Modeling of clouds and tracer transport in WRF and NOAA's future models with MYNN-EDMF

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Bill Gustafson, Satoshi Endo, Jake Gristey, Ian Glenn, and Graham Feingold

Outline:

EDMF and MYNN-EDMF

Evaluation with LASSO cases

Chemical and tracer transport

CCPP SCM evaluation

Areas for improvement and future investigation

Objectives

Tune and test the evolving MYNN-EDMF parameterization of the boundary layer and shallow cumulus

Single-column tests in WRF

Compare with LES

Test in CCPP SCM

Motivation

Shallow cumulus present an ongoing challenge to mesoscale models. They are particularly important for chemical and tracer transport.

Single-column modeling allows us to isolate the parameterization from other effects in the model

The DOE ARM project LASSO now provides many cases with shallow cumulus, and some with other regimes.

Cases are based on observations at the ARM Southern Great Plains site.

EDMF schemes for PBL and shallow Cu

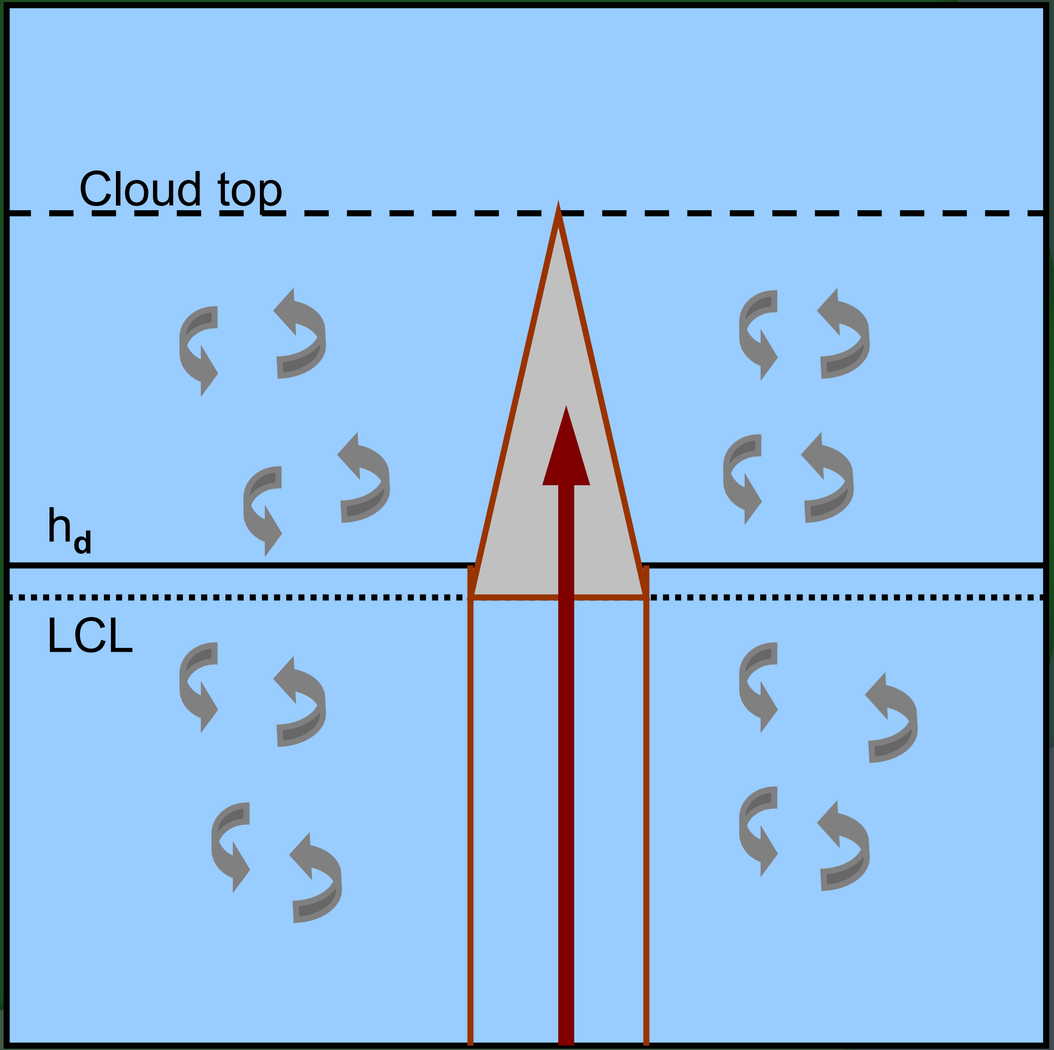
The so-called "PBL" scheme is responsible for **ALL** vertical mixing

EDMF originated with Pier Siebesma and Joao Teixeira about year 2000

Mass flux provides non-local transport in convective BL (with or without cloud) and natural representation of BL-rooted clouds; Eddy diffusion represents small scales

Many EDMF schemes are in use for research and operations, mostly in Europe, and now in RAP/HRRR

Simple concept, complex implementation



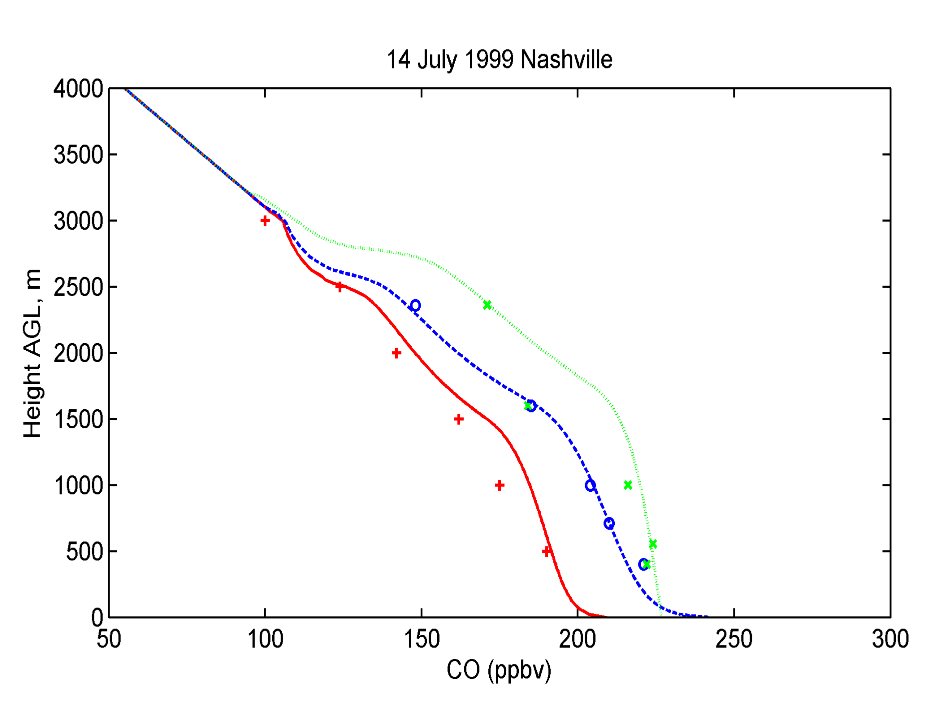
Why do we care about shallow cumulus?

Vertical transport of chemical species
– raises effective PBL height
- changes horizontal distribution

Radiative impact
– decreases solar input to surface, reducing turbulence intensity and chemical reaction rates

Aqueous processing
– heterogeneous chemistry of gasses and aerosols

Moistening of cloud layer
– preconditioning for deep convection

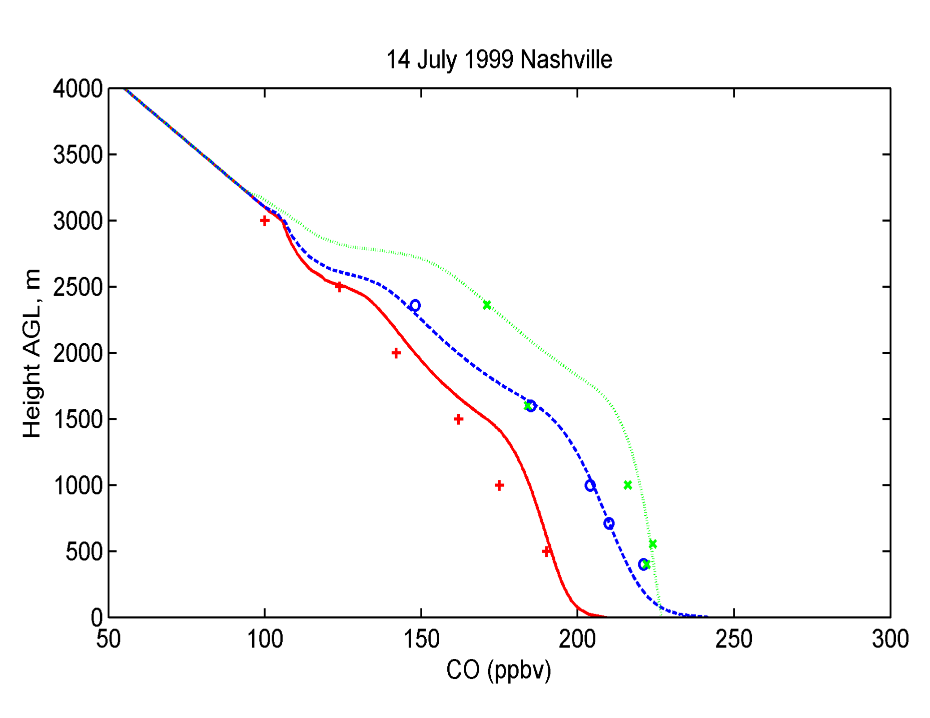


Profiles of CO upwind of Nashville (red), over downtown (blue), and downwind (green)

Lines are 1D model, markers are aircraft measurements

Not possible to simulate without cloud transport

Consistent chemical and tracer mixing



Standard WRF-Chem only uses eddy diffusion from the PBL scheme

Consistent only for purely local schemes (e.g. MYJ but not YSU)

Chemical and tracer transport including non-local terms is coded in MYNN-EDMF

Testing is needed

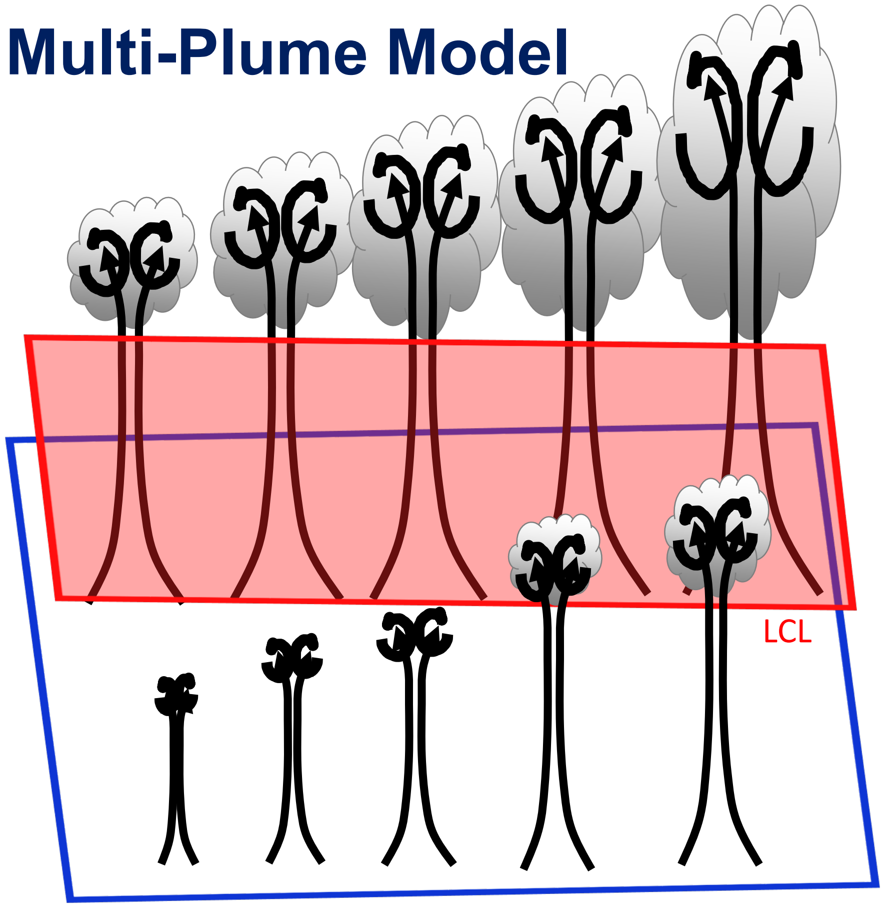
Good test cases would have shallow clouds in a polluted environment, e.g. Southeast U.S.

MYNN-EDMF: Dynamic Multi-Plume Model

An attempt to explicitly model plumes of various sizes that are likely to exist in a given atmospheric state, following **Neggers (2015, JAMES)** and **Suselj et al. (2013, JAS)**.

- Total maximum number of plumes possible in a single column: 10.
- Diameters (ℓ): 100, 200, 300, 400, 500, 600, 700, 800, 900, and 1000 m.
- Lateral entrainment varies for each plume $\propto (w\ell)^{-1}$.
- Plumes condense only if they surpass the lifting condensation level (LCL).

The scheme also includes non-convective subgrid cloud from a statistical diagnosis, quasi-independent from the MF clouds



Process-level diagnosis

Cloud characteristics

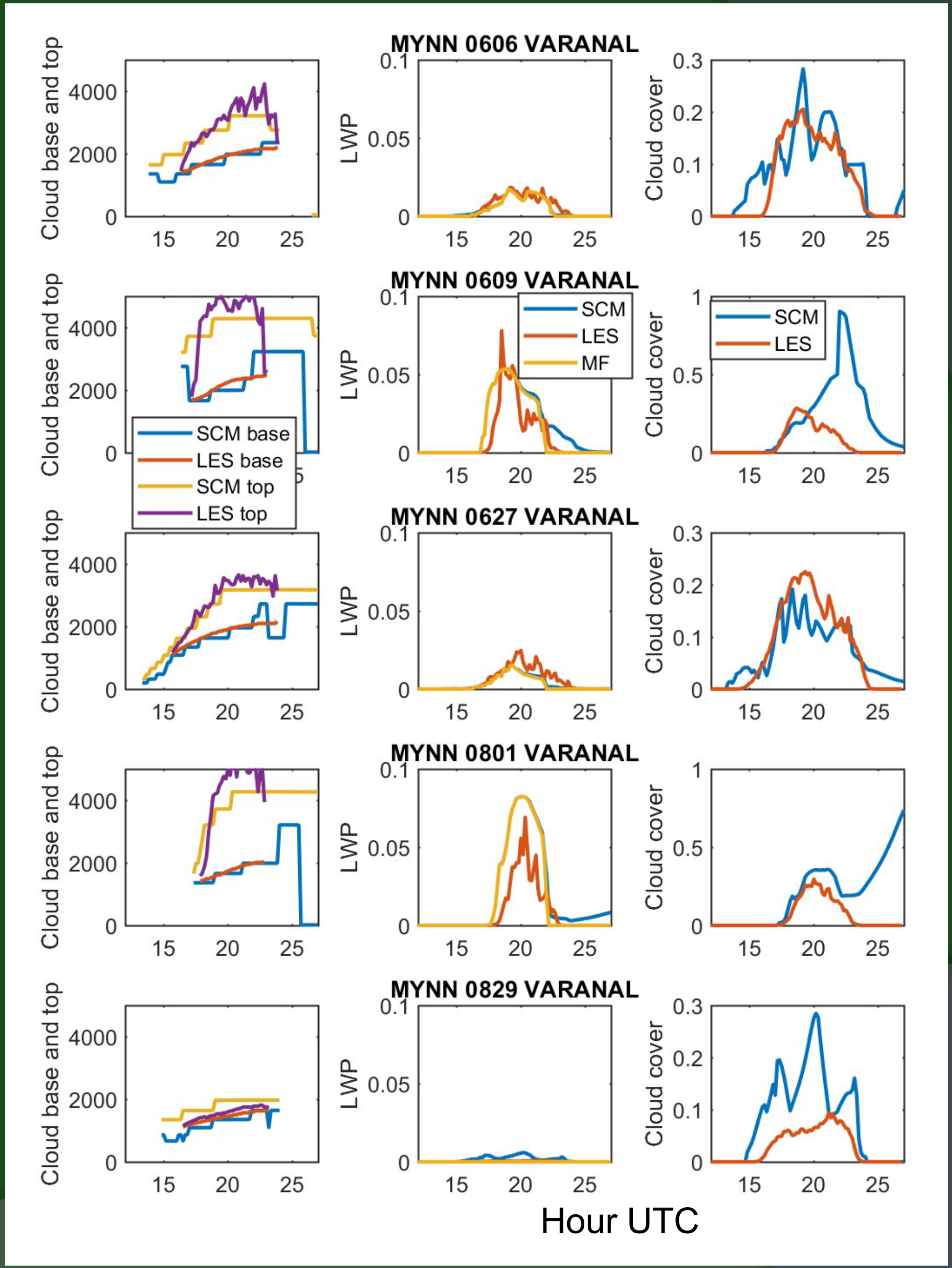
LASSO alpha 1 cases (2015)

Comparing to large-eddy simulations (LES)

MYNN-EDMF reproduces cloud base, cloud top, liquid water path very well

Cloud cover also good midday

These process-level comparisons allow us to take a good scheme and improve it further



Evaluating cloud liquid water path

52 cases from 2015, 2016, 2017, 2018

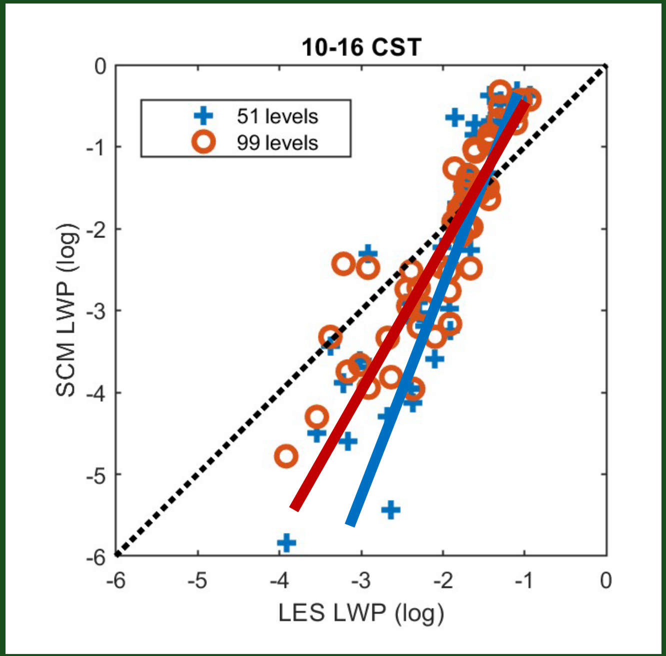
LWP is well captured over 3 orders of magnitude (note log scale)

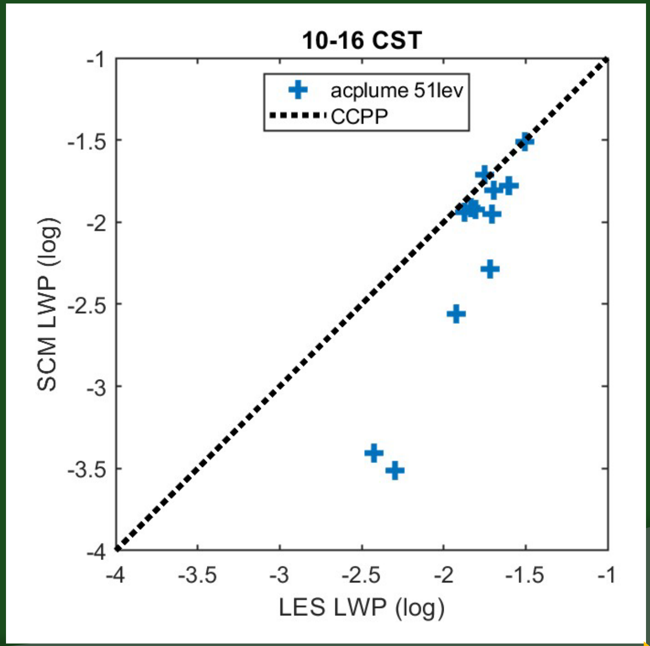
Tendency to overpredict wetter cloud, and underpredict cloud with less water (blue)

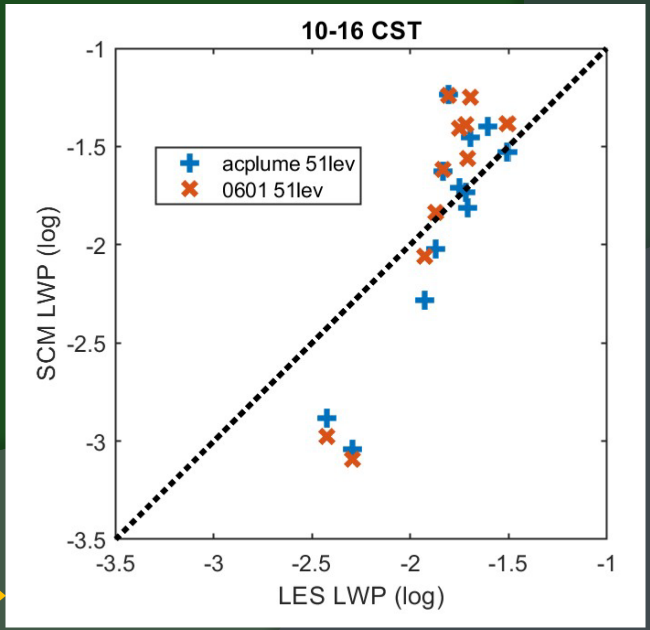
Doubling vertical levels improves this (orange/red)

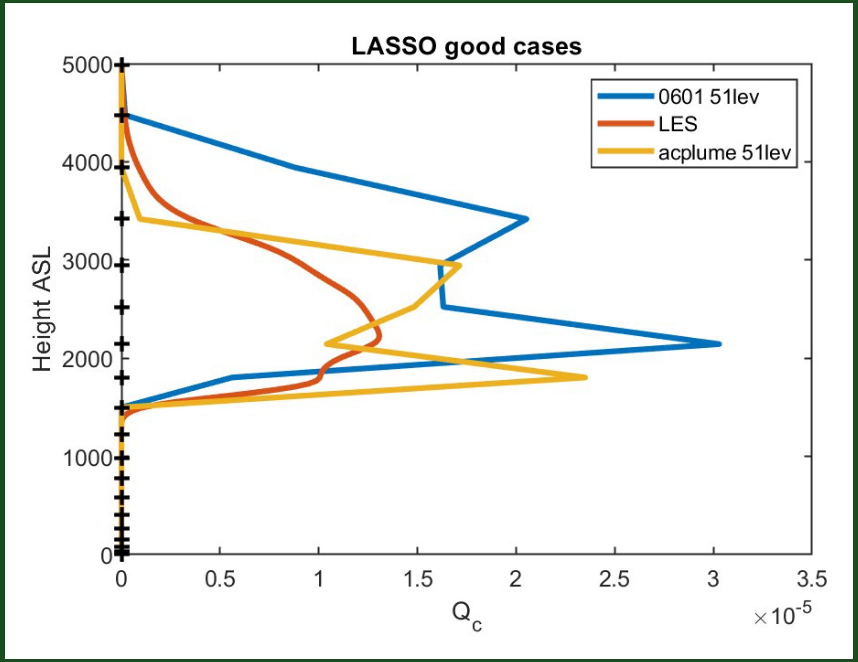
Damping accelerating plumes or tweaking stability criteria also improves results in “good” 2018 cases

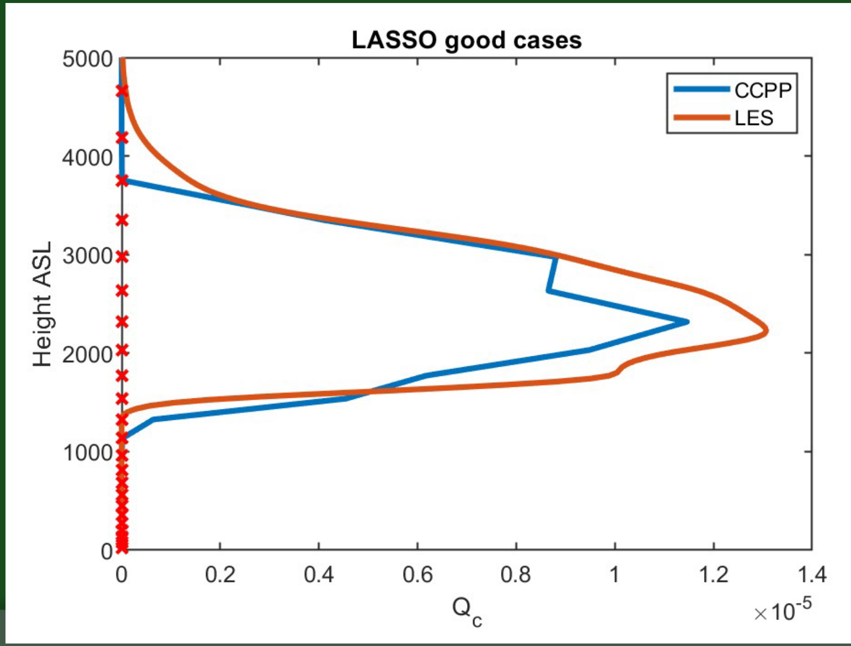
CCPP SCM performance similar or a little better











Cloud liquid profiles

12 “good” cases from 2018

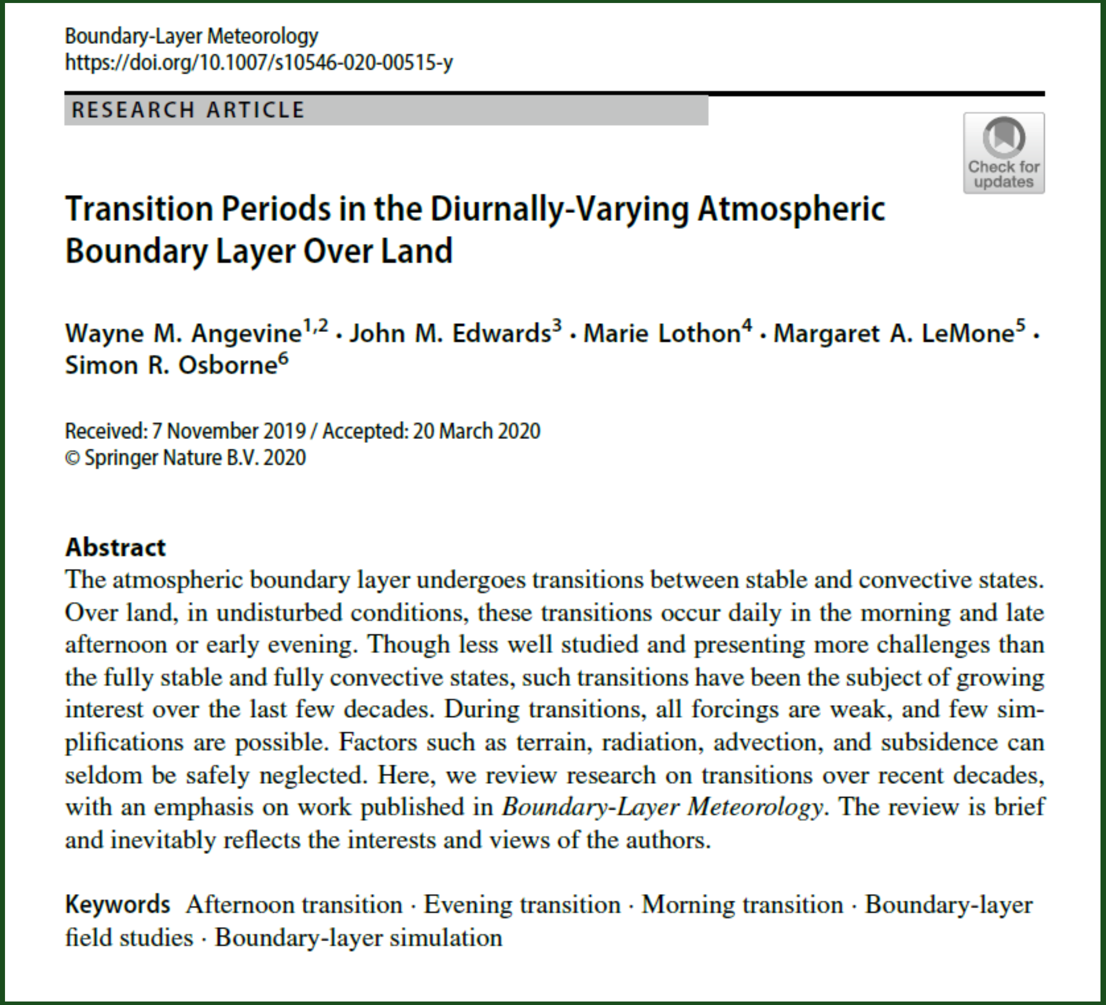
Using LASSO (WRF) LES

LES profile is smooth, weighted toward cloud base (as expected)

Levels are marked by plus signs on the left axis

CCPP has less liquid and smoother shape, better matching LES (note different horizontal scale)

Shameless plug



Boundary-Layer Meteorology
https://doi.org/10.1007/s10546-020-00515-y

RESEARCH ARTICLE

Check for updates

Transition Periods in the Diurnally-Varying Atmospheric Boundary Layer Over Land

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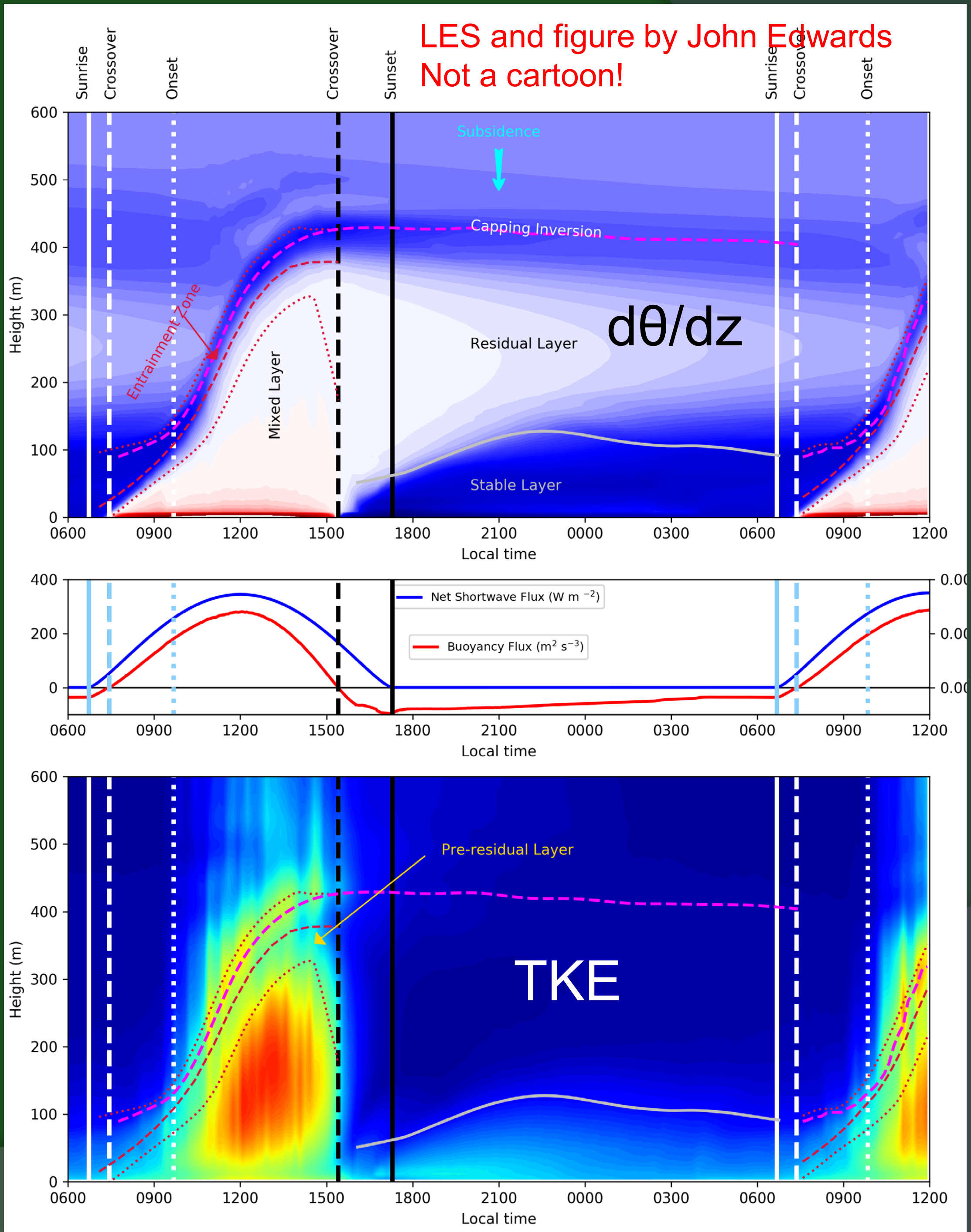
Abstract
The atmospheric boundary layer undergoes transitions between stable and convective states. Over land, in undisturbed conditions, these transitions occur daily in the morning and late afternoon or early evening. Though less well studied and presenting more challenges than the fully stable and fully convective states, such transitions have been the subject of growing interest over the last few decades. During transitions, all forcings are weak, and few simplifications are possible. Factors such as terrain, radiation, advection, and subsidence can seldom be safely neglected. Here, we review research on transitions over recent decades, with an emphasis on work published in *Boundary-Layer Meteorology*. The review is brief and inevitably reflects the interests and views of the authors.

Keywords Afternoon transition · Evening transition · Morning transition · Boundary-layer field studies · Boundary-layer simulation



Summary

MYNN-EDMF represents the convective boundary layer and shallow cumulus well

LASSO has provided us with process information for targeted action to improve parameters

Performance in CCPP (for NOAA's future models) is similar or even better

Future plans:

Move into CCPP SCM and FV3 context

Evaluate chemical and tracer mixing

References:
Angevine et al. 2018, Monthly Weather Review
Olson et al. 2020, BAMS
Olson et al. 2019, NOAA Tech Memo
Angevine et al. 2020, MWR, in review
Angevine et al. 2020, ACP(D), in discussion

Recommendation:

Use it!