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MEASUREMENTS OF STRATOSPHERIC OZONE BY ROCKET OZONESONDES IN JAPAN

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ABSTRACT

A small optical ozone instrument has been developed for a rocket-borne dropsonde to measure the altitude profile of stratospheric ozone. It consists of a four-color filter photometer that measures the attenuation of sunlight as a function of altitude at four wavelengths in the middle ultraviolet. The ozone dropsonde is launched aboard a meteorological rocket MT-135, providing the altitude profiles of ozone as well as atmospheric temperature and wind. The rocket launchings have been carried out five times since August 1990 at Uchinoura (31° N, 131° E), Japan, to measure ozone concentration from 52 to 20 km altitudes during the slow fall of the dropsonde. The ozone profiles measured in summer (Aug. 27, 1990; Sep. 11 and 12, 1991) were very stable above an altitude of 28km. where as those measured in winter (Feb. 9 and 11, 1991) showed considerable day-to-day variations at the stratospheric altitudes. Ozone, temperature and wind profiles measured simultaneously by both rocket and balloon ozonsondes are compared with CIRA 1986 model atmosphere.

1. INTRODUCTION

A sounding rocket is useful for the direct measurement of vertical structures in the middle and upper stratosphere. A rocket-borne ozonesonde has been used for validating satellite measurements to detect long-term change in stratospheric ozone on a global scale. It is important to monitor ozone concentration in the upper stratosphere around 35-45km where long-term chemical perturbations occur most significantly. An optical ozonesonde is most suitable to measure ozone concentration accurately at those altitudes.

We developed an optical ozone dropsonde in 1987, and modified a MT-135 rocket to accomodate the dropsonde in 1989. Since the first successful measurement was made on Aug. 27, 1990 from Uchinoura (31°N, 131°E), so far we obtained five altitude profiles of ozone, atmospheric temperature and horizontal wind in the stratosphere.

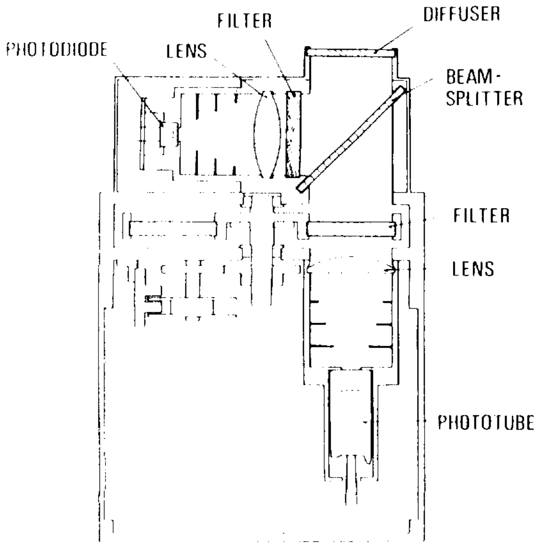

Fig.1 Optical configuration of the radiometer for the rocket borne drop ozonesonde.

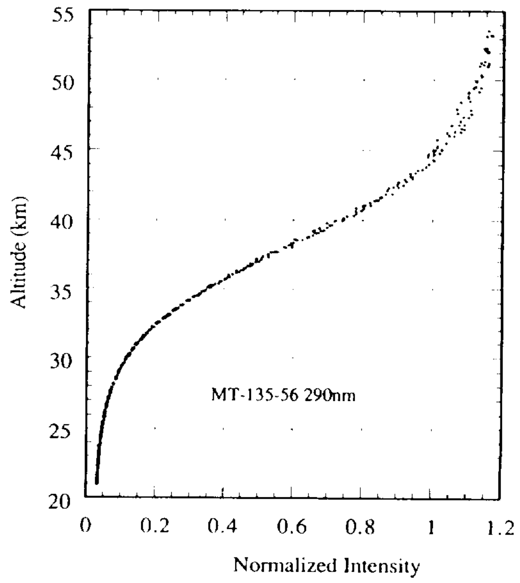

Fig.2 Altitude profile of the intensity measured by a 290nm radiometer aboard MT-135-56 flight.

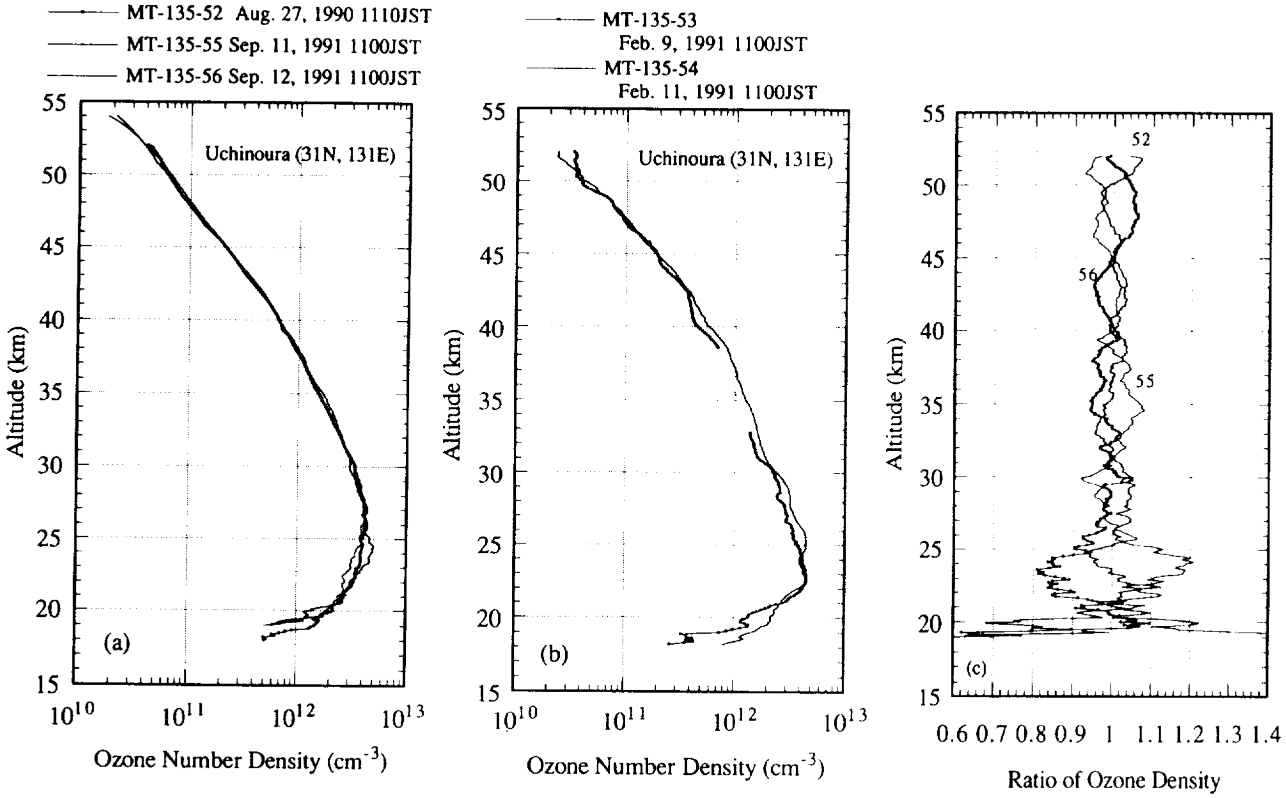

Fig.3 (a) Ozone number densities measured on August 27, 1990, September 11, and 12, 1991, respectively, at Uchinoura (31°N, 131°E). (b) Same as (a) for data on Februay 9 and 11, 1991at Uchinoura. (c) Ratios of the three August-September profiles to their mean profile.

2. INSTRUMENTAL

The ozone sensor is based on the solar middle ultraviolet absorption technique and its optics is quite similar to that of ROCOZ and ROCOZ-A (Krueger and McBride, 1968; Barnes and Simeth, 1986). It is a multi-color filter photometer (Fig.1) to measure the attenuation of the solar ultraviolet (UV) at the central wavelengths of 265, 290, 300, and 310 nm, with a pass band (full width at a half maximum) of 15-20 nm. The photometer receives the solar UV with a UV glass diffuser plate installed at the top of the instrument container. The effective aperture of the diffuser is 3 cm diameter. The light transmitted through the diffuser plate is then passes through a beam splitter, filter wheel, and a lens used to limit the convergence angle of the rays accepted by the phototube with SbCs photocathode. Four pieces of filter plates are mounted on a disk that rotates at a rate of about 3 Hz. Owing to the diffuser plate we do not need any pointing device for the sun, but the diffuser radiance depends on the incident angle of the solar UV onto the diffuser plate. The light from the diffuser plate is monitored at 420nm wavelength through the reflection by the beam splitter. We use an interference filter of 12 nm passband width and a Si photodiode detector for this monitor. Rationing the measured UV intensity to the reference 420nm intensity eliminates the modulation due to the change in solar incident angle. Fig. 2 shows the solar uv absorption measured as a function of altitude by the 290nm band, which is corrected for the attitude modulation of the instrument.

The dropsonde consists of the photometer, a temperature sensor, and a radar transponder / telemeter along with a parachute, and is placed in a airtight container that is installed in the payload section of the rocket. The payload is separated and ejected from the rocket at 95 sec after the launch. The dropsonde is ejected out of the container which is opened at 112 sec after the launch. The temperature sensor is deployed from the dropsonde at 117 sec after the launch. The single staged rocket reaches its appex of 56 - 60 km at about 110 sec after launch. The 6.8kg payload is hung from a parashute of 3.5m diameter and descends slowly through the stratosphere and troposphere. The temperature sensor is a wire of Fe-Ni alloy with a diameter of 20 μ m and approximate length of 18 cm. The atmospheric temperature is obtained by measuring the electrical resistence of the metal wire, as it depends on the temperature of the ambient atmosphere. The data from the photometer and the temperature sensor are converted in 40 bits digital form with a 10-bit A/D converter, and transmitted to the ground every 4 msec using a 1687MHz PCM transmitter. So the data rate is 10 k bits/sec. The transmitter also works as a radar transponder and the positioning of the dropsonde is possible by tracking it with the ground-based radar. Positioning accuracy of the radar tracking system is about 50 m. The positioning data are also used to deduce horizontal wind.

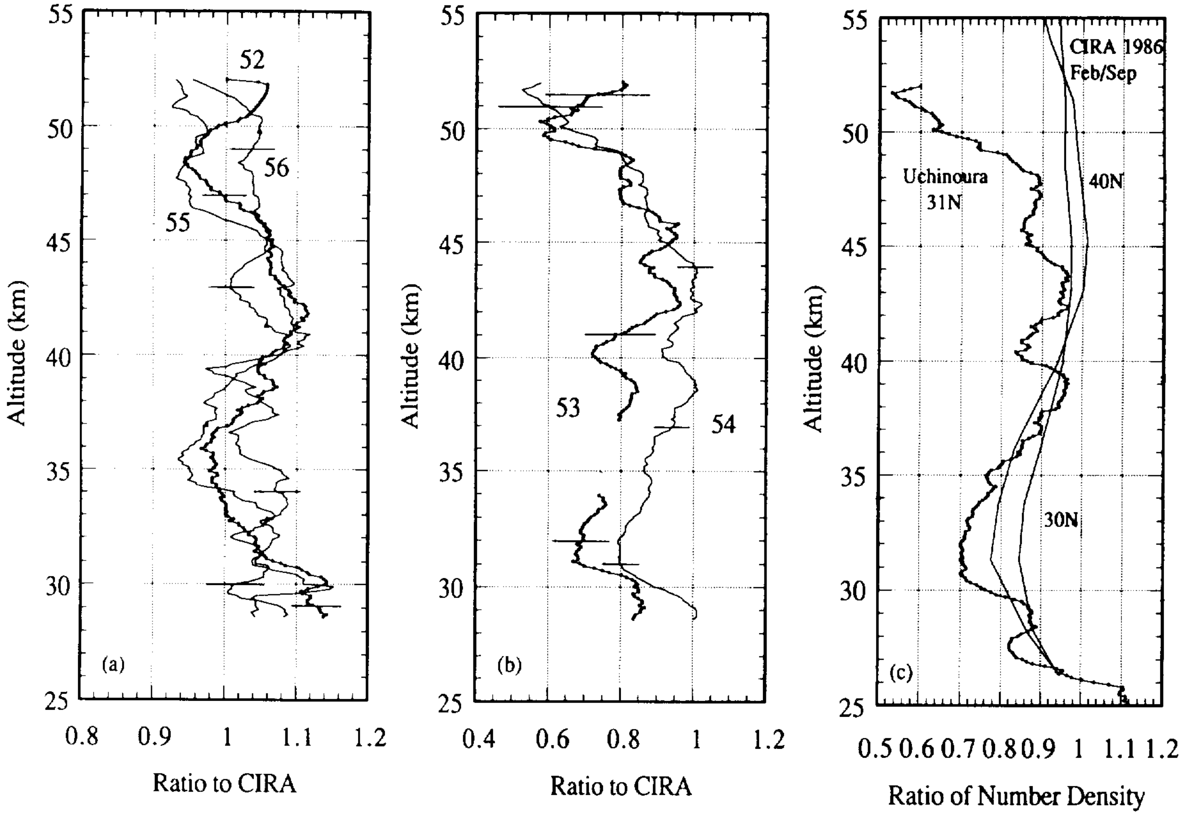

Fig.4 (a) Ozone number densities measured on August 27, 1990, September 11, and 12, 1991, respectively, at Uchinoura (31° N, 131° E). The values are normalized by CIRA 1986 average ozone model atmosphere for September at 30N. (b) Same as (a) for data on Februay 9 and 11, 1991at Uchinoura and CIRA average ozone for February at 30N. (c) Ratio of the mean February profile to the mean September profile. Thin curves show ozone number denstity ratios of February to September CIRA average ozone for 30N and 40N, respectively.

The data received on the ground are processed using a personal computer. The UV intensity data used for the data analysis are only those for limited phase of the filter rotation, as the filter wheel rotates continously. The effective data sampling rate becomes about 0.3 sec with respect to an individual filter. This sampling rate corresponds to an altitude width of about 40 m at an altitude of 55km and less than 15 m below 40 km. The modulation of the UV intensity data due to aerodynamic disturbances during the descend is eliminated in the data processing by taking the ratio of the UV intensity to the 420 nm intensity. In the retrieval procedure, we subtracted small component of the solar UV extinction due to the Rayleigh scattering.

The measured attenuation of solar UV due to ozone is converted to ozone column density along the solar ray path as a function of altitude using effective ozone absorption cross section for the wavelength range of filter pass band. We use the solar flux of Mentall et al. (1981) and the absorption cross sections of ozone measured by Bass and Paur (1985). A quadratic spline function is fitted to the derived column density against altitude with every 1 km bin, and the number density is derived as a derivative of this function. We got four ozone number density profiles retrieved from the attenuation curves measured at four wavelength bands for a rocket flight. Evaluating the retrieval sensitivity in the altitude range for the four wavelength bands, a synthesized ozone number density profile is obtained by taking with a weighted mean of the four ozone profiles. The retrieval error in the derived ozone density is estimated to be about 3-10% at altitudes between 25 and 50km.

3. RESULT AND DISCUSSION

Figures 3 (a) and (b) illustrate the altitude profiles of ozone concentrations observed by five MT-135 rocket flights. Also the observed number density values are normalized by that of the CIRA 1986 model atmosphere and shown in Fig.4 (a) and (b). Three summer profiles exhibit less variable ozone concentrations in the upper stratosphere than the February profiles. Indeed, as seen in Fig.3 (c), the variance of ozone density of the summer profiles is only 3% above 25km, and this is close to or less than the estimated measurement error. This may indicate the possibility to detect the long term ozone trend in the upper stratosphere by the dropsonde observations

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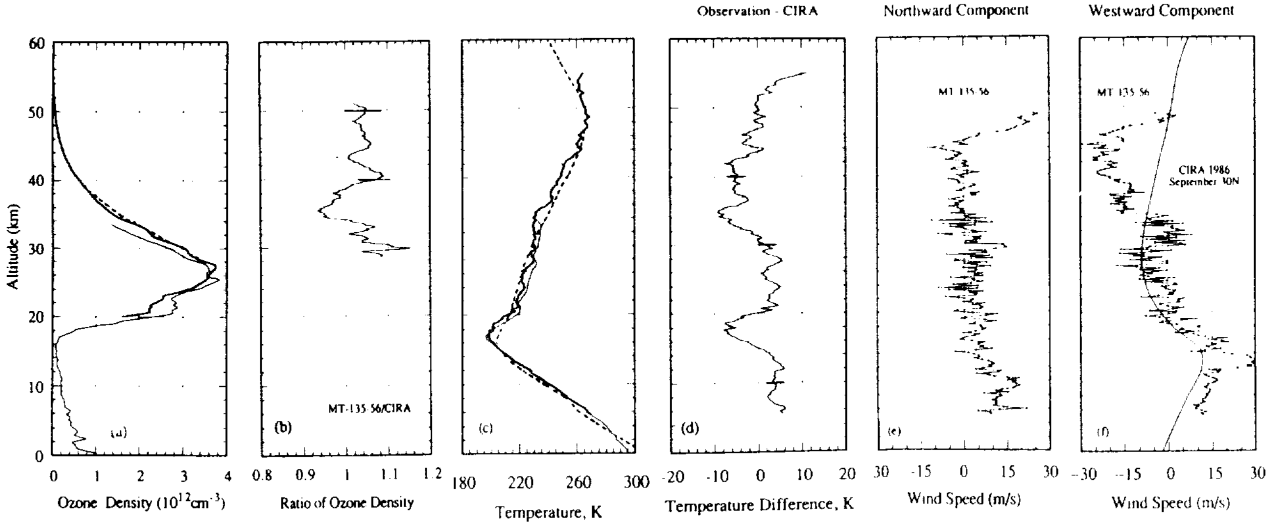

Fig.5 (a) Altitude profiles of ozone concentration measured by MT-135-56 on September 12, 1991 at 1100JST (closed circle), balloon ozonesonde (thin curve), CIRA 1986 model atmosphere September at 30N (broken curve). (b) Ratio of ozone concentration obtained by the rocket ozonesonde to CIRA. (c) Atmospheric temperature measured at flight MT-135-56 (thick curve), balloon ozonesonde at Uchinoura (thin curve), and CIRA 1986 September 30N(broken curve). (d) Deviations of temperature measured by the rocket from CIRA. (e) Northward wind component measured by the rocket. (f) Eastward wind component measured by the rocket (closed circle). CIRA 1986 zonal mean wind of September at 30N is shown by thin line.

extending in summertime for several years. On the contrary, two February ozone profiles show considerable day-to-day variations. Also ozone concentrations are smaller than CIRA in most of the stratospheric altitudes. They are partly due to the planetary wave activities, as intense westerly winds were observed from the radar data of the both flights. And they are partly due to the seasonal variation apppeared in CIRA model shown in Fig 4 (c), which would be explained by chemistry.

Balloon ozonesondes were also flown from the rocket launching site on the same day of the rocket flight to obtain ozone and temperature profiles in the altitude range of 0 - 30 km. Fig. 4 (a) - (d) show the ozone and temperature profiles measured by both rocket and balloon ozonesondes together with CIRA. Ozone profiles by both rocket and balloon ozonesonde observations agree well between 22 and 27 km. Measured ozone by the rocket agrees with that of CIRA within ± 10% in the altitudes of 28 - 52 km. Both rocket and balloon temperature measurements agree well. They show similar structures in the stratosphere. The temperature deviation from CIRA is the magnitude of about ± 10K. The atmospheric wind components are shown in Fig. 4 (e) and (f). Although CIRA model atmosphere provides only the zonal wind components, measured westward component generally agrees with the model. The observed easterly winds in the middle and upper stratosphere prevent planetary waves propagating upward from lower atmosphere. This would support the stable ozone profile in the upper stratosphere in September over Uchinoura.

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