Meteorological Characteristics Changes in Equatorial Latitude Associated with Solar Activity

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Abstract. We have made an attempt to study the influence of geomagnetic storm on the equatorial upper troposphere temperature and wind variability. The NCEP – Re analysis data has been taken as an input for the present study. The Dst index has been taken as an indicator of the onset of magnetic storm and its strength. The change in the upper tropospheric temperature and wind variation over equatorial latitude is found to be sensitive to the onset of geomagnetic storm. The superpose epoch analysis shows the changes in temperature and wind velocity after 3 days of the onset of the event. The influence of QBO phase has been found to be effective on the temperature as well as vertical wind velocity variation. The change in the magnitude is also sensitive to the solar activity condition. The increase in the temperature during W-phase of QBO and vice versa has been observed after the onset of the event. The horizontal wind velocity shows the influence of magnetic storm on the continent as well as over the Ocean. One of the possible mechanism is the geomagnetic activity influences equatorial tropospheric meteorological parameters via the stratosphere.

Keywords: Storms and substorms, Tropical meteorology, Pressure, density, and temperature
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INTRODUCTION

One of the earliest works of geomagnetic forcing of the lower atmosphere is by Macdonald and Woodbridge [1]. They examined changes in 'jet stream' level (300 hpa) circulation patterns following geomagnetic disturbances. Macdonald and Roberts [2] concluded that the time delay between a geomagnetic event and changes in atmospheric circulation is not constant. The geomagnetic nature of the relationship varies as each individual trough maximizes at a different location. Further studies (Woodbridge [3], Roberts and Olson [4], Mustel et al. [5], Wilcox et al [6], Taylor [7]) agreed with these results. Further, Burns et al [8] found that the relationship is not evident in the southern hemisphere. One aspect of geomagnetic – weather relationships is the timing of the effects. In majority

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of the studies (Vovk et al [9], Lastovicka et al. [10], Lastovicka [11], Arora and Padgaonkar [12], Arora [13], Pudovkin and Babushkina [14,15], Bucha and Bucha [16,17]), it is shown that the lower atmosphere responds to a geomagnetic disturbance within seven days. However, with some exceptions, Stening [18] and Tinsely and Dean [19], found significant response at larger time lag intervals. Bowman and Shrestha [20] found the relationship between tropospheric atmospheric gravity waves and their relationship with geomagnetic activity. Bhattacharaya et al [21] showed meteorological activity and associated solar geophysical phenomena at low latitudes. Lal [22] studied the geomagnetic storm induced acoustic gravity waves over the equatorial latitude.

Most of the studies has been done for the mid and high latitude region. The study of geomagnetic storm induced changes in equatorial upper tropospheric variability such as T,V,W has not been done, as per our knowledge. Therefore we have studied the influence of geomagnetic storm on the upper tropospheric wind and temperature variability over the equatorial latitude region.

RESULTS

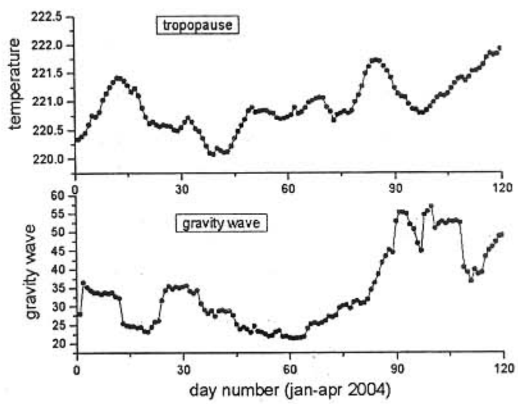

FIGURE 1. Lower panel shows the surface gravity wave amplitude variation observed between January and April 2004. Upper panel shows the tropopause temperature obtained over low latitude Indian station by NCAR-Re analysis data.

Figure1 shows the tropopause temperature variation and the surface gravity wave amplitude variation measured over low latitude station, Tirunelveli (8.7° N, 77.8° E), India. The tropopause temperature variation has been shown in the upper panel. The amplitude of surface gravity wave variation has been shown in the lower panel. The tropopause temperature variation has been obtained from the *NCEP-Re analysis data* [23] for the Indian low latitude region. The surface gravity wave has been derived from the ground based microbarograph data. This variability is shown for January to April 2004. This figure shows that there is a similar trend between these two parameters. These observations correspond to the winter period variation and almost clear sky condition. Apart from the seasonal variation, the varying meteorological conditions such as thunderstorm, convection, and presence of cloud etc. also changes the magnitude of gravity wave.

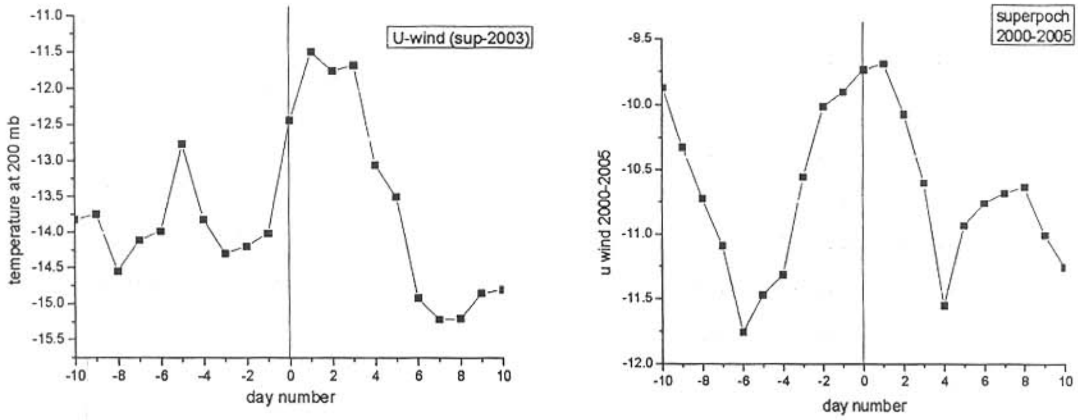

FIGURE 2. Shows the superpose epoch analysis of the horizontal wind variation over the Indian low latitude at 200 mb. Fig.2a shows the superpose epoch analysis for the period of 2003. Fig. 2b shows the superpose epoch analysis for the integrated period of 2000 to 2005.

Figure 2 shows the superpose epoch analysis of the horizontal wind variation over the Indian low latitude at 200mb height. Fig. 2a shows the superpose epoch analysis for the period of 2003. Fig.2b shows the superpose epoch analysis for the integrated period of 2000 to 2005. The influence of severe and strong geomagnetic storm on the horizontal wind velocity has been studied in the present case. Fig. 2a shows the superpose epoch analysis for the W-phase of QBO. Some of the severe geomagnetic storm during the period of 2003 were, 30 Oct 2003, Dst < -363 nT; 31 Oct 2003, Dst < -401 nT; 21 Nov 2003, Dst < -472 nT. Several studies have been done in the recent past to understand the upper atmospheric variability followed by the 2003 severe geomagnetic storm. But, the influence of magnetic storm on the equatorial troposphere is meager. Therefore, we have studied the influence of magnetic storm on the tropospheric wind variation in the present work. The x-axis shows the day number followed by the onset of event. The y-axis shows the horizontal wind velocity in m/s. The zero day number is the onset day. This figure is the resultant of nine (severe/strong geomagnetic storm) events during the year 2003. The change in the horizontal wind velocity of ~3 m/s has been observed after two days of the onset of the event. Also this shows the reversal of wind direction after the onset of the event. Figure 2b shows the superpose epoch analysis of the horizontal wind velocity for the integrated period of 2000 to 2005. The total number of 65 events has been considered in the present case. There is an increase in the horizontal wind velocity of ~2 m/s after two days of the onset of magnetic storm is observed.

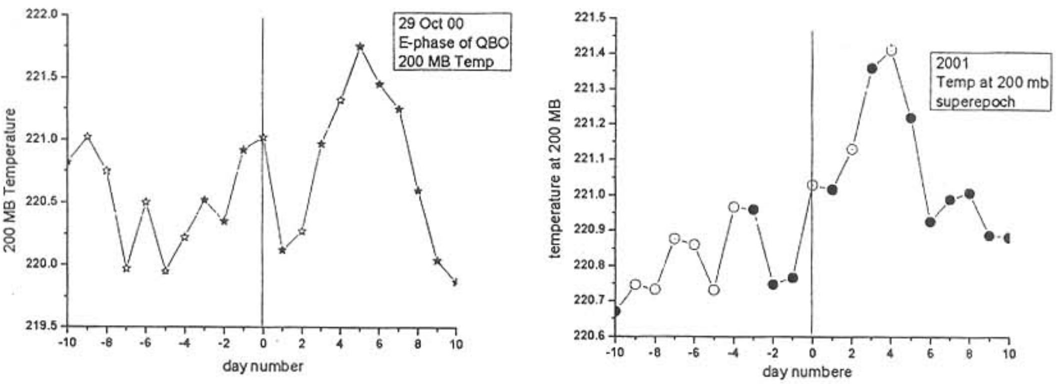

FIGURE 3. Shows the superpose epoch analysis done for the 200 mb, equatorial tropospheric temperature over the Indian latitude. Fig. 3a shows the variation in 200 mb temperature between 28 March and 17^{th} April 2000. Fig. 3b shows the 200 mb temperature between 21 March and 09 April 2001

Figure 3 shows the 200 mb temperature variation in the course of the geomagnetic disturbances. The change in temperature after geomagnetic storm is influenced by the topography as well. The change in temperature over continent is greater than the ocean. This may be due to the convective activity is more over the continent. Geomagnetic storm induced tropospheric temperature is also sensitive to the solar cycle variation. The influence of magnetic storm during high solar activity is found to be more significant than the low solar activity period. It has also been observed that the 200 mb temperature over the Indian equatorial region is also changes with QBO phase variation. The 200 mb temperature, after onset of storm, decreases in W-phase of QBO and increases in E-phase of QBO. Fig. 3a shows the temperature variation at 200 mb between 28 March and 17^{th} April 2000. The onset of severe geomagnetic storm was on 07 April 2000. The Dst index <-288 nT (magnetic activity index) has been reported by the Kyoto web page (http://swdcwww.kugi.kyoto-u.ac.jp/index.html). This event was in E-phase of QBO. This figure shows that there is an increase in the temperature by ~2°K after 5 days of the onset of event. Similar feature has not been observed over the ocean (Bay of Bengal). The convective activity over the continent is more than the ocean. Therefore, it may be possible that the temperature changes are more effective over the continent than the ocean. Fig.3b shows the 200 mb temperature variation over the Indian equatorial region (8°N, 80°E). The onset of severe geomagnetic storm (Dst <-387 nT) was on 31 March 2001. This Figure shows the 200 mb daily average temperature between 21 March and 09 April 2001. There is an increase of temperature by ~2°K has been observed after 4 days of the onset of severe geomagnetic storm. This was in E-phase of QBO. We have also seen the variability of 200 mb temperature during W-phase of QBO, in which a decrease in temperature after onset of the event has been observed. Hence, the 200 mb temperature increases during E-phase of QBO and decreases during W-phase of QBO.

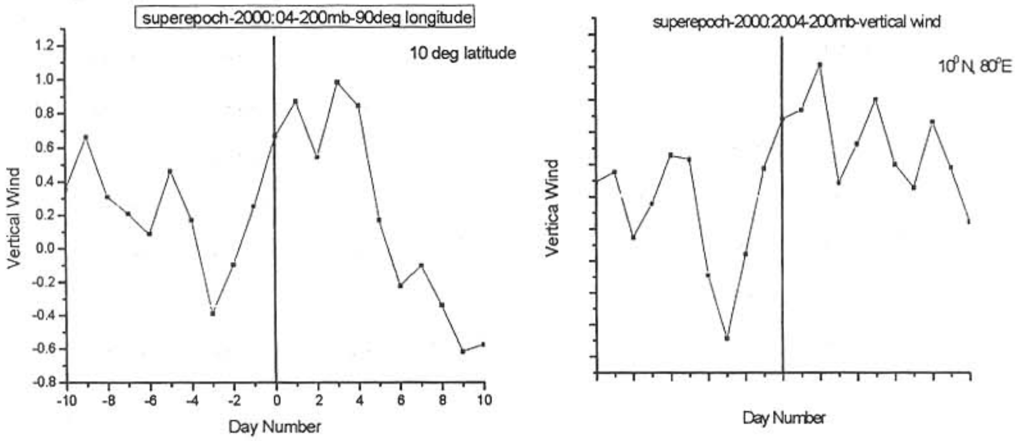

FIGURE 4. Shows the superpose epoch analysis of the vertical wind variation at 200 mb and equatorial latitude station. Fig. 4a shows the superpose epoch analysis obtained over Bay of Bengal (10°N, 90°E). Fig. 4b shows the superpose epoch analysis obtained over the continent (10°N, 80°E).

Figure 4 shows the superpose epoch analysis of vertical wind variation at 200mb and equatorial latitude station. The variability of vertical wind velocity has been studied over Indian continent as well as over the Bay of Bengal. Fig. 4a shows the superpose epoch analysis of the vertical wind velocity obtained over Bay of Bengal (10° N, 90° E). The onset of geomagnetic storm corresponds to the zero day number. This figure shows that there is an increase in the vertical wind velocity by ~2 m/s after 3 days of the onset of event. Also the velocity decreases by ~1.5 m/s before 3 days of the onset of event. Fig. 4b shows the superpose epoch analysis of the vertical wind velocity at 200 mb obtained over continent (i.e., Indian low latitude station). This figure shows that there is a decrease in the vertical wind velocity by ~2 m/s before the onset of the event, but almost there is no change has been seen after the onset of geomagnetic storm.

Daniel Palamar [24] has shown that the geomagnetic activity influences tropospheric circulation, and subsequently climate, via the stratosphere. Arnold and Robinson [25] believe that there is strong evidence that the source of variations in stratospheric circulation is the changes in upper atmospheric circulation and the interaction of the planetary waves. Lastovicka et al [10] formulated three specific features of the tropospheric response to geomagnetic storm:

- Tropospheric responses have a microregional character, possibly due to changes in circulation and orography.
- The tropospheric response to magnetic storm is much more pronounced in winter than in summer, possibly, because the direct solar radiation input to the troposphere is lower, and the atmosphere is less stable in winter.

• The winter response of the troposphere substantially depends on the phase of the QBO.

Our analysis shows that tropospheric changes are different for continent and ocean. The convective activity is large over the continent, therefore, the changes in temperature is effective over the continent. The horizontal wind velocity near to the equatorial region is very strong. Thus the topography does not show any impact on the changes of horizontal wind followed by the onset of event. The vertical wind velocity is also sensitive to the microregional character. It shows pronounced effect of the event over the Bay of Bengal and not over the Indian continent. These parameters also influenced by the QBO phase. The delay time between onset of the event and its effect is appearing to be affected by the season, QBO phase, and solar activity period. Hence the geomagnetic activity may be affecting the troposphere via the ionosphere and stratosphere over the equatorial latitude.

CONCLUSION

The influence of geomagnetic storm on the upper troposphere has been studied for various atmospheric conditions. The temperature and wind velocity variation shows QBO phase and solar activity influence. The more changes in temperature are found during high solar activity and large wind velocity variation found during low solar activity, followed by the onset of magnetic storm. The increase in 200mb temperature over Indian equatorial continent has been observed during W-phase of QBO, after 3 days of the onset of the events, and decrease in temperature during E-phase of QBO. There is no significant change in the 200mb temperature has been observed over Bay of Bengal after magnetic storm. The vertical wind velocity at 200mb shows that there is an increase in the velocity over Bay of Bengal after onset of the event; on the other hand the vertical wind velocity does not show any effective change over the Indian equatorial continent. The horizontal wind velocity shows the influence of magnetic storm on the continent as well as over the Ocean. There is an increase in the horizontal wind velocity has been observed after few days of the onset of the event. One of the possible mechanism is the geomagnetic activity influences tropospheric circulation, and subsequently climate, via the stratosphere.

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REFERENCES

1. Mack Donald, N.J., and D.D. Woodbridge, *Science (USA)*, **129**, 638 (1959).
2. Mack Donald, N.J., and W.O. Roberts, *J. Geophys Res (USA)*, **65**, 529 (1960).
3. Woodbridge, D.D., *Planet & Space Sci (UK)*, **19**, 821 (1971).
4. Roberts, W.O., and Olson, R.H., *J Atmos Sci (USA)*, **30**, 135 (1973).
5. Mustel, E.Z., V.E. Chertoprud, and V.A. Kovedliani, *Astron Zh (Russia)*, **54**, 682 (1977).
6. Wilcox, J.M., P.H. Scherrer and J.T. Hoeksema, *In weather and climate responses to solar variations,edited by B.M. McCormac (Colarado Associated University Press, Baulder)*, 365 (1983).
7. Taylor (Jr.), H.A., *Rev. Geophys (USA)*, **24**, 329 (1986).
8. Burns, G.B., F.R. Bond, and K.D. Cole, *J. Atmos & Terr Phys (UK)*, **42**, 765 (1980).
9. Vovk, V.Y., L.V. Egorova, and I.V. Moskvin, *Geomag & Aeron (Russia)*, **40**, 792 (2000).
10. Lastovicka, J., J. Bremer, and M. Gill, *Ann Geophys (France)*, **10**, 683 (1992).
11. Lastovicka, J., J Atmos Sol- Terrs Phys, **64**, 697 – 705 (2002).
12. Arora, B.R., and A.D. Padgaonkar, *J. Atmos. Terrs. Phys.*, **43**, 91-95 (1981).
13. Arora. B.R., *J. Atmos Terrs Phys.*, **45**, 569 – 572 (1983).
14. Pudovkin, M.I., and S.V. Babushkina, *J. Atmos Terrs Phys.*, **54**, 841– 846 (1992).
15. Pudovkin, M.I., and S.V. Babushkina, *J Atmos Terr Phys.*, **54**, 1135 – 1138 (1992).
16. Bucha, V., *J Atmos & Terr Phys (UK)*, **53**, 1161 (1991).
17. Bucha, V., and V(Jr). Bucha, *J Atmos & Solar Terr Phys (UK)*, **60**, 145 – 169 (1998).
18. Stening, R.J., *J. Atmos & Terr Phys (UK)*, **56**, 543 (1994).
19. Tinsely, B.A., and G.W. Deen, *J. Geophys Res (USA)*, **96**, 22283 (1991).
20. Bowman, G.G., and K.L. Shrestha, *Ind J Radio & Space Phys*, **27**, 110 (1998).
21. Bhattacharya, A.B., S.K. Karr, M.K. Chatterjee & R. Bhattacharya, *Ann. Geophys (France)*, **16**, 183 (1998).
22. Lal, M., Ind. *J. Radio & Space Phys.*, **35**, 174 -180 (2006).
23. *NCEP Reanalysis data provided by the NOAA/OAR/ESRL PSD, Boulder, Colorado, USA, from their Web site at http://www.cdc.noaa.gov/*
24. Daniel, Palamara, *Ph.D. thesis, School of Geosciences, the University of Wollongong, Australia*, 2003.
25. Arnold, N.F., and T.R. Robinson, *Geophys Res Lett (USA)*, **28**, 2381 (2001).