Impact of assimilating the VIIRS-based CrIS cloud-cleared radiances on hurricane forecasts

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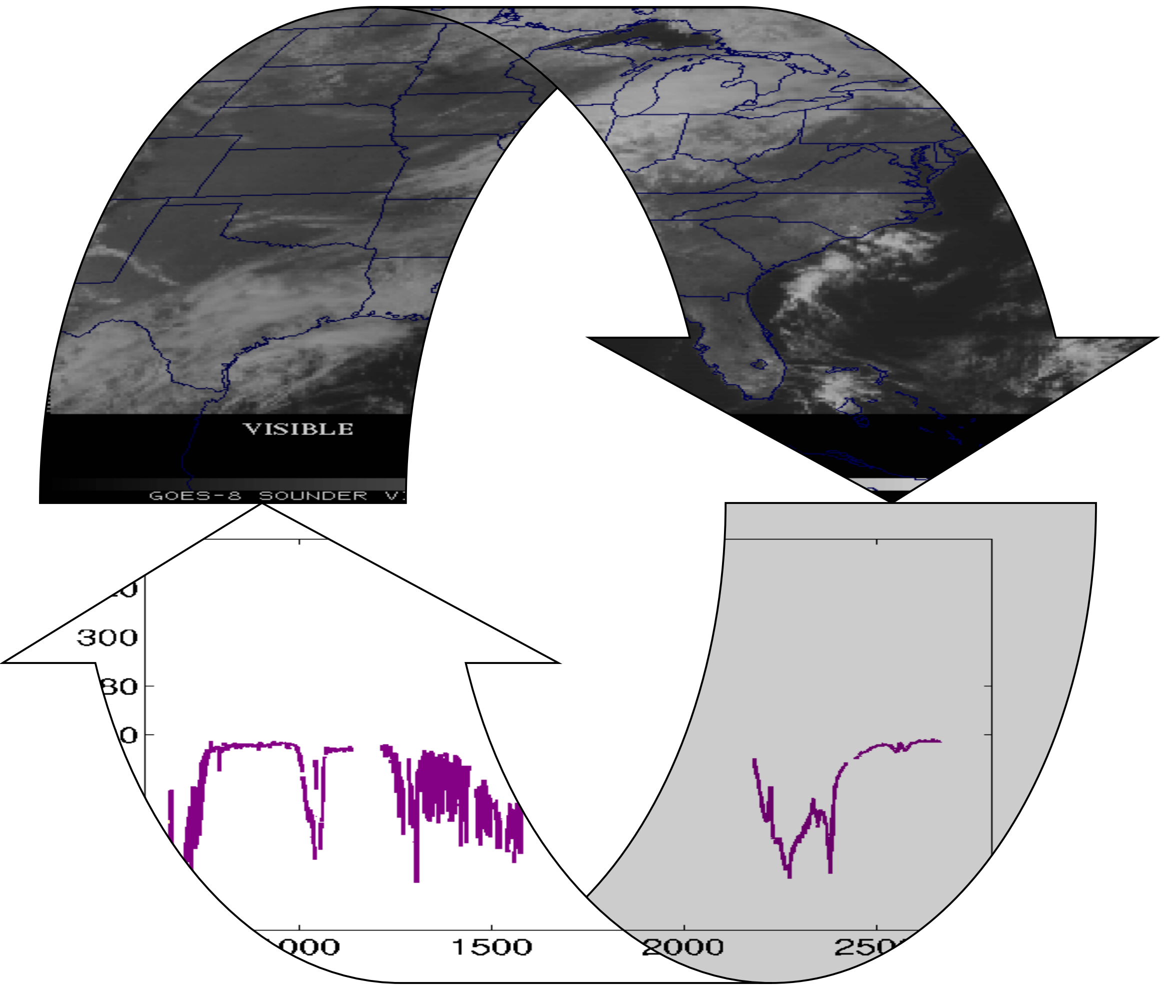
Outlines

- Motivation and current status on using imager to assist handling clouds for IR sounder radiance assimilation;
- VIIRS-based CrIS cloud-cleared radiances (CCRs);
- Impact from CCRs and GOES-16 moisture on recently hurricanes;
- Summary and future work.

Using high resolution imager measurements to assist hyperspectral IR sounder radiance assimilation

MODIS, AVHRR, VIIRS, MERSI (LEO Imager)
AGRI (GEO Imager)



AIRS, IASI, CrIS, HIRAS (LEO sounder)
GIIRS (GEO sounder)

1. Both instruments (sounder and imager) have good signal-to-noise ratio, have overlap spectral coverages;
2. They are comparable through convolving sounder to imager spectrally and averaging imager to sounder spatially.

Using imager for assisting IR sounder radiance assimilation:
1. IR sounder sub-pixel cloud-detection and QC for radiance assimilation;
2. Cloud-cleared radiances (CCRs) in cloudy skies for assimilation.

Current status on using imager for sounder radiance assimilation

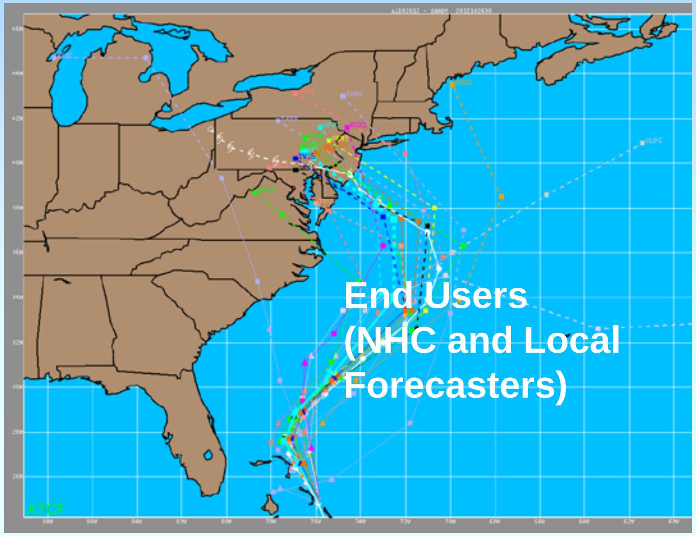
- IR sounder sub-pixel cloud characterization has been demonstrated and recommended by ITWG to operational centers at ITSC20;
- Using collocated imager data (IR band radiances and cloud mask) to derive the sounder cloud-cleared radiances
  - AIRS/MODIS demonstrated (Wang et al. 2016);
  - Algorithm implemented for CrIS/VIIRS, demonstrated with CIMSS SDAT for recent hurricanes;
  - VIIRS-base CrIS CCRs tested in GFS by EMC (Dr. Collard and Dr. Liu) (9p.09 - Liu et al.);
  - VIIRS-based CrIS CCRs tested in RAP by ESRL;
  - Test by NRL planned (Dr. Ruston).

CIMSS near real-time Satellite Data Assimilation for Tropical storms forecasts (SDAT) (http://cimss.ssec.wisc.edu/sdat)

SDAT
(http://cimss.ssec.wisc.edu/sdat)

Applications

WRF/GSI at CIMSS



Research testbed for improving the assimilation of JPSS/GOE-R data (Sounder, ABI, radiances, TPW, AMVs, Clouds, etc.)

TC Forecast Improvement

R2O Research

Refining the Operational Path

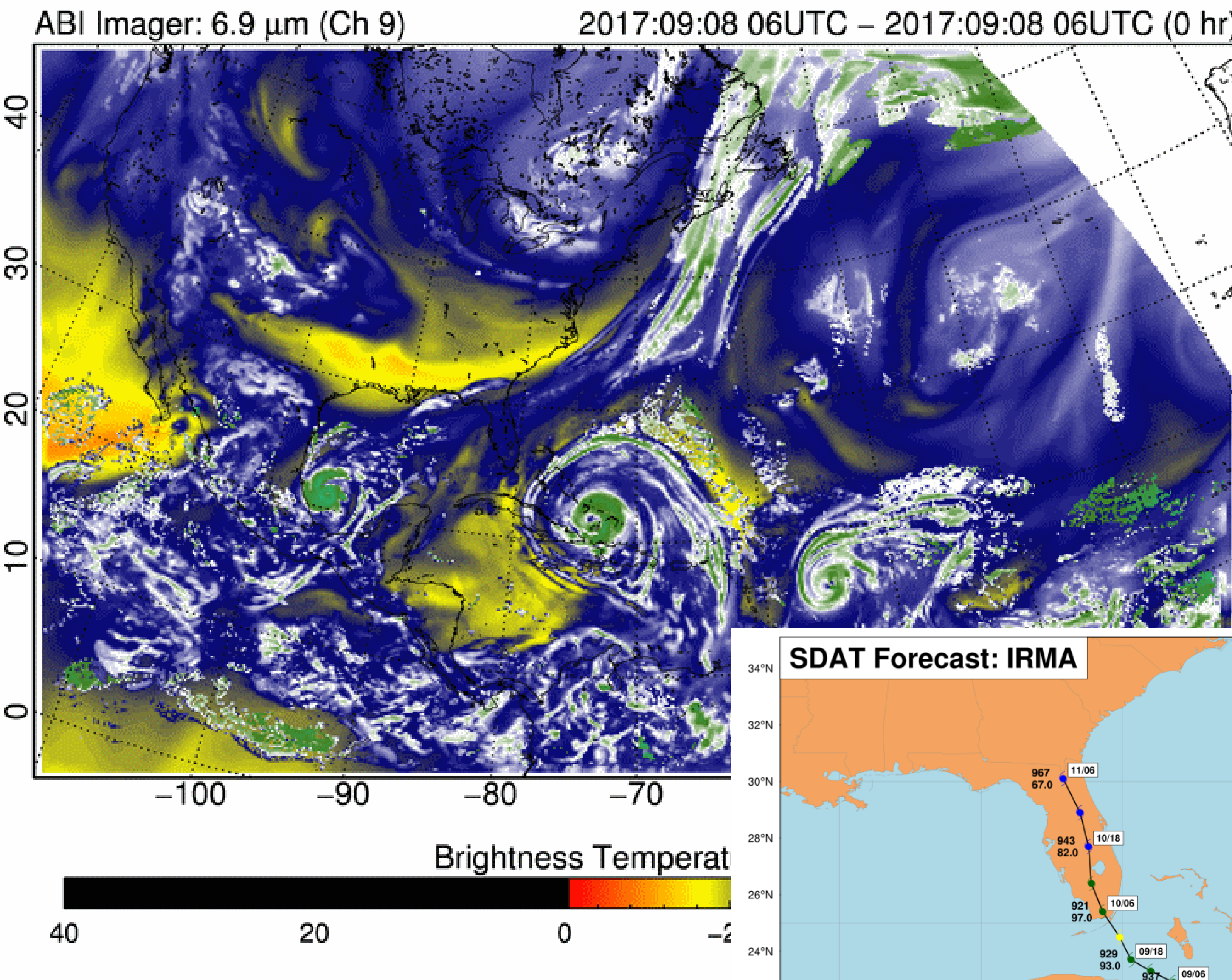
Operational NWP models:

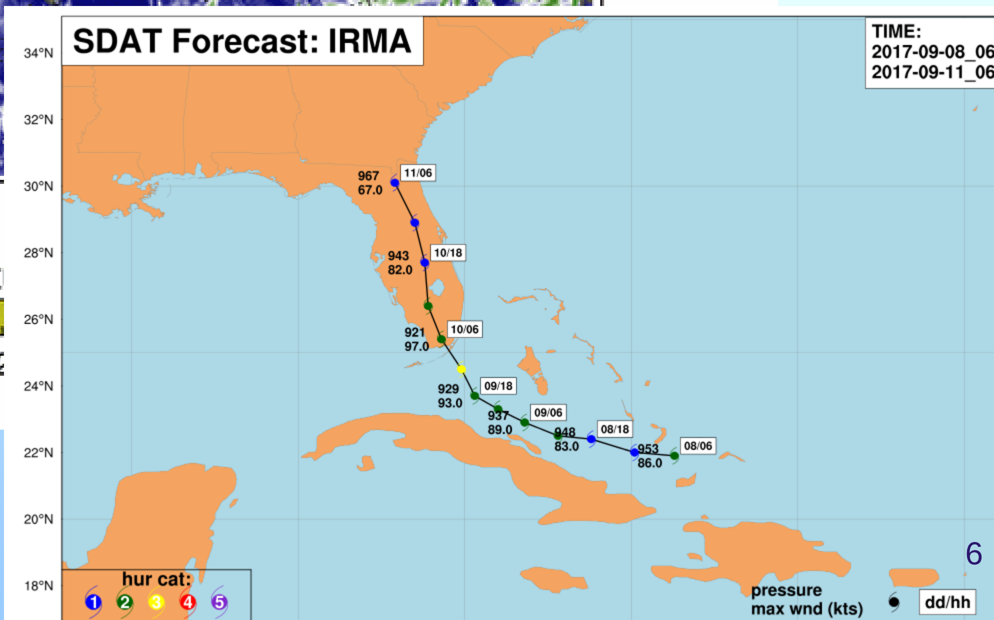
EMC GFS

EMC HWRF

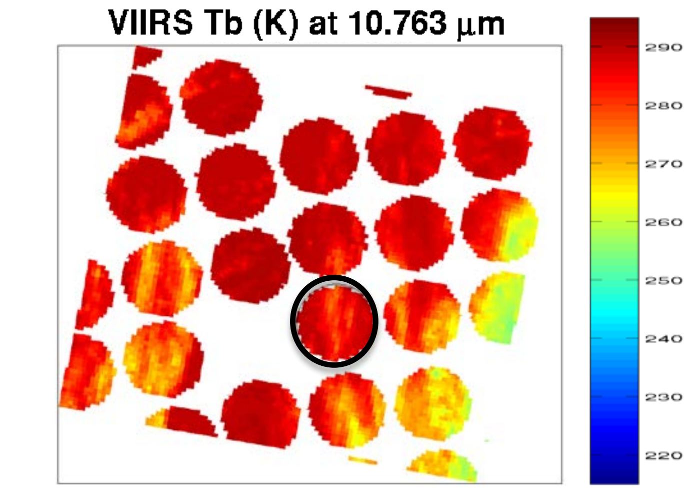
ESRL RAP

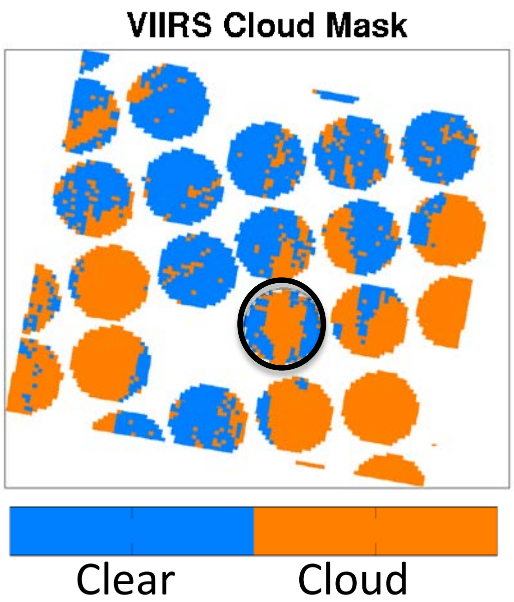
CIMSS SDAT 2017090806 00-72 hours forecasted IR-WV ABI Imager - IRMA

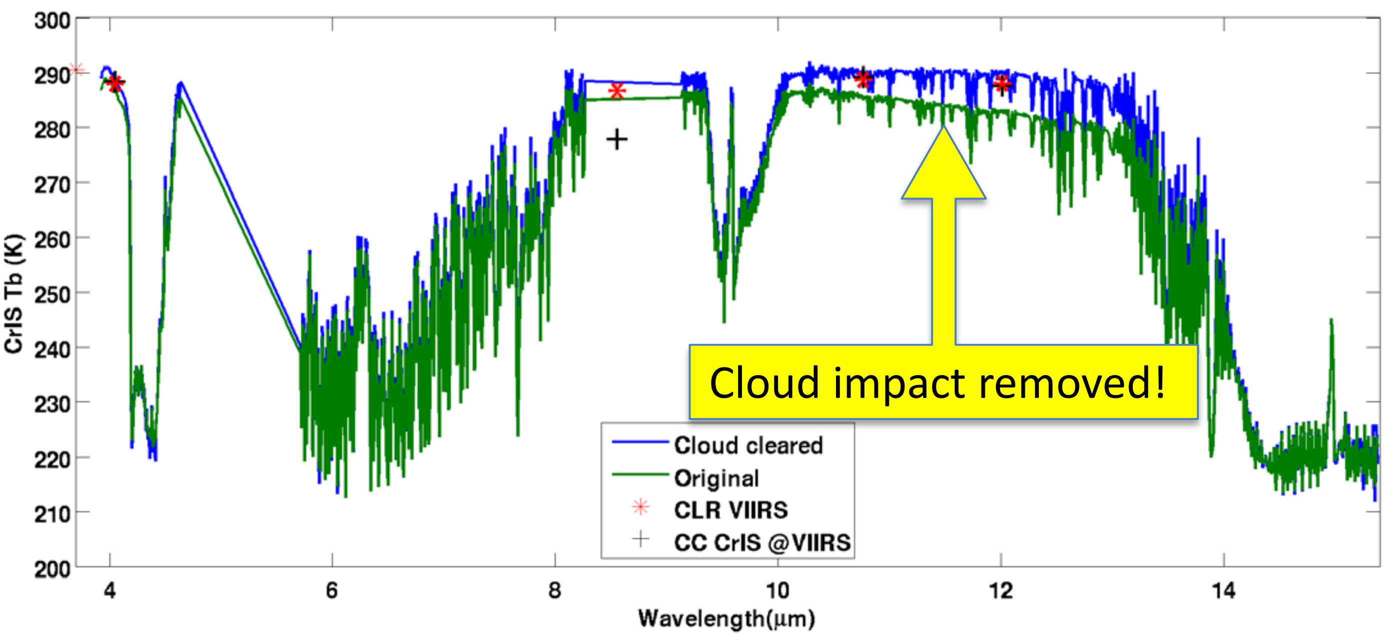




CrIS/VIIRS cloud clearing for CrIS radiance assimilation



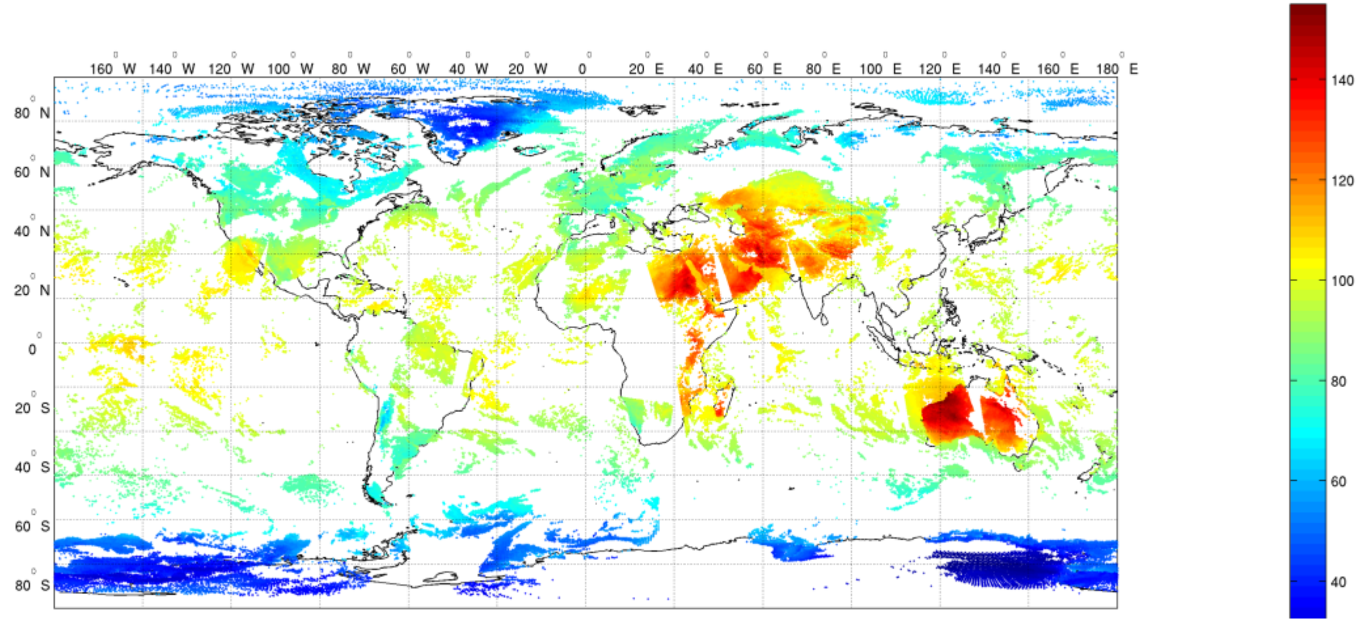




- The CC method (Li et al., 2005);
- VIIRS cloud mask identifies partially cloudy FOVs **(black circle);**
- VIIRS radiances help quality control cloud cleared CrIS radiances;
- Only three VIIRS bands (4.05, 10.763, and 12.013 um) used (overlapped with CrIS);
- Cloud cleared radiances very close to VIIRS clear sky radiances;
- 12.5 % of partially cloudy FOVs are successfully cloud cleared for Hurricane Sandy (2012) case.

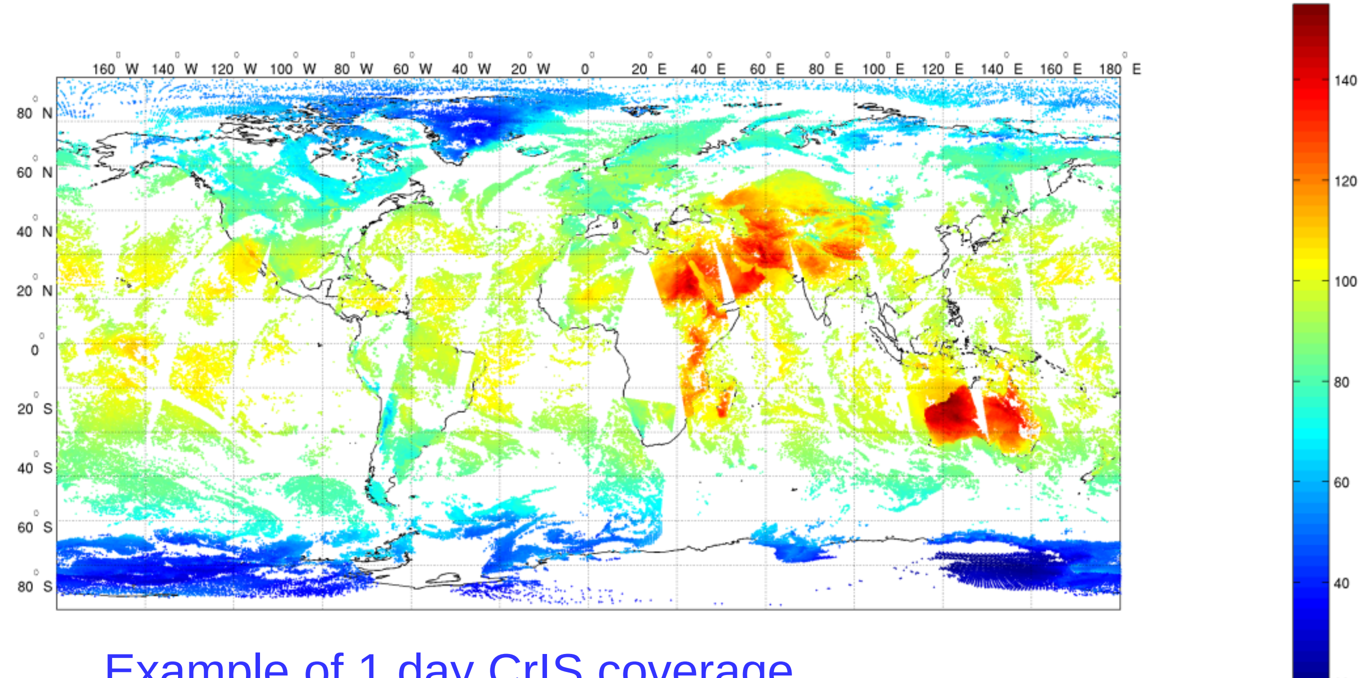
CrIS clear radiances:
(clear FOVs + radiances not affected by clouds)

11 µm radiance (mW/(m^2 sr cm^{-1})) from CrIS clear only



CrIS CCRs:
(clear + CC coverage)

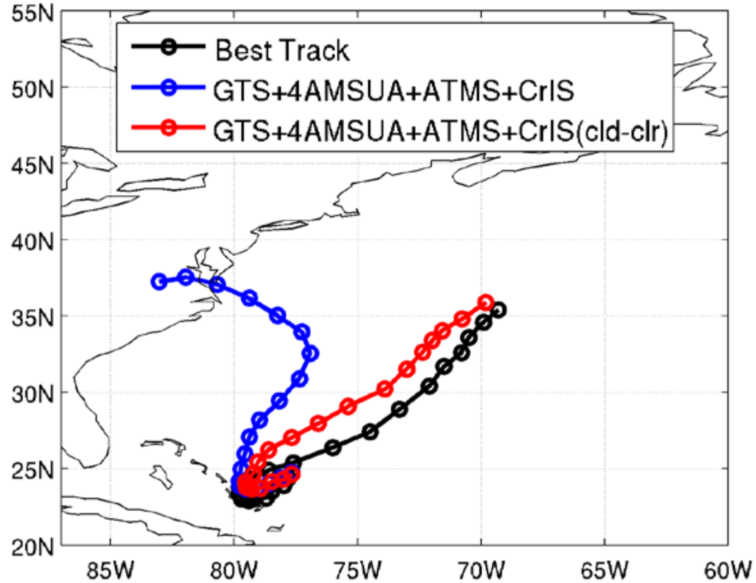
11 µm radiance (mW/(m^2 sr cm^{-1})) from CrIS clear plus cloud cleared

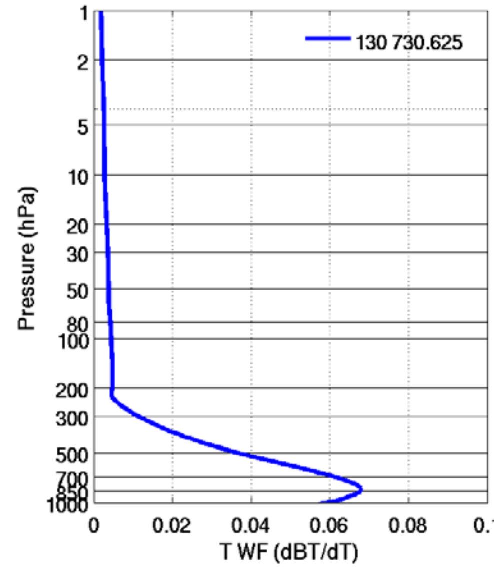


Example of 1 day CrIS coverage

Analyzing 120hr forecasts from 18 UTC 09-30 2015

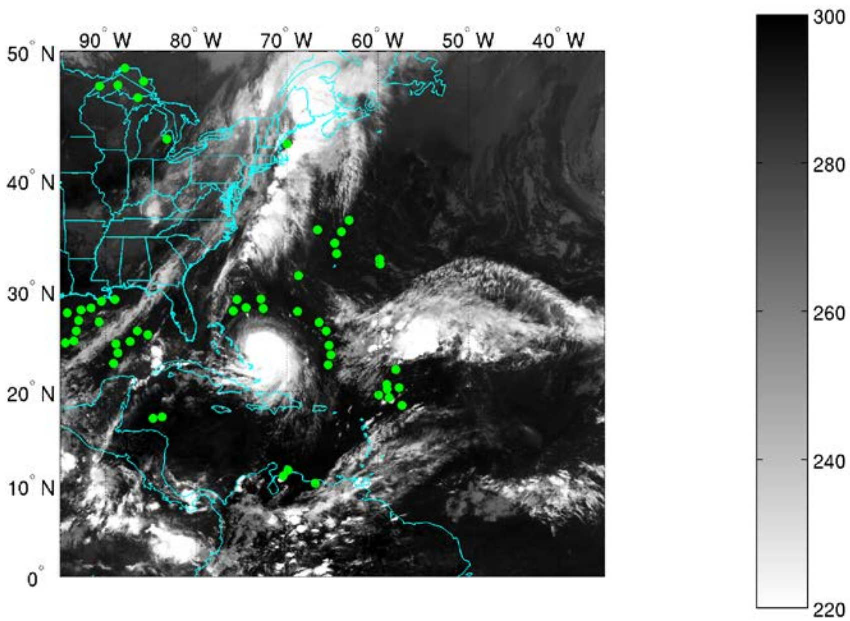
How do CrIS CCRs improve tropical cyclone forecast?





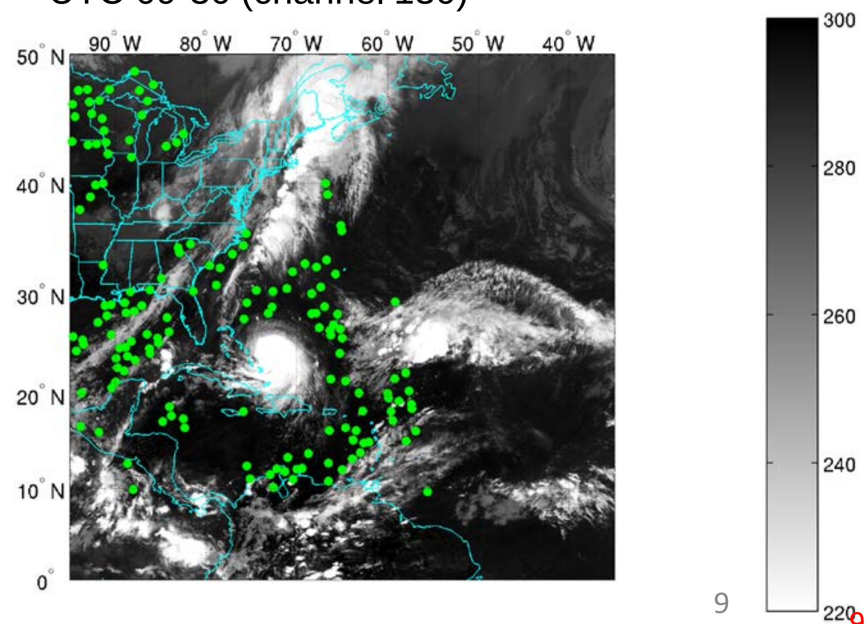
CrIS original radiances assimilated at 18 UTC 09-30 (channel 130)

BT (K)



CrIS CCRs assimilated at 18 UTC 09-30 (channel 130)

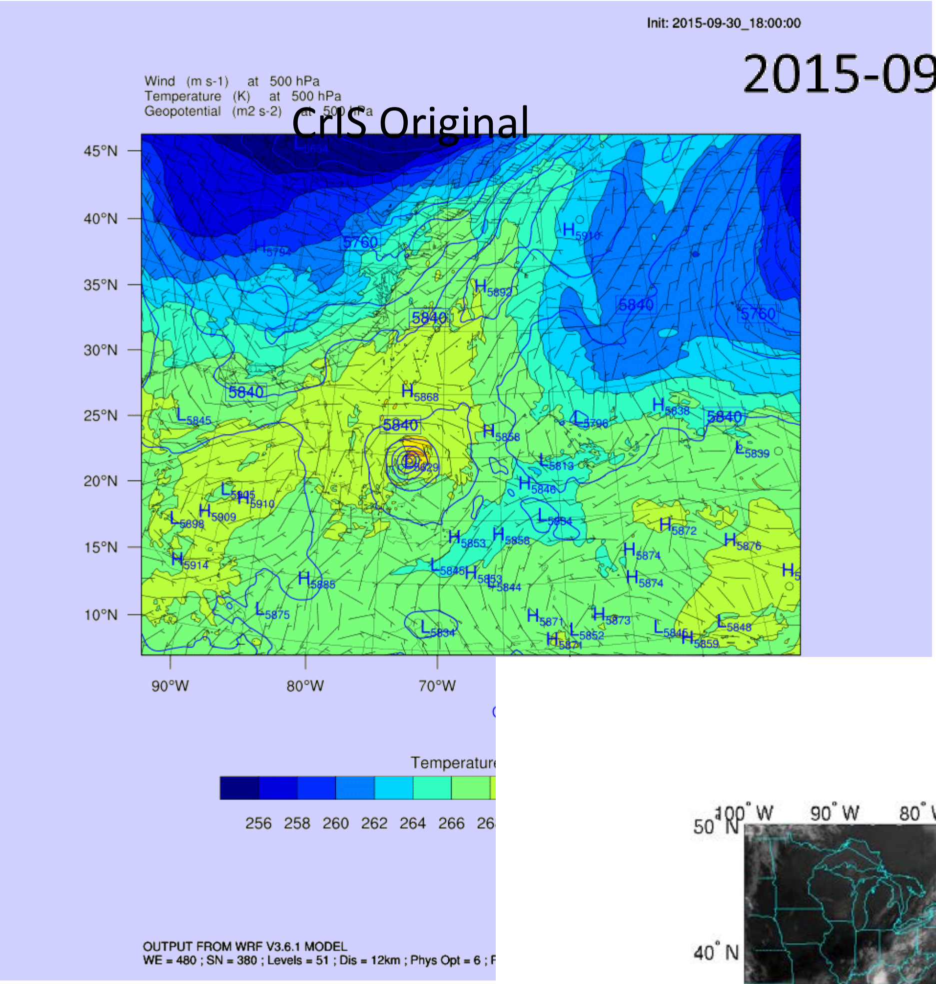
BT (K)



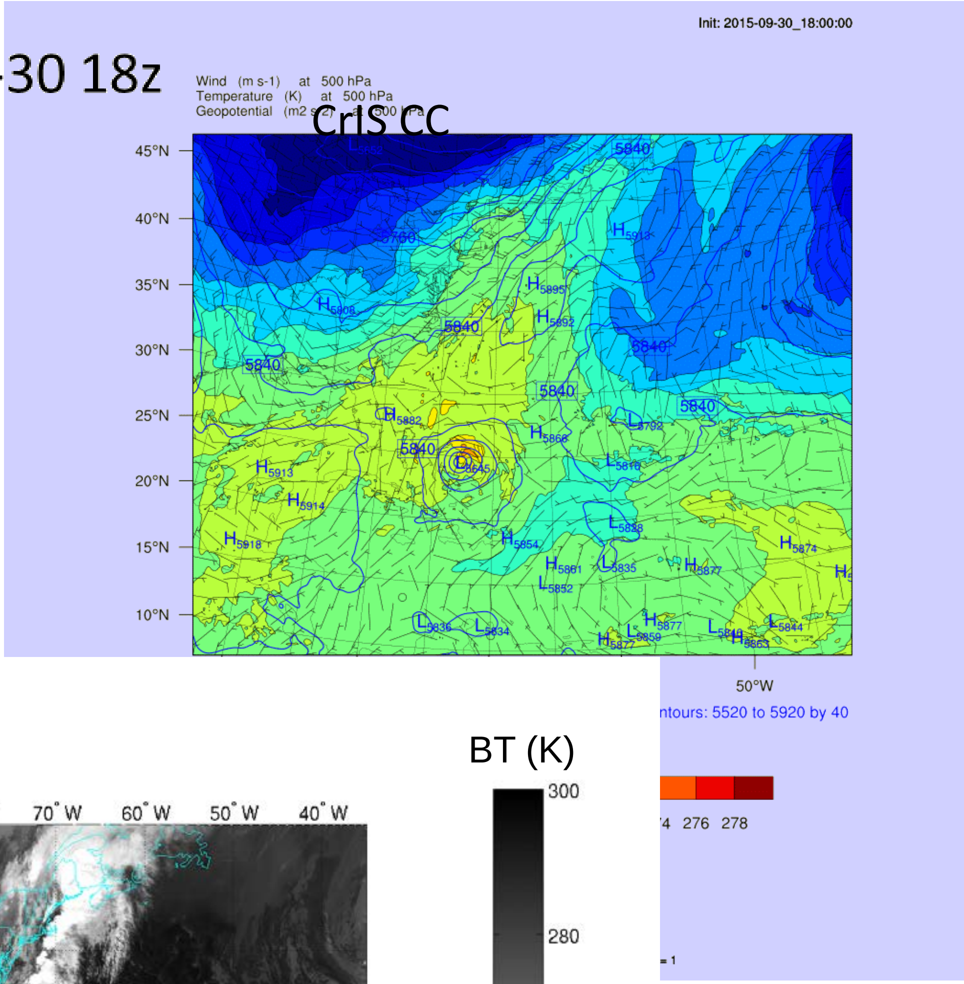
120 hr forecasting from 09-30 18z 500hPa

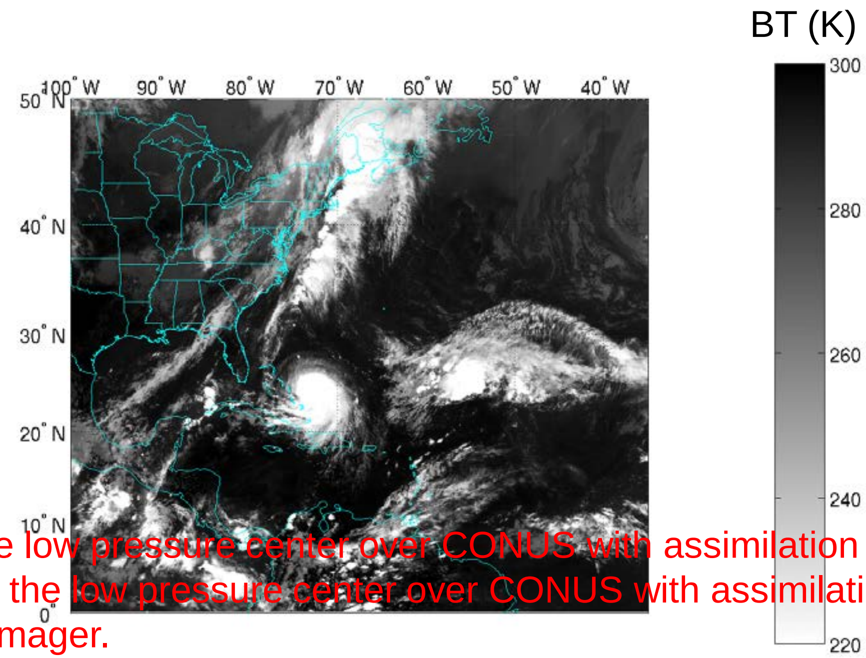
2015-09-30 18z

CrIS Original



CrIS CC





- ➢ Hurricane Joaquin is merged with the low pressure center over CONUS with assimilation of CrIS radiances (left)
- ➢ Hurricane Joaquin is separated from the low pressure center over CONUS with assimilation of CrIS CCRs (right), which is verified with GOES Imager.

Experiments on Hurricane Harvey (2017)

WRF-ARW v3.6.1: 12 km horizontal resolution (400*300) , 52 vertical layers from surface to 10hPa

GSI v3.3: 3D-Var Data Assimilation Method

- NAM background error covariance matrix
- Conventional Data (GTS)
- AMUS-A radiances onboard NOAA-15, NOAA-18, NOAA-19, and Metop-A
- IASI onboard Metop-A and Metop-B
- ATMS onboard Suomi-NPP
- CrIS radiances onboard Suomi-NPP
- Updated bias correction for each cycling, enhanced bias correction method in GSI
- Background and initial conditions: NCEP FNL (BG: GFS).

Hurricane Harvey (2017)

- Assimilation : Aug 23 00z to Aug 25 18z, 2017
- Forecasts: Aug 23 12z to Aug 28 18z, 2017
- Assimilation every 6 hour, 10 groups in statistics

Data:

Conv from GTS;

POES: AMSU-A, IASI, ATMS and CrIS;

CCRs: CrIS cloud-cleared radiances (CCRs) in cloudy skies;

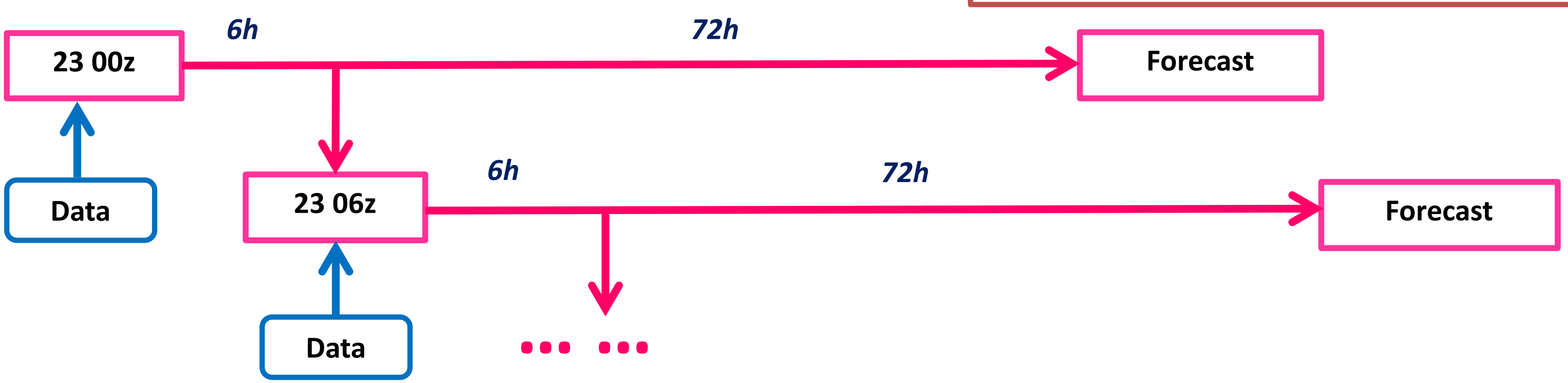
GOES-16: Three layered precipitable water (LPW) from ABI at: 0.3 - 0.7, 0.7 - 0.9, and 0.9 – 1.0 in sigma level.

Experiments

CNTRL: Conv+AMSUA+IASI+ATMS+CrIS (Conv + POES)

CNTRL+CCRs: adding radiances in cloudy skies

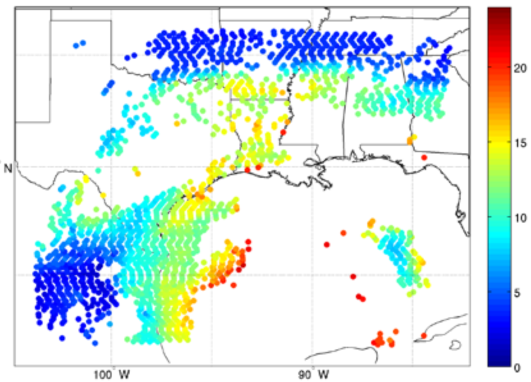
CNTRL+LPW: adding GOES-16 moisture information

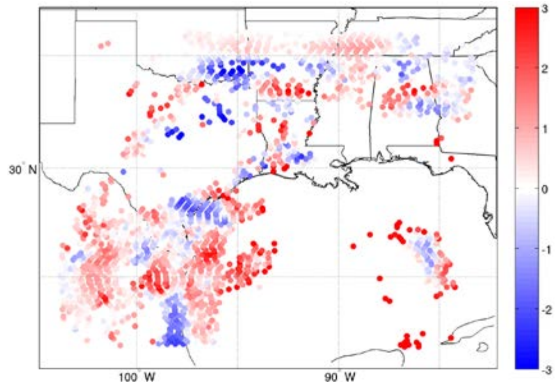


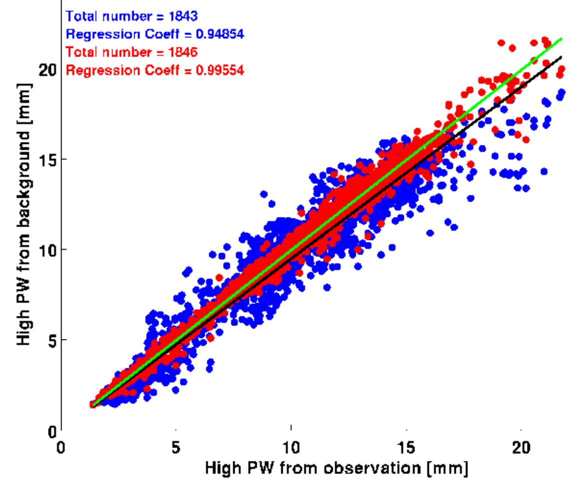
2017-8-24 06z

GOES-16 Observations (mm)

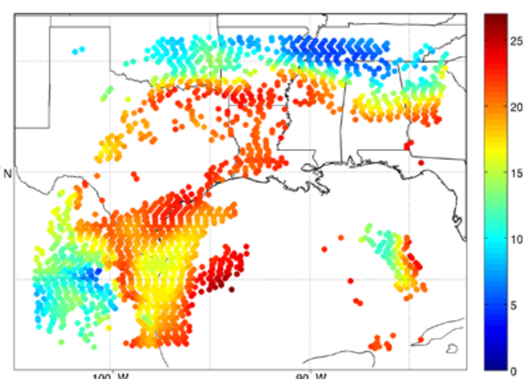
O-B (mm)

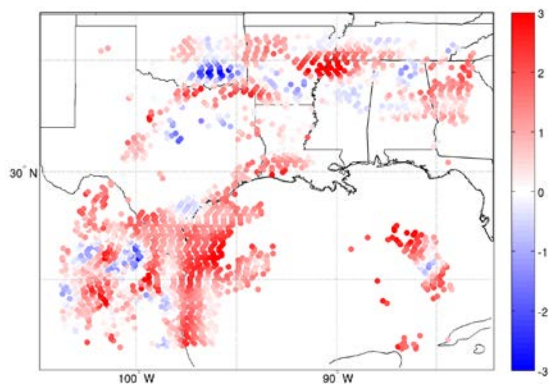


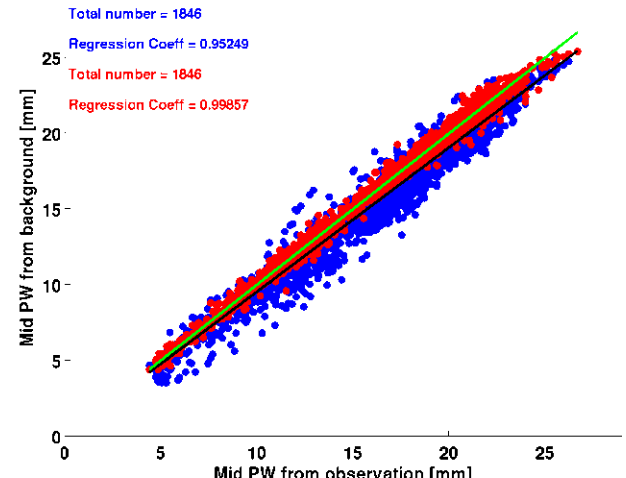




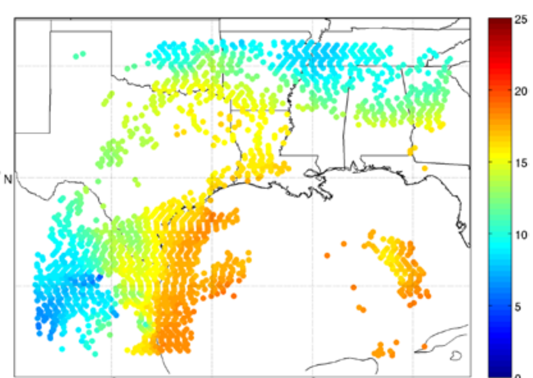
L-LPW: 900 hPa - SFC

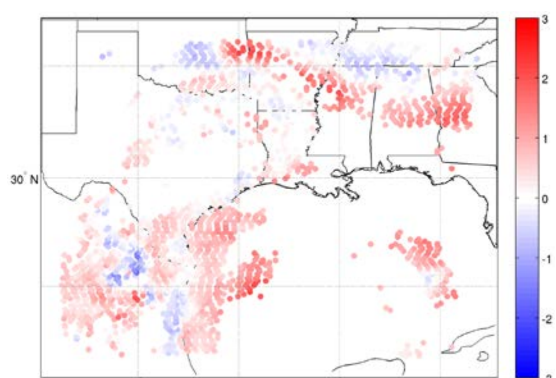


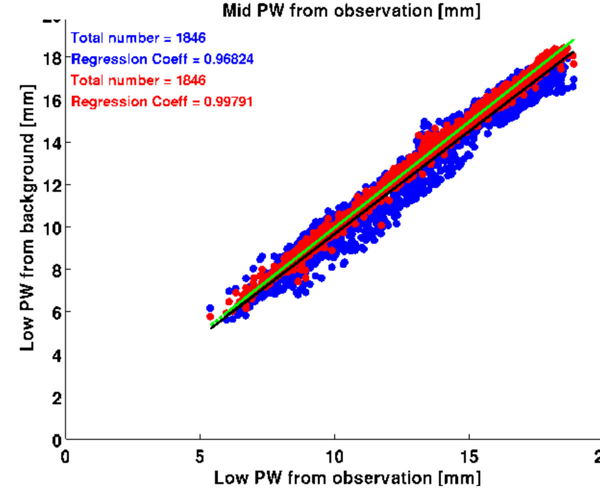




M-LPW: 700 – 900 hPa

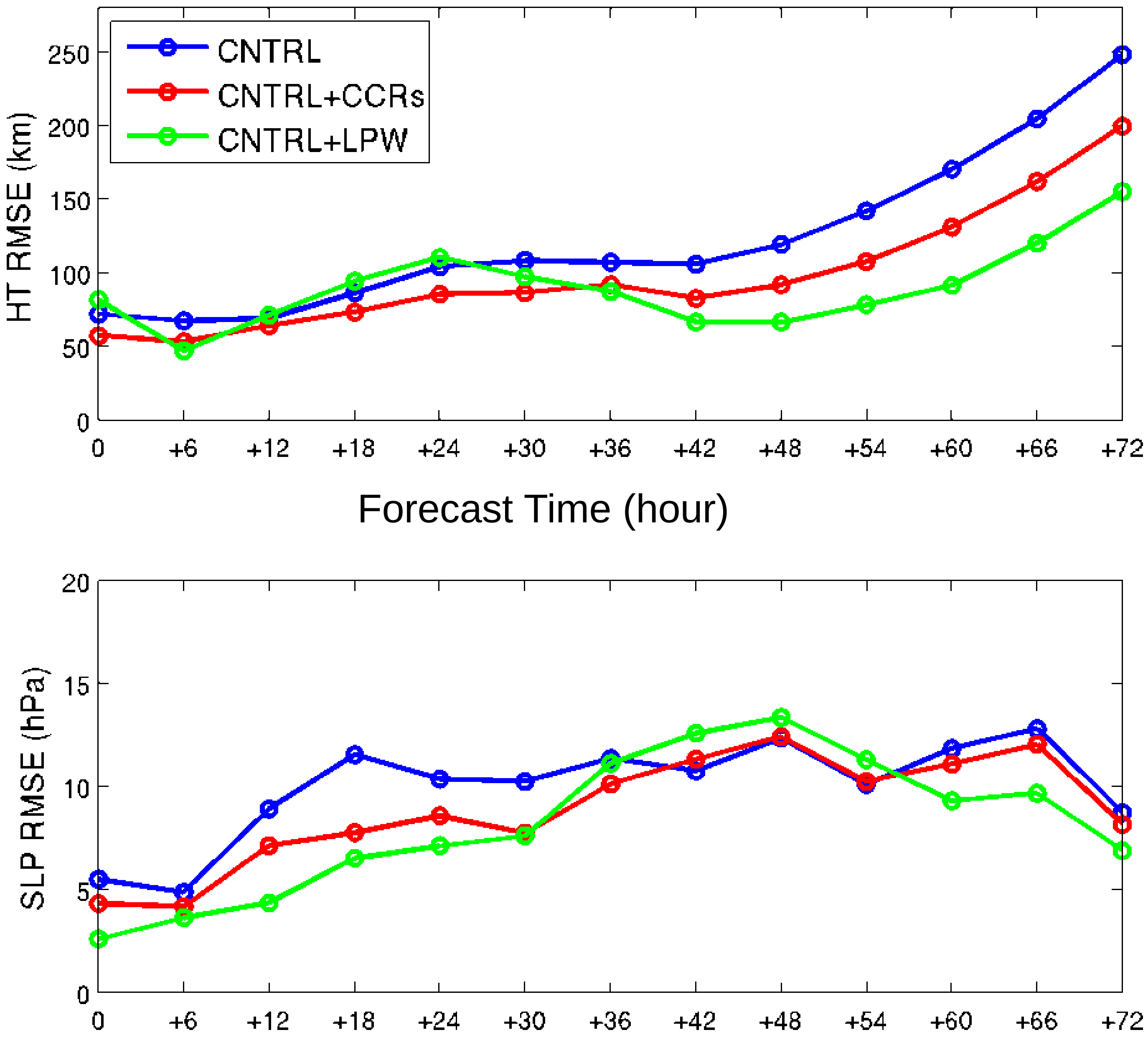




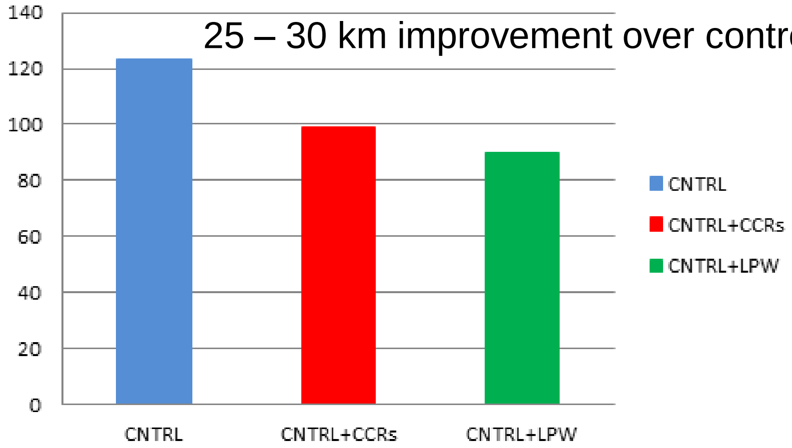


H-LPW: 300 – 700 hPa

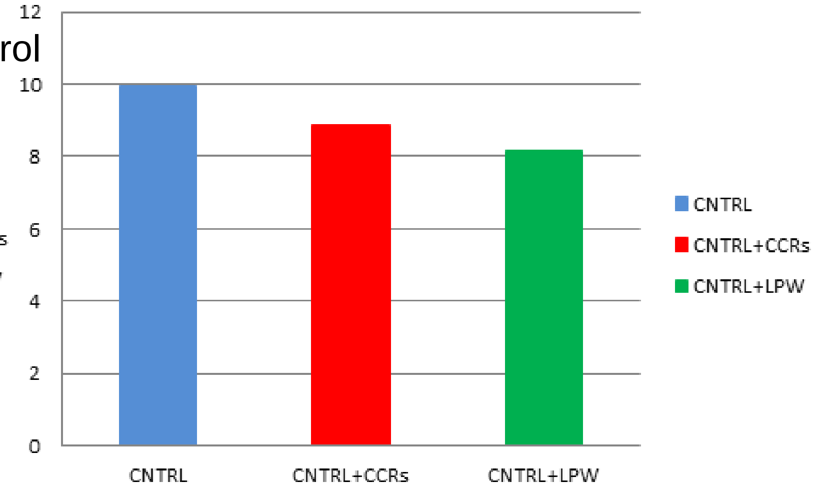
Statistics (RMSE) from the experiments



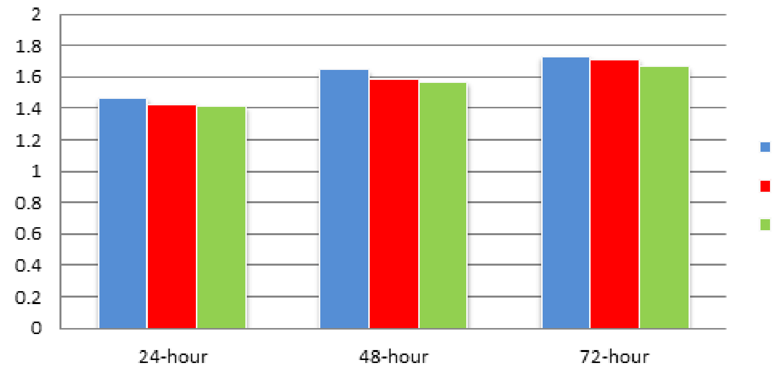
Mean RMSE of Track (Km)



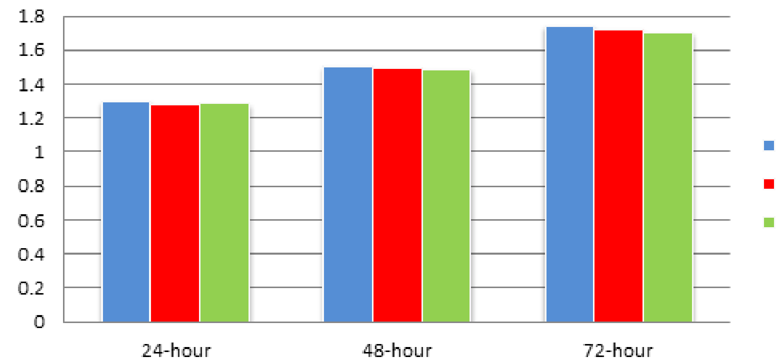
Mean RMSE of SLP (hPa)



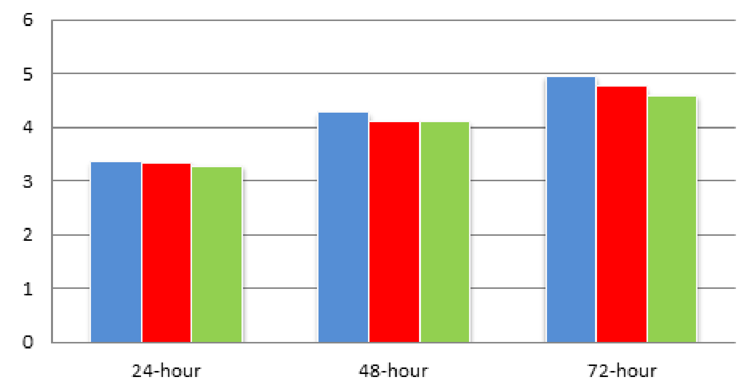
200 – 1000 hPa Temperature RMSE (K) with Radiosonde



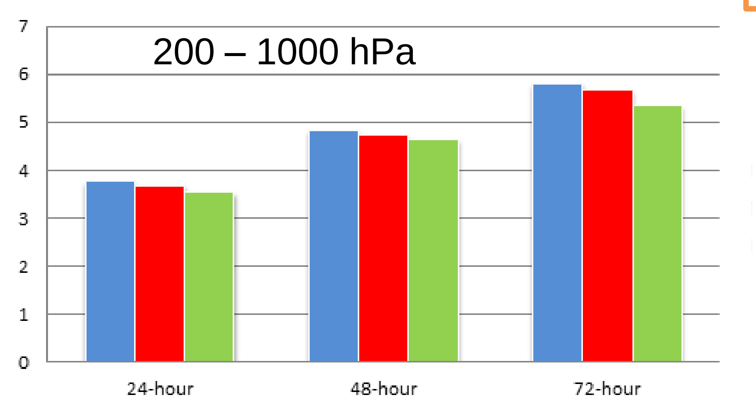
Humidity RMSE (g/kg) with Radiosonde **300 – 1000 hPa**



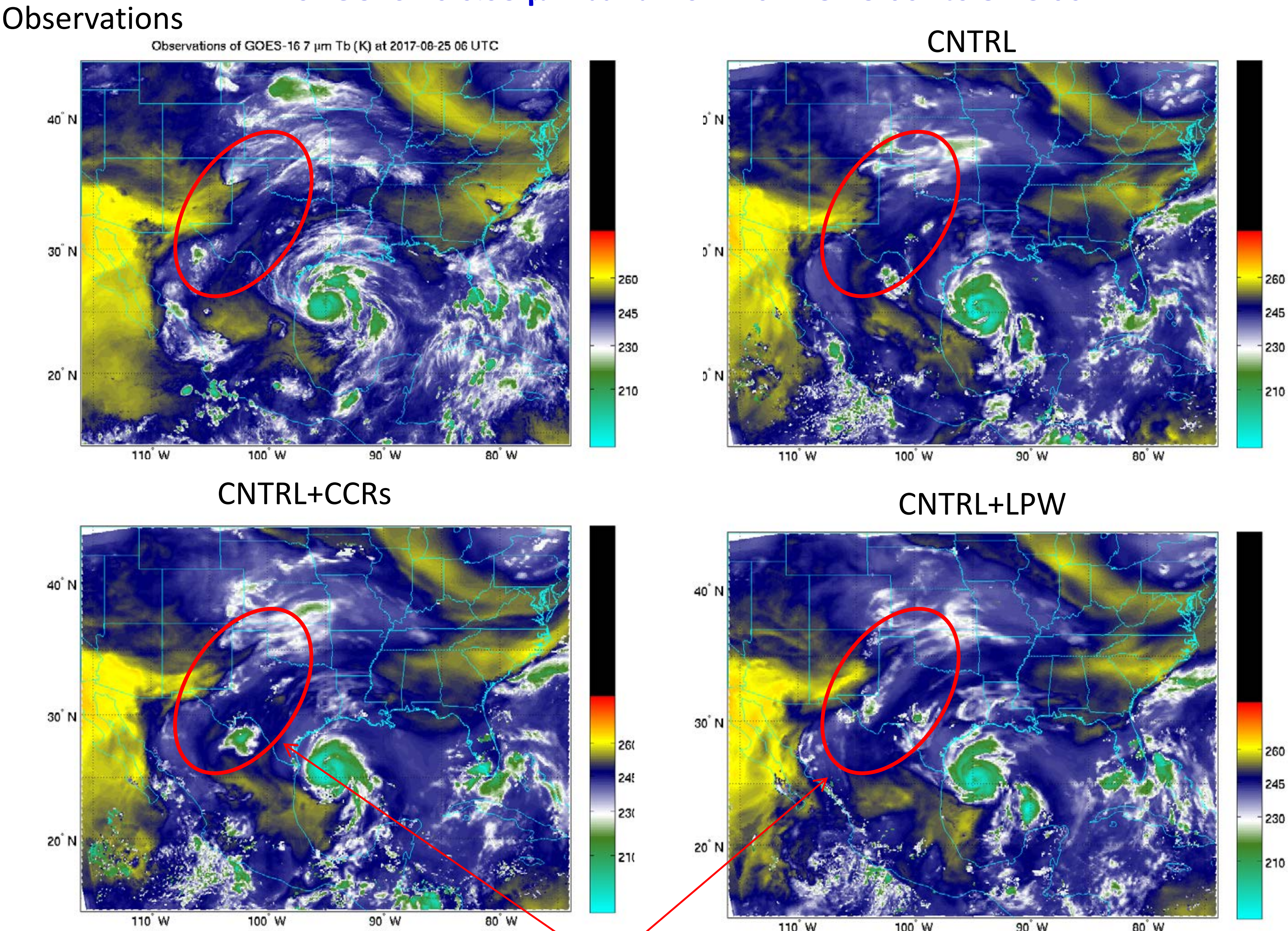
200 – 1000 hPa U-wind RMSE (m/s) with Radiosonde



V-wind RMSE (m/s) with Radiosonde **200 – 1000 hPa**



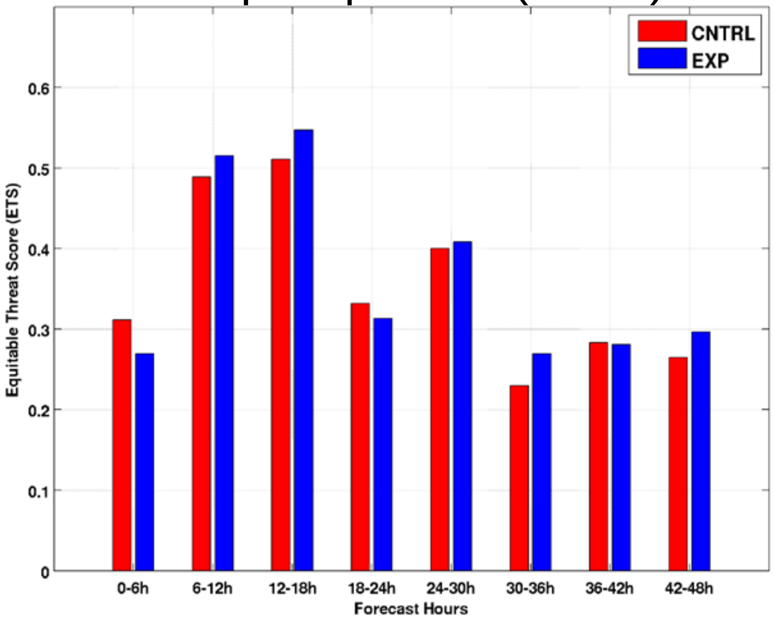
BT of GOES 16 6.95 µm band from 2017-8-25 06z to 8-28 06z



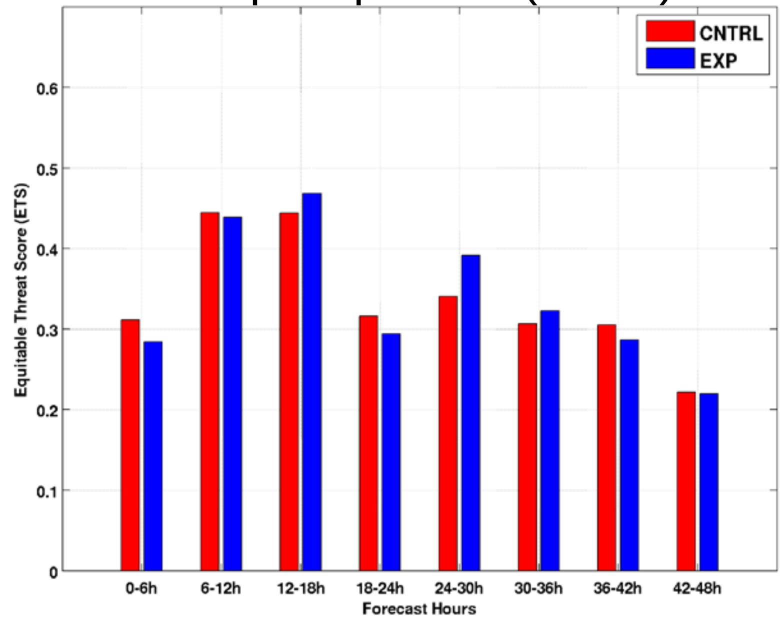
Better moisture distribution

ETS scores for 06 – 48 hour forecasts

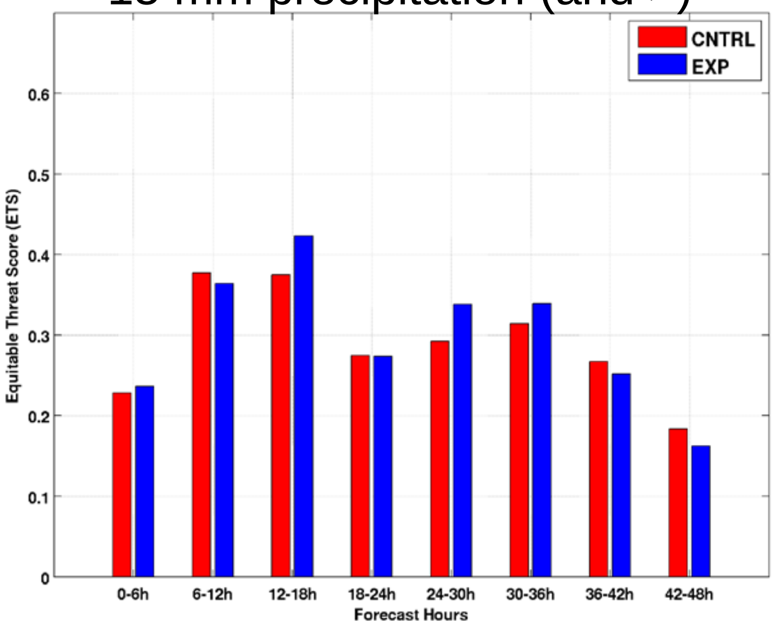
1 mm precipitation (and >)



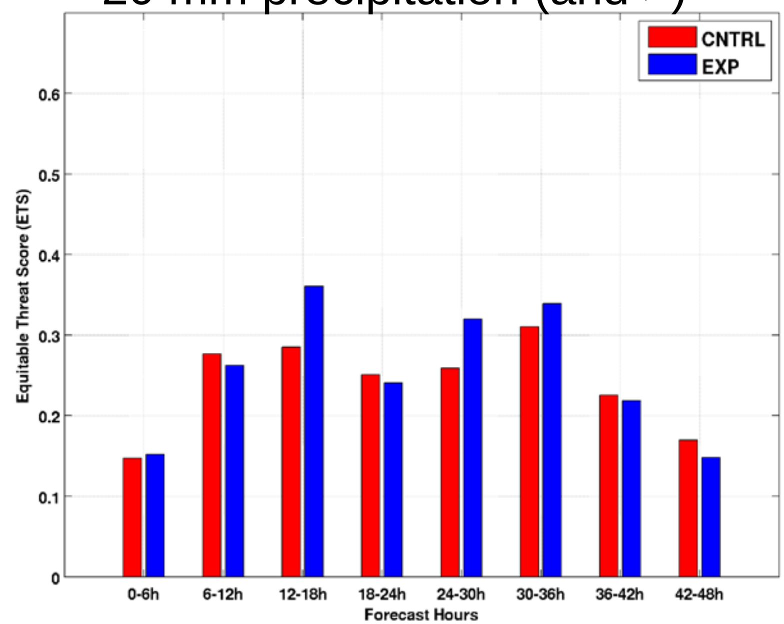
10 mm precipitation (and >)

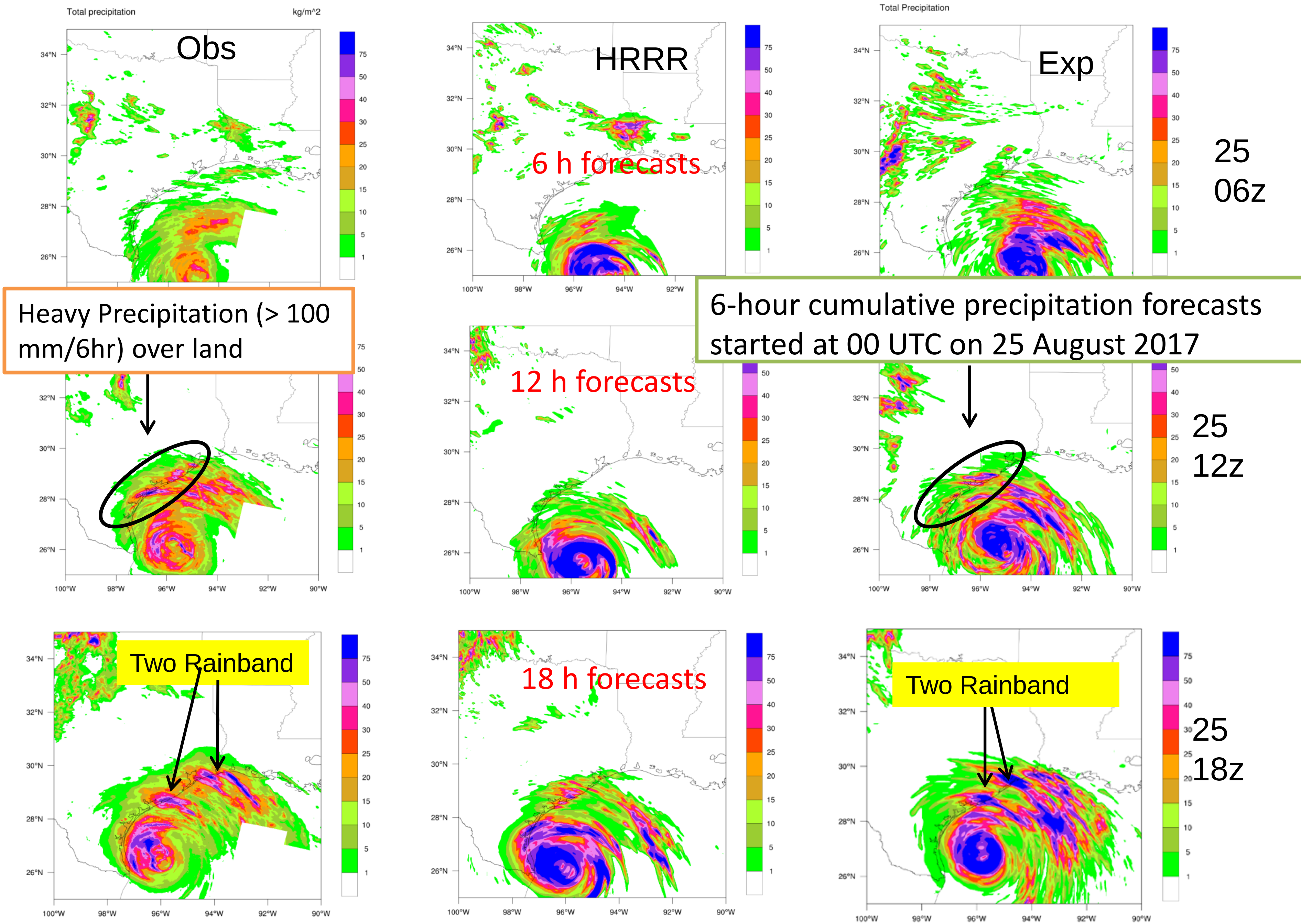


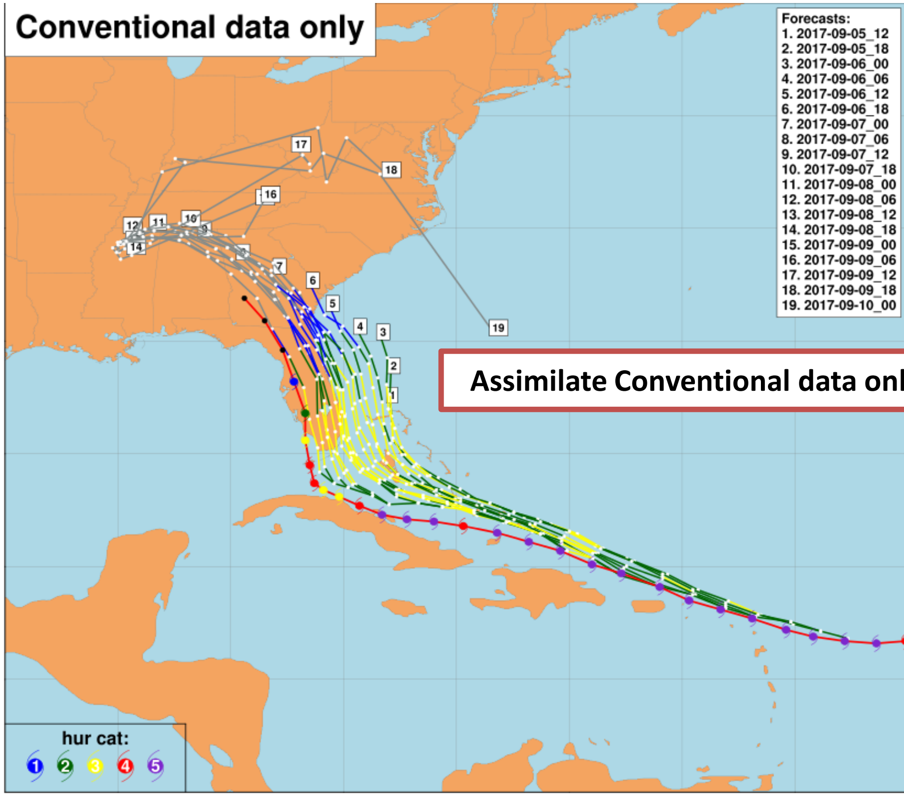
15 mm precipitation (and >)



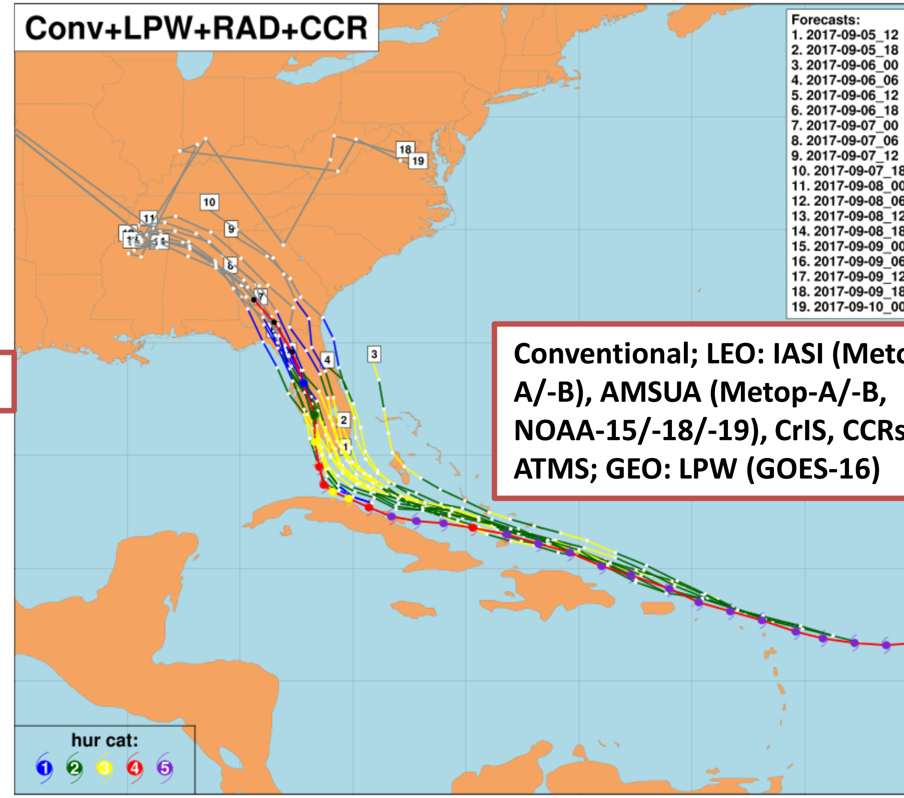
20 mm precipitation (and >)



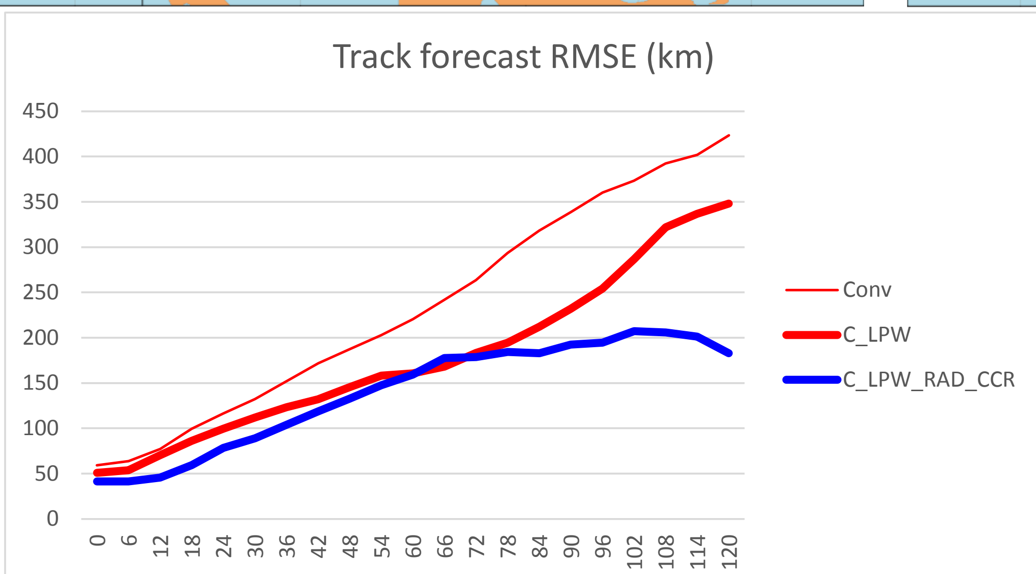

Total precipitation
kg/m^2
Obs
HRRR
Exp
Total Precipitation
6 h forecasts
12 h forecasts
18 h forecasts
25
06z
25
12z
25
18z
Heavy Precipitation (> 100 mm/6hr) over land
6-hour cumulative precipitation forecasts started at 00 UTC on 25 August 2017
Two Rainband
Two Rainband
75
50
40
30
25
20
15
10
5
1
34°N
32°N
30°N
28°N
26°N
100°W
98°W
96°W
94°W
92°W
90°W

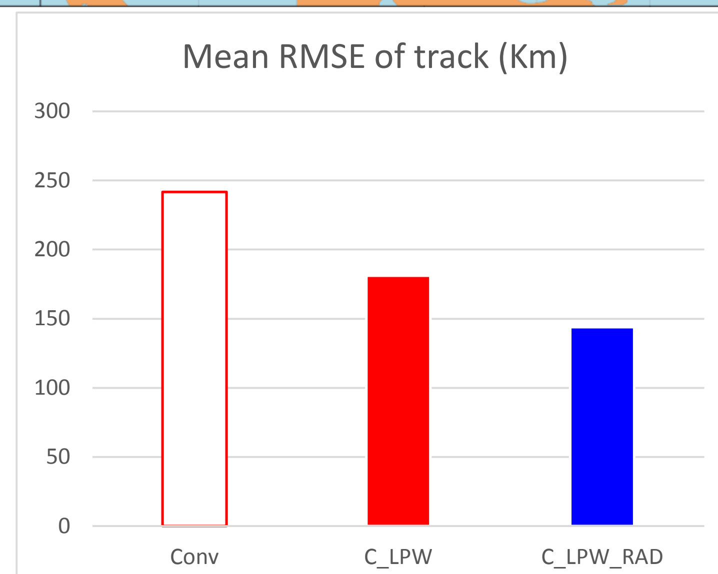


Assimilate Conventional data only



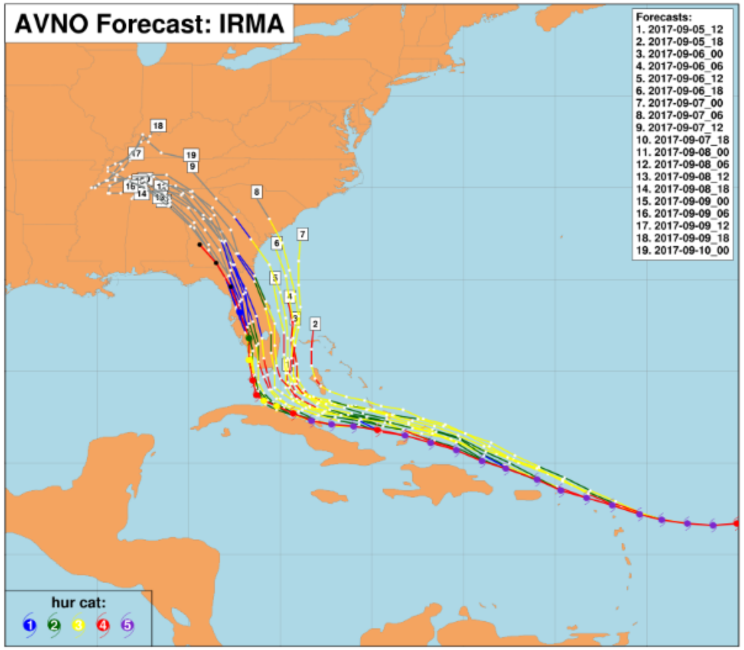
Conventional; LEO: IASI (Metop-A/-B), AMSUA (Metop-A/-B, NOAA-15/-18/-19), CrIS, CCRs, ATMS; GEO: LPW (GOES-16)

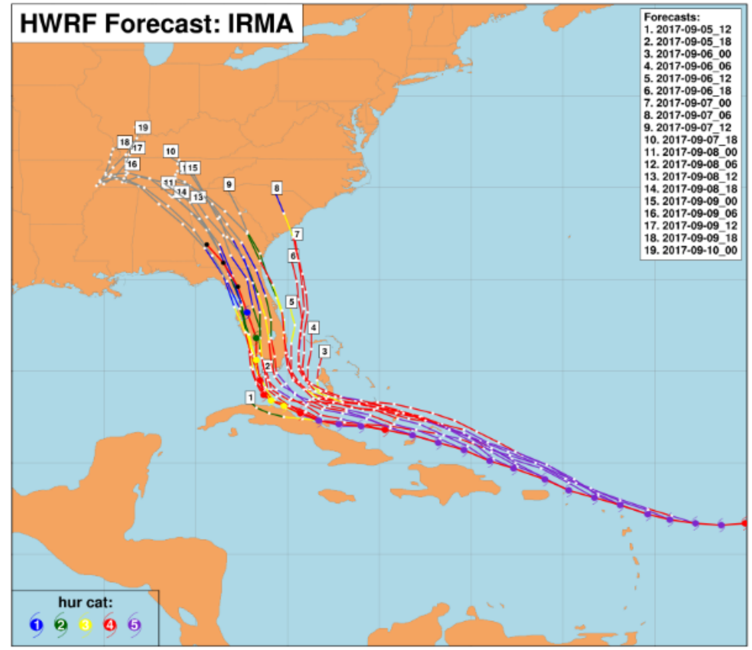


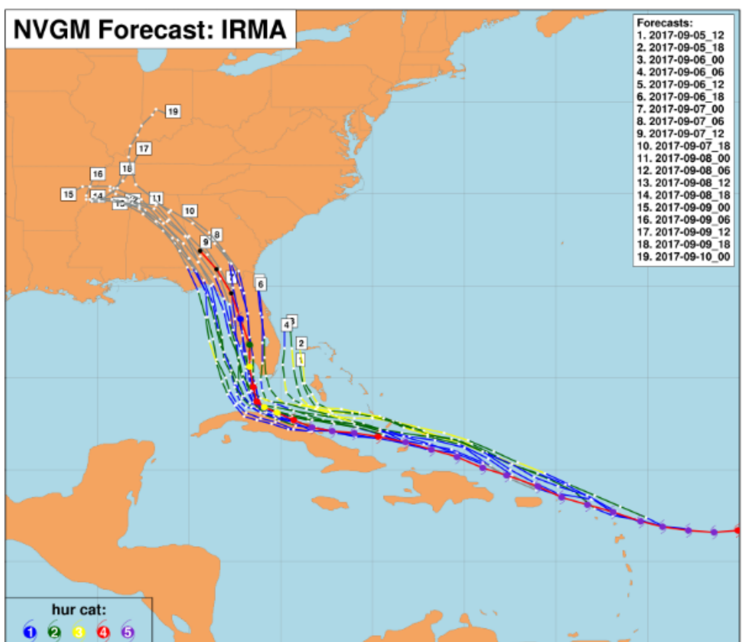


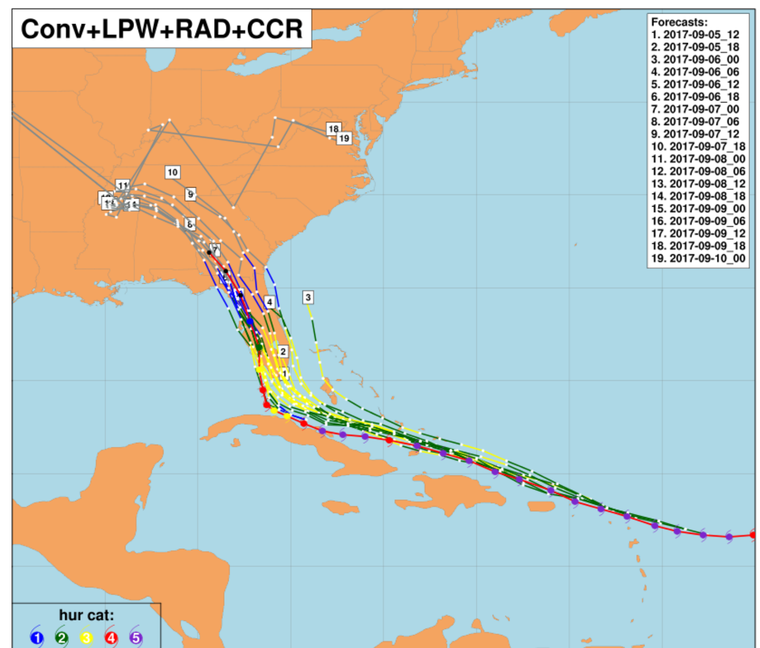
2017090512 – 2017091018, 5-day Irma forecasts updated 6-hourly

Operational models compare to the best-track estimate (2017090512 - 2017091018)









Summary and future work

- Assimilating CrIS CCRs show positive impact on hurricane track forecasts, could be an alternative of radiance assimilation in cloudy skies;
- QC is important, since atmosphere might be inhomogeneous within IR sounder sub-pixel in cloudy condition;
- Future work will focus on full spectral resolution CrIS from NOAA-20, improve QC on CrIS CCRs, collaborate with users on more experiments in NOAA and other models for potential operational application.