ATMOSPHERIC CONTRIBUTIONS TO THE COLUMN VARIANCE IN DIRECT-DETECTION DIAL N87-10289

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One of the most important parameters of a DIAL system is the delay time between the on and off-resonant pulses. It is important that this delay time is sufficiently small to ensure that the atmosphere is effectively "frozen" between the pulses. Therefore, most DIAL systems have been designed with two lasers firing alternately less than 1 msec apart (Schotland 1974). Despite the importance of this parameter in the design of DIAL systems and its contribution to the overall error of a column measurement, very little is known about the size of the error for the case of a direct-detection system using atmospheric backscatter.

The UV DIAL system at NPL uses two independent YAG/dye lasers and is therefore suitable for measuring the effects of different pulse delays on the variance of column measurements for a variety of atmospheric conditions. A set of DIAL returns has been acquired with the two lasers tuned to the same wavelength and with a range of pulse delay times between 250 microseconds and several minutes. This data set was recorded in full on a computer and has been used both to test different averaging techniques and also to evaluate atmospheric contributions to DIAL columns.

1 PULSE AVERAGING

In order to produce good measurements of column content, the return-signals from a DIAL system are generally averaged over many pulse pairs. For a system that acquires on and off-resonant pulses alternately, there are three methods (Warren 1986) for performing this average.

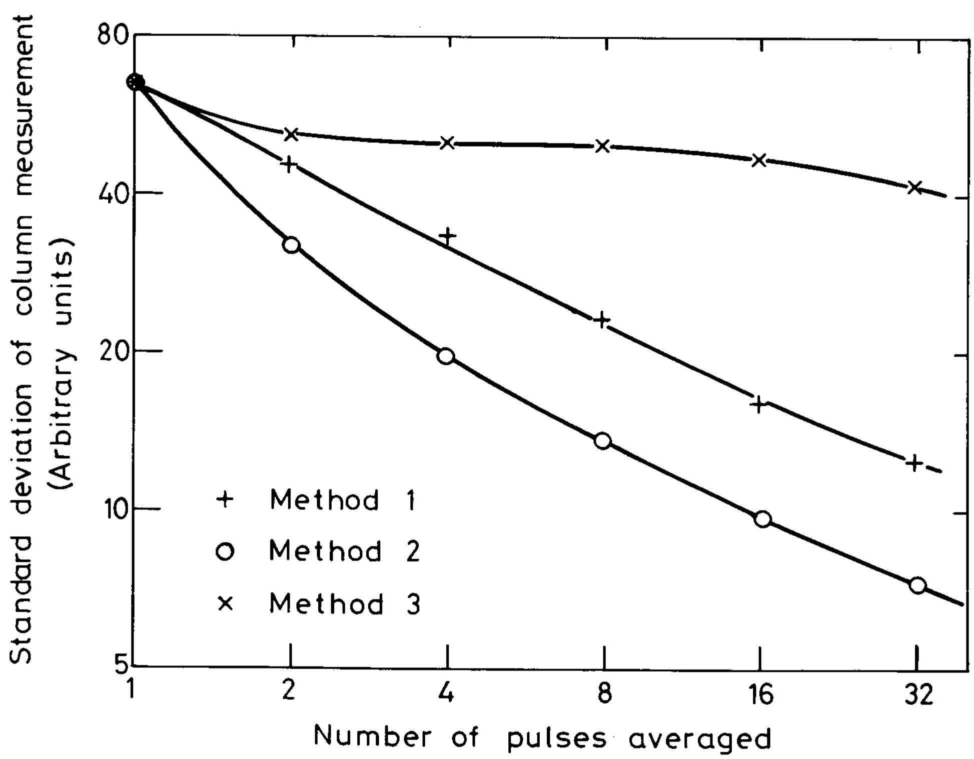
$$CL(r) = \frac{1}{2\Delta\alpha} \frac{1}{N} \sum_{i=1}^{N} \log \frac{P_i^{ON}(r)}{P_i^{OFF}(r)} \qquad (1)$$

$$CL(r) = \frac{1}{2\Delta\alpha} \log \frac{\sum_i P_i^{ON}(r)}{\sum_i P_i^{OFF}(r)} \qquad (2)$$

$$CL(r) = \frac{1}{2\Delta\alpha} \log \frac{1}{N} \sum_{i=1}^{N} \frac{P_i^{ON}(r)}{P_i^{OFF}(r)} \qquad (3)$$

where $P_i^{ON}(r)$ is the power received from a distance r from the on-resonant pulse i , CL(r) is the integrated column content up to the distance r and N is the total number of pulse-pairs averaged.

These three different algorithms have been applied at NPL to the atmospheric backscatter returns produced by a set of 32 pulse pairs. Some typical results are shown below. It can be seen that the standard deviation of the column decreases in proportion to $N^{-1/2}$ for method 1, but not for either method 2 or 3. This kind of behaviour has been observed before (Menyuk 1985), in experiments using a topographic target to provide the return signal.



Pulse averaging for an ensemble of 32 pulses

This technique of calculating standard deviations for various averaging intervals does not produce unambiguous information about the atmospheric contribution to DIAL errors because of the other errors that are involved. Most importantly, the methods used for background subtraction and pulse energy normalisation effect the algorithms in different ways. In addition, the bias introduced (Rye 1978) and the effects of shot noise must also be considered. However, it is a useful pragmatic exercise for selecting an optimum signal averaging method.

2 CROSS CORRELATION

A more direct method for assessing the atmospheric contribution to the column error is by evaluating the cross correlation between two pulses:

$$\rho_{ij}(r) = \frac{\langle (P_i^{ON}(r) - \overline{P_i^{ON}}(r))(P_j^{OFF}(r) - \overline{P_j^{OFF}}(r)) \rangle}{\sqrt{\langle (P_i^{ON}(r) - \overline{P_i^{ON}}(r))^2 \rangle \langle (P_j^{OFF}(r) - \overline{P_j^{OFF}}(r))^2 \rangle}}$$

This kind of method has been used before (Sugimoto 1986) for atmospheric backscatter returns and shows that the atmospheric contributions depend upon the exact measurement set-up (eg horizontal or vertical pointing) and the size of the receiver field of view.

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