The International Magnetospheric Study (IMS) and the Antarctic and Southern Hemisphere Aeronomy Year (ASHAY)

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In the eighteen years since the discovery of the radiation belts by James van Allen our knowledge of the earth's immediate surroundings in space has advanced beyond recognition. Fig. 1 summarizes our present view of the complex structure now known as the 'magnetosphere'. The earth is the small sphere towards the left, and the van Allen radiation belts are represented by the dotted region labelled 'trapped particles'. These protons and electrons execute a complex motion, spiralling around lines of force of the geomagnetic field, 'bouncing' back and forth from north to south as they do so, with periods of the order of a few tenths of a second, and 'drifting' round the earth, electrons eastwards and protons westwards, taking from a few minutes to several hours to complete one circuit, depending on their energy. These energies range from a fraction of an electron volt to several MeV.

The 'plasmasphere' is the more heavily shaded region nearest to the earth in Fig. 1 and it represents the upward extension of the ionosphere, following the lines of force of the magnetic field to great heights. The outer boundary of the plasmasphere is the 'plasmapause', where the plasma density falls rather suddenly by a factor of 100 or so. It is probable that this also marks the limit beyond which the plasma does not co-rotate with the earth.

Outside the plasmapause the earth's magnetic field is severely distorted by the 'solar wind', which consists of the protons and electrons which are constantly streaming out of the sun, having been accelerated into the corona above the photosphere; this 'wind' blows at a variable speed, averaging about 300 km s^{-1} and is thus supersonic. When it encounters the earth's magnetic field it is deviated, the protons going towards the right as we approach the earth with the solar wind, i.e. towards the dusk side, the electrons towards the dawn side. These oppositely-moving charges constitute an electric current, which modifies the magnetic field, producing a boundary outside which the field is essentially of solar origin, but inside which it is of terrestrial origin. This is the 'magnetopause' (Fig. 1). The magnetopause is an obstacle to the supersonic flow of the solar wind, and accordingly a shock wave forms upstream of the boundary, the 'bow shock' of the figure. The region between the magnetopause and the shock wave contains more or less turbulent plasma and magnetic fields and is called the 'magnetosheath'.

The lines of force of the geomagnetic field are modified by these currents so as to take on the appearance of having been swept backwards by the solar wind, rather like a comet's tail, so forming the 'geomagnetic tail', which may extend for several thousand earth radii in the antisolar direction. Since the lines of force run inwards towards the north magnetic pole but outwards from the south pole (Fig. 2), there must be a

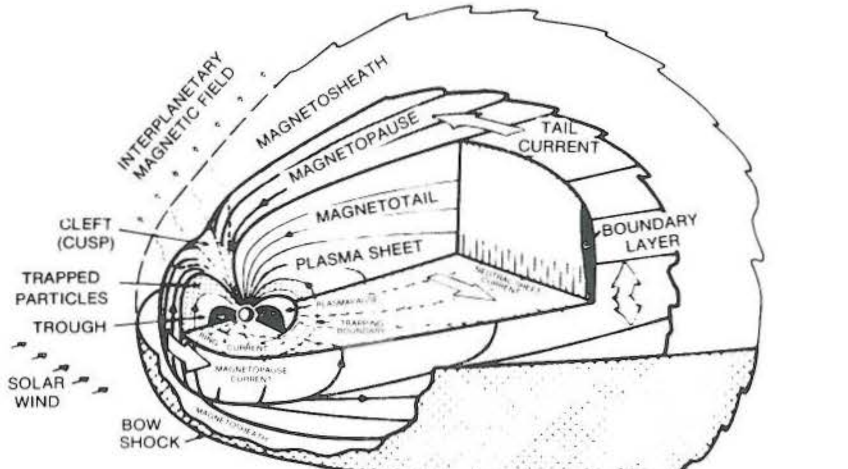

Fig. 1. An artist's conception of the magnetosphere (from *International Magnetospheric Study — Guidelines for United States Participation.* Washington D.C., National Academy of Sciences, 1973)

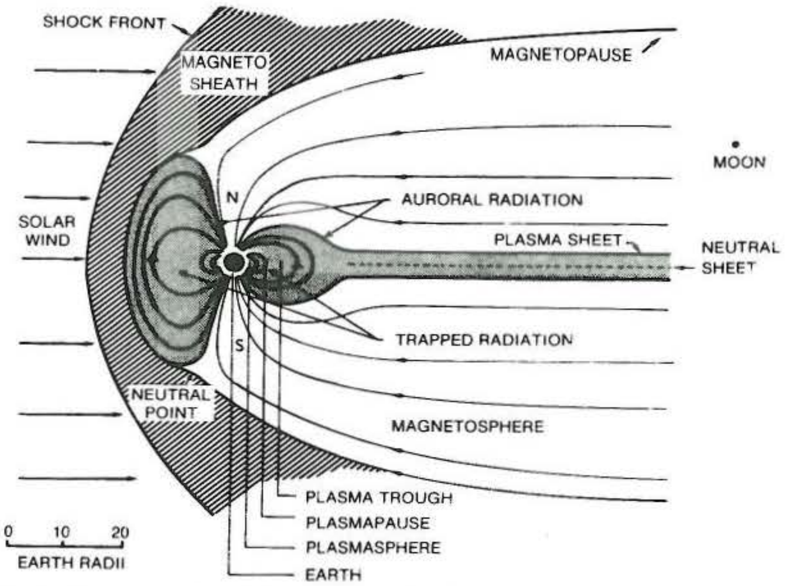

Fig. 2. A cross-section of the magnetosphere in the noon-midnight meridian plane (from *International Magnetospheric Study — Guidelines for United States participation.* Washington D.C., National Academy of Sciences, 1973).

region in the middle of the tail where the field reverses its direction. A current sheet is necessary to accomplish this, flowing across the tail from the dawn side towards the dusk side as shown in the figures. Surrounding this 'neutral sheet' is a much thicker 'plasma sheet'; this is the plasma which conducts the current. The sweeping back of the geomagnetic tail leaves two neutral lines on the front of the magnetopause, and near these lines the plasma of the magnetosheath can penetrate the boundary and come right down into the ionosphere through the 'clefts' or 'cusps'. These regions also appear to be connected to the plasma sheet in some way.

Although all this has been learned during the past 18 years, we still have very little quantitative understanding of the magnetosphere. We know that solar disturbances can produce changes in the density and speed of the solar wind and so affect the magnetosphere that, for example, the magnetic intensity at the surface of the earth is considerably altered. The earthward end of the neutral sheet moves inwards and with it the plasmapause, while particles are precipitated into the atmosphere just outside the plasmapause, producing auroral displays. We are far from being able to give a quantitative account of cause and effect in such a 'magnetic storm'. We do not understand much about the generation of electric fields in the magnetosphere nor the part they play in its behaviour. We need to understand the interaction of the 'cool plasma' of the plasmasphere, the 'hot plasma' of the radiation belts, and the magnetosheath plasma.

The equilibrium particle population of the various parts of the magnetosphere — if indeed there is ever an equilibrium condition — probably depends on the interaction of the particles with electromagnetic and hydromagnetic waves, which throw the particles off their stable trajectories and cause them to be lost from the region concerned. We know very little about the mechanisms by which such waves are generated. We do not even know whether the auroras are caused by processes of this type or by others, or how the auroral particles are accelerated to their relatively high energies.

Nor is all this of purely academic interest. There is a growing body of evidence that these solar wind-magnetosphere-ionosphere interactions may profoundly influence the weather by the further step, ionosphere-lower atmosphere interaction. Communications are seriously impeded by magnetic storms, even if they are on high frequency channels via satellites, and trouble has been experienced by tripping of alarm relays, resulting in major blackouts on power distribution systems. It is clear that the more we understand about the magnetosphere, the better we shall understand our own immediate environment down here at the surface of the earth, and its vagaries.

I M S

The International Magnetospheric Study was proposed as a period of loosely-knit international co-operation during 1976-1978 and perhaps longer. Efforts will be made to synchronize and co-ordinate the work of participating groups, to give the best return for the considerable investment in time and money. The committee which has been set up to steer the programme, under the auspices of the Special Committee on Solar-Terrestrial Physics (SCOSTEP) of the International Council of Scientific Unions, regards its main task not to be the initiation of new experiments, but to keep the different groups informed of each other's plans, interests and progress, to facilitate the exchange of views and data, and to encourage international co-operation in the study of the magnetosphere from satellites, rockets, balloons, aircraft, ships and from the surface of the earth. All kinds of studies which could be useful in improving our understanding of the magnetosphere are included in the plans, from observations of the sun to those of the ionosphere and theories of the interaction of waves and particles.

Table 1

South African participation in the IMS. Participating institutions: M - Magnetic Observatory of the CSIR, Hermanus; N - Department of Physics, University of Natal, Durban; P - Department of Physics, Potchefstroom University for CHE, Potchefstroom; R - Department of Physics, Rhodes University, Grahamstown; T - National Institute for Telecommunications Research of the CSIR, Johannesburg.

		Sanae	Marion Island	Hermanus	Grahams-town	Suther-land	Ngoya	Potchef-stroom	Johannes-burg	Hartebees-poort	Tsumeb
Ionosphere	vertical	R	T	T	R				T		T
	oblique	R			R						
	riometer	P		P							
Airglow		R	T		R	T				T	T
Aurora		M,N									
VLF	emissions	N									
	whistlers	N									
	micro-pulsations	M,N		M			N				
	satellite telemetry	N									
Cosmic rays	neutrons	P		P				P			
X-rays (Balloons)		P									
Geomagnetism		M	M	M	M					M	M

The Chairman of the IMS Steering Committee is Prof. Juan G. Roederer, who visited South Africa in 1973 to discuss South African participation, and the Secretary is Dr Edward R. Dyer, Jr, of the U.S. National Academy of Sciences. A major facility is the Satellite Situation Center at Goddard Flight Center, Maryland, under the direction of Dr James Vette. This will provide information about the types of satellite-based measurements which are available, times of satellite passes near to any station, and similar predictions, and will organize the exchange of data between satellite groups and others. The Committee also publishes the computerized *IMS Bulletin,* which contains details of all the groups which are participating in the IMS and is updated at approximately yearly intervals.

Apart from actual observations of electric fields, magnetic fields and particles in the magnetosphere and beyond from space vehicles, measurements made from the ground and from ships, aircraft and balloons are of the greatest importance for the IMS. Thus, the ionosphere forms the lower boundary of the magnetosphere, and happenings far out in space are 'mapped' along the magnetic field lines into the ionosphere, where they produce effects which, once recognized, are almost 'signatures' of the causes far away. Conversely, ionospheric disturbances produce magnetospheric consequences and one cannot hope to understand the one without the other. Constant monitoring of both the sun and the geomagnetic field are clearly necessary parts of the total effort and a number of types of observation, such as those of 'whistlers' and 'micropulsations' are very useful for tracing the position of the plasmapause, for they propagate up to the edge of the plasmasphere but not beyond it.

The South African contribution is essentially of the ground-based type. The South African Antarctic base, Sanae, is very fortunately situated for observation of the inward and outward movements of the plasmapause, for auroral work and for measurements of the plasma density in the plasmasphere by means of whistlers. The following table gives a brief summary of the South African effort.

ASHAY

Parallel to the first stages of the IMS, but separately organized, is the Antarctic and Southern Hemisphere Aeronomy Year project. This was originally proposed by Prof. Sandro Radicella, of Argentina, who is Chairman of the Organizing Committee. ASHAY grew out of a feeling that it was time to improve international co-operation among the countries of the southern hemisphere, whose efforts sometimes fall short of what could have been achieved, because of the absence of co-ordination such as is often found between northern hemisphere countries. The main object of ASHAY is to provide the organization for such co-operation between southern groups which work on problems of the physics and chemistry of the atmosphere (aeronomy). An enthisiastic response has come from Argentina, Australia, Bolivia, Brazil, Chile, New Zealand, Peru, Rhodesia and South Africa, with much interest in participation from Germany, Japan, the U.K., the U.S.A. and the U.S.S.R., among others.

ASHAY has three working groups, devoted to different aspects of southern hemisphere aeronomy:

Working Group 1 (Chairman Prof. J.A. Gledhill, South Africa) deals with the South Atlantic Anomaly

(Gledhill, 1971). Because of the asymmetry of the geomagnetic field, and its 'weak spot' in the South Atlantic area, which causes trapped particles to penetrate to ionospheric heights in that region, there should be unusual aeronomic effects there, such as increased airglow intensity and perhaps unusual emission lines, or abnormal intensities of X-ray bremsstrahlung. The working group is analysing observations of precipitated particles over the South Atlantic from various satellites, measuring the phase of very low frequency transmissions passing through the region, observing airglow and ionospheric electron densities and measuring X-ray intensities from balloons. It has organized aircraft flights, with appropriate instruments on board, into the anomalous region and will send instruments on ships through the area concerned.

Working Group 2 has no chairman at present; it is concerned with the study of effects which are caused by the very large deviation to the south of the magnetic equator in the South American region. At its maximum, the magnetic equator is nearly 15° south of the geographic equator in this area. This should produce unusual phenomena in the ionosphere because of the interplay between solar and magnetic effects. The radio observatory of Jicamarca, Peru, with its incoherent backscatter facility, is very strategically situated to take part in this project. Unfortunately, owing to the resignation of the Director of Jicamarca, Dr Ronald Woodman, who was also the Chairman of the Working Group, its work has been held up, but it is expected that rapid progress will be made in the near future.

Working Group 3 (Chairman Prof. K.D. Cole, Australia) is concerned with effects in the Antarctic ionosphere, and the interaction between it and the surrounding sub-Antarctic regions of the atmosphere. When auroras occur (and probably even when they are not visible) energy is deposited by precipitated particles in the atmosphere at heights above 80 km, producing various aeronomic effects and heating the neutral gas considerably. It is believed that this heated air, expanding upwards, spills over and is convected towards the equator at the upper levels, descending in the tropical zones and moving back towards the polar regions at lower levels. One of the main objects of the Working Group is to encourage all kinds of observations which would throw light on this circulation. Clearly it involves the co-ordination of measurements made by many different groups, in different parts of the southern hemisphere, using different techniques. It is hoped, for example, to be able to follow the progress of ionospheric disturbances propagating towards the equator by their effects on the oblique ionograms now being taken every 15 minutes between Sanae and Grahamstown.

In ASHAY, as in the IMS, the primary object of the Committee is not to initiate new experiments itself, but to encourage co-operation between existing groups, using their routine observations for the joint project. At an informal meeting in Lima, Peru, in August 1975, the following periods of co-operative effort were agreed upon:

Period 1:	March 21 - April 3, 1976	(14 days)
Period 2:	June 17 - June 30, 1976	(14 days)
Period 3:	Sept. 15 - Sept. 29, 1976	(15 days)
Period 4:	Dec. 8 - Dec. 23, 1976	(16 days)

It is the sincere hope of all participants that this effort will be the beginning of much fruitful international co-operation in the southern hemisphere.

References

Gledhill, J.A. Scientific results of the South African Antarctic Ionosphere Programme 1962-1970. *S. Afr. J. Antarct. Res.*, No. 1, 3-10, 1971.