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

Satoshi Endo¹, Zhijin Li²,³, Xiaoping Cheng², Heng Xiao⁴, William I Gustafson Jr⁴, Andrew M Vogelmann¹, Tami Toto¹, Maike Ahlgrimm⁵, Shaocheng Xie⁶, and Tang Shuaiqi⁶

¹Brookhaven National Laboratory, ²University of California, Los Angeles, ³NASA Jet Propulsion Laboratory, ⁴Pacific Northwest National Laboratory, ⁵European Centre for Medium-Range Weather Forecasts, ⁶Lawrence Livermore National Laboratory

---

### 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.

![Forcing Diagram](image1)

*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 (EBA) and eddy correlation (ECOR) stations. “SIMPLE” averages surface heat flux distributions obtained by EBA 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.

3. **LES Sensitivity to the Ensemble Forcings**
   - An ensemble of small LES runs is 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.

   - 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).

   ![Cloud Fraction vs. LWP](image2)

*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.*

*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.*

---

### 3. LES Sensitivity to Model Configurations

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

#### Domain Size

- 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.

#### Vertical Grid Spacing

- There are no major differences except for those obtained by more expensive LES runs.

#### Microphysics

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

![LES Sensitivity](image3)

*Figure 5: LES sensitivity to horizontal domain size (Lx and Ly) and number of vertical levels (Lz) for the 20150627 case, and microphysics scheme for the 20150609 case.*

---

### 4. LES Sensitivity to Model Configurations

#### Domain Size

- 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.

#### Vertical Grid Spacing

- There are no major differences except for those obtained by more expensive LES runs.

#### Microphysics

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

---

### 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 cloud 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.