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Atmospheric Chemistry and Physics
Discussions

# *Interactive comment on* "Meridional distribution of aerosol optical thickness over the tropical Atlantic Ocean" *by* P. Kishcha et al.

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1 Motivation and importance of our study (acp-2014-540 by Kishcha et al.)

Hemispheric asymmetry in cloud fraction (CF) and aerosols could lead to hemispheric imbalance in surface solar radiation. Consequently, analyzing hemispheric asymmetry in CF and aerosols is essential for understanding climate formation and its changes. Previous studies showed that, over the global ocean, there is hemispheric asymmetry in aerosols and no noticeable asymmetry in cloud fraction (CF). This contributes to the hemispheric balance in surface solar radiation. We chose the tropical Atlantic because it is characterized by significant amounts of Saharan dust dominating other aerosol species over the North Atlantic. We wished to find out if the meridional CF distribution



remains symmetrical in the presence of such strong hemispheric aerosol asymmetry.

In the summer months, along the Saharan Air Layer, significant cloud cover (up to 0.8 – 0.9) was observed, based on MODIS CF data. This cloud fraction along SAL together with clouds over the Atlantic Inter-tropical Convergence Zone contributes to the hemispheric 20% CF asymmetry. This could lead to the hemispheric imbalance in surface solar radiation over the tropical Atlantic. The phenomenon of hemispheric 20% CF asymmetry over the tropical Atlantic Ocean has not been reported so far, to our knowledge.

2. Satellite data used

In the current research, we did not study cloud microphysics and aerosol – cloud interaction. We consider that MODIS Level 3 data are suitable for averaging AOT and CF over significant territories or for determining their meridional distribution. Note that there are almost a thousand peer-reviewed publications based on satellite data provided by the NASA Giovanni interface (http://disc.sci.gsfc.nasa.gov/giovanni/additional/publications).

We used MODIS Level 3 CF and AOT data to study meridional distribution of aerosols and cloud fraction. In our previous study (Kishcha et al., JGR, 2009), we used MODIS CF and AOT data from the Giovanni NASA interface. Our results have not been disproved. The current study is a continuation of the above-mentioned previous research. In order to compare the results obtained over the tropical Atlantic with those from the previous study, the same data from the Giovanni had to be used.

3. MODIS CF contamination by heavy dust loading

Collection 5 of MODIS-Terra monthly daytime cloud fraction data used are derived from the standard cloud mask product based on the cloud mask algorithm MOD35 (Ackerman et al., 1998, Frey et al., 2008). In heavy dust loading situations, such as dust storms over deserts, MOD35 may flag the aerosol-laden atmosphere as cloudy

(Ackerman et al., 1998). During dust storms over deserts, observed AOT values range from 2 to 5 (e.g. Alam et al., 2014). However, over the tropical North Atlantic in July, strong AOT exceeding 1 is a rare phenomenon. To illustrate the frequency of AOT occurrence within certain intervals of AOT values, Fig. 1a represents a histogram of AOT observed over the tropical North Atlantic in July, 2010, based on MODIS Level 3 AOT daily data. July 2010 was chosen because AOT, averaged over the tropical North Atlantic, was maximal compared to AOT in other July months, during the 10-year study period. One can see that AOT mainly did not exceed 1. A similar situation can be seen over the latitudes with SAL presence (12N – 24N) (Fig. 1b). Therefore, the effect of MODIS cloud fraction contamination by heavy dust loading cannot essentially contribute to averaging CF over the tropical North Atlantic. Consequently, given the large amount of available MODIS CF daily data over the 10-year study period, cloud fraction contamination does not account for the obtained hemispheric CF asymmetry.

4. Physical mechanisms for the formation of significant CF along SAL

We consider that the most likely physical mechanism for the formation of significant cloud cover along SAL is as follows: meteorological conditions below the temperature inversion at the SAL base include significant atmospheric humidity and the presence of marine aerosols. The temperature inversion prevents deep cloud formation. On the other hand, these meteorological conditions are favorable for marine shallow stratocumulus cloud formation. As discussed in Section 4.5.1, there was a decline in dust AOT from zone 1 to zone 6 due to gravitational settling of dust particles. The number of settling dust particles decreases with the distance from the Sahara. Settling dust particles penetrate below the temperature inversion. Consequently, below the temperature inversion, aerosols consist of marine aerosols and dust particles. As known, aerosol species often combine to form mixed particles, with properties different from those of their components (Andreae et al., 2009). Mineral dust particles are known to be not very efficient CCN, unless they are coated with soluble materials (Andreae et al., 2009). Levin et al. (2005) showed that dust transport over the sea could lead to sea-salt coat-



ing on dust particles. This coating could modify the dust particles into effective CCN. Being below the temperature inversion and acting as efficient CCN, Saharan dust particles coated with soluble material contribute to the formation of cloud cover. This physical mechanism, based on the indirect effect of Saharan dust on stratocumulus clouds below the temperature inversion, could explain the observed significant cloud cover (CF up to 0.8 – 0.9) along the Saharan Air Layer. Moreover, the observed decrease in CF along SAL from zone 1 to zone 4 can be explained by the above-mentioned spatial decline in the number of settling dust particles with the distance from the Sahara. The significant cloud fraction along SAL contributes to hemispheric CF asymmetry over the tropical Atlantic. In accordance with the above-mentioned mechanism of cloud formation along SAL, there are different cloud types over zones 1 – 4 on the one hand, and over zones 5 – 6 on the other hand. Over zones 1 – 4, we consider the presence of shallow stratocumulus clouds below the temperature inversion at the SAL base. These shallow stratocumulus clouds are characterized by limited precipitation. Over zones 5 – 6, we consider the presence of developed clouds capable of producing strong precipitation up to 110 mm month-1. As mentioned in Section 1 (Introduction), Saharan dust particles can influence the vertical temperature profile in the atmosphere directly by absorbing solar radiation. Aerosol absorption by Saharan dust may decrease cloud cover by heating the air and reducing relative humidity (the semi-direct aerosol effect) (Kaufman et al., 2005b, Johnson et al., 2004). So that there should be a negative correlation between dust loading and cloud fraction along SAL. However, this is not the case: both dust AOT and CF decrease with the distance from the Sahara (Figs. 8b and 9b). On the other hand, the presence of maximal dust AOT and CF over zone 1 provides us with additional evidence for cloud formation below the temperature inversion at the SAL base. When dust is located above the inversion and clouds are located below the inversion, dust absorption of solar radiation could not influence cloud cover below the inversion.

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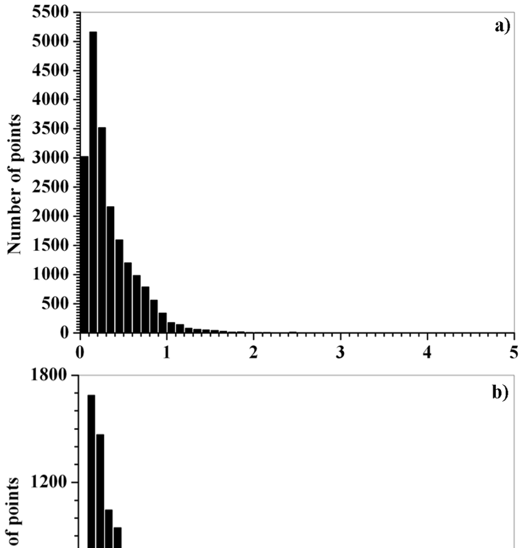


**Fig. 1.** The histogram of AOT in July 2010, based on MODIS L3 daily data 1 x 1 degr: (a) over the tropical North Atlantic (30N – 0N; 60W – 0E); (b) over the latitudes with SAL (12N – 24N; 60W – 0E).