A missing term in ground-based satellite validation: Spatiotemporal mismatch quantified

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Data comparisons as the cornerstone of satellite validation

\[ |m_1 - m_2| < \sqrt{u_1^2 + u_2^2} \]

Ground-based Reference

\[ m_1/u_1 \]
Measurement
Raw measurement
Système International standard

Validation

\[ m_2/u_2 \]
Measurement
Raw measurement
Système International standard

Traceability
FRM4DOAS
FRM4GHG

Satellite

Traceability?

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ATMOSPHERIC COMPOSITION VALIDATION AND EVOLUTION
GOME/ERS-2 (nadir scattered UV-Vis) satellite data (GODFITv3 retrievals) co-located with the SAOZ (zenith scattered UV-Vis) ground-instrument installed at Dumont d’Urville, Antarctica (latest LATMOS processing)

Consistency check example

Mean diff: 0.20%; RMSE: 6.43 %
Consistency check example

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Ground-based validation: spatiotemporal mismatch

\[ |m_1 - m_2| < \sqrt{\sigma^2 + u_1^2 + u_2^2} \]

\[ \Delta_{\text{sat-gnd}} = \varepsilon_{\text{sat}} - \varepsilon_{\text{gnd}} + \varepsilon_{\text{smoothing diff}} + \varepsilon_{\text{spatial sampling mismatch}} + \varepsilon_{\text{temporal sampling mismatch}} \]
The Multi-TASTE validation system

VERSATILE QA/VALIDATION SYSTEM

CORRELATIVE DATABASE
- Satellites
- Networks
- Campaigns
- DA / CTM

QUALITY INDICATORS
- Selection
- Co-locator
- Harmonisation
- Comparator
- Reporting

VALIDATION SIMULATOR OSSMOSE
- Measurement Simulator
- Observing Systems Simulator
- Comparison Simulator
- Error Budget Closure Simulator

USER REQUIREMENTS

QA / VAL REQUIREMENTS

VERIFICATION CHAIN MULTI-TASTE

Translation

QA4ECV QA System Validation protocols

SAFETY & SERVICES
- Research & development
- Satellite validation
- Algorithm evolution
- Scientific assessments

ATMOSPHERIC COMPOSITION VALIDATION AND EVOLUTION
The Multi-TASTE validation system: the OSSSMOSE component

VERSTABLE QA/VALIDATION SYSTEM

CORRELATIVE DATABASE
- Satellites
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VALIDATION SIMULATOR
- OSSSMOSE
  - Measurement Simulator
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  - Comparator Simulator
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VALIDATION CHAIN
- MULTI-TASTE
  - Selection
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QA / VAL requirements

Translation

User requirements

Science & Services
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QA4EO VIM Metrology GUM ISO Standards

Sentinels-2/S
TROPOMI
MetOp OMPS
Aura Envisat
ACE Odin SAGE
UARS ...

GAW
NdACC TCCON
SHADOZ ESRL
EVD C AVDC ...

CINDI-2
AROMAT
ACVT SAUNA
EC Campaigns ...

ERA-I
CAMS-IFS
MERRA BASCHE
OSSSMOSE: Observing System of Systems Simulator for Multi-missiOn Synergies Exploration

- Multi-dimensional observation operators
  - Multi-D Averaging Kernels
  - 4-D airmass parametrization
  - Balloon trajectories
  - ...

- High resolution atmospheric fields library
  - ERA-Interim
  - CAMS
  - MERRA(-2)
  - BASCOE

Observing systems metadata library
- ESA
- EUMETSAT
- NASA
- NDACC
- SHADOZ
- GAW

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ATMOSPHERIC COMPOSITION VALIDATION AND EVOLUTION
Illustrations: GOME-2/MetOp vs. ZSL-DOAS TOC at Harestua (60°N)

Co-location at Harestua, 23-Dec-2007

- Station zenith: 309.6 DU
- ZSL-DOAS footprint: 299.0 DU
- GOME-2A pixel: 305.6 DU
- GOME-2A full footprint: 302.2 DU
Error budget at Dumont d’Urville (66.7°S):
GOME-2A (GODFITv3) vs. NDACC SAOZ (LATMOSv2)

Verhoelst et al., AMT v8, 2015
Illustrations: Ozone profile validation

Spatio-temporal mismatch issues: satellite vertical and horizontal resolution versus sonde vertical resolution and sonde drift; imperfect co-location

(*) TROPOMI ATBD: Table 7.1 in S5P-KNMI-L2-0004-RP, issue 0.13.0

Verhoelst et al., in prep.
Illustrations: Representativeness of the ground network for zonal monthly mean validation

Total ozone column measuring network (Brewers, Dobson and ZSL-DOAS)

From Coldewey-Egbers et al., 2015
Conclusions and prospects

- Spatio-temporal variability of several atmospheric variables is significant at the scale and precision of many of today’s observing systems.
- Combined with the specific sampling and smoothing properties of the observing systems, this may cause both random and systematic errors (in data and in their comparison).
- Variability associated errors depend obviously on location, time-of-year, peculiar atmospheric states, ancillary conditions...
- OSSEs based on advanced 3D observation operators and high-resolution gridded fields are able to capture and quantify these errors.
- OSSSMOSE system and TOC results published (Verhoelst et al., AMT v8, 2015); profile results and other studies published soon.
- OSSSMOSE tools and results support accurate CDR validations (CCI, QA4ECV) and are being implemented in the GAIA-CLIM Virtual Observatory and QA4ECV Atmosphere ECV Validation Server (C3S pioneering projects).