Review of manuscript GMD-2020-84.V5

On the suitability of second-order accurate finite-volume solvers for the simulation of atmospheric boundary layer flow

Beatrice Giacomini[1] and Marco G. Giometto[1]

[1]Department of Civil Engineering and Engineering Mechanics, Columbia University in the City of New York, 500 W 120th St, New York, NY 10027, USA.

Recommendation: minor revisions

The manuscript has been significantly improved compared to the original version. Now it documents even more convincingly that, at investigated grid resolutions, FV-based solvers of the considered class are "not able to accurately capture the dominant mechanisms responsible for momentum transport" in neutrally stratified atmospheric boundary layer flows — a rather discouraging, albeit just, conclusion.

While reading the revised manuscript, I found (I should had noticed this earlier) that governing equations (1), (2), and subsequent material are presented in a very confusing manner, using notation that does not make sense to me.

Assuming that ∇ is a regular del operator ($\nabla = \mathbf{i}\frac{\partial}{\partial x} + \mathbf{j}\frac{\partial}{\partial y} + \mathbf{k}\frac{\partial}{\partial z}$), Eq. 1 for the nondivergent filtered velocity field, $\nabla \cdot \mathbf{u} = 0$, is fine, but what does $\nabla\mathbf{u} \cdot \mathbf{u}$ in (2) then mean? Operator ∇ does not apply to a vector $\mathbf{u}$ as $\nabla\mathbf{u}$, so apparently $\nabla\mathbf{u} \cdot \mathbf{u}$ is supposed to read $\nabla(\mathbf{u} \cdot \mathbf{u})$, but this is wrong, as one expects this term to be $(\mathbf{u} \cdot \nabla)\mathbf{u}$ (provided $\nabla \cdot \mathbf{u} = 0$).

Furthermore, ∇ is also applied to tensors ($\boldsymbol{\tau}$ and $\boldsymbol{\tau}^{SGS,dev}$) as $\nabla \cdot \boldsymbol{\tau}$ and $\nabla \cdot \boldsymbol{\tau}^{SGS,dev}$, while the operation $\nabla \cdot$ for tensors is generally not defined. Besides this, terms $\nabla \cdot \boldsymbol{\tau}$ and $\nabla \cdot \boldsymbol{\tau}^{SGS,dev}$ (whatever they mean) must enter (2) with the same sign, as $\boldsymbol{\tau}$ and $\boldsymbol{\tau}^{SGS,dev}$ are quantities of the same physical nature (kinematic stresses). But in fact, concluding from how these variables are defined, $\boldsymbol{\tau} = -2\nu\mathbf{S}$ and $\boldsymbol{\tau}^{SGS,dev} = -2\nu^{SGS}\mathbf{S}$, they are rather kinematic momentum fluxes (negative of stresses, cf. Eqs. 5 and 6).

This has to be straightened out and corrected, if needed. Maybe, presenting Eqs. 1 and 2 in tensor (rather than in vector) notation will help to make things clearer. Hopefully, for simulations the discretized equations have been employed in their correct forms.

Another problem I have is related to the choice of notation for horizontal velocity vector in (4). Notation $\mathbf{u}$ is already reserved for the 3D filtered velocity vector in Eqs. 1 and 2, which implies that $|\mathbf{u}|$ can be nothing else than $\sqrt{u^2+v^2+w^2}$, so it would be necessary to introduce a horizontal 2D velocity vector $\mathbf{v}=(u,v)$ with $|\mathbf{v}|=\sqrt{u^2+v^2}$ and make corresponding adjustments in the remaining equations of Sect. 2.1.

Other minor points.

1. Table 1. Total number of grid/cell points (e.g., 160^3) is not a measure of grid resolution.
2. Figure 1. Primes (′) are typically reserved for denoting fluctuations, not their RMS values. May be a source of confusion.
3. Table 2. Are you sure that you need four decimal places to characterize the relative error?
4. Table 3. Same problem. Here you even use five decimal places…
5. Table 4. See two previous points.
6. Line 294. You need to be more specific about the way double-primed quantities have been evaluated and comment on meaning of their signs.
7. Line 321. Apparently, it should be $C_S = 0.1678$.