Polarization Study

B. J Elash, A. E. Bourassa, L. A. Rieger, Seth?, Dan?, D. A. Degenstein

**Abstract:**

# **1 Introduction**

# **2 Model and Scenarios and Aerosol Sensitivity**

In order to compare the effect of polarization on the sensitivity to model to accurate computer polarized radiance models is required as well as suitable set of aerosol profiles for the retrieval. In this section the SASKTRAN model used for the analysis with be discussed and the aerosol scenarios used for the analysis.

## 2.1 SASKTRAN model

I figured I would ask Dan or Seth to write this portion as they know the details better than I do.

## 2.2 Aerosol Scenarios

The range of plausible aerosol profiles within the atmosphere are vast and cannot be completely covered due to the vast range of particle size distributions and possible consternations which affect their importance in radiative forcing. Furthermore, with the limb scatter technique the geometry of the measurement also can have a large effect on the sensitivity of the measurement to aerosol. To probe a large portion of this space a series of scenarios were derived.

To probe the aerosol space two profile and four particle size distribution were used. The two profiles are a background aerosol extinction profile typically during the volcanically quiet period starting in 1997, and the second profile is a representative volcanic profile after the Nabro eruption in 2012 with a higher sulfur injection from the eruption at approximately 20 km. Both profile can be observed in Figure 1. A log-normal particle size distribution was selected with two fine modes and one coarse mode which can be seen in Table 1. The aerosol profile could either completely consist of only one of the fine mode or a mix of 50% fine mode and 50% coarse mode. The fine modes are representation of two background aerosol particle size distributions and the coarse mode is a representation the effect of a volcanic eruption on the size of the aerosol droplets (Deshler et al, 2003).

To scan the entire geometry a range of Solar Zenith Angles (SZAs) and Solar Scattering Angles (SSA) were selected. The range of SZA are 15 o, 45 o, and 75o and SSA of 30 o, 60 o, 90 o, 120 o, 150 o, and 180o cover the a large portion of the possible geometries for limb scatter. An albedo of 0 and 1 were used to determine how ground reflectance effect aerosol sensitivity on polarization measurements. And the wavelengths chosen were 500, 750, 1000, 1250, 1500 nm to cover the effect of polarized measurements for wavelengths commonly used by instruments to achieve aerosol profiles from limb instruments (i.e. OSIRIS and SCHIAMACHY aerosol products used 750 nm TODO:ADD CITATIONS) and from work done by Rieger er al. (2014) has shown near infrared is needed to discern particle size from limb scatter measurements.

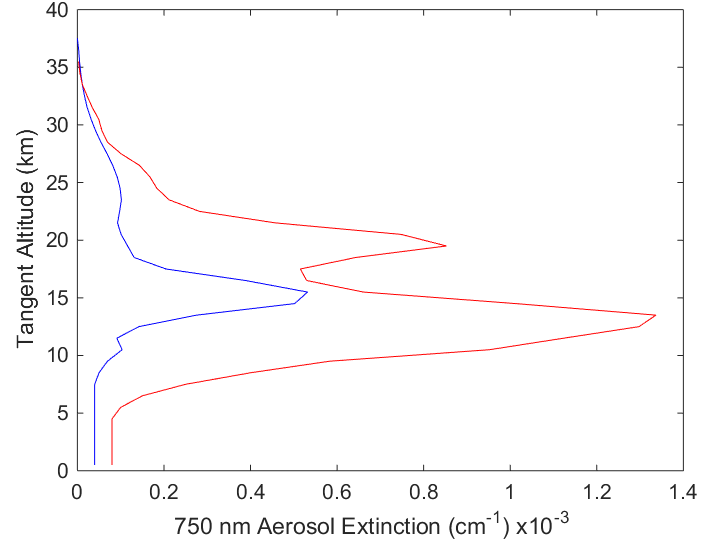


Figure 1: The two aerosol profiles used in this study. The blue is a background aerosol extinction levels, and the red curve is a representative aerosol profile after the Nabro eruption.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Particle size distributions | Fine mode radius (µm) | Fine mode width | Coarse mode radius (µm) | Coarse mode width | Percent extinction coarse mode (%) |
| 1 | 0.04 | 1.8 | -- | -- | 0 |
| 2 | 0.12 | 1.25 | -- | -- | 0 |
| 3 | 0.04 | 1.8 | 0.30 | 1.15 | 50 |
| 4 | 0.12 | 1.25 | 0.30 | 1.15 | 50 |

Table 1: Different particle size distributions used to test the sensitivity of the aerosol retrieval.

## 2.3 Methodology

In order to limit the polarization space of this study a linear polarized instrument will be assumed that either measures the vertical or horizontal linear polarizations. This was chosen since upcoming instruments like ALTIUS (Dekemper et al. 2012) and ALI (Elash et al., 2015) use an acousto-optic tunable filter for a spectral filter which can only measure linear polarizations. So if a linear polarization must be used which is the best option, and how do the polarized measurements compare to the sensitivity of an instrument that measures scaler radiance. The three polarizations used will be define as the following: radiance that aligned with the horizon will be known as the horizontal polarization and radiance that perpendicular the horizon will be known as the vertical polarization. The third polarization used the total radiance which will be known as the scaler radiance. Using the Stokes parameters, the scaler radiance is defined as , the horizontal polarization is given by and the vertical polarization is given by .

The study looks at the problem is three section. How does the percent of the aerosol signal compare to the overall radiance for a variety geometries and aerosol profiles? How does the polarization affect the ability to retrieve aerosol from a simulated measurement using a consistent particle size distribution? And how does the sensitivity effect the error on the retrieved profile? Within this section the methodology for each question will be described.

First, the modeled radiance will be compared for a series of geometries, wavelengths, and altitudes to determine the percent of the radiance that is inherent to aerosol. The model is ran using a polarization mode that accurately models the polarized radiance for the first three orders of scatter, then the scattering are assumed to be completely scaler in nature. The model is ran with a nominal atmosphere that consists of molecular air, ozone, and NO2 which is kept constant, and with a variable altitude and albedo. The sensitivity was determined by calculating the radiance without aerosol in the model, , and the radiance including the aerosol known as the total radiance, , and using the difference between the total radiance and nominal radiance would yield the aerosol radiance look at a percent of the signal that come from aerosol gives the relative sensitivity for aerosol with a particular polarization in the form

From this information it can be determined where the aerosol contributes the large percentage of the signal. On the other hand a look at the loss of radiance will be looked at when using a polarized measurement to a scaler instrument to determine the required increase in exposure time for the polarized measurements.

To determine the effect of polarization on the retrieval a retrieval method will be used similar to aerosol extinction retrieval by Bourassa et al. (2012). A minor change to the algorithm is the measurement vector will not be normalized by a shorter wavelength since work by Rieger et al. (2014) has shown this decreases sensitivity to particle size distributions. For the retrievals a simulated measurement radiance profile will be calculated using the SASKTRAN-HR model with a nominal Ozone, and NO2 profiles for each of the scenarios listed in section 2.2. The simulated measurements will be used to retrieve aerosol profiles using the multiplicative algebra reconstruction technique for all three polarization states. Additionally, a retrieval will be performed with the scaler SASKTRAN-HR model to see if there is a large discrepancy between using the scaler and the polarized model to retrieve aerosol profiles from a scaler measurement. For each aerosol retrieval the Ozone, NO2, and albedo are set the same in the modeled measurement but the aerosol particle size is to be set to 0.08 µm mode radius and 1.6 mode width. The assumption of an incorrect particle size is very common in current limb scatter instruments (i.e. OSIRIS and SCIAMACHY) will be used to see how the different polarizations are sensitivity to particle size distributions and if this incorrect assumption greatly affects the retrieved extinctions.

Lastly, In order to check the precision of the retrieved aerosol profile an error analysis of the revivals will be performed. The method used for this analysis is one presented by Bourassa et al. (2012) in which it is assumed that the Jacobian, , times the Gain matrix, is approximately equal to the identity matrix so

With an assumed covariance on the aerosol retrieval, , the covariance on the aerosol profiles can be found by

Finally the square root of the diagonal of the aerosol covariance is taken as the final error profile.

# 3 Analysis

## 3.1 Aerosol Sensitivity

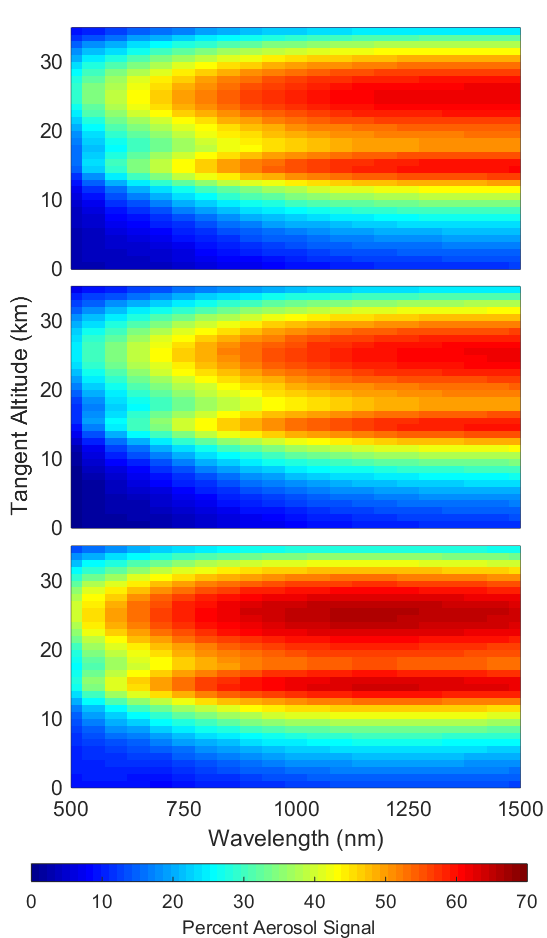


Figure 2: A computation of the percentage of aerosol radiance signal over the total radiance for a series of three polarizations. The top, middle, and bottom figures are the scaler, horizontal polarization, and vertical polarization respectively. The geometry for the simulation is set up with SZA of 45o and SSA of 60o with an Albedo of 0 and using the background aerosol profile.

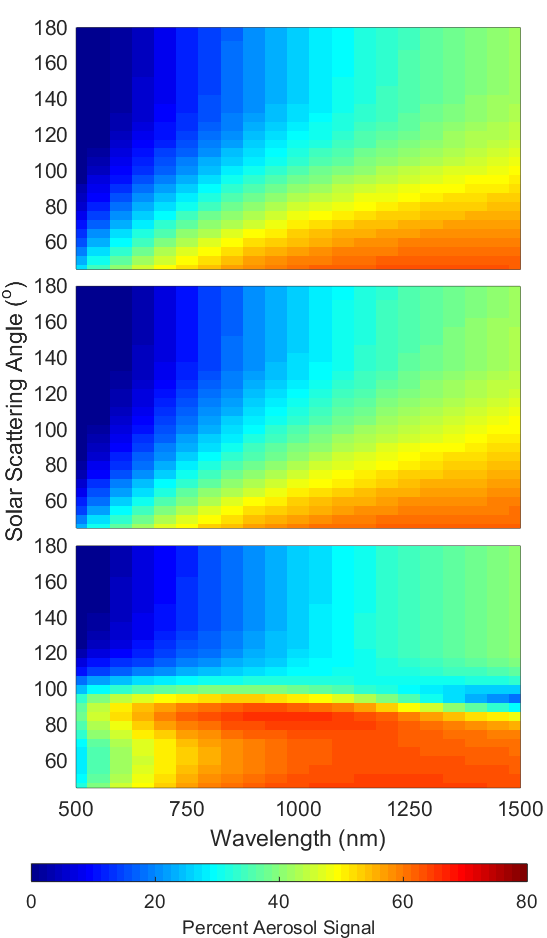


Figure 3: A computation of the percentage of aerosol radiance signal over the total radiance for a series of three polarizations. The top, middle, and bottom figures are the scaler, horizontal polarization, and vertical polarization respectively. The geometry for the simulation is set up with SZA of 60o at a tangent point of 15.5 km with an Albedo of 0 and using the background aerosol profile.

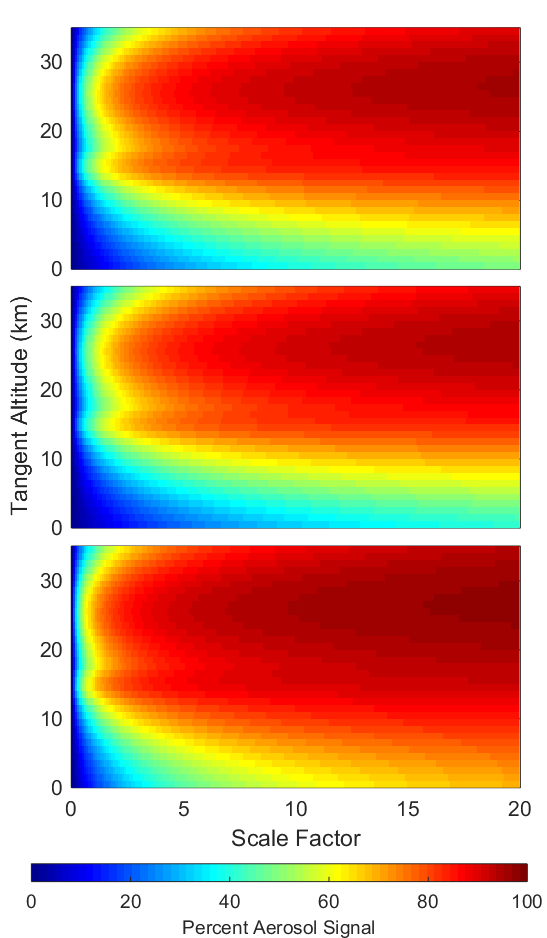


Figure 4: A computation of the percentage of aerosol radiance signal over the total radiance for a series of three polarizations. The top, middle, and bottom figures are the scaler, horizontal polarization, and vertical polarization respectively. The geometry for the simulation is set up with SZA of 60o and SSA of 45o with an Albedo of 0 and using the background aerosol profile.

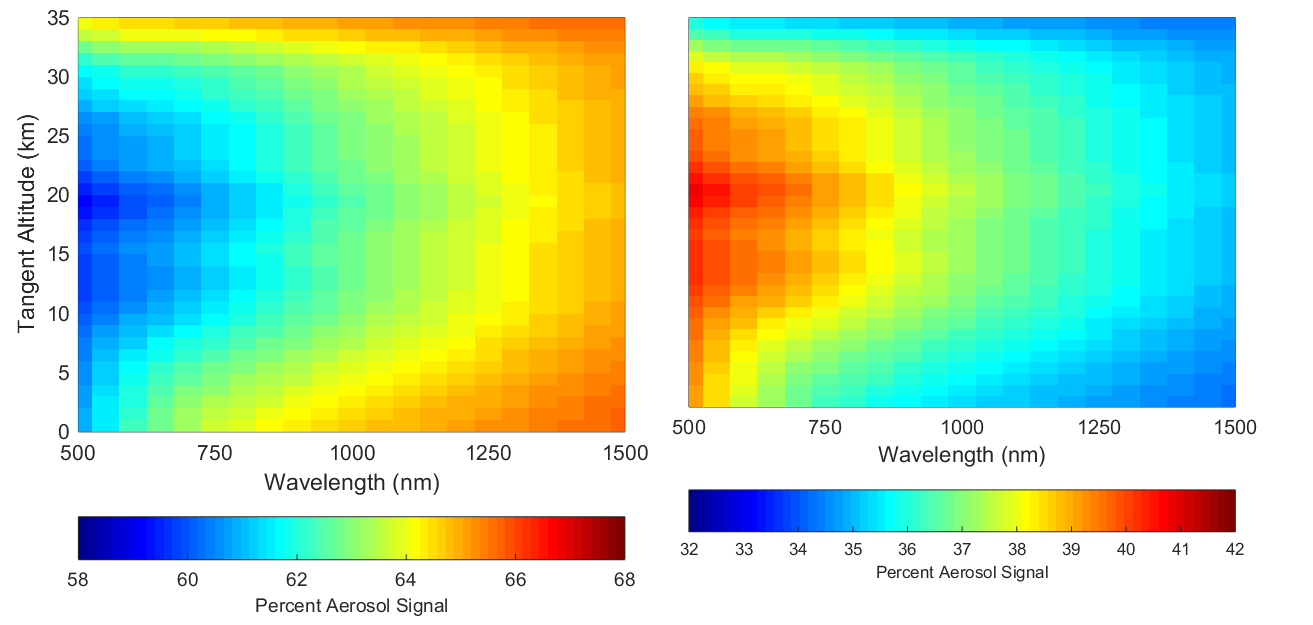


Figure 5: A percent of the linear polarized radiances to the scaler radiance, the left and right figures are the horizontal and vertical polarizations respectively. The radiances were calculated with a geometry of 60o SZA and 45o SSA with an albedo of 0 and using the background aerosol profile. Note that the scale for each plot are different.

## 3.2 Retrievals

TO CREATE FIGURE

Figure 6: The retrieved aerosol profiles for each unique combination of geometry and aerosol profile are compared again the known original sates. The plot are separated into 16 cases. The four columns represent the four polarization used for the analysis and from left to right is the scaler radiance with the scaler SASKTRAN-HR model, the scalar radiance with the polarizations models, the horizontal polarization, and the vertical polarization. The rows represent the four particle size distributions from one to four from top to bottom as listed in Table 1.

## 3.3 Error analysis

TO CREATE FIGURE

Figure 7: Not sure have not been able to complete this yet. Will discuss in Email.

# **4. Conclusions**

# Acknowledgements