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Divergence of sun-rays by atmospheric refraction at large solar zenith angles

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Abstract. For the determination of photolysis rates at large zenith angles it has been demonstrated that refraction by the earth's atmosphere must be taken into account. In fact, due to the modified optical path the optical transmittance is thereby increased in most instances. Here we show that in addition the divergence of sun-rays, which is also caused by refraction but which reduces the direct solar irradiance, should not be neglected. Our calculations are based on a spherically symmetric atmosphere and include extinction by Rayleigh scattering, ozone, and background aerosol. For rays with 10km tangent altitude the divergence yields a reduction of about 10% to 40% at solar zenith angles of 91° to 96°. Moreover, we find that the divergence effect can completely cancel the relative enhancement caused by the increase of transmittance.

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