Multi-mode states in quasi-two-dimensional rotating flows

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The idea of the multiplicity of equilibrium states of the atmospheric circulation in geophysical hydrodynamics goes back to Charne and Devore 1979, where, for a model with a small number of variables, solutions with significantly different values of the zonal and wave velocity components were obtained (see also Laurie, Bouchet 2015, Herbert et al. 2020). The results of similar studies for low-parameter approximations were given by Kallen 1980, Gluhovsky 2001, Koo, Ghil 2002 ... The circulation modes differed in the magnitude of the zonal component of the flow. At weak transport, the role of almost stationary atmospheric eddies is enhanced, which corresponds to circulation blocking modes. Laboratory confirmation of the effect was obtained from Weeks et al. 1997, Tian et al. 2001.

In the same years, in the experiments of A.M. Obukhov and coworkers, modes with differently directed axes of large-scale fluid rotation were observed in closed vessels at the same value of external generation - Obukhov et al. 1976, Gledzer et al. 1981.

In the present study, supported by Russian Science Foundation (Project 19-17-00248), the above types of multi-mode are considered based on laboratory and numerical experiments in circular rotating channels. It is known that the permanent magnet location configurations (source-sinks) could create an almost stationary vortex distribution pattern Gledzer et al. 2013,2014. The transition between different states is provided by a change in the value of the main parameter of electric current generation with subsequent restoration of its initial value.

The experimental results presented below are obtained for a rotating annular channel (rotation periods up to 1 minute) filled with an electrically conductive 10% copper sulfate solution. The bottoms of circular channels with inner and outer radii of 1) 5.5 cm and 18 cm 2) 5 cm and 36 cm have an axisymmetric conical shape with a height of 1 cm.

Depending on channel rotation periods or source configurations, it is possible: 1) Initial and final modes differ quantitatively in the number of generated vortices. 2) The number of vortex formations does not change, but differ in their spatial localization. 3) After changing and restoring the value of the defining parameter, the flow returns to the mode which is practically the same as the initial one.

Numerical experiments with the shallow water model confirmed the results obtained in laboratory experiments on the possibility of transition to new modes when the parameter determining the external force is changed for some time. For the source-sink method, a change in the number of...
large vortices (cyclones) is observed. At MHD generation it is possible to detect a change in the finite spatial position of vortices with preservation of their number.

Experiments support the conclusion that different modes of barotropic dynamics may exist. And it is unlikely to be associated with any low-parameter approximation of the velocity field in the model.

In our and earlier experiments and models, multi-mode is a property of dynamics in general. The mechanism of multi-mode may be an alternative to the traditional scenario of transition to other modes when external conditions change.