OVER-REFLECTION OF HYDROMAGNETIC PLANETARY-GRAVITY WAVES AT THE SOLAR HELMET STREAMERS AND MAGNETIC SECTORS

O. M. EL MEKKI*
National Center for Atmospheric Research**, Boulder, CO 80307, U.S.A.

(Received 6 July, 1984; in revised form 11 February, 1985)

Abstract. Over-reflection of propagating hydromagnetic planetary-gravity waves incident on the current sheets of the helmet streamers and magnetic sectors of the solar corona is investigated.

It is shown that over-reflection arises only if the wavenumbers, or the energy fluxes per unit mass, perpendicular to the current sheet of the incident and the transmitted waves in both cases are in opposite directions. The over-reflected waves then draw magnetic energy from the sun's field and communicate it to the interplanetary magnetic field.

1. Introduction

A comprehensive theory of the coronal magnetic fields structure and the solar wind originating from the Sun is still out of reach despite the information gathered in the last decade from radio-heliographic analysis as well as from satellite photographs. However, two phenomena are fairly established to exist in the structure of the solar corona, namely the helmet streamers (Avignon et al., 1971) and the magnetic sectors (Newkirk, 1971).

Helmet streamers are produced by the breaking of magnetic arches in the coronal field which produces a current sheet extending radially away from the Sun into the interplanetary field. The magnetic fields on both sides of the current sheet are oppositely oriented and are of the same magnitude. The reason why the lines of force break to produce the helmet streamers is not yet clear but the phenomenon is readily visible during an eclipse of the Sun.

The magnetic sectors of the solar corona are also readily observable. They may be visualized as bounding current sheets extending globally around the Sun at a height of several solar radii. The mechanism which gives rise to the magnetic sectors where the coronal field suddenly terminates is not yet clear. However, they can be thought of as zero potential surfaces at which there is a jump discontinuity in the coronal magnetic field and hence the current sheet (Jones, 1971). A schematic illustration of both streamers and sectors is given in Figure 1.

The motion which takes place in the solar corona and its relation to the interplanetary solar wind is both irregular and complicated which suggests that a number of physical processes are involved. In this study we investigate the problem of over-reflection, or amplification, of hydromagnetic planetary waves incident on the current sheets associated with helmet streamers and magnetic sectors.

* Permanent address: School of Mathematical Sciences, University of Khartoum, Sudan.
** The National Center for Atmospheric Research is sponsored by the National Science Foundation.
It is found that over-reflection can only arise provided that real propagation is secured on both sides of the current sheet and that the wavenumbers of the incident and transmitted waves in the direction perpendicular to the current sheet are of opposite signs. In other words the reflected wave will be amplified at the current sheet if, by some physical process, the incident wave reverses its direction of propagation perpendicular to the current sheet on crossing it.

In terms of energy and momentum considerations this condition equivalently states that for over-reflection to arise the reflected wave must draw energy and momentum from the background motion and hence the energy fluxes of the incident and transmitted waves in the direction perpendicular to the current sheet must have opposite orientations, so that an energy balance can be maintained.

2. Equations

The equations which govern the motion of an isothermal, perfectly conducting, dissipationless, Boussinesq, incompressible and rotating fluid are (El Mekki, 1982),

$$\rho \left( \frac{D\mathbf{q}}{Dt} + 2\Omega \times \mathbf{q} \right) = -\nabla P + \frac{1}{\mu} (\nabla \times \mathbf{B}) \times \mathbf{B} - \rho g \hat{z},$$

(2.1)