WHISTLER OBSERVATIONS OF THE DYNAMICAL BEHAVIOR OF THE PLASMAPAUSE DURING JUNE 17-22, 1973

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Abstract. The dynamical behavior of the plasmapause is studied using whistlers recorded at Siple, Antarctica (~84°W, L ~ 4) during June 17-22, 1973. The magnetic activity during this period remained fairly disturbed until June 21, causing the plasmapause to contract to less than 3 earth radii (R_E). Sudden quieting on June 22 caused the plasmasphere to develop complex outlying structures with the high density region extending out to about 6 R_E. The plasmapause data show a repeated diurnal pattern of a relatively slow decrease in equatorial radius by ~0.5-1 R_E during the night and a more rapid increase by about the same amount near dusk when the plasmasphere bulge is encountered. These data should provide a basis for detailed correlative studies of many plasmapause-associated phenomena.

This note describes the dynamic behavior of the plasmapause deduced from whistlers recorded at Siple, Antarctica (~84°W; L ~ 4) during the period June 17-22, 1973. The plasmapause is of great geophysical interest not only because its dynamic behavior serves as an indicator of large-scale magnetospheric convection activity but also because the sharp density drop across the field-aligned boundary gives rise to a variety of interesting phenomena. Examples include the generation of intense VLF noise [e.g. Carpenter et al., 1968], strong pitch angle diffusion of energetic particles [e.g. Williams and Lyons, 1974], excitation of SAR arcs [e.g. Hoch, 1973] and changes in the polarization and amplitude of ULF waves [e.g. Lanzerotti et al., 1974]. The plasmapause has also been associated with a number of ionospheric features such as the mid-latitude electron density trough [e.g. Rycroft and Thomas, 1970], and the light ion trough [e.g. Taylor and Walsh, 1972].

The plasmasphere contracts quickly (time scales of ~1 day) in response to increasing geomagnetic activity, but its subsequent recovery is a long process that takes 10 days or more [Park, 1974]. During this long recovery, plasma density profiles may show multiple discontinuities with complex spatial and temporal behavior, and it may not be possible to uniquely define the plasmapause [e.g. Carpenter and Park, 1973; Chappell, 1972]. It is important to distinguish between these two fundamentally different states of the plasmasphere when we study the relationships between the plasmapause and other geophysical phenomena. Certain phenomena may be closely correlated with the plasmapause during periods of increasing geomagnetic activity but not during subsequent recovery. In particular, the relationships between the plasmapause and ionospheric troughs may depend on the history of geomagnetic activity as well as on local time.

The results presented here provide opportunities for detailed comparisons between the whistler description of the plasmapause and other data on related phenomena. A number of correlative studies involving satellite as well as ground-based experiments are already underway, and their results will be reported separately. It is the purpose of this note to report the whistler results to a larger community of experimenters who may have data on related phenomena.

Figure 1 shows an equatorial electron density profile deduced from whistlers recorded between 1405 and 1620 UT on June 19, 1973. The plasmapause is particularly well defined in this case. The methods of deriving such density profiles and tracking the plasmapause in time have been described elsewhere [e.g. Carpenter, 1966; Angerami and Carpenter, 1966; Park, 1972]. In the present study, some improvements were made by adopting a more realistic model for the geomagnetic field instead of a simple dipole model used in earlier work. This new model combines the IGRF 1965 inter-

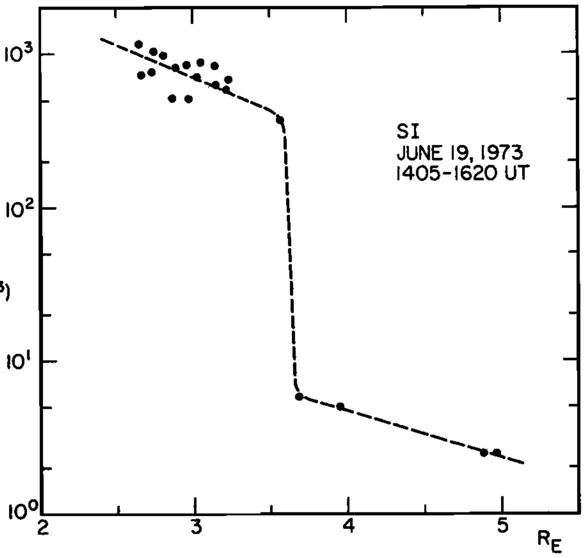

Figure 1. Equatorial electron density vs. geocentric distance.

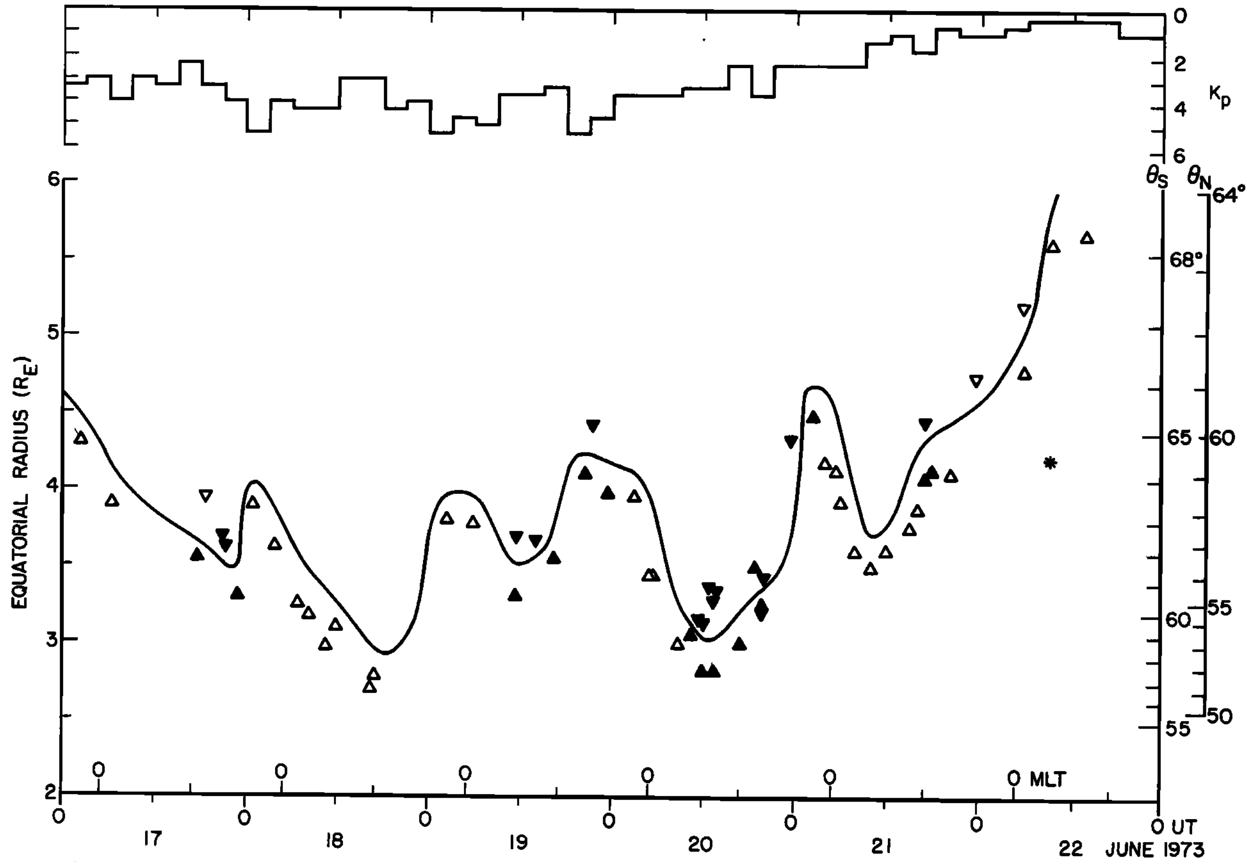

Figure 2. Plasmapause equatorial radius deduced from Siple, Antarctica whistlers during the period June 17-22, 1973. See text for details.

nal field model [IAGA Commission 2 Working Group 4, 1969] with external fields due to the magnetopause, neutral sheet and quiettime ring current systems [Olson and Pfitzer, 1974]. Near the Siple meridian, the geomagnetic field can depart significantly from a dipole model even during very quiet times, and it is important to trace field lines using a realistic model when phenomena occurring at different altitudes are to be compared. The horizontal scale in Figure 1 is in geocentric distance, in units of earth radius, to the point on a field line where the field strength is minimum. A diffusive equilibrium model has been adopted for plasma distribution along field lines inside the plasmapause, and a collisionless model has been adopted for outside [see Angerami and Carpenter, 1966 or Park, 1972].

The plasmapause position has been tracked during the six-day period, June 17 through 22, by using the same technique and models as in Figure 1. The results are shown in Figure 2 along with the 3-hr Kp index for the same period. The vertical scale on the left is geocentric distance to the minimum B-field point as in Figure 1, and the two vertical scales on the right are the corresponding geomagnetic latitudes (in a centered dipole coordinate system) where the field lines intersect the earth's surface at the Siple meridian. The exact correspondence between these latitude scales and the distance scale on the left depend on local time, because a field line anchored at fixed points on the earth's surface is stretched out more on the nightside compared to the dayside. Below 5 R_E where most of the data points lie, however, the non-midnight difference in latitude scale is less than 1°. The latitude scales in Figure 2 are halfway between the noon and midnight values. The horizontal scales are Universal Time (UT) and Magnetic Local Time (MLT) at Siple. The triangles with the apex pointing upward represent the inner limit of the plasmapause, while those with the apex pointing downward represent the outer limit. Filled triangles are used when whistlers were observed to propagate just inside and just outside the plasmapause, thereby making it possible to define the plasmapause position with greater degree of accuracy, say within ±0.2 R_E. Unfilled triangles are used when only the inner or the outer limit of the plasmapause could be clearly established. Uncertainties in the plasmapause position in these cases are estimated to be ~0.5 R_E in the direction of the apex. The solid curve in the figure represents our best estimate of the plasmapause position. However, when information is available only on the inner limit of the plasmapause for many hours (June 18 is an example), the solid curve must be considered tentative until detailed drift measurements can be made to establish whether the actual plasma motion is consistent with the apparent motion of the plasmapause.

The whistler receiver at Siple has a viewing longitude range of ~±30°, and on occasion the plasmapause position shows clear longitude variations within this viewing range. An example of

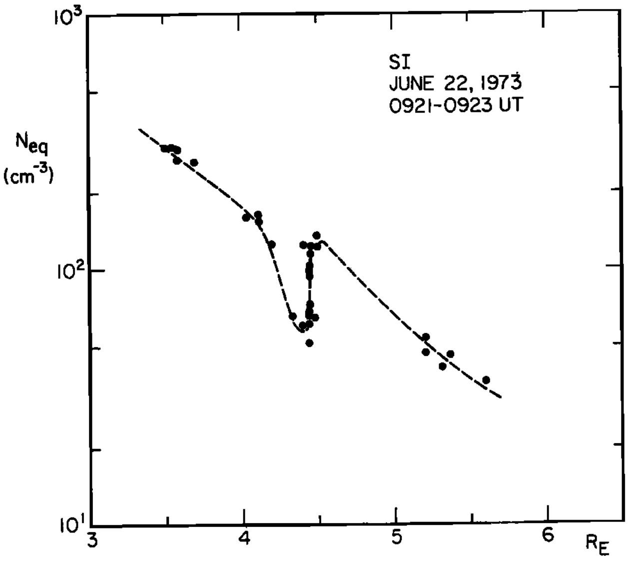

Figure 3. Equatorial electron density profile showing an outlying high density region.

this can be seen in Figure 2 where the inner and the outer limits of the plasmapause position overlap near 20 UT on June 20.

The magnetic condition during this period remained fairly disturbed through the middle of June 21, which accounts for the generally contracted state of the plasmapause. When the magnetic activity dropped to a very low level on June 22, the plasmapause moved outward, and complex density structures started to develop. These structures will be described later.

Two diurnal effects are evident in the plasmapause data: gradual decreases in the plasmapause radius by ~0.5-1 R_E during the night and more rapid increases by about the same amount near dusk. The first effect is believed to be due to inward convection of plasma by substorm electric fields [see, for example, Park and Carpenter, 1970], whereas the second effect is the result of the whistler station's rotation into the plasmasphere bulge region [Carpenter, 1970; Chappell et al., 1970]. The bulge encounter occurred near 1800 MLT on June 17, 18 and 20. On June 19, the encounter occurred about 5 hr earlier, possibly due to the sunward surge of the bulge region in response to the sudden increase in Kp at that time [Carpenter, 1970].

On June 22, electron density profiles showed multiple discontinuities as illustrated in Figure 3. The density drops abruptly at ~4.2 R_E, recovers back to a plasmaspheric level at 4.45 R_E and then remains at a fairly high level beyond 5.6 R_E. This structure was observed for approximately 1 hour between ~09 and ~10 UT. The sharp drop at ~4.2 R_E is marked by (*) in Figure 2. The triangles and the solid curve in that figure for June 22 represent the estimated position of the outer boundary of the outlying dense region. In Figure 3 a diffusive equilibrium model was used everywhere including the low density region between ~4.2-4.45 R_E. If a collisionless model were used in this low density region the density level would be adjusted downwards by a factor of ~2.5.

The kind of density structure illustrated in Figure 3 tends to develop during very quiet periods immediately following magnetic disturbances. Such structures have been observed by satellites [Taylor et al., 1971; Chappell, 1974; Chen and Grebowsky, 1974] as well as by ground-based whistler techniques [Ho and Carpenter, 1976], and have also been predicted by theoretical convection models [Chen and Wolf, 1972; Grebowsky and Chen, 1976].

We have presented only a brief summary of whistler results here. Most of the time during June 17-22, 1973, electron density profiles can be obtained with ~5 min time resolution. Scientists interested in further details are encouraged to communicate with the authors.

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