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Partitioning aerosol optical depth between the boundary layer and the free troposphere

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Aerosols are short-lived (about a week) compounds in the atmosphere due to the efficient removal by dry and wet deposition in the boundary layer (BL) where a majority of the emission sources are located. As a consequence, most of the aerosol mass should be found in the BL and the aerosol optical depth (AOD) integrated over the atmospheric column should be dominated by the BL contribution. As a consequence, BL aerosols would most likely have the largest climate effect. However, aerosols advected to the free troposphere (FT) have a much longer residence time (typically a few weeks) than those in the BL, potentially inducing a more long-term effect on climate. Light-absorbing aerosols may in addition have an enhanced absorption, and thereby climate warming effect, if they are located above low-level reflective clouds. Light-absorbing aerosols above clouds may also modify below cloud formation and transformation. In this study, the global AOD has been retrieved using satellite observations from CALIOP (Cloud-Aerosol Lidar with Orthogonal Polarization) over a nine-year period (2007-2015) and partitioned between the BL and FT using BL heights obtained from the ERA-Interim re-analysis data. The results show that the vertical distribution of AOD does not follow the diurnal cycle of the BL but remains similar between day and night highlighting the role of a residual layer during night. The BL and FT contribute 71% and 29%, respectively, to the global AOD during daytime. The FT AOD contribution is larger in the tropics than at mid-latitudes which indicates that convective transport largely controls the vertical profile of aerosols, and the FT AOD contribution over oceans is governed by neighboring continents. According to the CALIOP aerosol classification, dust and smoke particles are the main aerosol types transported into the FT. Overall, the study shows that the fraction of AOD in the FT – and thus potentially located above low-level clouds – is substantial and should receive more attention when evaluating the radiative effect of aerosols in climate models.