A consistent representation of cloud overlap and cloud subgrid vertical heterogeneity

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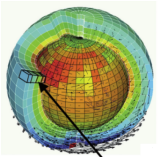
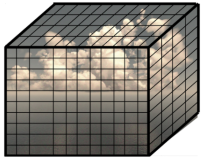
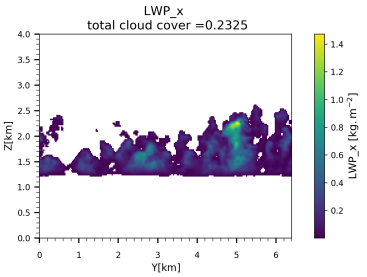
EGU - Clouds, Aerosols, Radiation and Precipitation

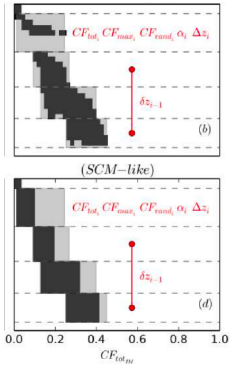
Aim of the current work





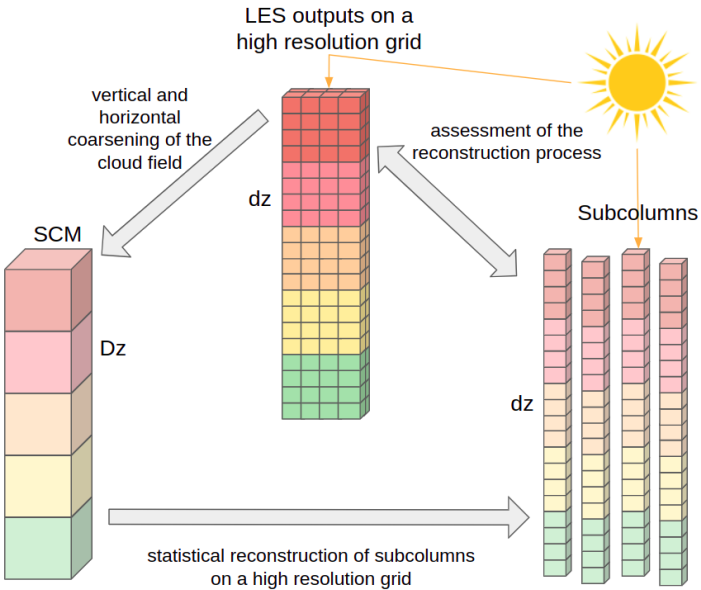


ARMCumulus (h=10) LES



- Overlap
- Subgrid variability

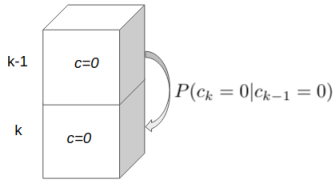
Methodology

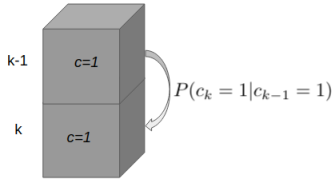


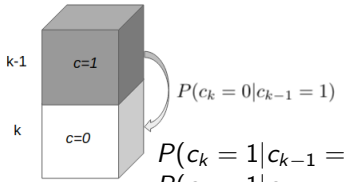
Overlap as a Markov chain

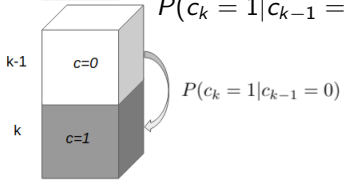
The cloud fraction overlap is a product of conditional probabilities :

$$P(C=(c_k)_{k=1,N}) = P(C_1 = c_1) \prod_{k=2}^{N} P(C_k = c_k \mid C_{k-1} = c_{k-1})$$









$$P(c_k = 1|c_{k-1} = 1) = 1 - P(c_k = 0|c_{k-1} = 1)$$
$$P(c_k = 1|c_{k-1} = 0) = 1 - P(c_k = 0|c_{k-1} = 0)$$

Using overlap to match the total cloud cover

Exponantial-Random Overlap :

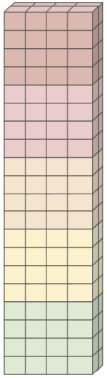
$$\boxed{C_{1,2} = \alpha C_{max,1,2} + (1-\alpha) C_{rand,1,2}}$$

Probability of generating a free-sky sub-column :

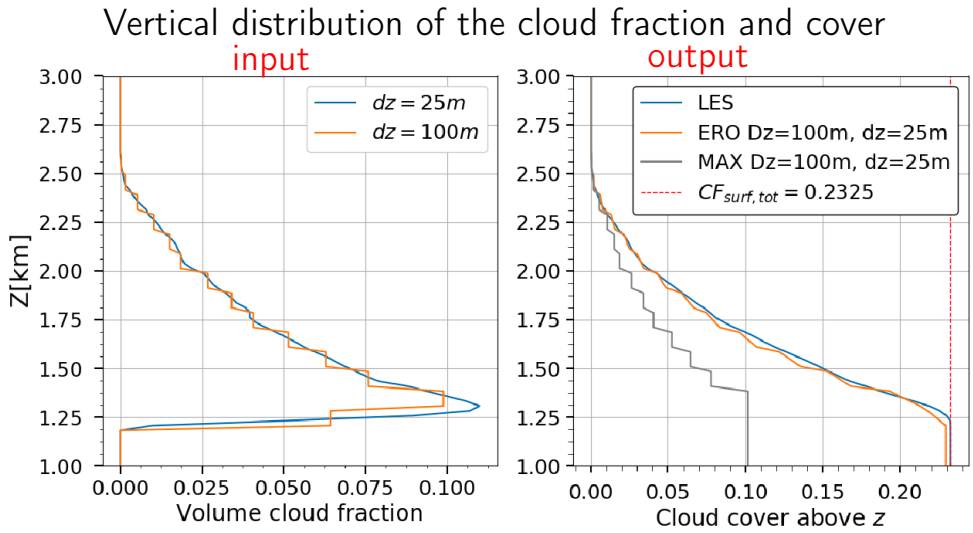
$$P_{\emptyset}(\alpha, N, n, CF) = \prod_{k=1}^{N} \left[P_{\text{inter},k}(0|0) \prod_{1}^{n-1} P_{sub,k}(0|0) \right]$$

$$CF_{surf,ERO} = 1 - P_{\emptyset}(\alpha, N, n, CF)$$

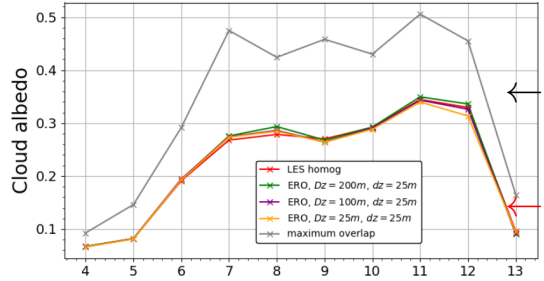
$$\alpha = P_{\emptyset}^{-1}(1 - CF_{surf,LES}, N, n, CF)$$



Results

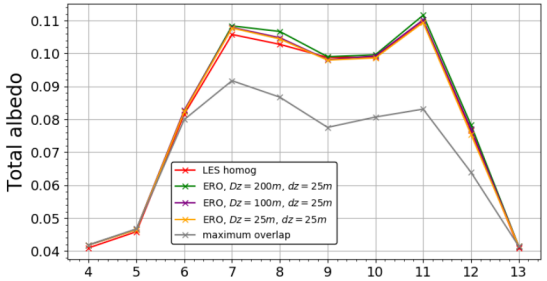

Vertical distribution of the cloud fraction and cover
input
output
Z[km]
3.00
2.75
2.50
2.25
2.00
1.75
1.50
1.25
1.00
$dz = 25m$
$dz = 100m$
0.000
0.025
0.050
0.075
0.100
Volume cloud fraction
LES
ERO Dz=100m, dz=25m
MAX Dz=100m, dz=25m
$CF_{surf,tot} = 0.2325$
0.00
0.05
0.10
0.15
0.20
Cloud cover above z

Radiative transfer : Impact on the SW reflectivity



← MAX-RAND

← LES,ERO



Conclusion

- Exp-Rand overlap is able to represent both interlayer overlap and subgrid heterogeneity
- The maximum-random approximation contributes to the "too few too bright" bias
- Vertical subgriding allows a better representation of the cloud fraction profile and of radiative properties
- This work has been done with the Independent Column Approximation, future work would be to consider 3D effects.

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Thank you for your attention !

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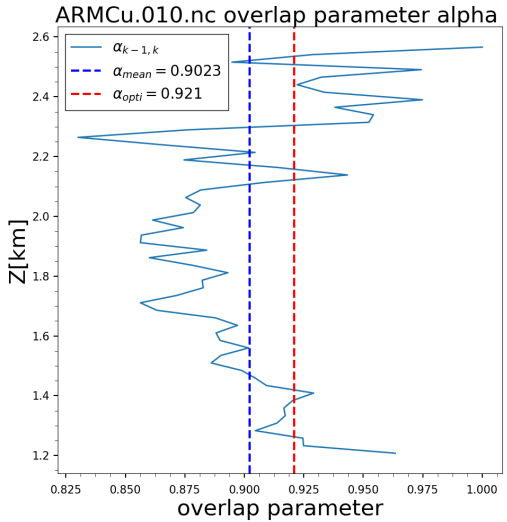
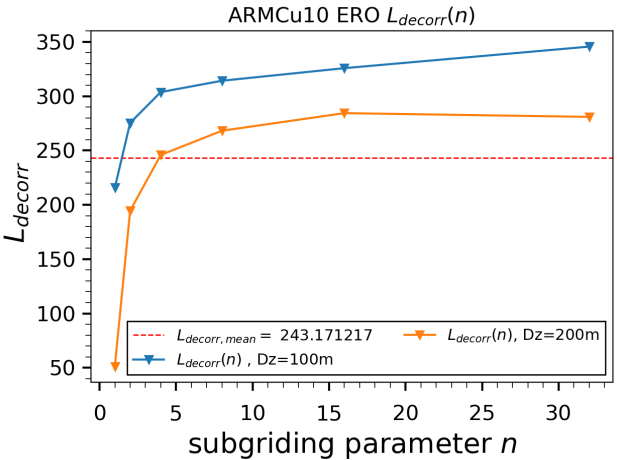
Two different overlap parameter ? α vs α_{LES} :



Overlap parameter computed from the LES : $\alpha_{k-1,k}$

$$CF_{tot} = \alpha CF_{max} + (1 - \alpha) CF_{rand}$$

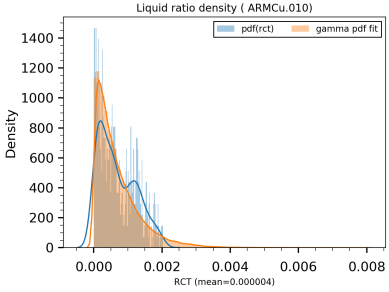
Decorrelation length



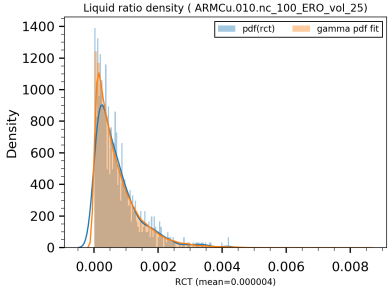
$$\alpha_{k,l} = \exp\left(-\int_{z_k}^{z_l} \frac{\mathrm{d}z}{L_{\mathrm{cf}}(z)}\right)$$

Liquid Water Content : γ-distributions

$\rightarrow$ Quantile correlation for adjacent layers, with α. (Raisanen et al, 2004)



Pdf of the LWC
z=2.25km



Pdf of the LWC
after generation z=2.25km

$$f(x,a) = \frac{x^{a-1}\exp(-x)}{\Gamma(a)} \qquad \gamma(x,a,loc,\beta) = f(\frac{x-loc}{\beta},a)$$

References

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- Villefranque, N., Fournier, R., Couvreux, F., Blanco, S., Cornet, C., Eymet, V., Tregan, J.-M. (2019). A path-tracing monte carlo library for 3-d radiative transfer in highly resolved cloudy atmospheres. Journal of Advances in Modeling Earth Systems, 11 (8), 2449–2473.