EGU2020-4137
https://doi.org/10.5194/egusphere-egu2020-4137
EGU General Assembly 2020

Barotropic instability of a zonal jet on the sphere: From non-divergence through quasi-geostrophy to shallow water

Ofer Shamir, Nathan Paldor, and **Chaim Garfinkel**
The Hebrew University of Jerusalem, Institute of Earth Sciences, Israel (ofer.shamir@mail.huji.ac.il)

Two common approximations to the full Shallow Water Equations (SWEs) are non-divergence and quasi-geostrophy, and the degree to which these approximations lead to biases in numerical solutions are explored using the testbed of barotropic instability. Specifically, we examine the linear stability of strong polar and equatorial jets and compare the growth rates obtained from the SWEs along with those obtained from the Non-Divergent barotropic vorticity (ND) equation and the Quasi-Geostrophic (QG) equation. The main result of this paper is that the depth over which a layer is barotropically unstable is a crucial parameter in controlling the growth rate of small-amplitude perturbations and this dependence is completely lost in the ND equation and is overly weak in the QG system. Only for depths of 30 km or more are the growth rates predicted by the ND and QG systems a good approximation to those of the SWEs, and such a convergence for deep layers can be explained using theoretical considerations. However, for smaller depths, the growth rates predicted by the SWEs become smaller than those of the ND and QG systems and for depths of between 5 and 10 km they can be smaller by more than 50%. For polar jets, and for depths below 2 km the mean height in geostrophic balance with the strong zonal jet becomes negative and hence the barotropic instability problem is ill-defined. While in the SWEs an equatorial jet becomes stable for layer depths smaller than ~3-4 km, in the QG and ND approximation it is unstable for layer depths down to 1 km. These results may have implications for the importance of barotropic instability in Earth's upper stratosphere and perhaps also other planets such as Venus.

How to cite: Shamir, O., Paldor, N., and Garfinkel, C.: Barotropic instability of a zonal jet on the sphere: From non-divergence through quasi-geostrophy to shallow water, EGU General Assembly 2020, Online, 4–8 May 2020, EGU2020-4137, https://doi.org/10.5194/egusphere-egu2020-4137, 2020