The impact of aerosol optical characteristics on the long-time UV index measurements in the urban area of Rome, Italy

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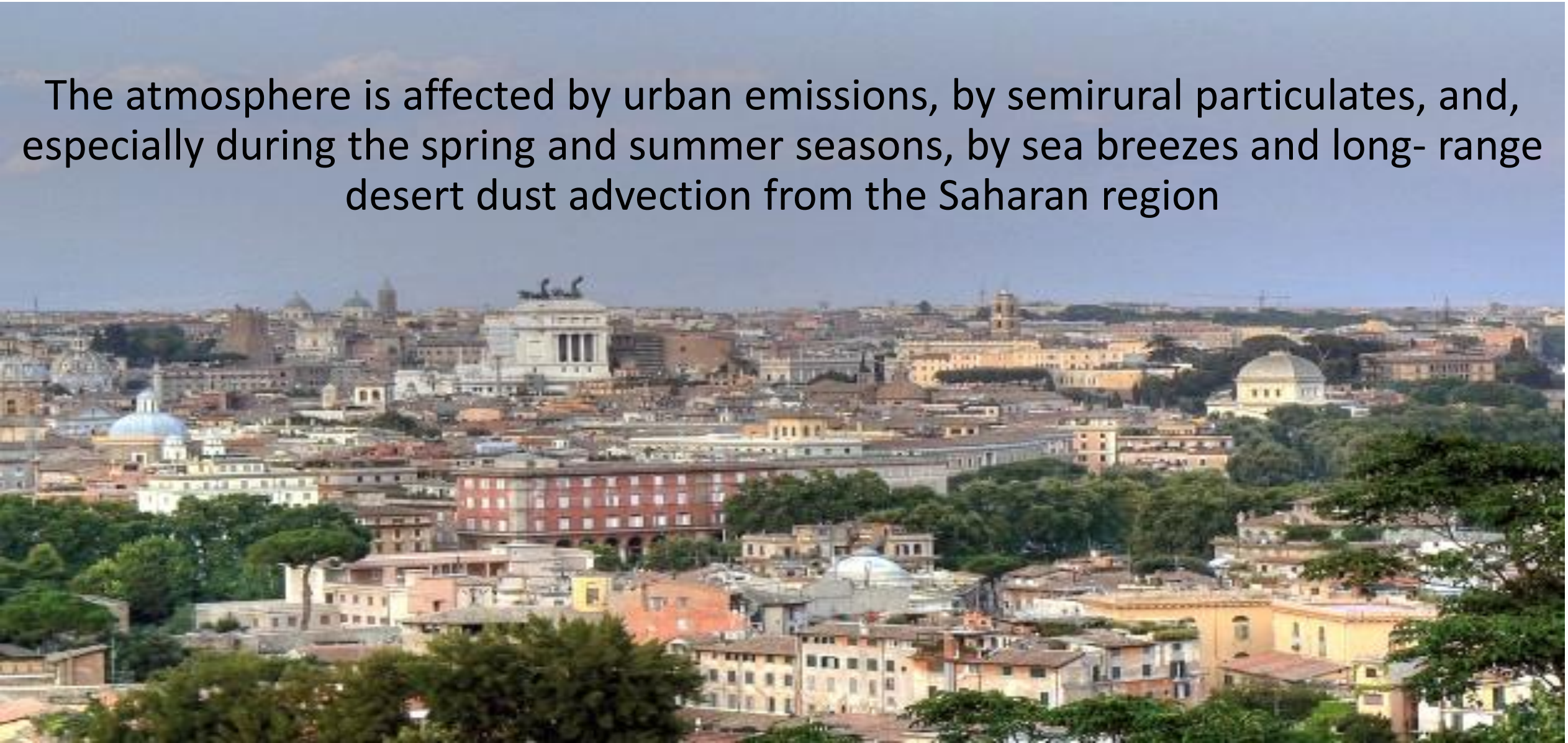
Rome is a large urban site , about 3 million inhabitants,

25 km east of the Tyrrhenian Sea, in the middle of an undulating plain.



The atmosphere is affected by urban emissions, by semirural particulates, and, especially during the spring and summer seasons, by sea breezes and long- range desert dust advection from the Saharan region

Aim of the work

Investigating the impact of the aerosol optical properties on the ultraviolet index (UVI) in the urban area of Rome

Understanding the influence of aerosol optical depth (AOD) and single scattering albedo (SSA), estimated at the wavelength of 340 nm, and of the Ångström exponent, calculated in the range 340–500nm

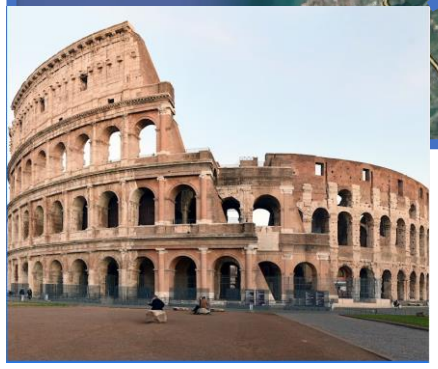
Period of 11 years (2010–2020) in the months from March to September

Measurements are carried out in Rome, on the roof of the Physics Department of Sapienza University (41.9◦ N, 12.5◦ E; altitude 75 m), in the central sector of the city.

This site has, since 2019 been part of the BAQUNIN project (Boundary- layer Air Quality-analysis Using Network of INstruments; Iannarelli et al., 2021).

Sapienza University
Atmospheric Physics Laboratory

BAQUNIN Supersite Pres. 365, Stefano Casadio



Measurements

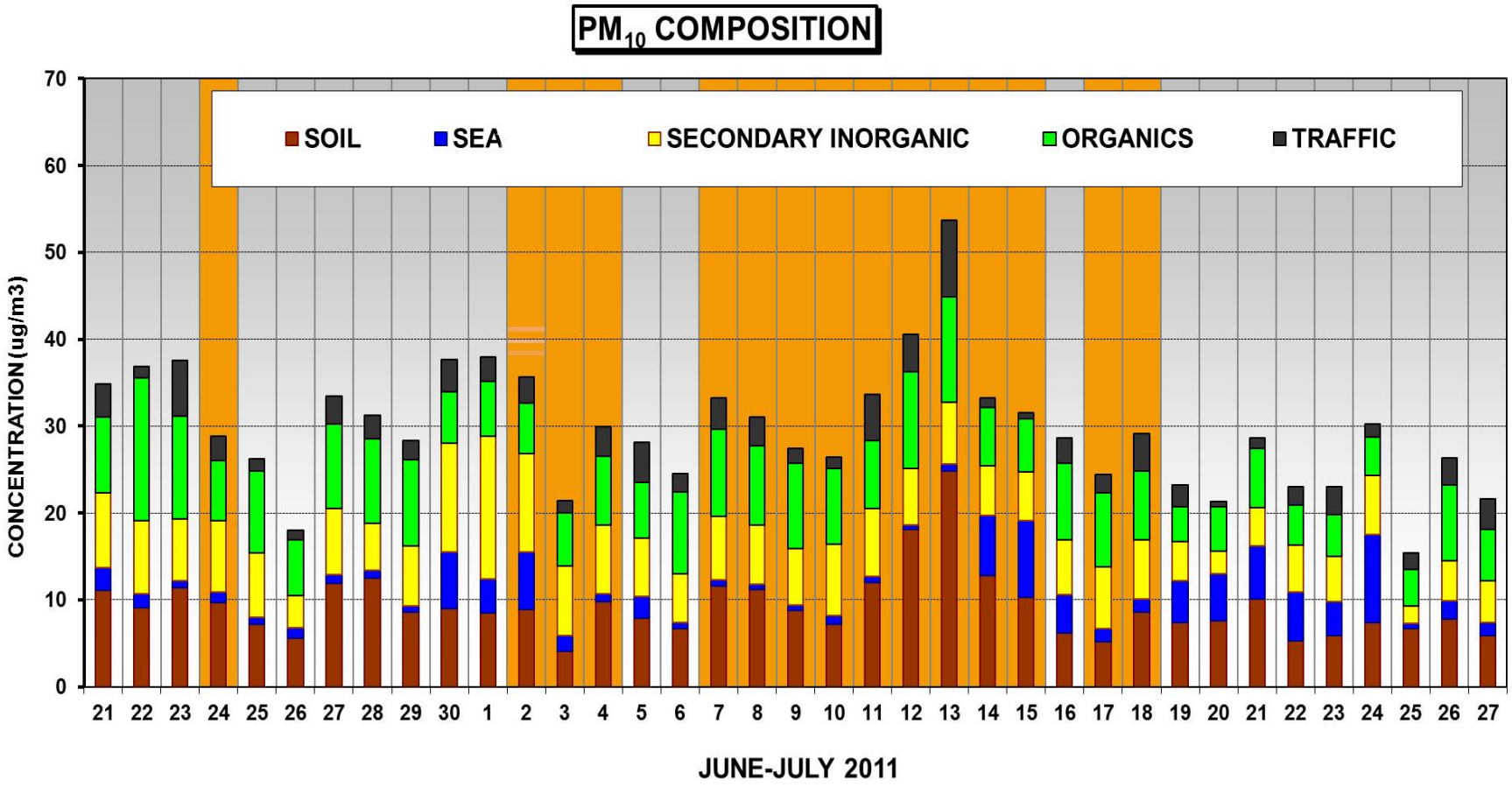
The UVI is monitored by a Brewer spectrophotometer (067) part of the European Brewer Network (EUBREWNET)

Measurements of the direct Sun and diffuse sky irradiances are performed by a colocated PREDE-POM sun–sky radiometer of the ESR/SKYNET network;

the chemical characterization of urban PM10 samples collected during an intensive field campaign held in summer 2011 at the same site (URBan Sustainability Related to Observed and Monitored Aerosol – URBS ROMA) is also taken into account.

PM10 chemical analyses (Summer 2011) show an average contribution over the entire sampled mass of about

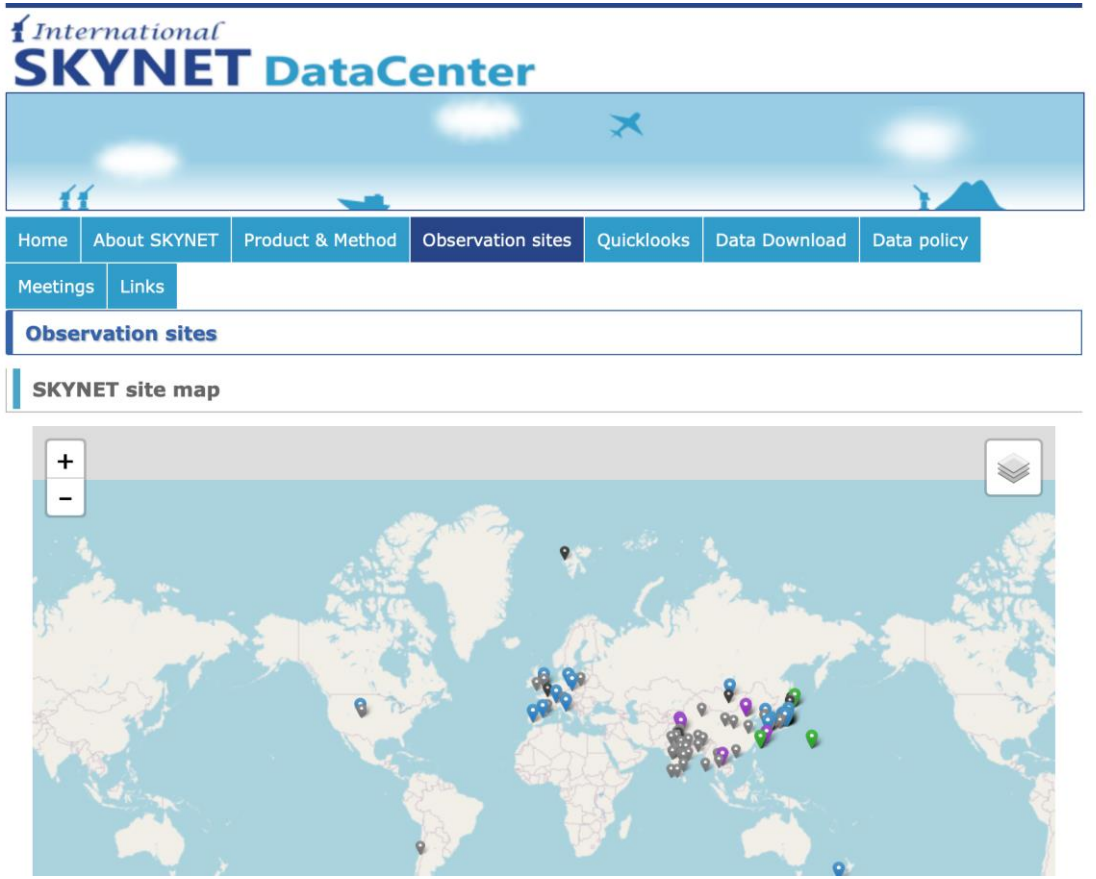
- **29 % of soil,**
- **6 % of sea,**
- **23 % of secondary inorganics,**
- **28% of organics,**
- **9% of traffic components.**



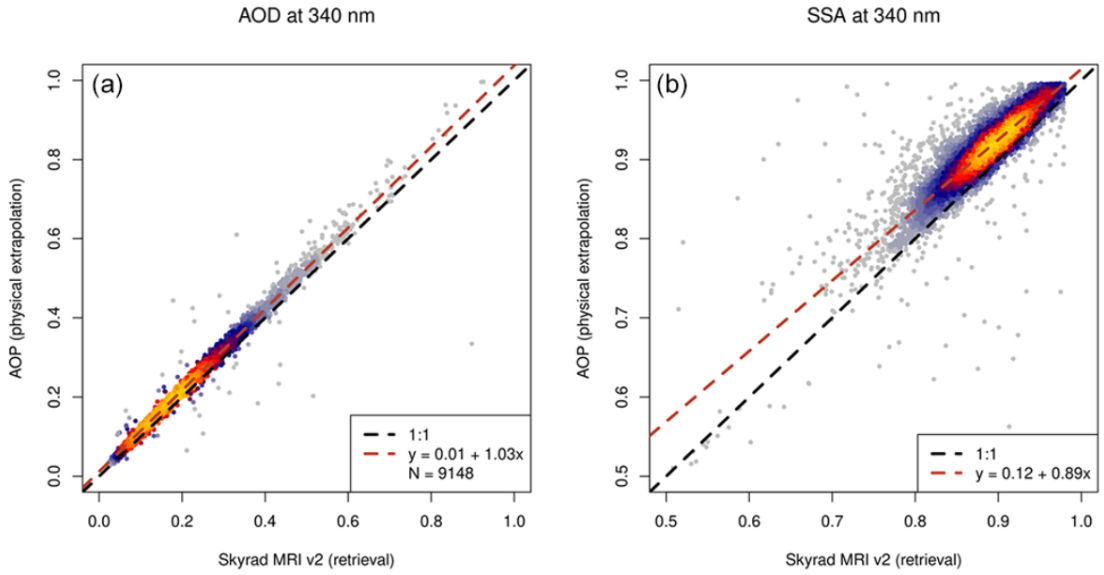
The absorption capability of these components is very different, therefore the modulation of the concentration of these co-existent materials can strongly affect the absorption capability of the atmosphere over Rome.

The aerosol optical properties are obtained by the Skyrad MRIv2 retrieval

(Kudo et al., 2021 https://doi.org/10.5194/amt-14-3395-2021) one of the official computer codes employed in the **SKYNET network (https://www.skynet-isdc.org).**



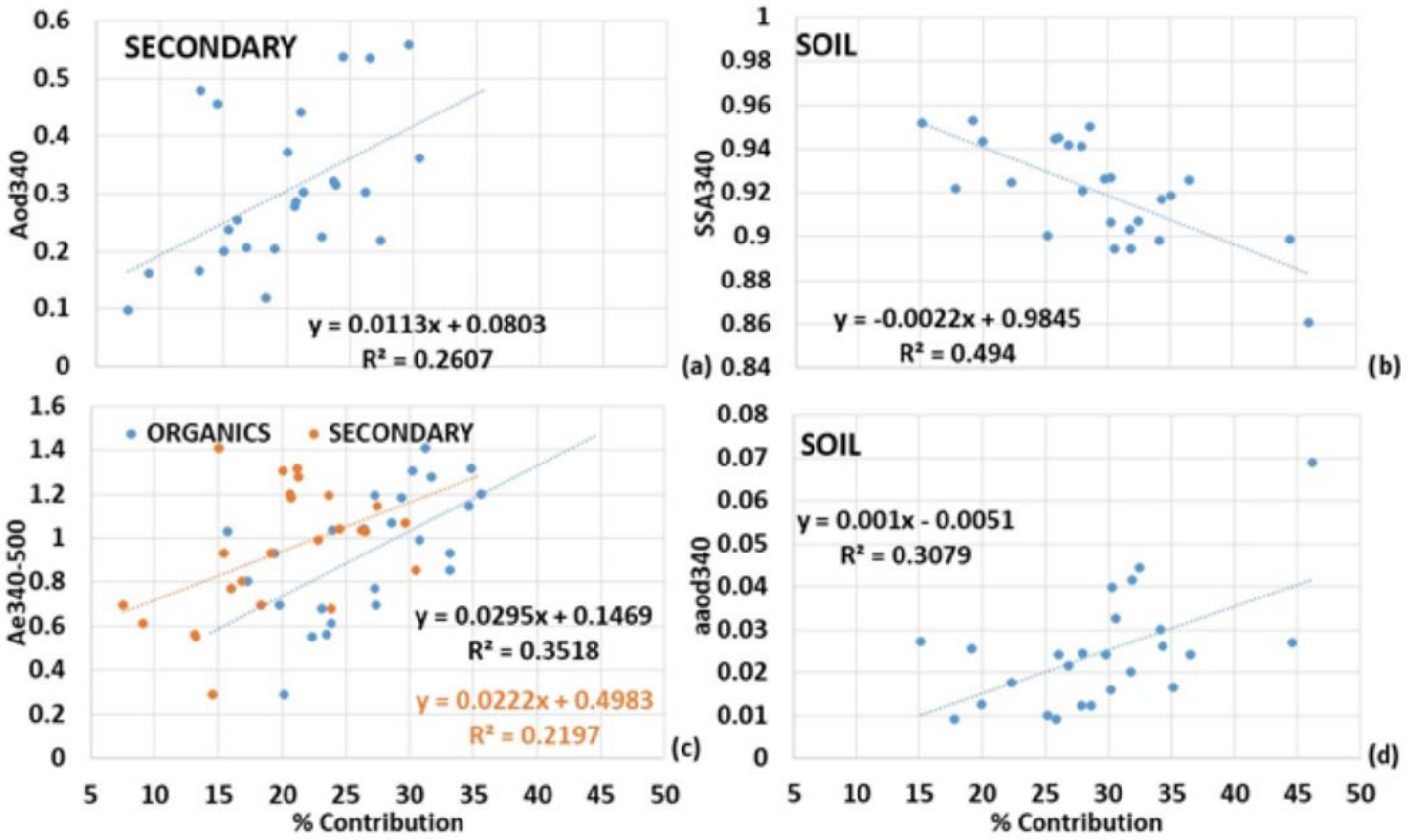
UV index and aerosol optical properties: measurements at a wavelength as close as possible to the one corresponding to the maximum of the erythemally weighted solar spectrum (< 320 nm). From the POM in Rome is 340nm…but abailable only from 2016…. Before, the shortest was 400 nm



The aerosol optical properties (AOPs) program included in the Skyrad MRIv2 package allowed to reconstruct the aerosol optical properties at 340 nm for the missing period, from the results of the Skyrad inversion, using the same kernels as in the retrieval.

it is possible that the extrapolation leads to a slight overestimation due to neglecting organic aerosols in the atmosphere that are, instead, present in Rome as found during the URBS campaign

Secondary inorganics seem also to be weakly correlated with AOD340



SSA340 and **AAOD340** versus the fraction of the **soil component** exhibit a reasonable correlation (R_2 = 0.49 and 0.31, respectively) showing an increase of the absorption capability in the atmosphere (lower SSA340 and higher AAOD340 values), with the enhancement of the soil contribution.

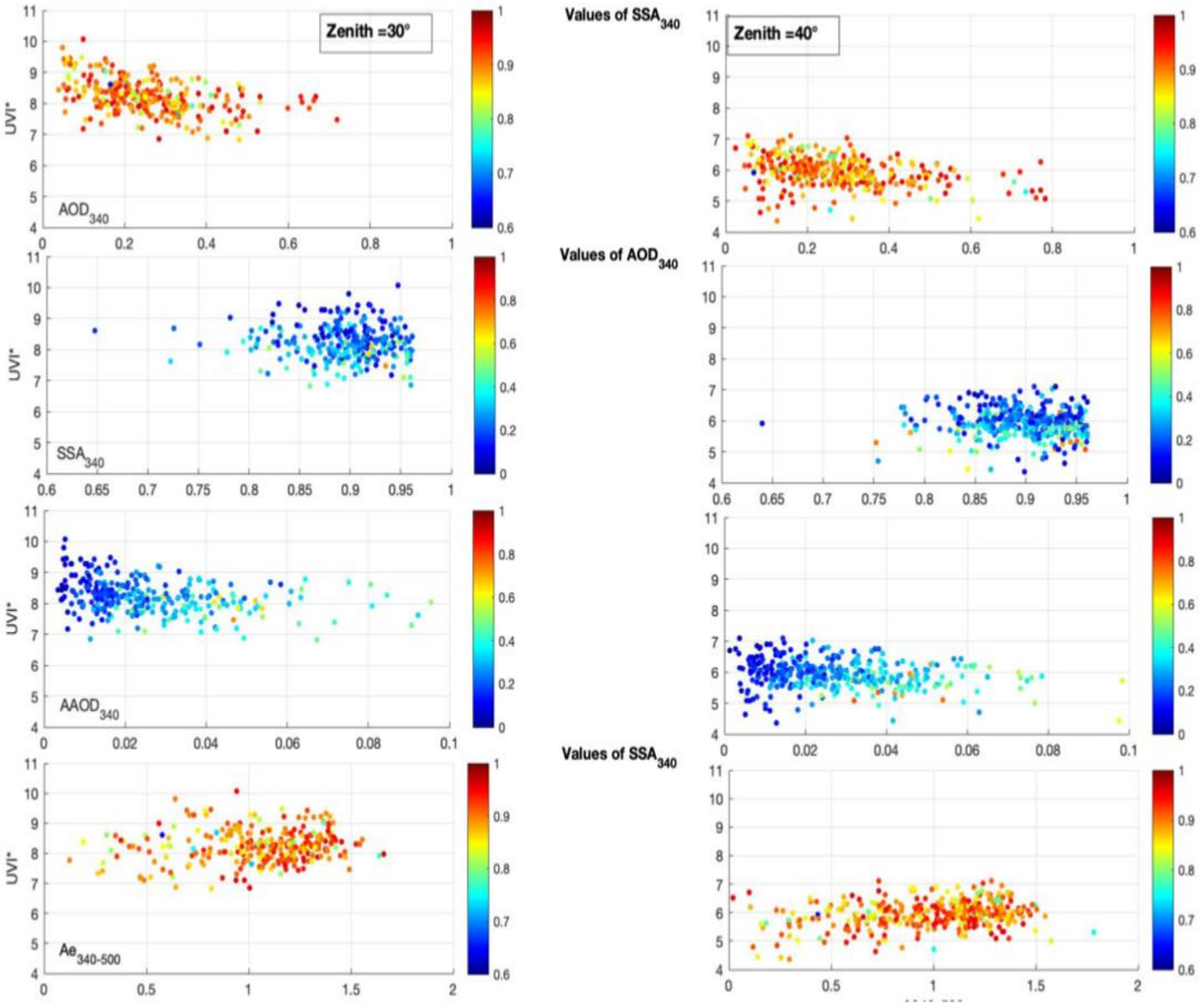
A weaker correlation is found between Ae340−500 and the percent amount of organics and secondary INORGANICS contributions (R2 = 0.35 and 0.22, respecively), highlighting that an enrichment of these particulates sampled at ground level may be associated with higher values of Ae340−500 due to the presence of smaller particles in the atmosphere

Absorption aerosol optical depth (AAOD340 = AOD340 · (1−SSA340))

The slope retrieved for UVI* versus AOD corresponds to the **UVI radiative forcing efficiency**, i.e., the change in UVI produced by a unit change in AOD.

The UVI dependence on total O_3 has been removed using the radiation amplification factor (RAF) and scaling the UVI to the total ozone daily average value for the day with the lowest AOD_{340} recorded in the entire dataset (283 DU on 8 July 2014).

A slight decreasing trend of UVI* when AOD_{340} increases is evident at the smaller solar zenith angle, which is in agreement with what is found by previous studies (di Sarra et al., 2008; Antón et al., 2011). For the other parameters, no dependence is visible from this first analysis.



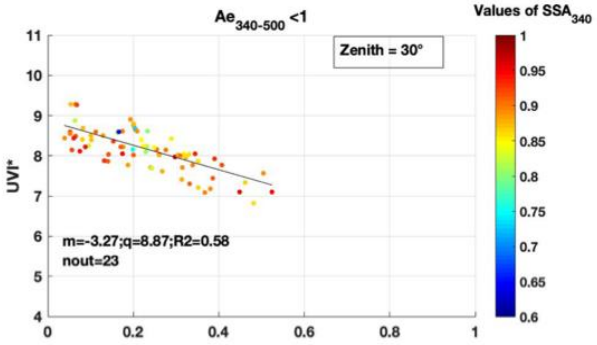
			SZA = 30°			SZA = 40°		
		UVI* vs.	Slope	Intercept	R^2	Slope	Intercept	R^2
	All data	AOD_{340}	-1.91 ± 0.23	8.72	0.21	-1.00 ± 0.15	6.21	0.11
		$AAOD_{340}$	-9.57 ± 1.76	8.48	0.10	-5.51 ± 1.12	6.09	0.06
		SSA_{340}	-0.79 ± 0.71	8.94	0.01	-0.66 ± 0.53	6.52	0.004
Median	$Ae_{340-500} < 1.0$	AOD_{340}	-3.27 ± 0.32	8.87	0.58	-1.17 ± 0.20	6.17	0.23
	$Ae_{340-500} \geq 1.0$	AOD_{340}	-1.28 ± 0.18	8.55	0.27	-1.36 ± 0.12	6.37	0.41
Quartiles	$Ae_{340-500} < 0.8$	AOD_{340}	-3.02 ± 0.35	8.68	0.66	-0.96 ± 0.25	6.07	0.15
	$Ae_{340-500} \geq 1.2$	AOD_{340}	-1.34 ± 0.22	8.63	0.33	-1.56 ± 0.15	6.49	0.55
Median	$SSA_{340} < 0.9$	AOD_{340}	-2.68 ± 0.28	8.92	0.47	-1.65 ± 0.18	6.45	0.34
	$SSA_{340} \geq 0.9$	AOD_{340}	-1.08 ± 0.19	8.47	0.21	-1.05 ± 0.13	6.18	0.29
Quartiles	$SSA_{340} < 0.87$	AOD_{340}	-2.52 ± 0.38	8.87	0.48	-1.83 ± 0.22	6.48	0.46
	$SSA_{340} \geq 0.93$	AOD_{340}	-0.97 ± 0.26	8.50	0.20	-0.78 ± 0.17	6.12	0.22

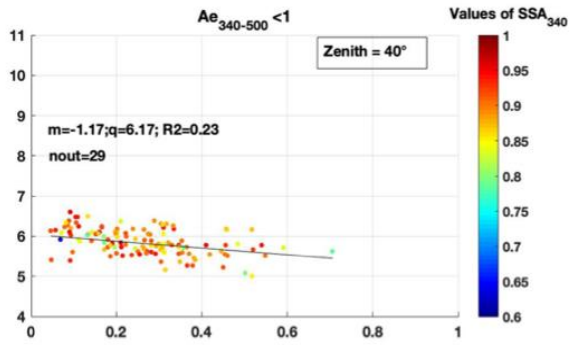
To investigate in more detail the possible effects on UVI_* caused by particles dimensions and atmospheric absorption capabilities, the entire dataset was divided in:

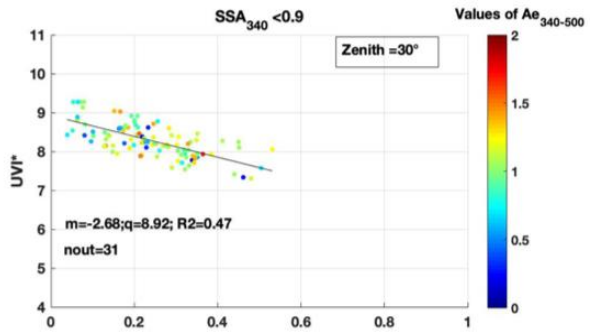
Ae_{340_500} values below and above 1,
SSA_{340} values smaller and larger than 0.9,
(median values of the distributions)

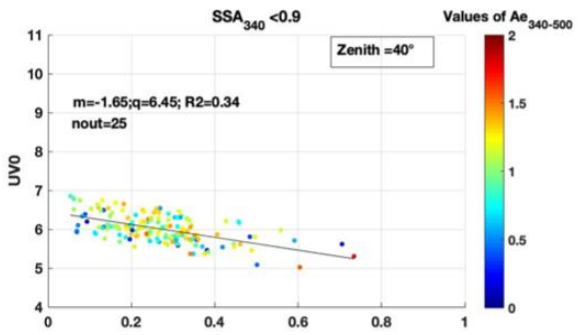
To understand if the extreme values of the distributions have a different impact on UVI_*, the first and fourth quartiles were also considered as threshold values.

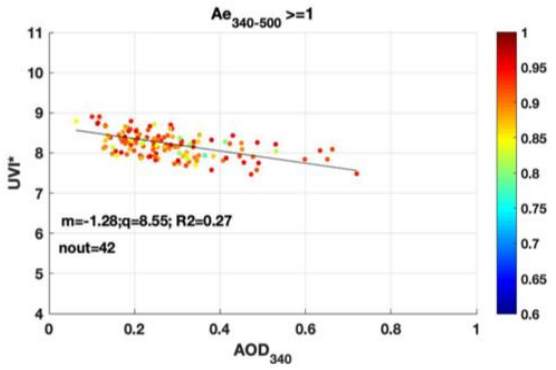
Results

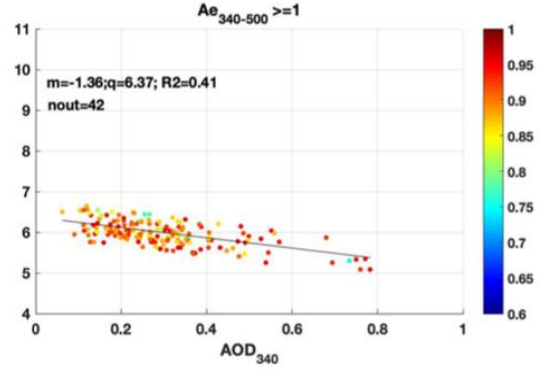


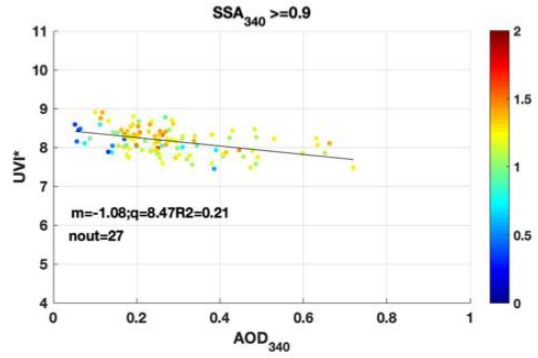


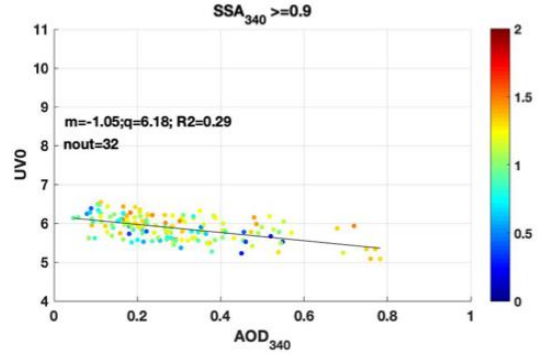












The forcing efficiency was found **greater** for the lower zenith angle and smaller values of $Ae_{340-500}$ in both the case of median and quartile thresholds. Small values of Ångström exponents are related to the presence of coarse particles that, in Rome, are generally linked to the presence of Saharan dust in the atmospheric column, with more being absorbed in the UV than VIS regions.

More absorbent particles ($SSA_{340} < 0.9$) showed **a larger** forcing efficiency at smaller zenith angles. According to the results from the URBS campaign in Rome, the absorption capability is correlated to the increase in the soil fraction; therefore, it could be inferred that, the greater this component in the atmosphere, the larger the radiative forcing efficiency.

The obtained results could be partly affected by the spectral behavior of both AOD and SSA in the 305–340 nm range:

*The UVI effective wavelengths are around 305–310 nm, depending on solar elevation, whereas aerosol properties are here retrieved at 340 nm.

*AOD305 is theoretically higher than AOD340 for the same instant, but it could be not.

*the relationship between AAOD305 and AAOD340 depends on SSA spectral behavior in the UVB

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