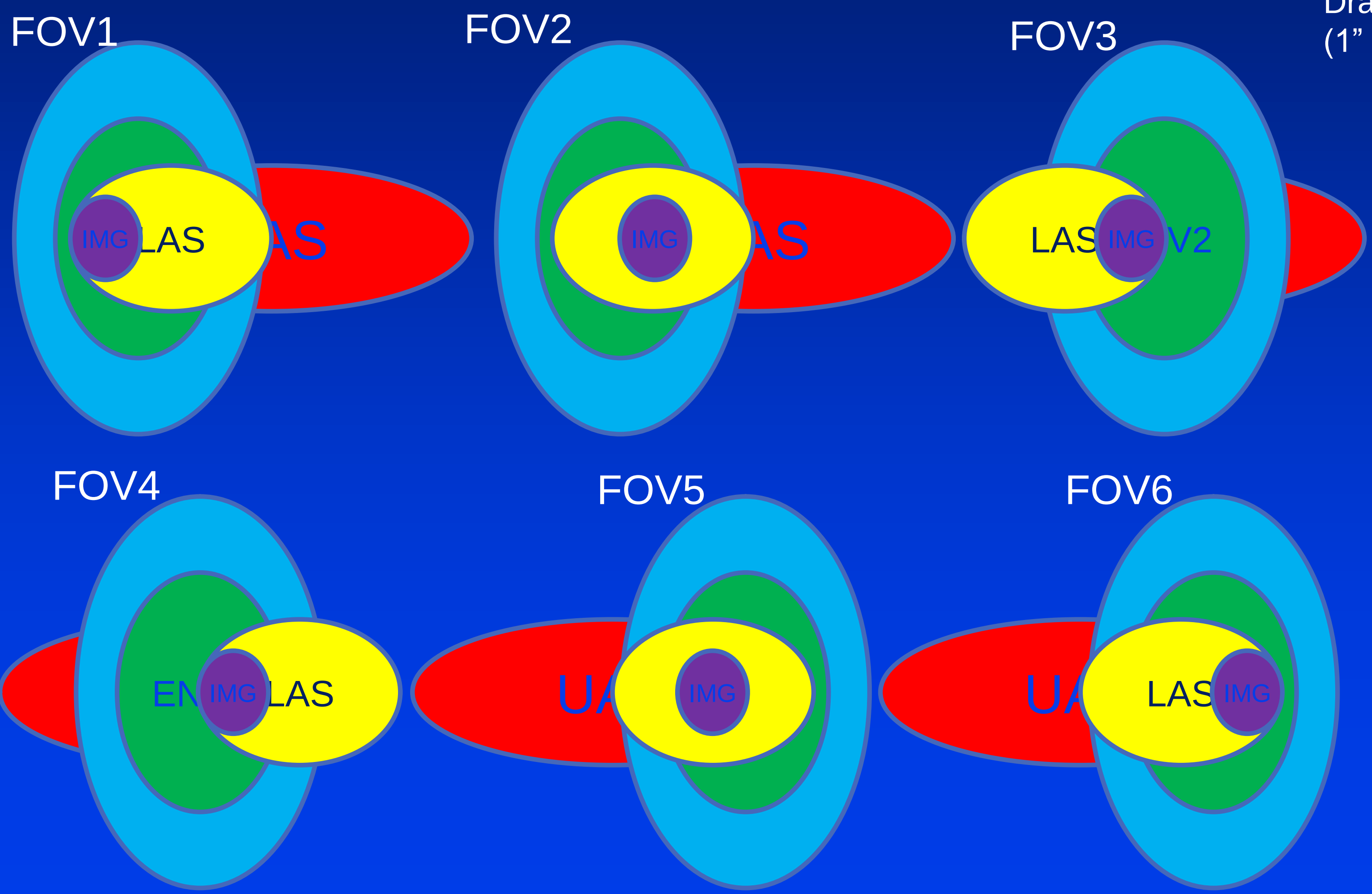
IMG measurements for FOVs 2+3n have excellent match with LAS centroids (0 km)

All other FOVs have a centroid mismatch of 12.5 km between IMG and LAS measurements

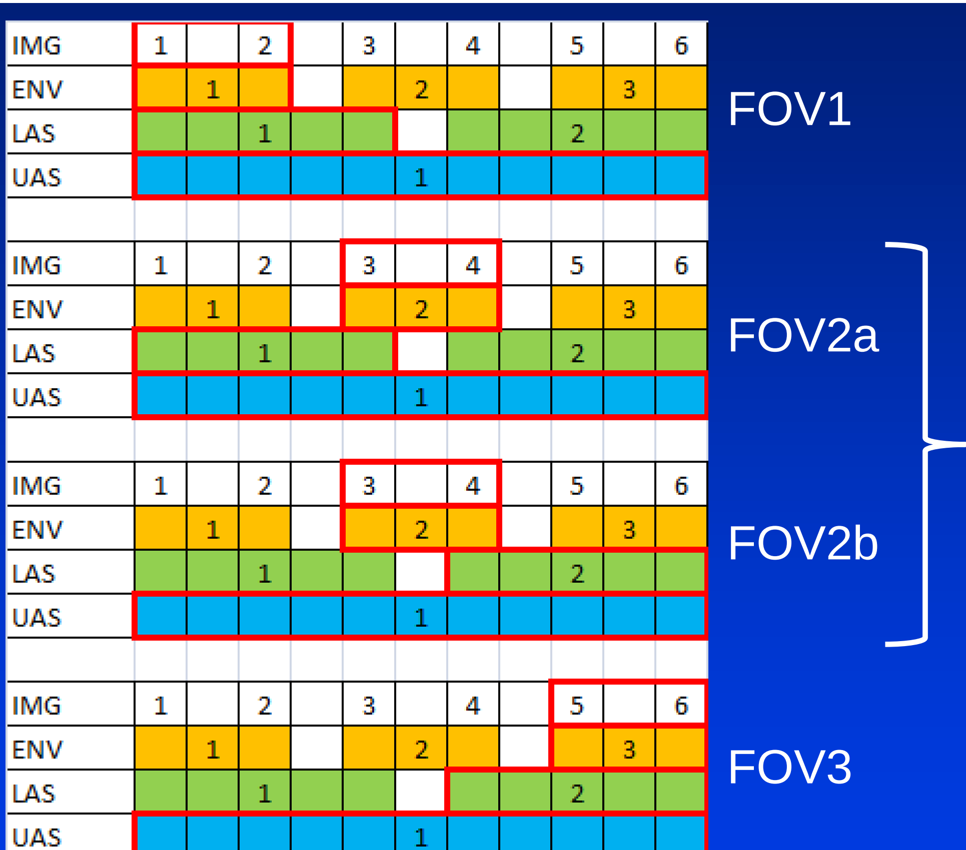
Note: UAS channels are not used in MIRS 1DVAR retrievals

MIRS Res 3 Footprint Matchup Within the 6 Different FOVs

Drawings are to scale
(1” = 31.25 km)



Res2 Option 1 Footprint Matching



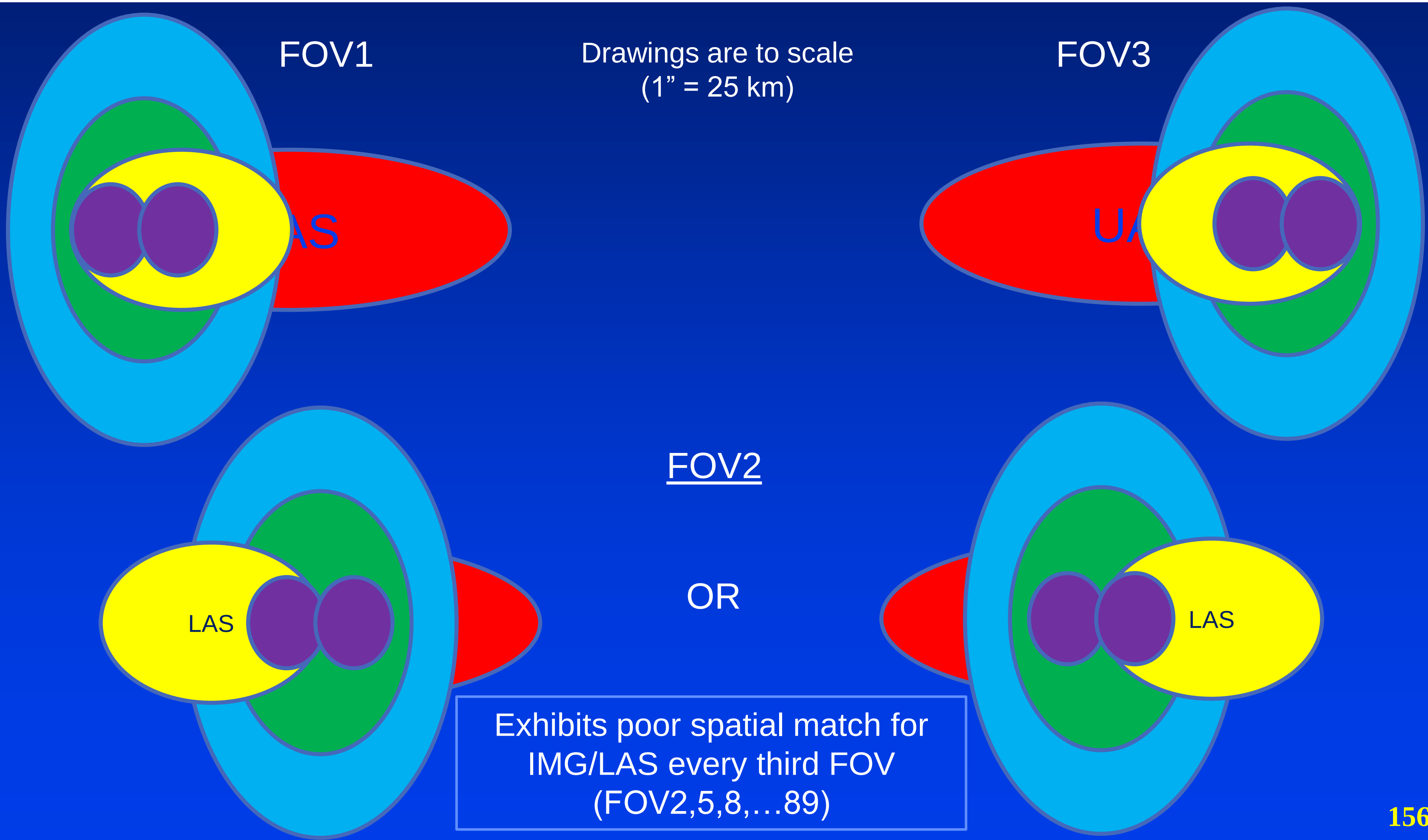
Two choices of match with LAS

FM Scheme:
Average 2 IMG, take nearest neighbor ENV/LAS/UAS.
No scan averaging.

- While this gives optimal matchup of IMG/ENV centroids, it
  - » Has a poor IMG/LAS centroid mismatch error of 18.75 km for FOV2 (1/3 of FOVs)
  - » Has a modest IMG/LAS centroid mismatch of 6.25 km for the other 2/3rds of FOVs

Res2 Option 1 Footprint Matchup

Drawings are to scale
(1” = 25 km)



Exhibits poor spatial match for IMG/LAS every third FOV (FOV2,5,8,…89)

Res 2 Option 2 Footprint Matching (Our Baseline Hi-Res Option)

- Because of the poor spatial match between IMG and LAS for FOVs numbered 2 + 3n, average 2 LAS footprints along-scan <u>only for these FOVs</u>

FOV1

IMG	1		2		3		4		5		6
ENV		1				2				3	
LAS			1						2		
UAS						1					

FOV2

IMG	1		2		3		4		5		6
ENV		1				2				3	
LAS			1						2		
UAS						1					

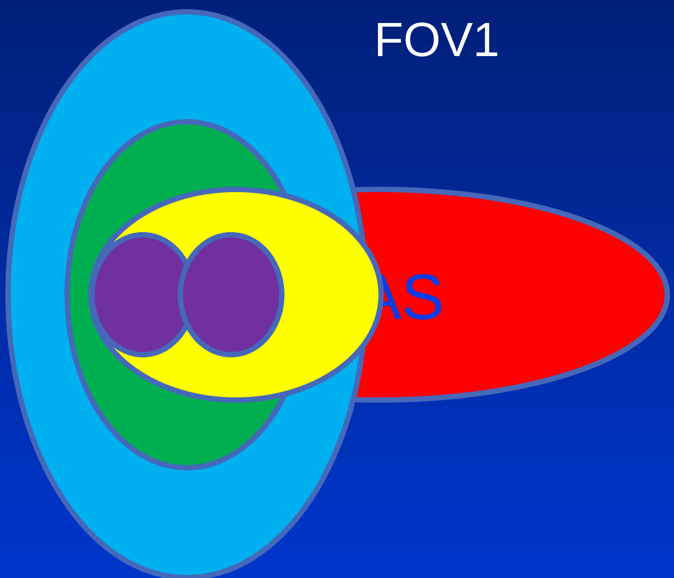
FOV3

IMG	1		2		3		4		5		6
ENV		1				2				3	
LAS			1						2		
UAS						1					

Matching Scheme:
Average 2 IMG, take nearest neighbor ENV/LAS/UAS—except for scan positions 2+3n (only then average 2 LAS).
No scans averaged.

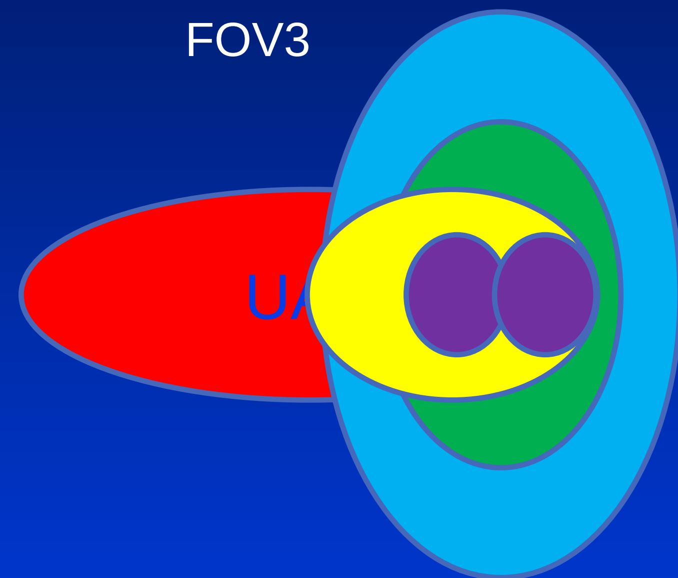
- The advantage is
  - Good spatial match for IMG/LAS over 2/3 of scan, while the other 1/3 has maximum overlapping IMG/LAS power
  - Any “blockishness” of Temperature Profile retrievals should be removed, and such retrievals for FOV2+3n should be close to the average of those for FOV1+3n and FOV3+3n

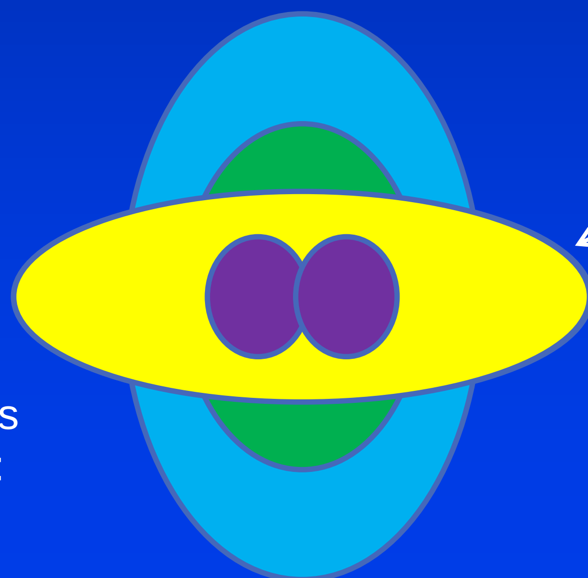
Hi-Res Baseline Footprint Matchup (Res2 Option 2, 90 FOVs/scan)



<u>Scheme</u>: Average 2 IMG, choose nearest neighbor single ENV/LAS/UAS

FOV Spacing:
25 km along-scan
12.5 km along-track





For every 3rd FOV, average two LAS to improve spatial match (maximum power) with IMG

No IMG/ENV/LAS measurements are replicated for different FOVs: no chance of “blocky” retrievals!

Drawings are to scale
(1” = 25 km)

AMSU-A and MHS Scan Geometry

	AMSU-A	Metop AMSU Nadir (km)	MHS	Metop MHS Nadir (km)
Footprint Size (3 dB)	3.3 deg	47.63 km (146.89 @ edge)	1.1 deg	15.88 km (52.83 @ edge)
Scene Spacing	3 1/3 deg	48.111 km	1 1/9 deg	16.037 km
Scan Positions	30		90	
Scan Angle Coverage	29 x 3 1/3 / 2 = 48.3333 deg	1026.31 km	89 x 1 1/9 / 2 = 49.4444 deg	1077.68 km
Total Angle Coverage (Incl IFOV)	48.3333 + 3.3/2 = 49.9833 deg	1026.31 + 146.89/2 = 1099.76 km	49.444 + 1.1/2 = 49.9944 deg	1077.68 + 52.83/2 = 1104.09 km
Scan Period	8.000 sec	52.68 km along track	8.000 / 3 sec	17.56 km along track
Delay relative to AMSU-A	0 scans		2 scans, synchronized with AMSU-A	

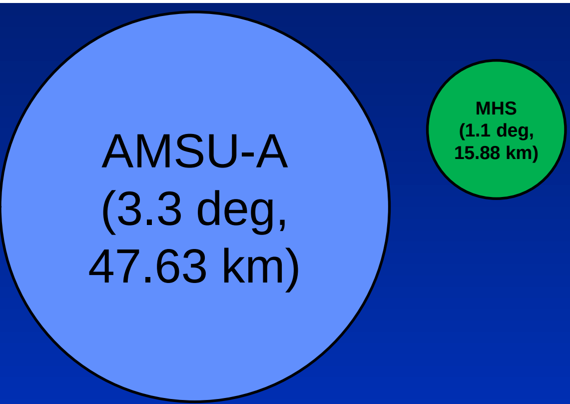
MHS footprint size and along-scan & along-track spacing is 1/3 of AMSU

Every third MHS scan line matches an AMSU Scan Line

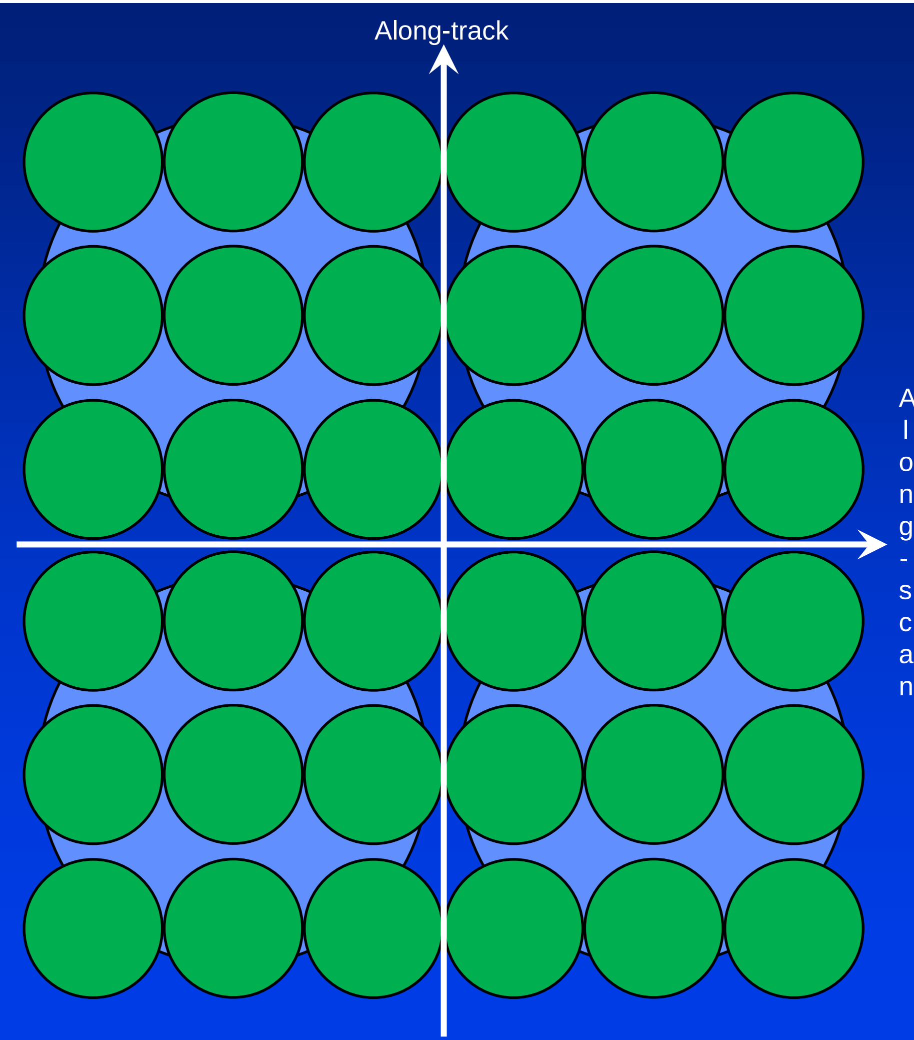
On those scan lines, every third MHS footprint is co-centered with an AMSU footprint

Data Obtained from EUMETSAT ATOVS Web page, http://oiswww.eumetsat.org/WEBOPS/eps-pg/ATOVS-L1/ATOVSL1-PG-4ProdOverview.htm

AMSU-A & MHS Scan Geometry



Diagrams are to scale at Nadir (22km = 1 inch)



- Geometry is shown at center of scan
    - Identical pattern is simply stretched in both dimensions away from the center of scan
- Every 3rd MHS scan line matches each AMSU scan line
- Pattern repeats 15 times on each side of scan, and indefinitely along-track
    - Relative arrangement and sizes of AMSU and MHS footprints does not change

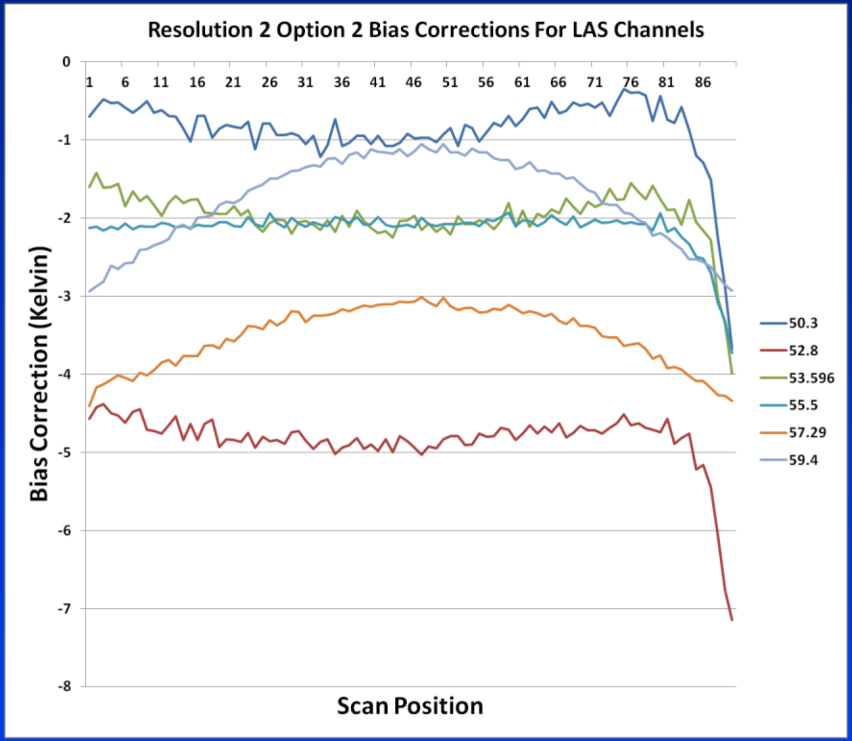
Backup Slides

F17 SSMIS Calibration Issues

F17 Calibration Anomalies: Dominant Stationary Effects

- Field of View Obstructions
  - » The feedhorns' view of the earth scene radiation reflected by the main reflector is occluded by:
    - – The shroud of warm load near the end of scan, and/or
    - – The edge of cold sky reflector near the beginning of scan
  - » Occluded view is replaced with a reflection of cold space temperature
  - » Is physically a multiplicative bias
    - – A fraction of the view is occluded
    - – But, can be modeled accurately with an additive bias if:
      - The obstructed fraction is not too large
      - The dynamic range of the TBs for that channel is small
- Sidelobes of the antenna pattern can also create bias variations throughout the scan
  - » As they view various features of the spacecraft

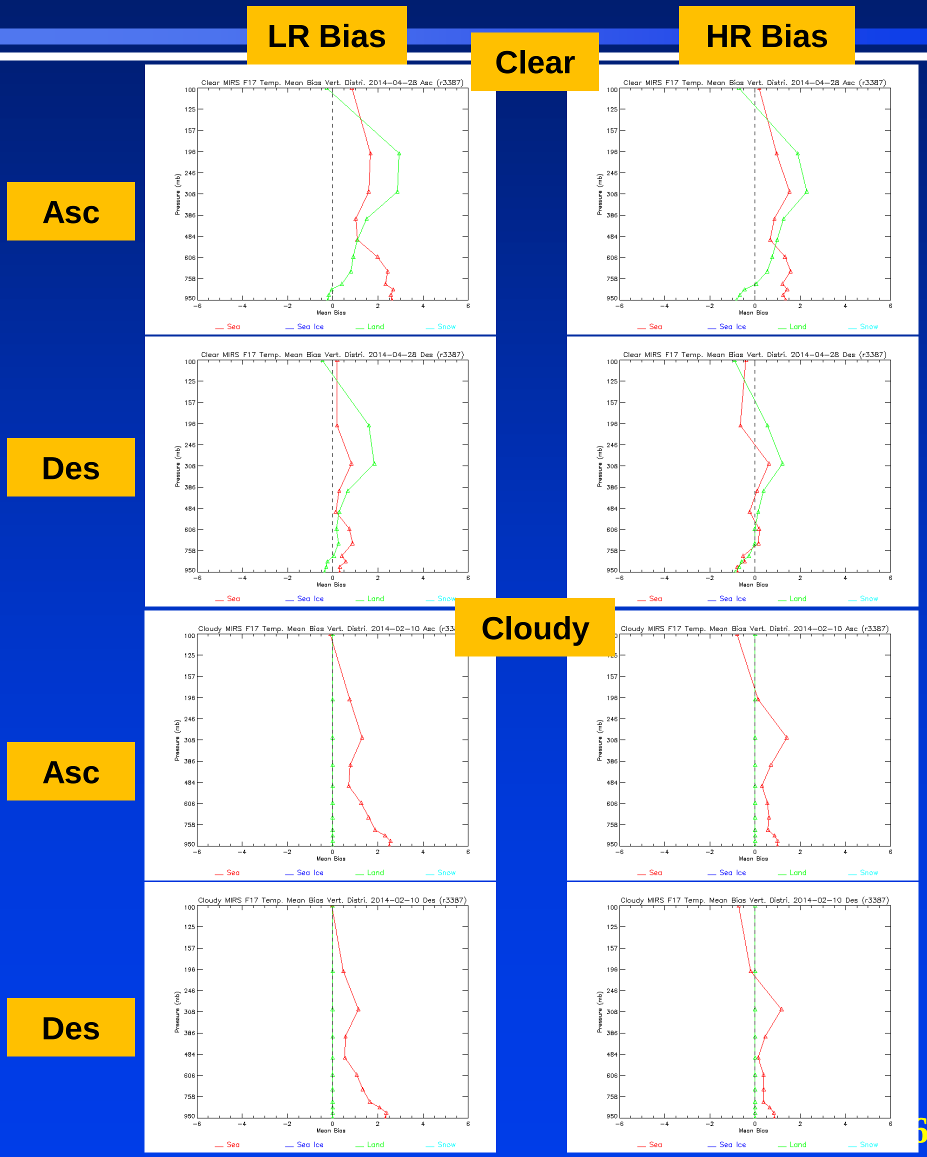
Sample of MIRS Additive Bias Corrections



(These are subtracted from TDR TBs)

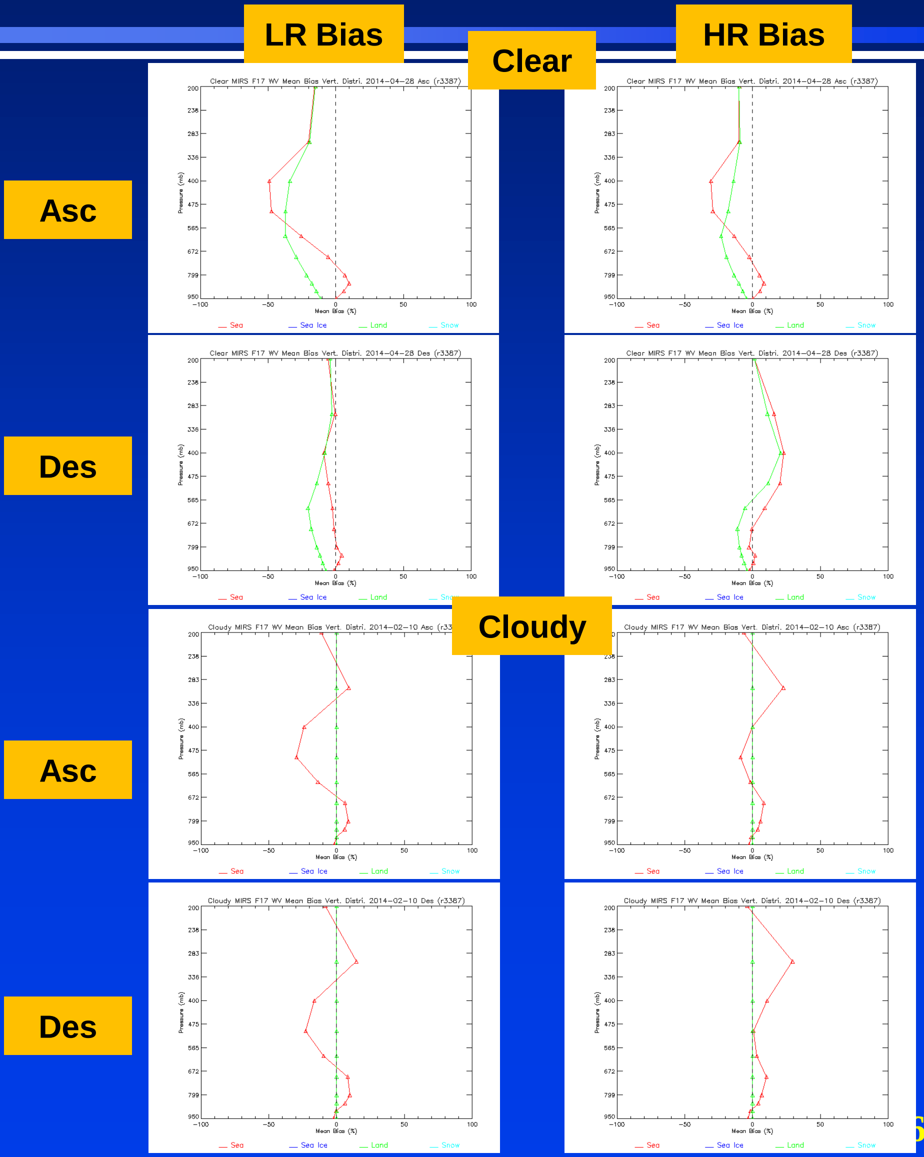
Improvement in Temp Profile Biases Using HR Bias Corrections

- Performed retrievals using LR and HR bias corrections over several days across the year (Jan 27, Feb 10, April 28, several days in August)
- HR biases seem to improve Temp Profile global bias errors (loser to zero) in both clear and cloudy conditions
- Shown to the right is Apr 28
  - » A day with a warm bias (due to reflector emissivity) in the ascending orbits, and a cold bias over most latitudes in the descending orbits.
- Temp profile std. dev. errors show slight improvement (not shown)



General Improvement in WV Profile Biases Using HR Bias Corrections

- With new high resolution bias corrections, WV profile bias errors are often improved, but not always
- Shown to the right is Apr 28
  - » A day with mixed improvement and degradation in WV profile bias errors
- WV profile std. dev. errors show some improvement between 300 and 600 mb (not shown)



F17 Global Single Bias Correction

- The annual cycle of the orbital pattern of F17 TB biases that result from reflector emissivity means **no single set of bias corrections is optimal for all days**, or even all latitudes within a given day
  - » Impact mainly on 150-183 GHz channels, and therefore affects EDRs sensitive to these channels (e.g. water vapor retrievals); other EDRs less affected.
- Development of bias corrections with proper temporal, spatial, nodal dependence a significant challenge:
  - » **Accurate modeling** of calibration biases over the annual cycle of the orbital pattern required to avoid introducing additional errors
    - – Requires extensive work beyond current scope/manpower/funding for project
  - » Because the bulk of the F17 pattern results from shadowing by the solar array, repositioning of the array (e.g. Oct 2011, and as happens on an irregular basis) can alter the orbital pattern enough to necessitate rederiving all the bias corrections

UPP Corrected SSMIS TDR Data

- NRL is the data enter for SSMIS data
- A Universal Pre-Processor (UPP) was developed for all SSMIS's by NRL and the UK Met Office
- UPP Corrects for:
  - » Reflector emissivity
    - – Major effect only for F16 and F17, but applied to F-18 as well
  - » Radiometer gain
    - – Solar intrusions into warm load
    - – Uses Operational NGES Fourier Filtered Gain Files to Correct Gain Anomalies (one per TDR file)
  - » Scan Non-uniformity
    - – Static, channel dependent multiplicative coefficient applied to each scan position
- Enables ~1 Kelvin accuracy w/r/t ECMWF + RTTOV 8
  - » Sufficient accuracy for assimilation in NWP systems (the goal and driver behind UPP)

MiRS Uses Uncorrected F-17 TDRs

- UPP-corrected TDRs exist in two main flavors
  - NRL (operational)
    - BUFR format (not original TDR format)
      - We can't use—developing BUFR reader beyond our current project scope, manpower, funding
    - Remapped to LAS observations
      - 37.5 km along-scan spacing
      - Not useful for MIRS high resolution (25 km along-scan) F-17 retrievals
    - Optionally smoothed with a 56 km Gaussian
      - Unsmoothed data used by GSI (NCEP assimilation)
  - CSU UPP for Climate Records
    - Original TDR format
    - Native resolution--no remapping or averaging
    - ENV (19-37 GHz) and 91 GHz (SSMI equivalent) channels only
      - MiRS requires all IMG, ENV, and LAS channels for retrievals
- Currently, there is no UPP-corrected F17 data stream that could be used operationally by MiRS