2010 Atlantic Hurricane Season Dust Outlook

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Summary

There is reason to believe that African dust outbreaks may both directly and indirectly impact Atlantic hurricane genesis and intensification. As such, a summertime forecast of Atlantic dust cover may be a useful aid in predicting seasonal hurricane activity. Here I present a qualitative forecast of Atlantic main development region (MDR) dust cover for the 2010 hurricane season (July–November). Based on persistence in dust, and Sahelian rainfall anomalies during the *previous* year, MDR dust cover during the 2010 hurricane season will be near-normal to one standard deviation below-average (relative to 1982–2009). This is not to say that one month will not show anomalously high or low dust values, or that particularly strong dust outbreaks (or prolonged periods of no dust) won't occur, but that averaged over the hurricane season dustiness will be near to below average.

Along with this report I am making available online an updated data set of tropical northern Atlantic dust optical depth that spans the period of January 1982 through May 2010.

Introduction & Data

There is a wealth of recent publications making the case for either direct or indirect influences of African dust outbreaks on Atlantic tropical cyclones. Here I refer the reader to the following papers for further reading on this topic: Dunion and Velden (2004), Dunion and Marron (2009), Evan et al. (2006a, 2008), Wong and Desser (2005), and Wong et al. (2009). In addition, there is a long history of the study of Atlantic dust outbreaks. Some of those relevant to summertime dust outbreaks are: Chiapello et al. (2005), Evan et al. (2009), Foltz and McPhadden (2008), Prospero and Lamb (2003).

Here I use over-water aerosol optical depth (AOD) retrievals from the 5-channel Advanced Very High Resolution Radiometer (AVHRR) Pathfinder Atmospheres-Extended Project over the period 1982–2009 (Stowe et al. 1997; Evan et al. 2006b)[1]. Updates to this record are made using AOD retrievals from the Moderate Resolution Imaging Spectrometer (MODIS) AQUA satellite for the period 2003–2010 (Remer et al. 2005)[2]. MODIS and AVHRR AOD data is well correlated over the northern tropical Atlantic, and so I create a long-term data set of AOD using AVHRR data for the 1982–2008 period, and AQUA for the 2009–2010 period (using an AVHRR/AQUA average for the 2003–2008 time span instead of only AVHRR data produced nearly identical results).

I subtract out contributions to the AOD from stratospheric volcanic aerosols using estimates from Sato et al. (1993)[3]. Satellite AOD is then converted to a dust aerosol optical depth (τ_{dust} or DAOD) using the methodology of Kaufman et al. (2005),

$$\tau_{dust} = \frac{AOT \times (0.9 - FMF) - 0.6 \times \tau_{marine}}{0.4}, \quad (1)$$

where

$$\tau_{marine} = 0.007 \times W_{10m} + 0.02, \quad (2)$$

W_{10m} is the mean wind speed (ms^{-1}) at 10 meters, from NCEP reanalysis (Kalnay et al. 1996), and FMF is an AQUA-derived fraction of the fine to coarse mode aerosols (Remer et al. 2005). To calculate a consistent τ_{dust} for AVHRR and MODIS data, I use long-term monthly mean FMF and τ_{marine} values. Please see Evan and Mukhopadhyay (2010) for details on the methodology and validation for calculating historical τ_{dust}. I create a main development region (MDR; 8-20N & 20-65W) time series of DAOD for the hurricane season (July–November, or JASON), and for the remainder of this report I will utilize these JASON-mean MDR DAOD data[4].

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[1] AVHRR satellite products and description from http://cimss.ssec.wisc.edu/patmosx/
[2] MODIS satellite products available from http://daac.gsfc.nasa.gov/giovanni/
[3] Stratospheric aerosol optical depths from http://data.giss.nasa.gov/modelforce/strataer/
[4] DAOD data for the northern tropical Atlantic, over the period of 1982-2010, is available at http://trane.evsc.virginia.edu/Data.html.

Sahel (rain gauge) precipitation anomalies are monsoon season averages (JJASO) and cover the period 1982–2009[5]. The precipitation anomalies are referenced to a 1950–1979 base period and are in units of cm/month.

Persistence in Atlantic Dust Cover

Several long-term data sets show that Atlantic dust cover varies on decadal to monthly time scales (Chiapello et al. 2005, Prospero and Lamb 2003, Mukhopadhyay and Kreycik 2008, Evan and Mukhapadhyay 2010). In particular, over the last 30 years Atlantic dust cover has steadily declined, with dustiness in the 1980s almost double that of the first decade of the 21st century (Figure 1). This decline is likely part of a larger multidecadal oscillation in African dust outbreaks (e.g., Prospero and Lamb 2003, Mukhopadhyay and Kreycik 2008), and should not be interpreted to imply that dust values will continue to decline indefinitely.

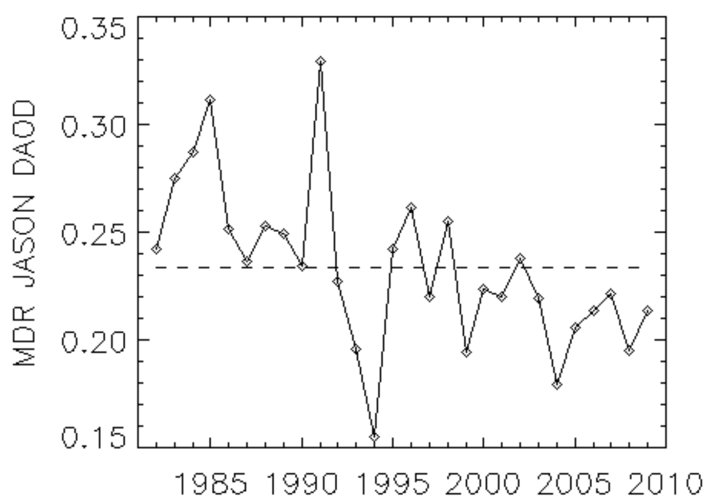

Figure 1 Time series of Atlantic dust optical depth averaged over the MDR for the months of July–November. The dashed line indicates the mean MDR JASON DAOD over this period. High dust cover in 1991 is likely an artifact of aerosols from the Pinatubo eruption that are not properly accounted for. Low dust cover in 1994 may result from spotty satellite coverage this year. The seasonal cycle of dust was removed before JASON averages were calculated.

There is skill in predicting MDR JASON DAOD using 1) MDR JASON DAOD values from the previous year, and 2) May MDR DAOD from the current year, although much of this skill comes from the downward trend in Atlantic dust cover observed since 1985 (Figure 1). However, there is reason to believe that a persistence forecast is useful; primarily because periods of elevated dust (like in the early 1980s) exhibited large positive dust anomalies in the spring and summer months that lasted for several years. Therefore, a persistence forecast may be a fair indicator of the onset of a period of anomalously high (or low) dust activity.

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[5] Sahel precipitation data and description from http://www.jisao.washington.edu/data_sets/sahel/

Relative to the last 27 years MDR dust during the 2009 hurricane season was close to the long-term average (0.5 standard deviations *below* the mean), and May 2010 dust cover was 0.5 standard deviations *above* the long-term May-average (2010 March and April MDR DAOD values were also around 0.5 standard deviations above the long-term means of the respective months). Therefore, there is no indication from persistence that 2010 hurricane season MDR DAOD will be anomalously strong or weak.

Previous Year Sahel Rainfall

Monsoon season precipitation over West Africa is well-known to be negatively correlated to Atlantic dust cover during the boreal summer months *of the following year* (Prospero and Lamb, 2003; Mukhopadhyay and Kreycik, 2008). Therefore, based on this relationship there should be some predictability in hurricane season dust cover. However, at least over the last 30 years, the statistically significant correlation between summertime dust and previous year precipitation is largely a result of the downward trend in dust cover and upward trend in precipitation, and the statistical significance of the correlation between the two time series when those trends are removed from each is a meager 90%. This is not to say that the relationship between dust and precipitation is non-physical, but only that its utility is only realized on multi-year time scales. Nevertheless, a very large wet or dry anomaly during the previous year would likely be a good indicator of dust cover during the 2010 hurricane season, where responses by vegetation cover to rainfall would then alter the amount of dust lifted from the surface to the atmospheric boundary layer (see Goudie and Middleton 2006 for a thorough description of the relationship between vegetation cover and atmospheric dust).

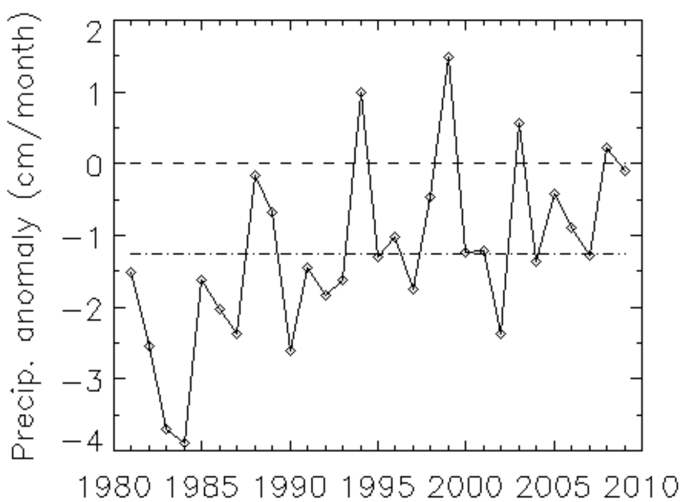

Figure 2 Time series of June–October Sahel Precipitation for the period 1981–2009. Data is in units of precipitation anomalies (cm/month), normalized to a 1950–1979 base period (dashed line). The average precipitation anomaly for the 1981–2009 period is indicated by the dash-dotted line. More details on the construction of the Sahel precipitation index can be found at http://www.jisao.washington.edu/data_sets/sahel/.

The 2009 Sahel monsoon-season (June–October, JJASO) precipitation anomaly was near zero, or equal to the long-term mean (Figure 2). Considering that Sahel precipitation anomalies were on the order of -2 to -4 cm/month during the early 1980s (when Atlantic dust cover was twice that of the last 5-10 years), the normal precipitation levels of 2009 seem to indicate that dust during the 2010 hurricane season will also be near the long-term average. However, over the last 30-years the average JJASO Sahelian precipitation anomaly is -1.2 cm/month (relative to the 1950-1979 base period), so that 2009 precipitation levels are anomalously positive relative to the time period over which we have satellite-based observations of Atlantic dust cover (Figure 1).

The correct way to interpret the importance of near-normal 2009 Sahelian precipitation levels is not completely clear. But it is probably more relevant to think of the precipitation anomalies in terms of the 1981–2009 mean, since this is the period (plus one year) over which we are considering dustiness. Therefore, the near-zero 2009 precipitation anomaly is one standard deviation above the 1981–2009 average. Either though linear regression or by equating a one standard deviation *increase* in precipitation to a one standard deviation *decrease* in dust cover (from the 1982–2009 JASON DAOD mean), the 2009 preciptation anomaly suggests that 2010 hurricane season MDR dust levels will be one standard deviation below average.

Conclusions

It is possible that Atlantic dust cover can both directly and indirectly alter Atlantic tropical cyclone genesis and intensification, and therefore a forecast of Atlantic dust cover may be useful for predicting seasonal hurricane activity. Based on persistence, dust cover during the 2010 hurricane season will be near normal. Based on previous-year Sahel precipitation, dust cover during the 2010 hurricane season will be below-normal. It is not possible, using our current data, to determine which factor is more important in governing summertime dust cover. While more sophisticated statistical techniques could be used to squeeze out some certainty in the dust forecast, errors in the satellite data and uncertainty in the methods for estimating the dust product would deem the results of a more-involved data manipulation effort tenuous.

Therefore, based on the available data, I suggest that Atlantic dust cover during the 2010 hurricane season will be average to one standard deviation below-average. The other years in which JASON MDR DAOD fell into a similar range were: 1992, 1993, 1997, 1999–2001, 2003, and 2005–2009. I also note that there is variability in African dust outbreaks on decadal to hourly time scales, and it is important to keep in mind that normal to below-normal summertime dust cover does not imply a steady level of weak dust storms being advected from West Africa. In other words, there may be periods (days, weeks, a month) during this hurricane season of very high and/or very low dust activity.

Those interested in monitoring daily dust activity are encouraged to utilize the NRL/Monterey Aerosol website (http://www.nrlmry.navy.mil/aerosol_web/). In addition, the northern tropical Atlantic data set of dust optical depths I use here are available online (http://trane.evsc.virginia.edu/Data.html). I will be updating these estimates periodically throughout the 2010 hurricane season.

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