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Structure of field lines associated with ionosphere-driven interchange instability from the magnetosphere to atmosphere

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On the basis of a magnetospheric energy principle the existence of an ionosphere-driven magnetospheric interchange instability has been suggested. The ionosphere-driven interchange instability is a new type of driving magnetospheric interchange instability. Therefore, a test of the existence of the ionosphere-driven interchange instability is very important in testing the validity and usefulness of the magnetospheric energy principle in discussing magnetospheric dynamics. The existence of the ionosphere-driven interchange instability is also important in discussing radiation belt dynamics and auroras in the inner magnetosphere, since in such a region the pressure gradient is so small that a conventional pressure-driven magnetospheric interchange instability cannot be destabilized. In the magnetospheric energy principle the existence of the neutral atomosphere under the ionosphere is completely neglected. Thus the magnetospheric energy principle cannot clarify the structure of perturbations from the magnetosphere to the neutral atmosphere. However, the magnetospheric energy principle has recently been extended to include the neutral atmosphere and it is now possible to discuss the structure of perturbations in the atmosphere associated with the ionosphere-driven interchange mode. Thus it is now possible to test the validity of the extended magnetospheric energy principle by examining the structure of perturbations not only in the magnetosphere but also in the atmosphere. In this paper the structure of magnetic field lines associated with the instability in the magnetosphere and in the atmosphere is clarified. Owing to the ideal MHD frozen-in law the concept of magnetic field lines is very useful in the magentosphere and field lines are interpreted to comove with plasma. On the other hand there is no electric current in the neutral atmosphere and the magnetic field is represented by a potential field. Since there is no plasma in the atmosphere, the concept of field line motion comoving with plasma is not useful. Nevertheless, in the atmosphere there is also a magnetic field and it is possible to define magnetic field lines. In the ionosphere, which is a boundary region between the magnetospheric plasma and the neutral atmosphere, there is a magnetic field and field lines can be defined. Owing to the existence of dissipation in the ionosphere the frozen-in law is not valid and the concept of field line motion comoving with plasma is not valid. According to the magnetospheric energy principle, when the unperturbed field line is incident vertically on the spherical ionospheric surface, a horizontal magnetic perturbation is induced at the ionosphere due to the convective motion of field lines by an electric field perturbation. In the magnetosphere the magnetospheric interchange instability has no horizontal magnetic field perturbation. Thus it is expected that field lines are kinked at the ionosphere in an ionosphere-driven interchange instability. Owing to the continuity of a tangential electric field across the ionospheric surface, there also arises a horizontal magnetic field perturbation just below the ionosphere. Since the magnetic field in the atmosphere is a potential field, this horizontal component of the magnetic field must decrease toward the earth's surface. Therefore, in the ionosphere-driven magnetospheric interchange instability it is expected that the magnetic field has no horizontal component in the magnetosphere, has a kink in the ionosphere and decreases rapidly toward the earth's surface in the atmosphere. If such a field line structure is truly observed, the existence of the ionosphere-driven interchange instability predicted by the magnetospheric energy principle is confirmed and hence the validity and usefulness of the magnetospheric energy principle in discussing magnetospheric dynamics are verified.

Keywords: magnetosphere, ionosphere-driven interchange instability, MHD instability, neutral atmosphere, magnetic field lines, energy principle