Impact of Aerosol Contamination On Radiative Forcing to the Atmosphere Over Kyiv According to Lidar Campaign and Sun Photometer Observations

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Abstract

The report presents the results of aerosol observations by lidar and sun photometer in the atmosphere over Kyiv, Ukraine. The lidar campaign in Kyiv took place in July – September, 2015. The lidar observations were the first study of the aerosol particles altitude variations in the atmosphere over Kyiv. Also, lidar measurements were validated with the sun photometer of the AERONET network. Both instruments were located at the Main Astronomical Observatory of the National Academy of Sciences of Ukraine to avoid the impact of different meteorological conditions or the plume sources. Simultaneous lidar and sun photometer observations were chosen for analysis. The typical and anomalous values of aerosol optical thickness have been used for the radiative forcing calculation with the radiative transfer model GAME. The results were compared with the radiative forcing calculation by the AERONET tool. In addition, the annual trends of aerosol optical thickness and Angstrom Exponent are discussed.

Methods

➢The international network of automatic sun photometers AERONET (Aerosol Robotic NETwork) is one of the most advanced remote sensing monitoring networks in the world [1]. AERONET is operated by NASA (USA) and CNRS (France) and includes several hundred stations around the world. The tools of this network allow obtaining long-term series of the accurate aerosol parameters data, that can be used for the analysis of particle variations [2, 3, 4]. Kyiv station is located at the Main Astronomical Observatory of the National Academy of Sciences of Ukraine.

➢Atmospheric lidar (Light Detection and Ranging) is a remote sensing method that uses a pulsed laser for range and distance measuring to the Earth [5] or from the Earth to some obstacles. The lidar CIMEL370 was provided by the Laboratoire d'Optique Atmosphérique, Université de Lille 1 for field campaign in Kyiv for period July–September, 2015.

➢GAME (Global Atmospheric ModEl) is a radiative transfer code what is used for calculation of radiation flux and direct radiation forcing, which is formed by aerosol and gazes. The radiative transfer equation is accurately solved by algorithm DISORT (Discrete Ordinate Radiative Transfer) in GAME. Radiances, fluxes, and heating rate are calculated for each atmospheric level into the assumption of vertical inhomogeneous atmosphere [6]. The GAME code was provided by the Laboratoire d'Optique Atmosphérique, Université de Lille 1.

Results

The extinction coefficient describes the radiance attenuation due to scattering and absorption. Monthly changes in extinction coefficient are shown in Fig. 1. The lidar profiles were validated with AERONET Kyiv site observations. The sorted data were used for monthly extinction coefficient visualization (see Fig. 1) and calculation of the median of the extinction coefficient for each altitude. In this case, we get the average profile with less impact of anomaly values during high aerosol contamination as for peat fires at the beginning of September 2015. The results are shown in Fig 2.

The median calculation shows (see Fig 2.) that the extinction coefficient for aerosol particles in the atmosphere over Kyiv variates usually from 0 to 0.05 1/km in the altitude range from ground to 2 km. Anomalies in September connected with biomass burning contamination.

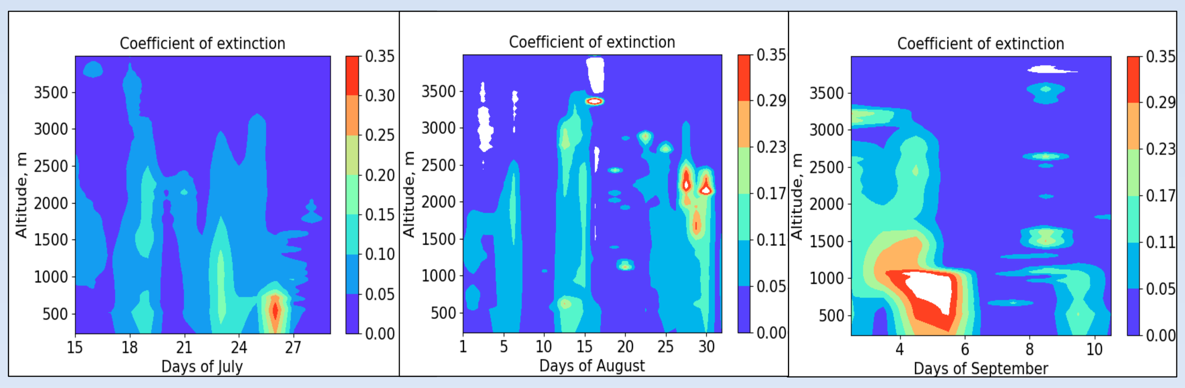

Fig. 1. Monthly changes of extinction coefficient based on lidar observations. July, August, and September 2015. Kyiv, Ukraine

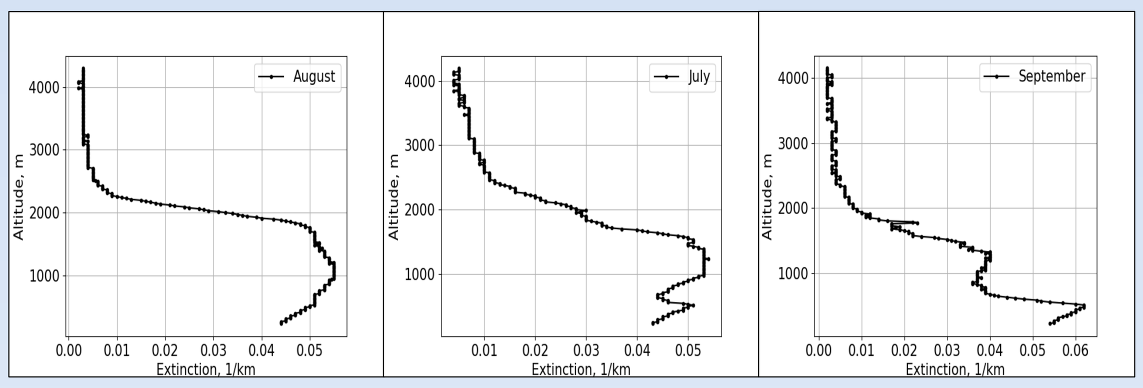

Fig. 2. The median of monthly extinction coefficient that based on lidar observations. July, August, and September 2015. Kyiv, Ukraine

Radiative forcing is defined as a perturbation caused by some atmospheric component into the difference between the solar radiation flux entering the climate system and the radiation flux of the Earth's atmosphere leaving it. The variations in this flow can be caused by changes in both input and output fluxes. These changes in the climate system caused by external factors produce the radiative forcing. Using the lidar and sun photometer measurements, the RF calculations were provided for the observed AOT values. For this purpose, the AOT values of 0.1. 0.4, 0.8 were used (see Fig. 3).

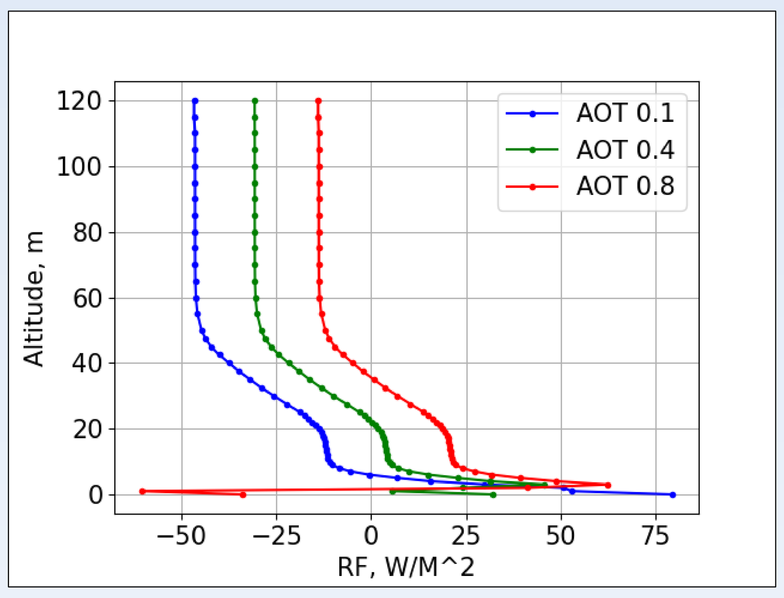

Fig. 3. Radiative forcing for the different observed AOT values over Kyiv AERONET site, Ukraine. Calculation made with algorithm GAME

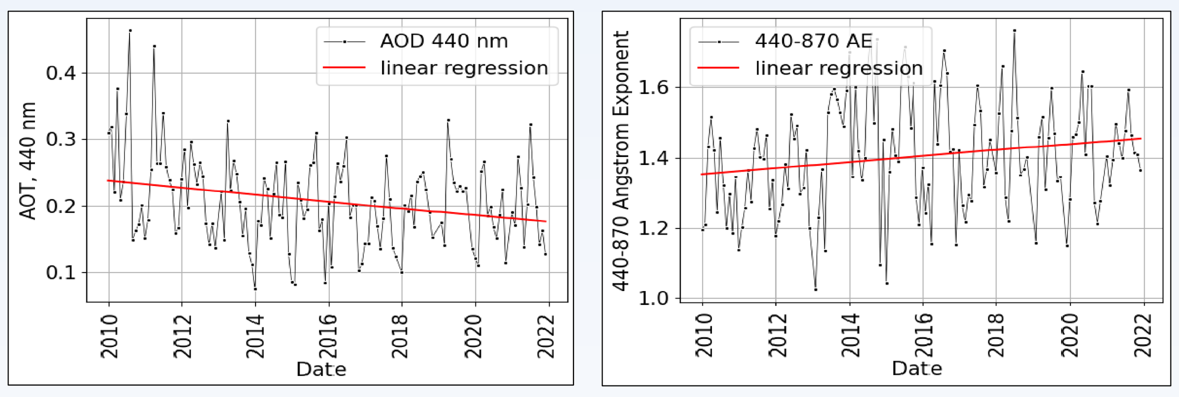

Fig. 4. The variations of Aerosol Optical Thickness and Angstrom Exponent during the 2010–2022 years. The AERONET Kyiv site.

For the last 12 years sun photometer the observed trends show the decreasing of Aerosol Optical Thickness and increasing of Angstrom Exponent (see Fig 4.). This result could be connected to the reduction of air contamination. However, the growing fine mode of aerosol particles shows about stronger impact of industry or/and biomass burning pollution.

Conclusion

This research considers the altitude distribution and properties of aerosols during the July–September lidar campaign in Kyiv, Ukraine in 2015. During the observation period, the burning of peatlands and forests impacted (at the beginning of September 2015) the atmosphere over the city and the Kyiv region. Using the data of lidar CE370 and sun photometer of AERONET Kyiv site observations, the aerosol properties: extinction coefficient, aerosol optical thickness, and Angstrom exponent, were studied for short-term (July–September 2015) and long-term periods (2010–2022 years). Radiative forcing by AERONET observations and GAME calculation were evaluated.

Acknowledgements

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