

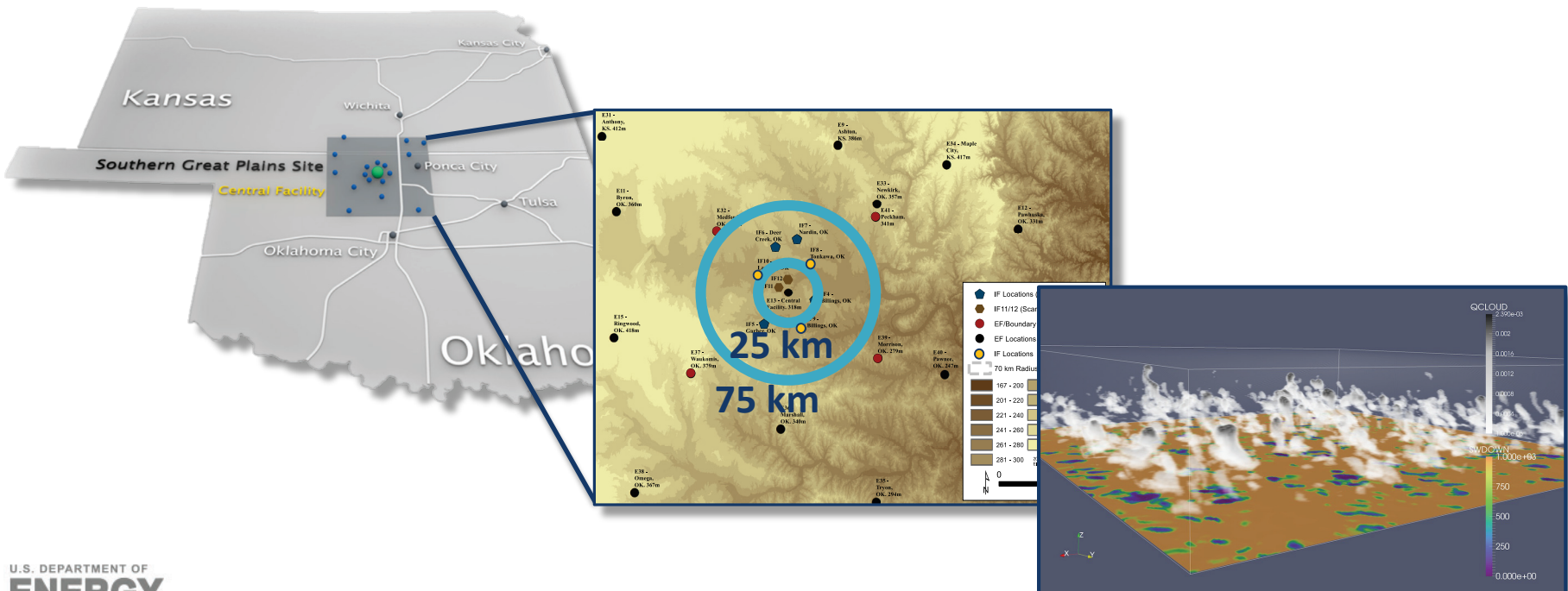
SENSITIVITY OF SHALLOW CONVECTION IN LARGE-EDDY SIMULATIONS TO FORCING DATASETS ACROSS A RANGE OF DAYS: EXAMINING RESULTS FROM THE DOE LASSO PROJECT

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BNL: Andrew M. Vogelmann (Co-PI), Satoshi Endo, Tami Toto
UCLA: Zhijin Li, Xiaoping Cheng
ORNL: Bhargavi Krishna

AGU Fall Meeting, 15-Dec-2017

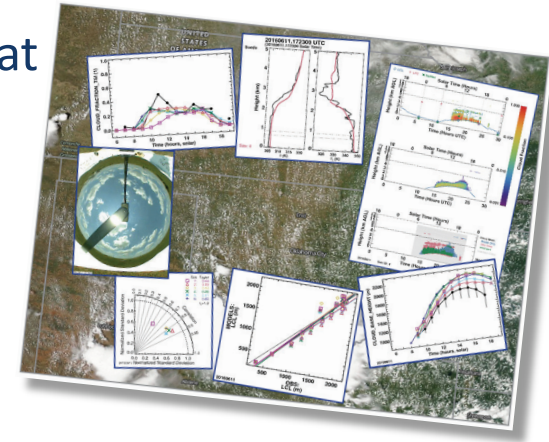
What is LASSO?

- LASSO = LES ARM Symbiotic Simulation and Observation workflow
 - ▶ <https://www.arm.gov/capabilities/modeling/lasso>
- The DOE Atmospheric Radiation Measurement (ARM) Facility completed the LASSO pilot phase and is working to make LASSO operational

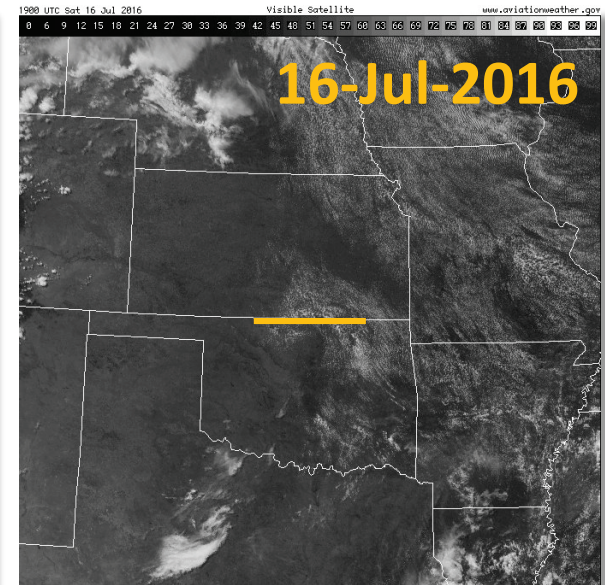
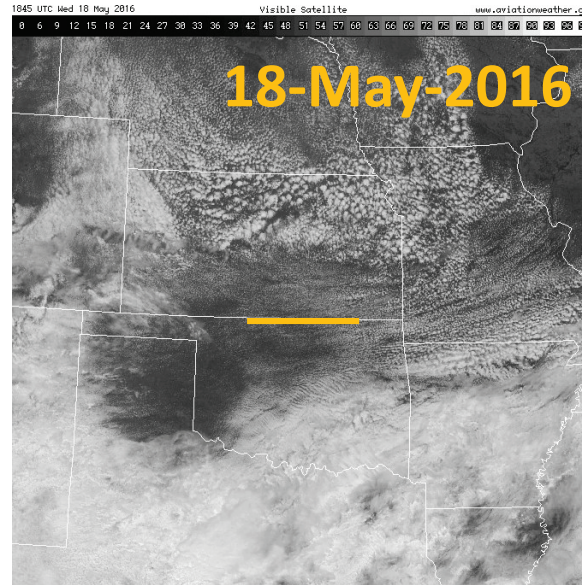
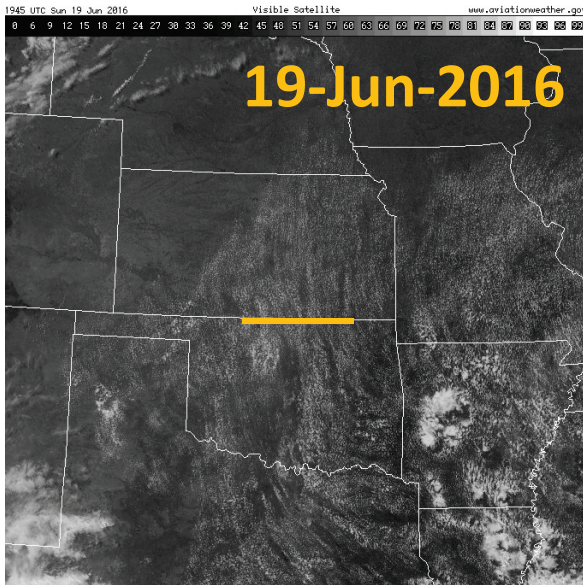


Core LASSO components

- Library of LES simulations for **shallow convection** cases at ARM's **Southern Great Plains** observatory: currently 18 days and growing
- For each case:
 - ▶ Ensemble of large-scale forcing data sets drives the LES
 - ▶ LES inputs and outputs for the ensemble
 - ▶ Selection of concurrent observations for cloud and boundary layer variables
 - ▶ Skill scores and diagnostics evaluating the simulations
- Bundle Browser interface to find simulations of interest
 - ▶ <http://archive.arm.gov/lassobrowser>



Shallow convection can occur in the midst of widely varying conditions



Yellow bars are approximately 300 km long, a commonly used forcing scale.

LASSO employs an ensemble of forcings to capture the range of possible conditions



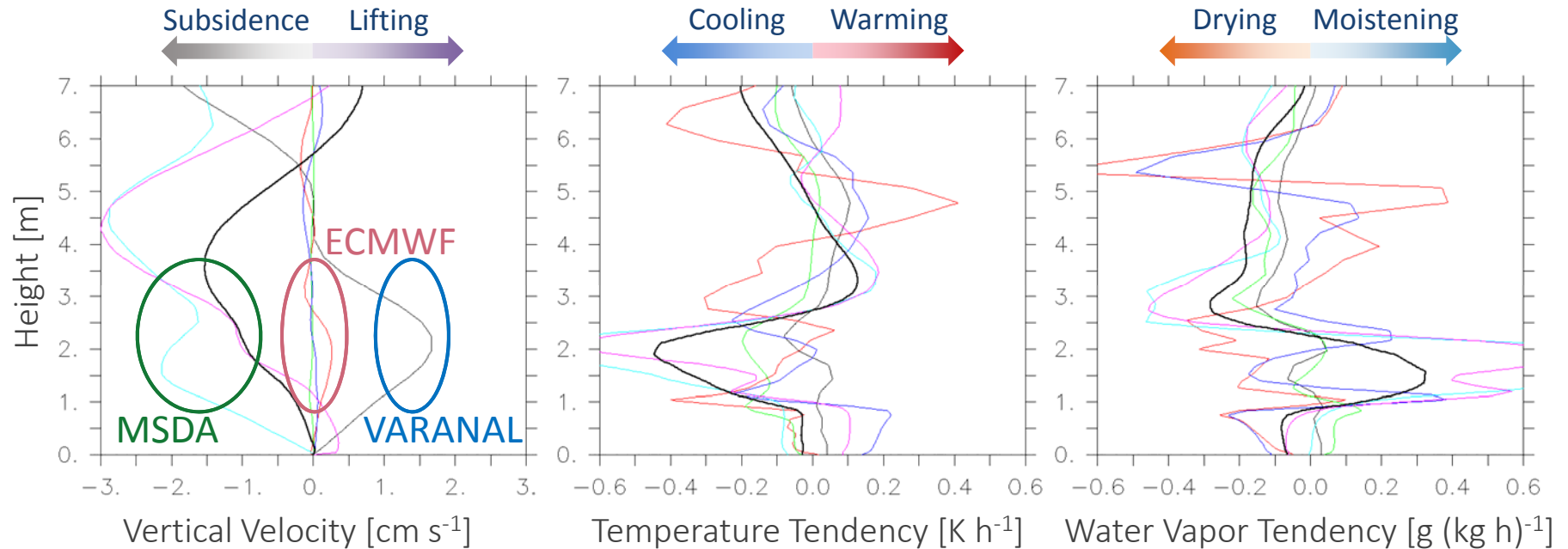
- Large-scale forcing datasets generated from 3 sources
 - ▶ Variational Analysis: ARM product, 300 km spatial scale
 - ▶ ECMWF IFS model: ~16, 115, & 413 km spatial scales
 - ▶ Multiscale Data Assimilation (MSDA): 75, 150, & 300 km scales; can directly incorporate ARM observations into the analysis
 - Hybrid AERI+Raman Lidar T profiles
 - Raman Lidar Qv profiles
 - RWP wind profiles
 - Surface meteorology

Typical forcing ensemble displays significant differences



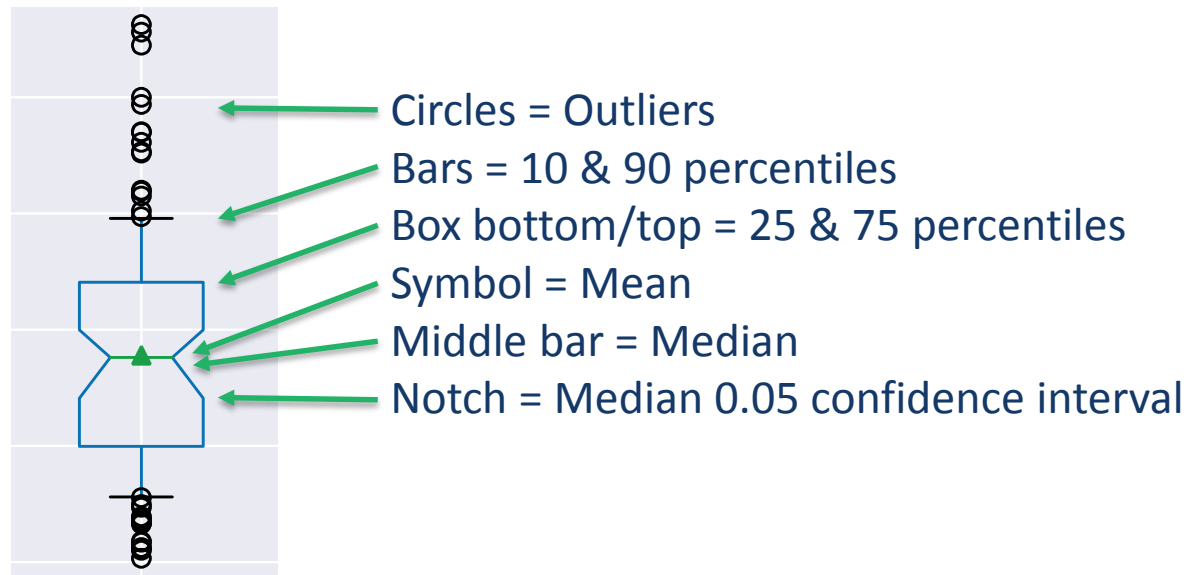
- Even the sign of the forcing differs between different forcing datasets...

Large-Scale Advective Tendencies, Ensemble from 25-Jun-2016 17 UTC



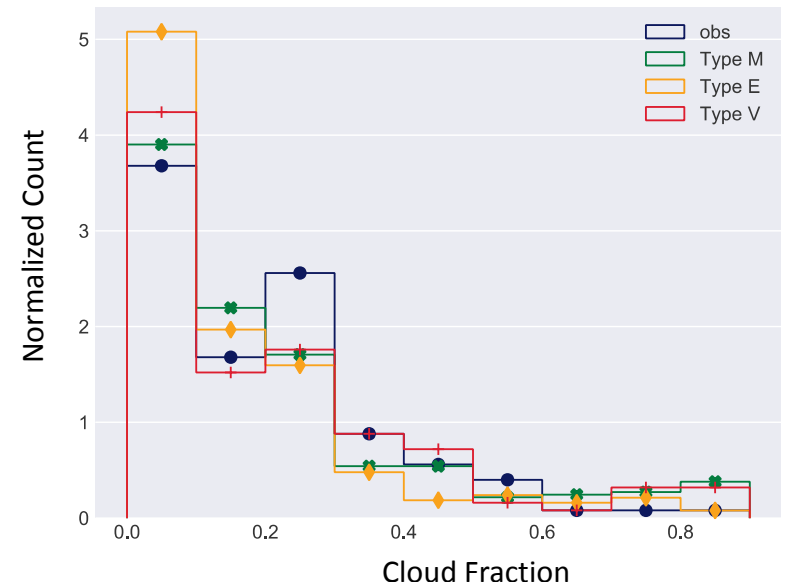
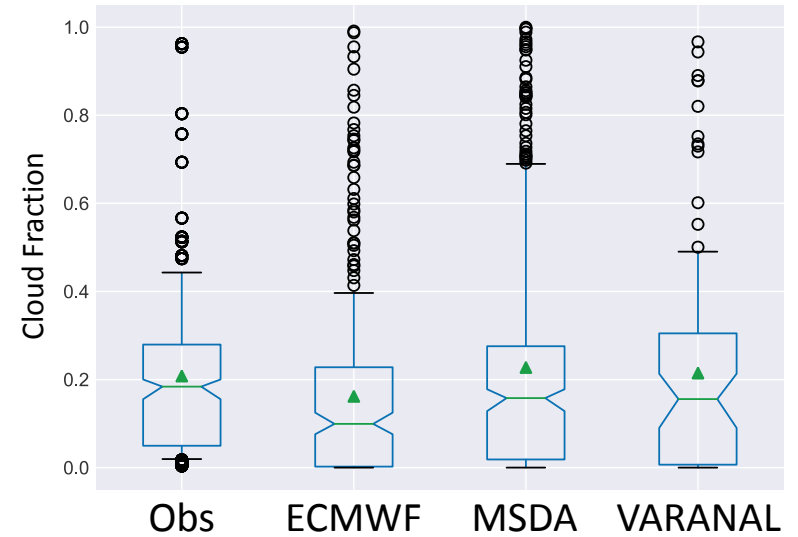
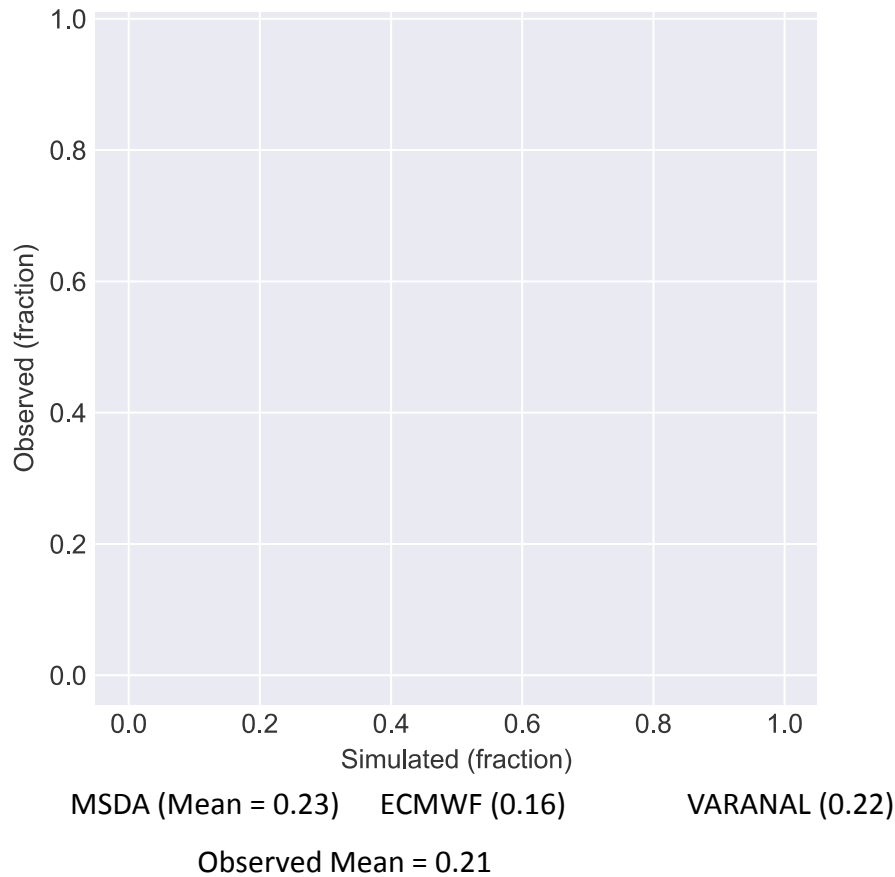
Simulations included in analysis

- 11 cases from 2016 (Alpha 2 release)
- Model = WRF
- Microphysics = Thompson
- Domain extent = 14.5 km square
- Grid spacing = 100 m
- Forcings
 - ECMWF @ 16, 114, & 413 km
 - MSDA w/ RWP @ 75, 150, & 300 km
 - VARANAL @ 300 km



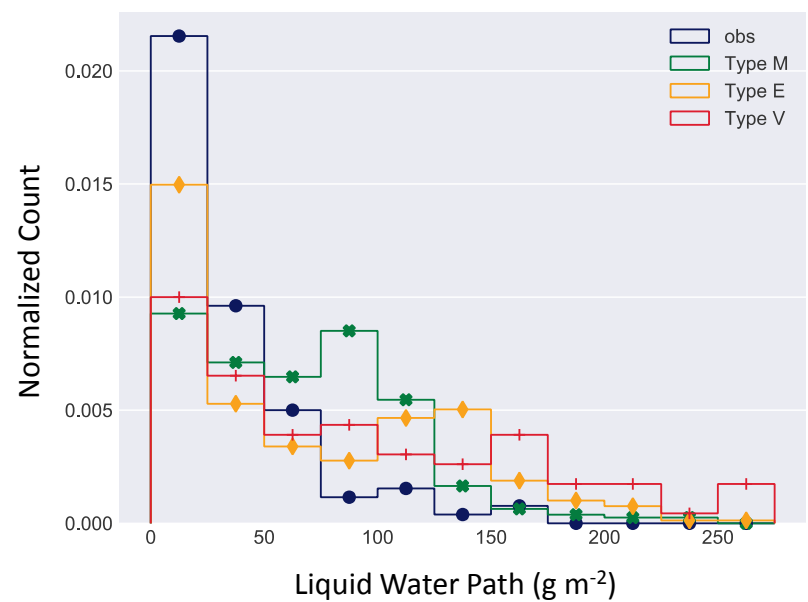
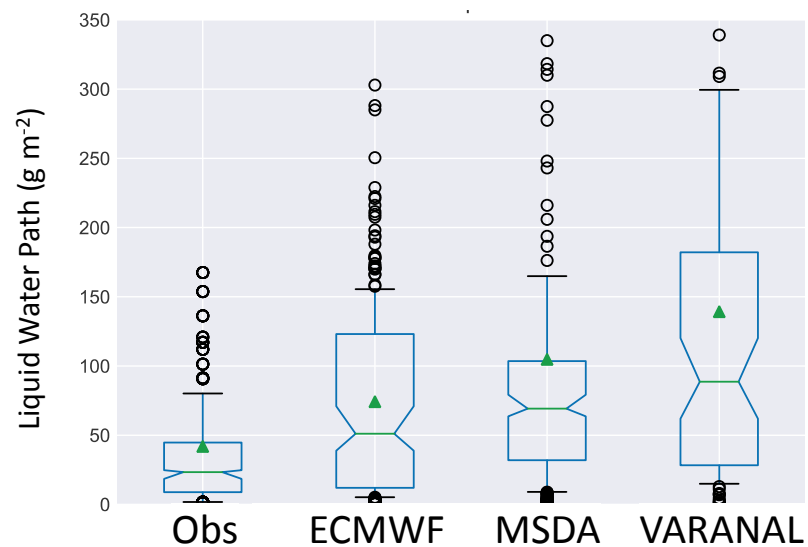
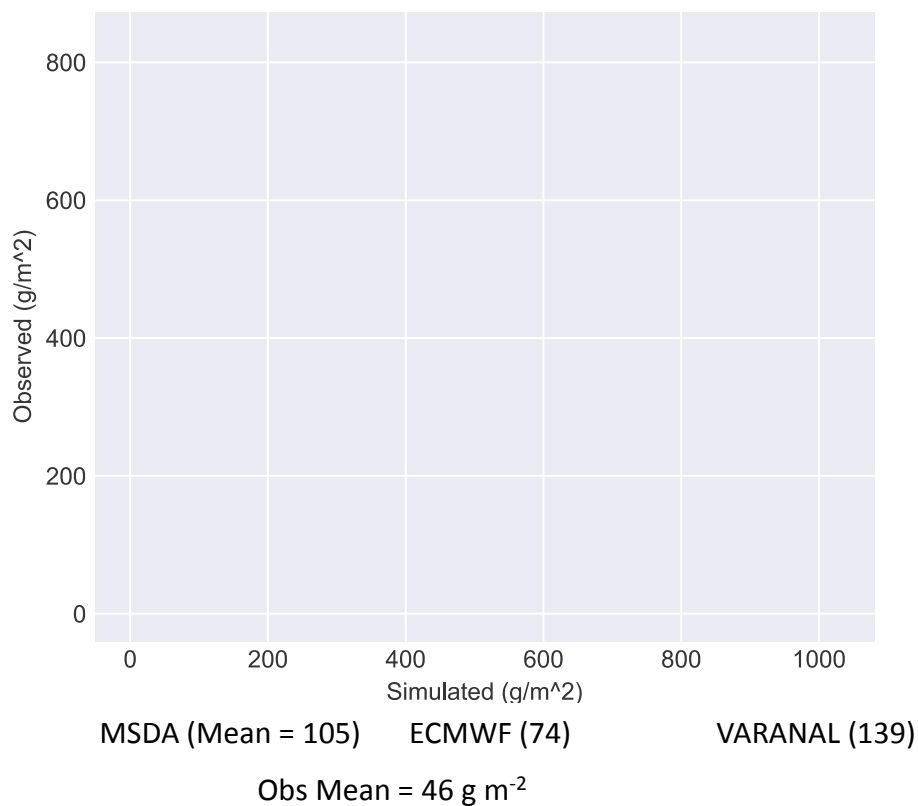
Cloud fraction from TSI

- One-to-one comparisons are pretty messy...
ECMWF has lowest mean CF



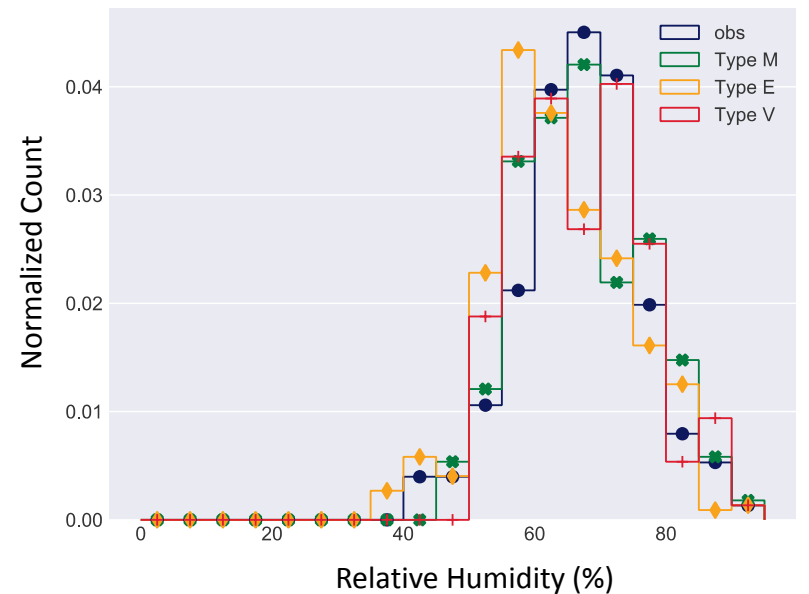
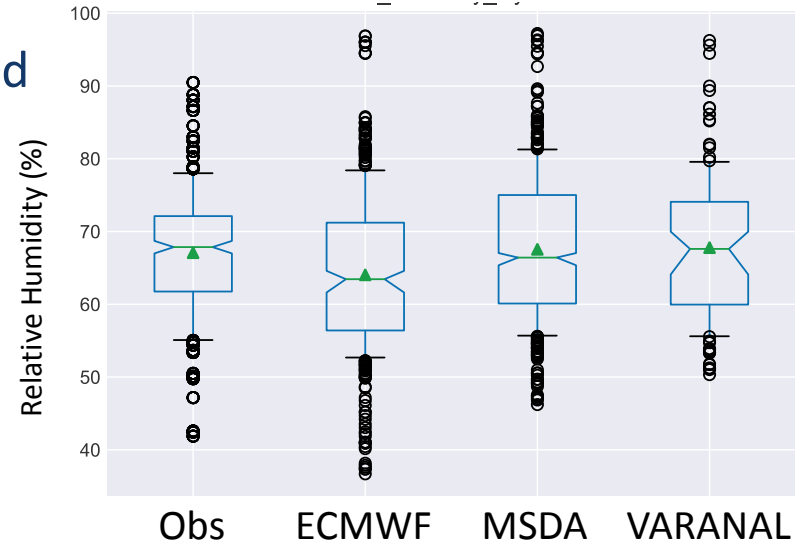
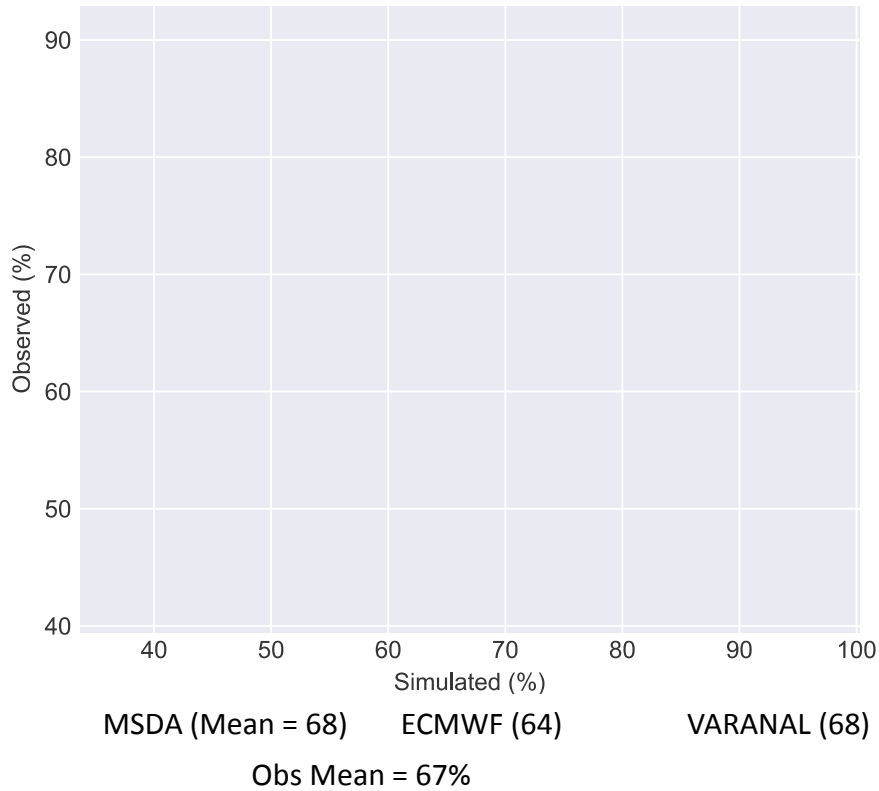
Liquid water path

■ ECMWF has notably lower mean LWP



Relative humidity in mid-boundary-layer

- ECMWF RH is lower by ~5% than MSDA and VARANAL forcings



Summary so far...

	ECMWF	MSDA	VARANAL
Liquid water path	↗ (closest to obs.)	↑	↑
Cloud Fraction	↓	✓	✓
Relative Humidity	↓	✓	✓
Water Vapor	↓	✓	✓
Temperature	✓	↓	↓

- ECMWF's RH lower than obs., whereas other forcings capture mean RH well
- RH differences caused by offsets in opposite directions for T and Qv
 - ▶ ECMWF has best T but too low Qv
 - ▶ MSDA and VARANAL have good Qv but are too cold

- Results so far support the general statistical similarity between forcings in that differences offset each other
- A logical next step is to evaluate the ensemble mean and see if it outperforms individual forcing selections
- Discover more about LASSO
 - ▶ Top-level webpage: <https://www.arm.gov/capabilities/modeling>
 - ▶ E-mail list: <http://eepurl.com/bCS8s5>
 - ▶ Contacts: William Gustafson and Andrew Vogelmann at lasso@arm.gov

Extra...



Introduction

Welcome to the LASSO Bundle Browser that is designed to assist users with identifying LASSO large-eddy simulations (LES) of interest for their research. The plots and associated data table update dynamically based on user search criteria, and links within the table enable direct access to order the data bundles of the displayed simulations. More information on LASSO and the data bundles can be found at the [LASSO home page](#) and on the [Alpha 1 Release web page](#). Note that this is an initial evaluation version of the browser that specifically queries and displays observed and simulated cloud properties for the five days worth of simulations released in the LASSO Alpha 1 release. There are 192 simulations between the five days that differ in terms of the LES model, forcing dataset, domain size, and model physics.

Select All

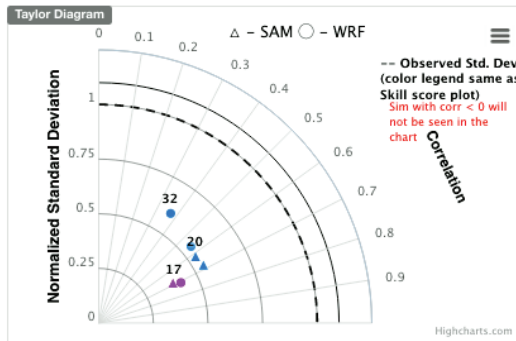
- ▶ Date
- ▶ Measurements
- ▶ Model Type
- ▶ Output Domain Size
- ▶ Number of Levels
- ▶ Large Scale Forcing
- ▶ Large Scale Forcing Scale
- ▶ Initial Condition
- ▶ Surface Treatment
- ▶ Microphysics

Submit

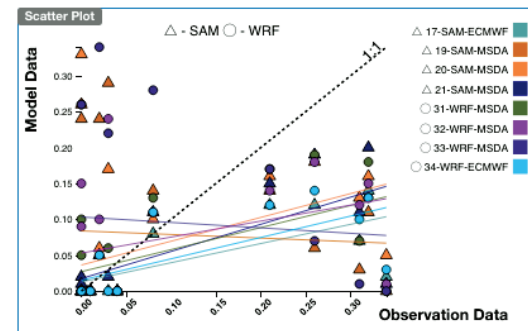
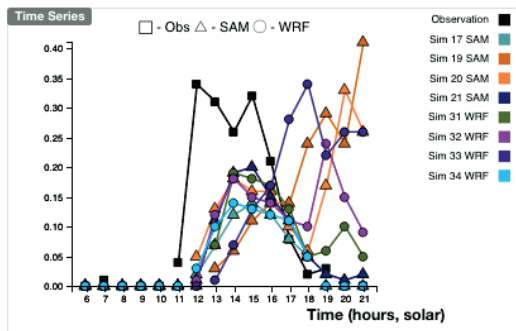
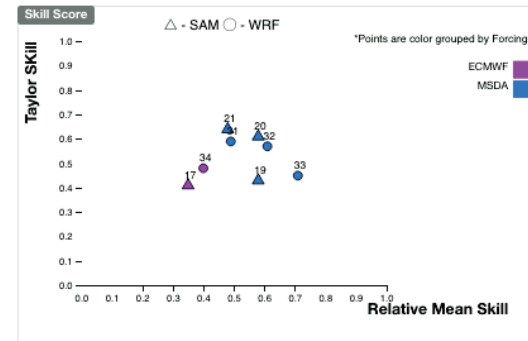
Overview Plots

- Heat Maps
- Metrics

Date: June 9, 2015



Measurement: Cloud Fraction TSI



Skill Scores on June 9, 2015

Measurement Skill

1D Cloud Skill

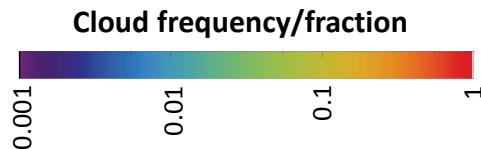
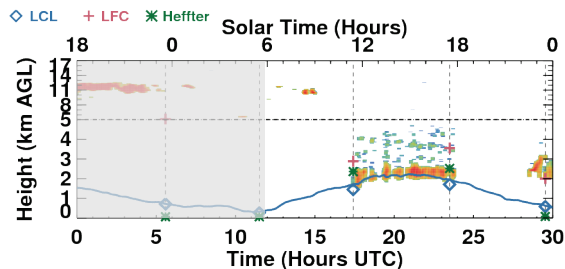
Copy CSV Print PDF

Search:

Simulation ID	Measurement Skill (Cloud Fraction TSI)	1D Cloud Skill	2D Cloud Mask Skill	Total Cloud Skill
17 (Diagnostics) (Data)	0.38	0.5	0.23	0.34
19 (Diagnostics) (Data)	0.5	0.47	0.26	0.35
20 (Diagnostics) (Data)	0.6	0.67	0.28	0.43

Cloud frequency comparison: 25-Jun-2016

Observed
from
ARSCCL

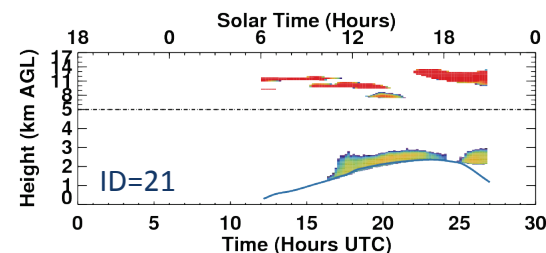
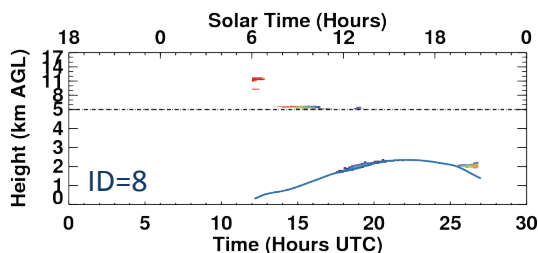


VARANAL

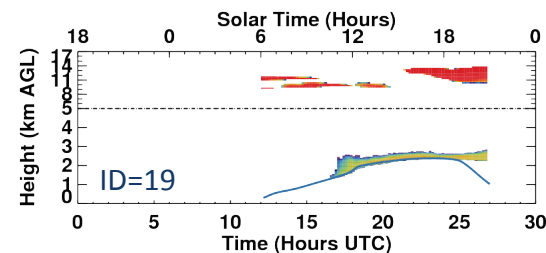
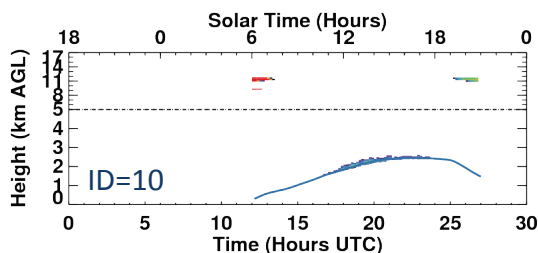
ECMWF

MSDA w/ RWP

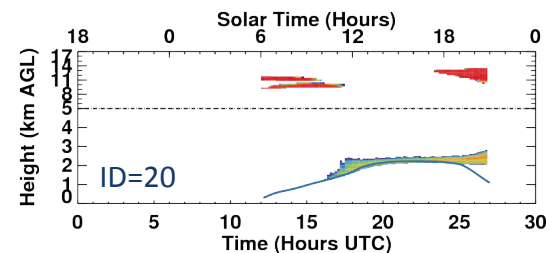
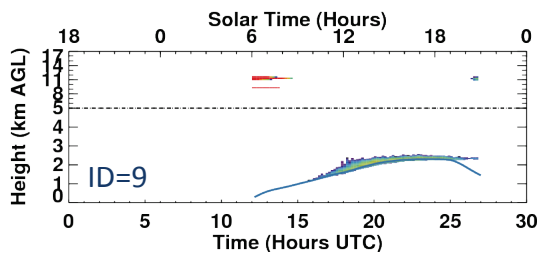
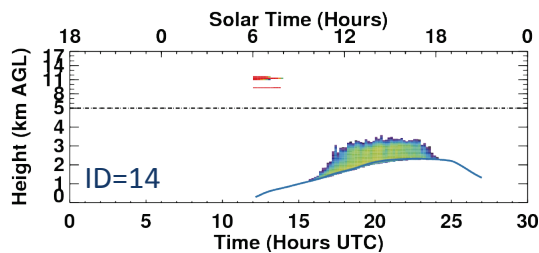
16 to
75 km



114 to
150 km



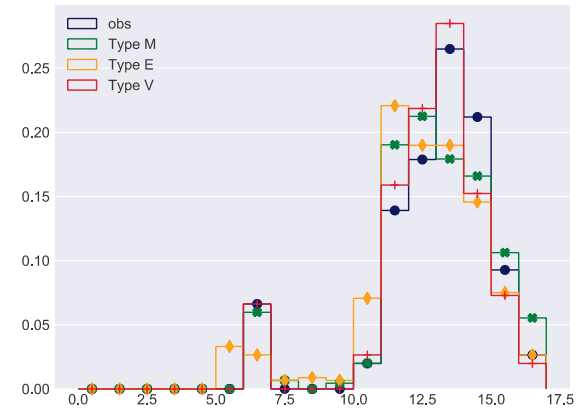
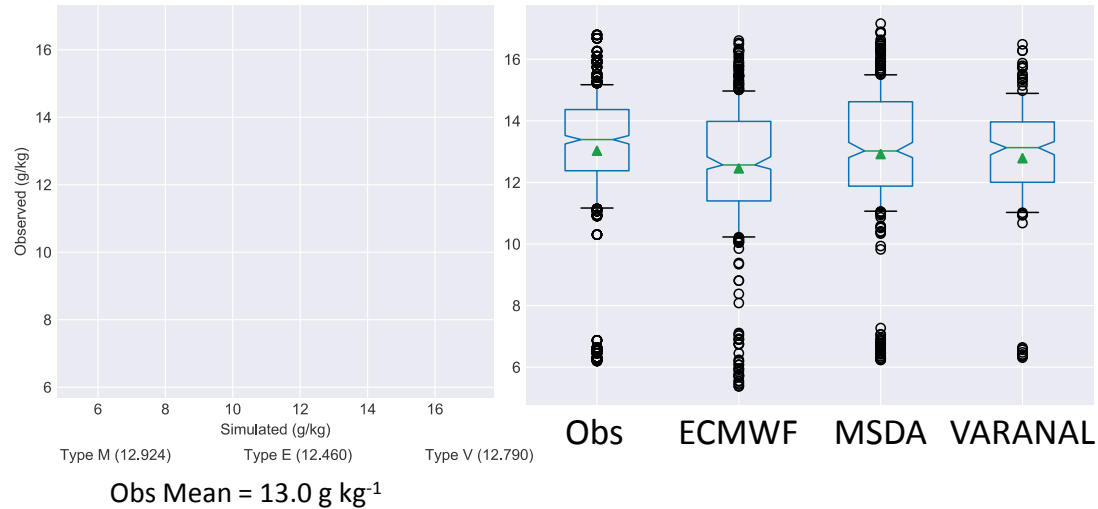
300 to
413 km



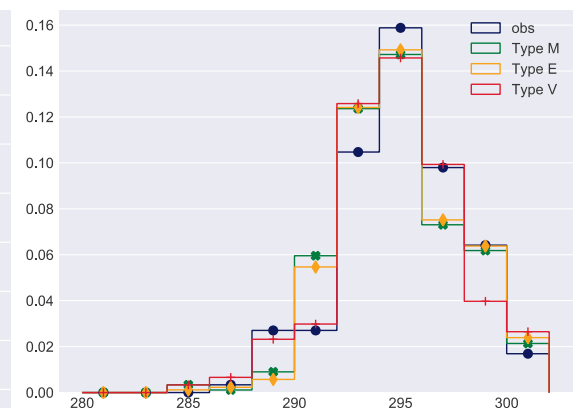
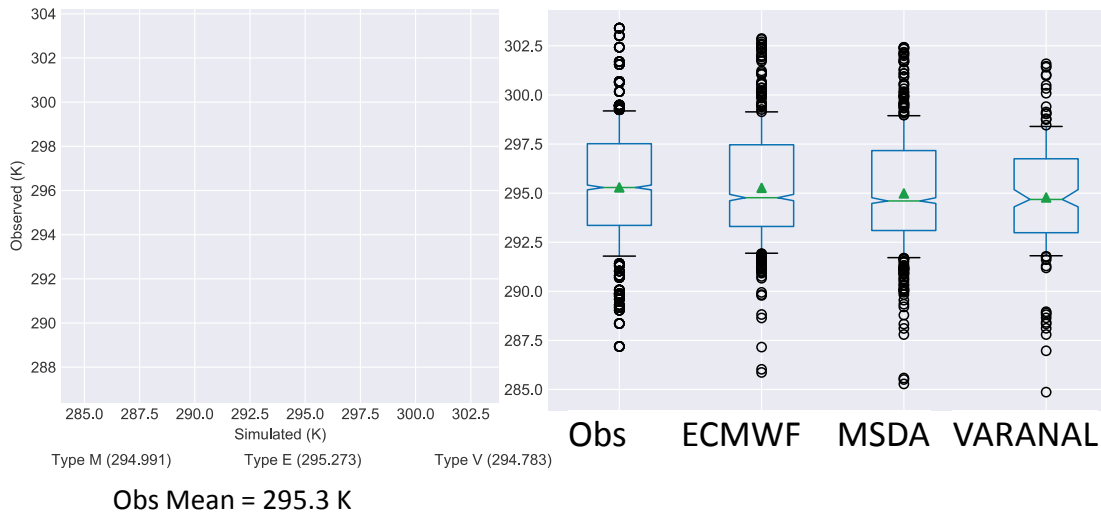
Water vapor & temperature in mid-boundary-layer

- ECMWF is slightly dry ($\sim 0.5 \text{ g kg}^{-1}$) and warmer than other forcings

Mid-Boundary-Layer Water Vapor Mixing Ratio (g kg^{-1})



Mid-Boundary-Layer Temperature (K)



Skill scores for comparing simulations

■ Relative mean

$$S_{RM}(var) = \begin{cases} \alpha, & \alpha \leq 1 \\ 1/\alpha, & \alpha > 1 \end{cases}$$

where

$$\alpha = \frac{\overline{x_m}}{\overline{x_o}}$$

■ Net skill

$$S_{net}(var) = (S_T(var) \cdot S_{RM}(var))^{\frac{1}{2}}$$

■ Taylor skill

$$S_T(var) = \frac{4(1 + R)}{(\sigma_r + 1/\sigma_r)^2 (1 + R_0)}$$

where

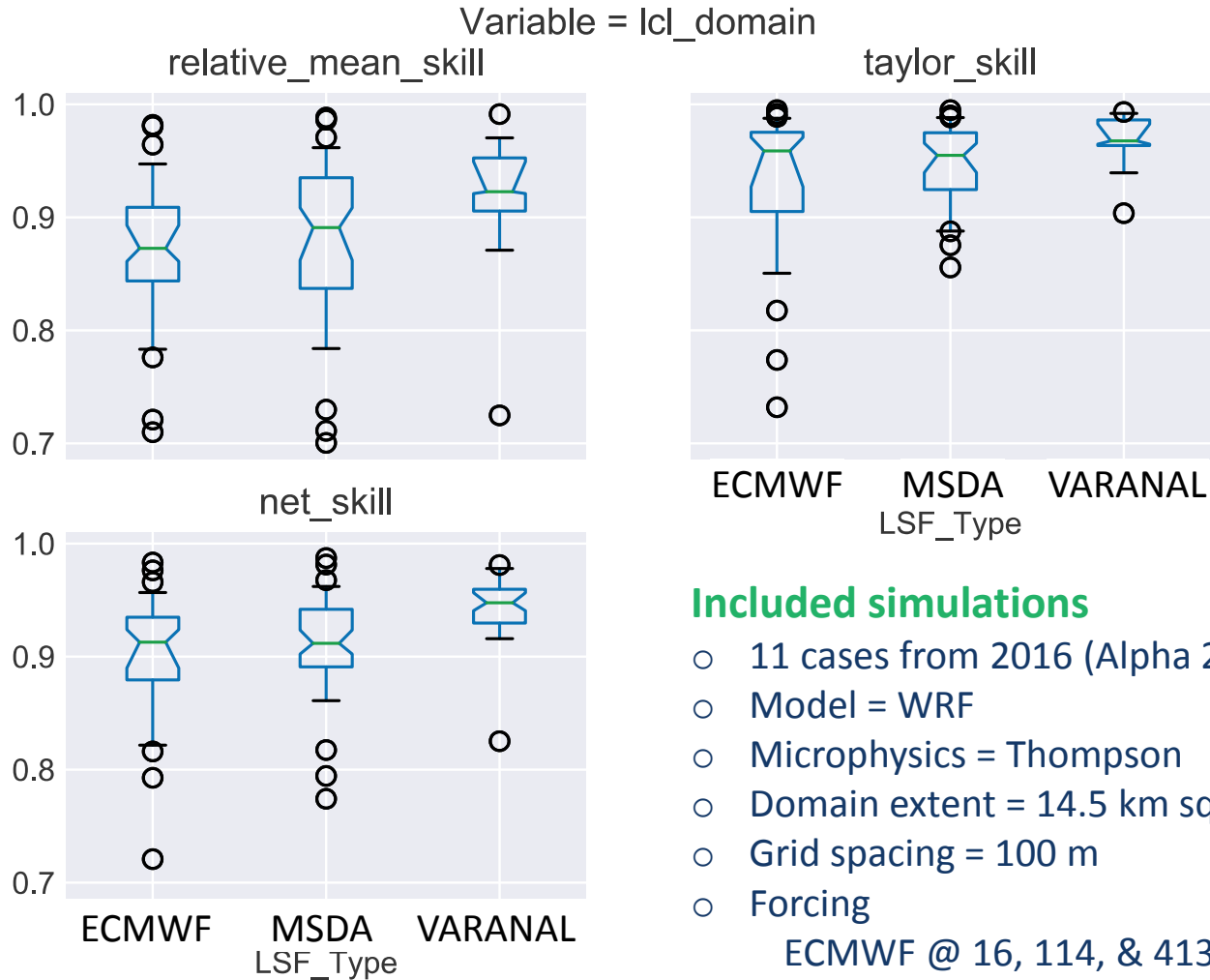
σ_r = normalized std. deviation

R = correlation coefficient

R_0 = max. correlation attainable

Comparison by large-scale forcing type:

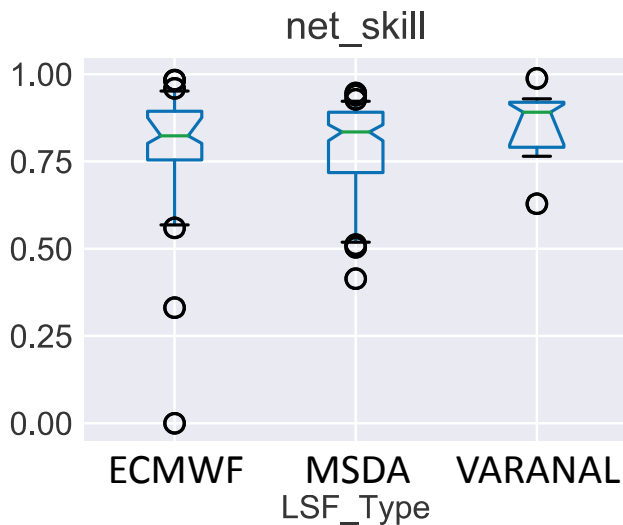
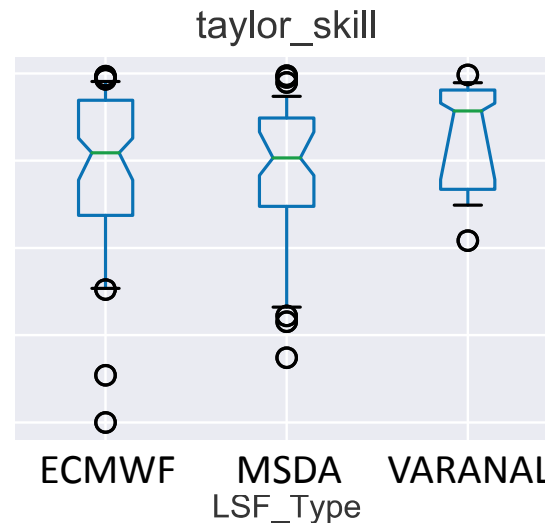
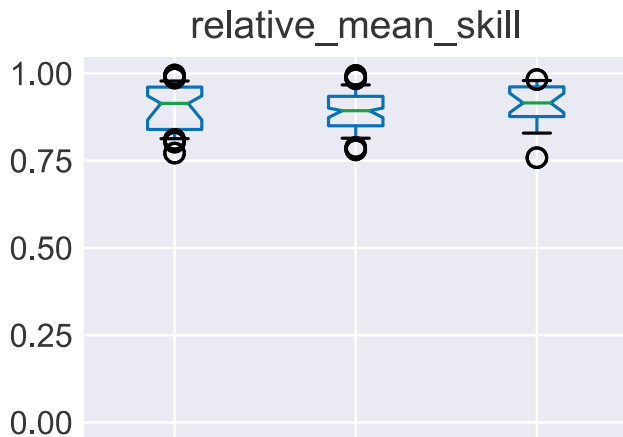
Skill of domain average lifting condensation level



Included simulations

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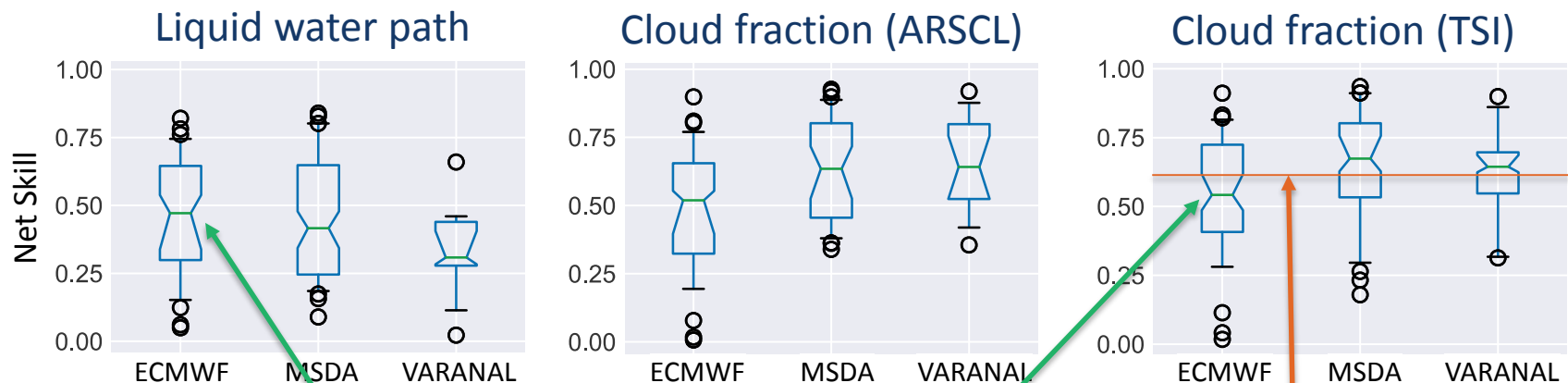
Comparison by large-scale forcing type: Skill of cloud-base height



- Statistically unable to differentiate, but...
- VARANAL scores better for cloud-base height, mainly from Taylor skill score
- Consistent results with LCL

Comparison by large-scale forcing type:

Net Skill of liquid water path & cloud fraction

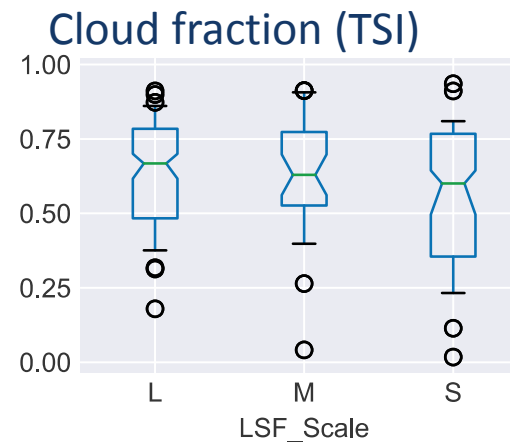
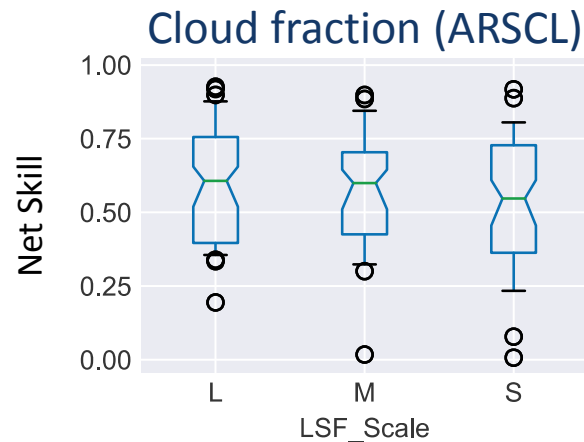
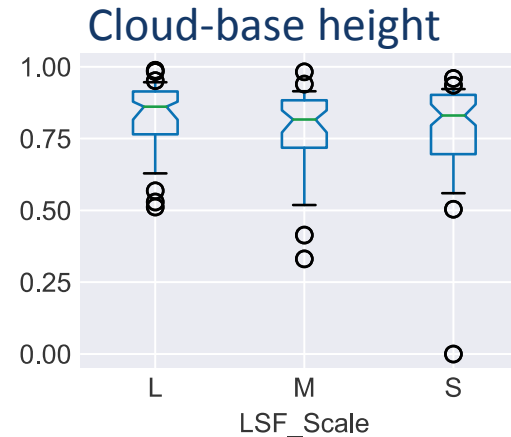
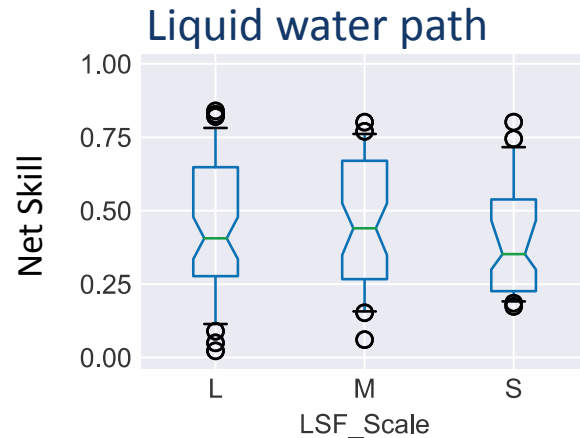


■ ECMWF scores highest for LWP but lowest for cloud fraction

■ Confidence intervals for medians overlap for all except ECMWF & MSDA CF_{TSI}

Comparison by large-scale forcing scale (net skill)

Large, medium, vs. small forcing area



- Differences between forcing scales are statistically indiscernible, but generally a slightly lower score for small scale