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THE REDUCTION OF GEOMAGNETIC DATA FOR THE TERRITORY OF LATVIA TO THE EPOCH 2021.5

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Abstract. The article describes the sources of geomagnetic data, the reduction of geomagnetic data for the territory of Latvia to the epoch 2021.5, the history of previous magnetic observations in Latvia, the information available in the State Geodetic Network database and the information available in the World Geomagnetism Data Centre. The sequence of absolute measurements is described in detail. To visualise the changes in the magnetic declination value in the territory of Latvia, a 2021.5 year declination fluctuation has been created using ArcGIS Pro. The declination values in Latvia range from 6.68° to 10°, the inclination values range from 71.089° to 72.245° and the total magnetic field values from 51100 nT to 52594 nT. The values obtained for the magnetic field components refer to a magnetically clean environment, and there can be, and are, differences in the natural conditions in the Latvian territory, in natural anomalous locations and in locations with artificially high magnetic field noise (e.g. in cities, near railways, near high voltage lines, etc.). In the Latvian network, points have been selected in locations where the magnetic noise is minimal, as this is the technological process for building such stations. Magnetic observatories are even stricter, so the data coming from the observatories reflect the natural magnetic field without the influence of magnetic anomalies. The reduced magnetic field values and their representation on a map can be used for aeronautical navigation, military applications, identification of local magnetic anomaly sites or search for magnetically clean environments.

Keywords: geomagnetic field, geomagnetic data, declination, inclination, geomagnetic data reduction, magnetic field components.

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1. Introduction

"Strong increases in solar activity during solar storms can adversely affect critical technological infrastructures, electricity and rail networks, aviation, telecommunications, satellite navigation when prevailing interplanetary conditions cause geomagnetic storms. Society is becoming increasingly dependent on technology. The sensitivity of these advanced technologies to severe space weather phenomena increases our vulnerability to their negative impacts." (Mandea et al., 2020).

The idea of reducing the measurement data came from several searches for information on changes in the geomagnetic field for the territory of Latvia. In 2007, the Latvian Geospatial Information Agency started to measure magnetic declination in the Gravimetry and Magnetometry Department of the Geodesy Department for 1:50 000 scale topographic map sheets. The national geomagnetic measurement network covers the territory with measurement points so that the measurement data ensure the objectivity of geomagnetic information throughout the national territory. The declination rates in Latvia as of 2009 range from 4° to 9°. The geomagnetic data are processed using data from the variometer of the Geophysical Observatory of Nurmijarvi (Finland), located at the observatory in Tartu (Estonia) (Shuljakova, 2012). The National Geodetic Network database does not contain information on 2022 observations and information on Class 1 grid points is very limited, i.e. no information is available on the values of the ground magnetic field components obtained. "According to the LGIA public report for 2022, the Agency will continue to operate the variometer station in the Dagda region on a permanent basis. 73 new geomagnetic observation points have been surveyed, which are necessary for accurate determination of magnetic declination for cartographic purposes." (Latvijas Ģeotelpiskās informācijas aģentūra, 2022). The Latvian State Geodetic Grid database no longer contains information on the D, I and F values of the national grid points and data on the Latvian State Grid had to be searched in the World Data Centre for Geomagnetism.

Data for the Latvian territory are available in the World Data Centre until 2009.5.

2. Observatory data selection

For the reduction of the 2009 measurement components, observatories should be selected that are stable and have a good amount of accumulated data, such as the INTERMAGNETE observatories. Most modern observatories now publish 1 min data, and an increasing number of observatories publish 1 s data. This development was largely driven by INTERMAGNET (the International Network of Real-Time Magnetic Observatories) (Love & Chulliat, 2013). Currently, between 60 and 70 observatories routinely produce quasi-definitive data using various processing techniques (Peltier & Chulliat, 2010; Matzka, 2012; Clarke et al., 2013) and disseminate them via INTERMAGNET. Quasi-definitive data provide information on the latest geomagnetic secular fluctuations without waiting for the final data to be published, which usually occurs with a delay of one year. Observatory data are also searched in the Global Data Centre, where the mean values of the observatory components of interest by year are stored https://geomag.bgs.ac.uk/data_service/data/annual_means.shtml. Eight observatories were selected from the INTERMAGNETE network in the early stages of the work: NUR – Nurmijarvi, Finland; UPS – Uppsala (Fiby), Sweden; SPB – St Petersburg, Russia; BOX – Borok, Russia; HLP – Hel, Poland; BEL – Belsk, Poland; LVV – Lviv, Ukraine; KIV2 – Kyiv, Ukraine. For each of the observatories, data are available on the annual average of the D, I, H, X, Y, Z and F components of the magnetic field, starting from 2009.5. In order to check that the values of the components do not exhibit different dynamics at any of the observatories, a plot of each component has been produced for the period of interest. The graphs make it easy to see the change by year (Figure 1).

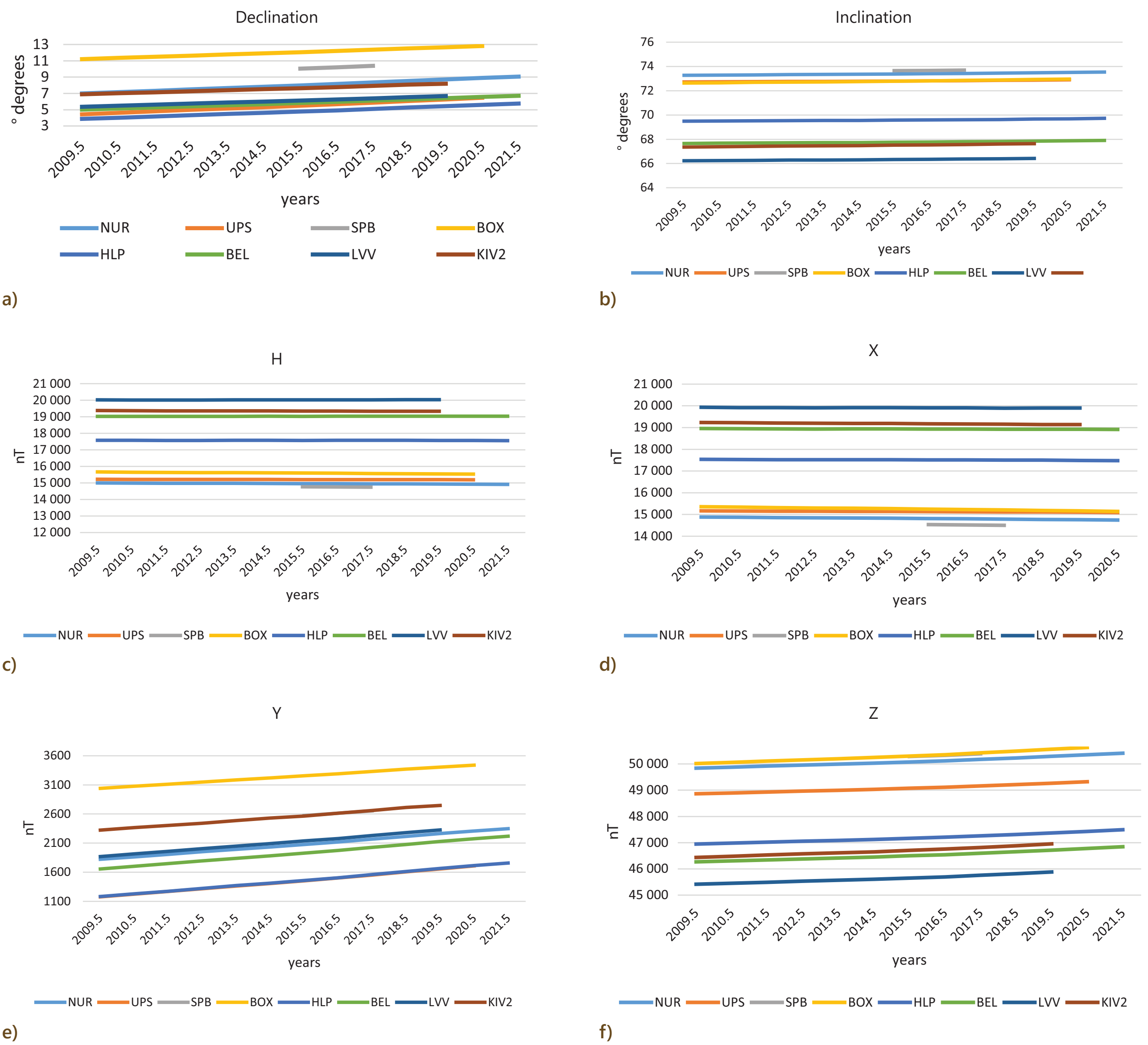
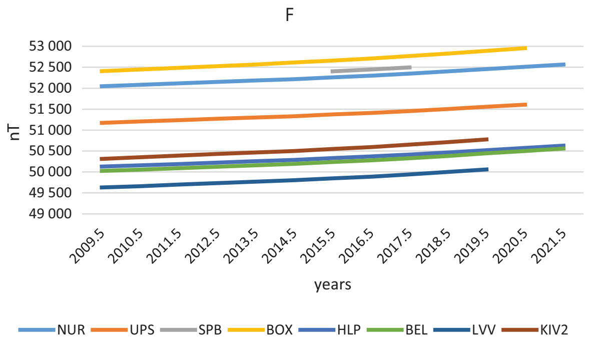


Figure 1. *To be continued*



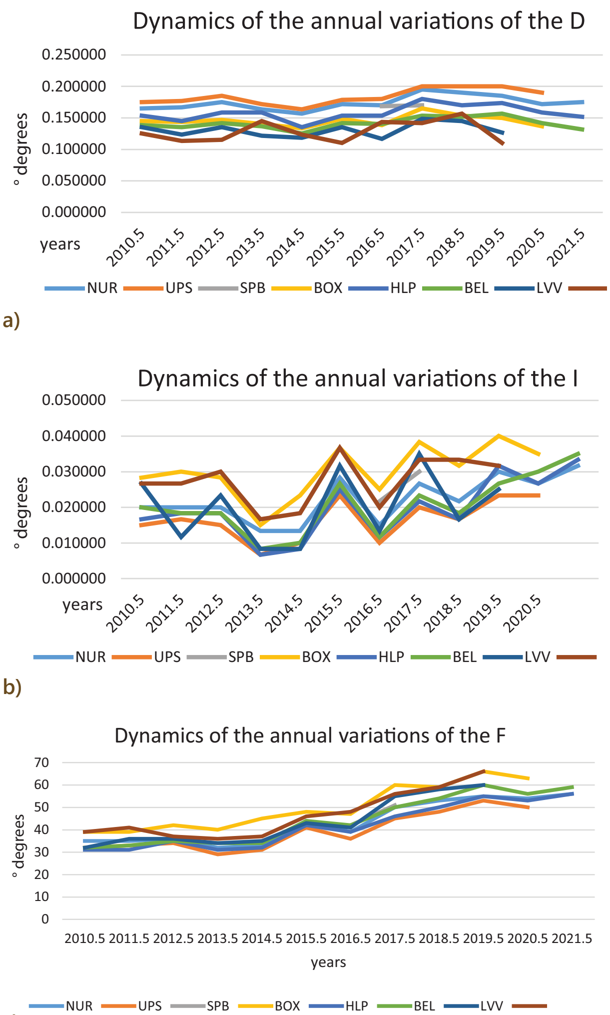
j)

Figure 1. Dynamics of the observatory component values from 2009.5–2021.5: a – change in the declination value; b – change in the inclination value; c – change in the horizontal component value; d – change in the northern component of the horizontal intensity; e – change in the eastern component of the horizontal intensity; f – change in the vertical intensity; j – change in the total intensity

The graphs of the magnetic components (Figure 1) show reasonably similar trends year by year, but stand out for example the KIV2 2018.5 declination value, and the inability to assess the SPB observatory data as it is largely unavailable. To further investigate the consistency of the data and the dynamics of the fluctuations, annual variation plots of the D, I, and F components have been produced. These graphs are only for these three components, as the Latvian surveys have three values determined by instrumental field measurements, while all other components are calculated from the D, I and F values (Figure 2).

These graphs show us the magnitude of the change in the magnetic component from year to year. Looking at the graphs of the variations of the components of the Earth's magnetic field, it can be seen that there are observatories where the annual variations do not follow the overall trends of the other observatories' data. LVV and KIV2 are two of them and given that no data for 2020 and 2021 are available for this observatory, the use of these observatory values for the recalculation of the data is not appropriate. These differences are due to the geographical location of the observatory and their use in the recalculation is questionable. The SPB Observatory stands out from the overall list of observatories, with data only available for 2016, 2017 and 2020. The use of data from such an observatory does not improve the accuracy of the final result, but the opposite. Data from NUR, UPS, BOX, HLP and BEL observatories will be used to recalculate the Latvian geomagnetic class 1 grid points for the year 2021.5. Further, the changes of the magnetic components for the period under study were calculated for each observatory separately and averaged over all selected observatories together. In order to compare which of the observatories is the closest or best match to the study area, an analytical table of calculated component changes was created (Table 1), where the average change of the magnetic components over the study period was compared with the change of each observatory over the study period.

By calculating for each observatory the average change in the components of the Earth's magnetic field over the study period and their difference with the average Δ over the period of all stations, it can be seen that the most relevant observatory for the study area is NUR. This is not surprising, as this was the observatory recommended for the processing of measurement data in the 2004 Latvian



c)

Figure 2. Dynamics of the annual variations of the D, I and F components: a – changes in declination; b – changes in inclination; c – changes in total magnetic field.

Table 1. Analytical table of changes in calculated components (source: Zjatkovs, 2024)

Difference to average	UPS	–0.28015158	0.0649396	–25.218182	–36.309091	–44.2	69.909091	53.745455
	NUR	–0.16151522	–0.0053638	30.327273	38.6	8.0727273	1.7272727	3.0181818
	BOX	0.178030236	–0.1005153	88.236364	117.50909	101.98182	–98.090909	–72.8
	HLP	0.033484782	0.0263032	–36.672727	–54.4	–40.927273	29.727273	24.018182
	BEL	0.230151782	0.0146362	–56.672727	–65.4	–24.927273	–3.2727273	–7.9818182

Geomagnetic Class 1 Network. It is also worth mentioning that this observatory was responsible for supervision and control during the first year of the Class 1 geomagnetic network survey.

3. Geomagnetic data reduction for the territory of Latvia to the 2021.5 epoch

The recalculation of the Earth's magnetic field components for the year 2021.5 was performed by adding to the Latvian Class 1 grid points the average changes of the components over the study period, but since the 2009.5 Latvian Class 1 grid point Ozolaine lacks an F value and only D and I component values are available, it was decided to recalculate the 2008.5 component values available at the World Geomagnetism Data Centre for this Class 1 grid point. The results of the conversion: the 2009.5 values calculated to 2021.5 for the Latvian geomagnetic observation points are summarised in Table 2.

This does not necessarily mean that the conversion result is 100% accurate, rather it explains that the Class 1 measurements in 2008.5 and 2009.5 have been carried out at a high level and with a high degree of accuracy. This fact confirms that any field measurement carried out with sufficient regularity and professional care cannot be replaced by a recalculation or reduction. In order to determine whether the correction value introduced for the declination is sufficiently accurate for data visualisation on a map basis, I will recalculate the 2008.5 declination value to the 2009.5 value using the calculated annual average change and compare it with the 2009.5 measurement result. Then if the 2008.5 declination value at Ozolaine was 5.543° and we have to add the calculated annual mean change of 0.1602904°, then the converted value to 2009.5 will be 5.7032904°. Comparing this calculated value with the 2009.5 surveyed value (5.707°) results in a difference = 0.0037096°≈13′′ (arcseconds). I can estimate my conversion factor to 2021.5 as ± 13′′ per year, or no worse than 2.6′ (arc minutes) for the whole period under study. Geomagnetic field component values for 2021.5 Table 3.

To visualise the changes in the magnetic declination value in the territory of Latvia, the 2021.5 declination fluctuation has been created using ArcGis Pro Figure 3.

Table 2. 2009.5 and calculated values of Latvian geomagnetic observation points for 2021.5 (source: Zjatkovs, 2024)

Latvia repeat station	D°	D red.°	I°	I red.°	H nT	H red. nT	X nT	X red. nT	Y nT	Y red. nT	Z nT	Z red. nT	F nT	F red. nT
Viljkene	5.81	7.73	71.43	71.695	16123	16068	16040	15919	1632	2167	48003	48575	50638	51163.02
Mikeltornis	4.80	6.72	71.69	71.948	16178	16123	16122	16001	1354	1889	48881	49453	51489	52014.02
Velena	7.66	9.59	71.98	72.245	15976	15921	15833	15712	2131	2666	49123	49695	51656	52181.02
Nigrande	5.46	7.38	70.95	71.211	16618	16563	16543	16422	1580	2115	48125	48697	50913	51438.02
Aglona	7.27	9.20	71.04	71.301	16432	16377	16300	16179	2080	2615	47831	48403	50575	51100.02
Ozolaine2009	5.71	7.63	70.79	71.053										
Ozolaine2008	5.54	7.63	70.81	71.089	17104	17045	17024	16892	1652	2232	49133	49752	52025	52593.77

Table 3. Geomagnetic field component values 2021.5 (source: Zjatkovs, 2024)

Latvia repeat station	D red. °	I red. °	H red. nT	X red. nT	Y red. nT	Z red. nT	F red. nT	Coordinates	
								B°	L°
Viljkene	7.73248	71.69530	16068	15919	2167	48575	51163	57.617	24.618
Mikeltornis	6.72348	71.94830	16123	16001	1889	49453	52014	57.597	21.982
Velena	9.58748	72.24530	15921	15712	2666	49695	52181	57.245	26.401
Nigrande	7.37848	71.21130	16563	16422	2115	48697	51438	56.491	22.086
Aglona	9.19648	71.30130	16377	16179	2615	48403	51100	56.121	26.999
Ozolaine	7.62678	71.08908	17045	16892	2232	49752	52594	56.428	24.505

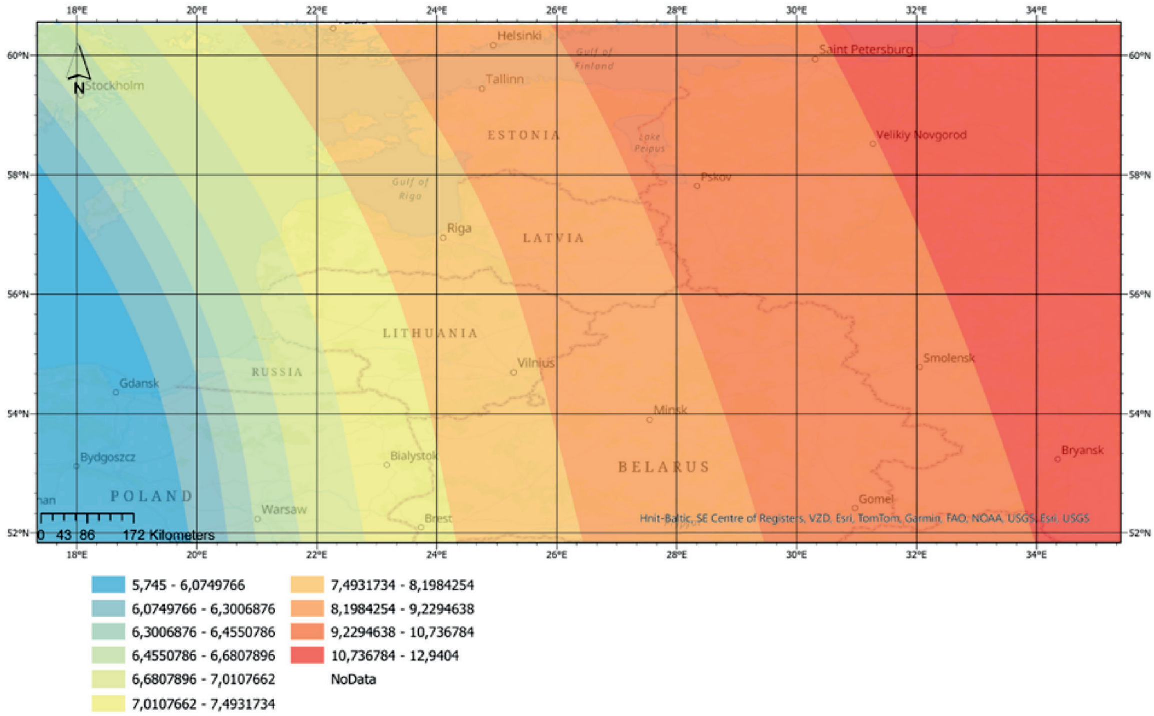


Figure 3. Magnetic declination radii for 2021.5 in Latvia range from 6.68° to 10°

4. Conclusions

Geomagnetic data for the territory of Latvia have been reduced to the 2021.5 epoch. To visualise the changes in the magnetic declination value in the territory of Latvia, a declination fluctuation map for the year 2021.5 has been created using ArcGIS Pro. The declination indices in Latvia range from 6.68° to 10°, the inclination indices range from 71.089° to 72.245° and the total magnetic field values from 51100 nT to 52594 nT. The values obtained for the magnetic field components refer to a magnetically clean environment, and there can be, and are, differences in the natural conditions in the Latvian territory, in natural anomalous locations and in locations with artificially high magnetic field noise (e.g. in cities, near railways, near high voltage lines, etc.). In the Latvian network, points have been selected in locations where the magnetic noise is minimal, as this is the technological process for building such stations. In magnetic observatories, these rules are even stricter, so that the data coming from the observatories reflect the natural magnetic field without the influence of magnetic anomalies. The magnetic field values seen and their representation on a map can be used for aeronautical navigation, military applications, the identification of local magnetic anomaly sites or the search for magnetically clean environments. The biggest challenge is the availability of data from the variometer station in Dagda and the baseline measurements on it. For the time being, the availability of this data is limited.

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