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# VERTICAL OZONE DENSITY PROFILING BY UV RADIOMETER ONBOARD KSR-III

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## ABSTRACT

The UV radiometer payload was launched successfully from the west coastal area of Korea Peninsula aboard KSR-III on 28, Nov 2002. KSR-III was the Korean third generation sounding rocket and was developed as intermediate step to larger space launch vehicle with liquid propulsion engine system. UV radiometer onboard KSR-III consists of UV and visible band optical phototubes to measure the direct solar attenuation during rocket ascending phase. For UV detection, 4 channel of sensors were installed in electronics payload section and each channel has 255, 290, 310nm center wavelengths, respectively. 450nm channel was used as reference for correction of the rocket attitude during the flight. Transmission characteristics of all channels were calibrated precisely prior to the flight test at the Optical Lab. in KARI (Korea Aerospace Research Institute). During a total of 231s flight time, the onboard data telemetered to the ground station in real time. The ozone column density was calculated by this telemetry raw data. From the calculated column density, the vertical ozone profile over Korea Peninsula was obtained with sensor calibration data. Our results had reasonable agreements compared with various observations such as ground Umkhr measurement at Yonsei site, ozonesonde at Pohang site, and satellite measurements of HALOE and POAM. The sensitivity analysis of retrieval algorithm for parameters was performed and it was provided that significant error sources of the retrieval algorithm.

*Keywords*: ozone profile, KSR-III, radiometer, instrumentation

## 1. INTRODUCTION

Numerous measurements of ozone, either its total amount or vertical profiles have been obtained from various platforms such as ground-based, balloons, satellites, and sounding rockets. The most famous rocket-borne instrument is ROCOZ (Rocket Ozonesonde) radiometer (Krueger 1984), while other rocket soundings by KARI (Korea Aerospace Research Institute) (Kim et al. 2001) and ISAS (Institute of Space and Astronautical Science), Japan (Watanabe et al. 1992) have been carried out using optical system. The satellite-based observations have been very popular due to its continuous

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global coverage, and recent well-known satellite missions for ozone measurements include TOMS (Total Ozone Mapping Spectrometer), SAGE (Stratospheric Aerosol and Gas Experiment), POAM (Polar Ozone and Aerosol Measurement), and HALOE (HALogen Occultation Experiment). With these missions, numerous studies including three-dimensional ozone distribution and even long-term trend analysis are actively in progress. In measuring ozone using the optical techniques by either in-situ or remote sensing, it is essential to characterize optical properties of filters, detectors, and cross sections. All the ozone soundings must have prelaunch calibrations performed as accurate as possible in the laboratory. The error sources of these optical measurements include the errors in absorption and scattering cross sections, characterization of filter and detector response functions, not to mention noises from telemetry and instruments. Previous studies have estimated and analyzed the magnitudes of above error sources in various measurements, but have not quantitatively investigated their actual effects on the retrieval algorithm with respect to altitudes focusing on the optical properties which is the largest error sources. This paper presents quantitative estimates of possible error sources in obtaining ozone density profile from the rocket sounding, which also could be applied to retrieve the ozone density profile by satellite remote sensing.

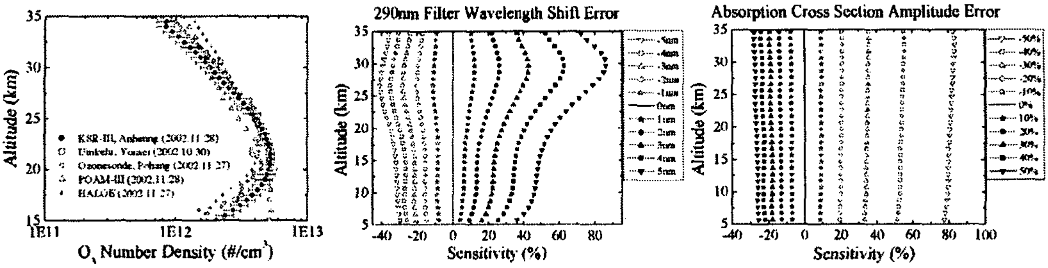
## 2. MEASUREMENT

KSR (Korea Sounding Rocket) series, first launched in June 4, 1993 obtained several sounding data on ozone concentration profiles in the middle atmosphere over the Korean Peninsula (Kim et al. 1997, 2001). Last year in Nov. 28, 2002, KSR-III was launched successfully at the west coast of the Korean Peninsula to obtain vertical profile of ozone density in the stratosphere (Hwang et al. 2004a). Hwang et al. (2004b) described the whole electronics system of the rocket with enhanced scheme. With the four-channel radiometers onboard centered at 255, 290, 310 and 450 nm, direct solar UV radiation were measured with respect to altitudes where visible channels were for the reference of detector with respect to sun during the ascending phase. Detailed retrieval algorithm was described in Kim et al. (1997) and Hwang et al. (2004a). Figure 1a shows the result from the ozone sounding by KSR-III. The figure compares the retrieved density profile with ground-based Dobson spectrophotometer (Umkehr at Yonsei Univ., Seoul), ozonesonde (at KMA Pohang site), and satellite (HALOE onboard the UARS and POAM-III onboard the SPOT-4) measurements. Our results are in reasonable agreement with others in the lower stratosphere altitudes with increasing discrepancies with altitudes above the ozone layer peak, which can be attributed to the attenuation of the signal due to rocket attitude change near the apogee. Although all compared measurements are not carried out at the same location, their values are taken over the Korean Peninsula (near at 36N, 126E) except POAM-III instrument which is passing at 60N, 130E at launch date of KSR-III. Considering the typical spatial variation of ozone number density profiles, they are considered to be reasonable to compare with.

The calibration of interference filter or detector (phototube) may include error sources in characterizing the wavelength and/or measuring the amplitude of the response function with the photomultiplier tube and optical power meters.

There are various random error sources on our measurement due to the calibration, telemetry system and electronics, rocket altitude by radar tracking, and retrieval algorithm parameters. The calibration error is estimated to be less than 1.2%. The radar tracking has 20m errors causing less than 1% error on ozone number density above 15 km. Total errors below 20 km altitude are estimated to be 15%, 7% for the altitude range between 20 and 25 km, and 15% for above 25 km for this flight.

Among the retrieval parameters in the algorithm, errors in characterizing wavelengths to measure interference filter response function and absorption cross section are found to be the most sig-




(a) (b) (c)

Figure 1. (a) Comparison of vertical profiles, (b) Errors in ozone density profile due to wavelength shift in characterizing the filter response function, and (c) Errors in ozone density profile due to different values of absorption cross section errors.

nificant sources for ozone number density profiles. Figure 1b shows the profile sensitivity due to errors on wavelength shifts for 290nm filter response function from -5nm to +5nm range with 1nm step. This error is feasible with the monochromator when it is not maintained to calibrate its absolute wavelengths regularly. Figure 1c shows the case with errors in magnitude of absorption cross section from –50% to +50% with 10% steps. This large magnitude of errors in absorption cross section is not realistic, but this is to see how large errors are required in the cross section in order to have comparable magnitudes with wavelength shift errors. The +5 nm shift in filter response function contributes to $\sim$ 80% increase of the profile at near 30 km, but in case of +50% errors in absorption cross section, the profile is reduced by about –30%. These can be explained with the absorption characteristics of ozone at the altitudes considered in the stratosphere. It is found that the profile is more sensitive by positive wavelength shifts than negative of filter response function, but in case of errors on absorption cross section amplitude, the profile is more sensitive by the negative errors. Note that the ozone absorption cross section peaks near 255 nm and is decreasing with wavelengths for wavelengths greater than 255 nm.

## 3. CONCLUSION

In this paper, the development, the calibration, and the flight tests of a radiometer applicable with the sounding rocket KSR-III were presented with detail descriptions of the calibration, the data retrieval algorithm and the error analysis. The radiometer consists of a quartz lens, interference filters, phototubes, and electronic circuits. Four-channel radiometers were onboard KSR-III: 255, 290, and 310 nm channels for UV measurements and 450nm visible channels for the correction of the rocket attitude change. The calibration system mainly consisted of a monochromator, light sources, detectors, an OPM, a control PC, and data acquisition software. With the calibration of each interference filter, the light intensity response function for each filter was successfully obtained and the center wavelength shift was confirmed to have a tendency to move toward shorter wavelength as the angle of incidence increased. The angular response of the integrated radiometer was also measured. The flight test of the radiometer onboard the KSR-III was carried out on Nov. 28, 2002, to measure the UV intensity and to transmit the data to the ground station in real time during the flight. The data reduction algorithm provided the ozone number density which was calculated numerically by using the calibration results and the measured flight data. Our result, in general, shows reasonable agreement with other measurements in the lower stratosphere.

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