Tropospheric NO₂ retrieved from OMI, GOME(-2) and SCIAMACHY within the QA4ECV project: retrieval improvement, harmonization and quality assurance


European Geophysical Union, Vienna, 26 April 2017 - EGU2017-8311

www.qa4ecv.eu
Users need clear info on validity of EO/climate data sets, Producers have unique records, but need to provide quality info

www.qa4ecv.eu

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Slide 2
Central idea of QA4ECV

1. Generate climate data records of Essential Climate Variables (ECVs) or precursors thereof
2. Traceable Quality Assurance of the algorithm and data records

How do we do that for QA4ECV tropospheric NO$_2$ retrievals?

<table>
<thead>
<tr>
<th>Algorithm design</th>
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<th>Algorithm evaluation</th>
<th>Product validation</th>
<th>Product use</th>
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- Provide interactive traceability chain for retrieval algorithm
- Harmonize retrieval approaches between participating institutes
- Provide traceable algorithm uncertainty estimates in product
- Evaluate data product quality through validation
- Apply the data to test their fitness-for-purpose

Project timeline

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QA4ECV NO₂ ECV precursor

A joint product by: KNMI, BIRA-IASB, University of Bremen, MPI-C, and Wageningen University

Clicking on ‘Data Access’ below takes you to version 1.0 data retrieved for OMI. This version of the data has been quality assured for January 2005. For other months, the data has not yet been quality assured.

By clicking on Data Access you will find harmonized vertical columns of NO₂ derived from satellite observations from OMI for the period 2004-2015.

Do you have questions on how the satellite NO₂ data is produced, how good it is, or how useful for your application? Then please post your questions or comments on this NO₂ ECV Forum.

By clicking on the Traceability Chain you will find specific information on how the NO₂ ECV precursor is retrieved.

NO₂, HCHO, and CO data and algorithm information to be found at:
http://www.qa4ecv.eu/ecvs
1. Traceability Chain for QA4ECV NO₂

Key
- Main Process
- Data / Product
- Click to see process
- Click to see more details
- Click to return to main chain

\[ N_{ν,trop} = \frac{N_S - N_{S,strat}}{M_{trop}} \]
1. Traceability Chain for QA4ECV NO$_2$

Laboratory Absorption Cross Sections and Ring Effect Cross Section

The reference spectra used in NO$_2$ spectral fitting are: NO$_2$ from Vandelee et al. [1998], O$_3$ from Serdyuchenko et al. [2014], O$_2$-O$_2$ from Thalman and Volkamer [2013], H$_2$O from Rothman et al. [2013], and Ring from Chance and Spurr [1997], and liquid water from Pope and Fry [1997]. See Table 1 for references.
2. Evaluate & harmonize retrieval approaches

Detailed DOAS OMI NO$_2$ evaluation BIRA, IUPB, KNMI, MPIC

Detailed comparison between spectral fits suggests:
- Include liquid water
- Including an intensity offset avoids misfits

\[
\tau(\lambda) = \ln\left(\frac{I(\lambda) + C}{I_0(\lambda)}\right) \approx \ln\left(\frac{I(\lambda)}{I_0(\lambda)}\right) + \frac{C}{I(\lambda)},
\]

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2. Evaluate & harmonize retrieval approaches

Round Robin for Air Mass Factor calculations

- Excellent agreement between radiative transfer codes
- Very good agreement between AMFs under same settings
- 30-40% structural uncertainty in AMFs
## QA4ECV algorithm settings for OMI NO₂

<table>
<thead>
<tr>
<th></th>
<th>QA4ECV</th>
<th>DOMINO v2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Spectral fitting</strong></td>
<td>QDOAS/NLIN 405-465 nm</td>
<td>OMNO2A v1 405-465 nm</td>
</tr>
<tr>
<td></td>
<td>Intensity offset correction, liquid water, O₂-O₂</td>
<td>Only NO₂, O₃, H₂O, Ring, polynomial</td>
</tr>
<tr>
<td></td>
<td>Optimized wavelength calibration</td>
<td></td>
</tr>
<tr>
<td><strong>Stratospheric correction</strong></td>
<td>TM5 1° x 1°, nudging to HNO₃:O₃ climatologies from ODIN, major speed-up, versatile code</td>
<td>TM4 3° x 2°, nudging to HNO₃:O₃ ratios from UARS + O3MSR climatologies</td>
</tr>
<tr>
<td></td>
<td>STREAM</td>
<td></td>
</tr>
<tr>
<td><strong>Stripe correction</strong></td>
<td>Online</td>
<td>A posteriori</td>
</tr>
<tr>
<td><strong>AMF LUT</strong></td>
<td>More reference points (437.5 nm) 173 x 14 x 26 x 10 x 11 x 16</td>
<td>Fewer reference points (439 nm) 24 x 10 x 10 x 10 x 13 x 16</td>
</tr>
<tr>
<td></td>
<td>Sphericity-corrected</td>
<td>Pseudo-spherical</td>
</tr>
<tr>
<td><strong>Surface albedo</strong></td>
<td>OMI LER 5-year</td>
<td>OMI LER 3-year</td>
</tr>
<tr>
<td><strong>Clouds</strong></td>
<td>Improved O₂-O₂ [Veefkind et al., 2016]</td>
<td>O₂-O₂ [Acarreta et al., 2004]</td>
</tr>
<tr>
<td><strong>A priori profile</strong></td>
<td>TM5-mp 1° x 1°</td>
<td>TM4 3° x 2°</td>
</tr>
<tr>
<td><strong>Terrain height</strong></td>
<td>Pixel average GMTED2010</td>
<td>Center of DEM_3KM</td>
</tr>
</tbody>
</table>
3. Provide traceable uncertainty estimates

Check QA4ECV SCD against OMNO2A v2

Lower fitting uncertainties and less degradation of fit quality
3. Provide traceable uncertainty estimates

Comparison between STREAM and TM5 assimilation revealed issues with assimilation in v1.0 at high SZA. These have been solved and O-F statistics suggest uncertainty in stratospheric NO$_2$ estimate of 0.2x$10^{15}$ molecules cm$^{-2}$. 

Algorithm evaluation
4. Validation with MAX-DOAS in Xianghe

MAX-DOAS and QA4ECV NO$_2$ v1 extracted from HARP Atmosphere Validation Server
https://github.com/stcorp/harp

Clear-sky retrievals:
High correlation ($R=0.6-0.9$)
QA4ECV ±10% lower than MAX-DOAS
Available data

<table>
<thead>
<tr>
<th>Product</th>
<th>Year</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>QA4ECV OMI v1.0</td>
<td>2004-2015</td>
<td>Available, with known issues</td>
</tr>
<tr>
<td>QA4ECV OMI v1.1</td>
<td>2005</td>
<td>Not yet online</td>
</tr>
<tr>
<td>GOME-2(A) v1.1</td>
<td>2007</td>
<td>Not yet online, processing</td>
</tr>
</tbody>
</table>

US -10%
EU -20%
China -10%

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The research leading to these results has received funding from the European Community's Seventh Framework Programme ([FP7/2007-2013]) under grant agreement n° 607405

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Summary

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Project timeline

- Interactive traceability chain provides transparency
- Learned lessons from comparing approaches between institutes
- Provide traceable algorithm uncertainty estimates in product
- Evaluate data product quality through validation
- Apply the data to test their fitness-for-purpose

QA4ECV

These new QA4ECV data are very good! I quickly see how the data was retrieved, and where the main uncertainties are. And because this is all described very well, I can see that it they are fit for my purpose. I will definitely use these data for my new project!

2016-2017
Leptoukh QA4EO'11
Main improvements of the QA4ECV HCHO retrieval baseline:

1. Use of a large 328.5-359 nm fitting window
2. Background correction based on reference sector method
3. HCHO profiles from the 1°x1° TM5 model are used as a priori in the AMF calculation.

See Poster: X5.422 EGU2017-4453: De Smedt et al., Tropospheric HCHO retrieved from OMI, GOME(-2), and SCIAMACHY within the Quality Assurance For Essential Climate Variables (QA4ECV) project.

See poster: Pinardi et al. (15858, X5.403): On the use of harmonized HCHO and NO₂ MAXDOAS measurements for the validation of GOME-2 and OMI satellite sensors.