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Estimation of DIAL algorithms for stratospheric ozone

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1. Introduction

Lidars utilizing developments in the laser technology are now applied to measure ozone, improving accuracy and measuring range (McDermid et al., 1990; Steinbrecht et al., 1989; McGee et al. 1991; Nakane et al. 1993). Due to these advantages, lidar systems were recommended as primary instruments in the NDSC (Network for the Detection of Stratospheric Changes, 1990) project. Thus with this reason, the number of lidar stations is increasing worldwide.

Our mobile lidar, the MRI Mark II, employs three wavelengths, 308nm, 355nm and 532nm and has been developed for the simultaneous observation of stratospheric ozone, temperature and aerosols (Uchino and Tabata, 1990). It has operated since 1988 (Fig. 1).

However recently, a problem has been encountered in comparing results. Namely, the systematic error caused by smoothing which depends on the retrieval algorithm applied. Focusing on the retrieval method, namely DIAL, we tried to estimate the errors including in algorithms. Upon estimating the error, we defined a common range resolution because each algorithm has its own smoothing parameters and range resolution. We discuss these findings.

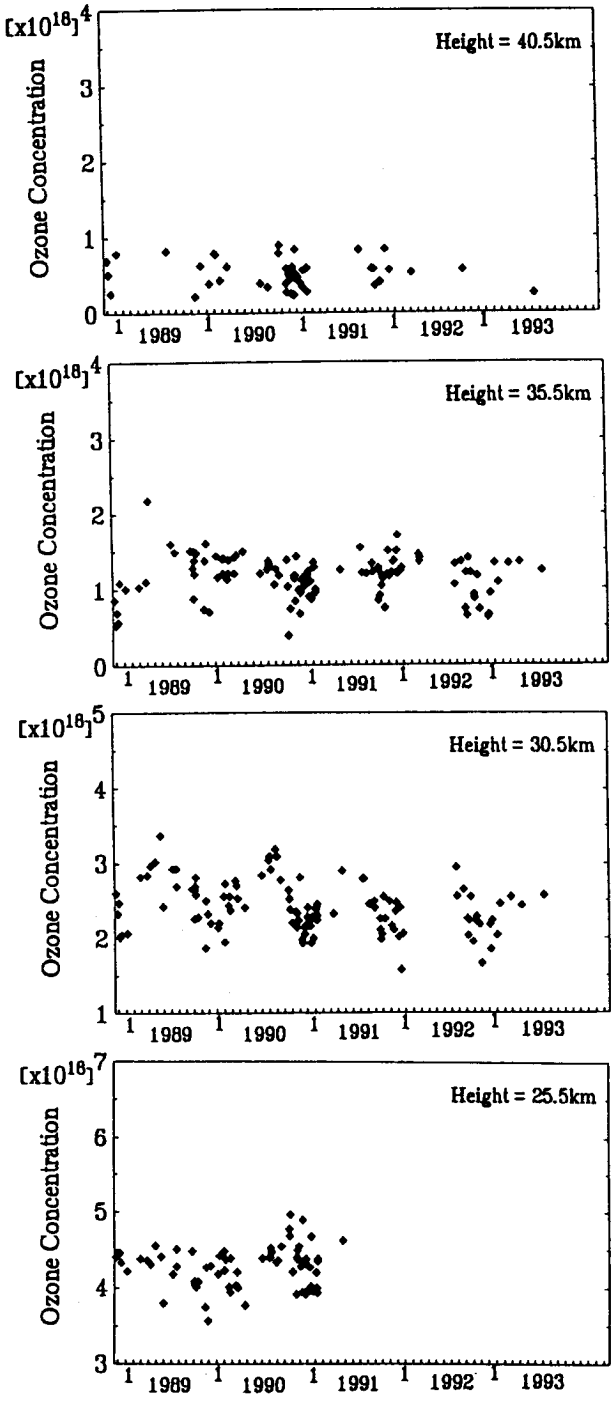

Fig.1 Variation of ozone concentration at Tsukuba (36°N, 140°E).

2. DIAL algorithms

The DIAL is one of the methods that retrieves ozone concentration by means of using lidar system. The DIAL uses at least two different laser lines. For example, the MRI lidar system uses 308nm and 355nm. The backscattered photon number decreases in inverse proportion to the square of altitude. Then the signals from higher altitude are weaker and the signal to noise ratio is smaller. To make signal to noise ratio larger, we usually adopt the method of smoothing. The smoothing procedure makes the statistical error small, but it makes some distortion as a result.

There are several ozone retrieval algorithms based on the DIAL method. Each method has its own smoothing. In this paper, some representative algorithms are dealt with.

These algorithms remarked are defined as follows:

A) difference method type
(Uchino and Tabata, 1990)

B) differential type
(Pelon and Megie, 1982)

C1)differential 2nd-polynomial fitting
(McDermid and Gordin, 1988)

C2)differential 3rd-polynomial fitting
(Nakane et al., 1992)

Each algorithm is deduced from the lidar equation and estimated.

3. Results

For a common range resolution, a noise is made as a pile of various wave number sine curves. Loading this noise onto the constant ozone concentration, the return-signals can be calculated under the ideal conditions that the atmospheric density is constant, aerosols and other noises source are excluded. Using these signals, we can re-calculate the ozone concentrations with each algorithm. After this procedure, the calculated

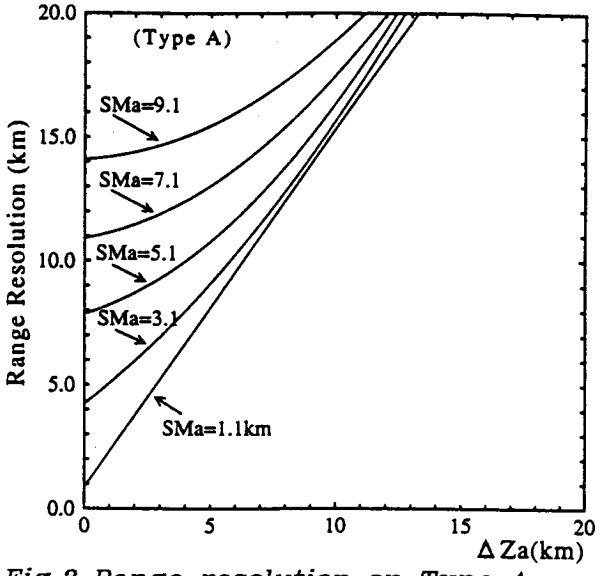

Fig.2 Range resolution on Type A.

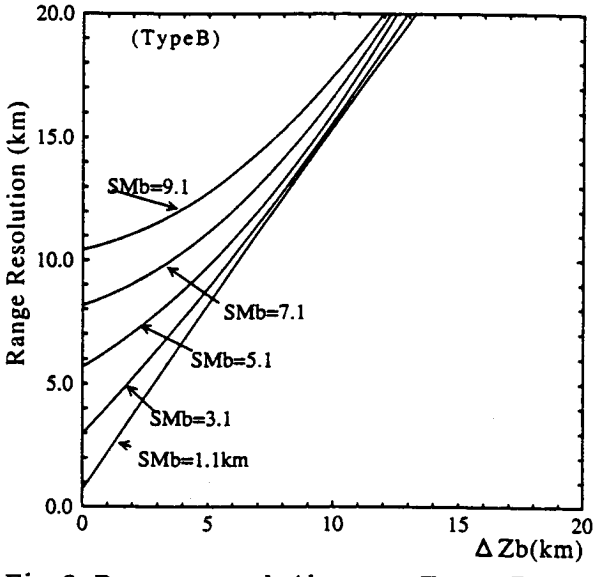

Fig.3 Range resolution on Type B.

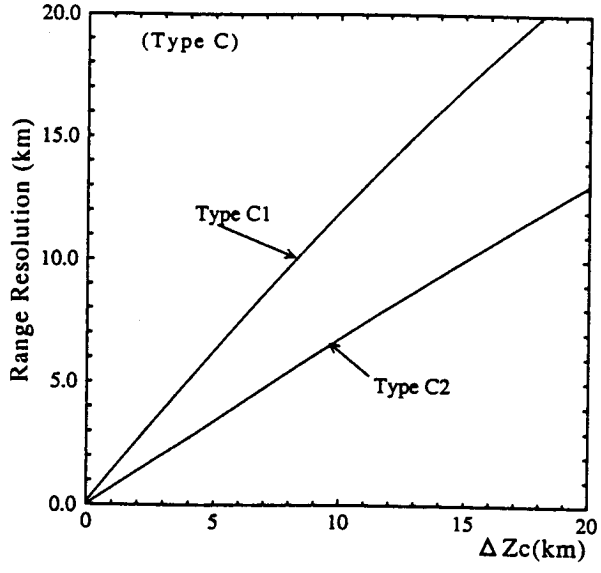

Fig.4 Range resolution on Type C1&C2.

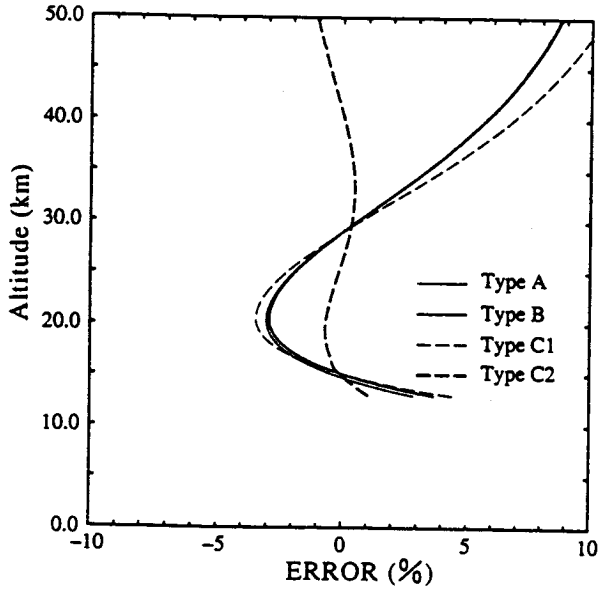

Fig.5 Distortion at the common range solution 10km.

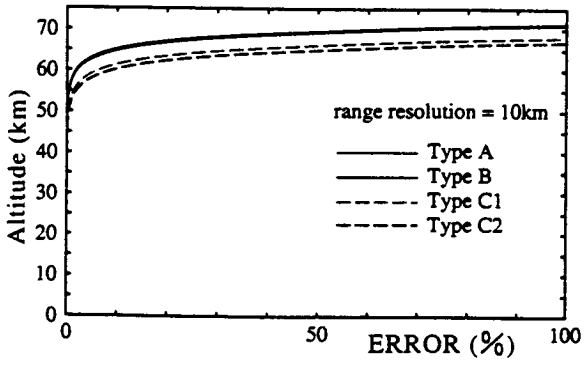

Fig.6 Relative uncertainty at the common range resolution 10km.

noise can be analyzed spectroscopically with a FFT (Fast Fourier Transform) method and the range resolution can be defined as the wavelength which indicates 1/2 of the intensity of the original noise. Figures. 2-4 represent the relationship between the common range resolution and the original range resolutions of the algorithms. The original resolutions are Δz_a, Δz_b and Δz_c in Type A, Type B and Type C respectively. SM_a in Fig. 2 is a width of running mean. SM_b in Fig. 3 is a fitting width.

Taking atmospheric model from U.S. Standard and using the lidar equation, the photon numbers of on-line 308nm and off-line 355nm wavelength pair are calculated. The system coefficient is supposed to be same as MRI Mark II lidar's.

Using these signals, the ozone concentration can be re-calculate on each algorithm. Figure 5 shows the percent differences between the calculated ozone concentration and the reference value in each algorithm, type A, B, C1 and C2. This figure shows the distributions of the error arising from each smoothing method as a function of altitude.

Adopting these signals to the equation of error propagation (Russell et al., 1979), the statistical errors are estimated. Figure 6 is a result in a same common range resolution with each algorithm.

4. Conclusions

In DIAL algorithms of ozone lidar, smoothing procedure is necessary both to take off high frequent noises and to make signal to noise ratio larger. On the contrary, smoothing causes systematic errors, the distortion.

In Type A and Type B, the errors are increasingly biased in higher altitude, above 30 km, and the errors are negative bias around the maximum of ozone concentration, 20-25 km. Though the negative errors are less than 1% at a range resolution 5 km, the error in higher altitude is to be taken into account. Comparing the systematic errors, we found that Type C2 produces the smallest distortion of three representative algorithms. But Type C2 is not so effective in the view point of statistical error. Then we have to consider the quantity of the objects, the objective height, lidar configuration and etcetera before employing DIAL algorithm.

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