Brewers and NO$_2$: algorithms and calibration issues

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Overview of some NO$_2$ retrieval algorithms

Calibration issues

Langley calibration with a long series (using Kerr’s algorithm)

Langley calibration at a high altitude station (using Kerr’s algorithm)

Conclusions and further work
Overview of some NO$_2$ retrieval algorithms

J. B. Kerr, 1989

“Classical” NO$_2$ retrieval algorithm

- DS and ZS measurements
- 5 slits, 431÷453 nm (.85 nm resolution)
- weighting coefficients are selected so that
  - the sum of coefficients is zero
  - the Rayleigh scattering is removed
  - the ozone absorption is removed
  - the linear combination of $1/\lambda_i$ is zero
- no other absorbers are considered
- old cross sections (Johnston 1976, unpublished)
- same airmass as ozone ($M_2$)
Overview of some $\text{NO}_2$ retrieval algorithms

Some limitations of the classical algorithm

$$F_{corr}(\lambda_i) = ETC(\lambda_i) - [K_{\text{NO}_2}(\lambda_i)\mu_{\text{NO}_2}X_{\text{NO}_2}$$
$$+ K_{\text{O}_3}(\lambda_i)\mu_{\text{O}_3}X_{\text{O}_3}$$
$$+ \delta_{\text{aer}}(\lambda_i)\mu_{\text{aer}}]$$

- this is true only if the contribution of other atmospheric species is negligible
- $F_{corr}$ should be calculated using actual attenuations of the filters
- $F_{corr}$ takes into account the Rayleigh scattering... ← the Brewer Rayleigh coefficients can be improved
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\[ \Sigma \gamma_i F_i = \Sigma \gamma_i ETC_i - \mu_{NO_2} X_{NO_2} (\Sigma \gamma_i K_i) \]  
\[ MS_9 = NB_1 + M_2 MS_{11} NA_1 \]

- only NO$_2$ contribution remains if weighting coefficients are correctly calculated
- the retrieved NO$_2$ content depends on the NO$_2$ X-secs (X-secs from Johnston 1976 could be avoided, since more recent data exist. Is there any “standard”?)
- weighting coefficients depend on the X-secs used for species different from NO$_2$
- effective X-secs strongly depends on operational wavelengths and shape of the transmission function
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Overview of some NO\textsubscript{2} retrieval algorithms

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\[ \Sigma \gamma_i F_i = \Sigma \gamma_i ETC_i - \mu_{NO_2} X_{NO_2} (\Sigma \gamma_i K_i) \]  \hspace{1cm} (2)

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Overview of some NO$_2$ retrieval algorithms
A. Cede, 2005-2006

Development of a new DS algorithm for MKIII Brewers

- NO$_2$ retrieval in the UV-A range (349 ÷ 363 nm)
- Different absorbing species (in MKIII range) are considered
  - NO$_2$, O$_3$, SO$_2$, HCHO, BrO, O$_4$, Rayleigh, aerosol
- 6 slits (× 3 micrometer positions) are used
- Measured FOV is considered for circumsolar radiation at lower wavelengths (but not at higher)
- NO$_2$ assumed to accumulate in troposphere
- “Bootstrap method” for determining the ETCs
Overview of some NO$_2$ retrieval algorithms

D. V. Barton, 2007

Development of a new ZS algorithm for MKIV Brewers

- different absorbing species (MKIV range) are considered
  - NO$_2$, O$_3$, O$_4$, H$_2$O, Raman scattering, Rayleigh, aerosol
- additional DOAS algorithm
- all 6 slits are used
- measurements in weak/strong polarizations (zs, zw)
1 Overview of some NO₂ retrieval algorithms

2 Calibration issues

3 Langley calibration with a long series (using Kerr’s algorithm)

4 Langley calibration at a high altitude station (using Kerr’s algorithm)

5 Conclusions and further work
Calibration issues

Whichever method you use,

\[ \sum \gamma_i F_i = \sum \gamma_i ETC_i - \mu_{NO_2} X_{NO_2} (\sum \gamma_i K_i) \]  

\[ MS_9 = NB_1 + M_2 MS_{11} NA_1 \]  

- we need to know with good accuracy the linear combination of extraterrestrial constants NB1
- what is the appropriate NO\(_2\) airmass? Is it M\(_2\) or M\(_3\)? Probably something else...
- \( MS_9 \) can be regressed against \( M_2 \) (Langley Plot) \( \leftarrow \) Only if \( MS_{11} \) is constant!
Calibration issues

Whichever method you use,

\[ \Sigma \gamma_i F_i = \Sigma \gamma_i ETC_i - \mu_{NO_2} X_{NO_2} (\Sigma \gamma_i K_i) \]  \hspace{1cm} (4)

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Whichever method you use,

\[ \Sigma \gamma_i F_i = \Sigma \gamma_i ETC_i - \mu_{NO_2} X_{NO_2}(\Sigma \gamma_i K_i) \]  \hspace{2cm} (4)

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Calibration issues
Complications for NO\textsubscript{2}

Strong diurnal NO\textsubscript{2} photochemistry may originate large uncertainties ($MS_{11}$ is not a constant) (Marenco, JGR 2007)

- analyze only measurements at large SZA, since there the airmass changes quickly ← this is a problem for straylight, polarization, etc.
- select only days with small amount of NO\textsubscript{2} (this is the aim of the “Bootstrap method”)
- improved algorithms (e.g. ALPS, Terez JGR 2003)
- use of satellite maps can help?
- use of photochemical models?
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Two Langley calibrations were attempted using the Brewer classical algorithm (Kerr, 1989)

1. long series at a low altitude site (Aosta, 570 m asl)
2. short series at a high altitude station (Plateau Rosa, 3500 m asl)

Objective algorithms (e.g. Smirnov et al. 2001, Cheymol 2003, Gröbner 2004, ...) were employed for cloud-screening (now routinely used for AOD...).
1. Overview of some NO$_2$ retrieval algorithms

2. Calibration issues

3. Langley calibration with a long series (using Kerr’s algorithm)

4. Langley calibration at a high altitude station (using Kerr’s algorithm)

5. Conclusions and further work
Long series
Long series

\[ NB1 = 728 \pm 11 \]
11 units on NB1 correspond to \( \frac{1}{10} \frac{11}{3} = 0.4 \) DU for NO\(_2\) (\(@ airmass = 1\))
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High altitude station

Brewer #066 at Plateau Rosa (3500 m asl), July 2011
Brewer #066 at Plateau Rosa (3500 m asl), June 2011

- all data were rejected by the algorithm, since clouds perturbed the measurements for a full month!
- need to find a better location to calibrate Brewer #066 (is Izana a practical option?)
Brewer #066 at Plateau Rosa (3500 m asl), June 2011

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Conclusions and further work

- calibrations for both \textbf{ds} and \textbf{zs} modes need to be performed
- a Langley plot (classical algorithm) was attempted, but a better station needs to be found
- before that, the retrieval algorithm should be revised
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TODOs:

- understand which absorbers should be considered in the NO$_2$ MKIV range
- choose a set of X-secs for each absorber and, in particular, for NO$_2$ (e.g. Burrows?)
- analyse some NO$_2$ profile data (and make some RT simulations) for finding the right airmass
- employ improved Rayleigh coefficients
- find a method for calculating the ETCs despite the diurnal photochemical cycle
- we probably need to find a new monochromator offset (i.e. different set of wavelengths) in order to remove contaminations from other species (and obtain better SC results)