Scale-aware tests of the MYNN-EDMF PBL and shallow cumulus scheme in a multi-column framework

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

Conclusions:
Scale awareness should be based on effective resolution, not grid spacing
At 600m spacing, reducing parameterized mixing degrades performance
M-CISCs are not an adequate substitute for parameterized mixing
The grey zone is a real problem, not so easily solved
MYNN-EDMF in WRFv4.1 has features to reduce the intensity of mixing at small grid spacings (below ~1 km).

Do the scale-aware aspects of MYNN-EDMF behave as expected?

What do we expect as grid spacing decreases?
- Resolved vertical motions should increase
- Parameterized (vertical) mixing should decrease
- Net result should be equal mean mixing on the aggregated cell

Some information provided by coarsened LES (e.g. Honnert et al.)

**BUT**

Resolved vertical motions on gray-zone grids are not the same as in the real atmosphere, but are governed by grid size and effective resolution [Ching et al. (2014) and Zhou et al. (2014)]

“Model Convectively Induced Secondary Circulations” (M-CISCs)

Effective resolution is larger than grid spacing (4-8*Δx) [Beare 2014, many others]

What do we mean by “gray zone”?

Also known as “terra incognita” (Wyngaard)

The range of grid spacing where important motions are neither fully resolved nor completely subgrid

For PBL and shallow cumulus, characteristic scales are 200-2000 m, depending on BL depth and cloud layer depth
Test method: Multi-column or Partially-convection-permitting model

Usual WRF “single-column” setup is a 2x2 grid with doubly-periodic boundary conditions and strong horizontal diffusion.

Here the grid spacing is decreased but the grid covers the same area, still doubly-periodic, no artificial diffusion.
Using standard mesoscale horizontal (only) diffusion.
Grid spacing controls scale-aware aspects of the PBL / shallow Cu scheme.

Initialization:
- Uniform vertical sounding
- Coupled land surface
- Perturbed soil moisture to break symmetry (0.1% perturbation)

Cases: LASSO (DOE ARM) 2015, 2016, and 2017
What happens in the multi-column simulation (without scale awareness)?

Fine grid has higher cloud base and top, similar cloud cover
LWP proportion between mass flux, non-convective subgrid, and grid scale cloud changes
Vertical velocity pattern varies in time (linear to cellular)
Profiles smoother at 600m (not shown)

In LWP plots:
Red: LES
Yellow: MF cloud
Blue: Total cloud
Purple: Grid cloud
Is scale awareness beneficial?

Scale-aware cloud is later and has less LWP.

In LWP plots:
- Red: LES
- Yellow: MF cloud
- Blue: Total cloud
- Purple: Grid cloud
“Best” cases

Most pure shallow Cu days
Same message:
Scale-aware cloud is late and has less LWP

In LWP plots:
Red: LES
Yellow: MF cloud
Blue: Total cloud
Purple: Grid cloud
No scale awareness is superior or equal in 12 of 16 cases with respect to LES.

If 13km overestimates, scale aware looks better.

Non-scale-aware is always closer to 13km solution.

Results depend on averaging period (time of day).

Some of these are not ideal shallow Cu cases.

(Note log scale)
What about the circulations (M-CISCs)?

✓ Grid-dependent magnitude and pattern
✓ Delayed onset

Now showing 1200m vs. 600m grid

Parameterized and grid scale motions trade off in managing instability in the surface layer

Note that M-CISCs are present even though this is a non-local scheme

Additional diffusion damps M-CISCs (not shown)
Patterns vary in a realistic way
Realistic not necessarily real

0627 has moderate instability
0611 has the least instability and the largest difference between scale-aware and non-scale-aware

Both have similar $u^*$
LES cellular in both cases
Summary

Multi-column framework is effective for testing scaling behavior and scale awareness.

Scale awareness in MYNN-EDMF v4.1 works as designed, but more thought is needed. In these cases, scale awareness is detrimental to performance:
- Timing delay
- LWP reduction

Why?
- Grid size is not resolution
- M-CISCs are slow, weak, and grid-dependent
- Coarsened LES represents more scales of motion

Some cases are too strong at 13km; weakening parameterized mixing seems good in these cases, but better to fix 13km.

Are M-CISCs desirable or not?
- Maybe, if users are educated about what they’re seeing
- Timing and pattern are wrong

Perfect performance in SCM/MCM may not be what we want in 3D. Numerical details and dynamics options affect the results.

Simply reducing activity of parameterized mixing is not a full solution to the grey zone problem of sub-3-km grids for convective PBL and shallow Cu.

Full description of MYNN-EDMF out soon in BAMS (Olson et al.)