Ocean Sci. Discuss., author comment AC4
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Reply on RC5

Peter Chu

Author comment on "Gravity disturbance driven ocean circulation" by Peter C. Chu, Ocean Sci. Discuss., https://doi.org/10.5194/os-2022-12-AC4, 2022

General Response

When I am a reviewer, I read paper many times, identify the merit (especially the creativity)/flaw, and make positive or negative recommendation after careful thought.

I am amazed that you have made the negative recommendation after only reading first several pages of the manuscript. Your negative recommendation is on the base of a simple thought experiment.

Response to the Simple Thought Experiment

" I ask the author to consider the following situation where the planet is an aqua planet, and the ocean is not in motion. This requires that in situ density is constant at each point on the real geoid surface (not the ellipsoidal approximation to it). The author's GFD is however non-zero and large in this situation; that is, his equation (22). But this turns out only to be that he has not chosen his vertical distance to be measured from the real geopotential. Rather he has chosen the zero of his height to be in an ellipsoidal surface. So his equations show substantial motion, but we know that there should be no motion."

I disagree.

In Equation (22), the Jacobian of the in-situ density (ρ) and the gravity disturbance (T) is the projection of the vector product of (del ρ) and (del T) on the z-direction. Consider that the in-situ density is constant at each point on the true geopotential surface, i.e., the isopycnal surface coincides with the true geopotential surface. This requires that the two vectors (del ρ) and (del T) are parallel. Their vector product is zero,

(del ρ) ×(del T) = 0

which leads to

GDF = 0

which shows that the GDF does not drive any motion in this simple thought experiment. It is the opposite outcome as you thought. It demonstrates the merit of the manuscript (also see Supplement).

Response on the Geopotential and Geopotential Surface

"*The development of the equations with respect to the geoid is done in textbooks, for example in the early pages of the text "Fundamentals of Ocean Climate Models" by S. M. Griffies, published in 2004. These ocean models do not put the ocean in motion if the in situ density is constant on geopotential surfaces*."

The geopotential and geopotential surface used in oceanography and meteorology including in the text "Fundamentals of Ocean Climate Models" by S. M. Griffies are the normal geopotential and normal geopotential surface, but not the TRUE GEOPOTENTIAL and TRUE GEOPOTENTIAL SURFACE.

The two attached figures illustrate the difference between the normal gravity which is called the effective gravity and used in oceanography and meteorology, and the true gravity which is the most important variable in geodesy.

Figure A shows the main features of the effective gravity [$-g(\varphi)\mathbf{K}$]: (1) it is determined from the solid Earth with rotation and uniform mass density; (2) the unit vector **K** is perpendicular to the z surface (z = constant) and points the normal vertical; (3) the z surface is the normal horizontal and coincides with the normal geopotential surface; (4) any movement on the z surface (i.e., normal geopotential surface) is not against the normal gravity.

Figure B shows the main features of the true gravity [$\mathbf{g}(\lambda, \varphi, z) = -g(\varphi)\mathbf{K} + \delta\mathbf{g}$]: (1) it is determined from the solid Earth with rotation and non-uniform mass density; (2) the true gravity has never been used in oceanography and meteorology; (3) the true gravity vector $\mathbf{g}(\lambda, \varphi, z)$ is perpendicular to the true geopotential surface such as the geoid surface, which represents the true horizontal; (4) any movement on the true geopotential surface is not against the true gravity; (5) any movement on the z-surface is against the true gravity. An additional force, the gravity disturbance, shows up in the z-surface momentum equations, such as in Equation (18) of the manuscript.

Finally, I hope you may change your recommendation after reading my responses.

Please also note the supplement to this comment:
https://os.copernicus.org/preprints/os-2022-12/os-2022-12-AC4-supplement.pdf