The influence of desertic aerosols on tropical cyclones

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1. Introduction

Saharan dust that crosses periodically the Atlantic in the air layer between 1000 and 5000 meters (Saharan Air Layer hereafter referred to as SAL) may play a role on the genesis and the evolution of tropical cyclones. As suggested in recent studies (Dunion and Velden, 2004, Evan et al., 2006), the presence of dust may inhibit the formation and the development of tropical cyclonic disturbances. Indeed, the SAL constitutes a dry layer and its presence usually coincides with the presence of a mid-level jet, that enhances vertical shear. Further, it modifies the radiation amount at surface level by reflecting and absorbing a part of the incident solar radiation and also induces a strong temperature inversion thus inhibiting convection. These air mass characteristics (dry warm stable layer) tend to inhibit cyclogenesis and cyclonic development. However, the influence of other periodical climatic phenomena (El Nino, climatic cycles, etc.) on the formation and production of tropical cyclones may mask the effect of the SAL. This introduces some ambiguity in the conclusions of studies that attempt to determine the influence of the SAL on cyclonic development.
The work presented here constitutes an attempt to check the inhibitive role of the SAL on cyclogenesis and cyclonic evolution by using the satellite measured TOMS absorbing aerosol index values and corresponding tropical cyclone observations for the 1979-2006 period.

2. Methodology

Similarly to Evan et al. (2006), we consider in this study a tropical North Atlantic box within 0-30N and 15W-60W latitude and longitude limits representing the area over which we collect data for dust and tropical cyclone days, over the period August 20 through September 30. During this time period, more than half of all North Atlantic tropical cyclone activity occurs. The TOMS absorbing aerosol index value (http://toms.gsfc.nasa.gov/aerosols) I and the number of pixels P (1°latitude x1.25°longitude) with I equal or larger than 10 have been used as an indicator of the presence of Saharan dust over the Atlantic. For each day, the mean I value and the corresponding P value are combined in order to obtain a modified aerosol index C value (C=I x P)., representative of both the area covered and the amount of dust.
The number of tropical cyclone days (http://www.weather.unisys.com) are defined as the number of days during which at least one named cyclonic perturbation is present in the concerned Atlantic box. Note that, for the given time period, the yearly number of named cyclonic disturbances (TS) is proportional to the yearly cyclonic day number (CD.

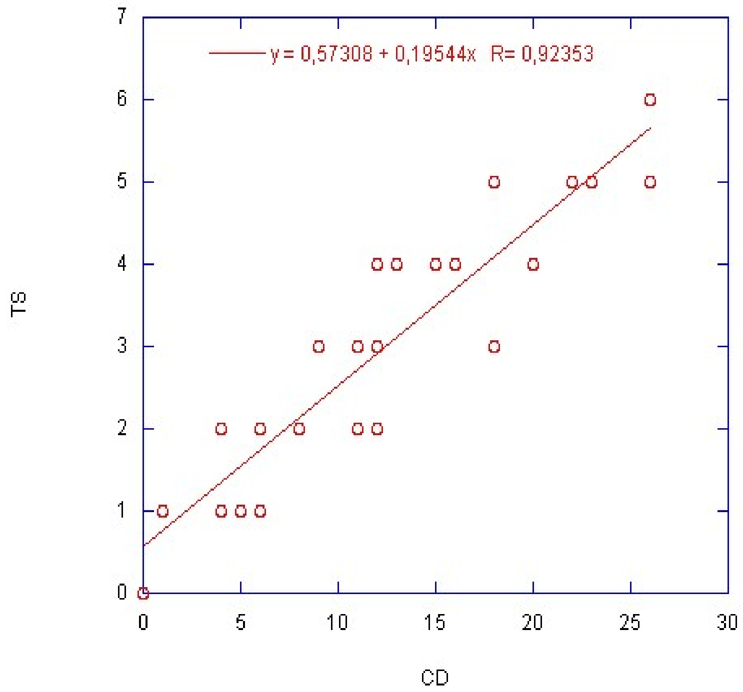


Fig.1 : Number of yearly named cyclonic perturbations (TS) present in the 0°-30° N/15°-60° box versus the corresponding cyclonic days (CD), in the time lapse 20 August-30 September, between 1979 and 2006.

This is shown in Fig.1, whereby TS is very well correlated to CD, thus allowing the use of one or the other parameter indifferently to describe the cyclonic activity in the considered Atlantic box.

First, the behavior of the yearly CD number has been studied in relation to the corresponding yearly mean modified aerosol index.C. Then, the daily positions of each cyclone of the climatological data set have been projected on the TOMS aerosol index map of the corresponding day, in order to make a statistical evaluation of the possible dependence of hurricane formation and intensity on the presence of desertic aerosols.

3. Data and processing

The aerosol index I values are available for the different time lapses : 1979-1993 (TOMS -Nimbus 7, n7t), 1996-2005 (TOMS-EP-PEGASUS-XL, ept) and 2005-today (OMI-Aura, omi).

The I values from 2002 to 2004 appear to be abnormally high compared to the values obtained during the previous years. This overestimation is confirmed when comparing the ept and omi C index values for the time period during which ept and omi measurements overlap (09 September 2004-31 December 2004), as may be seen in Fig 2. The proportionality between these two series of values gives some confidence to the qualitative trend of the corresponding time series.

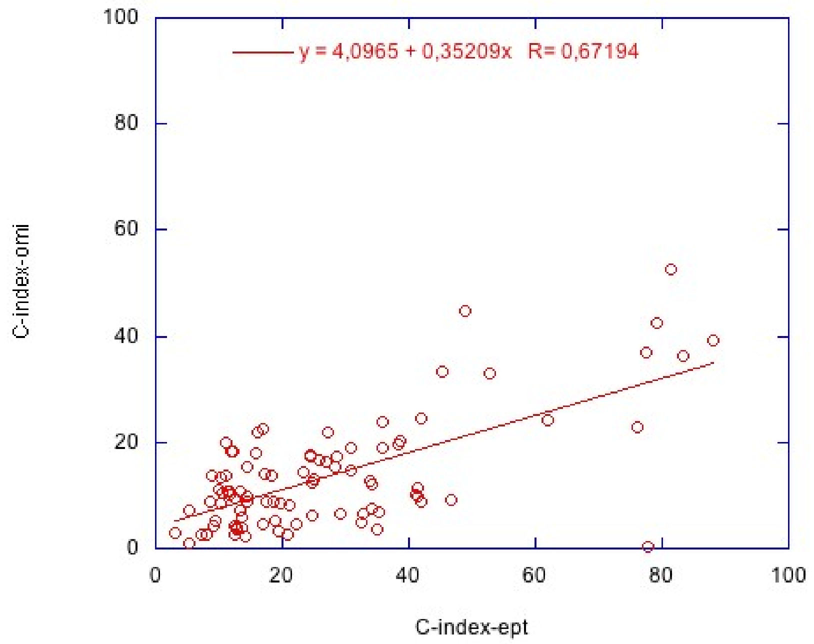


Figure 2 : C-index omi versus C-Index ept for 2004.

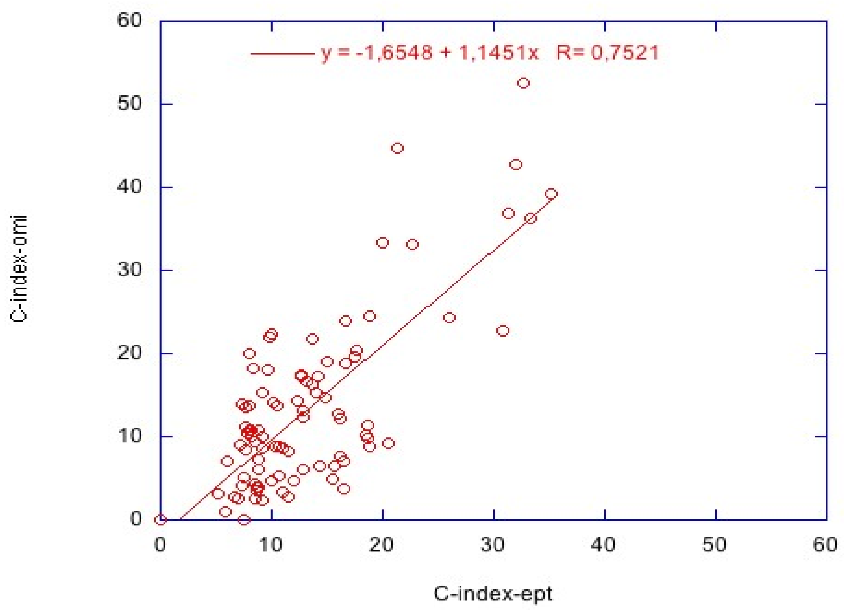


Figure 3 : C-index omi versus corrected C-index ept for 2004 overlap period.

Assuming that omi (more recent) correctly restitutes the values of these indices, the ept overestimation could be as large as 100%. In order to ensure a pertinent correction for the ept I and P values for the 2002 - 2004 period, the regression line equation given in Fig. 2 has been used to calculate the C values that should have been determined by ept, during these three years, if the latter had a quantitative behavior similar to the omi behavior. The results of this correction are shown in Fig. 3 for the 2004 overlap period.

4 Data analysis and discussion

The average (between August, 20 and September, 30) C-index values have been calculated for each year between 1979 and 2007. Figure 4 presents the C-index time series for this time lapse (note the absence of data from 1993, to 1995 due to unsuccessful launch of the Pegasus-XL satellite). The years with low, moderate and high dust concentrations are indicated in Table 1. These years are in a relatively good agreement with the low, moderate and high dust concentrations years as determined by Chiapello et al. (2005), using yearly TOMS dust optical thickness data over the tropical North Atlantic.

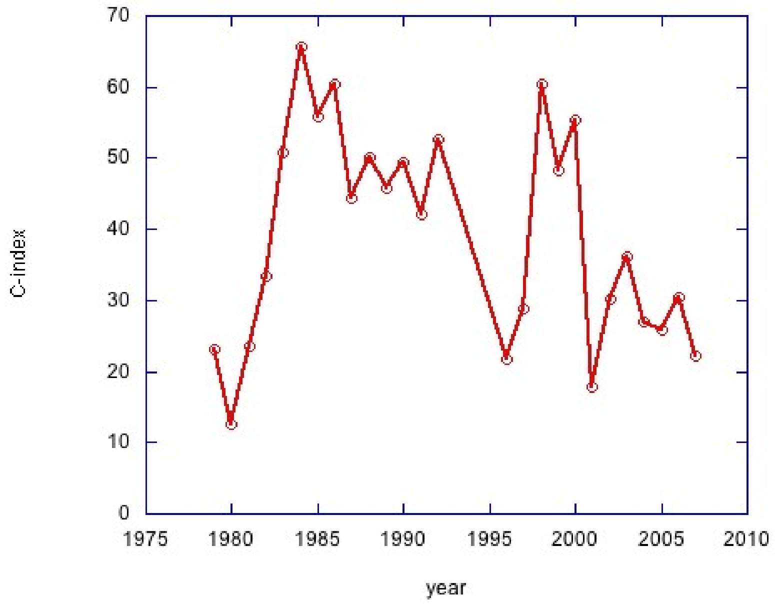


Figure 4 : Mean C-index time series from 1979 to 2007.

Table 1. Years corresponding to low, moderate and high dust content for the time period between August, 20 and September, 30.

High dust concentration years	1983, 1984, 1985, 1986, 1987, 1988, 1989, 1990, 1992,1998, 1999, 2000
Moderate dust concentration years	1982, 1991, 1997, 2002, 2003, 2004, 2005, 2006
Low dust concentration years	1979, 1980, 1981, 1996, 2001, 2007

Further, the mean modified aerosol index C. behavior has been examined in relation to the cyclonic day number behavior.

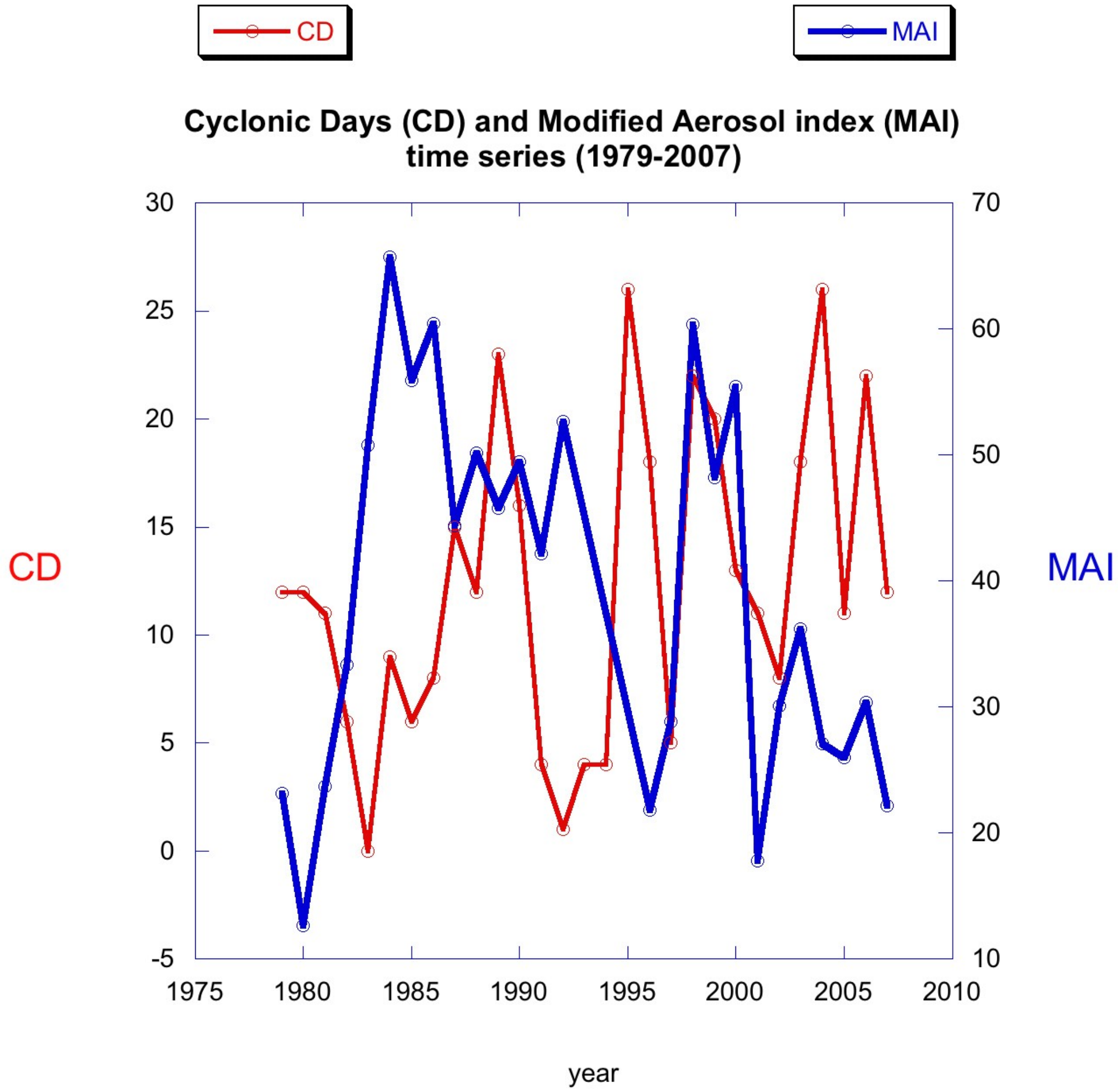
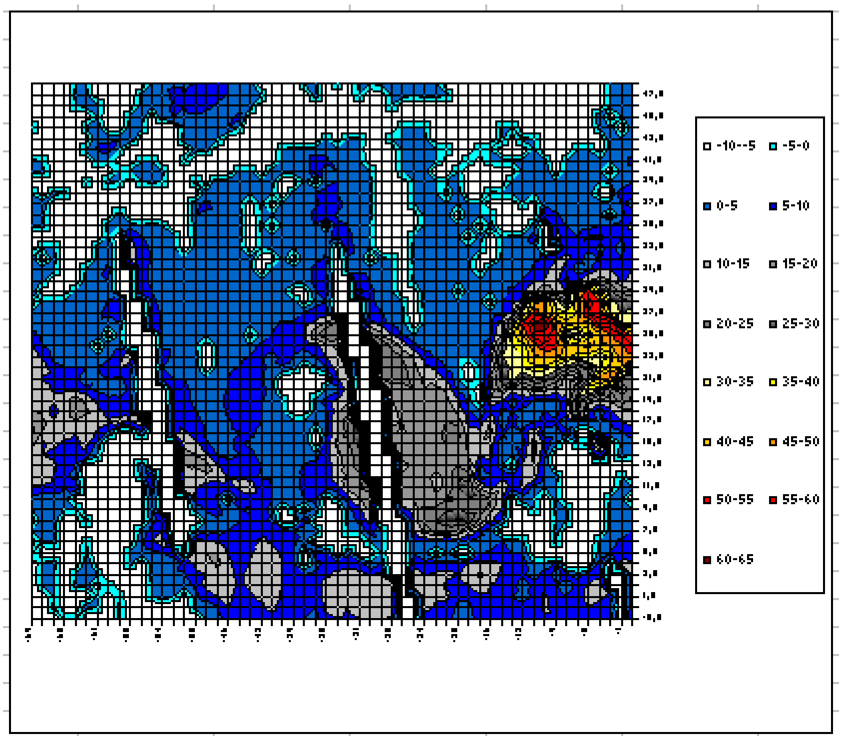


Figure 5 : Time series of yearly number of cyclonic days (CD) and modified aerosol index C (August 20 - 30 September) from 1979 and 2007.

As may be seen in Fig 5 , that shows the time series of these two parameters, there is a negative correlation between CD and the modified aerosol index C between 1979 and 1997 and as from 1998, these two series of values appear more positively correlated than negatively. Note that El Nino years corresponding to years with low cyclonic activity have not been removed. Time series of running means (3 years and 5 years) were also performed and show the same trend in the data. This behavior attenuates the conclusions of previous works that tend to confirm a negative correlation between CD and dust covered surface.
Then, for the 78 tropical cyclones that crossed the chosen Atlantic box between 20 August and 30 September from 1979 to 2007, i.e.344 cyclonic days, the different daily positions of each cyclone was projected on the TOMS aerosol index map of the corresponding day. As an example, Figure 6 shows the different positions of Debby (24 August 2006) on the corresponding OMI aerosol index (I) map.



Tropical Storm DEBBY 24 August 2006

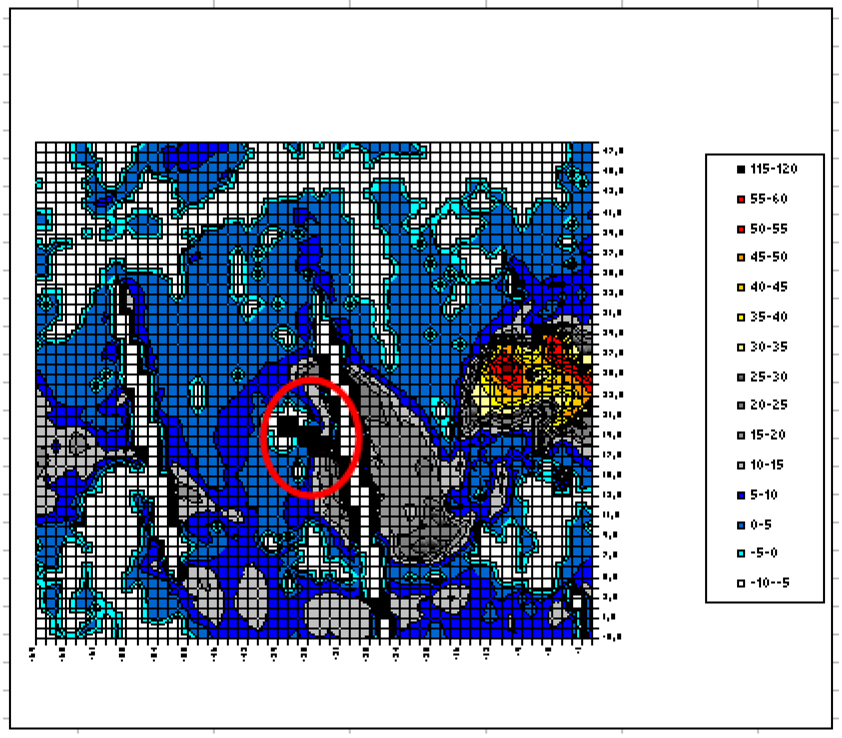


Figure 6 : Different positions of Debby (24 August 2006) projected on the OMI corresponding aerosol index map.

On the 344 cyclonic days studied, the position of the cyclone coincides with certainty with the presence of desertic aerosols for 55 days (16%). Amongst the 78 studied cyclones (tropical storm and hurricanes), 71 were named in the studied tropical North Atlantic box between 20 August and 30 September, and only 18% were with certainty named in a region containing aerosols. Unfortunately, TOMS observations suffer from large uncertainties, partly due to possible cloud contamination. However, there is a high probability that 35% more tropical

cyclones were named in a region containing aerosols (TOMS AI error message on the TC position but presence of surrounding desertic aerosols), thus suggesting that up to half of the cyclones may have be named in a dusty region.
The role of aerosols on the intensity of cyclones, once they have been named, has also been studied and the results are summarized in table 2, whereby the unambiguous cases are separated from the ambiguous ones.

Table 2. Influence of desertic aerosols on tropical cyclone intensity

	Number of days with TC on desertic aerosols	Number of days with high probability of TC on desertic aerosols
No intensity change	26 (62 %)	39 (42 %)
Increase in intensity	11 (26 %)	38 (41 %)
Decrease in intensity	5 (12 %)	16 (17 %)

In both cases, we observe the same trend in the data. Tropical cyclones in a dusty region tend mainly to either remain with the same intensity or increase in intensity., in opposition with the common belief that dust reduces cyclone intensity.

5. Conclusion

This work constitutes an attempt to study the role of the SAL on the genesis and the evolution of tropical cyclones in the tropical North Atlantic basin.
The relative agreement between the years with low, moderate and high dust concentrations as determined by this analysis and those determined by Chiapello et al. (2005) attests for the validity of the modified aerosol C-index .
The behavior of the cyclonic day number as a function of the dust cover and amount shows that the influence of the SAL on tropical cyclones may be some times negative, thus decreasing the number of observed storms and sometimes positive. A possible explanation of this dual influence could be the negative role of the SAL on cyclogenesis and the null or positive role of the SAL on already formed cyclones. In the first case (cyclogenesis), the atmospheric characteristics (radiative amount reaching the surface, important shear, presence of a mid-level jet) in presence of SAL do not favor convection and consequently cyclonic development. In the second case, the presence of dust entrained inside the cyclonic system and acting as CCN may inhibit the early development of warm precipitation thus favoring convection and consequently enhancing the intensity of the system. Further studies are necessary in order to confirm or to infirm such speculations.

Acknowledgments .Funding for this study was obtained from the Interreg IIIB program (Guadeloupe-European commission) and the authors wish to thank the regional and European authorities.

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