Numerical Simulation of Tropical Cyclone Intensity Change with High Resolution WRF Model and Assimilation of multi-Sensor Remote Sensing and In-Situ Data

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JCSDA Seminar
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Motivation

- Limiting factors for hurricane intensity forecast:
- Physical parameterizations
- Initial conditions
- Understanding of TC intensity change

Questions

- What are the physical mechanisms influencing TC intensity change?

- To what extent can data assimilation improve the forecast of TC intensity change?

Observational Data & Numerical Model

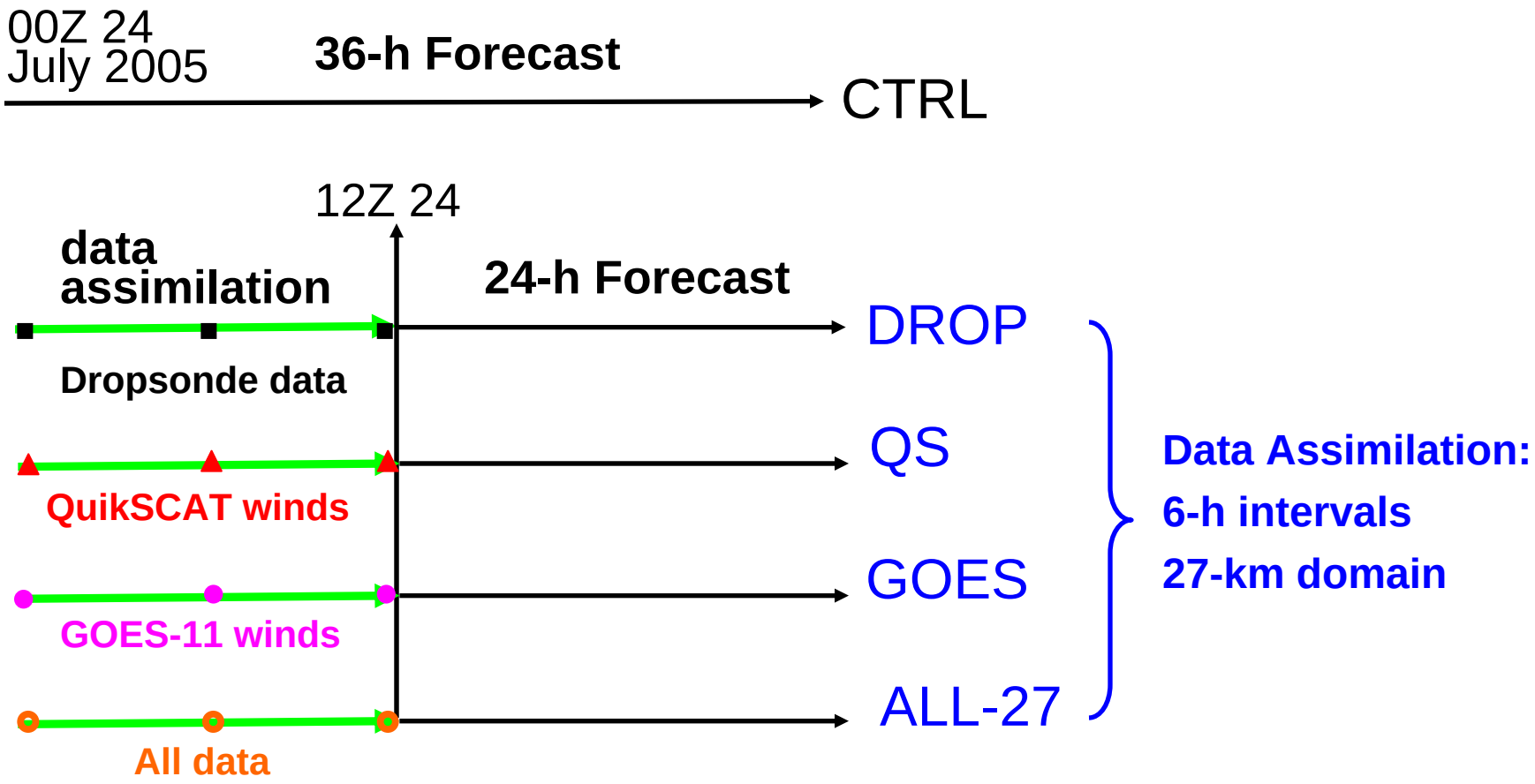
- Satellite wind
- QuikSCAT ocean surface winds
- GOES-11AMVs
- AIRS sounding data
- Aircraft dropsonde
- Airborne Doppler radar data

- WRF model

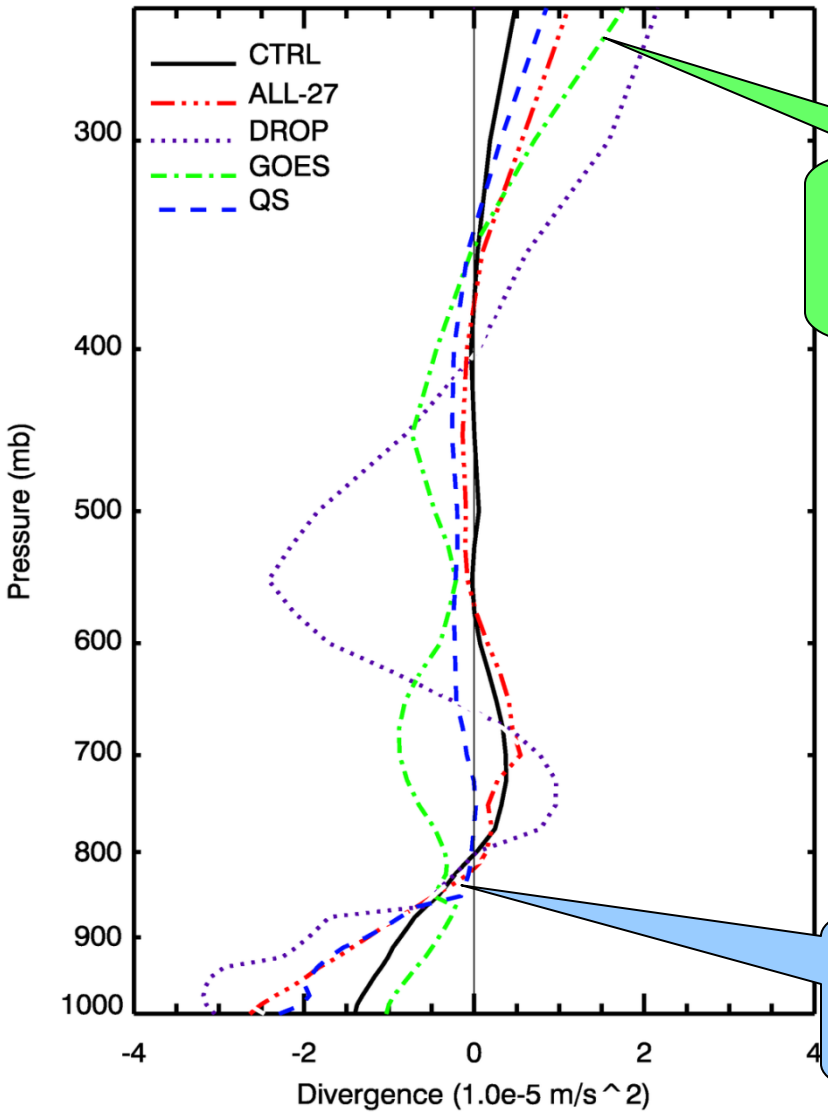
- WRF-3DVAR system

Impact of the Satellite Wind and Dropsonde Data on Tropical Storms Cindy (2005) and Gert(2005)

Experiments for Gert



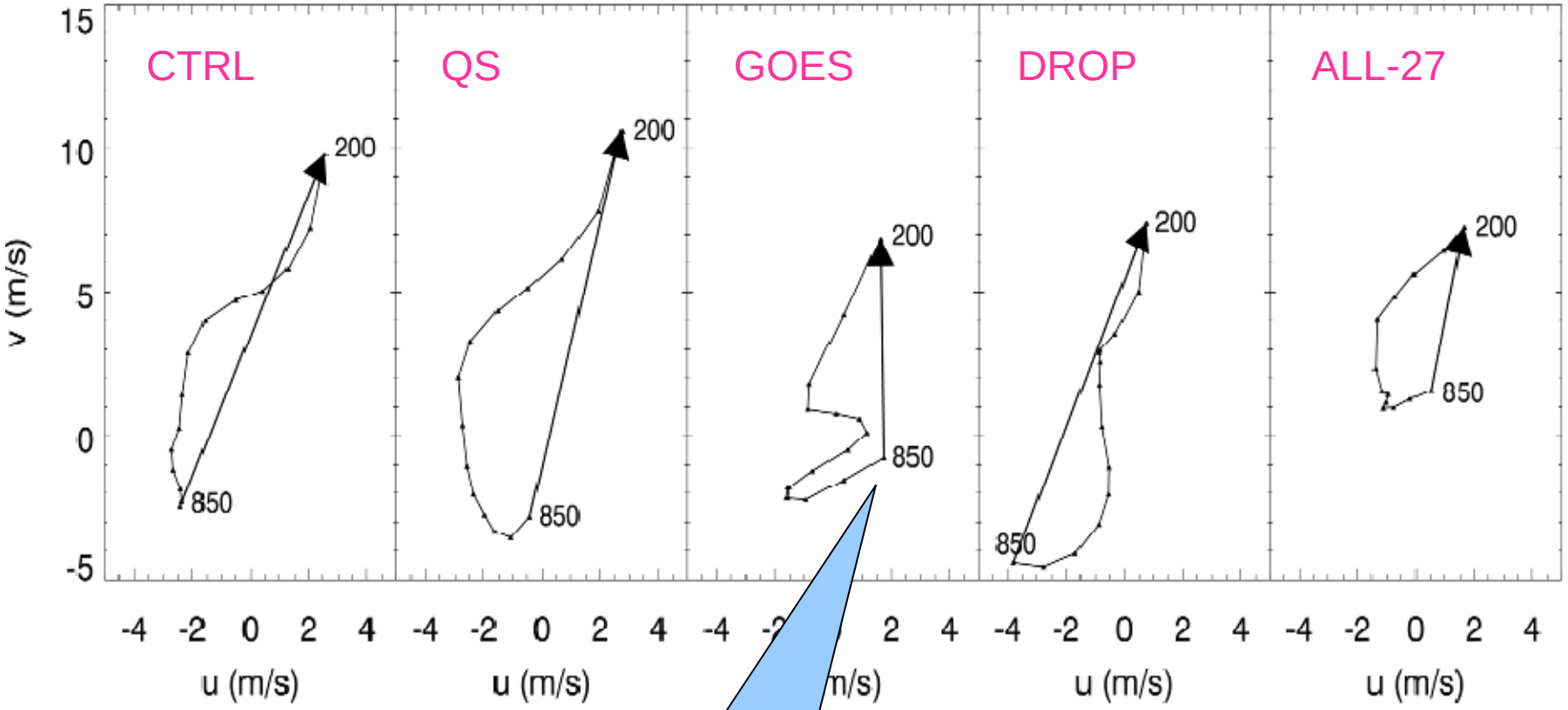
Area Averaged Divergence for Gert



GOES wind: large impact in high level

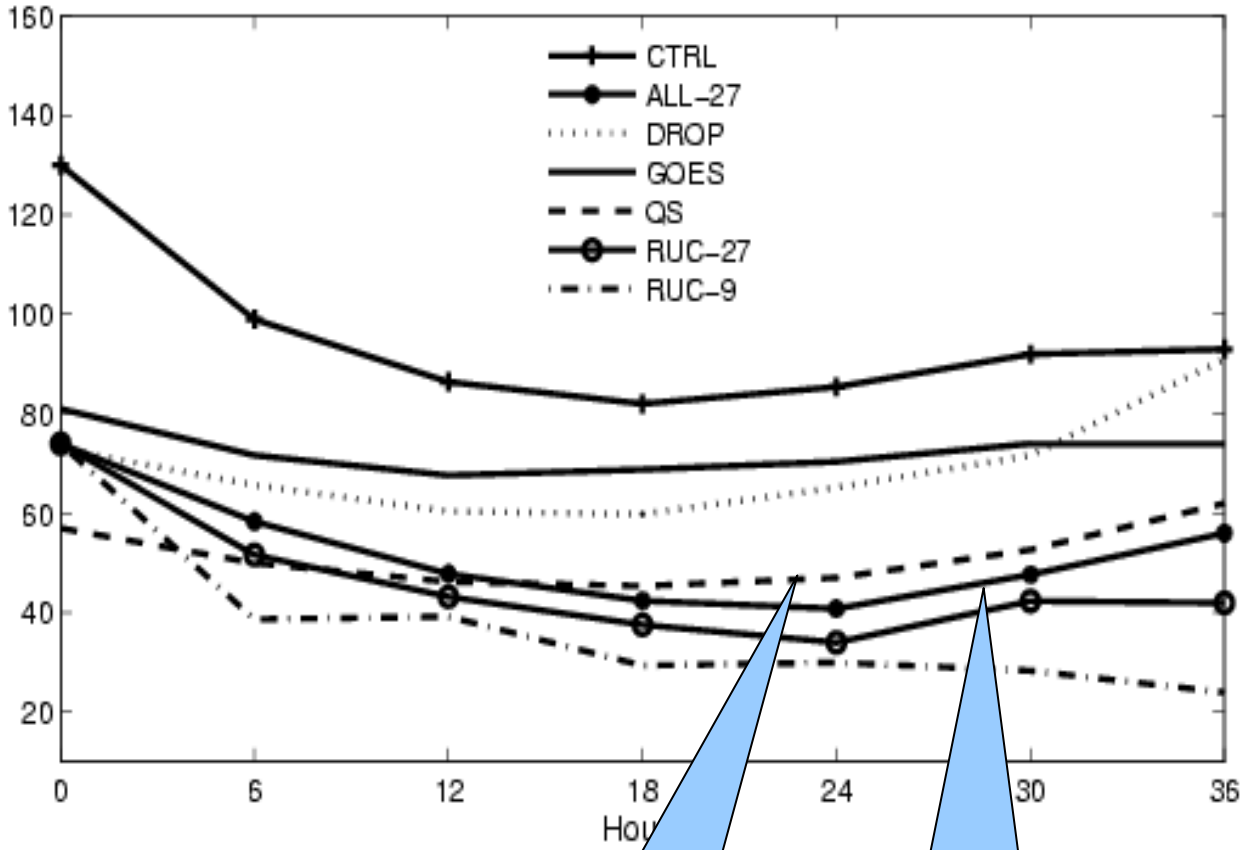
QuikSCAT data: impact concentrate in low level

Environment Vertical Wind Shear for Gert



GOES wind:
impact on direction
and magnitude

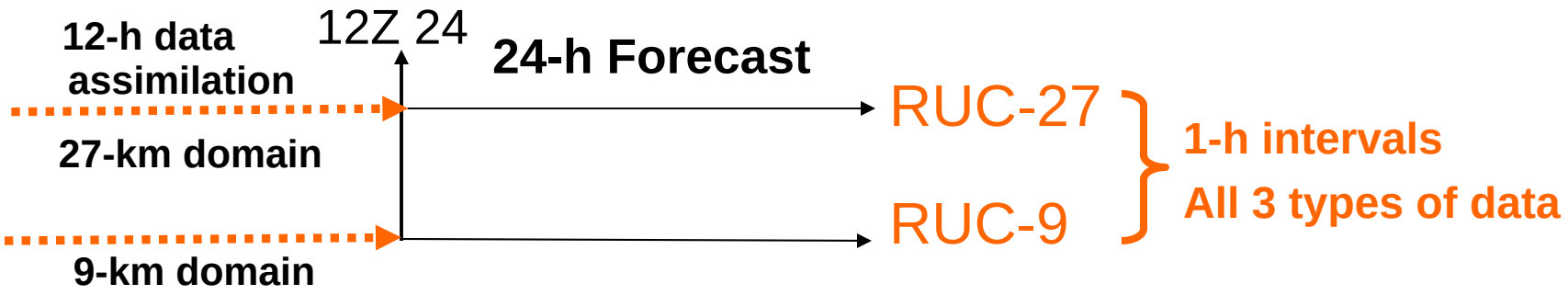
Track Forecast for Gert

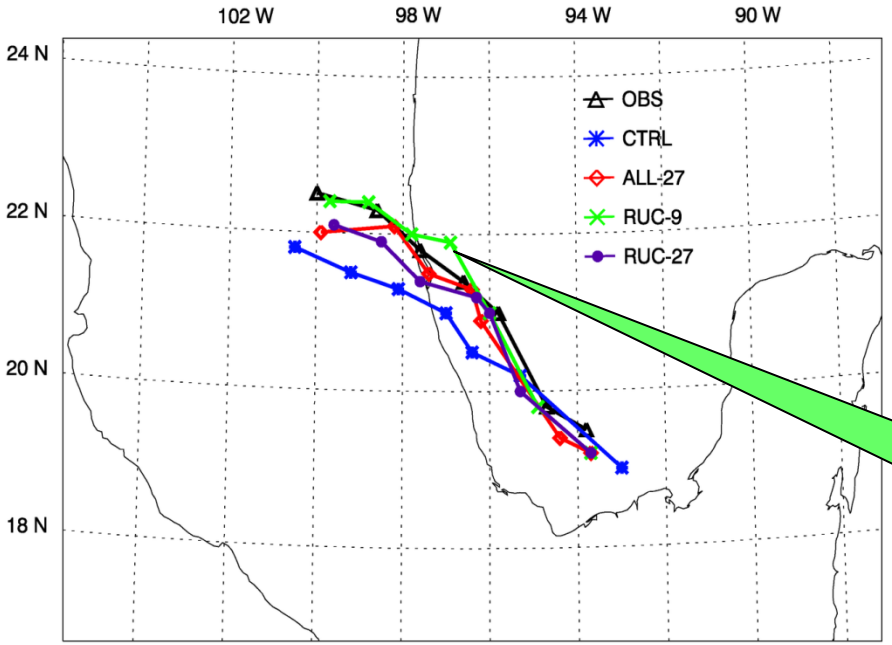


QuikSCAT wind: larger impact on track

All-27: better track forecast than DROP, QS, and GOES

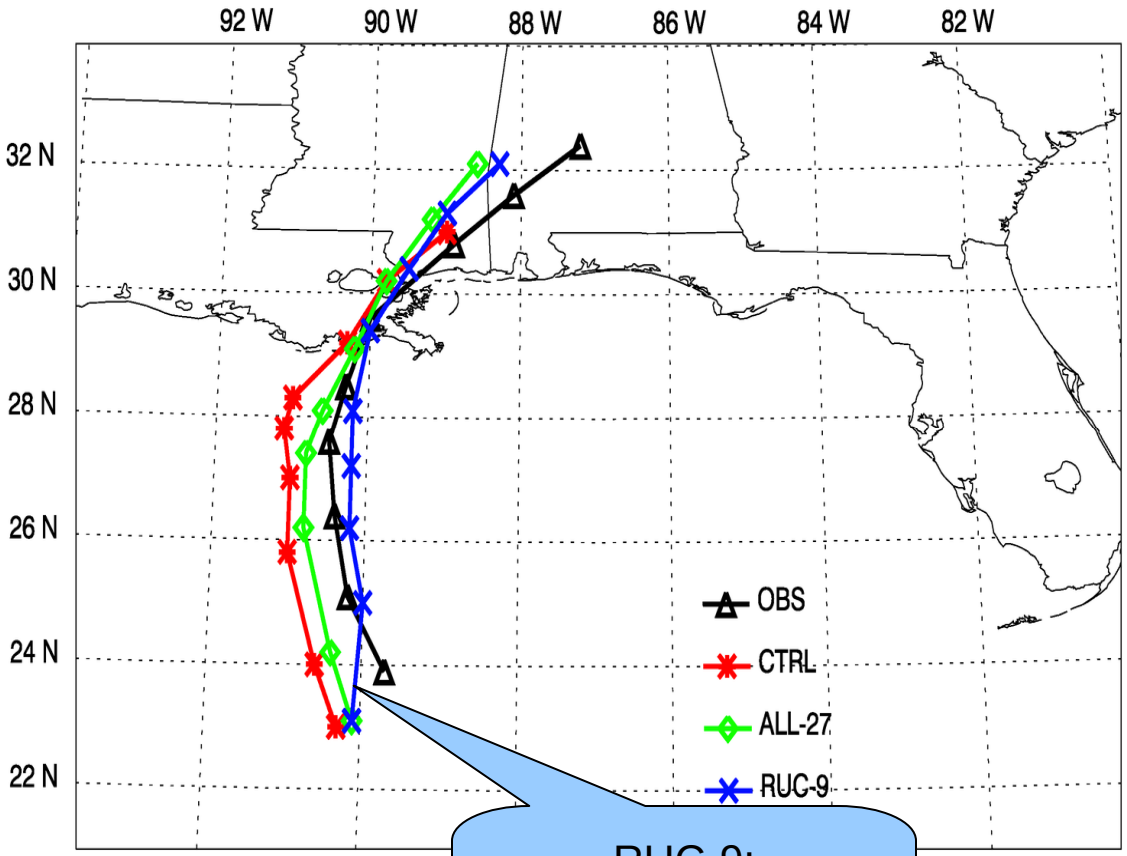
Track Forecast for Gert





RUC-9:
The best track forecast

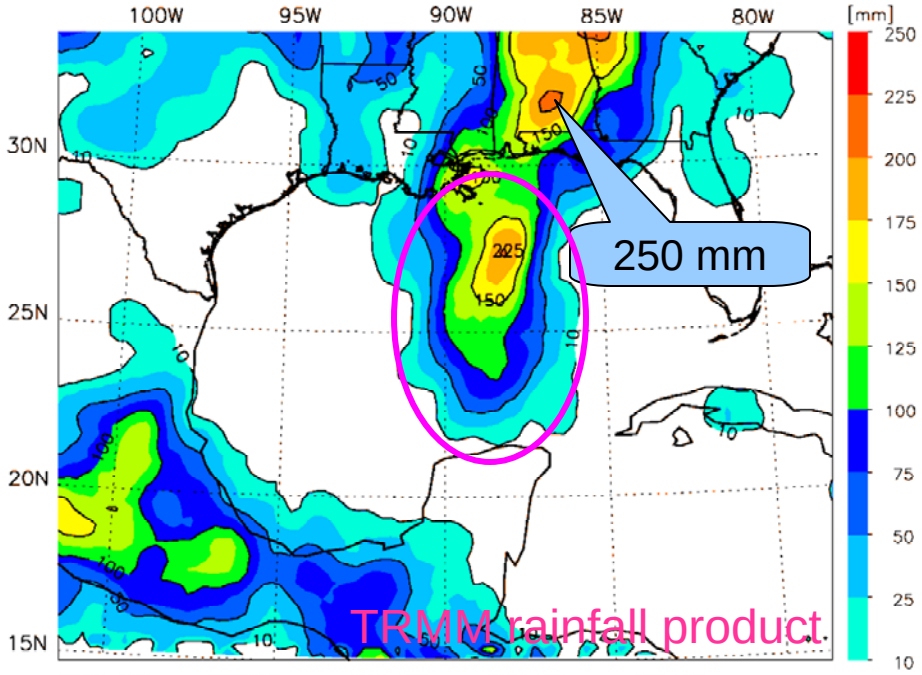
Track Forecast for Cindy

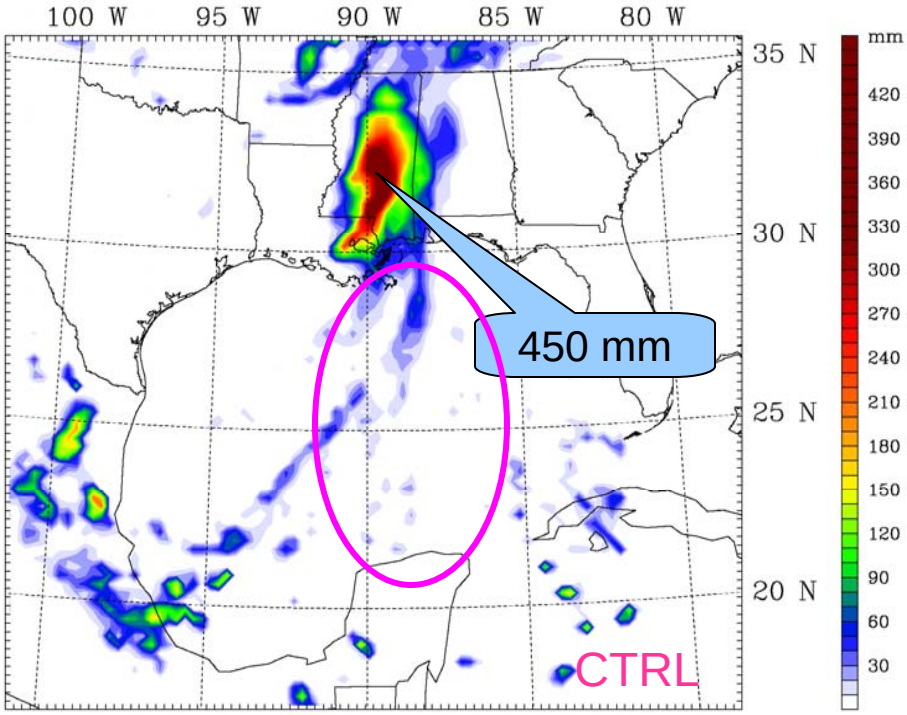


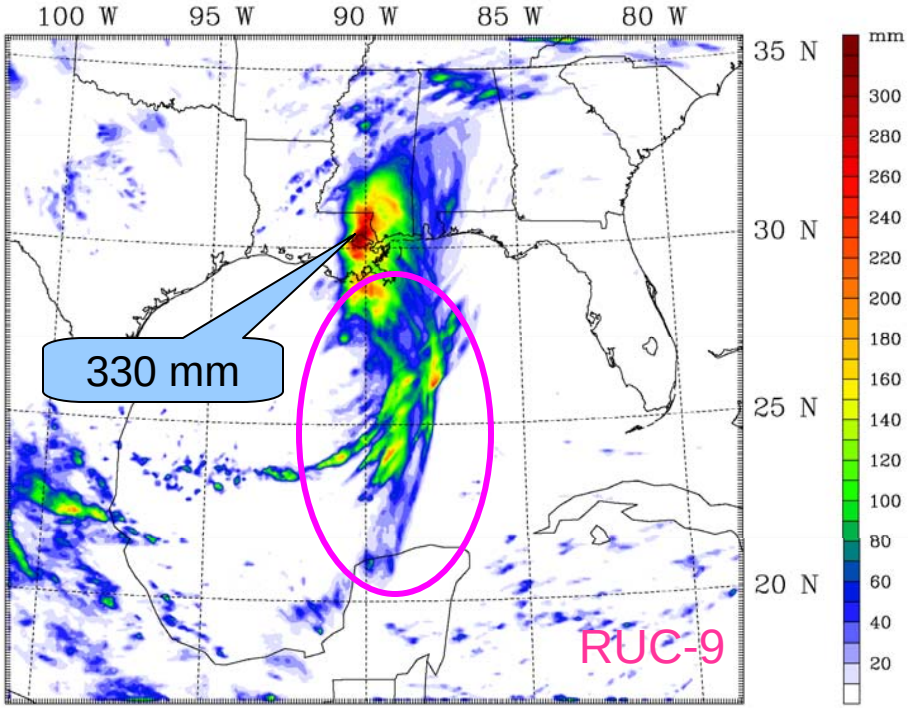
RUC-9:
The best track forecast

Experiment	Data assimilation
CTRL	N/A
ALL-27	6-h interval 27-km domain
RUC-9	1-h interval 9-km domain

48-h Accumulated Rainfall Along Cindy's Track between 5 and 7 July 2005





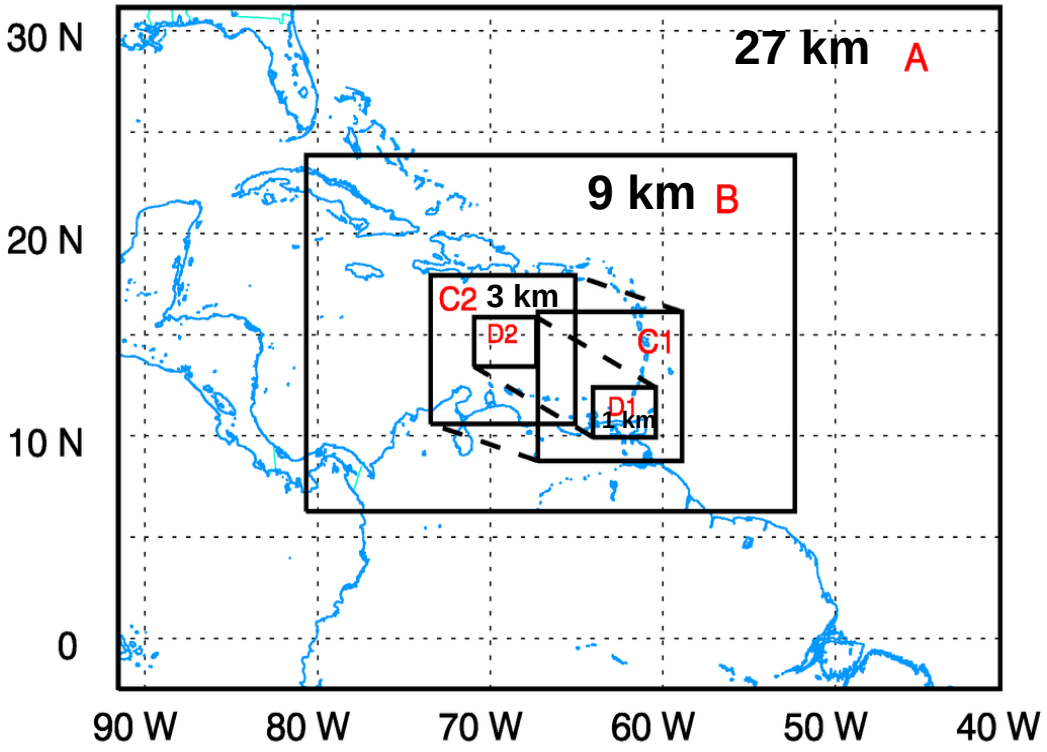


Summary I

- The satellite winds and aircraft dropsonde data have a positive impact on the track, intensity, and precipitation forecast for Cindy and Gert.
- Various types of data have different influences on the structure of the storm vortex and the environmental feature.
- QuickScat data has a large impact for track forecast.
- 1-h rapid update analysis cycle at higher resolution (9-km) is a more effective way to do data assimilation with 3DVAR

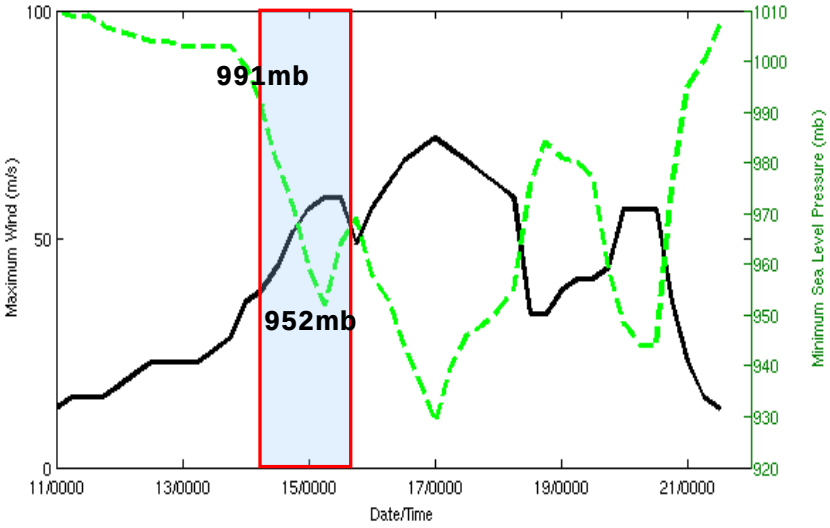
Impact of the Satellite Wind and Dropsonde Data on Hurricane Emily (2005)

Numerical Simulation of Hurricane Emily



Experiment	Resolution
CTRL-1	1 km
CTRL-3	3 km
DA-1	1 km
DA-3	3 km

Numerical Experiments



06Z 14
July 2005

6-h cycled data assimilation

30-h Forecast

CTRL-1

CTRL-3

6-h intervals
9-km domain
18Z 13 – 06Z 14

6-h cycled data assimilation

DA-1

DA-3

6-h intervals
9-km domain
18Z 13 – 06Z 15

18Z 13
July 2005

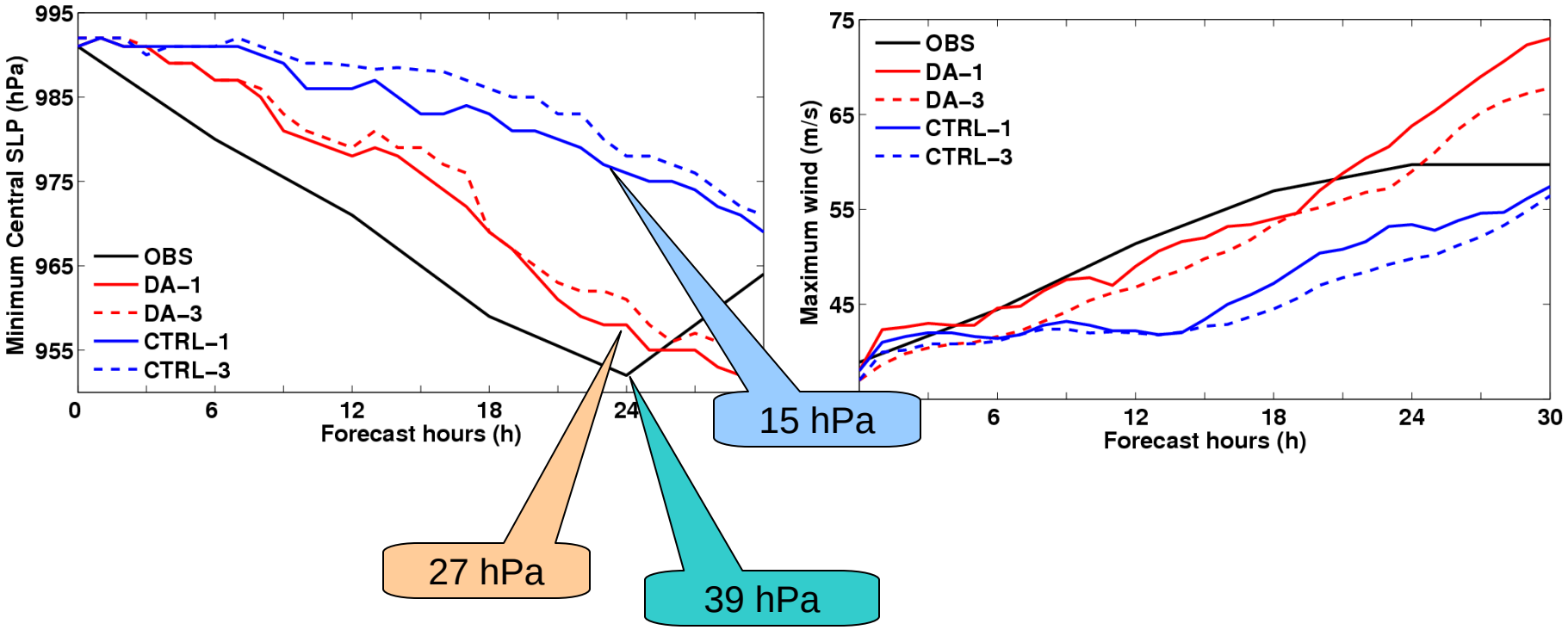
12Z 15
July 2005

Data
- QuikSCAT winds
- GOES-11 winds
- Dropsondes data

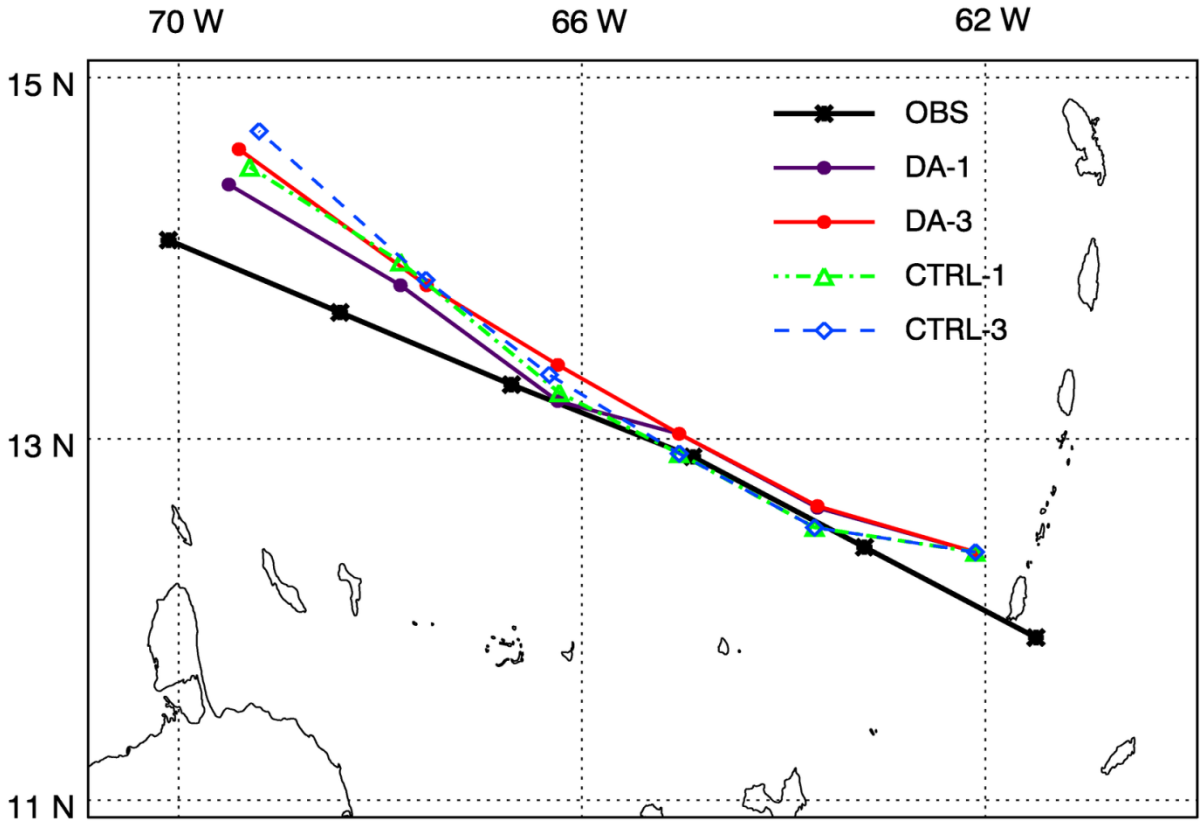
Intensity Forecast for Emily

Minimum sea level pressure

Maximum surface wind



Track Forecast for Emily

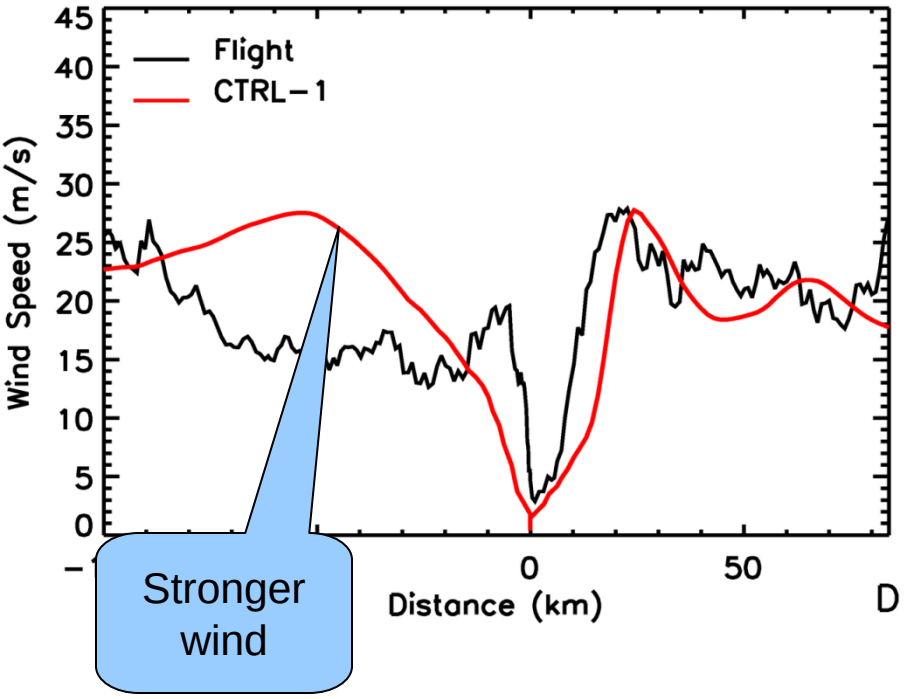


- Moderate impact of the data assimilation on the track

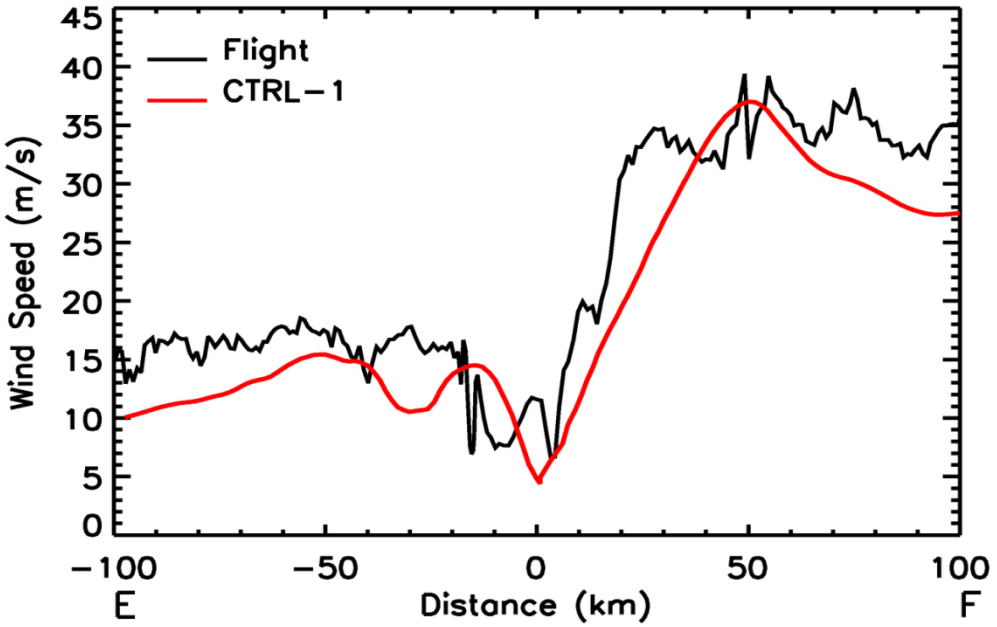
Comparison: Initial Wind Speed

06Z 14 July 2005
810 hPa

NW - SE

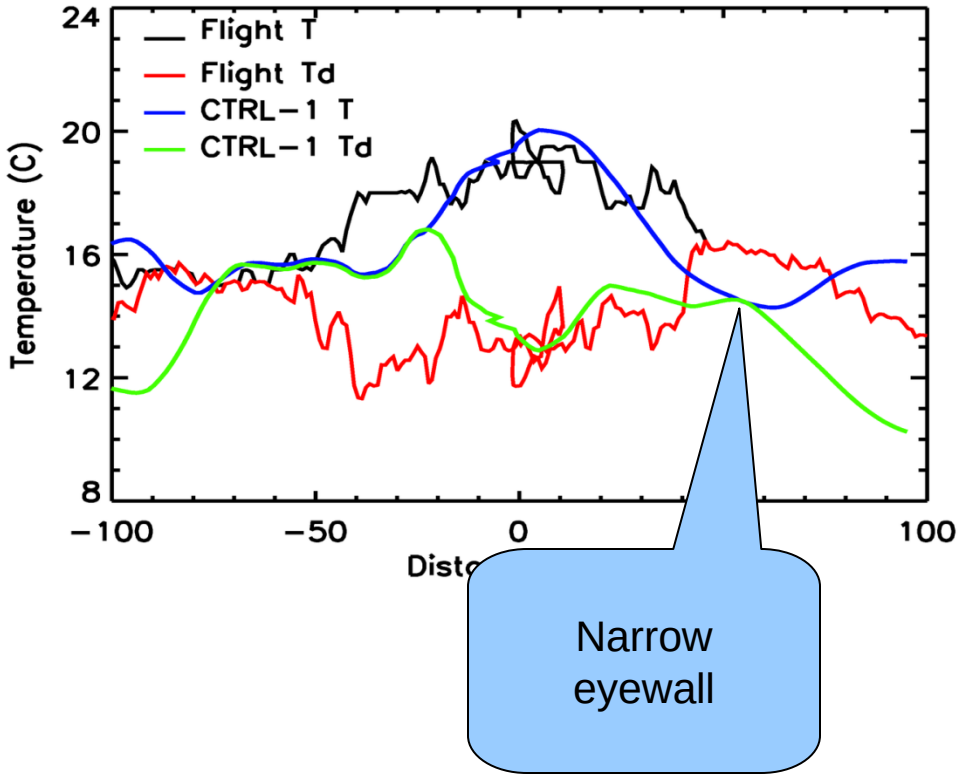


SW - NE

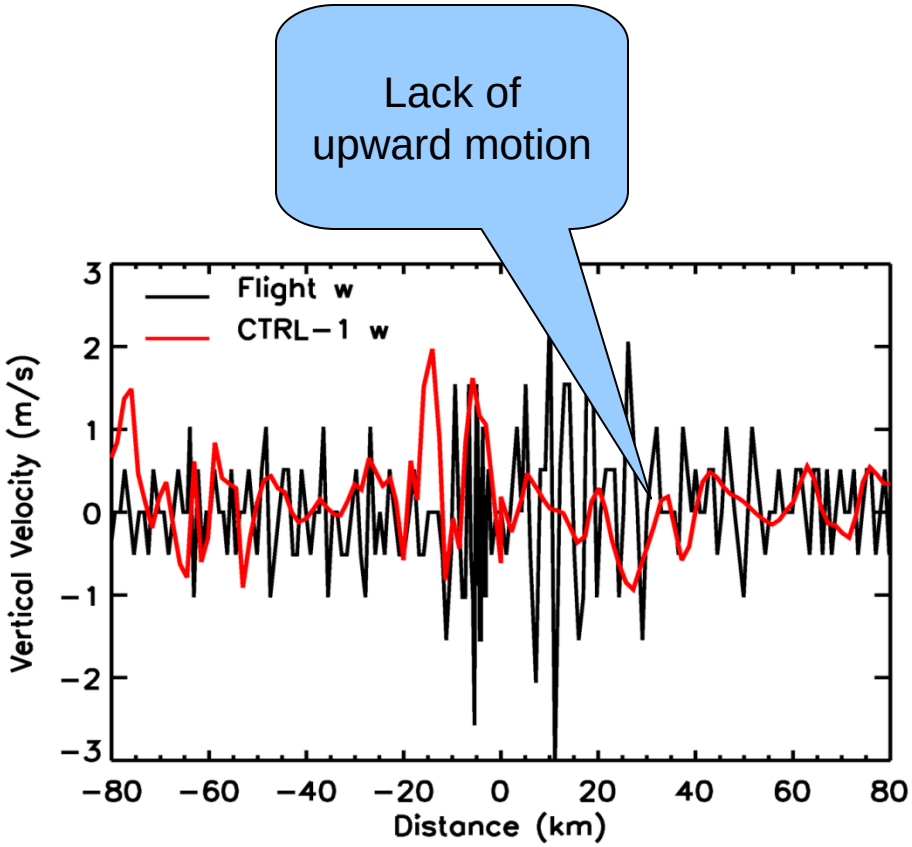


- **Comparison: USAF flight level data**

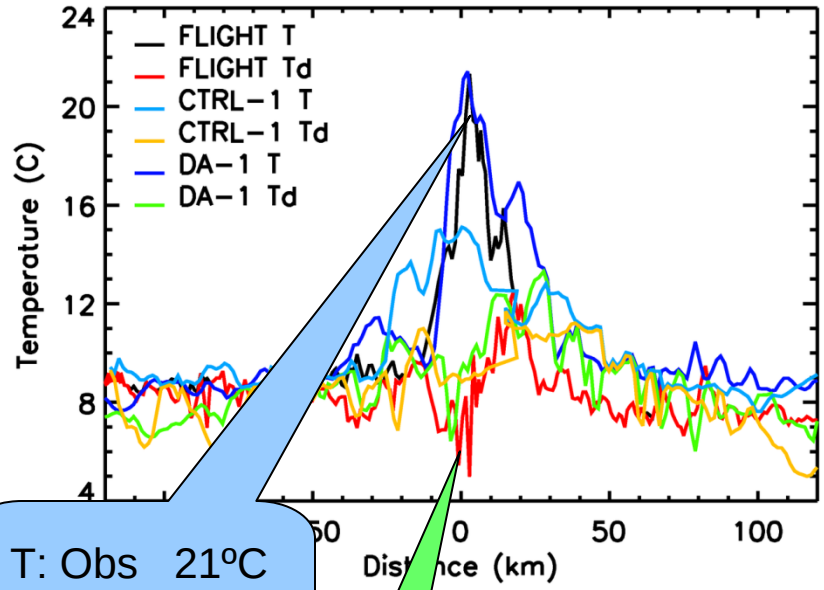
Comparison: Initial Thermal & Convective Fields



06Z 14 July 2005
810 hPa



Comparison: Forecast of Thermal & Convective Fields

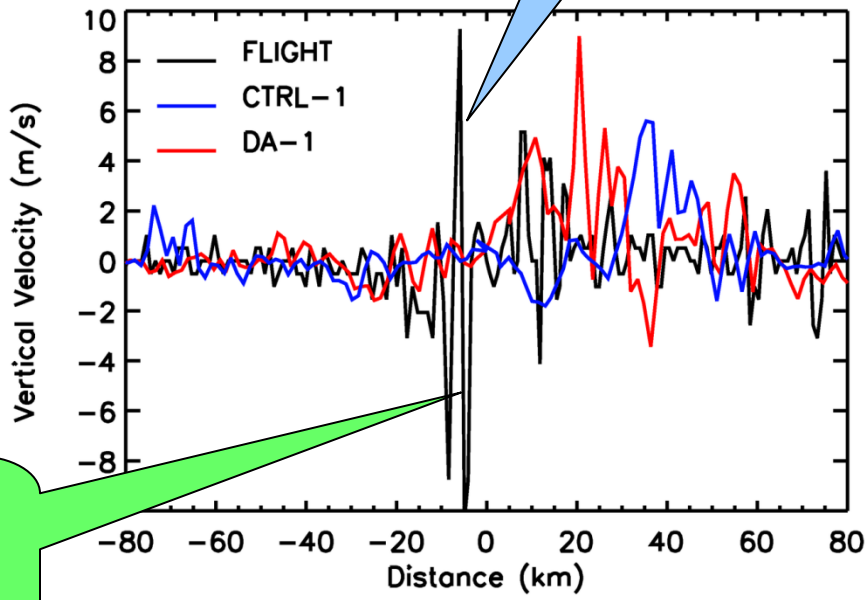


T: Obs 21ºC
DA-1 21ºC
CTRL-1 16 ºC

Td: Obs 5ºC
DA-1 7ºC
CTRL-1 10ºC

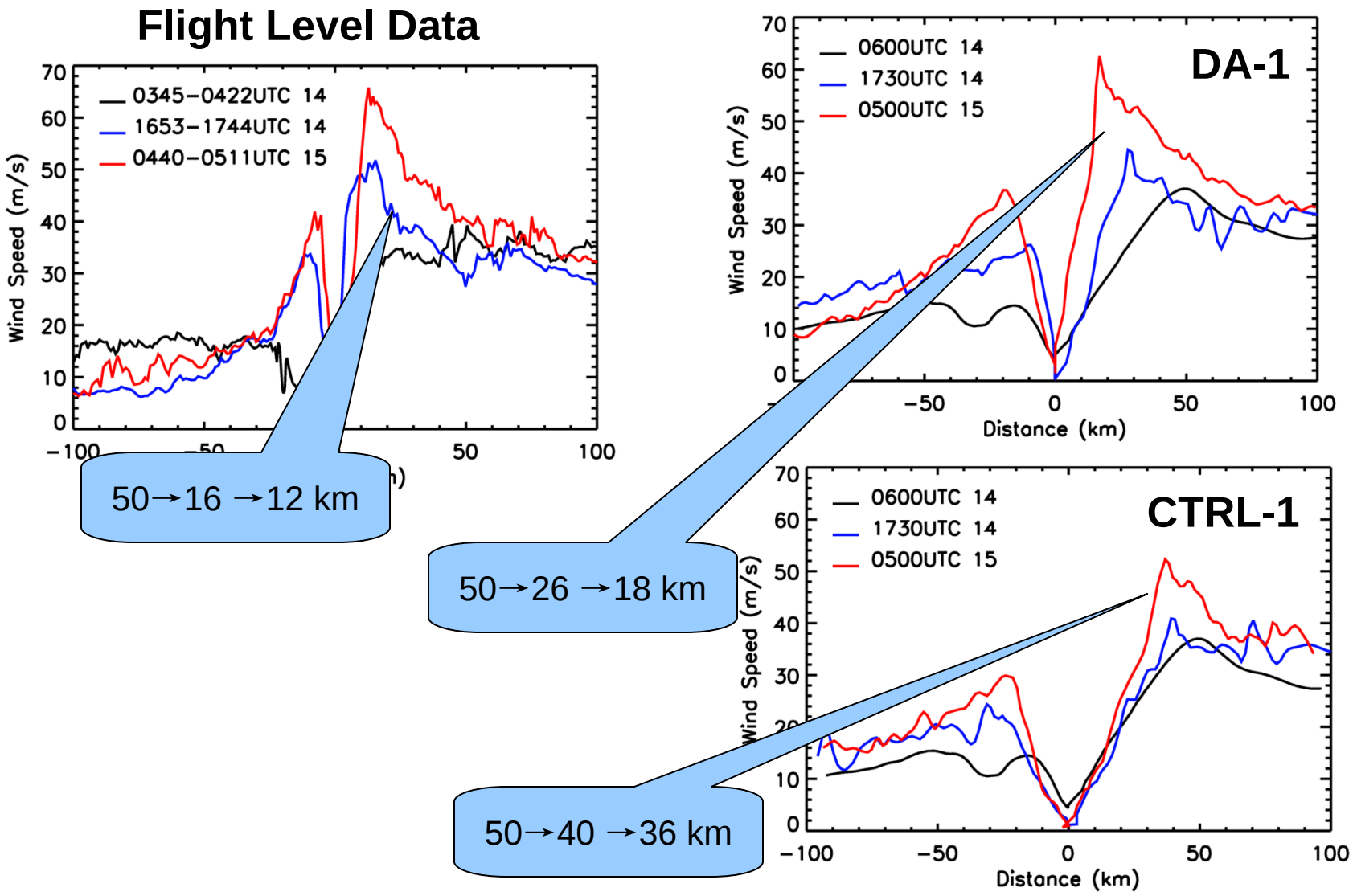
05Z 15 July 2005
700 hPa

Obs 9 m/s
DA-1 8.4 m/s
CTRL-1 6 m/s

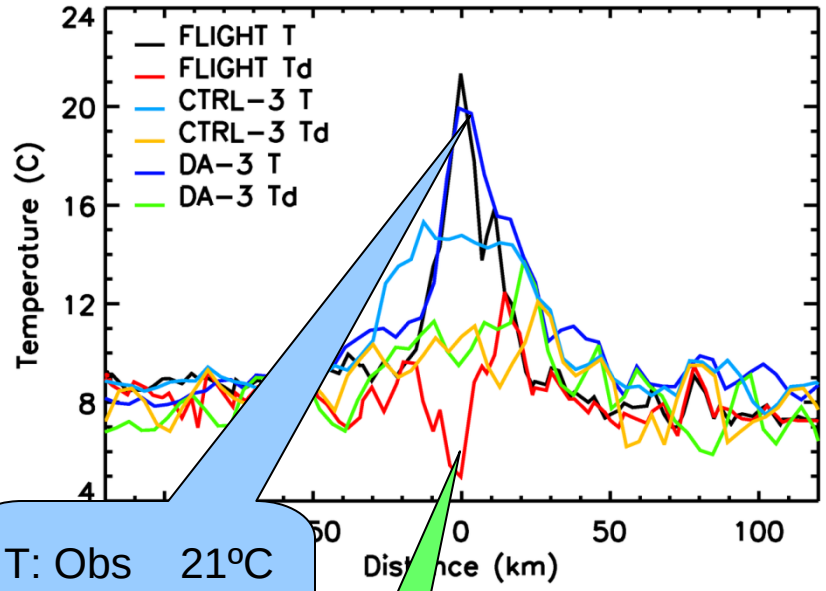


Obs -10 m/s
DA-1 -4 m/s
CTRL-1 -2 m/s

Comparison: Eyewall Contraction Procedure



Comparison: Forecast of Thermal & Convective Fields at 3-km Domain

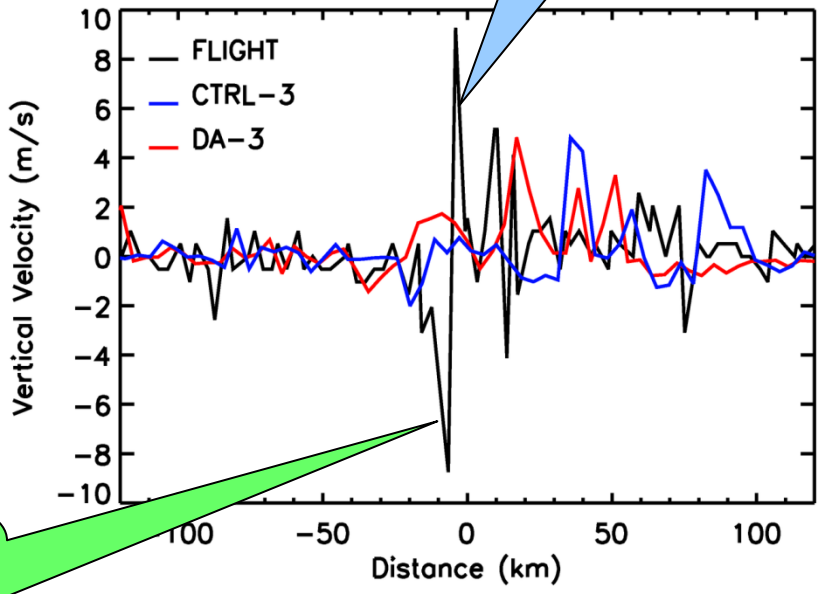


T: Obs 21ºC
DA-3 20ºC
CTRL-3 16 ºC

Td: Obs 5ºC
DA-3 9ºC
CTRL-3 10ºC

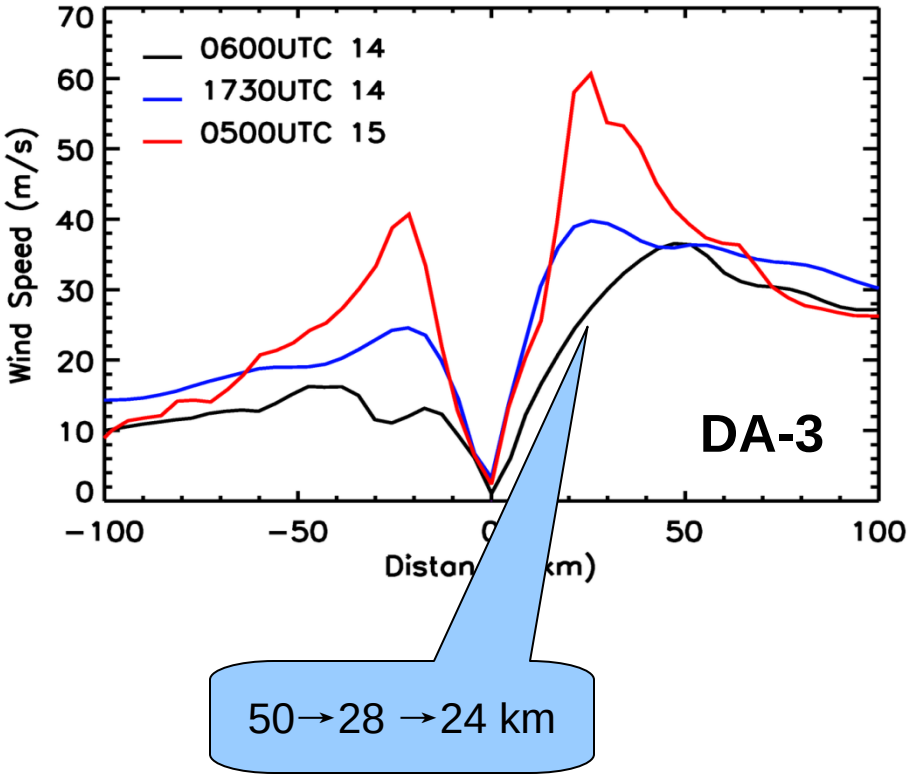
05Z 15 July 2005
700 hPa

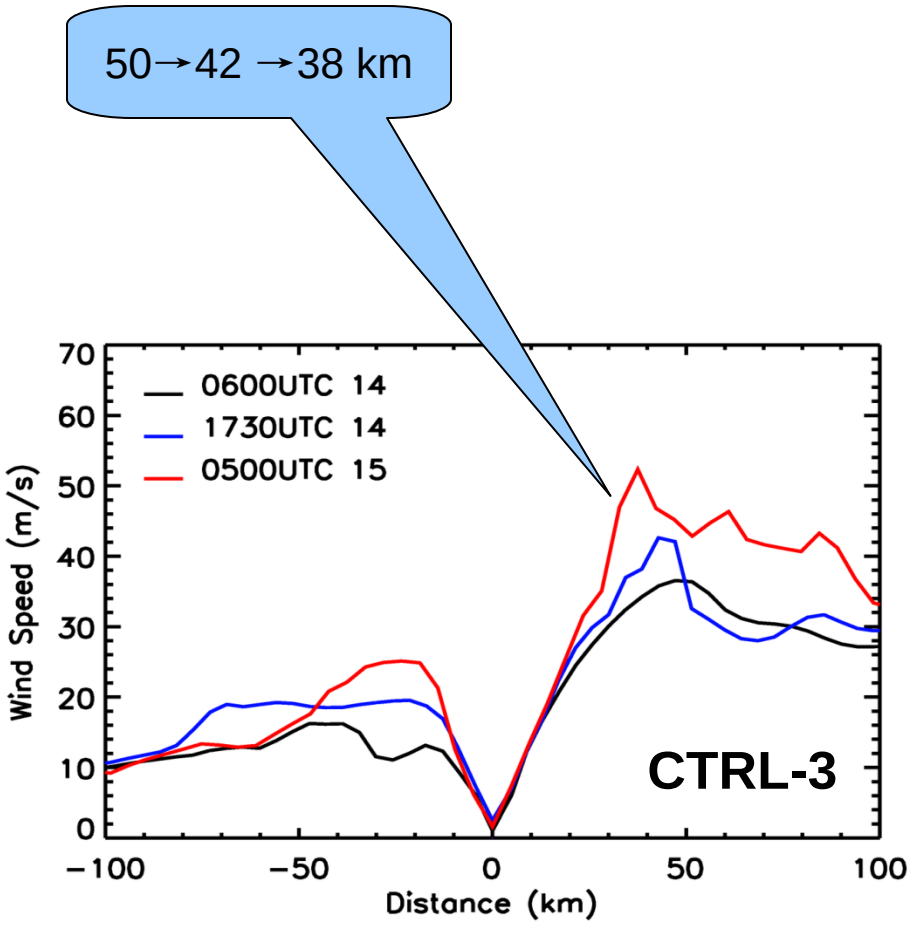
Obs 9 m/s
DA-3 5 m/s
CTRL-3 5 m/s



Obs -10 m/s
DA-1 -4 m/s
CTRL-1 -2 m/s

Comparison:
Eyewall Contraction at 3-km Domain



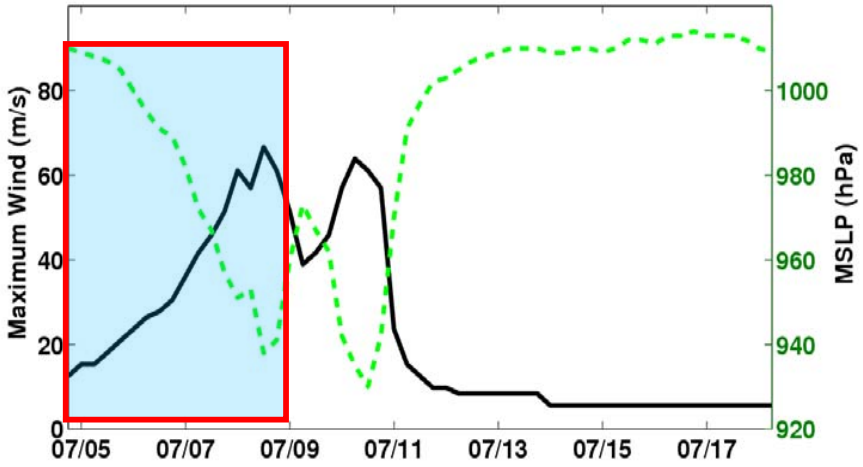


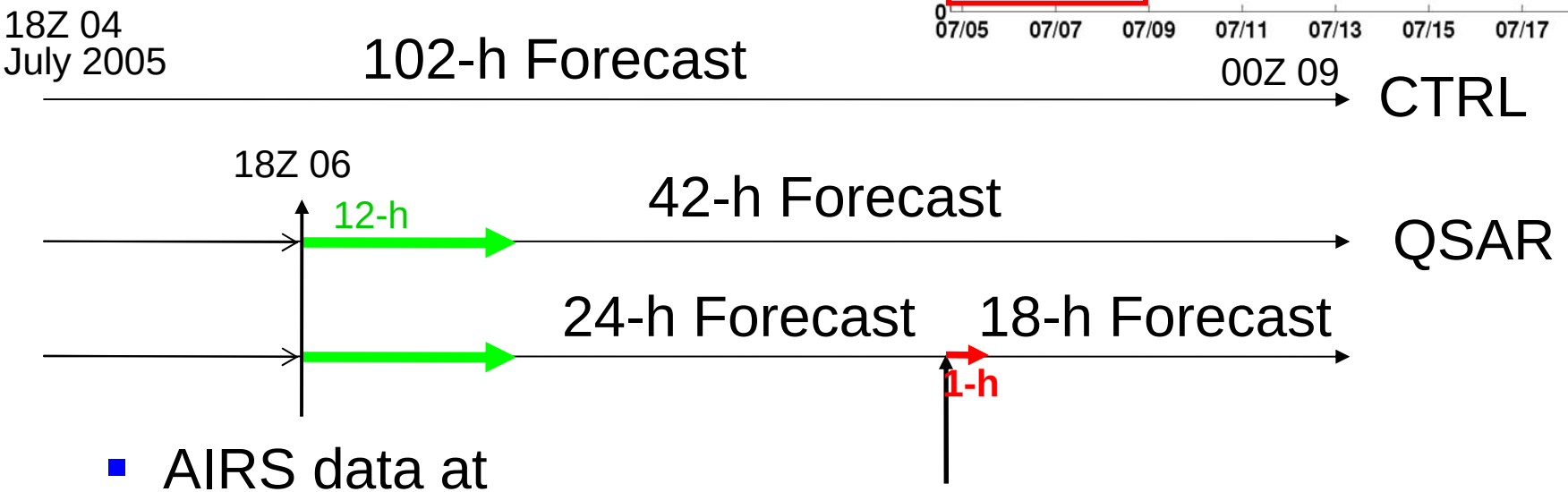
Summary II

- **Initial condition: weak convective structure, unrealistic asymmetric features.**
- **Model: Slow eyewall contraction, large storm eye.**
- **Horizontal resolution: marginal improvement in the intensity forecast.**
- **Data assimilation: positive impact on the storm structure and the eyewall contraction procedure.**

Impact of the QuikSCAT wind, AIRS sounding data, and airborne Doppler radar data on Hurricane Dennis (2005)

Experiments

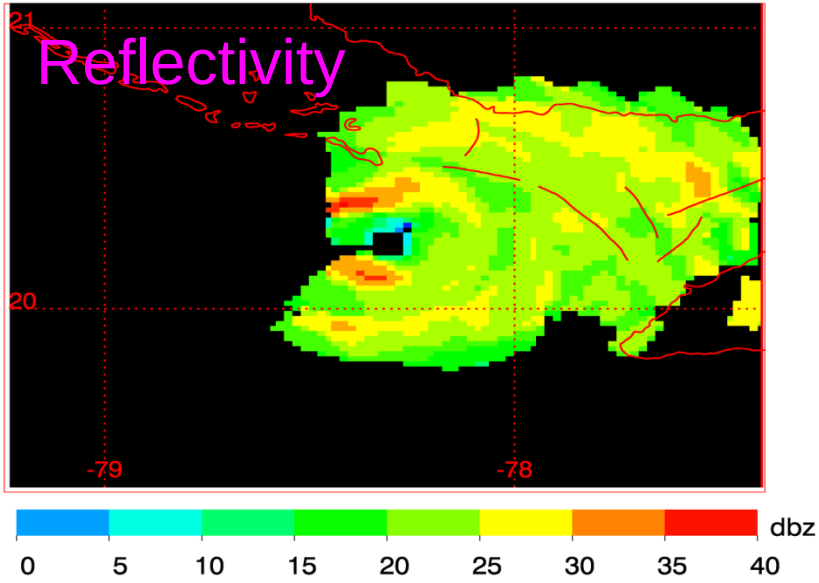


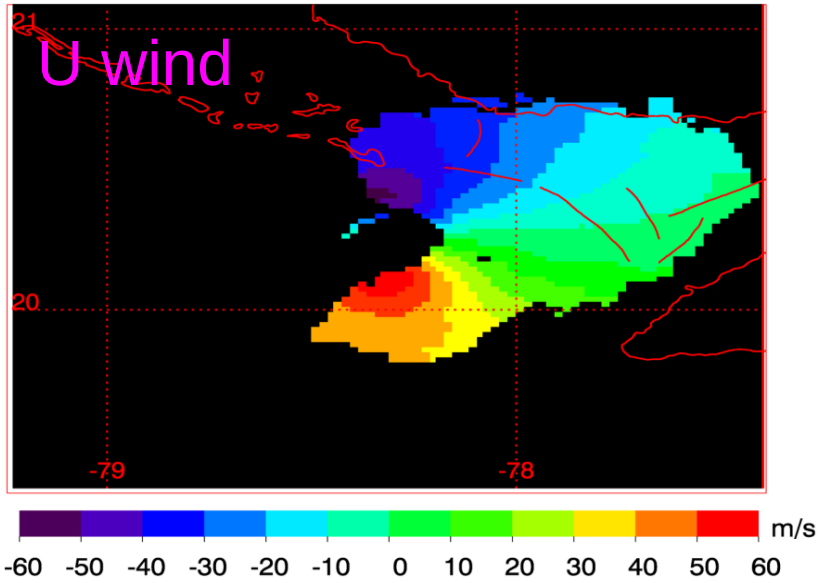


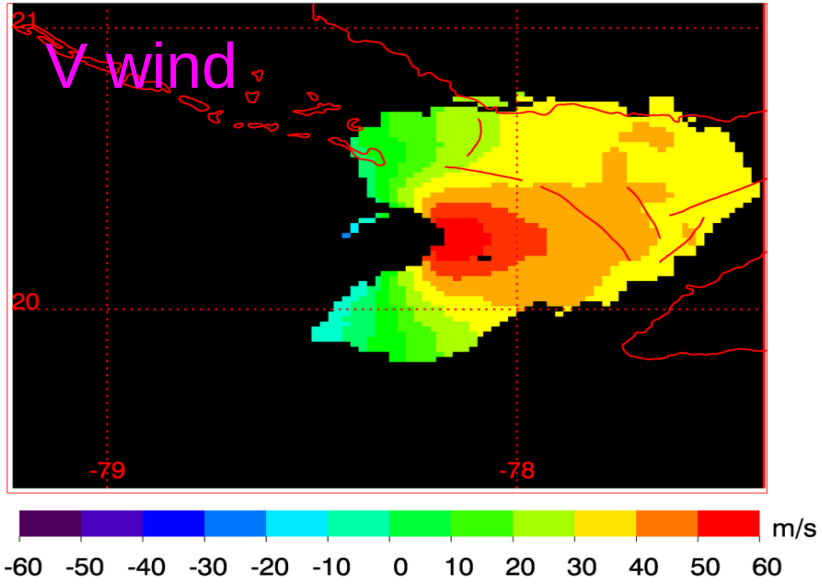
- AIRS data at
  18Z 06 & 06Z 07
- QuikSCAT data at
  00Z 07

- Radar reflectivity – **QSARRD1**
- Radar wind – **QSARRD2**
- Both -- **QSARRD3**
- 0500Z, 0530Z, 0600Z 08

Doppler Radar Observation

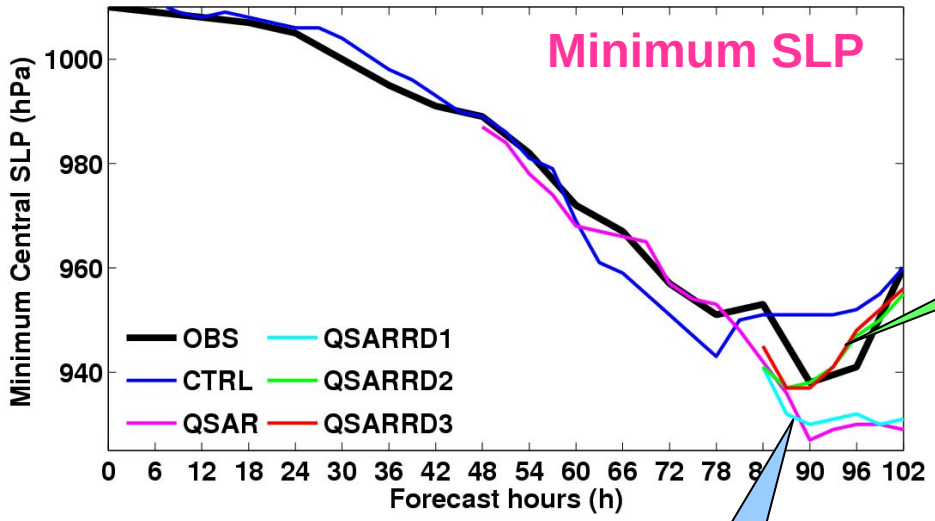






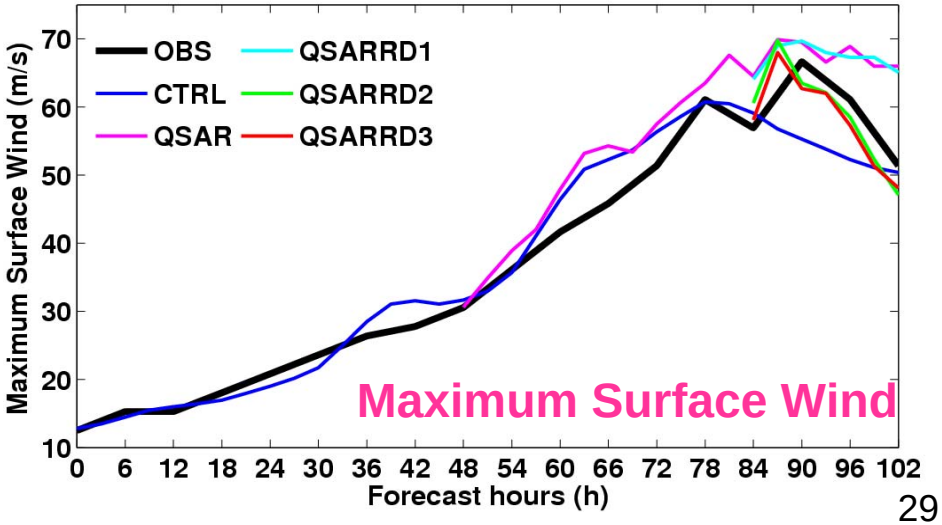
2 km altitude
NOAA P3 aircraft N42RF
0605Z 08 July 2005

Intensity Forecast of Dennis

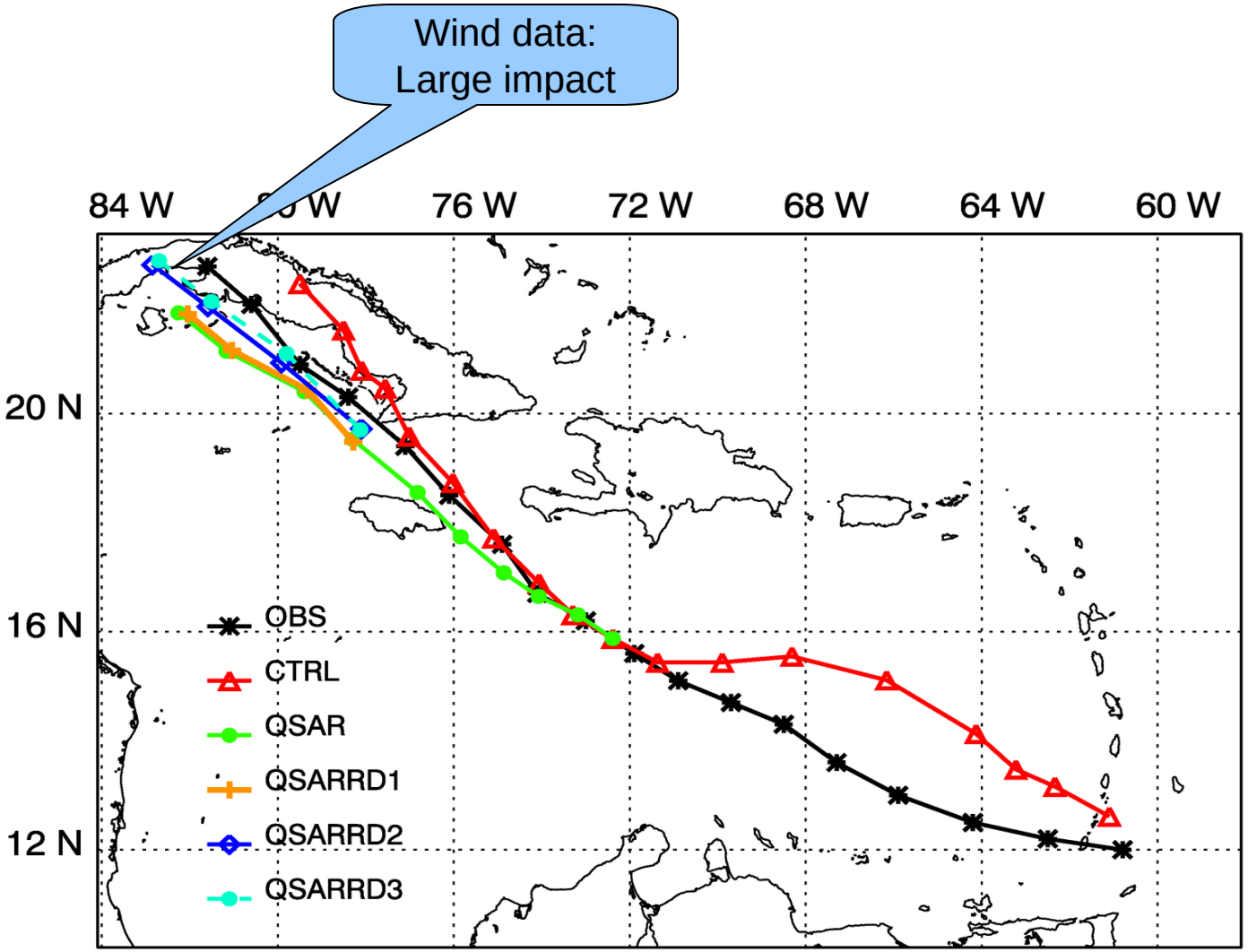


Wind data:
Large impact

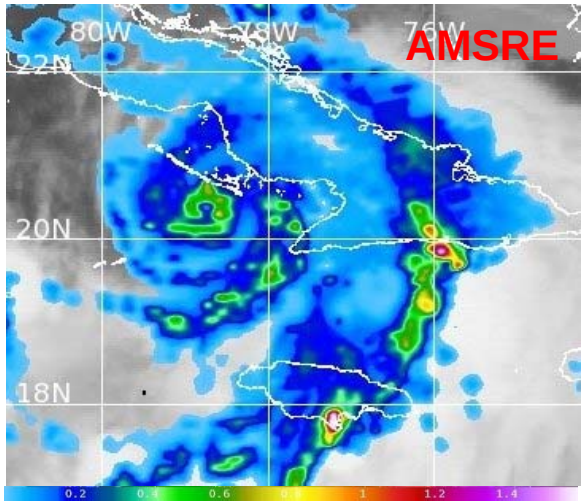
Reflectivity data:
Moderate impact

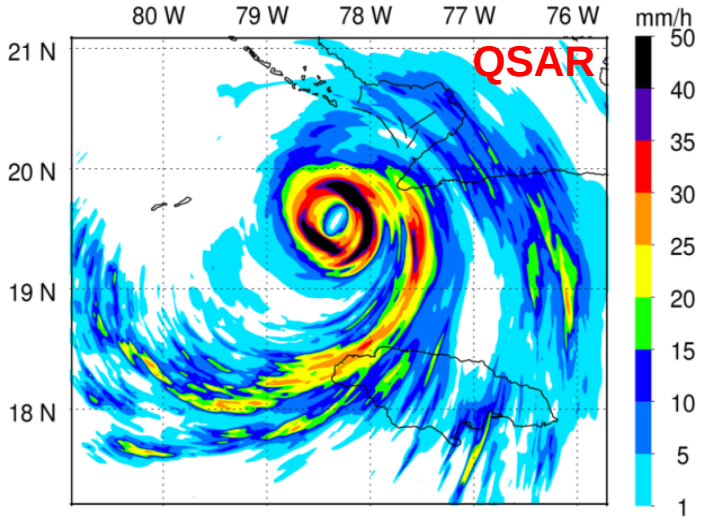


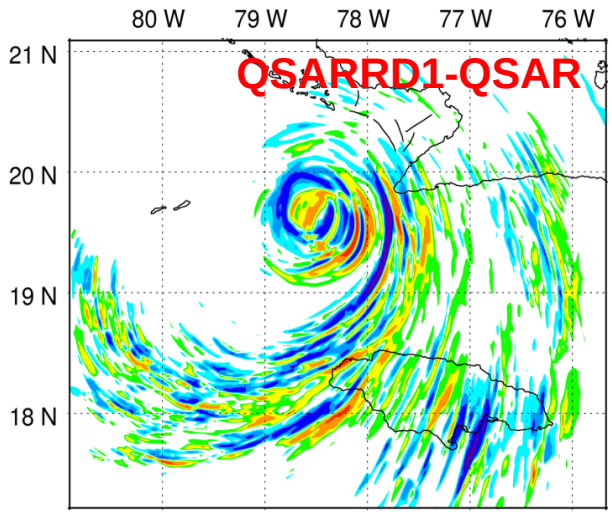
Track Forecast of Dennis

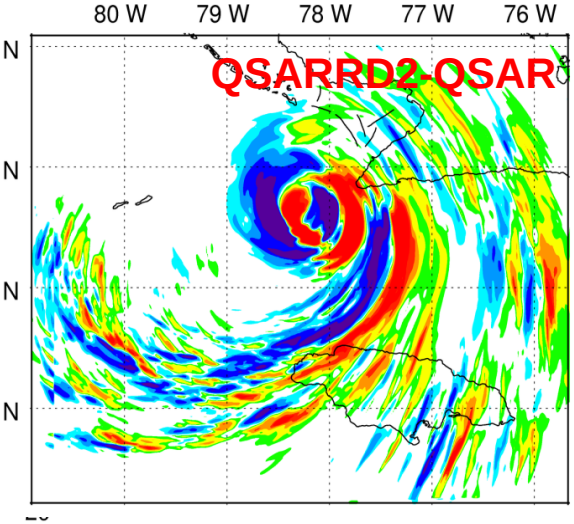


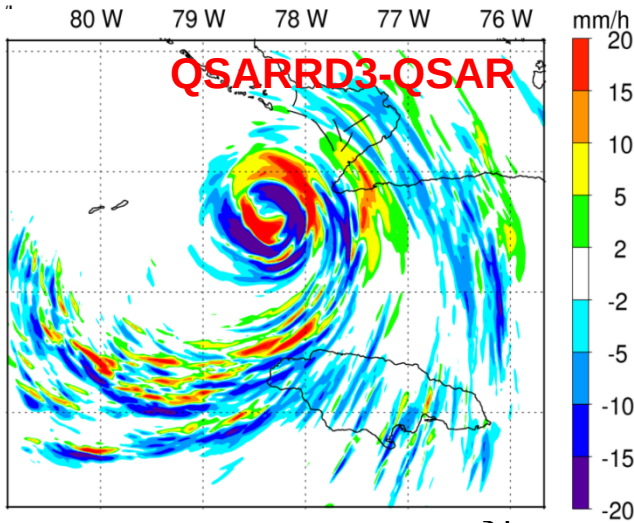
Radar Data Impact on Precipitation



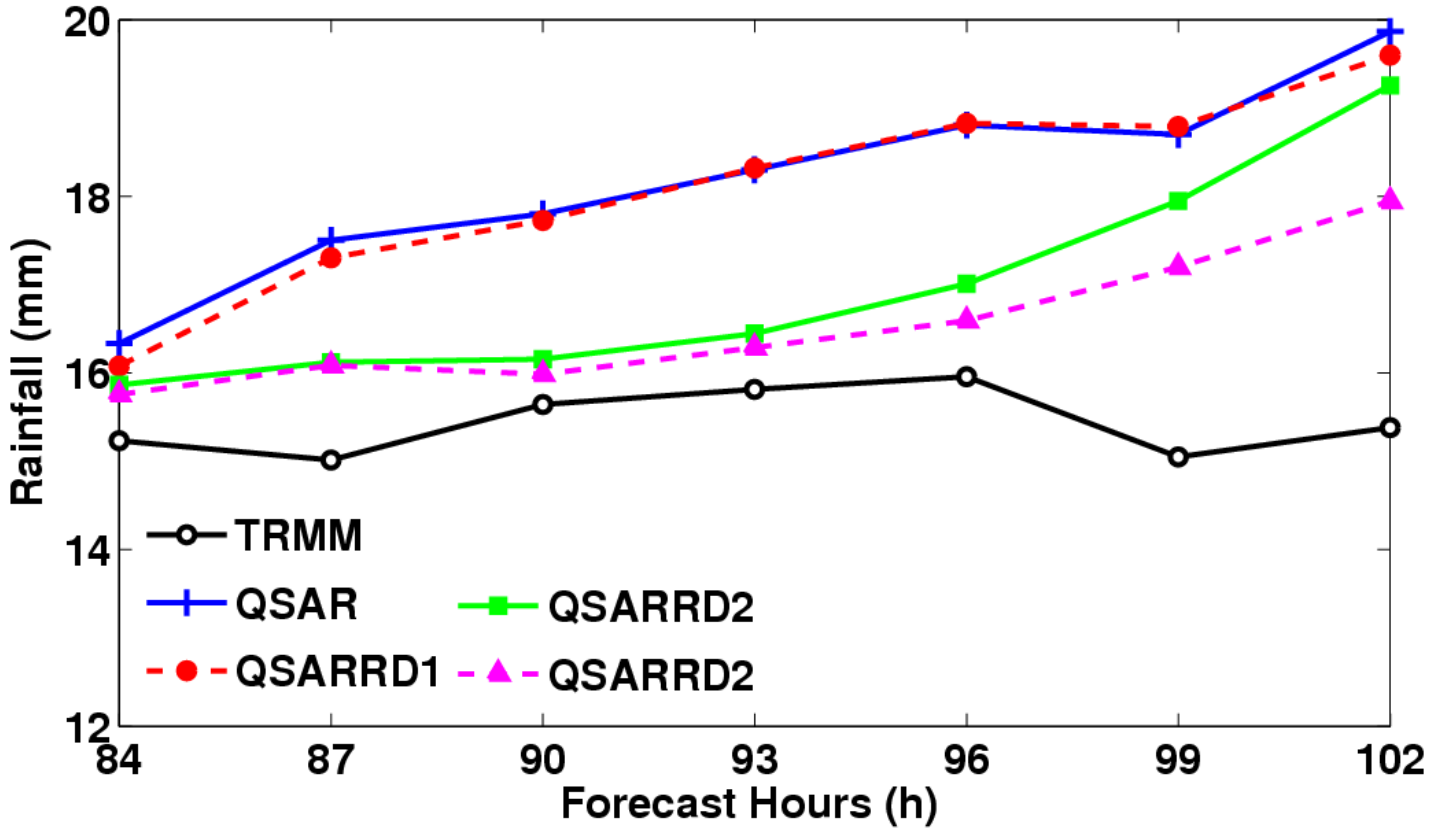








3 h Accumulated Rainfall Amount for Dennis



Summary III

- **The QuikSCAT wind and AIRS sounding data greatly improve the intensity forecast.**
- **Radar reflectivity data have a slight impact on intensity and track forecast.**
- **Radar wind data show a remarkable impact on the intensity, track and storm structure of Dennis.**

Thanks!

Questions?