Development of a cloud-screening method for MAX-DOAS measurements

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1. Abstract

In recent years, ground-based multi-axis differential absorption optical spectroscopy (MAX-DOAS) has shown to be well suited for the retrieval of tropospheric trace gases and deriving information on the aerosol properties. However, MAX-DOAS measurements are often performed under (partially) cloudy conditions, causing possible data quality degradation, leading to larger uncertainties on the retrievals.

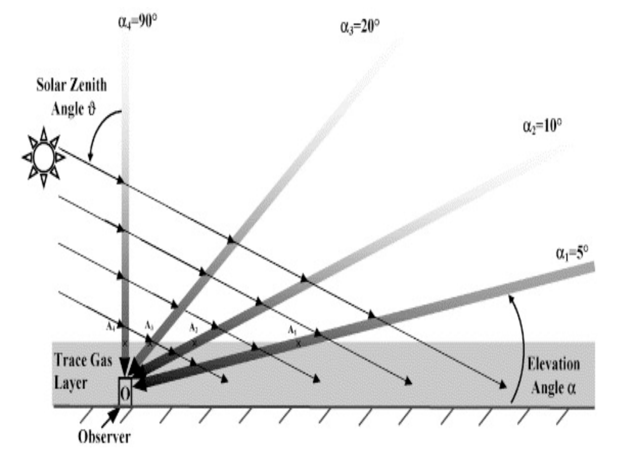
A high aerosol load or cloud cover can introduce a difference in photon absorption due to scattering or multiple scattering. This strongly affects the retrieved differential slant columns (DSCDs) of the trace gases, leading to an under- or overestimation of the atmospheric column density. If the cloud cover consists of broken or scattered clouds, the MAX-DOAS method may become very unstable, since the different elevation angles will probe regions of the sky with strongly deviating properties.

Here we present a method to qualify the sky and cloud conditions, using the colour index derived from MAX-DOAS measurements.

2. MAX-DOAS Measurements

- Xianghe (Beijing suburban area) dataset: Jan-Dec 2011
- ideal dataset since site experiences a broad variety of sky conditions

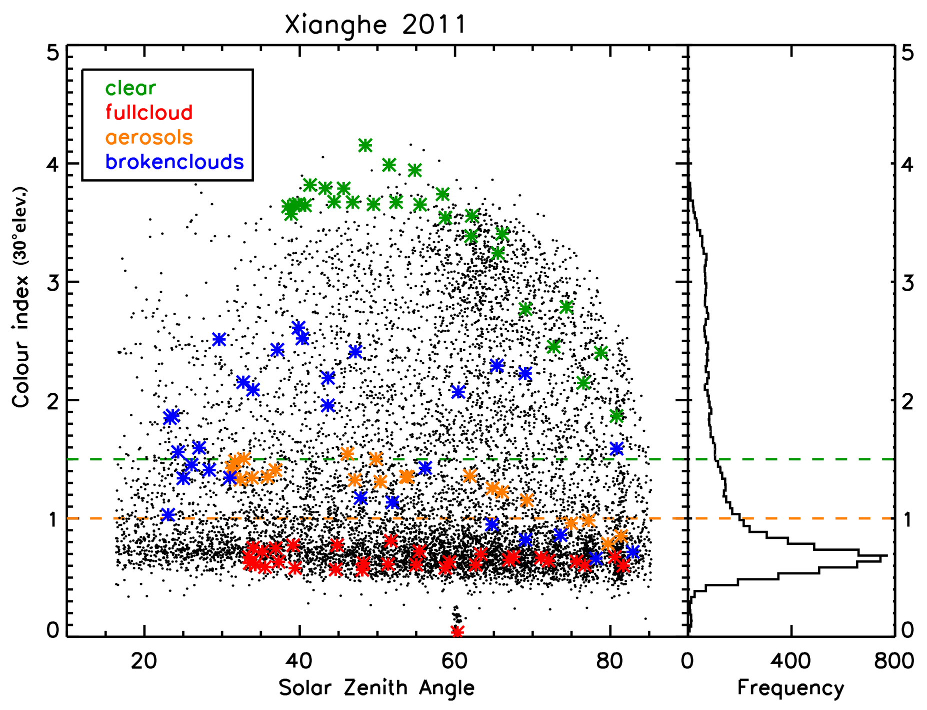
- multiple elevation angles from horizon to zenith
- UV+VIS spectroscopic data
- information on vertical distribution of gases and aerosols

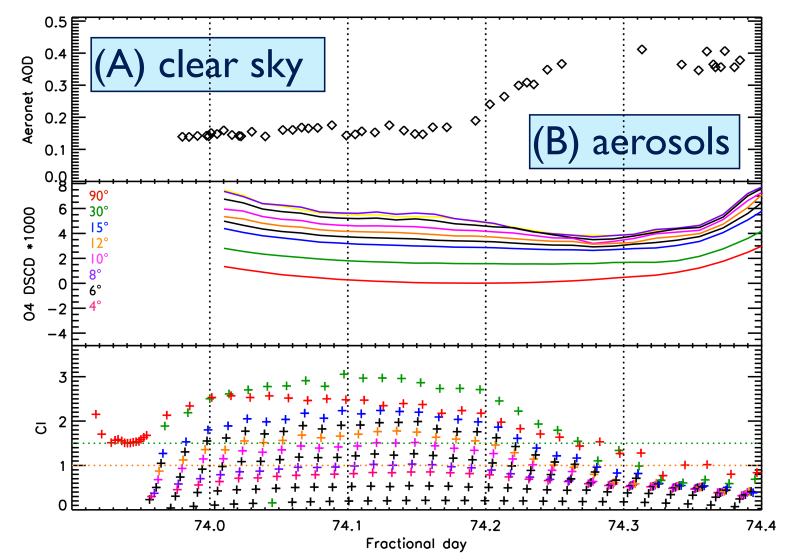


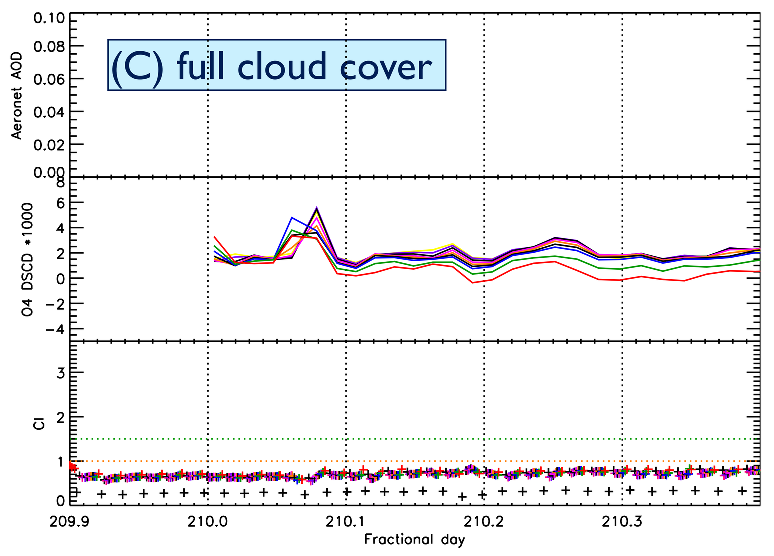
3. The Colour Index

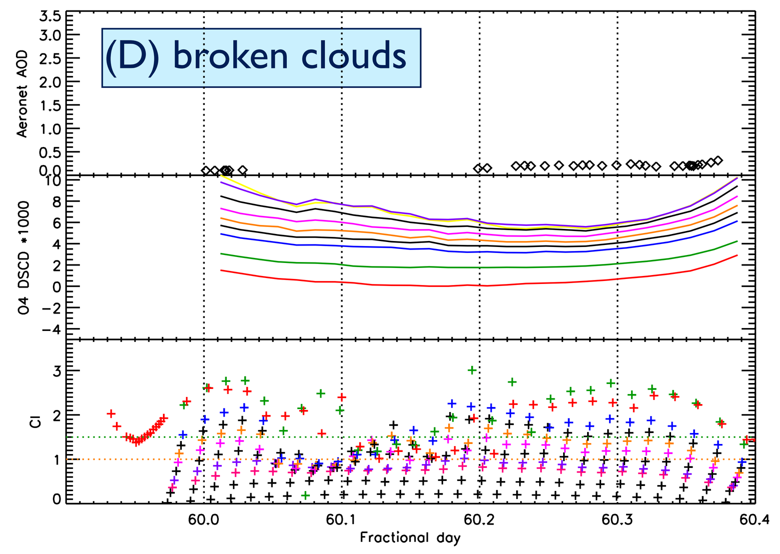
We define the colour index as ratio between the 450 and 670nm intensities:

$$CI = \frac{I_{405\text{nm}}}{I_{670\text{nm}}}$$









CI values dependent on sky conditions and elevation:

(A) clear sky: high CI values (>1.5)
elevation ↘ then CI ↘
(B) aerosols: CI ↘ (CI<1.5)
elevation difference ↘
(C) cloud cover: very low CI (≈0.6)
no elevation difference
(D) broken clouds: CI on average high
but strong temporal variation

4. Quality Control

- day divided in AM and PM part
- 30° elevation data used for modelling
- data fitted with double-sine function

We define two flags to characterize the sky condition:

*** *Colour-index flag:***

→ information on optical depth due to aerosols or cloud cover

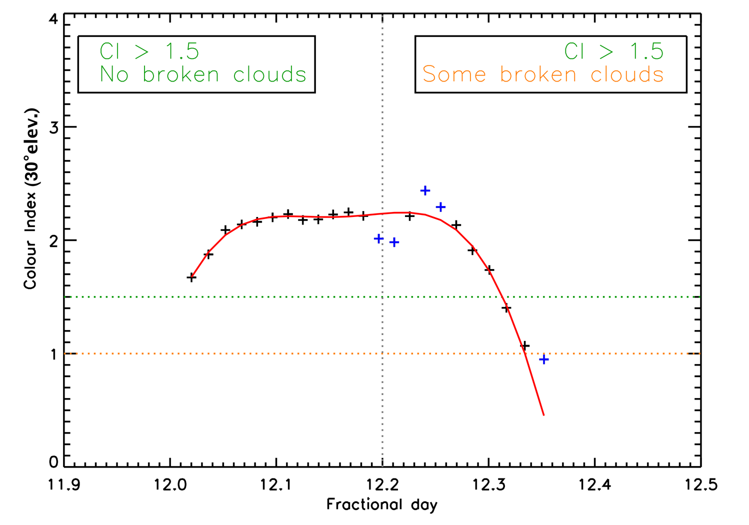
- 70% CI > 1.5 = 'GOOD'
- $1 <$ 70% CI < 1.5 = 'MEDIOCRE'
- 70% CI < 1 = 'BAD'

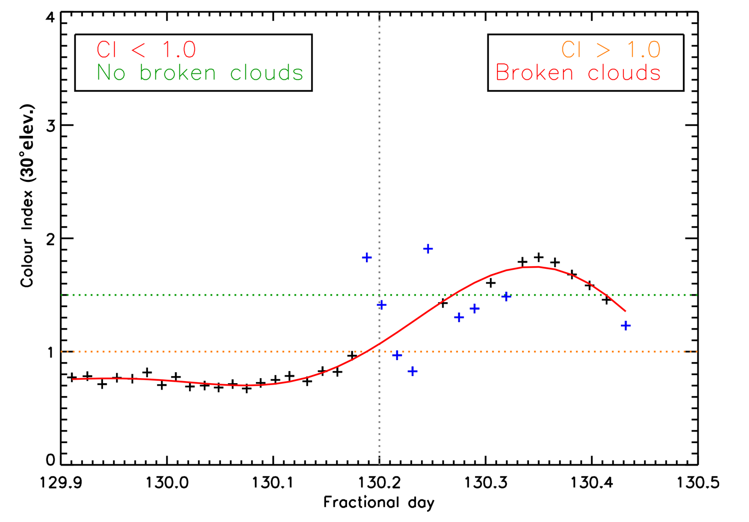
*** *Broken-clouds flag:***

use outliers to determine CI temporal variability

→ information on scattered clouds

- # outliers $< 20\%$ = 'GOOD'
- $20\% <$ # outliers $< 40\%$ = 'MEDIOCRE'
- # outliers $> 40\%$ = 'BAD'





5. CS flags vs. AERONET

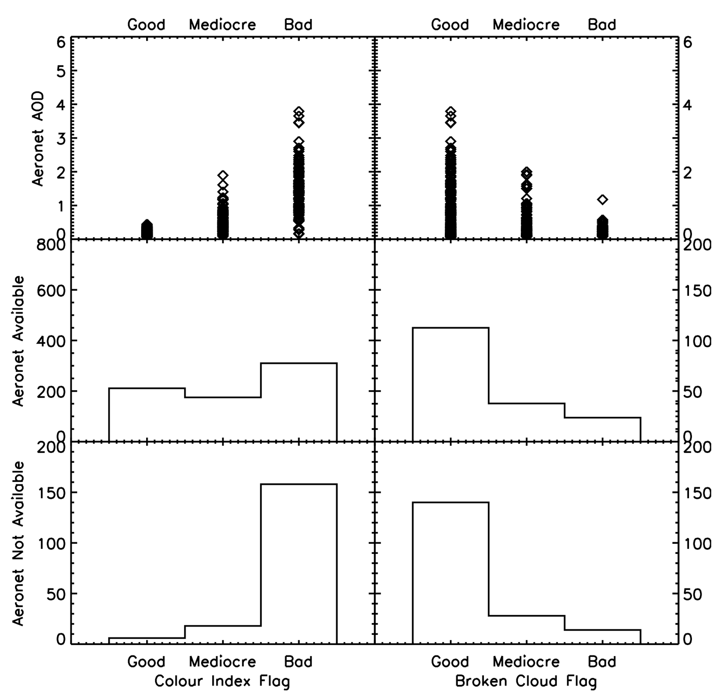
- compare half-day cloud-screening (CS) quality flags with mean half-day AERONET AOD values

- good correlation between colour-index flag and AERONET AOD:

low AERONET AOD
→ good CI flag

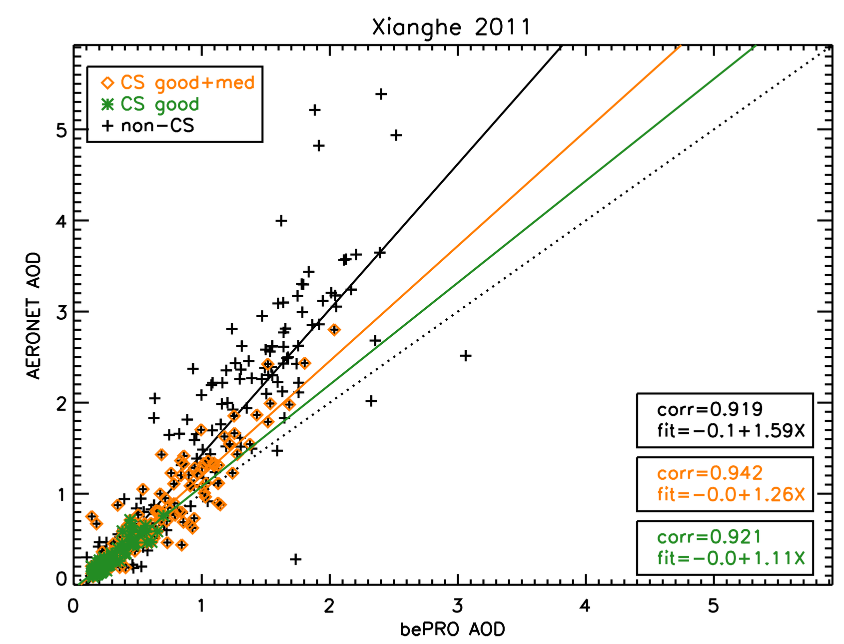
higher AERONET AOD
→ mediocre/bad CI flag

days without AERONET (clouds)
→ bad CI flag



6. AOD retrievals vs. AERONET

- aerosol AODs retrieved using the bePRO radiative transfer profiling routine (Clémer et al. AMT, 3, 863-878, 2010)
- comparison full dataset with cloud-screened data: removal days with broken clouds, extreme aerosol load and/or thick cloud cover
- cloud-screening improves correlation between retrievals and observations



Conclusions

Our method shows promising results in characterizing the sky and cloud conditions of MAX-DOAS observations, without the need for other external cloud-detection systems. Moreover, the method can be used to clean the dataset of observations made during adverse sky conditions.

Applying the cloud-screening to MAX-DOAS measurements results in a better agreement between aerosol AOD radiative transfer retrievals and AERONET measurements.

As a next step we will use the observed O_4 DSCDs to further characterize the sky conditions, and distinguish between high aerosol load and different cloud types. We will also test the impact of cloud screening on the retrieval of trace gas concentrations from the MAX-DOAS data set.

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