Application of Radio Occultation Data in Analyses and Forecasts of Tropical Cyclones Using an Ensemble Assimilation System

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Acknowledgment: C. Snyder, Y. Chen, T. Hoar, K. Raeder, N. Collins

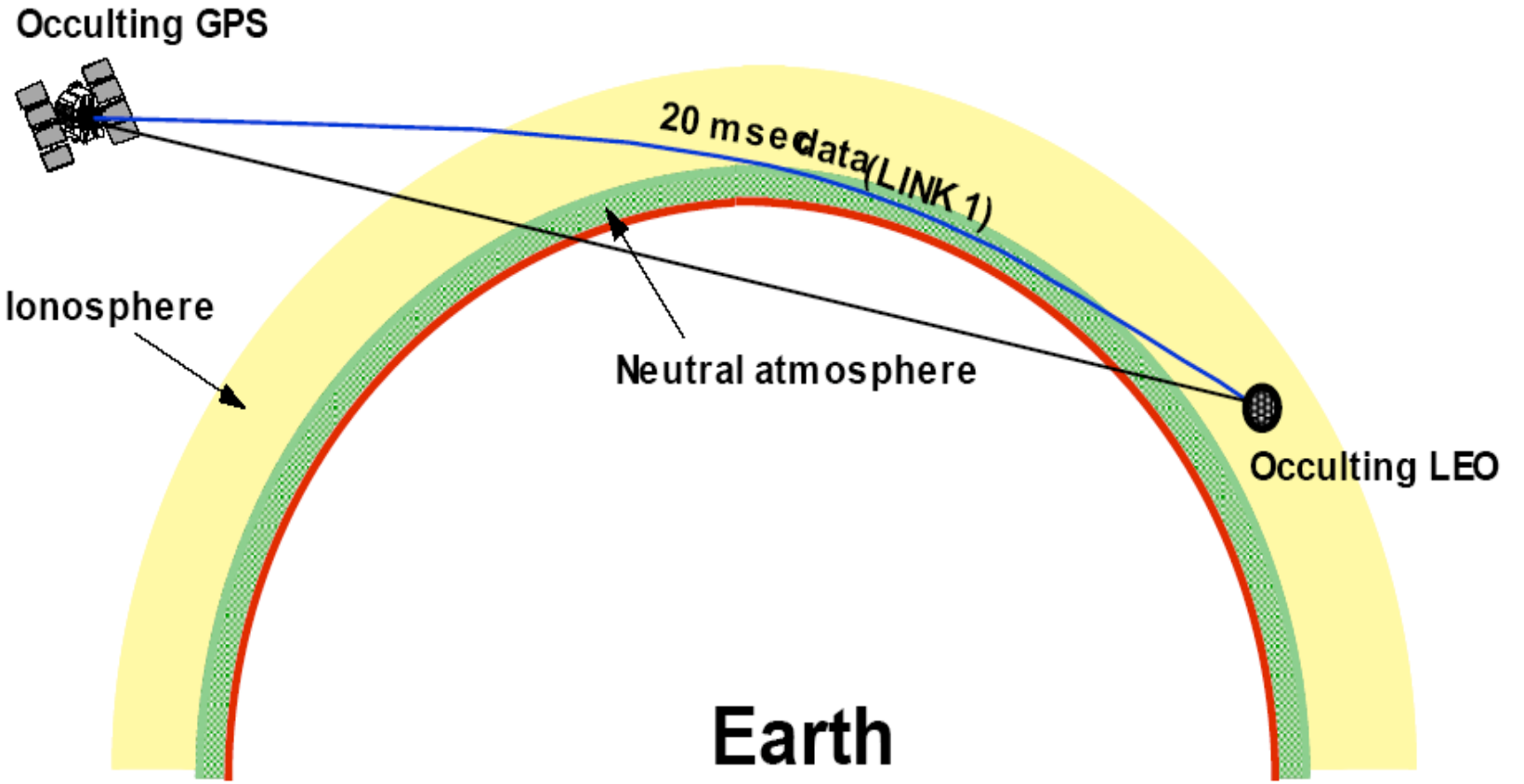
Introduction

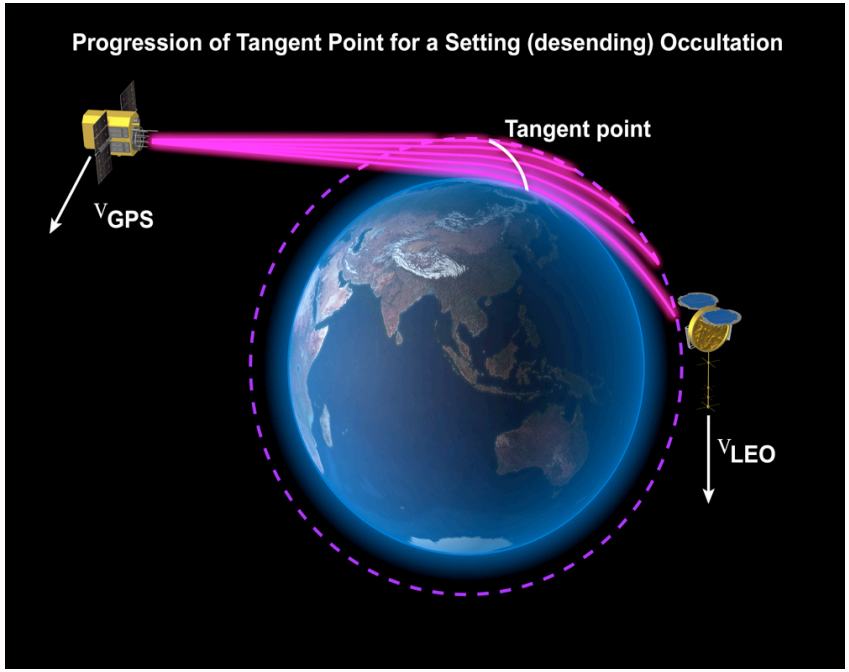
- Operational analyses and forecasts of tropical cyclones, especially their intensity, have large errors
- Lack of accurate observations of atmospheric water vapor and temperature near the cyclones is one of the reasons
- New type of satellite observations has room to improve forecasts of tropical cyclones

GPS Radio Occultation (RO)

Basic measurement principle:

Deduce atmospheric water vapor and temperature based on measurement of GPS signal phase delay.



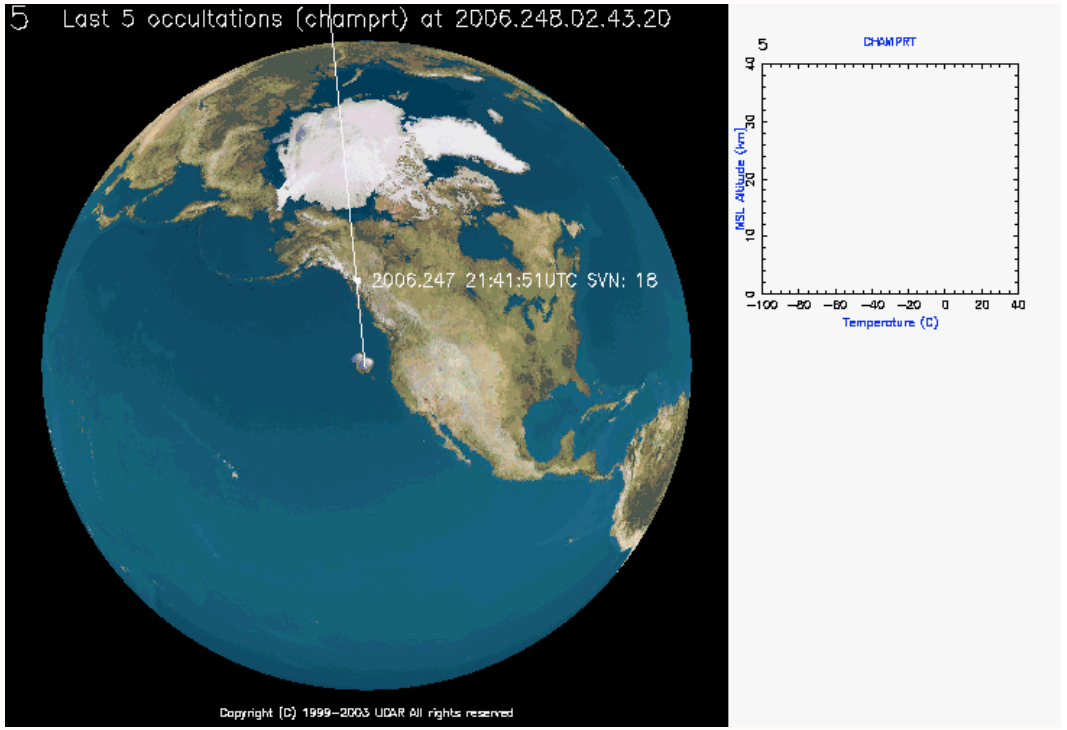


Limb sounding of atmosphere as LEO satellite receivers rise or set with respect to GPS satellites

Global observations of:

Temperature, Humidity, Refractivity.

(~2500 profiles per day)



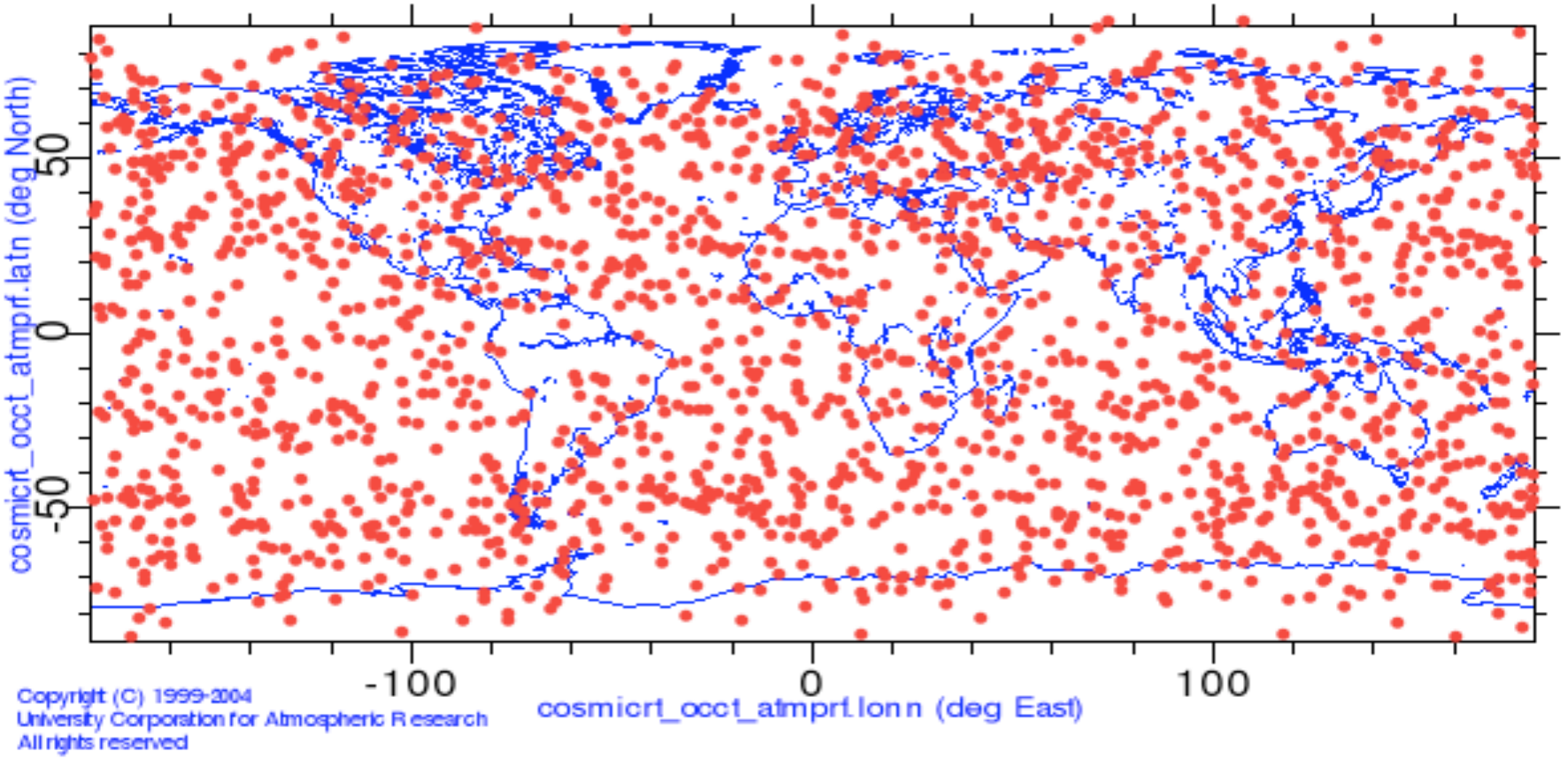
COSMIC GPS RO Research Mission (2006 - 2011)

A set of six mini-satellites in Low Earth Orbit (LEOs) with GPS receivers were launched on

15 April 2006.

COSMIC launch picture provided by Orbital Sciences Corporation

Dec 7, 2007
Global coverage including over oceans and polar areas
1878 soundings



GPS Radio Occultation Refractivity

- Has accurate measurements of both water vapor and temperature with high vertical resolution
- Minimally affected by clouds and precipitation
- Has great potential to improve weather analyses and forecasts over data-sparse and cloudy areas like tropical oceans

So, RO is especially useful for tropical cyclone forecasts

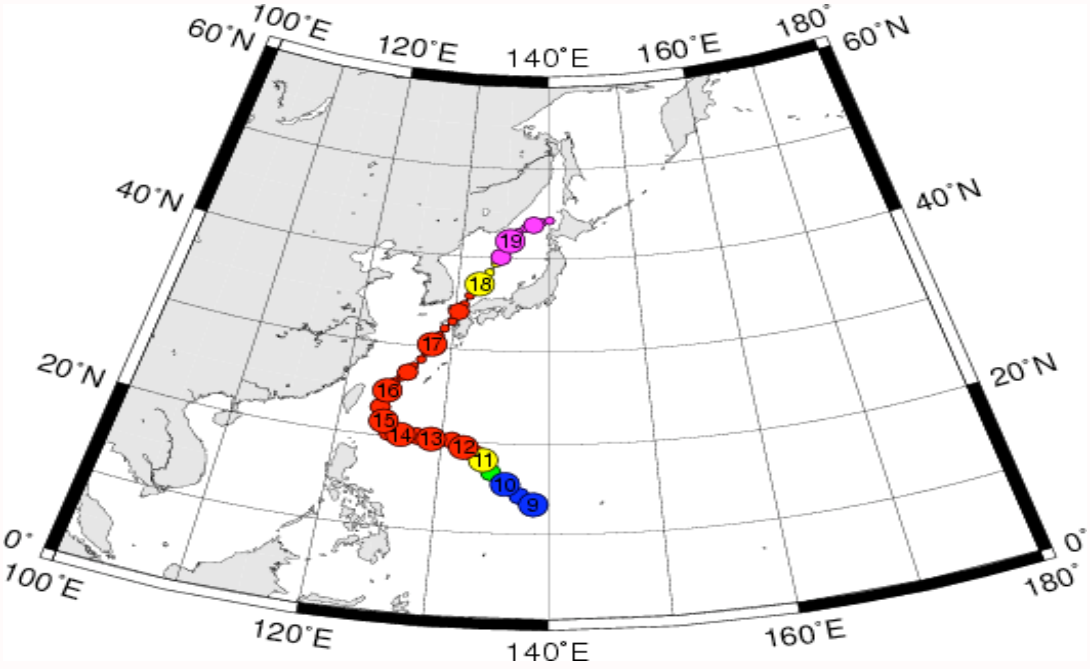
Challenges for Assimilation of RO Refractivity

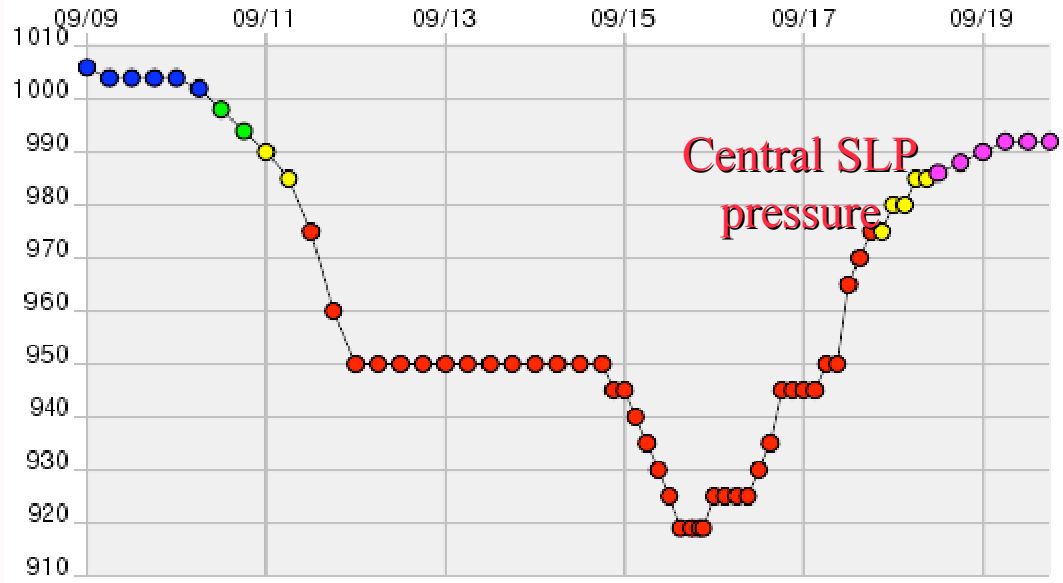
- RO refractivity is a function of both water vapor and temperature
- Retrieval of water vapor and temperature requires accurate estimate of covariance between RO data, temperature, and moisture
- These covariances are highly time-varying and not well known

Ensemble Kalman Filter Assimilation

- Covariance of RO refractivity with water vapor and temperature is computed from online ensemble forecasts
- The error covariance is time-varying, related to weather patterns

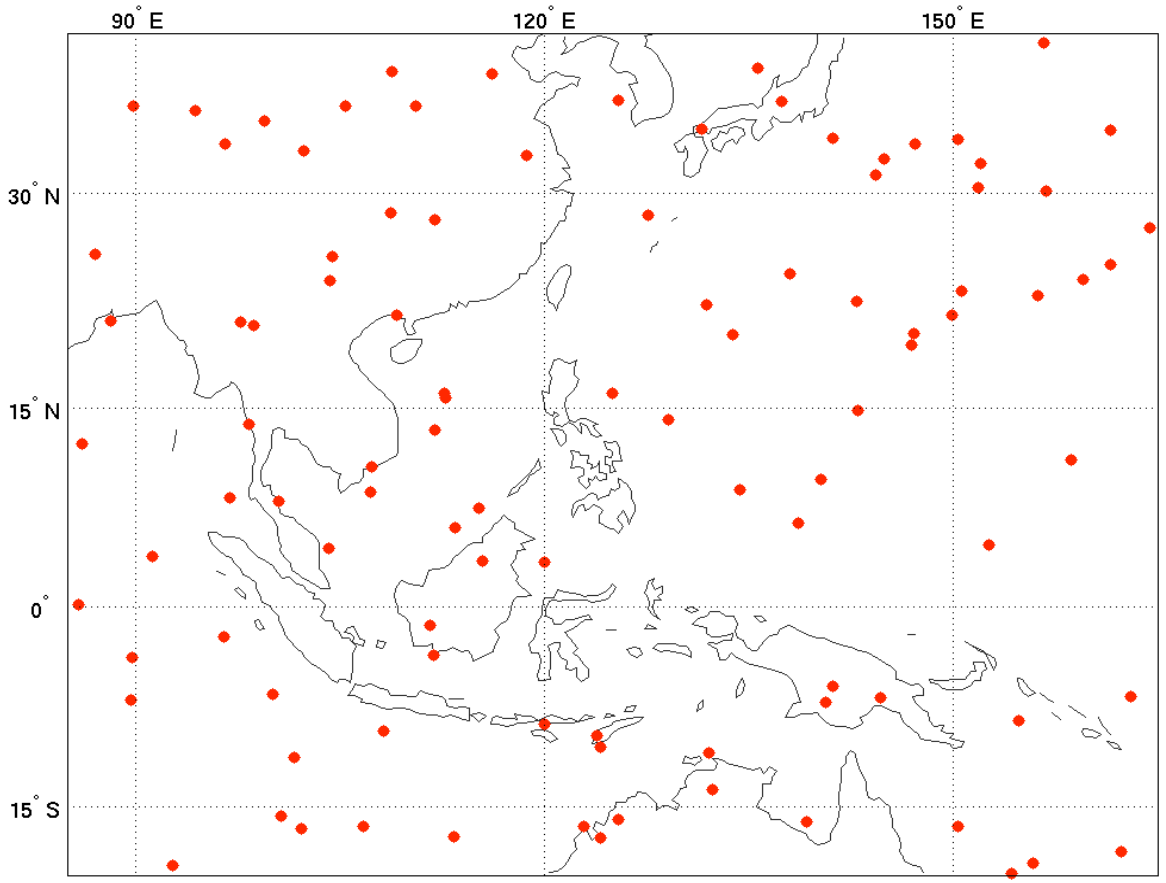
Typhoon Shanshan Case (Sept 10-17, 2006)





Operational forecasts using variational assimilation failed to predict the curving of the typhoon

COSMIC RO soundings (September 13, 2006)



RO soundings, randomly distributed over the domain, provide large-scale information.

Assimilation experiments

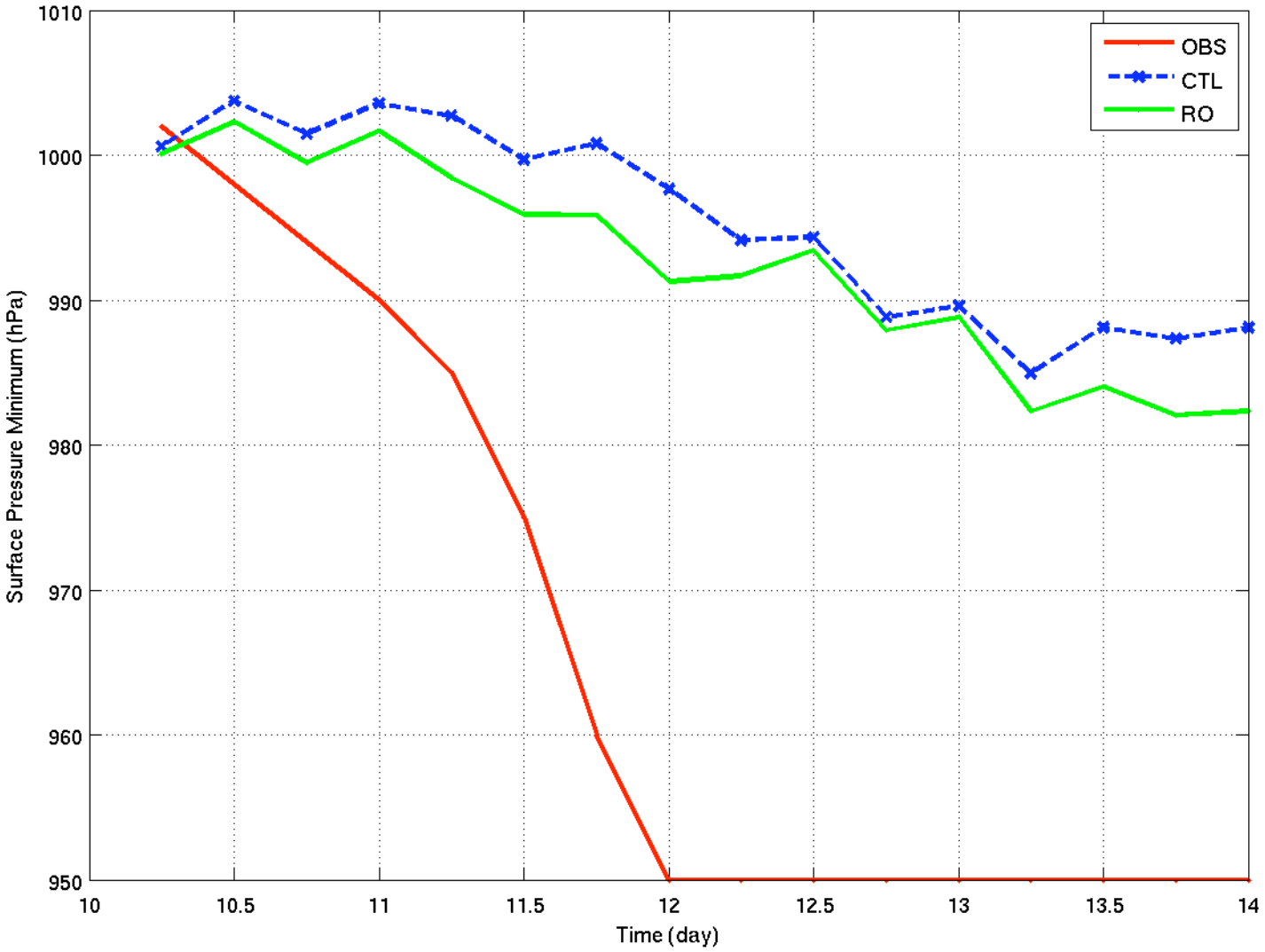
- WRF/DART ensemble assimilation at 45km resolution for 8-14 September 2006.
- 32 ensemble members.
- *Control/NoGPS run*:

  Assimilate operational datasets including radiosonde, cloud winds, land and ocean surface observations, SATEM thickness, and QuikScat surface winds.

- *GPS run*:

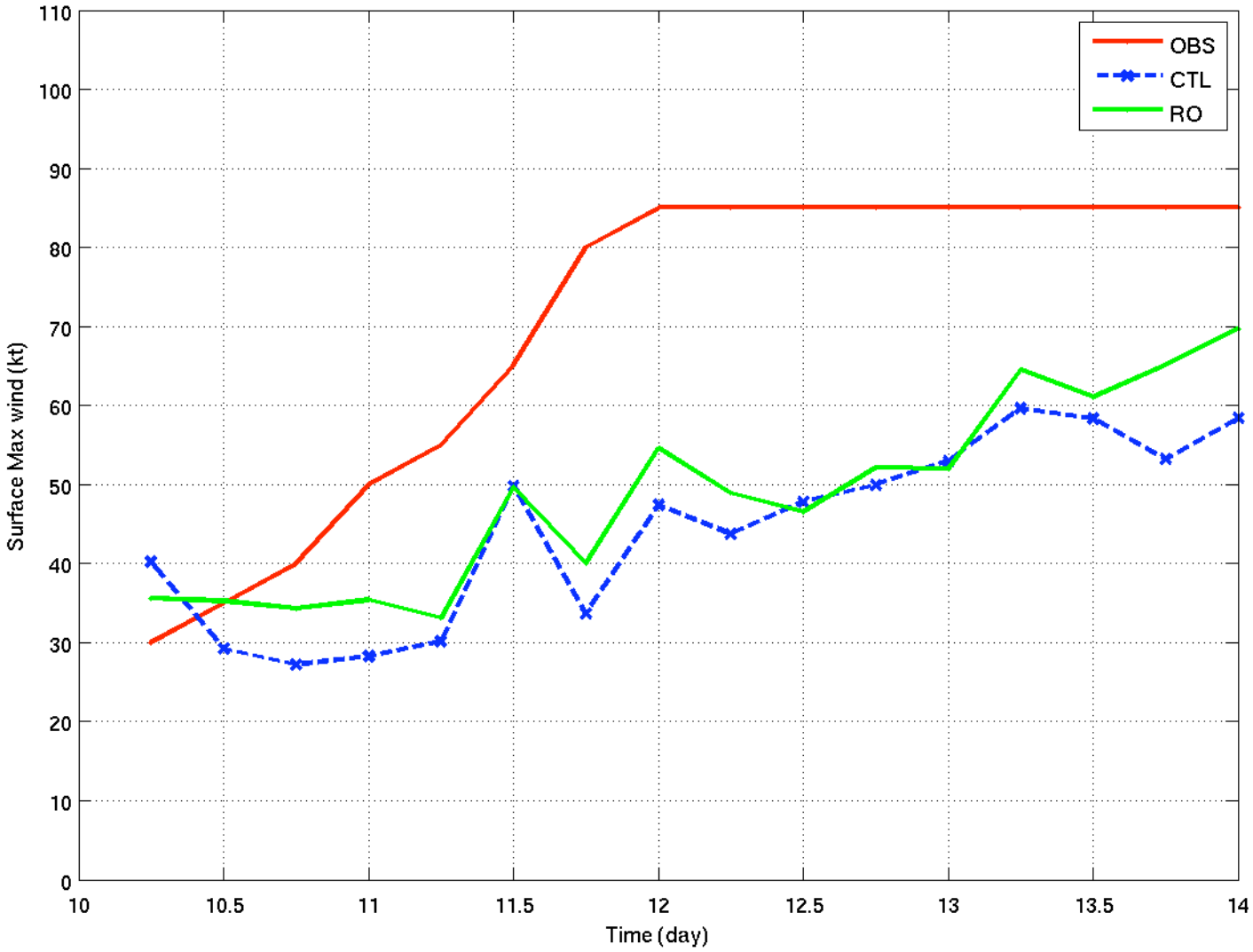
  Assimilate the above observations + RO refractivity.

Typhoon central pressure in analyses (8-14, Sept.)



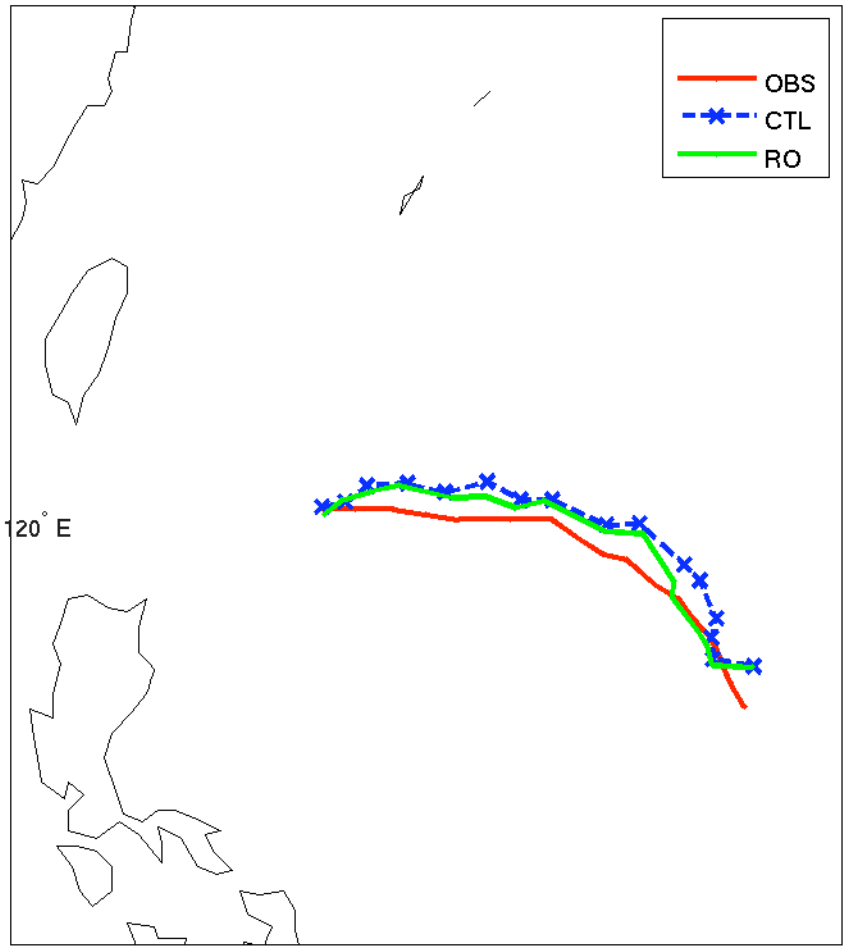
Intensity of the typhoon is enhanced with RO data.

Typhoon Maximum surface wind in analyses (8-14, Sept.)



Intensity of the typhoon is enhanced with RO data.

Typhoon Tracks (ensemble mean) in analyses (8-14 Sept.)



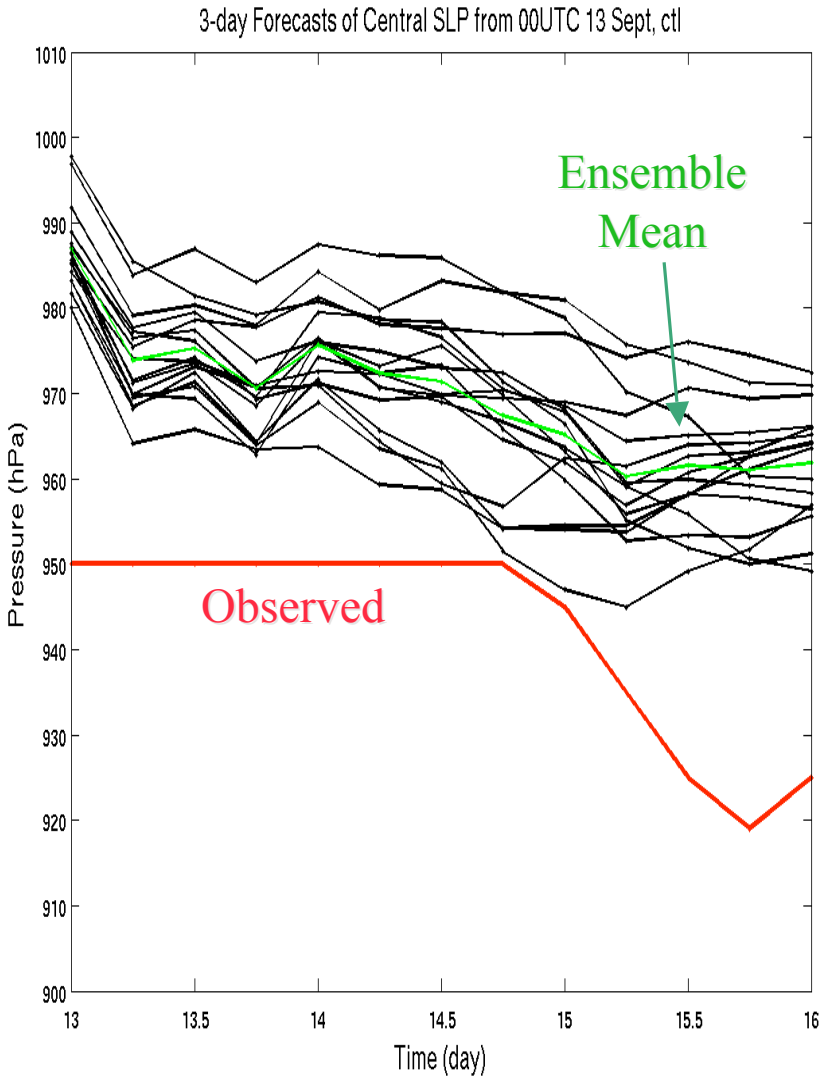
Typhoon track with GPS data is closer to observations.

Impact of RO refractivity on Ensemble forecasts
(16 members, with a finer nested grid of 15km)
initialized at 00UTC 13 and 14 Sept 2006.

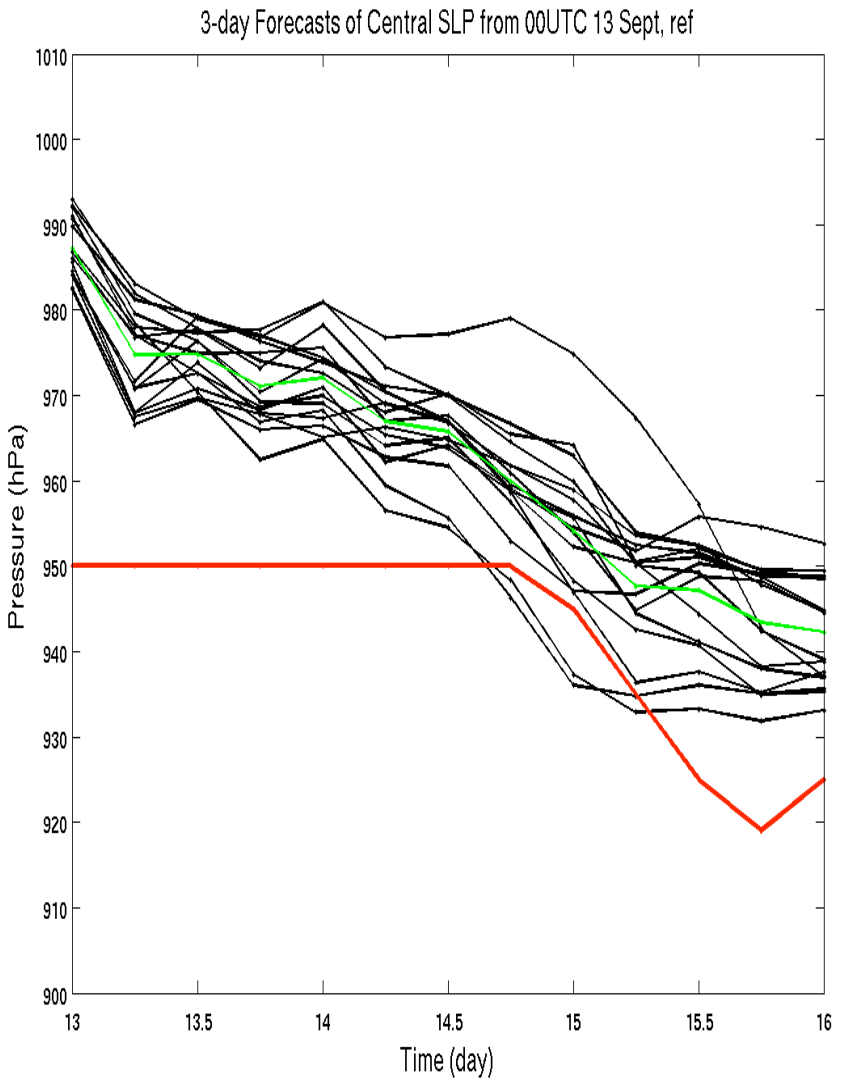
1. Forecast from 00UTC 13 Sept 2006

Ensemble Forecasts of Central Sea Level Pressure

NoGPS



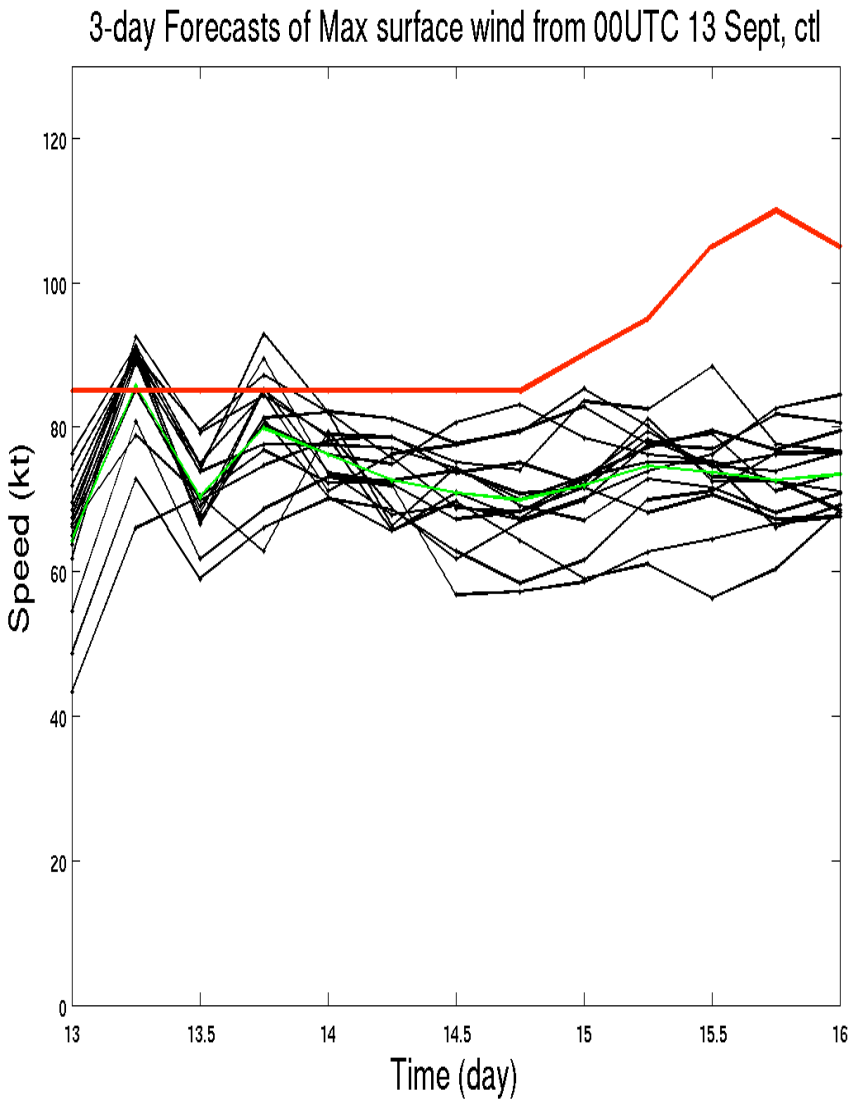
GPS



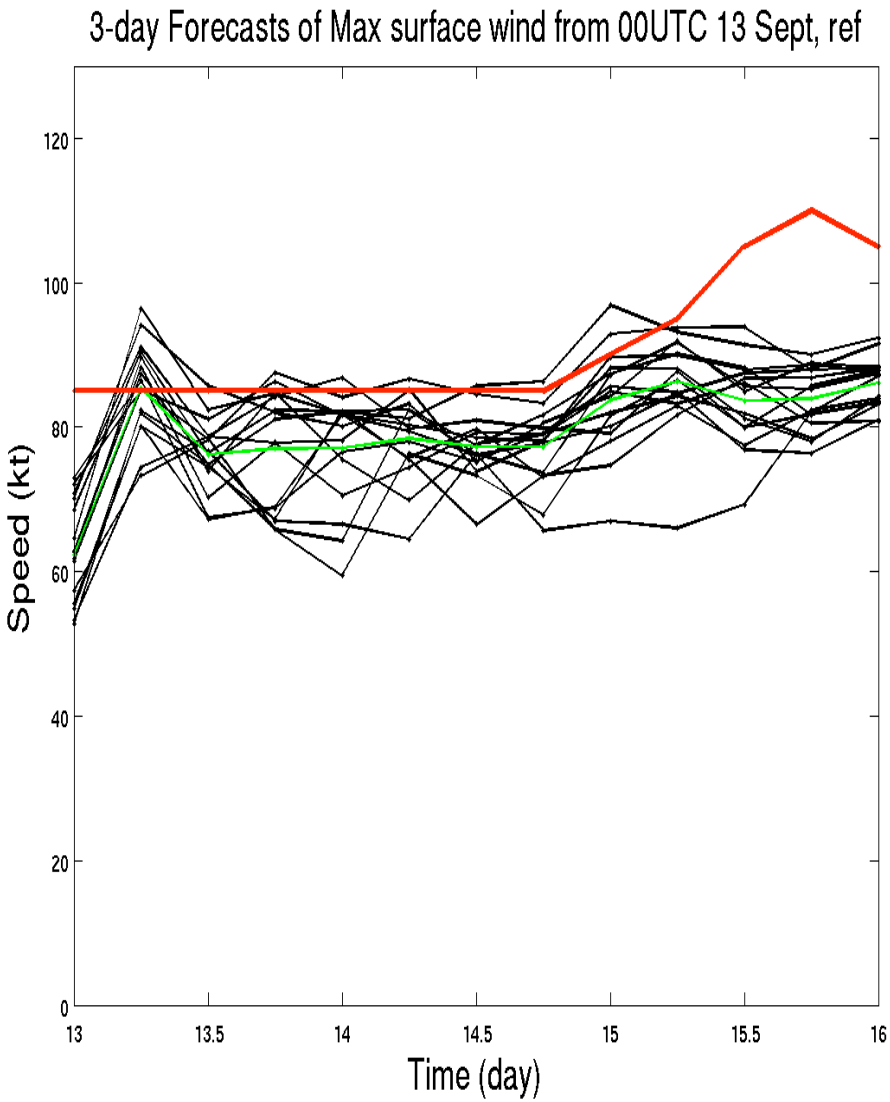
Intensity of the typhoon is increased with RO data

Ensemble Forecasts of Maximum surface wind

NoGPS



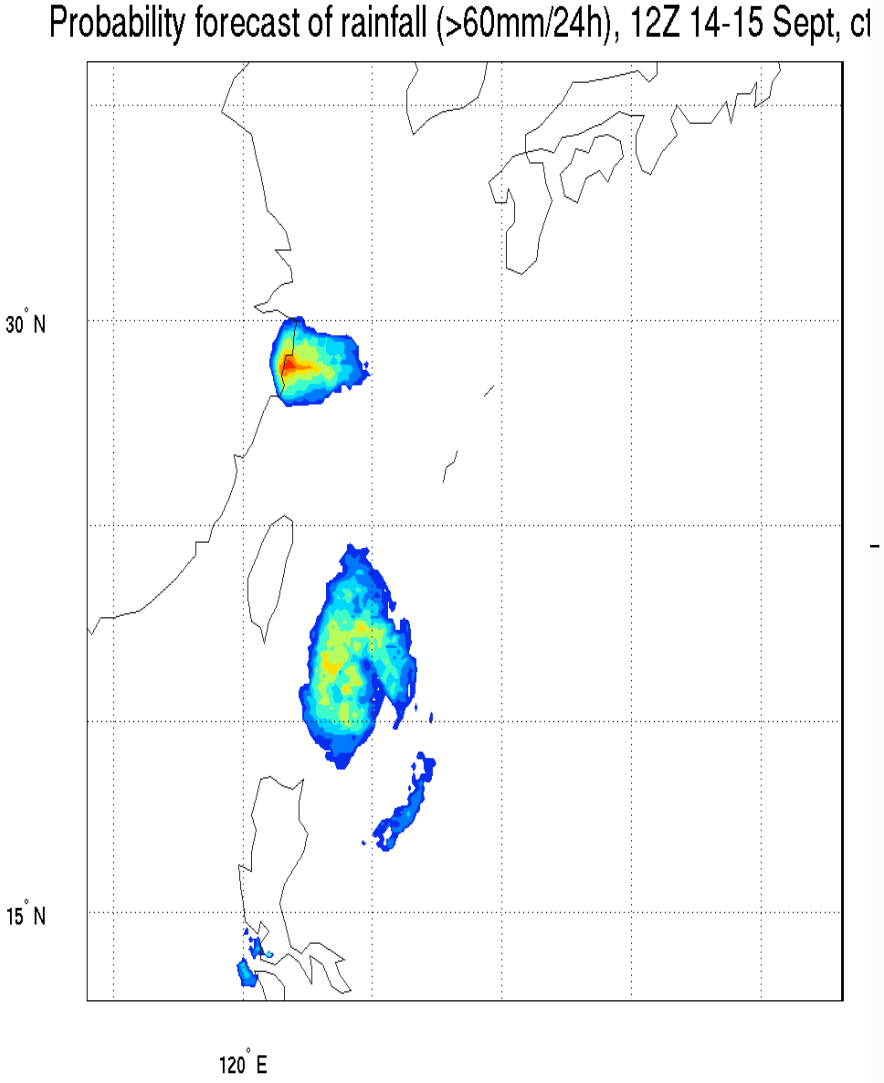
GPS



Intensity of the typhoon is increased with RO data

Forecast Probability of Rainfall >60mm/24h, 12Z 14-15 Sept.

NoGPS



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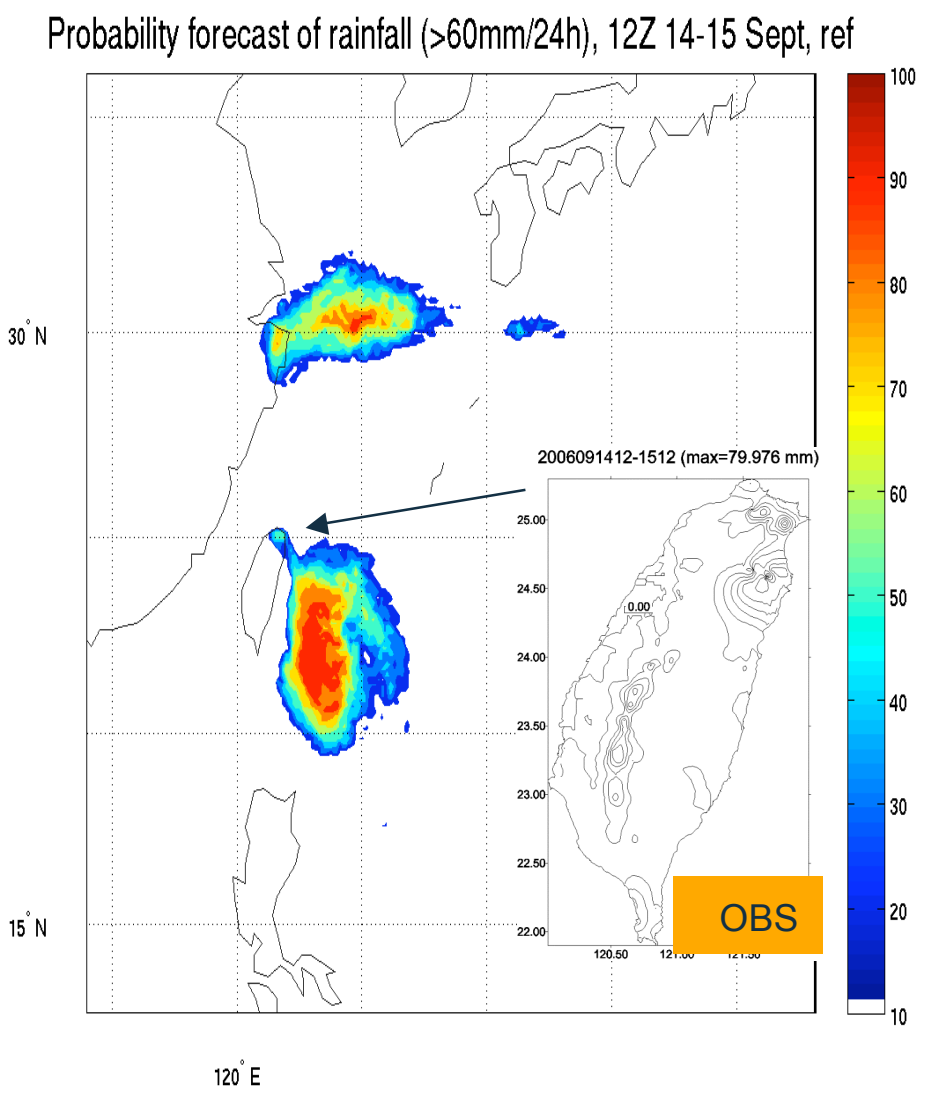
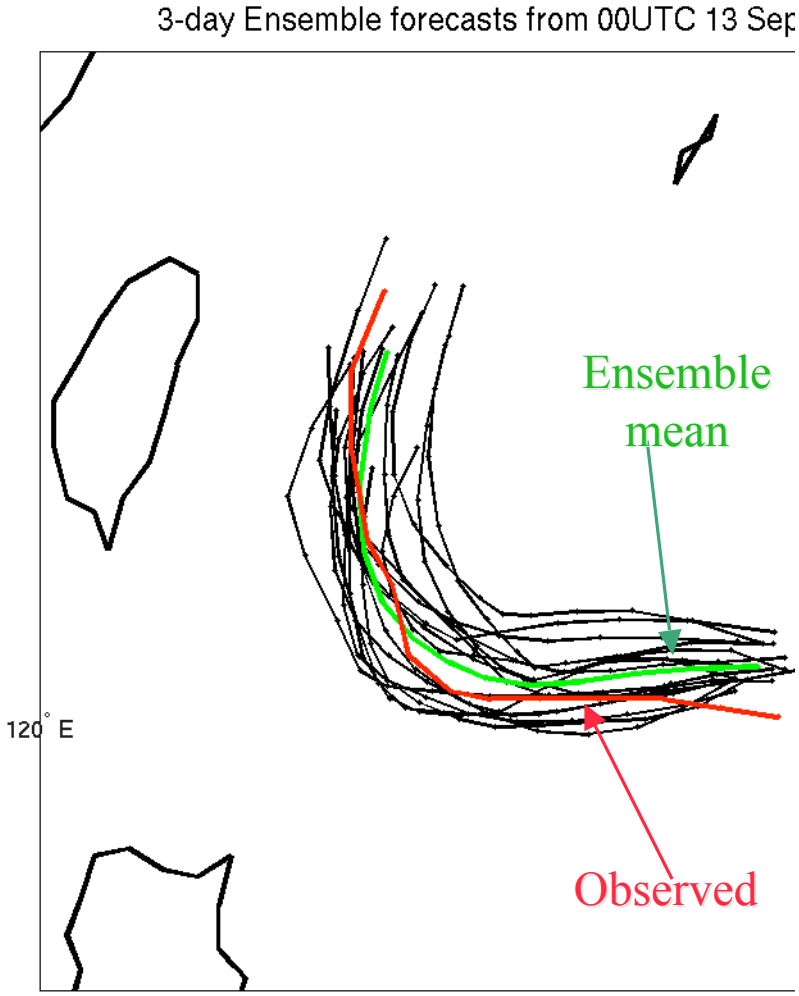


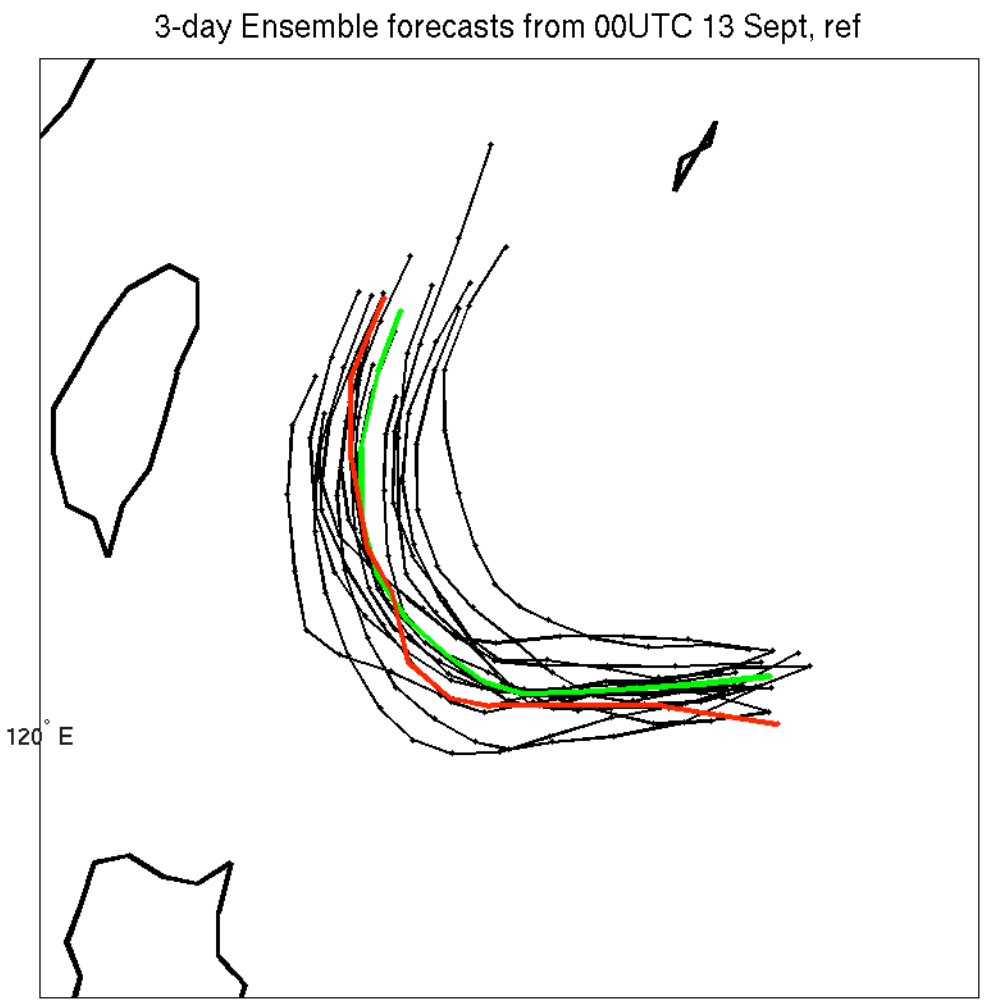
Rainfall probability is increased with RO data

Ensemble Forecasts of Typhoon Track

NoGPS



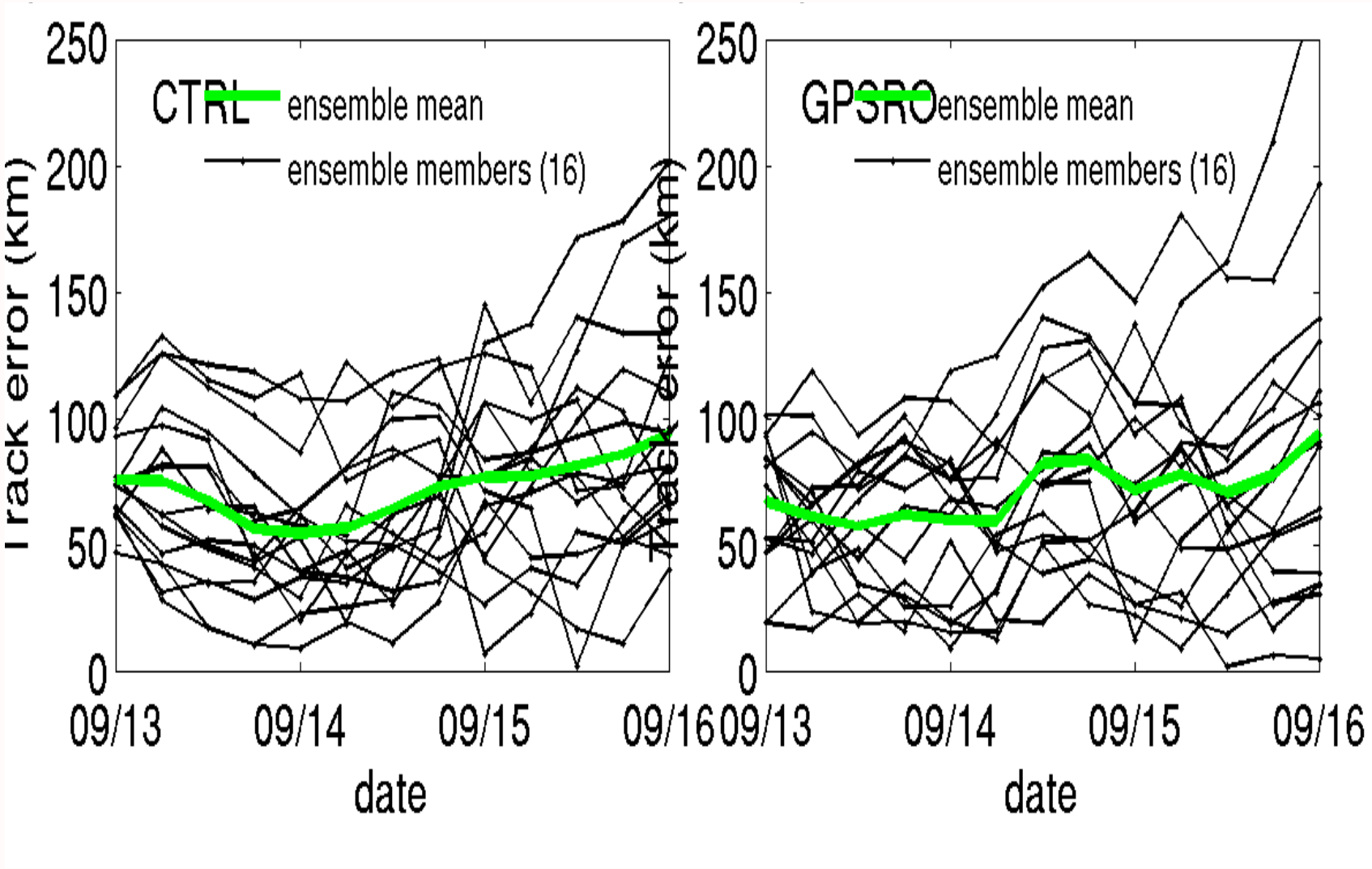
GPS



Curving of the Typhoon is well predicted in both cases.

Ensemble Forecasts of Typhoon Track

NoGPS GPS

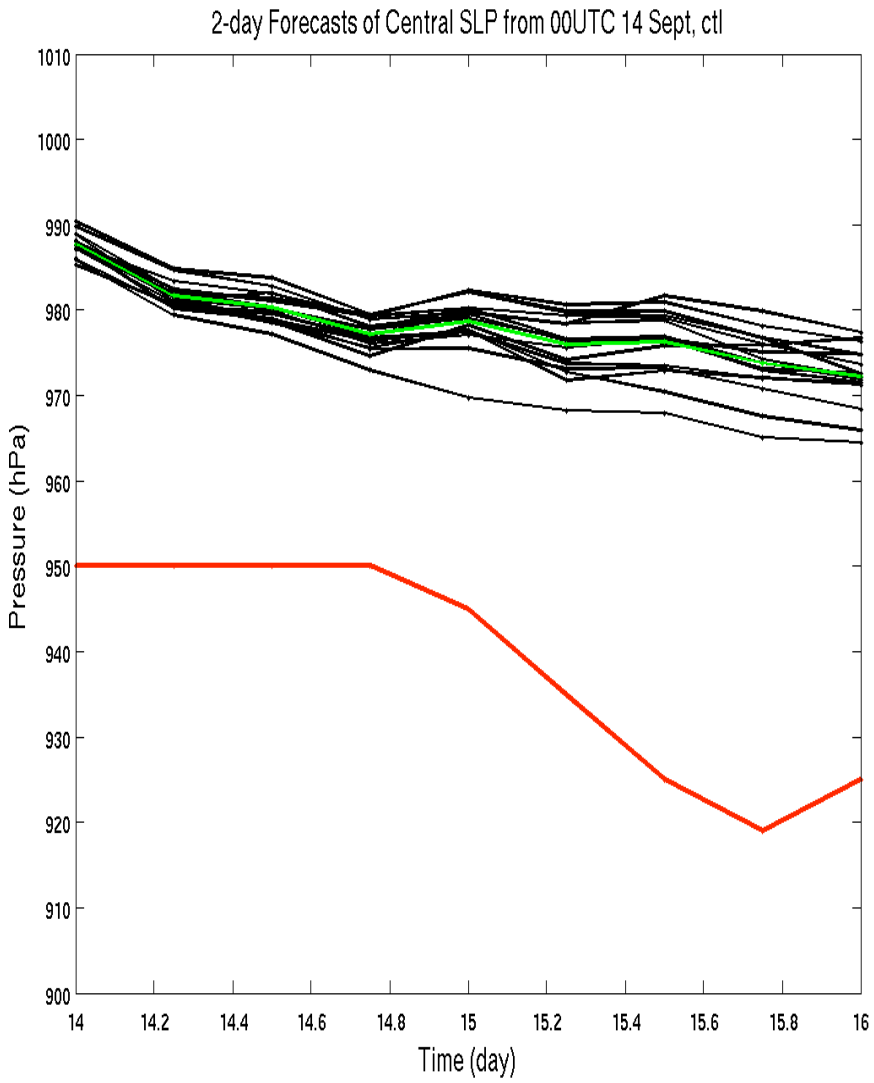


Curving of the Typhoon is well predicted in both cases.

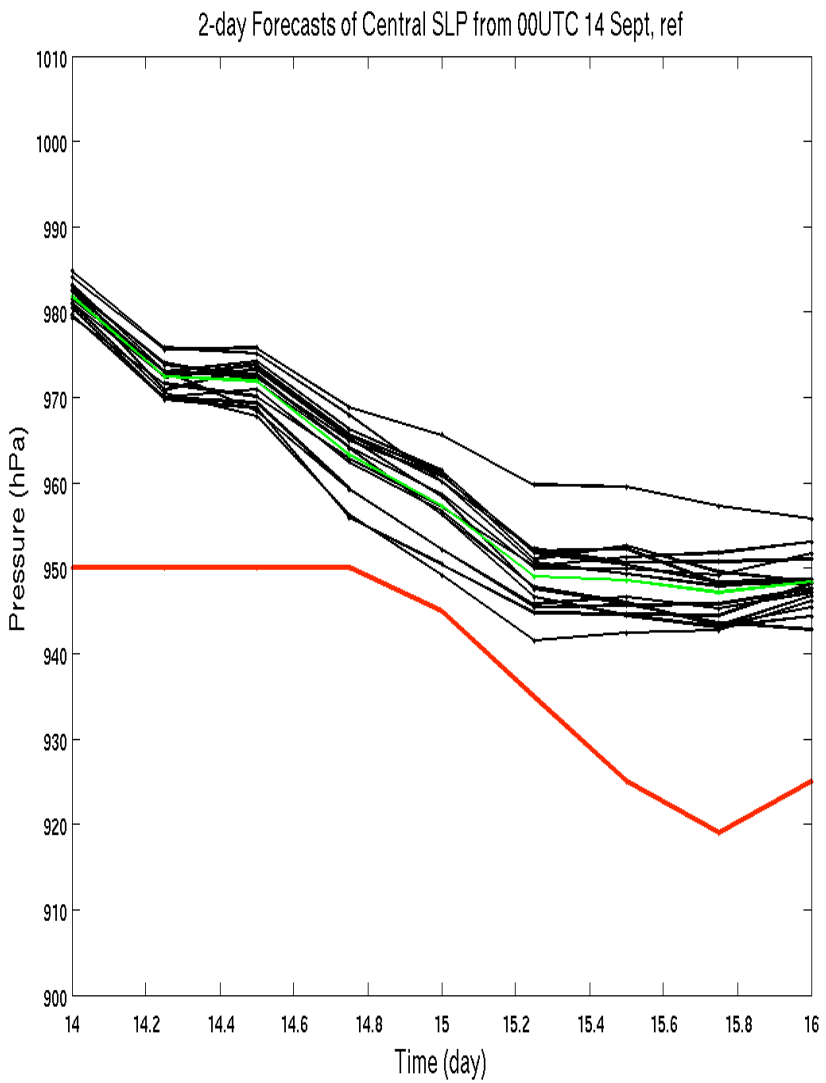
2. Forecast from 00UTC 14 Sept 2006

Ensemble Forecasts of Minimum Sea Level Pressure

NoGPS



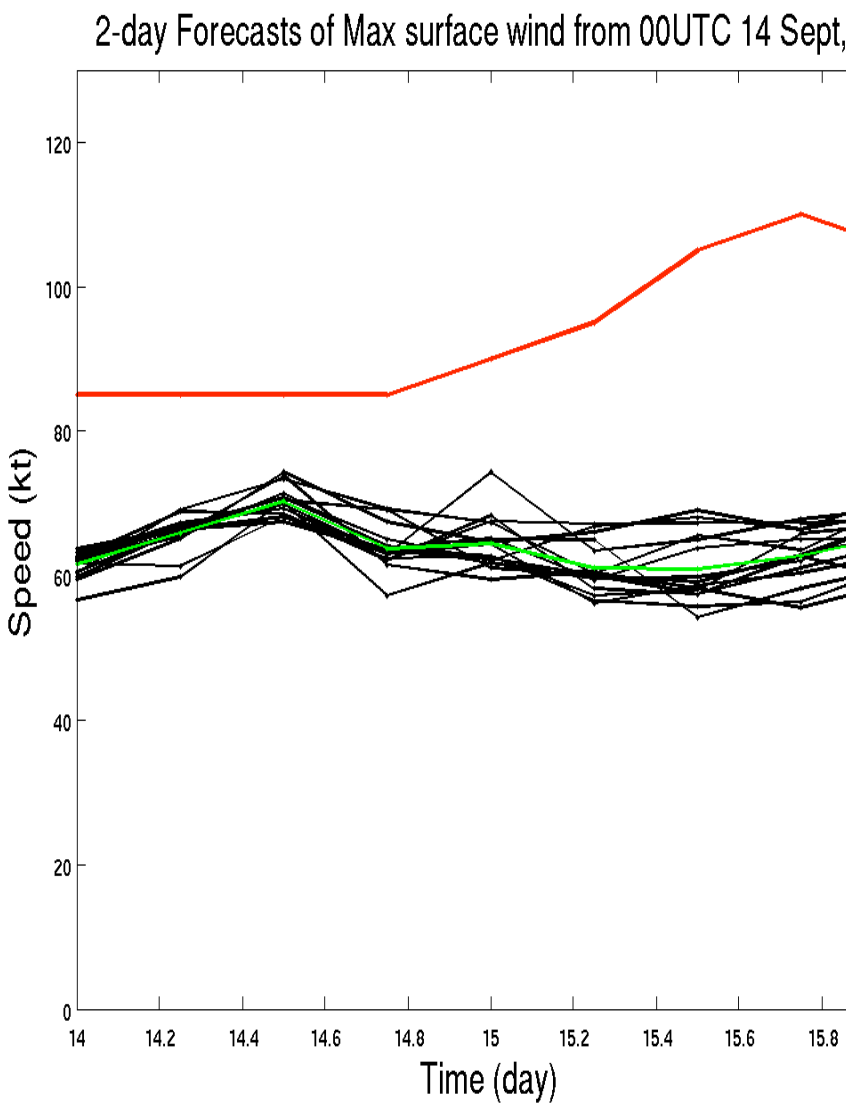
GPS



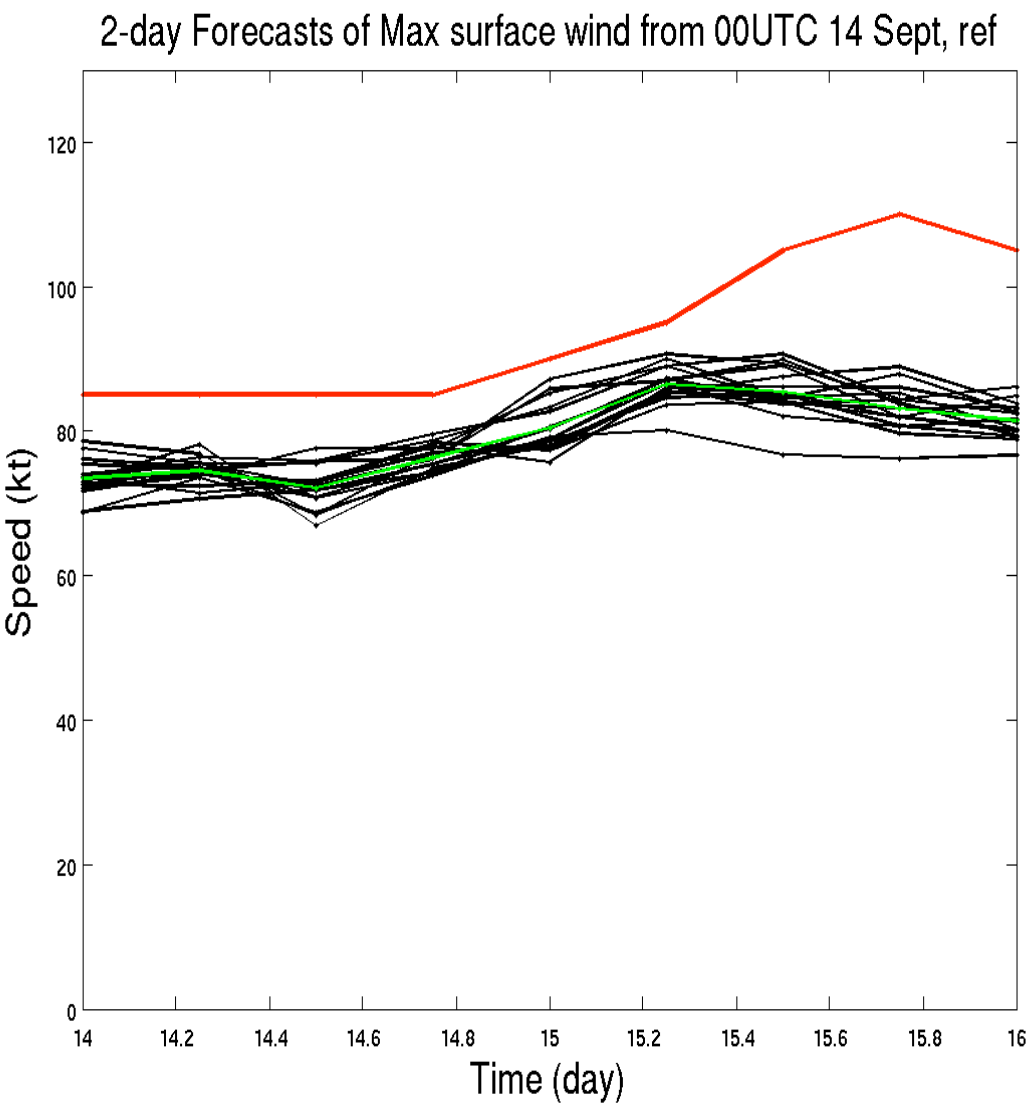
Intensity of the typhoon is increased with RO data

Ensemble Forecasts of Maximum surface wind

NoGPS



GPS



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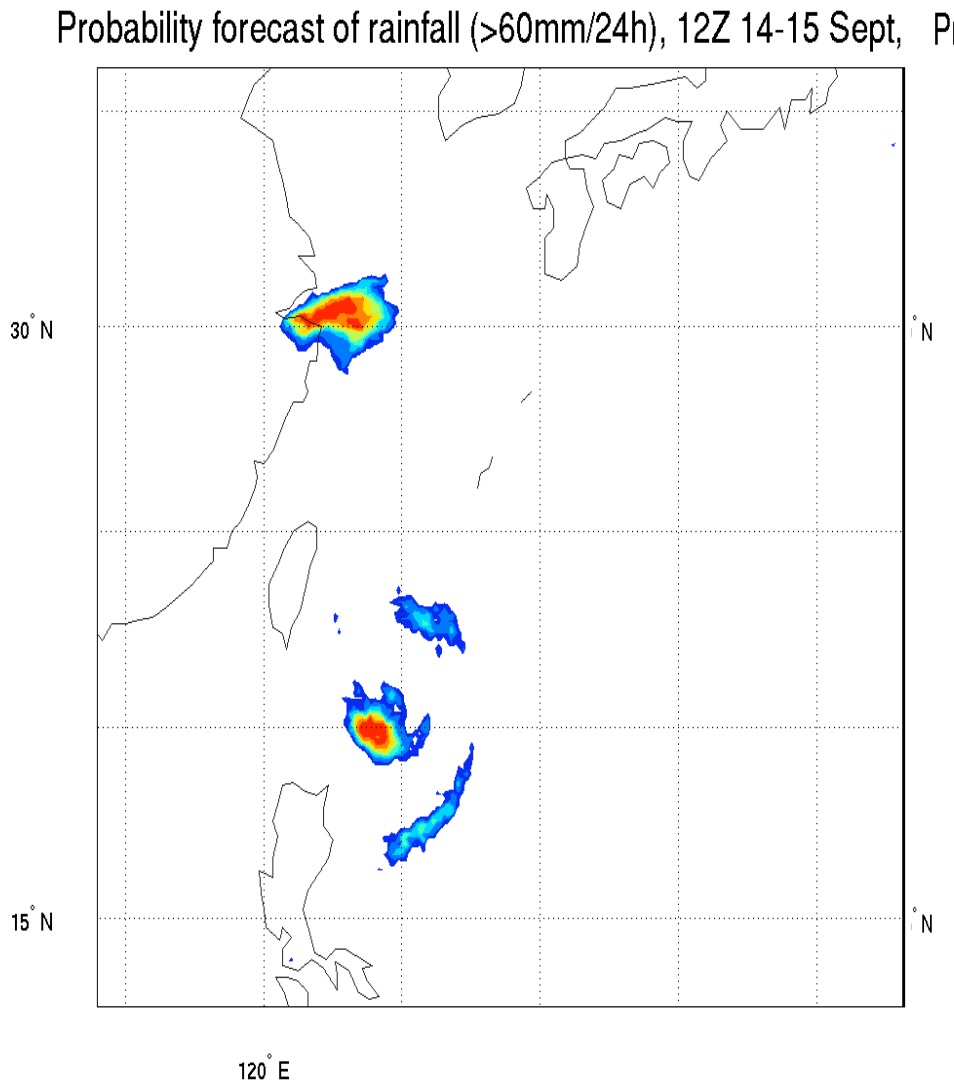
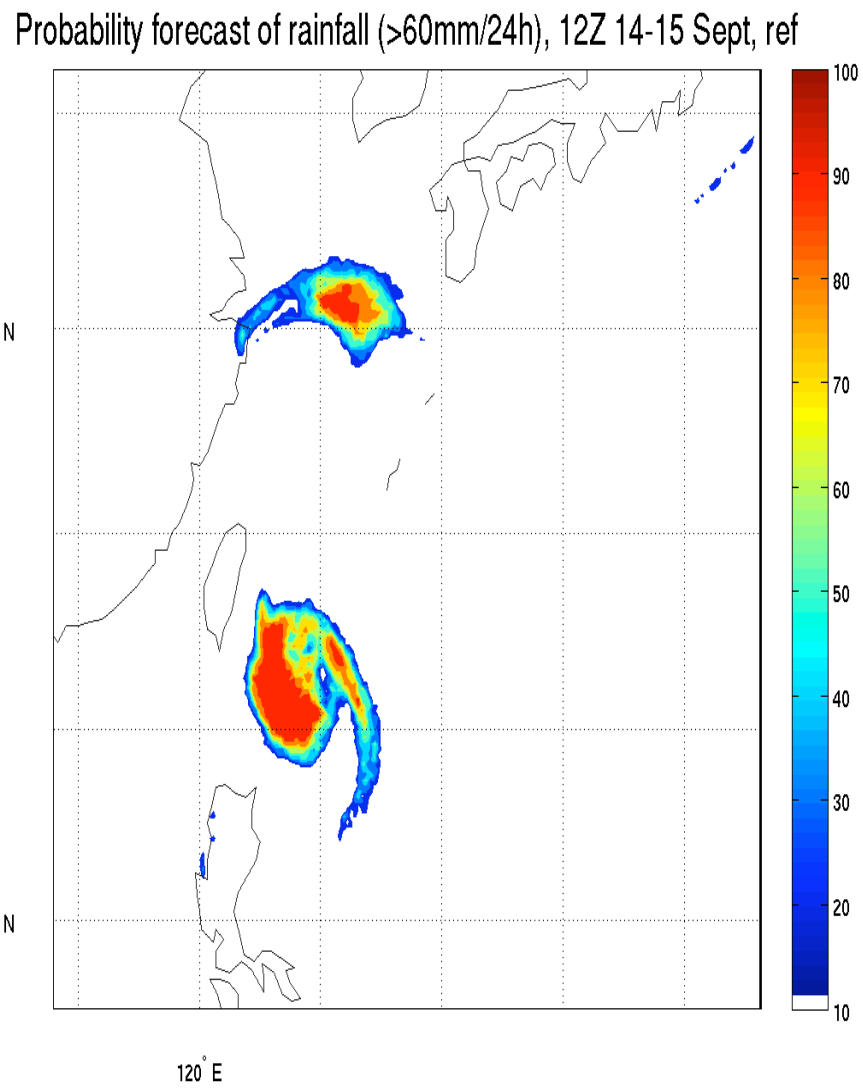


GPS



Rainfall probability is increased with RO data

Summary

- Forecasts of the typhoon intensity and rainfall probability are improved by using RO refractivity observations with the WRF/DART ensemble system.
- The curving path of the typhoon is well predicted.

Next Efforts

- More hurricane cases
- Quasi-operational testing at Taiwan Central Weather Bureau, etc
- Genesis of tropical cyclones
- Combination of other satellite observations with RO data to further improve analyses and forecasts of tropical cyclones
- Weather analysis with use of RO data for:
  - Tropical convection study
  - Forecasts over Antarctic/Arctic, etc.