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Influence of the Solar Wind on Climate and Weather - Towards Constructing Space Meteorology

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Introduction. Elucidating/analyzing the influence of solar activity changes on climate and weather is a centuries-long topic [1], and is important as well for estimating the contributions of natural variations and anthropogenic influences. In environmental policies, local and short-term approaches are necessary, and hence, conventional yearly/globally averages are often meaningless. The effect of solar activity changes should be discussed in such a view as well. In fact, we recently demonstrated high correlations between winter geomagnetic indices (aa index, in particular) and spring surface temperatures, and suggested the participation of the Arctic Oscillation [2].

Thus, it should be beneficial to discuss solar wind parameters which directly control the geomagnetic activities. Here, the OMNI 2 data set (daily data, in particular) [3] was employe.

Method. According to Finch & Lockwood [4], P_{alpha} (eq.1, power extracted from solar wind into magnetosphere) [5, 6] is most suitable to discuss the relation between the geomagnetic activities and the solar wind. We mainly used P_{alpha} because it has a clear physical meaning.

P_{alpha} = k $m^{(2/3-alpha)} M_E{}^{2/3}$ $N^{(2/3-alpha)}$ $V^{(7/3-alpha)}$ $|B|^{2\ x\ alpha}$ $\sin^4$(theta/2) (1)

Here, k is a constant, m is the mean ion mass, M_E is the magnetic moment of the earth (assumed to decrease about 5%/century), N is the solar wind particle density, V is the solar wind velocity, B is the solar wind magnetic field, and theata is the clock angle of the interplanetary magnetic field (GSM frame). Coupling exponent, alpha, was set as 0.3. Since the OMNI 2 data set is not continuous, months with little data were not included in the analysis.

The surface station data employed are, for instance, those of Sodankyla (Finland) [2]. The Arctic oscillation (AO) and the quasi-biennial oscillation (QBO) of tropical stratospheric wind were taken into account.

Results and discussion. Winter P_{alpha} showed high correlations with the surface temperature and with AO when the January QBO was easterly. Figure 1 shows the surface temperature of Sodankyla (March to May average) vs P_{alpha} (January) and AO (March) vs P_{alpha} (February). Correlation coefficient values for these examples were, 0.75 for the surface temperature (1966-2004) and 0.63 for the AO (1968-2008). With the QBO westerly phase, correlation was weak, and negative for the temperature and positive for AO.

From Fig. 1, the surface temperature and AO appear to change with P_{alpha}. The geomagnetic activity indices like the aa index have high correlations with P_{alpha}, and hence, they are nearly linear to the energy flowing from solar wind to the magnetosphere [1]. Thus, the correlation between the aa index and the surface temperature [2] can be explained by the energy flow from solar wind and subsequent processes.

As for the participation of QBO, significant correlations are observed for meteorological phenomena synchronized with the sunspot number when QBO is westerly [1], contrary to the present work that showed high correlations for the QBO easterly phase.

From the results above, we think it possible to construct Space Meteorology that deals with the influence of solar activity changes (and other space-origin influences) on short-term local meteorological phenomena.

References

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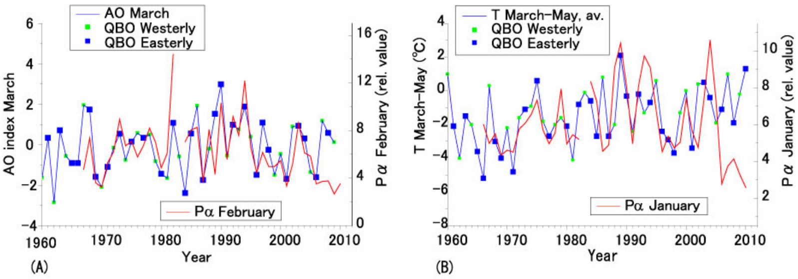

Fig. 1. (A) Relation between the AO index (March) and February Pα (energy extracted from solar wind), and (B) that between the surface temperature (Sodankyla, Finland, March – May average) and January Pα. Easterly and westerly phases of the QBO are marked with blue squares, and green small squares, respectively.

Keywords: solar wind, climate, weather, geomagnetic activity, space meteorology