The Impact of Saharan Air Layer and Dust on Tropical Cyclone Genesis and Intensification

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&

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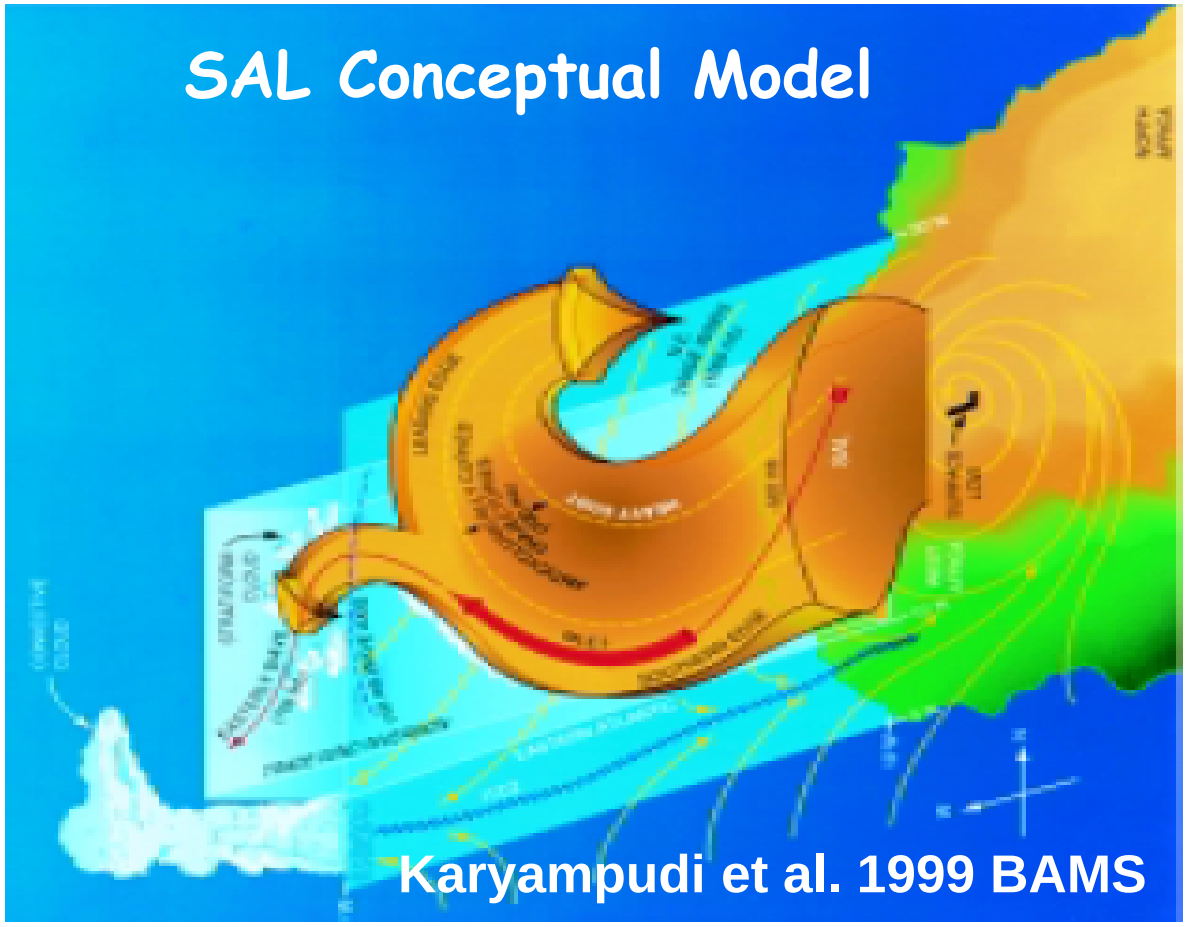
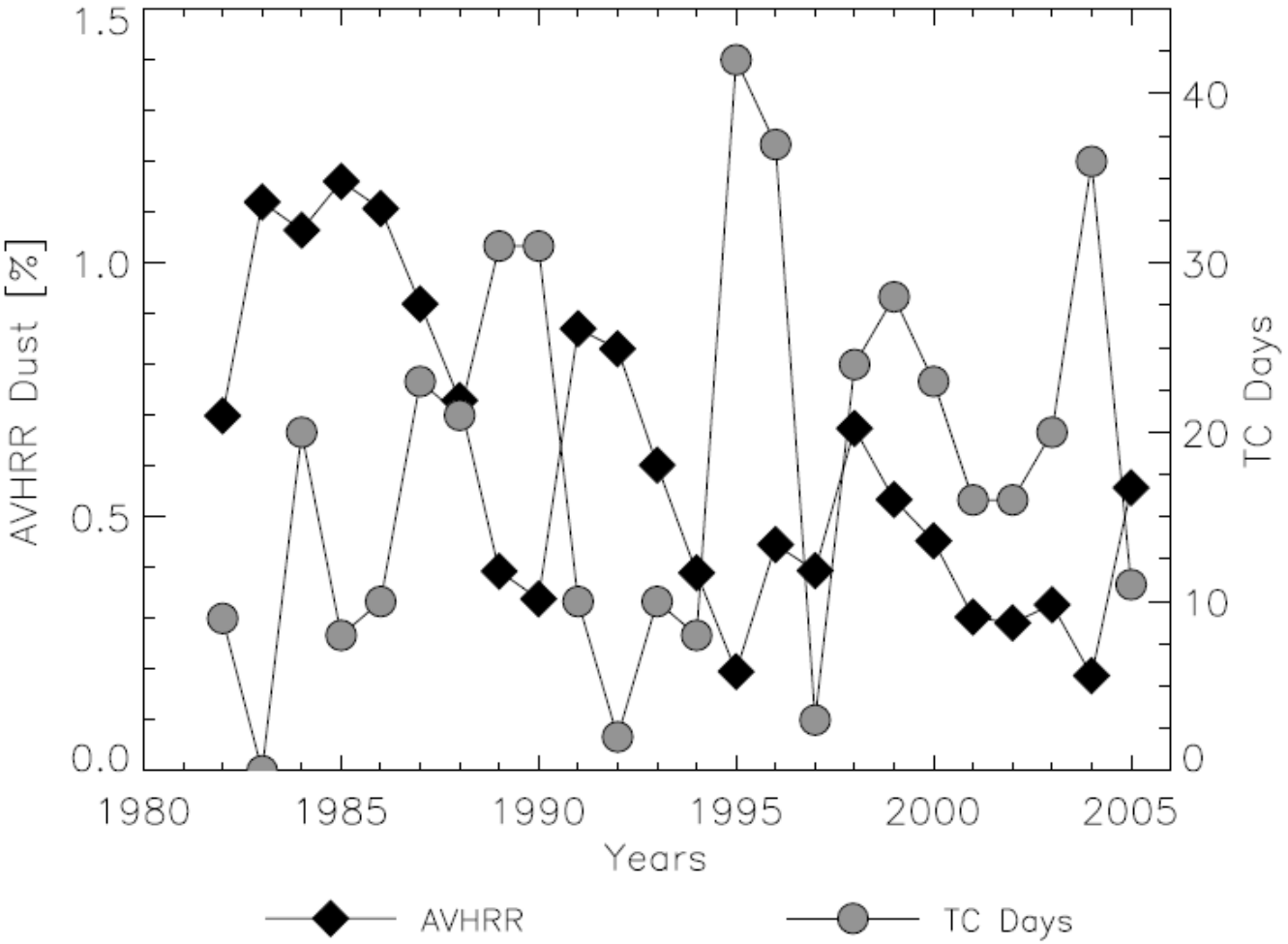
Saharan Air Layer (SAL)

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



Dust & TC Activities

15-60 W 0-30 N, Aug 20 – Sep 30

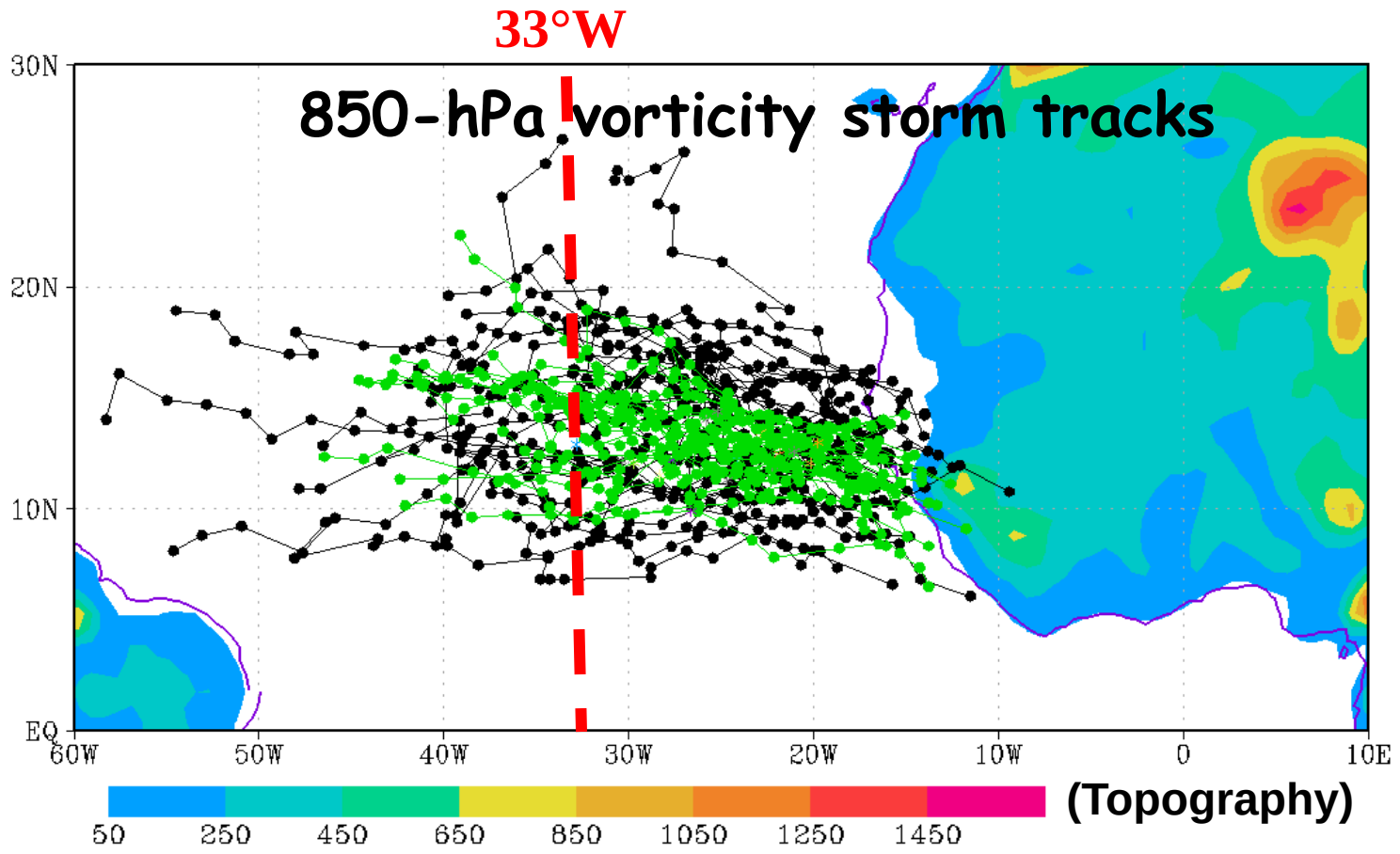


(Evan et al. 2006)

Questions to address

- Is there any relation between SLA and TC genesis? (use ERA Interim data)
- Does dust have any influence on hurricane intensification? (use numerical simulation)

Storm tracks (ERA 850-mb vorticity)



Early developing disturbance (EDD) (green; 25 cases)

Non-early developing disturbances (NON) black; 33 cases)

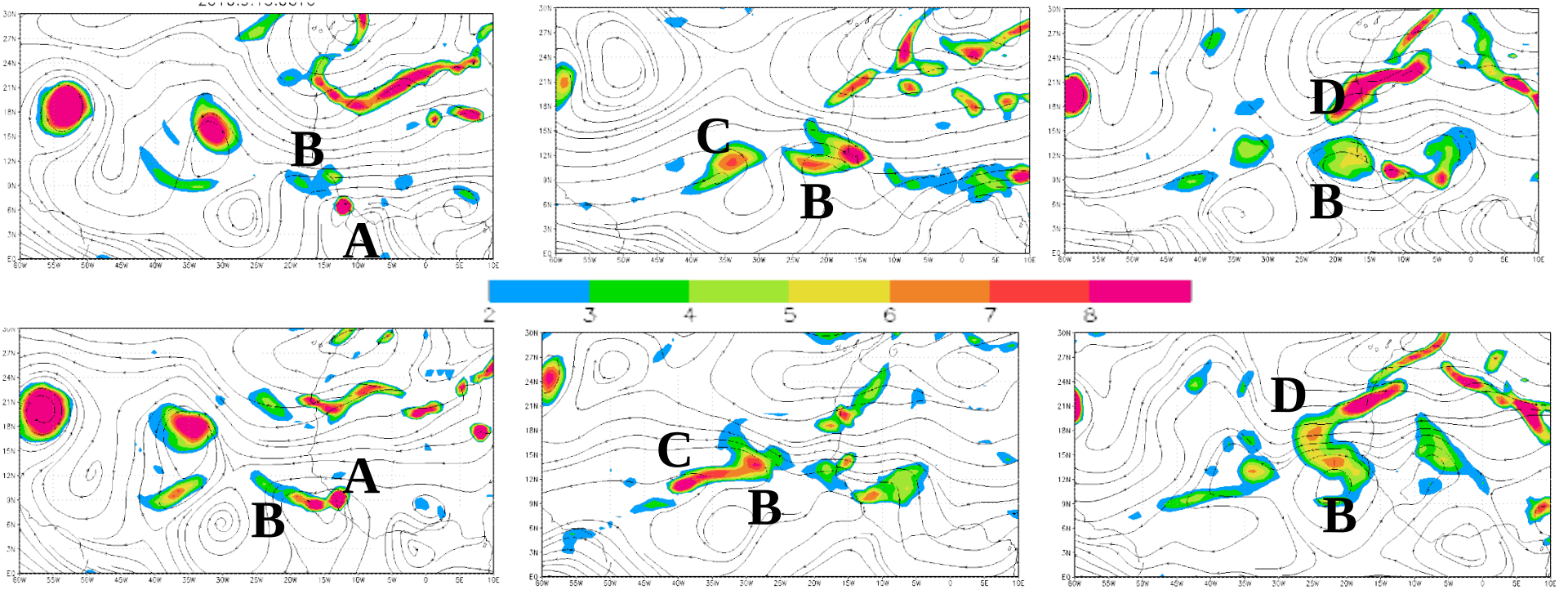
8/33 are late developing disturbances (LDD)

Vortex Merger Processes

Type 1 (southern local vortex)

Type 2 (remnant vortex)

Type 3 (northern elongated vortex)



24/25 EDDs & 11/33 NONs involved vortex merger

20/24 EDDs (83%) involved type 3.

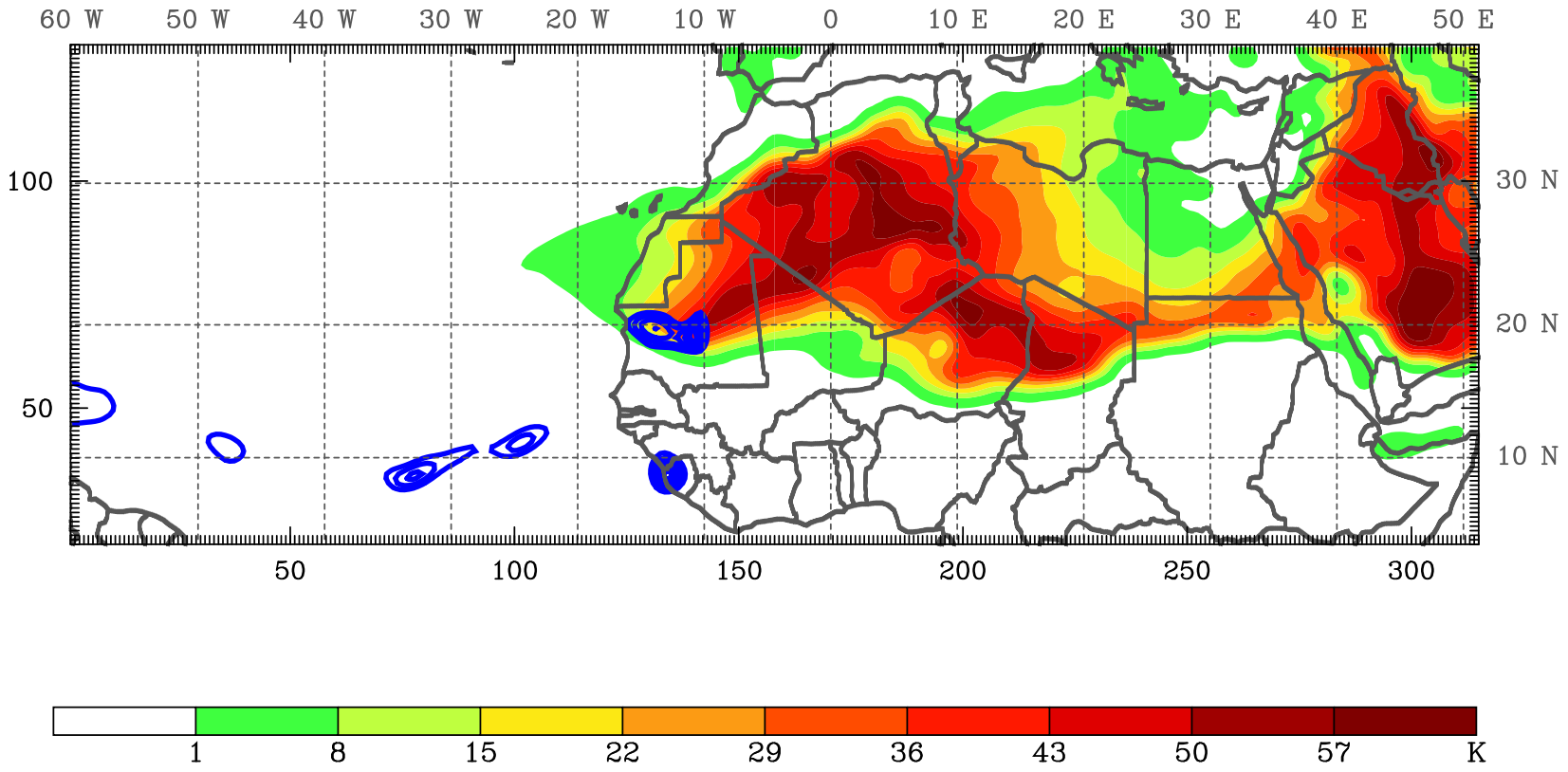
8/33 are LDDs & 5/8 involved vortex merger

ECMWF Re-Analysis (ERA) Interim dataset

Shading: 900-mb SAL

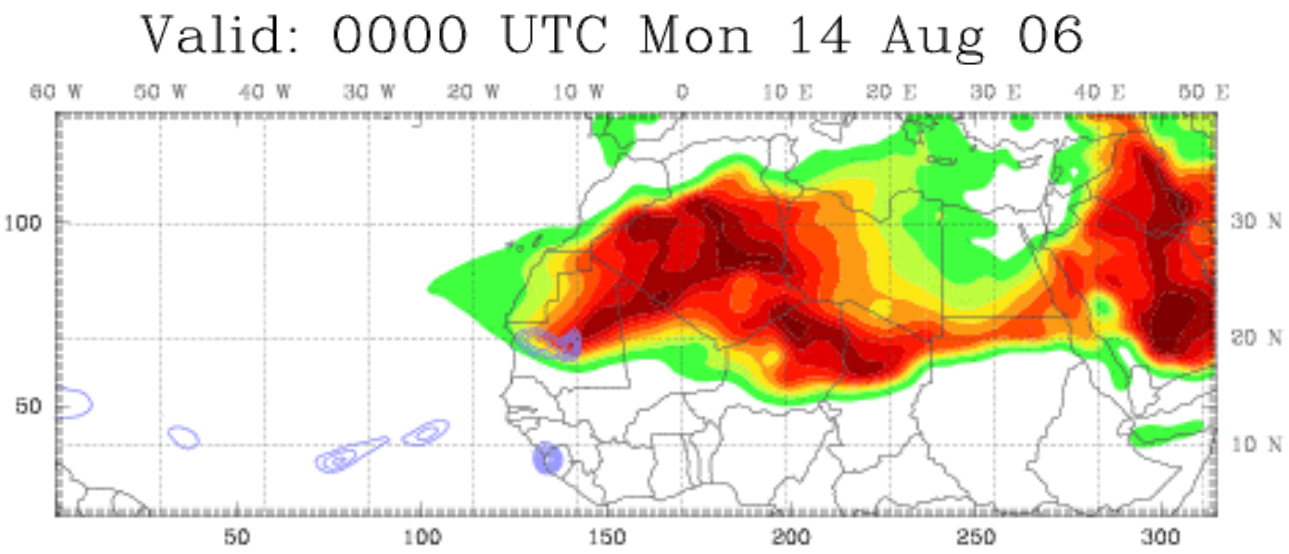
Contour lines: 900-mb vorticity

$$\mathrm{SAL} = (\theta - \overline{\theta}) \times \mathrm{RH}_{\mathrm{depression}} / 10$$



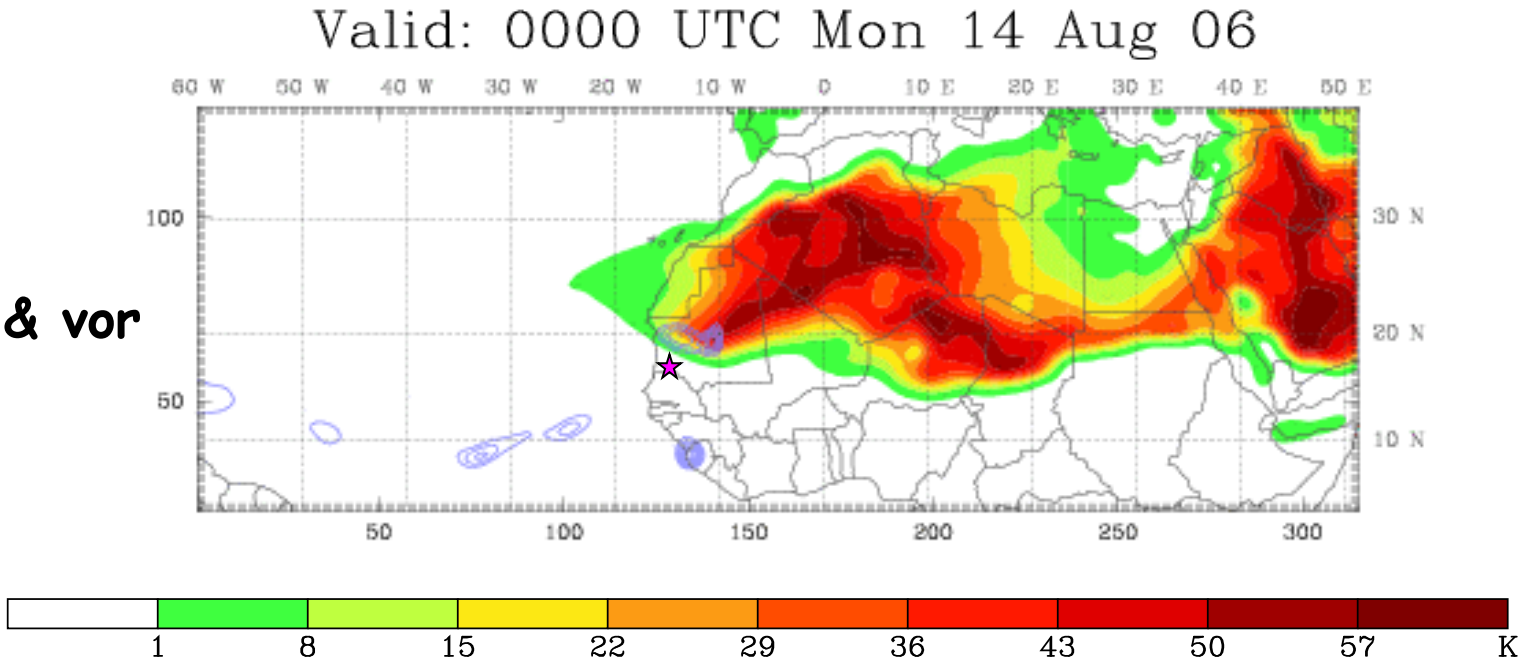
900-mb SAL & Vorticity

SAL & vor

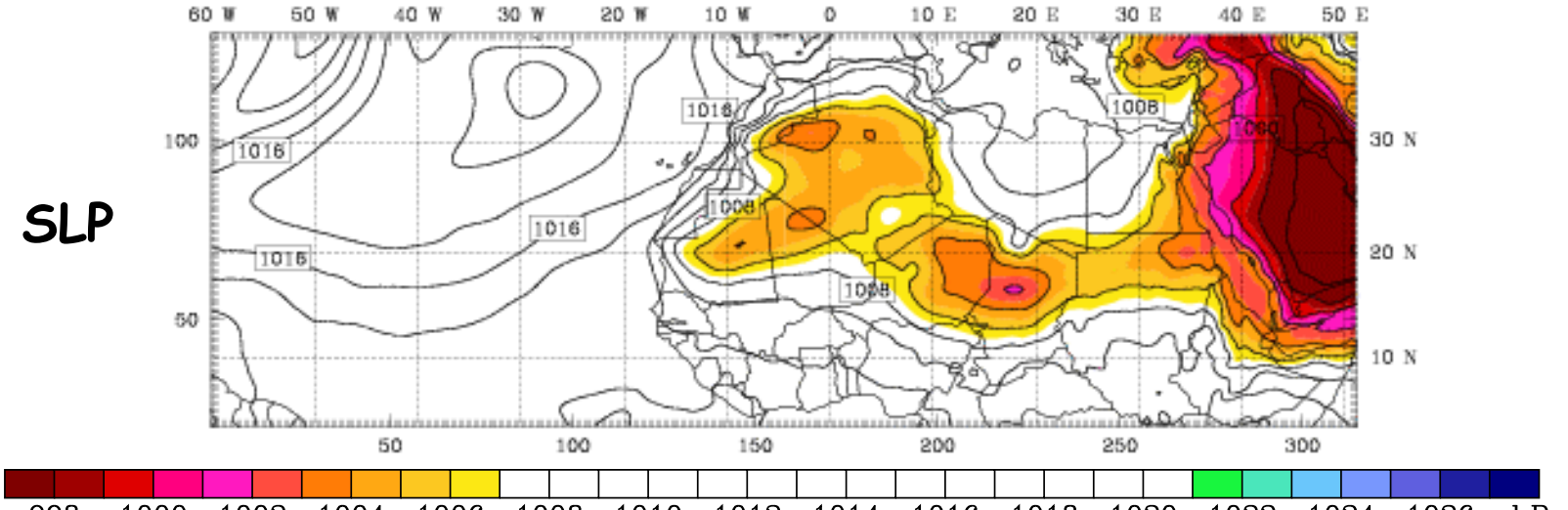


900-mb SAL & Vorticity, and SLP

SAL & vor



SLP

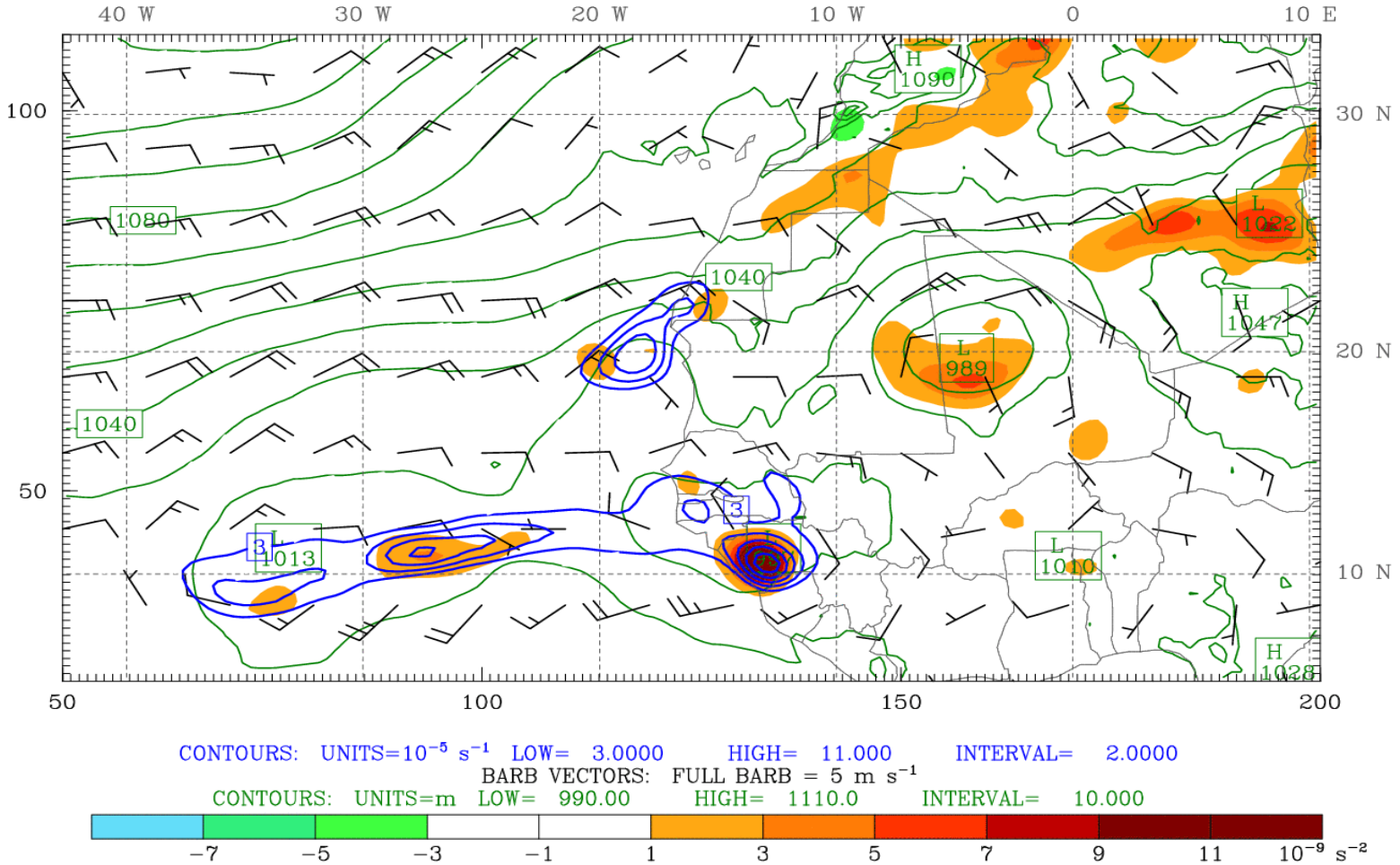


Vorticity Budget

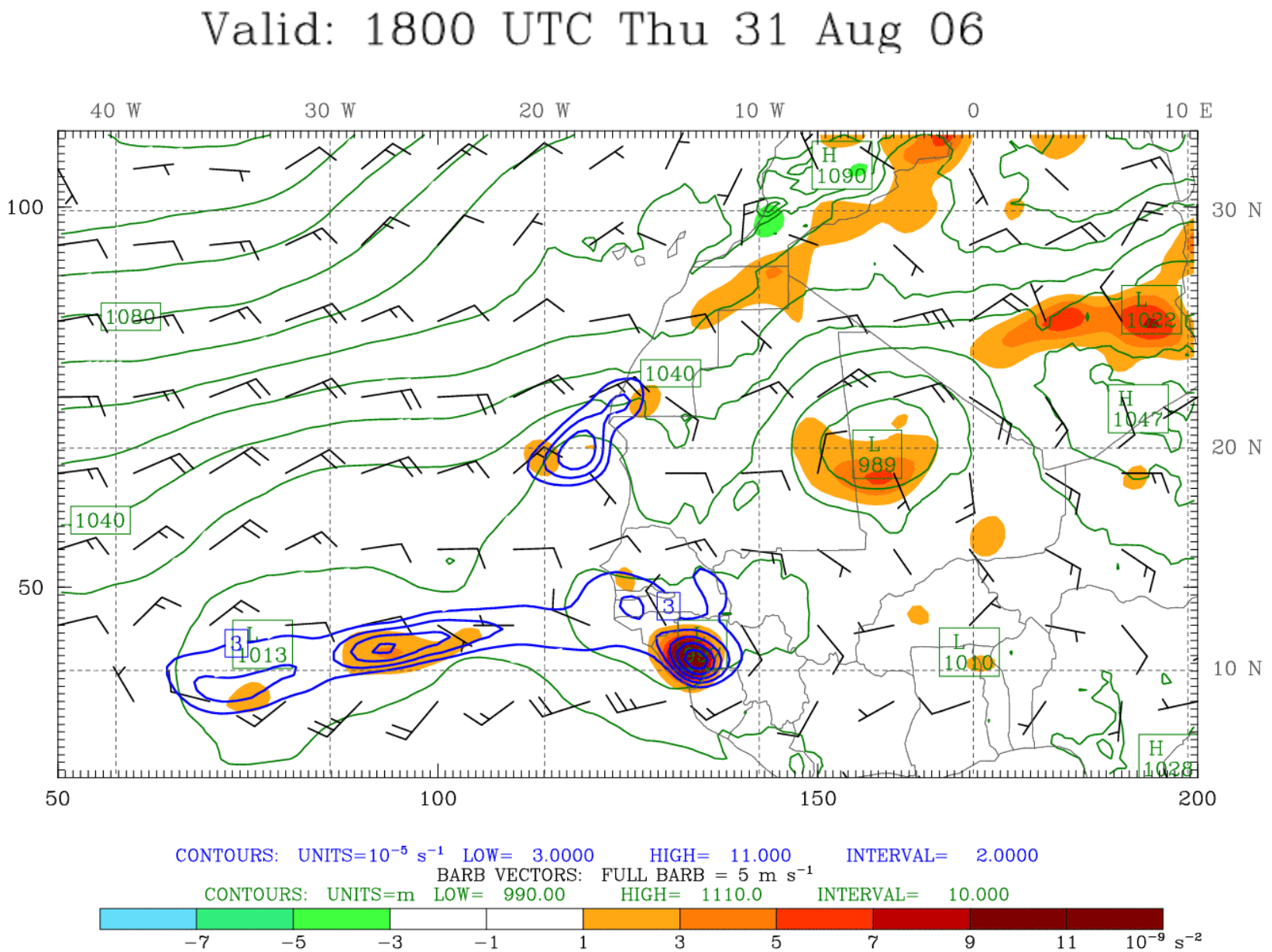
Shading: divergence forcing

Blue contours: 900-mb vorticity

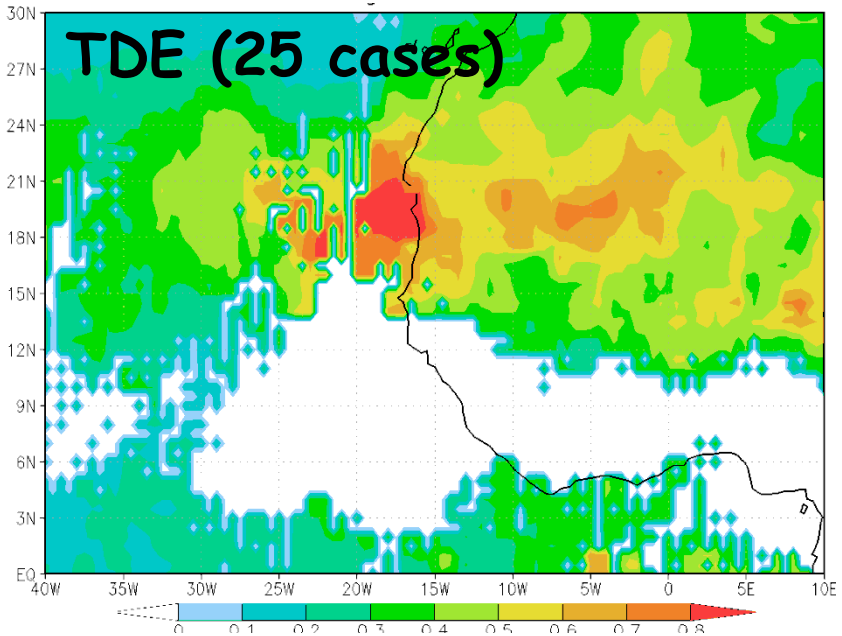
Green contours: 900-mb geopotential

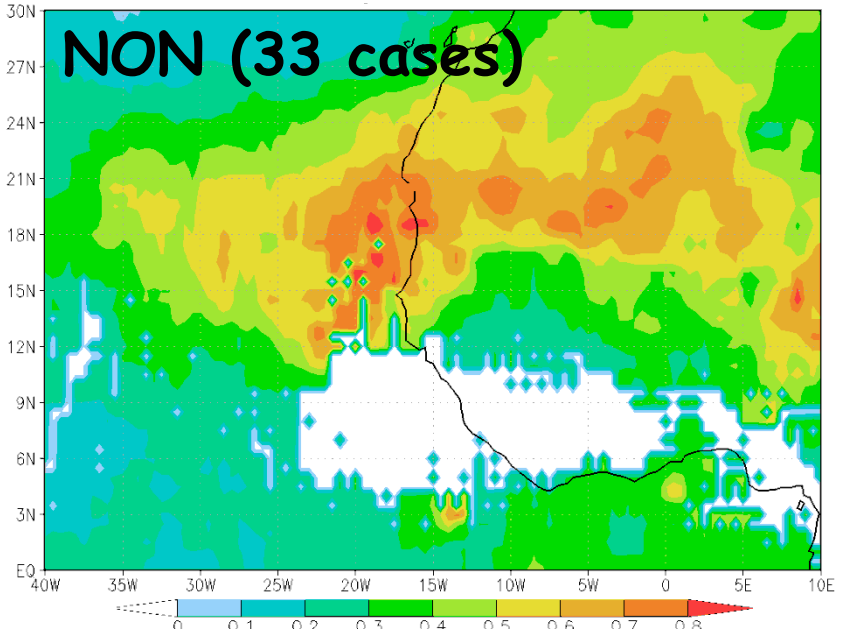


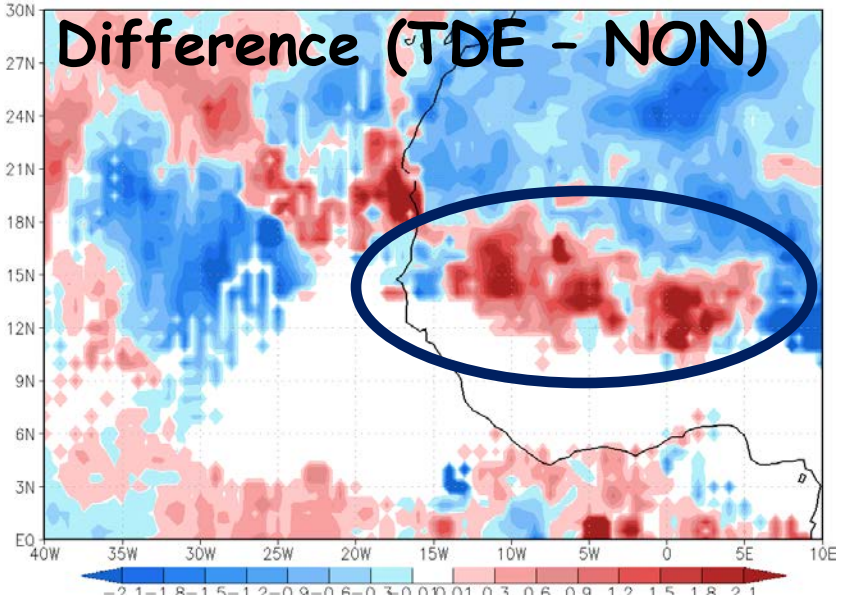
Vorticity Budget



Composite Daily Aerosol Optical Depth (AOD)







- **Does dust matter to hurricane intensity?**

Potential Impact of Saharan Dust on TC Activities

Influences on the energy budget

Direct effect: dust absorbing and scattering radiation
=> directly modifies energy in the atmosphere and surface

Indirect effect: dust acting as cloud condensation nuclei and ice nuclei
=> changes cloud properties
=> indirectly modifies energy budget

Development of WRF Tracer Model (V3.2)

WRF + Dust continuity equation

+ Dust-cloud-radiation effects

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

$C = \mu c$ (coupled variable)

$\mu = p_{hs} - p_{ht}$

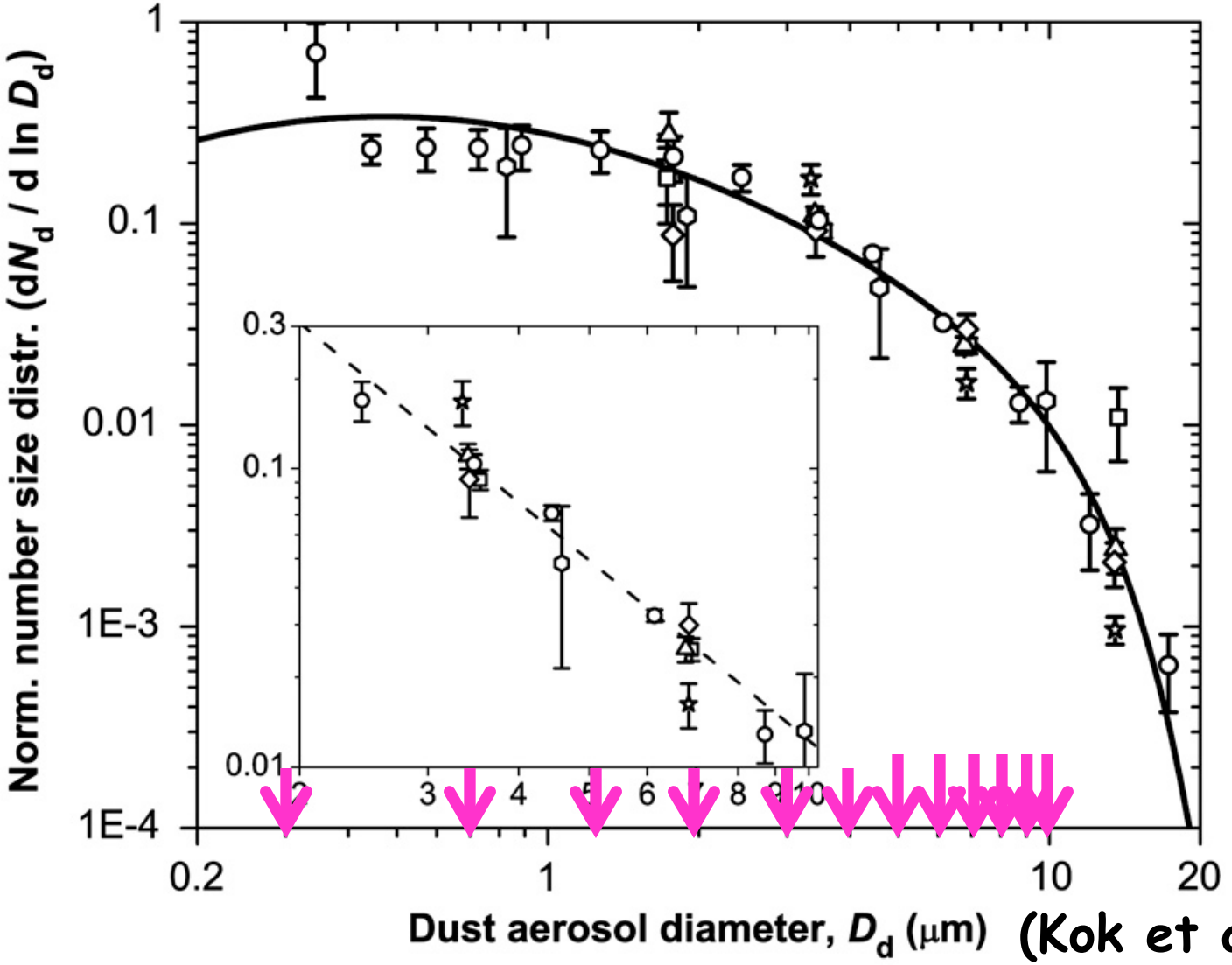
c : Dust mixing ratio

S_c : Sedimentation (time splitting)

E_c : Source / Sink - emission, wet scavanging

Dust Particle Distribution

12 dust bins

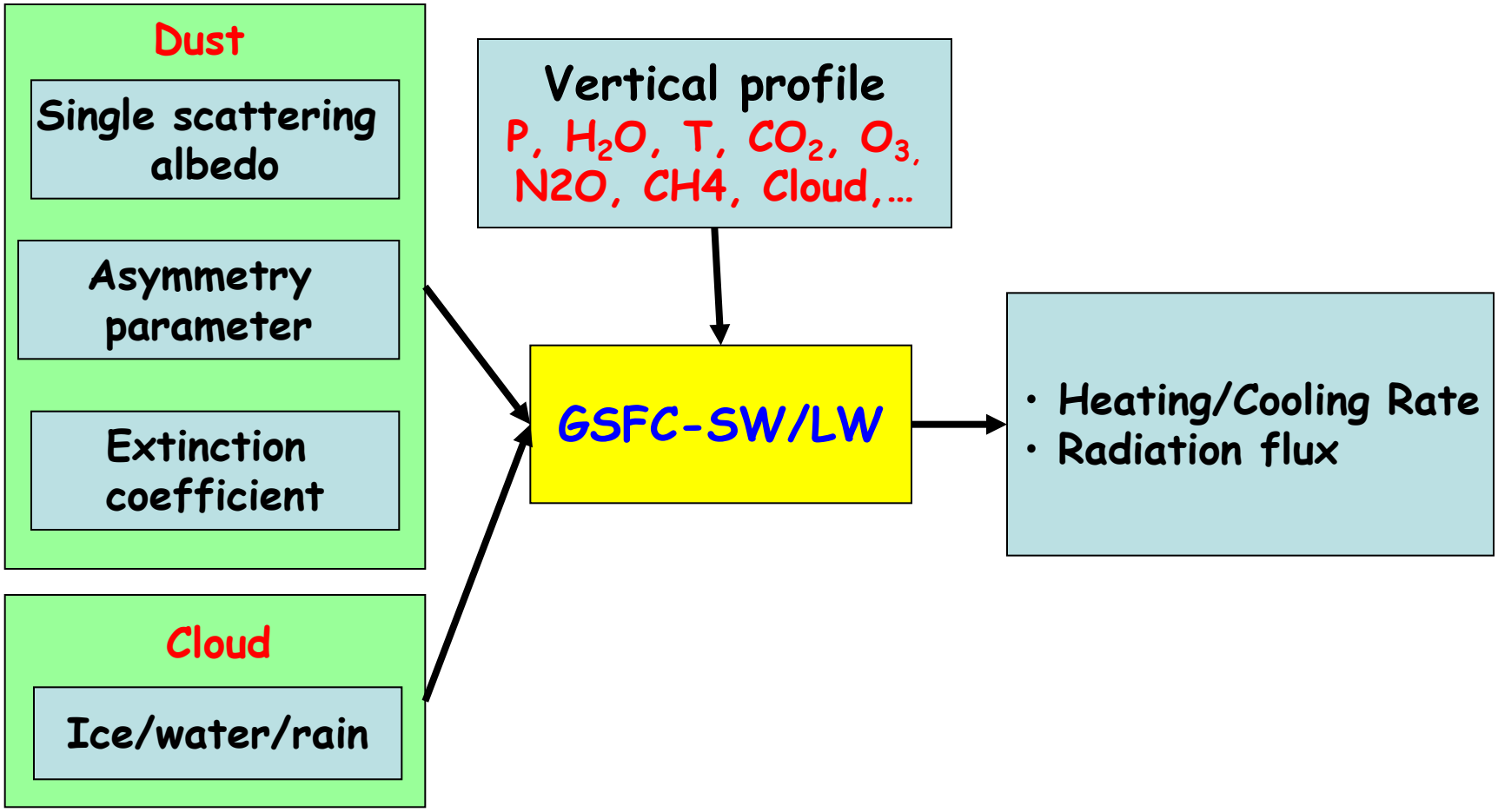


(Kok et al. 2011)

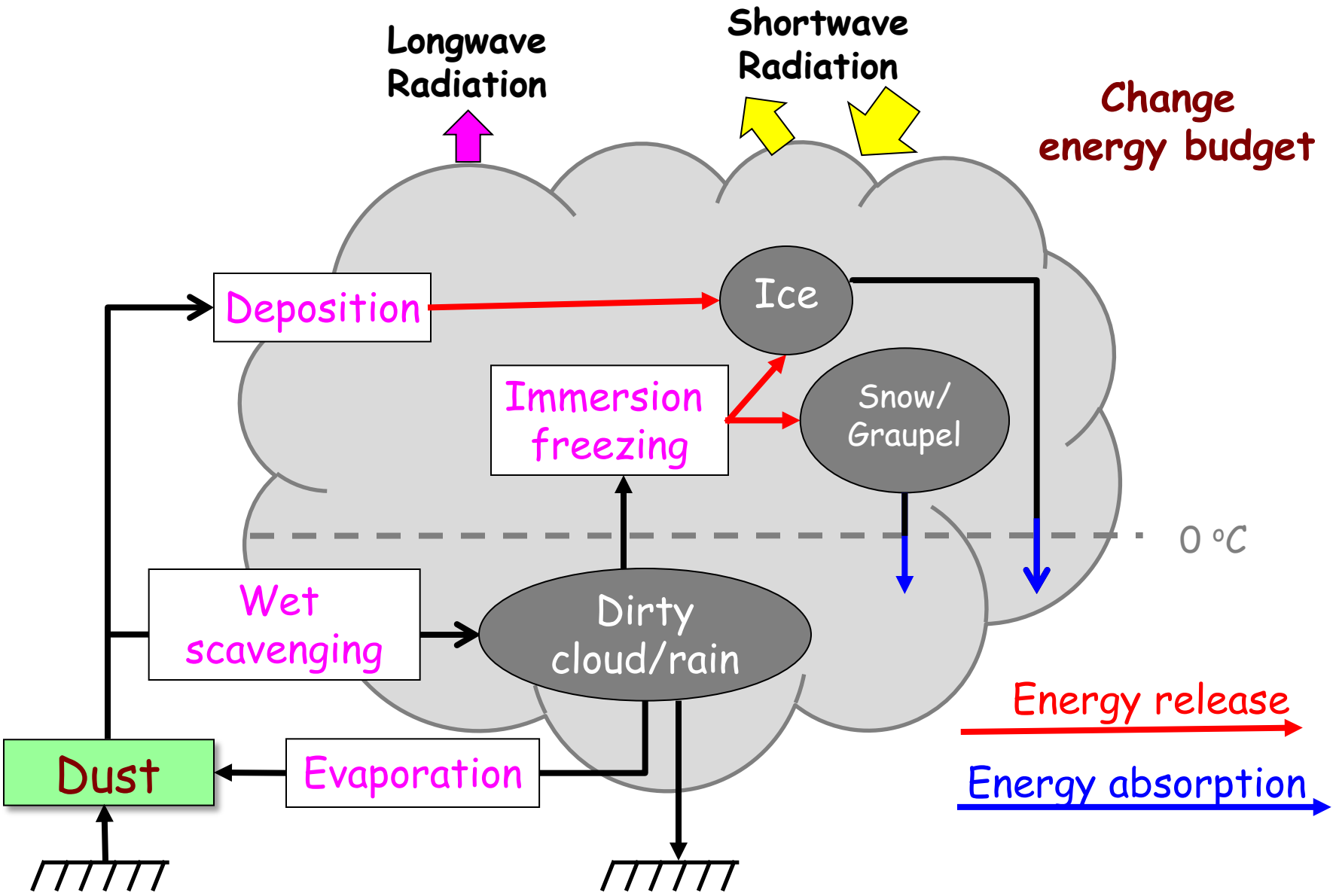
GSFC Radiation

Short wave spectrum bands: 0.175 – 10 μm divided into 11 bands

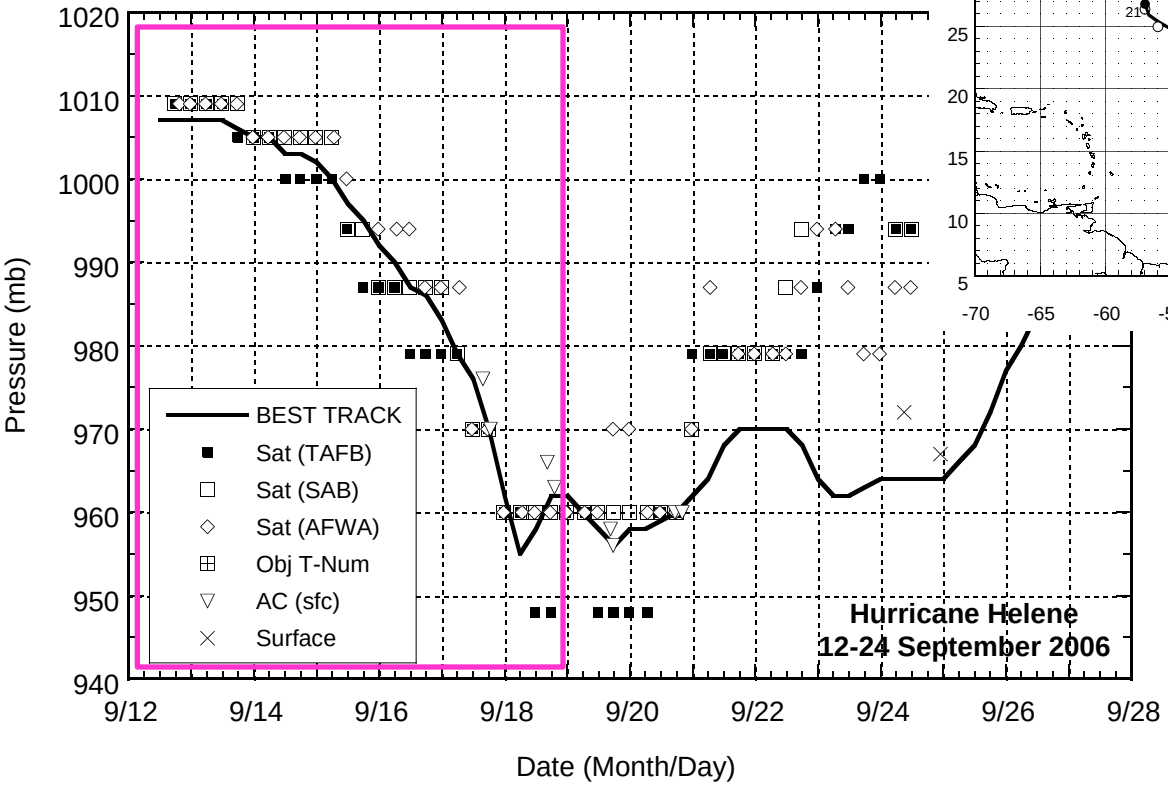
Long wave spectrum bands: 3.33 μm and above, divided into 9 bands

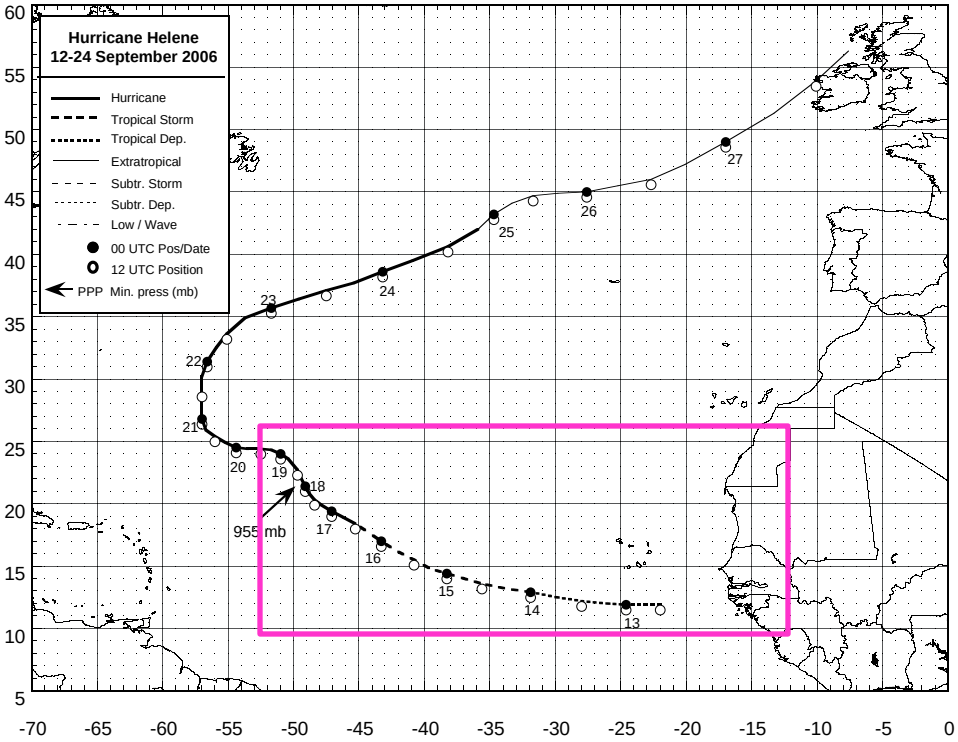


Dust-Microphysics Processes (2-moment scheme)



Hurricane Helene (12-24, Sep 2006)





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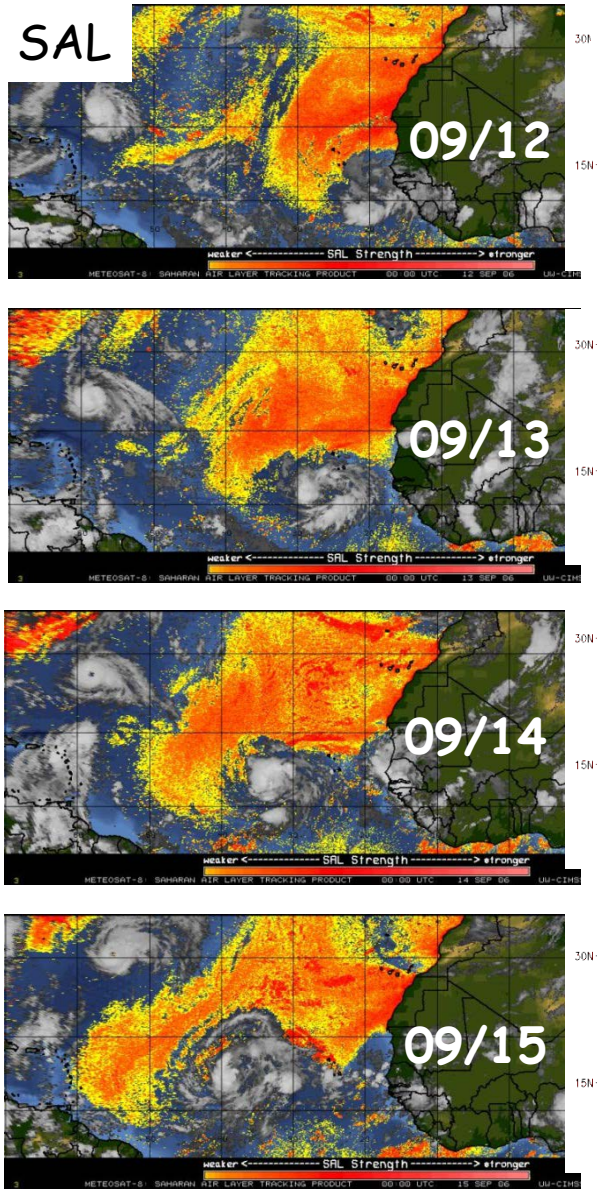
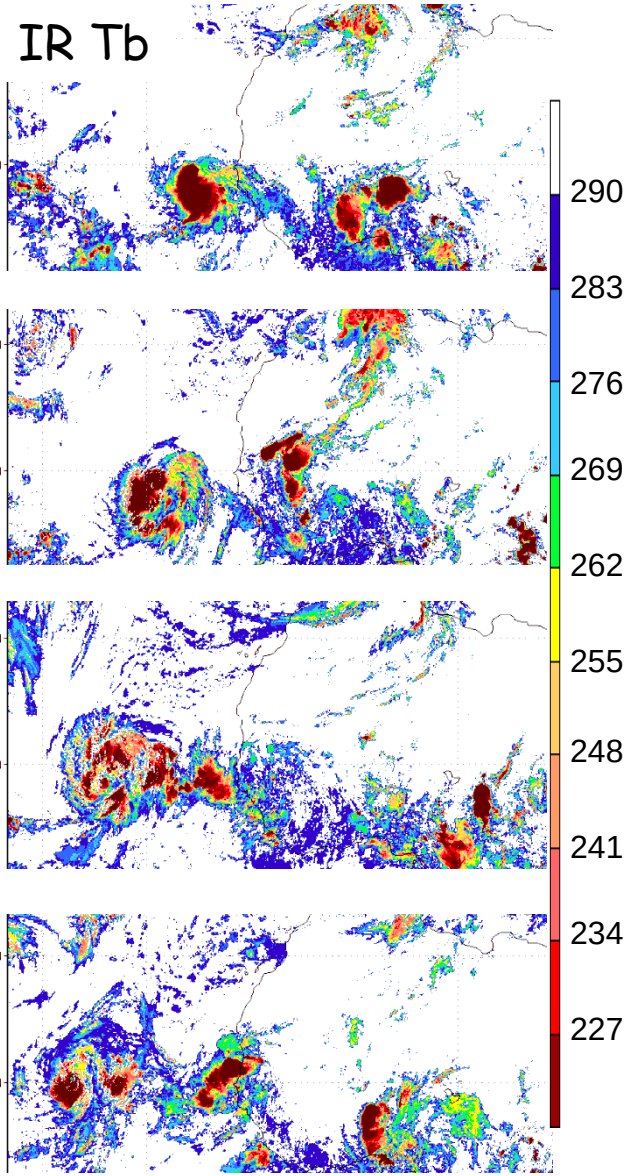
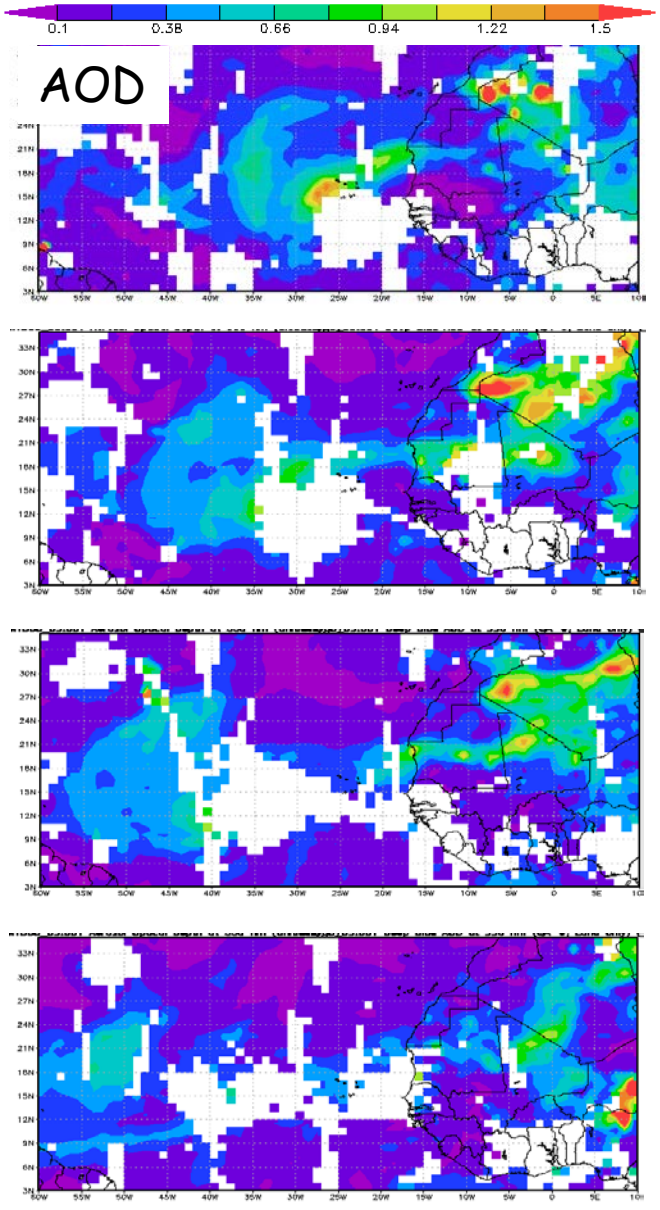


(METEOSAT, CIMSS/UW)



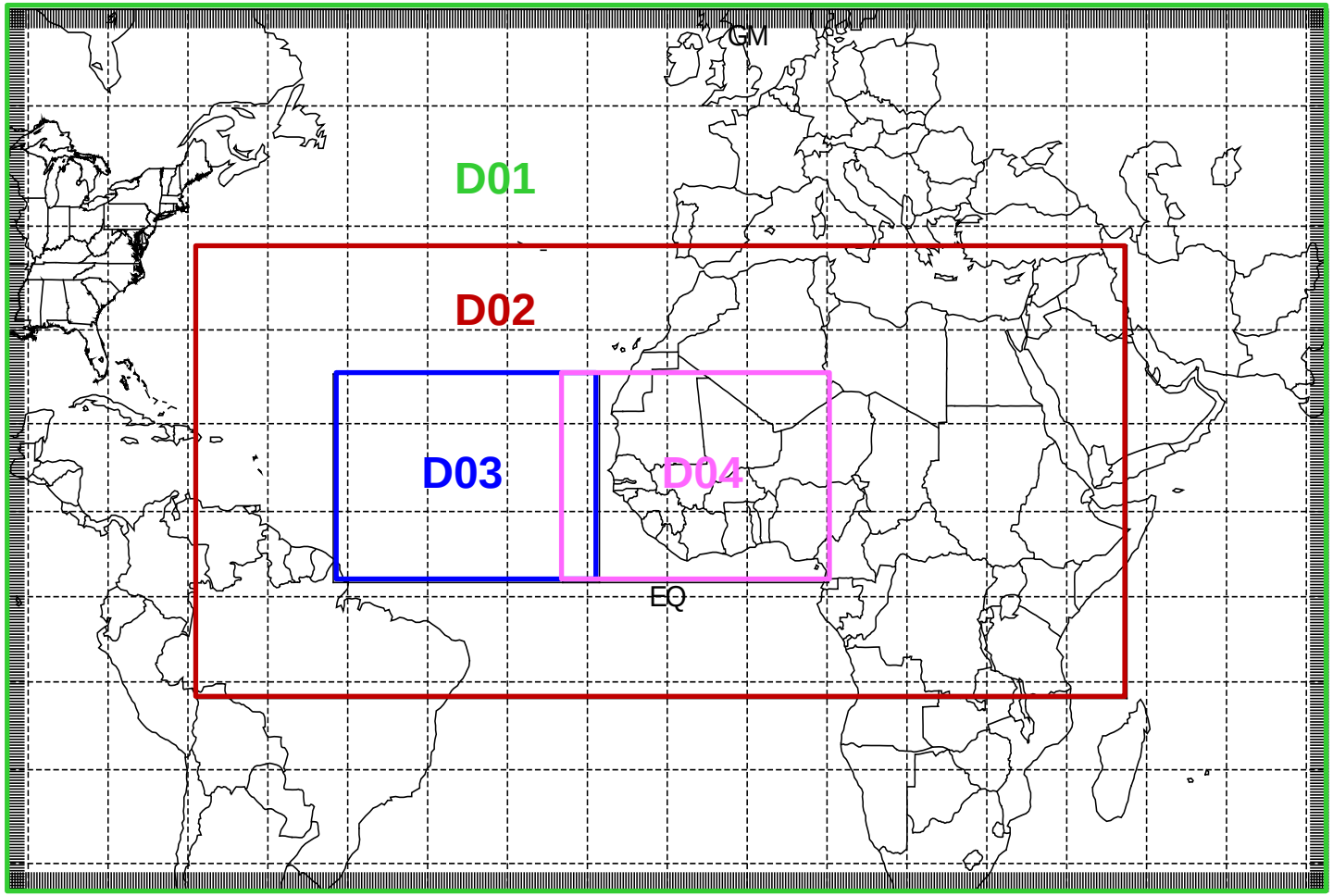
(IR brightness T)



MODIS/MISR

Domain Configuration

WRF tracer model

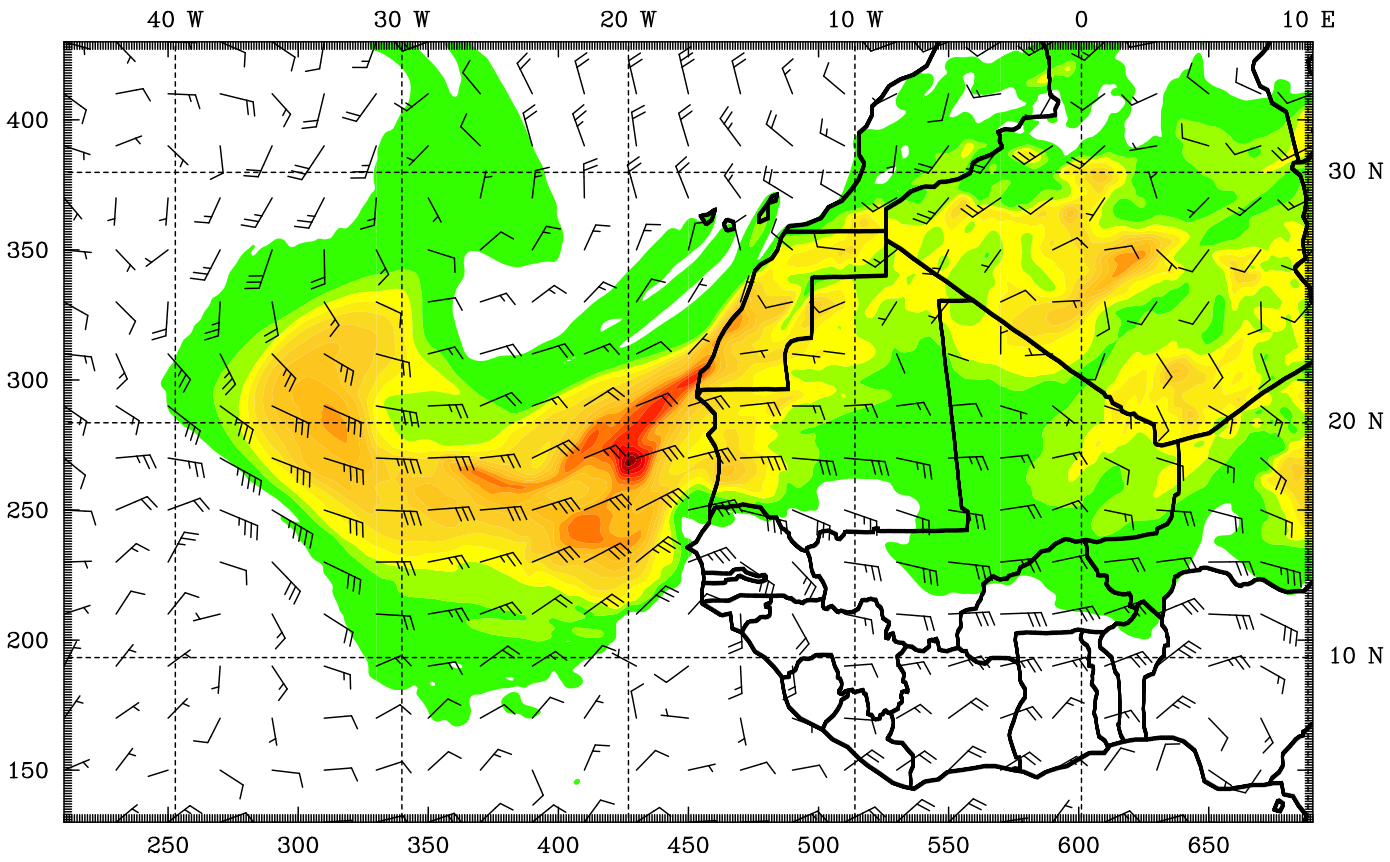


Numerical Experiments

00Z 08 – 00Z 18September, 2006

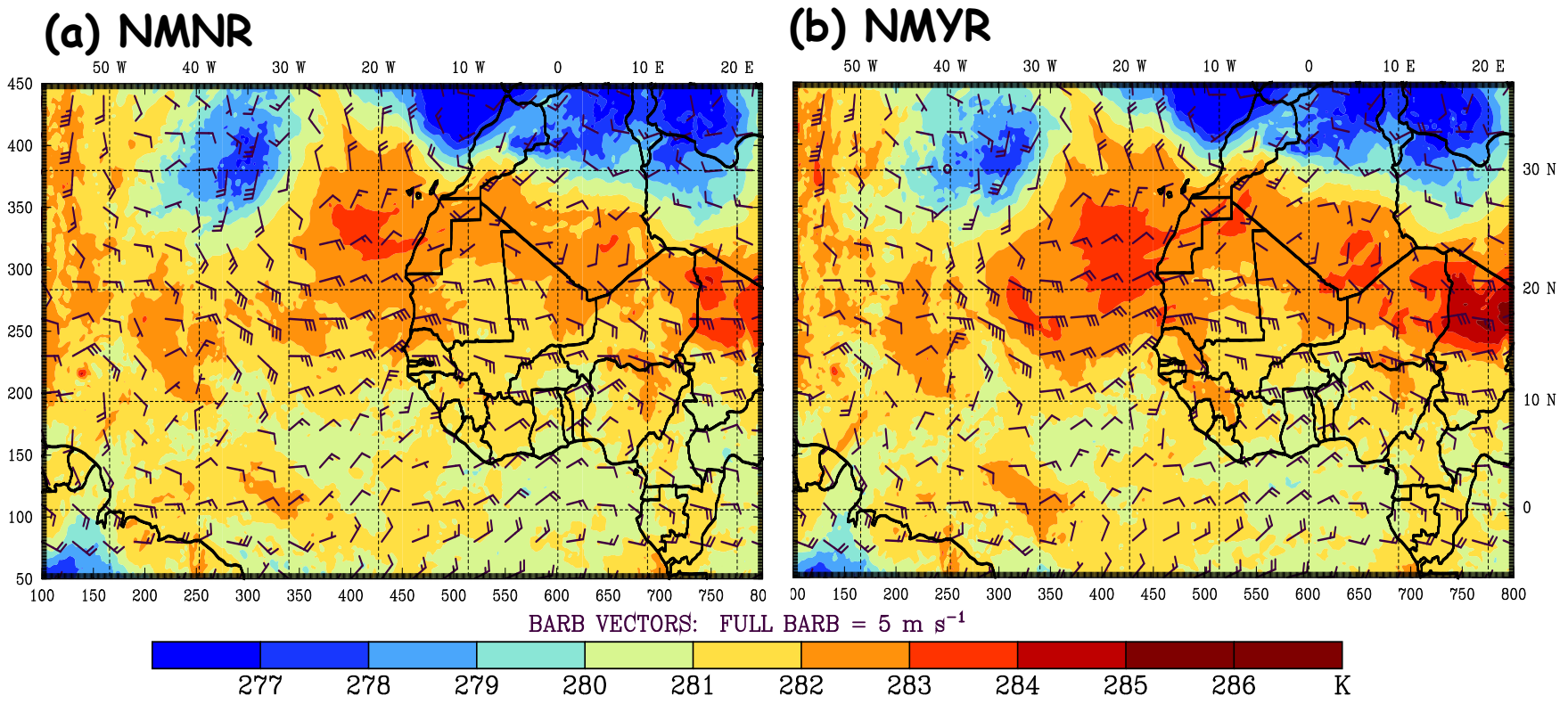
EXP	*Dust-microphysics interaction*	*Dust-radiation interaction*	*Dust emission*
NMNR			Regular

Integrated Dust & 700-mb Wind Vectors

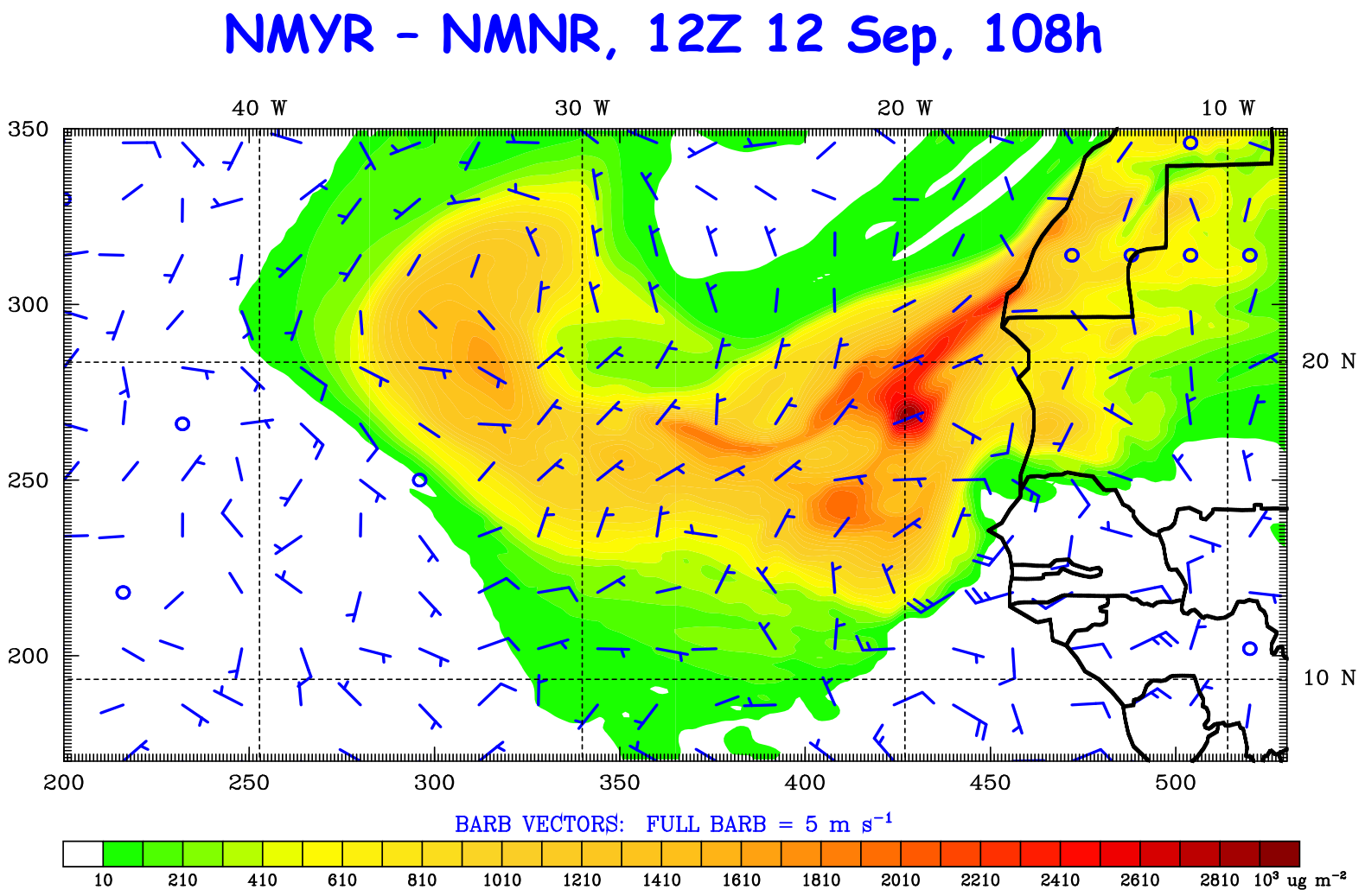


700-mb T and Wind Vectors

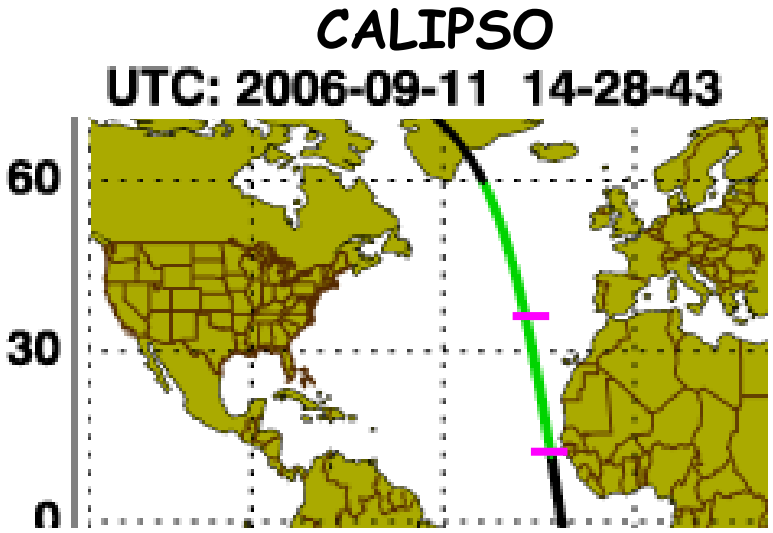
12Z 12 September 2006, 108h, YMYR

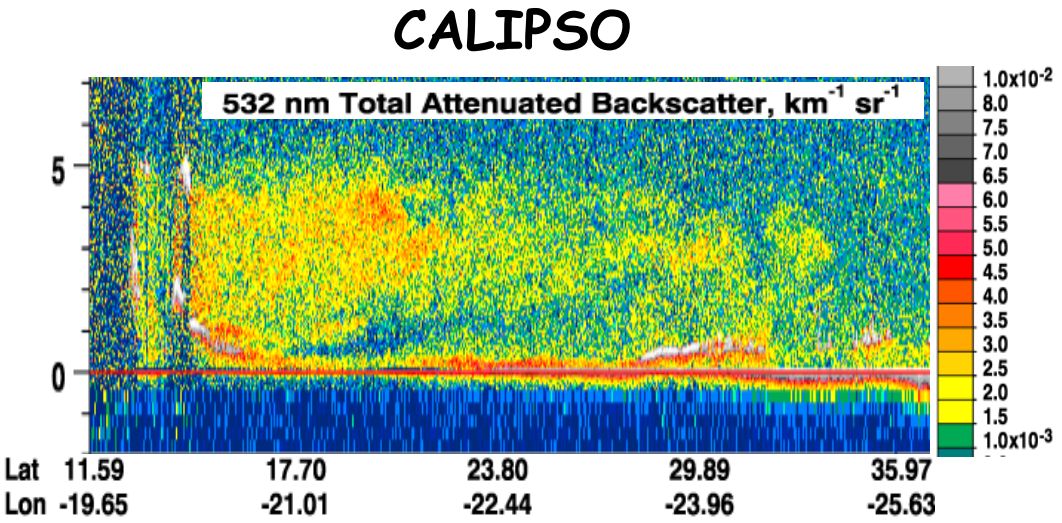


Wind Difference at 600 mb (dust-rad effect)

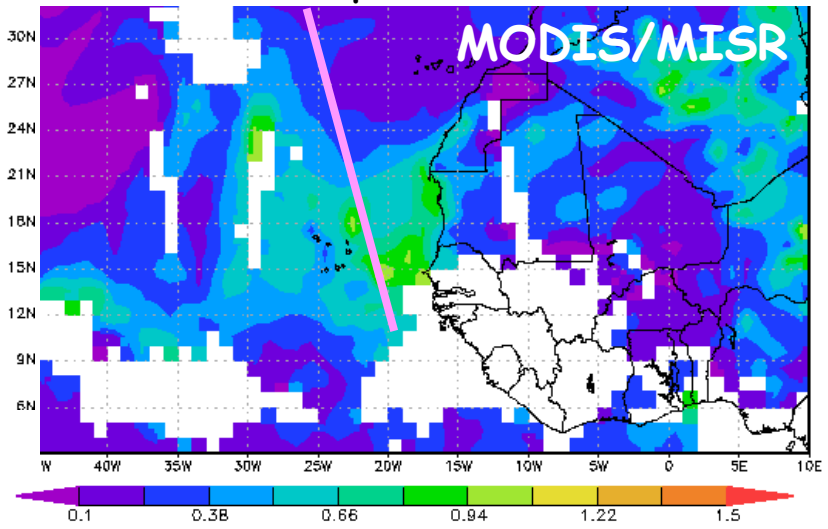


CALIPSO

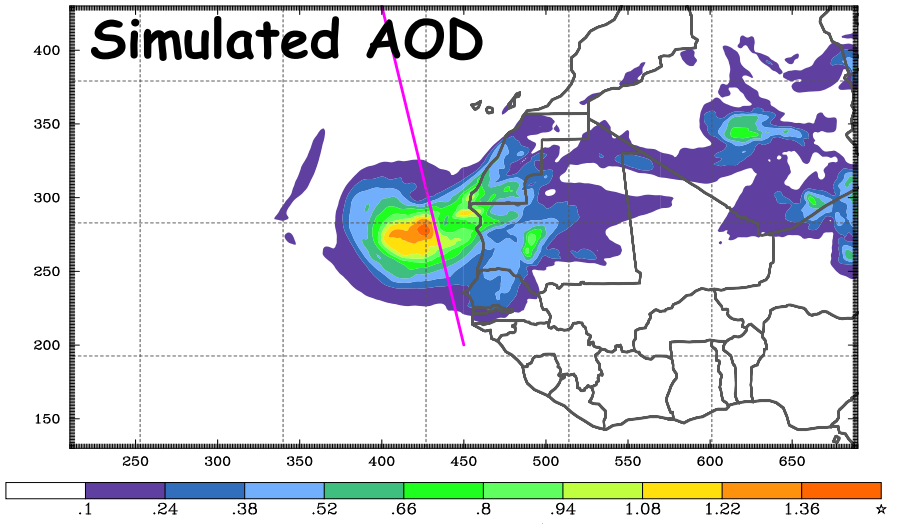




Sep 11, 2006

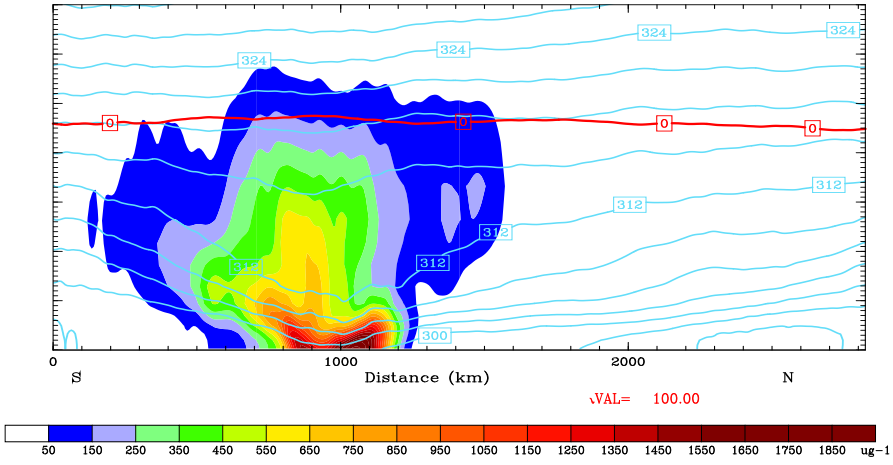


12Z, Sep 11, 2006

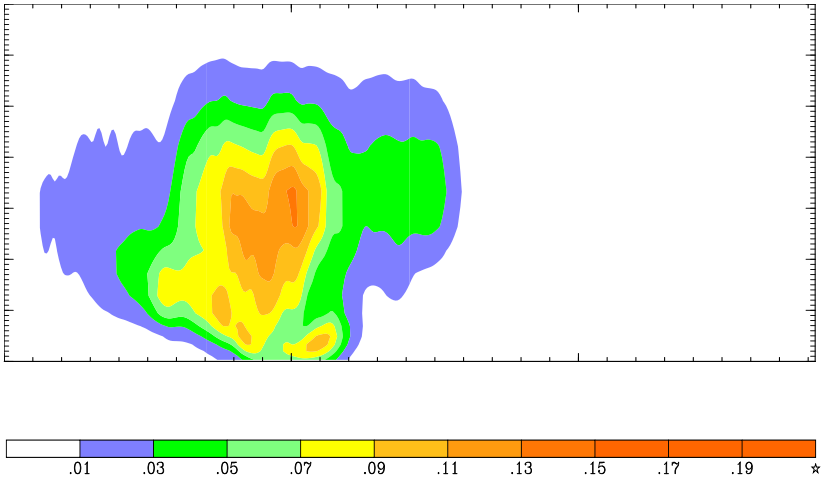


CALIPSO vs. Model Simulation

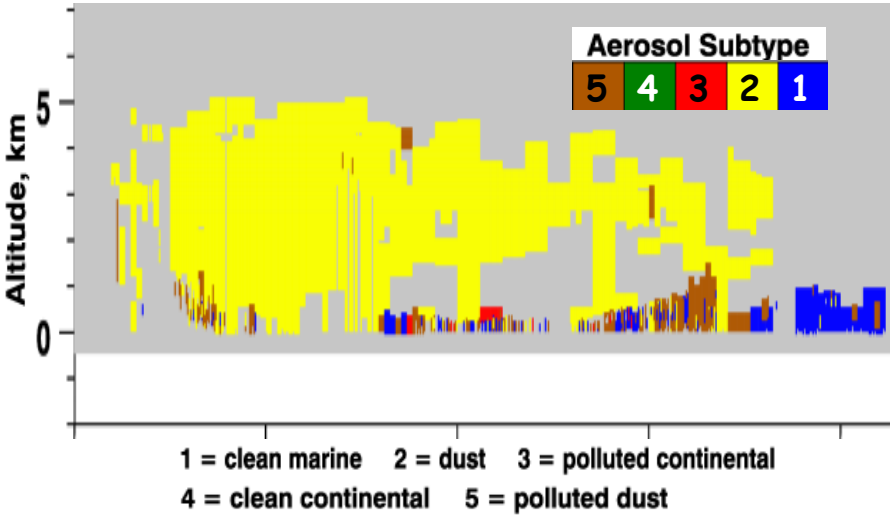
Simulated total dust (YMYR)



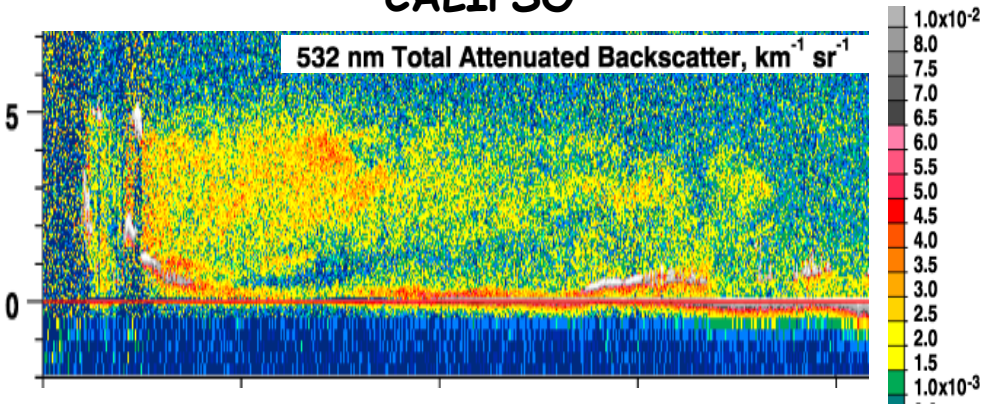
Simulated extinction coefficient (817 nm)



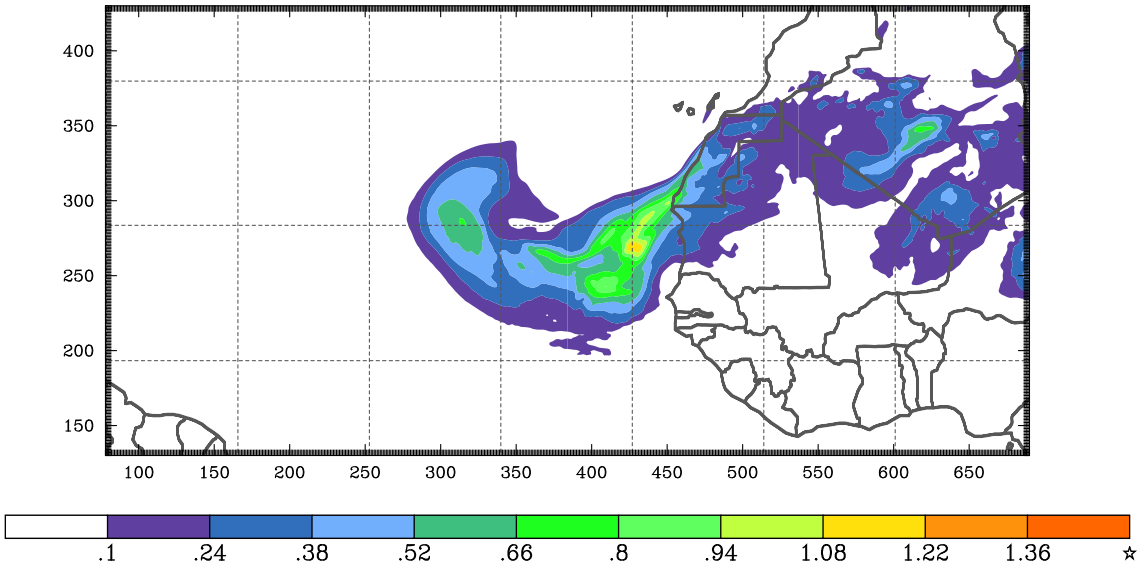
CALIPSO



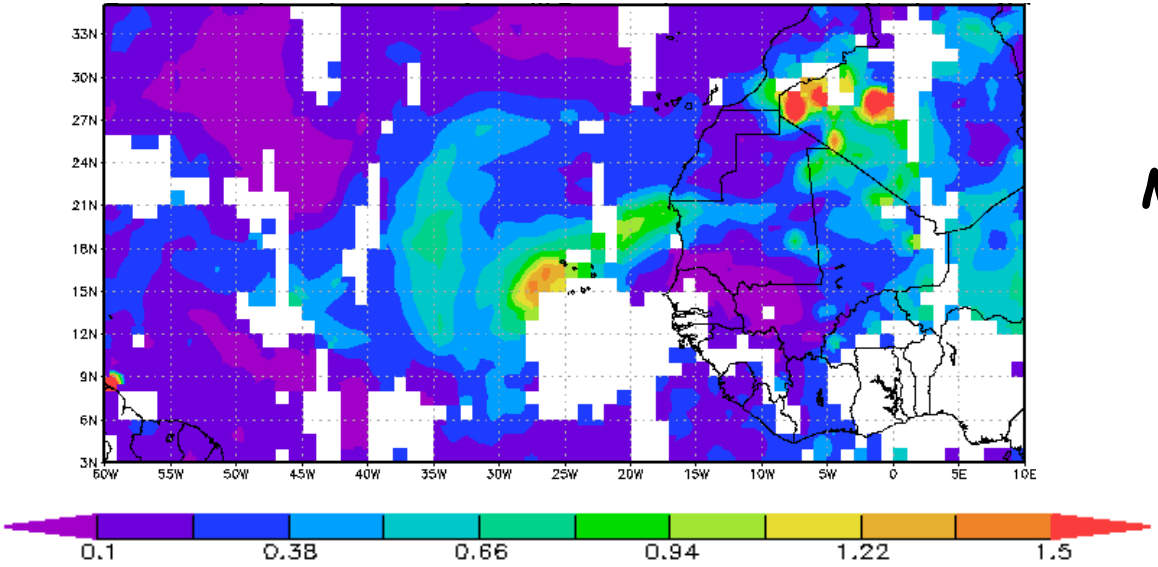
CALIPSO



Aerosol Optical Depth (12Z 12 Sep, 108h)

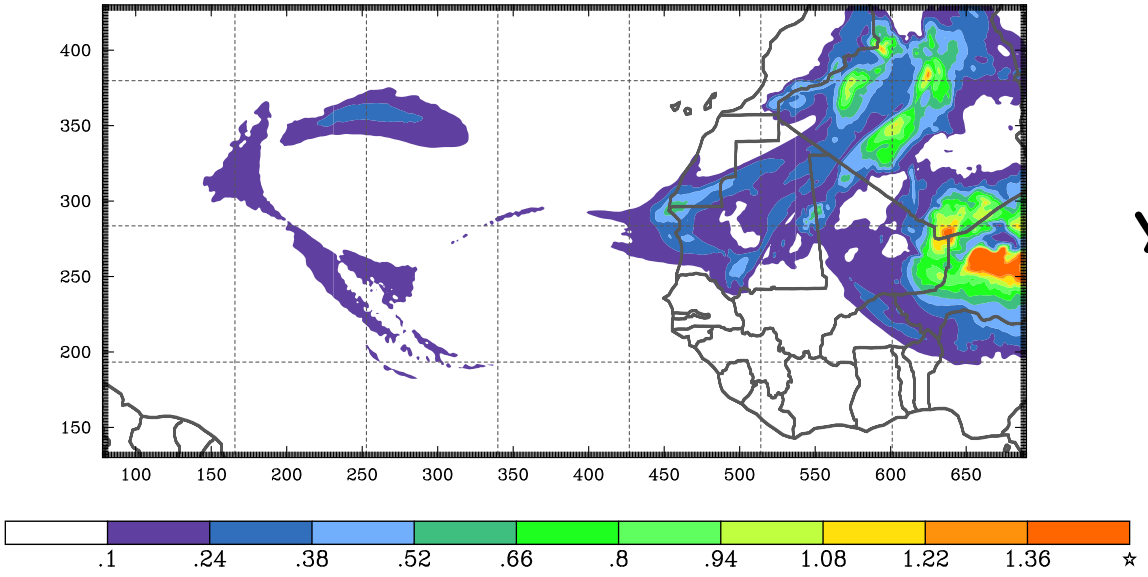


YMYR

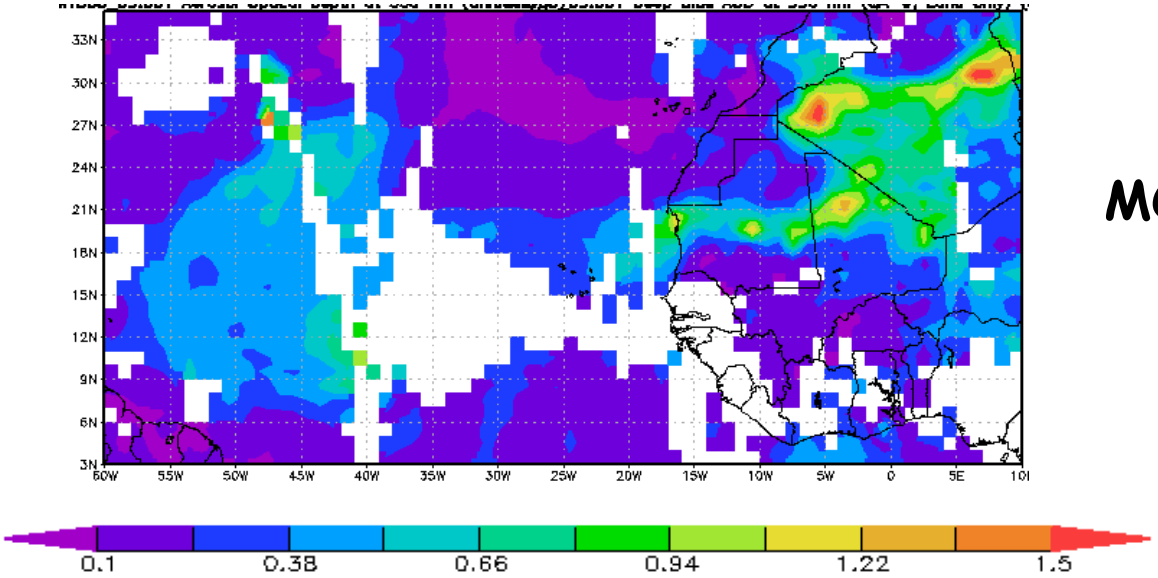


MODIS/MISR

Aerosol Optical Depth (12Z 14 Sep, 156h)

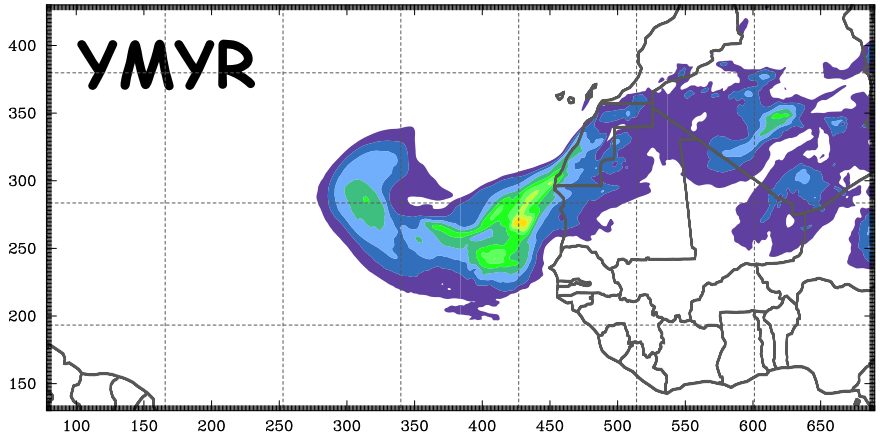


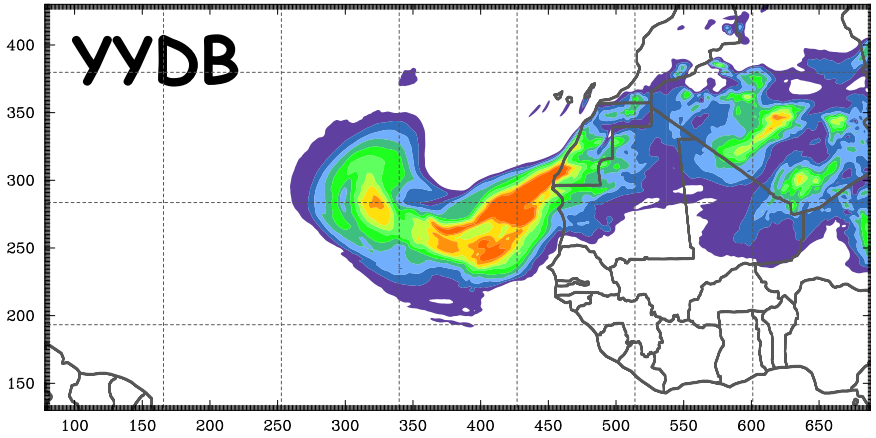
YMYR

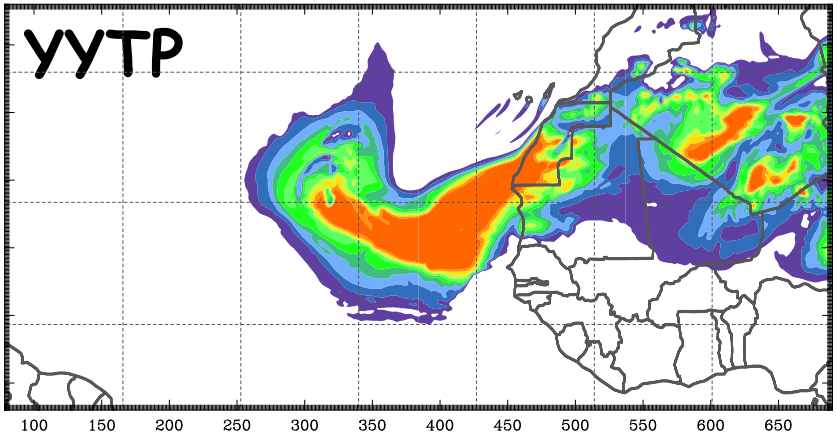


MODIS/MISR

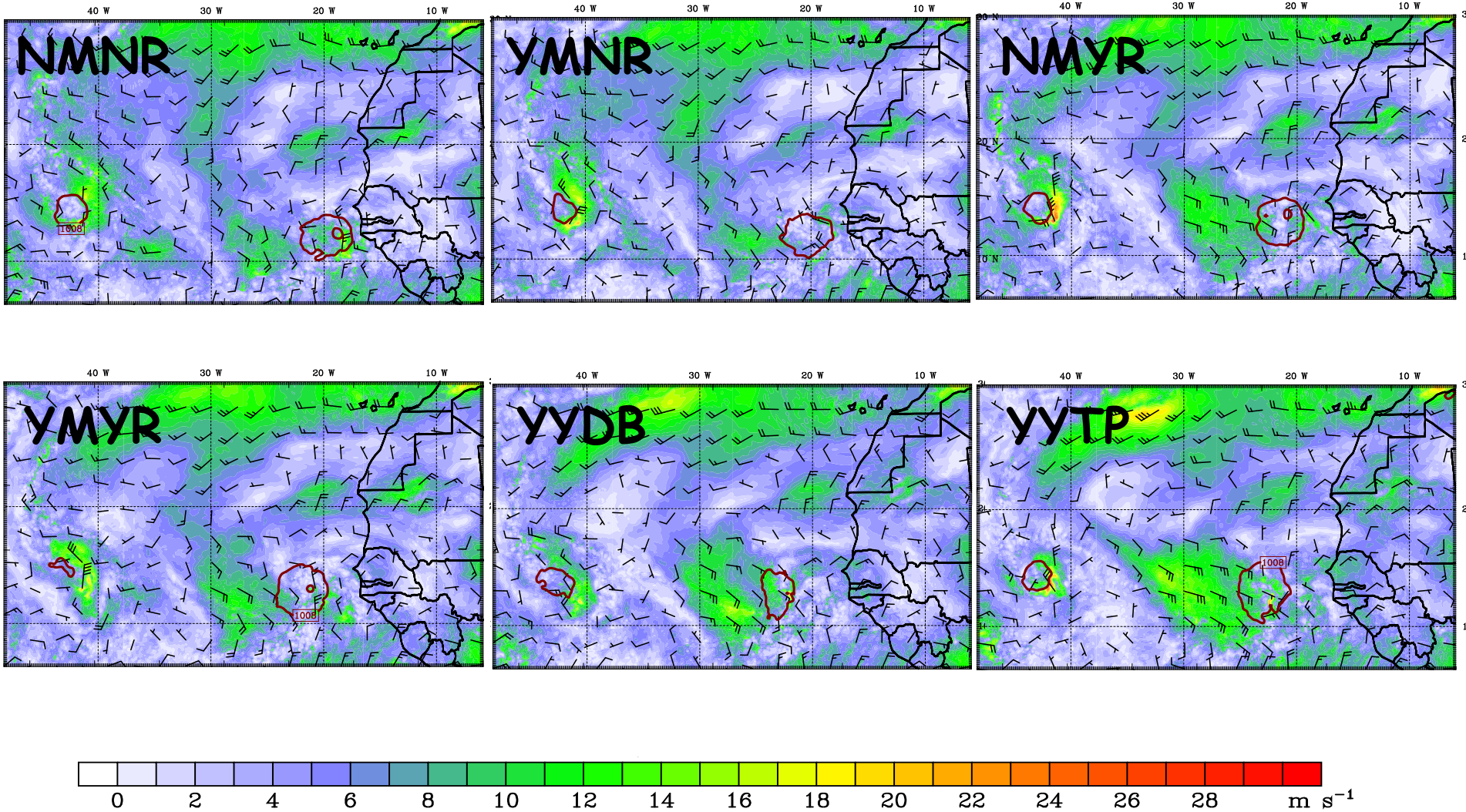
Aerosol Optical Depth (12Z 12 Sep, 108h)



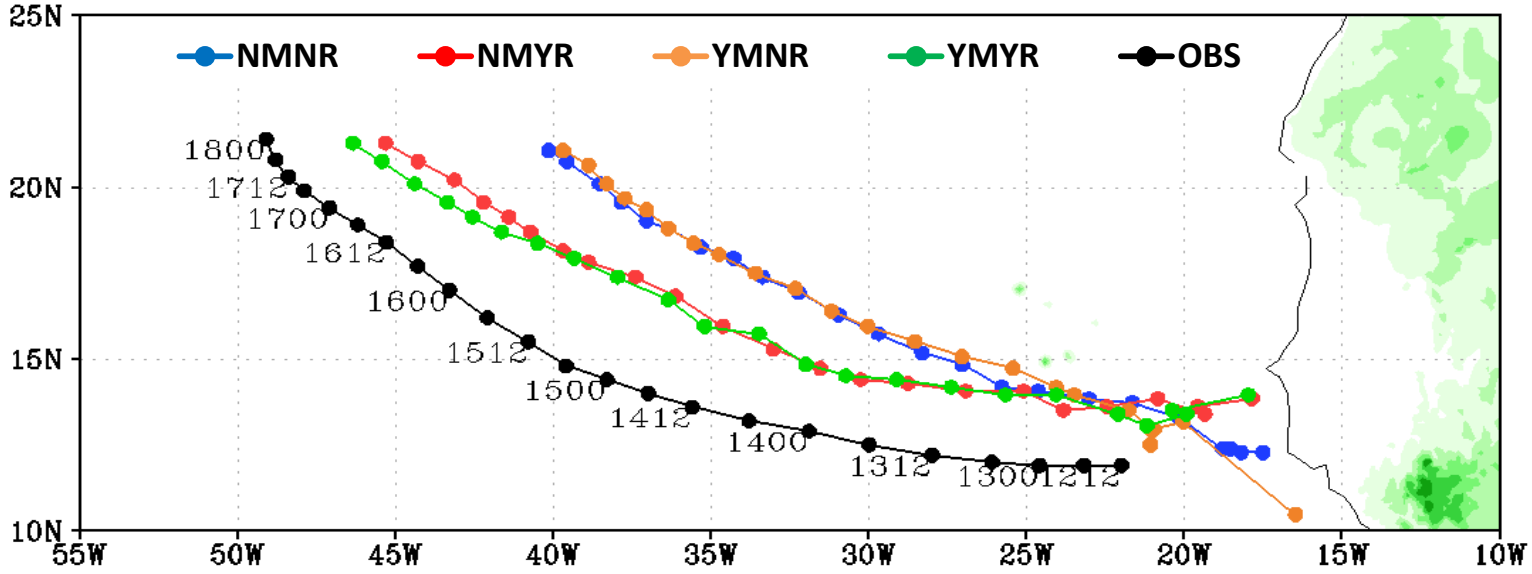


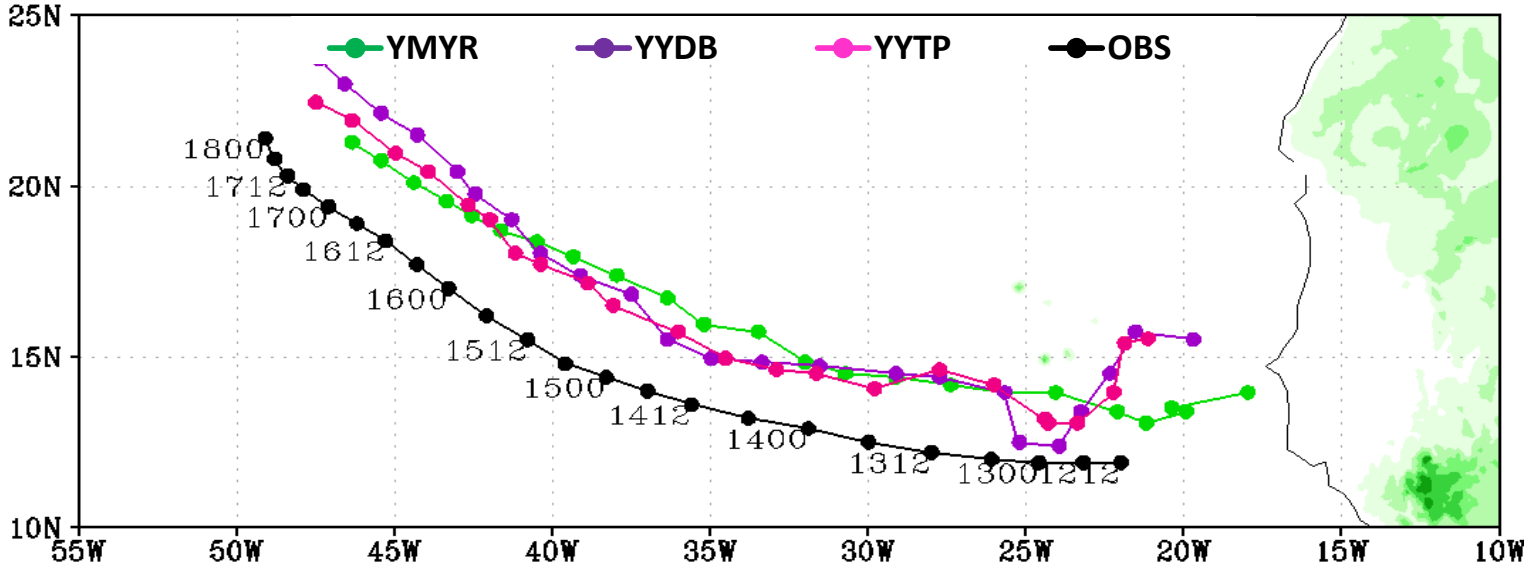


Shallow Vertical Wind Shear (126h, 06Z Sep 13)

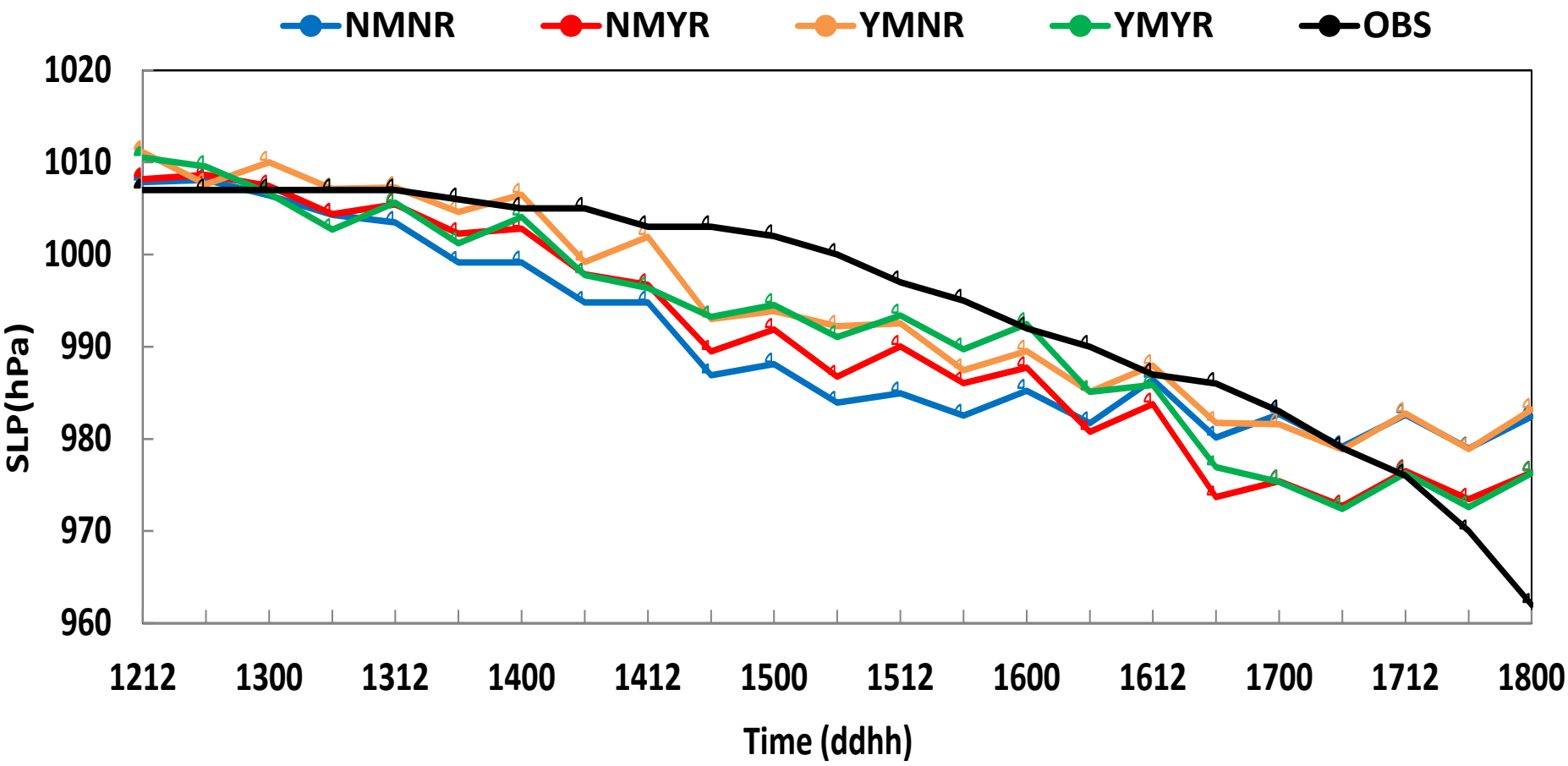


Tracks (Sep 2006)



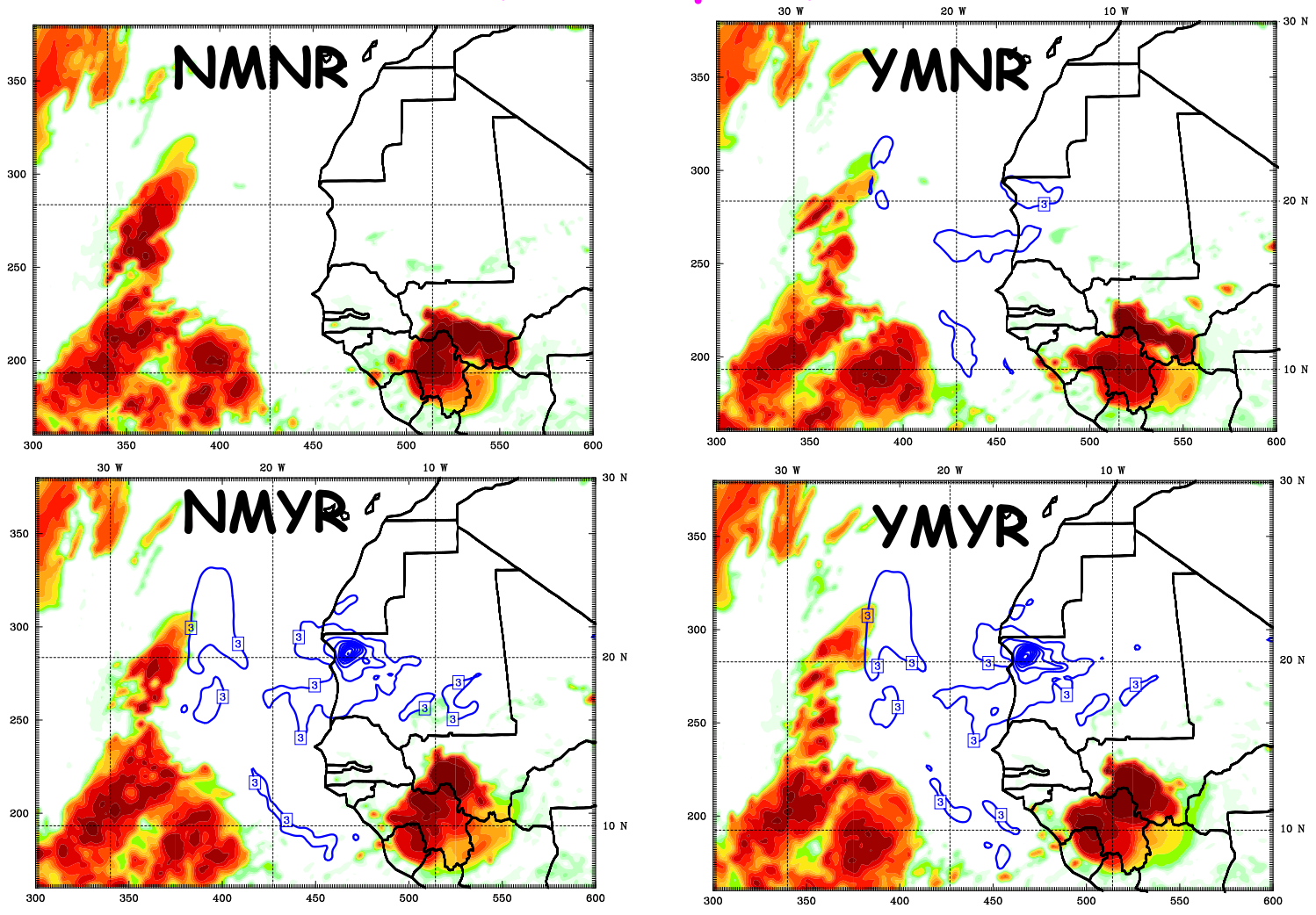


Min SLP (Sep 2006)

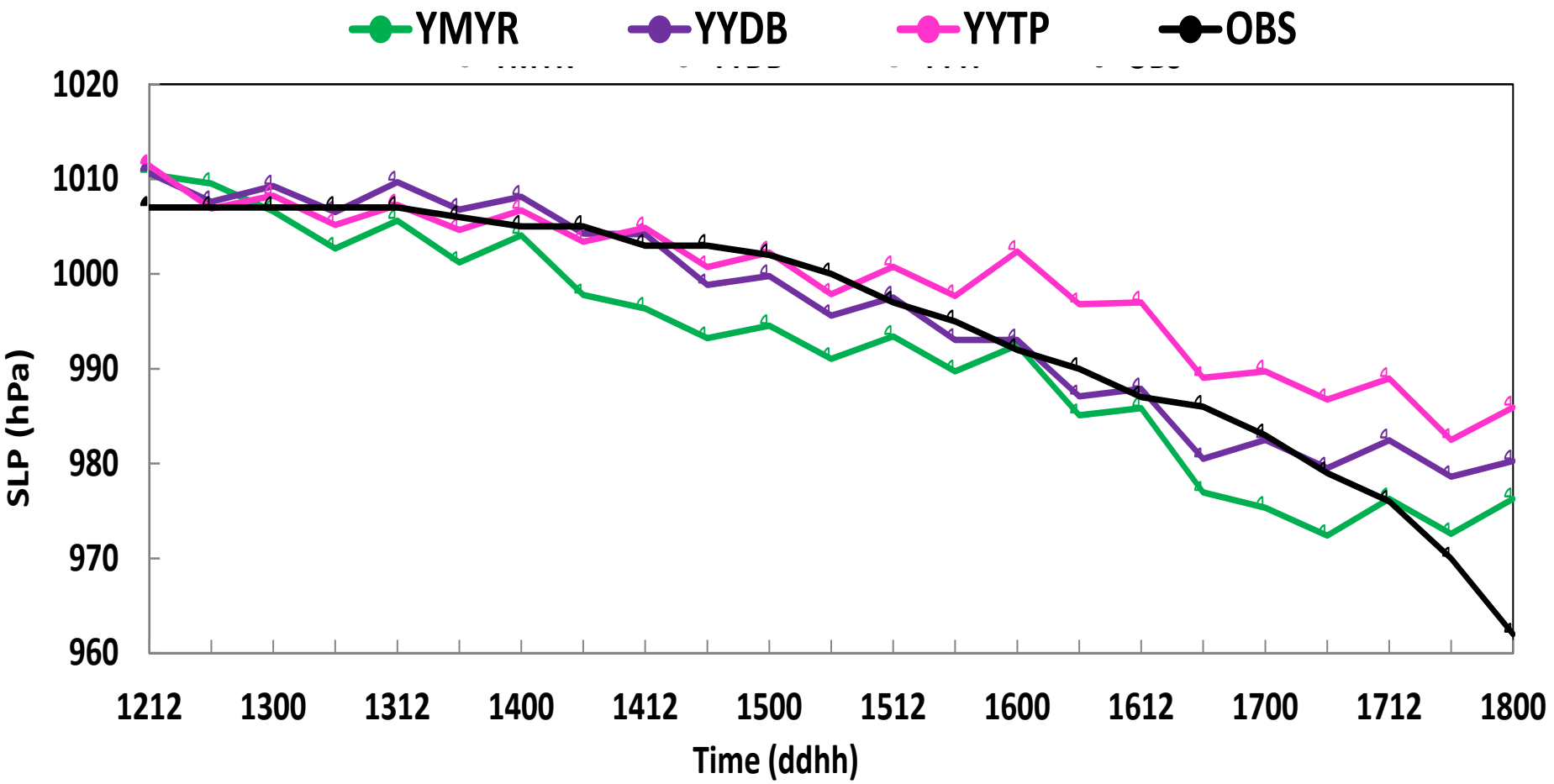


Simulated Tb & 500-mb dust

(18Z Sep 10)



Min SLP (Sep 2006)



Summary

SAL and TC genesis

- Most of TC s starting from African easterly waves (disturbances) involve the type 3 merger process.
- EC reanalysis shows an elongated vortex often existing at the southwest of Saharan low due to strong convergence.
- The vortex will be pushed southward when a low propagates to western coast along the south edge of SAL, increasing the opportunity of the type 3 merger process and TC genesis.

Dust simulation:

- Dust-radiation interaction increases hurricane propagating speed over Atlantic Ocean.
- A strong dust outbreak will very likely suppress hurricane intensity.