GAIA-CLIM

Response to FIDUCEO remarks on metrological uncertainties

September 28th 2016

Peter Thorne and Tijl Verhoelst

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 640276.

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Outline

- FIDUCEO have covered the metrological characterisation of families of sensors, including their harmonization
- We shall cover:
  - Metrology of a comparison with ground-based reference measurements
  - Quantification of irreducible co-location uncertainty effects

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Toy example of underlying concepts

A lidar – red points

A satellite – black line

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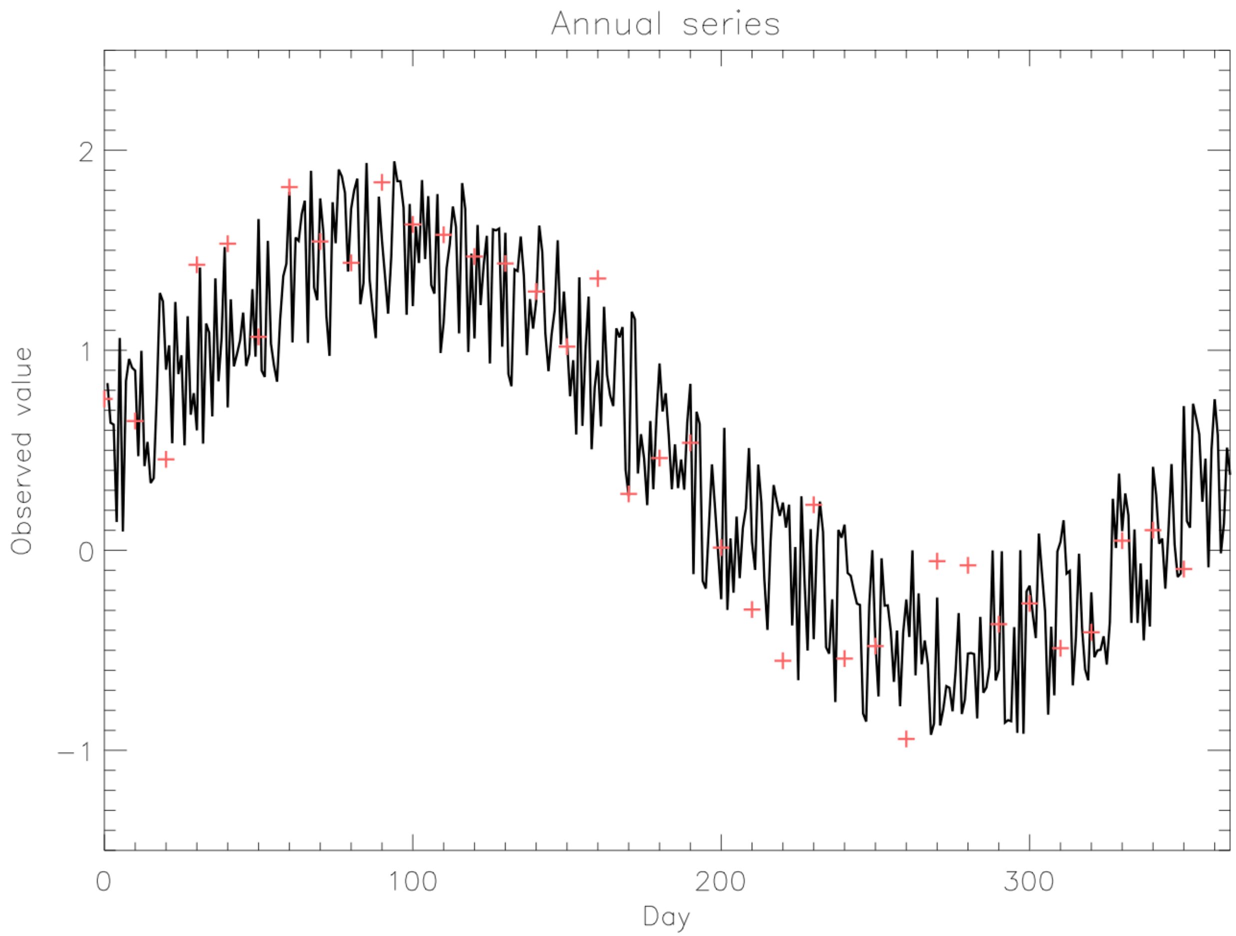
Toy example series



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Measurement A /= Measurement B

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Focus on *reference* in-situ observations

A reference observation is defined as having the following characteristics:

- ✓ Is traceable to an SI unit or an accepted standard
- ✓ Provides a comprehensive uncertainty analysis
- ✓ Is documented in accessible literature
- ✓ Is validated (e.g. by inter-comparison or redundant observations)
- ✓ Includes complete meta data description

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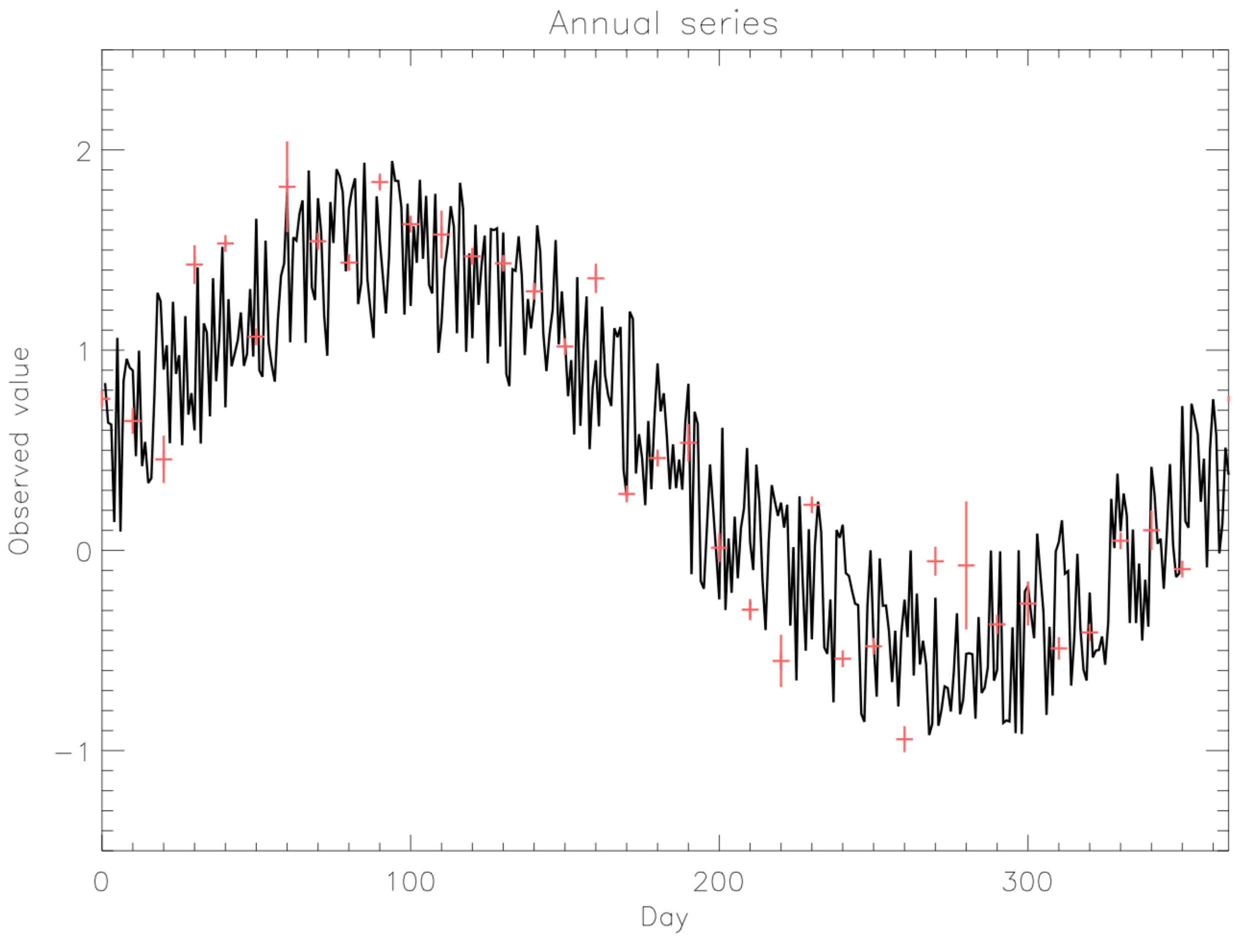
Lidar measurements with uncertainties



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But what about the satellite?

- In the absence of other information a useful test is whether the satellite is performing within design build specification …
- But I'd rather be using FIduceo

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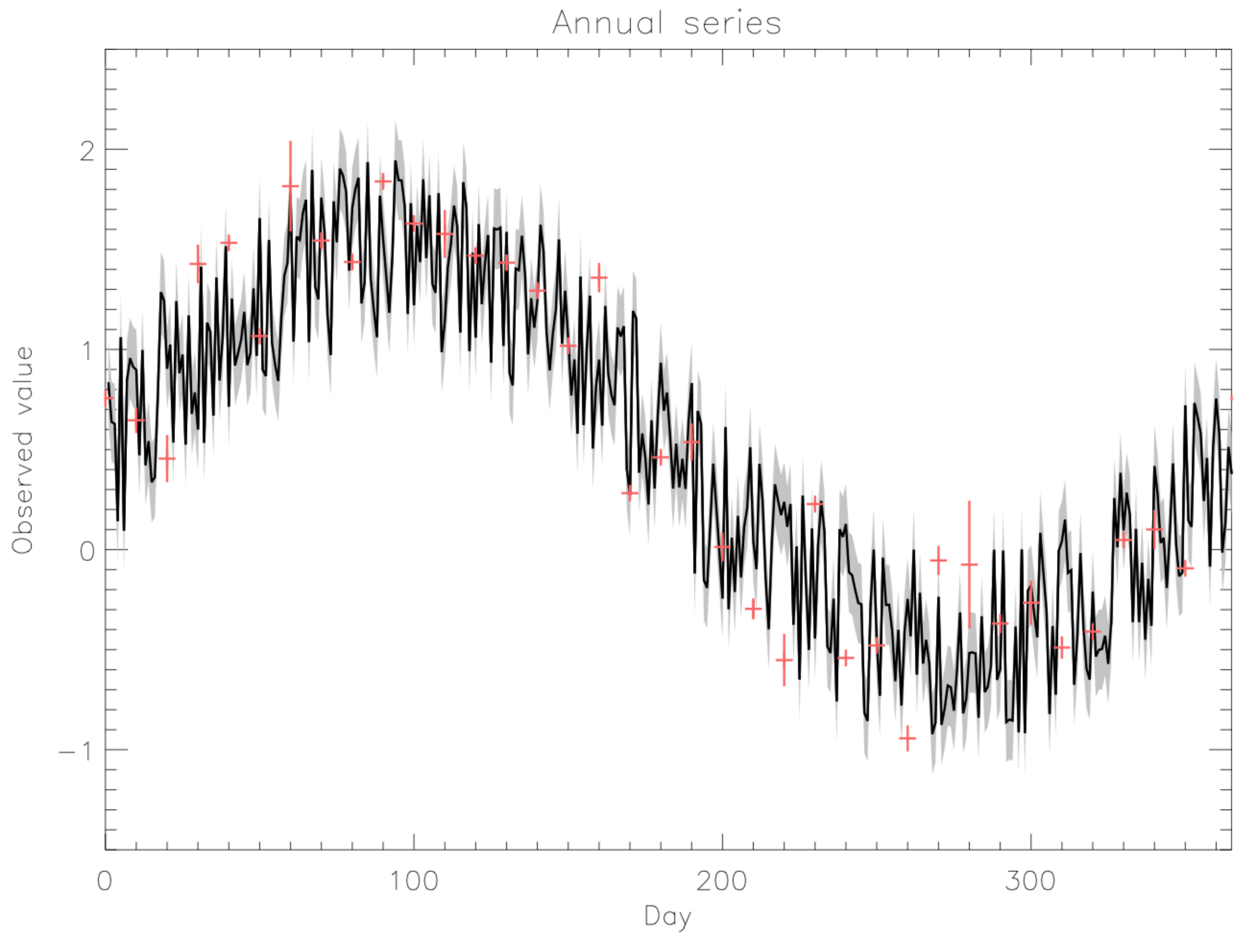
Satellite measurements with design specification ranges



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Consistency for perfectly co-located measures

- Reference quality in-situ (m1) and satellite measurements (m2) should be consistent:

$$|m_1 - m_2| < k\sqrt{u_1^2 + u_2^2}$$

  - ✓ No meaningful consistency analysis possible without uncertainties
  - ✓ if m_2 has no uncertainties use u_2 = satellite instrument specification

$\|m_1 - m_2\| < k\sqrt{u_1^2 + u_2^2}$	TRUE	FALSE	significance level
k=1	consistent	suspicious	32%
k=2	in agreement	significantly different	4.5%
k=3	-	inconsistent	0.27%

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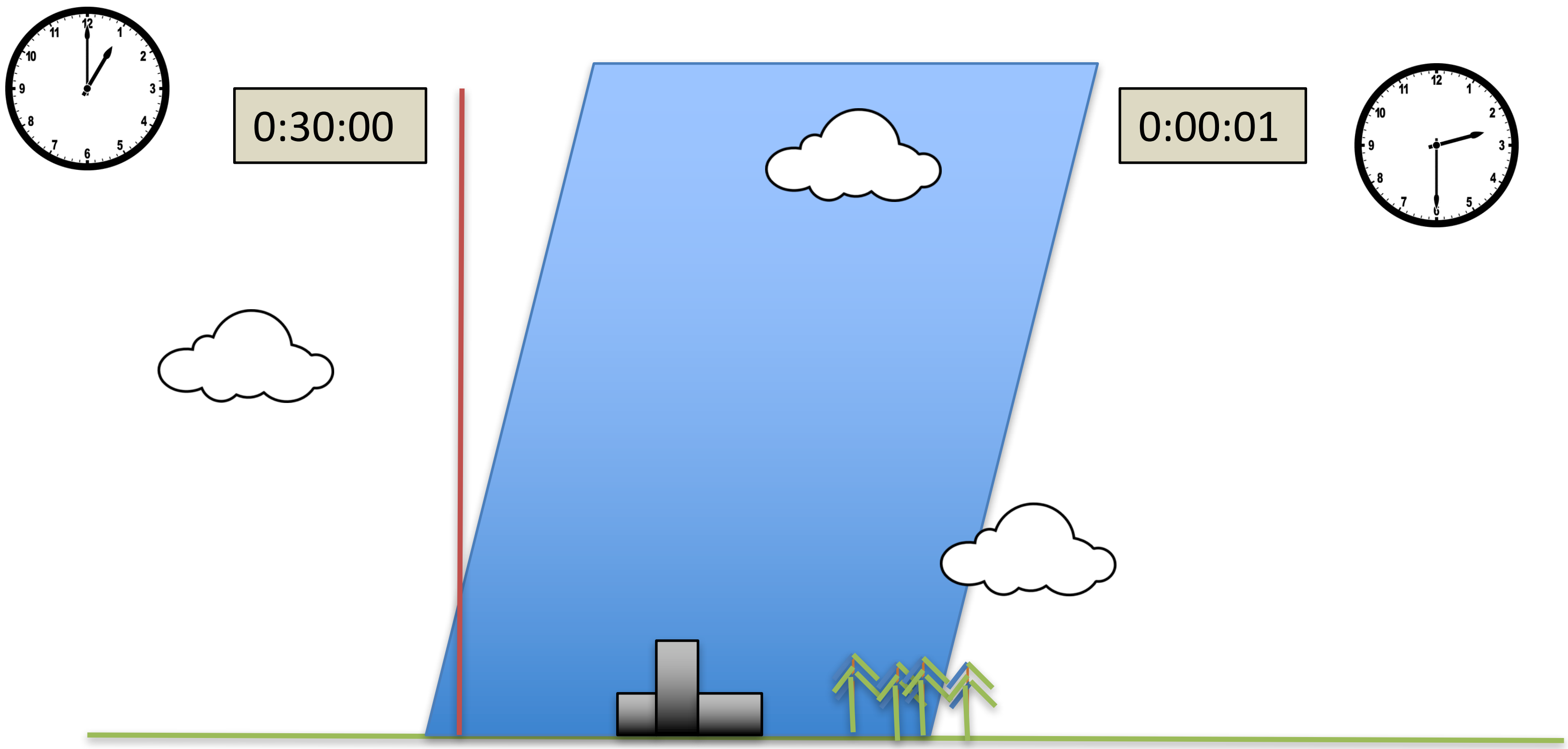
Co-location uncertainties



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Consistency in a finite atmospheric region

- Co-location / co-incidence matters and inflates the expected difference
- Determine the variability (σ) of a variable (m) in time and space from measurements or models
- Two observations on different platforms are consistent if

$$|m_1 - m_2| < k\sqrt{\sigma^2 + u_1^2 + u_2^2}$$

✓ We need to either minimize σ so that $\sigma << \sqrt{u_1^2 + u_2^2}$ or quantify σ so that it can be included in the above test.

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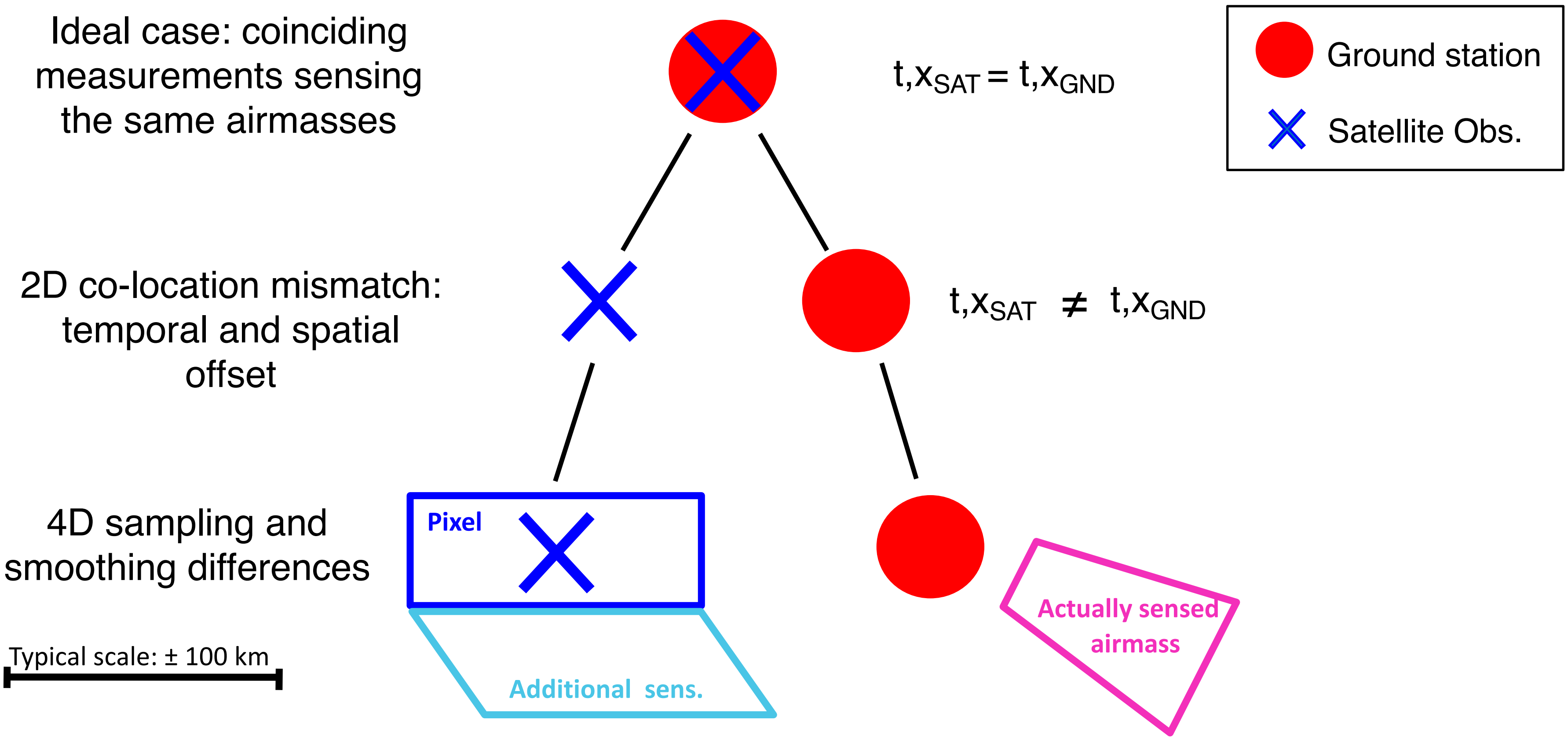
Metrology of a comparison



Cfr. **GAIA-CLIM D3.2**: *"Generic metrology aspects of an atmospheric composition measurement and of data comparisons"*

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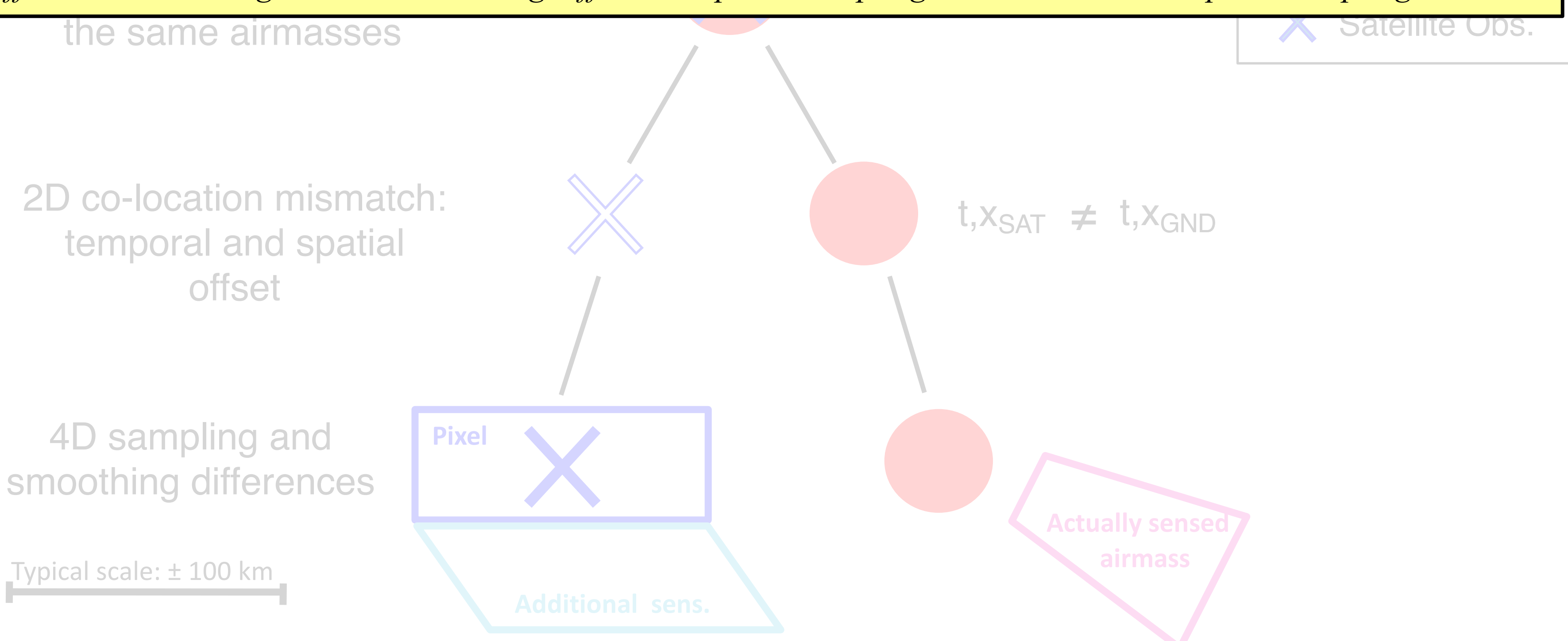
Metrology of a comparison

The uncertainty budget of a comparison:

$$\sigma^2_{diff} = u^2_{sat} + u^2_{gnd} + \sigma^2_{smoothing\ diff} + \sigma^2_{spatial\ sampling\ mismatch} + \sigma^2_{temporal\ sampling\ mismatch}$$



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What about correlations?

Are we sure the PDFs are Gaussian?

Uncertainty domain -> error domain (VIM/GUM terminology)

The error budget of a comparison:

$$\Delta_{sat-gnd} = \varepsilon_{sat} - \varepsilon_{gnd} + \varepsilon_{smoothing\ diff} + \varepsilon_{spatial\ sampling\ mismatch} + \varepsilon_{temporal\ sampling\ mismatch}$$

Random draws from PDFs with stdev u_{sat} and u_{gnd}

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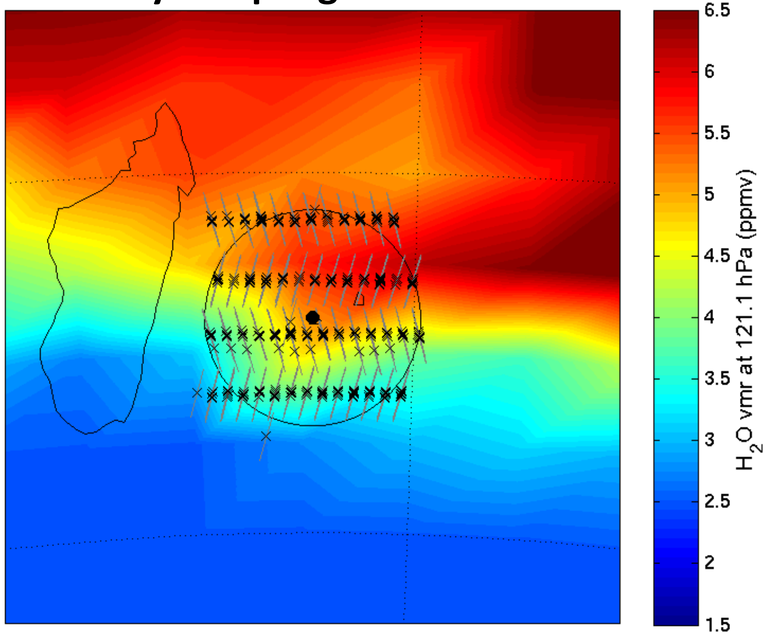
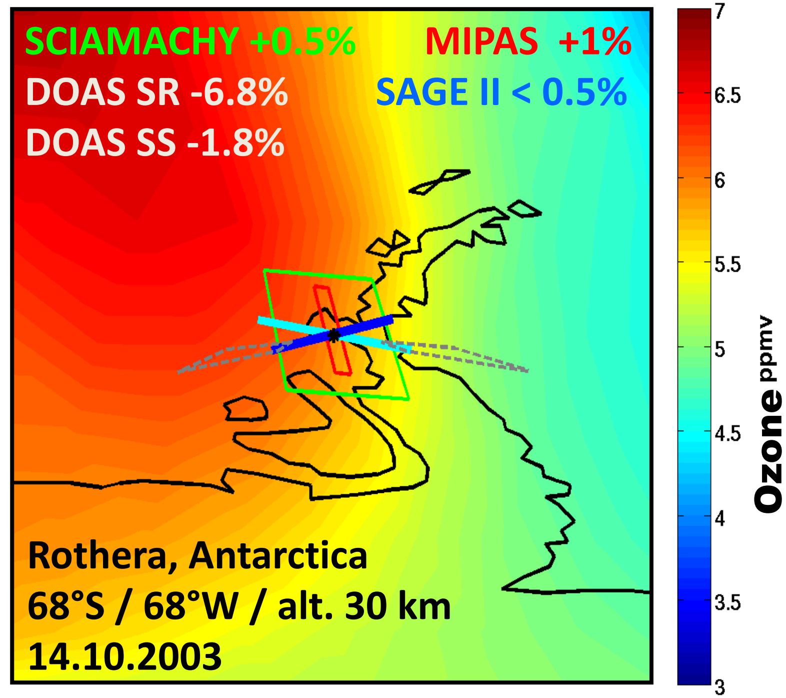
Sampling and smoothing differences

MIPAS daily sampling around Reunion Island



Lambert et al, ISSI Book on Atmospheric Water Vapour, Chapter 10, 2012



Vandenbussche et al., Lambert et al., GEOmon TNs, 2011

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Minimizing and quantifying co-location mismatch

Minimizing mismatch through airmass matching (e.g. QA4ECV validation server):

- Using observation operators
- Using back- and forward trajectories
- Using auxiliary data (e.g. PV difference constraints)

Quantifying mismatch (WP3 of GAIA-CLIM)

- Quality Indicators as a function of spatiotemporal separation
- Statistical (heteroskedastic) modelling to separate measurement from mismatch uncertainties
- **Observing System Simulation Experiments** (OSSEs) to decompose the comparison error budget

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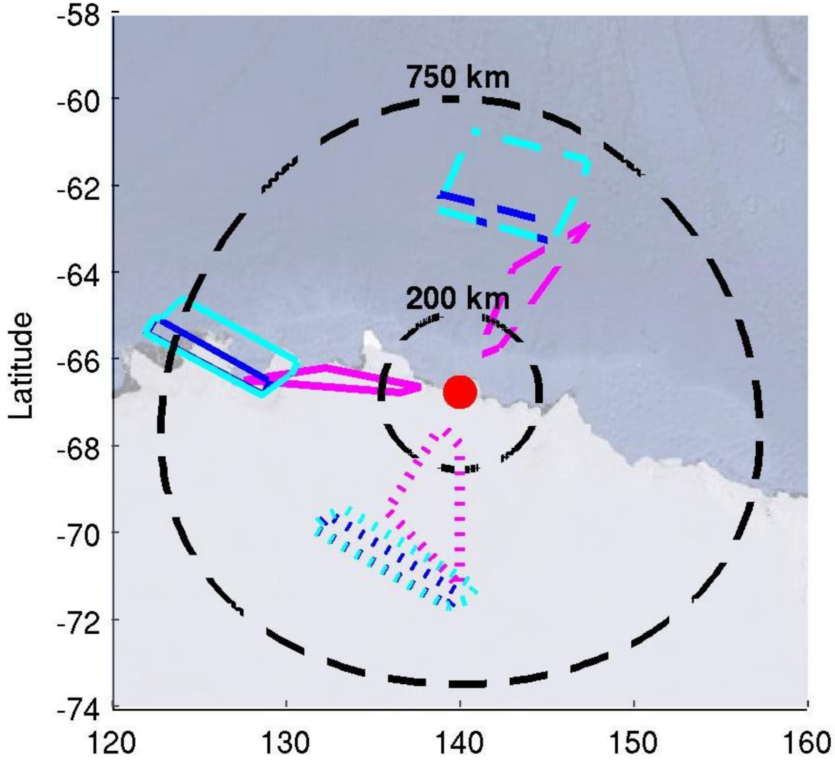
A real-world case study: total ozone column comparisons

GOME/ERS-2 vs. NDACC SAOZ at Dumont d'Urville (67°S)



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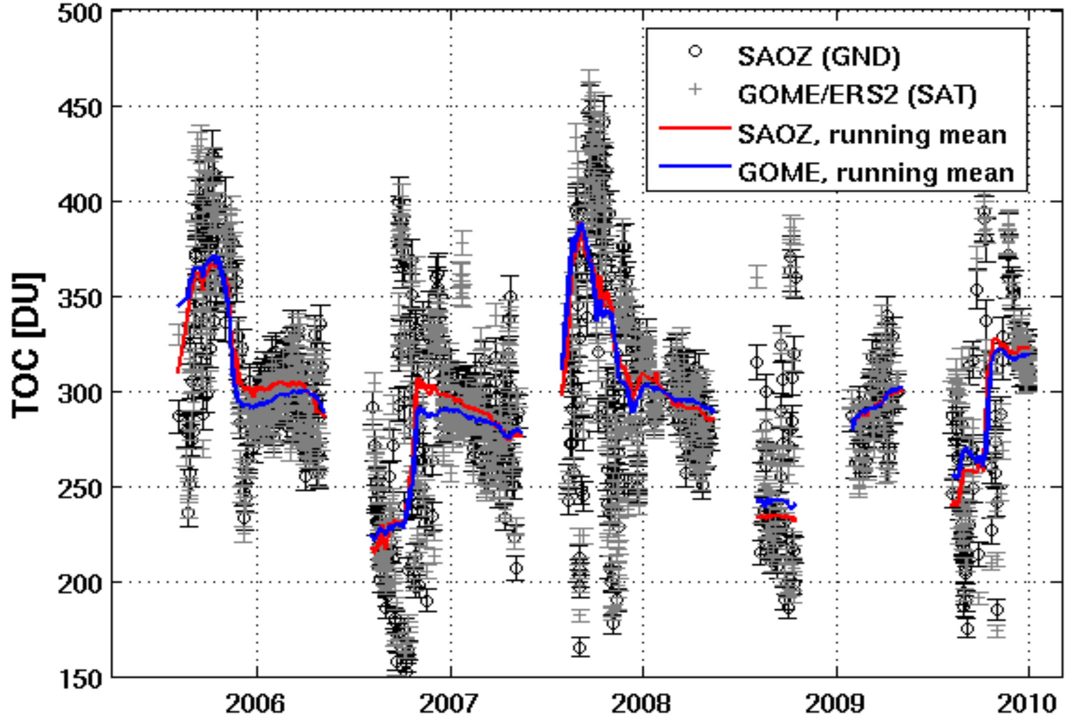

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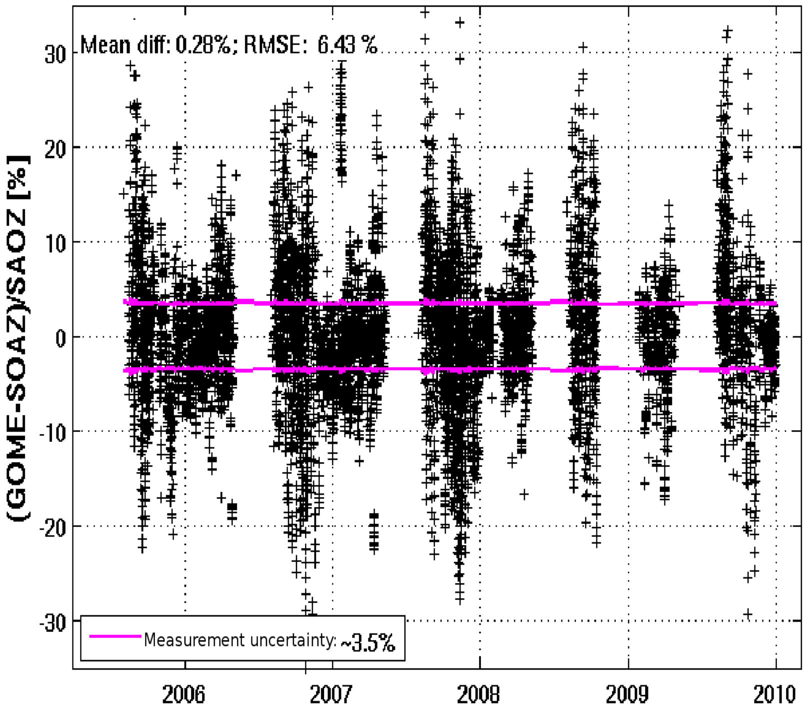

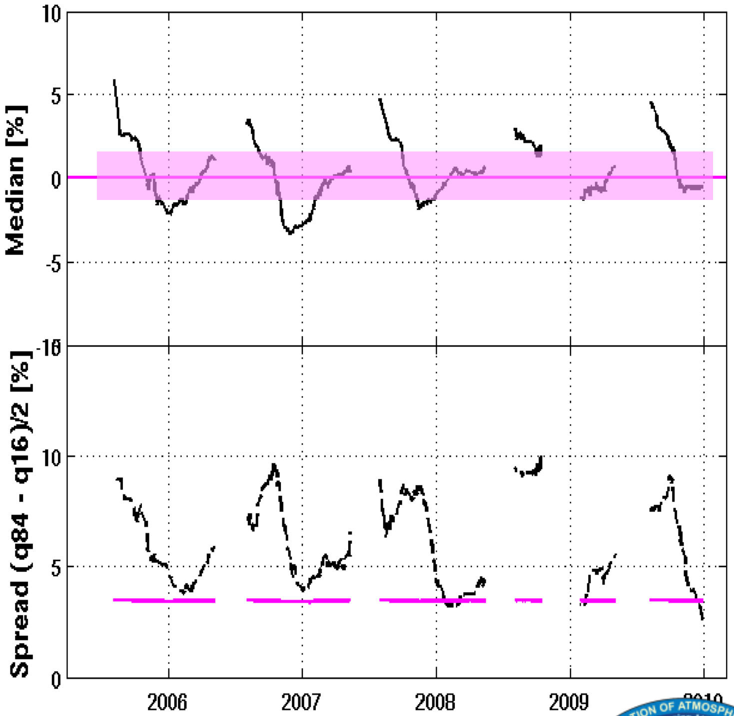

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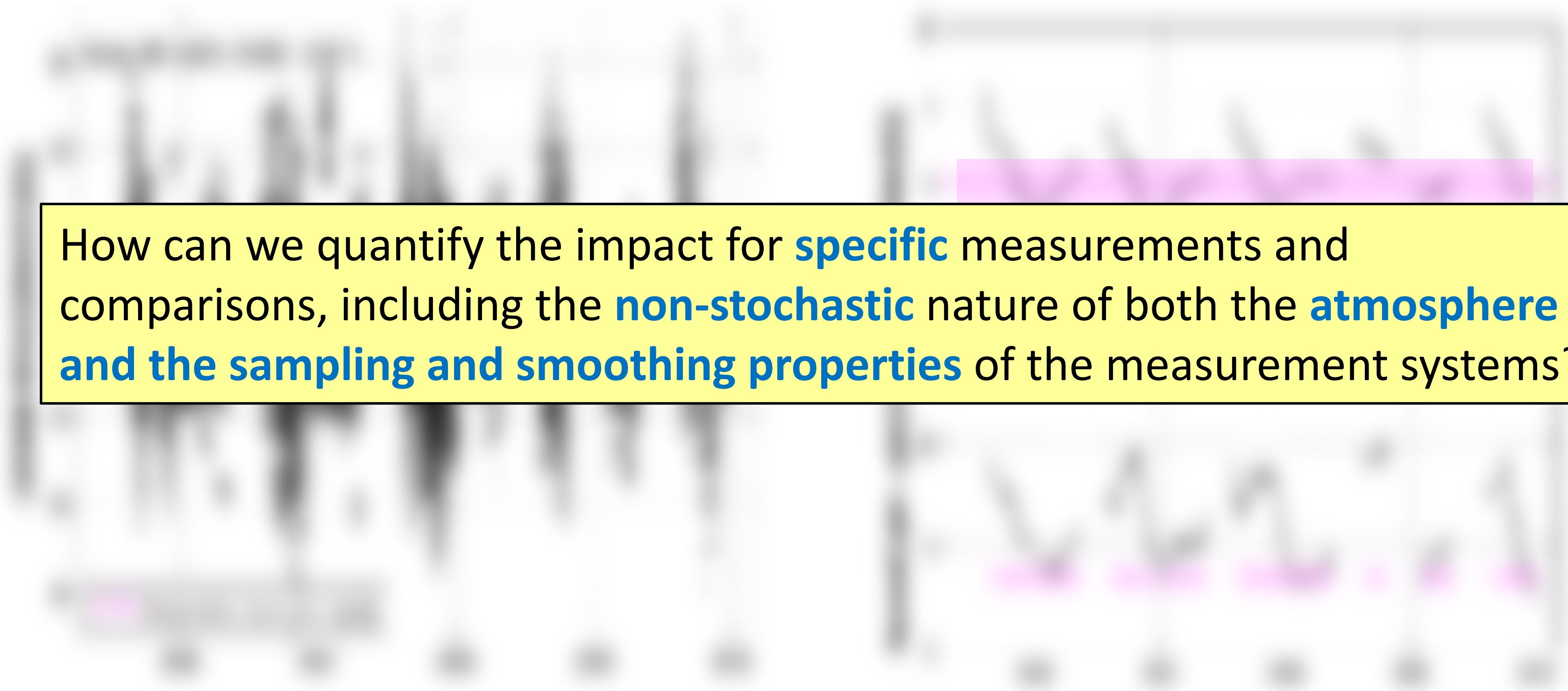

How can we quantify the impact for **specific** measurements and comparisons, including the **non-stochastic** nature of both the **atmosphere and the sampling and smoothing properties** of the measurement systems?

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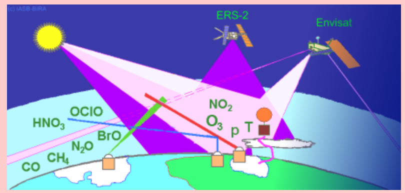
The OSSSMOSE system

Observing systems metadata library

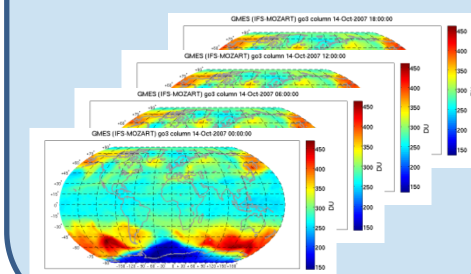


Multi-dimensional observation operators

- Multi-D Averaging Kernels
- 4-D airmass parametrization
- Balloon trajectories
- …

- ERA-Interim
- CAMS
- MERRA(-2)
- BASCOE

High resolution atmospheric fields library



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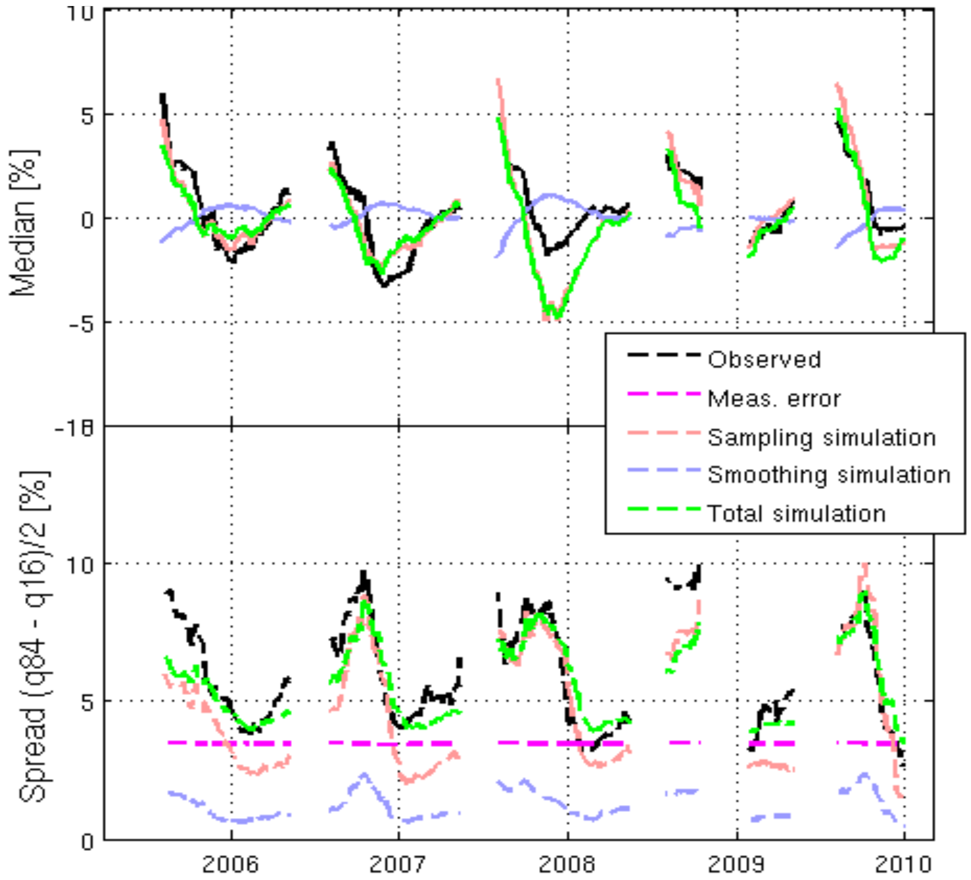

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Atmos. Meas. Tech., 8, 5039–5062, 2015
www.atmos-meas-tech.net/8/5039/2015/
doi:10.5194/amt-8-5039-2015

Atmospheric Measurement Techniques
Open Access

Metrology of ground-based satellite validation: co-location mismatch and smoothing issues of total ozone comparisons

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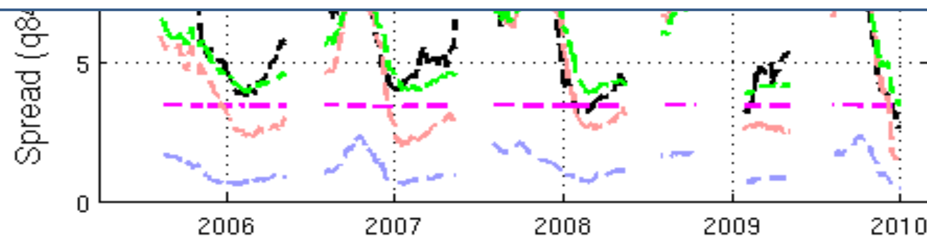

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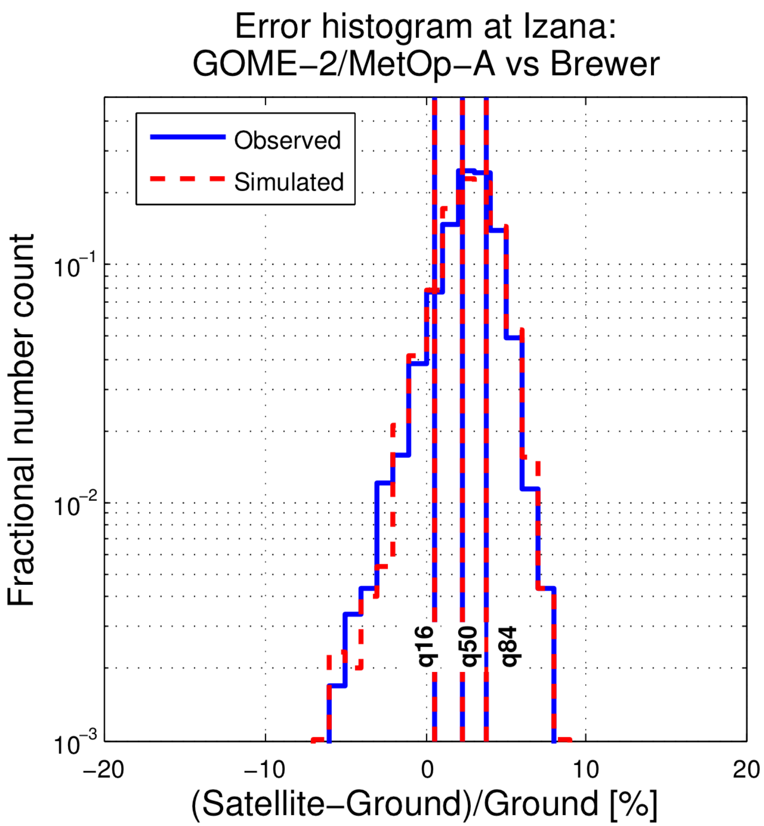

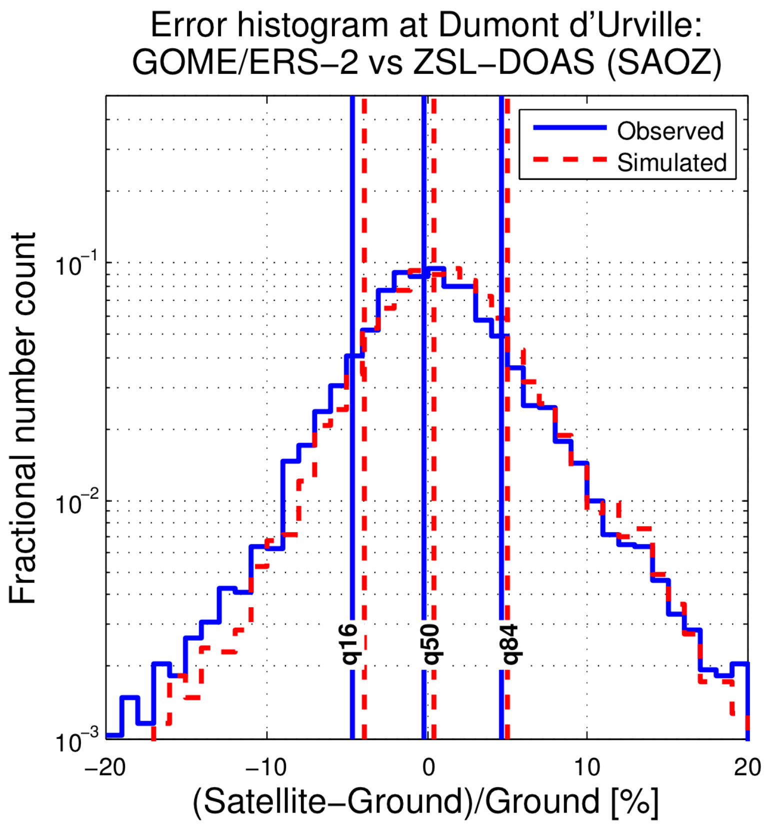

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Operationalization for Copernicus

- Implementation in C3S precursors (tools, recommendations, documentation):
  - GAIA-CLIM Virtual Observatory
  - ESA CCI, EUMETSAT O3M-SAF
  - Multi-TASTE multi-mission validation system

- Implementation in Copernicus Space Segment:
  - EUMETSAT O3M-SAF
  - S5p MPC VDAF

- Transfer of knowledge to the community through S[&]T HARP tools

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