Application of First Principle Optimal Estimation Method (OEM) to Retrieve the Stratospheric Ozone Density

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Abstract
The first-principle application of the Optimal Estimation Method (OEM) for lidar retrievals uses the lidar equation as a first-principle forward model, from which geophysical quantities are retrieved. OEM retrievals allow the calculation of averaging kernels, which in addition to giving the vertical resolution of the retrieval, allow comparison between other measurements with different resolutions, an important advantage for comparison with other ground-based instruments and satellite measurements. We are applying OEM to retrieve stratospheric ozone profiles from the CANDAC Stratospheric Ozone Differential Absorption Lidar located in Eureka, Nunavut and will show examples of our new method and its close agreement to the traditional method and coincident ozone soundings.

Ozone – how to detect its changes?
Under the Montreal protocol, the emission and thus abundance of anthropogenic ozone depleting sub-stances (ODSs) in the troposphere and stratosphere have been decreased. To monitor the ozone recovery in a global scale, both short-term and long-term measurements of ozone are needed. Using the Stratospheric Ozone Differential Absorption Lidar (DIAL), located in Eureka, ozone measurements have been carried out for over two decades.

Lidar and its application in ozone density retrievals
Lidar (Light Detection And Ranging) is a ground-based active remote sensing instrument which is similar to radar but operates in the optical range. Measurements of the ozone vertical distribution are carried by Differential Absorption Laser technique Lidar (DIAL). Figure 1 is the schematic Diagram of a DIAL. In this technique two laser beams at different wavelengths are simultaneously transmitted to the atmosphere. Typically, the back scattered signals are collected and the derivation of the ratio between the two signals are converted to the ozone density profiles.

The Optimal Estimation Method (OEM): new approach to ozone retrievals

Retrieval & Model Parameters \( \{k_b\} \)

measurement = Forward Model + detector noise

\[ y = F(x, b) + \epsilon \]

\[ \text{minimize: } \quad \text{cost} = |y - F(x, b)|^2 S^{-1} |y - F(x, b)| + (k - x_0)^T S^{-1} (k - x_0) \]

Uncertainties: retrieved parameters, model parameters, model smoothing

Retrieved Parameters & Uncertainties

Conclusions
The OEM is successfully implemented, and the stratospheric ozone density is retrieved. Our results are consistent with the sonde profiles and the traditional analysis. A complete uncertainty budget on a profile by profile basis is calculated as well. Our retrieval has been tested for clear sky conditions with moderate aerosol loading. Under a volcanic eruption event, when the concentration of stratospheric aerosol is increased, the ozone profile retrievals can be affected. Using the Eureka DIAL’s two Raman channels, we are improving our retrieval to include the aerosol extinction coefficients along with the ozone and air density profiles. We have validated our method by using the measurements from the Observatoire de Haute-Proneclocated in south-east France. The comparison with this well validated system is within a good agreement with the traditional analysis methods as well.