



# Recent Progress on Soundings and Derived Parameters such as Total Precipitable Water vapor

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**STAR** Center for Satellite Applications and Research  
*formerly ORA — Office of Research and Applications*



# Acknowledgements

GOES-R Program: Steve Goodman

JPSS Program: Mitch Goldberg, Lihang Zhou

AWG: Jaime Daniels

CIMSS: Zhenglong Li, Bill Smith, Elisabeth Weisz, Jinlong Li, Yong-Keun Lee, Dave Tobin, Pei Wang, Joleen Feltz, etc. ....

AIT: Graeme Martin, Walter Wolf, etc....

# Outline

- **Synopsis of GOES-R Product Algorithm**
  - Algorithm description
  - Product example(s)
- **Continuing AWG Validation Activities**
  - Latest algorithm performance statistics obtained
  - Results/examples from any case study analyses
  - Synopsis of any algorithm enhancements
  - Showcasing of any validation tools developed
- **Thoughts, Plans, and Opportunities for:**
  - Satellite product algorithm enterprise solutions
  - Smart multi-sensor applications
    - integration of geo and leo products



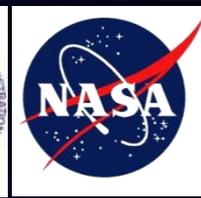
# Products



- Legacy atmospheric temperature profile (10 km, hourly, disk)
- Legacy atmospheric moisture profile (10 km, hourly, disk)
- Total precipitable water (10 km, hourly, disk)
  - Layered PW only an intermediate product
- Lifted index (10 km, hourly, disk)
- Convective available potential energy (10 km, hourly, disk)
- Total totals index (10 km, hourly, disk)
- Showalter index (10 km, hourly, disk)
- K-index (10 km, hourly, disk)



# Requirements (Legacy Atmospheric Profiles)



<i>Product</i>	<i>Accuracy</i>	<i>Precision</i>	<i>Latency (mesoscale)</i>	<i>horizontal resolution</i>
<i>Temperature profile (K)</i>	1K below 400 hPa and above boundary	2K below 400 hPa and above boundary	4.4 min	10 km
<i>Moisture profile (RH)</i>	Sfc-500 mb: 18% relative humidity; 500-300 mb: 18% relative humidity; 300-100 mb: 20% relative humidity	Sfc-500 mb: 18% relative humidity 500-300 mb: 18% relative humidity 300-100 mb: 20% relative humidity	4.4 min	10 km
<i>Derived stability indices</i>	LI: 2 K CAPE: 1000 J/ kg SI: 2 K TT: 1 KI: 2	Lifted Index: 6.5 K CAPE: 2500 J/ kg Showalter index:6.5 K Total totals Index:4 K index: 5	2.7 min	10 km
<i>TPW</i>	1 mm	3 mm	4.4 min	10 km



# LAP Sounding Processing Schematic



BT: Channel 7 to 16 IR Brightness Temperature

$T(p)$  = Temperature profile

$W(p)$  = Moisture profile

$P_{sfc}$  = Surface air pressure

$T_{skin}$  = Surface skin temperature

$E_{sfc}$  = Surface IR emissivity

$Flag_{lw}$  = Land/water flag

LZA = Local zenith angle

Lat = Latitude

Mon = numerical month ID (1 to 12)

$WS_{sfc}$  = Near surface wind speed

$T_{sfc}$  = Near surface air temperature

$W_{sfc}$  = Near surface air moisture

**INPUT: (Required) BT, forecast  $T(p)/W(p)/P_{sfc}/T_{skin}$ ,  $E_{sfc}$ ,  $Flag_{lw}$ , LZA, Lat, Mon; (Optional)  $WS_{sfc}$ ,  $T_{sfc}$ ,  $W_{sfc}$**

**Retrieval Algorithm**  
*(Regression followed by physical iteration)*

**OUTPUT: Retrieved  $T(p)/W(p)/T_s$**

**Calculate derived products**

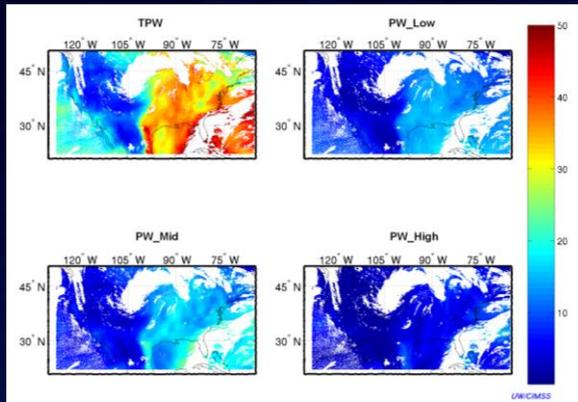
**OUTPUT: TPW, layered PW, LI, CAPE, KI, TT, SI**



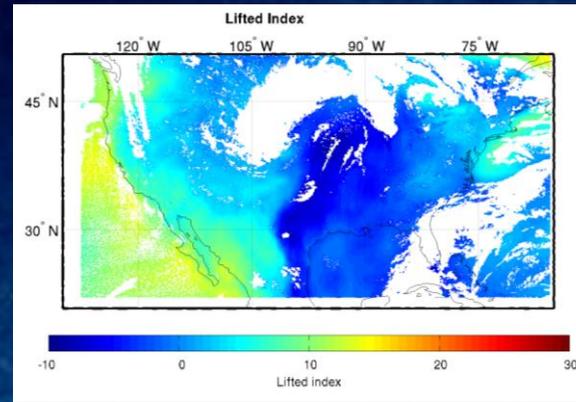
# Example LAP Output using Simulated ABI data



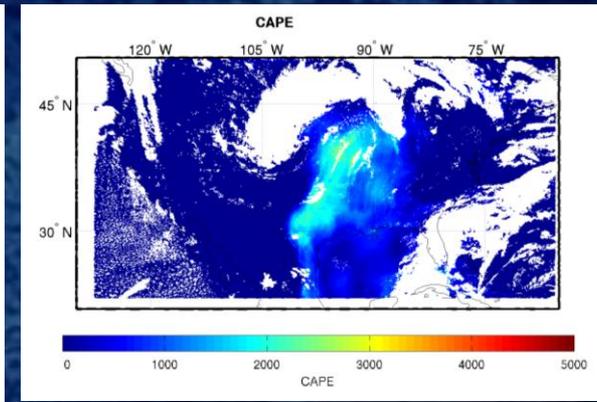
## TPW and layered PW



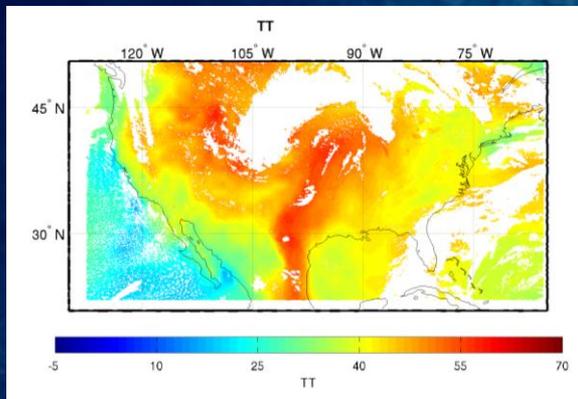
## Lifted Index



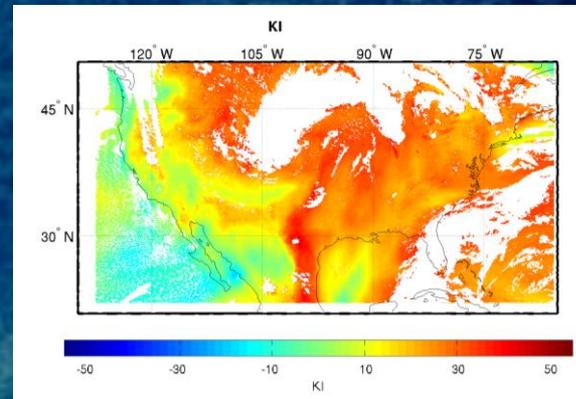
## Convective Available Potential Energy



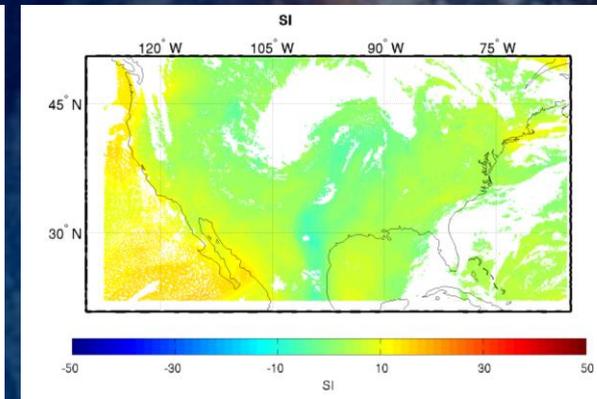
## Total Totals



## K Index



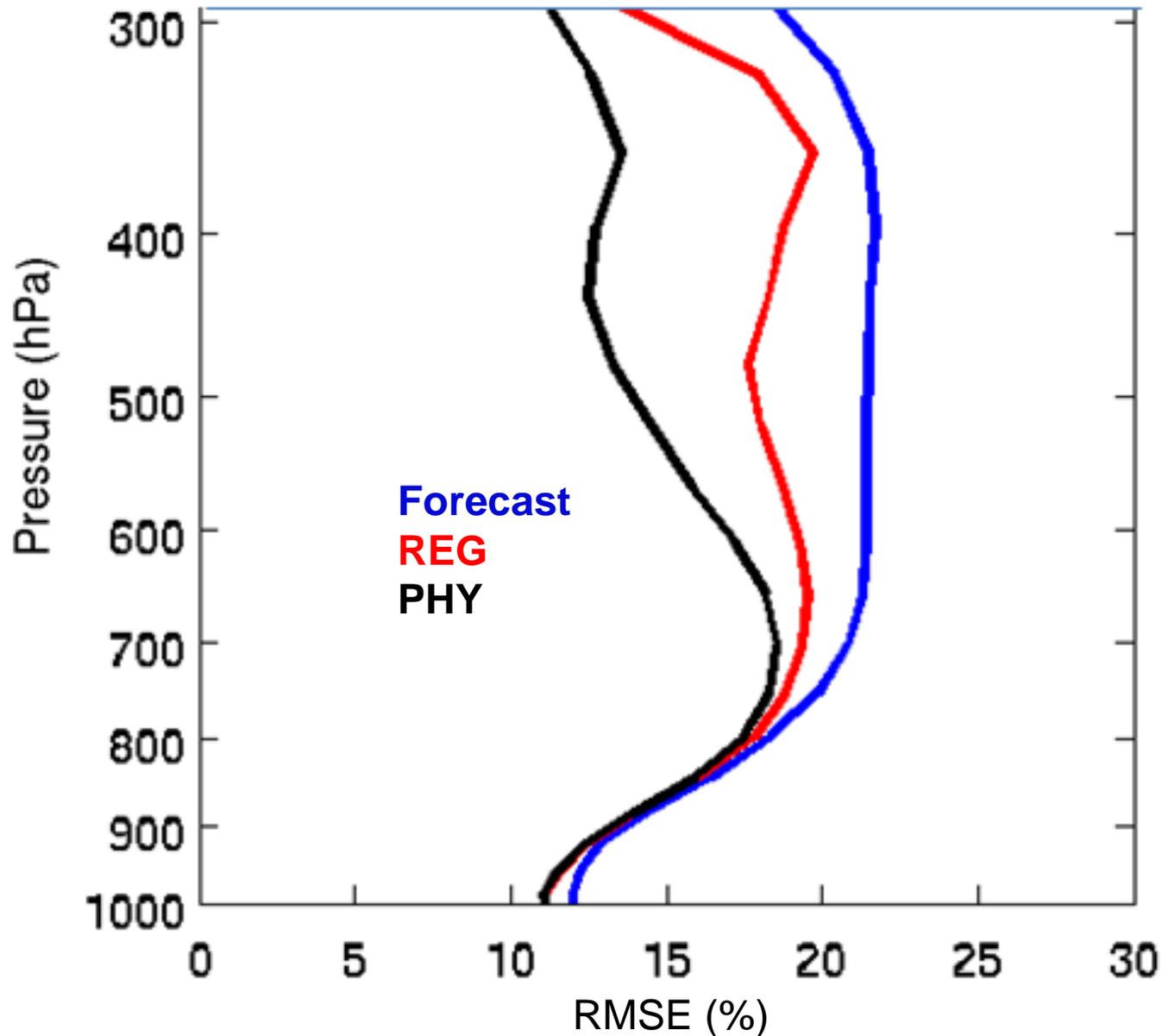
## Showalter Index



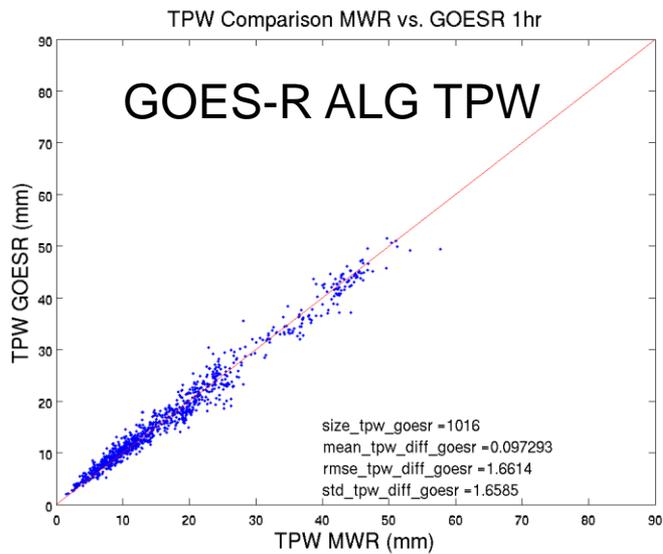
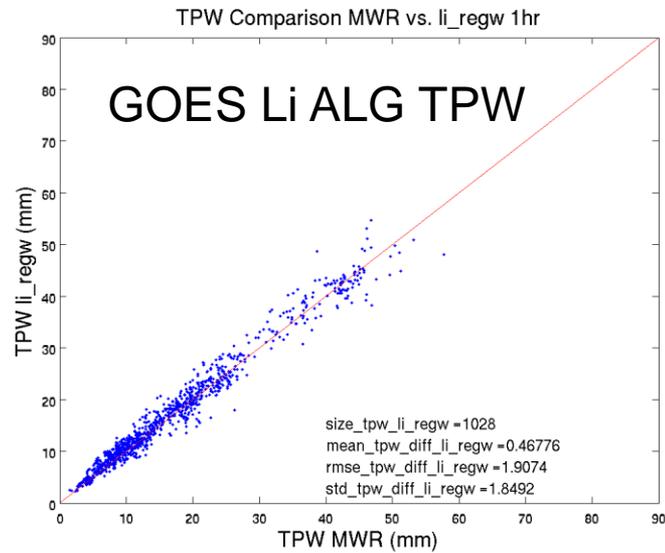
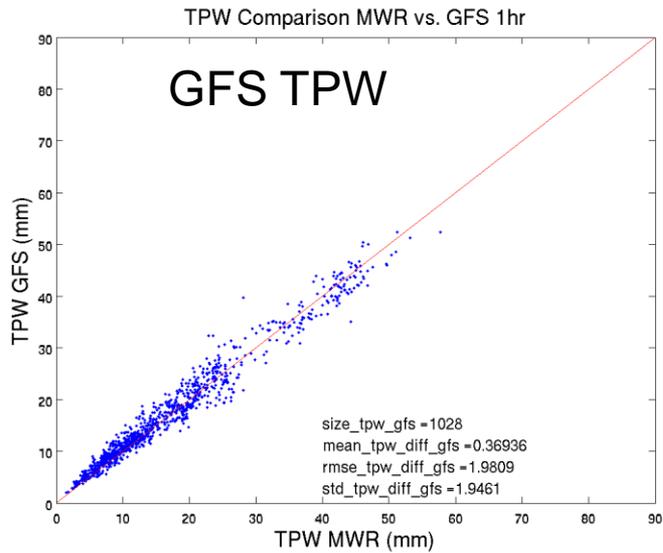
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# Validation with SEVIRI (both Meteosat-8 and -9)

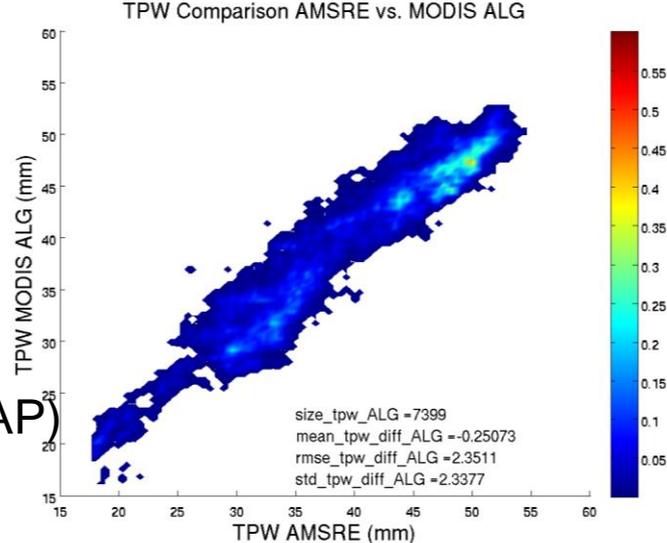
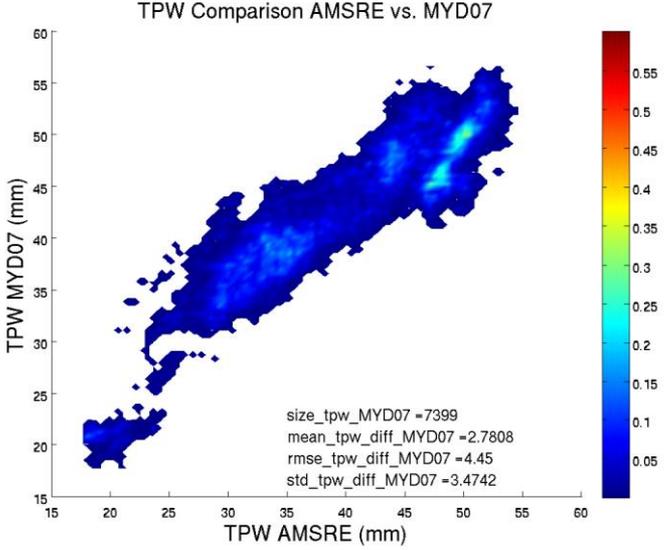
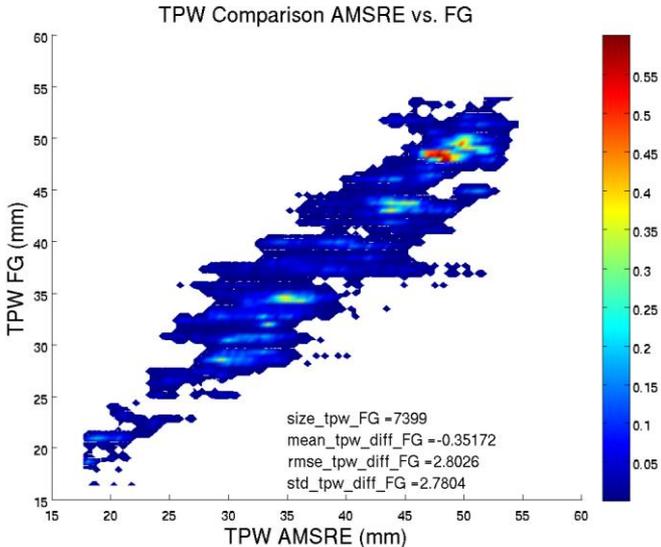


The RH retrieval root mean square error (RMSE) from SEVIRI of **Meteosat-9** compared with the spatially and temporally collocated radiosondes. Results are consistent with that of **Meteosat-8**



TPW (mm)	Mean	RMSE	STD
GFS	0.37	1.98	1.95
Li ALG	0.47	1.90	1.85
<b>GOES-R ALG</b>	<b>0.10</b>	<b>1.66</b>	<b>1.66</b>
Spec	1.00		3.00

# GOES-R algorithm validation with MODIS (2008 Sep. 07 1825 UTC)



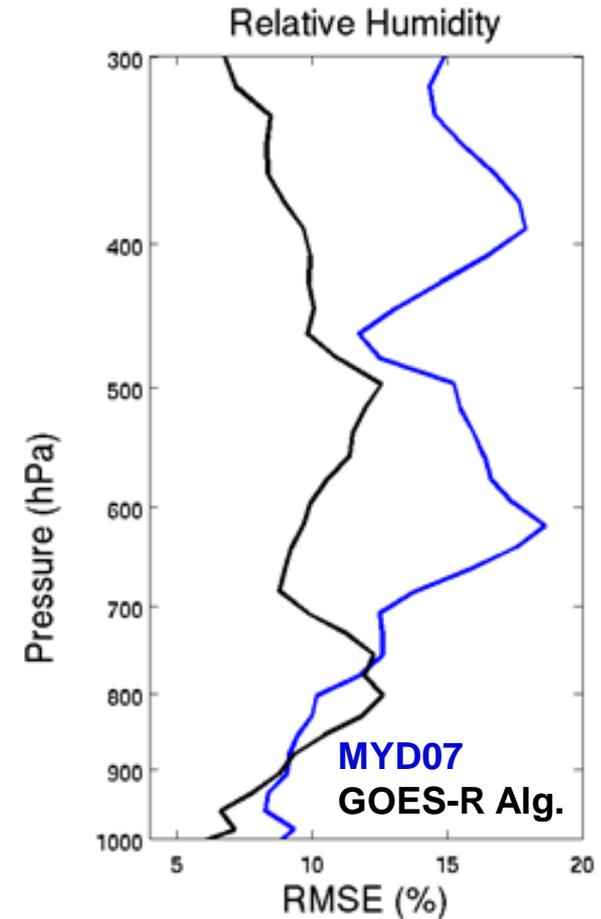
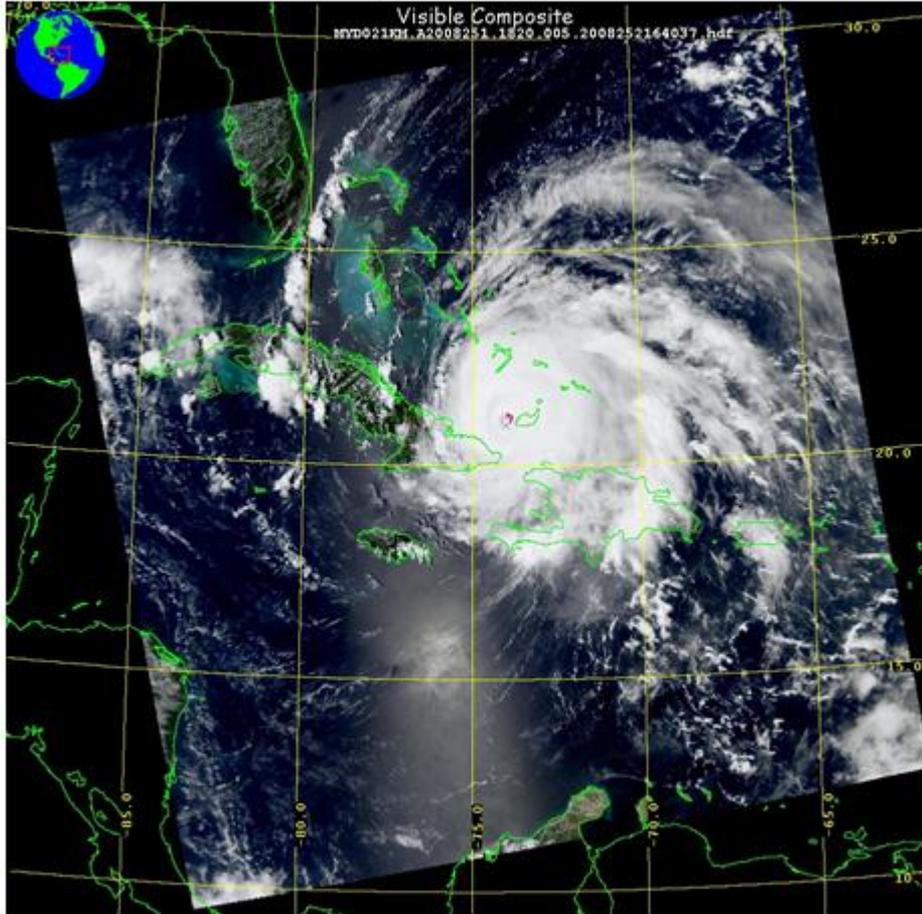
AMSR-E  
GFS

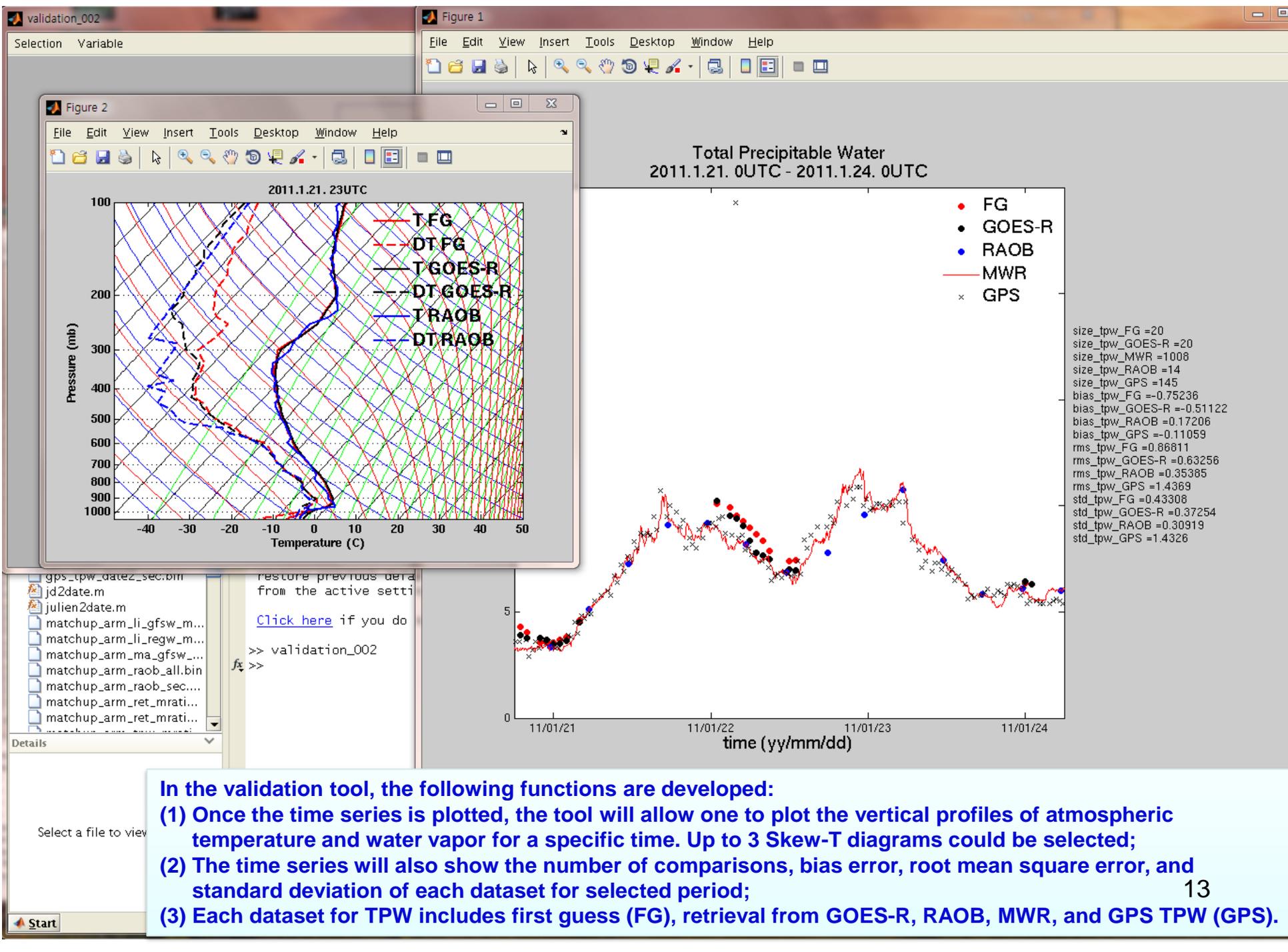
AMSR-E  
MODIS (Operational)

AMSR-E  
MODIS (GOES-R LAP)

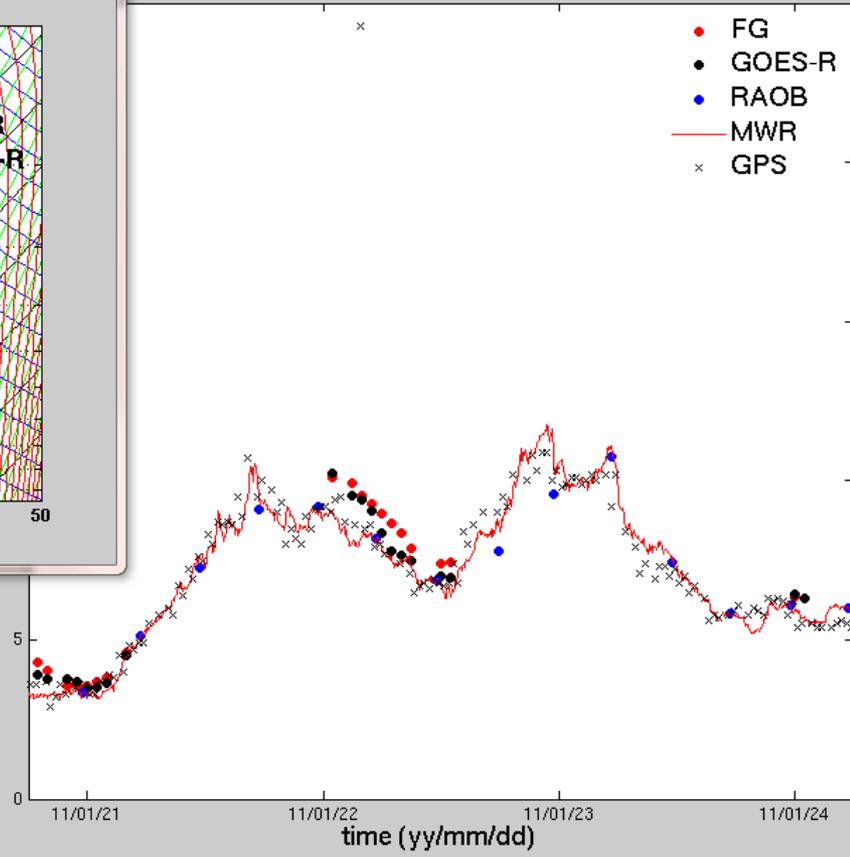
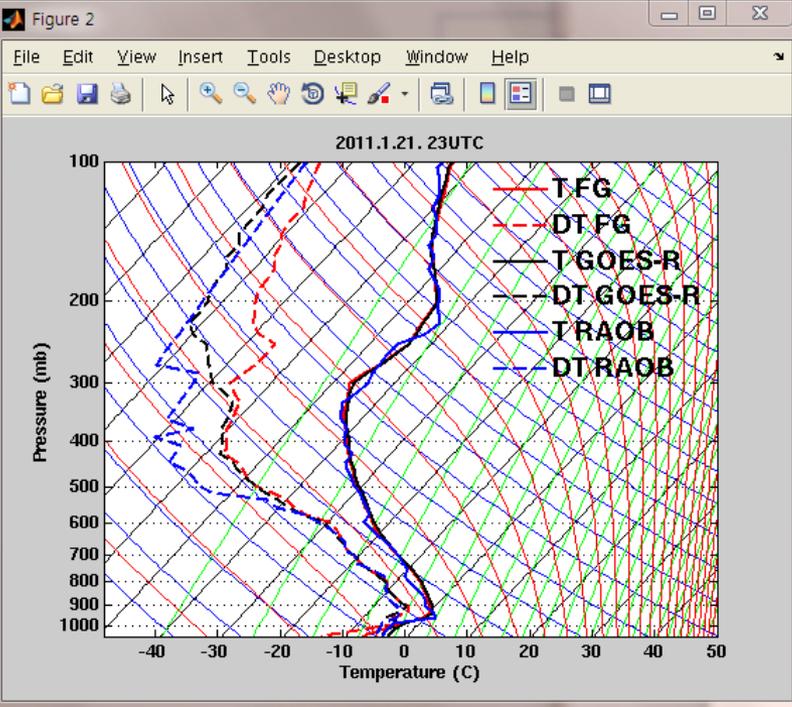
# GOES-R LAP algorithm improves operational MODIS TPW product; the new MODIS TPW with GOES-R algorithm will be used in 2012 HIW studies

MODIS visible image on 2008.09.07. 1820 UTC





Total Precipitable Water  
2011.1.21. 0UTC - 2011.1.24. 0UTC

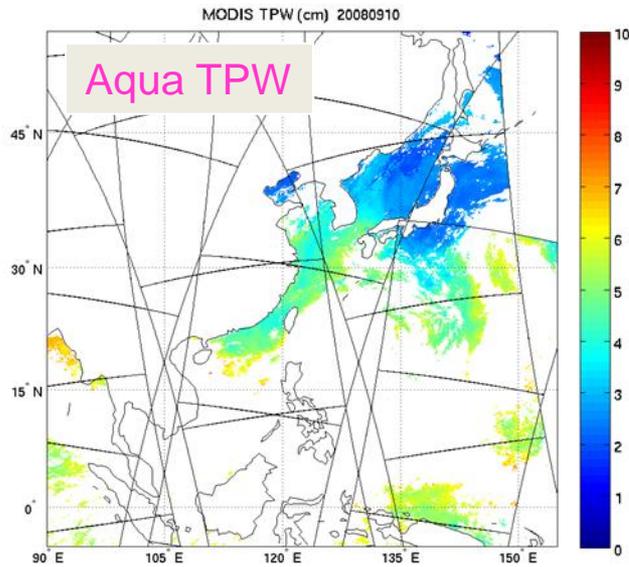
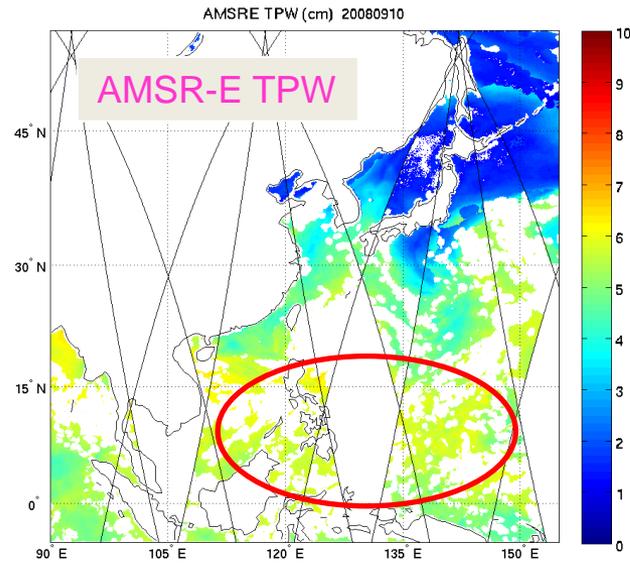
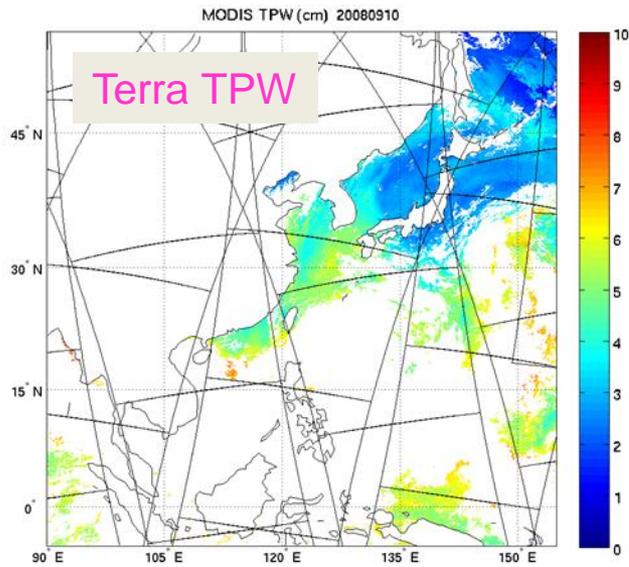


size_tpw_FG	=20
size_tpw_GOES-R	=20
size_tpw_MWR	=1008
size_tpw_RAOB	=14
size_tpw_GPS	=145
bias_tpw_FG	=-0.75236
bias_tpw_GOES-R	=-0.51122
bias_tpw_RAOB	=0.17206
bias_tpw_GPS	=-0.11059
rms_tpw_FG	=0.86811
rms_tpw_GOES-R	=0.63256
rms_tpw_RAOB	=0.35385
rms_tpw_GPS	=1.4369
std_tpw_FG	=0.43308
std_tpw_GOES-R	=0.37254
std_tpw_RAOB	=0.30919
std_tpw_GPS	=1.4326

- In the validation tool, the following functions are developed:**
- (1) Once the time series is plotted, the tool will allow one to plot the vertical profiles of atmospheric temperature and water vapor for a specific time. Up to 3 Skew-T diagrams could be selected;**
  - (2) The time series will also show the number of comparisons, bias error, root mean square error, and standard deviation of each dataset for selected period;**
  - (3) Each dataset for TPW includes first guess (FG), retrieval from GOES-R, RAOB, MWR, and GPS TPW (GPS).**

# Outline

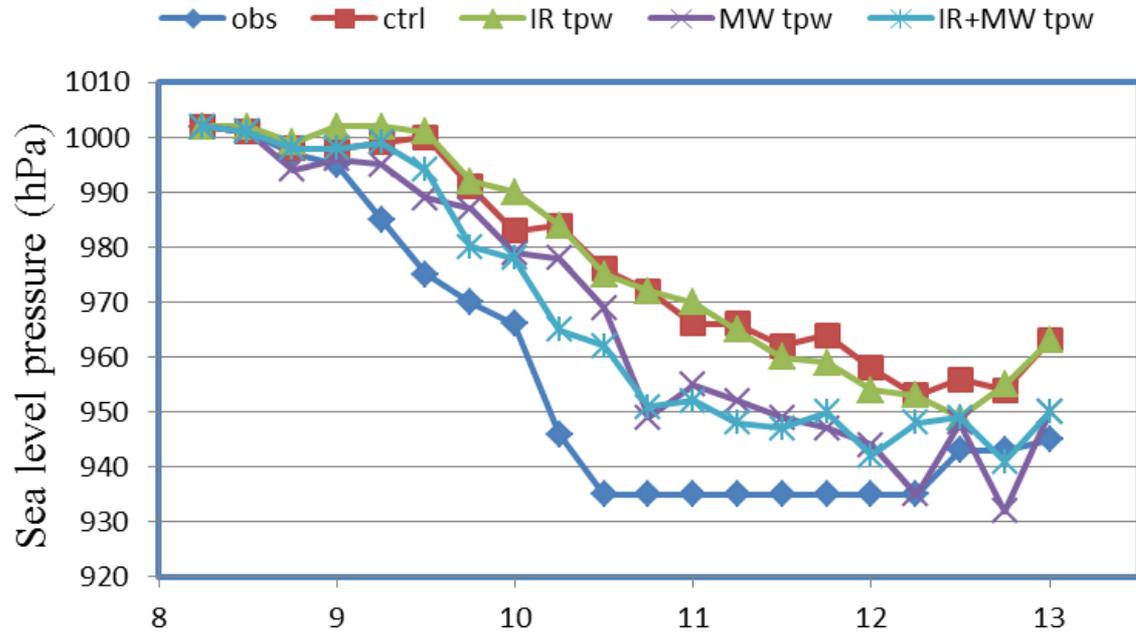
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Terra MODIS (upper left), Aqua MODIS (lower left) and AMSR-E (upper right) TPW images over ocean for 10 September 2008. The spatial resolution is 5 km for MODIS TPW and 17 km for AMSR-E TPW.

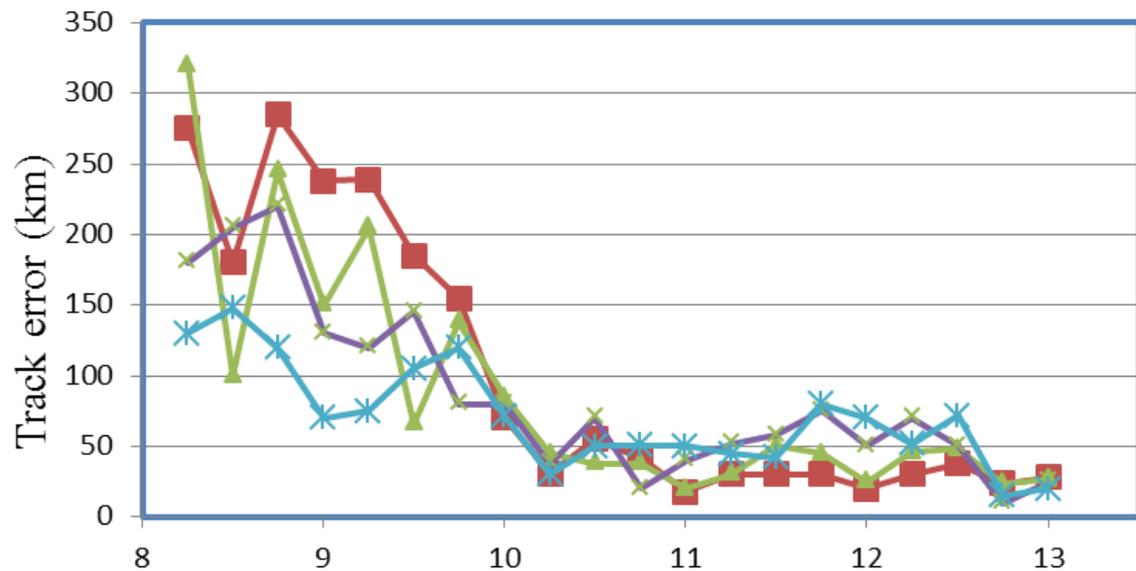
# Sinlaku intensity and path analysis with TPW (WRF/DART)

## (IR – MODIS; MW – AMSR-E)



**CTL run:** assimilate radiosonde, satellite cloud winds, QuikSCAT winds, aircraft data, COSMIC GPS refractivity, ship, and land surface data.

**Rapid intensification from 9 to 10 September 2008 captured with TPW assimilated**



NPP/JPSS soundings , GCOM AMSR TPW and GOES-R TPW will be used in tropical cyclone applications

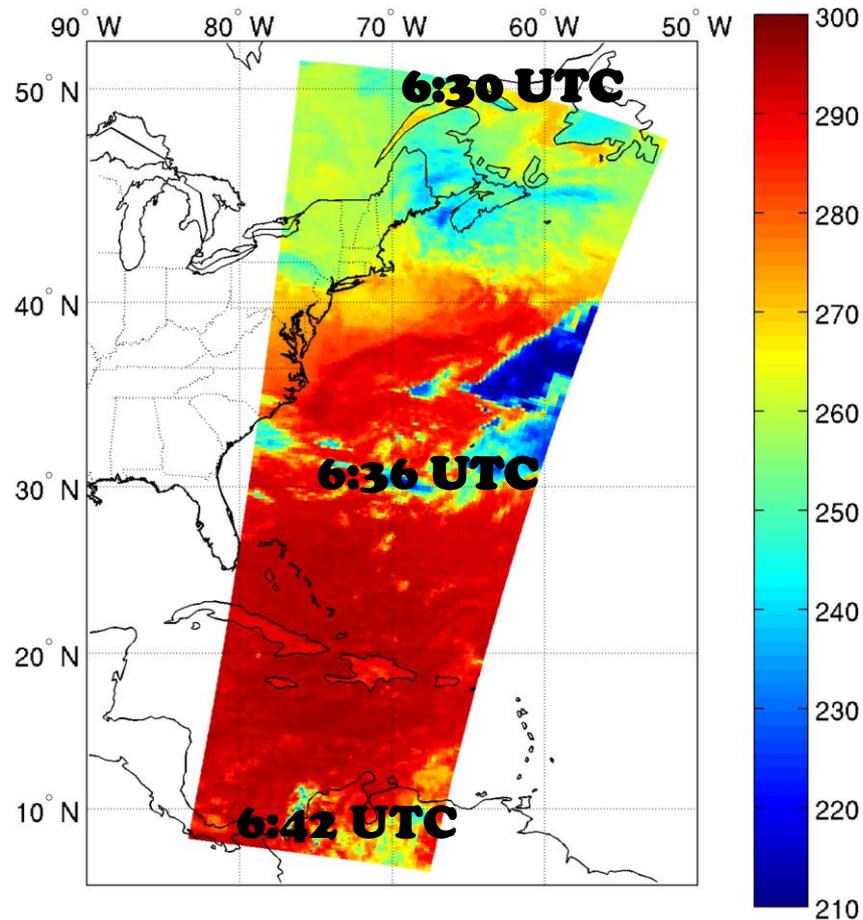
# NPP/JPSS sounding evaluation and applications

- AIRS/CrIS brightness temperature comparison
- AIRS/CrIS sounding comparisons with the same retrieval algorithm (CIMSS single FOV algorithm)
- Radiances/soundings application demonstration

# CrIS/AIRS BT Comparison

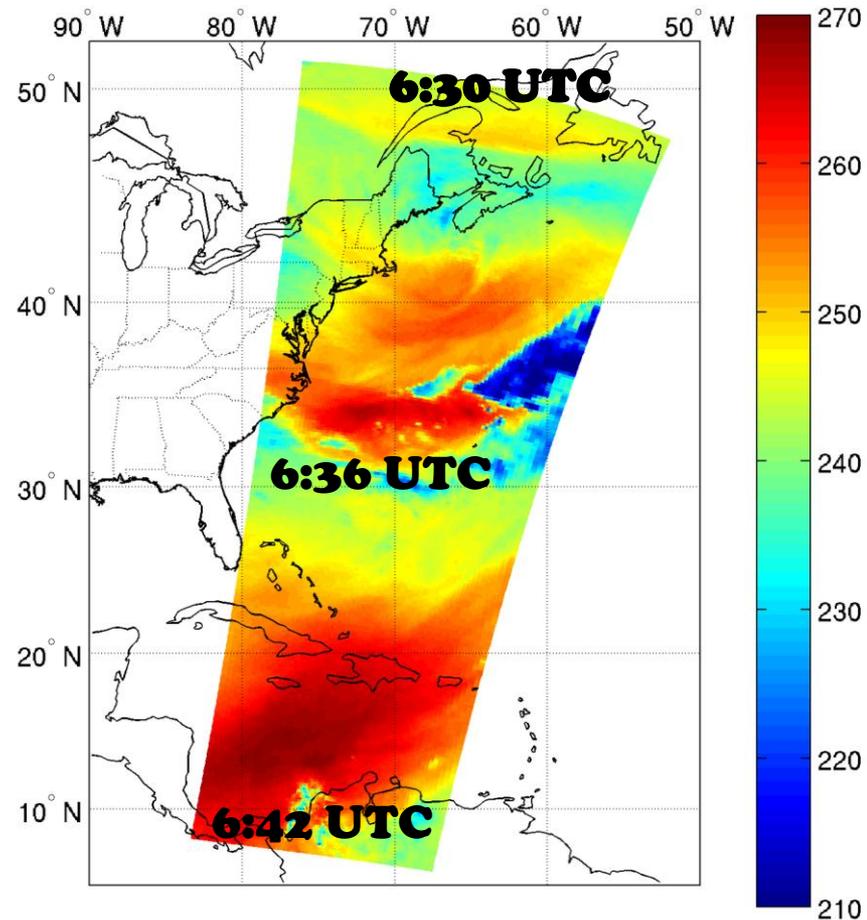
AIRS Window Channel Tb (K)

AIRS Tb (K) of  $911.24 \text{ cm}^{-1}$



AIRS Water Vapor Channel Tb (K)

AIRS Tb (K) of  $1477.5 \text{ cm}^{-1}$



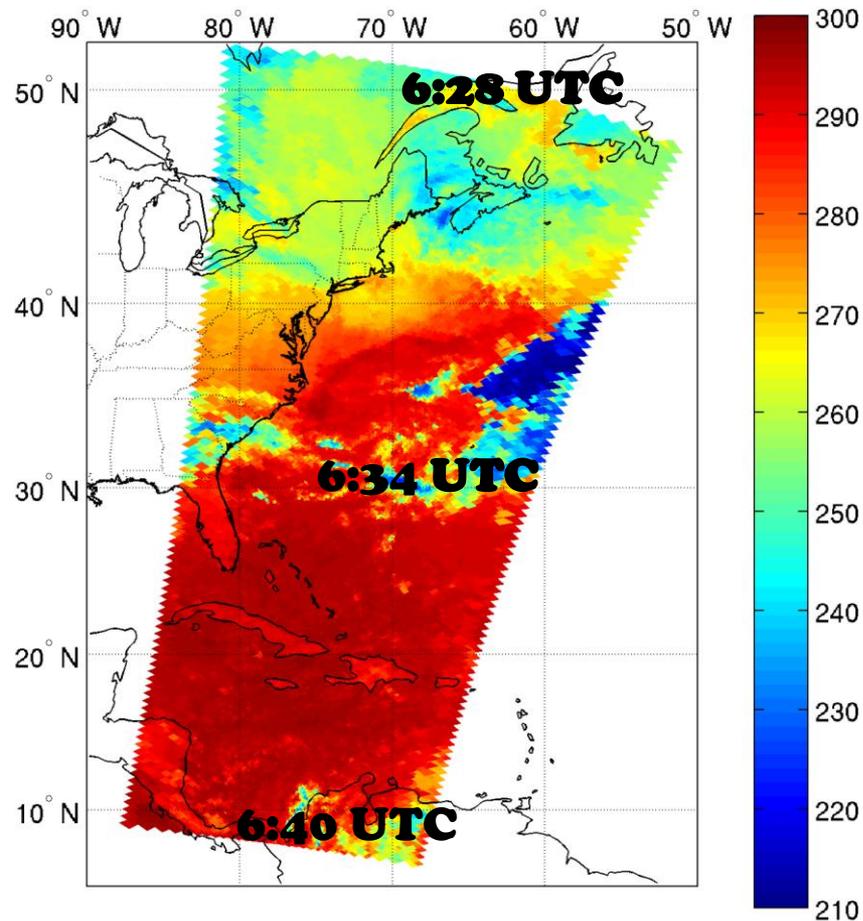
03/12/2012

Two Granules

# CrIS/AIRS BT Comparison

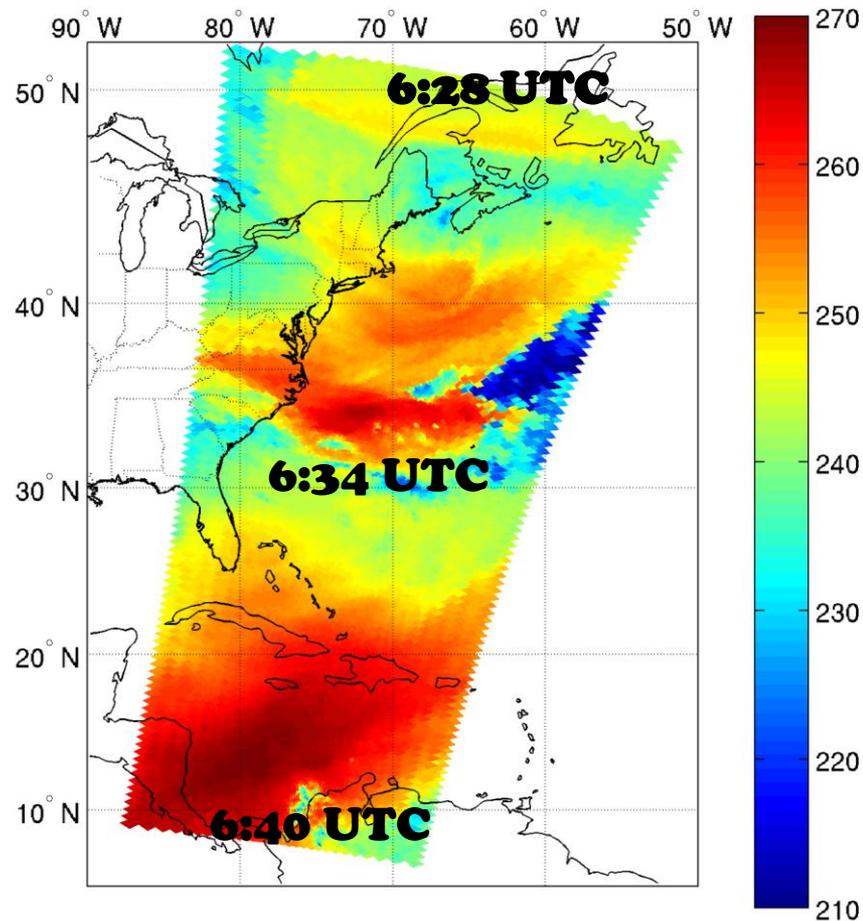
CrIS Window Channel Tb (K)

CrIS Tb (K) of  $911.25 \text{ cm}^{-1}$



CrIS Water Vapor Channel Tb (K)

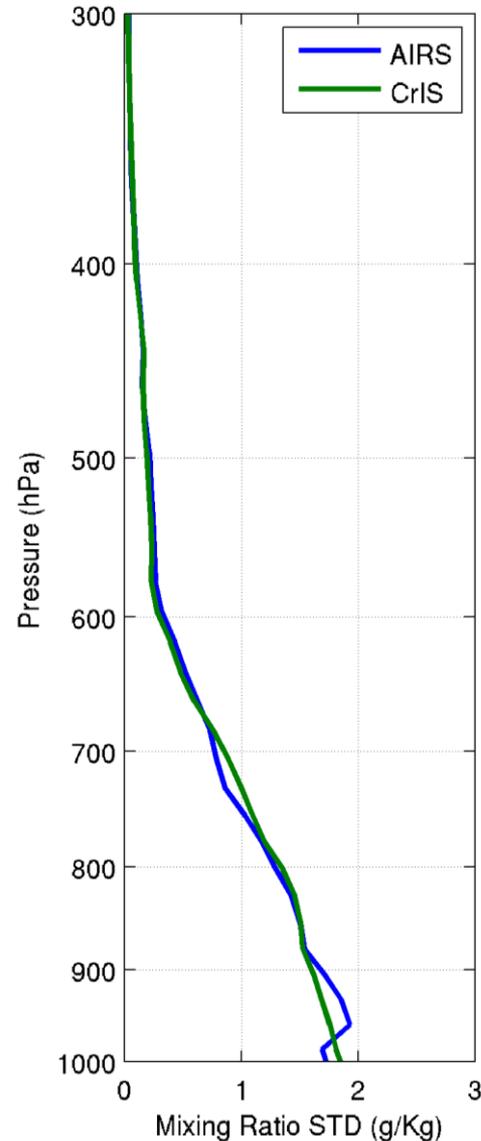
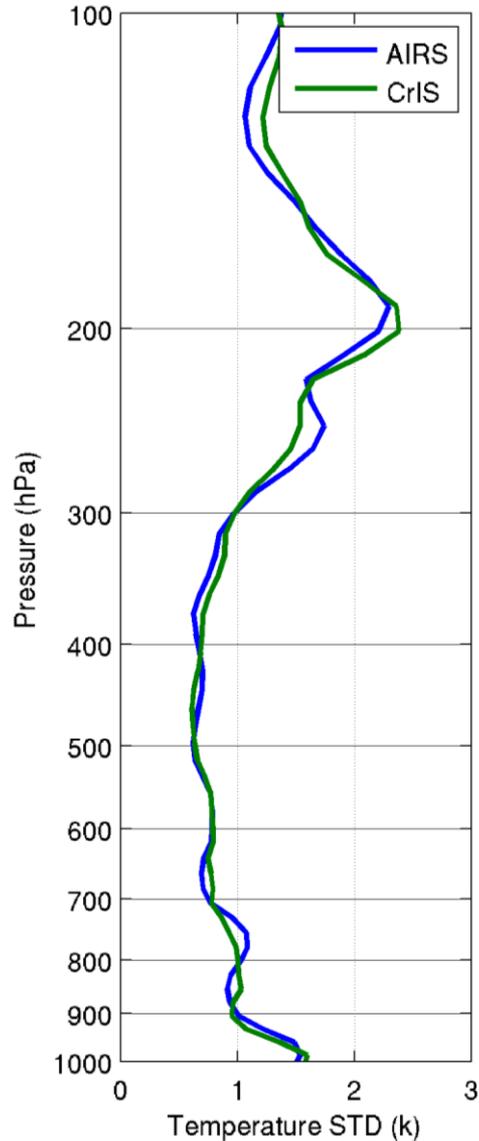
CrIS Tb (K) of  $1477.5 \text{ cm}^{-1}$



03/12/2012

# AIRS/CrIS sounding comparisons – AIRS and CrIS have the similar sounding precision

(2275 matchup comparisons, ECMWF analysis as reference)

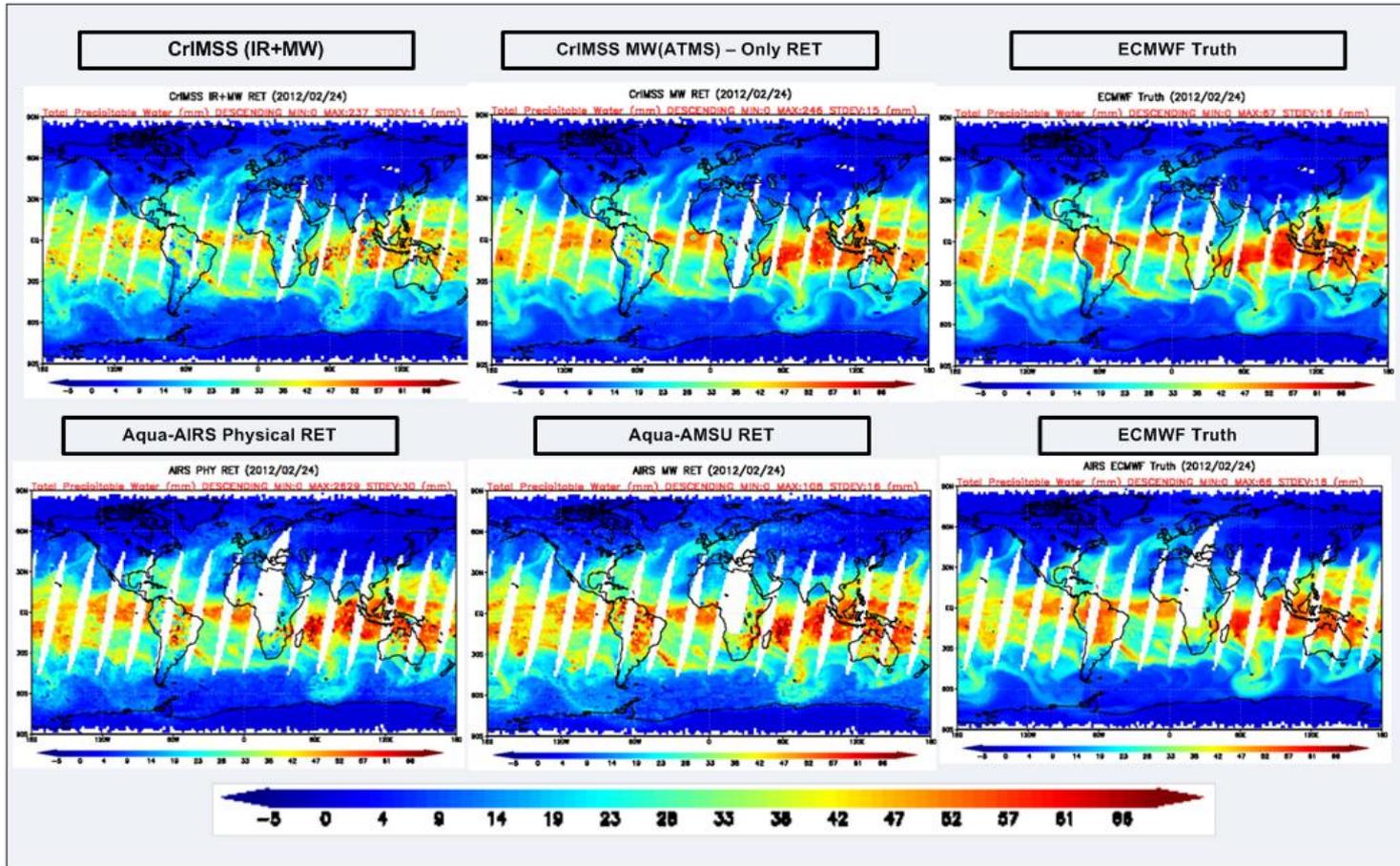




# NGAS CrIMSS AVMP EDR: TPW (Feb. 24, 2012 focus day)



Northrop Grumman Aerospace Systems Crosstrack Infrared and Microwave Sounding Suite Atmospheric Vertical Moisture Profile Environmental Data Record : Total Precipitable Water



- Preliminary TPW without QC
  - Seem to be issues with dry retrievals over land



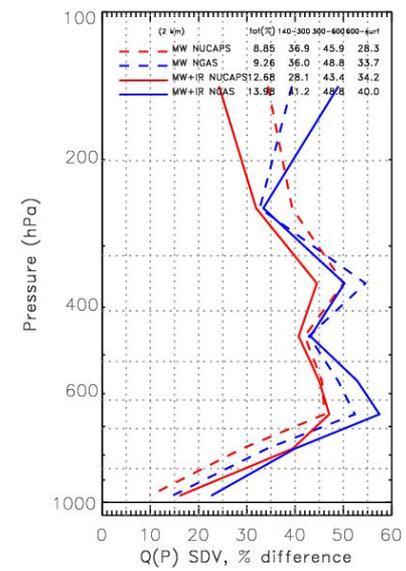
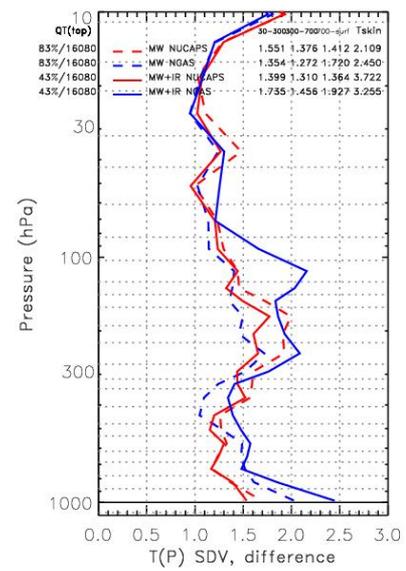
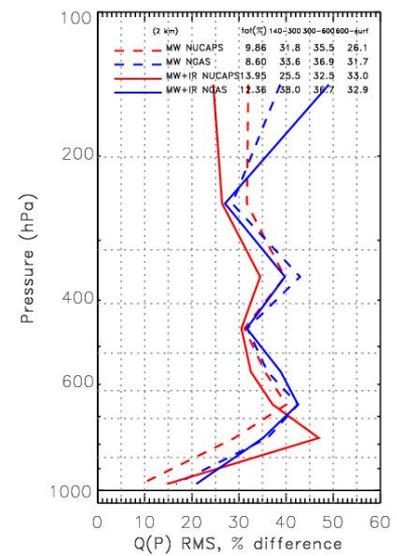
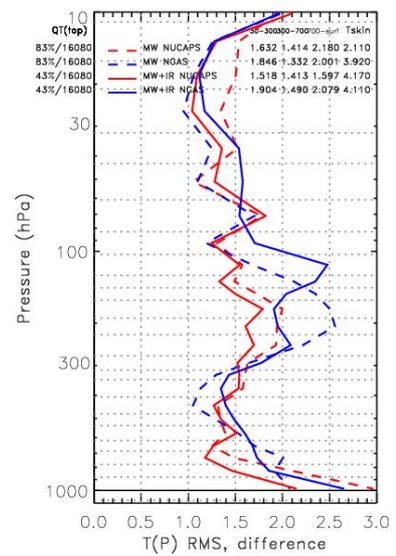
# Preliminary comparison of NGAS & NUCAPS



(Northrop Grumman Aerospace Systems and NOAA-Unique CrIS/ATMS Processing system)

(134 ocean, night granules on Feb. 24, 2012)

- Top panels shows the RMS difference of AVTP and AVMP w.r.t. ECMWF
  - Solid lines are ATMS+CrIS (43% of the cases)
  - Dashed lines are ATMS-only (83% of the cases)
  - **NUCAPS in red**
  - **NGAS in blue**
- NUCAPS acceptance used for all cases
  - Potentially some cases rejected by NGAS should be ignored
- Bottom panel: Once empirical bias corrections are applied results should approach the SDV at right.



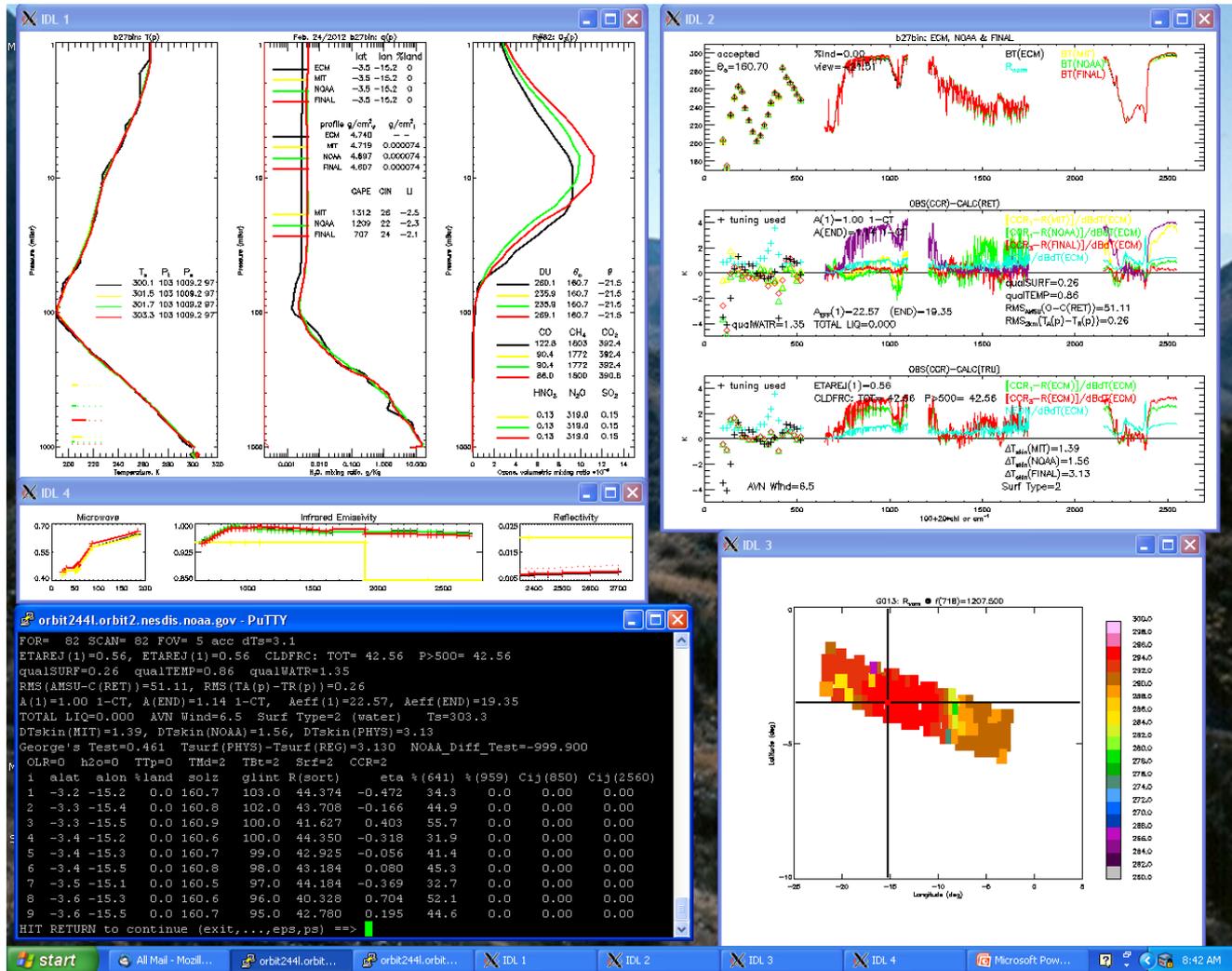


# Preliminary example of diagnostic capability of NUCAPS: individual retrievals



Full state including AVTP, AVMP, clouds, trace gases, emissivity, and reflectivity

Details on QC, location, clouds, etc.



Radiance

Residuals

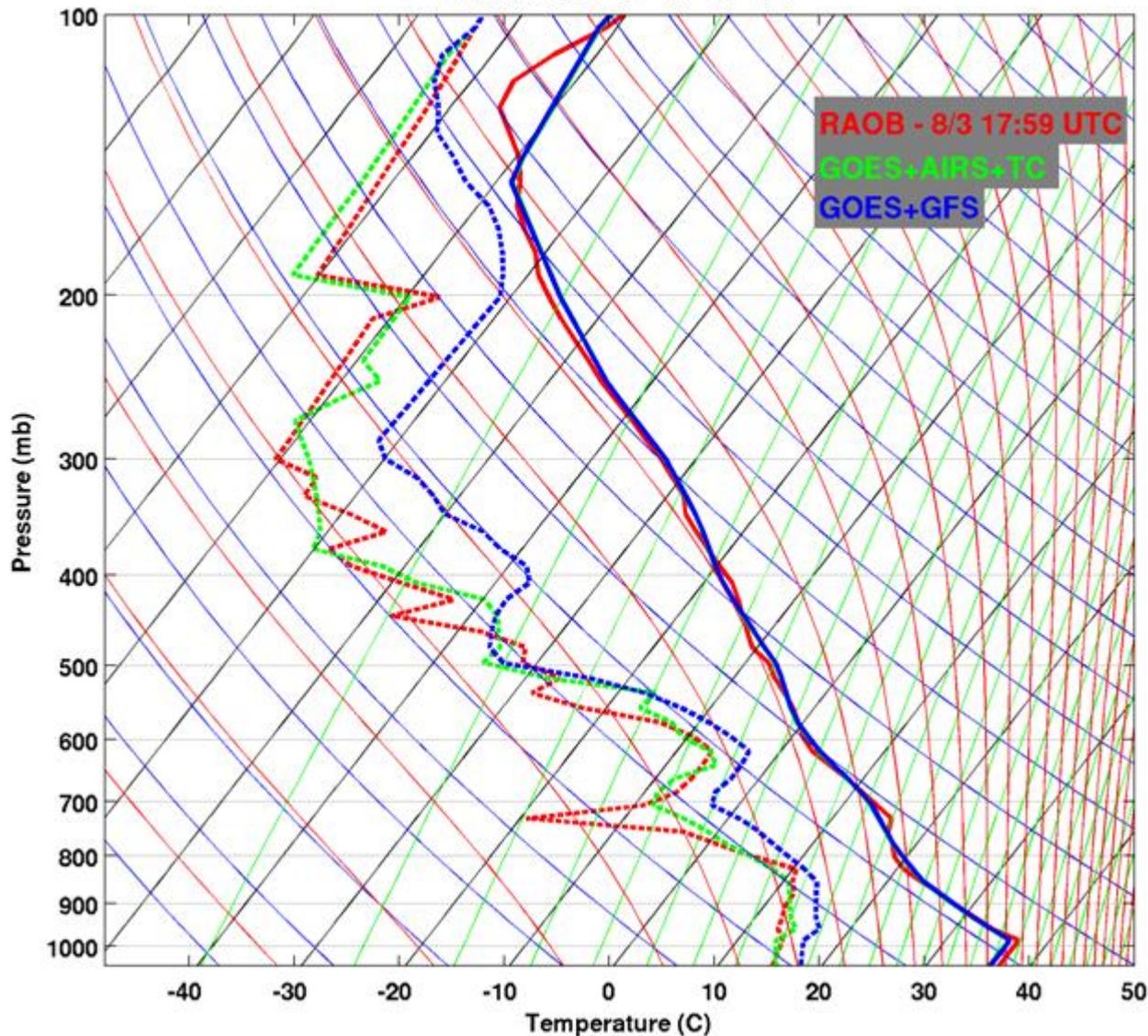
Obs-  
Calc(ECMWF)

Map of 1  
channel

This is a screen capture from a “deep-dive” diagnostic tool that allows simultaneous viewing of a single retrieval in geophysical and radiance space.

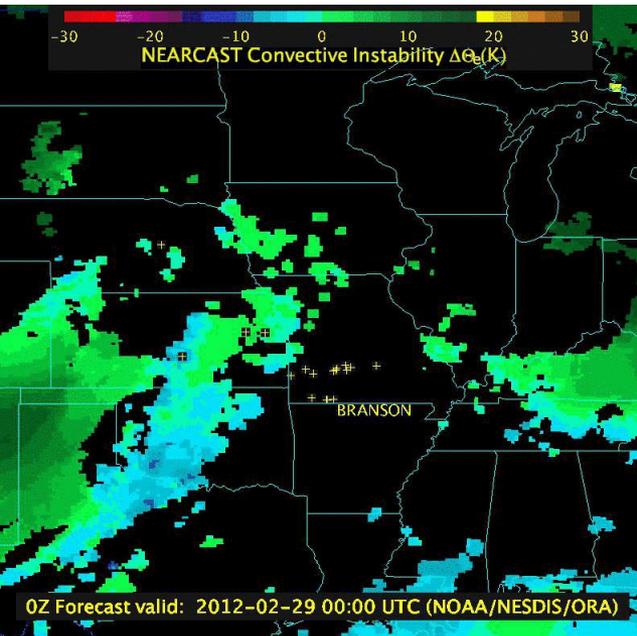
# After 6 hours

SkewT: 2008 8 3 17 59

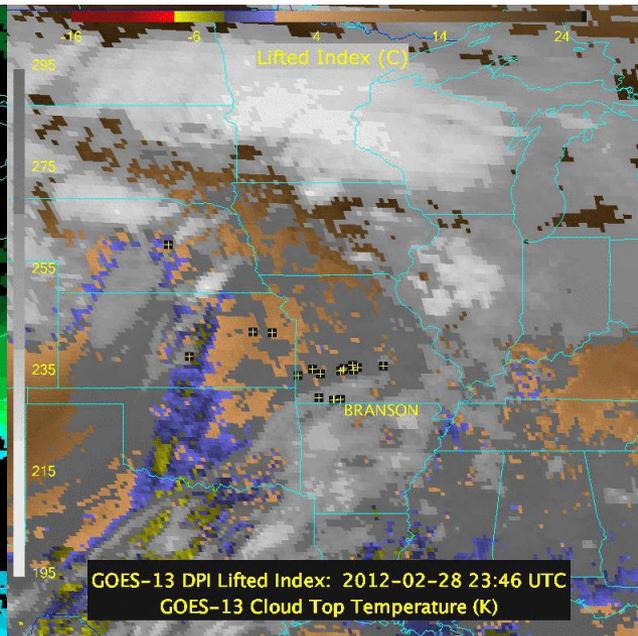


GOES+AIRS+TC:  
using AIRS SFOV  
sounding as first  
guess for physical  
retrieval, and then  
using the previous  
time step retrieval  
as the first guess  
for the current time  
physical retrieval.

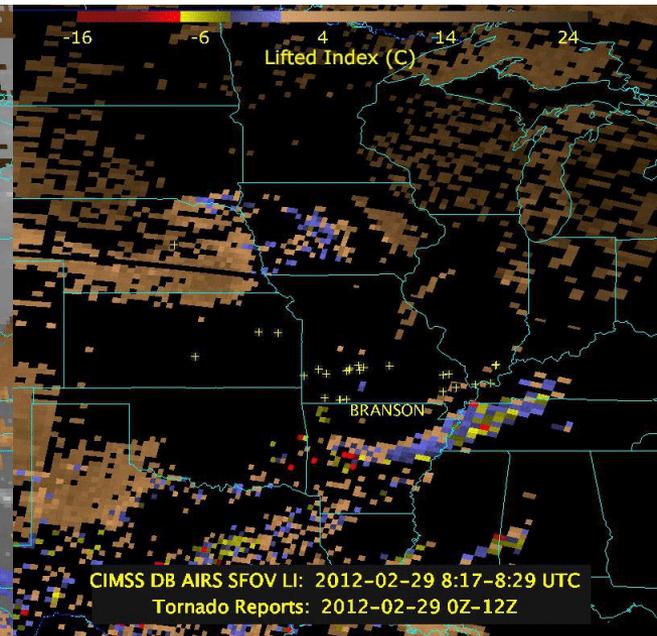
# Animation (GOES Sounder and AIRS)



Nearcast (using Sounder)



Sounder (Lifted Index)



AIRS (Lifted Index)

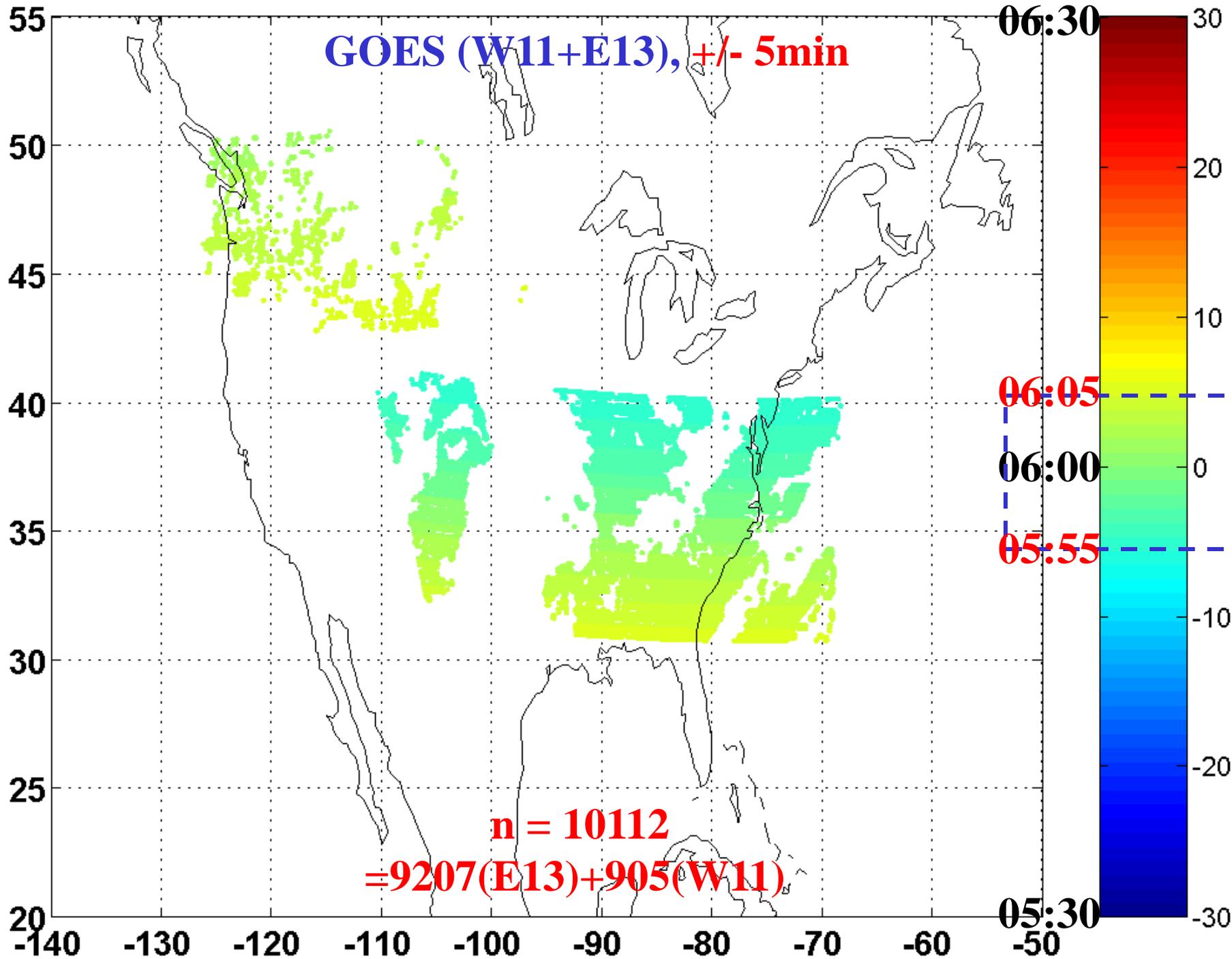
See poster on Nearcast

# Summary

- GOES Sounder, MODIS, SEVIRI AMSR-E TPW as proxy show that GOES-R LAP algorithm provide moisture profiles better than forecasts
- GOES-R LAP algorithm provide better TPW accuracy than the current GOES Sounder algorithm (Li-ALG), suggest to use GOES-R LAP algorithm for operational GOES sounding product
- Recent work done with the CRTM team speeding up the processing
- CrIS has the similar sounding precision of AIRS according to both retrieval and PC analysis
- Combined GOES-R TPW, JPSS soundings and GCOM AMSR TPW can improve hurricane forecasts
- Awaiting validation ATBD template
- ABI isn't a full sounder!

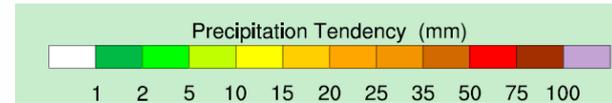
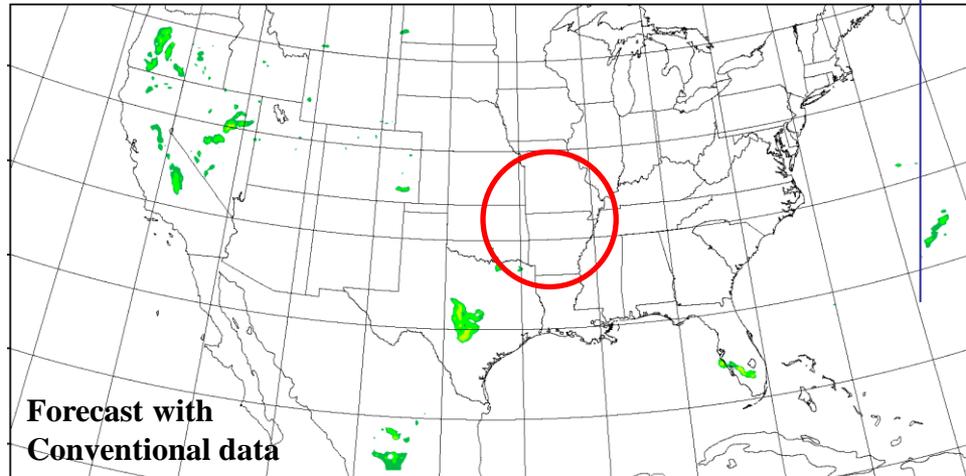
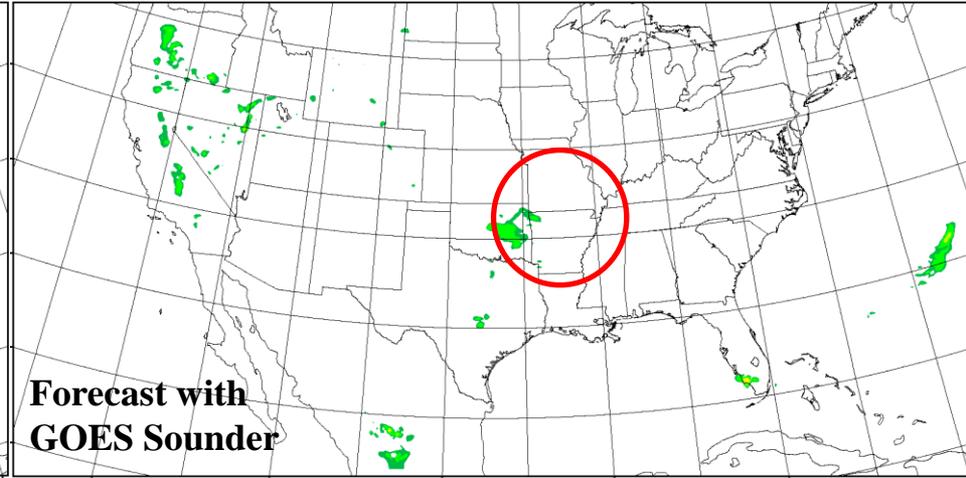
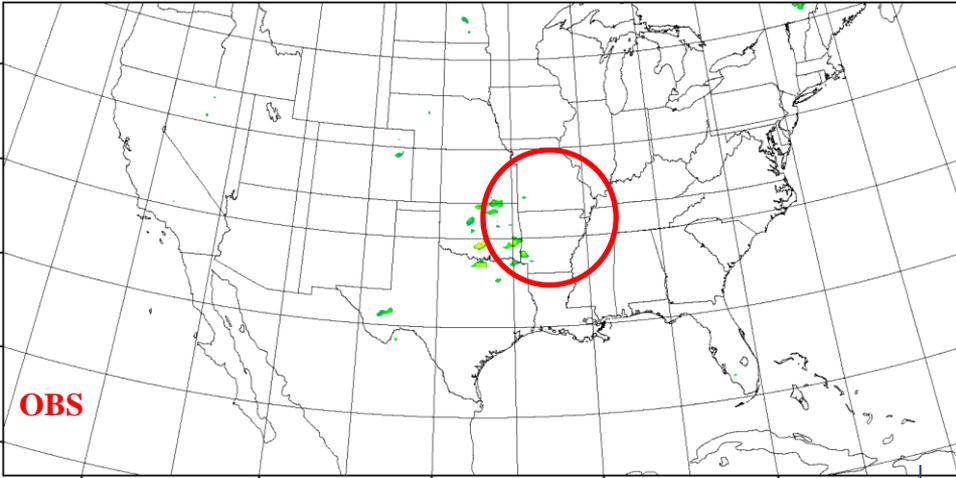
# Back-up slides

- Storm forecast in early stages
- AIRS/CrIS/IASI principal component analysis
- The ABI isn't a full sounder!

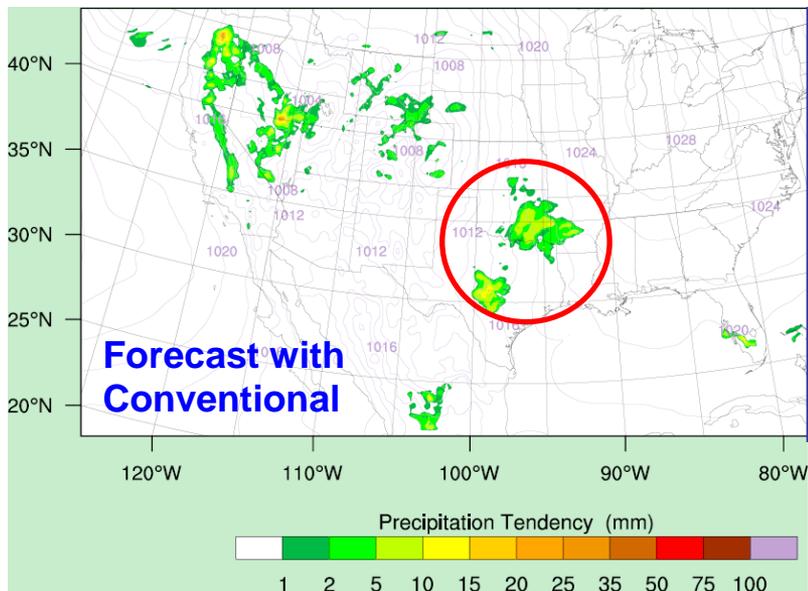
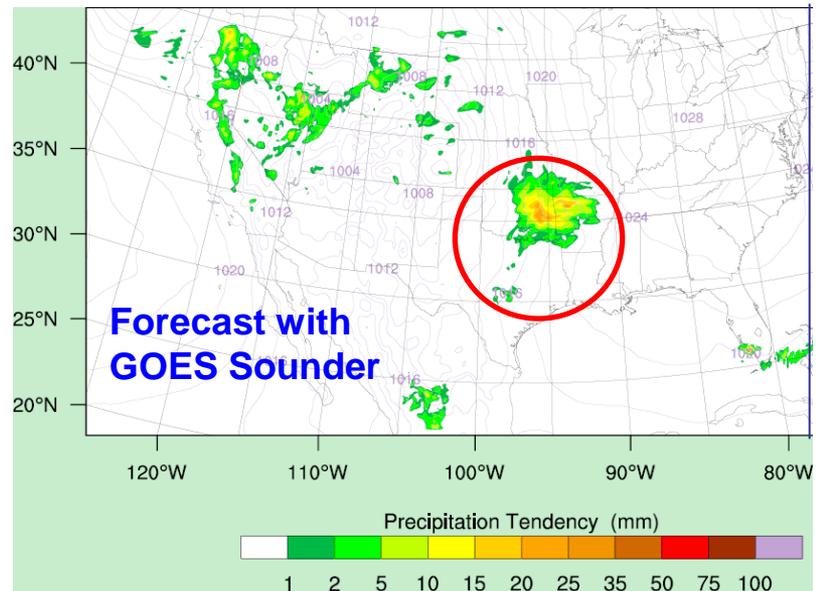
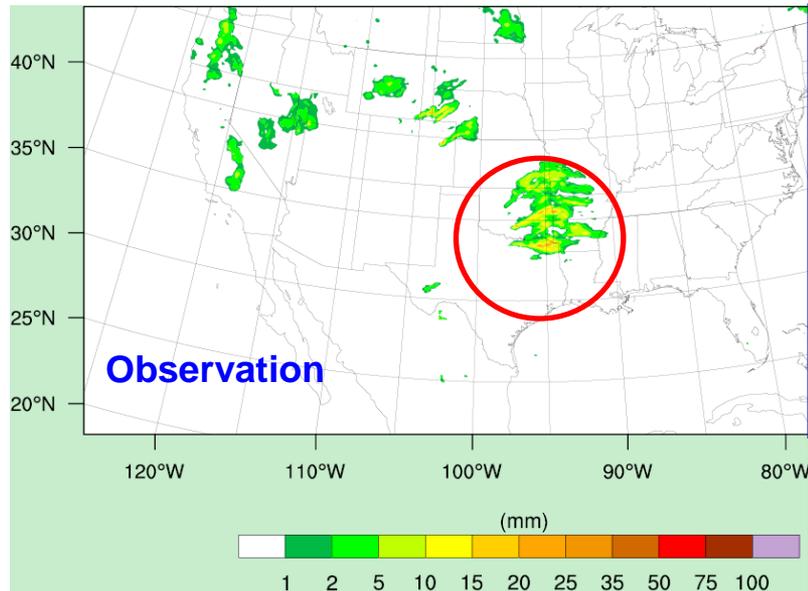


# Hourly Precipitation Forecasts in Early Stage

2012/5/10 01 Z ~ 2012/5/10 12 Z

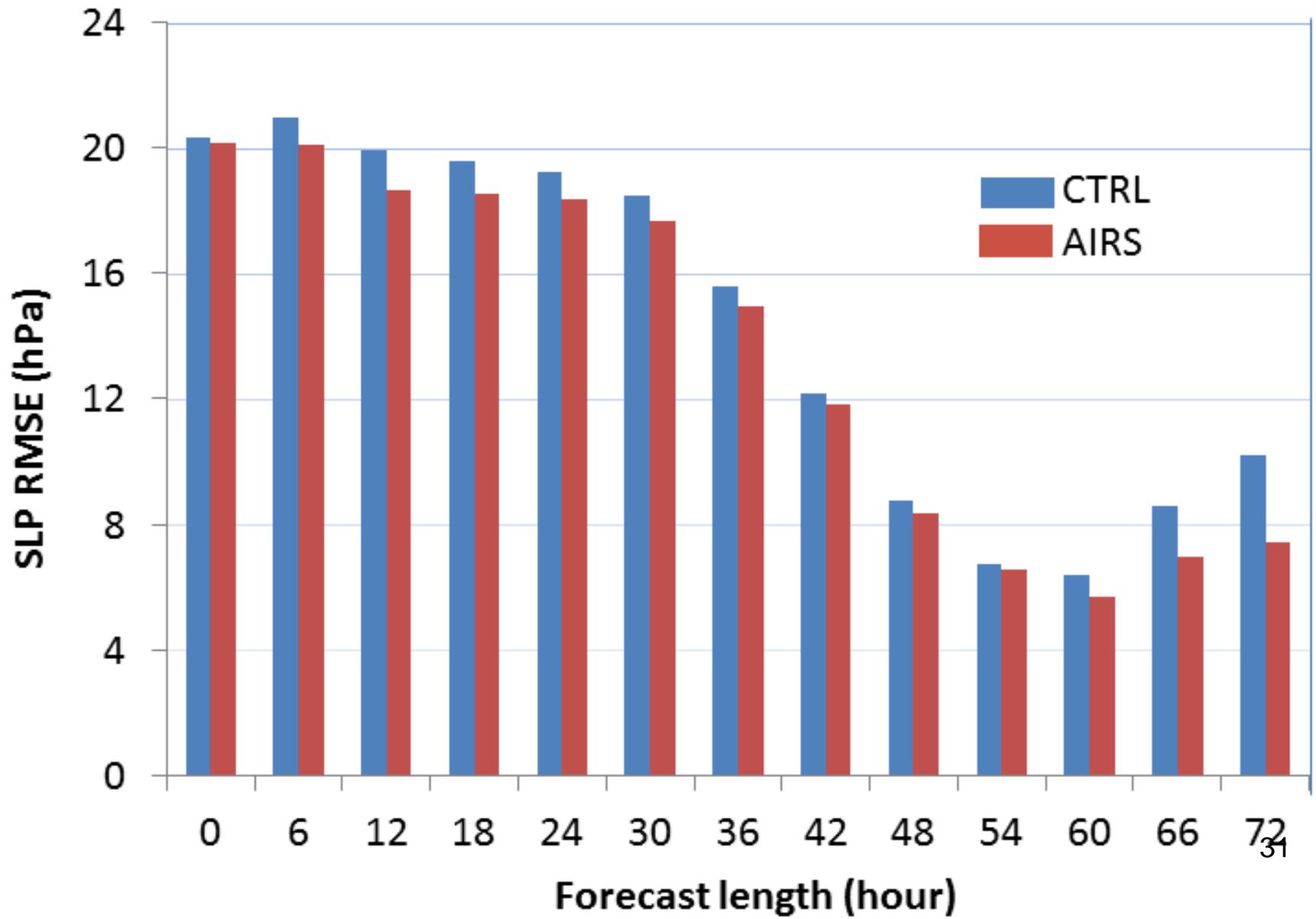


Hourly precipitation forecast from 00 Z – 12 Z 05-10-2010 over CONUS with WRF/3DVAR, model resolution is 12 km, GOES Sounder 300 – 700 hPa precipitable water (PW) is used every 3 hours (preliminary results).

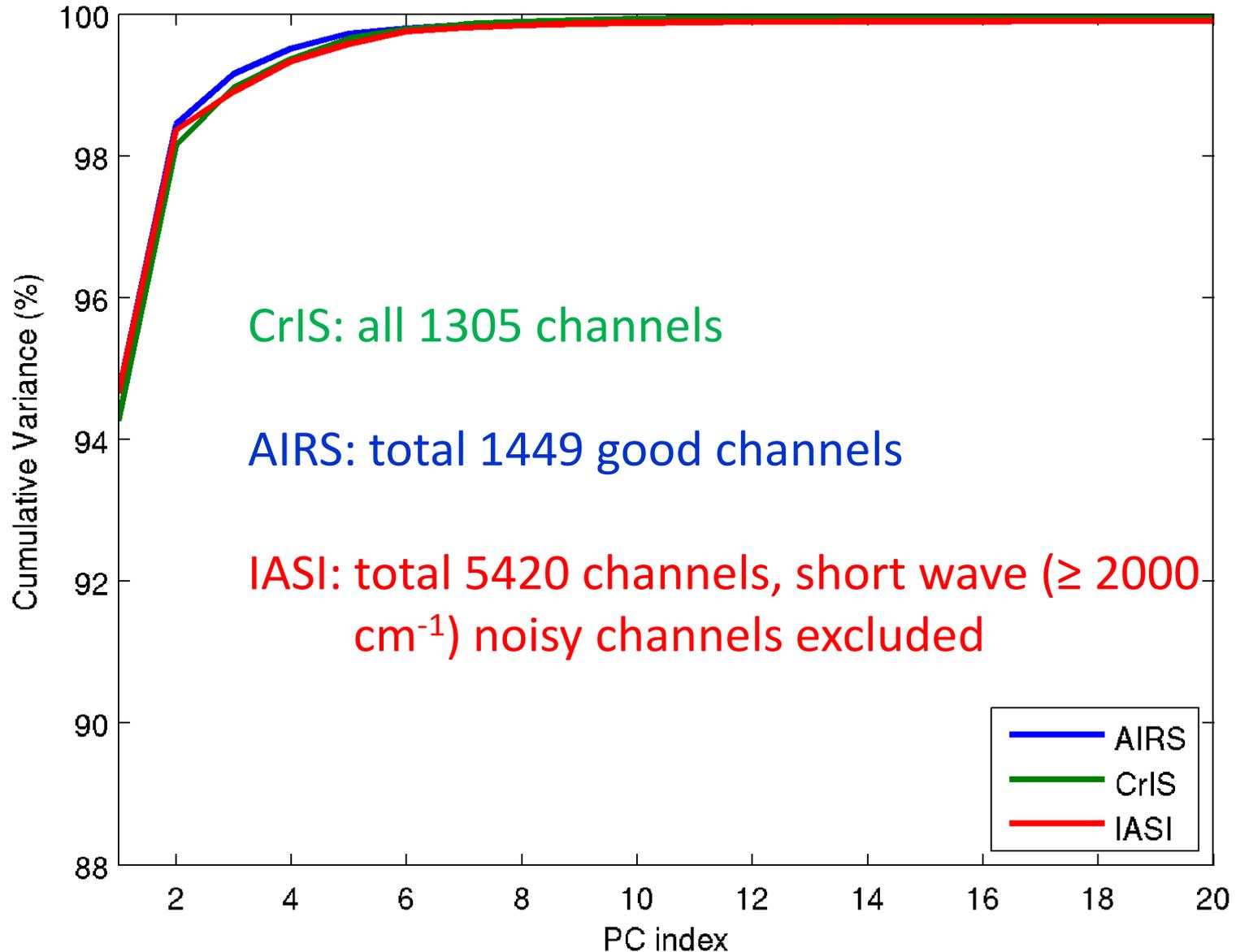


Cumulative precipitation forecast from 00Z to 06 Z 05-10-2010 over CONUS with WRF/3DVAR, model resolution is 12 km, GOES Sounder 300 – 700 hPa precipitable water (PW) is used every 3 hours (preliminary results).

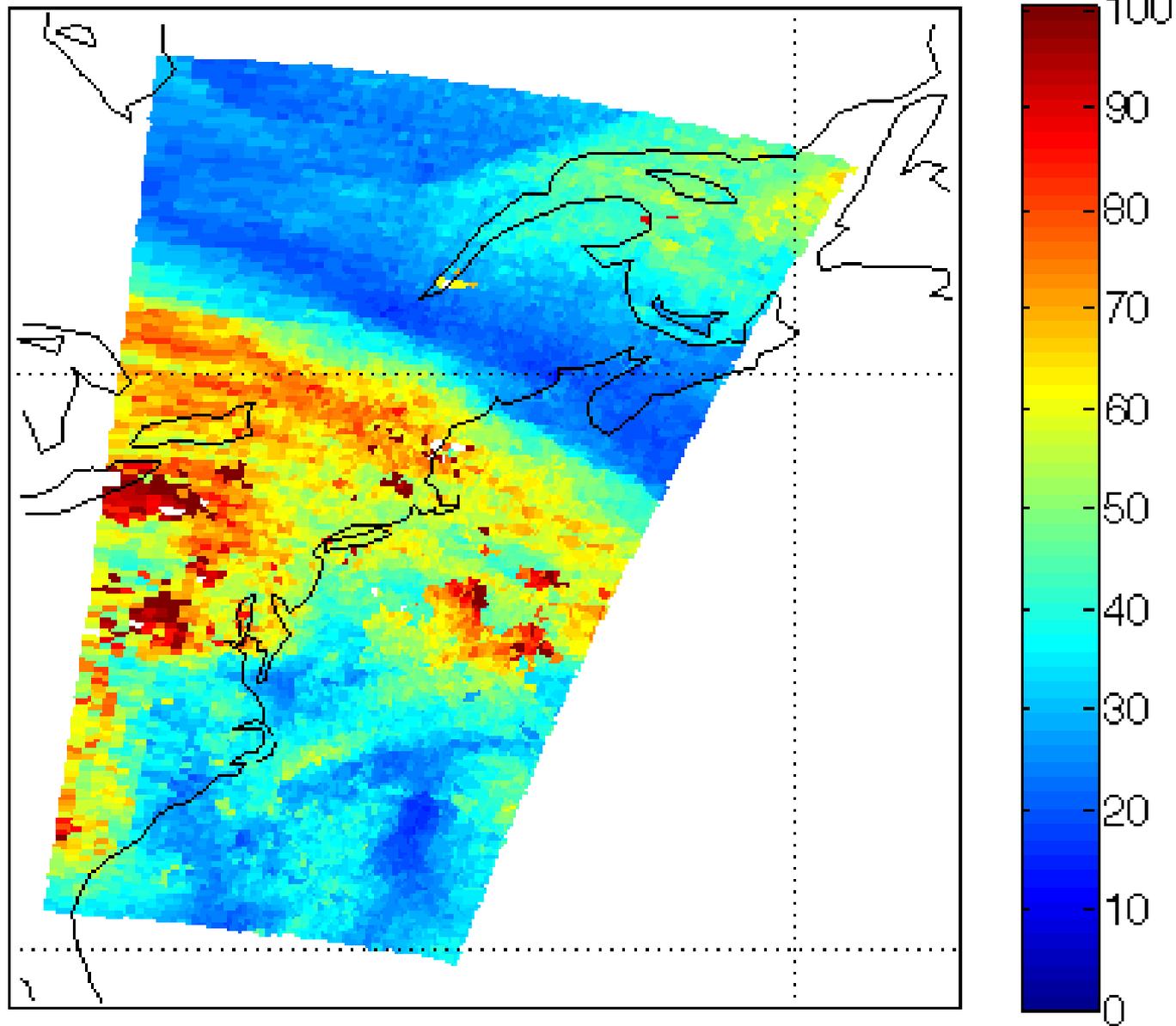
The Hurricane Irene (2011) central SLP forecast RMSE for 0-h (analysis), 6-h, to 72-h forecasts. Every 6 hours between 06 UTC 23 and 00 UTC 25 August 2011 the data are assimilated with WRF/DART followed by a 72-hour forecast. The SLP RMSE is calculated from comparisons with the best track observations from NHC. Control run assimilates radiosondes, AMVs, COSMIC GPS reflectivity, ship and land surface observations.



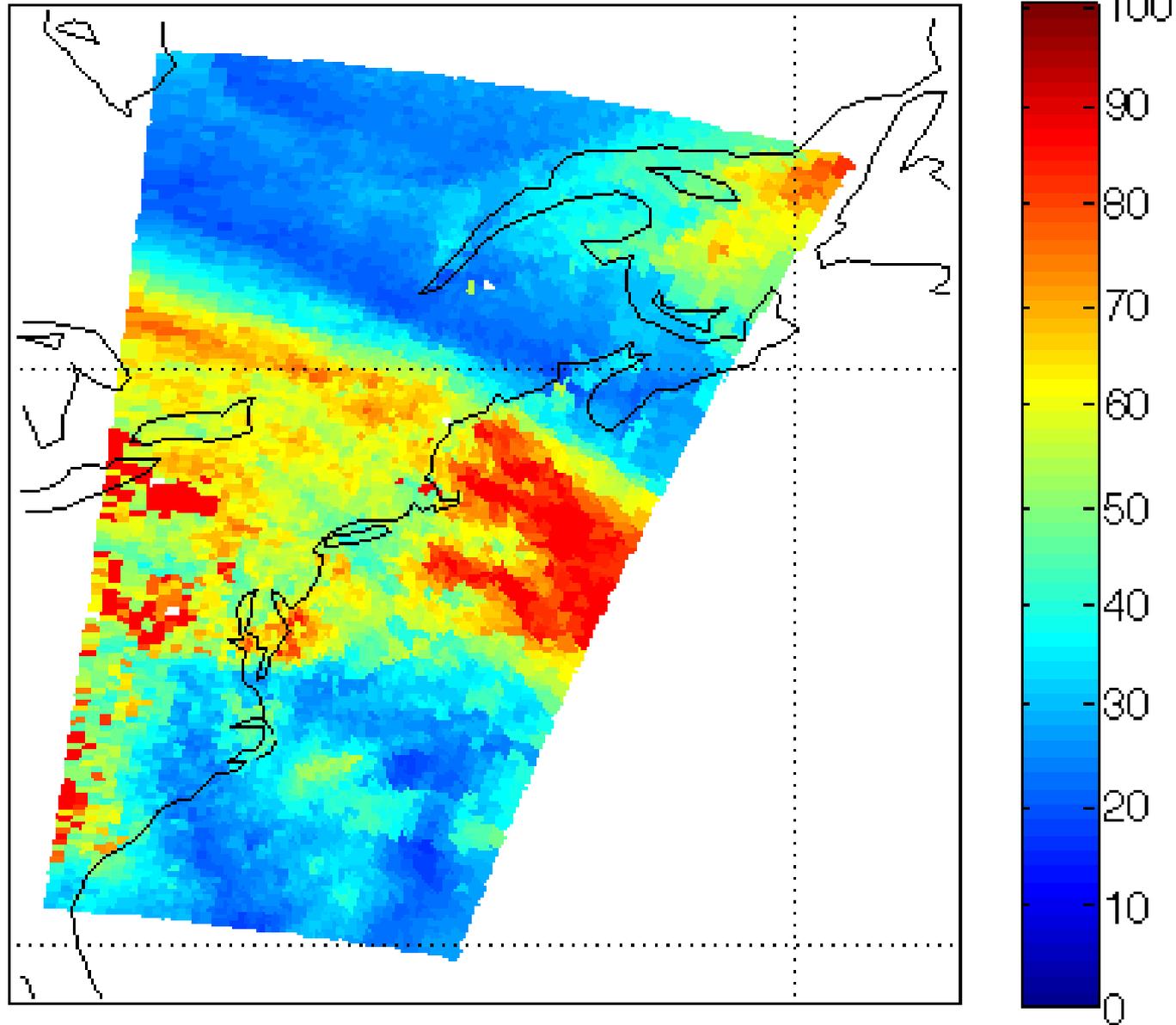
# Cumulative total variances in percentage (AIRS/CrIS/IASI have the similar information based on PCA)

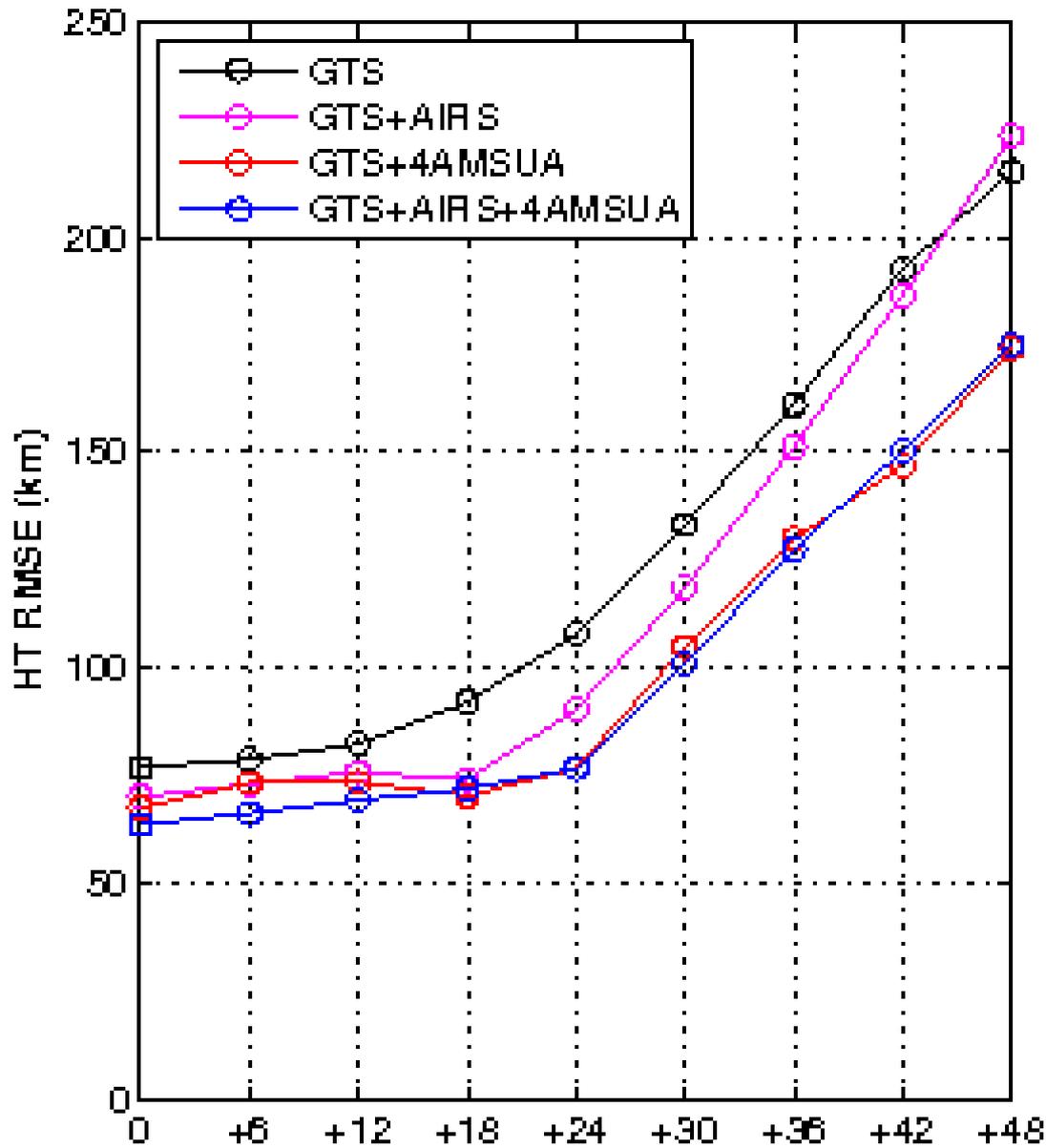


AIRS granule .06 (2012.02.29)  
Relative Humidity [percent] at 300 mbar



CrIS granule .06 (2012.02.29)  
Relative Humidity [percent] at 300 mbar



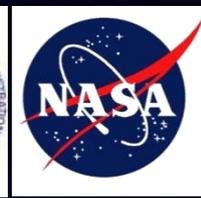


Lifecycle Hurricane Ike (2008) track RMSE for 0-h (analysis), 6-h to 48-h forecasts. The radiance assimilation of AIRS and AMSU are used in the experiments. GTS contains all the conventional data. WRF/GSI are used in the experiments.

Future work will include assimilation of radiances and/or soundings.



# Routine Validation Tools



## Capabilities:

- Monitoring the quality of atmospheric temperature and moisture profiles in near real time
- Monitoring the quality of TPW, LI, TT, CAPE, KI, and SI in near real time

## Datasets used:

Radiosondes (conventional, ARM site); ARM site microwave radiometer TPW; NWP forecast used in the LAP retrieval; ABI IR brightness temperatures

## Visualization and software tools (scripts + McIDAS + Matlab)

- Time series of BT difference (obs – cals (FCST)) images for ABI IR channels
- Time series of difference (RTVL - FCST) images (TWP, LI, CAPE, TT, KI, SI)
- Time series of LI, CAPE, TT, KI, SI from GOES-R RTVLs, FCSTs and radiosondes at ARM site
- Time series of GOES-R TPW, FCST TPW, and MWR TPW at ARM site
- Statistics of retrievals against conventional radiosondes over land
- Statistics of retrievals against ECMWF analysis over ocean
- Animations
- Generate zoomed difference images
- Monitor product quality
- Compare to other products (e.g., CrIS)

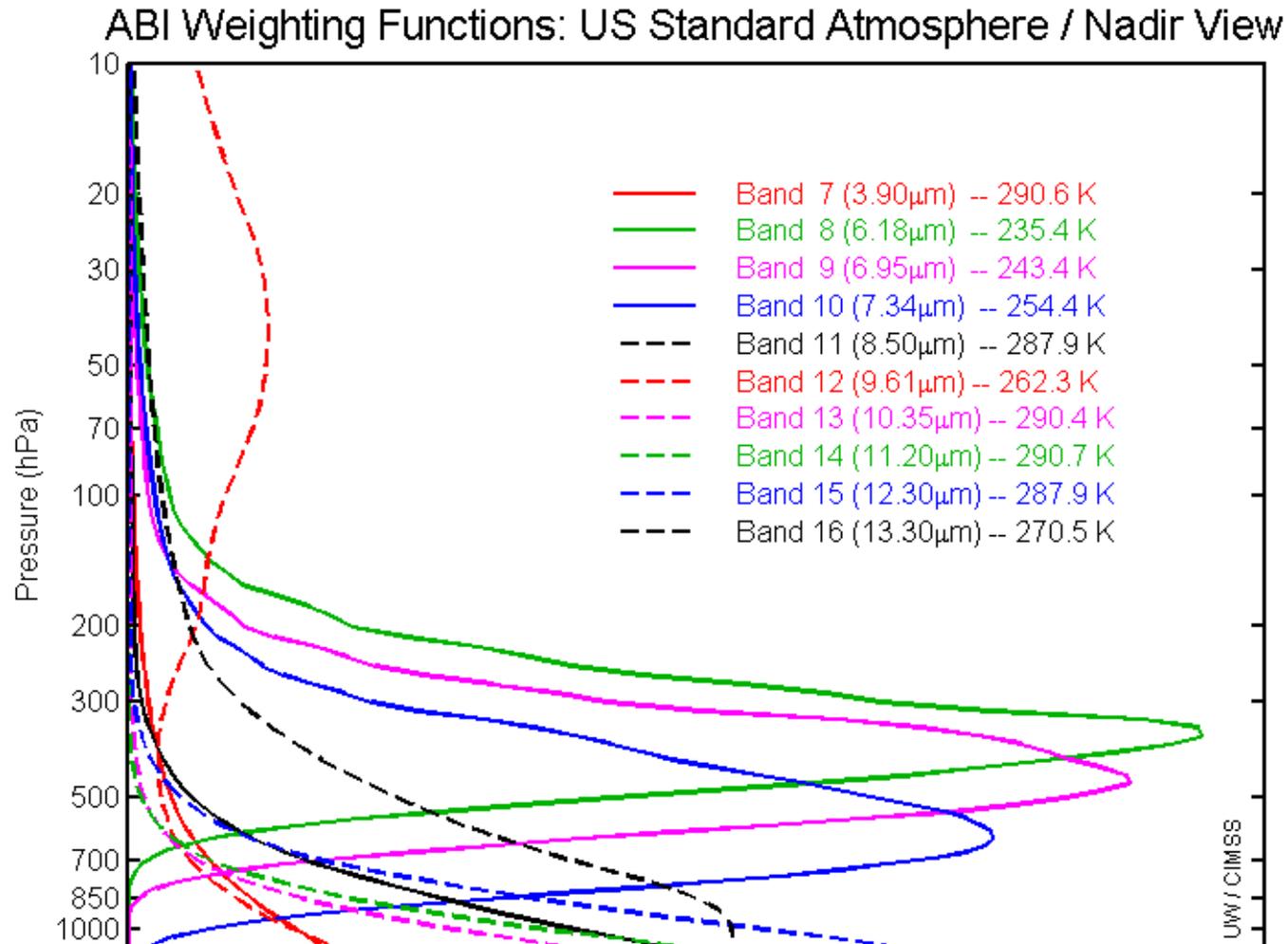


# "Deep-Dive" Validation Tools



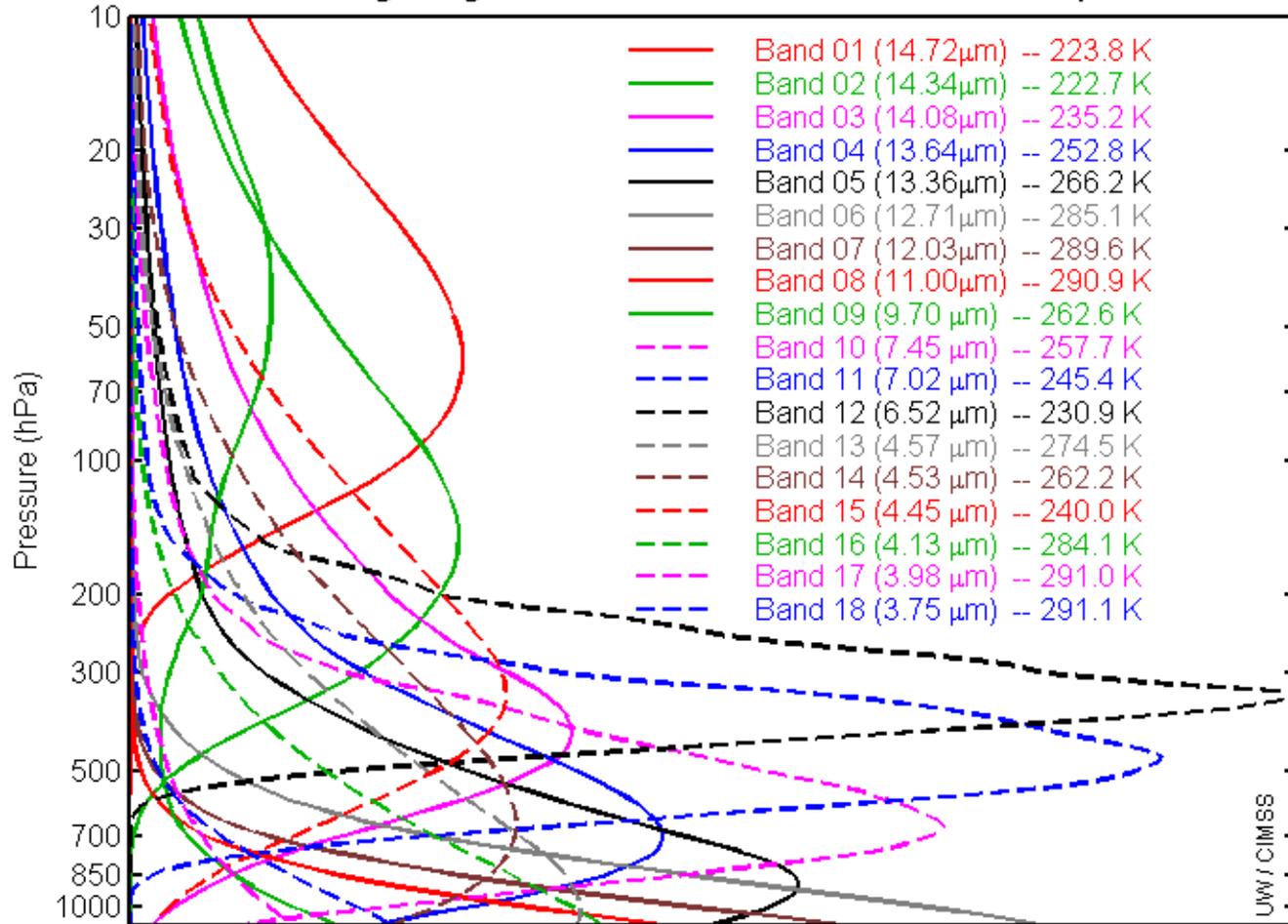
- Capabilities:
  - Monitor any anomalies of any GOES-R LAP product and identify the cause
  - Quantify the error/uncertainty of GOES-R LAP products for better applications
- Tools include, but is not limited to:
  - Full and/or zoomed difference (TPW, LI, CAPE, KI, TT, SI) between RTVLs and FCSTs images
  - Generate residual images (obs – calcs from FCSTs) for each IR channel
  - Generate quality flag images
  - Times series of GOES-R TPW, FCST TPW and microwave radiometer TPW over ARM CART site
    - Longer times series
  - Daily statistics of temperature and moisture profiles against radiosondes (FCSTs, RTVLs) over CONUS
    - Longer times series
  - Individual IR brightness temperature images with calibration events
  - Cloud mask image
  - Aerosol/dust product images
- McIDAS + Matlab + scripts

# GOES-R ABI Weighting Functions



# GOES-13 Sounder WFs

GOES-13 Sndr Weighting Functions: US Standard Atmosphere / Nadir View



# **Profile information content analysis**

**J. Li et al  
CIMSS**

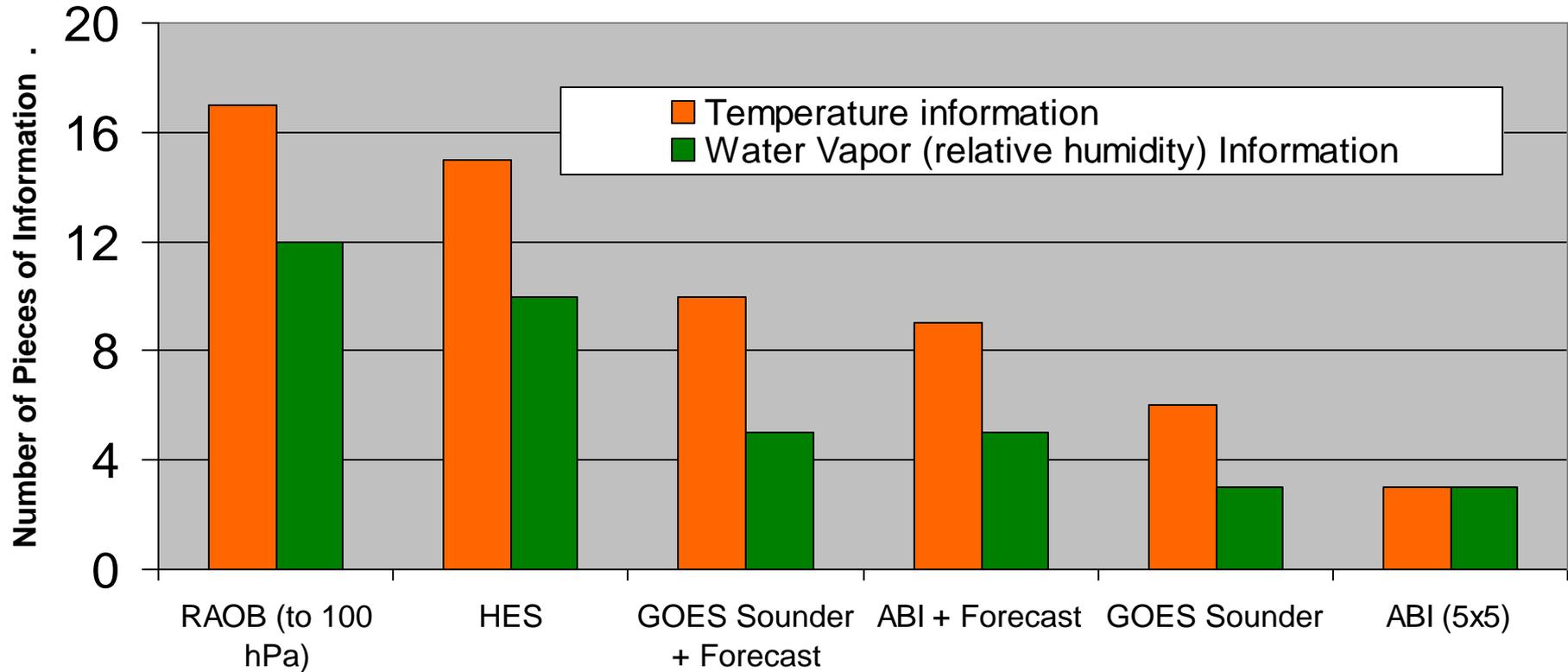
**In general, note that the moisture content is similar between the ABI and the current GOES Sounder. The Sounder does show more temperature information than the ABI.**

**More than 300 profiles over CONUS with lifted index  $<0$  (unstable atmosphere) are used in analysis.**

**This information content does not include any spatial or temporal differences.**

**November 6<sup>th</sup>, 2006**

# Profile Information Content



The relative vertical number of independent pieces of information is shown. Note that the moisture content is similar between the ABI and the current GOES Sounder. The Sounder does show more temperature information than the ABI. Caveat: Even if two systems have the same number of pieces of information, they may represent different vertical levels. This information content analysis does not account for any spatial or temporal differences.