1.Classification INPE.COM.10/PE
CDU: 550.388.2

2.Period
December 1978

4.Distribution Criterion
internal ☐
external ☒

3.Key Words (selected by the author)
Ionosphere,
Dynamics of the Ionosphere,
Incoherent Scatter,
Airglow.

5.Report No.
INPE-1410-PE/189

6.Date December 1978

7.Revised by
Mangalathayil Ali Abdu

8. Title and Sub-title
A SEMI-EXPERIMENTAL ESTIMATION OF THE LOCATION OF THE F-REGION MAXIMUM INTENSITY EMISSION LAYER

9.Authorized by
Nelson de Jesus Parada
Director

10.Sector DCE/GIO Code 30.371

11.No. of Copies 18

12.Authorship J.H.A. Sobral
C.J. Zamlutti

14.No. of Pages 12

15.Price

13.Signature of first author Jose' Sobral

16.Summary/Notes

About 232 electron density profiles obtained by the incoherent scatter radar facility at Arecibo ar used here to make a statistical estimation of the location of the F-region OI 63000Å maximum intensity emission layer. These experiments were carried out during six nights and the electron density profiles obtained were used to construct the 6300 Å emission profiles which, in turn, provided the height of the maximum intensity emission layer. Calculation of the emission profile utilized also the observed red line intensity in order to determine the neutral profile which would yield the observed airglow intensity as observed from the ground. The results show that the maximum intensity emission layer is located, on an average, at about 56 km below the electron density peak. This difference between peaks is, as claimed by some authors, comparable to one average scale height, which is about 50 km, near the electron density peak. Some other dynamical features of the maximum intensity emission layer are also commented.

17.Remarks This work was partially supported by "Fundo Nacional de Desenvolvimento Cientifico e Tecnológico (FNDCT)", Brazil under contract FINEP-CT/271.

A SEMI-EXPERIMENTAL ESTIMATION OF THE LOCATION OF THE F-REGION MAXIMUM INTENSITY EMISSION LAYER*

by

J.H.A. Sobral and C.J. Zamlutti
Instituto de Pesquisas Espaciais - INPE
Conselho Nacional de Desenvolvimento Científico e Tecnológico - CNPq
12200 São José dos Campos, SP

ABSTRACT - About 232 electron density profiles obtained by the incoherent scatter radar facility at Arecibo are used here to make a statistical estimation of the location of the F-region OI 6300Å maximum intensity emission layer. These experiments were carried out during six nights and the electron density profiles obtained were used to construct the 6300 Å emission profiles which, in turn, provided the height of the maximum intensity emission layer. Calculation of the emission profile utilized also the observed red line intensity in order to determine the neutral profile which would yield the observed airglow intensity as observed from the ground. The results show that the maximum intensity emission layer is located, on an average, at about 56 km below the electron density peak. This difference between peaks is, as claimed by some authors, comparable to one average scale height, which is about 50 km, near the electron density peak. Some other dynamical features of the maximum intensity emission layer are also commented.

---

* *This work was partially supported by "Fundo Nacional de Desenvolvimento Científico e Tecnológico (FNDCT)", Brazil under contract FINEP-CT/271.*

INTRODUCTION

The dynamics of the nighttime ionosphere has been extensively studied by means of the atomic oxygen emission at $\lambda = 6300$ Å (Cogger et al., 1974; Fukuyama, 1976; Skinner et al., 1977; Sobral et al., 1978 and many other papers). If the ionospheric plasma goes down (up) in altitude, the red ($\lambda = 6300$ Å) line intensity becomes more (less) intense. Therefore the zenith intensities of the red nightglow versus time well represent, in general, the time progress of the vertical component of the ionospheric plasma displacements. Consequently, ground based scanning measurements of such emission should provide information about time and space progress of the vertical motions of the ionospheric plasma, over the scanned region. The spatial nightglow patterns, resulting from such measurements, have significantly helped the study of the dynamics of the nighttime ionosphere. Whenever wave patterns of the OI 6300 Å intensity appear on the scanning data, the first thing that comes to one's mind is to measure their period, wavelength and horizontal trace speed. In general, the atomic oxygen red line is assumed to stem from a thin emitting layer located below the F-region peak, at an altitude that is generally quoted in the literature as "reference altitude", to which the horizontal trace speeds and disturbances of the nightglow are referred. Therefore, the estimated wavelengths and velocities depend upon the chosen reference altitude. On the other hand, the reference altitude cannot be directly determined by photometers placed on the ground. The choice of this altitude affects the measurements of the wave paramenters as in the following example: one given nightglow disturbance observed to travel a zenith distance of 150^{0} (centered at zenith) has its horizontal trace speed of either v_{250} or $v_{300} \approx 1.17\ v_{250}$ depending on whether the reference altitude is 250 km or 300 km, respectively. In the case of the OI 6300 Å nightglow the reference altitude of 300 km is mostly adopted because, perhaps, this is a typical height of the nighttime electron density peak. However, since the maximum emission layer is located a couple of tens of kilometers below the electron density peak, the estimated wavelength and trace speed will be somewhat uncertain. The reference level is always referred to the electron density peak (rather than to the ground) due to the fact that both these levels generally move in phase.

The availability of an extensive set of accurate incoherent scatter electron density data with the concurrent measurements of the OI 6300 Å nightglow prompted us to undertake the present work. Further, no similar estimation of the height of the maximum intensity emission layer has previously been made, as far as the authors are aware, in spite of the significance of such studies to the accuracy factors involved in determining the parameters of the propagating disturbance, using the scanning photometer. The airglow and incoherent scatter discussed here have been obtained during the following six nights: October 2-3, 1970 and March 26-27, March 31 - April 1, June 2-3, June 16-17 and June 30 - July 1, all in 1971. In the discussion to follow we will be using h' and h" to represent the heights of the F-layer peak and the maximum intensity emission layer, respectively.

THE EXPERIMENTAL DATA

The electron density data were obtained by means of the incoherent scatter radar facility at Arecibo, Puerto Rico. Electron density measurements were taken at 11-12 km height intervals, covering a height range from about 160 or 180 km to 400 km and a complete profile was taken every 10 minutes. The accuracy of the electron density measurements is of the order of 5%.

The red (λ = 6300 Å) airglow data was obtained by means of a tilting filter photometer whose view angle is 5^{o}. Its line of sight was set at zenith for all measurements.

PARAMETERS USED

The integrated emission intensity for the OI 6300 Å line (I_{6300}) is given, in Rayleighs, by the following expresion:

$$I_{6300} = 10^{-1} \int_{0}^{\infty} \gamma_1 \, R \left[\frac{A_{6300}}{A+Q[N_2]} \right] [O_2] \; [e] \; F\,(h)\; dh$$

where h is in km and the particle concentration in cm^{-3}. We shall omit the definition of every term in the above equation. Each of them is described in detail by some authors (Peterson et al. 1969; Wickwar et al. 1974). Following, are the parameter values used in this work:

$R = 0.45$ (Zipf, 1970)

$$F = \frac{[O^+]}{[e]} = \frac{1}{1 + \frac{\gamma_1 [O_2]}{\alpha_1 [e]} + \frac{\gamma_2 [N_2]}{\alpha_2 [e]}}$$

$$\alpha_1 = 1{,}95 \times 10^{-7} \left(\frac{300}{T_n(n)}\right)^{0.7} cm^3\ sec^{-1}$$ (Mehr and Biondi, 1969)

$$\gamma_1 = 3{,}5 \times 10^{-10}\ T_n(h)^{-0.45}\ cm^3\ sec^{-1}$$ (Smith and Fouracre, 1968)

$$\alpha_1 = 4{,}1 \times 10^{-7} \left(\frac{300}{T_n(h)}\right) cm^3\ sec^{-1}$$ (Zipf, 1970)

$$\gamma_2 = 2 \times 10^{-12}\ cm^3\ sec^{-1}$$ (Fite, 1969)

$A = A_{6300} + A_{6392} + A_{6364}$ (where the A's are the Einstein's coefficients)

DISCUSSION

Height profiles of the OI 6300 Å emission were calculated in order to determine the values of h" to be used in our statistical study. The calculation was carried out using the electron densities at five km intervals (obtained from the interpolation of the measured values) and integrating the uniform emission rate in this height interval. The resulting airglow intensity for each height interval was then used to represent the intensity at the midpoint of these intervals and thus has an error of ± 2.5 km in height. In calculating these airglow profiles, only one neutral profile was used for each night and chosen so as to make the predicted airglow values to coincide with the observed ones.

Table 1 displays the exospheric temperatures utilized in the calculations of each night. Such temperatures are indexes of the Jacchia (1971) profiles. The electron density and airglow data used in this work were selected from the time periods during which the calculated and observed airglow intensities coincided within the arbitrarily chosen limit of 10%. Considering that the neutral profile was assumed constant during the night, a natural consequence of adopting such an error bar is that near-sunset and near-sunrise data were automatically discarded from our statistics because during these periods of time the differences between calculated and observed airglow becomes rapidly larger with time. Such difference arises because for solar zenith angles between 105° and 95° the production of $O(^1D)$ atoms generated by photolysis of O_2 in the Schumann-Runge continuum (1300-1750 Å) becomes relevant. For solar zenith angles less than about 90°, most of the $O(^1D)$ population is generated by the photoelectron excitation of oxygen atoms.

In the following, the neutral atmosphere scale heights corresponding to the altitude of the electron density peak are compared with the differences h'-h". Such a height difference has already been supposed to be comparable with the F-region scale height (Carlson, 1972). The scale heights used here are taken from the Jacchia (1971) atmospheric model. For convenience of the discussion we shall use the following notation:

ΔH = h' - h"

SH = scale height of the neutral atmosphere at the level of the electron density peak

$M_{\Delta H}$, M_{SH} = time average of ΔH and SH, respectively, considering one night of experiment

$\tau_{\Delta H}$, τ_{SH} = standard deviations of ΔH and SH, respectively, considering one night of experiment.

Table 1 shows the values of these parameters, as obtained in this work. The values of $\tau_{\Delta H}$ shown in the table are apparently large, mainly because ΔH varies considerably during the very large descents and ascents of the ionospheric plasma that commonly occur over Arecibo during the post-midnight hours, as are illustrated in the h' curves plotted in Figure 1. The causing mechanisms of such large descents will not be discussed here but the reader may refer to Behnke and Kohl (1974) or to Sobral et al. (1978).

Table 1 also shows that the average value of $M_{\Delta H}(\overline{M}_{\Delta H})$ is in fact comparable to the average value of $M_{SH}(\overline{M}_{SH})$. Notice in this table that, for the cases where the exospheric temperature is equal to 900^{o}k, we get $M_{\Delta H} > M_{SH}$, and in the case of higher exospheric temperatures we get $M_{\Delta H} < M_{SH}$. This indicates that the scale height increases more rapidly with temperature than ΔH does.

Figure 1 clearly shows the in-phase oscillation of ΔH and h' and there we see that h", on an average, is located some 40 to 60 km below h'. The smooth variation of the scale height curve in this figure is due to the use of a single atmospheric profile during one hight of experiment. It may be noticed that ΔH varies by large magnitudes during the events marked as ionospheric descents in Figure 2. During the periods of large descents it may not be practical to consider the ΔH variations, for the purpose of determining the height of the emitting layer, because it would considerably complicate the geometry to infer horizontal trace speed and wavelengths of the nightglow disturbances.

CONCLUSIONS

Utilizing accurate and extensive incoherent scatter electron density data, plus atomic oxygen 6300 Å intensity data, we have estimated the location of the OI 6300 Å maximum intensity emission layer to be, on an average, around 56 km below the nighttime F-region peak. The values of ΔH (the distance between the F_2 peak and the maximum intensity emission layer) have shown large variations as compared with the scale height values during some nights, when large ionospheric descents occurred. However, the <u>average</u> ΔH over about 232 values is indeed of the same order of magnitude as the analogous <u>average</u> of the scale height, 51 km, of the neutral atmosphere at the altitude of the electron density peak.

During the large descents of the ionosphere, the distance between the electron density peak and the maximum intensity emission layer follow the h' variations. Therefore, it doesn't seem practical to consider the ΔH variations, during these periods, in calculating horizontal trace speeds or wavelengths because of the complications involved in the geometric shape of the emitting layer.

Acknowledgements - The authors are indebted to V.B. Wickwar and R.B. Harper who made the incoherent scatter data available and also to M.A. Abdu for his useful comments on this work. This work has been jointly supported by Cornell University and the Instituto de Pesquisas Espaciais (INPE-the Brazilian Space Comission).

REFERENCES

Behnke R. and Kohl H.	1974	J.Atm.Terr.Phys.36.325
Cogger L.L.,Wickwar V.B. and Carlson H.C.	1974	Radio Sci.9,205
Fite W.L.	1969	Can.J.Chem.47,1797
Fukuyama K.	1976	J.Atm.Terr.Phys.38,1279
Jacchia L.G.	1971	Smithsonian Astrophys.Obs.Cambridge Spec.Rep.nº332
Mehs F.J.and Biondi M.A.	1969	Phys.Rev.181,264
Peterson V.L.,VanZandt T.E. and Norton R.B	1969	J.Geophys.Res.71,1715
Skinner N.J.,Carman E.H. and Heeran M.P.	1977	J.Atm.Terr.Phys.39,1395
Smith D. and Fouracre R.A.	1968	Planet.Space Sci.16,243
Sobral J.H.A., Carlson H.C.,	1978	J.Geophys. Res.83,2561
Zipf E.C.	1970	Bull.Am.Phys.Soc.15,418

Wickwar V.B.,Cogger L.L. and Carlson H.C. 1974 Planet.Space Sci.122,709

Reference is also made to the following unpublished material

Carlson H.C. 1972 Private communication

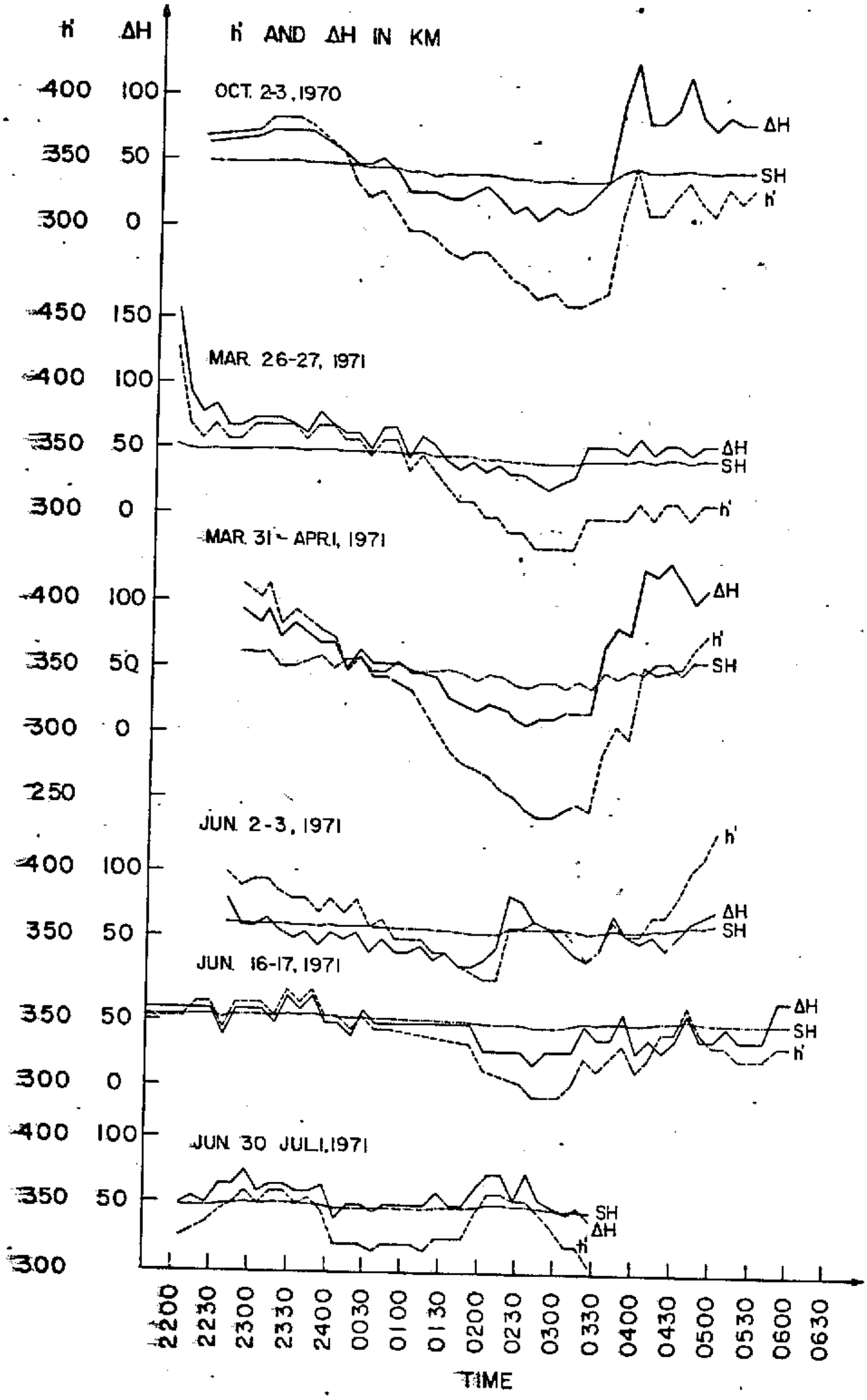
FIGURE AND TABLE CAPTIONS

Figure 1 - Time variation of h', SH and ΔH (see definitions in the text) at Arecibo, Puerto Rico. Notice the large post-midnight descents of h' which are typical of the nighttime dynamics of the ionosphere over Arecibo.

Table 1 - Days of the experiments, their respective number of electron density profiles, the results for $M_{\Delta H}$, $\overline{M}_{\Delta H}$, M_{SH}, $\overline{M}_{SH}$, $\tau_{\Delta H}$, τ_{SH} (see definitions in the text) and the exospheric temperatures used.

TABLE I

DAY	NUMBER OF ELECTRON DENSITY PROFILES	$M_{\Delta H} \pm \tau_{\Delta H}$ (KM)	$M_{SH} \pm \tau_{SH}$ (KM)	EXOSPHERIC TEMPERATURE (^{o}K)
OCTOBER 2-3,1970	38	56.± 31	46 ± 4	900
MARCH 26-27,1971	43	59 ± 22	48 ± 3	900
MARCH 31-APRIL 1,1971	35	61 ± 37	51 ± 7	900
JUNE 2-3,1971	39	53 ± 14	59 ± 2	1100
JUNE 16-17,1971	44	48 ± 13	53 ± 2	1000
JUNE 30-JULY 1,1971	33	57 ± 10	48 ± 1	900
AVERAGES	(Total = 232)	$\overline{M}_{\Delta H} = 56 \pm 21$	$\overline{M}_{SH} = 51 \pm 3$	-


h′
ΔH
h′ AND ΔH IN KM
OCT. 2-3, 1970
MAR. 26-27, 1971
MAR. 31 – APRI, 1971
JUN. 2-3, 1971
JUN. 16-17, 1971
JUN. 30 JUL.1, 1971
400 100
350 50
300 0
450 150
400 100
350 50
300 0
400 100
350 50
300 0
250
400 100
350 50
350 50
300 0
400 100
350 50
300
ΔH
SH
h′
2200
2230
2300
2330
2400
0030
0100
0130
0200
0230
0300
0330
0400
0430
0500
0530
0600
0630
TIME