The impact of ensemble-based data assimilation on the predictability of landfalling hurricanes

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Background

- Among many recent advancements in hurricane research, few studies have emphasized landfalling hurricanes.

- Accurate representation of near surface atmospheric conditions is important but uncertain in many numerical weather prediction (NWP) models.

- Assimilating surface observations in NWP models has been a problem.

- Recent studies (e.g., Pu et al. 2013, Tellus A) demonstrated that ensemble Kalman filter (EnKF) handles surface data assimilation well.

Objectives

- Examine the impact of surface observations (QuikSCAT ocean surface vectors and surface Mesonet observations over land) on the predictability of landfalling hurricanes.

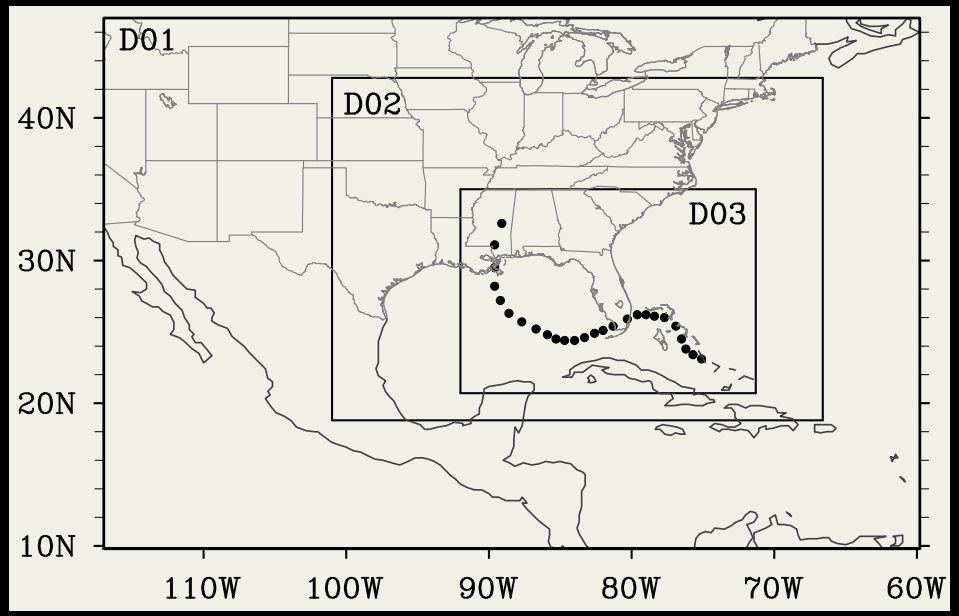
- Evaluate the relative impact of surface observations, compared with conventional and radar observations.

Model, Data Assimilation System and Observations

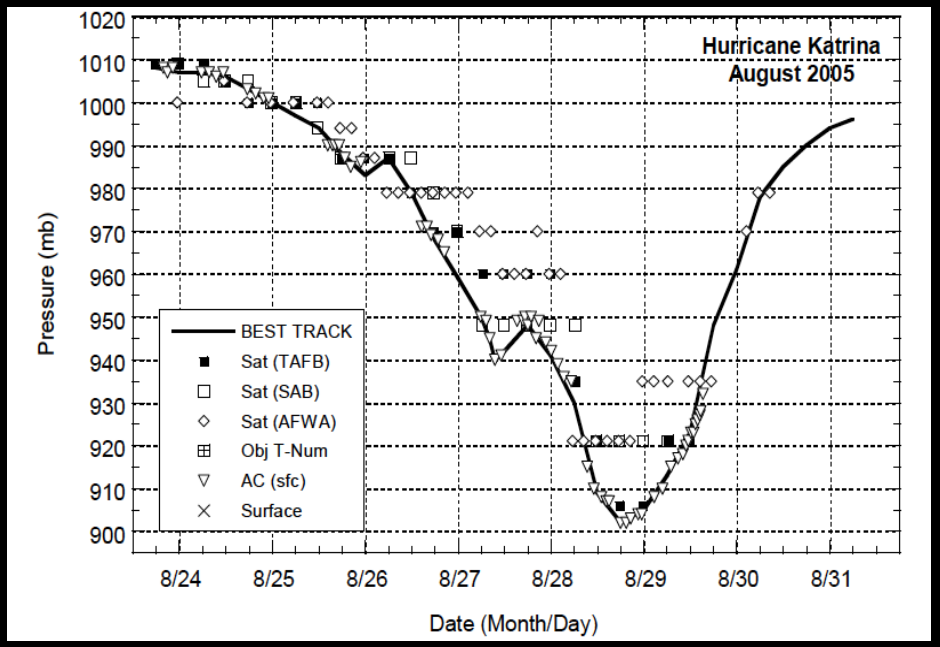
- An advanced research version of Weather Research and Forecasting (WRF ARW) model, triple nested domain (27/9/3km), *Skamarock et al. 2008*

- DART/WRF--- NCAR Data Assimilation Research Testbed (DART) ensemble Kalman filter (EnKF) system, *Anderson et al. 2009*
- **Observations**
  - TC position, Minimum sea level pressure (from NHC best track)
  - QuikSCAT satellite sea surface wind vectors and Mesonet surface wind vectors over land
  - Airborne Doppler radar derived wind components obtained from NOAA Hurricane Research Division (HRD)
  - NCEP ADP observations in Bufr format

Case: Hurricane Katrina (2005)



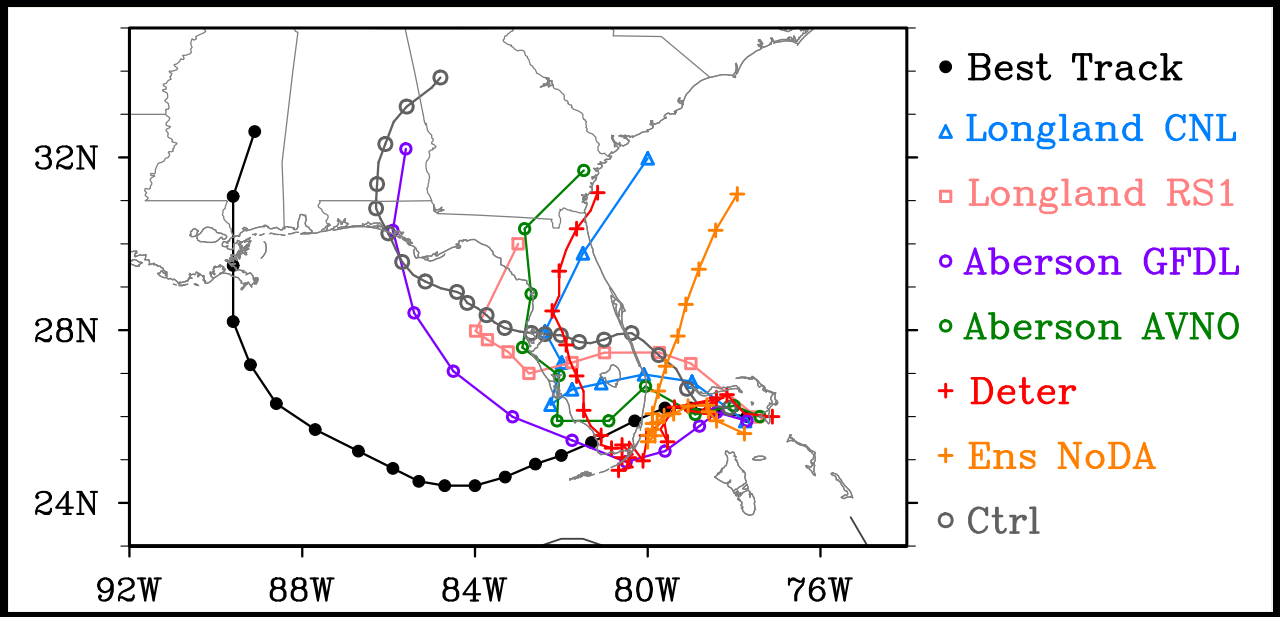
- Katrina was identified as a tropical storm at 1200UTC 24 and a hurricane at 0000UTC 26 August.
- First landfall: 0000UTC 26 August at south Florida.
- Second landfall: 1200UTC 29 August at Louisiana.



- Two rapid intensifications
- Minimum sea level pressure of 902 hPa at 1800 UTC 28 August

Knabb et al. 2005

Poor predictability from 0000 UTC 25 August 2005



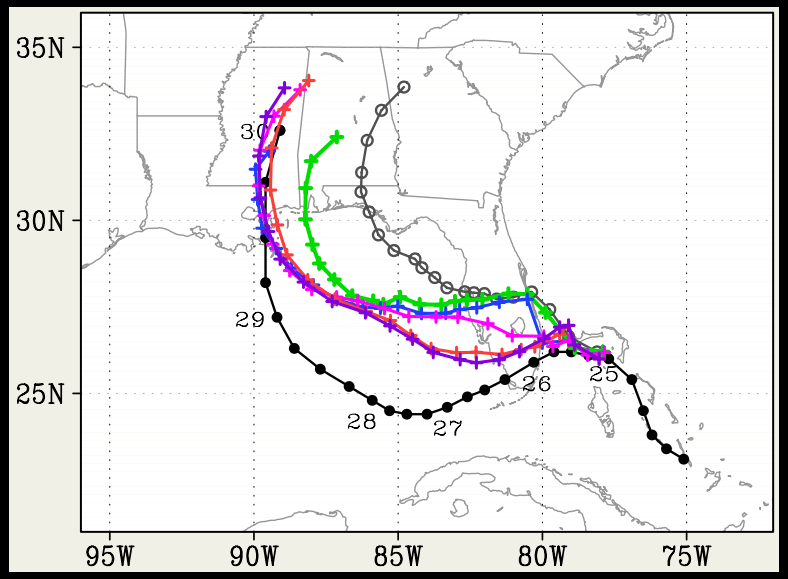
- Longland et al. 2009; Aberson 2010
- WRF simulation initialized from NCEP GFS
- All the track forecasts show significant errors

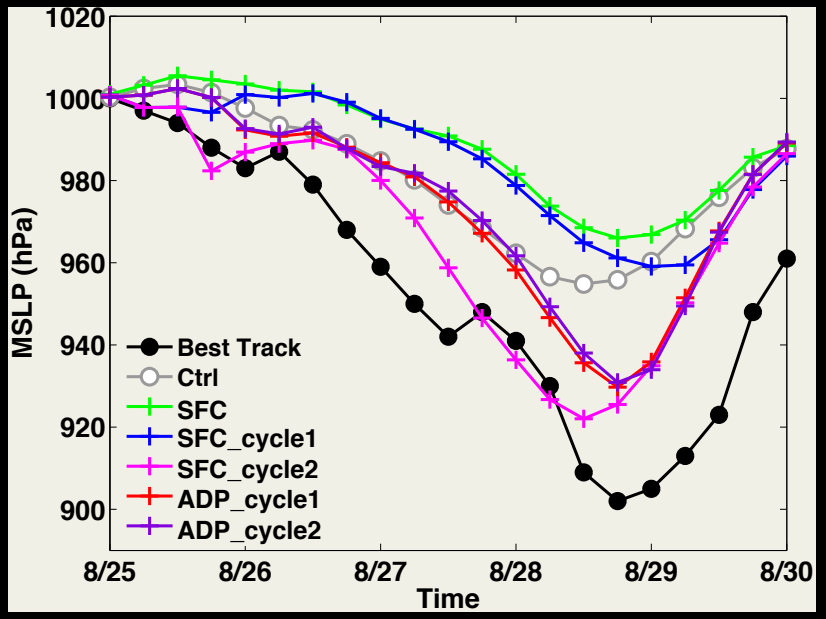
- Forecasts were improved with WRF assimilation of minimum central sea level pressure (Ctrl)

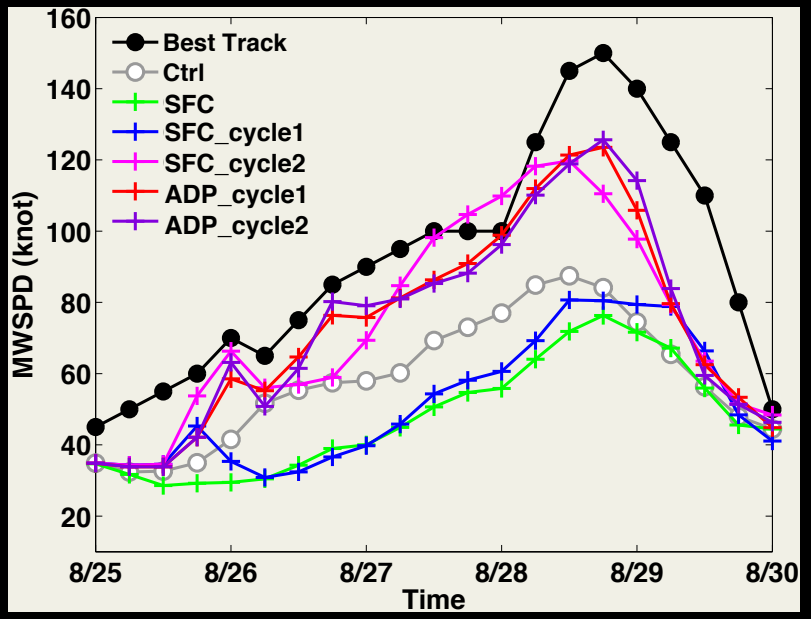
Data assimilation experiments

	Observation types	Observation time August 25 2005
Ctrl	Minimum sea level pressure	0000UTC
SFC	QuikSCAT/Mesonet	0000UTC
SFC_cycle1	QuikSCAT/Mesonet	0000UTC - 1800UTC
SFC_cycle2	QuikSCAT/Mesonet /Radar u and v components	0000UTC - 1800UTC
ADP_cycle1	NCEP ADP	0000UTC - 1800UTC
ADP_cycle2	NCEP ADP QuikSCAT/Mesonet	0000UTC - 1800UTC

Impact of data assimilation - Track and Intensity

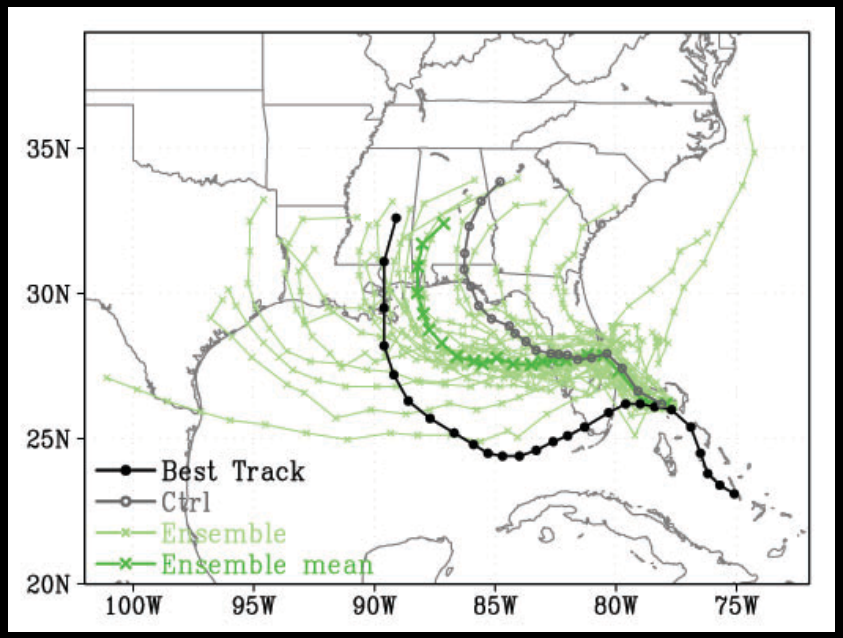




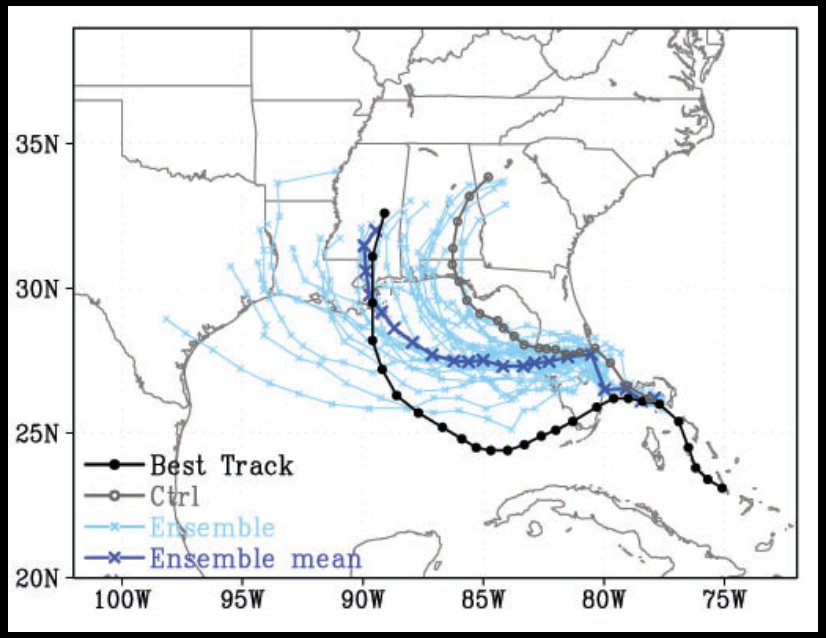


Impact of surface observations

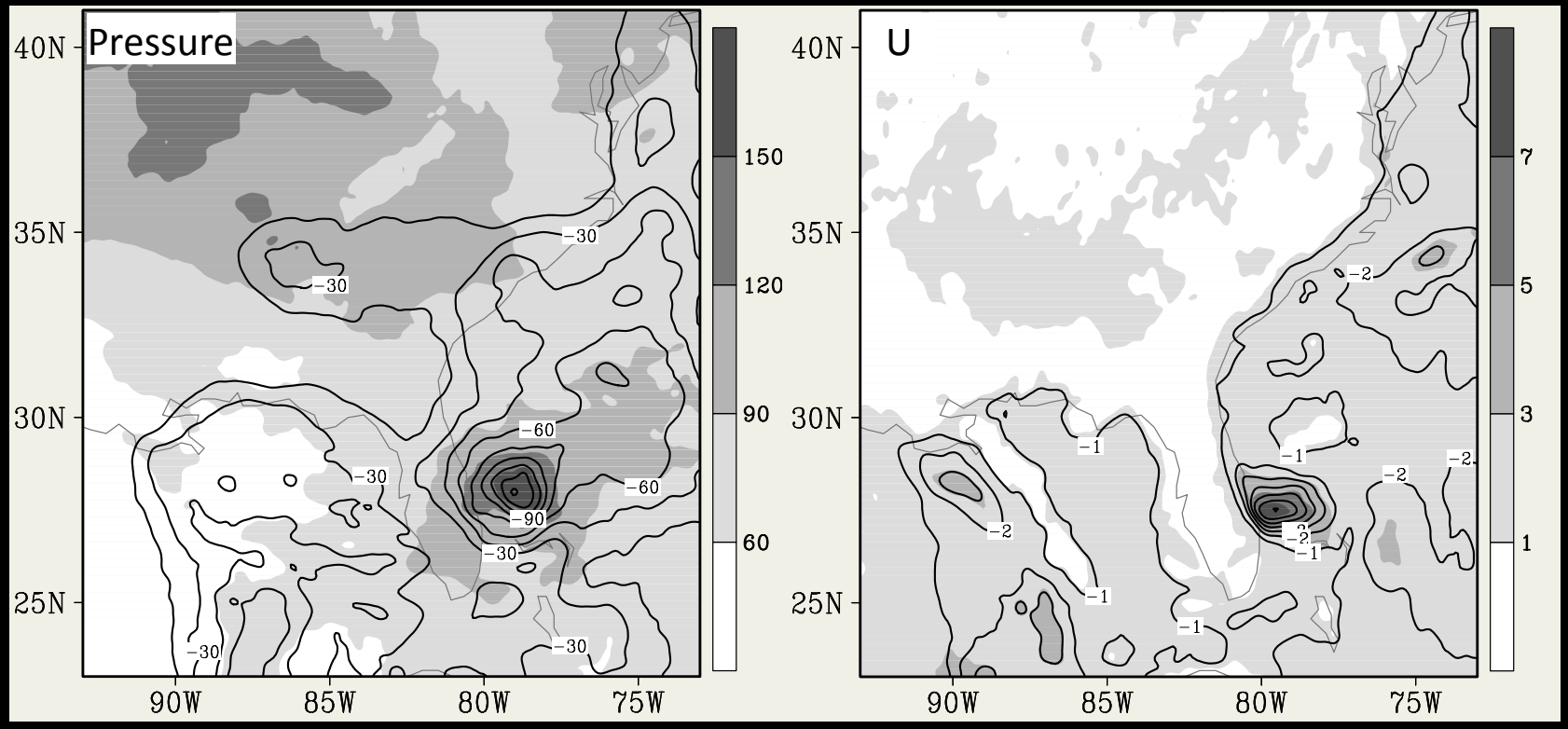
SFC



SFC_cycle1



Prior spread (shaded) and analysis increment of spread (contours)

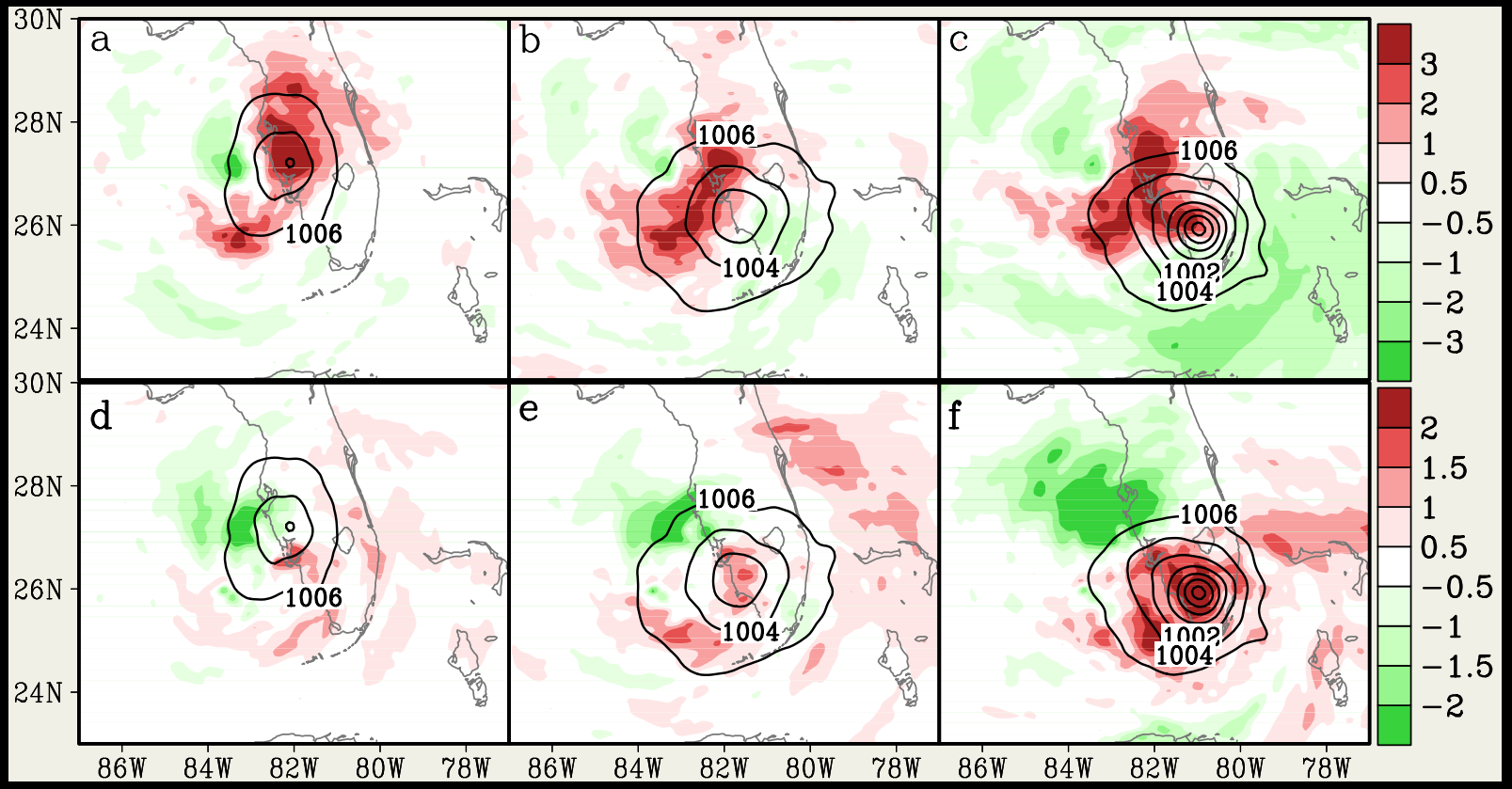


Impact on temperature – (12 h Exp-CTRL)

SFC_cycle1 SFC_cycle2 ADP_cycle2

700hPa

500hPa

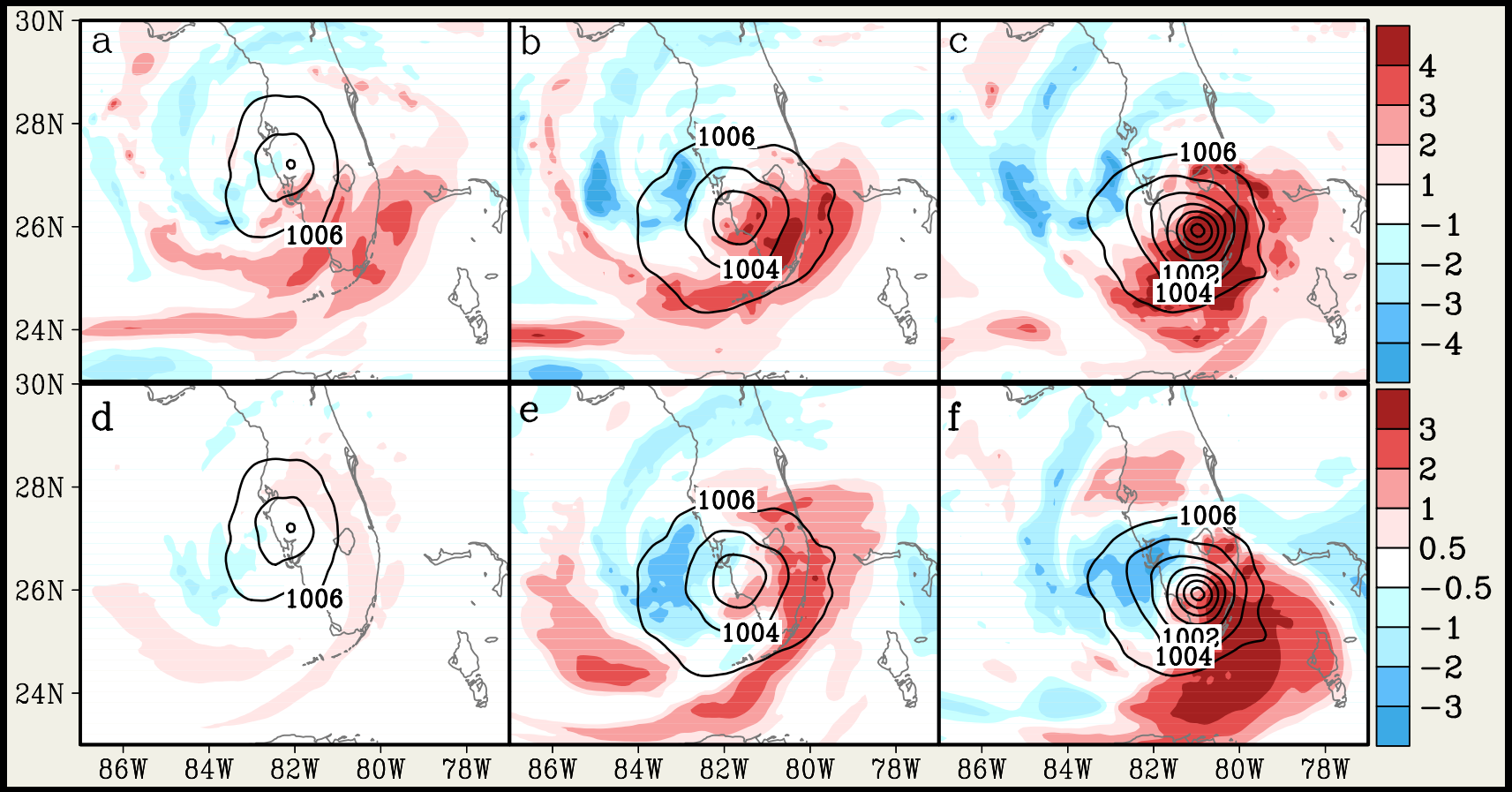


Impact on moisture field – (12 h Exp-CTRL)

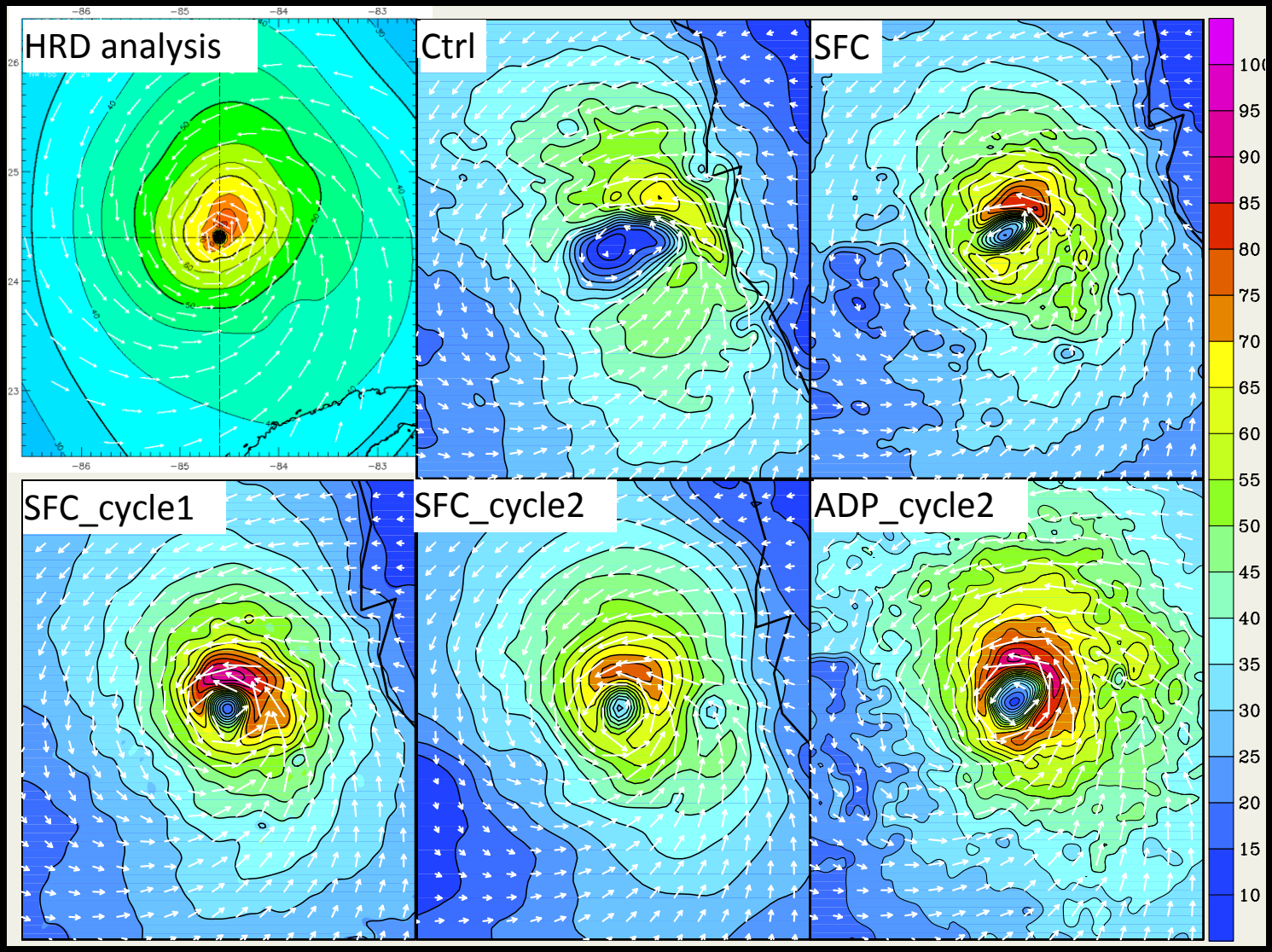
SFC_cycle1 SFC_cycle2 ADP_cycle2

700hPa

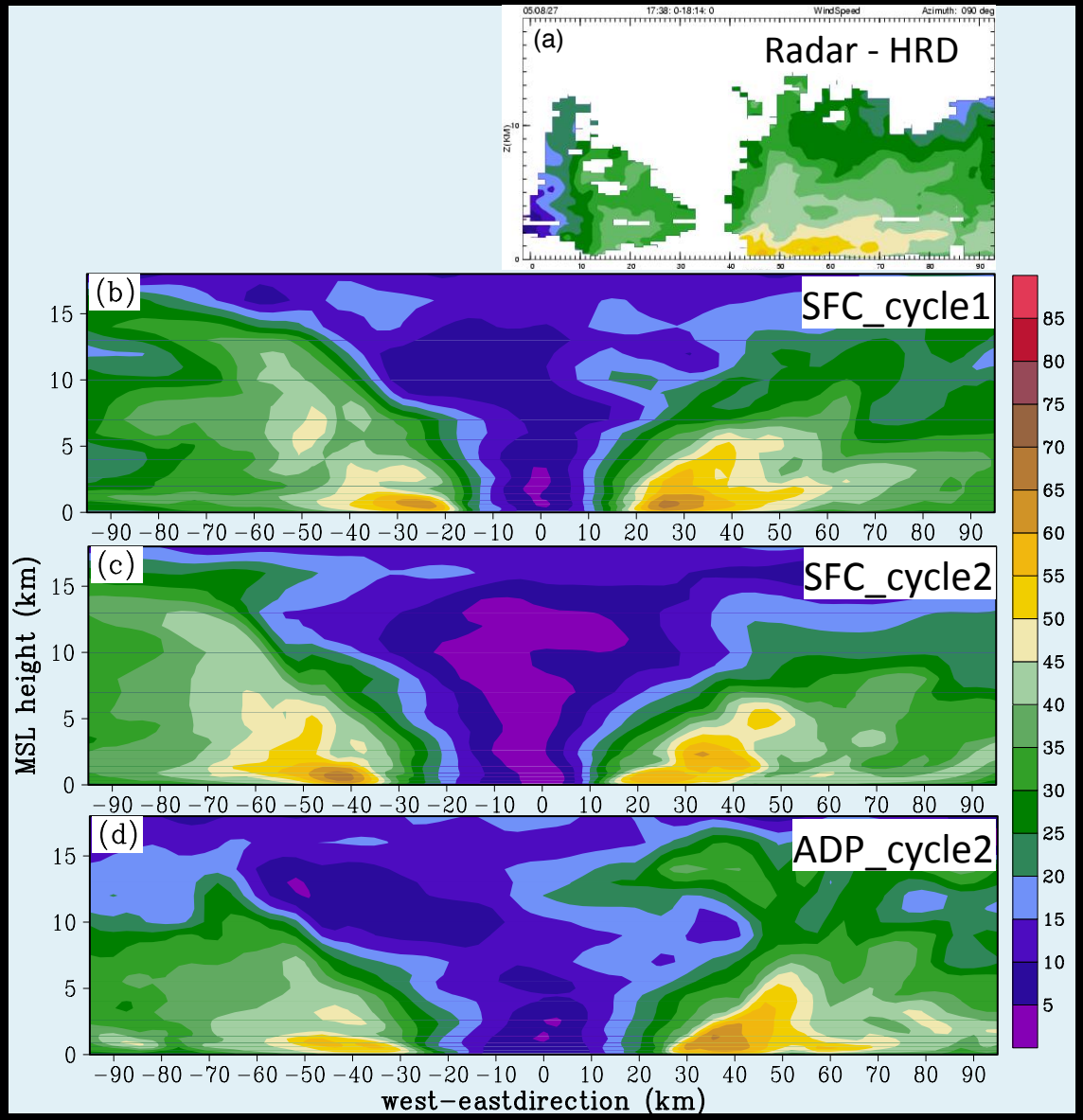
500hPa



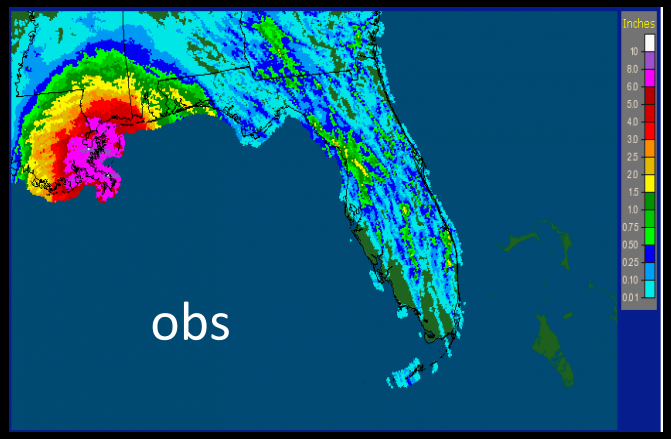
Surface wind structure at 1200UTC 27 (60 h)

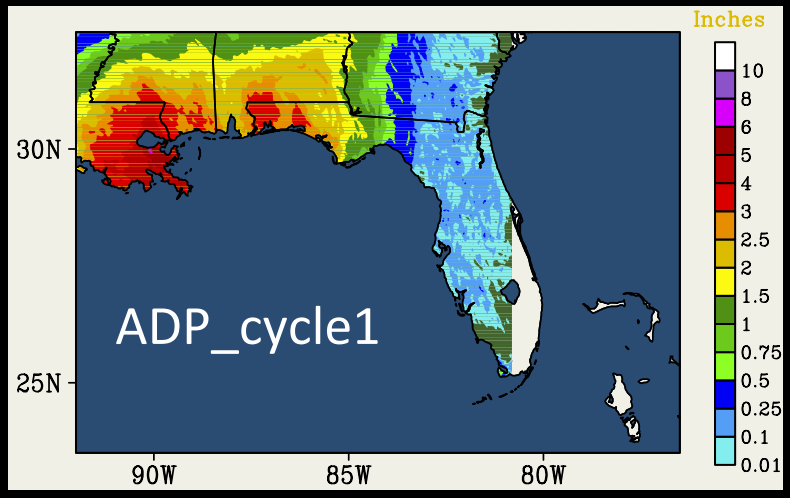


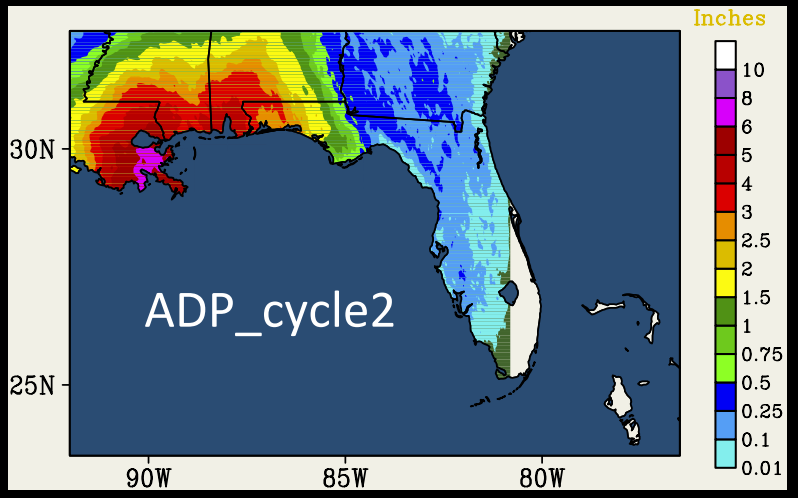
Cross section of wind speed at 1800UTC 27 (66h)



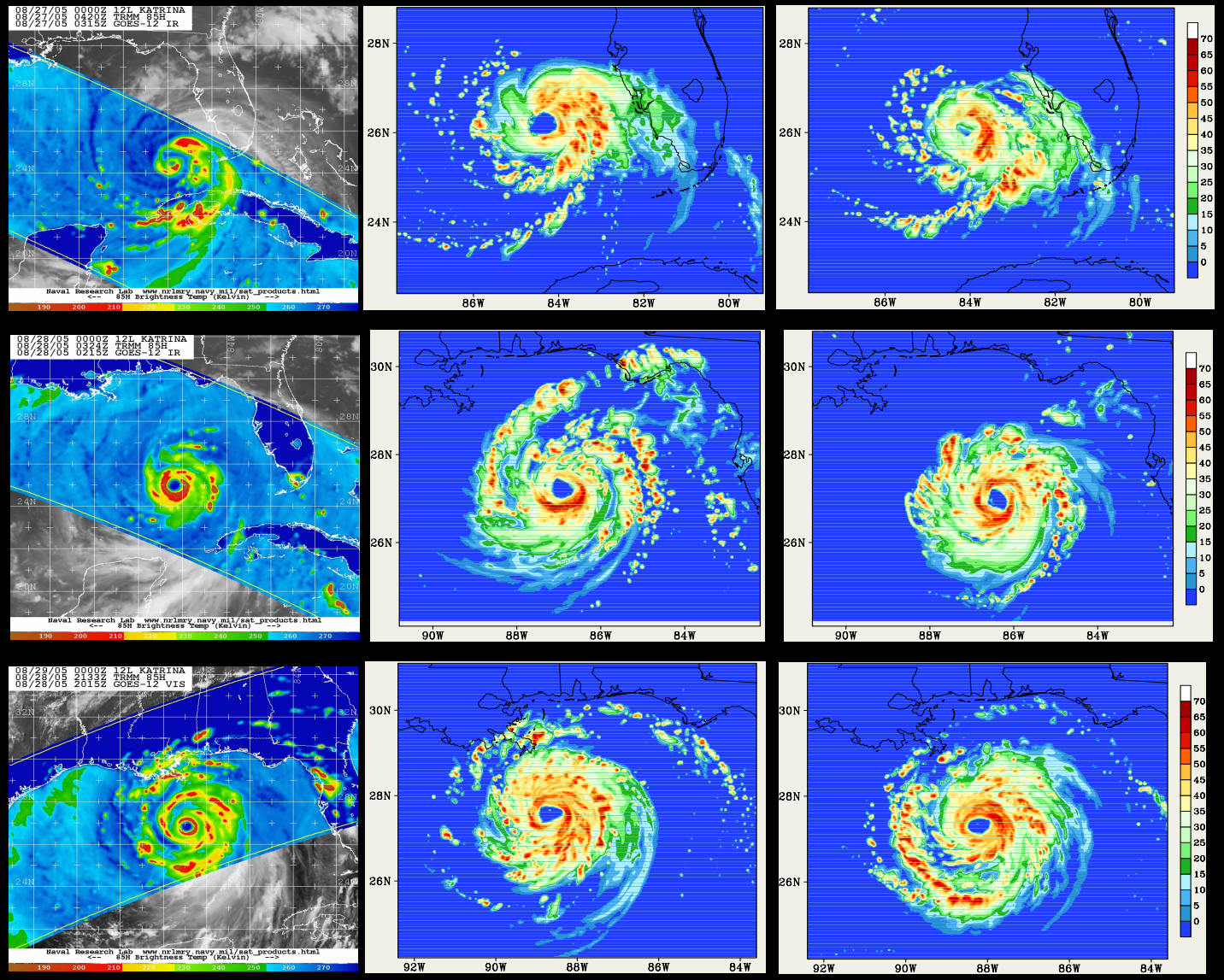
Daily accumulated precipitation
12UTC 29 August







Simulated radar reflectivity



Satellite imagery
NRL_TC page

ADP_cycle1

ADP_cycle2

Summary

- Ensemble-based data assimilation has great potential for improving the predictability of landfalling hurricanes

- The assimilation of surface observations helps
  - Modify the surface wind fields
  - Refine the low and mid-level temperature and moisture fields
  - Enhance the low-level convergence and vorticity
  - Organize the storm structure and improve the track forecast

On-going work

- Near real-time research experimental forecasting capability

- Support basic research

- Understanding of predictability of landfalling hurricanes
- Interaction between landfalling hurricanes and the atmospheric boundary layer

- Support graduate/undergraduate education

Acknowledgements

- National Science foundation
- Office of Naval Research
- NOAA Tjet computing resources through HFIP

Zhang, H. and Z. Pu, 2013: Impact of surface observations on the predictability of landfalls of Hurricane Katrina (2005) with ensemble-based data assimilation. *Mon. Wea. Rev.*, Submitted.