Shallow Cumulus Cloud-Base Vertical Velocity I: Difference Between Simulations and Observations

Coupling Mechanistically the Convective Motions and Cloud Macrophysics in a Climate Model, (CM)⁴

a Climate Model Development and Validation (CMDV) Project

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Summary

Observations from the Doppler Lidar network at the ARM Southern Great Plains (SGP) Facility are used to benchmark first-light, ensemble, large-eddy simulations by the ARM LASSO Project. Results suggest that simulations significantly underestimate the occurrence of downdrafts at cloud base, which may be important to parameterization and model improvement studies.

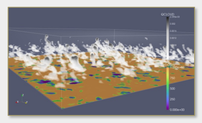
1. Motivation

Continental boundary layer clouds are important because of their impact on the lower atmospheric energy and moisture budgets.

Model parameterizations are challenged by these clouds partly since small-scale turbulence & convection are not well represented.

Large-eddy simulations (LES) resolve most small-scale dynamics and are frequently used to develop & test cloud parameterizations.

Observational constraints are needed for critical parameters such as cloud-base vertical velocity and cloud cover to perform model evaluation and adjustments.



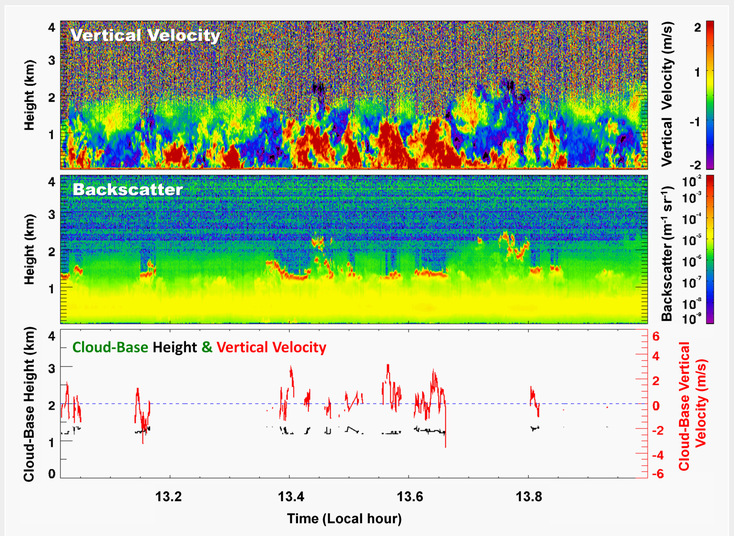
2. Objectives

- ❑ Derive statistical, observed constraints at the ARM SGP Facility
  - Network of 5 Doppler Lidars → Regional representation
  - Classify shallow convection as being active or forced
- ❑ Assess ability of large-eddy simulations to reproduce statistics
  - Use newly available ARM routine large-eddy simulations

3. ARM Observations

- ❑ **Doppler Lidar data**
  - 5 sites: May-Sept. in 2016 and 2017
  - Cloud base determined from lidar backscatter
- ❑ **Fair-weather shallow cumuli identification**
  - Follows Lamer and Kollias (2015), similar to Zhang and Klein (2010, 2013)
  - Cloud fraction between 3-60%
  - Only include boundary layer clouds
  - Residual layer clouds are removed
  - No stratiform clouds
  - No deep convection
  - No rain at central location for day

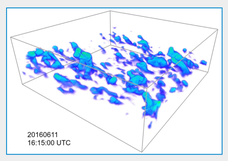
- ❑ **Cumuli active vs. forced identification at Central Facility**
  - Active if radar cloud thickness ≥ 300 m



4. LASSO Large-Eddy Simulations

- ❑ **LES ARM Symbiotic Simulation & Observation Workflow**
  - Complements ARM observations with routinely run LES
  - See Gustafson et al. poster #77
  - Breakout Session Thursday 10:45 am – 12:45 pm
  - Webpage: https://www.arm.gov/capabilities/modeling/lasso

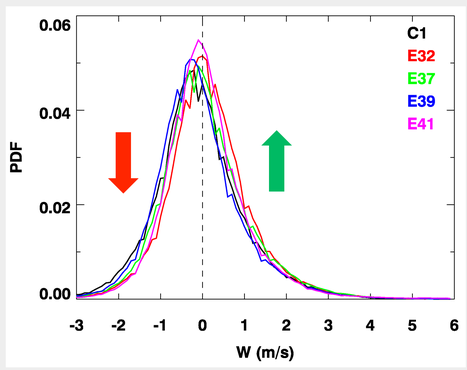
- ❑ **LASSO Features**
  - Constrained and evaluated with ARM observations
  - Ensemble forcings: 3 Sources plus different forcing scaled
  - Routine simulations yield a library for research
    - Enable statistical approaches beyond single-cases
    - Provide information for modelers to reproduce the LES
  - Run at the SGP for shallow convection → expand later



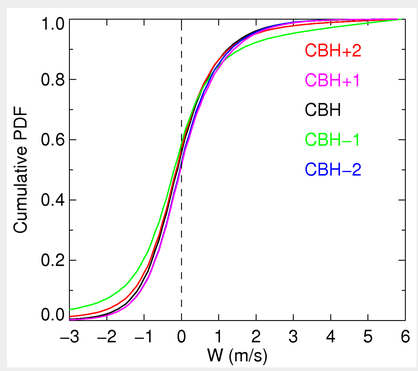
- ❑ **LASSO Simulations and Analysis**
  - Use 11 days from the LASSO Alpha2 release for 2016
  - 14.4 km domain, Doubly periodic lateral boundaries
  - WRF simulations complemented with SAM simulations
  - Control case:
    - Δx=100 m, Δz=30 m in boundary layer (BL)
    - Forced with ARM VARANAL advective tendencies and observed surface fluxes

5. Results for Cloud-Base Vertical Velocity

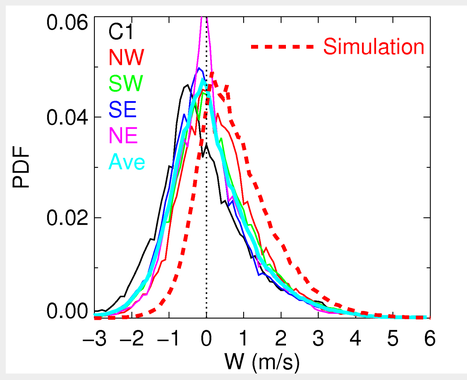
Observed Two-Year Statistics

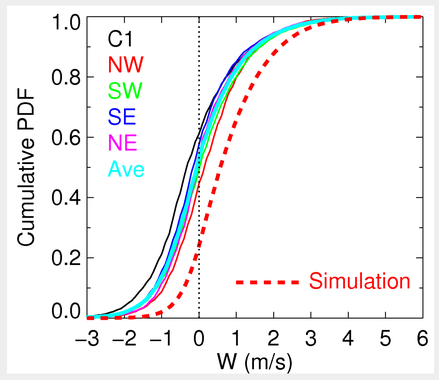


Sensitivity of Vertical Velocity to Cloud-Base Height from Lidar Gate

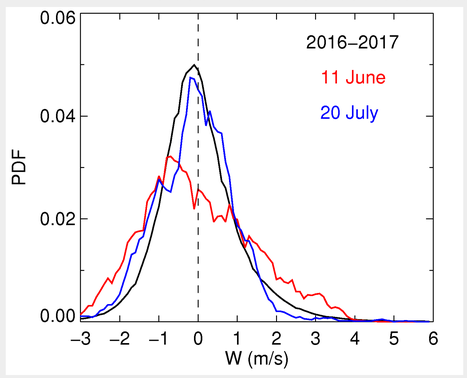


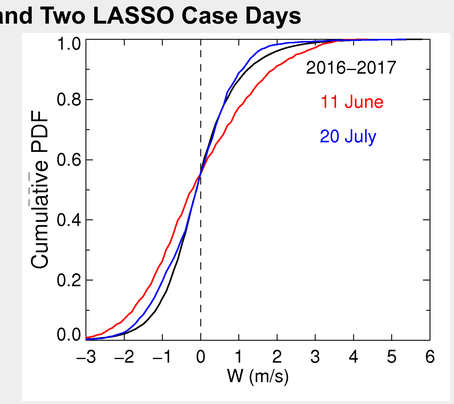
Observed and Simulated Vertical Velocity:
11-Day Means from Observations and LASSO Cases from 2016





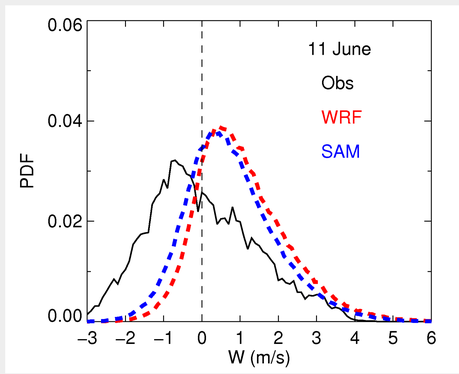
Observed Two-Year Statistics and Two LASSO Case Days



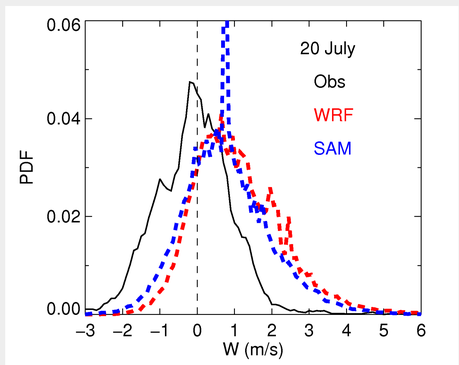


6. Sensitivity Studies: WRF & SAM

11 June: WRF and SAM



20 July: WRF and SAM



7. Sensitivity Studies: 11 June

11 June: WRF Large-Scale Forcing

11 June: SAM Horizontal Resolution

See Endo et al. poster #218 for numerical sensitivity studies related to these results.