Routine Large-Eddy Simulations of Continental Shallow Convection – Workflow Development

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ARM CLIMATE RESEARCH FACILITY

Summary

- The U.S. Department of Energy's Atmospheric Radiation Measurement (ARM) Climate Research Facility is developing the capability to routinely perform large-eddy simulation (LES) modeling at its permanent sites.
- The effort, called the LES ARM Symbiotic Simulation and Observation (**LASSO**) Workflow, will use ARM observations to constrain LES simulations and produce dynamically consistent "data cubes," aimed at providing the best description of the atmospheric state.
- The data cubes will be available to the community to complement the megasite observations to support the study of atmospheric processes and support the improvement of the parameterizations of these processes in climate models.

1. LASSO Background

Over two years, the ARM Climate Research Facility will develop LASSO to conduct ongoing, routine LES at its research sites.

- Simulations will initially target shallow convection at the ARM Southern Great Plains (SGP) megasite in Oklahoma and will go online in mid-late 2017.
- ARM then plans to expand the LES modeling to include additional cloud types (e.g., deep convection) and locations, such as the ARM East North Atlantic (Azores) and the North Slope of Alaska sites.
- LASSO is designed to generate an ever expanding library of LES simulations that will add value to ARM's observations and expand beyond the typical case-specific mentality used in much of LES modeling.
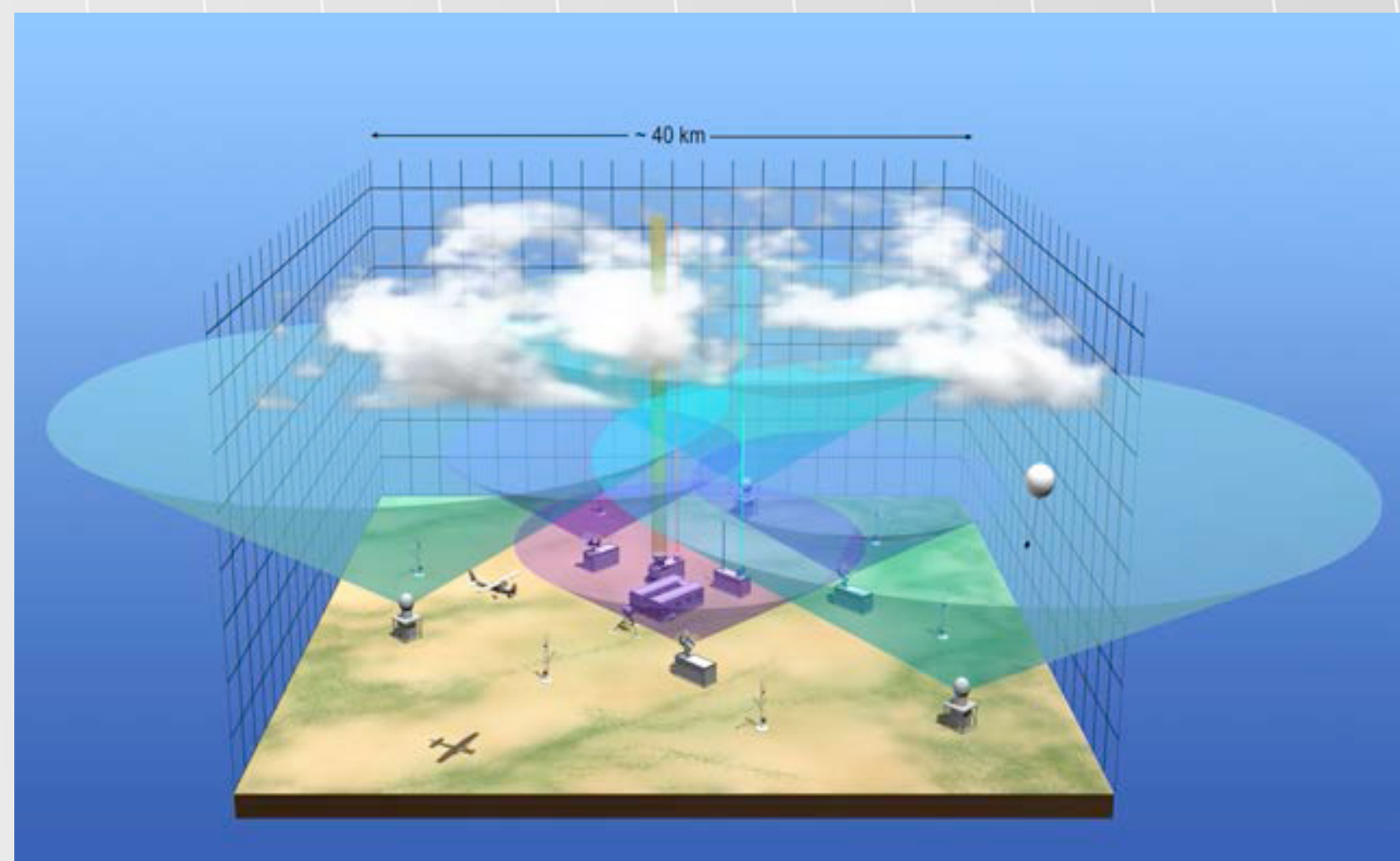
Enhanced Megasite Observations: ARM is deploying multiple scanning cloud radars at the SGP. To better constrain the large-scale forcing it's:

- Establishing 4 profiling sites at facilities ~40 km from the SGP to provide boundary layer temperature, humidity, and winds, as well as other surface observations (Spring 2016).
- Establishing 3 radar wind profilers ~15 km from the SGP central.

2. LASSO Overview

The LASSO workflow is an end-to-end process, where ARM data are used to generate ensemble forcing data sets and evaluate the LES simulations. The LES output and observations are packaged into "data cubes" aimed at providing the best description of the atmospheric state for analysis by the community. The data cubes will be searchable, have quicklooks and efficient filtering methods for users to find and order cases of interest. Tools will be developed to simplify analysis and visualization. User feedback will be used in the design and post-operational refinements.

LES ARM Symbiotic Simulation and Observation (LASSO) Workflow
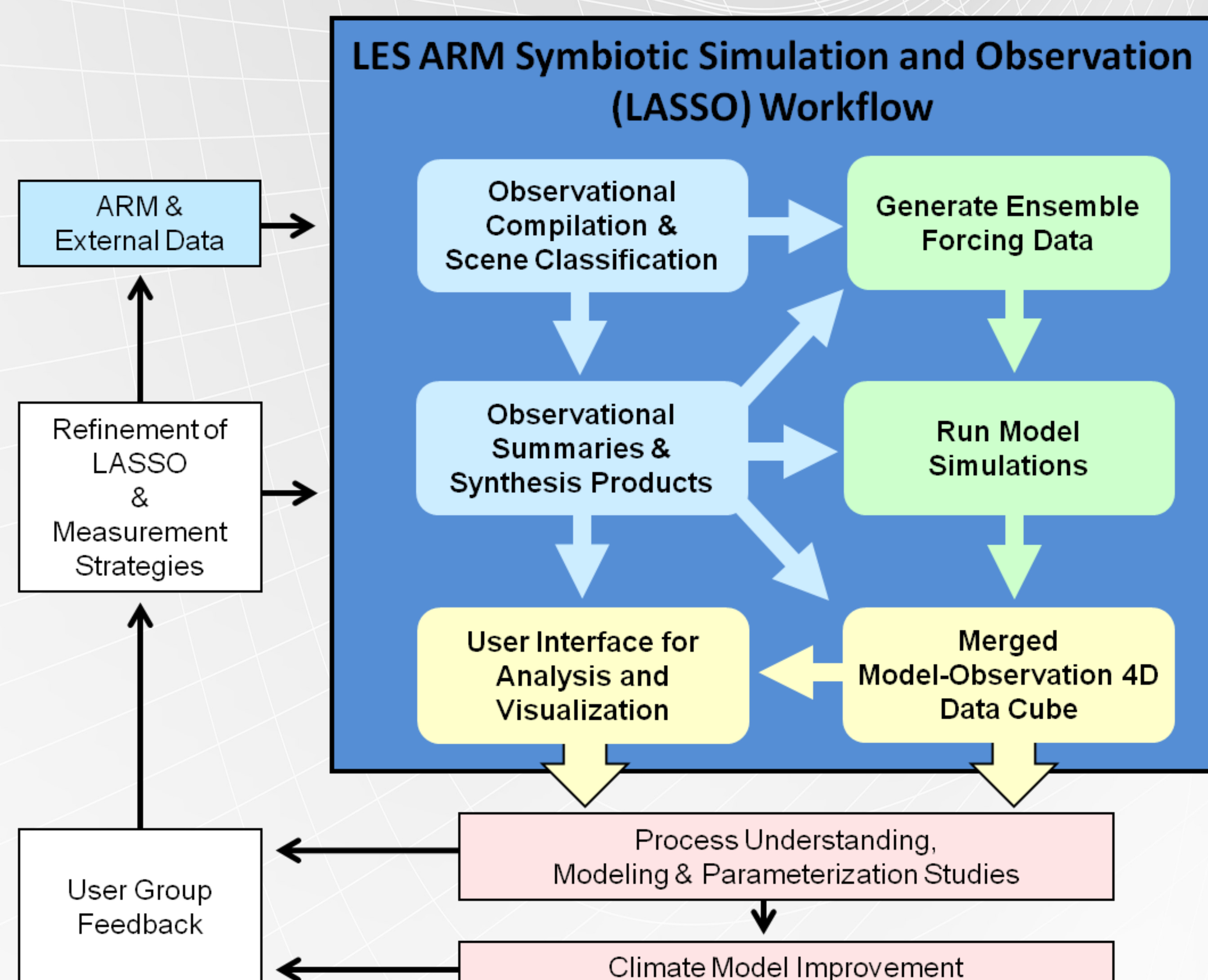
3. Ensemble Forcings

Ensembles will be used based on multiple forcing data sets, as uncertainty in the forcing will be the biggest driver of model spread. We are exploring three forcing data set methodologies:

1) The ARM continuous forcing data [Xie et al., 2004] is based on a constrained variational-analysis approach that combines National Weather Service analyses with ARM observations.
   - A 3-D variational analysis product will be tested when available

2) Derived from short-term ECMWF forecasts that incorporate ARM radiosonde data (Contact: Maike Ahlgrimm)

3) Derived by a WRF-3DVar-based multi-scale data assimilation (MS-DA) system [Li et al., 2015], which efficiently assimilates high-resolution data to generate forcings down to order(1 km) scale. It accomplishes this using the community-based Gridpoint Statistical Interpolation (GSI) system in conjunction with a scale separation algorithm to combine observations representing coarse and fine scales.
   - Assimilates high-resolution ARM data along with operational DA input fields
   - Initialization /boundary conditions with GFS, HRRR, NAM, NARR, & possibly ECMWF
   - Will explore hybrid ensemble Kalman filter (EnKF) DA for ensemble scenarios

4. Ensemble of LES Simulations

Each simulated event will consist of an ensemble of LES simulations using 2-moment bulk microphysics based on the forcings. Additionally, considering running one simulation using spectral bin microphysics. The following configurations are being tested for operational use:

- The Weather Research and Forecasting (WRF) model and System for Atmospheric Modeling (SAM), where one will be selected
- Different domains and resolutions (e.g., 25 km box, top=tropopause, dx,dy=100 m, dz=40 m and stretched in the free atmosphere)
- The benefit vs. computational cost of the spectral bin microphysics run
- Model physics options
- Periodic (WRF and SAM) and nested domains (WRF)

## 5. Ensemble Diagnostics and Metrics

Ensemble LES simulations are assessed using ARM observations of cloud and environmental variables in a series of evaluation diagnostics and metrics including:

a) Time series, with average difference, RMS and correlation coefficient
b) Heat maps, for differences of the simulated time series from observations
c) Regression analysis, for slope and intercept
d) Taylor diagrams, for standard deviation and correlation phase space
e) Phase space relationships, for relative relationships between a set of variables
f) Relative Euclidean distance (Wu et al., 2012), for overall model performance of a variable
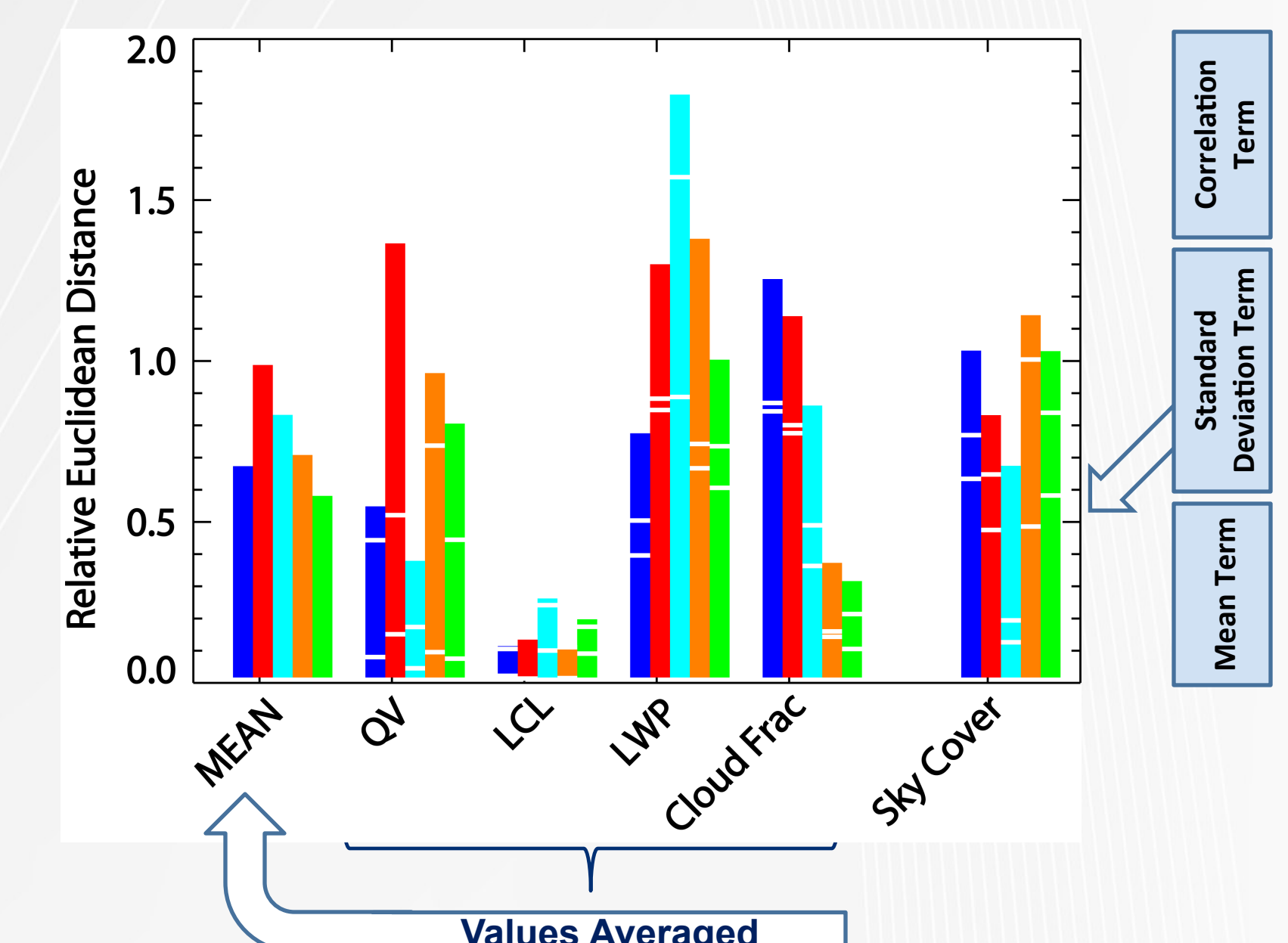
$$RED = \sqrt{\left[\frac{(\overline{M}-\overline{O})}{\overline{O}}\right]^2 + \left[\frac{(\sigma_u - \sigma_o)}{\sigma_o}\right]^2 + (1-r)^2}$$

Heat maps
Absolute differences followed by (Percentage differences)
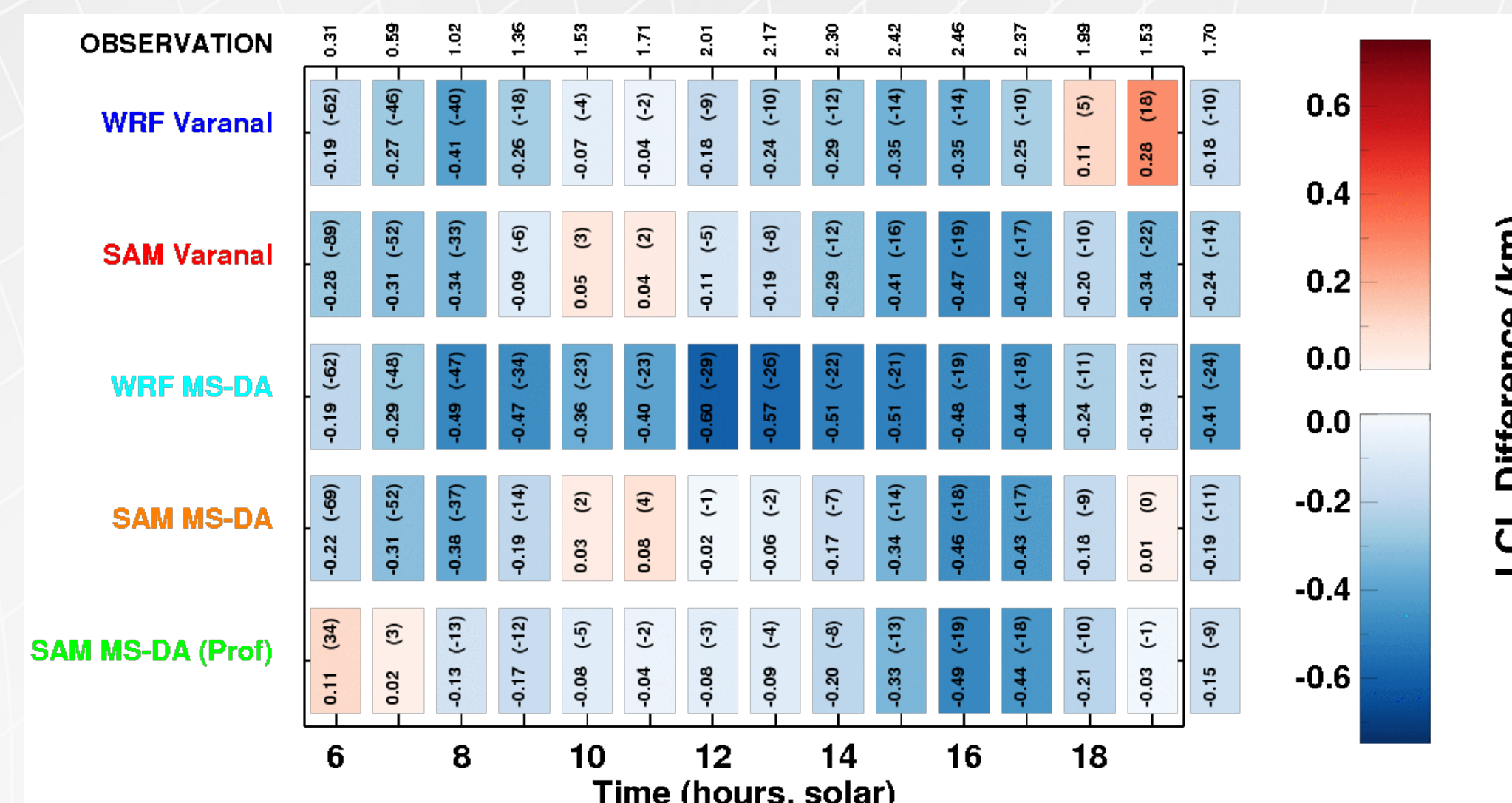
Relative Euclidean Distance (RED)

References

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