# Accelerated Uses of Suomi NPP Data in HWRF for Improving Hurricane/Typhoon Forecasts

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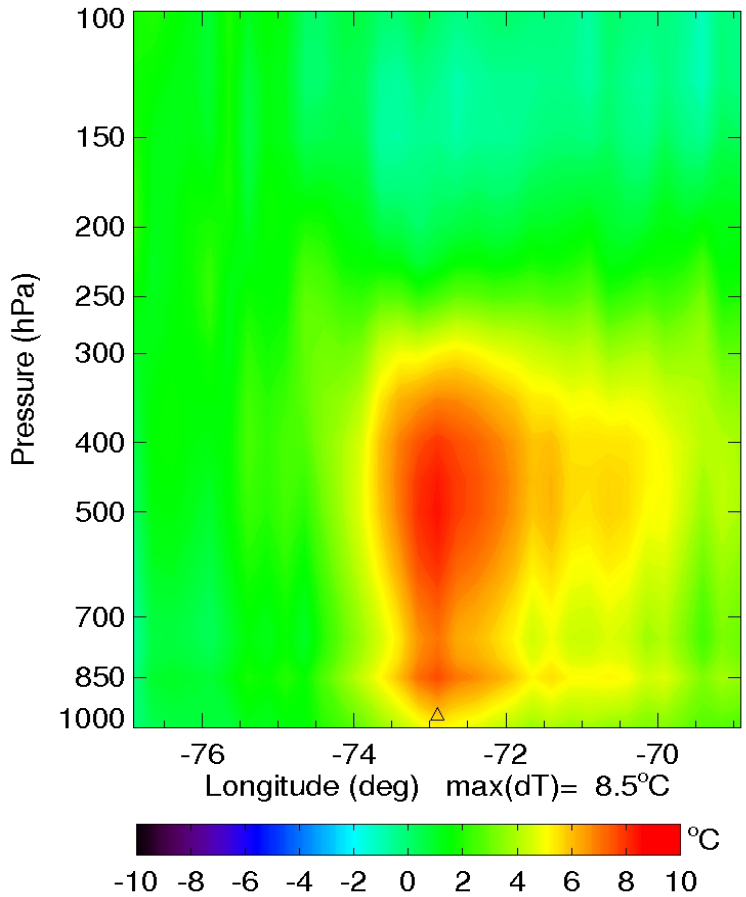
# Our Focus on Uses of Satellite Data in HWRF

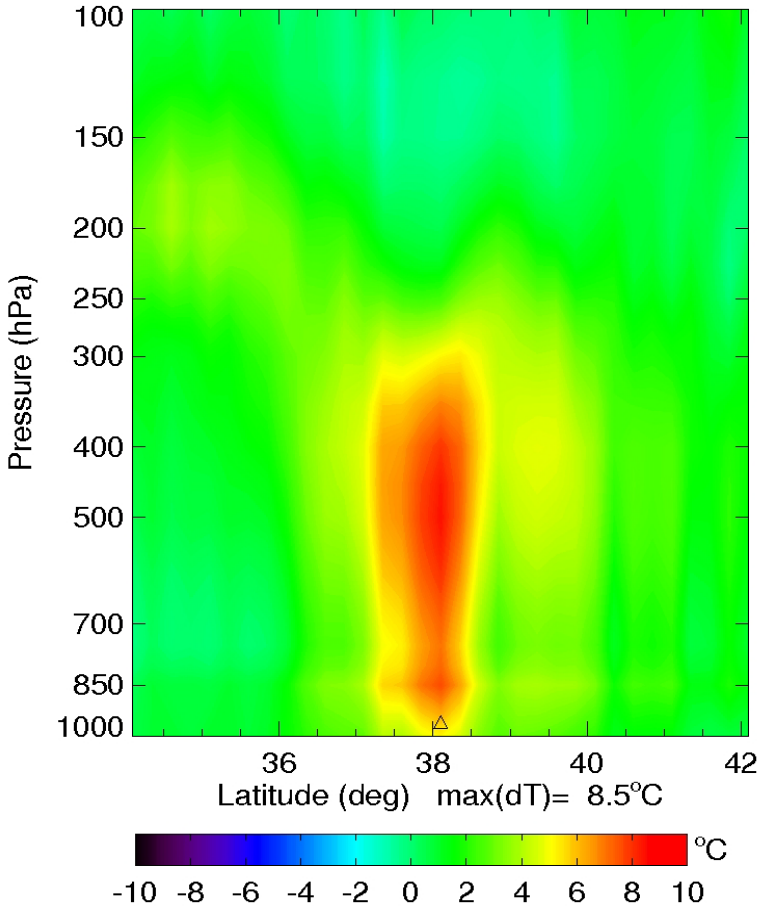
- New satellite data streams
- HWRF model top issues
- Quality control and bias correction
- Observing system experiments

# Hurricane Sandy Warm Core Retrieved from Suomi NPP ATMS Ascending 1730 UTC, 29 October 2012

**At 1800 UTC Oct 29 Max Wind: 90 MPH, Min Pressure: 940 hPa**



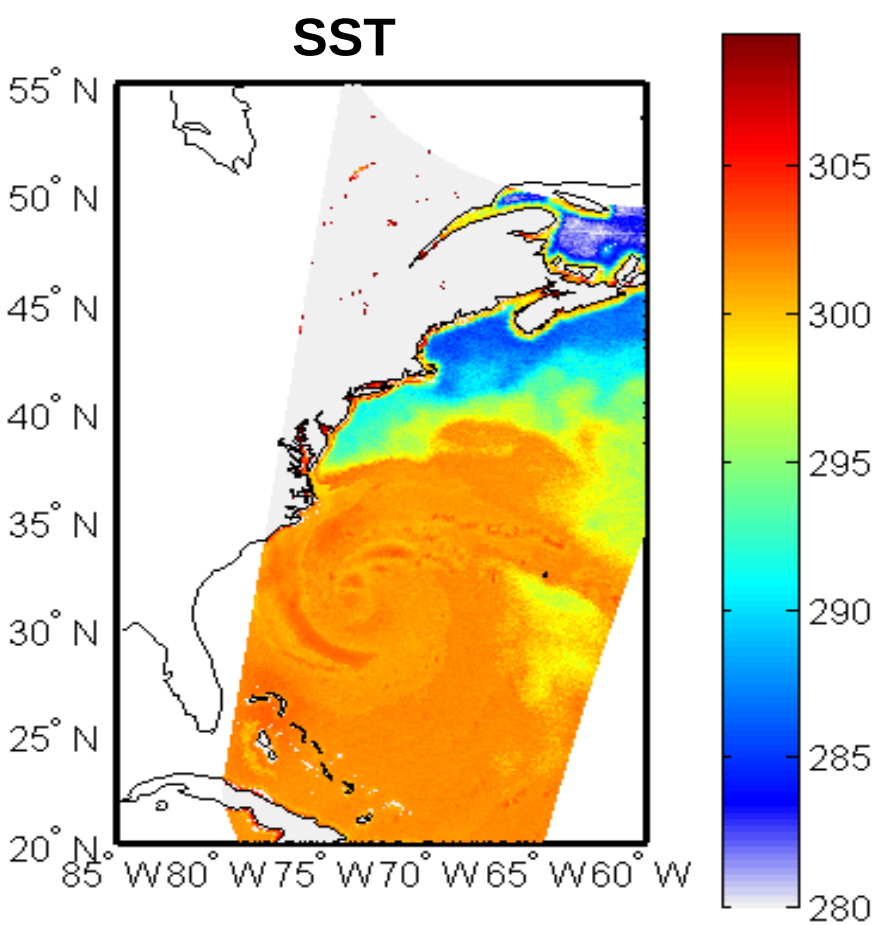

**Cross section along Latitude 38.1 N**

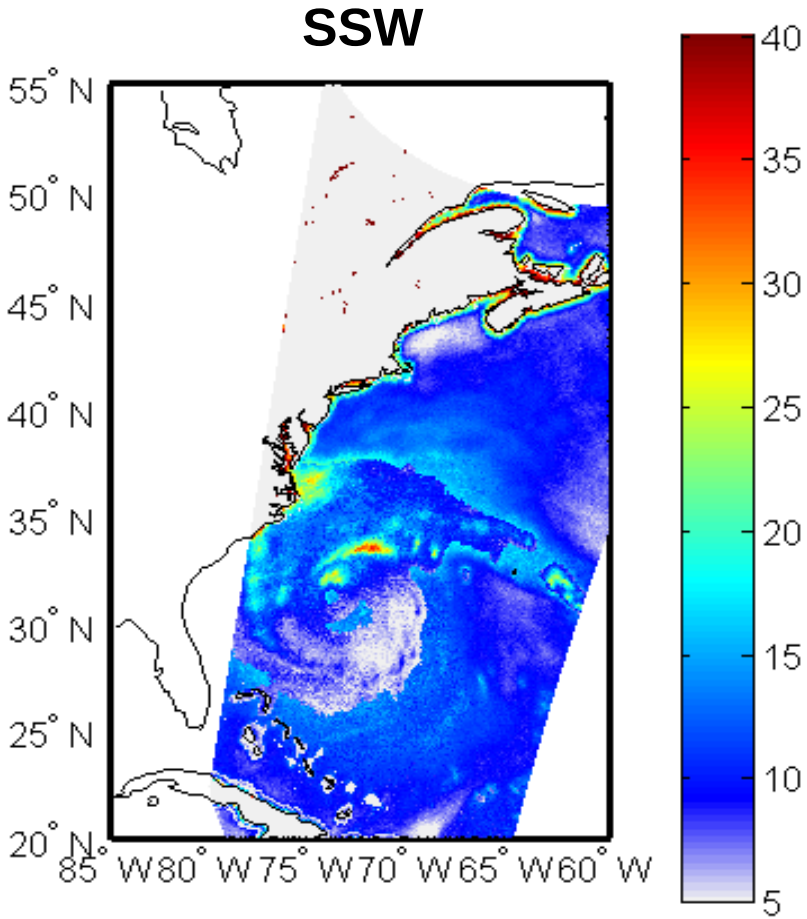



**Cross section along Longitude 72.9 W**

*Zhu and Weng, 2013, GRL*

# Information Content from GCOM-W1 AMSR2
# Hurricane Sandy-10-28-2012 06 UTC



# Information Content from GCOM-W1 AMSR2
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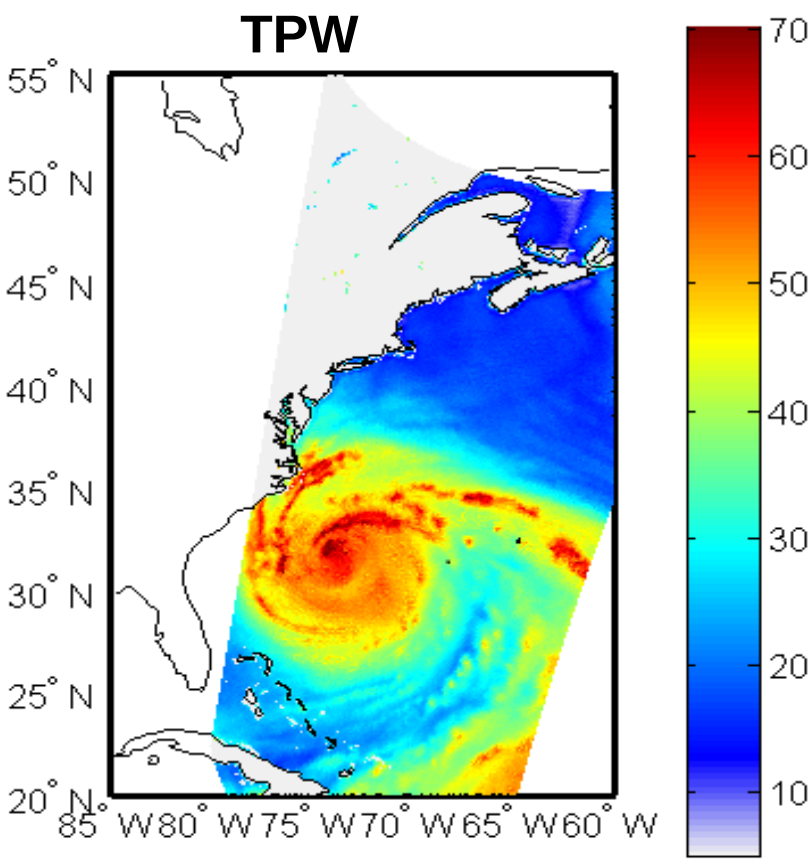
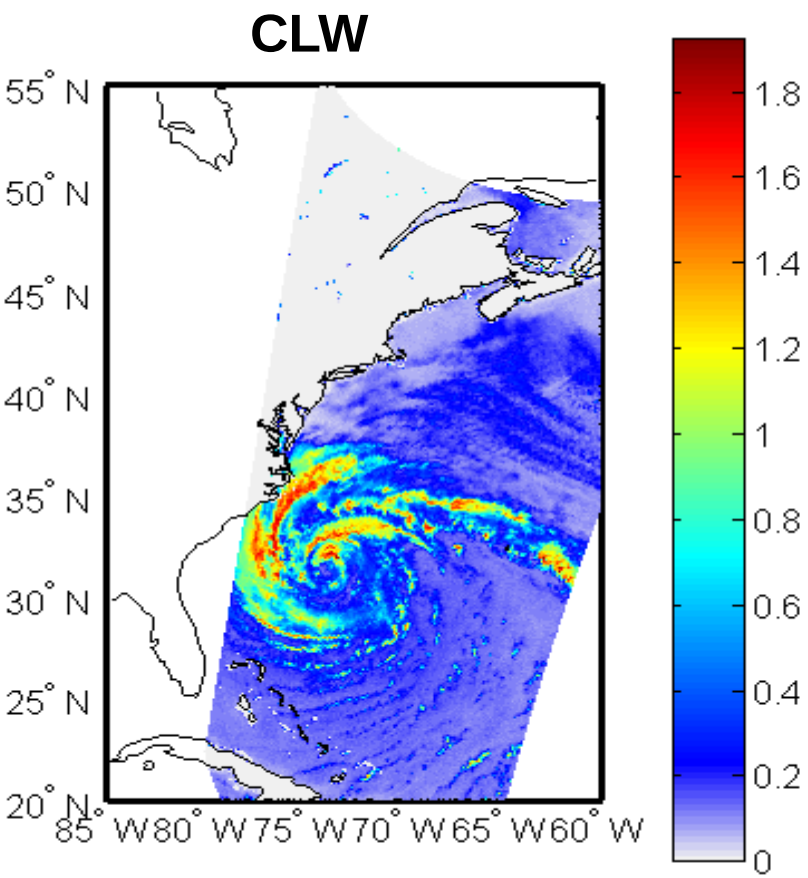


# Control Experiment – L61

**HWRF/GSI System**

- Three telescoping domains: *Outer domain: 27km: 75x75$^o$; Inner domain: 9km ~11x10$^o$ Inner-most domain: 3km inner-most*
- HWRF/GSI Vertical levels: 61 and model top: 0.5 hPa
- HWRF 6 hour forecasts,

## Conventional Data:

Radiosondes, aircraft reports (AIREP/PIREP, RECCO, MDCRS-ACARS, TAMDAR, AMDAR), Surface ship and buoy observations , Surface observations over land, Pibal winds,Wind profilers, VAD wind, Dropsondes

## Satellite Instrument Data:

- AMSU-A (channel 5-14) from NOAA, NOAA and METOP
- HIRS from NOAA-19 and METOP-A
- AIRS from EOS Aqua
- ASCAT from METOP-A
- GPSRO from GRAS/COSMIC

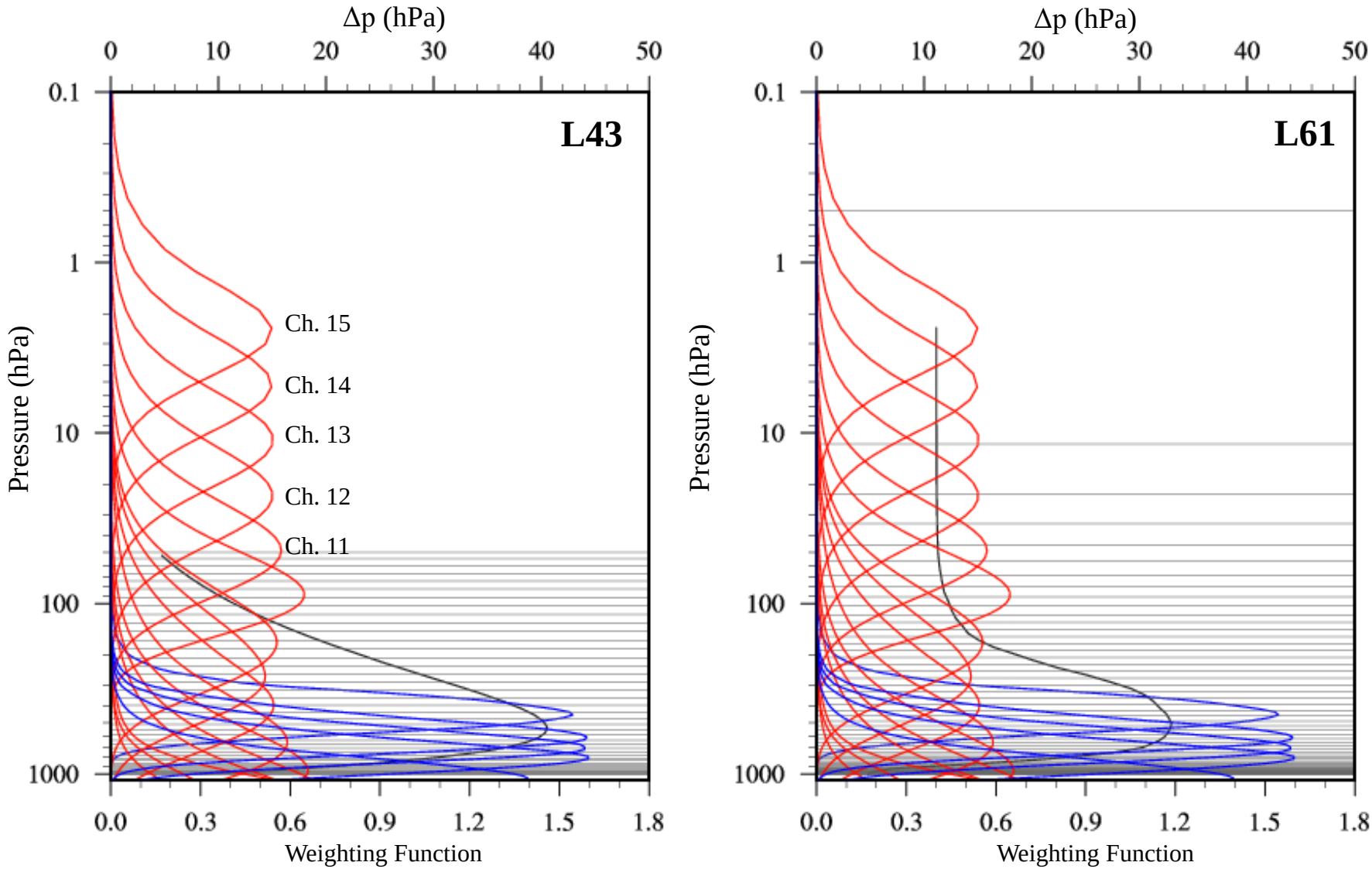
# Observing System Experiments in HWRF/GSI

1. **L61 (0.5mb) vs. L43 (50mb)** ***(Completed)***
2. **L61+ATMS** ***(Completed)***
3. **L61+CrIS** ***(Completed)***
4. **L61+IASI** ***(Completed)***
5. **L61+GOES imager radiance** ***(Completed)***
6. **L61+CrIS/VIIRS (on going)**
7. **L61+SSMIS imaging channels (on going)**
8. **L61 + AMSR2 (on going)**
9. **L61 + Combined AMSU-A/MHS data steam (on going)**

# Model Top Experiment Setup

- Model: 2012 HWRF (triple-nested, warm start)
- Satellite Data:  GPS, ASCAT, AMSU-A (N18, N19, and MetOp-A), AIRS (Aqua), HIRS (N19 and MetOp-A)
- Control: L43 (43 levels, model top 50 mb)
- Sensitivity: L61 (61 levels, model top 0.5 mb)
- Forecasts of Hurricane Isaac

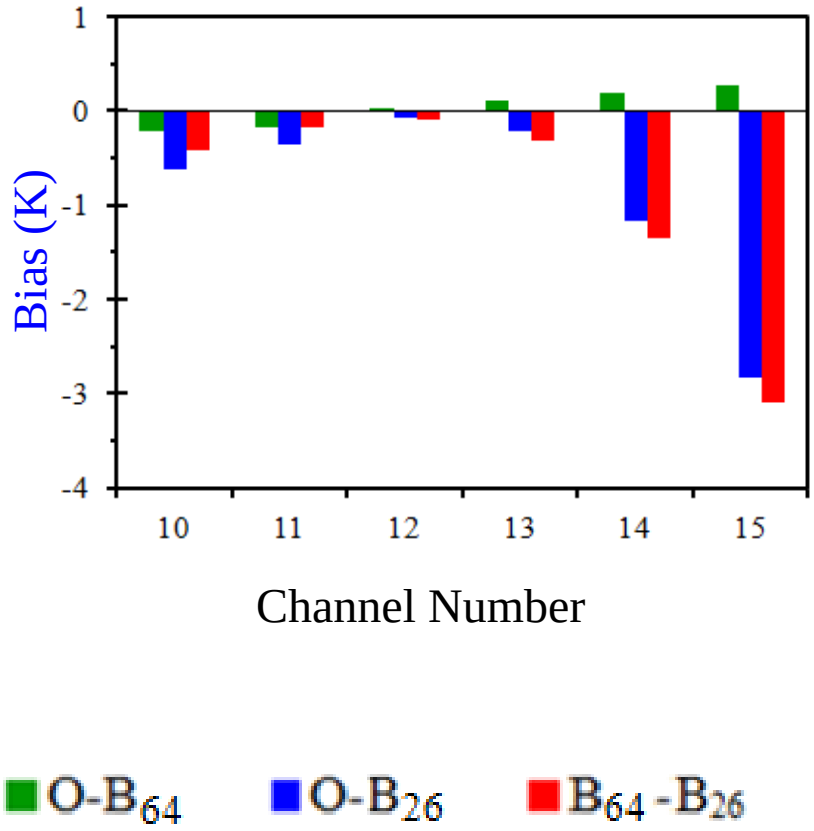
# Weighting Functions for ATMS Channels






*Zou et al. (2013)*

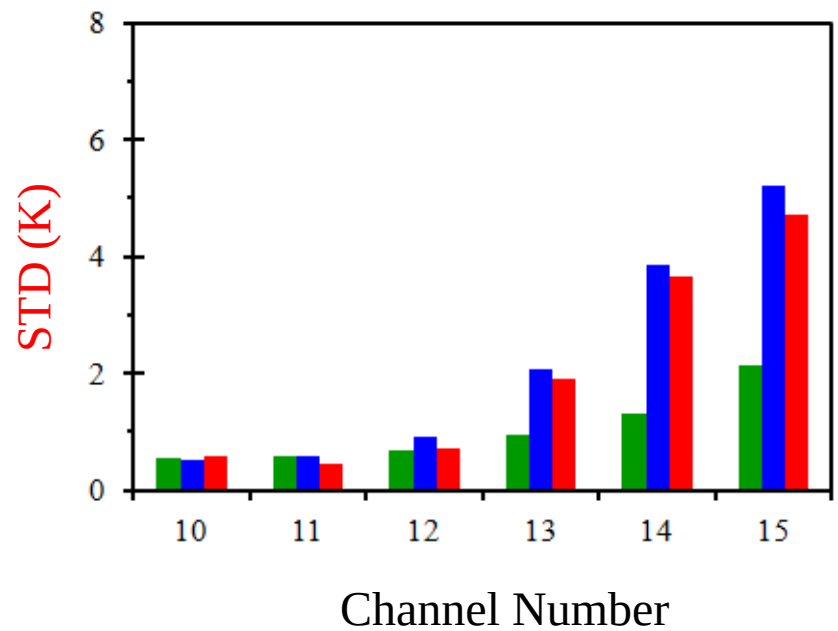
# Comparison of GFS 64-level and 26-level Data




Model top level pressure

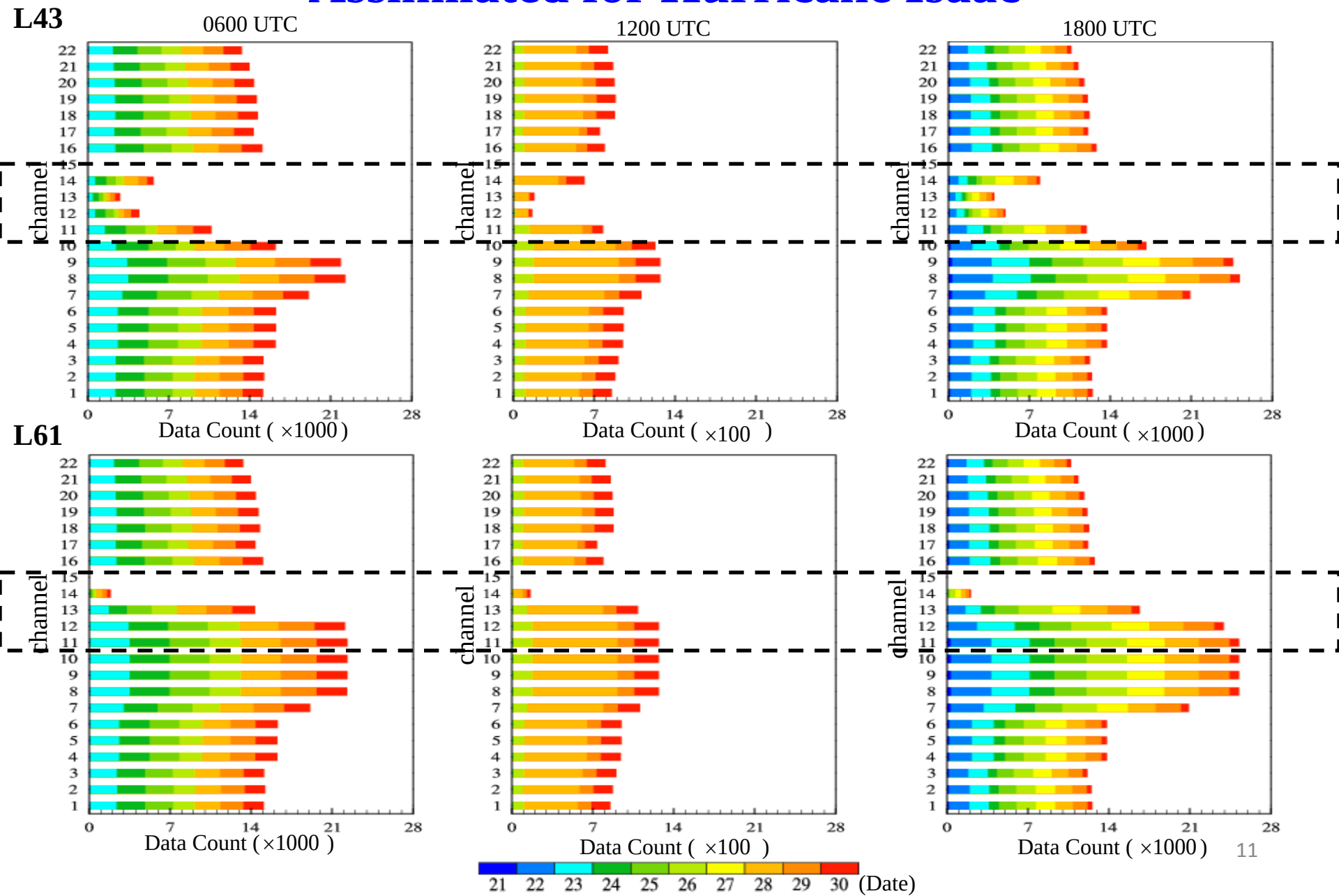
**GFS 64: 0.01hPa**

**GFS 26: 10hPa**



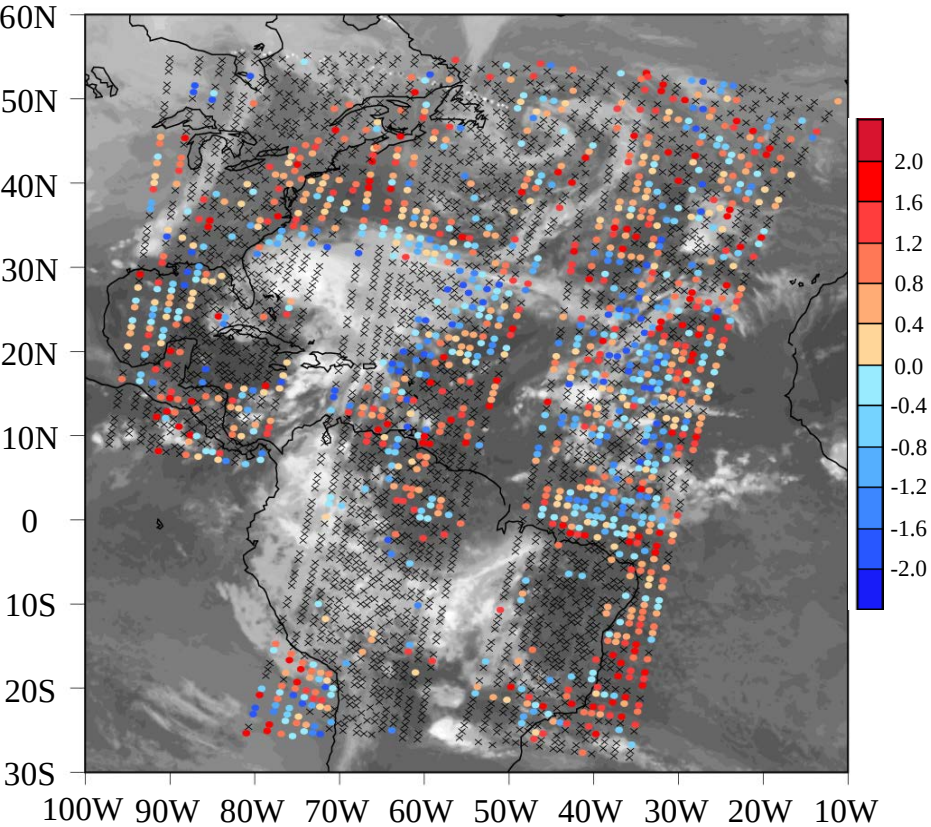

20-27 December 2011

# Data Counts of ATMS Radiance Data Assimilated for Hurricane Isaac

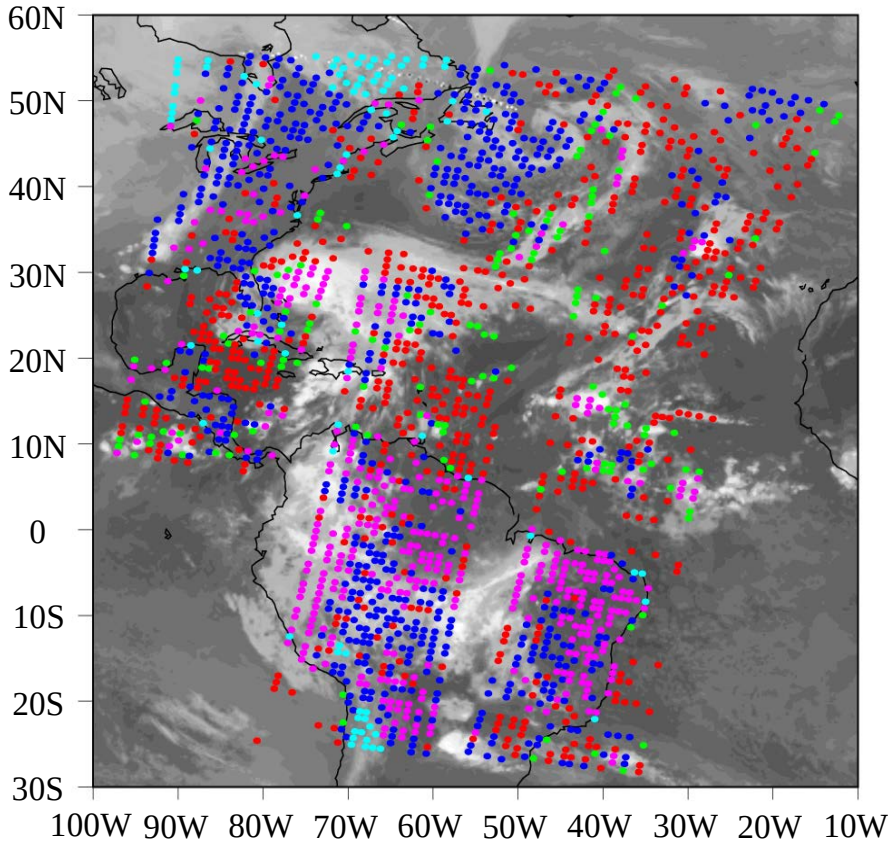


# ATMS Quality Control in HWRF/GSI

ATMS ch 19 passing QC




ATMS ch 19 data rejected by various QC indices




*For ATMS Quality control, GSI QC performs well at water vapor sounding channels due to the uses of more channel 1 and 2 for cloud detection*

***For more details, please see Zou, X., F. Weng, B. Zhang, L Lin, V. Talapragada,, 2013, JGR***

# Current Cloud Check Algorithm

Assume cloud is at model layer $k$, calculate fractional cloud amount $N_k$ at this layer:

$$N_k = \min(\max(Sum_{1,k} / Sum_{2,k}, 0), 1)$$

$$Sum_{1,k} = \sum_{i=1}^{n} (T_{B,i}^{Obs} - T_{B,i}^{Sim} - b_i) \cdot \sum_{kk=1}^{k-1} (T_{temp,k} - T_{temp,kk}) \cdot temp_{kk,i} \cdot W_i$$

$$Sum_{2,k} = \sum_{i=1}^{n} \left[ \sum_{kk=1}^{k-1} (T_{temp,k} - T_{temp,kk}) \cdot temp_{kk,i} \right]^2 \cdot W_i$$

$$Sum_{3,k} = \sum_{i=1}^{n} \left[ (T_{B,i}^{Obs} - T_{B,i}^{Sim} - b_i) - N_k \cdot \sum_{kk=1}^{k-1} (T_{temp,k} - T_{temp,kk}) \cdot temp_{kk,i} \right]^2 \cdot W_i$$

$$Sum_{3,\max} = 0.75 \cdot \sum_{i=1}^{n} \left[ (T_{B,i}^{Obs} - T_{B,i}^{Sim} - b_i) \right]^2 \cdot W_i$$

When $k$ =1

$$Sum_{1,1} = \sum_{i=1}^{n} (T_{B,i}^{Obs} - T_{B,i}^{Sim} - b_i) \cdot (T_{temp,1} - T_{surf}) \cdot ts_i \cdot W_i$$

$$Sum_{2,1} = \sum_{i=1}^{n} \left[ (T_{temp,1} - T_{surf}) \cdot ts_i \right]^2 \cdot W_i$$

$$Sum_{3,1} = \sum_{i=1}^{n} \left[ (T_{B,i}^{Obs} - T_{B,i}^{Sim} - b_i) - N_k \cdot (T_{temp,1} - T_{surf}) \cdot ts_i \right]^2 \cdot W_i$$

$N_k$ : Fractional cloud amount at model layer k

$i$ : Channel index

$n$ : Number of channels

$k$ : Model layer index

$T_{B,i}^{Obs}$ : Channel i Brightness Temperature observation

$T_{B,i}^{Sim}$ : Channel i Brightness Temperature simulation

$T_{temp,k}$ : Atmosphere temperature at layer k

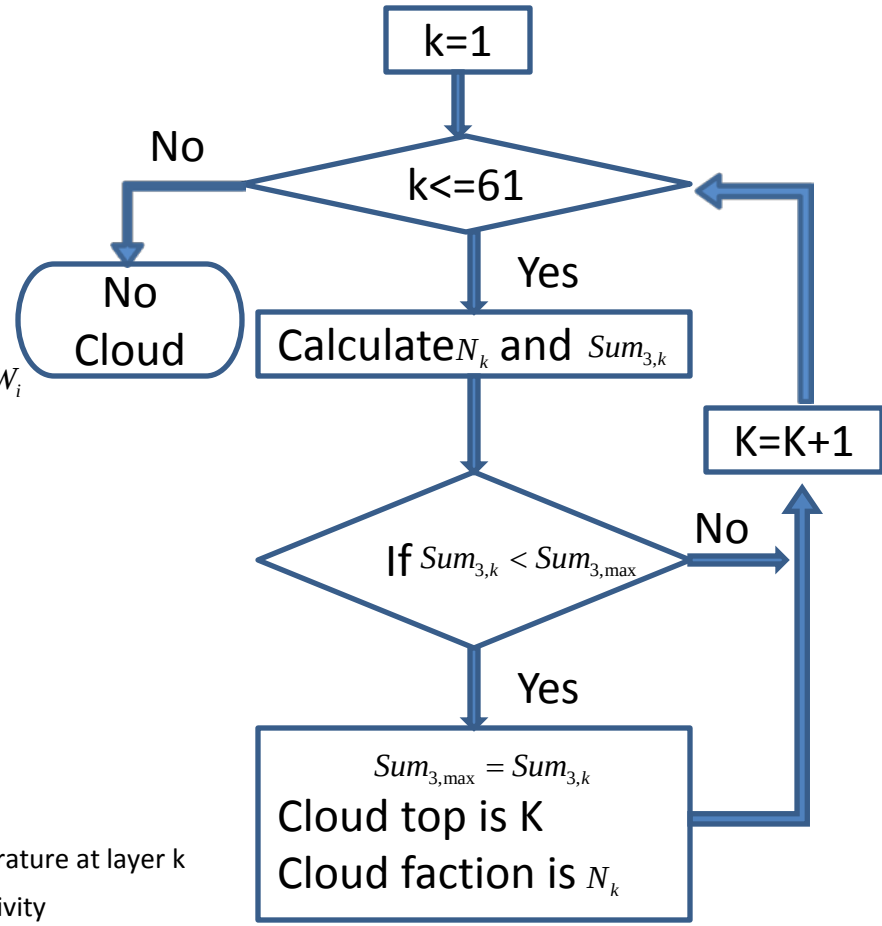
$temp_{kk,i}$: Temperature sensitivity

$W_i$ : Weighting function given to observation

$b_i$ : Bias correction term

$ts_i$ : Skin temperature sensitivity

$T_{surf}$ : Surface skin temperature

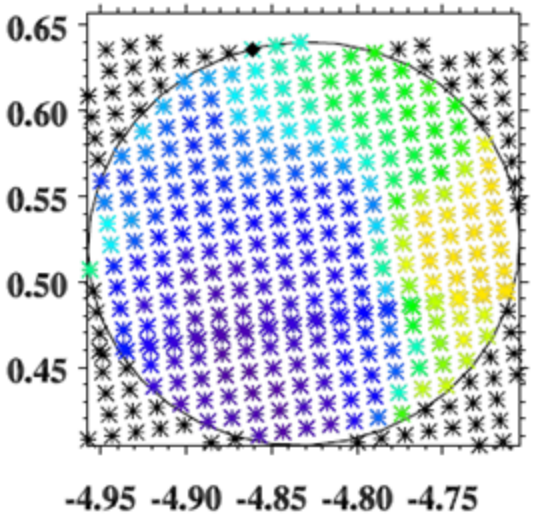



Flowchart for cloud top height and cloud fraction calculation

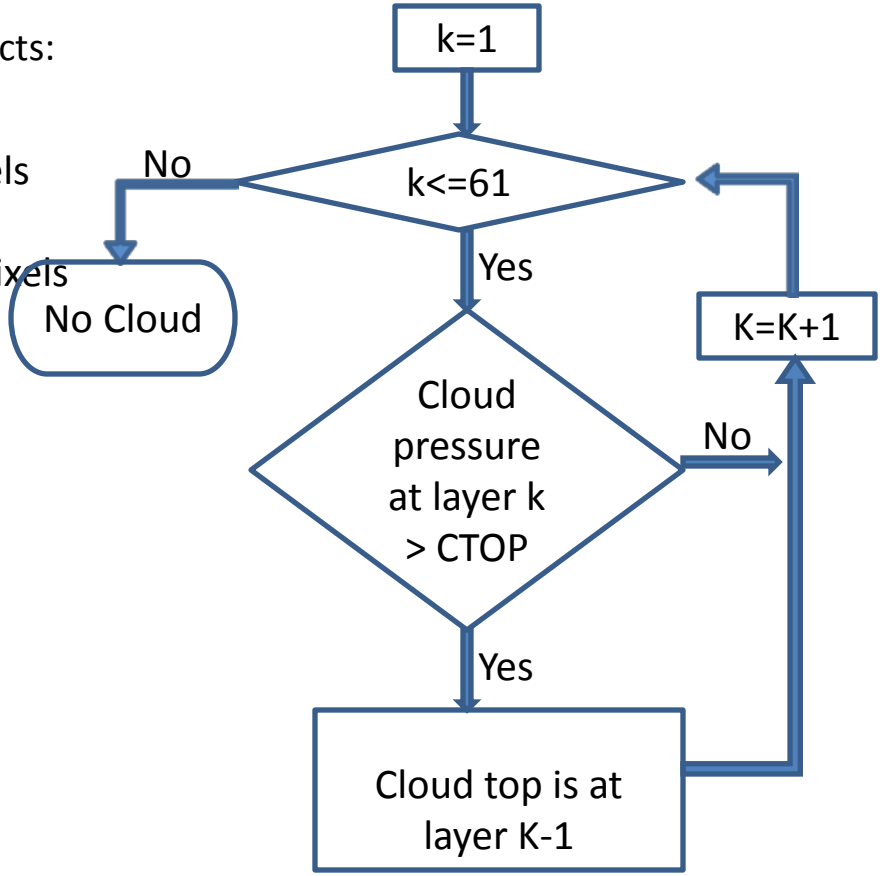
# New Cloud Check Method

New parameters from SNPP VIIRS Cloud Properties Products:

- CLDMNT: percentage of confident cloudy VIIRS pixels within a CrIS FOV
- CTOP: Lowest cloud top pressure among all VIIRS pixels within a CrIS FOV



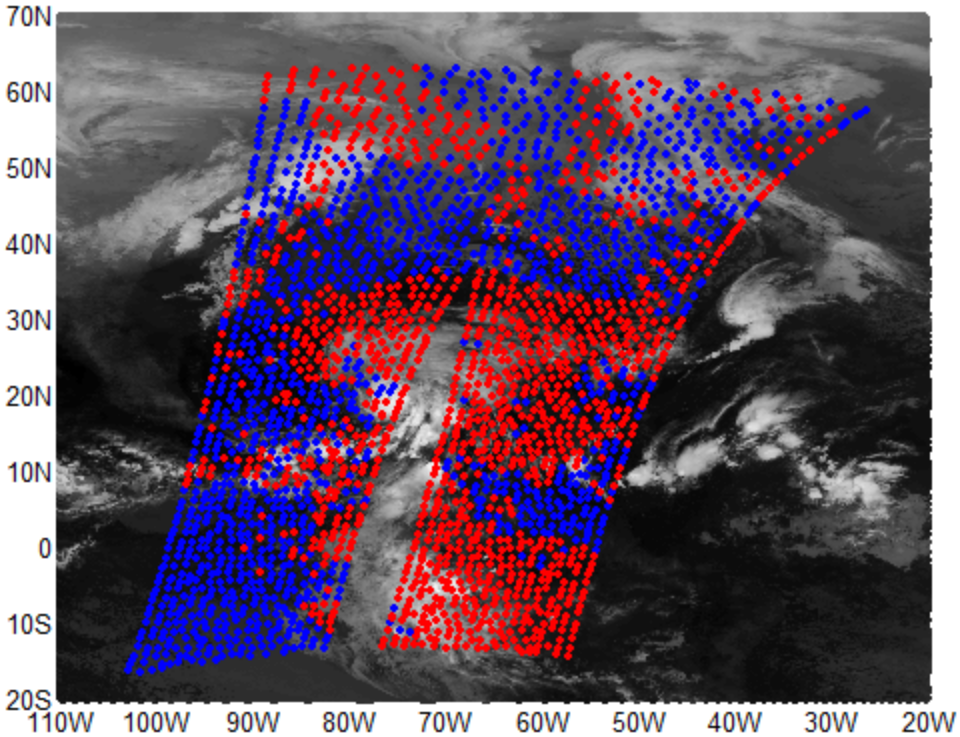

**VIIRS pixels within a CrIS FOV at nadir position**



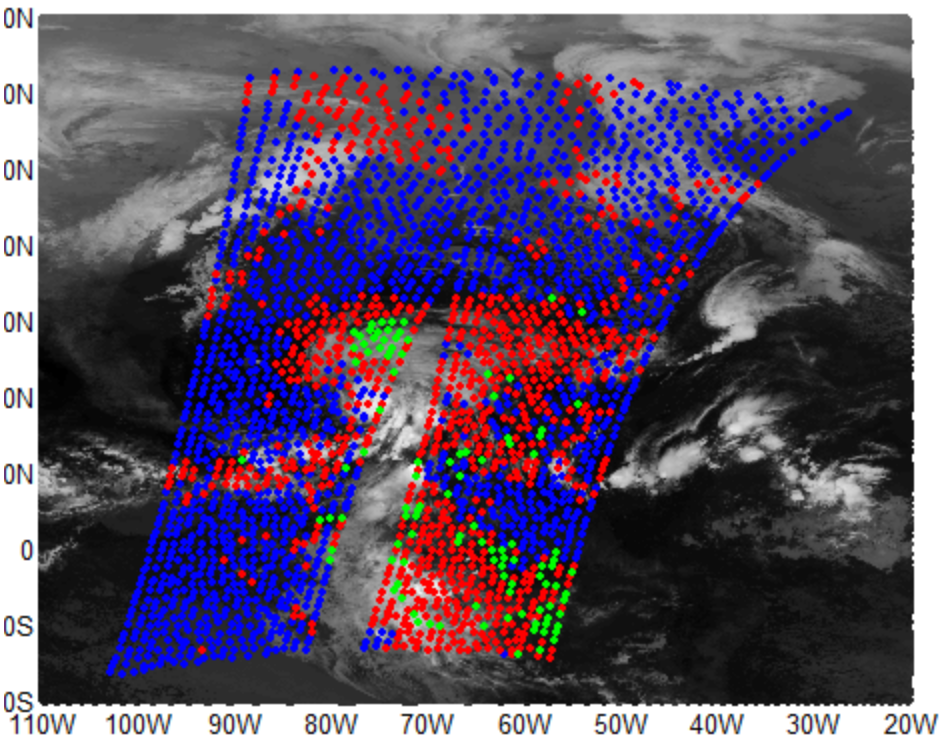

Flowchart for cloud top layer calculation

# QC for Channel 80 (699cm-1)

Current GSI QC



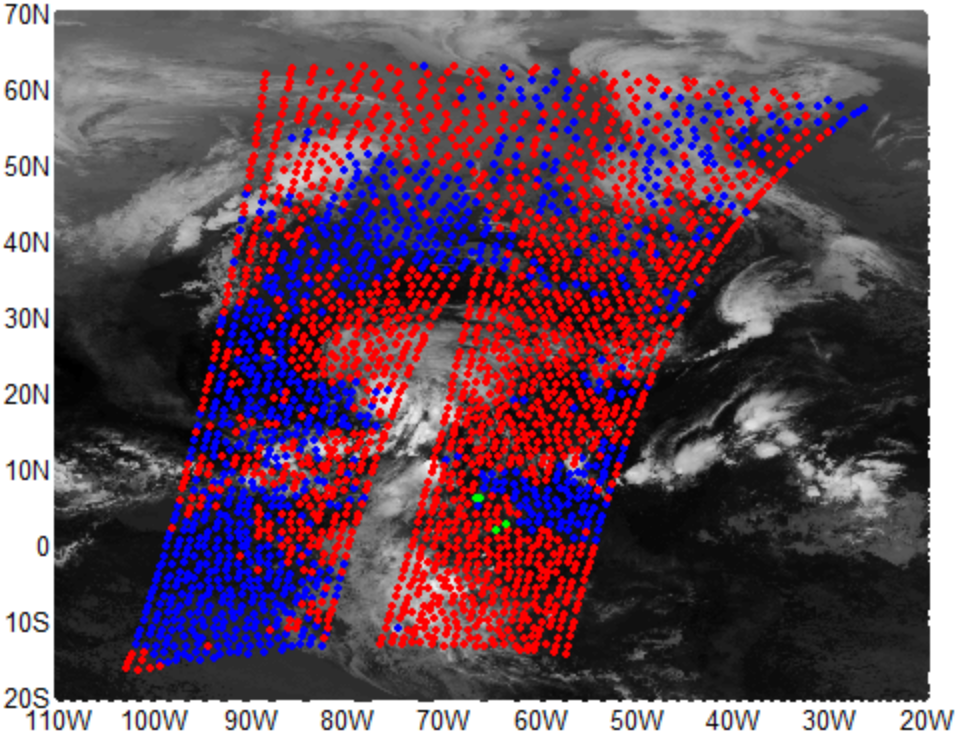

New QC



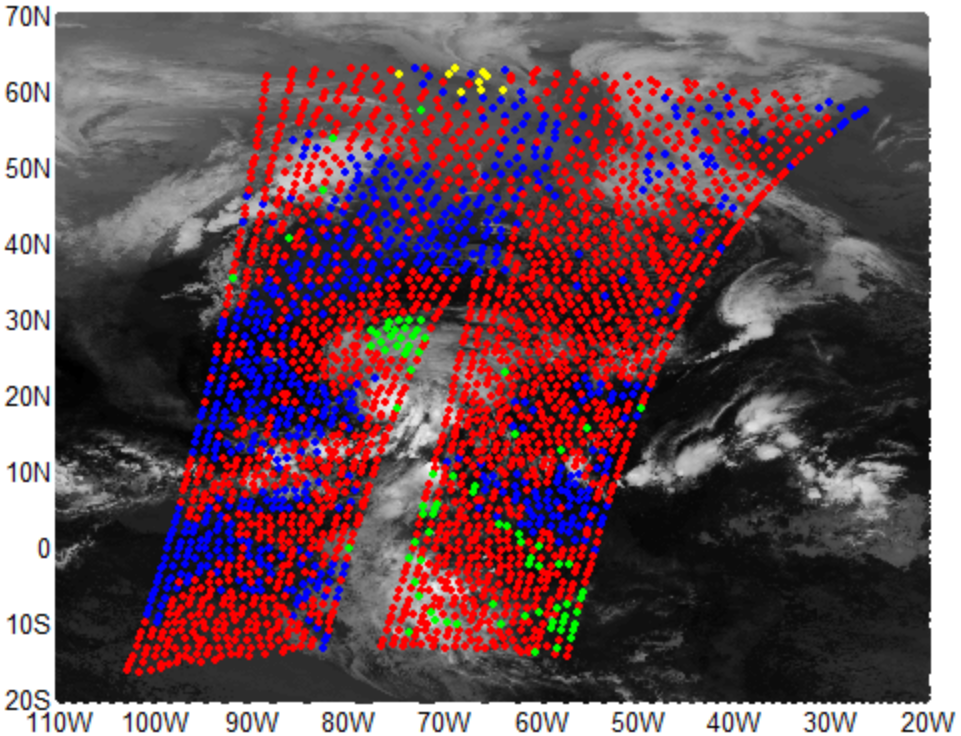

**Spatial distribution of CrIS channel 80 data points (699cm-1) passing all QC check (blue) , failed through cloud check (red) and failed through gross check (green), overlapped on GOES-13 brightness temperature at 0600 UTC Oct. 26, 2012.**

# QC for Channel 102 (713cm-1)

Current GSI QC



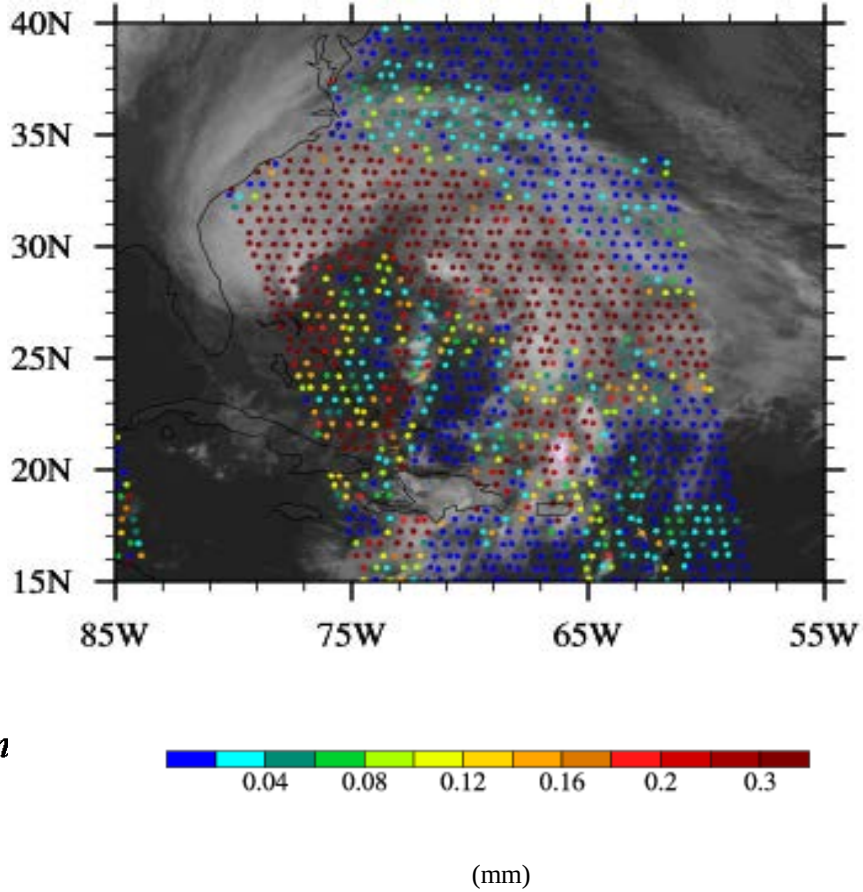

New QC




**Spatial distribution of CrIS channel 102 data points (713cm-1) passes all QC check (blue) , failed through cloud check (red) , failed through gross check (green) and through failed Surface emissivity/temperature check (yellow) overlapped on GOES-13 brightness temperature at 0600 UTC Oct. 26,2012.**

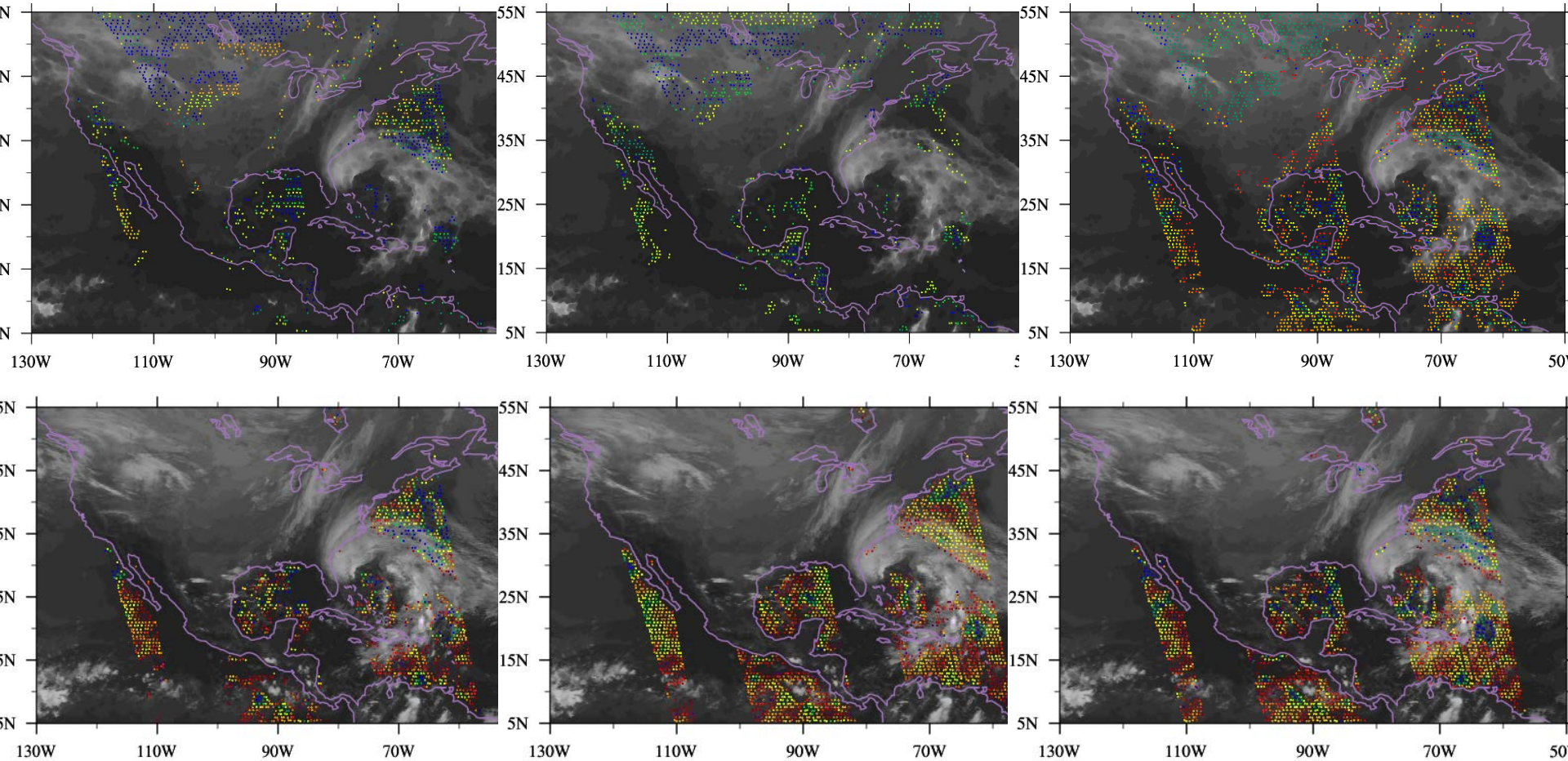
# Improved SSMIS Imager Channel Quality Control Using Cloud Liquid Water Algorithm

- ✓ Use SSMIS cloud liquid water composite algorithm for GSI QC
- ✓ Reject the measurements having LWP greater than 0.3 mm
- ✓ Reject the imager data over land.



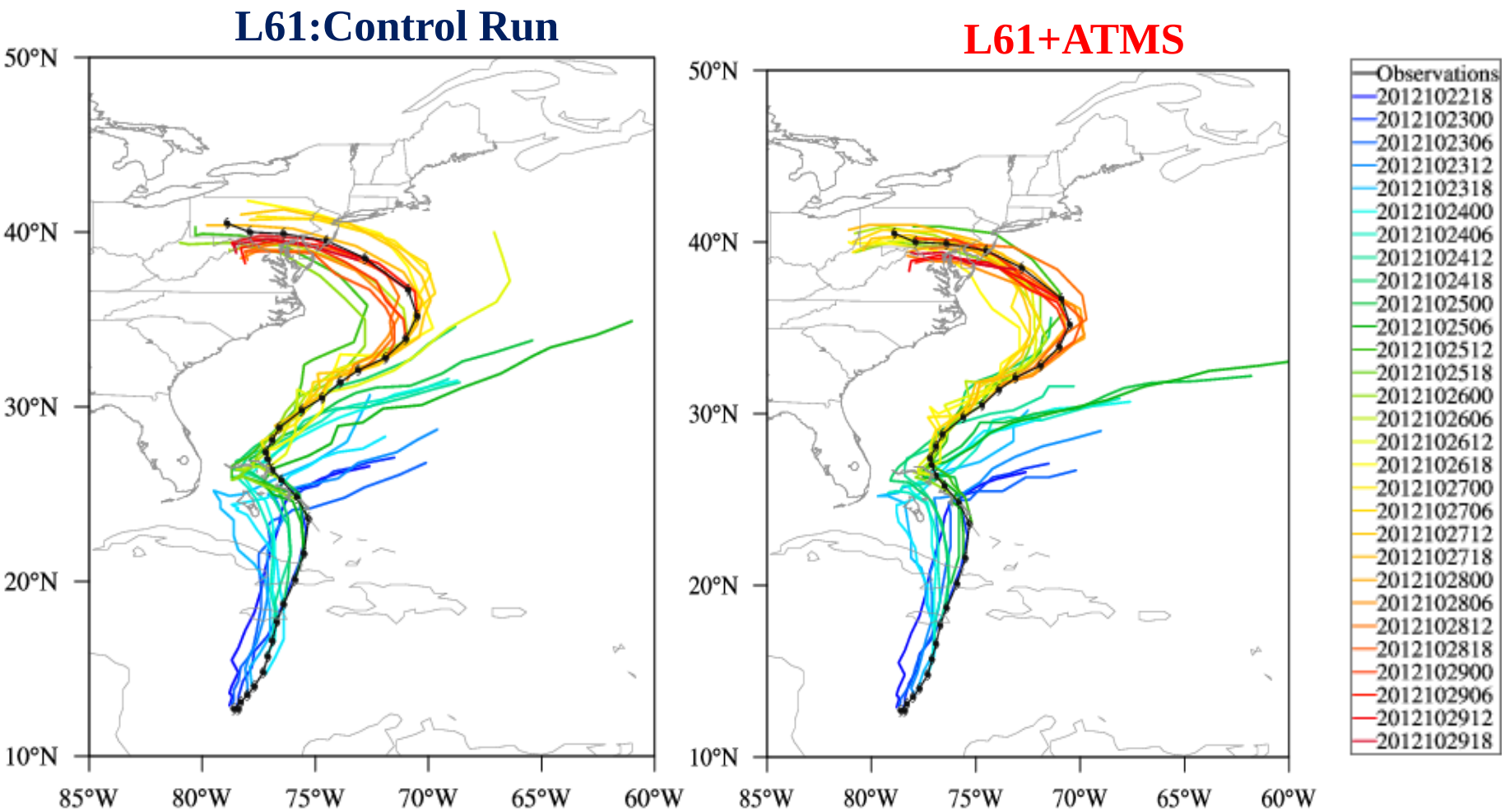

$$LWP_{comp} = \begin{cases} LWP_{19v}, & LWP_{19v} > 0.7\ mm \\ LWP_{37v}, & LWP_{37v} > 0.28\ mm\ or\ WVP \geq 60\ mm \\ LWP_{91h}, & otherwise \end{cases}$$

# Improved SSMIS Imager Channel Quality Control Using Cloud Liquid Water Algorithm

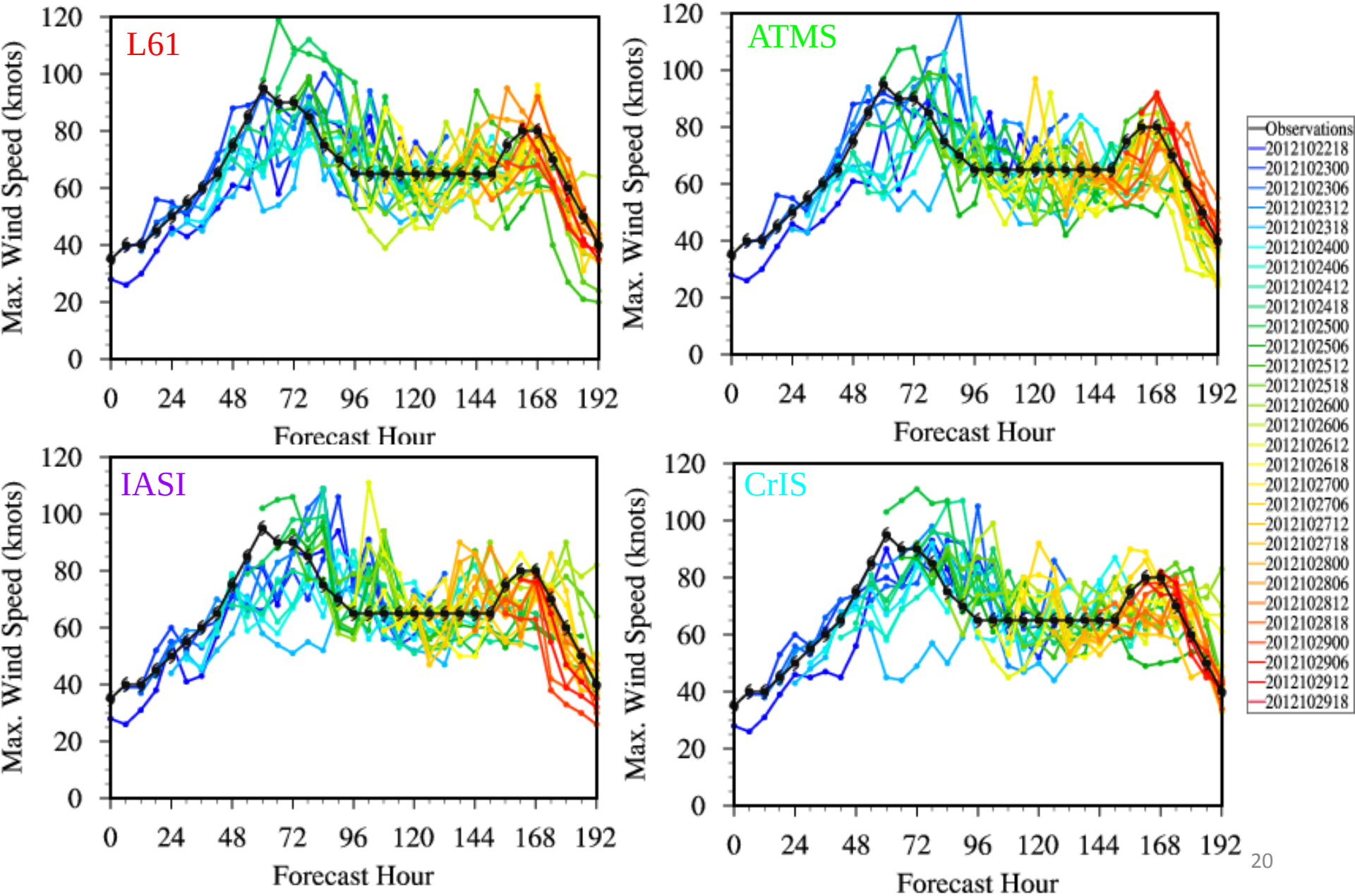



*Upper panels: SSMIS data distribution retained for assimilation for Ch12-19V, ch13-19H and ch14-22V with the current GSI QC. The data remain over land and most of data are limited, and their distributions are inconsistent in space. Lower panels: SSMIS data distribution retained for assimilation with new QC which shows consistent responses to clouds and precipitation. Also, the data over land is removed.*

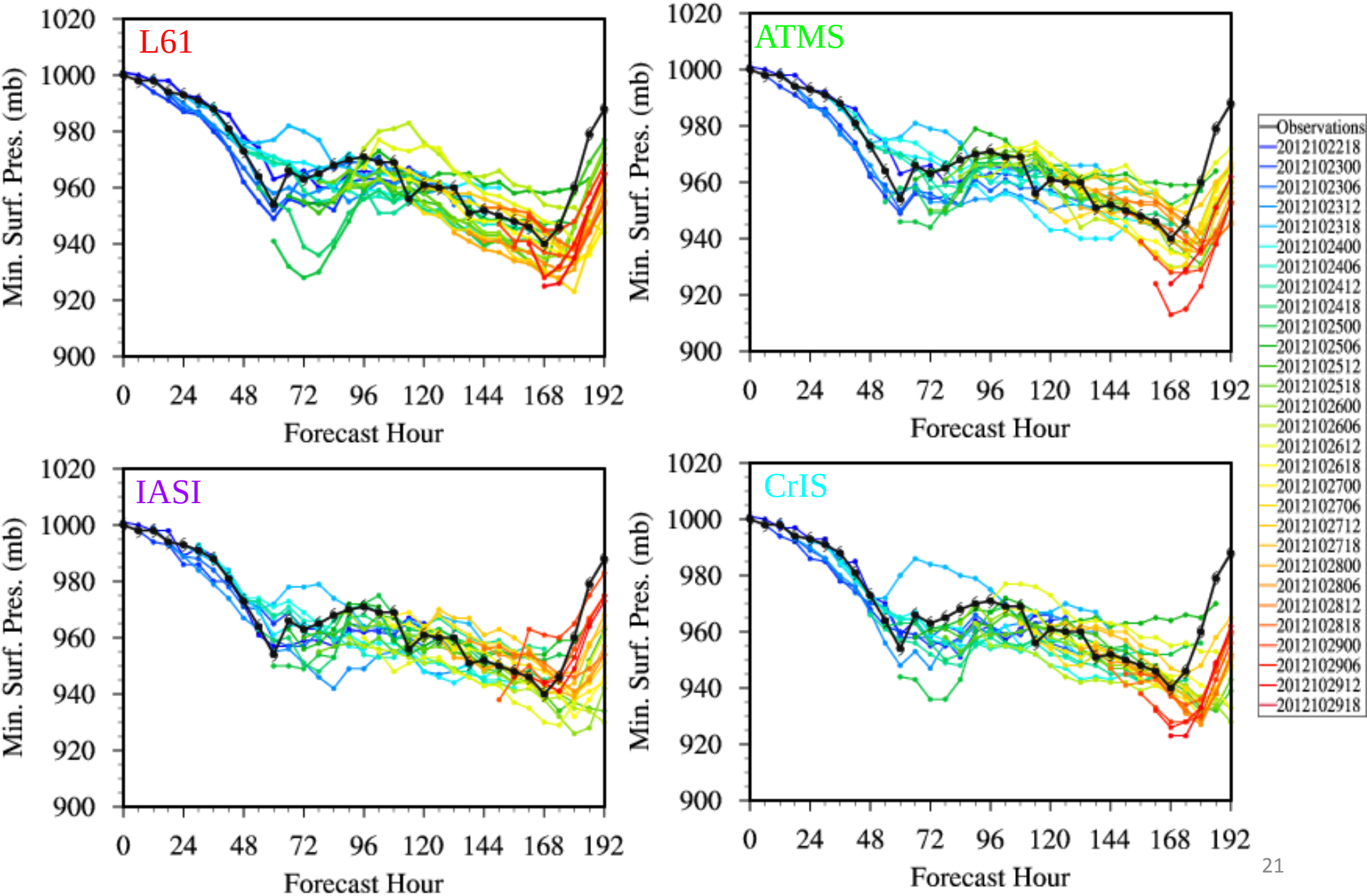
# Impacts of Direct Assimilation of Suomi NPP ATMS Radiances on Hurricane Sandy's Track



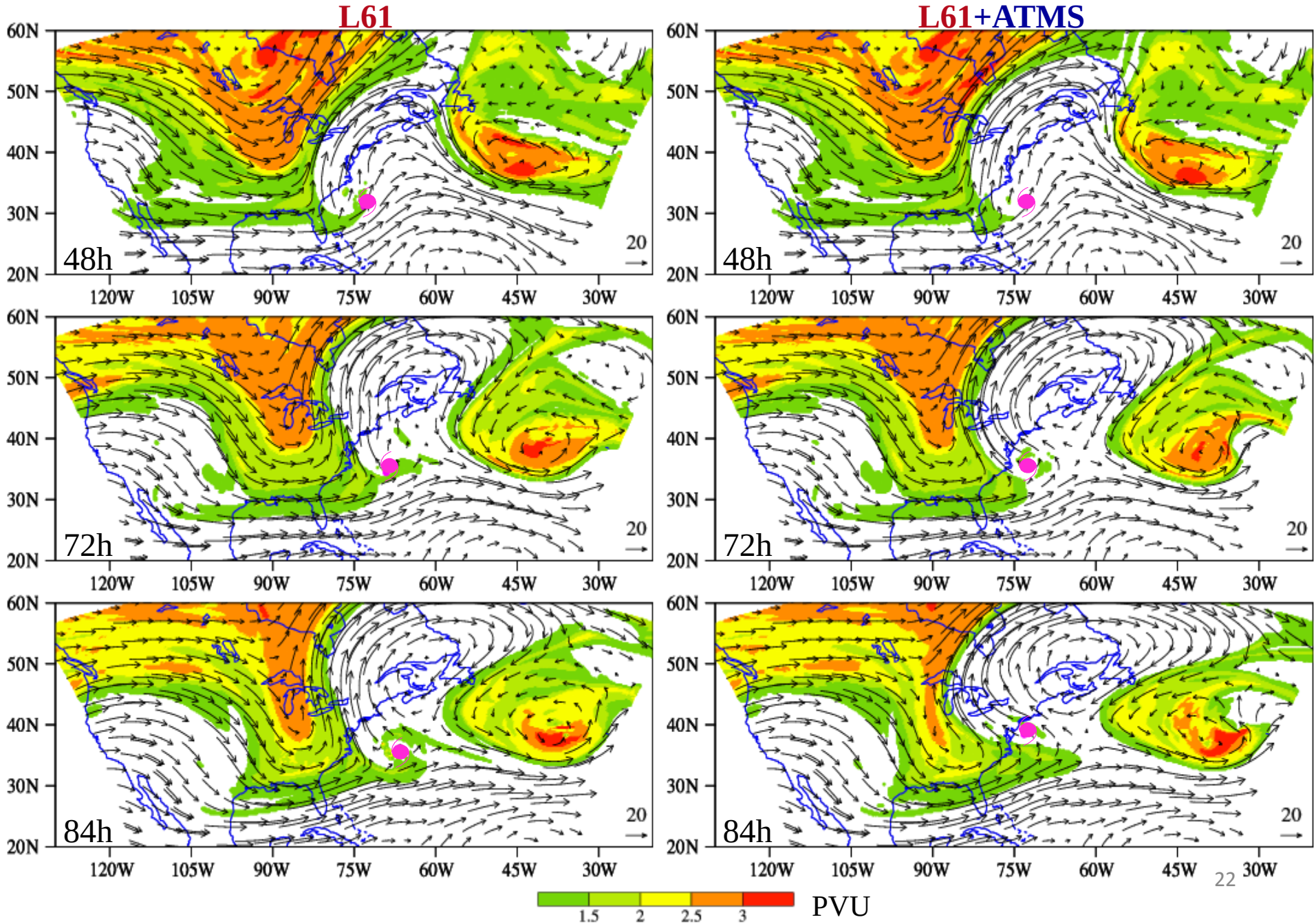
# Multiple Forecasts of Max. Wind Speed for Hurricane Sandy



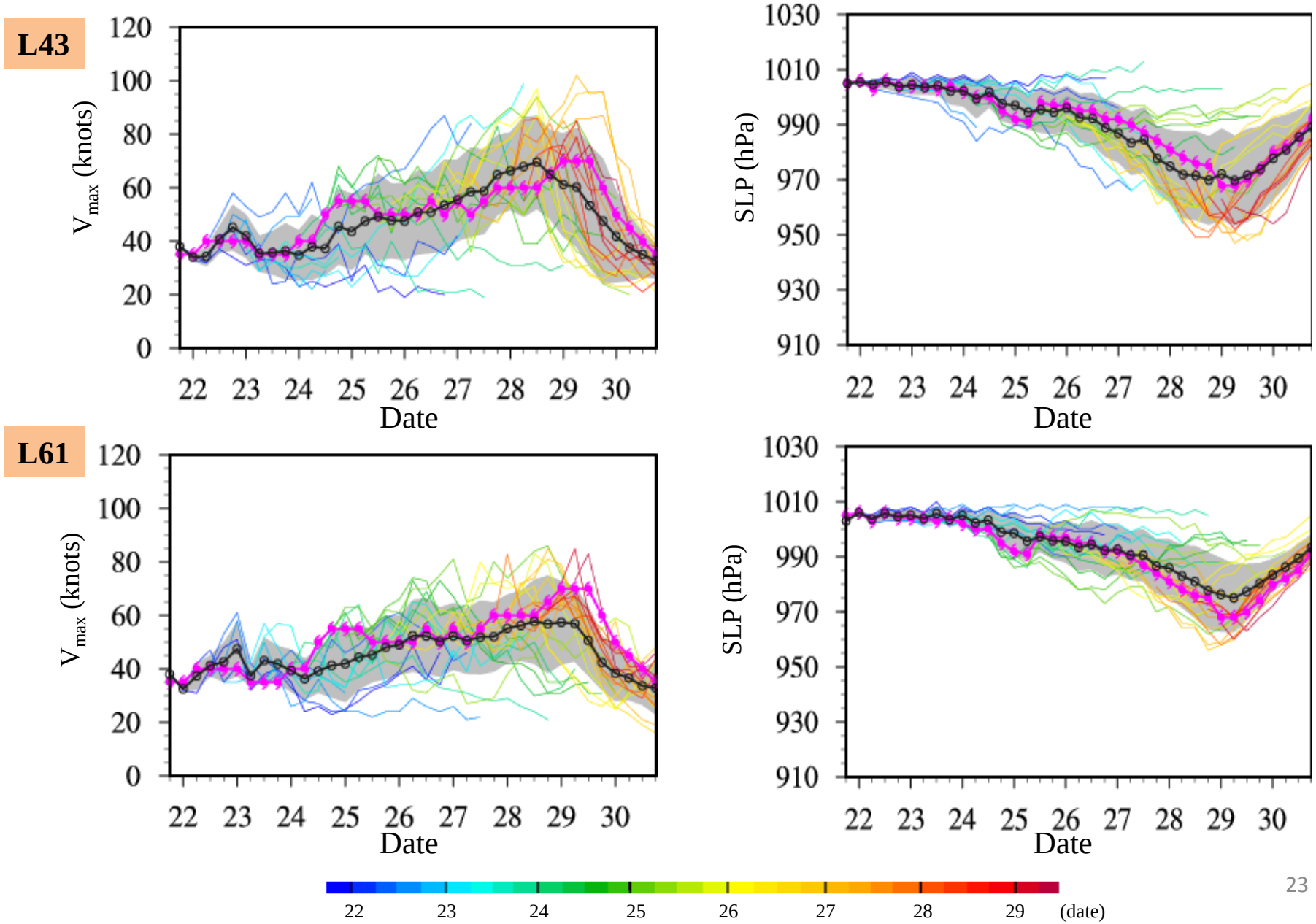
# Multiple Forecasts of Min. Surf. Pres.



# 200 mb PV and wind for 48h, 72h and 84h forecast



# Forecast Intensities of Hurricane Isaac



# Summary

- HWRF/GSI model is re-configured to include more vertical layers and higher model top for more effective uses of satellite sounding data in the analysis

- For 2012 hurricane cases, assimilation of satellite data in HWRF improves the storm intensity forecast in terms of both maximum wind and minimum pressure. The impact on track forecast is positive up to forecast day 3,

- Improvements in the GSI quality control for new instruments (e.g. CrIS and AMSR2/SSMIS imaging channels) remain critical. Sensitivity tests show SSMIS imaging channels have some impacts on hurricane forecasts.

- Control and sensitivity experiments show uses of ATMS in HWRF improve the hurricane forecasts in both intensity and track.

- Characterization of observation error covariance in cloudy conditions is developed for future tests of cloudy radiances assimilation

# References


- Zou, X., Qin. Z., and F. Weng, 2012: Improved Coastal Precipitation Forecasts with Direct Assimilation of GOES 11/12 Imager Radiances, *Mon. Wea. Rev*., **10**.1175/MWR-D-10-05040.1
- Yan, B. and F. Weng, 2012: Assimilation of F16 Special Sensor Microwave Imager/Sounder Data in the NCEP Global Forecast System, *Weather and Forecast*, **27**, 700-714.
- Zou, X., Qin Z., and F. Weng, 2013: Improved quantitative precipitation forecasts by MHS radiance data Assimilation with a newly added cloud detection algorithm, *Mon. Wea. Rev*., DOI: 10.1175/MWR-D-13-00009.1
- Zhu, T. and F. Weng, 2013**:** Hurricane Sandy warm-core structure observed from advanced Technology Microwave Sounder, *Geophys. Res Lett.*, **40**, 3325–3330, doi:10.1002/grl.50626
- Zou, X., F. Weng, B. Zhang, L, Lin, Z. Qin, and V. Tallaparada**:** 2013**:** Impacts of assimilation of ATMS data in HWRF on track and intensity forecasts of 2012 four landfall hurricanes, *J. Geophys. Res.*, **118**, 1-19, doi:10.1002/2013JD020405