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Snowstorm at the geomagnetic observatory

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Abstract

The Sinji Vrh Geomagnetic Observatory is situated on Gora above Ajdovščina, a highland Karst Plateau, in the southwest part of Slovenia. The observatory operates in exceptional geological and meteorological conditions due to its location. Already first measurements at the time of initial tests showed that weather fronts induce changes in the local magnetic field. The first dedicated measurements for determining the value of this influence were carried out at the end of summer 2011. On January 2013 the first such measurements were carried out during the winter. This article presents the results of these measurements, showing how the snowstorm induced changes in the earth magnetic field.

1 Sinji Vrh Geomagnetic Observatory

Gora, above Ajdovščina, is a highland Karst Plateau. The Sinji Vrh Geomagnetic Observatory (here and after: Observatory) is built on its edge, which is facing the southwest (Paliska, 2010). The measuring post for the Observatory is located on the spot (45.899094° N, 13.940047° E) above Ajdovščina, a town that lies at a height of 106 m a.s.l., at the foothills of the mountain Gora. The measuring post is northeast from Ajdovščina at a directed distance of 2.8 km, where the Gora's edge reaches a height of 867 m a.s.l.

In summer of 2009 a first storm with lightning stroke on the location where the Observatory is situated was recorded and also confirmed by neighbors of it. This storm was recorded during the test measurements if that place is right for geomagnetic observatory. In the 22 August 2009 at 20:08:50 UTC were registered lightning stroke in the middle of the second wave of geomagnetic field with period of $T = 3.43$ h as presented on Fig. 1.

The Observatory has a special construction and operates in exceptional geological and meteorological conditions because of its location, recommendations and the

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conditions prescribed by nature protection technicians (Čop, 2012). The first dedicated measurements for determining the value of this influence on the local geomagnetic field were carried out on 4 September 2011. They showed that atmospheric discharge, the transitions of the weather fronts and the Karst underground also induce the changes in the local geomagnetic fields.

2 Snowstorm on Gora

The meteorological measurements for Gora's area are carried out at the meteorological station called AMP Otlica (45.938056° N, 13.916111° E). This is an ecological meteorological station, which monitors environmental changes on Gora. It is located on the south slope of the hill Sibirija, above the village Otlica, at a height of 965 m a.s.l., 4.8 km away from the Observatory in the direction towards northwest.

The period of several months with the exceptionally abundant snowfalls, which marked the winter in 2012/2013 stopped with the snowstorm at Gora on Tuesday, 15 January 2013. On the night from 14 to 15 January the wind which was blowing from the northeast changed its direction and started to blow from the south as shown in Fig. 2. About 03:00 UTC along with the change of the wind direction the weather warmed and one hour later the snow started to fall. The first wave of the snowstorm diminished after 4 h when it became a little bit brighter as shown on Fig. 3. After intermediate calmness, at 10:20 UTC the second wave of storm reached Gora. At the same time air discharges started and of the registered lightning flashes only one occurred between a cloud and the ground. The next wave of the snowstorm passed over Gora at 13:30 UTC. At that time the wind speed decreased from the previous average value of 2.77 to 1.29 $\mathrm{m\,s^{-1}}$, and this value was observed during the rest of the day as well presented on Fig. 2.

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3 Air discharges

Winds blowing from the south often bring storms to Gora. These southerly winds come from the sea; therefore the Slovenian locals call it "mornik" or, in English, "the sea wind". The southerly winds bring the humid air masses of a storm front which hits the edge of Gora and rises up more than 1000 m in a very short time, causing the additional electrical charge of stormy clouds. The wind "bora", in Slovenian language "burja", blows from north-east in opposite direction like "mornik". It is fall wind and rush down from Gora also in gusts which overlap also 150 $\mathrm{km\,h^{-1}}$. It blows very tiny in troposphere over the ground floor and not produces additional electrical charge in stormy clouds.

The lightning stroke which, during the thunderstorm on 12 September 2012, destroyed the electronic parts of the 3-axis fluxgate magnetometer was the ninth in a row, and was 1.111 km far away from the Observatory (Čop, 2014). The positive particles carry an electric current of 106.264 kA. On the basis of the assumption that the overvoltage is induced in the coils of the magnetometer's sensor the adequate Eq. (1) was developed.

$$u_i = -N\frac{\mathrm{d}\Phi}{\mathrm{d}t} = -N\frac{\mathrm{d}}{\mathrm{d}t}(S\mu_0 H) = -k\frac{1}{L}\frac{\mathrm{d}I}{\mathrm{d}t} \tag{1}$$

If the time-variations of the lightning currents are approximately equal, we can calculate the influence of each separate lightning stroke on a measuring instrument N_x/N_9. Table 1 presents the characteristics of the destructive lightning strike, the ninth in a row, which occurred during the summer thunderstorm on 12 September 2012 and of the only lightning strike registered during the snowstorm on 15 January 2013. The value of its effect was equal to the value of 8 % of the destructive lightning strike effect (Čop, 2014).

The detailed analyses of a magnetogram in Fig. 4 showed the occurrence of more atmospheric discharges during the half hour period of the second wave of the snow storm on Gora. Most of the electrical discharges happened within a cloud or between clouds. The only lightning flash, which occurred due to the electrical discharge of a negative

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charge between a cloud and the ground, happened at 10:20:45 UTC. It was between the last air discharges registered that day at the Observatory.

4 Changes in the local geomagnetic field

On Tuesday 15 January 2013 our planet had its magnetically quiet day. It is evident from the diagram of the planetary three-hour-range Kp indexes for that day (Estimated Planetary K index, 2015), which showed that the Kp-index reached its maximum value of Kp = 2 during the three-hour-range from 06:00 by 09:00 UTC. The planetary Kp-indexes for the rest of that day were 1 or even lower. The planetary three-hour-range Kp indexes for 5 January 2013 indicated that it also was a magnetically quiet day as also presented in Fig. 5. The first half of that day the planetary geomagnetic index Kp = 1, and the second half of the day Kp = 0.

On 15 January 2013 the magnetogram of change in the absolute value of the geomagnetic field recorded at the Observatory were presented on Figs. 3 and 6. The characteristic changes in the geomagnetic field which began after the 03:00 UTC and its duration was approximately six hours. This change was followed by a change with the same period but with approximately twice as big as the amplitude.

Relating to the values of the planetary Kp-index this change in the geomagnetic field had a local character. The comparison of these measurements with the parallel measurements of change in the geomagnetic field performed at the geomagnetic observatory Grocka (GCK), Serbia, on 15 January 2013 indicated the close similarity of the magnetograms. This means that the local geomagnetic disturbance was presented in the broader geographic area which also encompassed a large part of the Balkans. At the Observatory this disturbance started with the increase of relative humidity to 100 % at the outdoor air temperature −3 °C and it was changing according to the solar radiation level as presented on Fig. 3.

The parallel measurements on 15 January 2013 at the Observatory and GCK geomagnetic observatory viewed on Fig. 6 had the value of a correlation coefficient

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$r = 0.803$ as presented in Table 2. This is a little bit under the mean value of this coefficient $r_{mean} = 0.854$ for both geomagnetic observatories (Čop, 2011). This proves that the impact of the weather front on the geomagnetic field was pretty much the same for both locations and any distinction was in details.

5 Frequency characteristics

The available measuring equipment at the Observatory enables the analyses of measuring results in frequency-domain for signals with the time period from 0.5 s to 24 h as presented on Fig. 7. Comparison of values of the local geomagnetic field – measured and analyzed with respect to frequency during the snowstorm above Gora on 15 January 2013 – with those measured during the magnetically quiet day on 5 January 2013, shows that signal power during the snow storm drops sharply at the time period of $t = 24$ and $t = 12$ h, while the signal power at $t = 6$ and $t = 7.5$ h increased.

The analyses in frequency-domain of the signals with the time period $t < 2$ h, which were recorded during the snowstorm, did not show any significant increase of amplitudes of resonant frequencies. However, the time period of the signals was prolonged compared to its value during the magnetically quiet day.

The function of geomagnetic field variation of the day with snow storm $f(t)$ is also possible to present as superposition of moments. The function $f(t)$ can be transformed by integral Laplace transform into the function of complex frequency $f(s)$. This transform is possible because the function $f(t)$ is continuous function in all observed interval of time. If it is known also the function of geomagnetic field variation in geomagnetic calm day $f_0(s)$ expressed in complex frequency than the function of disturbance of snowstorm $g(t)$ can also be calculated. This calculation by inverse Laplace transform is presented in Eq. (2).

$$g(t) = L^{-1}[g(s)] = L^{-1}[f(s) - f_0(s)] \quad (2)$$

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The function of disturbance of local geomagnetic field by snowstorm $g(t)$ can be used for comparisons and for predictions.

6 Conclusions

The systematical observation of weather fronts crossing the local area during several years and in different seasons may provide enough data to entirely understand their influence on the local geomagnetic field. The comparison of parallel measurements at the geomagnetic observatories in the vicinity would give more precisely the geographic size of influence of an individual weather front.

The influence of storm fronts on the biosphere could be determined by researching also the conditions of the area two days before and two days after the storm crosses the area. The parallel measurements of parameters of personal health conditions may show the influence of both the storm front crossing and the change in the geomagnetic filed on personal health conditions (Deželjin, 2013). Additionally the influence of the Schumann resonances may be determined by researching electromagnetic pulses in the range of frequency from 0.2 to 50 Hz.

Same weather fronts passing the southwest part of Slovenia have the characteristics of mesoscale convective systems MCS (Morel, 2002). For this reason in this location is possible to study also the transient luminous events TLE. They are upper atmospheric electrical discharges that occur above thunderstorms from clouds top to as high as 90 km. TLE are initiated by the strong positive lightning strokes from cloud to ground and are well documented only in last two decades (Pasko, 1996; Chen, 2008). The main reason for their development is exponential reduction of pressure with high of atmosphere (Raizer, 1998). They produce pulses of extremely low frequency ELF lower than 1 kHz (Cummer, 1998). Evidently they have the impact also on instruments for measuring the variation of geomagnetic field on Observatory (Čop, 2014).

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– Agency of the Republic of Slovenia for Environment [ARSO – Agencija Republike Slovenije za okolje], Meteorology Office, for results of measurements of the Meteorological Station AMP Otlica for 15 January 2013;

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– Geomagnetic Observatory, Grocka, Serbia for the results of measurements of change in the geomagnetic field for 15 January 2013.

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Table 1. Data on lightning strokes during the thunderstorms on Gora above Ajdovščina.

Number N	Date	Time	Y	X	Amplitude I [kA]	Distance L [km]	Proportion N_x/N_9
9	12 Sep 2012	13:55:07.4	5417713	5083341	+106 264	1.111	1.00
1	15 Jan 2013	10:20:45.1	5417462	5085321	−7289	0.902	0.08

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Table 2. The comparison of the statistical values and the correlation of the measurement results obtained on 15 January 2013, at the Sinji Vrh with those obtained at the Grocka.

Observatory	Mean value μ [nT]	Deviation σ [nT]	Variation CV [%]	Correlation r
Sinji vrh	47651.12	2.62	0.0055	1.00000
Grocka	47712.76	2.19	0.0046	0.803

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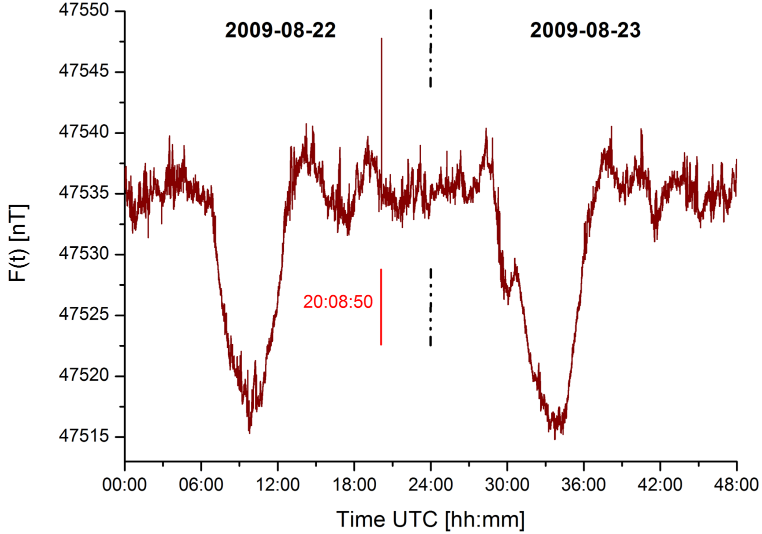

Figure 1. The daily variation of geomagnetic field $F(t)$ at Sinji vrh in two successive days in summer time in 2009.

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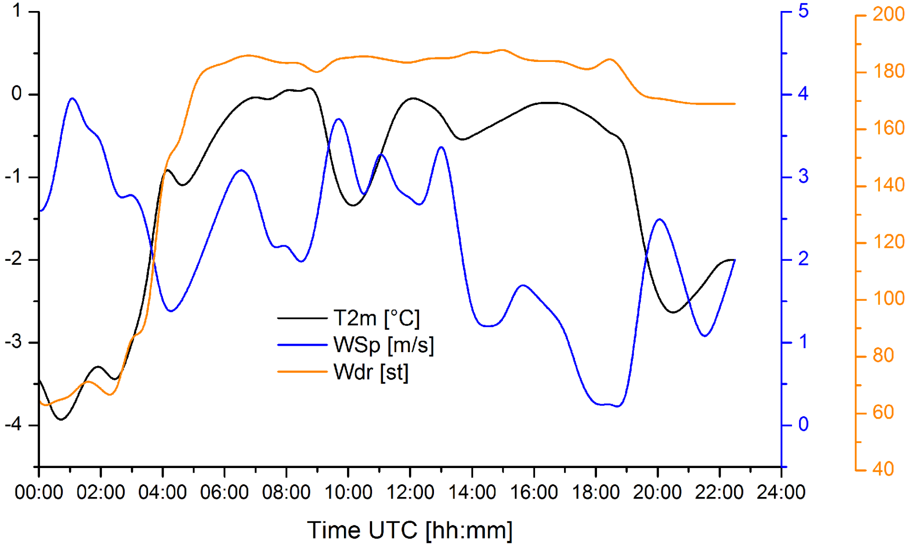

Figure 2. Temperature change (T2m), wind speed (WSp), wind direction (Wdr) – measured at AMP Otlica during the 15 January 2013 snow storm.

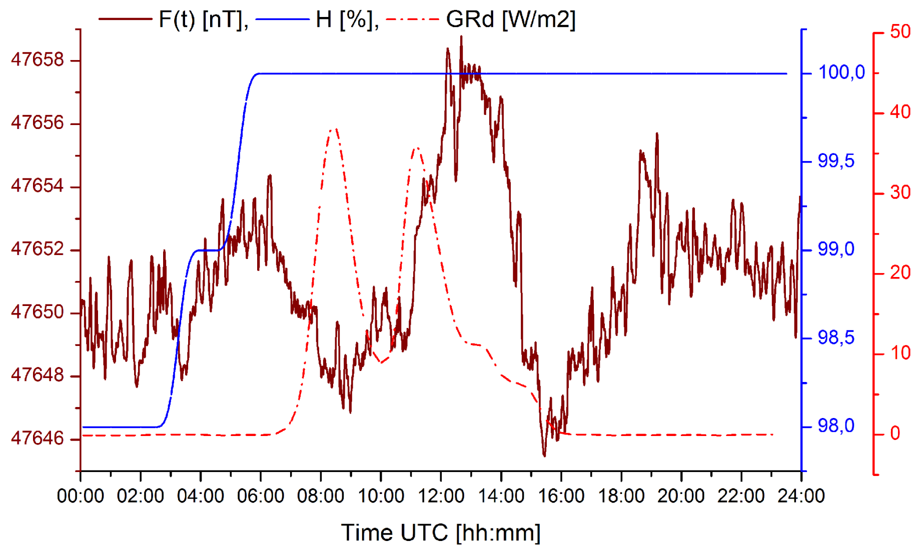

Figure 3. The local geomagnetic field's variations at the Observatory on 15 January 2013 snow storm and the values of humidity (*H*) and solar radiation (GRd) measured the same day at AMP Otilica.

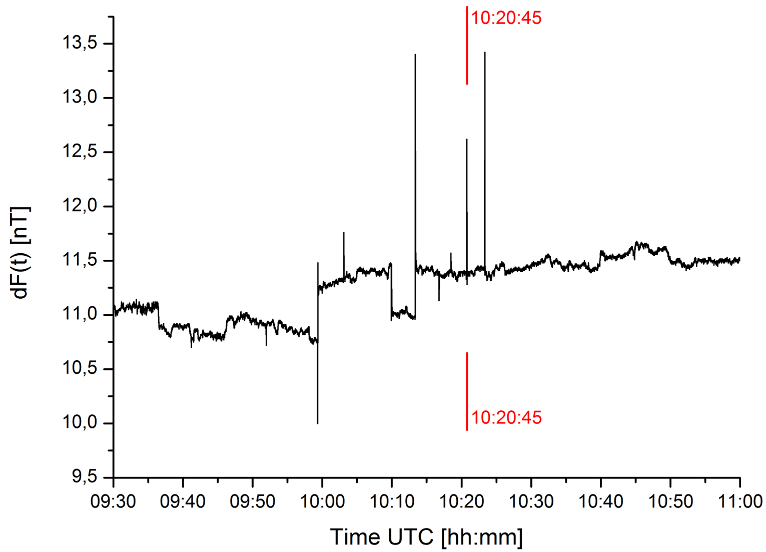

Figure 4. Change of the geomagnetic field d$F(t)$ recorded during the measurements on 15 January 2013, at the beginning of the second part of the snow storm on Gora.

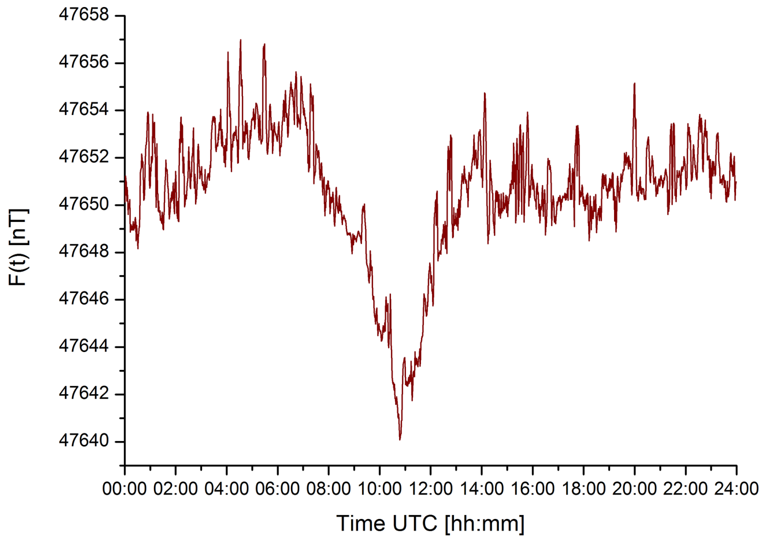

Figure 5. The daily variation of the geomagnetic field $F(t)$ at Sinji Vrh during the geomagnetic calm day on 5 January 2013.

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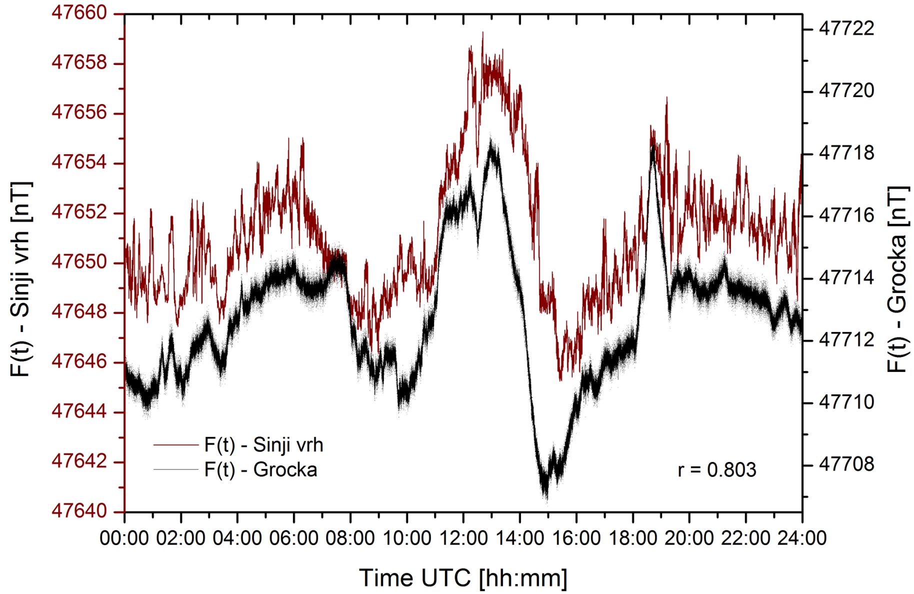

Figure 6. Change in the absolute value of the geomagnetic field vector $F(t)$ recorded at the Observatory and GCK geomagnetic observatory during 15 January 2013 snow storm.

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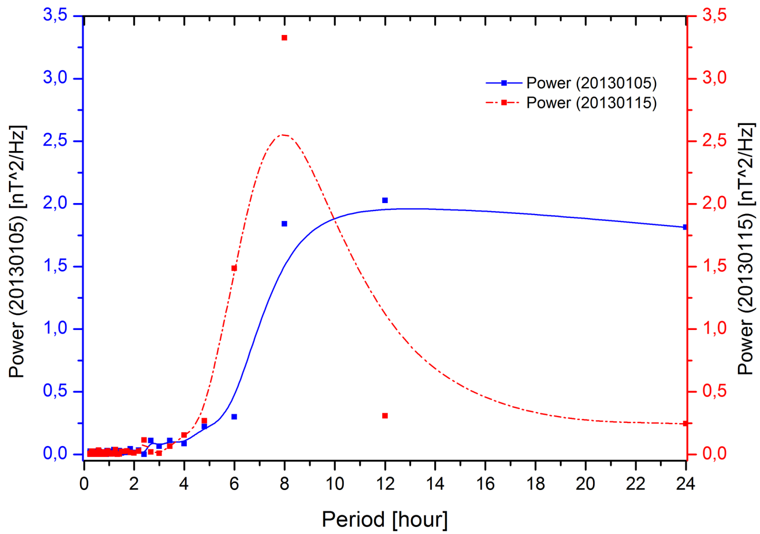

Figure 7. The power spectrums of the local geomagnetic field on Observatory during the snowstorm crossing on 15 January 2013 (20130115) and during the magnetically quiet day on 5 January 2013 (20130105).

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