P1.40 Comparisons of Large-Eddy Simulations with a Single Column Model: Implications for Mid-Level Cloud Parameterization

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Introduction

We have previously tested a single-column model (SCM) for boundary-layer clouds (Golaz et al. 2002b). Now, we wish to extend this study to mid-level clouds. This poster reveals results of a comparison between our SCM and a high-resolution, 3-D large-eddy simulation (LES). Our goal is to use these and other results to improve parameterization of layer clouds in large-scale models.

Using both the LES and SCM, we simulate a single-layer altocumulus cloud that was observed on 11 Nov 1999 during the CLEX-5 field experiment. Both models use identical initial conditions and large-scale forcings. A sensitivity study of the case is also performed, to compare the models under a wide range of conditions.

Results indicate that the models produce very similar time evolutions, including nearly equal cloud lifetime. Both models produce similar profiles of cloud fraction, liquid water, and turbulent fluxes of heat and moisture. The models also behave similarly between corresponding sensitivity runs, regardless of the physical parameter being varied. These results indicate that our SCM simulates aspects of the cloud accurately and similarly to the LES model.

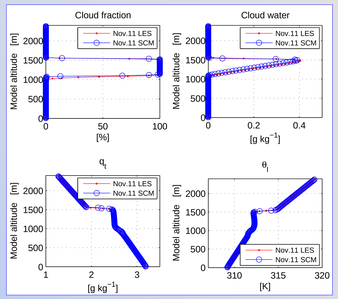
Model Specifications

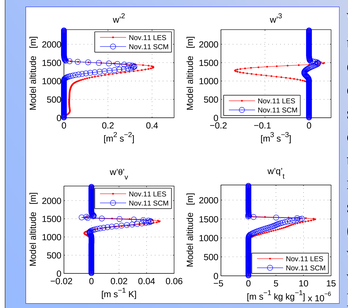
To provide a comparison, we perform a 3-D simulation using the COAMPS-LES model. The simulation has a vertical grid spacing of 15 m. Time step is 1 s. Additional details of the Nov. 11 cloud can be found in Fleishauer et al. (2002) and Larson et al. (2001). The LES simulation is described in Larson et al. (2006).

We also simulate the observed cloud using a 1-D single-column model (SCM). The SCM uses the same setup and forcings as the LES. Time step for the SCM is 1 min. Additional details of the SCM are provided in Golaz et al. (2002a). Both simulations last four hours, with a one-hour spinup to allow for mixing to occur.

Comparisons of Profiles

We first examine profiles for the LES (dots) and SCM (circles) at our initial observation time, immediately after the 1-hour spinup period. These profiles depict cloud fraction (upper-left), cloud water mixing ratio (upper-right), total water mixing ratio (lower-left), and liquid water potential temperature (lower-right). At this time, all SCM profiles match up with corresponding LES profiles. This indicates that the SCM has properly generated moisture and temperature profiles at the end of the spinup period.

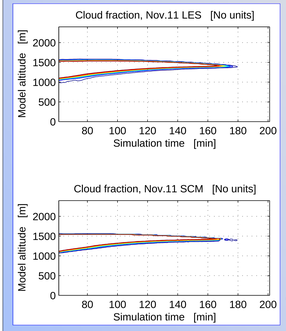




We also compare higher-order vertical flux profiles from both models. These profiles are averaged over the first observation hour after spinup. In our notation, w is vertical velocity, θ_v is virtual potential temperature, and q_t is total water mixing ratio. Profiles plotted are second-moment of vertical velocity ($\overline{w'^2}$, upper-left), third-moment of vertical velocity ($\overline{w'^3}$, upper-right), vertical buoyancy flux ($\overline{w'\theta'_v}$, lower-left), and vertical turbulent moisture flux ($\overline{w'q'_t}$, lower-right). All second-order flux profiles match quite well between SCM and LES. $\overline{w'^3}$ does not match well on a percentage basis, but its values are small in both the SCM and LES.

The LES was completed in 8 hours of computer runtime, while the SCM finished in 35 seconds. Therefore, the SCM generates reliable turbulence profiles in much less time.

Comparison of Cloud Evolution



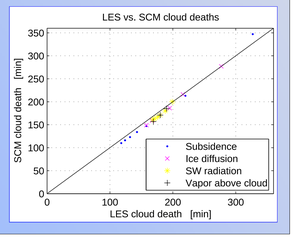
Cloud evolution is nontrivial, because it requires accurate calculation of many factors, including turbulent flux of heat and moisture. If overall cloud behavior is comparable between LES and SCM, then we can presume that the overall turbulence in the SCM is calculated without serious error.

The two simulations show similar cloud lifetimes and consistent behaviors. We define the cloud dissipation time as the first time step when cloud fraction is less than 1% over the entire vertical domain. LES cloud dissipation occurs at t = 179 min, and the SCM cloud dissipates at t = 180 min. **This tells us that the SCM simulates the overall cloud structure in a manner similar to the LES.**

Comparing Sensitivity Simulations

We also conduct a sensitivity study using both the LES and the SCM. Each model generates a series of simulations, with each simulation containing a single perturbed forcing from the control case. Perturbed forcings in the study include large-scale subsidence velocity, ice particle number concentration, solar zenith angle, and the amount of water vapor above cloud. Each point in the figure indicates LES cloud death time versus SCM cloud death time for a single sensitivity case.

Differences in cloud death times are less than or equal to 20 minutes for all comparisons, regardless of the forcing being modified. This indicates that the SCM faithfully simulates cloud evolution for a broad range of meteorological conditions.



Conclusions

This poster compares simulations of an observed altocumulus cloud, using a large-eddy simulation (LES) and a single-column model (SCM). The SCM's initial profiles and forcings duplicate those of the LES. Results show that the SCM produces qualitatively accurate profiles of moisture flux, heat flux, and turbulence. The SCM and LES also simulate similar time evolutions of the cloud layer when forcings are varied over broad ranges.

The SCM used here is the same model that is being used in other research to simulate boundary layer clouds (Golaz et al. 2002b). The present tests show that the applicability of the SCM extends beyond boundary layer clouds to at least one midlevel-layer cloud.

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Acknowledgments

The authors are grateful for financial support provided by subcontracts G-7420-2, G-7470-2, and G-7424-1 from the DoD Center for Geosciences at Colorado State University, and grant ATM-0239982 from the National Science Foundation. COAMPS is a registered trademark of the Naval Research Laboratory.

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