

Ionosphere-driven versus pressure-driven interchange instability in the inner magnetosphere

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Magnetohydrodynamic stability of plasma in the inner magnetosphere against ionosphere-driven and pressure-driven modes of interchange instability, which does not bend magnetic field, is investigated. The validity of necessary assumptions for a general stability criterion and instability conditions derived from the criterion are tested for parameters in the ionosphere and the inner magnetosphere. The general stability criterion is derived from the magnetospheric energy principle, which assumes that the unperturbed magnetic field is incident vertically on the spherical ionospheric surface. Since the incident angle of the dipole field on the ionospheric surface, which is measured from the surface, is larger than 63 degrees for L larger than 2, the assumption of the normal incidence of the unperturbed magnetic field on the ionospheric surface may well be satisfied and the general stability criterion may be valid for L larger than 2. Since a whole flux tube from the equator down to the ionosphere is interchanged in the interchange motion, the ionospheric Pedersen conductivity must be small for the development of interchange instability. This is also a necessary requirement for the magnetospheric energy principle, upon which the stability analysis is based, since the magnetospheric energy principle assumes that field-aligned currents are closed via diamagnetic currents and not via conduction currents in the ionosphere. From a quantitative argument it is shown that a Pedersen conductivity smaller than about 0.5 mho is necessary for interchange instability when the average Alfvén speed in the magnetosphere is 500 km/sec. Such a low conductivity may be realized in the night side ionosphere. The general stability criterion for interchange perturbations shows that an axisymmetric magnetosphere with a dipole magnetic field becomes unstable against ionosphere-driven interchange instability caused by a horizontal plasma displacement on the spherical ionospheric surface, when the equatorial plasma beta is smaller than the order of one regardless of profiles of plasma pressure distribution. It is known that when the plasma pressure distribution of axisymmetric magnetospheric plasma in the dipole field is steeper than the minus 20/3 to the power of the geocentric distance R, which corresponds to the adiabatic gradient for the magnetohydrostatics of plasma in the dipole field, the magnetospheric plasma becomes unstable against fast adiabatic convection driven by pressure-driven interchange instability. In the real inner magnetosphere the equatorial plasma beta is several tenths of one and the unperturbed plasma pressure distribution is much gentler than the minus 20/3 to the power of the geocentric distance R. Therefore, although the instability conditions are well satisfied for ionosphere-driven modes, the plasma pressure distribution does not seem to be steep enough to destabilize pressure-driven modes. Thus, if the dipole magnetic field is assumed, the plasma in the night side inner magnetosphere is more susceptible to an ionosphere-driven interchange instability than a pressure-driven interchange instability.