Plenary #2: How do we present uncertainties?

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Outline

- What is uncertainty and why present it?
- Different layers for different users
- Which uncertainties?
- Visualizing uncertainties
- Consistency tests using the uncertainties

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What is uncertainty and why present it?

Measurement uncertainty : non-negative parameter characterizing the dispersion of the quantity values being attributed to a measurand (VIM def. 2.26)

Confidence in Climate Services workshop (10 EU climate-related projects):
"the communication of uncertainty is critical in developing confidence in climate services " + need for "*Transparancy,* ***Layering****, and Disclosure of uncertainty information*" (Otto et al., BAMS, 2016)

Recent emerging SPARC activity: TUNER (Towards UNified ~~Error~~ Reporting)
Uncertainty

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Different layers for different users

Product level →

User level ↓

	Level 1	Level 2	Level 3	Level 4	Climate indicators
Instrument scientist	Detailed metrological uncertainty budget		NA		NA
Validation and research user	Summarized metrological uncertainty budget			NA	NA
Virtual Observatory user	Total uncertainty budget			NA	NA
C3S/CDS user	NA	NA	Total Uncertainty or other high-level confidence indicators		

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Which uncertainties?

- Measurement uncertainty:
  - Type: random, systematic, structured random
  - Source: instrument, retrieval, parameter, model, combined,…
  - Method: repetition, analytical propagation, MC, bootstrapping,…
  - Representation: stdev, variance, covariance matrix, interquantiles, PDF, ensemble,…
- Harmonization uncertainty:
  - Vertical smoothing and/or “a priori” harmonization
  - Unit/quantity conversions (propagation + auxiliary data have uncertainties!)
- “Averaging” uncertainty (L3-type data)
  - Uncertainty on the mean
  - Variance/stdev around the mean (higher order moment)
  - Representativeness uncertainty (non-uniform sampling)
- Co-location uncertainties (excl. dimensions addressed in the harmonization)
  - Smoothing mismatch uncertainties
  - Sampling mismatch uncertainties

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What we should dream of: Full PDFs or ensembles, based on repetition and sophisticated propagation schemes, including all contributions, differentiated by type and source.

Failing that, the best you can do.

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  - Smoothing mismatch uncertainties
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Visualizing uncertainties

Main message: The sky is the limit!

- Individual measurements with error bars (total or different components in different colours)
- Differences* with “combined uncertainty” error bars
- Running statistics on differences (mean, median, stdev, interquantile) versus corresponding uncertainties (mean -> systematic; spread -> random)
- PDF of differences versus PDF of errors
- …

* There exist many different preferences regarding the exact calculation and normalization of the differences. In the context of EO data validation, the **best practice is to look at both absolute differences and differences normalized <u>with the reference</u>**.

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Visualizing uncertainties

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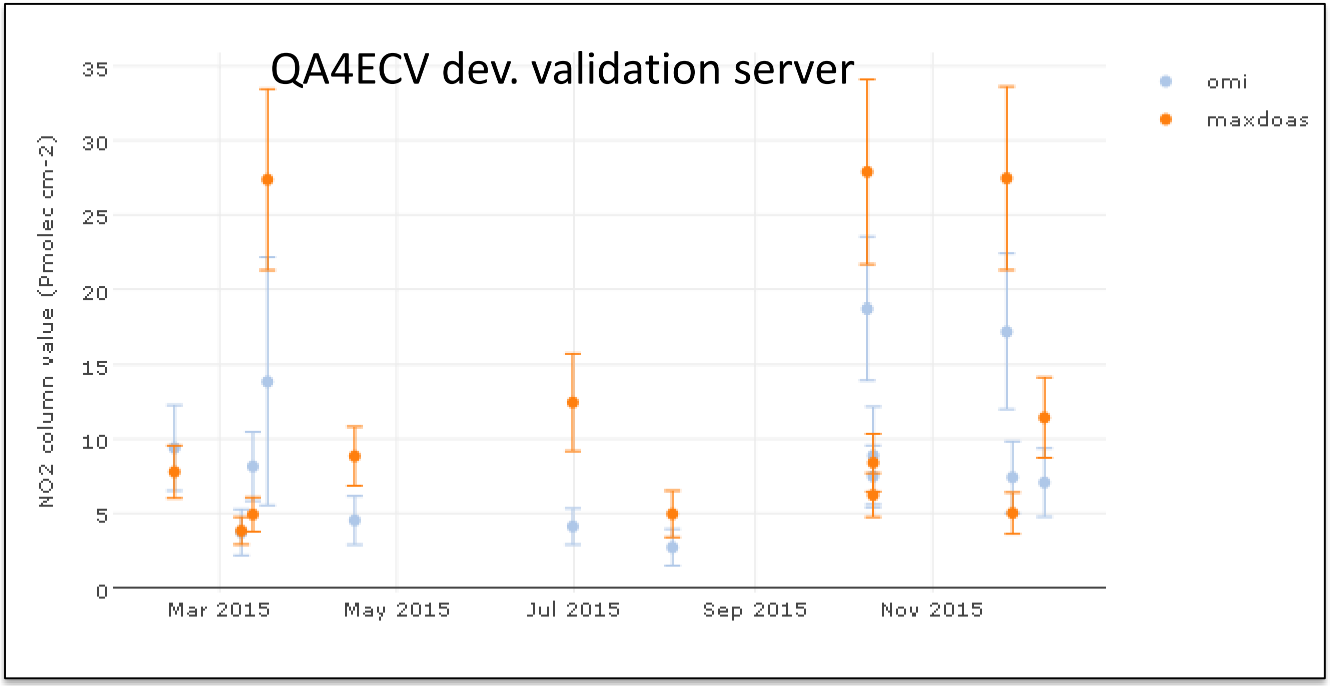

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Visualizing uncertainties

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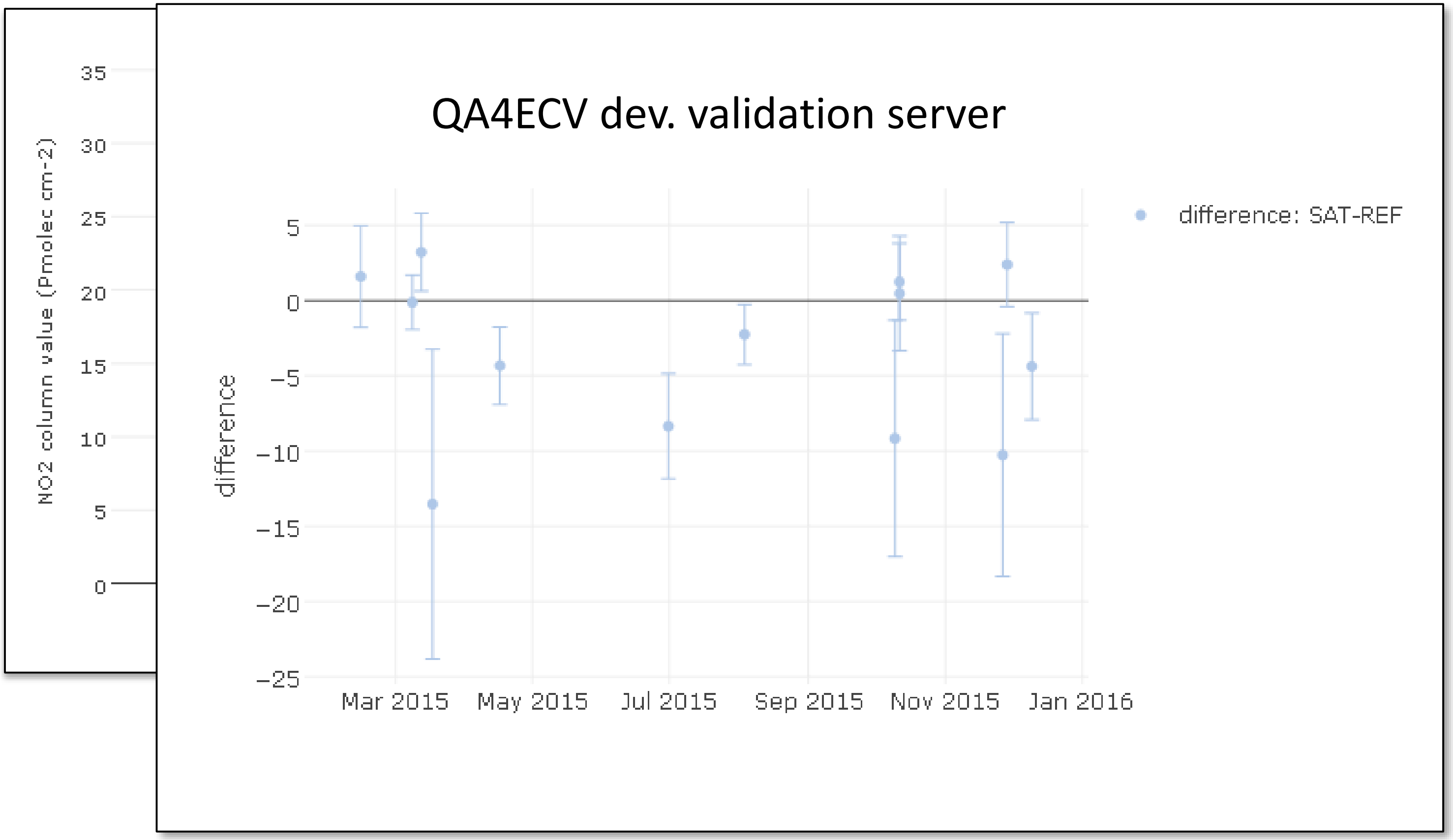

For relative differences, normalize with the reference measurement!

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Visualizing uncertainties

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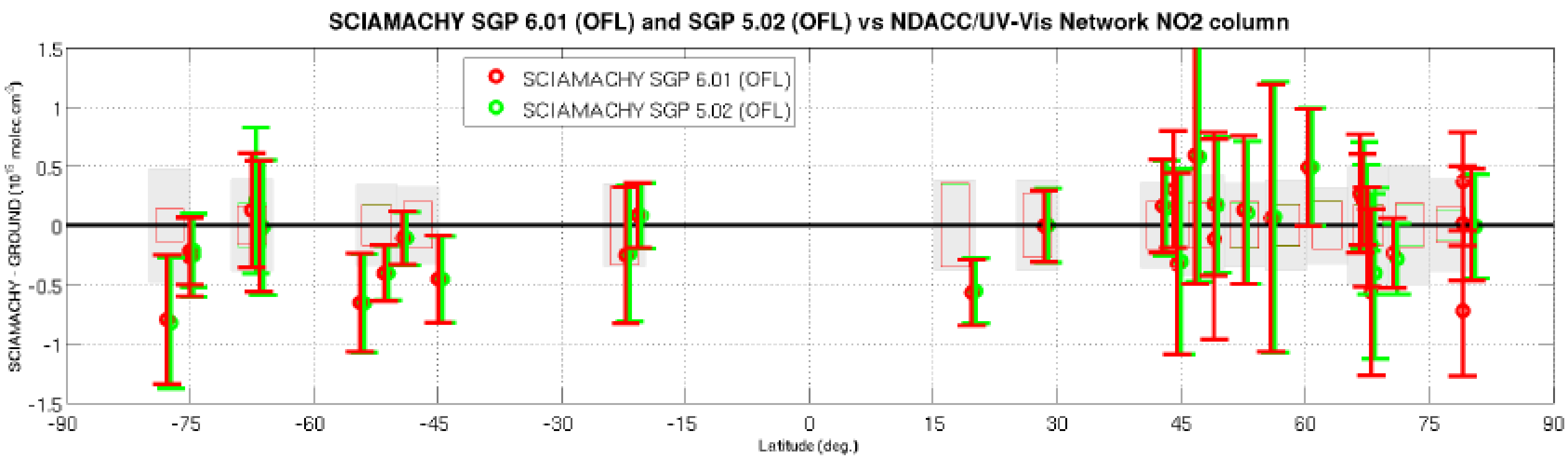

Figure 7: 10-year mean value (bullet) and 1sigma spread (error bar) of the absolute difference between SCIAMACHY SGP and NDACC/UV-visible network NO2 column data, as a function of latitude. SGP 5.02 results are depicted in green and new SGP 6.01 results in red. The shaded area represents the indicative uncertainty of the NDACC/UV-visible NO2 column measurement. Green and red square contours represent the median value of the uncertainty on SCIAMACHY NO2 column data as reported in SGP 5.02 (green) and 6.01 (red) data files, respectively.

From a MultiTASTE Phase F validation report, for ESA by BIRA-IASB (Keppens et al., December 2016)

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Visualizing uncertainties

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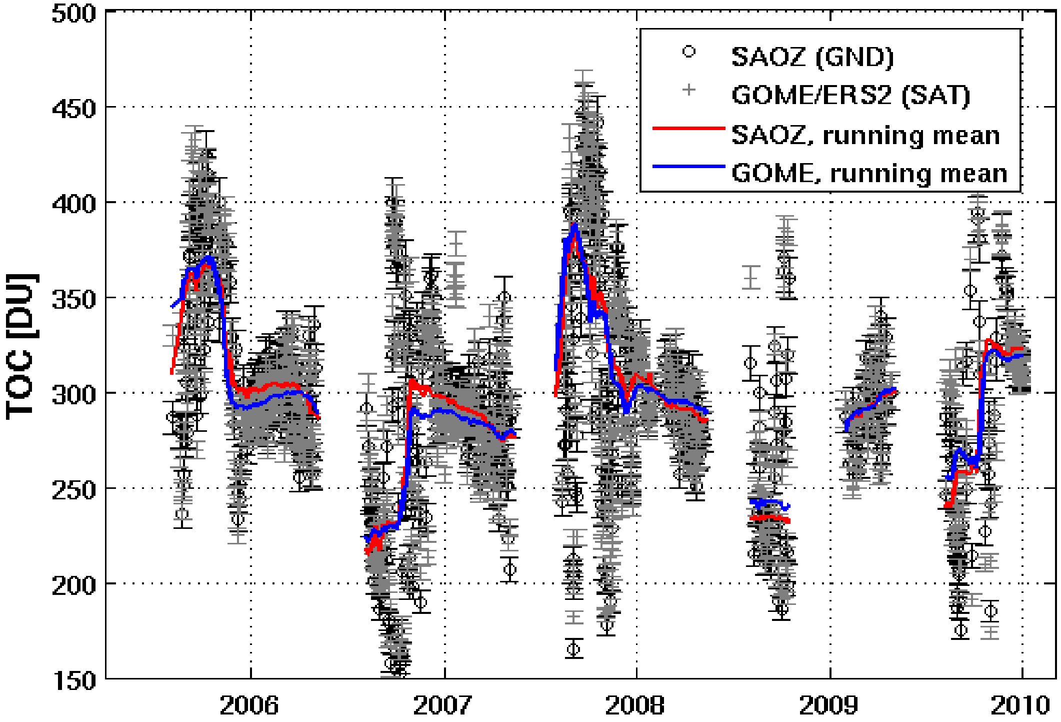

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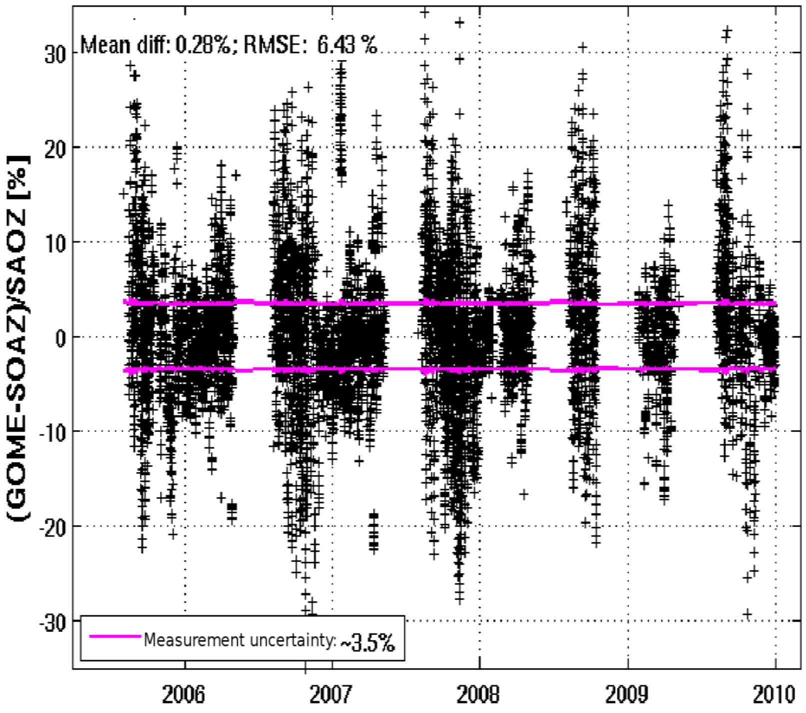

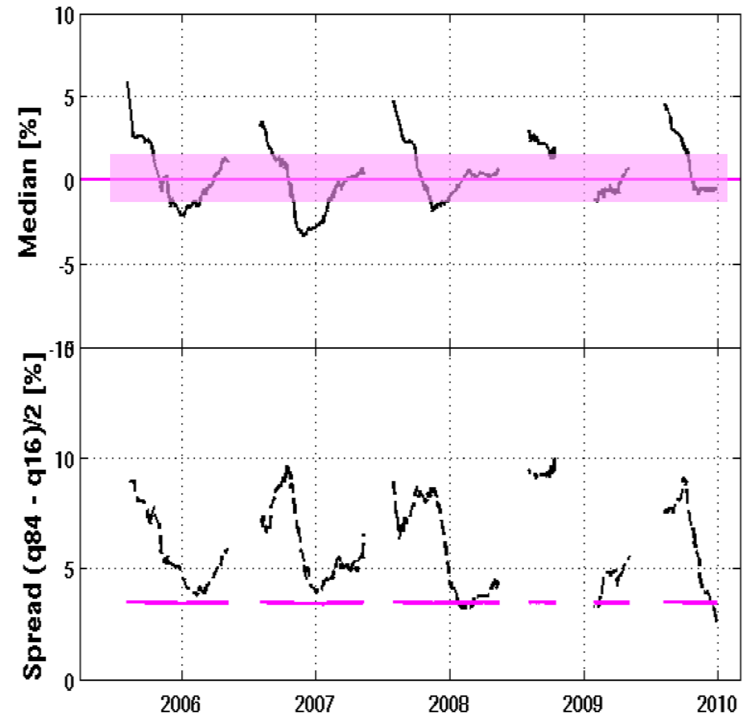

Combined measurement uncertainty (random and/or systematic)

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Visualizing uncertainties

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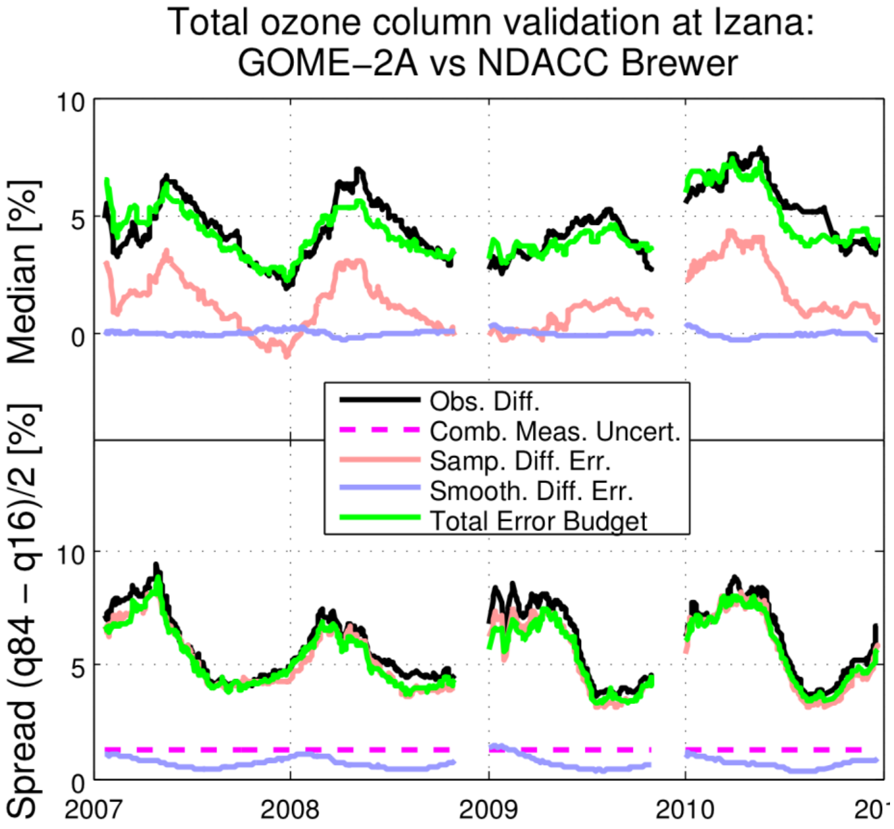

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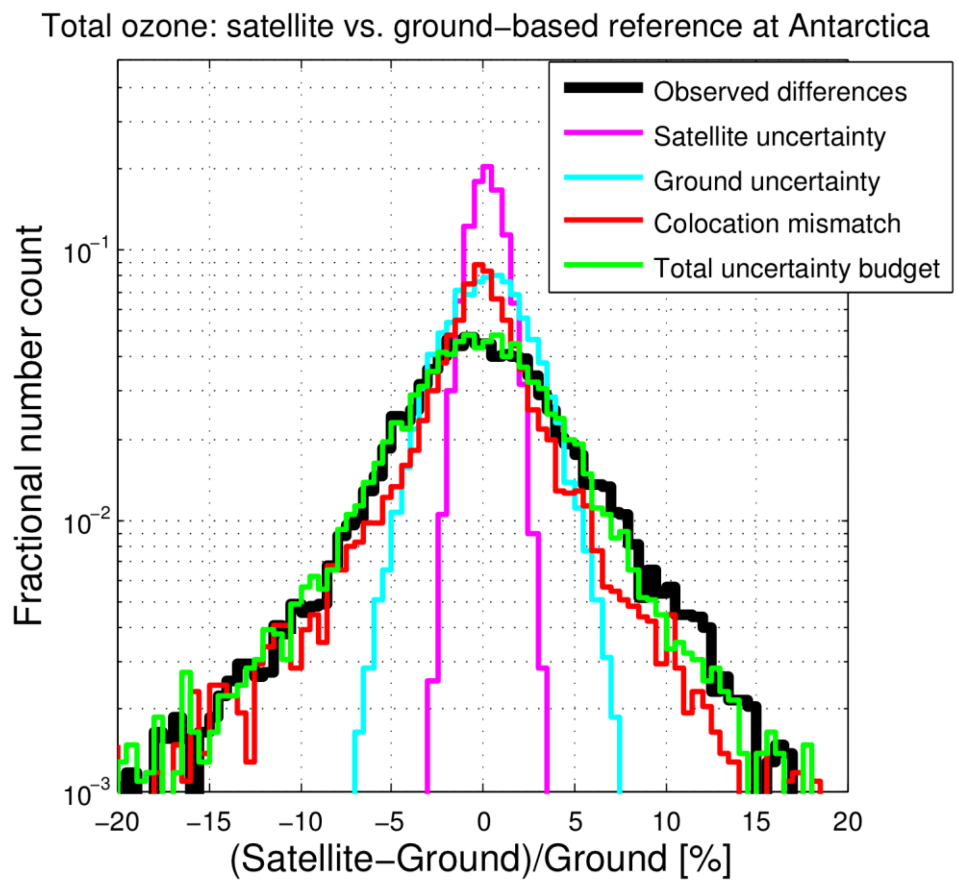

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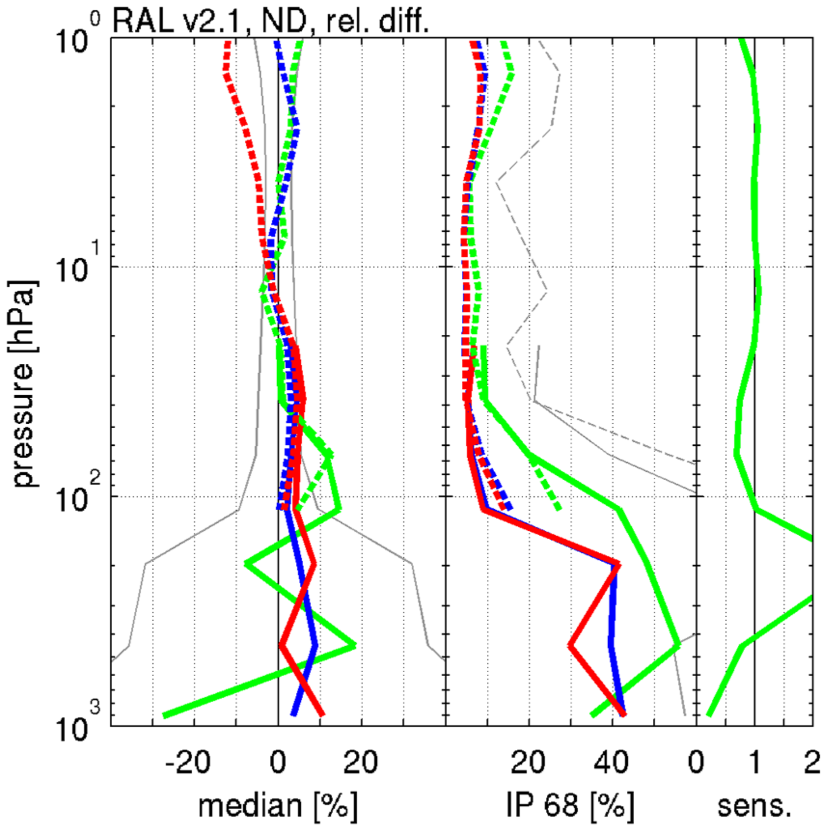

More difficult: integrating covariance matrices

From Keppens et al., AMT v8, 2015

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Consistency tests using the uncertainties

Note: there exist many metrics that do not use the uncertainties: RMSD, correlation coefficients (Pearson's R, Spearman's ρ), rank tests (Kendall's τ),…

I. Compare statistics, as in the figures. E.g.:
   - Mean difference* versus systematic uncertainty,
   - Spread on differences versus random uncertainty.

II. Consistency check as in Immler et al. (2010):

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

III. χ^2-tests (see Rodgers, 2000, Rodgers & Connor, 2003, and von Clarmann,2006)

IV. Other hypothesis tests

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