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

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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

Scale awareness

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 "terrra 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

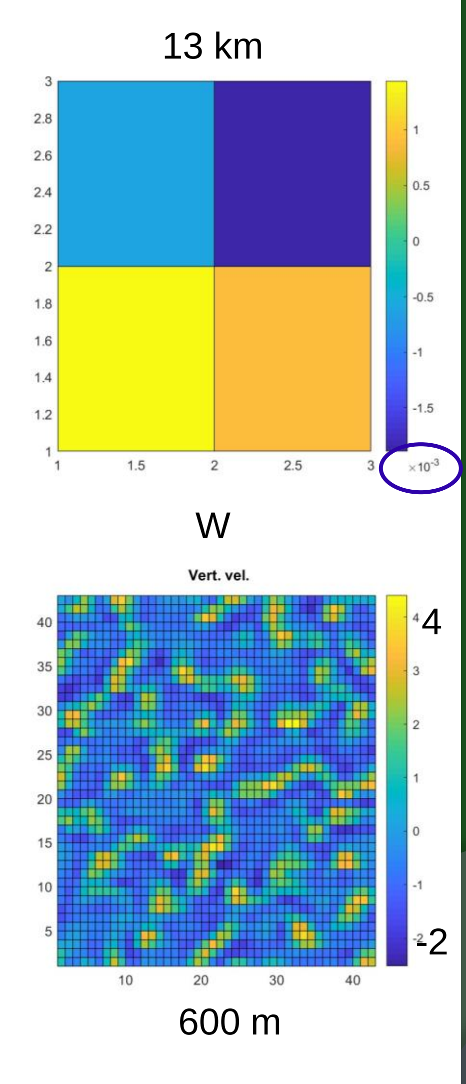
Using standard mesoscale horizontal (only) diffusion

Grid spacing controls scale-aware aspects of the PBL / shallow Cu scheme

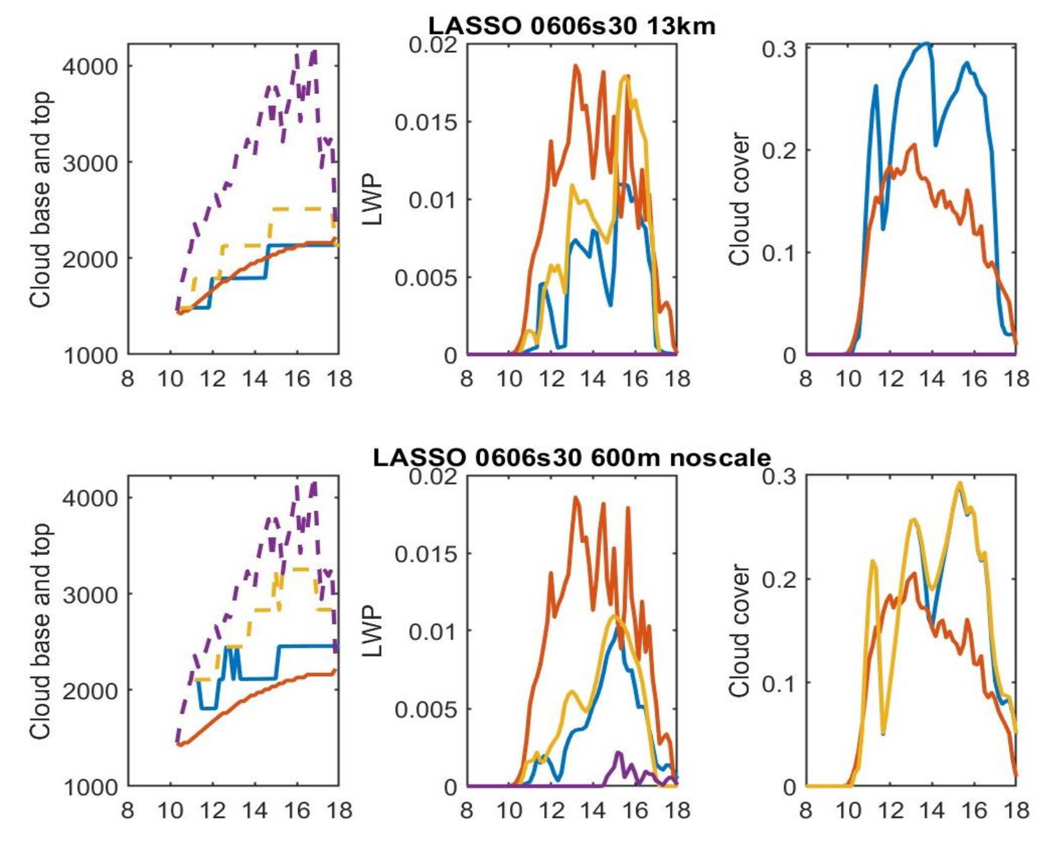
Initialization:

- 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)?



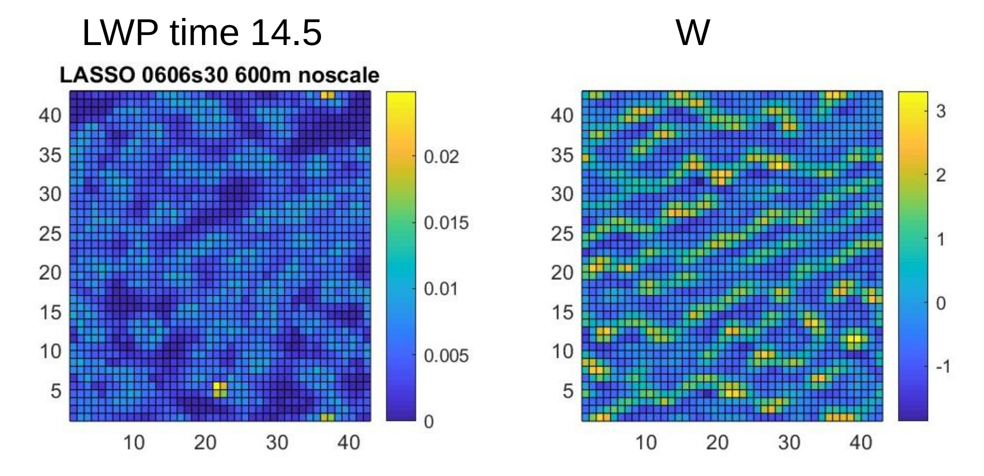
In LWP plots:
Red: LES
Yellow: MF cloud
Blue: Total cloud
Purple: Grid cloud

Fine grid has higher cloud base and top, similar cloud cover

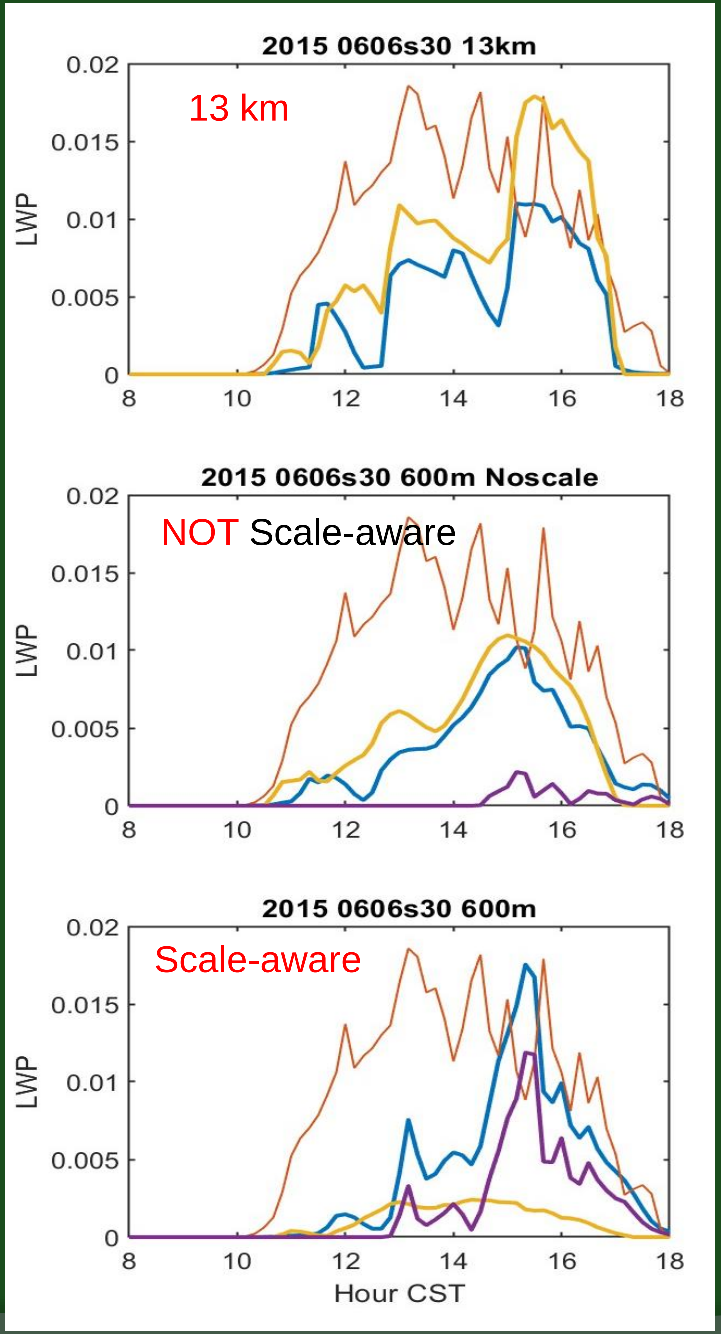
LWP proportion between mass flux, non-convective subgrid, and grid scale cloud changes

Vertical velocity pattern varies in time (linear to cellular)

Profiles smoother at 600m (not shown)

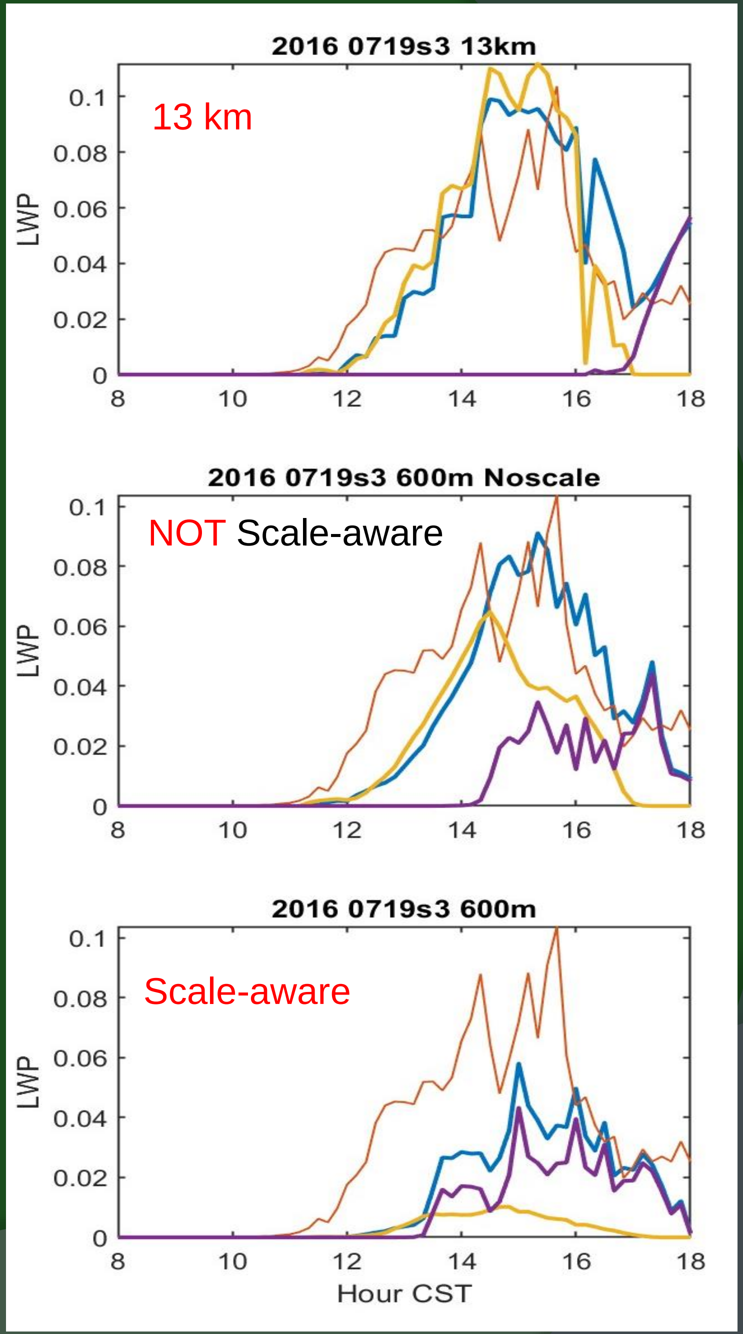


Is scale awareness beneficial?



6 June 2015

19 July 2016



Scale-aware cloud is late(r) 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:
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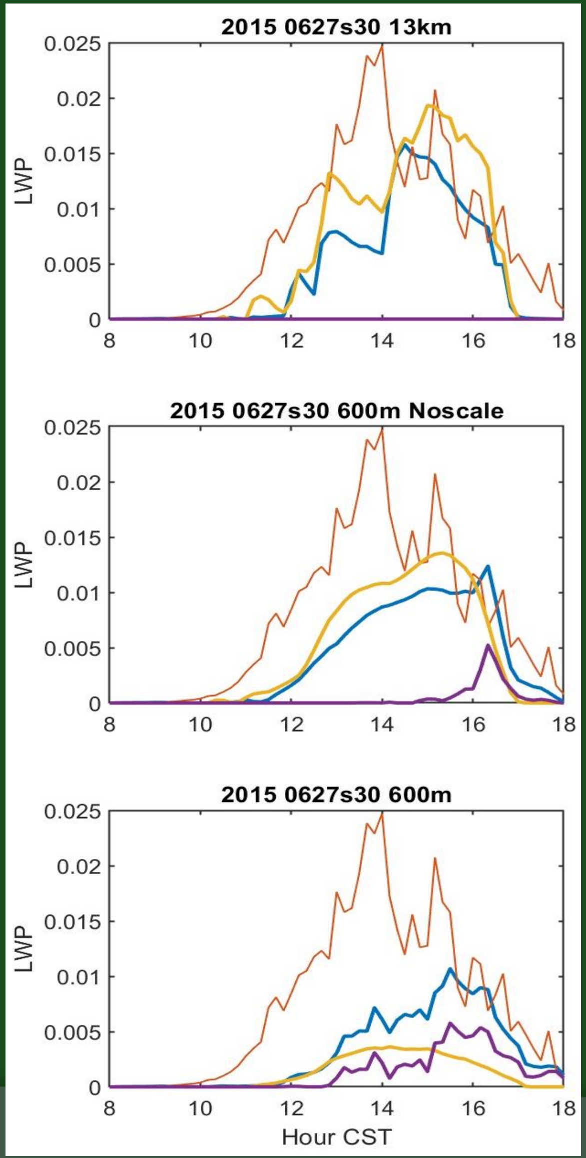
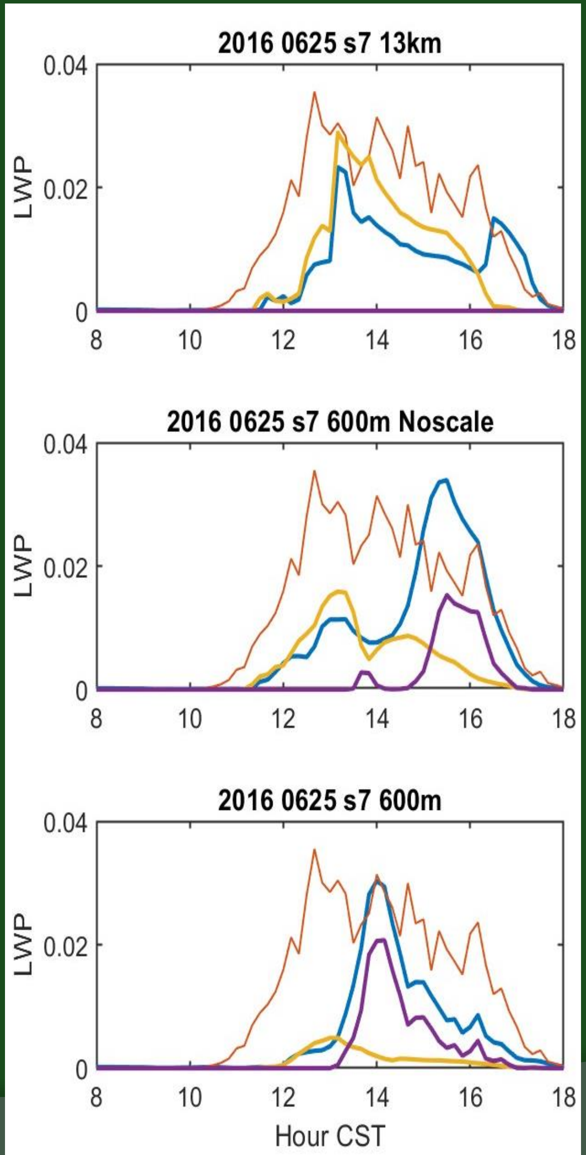
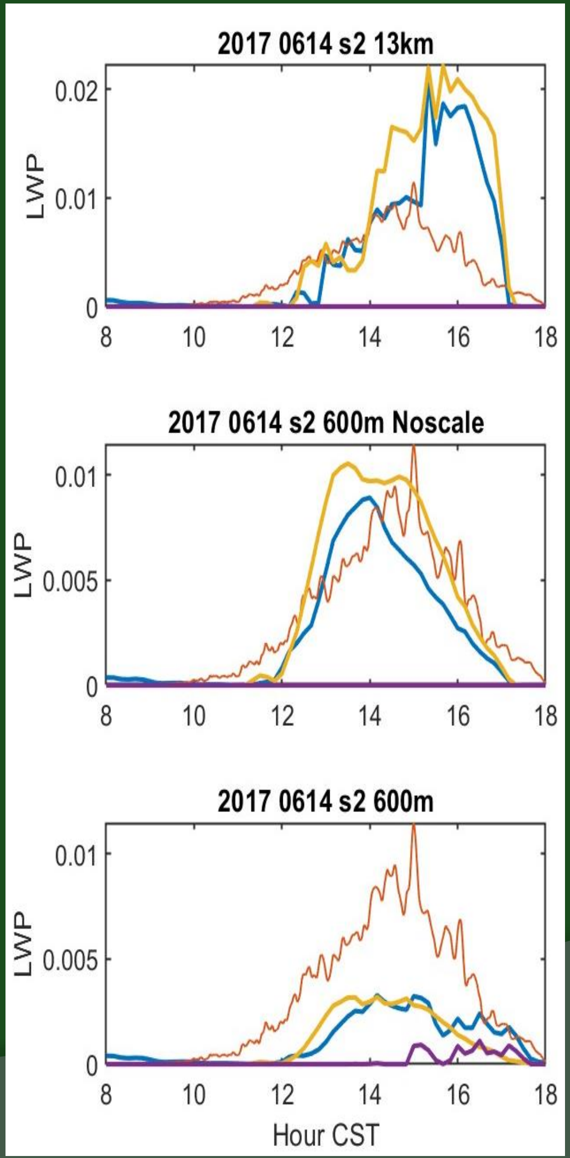
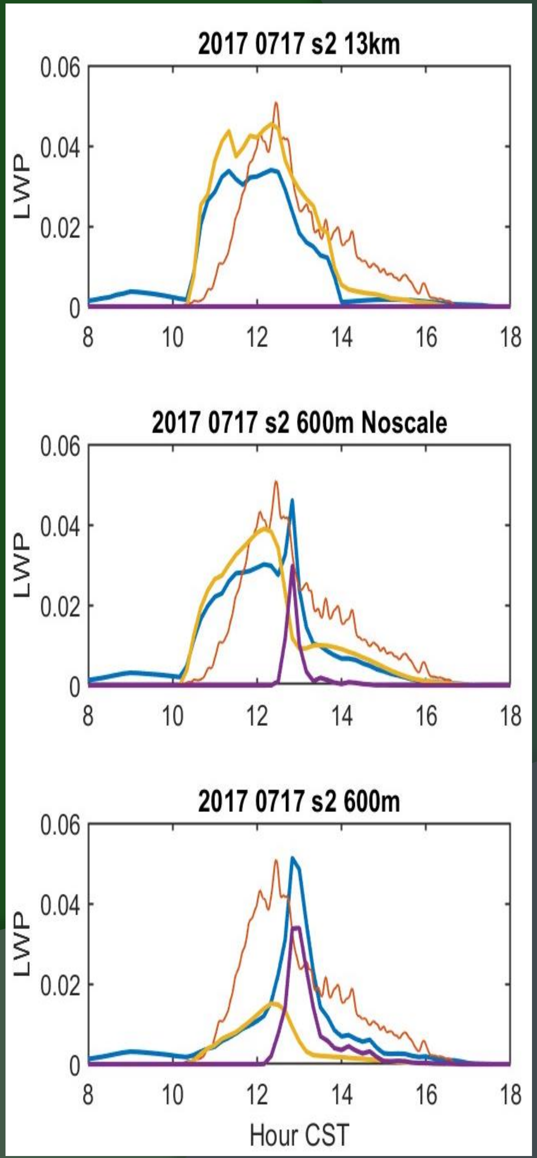








Mean LWP

No scale awareness is superior or equal in 12 of 16 cases with respect to LES

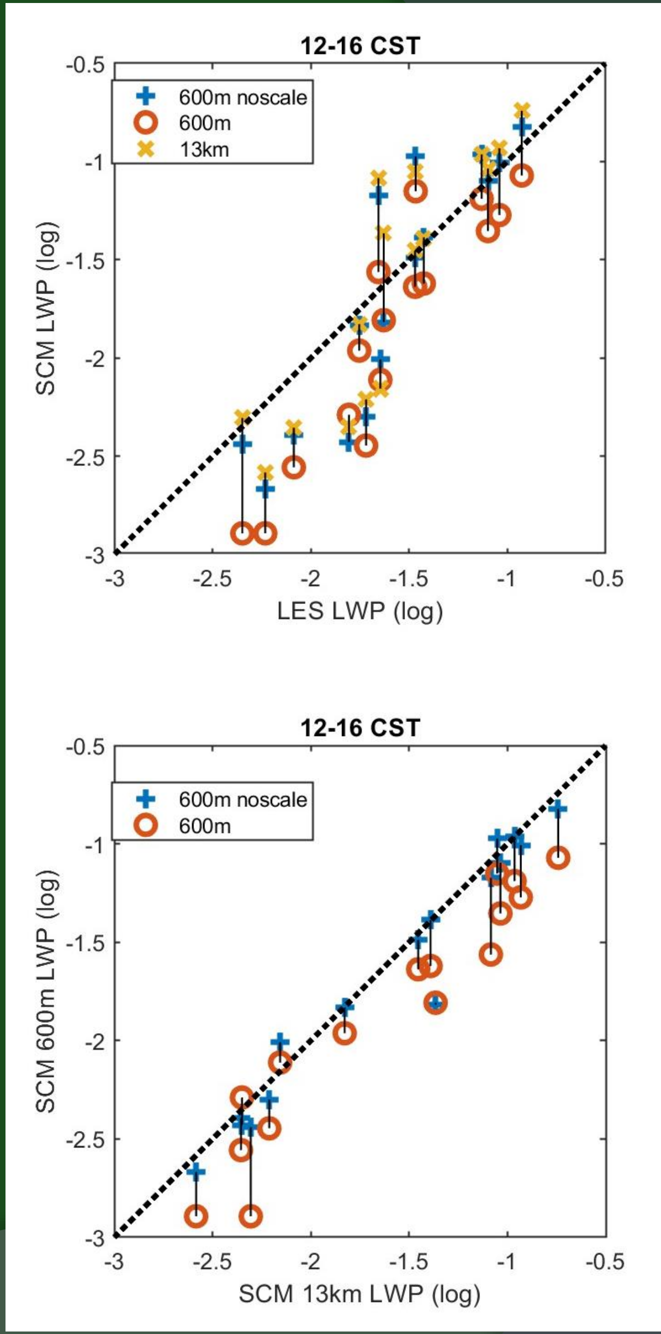
If 13km overestimates, scale aware looks better

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)?

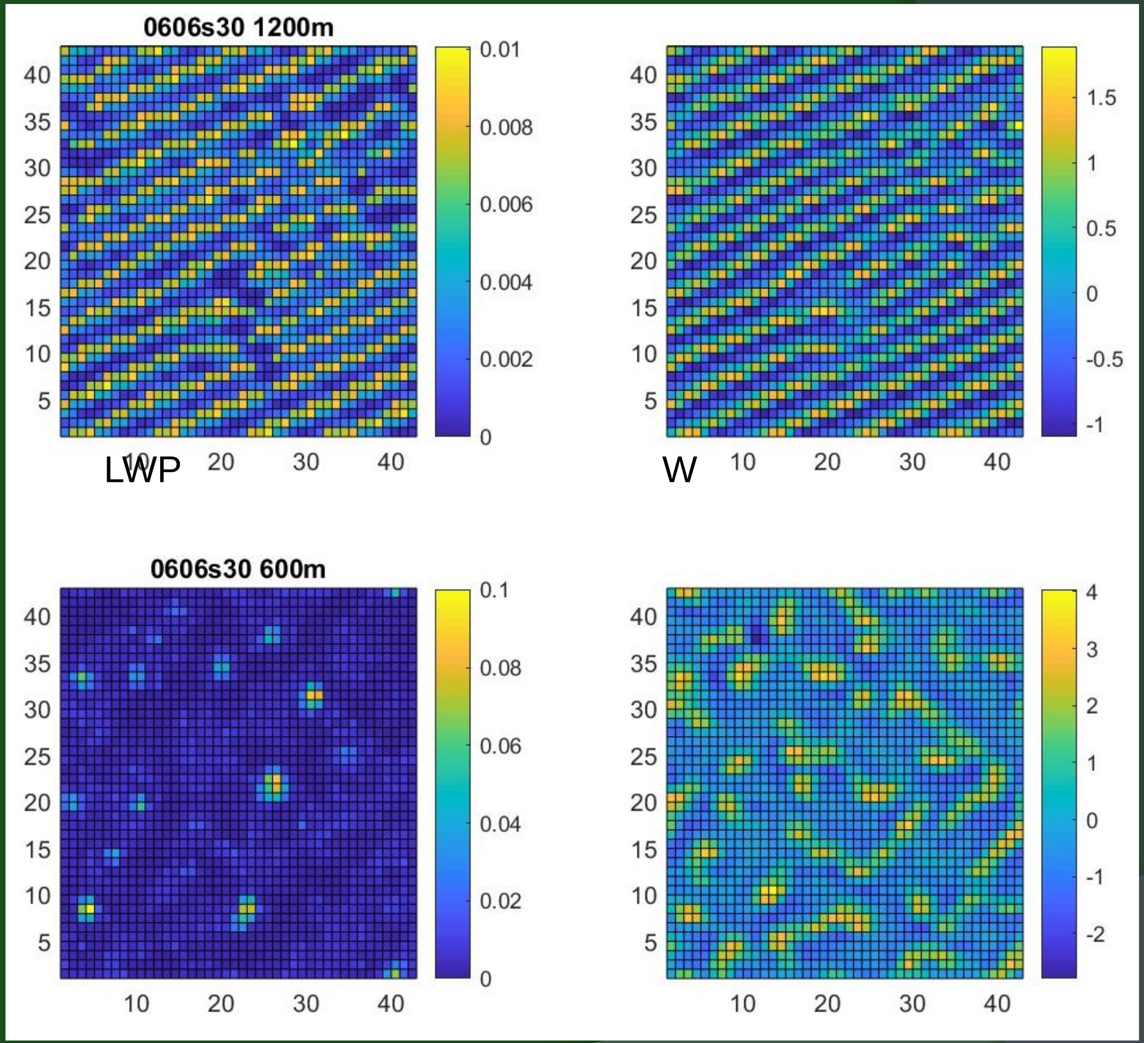
- ✓ Grid-dependent magnitude and pattern
- ✓ Delayed onset

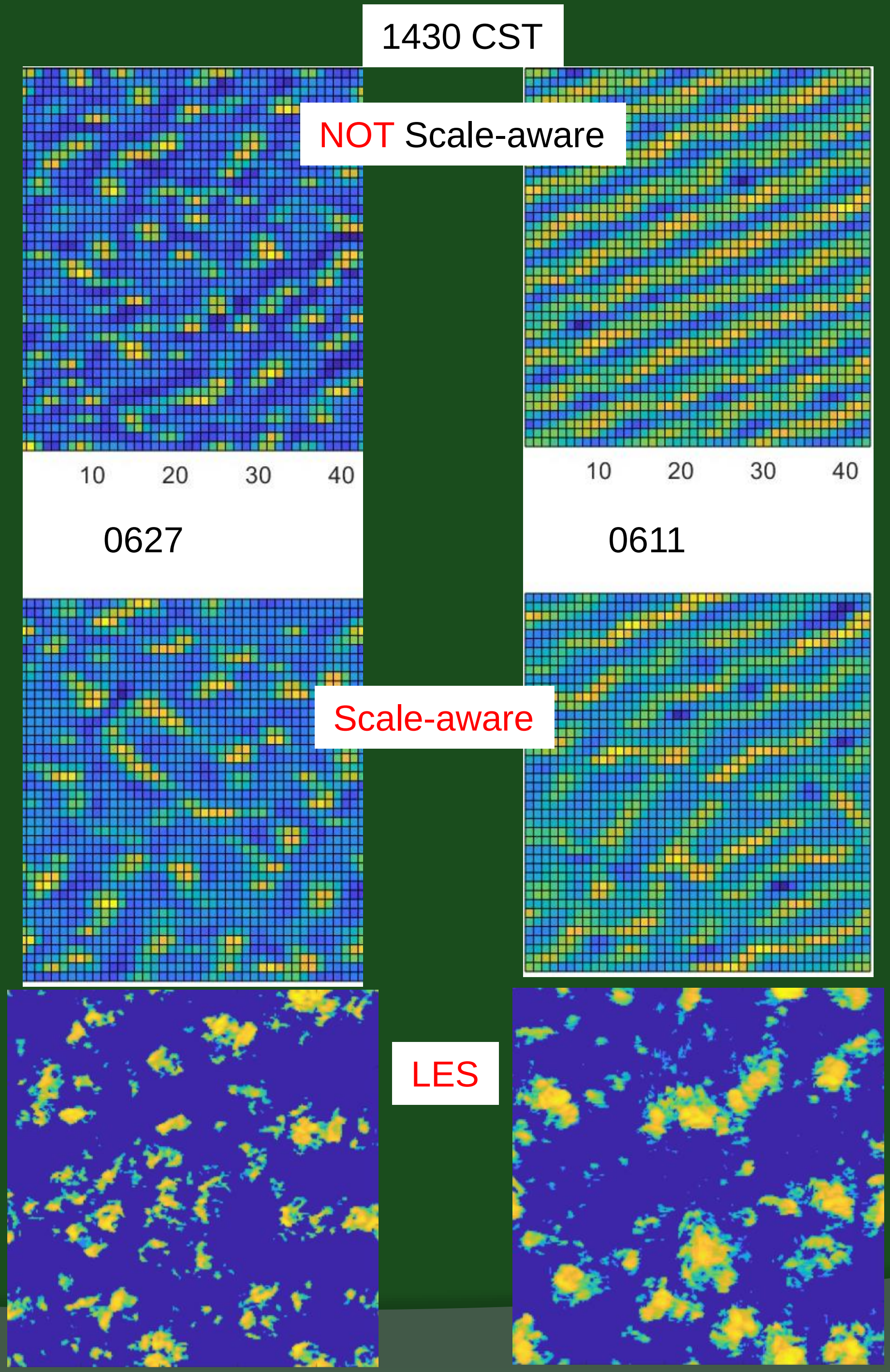
Now showing 1200m vs. 600m grid

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)





Are M-CISCs good?

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.)

For details of 2015 cases see Angevine et al. (2018) Monthly Weather Review