1A2) Assessment on the Variability of Total Ozone for Climate Change over Korea

Yun-Seob Moon[1] · Hye-Jung Shin[1] · Sung-Nam Oh[1] · Byoung Cheol Choi[1] · Hyo-Sang Chung[1] · Yoo-Keun Kim[2] · Seong-Kyoun Kim[3]
[1]Meteorological Research Institute, KMA, [2]Department of Atmospheric Sciences, Pusan National University, [3]Climate Bureau, KMA

1. Introduction

Ozone is one of the most significant atmospheric constituents controlling the intensity of solar UV-B irradiance (280 to 320 nm), and the decrease of the total ozone amount supported by ozonesondes and spectrometers will result in the increase of UV-B irradiance at the earth's surface. For example, 1% decrease in stratospheric ozone is expected to yield a 2-3% increase in UV-B irradiance and in the incidence of skin cancer. Recently, although satellite measurements of ozone such as TOMS (Total Ozone Mapping Spectrometer), SBUV (Solar Backscatter Ultraviolet) and TOVS (TIROS Operational Vertical Sounder) have been carried out, the long-term monitoring of ground-based total ozone is necessary for evaluating and predicting these impacts on human health and Earth's ecosystems.

Total ozone on time-scale from hours to several days has been shown to be correlated with lower stratospheric temperatures, 500 hPa geopotential heights, winds, tropopause pressure (or height), and isentrophic potential vorticity near the tropopause (Kim *et al.*, 2002, Moon *et al.*, 2002). A number of recent studies have presented methods for predicting total ozone based on statistical correlations between total ozone and these meteorological variables (Stanford and Ziemke, 1996; Ziemke et al., 1998). That is, they have presented regression models based on an analysis using daily total ozone observations by TOMS, SBUV and TOVS and meteorological variables provided by NCEP (National Centers for Environmental Prediction), ECMWF (European Centre for Medium-Range Weather Forecasts), NWS (National Weather Service), NMSs (National Meteorological Services) and any regional NWP (Numerical Weather Prediction model output. However, it is necessary that the prediction model of total ozone in narrow regions including high density of population and complicated mountains like South Korea is to be considered with total ozone itself and meteorological factors observed in the Korean peninsular (Kim and Moon, 2001).

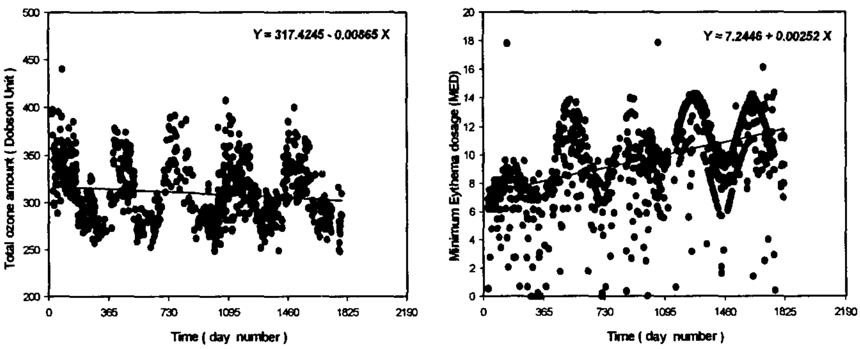
Recently, we have observed the increase of total ozone at Seoul, Pohang, and Jeju in Korea for the period of 6 yr (1997-2002). The purpose of this study is to identify and predict the effects of total ozone over Korea. To predict long-term variations in total ozone, we are to introduce ARIMA (Auto-Regressive Integrated Moving Average) model which is one of the most general class of models for forecasting a time series using single variable. In particular, these statistical models are useful when the remote sounding data such as TOMS have not been provided.

2. Data

The units of total column ozone are Dobson Units (DU). One DU is equivalent to 1 milliatmosphere centimeter (m-atm-cm) or 10^{-3}cm of pure ozone at STP. Conversions are possible to transform the total column DU to local ozone SI units. The data of total ozone for the regression and ARIMA are used in daily and monthly TOMS data for the period of 24 yr (1979-2002) interpolated at Seoul, Pohang, and Jeju in Korea (http://jwocky.gsfc.nasa.gov/news/ news.html). In particular, it was compared with the data of both Brewer and Dobson spectrometers at Pohang and Seoul, respectively.

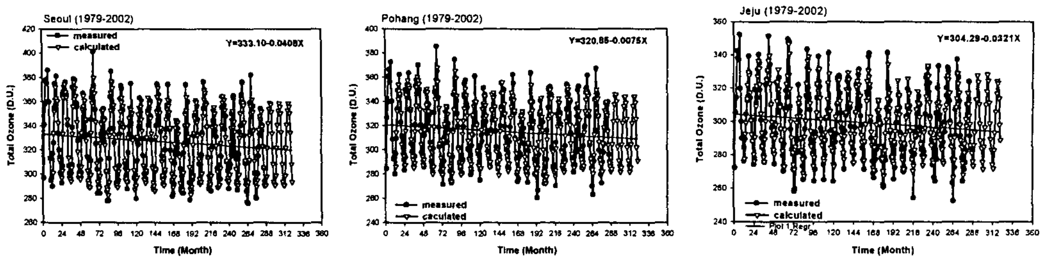
3. How does total ozone change in the future?

Fig. 1 shows the daily variation with increases in McKinley-Diffey action UV-B irradiance (J/cm2/day) due to decreases in total ozone by Brewer spectrometer at Pohang for the period of 5 yr (1994-1998). Total ozone is an important factor in determining the UV-B irradiance reaching the surface. Although total ozone is presented in decrease during the observed period, the variation of that in the future may not decrease. Fig. 2 shows that the long-term monthly trend of total ozone interpolated by TOMS at Jeju, Pohang and Seoul for the period of 24 yr (1979~2002) is decreasing. In general, we know that the decreasing trend of total ozone is due to the effect of increase in trace gases of the ozone depletion such as total chlorine (Cl) and fluorine (F). In particular, the smallest amount of total ozone in 1993 is due to aerosols by volcanic eruptions of Mount Pinatubo in 1991. However, recently, Anderson *et al.* (2000) have confirmed that the trends of tropospheric Cl and methyl chloroform (CH_3CCl_3) from the UNEP (United Nations Environment programme) are decreasing since 1993 (see Fig. 5), at the same time, that of the stratospheric chlorine (Cl) from HALOE (Halogan Occiltation Experiment) since 1997 are decreasing, and these decrease are driven by the tropospheric decrease of Cl and CH_3CCl_3 due to a lag time for tropospheric gases to reach 55 km of 5.9±2 years. These results are in accordance with Montreal Protocol which desires the reducing of the stratospheric Cl and F since 1987. In fact, the daily trends of total ozone since 1996 except for no observation data of TOMS from 24 November 1994 to 25 July 1996 as seen in Figs. 2 and 3 have not been decreasing any more. It is expected that increased total ozone will lead to decreased UV-B irradiance at the surface. Above all, because analyses on the trends of total ozone and UV-B irradiance since 1996 require long-term data over ten years and accuracy of instrumentation, we may treat the prediction of daily total ozone and hourly UV-B MED with these observation data. It is a difficult task to maintain the instrumentation at a site in a consistent manner over such a long period of time and to compare with other instruments at a site. Many other factors such as local cover cloud and aerosols with altitude and latitude including the measuring errors.



(a) (b)

Fig. 1. Increases in McKinley-Diffey action UV-B irradiance (J/cm2/day) due to decreases in total ozone at Pohang for the 5 yr period 1994-1998. (a) Daily time series plot of total ozone, and (b) UV-B irradiance.



(a) (b) (c)

Fig. 2. Monthly time series of total ozone fitted by the multiplicative seasonal ARIMA model at Pohang, Korea for the 24 yr period of 1979-2002.

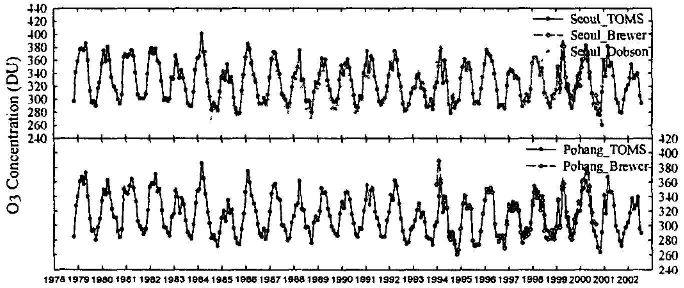


Fig. 3. Intercomparison of total ozone between a Brewer or Dobson spectrometer and TOMS at Seoul and Pohang in Korea.

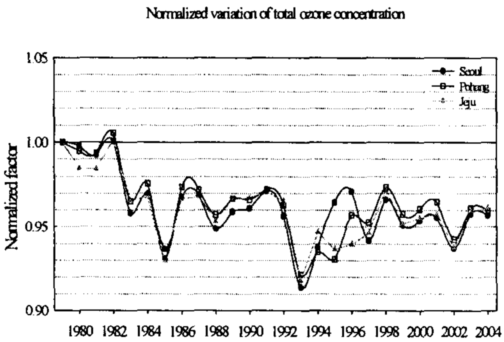


Fig. 4. Normalized variation of total ozone from 1979 to 2002 at Seoul, Pohang, and Jeju in Korea.

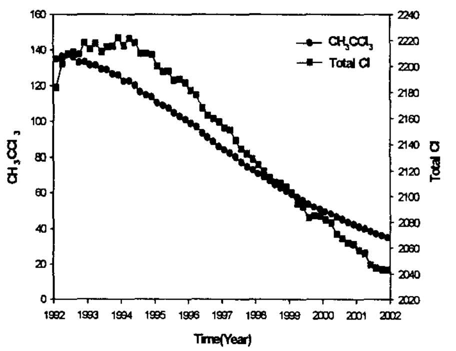


Fig. 5. Time series of CH_3CCl_3 and total Cl for the period of 10 yr (1992 -2001).

4. Prediction of total ozone

Total ozone data between Brewer or Dobson spectrometer and TOMS at Pohang are compared in Fig. 3. There are distinct differences between ground-based Brewer or Dobson spectrometer and nadir-viewing TOMS, but the correlation coefficient between both daily total ozone data was presented high more than 0.95. It is showed that next-day ozone at each meteorological site which can't observe the ground-based total ozone can be predicted by using the daily or monthly mean TOMS data. Multiplicative seasonal ARIMA (AutoRegressive Integrated Moving Average) model was examined to predict monthly mean variation of total ozone that presents time series of a strong seasonal sinusoid with no observation data of TOMS from November 1994 to July 1996.

Fig. 2 presents also monthly time series plot of total ozone fitted and predicted by the multiplicative seasonal ARIMA model of at Seoul, Pohang and Jeju in Korea for the period of 24 yr (1979-2002). After the ARIMA model was composed by using TOMS data for the period of 16 yr (1979-1994), monthly mean total ozone was predicted for next three years (2002.9-2005.8). Monthly averaged total ozone of long-term predicted by the multiplicative seasonal ARIMA model is useful for predicting hourly mean UV-B irradiance by interpolating daily mean total ozone for the predicted period. In this way, we can predict the long-term mean variation of total ozone more than a year at each meteorological monitoring site in Korea or other countries.

5. Conclusions

The total amount of ozone has been analyzed and predicted by using statistical methods. The long-term daily trend of total ozone interpolated by TOMS at Seoul, Pohang, and Jeju for the period of 24 yr (1979~2002) is decreasing. Although total ozone is presented in decrease during the observed period, the variation of that in the future may not decrease because tropospheric Cl and CH_3CCl_3 are decreasing since 1993, at the same time, that of the stratospheric Cl since 1997 are decreasing. In particular, detection of trends in UV-B radiation associated with decreases or increases of total ozone can be further complicated by changes in cloudiness, by local pollution, and by difficulties in keeping the detection instrument in precisely the same operating condition over many years. Therefore, we need to predict the variation by using valid models of total ozone and UV-B irradiance by readily available meteorological parameters.

Acknowledgements

This research was supported by funding of National Research Labratory (NRL) of Ministry of Science and Technology (MOST) at Meteorological Research Institute (METRI), Korea Meteorology Administration (KMA) and by the grant of the Climate Environment System Research Center sponsored by the SRC program of the Korea Science and Engineering Foundation.

References

Anderson J., Russell III J. M., Solomon S., Deaver L. E. (2000) Halogan Occultation Experiment confirmation of stratospheric chlorine decrease in accordance with the Montreal Protocol, J. Gephy. Res., Vol 105, 4483-4490.

Kim Y. K., Moon Y. S. (2001) A study on statistical prediction models of total ozone amount, J. Kor. Meteo. Soc., Vol. 37, No. 2, 169-180.

Kim Y. K., Lee H. W., Park J. K., Moon Y. S. (2002) The stratosphere-troposphere exchange of ozone and aerosols over Korea, Atmos. Environ., Vol. 36, 449-463.

Moon Y. S., Kim Y. K., Strong K., Kim S. H., Lim Y. K., Oh I. B., Song, S. K. (2002) Surface ozone episode due to staratosphere-troposphere exchange and free troposphere-boundary layer exchange in Busan during Asian dust events, Kor. Environ. Sci, Soc., Vol 11, 419-436.

Stanford J. L., Ziemke J. R. (1996) A practical method for predicting midlatitude total column ozone from operational temperature fields, J. Geophy. Res., Vol 1011, 28769-28773.

Ziemke J. R., Herman J. R., Stanford J. L., Bbartia P. K. (1998) Total ozone/UVB monitoring and forecasting: Impact of clouds and horizontal resolution of satellite retrievals. J. Geophy. Res., Vol 103, 3865-3871.