Impact of Assimilating GPS RO refractivity on Tropical Cyclone Position and Intensity Analyses and Forecasts

Liu Hui, Bill Kuo, and Jeff Anderson

NCAR

Acknowledgements: Chris Snyder/NCAR, Ryan Torn/SUNY

Outline

- Brief overview of GPS RO soundings
- Hurricane Ernesto (2006):

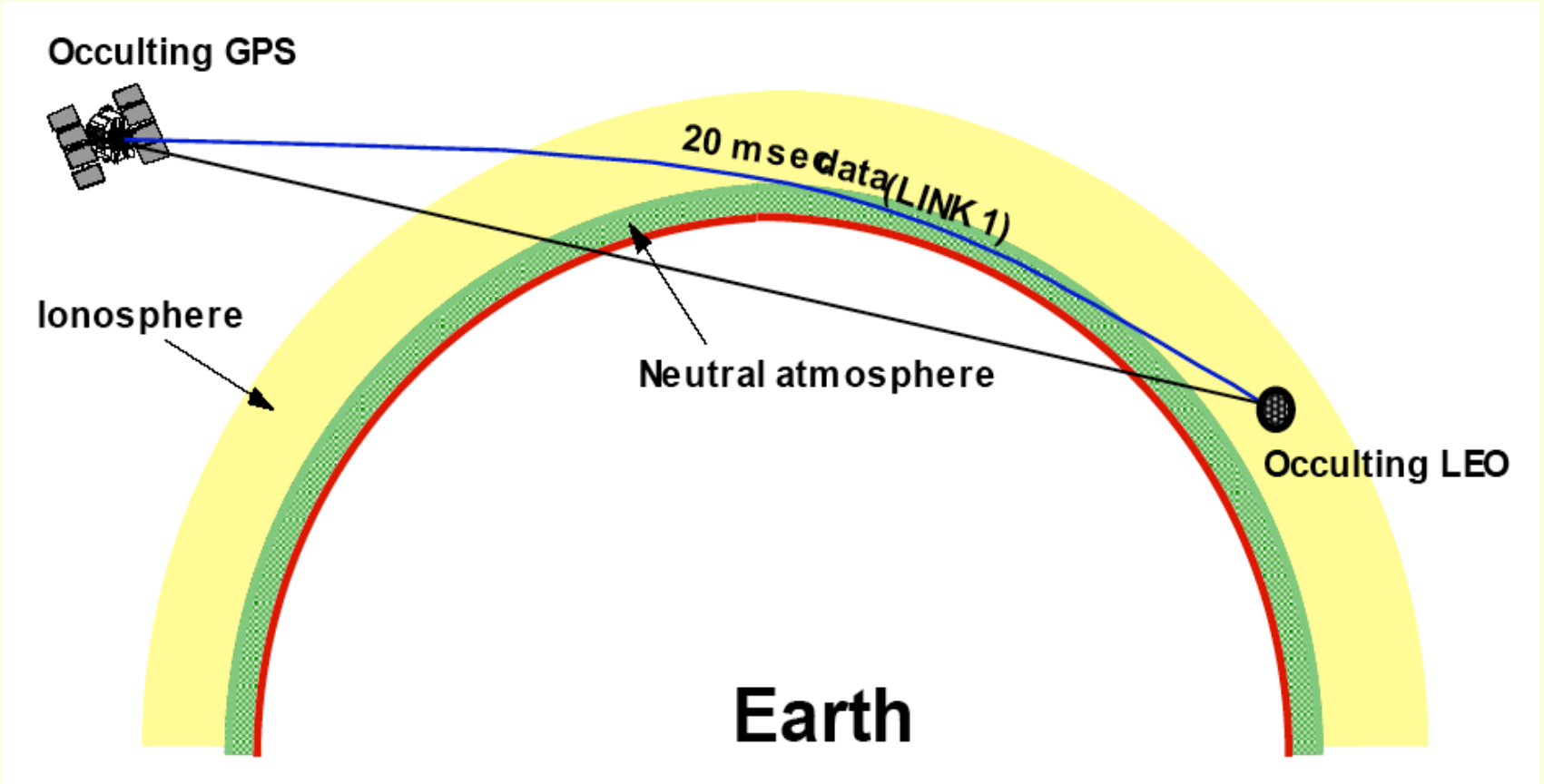
  Explore how RO refractivity impacts analyses of Q, T, and wind with EnKF and if EnKF can make meaningful multivariate covariance estimate in convective environment of tropics
- All typhoons of 2008:

  Examine impact of RO data on forecasts of the typhoons
- Summary

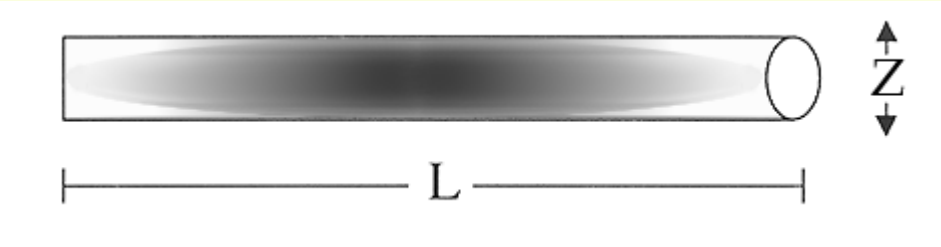
GPS Radio Occultation (GPS RO)

Basic measurement principle:

Deduce atmospheric refractivity properties based on measurement of radio wave phase/time delay and amplitude.

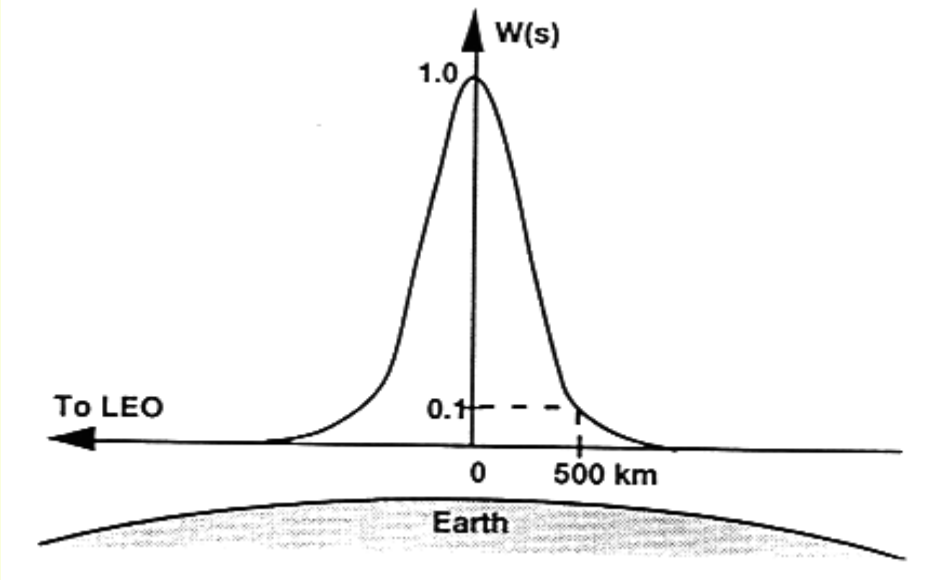


Observed Atmospheric Volume



L~300 km

Z~1 km



RO refractivity data:

1. High vertical and coarse horizontal resolution.

2. Refractivity can be retrieved from the signal's time delay.

3. Determined by water vapor and temperature in the troposphere.

Challenges to Assimilation of GPS RO for TC Forecasts

- GPS RO data available for clear and cloudy skies.
- Mainly water vapor information in the lower troposphere.
- Complicated RO refractivity forecast error variances and correlations with T and winds.
- Hard to describe the complicated covariance in a static covariance function.
- Ensemble forecasts provide an alternative way to estimate the full multivariate and flow-dependent error covariance.

Assimilation of RO Refractivity for TC Forecasts with Ensemble DA at NCAR

- Multiple TC cases studied:

  Hurricane Ernesto (2006)

  Typhoon Shanshan (2007)

  All typhoons of 2008: Nuri, Sinlaku, Hagupit, and Jangmi

  Typhoon Morakot (2009)

Results:

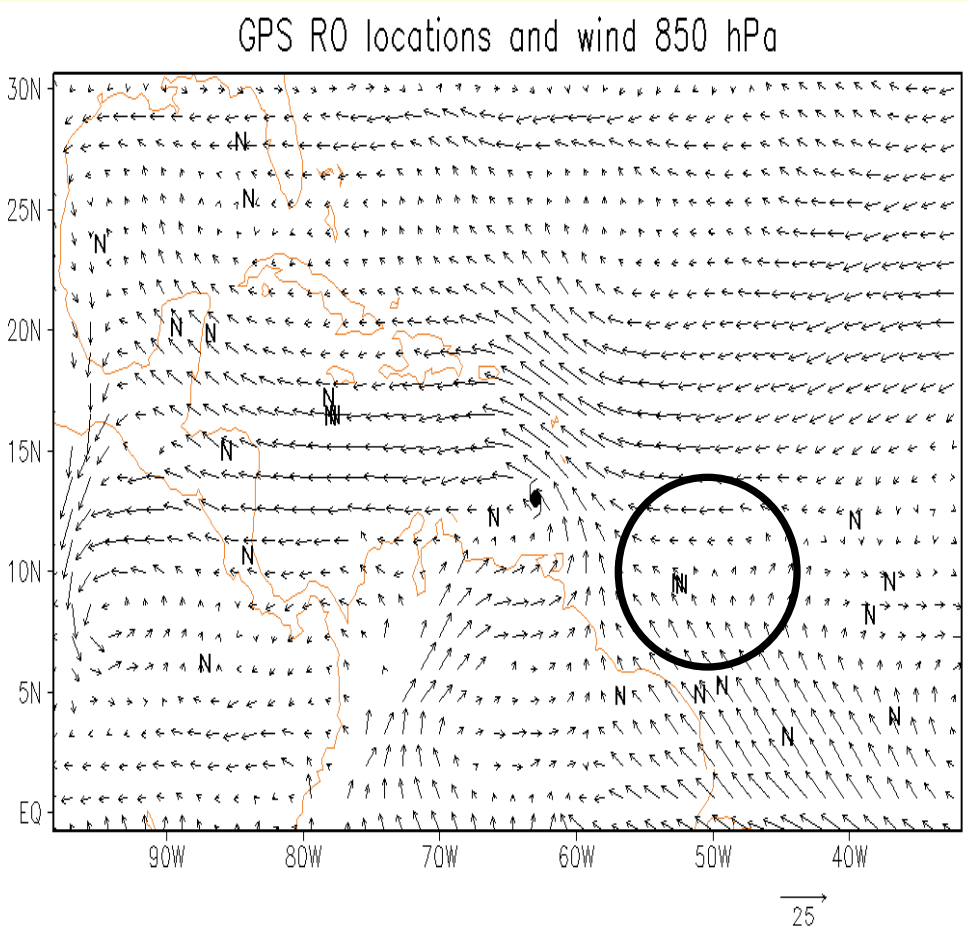
- Assimilation of RO refractivity in cycling mode produces meaningful corrections to large-scale environment water vapor and winds around TCs.
- RO data in the lower troposphere has positive impact.
- RO data reduces TC track and intensity forecast errors.

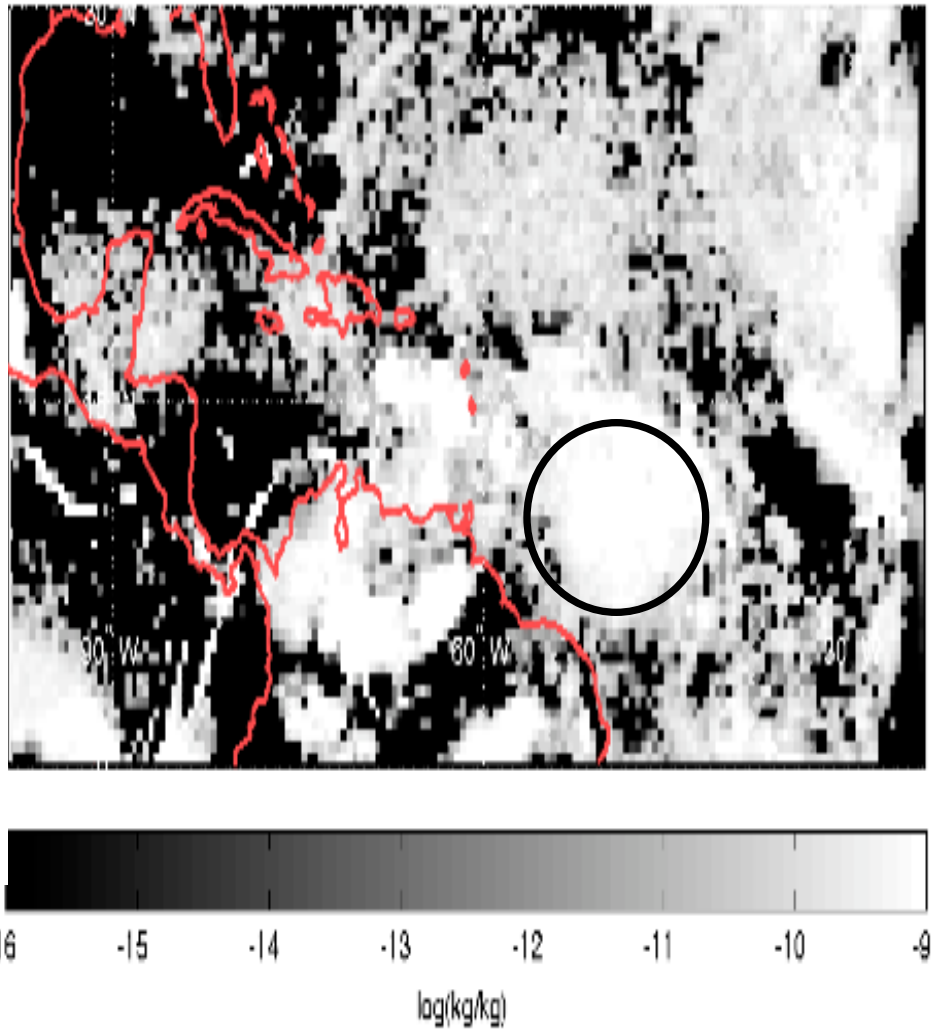
Analyses for Hurricane Ernesto (2006, August 25-30)

- Analysis 2-hourly, cycling August 21-26, 2006.
- GPSonly run: Assimilate ONLY RO refractivity data.
- GPSonly>6km run: Assimilate ONLY RO refractivity data higher than 6km.
- FCST run: Ensemble forecasts from NCEP FNL starting at 00Z August 21 with no additional assimilation.
- Radiosondes/dropsondes held to validate the analyses
- WRF-ARW/DART ensemble assimilation system.
- 32 ensembles, 36km grid over Atlantic, 35 levels.
- Initial and boundary conditions from NCEP FNL global analyses; ensemble is created by WRF/3DVAR covariance.

Analysis of 850 hPa Wind and Total Column Cloud Water

(06Z August 23, 36 hours before Ernesto's genesis, GPSonly run)

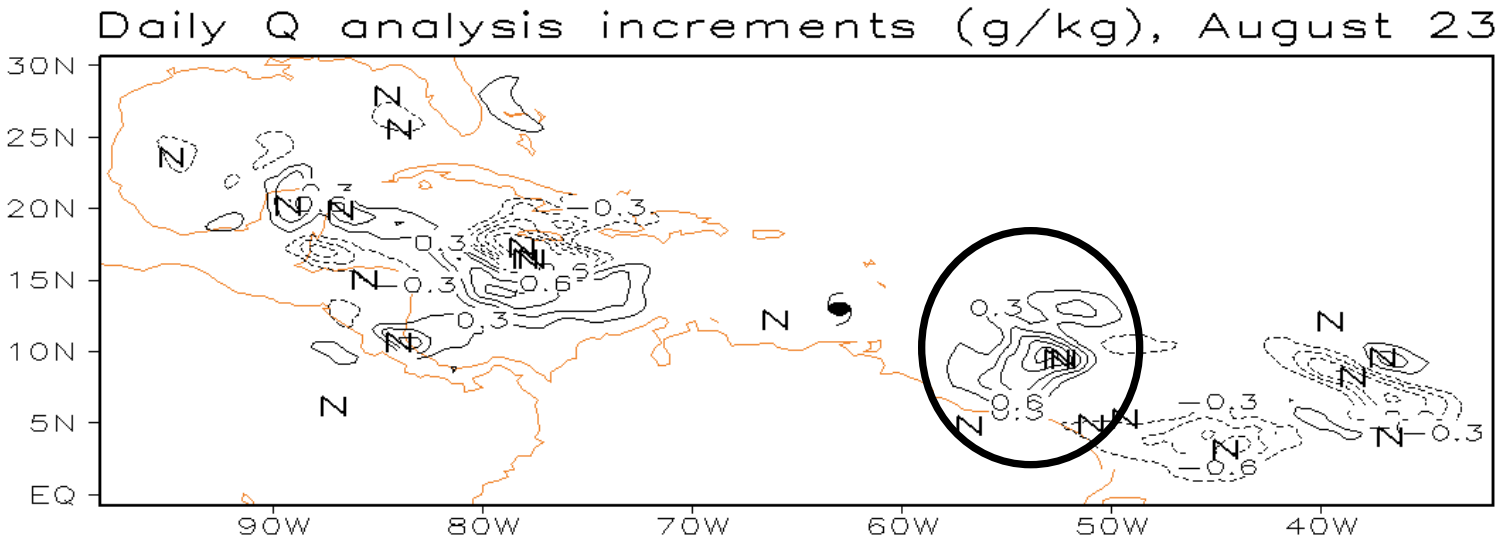


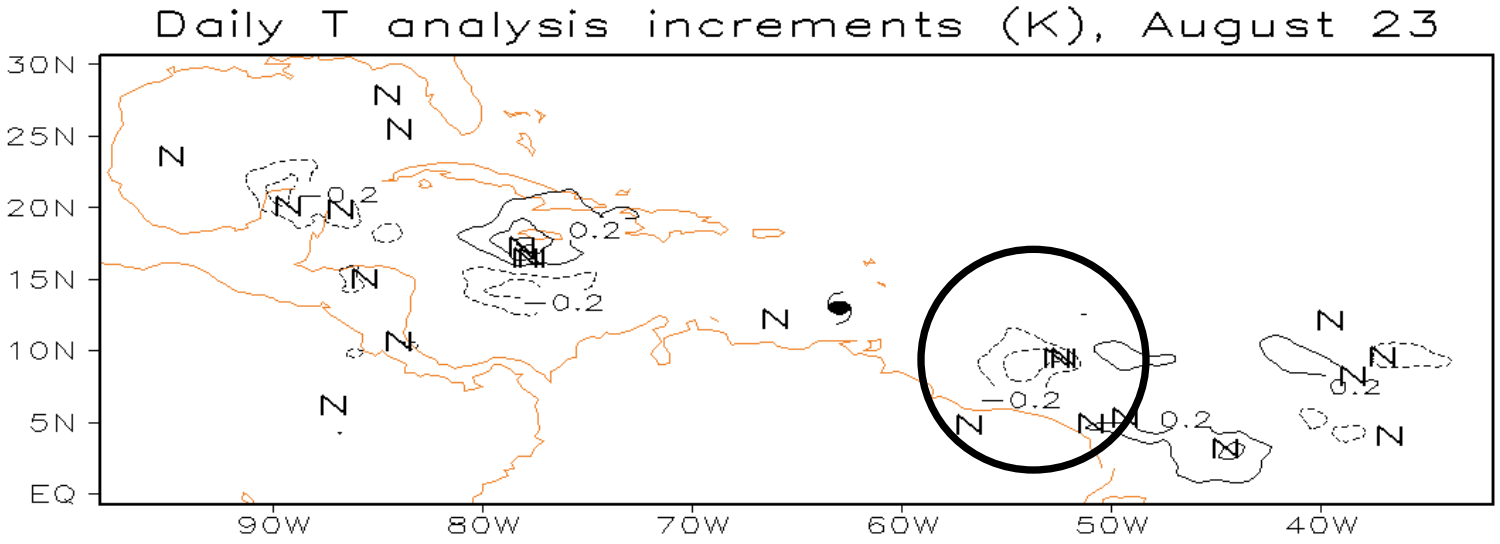


Convergence and convection in Ernesto's genesis area.

Daily Analysis Increments of Q and T (GPSonly run)

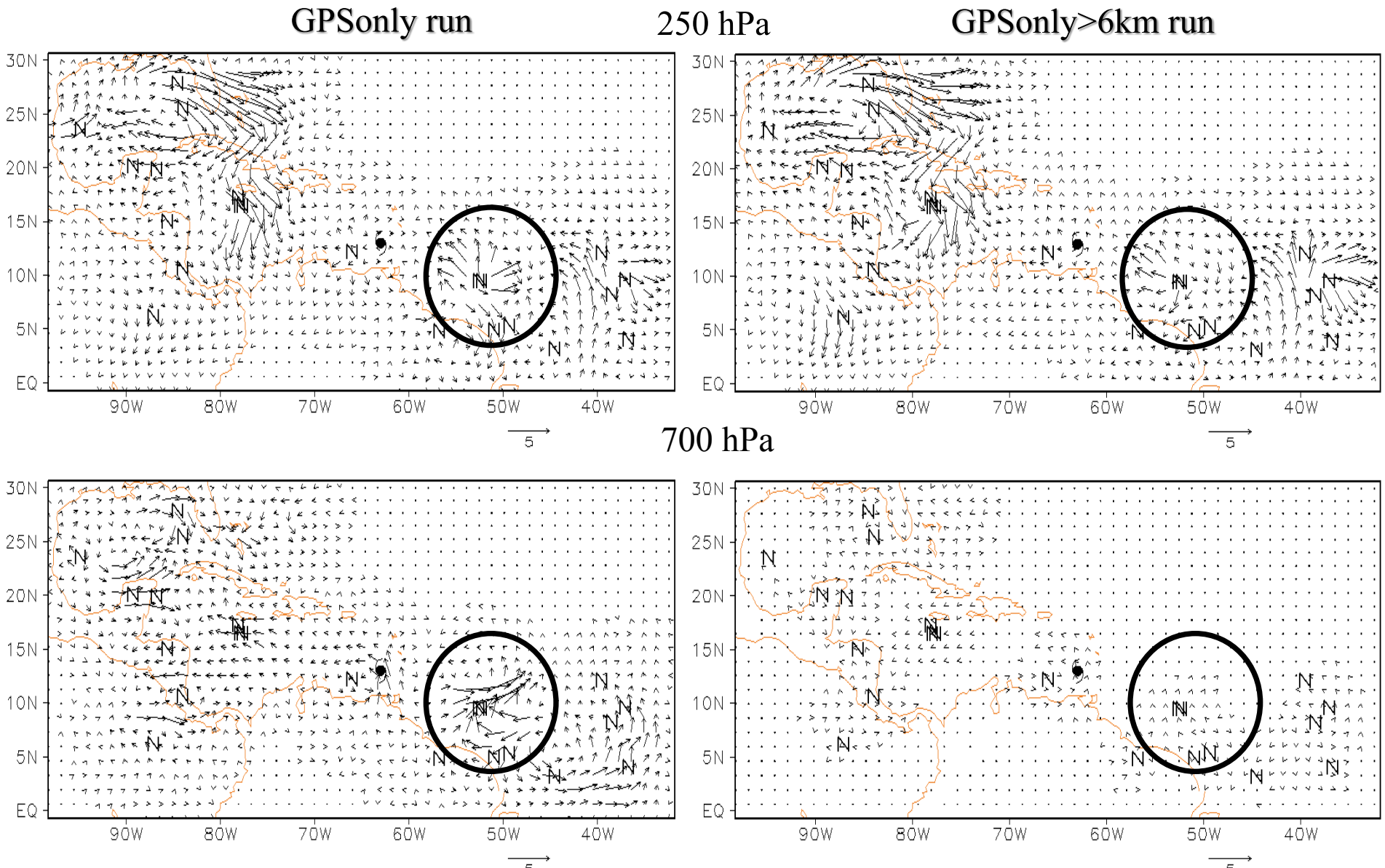
(850 hPa, August 23, 2 days before Ernesto's genesis)





Daily Analysis Increments of Wind

(August 23, 2 days before Ernesto's genesis, m/s)



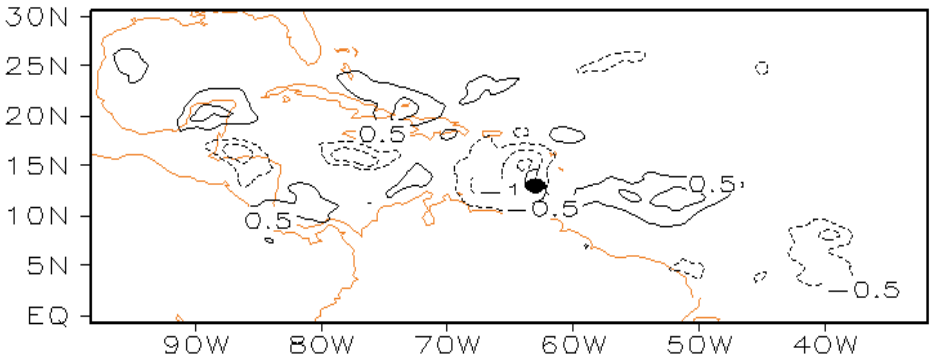
Strong correlation between GPS in the lower troposphere and winds at all levels.

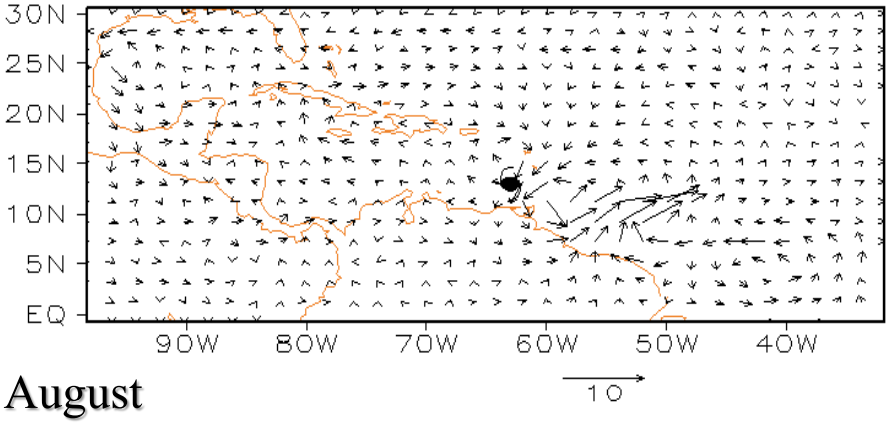
Forecast Difference of GPSonly-FCST (700 hPa)

Water vapor

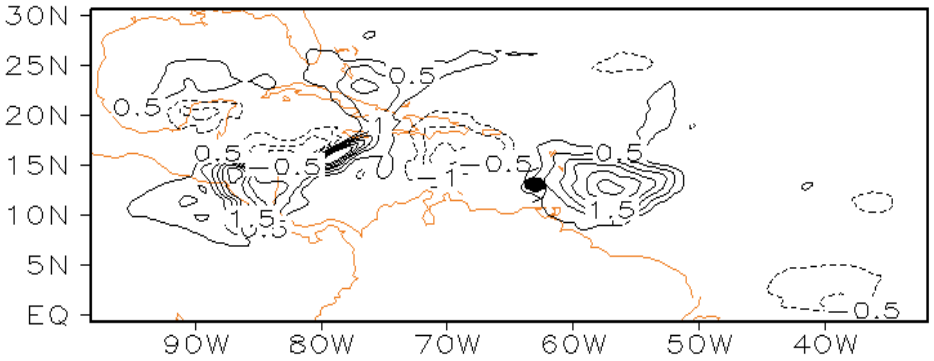
06Z 23 August

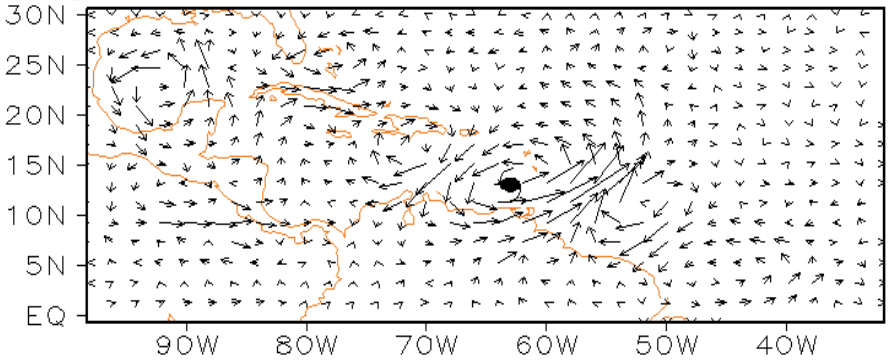
Wind



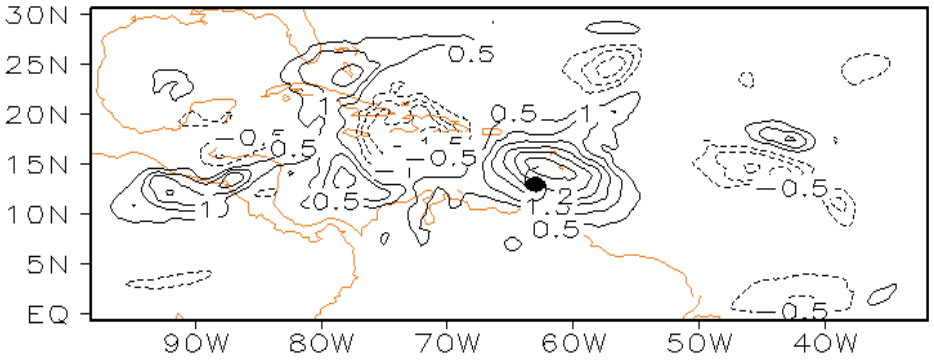


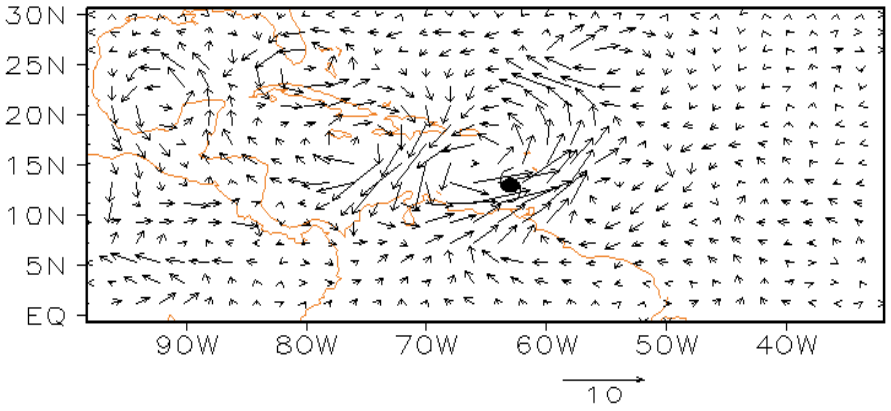
00Z 24 August





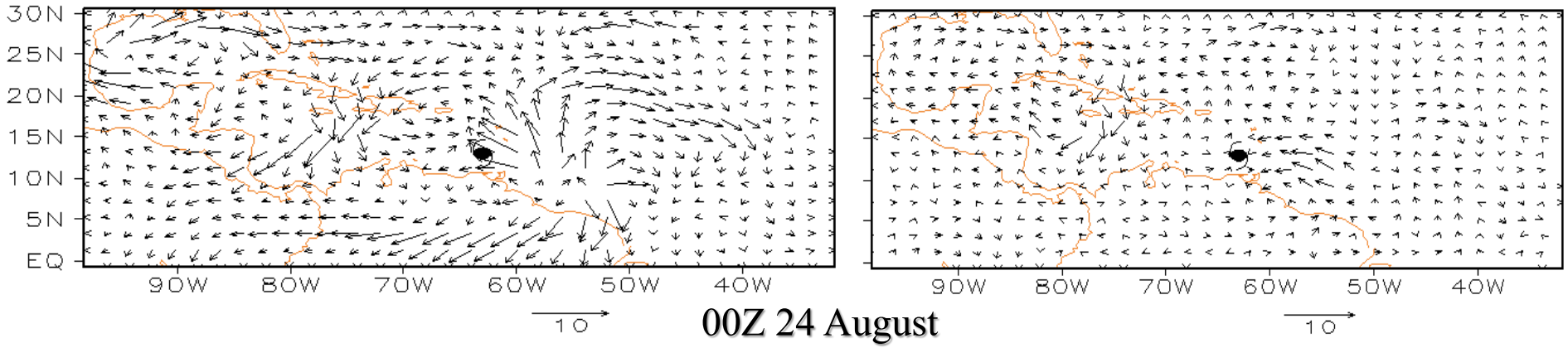
00Z 25 August Ernesto's genesis time



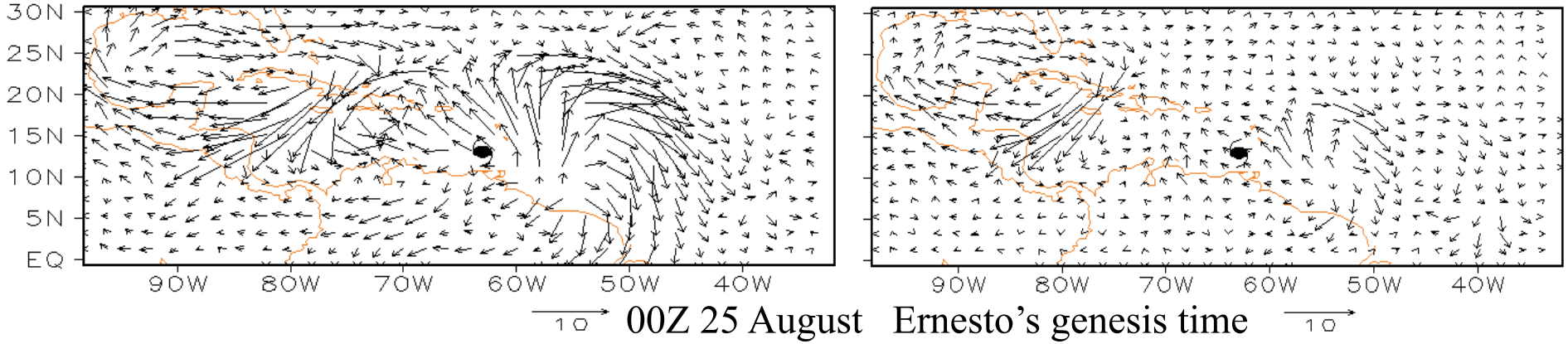


Wind Forecast Differences (250 hPa)

GPSonly-FCST 06Z 23 August GPSonly>6km-FCST



00Z 24 August



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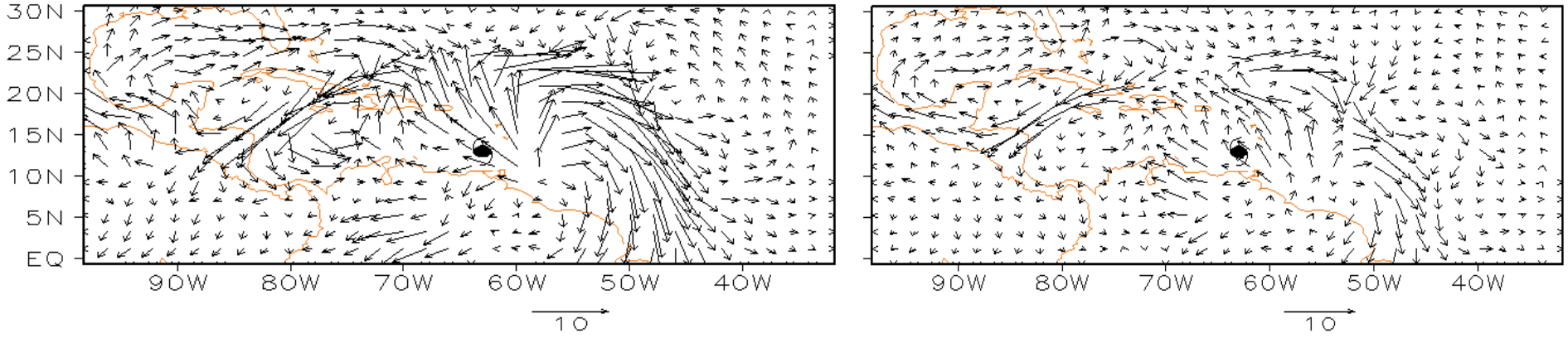
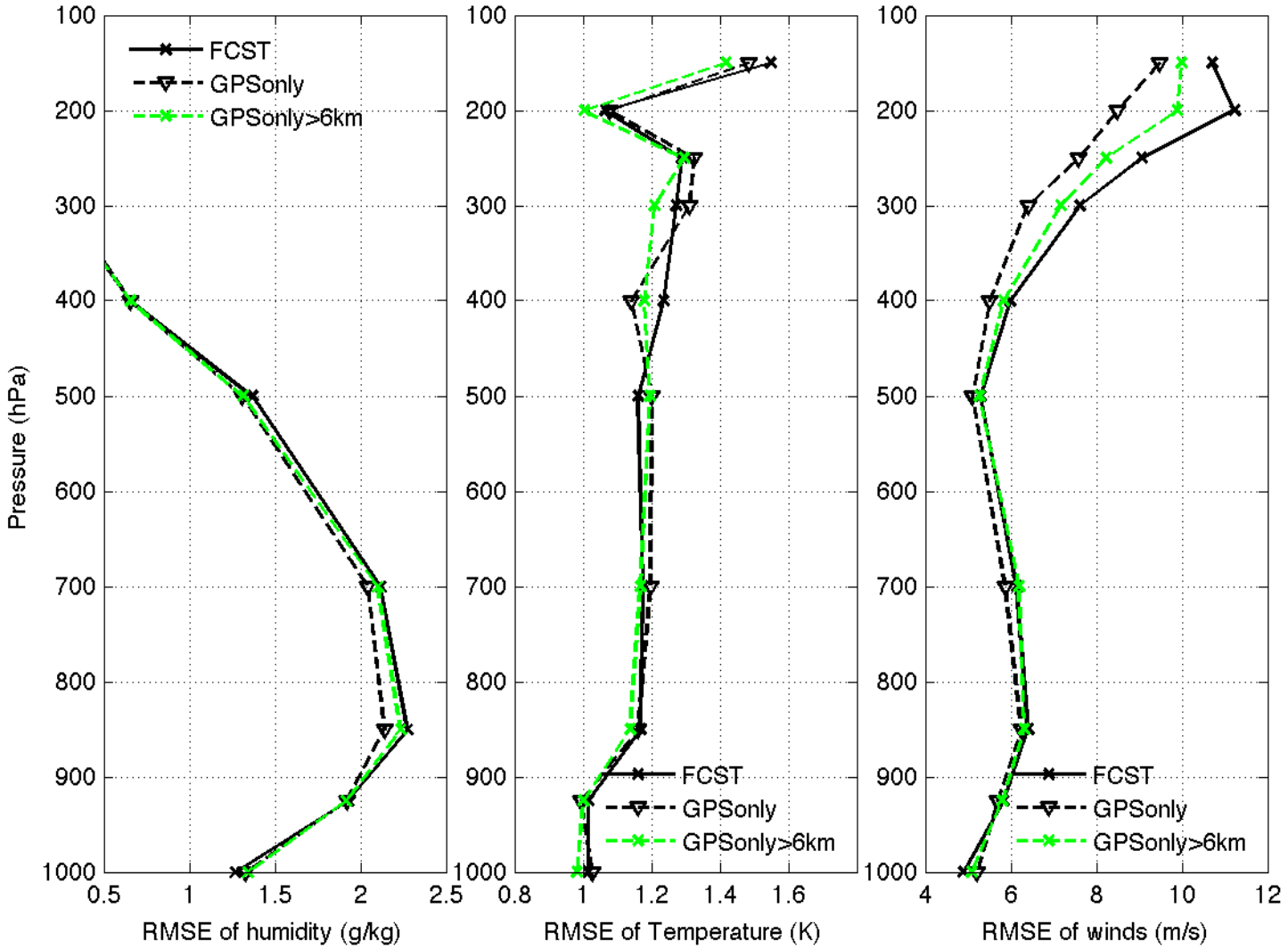
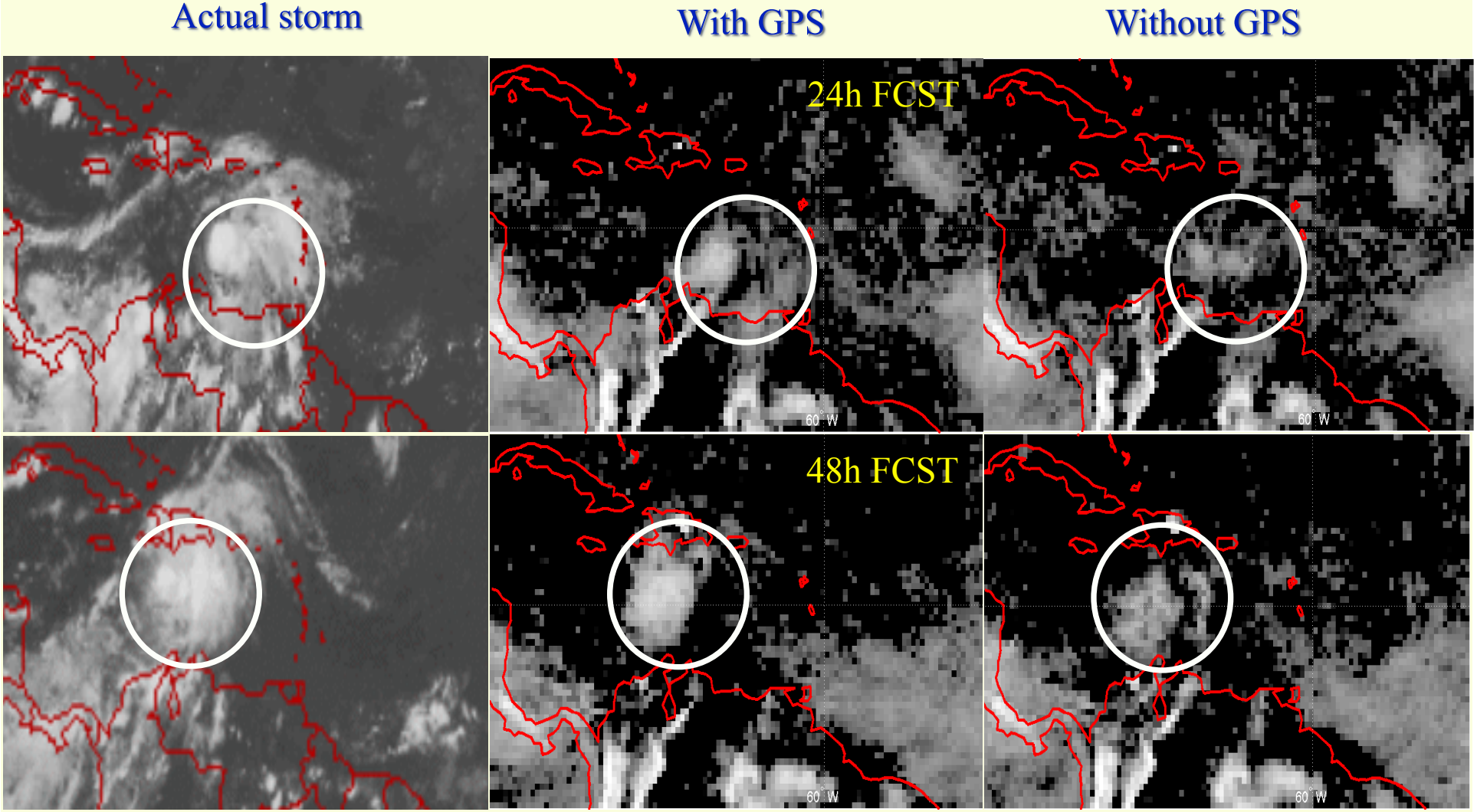


2-hour Forecast RMS fit to Radiosondes

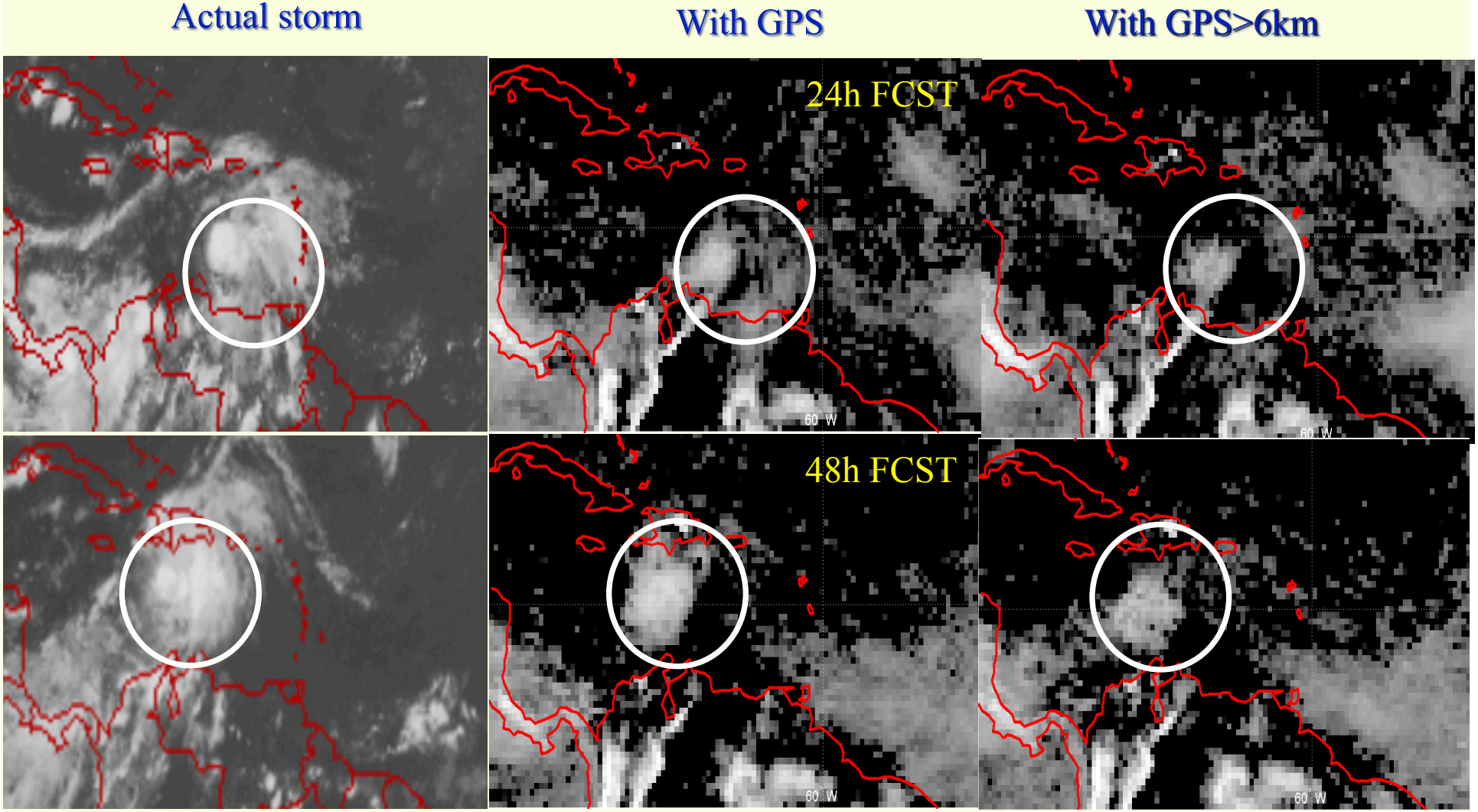
(Averaged over tropical Atlantic, 21-26 August, 2006)



48-hour Forecasts of Ernesto (2006) with Assimilation of GPS and Conventional Observations

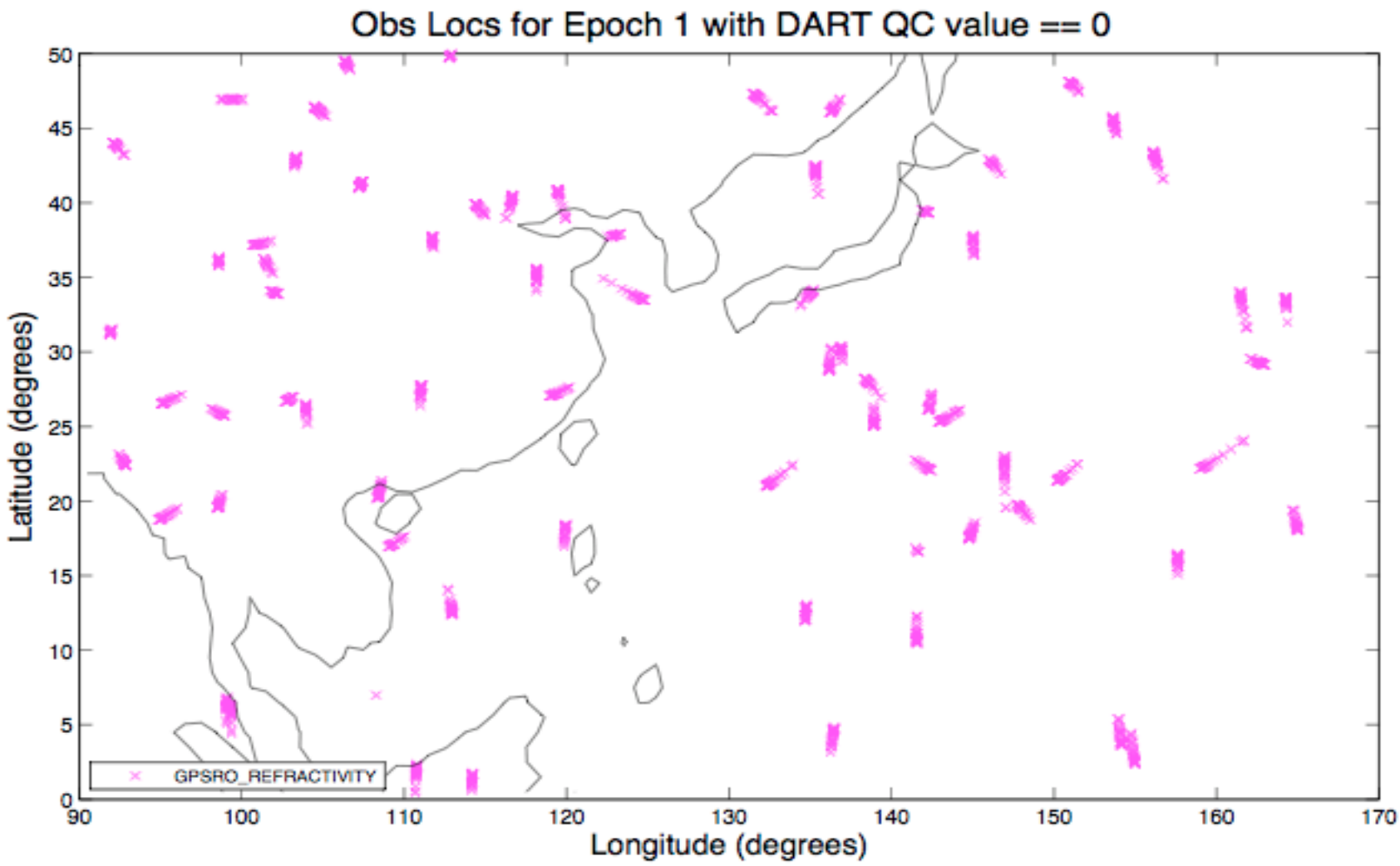


48-hour Forecasts of Ernesto (2006) with Assimilation of GPS and Conventional Observations



Assimilation of GPS > 6km shows less positive impact

Distribution of RO Data (September 8, 2008)



96 RO profiles, 50% penetrated into the lowest 1km layer

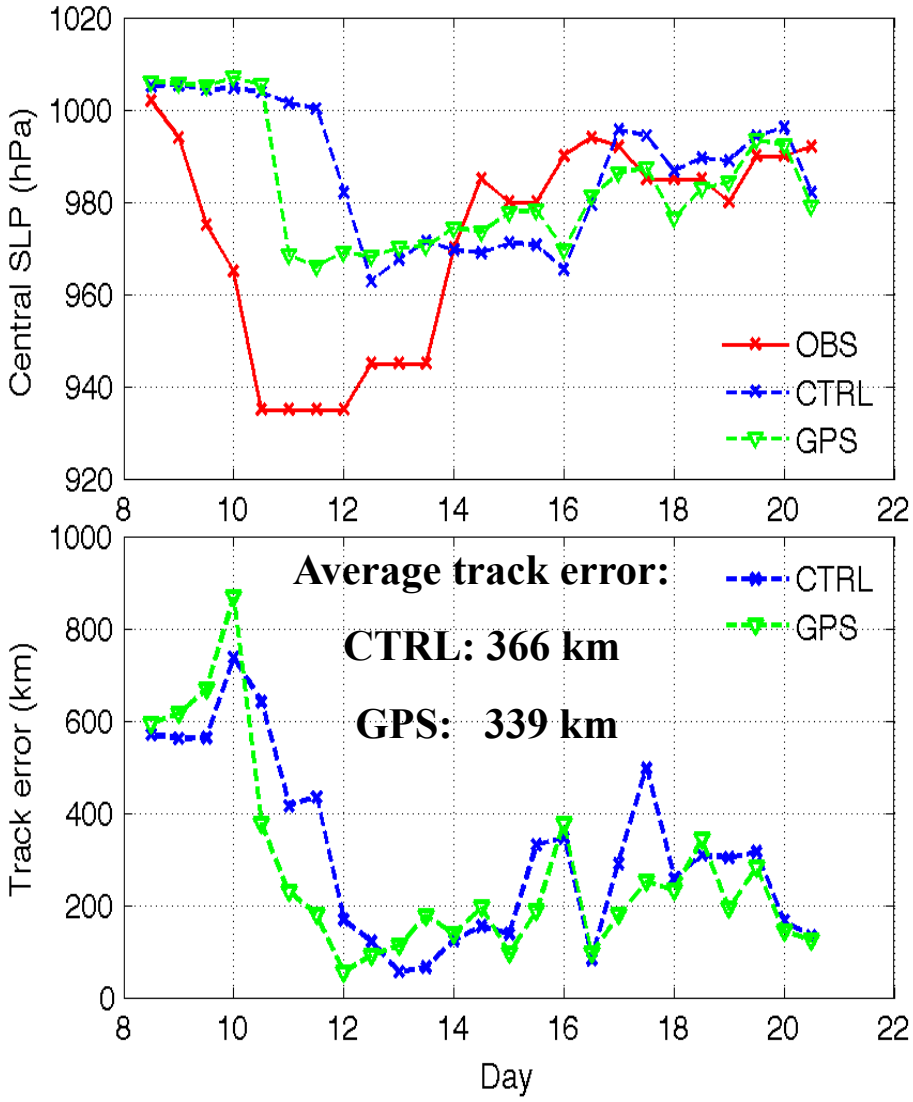
Assimilation Experiments for 2008 Typhoons

- Four major typhoons occurred in 2008 over W Pacific.
- Analyses cycling 11 August – 30 September 2008; 3-hourly.
- CTRL run: Assimilate conventional observations.
- GPS run: Assimilate conventional data + RO refractivity.
- Conventional observations from NCEP GFS: rawinsonde T, Q and wind, cloud winds, aircraft T and Q, surface pressure, TC center positions.
- NO TC bogus and radiance data used.
- WRF-ARW/DART ensemble assimilation system.
- 96 ensembles, 27km grid over W. Pacific (95E- 165E, 0-50N).
- Initial and boundary conditions from NCEP global analyses; initial ensemble created by WRF/3DVAR covariance.
- 48 hour ensemble mean forecasts from 00Z and 12Z daily.

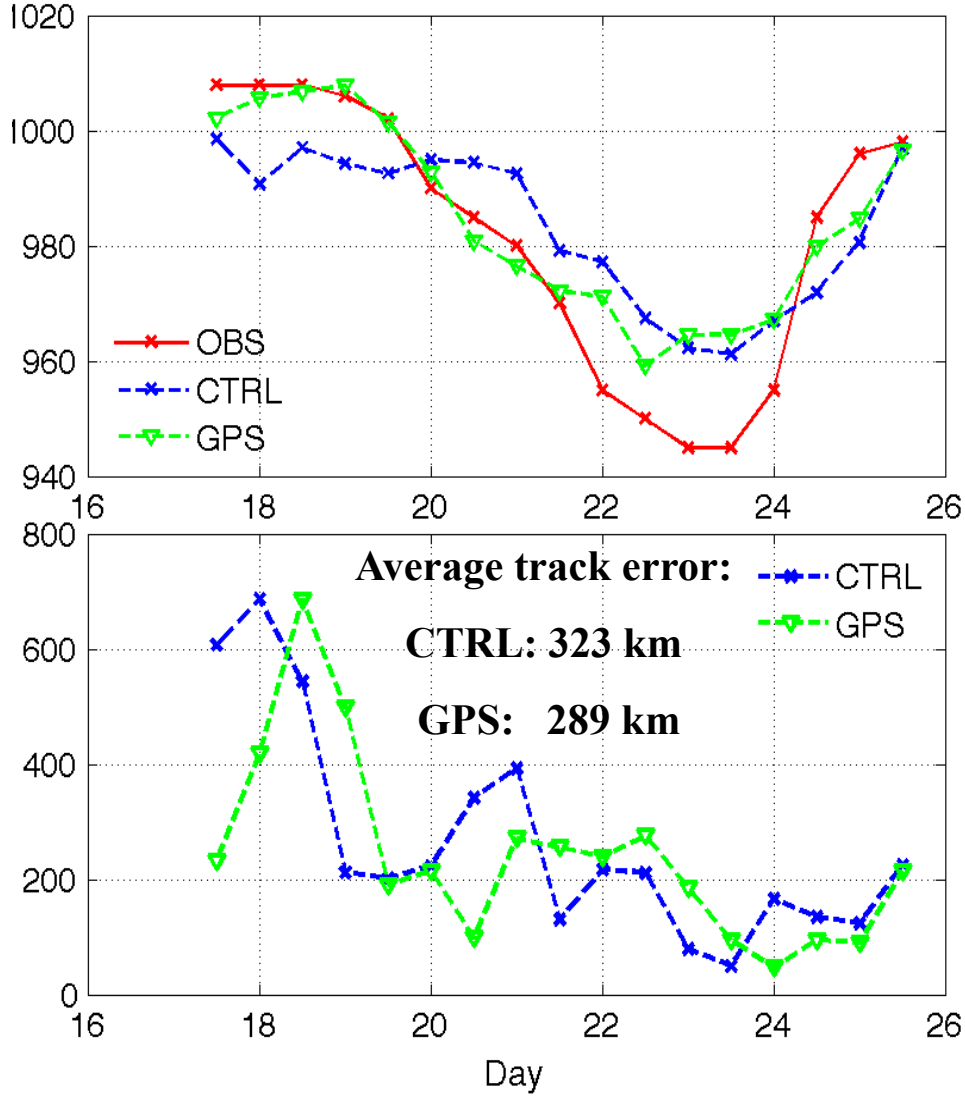
Ensemble Mean 48H Forecasts of Intensity and Track Error

(Valid at 00Z and 12Z, 8-26 September, 2008)

Typhoon Sinlaku (Sept 8-22)



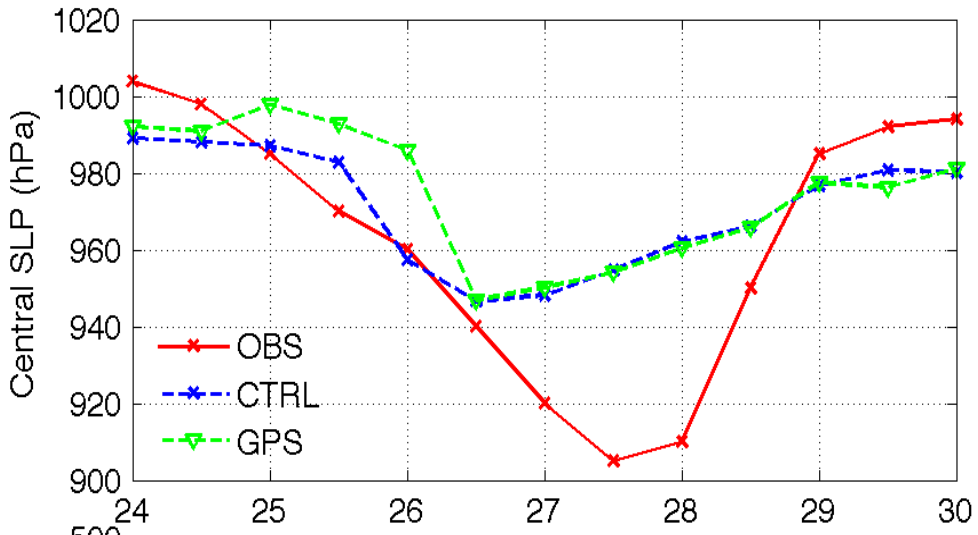
Typhoon Hagupit (Sept 16-26)

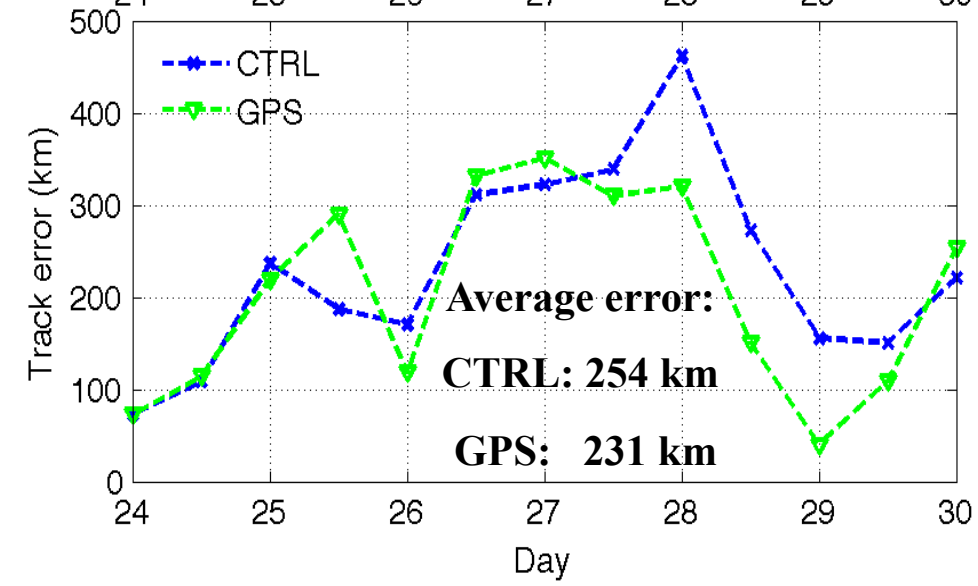


Ensemble Mean 48h Forecasts of Intensity and Track Error

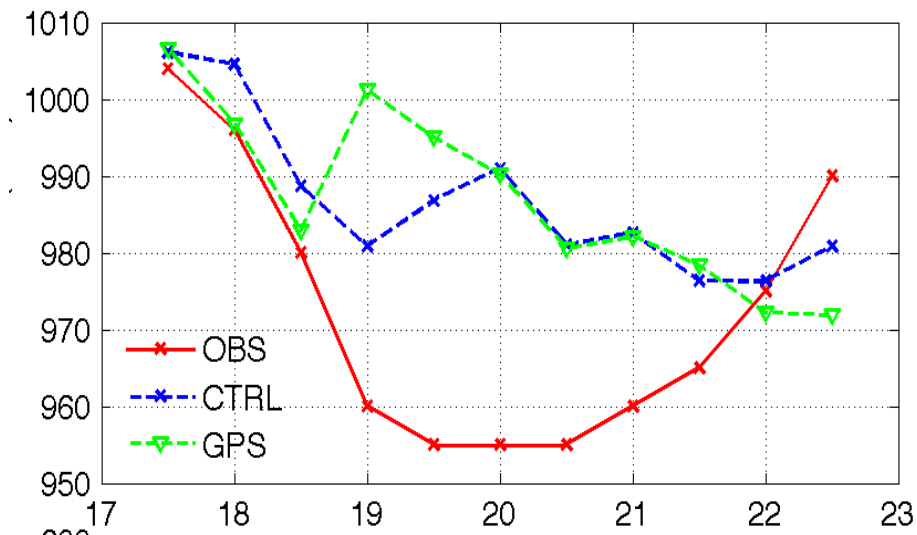
(Valid at 00Z and 12Z daily)

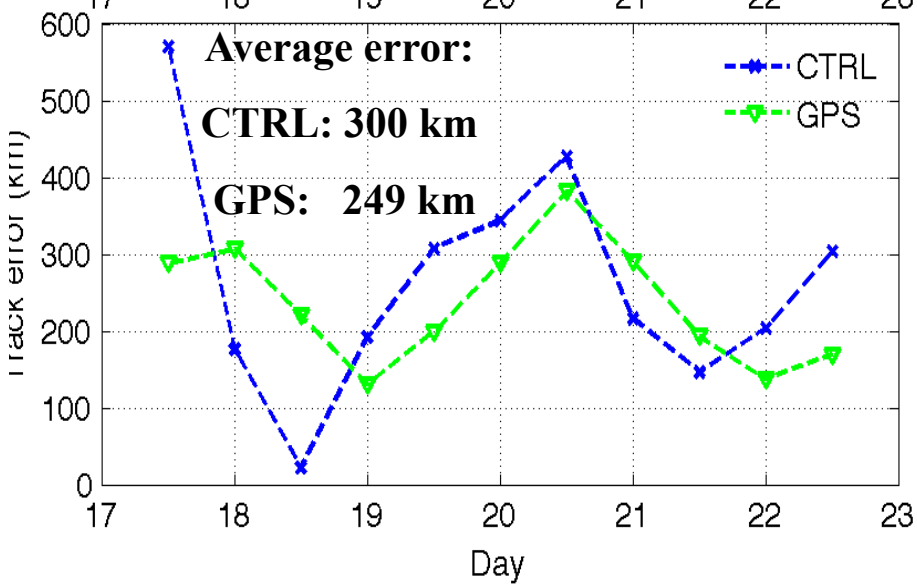
Typhoon Jangmi (Sept 24-30)





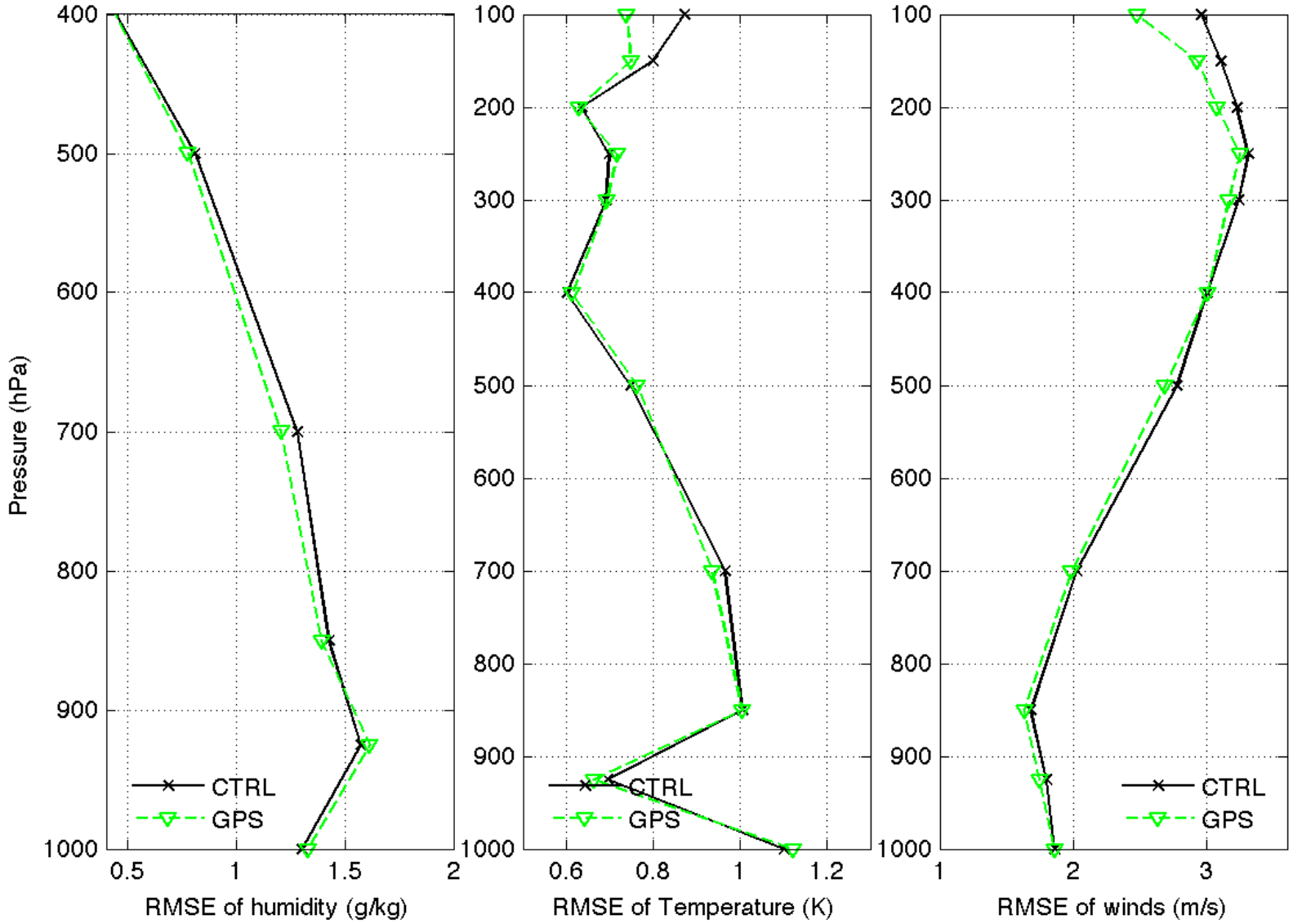
Typhoon Nuri (Aug 17-23)





Analysis RMS Fits to Dropsondes/Radiosondes

(domain averaged 11 August – 30 September, 2008)



Summary

- Use of GPS data improves forecasts of TC track and intensity.

  (In average, track errors are reduced ~11% for 48h forecasts)
- RO refractivity improves analysis of water vapor and wind in convective environment of TCs.
- Benefit of RO data is reduced when RO data in the lower troposphere is ignored.