QA4EO Test Case II - Atmospheric Composition and Climate

QA4EO and the Remote Sensing of Atmospheric Composition

Jean-Christopher LAMBERT
Belgian Institute for Space Aeronomy (IASB-BIRA), Brussels, Belgium
QA4EO and the Remote Sensing of Atmospheric Composition

1. Scientific/decision/policy thematic domains
2. Sources and characteristics of data
3. Quality requirements
4. Impact of not achieving requirements
5. Feedback and perspectives
1. Scientific/decision/policy thematic domains and goals
2. Data

Sources and characteristics
Integrated Global Observing Strategy

Satellites

Aircrafts and balloons

Ground networks

September 2004
An international partnership for cooperation in Earth observations
NETWORK FOR THE DETECTION OF ATMOSPHERIC COMPOSITION CHANGE (NDACC)

Observational Capabilities of the Network for the Detection of Atmospheric Composition Change

Ripples indicate approximate vertical resolution. Plain bars represent column measurements.

Cooperating Networks

http://ndacc.org
## SATELLITE MISSIONS FOR ATMOSPHERIC COMPOSITION (1978-2020)

### Sounder-Mission Timeline

<table>
<thead>
<tr>
<th>Year</th>
<th>Mission</th>
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<tr>
<td>1978</td>
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<td>2020</td>
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### Sounding Strategy
- **Nadir/Limb:** UV/VIS/NIR, Sun/Moon occultation, stellar occultation, multi-target
- **Spectral Range:** UV, VIS/IR, MW

*Compiled by CEOS ACSG and the NDACC Satellite WG*

*Details via [http://www.ndacc.org](http://www.ndacc.org) Satellite WG*
Information content of remote sensing data

Air masses probed by GOME, Envisat and NDACC ground-based instruments
Information content of remote sensing data

Nadir vertical sensitivity (GOME-1/2, SCIAMACHY, OMI...)

NO₂ COLUMN RETRIEVAL

UVSpec Nadir NO₂ (Summer Mid-Lat. Strato. Clim.) Averaging Kernels @ 439.0 nm

O₃ COLUMN RETRIEVAL

UVSpec Nadir O₃ (AFGL76) Averaging Kernels @ 325.5 nm
3. Quality requirements

What could be a valid Quality Indicator (providing evidence of fitness for purpose)?
Quality requirements

- Cardinal requirements
  - Error bars on species & on height
  - Vertical and horizontal resolution
  - Observation frequency
  - Info primarily from observation
  - Documentation, metadata

- Specific requirements
  - Air quality
  - Climate: GHG, ozone, water vapour, clouds, aerosols...
  - Polar ozone, UV radiation, circulation...
  - Particulate matter, allergens, health hazards
  - Volcanic hazards to aviation
  - Corrosion and abrasion, degradation by UV...
  - Radiative transfer, atmospheric correction...
  - ...
Evolution of GOME total ozone data accuracy since 1995...

SZA dependence is a QI.

GDP 1.20
1995

GDP 2.0
1996

All latitudes excepted Antarctica
Vertical error bars: standard deviation (2σ)

GDP 2.7 / 3.0 / 4.0

GDP 4.1 / 5.0
2008 / 2011

Tropic of Capricorn
Northern Mid-latitudes
60° North
Arctic Polar Circle
Northern Polar Latitudes
GOME NADIR O3P VERTICAL SMOOTHING

Vertical resolution and altitude registration as QI?

Meijer et al., JGR 2006

Figure 3a. Resolving lengths (asterisks) for retrieval results of three different algorithms near the lidar stations at Andoya, Observatoire Haute Provence (OHP), Mauna Loa (MLO), Lauder, and Dumont d’Urville, shown from the top downward ranging from north to south, respectively. See section 4.2.3 for collocation criteria. Black line shows the median value; for explanation of gray line, see section 3.7.

Meijer et al., JGR 2006

Figure 4a. Centroids of averaging kernels (asterisks) from retrieval results of three different algorithms near the lidar stations at Andoya, OHP, MLO, Lauder, and Dumont d’Urville, shown from the top downward ranging from north to south, respectively. See section 4.1 for location details and section 4.2.3 for collocation criteria. Black line shows the median values; for explanation of gray line, see section 3.7. Dotted lines serve as visual references; a vertical line at 15 km and two diagonal lines corresponding to ±4 km shift of nominal altitude.
GOME Nadir O₃P vertical smoothing error as QI?

Lambert et al., 2004; De Clercq et al., 2006
GOME NADIR $O_3P$ INFORMATION CONTENT

Averaging kernels and derived quantities as QIs?

De Clercq et al., ESA SP-636, 2007
GOME NADIR $O_3P$ INFORMATION CONTENT

Averaging kernels and derived quantities as QIs?

Improved version R2

De Clercq et al., ESA SP-636, 2007
GOME NADIR O$_3$P INFORMATION CONTENT vs. Altitude and Time: Northern Middle Latitudes

De Clercq et al., ESA SP-636, 2007
4. Impact of not achieving requirements
Impact of not achieving requirements

- No use of the data
- Fictitious patterns and temporal variations
- Inaccurate assessment of (polar) ozone loss/recovery
- Bias towards specific conditions (e.g., clouds, land...)
- Too noisy => many more years needed to detect trends
- Wrong trends, or inaccurate trends
- Erroneous interpretation of trends and events
- Erroneous conclusions on data quality
- Erroneous conclusions on climate-atmosphere interactions
- Etc.

- Clear impact on scientific results, on assessments, on protocol monitoring, on decision making...
Evolution of GOME total ozone data accuracy since 1995…

GOME Solar Zenith Angle at TOA (deg)

1995
GDP 1.20

GOME-SAOZ/SAOZ Total Ozone (%)

-30
-20
-10
0
10
20
30

Tropic of Capricorn
Northern Mid-latitudes
60° North
Arctic Polar Circle
Northern Polar Latitudes

GDP 2.0
1996

All latitudes excepted Antarctica
Vertical error bars: standard deviation (2σ)

GDP 4.1 / 5.0
2008 / 2010

How valid are uncertainty estimates given in a data file / derived from a data comparison?

Method described in Section 4.1 of Cortesi et al., ACP 2007
How compact are tracer-tracer correlations and hydrogen budgets?

Figure 9.6: Horizontal averaging kernels for the MIPAS off-line retrieval of water vapour, methane, ozone and temperature vertical profiles, calculated for a tropical standard atmosphere. The colour scale.

Lambert et al., ISSI 2011 (with figures adapted from von Clarmann et al., AMT 2009)
5. Feedback and perspectives on QA4EO role and implementation
Feedback on QA4EO Role

- As usually, QA is considered as crucial, but remains given poor attention and resource.
- QA4EO advertised in CEOS WGCV ACWG, in NDACC, in GMES Atmospheric Service, in SPARC, in UNEP/WMO ORM... and within space agencies and validation groups.
- QA4EO principles are agreed to be key to success. But QA4EO framework judged from “too simple” to “too demanding”.
- Level of detail needed is not clear. Costs can grow exponentially => Guidance is requested.
- What constitutes a valid Quality Indicator is unclear, especially if it has to be “traceable to possibly SI”.
- Concerns with the ambiguous concept of compliance.
- Sometimes confusion with ISO and with European Directive INSPIRE
Feedback on QA Strategy Implementation

- Principles implemented - at least partly and/or formally - in ESA projects (GOME, GSE, GECA, CCI...), NASA ROSES, EUMETSAT O3M-SAF, NDACC WGs, GMES Atmospheric Service etc.

- Degree and quality of implementation very unequal from one team to another. In many teams and communities, systematic characterisation and error budget studies have been ongoing effort for years. But for a few others, EO is a “beautiful picture” science and does not need QI as long as detection of events is a validation!

- Very broad range of user requirements, sometimes contradicting, not always clear or available to the retrieval teams. URDs need translation into Cal/Val Req.

- Cyclic renewal of AC&C RS community => Sustainability of QA4EO type implementation beyond the 4-year horizon?
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Feedback on QA Strategy Implementation

- A QI can’t be valid/tested on every satellite pixel and assumptions are to be made. So, the same product can be QA4EO compliant globally but not at pixel scale. Idem for multi-mission data sets.
- Although standards exist (VIM, GUM…), terminology is not consistently used (e.g. “accuracy”).
- Terminology taken from metrology not always applicable, specially to models.
- QA practices with different quality live in parallel.
- Bias and noise introduced by neglecting smoothing and sampling errors can spoil the value of validation efforts and lead to misinterpretations of the data.
- Information content studies based on AKs are encouraged. But AK availability is an issue.
End-to-end QI

- End-to-end validation is recommended in theory, e.g. in formal validation protocols. In the facts, most of components of a production chain are characterised for level-1 up to level-2, although unequally and without coordination. Documentation is scattered and incomplete.

- Propagation of uncertainties from Level-0 to Level-2 is established practice. Propagation of uncertainties up to Level-3/4 not straightforward, not always feasible.

- Information content is an known issue in the DA community but the implementation of improved observation operators is not a priority.

- Information content aspects of merged data sets?