Assimilation of Doppler Wind Lidar (DWL) Wind Profiles for Improved Severe Weather Forecasts

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Background

Winds = Dynamics of Atmosphere
Winds = Primary driver of evolution of atmosphere

Wind data available in weather/climate analysis

- Radiosonde
- Satellite-derived atmospheric motion vectors (AMVs)
- Radar radial velocity
- Ocean surface winds from the satellites (e.g., CYGNSS, ASCAT)
- Surface or local measurements from some special networks and field campaigns

There is a lack of wind profile measurements

Significant efforts and development have been devoted for potential space-based wind mission by US scientists.

Baker et al. (2014) BAMS

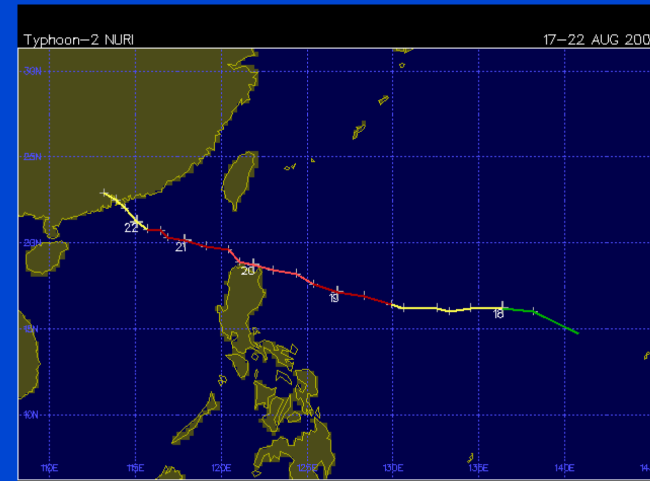
In this talk

- Summarizes studies we have been done to explore the options and influences of wind profile measurements on numerical prediction of high-impact weather systems
  - Data assimilation and observing system simulation experiments (OSSEs) using ground, airborne, and satellite-based Doppler Wind Lidar (DWL) platforms for more than a decade

- Results from recent data impact study with DAWN wind profiles during NASA Convective Processes Experiment (CPEX)

- Concluding remarks and ongoing work

Airborne DWL profiles, collected during TPARC/TCS-08 from ONR P-3



Life cycle: 17Aug – 22 Aug 2008

Case

Typhoon Nuri over the Western Pacific

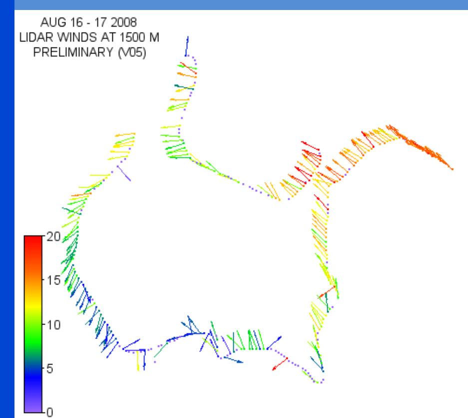
Typhoon Nuri

- Wind profiles with 50 m vertical and 1 km horizontal resolution

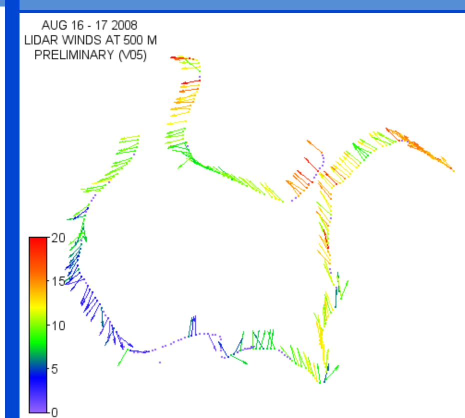
Time period of data

2330UTC 16 August to 0200UTC 17 August 2008 (about 3-h)

P3DWL winds at1500m



P3DWL winds at 500m

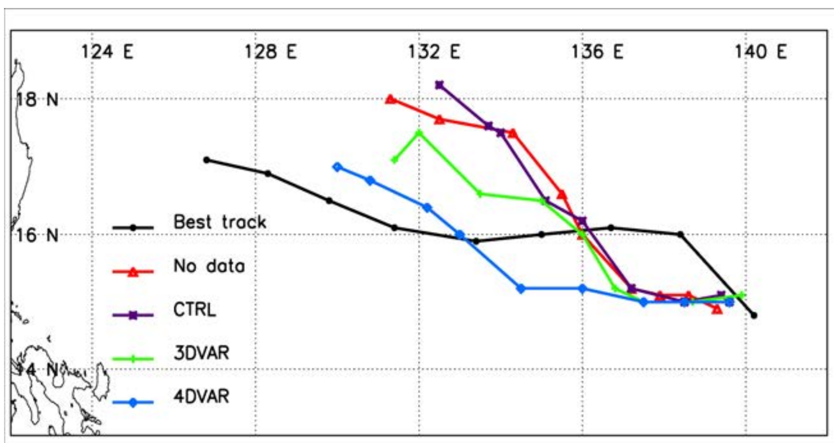


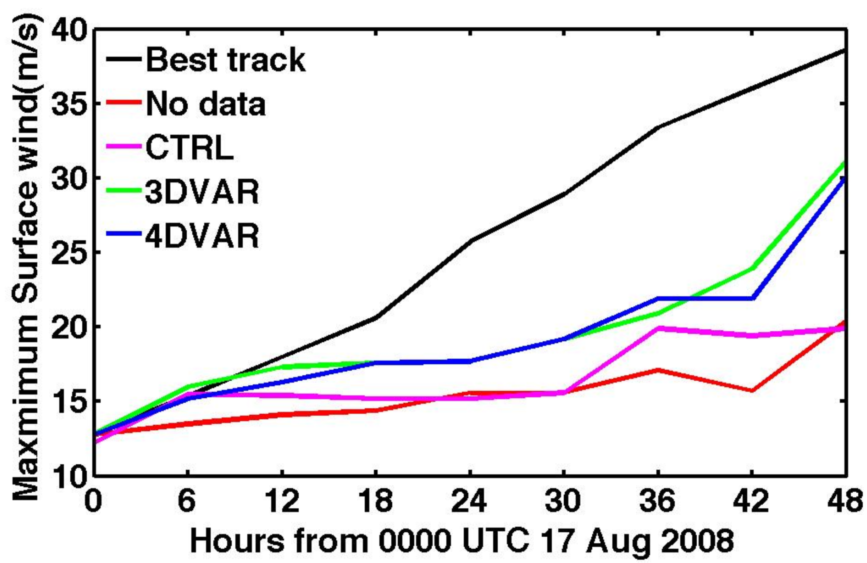
Impact of Airborne Doppler Wind Lidar Profiles on Numerical Simulation of Tropical cyclones: First snapshot with Typhoon Nuri (2008)

Zhaoxia Pu and Lei Zhang, ***Department of Atmospheric Sciences, University of Utah***
G. David Emmitt, ***Simpson Weather Associates, Inc.***

Model: Mesoscale community Weather Research and Forecasting (WRF) model
Data: Doppler wind Lidar (DWL) profiles during T-PARC for the period of 0000UTC –0200 UTC 17 August 2008
Forecast Period: 48-h forecast from 0000UTC 17 August 2008 to 0000UTC 19 August 2008
Control: without DWL data assimilated into the WRF model.
Data Assimilation: With DWL data assimilated into the WRF model

Data impact: Control vs. Data assimilation





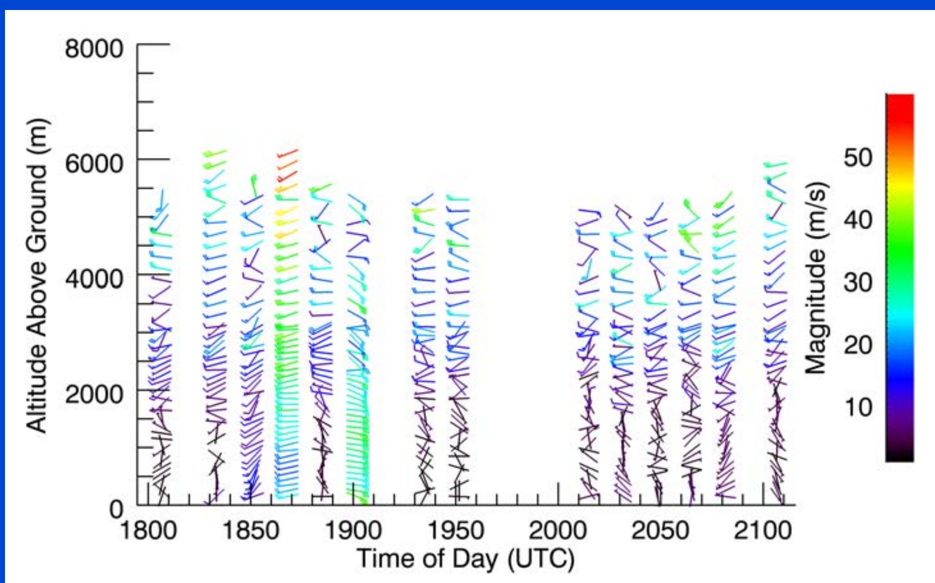
Pu et al. 2010. GRL

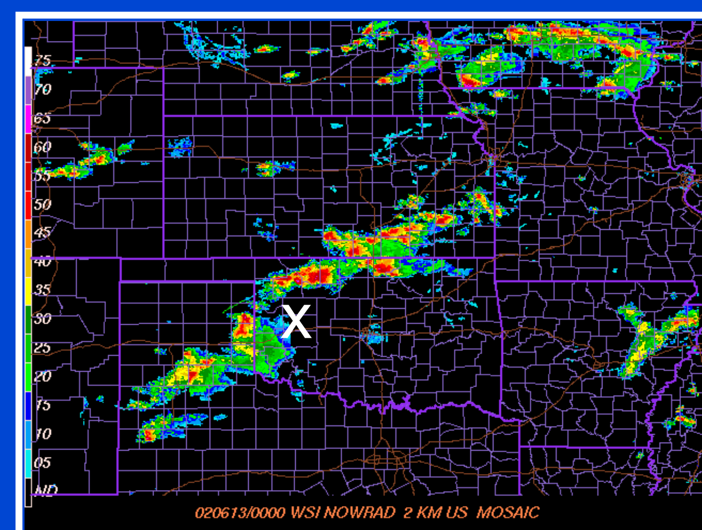
Ground-based Lidar Winds (B. Gentry and B. Demoz, NASA/GSFC)

GLOW (Goddard Lidar Observatory for Winds) Lidar Wind Observations

International H_2O Program (IHOP) field program: May and June 2002

Wind profile Resolution: 10 minutes; 100m below 3km and 200m above 3km of the height over 240 h of data in 35 days





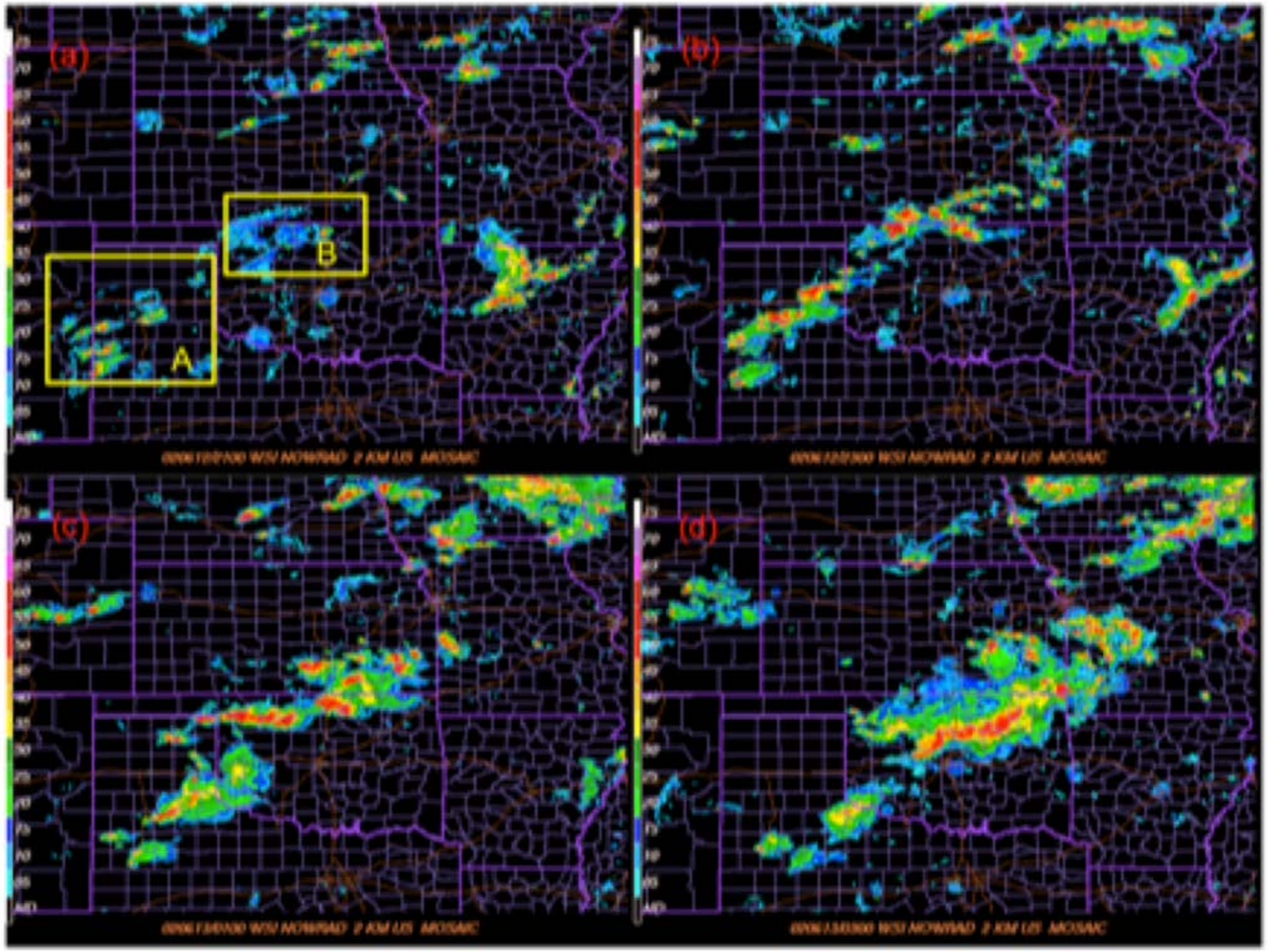
Observations at Homestead site, OK during 12-13 June 2002

June 12 2002 Convection Case

Composite radar reflectivity observations

2100 UTC
12 June
2002

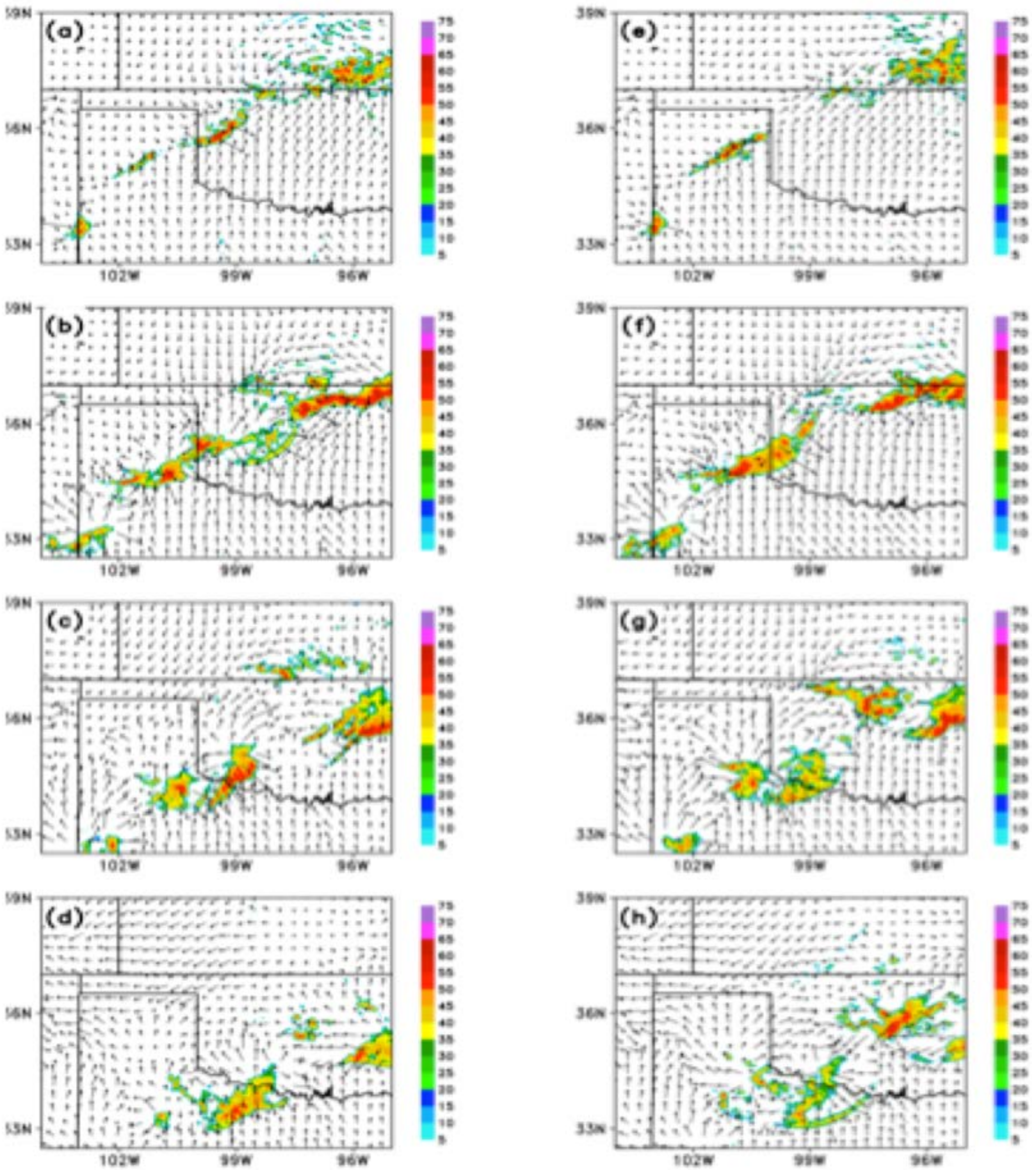
2300 UTC
12 June
2002



0100 UTC
13 June
2002

0300 UTC
13 June
2002

CTRL (Left) Vs. 4DVAR (right): Simulated Radar Reflectivity



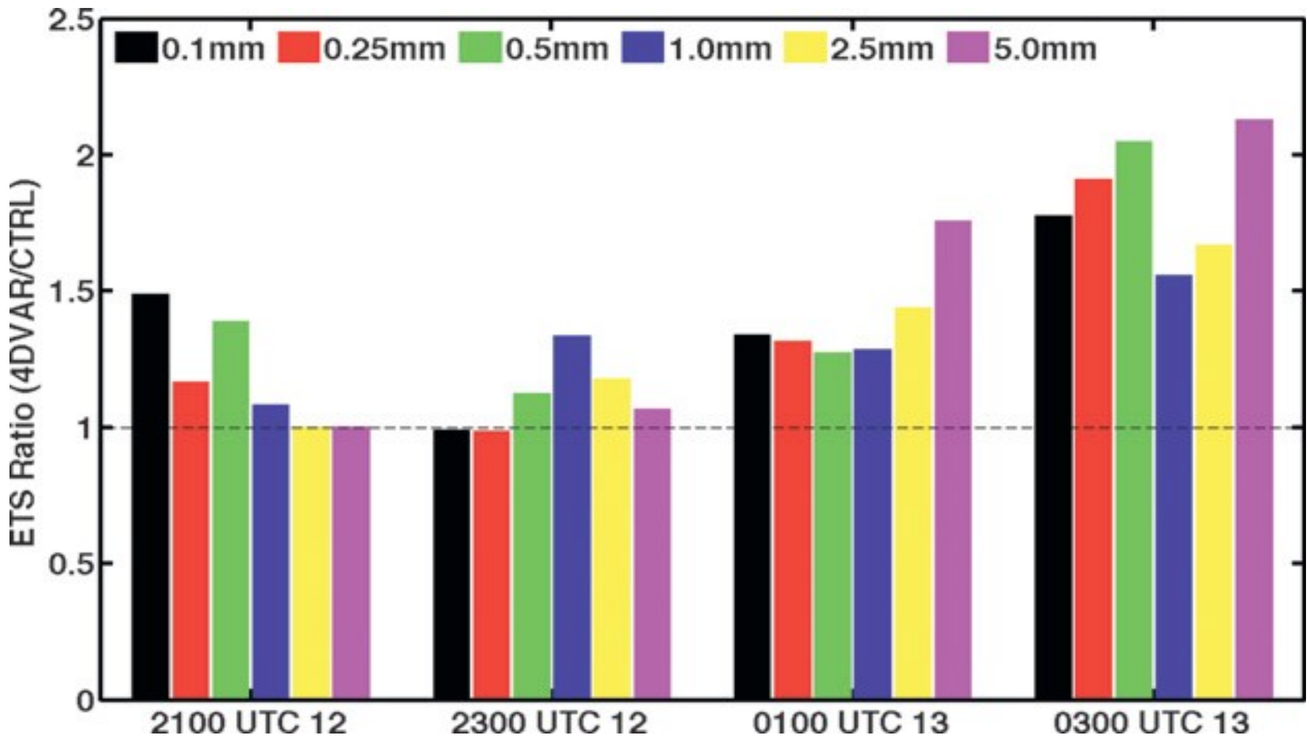
2100 UTC
12 June

2300 UTC
12 June

0100 UTC
13 June

0300 UTC
13 June

Quantitative Precipitation Forecasting Scores

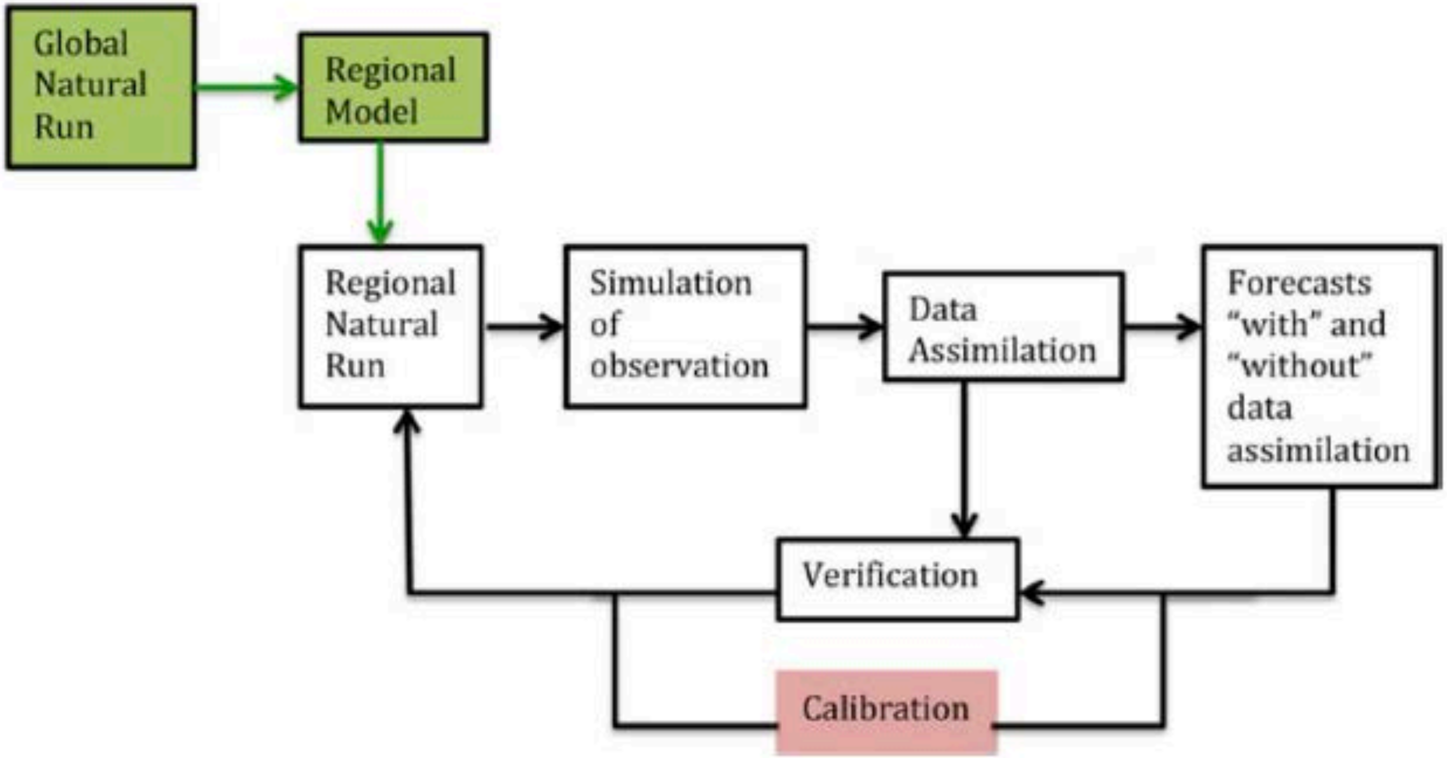


Ratio of equitable threat scores (ETS)
4DVAR vs. CTRL

Zhang and Pu 2011, MWR

Satellite-based Doppler Wind Lidar

Regional OSSEs

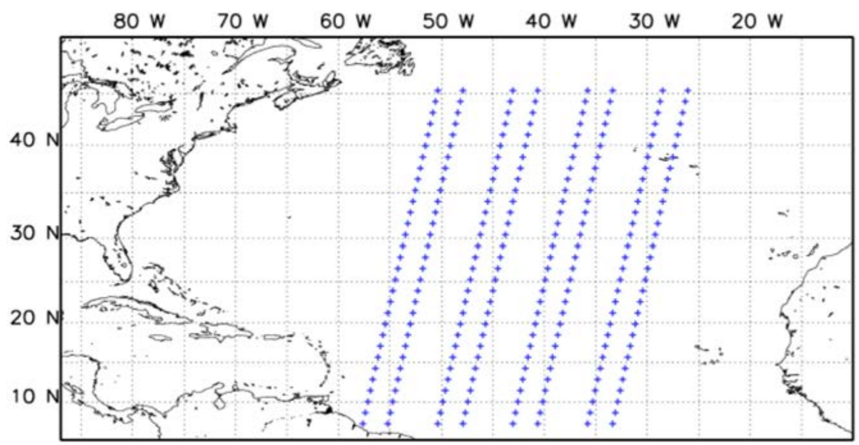


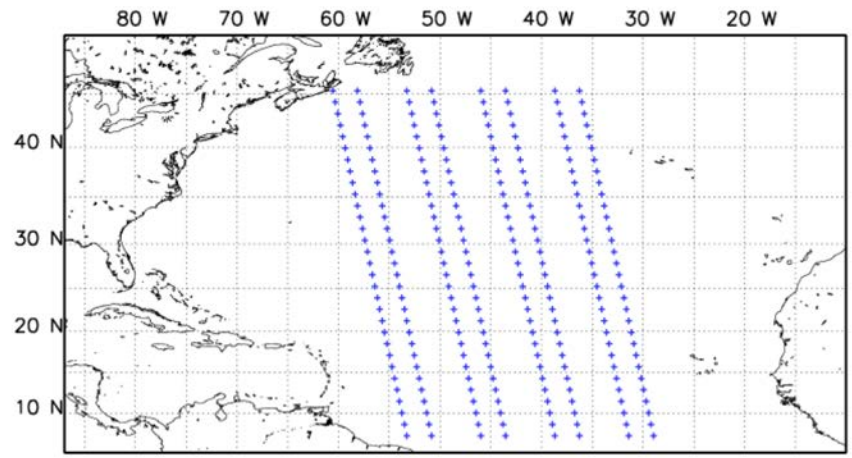
Pu et al. 2017

Exp. I: First Snapshots of the Satellite-based DWL Observations

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

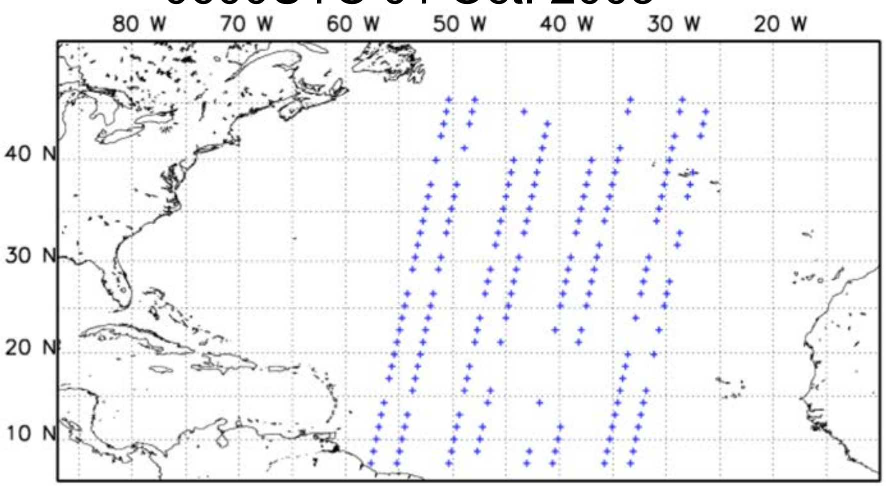
Case 1: No cloud impact

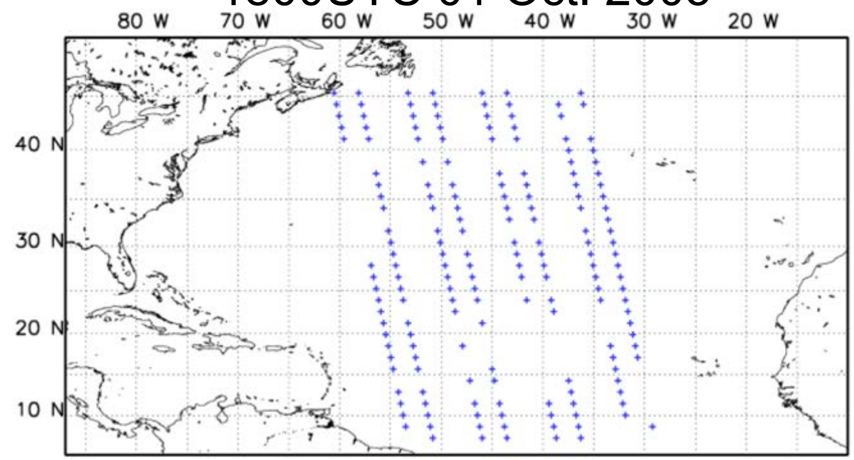




0600UTC 01 Oct. 2005

1800UTC 01 Oct. 2005

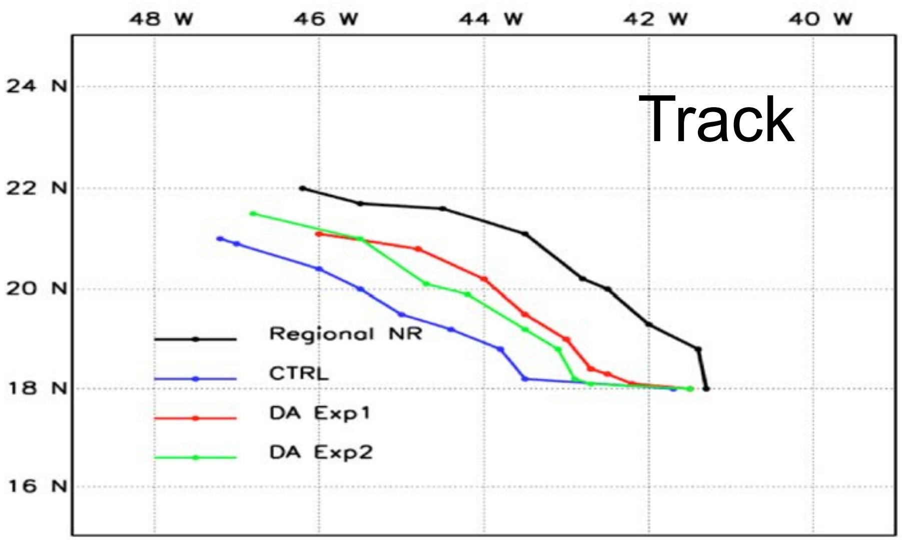




Case 2: With cloud impact

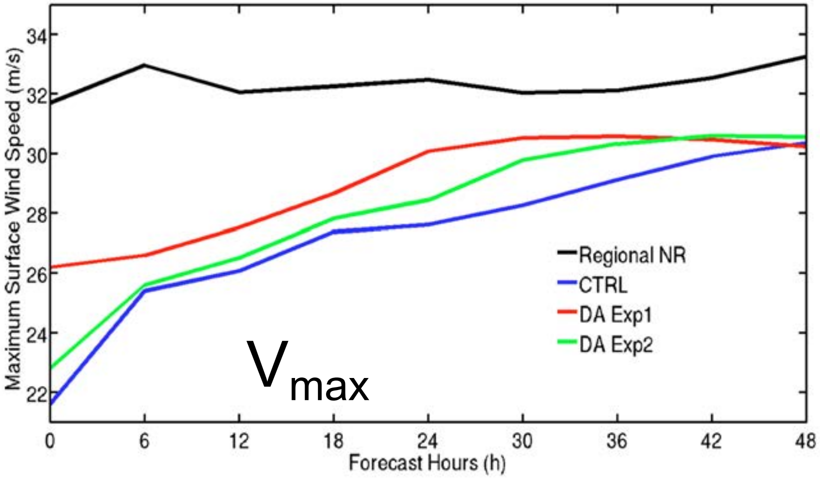
Impact of Satellite-based DWL Observations

A regional OSSE study



Impacts from assimilation of "DWL" profiles

(48-h FCST)



Zhang and Pu (2010)
Adv. Meteor.

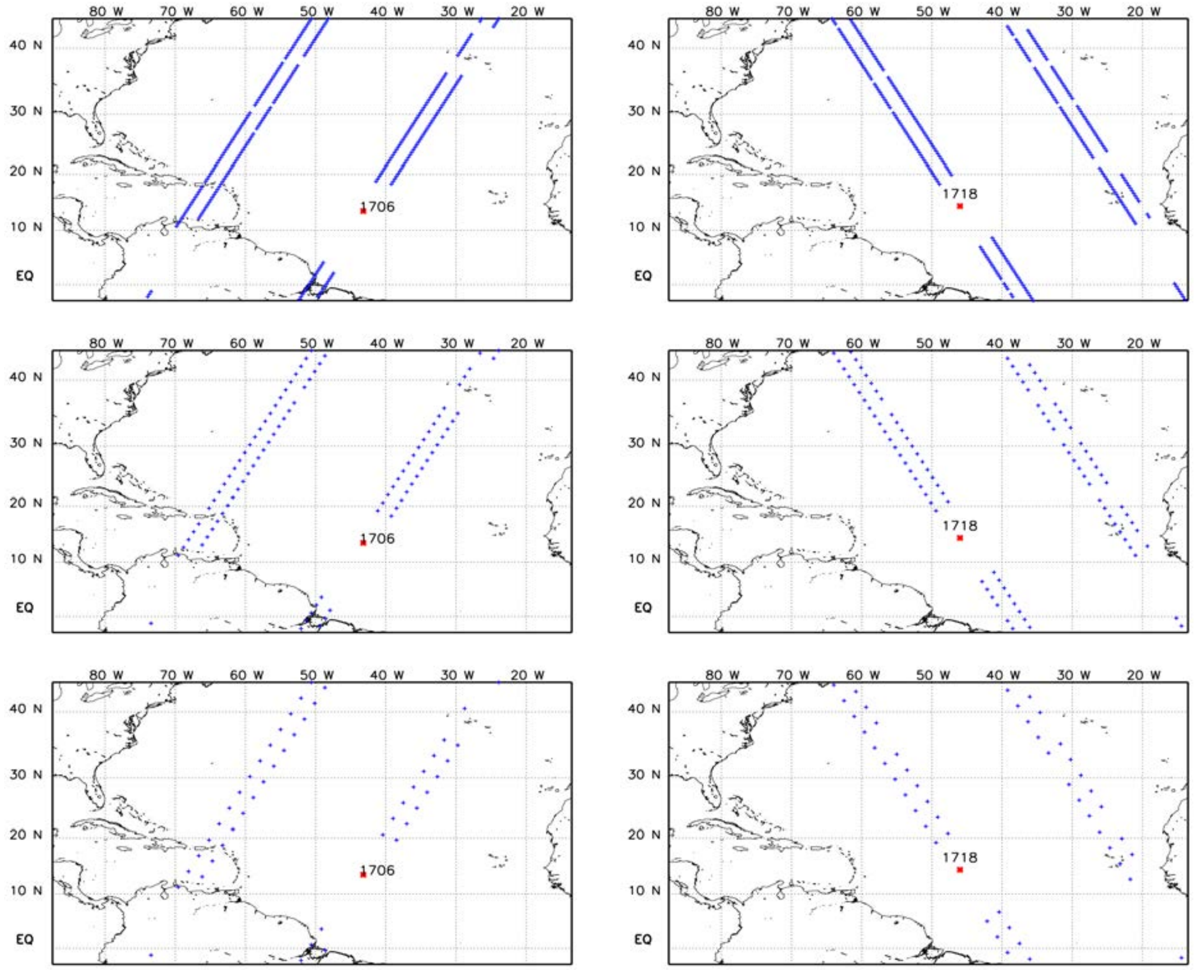
Data samples in various resolutions (Hurricane "Bill" 2009)

0600 UTC 17 August **1800 UTC 17 August**

1 (60km)

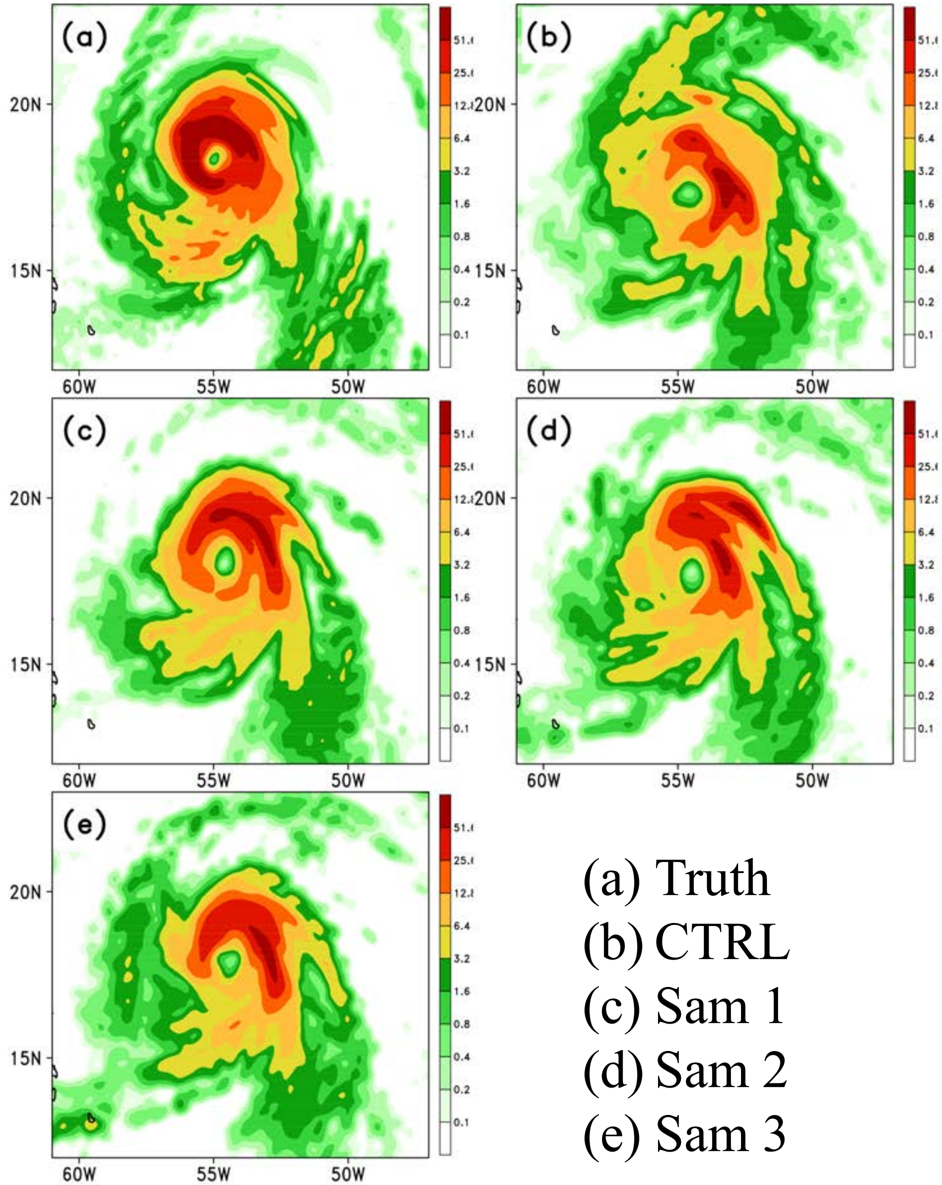
2 (120km)

3 (180km)



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

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

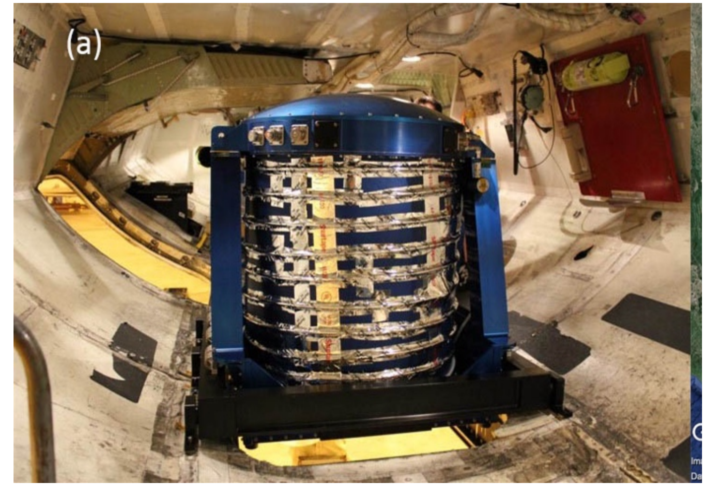


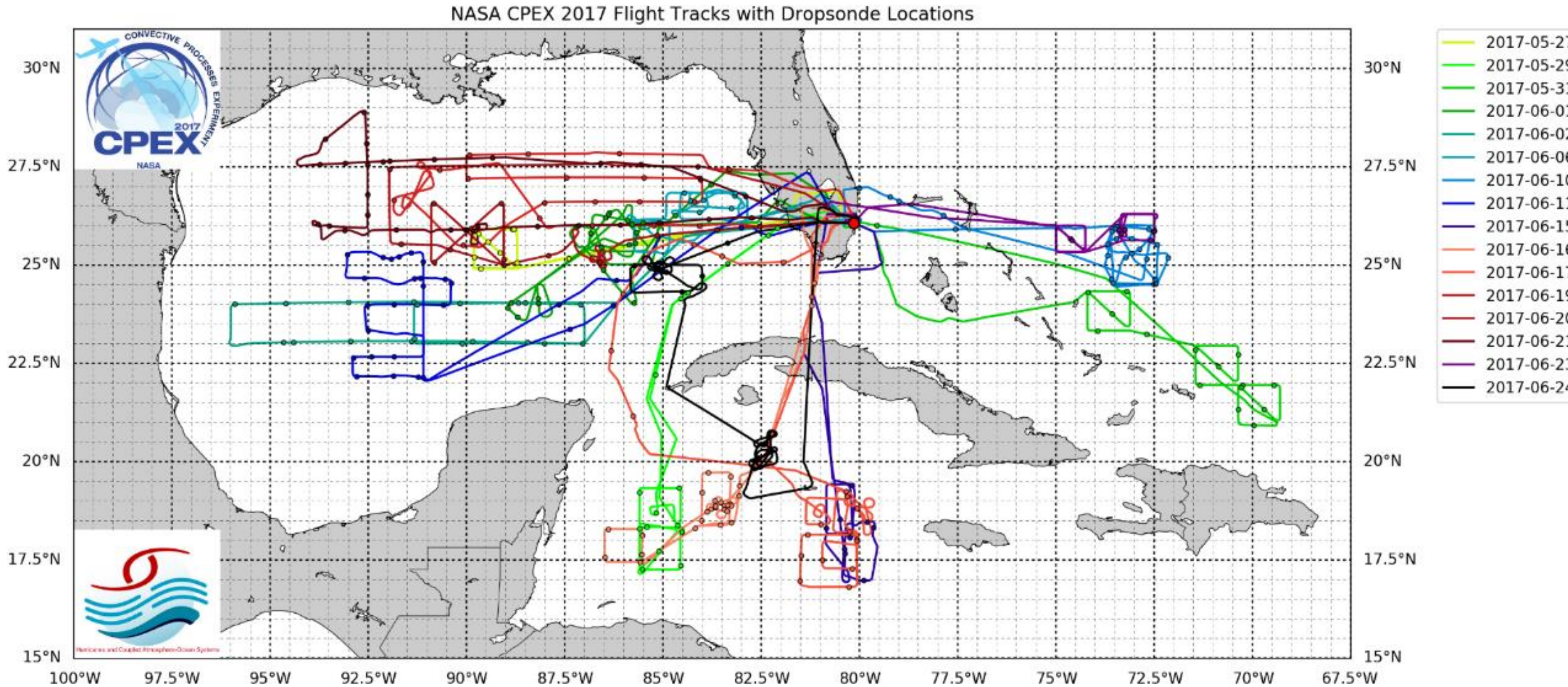
(a) Truth
(b) CTRL
(c) Sam 1
(d) Sam 2
(e) Sam 3

Pu et al. (2017)

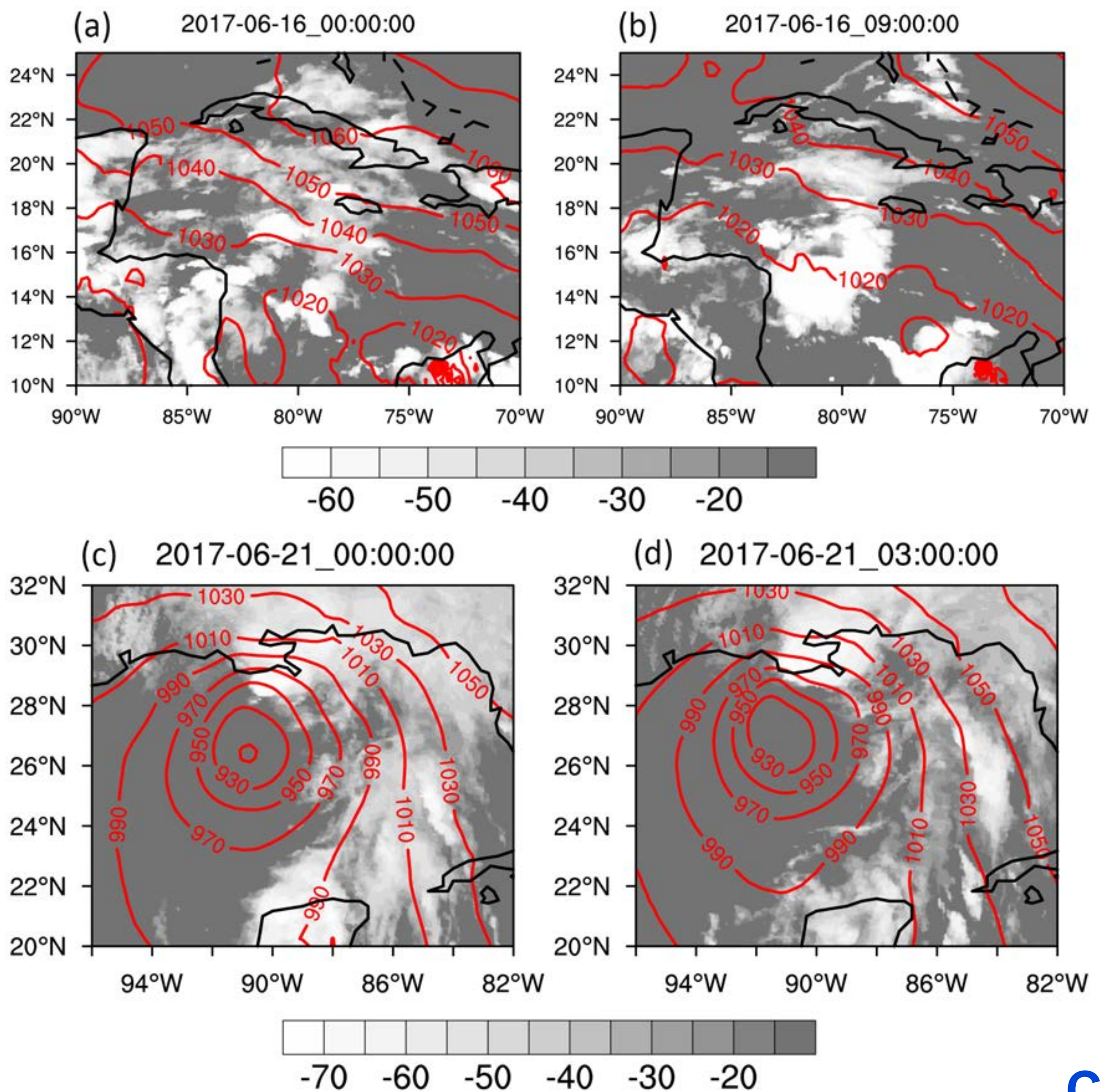
NASA CPEX June 2017

Doppler Aerosol WiNd (DAWN) Lidar





Satellite infrared brightness temperature & ERA5 900hPa height

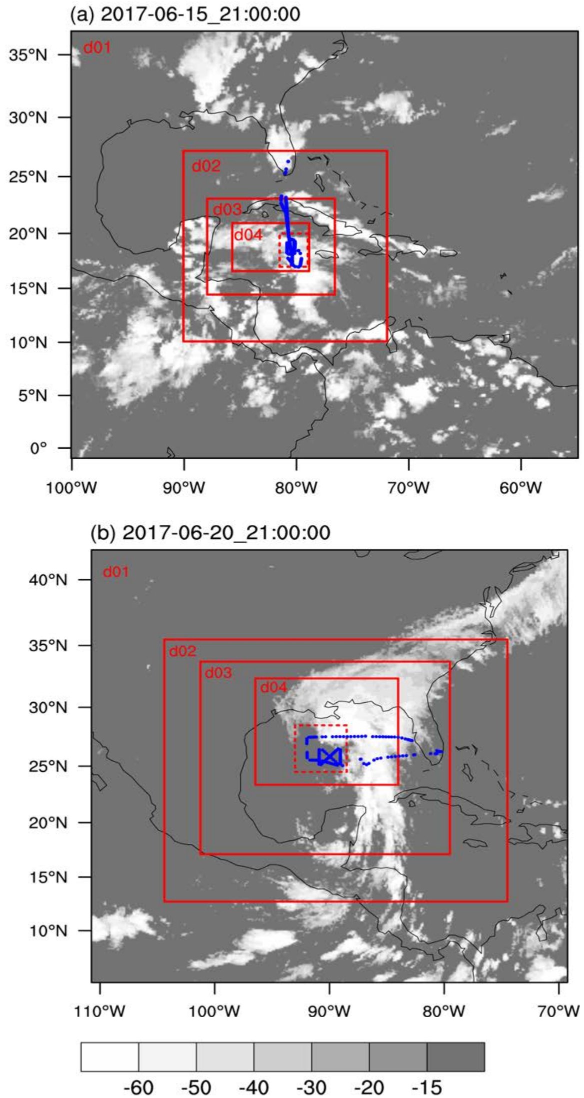


Case 1
June 15-16, 2017

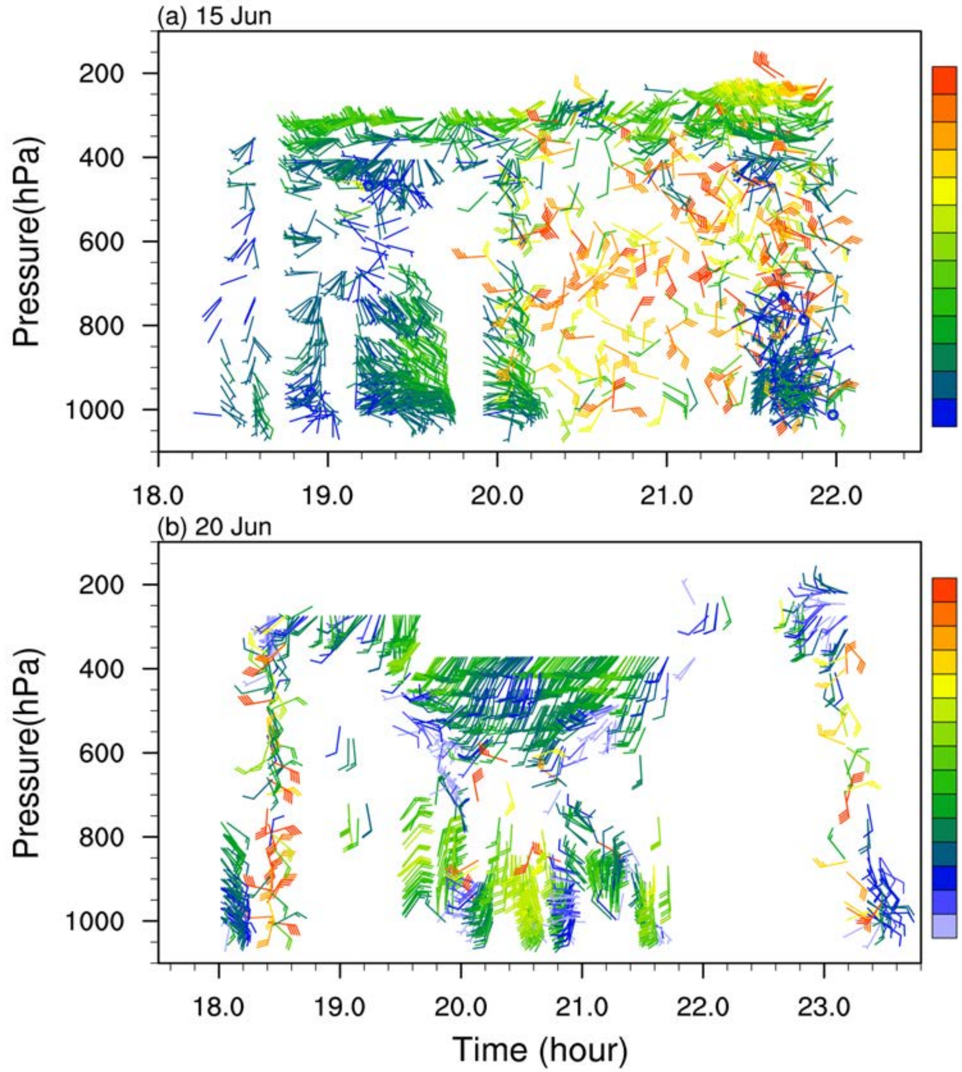
Case 2
June 20-21, 2017
TS Cindy

Cui et al. (2019)

WRF model domains & DAWN data sample



June 15



June 20

Data Assimilation methods

NCEP GSI-Based 3D Ensemble-Variational Hybrid Data Assimilation

$$J(x) = \frac{1}{2}\left(x - x^b\right)^T (\beta_1 B_1 + \beta_2 B_2)^{-1}\left(x - x^b\right) + \frac{1}{2}\left(y^0 - H(x)\right)^T R^{-1}\left(y^0 - H(x)\right)$$

B_1 : Static, pre-generated matrix using NMC method

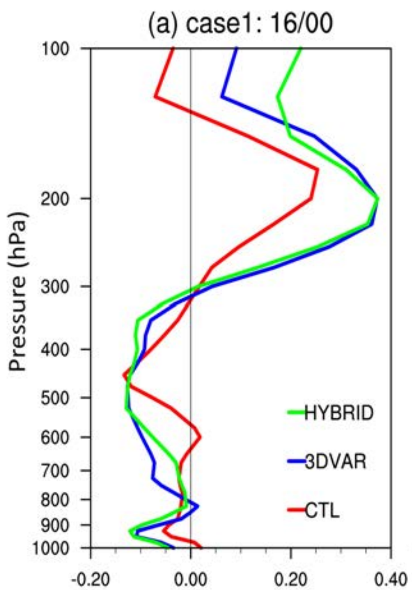
B_2 : A flow-depend matrix derived from ensemble forecasts

Weighting factors: β_1 and β_2

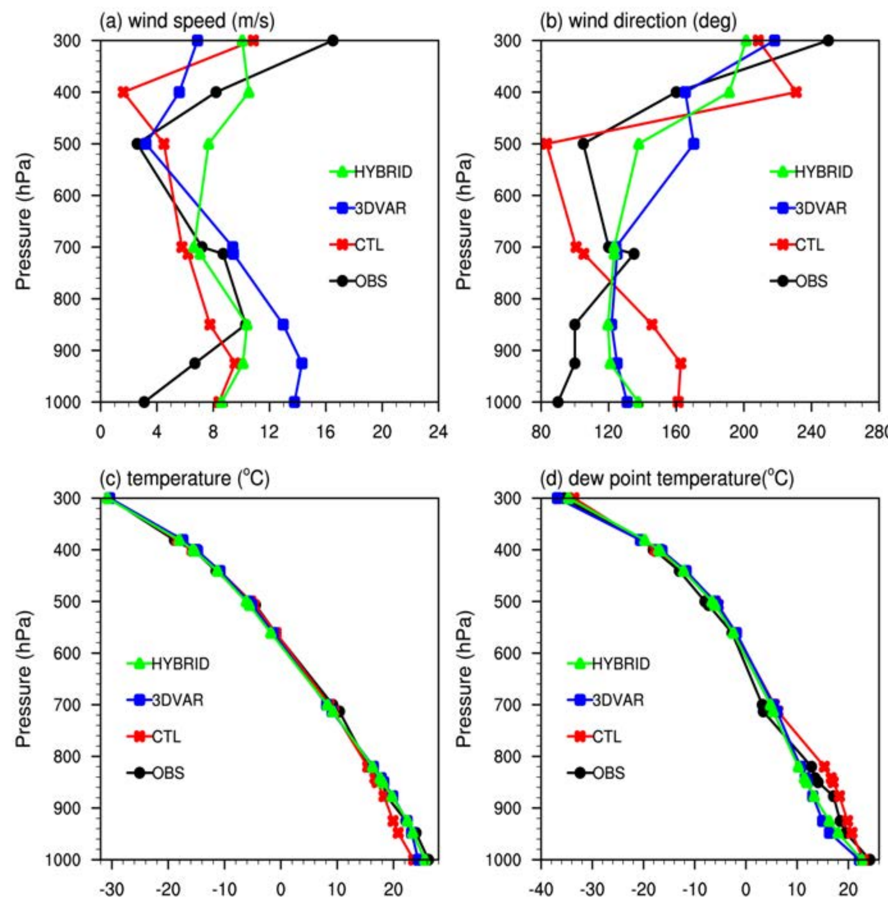
NCEP GSI 3D Variational Data Assimilation (3DVAR)

When $\beta_2 = 0$

Area Averaged Divergence



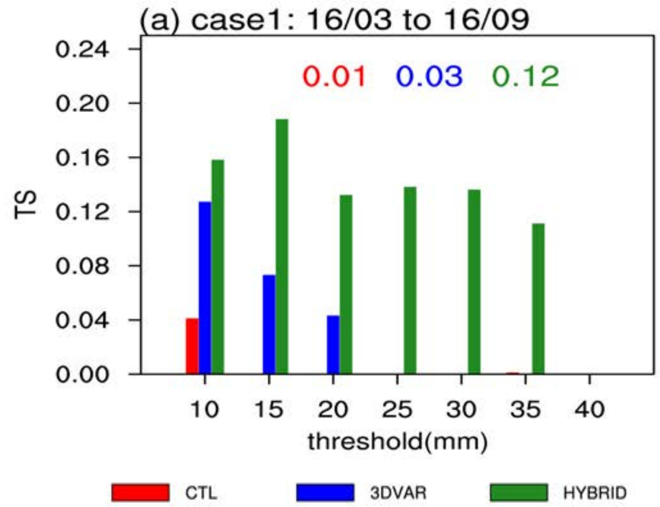
Compare with radiosonde obs.

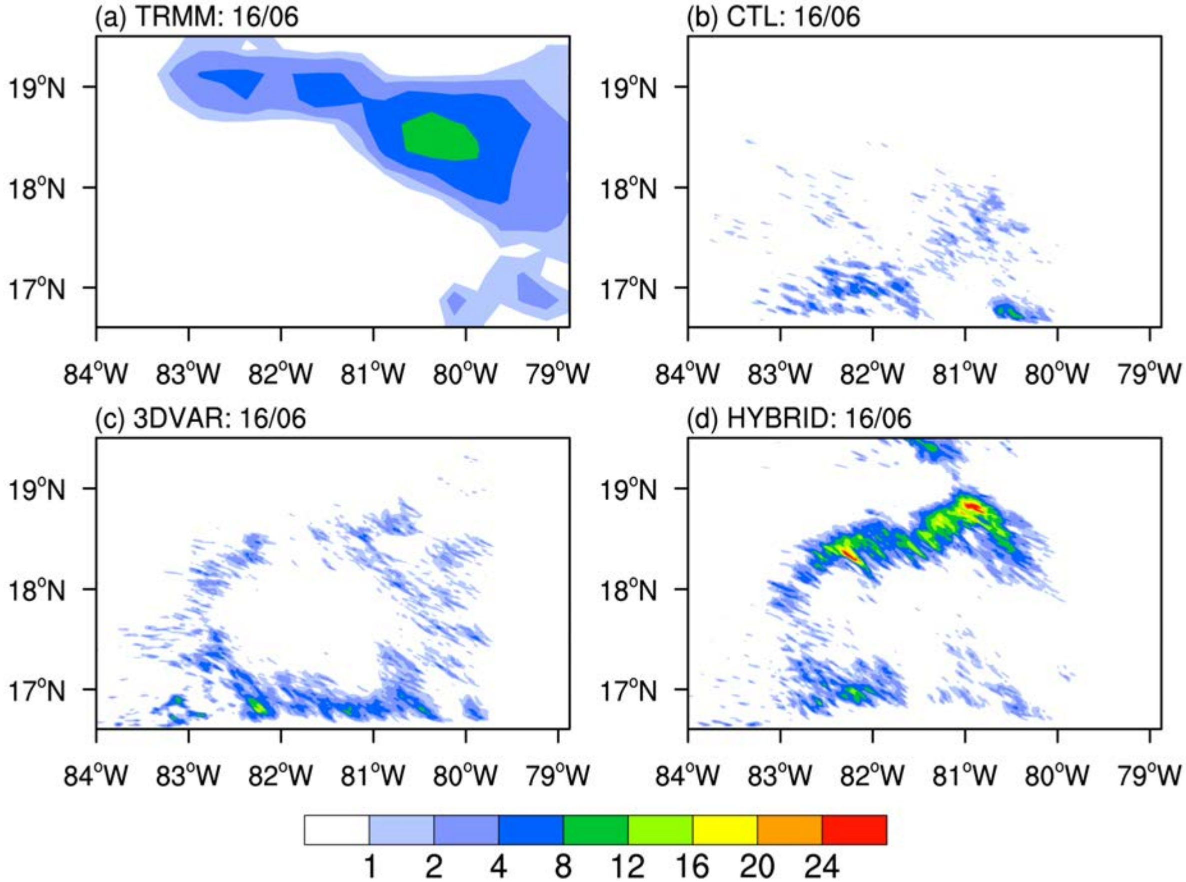


Cui et al. (2019)

Case 1, 12 UTC 16 June 2017

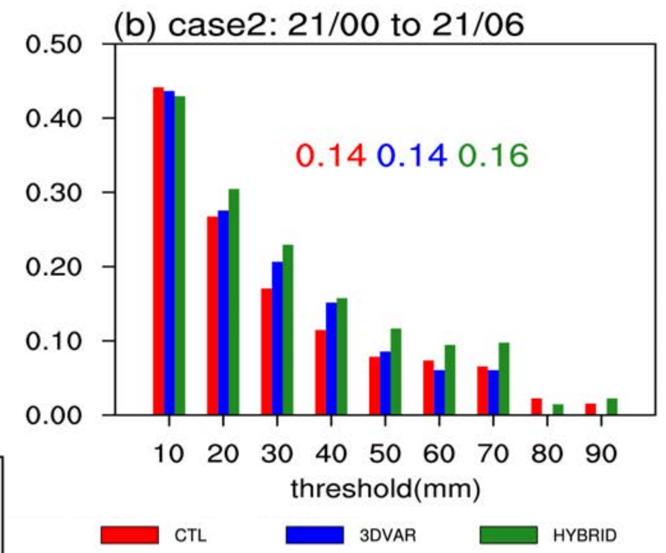
Rainfall rates and QPFs
Case 1

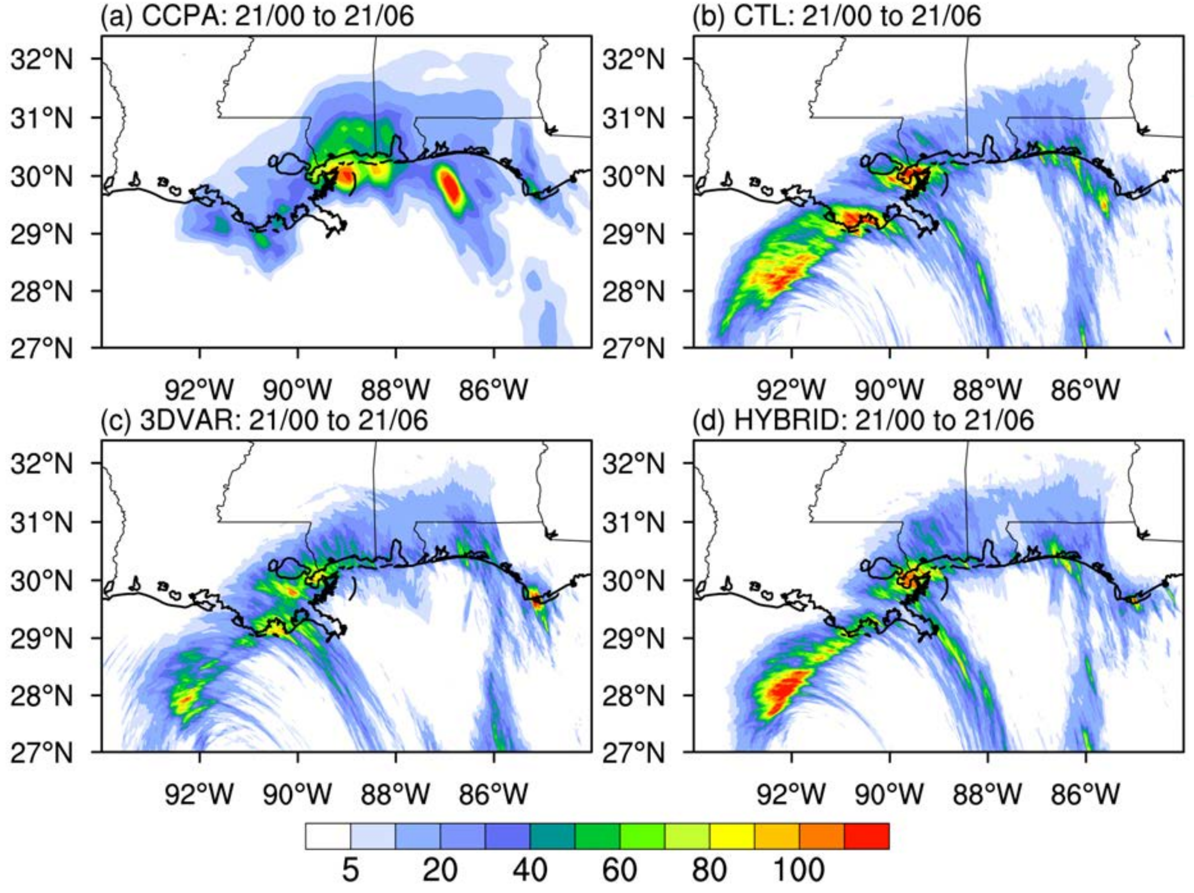




Cui et al. (2019)

Rainfall rates and QPFs
Case 2





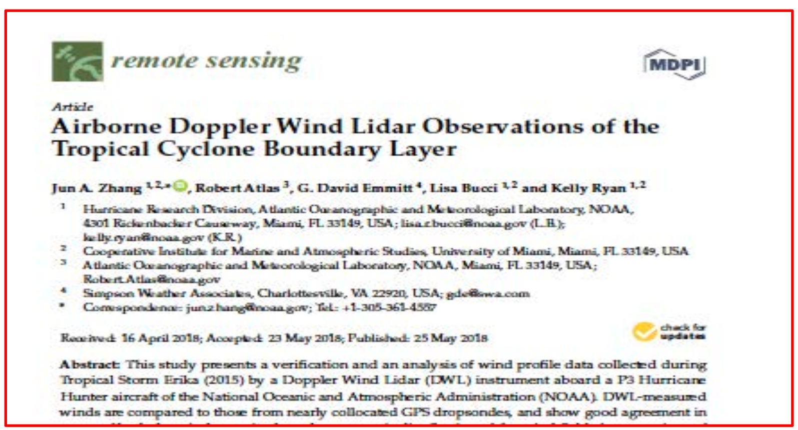
Cui et al. (2019)

Concluding remarks and ongoing work

- Space-based 3-D wind profiling measurements are essential for improving high-impact severe weather events
- Both Ground-based and airborne Doppler wind lidar measurements are valuable for high-impact weather forecasting. They should be actively used in the future field campaigns and operational missions

- **Assimilation of DAWN wind profiles results in improved numerical simulations of tropical convection during NASA CPEX**

- **Ongoing studies emphasize 1) NOAA/HJRD/P3 lidar winds for hurricanes and 2) Aeolus wind data**


remote sensing
MDPI

Article

Airborne Doppler Wind Lidar Observations of the Tropical Cyclone Boundary Layer

Jun A. Zhang [1,2,*], Robert Atlas [3], G. David Emmitt [4], Lisa Bucci [1,2] and Kelly Ryan [1,2]

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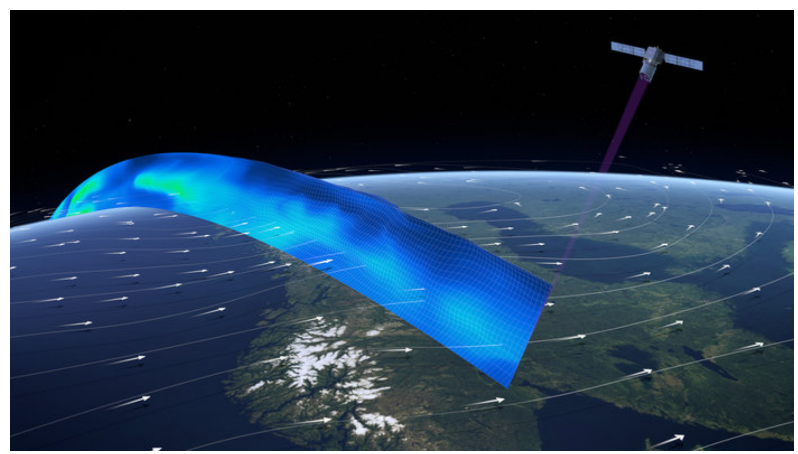
Abstract: This study presents a verification and an analysis of wind profile data collected during Tropical Storm Erika (2015) by a Doppler Wind Lidar (DWL) instrument aboard a P3 Hurricane Hunter aircraft of the National Oceanic and Atmospheric Administration (NOAA). DWL-measured winds are compared to those from nearly collocated GPS dropsondes, and show good agreement in

NOAA/HRD/P3



European Space Agency - Aeolus

Thank you very much for your attention!

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