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Geoscientific Model Development Discussions

Interactive comment on "Quasi-hydrostatic equations for climate models and the study on linear instability" *by* Robert Nigmatulin and Xiulin Xu

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Dear Ilias Sibgatullin,

Thank you for your consistent attention to our paper. In some sense, all models are not correct. We have to admit that there is a controversial moment for the hydrostatic equations, in which the vertical velocity is ignored in the vertical momentum equation and evaluated at the same time. Such approximation is of course not correct for any "strange" scales, it is just an approximation for some particular scales.

Although we have answered your questions in a lot of conferences, we repeat it here for

the new readers of this paper and for the improvement of the manuscript, concerning the "another two incorrectness" (the comments are in italic, and the answers are in regular letters):

1. *They estimate the scale of the divergence of the first term by the scale of only one component. But the divergence itself is by order(s) of magnitude less than scale its components.*

   Answer: Let's express the two terms of the right side of equation (2) in your comment as following
   $A = -g\int_z^H div\,(\rho\overrightarrow{v}_{hor})dz', \;\; B = \;\overrightarrow{v}_{hor}\nabla_{hor}p.$
   From the momentum conservation equations for horizontal motion the following estimation takes place

$$B = v_x\frac{\partial p}{\partial x} + v_y\frac{\partial p}{\partial y} = O\left(V_{hor}\times\rho\left(\frac{V_{hor}^2}{L_{hor}}+\frac{V_{hor}^2}{L_{cor}}\right)\right)$$

   Then we have the following estimations

$$\frac{B}{\gamma p} = O\left(V_{hor}\times\frac{\rho}{\gamma p}\left(\frac{V_{hor}^2}{L_{hor}}+\frac{V_{hor}^2}{L_{cor}}\right)\right),$$

$$\frac{A}{\gamma p} = -\frac{g}{\gamma p}\int_z^H div\,(\rho\overrightarrow{v}_{hor})dz' = O\left(\frac{V_{hor}}{L_{hor}}\times\frac{g\widehat{\rho}\,(H-z)}{p}\right) = O\left(\frac{V_{hor}}{L_{hor}}\right)$$

Finally, using the two expressions above we get

$$\frac{B}{A} = O\left(\frac{L_{hor}}{V_{hor}} V_{hor} \times \frac{\rho}{\gamma p}\left(\frac{V_{hor}^2}{L_{hor}} + \frac{V_{hor}^2}{L_{cor}}\right)\right) = O\left(\frac{V_{hor}^2}{C^2}\left(1 + \frac{L_{hor}}{L_{cor}}\right)\right) = O\left(\mathbf{M}^2\left(1 + \frac{L_{hor}}{L_{cor}}\right)\right)$$

$$\mathbf{M} = \frac{V_{hor}}{C}, \;\; C = \left(\frac{\gamma p}{\rho}\right)^{1/2} \sim \; 300 \; m/s$$

As in this case the Mach number $\mathbf{M}$ is small, we can confidently ignore *B* with the existence of *A* in equation (2.13) of the manuscript.

2. *They estimate the* $\nabla_{hor} p$ *dynamically as* U^2/L.

   Answer: This statement does not match the description in the manuscript. As we have mentioned above, the value of *B* ($B = \; \overrightarrow{v}_{hor} \nabla_{hor} p$) is evaluated by the horizontal momentum equations (1.2) and (1.3) in the manuscript. By the way, we have answered this in the reply to your previous comment: $\frac{\partial p}{\partial x}, \frac{\partial p}{\partial y} = \rho O\left(\frac{V_{hor}^2}{L_{hor}} + \frac{V_{hor}^2}{L_{cor}}\right)$,

   and the neglection of *B* over *A* takes place only in equation (2.13).

   We admit that in some situations (such as extreme weather, hurricanes) when both the horizontal wind and the horizontal gradient of pressure are large, the value of $B = \; \overrightarrow{v}_{hor} \nabla_{hor} p$ cannot be neglected.

   Thank you also for your brilliant illustration with beautiful pictures, which is irrelevant to the topic of this paper. And we have to point out that in the stationary state when your wagon moves with a constant velocity $v = const$, the pressure gradient always equals to zero ($\partial p/\partial x = 0$).

About the violation of energy conservation, please refer to our reply to Anonymous Referee #1.

Best regards,

Robert Nigmatulin and Xiulin Xu

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