Confronting a multi-plume scheme with observations of continental shallow convection

Philipp Griewank[1], Roel Neggers[1], Thijs Heus[2], and Neil Lareau[3]

[1]University of Cologne
[2]Cleveland State University
[3]University of Nevada, Reno

November 21, 2022

Abstract

Multi-plume convection schemes based on discretized size densities can be easily made scale-aware by size filtering the parametrized plumes to fit the model resolution. Combined with their capability to smoothly transition from shallow to deep convection while being both numerically robust and computationally viable, these bin macrophysics models are well suited to the needs of high resolution NWP and regional climate modeling. One such approach is the ED(MF)n scheme which has previously been evaluated in a single column model against maritime cumulus LES. In this presentation we will confront the ED(MF)n scheme with long-term Doppler lidar observations of shallow cumulus days from the ARM-SGP site in Oklahoma. To do so the ED(MF)n scheme is implemented and tested in a non-hydrostatic model on a microgrid of 8x8 or 16x16 gridpoints. By using a ˜10 km resolution this system behaves as a collection of weakly interacting single column models. We will compare the modeled relationship of vertical velocity to plume size against the relationship found in both the Doppler lidar observations and the LASSO LES run routinely at the ARM-SGP site. Next we examine which effect the assumed cloud-size distribution and entrainment as a function of plume size have on the resulting vertical transport.

Confronting a multi-plume scheme with observations of continental shallow convection

Philipp J. Griewank[1], Thijs Heus[2], Neil Lareau[3], Roel Neggers[1] - philipp.griewank@uni-koeln.de

1: University of Cologne, 2: Cleveland University, 3: University of Nevada, Reno

1. Introduction

Motivation:

Multi-plume parametrizations have shown promise to smoothly and stably parametrize unresolved convection through the grey zone, but contain many aspects that are poorly constrained by observations.

Poster questions:

1. Is the assumed size-dependent scaling of convective plumes observable?
2. How can parametrized plumes be quantitatively evaluated?

Approach:

1. Search for size dependence of LES and LIDAR updrafts below shallow cumulus clouds.
2. Attempt to detect convective clusters from LES able to serve as a direct analog to the parametrized plumes of the convection scheme.

2. Models and data

Large Eddy Simulations (LES):

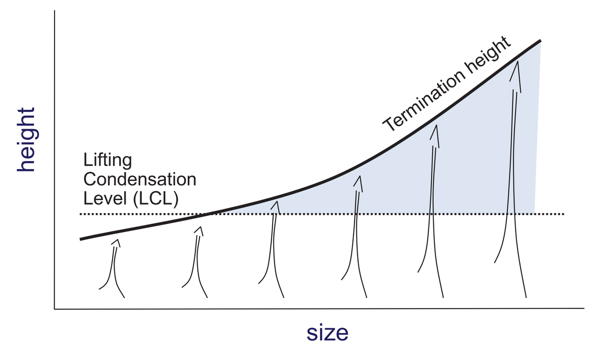
MicroHH (*van Heerwaarden 2017*) runs over Oklahoma with *LASSO* forcing at 25 m resolution, from 6am to 6pm, with 1024x1024x256 cells. All simulation from 2016.

Chord lengths dates: 05-18, 06-19, 06-25, 07-16, and 08-18.

Clustering dates: 06-11

Multi-plume scheme:

ED(MF)^n implementation of *Neggers 2015* in which plume properties depend on size, resulting in differing termination heights.

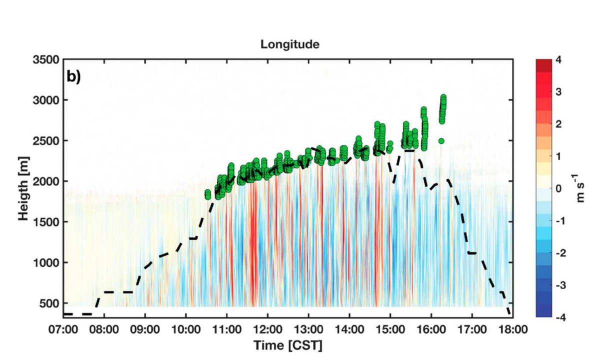


Clustering criteria:

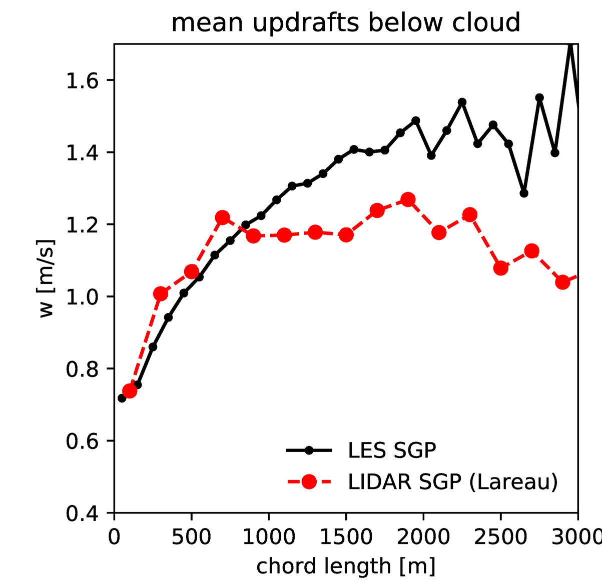
1. Vertical velocity > 0
2. Time-decaying surface-emitted tracer (*Couvreux 2009*) is larger than twice the standard deviation.
3. Cluster begins lower than 2000 m with a vertical extent greater 200 m (8 cells).

LIDAR data:

Vertical velocities below shallow cumulus clouds are detected and binned by chord length at the ARM-SGP site (*Lareau 2018*).

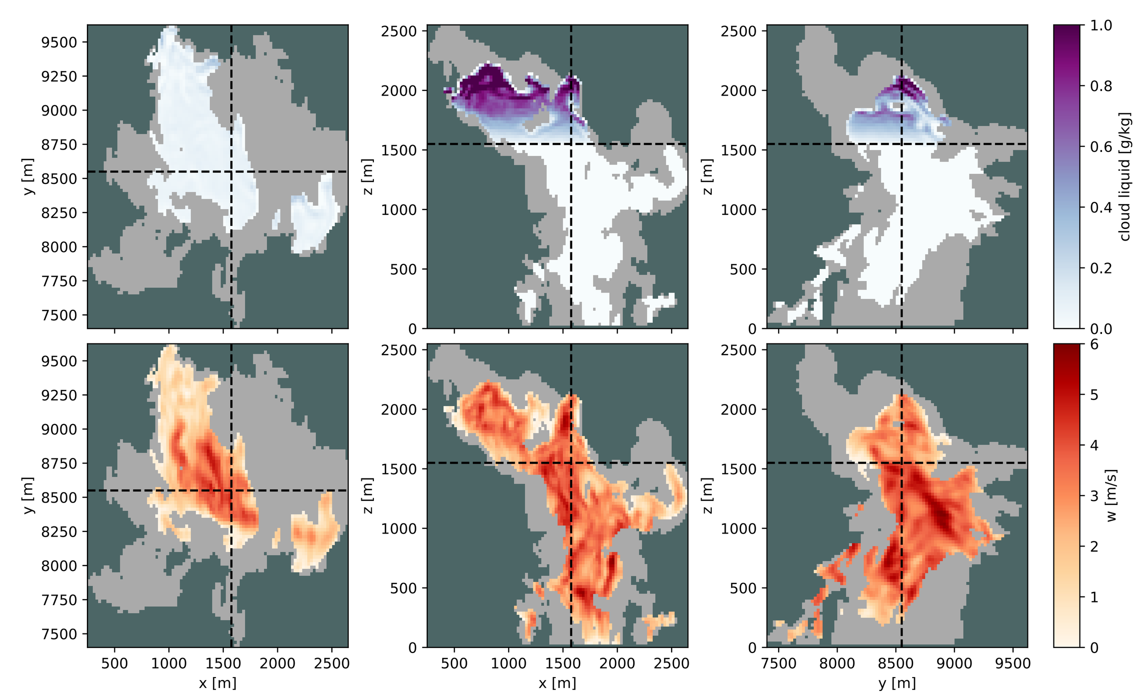


3. LIDAR vs LES updrafts

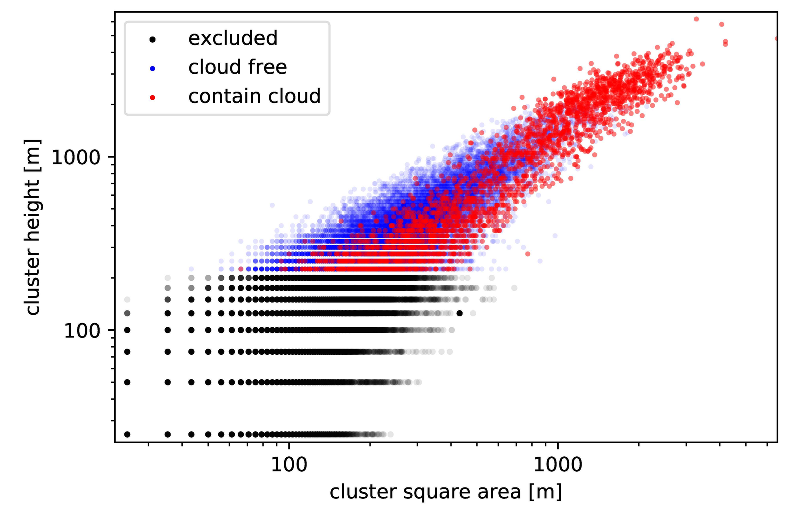


Mean updraft speed below cloud, binned and averaged by chord length. LIDAR chord lengths are determined from wind speed and detection duration, LES chord lengths by slicing a 3D output field and scanning from the surface.

4. Convective clustering

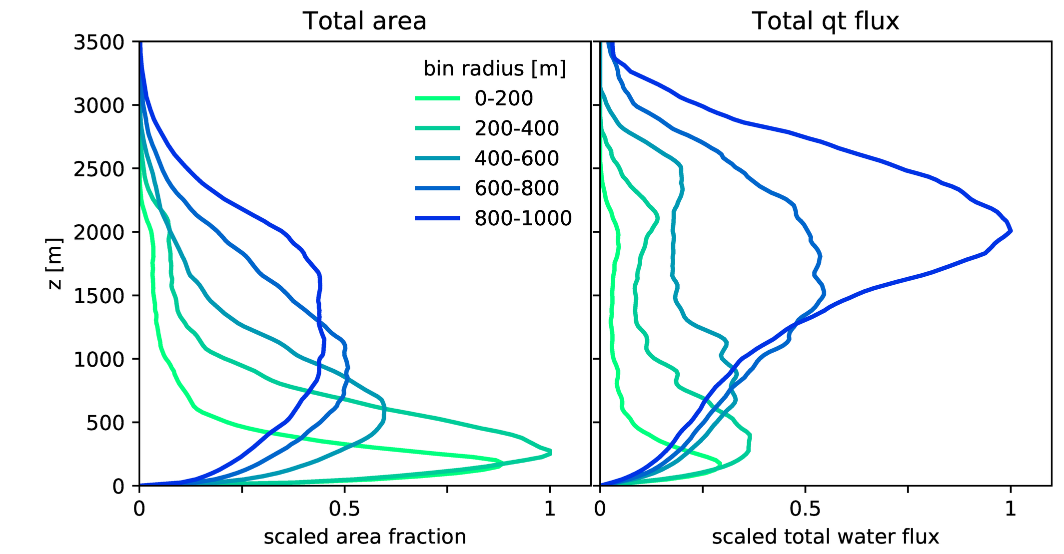


2D slices through a convective cluster showing liquid water content and vertical velocity. Grey shading marks the projected cluster outline, dashed lines the slice locations.



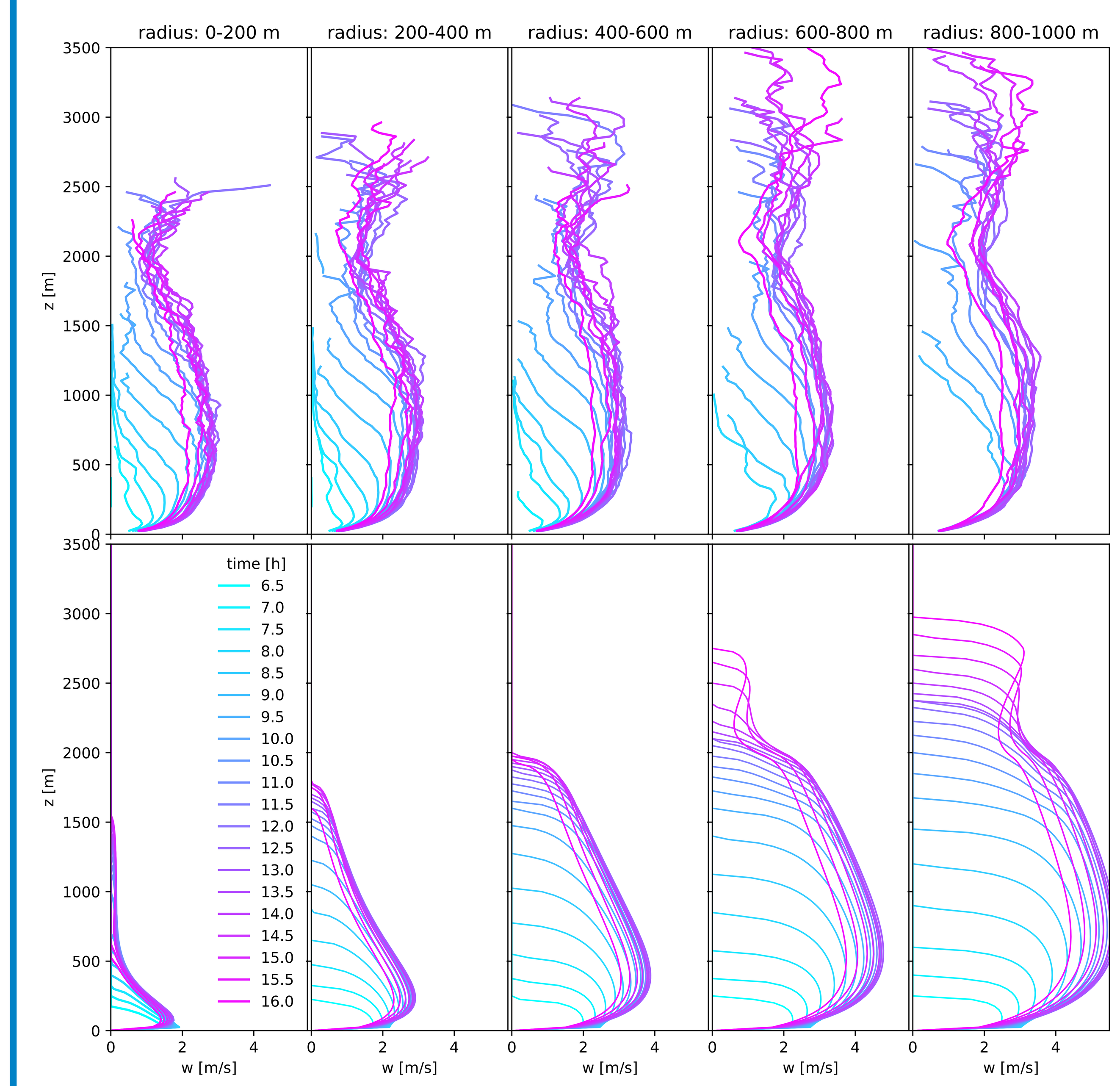
Square area vs height of all clusters detected from 2016-06-11 before filtering out all shorter than 200 m.

5. Cluster contribution binned by area



Relative contribution to total area fraction and total water flux averaged over 24 half hour snapshots from 2016-06-11.

6. Daily evolution of convection



Mean vertical velocity profile of clusters binned by area (top), and parametrized plumes (bottom) of same area throughout 2016-06-11. Parametrized plumes commence and terminate at zero, while the clutering only detects the active part.

7. Conclusions

Is the assumed size-dependent scaling of convective plumes observable?

- Updrafts scale strongly with smaller chord lengths (box 3).
- The area of convective clusters is strongly related to cluster height (box 4, 5), and less strongly linked to vertical velocity (box 6).

How can parametrized plumes be quantitatively evaluated?

- The convective clustering enables a direct comparison of parametrized plumes to LES simulations (box 4,5). However, cluster properties are highly sensitive to the chosen clustering criteria, tend to have highly complex geometry, and seldom capture initial plume acceleration and final plume deceleration (box 6).
- Without any tuning, ED(MF)^n plumes are quantitatively and qualitatively similar to the cluster updrafts, but with a much clearer size-dependent scaling. We are not yet sure how much is due to clustering noise and limited LES resolution versus the implementation of too strong plume scaling in ED(MF)^n (box 6).

8. Outlook

- Expand LIDAR vs LES chord length comparison further below the cloud.
- Fine tune and generalize clustering criteria before expanding the analysis to further LASSO shallow cumulus days.
- Tune ED(MF)^n to match cluster properties, evaluate progress by independently evaluating mean and bulk properties against ARM-SGP measurements.

Citations & acknowledgements

Couvreux et al 2009: Resolved Versus Parametrized Boundary-Layer Plumes. Part I: A Parametrization-Oriented Conditional Sampling in Large Eddy Simulations, BLM

Neggers 2015: Exploring bin-macrophysics models for moist convective transport and clouds, JAMES

van Heerwaarden et al 2017, MicroHH 1.0: a computational fluid dynamics code for direct numerical simulation and large-eddy simulation of atmospheric boundary layer flows, GMD

Lareau et al 2018, Observed Boundary Layer Controls on Shallow Cumulus at the ARM Southern Great Plains Site, JAS

LASSO: Gustafson Jr et al 2018, Description of the LASSO Alpha 2 Release, DOE/SC-ARM-TR-199, Rev. 1

This work is funded by grant DE-SC0017999 & DE-SC0019124 of the Department of Energy's Atmospheric System Research program.

University of Cologne

Faculty of Mathematics and Natural Sciences

Institute for Geophysics and Meteorology

ASR Atmospheric System Research

ARM U.S. DEPARTMENT OF ENERGY Office of Science

University of Nevada, Reno

InScAPE

Integrated Scale-Adaptive Parameterization and Evaluation