A CONSISTENT REPRESENTATION OF CLOUD OVERLAP AND CLOUD SUBGRID VERTICAL HETEROGENEITY

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ABSTRACT

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.

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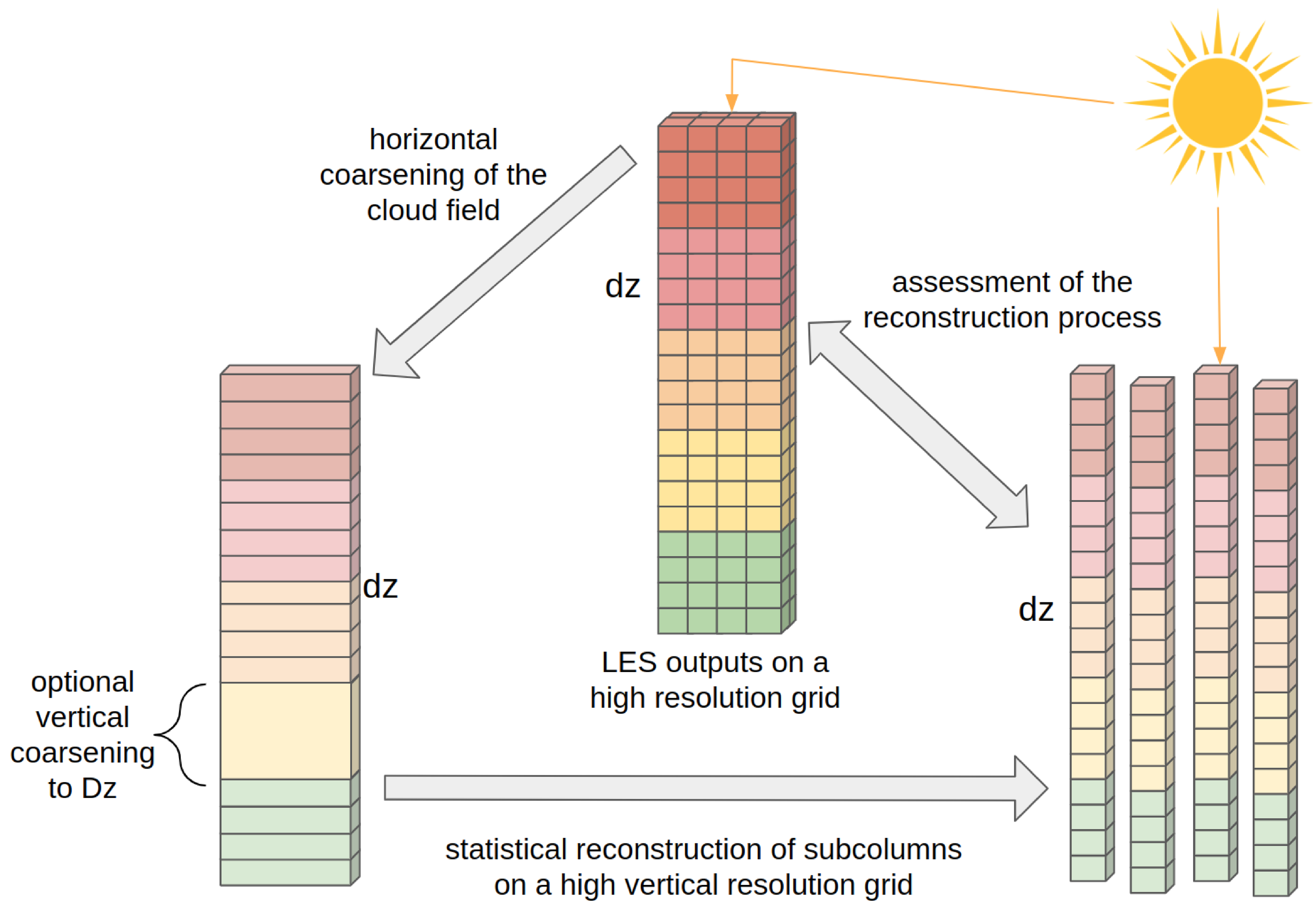
THE METHOD: EXPONENTIAL RANDOM OVERLAP

Method used to develop and assess our algorithm:



The cloud field of resolution $dx=dy=dz=25m$ is horizontally averaged into a single column and eventually averaged vertically to a coarse resolution $Dz>dz$.

- LES used as references (ARMCU, BOMEX) : profiles of cloud fraction CF and liquid water content LWC
- Exponential Random Overlap : $CF_{1,2}=\alpha CF_{max}+(1-\alpha)CF_{rand}$
- Use Exp-Rand to compute conditional *transition probabilities* to generate the cloud states of 1D subcolumns, one cell after another, starting from the top : $P(0|0)$, $P(0|1)$...
- We can compute the generated cloud cover CC by computing the proabbility to generate a clear-sky subcolumn : $P_\emptyset = \prod P(C_k=0 \mid C_{k-1}=0) = 1-CC$
- Compute the overlap parameter that generates the cloud cover CC_{LES} $\alpha = P_\emptyset^{-1}(1-CC,(CF)_z)$

REFERENCES

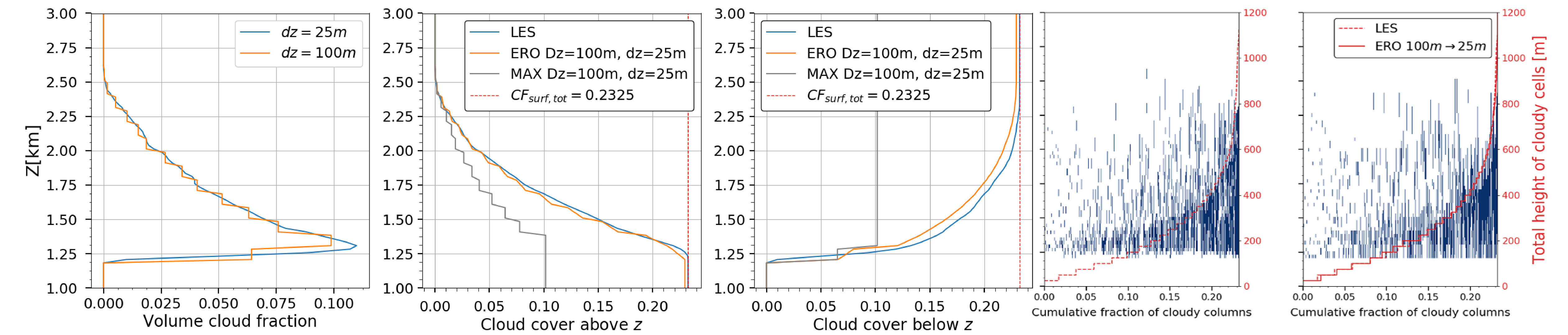
[1] Räisänen *et al.* Stochastic generation of subgrid-scale cloudy columns for large-scale models. 2004.

[2] Bergman and Rasch. Parameterizing Vertically Coherent Cloud Distributions. 2002.

[3] Pincus *et al.* A fast, flexible, approximate technique for computing radiative transfer in inhomogeneous cloud fields. 2003.

[4] Villefranque *et al.* A path-tracing monte carlo library for 3-d radiative transfer in highly resolved cloudy atmospheres. 2019.

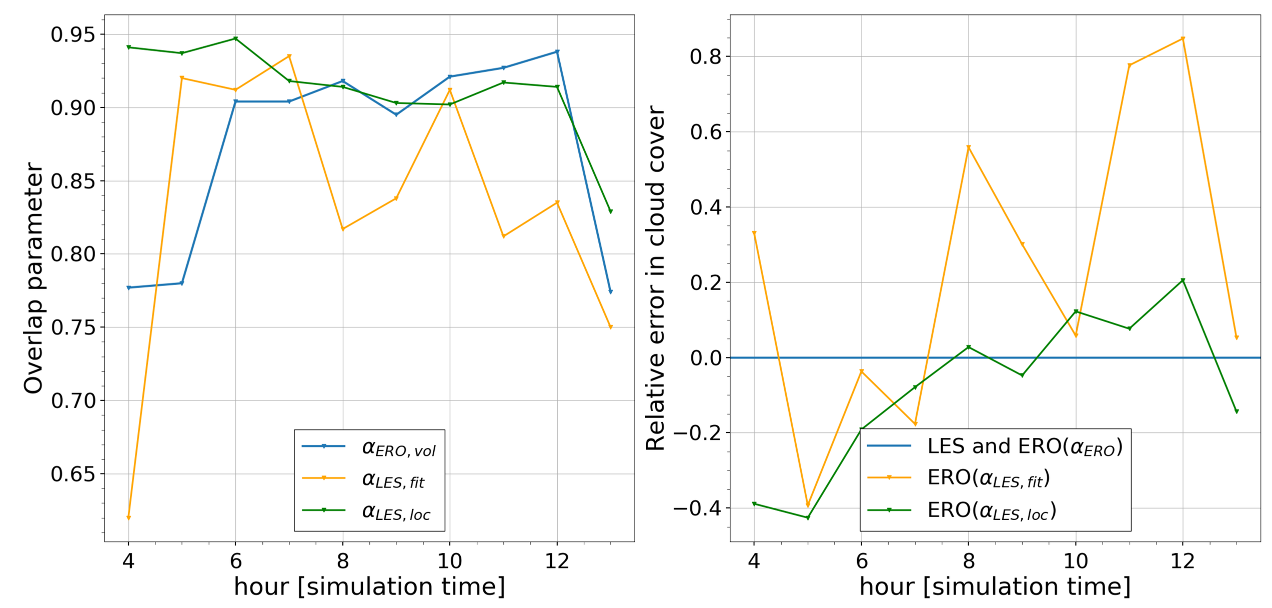
GEOMETRICAL RESULTS



The Maximum-Random overlap assumption produces a cloud cover smaller than the original (panels 2 and 3), but with the correct overlap parameter, ERO can produce the correct total cloud cover as well as the vertical distribution of the cloud cover seen from above and from below.
The cumulative cloud fraction and vertical distribution of cloudy cells are very close, it shows the ERO reconstruction not only reproduce the total cloud cover of the original scene, but also the distribution of cumulative cloud fraction (panels 4 and 5).
Similar results are obtained when also using Liquid Water Content distributions

OVERLAP AND RADIATIVE TRANSFER RESULTS

Comparison of the overlap parameter computed for ERO, the overlap parameter computed locally on the LES using $CF_{1,2}=\alpha CF_{max}+(1-\alpha)CF_{rand}$ and by fitting a decorrelation length L_α to the vertical profile of the LES : $\alpha_{k,l} = e^{-|z_l-z_k|/L_\alpha}$. The corresponding generated cloud cover is given:



- Left : using the overlap parameter computed on the LES on consecutive cloud layers or by fitting an exponential to the data can lead to a significant error in cloud cover.
- Right : comparison for the cloud and total albedo and cloud cover for different reconstructions: vertical subgriding can be used to compensate an initial coarse vertical resolution, if the proper overlap parameter is computed.