Letter to Editor

CONCERNING THE OUTER IONOSPHERE AND ITS TRANSITION INTO THE INTERPLANETARY MEDIUM

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THE notions concerning the outer part of the earth's ionosphere have been greatly altered during the last ten years, owing to the large number of new experiments performed mostly with the aid of rockets and artificial earth satellites. Therefore the review "The Outer Ionosphere and Its Transition into the Interplanetary Medium" by Ya. L. Al'pert, published in Usp. Fiz. Nauk [1], would be welcome were it not for its errors, statements made without proof, and its bias.

Let us indicate some of the errors.

1. We begin with Sec. 5, which is devoted to the most important problem of the origin of the outer ionosphere, and in which the ionization balance is described. Indicating that the boundary of ionosphere occurs at altitudes (3–3.5) R_0 (R_0 is the earth's radius)*, the author states: "With such a definition of the boundary of the ionosphere, it becomes apparently possible to describe the ionization balance by a single equation for the formation of the ionosphere, which will be considered in Sec. 5" (p. 409 [transl. p. 790]). Yet in [1] the equations for the ionization balance (26) were obtained in the usual manner from the kinetic equation (see, for example, [2,3]), for which purpose it is necessary to know the upper boundary of the ionosphere. The main conclusion drawn by Al'pert from his analysis is the trivial statement that it is necessary to know the distribution function.

On the other hand, a new statement in this section is that the ionization in the outer ionosphere, up to its upper boundary, "is due to incident ultraviolet radiation, and the annihilation of the particle is via photorecombination and electron adhesion" (p. 432 [transl. p. 803]). It is well known that actually photoionization due to ultraviolet radiation occurs principally in the region lower than 250 km (see, for example, [4,5]), and that electron adhesion takes place at altitudes lower than 100 km (there are practically no negative ions higher than that; see, for example, [6]). The outer ionosphere at altitudes above 1000 km consist essentially of hydrogen ions, which are produced here principally not as a result of photoionization, but by diffusion along the magnetic force tubes from the ionosphere regions lying below 500–1000 km, where the intense proton production is due to charge exchange of hydrogen atoms with oxygen ions [7], $H + O^+ \rightleftarrows H^+ + O$. Thus, Alpert explains incorrectly the origin of the ions in the outer ionosphere, ascribing to it ion-production mechanisms which are effective in the lower ionosphere.

2. In page 409 [transl. p. 790] of [1] it is stated that "the region of the non-stationary state of the near-earth plasma (above (3–3.5) R_0) is the upper part of the magnetosphere. It is here that the magnetic field of the earth begins to break up even under undisturbed conditions, inasmuch as frequently $H_0/8 \sim (N_0 M v_0^2/2)$. At a distance (8–10) R_0 from the earth, as is well known, the regular magnetic field of the earth plays already a minor role, with fields of fluctuation type prevailing." This statement, made incidentally without literature references, is incorrect. It is known from results of measurements performed with the aid of rockets and satellites that the regular magnetic field is observed up to distances (8–10) R_0 (see, for example, [8]) in the direction towards the sun, and to much larger distances in the opposite direction (in the so-called "tail" of the magnetosphere) [9].

3. It is stated in p. 410 [transl. p. 791] that the average altitude variation of the electron density $N(Z)$, is obtained by measurements made with the aid of coherent radio waves from satellites [10,11], has additional maxima which lie near the maximum of the F region (see curves 18 and 19 of Fig. 1 of [1]), and "the nature of these maxima is not clear."

The nature of these maxima was analyzed in [12], a fact about which Al'pert is silent, and is explained by means of an erroneous interpretation of the primary data in [10,11] (in particular, the plots of $N(Z)$ were constructed using values of N obtained in different days, in different times of the day, and over geographic locations separated by hundreds of kilometers; this, taking into account the variability of the ionosphere in space and in time, is meaningless). We therefore see no grounds for connecting the nonexisting additional maxima with the "complicated dynamics of the upper atmosphere," as does Al'pert.

4. On pp. 429 and 430 [transl. pp. 801 and 802] of [1] are shown spectra of the dimensions of ionospheric inhomogeneities and fluctuations of the electron concentration of these inhomogeneities, which for some reason are credited to the Gor'kii group (E. A. Benediktov, G. G. Getmantsev, N. A. Mityakov et al. [13]), although actually these spectra are con-

*We use the notation of [1] throughout.

tained neither in the cited paper nor in other papers by these authors. In this connection, the method of obtaining the inhomogeneity spectra shown in Figs. 15 and 16 of [1] is not clear, although it is noted that they were obtained by "analyzing the fluctuations of the difference of the Doppler frequency shifts $\delta\Phi$" of radial waves emitted from the "Elektron" satellite. We note that if this refers to the method described by Ya L. Al'pert in 1965 [14], then the inconsistency of this method was demonstrated in [12].

5. Al'pert states that there are no methods for determining the potential of a space ship in the ionosphere. Thus, he says on p. 427 [transl. p. 800]:"... not only is the potential of the body unknown during the time of the measurements, but there are even no sufficiently accurate methods of its determination." It is not clear from this statement whether the potential of the body is unknown during the time of the measurements, or whether it is measured but with insufficient accuracy. The criterion of sufficiency of the accuracy is not indicated in this case. At the same time, methods of determining the potentials of satellites exist and are reported in a number of known papers (for example [16,17]), and the values of the potential were measured in different regions of the ionosphere [15,16].

6. Casting doubts on the possibility of probe measurements in the ionosphere, Al'pert makes (pp. 414–415 [transl. p. 793] many far-fetched assumptions concerning the physical properties of the outer ionosphere, namely those based on probe measurements made with the satellite OGO-A. and described in the paper of Sagalyn and Smidd.* According to the data on the fluxes of positive ions $(\overline{Nv})_i$, the ion density N_i, and the electron fluxes $(\overline{Nv})_e$ (apparently recalculated to refer to the unperturbed ionosphere), it is assumed that there is no quasineutrality and an intense electric field $E_0 \sim 10^{-2}$ V/cm exists at distances from 20,000 to 160,000 km from the earth. In spite of the fact that these authors themselves, as follows from [1], were unable to obtain information on the electron density from their own primary data.

It is not clear from [1] how it is possible to determine the electron and ion fluxes in the unperturbed ionosphere from satellite measurements without information concerning the satellite potential (the determination of which is assumed in [1] to be impossible; see our preceding remark 5).

7. It is stated in pp. 426–427 [transl. p. 800] that there are no rigorous theoretical formulas which relate functionally the measured ion current I with N_i, and that at altitudes ~2000 km the formula frequently used for $V_0/v_i \gg 1$, namely $I = SeN_iV_0$ (S—effective area of the instrument, V_0—velocity of space probe) is not valid.

Actually, there are formulas more rigorous than those presented in [1], which establish the connection between the ion density and the current I measured in the instrument, with allowance for the thermal pressure of the ions (see, for example, [15,16,18,19])*, and which are indeed used in the reduction of the experimental data (for example [16,20]).

We must mention again the already stated feature of the article [1] connected with the bias of its author both in the choice of material included in the review and in its exposition.

It is stated in p. 405 [transl. p. 787] that the existence of the outer ionosphere, up to its upper boundary, as outlined in accordance with modern data, has been known "long ago from general considerations," and that observations of whistling atmospherics, made in 1953, have demonstrated that $N \sim 400$—600 cm^{-3} at altitudes ~12 500 km (the figure 18 000—19 000 km given in the article is wrong). Therefore, the fact established in 1959 that the ionosphere extends to distances up to ~20 000 km from the earth's surface [22,23] did not introduce, as it were, any changes in the notions concerning the upper boundary of the ionosphere.

Actually, some papers published prior to 1959 (for example, [21] and [24]) and cited in [1], contain statements to the effect that there exists an extensive ionosphere (which according to [24] reaches distances up to (8—9) R_0 from the earth). These, however, did not contain the necessary experimental proof of the existence of such an ionosphere, and the quantitative characteristics claimed for it were incorrect. It should be noted that if the boundary of the ionosphere is taken to mean the region in which the concentration of the ionospheric particles is equal to the concentration of the interplanetary-plasma particles, then there can be no word at all of a correct determination of the position of the limit of the ionosphere and quantitative characteristics of the peripheral region of the ionosphere before 1959, for until the measurements made with the first space rockets the fluxes and the concentrations of the charged particles in the interplanetary space were exaggerated by 2—3 orders of magnitude (this is seen, for example, from [25]). In particular, in Al'perts papers, dating to 1958 (for example [26]), the height of the boundary of the ionosphere was estimated at 2000—3000 km, from which it follows that in 1958 Al'pert had neither a priori concepts nor experimental information concerning a more extended ionosphere.

We must dwell on the manner in which Soviet experimental work on the outermost part of the ionosphere are treated in Al'pert's review. In plotting

*Unfortunately, the reference to this paper (R. C. Saglyn and M. Smiddy, Preprint, 1965) is given in [1] without indicating the name of the paper and the proposed publication journal.

*Since Al'pert is the co-author of [19], it is all the more strange that he does not mention these formulas.

(Fig. 1) a summary review of the altitude variation of the ion concentration, taken from [27] and obtained in 1959, Al'pert does not mention the fact that in [27] itself notice was taken of both the unconditional reliability of the bend of the upper part of the curve of the altitude variation of the concentration, and of the fact that the values of the concentration pertaining to altitudes 2000—15 000 km are only the lower limits of its possible values, since the recorded ion currents could be greatly underestimated.

The question of the possible causes of the difference between the ion-concentration curve given in [27] and the data obtained later (including the data by V. V. Bezrukikh and K. I. Gringauz on the satellite Elektron-2) was considered in [23], which presents besides a possible methodological cause also considerations, first advanced by Obajashi [28], connected with the fact that the data obtained with the space ship Luna-2 [27] pertain to higher latitudes than the later results. This argument, presented in [23], and also data obtained with Elektron-2 and published in the same paper [23], are not mentioned at all in [1], although Al'pert could not be unaware of them, since he was one of the editors of the book in which [23] was published. Al'pert's bias in this case is perfectly obvious.

The list of the errors in the review [1] could be expanded. For example, on p. 409 [transl. p. 789] the boundary of the ionosphere is defined as "the region of formation of the knee" (as is well known, the "knee" is not always observed, see, for example, [29], and consequently, according to Al'pert, the ionosphere has no boundary in such cases); on p. 415 [transl. p. 793] there is an error in the normalization of the distribution function, etc. We consider it unadvisable, however, to increase the size of the present note, since, in our opinion, both the scientific level and the degree of objectivity of [1] are obvious from the examples considered above.

Note: After this letter was sent to the editor of Usp. Fiz. Nauk, the authors have learned of one later paper by Ya. L. Alpert, this time published in a foreign journal [30], which differs from [1] only in small details. In particular, it makes no mention of the work by the Gorkiĭ radiophysicists on the ionosphere inhomogeneities, and indicates that the inhomogeneity-size spectrum shown in Fig. 15 of [30] (Fig. 15 of [1]) was obtained by Alpert and his co-workers in [14]. We note that Fig. 15 of [30] is not contained in [14]. All other errors of [1] are fully repeated in [30].

A second publication of this article, whose contents was briefly analyzed above makes it particularly important, in our opinion, that it be properly judged.

[1] Ya. L. Al'pert, Usp. Fiz. Nauk 90, 405 (1966 [Sov. Phys.-Usp. 9, 787 (1967)].

[2] V. L. Granovskii, Elektricheskiĭ tok v gaze (Electric Current in Gas), V. 1, Gostekhizdat, 1952.

[3] V. L. Ginzburg, Rasprostranenie elektromagnitnykh voln v plazme (Propagation of Electromagnetic Waves in a Plasma, Fizmatgiz, 1960 [Addison-Wesley, 1964].

[4] H. E. Hinteregger, L. A. Hall, and G. Schmidtke, Space Res. V, North-Holland Publ. Co., Amsterdam, 1965, p. 1175.

[5] G. S. Ivanov-Kholodnyĭ, Geomagnetizm i aéronomiya 6, 382 (1966).

[6] G. C. Reid, Rev. of Geoph. 2, 311 (1964).

[7] W. B. Hanson and I. B. Ortenburger, J. Geoph. Res. 66, 1425 (1961).

[8] I. W. Freeman, J. A. Van Allen, and L. I. Cahill, J. Geoph Res. 68, 2121 (1963).

[9] N. F. Ness, J. Geoph. Res. 70, 2989 (1965).

[10] Ya. L. Al'pert and V. M. Sinel'nikov, Geomagnetizm i aéronomiya 5, 209 (1965).

[11] V. A. Misyura, G. K. Solodovnikov, and V. M. Migunov, Kosmicheskie issledovaniya (Cosmic Research) 3, 595 and 604 (1965).

[12] K. I. Gringauz, Yu. A. Kravtsov, V. A. Rudakov, and S. M. Rytov, Geomagnetizm i aéronomiya 6, 568 (1966).

[13] E. A. Benediktov, G. G. Getmantsev, N. A. Mityakov, V. O. Rapoport, Yu. A. Sazonov, and A. F. Tarosov, in; Issledovaniya kosmicheskogo prostranstva (Outer Space Research), Nauka, 1965.

[14] Y. A. Al'pert, L. M. Vitshas, and V. M. Sinel'nikov, Geomagnetizm i aéronomiya 5, 649 (1965).

[15] K. I. Gringauz, V. V. Bezrukikh, and V. D. Ozerov, in: Iskusstvennye sputniki zemli (Artificial Earth Satellites), No. 6, 1961, p. 63.

[16] R. C. Sagalin, M. Smiddy, and J. Wisnia, J. Geoph. Res. 68, 199 (1963); 69, 1809 (1964).

[17] G. P. Serbu and E. J. R. Maier, J. Geoph. Res. 71, 3755 (1966).

[18] E. C. Whipple, Proc. IRE 47, 2023 (1959).

[19] Ya. L. Al'pert, A. V. Gurevich, and L. P. Pitaevskiĭ, Iskusstvennye sputniki v razrezhennoĭ plazme (Artificial Satellites in a Rarefied Plasma, Nauka, 1964.

[20] V. V. Bezrukikh, T. K. Breus, and K. I. Gringauz, Kosmicheskie issledovaniya (Cosmic Investigations) 5, 258 (1967).

[21] L. R. O. Storey, Phil. Trans. Roy. Soc. A246, 113 (1953).

[22] V. V. Bezrukikh, K. I. Gringauz, V. D. Ozerov, and R. E. Rybchinskiĭ. Dokl. Akad. Nauk SSSR 131, 1301 (1960) [Sov. Phys. Doklady 5, 361 (1960)].

[23] V. V. Bezrukikh, K. I. Gringauz, in: Issledovaniya kosmicheskogo prostranstva (Investigations of Outer Space) (G. A. Skuridina, Ya. L. Al'pert, and V. I. Krásovskiĭ, eds.,) Nauka, 1965.

[24] L. R. O. Storey, Ann. de Geophys. 14, 144 (1958).

[25] K. I. Gringauz, in: Iskusstvennye sputniki zemli (Artificial Earth Satellites), No. 12, 1962, p. 119.

[26] Ya. L. Al'pert, E. F. Chudesenko, and V. S. Shapiro, in: Predvaritel'nye itogi nauchnykh issledo-

vaniĭ s pomoshch'yu pervykh sovetskikh iskustvennykh sputnikov Zemli i raket (Preliminary summaries of Scientific Research with the Aid of the First Soviet Satellites and Rockets), No. 1, AN SSSR, 1958.

[27] K. I. Gringauz, Space Research, II, North Holland, 1961, p. 574.

[28] T. Obajashi, The Report on Ionosphere and Space Research in Japan, **28**, N 3, 1964, p. 228.

[29] D. L. Carpenter, J. Geophys. Res. **71**, 693 (1966).

[30] Ja. L. Al'pert, Space Sci. Rev. **6**, 419 (1967).

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