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A Note on the Post-Rosenbluth Quasilinear Diffusion Coefficient in the Ring Current Region

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Abstract. The Post-Rosenbluth diffusion coefficient in the equatorial magnetosphere is estimated using Explorer 45 satellite measurements of electrostatic wave intensity levels with frequencies well above the proton cyclotron frequency in the vicinity of the plasmapause in the ring current region during the magnetically disturbed period of December 17, 1971 by Anderson and Gurnett (1973). It has been found that the combined electrostatic pitch angle and energy diffusion coefficient in the region of the plasma density gradient is of the order of 10^{-5} s^{-1} for 10 keV ring current protons. The diffusion coefficient is a function of pitch angle and particle energy. It is minimum for $\alpha = \pi/2$ protons and maximises near the loss cone boundary. A comparison with measurements of proton precipitation near the loss cone by Amundsen (1973) shows that it is of the correct order expected under moderately disturbed magnetospheric conditions for electrostatic waves in the ring current region to be an important turbulent particle loss mechanism. Inside the plasmasphere the diffusion coefficient decreases by several orders of magnitude on a distance much shorter than the observed ring current decay. Ion-loss cone waves are hence of no importance for ring current dynamics here. It is concluded that they as well as ion-cyclotron waves play a significant rôle in ring current proton interactions inside the plasma density gradient region. This is in agreement with the picture of Williams (1976) for the ring current dynamics during storm recovery and completes it with respect to electrostatic waves.

Key words: Ring current – Electrostatic wave-particle interactions – Post-Rosenbluth instability – Phase-space diffusion coefficient.

Loss of ring current protons from the outer magnetosphere in the region outside and near to the plasmapause is often prescribed to the turbulent interaction between ion-cyclotron and/or electrostatic ion-loss cone waves and ring current protons (Cornwall et al., 1970, 1971; Coroniti and Fredricks, 1972; and others). Such an interaction, as is well known, leads to velocity-space diffusion of the particles and their subsequent precipitation into the atmosphere due to scattering in the dense region at ionospheric heights, if they reach the loss cone. This mechanism has been extensively studied over the past decade by Cornwall et al. (1970, 1971), Eather and Carovillano (1971) and others, where ion-cyclotron turbulence has been favored as the basic interaction mechanism. On the other hand, it has been demonstrated by Mizera (1974) that only a small fraction of ring current energy is lost by precipitation, giving a reason for a search for different loss mechanisms of ring current particles. Such additional mechanisms can be found in the convection process itself (Coroniti, 1973), and in the charge exchange process both outside and inside the plasmasphere (Swisher and Frank, 1968; Fritz and Williams, 1975) though strong arguments against the efficiency of the latter have been presented recently by Lyons and Evans (1976), Tinsley (1976) and Lyons (1976). So considerable interest remains in the question as to whether turbulent interaction between waves and particles would affect the ring current or not.

In a series of papers Williams and Lyons (1974a, b) demonstrated that the ion-cyclotron interaction can indeed produce the transition of the proton pitch angle distribution from isotropic distributions having nearly empty loss cones to well-rounded distributions measured in the vicinity of the plasmasphere during the large geomagnetic storm of December 17, 1971. Joselyn and Lyons (1976) recently very elegantly showed that the calculation of the linear wave growth rate of ion-cyclotron waves, propagating parallel to the magnetic field lines and resonating with ring current protons off the equator in higher latitudes, leads to reasonable values of the net wave energy gain. Using these calculations, based on measured proton flux and anisotropy values they were able to estimate the L-profile of the cold plasma density and recovered the density drop at the plasmapause. These are strong arguments for the significance of the ion-cyclotron interaction in ring current dynamics near the plasmapause as has been proposed in the model of Cornwall et al. (1970). Moreover, Wandzura and Coroniti (1975) pointed out the possibility that ion-cyclotron waves could become nonconvective well outside the plasmasphere thereby leading to largely enhanced phase-space diffusion. This type of interaction thus seems to be a fundamental one all over the region of the magnetosphere near and not too far outside the plasmapause (cf. also the reviews of Williams, 1975, 1976; Lyons, 1976). The theoretical calculations (Gendrin, 1975; Perraut and Roux, 1975) of the ion-cyclotron growth rates and resonant energies in this region are also in good agreement with this picture.

In the present note we investigate the importance of another likely candidate of ring current wave particle interaction, the electrostatic Post-Rosenbluth instability. This instability develops when a proton loss cone distribution is present. The unstable waves have frequencies well above the ion-cyclotron frequency and comparable with the ion plasma frequency; they propagate approximately perpendicular to the ambient magnetic field direction. It is interesting to remember that all particles of sufficiently high energy contribute to the development of the instability so that it can be expected that the instability is always present in the ring current region if only a loss cone distribution exists in one of the energy channels. Similarly as described above for the ion-cyclotron instability, the Post-Rosenbluth instability drives the particle distribution to isotropy by quasilinear phase-space diffusion, as has been demonstrated by Galeev (Sagdeev and Galeev, 1969). A discrimination between the two instabilities on the basis of particle measurements only seems difficult. The basic difference in the action of the two instabilities on the particles consists in the level of the energy diffusion. Ion-cyclotron turbulence results merely in pitch angle diffusion, whereas the pitch angle and energy diffusions caused by Post-Rosenbluth turbulence are of the same order of magnitude. In the latter case appreciable ring current cooling should be observed therefore simultaneously with the flux isotropisation.

On the other hand, wave intensity measurements in the turbulent region are a suitable instrument for calculating the relevant phase-space diffusion coefficients. Unfortunately, measurements of ion-cyclotron waves in space are rather rare. Only very low electromagnetic noise levels have been observed in the vicinity of the plasmasphere (Anderson and Gurnett, 1973; Parady and Cahill, 1973; Taylor et al., 1975). Instead in the region outside the plasmasphere intense electrostatic noise has been detected by Anderson and Gurnett (1973). So the possibility arises that electrostatic turbulence well above the proton cyclotron frequency is also effective in diffusing ring current protons into the loss cone at least throughout the region of the bulk plasma density drop farther away from the earth. In the plasmaspheric region itself one can expect that ion-cyclotron turbulence will dominate because of the lower threshold of the electromagnetic instability.

We have already mentioned that as to the kind of the relevant electrostatic instability one can refer to the proton distributions observed by Williams and Lyons (1974a, b) which in the region of interest are of loss-cone type. Thus the loss-cone or Post-Rosenbluth instability seems to be a serious candidate. In a recent investigation (Grafe and Treumann, 1976) these distributions have been used to determine the L-dependence of a proton pitch angle diffusion coefficient within the ring current region for different proton energies. There the interaction process has not been specified. The interesting result of that investigation was the detection of a double-structure in the energy dependence of the diffusion coefficient, suggesting 2 different, simultaneously acting turbulence mechanisms. The relevance of electrostatic interactions for the more distant ring current region and plasma sheet has been previously advocated by Coroniti et al. (1972) and Hultqvist (1975). The arguments of Hultqvist are based on the observation of proton precipitation in lower altitudes and for the region attached to the plasmapause agree very well with the equatorial picture drawn by Williams and Lyons (1974a, b).

The present study is a first attempt into the direction of calculating the phase space diffusion coefficient from wave turbulence measurements in space. In this sense it is to a certain degree complementary to our previous study (Grafe and Treumann, 1976) and to the investigation of Joselyn and Lyons (1976) where particle measurements have been used to obtain information about the pitch angle diffusion coefficient and the wave growth rate, respectively. Since electrostatic ion wave intensity measurements are rather sparse in the earth's environment, we use the only available to us published values of Anderson and Gurnett (1973). These authors measured appreciable electrostatic wave levels in the ring current region during the December 16/17, 1971 storm period. Unfortunately, from a more general point of view this storm must be considered with caution; it seems that it aborted itself and did not develop a symmetric phase where the ring current encircles the earth. Since however no wave intensity measurements have been published for the

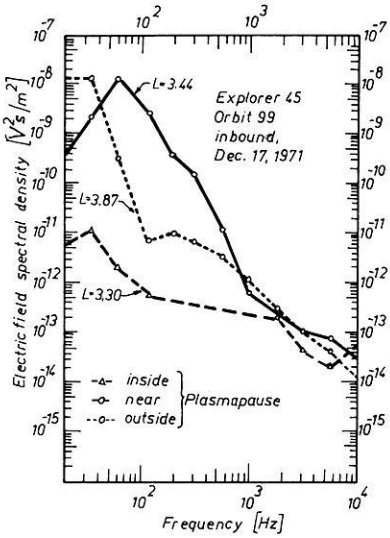

Fig. 1. Measured electrostatic spectral densities in the storm time ring current decay region near the midnight plasmapause with satellite Explorer 45 (S^3-A) on December 17, 1971. ELF hiss and banded chorus appearing on the original curves (Anderson and Gurnett, 1973) have been eliminated. The maximum observed spectral density is about $10^{-8}\,V^2s/m^2$. It is seen that the main spectral contribution comes from frequencies below about 10^3 Hz. Frequencies below 10 Hz do not contribute to the high frequency ion loss cone instability and have therefore not been taken into account in the present paper

main storm of that time period, beginning on December 17, 1971 (Explorer 45 orbit 101) and investigated by Williams and Lyons (1974a, b), we are forced to restrict our calculation on the above mentioned period.

The electrostatic spectral densities at three L-values taken from Anderson and Gurnett (1973) are shown in Figure 1, where the obvious contributions of ELF electromagnetic hiss and banded chorus have been eliminated from the curves. In the following these spectra will be normalised with respect to the maximum of the observed intensity. Knowledge of these spectra at the three spatial points $L=3.3$, $L=3.44$, and $L=3.87$ in the equatorial plane enables us to estimate the radial equatorial profile of the Post-Rosenbluth diffusion coefficient for the December 17, 1971 storm period under consideration. For comparison, the plasmapause had been found on the basis of dc electric field measurements near $L=3.4$ during the observation time (Anderson and Gurnett, 1973). All three spectra lie in the interesting plasma density gradient region in the vicinity of the plasmapause; the point $L=3.3$ can be interpreted as near its inner edge, $L=3.87$ is near its outer edge. $L=3.44$ is probably well within the steepest gradient. It should however be pointed out that no definite decision can be given with respect to the positions relative to the plasmapause, because the gradient region is rather broad when it is determined from particle measurements (Williams, 1976), and the position of the plasmapause has been taken from dc convection potential measurements which give no clear indication of the situation of the plasmapause in relation to the density gradient. We therefore restrict ourselves to the above somewhat imprecise localisation of the measurements.

A crude estimate of the Post-Rosenbluth diffusion coefficient D is obtained from the following expression:

$$D(w)=w^{-1/2}\sum_{\mathbf{k}}\frac{\omega_{\mathbf{k}}^2\,e^2\,|\mathbf{E}_{\mathbf{k}}|^2}{k_\perp^2\,m^2\,u^2} \qquad (1)$$

given in Sagdeev and Galeev (1969). Here $w=v_\perp^2/u^2$ is the perpendicular energy of the ring current protons normalised to the ion temperature, u the thermal proton velocity, m their mass, e the electronic charge, $\mathbf{k}$ and $\omega_\mathbf{k}$ wave number and frequency of the ion-loss cone waves, respectively, and $|\mathbf{E_k}|^2$ is the spectral density of the wave intensity. It has been further assumed that $w \gg \omega_\mathbf{k}^2/k_\perp^2 u^2$ since particles from this region of the velocity space contribute maximally to the quasilinear diffusion process (Sagdeev and Galeev, 1969).

Replacing the sum in (1) by an integral and stepping from $|\mathbf{E_k}|^2$ to $|\mathbf{E}_\omega|^2$ by use of the identity

$$\overline{|\mathbf{E}_{\text{wave}}|^2} = \frac{1}{(2\pi)^3} \int d^3 k\, |\mathbf{E_k}|^2 = \frac{1}{2\pi} \int d\omega\, |\mathbf{E}_\omega|^2 \tag{2}$$

where the bar indicates averaging, and the average in the k-integral has been taken with respect to the unit volume, whereas in the ω-integral it has been taken with respect to the time unit, and it has been assumed for simplicity that both procedures lead to the same value of $|\mathbf{E}_{\text{wave}}|^2$ (for a more rigorous procedure see Lyons (1974) and Grafe and Treumann (1976)).

Referring to the dispersion relation of Post-Rosenbluth waves

$$k^2 \lambda_d^2 = \frac{(\omega/\omega_p)^2\, \Psi}{\cos^2\theta - (\omega/\omega_p)^2} \approx \frac{(\omega/\omega_p)^2}{\cos^2\theta}\, \Psi, \tag{3}$$

where λ_d is the Debye radius, ω_p the electron plasma frequency, $\omega^2/\omega_p^2 \ll 1$, and

$$\Psi \equiv 2\pi u^2 \int_{-\infty}^{\infty} dv_\parallel\, F(0, v_\parallel) \tag{4}$$

has been defined in Sagdeev and Galeev (1969). θ is the angle between $\mathbf{k}$ and the magnetic field $\mathbf{B}$. Substituting (3) into (2), eliminating dk by means of the group velocity $v_g = d\omega/dk \approx (\lambda_d\, \omega_p/\Psi^{1/2})\cos\theta$, and performing the θ-integration in Equation (2), assuming that $|\mathbf{E_k}|^2$ is distributed uniformly over the θ-interval, we find the following approximate relation between $|\mathbf{E_k}|^2$ and $|\mathbf{E}_\omega|^2$:

$$\frac{|\mathbf{E}_{\mathbf{k}(\omega)}|^2}{|\mathbf{E}_\omega|^2} \approx \frac{2\pi}{\Psi^{3/2}}\, \lambda_d^3\, \omega_p \left(1 - \frac{\omega}{\omega_p}\right) \approx \frac{2\pi}{\Psi^{3/2}}\, \lambda_d^3\, \omega_p. \tag{5}$$

Because the wave frequency $\omega \lesssim \omega_{pi}$ is near but below the ion-plasma frequency, $\omega/\omega_p \ll 1$ has been neglected in Equations (3) and (5).

Substituting Equations (5) and (3) into (1) and repeating the same procedure, the k-integration in Equation (1) can be replaced by an ω-integration. We introduce the following abbreviations:

$$x \equiv \omega/\omega_{\text{max}} = f/f_{\text{max}}, \qquad |\mathbf{E}_x|_n^2 \equiv |\mathbf{E}_x|^2/|\mathbf{E}_x|_{\text{max}}^2, \tag{6}$$

$$D_0 \equiv \frac{2\pi^2 e^2}{w^{1/2}\, W_{th}\, m}\, \Psi^{-3/2} (\omega_{\text{max}}/\omega_{po})^2\, |\mathbf{E}_x|_{\text{max}}^2, \tag{7}$$

where f is the frequency, f_{max} the maximum of the observed frequency band, $|\mathbf{E}|_{\text{max}}^2$

the maximum spectral density, W_{th} the thermal energy of the particles, and ω_{po} the plasma frequency at the outer edge of the density gradient region. With these abbreviations the diffusion coefficient, normalised to D_0 can be written

$$D_n \equiv \frac{D}{D_0} \approx 2 \left(\frac{N_0}{N_L}\right)^{3/2} \int_{x_{\min}}^{1} x\,dx\,|\mathbf{E}_x|_n^2$$
$$\approx (N_0/N_L)^{3/2}\,\overline{|\mathbf{E}_x|_n^2}\,(1-f_{\min}^2/f_{\max}^2). \tag{8}$$

In the last expression $\overline{|\mathbf{E}_x|_n^2}$ denotes an average value of the energy density of the wave taken over the frequency band of the electrostatic emission. N_L and N_0 are the densities at the distance L and the outer edge of the density gradient region, respectively. Since, from Figure 1, $x_{\min} = f_{\min}/f_{\max} \lesssim 0.1$, the last term in the bracket can be neglected in comparison with 1.

Equation (8) indicates a decrease of D_n with increasing plasma density. So we expect D_n to be lower in a region of high than in the region of low density.

Table 1 gives the values of D_n calculated from Figure 1 and Equation (8). Of course the values given there are only crude estimates of the diffusion coefficient. On the other hand the approximations introduced in the previous discussion justify the roughness of our estimate.

The D_n values of Table 1 are used for depicting the approximate spatial variation of the Post-Rosenbluth instability quasilinear diffusion coefficient in the region adjacent to the plasmasphere in the magnetospheric equatorial plane in Figure 2, where the position of the plasmapause, as given by Anderson and Gurnett (1973), has been indicated by an arrow. From this picture it can be seen that the Post-Rosenbluth diffusion coefficient is approximately constant throughout the density gradient region at the plasmapause. Entering the plasmasphere from outside, the diffusion coefficient falls by about seven orders of magnitude on a distance of only one fifth earth radius thus pointing out that Post-Rosenbluth instability is of no importance for the behavior of the ring current protons within the plasmasphere. Since $|\mathbf{E}_\mathbf{k}|^2 \sim N^{-1}$ from Equation (5), the electric power density drops rapidly here, because the cold plasma density is too high so that the growth rates of the instability become low ($\gamma \sim N^{-1/2}$). The rapid ring current decay observed in this region cannot therefore be attributed to the electrostatic loss-cone instability of the protons, if only our estimates are correct. One expects that other process should be responsible for the observed ring current proton decay inside the plasmasphere. The remaining relevant processes are the ion-cyclotron mode turbulence, and charge exchange between hot ring current particles and cold plasmaspheric hydrogen. In low density regions however one can expect that phase-space diffusion driven by the electrostatic ion-loss cone instability does contribute to the ring current proton losses and cooling.

To obtain an estimate of the value of the diffusion coefficient, we return to Equation (7) for D_0. First we observe that this formula can be written

$$D_0(\alpha, W) = \frac{2\pi^2 e^2}{m W_{th}} \frac{\Psi^{-3/2}}{(W/W_{th})^{1/2} \sin\alpha} \frac{\omega_{\max}^2}{\omega_{po}^2} |\mathbf{E}_x|_{\max}^2. \tag{9}$$

It can be seen that the phase space diffusion coefficient depends strongly on the

Table 1.

L	3.3	3.44	3.87
N_0/N_L	10^{-3}	~ 1	1
f_p	$\sim 3\times 10^5$ Hz	$\sim 10^4$ Hz	$\sim 10^4$ Hz
f_{pi}	$\sim 7\times 10^3$ Hz	$\sim 2\times 10^2$ Hz	$\sim 2\times 10^2$ Hz
$\mathbf{E}^2_{x_n}$	$\sim 5\times 10^{-4}$	~ 0.6	~ 0.3
D_n	1.5×10^{-8}	0.6	0.3

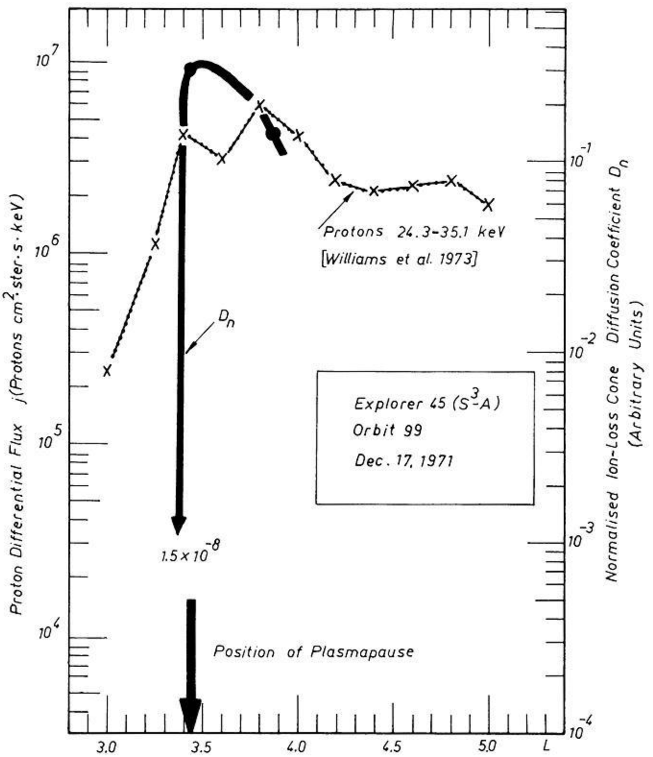

Fig. 2. The L-dependence of the estimated normalised diffusion coefficient D_n given in Table 1. High and nearly constant D_n values appear near the outer edge of the plasma density gradient region. Near the dc plasmapause indicated by an error, D_n decreases by several orders of magnitude. For comparison the L-profile of the ring current decay has been redrawn for the same orbit from Williams et al. (1973). The ring current proton distribution extends farther into the plasmasphere than the D_n profile. Hence inside the plasmasphere ion-loss cone modes become unimportant for ring current dynamics

pitch angle α and is a weak function of the particle energy W. For particles having pitch angles near the loss cone angle, D_0 becomes very large. Such particles experience strong diffusion both in pitch angle and in energy. Particles of large pitch angle near $\alpha=\pi/2$ diffuse the least. Writing

$$D_0(\alpha, W)=D_0(\pi/2, W)/\sin\alpha, \tag{10}$$

we can estimate $D_0(\pi/2, W)$ that is the minimum diffusion coefficient. Since particles having energies above W_{th} contribute most to the wave growth, D_0 maximises for $w \sim 1$ when the particle energy is of the order of the thermal energy. Arbitrarily choosing $W_{th} \approx 10\,\text{keV}$ for ring current protons, $f_{max}/f_{po} \approx 10^{-2}$, $|\mathbf{E}_x|^2_{max} \approx 10^{-8}\,V^2\text{s/m}^2$, and Ψ is of order 1, we get

$$D_0(\pi/2) \approx 2 \times 10^{-5}(10/W_{th}[\text{keV}])\,\text{s}^{-1}. \qquad (11)$$

Of course this value decreases for increasing thermal energy of the ring current protons. At the edge of the loss cone (approximately 6° near $L \approx 3.5$) this value has to be multiplied by $(\sin 6°)^{-1} = 9.57$ so that D_0 is here of the order $2 \times 10^{-4}\,\text{s}^{-1}$. One can compare this value with estimations of the proton diffusion coefficient based on low altitude proton intensity measurements near the loss cone by Amundsen (1973) who used energies between $125 \leqq W \leqq 190\,\text{keV}$ at $4 \leqq L \leqq 6$ and obtained values between $8 \times 10^{-5}\,\text{s}^{-1}$ and $30 \times 10^{-5}\,\text{s}^{-1}$ at $L = 4$. Taking into account that his energies are by a factor 20 higher than ours, we find from Equations (11) and (9) at $\alpha = 6°$ for $D_0(6°, 200\,\text{keV}) \approx 4.3 \times 10^{-5}(10/W_{th})\,\text{s}^{-1}$, a value smaller only by a factor between 2 and 7 than that found by Amundsen (1973). This difference can be attributed to the unknown thermal energy of the ring current protons which can be easily higher than 10 keV by a factor 2 or 3; it can also be attributed to the cold plasma density or different magnetospheric situation. We can therefore conclude that our value is not unreasonable when compared with the diffusion coefficients of Amundsen (1973). We note, however, that our estimate in (11) is by approximately 2 orders of magnitude lower than the estimated proton pitch angle diffusion coefficients for the main storm period following the disturbance considered in the present note. Indeed, Grafe and Treumann (1 76) obtained proton diffusion coefficients for the December 17/18, 1971 magnetic storm of the order of $10^{-3}\,\text{s}^{-1}$. Their calculations were based on the proton pitch angle distributions of Williams and Lyons (1974a, b). We dont know whether this discrepancy is a fundamental one or not. Since the measurements of Amundsen (1973) proceeded during quiet and moderately disturbed times, one could argue that our estimate during the not fully developed storm of December 17, 1971 belongs to similar magnetospheric conditions as those of Amundsen (1973). On the other hand, taking into account the rather sensitive dependence of D_0 on the cold plasma density, a further decrease of the latter by one order of magnitude only increases D by approximately 2 orders up to the value obtained by Grafe and Treumann (1976). Therefore no definite answer can be given concerning the reason of the discrepancy.

Summarising we conclude that the estimate of the Post-Rosenbluth diffusion coefficient based on electrostatic wave power measurements well above the ion-cyclotron frequency during a magnetically disturbed period led us to reasonably high diffusion coëfficients in the region of the steep plasma density gradient at the plasmapause. We argue that the Post-Rosenbluth instability is likely to exist here simultaneously with the ion-cyclotron instability. In such a case both electrostatic and electromagnetic turbulence are responsible for particle precipitation from the ring current, but the electrostatic ion-loss cone instability is mainly responsible for ring current cooling.

The strong radial dependence of the Post-Rosenbluth diffusion coefficient shown in Figure 2 indicates the existence of a limited range of L-values where the

Post-Rosenbluth instability can be excited in the magnetosphere. In fact, to generate ion loss-cone waves a loss cone distribution of ring current protons is required. In the near earth plasma sheet region mainly isotropic ring current proton distributions have been found (Williams and Lyons, 1974a, b) at least during storm recovery phase. Since it is not clear if this isotropy is a consequence of the presence of an instability, the existence of ion-loss cone waves in this region cannot be excluded a priori, though no empty loss cones have been observed. The possibility remains that the particle distribution is held isotropic in the regime of strong diffusion (Kennel, 1969) due to the presence of ion-loss cone turbulence. In such a case one assumes high wave turbulence levels and substantial particle cooling here. To our knowledge none of these effects has been observed yet in the plasma sheet region. Nearer to the earth but outside the plasma density gradient the plasma density is low but approximately independent on L, whereas high ring current proton fluxes having nearly empty loss cones are present. One could await that ion-loss cone waves would be excited here, and the low plasma density predicts high diffusion coefficients here. On the other hand the diffusion coefficient depends parametrically on the thermal energy W_{th} of the protons which increases exponentially with increasing distance L (Frank, 1971; Williams, 1976) and causes an exponential decrease of D according to $W_{th}^{-1/2}$. Moreover the smallness of the loss cone in this region and the fact that the distributions are isotropic suggest that the excited wave intensities will be low outside the density gradient. Hence protons might be stable against loss cone instability here, as they are with respect to the ion-cyclotron instability.

In the plasmaspheric boundary region we observe firstly a steep plasma density drop (Rycroft, 1975; Corcuff, 1975) of at least 2 orders of magnitude on a scale of $0.4\,L$, corresponding to a dependence of $N(L)$ proportional to $N(L) \sim \exp(-5\,L)$. At the same time the thermal energy increases as $W_{th}(L) \sim \exp(2.5\,L)$ for $L < 3.5$, and $W_{th}(L) \sim \exp(0.5–1.0)L$ for larger L. Since from Equations (7) and (8) $D \sim N^{-3/2}\,W_{th}^{-1/2}$, this gives (under the supposition of a constant wave intensity) an increase of D in the plasmapause density gradient region according to $D \sim \exp(5–7)L$ from the low values of D which we expect for the interior of the plasmasphere. So high diffusion coefficients can be expected only in the density gradient region. This confirms the results of our estimations.

We are now in the position to complete the picture drawn by Williams and Lyons (1974a, b) for the ring current behaviour in the vicinity of the plasmapause with respect to the electrostatic ion-loss cone instability. On the basis of our discussion we conclude that along with the ion-cyclotron instability electrostatic ion-loss cone turbulence can develop in the region of the steep plasmapause density gradient. The estimated diffusion coefficients for this kind of unstable wave-particle interaction are reasonably high here to be comparable with estimates obtained for the pitch angle diffusion coefficient from proton precipitation measurements during moderately disturbed times. If Post-Rosenbluth turbulence develops here, it will affect the ring current particle distribution and contribute as to proton precipitation as particle cooling. Inside the plasmasphere the diffusion coefficient is very low. It decreases in a distance of only 0,2 earth radii, whereas the ring current has been observed to penetrate the plasmasphere up to one earth radius (Fig. 2). Hence we conclude that the unstable ion-loss cone waves do not play any rôle in ring current dynamics inside the plasmasphere. Outside the density gradient we again expect low diffusion coefficients and minor losses of ring current protons due to Post-Rosenbluth turbulence. This would confirm the observation on stable distributions in this region (Williams, 1976).

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