IMPACT OF THE DUST-SHORTWAVE RADIATION EFFECT ON ATLANTIC HURRICANE ACTIVITY IN 2007

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Abstract

Mineral dust particles play a vital role in climate and the Earth's energy budget and can have impact on weather as well. This research is to investigate the dust-radiation effect on Atlantic tropical cyclone (TC) activities. To undertastand how the SAL and Saharan dust affect Atlantic tropical activities, tropical cyclone activities in 2007 were studied and connected to environmental conditions, such as sea surface temperature (SST) anomaly, vertical wind shear, and aerosol optical depth (AOD). The second objective of the research is to study the dust-radiation interaction on Atlantic seasonal TC activity in 2007 using a dust numerical model. Two numerical experiments were conducted. The dust short-wave radiation interaction was activated in one simulation (ON) and deactivated in the other one (OFF). An automatic program was developed to track simulated TCs. Nine TCs formed in the ON experiment, while only two TCs formed in the OFF experiment through July to September. The results show that for a normal year the dust-radiation interaction reduces vertical wind shear over West Atlantic and thus increases the TC development over region, which is more comparable to observations. It is unfortunate that the model did not produce any TC over the main developing region in both experiments, while five TCs formed in reality.

The WRF Dust Model

Weather Research and Forecast (WRF) dust model [Chen et al. 2015] is used to investigate the dust impact on seasonal hurricane activity. The WRF dust model is based on WRF V3.2. The WRF model is a community mesoscale model, which is used worldwide in both research and operational centers.

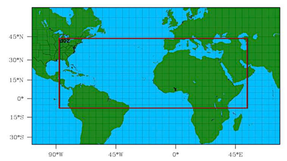


Figure 1. WRF dust model domain configuration.

In the dust model, there are 5 dust bin sizes with the diameters ranging from 0.3 mm to 10 mm. The aerosol optical properties that are used for radiation calculations are estimated using the Optical Properties of Aerosols and Clouds (OPAC) software package (Hess et al., 1998) and are implemented into the GSFC radiations schemes. Full details of the dust model can be found in Chen et al. (2015).

Table 1. Monthly and three month average shear values from July to September for both ON and OFF experiment over MDR

	ON		OFF	
	200-850 hPa Shear (m/s)	500-850 hPa Shear (m/s)	200-850 hPa Shear (m/s)	500-850 hPa Shear (m/s)
July	12.19	6.93	13.16	5.65
August	10.85	6.67	13.61	6.10
September	12.22	5.26	19.48	6.58
Average	11.75	6.29	15.42	6.11

Numerical Experiment Design

The 2007 hurricane season was chosen for the study because of its normal activity.

For WRF dust simulations:

- Simulation from June 25 to October 1, 2007
- The initial and boundary condition are from GFS, which has a spatial resolution of 1° x 1° and a temporal resolution of 6 hours.
- Two domains with two-way interaction are configured.
- The model spatial resolutions are 36 km and 12 km for domain 1 and 2, respectively.
- A time step of 120 seconds is used for domain 1.

Two numerical experiments are conducted. The dust short-wave radiation interaction is activated in one simulation (called ON) and is deactivated on the other (called OFF). The rest of numerical setting and configuration is exactly the same in both simulations

AOD Results

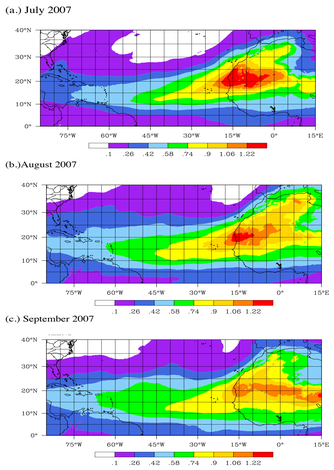
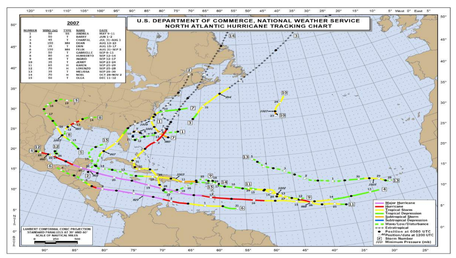


Figure 2. Monthly average of AOD for (a) July, (b) August, and (c) September2007.

2007 Hurricane activity over the Atlantic



Results

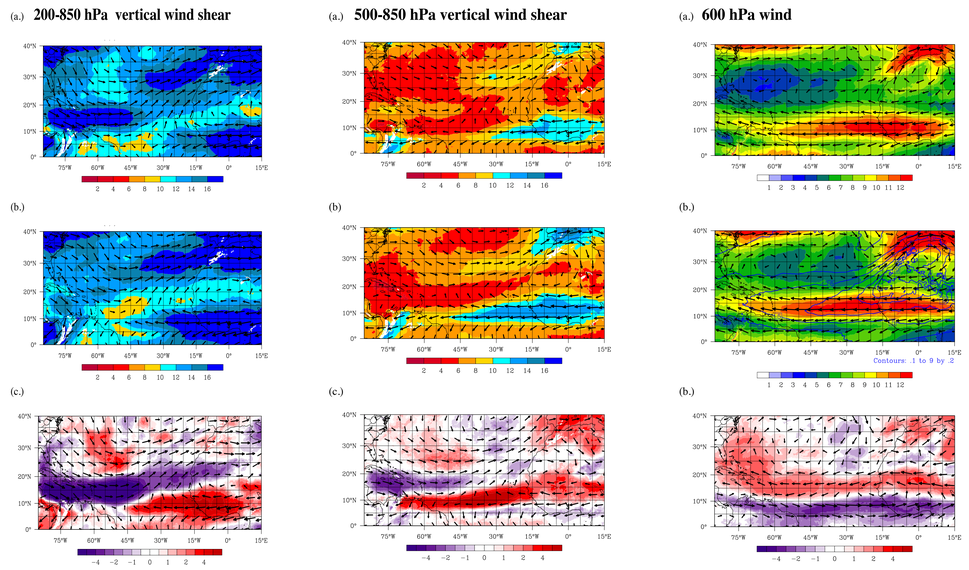


Figure 3. Three month average values (July-September 2007) with AOD contours and wind shear vectors from(a) OFF, (b) ON, and (c) difference of two experiments (ON-OFF).

Hurricane Tracking Results Over Atlantic

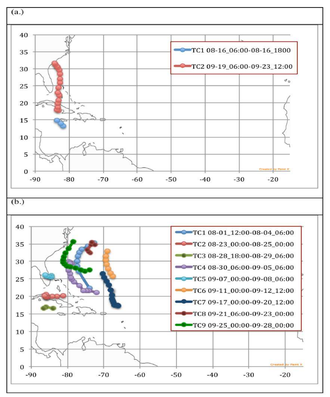


Figure 3. Hurricane tracks for the (a) OFF and (b) ON experiment . Starting and ending times of each storm (Month-Day-Time) are also provided.

Conclusion

For the 2007 TC season, the WRF model produced a larger number of TCs and more intense storms after the inclusion of the dust-radiation interaction, which was closer to real observations. This is partially due to the decrease of deep vertical shear over the West Atlantic by dust, and to some extent the increase of the relative humidity.

Future Work

Further analyses on both experiment outputs are required, such as the change of African easterly waves by dust, to better understand the mechanisms that influence Atlantic TC activities by the dust-radiation effect. More studies in different years and using an ensemble approach will help improve the robustness of model results regarding the dust-radiation impact on Atlantic TC development. Finally, further improvements on the WRF model performance are critical since both numerical experiments overestimate SAL intensity and underestimate TC numbers.

References

Chen, S.-H., Liu, Y.-C., Nathan, T. R., Davis, C., Torn, R., Sowa, N., Cheng, C.-T. and Chen, J.-P. 2015, Modeling the effects of dust-radiative forcing on the movement of Hurricane *Helene* (2006). Q.J.R. Meteorol. Soc.. doi: 10.1002/qj.2542