

Geomagnetic Field's Contribution to the Global Rise of Air Surface Temperature

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Abstract.

CO₂ is recognized as the greatest contributor to the global warming observed since the mid-20th century. Being a long-lived gas, the spatial distribution of CO₂ is largely homogenized by the global atmospheric circulation – particularly near the tropopause, where the effective radiative temperature of all atmospheric gases is very low and their impact in the greenhouse effect is largest. This spatially homogeneous forcing (inserted on the climate system) is not able, however, to explain the regional specificity of temperature evolution, observed during the period under review (1900-2010). Consequently, it is quite probable that the regional variability of the near surface temperature is determined by the action of some unknown additional forcing.

The current investigation demonstrates that the geomagnetic field could be a significant contributor not only to the regional variations but also to the global climatic changes. Analysis of the impact of globally averaged CO₂ density and geomagnetic field intensity into the global surface temperature variability reveals that the latter could be an alternative explanation of the global raise of near surface temperature (typically attributed to the increased anthropogenic forcing) – at least for the analysed 110 years.

Introduction

The global air surface temperature (T_{2m}) has been increasing substantially in the last few decades [IPCC, 2021]. The evidences of such a warming could be found in the field observations [Jones et al., 2012] and the model data [Lacis et al., 2010; Miller, 2014]. Many authors attributed the rise of global temperatures to the accumulation of greenhouse-gas emissions in the atmosphere due to human activity [Hansen et al., 2007; IPCC, 2007].

On other hand, model experiments of Schmidt et al [2010] show that the impact of CO₂ on planetary warming varies between 19 and 24%. In comparison, numerical experiments [Spencer & Braswell, 1997] and satellite measurements [Inamdar et al., 2004] demonstrate that about 90% of the greenhouse effect of the whole atmospheric water vapour is due to the upper tropospheric humidity. Moreover, the reduction of the positive trend in surface temperature, since the beginning of 21st century, does not correspond to the continuously increasing CO₂ density. For this reason, the search for alternative explanatory factors of global warming still continues.

The idea about geomagnetic influence on climate appears in the second half of 20-th century [Elsasser, 1956]. Furthermore, comparison of paleomagnetic and paleoclimatic records leads some authors to the conclusion that strengthening of geomagnetic field is accompanied by climate cooling [Valet & Meynadier, 1993; Worm, 1997; Courtillot et al., 2007; Knudsen & Riisager, 2009; Kitaba et al., 2013]. Despite some discrepancy with the results of other researches, stating just the opposite [Wollin et al., 1971; Nurgaliev, 1991; Butchvarova & Kovacheva, 1993; Gallet et al., 2005;], we decided to analyse the contemporary observational records of geomagnetic field and air surface temperature.

Data and methods

We have used average annual values of carbon dioxide from the Mauna Loa Observatory in Hawaii – since 1958. For the first half of 20-th century have been used historical records acquired from the Law Dome DE08, DE08-2, and DSS ice cores. For geomagnetic field we have taken the annual data from the International Geomagnetic Reference Field model. The gridded monthly data for the temperature at 2 m above the Earth's surface, for the period 1900-2010, is taken from ERA 20 century reanalysis (ERA20C).

The method used for data analyses is a nonlinear regression technic, adopting non-linear functional dependences between studied variables. The nonlinear regression coefficients (R) are calculated as the square root of the difference between the total variability of the dependent variable and the error of the regression model, normalized to the total variability. The square of the regression coefficient (R^2), multiplied by 100, illustrates the percentage of variability of the dependent variable, which the non-linear regression model is able to describe. The accuracy of the models is based on a number of criteria, which we will describe in the next paragraphs.

Results

We have examined the relationships of carbon dioxide density (CO_2) and geomagnetic field intensity (F) with the globally averaged near surface temperature T_{2m} , during the period 1900-2010. For the T_{2m} dependence on CO_2 is suggested a second order polynomial (Eq. 1), while the T_{2m} relation to F is modeled by a third order expression (Eq. 2):

$$T_{2m} = a_0 + a_1 * CO_2 + a_2 * (CO_2)^2 \quad (1)$$

$$T_{2m} = a_0 + a_1 * F + a_2 * (F)^2 + a_3 * (F)^3 \quad (2)$$

where coefficients a_i are regression coefficients, determined by minimisation of the model's error, applying the least square criterion and the *Levenberg-Marquardt* algorithm.

The first formal criterion for model's goodness shows that both regression coefficients are identical, having the value $R=0.87$. This means that each regression model explain 76% of the total temperature variability (i.e. R^2*100). This result implies that the geomagnetic field could be an alternative explanation of the observed warming trend in the surface temperature (since the beginning of 20-th century).

The scatter plots of T_{2m} with the CO_2 density and the geomagnetic field (blue dots), together with modelled functional dependencies (red curves) are shown in in Fig. 1 and Fig. 2. The figures illustrate fairly well the non-stationarity of the near surface air temperature relation with average CO_2 density and geomagnetic field intensity – especially well illustrated in Fig. 2. Moreover, the Fig. 2 reveals that strengthening of geomagnetic intensity is accompanied by cooling of the surface temperature. This result is in a good correspondence with the previous findings of [Valet and Meynadier, 1993; Worm, 1997; Knudsen and Riisager, 2009; Kitaba et al., 2013], based on the analyses of paleomagnetic and paleoclimatic data records.

Another diagnostic of model's goodness is the normal distribution of errors (residuals, i.e. measured – modelled values). There are different ways to estimate normality of errors' distribution. One of them is examination of histogram of model's residuals. In Fig. 3 and Fig.4 are presented normal probability plots of models' errors. On the x-axis are plotted observed model's residuals (i.e. the differences between the measured and modelled values of T_{2m}) while on the y-axis are plotted standardized values of the expected normally distributed errors. The proposed model is good when all values follow a straight line. If the model's errors are not normally distributed, then they will form an S shape pattern. Consequently, the Figs. 3 and 4 illustrate the fulfilment of the second requirement for model's goodness – i.e. normally distributed errors.

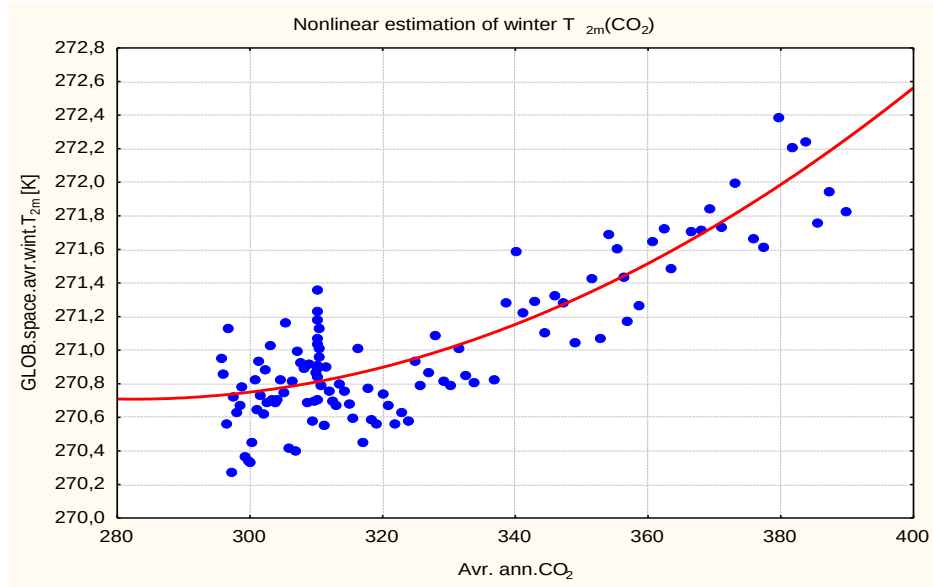


Fig.1. Scatterplot of CO_2 density and the global air surface temperature T_{2m} (spatially averaged) within the period 1900-2010. The functional dependency described by Eq.1 is presented by the red curve.

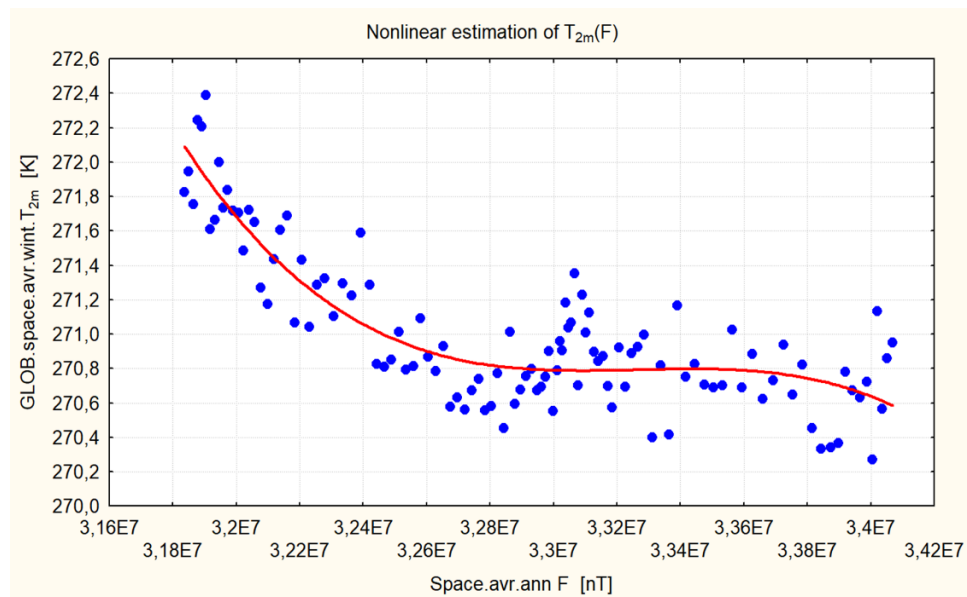


Fig.2. Scatterplot of geomagnetic field intensity and the global surface temperature T_{2m} (spatially averaged) within time interval 1900-2010 (blue dots). The functional dependency described by Eq.2 (red curve) matches fairly well the relationship between the two variables.

A third criterion for model's accuracy requires a randomness of the model's errors. The fulfilment of this criterion could be estimated by the analysis of the autocorrelation function of model's residuals. Fig.5 and Fig.6 illustrate that model's errors of each functional dependency do not auto-correlate. There are a lot of diagnostics, provided by the standard statistical packages (like STATISTICA), confirming the accuracy of our models, which have not been included in this paper. All of them, however, increase our confidence that temporal variations

of geomagnetic field intensity could be an alternative explanation of detected raise of near surface temperature during 20-th and 21-st centuries.

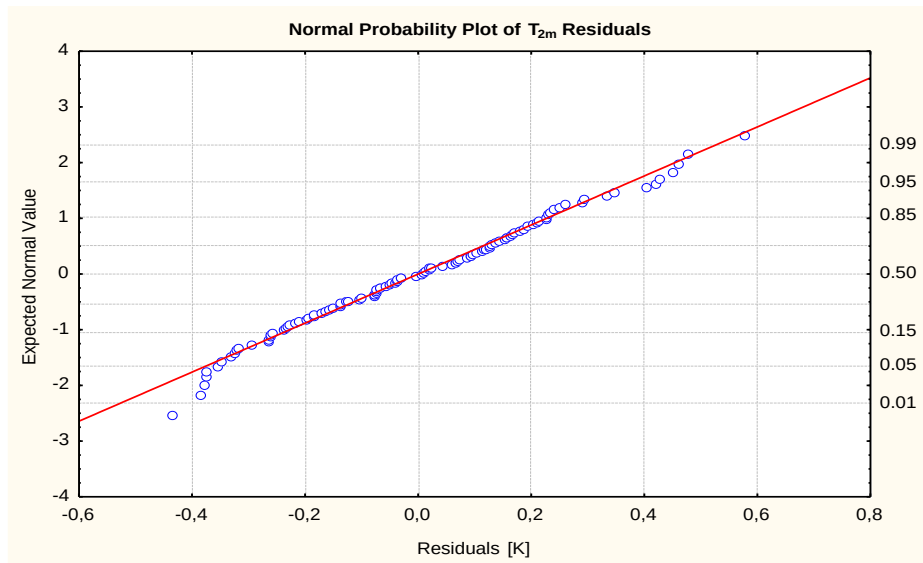


Fig.3. The normal probability plot of T_{2m} residuals for CO_2 model.

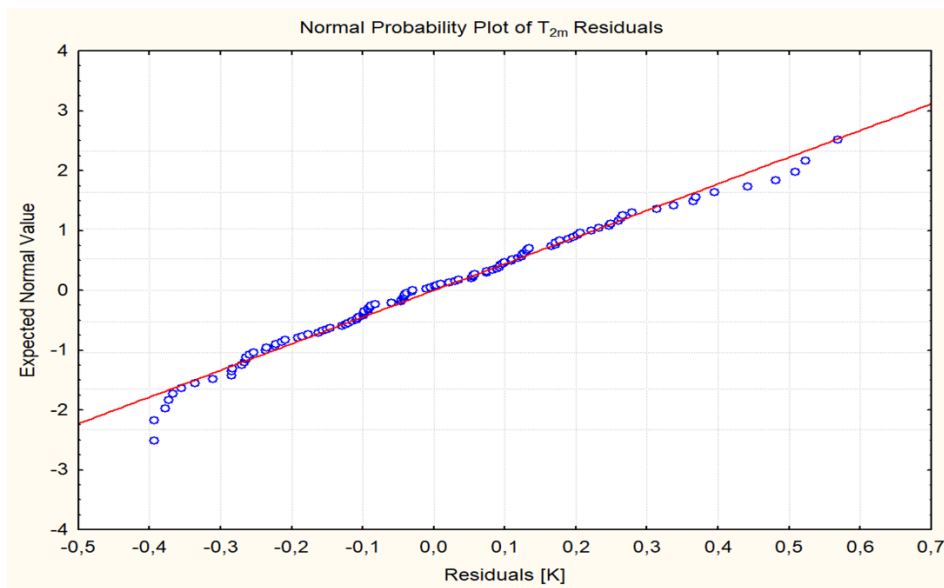


Fig.4. The normal probability plot of T_{2m} residuals for geomagnetic field model.

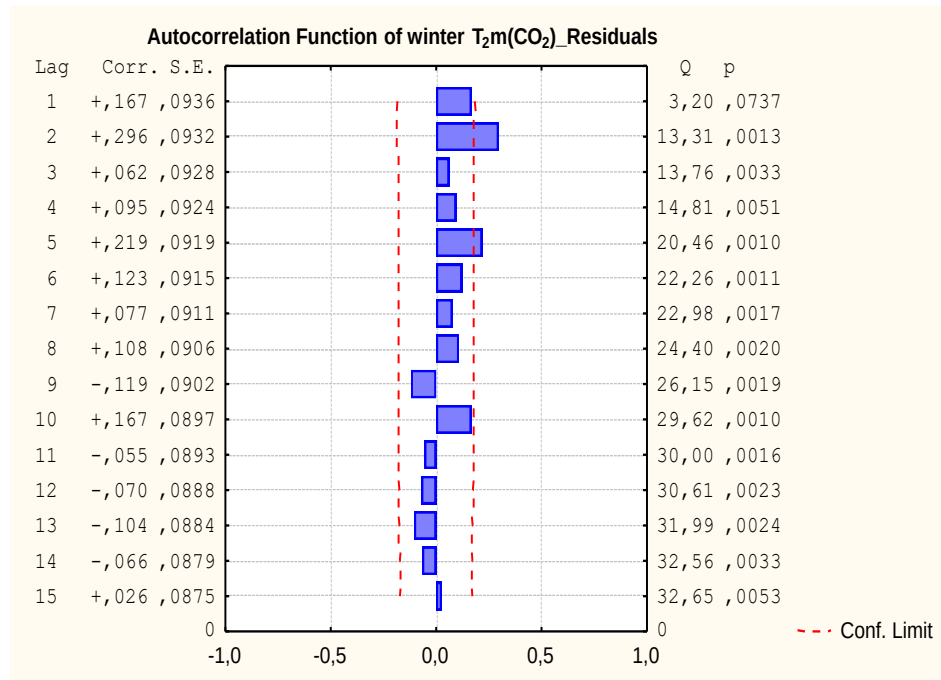


Fig.5. Autocorrelation of the model residuals $T_{2m} = f(CO_2)$. Model's errors do not correlate with each other, i.e. they are randomly distributed.

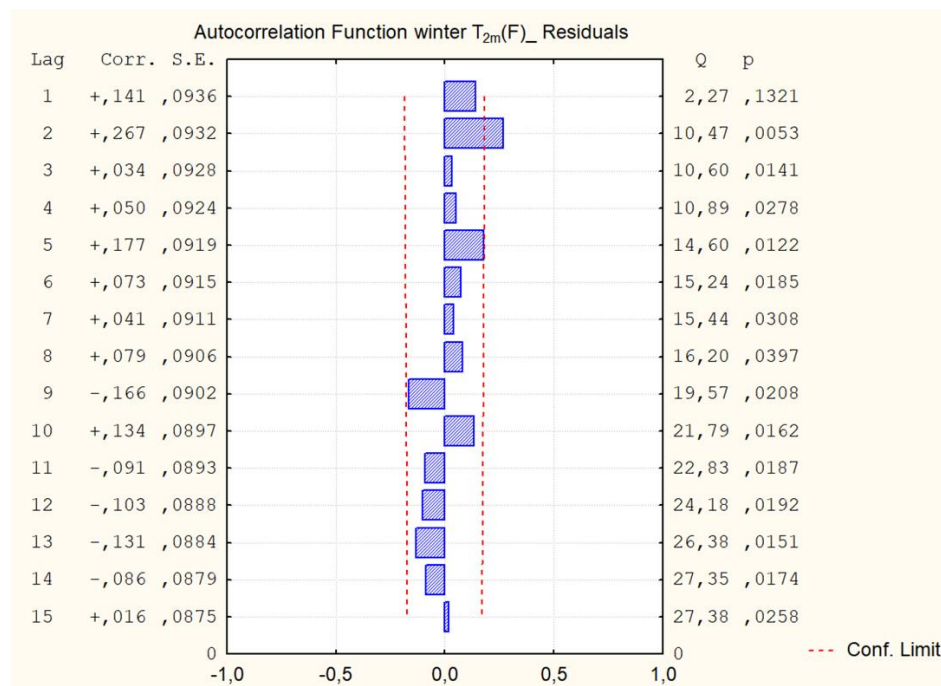


Fig.6. Autocorrelation of the model residuals $T_{2m} = f(F)$. Model's errors do not correlate with each other, i.e. they are randomly distributed.

Without a mechanism for geomagnetic influence on temperature, however, this statistical relation will remain only a curious result. Fortunately, recently has been proposed a mechanism of such an influence [Kilifarska et al., 2020a, b]. The hypothesis goes through the geomagnetic

modulation of the intensity and depth of galactic cosmic rays (GCR) penetration in Earth's atmosphere. The heterogeneously distributed geomagnetic field acts as a lens – focusing GCR in some regions over the globe and defocusing them in others – creating in such a way a heterogeneous ionization layer in the lower stratosphere (known as Regener-Pfotzer maximum). This secondary ionization alters the lower stratospheric ozone density through activation of various ion-molecular reactions [Kilifarska, 2013]. The ozone variability at these levels impacts the near tropopause temperature and humidity, which alter the strength of greenhouse warming and near surface temperature [Kilifarska, 2012; Velichkova and Kilifarska, 2019; Velichkova and Kilifarska, 2020].

Conclusions

The non-linear analysis of the global air surface temperature (T_{2m}), CO_2 density and geomagnetic field intensity during the period 1900-2010 reveals an alternative explanation of the recent global warming. We found that CO_2 and geomagnetic field statistical models describes equivalent part of the total T_{2m} variability (namely 76%). The mechanism of geomagnetic influence is described by a consecutive chain of relations between: (i) heterogeneous geomagnetic field intensity, (ii) secondary ionisation in the lower stratosphere, which alters the ozone density there, (iii) the near tropopause temperature and humidity, which are projected on the surface through modulation of the greenhouse effect.

This result indicates that the factors and mechanisms of the observed raise of global temperature need more careful examination, especially in the context of the regionality of climate changes.

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References

- Butchvarova V., Kovacheva M., 1993. European changes in the paleotemperature and Bulgarian rchaeomagnetic data, *Bulg. Geophys. J.* 19, 19 – 23.
- Courtillot V, Gallet Y, Le Mouél J-L, Fluteau F, Genevey A., 2007, Are there connections between the Earth's magnetic field and climate? *Earth Planet. Sci. Lett.*; 253: 328–339.
- Elsasser W., Ney E.P. and Winckler J.R., 1956. Cosmicray intensity and geomagnetism. *Nature*, 178, 1226, <https://doi.org/10.1038/1781226a0>
- Gallet Y, Genevet A, Fluteau F., 2005, Does Earth's magnetic field secular variation control centennial climate change? *Earth Planet. Sci. Lett.*; 236: 339–347.
- Hansen, J., Sato, M., Ruedy, R., Kharecha, P., Lacis, A. et al., 2007, Dangerous human-made interference with climate: a GISS modelE study, *Atmos. Chem. Phys.*, 7, 2287–2312, <https://doi.org/10.5194/acp-7-2287-2007>, 2007.
- Jones, P. D., Lister, D. H., Osborn, T. J., Harpham, C., Salmon, M., and Morice, C. P., 2012, Hemispheric and large-scale land-surface air temperature variations: An extensive revision and an update to 2010, *J. Geophys. Res.*, 117, D05127, doi:[10.1029/2011JD017139](https://doi.org/10.1029/2011JD017139).
- Inamdar, A.K., Ramanathan, V., Loeb, N.G., 2004, Satellite observations of the water vapour greenhouse effect and column longwave cooling rates: Relative roles of the continuum and vibration-rotation to pure rotation bands, *J.Geophys.Res.*, 10, D06104, doi:[10.1029/2003JD003980](https://doi.org/10.1029/2003JD003980).
- IPCC, 2007, (Intergovernmental Panel on Climate Change), *Climate Change 2007: The Physical Science Basis*, edited by Solomon, S., et al., Cambridge Univ. Press, New York. 996 pp.
- IPCC, 2021: *Climate Change 2021: The Physical Science Basis*. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Masson-Delmotte, V., P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy,

- J.B.R. Matthews, T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou (eds.)). Cambridge University Press. In Press
- Kilifarska, N. A., 2012, Mechanism of lower stratospheric ozone influence on climate, *Int. Rev. Phys.*, 6, 3, 279–290.
- Kilifarska, N. A., 2013, An autocatalytic cycle for ozone production in the lower stratosphere initiated by Galactic Cosmic rays, *C. R. Acad. Bulg. Sci.*, 66, 2, 243–252.
- Kilifarska, N. A., Bakhmutov, V. G. And Melnyk, G. V., 2020a, The hidden link between Earth’s magnetic field and climate, Elsevier, p. 215, ISBN: 978-0-12-819346-4.
- Kilifarska N.A., Bakhmutov V.G., Melnyk G.V., 2020b, Geomagnetic field’s imprint on the 20-th century climate variability, Geological Society of London Spatial Publications 497, GSLSpecPub2019-38R4, <https://doi.org/10.1144/SP497-2019-38>.
- Kitaba I., M. Hyodo, S. Katoh, D.L. Dettman, H. Sato, 2013, Midlatitude cooling caused by geomagnetic field minimum during polarity reversal, *PNAS*, 110, 1215–1220, <https://doi.org/10.1073/pnas.1213389110>.
- Knudsen M.F. and P. Riisager, 2009, Is there a link between Earth’s magnetic field and low-latitude precipitation?, *Geology* 37, 71–74. <https://doi.org/10.1130/G25238A.1>.
- Lacis, A. A., Schmidt, G. A., Rind, R. & Ruedy, R. A., 2010, Atmospheric CO₂: Principal Knob Governing Earth’s Temperature. *Science* 330, 356–359.
- Miller, R. L., et al., 2014, CMIP5 historical simulations (1850–2012) with GISS ModelE2, *J. Adv. Model. Earth Syst.*, 6, 441– 478, doi:[10.1002/2013MS000266](https://doi.org/10.1002/2013MS000266).
- Nurgaliev, D.K., 1991. Solar activity, geomagnetic variations, and climate changes. *Geomagnetism and Aeronomy* 31, 14–18.
- Schmidt, G.A., Ruedy, R.A., Miller, R.L., Lacis, A.A., 2010, Attribution of the present-day total greenhouse effect, *J. Geophys. Res.*, 115, D20106, doi:10.1029/2010JD014287.
- Spencer, R.W., Braswell, W.D., 1997, How Dry is the Tropical Free Troposphere? Implications for Global Warming Theory, *Bull. Amer. Meteor. Soc.* 78(6), 1097-1106.
- Valet, J., Meynadier, L., 1993, Geomagnetic field intensity and reversals during the past four million years, *Nature*, 366, 234. <https://doi.org/10.1038/366234a0>.
- Velichkova, Ts., Kilifarska, N., 2019. Lower stratospheric ozone’s influence on the NAO climatic mode, *Comptes rendus de l’Acad’mie bulgare des Sciences*, Vol 72, No2, pp.219-225, DOI: 10.7546/CRABS.2019.02.11.
- Velichkova, Tsvetelina & Kilifarska, Natalya, 2020, Inter-decadal Variations of the ENSO Climatic Mode and Lower Stratospheric Ozone. *Comptes rendus de l’Acad’mie bulgare des Sciences*, Vol 73, No4, pp.539-546, DOI: 10.7546/CRABS.2020.04.13.
- Wollin G, Ericson DB, Ryan WBF, 1971, Magnetism of the Earth and climatic changes. *Earth Planet. Sci. Lett.* 1971; 12: 175–183.
- Worm H.-U., 1997, A link between geomagnetic reversals and events and glaciations, *Earth and Planetary Science Letters*, 147, 55–67, [https://doi.org/10.1016/S0012-821X\(97\)00008-3](https://doi.org/10.1016/S0012-821X(97)00008-3).