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"Solar-terrestrial relations and physics of earthquakes precursors"
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Возможные эффекты от железной дороги в магнитных измерениях на Геофизической обсерватории "Новосибирск"

Possible railway effects in magnetic measurements at Geophysical Observatory Novosibirsk

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Introductions

Magnetic observatories are one of the most accurate and stable elements of the Earth's magnetic field observation system.

The historical trend of increasing the time and amplitude resolution of magnetometers and the development of more efficient methods of processing measurement results leads to the fact that the conditions under which these magnetic measurements are performed become a factor limiting the expected increase in the quality of the data obtained.

One of such factors is electromagnetic noise, including from distributed powerful current systems of railways, metro and tram lines operating on direct current. The problem has a long history, for example, it was reflected in the IAGA resolution decided in 1948, in Oslo "When planning new observatories, care should be taken about the choice of locations ... the distance from electrified railways should be at least 30 km." (cited by [Jankowski and Sucksdorff, 1996, p. 218]).

Introductions

For many old observatories that were established just after the Geophysical Year (1957), these recommendations were not implemented.

Three reasons (when choosing a place in the past):

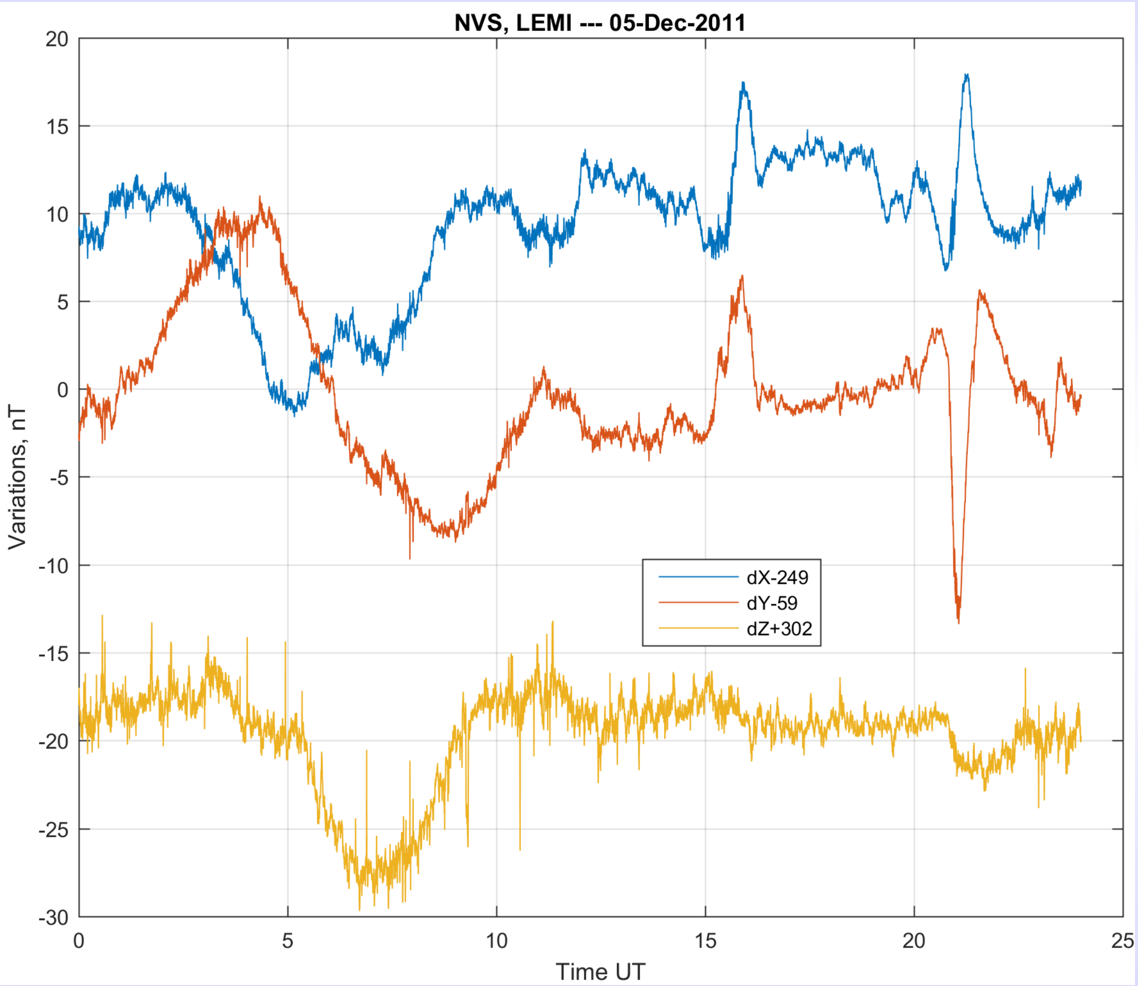
1) the magnetometers used had a sensitivity of 1 nT and a time resolution of up to 30 s (compared to modern specifications of 0.01 nT and 0.1 s – two order !)

2) possible sources of noise either did not exist or were underestimated

3) the availability of infrastructure (logistics, electricity, conditions for employees, etc.) often outweighed all other requirements, given the complex nature of the new observatories

As an example... The decision to build the Novosibirsk Observatory was made in 1962. The place was chosen in 1963. Just this time, the electrification of nearest sections of the railway from Novosibirsk to the south began only. And the place was very successful for seismological and ionospheric observations.

Noise in Novosibirsk data



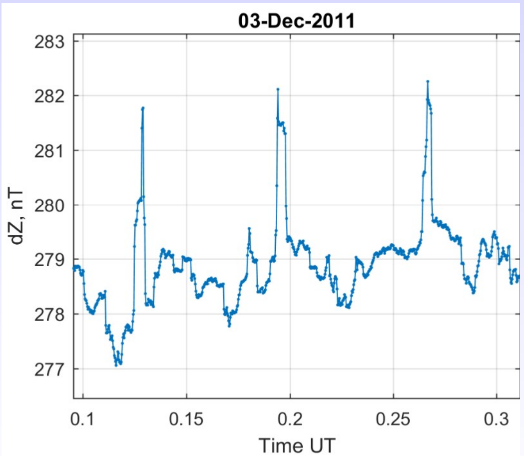
An example of a daily record of variations X,Y,Z obtained on December 5, 2011 using LEMI-008. The measurement frequency is 1 Hz. The data is noisy, especially the vertical component Z. The magnitude of the spike like noise reaches 5-8 nT.

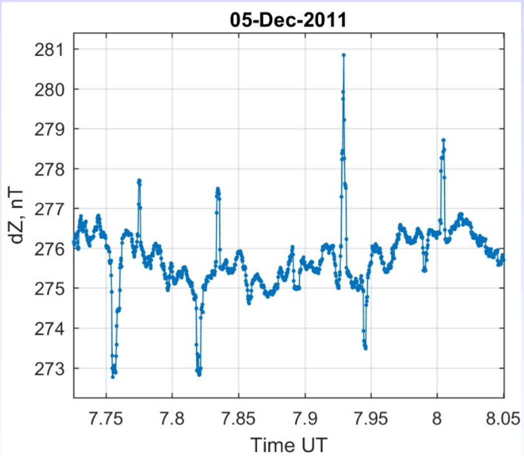
The magnetic observatory Novosibirsk ("Klyuchi", IAGA code is NVS) was founded in 1965. The first official magnetogram was received on March 17, 1966. Until 2003, measurements of magnetic field variations were carried out using Bobrov quartz sensors with recording on photopaper. Since May 2003, the digital tri-axial fluxgate variometer LEMI-008 and the scalar Overhauser magnetometer POS-1 have been used.

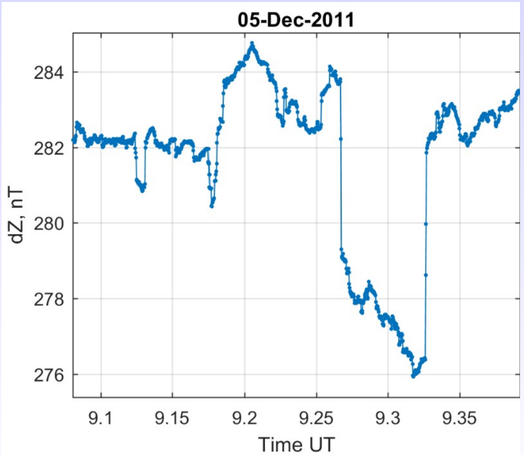
On November 20, 2004, the observatory was certified as an INTERMAGNET Observatory.

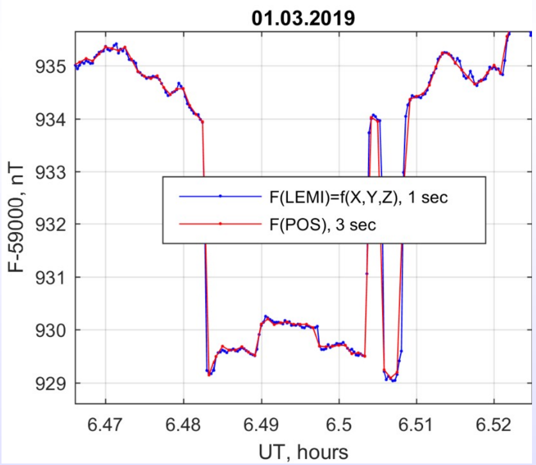
The measurement results of the new magnetometers showed what was previously hidden...

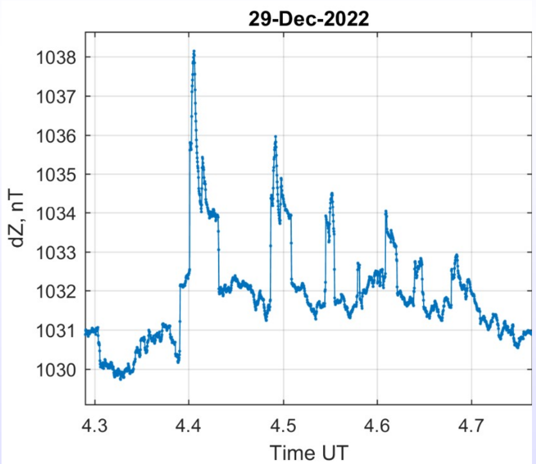
Noise in Novosibirsk data

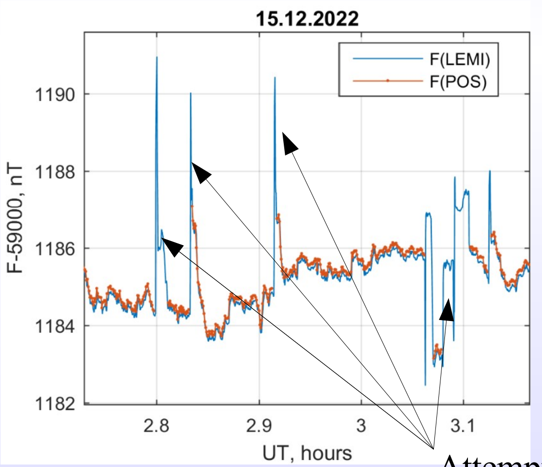












Attempt to remove noise in F(POS)

An example of noise in Z (LEMI-008) and F(LEMI,POS) in different years.
The duration of "spikes" and jumps is in seconds-minute range

A **direct current (DC) railway** running from the north (from Novosibirsk) to the south (to Altai) 10 km west of the observatory was considered as a possible source of noise.

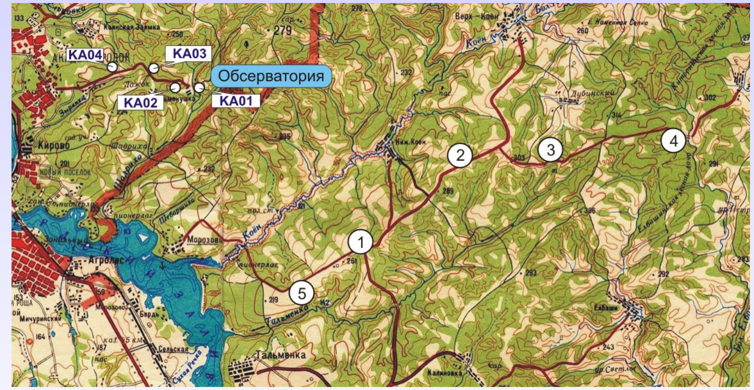
The natural way to localize the source was to make magnetic measurements at different distances from it, identify the noise appeared simultaneously in the records of the survey and at the observatory, and compare their magnitude. Such measurements were carried out in October-November 2006 and in September 2010 and 2012.

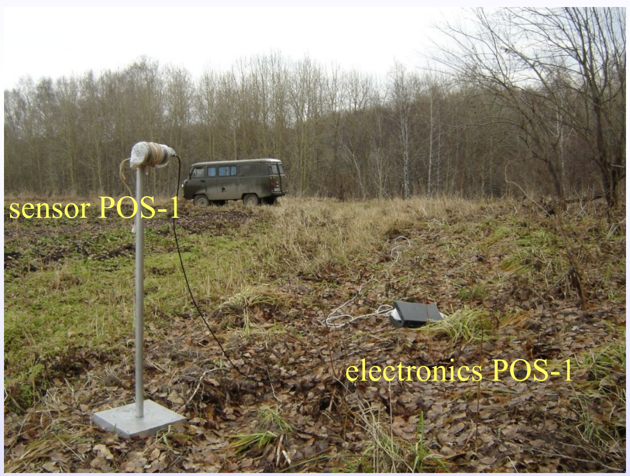
Introductions, goals

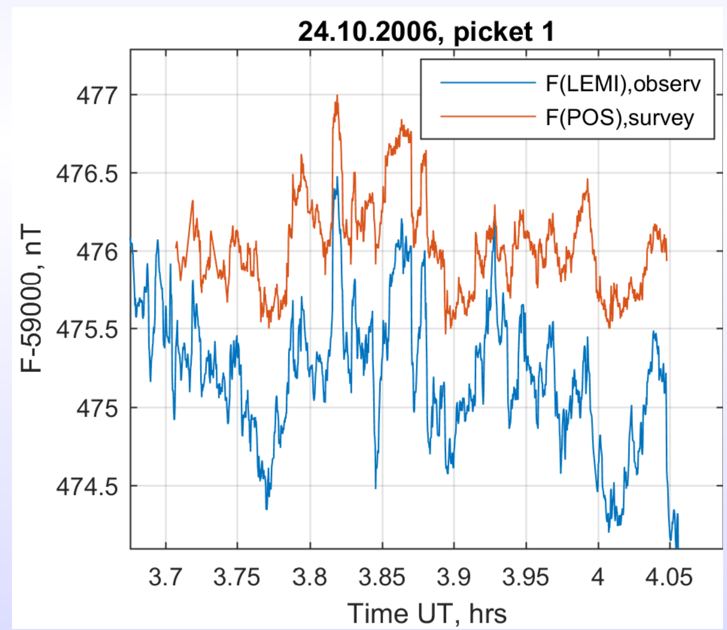
A map of the observatory's surroundings. The symbols Δ show the pickets of 2007 and 2012 survey, the symbols "o" show the 2006 survey pickets. The 2006 Eastern picket is actually outside the map.

Survey 2006

Survey of October 2006:
- Overhauser magnetometer POS-1 (5 sec)
- notebook for recording
- 100 m cable between notebook and POS-1
- battery 12 V, 17 A.hrs
- GPS Garmin eTrex Legend (time, coordinates)



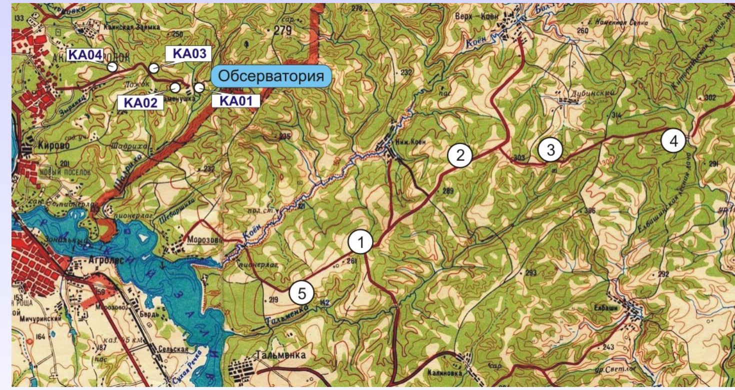


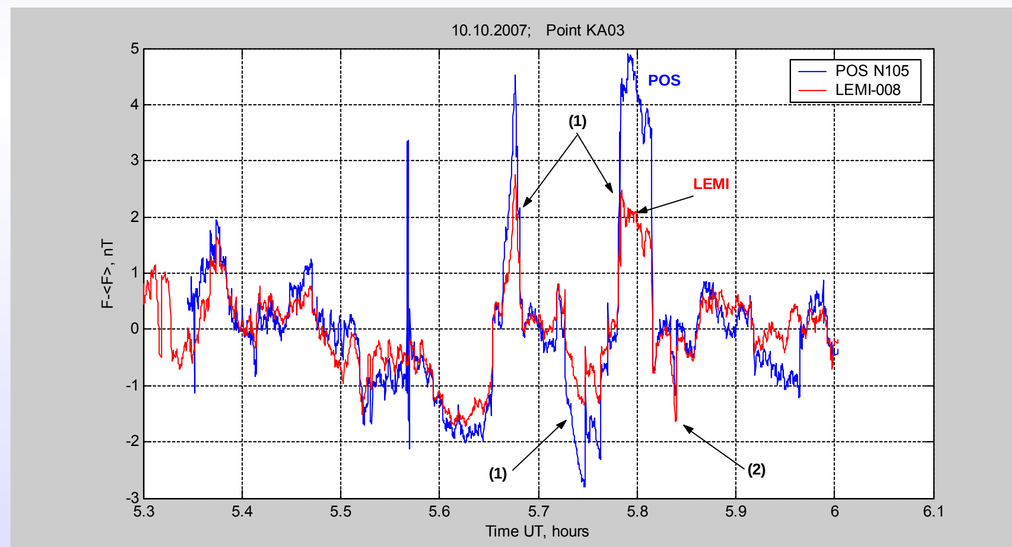


Results of measurements at piket 1 (POS-1) and at Observatory (LEMI), October 2006. Picket 1 at distance of 12.6 km from railway. The ratio dF(Obs)/dF(survey) is about 1.3-1.5.

Survey 2007

Survey of October 2007:
- Overhauser magnetometer POS-1 (5 sec)
- notebook for recording
- 100 m cable between notebook and POS-1
- battery 12 V, 17 A.hrs
- GPS Garmin eTrex Legend (time, coordinates)

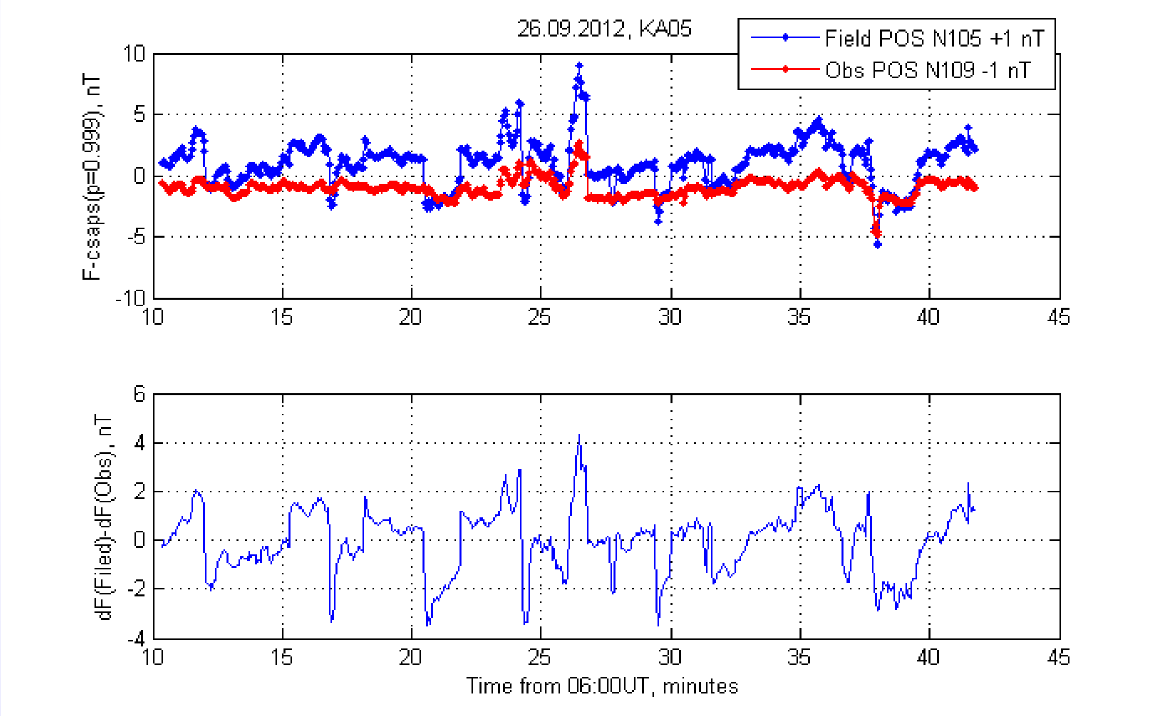




Results of measurements at piket KA03 (POS-1) and at Observatory (LEMI), October 2007. Picket KA03 at distance of 7.8 km from railway. The ratio dF(survey)/dF(Obs) is about 1.6.

Survey 2012

Survey of September 2012:
- Overhauser magnetometer POS-1 (5 sec)
- notebook for recording
- 30 m cable between notebook and POS-1
- battery 12 V, 17 A.hrs
- GPS Garmin eTrex Legend (time, coordinates)
- compass



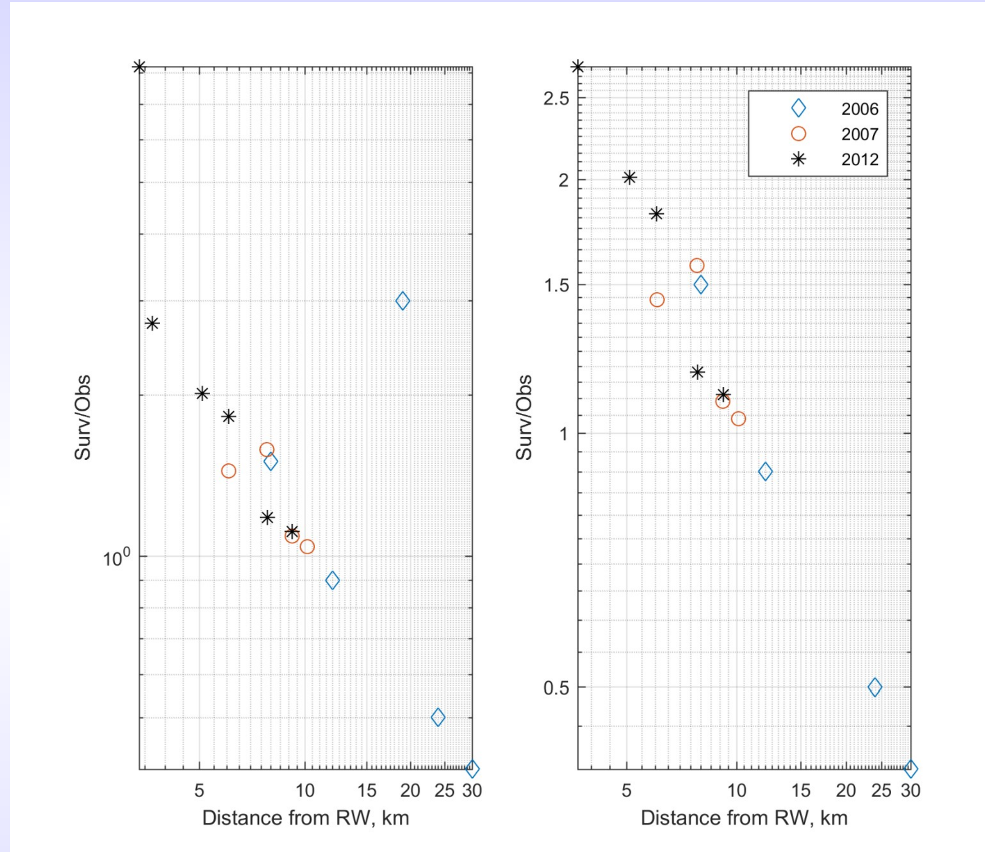
Results of measurements at piket KA5 (POS-1 #105) and at Observatory (POS-1 #109), September 2012. Picket KA5 at distance of 5.1 km from railway. The ratio dF(survey)/dF(Obs) is about 2.0.

Survey 2006-2012

year	picket	S from RW	S from Obs	V
2007	KA01	10.15	0.41	1.04
2007	KA02	9.20	1.34	1.09
2012		9.22	1.32	1.11
2007	KA03	7.80	3.05	1.58
2012		7.83	3.05	1.18
2007	KA04	6.07	4.70	1.44
2012		6.06	4.71	1.82
2012	KA05	5.10	5.60	2.01
2012	KA06	3.68	6.94	2.72
2012	KA07	3.37	7.32	8.22
2006	P5	8		1.4-1.6
2006	P1	12		0.8-1.0
2006	P2	19		1.0-6.0
2006	P3	24		0.4-0.6
2006	P4	30		0.2-0.6

Results of survey 2006, 2007, 2012. S is distance in km, "RW" is railway, "Obs" is Observatory, V is ratio of amplitude of manually selected pulses at survey pickets and at Observatory. Results of 2006 are obtained with unstable work of survey magnetometer. Pickets P2 and KA05 were placed near high voltage power line.

Survey 2006-2012



Results of survey 2006, 2007, 2012. S is distance in km, "RW" is railway, "Obs" is Observatory, V is ratio of amplitude of manually selected pulses at survey pickets and at Observatory. Results of 2006 are obtained with unstable work of survey magnetometer. Pickets P2 and KA07 were placed near high voltage power line. Approximation of data by log(V)=A*log(S) give A=0.9, that is the amplitude of "noise" decrease as 1/S.

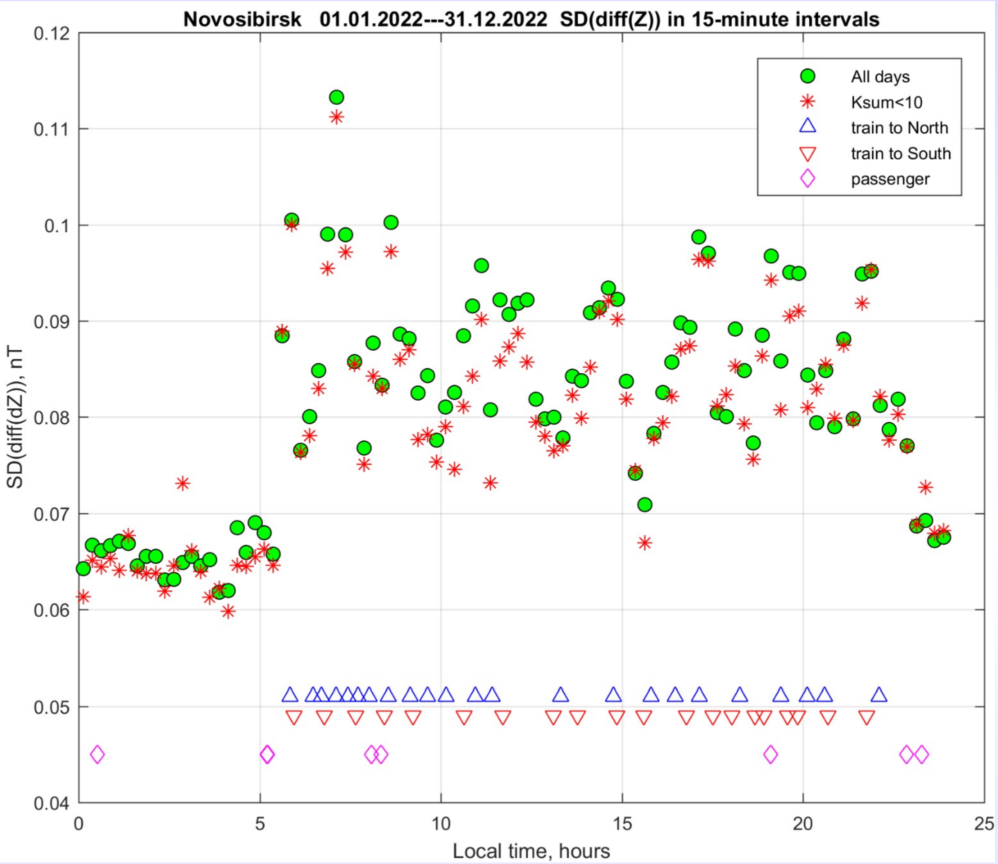
correlation with train schedule

1) for every day (of year) the first differences of 1-sec Z values diffZ=Z(k)-Z(k-1) was calculated

2) for every day (of year) for every 15-minute interval the standard deviations of diffZ were calculated (SDdiffZ)

3) for every 15-minute interval the mean values over all days mean(SDdiffZ) were calculated

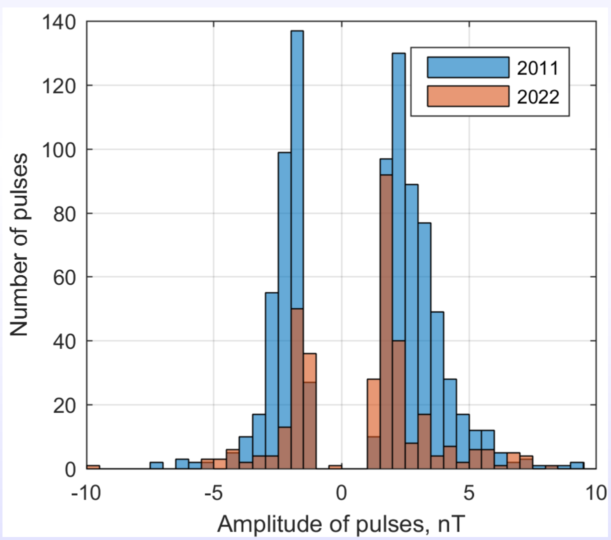
4) calculations were made for all days and for days with summary daily K-index < 10



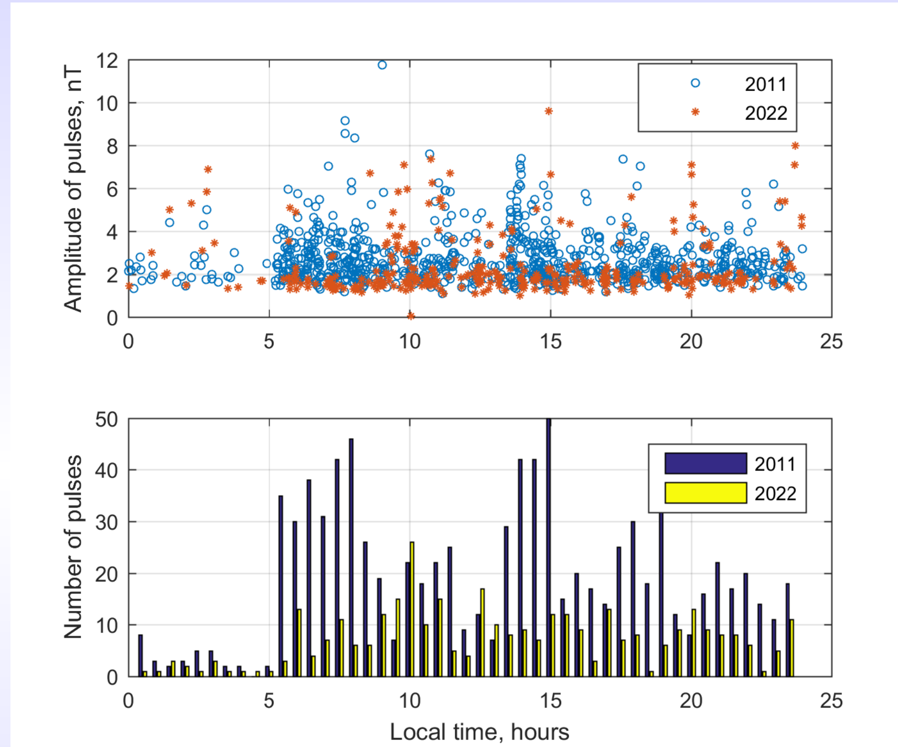
The estimation of noise in 1-second values of vertical component Z for 15-minute intervals of local time for all days of 2022 are presented. Special symbols show schedule of trains at railway station "Seyatel" in Novosibirsk Scientific Center (more close to Observatory) for "to North" and "to South" directions and Rapid (commuter) Trains and Passenger trains separately. It is evident that noise in magnetic data at Observatory has strong correlations with train schedule.

statistics of pulses

for every day of 01-20 December, 2011 and 2022 the time of leading and trailing edges of pulses in 1-second Z values and its amplitudes were estimated manually. The lower threshold is about 2 nT.



Number of Z-pulses in 1-second data with threshold of 2 nT for 01-20 December, 2011 and 2022.



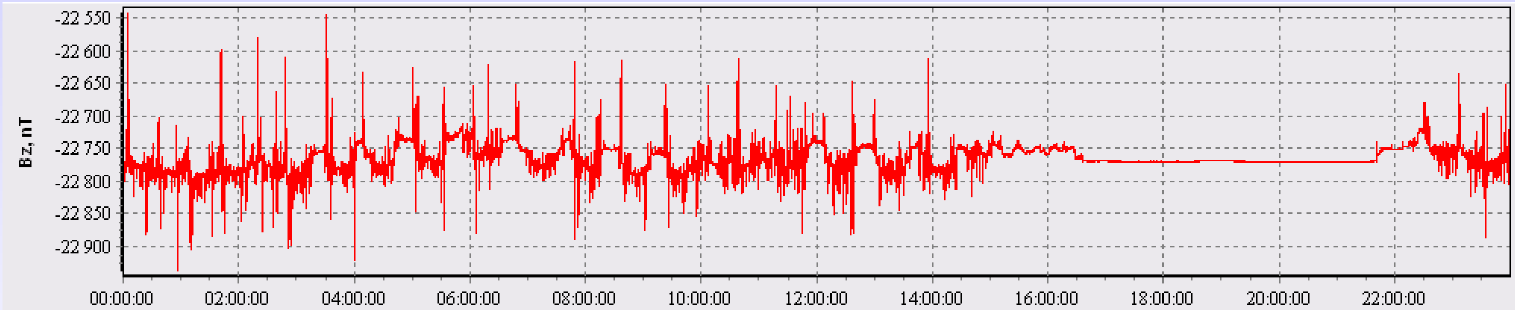
Z-pulses in 1-second data with threshold of 2 nT for 01-20 December, 2011 and 2022 (upper panel). Number of Z-pulses over 0.5-hour intervals of local time (lower panel).

Conclusions

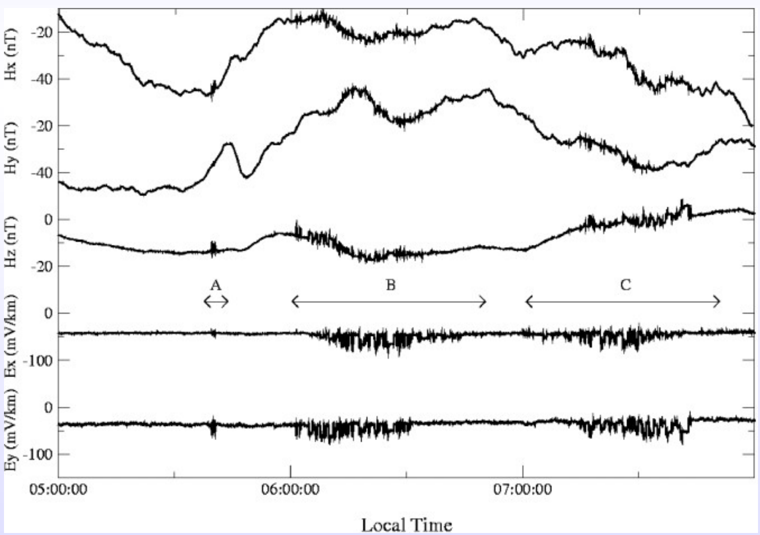
Preliminarily:
1) an increase in the intensity of noise when the distance to DC railway is decreased may indicate that the source of this noise is the railway
2) since the railway passes near Akademgorodok, the influence of power systems in the Akademgorodok itself is not excluded
3) the correlation of the noise level in the magnetic data with the start and end of the commuter train schedule may indicate that the assumption (1) is more correct than (2)
4) there is a noticeable reduction in continuous noise and in spikes from the late 2010s to the early 2020s. Perhaps the rolling stock has changed or special measures have been taken to optimize the railway electrical network, for example, to reduce leakage currents

Problems:
1) 13 km to the north there is a DC railway to Kuzbass
2) we do not know the schedule of freight trains
3) we do not know the parameters of trains used and details of electric railway networks
4) we do not know the schedule of commuter trains in the past years

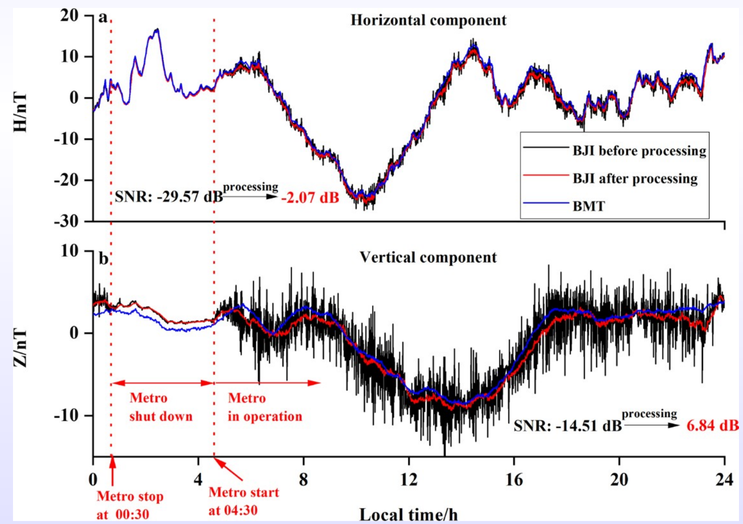
Discussion (not in this place...)



Magnetic variation signal at Tangerang observatory (Indonesia). All of component x, y, z have noise in any time (***Relly Margiono, Mahmud Yusuf, 2022***)

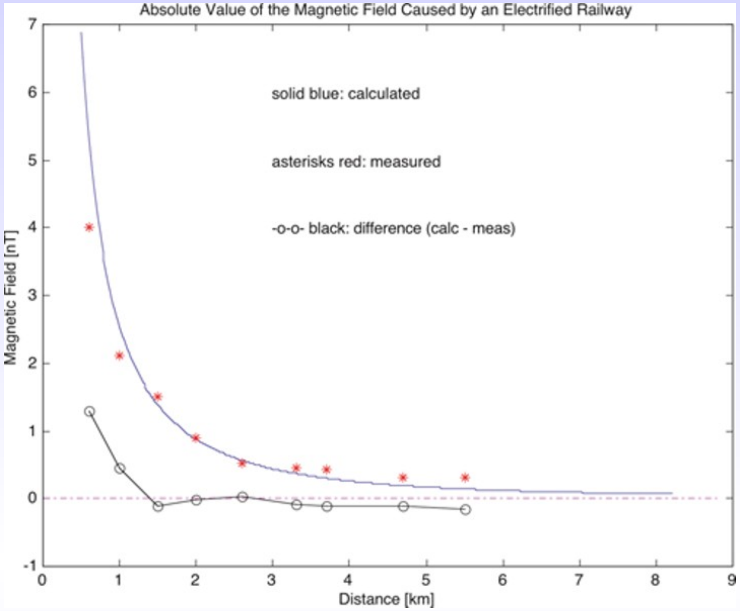


Time series of EM components as recorded at temporary station (Brazilia) on September 25, 1998 between 05:00 and 08:00LT (***Marcelo B. Padua, Antonio L. Padilha, and Icaro Vitorello, 2002***)

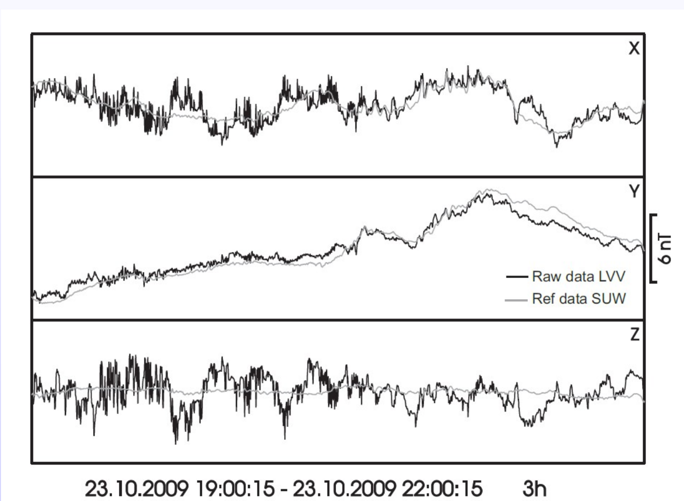


The geomagnetic data recorded at the Beijing Geomagnetic Observatory (BJI), which is located 3 km away from one of the Beijing metro lines (***Ding, X., Li, Y., Wu, Y. et al., 2021***)

Discussion (not in this place...)



Absolute value of the magnetic field created by the nearly straight north-south dc railway in Calgary, Canada. The red asterisks and the solid blue curve depict measured data and calculated results, respectively. The black circles show their difference. It is assumed that there is only one train powered by a substation located to the south at a distance of 3 km *(= L)*, and the height of the feeding line and its current are 5 m *(= h)* and 1000 A *(= J1)*. The total leakage current is 20 A *(= J0)*. The eastward line perpendicular to the railway along which the distance is measured is assumed to intersect the railway at the substation. (***Risto Pirjola, Larry Newitt, David Boteler, Larisa Trichtchenko, Peter Fernberg, Lorne McKee, Donald Danskin, and Gerrit Jansen van Beek, 2007***)



Original time series of LVV. For comparison, every panel contains the correspondent undisturbed time series of the reference in gray color. The spiky or rectangular shape deviations from the reference can be regarded as noise which is mainly caused by DC railways 7 rm away (Anne NESKA, Jan REDA, Mariusz NESKA, and Yuri SUMARUK., 2013)

"The question what to do in such cases has found various answers.

- The most radical one is to move the observatory
- An original solution has been found in Japan. A part of a railway line situated close to Kakioka observatory was changed from DC to AC drive
- In many cases the answer of the observatory worker on the challenge of disturbed data is that *one just has to live with it*"

(Anne NESKA, Jan REDA, Mariusz NESKA, and Yuri SUMARUK, On the influence of DC railway noise on variation data from Belsk and Lviv geomagnetic observatories. Acta Geophysica, vol. 61, no. 2, Apr. 2013, pp. 385-403; DOI: 10.2478/s11600-012-0058-0)

Thank you for your attention!