A Comparison of the Electron Density Variations in the F2 Region at Kokubunji and Yamagawa during the Night

By T. YONEZAWA

Central Radio Wave Observatory

Abstract

By comparing the electron density variations in the F2 region during the night at Kokubunji and Yamagawa it has been made clear that, if we assume a linear law of electron disappearance and somewhat higher temperature of the upper atmosphere at Yamagawa than at Kokubunji, the observational data fit theoretical expectation rather well, but a quadratic law can hardly be reconciled with the observations, unless recombination coefficient changes markedly with height.

1. Introduction

In a previous report⁽¹⁾ we made an analysis of the electron density variations during the night at Kokubunji and at Washington and revealed that electrons disappear more probably according to a linear law rather than a quadratic one. We have now made a further study along the same line by comparing the electron density variations in the F2 region during the night at two sites separated not very far from each other, namely at Kokubunji (35°42.4' N, 139°29.3' E) and at Yamagawa (31°12.5' N, 130°37.7' E), and the conclusion of the previous paper has again been confirmed. As a by-product we have also obtained a result that the upper atmospheric temperature above Yamagawa is probably somewhat higher than that above Kokubunji.

2. Method

The electron density variation during the night is governed by the following equation, if we adopt the linear law of electron disappearance :

$$\frac{1}{N} \frac{dN}{dt} = -B_0 e^{-\frac{z_m - z_0}{H}} - \frac{1}{T} \frac{dT}{dt}, \quad (1)$$

where N is the electron density, t is the time, B_0 is the attachment coefficient multiplied by the density, at a standard height z_0 , of atoms and molecules to which electrons attach themselves, z_m is the height of the level considered, H is the local scale height and T is the absolute temperature. In the following we shall take the maximum electron density of the F2 region as N and h_p as z_m . Writing down Eq. (1) for Kokubunji and Yamagawa and taking the differences of the both sides, we obtain

$$\frac{d}{dt} \ln \frac{N_2}{N_1} = -B_0 \left(e^{-\frac{z_{m2} - z_0}{H_2}} - e^{-\frac{z_{m1} - z_0}{H_1}} \right) + \text{const.}$$

$$\simeq B_0 \left(\frac{z_{m2}}{H_2} - \frac{z_{m1}}{H_1} \right) - B_0 z_0 \left(\frac{1}{H_2} - \frac{1}{H_1} \right) + \text{const.}, \quad (2)$$

where we have assumed that the *relative* temperature variation is the same at both sites (in this case, $\text{const.}=0$) or the temperature decrease is exponential, and where the letters with subscripts 1 and 2 denote the quantities at Kokubunji and Yamagawa, respectively; B_0 is also assumed to be the same at the both stations.

Now, if the difference between H_1 and H_2 is not large compared with H_1 and H_2 themselves we can replace H_1 and H_2 with their average value $\bar{H}$ in Eq. (2) to a very rough approximation and obtain

$$\frac{d}{dt} \Delta \ln N \simeq \frac{B_0}{\bar{H}} \Delta z_m + \text{const.}, \quad (3)$$

$$\Delta z_m \equiv z_{m2} - z_{m1}, \quad (4)$$

$$\Delta \ln N \equiv \ln N_2 - \ln N_1. \quad (5)$$

Eq. (3) shows that there should be a linear relation between $\frac{d}{dt} \Delta \ln N$ and Δz_m , if time variation of $\bar{H}$ (or H_1 and H_2) is neglected. This is roughly the case as will be described in the next section, which seems to indicate that the method of analysis here adopted is not very unreasonable.

On the other hand, if electrons disappear by recombination, we shall be led to the following equation by a similar analysis:

$$\frac{d}{dt} \Delta \ln N \simeq -\alpha \Delta N + \text{const.}, \quad (6)$$

$$\Delta N \equiv N_2 - N_1, \quad (7)$$

where α is the recombination coefficient which is assumed not to change markedly with height, as may be expected on theoretical grounds. But Eq. (6) can not be verified by observation (cf. § 3).

Having thus established the approximate correctness of our analysis, we have then fitted Eq. (2) to observational data. If time variations of H_1 and H_2 are neglected as before, Eq. (2) becomes

$$\frac{d}{dt} \Delta \ln N \simeq \frac{B_0}{H_2} z_{m2} - \frac{B_0}{H_1} z_{m1} + \text{const.} \quad (8)$$

Using the observational data of $\Delta \ln N$, z_{m2} and z_{m1} , we can determine the most probable values of parameters B_0/H_1 and B_0/H_2 by the method of least squares, and from these we can obtain the ratio between the absolute temperatures of the upper atmosphere above Kokubunji and Yamagawa, for the scale height H is proportional to the absolute temperature.

3. Results and discussions

Using median values of observational data for respective months we have calculated the values of $\frac{d}{dt} \Delta \ln N$ by numerical differentiation and plotted them (abscissa) against Δh_p (ordinate) in Fig. 1, (a)–(f) for some months in 1949. The

Fig. 1 (a) January, 1949

Fig. 1 (b) February, 1949

Fig. 1 (c) March, 1949

Fig. 1 (d) June, 1949

scales of both axes are arbitrary; the numbers attached to respective points in the figures show the hours of observation (J.S.T.).

We can see from these figures that in winter these points arrange themselves roughly along straight lines, with the exception of points corresponding to hours near sunrise or sunset. This exception is not surprising in view of the fact that we can not obtain accurate values of $\frac{d}{dt}\Delta \ln N$ by numerical differenti-

ation near sunrise or sunset (especially near the former) owing to the rapid change in slope of the diurnal variation curve of electron density. On the other hand, linear relation does not so well hold between $\frac{d}{dt}\Delta \ln N$ and Δh_p for other seasons.

It seems that this is, on the one hand, because the height determination in the ionospheric sounding is subject to not small errors, sometimes as high as 10km., so that the difference in height between two stations may be, in unfavourable cases, in error by about 20km., but, on the other, because height

Fig. 1 (e) September, 1949

Fig. 1 (f) December, 1949

(6). So an examination was made of this relation, and an example of its results is shown in Fig. 3 (February, 1949). We can see from the figure that the points are scattering more widely than in the corresponding Fig. 1 (b). But, what is more important, the correlation, if existing at all, is rather positive than negative, which contradicts the expectation from Eq. (6). Thus we can hardly support the recombination theory for electron dissipation during the night.

Entering into more details, we have then fitted Eq. (8) to observational data and determined the most probable values of B_0/H_2 and B_0/H_1 . In view of the above described facts, good results will not be expected except for winter. This was indeed the case. But in no case we have obtained

change of the F2 layer is not very great in seasons other than winter. In view of these disturbing factors it will not be far from truth that the linear relation between $\frac{d}{dt}\Delta \ln N$ and Δh_p is also existing for seasons other than winter. An evidence for this may be provided by the fact that, if we take a weighted running average of h_p instead of h_p itself for each hour, the linear relation becomes much more clear as shown in Fig. 2 for June, 1949.

Now, if recombination theory is correct, there must be a linear relation between $\frac{d}{dt}\Delta \ln N$ and ΔN , and the correlation must be negative, as shown in Eq.

Fig. 2 June, 1949
(Weighted running mean of Δh_p is used)

very unreasonable values, such as negative ones, for these parameters. The ratio

Fig. 3 February, 1949

that the result of analysis indicates higher upper atmospheric temperatures at Yamagawa ($31^{\circ}12.5'N$) than at Kokubunji ($35^{\circ}42.4'N$), which is consistent with our expectation.

4. Conclusion

Thus the comparison of nocturnal electron density variations at Kokubunji and Yamagawa showed that electrons disappear in the F2 region according to a linear law rather than a quadratic one, and the temperature of the upper atmosphere is somewhat higher at Yamagawa than at Kokubunji. But, in view of the limit of accuracy of height determination in ionospheric sounding, we can not hope to draw any quantitative deductions from such an analysis, and we must wait until more accurate data become available.

[1] T. Yonezawa, Rep. Ionosphere Res. Japan, 5, 1 (1951)

$H_2:H_1$ was 1.8, 1.6, and 2.0 for January, February, and December, 1949, respectively. In other seasons also this ratio had a tendency to be larger than 1, the average of all (including the above mentioned) being 1.9. Though we it can not place much weight on these figures, it is interesting to note