

Recent Development and Results of WRF/ DART Assimilation System

Hui Liu

Acknowledgements:

Yun-tien Lin, NCAR WRF/DART team

Recent Developments of WRF/DART

- Several problems/bugs with WRF/DART were finally resolved.
- Developed a 6-hourly cycling version of WRF/DART using CWB operational observations. Test results of TC Sinlaku and Morakot case look fine.
- CWB has tested WRF/DART system for SOWMEX period and typhoon Morakot case and results look encouraging.
- NCAR have tested impact of GPS RO data on forecast of TC Morakot and Ernetso. Positive impacts on the TC's track, intensity, and rainfall are found.

WRF/DART Configuration for CWB

- DART EAKF algorithm, 32 members, CWB 45km grid
- DART Adaptive ensemble inflation, fixed localization
- CWB operational WRF namelists setting
- CWB operational data, including radiosondes, aircraft data, satellite cloud winds, TC bogus data, TC position data, satellite thickness data, GPS RO refractivity.

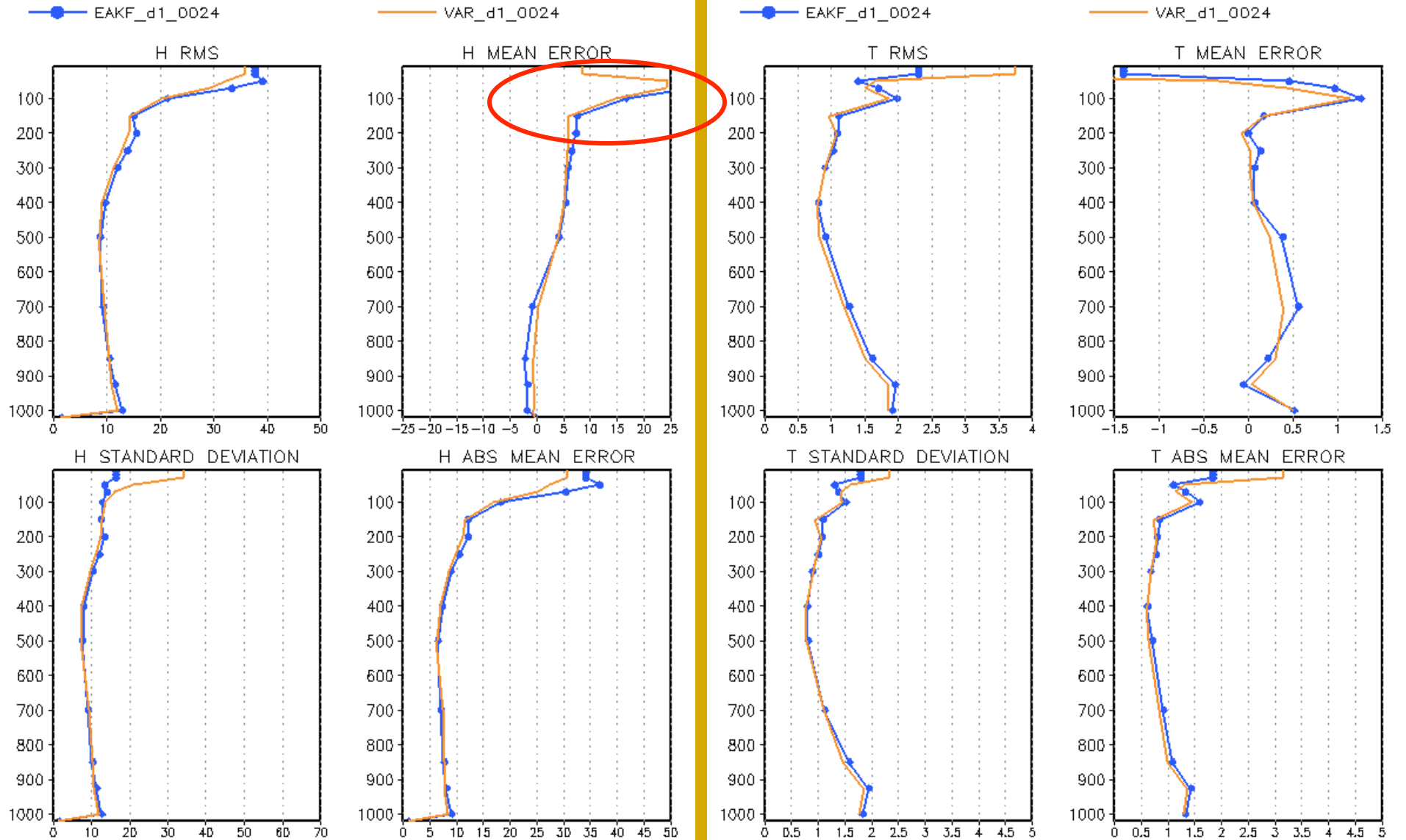
SOWMEX Forecasts: WRF/DART .vs. WRF/3D-Var

- EAKF assimilation starts at 20080601 00Z and ends at 20080614 18Z
- CWB operational data with GPS RO data
- Compared 48-hour forecasts of EAKF with WRFVAR (OP211)

Forecast 24h

H Profile

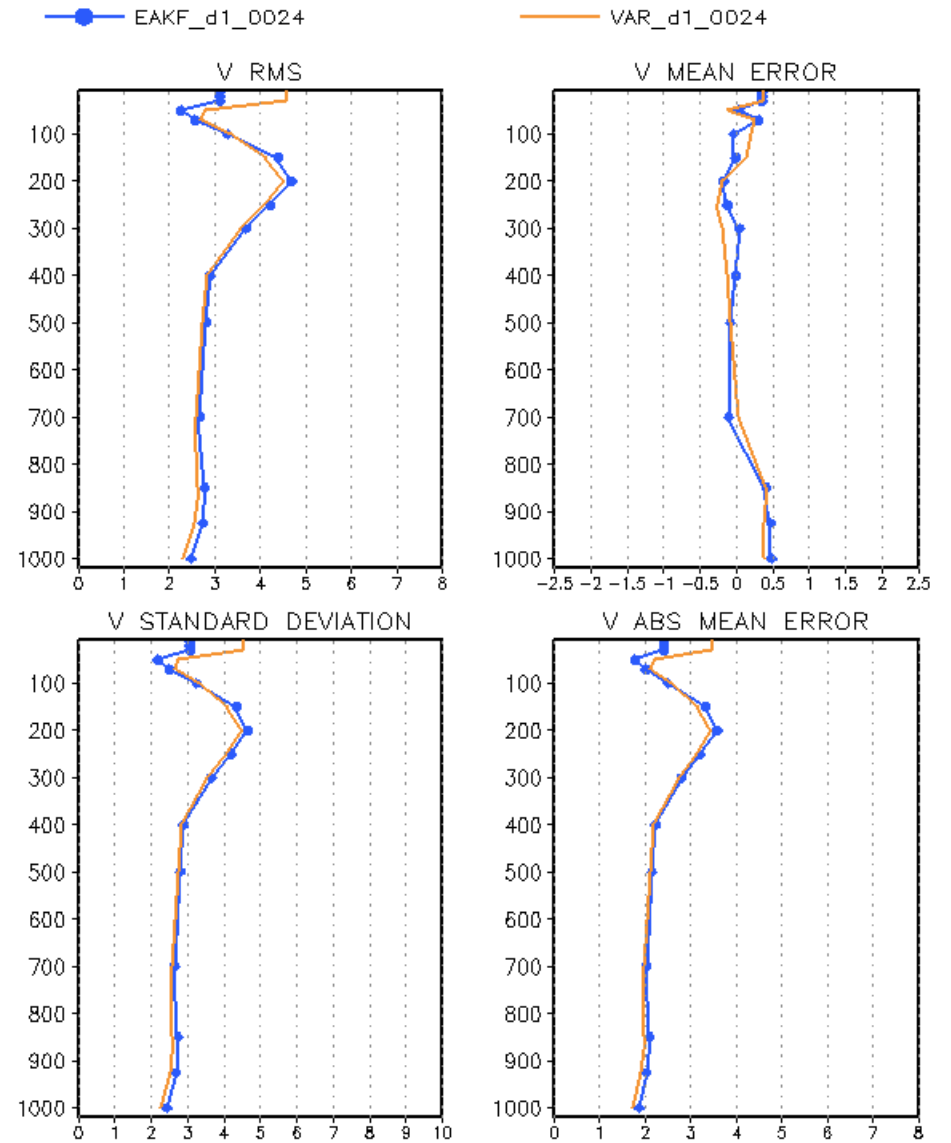
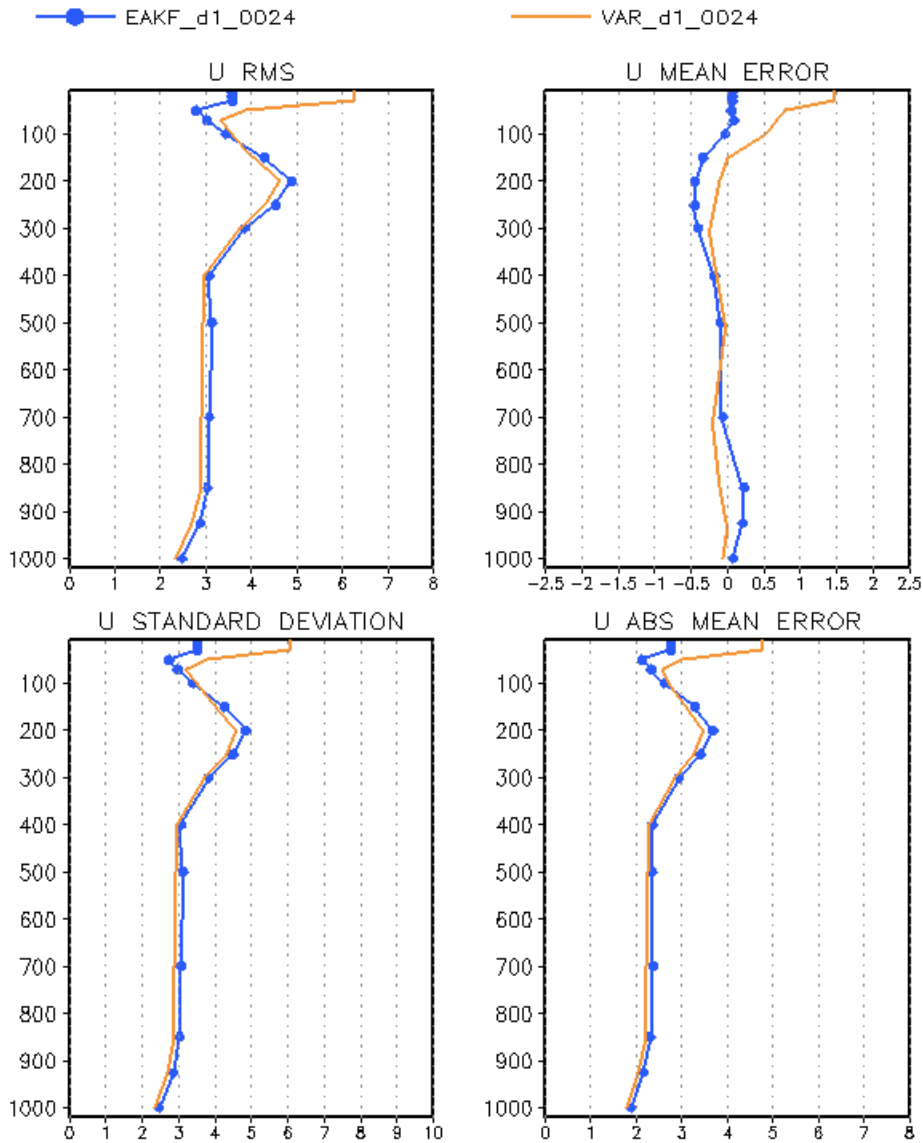
T Profile



Forecast 24h

U Profile

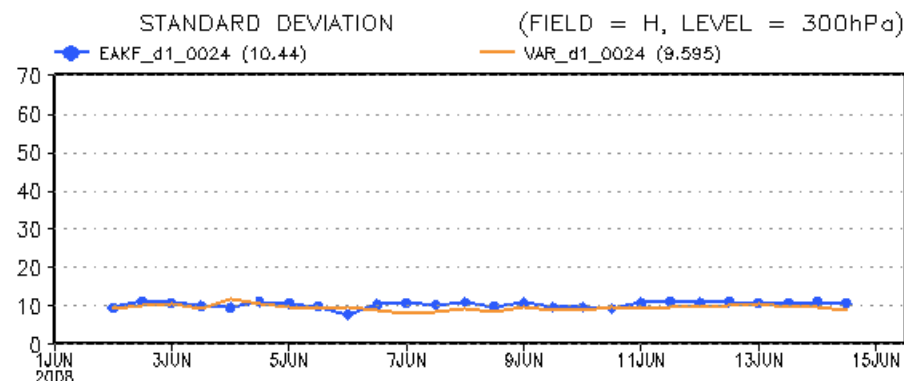
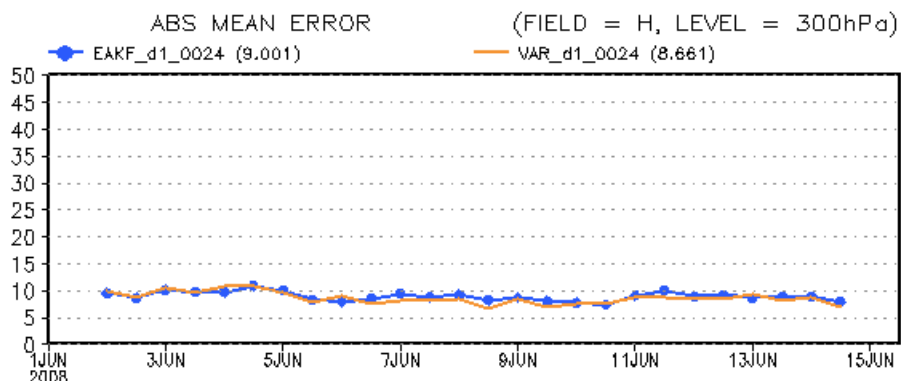
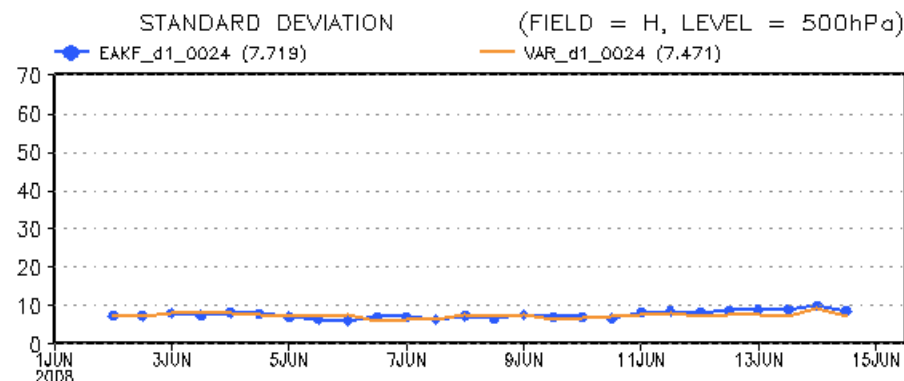
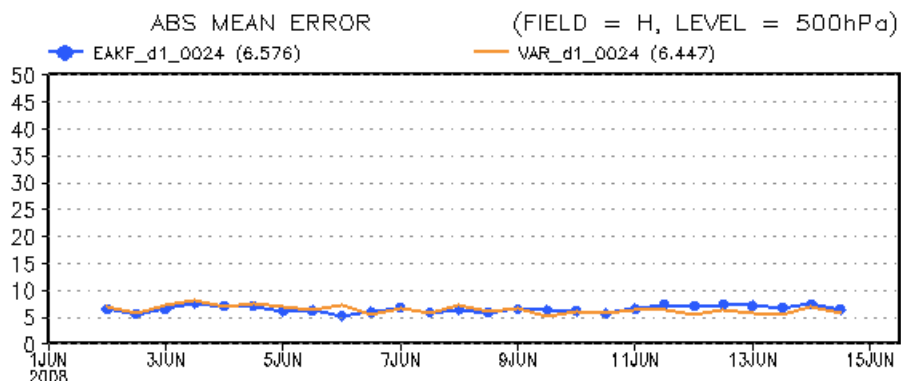
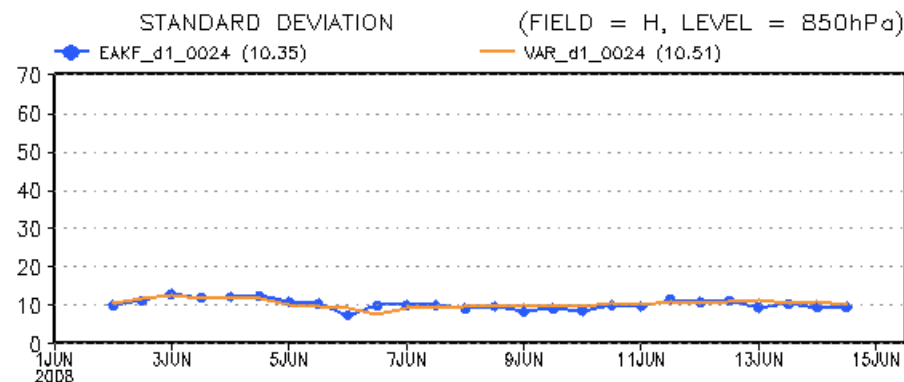
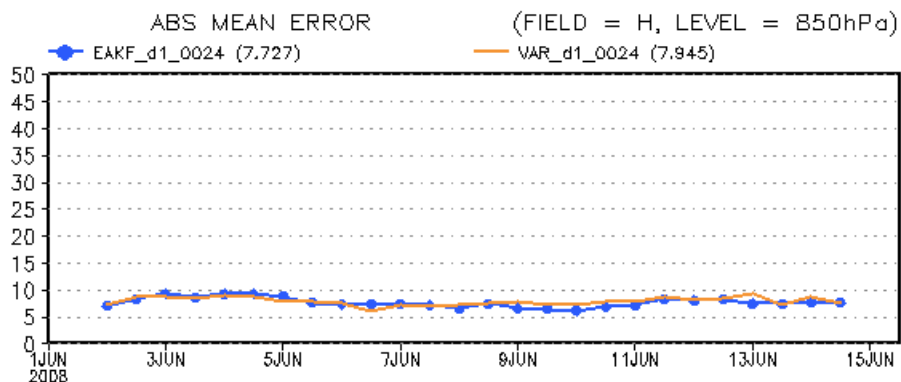
V Profile



Forecast 24h (H, 850, 500, 300 hPa)

ABS Mean Error

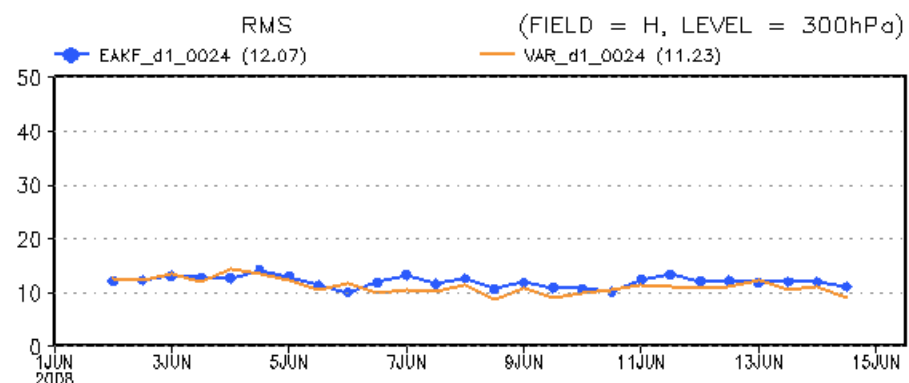
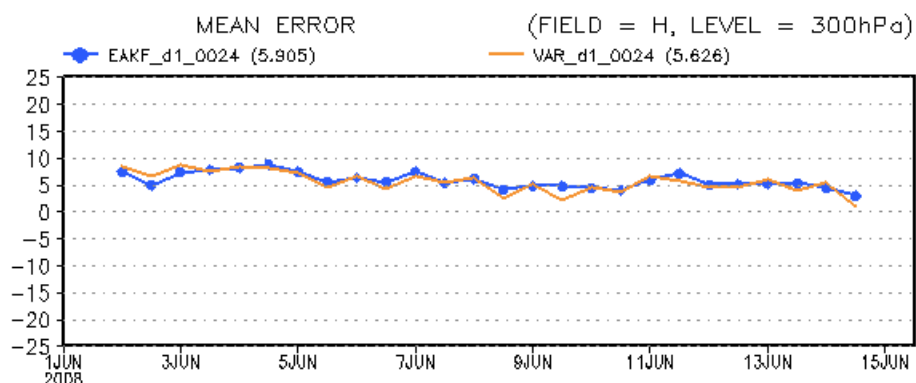
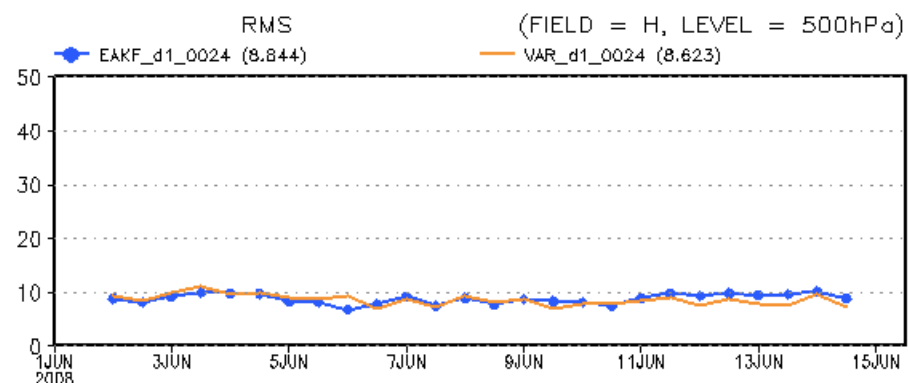
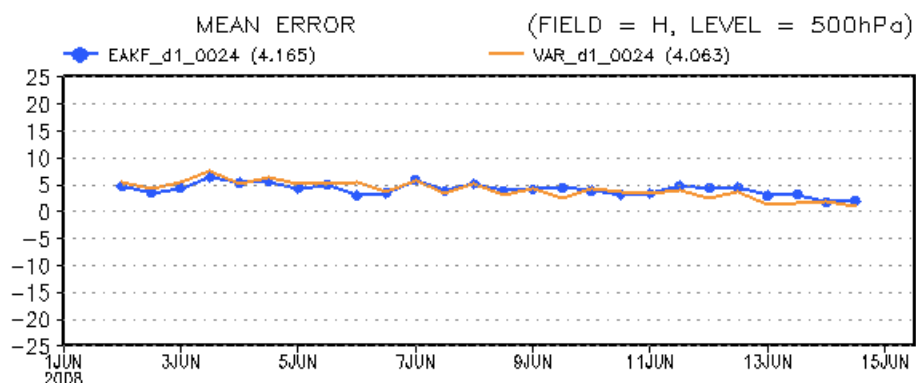
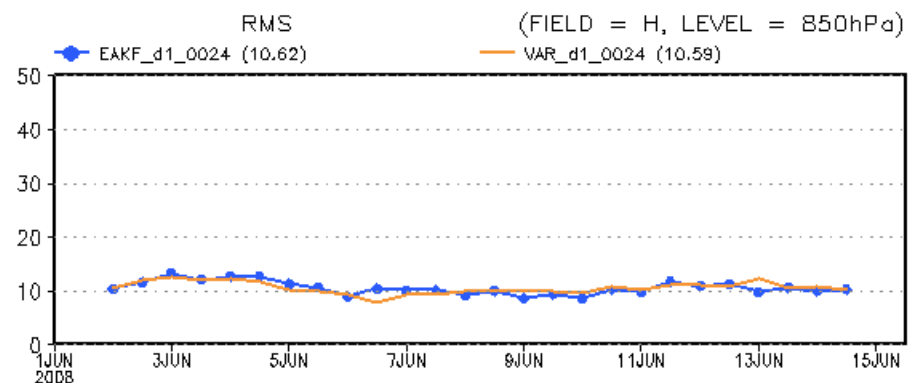
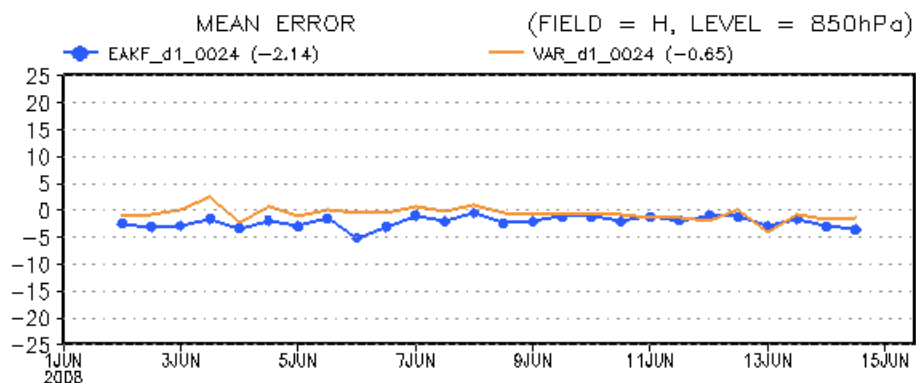
Standard Deviation



Forecast 24h (H, 850, 500, 300 hPa)

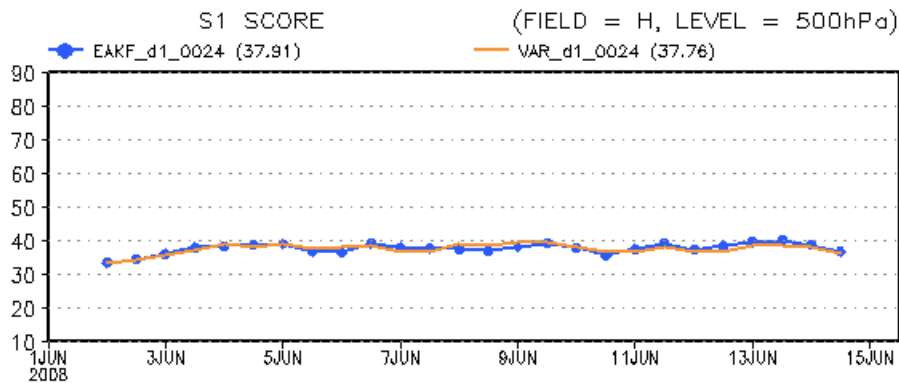
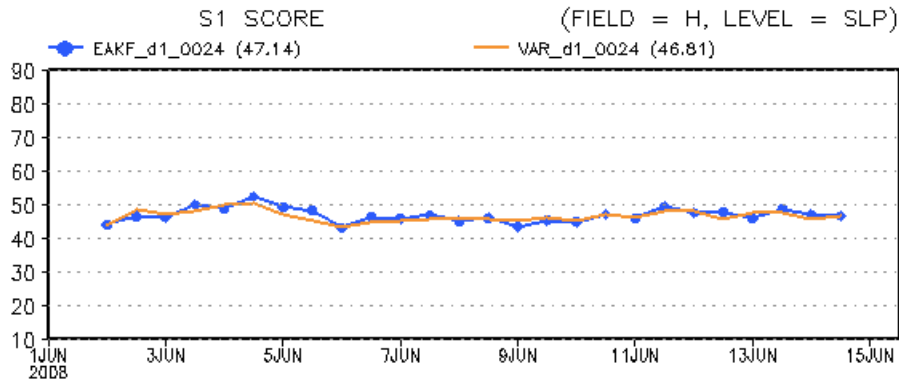
Mean Error

RMS

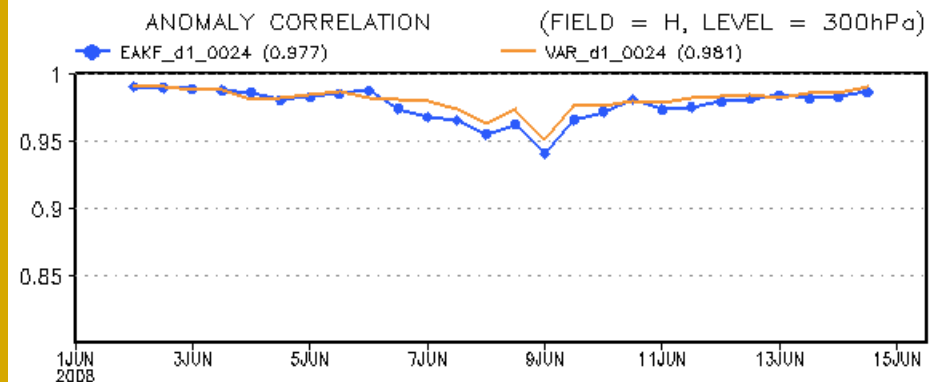
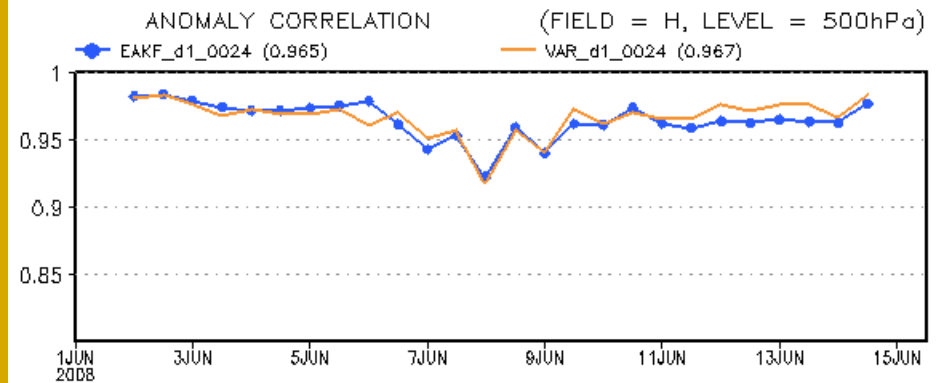
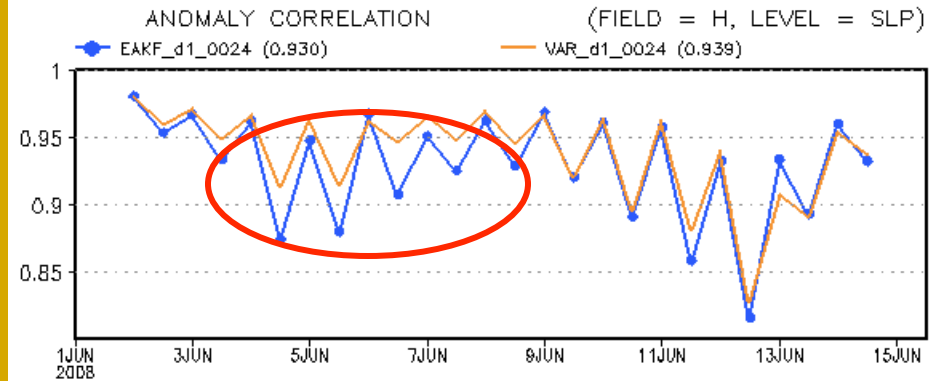


Forecast 24h (H, 850, 500, 300 hPa)

S1 Score



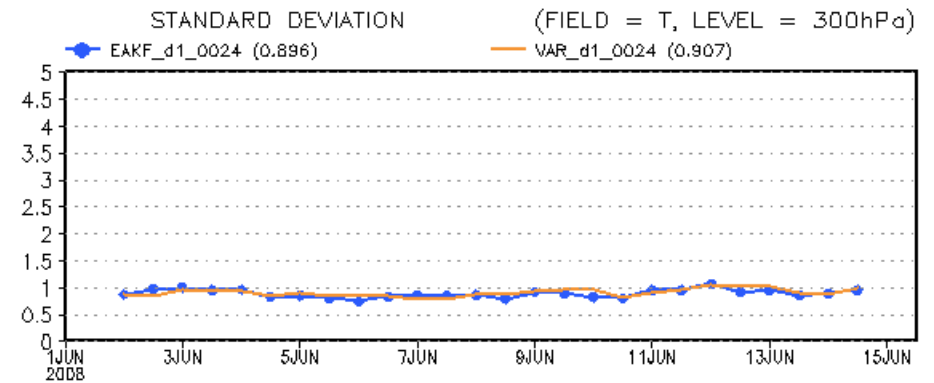
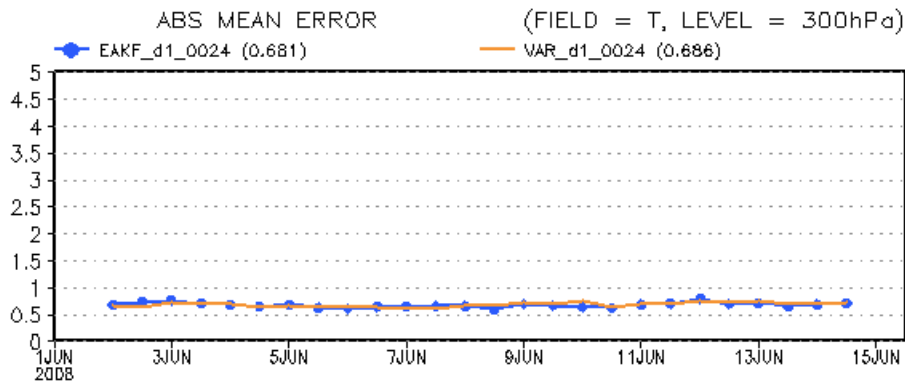
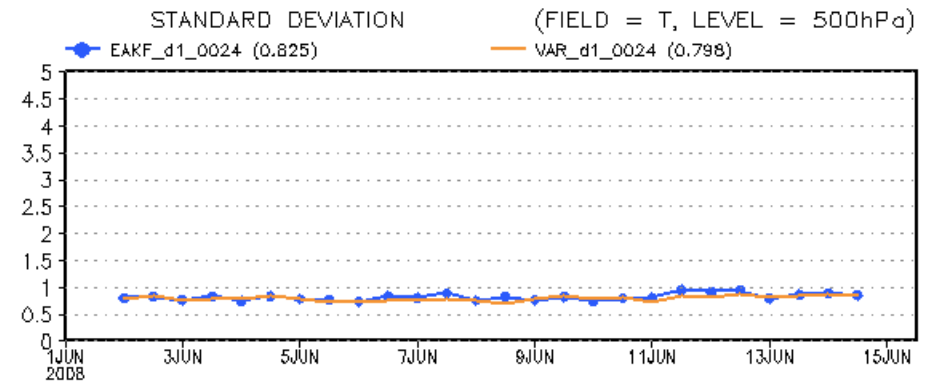
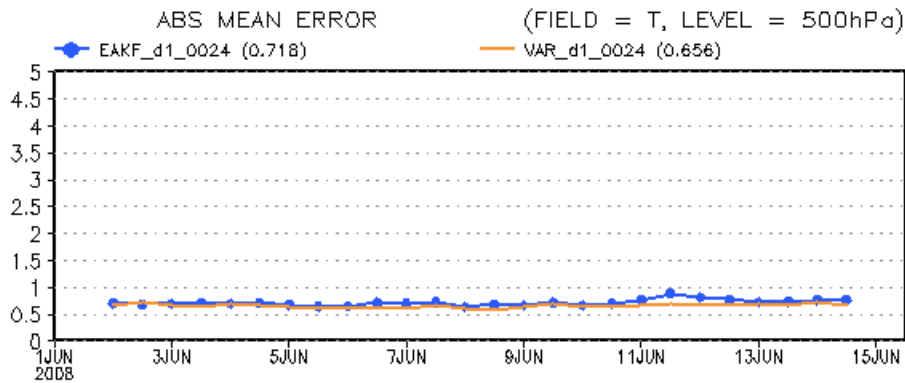
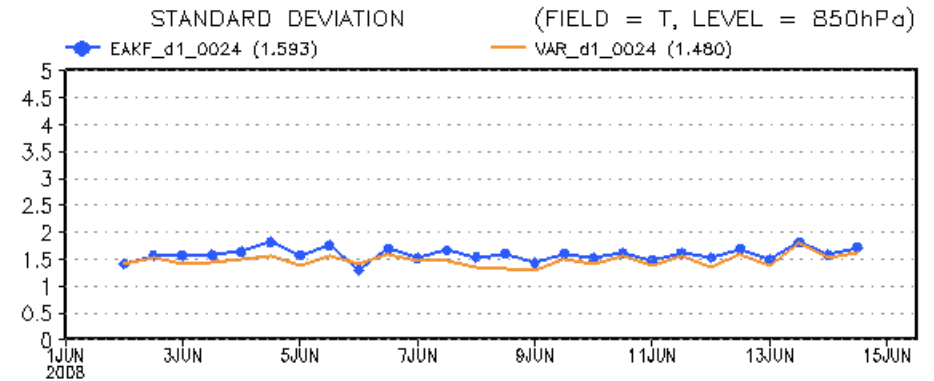
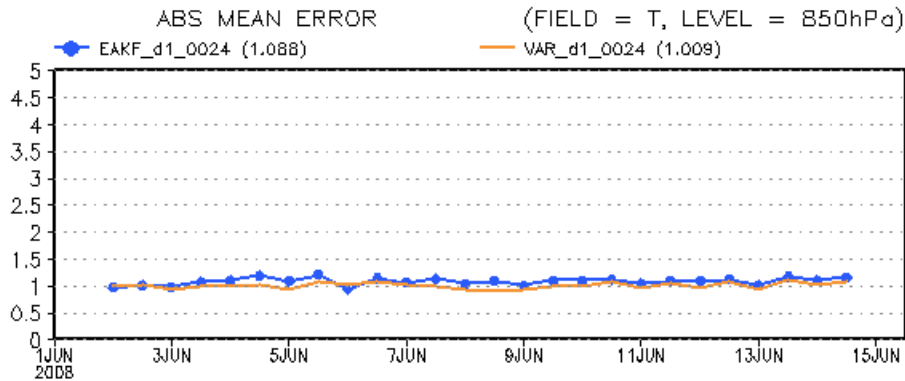
Anomaly Correlation



Forecast 24h (T)

ABS Mean Error

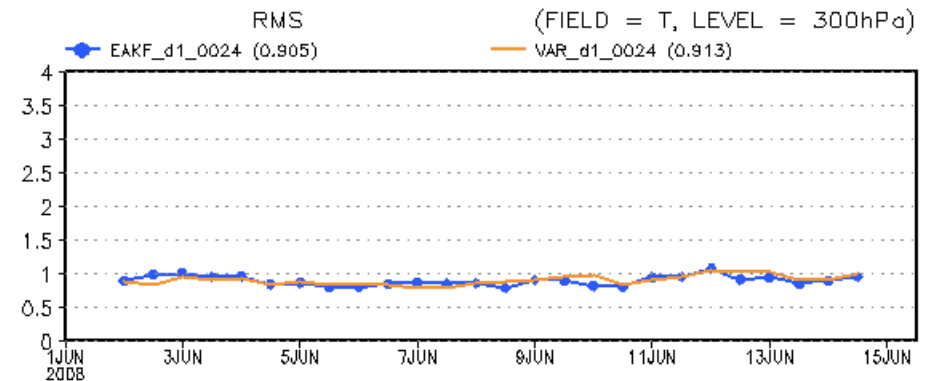
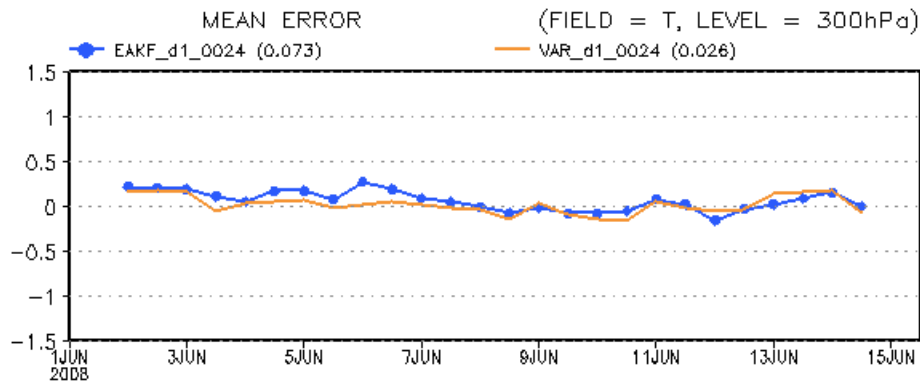
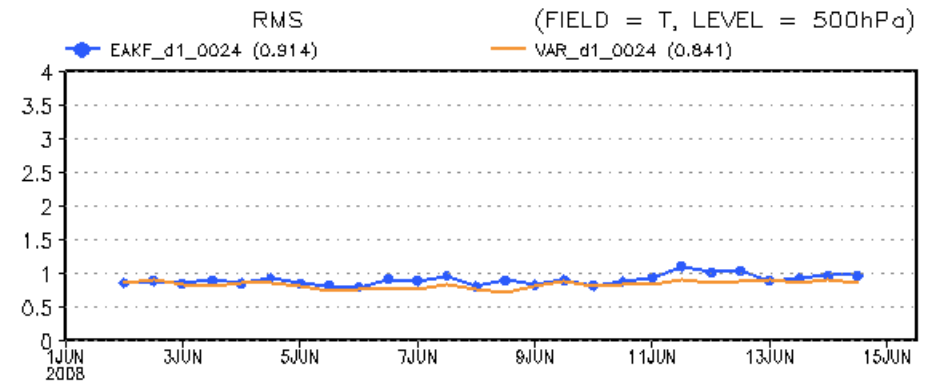
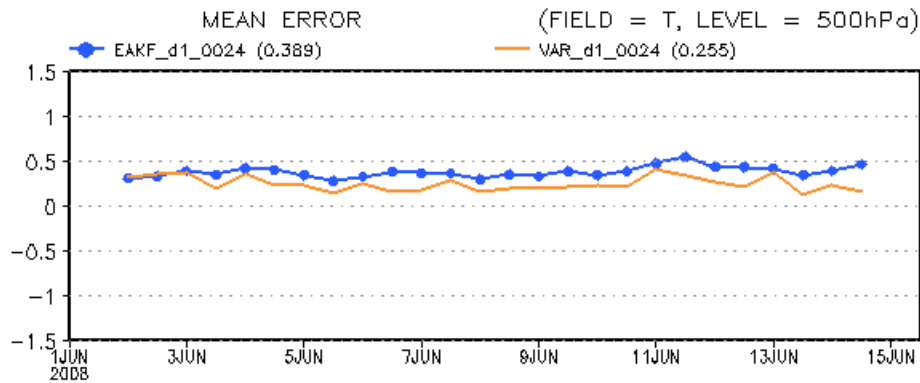
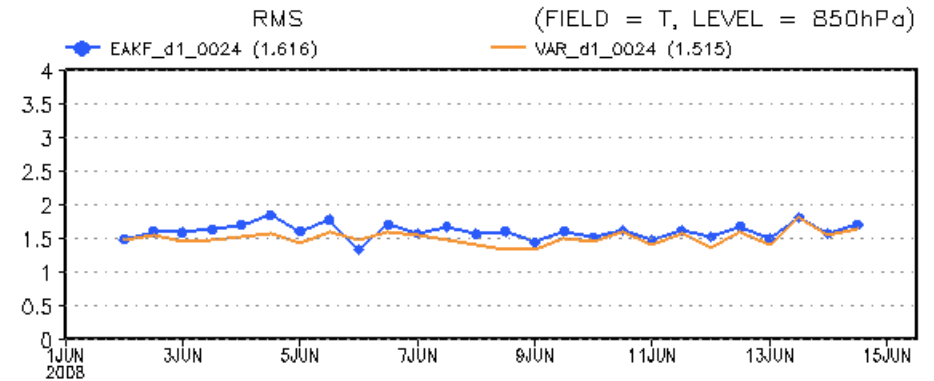
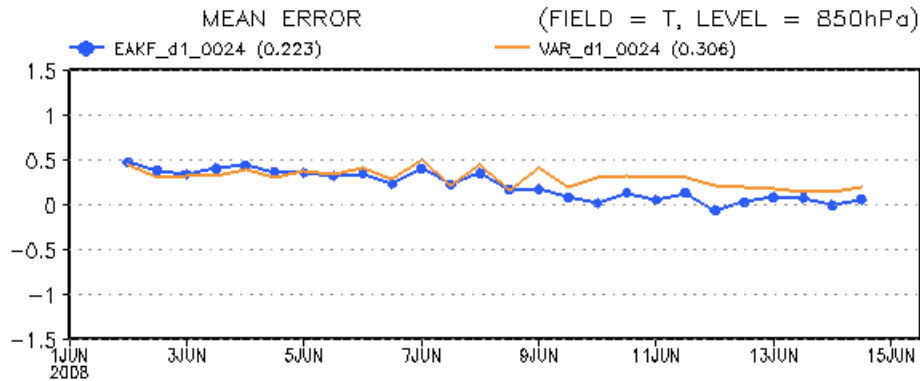
Standard Deviation



Forecast 24h (T)

Mean Error

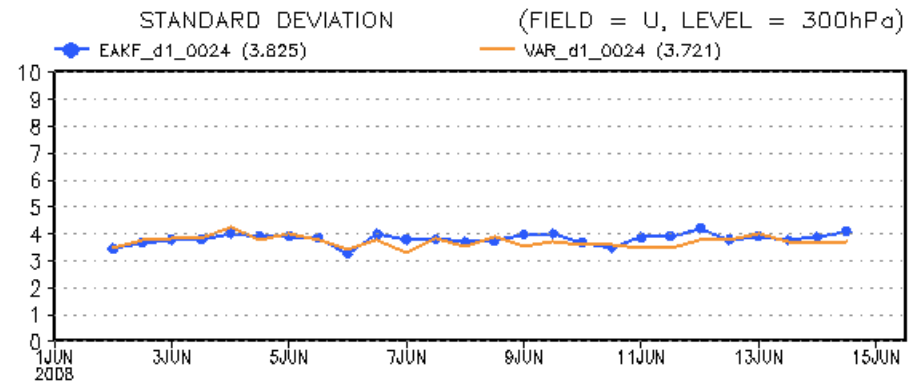
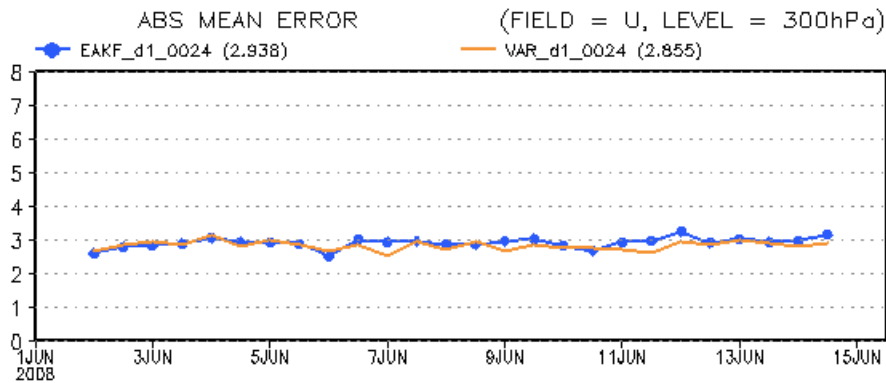
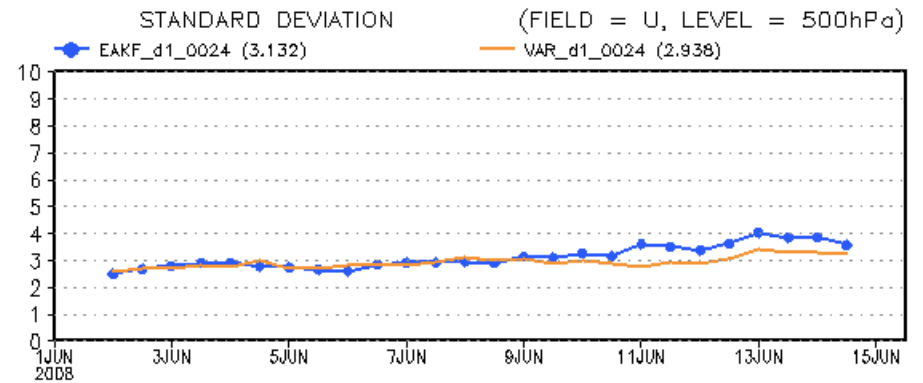
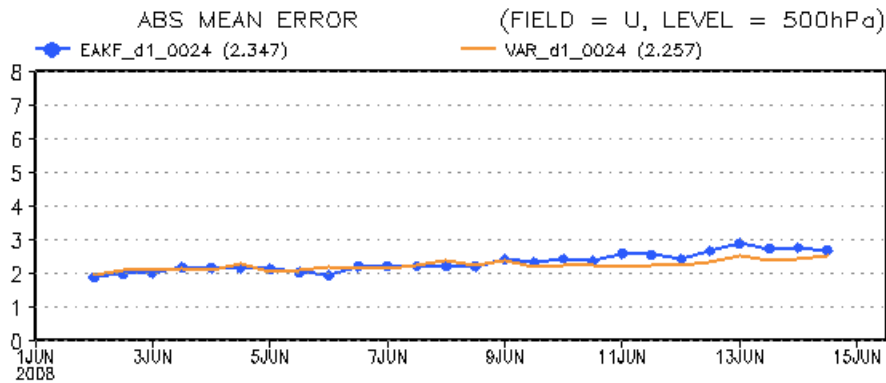
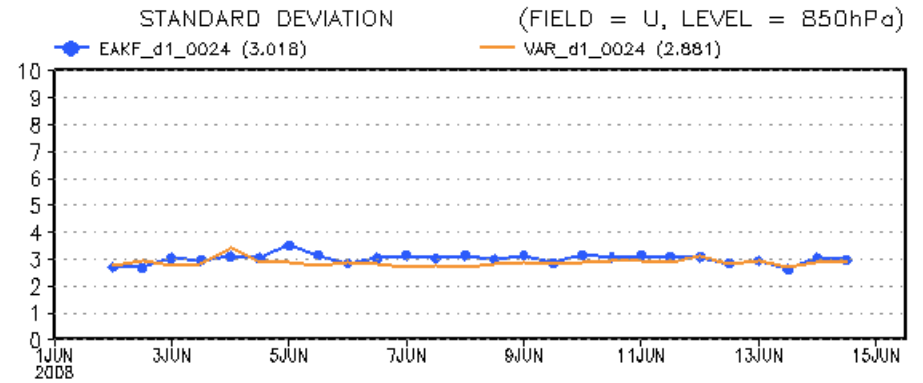
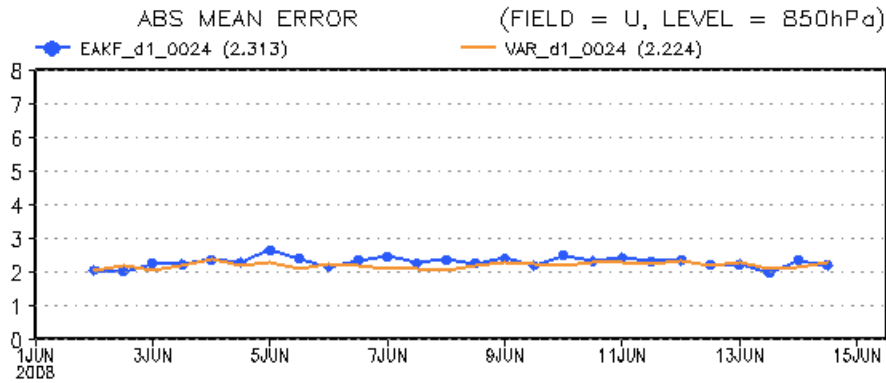
RMS



Forecast 24h (U)

ABS Mean Error

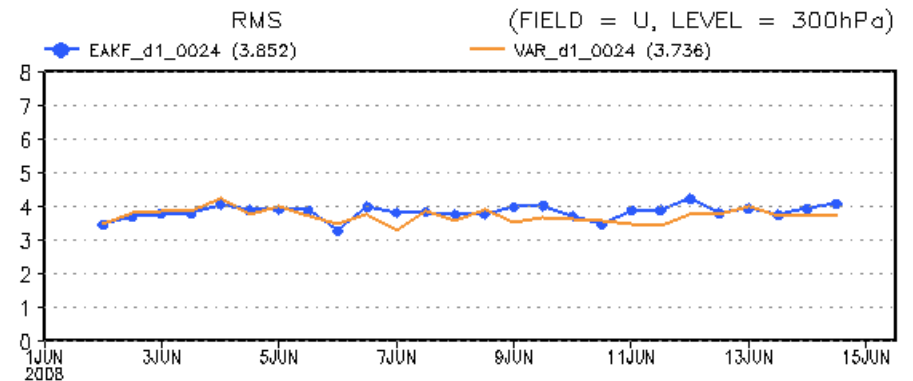
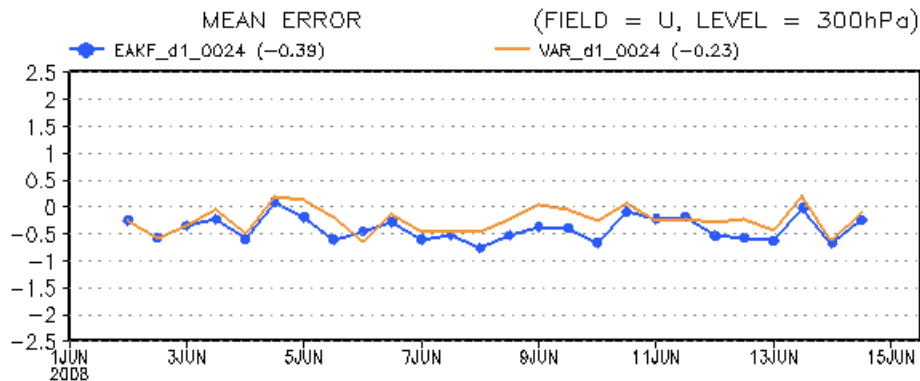
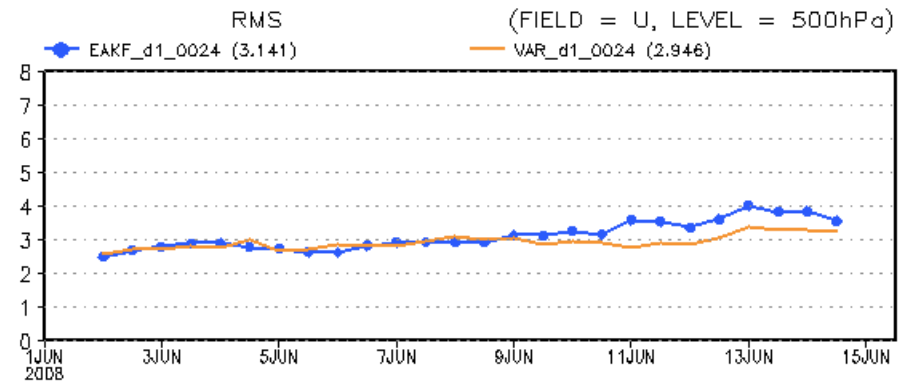
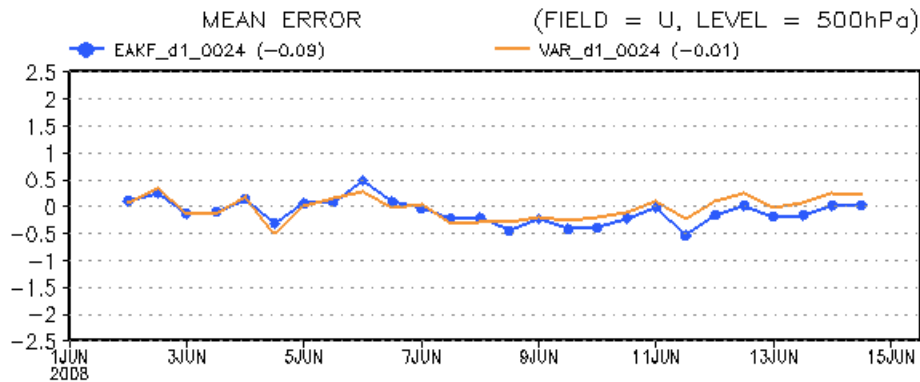
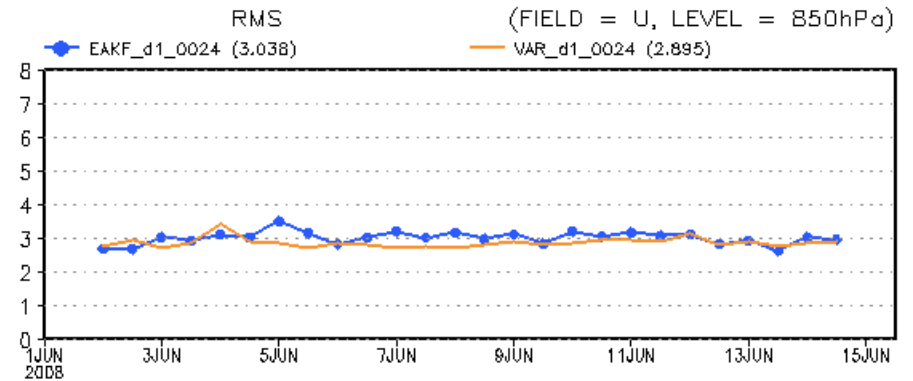
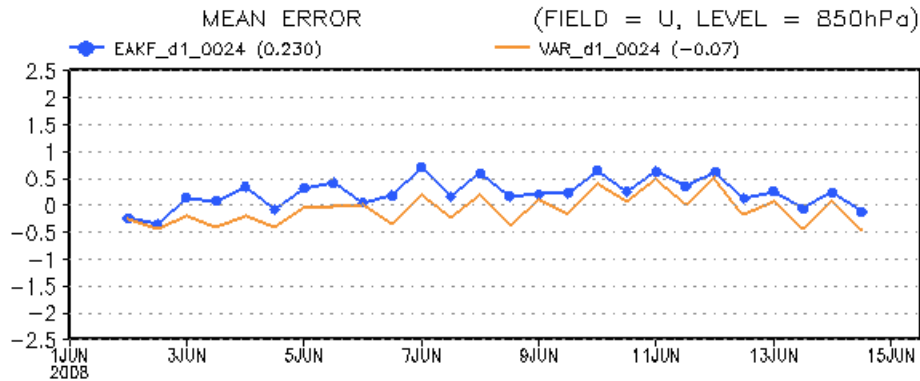
Standard Deviation



Forecast 24h (U)

Mean Error

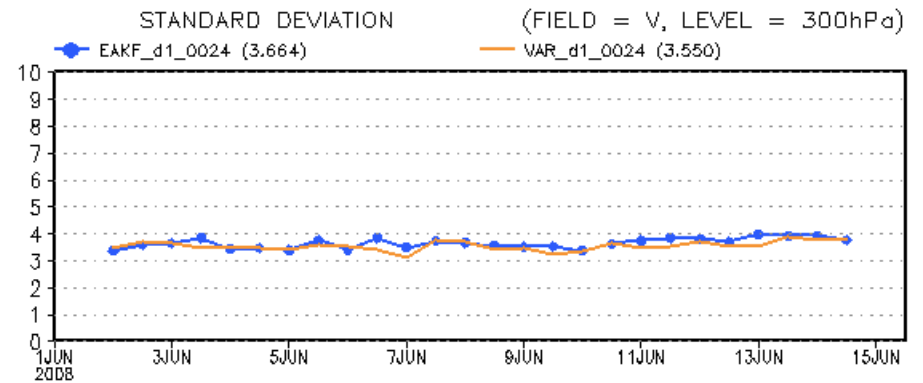
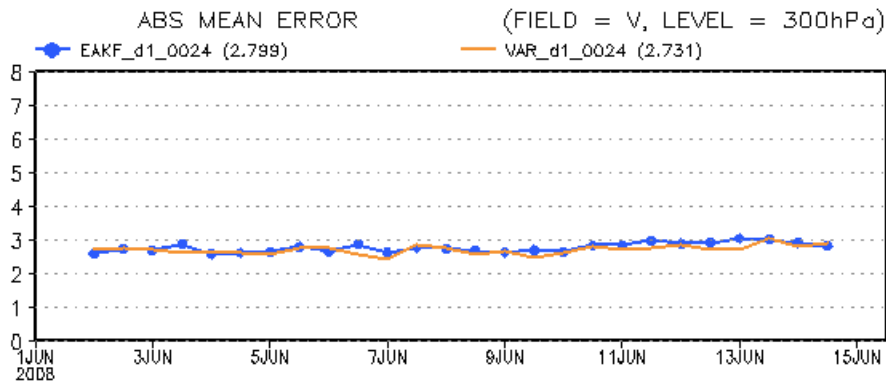
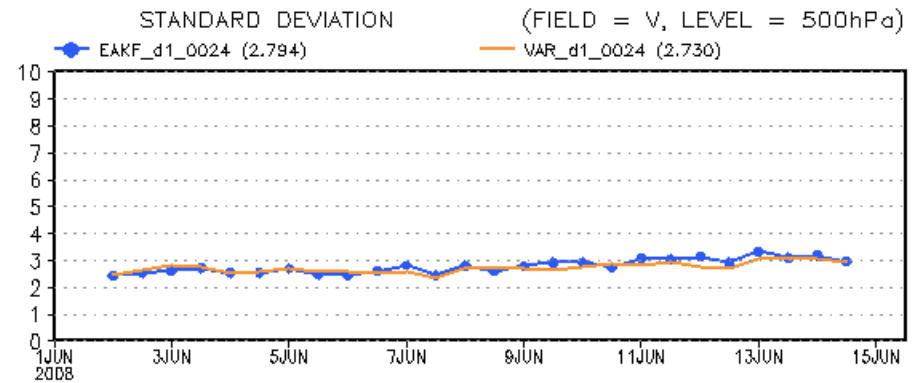
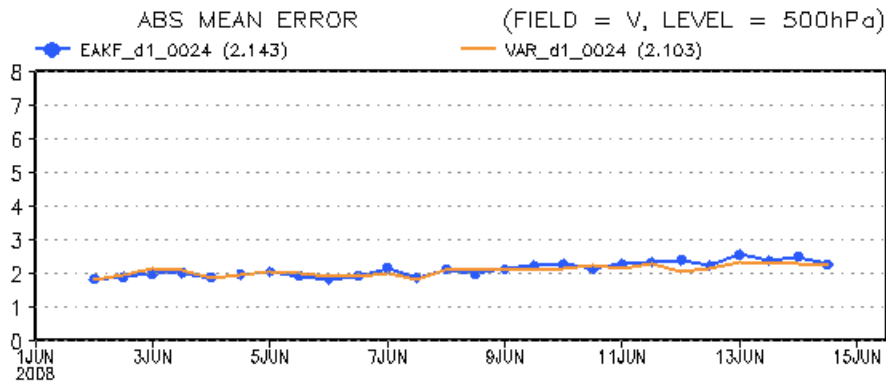
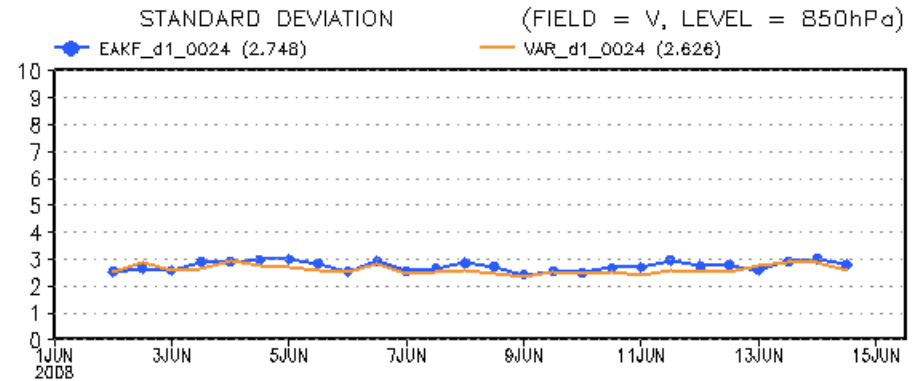
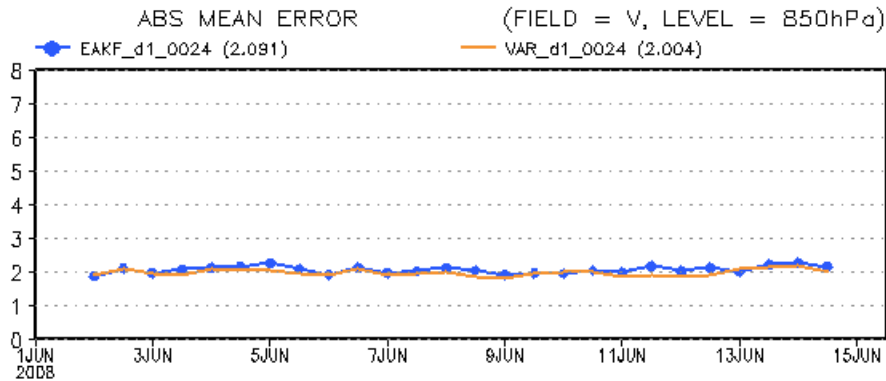
RMS



Forecast 24h (V)

ABS Mean Error

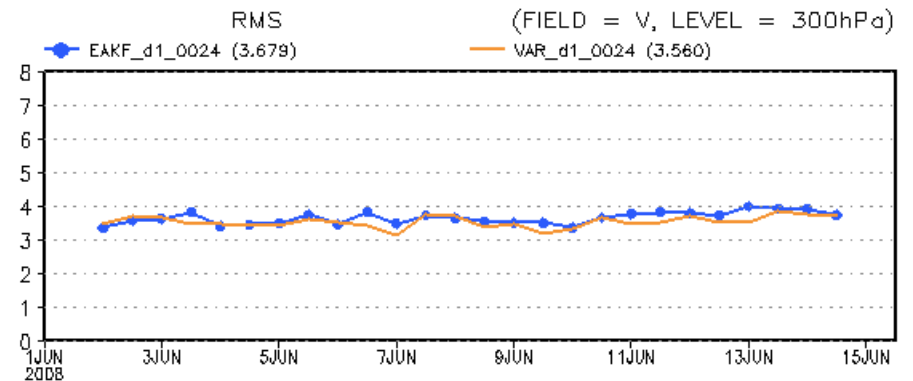
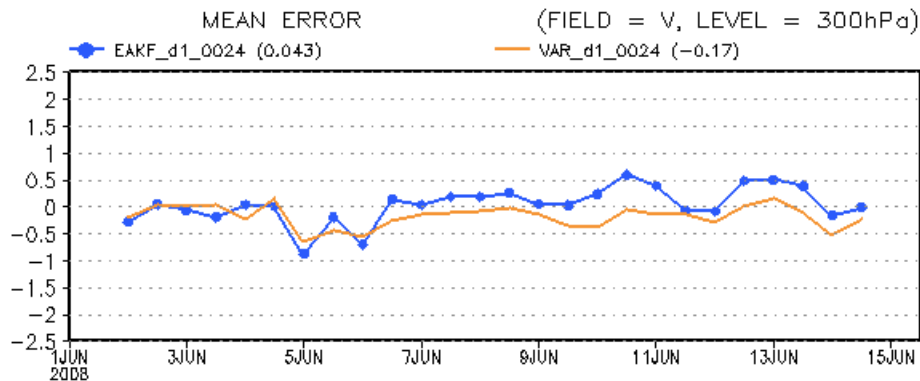
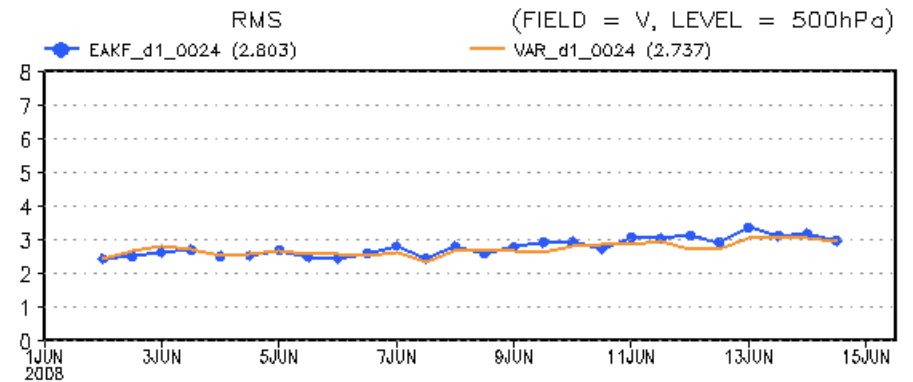
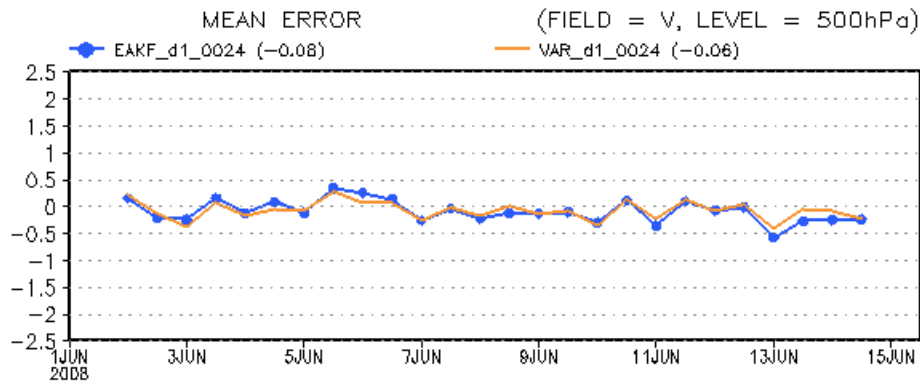
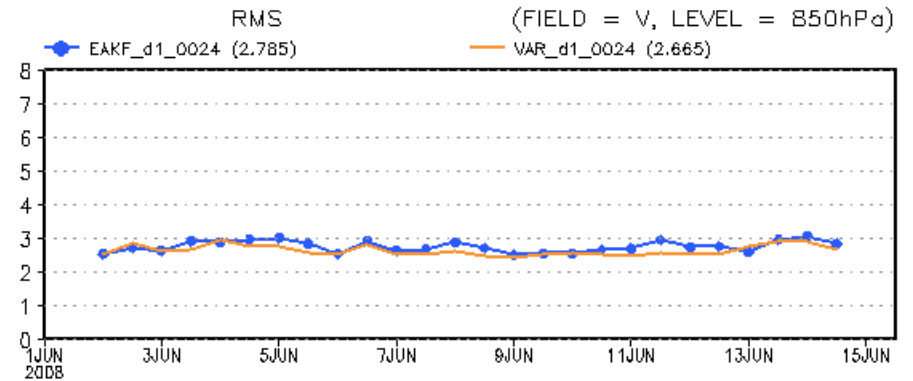
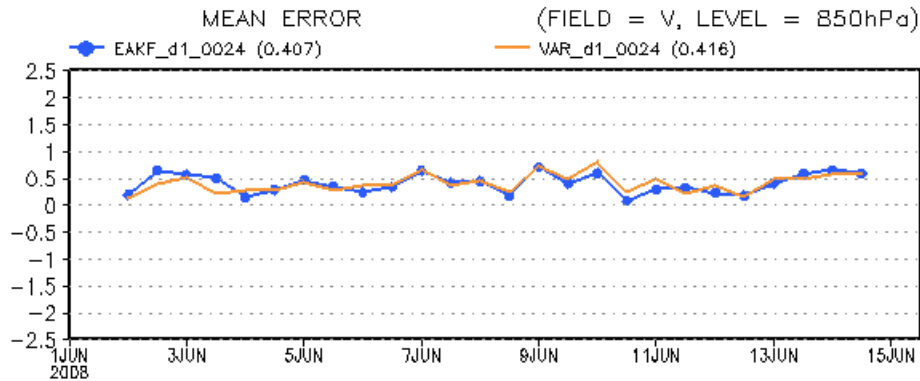
Standard Deviation



Forecast 24h (V)

Mean Error

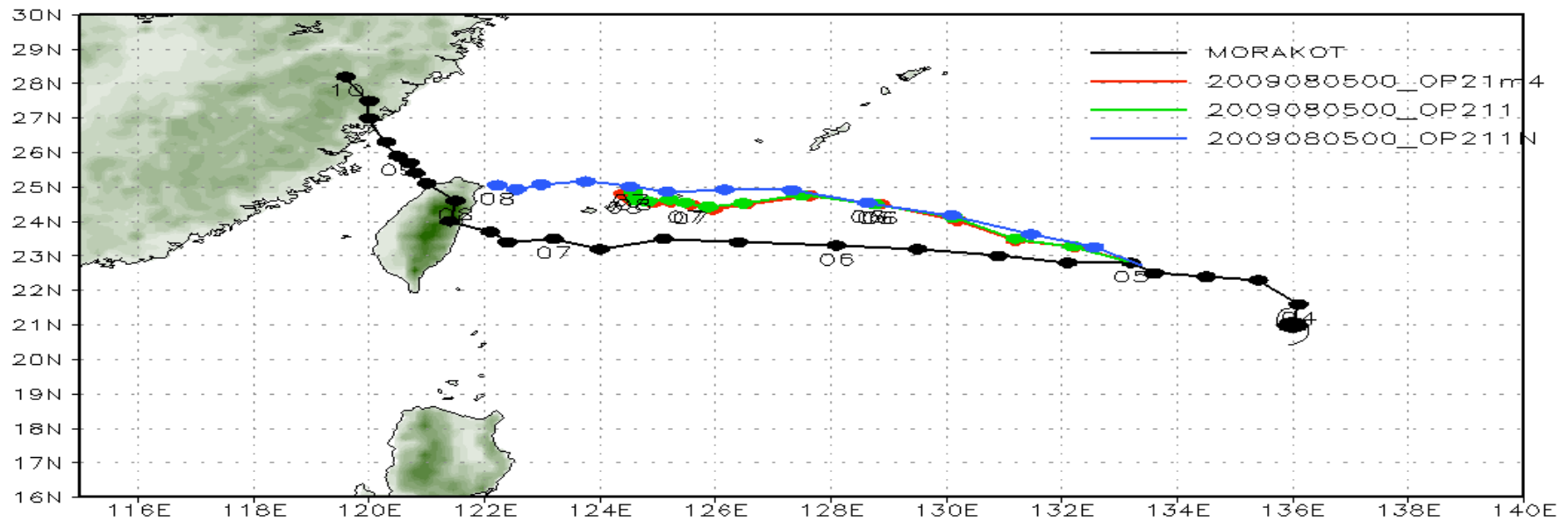
RMS



TC Morakot(2009) forecast tests at CWB

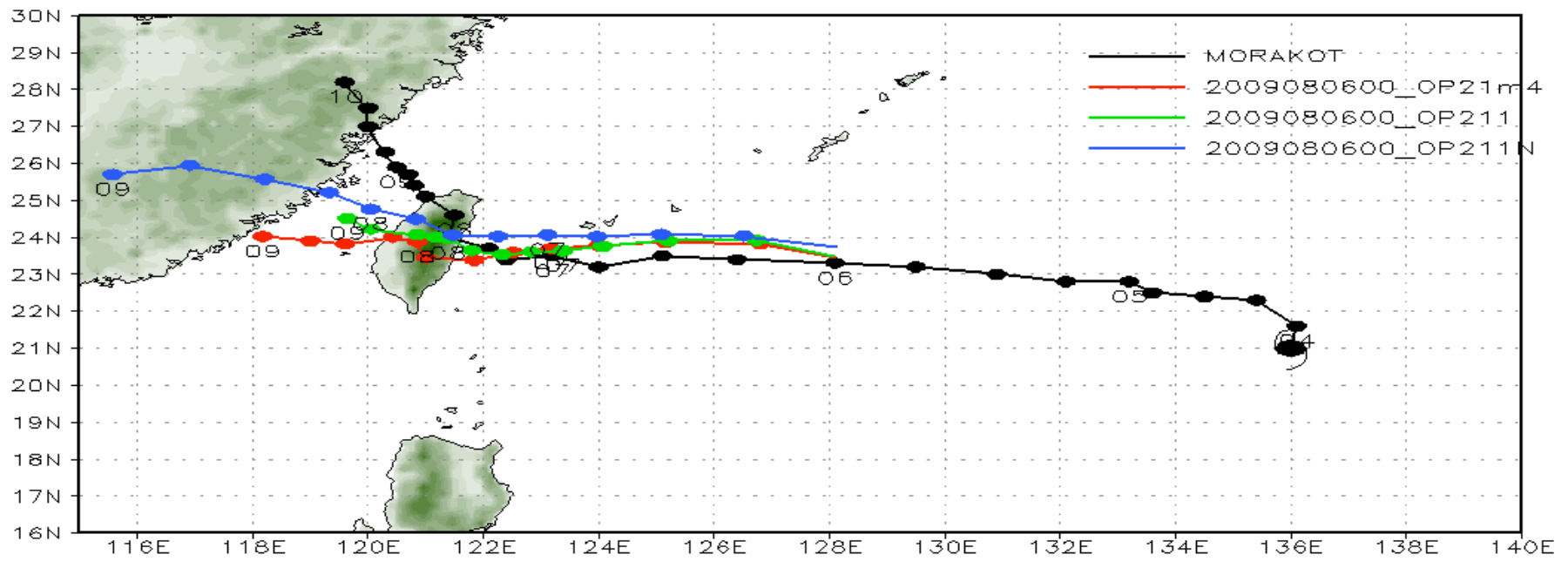
- **Blue line** : CWB tested forecasts with the new version of WRF/DART.

2009080500

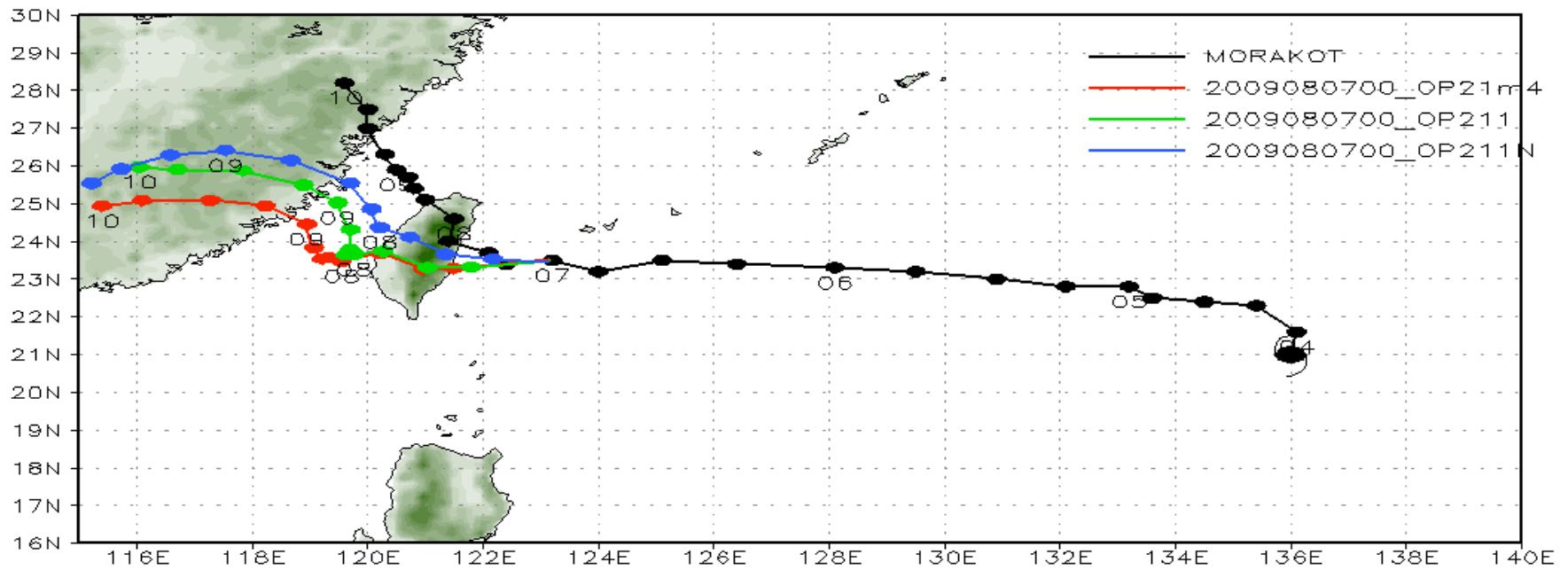


Blue line is new cwb_obs_process

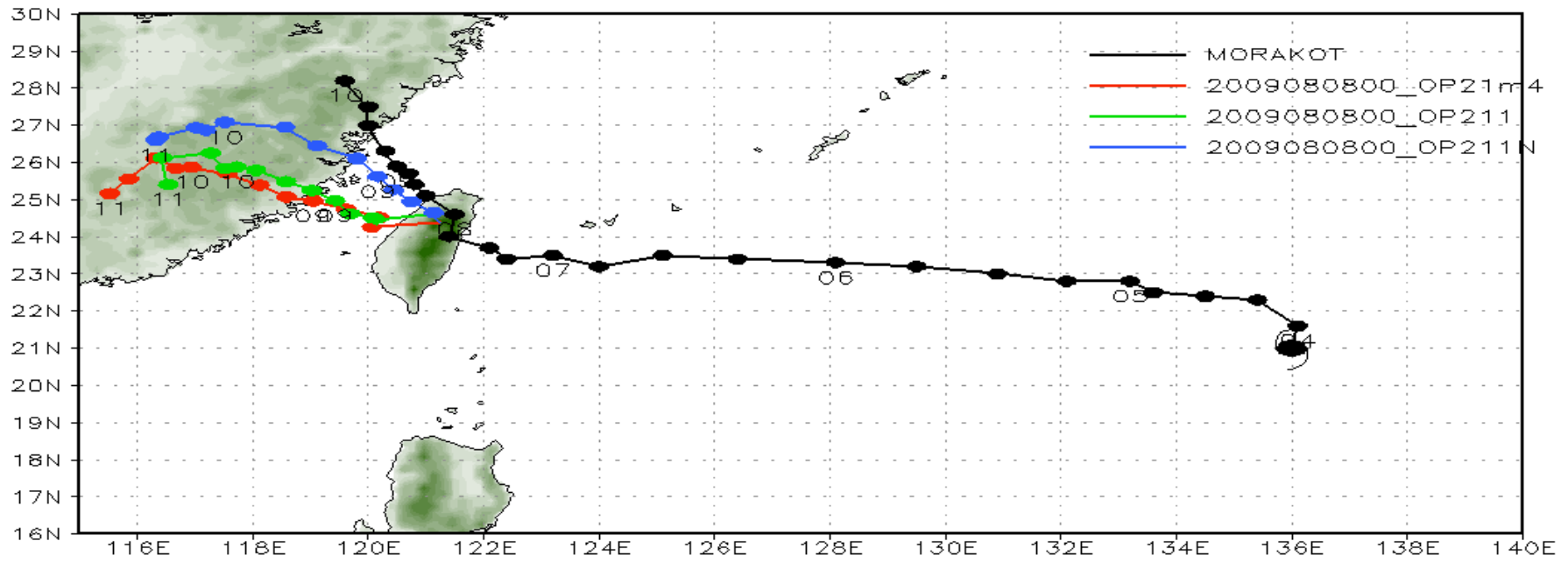
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2009080700



2009080800

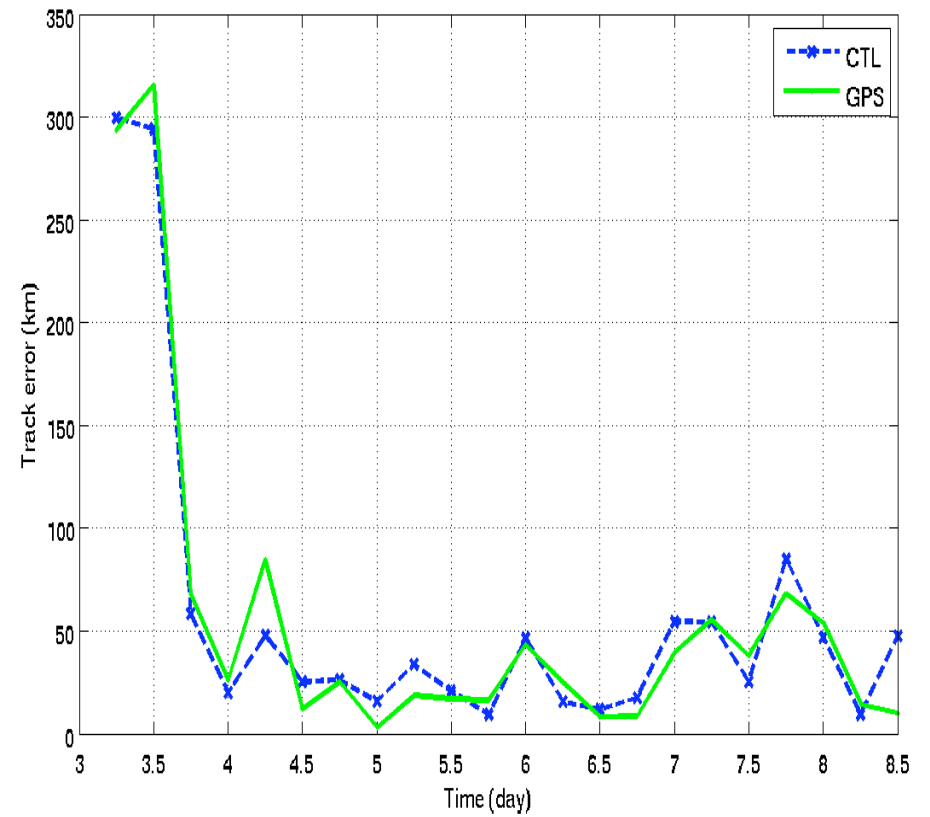
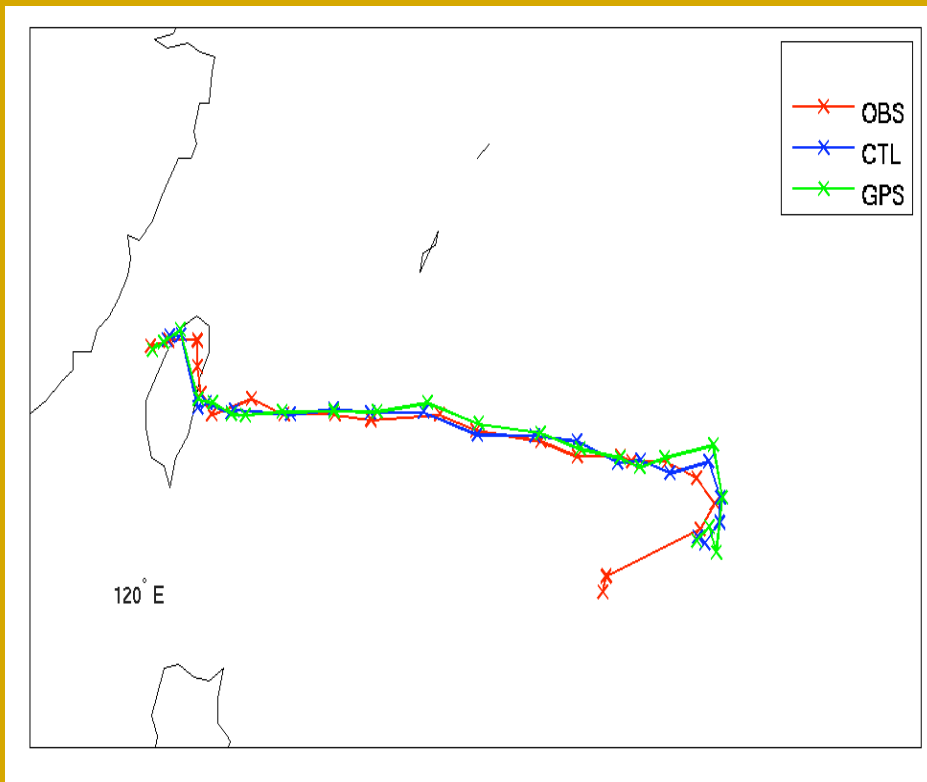


Impact of GPS data on rainfall forecast of typhoon Morakot (2009)

1. Assimilation experiments

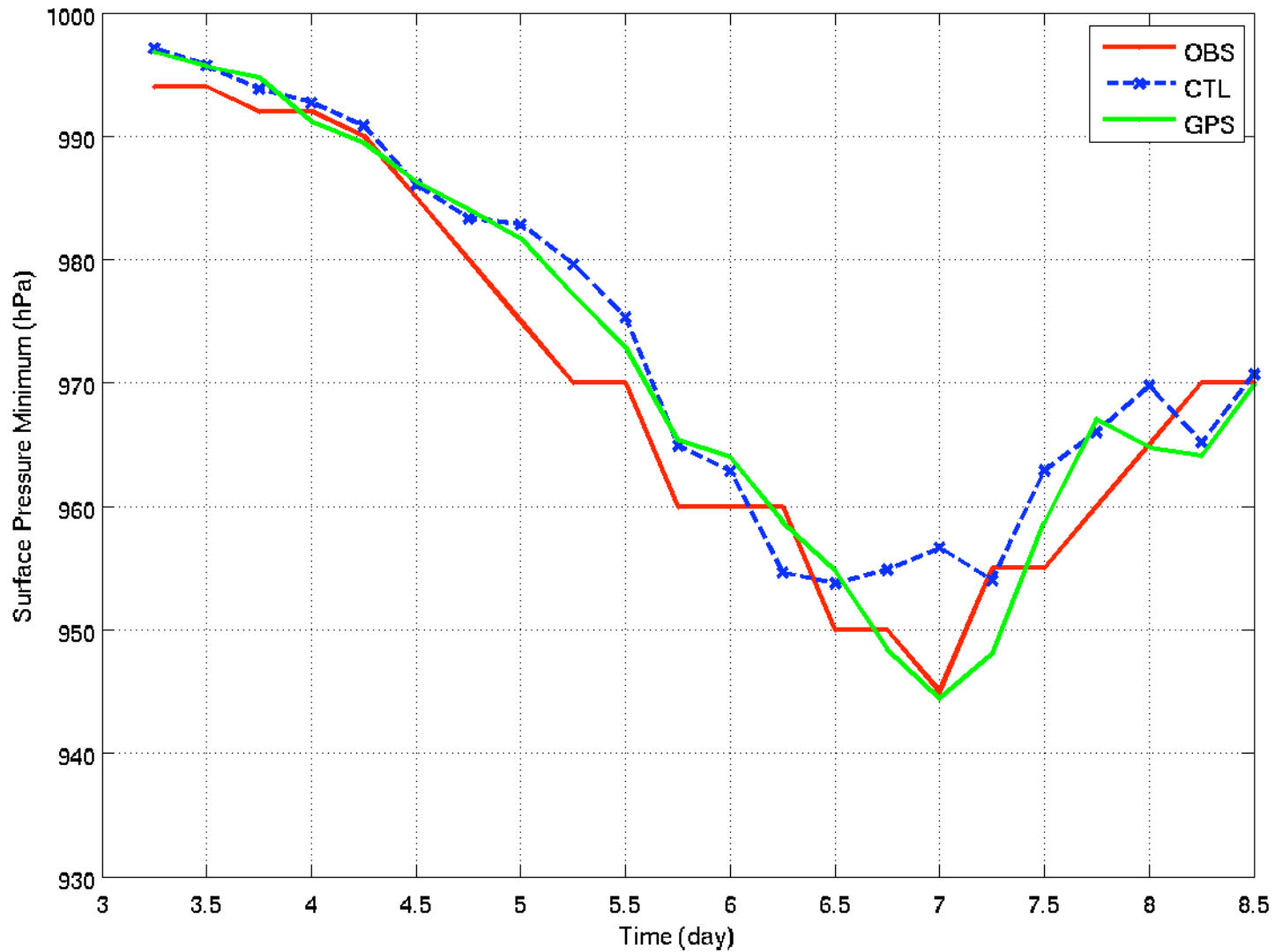
- Assimilation from 00Z 3 to 18Z 8 August, 2009 with 2-hourly cycling.
- 36km analysis grid
- 48h Forecast with nests 36/12/4km starting at August 7 00Z.
- CTL run: Assimilate CWB conventional observations
- GPS run: CTL run + COSMIC refractivity data.

Track analyses (August 3 06Z - 8 18Z)



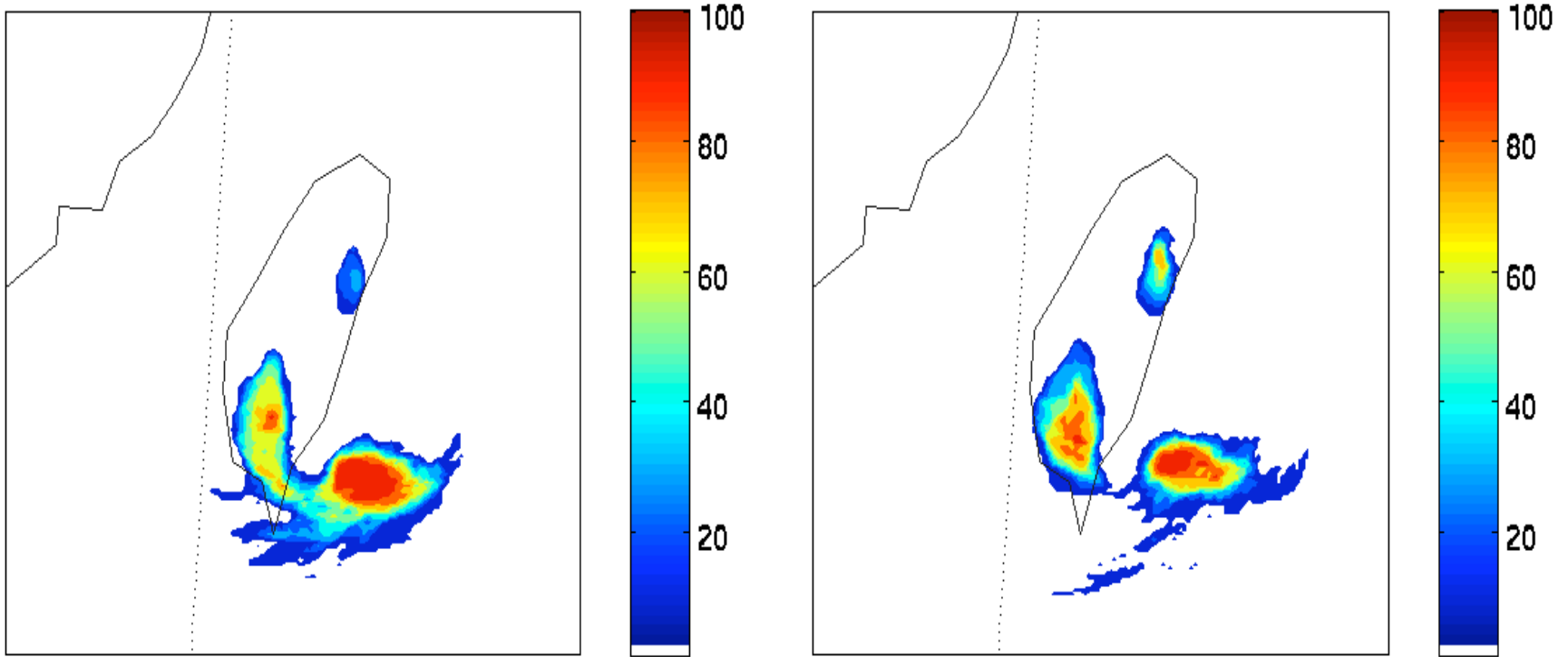
Minimum SLP analyses

(August 3 06Z - 8 18Z)



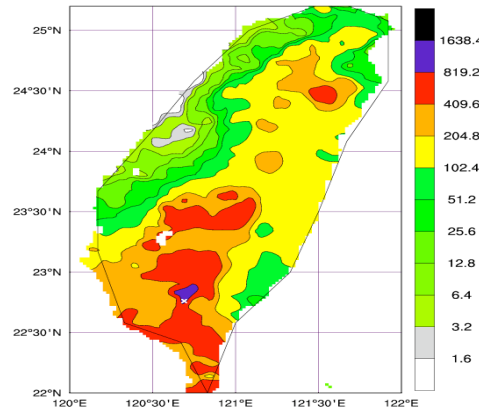
Rain Probability Forecast (August 7-8 00Z)

Probability forecast (% , >500mm, Aug 7-8 00Z), CTL Probability forecast (% , >500mm, Aug 7-8 00Z), GPS



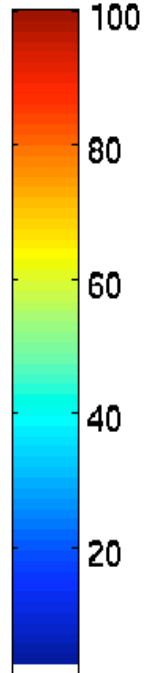
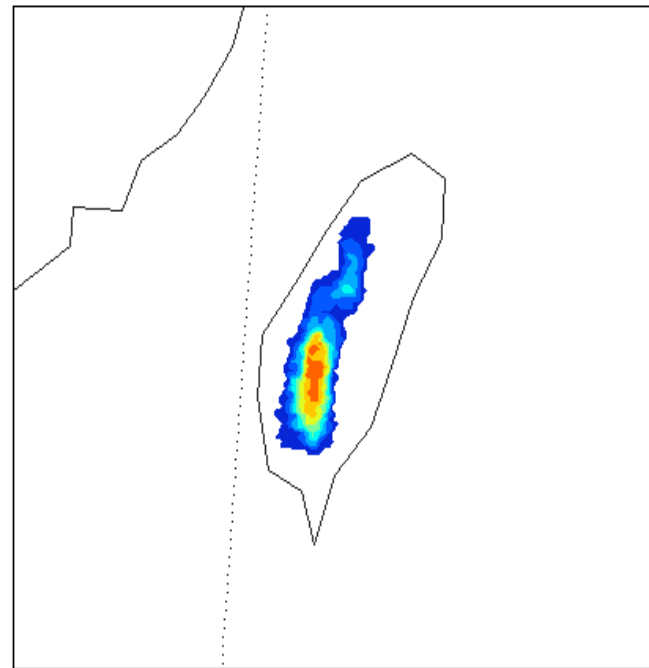
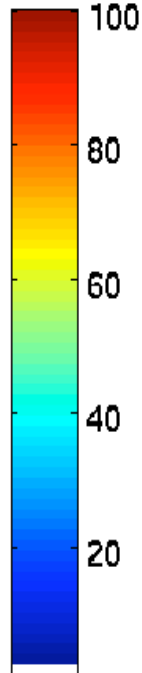
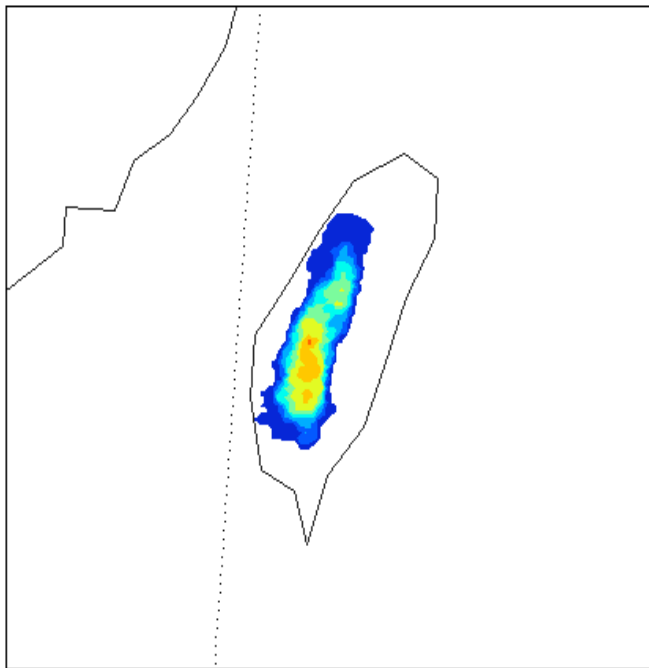
Obs pre on obs grid

Obs pre from 0700UTC to 0800UTC max1364 mm



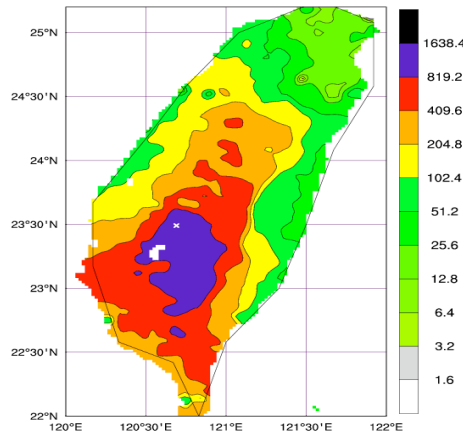
Rain Probability Forecast (August 8 - 9 00Z)

Probability forecast (% >500mm, Aug 8-9 00Z), CTL Probability forecast (% >500mm, Aug 8-9 00Z), GPS



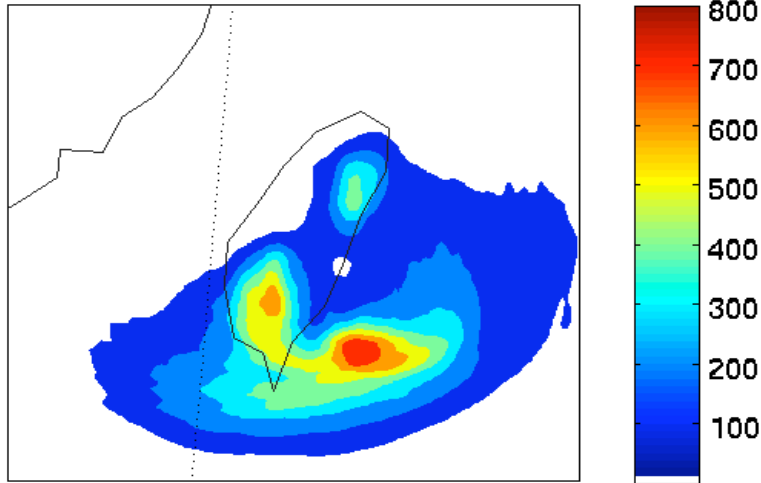
Obs pre on obs grid

Obs pre from 0800UTC to 0900UTC max1700 mm

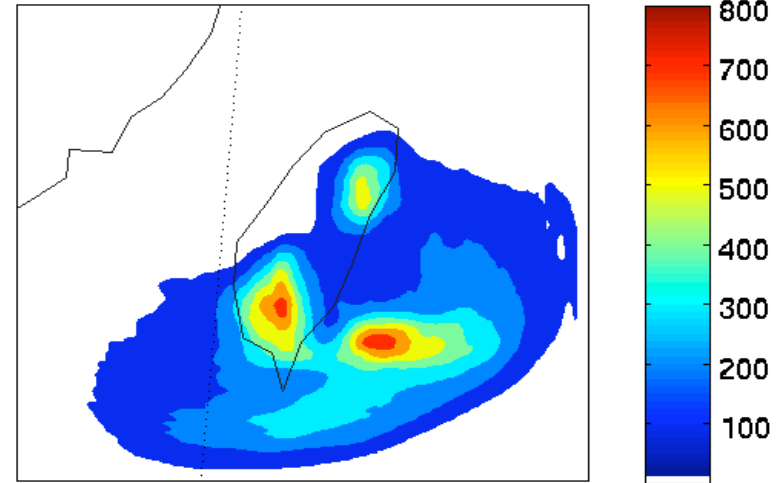


24h Rain forecast (August 7-8 00Z)

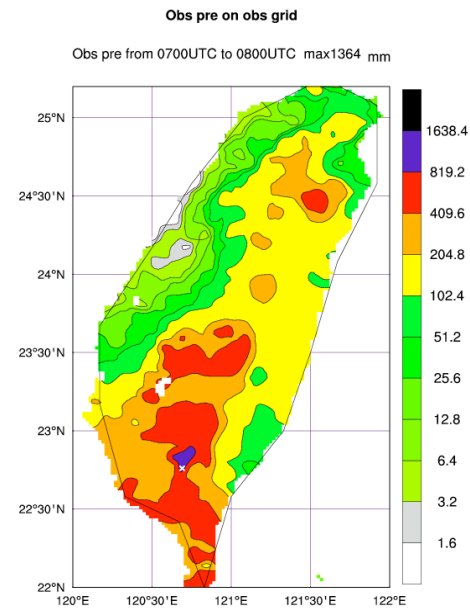
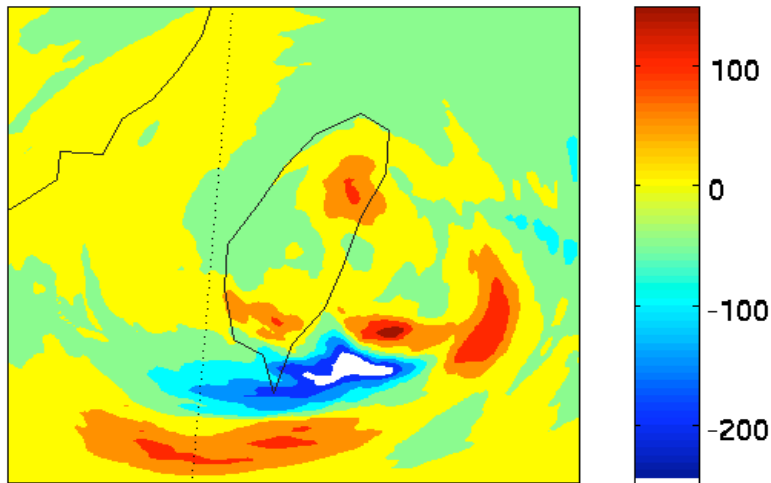
24h Prep forecast, ctl, Aug 7-8



24h Prep forecast, gps, Aug 7-8

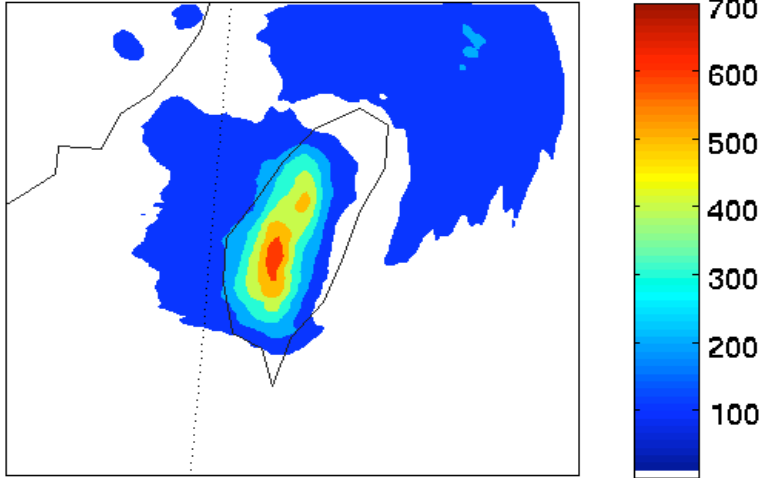


24h Prep forecast, gps - ctl, Aug 7-8

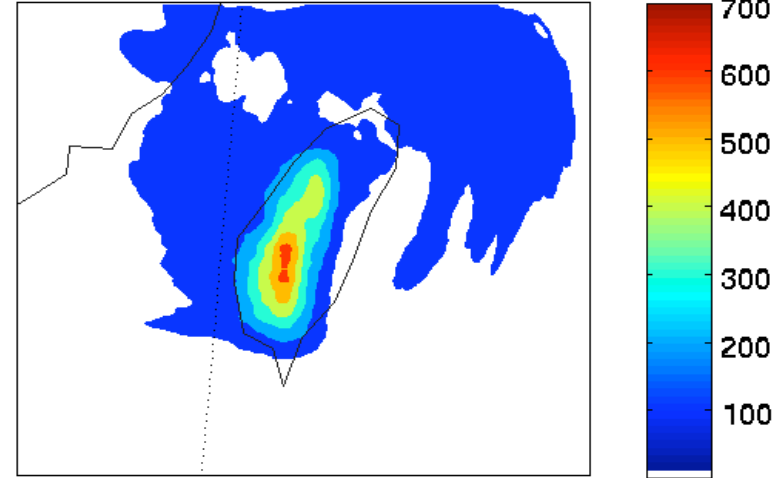


48h Rain forecast (August 8-9 00Z)

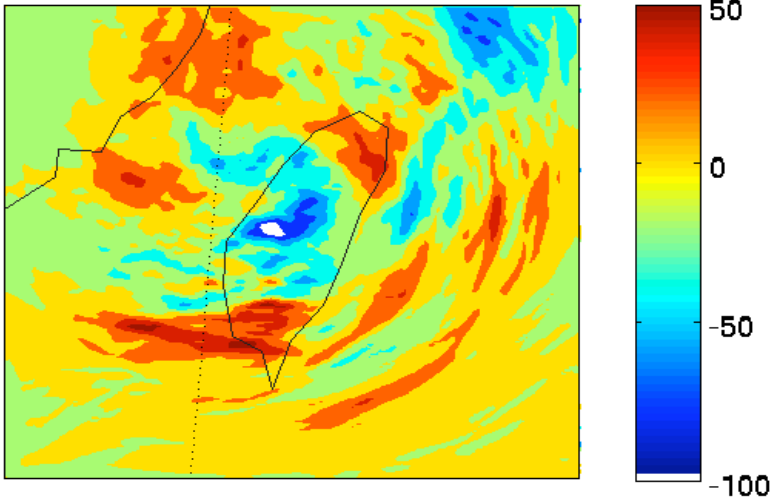
48h Prep forecast, ctl, Aug 8-9



48h Prep forecast, gps, Aug 8-9

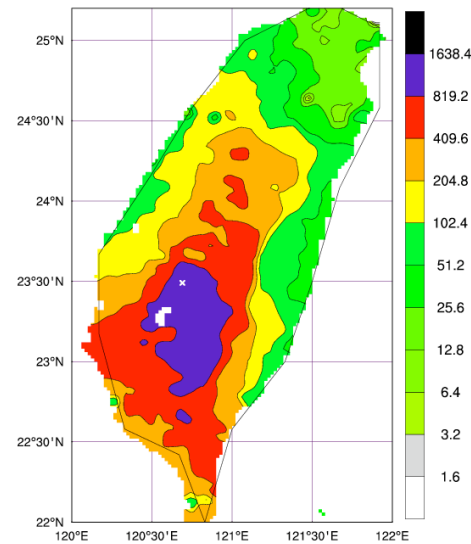


48h Prep forecast, gps - ctl, Aug 8-9

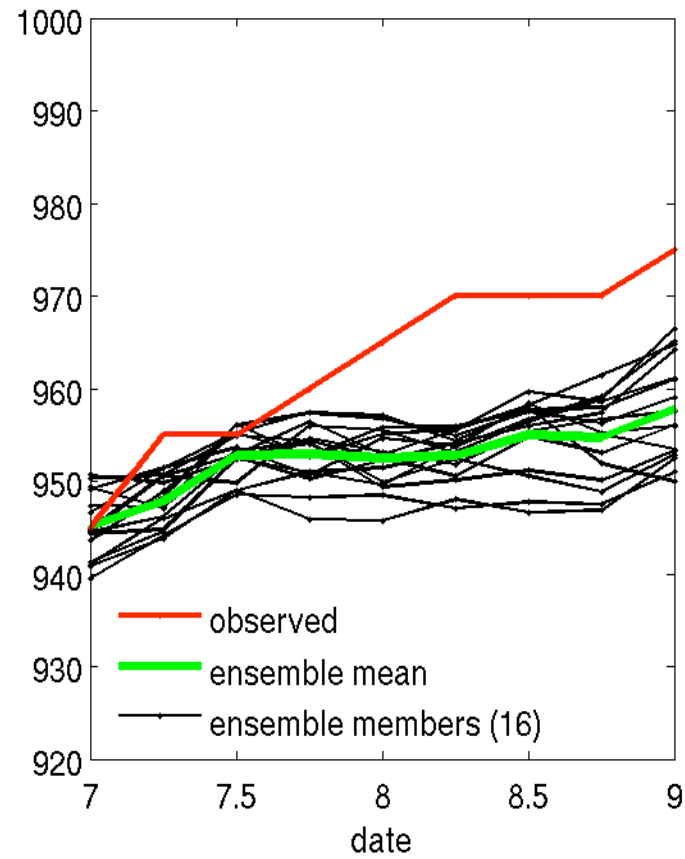
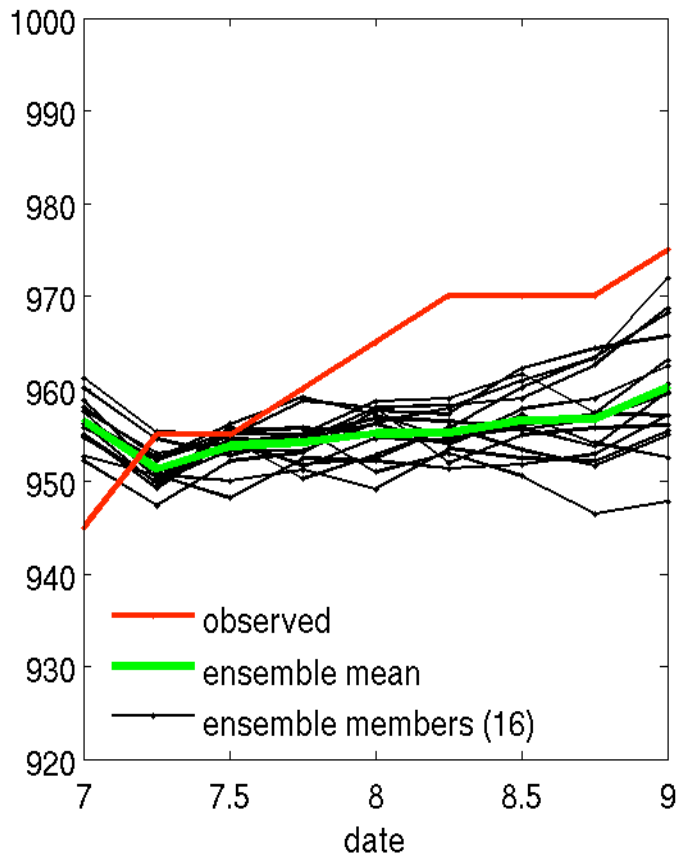


Obs pre on obs grid

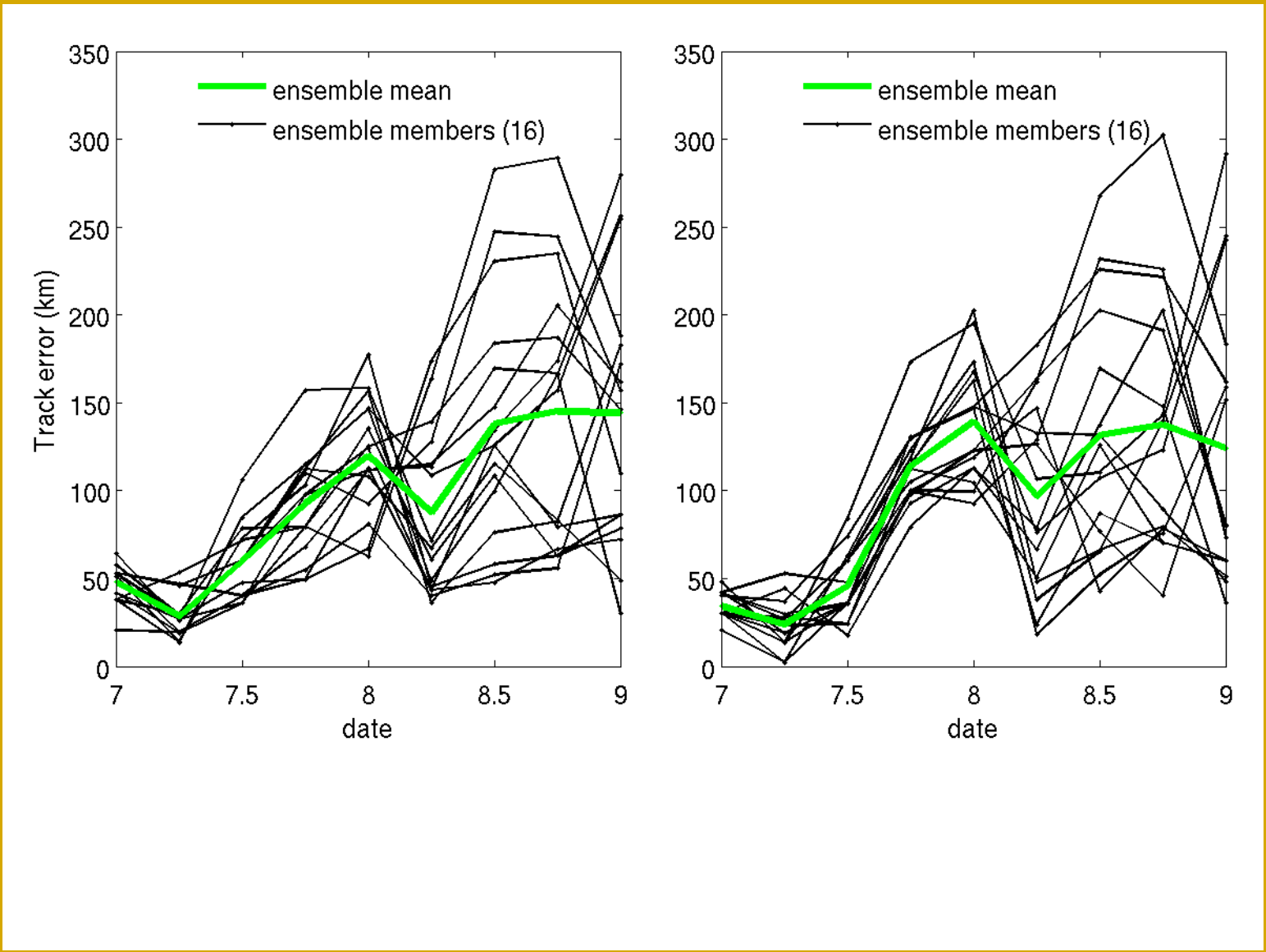
Obs pre from 0800UTC to 0900UTC max1700 mm



48h SLP intensity forecasts (August 7 - 9 00Z)

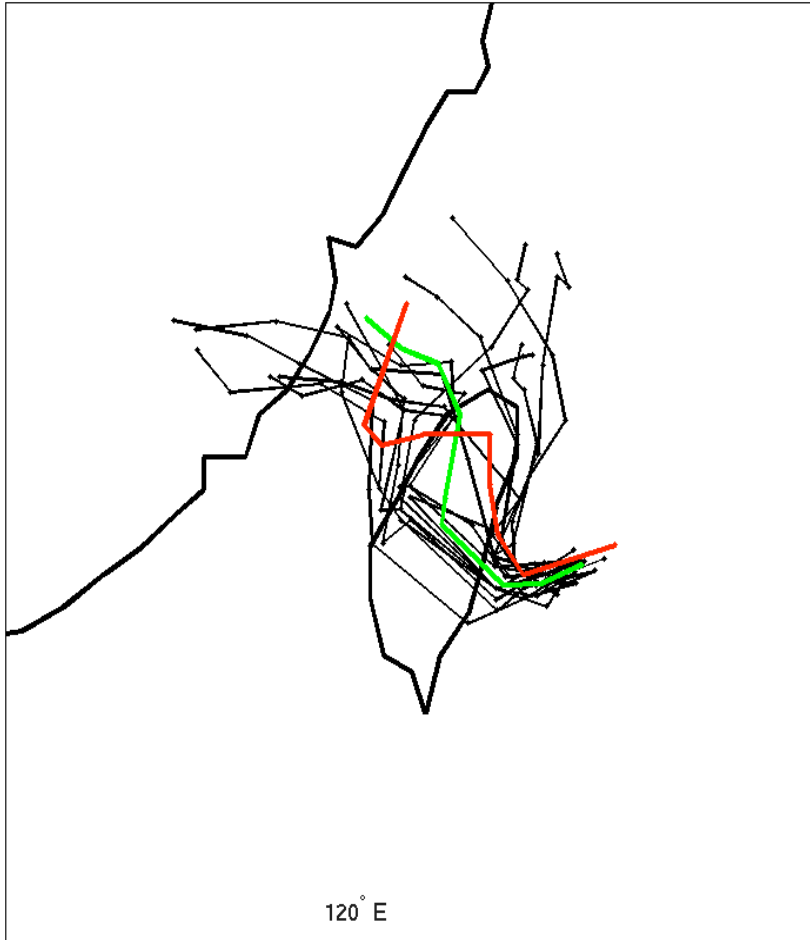


Track errors of 48h forecasts (August 7 - 9 00Z)



Track errors of 48h forecasts (August 7 - 9 00Z)

Ensemble forecasts from 00UTC 7 August, CTL



Ensemble forecasts from 00UTC 7 August, GPS



Impact of RO Data on track and intensity analyses of Hurricane Ernesto (2006)

Hui Liu

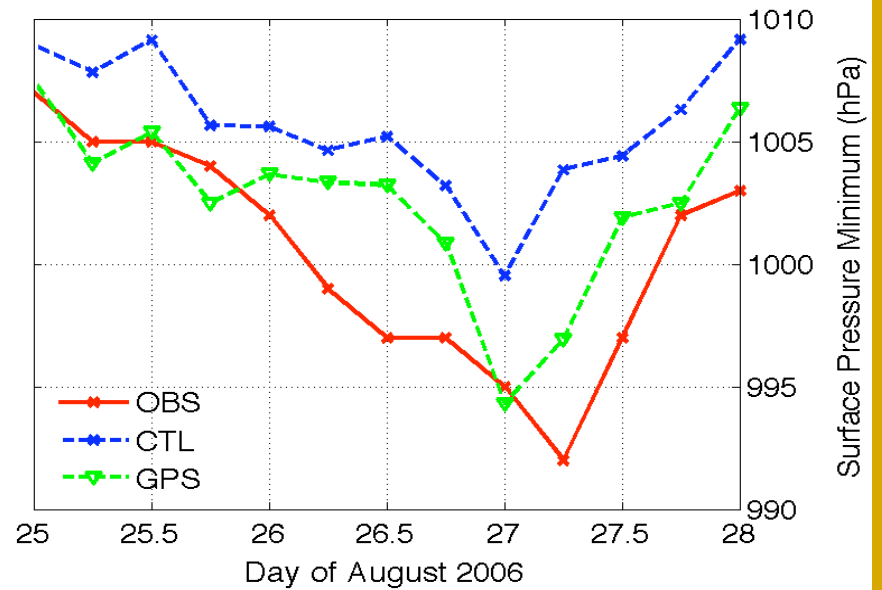
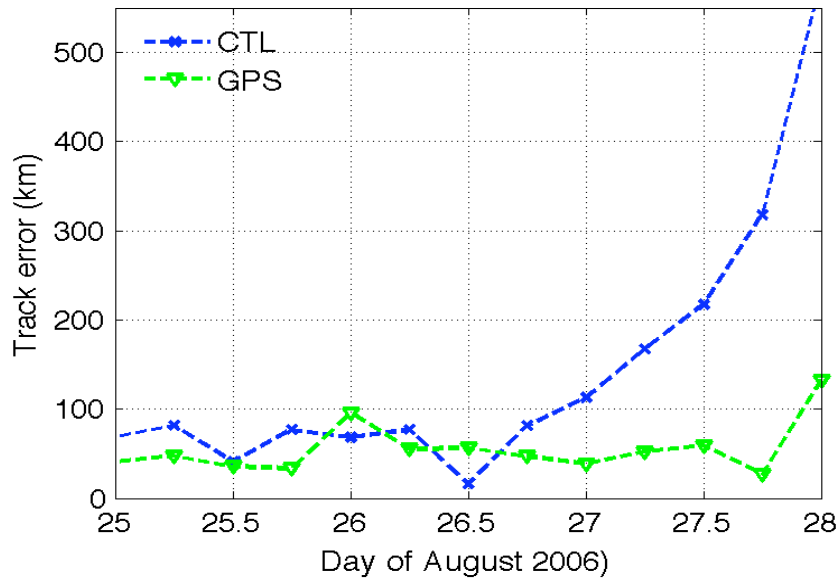
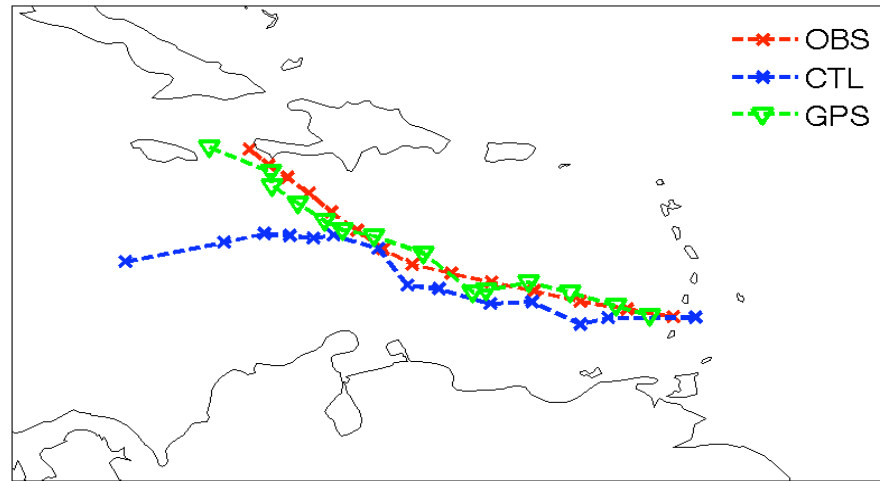


Assimilation experiments

- WRF/DART, 32 ensembles, 36km resolution
- Radiosondes, cloud winds, aircraft data, surface pressure data, RO refractivity soundings
- Cycling every 2-hours 21-28 00UTC, August 2006.
- CTL run: radiosondes, aircraft data, cloud winds, surface pressure data,
- GPS: same ad CTL run + GPS RO refractivity

Impact of RO data on Track and MSLP Analyses

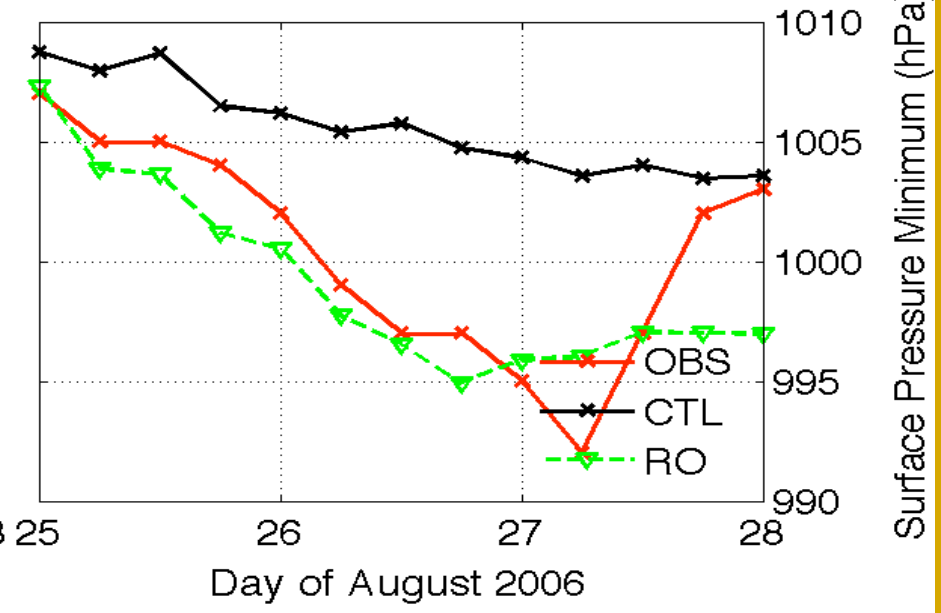
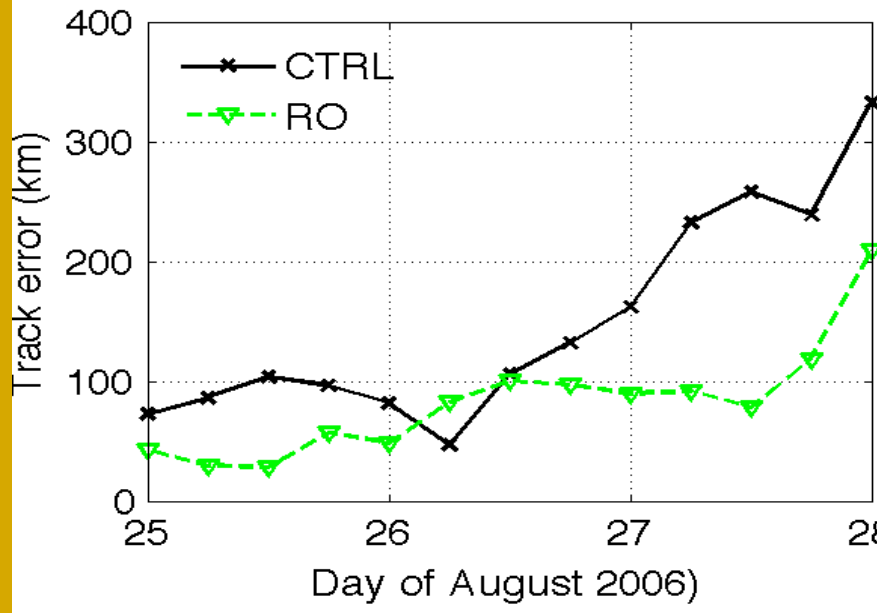
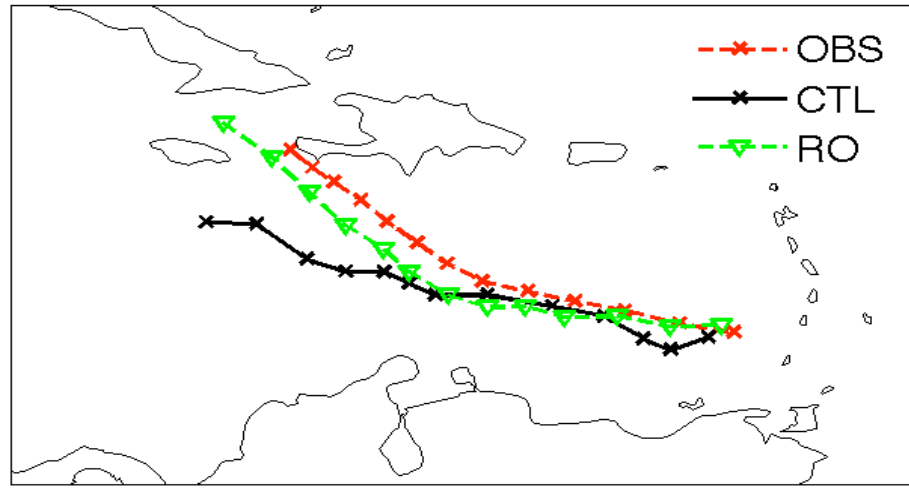
(00UTC 25-28, August 2006)



Impact on Track and MSLP 3-day Forecast

(from 00UTC 25, August 2006)

72-hour forecast (ensemble mean) from 00Z 25 August 2006)



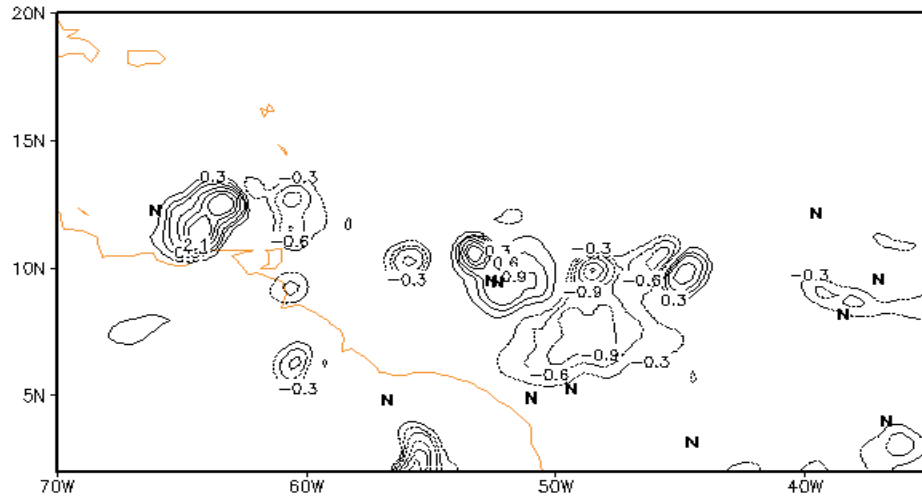
Assimilation experiments (2)

- NODA: assimilation of NO data, pure forecasts
- GPS only: assimilation of GPS refractivity only

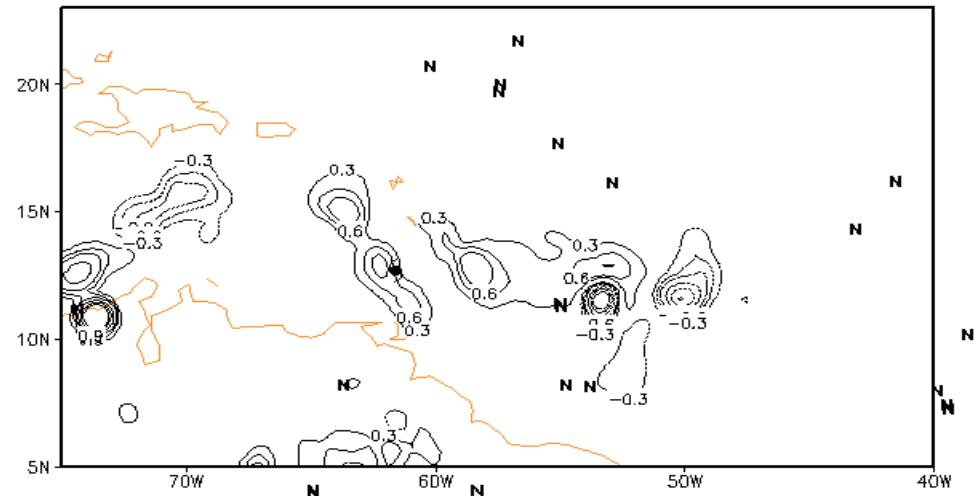
Daily Sum of Analysis Increments of Qvapor

(700 hPa, 23, 24, 26 and 27, August 2006, g/kg)

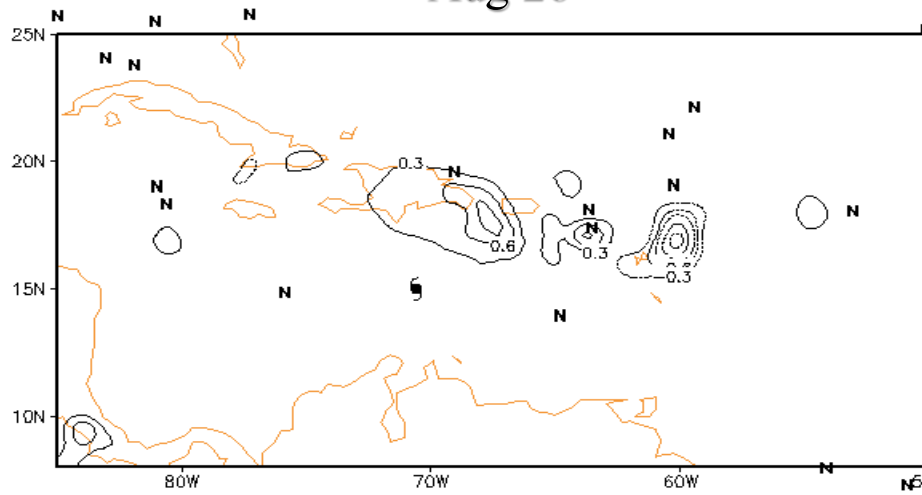
Aug 24



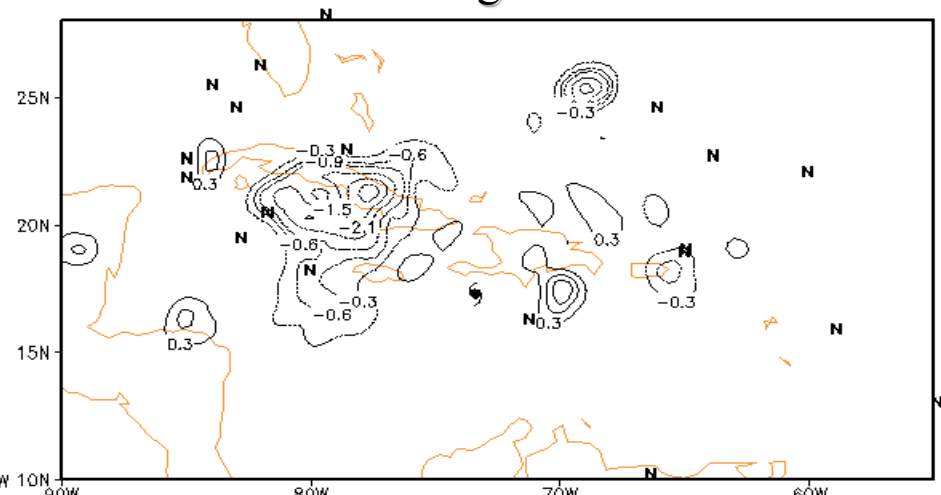
Aug 25



Aug 26

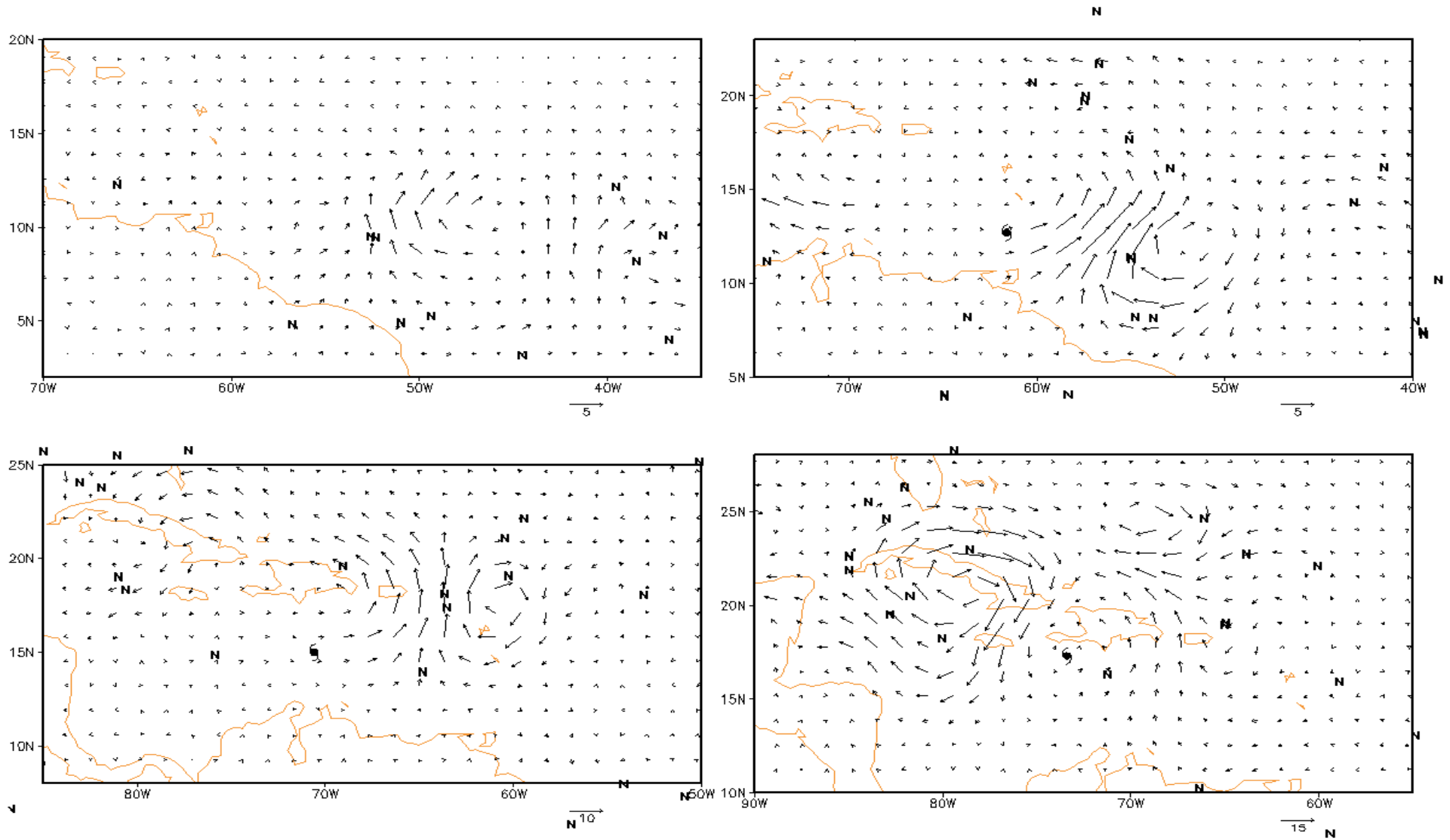


Aug 27



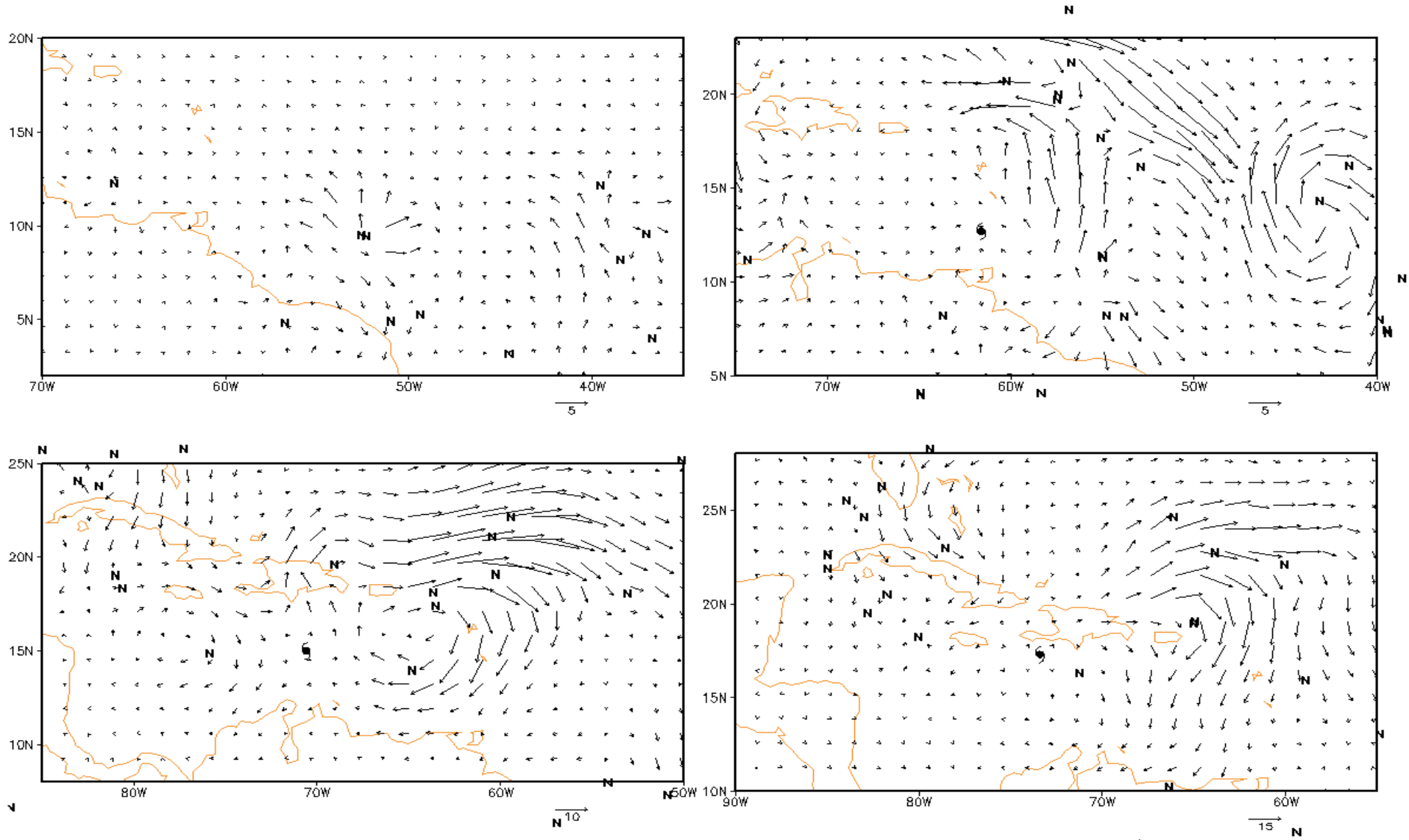
Daily Sum of Analysis Increments of Wind (m/s)

(700 hPa, 23-24, 26-27, August 2006)



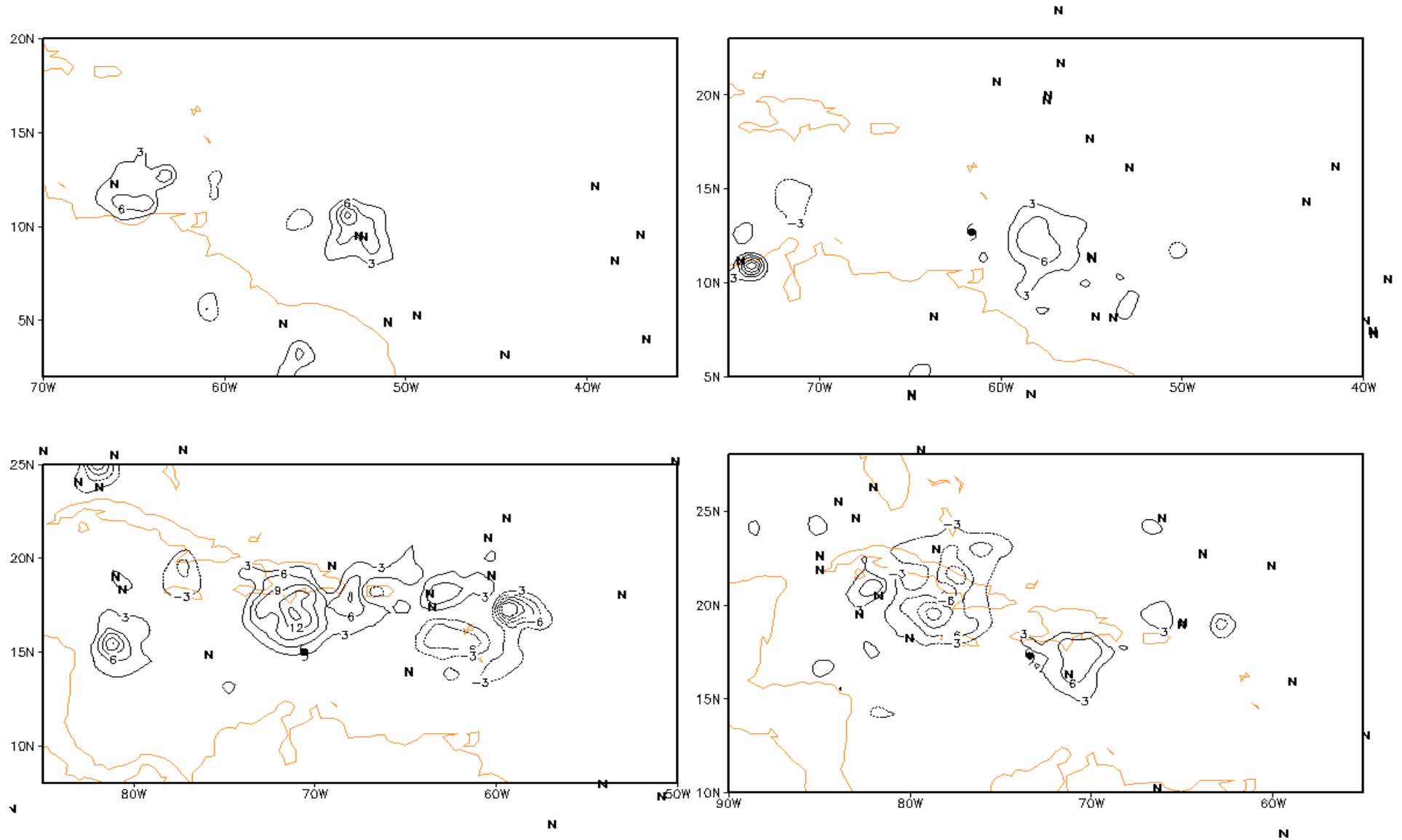
Daily Sum of Analysis Increments of Wind (m/s)

(250 hPa, 23, 24, 26 and 27, August 2006)



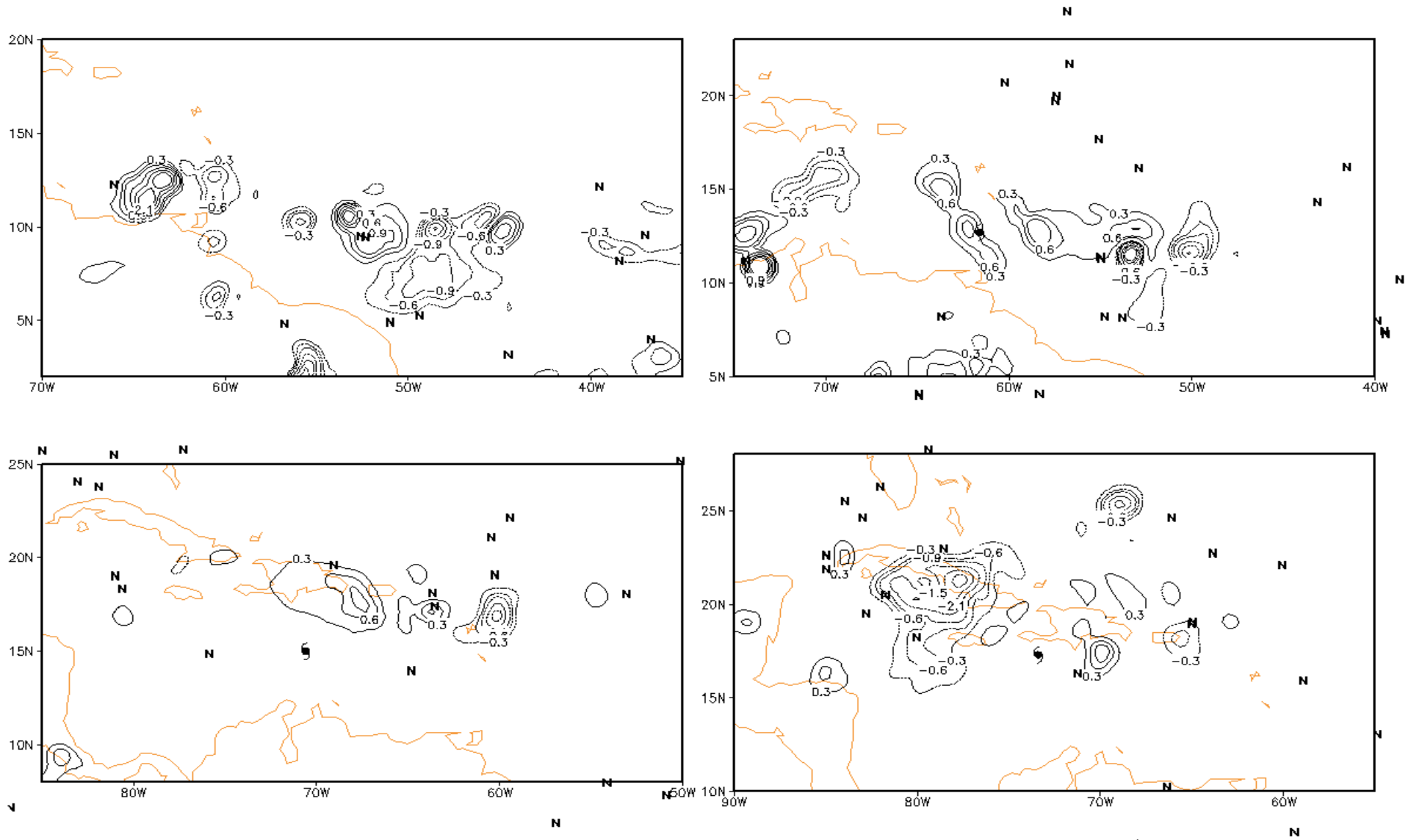
Daily Sum of Analysis Increments of Vertical wind

(500 hPa, 23, 24, 26 and 27, August 2006, cm/s)



Daily Sum of Analysis Increments of Rain water

(500 hPa, 23, 24, 26 and 27, August 2006, 0.1g/kg)



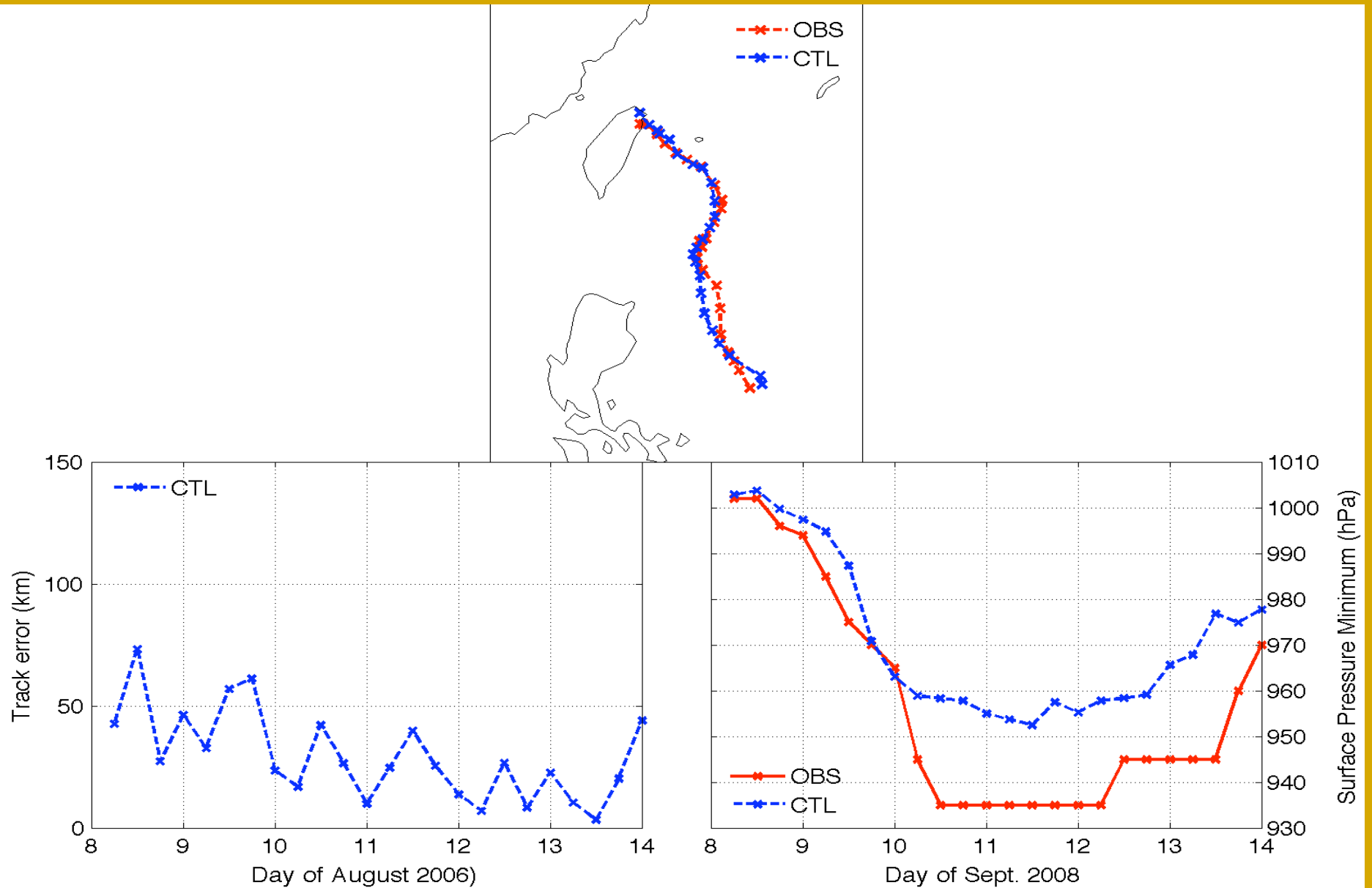
Recent Developments of WRF/DART (2)

- A high resolution (700kmx700km) moving nest with feedback is added to the 6-hour forecasts. This results better TC intensity analyses at out domain (MSLP is ~10 – 15 mb deeper) at low cost.
- A test with 27km/9km nested domains to study impact of satellite data's impact on TC intensity forecast. Analyses of intensity of TC Sinlaku and Hurricane Ike (2008) look encouraging.

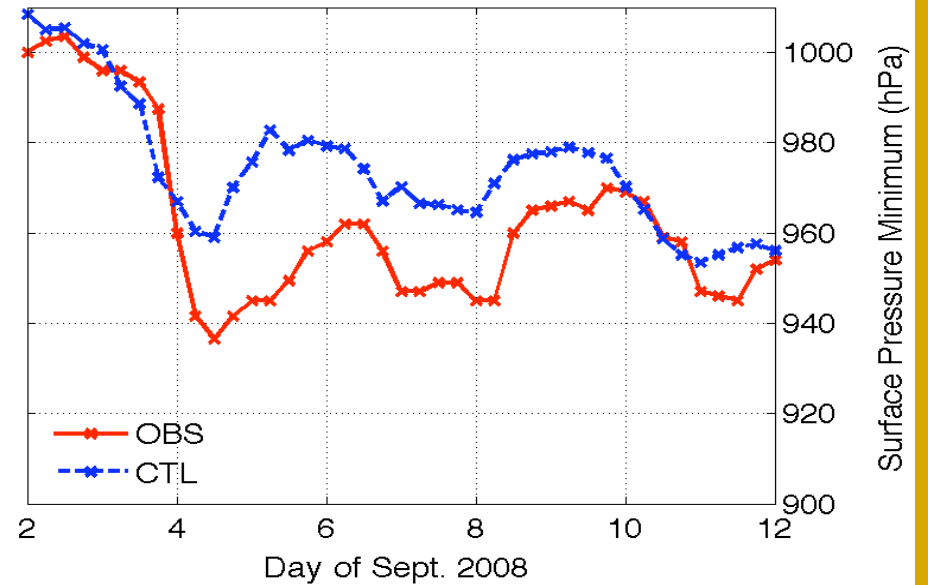
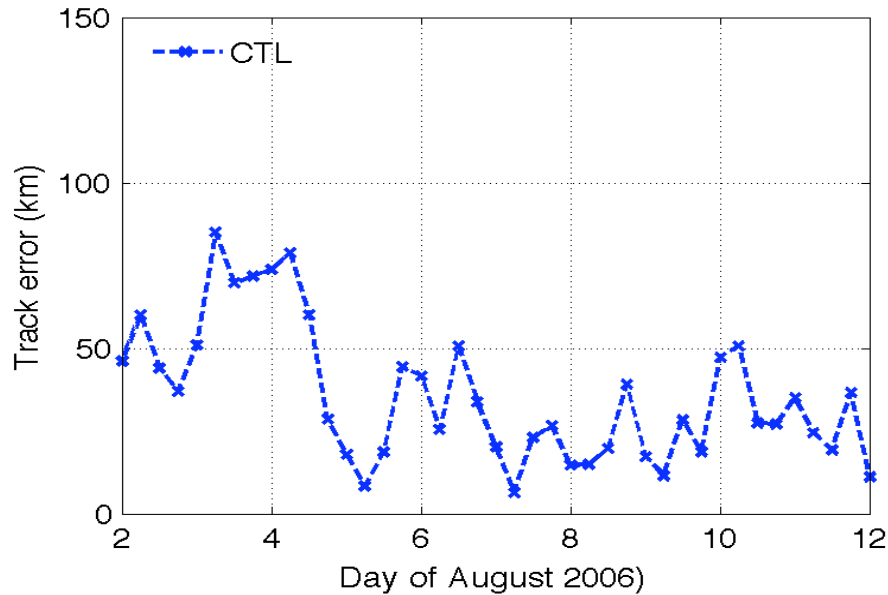
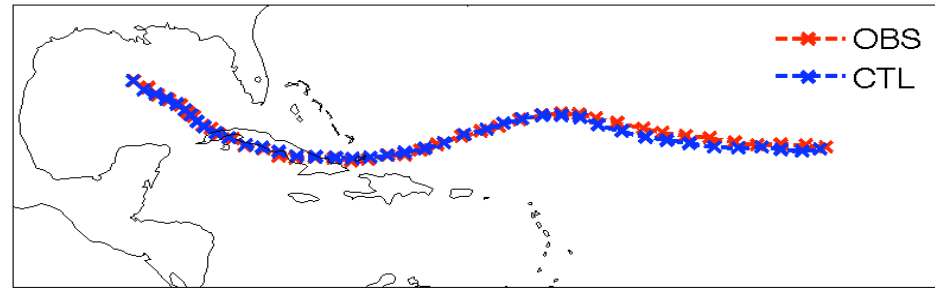
Assimilation tests of TC intensity at 27km/9km

- Radiosondes, cloud winds from CIMSS, aircraft data, GPS refractivity, vortex position data, 32 members.
- BOGUS data not assimilated yet.
- Start 7 days before TCs' genesis
- 9km moving nest with feedback to 27km grid in the 6-hourly forecast when TC present
- Analyses on 27km grid

Analyses at 27km grid for Sinlaku (8-14, Sept 2009)



Analyses at 27km grid for Hurricane Ike (2-12, Sept 2009)



Recent Developments of WRF/DART (3)

- WRF/DART hurricane analyses and forecasts for Atlantic Basin are also being tested in real-time at NCAR (36km/12km) last year and this year. The real-time products are available during hurricane season from the web:
- http://www.wrf-model.org/plots/realtime_main.php
- **Conclusion: WRF/DART has entered a new stage for operational testing and possible applications**

Next Potential Developments (at NCAR)

- Reducing analyses noise (DFI?)
- Further wrf/dart developments (e.g., allowing vertical localization vary with observation types)
- Additional observations
(QuikScat, Tsfc, higher frequency and resolution satellite winds and AIRS Q/T soundings,)
- Choosing one deterministical forecast (mean or one member)