Offline AOD calculations based on LOTOS-EUROS for quick assessment of sensitivities of the optical properties of the atmosphere to assumed aerosol characteristics

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Introduction

Exposure to ambient PM2.5 (Particulate Matter with a diameter <2.5 µm) is estimated to have caused around 4.2 million premature deaths worldwide in 2019 [WHO,2022]. Naturally attention goes out to reducing and monitoring PM concentrations. Accurate ground based measurements of chemically and size resolved PM are challenging, expensive and therefore relatively scarce in time and space.

Satellite data is homogeneous and has large spatial coverage whilst containing information on atmospheric aerosol size (through angstrom exponent, AE) and amount (through Aerosol Optical Depth, AOD). This led to attempts to validate and improve Chemical Transport Model (CTM) based estimates of PM surface concentrations [Jin,2023].

With the upcoming launches of 3MI and SPEXone more remote sensing data of aerosols will become available. Both in the retrieval algorithms and CTMs assumptions are made on aerosol characteristics like hygroscopicity, refractive index and modal distribution to model aerosol optics. To optimally exploit remote sensing data it is crucial to harmonize these assumptions in a favorable way. For this purpose a tool to compute optical properties of the atmosphere from aerosol concentrations was developed that avoids unnecessary CTM calculations.

Methods

A simulation with the CTM, LOTOS-EUROS (LE) [Manders, 2017], was performed to computed atmospheric aerosol concentrations (dust, Sea Salt, SIA, EC, POM, PPM) over Europe for the summer (JJA) of 2019. The part of this CTM that computes aerosol optical properties of the atmosphere was translated into a python tool to make 'offline' AOD and AE computations from aerosol concentrations (fig 1).

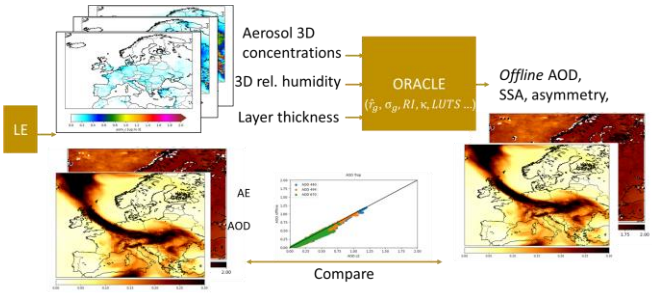


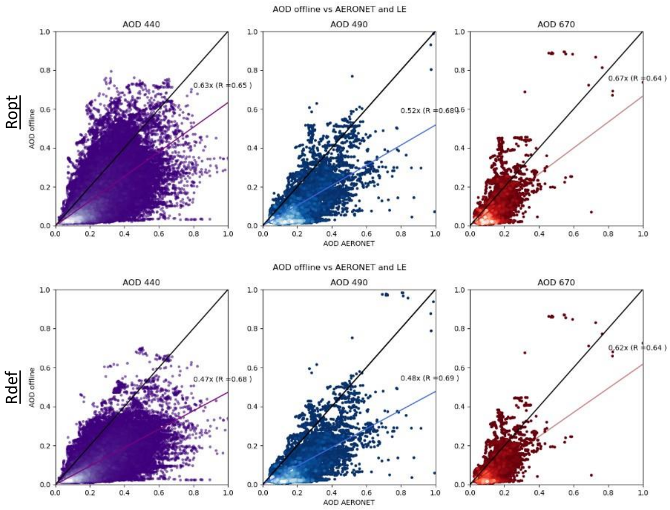
Figure 1. The 'offline' Optical Representation of Aerosol Concentrations in LOTOS-EUROS (ORACLE).

Subsequently, for the same period the geometric radius of the lognormally distributed particle number distributions were varied using a brute-force approach to give an optimal match with AERONET Version 3 Direct Sun Algorithm AODs.

Results

From simulated aerosol concentrations the AOD was computed at 440nm, 494nm and 670nm and compared with the direct LE equivalent. Both the online and offline AOD calculations give very similar ($\bar{R}^2 = 0.96$) results and mutual misrepresentation are negligible compared other uncertainties.

Optimizing the aerosol radii to match with AERONET observed AODs leads to an improved average slope with respect to using default radii (0.62 for default radii vs 0.69 for optimized radii) at the expense of a slightly deteriorated Pearson correlation (0.65 vs 0.63 respectively) as shown in figure 2.



Discussion

With ORACLE likewise explorations into:

- Aerosol size distribution ($\hat{r}_g$, σ_g)
- Aerosol dynamics (mixing state)
- Optimized properties of aerosols that influence their optical characteristics ($RI, \kappa,$ ...)

have been made and results will be presented at the conference. A similar tool is under development for the CAMS-IFS model.

References

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