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Global profiles of the direct aerosol effect using vertically resolved aerosol data

Marios Bruno Korras Carraca (1), Vasilios Pappas (2), Christos Matsoukas (1), Nikolaos Hatzianastassiou (2), and Ilias Vardavas (3)

(1) Department of Environment, University of the Aegean, Mytilene, Greece, (2) Laboratory of Meteorology, Department of Physics, University of Ioannina, Ioannina, Greece, (3) Department of Physics, University of Crete, Heraklion, Greece

Atmospheric aerosols, both natural and anthropogenic, can cause climate change through their direct, indirect, and semi-direct effects on the radiative energy budget of the Earth-atmosphere system. In general, aerosols cause cooling of the surface and the planet, while they warm the atmosphere due to scattering and absorption of incoming solar radiation. The importance of vertically resolved direct radiative effect (DRE) and heating/cooling effects of aerosols is strong, while large uncertainties still lie with their magnitudes. In order to be able to quantify them throughout the atmosphere, a detailed vertical profile of the aerosol effect is required. Such data were made available recently by the Cloud-Aerosol Lidar with Orthogonal Polarization (CALIOP) on board the Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO) satellite. CALIOP is the first polarization lidar to fly in space and has been acquiring unique data on aerosols and clouds since June 2006. The aim of this study is to investigate both the vertically resolved geographic and seasonal variation of the DRE due to aerosols.

The vertical profile of DRE under all-sky and clear-sky conditions is computed using the deterministic spectral radiative transfer model FORTH. From the DRE, the effect on atmospheric heating/cooling rate profiles due to aerosols can also be derived. We use CALIOP Level 2-Version 3 Layer aerosol optical depth data as input to our radiation transfer model, for a period of 3 complete years (2007–2009). These data are provided on a 5 km horizontal resolution and in up to 8 vertical layers and have been regridded on our model horizontal and vertical resolutions. We use cloud data from the International Satellite Cloud Climatology Project (ISCCP), while the aerosol asymmetry factor and single scattering albedo are taken from the Global Aerosol Data Set (GADS). The model computations are performed on a monthly, $2.5^\circ \times 2.5^\circ$ resolution on global scale, at 40 vertical layers from the ground level up to 50 mb. This is the first study to our knowledge that provides vertically resolved all-sky DRE globally.

We find that the columnar global average value of the CALIOP optical depth at 500 nm is 0.0815. The DRE at the surface is -3.14 Wm^{-2} (net) and -3.82 Wm^{-2} (downwelling), at the top of the atmosphere it is -1.21 Wm^{-2}, and in the atmosphere 1.94 Wm^{-2}. As expected however, very large local and seasonal differences from these values are found if one focuses on specific locations and months. Preliminary results show that that there are notable differences in the DRE produced by our radiation transfer model with vertically resolved aerosol profiles compared with columnar values over some cloudy areas, depending on the aerosol height relatively to the clouds. We examine more closely the interplay of radiation fluxes between aerosol and clouds for a few interesting cases.