Supplementary material

Table S1. Location of 29 AERONET stations in 10 European countries, the available number of daily AERONET measurements between 2010 and 2023, the percentage of retained collocations for both Terra and Aqua MODIS

Country	Station	Latitude	Longitude	Nr. AOD AERONET	% Terra MODIS	% Aqua MODIS
AU	Kanzelhohe_Obs	46.677	13.901	842	48.61	33.05
AU	Vienna_BOKU	48.237	16.331	957	60.47	48.22
AU	Vienna_UNIVIE	48.221	16.355	493	60.76	46.71
BG	Galata_Platform	43.044	28.193	1976	37.20	29.95
BG	Sofia_IEBAS	42.653	23.386	462	60.76	59.31
BY	Minsk	53.920	27.601	1435	59.41	59.72
EE	Toravere	58.264	26.466	1723	61.26	60.27
LT	Irbe_lighthouse	57.750	21.722	365	64.28	52.13
MD	Moldova	47.000	28.815	1465	61.92	67.40
PL	Belsk	51.836	20.791	1292	27.55	22.33
PL	Debrzyna_PULS	53.782	16.592	207	45.04	35.30
PL	POLWET_Rzecin	52.762	16.309	181	42.91	28.74
PL	Raciborz	50.083	18.191	1032	35.00	28.33
PL	Strzyzow	49.878	21.861	1061	56.91	45.53
PL	Warsaw UW	52.210	20.982	593	62.12	45.45
RO	Bucharest_Inoe	44.348	26.028	759	35.96	27.53
RO	CLUJ_UBB	46.768	23.551	1231	57.82	44.78
RO	Eforie	44.075	28.632	1106	43.65	37.02
RO	Gloria	44.599	29.359	1719	31.74	24.47
RO	Iasi_Loasl	47.193	27.555	1408	38.37	32.75
RO	Magurele_Inoe	44.348	26.030	1643	58.39	60.97
RO	Section-7_Platform	44.545	29.446	620	63.73	57.21
RO	Timisoara	45.746	21.227	970	52.38	40.48
SK	Poprad-Ganovce	49.035	20.322	1279	49.58	42.13
UA	Kyiv	50.363	30.496	1674	67.01	53.92
UA	Kyiv_AO	50.452	30.498	247	36.91	30.59
UA	Lugansk	48.570	39.364	60	46.39	39.81
UA	Martova	49.936	36.953	66	54.36	47.67
UA	Sevastopol	44.615	33.517	659	48.90	35.58

1. MODIS Terra and Aqua AOD difference across CEE, during the four seasons between 2010 and 2023.

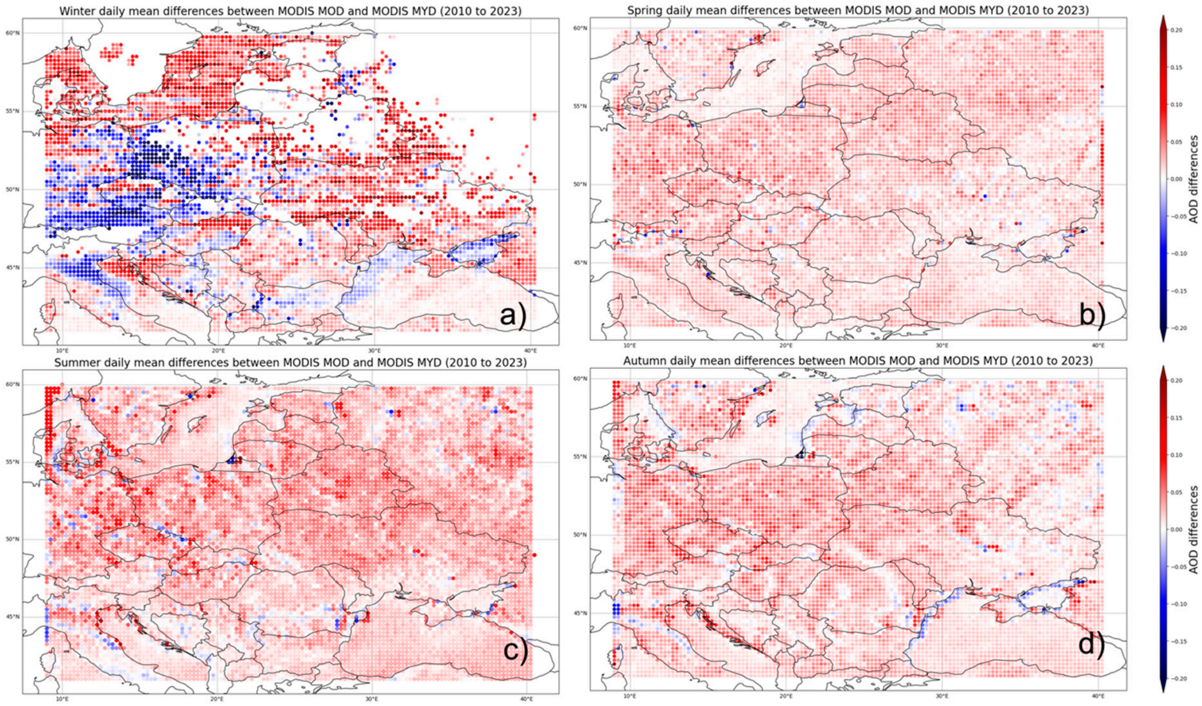

Figure S1. Spatial distribution of Aerosol Optical Depth (AOD) averaged difference from MODIS Terra and Aqua (MOD AOD – MYD AOD) over Central-East Europe for four seasons: (a) winter, (b) spring, (c) summer, and (d) autumn, between 2010 and 2023. The color bars indicate AOD difference values, with the cutoff at 0.2.

We analyzed the differences between MODIS Terra and Aqua for the 4 seasons, for the period 2010-2023, in the following plots. Figure S1 presents the spatial distribution of the difference of MODIS MOD AOD – MODIS MYD AOD. We notice the largest variability and AOD difference in winter followed by summer, autumn and lastly in spring the AOD differences are the smallest. In winter the number of measurements is low and the AOD values are small compared to other seasons, leading to larger biases and uncertainties in AOD retrievals for both instruments. In regions where the difference is negative, MODIS Terra (MOD) mean AOD is significantly lower than the AOD retrieved from Aqua, but also the number of retrievals is lower in Aqua (which influences the mean across season). In other seasons we observe discrepancies mainly on the coast and inland larger bodies of water (lakes, rivers), where the sediment masking leads to larger uncertainties.

2. Ångström exponent comparison and discussions

Figure S2 depicts a comparative analysis between the Ångström exponent products of MODIS Terra (a) and MODIS Aqua (b) at 440/675 nm and the corresponding AERONET AE values derived at 440/675 nm. The marginal histograms represent the data distribution in bins of 0.25, with the colour mapping indicating collocated MODIS AOD at 550 nm. Notably, while AERONET AE displays a reversed lognormal distribution, peaking at 1.5, the distribution of MODIS (both Terra and Aqua) does not conform to any established distribution due to the model-set nature of the AE values in look-up tables. It is observed in both cases that an AE of 1.5 corresponds to an AOD lower than 0.1, revealing a limitation in the MODIS algorithm. The MODIS AE parameter is obtained as a "derived" rather than a "retrieved" product of the retrieval algorithm and is typically considered unreliable in low AOD conditions, < 0.2 [48]. The Dark Target algorithm is known to have a poor performance when mixing fine and coarse aerosol models over land, resulting in clustered AE values [62,63]. Consequently, correlations between the MODIS AE and AERONET AE are suboptimal especially at transition points between fine and coarse mode, as evident by the clustering of AE at 1.5 in Figure 5. Hence, discussion across seasons is deemed redundant, as it would not reveal correlations between MODIS and AERONET AE or elucidate relationships between AOD and AE, given the influence of MODIS's AE modes.

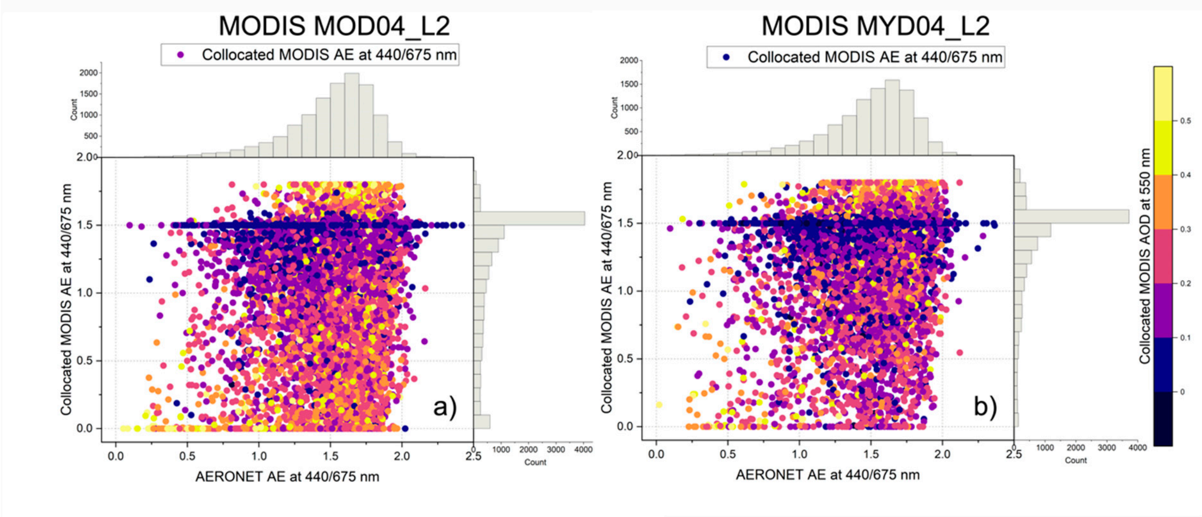

Figure S2. Central-East Europe comparative analysis between MODIS Terra (a) and MODIS Aqua (b) Ångström exponent product at 440/675 nm and AERONET AE calculated at 440/675 nm, for the period 2010-2023. The marginal histograms display data distribution for 0.25 bins, while the color mapping corresponds to collocated MODIS AOD at 550 nm.

3. Annual AERONET AOD trend – complementary visual representation in support for Section 3.3

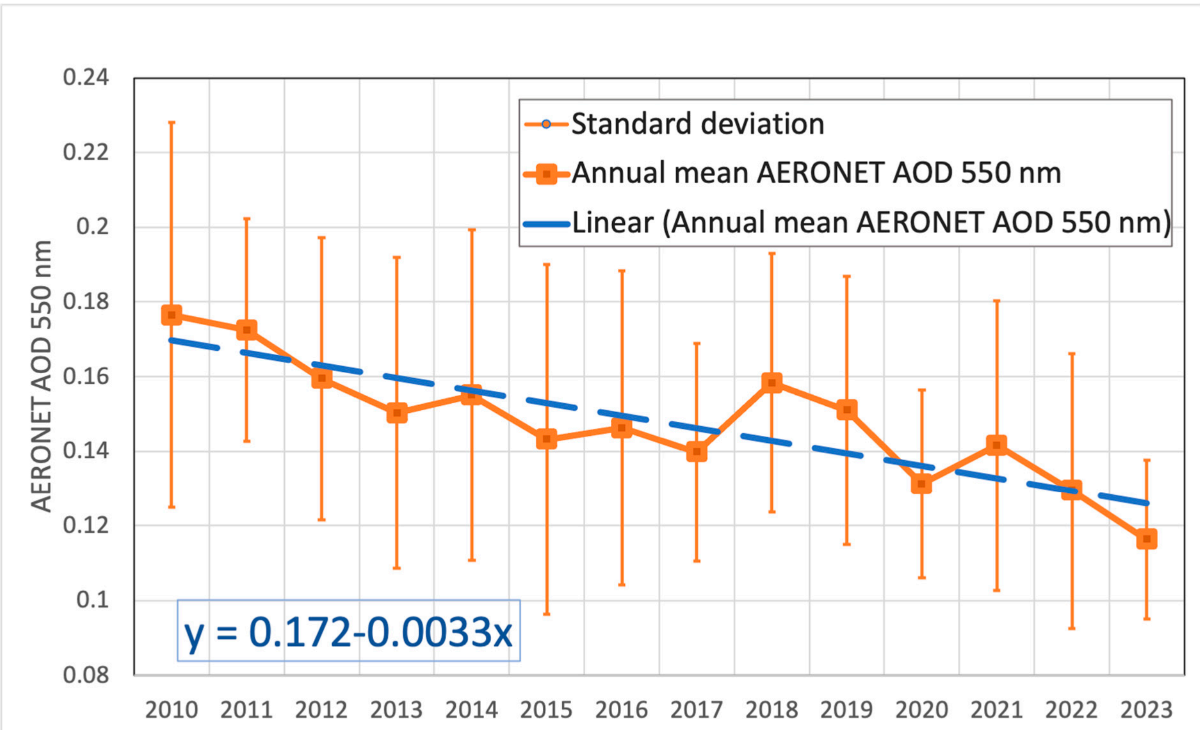

Figure S3. Annual mean AOD at 550 nm (orange line) and its trend (dotted blue line) are depicted in the subplot. Linear equation is shown.

4. MODIS Aqua AE biases for different types of aerosols

Table S2. Descriptive statistics for the differences between AERONET AE and MODIS AE. Values presented for the following aerosol classes: biomass burning, continental, dust, marine, mixed, and polluted.

AERONET AE - MODIS Aqua AE	N total	Mean	Standard Deviation	Lower 95% CI	Upper 95% CI
Biomass burning	629	0.328	0.420	0.295	0.361
Continental	1927	0.149	0.240	0.139	0.160
Dust	940	-0.157	0.481	-0.188	-0.126
Marine	694	-0.266	0.268	-0.286	-0.246
Mixed	3408	0.216	0.421	0.202	0.230
Polluted	1987	0.468	0.389	0.451	0.485

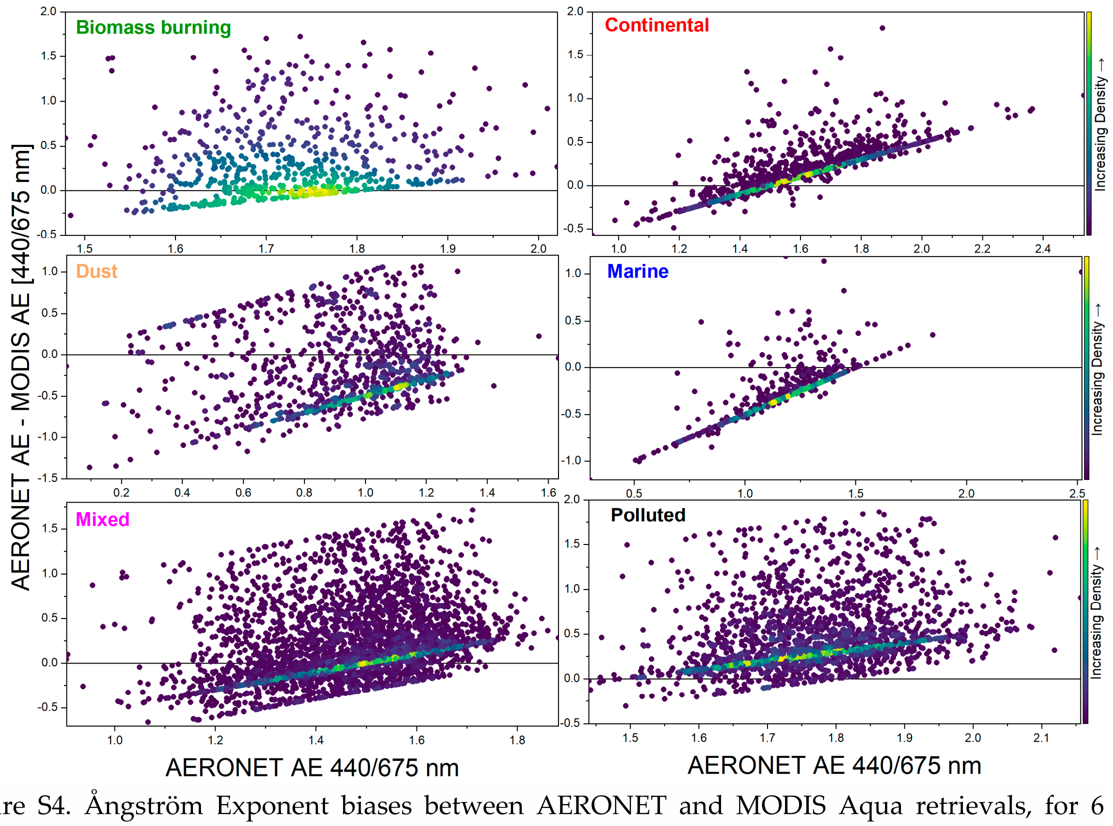

Figure S4. Ångström Exponent biases between AERONET and MODIS Aqua retrievals, for 6 aerosol types: biomass burning, continental, dust, marine, mixed and polluted. The color bar shows the points density. Descriptive statistics for these categories is presented in Table S2.