Community Radiative Transfer Model (CRTM) Applications to Support Sensor Cal/Val and EDR Generations

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November 29, 2017

The first and the last emails from Paul vanDelst

From Paul Van Delst
Subject **Bryan Baum - Cirrus Modeling**
3/30/2005 3:30 PM
To Me
Cc Yong Han <Yong.Han@noaa.gov>

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Hi Quanhua,

This is the page I mentioned before abuot the ice crystal work in the infrared at Wisc.

<http://www.ssec.wisc.edu/~baum/Cirrus/IceCloudModels.html>

Do you see anything in this that we can use in the CRTM? I'm going to have a closer look at it next week, but you're the scattering expert so I figured you might have some pointers as to what is important.

cheers,

paulv

--
Paul van Delst
CIMSS @ NOAA/NCEP/EMC

From Paul Van Delst
Subject **CRTM solar/visible flag change in CRTM_AMOM_Layer procedures.**
4/12/2016 2:34 PM
To Tong Zhu - NOAA Affiliate <tong.zhu@noaa.gov>
Cc Me

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Hello,

The problem is with the CRTM_AMOM_Layer[XXX] routines in ADA_Module.

The lines where we have

```
IF( RTV%Visible_Flag_true ) THEN
```

should perhaps be

```
IF( RTV%Solar_Flag_true ) THEN
```

?

Here are the actual lines in the current trunk:

CRTM_AMOM_layer():
https://svnemc.ncep.noaa.gov/trac/crtm/browser/trunk/src/RTSolution/ADA/ADA_Module.f90#L391

CRTM_AMOM_layer_TL():
https://svnemc.ncep.noaa.gov/trac/crtm/browser/trunk/src/RTSolution/ADA/ADA_Module.f90#L825

CRTM_AMOM_layer_AD():
https://svnemc.ncep.noaa.gov/trac/crtm/browser/trunk/src/RTSolution/ADA/ADA_Module.f90#L1255

Please confirm that these are the correct ones to change.

cheers,

paulv

Paul’s Final Work on CRTM Cloud Data Assimilation

The computer codes Paul left for us are still working daily for this community. He will live on in our memories forever!

$$C_k = \frac{F_k}{G_k}$$

$$F_k = F_{k-1} + w_k f_k$$

$$G_k = G_{k-1} + w_k$$

$$\delta F_k = \delta F_{k-1} + w_k \delta f_k + f_k \delta w_k$$

$$\delta^* w_k = \delta^* w_k + f_k \delta^* F_k$$

$$\delta^* f_k = \delta^* f_k + w_k \delta^* F_k$$

$$\delta^* F_{k-1} = \delta^* F_{k-1} + \delta^* F_k$$

$$\delta^* F_k = 0$$

$$\delta G_k = \delta G_{k-1} + \delta w_k$$

$$\delta^* w_k = \delta^* w_k + \delta^* G_k$$

$$\delta^* G_{k-1} = \delta^* G_{k-1} + \delta^* G_k$$

$$\delta^* G_k = 0$$

$$\delta C_k = \frac{G_k \delta F_k - F_k \delta G_k}{G_k^2} = \frac{1}{G_k}\delta F_k - \frac{F_k}{G_k^2}\delta G_k$$

$$\delta^* G_k = \delta^* G_k - \frac{F_k}{G_k^2}\delta^* C_k$$

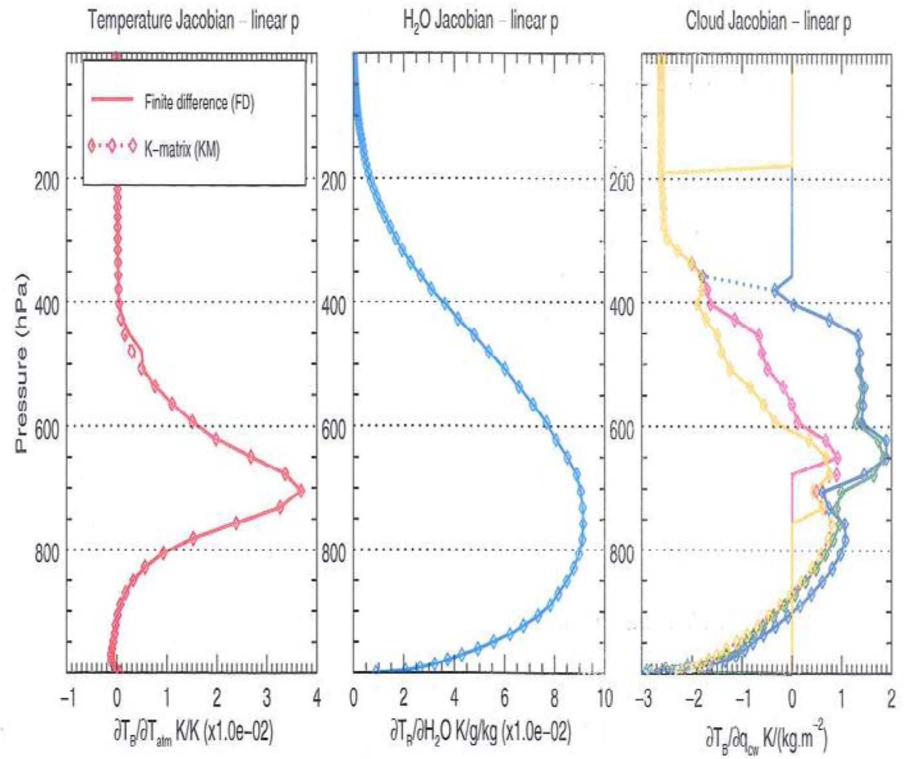
$$\delta^* F_k = \delta^* F_k + \frac{1}{G_k}\delta^* C_k$$

$$\delta^* C_k = 0$$

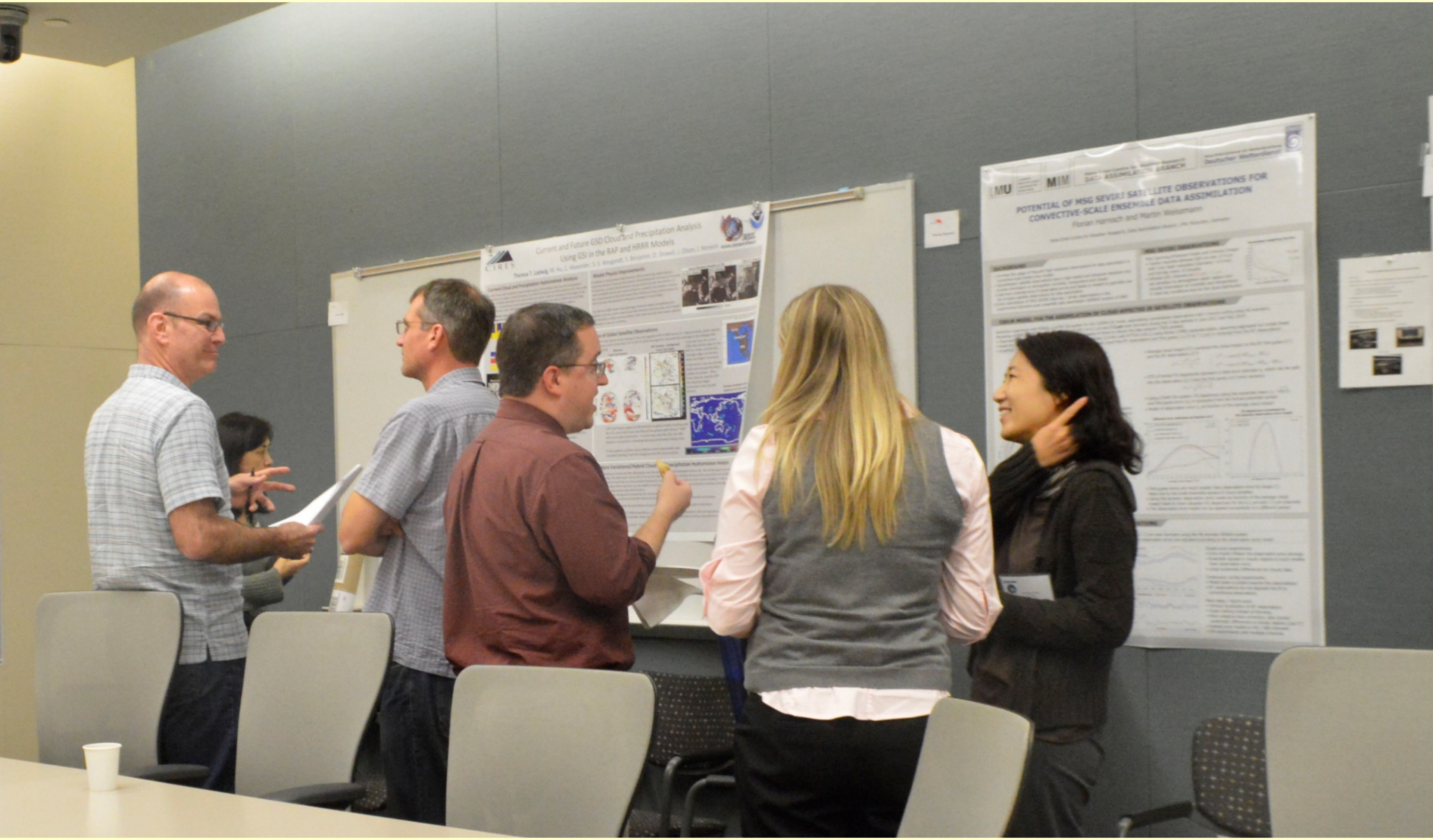
Every line he coded was just like his personality: neat, clean and clear;
Every module he designed was just like his attitude toward life: making the optimum trade-off among different resources in order to pursue the best of the whole system.

2 CODE TESTING — 2.3 Finite-difference and K-matrix Jacobian comparisons

Figure 2.13: Comparison of NPP ATMS channel 2 finite-difference and K-matrix T_B Jacobians for ECMWF5K profile 1 using the *cloud water amount weighted average* method to compute fractional cloud cover. **(Top)** Temperature, water vapour, and cloud water content Jacobians. The colours for the latter represent water, ice, rain, and snow clouds. **(Bottom)** Channel brightness temperatures. Channel 2 is highlighted by the vertical green line.

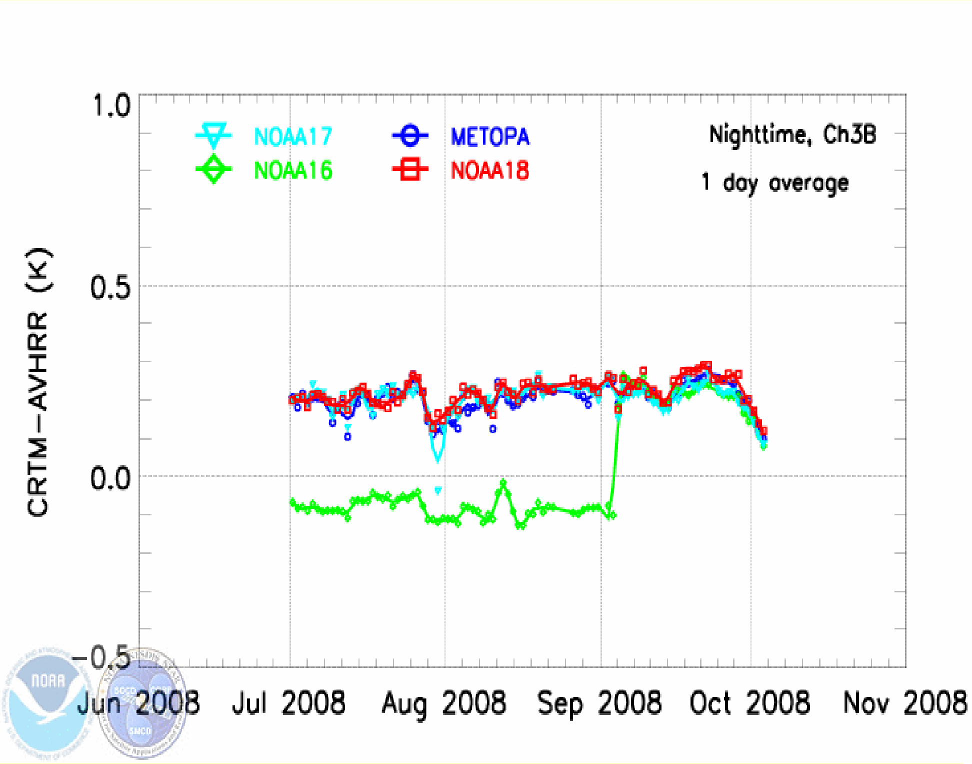


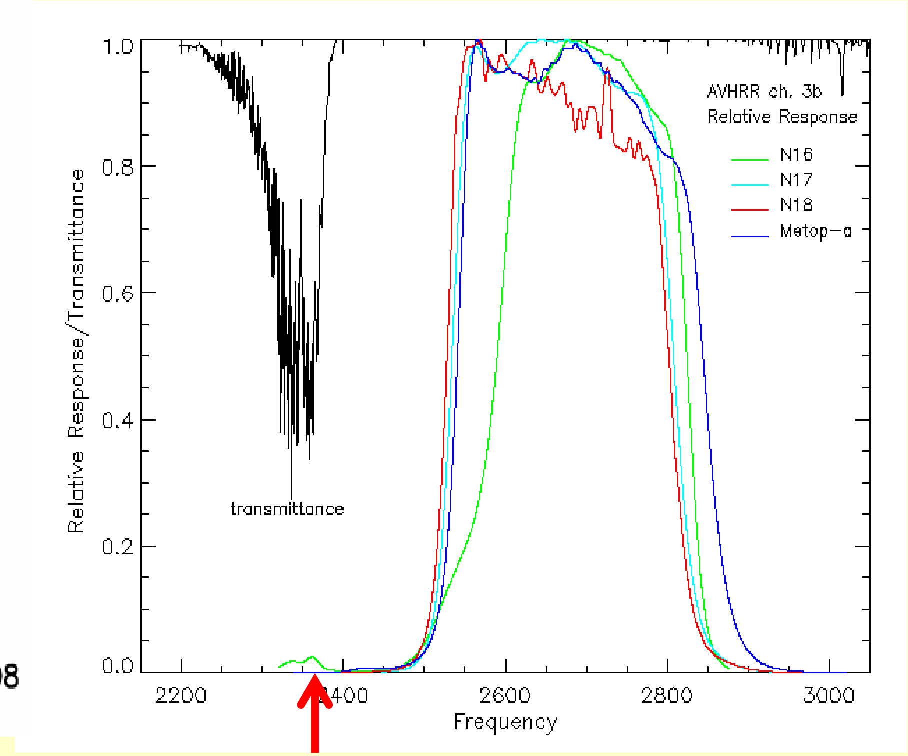
Paul vanDelst at JCSDA Annual Meeting



Paul vanDelst at Party

Collaboration: User -- CRTM – Sensor



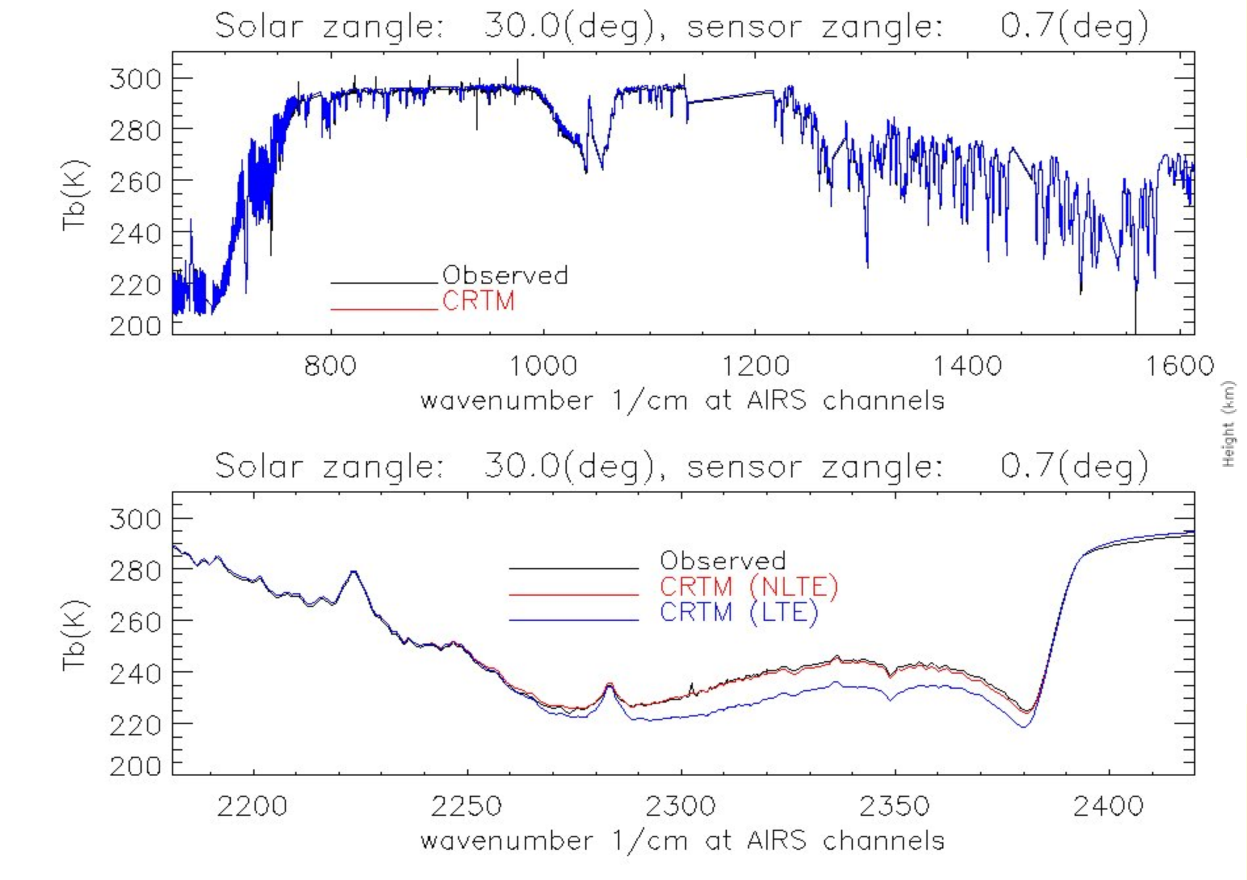


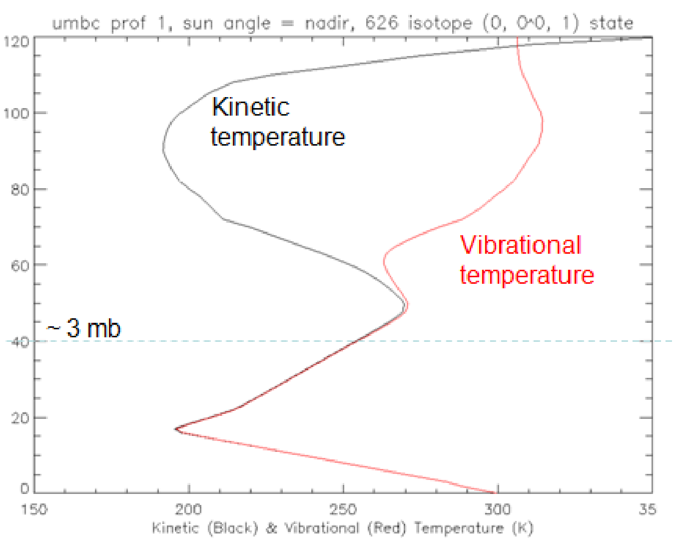
The black line is the transmittance between 0.005 (model top) and 20 hPa.

User reported an unexpected bias (B – O) for NOAA-16 Ch. 3b. CRTM team found that out-of-band was the root cause, and the sensor team confirmed the cause.

CRTM NLTE Simulation vs Observation, Solar zenith angle = 30°, Sensor zenith angle = 0.7°

AIRS

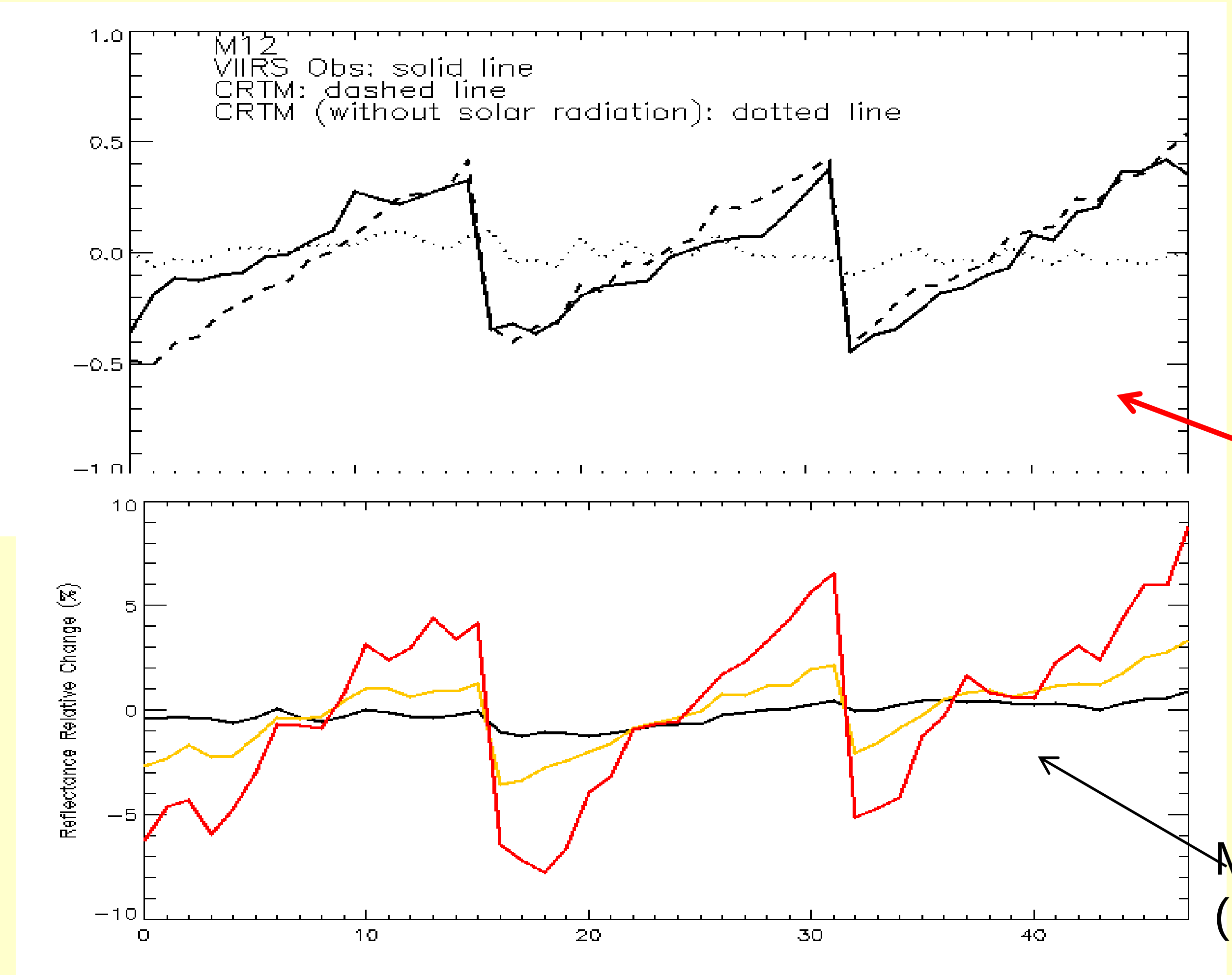


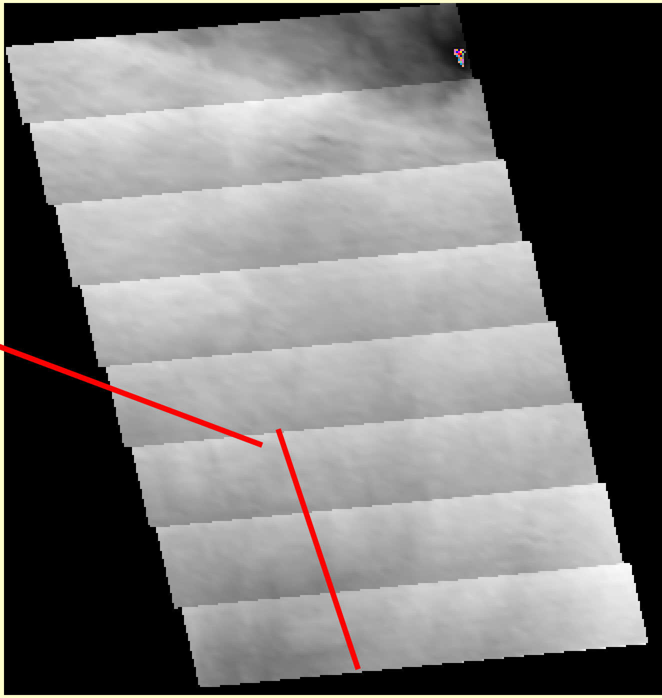


$$\Delta R_{ch}(\theta^{sen},\theta^{sun}) = c_0(\theta^{sen},\theta^{sun}) + c_1(\theta^{sen},\theta^{sun})T_{m1} + c_2(\theta^{sen},\theta^{sun})T_{m2}$$

$T_{m1\ (0.005\text{-}0.2hPa)}$, $T_{m2\ (0.2\text{-}52hPa)}$

VIIRS and CRTM Modeling for M12 Striping Investigation





M1, M4, and M11 measured (R-Rm)/Rm *100

The STAR team applied the CRTM to simulate the VIIRS SDR data. It is found that the M12 striping reported by the SST EDR team is caused by the difference in VIIRS azimuth angles among detectors.

Detailed CRTM Calculation for the Striping

Detector #	$\tau(\theta_{sat})$	ϕ_{sat}	BRDF	**A**	**B**	R	Brightness temperature
1	0.73685	80.368	0.04253	0.51055	0.10590	0.61645	302.666
2	0.73649	80.543	0.04309	0.50923	0.10717	0.61641	302.648
3	0.73700	80.717	0.04365	0.51022	0.10873	0.61894	302.738
4	0.73645	80.892	0.04422	0.50964	0.10999	0.61962	302.769
5	0.73705	81.066	0.04479	0.51114	0.11159	0.62273	302.871
6	0.73628	81.241	0.04537	0.51147	0.11280	0.62427	302.931
7	0.73701	81.415	0.04596	0.51164	0.11448	0.62612	302.987
8	0.73596	81.589	0.04656	0.51074	0.11566	0.62640	303.020
9	0.73673	81.764	0.04715	0.51175	0.11739	0.62914	303.115
10	0.73557	81.938	0.04776	0.51124	0.11855	0.62978	303.153
11	0.73641	82.113	0.04837	0.51120	0.12036	0.63157	303.230
12	0.73509	82.287	0.04901	0.51134	0.12155	0.63289	303.316
13	0.73562	82.461	0.04962	0.51180	0.12325	0.63505	303.396
14	0.73486	82.636	0.05026	0.51057	0.12461	0.63518	303.417
15	0.73526	82.810	0.05089	0.50993	0.12629	0.63622	303.439
16	0.73565	82.985	0.05154	0.50998	0.12812	0.63810	303.560

$$R = \tau(\theta_{sat})[\varepsilon B(T_s) + (1-\varepsilon)R_{atm\_d}] + R_{atm\_u} + F_0 \cos(\theta_{sun})\tau(\theta_{sun}) BRDF(\theta_{sun}, \theta_{sat}, \phi_{sun} - \phi_{sat})\tau(\theta_{sat})$$

A B

Microwave Integrated Retrieval System (MiRS)

- Cost Function to minimize:

$$J(X)=\left[\frac{1}{2}\underbrace{(X-X_0)^T\times B^{-1}\times(X-X_0)}\right]+\left[\frac{1}{2}\underbrace{\left(Y^m-Y(X)\right)^T\times E^{-1}\times\left(Y^m-Y(X)\right)}\right]$$

Bkg-departure normalized by Bkg Error

Measurements-departure normalized by Measurements+Modeling Errors

Previously updated in V11

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

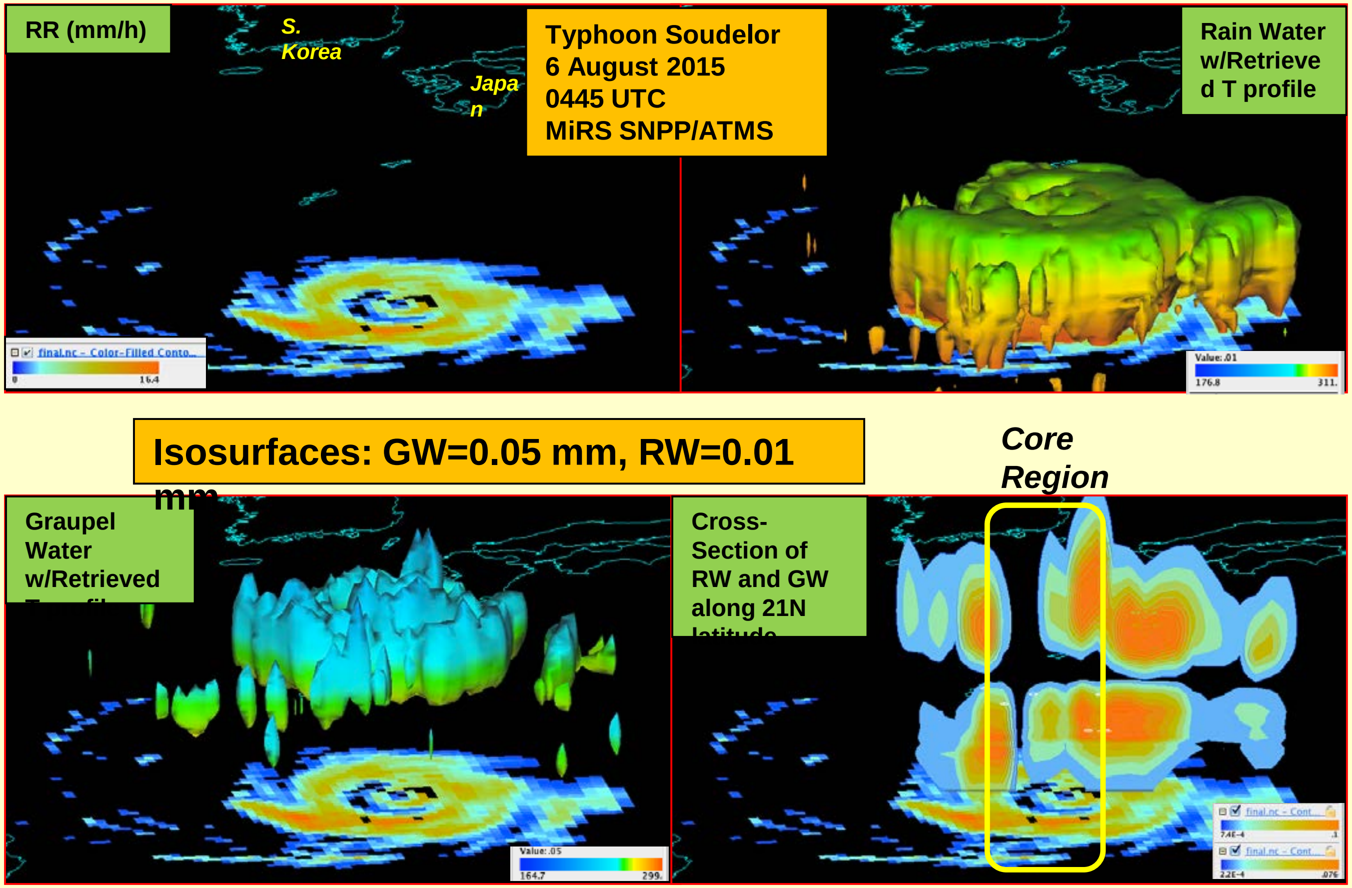
- Assuming local Linearity: $y(x)=y(x_0)+K\left[x-x_0\right]$

- This leads to iterative solution:

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

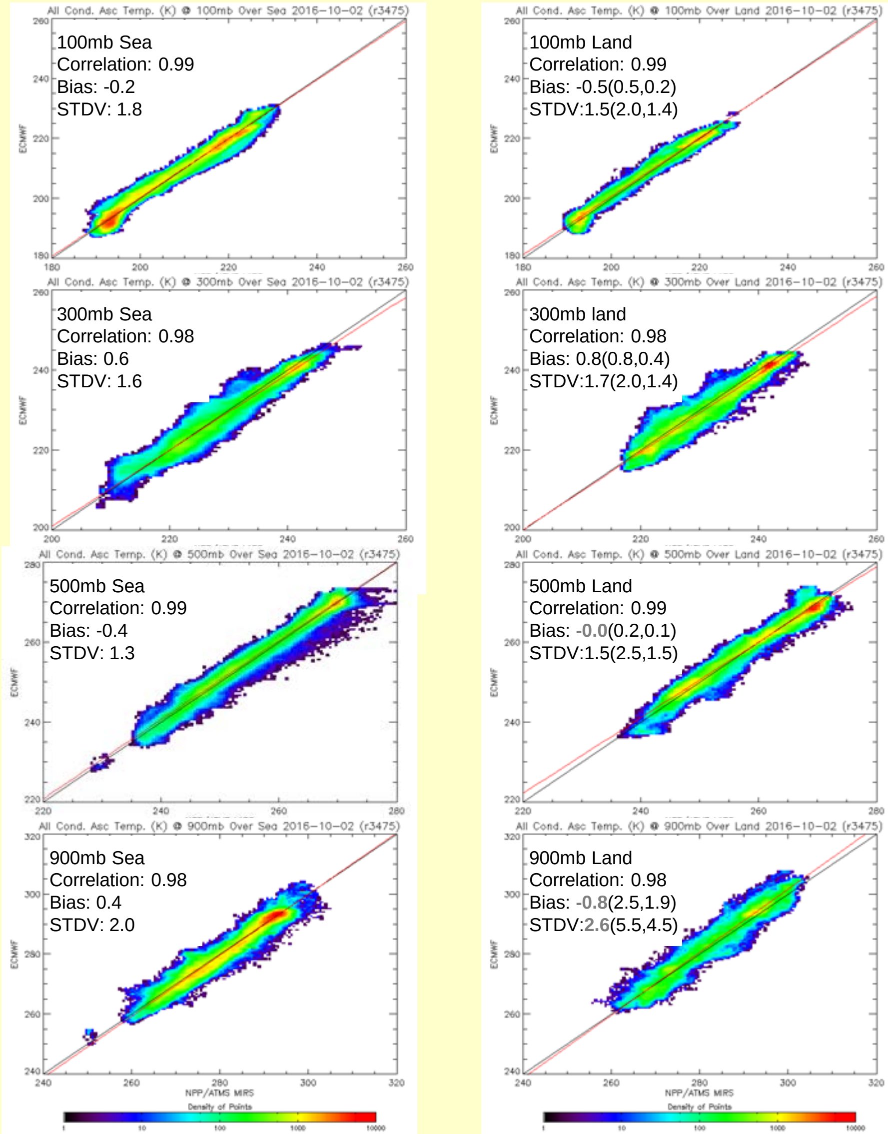
Typhoon Soudelor 3-Dimensional Structure

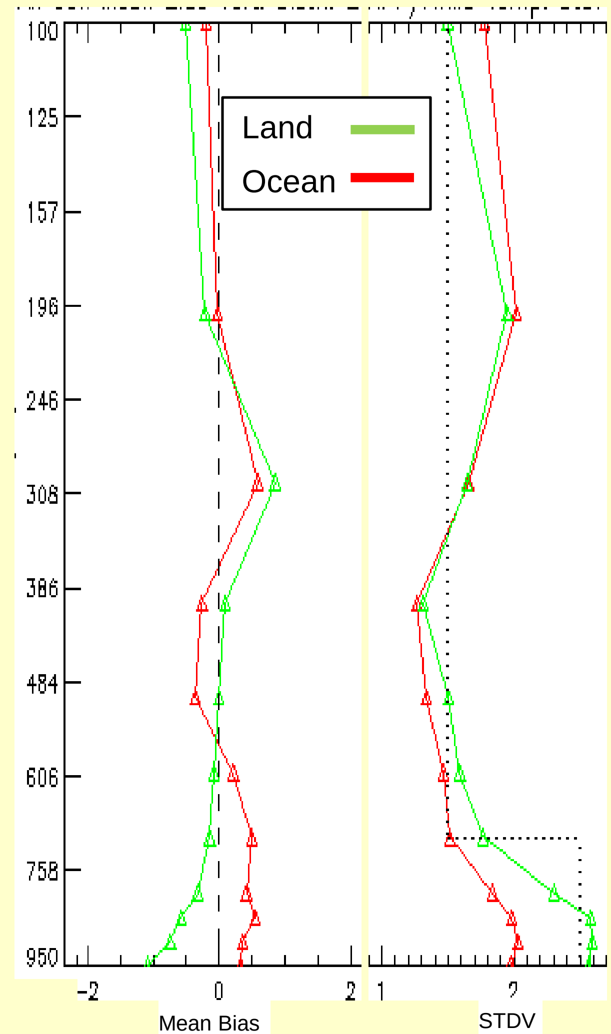
- **MiRS simultaneous retrieval of temperature profile and hydrometeors allows depiction of storm structure**



Validation Results: Temperature Profile

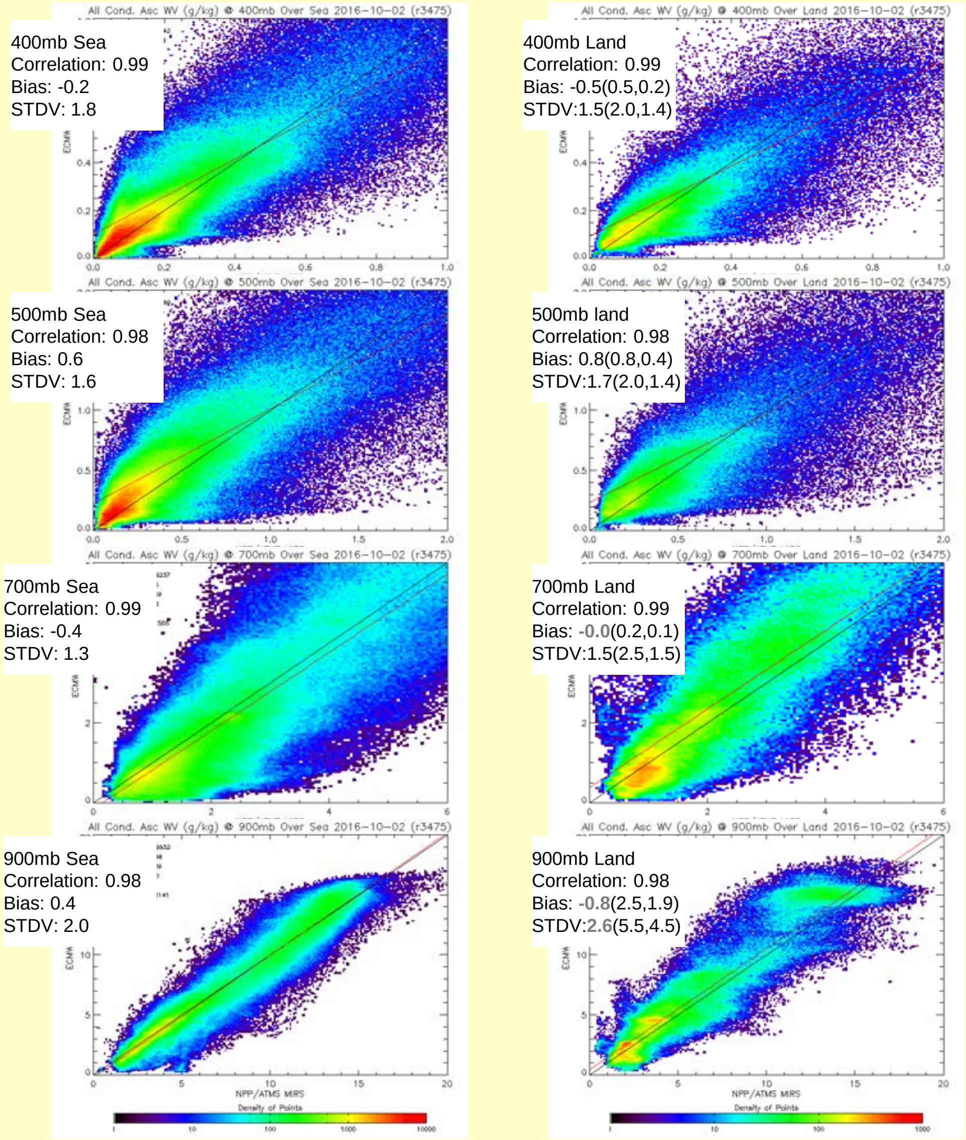
Global all Condition T Statistic refer to ECMWF

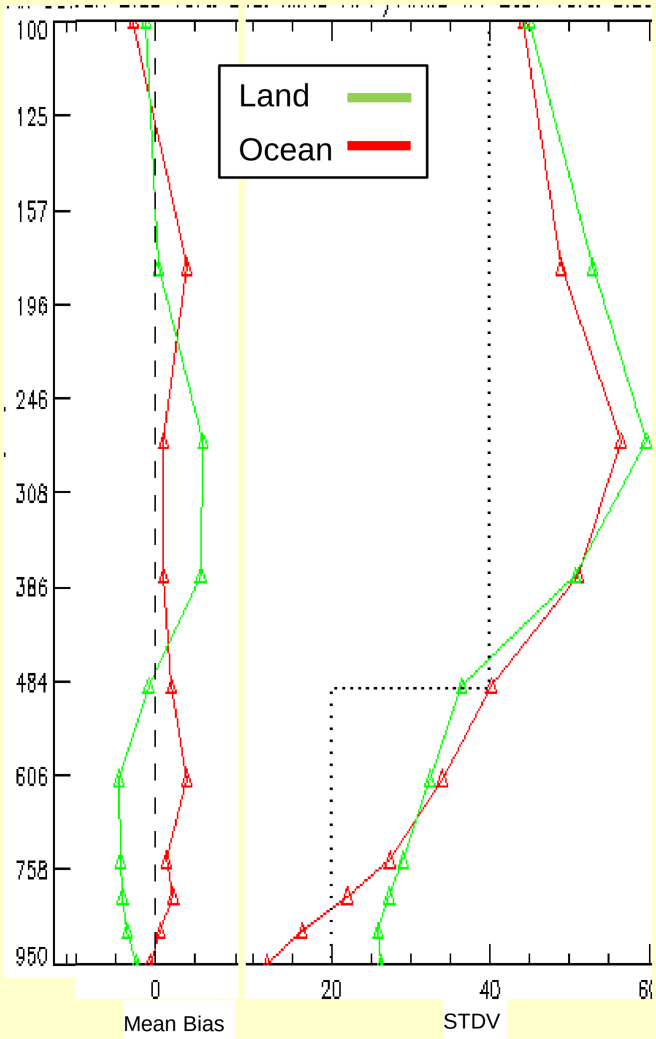




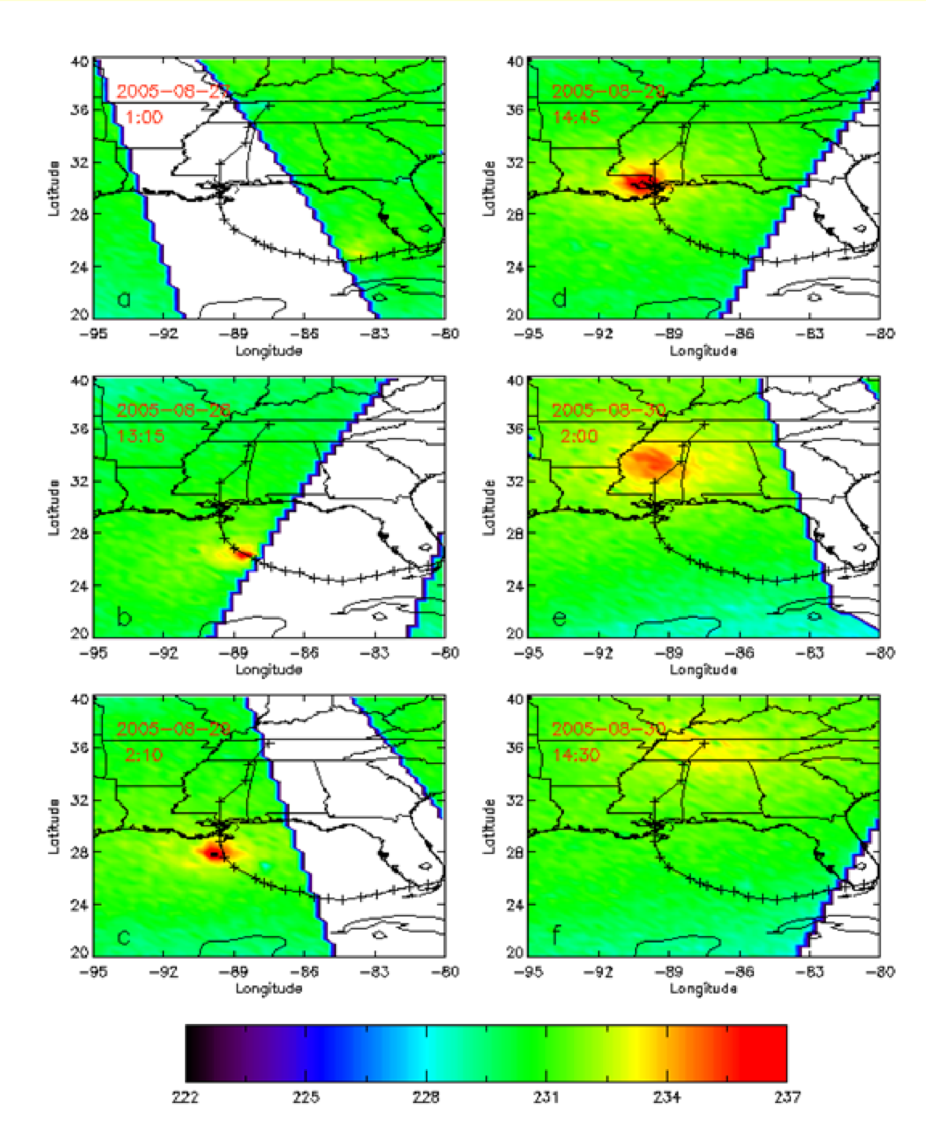
Validation Results: Water Vapor Profile

Global all Condition Water Vapor Statistic refer to ECMWF





Radiances in studying Hurricane (warm Core from SSMIS Observations at 54.4 GHz)



The SSMIS measures radiances in 24 channels covering a wide range of frequencies (19 – 183 GHz) conical

scan geometry at an earth incidence angle of 53 degrees maintains uniform spatial resolution,

across the entire swath of 1700 km.

Comparison between Test-run and Control-run

Forecasting time (hour)	Surface minimum pressure (hPa)			Surface maximum wind (m/s)		
	Control	Test	Observation	Control	Test	Observation
00	988.87	983.31	959.00	26.18	31.51	46.20
06	981.55	974.60	950.00	36.36	30.46	48.80
12	970.80	957.90	942.00	39.05	39.33	51.40
18	964.45	945.81	948.00	39.97	48.99	51.40
24	951.71	936.11	941.00	45.19	49.31	51.40
30	935.58	923.40	930.00	49.40	57.20	64.20
36	927.75	913.17	909.00	54.86	58.20	74.50
42	918.92	908.72	902.00	57.94	58.31	77.10
48	916.38	905.25	905.00	54.31	59.67	71.90

Control: operational at that time
Test: Control + SSMIS

Discussions

- Satellite sensor data assimilations for NWP and data assimilation at the STAR
- Radiometric data impact assessment in Observing System Simulation Experiments (OSSEs)
- Radiometric instrument design, calibration and monitoring (e.g. ICVS)
- Physical retrievals of atmospheric and surface state variables (JPSS MiRS, GOES-R sounding)
- Air-quality monitoring and forecast
- Reanalysis and climate studies
- Aircraft campaign
- SmallSat and CubeSat innovation (e.g. MicroMas-2)
- Scientific research and education