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Impact of aerosol vertical distribution on aerosol direct radiative effect and heating rate in the Mediterranean region

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It is now well-established that aerosols cause an overall cooling effect at the surface and a warming effect within the atmosphere. At the top of the atmosphere (TOA), both positive and negative forcing can be found, depending on a number of other factors, such as surface albedo and relative position of clouds and aerosols. Whilst aerosol surface cooling is important due to its relation with surface temperature and other bio-environmental reasons, atmospheric heating is of special interest as well having significant impacts on atmospheric dynamics, such as formation of clouds and subsequent precipitation.
The actual position of aerosols and their altitude relative to clouds is of major importance as certain types of aerosol, such as black carbon (BC) above clouds can have a significant impact on planetary albedo. The vertical distribution of aerosols and clouds has recently drawn the attention of the aerosol community, because partially can account for the differences between simulated aerosol radiative forcing with various models, and therefore decrease the level of our uncertainty regarding aerosol forcing, which is one of our priorities set by IPCC. The vertical profiles of aerosol optical and physical properties have been studied by various research groups around the world, following different methodologies and using various indices in order to present the impact of aerosols on radiation on different altitudes above the surface. However, there is still variability between the published results as to the actual effect of aerosols on shortwave radiation and on heating rate within the atmosphere.
This study uses vertical information on aerosols from the Max Planck Aerosol Climatology (MAC-v1) global dataset, which is a combination of model output with quality ground-based measurements, in order to provide useful insight into the vertical profile of atmospheric heating for the Mediterranean region. MAC-v1 and the science behind this aerosol dataset have already been presented and its validity has been tested against satellite-based retrievals. A detailed spectral radiative transfer model (RTM), already used in a number of planetary and regional studies, has been used in the present study to calculate the vertically distributed aerosol direct radiative effects (DREs) and the associated aerosol heating/cooling profiles within the troposphere. Specific emphasis is given to assessment of the crucial issue of the differences between modeling the aerosol DREs using either columnar aerosol optical properties, as usually done, or vertically layered information on those properties, which is the state of the art and ideal practice. To address this problem, the following experiment has been performed: the same RTM has been used twice with the same meteorological conditions but in the first run (set1) columnar values for aerosol optical depth (AOD) have been used while using vertically distributed AOD in the second run (set2). In the second run vertically layered information for AOD is considered for 20 layers extending from the surface to 20 km a.m.s.l.. The vertical profile of AOD has been mainly based on ECHAM model. The aerosol DREs are computed at the Earth's surface, at TOA and at various levels in the atmosphere. Apart from AOD, the model also requires single-scattering albedo (SSA) and asymmetry parameter (ASY) in 18 different wavelengths, which are obtained by linear interpolation from the available wavelengths in HAC. The comparison between the obtained two sets of DRE (set1 and set2) reveal small, but notable differences which vary from one place to another. Within the atmosphere, the difference -averaged over the four seasons - ranges from -0.3 to 1.7 Wm-2 with a mean value of 0.32 Wm-2. Given the fact that the average column-integrated DREAtm values for the entire Mediterranean region based on columnar aerosol optical properties is 11.44 Wm-2, there is an average variance of 3.7 %, which locally could get to 14.9 %. Differences between the columnar and the vertically layered versions of the model also exist for DRE(TOA) and DRE(NetSurface) calculations.