Abstract

Understanding the interactions between atmospheric aerosols and the evolution of the Planetary Boundary Layer (PBL) is paramount for human health, climate, and weather forecasting models. In this study, an Eddy-Diffusivity/Mass-Flux (EDMF) model is coupled with a radiative transfer model (RTM) to investigate the effects of aerosol optical properties on the growth and thermodynamics of the PBL, or the so-called Aerosol-PBL Interactions (API).

The developed model, called EDMF-AERO, is first validated against in-situ radiosonde (Meteomodem M20) and microwave radiometer (HATPRO G5) observations, showing satisfactory agreement. A sensitivity analysis was also performed on selected simulation parameters as part of a comprehensive study of the developed tool.

After the model verification stage, EDMF-AERO was used to confirm the dome and stove effects described in the literature for summer, spring/autumn, and winter solar conditions. Anomalous oscillations in PBLH forecasts reported in other scientific papers were also replicated.

Next, the dynamics of PBL growth and thermal structure changes were investigated as a function of aerosol extinction optical thickness at a wavelength of 500 nm τ_{500} and single scattering albedo ω_{520}. Based on these analyses, parameterization of PBL heating and growth rates was suggested. For the stove effect at extreme values of optical thickness $\tau_{500} = 1.5$ and single scattering albedo $\omega = 0.8$, PBL growth accelerates by up to $\sim 46\%$, and the PBL heating rate increases by $\sim 108\%$. For the dome effect at $\tau_{500} = 1.5$ and $\omega = 0.8$, the PBL growth slows down by $\sim 27\%$, and the GWA heats up $\sim 37\%$ slower.

A study of the isolated API components, known as "surface cooling"and "aerosol heating", was also performed. Based on these analyses, an estimate was made as to which component is stronger.

An additional case with an absorbing aerosol optical thickness $\tau_{500} = 0.18$ and high absorptivity ($\omega = 0.82$) was also investigated, based on data collected in 2014 near Świder, Warsaw.

Finally, the impact of API on the energy budget in PBL was analyzed.

The doctoral thesis aimed to investigate the impact of the optical properties of absorbing aerosols on the thermal structure and growth dynamics of PBL. This goal was achieved by conducting a series of analyses described above. One of the side effects of the work is the development of a fast and easy-to-use single-column numerical model called EDMF-AERO. Although it contains many simplifications, it realistically predicts the development of the convective boundary layer. Further development is planned to improve the parameterization of heat fluxes at the ground surface and the vertical distribution of aerosol.