Implementation of Assimilating MODIS Brightness Temperature into WRFDA and the Evaluation of its Impact on Severe Weather Simulation

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Outline

- Introduction
- Observations
- Numerical case studies
- Summary

Satellite Data Assimilation

- Retrieved data
  - Easier to assimilate
  - Computationally cost efficient
  - Potential error introduced by retrieval algorithms

- Raw measurements: e.g., radiance
  - Need a radiative transfer model (RTM)
  - More physically based (need radiative transfer operators)

    WRFV3.1: RTTOV & CRTM
  - More expensive
  - "In theory", more accurate

Radiative Transfer Model (RTM)

RTTOV

- ECMWF (Eyre 1991)
- Regression-based fast RTM
- Clear sky and cloudy radiances
- For infrared or microwave frequencies
- Transmittance coefficients provided at

  43 pre-defined pressure levels

Radiative Transfer Model (RTM)

CRTM

- Community Radiative Transfer Model
- Developed at U.S. Joint Center for Satellite Data Assimilation
- Based on OPTRAN
- Regression-based fast RTM
- Clear sky and cloudy radiances
- For infrared or microwave frequencies, & some visible channels

MODIS (MOD02)

- Moderate Resolution Imaging Spectroradiometer
- Aboard Aqua (2002) and Terra (2000)
- Sun-synchronous near polar-orbiting
- Mean altitude ~ 705 km (equator)
- Width of swath ~ 2300 km
- 36 spectral bands: 0.405-14.387 μm
- MOD02 data
  - L1B collection 5
  - from NASA GSFC, LAADS web (hdf format)
  - 16 bands of IR radiances
  - Brightness temperature derived from the Planck's law
  - 1-km resolution

$$E_\lambda^* = \frac{C_1}{\lambda^5\left[\exp\left(C_2/\lambda T\right)-1\right]}$$

MOD02 Data

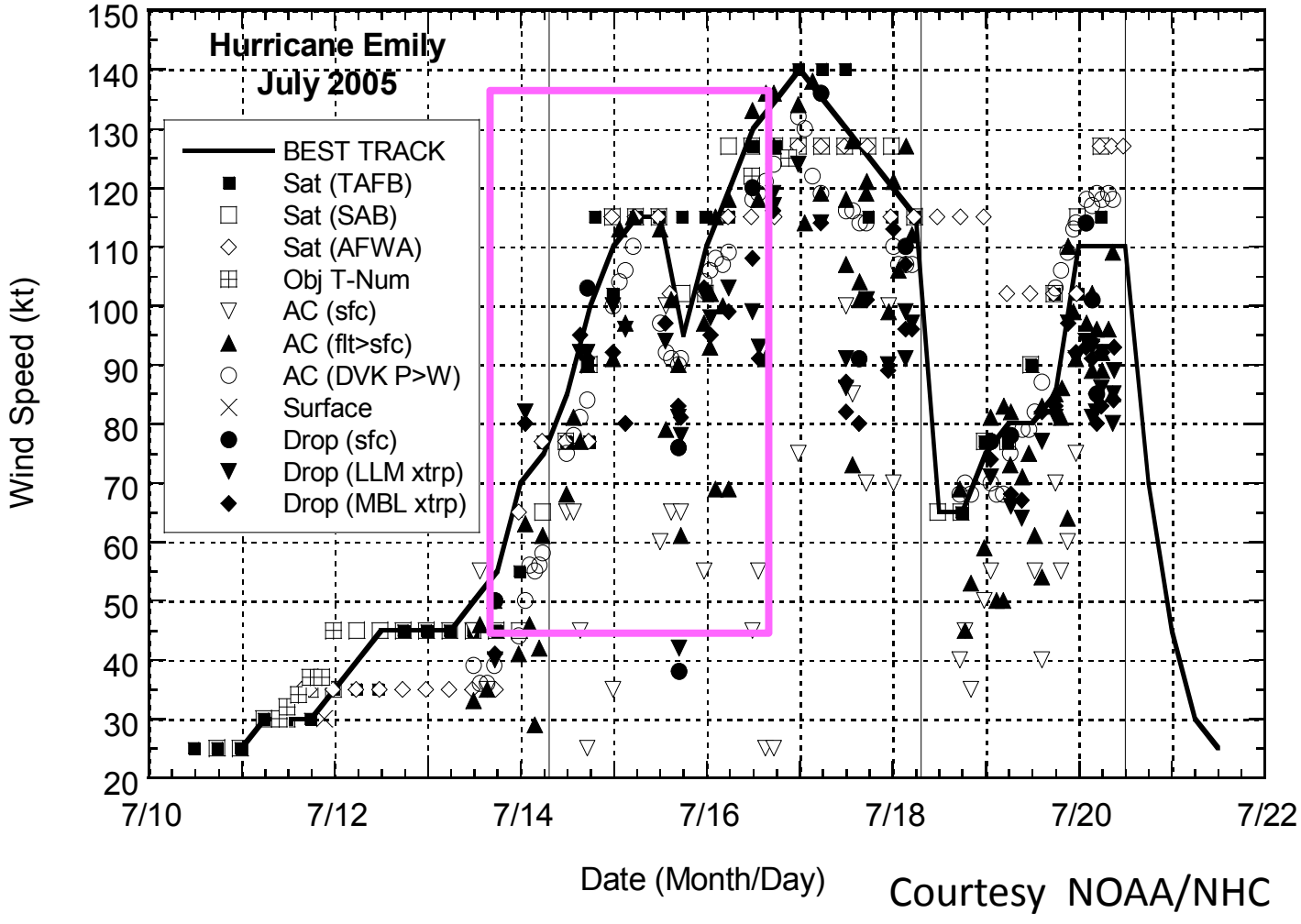
Primary use	band	Bandwidth (μm)
Surface/Cloud Temperature	20	3.660 - 3.840
	21	3.929 - 3.989
	22	3.929 - 3.989
	23	4.020 - 4.080
Atmospheric Temperature	24	4.433 - 4.498
	25	4.482 - 4.549
Cirrus Clouds Water Vapor	27	6.535 - 6.895
	28	7.175 - 7.475
Cloud Properties	29	8.400 - 8.700
Ozone	30	9.580 - 9.880
Surface/Cloud Temperature	31	10.780 - 11.280
	32	11.770 - 12.270
Cloud Top Altitude	33	13.185 - 13.485
	34	13.485 - 13.785
	35	13.785 - 14.085
	36	14.085 - 14.385

MOD07 IR

Case study

Hurricanes (2005)

Hurricane	*Emily*	*Dennis*
	18Z July 13 to 18Z July 16	18Z July 5 to 18Z July 8



Courtesy NOAA/NHC

Case study

Hurricanes (2005)

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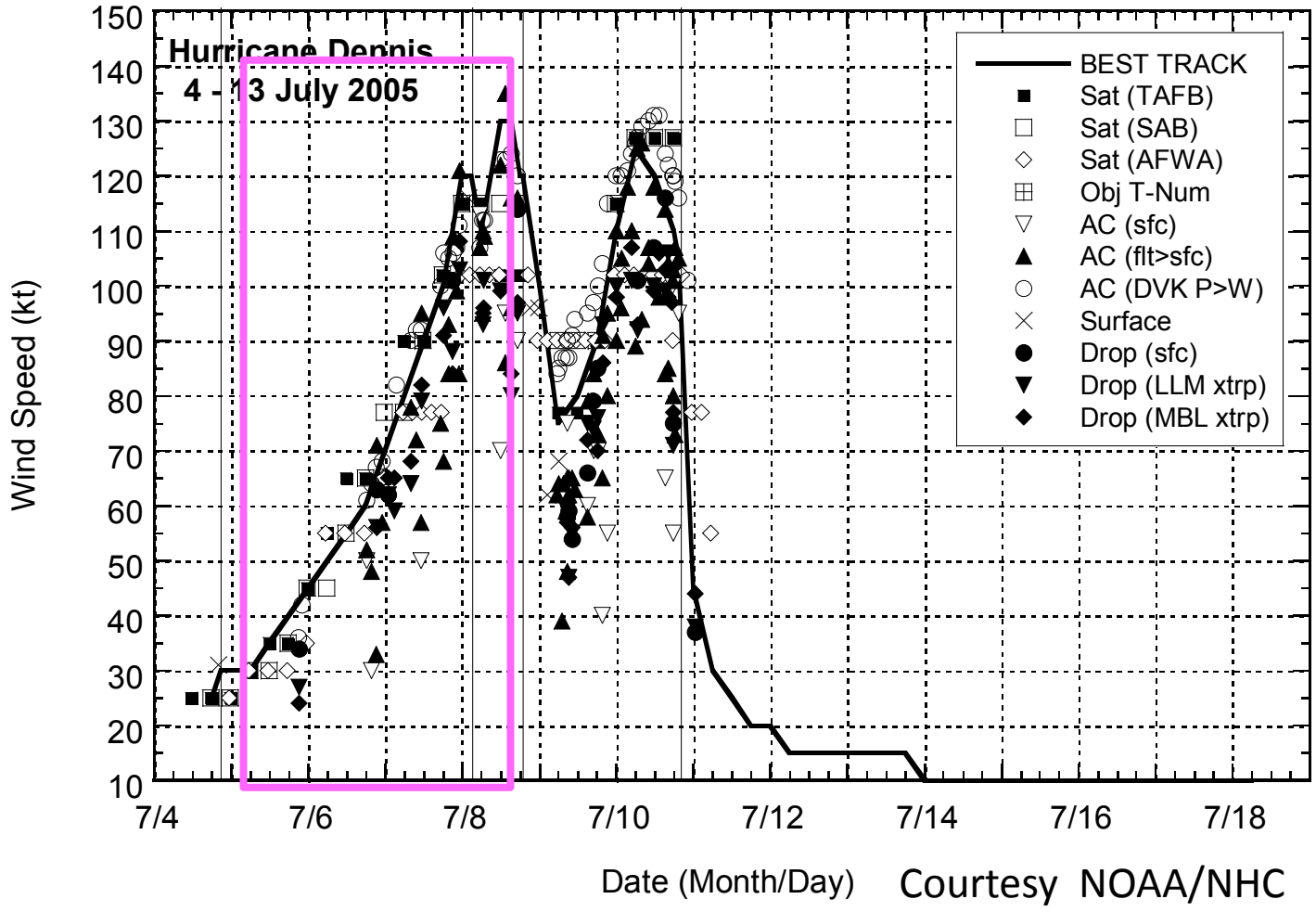
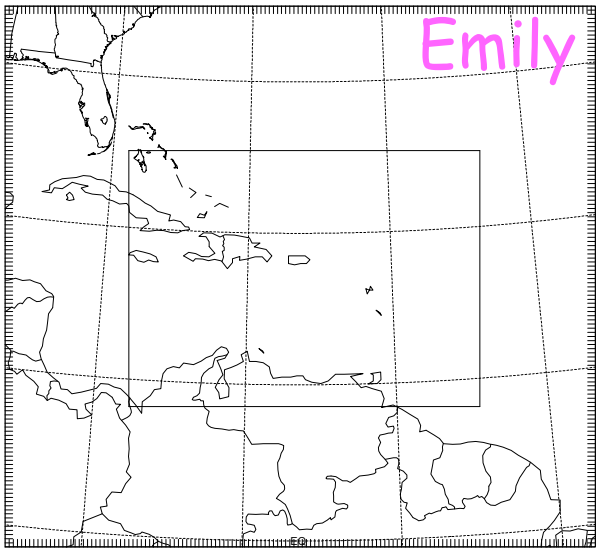
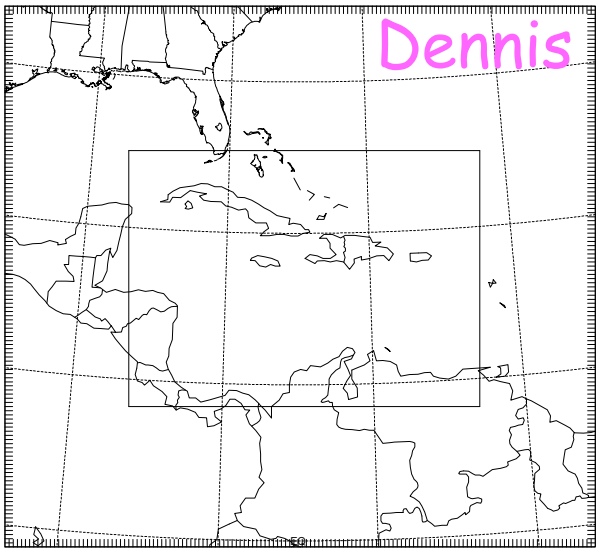


Courtesy NOAA/NHC

Case study

Model configurations (WRFV3.1)

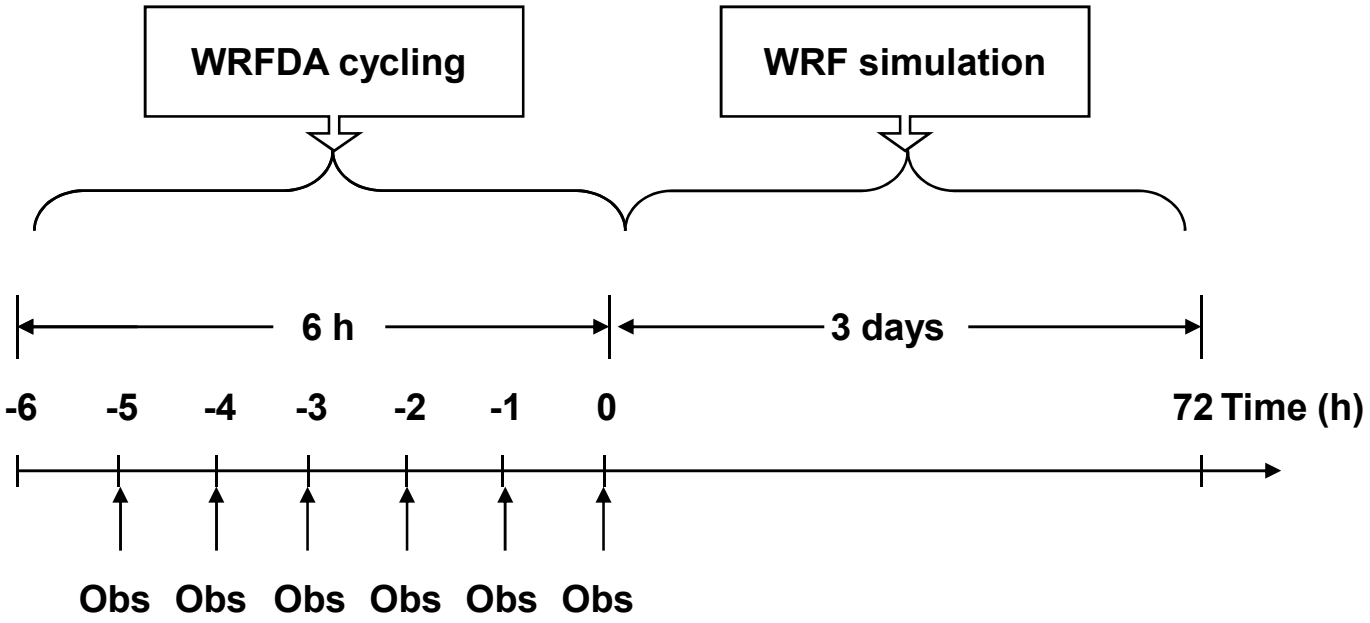




	Domain 1	Domain2
Resolution	30 km	10 km
Grid points	144 x 132 x 31	256 x 187 x 31
Microphysics	Purdue Lin	
Cumulus	Kain-Fritsch	
PBL	YSU	
Longwave	RRTM	
Shortwave	Dudhia	

Case study

Model Integration



Hurricane	*Data Assimilation*	*Model simulations*
Emily	12Z July 13 To 18Z July 13	18Z July 13 To 18Z July 16
Dennis	12Z July 5 To 18Z July 5	18Z July 5 To 18Z July 8

Numerical Experiments

Data assimilated

EXP	*GTS*	*MOD02*
NONE		
GTS	X	
RT		RTTOV
RTG	X	RTTOV
CT		CRTM
CTG	X	CRTM

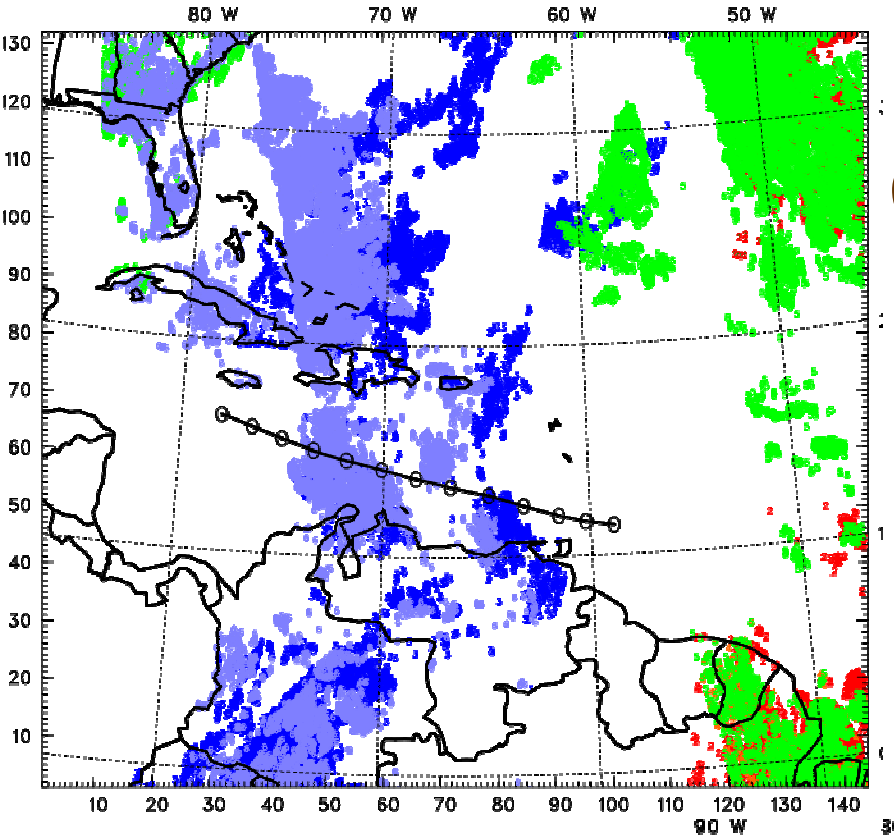
MOD02 Data Assimilation

- **WRFDA**

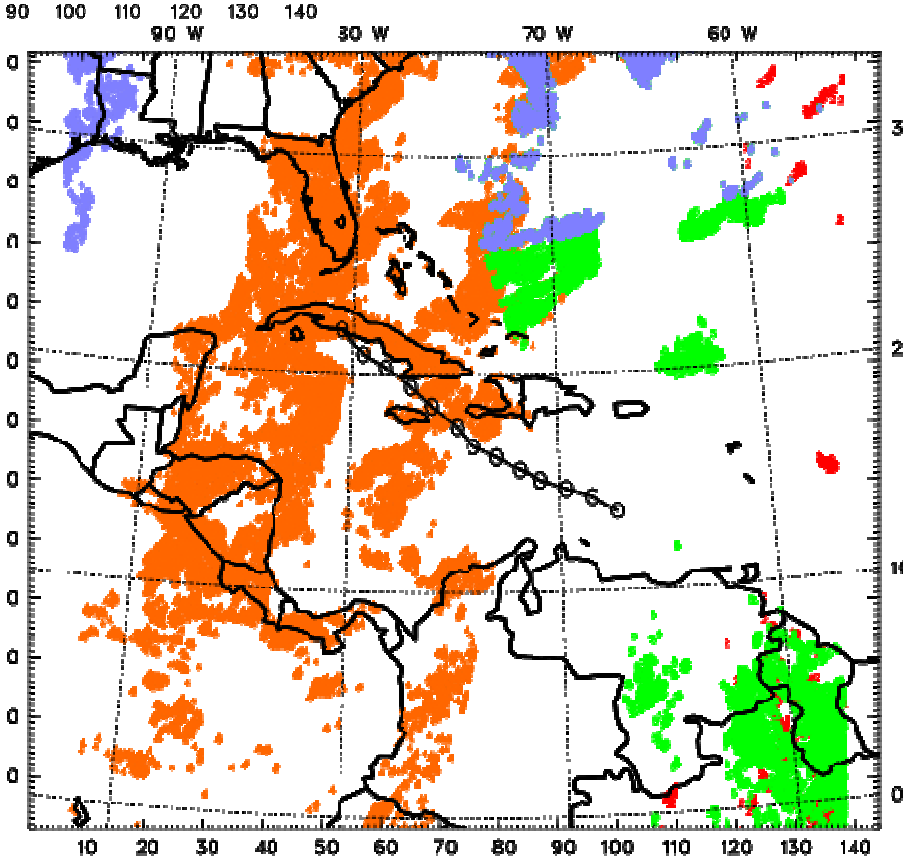
  Read in ASCII data (original – hdf format)

  (BUFR format for most other B.T. assimilation)

MOD02 Coverage

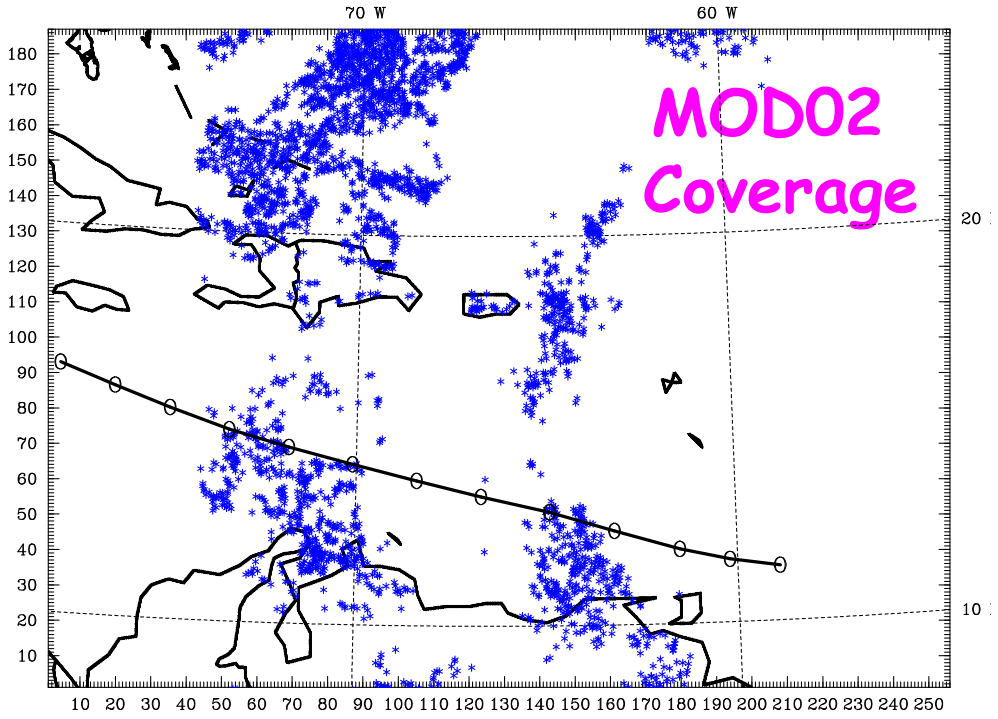


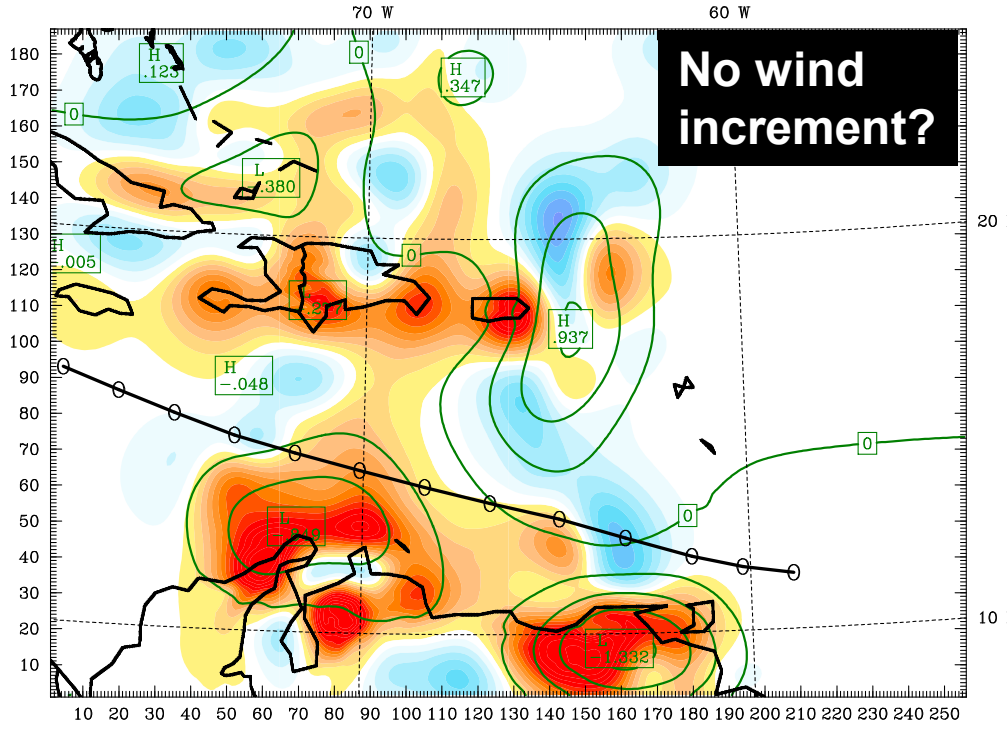
Emily (2005)
(12Z–18Z July 13)



Dennis (2005)
(12Z–18Z July 5)

TPW & 950 mb T Increments
(Emily (15Z July 13, 2005)

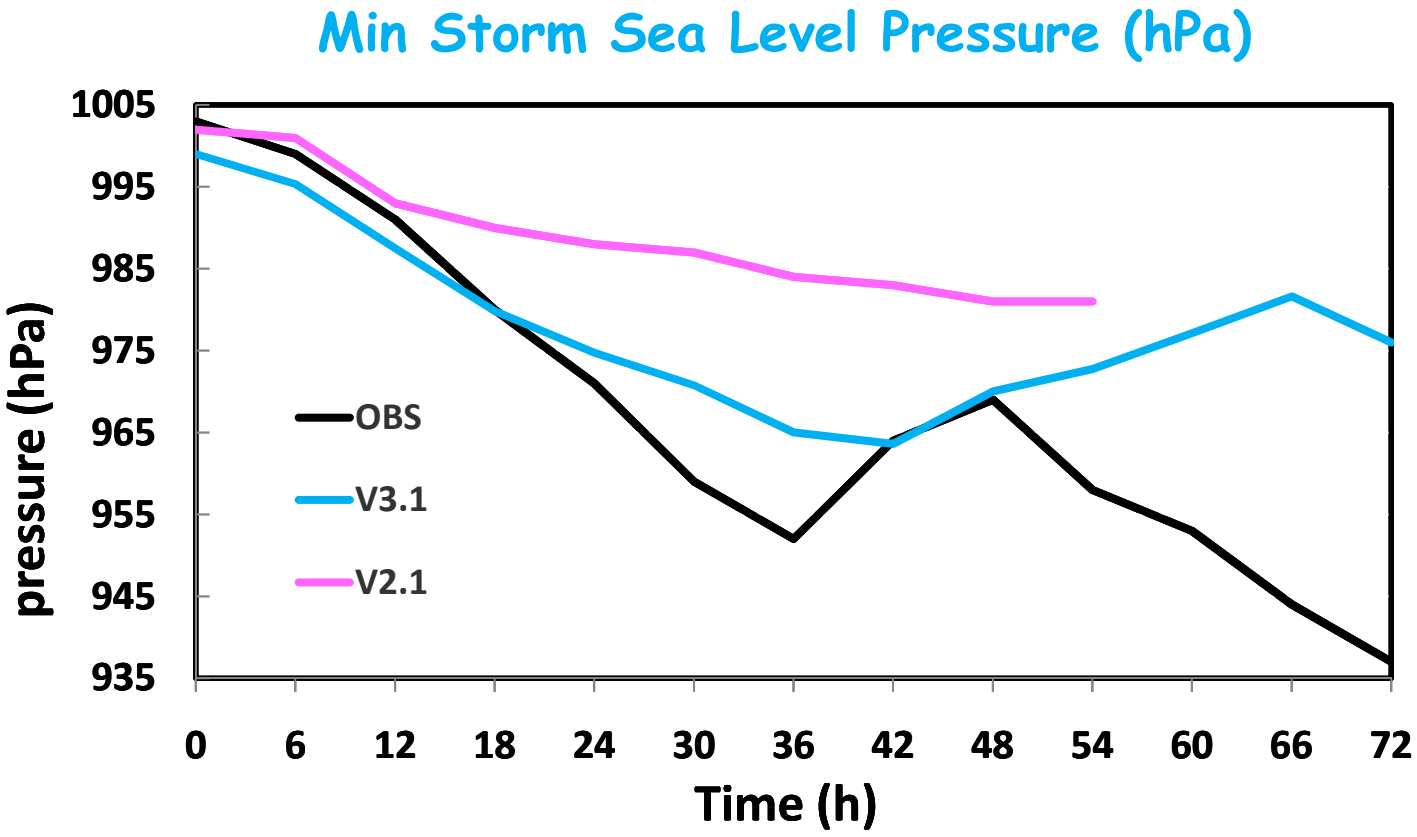




CONTOURS: UNITS=K LOW= −1.2000 HIGH= 0.90000 INTERVAL= 0.30000

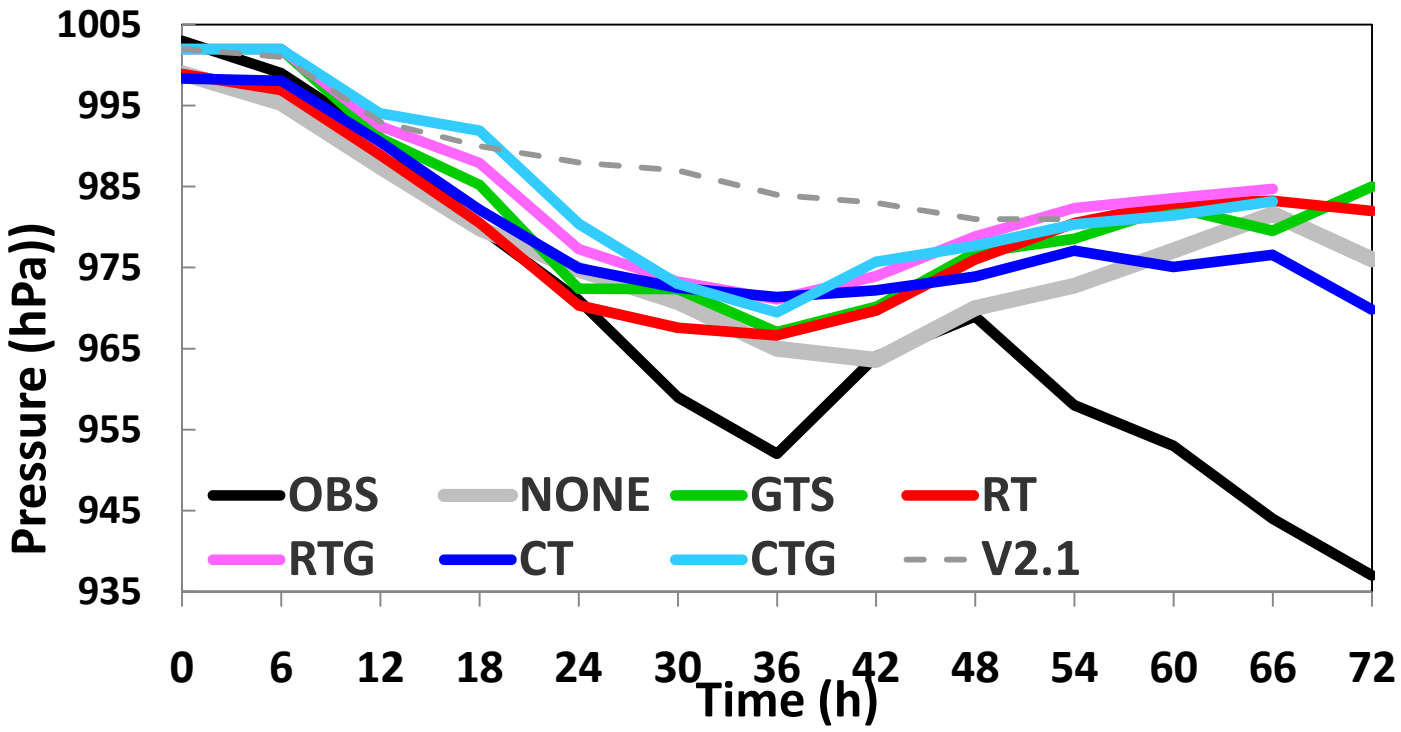
−12.5 −10.5 −8.5 −6.5 −4.5 −2.5 −.5 1.5 3.5 5.5 7.5 9.5 11.5 mm

Sea Level Pressure (Emily)
(18Z July 13 – 18Z July 16)

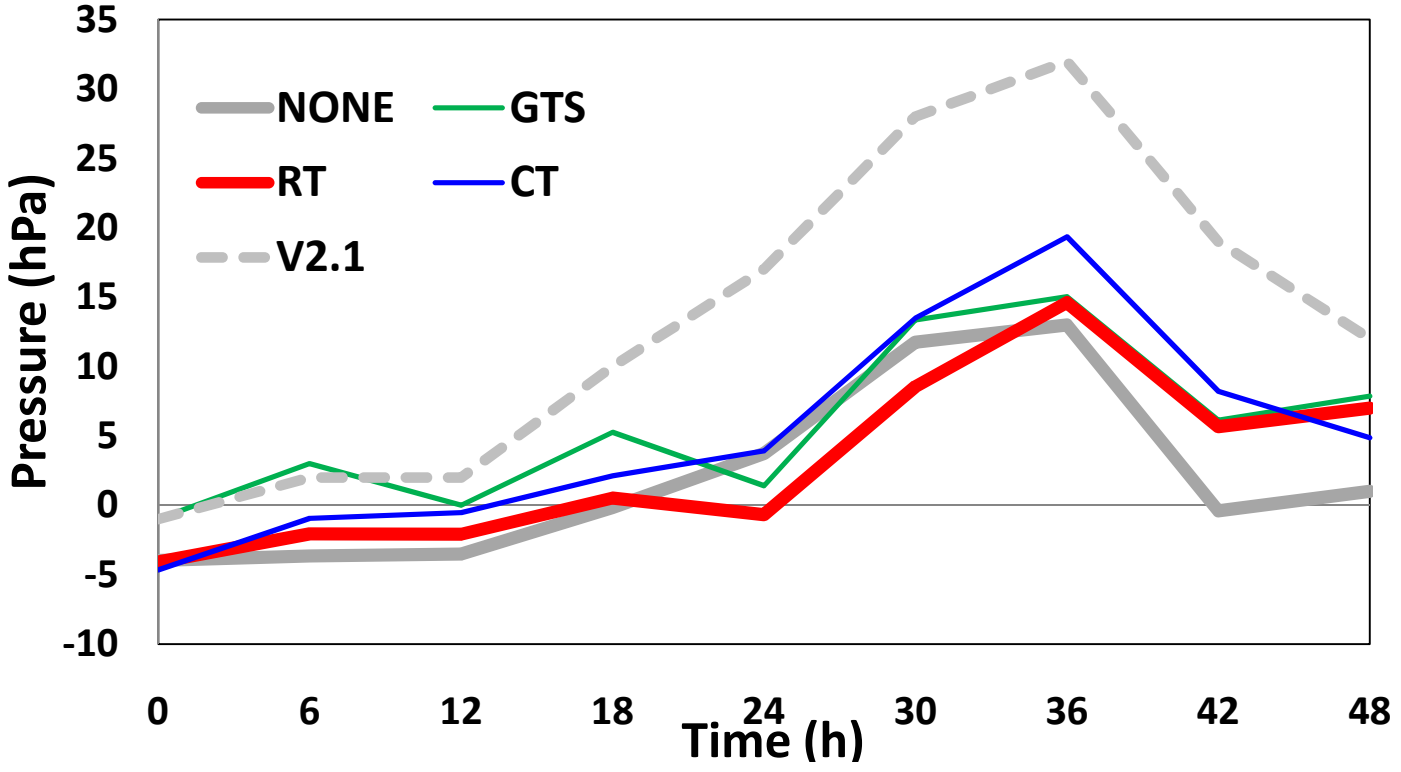


Sea Level Pressure (Emily)
(18Z July 13 – 18Z July 16)

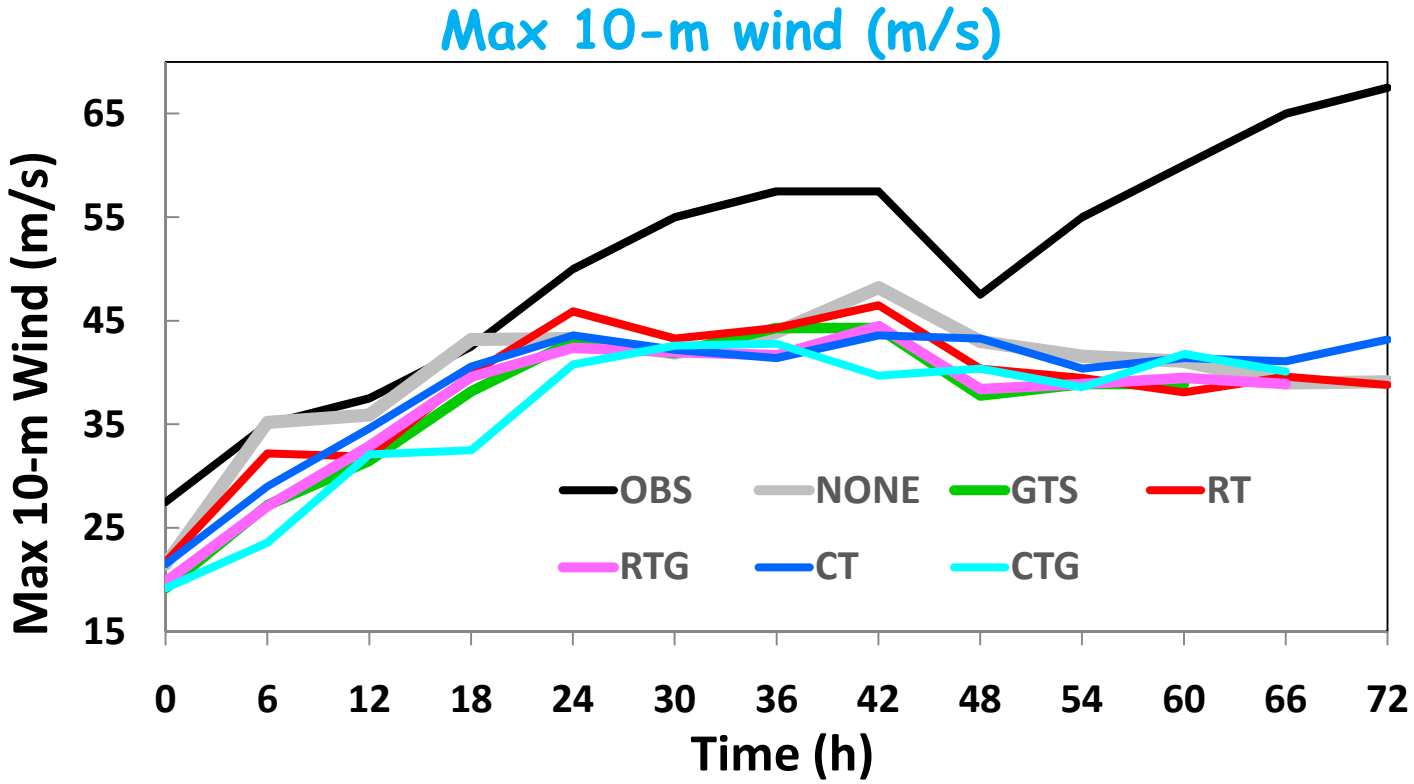
Min Storm Sea Level Pressure (hPa)

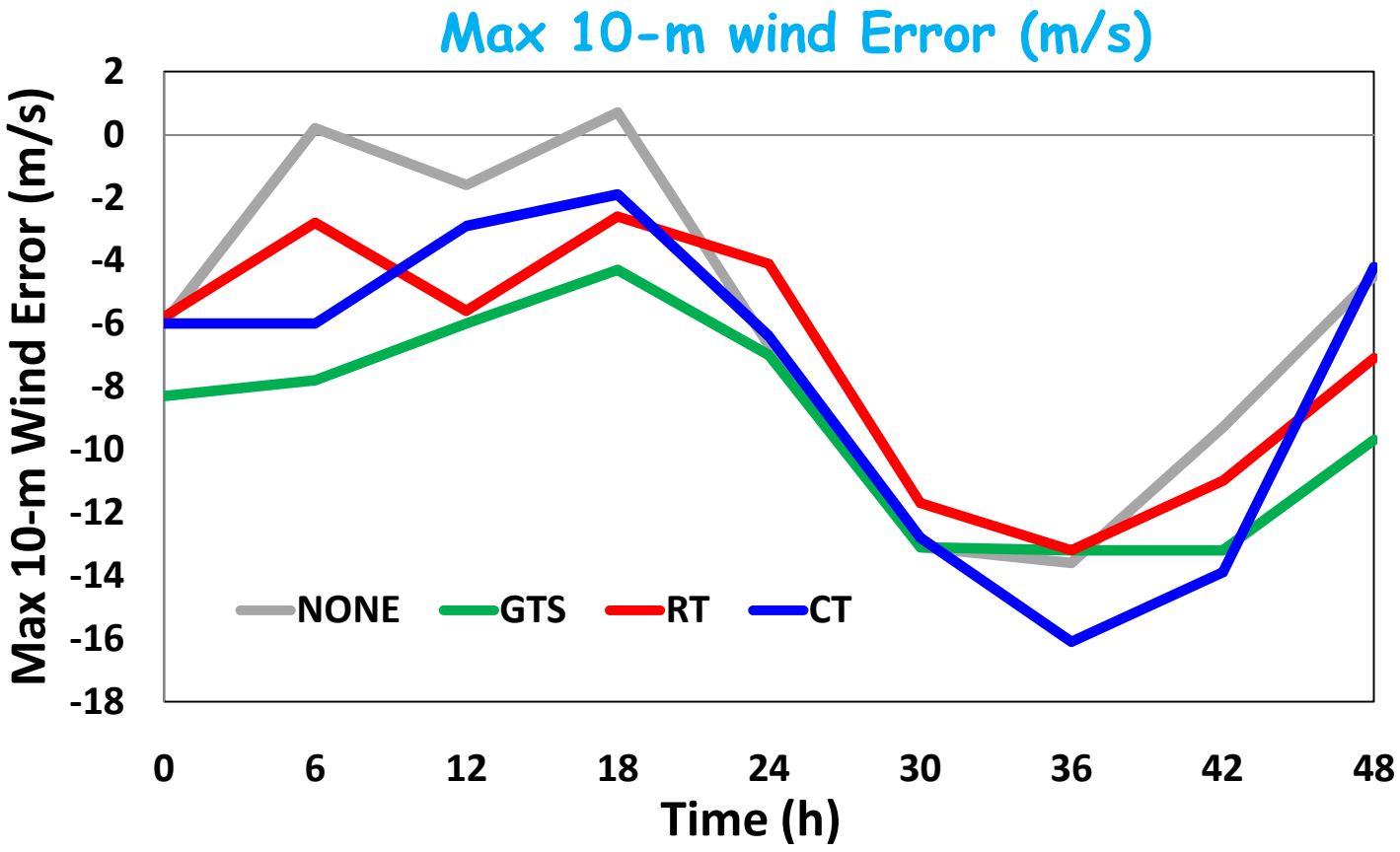


SLP Error (hPa)

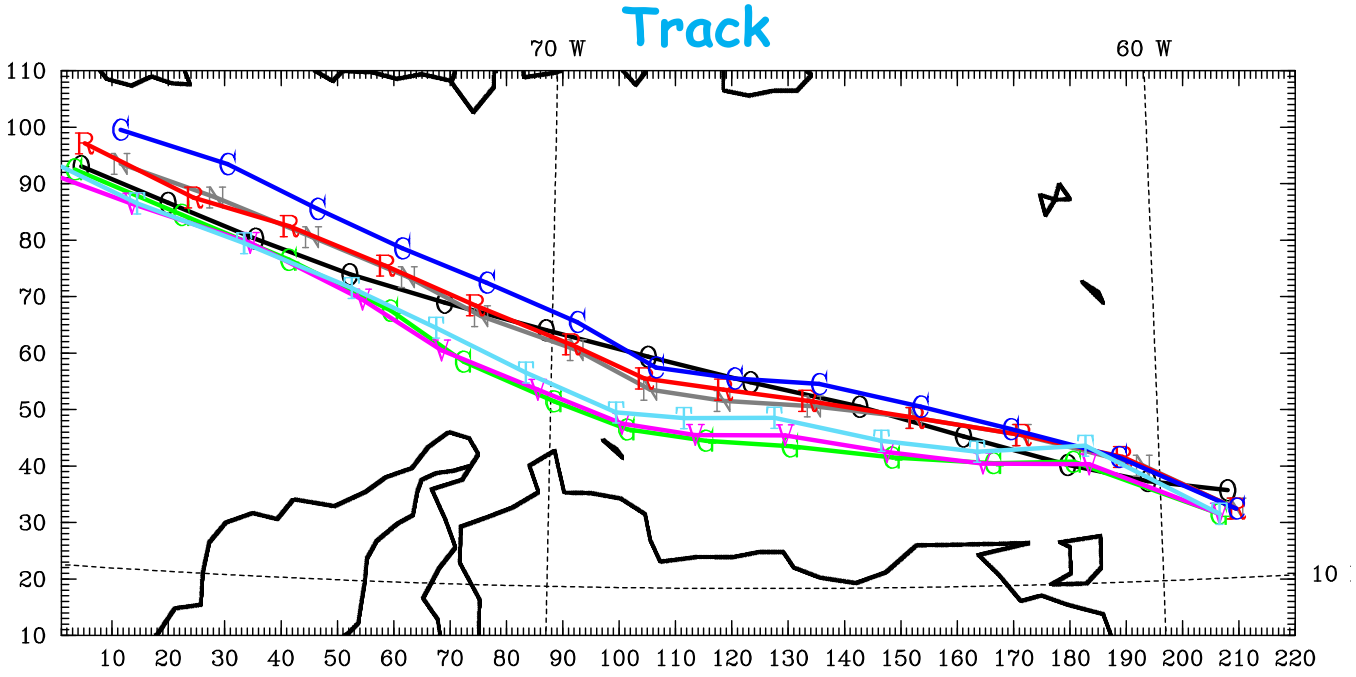


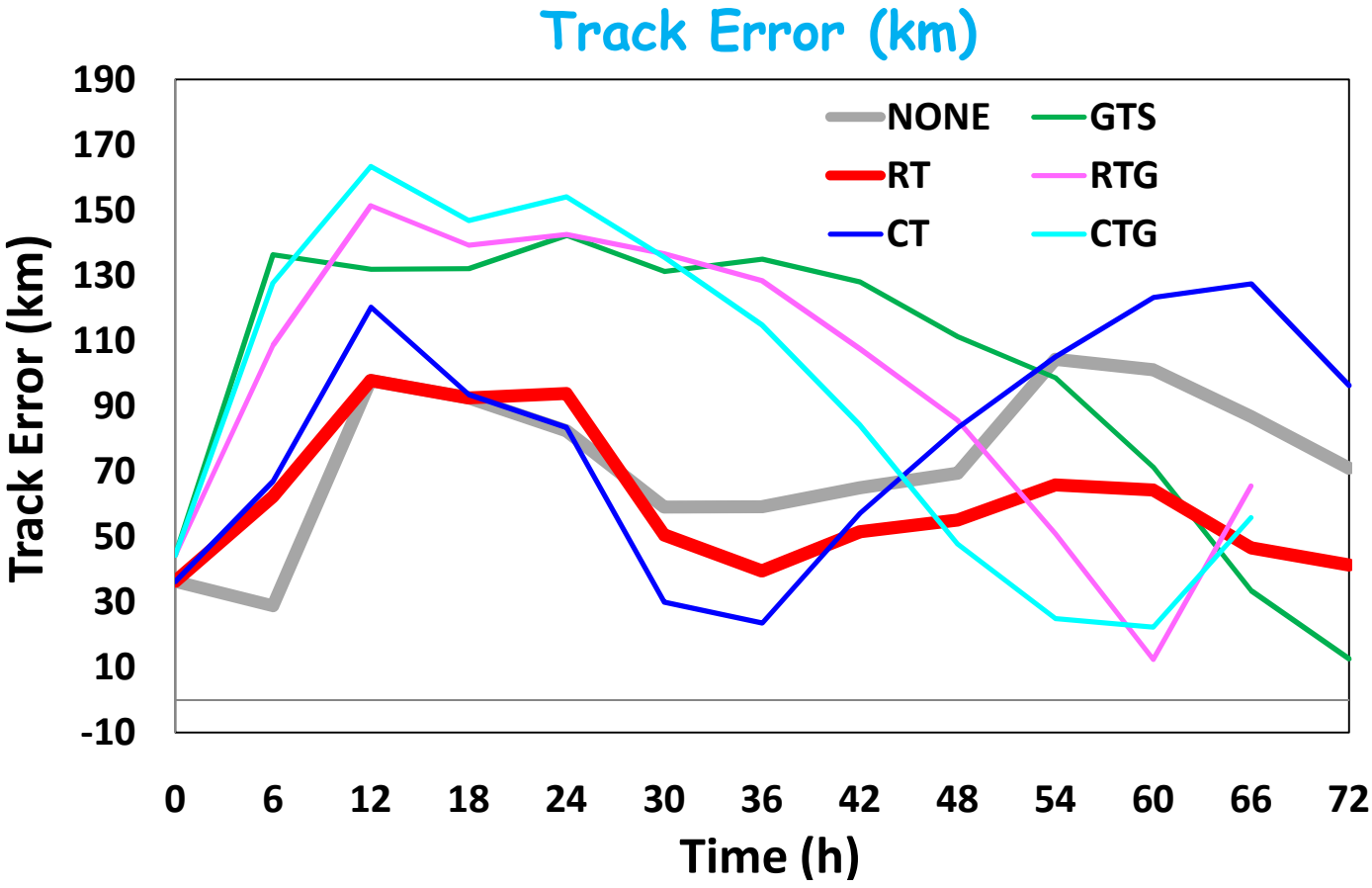
Max 10-m Wind (Emily)
(18Z July 13 – 18Z July 16)





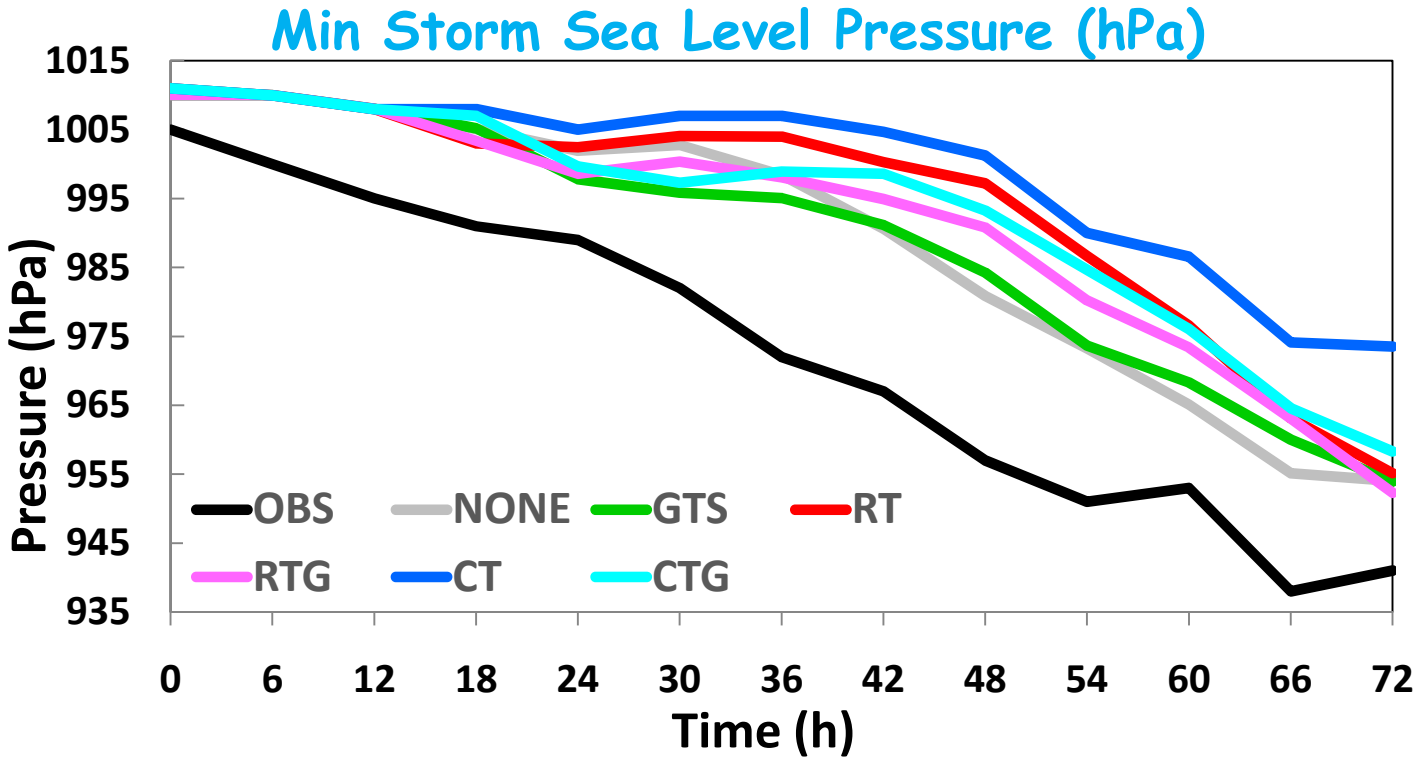
Track (Emily)
(18Z July 13 – 18Z July 16)

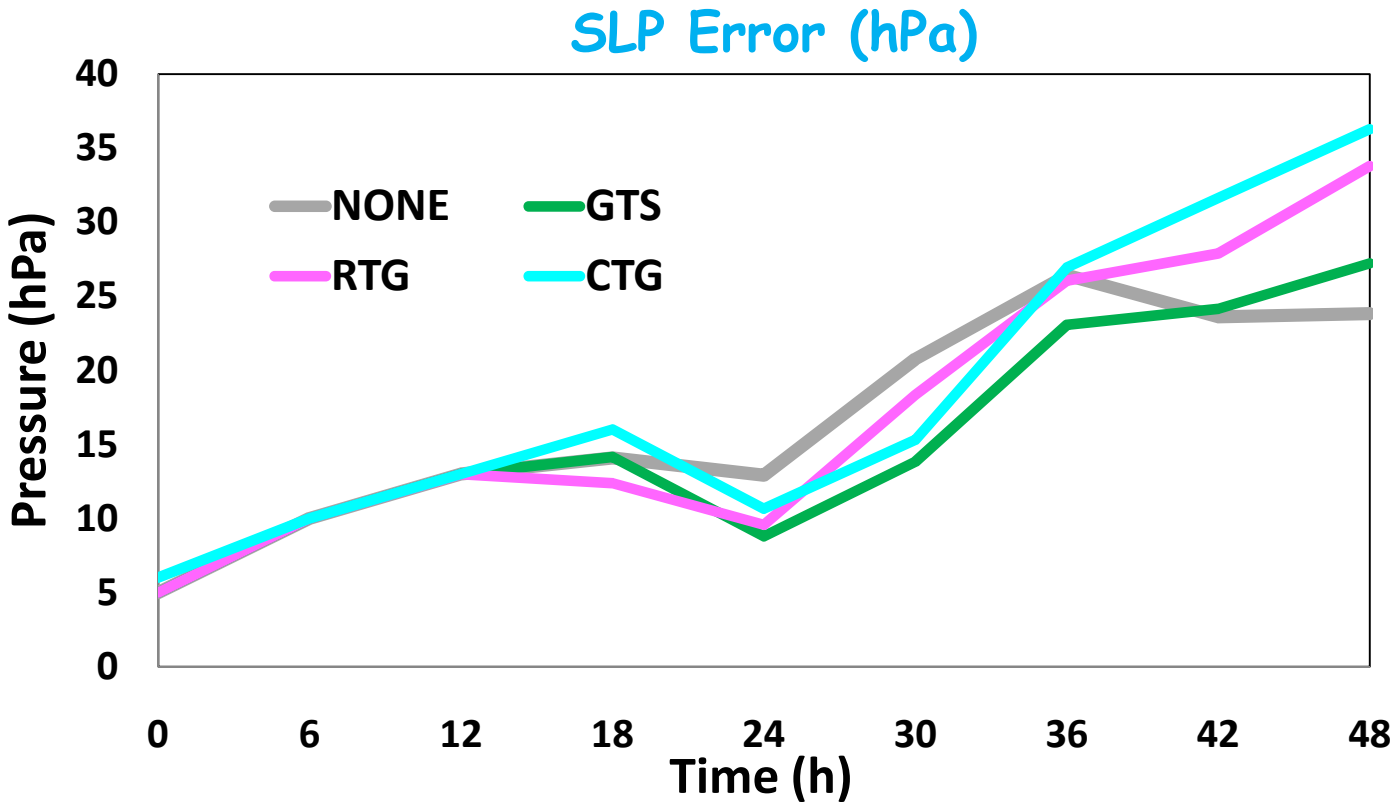




Sea Level Pressure (Dennis)

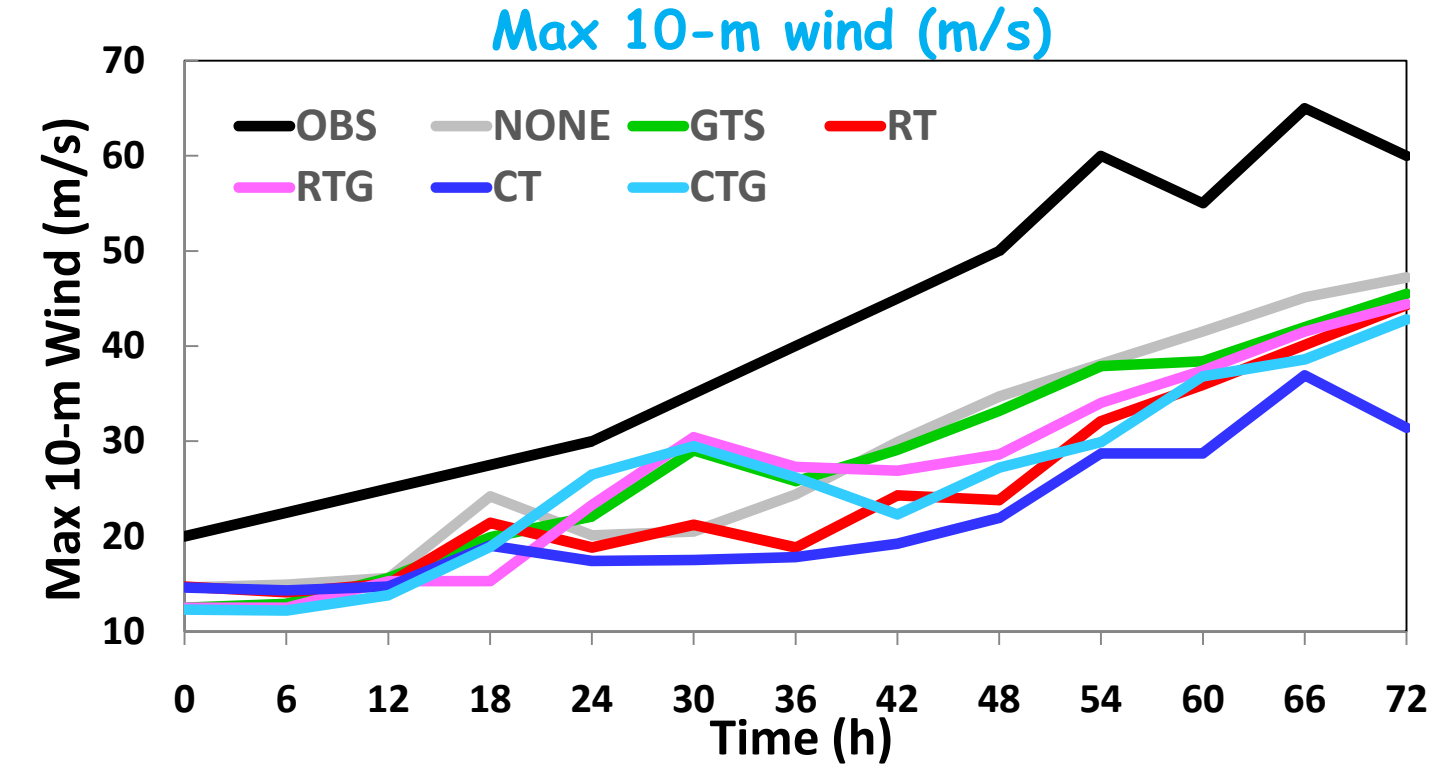
(18Z July 5 – 18Z July 8)

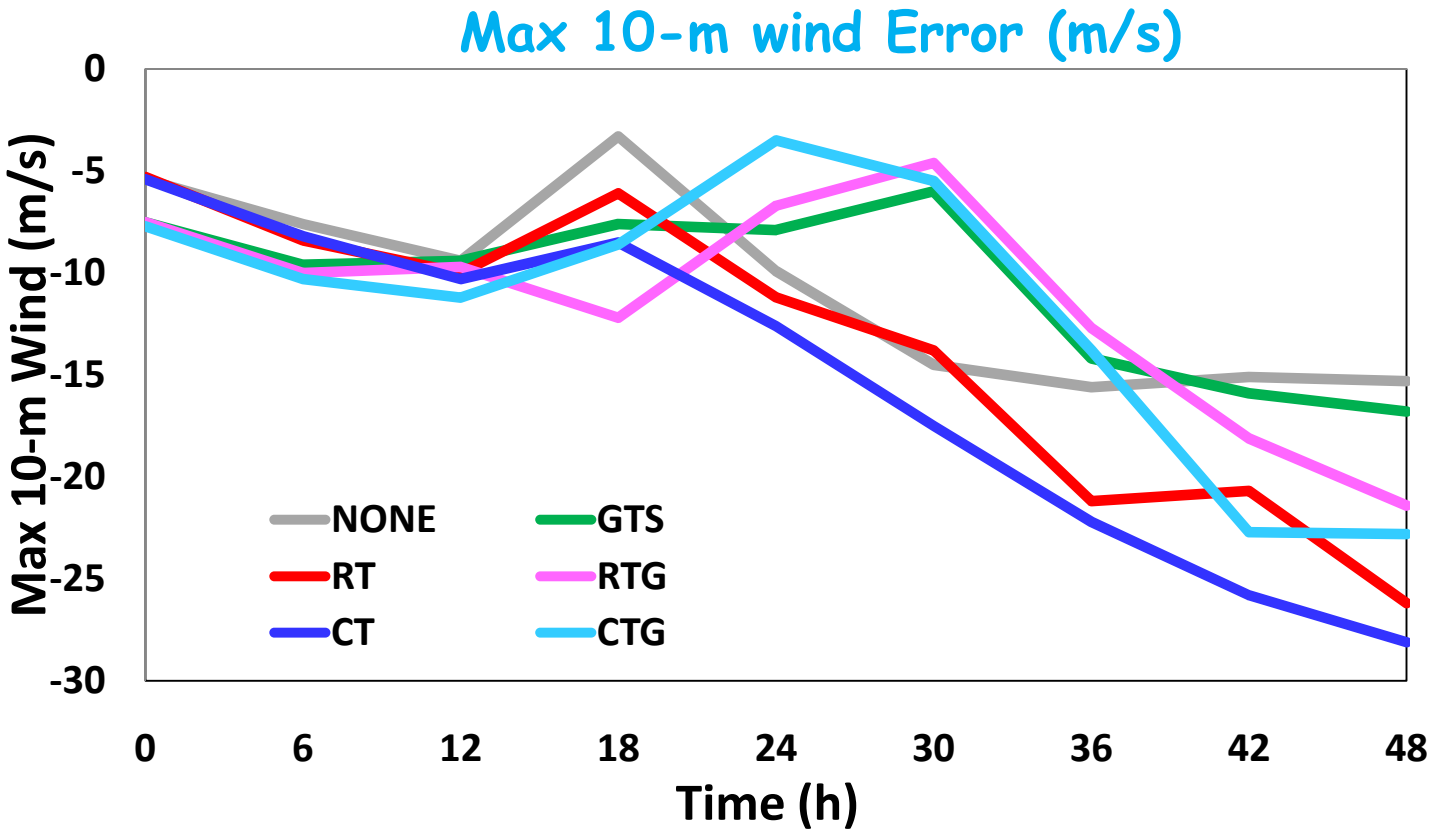




Max 10-m Wind (Dennis)

(18Z July 5 – 18Z July 8)



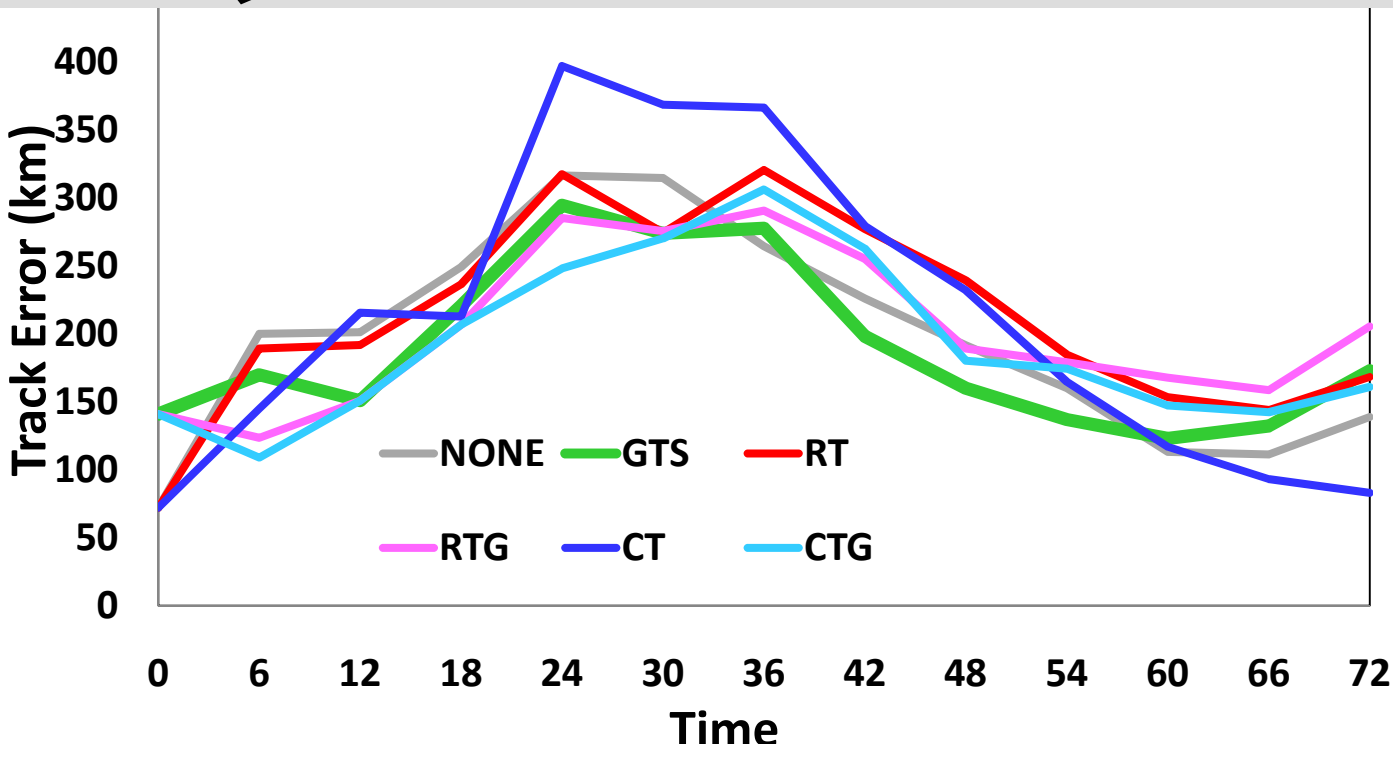


Track (Dennis)

(18Z July 5 – 18Z July 8)

WRF V3.1 is unbeatable……

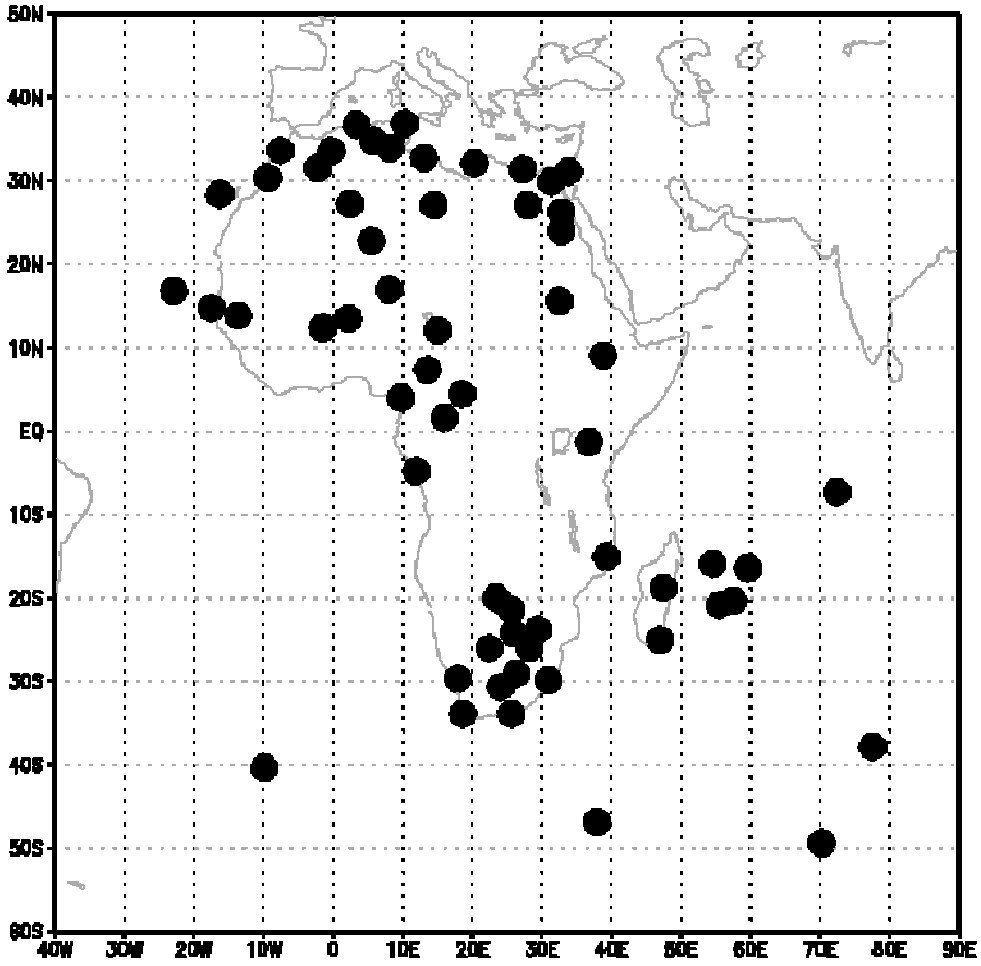
We need to know data a little bit more…



Data comparison

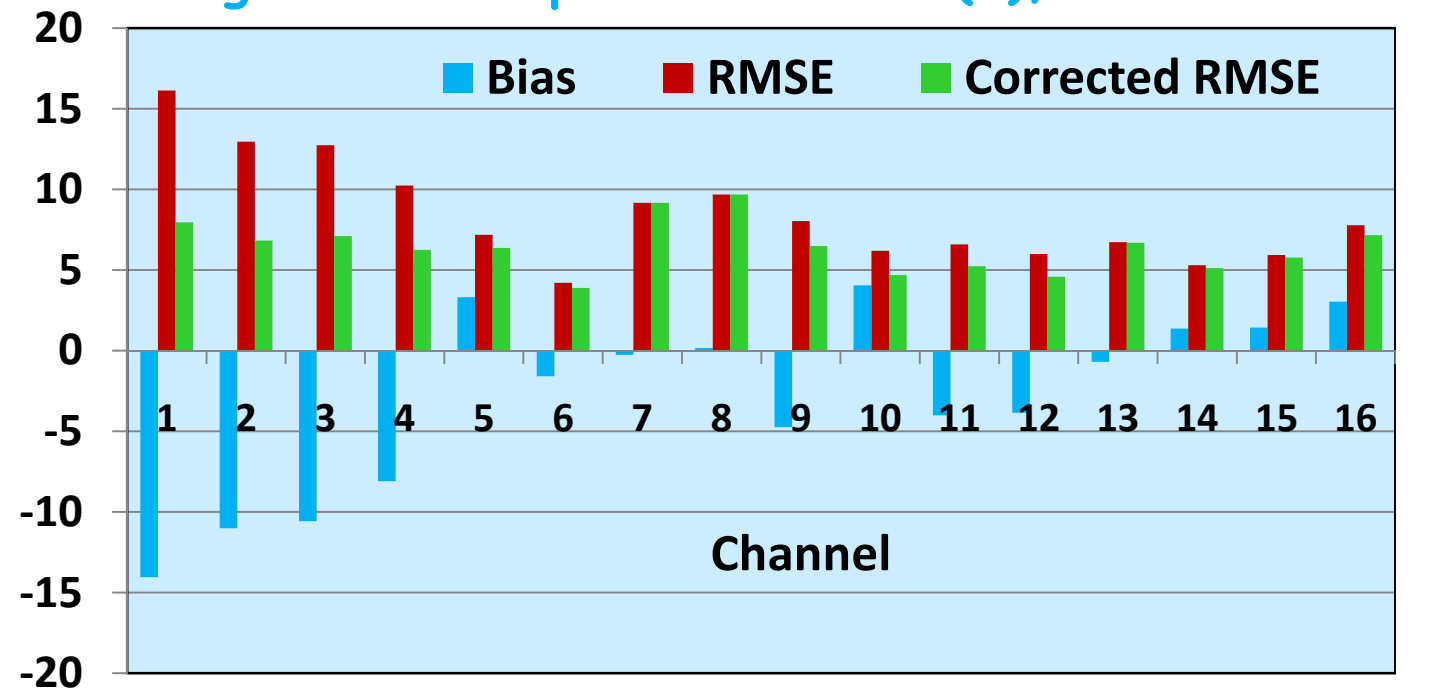
Radiosonde derived brightness temperature
vs.
MOD02 Brightness temperature

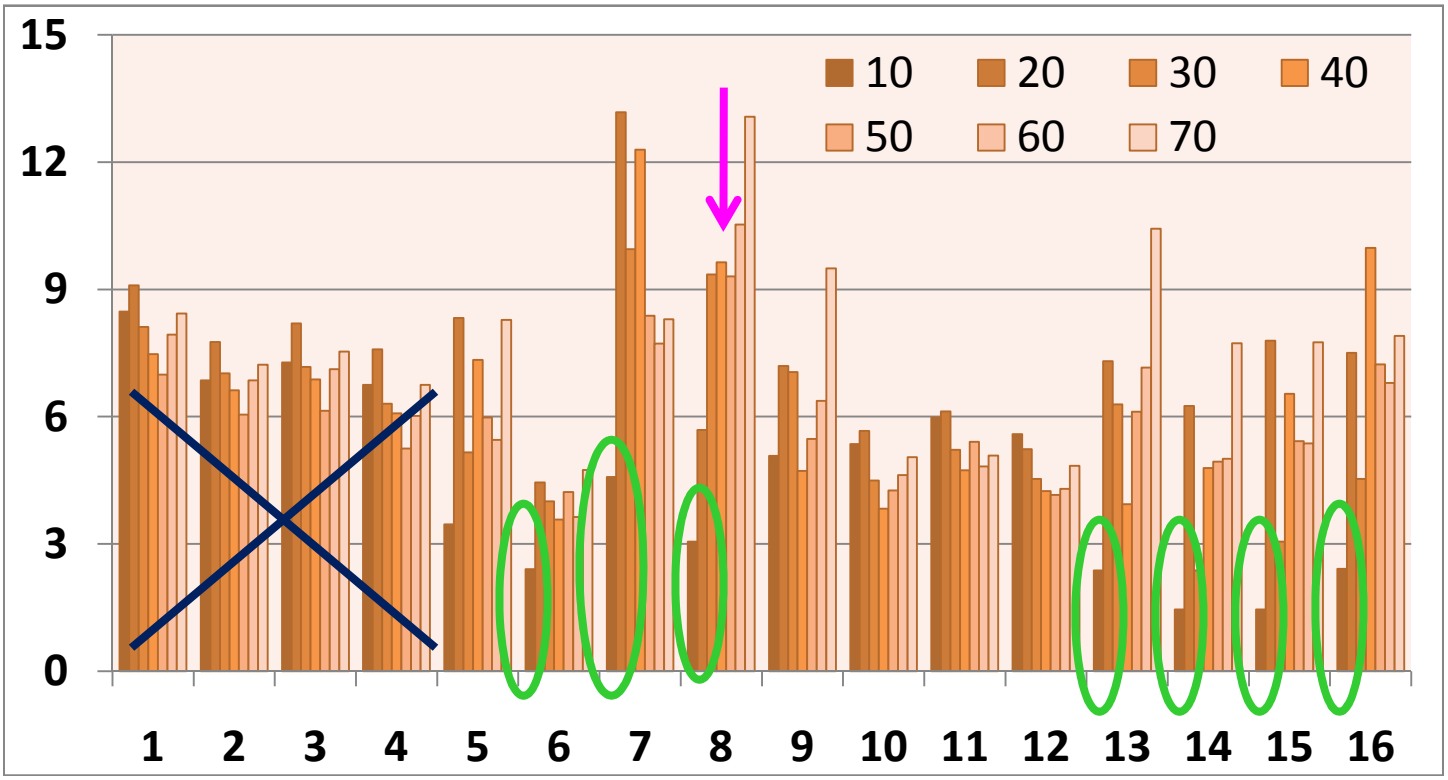
July – September, 2005



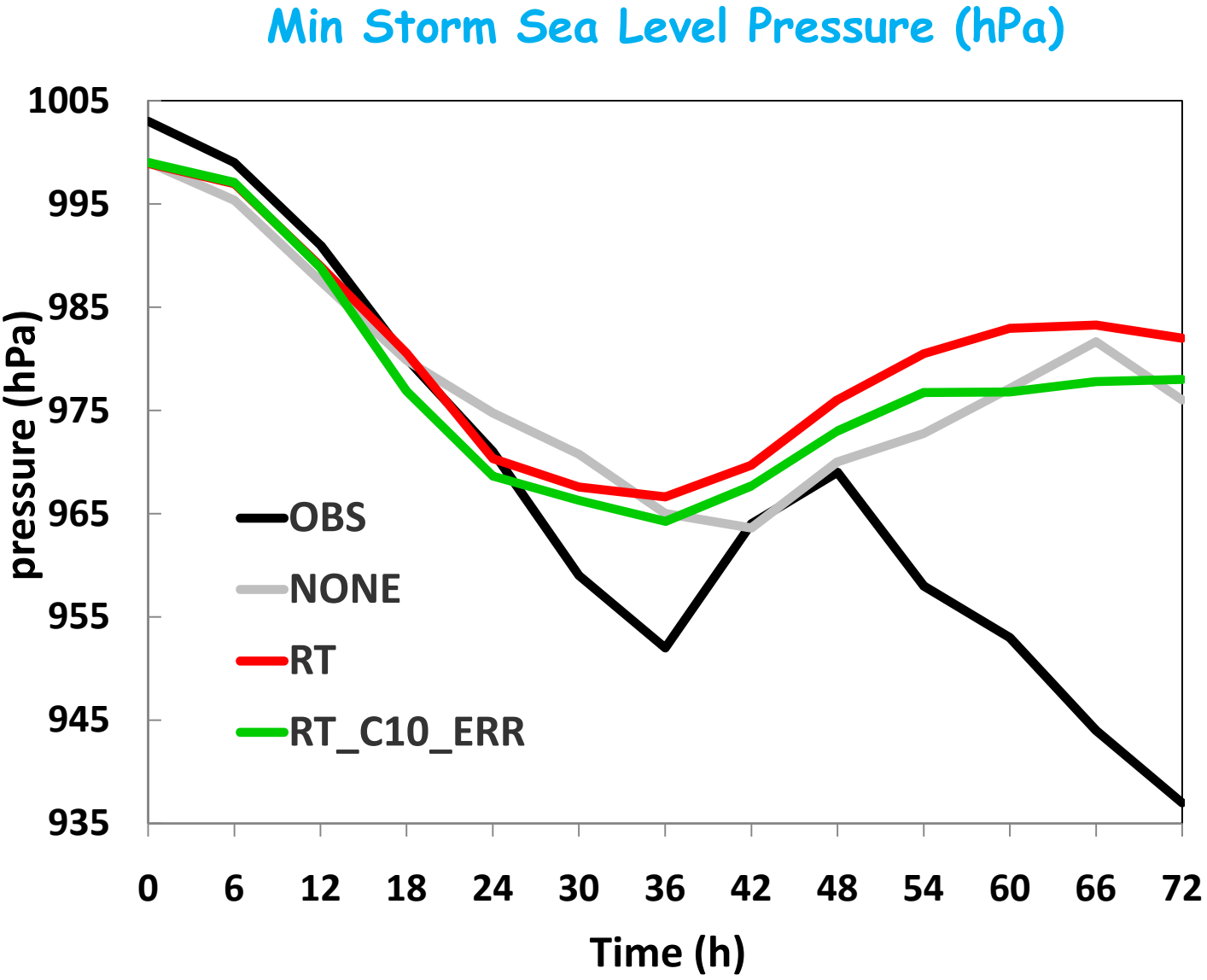
Radiosonde stations

Obs. Error Characteristics





Results (Emily)
(18Z 07/05 – 18Z 07/08)



Summary

- WRF V3.1 performs very well for our case studies.
  - Therefore, the impact of MOD02 on these case studies were almost nil or slightly negative.
- The errors of derived brightness temperature from RTTOV is almost independent of zenith angle, except when it is close to the nadir view (better quality).
- We will continue to study the error characteristics of MOD02 data and RTMS to improve the use of data.

Acknowledgement:
Thanks to the WRF team and wrfhelp.
This work is supported by NASA.