Variation of Total Column Ozone (TCO) during the time of Landfall of Extratropical Cyclone.

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ABSTRACT

The paper presents the variation of total column ozone (TCO) before, after and during landfall of European windstorm which is a type of extra-tropical cyclone over a specific station. Analysis reveals that rise in ozone concentration occurs during the occurrence of the cyclone. Possible explanations are also presented.

(Keywords: atmospheric physics, TCO, ozone concentration, European windstorm, O_3)

INTRODUCTION

Latitude 30˚ marks the boundary separating the tropics from the mid-latitude and thereby differentiates from the basic principle of cyclogenesis between the two zones. Mid-latitude cyclones, also known as extratropical cyclone, are synoptic scale low pressure systems originating in the mid-latitude belt is formed mainly along a front when a high temperature gradient exist across the front. These cyclonic activities are quite normal in the mid-latitude belt and signifying the presence of large amount of available potential energy (APE).

The fundamental principle governing their formation is the communion of two air masses (cold air mass from the higher latitudes and the warm air mass from the lower latitudes) leading to the formation of a front where the warm air mass glides over the denser, colder air to ascend and in presence of available water vapor, clouds are formed and finally precipitation over a particular location. Hence, research on these low pressure systems became an interesting section of knowledge and study.

Extratropical cyclone like tropical ones affects stratospheric dynamics and ozone content as it penetrates into the lower stratosphere. Browning et.al (1998) used a model to analyze a mature extra-tropical cyclone together with radar and satellite observations. He showed the troposphere stratosphere coupling during the mature stage of the strong cyclone. Intensity of a cyclone and its development is governed partially by the available solar energy. Smith (2000) presented the mechanism by which horizontal heating distribution varying relatively in small amount over the total spread of the cyclonic circulation, can yield vorticity tendency responses that could contribute to either development or decay of an underlying cyclone.

Monitoring a cyclone and tracking the track of a cyclone is very important in forecasting. Since the percentage of manual error is quite significant, so inaccurate numerical methods in tracking the storm is preferred. Gulev et al. (2001) studied 42-yr climatology of cyclone characteristics over Northern Hemisphere from NCEP/NCAR reanalysis data to compute finally a program to track the storm. Extratropical cyclone (ETC) forming from tropical cyclone is a known fact. But there had not been any definition of extratropical transition of tropical cyclone. Evans et.al (2003) examined 61 Atlantic storms from 1979-1993 and showed the objective indicators of the life cycle evolution of extratropical transition for Atlantic tropical cyclones. This extratropical transition was also studied by Atallah et al. (2003) with reference to precipitation distribution by hurricane which showed several anomalies especially in potential vorticity (PV).

Modeling ETC development in a unique technique of scale separation was done by Parsons and Smith (2004). Again, Intihar and Stewart (2005) studied the ETC development in order to figure out the real cause behind the heavy precipitation by ETC and they considered the precipitation over Canadian Archipelago during cold season. Critical analysis and study was done by Gray and Dacre (2006) who studied the details of about 68 700 cyclones in the mid-latitude and finally concluded the governing of dynamical forcings for those cyclones occurred.

Azad and Sorteberg (2009) interestingly diagnosed the warm and cold coric extratropical cyclones using the the Zwack-Okossi equation. Prikryl et al. (2009a) studied the influence of solar wind on ETC in relation with Wilcox effect.

In his continued research, Prikryl et al. (2009b) investigated on the link between auroral atmospheric gravity waves and solar wind effect on ETC. Since severe extratropical cyclone penetrate into the stratosphere, there occurs intrusion of tropospheric components into the stratosphere and this troposphere-stratosphere coupling and mixing of air parcels had been studied by Sigmond et al. (2000). Sigmond et al. developed a Lagrangian technique to calculate the troposphere-stratosphere exchange during an ETC. Similar stratosphere troposphere exchanges during extratropical cyclones and within extratropical belts had been studied and confirmed by several researchers and scientist around the globe (Olsen et al., 2004; Schoeberl 2004; Mizuta et al., 2009).

Thus, considering these troposphere-stratosphere exchange processes, the purpose of our research is to study the variation of stratospheric ozone concentration (total column ozone/TCO) during extratropical cyclone.

DATA AND METHODOLOGY

The extratropical cyclone data required for our study has been taken from CIMMS (http://www.ncdc.noaa.gov/sotc/hazards) and the column ozone data are from the nasa website on ozone mapping (http://toms.gsfc.nasa.gov/). Seven cases studies have been presented in our paper from the period 2005-2010.

RESULTS AND DISCUSSION

TOC of nearest station of cyclone center is plotted against days in a line diagram to show the variation of the TOC trend_during cyclone period over (Figure1) and (Figure2). The trend of ozone concentration is observed before, during and after the landfall. The general trend analysis clearly shows that the there is a sharp increase in the TOC during the windstorm approaches the station observed.

Figures 1 and 2 present the variation of ozone before, during and after the occurrence of an extratropical cyclone. From the figures, it is clear that ozone concentration increases gradually during the landfall of extratropical cyclone.

Extratropical cyclones are cold-core low vortex systems. An important feature of this low is that it intensifies with altitude, but remains within the troposphere under normal conditions. At the center of the low, there lies a pool of intense cold air which actually remains in vorticity. During a cyclonic development, the height of this low then increases. In case when the cyclonic circulation attains severity, this low then penetrates into the stratosphere. This penetration actually affects ozone concentration (Mitra, 1952).

Ozone formation and depletion are both kinetically controlled processes. During the formation stage of the cyclone, strong convective activity leads to the entry of water molecules in the stratosphere. Now, ozone formation from water molecule dissociation obeys the following path (Ghosh and Midya, 1994):

$$H_2O + hv \rightarrow OH + H$$

$$OH + hv \rightarrow O + H$$

$$O + O \rightarrow O_2 + M$$

$$O_2 + O + M \rightarrow O_3 + M$$

where M is the third body which conserves energy and momentum of the reaction.

The net reaction for the formation of ozone in stratosphere is given below:

$$O_2+O_2 \rightarrow O_2+O+O=O_3+O$$
$$\underline{O+O_2+M=O_3+M}$$
$$3O_2=2O_3$$

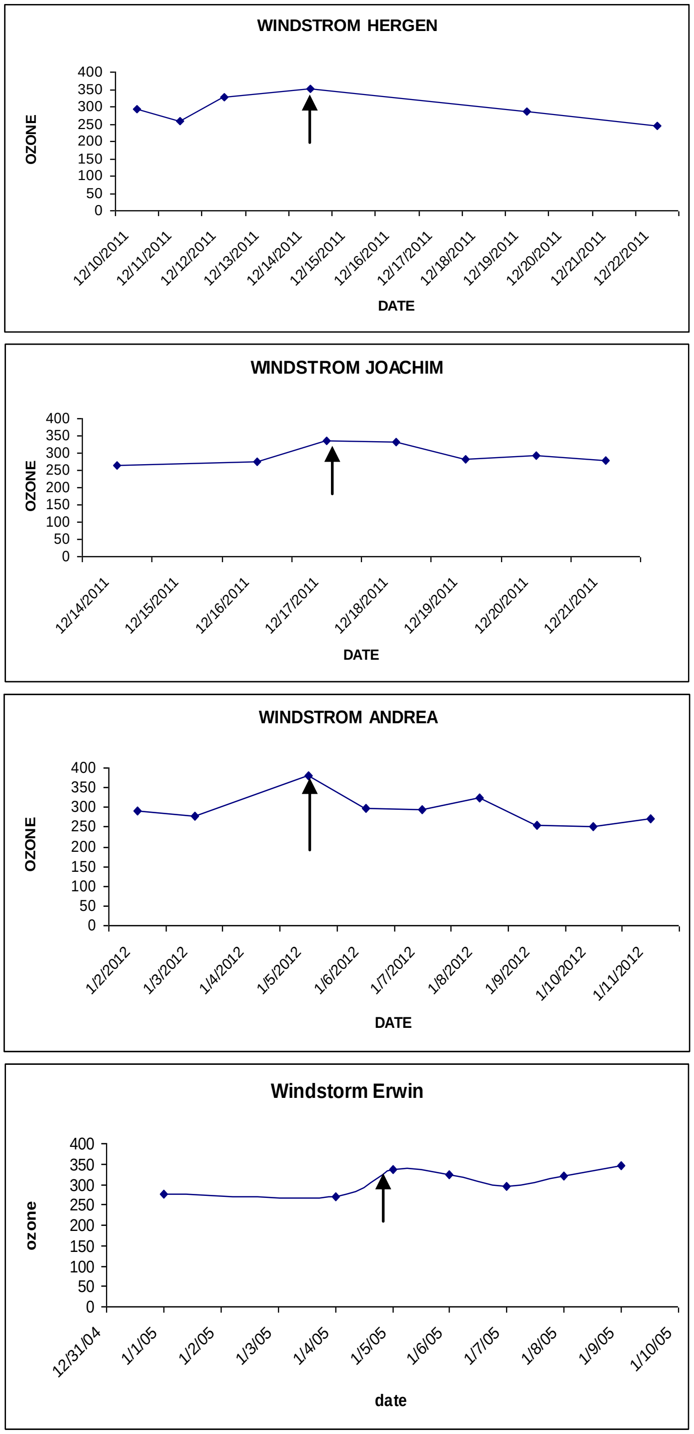

Figure 1: Variation of TCO during Landfall of different Extratropical Cyclones. Arrow marks indicate the date of landfall.

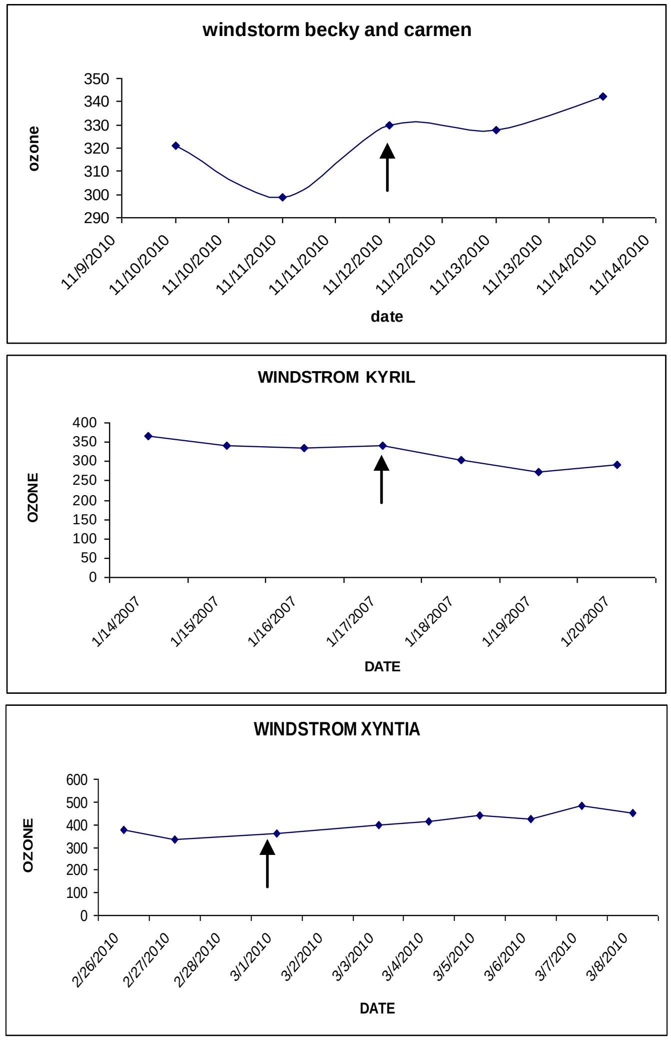

Figure 2: Variation of TCO during Landfall of different Extratropical Cyclones. Arrow marks indicate the date of landfall

The formation of ozone is endothermic reaction. That means if the temperature of the reaction medium is increased during the formation of ozone, the reaction will be in the forward direction (according to Le Chatelier's principle) i.e., the yield will increase.

CONCLUSION

Variation of TCO is studied during extratropical cyclone and its deviation from normal value is observed from which it can be concluded that TCO can serve as a precursor element in extratropical cyclone forecasting. It is concluded that formation rate of ozone increases due to the rise of temperature of lower stratosphere during landfall.

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