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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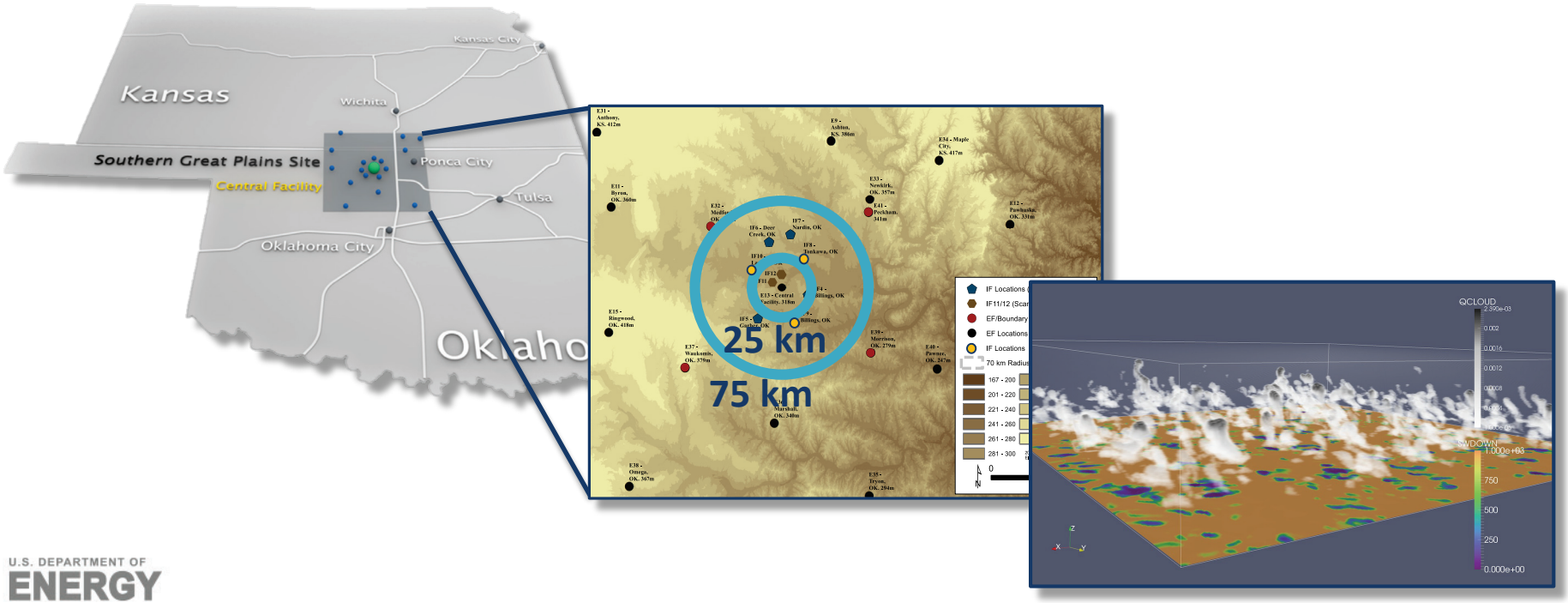
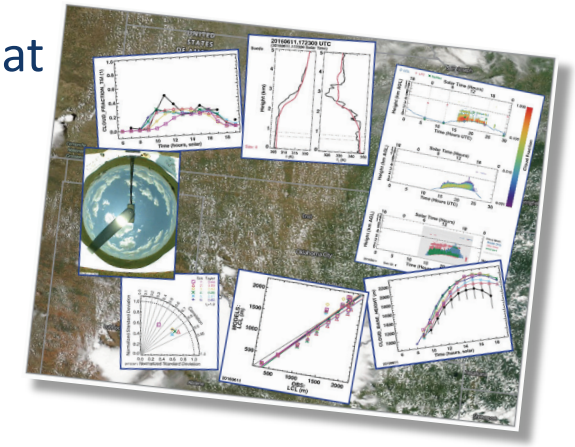
What is LASSO?

- 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

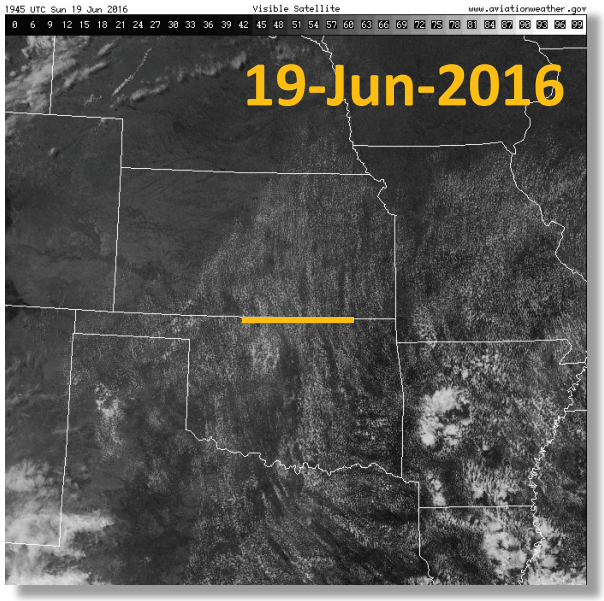


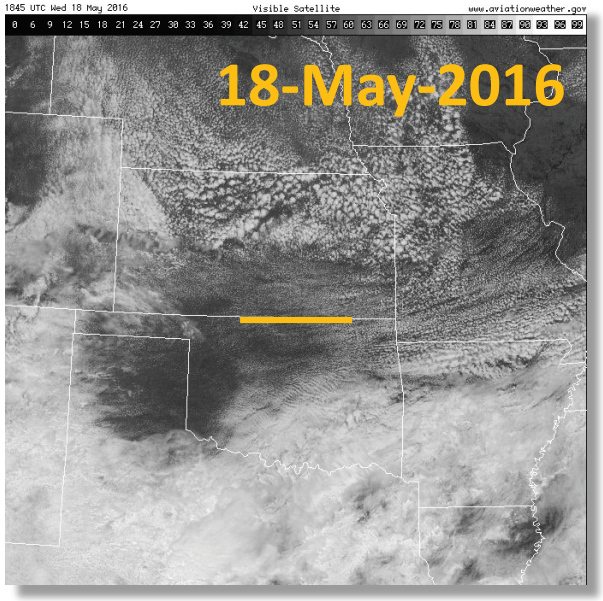
- Library of LES simulations for shallow convection cases at ARM's Southern Great Plains observatory: currently 18 days and growing

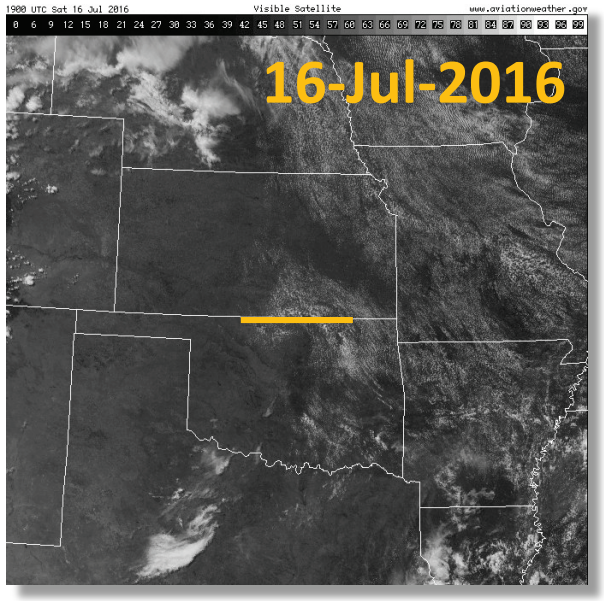
- For each case:
  - Ensemble of large-scale forcing data sets drives the LES
  - LES inputs and outputs for the ensemble
  - Selection of concurrent observations for cloud and boundary layer variables
  - Skill scores and diagnostics evaluating the simulations

- 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

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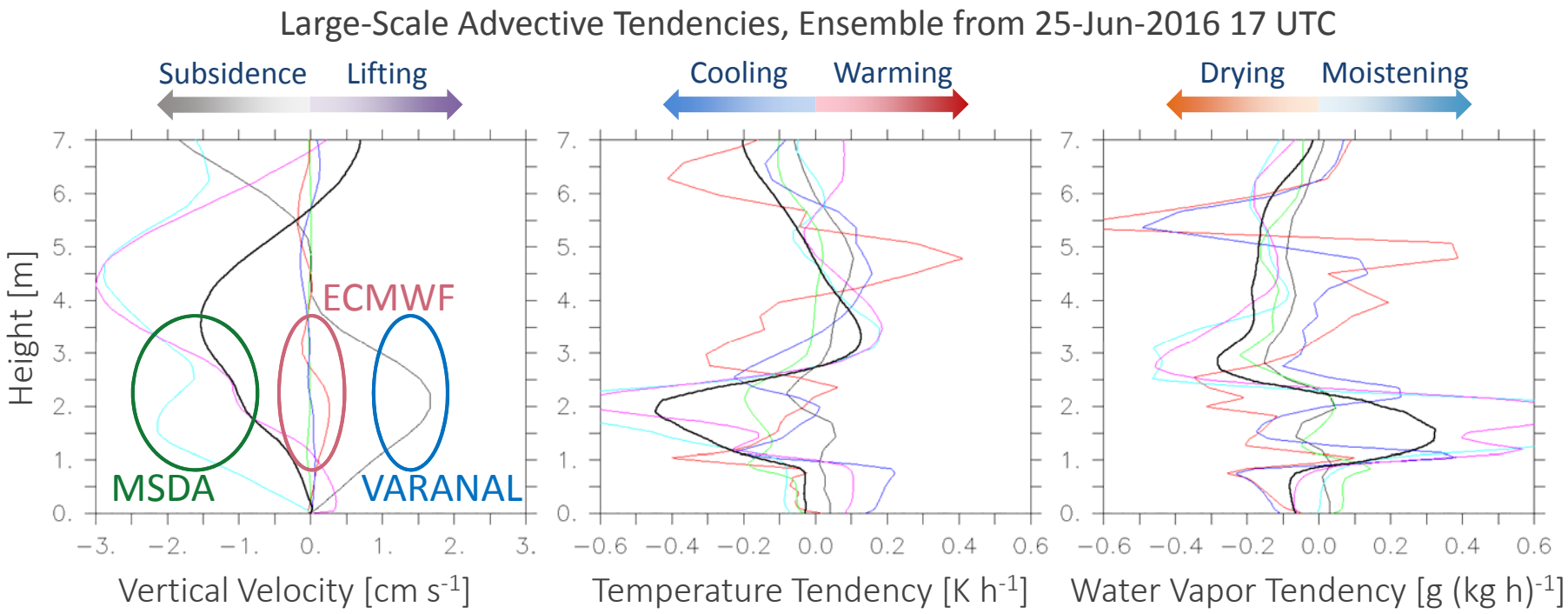
- Large-scale forcing datasets generated from 3 sources
  - Variational Analysis: ARM product, 300 km spatial scale
  - ECMWF IFS model: ~16, 115, & 413 km spatial scales
  - Multiscale Data Assimilation (MSDA): 75, 150, & 300 km scales; can directly incorporate ARM observations into the analysis
  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

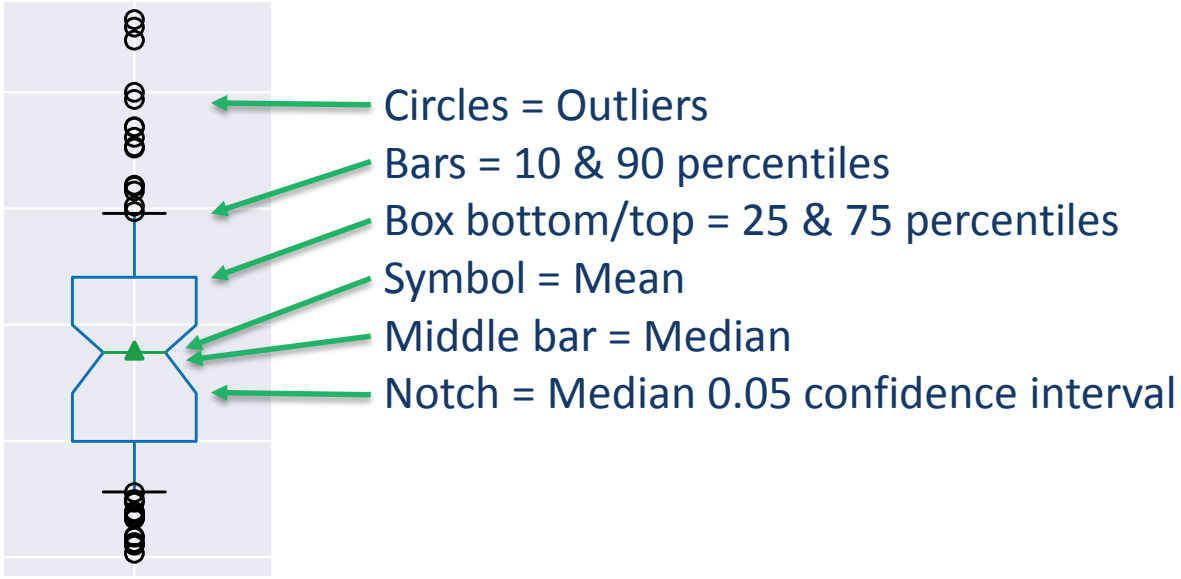
Typical forcing ensemble displays significant differences

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



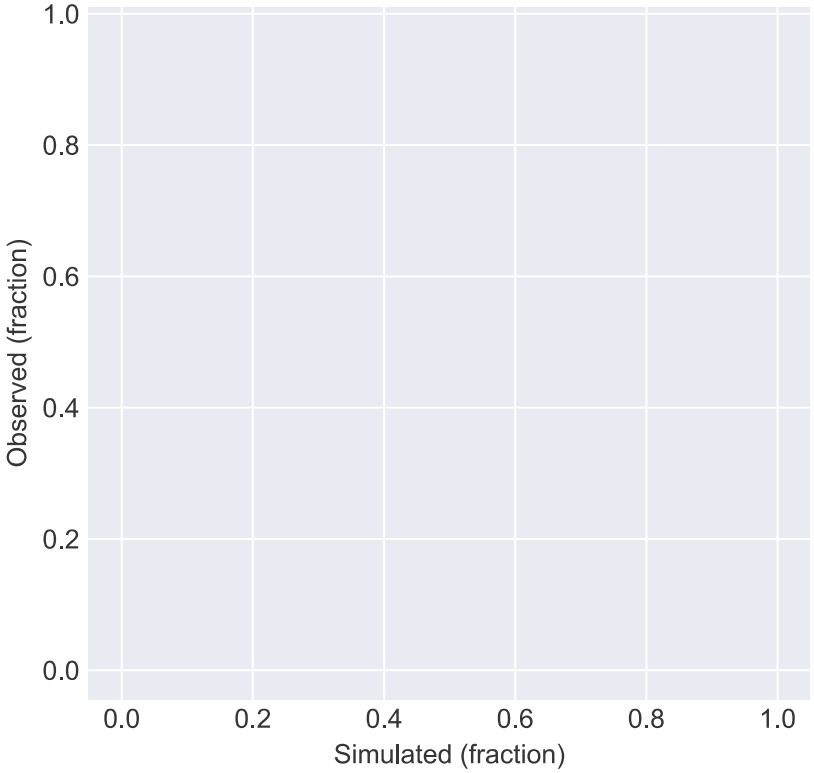
Simulations included in analysis

- 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



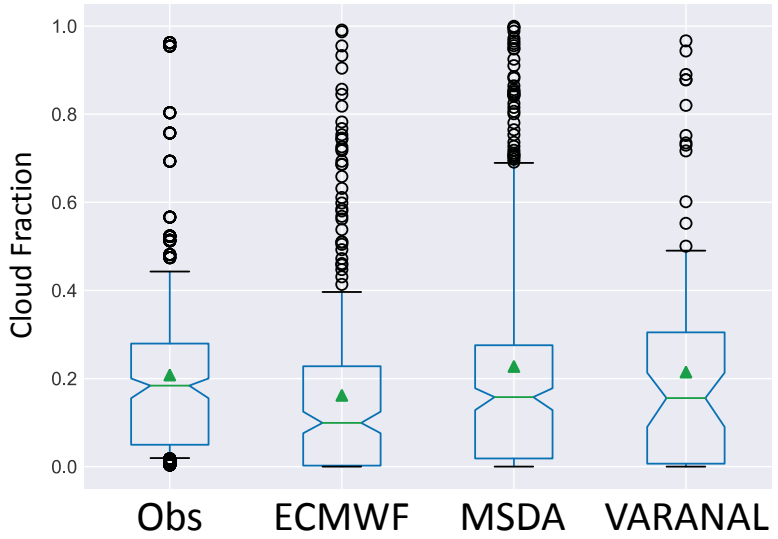
Cloud fraction from TSI

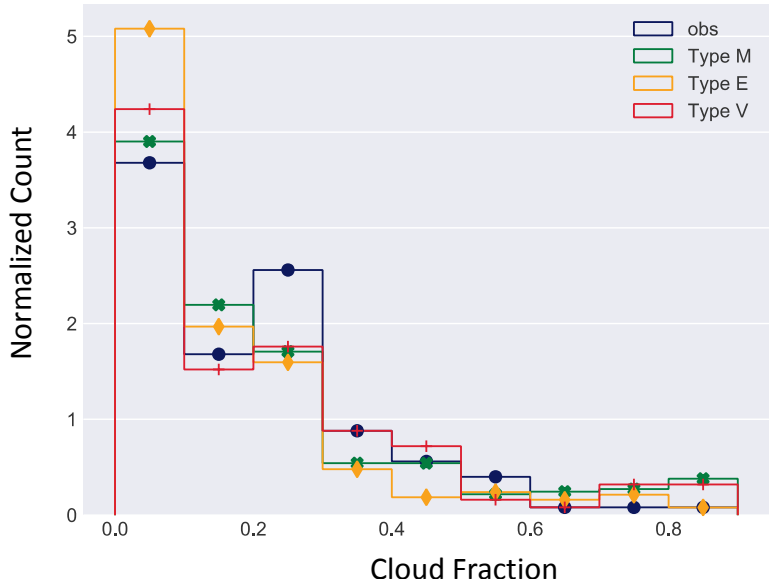
- One-to-one comparisons are pretty messy…
  ECMWF has lowest mean CF



MSDA (Mean = 0.23) ECMWF (0.16) VARANAL (0.22)

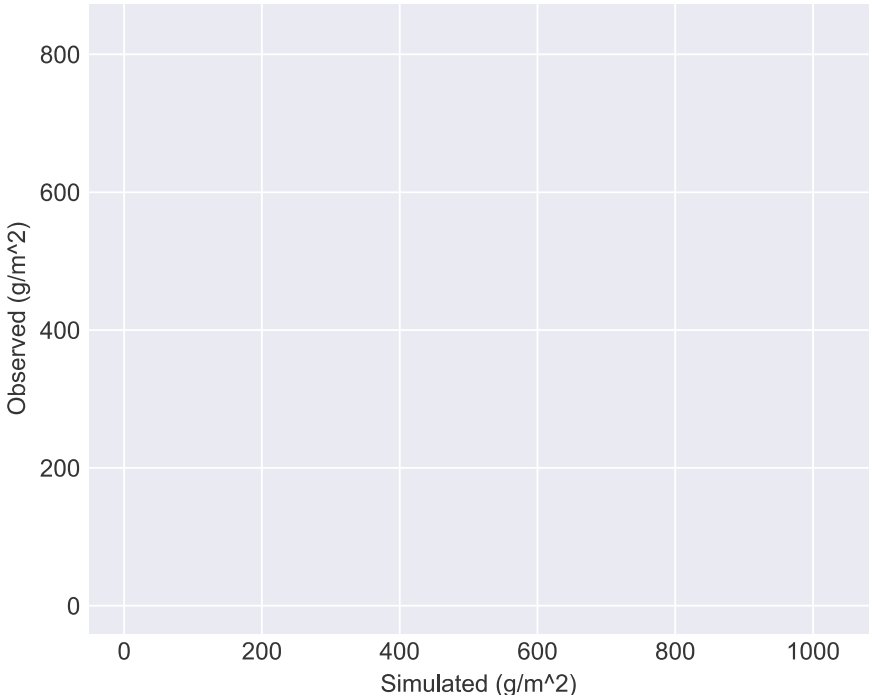
Observed Mean = 0.21





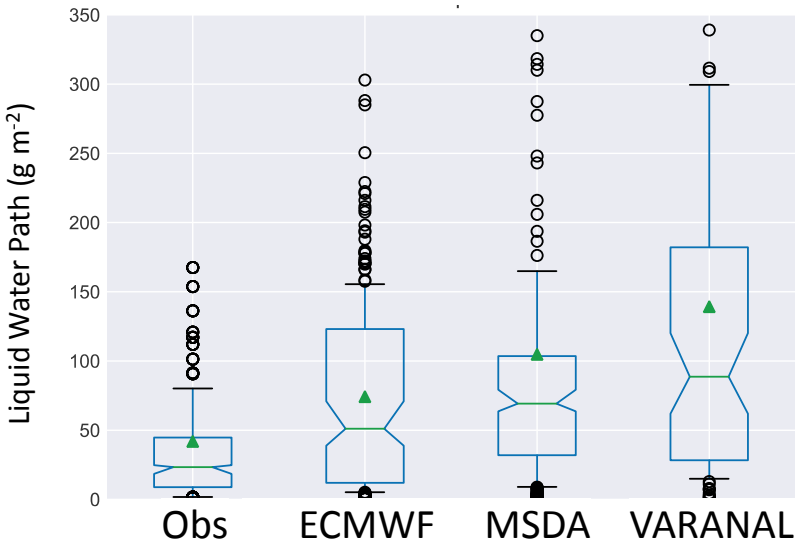
Liquid water path

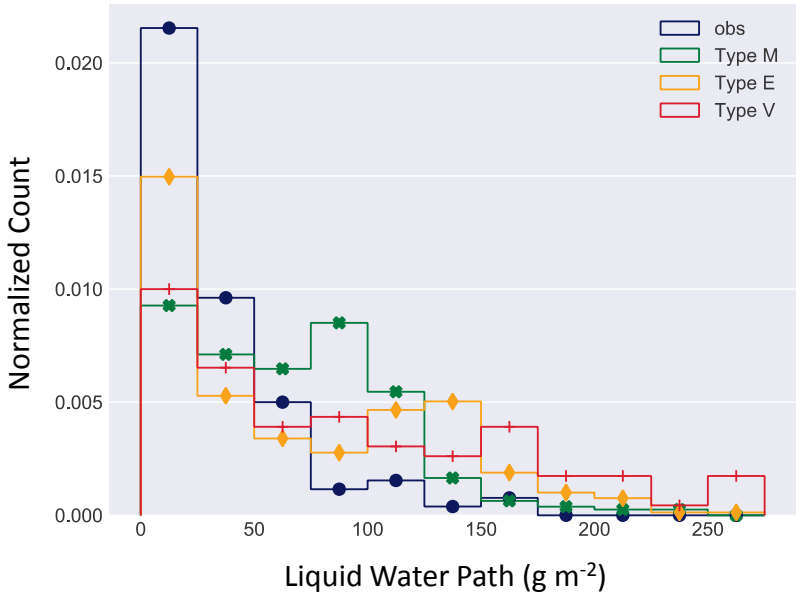
- ECMWF has notably lower mean LWP



MSDA (Mean = 105) ECMWF (74) VARANAL (139)

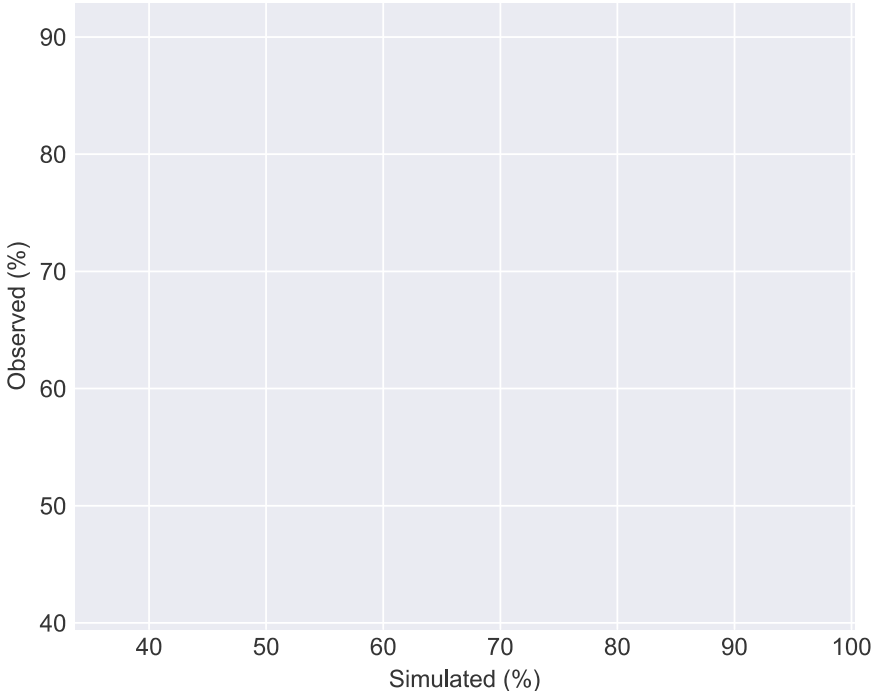
Obs Mean = 46 g m^{-2}





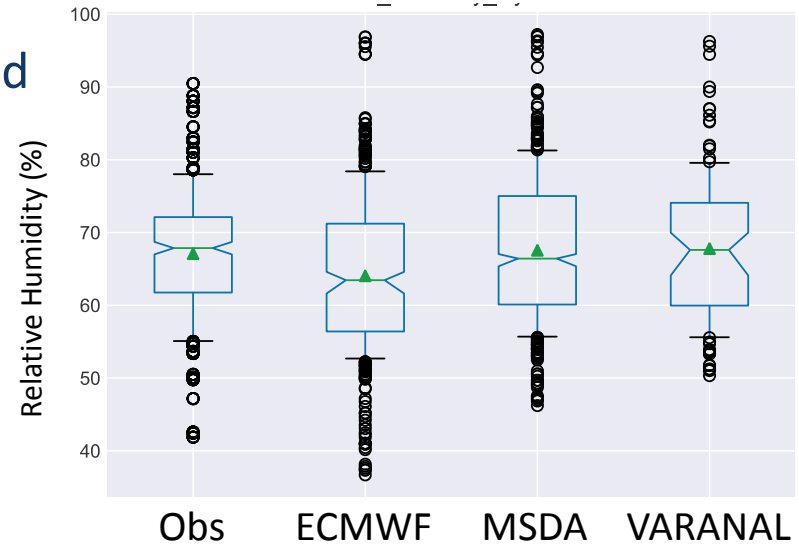
Relative humidity in mid-boundary-layer

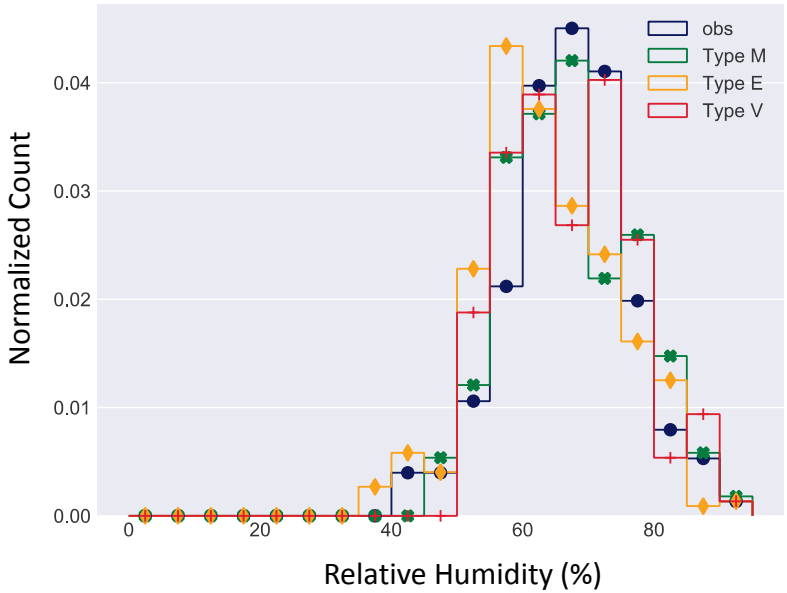
- ECMWF RH is lower by ~5% than MSDA and VARANAL forcings



MSDA (Mean = 68) ECMWF (64) VARANAL (68)

Obs Mean = 67%





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

Conclusions

- 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

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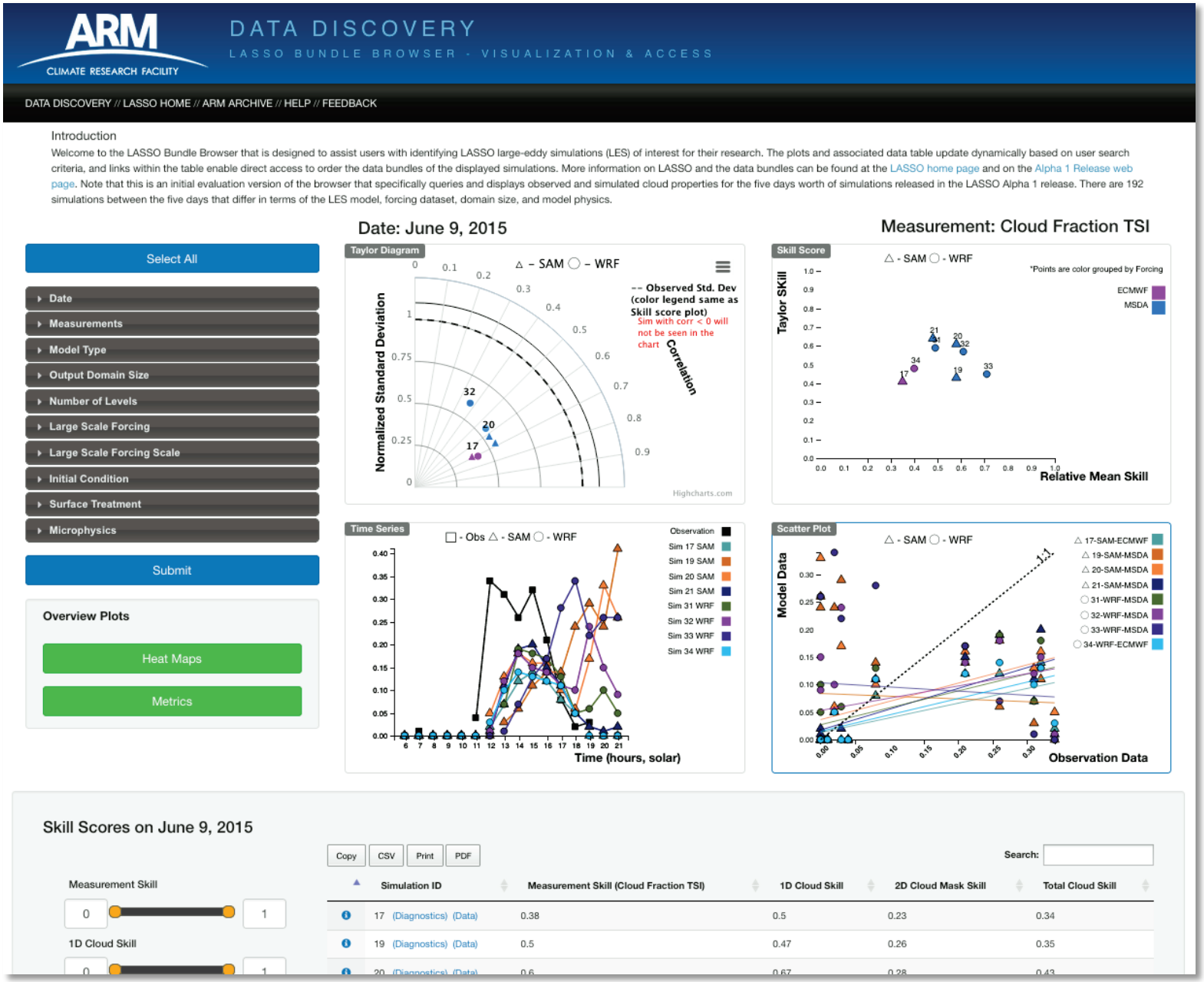
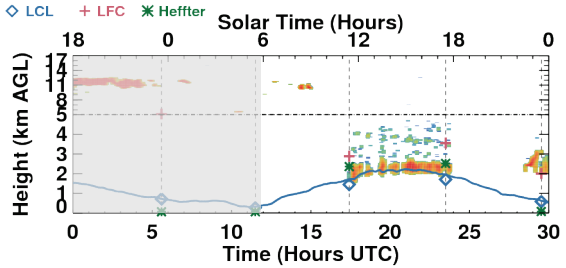
Extra…

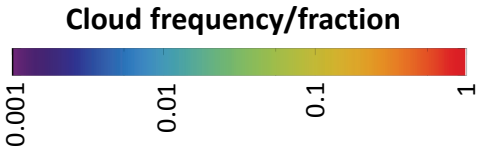
http://archive.arm.gov/lassobrowser

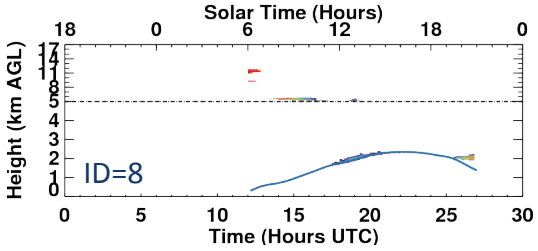
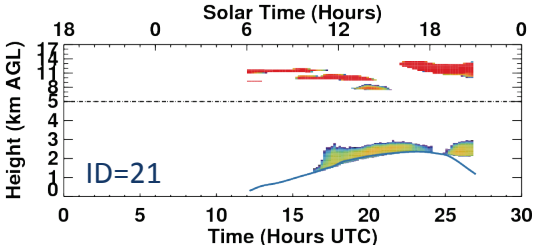
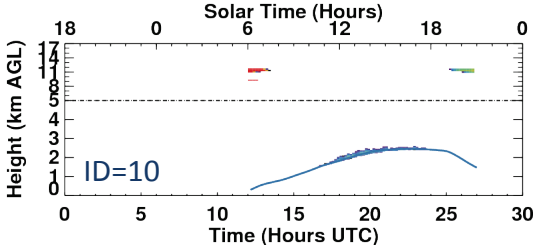
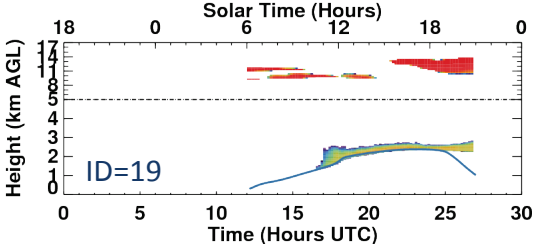
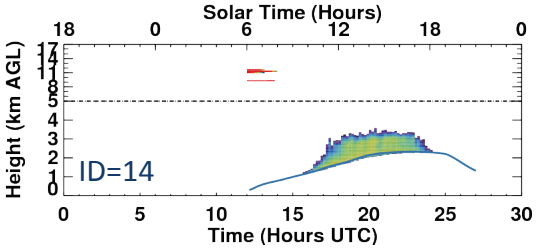
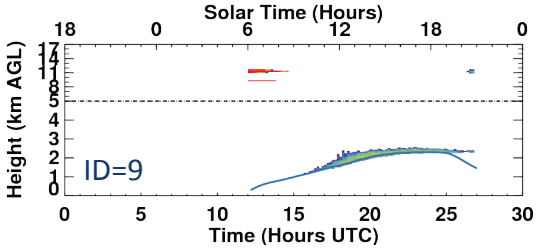
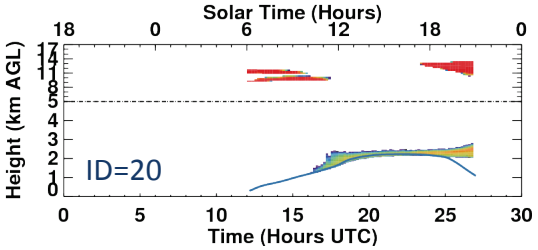


Cloud frequency comparison: 25-Jun-2016

Observed from ARSCL



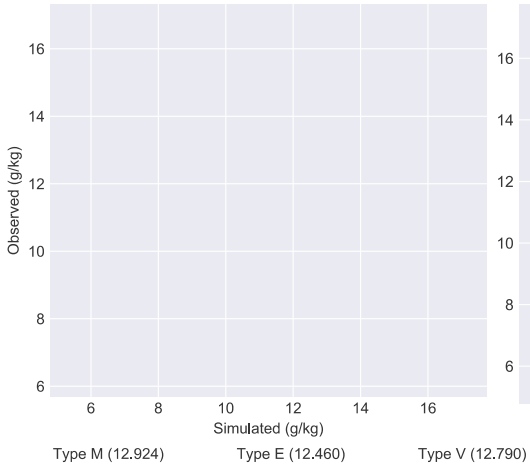


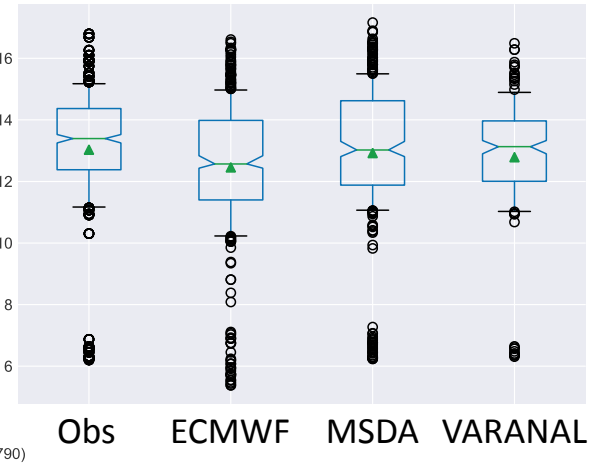
	VARANAL	ECMWF	MSDA w/ RWP
16 to 75 km			
114 to 150 km			
300 to 413 km			

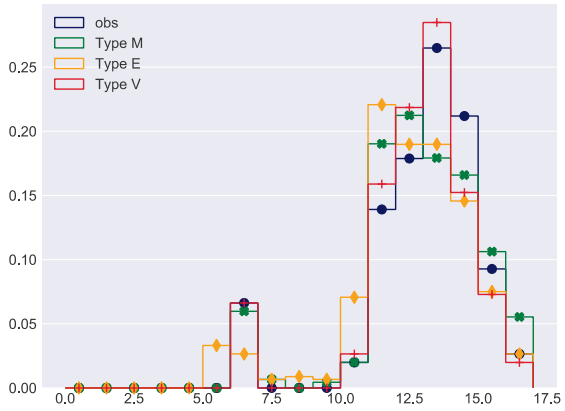
Water vapor & temperature in mid-boundary-layer

- ECMWF is slightly dry (~0.5 g kg^{-1}) and warmer than other forcings

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

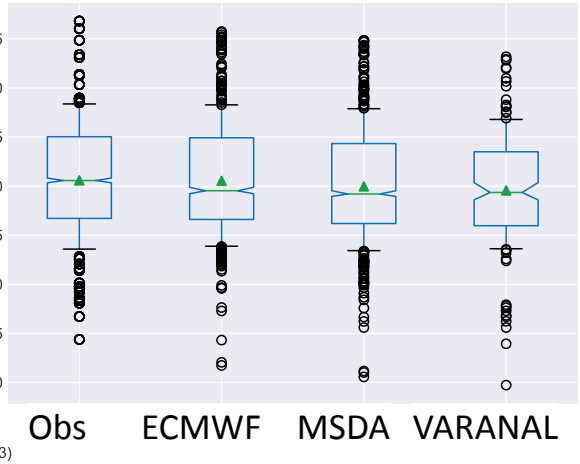


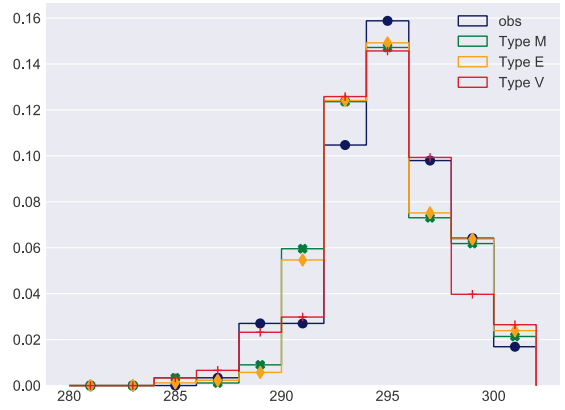




Obs Mean = 13.0 g kg^{-1}

Mid-Boundary-Layer Temperature (K)





Obs Mean = 295.3 K

Skill scores for comparing simulations

- Relative mean

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

where

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

- Net skill

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

- Taylor skill

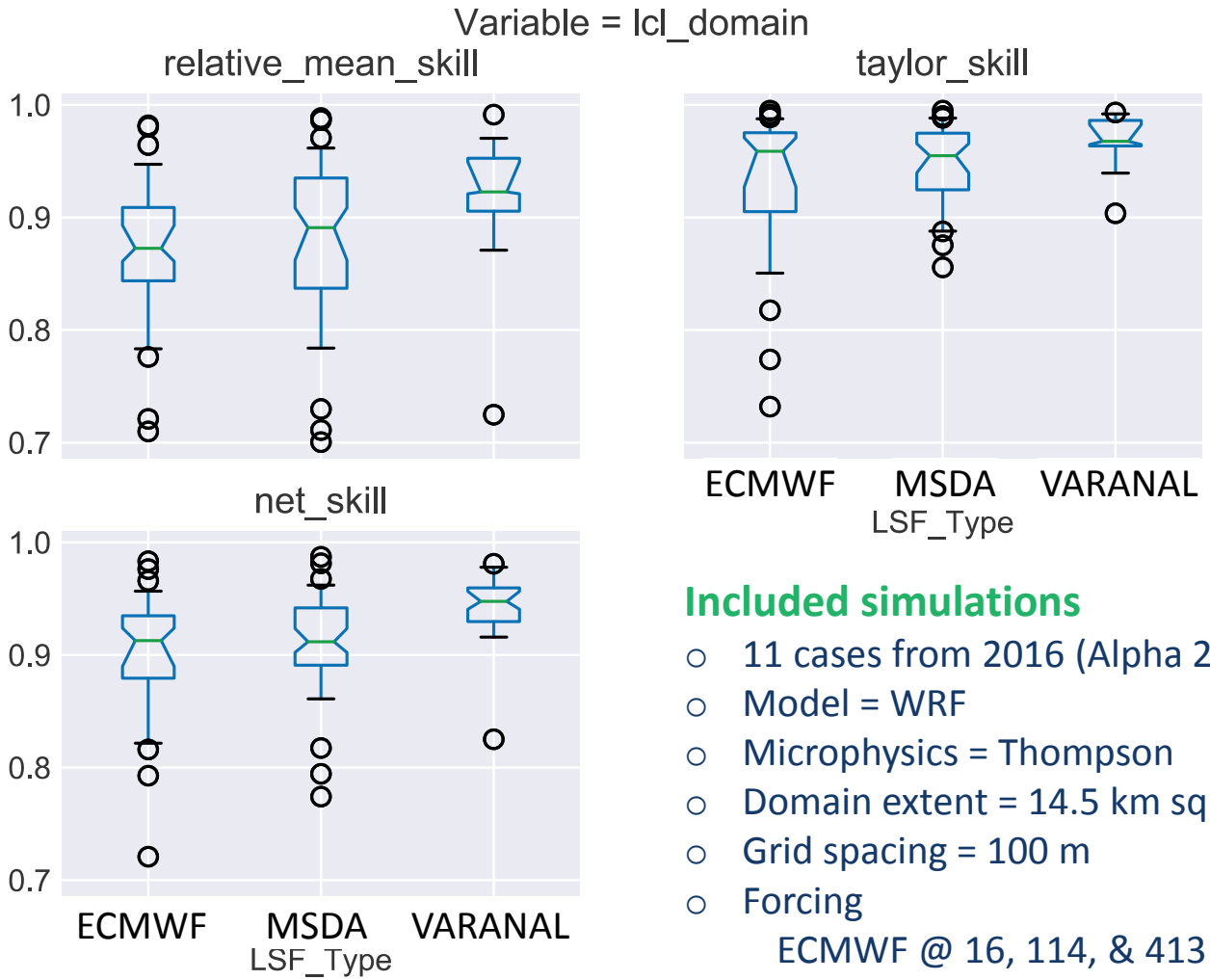
$$S_T(var) = \frac{4(1+R)}{\left(\sigma_r + 1/\sigma_r\right)^2 (1+R_0)}$$

where

$\sigma_r = normalized\ std.deviation$
$R = correlation\ coefficient$
$R_0 = max.correlation\ attainable$

Comparison by large-scale forcing type:

Skill of domain average lifting condensation level



Included simulations

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- Microphysics = Thompson
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- Grid spacing = 100 m
- Forcing
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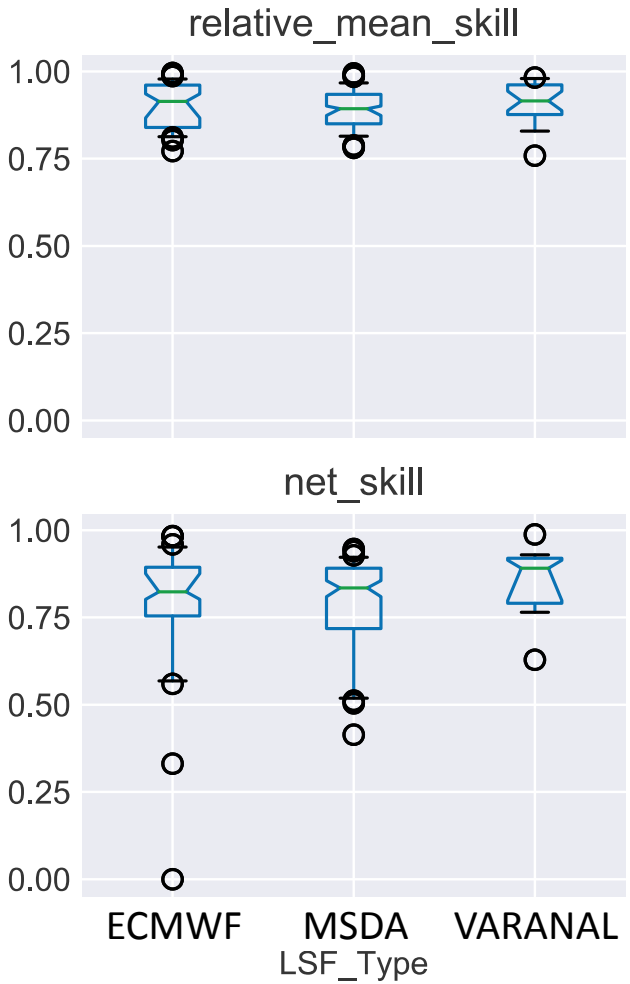
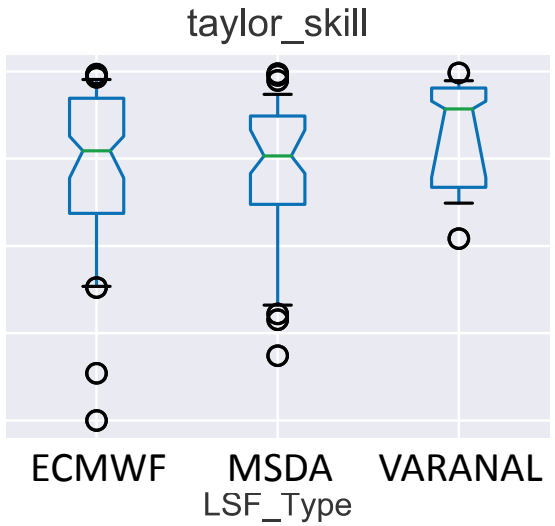
  - VARANAL @ 300 km

Comparison by large-scale forcing type:

Skill of cloud-base height

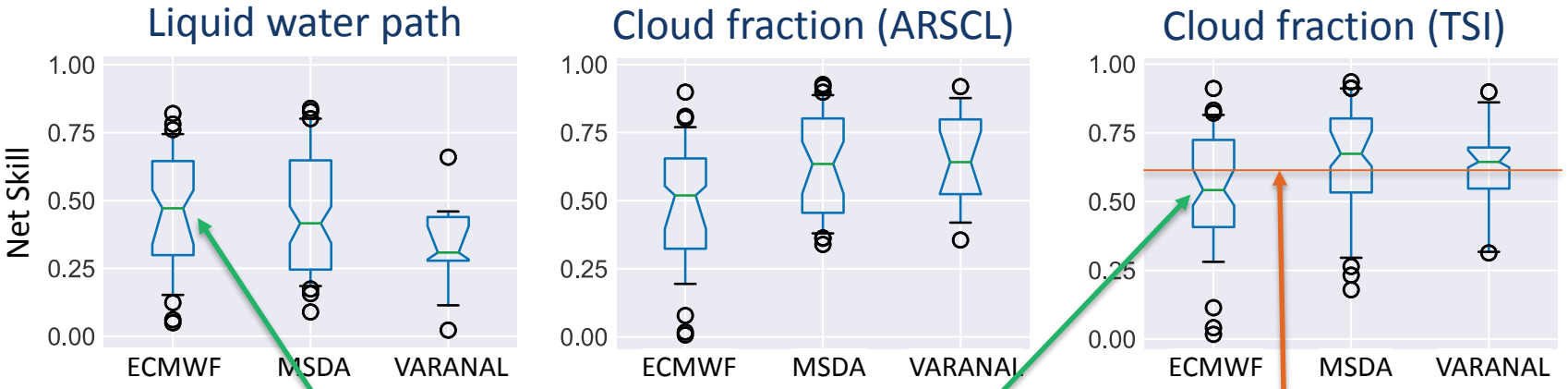




- Statistically unable to differentiate, but…
- VARANAL scores better for cloud-base height, mainly from Taylor skill score
- Consistent results with LCL

Comparison by large-scale forcing type:

Net Skill of liquid water path & cloud fraction

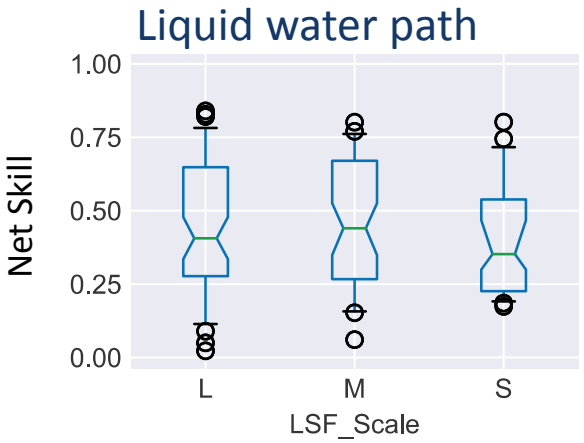


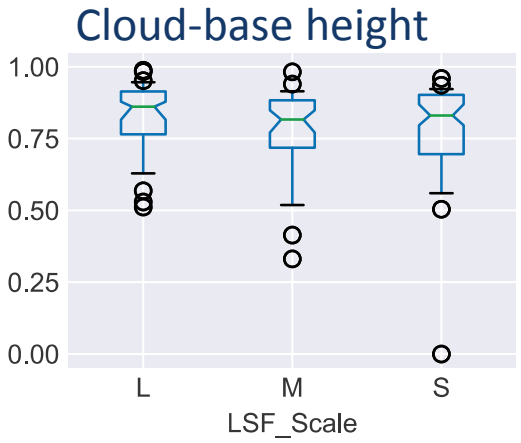
- ECMWF scores highest for LWP but lowest for cloud fraction
- Confidence intervals for medians overlap for all except ECMWF & MSDA CF_{TSI}

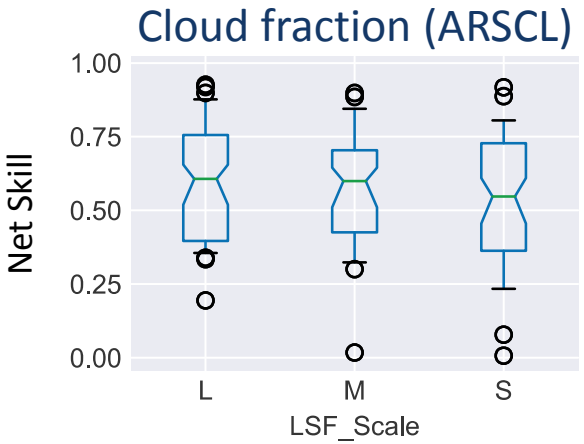
https://www.arm.gov/capabilities/modeling

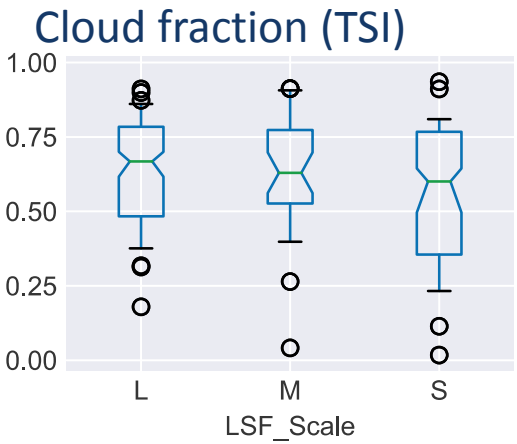
Comparison by large-scale forcing scale (net skill)

Large, medium, vs. small forcing area









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