GAIA-CLIM

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27/4/18

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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GAIA-CLIM key objectives

From call (paraphrased):

- Improve the utility of non-space component to characterize the satellite comnponent of EO
- Develop tools and techniques
- Provide advice on what next steps are required.

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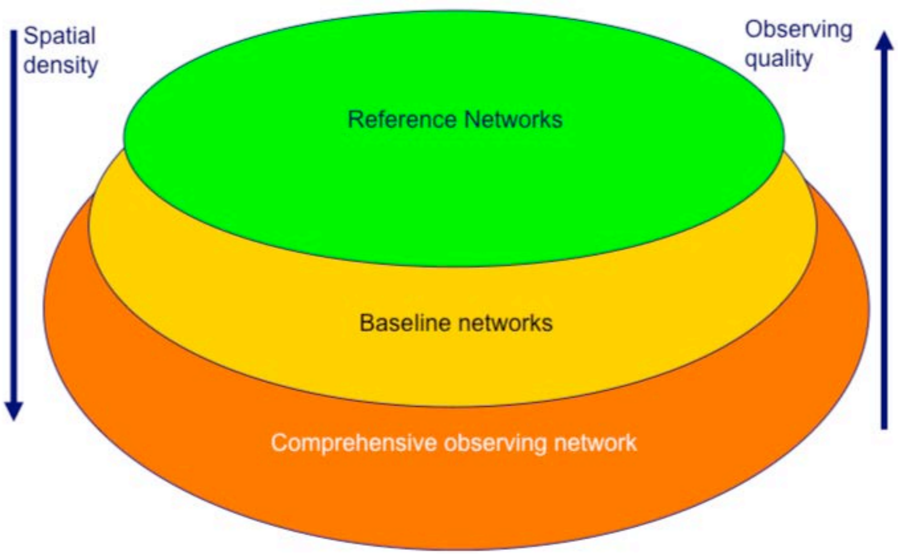
System of systems approach

Key innovation – a defensible means to assign to tiers

Published in peer review literature

Disseminated to WMO and used in subsequent H2020 INTAROS



NDACC

Metadata	Documentation	Uncertainty characterization	Public access, feedback and update	Usage	Sustainability	Software (optional)
Standards	Formal Description of Measurement Methodology	Traceability	Access	Research	Siting environment	Coding standards
Collection level	Formal Validation Report	Comparability	User feedback mechanism	Public and commercial exploitation	Scientific and expert support	Software documentation
File level	Formal Measurement Series User Guidance	Uncertainty Quantification	Updates to record		Programmatic support	Portability and numerical reproducibility
		Routine Quality Management	Version control			Security
			Long term data preservation			

Legend

1	2	3	4	5	6	Not applicable

The assessment carried out above was performed under the auspices of GAIA-CLIM ,http://www.gaia-clim.eu/page/maturity-matrix-assessment, in September 2016. It assesses certain quantifiable aspects of typical measurement system maturity across the network for those ECVs and associated measurement systems that are relevant to GAIA-CLIM (www.gaia-clim.eu).
Users should be aware that this is a first effort to systematically quantify measurement system performance. Redundant assessments suggest a minimum uncertainty arising from assessor-to-assessor variations in any category of at least 1 score. Although the assessment may be useful to use-case applications at this time and until more broadly tested it should not constitute a primary decision-making tool.

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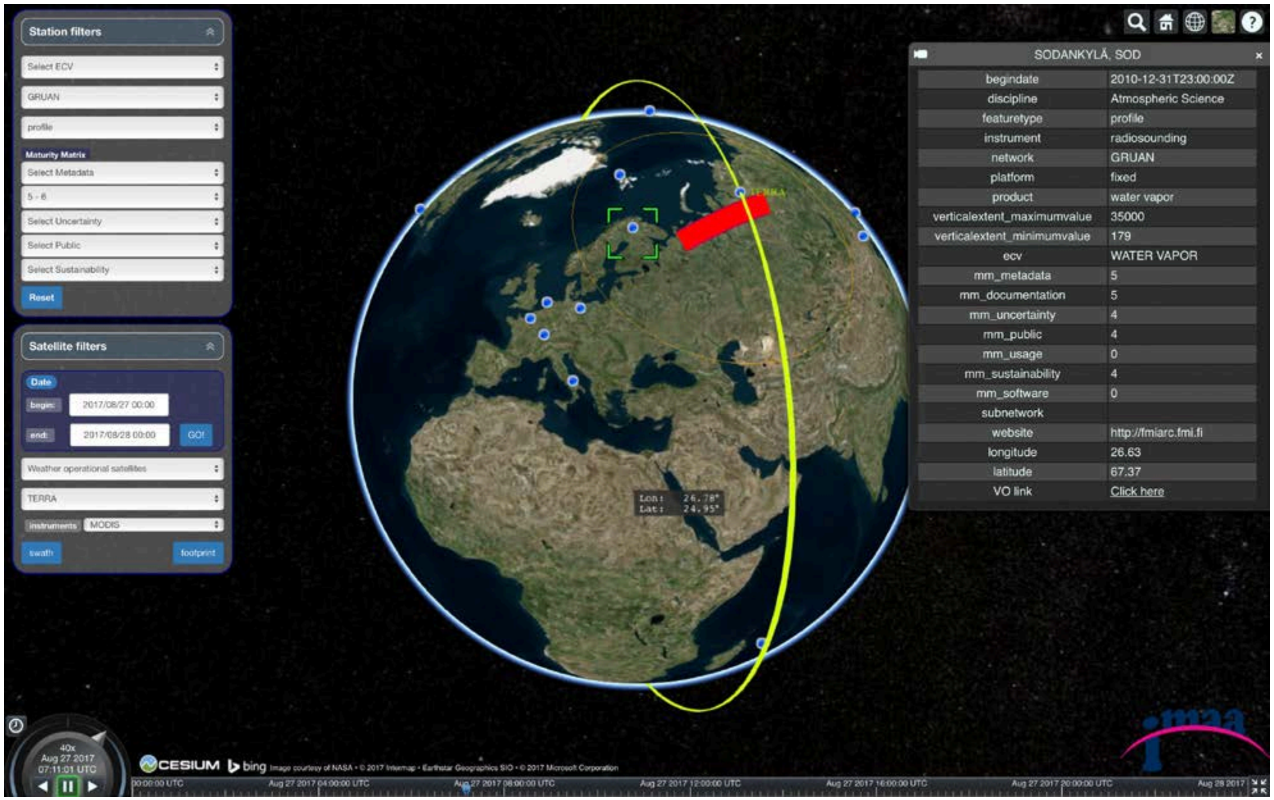
Visualisation of measurement metadata



Metadata visualization tool shall be maintained by CNR

The underlying metadata has been shared with WMO to help populate OSCAR Surface database

The collected metadata is key input to C3S 311a Lot 3 led by GAIA-CLIM partners

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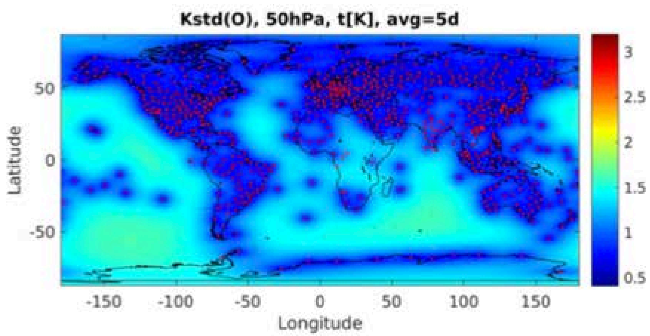
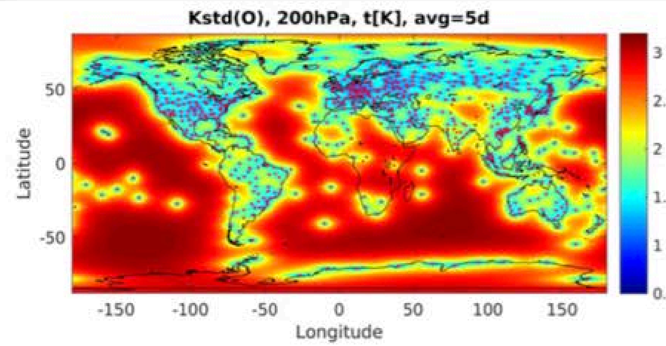
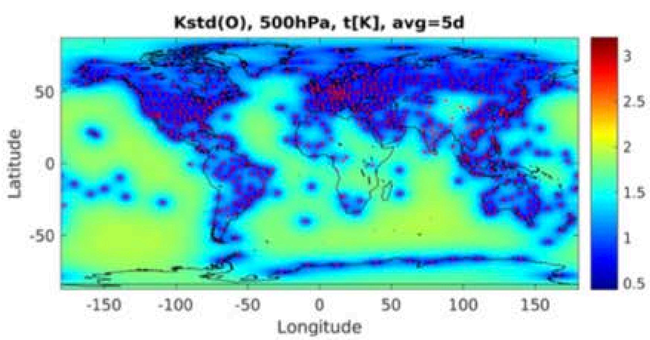
Better understanding of where missing non-satellite observations are limiting

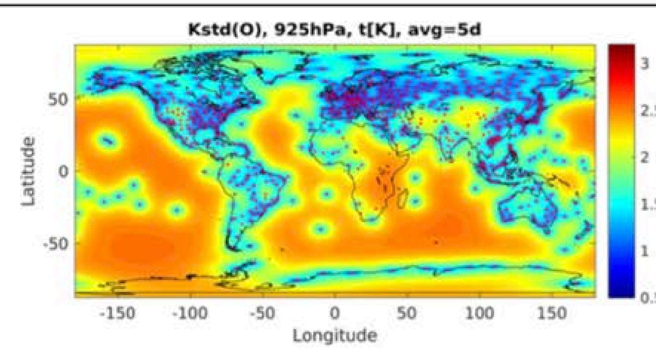
50 hPa: 0.4-1.6K	200 hPa: 0.7-3.2K





500 hPa: 0.4-1.9K	925 hPa: 0.7-2.5K





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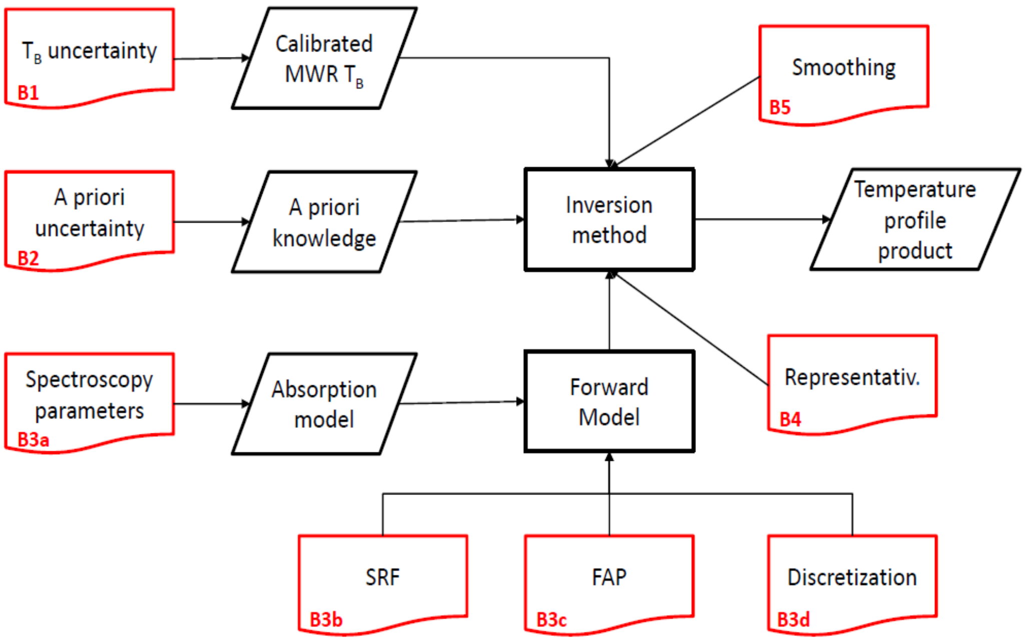
Improved metrological understanding

MWR temperature profile product



For six measurement techniques substantive progress towards metrologically traceable fiducial reference quality measurements.

Working with QA4ECV and FIDUCEO within a common framework that should allow interoperability

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PTU documents

- Provide a consistently structured documentation of understanding across diverse measurement techniques
  - Could be extended to other techniques and e.g. the ESA FRM program

- Highlight where further work and investigation are warranted

- All PTU documents we produced are hosted on the project website. Open to a much more long-term solution if felt useful.

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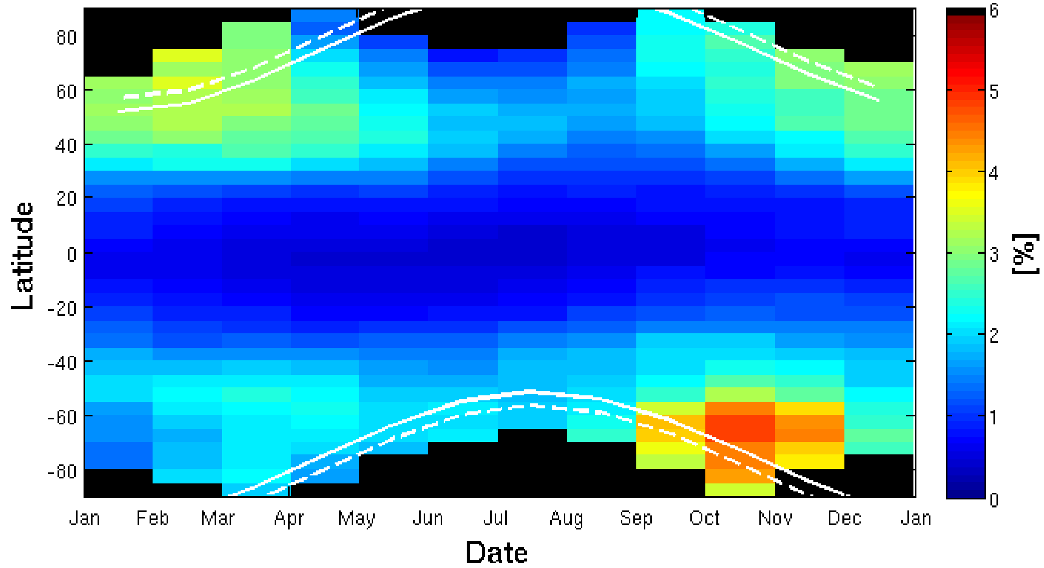
Improved understanding of co-location effects

Spread on smoothing errors (a.k.a. smoothing uncertainty) for sunset ZSL-DOAS obs.



Use of statistical and modelling based approaches to better understand all facets of sampling mis-match in space and time.

A set of look-up tables produced.

Work towards an operational provision would be possible in future

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Characterisation of biases in satellite observations using Numerical Weather Prediction

$$|m_{obs} - m_{NWP}| < k\sqrt{\sigma^2 + u_{obs}^2 + u_{NWP}^2}$$

with

$$u_{NWP} = f(u(x_{NWP}), u(z, z'), u(H), u(\Delta x), u(cloud))$$

Uncertainties in RT modelling
- Line-by-line to fast model
- Spectroscopic uncertainty
- Surface emissivity

Uncertainties due to scale mismatch
- Observation scale ≠ model scale
- Natural scale << obs and model

Uncertainties due to residual cloud after screening

Uncertainties in NWP T, q mapped to brightness temperature
- Estimate from NWP-GRUAN

Uncertainties due to vertical interpolation
- GRUAN processor

Addressed with the GRUAN Processor:

- Collocate GRUAN radiosondes and NWP fields
- Simulate satellite observations in radiance space
- Propagate GRUAN uncertainty in radiance space

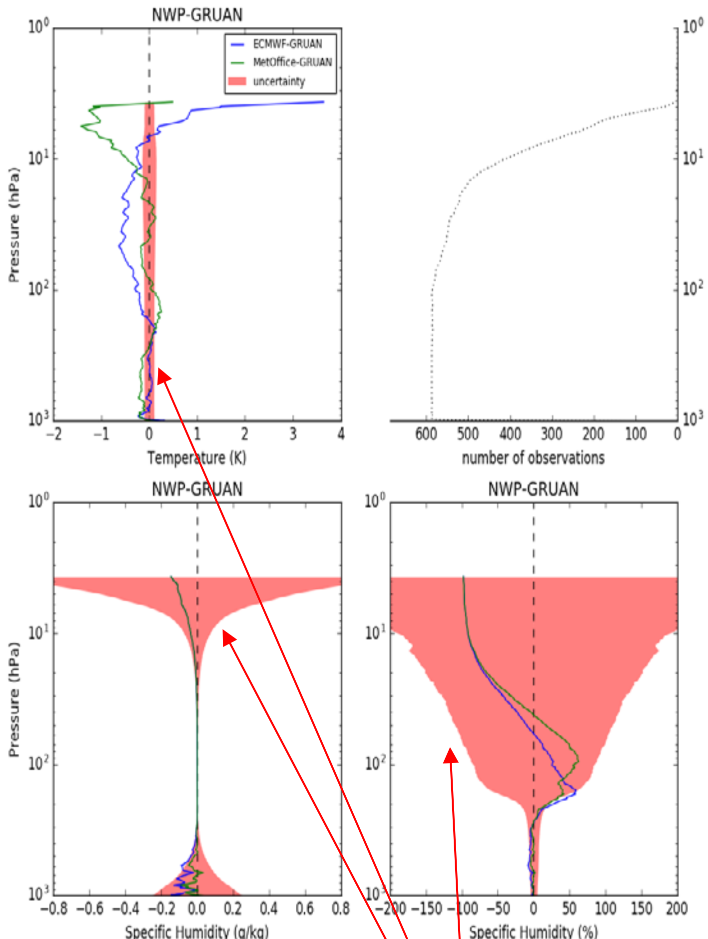
Addressed in the mathematical framework that come along with the GRUAN Processor:

- Estimation of the total uncertainty budget of the comparison NWP-GRUAN
- Statistically assess the comparison

The GRUAN Processor

Observation space

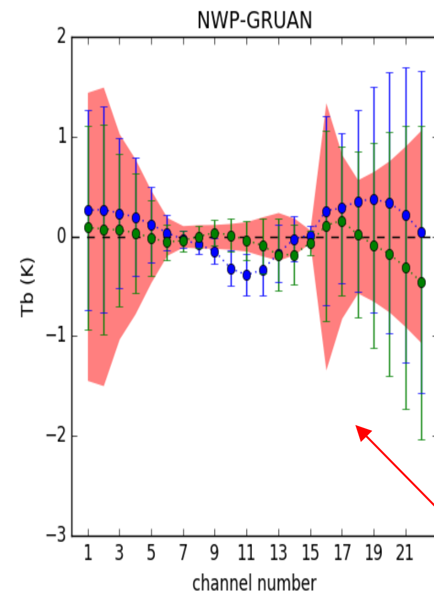
588 GRUAN profiles from Lindenberg, Germany, 2016, night-time



uncertainty from RS92-GDP

Radiance space

Tb simulated at ATMS channel frequencies



uncertainty from RS92-GDP (P, RH, T) propagated in radiance space

At temperature sensitive frequencies (channels 8-12), the difference is smaller than 0.1K (Met Office) and 0.4K (ECMWF).

At humidity sensitive frequencies (channels 18-22), the difference is smaller than 0.5K (Met Office) and 0.4K (ECMWF).

Uncertainty budget

For the NWP-GRUAN comparison in radiance space noted:

$$\delta \boldsymbol{y} \equiv \boldsymbol{y}_{NWP} - \boldsymbol{y}_{GRUAN}$$

We estimate the covariance of the comparison as follows:

$$\boldsymbol{S}_{\delta y} \equiv cov(\delta \boldsymbol{y}) \cong \boldsymbol{H}\boldsymbol{R}_{GRUAN}\boldsymbol{H}^T + \boldsymbol{H}\boldsymbol{W}\boldsymbol{B}_{NWP}\boldsymbol{W}^T\boldsymbol{H}^T + \boldsymbol{H}\boldsymbol{S}_{int}\boldsymbol{H}^T$$

Parameter derivatives (RTTOV Jacobians), provided in Processor output

GRUAN covariance matrix, defined as:

$$\boldsymbol{R}_{GRUAN} = diag(\boldsymbol{H}\boldsymbol{\varepsilon}_{GRUAN}\boldsymbol{H}^T + \boldsymbol{H}\boldsymbol{\varepsilon}_{GRUAN}^{surf})$$

where ε_{GRUAN} is the GRUAN uncertainty profiles (T, RH, P), and ε^{surf} is the uncertainty in surface measurement (0.15K, 0.04 RH, and 0.1hPa according to S. Brickmann, DWD)

Model covariance matrix, can use the operational matrix (not provided) or can be estimated (method in the paper)

Interpolation matrix, provided in Processor output

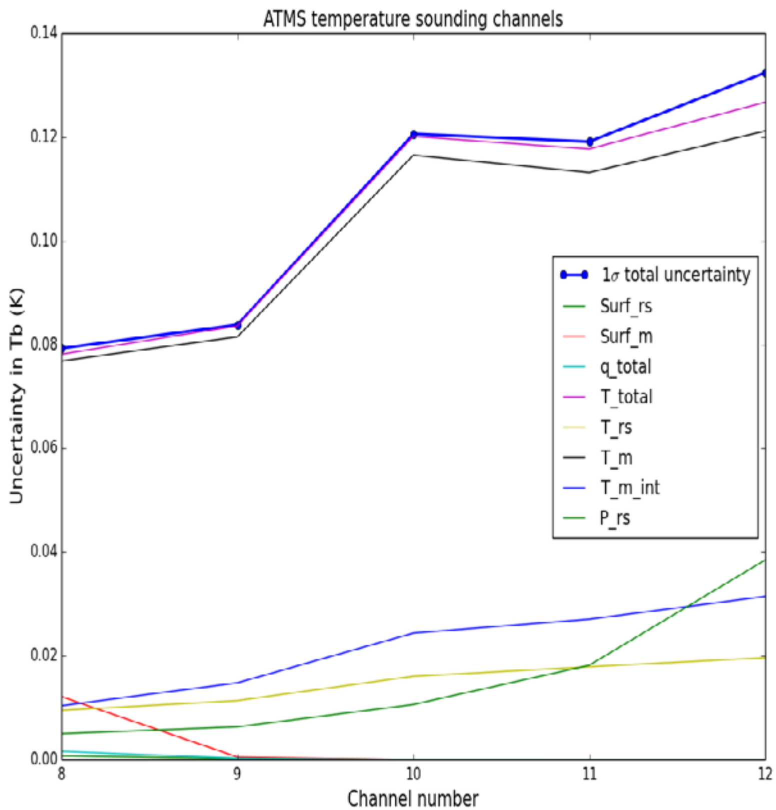
Vertical interpolation covariance matrix, can be estimated from Processor output (method provided in paper – in prep.)

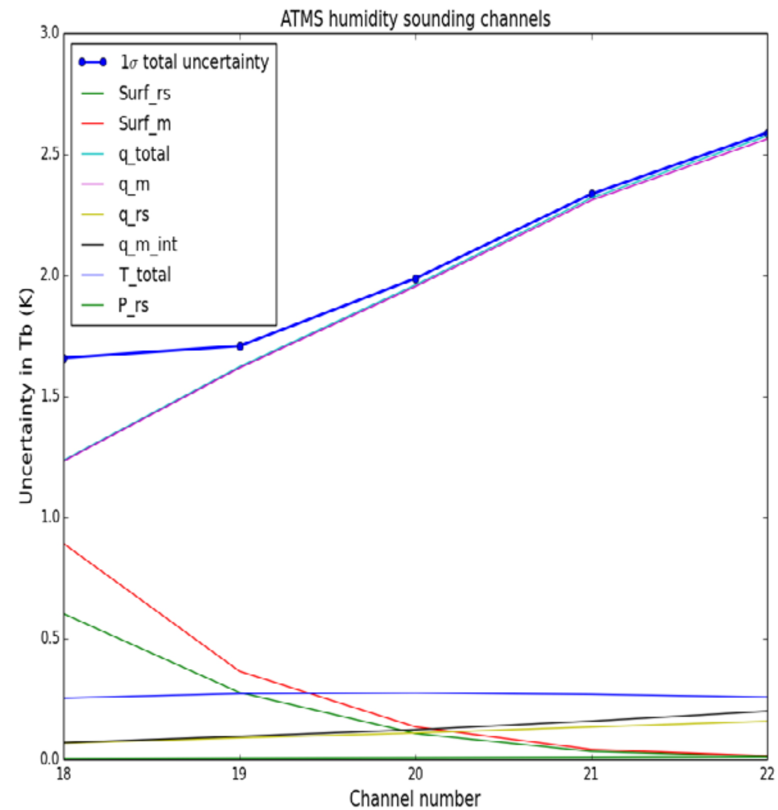
⚠ R_{GRUAN} is diagonal, this is not ideal.
We need a full covariance for optimal analysis.

Uncertainty budget

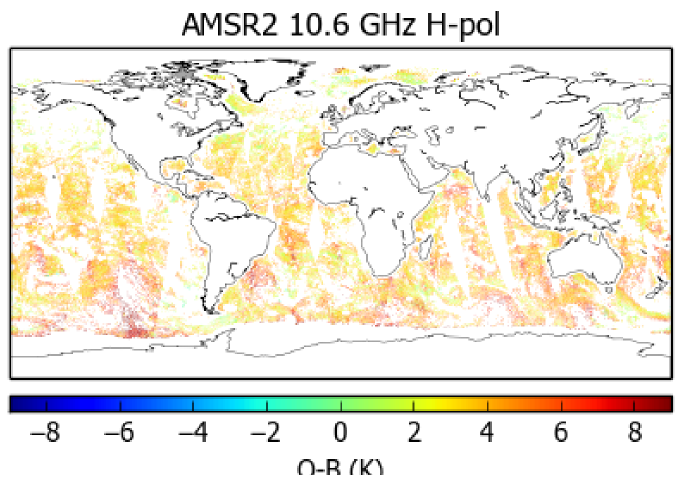
$$\boldsymbol{S}_{\delta \boldsymbol{y}} \equiv cov(\delta \boldsymbol{y}) \cong \boldsymbol{H}\boldsymbol{R}_{\boldsymbol{GRUAN}}\boldsymbol{H}^{\boldsymbol{T}} + \boldsymbol{H}\boldsymbol{W}\boldsymbol{B}_{\boldsymbol{NWP}}\boldsymbol{W}^{\boldsymbol{T}}\boldsymbol{H}^{\boldsymbol{T}} + \boldsymbol{H}\boldsymbol{S}_{\boldsymbol{int}}\boldsymbol{H}^{\boldsymbol{T}}$$

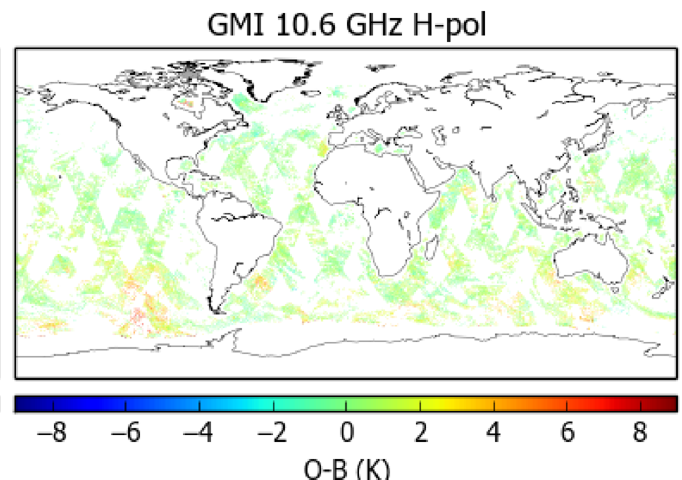
The uncertainty associated with δy is expressed as the standard deviation of $S_{\delta y}$ (i.e. the square root of it's diagonal)





Better quantification of the role of data assimilation

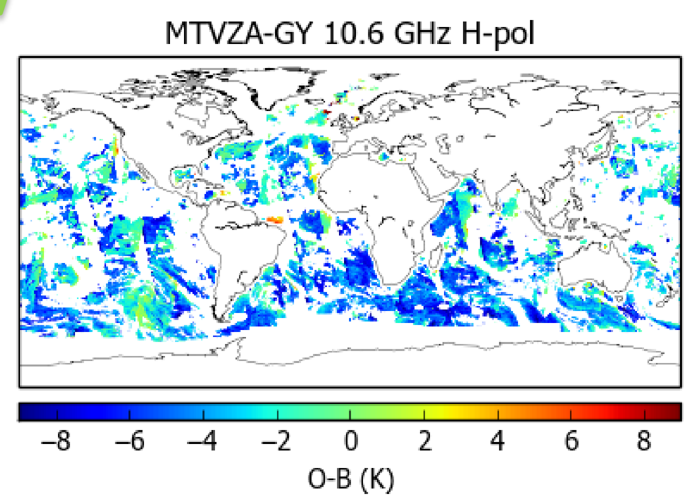




AMSR2 mean bias 3.9 K

GMI mean bias 0.9 K

MTVZA mean bias -3.9 K



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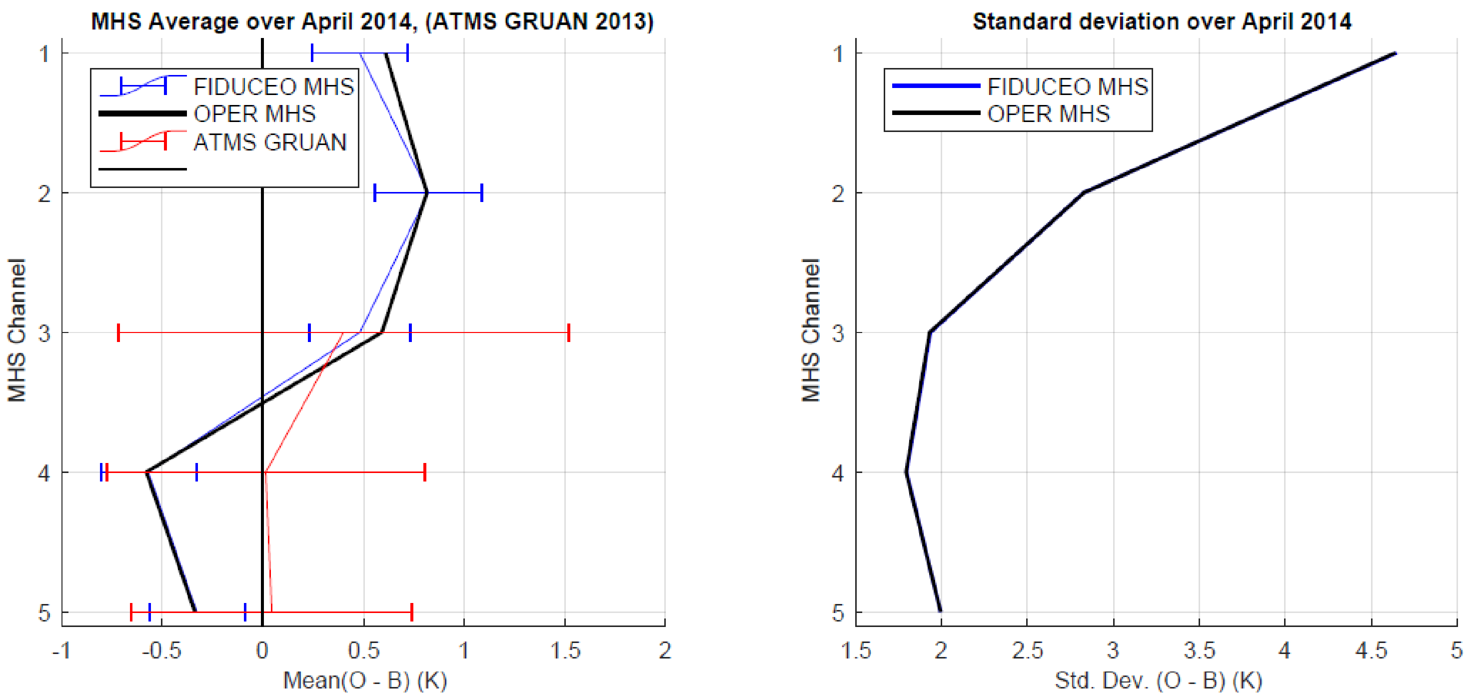
Towards a metrological closure comparison with FIDUCEO



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GAIA-CLIM Virtual Observatory

- The Virtual Observatory makes co-located non satellite reference and satellite data available via the internet;
- It supports the exploitation of ground-based reference data for satellite product validation at Level 1 and 2;
- It allows users to interrogate multiple data sources in a seamless way, and permits limited remote data analysis;
- Increases awareness among users of satellite and non satellite data on the concept of traceable uncertainty estimates;
- Provides a facility that has the potential to be developed into a routine application to analyse product quality.

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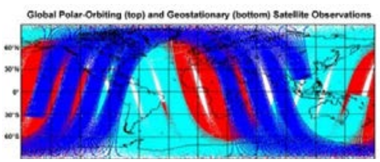
GAIA-CLIM Virtual Observatory (VO)

Characterised fiducial reference measurements



Satellite data (L1 and L2) partly characterised

Simulated satellite data form NWP model outputs

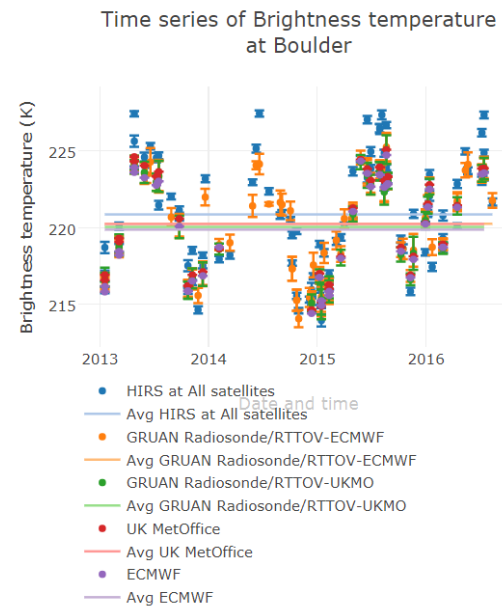
[The VO](#)

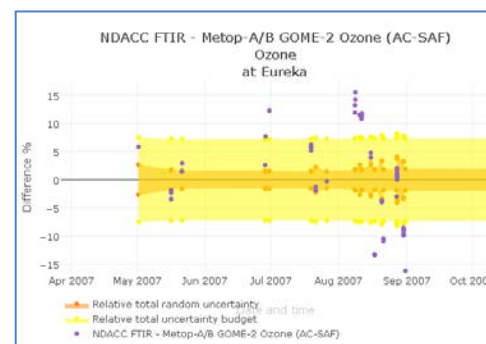
Co-locations data base (space/time)

Radiative Transfer model

Visualisation in the GUI

Data export (netCDF)





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Gaps assessment and impacts document

- A substantive and sustained effort at identifying and documenting all relevant gaps. The process evolved substantively over time.
  - Gap characteristics
  - Gap impacts
  - Gap potential remedies

- Gap traces put online and made searchable by user-driven cross-sections

- Gap traces shall remain online

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Recommendations

- Far from everything that could be done has been done
- 11 broad thematic recommendations have been formulated (this may change depending upon your feedback)
- Challenge is how this ends up being used
- We would welcome suggestions on how the recommendations can best gain visibility

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The final recommendations

Education and training
Maintaining and further developing a trained workforce competent in EO data characterisation and downstream applications to support Copernicus activities
Non-satellite data quality and availability
Improve the metrological characterisation of a suite of non-satellite measurement techniques: Striving for traceable, reference quality, fiducial measurement series
Augment and consolidate existing geographical coverage of fiducial reference quality observational networks to be more globally representative, including a range of surface types and climate zones
Improve time scheduling coherency of satellite and non-satellite measurements to minimise the need to account for co-location uncertainty effects
Instigate and sustain time-bounded access to a comprehensive set of harmonised fiducial reference data and metadata holdings under a common data model and open data policy that enables interoperability for applications

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Observational network governance
Take steps to reassess, rationalise, and improve coordination of high quality observing networks
Conversion of non-satellite measures to TOA radiance-equivalents and their use
Improve knowledge of fundamental spectroscopy and undertake associated innovations in radiative-transfer modelling
Improve quantification of the effects of surface properties to reduce uncertainties in satellite data assimilation and satellite to non-satellite data comparisons
Develop and provide tools that convert non-satellite fiducial reference quality measurements to TOA radiance equivalents with associated rigorously quantified uncertainties
Understanding and quantifying irreducible co-location mismatch effects
Improve the basis for assigning co-locations and quantifying rigorously the associated uncertainties, including steps towards operational provision of co-location uncertainties
Provision of user tools that enable exploitation
Operationalise co-location match-ups, visualisation and extraction tools, such as the GAIA-CLIM Virtual Observatory, to facilitate user access to satellite to non-satellite match-ups

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