Geophysical Research Abstracts,
Vol. 11, EGU2009-5, 2009
EGU General Assembly 2009

Experimental study of large-scale differential rotation in a convective layer

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The evolution of a large-scale azimuthal velocity field in a rotating cylindrical layer of fluid (radius 150 mm, depth 30 mm, free upper surface) with meridional convective circulation was studied experimentally. These laboratory flows may be considered as a rough model for atmospheric global circulation. Two cases were considered: inward circulation provided by a rim heater at the periphery and outward circulation provided by a central heater. The heating rate is characterized by the Grasshoff number $\mathrm{Gr_f}$ defined through the heat flux. The detailed 3D structure of the mean large-scale velocity field is reconstructed using the PIV technique for $10^5 < \mathrm{Gr_f} < 4 \cdot 10^7$. It was shown that the energy of meridional circulation grows with the Grasshoff number as $\sqrt{\mathrm{Gr_f}}$ in both directions of circulation. Due to the action of the Coriolis force the meridional flow results in differential rotation. Differential rotation is characterized by values of radial D_r and vertical D_z gradients of azimuthal velocity. Mean values of D_r and D_z for different $\mathrm{Gr_f}$ were obtained. Meridional circulation leads to substantial variation of the integral angular momentum. Inward circulation results in the growth of the integral angular momentum and outward circulation causes it to decrease. At the same heating power, the increase of angular momentum at inward circulation is much stronger than its decrease at outward circulation.