The impact of surface wind data and 3-D Doppler lidar wind profiles on high-impact weather forecasting: Data assimilation and OSSE studies

Zhaoxia Pu

Department of Atmospheric Sciences

University of Utah

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Working group on space-based lidar winds
Boulder, CO, April 27-29, 2015

Background

- **Measurement of global winds is recognized as a primary unmet observational requirement for understanding atmospheric dynamics and improving weather forecasts.**

- **The NASA Lidar wind science and weather programs as well as recent field programs offer great opportunities to explore the value of ocean surface wind measurements, Doppler lidar wind profiles, and a potential 3-D space-based lidar wind mission.**

Research objectives

- **Study the impact of lidar wind observations on the prediction of high impact weather systems**

- **Assess the potential impacts of future space-based Doppler wind lidar measurements on improving high impact weather systems**

Methodology

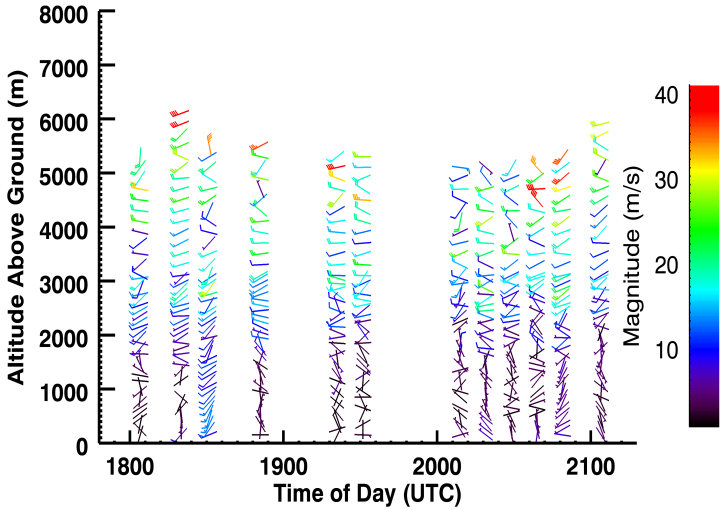
- **Data assimilation and numerical simulations/forecasts**

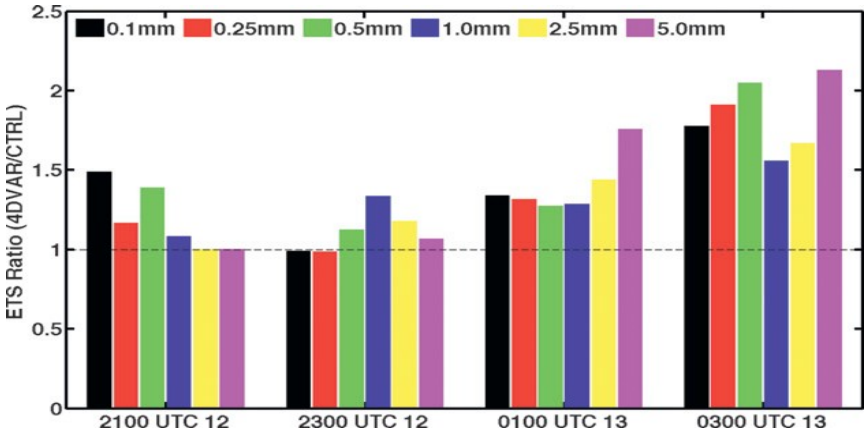
- **Advanced data assimilation system (3DVAR, 4DVAR, EnKF)**

- **Research and operational NWP models (WRF, HWRF etc.)**

Case I

The impact of NASA GLOW ground-based lidar wind profiles on the numerical simulation of a mesoscale convective system observed during IHOP_2002



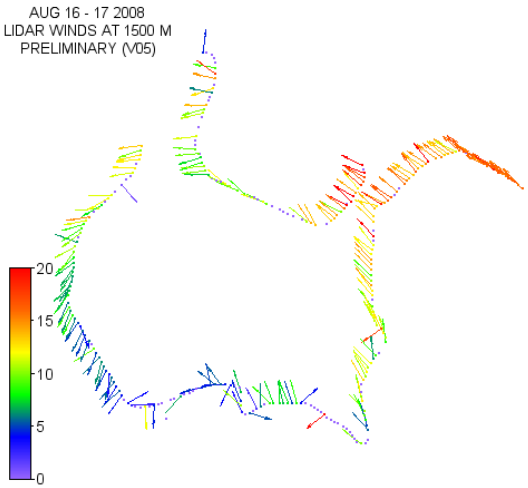


Zhang and Pu, Mon. Wea. Rev. 2011

Case II

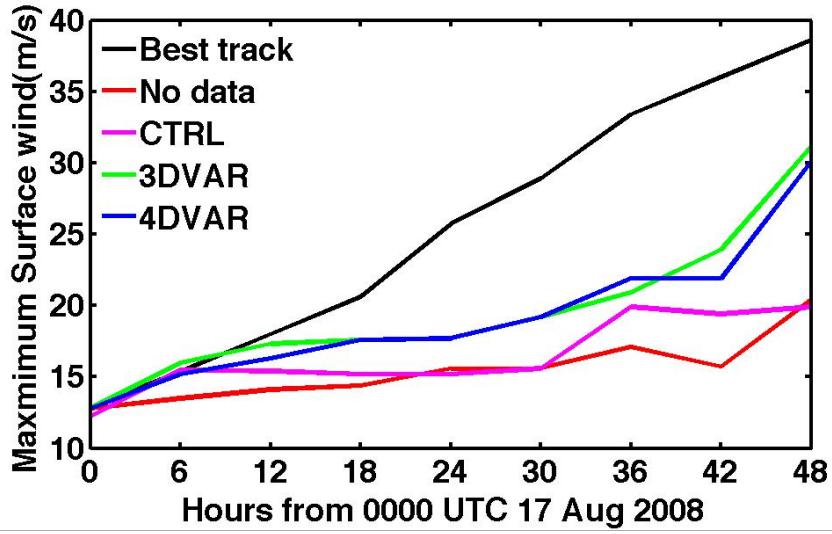
The Impact of airborne Doppler wind lidar profiles on numerical simulations of the gensis of Typhoon Nuri (2008) during ONR TCS-08

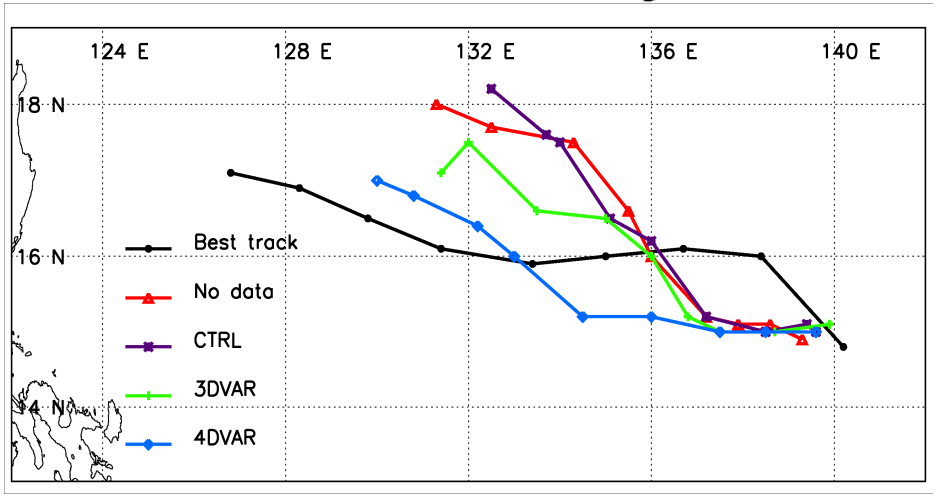
NRL P3-DWL winds at1500m



DWL data has positive impact on numerical simulation of Typhoon Nuri (2008)

Compared with 3DVAR, 4DVAR is deemed to be more promising for assimilating airborne DWL data.

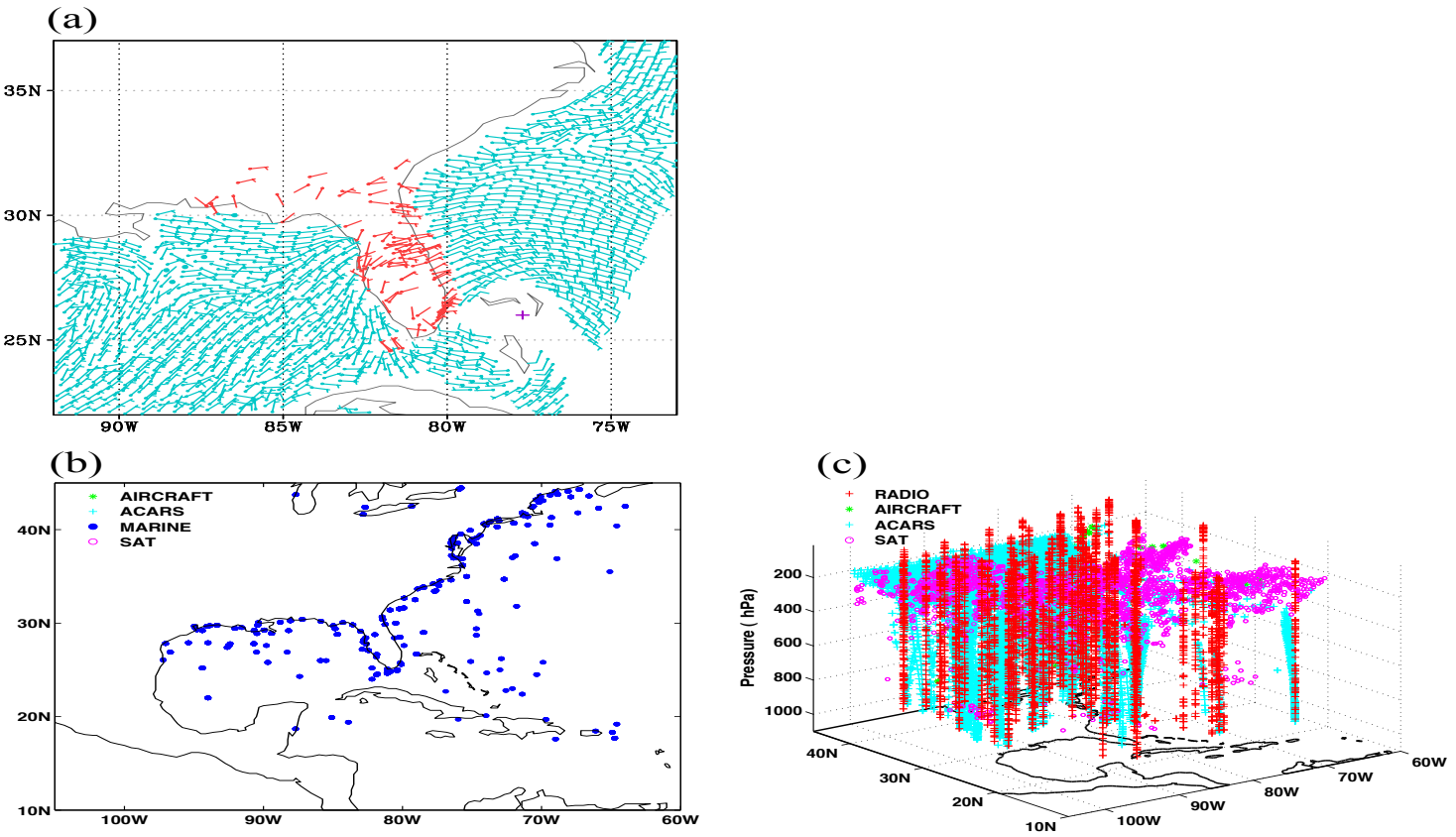




Pu, Zhang, Emmitt (2010) Geophys. Res. Lett.

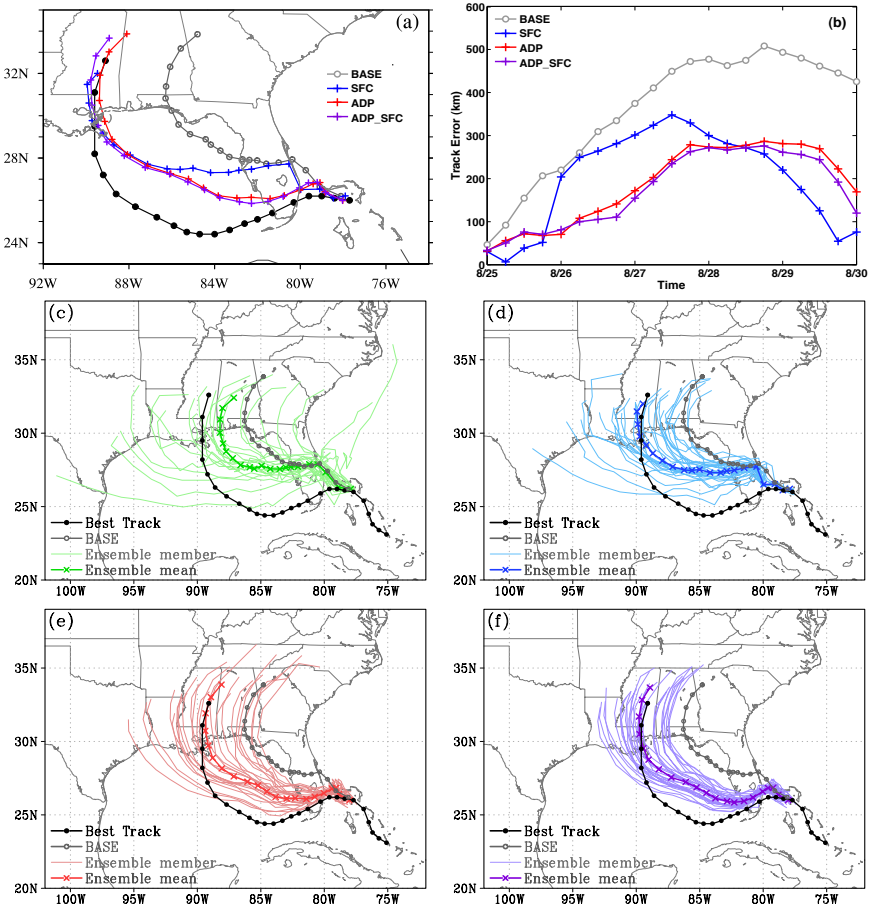
Case III

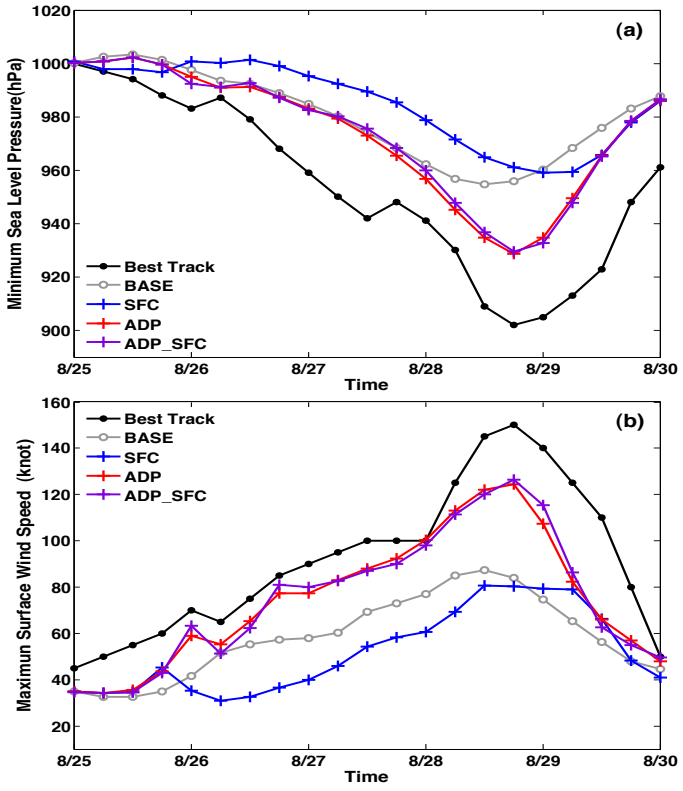
Influence of assimilating surface observations on numerical prediction of landfalls of Hurricane Katrina (2005) with an ensemble Kalman filter



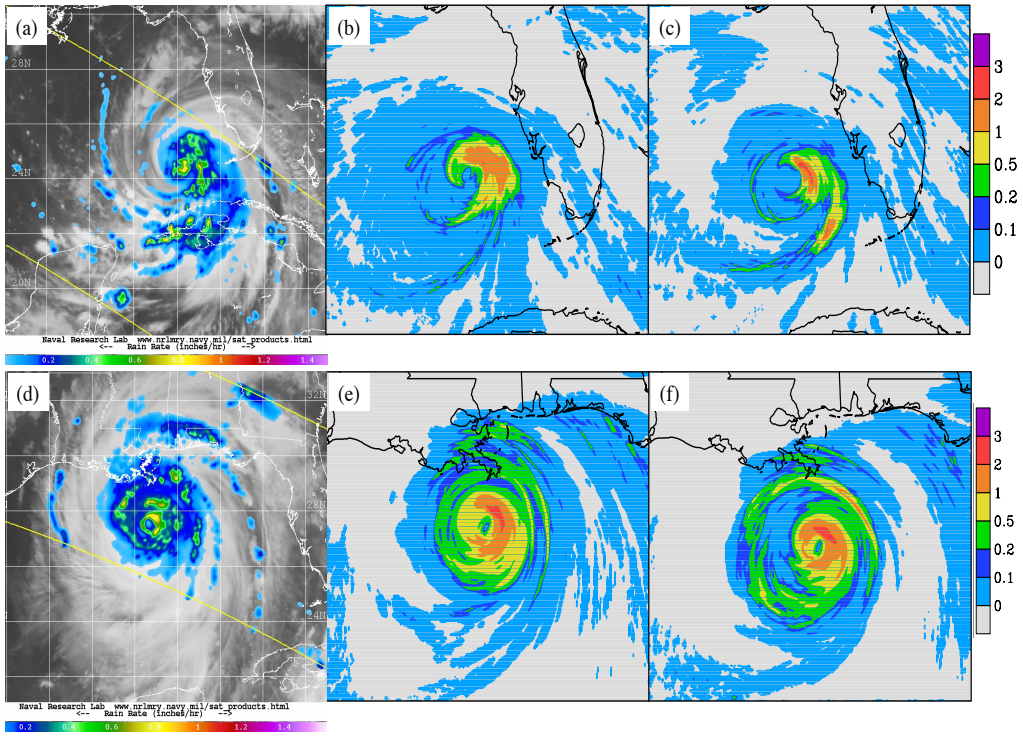
(Zhang and Pu, Mon. Wea. Rev., 2014)

Impact of surface wind obs. on track and intensity forecast of Hurricane Katrina (2005)





Influence on quantitative precipitation forecasting

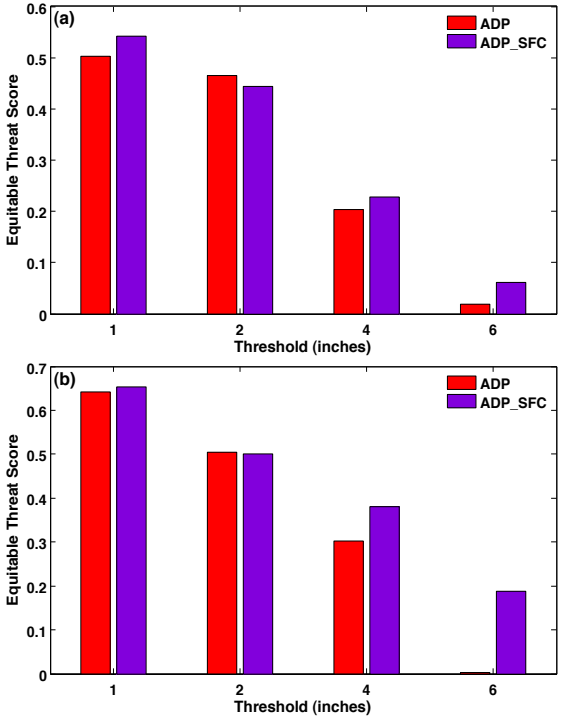


Rainfall rate at 0300 UTC 27 August (a, b, and c) and 0300 UTC 29 August (d, e, and f).

ETS scores

(a) 1200 UTC 26 August

(b) 1200 UTC 29 August

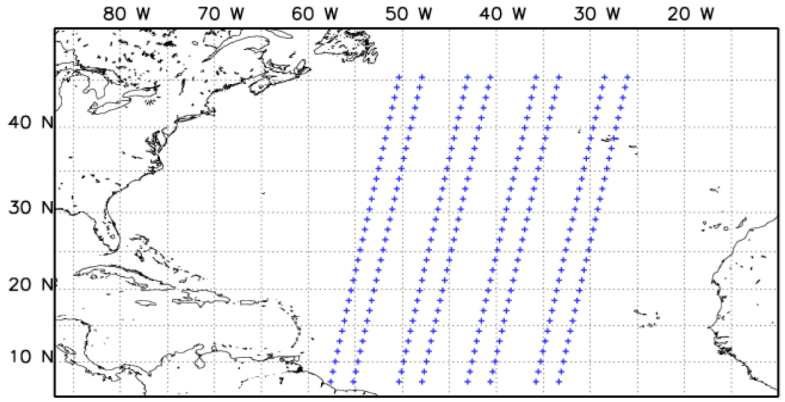


Case IV: An OSSE for space-based DWL measurements

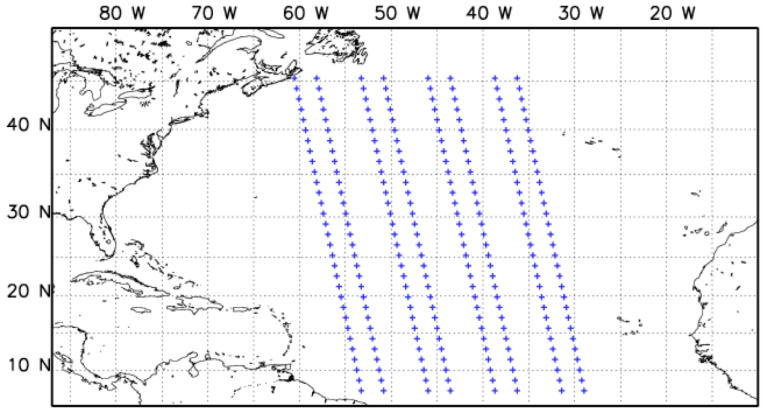
First Snapshots of the Satellite-based DWL Observations

3rd generation DWL configure (Dr. G. D. Emmitt)

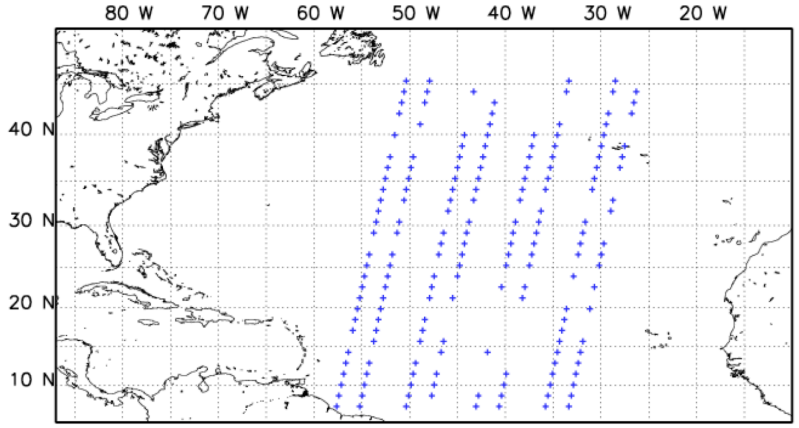
Case 1: No cloud impact



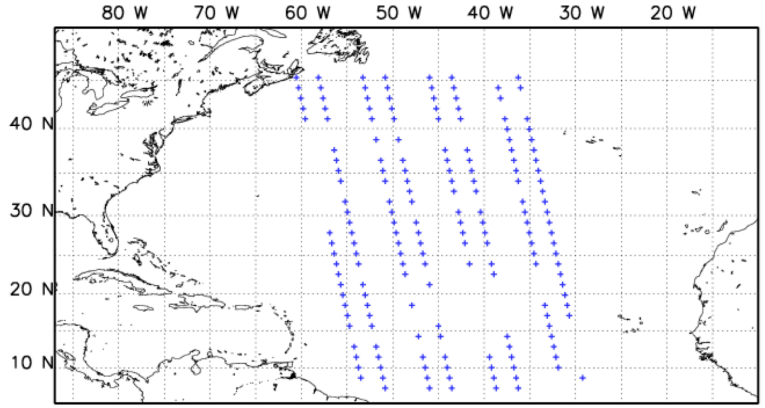
0600UTC 01 Oct. 2005



1800UTC 01 Oct. 2005



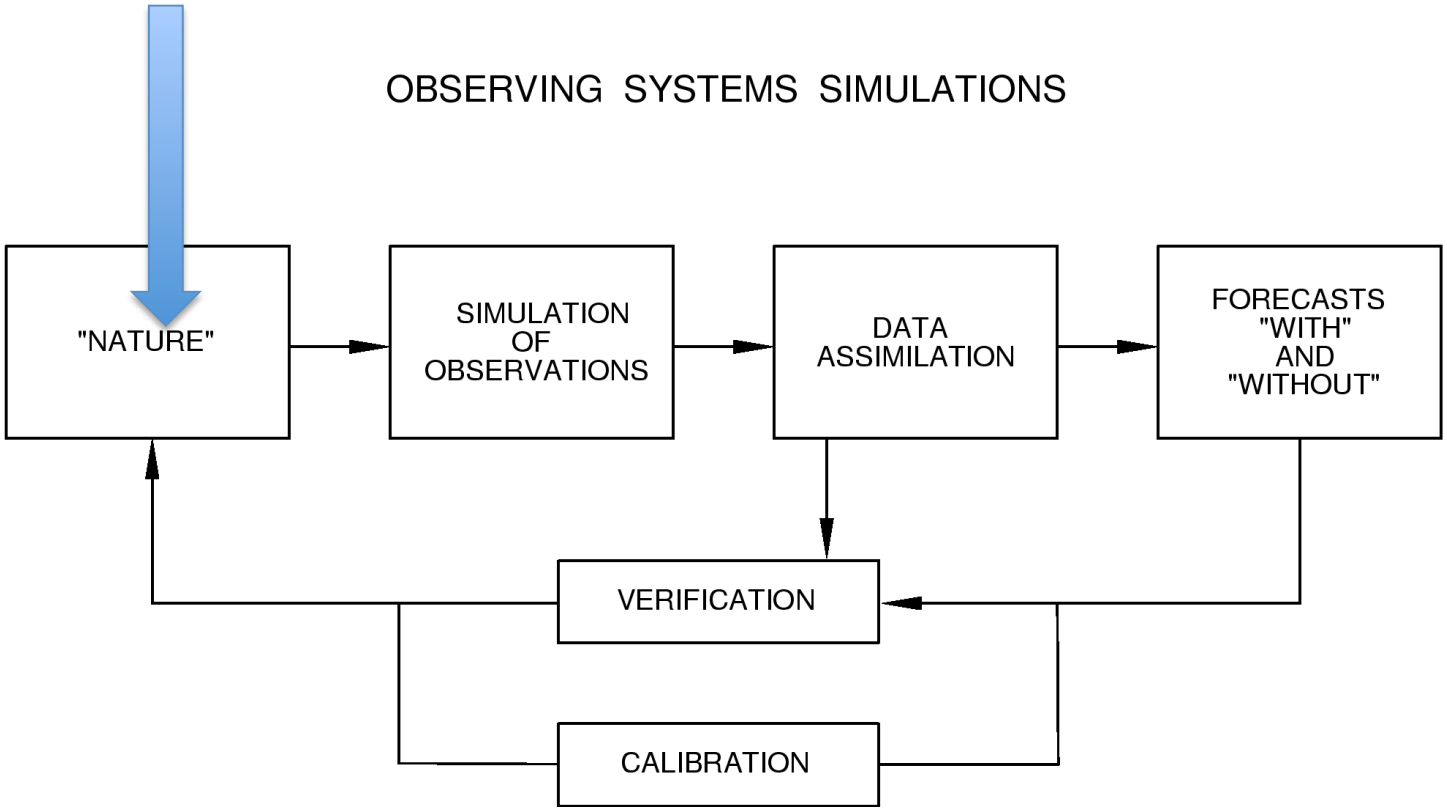
Case 2: With cloud impact



Zhang and Pu (2010) *Adv. Meteor.*

Regional OSSEs

"Regional Nature Run"



Data Impact from OSSEs

Experimental design

"Regional nature run"

- ✓ WRF 5-day forecast from 0000UTC 30 Sep. 2005
- ✓ Use **ECMWF T799 Nature Run** for generating ICs and BCs
- ✓ Lin microphysics, MYJ PBL, Betts-Miller-Janjic cumulus, RRTM longwave and Dudhia shortwave radiation.
- ✓ 27km, 9km, 3km

"Control"

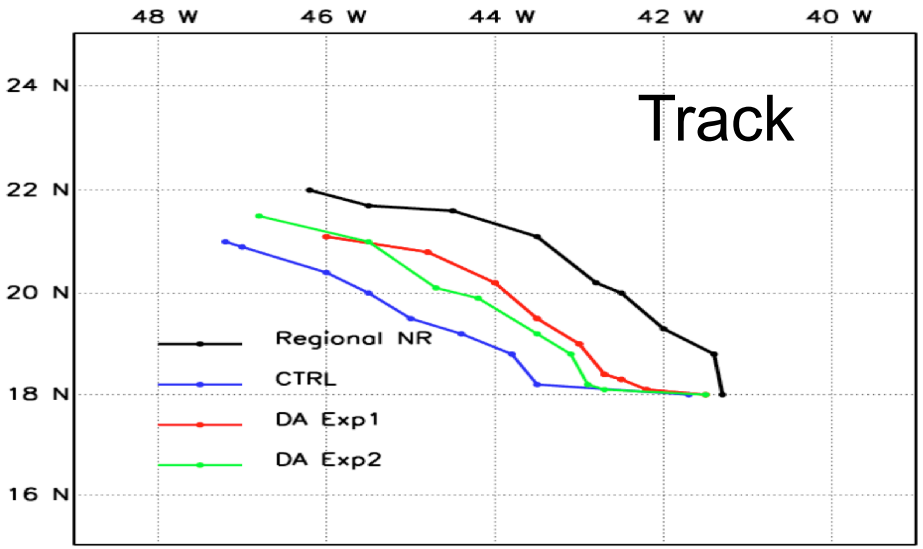
- ✓ WRF simulation with initial time at 0600 UTC 01 October 2005
- ✓ Use ECMWF T511Nature Run for generating ICs and BCs
- ✓ WSM-6 microphysics, YSU PBL, KF Grell-Devenyi ensemble cumulus, RRTM longwave and Dudhia shortwave radiation.
- ✓ 27km, 9km

"Data Assimilation Exps."

Similar to Control but assimilate data at 0600 UTC 01 October and 1800 UTC 01 October with WRF 3DVAR

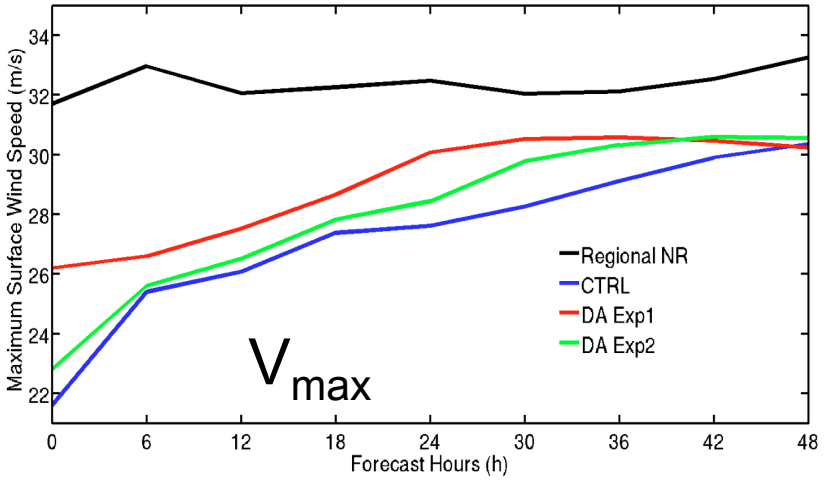
Impact of Satellite-based DWL Observations

A regional OSSE study



Impacts from assimilation of "DWL" profiles

(48-h FCST)

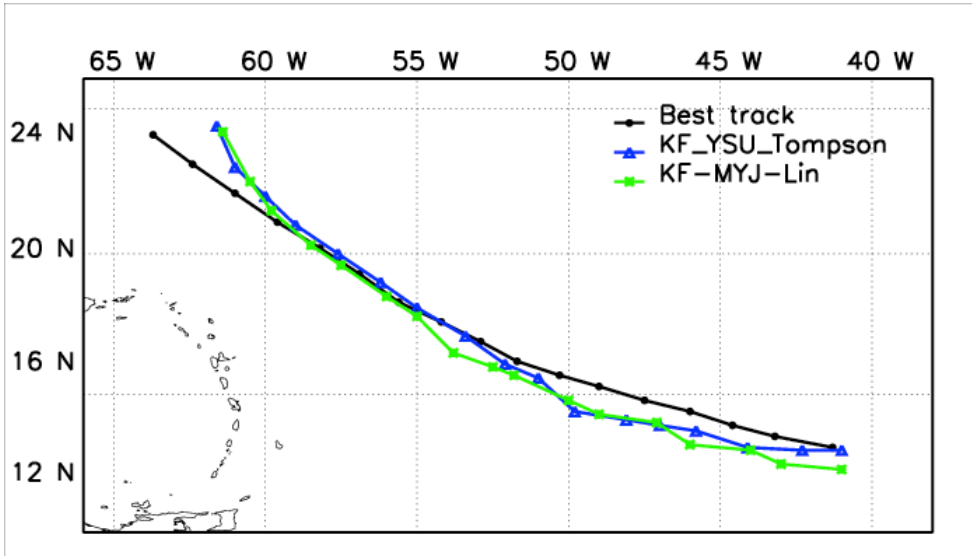


Zhang and Pu (2010)
Adv. Meteor.

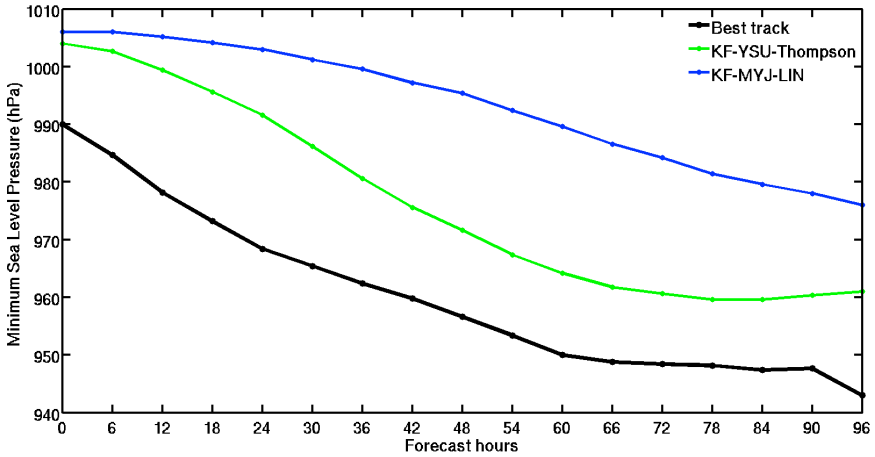
Case V: OSSE for space-based DWL with "Hurricane Bill (2009)

- Simulation period:

  00 UTC 17 Aug.----00 UTC 21 Aug. 2009



Numerical Simulations of Hurricane Bill(2009)

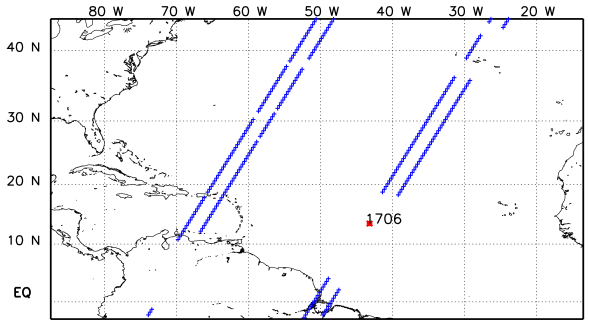


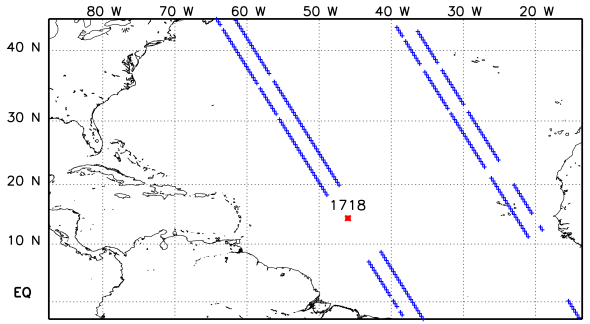
Data samples in various resolutions

0600 UTC 17 August

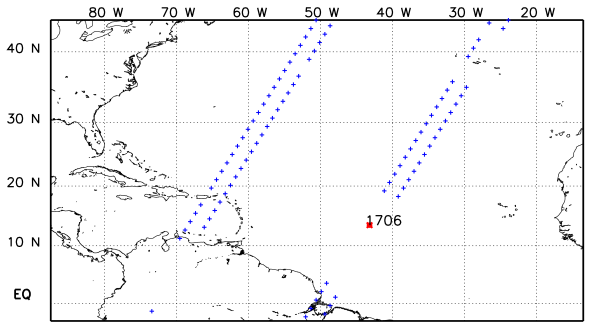
1800 UTC 17 August

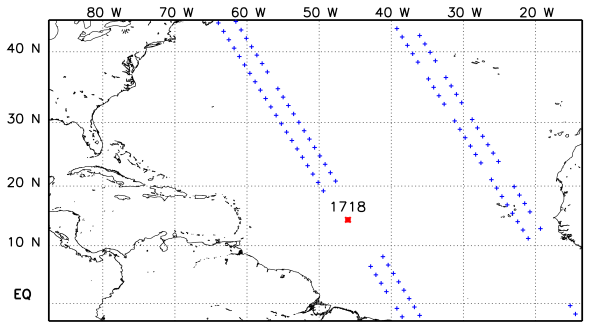
1 (60km)



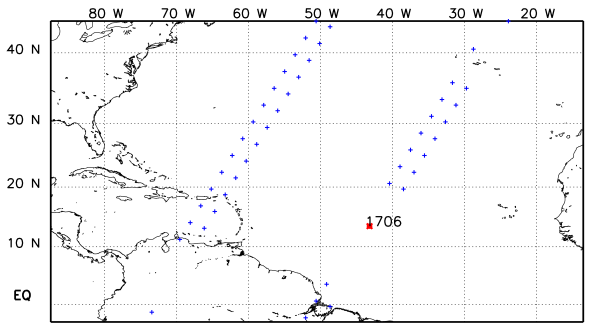


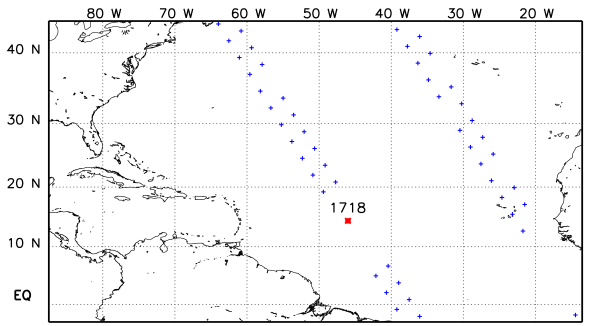
2 (120km)





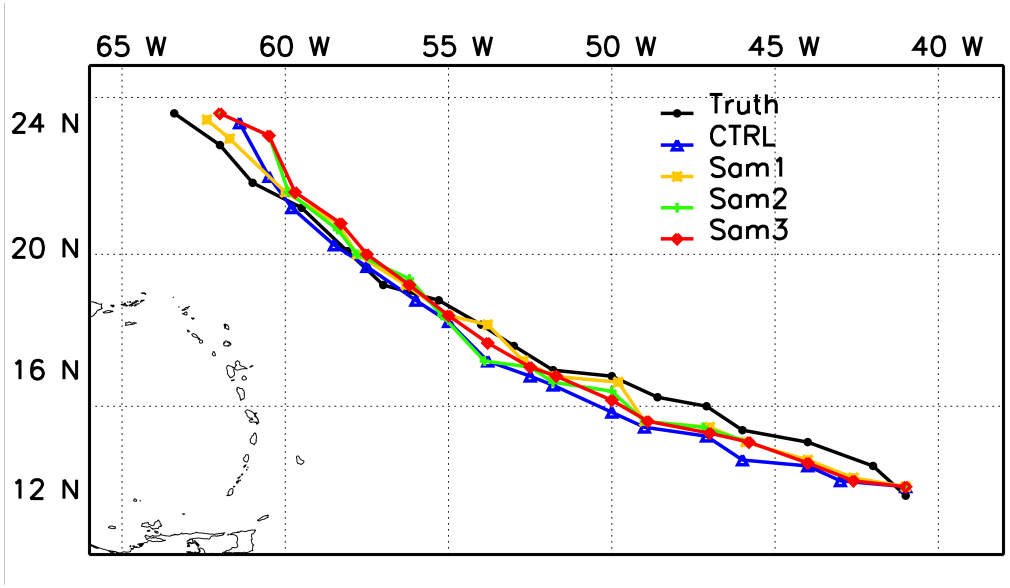
3 (180km)

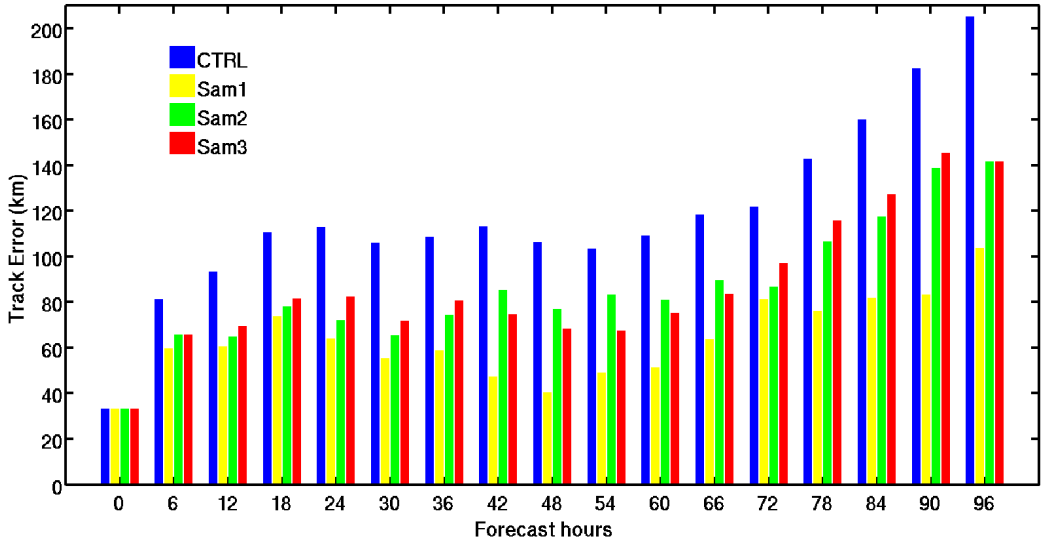




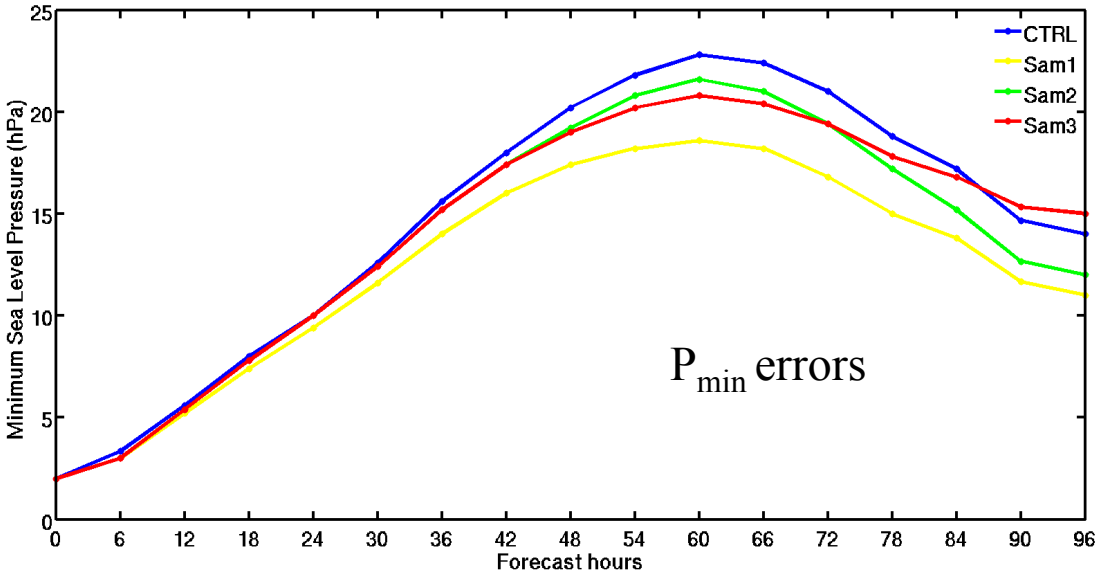
Vertical resolution: 250m below 2km; 1 km above 2km

Data impact: Track and track errors

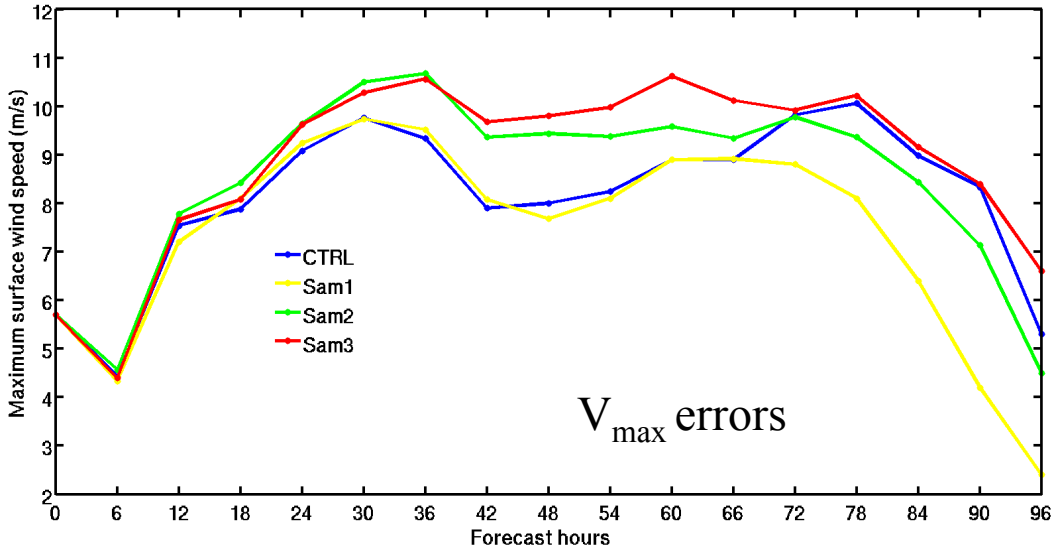




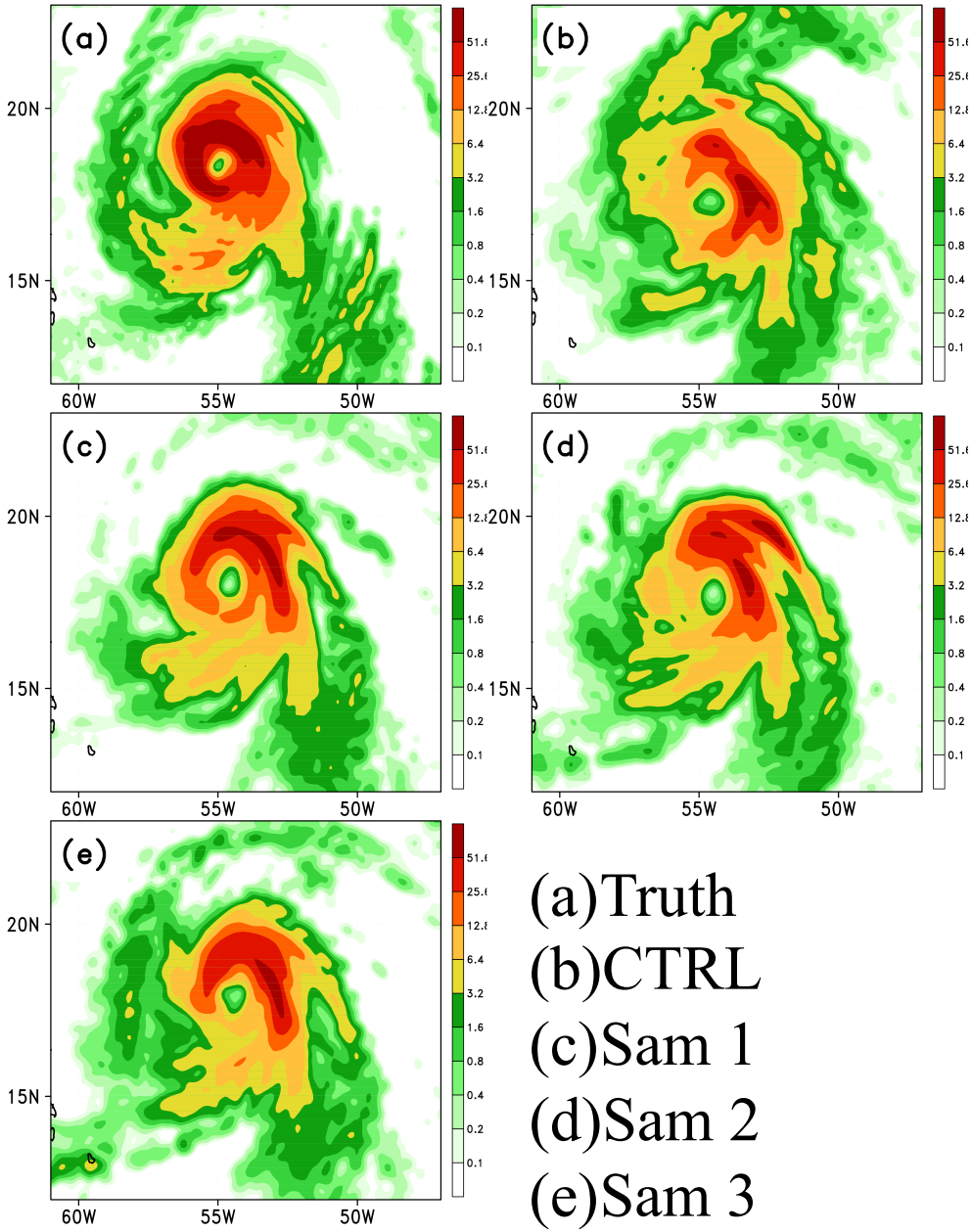
P_{min} and V_{max} Errors



High-resolution data lead to better forecasts.

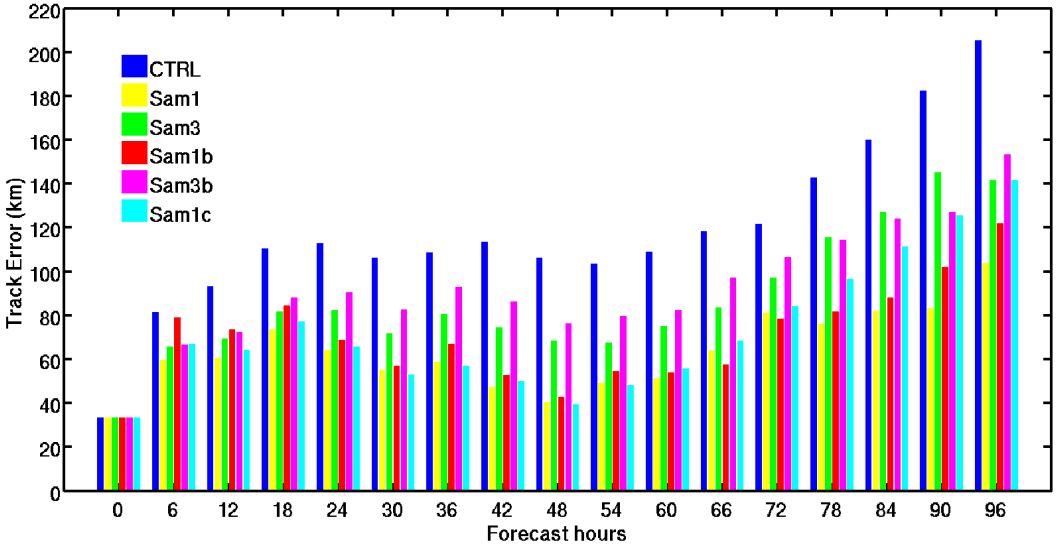


Accumulated 3-h rainfall forecasts at 1200 UTC 19 Aug.

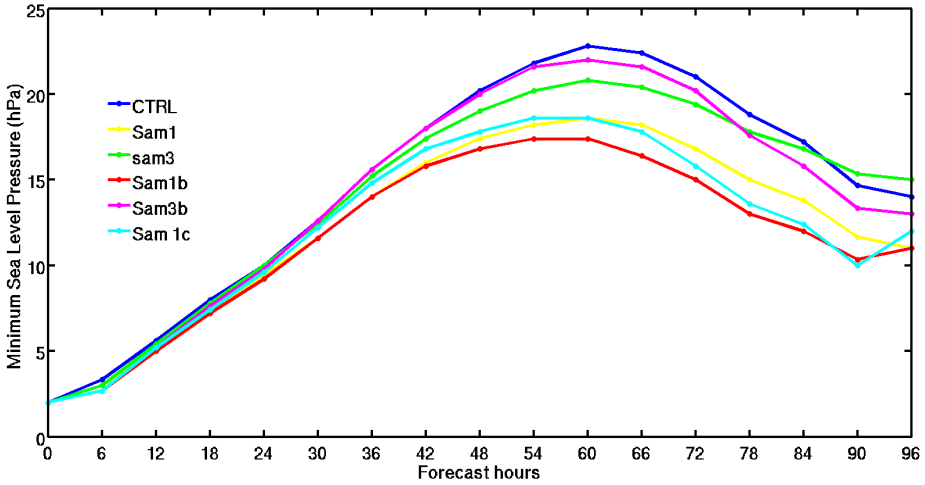


(a)Truth
(b)CTRL
(c)Sam 1
(d)Sam 2
(e)Sam 3

Impact of the observational errors: Track errors and P_{min} errors



Compared with the accurate observations at the coarser resolution, fairly good forecast impact could still be obtained from the high-resolution observations with large errors.

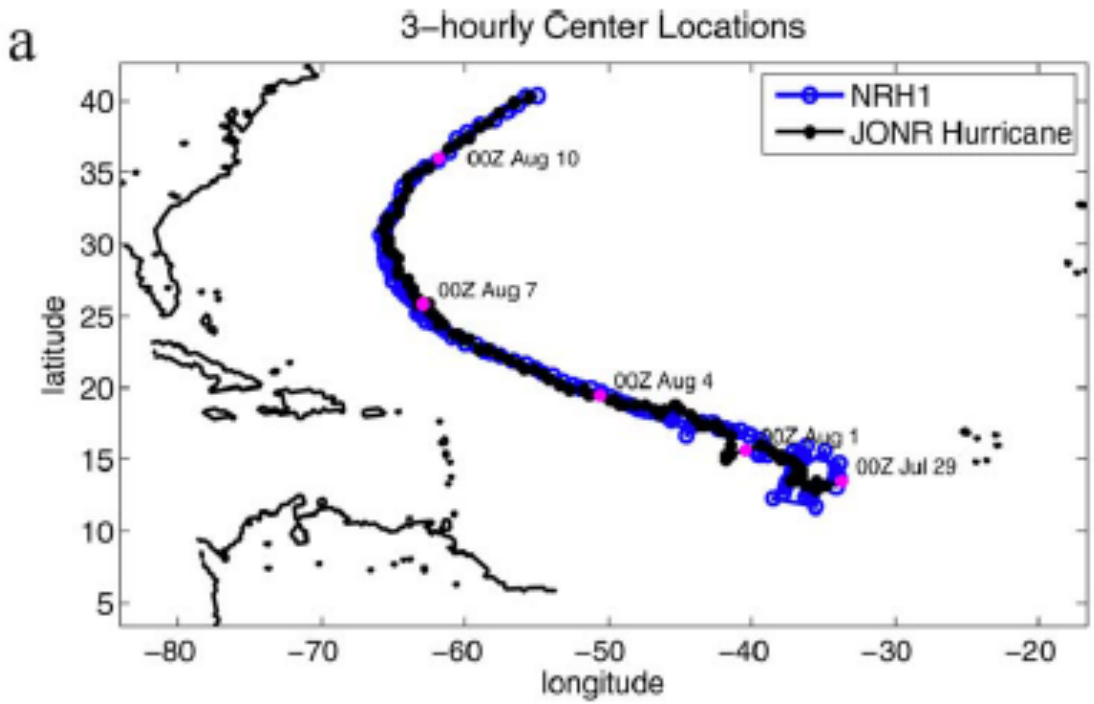


Recent update
OSSEs with NCEP HWRF and GSI

Model and Data Assimilation System

- **HWRF V3.5**
- 27km/9km/3km domains, 2-way interaction
- **GSI data assimilation system**

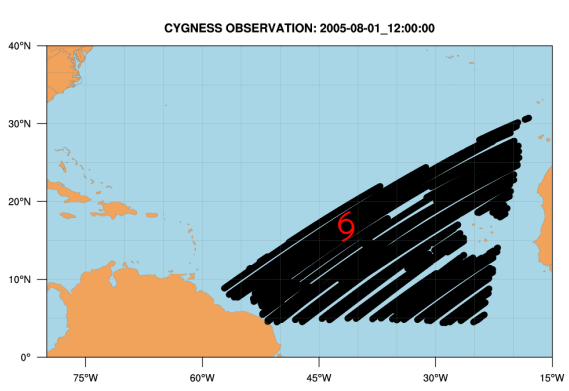
Case

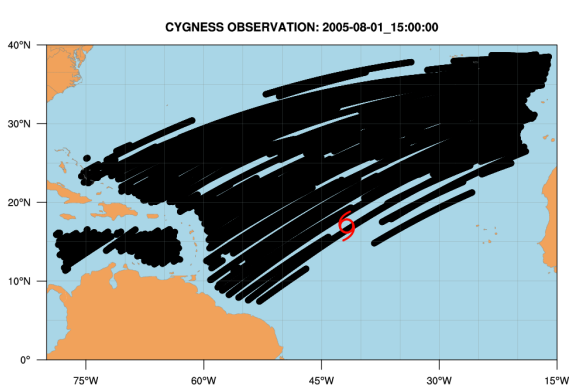


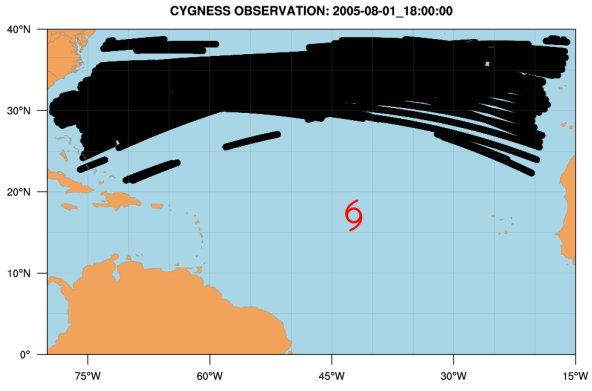
- RI stage: 00UTC 01 August---00UTC 04 August

I: RI stage [Ocean surface winds from CYGNSS team]

Data assimilation cycle: **2005-08-01-12:00:00, 2005-08-01-15:00:00, 2005-08-01_18:00:00**



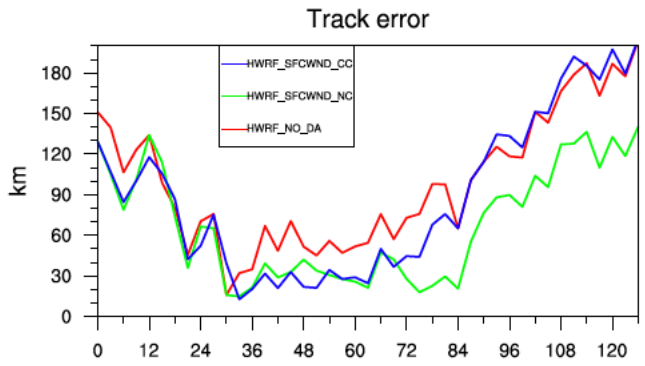


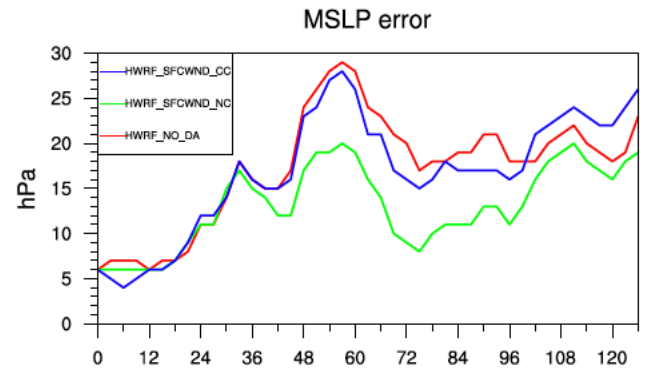


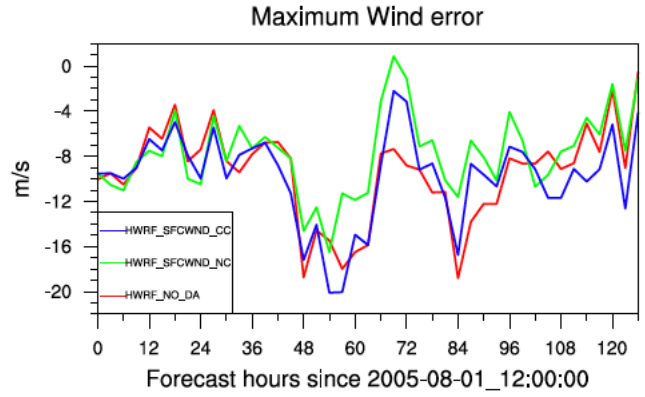
Impact of ocean surface Wind

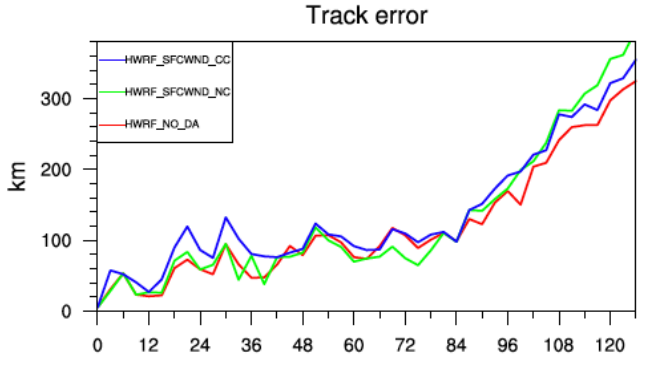
Track and Intensity Errors

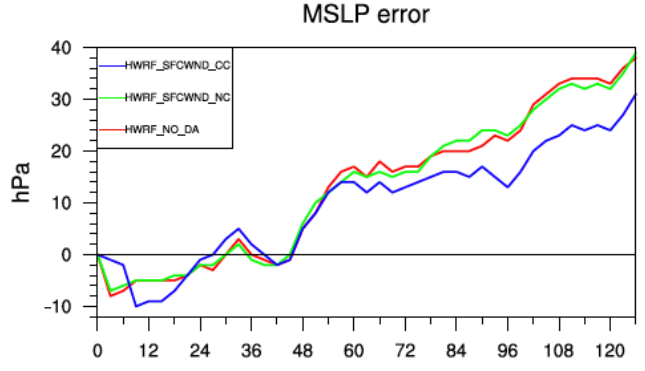
Without Relocation

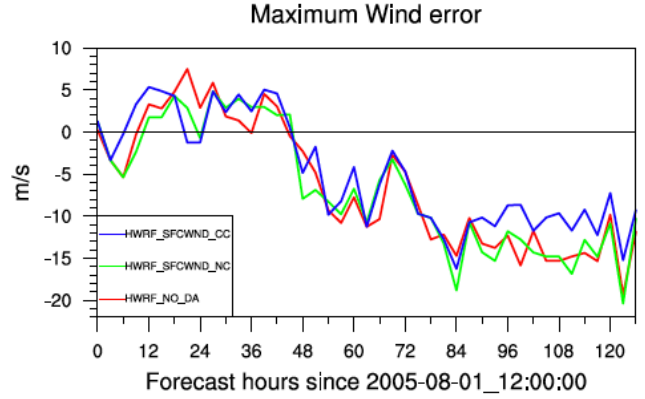










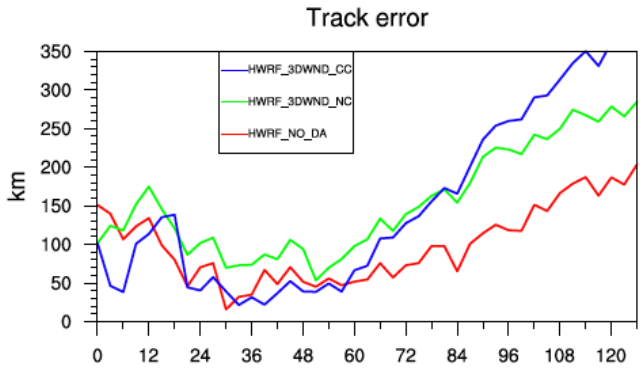


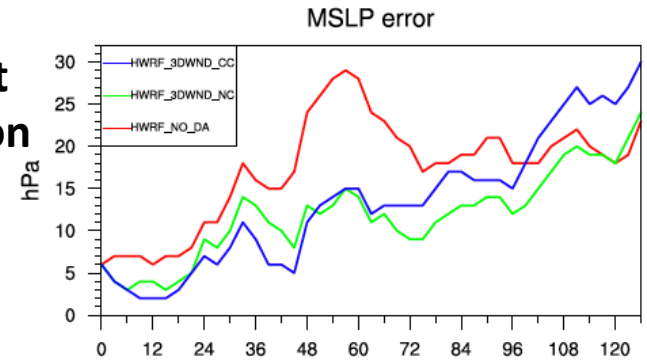
With Relocation

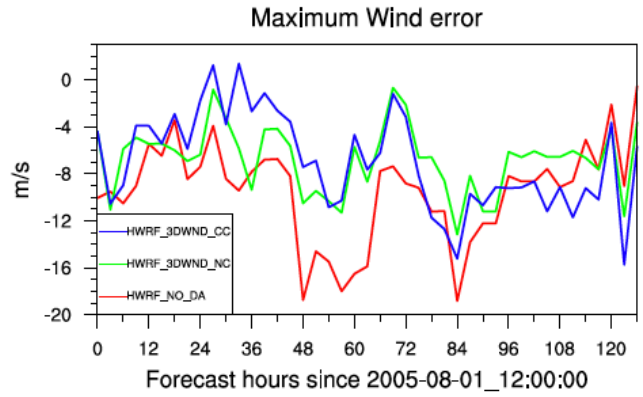
3D Wind

Track and Intensity Errors

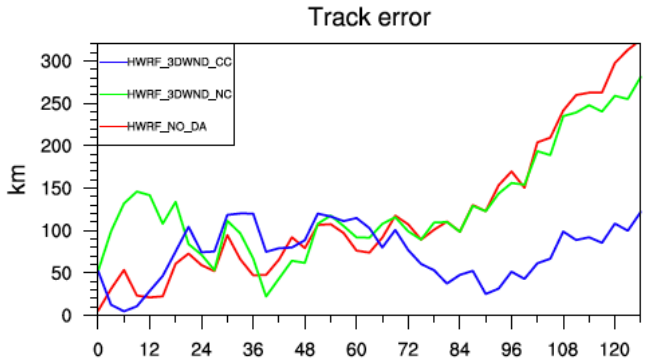
Without Relocation

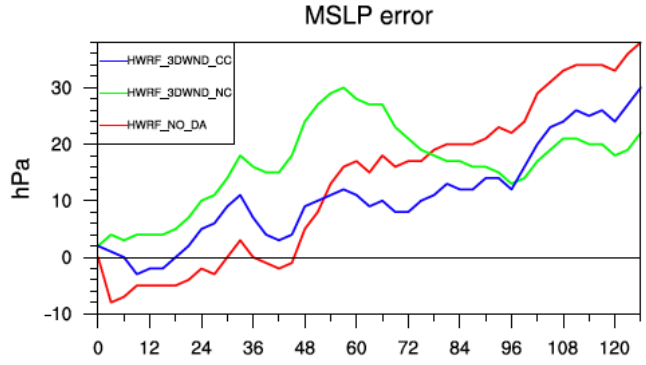


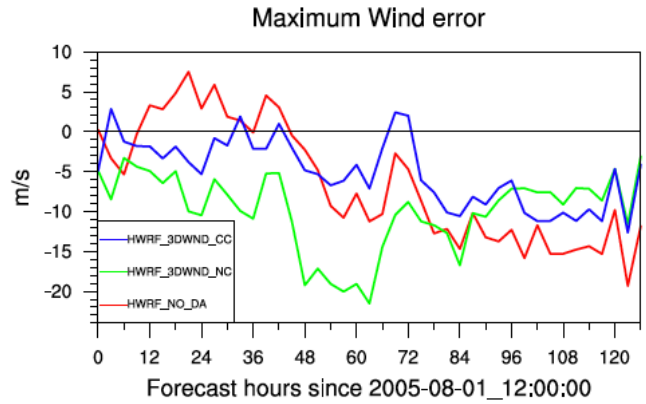




With Relocation

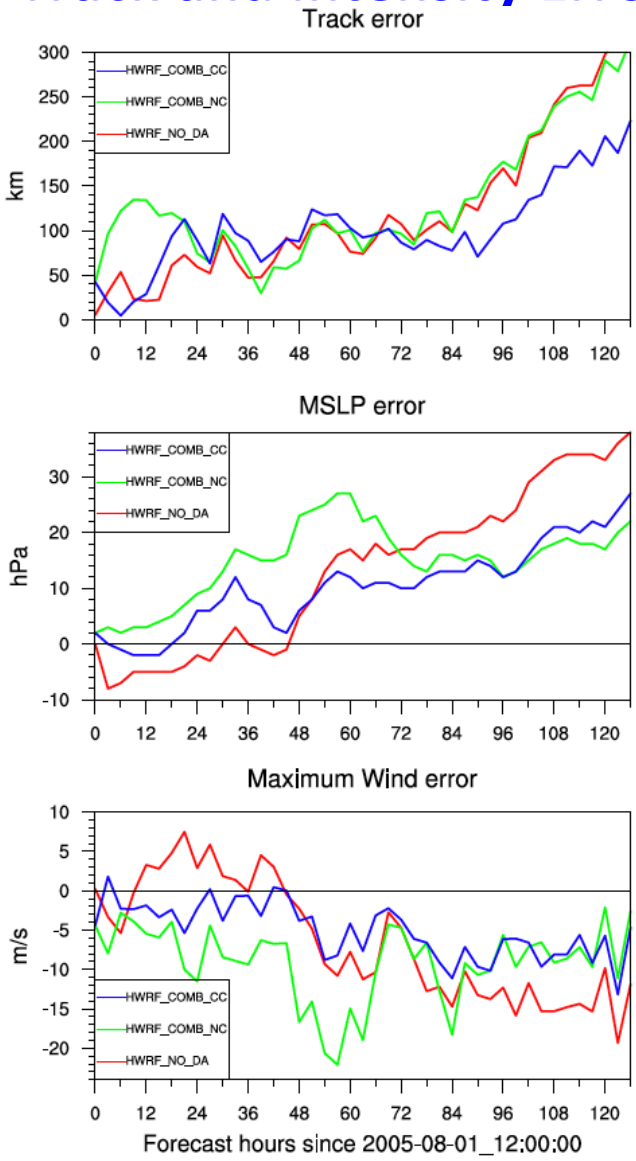






3D + surface Wind

Track and Intensity Errors



With vortex Relocation

Concluding remarks

- Both surface wind data and 3-D Doppler lidar wind profiles are helpful on improving high-impact weather forecasting

- 3-D lidar wind profiles are necessary and can be essential data sources for improving NWP skills.

- High-resolution measurement are desired

- Data assimilation with advanced research operational NWP models studies are the efficient way to demonstrate the value of DWL measurements
- OSSEs could be very helpful for design instrumentation configurations

Thanks for your attention!

Collaboration?
Contact: Zhaoxia.Pu@utah.edu