IAC ETH Institute for Atmospheric and Climate Science

Possible Influences of dust on Hurricanes

Sebastian Bretl[1], Philipp Reutter[2], Christoph Raible[3], Sylvaine Ferrachat[1] and Ulrike Lohmann[1]

1) Institute for Atmospheric and Climate Sciences, ETH Zürich, Switzerland
2) Institute for Atmospheric Physics, Johannes Gutenberg University, Mainz, Germany
3) Climate and Environmental Physics and Oeschger Centre for Climate Change Research, University of Bern, Switzerland

ETH Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

Contact:
Sebastian.Bretl@env.ethz.ch

Introduction

Tropical cyclones (TCs) belong to the most extraordinary and dangerous events in nature. They can devastate wide areas and cause damage to nature and human.

Fig. 1:
Hurricane Katrina, source: NOAA

A subject of increasing interest is the possible effect of aerosols on TCs, specifically of mineral dust on hurricanes in the North Atlantic. However, studies that include simulations of dust and hurricanes are quite rare. This study aims at investigating possible implications of dust on the frequency and intensity of hurricanes. Therefore we perform simulations with the recent version of the general circulation model ECHAM6-HAM.

The role of the Saharan air layer (SAL)

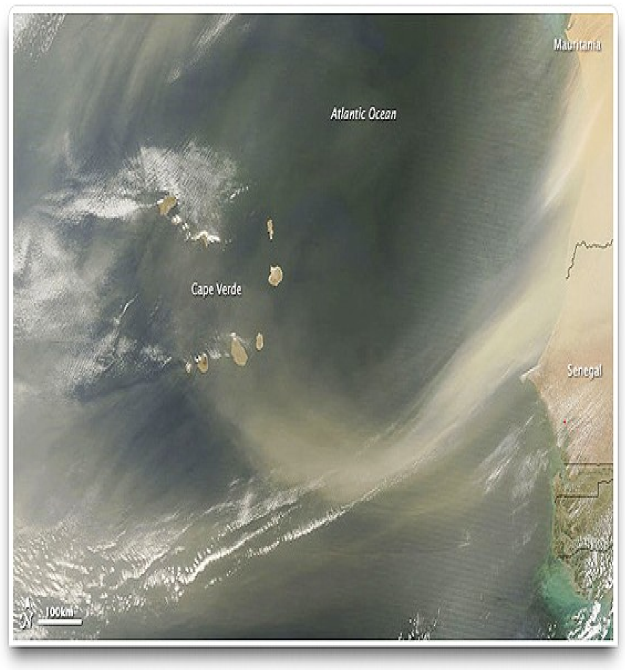

Fig. 2:
Dust plumes off Western Africa, picture taken by MODIS, source: http://www.satnews.com/cgi-bin/display_image.cgi?1994288896

The intense heating of air passing over the Sahara between June and November establishes a deep mixed layer, extending up to 7 km. This dust-laden air occasionally spreads out and moves above the denser, moist marine air of the North Atlantic. According to the current state of research, the SAL can decrease the intensity of a hurricane by the following mechanisms:

1.) It can intrude dry air into the vortex.
2.) The dust absorbs solar radiation and hence stabilizes the atmosphere.
3.) The SAL midlevel jet can increase the local vertical wind shear.

Radiation effect of dust

When dust is present, more solar radiation is scattered and does not reach the surface. Fig. 3 shows the difference of a simulation with dust being radiatively active to one with dust being radiatively passive.

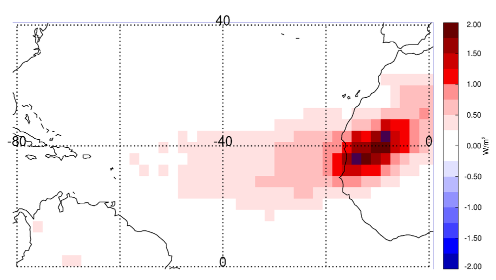

Fig. 3
Radiation effect (shortwave radiation at top of atmosphere - surface) of dust for the year 2000

Model: ECHAM6-HAM-M7D

All present and future simulations are performed with the general circulation model ECHAM6, coupled to the aerosol model HAM with a 1-moment microphysical scheme. Due to computational reasons, a simplified version of HAM will be used (HAM-M7D). Hereby only dust is prognostic, all other aerosol species contained in HAM are prescribed.

a) Future simulations

Past model studies (e.g. Bengtsson et al., 2007) have shown that too coarse resolutions do not simulate a realistic frequency of TCs. Therefore, we will use a spectral resolution of T255, which corresponds to a horizontal resolution of 0.5°x 0.5°.

b) Current simulations

To test its performance, a 10-year simulation of ECHAM6-HAM-M7D in T63 is compared to a control simulation of the regular ECHAM6-HAM. This was conducted in free mode. Tests of HAM with modified scavenging parameters are performed for one year by nudging the model towards ERA-Interim reanalyses in 2000, 2005 and 2006.

ECHAM6-HAM (control simulation) vs. ECHAM6-HAM-M7D

The modifications of HAM towards HAM-M7D are only minor. Nevertheless, the dynamics of the new model need to be tested. As already small changes in the initial settings can cause a significant difference in the meteorology, both simulations comprise the average of the years 2002-2011. In this study, only the influence of dust in the North Atlantic Hurricane Season is of interest, therefore solely June-September are taken into account. Figs. 5-10 show the dust burden, zonal wind in three and relative humidity in two levels for both simulations. Figs. a) and b) give the absolute values of the control run respectively of HAM-M7D while figs. c) denote their difference.

Dust Burden

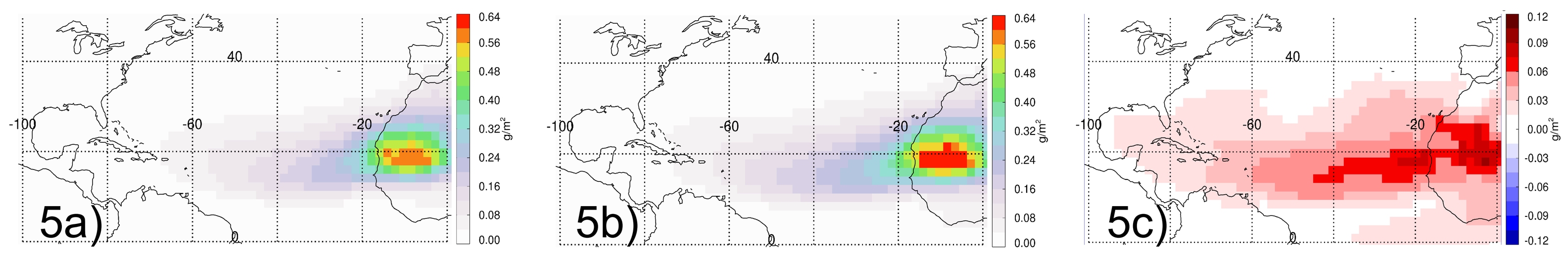

Fig. 5a-c
Dust burden of control run, HAM-M7D and difference HAM-M7D – control run.

Figs. 5 reveal an increase in the dust burden of HAM-M7D of approximately 5-20%, depending on the region. This is due to the following mechanism: After being emitted in the insoluble modes of HAM, sulfuric acid is attached to dust ("aging"), this enhances the wet deposition of dust. However, as dust is the only interactive species in HAM-M7D, it will remain insoluble and therefore stay longer in the atmosphere than usual. To keep dust approximately as long in the atmosphere as in HAM, this effect is counteracted in HAM-M7D with an increase of the scavenging parameters of the insoluble modes in HAM-M7D. As dust emissions in HAM are rather uncertain compared to observations (Stier et al, 2005), the remaining differences are tolerable.

Zonal Wind (850 hPa)

Zonal Wind (550 hPa)

Zonal Wind (200 hPa)

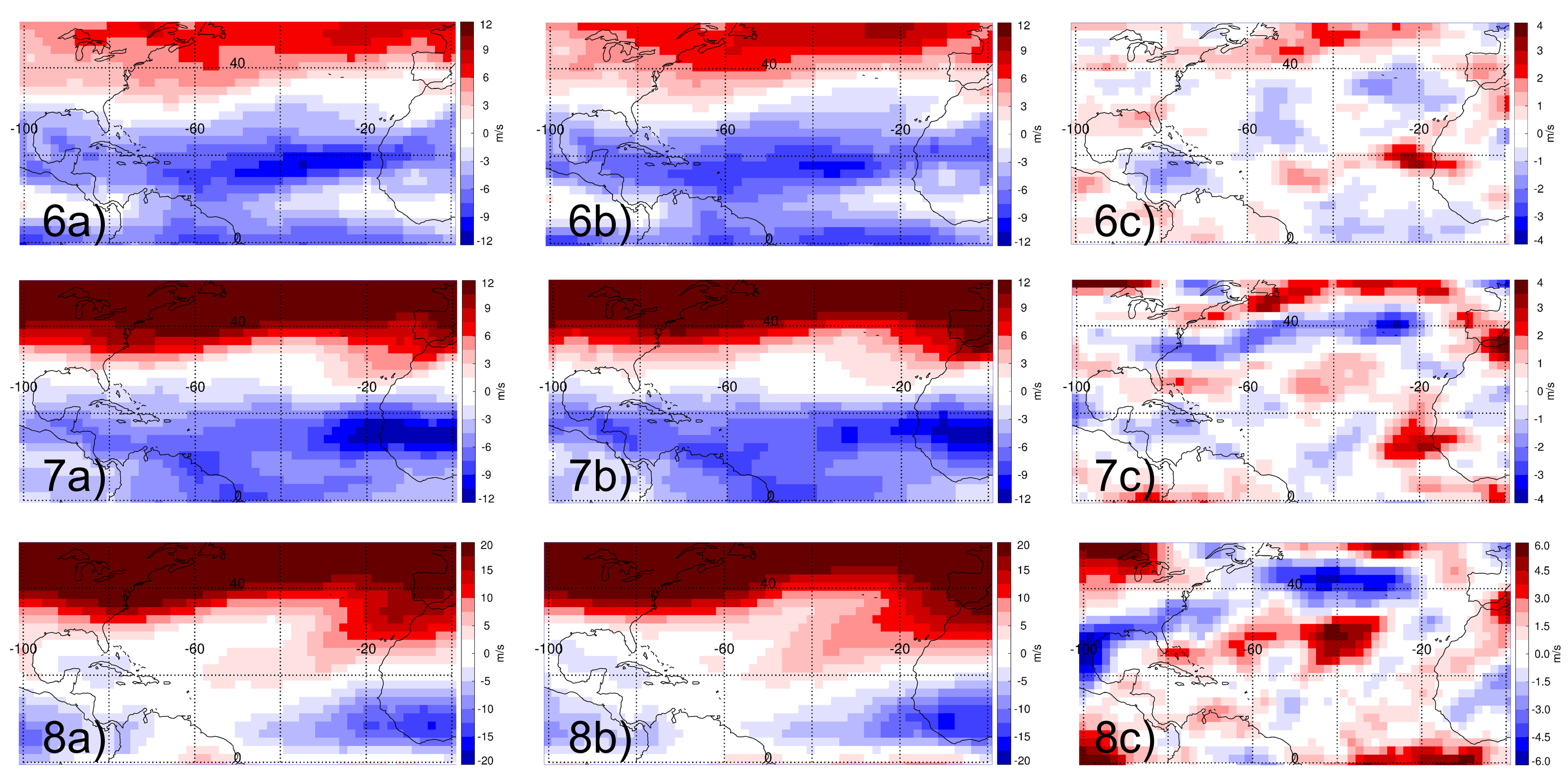

Fig. 6a-8c
Zonal wind in three levels of control run, HAM-M7D and difference HAM-M7D – control run. Note the difference in the color bars for 200 hPa.

The zonal wind is a good indicator of the general circulation (figs. 6 to 8). The pattern in the two simulations is very similar over the North Atlantic as well as globally (not shown). However, the lack of the radiative effects of the non-dust aerosols causes slight differences of the zonal wind and the relative humidity in some regions (figs. 9, 10).

Relative Humidity (850 hPa)

Relative Humidity (550 hPa)

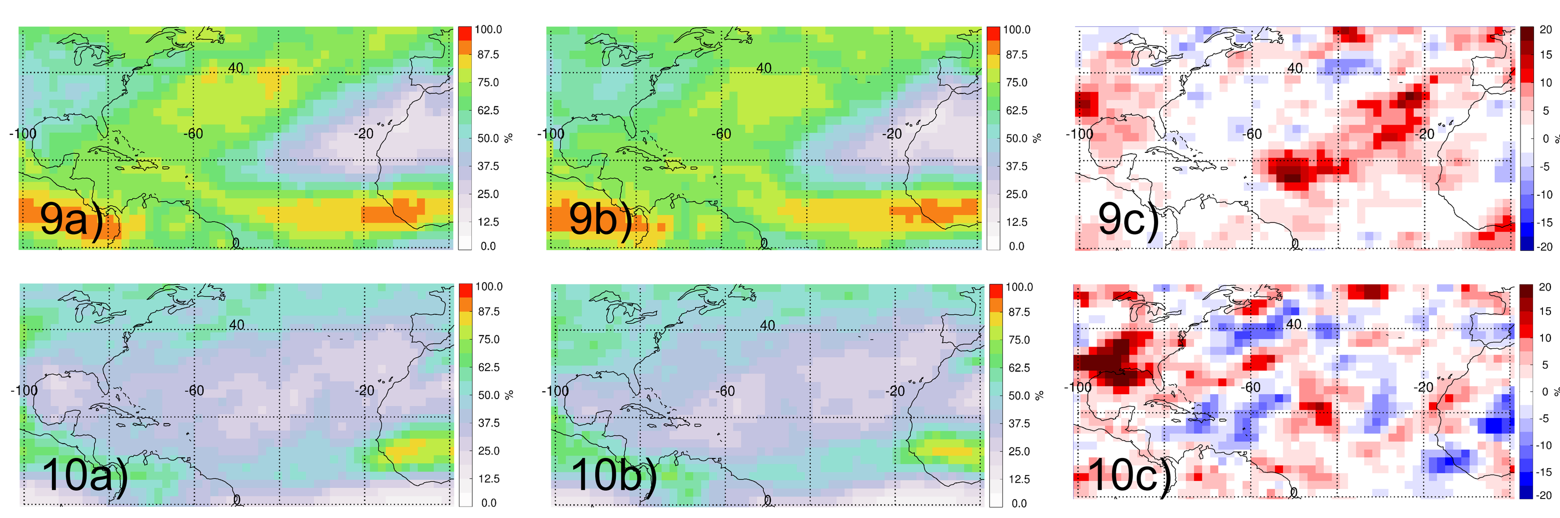

Fig. 9a-10c
Rel. humidity in two levels of control run, HAM-M7D and difference HAM-M7D – control.

Conclusion/Outlook

The comparisons of zonal winds and relative humidities show rather small changes. Therefore it is unlikely that hurricane activity in HAM-M7D will differ significantly from HAM. As hurricane activity in T63 is significantly decreased compared to higher resolutions, this question cannot be answered with these tests. In future T255-simulations, hurricanes in ECHAM6-HAM-M7D will be compared to ECHAM6, in which no active dust is present. To distinguish between changes in hurricane frequency and intensity due to changes in dynamics and presence of dust, these simulations will be analysed detailed.

References:

Bengtsson et al., 2007: *How may tropical cyclones change in a warmer climate*, Tellus, 59A, 539-561
Stier et al., 2005: *The aerosol-climate model ECHAM5-HAM*, ACP, 5, 1125-1156