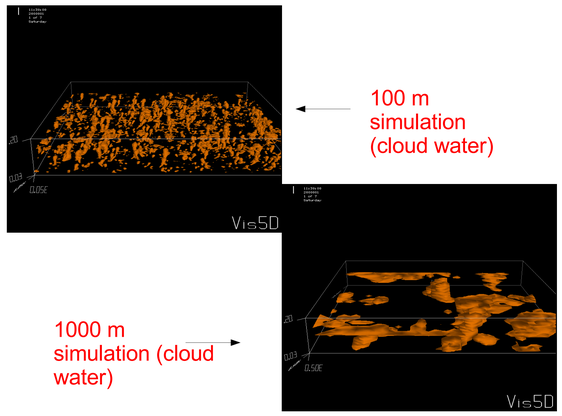
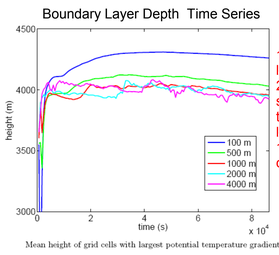
Aircraft Comparisons and Grid Dependence Studies of University of Utah Large Eddy Simulation

Peter A Bogenschutz, Steven K Krueger, and Michael Zulauf
University of Utah, Salt Lake City, UT

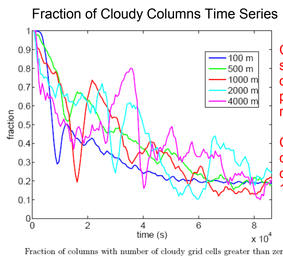
UU LES Grid Dependence Study

- A study of convective cloud systems that include a variety of co-existing cloud sizes and boundary layer circulations.
- Goal is to produce “benchmark” simulations that adequately resolve a large range of scales and that can therefore be used to evaluate and test sub-grid scale parameterizations for use in coarse grid CSRMS.
- Trade-wind cumuli cloud system is chosen for this study (UKMO heavy rain simulation, Abel and Shipway 2007).
- We used a large domain (40 km by 40 km) and a range of horizontal grid sizes (100 m, 500 m, 1000 m, 2000 m, 4000 m) to determine how well mesoscale organization is represented by different grid sizes.



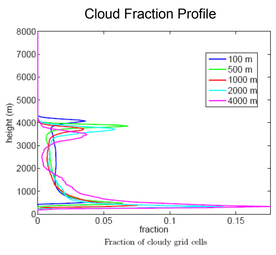


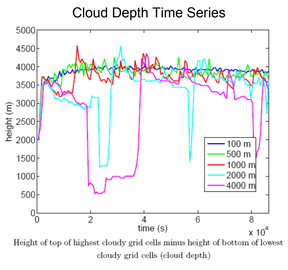
100 m simulation boundary layer deepens the most, around 200 m more than the rest of the simulations. Could be due to transport of TKE at top of cloud layer, which is strongest for the 100 m simulation, causing a net convergence of TKE.



Cloud cover for the coarse simulations is often variable, only the 100 m run (and possibly 500 m) appears to reach a true equilibrium.

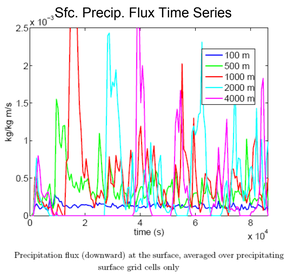
Coarse runs have more cloud cover near base and lower cloud top height compared to 100 m simulation.





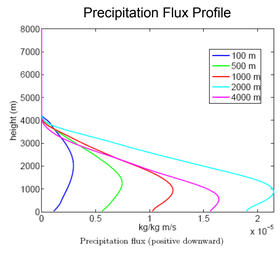
On average cloud depth for 100 m simulation is greatest, while the coarse runs (2000 m and 4000 m) goes through several cycles of shallow clouds.

Updraft cores for 100 m simulation ~ 1 km or less, which the coarse runs cannot resolve.



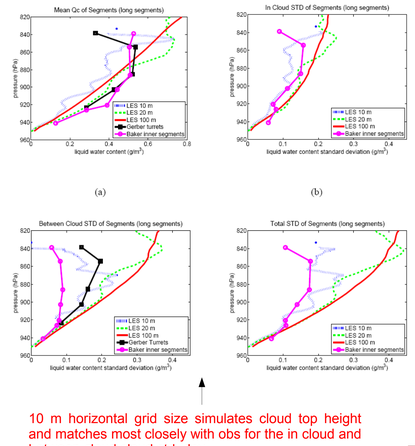
Surface precipitation flux shows the coarse simulations with strong periods of convection with little/no activity between and the 100 m simulation coming to equilibrium.

Precipitation for coarse runs are more intense, 100 m simulation uses more cloud water to deepen and moisten the cloud layer (by evaporation).



LES Vs. Aircraft Observations

- Goal is to utilize observational datasets for evaluation of fine and coarse grid UULES. Cloud segments are defined based on conditional sampling for both LES and observations (see below).
- UU LES runs compared against RICO flight data (RF 12), analyzed by Brad Baker and Hermann Gerber.



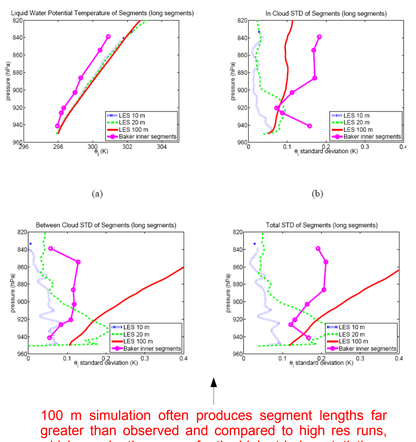
10 m horizontal grid size simulates cloud top height and matches most closely with obs for the in cloud and between cloud cloud std. dev.

Mean in-cloud profiles of total water differ between LES and obs. because environmental profiles differ for LES and obs. The LES has somewhat less in-cloud variability, and more between-cloud variability than observed.

UU Cloud Segments

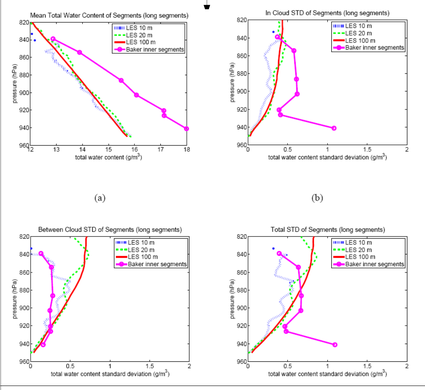
- UU LES cloud segments requires at least two consecutive grid points where qc (cloud water mixing ratio) > 0 and w > 0.
- Long segments are at least 100 m in length.
- Maximum of two grid points where qc = 0 is allowed between cloud points for that area to still be considered one segment.
- Grid scanned in the x direction at every level where qc > 0 exists.
- 100 m simulation sampled for 24 hours, 20 m sampled for thirty minutes and 10 m run sampled for 3 minutes.

•In Cloud STD: the mean of the standard deviations within each segment
•Between Cloud STD: the standard deviation of the segment means



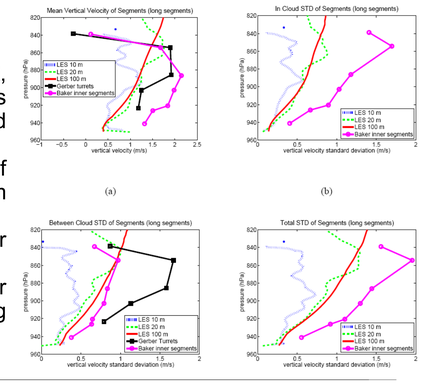
100 m simulation often produces segment lengths far greater than observed and compared to high res runs, which may be the reason for the high std. dev. statistics.

Although the simulations tend to underestimate both the mean vertical velocity and std. dev., the 10 m simulation generally matches the pattern set by the aircraft obs for these.



Obs. Cloud Segments

- Gerber Cu Turrets: 80% updraft, clouds sampled 20 m below cloud tops with 35-cloud subset of 200 cloud penetrations during RF-12.
- Baker inner cloud segments: areas of similar droplet concentration for 120 m or more.
- 130 inner cloud segments identified for RF 12, over seven layers.
- Baker inner segments and Gerber Turrets comparable to UU LES long segments.



UU LES Model Set-Ups

Grid Dependence Study:

- Total Domain size: 40 km * 40 km * 8 km
- 100, 500, 1000, 2000, and 4000 m horizontal resolution simulations run for 24 hours
- Initial profiles and large-scale forcing are the same as those used by Able and Shipway (2007) .
- Turbulent length scale is maximum of either 100 m or vertical grid size (in these simulations is is always 100 m).

LES vs. Aircraft Obs. Study:

- Initial profiles and large-scale forcing are based on profiles from radiosondes and aircraft dropsondes during RICO period of Dec 16, 2004 – Jan 8, 2005. They are the same as those used for the GCSS Precipitating Shallow Cumulus Case (http://www.kmni.nl.samenw.rico/).
- Total Domain size: 12.8 km * 12.8 km * 4 km
- Three simulations run; 100 m, 20 m , and 10 m horizontal grid sizes
- Hi-res region is 4 km * 4 km, outermost regions have 50 m horizontal grid sizes with a variable grid size region between outer and hi-res regions.
- 100 m simulation run for 24 hours. 20 m and 10 m runs are continuations of the coarse run, starting at approx 8.75 h and run for approximately 30 and 3 minutes, respectively. The 10 m run being a continuation of the 20 m run.

References

Abel, S. J., and B. J. Shipway, 2007: A comparison of cloud resolving model simulations of trade wind cumulus with aircraft observations taken during RICO. Quart. J. Roy. Meteor. Soc., **133**, 781–794.

Conclusions

LES Vs. Aircraft Observations Study

- Although sampling differences exist between aircraft and LES, there is a general agreement for segment statistics, especially for the 10 m simulations.
- 10 m simulation tends to capture cloud top height and the behavior of the in cloud and between cloud standard deviations the best.
- Either running the 10 m simulation for extended period of time or running simulation with double moment microphysics would produce results more comparable to Baker sampling method.

Grid Dependence Study

- Coarse resolution runs do not reach equilibrium (1000 m and greater).
- Simulations with resolutions greater than 1000 m are characterized by brief periods of intense convection and rainfall, while 100 m simulation has steady and consistent precipitation (averaged over the grid) more characteristic of trade cu.
- Mesoscale organization does not occur in coarse simulations.
- 100 m simulation most desirable to adequately resolve observed range of cloud scales, 500 m would be acceptable.

Acknowledgment: This research was supported by the National Science Foundation Science and Technology Center for Multi-Scale Modeling of Atmospheric Processes, managed by Colorado State University under cooperative agreement No. ATM-0425247