guidance. The thanks are also due to the Council of Scientific and Industrial Research, India, for financial support.

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Discussion

Hultqvist, B. K. G.: I have personally difficulties in understanding how the majority of non-deviative absorption can be produced above the level of $f_{\max}$ for 25 Mc/s radiation, as the cross section for absorption decreases so rapidly with height. Even very small ionization in the very lowest part of the ionosphere might give as much absorption as attributed to ionization above $f_{\max}$ level. Is really the accuracy in the knowledge about the ionization in the very low ionosphere good enough to rule out the possibility of the absorption being produced there?

Piggott, W. R.: The absorption coefficient depends on not only the product of electron density and the collisional frequency but also refractive index. The point is very much denser ionization in F region than D and E. Therefore, the refractive index is relatively low in F region.

Sarabhai, V. A.: Yes, the frequency is not all that above the critical frequency.

Knecht, R. W.: Regarding Dr. Hultqvist's comment, I should think one would expect a greater amount of deviative absorption to occur in the region just above the F layer maximum compared to the region just below because of the considerably lower electron density gradient on the topside.

JOURNAL OF THE PHYSICAL SOCIETY OF JAPAN Vol. 17, SUPPLEMENT A-I, 1962
INTERNATIONAL CONFERENCE ON COSMIC RAYS AND THE EARTH STORM Part I

I-5-7. Vertical Travelling Disturbances in the Ionosphere*

N. M. BOENKOVA and J. A. KUSHNEREVSKY
Soviet Geophysical Committee, Molodezhnaya 3, Moscow B-296, U.S.S.R.

An attention of a number of ionosphere investigators[1)–5)] has long ago been drawn to the appearance on $h'f$ records of unusual separations, which begin near critical frequencies of $F2$ layer and then displace to the low frequency end of F-trace. The presence of such separations shows the appearance of ionospheric irregularities of electron concentration. This paper considers some preliminary results of investigation of vertical travelling disturbance in the ionosphere, obtained by the data of the Moscow station of vertical sounding for 1958.

While investigations ionograms for RWD and SWI for winter, summer and equinox months were considered. For the days where they observed evident vertical travelling disturbances, f- and h-graphs were built. As a rule, ionograms, recorded in five minute interval, were used. Consider the case of the appearance of travelling disturbances, observed on 25 March 1958 at the Moscow station. Fig. 1 gives f- and h' -graphs for

* This paper was read by N. V. Pushkov.

this day. For these graphs standard symbols, adopted during the IGY, were used. Because of the fact that travelling disturbances are seen on the ionograms as additional separations on *F*-trace, which is very like *F1* layer appearance (it is usually interpreted in this way), we shall give him. The same symbols as for *F1* layer.

As it is seen from Fig. 1, disturbances began to appear at about 07^h45^m. and periodically repeated up to 16^h00^m. Disturbances appearance is obligatory accompanied by a change (though small) of normal variation of *F2* layer critical frequencies. When the disturbance goes to the lowest boundary of *F2* layer, minimum virtual heights of *F2* layer somewhat increase.

At *E* layer heights the irregularities dissipates and this often causes stronger absorption that is seen by the corresponding

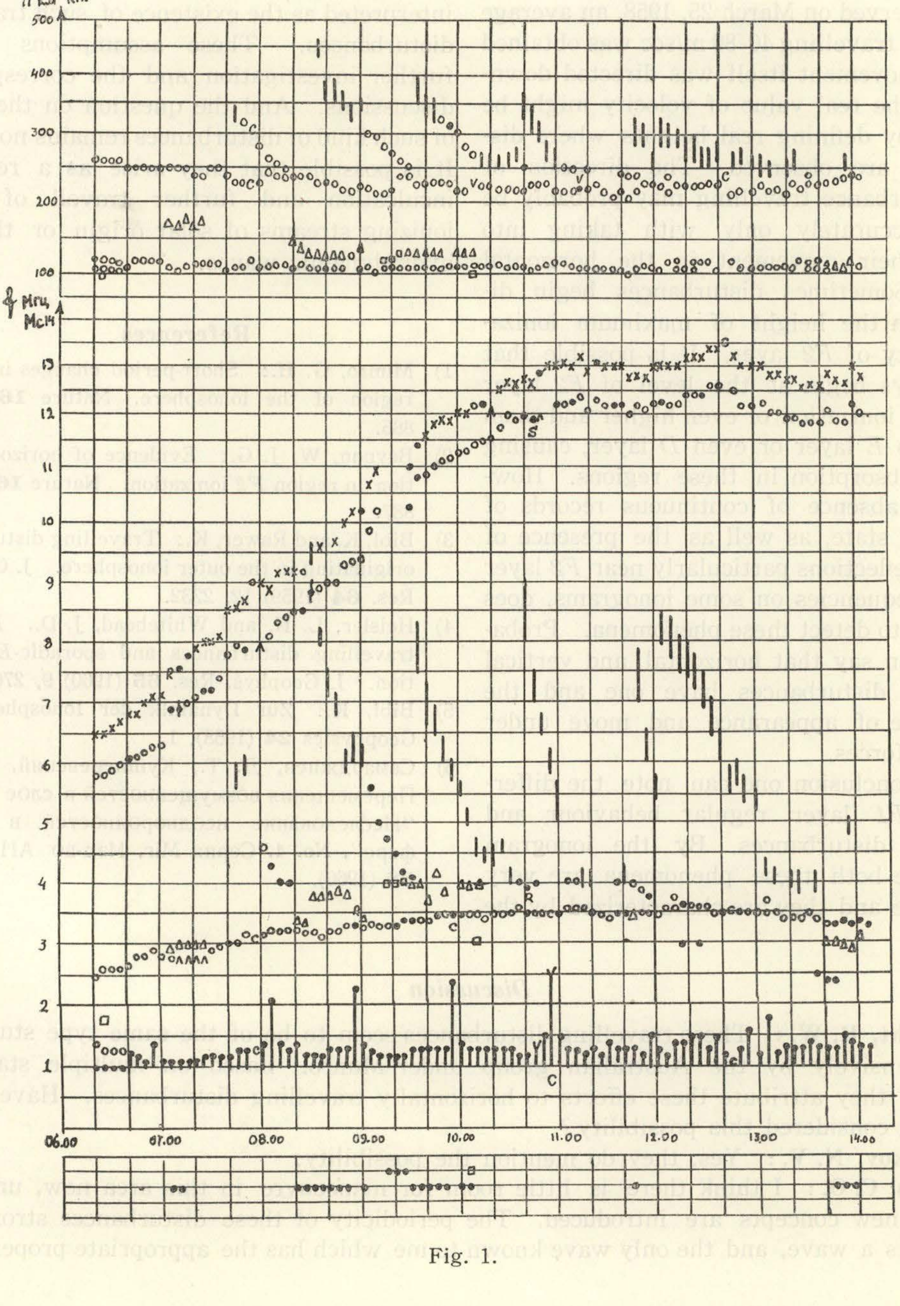

Fig. 1.

increase of f_{min}. Sometimes, a disturbance causes an appearance of additional separations in *E* layer or *Es* of different types. After the disappearance of such irregularity or even a little earlier the whole process of disturbance may be repeated. The period of disturbance displacement from the moment of appearence to their disappearance are 40-70 minutes. Knowing the time of movement of irregularities and the heights where they are observed, one can calculate apparent velocity of their displacement. For the cases, observed on March 25, 1958, an average velocity of travelling 40-80 m/sec was obtained and the movement itself was directed downwards. The real value of velocity might be obtained by defining real heights where disturbances are observed. The direction of such disturbance travelling may probably be defined accurately only with taking into account their movement in the horizontal plane[6]. Sometimes disturbances begin directly with the height of maximum ionization density of *F2* layer. It is possible that they always begin at the level of *F2* layer maximum ionization or even higher and them fall low to *E* layer or even *D* layer, causing stronger absorption in these regions. However, the absence of continuous records of ionosphere state, as well as the presence of no clear reflections particularly near *F2* layer critical frequencies on some ionograms, does not allow to detect these phenomena. Probably one can say that horizontal and vertical travelling disturbances have one and the same cause of appearance and move under the same forces.

In the conclusion one can note the difference of *F1* layer regular behaviour and travelling disturbances. By the ionogram appearance both these phenomena are very much alike and they are characterized by the appearance of additional seperations in *F* layer of ionosphere. *F1* layer critical frequencies, beginning at the low-frequencies end *F*-trace in the afternoon reaches its maximum value and then decreases again returning to lower frequencies. At the same time travelling disturbances, as a rule, arise near the critical frequences of *F2* layer and in the course of time displace to lower frequencies. Consequently, behaviour irregularities of normal summer *F1* layer and the appearance of winter *F1* layer may be interpreted as the existence of such travelling disturbances. These assumptions require further investigation and the corresponding discussions. And the question on the origin of such kind of disturbances remains non-clear. It is possible that they arise as a result of inculcation and further travell of small ionizing streams of solar origin or they are hydrodynamic waves.

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Discussion

Knecht, R. W.: These travelling disturbances seem to be of the same type studied so extensively by the Australian group under Munro. Based on multiple station studies, they attribute these effects to horizontally travelling disturbances. Have the authors considered this possibility?

Pushkov, N. V.: Yes, they do mention the possibility.

Hines, C. O.: I think there is little room for manoeuvre in this area now, unless totally new concepts are introduced. The periodicity of these disturbances strongly suggests a wave, and the only wave known to me which has the appropriate properties is an internal atmospheric gravity wave. Such waves are capable of explaining a large part of the pertinent observational data, and no serious inconsistency is known to me. Unless some other theoretical approach can come close to the degree of success, I see no reason for deviating from a gravity wave interpretation. The wave energy, incidentally would be going obliquely upwards even though the phase surfaces (which would be the observables, in a radio experiment,) are coming obliquely downwards. Dr. Axford has a paper in press (Can. Jour. Phys.) which points out that, in combination with the geomagnetic field, these waves could not only distort ionization but also transport ionization downwards. This would explain the descending ledges of ionization below the main *F* layer which are often observed in statistical association with *F*-region travelling disturbances including in particular "sequential spread-*F*".

Ratcliffe, J. A.: Is there any indication that these movements are associated with a horizontal movement?

Agy, V.: Isn't the fact that these disturbances appear first on the ordinary component a good indication of a strong horizontal component in the motion?

Dungey, J. W.: It is meaningless to say that these disturbances are moving horizontally, you can only discuss the wavefronts.

Nakata, Y.: From our continuous *h'f* observation there are following evidences: such a phenomenon of kink moving down on *h'f* occurs in all season, but its moving up occurs usually in winter. And also it is interesting that time difference of its appearance in ordinary and extra-ordinary components is seen and its diurnal variation is also shown. From these, it might be suggested that the discontinuity of layer in the ionosphere moves horizontally.

Maeda, K.: I could not quite realize how the plots in your slide was reduced from the actual ionogram record. Could you show me an example of ionogram record? (Mr. Shapley drew a picture on blackboard.)