Geophysical Research Abstracts,
Vol. 10, EGU2008-A-03601, 2008
SRef-ID: 1607-7962/gra/EGU2008-A-03601
EGU General Assembly 2008

Flow zonation in rotating turbulence

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Planetary rotation and density stratification strongly affect the global motions of geophysical fluid on the Earth and planetary atmospheres. As a matter of fact both of these mechanisms cause the inhibition of the vertical velocity component so that flows on large scales can be considered almost two-dimensional and described under the quasi-geostrophic formulation [1]. When a latitudinal variation of the Coriolis parameter holds (beta effect), turbulence theory for a two-dimensional rotating fluid predicts anisotropy in the upscale energy flux manifesting in a preferential energy transfer towards zonal wave numbers [2]. This paper is aimed to underline and investigate this mechanisms called flow zonation. In particular, the dynamical properties of horizontal two-dimensional fluid motions under the influence of strong rotation will be analyzed and discussed in relation to the emergence and maintenance of multiple zonal jet streams. Zonal jets consists in horizontal, intense and elongated eastward-westward bands and have been observed in the atmosphere of gaseous Giant Planets as well as in the Earth's Oceans [3][4]. Laboratory experiments will be performed generating turbulence in an electromagnetic cell [5] on a rotating tank. The rotating table has adjustable angular speed and the imposed sense of rotation is counter-clockwise in order to simulate the conditions in the northern hemisphere of a rotating sphere. The beta effect is simulated considering that in the polar region the Coriolis parameter varies quadratically with the distance from the pole. A similar effect of the quadratic variation of Coriolis parameter, can be reproduced in laboratory by using the parabolic profile assumed by the free surface of a rotating fluid in a tank [6]. Moreover the beta effect will be also simulated inserting a topography (i.e. a spherical plexiglas cap) on the bottom of the tank. The flow in the electro-magnetic cell is generated using the combined effect of electric and magnetic fields which, in a conductive fluid, induces the continuous formation of opposite signed small scales vortical structures whose characteristic length scales are related to the distance between magnets. Two different forcing regimes will be considered: decaying and continuously forced. In the first case, as predicted by Rhines [2], we expect to observe a soft barrier to the cascade process and a bump in the energy spectra in correspondence of the Rhines scale. In the continuously forced regime, we expect to observe a scale separation between the forcing scale, the Rhines scale and the friction scale in order to verify the existence of an universal spectrum corresponding to the so-called zonostrophic regime [7]. Moreover, different rotation rates and forcing conditions (i.e. magnets disposition, geometry) will be examined in order to investigate how this effects influence the process (number of jets, direction, dimension).

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