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Stability and the temporal variation of zonal flows under the influence of turbulence on a beta plane

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It has been well known that, in 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 then experience gradual mergers/disappearances, and 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 mergers/disappearances 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. However, it is difficult to investigate the properties of zonal flows induced by a small-scale stochastic forcing, because it is hard to construct an analytically tractable and reasonable physical configuration.

Zonal jets having a deterministic transverse sinusoidal background flow on a beta plane is one of the models used to investigate the effect of the turbulence to zonal jets and the mechanism of mergers/disappearances of the jets described above. This one-dimensional model was originally introduced and numerically investigated by Manfroi and Young [4] and is known to show a structure with many zonal jets that slowly disappear one by one. Later, Obuse *et al.* [5] have derived steady isolated zonal jet solutions of the model and studied its linear stability, clarifying that all the steady isolated zonal jet solutions are linearly unstable because of the effect of the nonzonal background flow, and deform to be a uniform flow in the end.

The Manfroi-Young model [4] above, however, only considers the situation that the zonal flow is governed by one-dimensional equation, whilst the real zonal jets observed in two-dimensional turbulence has its two-dimensional governing equation. Therefore in our study, we first modify the Manfroi-Young model [4] by taking account of spatial variation of the disturbance in the zonal direction. Then to make the model a little more realistic, we also add the surface variation of the fluid layer to the model by introducing the Rossby deformation radius .

References:
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