1. Introduction

The DOAS-approach uses a least-square-fit of trace gas cross-sections to retrieve differential slant column densities. In addition, a polynomial is fitted to the optical depth accounting for Rayleigh and Mie scattering on molecules and aerosols, broadband absorptions, cloud offsets, spectral surface reflectance and instrumental effects. Here, several radiative-transfer-model-simulations (RTM) were used to evaluate the impact of the different components on the polynomial. Therefore, ideal atmospheres and ground-based MAX-DOAS viewing geometries were simulated using the IUP-Bremen in-house RTM-software package SCIATRAN. Spectral surface reflectance and instrumental effects were neglected. The largest impact on the polynomial can be split up into scattering and cloud effects. Under clear sky conditions, we analyzed the effects of Rayleigh and Mie-scattering. Mainly, we focused on aerosols and their influence on the polynomial, which depends strongly on the aerosol optical thickness and on the wavelength and scattering angle dependency of aerosols.

The objective of this study is to investigate the feasibility of deriving aerosol information (e.g. optical thickness, phase function or Angström-exponent) from the DOAS polynomial.

2. Theoretical background

General DOAS – approach

\[ \tau(\lambda, \theta) = \ln \left( \frac{I(\lambda, \theta)}{I(\lambda, \theta_0)} \right) = \sum c_i \sigma_i(\lambda) + \text{normalization factors} + \text{offsets} \]

Possible information content of the polynomial:
- Rayleigh \( \lambda^4 \) and Mie-Scattering \( \lambda^4 \)
- Broadband absorption
- Cloud offsets
- Instrumental effects
- Surface spectral reflectance

Assumption for normal measurements:
\[ \tau(\lambda, \theta, \delta) = \ln \left( \frac{I(\lambda, \theta, \delta)}{I(\lambda, \theta, \delta_0)} \right) \]

Spectrum measured in an arbitrary direction divided by a spectrum in Zenith:
\[ \tau(a, \lambda) = \sum c_i \sigma_i(\lambda) = \sum c_i \sigma_i(a, \lambda) \]

3. Current Aerosol treatment

Aerosol information is only retrieved indirectly:
- Retrieval with simulated \( Q_a \) and \( Q_r \) clouds, because \( Q_a \) depends only on the \( Q_r \) profile and meteorological conditions.

Simulation need an a priori Aerosol-profile in Step 1!

Every additional Aerosol information would improve the retrieval algorithm

Can we retrieve Aerosol from the DOAS polynomial?

4. Basic idea

DOAS approach with real spectrum and synthetic spectrum within a pure Rayleigh-Atmosphere without trace gases as reference in the same geometry.

For an AOT-retrieval, we need to know the scattering-terms \( n(a) \) and \( \ln(b) \)

5. Rayleigh - scattering term \( \ln(b) \)

Atmosphere with only Rayleigh-scattering divided by a pure Rayleigh-atmosphere with single scattering:
\[ \tau(0, \theta) = \ln \left( \frac{I(\lambda, \theta)}{I(\lambda, 0)} \right) \]

\( n(a) \) depends only on wavelength on the basis of the law of geometrical optics, the aerosol phase function and the constant factor \( c_i \):
\[ \ln(\tau(0, \theta)) = \ln(n(a) \cdot \tau(0, \theta)) \]

with \( \tau(0, \theta) = \frac{3}{4} (1 + \cos(2\pi)) \)

6. Scattering term \( n(a) \):

Atmosphere with Rayleigh- and Mie-scattering divided by a pure Rayleigh-atmosphere with only single scattering:
\[ \tau(a, \lambda) = \ln \left( \frac{I(\lambda, \theta)}{I(\lambda, \theta, 0)} \right) \]

\( n(a) \) depends only on wavelength with dependency of the dominant factor \( \lambda^4 \) and Angström Exponent.
\[ \ln(n(a, \lambda)) = \ln(n(a) \cdot \tau(a, \lambda)) \]

7. Other geometries

The scattering term \( n(a) \) strongly depends on the geometry of the lightpath through the atmosphere.

The aerosol phase function depends on the angle between the incident lightpath and the scattering path of a photon and should be the dominant geometry-factor for the scattering term \( n(a) \).

8. Multiple scattering

It is well known that the Heney-Greenstein-phase function is not accurate enough for more realistic scenarios and leads to an unsuitable fit within multiple scattering atmospheres. This problem can be solved by using more accurate phase functions which might depend on more than one parameter. However, for these phase functions the fit is still not good enough and should be improved.

9. Summary / Outlook

With the above formulation of the DOAS approach (see section 2), one could retrieve Aerosol information by using a synthetic spectrum for a pure Rayleigh atmosphere in the same geometry. This means, that there is a need for a fully calibrated spectroscopic, since instrumental effects do not cancel any more. With knowledge of the Rayleigh-scattering-term \( \ln(b) \) the information in the optical depth contains only aerosol information. Then, it should be in principle possible to derive the asymmetry-factor by consideration of different geometries and to use this additional information to retrieve the AOT.

Nevertheless, several assumptions were made which were complicate the problem (e.g. no instrumental effects, no polarization, deprivations for multiple scattering..) and might lead to an underdetermined system which solution will be a challenging task. Since this study shows only preliminary analyses a lot of work has to be done.

10. Acknowledgement & Selected References

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