LES ARM Symbiotic Simulation and Observation (LASSO) Workflow: Ensemble Forcings and LES Sensitivity

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1. Introduction

- The Atmospheric Radiation Measurement (ARM) Climate Research Facility is developing a routine large-eddy simulation (LES) modeling framework at its permanent sites, called the LES ARM Symbiotic Simulation and Observation (LASSO) Workflow, to supplement its extensive observations (See Gustafson et al. poster for the project overview).
- An LES ensemble will be performed based on multiple forcing data sets, as uncertainty in the forcing will be the biggest driver of simulation spread.

This poster presents forcing derivation methodologies, efforts to improve the forcing data, and test LES simulations to evaluate the derived forcing datasets.

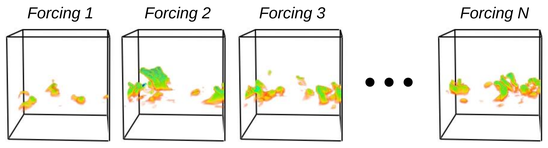


Figure 1: Schematic for the ensemble of "small" LES runs to test input forcing datasets.

2. Ensemble Forcings

We examine three forcing derivation methodologies and their variations:

1) ARM Constrained Variational Analysis (VARANAL) Product

- Based on a constrained variational-analysis approach that combines NWS Rapid Refresh (RAP) analysis with surface-level and profiling observations for a 300 km SGP domain.
- Two versions differently merge surface heat flux observations from the Bowen ratio method (EBBR) and eddy correlation (ECOR) stations: "**SIMPLE**" averages surface heat flux distributions obtained by EBBR and ECOR, "**LAND**" weights the station measurements by the land surface type.
- A 3-D VARANAL can soon be tested.

2) ECMWF/IFS Forcing

- Derived from the short term forecast by the ECMWF IFS model, which incorporates ARM sounding data.
- Two major versions take different approaches: the grid-point-value-based single column model forcing (**SCMF**) uses advection derived from grid-point values from the forecast (post-processing). **DDH** forcing utilizes budget terms from the Diagnostics in the Horizontal Domains (DDH) system that considers runtime tendency output from the forecast. The DDH forcing includes three domain sizes (**d20**: single column [~16 km box], **d29**: ~115 km box, **d27**: ~ 370-430 km box).
- The bug-fixed pre-released version is used.

2. Ensemble Forcings (Cont'd)

3) WRF Multi-Scale Data Assimilation (MS-DA) Forcing

- Derived by a WRF-3DVar-based MS-DA system that efficiently assimilates high-resolution data using the Grid-point Statistical Interpolation (GSI) system in conjunction with a scale separation algorithm to combine observations representing coarse and fine scales.
- The MS-DA system assimilates operational DA input fields as well as high-resolution measurements from ARM (currently, Radiosondes and AERIoe for temperature and water vapor) using a 2-km grid spacing. We examine the methodologies to better reproduce observed atmospheric conditions.

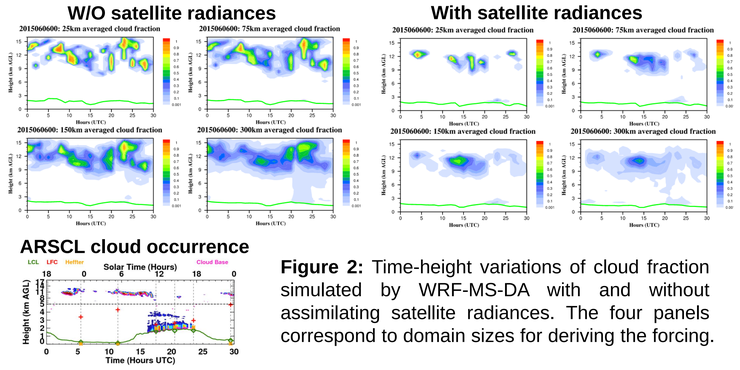


Figure 2: Time-height variations of cloud fraction simulated by WRF-MS-DA with and without assimilating satellite radiances. The four panels correspond to domain sizes for deriving the forcing.

Representation of high clouds is improved by assimilating satellite radiances.

A high model top (10 hPa) was required to effectively assimilate the satellite radiance (not shown).

Further improvement is expected by assimilating measurements from the new ARM profiling sites.

- The configuration for the MS-DA forcing could have a number of variations. For example, Figure 3 includes versions using 45 and 61 model levels (**45L** and **61L**), produced for **75, 150, 300 km** forcing scales. Also, different background fields may be used (e.g., FNL, NARR, ECMWF).

3. LES Sensitivity to the Ensemble Forcings

- An ensemble of small LES runs are performed to test the forcings. Shown here are results from WRF using the same configuration: 100 m horizontal grid spacing, 7.2 x 7.2 x 15 km domain, 120 model levels, Lin microphysics, RRTMG radiation, initialized with a 12 UTC sounding, and surface flux from VARANAL SIMPLE.

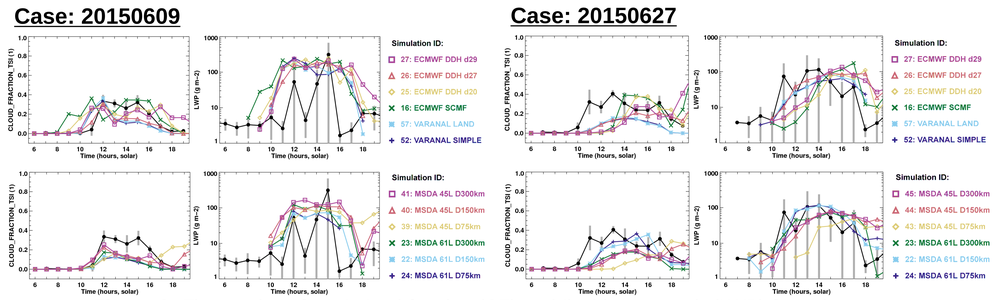


Figure 3: Time series of total cloud fraction (CF) and liquid water path (LWP) from the LES runs using different large-scale forcings for the 20150609 and 20150627 cases.

- Various skill scores are being developed to evaluate the LES ensemble with different forcings and configurations (See Vogelmann et al. poster for the metric development).

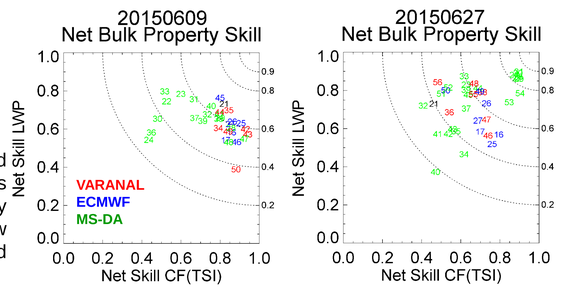


Figure 4: Skill scores based on the observed and simulated CF and LWP. The numbers indicate simulation IDs (not completely overlapped with those in Fig. 3). The lines show bulk property skill score that combine CF and LWP.

There is not a single forcing configuration that is consistently superior for different cases.

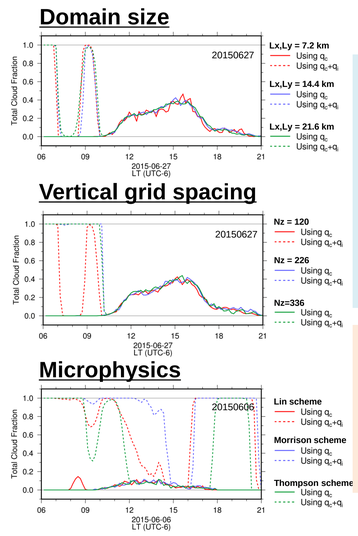
E.g., For the 20150609 case, VARANAL and ECMWF produced top-ranked LES runs; For the 20150627 case, MS-DA has several runs with highest skill.

Different forcings clearly provide spread, but it is unclear how to select "valid" ensemble members. Clear outliers are of little value.

The skill scores will help identify the simulations that best represent the observed properties and clear outliers.

4. LES Sensitivity to Model Configurations

- LES configurations are examined to evaluate the forcing tests by using the small LES runs.



There is not a major sensitivity in boundary layer cloud to LES domain size, vertical grid spacing, and microphysics scheme.

Upper-level ice clouds are sensitive to the microphysics scheme.

The "small" runs produce boundary layer clouds that are generally representative of those that obtained by more expensive LES runs.

Figure 5: LES sensitivity to horizontal domain size (L_x and L_y) and number of vertical levels (N_z) for the 20150627 case, and microphysics scheme for the 20150606 case.

5. Summary

- We investigated a forcing ensemble composed of VARANAL, ECMWF, and MS-DA forcings for the LASSO workflow.
- "Small" LES runs are used for the forcing tests. Sensitivity tests to model configurations show that the small LES runs can produce results similar to more expensive LES runs with larger domain and/or finer vertical grid spacing.
- There is not a single forcing configuration that consistently produces better cloud properties for the different cases tested.
- Newly-developed skill scores provide a means to identify LES runs that best represent the observed could properties.
- Other tests (e.g., using spectral bin microphysics; using nested approach) are in progress.
- Efforts to test and improve the forcings will continue. ARM's new profiling measurements are expected to improve the representation of spatial variability in the forcing derivation.

LASSO Webpage
http://www.arm.gov/science/themes/lasso

LASSO information e-mail list sign up
to receive LASSO project updates at
http://eepurl.com/bCS8s5

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