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On the motion and structure of 3D - mesoscale vortices within a baroclinic shear flow including diabatic effects

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A theory describing the structure, temporal evolution and trajectory of a three-dimensional concentrated atmospheric vortex is presented. The major emphasis in this theory is on the manner in which diabatic effects and a baroclinic background flow affect these vortex features. The vortices under consideration are rapidly rotating vortices ($\sim$ 30 ms^{-1}) with vertical extensions through the whole troposphere ($\sim$ 10 km) and radii corresponding to the sub-synoptic gradient wind regime ($\sim$ 260 km). The trajectory of the vortex is followed over the larger synoptic scales ($\sim$ 1000 km). Furthermore, we assume that the lateral displacement of the vortex center between the ground and the tropopause does not exceed $\sim$ 30 km. All of these scalings correspond to a particular asymptotic limit regime for low Rossby, Froude and Mach numbers (Klein, 2004).

Based on the three-dimensional compressible flow equations for an ideal gas and using asymptotic methods we derive a relation which is known as the weak temperature gradient approximation. Parameterizing a symmetric diabatic source term we obtain from this relation a diabatically induced vertical velocity field. (Please note that a systematic way of parameterizing the moisture effects in the diabatic source term is through matching our results with a thinner layer ($\sim$ 3 km) near the surface. The analysis of this layer will be presented briefly in the talk.) Further analysis yields a diagnostic equation for the vertical structure of the leading order circumferential velocity, given its radial distribution near the ground and the distribution of the diabatically induced vertical velocity field. Furthermore, a prognostic equation for the leading order circumferential flow can be derived from the next order equations in our perturbation theory.

Our current work also focuses on a derivation for an equation describing the leading order path of the vortex center on synoptic scales, where we take into account the effects of a baroclinic background flow. From the analysis we find, that the path of the vortex center is determined by a superposition of the background flow and the regular velocity field at the vortex center. The latter is induced by the vortex itself due to the beta - effect and a sheared background flow. Similar results were obtained by Reznik (1991) who studied two-dimensional point vortices embedded within a horizontal background flow. However, we consider the 3D case and currently it remains to be verified whether the shear of the vortex induced regular flow can compensate the shear of the background flow. We will report on this issue in the presentation.

References

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