VARIABILITY OF AEROSOL, OZONE, AND SULFUR DIOXIDE CHARACTERISTICS IN THE SURFACE LAYER ON EARTHQUAKE IN WEST MEXICO

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Variability of UV solar radiation, ozone and sulfur dioxide concentration, dispersivity, and element composition of aerosols were studied in the surface layer of the atmosphere in Guadalajara, West Mexico, before and during the earthquake on the 9th of October, 1995. We have detected anomalies in diurnal behavior and intensity of UV radiation, concentration of ozone, sulfur dioxide, and aerosols, as well as element composition of aerosols just before the earthquake and during it.

During the period from the 5th to the 9th of October, 1995, in Guadalajara, continuous comprehensive observations on UV intensity, aerosols, ozone, and sulfur dioxide in the surface layer of the atmosphere were performed jointly with standard meteorological observations. On the 9th of October, at 9:10 a.m., a strong shock of magnitude 7 occurred in the states of Colima and Jalizco. Its center was at the Pacific shore (near Manzanillo).

The use of the obtained experimental data in analysis of the earthquake (or predecessor events) influence on the characteristics studied by the authors is of doubtless interest. Any significant influence of the earthquake on the daytime behavior of UV radiation intensity was not revealed (Fig. 1), although the shift of intensity maximum of the incident radiation on the 8th of October to later hours (as compared with the 7th and 9th of October) seems to be interesting. A little decrease of intensity in the curve maximum on the 9th of October by about 10–15 kW/m^2 is probably caused by the increase of total content of dust and sulfur dioxide in the atmosphere.

Observations on sulfur dioxide before the 9th of October did not reveal any definite diurnal behavior of its content in the surface layer in Guadalajara. Maximums of SO_2 appeared irregularly and seemed to be determined first of all by wind direction. The largest values of sulfur dioxide concentration were usually detected in evening and night hours, and they did not exceed 300 $\mu g/m^3$. At night of the 9th of October, an unexpectedly high increase of sulfur dioxide concentration was detected from 1:30 a.m. till 6:00 a.m. Concentration reached 740 $\mu g/m^3$ (Fig. 3).

Analysis of the data on diurnal behavior of surface ozone concentration also demonstrated some distinctions (Fig. 2): first, in the morning of the earthquake day, ozone concentration increased markedly more slowly as compared with previous days; second, a temporary halt of concentration increase was observed just at the time of the first strong shock; third, during the later hours, ozone concentration considerably exceeded the values observed in the day hours on 7th and 8th of October.

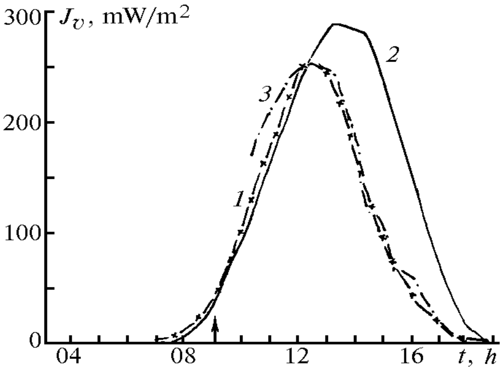

FIG. 1. Diurnal behavior of incident UV radiation intensity in the center of Guadalajara City (Observatory of Astrophysics and Meteorology). Curves 1, 2, and 3 correspond to the measurements on 7th, 8th, and 9th October, 1995.

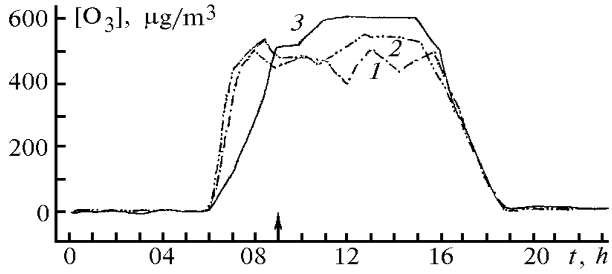

FIG. 2. Diurnal behavior of ozone concentration in the surface layer (in the center of Guadalajara City). Curves 1, 2, and 3 are for the measurements on 7th, 8th, and 9th October, 1995.

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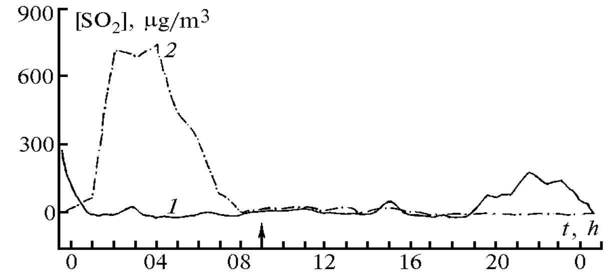

FIG. 3. Diurnal behavior of sulfur dioxide concentration in the surface layer (in the center of Guadalajara City). Curves 1 and 2 are for the measurements on 7th and 9th October, 1995.

The most complete analysis was performed on the base of the data on aerosol measurements of particle number density and dispersivity of particles with size $d \geq 0.4$ μm with the photoelectric counter AZ–5M and element composition of aerosol samples obtained with use of Petryanov three-layer filters.

Table I presents averaged values of particle number density in 12 size ranges from the results of continuous measurements from 4th to 8th of October. Every hour no less than three series of measurements were performed (in some cases, 4–5 runs were made).

Table I shows the values averaged over two hours, i.e., each value in the Table is averaged over about 24 indications that significantly smooths the curves of diurnal behavior of aerosol dispersivity. Note that the data clearly demonstrate the increase of largest particle number since about 10:00 a.m. Using the sufficiently reliable averaged data, we calculated the change of the particle size spectrum for the period previous to the earthquake and just after the first shock. These data are presented in Table II as the ratio of $\Delta N(r_i)$ to averaged $\Delta N(r_i)$ for the same hours. As follows from the data, significant increase of total number density of particles with $d \geq 0.4$ μm was detected neither before nor after the shock. Variations of N ($d \geq 0.4$ μm) occur at the level of measurement errors. However, transformation of the particle size spectrum is quite evident.

The increase of the fraction of large particles is observed already since 22:00 p.m. of October 8. The excess of particle number density over the mean values is most convincing in the size ranges $1.0 \leq d \leq 1.5$ μm and $0.7 \leq d \leq 0.8$ μm. Additional modes also appear. However, they are not sufficiently stable and sometimes give way to minimums (for instance, the mode $0.8 \leq d \leq 1.0$ μm). Perhaps, this is caused by spatial inhomogeneity of the number density field of aerosol particles with different size due to various separation mechanisms. Just after the first shock, we observed a sharp increase of the number of particles in the size range $d > 1.0$ μm, and then in the range $0.7 \leq d \leq 0.9$ μm.

Besides, we processed the results of fluoroscopic element analysis of samples taken at different time and with different volume of air passed through the filters. Total of 12 three-layer filters were exposed. Air volume passed through the filters varied from 18 to 72 m^3. This made it possible, with a little error, to elucidate the average diurnal behavior of concentration of some elements (the error was caused by a little difference in the behavior of element content in the surface layer of the atmosphere in different days). For the 9th of October, element concentration was determined both at night time (before the earthquake) and in the day time (after the earthquake). Main measurements were performed on the roof of the Observatory in the city center (Avenida Vallarda) at the height of 18 m above the Earth's surface. The nearest higher buildings are situated at the distance no less than 100 m.

TABLE I. Diurnal behavior of aerosol particle dispersivity in the surface layer of the atmosphere in Guadalajara (Observatory of Astrophysics and Meteorology of the Guadalajara University), October 4–9, 1995, $\Delta N(r)$, liter^{-1}.

d,	Time, h											
μm	04–05	06–07	08–09	10–11	12–13	14–15	16–17	18–19	20–21	22–23	00–01	02–03
> 10	2.95	2.50	3.80	7.45	8.75	6.55	7.80	13.2	17.0	16.0	7.90	3.00
7–10	4.86	3.95	5.70	11.0	9.60	8.60	6.75	12.2	30.5	27.5	12.4	3.25
4–7	28.5	22.6	42.2	53.6	31.0	47.6	26.6	112	140	75	58.0	23.5
2–4	92.5	89.2	134	140	136	64.4	78.6	274	550	500	274	92.0
1.5–2	71.8	58.0	93.5	65.2	25.2	99.0	113	72.2	257	161	169	77.2
1.0–1.5	120	99.2	319	135	80.8	507	950	118	580	376	420	830
0.9–1.0	136	1230	1440	880	324	714	1520	606	812	975	4320	7440
0.8–0.9	4630	7300	5570	4440	3660	6760	13000	2440	1410	4830	9220	7100
0.7–0.8	14400	17200	14100	13100	12100	8840	22500	20800	3380	13200	18400	29200
0.6–0.7	26900	32500	31400	33000	26100	17200	27600	31900	25400	21700	28600	23800
0.5–0.6	20200	17300	29600	23700	31300	29500	13400	22400	32000	24100	14800	9850
0.4–0.5	11700	750	2750	3320	3750	16000	2000	2060	17900	10400	1700	950
N, cm^{-3}	78.3	76.6	85.5	78.9	77.5	79.7	81.2	80.8	82.5	76.4	78.0	79.4

TABLE II. Change of particle number density and size spectrum in the surface layer of the atmosphere in Guadalajara, October 9, 1995 (the ratio $\Delta N(r)/\overline{\Delta N}(r_i)$, %*).*

d, μm	October, 8				October, 9		
	21 h	22 h	23 h	24 h	9 h 20 min	10 h 10 min	11 h
> 10	73	81	88	136	579	684	263
7–10	100	139	65	125	544	596	772
4–7	67	144	152	≥122	237	204	251
2–4	64	102	140	≥131	281	324	234
1.5–2	64	136	153	≥137	129	150	296
1.0–1.5	76	157	166	126	118	495	75
0.9–1.0	97	145	95	102	101	118	63
0.8–0.9	68	143	82	229	63	251	190
0.7–0.8	149	193	163	90	133	170	174
0.6–0.7	101	143	132	106	100	96	80
0.5–0.6	120	71	103	99	77	88	60
0.4–0.5	90	36	89	42	0	0	0
≥ 0.4	108	105	123	98	92	115	93

Some samples were taken at other points of the city: at the Cabacas Square (near the historical city center, approximately 3 km to the south from the Observatory, at the height of 7 m above the Earth's surface) and in the Barranca park at the edge of wide canyon cutting the northeast part of Guadalajara. The main results of element fluoroscopic analysis are presented in Tables III and IV.

The behavior of elements Si, Ca, Fe engages our attention because they clearly respond to the earthquake, behave almost similarly and, evidently, are a part of the substance emitted from the surface and possibly from the depth of the soil. Similar behavior is observed also for K, Ti, and Mn. For some elements, the earthquake did not have a significant effect on their content in the surface layer (Al, P, Ga, Se, Zr, Hg, Rb) or weakly affected the increase of concentration (S, V, Ni, Cu). We can definitely reveal some elements for which a decrease of concentration in the surface layer is observed: Cr, Cl, and, probably, Hg.

TABLE III. Concentration of elements in the surface layer of the atmosphere in Guadalajara before and during the earthquake of October 9, 1995, ng/m^3.

Element	Mean values over October, 4–8 (Observatory)					A. Martinez house (south-east)	Cabacas Square (center)	Barranca Square, October 7–8		Observatory, October 5–6	During the earthquake, October 8–9		
	24 hours	night (21–08)	day (10–18)	morning (08–11)	evening (18–21)	day 9.10.95 (08–18)	evening 6.10.95 (19–21)	evening (19–21)	night (21–08)	24 hours	24 hours	night (20–09)	day (09–18)
Al	4860	6620	5030	5450	4710	12100	15400	7900	2300	2000	4000	4400	3700
Si	49600	78600	36200	≤79000	295000	263000	203000	198000	44600	26200	117000	128000	106000
P	<900	<700	<1100	<600	<500	<1000	<4000	<3000	<800	<800	<700	<600	<800
S	34000	47000	29100	55900	61300	67300	32000	29000	9300	21800	40000	44800	35300
Cl	1800	2000	2200	4310	13200	3900	3300	4000	1800	900	950	900	1000
K	1800	2210	2030	≤1800	7900	5310	5900	4700	1910	840	3760	3540	3980
Ca	4120	6060	3710	≤4100	8600	11400	10600	3700	2850	1850	9080	9130	9020
Ti	361	498	381	≤450	2360	840	320	360	222	123	592	633	550
V	75	75	98	80	<40	103	300	260	54	43	111	84	138
Cr	33	55	24	–	74	36	40	<50	34	11	12	9	25
Mn	46	56	58	63	254	124	85	255	35	14	132	133	131
Fe	1980	3020	1640	≤3600	13000	6230	5340	2620	1600	950	4660	4800	4520
Ni	16	15	26	21	<5	26	57	25	14	5	24	21	26
Cu	46	62	50	≤60	102	106	198	118	60	18	81	74	88
Zn	74	78	88	≤74	520	106	191	57	51	46	266	334	138
Ga	5.9	8.2	6.3	–	<2	<4	86	17	<4	<2	<3.5	<3	<4
Se	4.1	4.5	5.7	8.5	<1	14	36	7	17	1	<3	<3	<3
Br	40	53	36	28	436	45	90	42	19	29	130	216	45
Rb	22	32	24	36	<2	42	50	67	5	2	18	23	14
Sr	56	76	57	≤57	180	96	108	94	52	24	62	77	47
Zr	62	152	96	–	220	105	210	206	70	10	158	188	129
W	11	<9	<17	8.5	<6	<10	<70	<30	<10	<6	14	15	12
Hg	5.3	2.2	6.0	3.8	44	–	–	20	–	9	–	–	–
Pb	418	486	538	≤278	872	159	221	794	82	134	701	1100	302

TABLE IV. Distribution of elements in three filter layers, %.

Element	October 5–8, mean	October 9, earthquake	October 12, Colima	Element	October 5–8, mean	October 9, earthquake	October 12, Colima
	67	84	77		60	80	78
Al	12	2	8	Mn	27	14	11
	21	14	15		13	6	11
	80	87	94		18	31	31
Ca	14	11	3	Cr	34	31	37
	6	2	3		48	38	32
	60	78	72		68	70	92
K	23	17	19	Sr	19	16	–
	17	5	9		13	14	8
	60	80	82		52	48	32
Ti	20	12	12	S	22	22	36
	20	8	6		26	30	32
	43	50	54		76	77	82
Cu	22	26	20	D	10	13	18
	35	24	26		14	10	–
	38	47	67		46	38	29
Pb	24	20	17	V	25	34	–
	38	33	16		29	28	71
	84	85	98		64	54	53
Si	12	11	2	Br	25	34	27
	4	4	–		11	12	20
	76	84	97		57	69	48
Fe	16	13	2	Rb	6	23	42
	8	3	1		37	8	10
	41	46	66		52	61	24
Ni	43	35	34	Zr	22	12	59
	16	19	–		26	27	17
	74	76	82		37	26	–
Zn	8	12	8	Se	60	38	42
	18	13	10		3	36	58

A specific behavior of some elements manifested itself as a sharp decrease of concentration in the afternoon of the 9th of October, after the first shock: Cr, Zn, Br, Zr, and Pb. We may suppose that anthropogenic sources of these elements stopped to operate. Besides, the data of Table III permit the conclusion that some elements (Si, K, Ca, Ti, Mn, Fe, Ni, Cu, Br) were emitted into the surface layer of the atmosphere already at night of October, 8–9, i.e., before the first shock.

Analyzing the size distribution of elements presented in Table IV (distribution over three filter layers), we can verify the conclusion about similar behavior of the elements Ca, Si, and Fe. These elements are contained mostly in the largest particles, and the earthquake significantly transforms the size spectrum of aerosol particles containing these elements in the direction of greater particles. It should be noted that this phenomenon is observed also for other elements: Al, Cl, K, Sr, Pb, Cr, Ti, Cu, Mn, Ni, and Zn, but to different degree. Analysis of size distribution of elements for the sample taken in the Center of Atmospheric Studies of Colima University on October, 12–13, verifies the conclusion that aerosol particles containing terrigenous elements become greater after the earthquake. For instance, the particles containing Ca, Cl, Ti, Cu, Zn, Fe, Ni, Pb, Cr continue to enlarge; as for particles containing Al, K, Mn, they tend to return into their state before the earthquake. A particular behavior of S is obviously connected with its predominantly volcanic origin. The elements Se, Br, V, and Rb, Zr should be classified into two particular groups: the former three elements demonstrate clear decrease of particle size during the earthquake; the later two behave similarly with S what permits one to suppose their predominantly volcanic origin. High errors in determining concentrations make it difficult to come to any conclusions about the elements P, Ga, W, Hg.

Thus, the considered experimental results suggest that an earthquake brings some changes into properties and composition of the atmosphere, at least its surface layer. This especially brightly manifests itself in the composition and structure of surface aerosols. It should be emphasized that generation of coarse-disperse aerosols takes place; it begins a few hours before the earthquake.

Observation of the increase of sulfur dioxide emission into the surface layer of the atmosphere several hours ahead the earthquake is of great prognostic importance. However, a single observation of this phenomenon does not permit us to make a definite conclusion. Repeated observations are necessary. Besides, the results of observations of surface ozone behavior also seem to be interesting. They suggest that heterogeneous processes of ozone molecule decomposition are rather important in variability of ozone content in lower layers of the atmosphere.