Geophysical Research Abstracts
Vol. 12, EGU2010-12558, 2010
EGU General Assembly 2010

On the role of negative viscosity in the emergence of jets

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Turbulent flows are often observed to be organized into large-spatial-scale coherent jets such as the Earth's polar front jet. These large-scale jets are maintained by the much smaller spatial and temporal scale turbulence with which they coexist and play an important role in the dynamics of the climate. Recently a comprehensive theory for the interaction of jets with turbulence has been developed called stochastic structural stability theory. According to this theory, the distribution of momentum fluxes arising from the turbulent wave field associated with a given jet structure is obtained using a linear model of stochastic turbulence that was extensively verified in GCM studies of storm track statistics. The resulting momentum flux distribution is then coupled with the mean zonal momentum equation to produce a closed set of wave-mean flow equations. In this work stochastic structural stability is used to study the stability of the equilibria of this coupled wave-mean flow system in order to understand the physical mechanism underlying the formation of multiple jets in barotropic turbulence and to predict the structure and spacing of the emerging jet. The eigenvalues of the linear operator governing the evolution of small perturbations in the jet structure and in the eddy statistics were analytically calculated for a quiescent mean flow equilibrium. Two competing mechanisms were found to be operating: small changes in the advection of the eddy vorticity organizes the turbulent field to produce anti-diffusive eddy fluxes, whereas advection of the altered mean vorticity gradient by the eddies produces diffusive or hyper-diffusive eddy fluxes. For stochastic forcing having small zonal extend and an amplitude larger than a certain threshold, the upgradient anti-diffusive fluxes prevail leading to the emergence of a zonal jet. The e-folding time for jet growth, as well as the width of the emerging jet are found to be proportional to the zonal extend of the forcing.