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THE EFFECT OF ATOMIC EXPLOSIONS ON THE IONOSPHERE

by

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Results taken from the World Data Center were used to investigate ionospheric disturbances of non-solar origin during the 1958 nuclear tests over the Pacific and Atlantic Oceans. It was found that the explosion set off on August 1, 1958, had an appreciable effect on the ionosphere. It gave rise to an increase in the absorption in the lower ionosphere, a reduction in the ionization in the F layer, and a considerable variation in its height. Ionospheric effects were detected at distances up to about 6000 km from the epicenter. The effects of the explosion of August 12, 1958, were investigated in a similar way. Here, the effects were somewhat different. Thus, at a distance of 1500 km from the epicenter there was a considerable increase in the absorption by the F2 layer 6 hours after the explosion. An initial reduction in the effective height of the F layer was followed by a rise above the normal level. At 4500 km there was also an initial reduction and a final rise in the effective height. At 6200 km, there was a tendency to a wave-like change in the effective height. At 7200 km the effective height increased up to 350 km, but no effects were observed in the critical frequencies.

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THE EFFECT OF ATOMIC EXPLOSIONS ON THE IONOSPHERE

N. P. Ben'kova and N. I. Potapova

Recently a number of works have been published dealing with the geophysical consequences of atomic explosions. In particular, works [1, 2] describe ionospheric effects of atomic explosions conducted on 1 and 12 August, 1958, at great altitude over Johnston Island in the Pacific Ocean. Ionospheric stations located fairly close to the epicenter of the explosion reported observations of significant increase of absorption (up to total disappearance of reflected signals) and a small perturbation in the F region, appearing mainly as a reduction in critical frequencies. Similar but less intense perturbations were noted by our ionspheric stations close to a point geomagnetically connected with the region of the explosion.

The analysis which we conducted of data from the world net of stations[1] for the periods of the explosions in the Pacific and Atlantic Oceans confirmed the presence of ionospheric perturbations of nonsolar origin and made it possible to establish certain properties of these perturbations.

The explosion of 1 August, 1959, was carried out at 10 h 50 min world time at an altitude of about 50 km. At the ionospheric station

[1]All of the data from observations of ionospheric stations used in this work were obtained at the World Data Center B2.

of Maui, closest to the epicenter of the explosion (the coordinates of Johnston Island and of the ionospheric station are given in Table 1), a growth in absorption was quickly noted (Fig. 1). Some 3-4 h after the explosion (4-5 h local time) a significant reduction in f^oF2 was observed, followed (6-9 h) by a sharp growth in h F (Fig. 2b). At the Raratonga station, lying close to a point linked with the site of the explosion, no significant absorption was observed; however, there was an increase in diffusivity in the F region from 1 to 4 h local time. In addition, unusual changes in h'F were established here (Fig. 2a): some 1 h 15 min after the explosion, at the moment of greatest diffusivity in the F layer, a sharp drop in h'F and then a sharp rise to h' = 500 km were noted. The change in h' in the course of an hour comprised about 300 km. This jump in altitude was repeated once more with smaller amplitude. Similar but weaker variations in h' were observed in Brisbane (Fig. 2c). At the Canberra station (Fig. 2d) similar oscillations of h'F were less clearly expressed; no increase in f_{min} was noted.

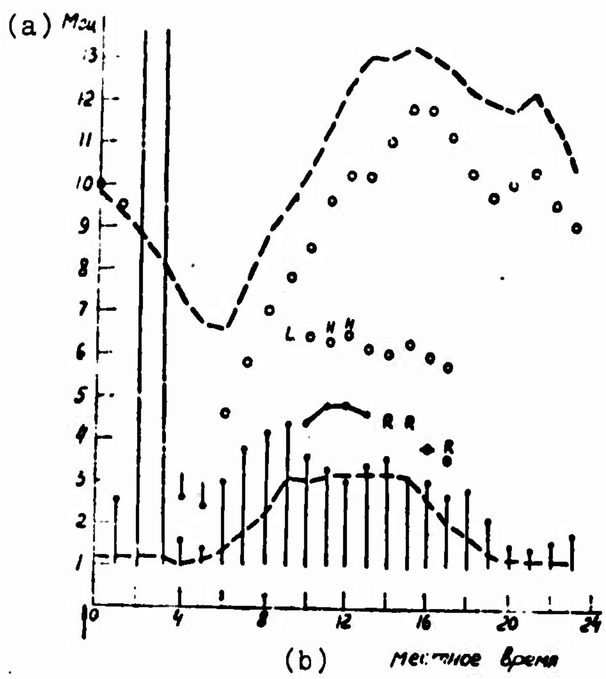

Fig. 1. The f-curve for 1 August 1958, Maui. Designations: O — f_{oF2}; f_{min}; diffusivity; —•— f_bE_s; -- median; the moment of the explosion is marked by the vertical arrow.

KEY: (a) MHz; (b) local time.

As a statistical check indicated, the oscillations of h'F on 1 August 1958 cannot be considered random (according to data from Raratonga the deviation from the normal values reaches 200 km and exceeds 7 σ, where σ is the mean square deviation for a month).

Table 1.

(a) Название	φ	λ	d
(b) О-н Джонстон	17°0'	169°5'	—
(c) Мауи	20°50'	156°30'	1,5 тыс. км (d)
(e) Раратонга	21°12'	159°46'	4,5 »
(f) Брисбен	27°32'	152°55' E	6,2 »
(g) Канберра	35°18'	149°12' E	7,2 »
(h) Адак	51°51'	176°39'	4,0 »

KEY: (a) Name; (b) Johnston Island; (c) Maui; (d) Thous. km; (e) Raratonga; (f) Brisbane; (g) Canberra; (h) Adak.

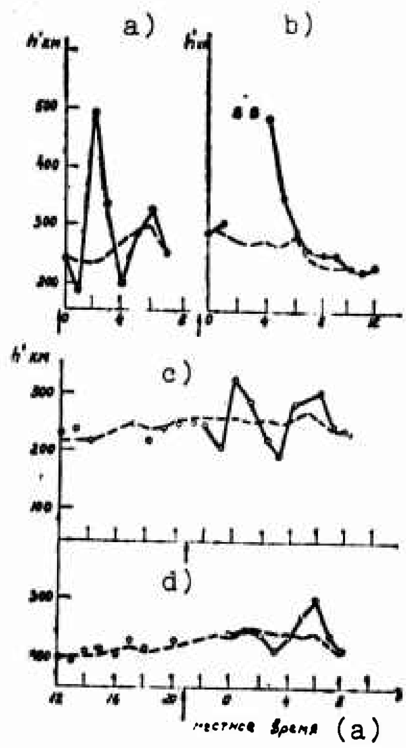

Fig. 2. Daily variations of h'F for 1 August 1958: a) Raratonga; b) Maui; c) Brisbane; d) Canberra; --- median.

KEY: (a) local time.

At the Uoteru [Wateru?] station no special phenomena were observed. At the Adak station, located north of the explosion site, at 23 h 30 min local time (40 min after the explosion) there was a sudden increase in h°F2; this was then followed by a reduction, achieving its maximum some 4 h after the explosion. However, the reduction in f°F2 began as early as the beginning of 31 July, so that all of these deviations cannot, with confidence, be regarded as results of the explosion. According to available data it is impossible to judge whether there were oscillations in h'F at Adak, since intensive ES began to be observed long before the testing of the atomic bomb and had a screening effect on the F region. According to the data from the

San Francisco station no effect connected with the explosion could be detected.

Inspection of data from stations still more distant did not reveal anomalous phenomena in these hours of the day either on those stations where this period fell in the hours when the earth's atmosphere was illuminated by the sun (Moscow, Budapest, Lwiro), nor on station where it was morning at the time (Talara, Chimbota, Uoteru). This indicates a nonplanetary nature of the described anomaly.

On 1 August, 1959, the magnetic field was weakly perturbed (diurnal characteristic C = 0.5; according to Soviet observatories the K-indices for the periods 0900-1200, 1200-1500, and 1500-1800 h were 4, 4, and 22). At magnetic observatories located in the region of the blast and close to conjugate points a magnetic perturbation was recorded.

Thus, the explosion of 1 August 1958 had an effect on the ionosphere reflected in an increase in absorption in the lower ionosphere, a reduction of ionization in the F layer, and significant variation in the height of the latter. The ionospheric effects were detected at distances up to 6,000 km from the epicenter of the explosion.

The explosion of 12 August 1958 was carried out at an altitude of about 30 km at 10 h 30 min world time. In Maui at 6 h local time, i.e., 6 h after the explosion, a significant increase in absorption in the F2 layer was observed (Fig. 3a); during this day a change in h'F was also observed (Fig. 3b). In distinction from 1 August the phenomenon began with a reduction in h'F (30 min after explosion), and after an hour the height grew sharply. At the Raratonga station (Fig. 3c) a drop and growth in h' were also registered. At Brisbane a tendency toward a wavy change in h'F appeared; however, as in the case of 1 August, the picture is not sufficiently clear. At Adak h'F was increased up to 350 km at zero hours local time; no effects of any kind were detected in the critical frequencies. At San Francisco no special ionospheric effects were detected.

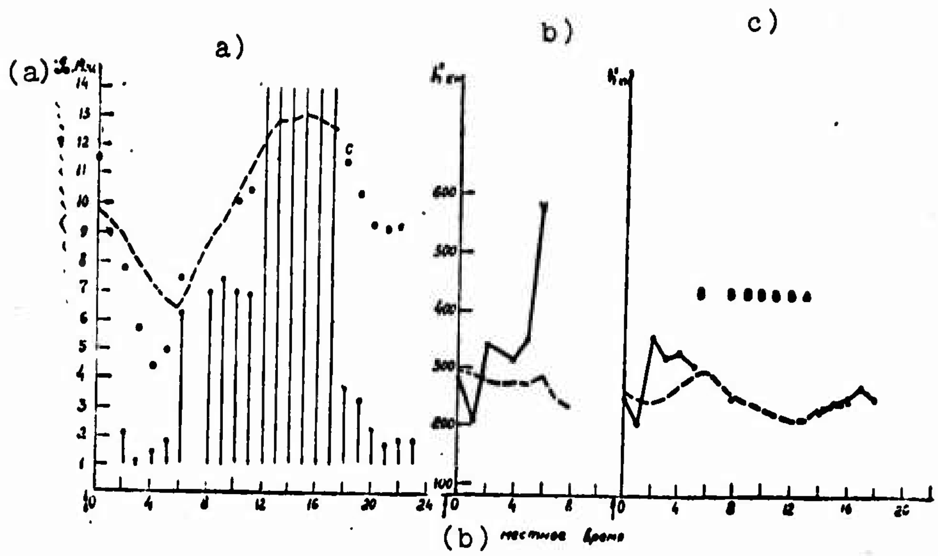

Fig. 3. Curves for f and h', 12 August 1958: a) Maui, f-curve; b) Maui, h'-curve; c) Raratonga, h'-curves.

Designations the same as in Figs. 1 and 2.

KEY: (a) f_0, MHz; (b) local time.

Table 2 shows the time intervals between the moment of explosion and the moments of appearance of maximum and minimum values.

Table 2.

Число (a)	Станция (b)	I минимум (c)	I максимум (d)	II минимум (c)	II максимум (d)
(e) 1 августа	(f) Раратонга	1 ч 10 мин.	2 ч 10 мин.	4 ч 10 мин.	6 ч 10 мин.
(g)	Брисбен	2 . 10 .	3 . 10 .	6 . 10 .	8 . 10 .
(h)	Канберра	—	—	6 . 10 .	8 . 10 .
(i)	Адак	—	—	—	—
(j) 12 августа	Мауи (k)	0 ч 30 мин.	1 ч 30 мин	2 ч 30 мин.	4 ч 30 мин.
	Раратонга (f)	1 . 30 .	2 . 30 .	(l) Нечетко	Нечетко (l)
	Брисбен (g)	1 . 30 .	2 . 30 .	3 ч. 30 мин.	6 ч. 30 мин.
	Адак (i)	1 . 30 .	—	—	—

KEY: (a) Date; (b) Station; (c) Minimum; (d) Maximum; (e) 1 August; (f) Raratonga; (g) Brisbane; (h) Canberra; (i) Adak; (j) 12 August; (k) Maui; (l) Not clear.

Designations: ч = h or hours; мин = min or minutes.

Table 3 shows the propagation rate, v, of the ionospheric perturbation as calculated by dividing the magnitude of the distance to the point explosion, d, by the delay time of the perturbation with respect to the moment of explosion. In this case the moment of onset of minimum I was taken at the beginning of perturbation.

Table 3. Propagation rate of ionospheric perturbation, v, km/s.

(1) Число	(2) Станции: Мауи (3)	(4) Раратонга	(5) Брисбен	(6) Адак
(7) 1 августа	—	1,1	0,800	—
(8) 12 августа	0,750	0,830	0,170	0,740

KEY: (1) Date; (2) Station; (3) Maui; (4) Raratonga; (5) Brisbane; (6) Adak; (7) 1 August; (8) 12 August.

Despite the fact that the moment of arrival is taken very tentatively and time is counted roughly (with an accuracy up to 1 h), these rates agree quite well with one another and with data presented by Matsushita [4], who indicated a speed of 1.3 km/s for 1 August and 0.9 km/s for 12 August (calculated according to the appearance of unusual reflections in the F regions).

Atomic explosions in the southern portion of the Atlantic Ocean ("Operation Argus") took place on 27 and 30 August and 6 September of 1958. No effects of increased absorption were detected in any of these explosions. In the remaining cases sudden variations in h'F, characteristic for the Pacific explosions, were noted. Explosions in the Atlantic Ocean were carried out at altitudes of about 400 km.

At present it is impossible to give a complete explanation of the observed phenomena. It is very possible that in regions close to the explosion site the increase in ionization occurs under the action of direct explosion products (electrons, nuclear fragments, λ-radiation). Apparently the electromagnetic perturbation is propagated in a direction toward the conjugate point along the force lines of the geomagnetic field. Thus, significant ionospheric perturbation was noted in Raratonga, while in Adak, at the same distance from Johnston Island, the ionospheric disturbance was more weakly reflected.

However, as was shown in works [3, 4] and is evident from Table 3, the propagation rate of the perturbation is identical in all directions. This forces us to propose that it is propagated together with the shock wave, carrying with it electromagnetic energy.

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