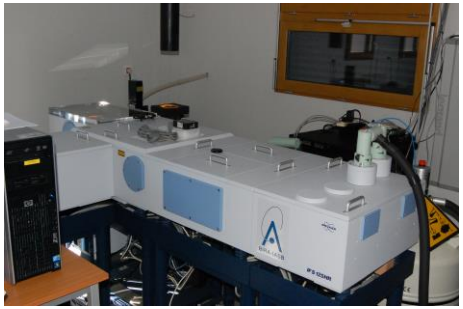

GAIA-CLIM

Work Package 2

Measurement uncertainty quantification

Karin Kreher (BKS) & the WP2 team

GAIA-CLIM GA, ECMWF, Reading (UK), 6-7 February 2017

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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Agenda

15:15-16:15 ***Work Package 2.***
Measurement uncertainty quantification (Karin Kreher)

15:15-15:30 Summary of the progress made to date in the 5 subtask 2.1.1 – 2.1.6, Karin Kreher, BKS & TBD

15:30 -15:45 Progress report on the development of best practices (task 2.3), Paul Green, NPL

15:45-16:00 Summary of the uncertainty assessment for the measurement capabilities provided to WP5 and discussion of the uncertainty questionnaires, Karin Kreher, BKS

16:00-16:15 Progress report on the uncertainty estimates identified for baseline network capability (task 2.2), Karin Kreher, BKS

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Uncertainty Assessment for the measurement capabilities provided to WP5 – D2.3

- Purpose: To provide **information on non-satellite data products and their uncertainties to WP5** - addressing data sets which are under consideration to be included into the VO (ROR table).
- These data streams are primarily being developed by WP2 Task 2.1, with some additional data streams being provided by third party projects and reviewed by WP2 participants.
- Aim: To **enable the VO user** to adequately interpret and utilise these data sets within the VO.

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- To this end: **Assessment of the measurement capabilities and uncertainty quantification** of the investigated data series, and hence the qualification of the data series suitable for inclusion into the VO.
- The **results are presented in D2.3**.

- To provide the information in a consistent manner, a **questionnaire** developed within the FP7 project **QA4ECV** has been slightly modified for our purpose.
- This **similarity** between the templates enables **cross-comparisons of outputs** and potential exploitation of outcomes across the projects by end-users as well as participants in each project.
- The only key change to the QA4ECV template:

  → Addition of a section on **measurement traceability and comparability.**

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Questionnaire

The main sections of the questionnaire are:

1. The **identification of respondent and of data product**
2. Short list of **recommended literature**
3. Description of **main measured quantity (measurand):** Includes the specification of the measurand and the measurement equation
4. **Traceability and comparability**: describes if the measurement quantity is traceable to SI units or community accepted standards, and if and how comparability between measurements made at different sites is achieved.

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5. **Representation of the uncertainty in the data product:** lists the uncertainty field names & brief description of the uncertainty form (i.e. uncertainty expressed as standard deviation).
6. The **uncertainty calculation** section: Information on how the uncertainty is calculated and the level of approximation used in these calculations.
7. The **uncertainty contributions** section: Main contributions to the uncertainty calculations such as a contribution introduced by the choice of **prior, smoothing error,** and **noise.**

   The section also describes if “random”, “structured random” and “systematic” contributions are considered separately and if so, how each of them are defined in the uncertainty calculations.

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This section further covers: if the data product depends on input quantities and how the final uncertainties then depend on the uncertainties of the input quantities, and finally: information on uncertainties due to model error.

8. **Correlations & covariances** in the data product. Also identifies any auto-correlation and correlation between the main measured quantity and other quantities.
9. **Bias handling introduced during processing** and if this is corrected for.
10. **Other remarks on data product uncertainty**

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WP5 ROR table for data input into the VO

	Measurement technique	ECV	Readiness of uncertainty chain	Smoothing & mismatch errors
Task 2.1.1	LIDAR	Aerosol	Ready	OSSSMOSE: target is mid 2017 Empirical methods: tbd
	LIDAR	H_20 profiles	Ready within GAIA-CLIM (mid-2017)	OSSSMOSE: late 2017 Empirical methods: tbd, but possibly earlier with STAT4COLL (5)
	LIDAR	O_3 profiles	Ready	Target: ready by end of 2016 (OSSSMOSE)
	LIDAR	Temperature profiles	Partially ready, remaining part ready within GAIA-CLIM (mid 2017)	Early 2017
Task 2.1.2	MWR (1)	Water vapour profiles	Not ready within GAIA-CLIM	Late 2017 (5)
	MWR (1)	Temperature profiles	Not ready within GAIA-CLIM	Early 2017
	MWR (1)	Total water vapour content	Not ready within GAIA-CLIM	Early 2017
	MWR (1)	Total liquid water content	Not ready within GAIA-CLIM	TBD
Task 2.1.3	FTIR (NDACC)	CH_4	Ready (2)	Possible by end of 2016
	FTIR (NDACC)	O_3	Ready	Target: ready by end of 2016
	FTIR (NDACC)	MUSICA H_20	Ready	OSSSMOSE not ready within GAIA-CLIM Errors to be derived from NWP (WP4) and STAT4COLL results - 2017
	FTIR (NDACC)	MUSICA H_20 isotopologues	Ready	Not ready within GAIA-CLIM
	FTIR (TCCON)	CH_4	Ready	Possible by end of 2016
	FTIR (TCCON)	CO2	Ready	TBD
Task 2.1.4	UV-vis/DOAS (3)	O_3	Ready within GAIA-CLIM (mid 2017), selected stations earlier	Smoothing: Ready co-location mismatch:Ready for comp. with GOME-2A/B
	Dobson/Brewer EUBREWNET	O_3	Ready within GAIA-CLIM (mid 2017), selected stations earlier	
Task 2.1.5	MAX-DOAS/ Pandora	Trop. O_3	Not ready within GAIA CLIM	Possible early 2017
	GNSS	Total column water vapour	To be determined (4)	Unlikely within GAIA-CLIM
Task 2.1.6	GRUAN radiosonde	O_3 profiles	Very likely ready early 2017	Target: ready by end of 2016 (OSSSMOSE)
	GRUAN radiosonde	Humidity & Temp profiles (Level 2)	Ready	OSSSMOSE: not ready within GAIA-CLIM Errors to be derived from NWP (WP4) and STAT4COLL results - 2017.
	GRUAN radiosonde	Brightness temperature profile (from humidity)	Ready by end of 2016	TBD

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Annex	Instrument	ECV(s)	Primary compiler
A	Lidar	Aerosols	CNR
B	Lidar	Water vapour profiles	KNMI
C	Lidar	Ozone profiles	KNMI
D	Lidar	Temperature profiles	KNMI
E	Microwave radiometer (MWR)	Water vapour profiles	CNR
F	Microwave radiometer (MWR)	Temperature profiles	CNR
G	Microwave radiometer (MWR)	Total water vapour content (TWVC)	CNR
H	Microwave radiometer (MWR)	Total liquid water content (TLWC)	CNR
I	FTIR Spectrometer (NDACC)	FTIR NDACC O_3 and CH_4 FTIR MUSICA H_2O	BIRA
J	FTIR Spectrometer (TCCON)	FTIR TCCON CO_2 and CH_4	UBremen
K	UV-visible spectrometer (DOAS)	Total ozone column	BIRA
L	Dobson	Total ozone column	BKS
M	GNSS	Total column water vapour	TUT
N	GRUAN RS92 radiosonde geophysical profiles	Temperature profile Humidity profile	NIUM
O	GRUAN RS92 radiosonde radiance equivalents	Top-of-atmosphere (TOA) brightness temperatures	MO

Overview table of the 15 compiled questionnaires

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Summary of the **uncertainty assessment for the measurement capabilities** completed by the relevant instrument experts within GAIA-CLIM with some guidance, where appropriate, from the wider community.

Annex A-D: Lidar measurements of aerosol, water profiles, ozone profiles and temperature profiles are either already ready to be included into the VO (ozone and aerosol) or expected to be ready within the GAIA-CLIM project time-period.

The lidar community has developed robust data processing procedures which include the estimation of the random uncertainty and a separate estimation of the systematic uncertainties due to a few retrieval assumptions, background models, and corrections implemented in a typical lidar data processing chain.

In-depth literature is available and up-to-date.

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Annex E-H: Water vapour and temperature profiles, total water vapour content and total liquid water content measured with **microwave radiometer (MWR).**

The uncertainties in MWR products are provided by the ARM Program (Atmospheric Measurement Program, www.arm.gov) and by the HD(CP)2 project (High Definition Clouds and Precipitation for Climate Prediction, https://hdcp2.zmaw.de).

Uncertainties in MWR derived products are usually estimated *ex ante* through simulated analysis and/or *ex post* through validation against collocated radiosonde profiles.

The literature sources provided in the questionnaires for the MWR products are up-to-date.

Under discussion if currently ready or not (see ROR table) → highlights need for a more rigorous and uniform assessment

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Annex I-J: Ozone and methane profiles measured by **FTIR** under the umbrella of **NDACC, TCCON**, and **MUSICA H_2O**.

The measured quantity is an interferogram which is then Fourier transformed to an absorption spectrum in arbitrary units. From the shape of the absorption lines in selected micro-windows, information on targeted gas concentrations using optimal estimation can be deduced.

The uncertainties are given as standard deviation and are reported as covariance matrices.

The literature sources provided in the questionnaires for the FTIR products are in-depth and up-to-date.

In the ROR table, from uncertainty perspective, listed as ready to be included in the VO.

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Annex K-L: Total ozone columns retrieved from twilight ground-based **UV-visible DOAS measurements** and **Dobson measurements.**

The **uncertainty budget for UV-visible ozone** columns is separated into random and systematic uncertainties for the three main retrieval steps (spectral fit, determination of the residual amount in the reference spectra and airmass factor extraction/calculation).

For the **Dobson uncertainties** a table is provided with preliminary entries based on model calculations. A more realistic and comprehensive uncertainty budget, is envisaged to be made available in October 2017. The corresponding **traceability chain for the Dobson measurements** has been developed in the framework of the WMO GAW Dobson network. The literature sources are up-to-date.
Listed as ready in ROR table within GAIA-CLIM time period.

Details on the **uncertainty of Brewer measurements** are also currently under review as part of the **ATMOZ project** which is addressing the traceability of atmospheric total column ozone specifically for Brewer and Dobson measurements with results expected to become available later in 2017.

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Annex M: GNSS Total Column Water Vapour (TCWV) is derived from GNSS signal Zenith Total Delays (ZTD) by adding atmospheric and surface meteorological constraints and processing with dedicated software.

The uncertainty in TCWV is **traceable via an unbroken chain** to the original time-delay measurement (the SI unit of seconds) and the product is **ready to be implemented within the GAIA-CLIM project lifetime (?),** in ROR table still listed as TBD.

The literature sources provided are up-to-date and in-depth.

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Annex N: The **GRUAN RS92 radiosonde product** undertakes a full metrological characterisation based upon lab, bench and field characterisation of the instrument.

The **analysis is fully traceable**.

For all measurements there exists a calibration uncertainty which is a perfectly correlated term within each measurement series profile.

Literature source for V2 is up-to-date, documentation for V3 will be made available via the GRUAN community asap.

Ready to be included into the VO from WP2 perspective.

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Annex O: Top-of-atmosphere (TOA) brightness temperatures are **simulated from GRUAN radiosonde measurements** and **NWP models** using the approach being developed in GAIA-CLIM by WP4.

This approach establishes the uncertainties in simulated TOA brightness temperatures generated from NWP models.

The **GRUAN measurements** themselves are **fully traceable**, but the radiative transfer model which projects these into TOA brightness temperatures is based on spectroscopic parameters (linestrength, linewidths, and pressure broadening parameters) that are **not yet fully traceable** and the complete uncertainty procedure is still under development.

WP4 presentation will provide more details.

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Still under discussion:

Unclear if **ozone profiles measured by ozonesondes** will be ready to be included as reference data set into the GAIA-CLIM VO with respect to full traceability of the uncertainty chain, and hence this data stream has not been included here.

At this stage, **MAX-DOAS measurements of tropospheric ozone** are not envisaged to be included in the VO since it is unlikely that the full traceability chain covering all processing steps will be available within the GAIA-CLIM time frame.

If either of these products available for use within the VO then WP2 will provide the additional questionnaire responses to WP5.

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Summary

- The **collation of the questionnaires → comprehensive overview of the status of the measurement uncertainties** for the data products under consideration to be included into the VO.
- The **information gathered by the instrument experts** provides users of these data products with **detailed and up-to-date information on the uncertainties**, in most cases both with **explicit descriptions** within the questionnaire as well as **with a list of the most relevant publications** for additional and more in-depth information.
- **Collating the uncertainty information** for data streams measured with a variety of diverse techniques **in a consistent manner** helps to **understand the differences between these data products -** in particular for the data streams such as ozone which are measured with several techniques such as lidar, FTIR, UV-vis spectroscopy, ozonesondes.
    - **Goal re interaction with WP5:** To make the information available to the VO development team so it can be implemented in fact sheets and/or interactive tools.

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