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Variability and trends in surface solar spectral ultraviolet irradiance in Italy: on the influence of geopotential height and lower-stratospheric ozone

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Attenuation by clouds

In order to investigate the spectral effect of different cloud types on spectral solar UV irradiance in the range 305 – 324 nm we performed simulations with the model uvspec of the libRadtran package (Mayer and Kylling, 2005). Simulations were performed for total ozone equal to 330 DU, AOD=0.1, and for two types of clouds: typical low altitude water clouds (base altitude=2 km, width=2 km, effective radius=10 μm) and typical high altitude cirrus clouds (base altitude=10 km, width=1km, effective radius=20 μm). The ratio between the spectral irradiance simulated for cloudless and cloudy conditions is presented in Figures S1 and S2.

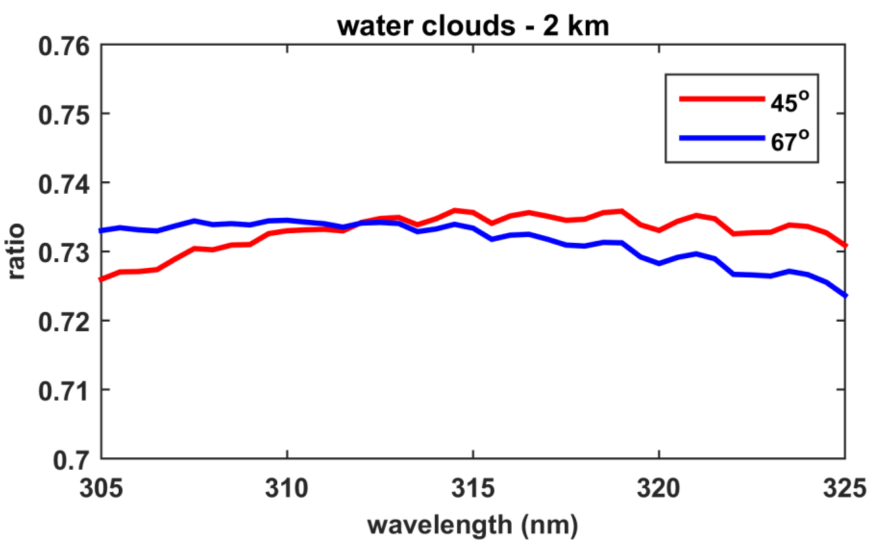

Figure S1: Ratio between the surface solar spectral irradiance at 305 – 325 nm reaching the Earth surface with and without low altitude clouds.

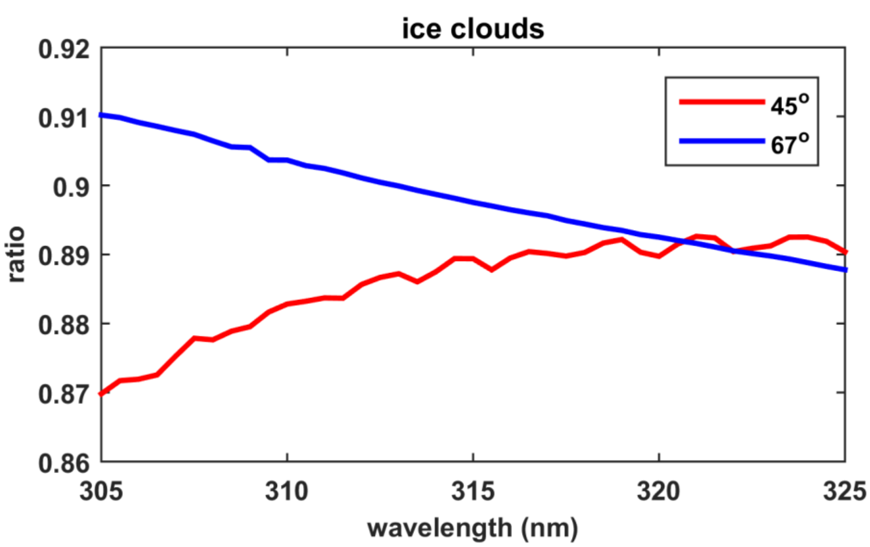

Figure S2: Ratio between the surface solar spectral irradiance at 305 – 325 nm reaching the Earth surface with and without high altitude clouds.

A Cloud Optical Depth (COD) of 1 was considered for the cirrus cloud (Figure S2), while a COD of 6 was considered for the low altitude cloud (Figure S1). For the low altitude clouds, the spectral shape of the attenuation is similar for the SZAs of 45° and 67° and the dependence from wavelength is in both cases small. For the high altitude clouds the attenuation decreases with wavelength at 45° and increases with wavelength at 67°. Attenuation of the irradiance at wavelengths larger than 320 nm is similar at both SZAs. At wavelengths that are affected stronger by ozone attenuation by high altitude clouds is significantly stronger at 45°. Performing the same analysis for different CODs ranging from 1 to 30 for the two cloud types resulted to similar conclusions. From the above discussion it is evident that changes in the occurrence of cirrus would result in more pronounced effects on the levels of UVB irradiance at smaller SZAs. Simulations assuming zero tropospheric ozone resulted to stronger attenuation (stronger by ~1% at all wavelengths) at 67° for high altitude clouds. Thus, a possible explanation for the results presented in Figure S2 is that the high-altitude cloud leads to a redistribution of the direct solar beam such that photons that would reach the ground at SZA=67° without cloud, travel more vertically through the troposphere below the cirrus cloud, and hence have a shorter optical path through the tropospheric ozone layer.

Correlation between GPH at 250 hPa, GPH at 850 hPa and tropopause altitude

As shown in Figure S3, there is a strong, statistically significant correlation between the GPH at 250 hPa and the tropopause altitude over Aosta, Rome and Lampedusa. As also shown in Figure S1 (panels d- f) GPH at 250 hPa is strongly correlated with GPH at 850 hPa.

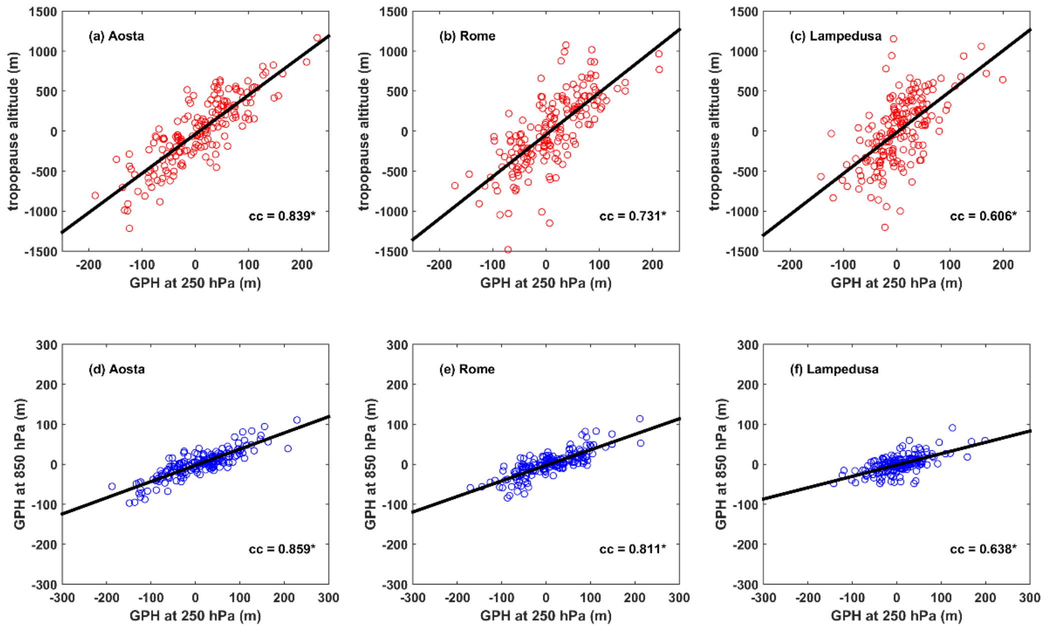

Figure S3: Correlation between the absolute anomalies (in m) between GPH at 250 hPa and tropopause altitude for (a) Aosta, (b) Rome, and (c) Lampedusa, and correlation between the GPH at 250 hPa and 850 hPa for (d) Aosta, (e) Rome, and (f) Lampedusa. The correlation coefficients (cc) are shown at the lower right side of each graph. Values in bold marked with an asterisk denote statistically significant correlation.

Ozone trends at different pressure levels

As shown in Figure S4, ozone over Rome increases significantly at higher stratospheric levels and decreases significantly at lower stratospheric levels.

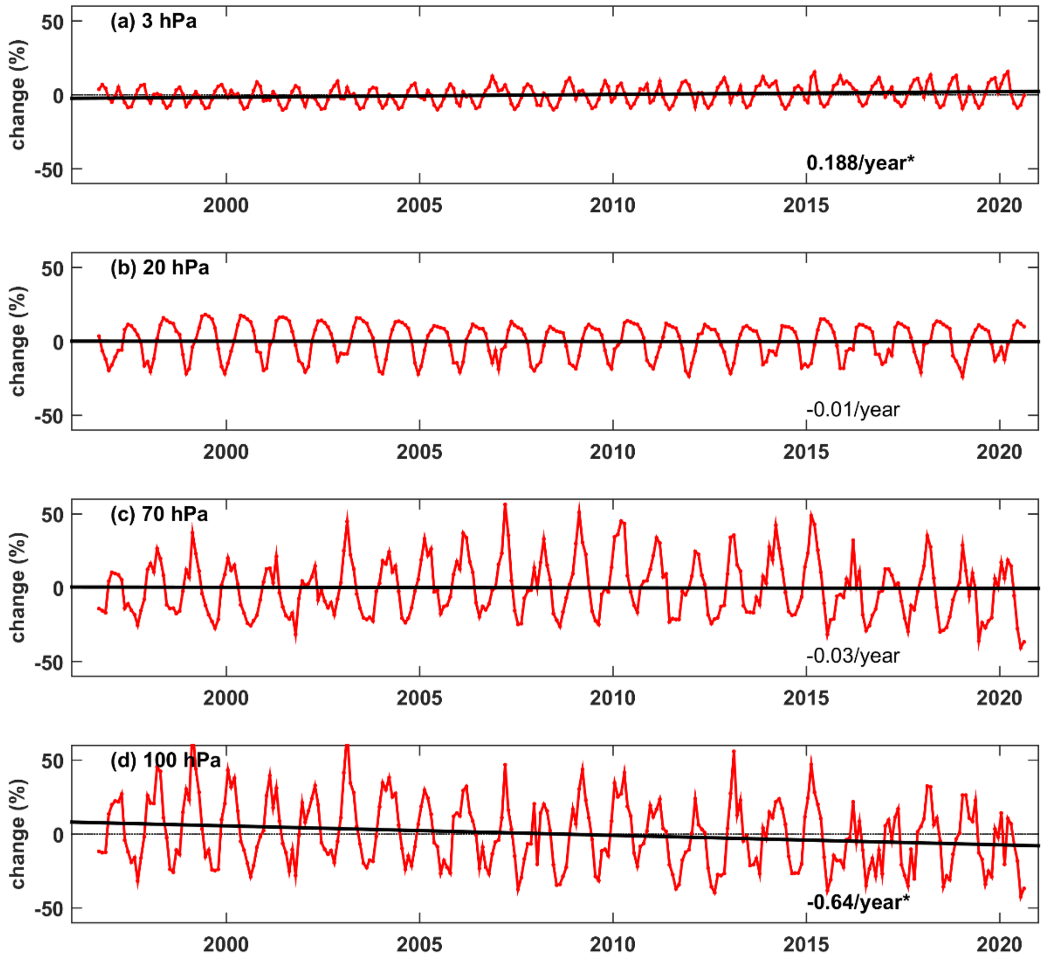

Figure S4: Variability and long-term trends (in %) of the ozone mixing ratio at different atmospheric pressure levels over Rome. Average change per year is shown at the lower right of each graph. Values in bold marked with an asterisk denote statistically significant changes.

References

Mayer, B. and Kylling, A.: The libRadtran software package for radiative transfer calculations-description and examples of use, Atmos. Chem. Phys., 5, 1855–1877, 2005.