Introducing scale awareness into a subgrid parameterization

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Goal: Develop a cloud parameterization that produces similar results for grid spacings ranging from 2 to 16 km

Developing a model that is robust to changes in grid spacing obviates the need for re-tuning the cloud parameterization whenever the grid box spacing is changed.

The main idea: Typically, a larger grid box should encompass more variability than a smaller grid box

We need to ensure that the parameterization recognizes when the grid box is small and, in those cases, reduces the variance of relevant fields.

Introduction of scale awareness into the equation set

The part of the equations that depends on grid size is the dissipation time scale. For example, consider the equation for variance of total water (vapor + liquid):

$$\frac{\partial \overline{{r'_t}^2}}{\partial t} = \ldots - \frac{\overline{{r'_t}^2}}{\tau}$$

τ, in turn, depends on the turbulent eddy length scale L, where

$$\tau = \frac{L}{\sqrt{\bar{e}}}$$

Our provisional approach

We limit the eddy length scale to a fraction of the horizontal grid spacing.

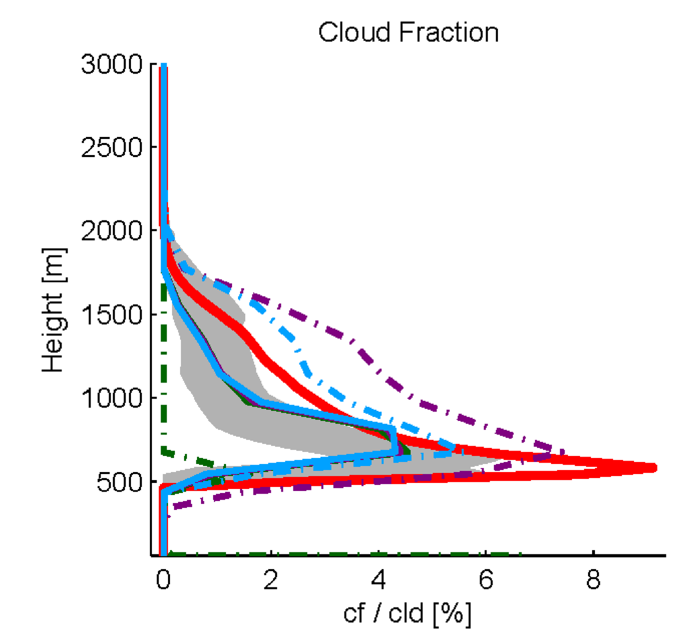
$$L = \min(L, 0.25\Delta x)$$

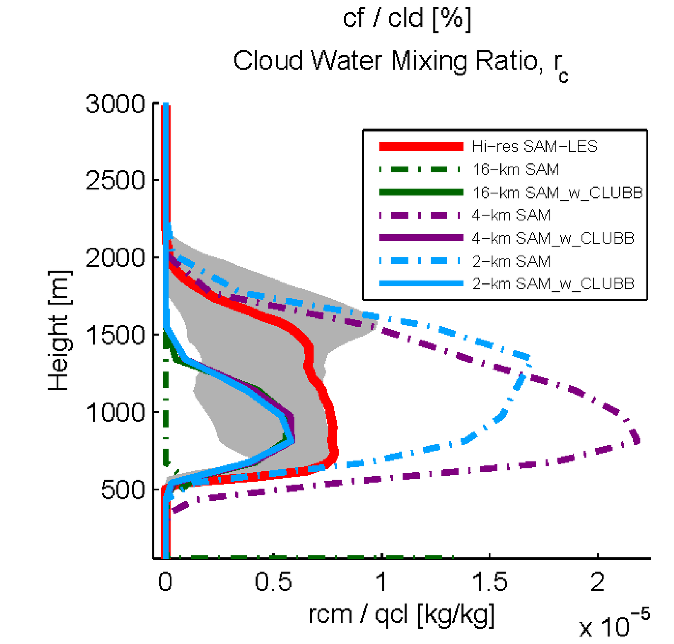
That is, we restrict our parameterization to representing only those turbulent eddies that are smaller than the horizontal grid spacing. Larger (resolved) eddies are handled by the host model.

Implementation and tests in a convection-permitting model

We have implemented this approach in a parameterization called "Cloud Layers Unified By Binormals" (CLUBB). In addition, we have implemented CLUBB in a convection permitting model, SAM. We simulate and present two cases: a marine stratocumulus case (DYCOMS-II RF01) and a shallow cumulus case (BOMEX).

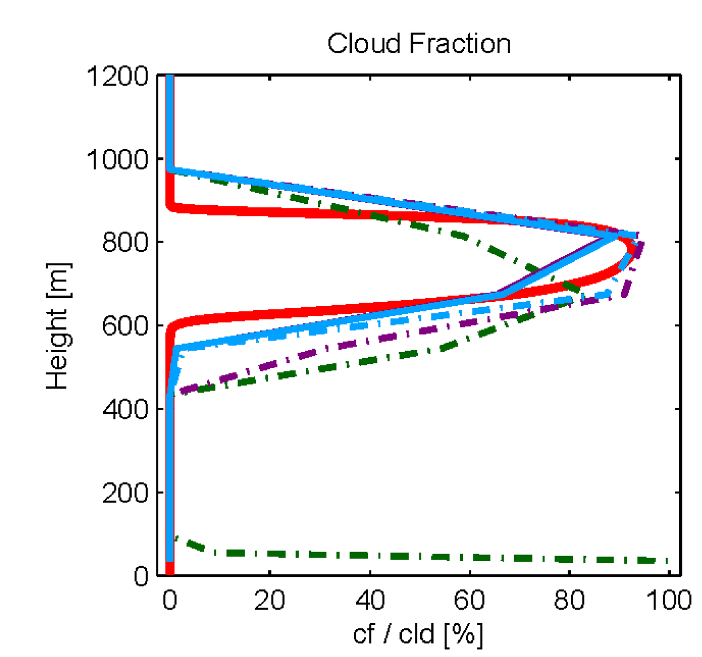
With CLUBB implemented, SAM is more robust to changes in grid spacing for shallow cumulus and stratocumulus

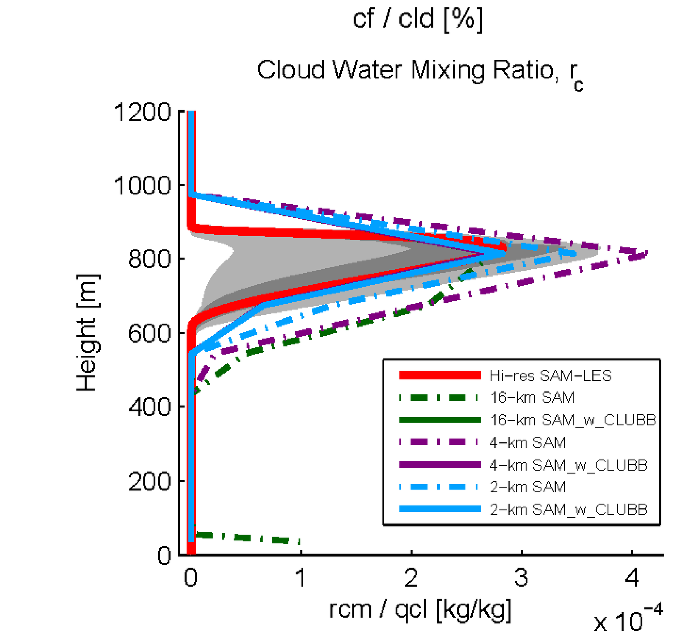




Here the thick red line is a reference LES and the grey shading demarcates a range of LES results. The solid lines represent SAM *with* CLUBB at various horizontal grid spacings. The dashed lines represent SAM *without* CLUBB at various grid spacings.

Our question regarding scale awareness is: Do the solid lines overlap each other more than do the dashed lines?





We see that SAM with CLUBB (solid lines) varies less with respect to changes in grid spacing than does SAM without CLUBB (dashed lines).

In this sense, the use of CLUBB makes the model more scale aware for these cases and grid spacings. Nevertheless, this method is relatively crude and in need of further testing and refinement. Of particular concern is deep convection.

Computational challenges

1. Parameter estimation
2. Numerics

Reference: Larson et al. (2012), Mon. Wea. Rev., **140**, 285—306.