Influence of space weather and seismic activity on the formation of thunderclouds in Kamchatka in winter

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Tropical cyclones bring warm and humid air to the peninsula, causing prolonged heavy rainfall in summer and snowstorms in winter.

Despite the high cyclonic activity, the average number of thunderstorm days per year in Kamchatka, according to the data (yandex.ru/pogoda/paratunka/month), is 10.8. According to archival data, from 1937 to 1982 (45 years), only 22 thunderstorms were recorded in Petropavlovsk [Kondratyuk, 1983].

For the formation of thunderclouds, in addition to cyclones, the action of other sources of additional heat energy entering the surface atmosphere is also possible.

With strong solar flares, a heat flux occurs in the visible and infrared ranges [Veselovsky et al., 2004; Ermolaev et al., 2005], sufficient to create conditions for the formation of thunderstorm activity.

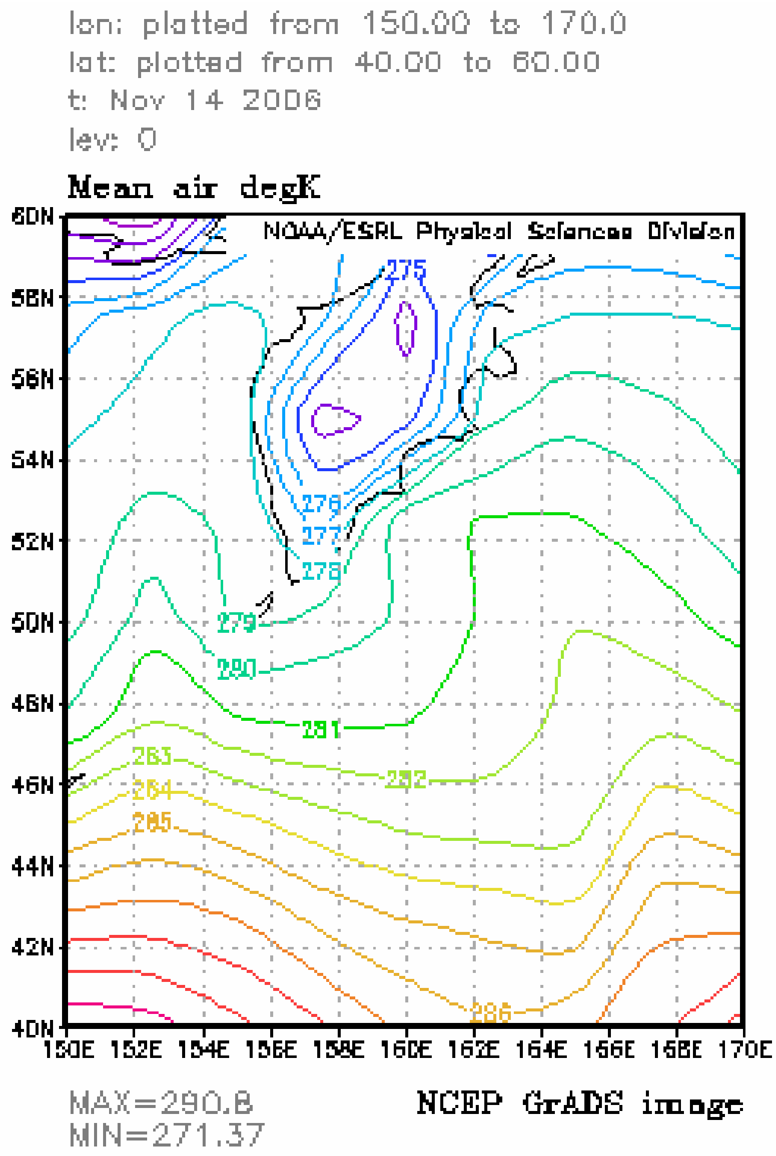
An additional source of heat in the infrared range can be seismic processes in the earth's crust before powerful earthquakes [Gorny et al., 1988]. One of the mechanisms of the formation of a thermal anomaly before an earthquake is presented in the model [Pulinets S., Ouzounov D., Lithosphere-Atmosphere-Ionosphere Coupling (LAIC) model - an unified concept for earthquake precursors validation, Journal of Asian Earth Sciences, 41, 371-382 , 2011]

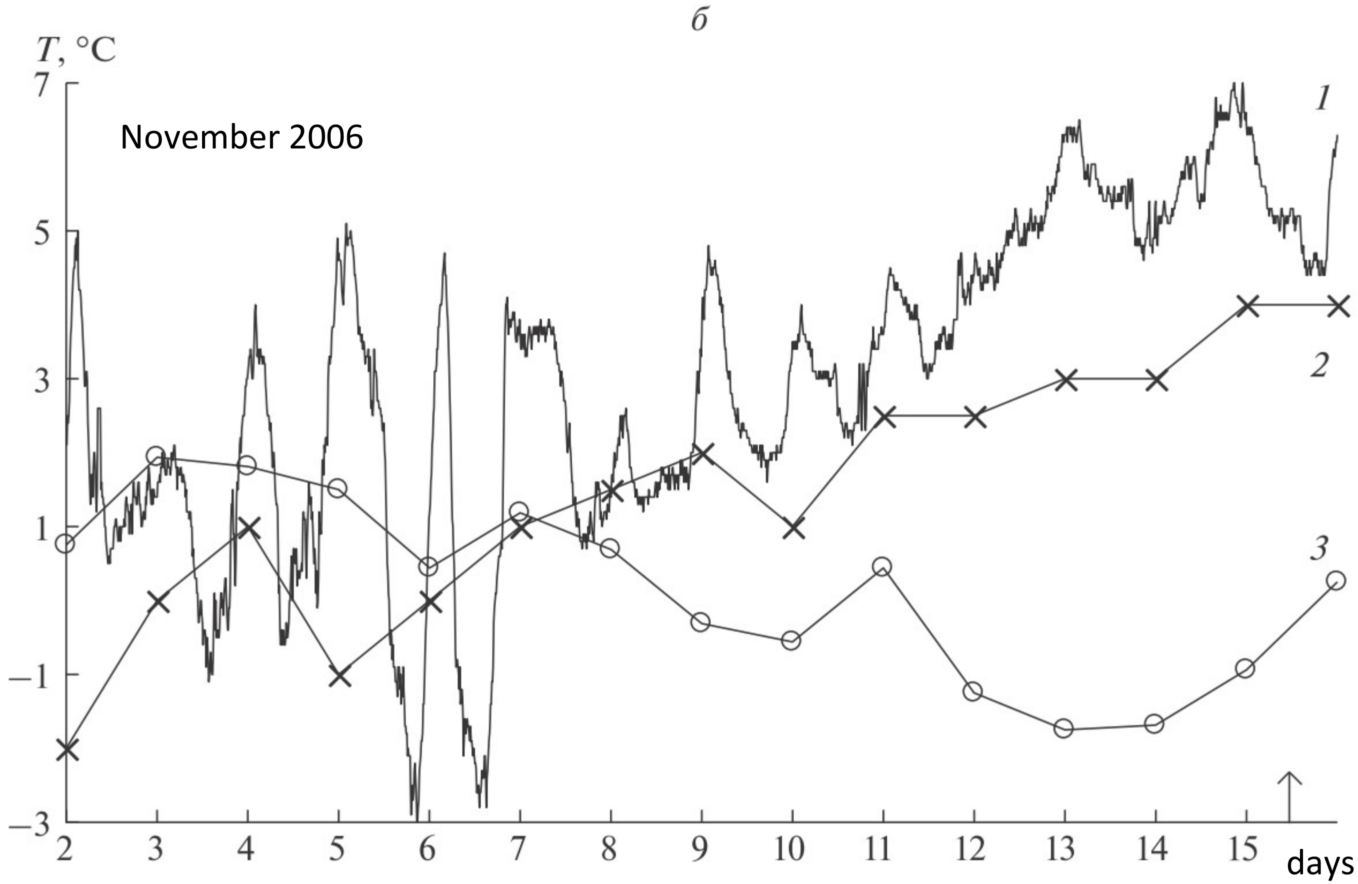
An example of a heat anomaly before an earthquake

Earthquake on November 15, 2006:

t = 11:14 UT;
M = 8.3;
h = 30.3 km;
ϕ = 46.614° N; λ = 153.23° E
($R = 10^{0.43M}$ = 3707 km; r ~ 800 km,
where R is the radius of a seismically active zone in the earth's crust on the eve of EQ [Dobrovolsky et al., 1979]; r is the distance from the observatory to the epicenter of the EQ).

Average daily temperature





Earthquake November 15, 2006

Air temperature variations (1), temperature variations estimated from satellite data (2), average daily temperatures in November, averaged over 2009–2016. (3).

November 2004 events

The peculiarity of these events is that they developed against the background of powerful solar flares, accompanied by two magnetic storms. This led to the initiation of abnormally strong thunderstorm processes in the surface atmosphere in Kamchatka.

During this period, cyclonic activity in the Pacific Ocean was calm; typhoon MUIFA emerged only on November 14 in a very remote place from Kamchatka.

Seismic activity during this period was also relatively calm.

Typhoon MUIFA track in November 2004

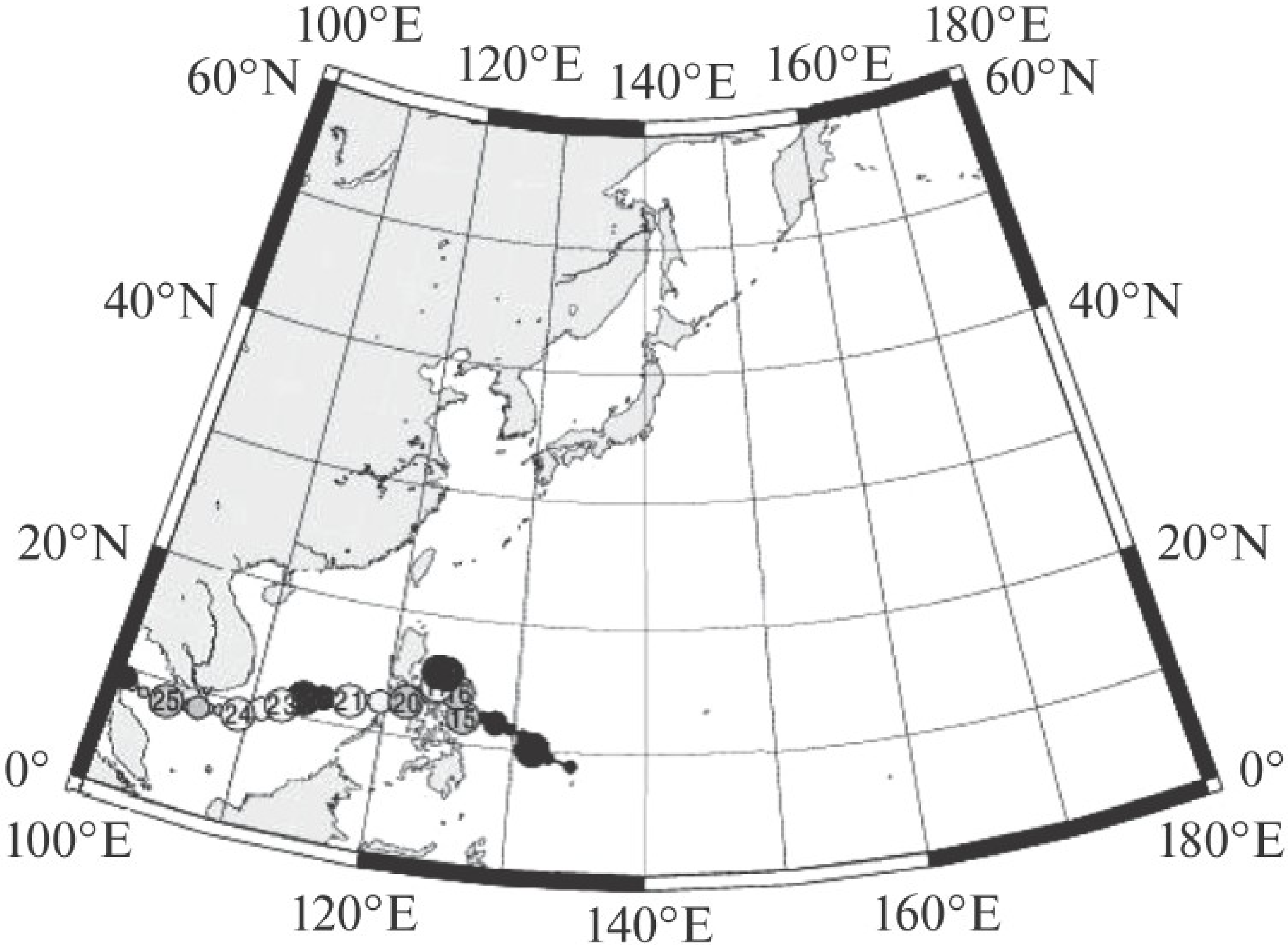
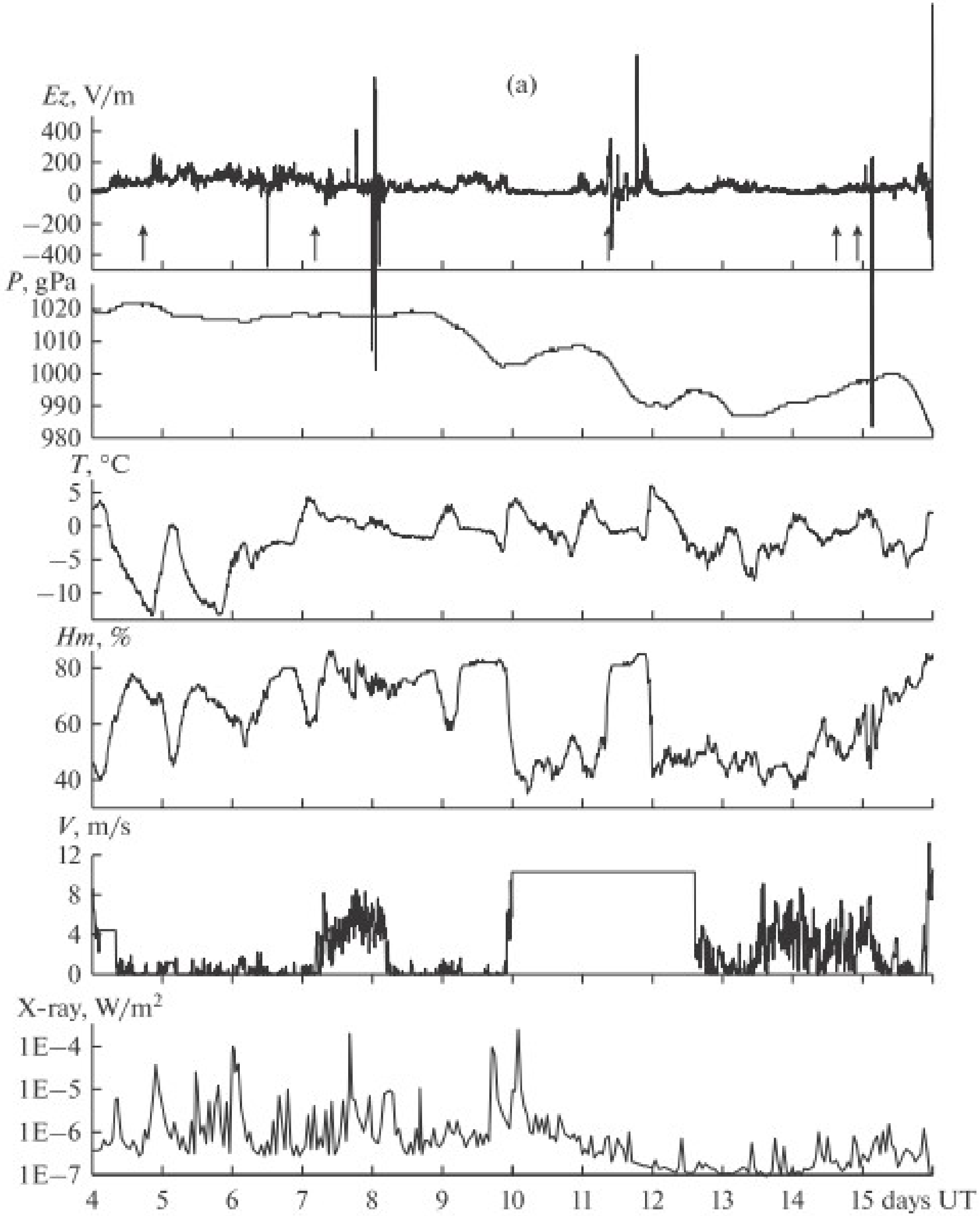


Table 1. Earthquakes near Kamchatka Peninsula recorded in November 2004

N	Date	UT time	Geographical coordinates		h, km	M	R, km
			φ° N	λ° E			
1	Nov. 4, 2004	14:03:11.74	43.665	146.812	62.4	5.8	312
2	Nov. 7, 2004	02:02:26.34	47.884	144.486	481.8	6.1	420
3	Nov. 11, 2004	10:02:47.12	42.164	144.331	32.2	6.1	420
4	Nov. 14, 2004	17:37:42.42	41.777	144.114	15.0	5.1	156
5	Nov. 14, 2004	17:57:40.66	41.781	144.064	30.3	5.0	140
6	Nov. 14, 2004	18:44:13.62	41.786	144.079	21.0	5.4	210

h is the epicenter depth; M is the magnitude; $R = 10^{0.43M}$ is the radius of the seismically active zone on the eve of the earthquake.



Daily variations in the Ez components of a quasi-static electric field in the surface atmosphere of Kamchatka, meteorological quantities, and fluxes of solar X-ray radiation (in the range 0.1–0.8 nm) in November 2004

October 2003 events

Events developed under conditions of increased solar activity on October 21-31, when X-ray fluxes during flares reached anomalous values of the order of 10^{-3} W/m^2. In this case, the radiation fluxes also increased in the visible part of the spectrum.

On these days, the maximum intensity of typhoon PARMA was noted, when the minimum pressure in its “eye” was 930 hPa, and the maximum speed was 95 knots / h. This powerful typhoon originated on October 21 at ~ 20-35º N and for 10 days moved along latitude from 140^0 to 180^0 E. At the same time, in the same period on October 19-26, a less powerful one operated in the Pacific Ocean (V = 90 knots / h; P = 940 hPa) typhoon KETSANA.

Seismic activity during this period was also relatively calm (M ~ 5).

Tracks of typhoons PARMA and KETSANA in October 2003.

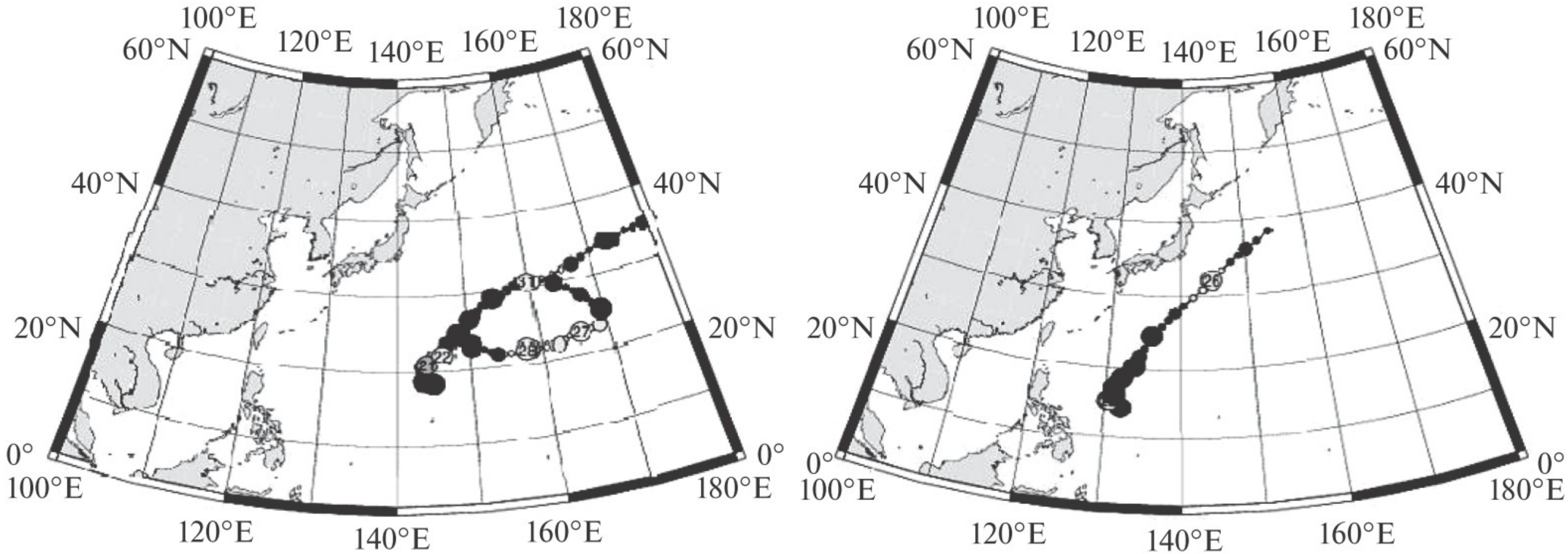
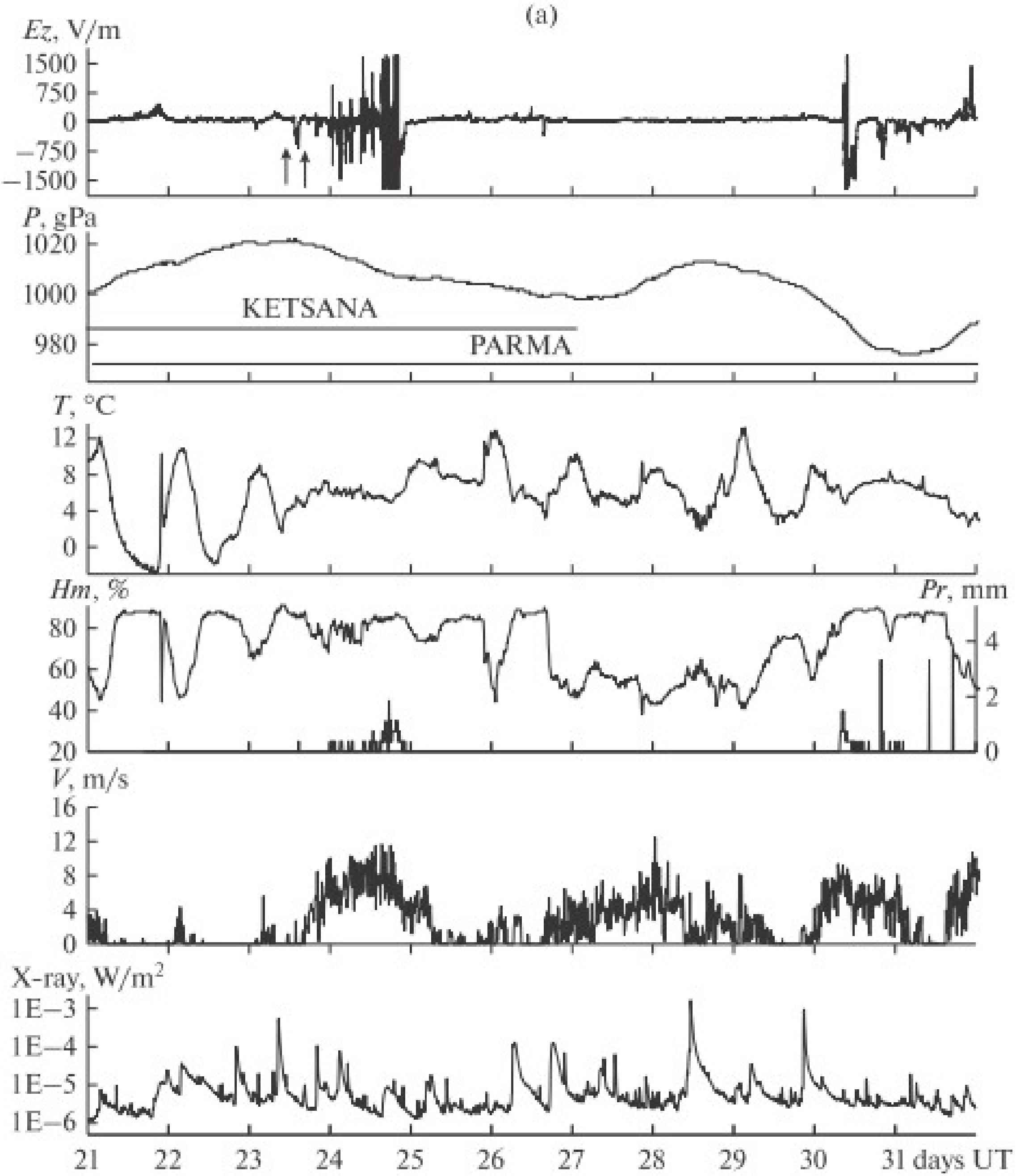


Table 2. Earthquakes near Kamchatka Peninsula recorded in October 2003

N	Date	UT time	Geographical coordinates		h, km	M	R, km
			φ° N	λ° E			
1	Oct. 23, 2003	1054:37.10	51.76	176.39	14	5.3	190
2	Oct. 23, 2003	1054:39.70	51.46	176.56	33	5.3	190
3	Oct. 23, 2003	1532:06.18	51.39	176.55	33	5.1	156



Daily variations in the Ez components of a quasi-static electric field in the surface atmosphere of Kamchatka, meteorological quantities, and fluxes of solar X-ray radiation (in the range 0.1–0.8 nm) in October 2003.

Events in November 2006

These events are associated with the strong Kuril earthquakes, the magnitude of which exceeded M ~ 8.

Solar activity during these periods remained relatively quiet, the X-ray fluxes were on the order of 10^{-6} W/m^2

Cyclonic activity was also very low: Typhoon CHEBI originated at latitudes below 20^0 N and shifted for four days (November 9-13) in the longitude range 115-135º E with a maximum wind speed of ~ 100 knots / h.

Typhoon CHEBI track in November 2006

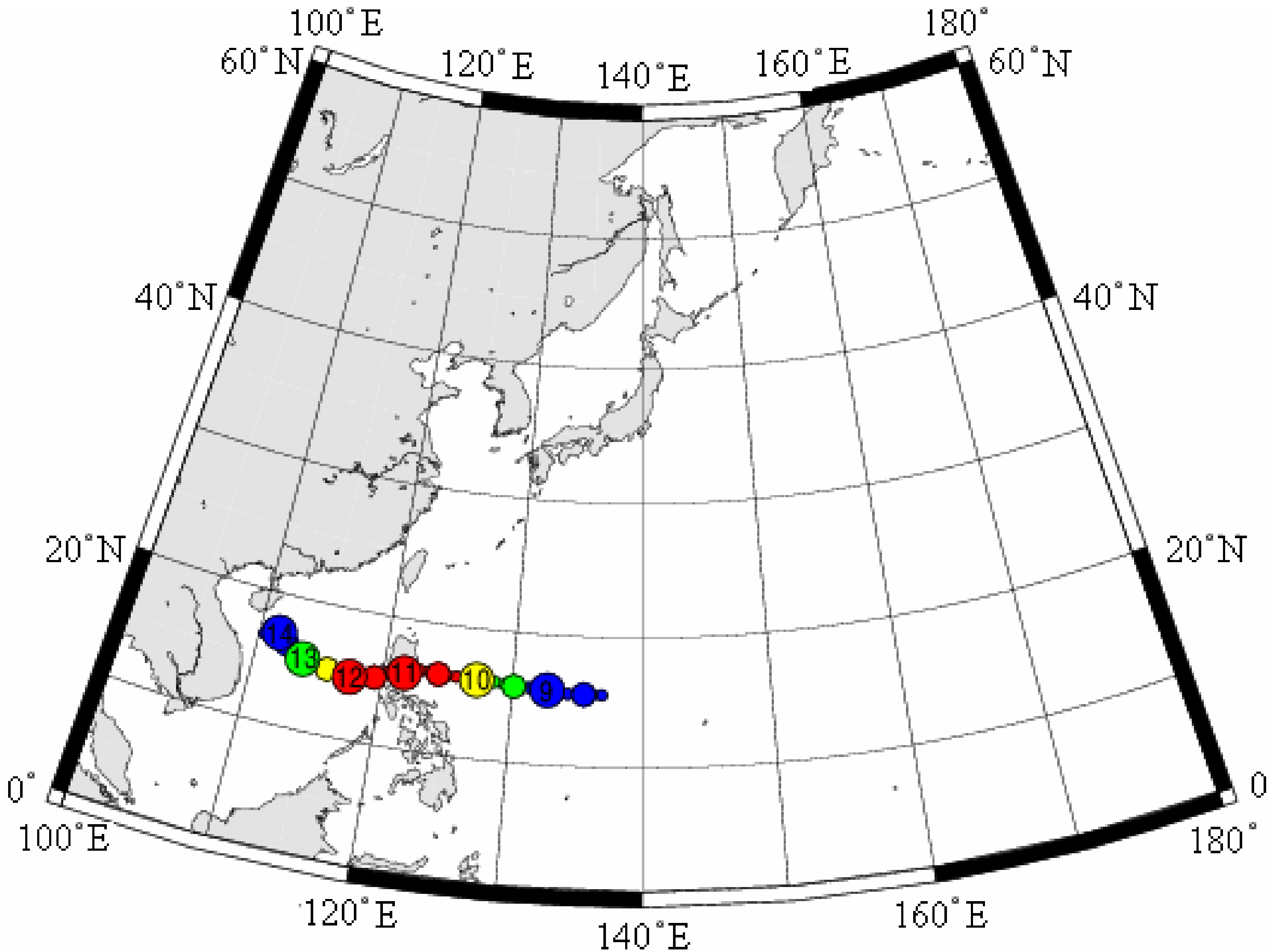
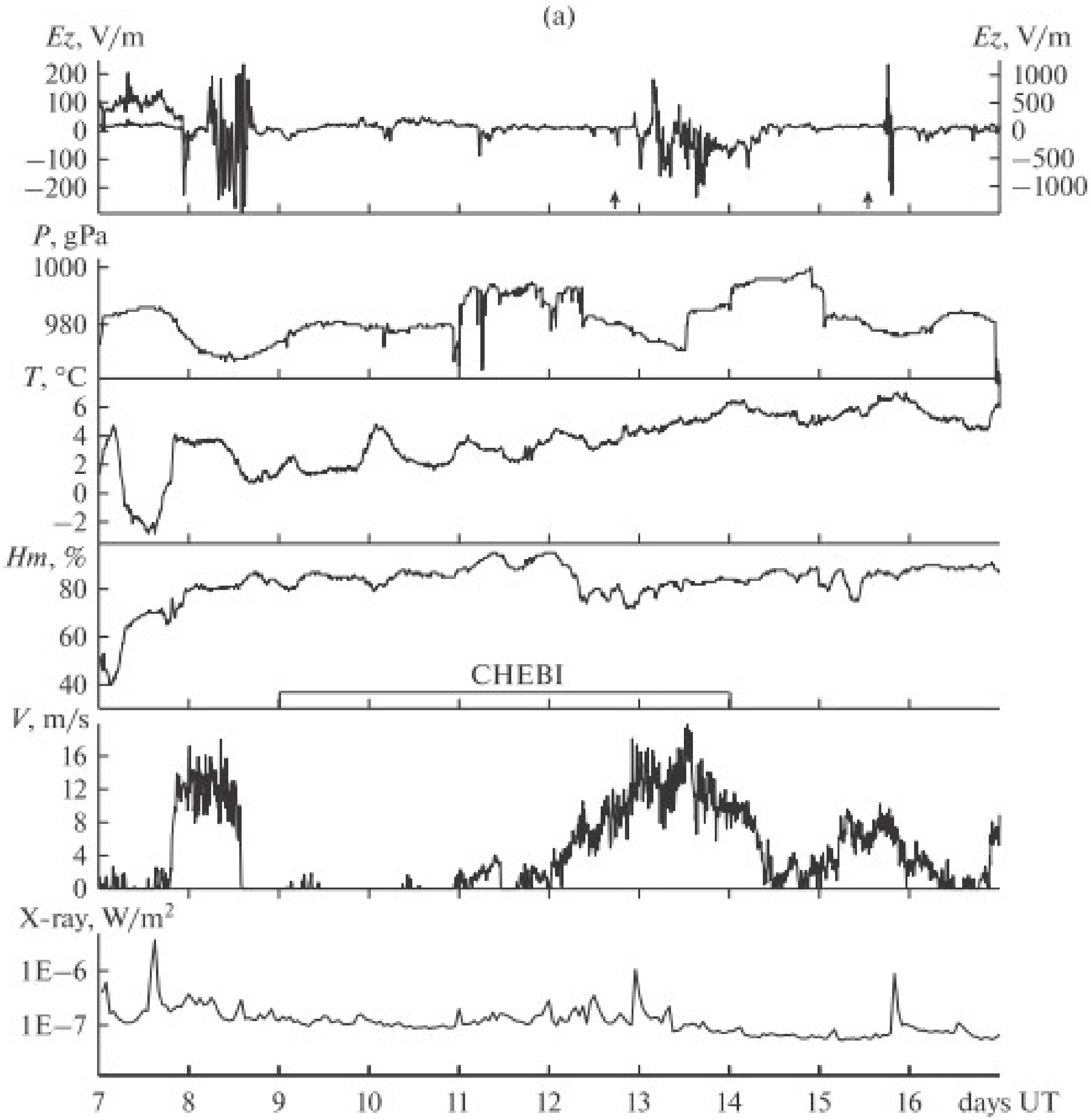


Table 3. Characteristics of earthquakes near the Kamchatka Peninsula in November 2006 and January 2007

N	Date	UT time	Geographical coordinates		*h*, km	*M*	*R*, km
			φ°, N	λ°, E			
1	Nov. 12, 2006	1442:24	55.164	165.295	37.4	5.0	140
2	Nov. 15, 2006	1114:13.57	46.592	153.266	30.3	8.3	3706
3	Jan. 8, 2007	1623:38.00	54.297	159.170	136.5	4.6	95
4	Jan. 11, 2007	0427:26.32	60.955	165.478	10.0	5.0	140
5	Jan. 13, 2007	0423:21.16	46.243	154.524	10.0	8.1	3040
6	Jan. 13, 2007	1735:22.51	54.796	166.192	10.0	4.9	127
7	Jan. 13, 2007	1737:06.31	46.913	156.276	10.0	6.0	380



Daily variations in the Ez components of a quasi-static electric field in the surface atmosphere of Kamchatka, meteorological quantities, and fluxes of solar X-ray radiation (in the range 0.1–0.8 nm) in November 2004.

Main results

Despite the active cyclonic activity in the autumn-winter period, very few thunderstorms are observed in Kamchatka. When studying the occurrence of winter thunderstorms, one should take into account additional factors of the influx of thermal energy during the formation of thunderstorm clouds.

In the events of November 2004, such a factor was the increased solar activity.

In October 2003, the action of a powerful tropical cyclone was superimposed on the increased solar activity.

In November 2006, a powerful seismic event with M> 8 could have been an additional inflow of heat into cyclonic activity.

Main results

In December 2014, in the absence of tropical cyclones on December 19 and 20, against the background of relatively weak solar activity, solar flares with an X-ray flux of ~10^{-4} W/m^2 occurred, which can be considered as a source of additional heat flux in the surface atmosphere.

In cases:
December 2008,
November 2012,
January 2018,
november 2018
under conditions of weak solar activity and the absence of tropical cyclones, a swarm of moderate earthquakes (up to 15) near the eastern border of the peninsula should apparently be considered as sources of additional heat flux in the surface atmosphere.

In the other cases of winter thunderstorms considered in the work, there were indeed tropical cyclones with an intensity of 18 to 59 m/s.

Conclusions

For the formation of thunderclouds in Kamchatka, heat sources can act:

Primary: tropical cyclones
Additional: solar activity
seismic activity

References

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Thank you!