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THE RELATION BETWEEN AEROSOL OPTICAL DEPTH AND LIGHTNING FROM THE TROPICS TO THE MID-LATITUDES

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1. INTRODUCTION

The influence of atmospheric aerosol particles on the development and evolution of cloud hydrometeors and cloud properties has been a subject of a deep research for many years. It was shown that aerosols can have a positive or a negative effect on cloud properties and on the formation of precipitation, depending on the meteorological conditions and on aerosols properties (e.g. Rosenfeld et al. 2008, Koren et al. 2012).

Recent studies that used satellite data indicate that aerosol particles have an influence on lightning density and distribution (Altaratz et al. 2010, Yuan et al. 2011). It is known that changes in the aerosol amount and properties affect drops, mixed-phase and ice particles size distributions, as aerosols serve as cloud condensation nuclei (CCN) and ice nuclei (IN). These changes affect various microphysical and dynamical processes, like condensation and evaporation rates, latent heat release, collision-coalescence efficiency, riming efficiency and others (Rosenfeld et al., 2008). It affects the formation and properties of clouds hydrometeors throughout the cloud, and the cloud convective intensity and thus impact the non-inductive charging process, which is the main charging mechanism in clouds (Takahashi 1978, Saunders 1993, Saunders 2008).

Recent studies indicate that for a certain range in aerosol loading values there is a positive correlation between aerosol amount and lightning activity (Altaratz et al. 2010). In the present study the relation between aerosol optical depth (AOD) and lightning is explored for several AOD categories.

2. METHODOLOGY

The data of aerosol optical depth (AOD) was registered by the Moderate Resolution Imaging Spectroradiometer (MODIS) on Aqua sun-synchronous satellite. Lightning density was recorded by the World Wide Lightning Location Network (WWLLN) developed through collaborations between research institutions across the globe to provide real-time locations of cloud to ground lightning strokes. The current network includes 40 stations which detect very low frequency radiation (3-30 kHZ) with an efficiency larger than 10% (35%) for lightning currents stronger than ±35 kA (-130 kA) (Abarca et al., 2010). The time of group arrival of VLF radiation from at least five stations is used to determine the location of each lightning stroke.

In this study the relation between lightning detected between 12:00pm and 3pm local time and AOD registered at 1:30pm local time during the year 2007 is examined. Grid resolution was 3º x 3º and the study area was bounded between latitudes 60ºS and 60ºN.

3. RESULTS AND DISCUSSION

The average lightning density was calculated for three AOD categories (AOD=0.07±0.07, AOD=0.17±0.03 and AOD=0.3±0.1) with the same average number of samples in each group in a grid box. For several large regions of the world, the increase in AOD implies increase in lightning density, as shown in Fig. 1. The correlation between both variables is stronger for continental regions than for maritime ones, although some maritime coastal regions also show a significant correlation.

The increase in flash density as a function of AOD is especially pronounced for the Amazon, Western Atlantic, Central Africa, Central Europe and Northwestern Asia (Fig. 2). Standard deviation of flash density is very significant since the regions selected in this study cover large fraction of continents.

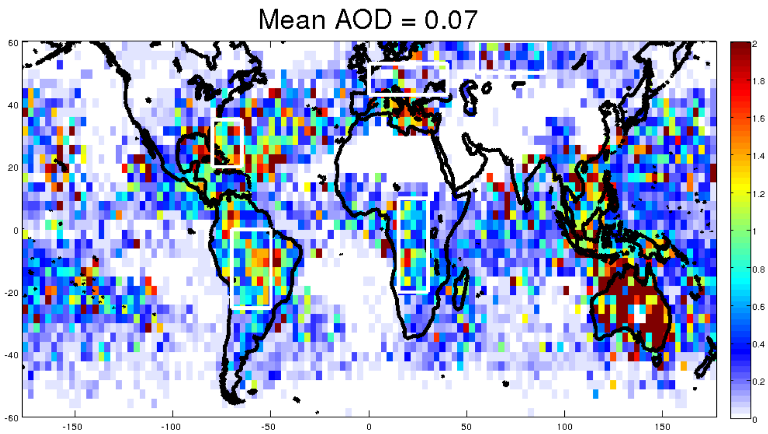
Western Atlantic region is an example of a large coastal area where flash density increases with AOD.

Other maritime coastal regions where a similar relation is observed are: eastern Pacific close to the Mexican coast (Kucienska et al., 2012), Caribbean Sea, eastern Atlantic close to Central Africa coast, Mediterranean Sea, some coastal regions of Australia, Indonesia, China etc. Most oceanic regions located far from the coastlines do not show correlation between AOD and lightning density. These areas exhibit small AOD variations and little electrical activity and for most of these regions there are almost no data on lightning for the highest AOD category days.

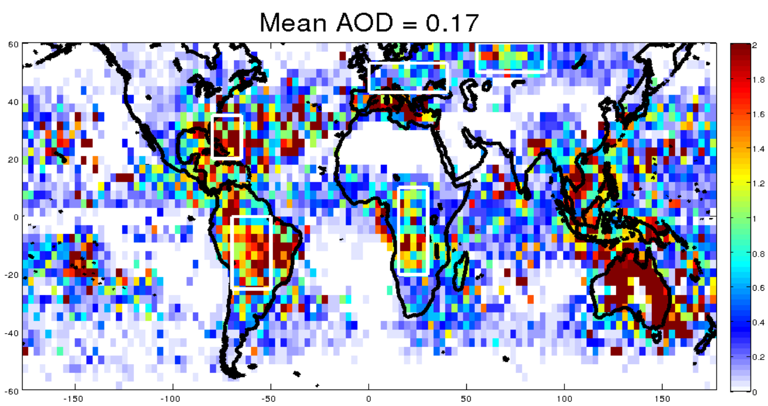
Over the Northwestern Asia region (Fig. 2e), the lightning density increases with AOD for AOD < 0.33, and decreases for higher AOD values. Over the Amazon (Fig. 2a) the increase of lightning with AOD is observed for AOD < 0.27. These findings are similar to that of Altaratz et al. (2010) who studied lightning response to smoke from Amazonian fires and observed lightning density increase with AOD, for AOD < 0.25 and a decrease for higher AOD values. It was suggested that the radiative effect of absorbing aerosols that heat their atmospheric layer and cool the surface, stabilize the atmosphere and reduce the surface moisture fluxes. It leads to a reduction of the cloudiness (Koren et al., 2004) and suppressed convection and electrical activity. The effect of aerosols on cloud development does not depend only on total aerosol loading but also on particle size distribution and chemical properties (e.g. Kucienska et al., 2010). Avila et al. (1999) for example observed that the size distribution of supercooled cloud droplets has an influence on the sign and the magnitude of graupel charge. Therefore it can be expected that the form of the curve of flash density as a function of AOD would be time and space dependent.

Fig. 3 shows differences between flash density recorded on days with moderate AOD (0.3) and low AOD (0.07). In case *a)* days with and without lightning were taken into account, while in case *b)* only days with lightning were included in the averages. The inclusion of days without lightning makes sense when it is hypothesized that a variation in aerosol loading can make a difference between the presence and the absence of lightning activity. The electric field that develops in thunderclouds must exceed a certain critical value in order to produce lightning discharge. Since aerosol affect many of the microphysical and dynamical processes related to charge separation in clouds it can be assumed that the aerosol loading value can make the difference between thunderclouds and clouds that produce no electrical activity (or weak activity). This critical aerosol loading value would be a function of other variables that influence cloud electrification (like the CAPE value for example).

a)



b)



c)

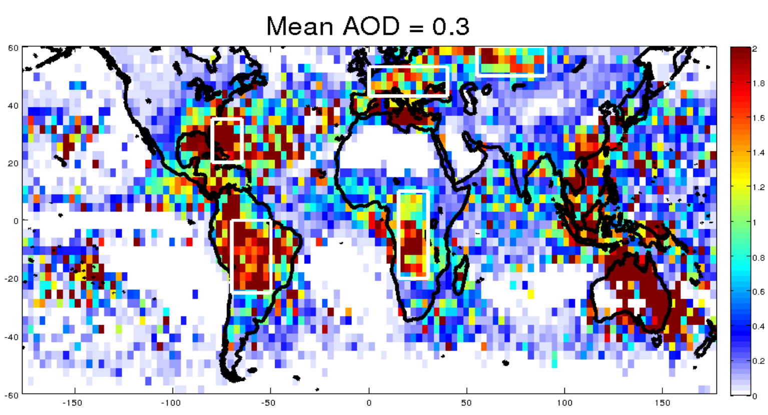


Figure 1. Lightning density [flashes /deg^2 /hour] for AOD=0.07 (a), AOD=0.17 (b) y AOD=0.3 (c).

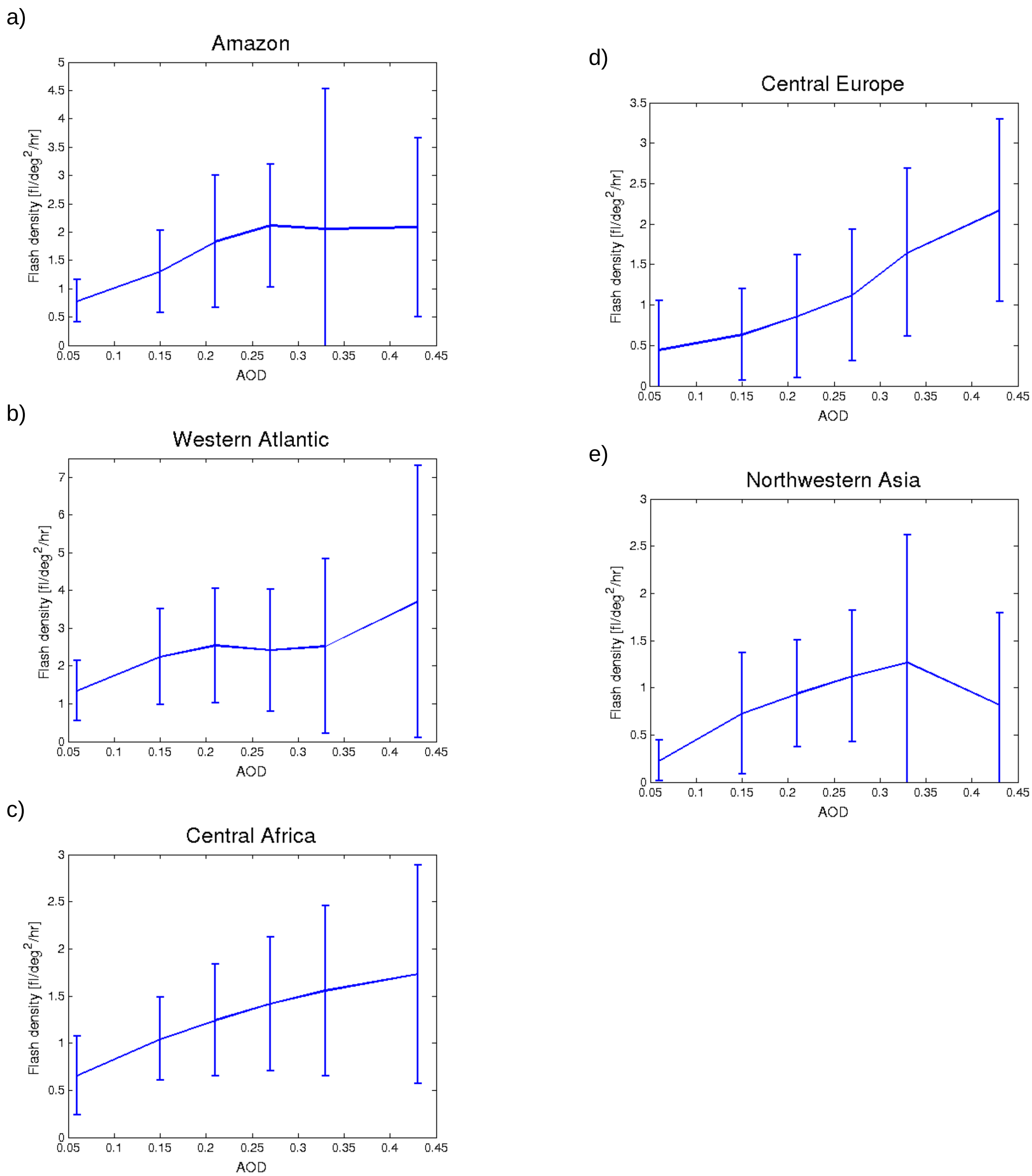
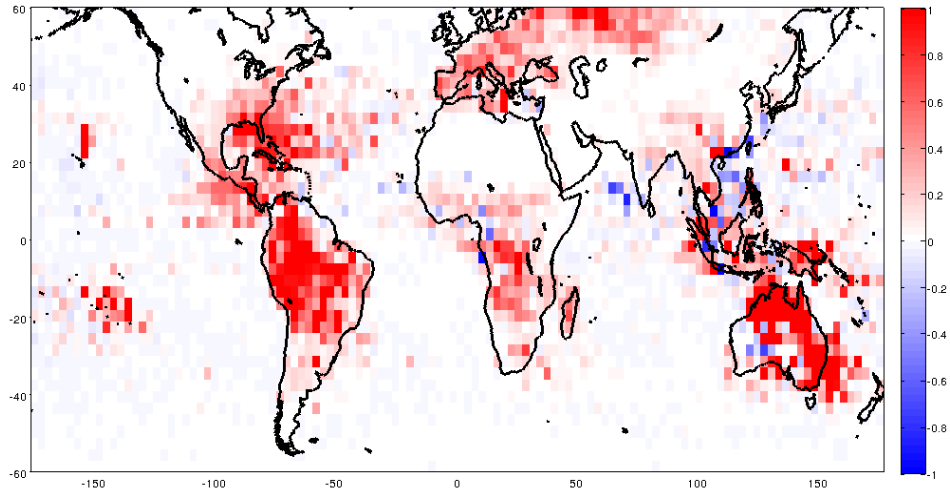


Figure 2. Relation between lightning density and AOD for 5 selected regions.

For both cases the differences between lightning density registered on days with moderate and low AOD are clearly positive over the continental regions. Over most of the oceanic regions located far from the coastlines, an increase in AOD can imply an increase or a decrease in flash density, as shown in Fig. 3b. About 70% of all grid squares show positive differences between lightning density recorded on days with moderate and low AOD, as shown in the Fig. 4a and 4b. In the case *a)*, which includes days with and without lightning, the histogram is much narrower than in the case *b)* where only days with lightning are taken into account.

This study is done for the whole year 2007, however the results are similar when each season is studied separately. Positive correlations between AOD and lightning may be due to meteorological conditions (should be checked in a future study), which can influence both variables in a similar way, or due to the aerosol impact on lightning. This research is complementary to that of Koren et al. (2012) who found similar relationships between AOD and rainfall from the tropics to the mid-latitudes.

a)



b)

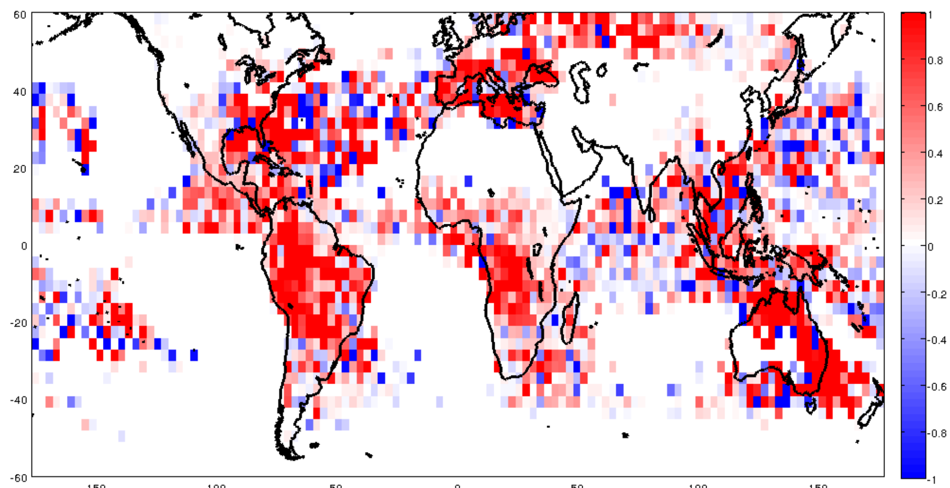


Figure 3. Differences between mean flash densities [fl /deg^2/hr] registered on days with mean AOD=0.3 and mean AOD=0.07. In case *a)* the averages include all days of 2007 that correspond to selected AOD categories, while in case *b)* only days with positive flash density are taken into account.

a) b)

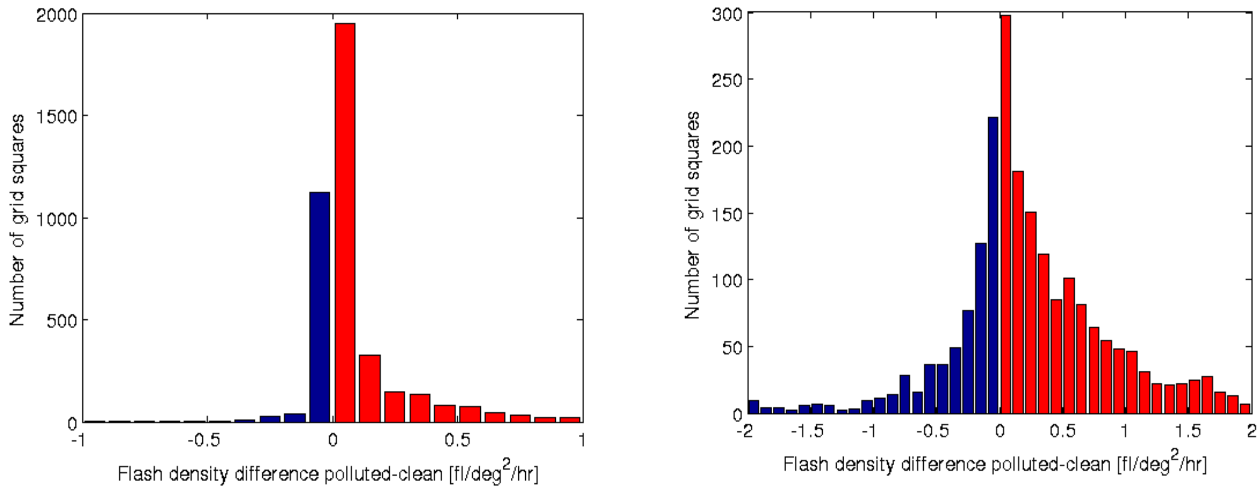


Figure 4. Histograms of the differences between mean flash densities registered on days with mean AOD=0.3 and mean AOD=0.07. In case *a)* the averages include all days of 2007 that correspond to selected AOD categories, while in case *b)* only days with positive flash density are taken into account.

4. CONCLUSIONS

Lightning density is positively correlated with AOD for very large continental regions and some coastal maritime regions of the Earth, which implies a possible influence of aerosol particles on the electrical activity of thunderclouds. This hypothesis has a strong physical basis, since aerosol particles that serve as CCN and IN influence the formation of cloud droplets, ice crystals, graupel particles and the cloud convective intensity which have an essential role in electrification processes.

Further studies are required in order to verify whether the correlation between AOD and lightning could be due to meteorological conditions that may influence both variables in a similar way. This work is in preparation.

5. ACKNOWLEDGMENTS

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