Ultra low-frequency electromagnetic variation observed prior to development of an earthquake followed by tsunami

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Analysis of experimental observations of variations in the magnetic field of the Earth recorded by instrumental complexes of the Northern-Caucasus Geophysical Observatory is performed. It is confirmed that it is possible to distinguish characteristic ultra-low-frequency (ULF) wave forms in the structure of the recorded electromagnetic signals preceding strong teleseismic events (earthquakes), especially ones being followed by tsunami.

The Alaska earthquake of March 27, 1964, with a magnitude of 9.2 was one of the strongest events in the history of instrumental seismic observations. At the end of 1964, G. W. Moore was the first to report about characteristic magnetic signals (forerunners), which appeared two hours before the earthquake [Fraser-Smith, 2008]. Investigation of forerunners of this class was continued [Gul'el'mi, 2007; Sobisevich et al., 2008a]. Anomalous electromagnetic signals before strong earthquakes were observed in a wide frequency range [Bakhmutov et al., 2003; Gul'el'mi, 2007; Sobisevich et al., 2008b]. The main efforts of scientists were focused on the study of anomalous broad-band electromagnetic disturbances [Barsukov, 1991]. Quasi-harmonic components almost fell out of consideration. This explains the fact that, during the last 50 years, ultra-low-frequency electromagnetic forerunners are periodically discussed, but so far there is no full agreement among geophysicists about the possibility of their reliable separation and practical application.

There is no satisfactory theoretical explanation of this effect so far [Alekseev et al., 2008; Gul'el'mi, 2008]. Therefore, field experiment becomes the first tool in the investigation of the revealed effect.

In recent years, systematic observations of magnetic field fluctuations with ultra-low frequency have been carried out at the Northern-Caucasus Geophysical Observatory of the Institute of Physics of the Earth (IPE RAS) equipped with modern geophysical instruments, including tiltmeters and triaxial magnetic variometers [Sobisevich et al., 2008a]. Analysis of the accumulated geophysical information about stimulated wave processes caused by remote earthquakes allowed us to confirm the existence of electromagnetic forerunners and distinguish anomalous wave forms with ultra-low-frequency of disturbances before strong teleseismic events 2—4 h before their beginning [Sobisevich et al., 2009].

Almost every earthquake with magnitude greater than 6 and followed by tsunami in 2007—2009 has been carefully analysed in terms of experimental observations over magnetic variations in the Northern-Caucasus geophysical Observatory (Table).

In every case there have been determined ULS geomagnetic variations, yet the first event registered and analysed was the Great Sumatera-Andaman earthquake back in 2004 (Fig. 1).

We refer to universal time here and further in this text. Analysis of magnetic variations has revealed the two time intervals with geomagnetic anomalies (possible precursors) may be clearly observed. Detailed representations of mentioned wave-forms are shown in the two incuts (1 and 2) while filtered anomalous ULF geomagnetic variations observed close to midnight December 24—25 are shown in Fig. 2.

It has been shown that quasi-harmonic wave forms of the geomagnetic variation determined in the time interval from 2006.12.24 23:58 to 2006.12.25 00:23 is containing information on electrodynamic processes in the domain of forthcoming seismic event.

It should be emphasized, that magnetic variometers are also registering well-known quasi-harmonic pulsations (Pc4 pulsations) of ionosphere origin. By comparing experimental records of the Pc4 geomagnetic

Date	Hypocenter/origin time	Location	Magnitude	Depth, km	Latitude	Longitude	Period of variations, s	Amplitude of variations, nT
01.04.2007	20:39:54.2	Solomon Islands	8.1	10.0	–8.3	156.9	120	1
16.07.2007	1:13:22.0	Japan	6.6	33.0	37.6	138.5	80	2.5
02.08.2007	2:37:42.3	Sakhalin	6.2	10.0	47.1	141.7	60	0.8
02.08.2007	3:21:42.8	Aleutian Islands	6.7		51.31	–180	60	0.8
15.08.2007	23:40:56.5	Near coast of Peru	8	40	–13.5	–76.6	120	1
02.09.2007	01:05:17.5	Santa-Cruz Islands	7.2	33.0	–11.3	165.8	60	2
12.09.2007	11:10:23.5	Indonesia	8.4	30.0	–4.4	101.5	75	1.8
30.09.2007	05:23:35.3	New Zealand	7.4	20	–49.31	163.8	50	3
14.11.2007	15:40:51.7	Northern Chile	7.7	60.0	–22.21	–69.93	80	2
03.12.2007		Canada					140	1.5
09.12.2007	07:28:24.0	Fiji	7.8	190.0	–25.8	–17.5	190	1.5
25.02.2008	0,35872	Indonesia	6.5	33.0	–2.5	99.9	80	3.5
09.04.2008	12:46:12.5	Loyalty Islands	7.3	40.0	–20.1	168.9	66	4
28.04.2008	18:33:34.2	Vanuatu Islands	6.4				52	4
12.05.2009	06:28:00.0	China	7.9	10.0	31.2	103.3	70	3.6
19.07.2008	2:29:28.7	Japan	6.9		37.6	142.2	75	1
11.09.2008	0:20:50.9	Japan	6.8	33.0	41.9	143.8	150	3
28.10.2008		USA			43.9	–69.6		
16.11.2009	17:02:31.8	South Peninsula Sulawesi	7.3	33	1.3	122.1	40	1
03.01.2009	19:43:53.0	Indonesia	7.6	33.0	–0.45	132.75	63	2.1
03.01.2009	22:33:40.2	Indonesia	7.3	33.0	–0.7	133.3	63	2.1
15.01.2009	17:49:36.8	East of Kuril Islands	7.4	33.0	46.9	155.2	126	3.4
11.02.2009	17:34:50.7	Indonesia	7.2	33.0	3.7	126.5	158	2
19.03.2009	18:17:38.8	Tonga Islands	7.6	33.0	–23.2	–174.6	95	1.2
28.05.2009	08:24:43.0	Caribbean Sea	7.3	10.0	16.7	–86.4	158	3
15.07.2009	09:22:31.8	New Zealand	7.8	33.0	–45.7	166.7	110	1.1
10.08.2009	19:55:38.5	Andaman Islands	7.5	33.0	14.1	92.92	126	2.9
10.08.2009	20:7:9.1	Japan	6.4	33	34.74	138.3	126	2.9
16.08.2009	7:38:21.7	Sumatra	6.7	50	–1.479	99.49	150	2
29.09.2009	17:48:11.0	Samoa Islands	8	20.0	–15.4	–172.2	150	4
30.09.2009	10:16:08.6	Indonesia	7.5	90.0	–0.8	99.9	150	4
07.10.2009	23:03:14.4	Vanuatu Islands	7.6	33	–13.01	166.5	250	2.5

pulsations with registered geomagnetic variations in question, one should note that for now there is no clear indication of what is the primary phenomena and what is the secondary one, in other words there is no clear indication that every magnetic variation in this frequency range is related to Solar activity only and is not related to electrodynamic processes accompanying the development of the domain of forthcoming seismic event.

For more than seven years we have been analyzing experimental records of ULF geomagnetic variations at the Northern-Caucasus Geophysical Observatory and based on this experience may we suppose that the initial phenomena is the geomagnetic signal generated in the domain of development of forthcoming seismic event.

In Fig. 3, 4 the time interval of several hours prior to the main shock of the Sumatra-Andaman earthquake featuring the fine structure of geomagnetic variation is shown.

Analysis of geodynamic settings in the course of preparation and development of the Sumatra-Andaman earthquake in combinations with records of magnetic variations has allowed to outline the specific type of quasi-harmonic ULF geomagnetic variations preceding an earthquake followed by tsunami. It has been suggested that the origin of mentioned geomagnetic variations is located within the

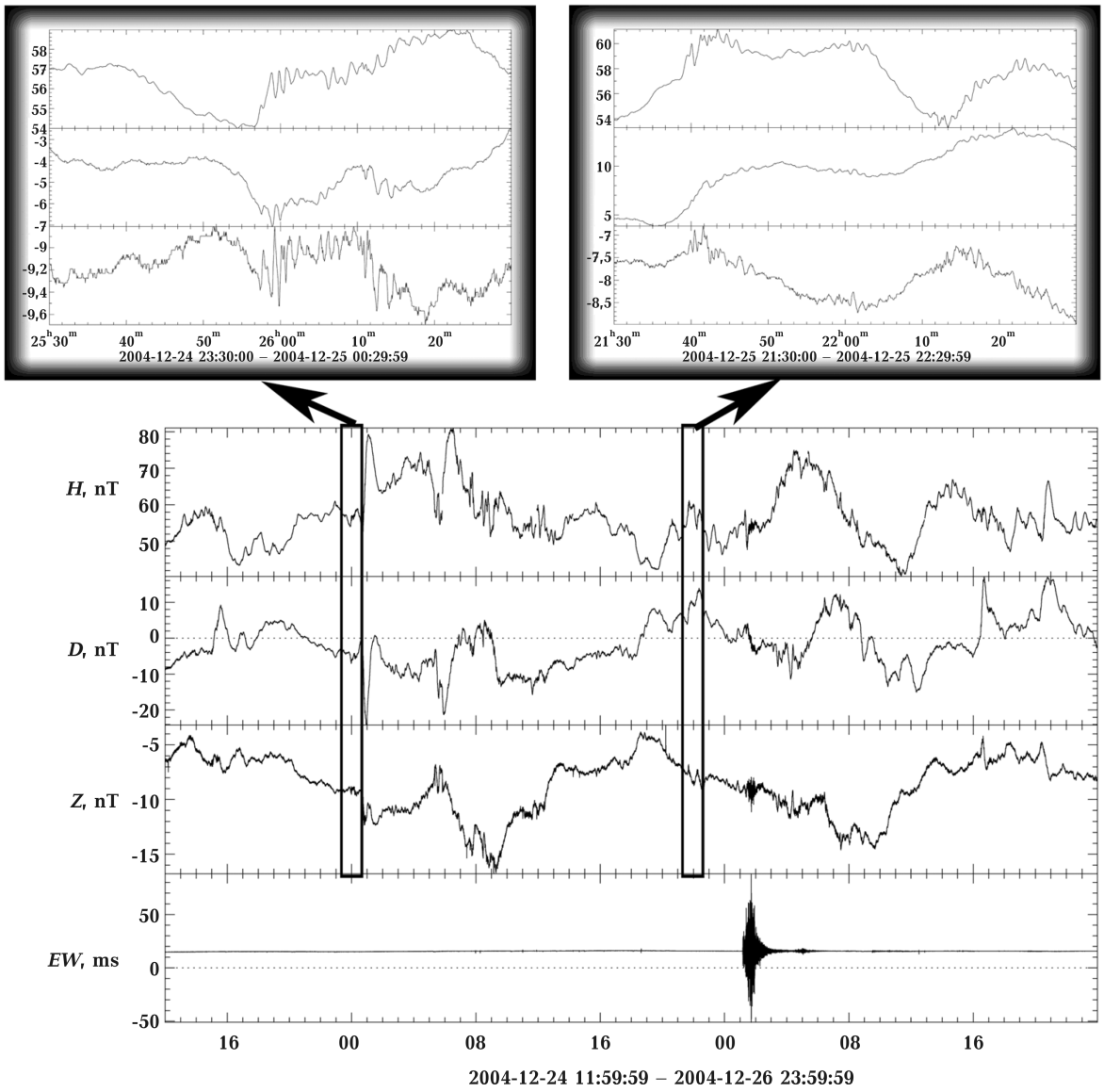

Fig. 1. Magnetic variations and tilt measurements recorded prior to the earthquake in Sumatra region as of 26.12.2004.

domain of a forthcoming epicenter and their amplitude observed at the distant locations (Laboratories 2 and 4, the Northern-Caucasus Geophysical Observatory, Elbrus volcanic area) varied from 0.5—1.2 nT.

Analysis of recorded data for the M=7.8 Northern Sumatera earthquake 06.04.2010 responsible for tsunami generation has confirmed the existence of ULF geomagnetic variations (Fig. 5, 6).

Analysis of ULF geomagnetic variations has revealed its quasi-harmonic nature and structure.

It should be emphasized, that experimental data collected by means of instrumental observations in the Northern-Caucasus Geophysical Observatory is of highest quality standards and thus is quite reliable in terms of short-time geomagnetic disturbances prior to development of an earthquake followed by tsunami (Table) are obtained for the first time and to the best of our knowledge there are no similar results obtained worldwide for now.

Results of experimental observations carried out in the Northern-Caucasus Geophysical Observatory are stored in the on-line flat file database (Public Domain) with the two following URLs: http://forecast.izmiran.ru/ and http://alex.uipe.ru/data/.

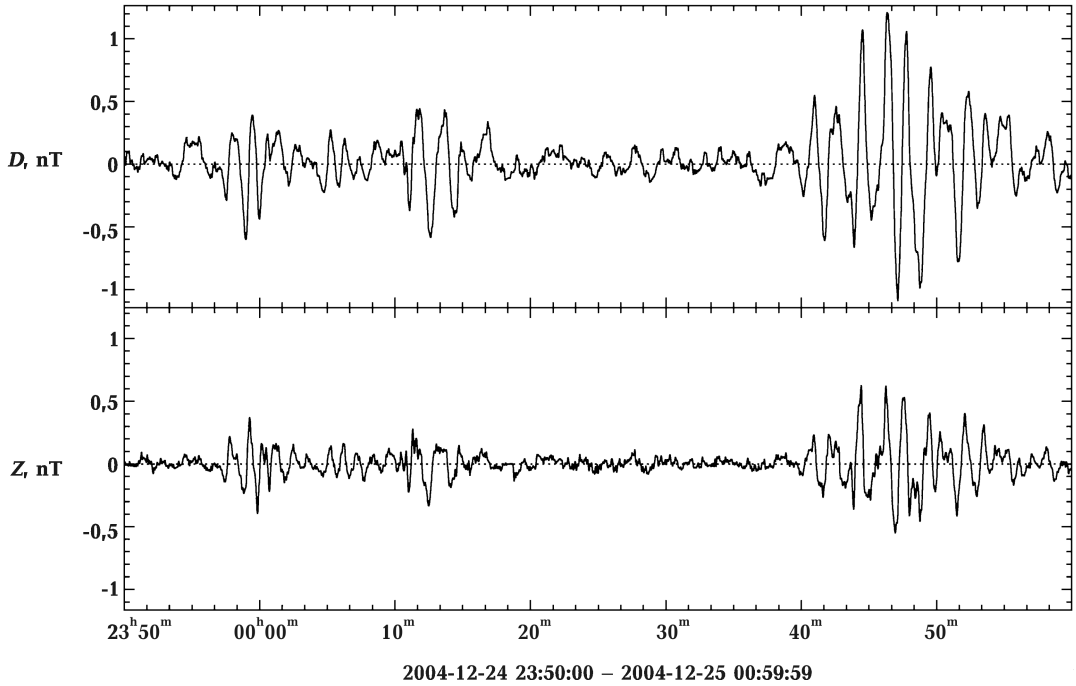

Fig. 2. Filtered quasi-periodic variations, featuring specific characteristics of geomagnetic disturbance originated approx. 24 hours prior to the Sumatra earthquake as of 26.12.2004.

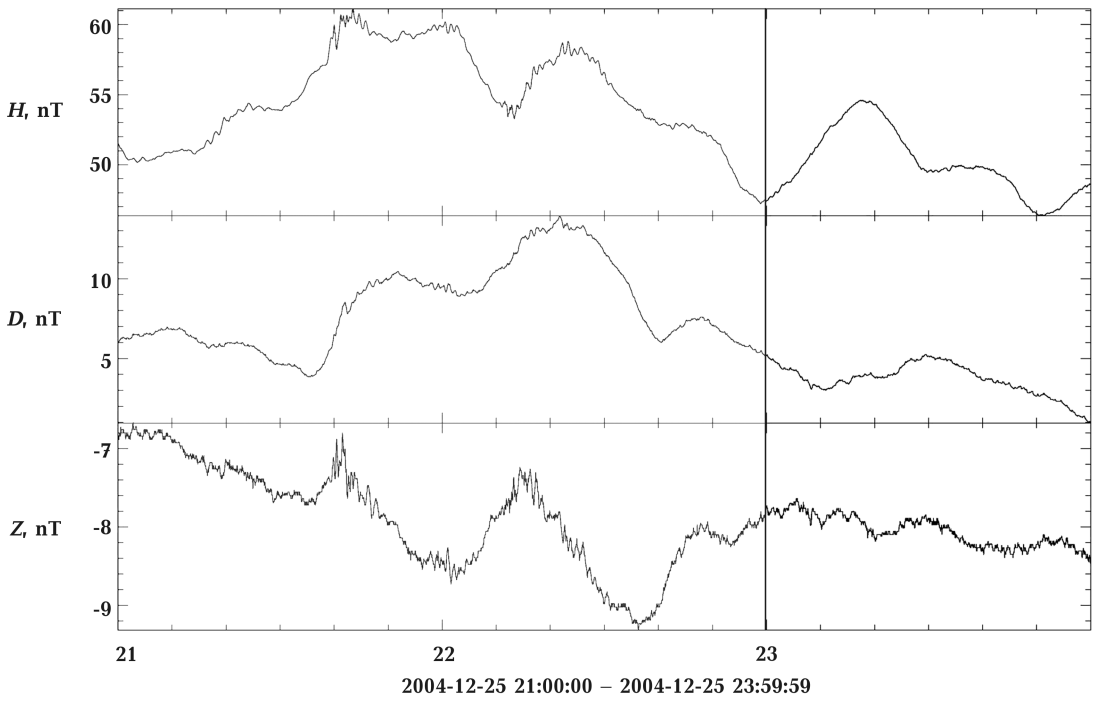

Fig. 3. Selected fragment of the record of magnetic variations in the region of Sumatra as of 26.12.2004.

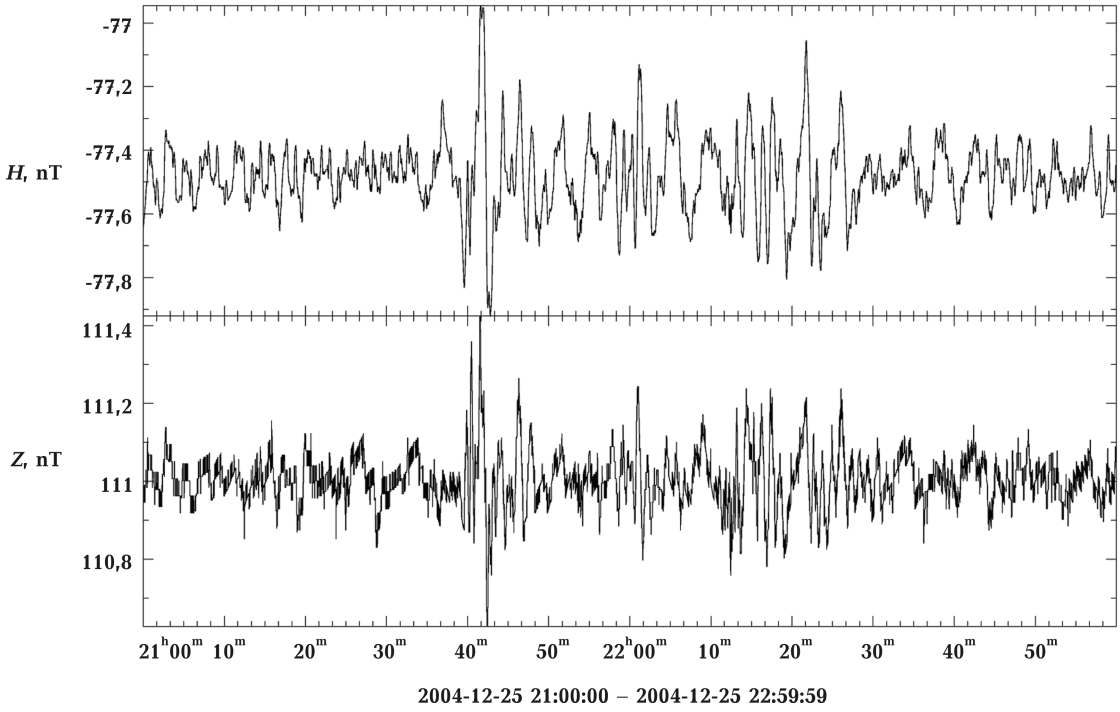

Fig. 4. The structure of geomagnetic variations preceding the Sumatra earthquake as of 26.12.2004.

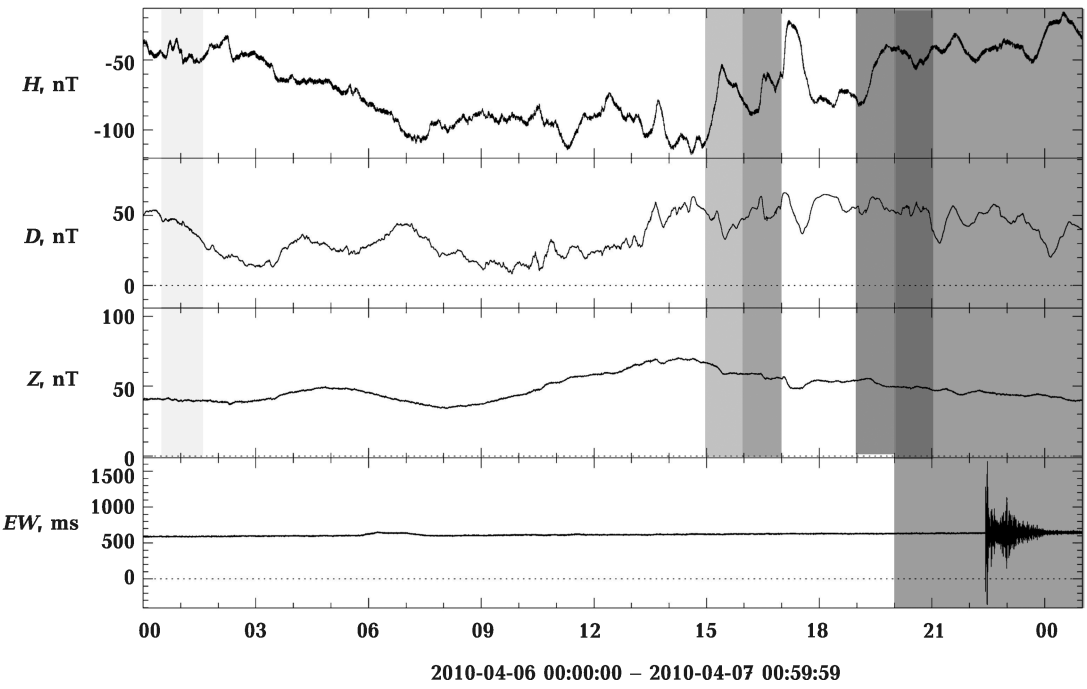

Fig. 5. The Northern Sumatra earthquake 06.04.2010 responsible for tsunami generation. Records of East-West tilt and triaxial magnetic variations. Colour selections represent specific fragments of the experimental records with anomalous ULF geomagnetic disturbances.

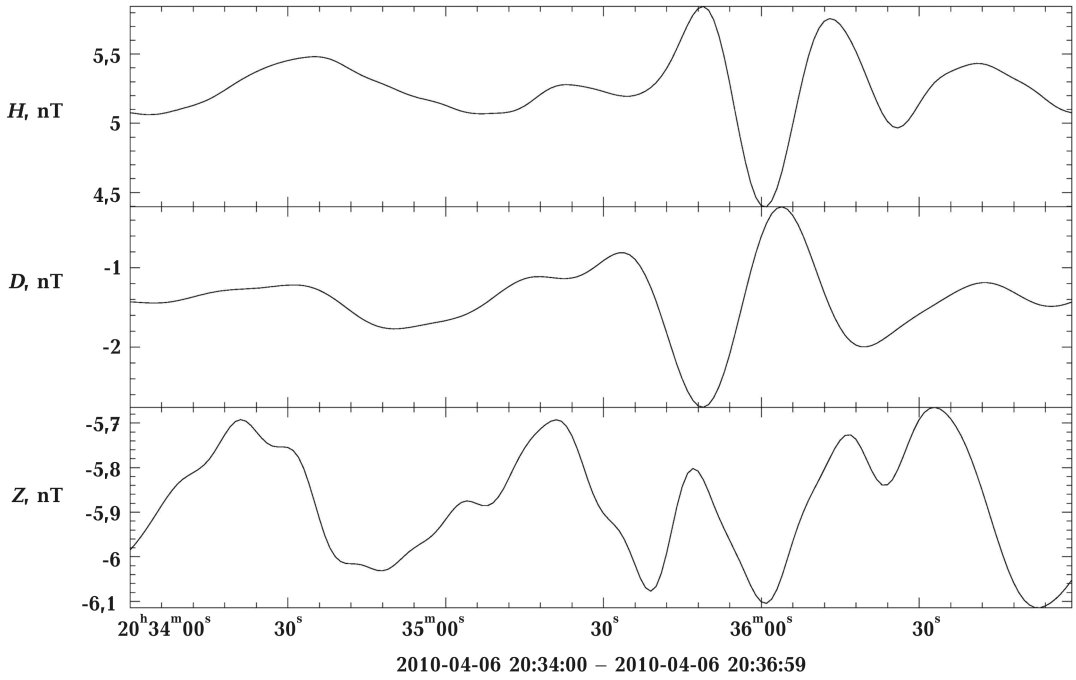

Fig. 6. Filtered and rescaled wave forms of the ULF geomagnetic disturbances observed one hour prior to the Northern Sumatra earthquake 06.04.2010.

This study was supported by the Russian Foundation for Basic Research (project nos. 09—05—00066 and 09—05—00431), and Program 4 of the Presidium of the Russian Academy of Sciences, and the Russian Science Support Foundation (www.science-support.ru).

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