Why was the geomagnetic activity in 2003 extraordinary high?

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The yearly average of the aa-index has increased more than twice during the past century. In particularly, the geomagnetic activity in 2003 was prominent: The aa-index in that year was the largest since 1868. Why was the geomagnetic activity in 2003 extraordinary high? This query is directly related to the problem what causes the year to year variation and long-term change in the geomagnetic activity.

To represent effects of solar wind on the geomagnetic activity a relation that the aa-index or ma-index is proportional to the product of the southward component of the interplanetary magnetic field (Bs) and square of the velocity has been proposed (Feynman and Crooker, 1978; Cliver et al., 2004). The proportional coefficient in the relation differs considerably depending on the procedure to make mean values of Bs and velocity and the period of the data used in the analysis. However, we would like to point out here a more essential problem existing in the relationship.

Yoshida (2008) showed that the am-index is larger for larger velocity and is smaller for larger Bs when data are confined to such that the product of Bs and square of the velocity enter in some prescribed range. This means that the contribution of Bs and that of square of the velocity on the am-index is not equal (the later contribution is larger than the former). In accord with the fact, the proportional coefficient in the above-mentioned relation becomes larger for larger velocities.

Another factor that brings about the difference in the coefficient in the relationship is the equinoctial effect that the geomagnetic activity is likely to become higher on average at the equinoxes than at the solstices which makes the coefficient at the equinoxes larger. This was noted by Cliver et al. (2000), but their estimate of the percentage of the equinoctial effect in the seasonal variation is problematic because they used average values of the am-index and the solar wind parameters in a long period (Yoshida 2008). An extraordinary feature of the geomagnetic activity in 2003 is that the mean am-index at the period around the summer solstice is larger than that at the period around the spring equinox, notwithstanding the Russell and McPherron effect that brought larger Bs values in the spring and the equinoctial effect that should have worked to make the Bs coupling less effective at the summer solstice. This is only due to the unusually large velocity in the summer of 2003.

It is meaningful that the proportional coefficient in the above-mentioned relation becomes not to depend much on the velocity if we assume that the am-index is proportional to the product of Bs and the cube of the solar wind velocity. We think it implies that the dynamic pressure of the solar wind plays some role in the mechanism that the solar wind produces the geomagnetic activity.

Because the solar wind velocity influences the geomagnetic activity more effectively than Bs, it is probable that the cause of the increase of the aa-index through the past century is not the doubling of the Bs (Lockwood et al., 1999), but the change in the solar wind velocity.