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The interaction between zonal jets on a beta plane

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It has been well known that, in the forced two-dimensional barotropic incompressible flows on a rotating sphere, a structure with many alternating eastward and westward jets emerges in the course of time development (Nozawa and Yoden[1]). The multiple zonal jets experience gradual mergers/disappearances, and then a structure with two or three alternating large zonal jets is realised asymptotically (Huang *et al.*[2], Obuse *et al.*[3]).

One of the possible interpretations of such a merger/disappearance of zonal jets is that the state with multiple zonal jets may be dynamically unstable and transitions to a stable state with wider and fewer zonal jets occur. It is accordingly tempted to examine the stability of zonal jets driven and maintained by a small-scale forcing and background small-scale turbulent motions.

Zonal jets having a transverse sinusoidal background flow on a beta plane is one of the models used to investigate the effect of the turbulence and the mechanism of mergers/disappearances of the jets described above. This model was originally introduced and numerically investigated in Manfroi and Young [4], and is known to show a structure with many zonal jets that slowly disappear one by one.

In our study, we use an analytical stationary solution of the governing equation of the zonal jets U_0 (x) (Obuse *et al.* [5]) and estimate the weak interaction between two zonal jets by a perturbation method to discuss the jets' gradual mergers/disappearances.

When two zonal jets are weakly interacting with each other though their small tails of O(e), we assume that the total velocity U(x, t) is approximately written as $U(x, t) = U_0(x - l_1(t)) + U_0(x - l_2(t)) + V(x, t)$, and put assumptions that $l_1(t)$, $l_2(t) = O(1)$, $V(x, t) = O(e^3)$, time derivative = $O(e^2)$, x-derivative = O(1). Here l_1 and l_2 are the centre positions of two jets and V is a two jets' deviation from stationary solution. The time derivative of the distance between two jets obtained from a perturbation method utilizing the small parameter e and the assumptions above well coincides with the one obtained from numerical time integration of the governing equation of U(x, t) in terms of the behavior. This may suggest that the mergers/disappearances seen in the numerical simulation can be explained by the weak interaction between two zonal jets though their tails.

References:
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