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Geomagnetic Pulsations

Solar wind-induced geomagnetic pulsations and fluctuations

K. D. Cole

Department of Physics, La Trobe University, Bundoora, Vic. 3083, Australia.

The solar wind generates geomagnetic pulsations by direct interaction with cold plasma of ionospheric origin in the geomagnetic field. The solar wind also induces changes in the energetic particle populations of the magnetosphere which cause further pulsations. Commonly, the upper limit of the period of pulsations is taken as about 5 min. Fluctuations with periods longer than 5 min are also induced by the action of the solar wind.

The amplitude distributions of such geomagnetic pulsations and fluctuations depend strongly on geomagnetic latitude (and thus also on geographic latitude). They have a peak in amplitude at the geomagnetic equator, but maximum amplitudes occur in the auroral zones. The extent of the auroral zones varies depending on the strength of the disturbance of the magnetosphere. In large magnetic storms the southern auroral zone extends up to Australia.

Propagation of Pc3–4 pulsations at low latitudes

F. W. Menk, B. J. Fraser, C. Ziesolleck and P. W. McNabb

Physics Department, University of Newcastle, NSW 2308, Australia.

Magnetic pulsations are ultra-low frequency (ULF) oscillations in the geomagnetic field with periods of the order of 1–1000 s. These pulsations are manifestations of hydromagnetic waves generated in the magnetosphere by a variety of physical processes and instabilities. Pc3–4 waves fall in the period range 10–150 s and appear to be produced by resonant oscillations of the earth's magnetic field lines, generally driven by the solar wind as it flows around the magnetosphere. Figure 1 shows a schematic representation of these interaction regions.

At synchronous orbit the Pc3–4 waves exhibit an harmonic structure which is characteristic of a driven resonance (Takahashi *et al.* 1984). This structure can be used to deduce the properties of the magnetospheric particles which are distributed along the particular oscillating field line. Furthermore, there is a correlation between the occurrence of Pc3–4 waves and properties of the solar wind (Greenstadt *et al.* 1981). This indicates that the energy source of the pulsations may lie in the solar wind. Recording Pc3–4 pulsations at ground stations thus provides a means of continuously monitoring the state of the magnetospheric plasma and the solar wind.

A puzzling feature of ground observations of Pc3–4 pulsations is that they may be seen at very low and high latitudes as well as middle latitudes (Campbell 1963). High latitude stations map to regions of the magnetosphere that are external to the plasmapause (Fig. 1), while low latitude stations correspond to regions inside. The plasmapause forms a boundary in the magnetospheric plasma representing a sharp increase, of over two orders of magnitude, in plasma density. Thus field lines mapping to low latitudes originate in a higher density region than those projecting to high latitudes. The plasmapause may act as a reflecting boundary to waves propagating in the outer magnetosphere, making it difficult for sufficient wave energy to penetrate and drive field line resonances within the plasmasphere. However, these waves are observed virtually every day at low latitudes.

At this stage, observations of wave phase and polarization characteristics at low latitudes have yielded contradictory results, and their propagation to these latitudes is not well understood. Several authors (e.g. Fraser & Ansari 1984) have reported propagation of signals away from the local noon meridian and left-handed polarization in the prenoon sector (right-handed postnoon) when viewed in the direction of the

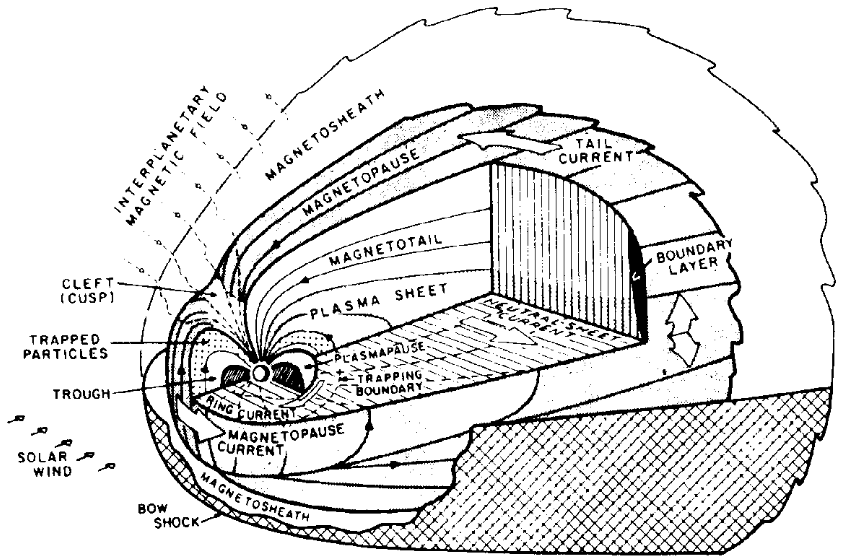

Fig 1 Diagrammatic representation of the magnetosphere showing the main features and regions (after Heikkila 1973).

ambient geomagnetic field lines. This propagation is consistent with the generation of the waves by field line resonances, in the vicinity of the plasmapause at middle latitudes, driven by the Kelvin-Helmholtz instability at the magnetopause. However, the observed signal amplitudes at low latitudes do not agree with the expected damping rate of externally excited hm waves inside the magnetosphere (Southwood 1979). Furthermore, it is not clear how significant wave energy can propagate from the magnetopause and across the plasmapause to couple with resonant field lines at low latitudes (Lanzerotti *et al.* 1981).

Conversely, some studies (Mier-Jedrzejowicz & Southwood 1981) have indicated the presence of long azimuthal wavelengths and propagation towards the noon meridian at low latitudes. These results are inconsistent with the Kelvin-Helmholtz instability model.

It has been recently suggested (Yumoto *et al.* 1985) that there may be two main sources of daytime Pc3–4 pulsations. Boundary waves may be generated in the Pc3–4 range near the magnetopause and penetrate into the outer magnetosphere. This would be a source of high latitude pulsations. Upstream waves in the foreshock region may be transmitted across the magnetosheath and magnetopause, deep into the magnetosphere where they are observed as compressional Pc3–4 waves at synchronous orbit (Yumoto & Saito 1983). The compressional waves may then propagate further into the inner magnetosphere and couple with transverse waves which exhibit field line resonance behaviour (Kivelson & Southwood 1985). Eigen frequencies would be determined mainly by local plasma parameters and the magnetospheric structure, and would be observed on the ground as low latitude Pc3–4 pulsations.

In order to clarify some of these aspects, a new project to investigate the spatial characteristics of low latitude Pc3–4 geomagnetic pulsations has commenced. Data will be recorded along a latitudinal chain of field stations across eastern Australia, over the L-value range 1.3–2.7 (approximately 29°–53° geomagnetic latitude). Figure 2 shows

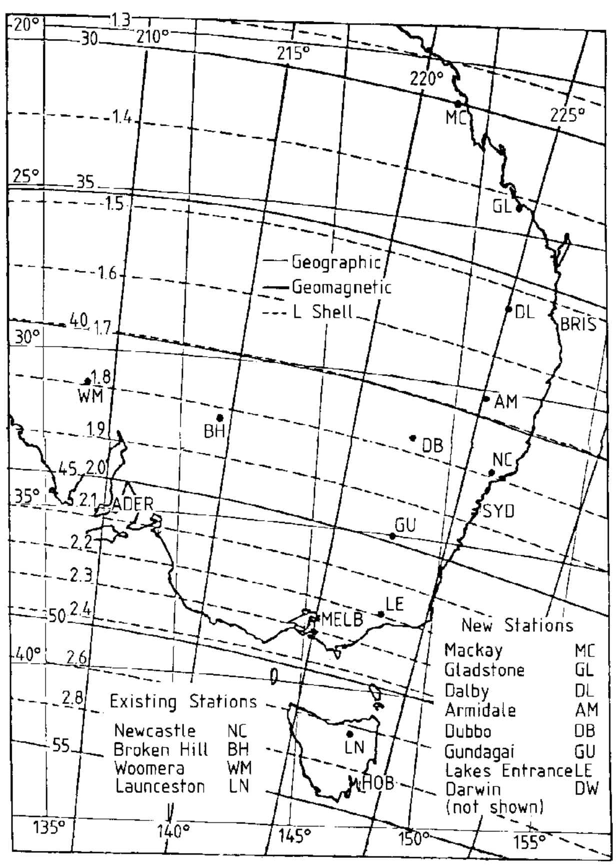

Fig 2 Pc3–4 recording stations of the University of Newcastle latitudinal and meridianal low latitude networks.

the locations of these recording sites with respect to geographic, geomagnetic and L-shell coordinates. Initially, Pc3–4 recording stations will be established at LN, NC, DB and WM. The array follows an earlier one deployed for studying the propagation of Pc1 (0.1–1 Hz) and the longitudinal phase structure of Pc3 pulsations. Phase and polarization measurements across the network will also yield information on pulsation characteristics around the region of the maximum Alfven velocity in the magnetosphere, situated near L = 1.5. This will link hitherto unexplained Japanese observations which are restricted to latitudes corresponding to L < 1.7. The station locations chosen represent a compromise between the ideal case, lying on the geomagnetic meridian, and prevailing geographic and geological conditions such as accessibility and uniform ground structure.

Recording equipment is designed to facilitate economic handling of data. Orthogonally oriented induction coil systems will be linked via dual mode amplification systems to microcomputers which store data in digital form on floppy disc. Timing at each site will be provided by an appropriate chronometer. During the initial planned few months of operation the stations will require only periodic attention to monitor operation and change discs. The NC station will form a reference station and will be equipped with a fluxgate magnetometer and chart recorders in addition to the digital Pc3–4 and Pc1 systems.

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The spatial integration of transient ULF pulsations observed by ground based magnetometers

E. M. Poulter and W. Allan

Physics and Engineering Laboratory, DSIR, Lower Hutt, New Zealand.

The major source of damping for resonant ULF pulsations is thought to be joule dissipation in the conducting ionosphere, determined by the Pedersen conductance, Σ_P. Transient pulsations (i.e. short-lived pulsations with latitude-dependent periods) are toroidal mode oscillations of the geomagnetic field shells (Poulter & Nielsen 1982), and are often associated with SSC and SI. In this paper empirical models of the toroidal mode east-west Hall current density J were used to calculate the associated ground magnetic fields in an attempt to resolve the following points:

(1) decay rates observed by ground magnetometers are in general larger than those observed by satellites and predicted by theory;

(2) estimates of the Pedersen conductance using ground magnetometer derived decay rates seem too low (Glassmeier *et al.* 1984);

(3) ground magnetometer observations of transient pulsations may show little or no period variation with latitude (Allan *et al.* 1985);

(4) the effect of non-monotonic latitudinal period variations (e.g. the plasmapause).

Since a ground based magnetometer integrates the ionospheric currents, any latitudinal period variation results in spatial incoherence of the oscillations. The effects of the spatial integration are shown in Fig. 1, for a Gaussian current distribution of half-width 2°. There is clearly an increased