Uncertainty assessment and reporting – RS92 Temperature GDP Case Study

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Background

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- Providing suitable information on measurement uncertainties to end users is a particular challenge in atmospheric measurements, particularly given the range of timescales of interest.
- Tools for uncertainty assessment and reporting are being developed over a series of collaborative projects and networks.
- This talk presents a Case Study on such an assessment carried out as part of the recent Copernicus Climate Change Service activity on ‘Access to observations from baseline and reference networks’ (C3S_311a_Lot3) led by CNR-IMAA.

imaa ECMWF Copernicus Europe's eyes on Earth European Commission

What is uncertainty?

Definition in the International Vocabulary of Basic and General Terms in Metrology (VIM) — Third edition (2006)

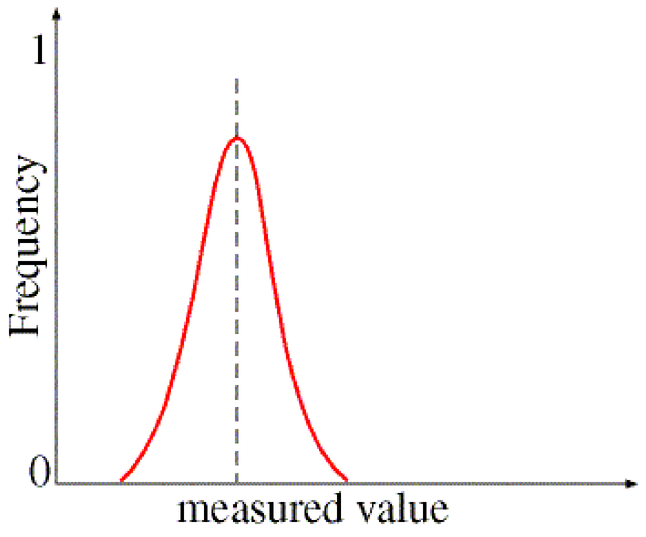
‘Parameter, associated with the result of a measurement, that characterises the dispersion of the values that could reasonably be attributed to the measurand’

From which we can conclude:

- Uncertainty is a topic which seems to attract the most obscure and convoluted definitions;
- Uncertainty is a **property of a result;**
- Indicates the likely range within which we think the ‘true’ value of a measured quantity lies, **given all the information we have;**
- Measurement uncertainty is a single value, expressed in terms of the measurand, either as a percentage or in units or the measurement.

$x \pm U$

(with a given confidence interval defined by a coverage factor, k)



Traceability and uncertainty assessment

- Traceability and uncertainty assessments were carried out in European H2020 GAIA-CLIM project for a range of atmospheric measurements.
- Linked to equivalent process for EO dataset developed in Fiduceo project.
- All steps in the process of generating the measurement product are considered in terms of:
  - The uncertainty related to that step.
  - The temporal and spatial correlation of the uncertainty.
  - The influence of the step on the final result.
  - Any correlations with other steps in the process.
  - The traceability and validation relevant to that step.
- Provides current best estimate of uncertainty contributions and their correlations, and identify gaps in current knowledge of uncertainties.
- G-C work didn’t resolve how to report correlation in overall uncertainty.

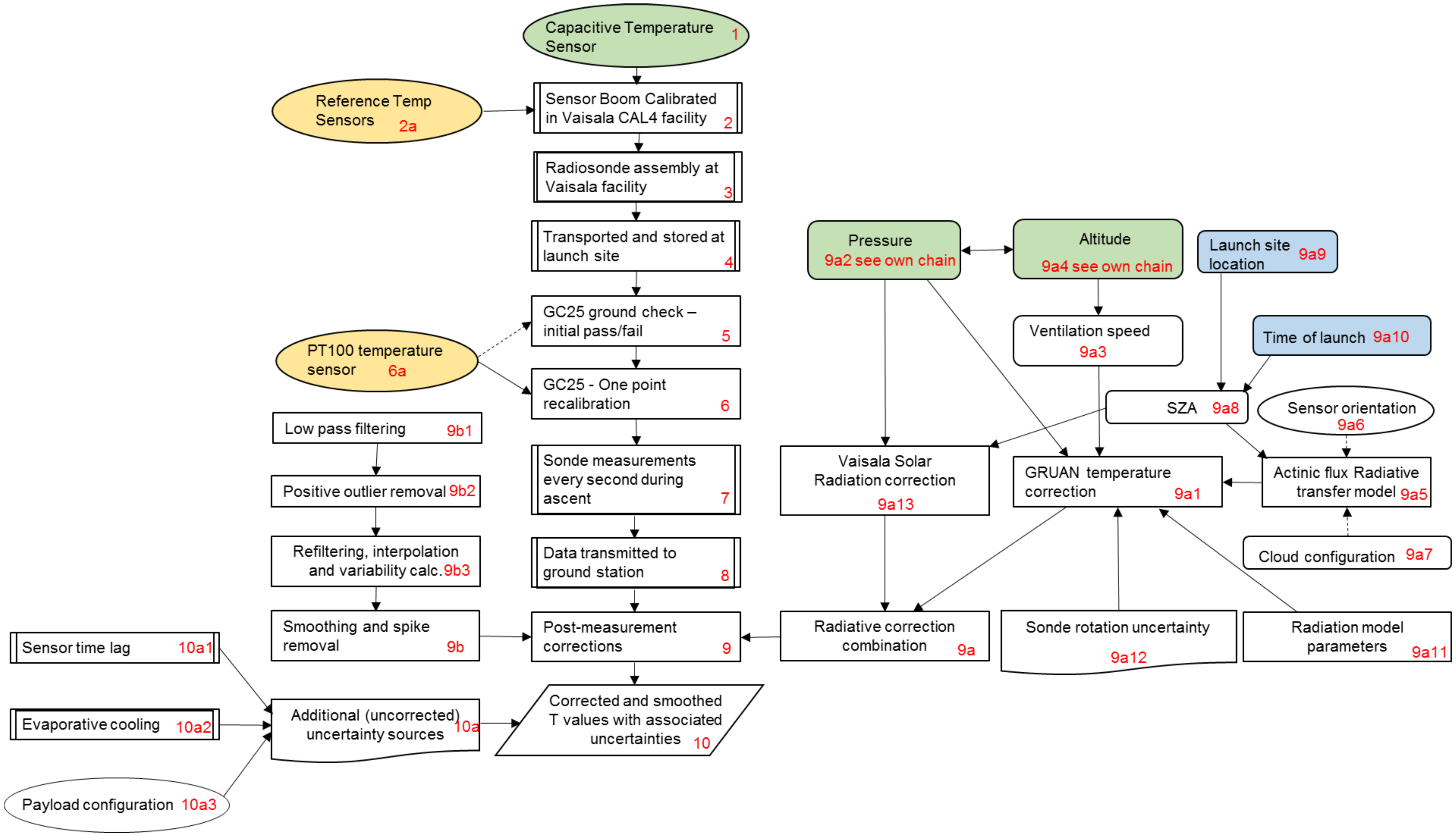
Combined uncertainty – correlation reporting options

- Report total uncertainty for results over different timescales
- Co-variance matrices
  - Matrix representation of uncertainties with random (diagonal) and correlated (off-diagonal) components.
  - Already used for optimal estimation analysis in a number of techniques.
  - Experience for 1-D variation, usually spatial, but harder to implement for 2-D variation – spatial & temporal.
- Uncertainty PDF’s and ensembles
  - Use Monte Carlo sampling of individual uncertainty components to generate ensemble of potential outcomes, and also giving combined probability density function.
  - Relatively easy to implement and deal with non-normal uncertainty distributions.
  - Potential issues of data volume and applicability to users.

Uncertainties for different ‘results’

- Follow the VIM uncertainty reporting definition, but provide total uncertainty values for different ‘results’, i.e. provide separate uncertainties values for different averaging periods.
- Users could select most appropriate timescale for their application and relatively easy to report/use.
- Loses some detail of the correlations, and this detail is still needed to calculate for different periods.
- Case study completed for RS92 GDP temperature measurements.

GRAUN RS-92 Temperature Traceability and Uncertainty Chain



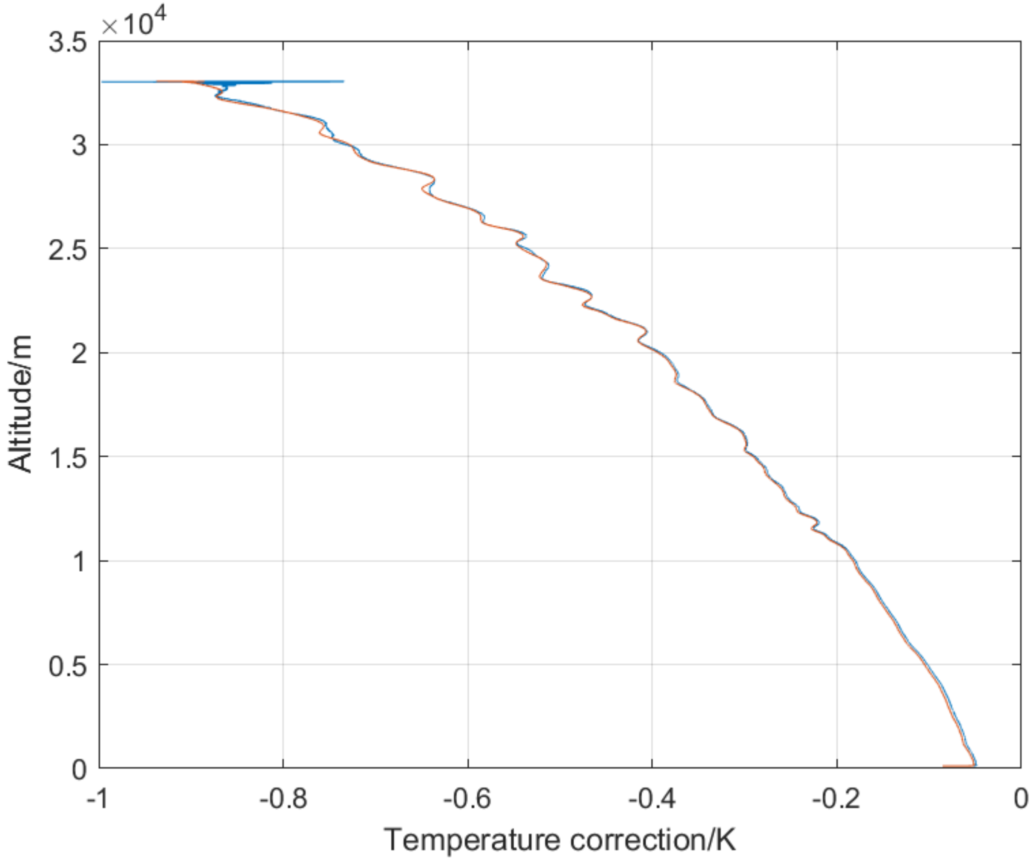
Uncertainty Breakdown Method

- Different uncertainty contributions were identified and classified – Random, Systematic, Structured Random, Quasi-systematic – according to how the uncertainty was expected to change between measurements.
- The method of the single-profile uncertainty breakdown was developed using Dirksen et al 2014, and discussion with the lead centre team.
- Two different methods used for night-time and daytime sondes, determined by SZA. For night-time sondes many uncertainties are set to 0.
- For the uncertainties of means of measurements, the uncertainty components of the contributing measurements where averaged then, if the contribution was determined to be random, reduced according to the number of measurements used to find the mean.

Contribution	Sub-contribution	Within profile	Profile-to-Profile Short term	Profile-to-Profile Long term
Calibration uncertainty, $u_{c,cal}(T)$	Cal 4 calibration, $u_{cal4}(T)$	Systematic	Random	Random
	Cal 4 reference sensor, $u_{cal4ref}(T)$	Systematic	Systematic	Random
	GC25 Ground check, $u_{GC25}(T)$	Systematic	Random	Random
	GC25 reference sensor, $u_{GC25ref}(T)$	Systematic	Systematic	Random
Statistical uncertainty, $u_u(T)$	none	Structured random, 10s	Random	Random
Radiation correction, $u(\Delta T)$	Rotating sonde, $u_{u,rot}(\Delta T)$	Structured Random, >6 s	Random	Random
	Ventilation speed, $u_{u,vent}(\Delta T)$	Random	Random	Random
	Radiation model parameters, $u_{c,RC}(\Delta T)$	Systematic	Systematic	Systematic
	Actinic flux, $u_{c,la}(\Delta T)$	Systematic	Random	Random
	Vaisala radiation correction, $u_{vaisala}(\Delta T)$	Systematic	Quasi-Systematic	Quasi-Systematic

Temperature Correction

- Many daytime uncertainty contributions depend on the temperature correction
- The Vaisala temperature correction is found by interpolating between points at reference pressures and SZA
- At night the only correction is the Vaisala correction
- During day the correction is the mean of Vaisala and GRUAN corrections, some uncertainty contributions are calculated using this mean, some use only the GRUAN correction



Mean of GRUAN and Vaisala temperature corrections for the sonde launched at 12 UTC on 1/4/2015 from Lindenberg, found in the file (blue) and calculated as part of the uncertainty breakdown process (red)

Uncertainty Reduction – Total Uncertainty

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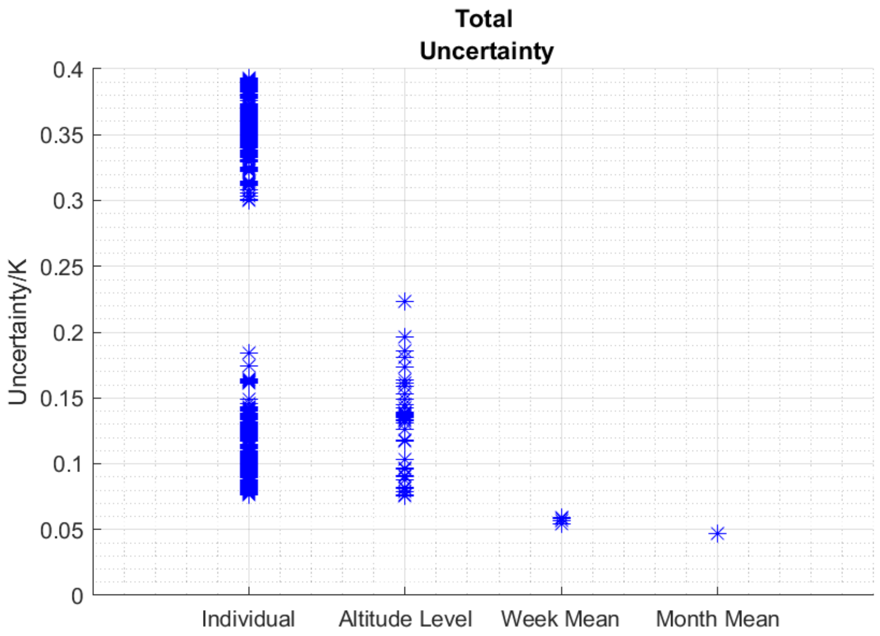
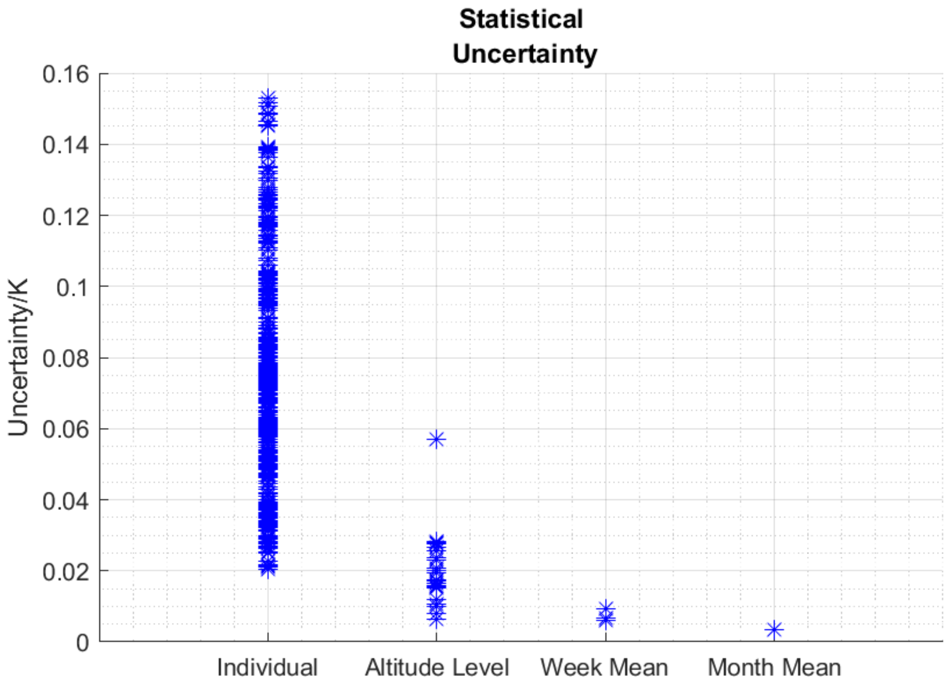
- Large amount of the variability in total uncertainty is from the statistical uncertainty, so it reduces quickly.
- Further reduction going from the altitude level mean to the weekly and monthly means as many of the uncertainty contributions change from systematic within a profile to random between profiles.

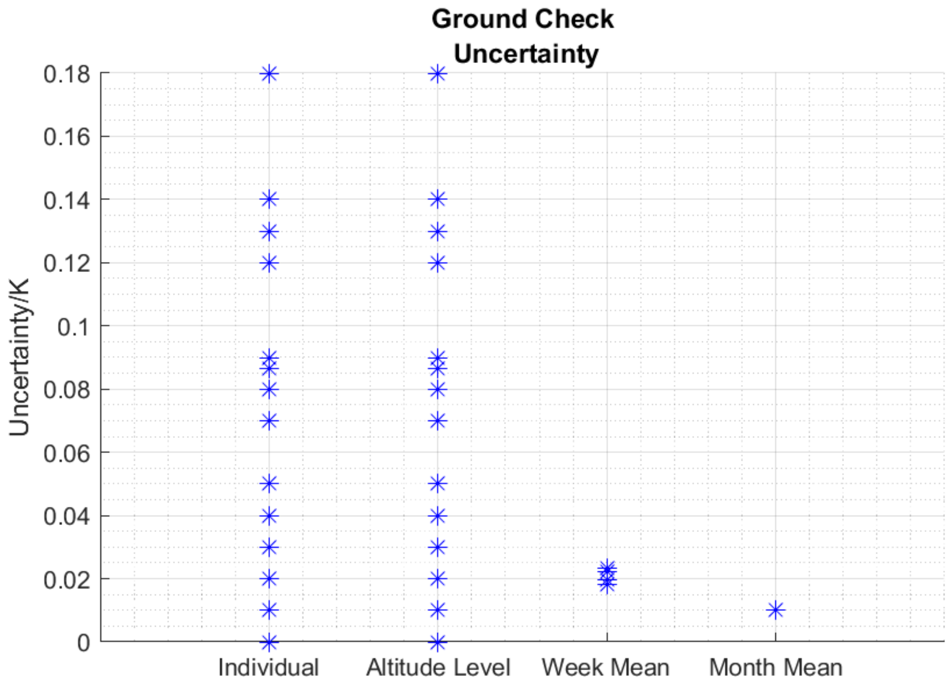


Uncertainties of measurements within 50 m of 25 km altitude for sondes launched between 1/4/2015 and 30/4/2015 at 00 and 12 UTC along with altitude mean uncertainty, weekly mean uncertainty and monthly mean uncertainty.

Uncertainty Reduction – ‘Random’ and ‘Systematic to Random’ uncertainties

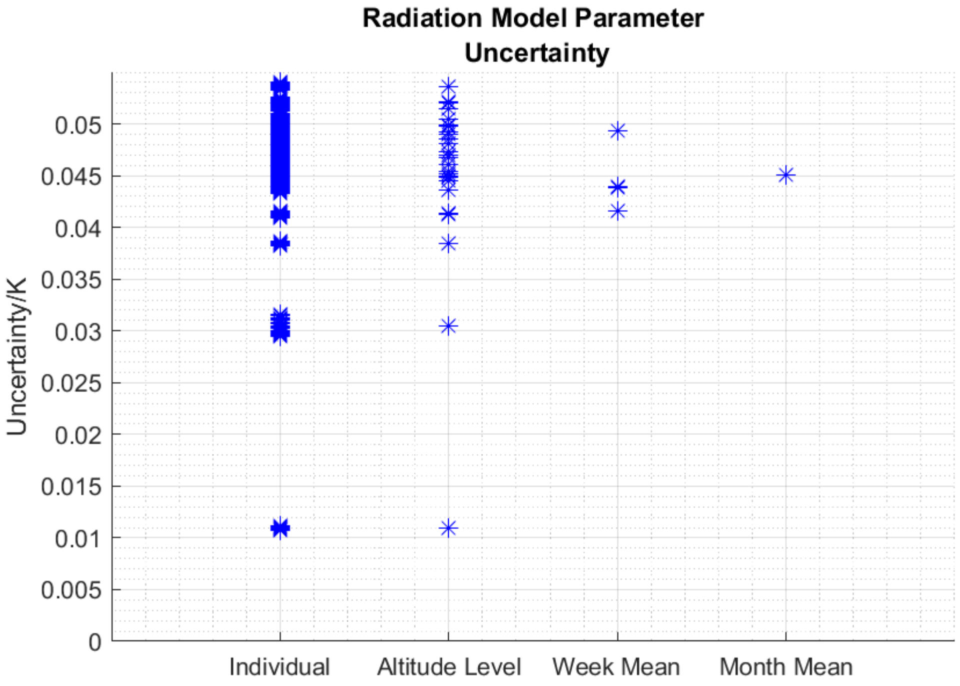


25 km Uncertainty in temperature as a result from statistical uncertainty for sondes launched between 1/4/2015 and 30/4/2015 at Lindenberg

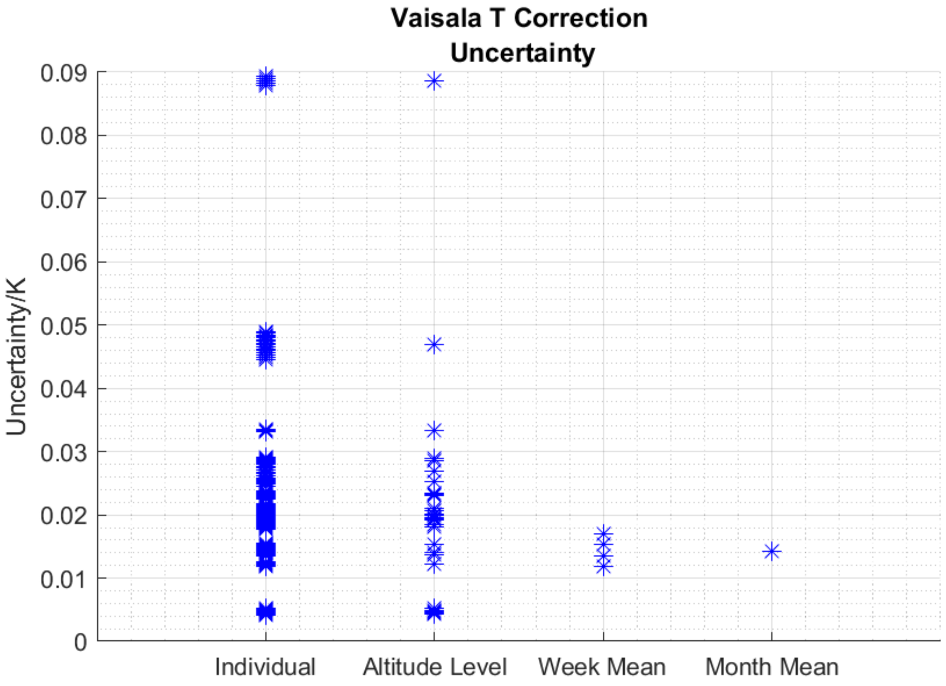


25 km Uncertainty in temperature as a result from uncertainty in the ground check for sondes launched between 1/4/2015 and 30/4/2015 at Lindenberg

Uncertainty Reduction – ‘Systematic’ Uncertainties



25 km Uncertainty in temperature as a result from uncertainty in the GRUAN radiation model parameters for sondes launched between 1/4/2015 and 30/4/2015 at Lindenberg



25 km Uncertainty in temperature as a result from uncertainty in the Vaisala contribution to the temperature correction for sondes launched between 1/4/2015 and 30/4/2015 at Lindenberg

Conclusions

- Traceability and uncertainty assessments provides a summary of all the potential uncertainty contributions (and the gaps in this knowledge) for different products.
- Reporting uncertainties on different timescale provides a simple way for different users to identify relevant uncertainty for their application.
- The work on the RS92 GDP provides an estimation of the uncertainty for different data products / reporting timescales.
- Provides a Case Study for uncertainty reporting which will be implemented through C3S (USCRN surface temperature uncertainties also assessed)
- Potential for implementation across other GDPs.
- Paper in preparation (preliminary draft with co-authors).

Thank you for your attention

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