The Essential Practices of Lidar Wind Data Assimilation for high-impact weather forecasting

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Working Group on Space-based Lidar Winds
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Outline

- **Uncertainties of wind analyses and their implications**

- **The impact of lidar wind data assimilation on high-impact weather forecasting**

  - **Real data assimilation (Ground-based and airborne Lidar winds)**
  - **Observing System Simulation Experiments (OSSEs)**
  - **3-D Lidar wind vs. ocean surface winds**
  - 3DVAR vs. 4DVAR
  - 3dEnVar vs. 4dEnVar

- **Comments on future missions**

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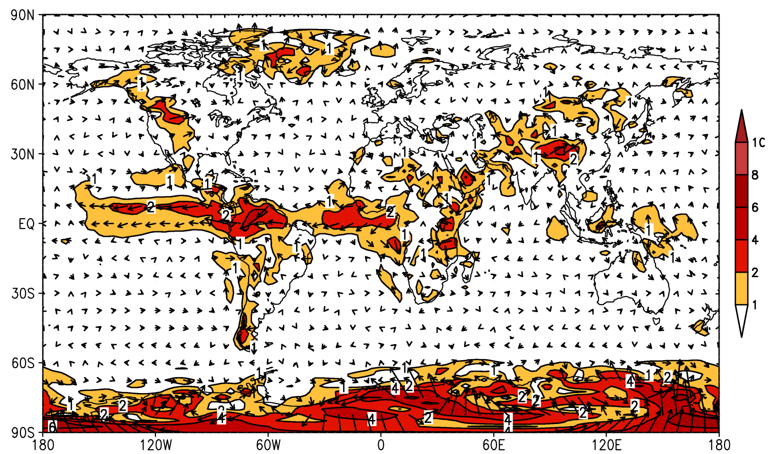
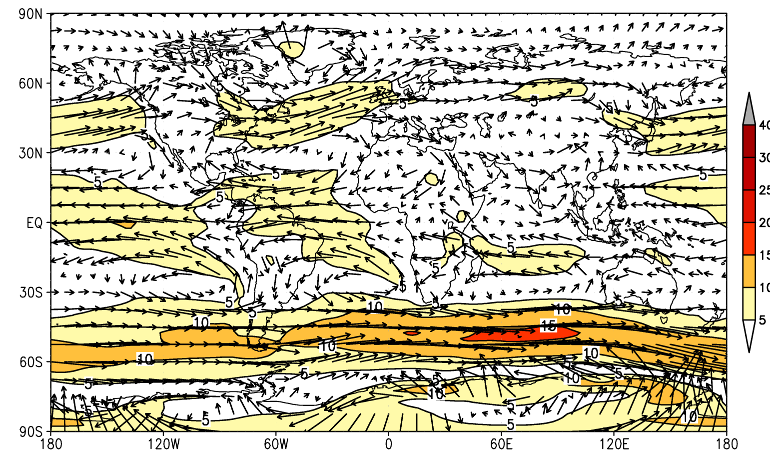
The uncertainties of global wind analysis

NCEP/NCAR Reanalysis vs. ERA-40, 1980-1999

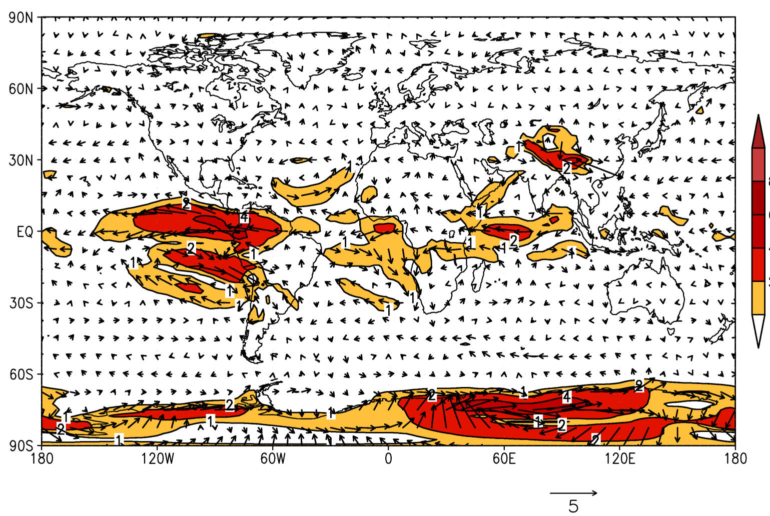
Mean wind speed and vector differences between two reanalyses at 850mb



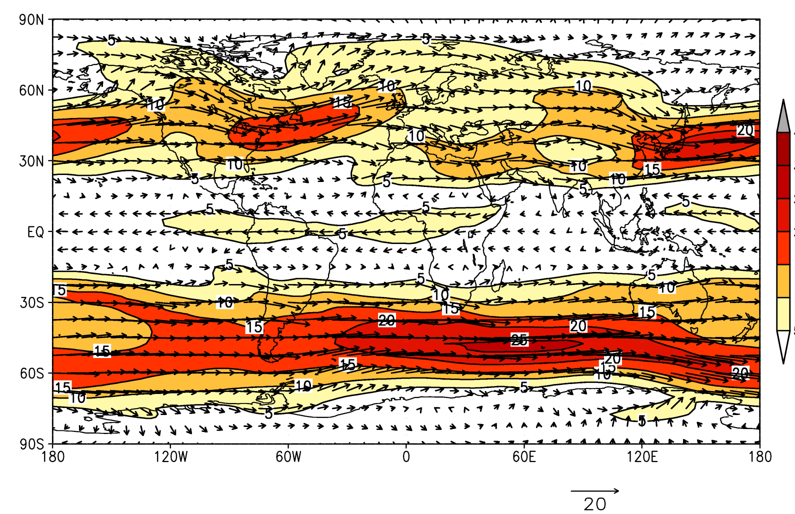
Mean wind speed and vector from NCEP reanalysis at 850mb



Mean wind speed and vector differences between two reanalyses at 500mb



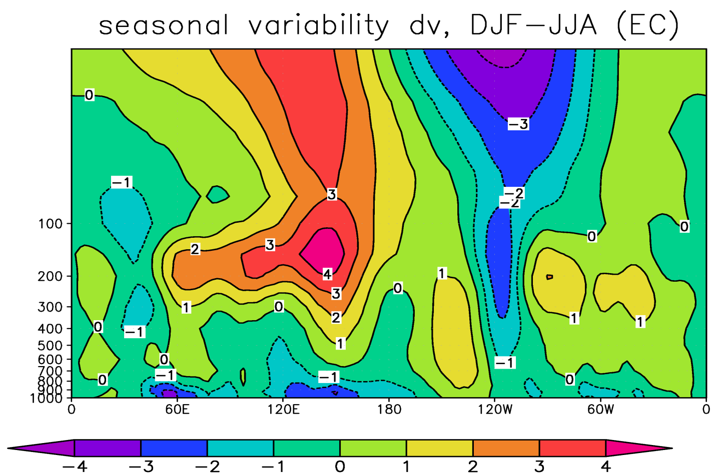
Mean wind speed and vector from NCEP reanalysis at 500mb

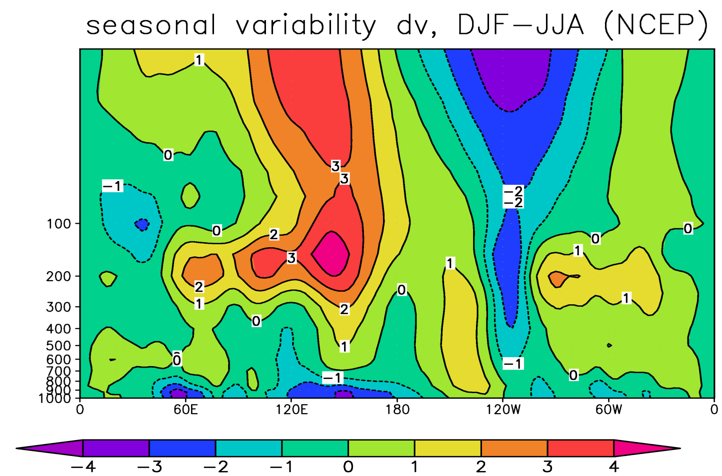


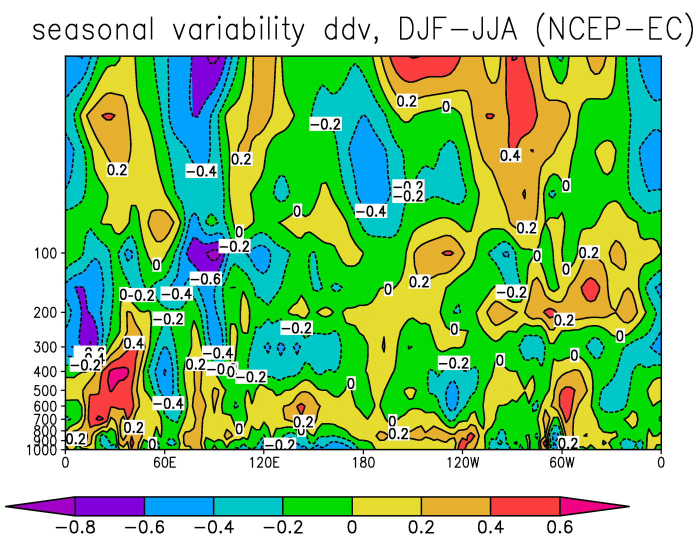
Uncertainties in global wind analysis

NCEP/NCAR Reanalysis vs. ERA-40, (1980-1999)

Seasonal variability of meridianally averaged v, DJF(winter) vs. JJA(summer)



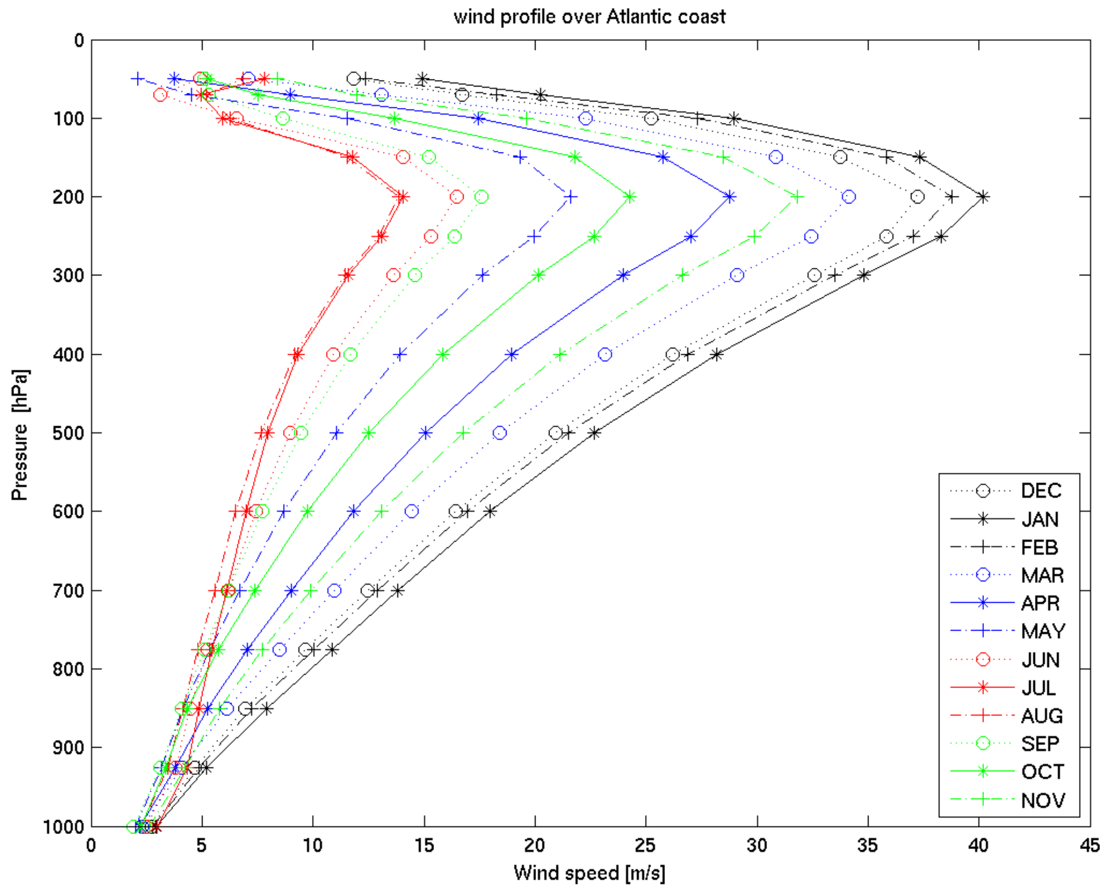




- There is difference in terms of the seasonal wind variability represented by two reanalysis products (at least in the magnitude of the variability)
- It is important that the future DWL data could be helpful to accurately present the seasonal wind variability.

Variation of monthly mean wind speed with height over the East Coast areas of US

(65W-85W, 25N-50N) from ECMWF reanalysis (1980-1999)



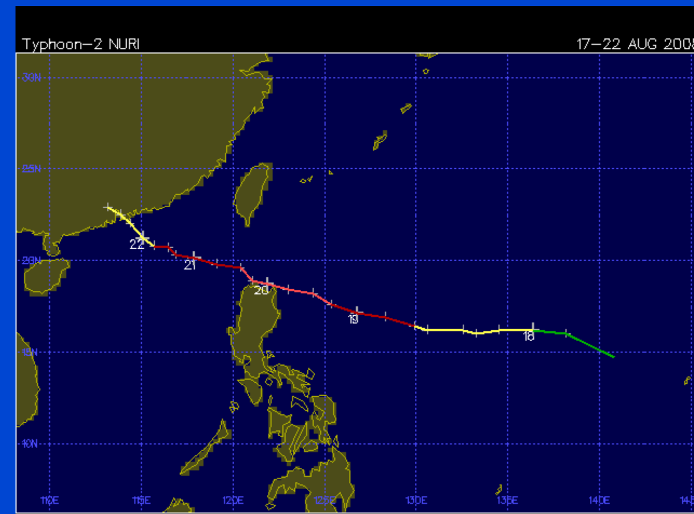
Future Doppler Lidar Wind should be good enough to detect monthly and seasonal variations of the wind profiles in details

Characteristics of Low-Level Jets over US SGP

HY 06 and 07

Data	Pressure	Speed	Lat	Lon	Direction	Time	Count
NARR	874.8	22.7	36.9	-98.6	206	10 z	285
MERRA2	879.0	23.8	36.0	-99.6	196	10 z	308

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



Life cycle: 17Aug – 22 Aug 2008

Typhoon Nuri

Case

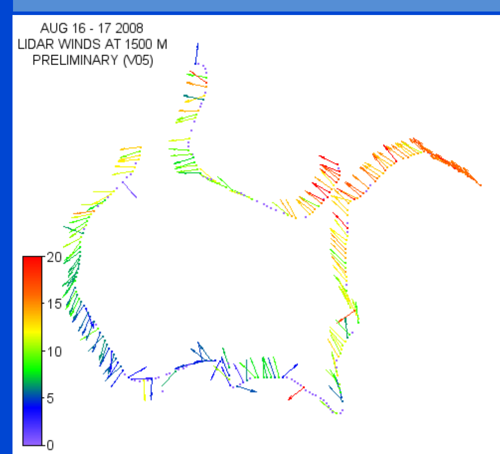
Typhoon Nuri over the Western Pacific

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

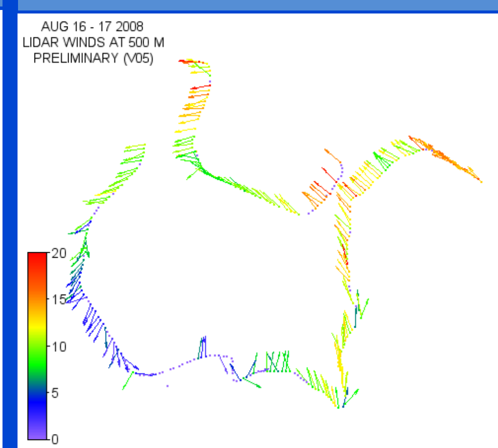
Time period of data

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

P3DWL winds at1500m

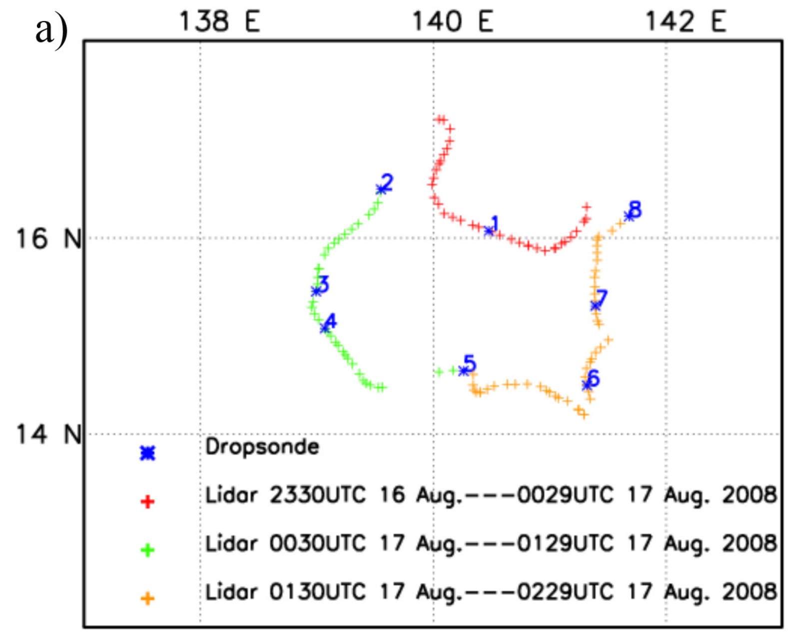


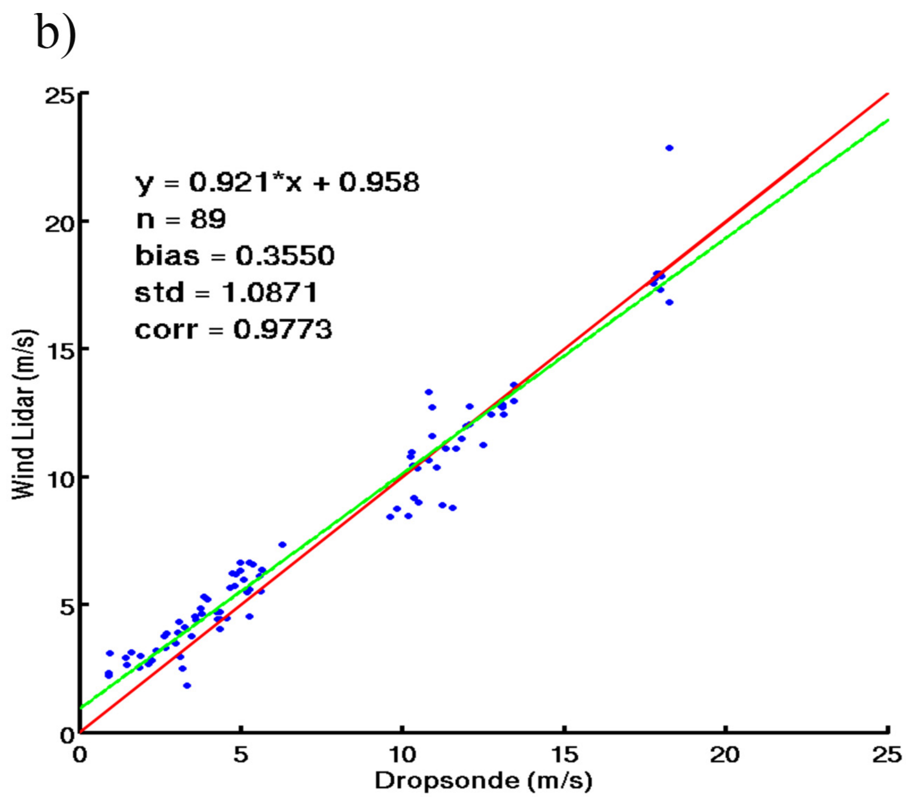
P3DWL winds at 500m



DWL vs. Dropsonde

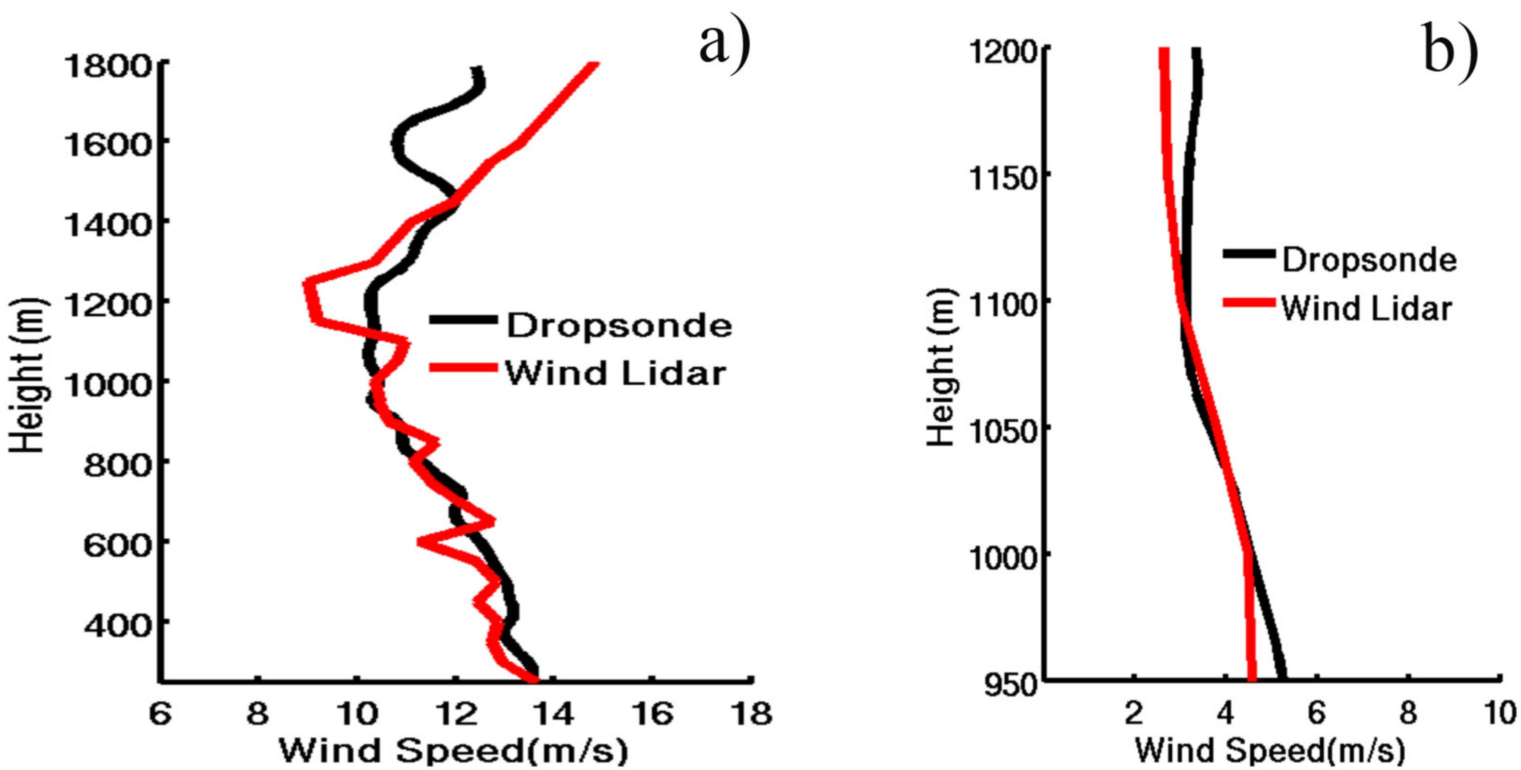
Quality of the data





Correlation of wind speed is nearly 98%

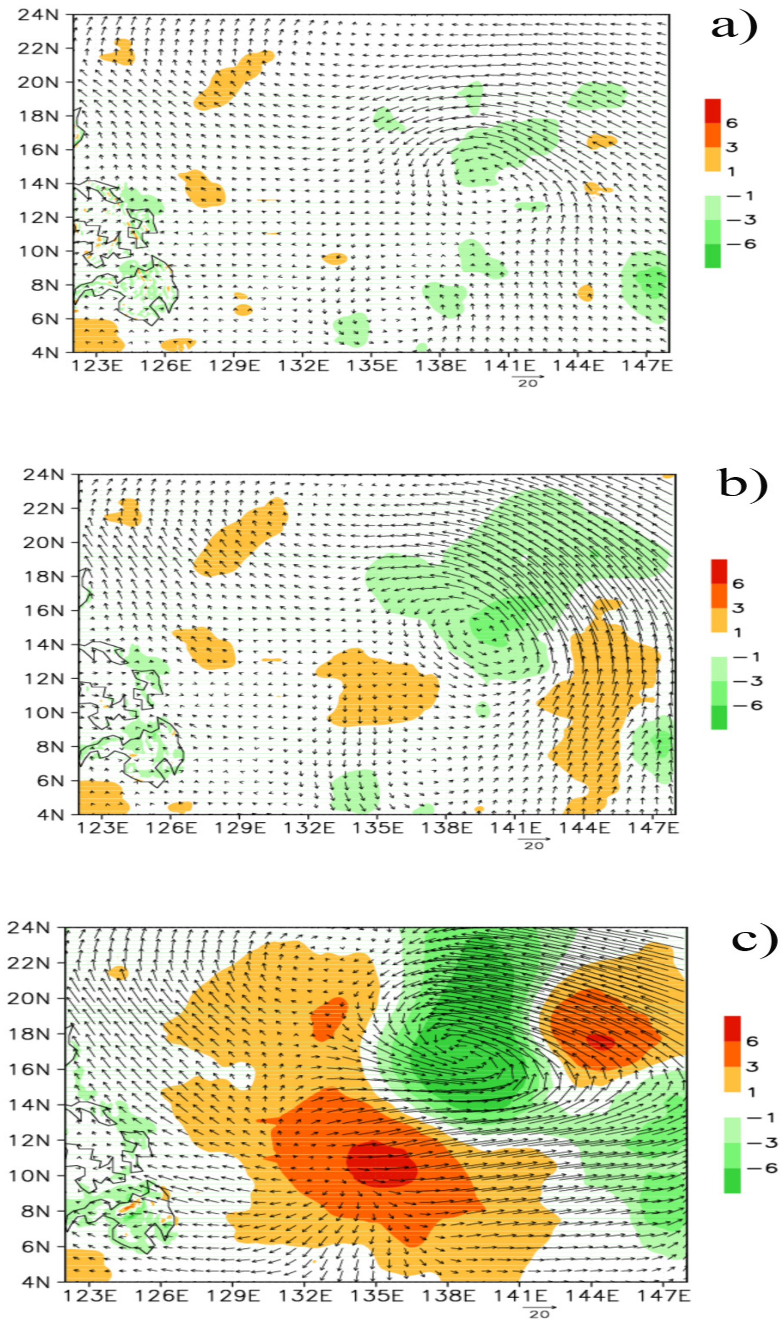
DWL vs. Dropsonde: Sample profiles



Impact study: Data Assimilation Experiments

WRF-ARW model: Two-level nested grids (27 km and 9km)

Experiments: "No Data" -- guess field (6 h WRF forecast)
CTRL -- 3DVAR assimilation of conventional and dropsonde data
3DVAR – 3DVAR assimilation of DWL profiles
4DVAR – 4DVAR assimilation of DWL profiles

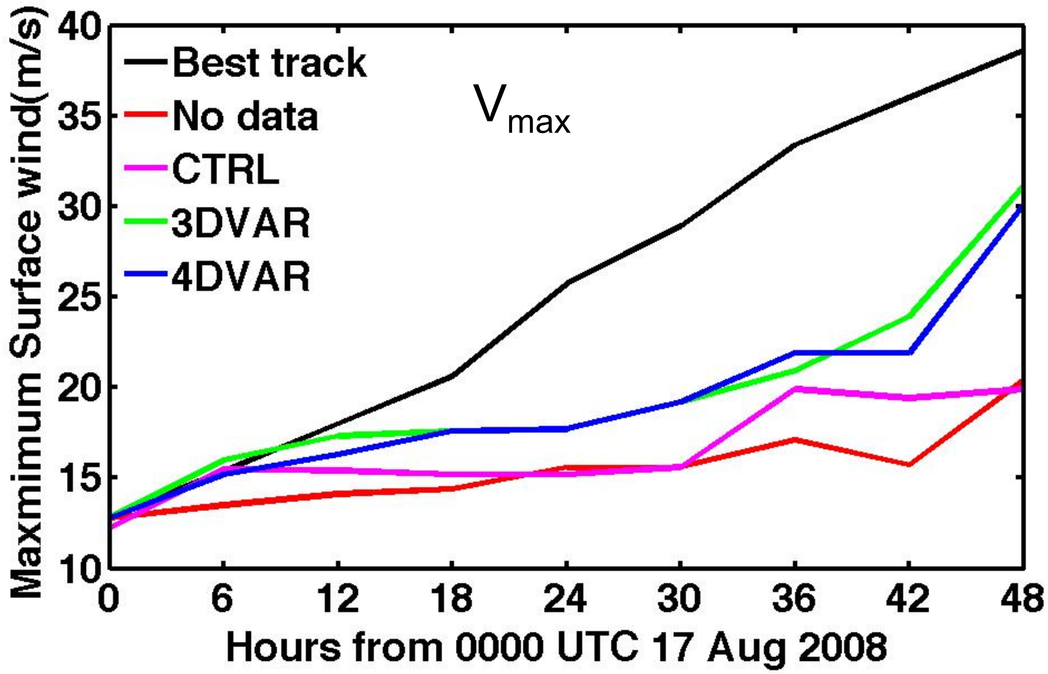


Divergence + Wind
“No Data”

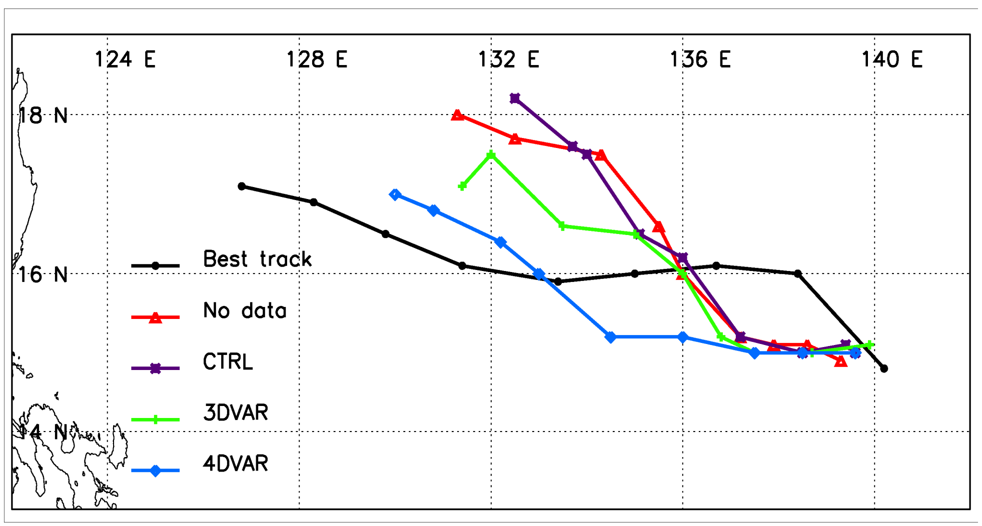
Divergence + analysis
increment of wind
-- “CTRL”

Divergence + analysis
increment of wind
--“3DVAR”

Use of DWL data enhanced the low level convergence of Nuri in the simulation



DWL data has positive impact on numerical simulation of Typhoon Nuri



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

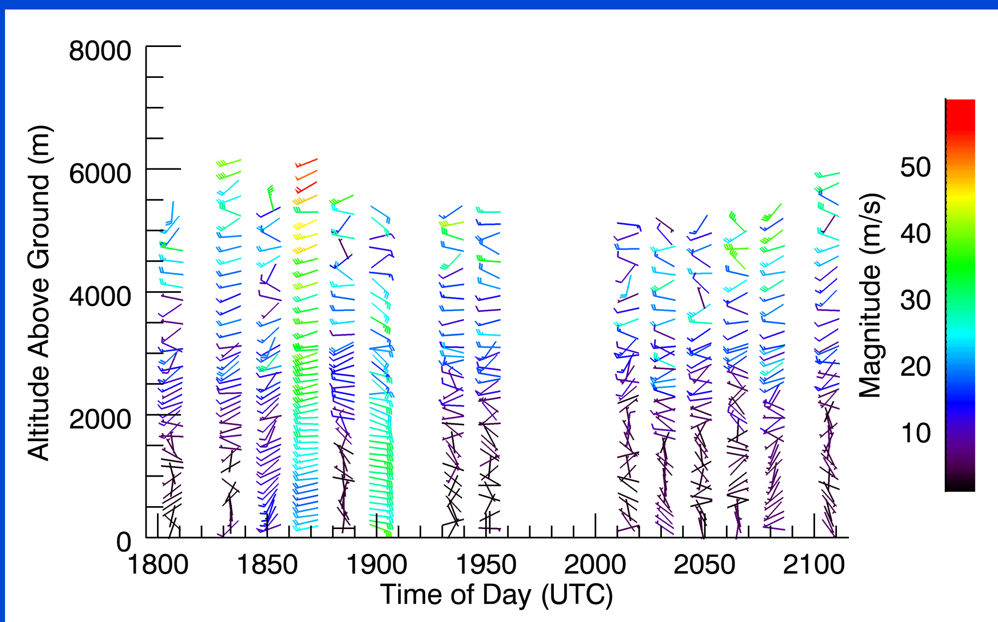
Pu et al. 2009, GRL

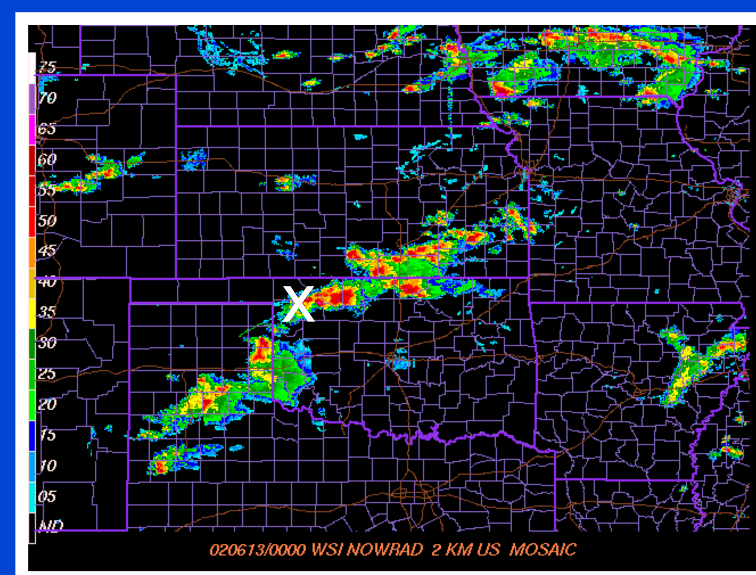
Ground-based Lidar Winds

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

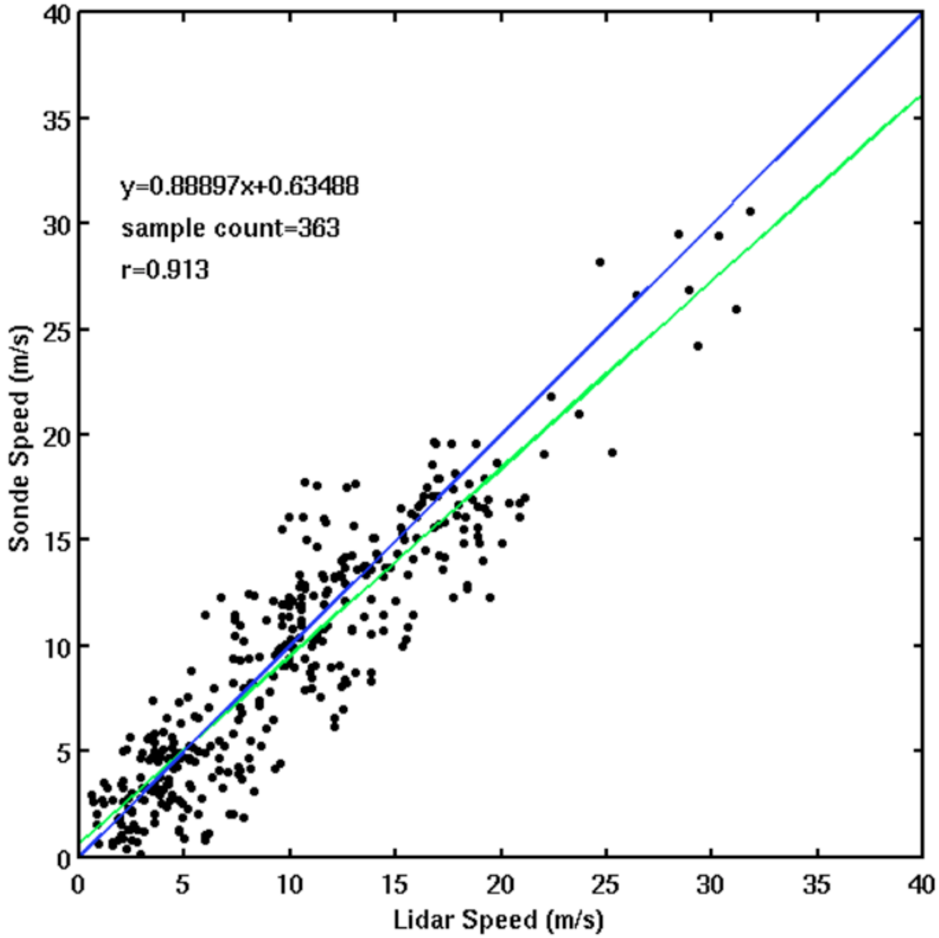




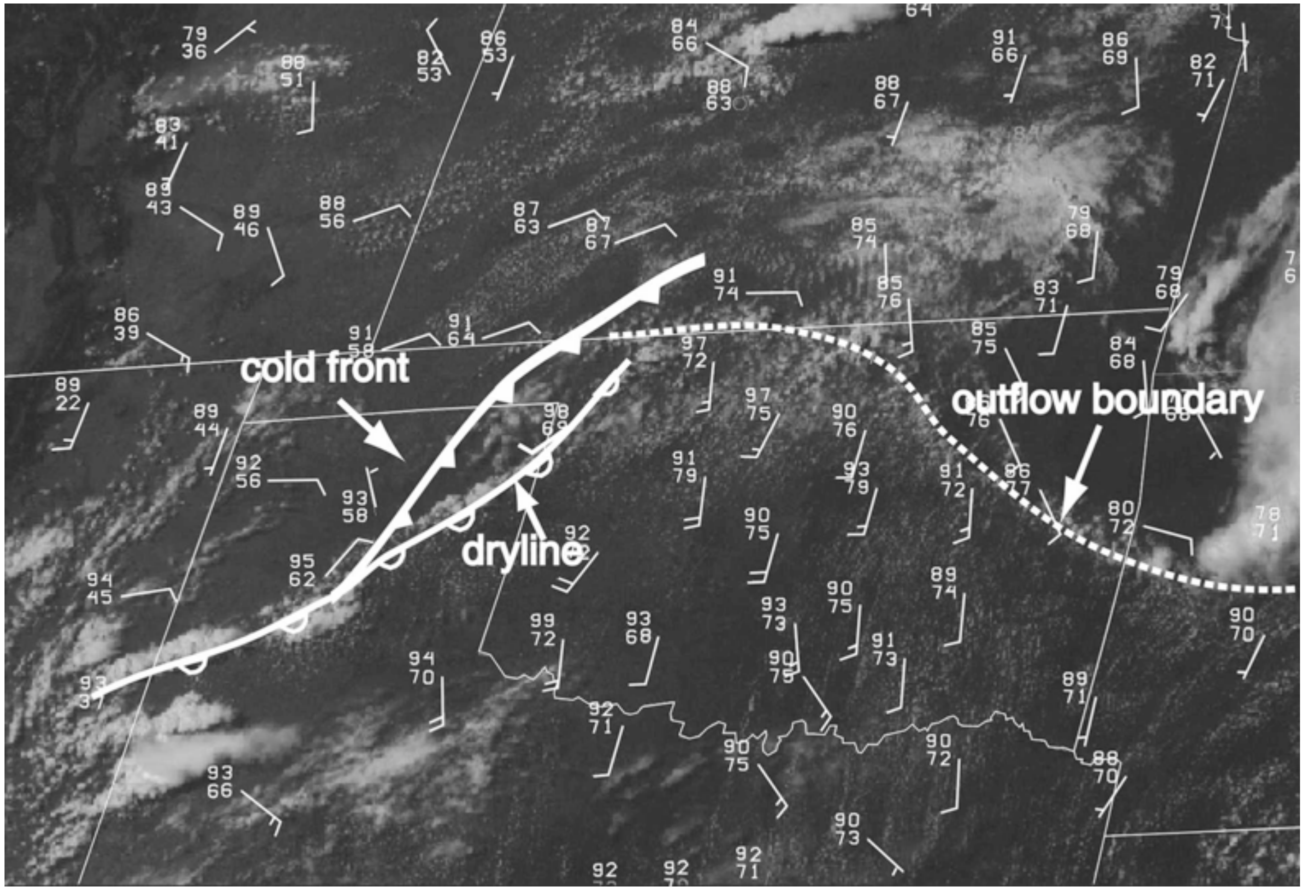
Observations at Homestead site, OK during 12-13 June 2002

Quality of the Lidar wind data

Wind speed: Lidar vs. Sonde

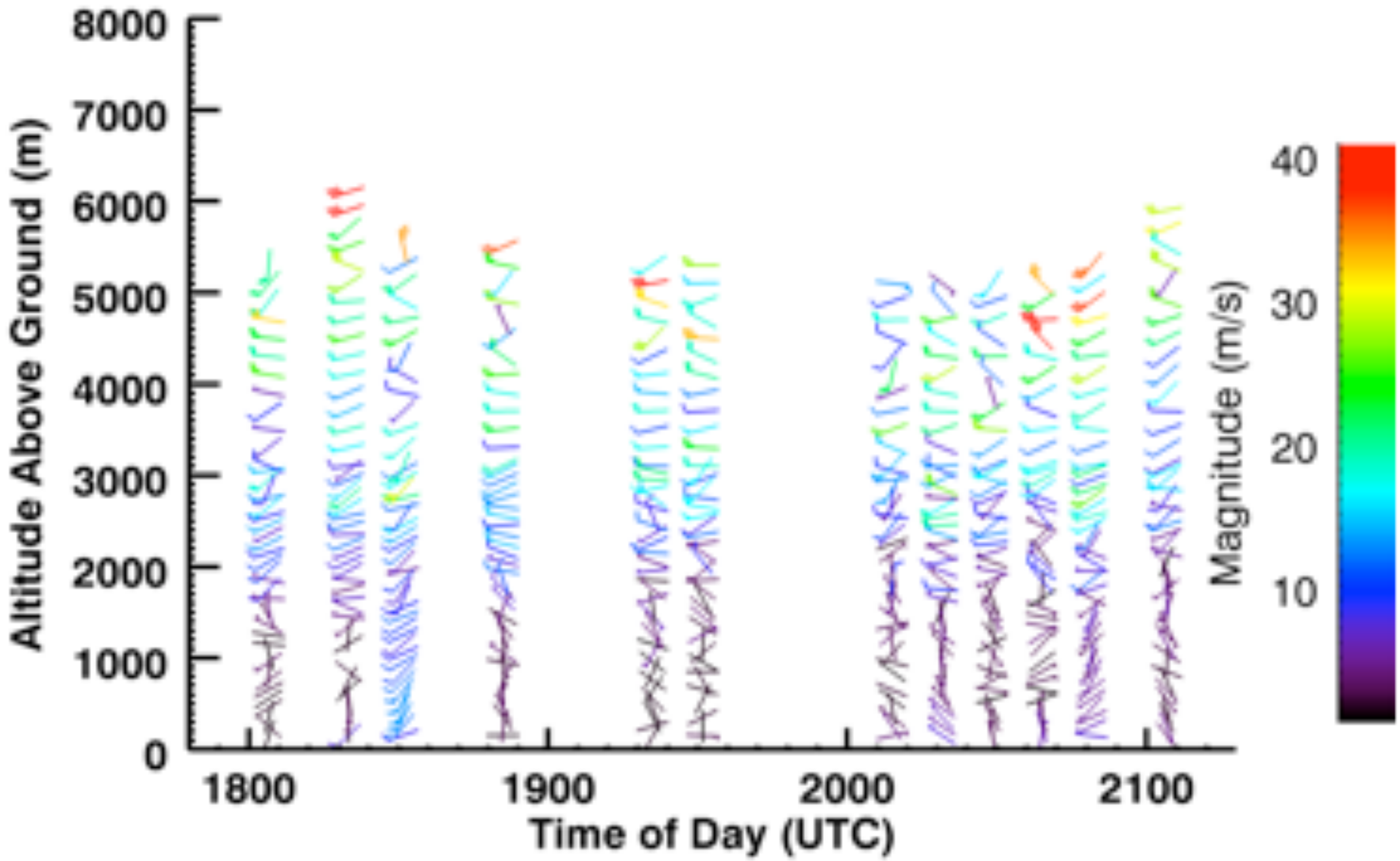


June 12 2002 Convection Case



Visible satellite imagery at 2045 UTC 12 Jun 2002, with surface observations overlaid.

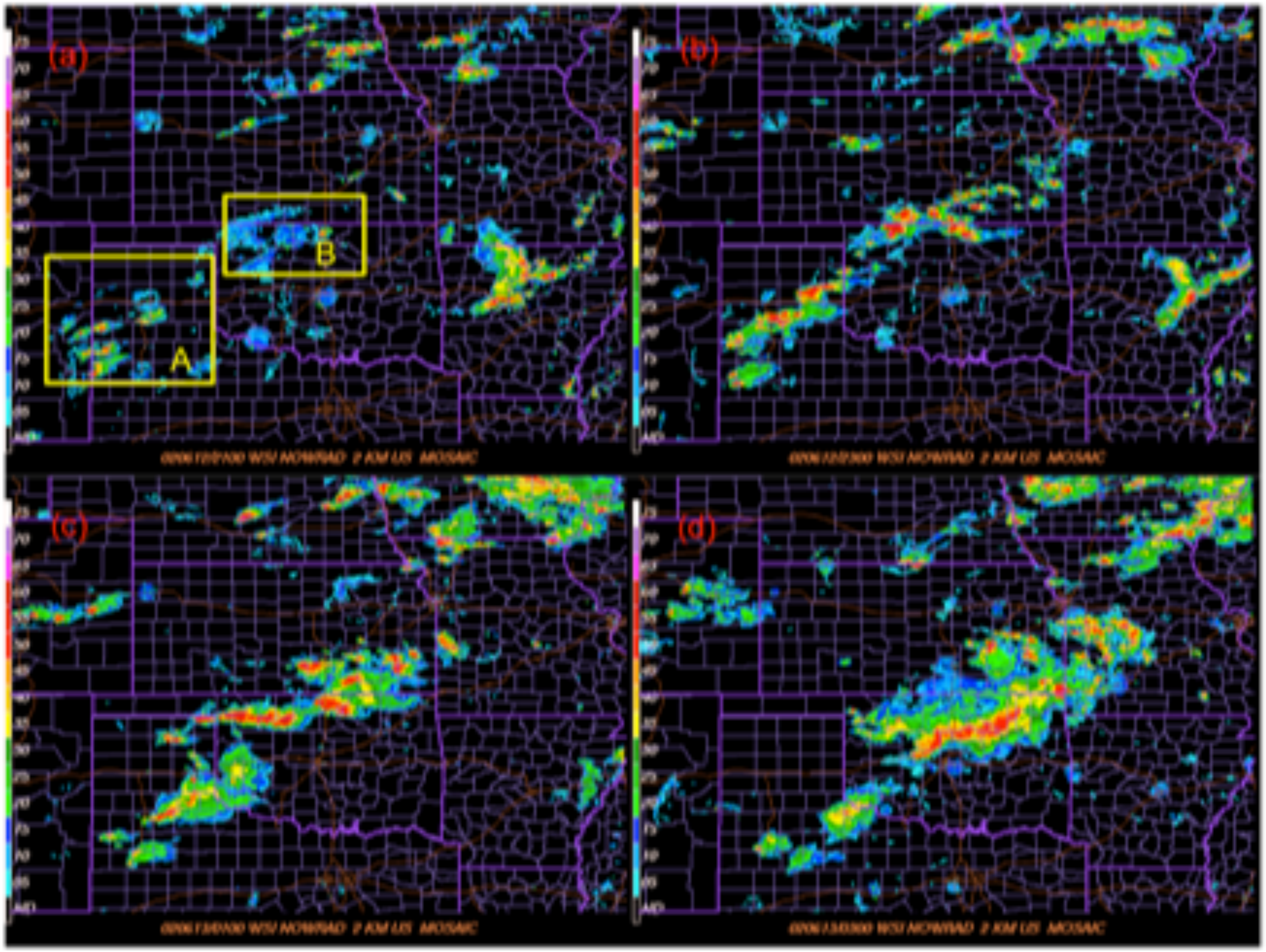
GLOW wind profiles from 1800 UTC to 2100 UTC June 2002



Composite radar reflectivity observations

2100 UTC
12 June
2002

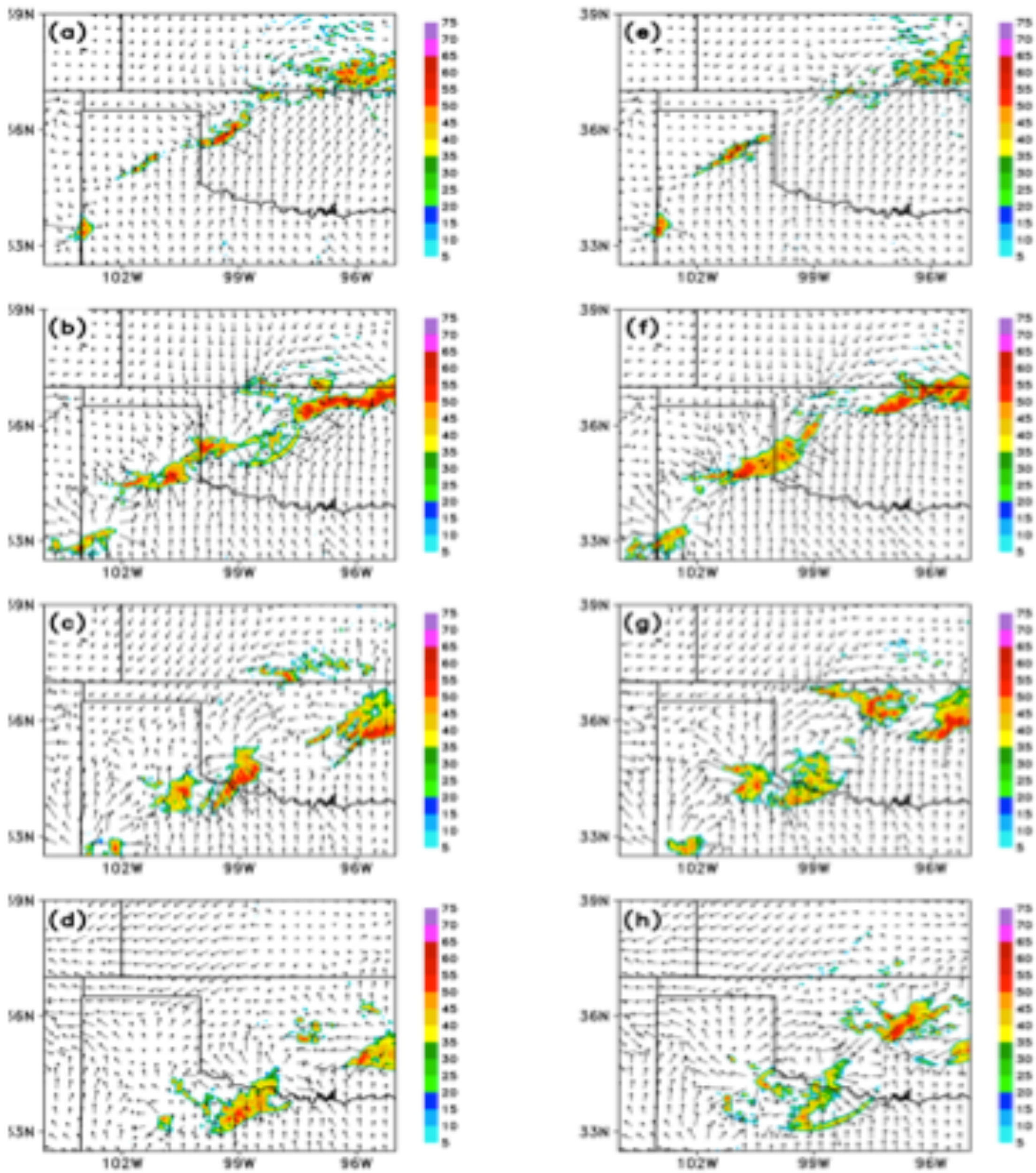
2300 UTC
12 June
2002



0100 UTC
13 June
2002

0300 UTC
13 June
2002

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



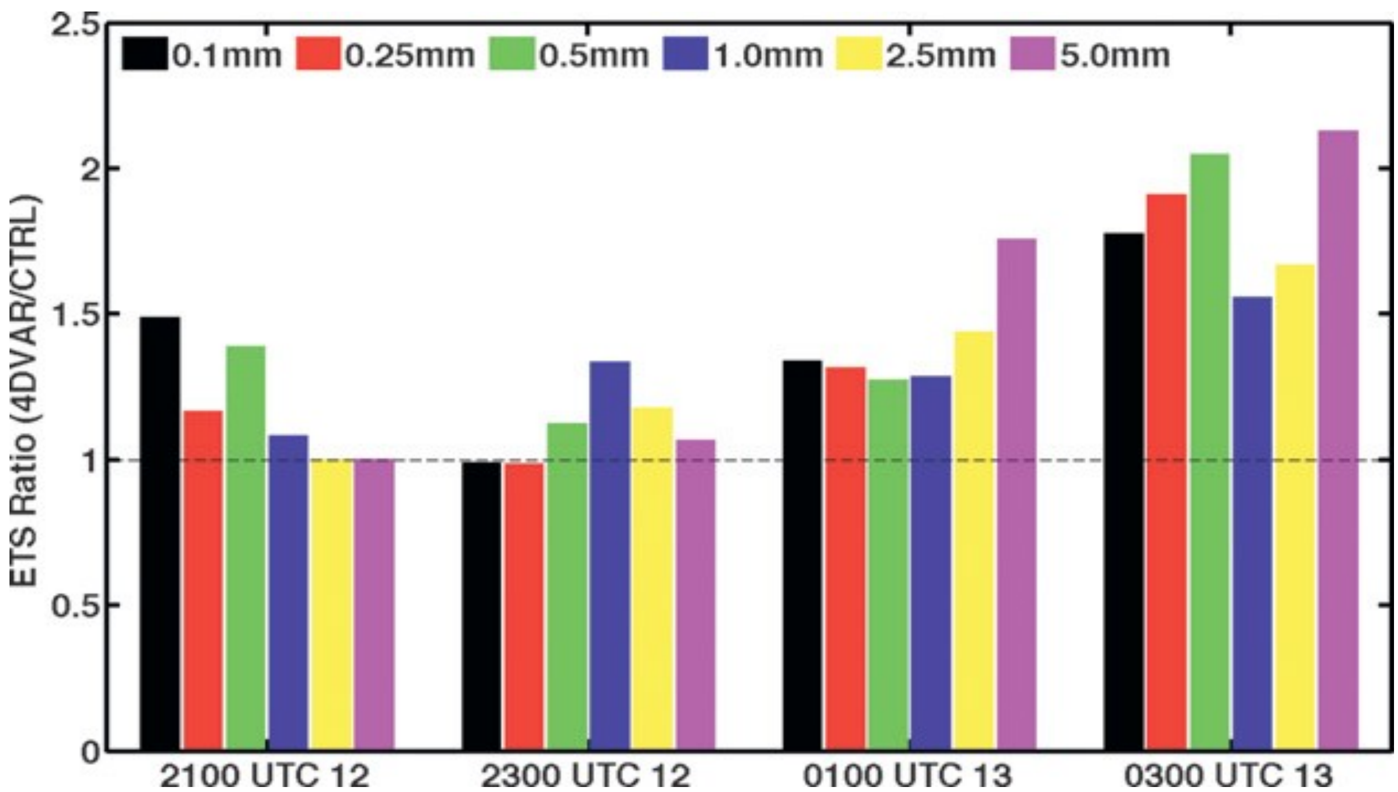
2100 UTC
12 June

2300 UTC
12 June

0100 UTC
13 June

0300 UTC
13 June

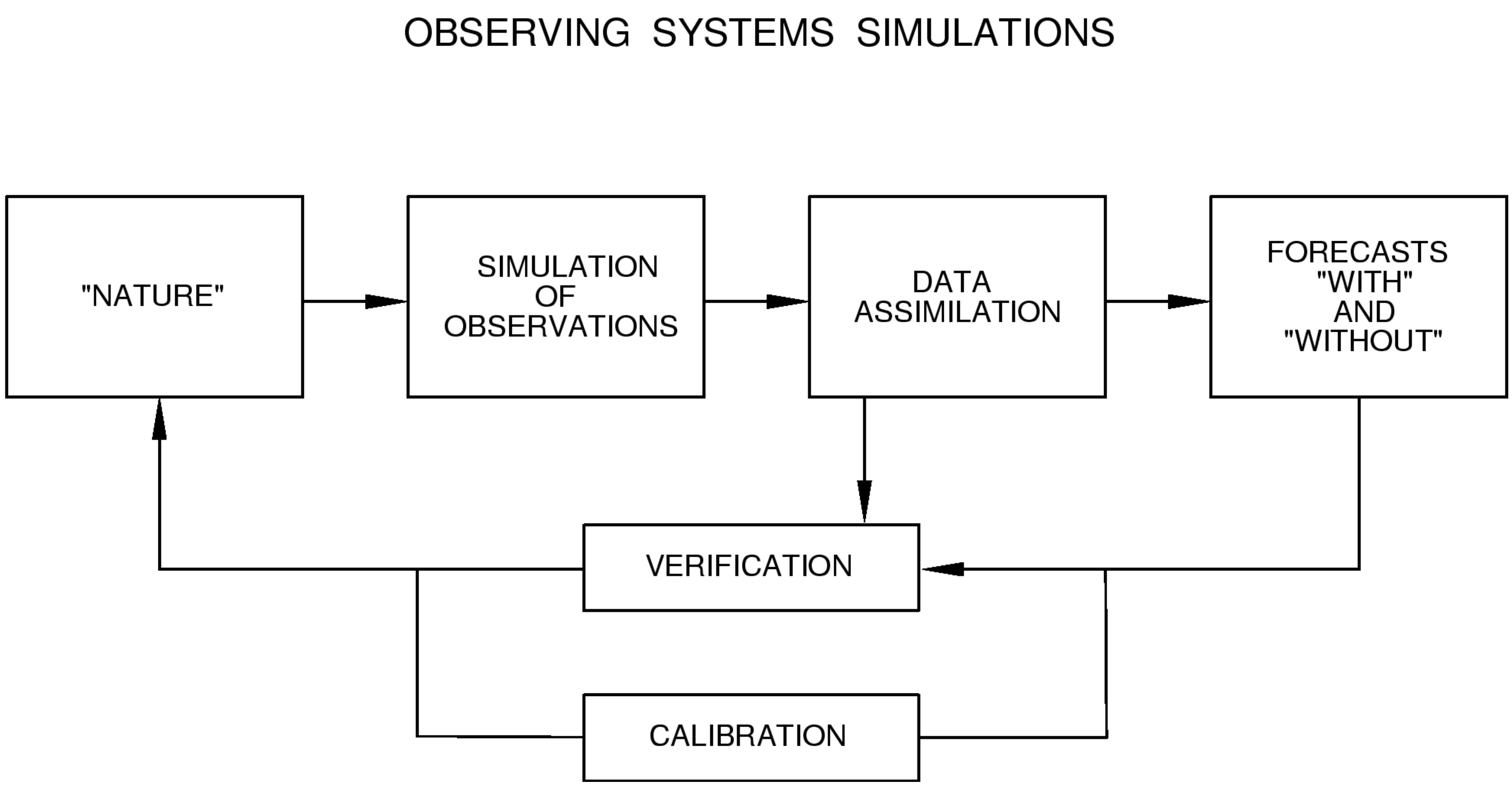
Quantitative Precipitation Forecasting Scores



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

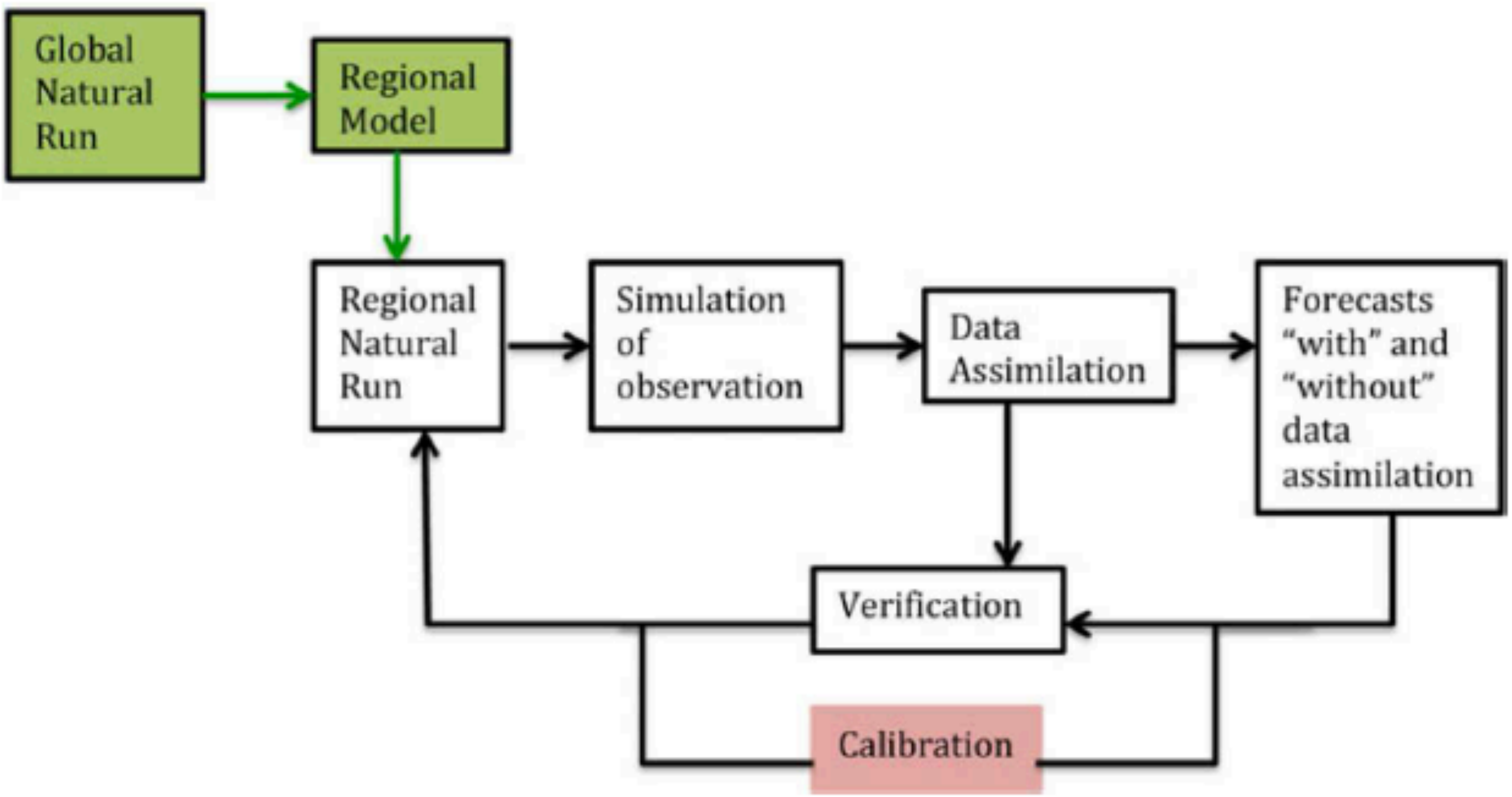
Zhang and Pu 2011, MWR

General concept of OSSEs



R. Atlas (1985)

Regional OSSEs

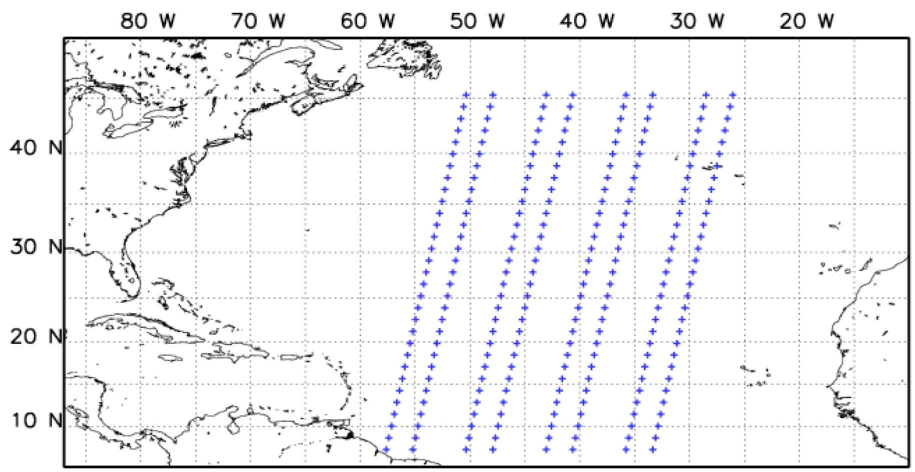


Pu et al. 2017

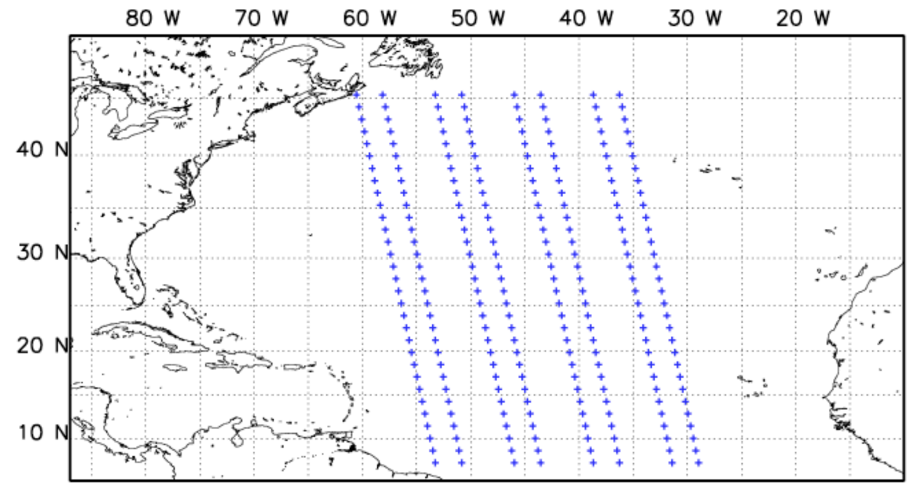
Exp. I: First Snapshots of the Satellite-based DWL Observations

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

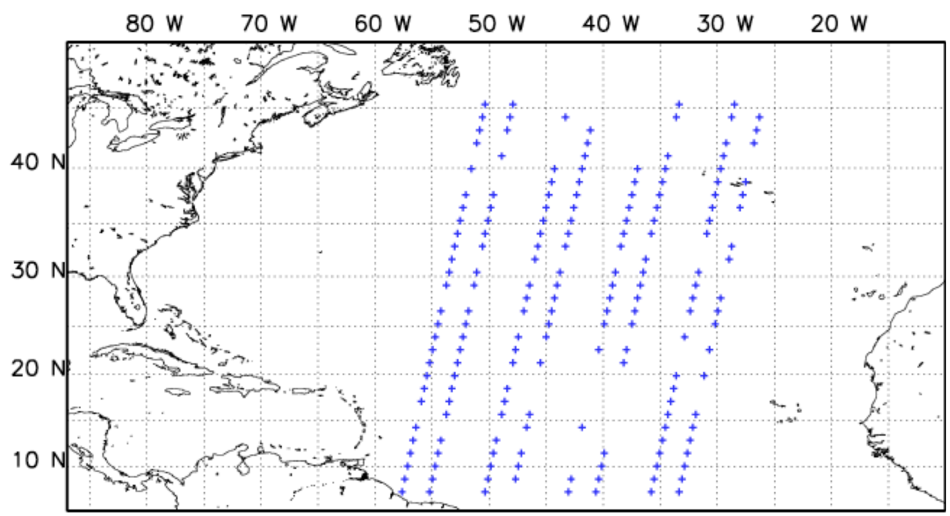
Case 1: No cloud impact

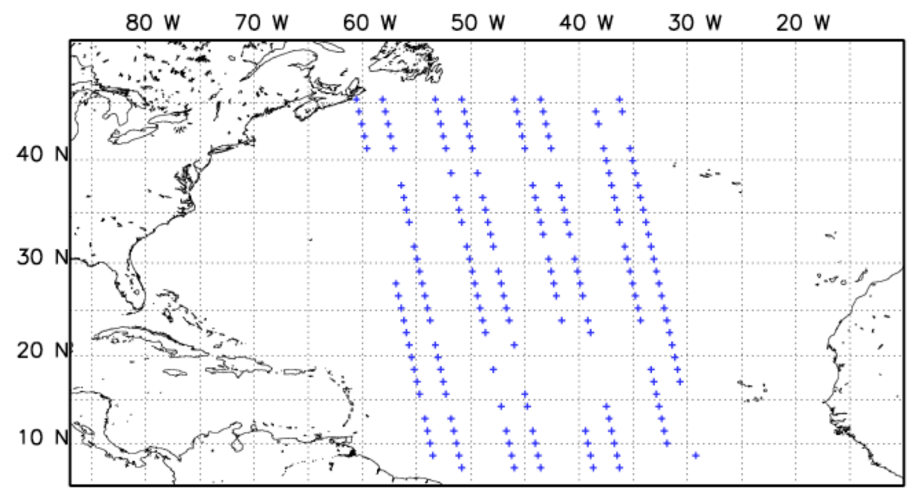


0600UTC 01 Oct. 2005



1800UTC 01 Oct. 2005

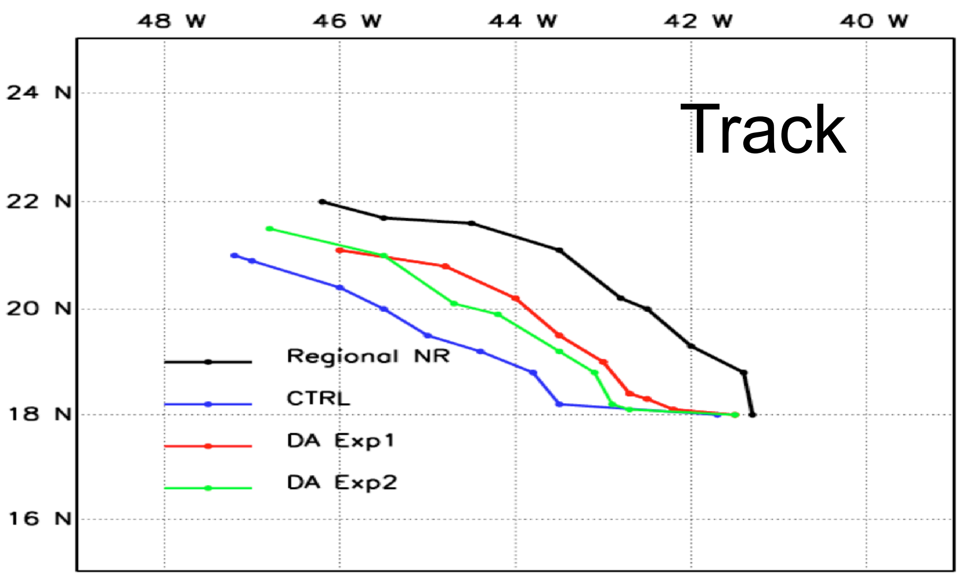




Case 2: With cloud impact

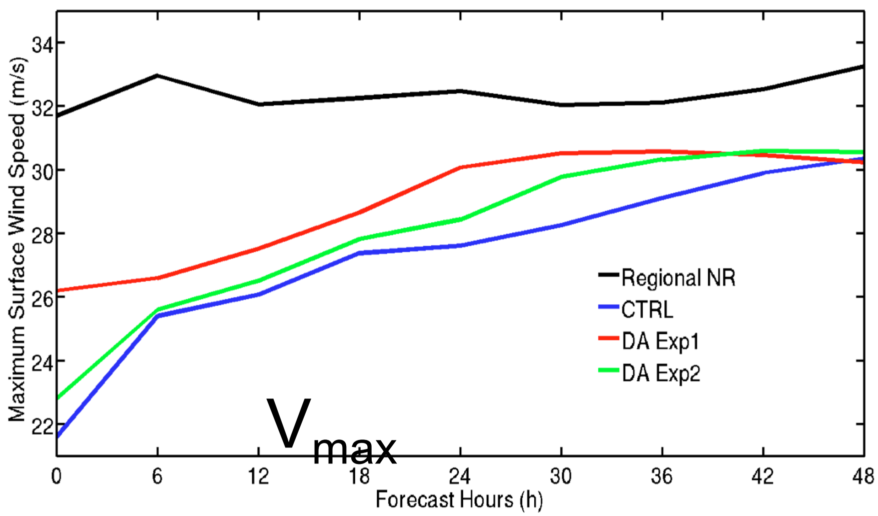
Impact of Satellite-based DWL Observations

A regional OSSE study



Impacts from assimilation of "DWL" profiles

(48-h FCST)



Zhang and Pu (2010)

Adv. Meteor.

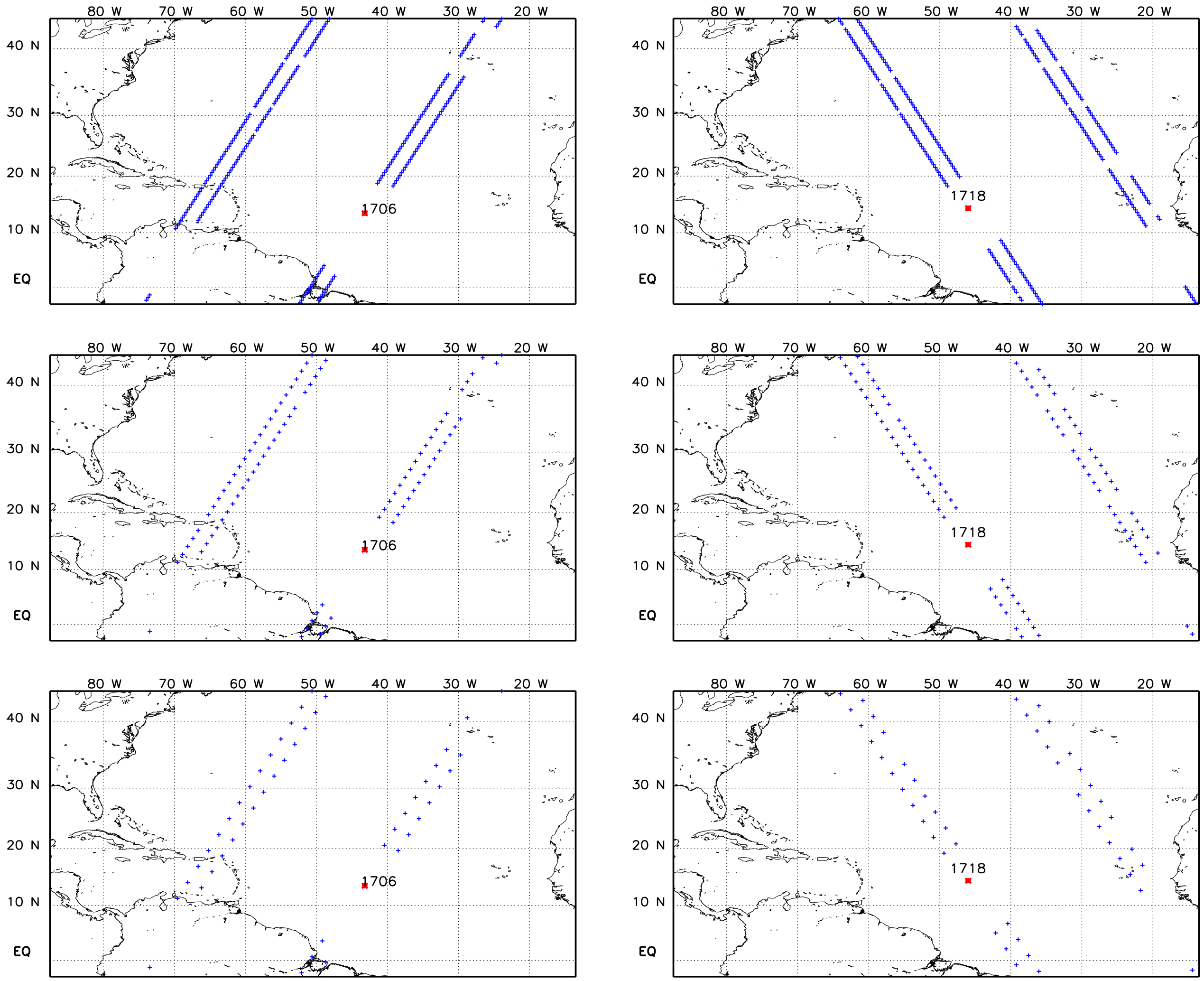
Data samples in various resolutions (Hurricane “Bill” 2009)

0600 UTC 17 August   1800 UTC 17 August

1 (60km)

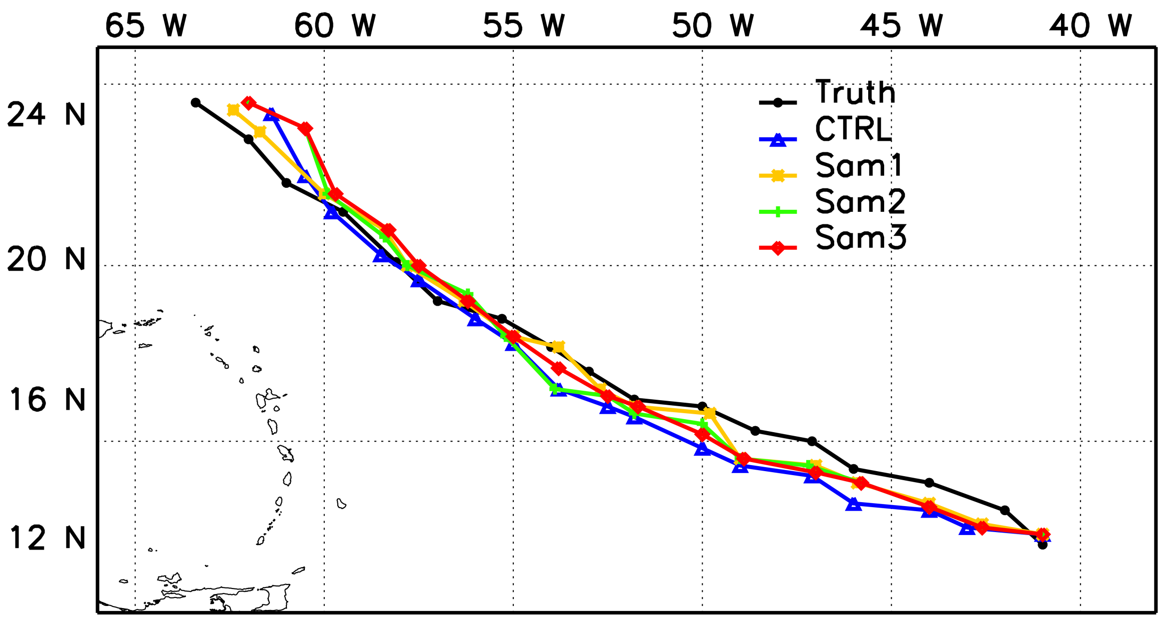
2 (120km)

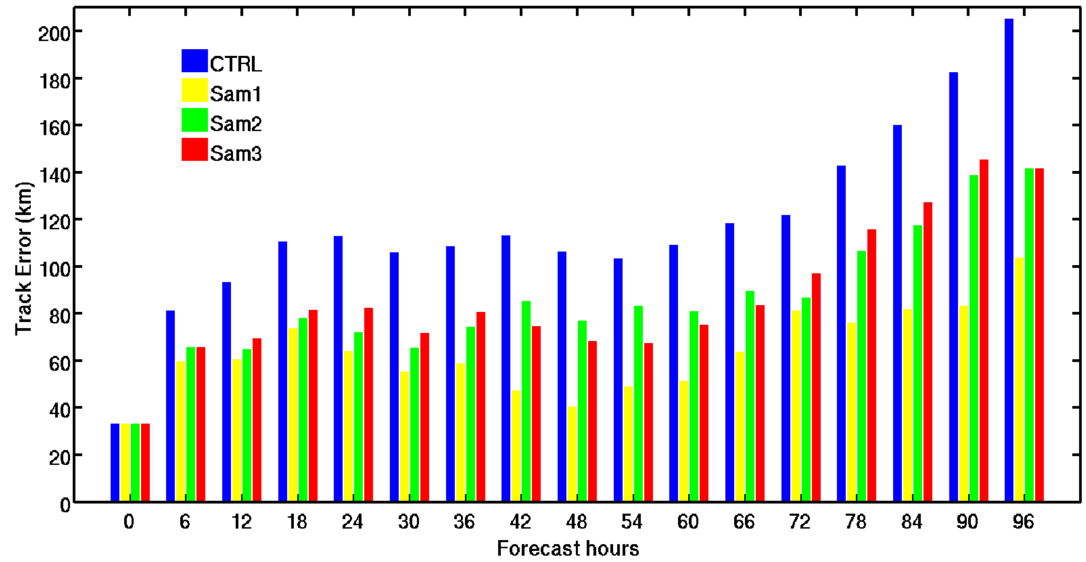
3 (180km)



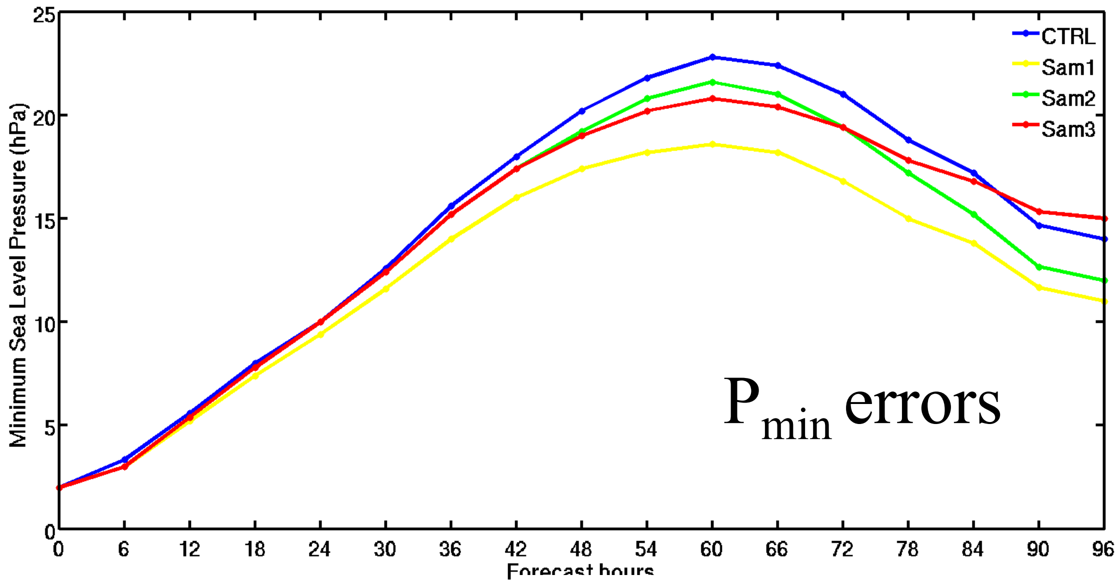
Vertical resolution: 250m below 2km; 1 km above 2km

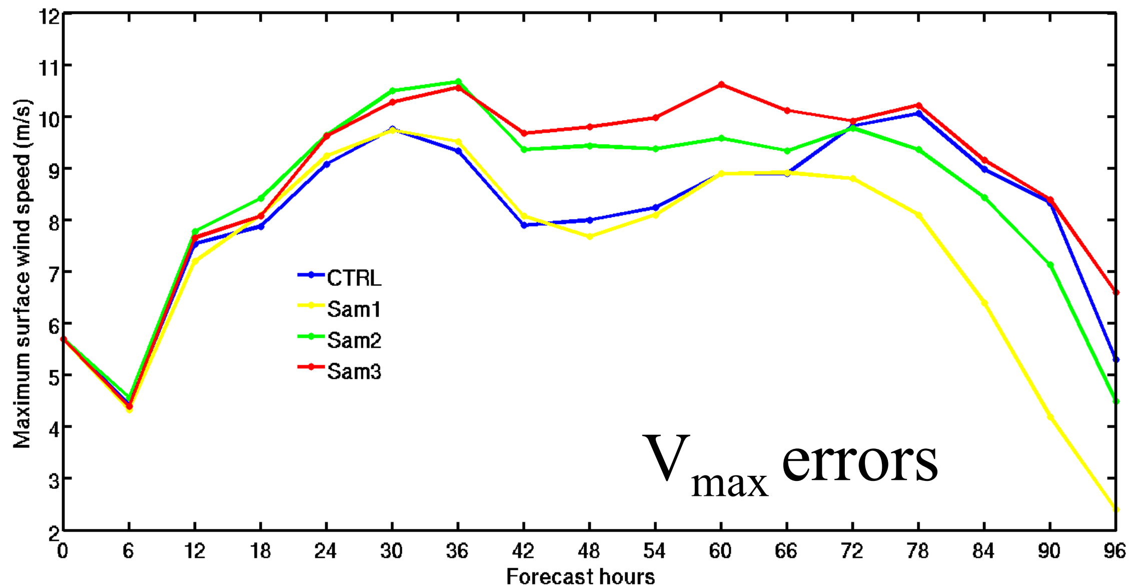
Data impact: Track and track errors



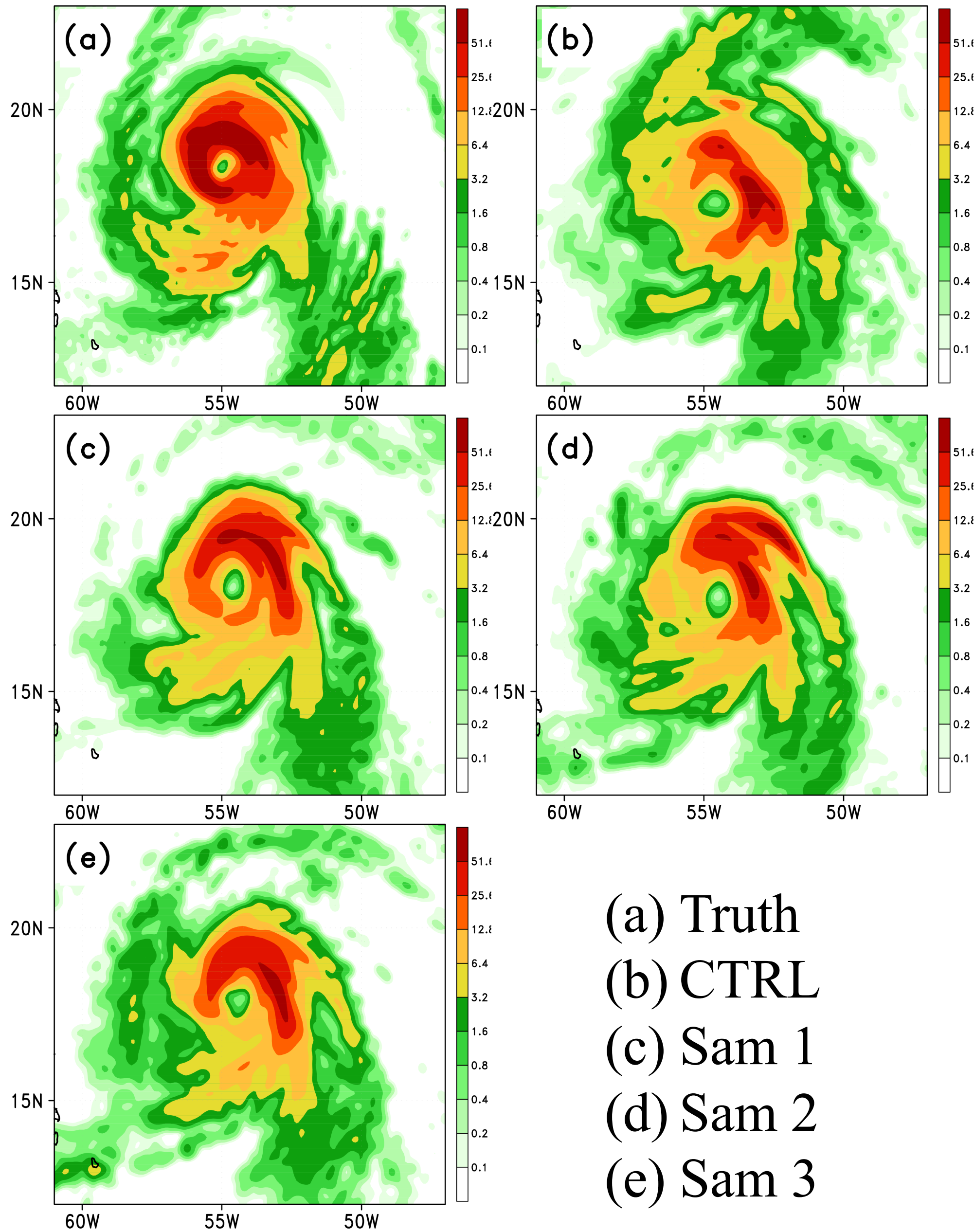


P_{min} and V_{max} Errors



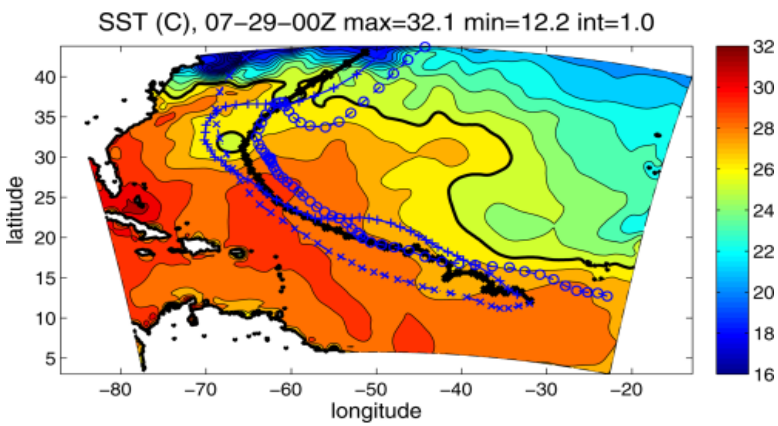


Accumulated 3-h rainfall forecasts at 1200 UTC 19 Aug.

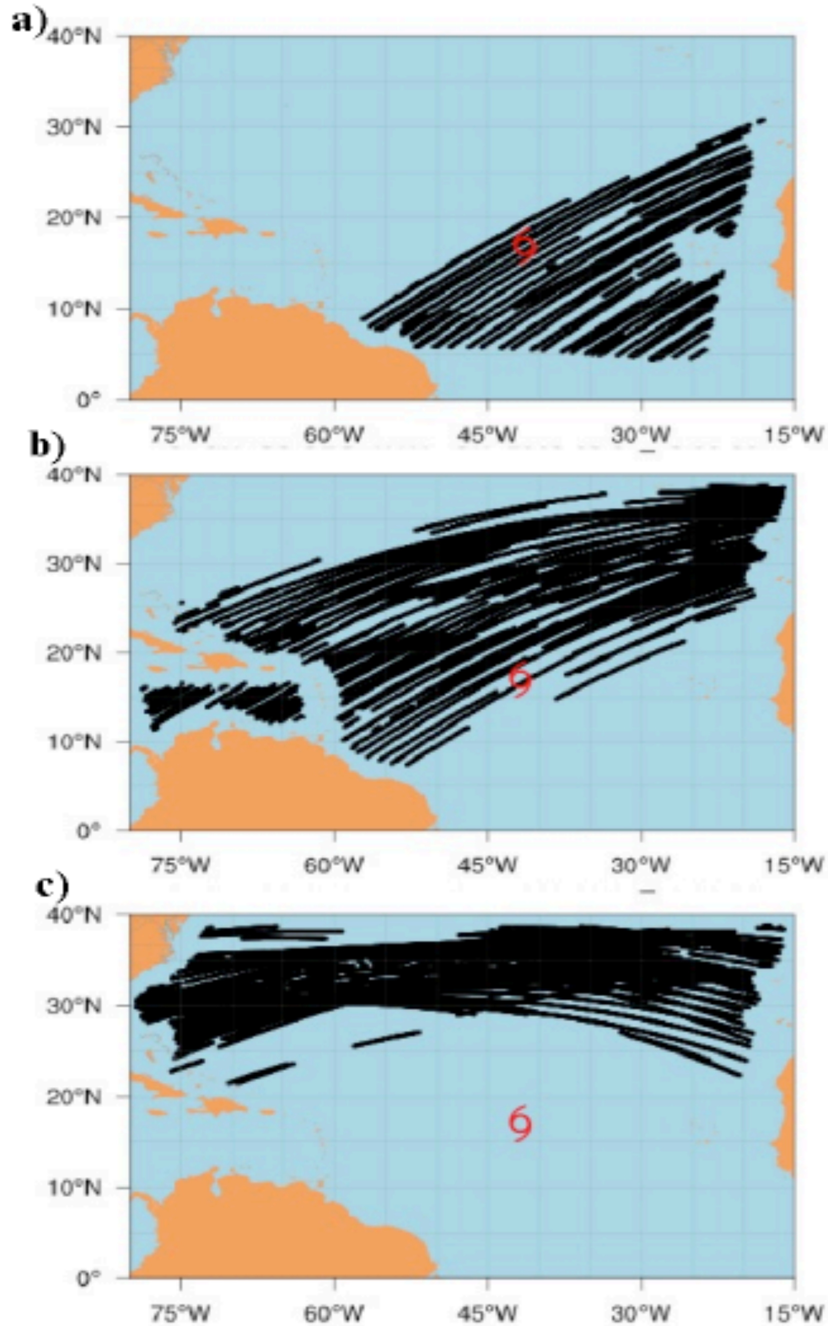


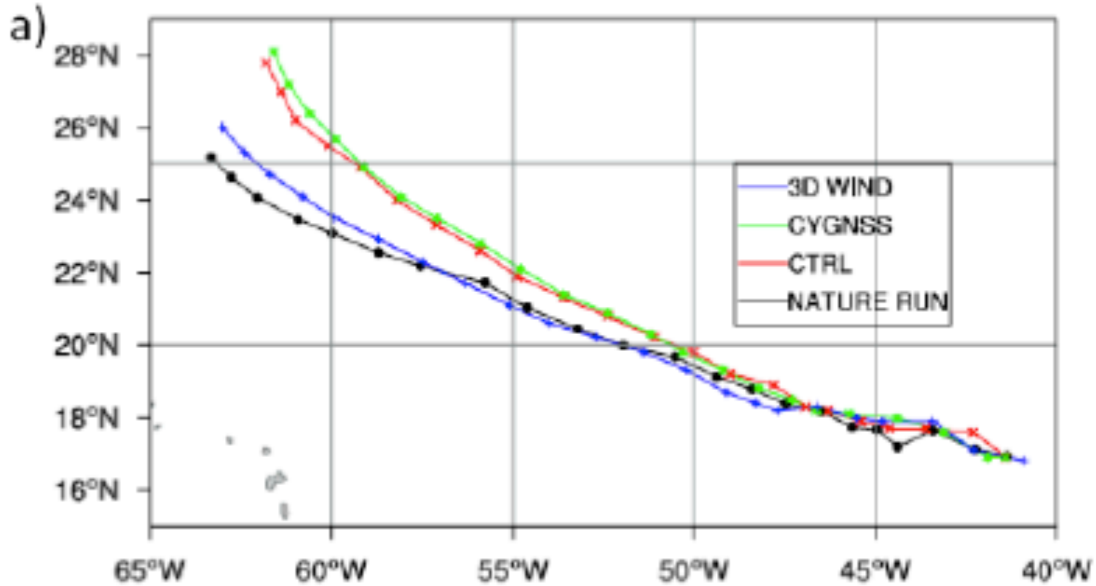
(a) Truth
(b) CTRL
(c) Sam 1
(d) Sam 2
(e) Sam 3

3-D Lidar winds
vs.
CYGNSS ocean surface winds

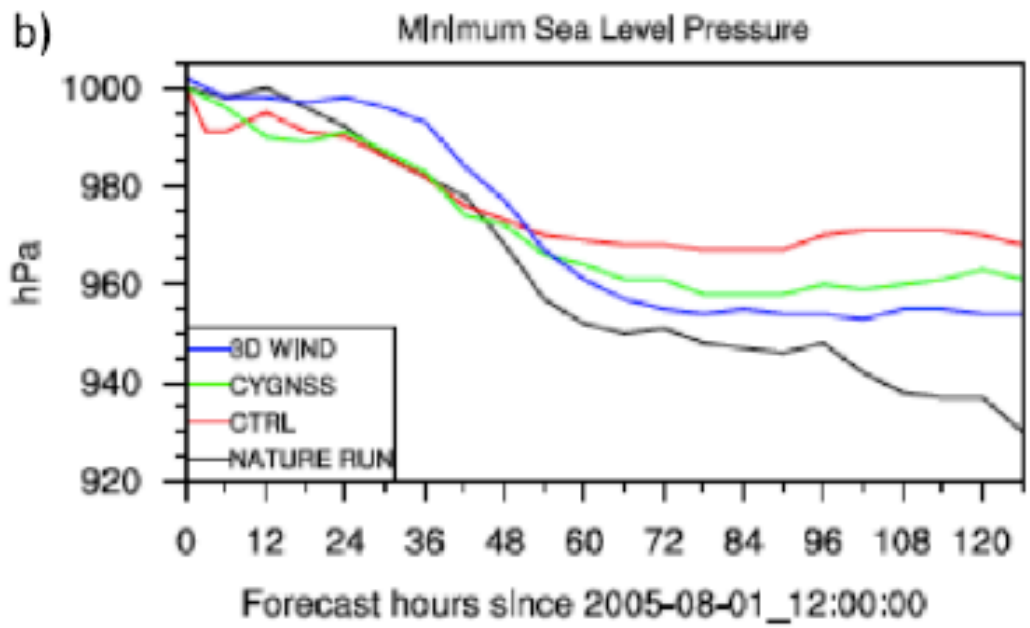


A Hurricane during
1200 UTC 28 July to
1200 UTC 11 August
Nolan et al. 2013




a)
28°N
26°N
24°N
22°N
20°N
18°N
16°N
65°W
60°W
55°W
50°W
45°W
40°W
3D WIND
CYGNSS
CTRL
NATURE RUN

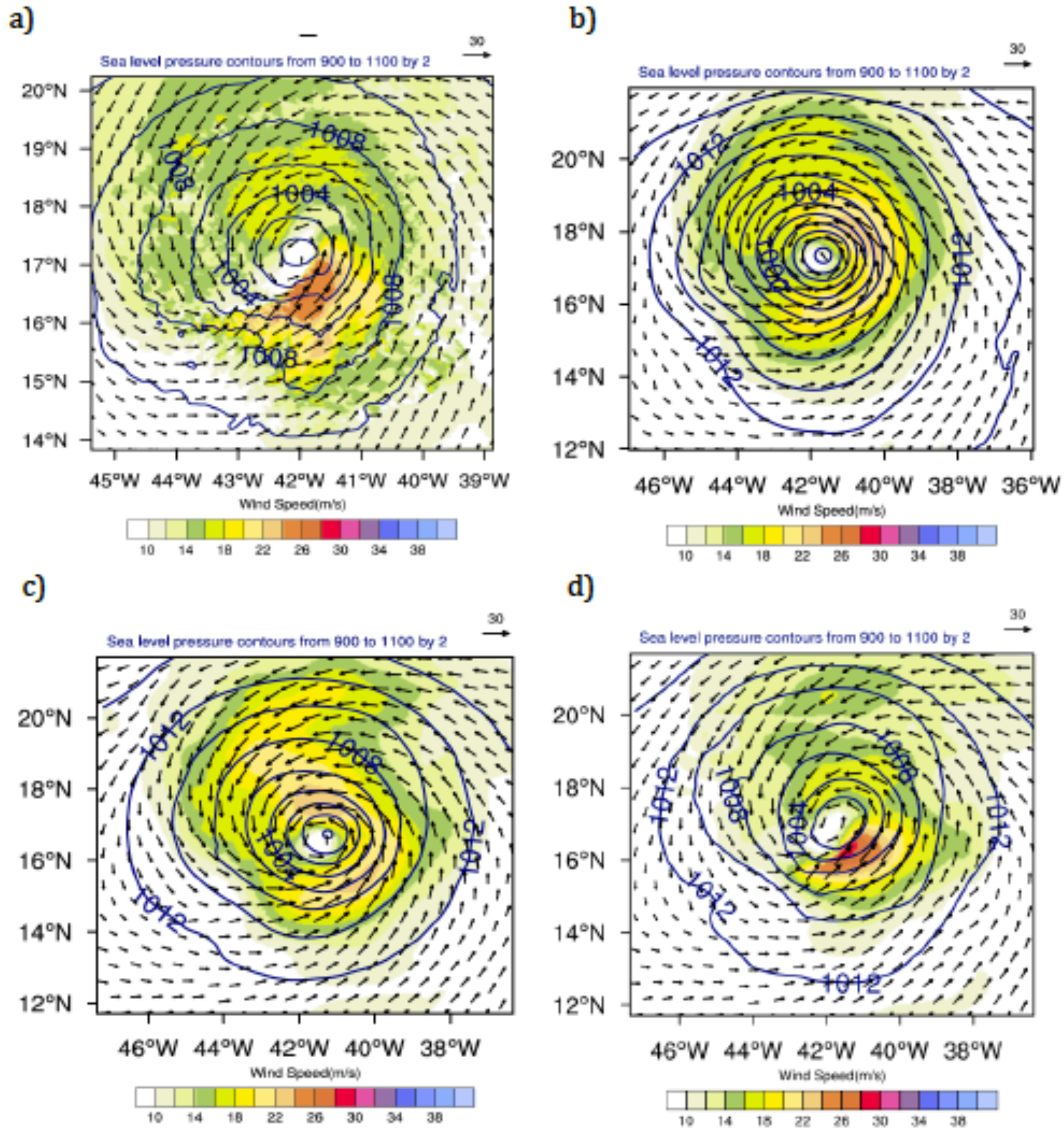
Track


b)
Minimum Sea Level Pressure
hPa
1000
980
960
940
920
0
12
24
36
48
60
72
84
96
108
120
3D WIND
CYGNSS
CTRL
NATURE RUN
Forecast hours since 2005-08-01_12:00:00

P_{min}

Nature Run

CTRL

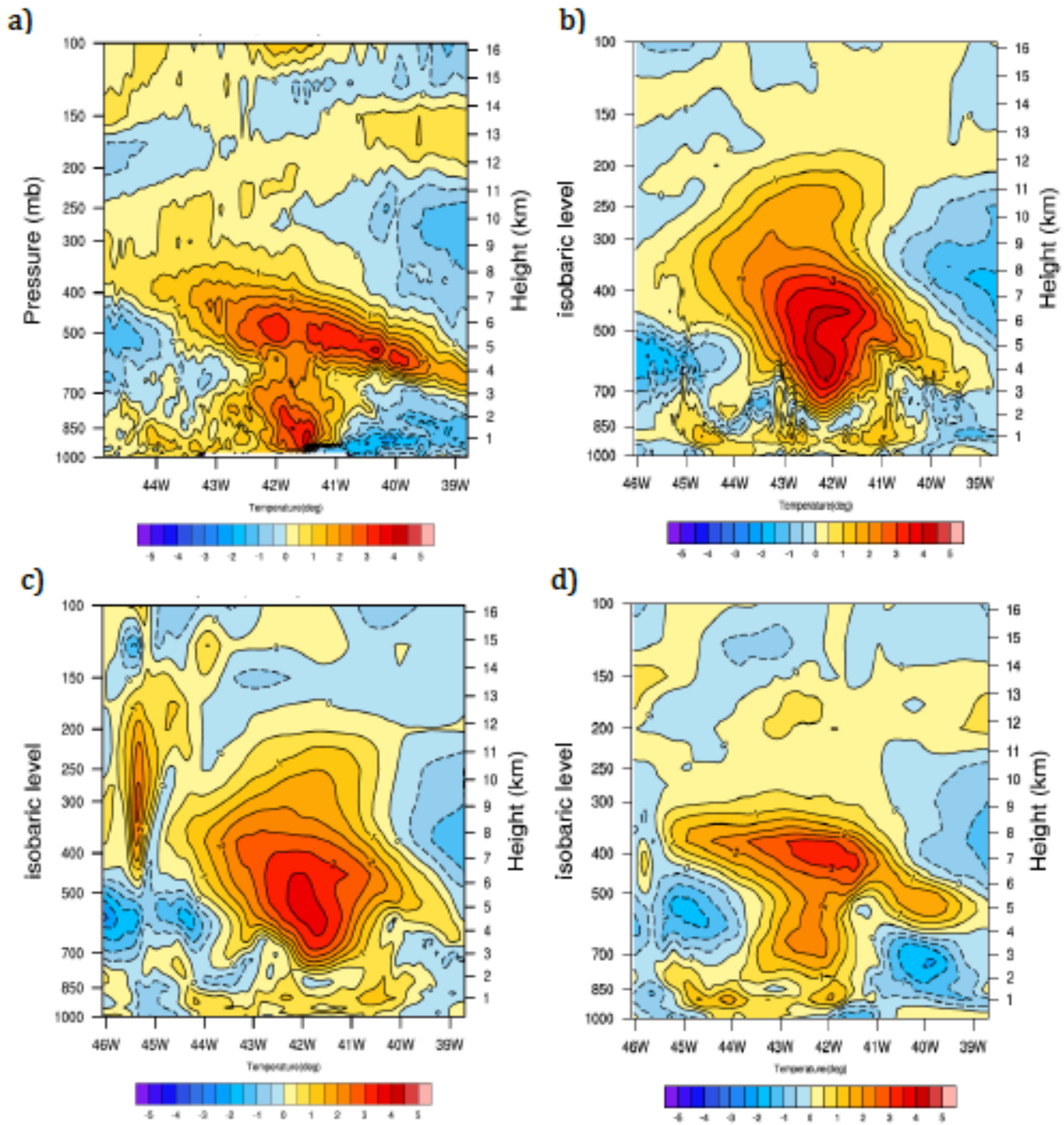


CYGNSS

3D wind

Nature Run

CTRL



CYGNSS

3D wind

Pu et al. - Wind Lidar WG 2018

Concluding remarks

- **There are significant uncertainties in global and regional wind analyses, implying the insufficient wind measurements**
- **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**
- **Space-based 3-D wind profiling measurements are essential for improving high-impact weather events.**

Thank you very much for your attention!

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