Belgian Science Policy Office (BELSPO) / Federal Scientific Institutes (FSIs)

I. Update on Cal/Val Activities

Jean-Christopher Lambert

Royal Belgian Institute for Space Aeronomy (IASB-BIRA)

Agency Reports I

WGCV Plenary # 41

Tokyo, September 5-7, 2016

Working Group on Calibration and Validation

Contributing institutes

Federal Scientific Institutes (FSIs) under BELSPO authority

- Royal Belgian Institute for Space Aeronomy, BIRA-IASB
- Royal Institute of Natural Sciences of Belgium, IRSN
- Royal Meteorological Institute of Belgium, RMIB
- Royal Observatory of Belgium, ROB
- Belgian User Support and Operation Centre, B-USOC

Regional partners

- Centre spatial de Liège, CSL
- Université libre de Bruxelles, ULB
- Université de Liège, ULg
- Vlaamse Instelling voor Technologisch Onderzoek, VITO

Working Group on Calibration and Validation

Updates on:

- EO missions
- Validation data
- Validation methods
- Validation systems

Background information (not presented)

Working Group on Calibration and Validation

Atmosphere:

- Phase F: ESA GOME, GOMOS, MIPAS, SCIAMACHY
- Phase E: EUMETSAT MetOp-A/B and MSG GOME-2 and IASI (CM-SAF, O3M-SAF); CSA ACE-FTS; KNMI/NASA Aura OMI
- 6 months ago: ESA-Roscosmos mission ExoMars with BIRA-IASB's NOMAD/TGO
- <u>Next year:</u> Sentinel-5 Precursor TROPOMI, BIRA-IASB's PICASSO/CubeSat
- Upcoming: MetOp-C, Sentinel-4 UVN, Sentinel-5 UVN and IASI-NG
- <u>Approved:</u> BIRA-IASB's Altius/PROBA (Phase B2)

Land, Oceans and Snow/Ice:

- PROBA-1 (L 2001/10) transferred to ESA
- PROBA V (L 2013/05)
- EU Sentinel-3 (S-3A L 2016/02)
- CONAE-CSL cooperation on SAOCOM-1A/1B (L 2017/10-2018/10): polarimetric SAR/ScanSAR + InSAR/DInSAR processor

Working Group on Calibration and Validation

ALTIUS

(Atmospheric Limb Tracker for the Investigation of the Upcoming Stratosphere)
**Royal Belgian Institute for Space Aeronomy** / contact: Didier.Fussen@oma.be

In brief...
- Atmospheric limb sounder (z=0-100 km, dz≤1 km) for O_3, NO_2, aerosols, PSC, PMC, CH_4, H_2O, OClO, BrO, NO_3, temperature
- 3 tunable **spectral imagers** (Fabry-Pérot in UV, AOTF in VIS, NIR) (λ=250-1800 nm, dλ=1-10 nm)
- Observations in **multi-mode geometries**: limb-scattering, solar, stellar, lunar, planetary occultations
- LEO sunsynchronous 10:30 LTDN, PROBA class (<=200 kg) with high inertial pointing stability and 1°/s agility.

Recent milestones
- **Aug 2005 (!):** first ideas ...
- **Jun 2015**: Intermediate payload Design Review by ESA (phase B1)
- **Dec 2015**:
  - technical and performance compliance reviews wrt OPEROZ study (User-driven O_3 requirements study) by ESA
  - scientific review by international panel
- **Feb 2016**: BELSPO approves the full mission and mandate ESA/EO to take actions for implementation

Future actions
- start Phase B2 asap towards PDR

belspo   BIRA-IASB   RMI   museum   ULB   Ug   VITO
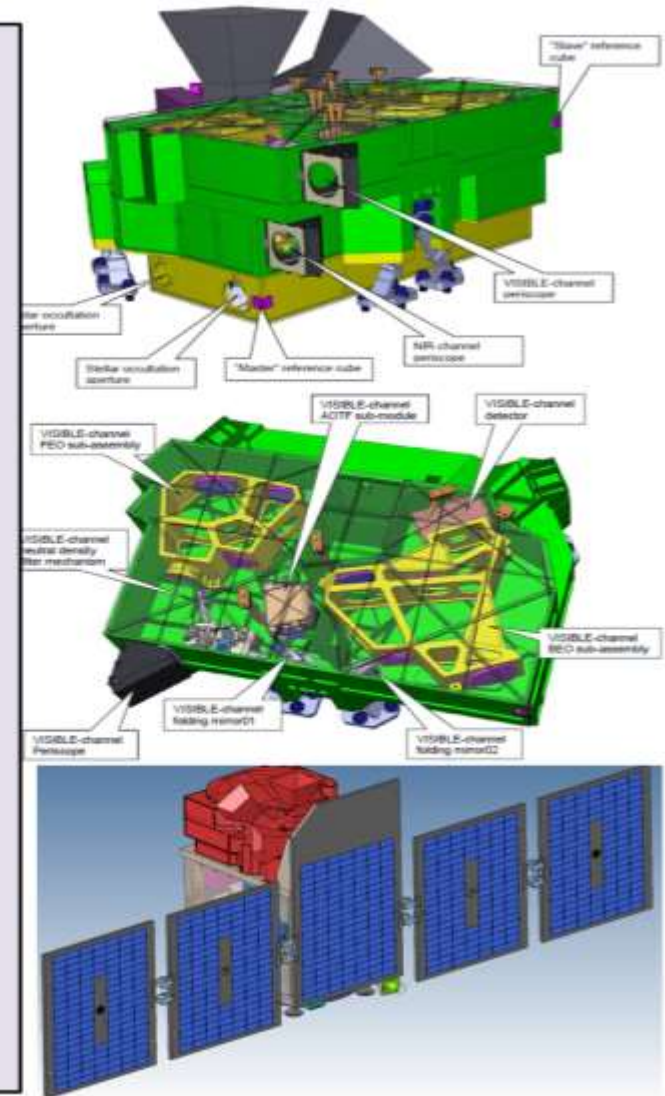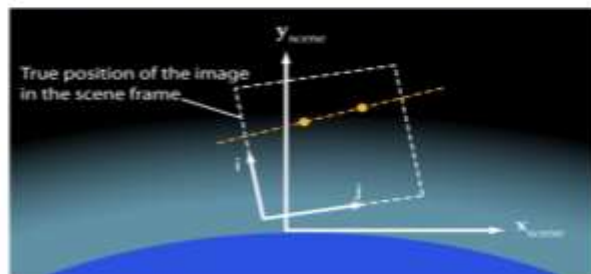
ALTIUS

Scientific objectives

Priority	Observable	Vertical range	Vertical res. [km]	Horizontal res. along parallels [km]	Horizontal res. along meridians [km]	Total error [%]	Coverage	Photo-chemistry [day/night]
A	O_3	UT-LS	1	10	500	5	global	d/n
A	O_3	US	1	10	500	5	global	d/n
A	O_3	MS	1	50	500	20	polar	n
B	NO_2	LS-US	2	50	500	30	global	d/n
B	H_2O	UT-LS	2	50	500	20	global	d/n
B	CH_4	UT-LS	2	50	500	20	global	d/n
B	aerosol	UT-LS	1	20	500	25	global	d/n
B	PSC	UT-LS	1	20	500	25	polar	d/n
C	PMC	MS	1	20	500	50	polar	d/n
C	OClO	LS-US	1	50	500	25	global	n
C	BrO	UT-LS	1	50	500	20	global	d
C	NO_3	LS-US	1	50	500	25	global	n
C	T*	LS-MS	2			2		
C	gradients	LS-US	1	10	10	30	global	d/n

In-flight calibration strategies

Flatfielding with clouds (target: 3% RMS PRNU)
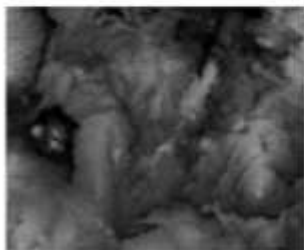
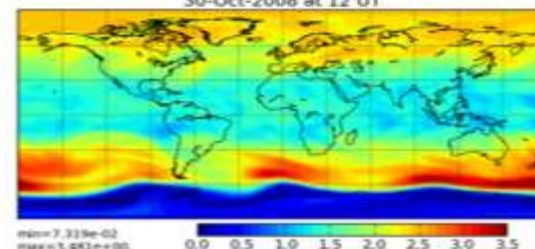**Pointing registration with stars in FOV (target: <150m, 1σ)**

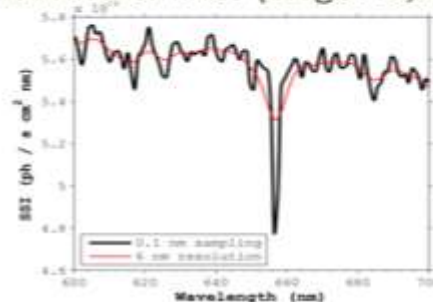True position of the image in the scene frame.

Wavelength registration with Fraunhofer lines (target: 0,1nm, 1σ)

O3 Level-3 product performance

BASCOE ALTIUS Assimilation
30-Oct-2008 at 12 UT

min=7.524e-02
max=3.665e+00

0.0 0.5 1.0 1.5 2.0 2.5 3.0 3.5
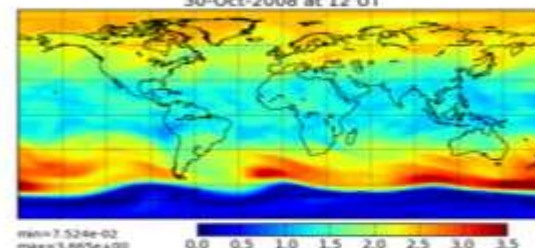
BASCOE Aura MLS v3.3 Assimilation
30-Oct-2008 at 12 UT

min=7.319e-02
max=3.481e+00

0.0 0.5 1.0 1.5 2.0 2.5 3.0 3.5

belspo · RMI · museum · ULB · ug · vito

Working Group on Calibration and Validation

SOLSPEC (SOLar SPECtrum)
from Spacelab 1 to the International Space Station

SOLAR on ISS/Columbus (L2008)

Facility Support Centre: Belgian USOC hosted by BIRA-IASB

Measurement of solar spectral irradiance from 17 nm to 100 µm (99% of solar energy)

- *SOLSPEC* (SOLar SPECtral Irradiance measurements): 180 nm – 3000 nm; developed by CNRS (France) in partnership with BIRA-IASB (Belgium) and LSW (Germany)
- *SOVIM* (SOlar Variable and Irradiance Monitor): near-UV, visible and thermal (200 nm – 100 µm); developed by PMOD/WRC (Davos, Switzerland) with one instrument's radiometers provided by IRM-KMI (Belgium)
- *SOL-ACES* (SOLar Auto-Calibrating Extreme UV/UV Spectrophotometers): EUV/UV; developed by IPM (Germany)

PROBA-2 (L2009) Space weather mission with Sun observations

PROBA-3 (L2018) Formation flying for solar corona observations

BELSPO / FSIs
Update on validation data

Atmosphere: [various websites]

- AERONET, EEA/EMEP, NDACC, TCCON, WMO/GAW stations
- International effort on harmonization, reprocessing, error characterization: FTIR & MAXDOAS bilateral cooperation with China, GAIA-CLIM WP2, QA4ECV WP4
- FRM4DOAS, CINDI-2 campaign
- FRM4GHG, AirCore+FTIRs campaign for TCCON/OCO-2 calibration
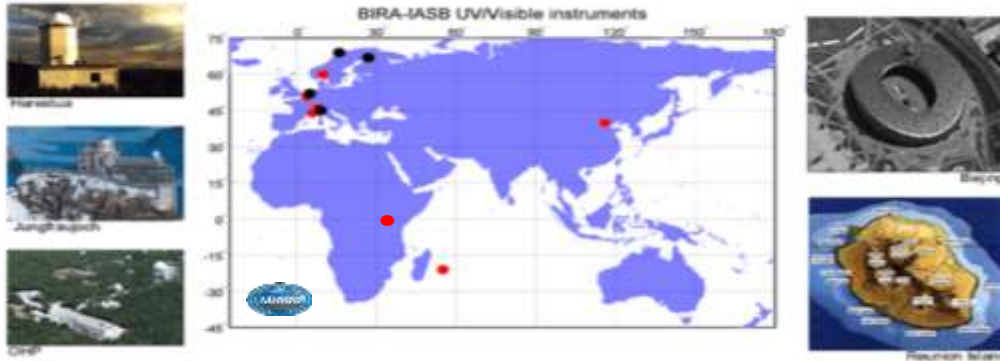- UAV- and car-based DOAS instruments in AROMAT and AROMAPEX campaigns

Marine: http://www.mumm.ac.be/datacentre

- Belgian Maritime Data Centre (BMDC), SeaDataNet member
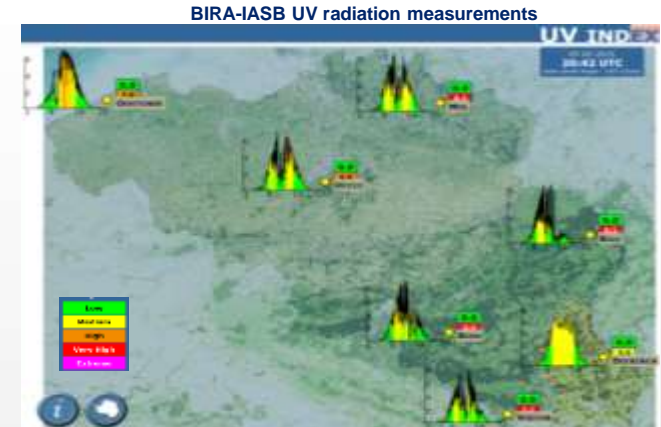- Physical, chemical and meteorological parameters over North Sea
- Ship- and shore-based

Solar: http://uvindex.aeronomie.be

- Solar UV-Visible Irradiance Monitoring Network (7 RT stations in Belgium + Belgian Antarctic Base), with centralised calibration centre in Uccle
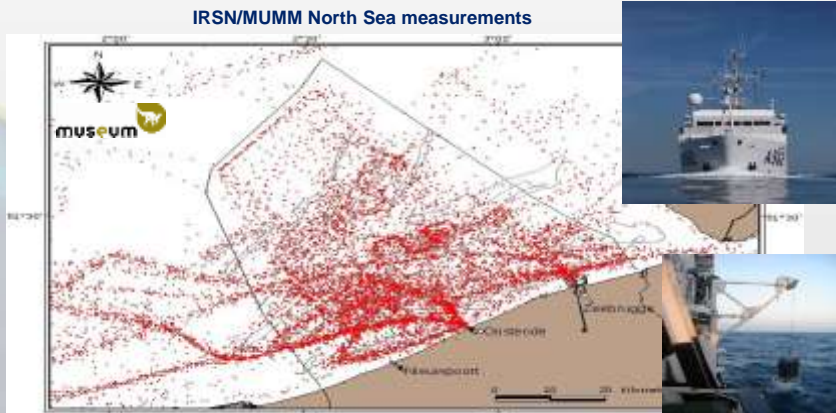- Spectral irradiance 280-600 nm, broadband, clouds, sunshine duration…

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BIRA-IASB UV/Visible instruments

Contact M. Van Roozendael and F. Hendrick, BIRA-IASB
+ Brewer/O_3sondes in Uccle, H. De Backer, RMIB

BIRA-IASB UV radiation measurements

Contact D. Bolsée, BIRA-IASB

IRSN/MUMM North Sea measurements

Contact S. Scory, IRSN/MUMM

BIRA-IASB and ULg FTIR instruments (NDACC and TCCON)

Uccle/Ukkel (50.8°N, 4.35°E)   Jungfraujoch (46.55°N, 7.98°E)

Porto Velho (8.8°S, 63.9°W)
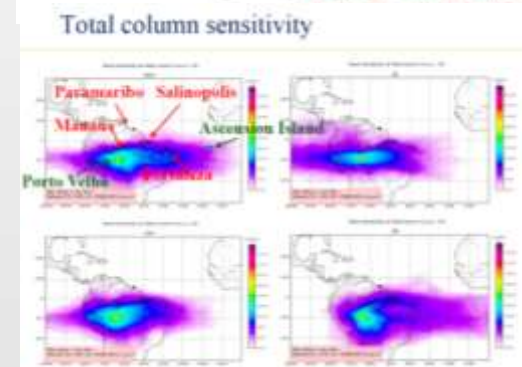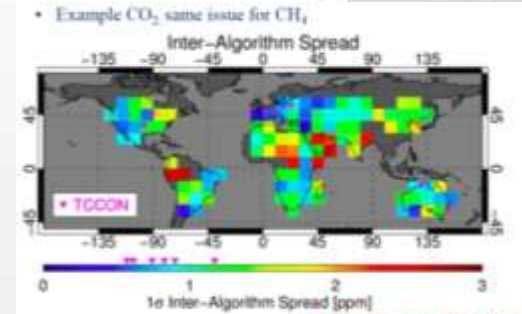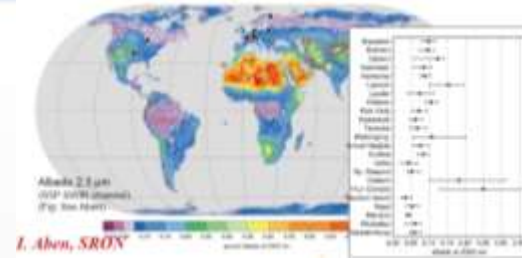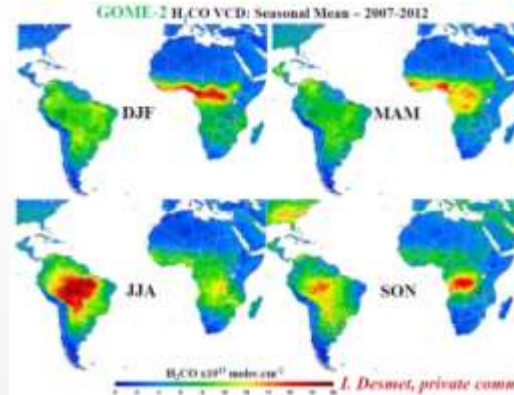
Saint Denis, Reunion (20.9°S, 55.5°E)
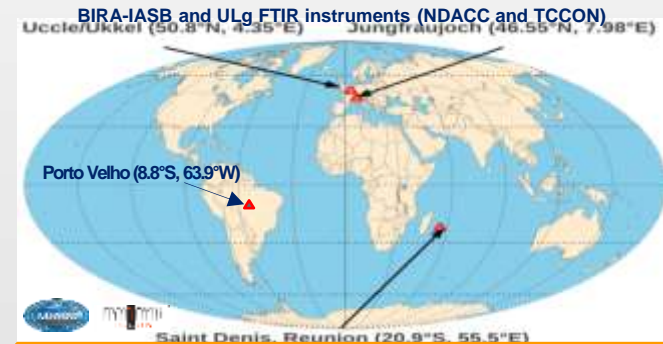
Contact M. De Mazière, BIRA-IASB

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9

Why Porto Velho in Brazil:

1. Amazon rainforest = important biogenic, biomass burning and greenhouse gas emissions
2. NIR-SWIR satellite observations of GHG have large uncertainties over the Amazon forest due to low albedo
3. Very few ground-based remote sensing (column/profile) observations over Amazon forest
4. Heterogeneity of Amazon forest => complementarity with Paramaribo FTIR
5. Area investigated by aircraft campaigns for atmospheric composition measurements
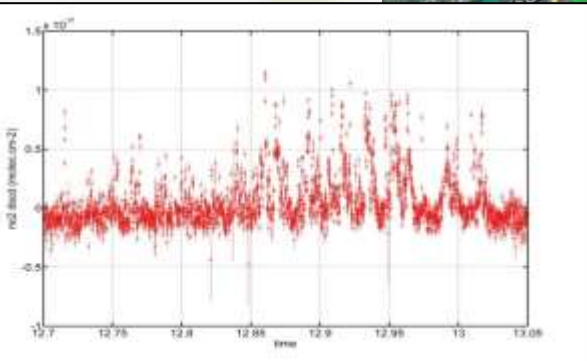

GOME-2 H$_2$CO VCD: Seasonal Mean – 2007-2012

DJF · MAM · JJA · SON

H$_2$CO x10^{15} molec.cm^{-2} · *I. Desmet, private comm.*

Albedo 2.3 μm · *I. Aben, SRON*

· Example CO$_2$: same issue for CH$_4$

Inter-Algorithm Spread

1σ Inter-Algorithm Spread [ppm]

Total column sensitivity

Paramaribo · Salinópolis · Manaus · Ascension Island · Porto Velho

○ TCCON site
☆ 125M spectrometers
★ TCCON future site

www.tccon.caltech.edu

IASB-BIRA SWING/UAV *Ref: Merlaud et al., 2013*

A·RO AT

ESA sponsored campaigns in 2014/09, 2015/08, 2017
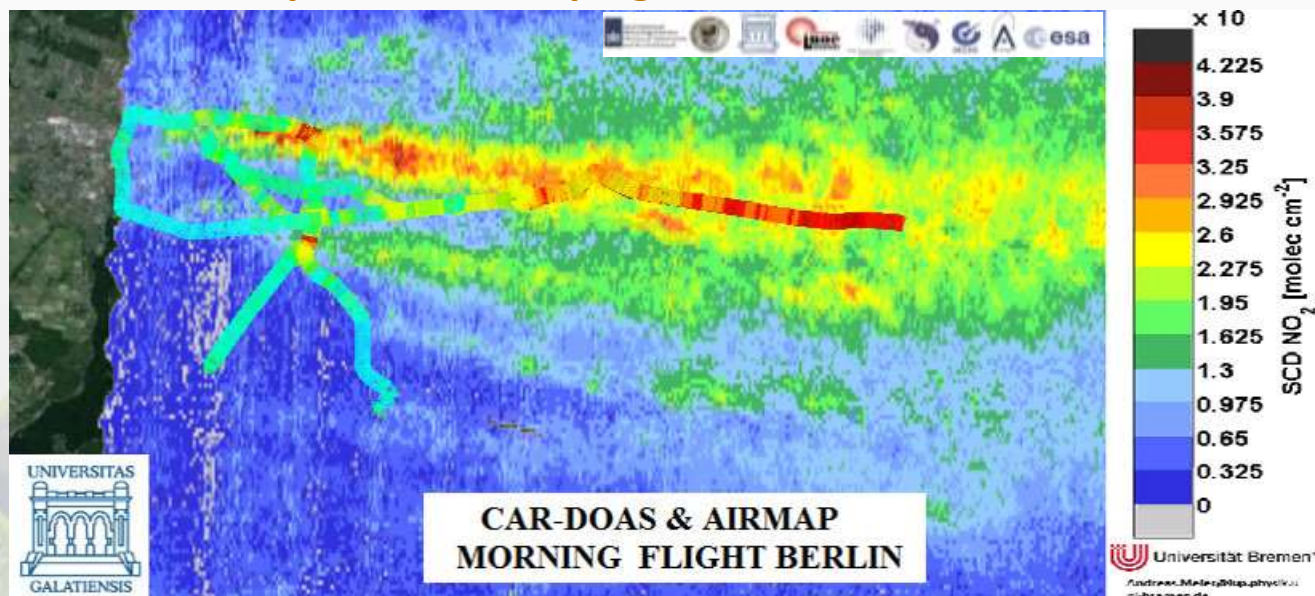

Turceni Power plant

IASB-BIRA SWING on FUB Cessna *Ref: Merlaud et al., 2013*

IASB-BIRA CAR-DOAS on Aeromobil
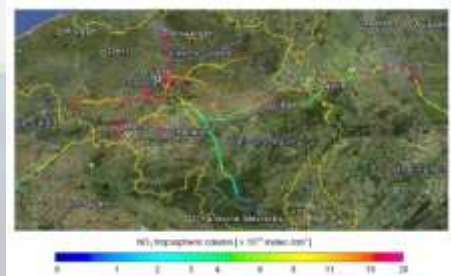
**EUFAR/ESA sponsored campaign over Berlin, in 2016/04**

Fig 3. Preliminary mobile-DOAS and AirMAP measurement results of the morning flight, 21 April 2016

Courtesy: A. Merlaud

Ozonesonde network homogeneity (contribution to WMO/GAW O3S-DQA)

- Satellite-based ensemble approach to evaluate homogeneity in bias and spread vs. altitude over all ozonesonde station (2000-2013; 60 WOUDC sites and 28 NDACC sites)
- Network inhomogeneity caused by ozonesonde type, manufacturer, solution strength
- By-product: mutual consistency of data archives (WOUDC, NDACC, SHADOZ, ESRL…)
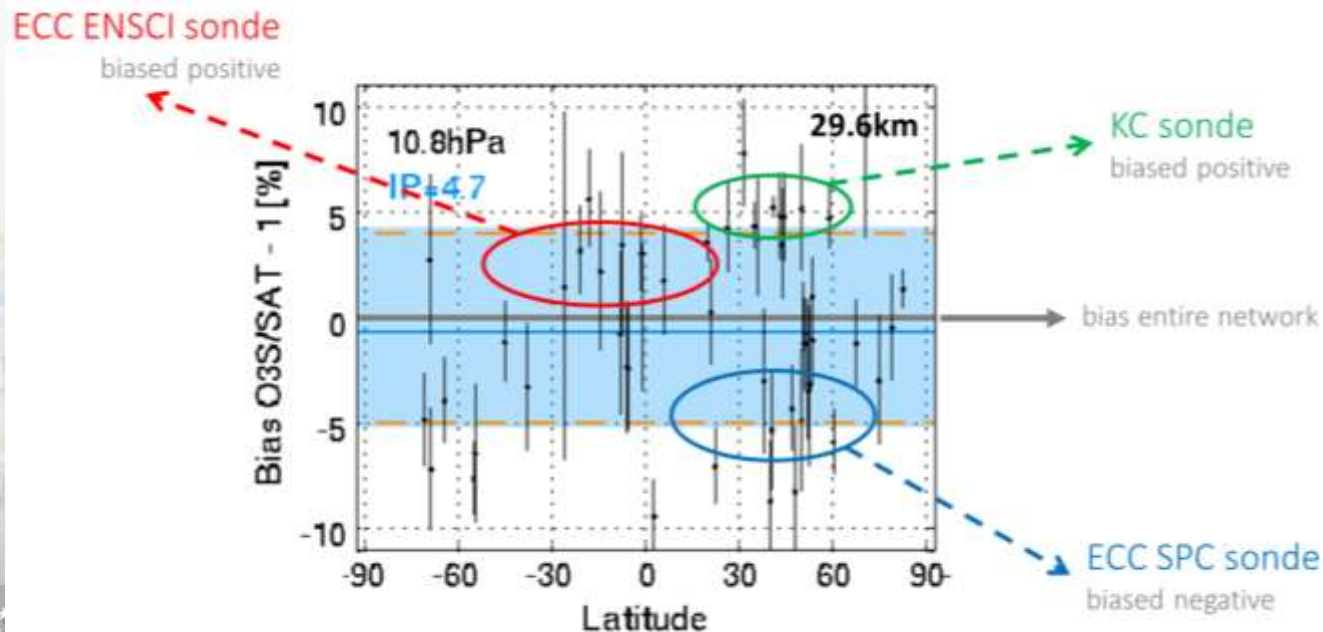
Courtesy: D. Hubert, O3S-DQA meeting, Sep. 2016

Working Group on Calibration and Validation

Atmospheric Measurement Techniques

Round-robin evaluation of nadir ozone profile retrievals: methodology and application to MetOp-A GOME-2

A. Keppens[1], J.-C. Lambert[1], J. Granville[1], G. Miles[2], R. Siddans[2], J. C. A. van Peet[3], R. J. van der A[3], D. Hubert[1], T. Verhoelst[1], A. Delcloo[4], S. Godin-Beekmann[5], R. Kivi[6], R. Stübi[7], and C. Zehner[8]

[1]Belgian Institute for Space Aeronomy (BIRA-IASB), Brussels, Belgium
[2]Rutherford Appleton Laboratory (RAL), Chilton, Didcot, UK
[3]Royal Netherlands Meteorological Institute (KNMI), De Bilt, the Netherlands
[4]Royal Meteorological Institute (KMI-IRM), Brussels, Belgium
[5]Laboratoire Atmosphère, Milieux, Observations Spatiales (LATMOS), Université Pierre et Marie Curie, Université Versailles St-Quentin-en-Yvelines, Centre National de la Recherche Scientifique, Paris, France
[6]Finnish Meteorological Institute (FMI-ARC), Sodankylä, Finland
[7]Federal Office of Meteorology and Climatology (MeteoSwiss), Payerne, Switzerland
[8]European Space Agency (ESA/ESRIN), Frascati, Italy

Correspondence to: A. Keppens (arno.keppens@aeronomie.be)

Abstract. A methodology for the round-robin evaluation and the geophysical validation of ozone profile data retrieved from nadir UV backscatter satellite measurements is de-
ferent recipes are investigated and discussed. Several approaches for information content quantification, vertical resolution estimation, and reference profile resampling are com-
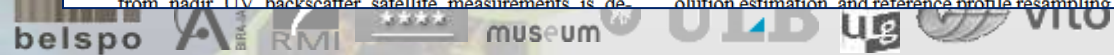
WGCV

CCi ozone

esa

ACC

QA4ECV

CEOS WGCV ACSG / ACC interaction through ESA CCI Ozone

Being implemented in QA4ECV Atmosphere Validation Server (AVS)

Working Group on Calibration and Validation

QA4ECV Report / Deliverable D2.5

QA4ECV

Quality Assurance for Essential Climate Variables

Prototype QA/Validation Service
for Atmospheric ECV Precursors

Detailed Processing Model
Version 2

MACC-II Deliverable D_163.4

Atm
Vali

Date: May 2013
Lead Beneficiary: BIRA-IASB
Nature: R
Dissemination level: PU

Air
Va

Valid
GME
on A

Date: 03/01/201
Version: 1.0
Phase 1, Task
Deliverable D2.

WP Manager
WP Manager
Otherpartne
VALT:
EOST:
CRG:

PROJECT:
SUB-PROJECT / CLUSTER: M
WORK PACKAGE / TASK: M
DELIVERABLE: D_MAN_34

DOSSIE

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Approaches and scopes in EU Climate Services pioneering projects

- QA4ECV Atmosphere list:
  - Heritage CEOS WGCV list proposed to GEO-CEOS Workshop on QA for the GEOSS (Geneva, 2008)
  - Terms and definitions literally from formal sources (e.g., VIM, GUM, ISO TDs, NIST)
  - Initially metrology, remote sensing, monitoring; further enhanced with modelling aspects in MACC
  - Implemented in QA/validation protocols for MACC-I/II, PASODOBLE, Multi-TASTE, CCI…
- FIDUCEO vocabulary (working draft) (www.fiduceo.eu/content/fiduceo-vocabulary)
  - More explanation and interpretation
  - Metrology, data correlation, data harmonization, geo-rectification, …
- GAIA-CLIM
  - Guidance note by NPL: short explanation of general GUM/VIM metrology terms
  - D3.2. Metrology of data comparisons: specialised terms and comparison error budget closure
- CLIPC (http://www.clipc.eu/glossary)
  - Drawn from IPCC Data distribution centre, EUPORIAS project, IS-ENES project (Climate4Impact)

Courtesy next slides: S. Compernolle and S. Niemeier, QA4ECV TR, June 2016

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Consistent definitions! (I guess)

non-negative parameter characterizing the dispersion of the quantity values being attributed to a measurand, based on the information used [VIM]

← VIM/GUM

quantified doubt about the result of a measurement

Guidance note

uncertainty

The GUM defines uncertainty as:
A parameter, associated with the result of a measurement, that characterises the dispersion of the values that could reasonably be attributed to the measurand. Uncertainty is a measure of the spread of the distribution of possible values.

means lack of precision or that the exact value for a given time is not predictable, but it does not usually imply lack of knowledge. Often, the future state of a process may not be predictable, such as a roll with dice, but the probability of finding it in a certain state may be well known (the probability of rolling a six is 1/6, and flipping tails with a coin is 1/2). In climate science, the dice may be loaded, and we may refer to uncertainties even with perfect knowledge of the odds. Uncertainties can be modelled statistically in terms of pdfs, extreme value theory and stochastic

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Inconsistent definitions!
1-2-3 (qualitative term) vs 4 (numerical)
1-2 (any deviation) vs 3-4 (systematic effect only)

VIM/GUM

closeness of agreement between a measured quantity value and a true quantity value of a [measurand] ...tity and it is ...rate when [VIM/GUM]

1

accuracy

closeness of the agreement between measurement result and true value. (Accuracy is a qualitative term only.)

2

Guidance note

3

F|duceo

A qualitative term describing the (lack of) systematic uncertainties. A measurement said to be "higher accuracy" would have smaller uncertainties associated with systematic effects. Note that it is possible to have a high accuracy measurement in the presence of large random effects.

the average distance between a set of measurements and the 'true' value of the object being measured. For climate prediction this can be defined as the average distance between a set of forecasts and an estimate of the observational reference. [Climate4Impact]

4

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18

GCOS accuracy
~ VIM's bias ?

GCOS
(Guideline for the generation of datasets and products meeting GCOS Requirements, 2010)

Measured by the bias or systematic error of the data, i.e. the difference between the short-term average measured value of a variable and the true value. The short-term average is the average of a sufficient number of successive measurements of the variable under identical conditions, such that the random error is negligible relative to the systematic error. The latter can be introduced by instrument biases or through the choice of remote sensing retrieval schemes.

GCOS accuracy
~ VIM/GUM's total uncertainty ?

GCOS
(Systematic observation requirements for satellite-based data products for climate, 2011 update)

The user requirement for accuracy is a requirement for **closeness of agreement between product values and true values**. As true values are unknown, users are provided in practice with product values that are estimates of true values, and producers may also provide **estimates of the uncertainties** of their product values. Product uncertainty may also be assessed by users' own validation activities or by independent evaluation of available products. Each approach has its merits and each is encouraged.

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Next steps (ongoing):

- Tentative harmonization between EU H2020 projects

- Propagation of standard terminology at working level (QA4ECV, NDACC WGs, CCI-ozone/GHG, O3M-SAF, S-5p MPC…)

- Questionnaire to QA4ECV ECV producers (NO_2, HCHO, CO) on terminology, traceability chains, calculation of uncertainties

- Audit of responses to this QA4ECV questionnaire

- Effects of non-linearities in error calculation

- Uncertainties on SI2N ozone profile trend assessments (single-/multi-mission, L2/L3, unsmoothed/smoothed…)

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Mission Exploration Platform (MEP) PROBA-V

http://proba-v-mep.esa.int

- ESA pathfinder project
- Operational platform hosted by VITO; big data and standards TRASYS, SPACEBEL
- Engaged third-party projects and users
- Data: SPOT-VEGETATION (1998) till present PROBA-V
- Also MERIS and AVHRR
- Also <u>correlative data</u> needed for Cal/Val and derived products
- Tools/libraries/applications
- Pre-release 2016, iterations 2016-2018

Consortium partners

Working Group on Calibration and Validation

Belgian Science Policy Office (BELSPO) / Federal Scientific Institutes (FSIs)

II. Background information

Jean-Christopher Lambert

Royal Belgian Institute for Space Aeronomy (IASB-BIRA)

Agency Reports I

WGCV Plenary # 41

Tokyo, September 5-8, 2016

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