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NEW EVIDENCE FOR A LONG–TERM RELATIONSHIP BETWEEN NORTH ATLANTIC TROPICAL CYCLONES AND AFRICAN DUST OUTBREAKS

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1. INTRODUCTION

The recent upswing in Atlantic tropical cyclones (including both hurricanes and tropical storms) affecting North America has raised the awareness of their impact on society and the economy. Here, we explore how atmospheric dust and the Saharan Air Layer may contribute to interannual changes tropical cyclone activity. This relationship was first suggested by Dunion and Velden (*2004*), who showed that tropical cyclone activity may be influenced by the presence of the dust–-laden Saharan Air Layer, which forms when a warm, well-mixed, dry and dusty layer over West Africa is advected over the low-level moist air of the tropical North Atlantic (Carlson and Prospero, 1972).

Based on their analysis of several case studies of individual tropical cyclone events, Dunion and Velden (2004) suggested that the Saharan Air Layer could inhibit the formation of, or reduce the intensity of, tropical cyclones in the North Atlantic through three primary ways. First, the Saharan Air Layer can introduce dry air into the storm, promoting downdrafts and disrupting the convective organization within the tropical cyclone vortex. Second, the midlevel jet found within the Saharan Air Layer increases the local vertical wind shear, which can decouple the storm's low–level circulation from its supporting mid– and upper–level deep convection. Third, the radiative effects of the dust in the Saharan Air Layer may enhance the preexisting trade wind inversion and act to stabilize the environment, thereby suppressing deep convection.

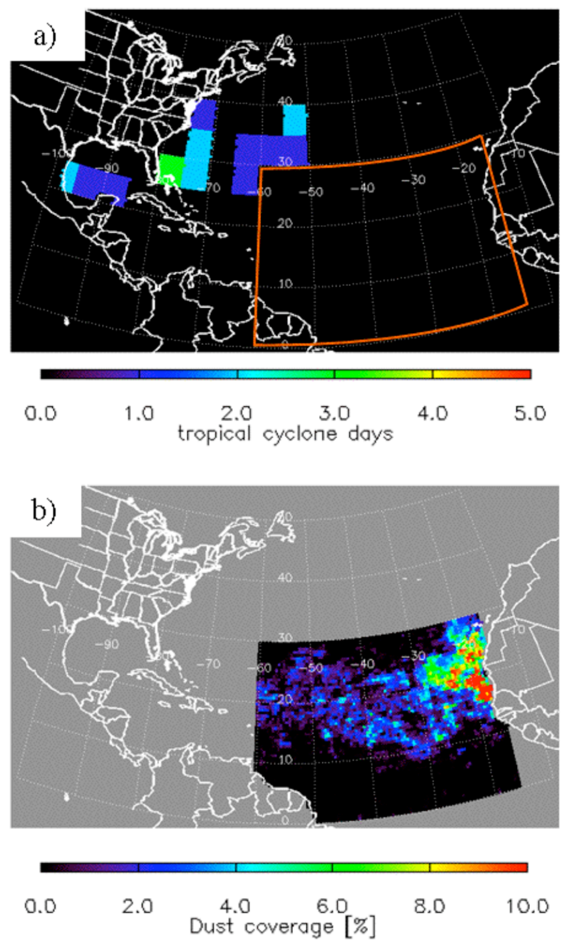

Figure 1. Saharan-induced dustiness and North Atlantic tropical cyclone activity for 1983. The tropical cyclone analyses (A) is of tropical cyclone days at 5–degree grid resolution. The dust analyses (B) is of dust coverage at 1/2–degree grid resolution. Both images represent average values over the period August 20–September 30. The red box in the tropical cyclone image represents the area over which we collected data (0–30N and 15–60W) for the tropical cyclone days and dust cover time series shown in Figs. 3 and 4. The dust maps represent the percent coverage of optically thick dust plumes and not the percent coverage of all atmospheric dust.

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2. METHODS

In our study we examine this hypothesis by putting it into a long-term, climatological context using a new satellite-based atmospheric dust record from the 5–channel Advanced Very High Resolution Radiometer (AVHRR). Our algorithm for dust detection Evan et al. (2006a) has been developed to improve the distinction between dust and clouds for very optically thick dust storms, which would have previously been classified as cloud under the National Oceanographic and Atmospheric Administration's operational AVHRR cloud mask algorithm. The final half–degree resolution dust dataset represents the fractional dust coverage of the gridcell. This is not a measure of the total amount of dust present, but rather the fractional coverage of optically thick dust in a gridcell. Further discussion of this methodology and its results can be found in Evan et al. (2006a; 2006b).

We derived a daily measure of North Atlantic dust cover by calculating the average number of dust–covered pixels over the oceanic region west of northern Africa, from 0–30˚N and 15–60˚W (Fig. 1). We then created a "tropical cyclone days" statistic by summing the total number of days any named Atlantic tropical storm was present over the same region used for the collection of dust statistics (Fig. 1). Tropical cyclone data were obtained from the National Hurricane Center (NHC) Hurricane Best Track Files (HURDAT) (data available at http://www.nhc.noaa.gov/pastall.shtml). Here, a "named storm" corresponds to a tropical cyclonic system with 1-minute-averaged maximum sustained winds of approximately 18 m/s or ~34 knots. For each year, we acquired dust and tropical cyclone statistics for August 20 – September 30, a period representing one standard deviation of the seasonal tropical cyclone dates, centered on the climatological peak of tropical cyclone activity for 1982–2004, September 9. Just over 50% of all North Atlantic tropical cyclone activity for these years occurs within this 50 day time period.

3. RESULTS

Figures 1 and 2 show the regions for which dust and tropical cyclone statistics were derived, superimposed over images of mean dust cover and total tropical cyclone days for the years with the maximum (1995) and minimum (1983) tropical storm days. For the 1983 case no tropical cyclone days (Fig. 1A) were observed inside of the region used for study. Correspondingly, significant dust is detected, mainly constrained to latitudes north of 10˚N. For the 1995 case, there is a large increase in tropical cyclone activity along the main development region of the North Atlantic Goldenberg and Shapiro, (1996) and across the Atlantic basin as a whole (Fig. 2A). Correspondingly, there is a clear reduction in dust cover over our study region (Fig. 2B), as compared to the 1983 case.

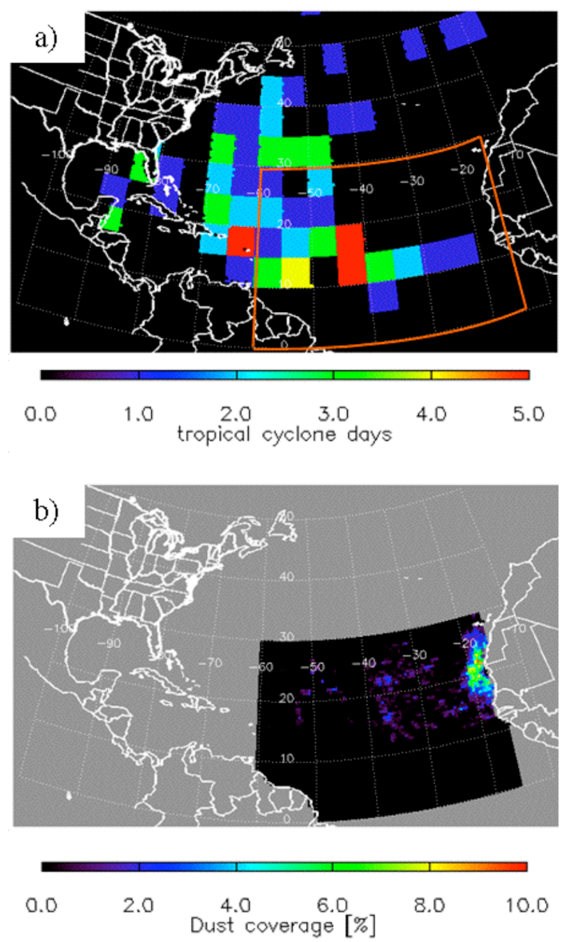

Figure 2. Saharan-induced dustiness and North Atlantic tropical cyclone activity for 1995. Same as Fig. 1 legend, except for 1995.

This contrast between the intensity of the mean dust activity, and the concurrent appearance of cyclone days where dust is lacking, suggest an inverse correlation between dust and tropical cyclone activity. Because the dust observations are a good proxy for the Saharan Air Layer, we suggest that this reduction in the activity of the Saharan Air Layer for the 1995 case could be indicative of an environment more conducive to deep convection and tropical cyclogenesis, consistent with Dunion and Velden (2004).

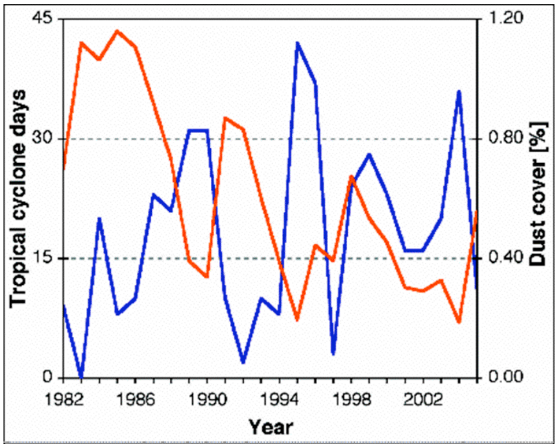

Figure 3. Time series of North Atlantic tropical cyclone days and AVHRR-detected Saharan-induced dust cover for 1982–2005. The orange line represents the detected dust cover and the blue represents tropical cyclone days. Both time series were created by averaging the dust coverage or summing tropical cyclone days over the region of 0¬–30N and 15–60W for the time period of August 20 through September 30, for each year of the sample The two time series have a correlation coefficient of -0.53, significant at the 98% level.

Figure 3 shows time series of annual tropical cyclone days and dust coverage, averaged over our entire study region for August 20–September 30 for the years 1982–2005. Dust activity during the 1980s was more intense than during any other period in the record. A 5 to 8–year oscillating behavior is also seen in the dust record, superimposed over a downward trend in dustiness. This interannual pattern in dustiness has been observed in other satellite studies and may be linked to changing rates of precipitation in the Sahel (Moulin and Chiapello, 2002). The early 1980s are characterized by a relatively suppressed period of cyclone activity, with the minimum of tropical cyclone days occurring in 1983. This is followed by several years of increased activity and then another period of decreased activity from 1991–1994. The maximum in tropical cyclone activity was observed in 1995 and is followed by a sharp drop during 1997, a strong El Niño year associated with reduced tropical storm activity (Gray, 1984). The last 8 years of the record show more consistent, and elevated, tropical cyclone activity, corresponding to some of the trends shown by Goldenberg et al. (2001). A correlation coefficient of –0.53 was observed between the two series, which is significant at 98% (significance values are based on the 2–tailed t–score for the correlation coefficient).

Figure 4 is the standardized (subtracting the mean and dividing by the standard deviation of the respective time series) version of the two data sets and their associated linear trends, with the dust series on an inverse scale. Here, the long–term relationship between observed dustiness and tropical cyclones, and the departure from this covariance during 1997, is clearer. Another El Niño event occurred in 2002, which could be the cause of the reduction in tropical cyclone days that is not accompanied by an equivalent increase in dustiness. Furthermore, the dust and cyclone days observations in 1994 are both nearly one standard deviation below the mean. The lack of a negative correlation for this year could be reflective of a gap in the AVHRR data record of more than 15 days in late September 1994. If we remove these years of El Niño activity (1997 and 2002) and the year containing the satellite data gap (1984) the correlation coefficient between dust and tropical cyclone days increases to -0.70, significant at 99.9%.

4. CONCLUSIONS

Although Figures 3 and 4 show that mean dust coverage and tropical cyclone activity are strongly (inversely) correlated over the tropical North Atlantic, this *does not* provide conclusive evidence that the dust itself is directly controlling tropical cyclone activity. It is still not known if dust drives changes in tropical cyclone formation or intensification. Nevertheless, dust is a good tracer of the Saharan Air Layer, which has previously been suggested as a potential control of cyclone activity in the Tropical Atlantic (Dunion and Velden, 2004). It is important to note that the variability in the dust time series may not only reflect variations of the *presence* of the Saharan Air Layer, but it may also reflect changes in dust loadings *within* the Saharan

Air Layer itself, which could have important meteorological implications.

While no *direct* causality has been established, our analysis suggests the variability in dust (and variability in the presence of the Saharan Air Layer) is strongly linked to changes in North Atlantic tropical cyclone activity. Whether there is a direct or indirect link remains elusive, but at the very least a strong argument is made for new field observations designed to further explain and understand the observed relationships between the Saharan Air Layer, African dust, and tropical cyclone activity over the North Atlantic.

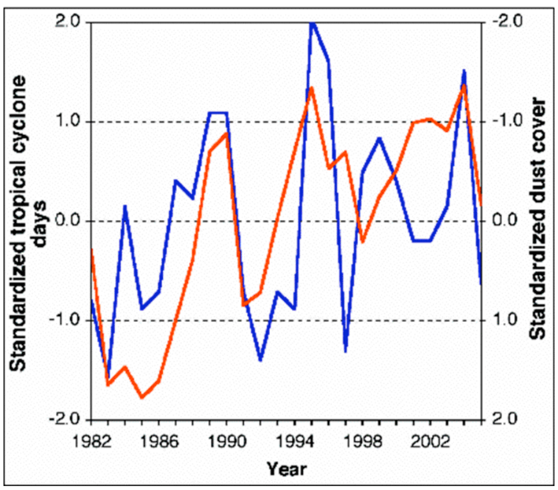

Figure 4. Standardized time series of North Atlantic tropical cyclone days and AVHRR-detected Saharan-induced dust cover for 1982–2005. Same description as Fig. 3, except that the time series have been standardized.

5. ACKNOWLEDGEMENTS

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