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Umkehr ozone profiles over Thessaloniki and comparison with satellite overpasses

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Regular measurements of the vertical ozone distribution with the Umkehr technique are conducted during twilight with a single monochromator Brewer spectrophotometer at Thessaloniki, Greece (40.634° N, 22.956° E, 60 m altitude) since the beginning of the 1990s. This dataset has been recently re-evaluated with the with the modified O_3BUmkehr processing software (V3.2, http://www.o3soft.eu), which is based on the UMK04 algorithm originally developed for the Dobson Umkehr retrievals and adopted for the Brewers. This algorithm incorporates significant improvements compared to the previous UMK92 algorithm, such as the use of unbiased, pre-calculated a priori profiles, as well as an improved forward model, it takes into account the stray light effect and is optimized for the calculation of long-term trends. In this study, we present analysis of Umkehr ozone profiles covering a 20-year period (1997 – 2017). The long-term trend analysis reveals that tropospheric ozone over Thessaloniki exhibits a statistical significant negative trend, while statistically significant positive trends appear at altitudes higher than 35 km, consistent with the expected recovery of the ozone layer from ODSs decline. In addition, the profiles have been compared with profiles from the Microwave Limb Sounder (MLS) instrument aboard the NASA's Aura spacecraft and the Infrared Atmospheric Sounding Interferometers (IASI) launched on board the MetOp-A satellite. Overpass data for Thessaloniki (12 hours, within a radius of 1000 km) are used in the comparisons. The satellite profiles have been smoothed with the Umkehr averaging kernels to reduce sampling differences from the Umkehr profiles arising from limitations in the Umkehr vertical resolution ($\sim$ 5-10 km). The overall agreement with datasets of both satellites is quite satisfactory (within $\pm$10%), with the highest variability observed in the lower stratosphere (Umkehr layers 2 and 3, between $\sim$10 and 20 km) for MLS and the troposphere (layers 0+1, between 0 and $\sim$10 km) for IASI. The best agreement is found for layers 4 and 5 (between $\sim$20 and 30 km), where the bulk of the ozone absorption occurs, while layers 6 and 7 show a negative bias, possibly connected with inadequate rejection of the stray light. The effect of the stray light in the Umkehr retrievals as revealed through the comparison of profiles with and without stray-light correction is quite significant for most layers ranging between -15% and +10%. The only exception is layer 5, for which the effect is negligible.