Contribution of underlying terrain to sunlight scattered by atmospheric aerosols

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On five epochs from May 17 through August 18 of 2023, we performed polarimetric measurements of aerosols populating the atmosphere over the Ussuriysk Astrophysical Observatory, a division of the Institute of Applied Astronomy of Russian Academy of Science (code C15; Russia). These measurements were started in the morning twilight, ~20-30 minutes before sunrise, and they were stopped about 3-6 minutes prior the sunrise. The measurements were resumed again 10-25 minutes after the sunrise. We follow the same routine that we use in a previous polarimetric survey the atmospheric aerosols as outlined by Zubko et al. [1].

When the measurements are conducted in the morning twilight, the substrate terrain remains in shadow, but the aerosol particles at high altitude are already illuminated by direct sunlight. Over the span of our measurements, the altitude of the shadow boundary gradually decreases from ~20-36 km up to ~1-2 km. During this time the measurements are performed at 6-7 different value of the scattering angles θ. At every angle θ, the measurements are repeated for 3-5 times to estimate their uncertainty. This yields 34 independent measurements in twilight, in addition to 155 measurements reported by Zubko et al. [1]. As such, the measurements were performed only in optically thin air and, hence, the obtained polarimetric response corresponds to aerosol particles in the single-scattering regime.

Our measurements reveal day-to-day variations in the polarimetric response. The maximum of positive polarization that is observed at scattering angle $\theta \sim 90°$ (near zenith direction in twilight) spans the range from P_{max} ~37% up to ~65%. It is worth noting that these data appear to be in good quantitative accordance with the previous 20-month survey of polarization over the Ussuriysk Astrophysical Observatory [1]. Furthermore, similar fluctuations were previously reported by Pavlov et al. [2] for another geographical site. Nearly all polarimetric measurements in twilight were satisfactorily reproduced using model *agglomerated debris particles*. These particles have highly irregular shape and they have revealed a capability in fitting polarimetric measurements of terrestrial-dust analogs [e.g., [3], [4]] and *in situ* measurements of atmospheric aerosols [1]. What came as a surprise is that the polarimetric response measured after sunrise closely resembles what was obtained in twilight on the same epoch. Namely, in two epochs the difference hardly exceeds the uncertainty. In the other three epochs, the difference appears to be noticeable mainly around

the polarization maximum P_{max}. These measurements suggest little (if any) contribution of the underlying terrain onto light scattering from aerosol particles, at least, during the summer season.

References

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