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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 Sir or Madam:

Thank you very much for reviewing our manuscript. We will try our best to clarify questionable moments and figure out the differences between our set of equations and yours in the following text.

The dispersion relation in the manuscript differs from that in your GW analysis due to the following differences:

1. For the horizontal momentum equations, the term $U\partial_z$ is ignored in unlinearized

equations of (11) and (12). While in our set of equations, we use the complete horizontal momentum equations, the second and third equations of (2.23).

2. For the vertical momentum equation, the buoyancy term $-b'$ is included in (13). In our set of equations, the vertical inertial is totally ignored in the vertical momentum equation, the sixth equation of (2.23).

3. The continuity equation uses the pressure as a prognostic variable in the unlinearized equation of (15). In our equations, the complete continuity equation with density as a prognostic variable is used, the first equation of (2.23).

4. The thermodynamic equation is explicitly used in your set of equations, the unlinearized equation of (14). Instead of this, we use the thermodynamic equation to evaluate the vertical velocity and use the fourth equation of (2.23) in the set of equations.

5. You have five equations and five independent variables. To close the system of equations, we use a new independent variable $\dot{M}$ and the equation corresponding to this variable, the fifth equation of (2.23).

Besides, in our paper the frequency $\overline{\omega}_*$ is complex, the positive sign of the imaginary part $\overline{\omega}_{**}$ corresponds to exponential growth of perturbation, i.e., instability. The purpose of the linear analysis of the system of equations (2.23) is to find out situations when perturbations (usually caused by numerical solutions to the original system of equations) grow or decay. The fact that "*The coefficient matrices do not have constant coefficients (appendix A)*" do not affect the result of dispersion relation, it allows us to study the instability property of different basic solutions to the original system, including the basic solution in your GW analysis (a hydrostatic state and a mean zonal current U).

Moreover, from the dispersion relation (27) we can get a result similar to (4.8) in the manuscript if we consider the frequency ω_I as complex. When $N^2 < 0$ and

$k^2 + l^2 \gg m^2$, we can get a root of ω_I with positive imaginary part, in particular, when $\left(k^2 + l^2\right)/m^2 \to \infty$, the solution is absolute unstable by definition (3.14). In the situation of Gravity Waves in a stably stratified atmosphere $N^2 > 0$, the dispersion relation (27) only gives a real root of ω_I, describing the intrinsic oscillation frequency of air deviating from the basic state.

Sincerely,

Xiulin Xu

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