Parkinson, W. D.: I have one comment on Dr. Hultqvist's remark. It seems to me that what Dr. Cole has suggested is a positive feedback mechanism which would make storm phenomena increase from a small beginning.

Also I have a question. You mentioned 1000 gammas disturbance, and a frequency of 3×10^{-1} cycles. Do you need these together, because even in the auroral zone you do not get such large changes as quickly?

Cole: No; these figures are used for two independent mechanisms.

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I-5-9. The Origin of Irregularities in the *F* Region

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In the absence of any accepted explanation for the origin of *F* layer irregularities, a new mechanism is suggested. This is in essence a feedback mechanism involving trapped energetic electrons from the Van Allen Belts and whistlers. It is argued that *F* region irregularities in electron density should extend a long way up lines of force and they will be identified with the magnetospheric ducts which are supposed to transmit *VLF*. The mechanism proposed would in fact cause ionisation at conjugate points, and this provides one possible test. The release of trapped electrons, other than by collisions, has to be considered. To defeat the trapping mechanism, the adiabatic invariant must be changed and this requires an electric field, which varies appreciably in a gyroperiod of the electrons. At a few earth radii this can be *VLF*. The suggestion is then that the enhancement of *VLF* in a duct accelerates the release of energetic electrons, some of whose energy goes into ionisation in the *F* layer, which is tied to the lines of force, and therefore enhances the duct.

Some quantitative considerations can be given. The effect of whistlers on electrons is very similar to the effect of hydromagnetic waves on protons, discussed by Dragt (1961). The change in $v_\perp$ can be written as an integral which is almost a Fourier integral of the electric field, the frequency being Doppler shifted from the gyrofrequency by $v_{/\!/}$. Assuming this integral can be treated as a Fourier ietegral, it is now pointed out that the other Fourier components of the whistler have no effect on the electron, and in particular their phases are not important. Then the change in $v_{/\!/}$ is the same as would have resulted from the lightning stroke, if there had been no dispersion, and this is easy to calculate, if the numbers are known. A field of E volts/metre lasting for τ microseconds gives on electron an impulsive velocity of 2×10^7 cms/sec. At a distance of 100 km from a lightning stroke E might be 0.5 and $\tau=20$, giving 2×10^8 cms/sec. Heppner's (1961) observations of whistlers from a satellite suggest a higher value that a whistler can change the pitch angle of a not quite relativistic electron by about half a degree. The result can be described as a random walk in pitch angle, as in Dragt's case, and this again can be regarded as a diffusion of the distribution in pitch angle, resulting in a flow of particles into the loss cone. For small pitch angles this diffusion must approximately balance the loss by collisions. Since the probability of loss by collisions varies very rapidly with height and hence with pitch angle, the intensity of trapped electrons must increase very rapidly with height, in the region where collisions are important, that is the *F* region and somewhat higher. The result is that many collisions between belt electrons and air molecules occur well above the E region, but of course a large fraction of the energy finds its way to lower levels carried by photons with a broad spectrum and to some extent by secondary electrons.

The mechanism suggested for building ducts is limited by the energy available in the trapped electrons. The energy required for ionisation is $\sim$10 eV. Suppose the energy density of trapped energetic electrons is W keV/cc and the efficiency with which this energy is used in ionisation in the F region and above is η. Then release of all the trapped electrons would give $100\eta W$ electrons/cc in the outer part of the duct, where the majority of the electrons must be because of its large volume. Assuming that a duct requires an excess of 10 electrons/cc and that $W \simeq 10$ and $\eta \simeq 0.1$, the mechanism seems to be significant.

The relationship found by Outsu and Iwai (1961) between *VLF* and magnetic activity might be interpreted in this way, because it is known that the outer belt is rebuilt during storms.

References

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Discussion

Knecht, R. W.: Dr. Beynon asked about the connection between F region irregularities and magnetic activity. Assuming the occurrence of spread F is indicative of the presence of F region irregularities, we see a positive correlation at high latitudes and a negative correlation in the equatorial region.

Hultqvist, B. K. G.: Do you know anything in nature, which might be connected with the process you have discussed?

Dungey, J. W.: I have not had time to look for correlations.

Piggott, W. R.: We are getting a large number of phenomena for which tentative explanations are based on the release of trapped particles. The necessary conditions do not appear to be consistent. Thus we are in fact implying different types or energies of particles for different purposes. This needs to be treated with caution and it may be possible to eliminate some alternatives by considering conditions of consistency.

I wish to ask Dr. Dungey if the particles he is considering are to be regarded as the same as those which cause storm types of sporadic E or D region absorption?

Dungey: I am thinking of middle latitudes. Ionization by particles in F would imply emission of X-rays which might be significant in D, but you must remember the lives of electrons are much shorter in D than F.

Aono, Y.: I would like to point out a result which is believed to have a close connection with this talk. Miss Yoshida looked for any ionospheric phenomenon which has most close relationship with the *VLF* emission. Finally, she found out that is the spread F which is one of the irregularity in F layer.