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Generalizing cloud overlap treatment to include solar zenith angle effects on cloud geometry

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Shortwave radiative transfer depends on the cloud field geometry as viewed from the direction of the sun. To date, the radiation schemes of large-scale models only consider a zenith view of the cloud field, and the apparent change in the cloud geometry with decreasing solar zenith angle is neglected. A simple extension to an existing cloud overlap scheme is suggested to account for this for the first time. It is based on the assumption that at low sun angles the overlap between cloud elements is random for an unscattered photon. Using cloud scenes derived from radar retrievals at two European sites, it is shown that the increase of the apparent cloud cover with a descending sun is reproduced very well with the new scheme. Associated with this, there is a marked reduction in the mean radiative biases averaged across all solar zenith angles with respect to benchmark calculations. The scheme is implemented into the ECMWF global forecast model using imposed sea surface temperatures, and while the impact on the radiative statistics is significant, the feedback on the large-scale dynamics is minimal.