EFFECTS OF THE INTERPLANETARY MAGNETIC FIELD ON THE AURORAL OVAL AND PLASMAPAUSE*

J. L. BURCH
Southwest Research Institute, P.O. Drawer 28510, San Antonio, Tex. 78284, U.S.A.

Abstract. Recent research into the effects of the interplanetary magnetic field (IMF) on the Earth's auroral oval and plasmapause are reviewed. While the IMF sector structure has been known for some time to produce asymmetries in polar-cap convection, recent work has shown these effects to extend into the dayside auroral oval. A restricted region of local times referred to as the convection 'throat' is found to move to either side of the noon meridian in response to changes in the IMF \( B_y \) component.

The question of the entry of solar-wind plasma into the magnetosphere continues to be a prime area of research. While it is generally felt that magnetic merging must play some significant role, evidence continues to mount that it does not occur at the subsolar magnetopause, as previously supposed, and that other driving forces for antisunward convection must occur on closed field lines. A suggestion is made that many of the seemingly conflicting observations that have been made in the region of the dayside cusps can be explained if significant distortions of closed field lines near the dayside magnetopause are allowed and if closed and open field lines coexist in the cusp, particularly near the entry layer.

Effects of the IMF on the nightside auroral oval and on the plasmapause stem chiefly from the expansion of the oval to lower latitudes which is produced by southward IMF components and from the impulsive substorm phenomena that become stronger and more probable with increasingly southward IMF.

1. Introduction

This paper reviews and attempts to synthesize recent experimental results and theoretical models on the effects of the interplanetary magnetic field (IMF) on the Earth's auroral oval and plasmapause. Quite a number of phenomena involving electric and magnetic fields, currents, plasmas, and auroral displays have been attributed to interactions between the IMF and the geomagnetic field. Progress until 1974 has been reviewed by Burch (1974) and Nishida (1975). Attention here will be focused on more recent work. Much of the recent progress has resulted from new data on near-earth field-aligned currents provided by the Triad satellite and on distant plasma flows by the HEOS satellite, from new analyses of older data from the ISIS-2 satellite, and from ground-based data taken at observatories such as the Chatanika radar. The IMF data for these studies have generally been obtained from the IMP series of satellites through the National Space Science Data Center.

The auroral oval, in its essence as the instantaneous locus of discrete visible auroras, is the region of near-earth space which experiences by far the greatest input of energy from the solar wind and the magnetosphere. Although the auroral oval is readily discernible near the Earth, its extension into space is not understood. At higher latitudes the field lines of the polar cap are open, while the lower latitude field lines, extending through the diffuse aurora equatorward to the plasmapause, are closed. The auroral oval, on the other hand, is probably threaded by both types of


Copyright © 1979 by D. Reidel Publishing Co., Dordrecht, Holland, and Boston, U.S.A.
field lines. Field-aligned currents transfer energy from the solar wind and outer magnetosphere to the ionosphere through the auroral oval. These currents are produced in the conversion of closed field lines to open ones (and vice-versa) and in the reversal of plasma flows. The dayside of the auroral oval is the site of direct entry of solar wind plasma into the magnetosphere and of the generation of electric fields that drive plasma convection within it. The night side of the oval is a site of strong dissipation of energy that is temporarily stored in the magnetosphere. This dissipation occurs through substorms. Although substorms are not generally triggered by the IMF, their size and intensity are closely related to it.

The following sections begin with a discussion of phenomena that occur in the dayside auroral oval and proceed to considerations of night-side processes. These sections are followed by a brief discussion of plasmapause phenomena since their relationships with the IMF have not been the subject of intensive study.

2. Effects of the IMF on the Dayside Auroral Oval

A. Ionospheric Convection

At low and mid-altitudes (out several Earth radii along magnetic field lines) the auroral oval is identified as the magnetospheric cusps or clefts within which plasmas of apparent magnetosheath origin are observed. Although localized acceleration of electrons occurs in the cusp, essentially unmodified magnetosheath positive-ion populations are observed at low altitudes over its entire 09 to 15 hr local-time width. This observation has led to a generally accepted belief that plasma enters the magnetosphere over the entire dayside magnetopause. However, recent measurements of magnetic and electric fields and of field-aligned currents in this region have shown the entry to be confined to a much narrower local-time sector which moves eastward and westward across the noon meridian in response to changes in the east-west component of the IMF.

The first hint of this localized entry region came from the HEOS magnetic-field measurements reported by Hedgecock and Thomas (1975). Reviewed recently by Fairfield (1977), the HEOS data showed the dayside magnetic-field vectors near the magnetopause to converge to a small region in a 'cusp-like' rather than a 'cleft-like' configuration. This discovery was followed closely by the findings of Heelis et al. (1976) who used the convection velocity measurements of Atmosphere Explorer C to identify a narrow 'throat' through which plasma is channeled in its reversal from sunward to antisunward convection. A conceptual diagram presented by Fairfield (1977) combines the Heelis et al. results with those of Heppner (1977) to suggest a possible convection pattern for the entire northern polar regions for conditions of positive IMF $B_y$ ('away' sector). Fairfield's conceptual diagram is reproduced here as Figure 1. Confirmation of this displacement of the northern hemisphere 'throat' toward dusk for positive IMF $B_y$ has been indirectly confirmed by ISIS-2 magnetic-field measurements of McDiarmid et al. (1978a). It is expected from the asymmetries that exist in polar-cap convection (Heppner, 1972) that shifts in the opposite sense