The Influence of Dust-radiation-microphysics Processes on Tropical Cyclone Development

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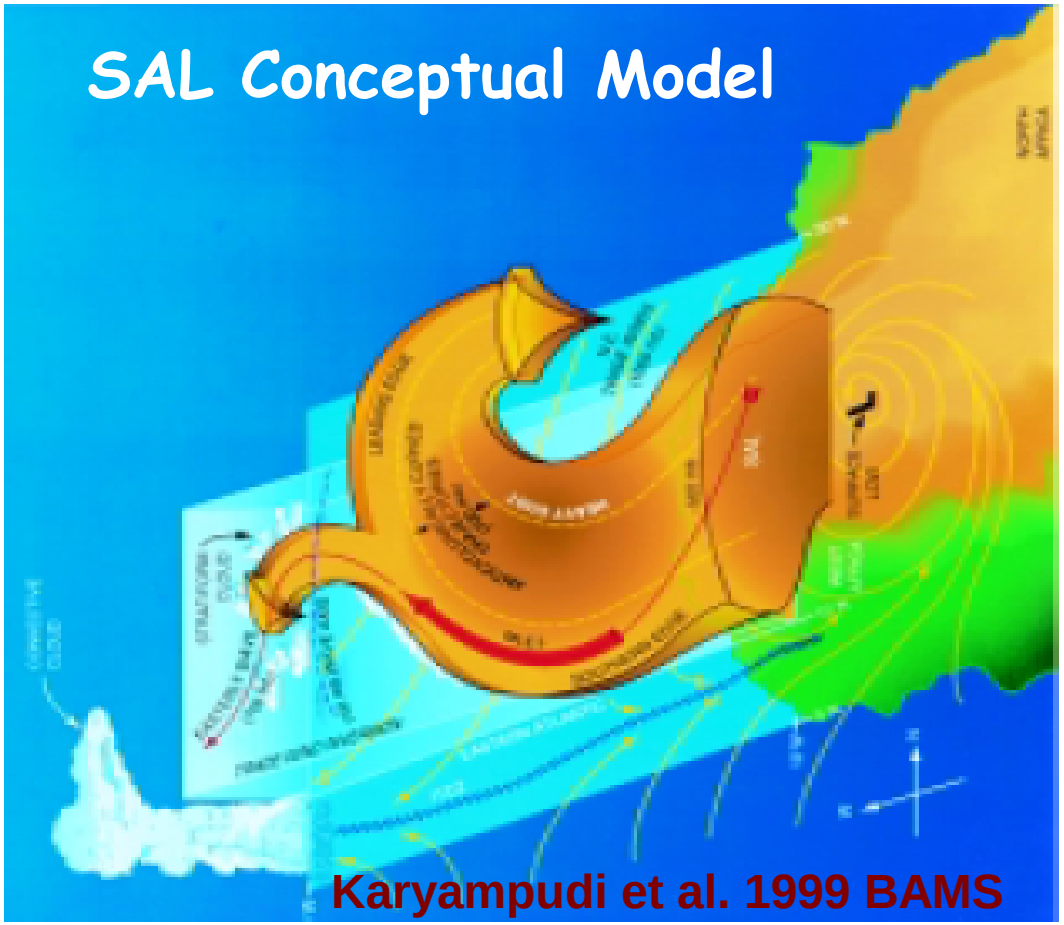
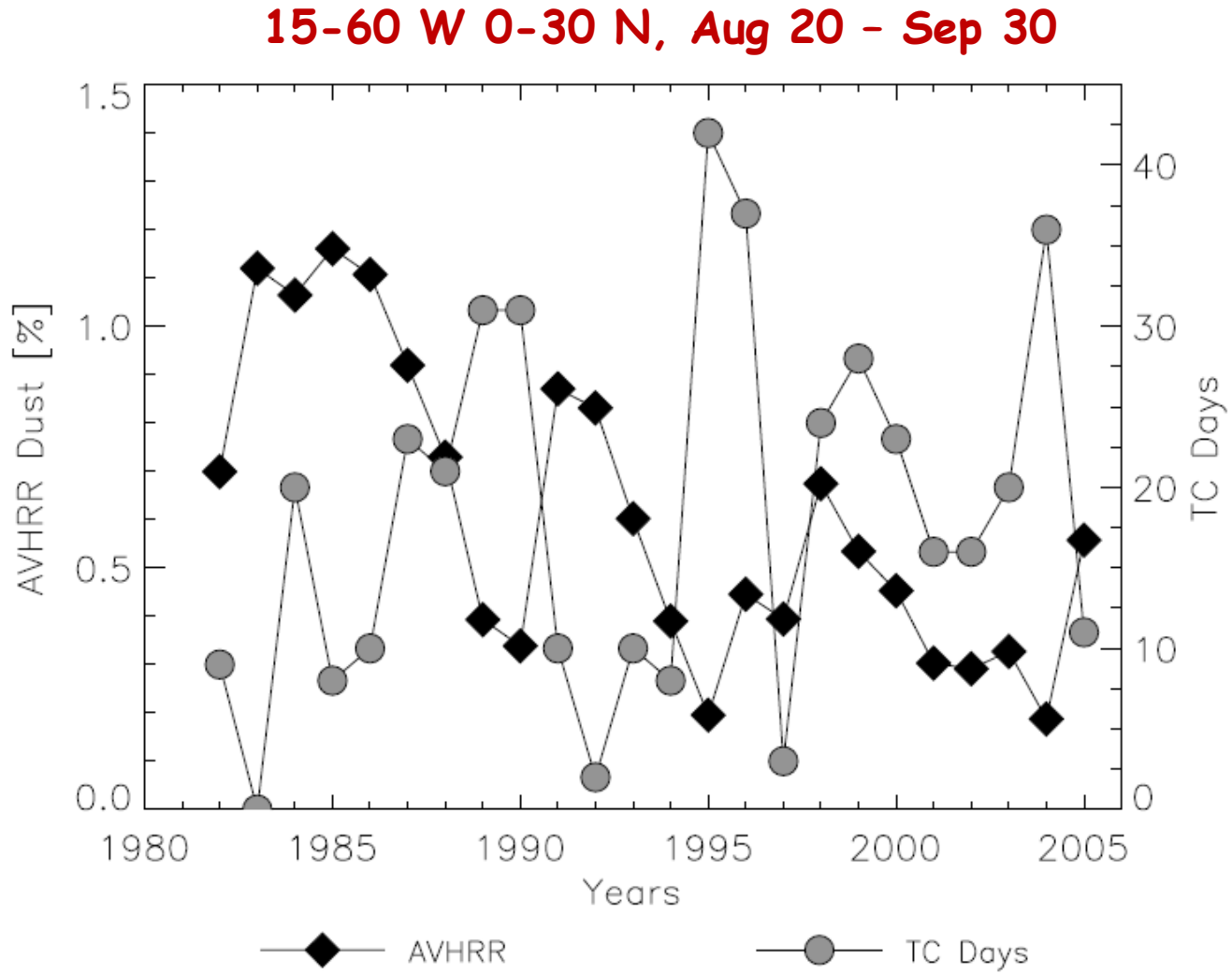
Saharan Air Layer (SAL)

- An extended warm, dry, and potentially dusty air mass from the Saharan Desert to the Atlantic Ocean (~ 850 to 500 mb)



Dust & TC Activities



(Evan et al. 2006)

Objective

To investigate the influence of dust-radiation-microphysics processes on TC genesis and intensification.

Development of WRF Tracer Model (V3.2)

WRF + Dust continuity equation

+ Dust-cloud-radiation effects

$$\frac{\partial C}{\partial t} = - \square \cdot \vec{V}C + C_{pbl} + C_{cov} + C_{mic} + S_c + E_c$$

C = μc (coupled variable)

μ = $P_{hs} - P_{ht}$

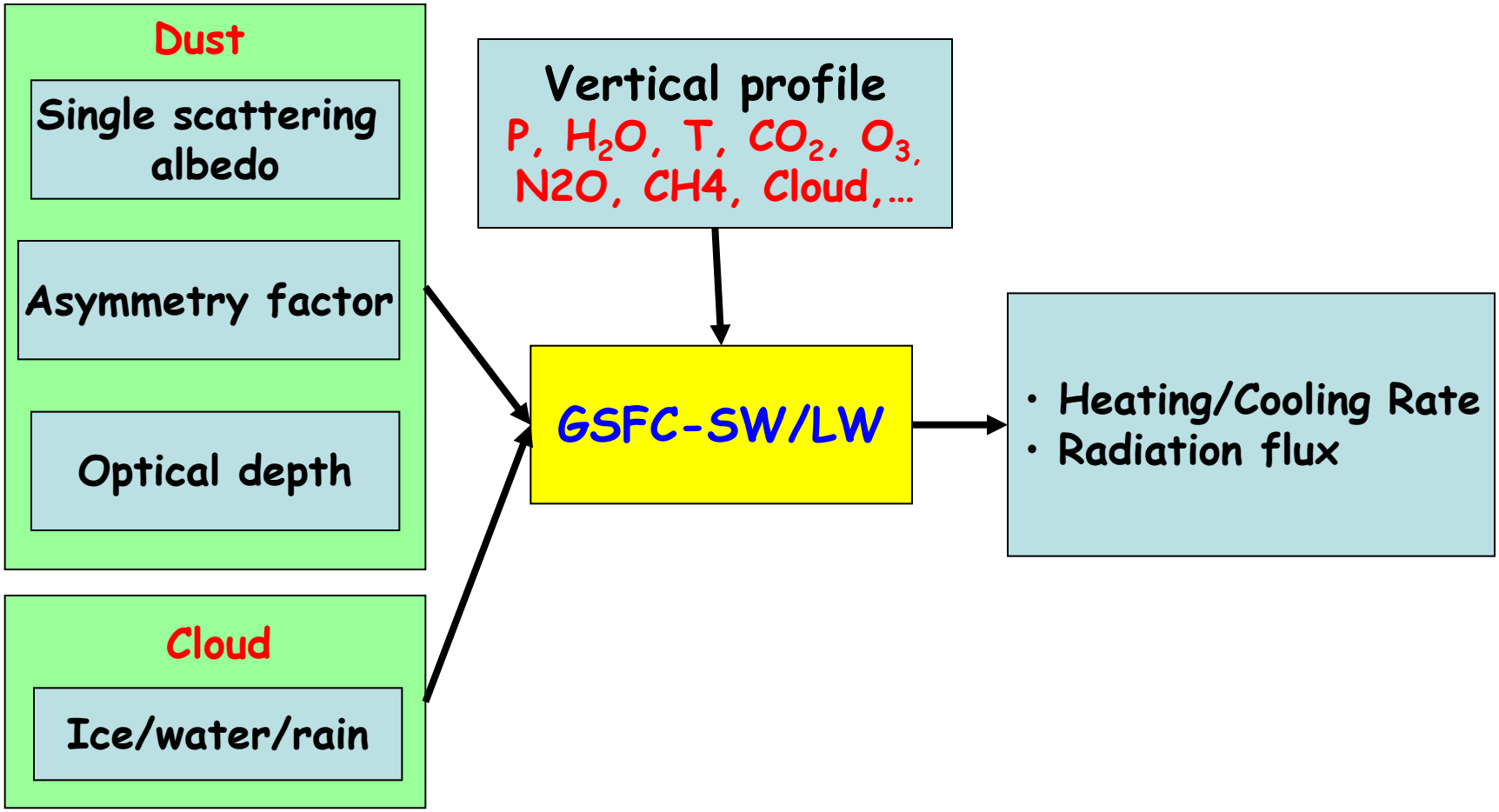
c : Dust mixing ratio

S_c : Sedimentation (time splitting)

E_c : Source / Sink - emission, wet scavanging

GSFC Radiation

Short wave spectrum bands: 0.175 – 10 μm divided into 11 bands
Long wave spectrum bands: 3.33 μm and above, divided into 9 bands



2-Moment Microphysics Scheme

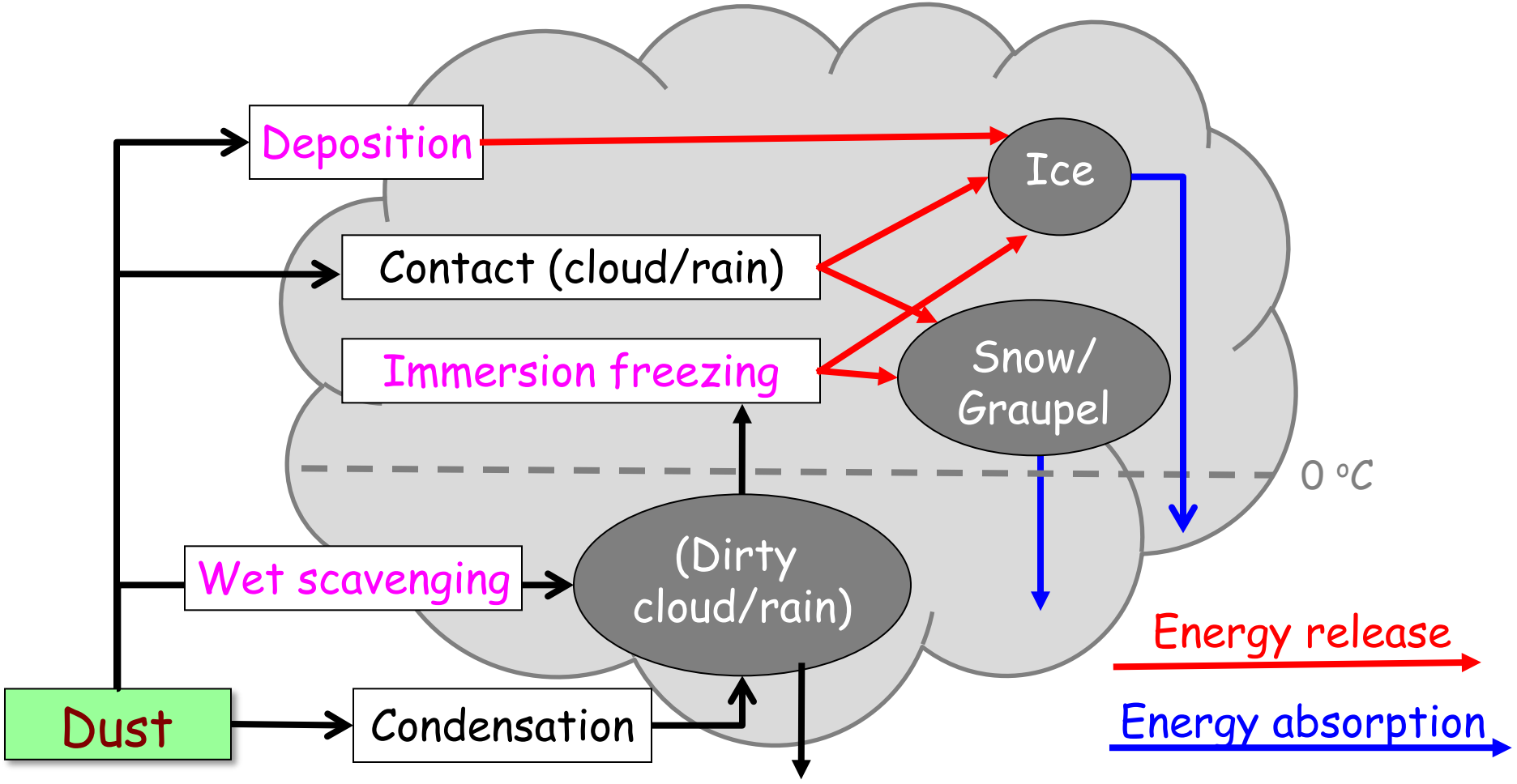
Cheng et al. (2010) – modification based on

- Warm cloud microphysics - Chen and Liu (2004)
- Mixed-phase cloud microphysics (Reisner et al. 1998)
- Cloud droplet, ice, rain - two moments

  Snow, graupel – one moment

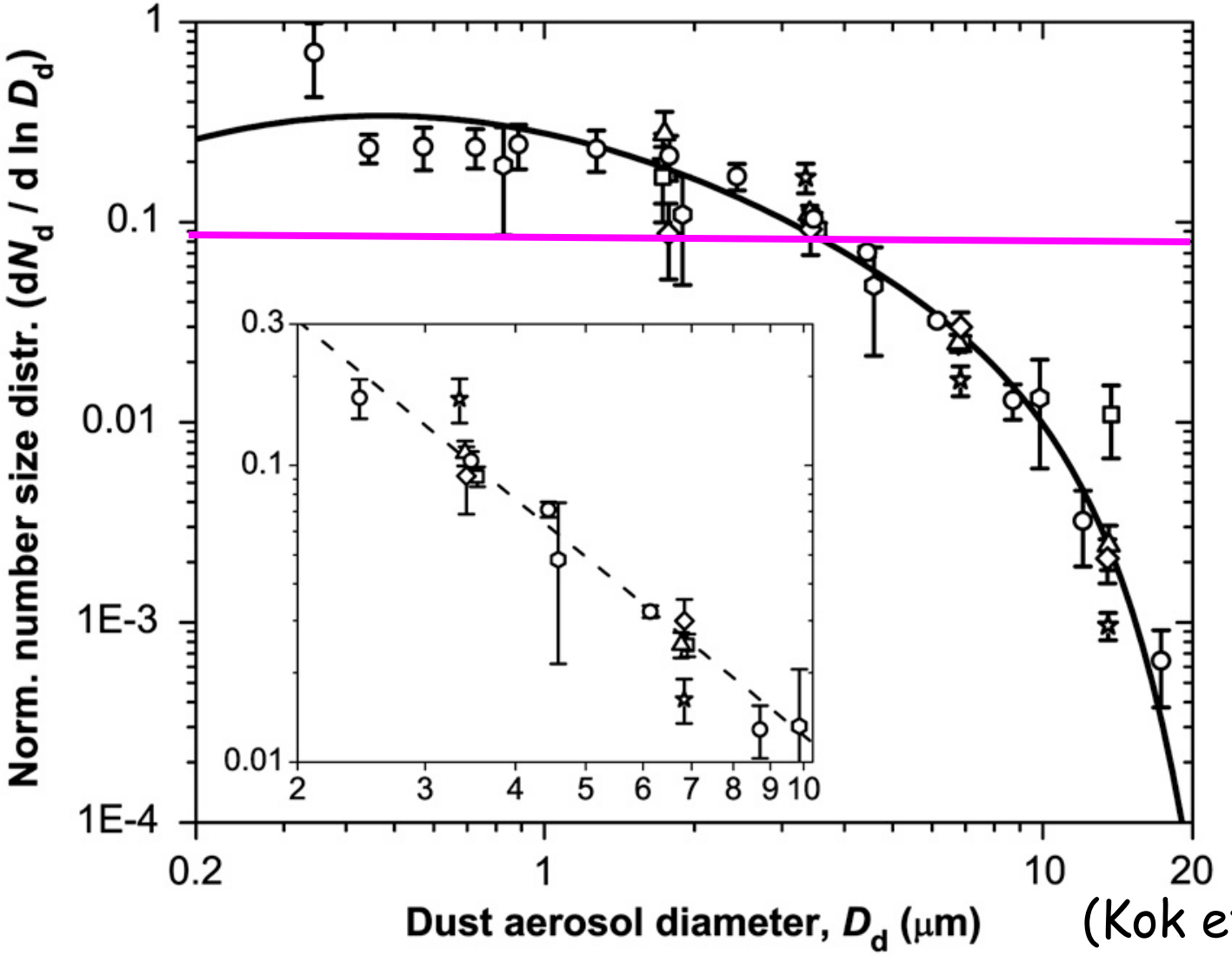
2-Moment Microphysics Scheme

Dust-microphysics processes



Dust Particle Distribution

12 dust sizes



(Kok et al. 2011)

Dust Emission

- Vegetation Type – Barren
- Moist volumetric fraction < 0.2
- Wind > 6.5 ms^{-1}
- Soil Type – 12 categories

Surface dust flux

$$E_c(\mu g\ s^{-1} m^{-2}) = \max\left[c_1 (u - u_c) u^2,\ 0. \right]$$

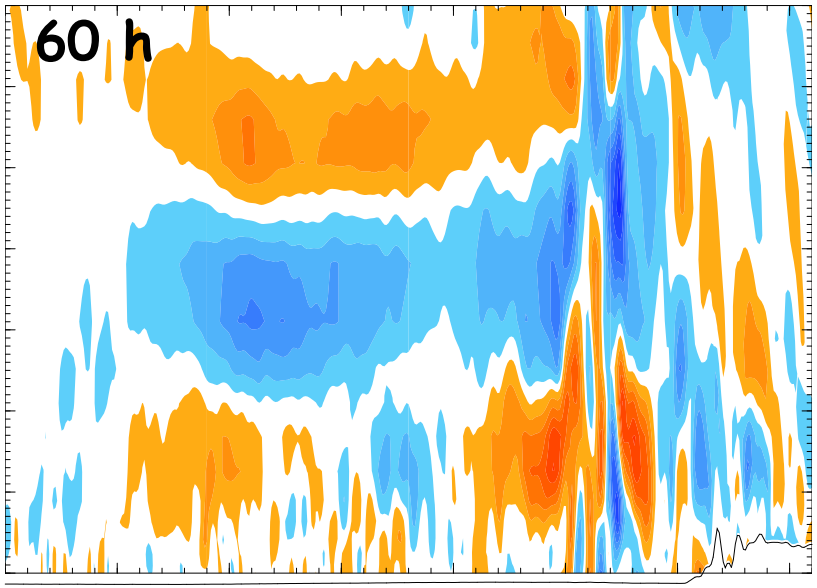
$$c_1 = 1.0\ \mu g\ m^2\ s^{-5}, \qquad u_c = 6.5\ m\ s^{-1}$$

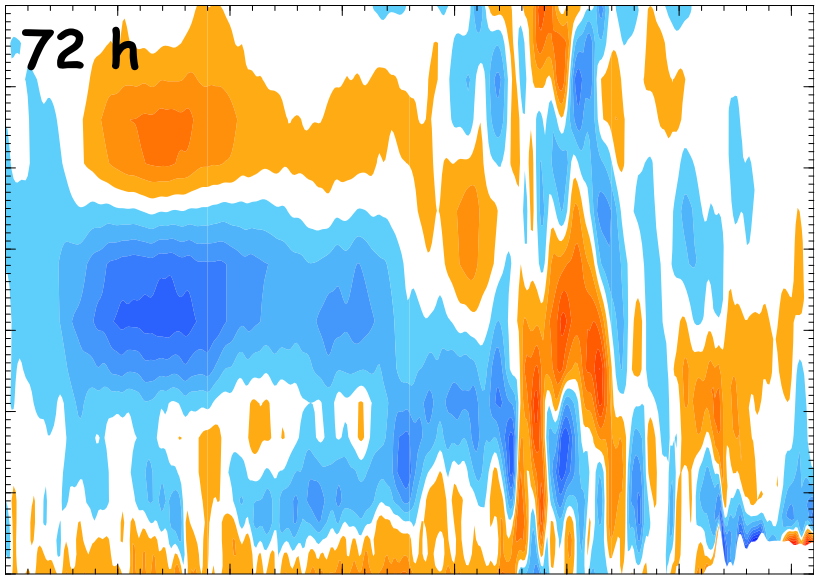
Tegen and Fung (1994)

Vertical Cross Section (south of AEJ)

$\frac{ms^{-1}}{km}$

Difference in shear (ON – OFF)

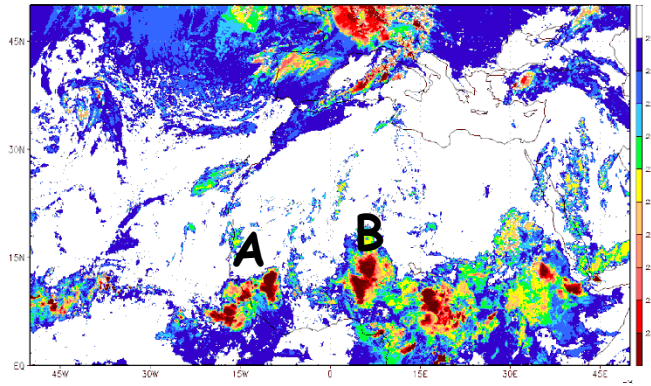




obs

Hurricane Ernesto and TS Debby (2006)

2006081800



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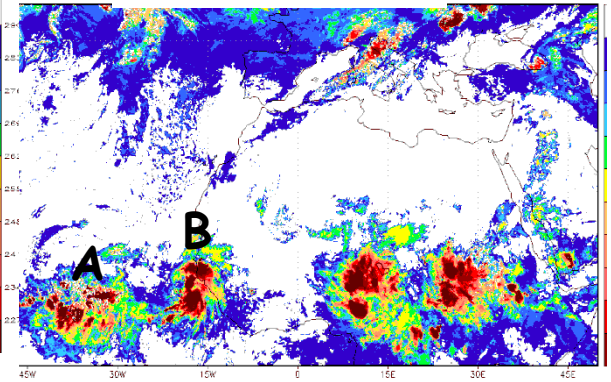

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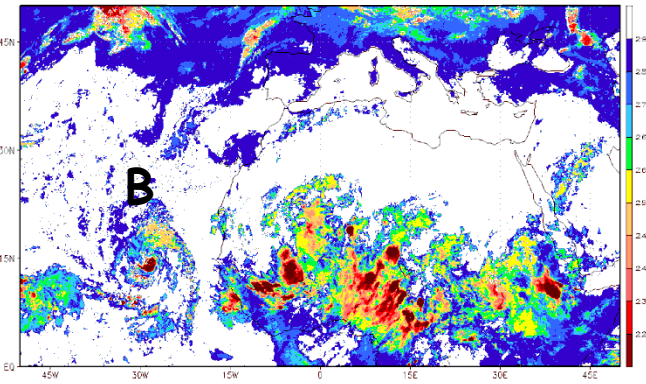


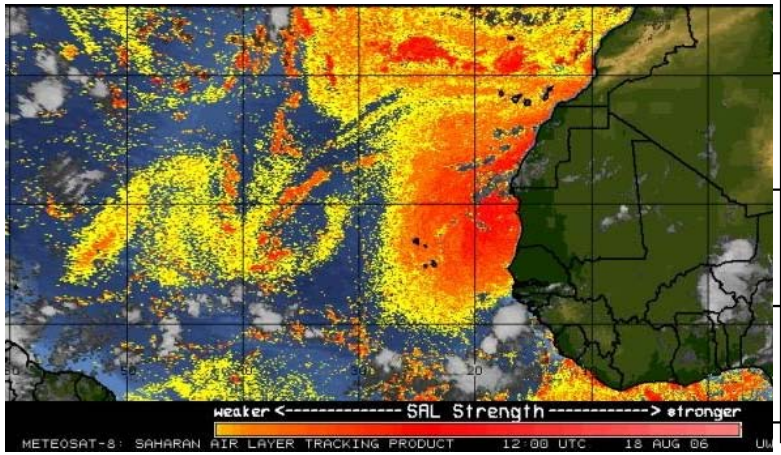
(IR, NASA)

Date/Time (UTC)	Latitude (°N)	Longitude (°W)	Pressure (mb)	Wind Speed (kt)	Stage
24 / 1800	12.7	21.6	1008	30	tropical depression
21 / 1800	11.6	21.7	1007	30	tropical depression
25 / 0000	13.0	63.0	1007	30	"
22 / 0000	12.0	22.7	1007	30	"
25 / 0600	13.3	64.4	1005	30	"
22 / 0600	12.6	23.9	1007	30	"
25 / 1200	13.7	65.8	1005	35	tropical storm
22 / 1200	13.4	25.3	1007	30	"
25 / 1800	14.0	67.1	1004	35	"
22 / 1800	14.2	26.7	1005	30	"
26 / 0000	14.3	68.3	1002	40	"
23 / 0000	14.9	28.1	1003	35	tropical storm
26 / 0600	14.6	69.5	999	45	"
23 / 0600	15.7	29.5	1002	40	"
26 / 1200	15.1	70.4	997	50	"
23 / 1200	16.7	31.0	1001	45	"
26 / 1800	15.7	71.2	997	55	"
23 / 1800	17.6	32.4	1001	45	"
27 / 0000	16.3	72.0	995	55	"
27 / 0600	16.9	72.7	992	65	hurricane

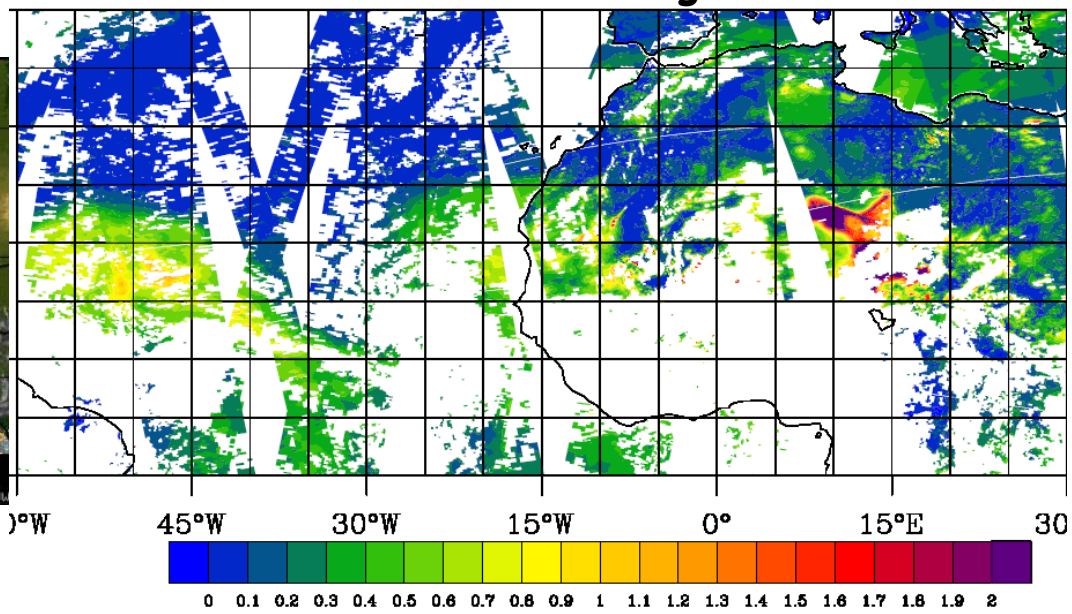
Ernesto (A) Debby (B)

SAL and AOD

12Z 18 Aug



12Z 22 Aug



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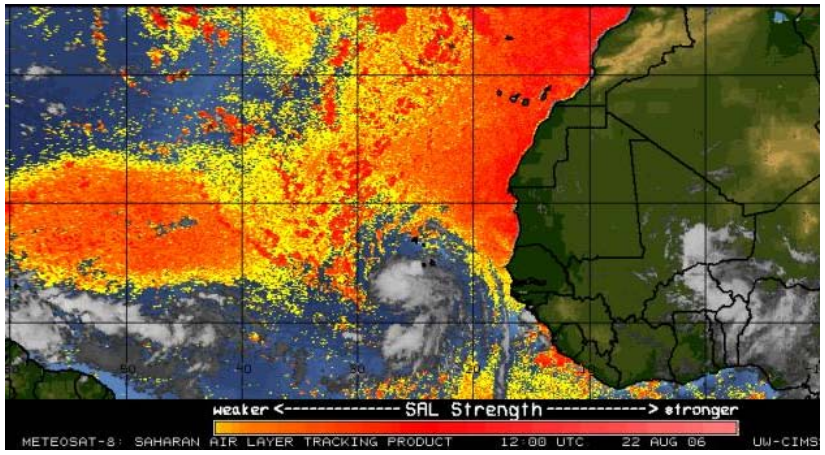
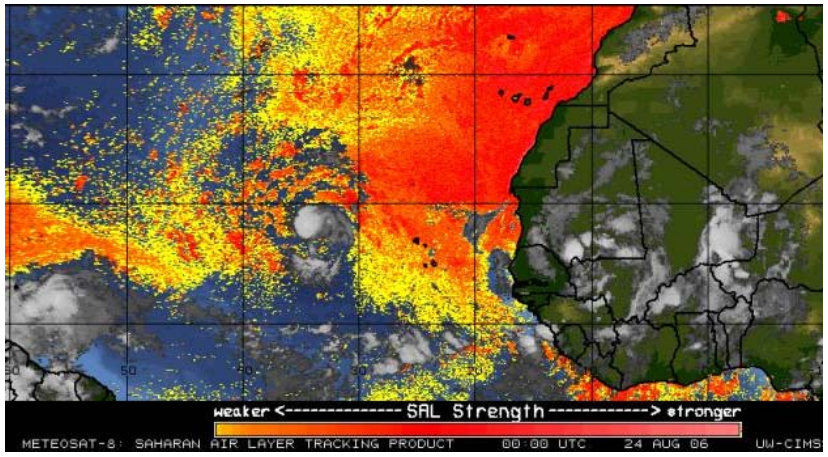
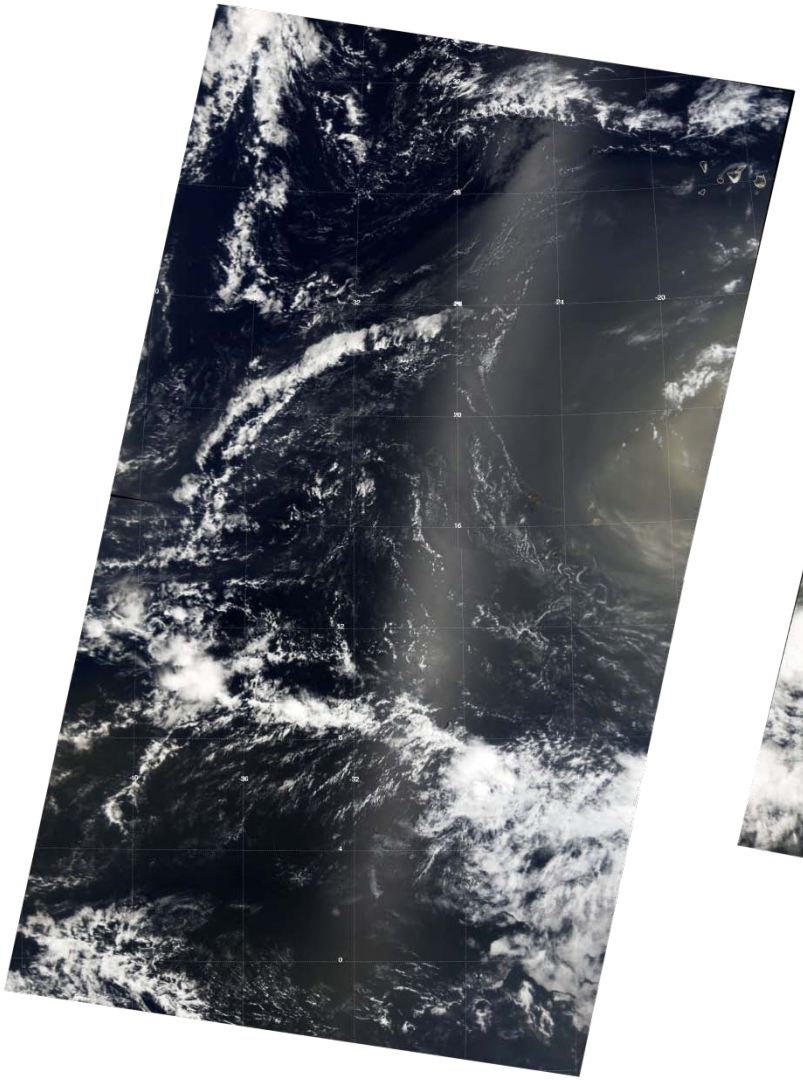


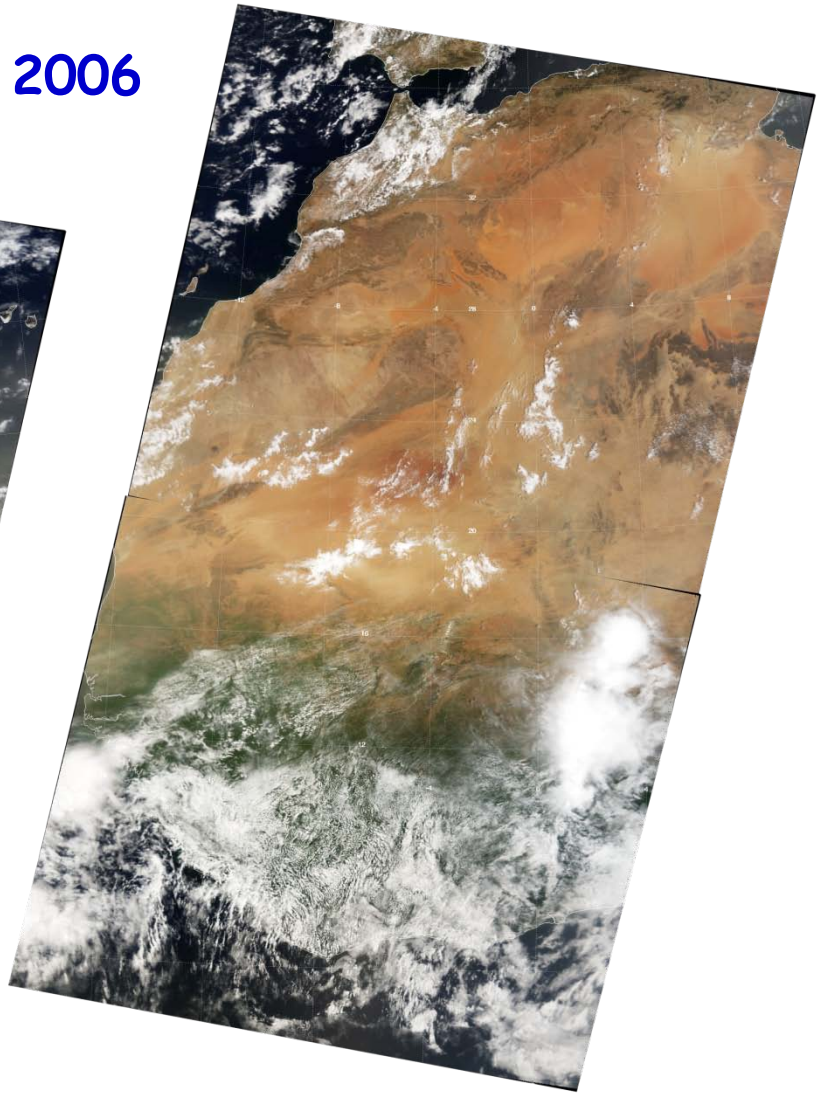


(METEOSAT, CIMSS/UW)

MODIS True Color Scene

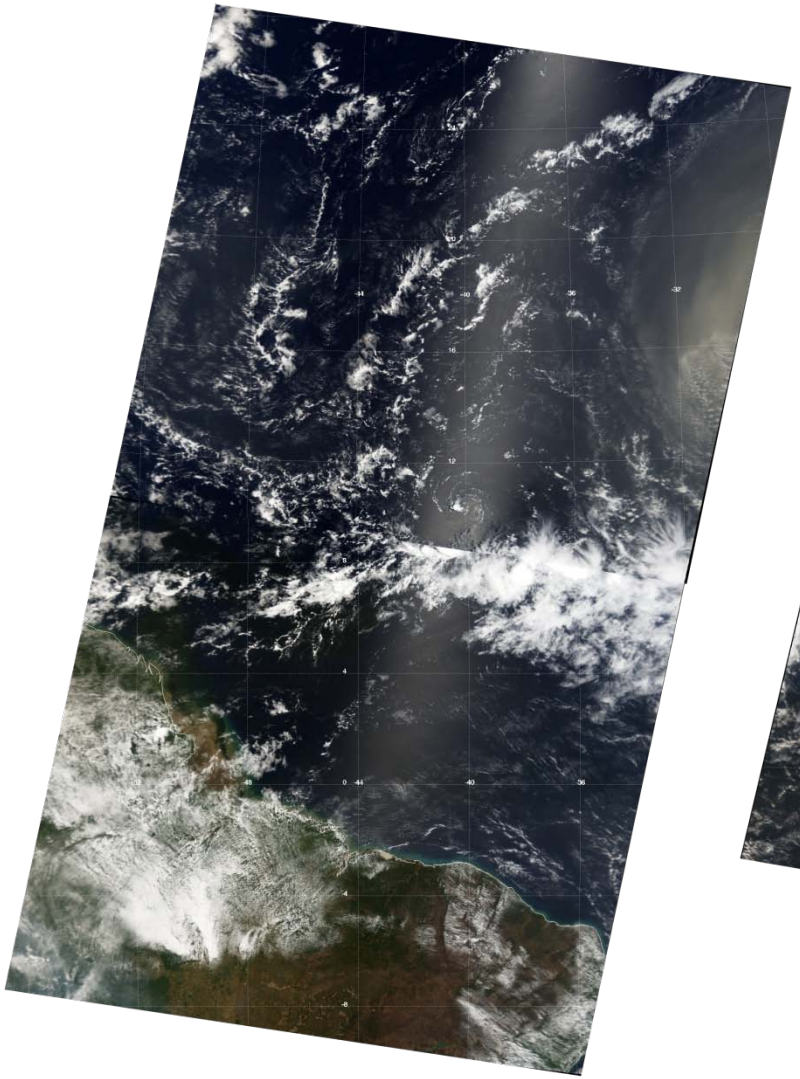
10:55-12:40Z 18 Aug 2006

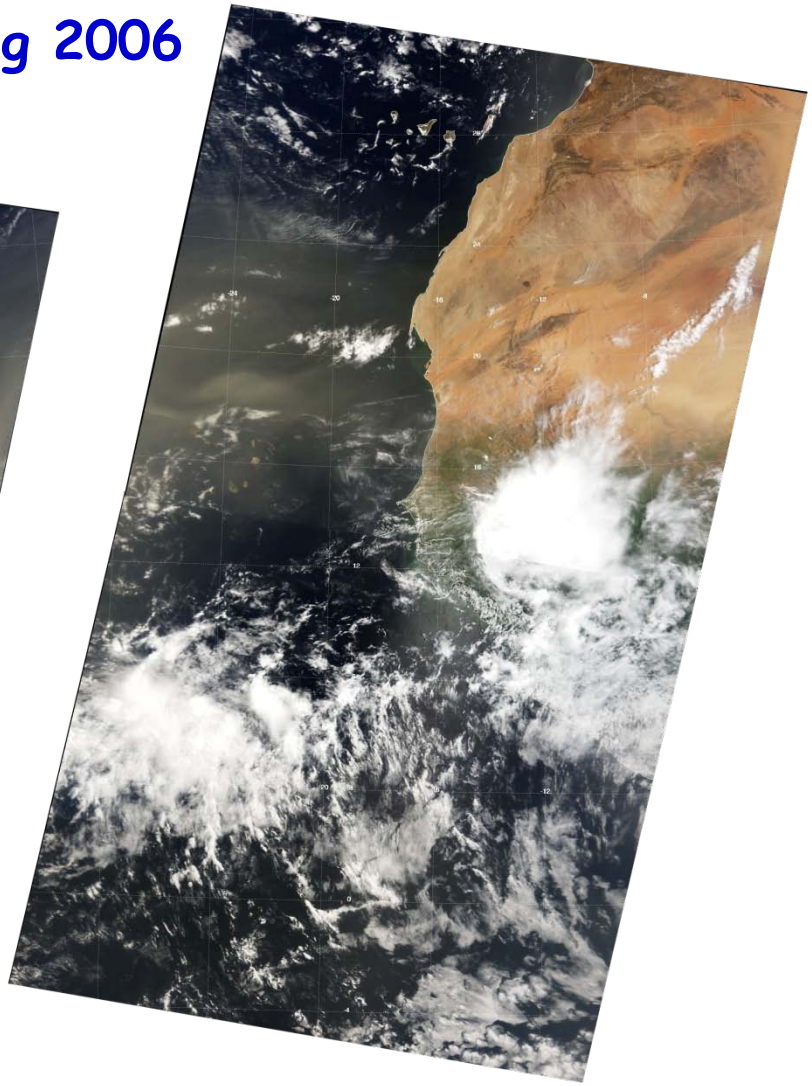




MODIS True Color Scene

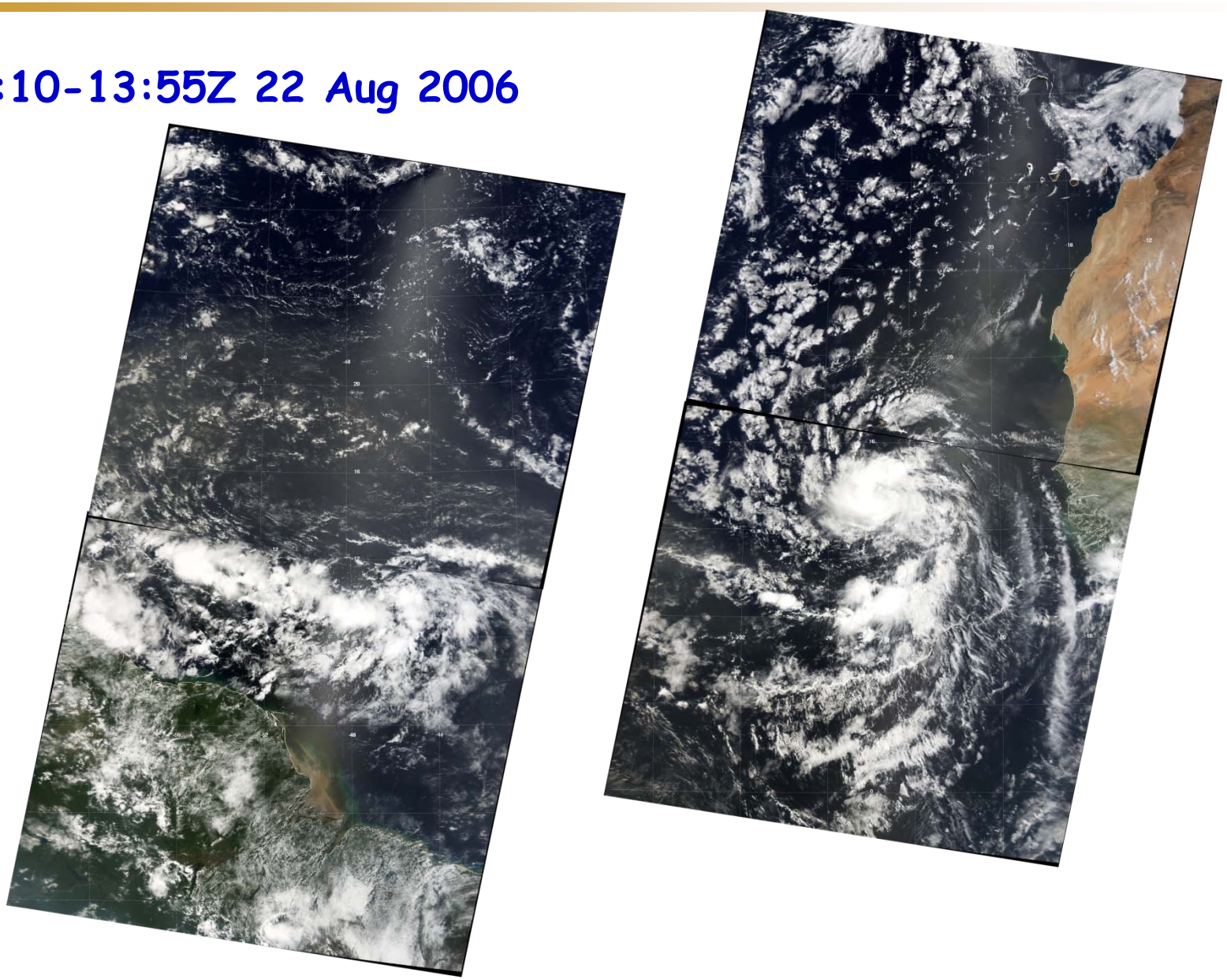
11:40-13:25Z 19 Aug 2006





MODIS True Color Scene

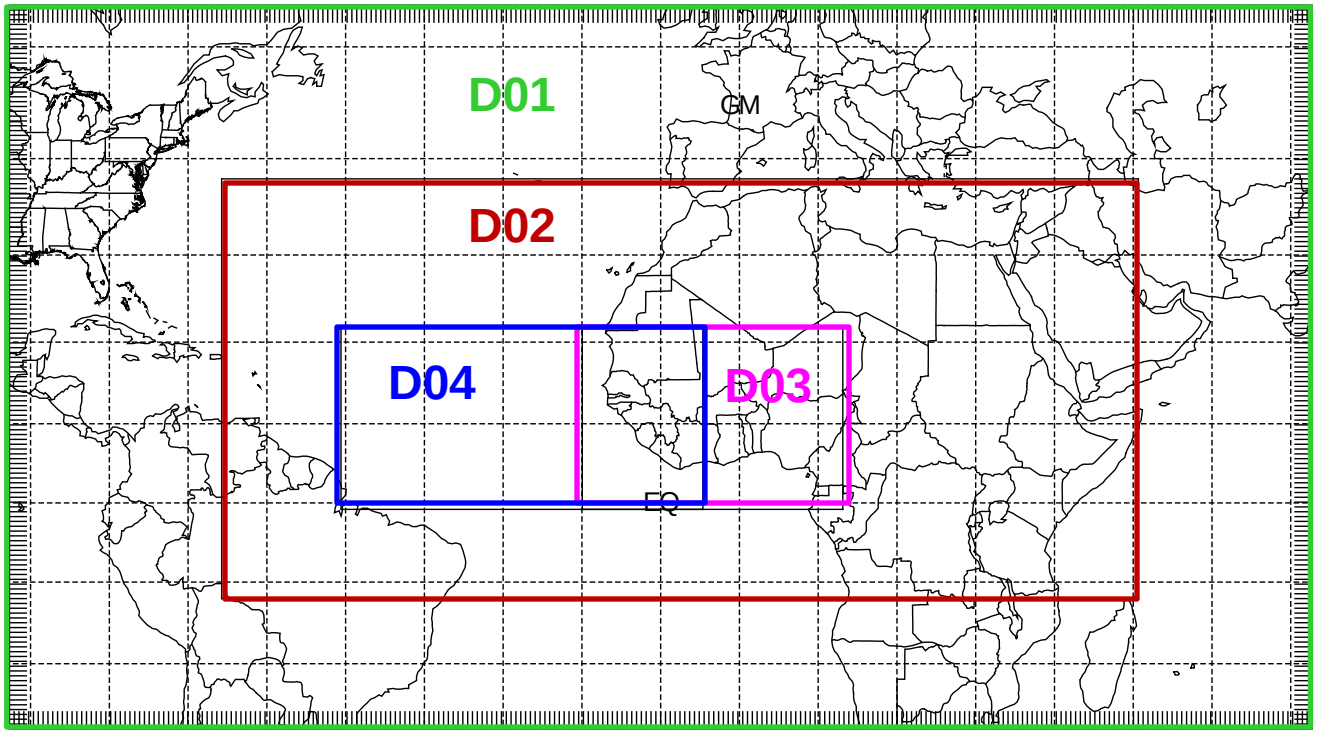
12:10-13:55Z 22 Aug 2006



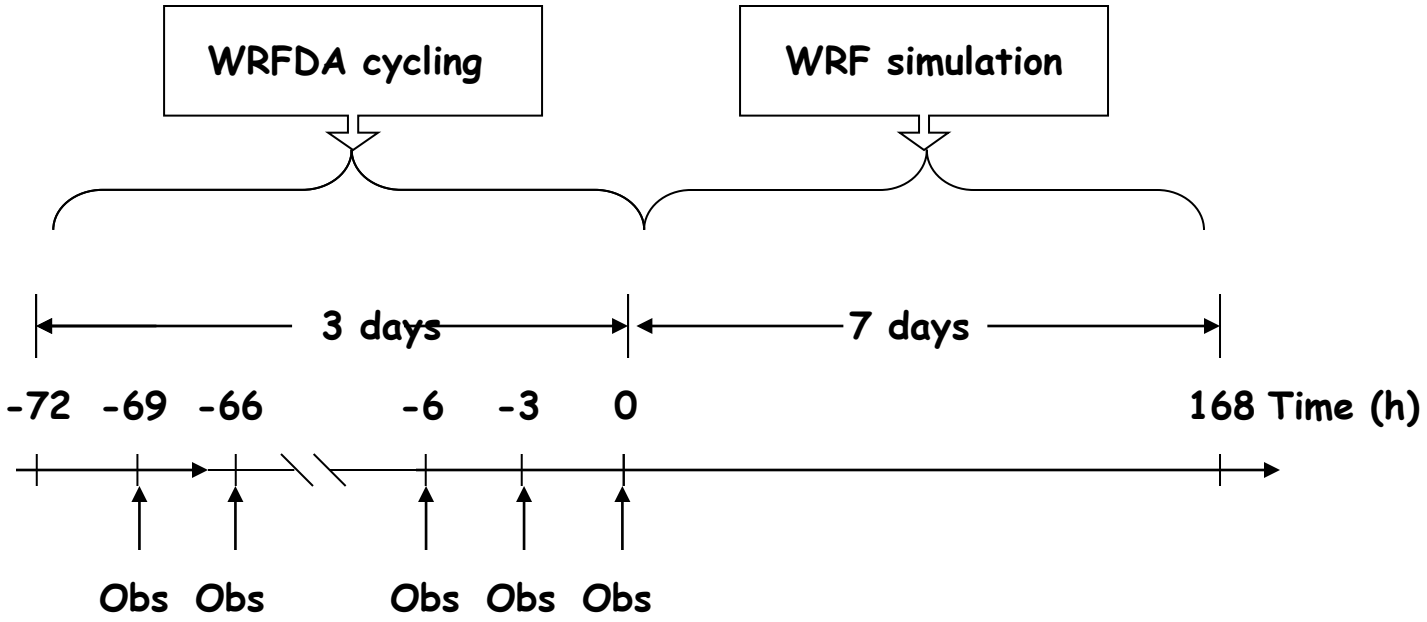
Numerical Configuration

WRF dust model

	Domains 1-4 (D01-04)
Resolution	64, 16, 4, 4 km



Model Integration



Storm	*Data Assimilation (D01, 02, 03)*	*Model simulation (D01, D02, D04)*
Ernesto-Debby (2006)	00Z 15 Aug To 00Z 18 Aug	00Z 18 Aug To 00Z 25 Aug

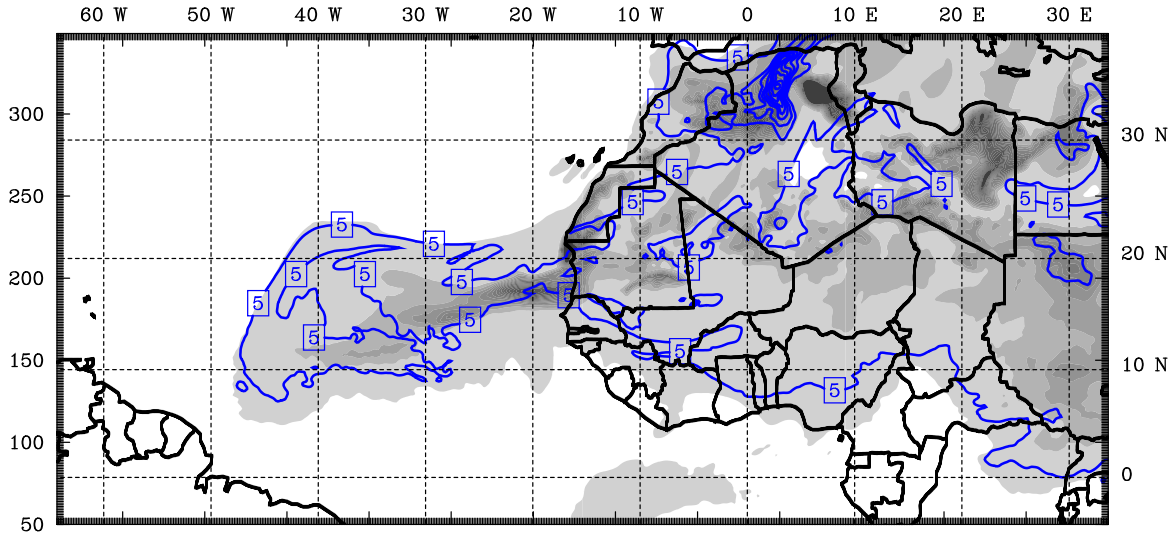
Numerical Experiments

EXP	*Dust-microphysics interaction*	*Dust-radiation interaction*
NMNR		
NMYR		X
YMNR	X	
YMYR	X	X

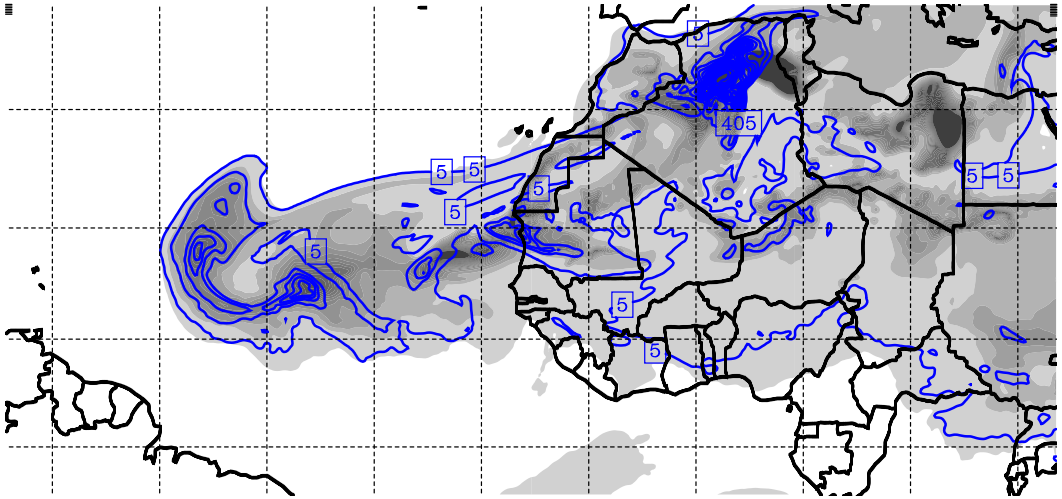
(00Z 21 Aug, 2011)

Column Dust, 700-mb dust at 72-h simulation

NMNR



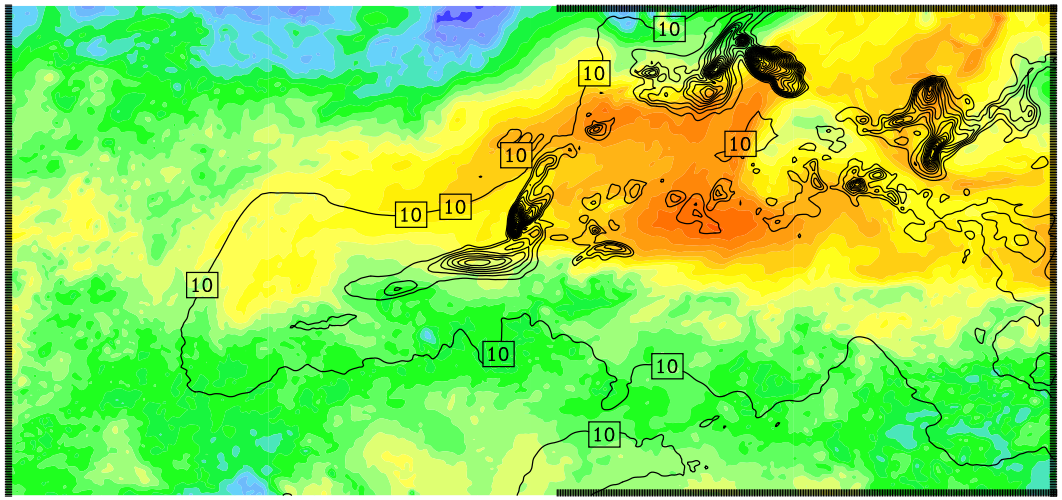
NMYR



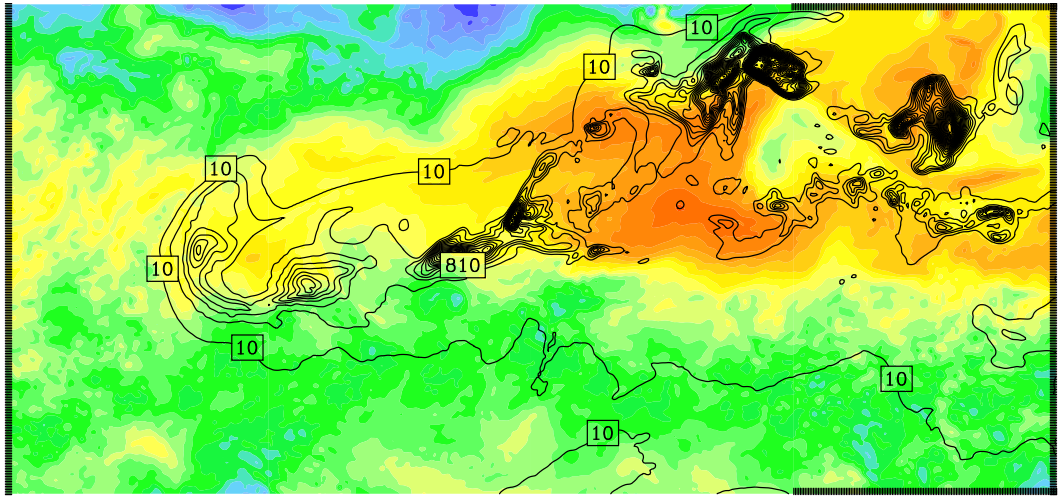
(00Z 21 Aug, 2011)

Column Dust, 700-mb T at 72-h simulation

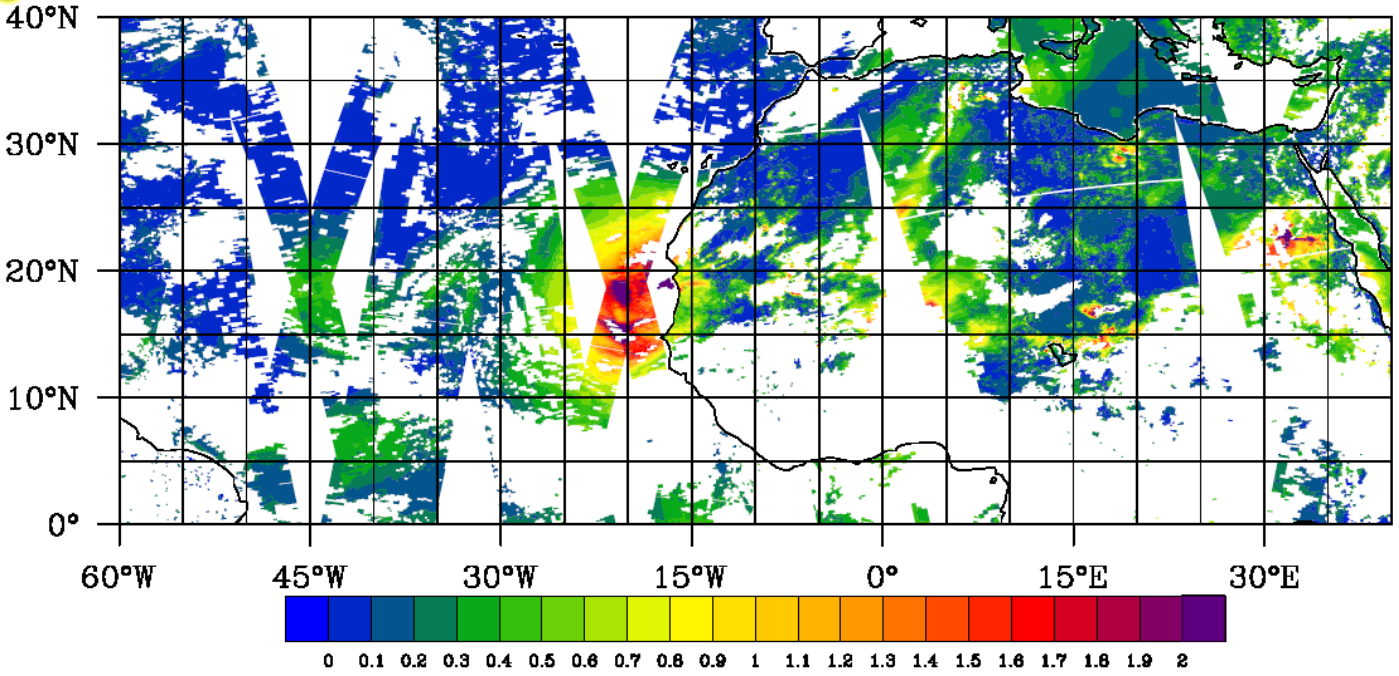
NMNR



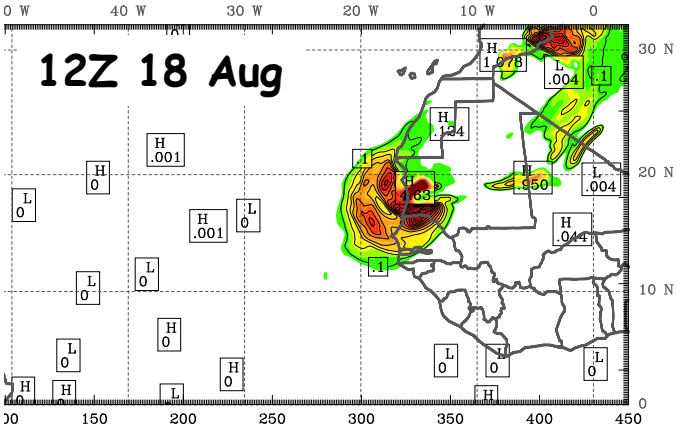
NMYR

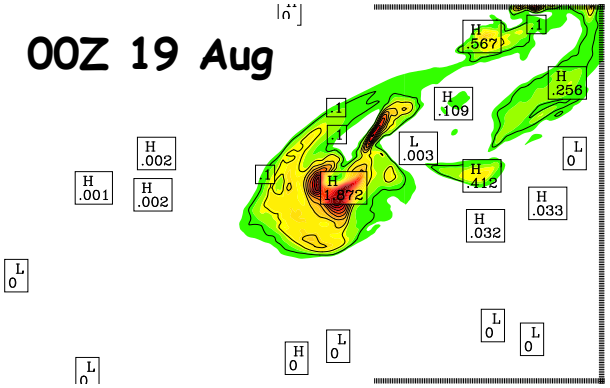


AOD, 12-h simulation

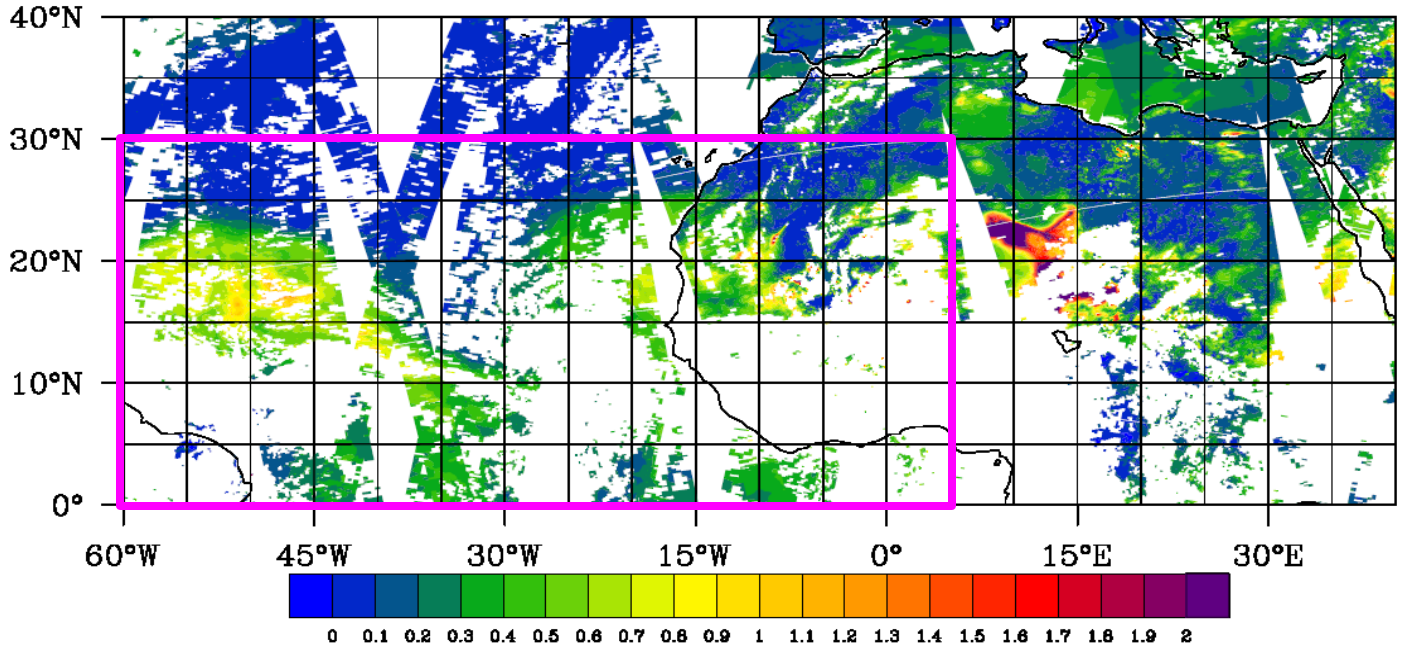


MODIS
12Z 18 Aug

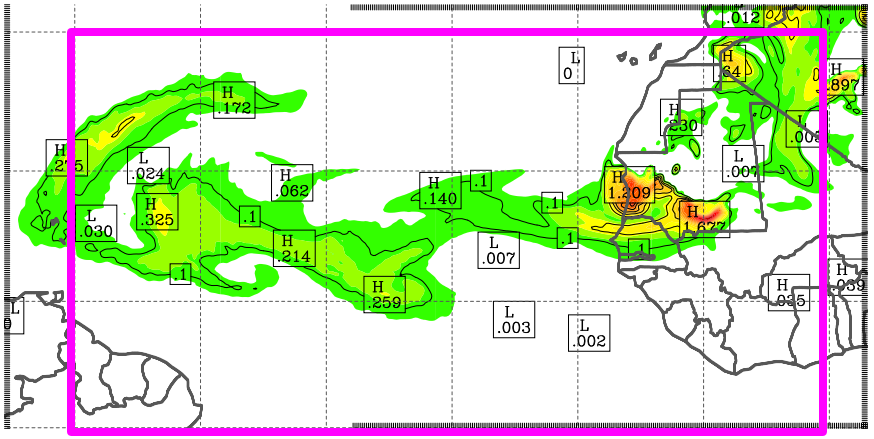




AOD (MODIS), 108-h simulation

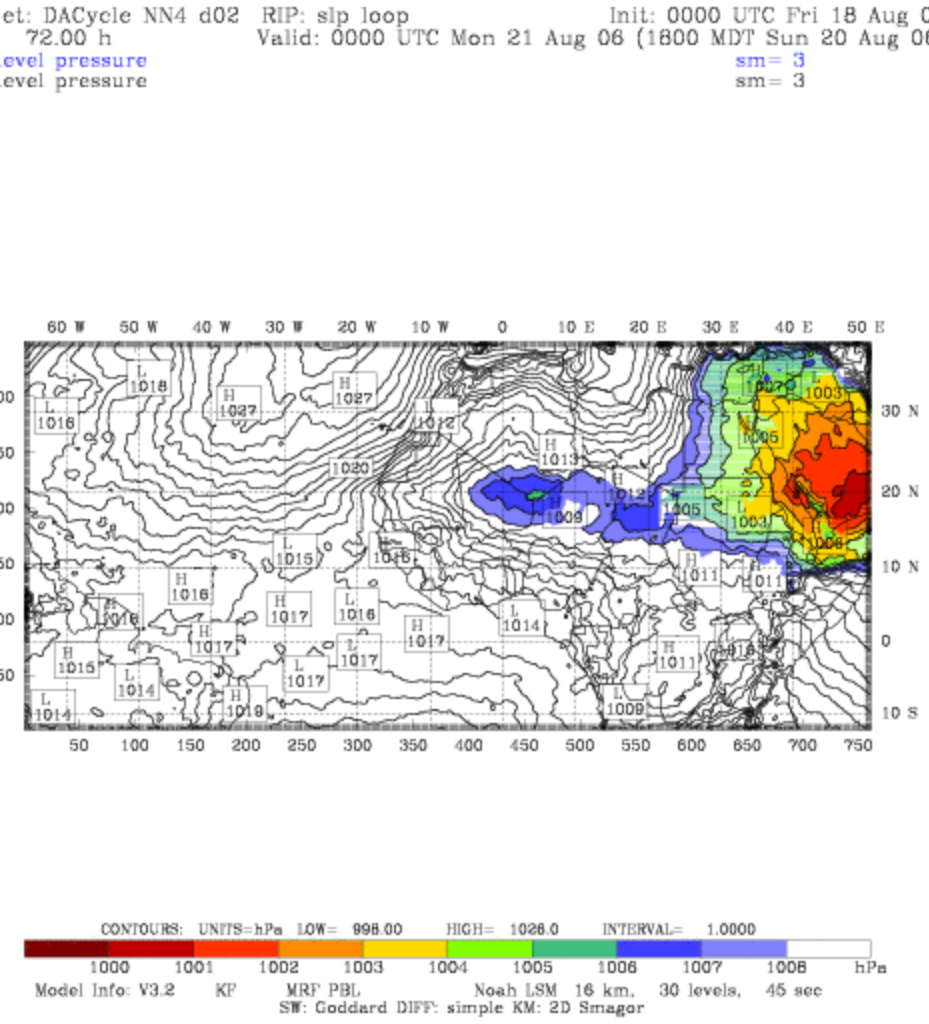


MODIS
12Z 2 Aug

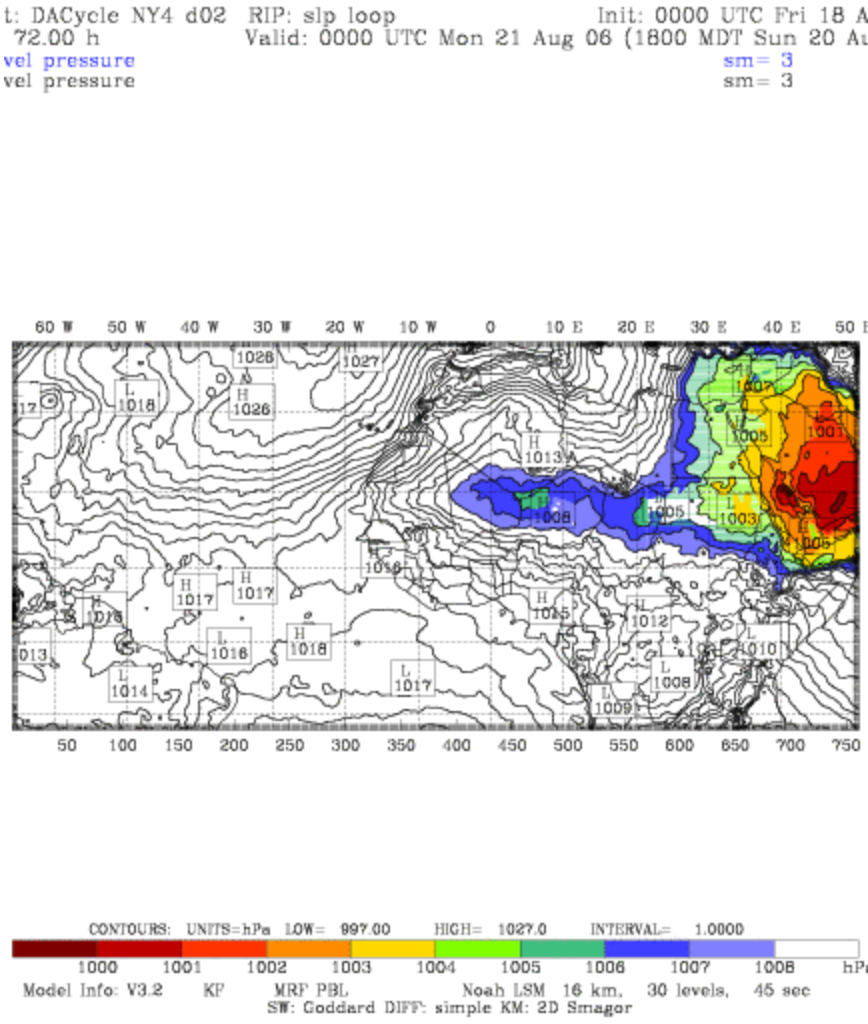


SLP, 132-h simulation (12Z 23 Aug, 2011)

NMNR

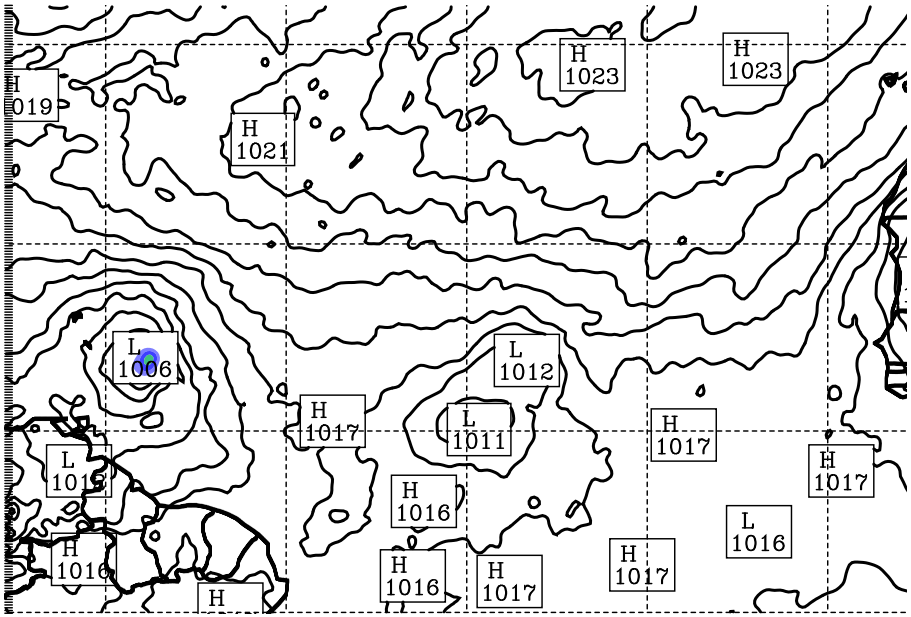


NMYR



SLP, 132-h simulation (12Z 23 Aug, 2011)

NMNR



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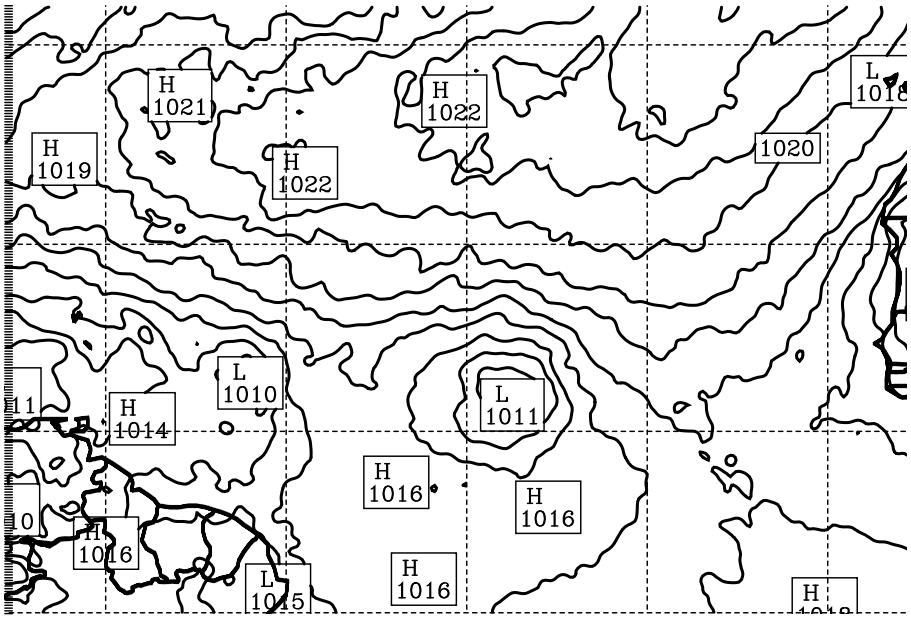
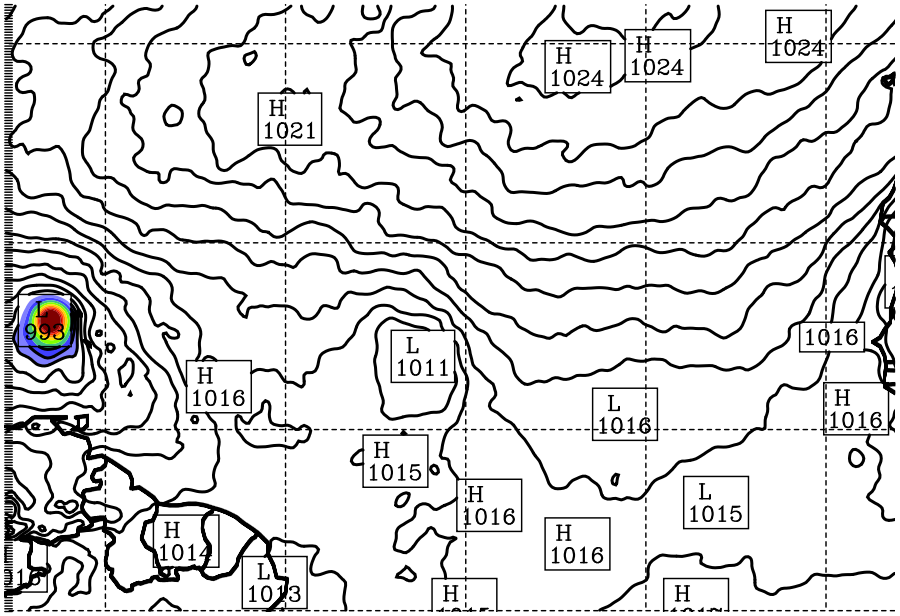


Date/Time (UTC)	Latitude (°N)	Longitude (°W)	Pressure (mb)	Wind Speed (kt)	Stage
24 / 1800	12.7	61.6	1008	30	tropical depression
25 / 0000	13.0	63.0	1007	30	"
25 / 0600	13.3	64.4	1005	30	"
25 / 1200	13.7	65.8	1005	35	tropical storm
25 / 1800	14.0	67.1	1004	35	"

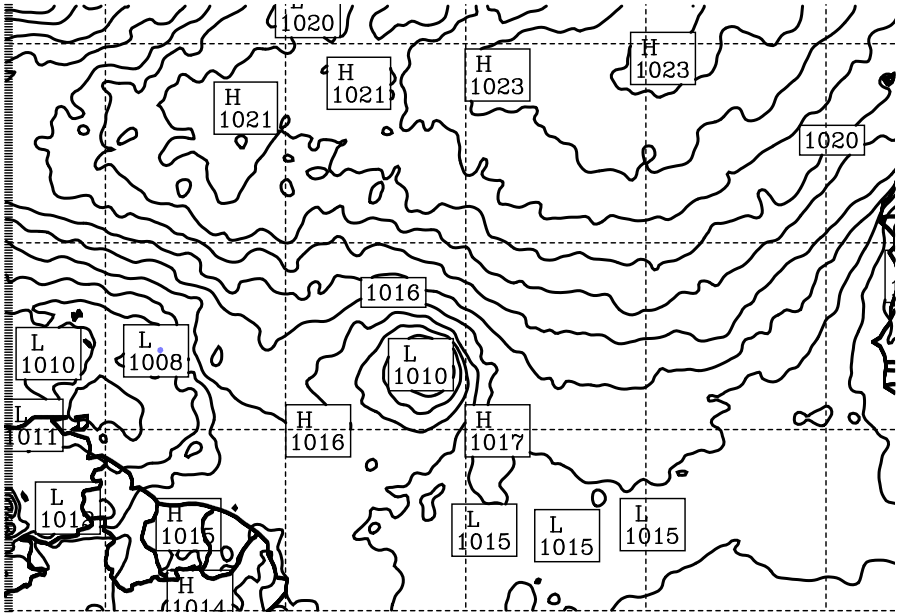
Ernesto

SLP, 156-h simulation (12Z 24 Aug, 2011)

NMNR



NMYR



Date/Time (UTC)	Latitude (°N)	Longitude (°W)	Pressure (mb)	Wind Speed (kt)	Stage
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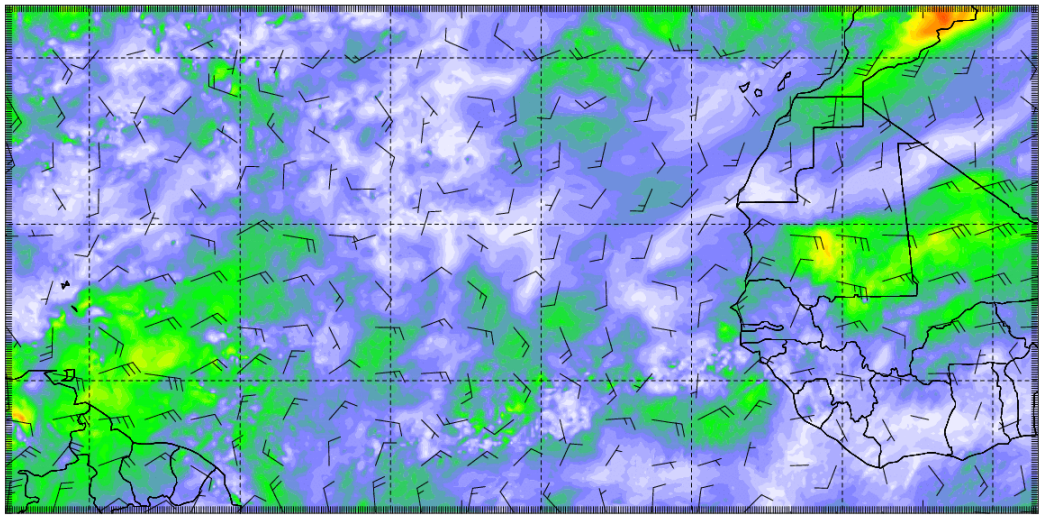
25 / 0600	13.3	64.4	1005	30	"
25 / 1200	13.7	65.8	1005	35	tropical storm
25 / 1800	14.0	67.1	1004	35	"

Ernesto

Vertical Wind Shear, 36-h simulation

NMNR



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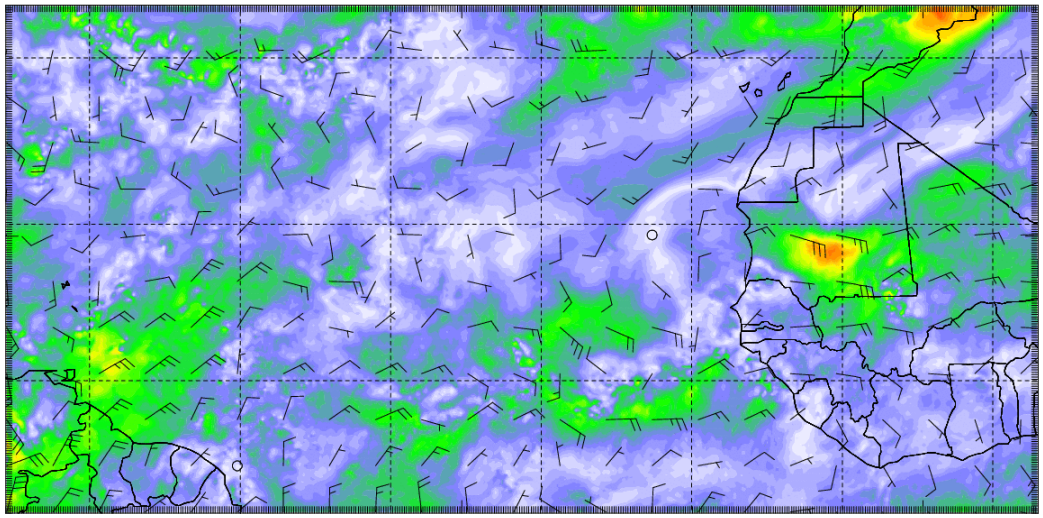
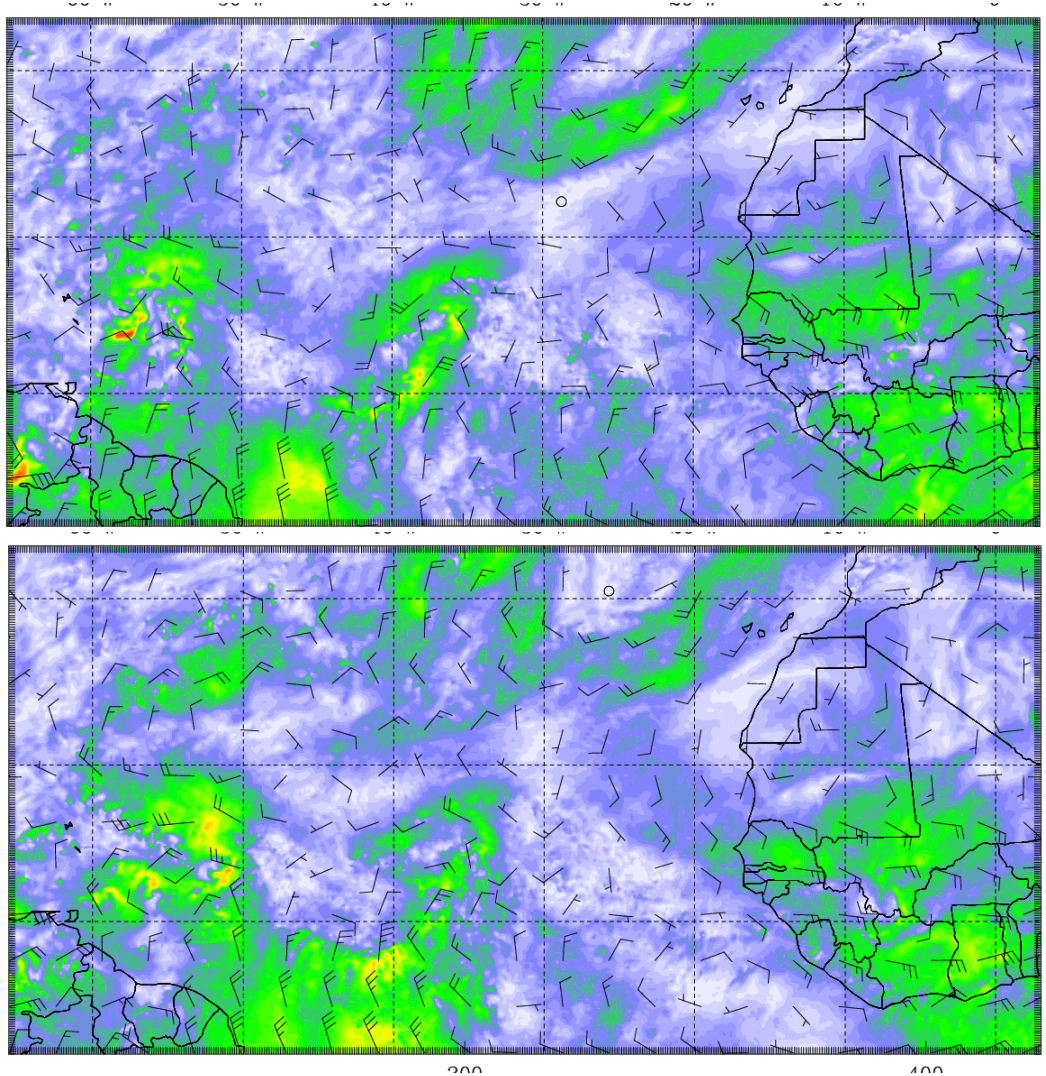


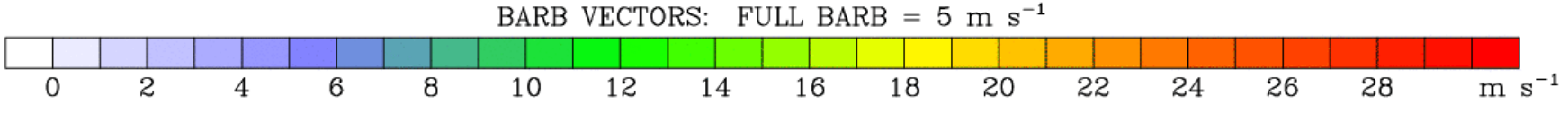
BARB VECTORS: FULL BARB = 5 m s^{-1}

Vertical Wind Shear, 132-h simulation

NMNR

NMYR

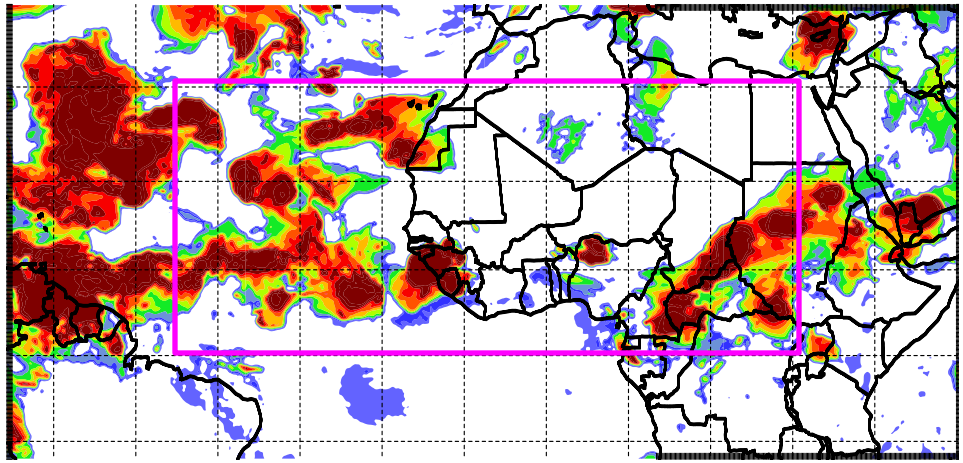




(00Z 18 Aug, 2011)

Cloud Top Temperature, 3DVAR analysis

NMNR



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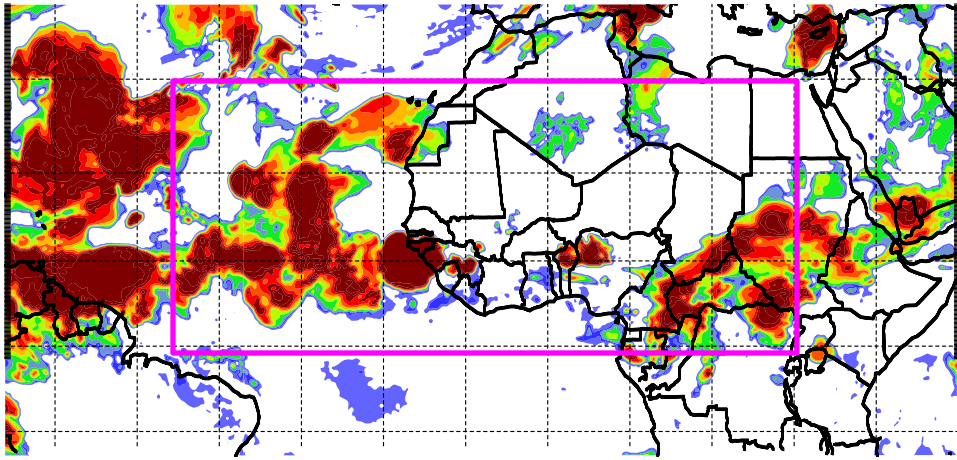
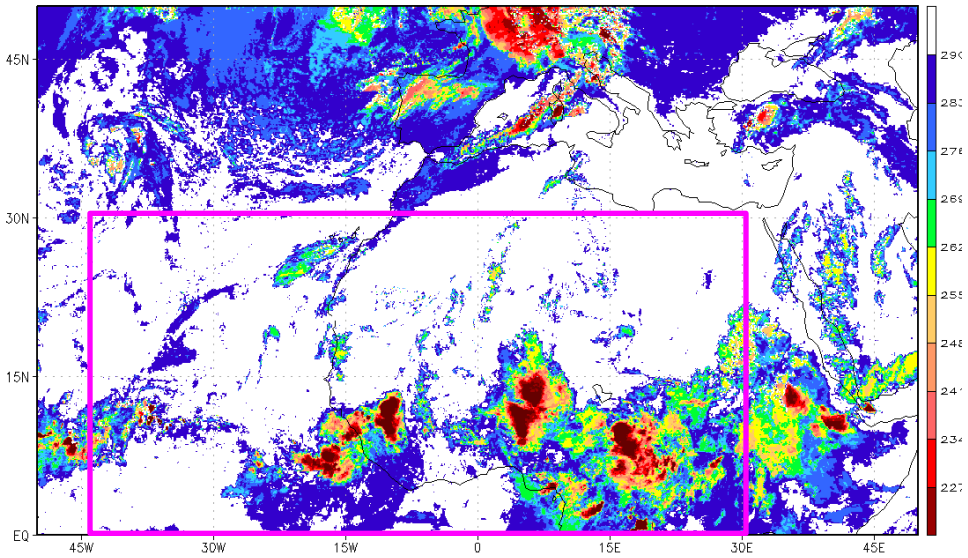




Satellite IR
NASA?

Summary

- Dust-radiation interaction has the potential to influence hurricane genesis and intensification. More studies are required.

- Near term tasks:

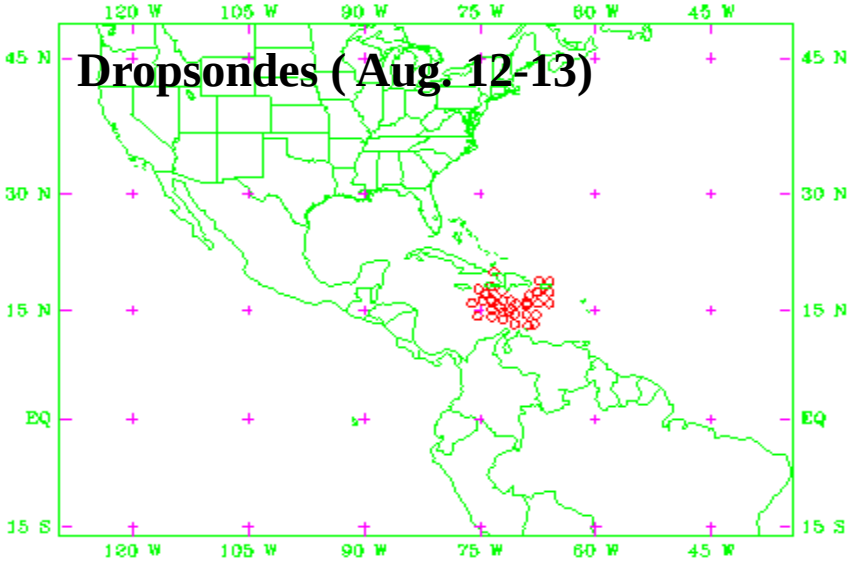
  ⇨ Fix bug(s) in the immersion freezing process

  ⇨Improve model initial conditions
  (better use of data, use of more data)

  ⇨ Dust emission and simulation

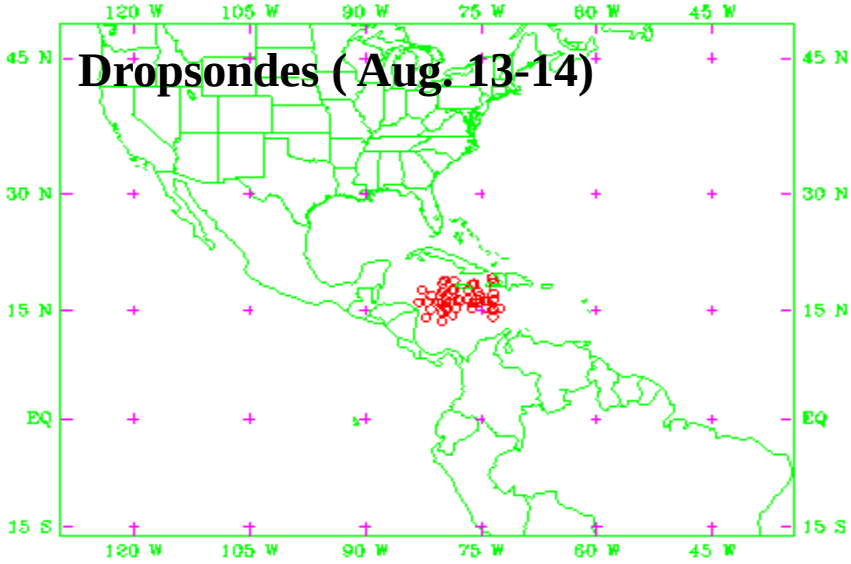
  ⇨ Observations for model verification and improvement

Dropsondes (Aug. 12-13)

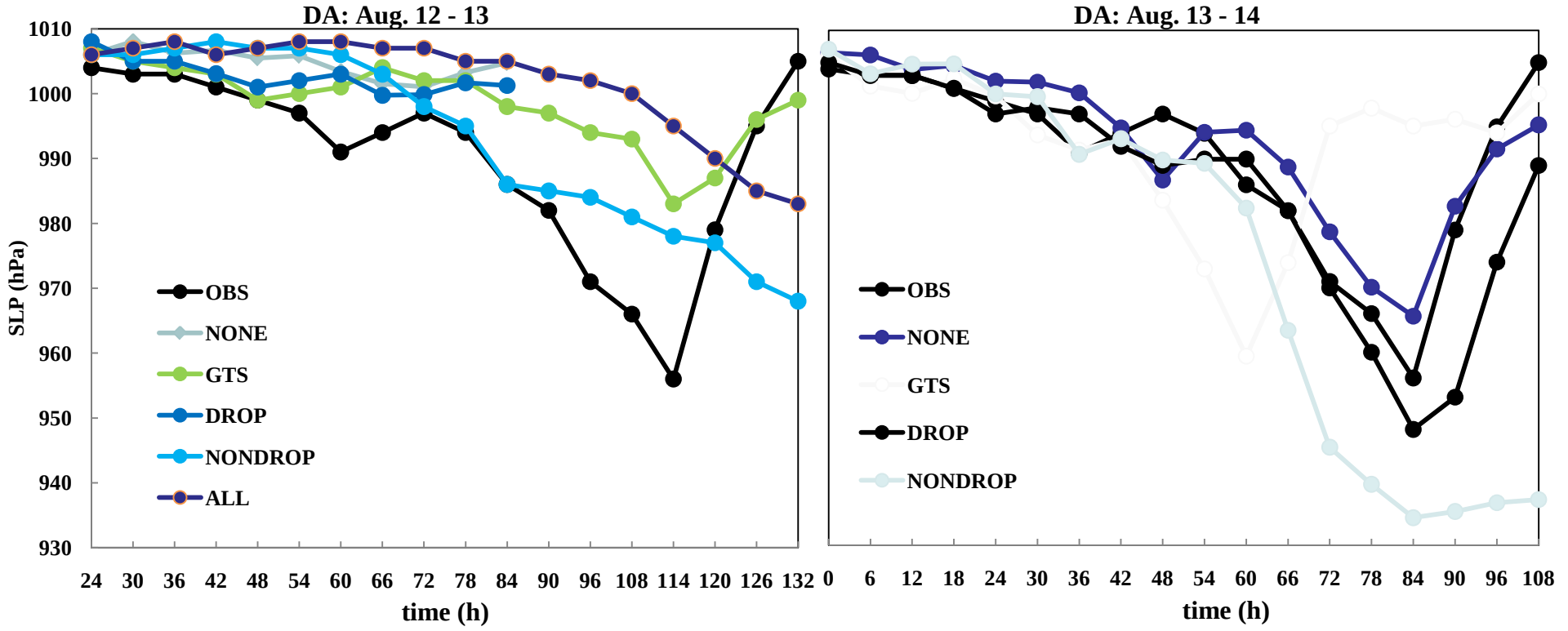


Time	Number
1200 UTC Aug. 12	7
1300 UTC Aug. 12	5
1400 UTC Aug. 12	5
1500 UTC Aug. 12	5
1900 UTC Aug. 12	1
2000 UTC Aug. 12	1
2100 UTC Aug. 12	2
2200 UTC Aug. 12	5
2300 UTC Aug. 12	5
0000 UTC Aug. 13	4

Dropsondes (Aug. 13-14)



Time	Number
0100 UTC Aug. 13	3
1100 UTC Aug. 13	2
1200 UTC Aug. 13	6
1300 UTC Aug. 13	4
1400 UTC Aug. 13	6
1500 UTC Aug. 13	2
2000 UTC Aug. 13	2
2100 UTC Aug. 13	4
2200 UTC Aug. 13	5
2300 UTC Aug. 13	4
0000 UTC Aug. 14	5


DA: Aug. 12 - 13
DA: Aug. 13 - 14
SLP (hPa)
1010
1000
990
980
970
960
950
940
930
OBS
NONE
GTS
DROP
NONDROP
ALL
24 30 36 42 48 54 60 66 72 78 84 90 96 108 114 120 126 132
0 6 12 18 24 30 36 42 48 54 60 66 72 78 84 90 96 108
time (h)
time (h)