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Study of ozone variability at equatorial latitude during severe geomagnetic storm

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Abstract. We have studied the influence of geomagnetic storms on the total ozone variability over equatorial and polar latitude region. Total Ozone Mapping Spectrometer (TOMS) and METEOR- 3 satellite have provided the long duration ozone variability from polar to equatorial latitude region. In the present study we have considered only severe and strong geomagnetic storm events between 2000 and 2005. The polar region shows an increase in the total ozone column abundance after the onset of geomagnetic storm. The equatorial region shows the increase in ozone abundance before as well as after the onset of severe magnetic storm. The increase in the total ozone column density is localized over the Pacific ocean. Solar flares could be the cause for the increase in ozone column density before the onset of geomagnetic storms.

Keywords : ozone, geomagnetic storm, stratosphere, TOMS satellite

1. Introduction

Geomagnetic storms belong to the component of the space weather, which affects the earth's atmosphere. Geomagnetic storms are probably the most important among space weather phenomena. They produce large disturbances in the ionosphere, but they also affect the neutral atmosphere including the middle atmosphere and troposphere (Lastovicka 1996). There is, as yet, no proven physical mechanism that can explain solar-climate relationships. The influence of magnetic storm on the total column ozone has been initiated as early as 90's. Before Lastovicka et al. 1992, the results obtained by various authors

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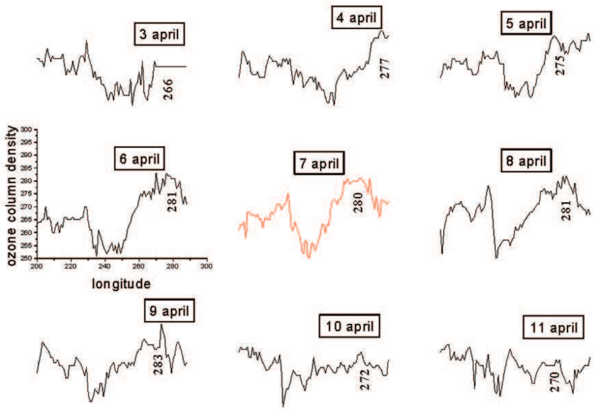

Figure 1. The longitudinal variation of total ozone column abundance over the equatorial (10°N) region from 3 to 11 April 2000.

on effect of geomagnetic storms on the total ozone differed substantially. They apparently did not provide a consistent pattern. More recent results of other authors (e.g., Storini 2003; Belinskaya et al. 2001; Tassev et al. 2003) confirm this apparent inconsistency. However, further investigations (Mlch 1994; Mlch & Lastovicka 1995; Lastovicka & Mlch 1999; Lastovicka & Krizan 2005) provided a consistent pattern of the geomagnetic storm effect on total ozone at northern middle latitudes. Fedulina & Lastovicka (2001) described a significant increase in total column ozone, over Europe, three days after Forbush decrease events and increased geomagnetic activity. We have studied the influence of geomagnetic storm on the total ozone variability over the equatorial latitude region. Our result shows the systematic and large effect of geomagnetic storm on the total ozone at equatorial latitude, particularly over the Pacific Ocean between equator and 10°N. The influence has not been seen between equator and 10°S, which is the region, with several small islands. The topography is also an important factor, which affects the ozone variability followed by the onset of magnetic storm.

Fig. 1 shows the longitudinal variation of total ozone column abundance obtained over 10^0N latitude and between 03 and 11 April 2000. The onset of the magnetic storm was on 07 April 2000. The minimum value of the Dst index has been recorded as −288 nT. This was the severe geomagnetic storm condition. The ozone variability is also sensitive to the phase of Quasi Biennial Oscillation (QBO). This observation corresponds to the west phase of QBO. There is an increase in the total ozone column over the Pacific Ocean before onset of the event and it continued during the recovery of magnetic storm. The maximum increase in the total column ozone has been obtained on 07 April 2000, which is the onset day of magnetic storm. The total column ozone density starts decreasing after 07 April and is minimum on 10 April 2000. This shows an increase in the total column ozone over the Pacific Ocean before and after the onset of severe geomagnetic storms.

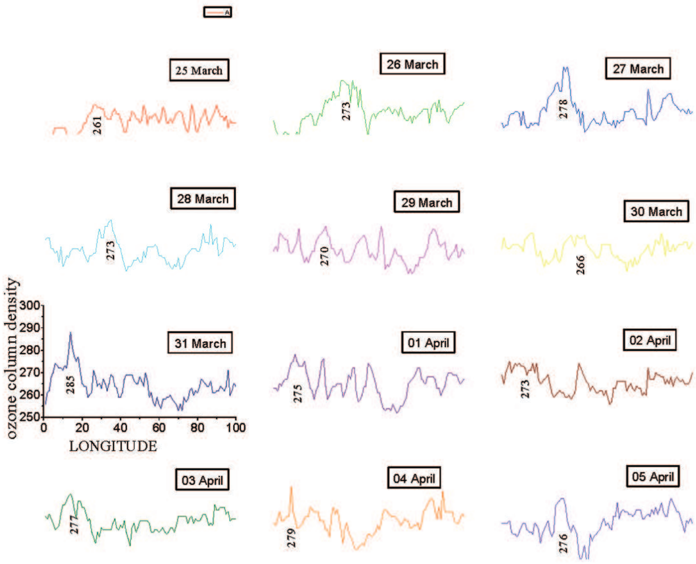

Figure 2. The longitudinal variation of total ozone column abundance over the equatorial (10°N) region from 25 March to 5 April 2001.

Similar studies have been done for the equator. The equator also shows the longitudinal variation with maximum between African and Asian continent (figure is not shown due to limited space). The influence of magnetic storm on the total ozone abundance over the equator is not found to be prominent during the W-phase of QBO.

We have also studied severe magnetic storm event of 31 March 2001 and it is shown in Fig. 2. The minimum value of the Dst index was −387 nT. The longitudinal variation of the ozone density shows that there is an increase in the total column ozone on 29th March (i.e., two days before the onset of events) over the Pacific Ocean. The increased ozone abundance has continued after the onset of magnetic storm for about a period of 2 days.

Fig. 3 shows the ozone column abundance obtained over the polar latitude. The lower panel shows the total column abundance obtained over the Arctic and the upper panel over the Antarctic, between March and April 2001. The onset of the geomagnetic storm was on 31 March 2001.

The total column abundance shows an increase in its magnitude after two days of the onset of the event. Hence the total column of ozone over the equatorial as well as polar latitude region shows an increase after the onset of the magnetic storm. The equatorial latitude shows an increase in the total ozone density before as well as after the onset of the magnetic storm. The polar latitude shows the increase in total ozone density only

Table 1. Daily solar data.

Data			Radio flux 10.7 cm	SESC sunspot number	Sunspot area 10E-6 Hemis	New regions	Stanford solar mean field	GOES8 X-ray Bkgd flux	Flares X-ray c	M	X	S	Optical 1	2	3
2001	03	25	217	276	1870	2	-999*	C2.6	5	2	0	13	2	1	0
2001	03	26	264	339	2290	1	-999	C1.4	5	2	0	24	2	0	0
2001	03	27	273	291	2830	1	-999	C2.1	9	1	0	34	1	0	0
2001	03	28	274	352	3830	4	-999	C2.8	6	6	0	19	5	0	0
2001	03	29	262	315	3940	0	-999	C3.8	8	7	1	22	2	0	0
2001	03	30	257	349	3620	4	-999	C3.4	9	2	0	24	2	0	0
2001	03	31	246	326	3100	0	-999	C2.8	7	1	0	17	0	0	0
2001	04	01	258	320	2830	1	-999	C2.4	2	4	0	20	2	0	0
2001	04	02	228	223	2780	1	-999	C6.5	2	4	3	12	3	0	0
2001	04	03	223	228	2600	3	-999	M2.0	3	2	1	8	1	1	0
2001	04	04	205	217	1950	2	-999	C2.6	5	3	0	7	3	0	0
2001	04	05	210	214	1810	1	-999	C1.7	1	5	0	8	0	1	0
2000	04	01	223	287	1430	2	-47	C1.3	8	0	0	20	1	0	0
2000	04	02	219	301	1700	0	-38	C1.2	3	0	0	20	0	0	0
2000	04	03	215	252	1100	2	-22	C1.0	4	0	0	7	0	0	0
2000	04	04	207	184	1180	1	8	C1.1	4	1	0	6	0	1	0
2000	04	05	194	221	1040	2	9	C1.5	1	0	0	16	0	0	0
2000	04	06	178	155	620	0	17	B9.6	2	1	0	4	1	1	0
2000	04	07	175	172	730	2	6	B8.7	4	0	0	5	0	0	0
2000	04	08	182	167	760	0	-999	B7.6	9	2	0	15	2	0	0
2000	04	09	176	160	630	1	30	C1.0	6	2	0	6	1	1	0
2000	04	10	178	175	590	4	25	C1.8	7	0	0	3	2	0	0

*-999 (indicates no data)

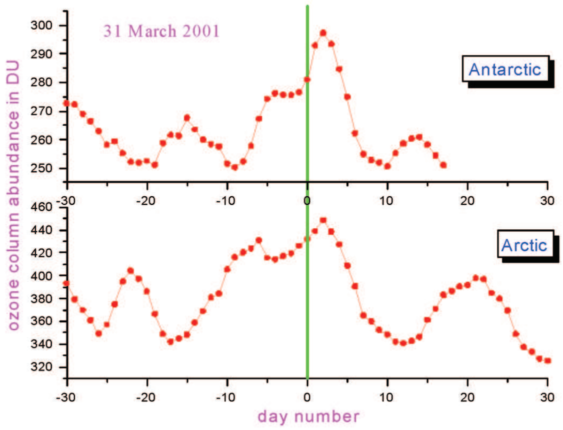

Figure 3. The total column abundance of ozone (in DU) obtained over Arctic (lower panel) and Antarctic (upper panel) before and after the onset of magnetic storms. The onset of the storm is on zero day.

after the onset of geomagnetic storm. Since the solar flare occurs before the onset of the geomagnetic storm, one of the possible causes for the changes in total column abundance over the equatorial latitude region before the onset of the magnetic storm could be due to the solar flare. The solar flare index obtained from the daily solar data is shown in Table 1. The flare indices show that there are enhancements before the onset of the event.

Convection is deep and maximum over the Indian land mass region during the summer monsoon season (June-September). Kulkarni & Verma (1993) have studied the relation between tropopause height over India and the Indian summer monsoon activity. They noticed that all India mean tropopause height shows statistically higher value in the composites of good monsoon years than the value in bad monsoon years for the months May to September. Steinbrecht et al. 1998 have examined the correlation between tropopause height and total ozone. They suggested that a high tropopause is correlated with low total ozone and low tropopause with high total ozone. Independent of season, total ozone decreases by 16 DU per km increase in tropopause height. Thus, the above results together suggest that the tropopause height during wet weather condition is more than in the dry weather and the increase in tropopause height causes decrease in TCO (Total Column Ozone).

In addition to dynamical processes (convective activity) tropospheric H2O chemistry may be playing a role in the redistribution of TCO. In general O3 and H2O are negatively correlated with high (low) O3 and low (high) humidity in the region of enhanced (suppressed) convection (Chandra et al. 1998). O3 may be destroyed by the reaction of O(1D) with H2O in the following way:

$$O3 + h\nu \rightarrow O(1D) + O2$$
$$O(1D) + H2O \rightarrow OH + OH$$
$$HO2 + O3 \rightarrow OH + 2O2$$
$$OH + O3 \rightarrow HO2 + O2$$

The enhanced convection, which is associated with rich water vapour during the wet season, may be responsible for more O3 losses than in the dry season (Londhe et al. 2006).

2. Conclusion

We have studied the influence of geomagnetic storms on the total ozone variability at equatorial as well as polar latitude. Geomagnetic storms produce larger disturbances in the ionosphere, but they also affect the neutral atmosphere including the middle atmosphere and troposphere. We have studied some of the major geomagnetic storms. The polar latitude shows the increase in total column ozone after the onset of the severe magnetic storms. The equatorial region shows an increase in the total column ozone over the limited region. The total column abundance of ozone shows an increase over the Pacific ocean before as well as after the onset of magnetic storms. The convection process increase after the onset of magnetic storms and it lowers the tropopause height, which might cause increase in the total column ozone abundance in the stratospheric region.

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