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Geoscientific Model Development Discussions

Interactive comment on "A Nested Multi-Scale System Implemented in the Large-Eddy Simulation Model PALM model system 6.0" *by* Antti Hellsten et al.

Anonymous Referee #2

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Thank you authors and GMD for giving me an opportunity to review this paper, I hope you find this feedback with the intent of improving the manuscript/significance and not just criticism.

The manuscript describes a new finite difference LES code for incompressible flow with a Boussinesq approximation, that allows for nested ("parent/child") grids that can also address "canopy" boundary conditions. A majority of the manuscript is dedicated to evaluating the effect of the p/c choices on a variety of test cases.

Major revisions / missing ideas:

1. Overall the algorithm is defined relative to previous versions of the code, which

makes it difficult for a new reader to understand what PALM 6.0 is capable of and how one might reproduce the results. Is the code open source? Are there any reproducibility artifacts with this manuscript?

2. I was confused in many cases about the base method (5th order in space, 3rd-order in time) with all the interpolation caveats ("0th order" or "constant velocity correction") for nested grids. The full set of compromises is not clear, and their impact is argued away in a few sentences.

3. Several tests are defined and the nested grids are tested in a number of different contexts. However, classical grid convergence studies are lacking (usually 1-2 resolutions, 3-4 to identify any trends would be better), and most of the results are "eyeball norm" comparisons between simulations, time- or space-average statistics, and in one case, experiment.

4. There are a number of algorithm compromises that are made for computational, conservation, or accuracy considerations that make it difficult to know when it would be appropriate to apply the code. The authors do discuss identified anomalies and potential causes, which is refreshing, but it is not clear what limitations this might mean for large-scale simulations.

5. Your efficiency numbers are only relative to nested or not. You should clarify the total number of grid points in each simulation, and a metric like "grid points * total time of simulation / wall clock time" is a decent measure of throughput that others can compare to. You never mention what kind of/how many processors and MPI ranks, etc. Scaling with MPI nodes for weak/strong scaling is an important aspect as well.

Minor revisions / specific suggestions:

Clarification / expansion

A3 - global time step, this should be mentioned up front

Would be good early on to show a picture of C-grid with topography representation, stair-step “canopy” example

There are several conservative finite difference algorithms that can handle geometry: see "ghost fluid method” and work by Weller & Shaw @ Reading.

P2, 15 "However, only unstructured grid systems allow to take full advantage of spatially variable resolution.” - IBM, cut cell, ghost fluid, etc.

P2, 29 - “anterpolation” from child (nested) to parent? I have never heard that term before.

P3, 5-10 - "blunt-obstacle resolving LES” vs. terrain-following approaches. ** You should include a picture making the distinction in your case (stair step on a terrain-following mesh?) Is this a terrain-following code? Mesh for 4.2.2 smooth hill problem?

Note that the child meshes don’t move, as in adaptive mesh refinement.

P3, 19-20 - "we are not aware of any research on obstacle-resolving LES employing two-way coupled nesting approach”. In this field, there are many in aeronautics and other CFD.

P4, 3-4 - equidistant horizontal spacing? Variable vertical? (How does it line up?)

P5, 10-15 - maybe a picture showing “allowed” and “not allowed” nesting would help? Are nested child regions allowed to “touch” on faces if their resolutions match (or don’t)?

P10-11, Fig 3 - should modify to show grid above/below, showing the values that are required to interpolate onto the fine grid

P13, L20 - again, a picture would help explain “canopy-restricted” interpolation

P30, does this test use a vertically-graded mesh? How is the “cube” cut out of the mesh (does it have to land on grid lines, for example?)

P37, L4 - ah, “globally synchronized time step” should be said up front in introduction . . .

P38, L23 - coupling only at the end of time steps? How would child BC’s be interpolated in time without “choppy” 0th-order interpolation (which might create time error imprinting)?

P41 L3, “lead to negative values” well-known problem for “positivity preserving limiters" in weather and CFD

Numerics / testing

Overall, the nested parent/child problems this really should have a numerical convergence study applied to it (without LES, to make it reproducible). I would be surprised if it is first-order accurate at p/c boundaries, at best, leading to some steep gradients, which may not be interacting well with the LES model and may take many grid cells to “dissipate”.

P11 - L5 - why are you doing first-order upwind just to avoid ghost cells? In general, exchanging a few more ghost cells is not that expensive in terms of communication.

P6, mass / vel correction: P7 top L1-15 "According to our tests, Δupre is typically three or four orders of magnitude smaller than the dominant velocity scales of the flow.” However what is the order of accuracy of it? The conservation “fix” effectively introduces a discontinuity into grad p, like a dipole in the child domain.

P10, 10-25, couldn’t you do a constrained interpolation instead? That is, one that forces any interpolated values to average to the parent (coarse) value to maintain conservation?

P7, 20 - this makes an assumption that production is always high everywhere. What about the classic Blasius flat plate problem with nested child cutting through the turbulent parts? Later on you argue that’s not realistic in fully-developed BL turbulence, but your smooth hill example shows how that model is not always true.

P9, L1 - 0th-order interpolation!, L5 - should say “linear” interpolation as this is just for refinement ratio 2

P12, L9-12 - "According to our experience, the conservation properties of an interpolation method are more important than its local accuracy" is entirely problem dependent, and also relates to what happens when you split/place your child meshes in different locations. You could demonstrate this with a few tests.

P14 - 28, "without any obvious" . . . how would you quantify this?

Fig 5 - instead of showing values, you might assess "convergence" by comparing to "ref fine" and noting the (quantitative) differences?

P17, L 10 - is this "kink" introduced from error at p/c interface from vertical grid space changes or from low-order interpolation or conservation fixes?

P17, L24 - "different places" are these close to or far from the p/c interface? .48 km vertical vs. 500m would indicate it's outside the child domain?

Fig 6 - very nice spectral analysis, there seems to be very little deviation. But I would like to see 1 more "ref fine" result, as it is not clear if this is a trend.

Fig. 6 - but again, wouldn't it be better to compare to a very-ref-fine result, and just plot the difference in spectrum? What would be an "acceptable" difference in that case?

Fig 7 - what happens if you move the child mesh to a different location, do you see the same result? Or add a second? Or refine everything to allow "more than 1" recirculation cell?

Fig 9 - what is the "tail" at the outflow edge of the child grid? Is that due to velocity conservation corrections?

Fig's 10 / 11 - again, (relative) diff vs. reference solution is more informative perhaps?

Again, Fig 12 - why such a difference between two "reference" solutions? Again, a difference between them would be more informative. And not clear where the "child domains" are? Oh maybe this *is* the entire child domain? How big is the whole domain?

Fig 13-14 - while comparing to wind tunnel is interesting, is it converging with refinement? Maybe an experiment that moves the child domain around, does 1, 2, or 3, nested?

P32, T1 - is this converging with refinement or technique?

Edits / small items

"Cyclic" lateral bc's usually are "periodic" boundary conditions?

Fig 5 - is "ref fine" the same resolution as "child 4" or ?? Should be stated clearly

Fig 5 - "squared brackets" should say "angle brackets"?

P17, L 21 - "fetch" - please explain? Maybe "offset" or "shift"?

P18, L34 - "on the order of"? "Superimpose on"

P20 - dangling sentence is hard to find when reading the text

P30, L32 - "become dependent on"?

P31, L4 - "are closest"?

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