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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Quasi-geostrophic turbulence and generalized scale invariance, a theoretical reply" *by* D. Schertzer et al.

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A reply to the interactive comment by Anonymous Referee #1 on " Quasi-geostrophic turbulence and generalized scale invariance, a theoretical reply " by D. Schertzer et al

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1 Reply to general comments

We greatly appreciate the referee's agreement with our "basic thesis that it is necessary to go beyond the QG [Quasi Geostrophic] equations in discussing the observed behaviour of the atmospheric spectrum; and that it is necessary to derive better analytical models". We partially agree with her/his reservation on our focus on vorticity dynamics, whereas stratification should be also taken into account and can play a somewhat opposite role. We therefore clarify in the revised version the fact that it corresponds to a first step to be completed by a similar treatment of the thermodynamic energy evolution equation. Due to the fact that our paper is already long with a given complexity, which generated some misunderstandings (see our reply to referee #2), we prefer to acknowledge this problem rather than to solve it at once. To avoid to give the wrong impression that "classical 2D and 3D turbulence are the main options", we emphasise the fact that, although $(2 + H_z)$-D turbulence has more common features with 3D turbulence (e.g. both have a non-zero stretching vector) than with 2D turbulence, it has nevertheless very distinctive features, i.e. scaling anisotropy is not a minor characteristic with respect to isotropy. For instance, this anisotropy is in agreement with the layered pancake structure, which is often mentioned for rotating and stratified turbulence.

2 Reply to detailed comments

We agree that it is important to mention that the global mathematical properties (e.g. for large times) of QG solutions are known contrary to those of the Navier-Stokes equations, as well as the fact that exact results were obtained on their order of approximation with respect to the primitive equations (PE) with rather mild restrictions on the initial conditions (Bourgeois and Beale, 1994). However, PE correspond already to a given set of approximations (e.g. inviscid, incompressible flow with variable density, Boussinesq and (quasi-) hydrostatic assumptions), which can be put into question on various ranges of scale.

We clarify the fact that the definition of the geostrophic approximation of the material derivative with the help of he stream function (Eq. 10) make intervene, among approximations related to the geostrophism, the assumption of incompressibility. However, as stated by the referee, we also mention in the revised version that it could be argued that this assumption is justifiable for small scales and pressure coordinates may avoid this issue for large scales.

We agree with the referee's suggestion that what we called "large scales" in the beginning of Section 3 should be rather called "intermediate scales" and we now mention the QG validity problem on (very) large scales due to the assumption of uniform reference

state density and the simplified representation of the Coriolis force.

Following the referee's suggestion, we now mention in the discussion of the TO's model the problem of the upper rigid boundary and the necessity of Ekman damping whose exact choice would influence the large scale behaviour.

Following the referee's suggestion to consider on scales smaller than the deformation radius that a self-destructive regime could develop into a kind of QG degeneracy into 2D layers with no vertical coupling, we had an email discussion with P. Billant. It turns out that the zigzag instability (Billant, 2010; Billant et al., 2010), which bends 2D columnar vortices, rather introduces a full 3D regime. We therefore mention this instability as a further indication of the strong limitation of the linearisation of the stretching vector.

In agreement with suggestions of both referees, we included in the revised version the baroclinic term.

References

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