ARM LES Testbed Prototype: Multi-Scale WRF Simulations of Boundary Layer Clouds

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1. INTRODUCTION

Boundary layer clouds (BLCs) have a significant impact on the radiative budget of the Earth but are difficult to represent in climate models. In the past, large eddy simulation (LES) has served as a major role in providing a better understanding of the BLCs and developing parameterizations of cloud turbulence and convection processes. ARM over the years has made a great progress in developing a suite of key remote sensing instruments, such as MMCR and WACR, for observing BLCs under various weather conditions. The primary goal of the ARM LES Testbed (ALT) is to improve parameterizations of BLCs through systematically evaluating LESs using ARM high temporal and spatial resolution cloud radar measurements. To cope with the advanced ARM cloud radar data and fulfill the goal of ALT, we propose to develop a multiple two-nested WRF LES framework applied to ARM sites. The WRF-LES system distinguishes itself from the classic LESs in four ways.

- WRF-LES is nested within WRF mesoscale simulations to ensure robust up-scale and down-scale interactions cross a spectrum of scales. This feature allows WRF-LES to be able to simulate boundary layer clouds in all weather conditions.

- WRF-LES can be developed into an operational mode, which can be executed at regular bases in parallel with MMCR and WACR observations.

- WRF-LES can be initialized using forecast data or reanalyses data through WRF Preprocessing Systems. WRF data assimilation package also provides a means to assimilate ARM observations, such as soundings, surface measurements, wind profile data, and radar observations, into WRF-LES simulations.

- The coarse grid simulations from WRF-LES can be used to generate suitable forcing data to drive various existing LES models in the community.

Here, we present the feasibility of ATL using the stratocumulus case observed at the ARM SGP site during March 25th-26th 2005.

2. MULTI-SCALE WRF SIMULATION

- Configuration.
  - 5 domain with 4 two-way nests.
  - Vertical resolution: 24.0 to 55.7 m below 1845 m.
  - Simulation (domain-1) started at Mar. 25th 2005, 00:00 Z. Four nests were activated 6 hrs later at 06:00Z.
- Initialization
  - Initialized with NCEP reanalyses (1X1 degree).
  - Initialized with NCEP reanalysis and assimilated with ARM sounding.
- Microphysics
  - Thompson graupel scheme.
  - RRTM longwave, Dudhia shortwave
  - MY TKE scheme, M-O surface layer
  - K-F cumulus (D-1 and D-2)
  - Noah land-surface model, thermal diffusion scheme for temp only

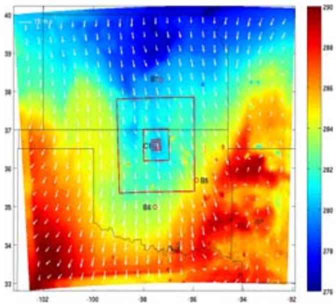


Fig. 1 Background: 2 m high potential temperature with 10 m high wind vectors

Domain - 1 : $121\times101\times54$, $\Delta x = 8100$ m

Domain - 2 : $103\times103\times54$, $\Delta x = 2700$ m

Domain - 3 : $103\times103\times54$, $\Delta x = 900$ m

Domain - 4 : $103\times103\times54$, $\Delta x = 300$ m

Domain - 5 : $181\times181\times54$, $\Delta x = 100$ m

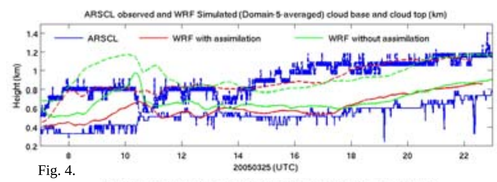
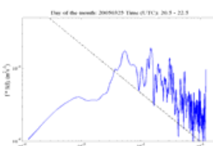


Fig. 4.



WRF simulated spectrum at 20:30UTC

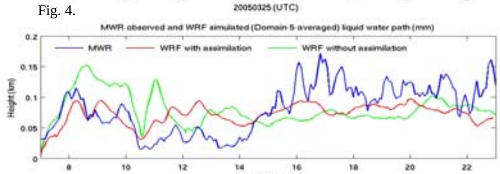


Fig. 5.

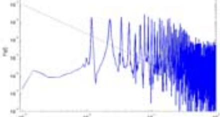


Fig. 6. Comparison of spectrum

Figs. 4 and 5 show the improvement of the simulated cloud properties due to the assimilation of ARM observations in WRF simulations.

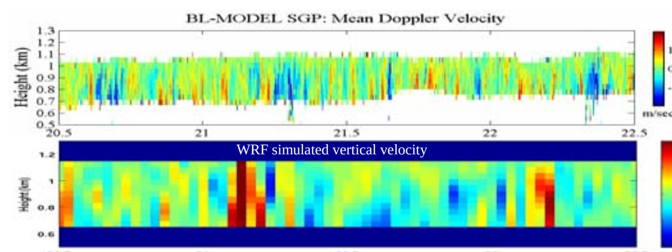


Fig. 7: Up- and downdraft structures Time (UTC) 2005, 03, 25

3. COMPARISON

Fig. 2 shows that the large-scale horizontal distribution of cloud fields is reasonably reproduced by the WRF simulation (Domain-1).

Fig. 3 shows the evolution of mesoscale Structures of clouds Simulated by the WRF Domain-3.

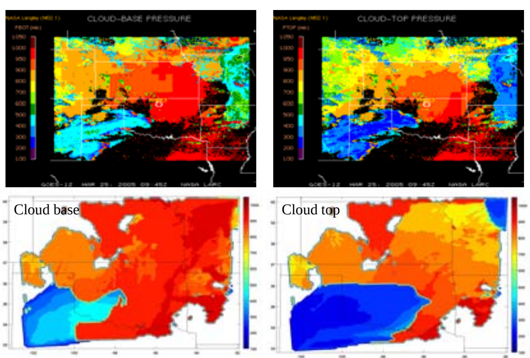


Fig. 2: Observed and simulated (D-1) cloud boundary pressure Mar. 25th 09:45Z

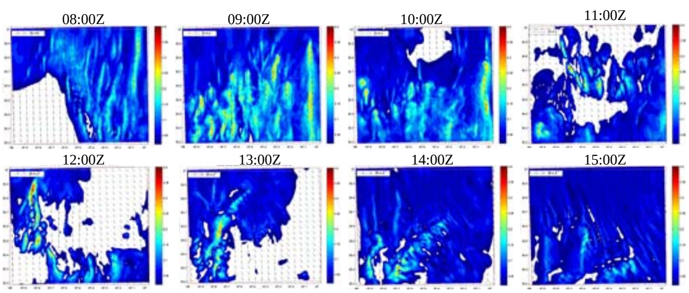


Fig. 3: Simulated cloud water path (mm) along with 10 m wind vectors (Domain-3)

4. SUMMARY

- The comparison between WRF simulations and ARM observations at various scales indicates that WRF-LES captures adequately the synoptic-scale and mesoscale low cloud features and realistically reproduces the observed fine-scale turbulent structures of BLCs. The study indicates that WRF-LES could serve as an appropriate modeling platform for the proposed ARM-LES-Testbed. WRF-LES can also generate LES forcing data to drive various existing LESs.
- WRF-LESs can be much improved through assimilating ARM observations in the simulations.