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Aerosol indirect effect on warm clouds over South-East Atlantic, from co-located MODIS and CALIPSO observations

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In this study, we provide a comprehensive analysis of aerosol interaction with warm boundary layer clouds over the South-East Atlantic. We use aerosol and cloud parameters derived from MODIS observations, together with co-located CALIPSO estimates of the layer altitudes, to derive statistical relationships between aerosol concentration and cloud properties. The CALIPSO products are used to differentiate between cases of mixed cloud-aerosol layers from cases where the aerosol is located well-above the cloud top. This technique allows us to obtain more reliable estimates of the aerosol indirect effect than from simple relationships based on vertically integrated measurements of aerosol and cloud properties. Indeed, it permits us to somewhat distinguish the effects of aerosol and meteorology on the clouds, although it is not possible to fully ascertain the relative contribution of each on the derived statistics.

Consistently with the results from previous studies, our statistics clearly show that aerosol affects cloud microphysics, decreasing the Cloud Droplet Radius (CDR). The same data indicate a concomitant strong decrease in cloud Liquid Water Path (LWP), which is inconsistent with the hypothesis of aerosol inhibition of precipitation (Albrecht, 1989). We hypothesise that the observed reduction in LWP is the consequence of dry air entrainment at cloud top. The combined effect of CDR decrease and LWP decrease leads to rather small sensitivity of the Cloud Optical Thickness (COT) to an increase in aerosol concentration. The analysis of MODIS-CALIPSO coincidences also evidences an aerosol enhancement of low cloud cover. Surprisingly, the Cloud Fraction (CLF) response to aerosol invigoration is much stronger when (absorbing) particles are located above cloud top than in cases of physical interaction. This result suggests a relevant aerosol radiative effect on low cloud occurrence: absorbing particles above the cloud top may heat the corresponding atmosphere layer, decrease the vertical temperature gradient, increase the low tropospheric stability and provide favourable conditions for low cloud formation.

We also analyse the impact of anthropogenic aerosols on precipitation, through the statistical analysis of CDR-COT co-variations. A COT value of 10 is found to be the threshold beyond which precipitation is mostly formed, in both clean and polluted environments. For larger COT, polluted clouds show evidence of precipitation suppression.

Results suggest the presence of two competing mechanisms governing LWP response to aerosol invigoration: a drying effect due to aerosol enhanced entrainment of dry air at cloud top (predominant for optically thin clouds) and a moistening effect due to aerosol inhibition of precipitation (predominant for optically thick clouds).