## Acknowledgements

Comments from Jean-Michel Campin are deeply acknowledged. MC is Research Fellow at the Belgian National Fund of Scientific Research.

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# Geomagnetic Forcing on Climatic Variations

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*ABSTRACT. The influence of geomagnetic forcing on variations of the global circulation including North Atlantic Oscillation (NAO) in the region between Europe and North America, variability of the rainfall in the Asian Monsoon region and the El Niño-Southern Oscillation (ENSO) in the Pacific region is studied. Statistically significant correlation coefficients were found between geomagnetic activity, the sea level atmospheric pressure (s.l.p.) and temperature. Enhanced geomagnetic forcing is shown to lead to the intensification of the westerly zonal flow across the Atlantic and to above-normal winter temperatures in Europe and northern Asia. Relatively high correlation coefficients that were found between changes in geomagnetic activity, the All India Rainfall Index (AIRI) and ENSO justify us to suggest that the increase of geomagnetic activity in April strengthens the zonal flow also on the southern hemisphere in the southern fall and winter. Strong southerly winds and the cross-equatorial flow extend across the entire Indian Ocean leading to the above-normal monsoon rainfall in India in June, July and August; La Niña (Cold event - CE) usually follows in the Pacific Ocean. At a time of the decreased geomagnetic activity in April the Australian high intensifies, the southerly cross-equatorial flow in the Indian Ocean is much weaker in the southern winter and the monsoon rainfall is deficient. El Niño (Warm event - WE) is usually observed in the Pacific.*

*KEY WORDS: geomagnetic activity, zonal flow, North Atlantic Oscillation, monsoon rainfall, El Niño.*

## Introduction

Climatically sensitive regions constitute a dominate source of yearly global climatic variations with great consequences for human society (Bradley, 1989). The NAO has strong effects on westerlies across the Atlantic and on temperatures in Eurasia. The variability of Asian monsoons affects a large portion of the world and three fifths of the world population depend on summer monsoon rainfall as given e.g. by the AIRI. The impact of the ENSO conditions is felt mainly in the Pacific even though its effect over an enormous region seems to influence the climatic variability on a global scale. Further study can help to answer the question whether the unusual NAO and ENSO behavior of the past two decades is due to global warming and anthropogenic changes or is consistent with natural variability of the climate system. Recent studies (Bucha,1976; or recently Bucha and Bucha, Jr., 1998; Pýcha et al., 1992 ; Bochníček et al., 1996 and Laštovička, 1996) have shown that geomagnetic activity may be regarded as an external forcing factor influencing fluctuations of climate and weather.

## Methods and material studied

Statistical methods were used for the study of relations between geomagnetic and climatic data. Meteorological data are from Deutscher Wetterdienst, Offenbach am Main, updated NAO winter indices from Jones (Sarachik and Alverson, 2000), ENSO data from World Climate News (1997, 1998) and geomagnetic indices from the World Data Center, Boulder.

## Results and analyses

The NAO winter index (WI) is positive when the Azores high is strong and the Icelandic low is deep and negative when reversed. We have found statistically significant correlation coefficients between geomagnetic activity (aa index) and the normalized WI as given by Jones (Sarachik and Alverson, 2000) r(aa,WI) = 0.65 for the period 1970–1999 and r(aa,WI) = 0.52 for the period 1946–1999. For the region of the Atlantic Ocean, Europe and the eastern part of North America we obtained r(aa,P) = 0.82 and r(aa,T) = 0.78 for the period 1970–1996 (Bucha and Bucha, Jr., 1998). With the aim of showing the real effect of geomagnetic forcing on pressure changes in the northern hemisphere we constructed composites of the s.l.p. distribution in the northern hemisphere (Die Grosswetterlagen Europas, 1970–1998) for 16 months (February, March) with low and for 16 months with high geomagnetic activity. The composite for months when geomagnetic activity was low shows that the Icelandic low is shallow and is displaced westward towards Newfoundland, the Siberian high strengthens and extends toward Europe - the NAO WI is negative. On the other hand, as follows from the composite for 16 months with high geomagnetic activity the Icelandic low deepens considerably and extends to the northeast influencing the whole Europe and polar areas of Siberia and Canada. The Azores high strengthens, extends south-eastward to southern Europe and along the strong Icelandic low a substantial intensification of the zonal flow occurs - the NAO WI is positive. At times of low geomagnetic activity the positive anomalies occur in the region of the northern Atlantic and Eurasia (Fig. 1a) while a negative anomaly is located over the northern Pacific. At a time of high geomagnetic activity the composite of pressure anomalies shows a zone in mid-latitudes encircling the very deep Icelandic low (Fig. 1b). We found also a short-term atmospheric response and suggested (Bucha and Bucha, Jr., 1998) that the intensification of the zonal flow is influenced by geomagnetic forcing: downward winds which are generated in the polar thermosphere at times of high geomagnetic activity (Crowley et al., 1989) penetrate through the stratosphere to the troposphere and accelerate the subsidence of the air especially along the northern margin of the Siberian high and the west coast North American ridge. This process is accompanied by an increase of westerlies.

## Discussion

Now let us consider a possible effect of geomagnetic forcing on the intensification of the zonal flow also in the southern hemisphere and an impact on the variability in the climatically sensitive Asian Monsoon region and in the Pacific ENSO region. Van Loon and Shea (1985) have constructed the maps of the s.l.p. anomalies for the mean of May, June and July of six El Niño years when the mean s.l.p. tended to be higher over Australia. Also geomagnetic activity was in April lower than the mean for January, February and March. Similarly they constructed the map of anomalies for four non-El Niño (La Niña) years. Here, the mean s.l.p. over Australia is below-normal and the high pressure belt in moderate latitudes is continuous. Geomagnetic activity in April was higher than the mean of previous three months which seems to intensify, similarly as in the northern hemisphere, the zonal flow. Webster et al. (1998) have shown a sequence of the wind flow and precipitation charts for an active and break period of the south Asian monsoon. We have found that in the period 1961–1999 the AIRI was negative in 14 cases for negative differences and only in 3 cases for positive differences of geomagnetic activity aa(Apr)–aa(Jan+Feb+Mar/3). The coincidence just for this difference seems to react to strong climatic instability during the transition from the southern summer circulation to the winter circulation in April. Vice versa, the coincidence of the positive AIRI with geomagnetic activity was found for 18 cases and the disagreement for only 4 cases. The success of forecasting the monsoon rainfall would then be also for 18 of 22 cases. At a time of negative difference of geomagnetic activity the zonal flow weakens and the Australian high in May, June and July is stronger. The anomalous northerly winds prevail west

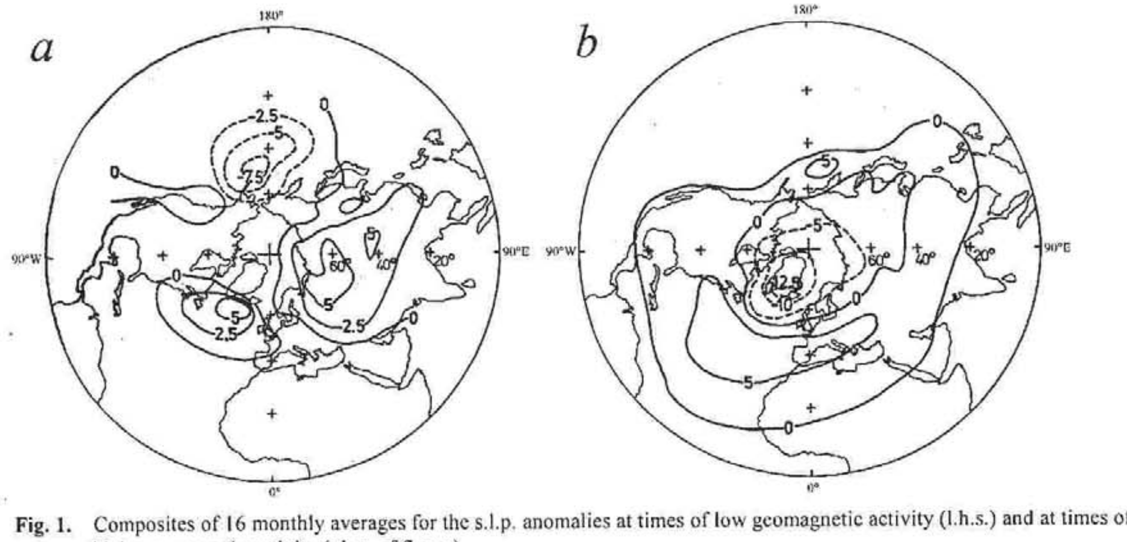


**Fig. 1.** Composites of 16 monthly averages for the s.l.p. anomalies at times of low geomagnetic activity (l.h.s.) and at times of high geomagnetic activity (r.h.s. of figure).

of Australia and this leads to the weakening of the southerly cross-equatorial flow across the Indian Ocean and to the decrease of intensity of Asian monsoons. Vice versa, at a time of positive difference of geomagnetic activity the Australian high is weak, the southerly cross-equatorial flow in the entire Indian Ocean is strong due to southerly winds enhancing the intensity of the Asian monsoon (Webster et al., 1998). We have also found a short-term atmospheric response in the s.l.p. in India to changes in geomagnetic activity in more time series where correlation coefficients were higher than 0.70.

Now let us try to discuss also possible causes leading to the origin of ENSO (WE). It turned out that the highest correlation exists again for the difference of geomagnetic activity aa, i.e. for aa(Feb+Mar/2)–aa(Apr). Positive differences correlate with the occurrence of ENSO (WE) in the Pacific while negative value of this difference corresponds to La Niña (CE). We calculated correlation coefficients for several time intervals: r(aa,DT) = 0,67 for 1976–1998, r(aa,DT) = 0,59 for 1968–1998 and r(aa,DT) = 0,44 for 1935–1998 that are statistically significant at the 99% confidence level. We found that the coincidence of signs (i.e. when positive differences of geomagnetic activity aa correspond to the WE and, vice versa, negative differences to CE) holds for 28 couples and disagreement for only 3 couples in the time interval 1968–1998. Again, we can conclude that lower values of geomagnetic activity in April than in previous months participate in the intensification of the Australian high persisting during the southern winter and in the amplification of the trough in the westerlies at the surface over the South Pacific Ocean. This is associated with southerly winds east of Australia to 140°W between 15°S and 45°S which initiate here the penetration of air from the southern polar area to the north-east. This creates conditions for the origin of the ENSO (WE) because the southerly wind in the southern Pacific together with displaced intense Aleutian low blocks outflow of warm air from equatorial areas. During the WE equatorial upwelling decreases, easterly surface winds weaken and retreat to the eastern Pacific allowing the central Pacific to warm, and the rain area to migrate eastward. Obviously, geomagnetic activity should be considered as a forcing of meteorological processes only.

## Conclusions

By using statistical methods the results have shown that the geomagnetic forcing generates processes participating significantly in the intensification of the zonal flow in mid-latitudes and thus in the global variability of key climatic systems, probably also in Holocene. Enhanced geomagnetic activity leads to the positive phase of the NAO connected with the strong increase of temperature in Europe, north Asia and eastern North America. Low geomagnetic activity is connected with meridional incursions of Arctic air during the negative phase of the NAO. Similarly, increased intensity of the Asian Monsoon rainfall can be explained as due to the weaker Australian high and stronger southerly winds in the Indian Ocean at a time of high geomagnetic activity in April while deficient rainfall is influenced by the positive s.l.p. anomaly which develops over Australia at a time of decreased geomagnetic activity in April, weakens the southerly cross-equatorial flow in the Indian Ocean and decreases the intensity of monsoons. Decreased geomagnetic activity in April participates also on the creation of ENSO (WE) conditions due to the strengthened southerly wind in the western Pacific leading to the northeastward flow of air and to the warming in the equatorial Pacific Ocean.

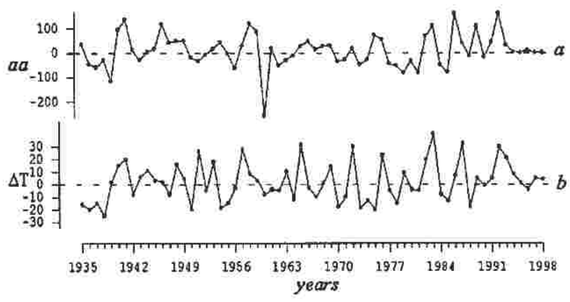


**Fig. 2.** Differences between mean values of geomagnetic activity aa for aa(Feb+Mar)/2–aa(Apr) (curve a), temperature anomalies ΔT representing WE and CE as defined by values in the equatorial area of the Pacific Ocean in the time interval 1935–1998 (curve b) (World Climate News, 1997).


## Acknowledgements

This research was supported by the Grant Agency of the Academy of Sciences of the Czech Republic within project No. A3012806/98 "Extraterrestrial influences on the circulation of the winter troposphere". The author would like to thank V. Bucha, Jr. for valuable help and comments.


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