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A consistent representation of cloud overlap and cloud subgrid vertical heterogeneity

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Global or regional atmospheric circulation models often work with horizontal resolutions too large to be able to represent clouds, who have to be parameterized. The way clouds are parameterized and the way they overlap can have a significant impact on their radiative properties. A first objective of this work is to quantify the effect of a vertical description of cloud properties finer than that of current atmospheric models on the calculation of the radiative fluxes at the top of the atmosphere. A second objective is to propose a representation of these subgrid effects that is consistent with the representation of the cloud overlap between layers. For low-level clouds and using LES results as reference, we show the ability of the exponential-random overlap algorithm to represent the vertical distribution of the cloud fraction over a wide range of vertical scales that includes both subgrid scales and overlap between layers, with a constant value of the overlap parameter. Starting from a coarse vertical grid representative of that of atmospheric models, this algorithm is then used to construct the vertical profile of the cloud fraction with a much finer vertical resolution. This reconstruction allows us to test different simplifying hypotheses. We confirm that the frequently used maximum-random overlap leads to a significant error by underestimating the low-level clouds cover with a relative error of about 50%. We suggest some possible representations of subgrid effects and recommend to consider the vertical distribution of the cloud fraction seen from above, which depends on the volume cloud fraction but also on the cloud overlap and the subgrid vertical heterogeneity, when developing or evaluating cloud properties.