A–1.1 Research on Variations of Ozone and Related Minor Species with an Infrared Laser Heterodyne Spectrometer

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Abstract Decline of ozone amounts in the mid-latitude regions in the northern hemisphere has been reported in recent years. The purpose of this study is to clear causes of ozone variations in the mid-latitude regions using ozone vertical profile data observed by the infrared laser heterodyne spectrometer and potential vorticity data calculated from the global analysis data provided by the Japan Meteorological Agency. Observations of ozone vertical profiles were made at the National Institute for Environmental Studies in Tsukuba in the 1991/1992 and 1992/1993 winter seasons. From comparison between the ozone data and the potential vorticity data, it is found that natural ozone variations due to air transport dominate in winter seasons around Japan, however, there was a case that ozone poor air originating from the high latitude regions where ozone may be destroyed through heterogeneous processes was transported to Japan.

Key Words Ozone Minor Species Infrared Spectroscopy Laser Heterodyne Remote Sensing

1. Introduction

In recent years, decline of ozone amounts in winter time at Sapporo has been reported according to observations of the ozone layer by the Japan Meteorological Agency, while the antarctic ozone hole is growing much larger and deeper year after year. Since the population and agricultural and forest land area in the northern hemisphere are larger than those in the southern hemisphere, influence of the destruction of the ozone layer to human life is quite serious. However, there have been insufficient number of observations of minor species related to ozone destruction, which is caused by a chain reaction including halogen radicals produced through heterogeneous reactions from CFCs artificially released into the atmosphere. It is now an urgent social problem to investigate the present situation and mechanism of ozone destruction.

2. Research Objective

The purpose of this study is to observe altitude distributions of ozone and related minor species by remote sensing with an infrared laser heterodyne spectrometer developed by Tohoku University, and to reveal causes of the variation of those minor species using the observed ozone data, the TOMS total ozone data, and the potential vorticity data calculated from the global analysis data provided by the Japan Meteorological Agency.

3. Instrumentation

We have been applying the infrared laser heterodyne spectroscopy for remote sounding of atmospheric minor constituents [1), 2)]. Development of a portable laser heterodyne spectrometer, which can observe ozone, methane and nitrous oxide, was completed in August, 1991. Methane and nitrous oxide are important minor species, because they are not only greenhouse gases but also sources of HO_x and NO_x, respectively, in the stratosphere. This spectrometer is suitable for the purpose of this study, because it can achieve an ultra-high spectral resolution of $8.5 - 9.4 \times 10^5$ and quantum limited sensitivity. The size and weight of the optical system are 800 mm × 600 mm × 500 mm and 70 kg, respectively. The bandwidth of this spectrometer is 40 MHz (0.0013 cm^{-1}).

Diode lasers are used for a local oscillator of the laser heterodyne spectrometer. Their operating wavenumber can be selected and continuously tuned by changing the laser temperature and current. The operating wavenumbers of the current system for observations of atmospheric ozone, nitrous oxide and methane are 1100 cm^{-1}, 1180 cm^{-1} and 1220 cm^{-1}, respectively. An atmospheric spectrum can be obtained in a scan time of 512 sec.

4. Results

In FY1990, observations of ozone vertical profiles were made in the Aobayama campus of Tohoku University in Sendai with the infrared tunable diode laser heterodyne spectrometer. In February, 1991 an intensive observation campaign of the ozone layer by ozonesondes was performed in Sapporo. During this period the observations with the laser heterodyne spectrometer were also made in Sendai and the variation of three-dimensional ozone distribution was studied along with the three-dimensional distribution of potential vorticity calculated from the global analysis data provided by the Japan Meteorological Agency.

In FY1991, the second intensive observation campaign of the ozone layer was performed in Tsukuba from December, 1991 to February, 1992 with the portable laser heterodyne spectrometer, ozonesondes, the ozone lidar and the aerosol lidar of the National Institute for Environmental Studies, and a millimeter-wave radiometer of Nagoya University. Observations of atmospheric methane and nitrous oxide were also made with the laser heterodyne spectrometer. It was confirmed by the aerosol lidar observations that a thick layer of aerosol due to the eruption of Mt. Pinatubo in Philippine in June, 1991 existed in the lower stratosphere during this period, however, no significant perturbation due to the aerosol layer was detected in the observed ozone vertical profiles.

Methane vertical profiles were retrieved from the absorption spectra observed by the laser heterodyne spectrometer for the first time [3].

In FY1992, the third intensive observation campaign of the ozone layer was performed in Tsukuba from December 1992 to January 1993 with the laser heterodyne spectrometer. Consecutive observations were made for six days in December, obtaining valuable data, however, few data were obtained in January because of bad weather.

From comparison between the ozone vertical profiles observed from December 11 through 16, 1992 and the vertical profiles of potential vorticity in the same period, they showed good correlation around the tropopause altitudes except for some small discrepancy. An another case study using the ozonesonde data obtained in Sapporo in January, 1992 showed that there was an evidence that ozone poor air covered over Sapporo at that time came from the high latitude regions where total ozone was extremely small.

5. Conclusion

From this study, it is concluded that ozone variations over Japan in winter seasons are mainly caused by transport process of air which originates from the low latitude regions where ozone amounts are naturally small, and/or from the high latitude regions where ozone may be destroyed through chemical reactions.

International Cooperation

Publication

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