Variation of Total Column Ozone (TCO) during the time of Landfall of Tropical Cyclone in Extra-tropical Region.

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ABSTRACT

The paper presents the variation of total column ozone (TCO) before, after and during landfall of tropical cyclone when it passes through an extra-tropical zone over the East Pacific region. Analysis reveals that there occurs a variation in ozone concentration during the occurrence of the tropical cyclone − a rise in ozone concentration occurs during the landfall of tropical cyclone in the extra-tropical region. It is also confirmed that increase of TCO in percentage decreases with the increase of wind speed. Possible explanations are also presented.

(Keywords: tropical cyclone, extra-tropical, TCO, O_3)

INTRODUCTION

The purpose of this paper is to present the variation of total column ozone (TCO) before, after and during landfall of tropical cyclone when it passes through an extra-tropical region. Midya et al., 2012 already reported the variation of TCO before, during, and after tropical cyclones occurred in pre-monsoon and post monsoon periods over Bay of Bengal and Arabian Sea when landfall takes place over tropical country for the period 1997 to 2009. From this analysis it was concluded that TCO decreases steadily before and during the formation of cyclone and more or less an increasing trend is followed after dissipation of cyclone over land. It is also observed that when a cyclone reaches its pick intensity with its maximum wind speed there is a sudden fall in ozone concentration over those regions where the cyclones are intensified and depletion of TCO in percentage increases with the increase of wind speed of cyclone. When a tropical cyclone passes through an extra-tropical region, the nature of change of TCO may not be same as we have obtained for landfall of tropical cyclone over tropical country (Midya et al., 2012). The purpose of the paper is to verify this hypothesis.

A tropical cyclonic storm forms a large vortex in the atmosphere with diameters between 150 to 1200 km. They intensify over tropical oceans and cross over land and dissipate. Sometimes they move towards extra-tropical regions and ultimately dissipate over land.

The storms have different names in different areas such as Cyclone in Indian Ocean, Hurricanes in Atlantic, Typhoons in West Pacific and South China Sea and Willy-willies in West Australia. Seasonal variations in tropical cyclone activity depend upon several factors. Globally, tropical cyclones are affected dramatically by the El Niño-Southern Oscillation. In some basins, El Niño events increase tropical cyclone formation (Revell and Goulter, 1986). Decreases of tropical cyclone events were observed with the El Niño events in the Australian region (Nicholls, 1979).

In another study, it was reported that La Niña's typically related with tropical cyclone in opposite conditions (Chan, 1985). It was also reported that global warming is highly related with typhoon activity (Chan and Liu, 2004) and more frequent or more intense hurricanes are expected from an increase in the local sea surface temperature (Arpe and Leroy, 2009). Solar activity may directly influence a hurricane's intensity. It was reported that Caribbean tropical cyclone activity and U.S. hurricane counts have a pronounced 10-year periodicity. The tropical cyclone intensities inversely correlated with sunspot number on the inter-annual and daily time scales (Elsner et al., 2008).

Ozone is a minor constituent of the atmosphere and it is mainly distributed in the stratosphere. The unique role of ozone in absorbing certain wavelengths of incoming solar ultraviolet light was recognized in the latter part of the nineteenth century. Maximum concentration of ozone takes place around 25 km altitude. This layer absorbs 97–99% of the sun's high frequency ultraviolet light, which is potentially damaging to life on Earth (Alexandris et al., 1999).

Several studies have investigated ozone trends over different places of the world (Varotsos, 2004; Gernandt et al., 1995; Kondratyev et al., 1994; Varotsos et al., 1994). Total ozone content exhibits high natural variability in both space and time (Varotsos, 2002). It's variability at a particular location is strongly influenced by the movement of air from one region to another (Varotsos, 1989). Thus, ozone exhibits temporal variability over hourly, diurnal, synoptic (3–5 days), weekly, seasonal, and long-term (5–20 years) timescales (Varotsos, et al. 2004).

Several studies on ozone concentration related to solar control and associated meteorological parameters are now a hot topic of research (Cracknell and Varotsos, 1994, 1995; Varotsos et al., 1995; Katsambas et al., 1997; Kondratyev et al., 1996). It has now been established that definite correlation exists between weather conditions in troposphere and ozone content in the stratosphere. There is a relation between the long-term coupling between column ozone and tropopause properties (Varotsos et al., 2001). The passage of a warm front is accompanied by a fall in the ozone content, while a cold front is accompanied by a rise in the ozone concentration. These effects are, however, observed only when the fronts extend well into the stratosphere (Mitra, 1992). At the time of maximum intensity of cyclones, the negative TCO anomalies (more than 20 DU) is also reported (Singh and Singh, 2007).

DATA AND METHODOLOGY

The tropical 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/). TCO variation over a particular location is plotted, considering 15 days before and 15 days after the cyclonic disturbance. The cyclone occurrence day has been indicated with an arrow marks in Figure 1 (a-g).

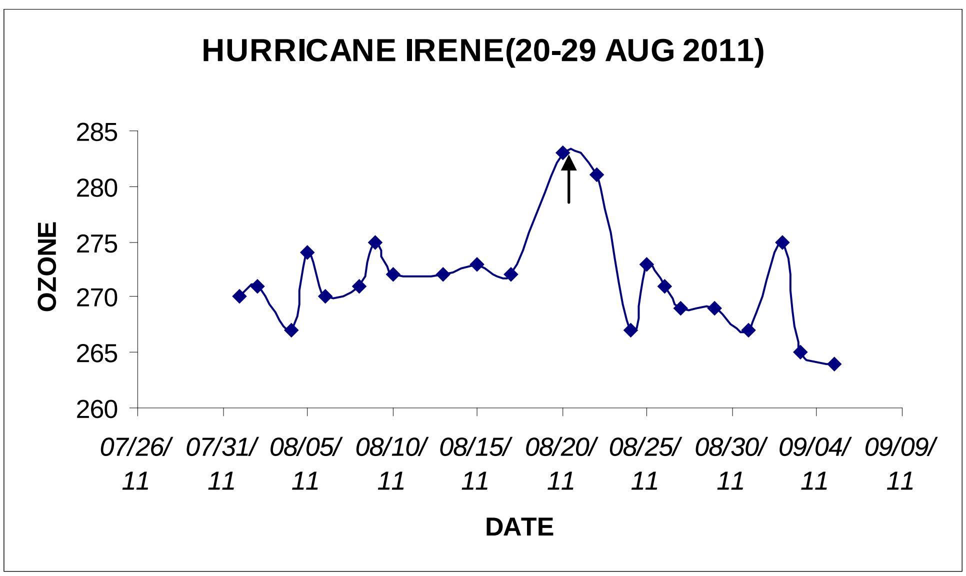


Figure 1a.

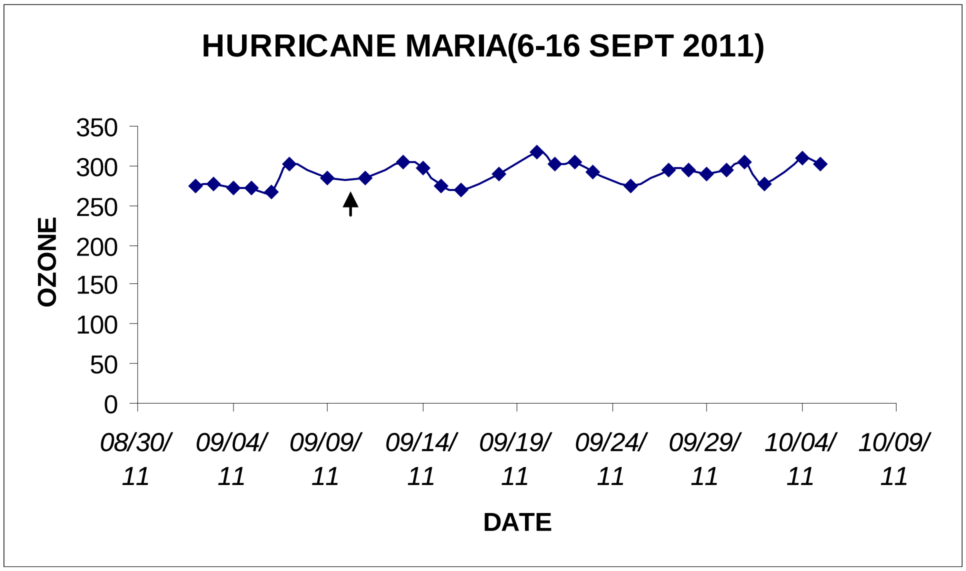
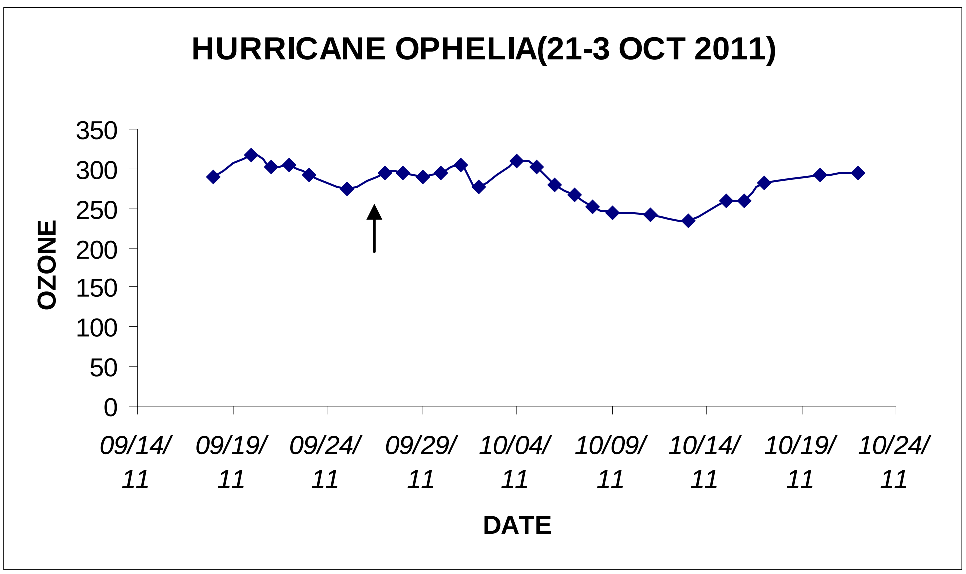


Figure 1b.



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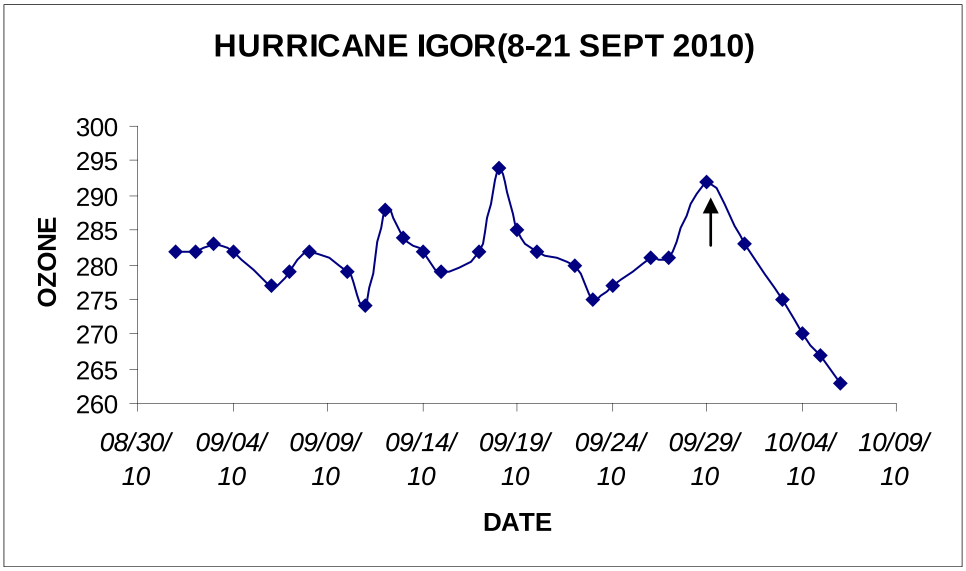

Figure 1d.

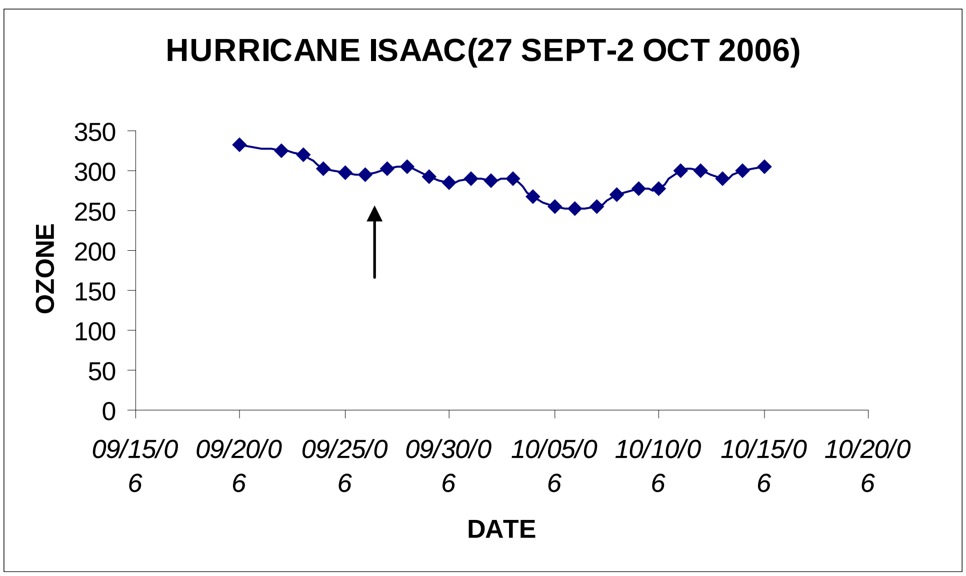

Figure 1e.

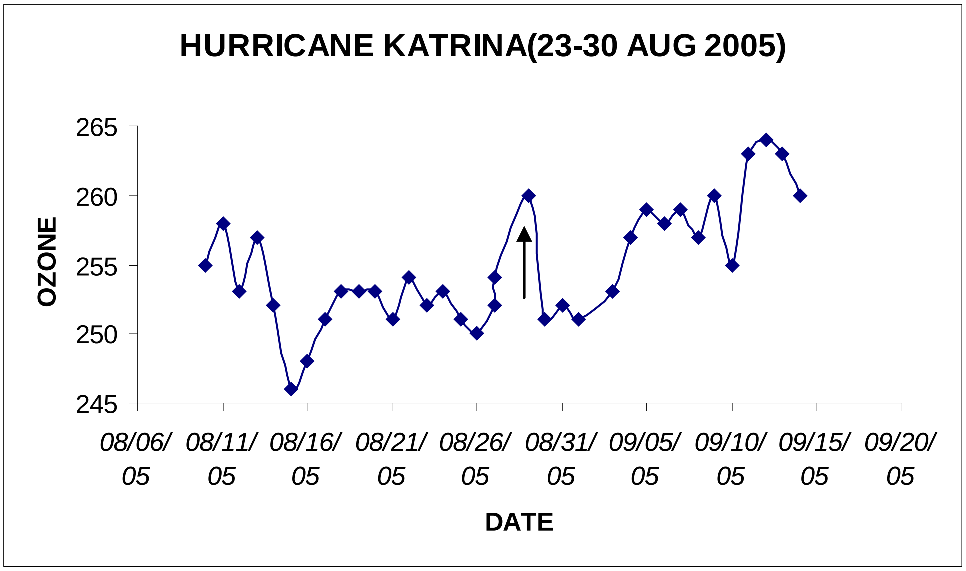

Figure 1f.

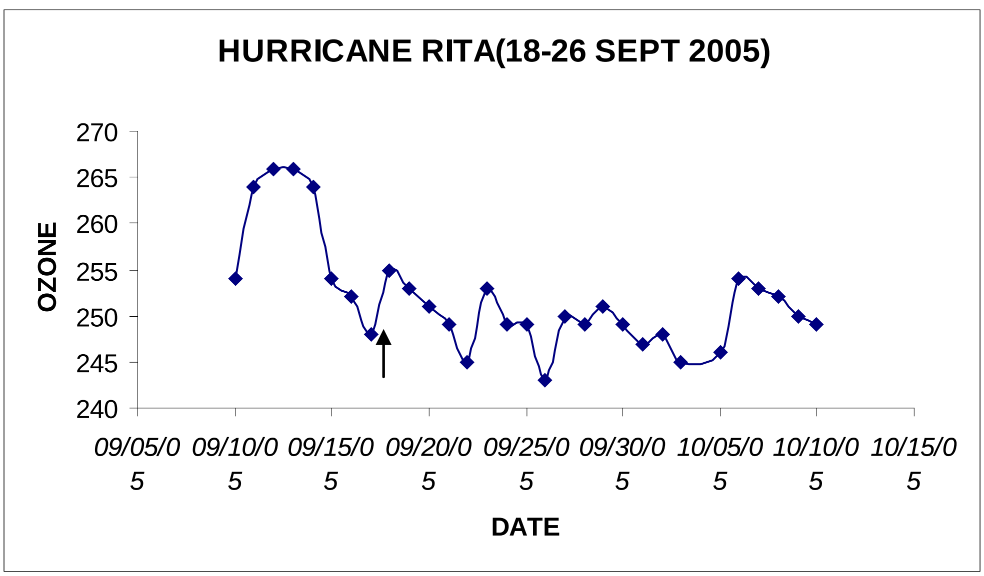

Figure 1g.

Figure 1: Variation of Ozone Concentration During Landfall of Tropical Cyclone in the Extra-tropical Zone. Arrow Marks Show the Landfall Date.

RESULTS AND DISCUSSION

Several cyclones between the time periods 2005-2011 are taken into consideration. The ozone data of first landfall is taken to find the trend of variation of TCO for the period of 15 days before to 15 days after the landfall of the cyclone in the extra-tropical zone.

Variation of TCO over different places on which the cyclone hits is shown in Figure1. The general trend analysis clearly shows that the trend is increasing before and during the cyclone period and it follow more or less decreasing trend after dissipation of cyclone. It is also observed for severe or very severe cyclone when cyclone has reached its pick intensity there is an increasing trend of ozone concentration over the zones where cyclones attain its peak value in Pacific Ocean.

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:

$O_2+O_2 \rightarrow O_2+O+O=O_3+O$

$\underline{O+O_2+M=O_3+M}$

$3O_2=2O_3$

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). Stratosphere starts at lower altitude in the extra-tropical region. During the landfall of tropical cyclone the warm air reaches above the tropopause (i.e., lower stratosphere) and the temperature of that. Again from the above results we can see O_3 is created in the atmosphere due to the decomposition of water molecules in the atmosphere. When the cyclone leaves the place the rate of formation of ozone become normal and that's why the there is a decrease in TCO after few days of the landfall. Outflow of ozone takes place due to high wind speed of cyclone in its matured stage. As a result, rate of increase of ozone decreases with the increase wind speed of the cyclones (Figure 2).

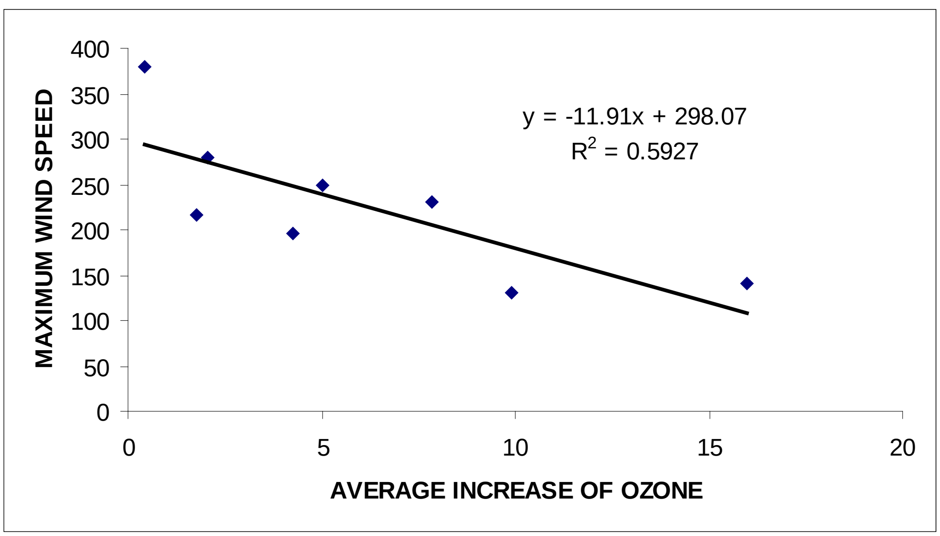

Figure 2: Variation of Ozone Concentration with the Wind Speed of Cyclone.

CONCLUSION

TCO increases during landfall of tropical cyclone in extra-tropical region. It is also concluded that the rise of TCO is highly correlated to rise of temperature. As ozone formation process is endothermic process, rise of temperature helps formation of TCO. Thus the increase of TCO is quite expected.

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REFERENCES

1. Alexandris, D., C. Varotsos, K.Y. Kondratyev, and G. Chronopoulos. 1999. "On the Altitude Dependence of Solar Effective UV". *Phys Chem Earth PT C-Solar-Terr. Planet Sci*. 24(5):515-517.

2. Arpe, K. and S.A.G. Leroy. 2009. "Atlantic Hurricanes—Testing Impacts of Local SSTs, ENSO, Stratospheric QBO—Implications for Global Warming". *Quaternary International*. 195:4-14.

3. Bates, D.R. and M. Nicolet. 1950. "The Photochemistry of Atmospheric Water Vapor". *J Geophys Res.* 55:301- 327.

4. Chan, J.C.L. 1985. "Tropical Cyclone Activity in the North-west Pacific in Relation to the El Nino/Southern Oscillation Phenomenon". *Mon Weather Rev*. 113:599-606.

5. Chan, J.C.L. and S.L. Liu. 2004. "Global Warming and Western North Pacific Typhoon Activity from an Observational Perspective". *J Climate*. 17: 4590-4602.

6. Cracknell, A.P. and C.A. Varotsos. 1994. "Ozone Depletion over Scotland as Derived from Nimbus -7 TOMS Measurements". *Int J Remote Sens*. 15: 2659-2668.

7. Cracknell, A.P. and C.A. Varotsos. 1995. "The Present Status of the Total Ozone Depletion Over Greece and Scotland: A Comparison between Mediterranean and More Northerly Latitudes". *Int J Remote Sens*.16:1751-1763.

8. Elsner, J.B., T.H. Jagger, M. Dickinson, and D. Rowe. 2008. "Improving Multiseason Forecasts of North Atlantic Hurricane Activity". *J Appl Meteorol Clim.* 21:1209-1219.

9. Gernandt, H., U. Goersdorf, H. Claude, and C.A. Varotsos. 1995. "Possible Impact of Polar Stratospheric Processes on Midlatitudes Vertical Ozone Distributions". *Int J Remote Sens*. 16:1839-1850.

10. Ghosh, S.N. and S.K. Midya. 1994. "Atmospheric Ozone, Its Depletion and Antarctic Ozone Hole". *Indian J. Phys.* 68B(6):473-493.

11. Katsambas, A, C.A. Varotsos, G. Veziryianni, and C. Antoniou. 1997. "Surface Solar Ultraviolet Radiation: A Theoretical Approach of the SUVR Reaching the Ground in Athens, Greece". *Environ Sci Pollut R*. 4:69-73.

12. Kondratyev, K.Y., C.A. Varotsos, and A.P. Cracknell. 1994. "Total Ozone amount Trend at St.Petersburg as Deduced from Nimbus-7 TOMS Observations". *Int J Remote Sens*. 15:2669- 2677.

13. Kondratyev, K.Y. and C.A. Varotsos. 1996. "Global Total Ozone Dynamics: Impact on Surface Solar Ultraviolet Radiation Variability and Ecosystems". *Environ Sci Pollut R*. 3:205-209.

14. Midya, S.K., S.S. Dey, and B. Chakraborty. 2012 "Variation of TOC (Total Ozone Column) during Tropical Cyclone over Bay of Bengal and Arabian Sea". *Meterology and Atmos.Phys.(Germany)* . DOI 10.1007/s00703-011-0169-1. 117:63-71.

15. Mitra, S.K. 1992 *The Upper Atmosphere*. The Asiatic Society: Calcutta, India.156-159.

16. Nicholls, N. 1979. "A Possible Method for Predicting Seasonal Tropical Cyclone Activity in the Australian Region". *Mon Weather Rev*. 107:1221–1224.

17. Revell, C.G. and S.W. Goulter. 1986. "South Pacific Tropical Cyclones and the Southern Oscillation". *Mon Weather Rev*. 114:1138–1145.

18. Romps, D.M. and K. Zhiming. 2010. "Do Undiluted Convective Plumes Exist in the Upper Tropical Troposphere". *J Atmos Sci*. 67:468–484.

19. Singh, D. and V. Singh. 2007. "Impact of Tropical Cyclone on Total Ozone Measured by TOMS-EP over the Indian Region". *Curr Sci*. 93(4):471-476.

20. Tzanis, C. and C.A. Varotsos. 2008. "Tropospheric Aerosol Forcing of Climate: A Case Study for the Greater Area of Greece". *Int J Remote Sens*. 29:2507-2517.

21. Varotsos, C.A. 1989. "Connections between the 11-Year Solar-Cycle, the QBO, and Total Ozone – Comments". *J Atmos Terr Phys*. 51(5):367-370.

22. Varotsos, C.A., P. Kalabokas, and G.J. Chronopoulos. 1994. "Association of the Laminated Vertical Ozone Structure with the Lower-Stratospheric Circulation". *J Appl Meteorol*. 33:473-476.

23. Varotsos, C.A., G.J. Chronopoulos, S. Katsikis, and N.K. Sakellariou. 1995. "Further Evidence of the Role of Air-Pollution on Solar Ultraviolet-Radiation Reaching the Ground". *Int J Remote Sens*. 16:1883-1886.

24. Varotsos, C.A., D. Alexandris, G. Chronopoulos, and C. Tzanis. 2001. "Aircraft Observations of the Solar Ultraviolet Irradiance throughout the Troposphere". *J Geophys Res*. 106(D14):14843-14854.

25. Varotsos, C.A. 2002. "The Southern Hemisphere Ozone Hole Split in 2002". *Environ Sci Pollut R*. 9: 375-376.

26. Varotsos, C.A. 2004. "Atmospheric Pollution and Remote Sensing: Implications for the Southern Hemisphere Ozone Hole Split in 2002 and the Northern Mid-Latitude Ozone Trend". *Adv Space Res*. 33:249-253.

27. Varotsos, C.A., C. Cartalis, A. Vlamakis, C. Tzanis, and I. Keramitsoglou. 2004. "The Long-term Coupling between Column Ozone and Tropopause Properties. *J Climate*. 17: 3843–3854.

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