

ABSTRACT

The possibility of zonal flows generation by low-frequency waves in magnetized space and laboratory plasmas is studied. Namely the zonal flows generation in the Earth's ionospheric E- and F-layers by Rossby waves and in electron-positron-ion (EPI) plasmas by electrostatic drift waves is investigated. The modified parametric approach is used considering the arbitrary spectrum of primary modes. The driving forces of zonal flows are Reynolds stresses. An important nonlinear mechanism for the transfer of spectral energy from small-scale pumping waves to large-scale enhanced zonal flows (inverse cascade) is investigated.

The dynamics of Rossby waves in the electrically conducting ionospheric layers strongly depends on the interaction of inductive currents with the geomagnetic field. Such interaction in the ionospheric E-layer due to the prevalent effect of Hall conductivity gives rise to, so called magnetized Rossby (MR) waves to be propagating. But in the ionospheric F-layer, under such interaction dissipation arises due to Pedersen conductivity acting as the inductive (magnetic) inhibition. Modified by the interaction of inductive currents with the geomagnetic field Charney equation is used as the basic nonlinear equation. Considering comparatively short-scale perturbations only vector nonlinearity is responsible for the coupling between different modes in Charney equation. The nonlinear interaction of short-scale pump Rossby waves, two satellites of the pump waves (side-band waves) and a large-scale shear zonal flow is studied.

Propagating in the ionospheric E-layer MR waves do not significantly perturb the geomagnetic field. Zonal flow dispersion relation for an arbitrary spectrum of MR waves is obtained. Monochromatic and non-monochromatic wave packets of primary modes are discussed. In the case of monochromatic wave packet the instability is of the hydrodynamic type. It is found that the broadening of the wave packet spectrum of pump MR waves leads to a resonant interaction with a growth rate of the order of the monochromatic case. In the case when zonal flow generation by MR modes is prohibited by the Lighthill stability criterion, the so-called two-stream-like mechanism for the generation of sheared zonal flows by finite-amplitude MR waves in the ionospheric E-

layer is possible. The growth rates of zonal flow instabilities and the corresponding conditions are determined.

The possibility of zonal flow generation and appropriate distinctive properties are revealed when Rossby waves are propagating through the dissipative ionospheric F-layer.

To describe the nonlinear propagation of electrostatic drift waves the generalized Hasegawa-Mima (HM) equation containing one vector (Jacobian) and two scalar nonlinearities of different nature for the case of EPI plasma is obtained. The drift waves are supposed to have arbitrary wavelengths (as compared with the Larmor radius of plasma ions at the plasma electron temperature). Temperature inhomogeneity of electrons and positrons is taken into account, while ions are considered to be cold. The new space structure of drift waves is obtained. Spatial increase of the linear plasma-potential perturbations in the direction of density and temperature inhomogeneities is shown.

As long as under the zonal flow action different vortical structures can be maintained, possibility of the existence of drift vortical motions and the appropriate properties also are investigated in case of EPI plasma. It is shown that the vector nonlinearity is responsible for the existence of small-scale dipole-type solitary vortical structures. One of the scalar nonlinearities of KdV-type is responsible for the existence of the intermediate-scale vortical structures. The other scalar nonlinearity under the time derivative creates intermediate and large-scale monopole vortical structures and plays an essential role in different possibilities of zonal flows generation. It causes nonlinear interaction with vector and KdV-type nonlinearities and itself also. It is shown that the dynamics of low-frequency waves studied in usual electron-ion (EI) plasmas is generally modified in EPI plasmas. A new self-organization mechanism of formation of large-scale electrostatic drift vortical structures in EPI plasmas based on the competition between scalar and vector nonlinearities has been discussed.

Generation of large-scale zonal flows by relatively small-scale electrostatic drift waves of arbitrary wavelength in a nonuniform EPI plasma is studied. To describe the generation of zonal flow the generalized Hasegawa-Mima equation containing both vector and two scalar (of different nature) nonlinearities is used. The system of coupled equations describing the nonlinear interaction of drift waves and zonal flows is derived. Enriched possibilities of zonal flow generation with different growth rates are revealed.

Explicit expressions for the appropriate maximum growth rates are obtained.

Obtained results may be useful to explain different observations on zonal flows and vortical motions in laboratory and astrophysical plasmas.