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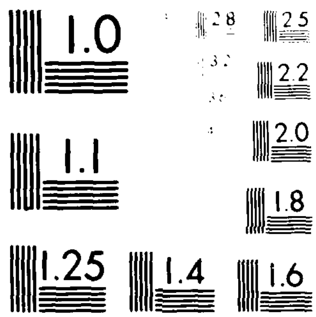

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Comments on "The Energy Selective Precipitation of Inner Zone Electrons" by Imhof et al.

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This report has been reviewed by the Public Affairs Office (PAS) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nations.

This technical report has been reviewed and is approved for publication. Publication of this report does not constitute Air Force approval of the report's findings or conclusions. It is published only for the exchange and stimulation of ideas.

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This note addresses the interpretation of data from the 1971-89A satellite as published by Imhof et al. in "The Energy Selective Precipitation of Inner Zone Electrons" in the Journal of Geophysical Research. It discusses the limitations of the data set and demonstrates that the data set is in agreement with the thesis that a source of electron precipitation is colocated with the Soviet VLF transmitter UMS.

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Introduction

Imhof et al., 1978 (hereafter designated IRG) review data from instrumentation on the 1971-89A satellite in order to determine whether it is consistent with the findings of Vampola and Kuck (1978) that the probable cause of a certain type of electron precipitation event in the inner zone is interaction with VLF emissions from ground-based transmitters. The conclusion IRG arrived at is that the source is distributed in longitude. In this note, we shall address the IRG instrumentation, the data and data analysis, and the results presented in IRG to show that the data set is consistent with a single source longitude but not a distributed source longitude and the data set supports the VK conclusions.

Instrumentation Implications

The IRG instrumentation consisted of two plastic scintillator/photomultiplier electron spectrometers, each feeding into a 256-channel pulse-height analyzer. The acceptance angle of the collimators was 54°, centered on angles of 90° and 20° with respect to the local zenith. The 1971-89A satellite was gravity-gradient oriented in an approximately circular polar orbit (93° inclination, 800 km altitude). All of the data presented came from the 90° instrument. For the longitude regions under discussion, the 90° instrument covers local pitch-angles which include those particles mirroring near 100 km. Thus, the 90° instrument can detect all particles in the drift loss cone which have mirror B values greater than or equal to the local B value. It cannot detect that portion of the drift loss cone distribution which has a mirror B less than the local B. This, as was pointed out in Luhmann and Vampola (1977), places severe restrictions on the utility of the data set in investigating drift loss cone phenomenology and creates a requirement for extreme caution in the interpretation of the data when addressing the same subject. The 20° instrument can detect only those particles which are in the local bounce loss-cone.

The events presented exhibit peaks which have a half-width consistent with a monoenergetic spectrum and have a peak-to-continuum ratio of up to 10, which is relatively good resolution for a plastic scintillator on a spacecraft immersed in an energetic electron flux producing bremsstrahlung background. The energy vs L characteristics of these peaks identify them as probably being the same phenomenon as observed by VK, although the latter study discussed events which appeared as monoenergetic spectra with peaks three to four orders of magnitude above background with no continuum present. The difference in apparent background is due to the difference in detection method. However, this difference may cause a bias in the 1971-89A data base in the following manner: If a precipitation event of short duration (by precipitation we mean a lowering of mirror points to altitudes within either the drift loss cone or the local bounce loss cone) occurs over a narrow longitude interval, drift dispersion will produce a narrowing of the energy peak and a consequent reduction in the integral of the flux above the continuum, reducing the probability of identifying the event in the IRG data. Energy spectra from precipitation occurring over a wide longitude region or for a long time duration (tens of minutes) would not be degraded by this effect and could then predominate in the data base even if they were not the dominant precipitation pattern. Identification of events in the VK data is not affected by drift dispersion since events are readily identified in a single channel. Some events appeared in only one or two channels in the VK data. The drift dispersion effects will be discussed in more detail later.

The VK analysis utilized pitch-angle distribution information to determine the probable longitude at which the particle distribution last interacted with the atmosphere, and by inference, the longitude and local time at which the precipitation occurred. By contrast, the 1971-89A data set contains no information about the pitch-angle distribution other than that particles are in the local bounce loss cone or in that portion of the drift loss cone locally observable. The circular orbit of the 1971-89A, along with the lack of pitch-angle information, restricts the data set to a single B value at a given longitude and hemisphere for each L-value. Measurements obtained at different longitudes are, in general, also obtained at different B values and hence are not directly comparable. Intensity measurements, to be valid as an indicator of the longitudinal extent of precipitation, must be of particle distributions on the same drift shell and mirror B. No events were observed in the local bounce loss cone (presumably indicating that either the distribution of strong precipitation events is isolated in time and longitude and the probability of observing them is low; or, continuous slow diffusion is responsible for the appearance of electrons in the drift loss cone and the local intensity is too low everywhere for detection).

Drift Dispersion

The effect of drift dispersion in the IRG data will be to increase the probability of observing an event far to the east of where it occurred and to bias the data base in favor of precipitation events of long duration. If one assumes a precipitation event occurs at 50^{o} east longitude and covers a narrow longitudinal region at the time of precipitation, one can consider the longitudinal extent of the event at 190^{o} EL and 270^{o} EL, the centers of the two eastern regions in the IRG study. Using the E vs L dependency shown in Figure 1 of IRG, we get the following L values for 400 keV, 300 keV, and 200 keV, respectively: 1.55, 1.64, and 1.74. The B values at 50^{o} EL for each of these L values at 100 km are about .341, .341, and .342. These values are somewhat lower than those obtained from the IGRF 1965 model for epoch 1969 used in the OV1-19 data analysis, but for consistency in discussing the IRG data we must use their values. The equatorial pitch-angles and drift rates for each of these energies are then: 29.66°, 27.05° and 24.55°; 17.92 sec/deg, 21.92 sec/deg, and 29.79 sec/deg. At a time when the drifting 300 keV electron bunch is centered around 190° EL, the 400 keV electrons will have drifted to 221° EL and the 200 keV electrons to only 154° EL. Intermediate energies will, of course, be located at intermediate longitudes. For a time at which the 300 keV electrons are centered at 270° EL, the 200 keV electrons will be found at 212° and the 400 keV would have been lost into the south Atlantic anomaly (drift without atmospheric losses would have placed them at 319° EL). The net effect of this dispersion is to increase the likelyhood of a satellite passing through a spike structure of particles from a discrete precipitation event at positions east of the location where it occurred since the structure occupies a wider longitudinal extent at the more eastern location. For precipitation events of longer duration or wider initial longitudinal distribution, the likelyhood of observing the event will also increase, since the above effect will extend the leading and trailing edges of the event in longitude. However, the data will also be biased by events in which precipitation has continued for some time because of the lower probability of identifying an event in the IRG data if only a very narrow energy range and hence very small integral flux spectrum above the continuum is present as in drift-dispersed short precipitation events. As a result, the majority of IRG events are probably of long duration, requiring a continuous energy-selective diffusion process such as VLF transmissions rather than discrete events.

Intensity vs. Longitude

Because the IRG data set includes measurements at only one B at any given longitude and L shell in a hemisphere, it is inappropriate to compare intensities at different longitudes and ascribe the results to a longitudinal rather than B effect. There appears to be no buildup with longitude as far as can be determined from the data presented (Figure 5 of IRG). Slow diffusion cannot be responsible for the entrance of these particles into the drift loss cone because it has already been shown that the Energy Vs L dependence of the peaks is consistent with a strong resonance interaction. All of the data are obtained from the 90° (i.e., locally trapped) instrument, indicating the probability of being in the region where precipitation is occurring at the time it is occurring is very low. The fluxes appear to be about four orders of magnitude above background. If the precipitation events are uniformly distributed in longitude, or if the local cut-off in pitch angle is frequently equal to the local bounce loss cone angle, the 20° instruments should see some portion of the events. If, however, the cutoff was determined by atmospheric geometry west of the sampling regions (e.g., in the region around 50° EL), then the particles could drift undisturbed until they encounter the atmosphere in the anomaly. In that case, they would be observable only in the 90° instrument and the intensity distribution would not be directly related to longitude. If the data were all obtained at the same B value or if detailed pitch-angle distributions were available to make comparisons at the same B, one could examine both hypotheses: precipitation occurring at $\sim 50°$ EL and a subsequent decay of intensity as the particles drift eastward; and, precipitation occurring at all longitudes, resulting in a build-up of intensity as one proceeds eastward.

Local Time Effects

The data presented in IRG present a consistent local-time effect with an afternoon-to-evening source just east of the anomaly. Since the study cannot identify the longitudinal location at which an electron entered the drift loss cone, a particle observed at 295° EL could have entered that distribution at any longitude east of about

50°. The longitude range covers 16 hours in local time. The time required to drift from 50° to 295° EL varies from one to two hours for electrons from 400 keV to 200 keV. This time must be added to the above 16 hours, giving a possible variation of up to 17 or 18 hours between the local time of precipitation into the drift loss cone and the local time of the observation. For the intermediate longitude, the variation is about 10 hours. For the data of IRG Figure 3, the 245°-295° EL location shows a minimum in the identification of events during the local time period of 20 to 04 MLT. These would transform to a minimum between 02 and 10 MLT for events which occur at 50° EL. For the 175°-205° data, the minimum is from 12 to 22 MLT. These again transform to 02 and 12 MLT for 50° EL events. There doesn't seem to be any preferred MLT for observation of events in the 53°-96° EL interval in Figure 3. However IRG Figures 4 and 5 show a minimum in flux ratio and flux intensity in the peak compared to the continuum between 5 and 16 MLT. Again these would translate to a minimum between 2 and 13 MLT. Thus, to the extent that anything can be said about the MLT dependence of precipitation (as opposed to observation), it appears that the source is more active in the afternoon and evening or that precipitations occurring then are more readily observable by the IRG instrumentation. (This is true even if the location of the source is distributed eastward of 50° EL.) The events in the VK study had a similar local-time behavior. In any event, because of the large variation in possible local time of precipitation (assuming random occurrence as a function of longitude) it is inappropriate to draw conclusions on the basis of local time of observation and apply that local time to conclusions about the source. If anything can be said about these data, it is that they are consistent with an evening source just past the anomaly.

Variation of B

The orbit of the 1971-89A satellite is such that variations in longitude are uniquely coupled to variations in B. This coupling can be used to separate the data by B to determine whether the data are consistent with a source in the vicinity of 50^{o} EL and also to determine whether they are consistent with source regions uniformly distributed in longitude. Figure 1, derived from Figure 1 of IRG, shows the 100 km B (minimum of either the northern or southern hemisphere) and the B sampled by 1971-89A as a function of east longitude. The L value used for the example is 1.65, but one must bear in mind the actual variation in L as a function of energy and event and the slight variations in magnetic topography as a function of L. The shaded region represents the range of mirror B which is filled by a precipitation event at 50^{o} EL. The figure demonstrates that the satellite is below the drift altitude for these electrons for Region 1 in the northern hemisphere and for Region 2 in the southern hemisphere. The IRG study did not use data from the northern hemisphere of Region 1. Observations in Region 3 sample the appropriate drift region except for southern hemisphere passes east of 270^{o}, which sample the stably trapped population. Since events were observed in Region 3 71% of the time, one would expect to observe events 71% of the time in northern Region 2, 0% in southern Region 2, and 40% of the time in Region 1, provided that sampling is uniform in longitude and latitude and drift-dispersion effects are unimportant. The actual results were 38% in northern Region 2, 0% in southern Region 2 (Imhof, private communication), and 23% in Region 1. The difference between the predicted and observed rates in Region 1 and northern Region 2 may be explained as either due to discrete narrow events at 50^{o} EL which have not completely filled in the time-longitude space due to insufficient drift time (the VK explanation) or due to fewer precipitation events in the longitude interval preceding the longitude of observation (the IRG explanation involving pricipitation at all longitudes). The lack of events in southern Region 2 cannot be explained by the IRG distribution. It is predicted by the VK hypothesis.

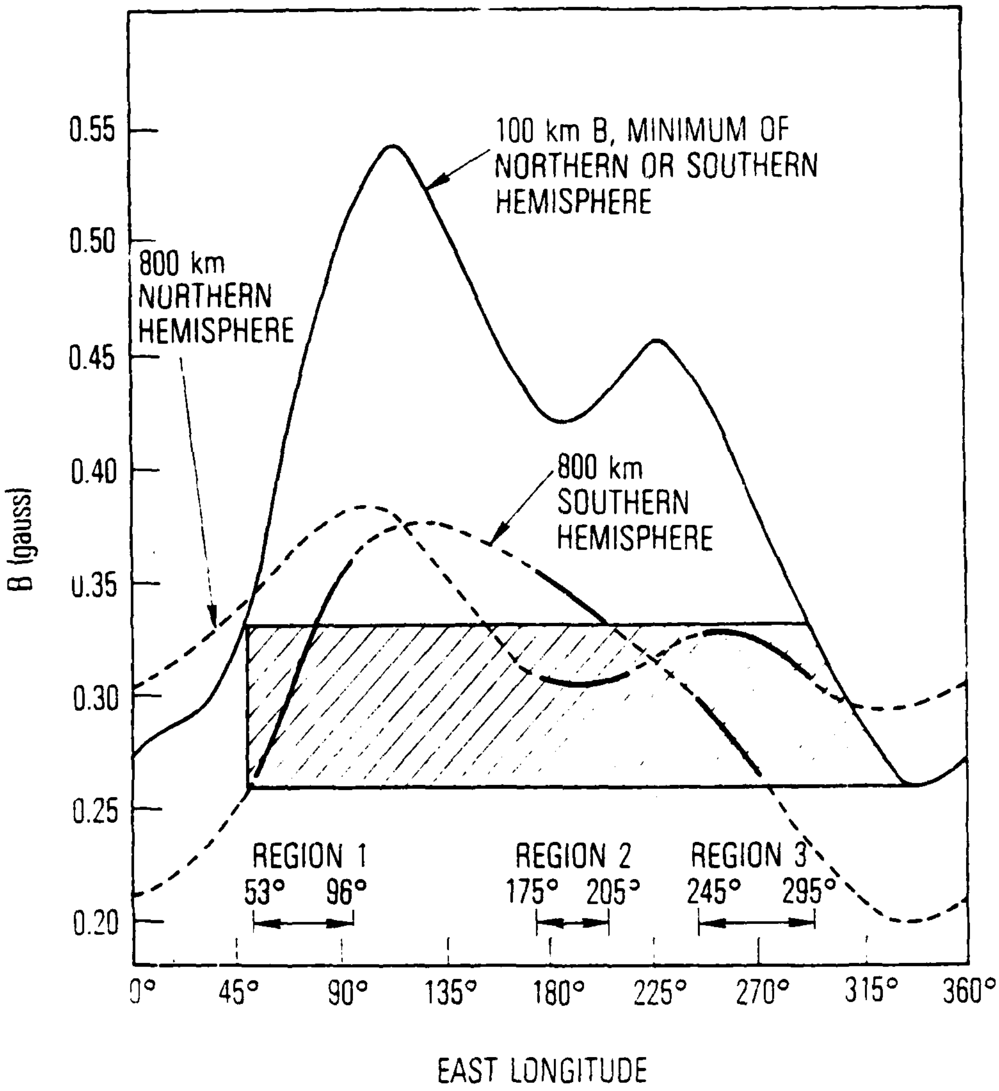

Figure 1. The magnetic field value for various parameters of the 1971-89A study are shown as a function of east longitude. The field sampled by the satellite as it crosses the L=1.65 shell in the northern and southern hemispheres is shown by the dashed line, with the actual portions of the orbit used in the IRG study accented with bars. The solid line shows the field intensity at 100 km altitude which nominally corresponds to the local bounce loss cone. The shaded area depicts the portion of the drift loss cone which would be filled by electrons pitch-angle scattered at 50° EL. The region below the shaded area contains stably trapped particles.

Summary

The instrumentation used in the IRG study could not make comparisons at constant B_{mirror} and therefore cannot readily be used to determine the variation of intensity with longitude. The instrumentation did not make pitch angle measurements with which local time of precipitation could be inferred. Finally, the instrumentation did not have access to the entire drift loss cone at all longitudes. Each of these limitations restricts the uses to which the data set may be put. For the IRG analysis, using the data set to determine the longitudinal pattern of precipitation and the local time of precipitation, the data set is inappropriate. If one hypothesizes a single precipitation location, at 50^{o} EL in accord with the findings of VK in their earlier paper, the data presented by IRG consistently agree with the predictions. The data thus support, rather than refute, the thesis that the primary source of these events is located at a narrow region east of the anomaly longitudes.

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