EnKF Assimilation of All-sky Infrared Radiances for Hurricane Prediction

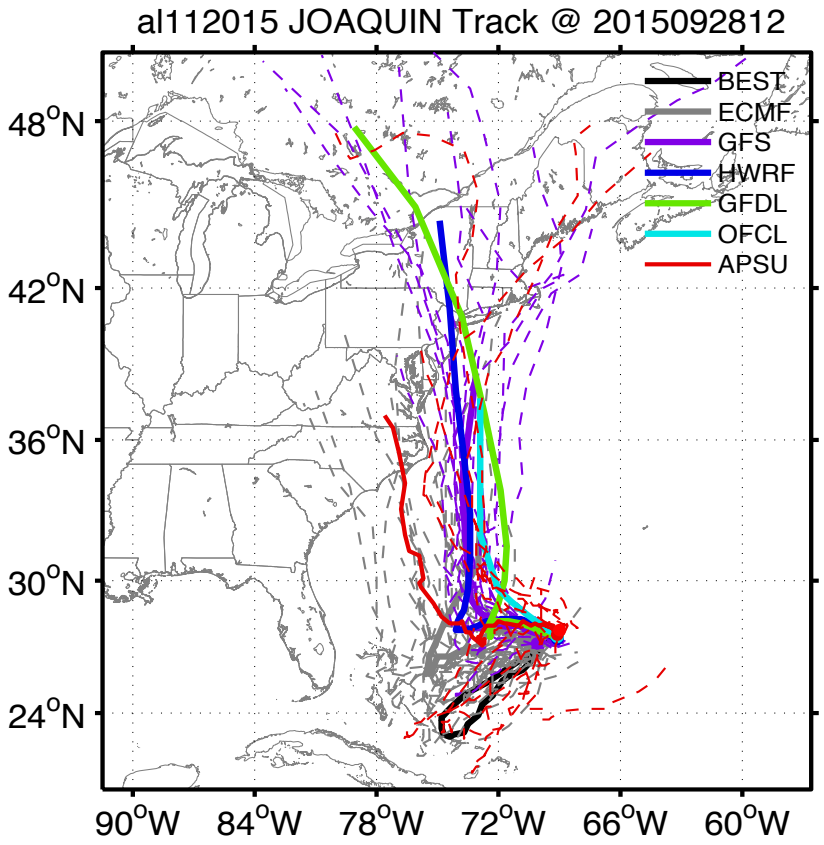
Yonghui Weng and Fuqing Zhang

The Pennsylvania State University

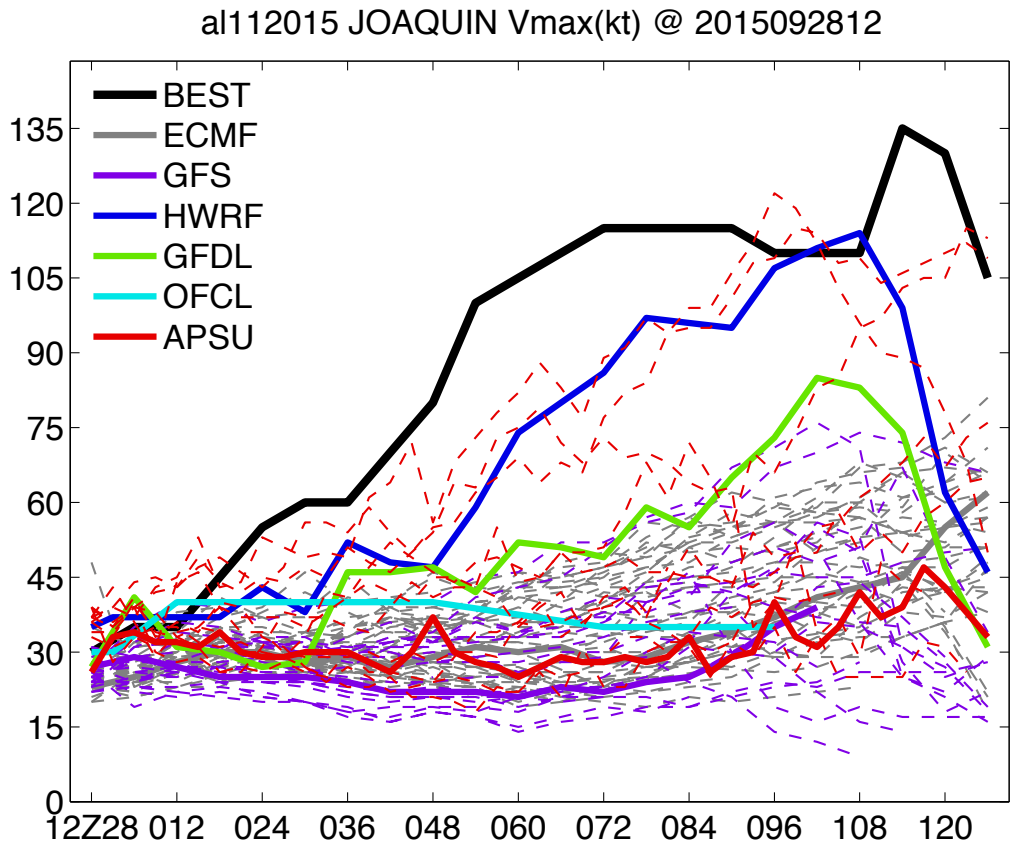
2016/05/26

7th EnKF Workshop, State College, PA

Case Review for hurricane Joaquin (2015)



Hurricane Track



Hurricane Intensity (knots)

Forecasts with infrared radiances assimilation

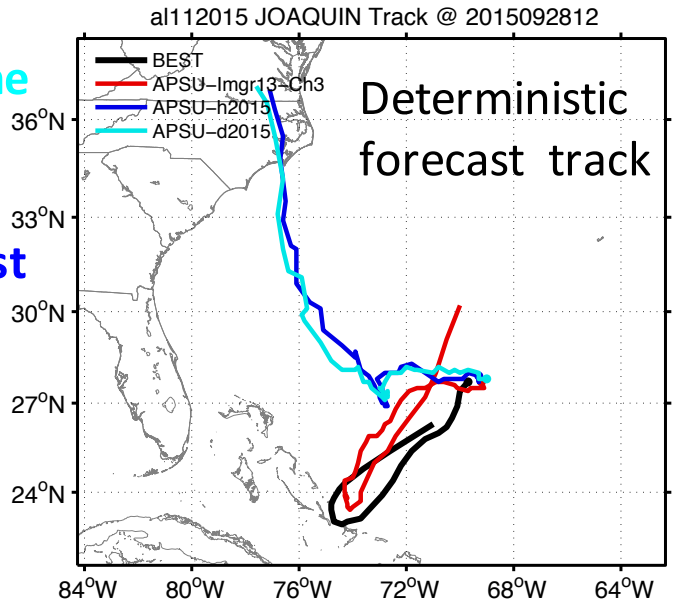
Best Track

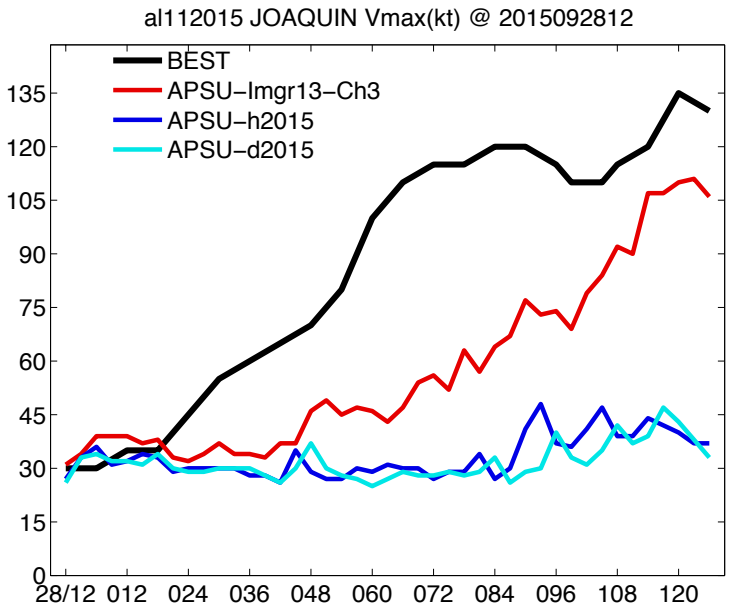
PSU realtime without radiance

PSU hindcast without radiance

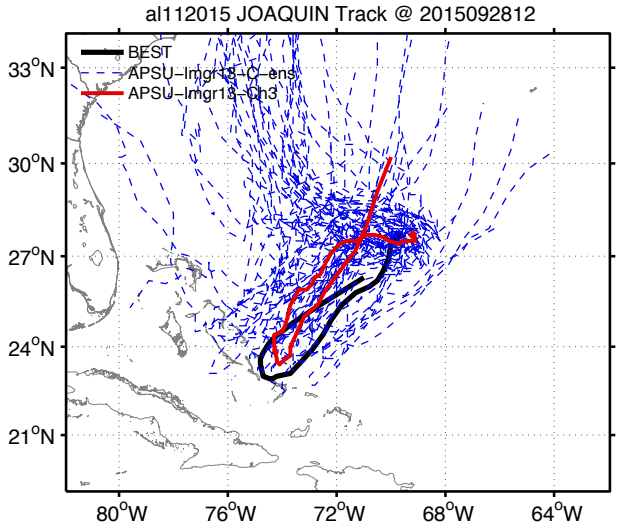
EnKF with radiance

Dash-blue: members

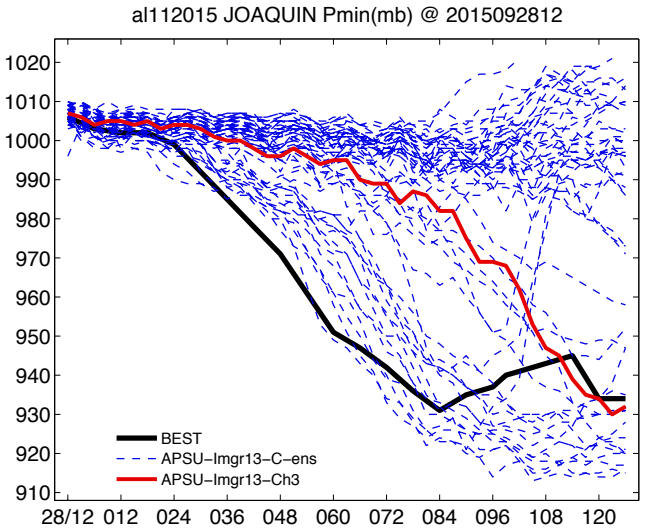




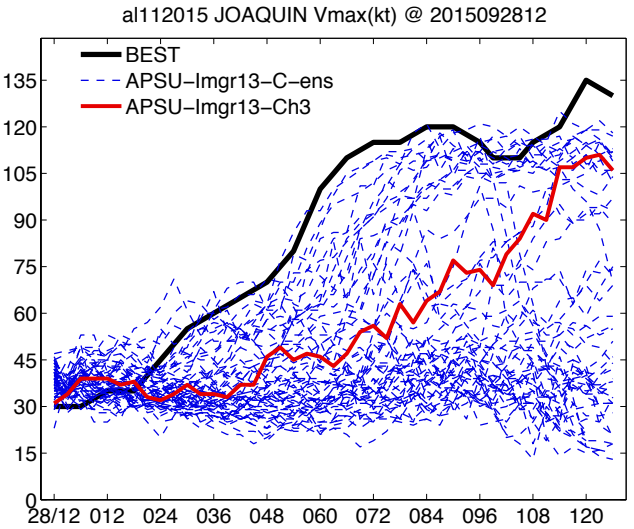
Deterministic forecast intensity (knots)



ensemble tracks



ensemble intensity in term of Pmin (mb)

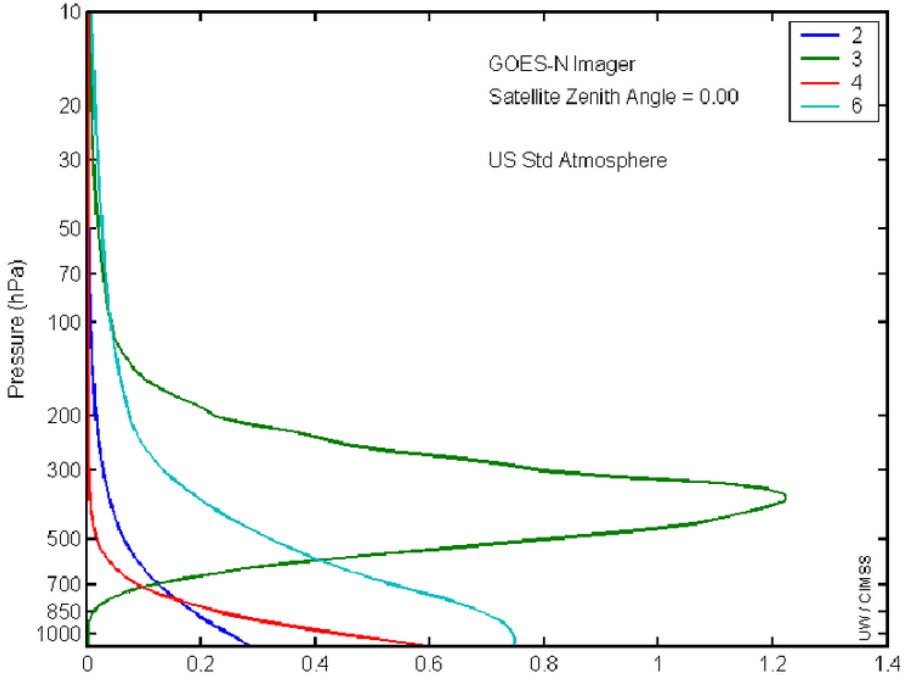


ensemble intensity in term of Vmax (knots)

OBS: GOES-13 Imager – imgr_g13

- GOES-13: Geostationary orbit; altitude 35786km; 75° W;
- IMAGER:
  - 5 channels covering VIS, MWIR and TIR
    - ✓ 0.65μm (0.55-0.75);
    - ✓ 3.90μm (3.80-4.00);
      6.55μm (5.80-7.30);
      10.70μm (10.2-11.2);
      13.25μm (13.0-13.7)
  - 4.0 km for IR channels; 1.0 km for the VIS channel;
  - Full disk every 30 min.

- Only assimilates Channel 3 by considering to reduce the impact of clouds.



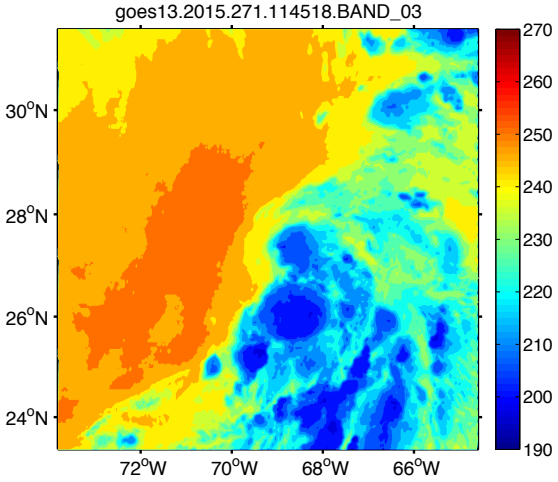
GOES-13 Imager Waiting Functions

System: APSU system with Satellite Radiance

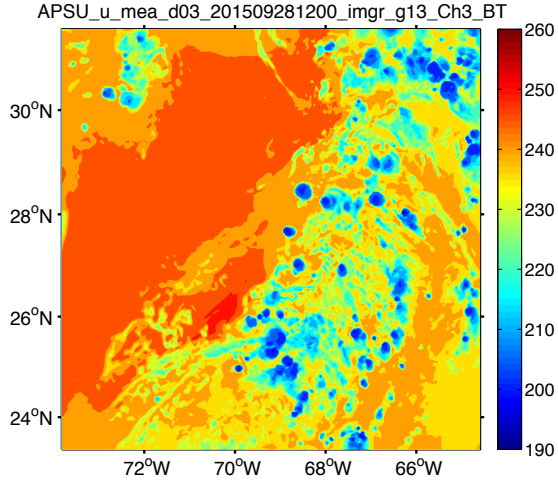
- GVAR Imager Data:
  - Raw Netcdf from CLASS/NOAA;
  - Create SOs for selected sensors and channels for specified model area (d02);
  - Thinned to 8km x 8km;
  - Randomly sorted before EnKF;
  - Obs error is set to 5.0K
- XB
  - CRTM v2.1.3;
- EnKF
  - 2D interpolation: Interpolate XB to SO's position;
  - Horizontal roi=15km;
  - Vertical ROI is centered at the cloud top;
  - SOs will be assimilated for all 3 domains with 1/9:2/9:6/9 SCL technique;
  - AOEI – Adaptive Observation Error Inflation;
- WRF
  - Version 3.5.1 with BZ isftcflux option 99;
  - Model top = 10mb.

EnKF increments @ BT

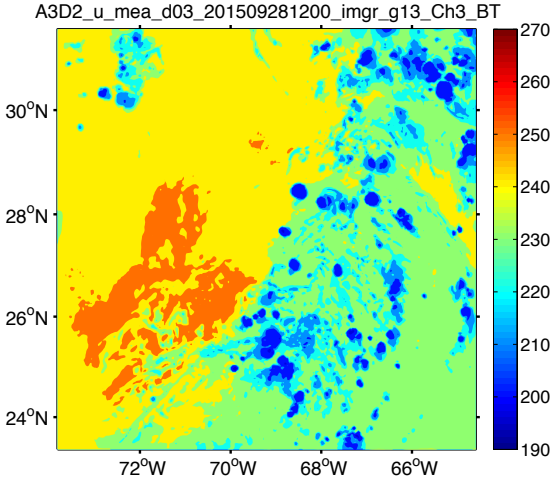
GOES-13 Imager Ch3

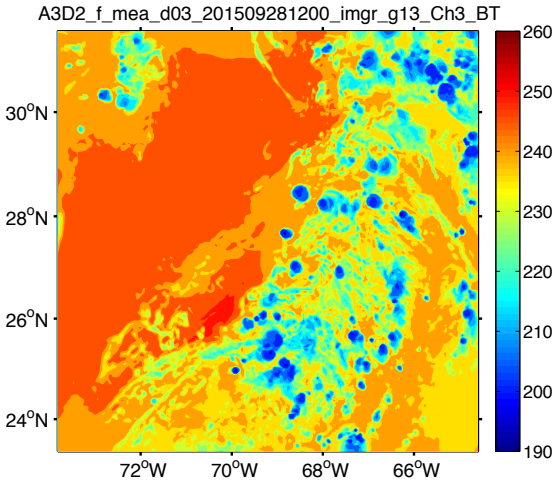


Analysis without BT

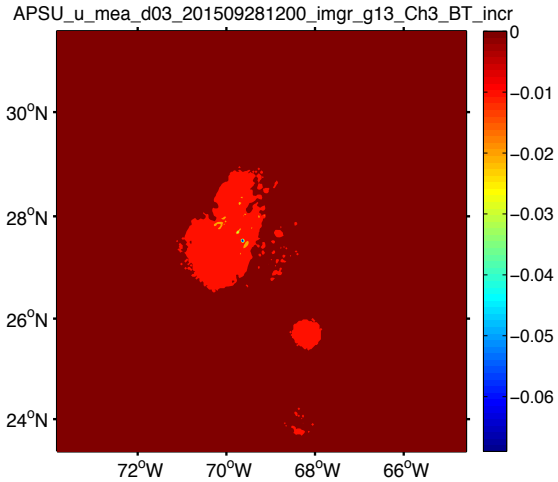


Analysis with BT

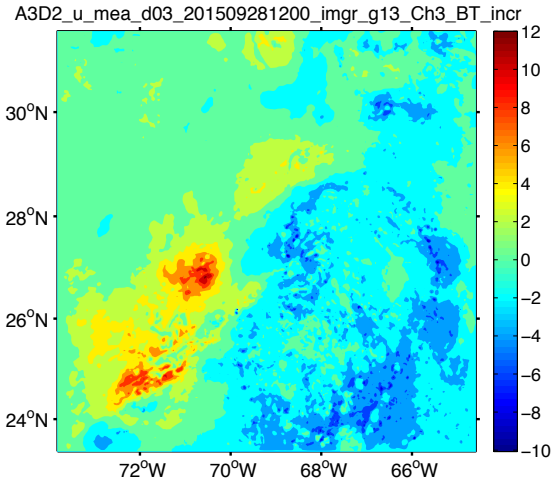




Prior—before EnKF



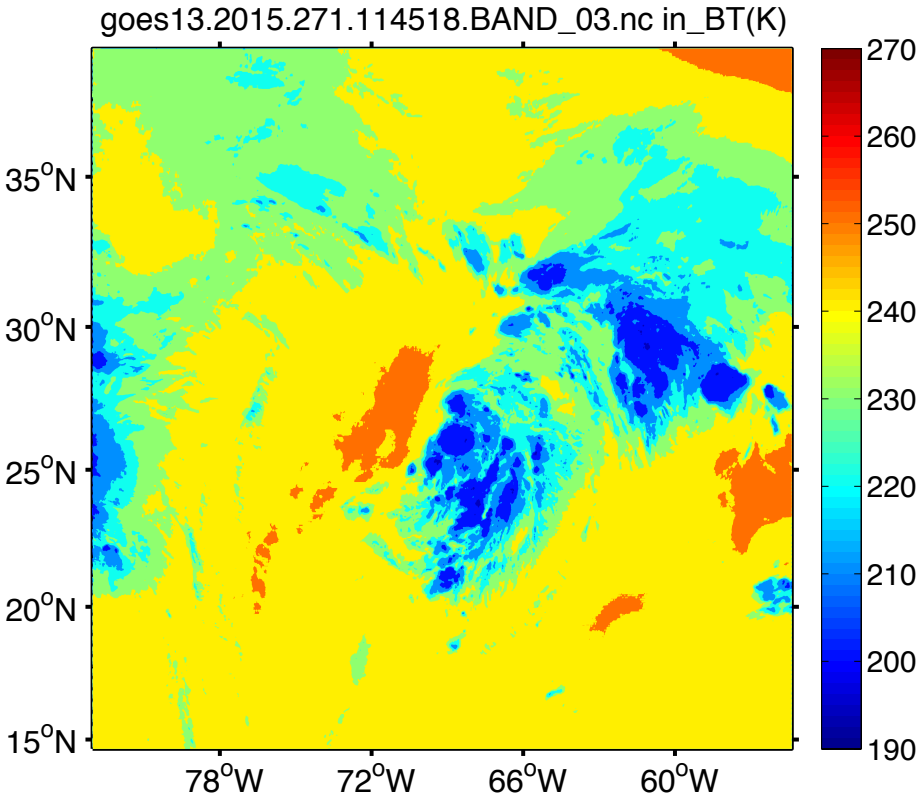
Increments without BT



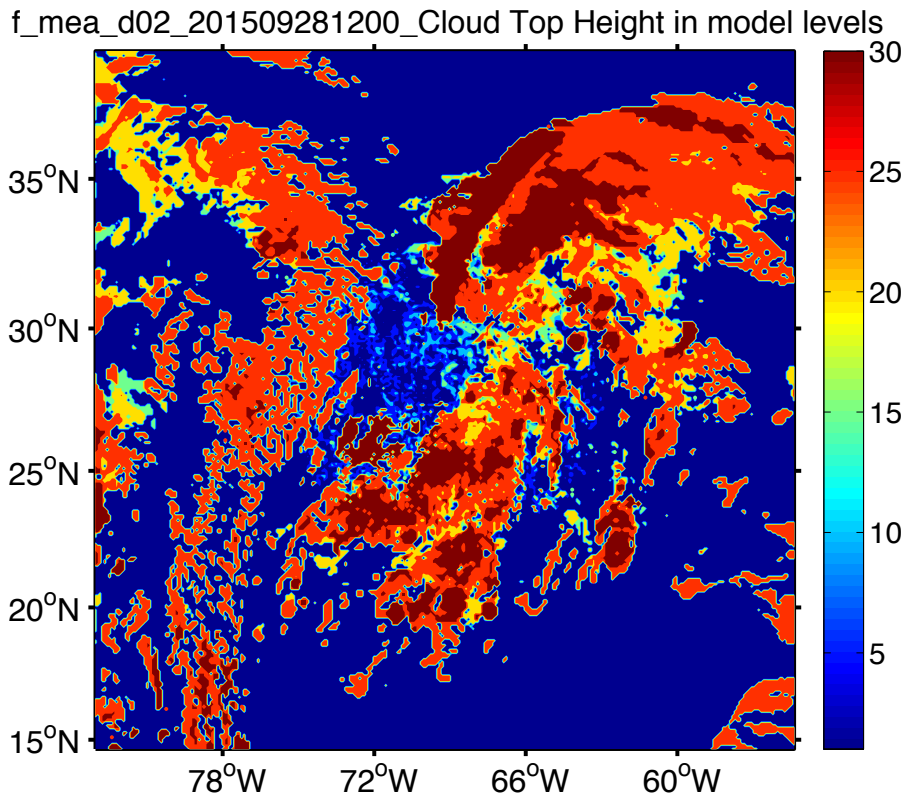
Increments with BT

Vertical Localization

- The fifth-order correlation function (Gaspari and Cohn, 1999) is used for horizontal and vertical localization;
- BT vertical ROI function is centered at the model level of cloud top.

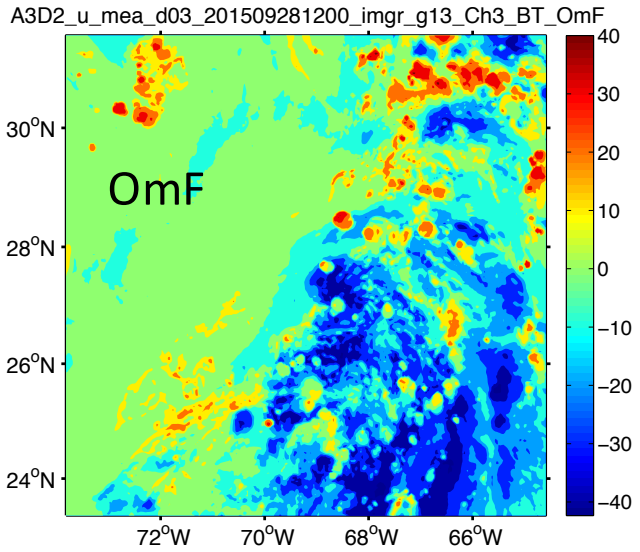


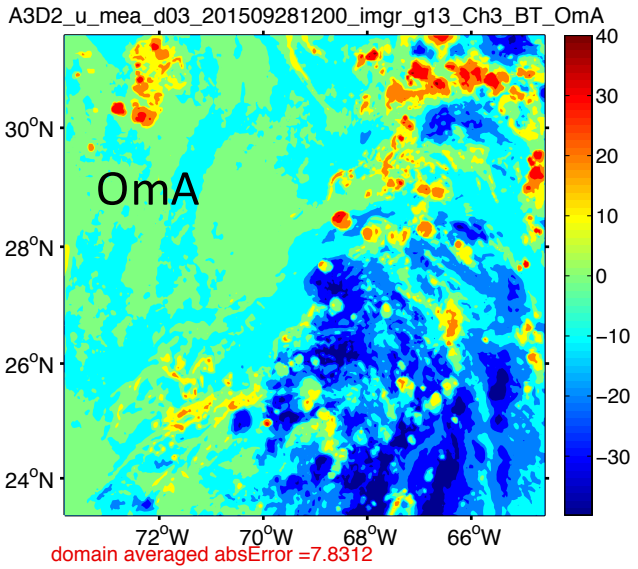
GOES-13 Imager channel 3 BT

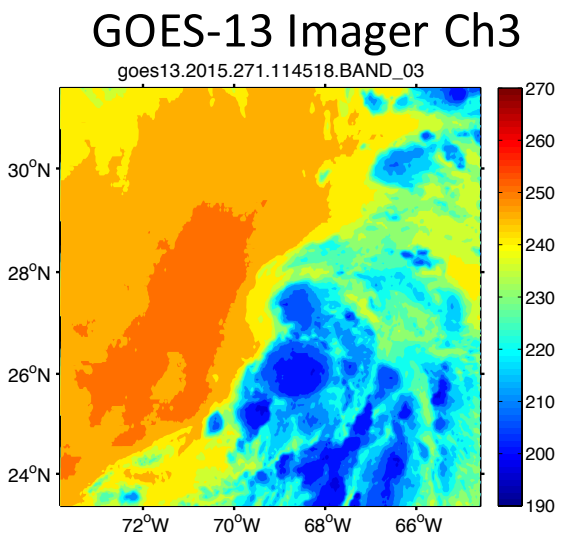


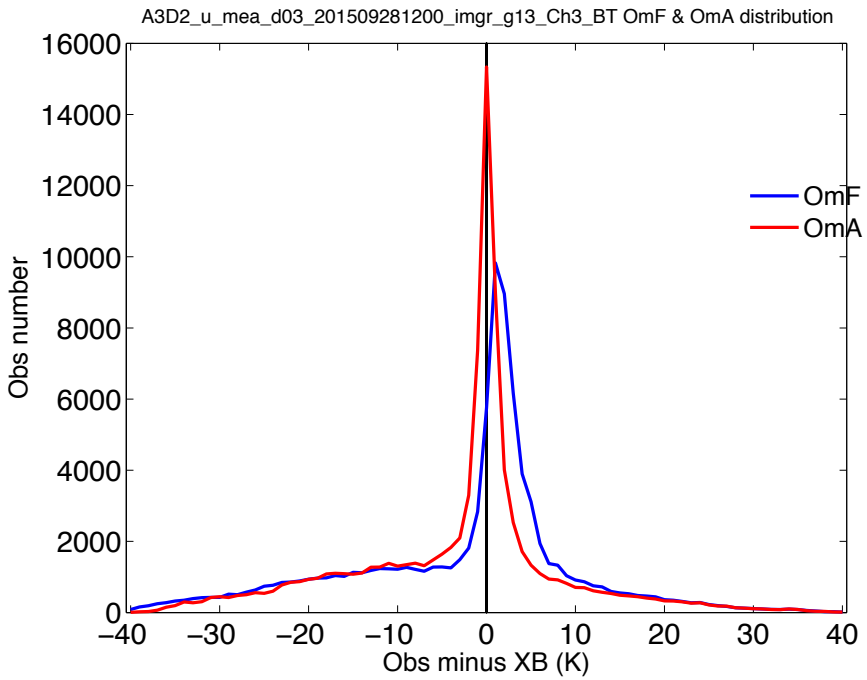
Cloud top height derived from model

Observation Bias





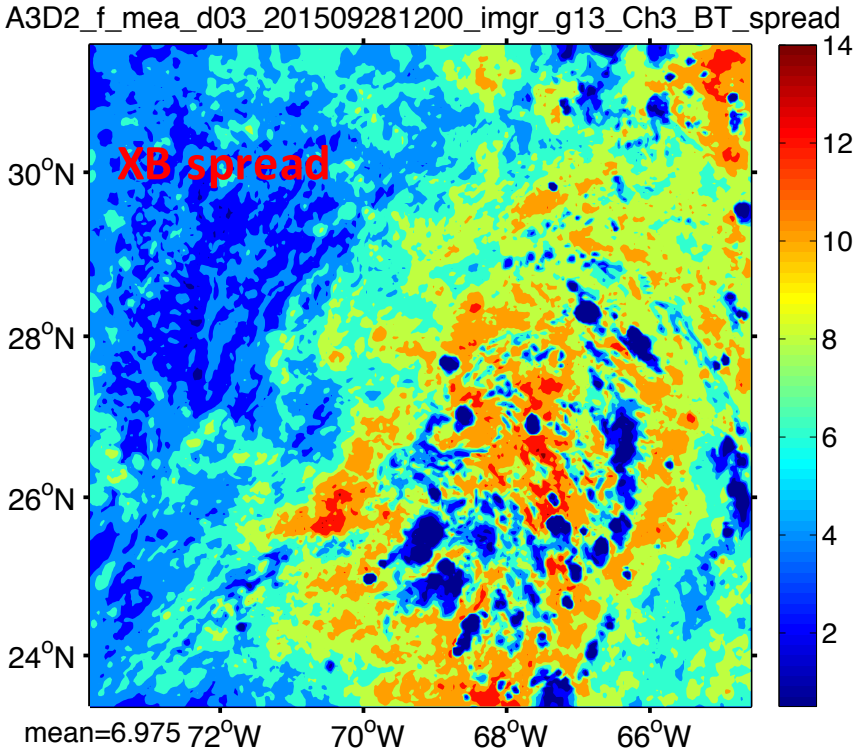


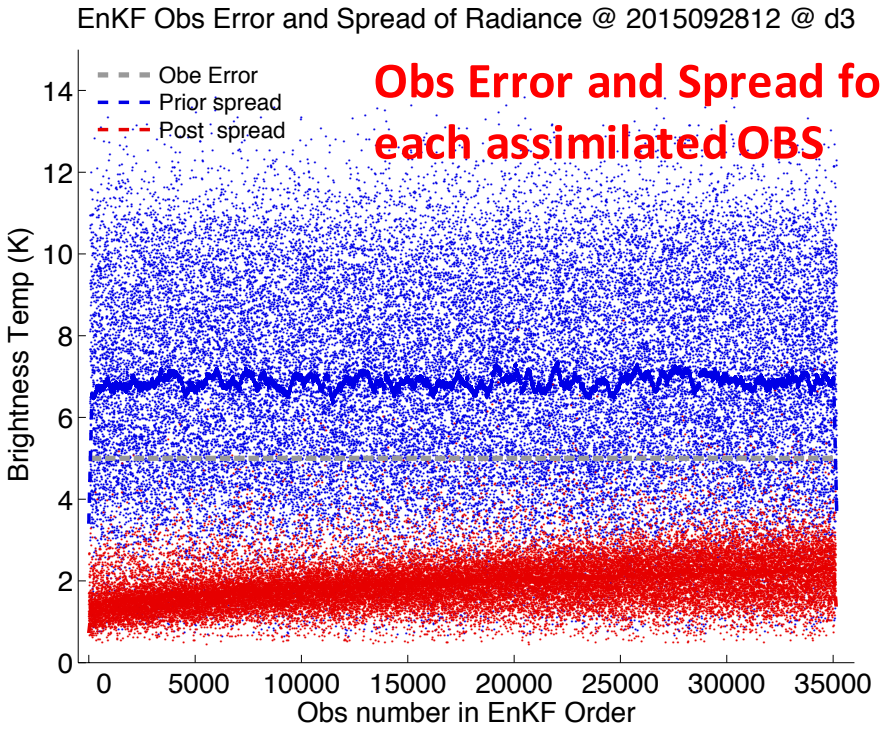


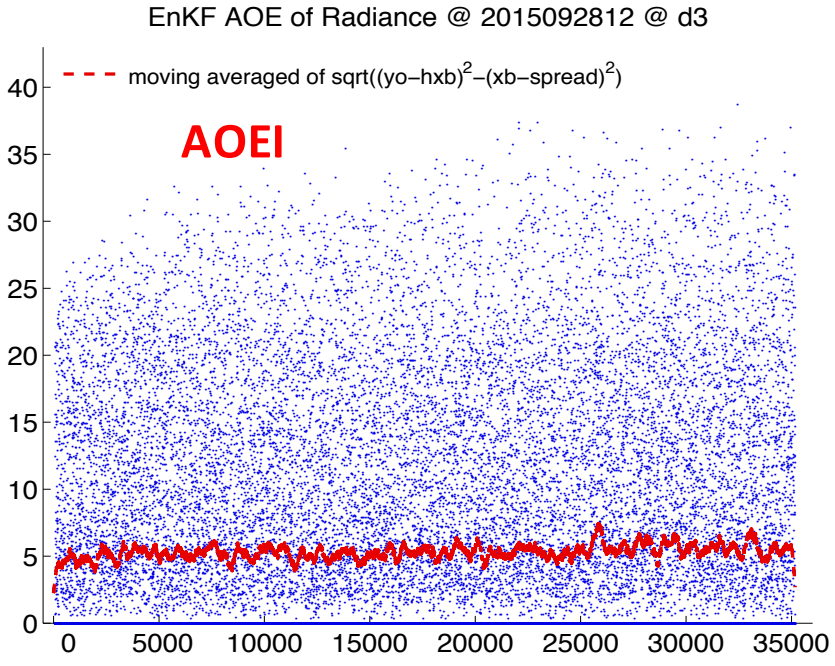
Observation Error

- ECMWF & NCEP: assign different observation errors for clear-air and cloudy radiances, and combine them based on the cloud coverage.
- Zhang et al., 2016: adaptive observation error inflation (AOEI)

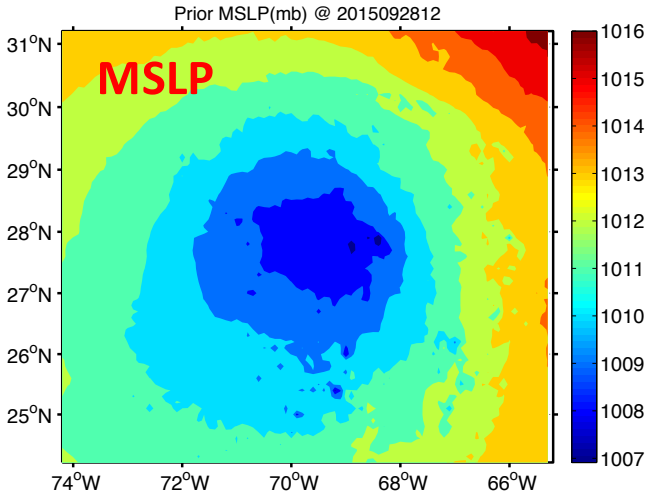
$$\sigma_o^2 = \max\left\{\sigma_{ot}^2, [y_o - H(x_b)]^2 - \sigma_b^2\right\},$$

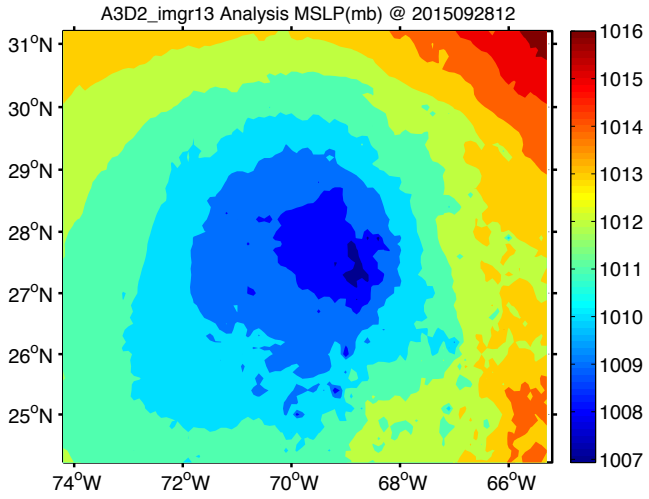


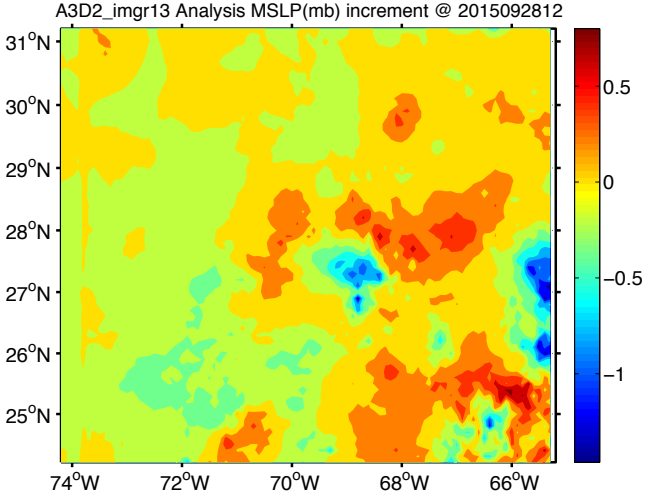


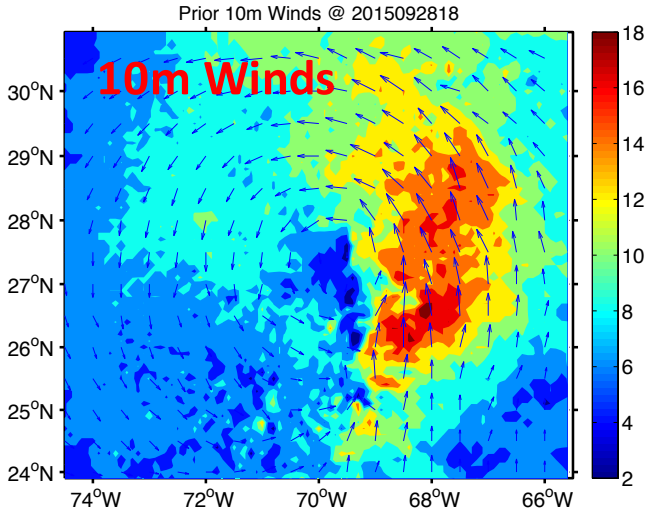


Increments @ Surface

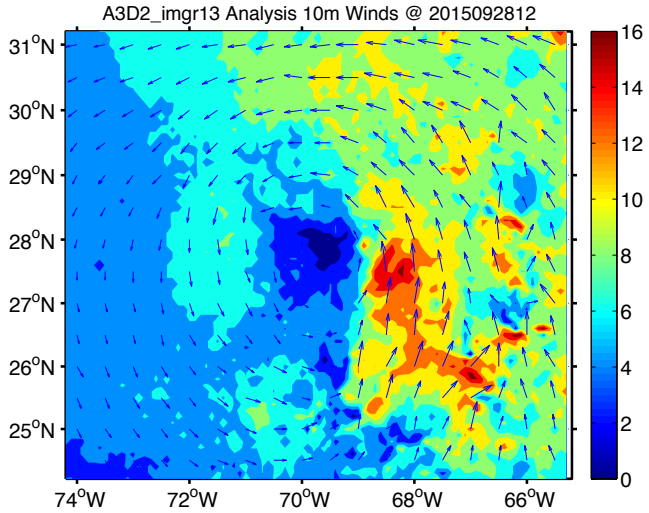




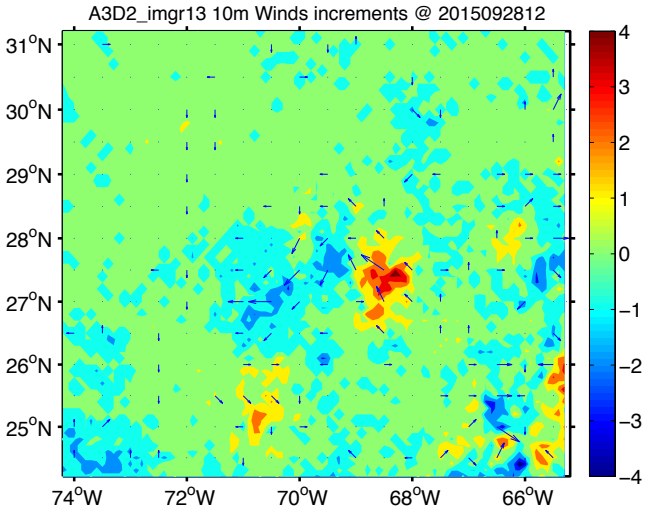




Prior—before EnKF



EnKF Analysis

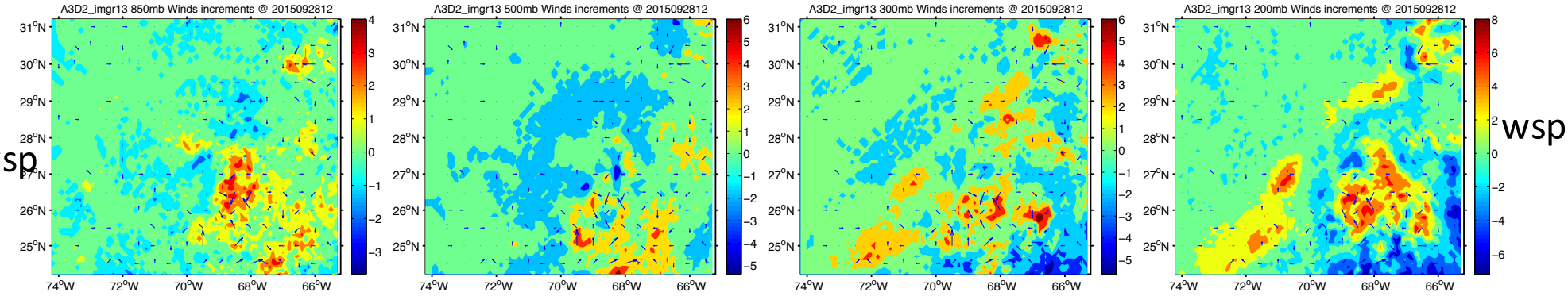


Increments

Increments @ Upper

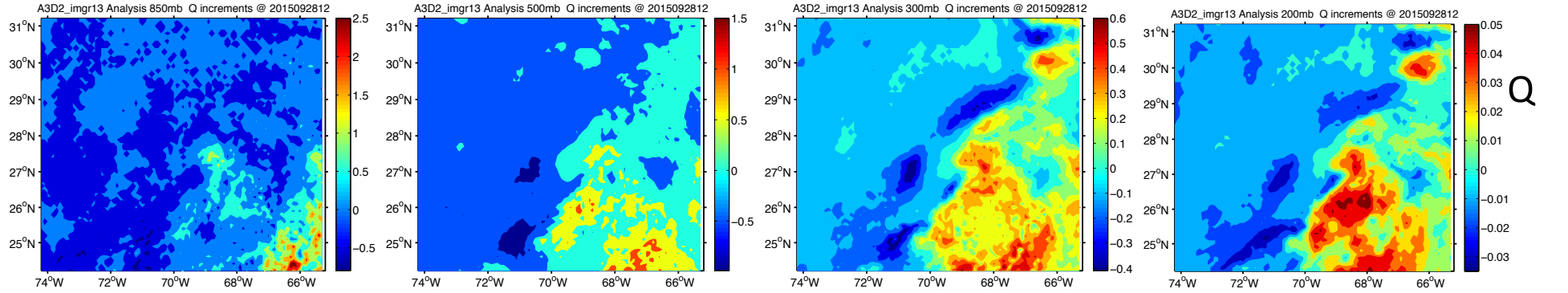
850mb 500mb 300mb 200mb

wsp



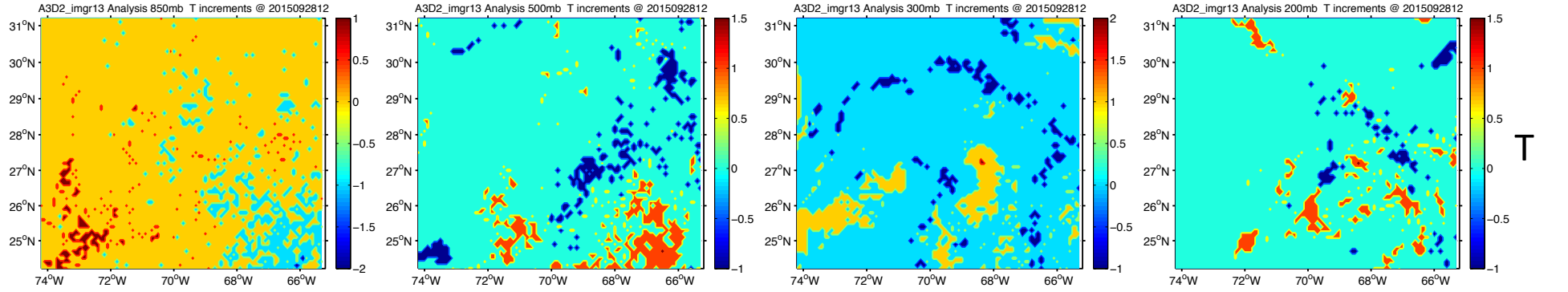
wsp

Q



Q

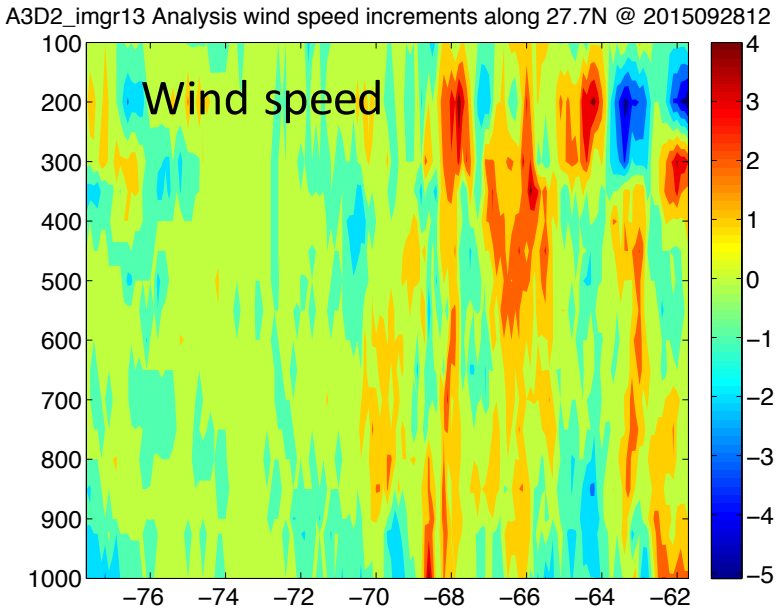
T

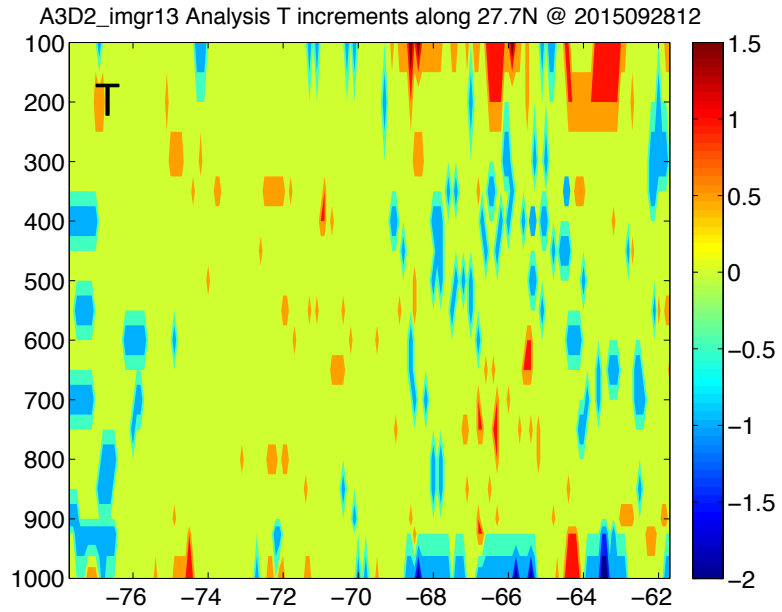


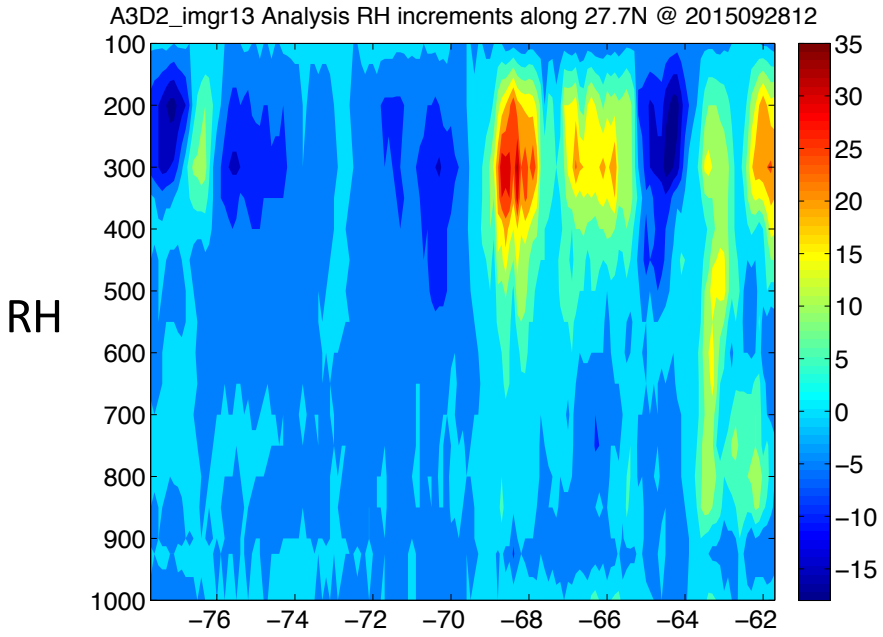
T

850mb 500mb 300mb 200mb

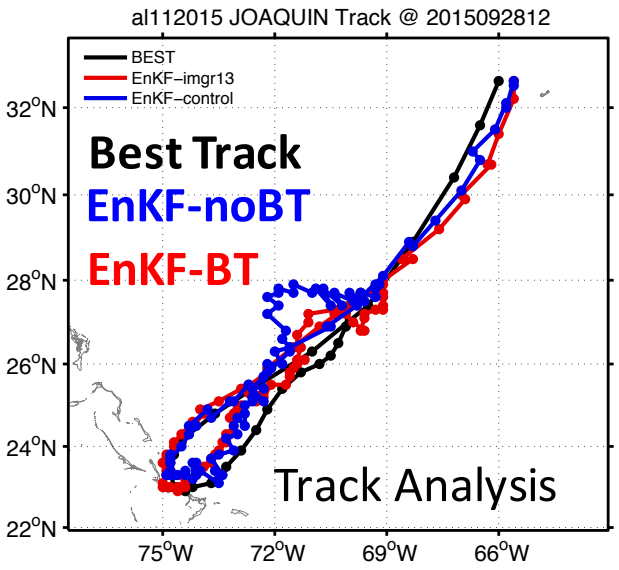
Increments @ P-Lon profile crossing the storm center

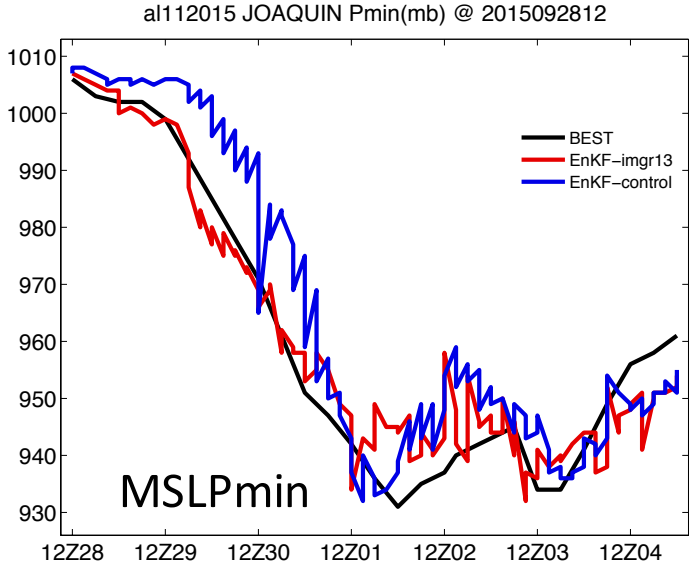


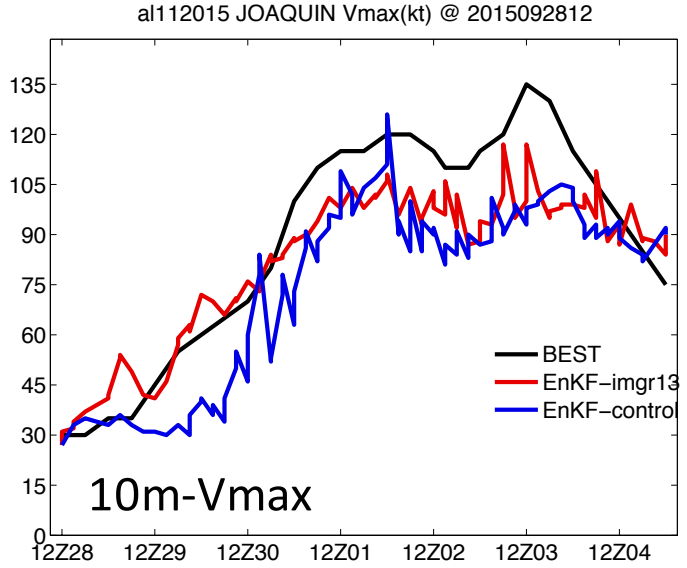


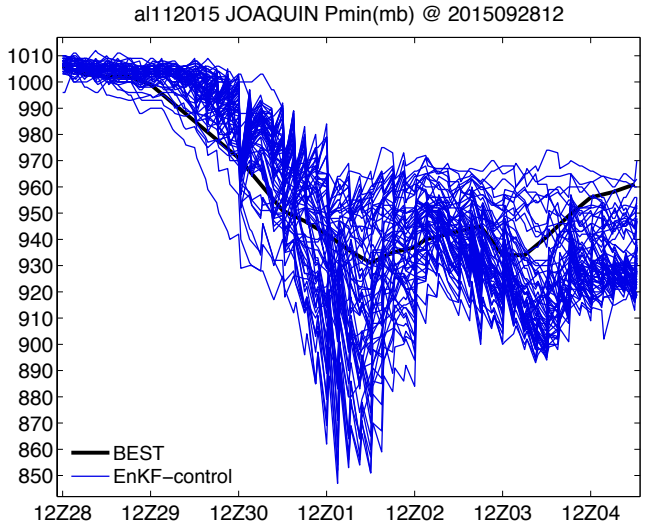


Cycling Assimilation for Joaquin (2015)

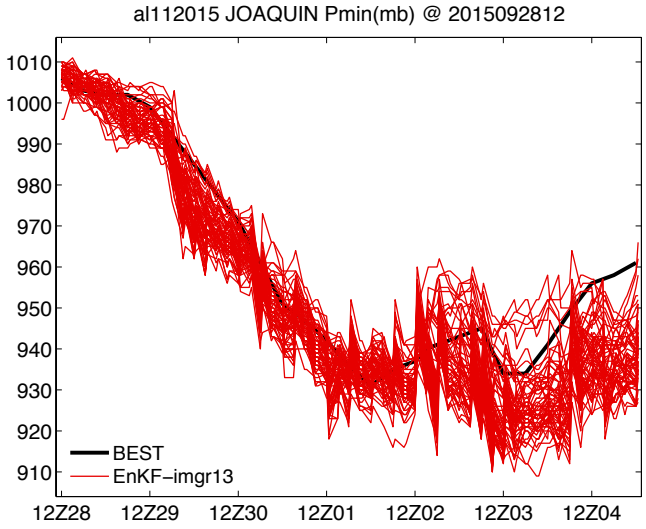




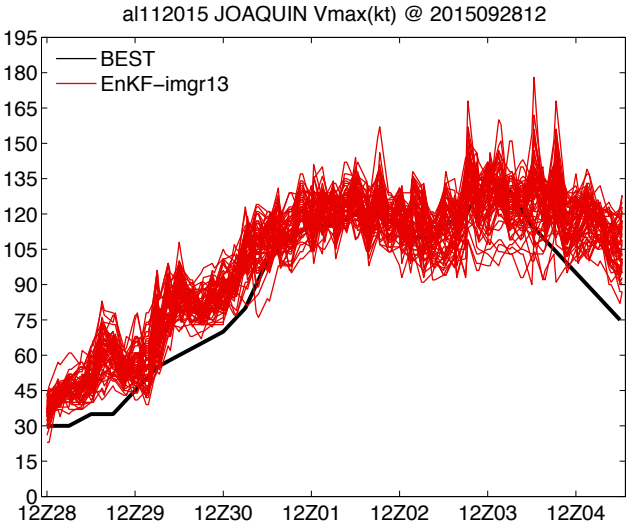




MSLPmin of EnKF members without BT

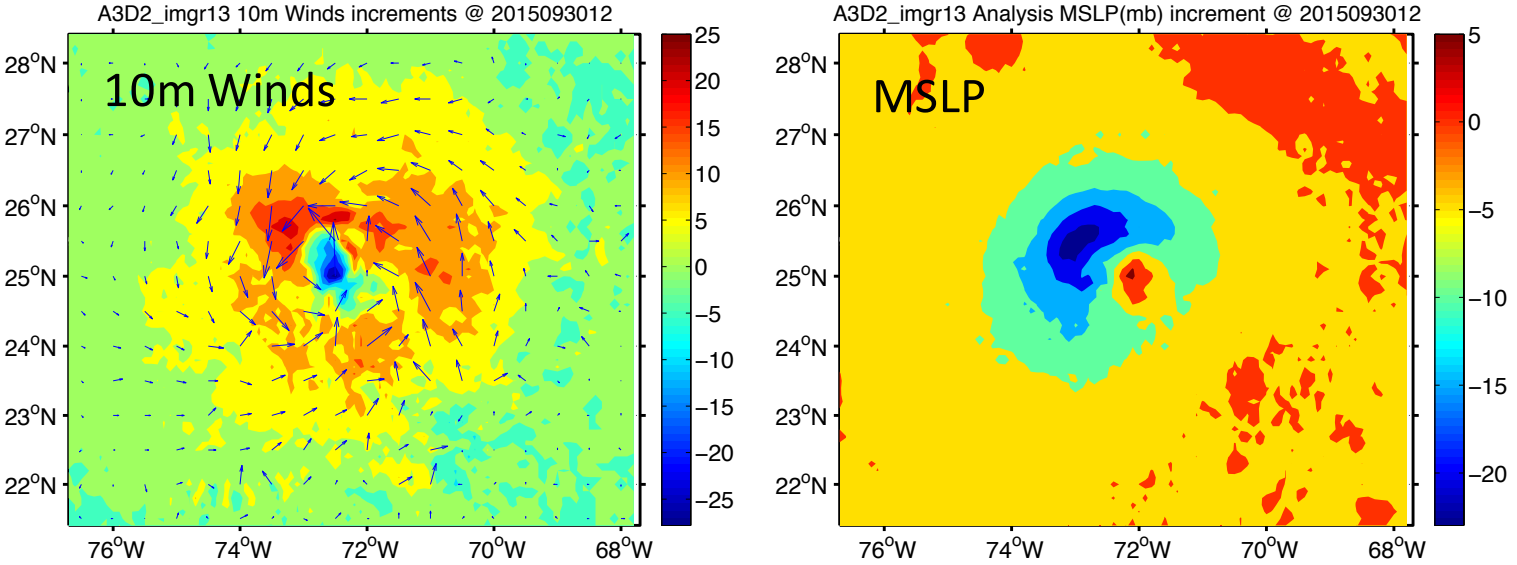


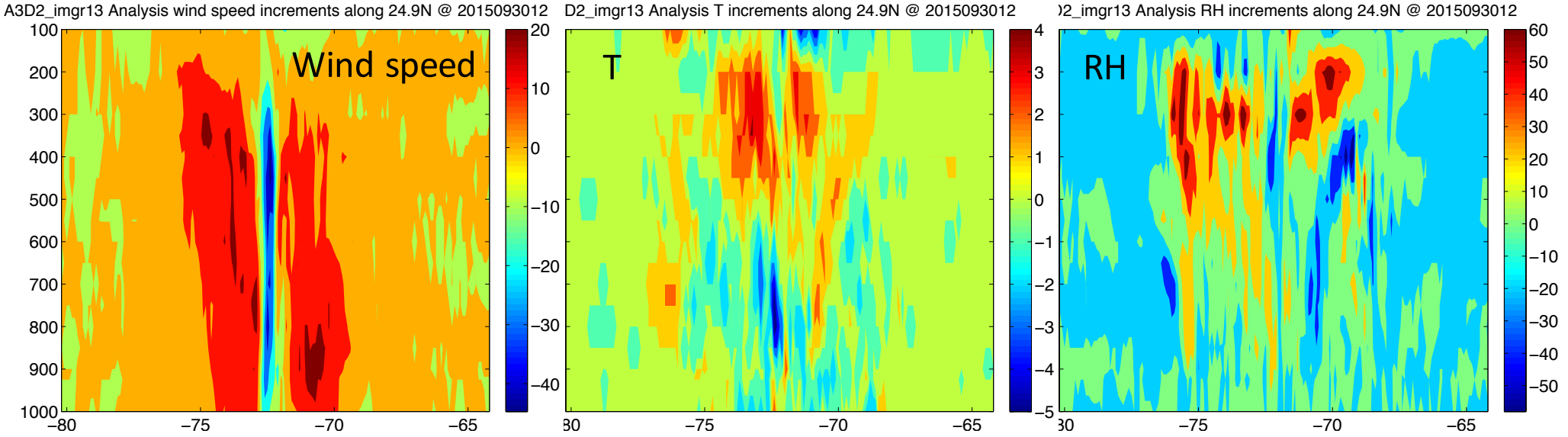
MSLPmin of EnKF members with BT



10m-Vmax of EnKF members with BT

Difference after 48h cycling assimilation

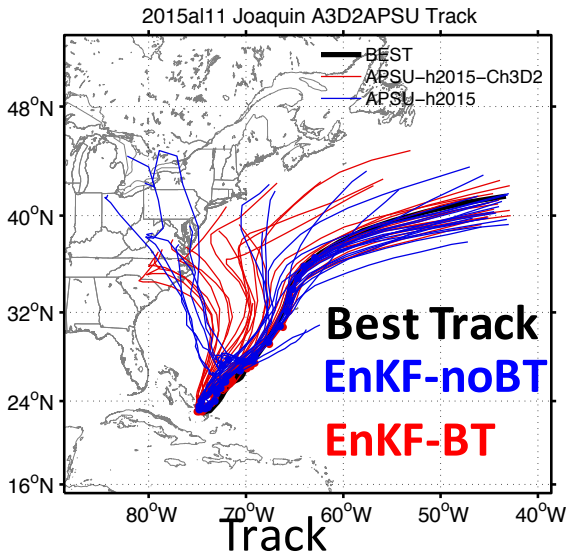




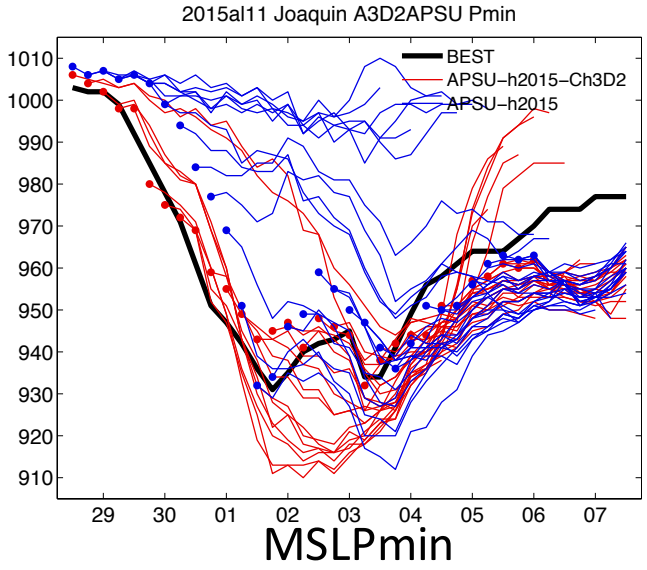
P-Lon profile along 24.9N – the storm position in Best Track

Deterministic Forecasts for Joaquin (2015)： w/o Radiance

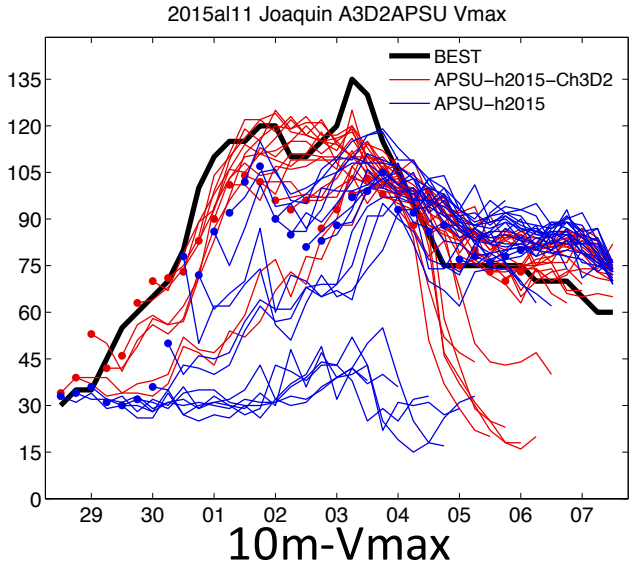
Deterministic forecasts from EnKF analysis every 6 hours



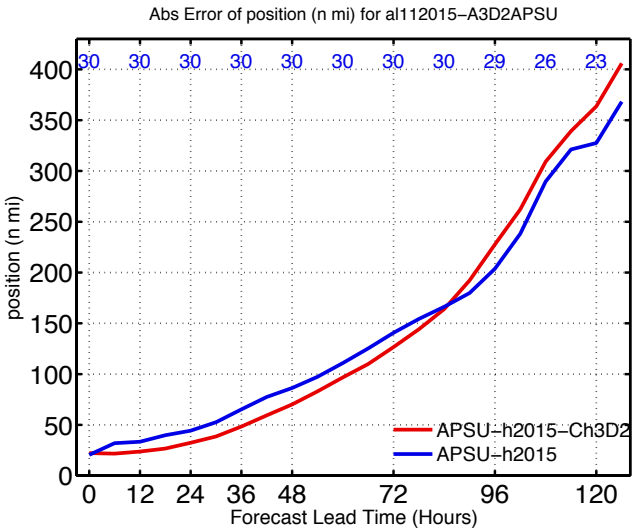
Track

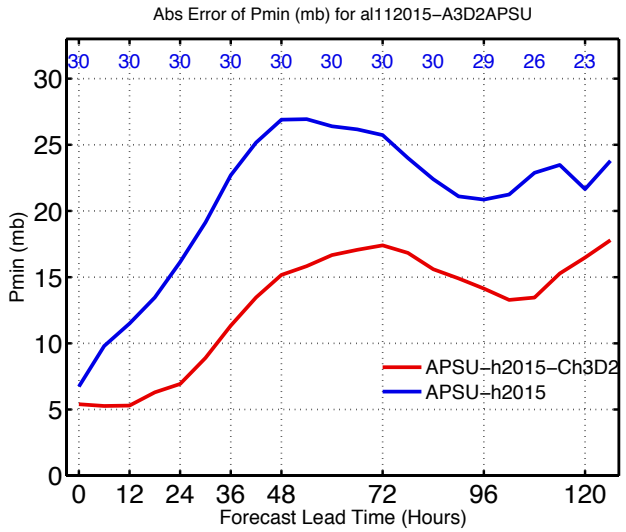


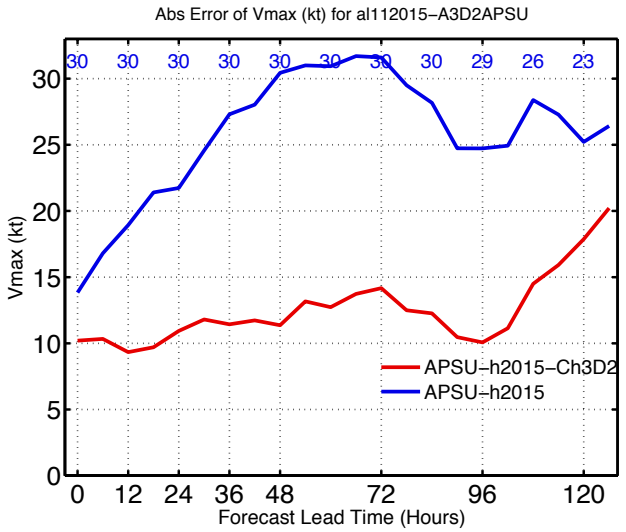
MSLPmin



10m-Vmax



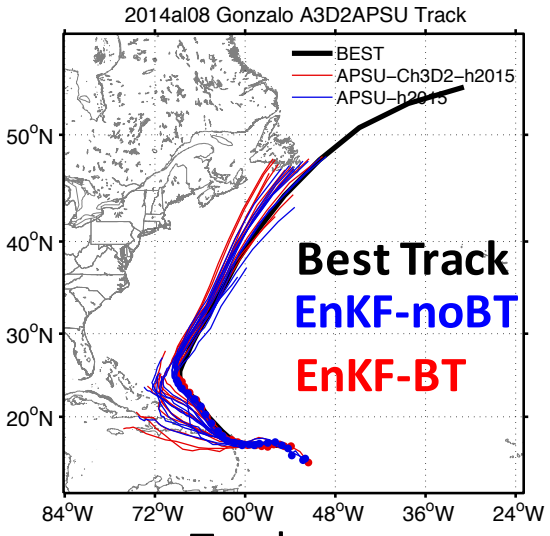




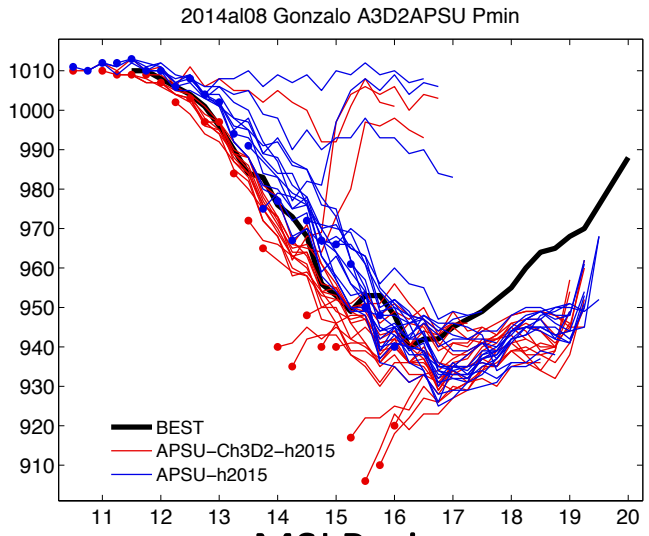
Averaged absolute error reference to Best Track

Deterministic Forecasts for Gonzalo (2014)： w/o Radiance

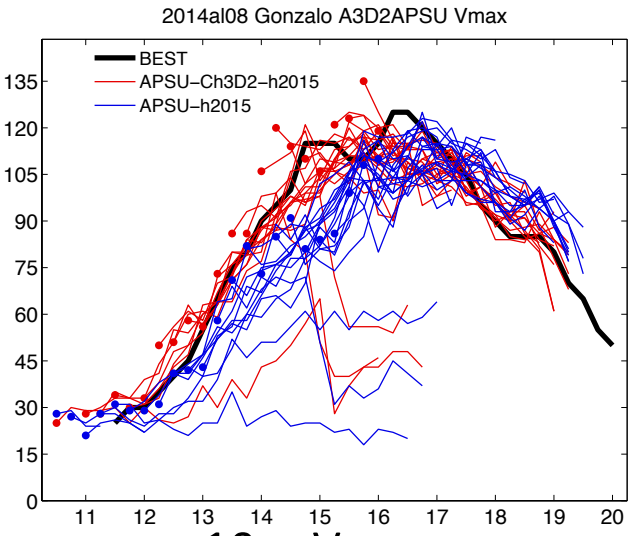
Deterministic forecasts from EnKF analysis every 6 hours



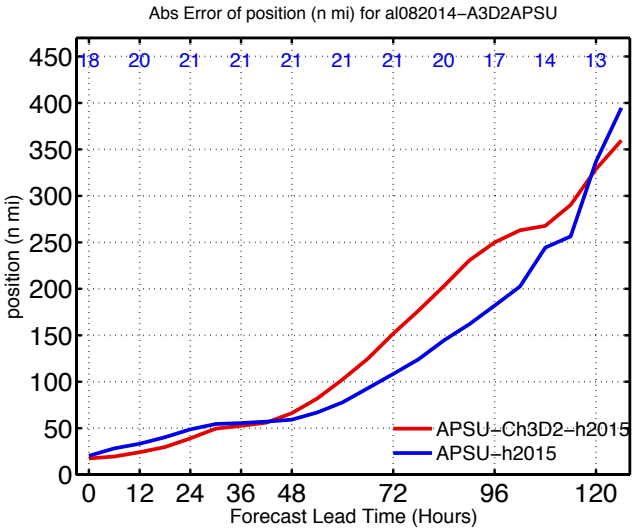
Track

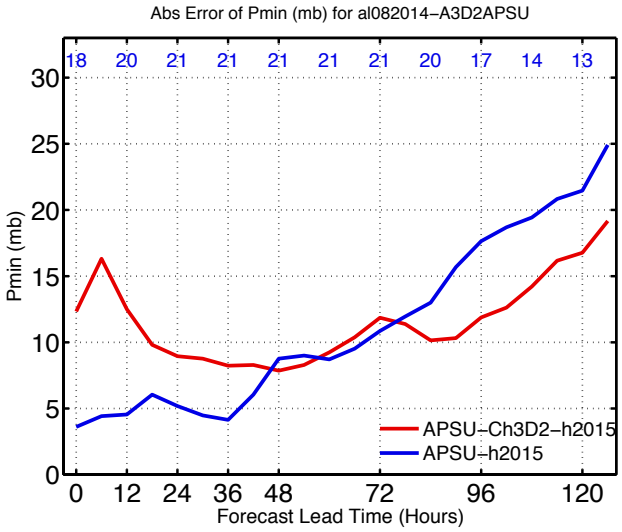


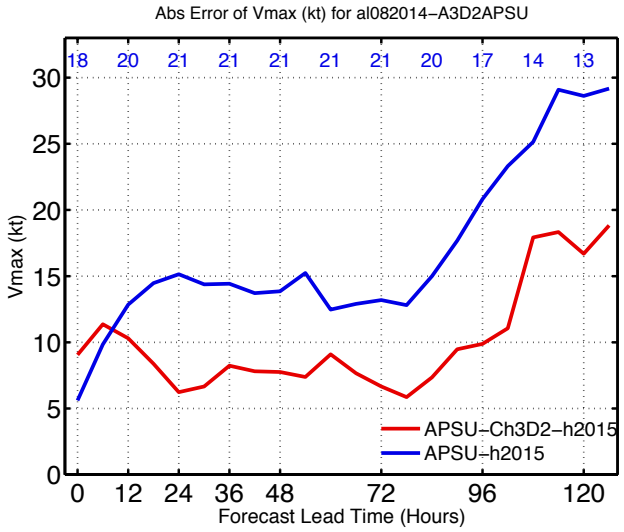
MSLPmin



10m-Vmax







Averaged absolute error reference to Best Track

Summary

- Based on the PSU WRF-EnKF system, the assimilation with cloudy radiance shows large improvements on hurricane intensity forecast in this case study;
- EnKF be able to reduce the radiance bias;
- The radiance assimilation has more impacts on wind and moisture, and has little impact on temperature, and make the storm more stronger in this case study;
- Plans
  - Continue sensitive experiments of observation error, data thinning and ROI, GFS-relaxation distance, different sensor channels, et al.;
  - Case study for weak storms;
  - More diagnosis for moisture and temperature increments, structure.