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 calculations 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 Euareka, 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.

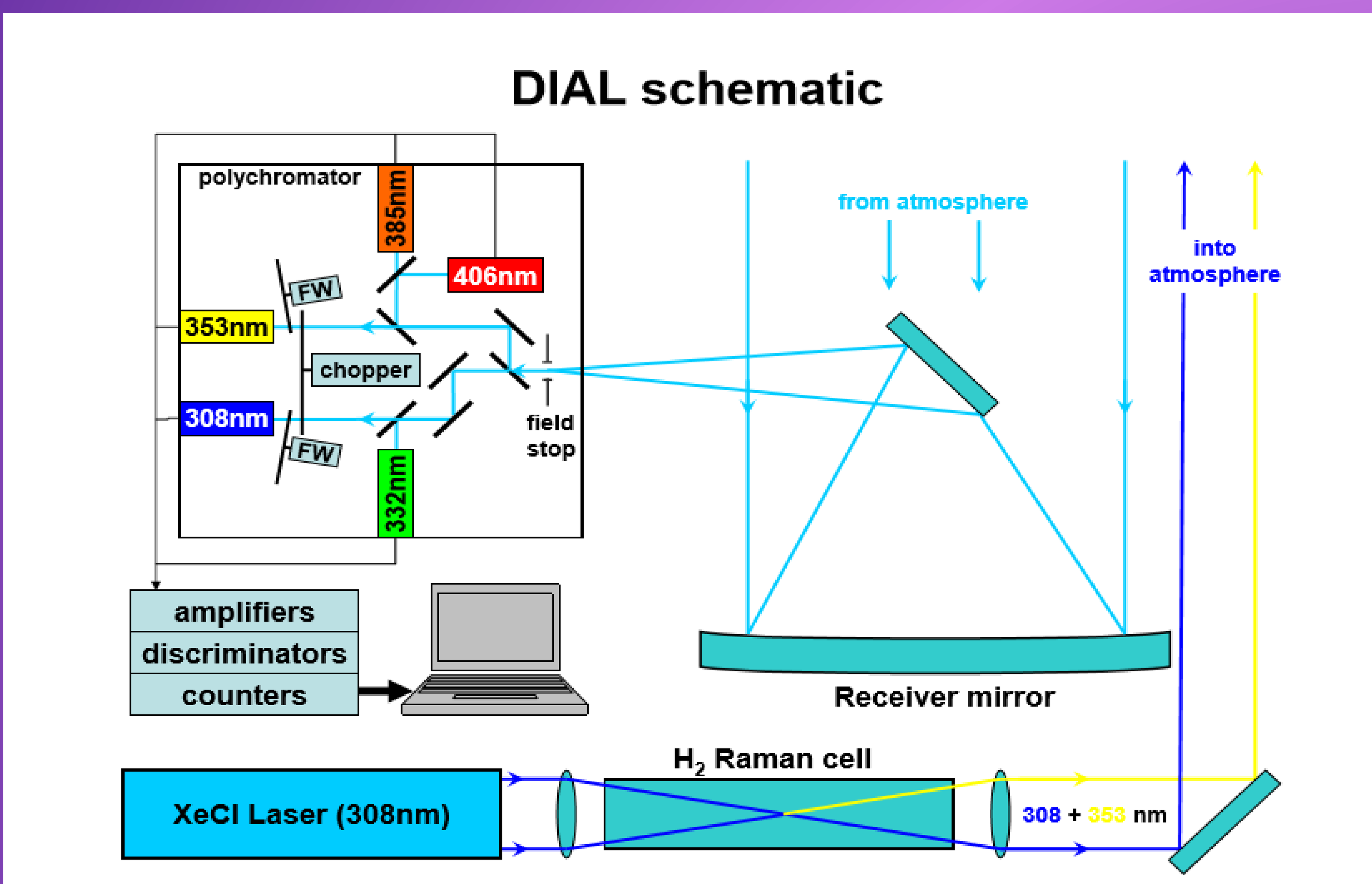
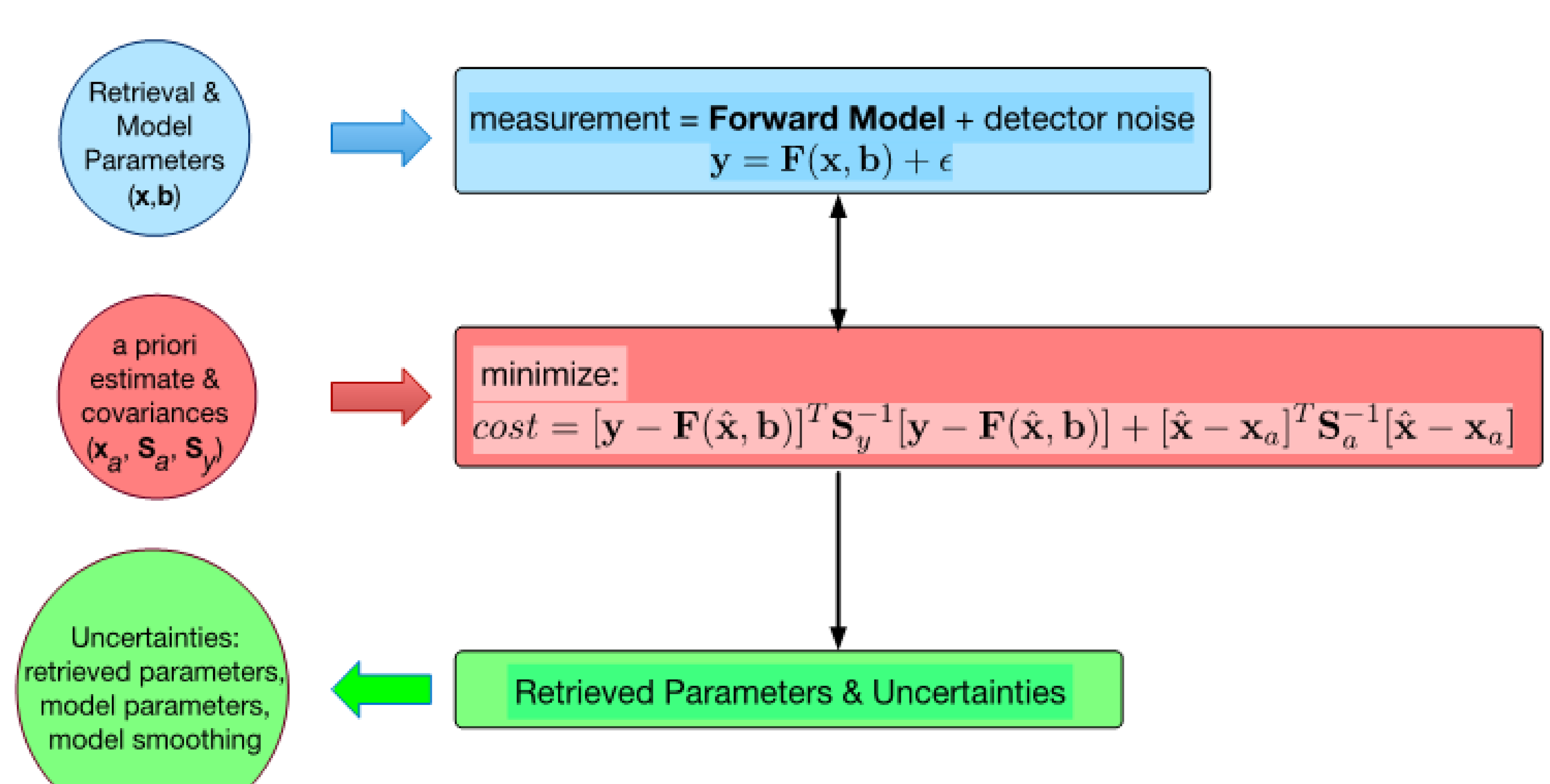


Figure 1. The spectral range for the laser beams is chosen in the UV range where one of the wavelengths is highly absorbed by ozone, and is called the on-line wavelength. The other wavelength has a low absorption by ozone and is called the off-line wavelength. Typically, the derivation of the ratio between the on-line and off-line signals is calculated and the ozone density profile is derived.

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



Rodgers, C. D. (2011), *Inverse Methods for Atmospheric Sounding: Theory and Practice*, World Scientific.

Analysis – Implementing OEM

Our retrievals simultaneously use 3 channels of measurements at 2 wavelengths to determine an ozone profile. In addition to an ozone , an air density profile is retrieved, along with the lidar constant and the background for each channel. A valid retrieval is possible from 7 km to 42 km altitude. The complete uncertainty budget is calculated as well.

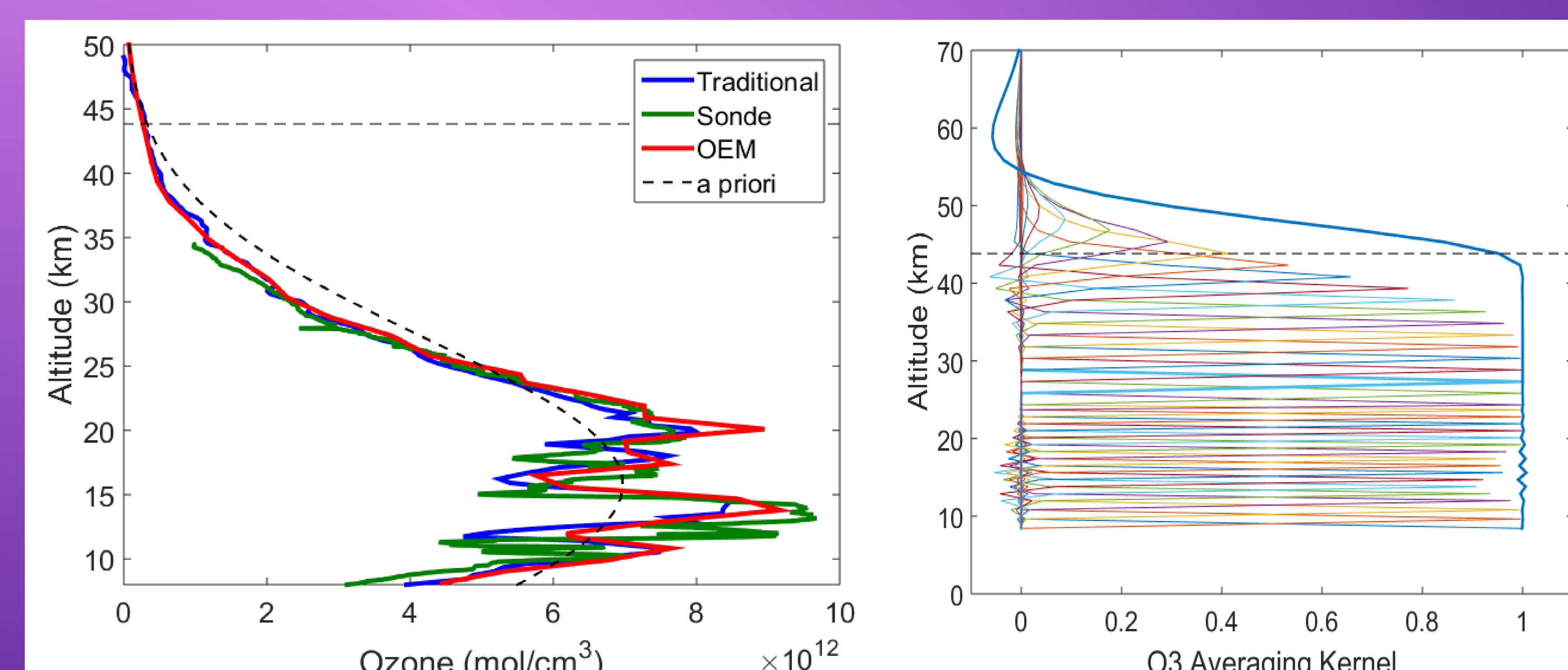


Figure 3. using two hours of measurements on February, 27. 2007 the ozone density profile is retrieved. In the left panel, the OEM result is plotted against the coincidental ozonesonde measurements, and the traditional method analysis. The *a-priori* profile which is our initial guess is plotted as well. In the right panel, the averaging kernel of retrieval is shown. When the summation on the rows for the matrix of averaging kernel (the solid blue line) is around 1 the retrieval is independent of the *a-priori* profile, in higher altitudes this value becomes smaller and the retrieval sets back to the *a-priori* profile. The horizontal dashed line indicates the maximum height of acceptable result for the OEM retrieval.

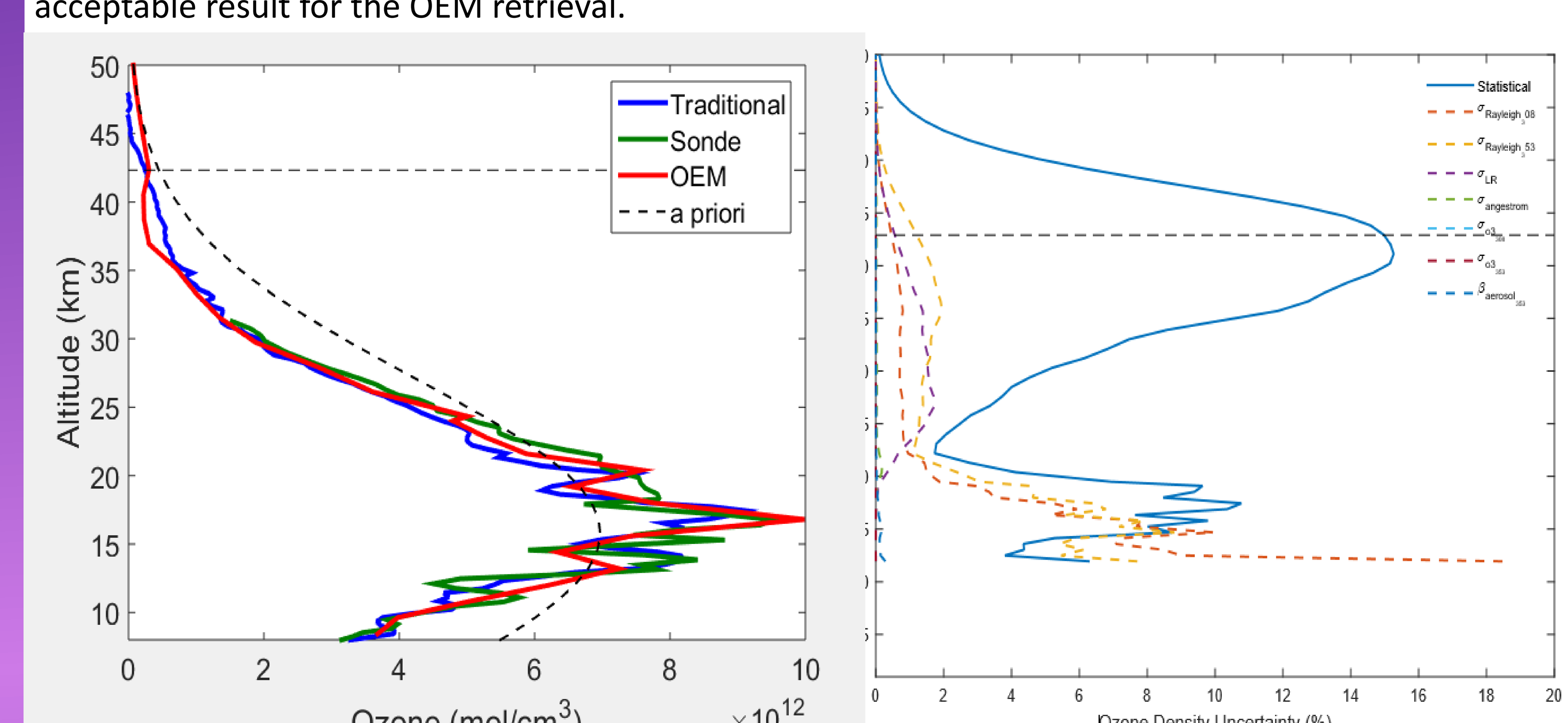


Figure 4. Right panel is another example of retrievals for 3 hours of measurements February, 24. 2004. Left panel is a complete systematic and statistical error analysis of the same night.

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.