National Physical Laboratory

GRUAN ICM-10 Uncertainty Discussion

Tom Gardiner

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Uncertainty Issues

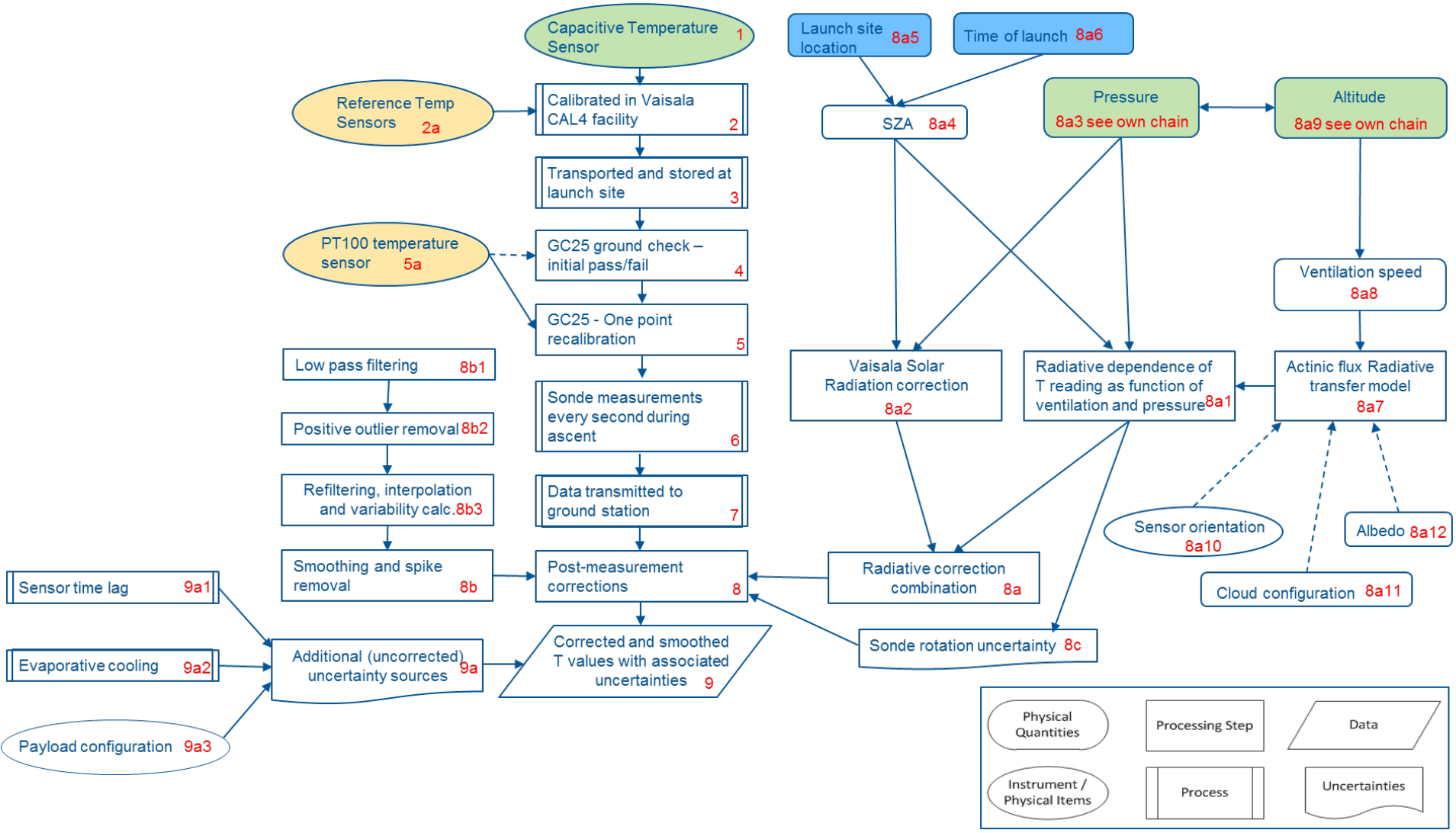
NPL National Physical Laboratory

- Need to agree common method(s) to determine and report GRUAN uncertainties with particular reference to their temporal correlation.
- First step is to identify correlation behaviour of the individual components making up overall uncertainty.
- Need to combine these and determine temporal behaviour of overall uncertainty.
- This then should be reported in a way that is understandable and useable by different user-groups.

Traceability and uncertainty assessment

- Traceability and uncertainty assessments were carried out in GAIA-CLIM project for a range of ECV measurements, a number of which are relevant to GRUAN.
- 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.
- Doesn’t resolve how to report correlation in overall uncertainty.

Traceability and uncertainty assessment – RS-92 example



Correlation descriptors for uncertainty components

- Random
  - uncorrelated uncertainty (noise) on individual measurements.
- Structured Random
  - vertical correlation within a profile but random from one profile to the next.
- Quasi-systematic
  - some correlation from one launch to the next but only for a limited period of time.
- Systematic
  - long-term correlated uncertainties (bias).

Uncertainties for different ‘results’

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’

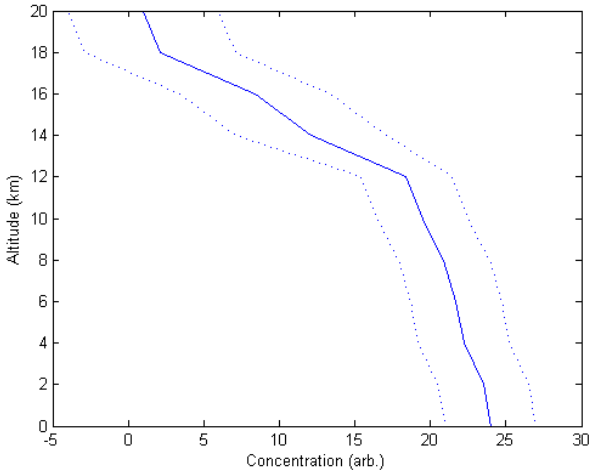
- Follow the VIM uncertainty reporting definition, but provide total uncertainty values for different ‘results’, e.g. provide separate uncertainties values for:
  - Single measurement within profile;
  - Combined profile (total column);
  - Short- (daily), medium- (weekly, monthly) and long-term (annual, decadal) averages.
- 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.

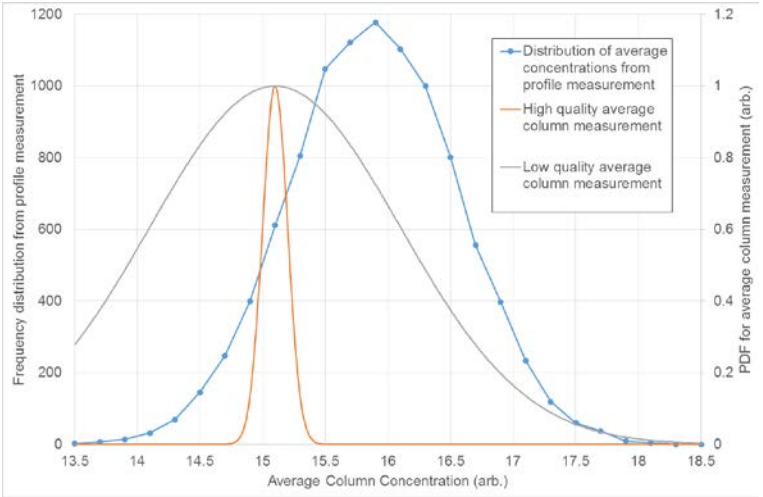
Combined uncertainty – correlation reporting options

- 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 less clear (to me) how 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.

Integrating independent measurements and uncertainties

- Simple example of Monte Carlo resampling of uncertainty probability density functions (PDFs)
- Based on two separate measurements of an arbitrary atmospheric variable – a vertical profile and a column average.
- A large set of potential profiles are modelled based on the profile uncertainty, and the column averages calculated.
- The likelihood of each profile result can be assessed based on the column average PDF.
- The profile dataset can be recombined and an new column-uncertainty-weighted average profile derived, together with an estimate of the revised profile uncertainty.





Integrating independent measurements and uncertainties

- The upper figure shows the new profile (in red) derived from the high quality average profile measurement, with a shifted profile and reduced uncertainties.
- If the average profile is not as well constrained, then the result is the lower figure where:
  - The shift in the column is reduced as there is weaker evidence.
  - The reduction in profile uncertainty is also less.
- This simple example can easily be extended to introduce other data sources and the effect of collocation uncertainties.