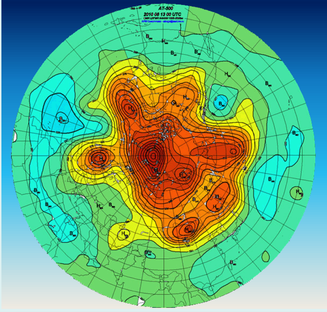


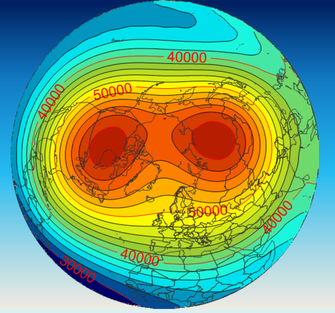
GC31F-1234 Variability of atmospheric circulation and geomagnetic field in the Northern Hemisphere

V. Martazinova (vazira@gmail.com)

Ukrainian Hydrometeorological Institute of the State Emergency Service of Ukraine and of the National Aacademy of Science of Ukraine, Prospekt Nauki, 37, 03680 Kyiv Ukraine

V. Bakhmutov (bakhmutovvg@gmail.com) , G. Melnyk (melnykgv@gmail.com)

S. I. Subbotin Institute of Geophysics of the National Aacademy of Science of Ukraine, Palladin av. 32, 03680 Kyiv, Ukraine



INTRODUCTION

Climate change in finally manifests itself in a change in the large-scale atmospheric circulation and the state of its atmospheric action centers (SAA). These changes subsequently form regional weather conditions that differ from previous periods. We studied and analyzed the change in the large-scale atmospheric circulation whith always accompanies climate change. The study (Martazinova,2014) revealed a period of fluctuations in large-scale atmospheric circulation of about 50-60 years. A shift of circulation to the west from decade to decade over a period of 50-60 years leads to active circulation with frosty winters, after which circulation in subsequent decades moves east and is accompanied by weakened circulation with warm winters. Therefore, to clarify the causes of climate change in the past, present and future, we tried to obtained and study the relationships between atmospheric circulation in the lower troposphere and the geomagnetic field of the Earth over Northern Hemisphere during the 20th and early 21st centuries and determined the spatial-temporal relationships between them. Their connection showed that there is a high correlation between the minima and maxima of these fields (Bakhmutov et al., 2014). We assume that the trends in the geomagnetic field and atmospheric circulation whith were outlined at the beginning of this millennium will continue in the coming decades.

Questions to consider:

- *How was changed the atmospheric circulation and geomagnetic field over the Northern Hemisphere during the 20th century?*
- *How was the reconstruction of the state of atmospheric circulation obtained over the Northern Hemisphere of the mid-19th century?*
- *What will be the forecast of the global large-scale atmospheric circulation and geomagnetic field over the Northern Hemisphere by the middle of the 21st century?*

MATERIALS.

For the analysis of the fields of air pressure, we used the archive of monthly fields of air pressure at sea level in temperate latitudes of the NH on a regular grid from a database of the department of climate research and long-term weather forecasting of Ukrainian Hydrometeorological Institute (DCRLWF UHMI) since 1986, the archive since 1900 of the RIHMI—WDC, (Obninsk, Russia), data of the University of Cologne and ERA-40 (ECMWF the 40 Years Re-Analysis). For magnetic field we used f the International Geomagnetic Reference Field model (https://www.ngdc.noaa.gov/geomag/geomag.shtml) with 10° steps in latitude and longitude. For the analyzed period of time there is the most complete set of observational data, which ensures high .

RESEARCH METODS

The latitudinal average sea-level pressure and magnetic fields of Northern Hemisphere ($\overline{P}$).

If the sea-level pressure and the magnetic fields is written as a matrix P with elements p_{ij} which correspond to the values in the point i and j of a regular grid of field for every decade, then its latitudinal average of their field will be $P=(p_1\ p_2\ \cdots\ p_j\ \cdots\ p_{n-1}\ p_n)$ by $\overline{P}_j = 1/n \sum_{i=1}^{n} p_{ij}$. An example is given fig. 1.

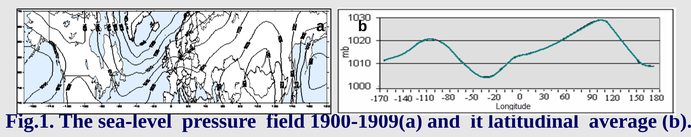


Fig.1. The sea-level pressure field 1900-1909(a) and it latitudinal average (b).

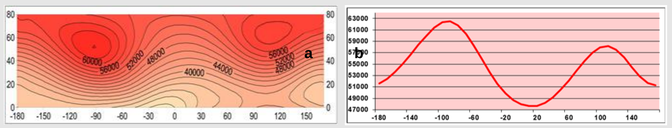


Fig.2. The magnetic field 1900-1909(a) and it latitudinal average (b).

The decomposition of latitudinal average pressure and magnetic fields in the Fourier series.

We decomposed $\overline{P}$ in the Fourier series to determine the changes of atmospheric circulation and magnetic field over the NH during the 20th century:

$$\overline{p}(j) = \overline{p} + \sum_{m=1}^{n/2} \left(a_m \cos \frac{2\pi m}{n} j + b_m \sin \frac{2\pi m}{n} j \right)$$

and then calculated the phase angles $\Phi_m = arctg(b_m / a_m)$ from decade to decade in Northern Hemisphere for $\overline{P}$ of pressure and magnetic from beginning of the 20th century to present time. Wave numbers for the three-vortex system of the NH of this fields is m = 3, then $\Delta\Phi m = \Phi tm - \Phi(t-1)m$ shows shift of wave m in time t with the step of 10 years.

➢ *The change of atmospheric circulation and geomagnetic field over the Northern Hemisphere during the 20th century.*

Integral characteristics of atmospheric circulation and geomagnetic field have been investigated in the latitudinal band 40-70ºN in the Northern Hemisphere during the 20th and beginning of the 21th centuries. In this latitudinal range of the Northern Hemisphere main centers of action of the large-scale atmospheric circulation (Canadian and Siberian anticyclones, Northern Atlantic ridge and between them Aleutian and Icelandic depressions and European trough) and geomagnetic anomalies (Canadian and Siberian) are located . The temporal diagrams of these fields showed in fig. 3 and 4. As can be seen from their diagrams, Geomagnetic field and field of sea-level pressure have a fairly good agree in time and space . The high statically significant correlation (r=0.7) was obtained between the minima and maxima of these fields.

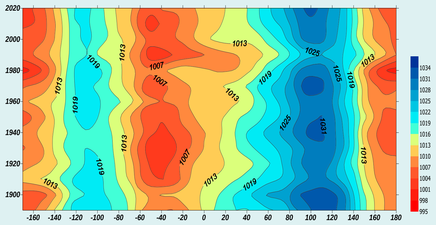


Fig.3.The Hovmöller diagram of pressure field in period 1890-2020.

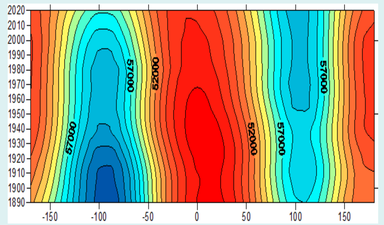
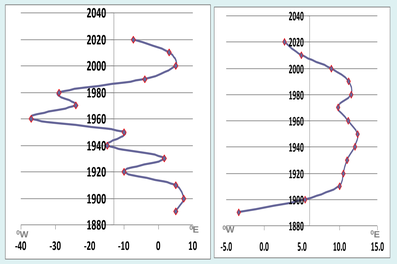


Fig.4.The Hovmöller diagram of geomagnetic field in period 1890-2020.

The figure 5 showed the position of phase angles Φ_3 in Northern Hemisphere for pressure and magnetic fields during 1890-2020. Despite that since the beginning of the 20th century the magnetic field shifted from decade to decade to the east, and the pressure field to the west, the main decades of change coincide between them. For example, the period of oscillations of the magnetic field in the period 1890-2020 is similar to the oscillation of the field of atmospheric circulation, sharp shifts in the fields in 1960-1980 also coincide. As seen from fig. 86 the weakening of both fields by the present time occurs .



. Fig.5 The position of phase angles Φ_3 for pressure (a) and magnetic (b) fields in period 1890-2020

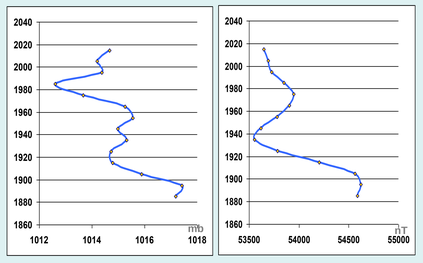


Fig.6. The average value pressure(a) and magnetic (b) fields over Northern Hemisphere during period 1890-2020

➢ *Reconstruction of the state of atmospheric circulation over the Northern Hemisphere from the mid-19th century.*

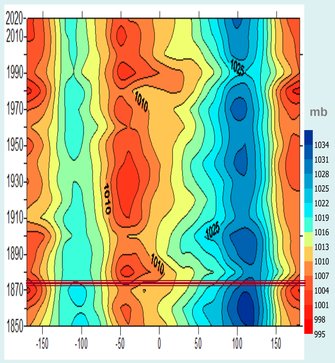


Fig.7. The reconstruction of the latitudinal averaging of the pressure field in the lower troposphere for period 1850-1880.

The reconstruction of the latitudinal averaging of the pressure field in the lower troposphere was obtained taking into account the period of fluctuation of the global large-scale atmospheric circulation of the Northern Hemisphere about 50-60 years. This period corresponds (fig.7) to a change in the direction of the displacement of the circulation to west or east until ± 20 degrees longitude. The fields of reconstruction have for Itself analogs of change atmospheric circulation from 2000 to preceding decades. But all changes in the circulation of this period must take into account the opposite sign of their changes.

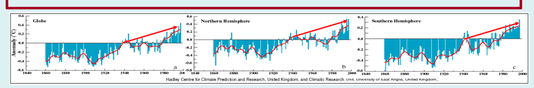
Therefore:

$\overline{P}_{1880} = \overline{P}_{1890} - \Delta\overline{P}_{2000}$, were $\Delta\overline{P}_{2000} = \overline{P}_{2000} - \overline{P}_{1990}$

$\overline{P}_{1870} = \overline{P}_{1880} - \Delta\overline{P}_{1990}$, were $\Delta\overline{P}_{1990} = \overline{P}_{1990} - \overline{P}_{1980}$

… … … … … … … … … … ……

$\overline{P}_{1850} = \overline{P}_{1860} - \Delta\overline{P}_{1970}$, were $\Delta\overline{P}_{1970} = \overline{P}_{1970} - \overline{P}_{1960}$



➢ *Forecast of the state of the global large-scale atmospheric circulation and geomagnetic field in the Northern Hemisphere to the end of the 21st century.*

The method of analogues is widely and used in meteorological practice for weather forecasting for more than a century, was applied to build the pressure and magnetic fields forecast. To select of an analog was by the position of the phase angle Φ_3 and the amplitude of wave of latitudinal average fields . A high correlation coefficient in time and space between these fields over the 20th century was preserved at the beginning of this millennium and therefore allow to expect its persistence over the 21st century.

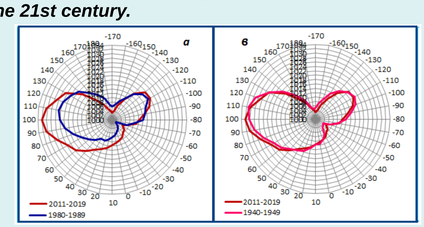


Fig.8. Similarity to the current sea-level pressure field.

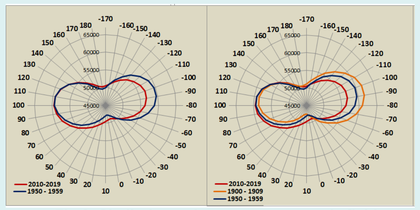


Fig.9. Similarity to the current magnetic field.

➢ *Fig. 8a shows that the pressure field 1980-1989 cannot be analogue for the current field. It is determined by difference in the position of circulation - active western circulation and weakened eastern circulation. Analogs for the current circulation are possible only among the processes of western circulation, as shown in Fig. 8. Therefore, all previous fields before the circulation field 2010–2019 have successive analogs up to his analogue. Magnetic field analogs were chosen by the same way as the atmospheric circulation field (Fig. 8 a, b). In fig. 8b, an analog of the current magnetic field and an analog of its analog field can be also seen. Forecast of the state of the global large-scale atmospheric circulation and geomagnetic field in the Northern Hemisphere to the end of the 21st century are given below.*

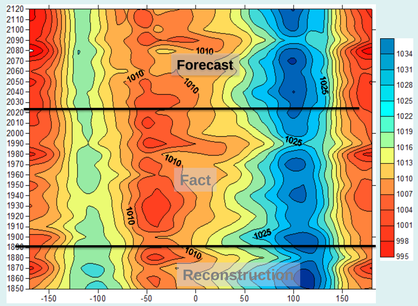


Fig. 10 .Forecast of the state of the global large-scale atmospheric circulation in the Northern Hemisphere to the end of the 21st century.

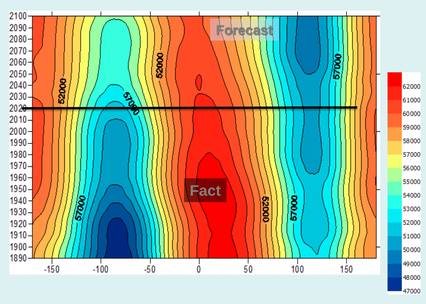


Fig. 11 .Forecast of the state of the magnetic field in the Northern Hemisphere to the end of the 21st century.

FORECAST OF THE CHANGES OF ATMOSPHERIC CIRCULATION AND GEOMAGNETIC FIELD IN NORTHERN HEMISPHERE TO THE END OF THE 21st CENTURY

The method of analogues of long-range forecast shows:

- **for change general circulation atmosphere in Northern hemisphere**

we expect an increase in the activity of all atmospheric action centers of the temperate latitudes of the Northern hemisphere by the middle of the century, which will create extreme weather conditions in the winter in their regions. From the middle of the century we can expect a weakening of all atmospheric action centers, but at the same time the increased activity of the Aleutian depression will remain

- **for change of the magnetic field in Northern hemisphere**

Present trend of the geomagnetic field will continue until the end of our century, which will continued to the weakening of the Canadian and the strengthening of the Siberian geomagnetic anomalies. Our assumption is confirmed by observations of the movement of the magnetic pole in the Northern Hemisphere from the Canadian Arctic towards Siberia (Olsen, 2007). In 2018 the pole crossed the International Date Line in the Eastern Hemisphere (Witze, 2019). The connection between this movement and world geomagnetic anomalies was show in (Hope, 1959).

- **This study showed that atmospheric circulation and the geomagnetic field do not belong to the causes of climate change, they accompany this change; but it is possible that the geomagnetic field is an intermediate connection in the formation of atmospheric circulation from the main source of change . The question remains open for discussion.**

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