Insights on Tropical Convection from MIRS (*NESDIS Microwave Integrated Retrieval System*) and TRMM Inter-comparisons

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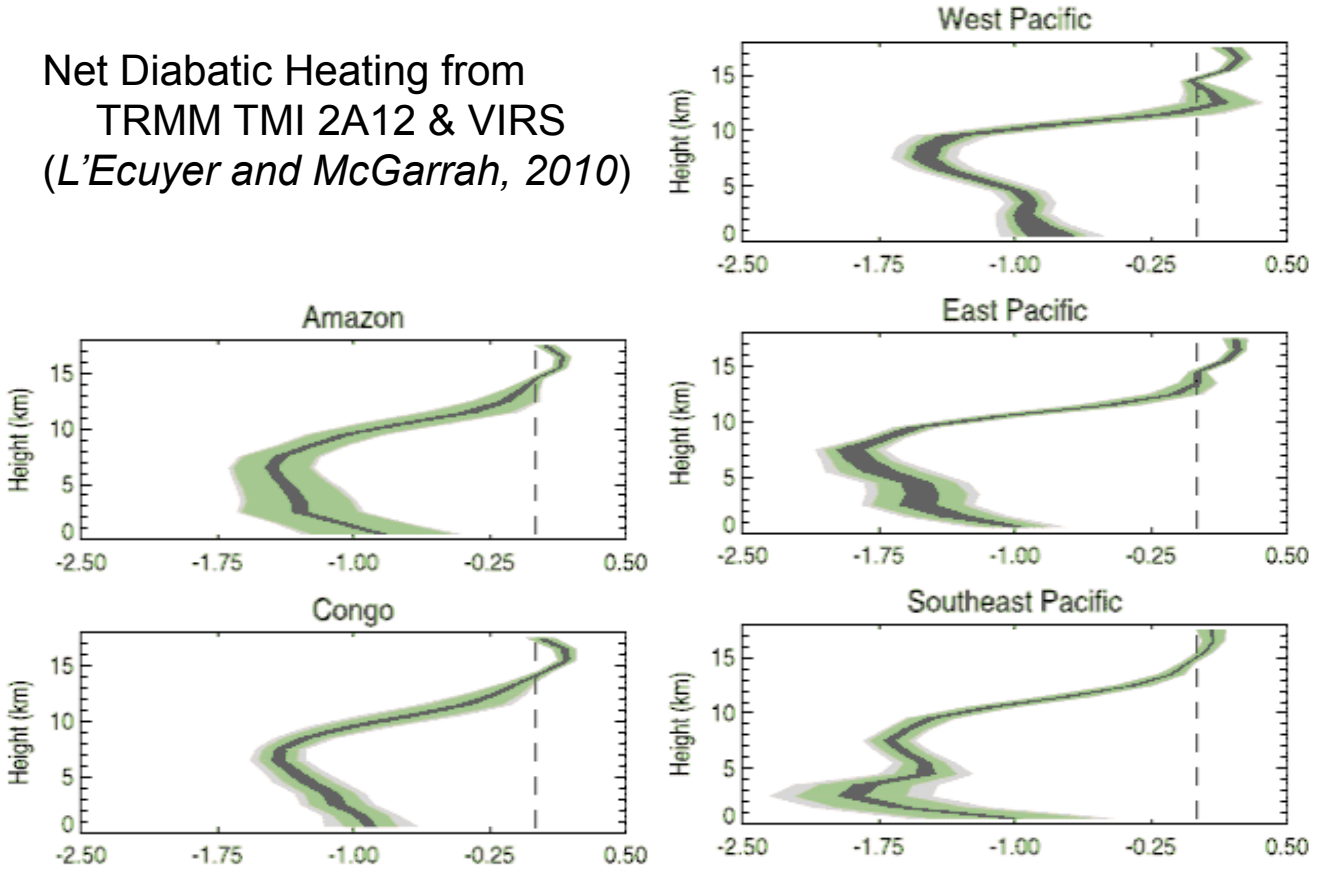
Focus of this work:

- Better understand the information content of hydrometeor signatures from polar orbiter sounders (i.e. AMSU, ATMS, SAPHIR) vis-à-vis *a priori*
- Make use of co-incident TRMM and POES data to examine cloud / precipitation regime-stratified statistics

- *Science Motivation*
- *Some background on MIRS*
- *Comparison of rain and precipitation ice water content / paths to TMI*
- *Case study and sensitivity experiments*
- *Summary / Next Steps*

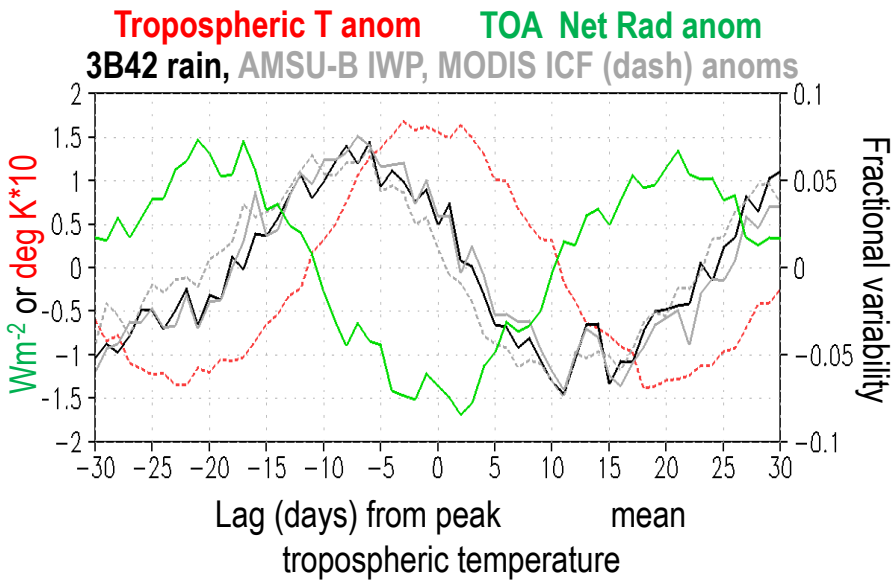
Science Motivation: TRMM / GPM contribution beyond precipitation at the surface is important to better link tropical precipitation, relative water / ice amounts to cloud radiative effects on the tropical heat budget *and its variability*

Net Diabatic Heating from
TRMM TMI 2A12 & VIRS
(*L'Ecuyer and McGarrah, 2010*)



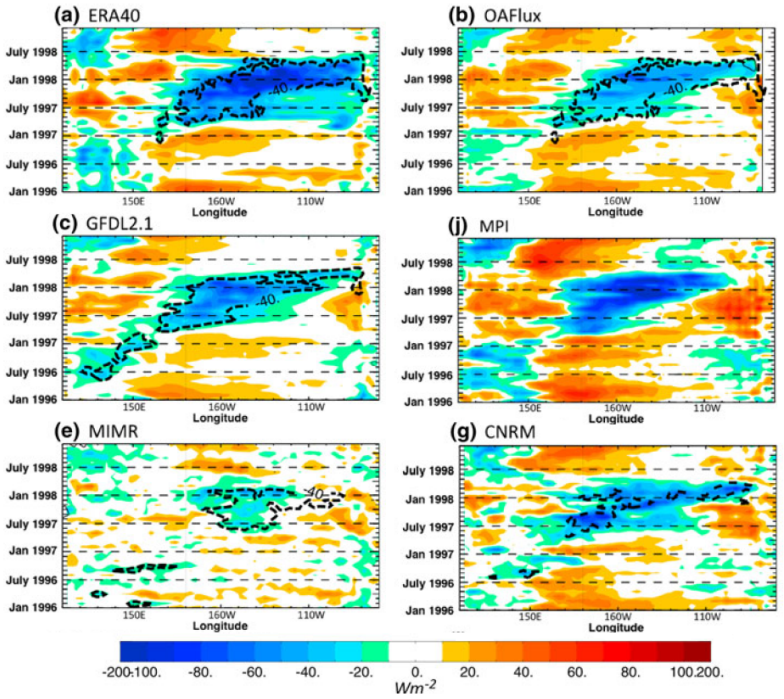
Science Motivation cont:

Composite Intraseasonal Variability over the Tropical Oceans (*Robertson et al., 2011*)



Decrease in TOA net radiation to the planet follows increase of convective precipitation and expansion of upper-tropospheric cloudiness.

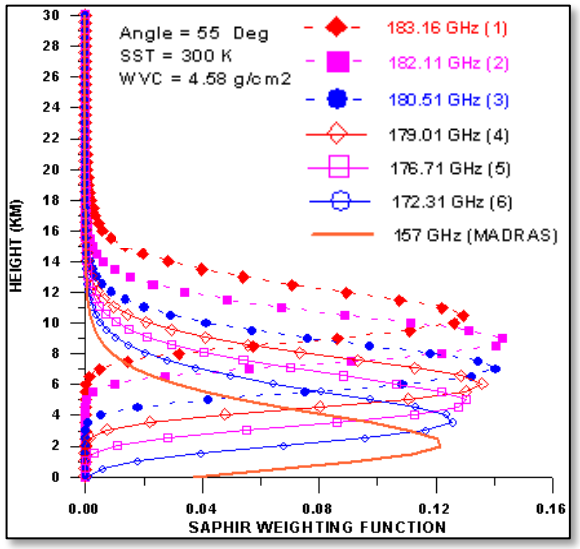
AR4 Model Variations in Equatorial SW Cloud Forcing During 1997/8 ENSO (*Lloyd et al., 2010*)



Uncertainty in model surface SW cloud feedback from deep and shallow clouds is a key source of model spread in structure and intensity of ENSO events.

Newer sensors (M-T Saphir, ATMS) have added channels... but they are still broad.

Megha-Tropiques Saphir



ATMS High Frequency Channels					
Channel	Center Freq. (GHz)	Max Bandwidth (GHz)	NE∆T (K)	Calibration Accuracy	Attribute
1 -15	Window (23.8, 31, 50.3) and O_2 Temperature Sounding				
16	88.20	2.0	0.5	2.0	window 3-phase H_20
17	165.5	3.0	0.6	2.0	H_2O 18 mm
18	183.31±7.0	2.0	0.8	2.0	H_2O 18 mm
19	183.31±4.5	2.0	0.8	2.0	H_2O 4.5 mm
20	183.31±3.0	1.0	0.8	2.0	H_2O 2.5 mm
21	183.31±1.8	1.0	0.8	2.0	H_2O 1.2 mm
22	183.31±1.0	0.5	0.9	2.0	H_2O 0.5 mm

GMI High Frequency Channels							
Ch #	Center Freq (GHz)	Width (MHz)	Pol	Nadir Angle	Beam Width	Footprint	Max NE∆T
10,11	166.00	4000	V , H	45.36	0.396	6.3 x 4.1	1.50
12	183.31±3.0	2000	V	45.36	0.361	5.8 x 3.8	1.50
13	183.31±7.0	2000	V	45.36	0.361	5.8 x 3.8	1.50

Microwave Integrated Retrieval System (MIRS)

- NOAA NESDIS 1DVAR physical retrieval algorithm based on OI theory; assumes local linearity and gaussian pdf of state variables; [i.e. ln (hydrometeor water content, specific humidity) are retrieved].
- Heritage is Microwave Surface and Precipitation Products System (MSPPS)
- Applicable to any PMW sensor combining imaging /sounding capabilities.
- Community Radiative Transfer Model (CRTM) forward model computes radiances and adjoints needed to minimize cost function, J(x).

$$J(x) = \left[\frac{1}{2}(X - X_o)^T \times B^{-1} \times (X - X_o)\right] + \left[\frac{1}{2}(Y^m - Y(X))^T \times E^{-1} \times (Y^m - Y(X))\right]$$

penalty for departing from background estimate

penalty for modeled radiances not matching measured/observed

X : *retrieved geophysicd quantity (e.g. hydrometeor, atmos or sf cstate)*

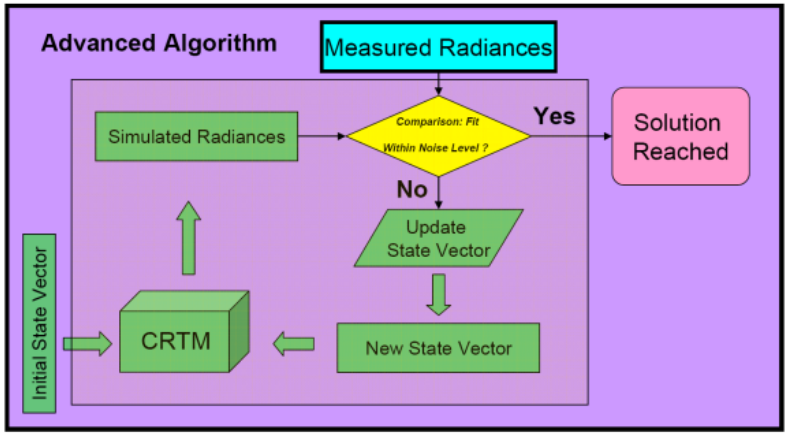
X_o : *background or a priori of retrieved quantity*

Y^m : *measured channel radiances*

$Y(X)$: *forwardmodel estimates based on Xs*

B : *background covariance*

E : *forwardmodel error covariance*

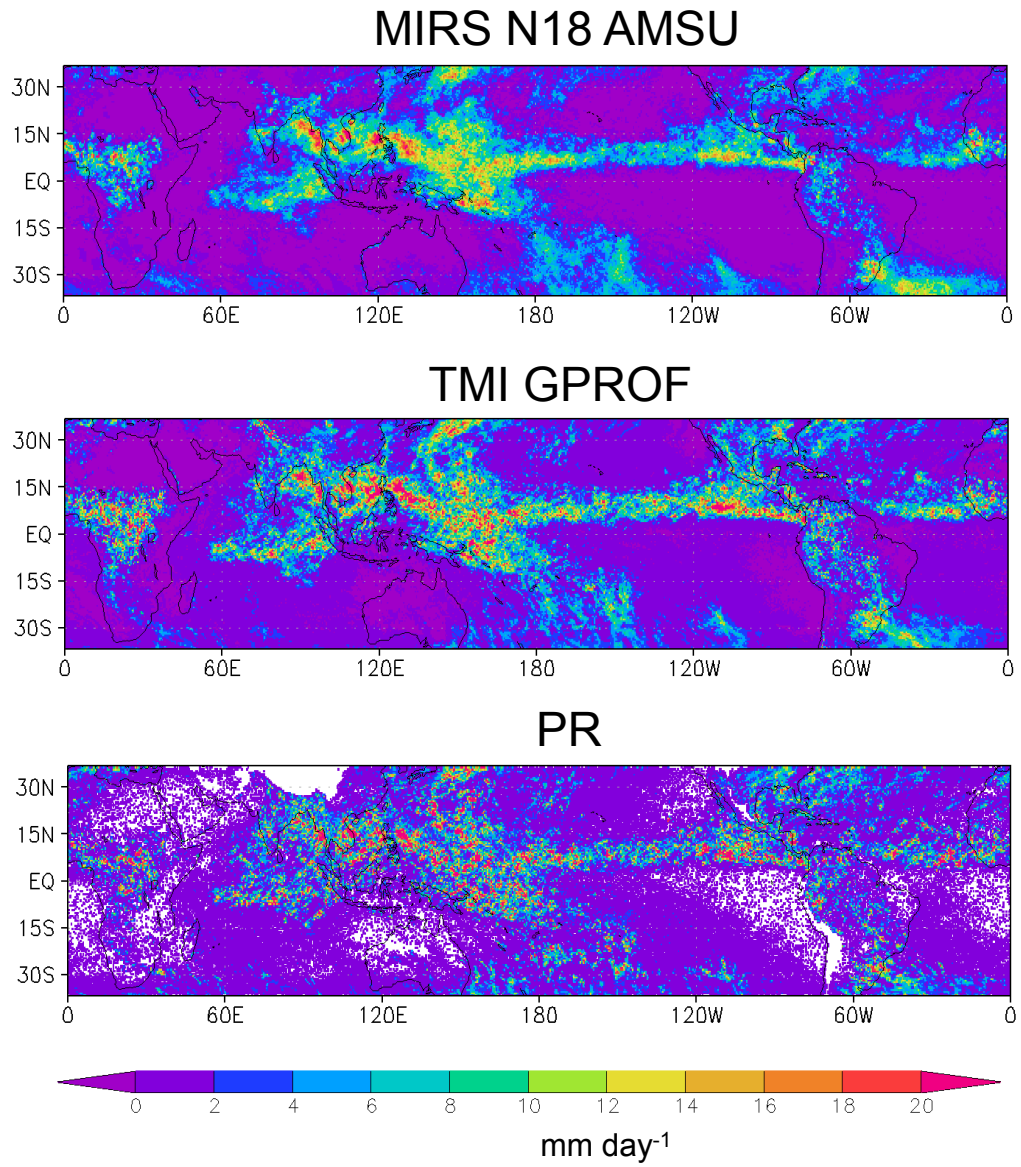


Retrievals:

- 1st sweep: temperature, water vapor, non-precipitating liquid, skin temperature, emissivity spectrum; 2nd sweep: rain, snow, graupel.
- Hydrometeor background and covariance statistics come from the ECMWF 60-Level and a 4 km MM5 simulation (Hurricane Bonnie, 1998).
- Retrievals performed in a reduced space (EOFs of vertical structure) → more stable inversion.
- Convergence criteria is Chi-square from matching observed and forward modeled radiances (< 1.0 s.d. assumed channel noise)
- Surface emissivity spectrum is part of the retrieved state vector enabling more direct response to precipitation over land.

☹Uncertainties in distributions of particle size, shape, density, orientation, beam filling effect, etc.

TRMM and MIRS N18 AMSU Rainfall (Sep 2009)



- MIRS column integrated cloud, rain, ice water paths are used in a statistical regression algorithm to generate a rain rate (See Iturbide-Sanchez et al., 2011):

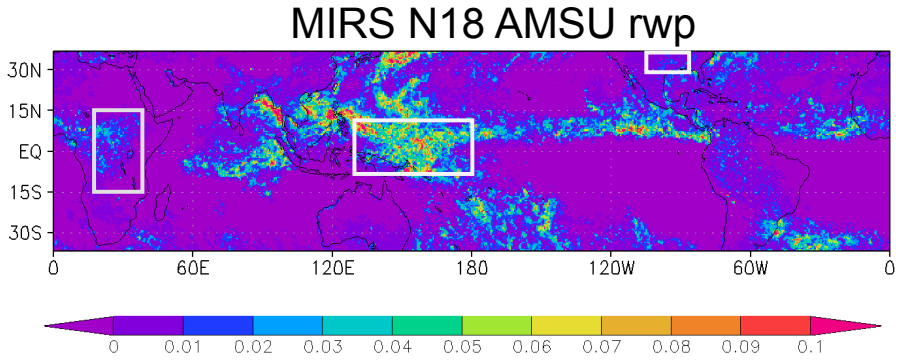
RR_{oc} = .274 + 2.202 CLWP
+5.329 RWP – 0.302 IWP

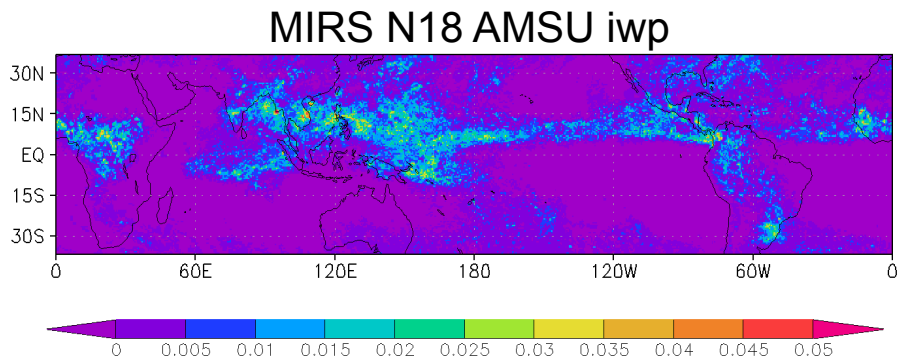
RR_{la} = -.0264 +9.742 RWP + 12.036 IWP

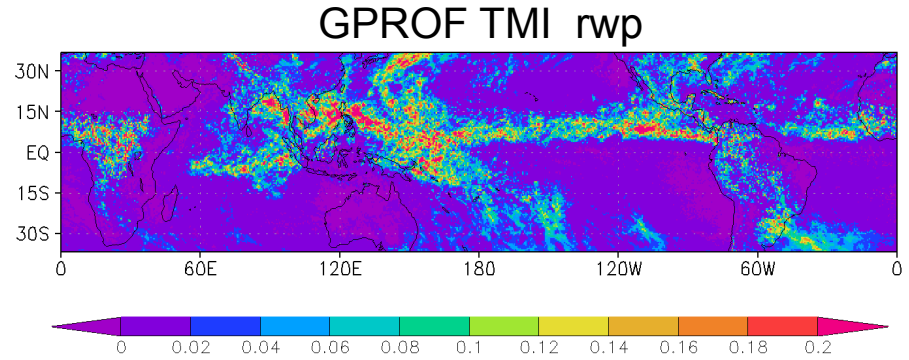
- Despite different sampling strategies (cross-track vs conical; diurnal vs sun-synchronous) MIRS rain rates *on a monthly basis* are similar in structure and magnitude to those from TRMM.

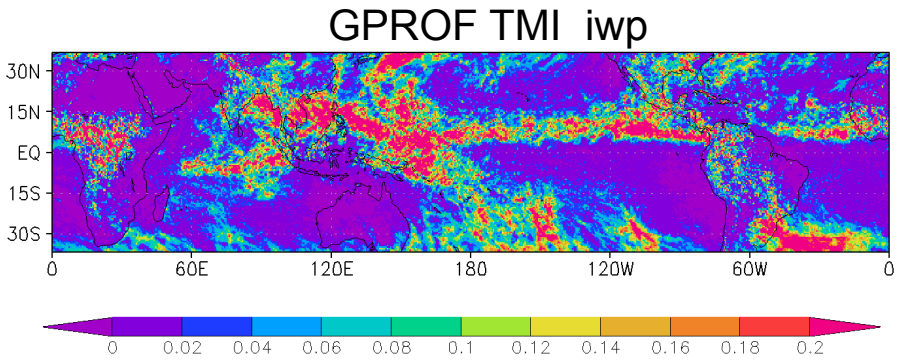
Monthly Rainwater and Precipitating Ice Path *(mm)*

- RWP and IWP retrievals from MIRS N18 AMSU are smaller than those from TMI 2A12 (2-3x and 5-10x, respectively).
- Global and even regional scale patterns are in reasonable agreement between GPROF and MIRS.





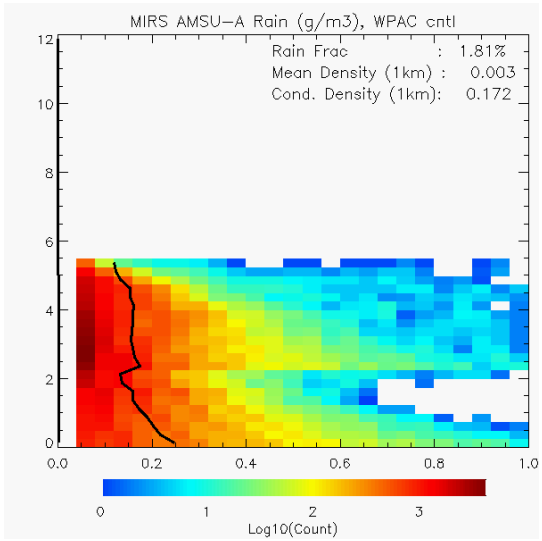


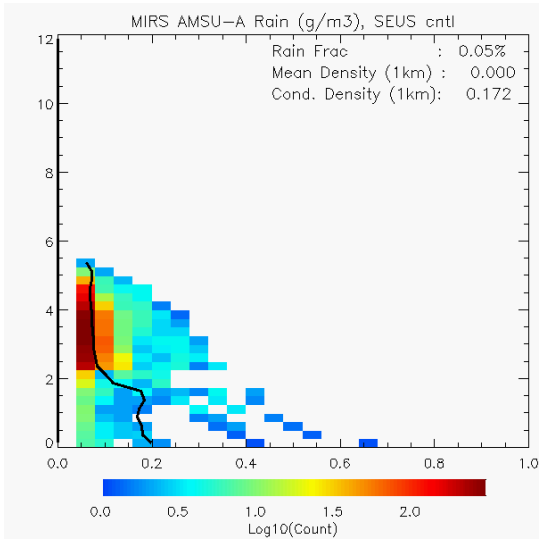


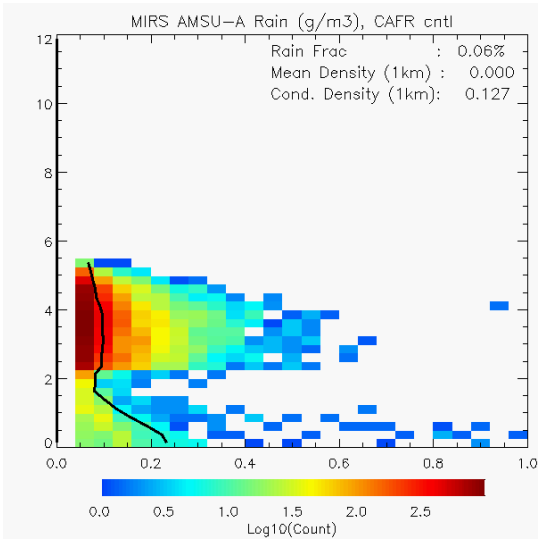
Regional CFADS (frequency-altitude) of Rainwater

W. Pac. **SE US** **C. Africa**

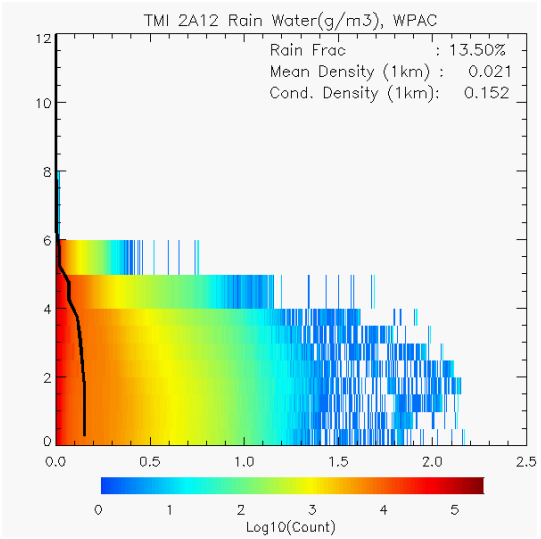
MIRS N18 AMSU

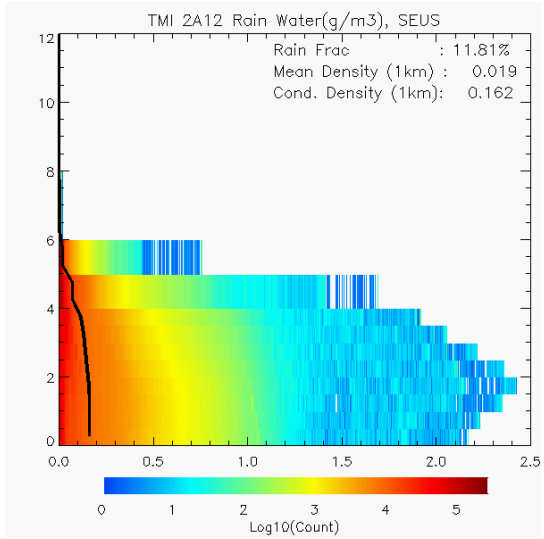


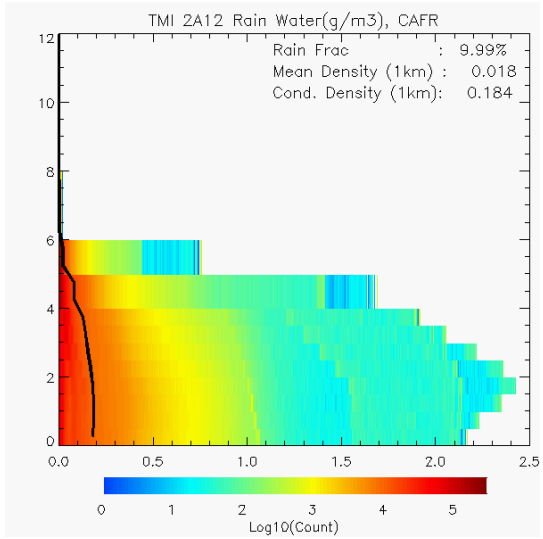




TMI GPROF 04

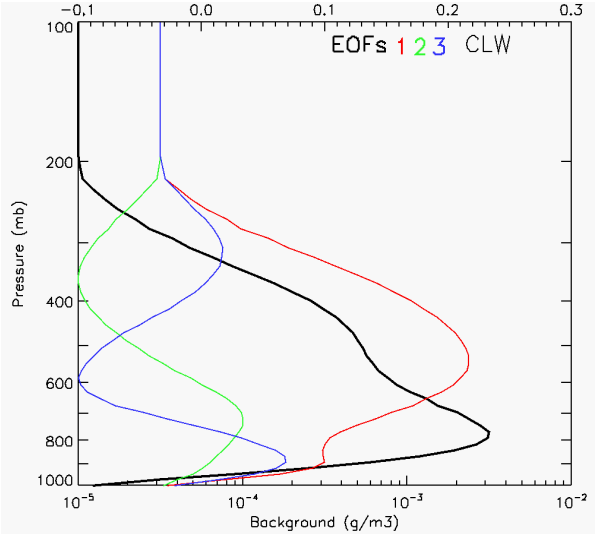


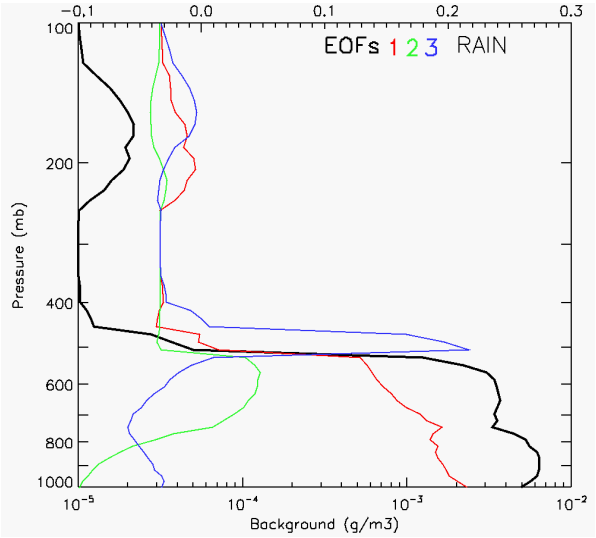


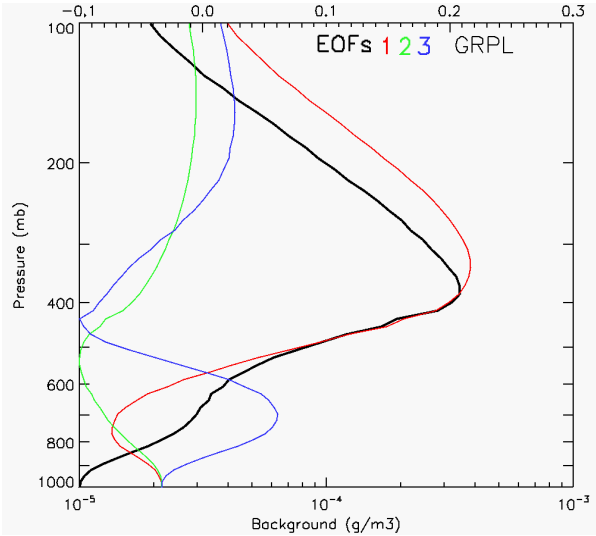


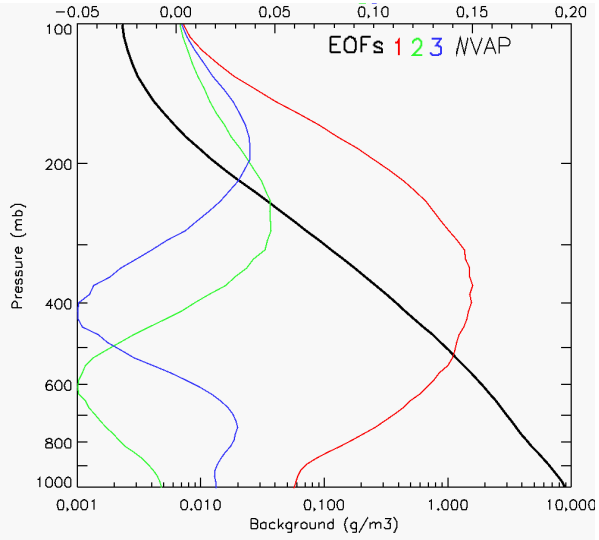
EOFs of Background Covariances and Mean Profiles

- *Initial guess can be modified by EOF structures to produce profiles.*
- *Departures from the mean profile are penalized in the cost function.*









Regional CFADS (frequency-altitude) of Graupel

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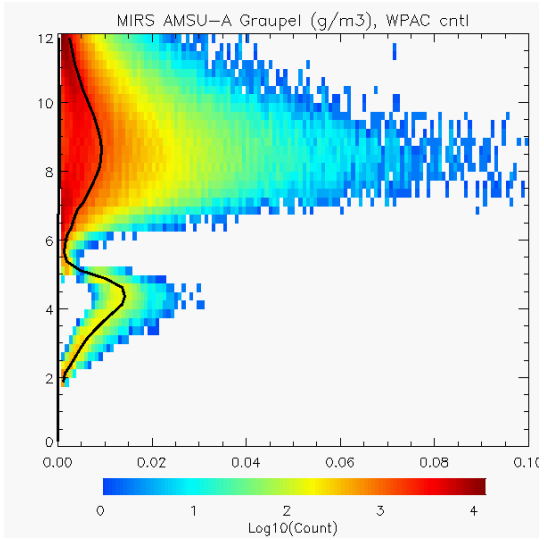
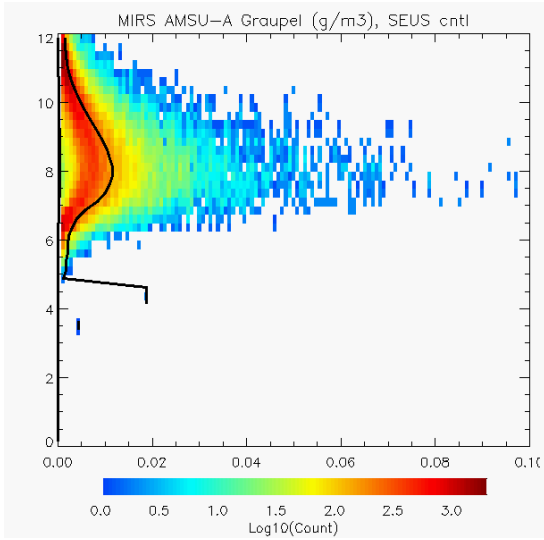
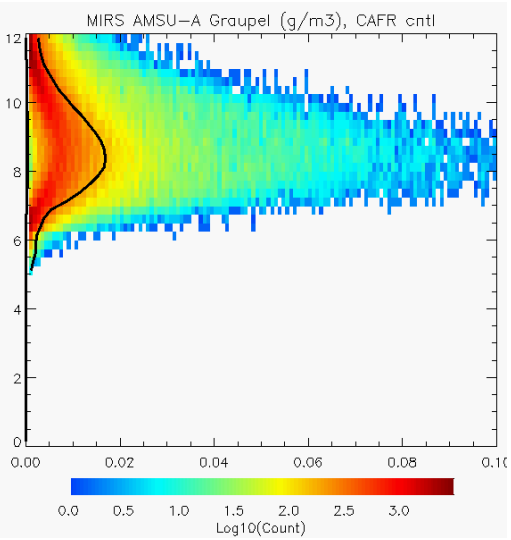
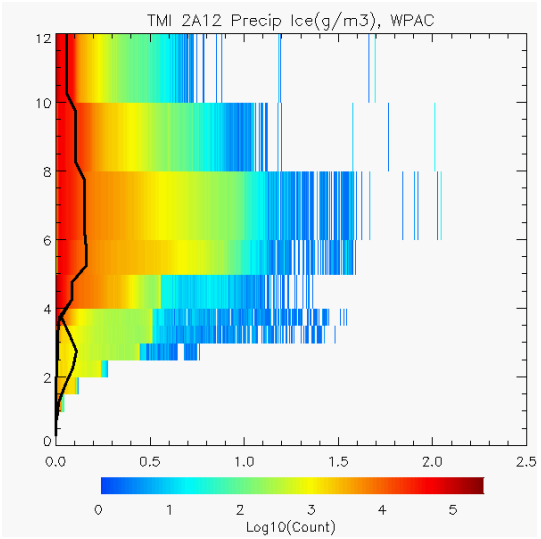
MIRS N18 AMSU

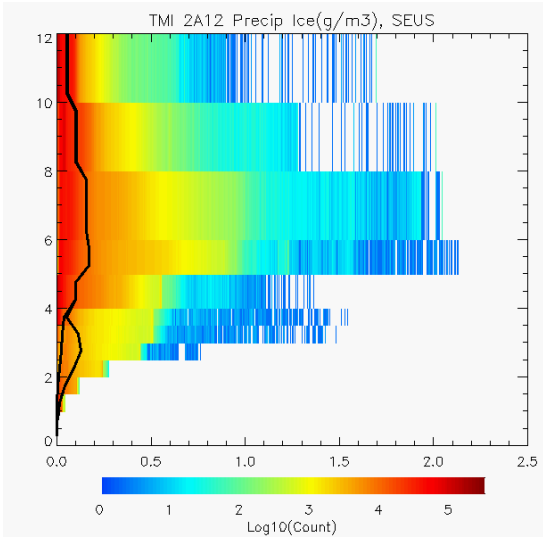


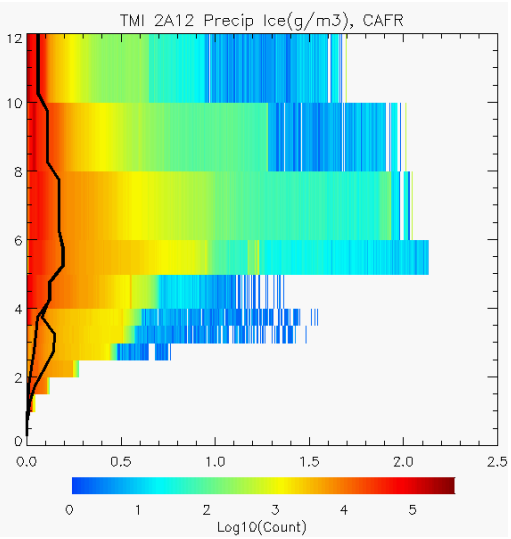




TMI GPROF 04







TS Lee (Sep 2, 2011) Case Study

- MIRS TMI, N18 AMSU

- GPROF10 TMI

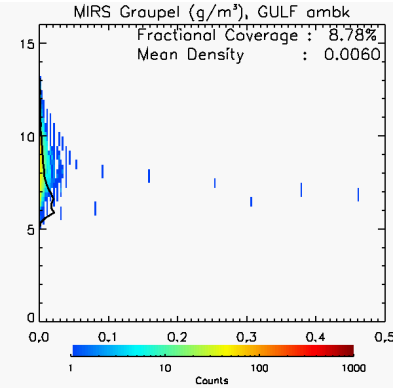
CFADS (counts) TS Lee Sep 2, 2011

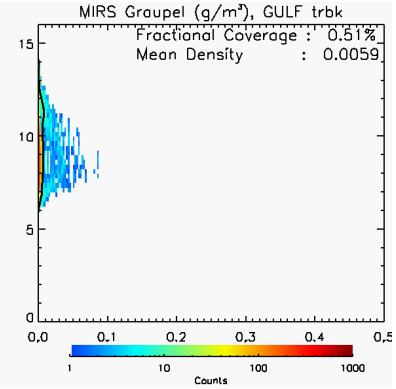
MIRS N19 AMSU

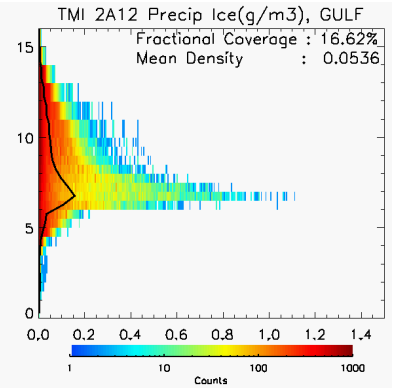
MIRS TMI

GPROF10

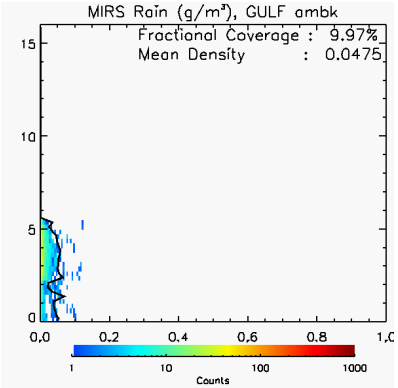
Precipitating Ice

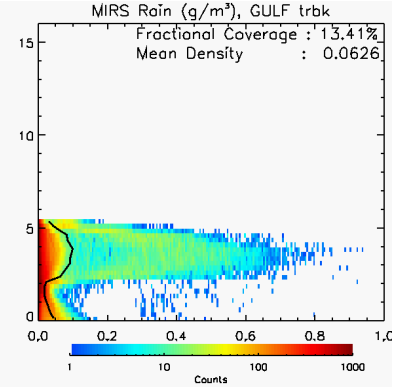


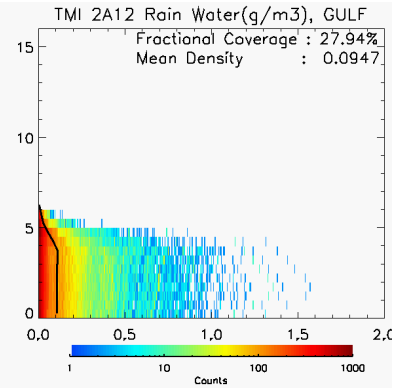




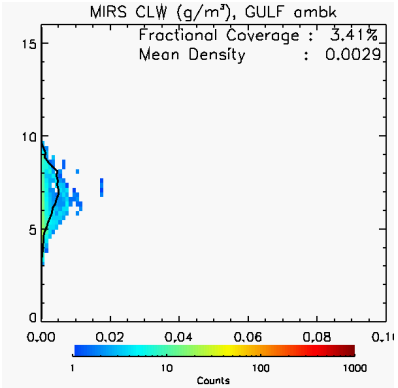
Rainwater

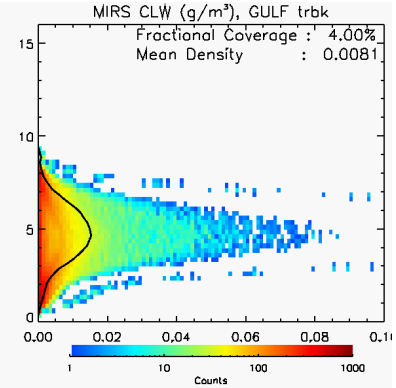


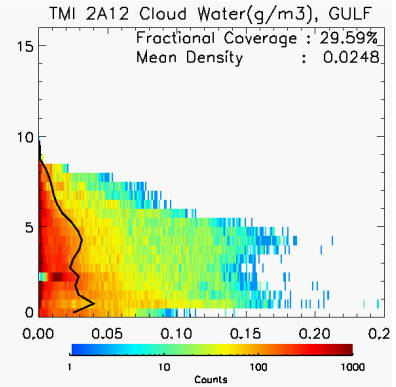




Cloud Water



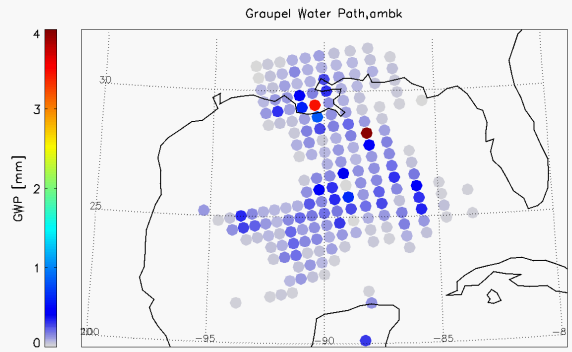


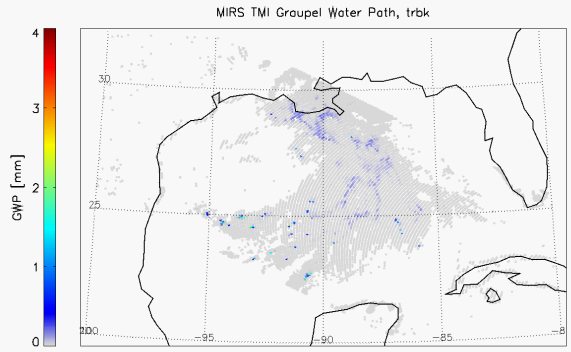


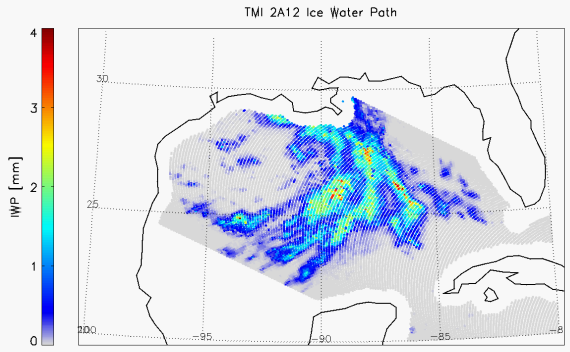
Column-Integrated Water Path (mm) TS Lee Sep 2, 2011

MIRS N19 AMSU | MIRS TMI | GPROF10

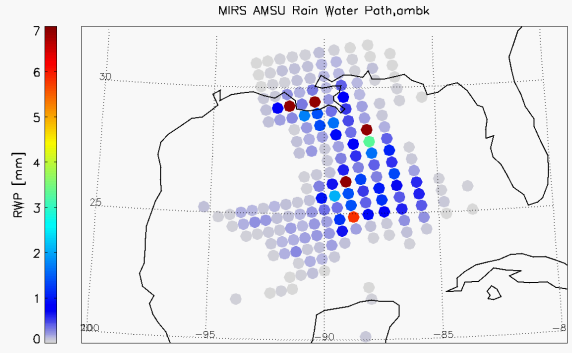
Precipitating Ice

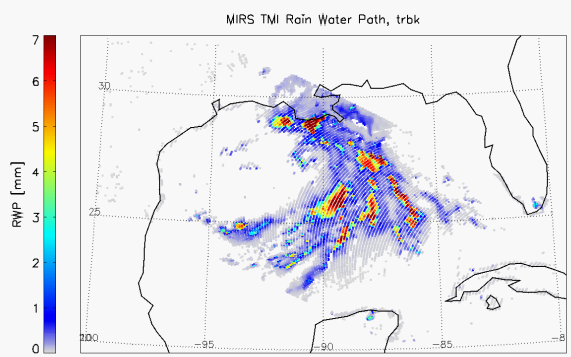


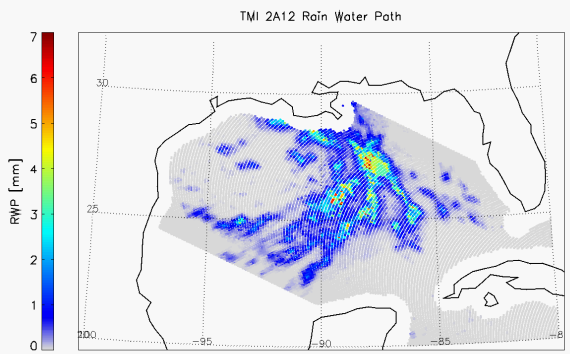




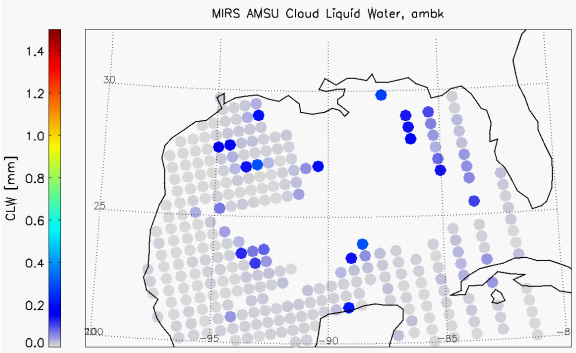
Rainwater

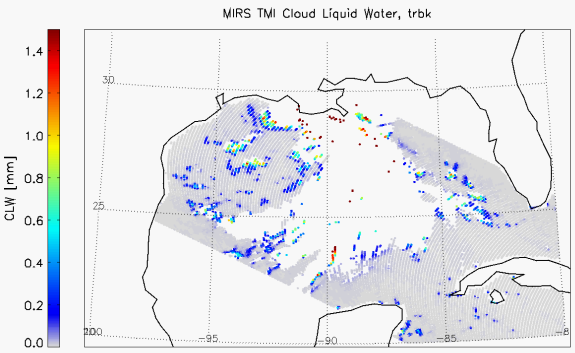


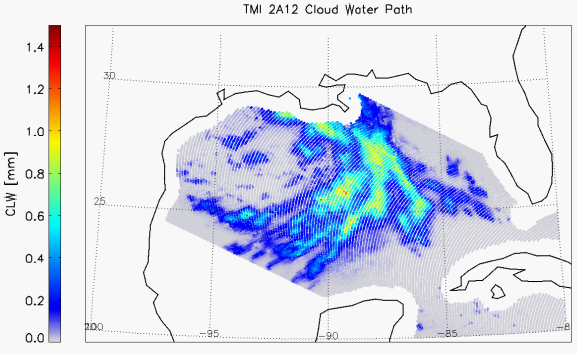




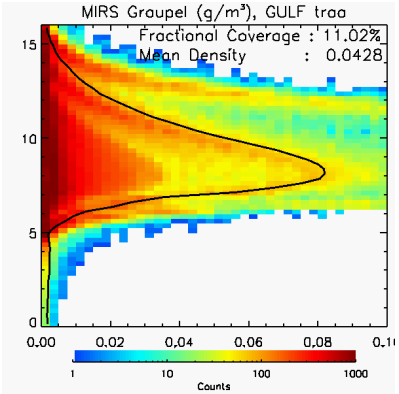
Cloud Water

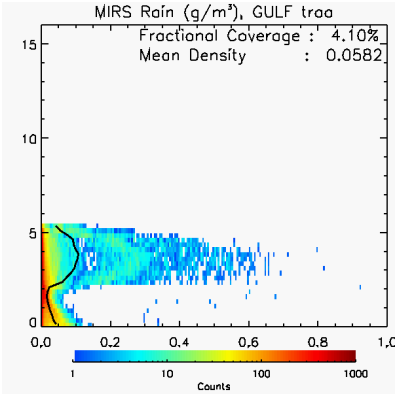


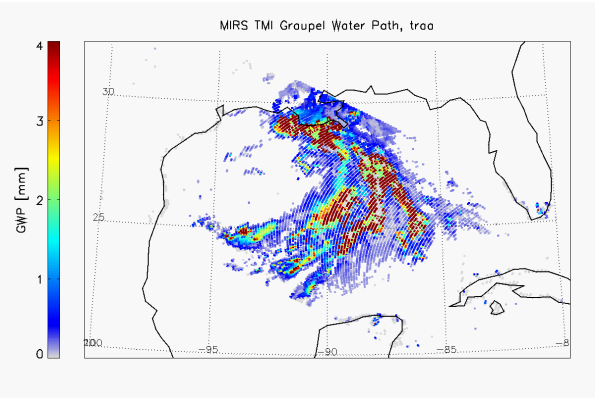


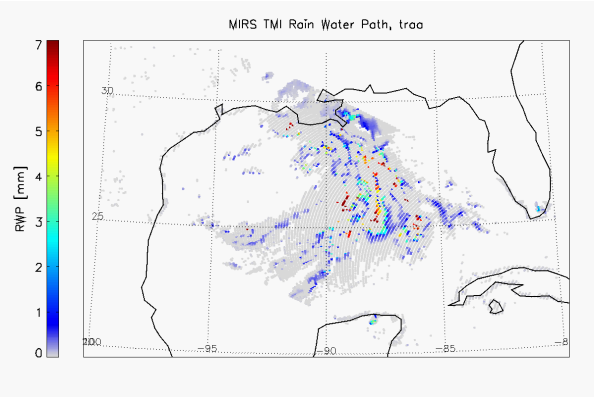


Sensitivity to Initial Guess









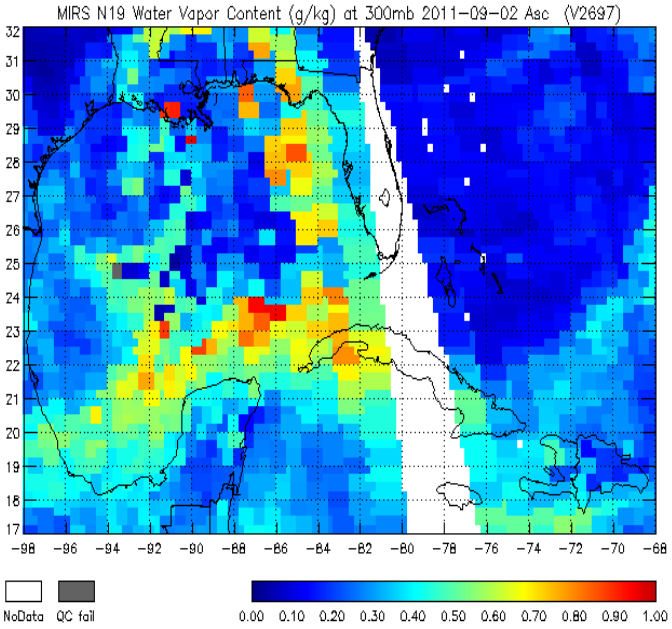
Graupel

Rainwater

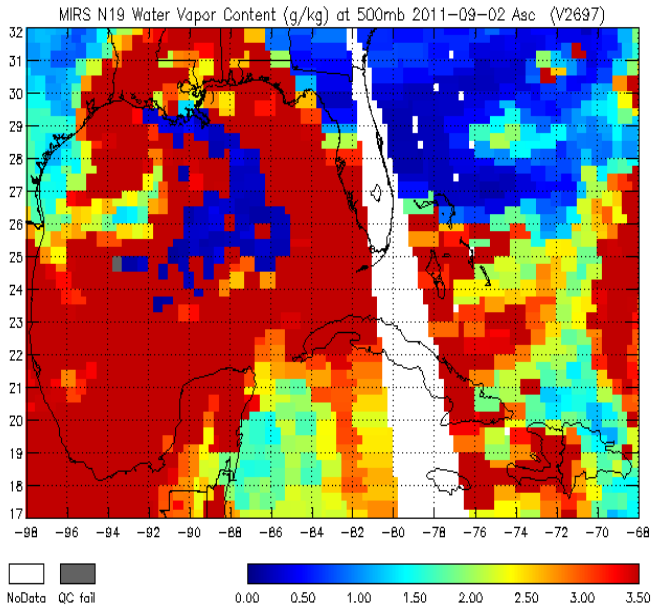
Regression first guess used for graupel in TMI instead of climatological background results in much larger graupel amount but greatly reduces rainwater amounts.

N19 AMSU Upper-tropospheric Specific Humidity

300 hPa Spec Hum (gm^{-3})



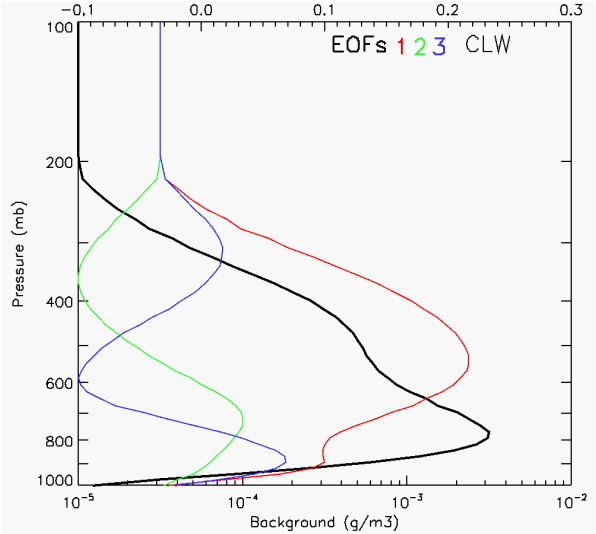
500 hPa Spec Hum (gm^{-3})

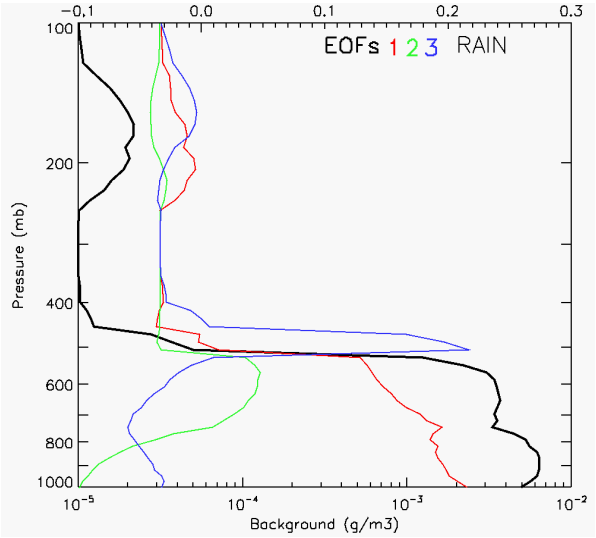


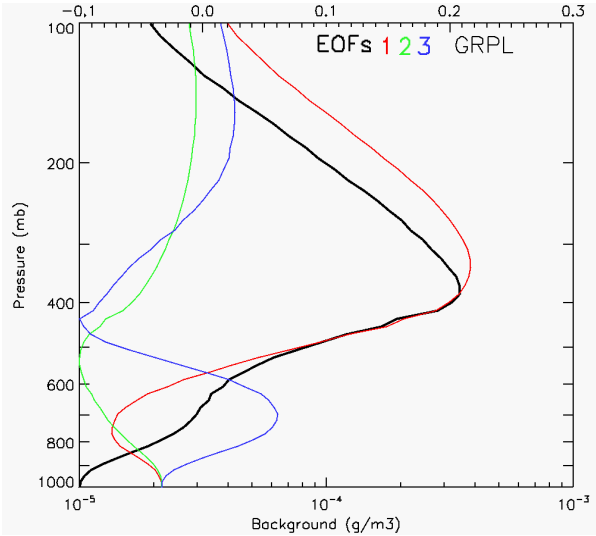
Background upper tropospheric water vapor is systematically too dry in regions of strong precipitation and is not being effectively changed. High resolution reanalysis could provide effective guess or input to background constraint.

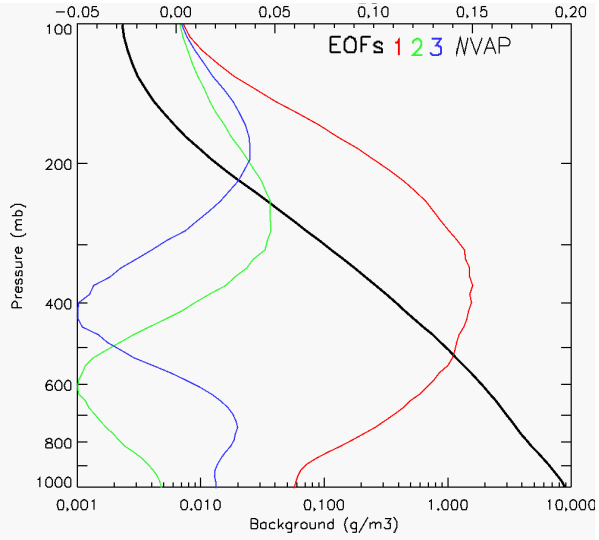
EOFs of Background Covariances and Mean Profiles

- *Initial guess can be modified by EOF structures to produce profiles.*
- *Departures from the mean profile are penalized in the cost function.*









Summary / Conclusions

- 1st generation MIRS hydrometeor profiles are, in a physical sense, too narrowly constrained.
  - A single *a priori* background profile for each species is derived from limited sampling of ECMWF 60L and MM5 hydrometeors.
  - Integrated AMSU rainwater and precipitating ice are underestimated relative to GPROF. (But TMI rainwater overestimated.)

- Despite these artificial restrictions, MIRS is able to retrieve integrated rain and precipitating ice water paths sufficient to enable reasonable surface RR estimates via multiple regression / calibration.

- Sensitivity to initial guess is evident and suggests that multiple minima in cost function is likely a frequent occurrence.

Next Steps / Priorities

- Efforts are underway to generalize / stratify the background to build in regime dependence of background:
  - Seasonal / latitudinal modification
  - Adopt regime-dependent structure more in line with GPROF cloud library
  - Effect of high resolution reanalysis moisture as part of background

- Intercomparison of MIRS on SSMIS (f18) with GPROF. Channel witholding experiments and follow MIRS iterative solution

- Extension to ATMS, then Megha-Tropiques