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Derivation of Covariance Matrices based on GDP Uncertainties

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Background

- On-going discussions about the need to generate covariance matrices based on reported GDP uncertainties
  - ICM-15 Action TT2.
- Particularly relevant for use of GRUAN data in Radiative Transfer Models.
- Had an opportunity for an NPL Early Career Researcher (Rasma Osmane) to carry out a short case study.
- Builds on metrological tools developed within the Climate and Earth Observation Group at NPL.
- Took place with discussion and feedback from a number of GRUAN TT members.

Collaborators

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Aims & Objectives

The aim of this study is to **improve our understanding** of *Vaisala Radiosonde RS41* Data Product (GDP):

1. Measurements
2. Uncertainties
3. **Covariance information**

To achieve that, a number of realistic case studies are established, exploring **temperature** (T) and **relative humidity** (RH) measurements and their uncertainties.

Results compiled into a draft GRUAN **Technical Note** (undergoing LC review).

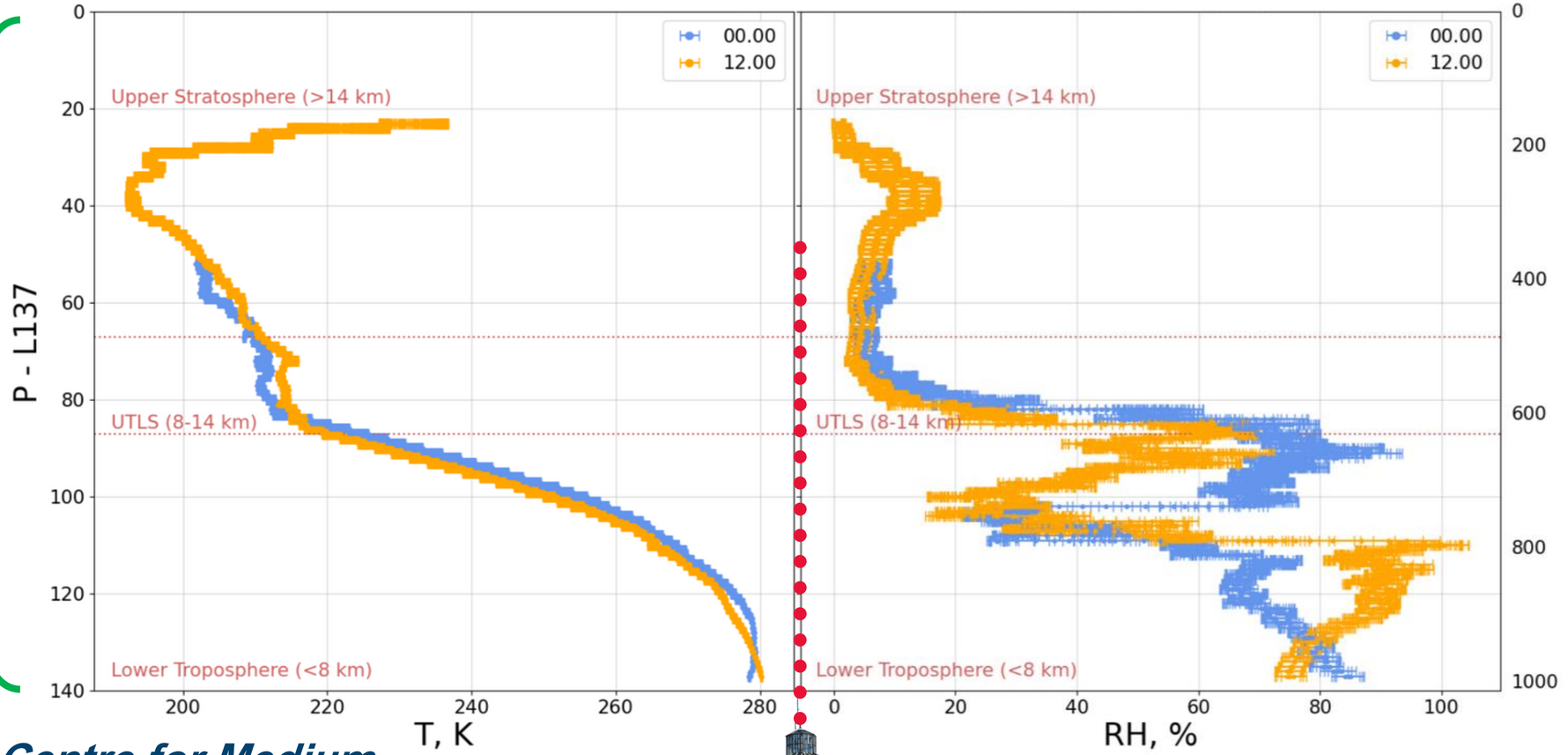
Measurements

00:00 – 3,684 data points
12:00 – 6,864 data points

Temperature

Relative Humidity

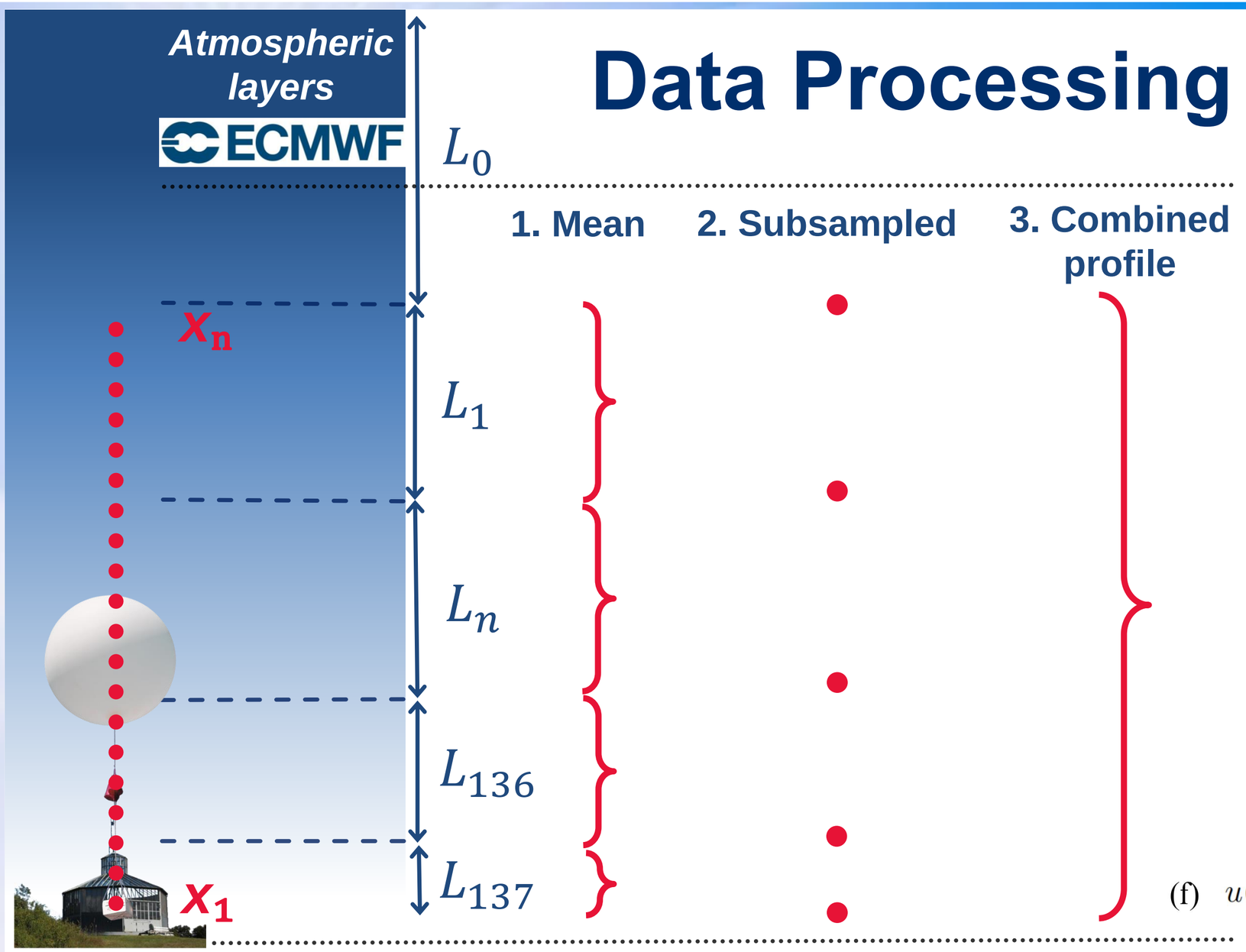
ECMWF* 137 pressure layers



GDP pressure

*European Centre for Medium-Range Weather Forecasts ECMWF

Data Processing



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GRUAN combined uncertainty calculations:

(a) $u_{\mathrm{ucor}}(\nu_s) = u_{\mathrm{ucor}}(\overline{\nu}) = \frac{1}{N}\sqrt{\sum_{j=1}^{N} u_{\mathrm{ucor}}^2(\nu_j)}$

variability

(b) $u_{\mathrm{var}}(\nu_s) = u_{\mathrm{var}}(\overline{\nu}) = \sqrt{\frac{1}{N(N-1)}\sum_{j=1}^{N}(\nu_j - \overline{\nu})^2}$

↓

(c) $u_{\mathrm{uc}}(\nu_s) = u_{\mathrm{uc}}(\overline{\nu}) = \sqrt{u_{\mathrm{ucor}}^2(\nu_s) + u_{\mathrm{var}}^2(\nu_s)}$

uncorrelated

(d) $u_{\mathrm{sc}}(\nu_s) = u_{\mathrm{sc}}(\overline{\nu}) = \frac{1}{N}\sum_{j=1}^{N} u_{\mathrm{scor}}(\nu_j)$

spatially correlated

(e) $u_{\mathrm{tc}}(\nu_s) = u_{\mathrm{tc}}(\overline{\nu}) = \frac{1}{N}\sum_{j=1}^{N} u_{\mathrm{tcor}}(\nu_j)$

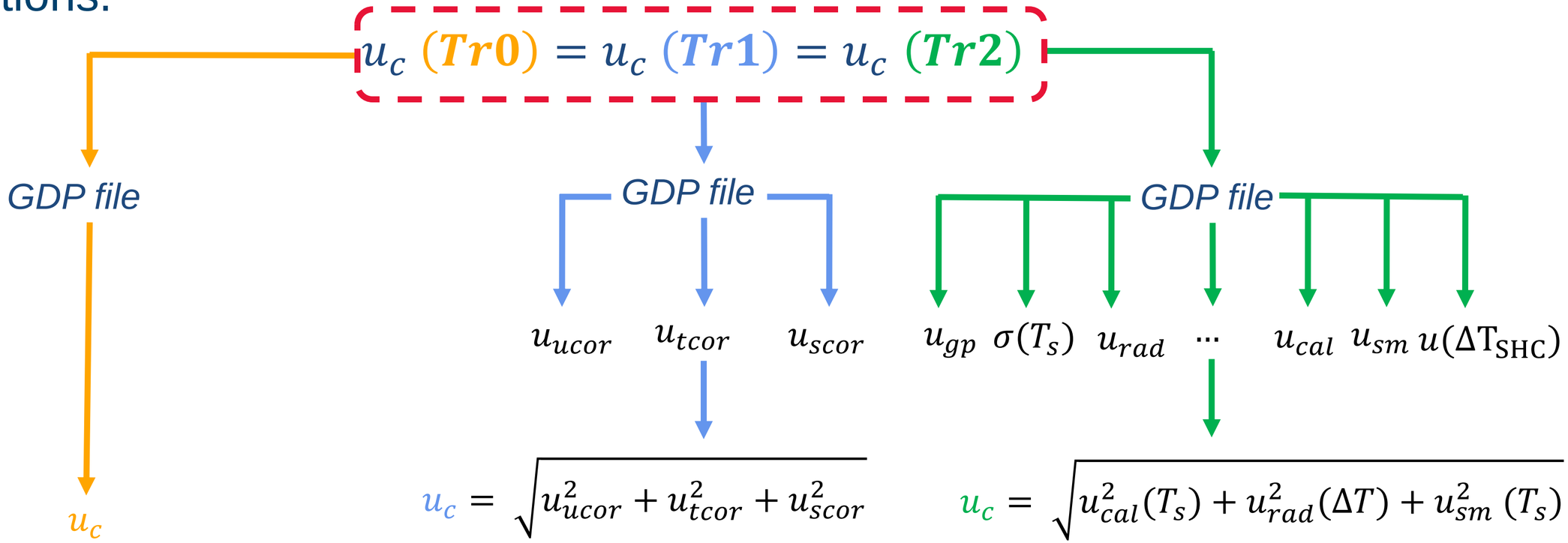
temporally correlated

(f) $u(\nu_s) = u(\overline{\nu}) = \sqrt{\overset{(c)}{u_{\mathrm{uc}}^2(\nu_s)} + \overset{(d)}{u_{\mathrm{sc}}^2(\nu_s)} + \overset{(e)}{u_{\mathrm{tc}}^2(\nu_s)}}$

*combined layered uncertainty**

Uncertainties

Tier 0: combined uncertainty $u_c\ (\boldsymbol{Tr0})$ provided in GDP.
Tier 1: calculated combined uncertainty $u_c(\boldsymbol{Tr1})$ using GDP correlation components.
Tier 2: calculated combined uncertainty $u_c(\boldsymbol{Tr2})$ with all individual uncertainty contributions.



Correlation components: Tier 1

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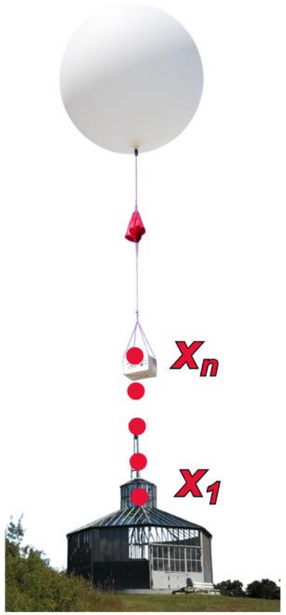
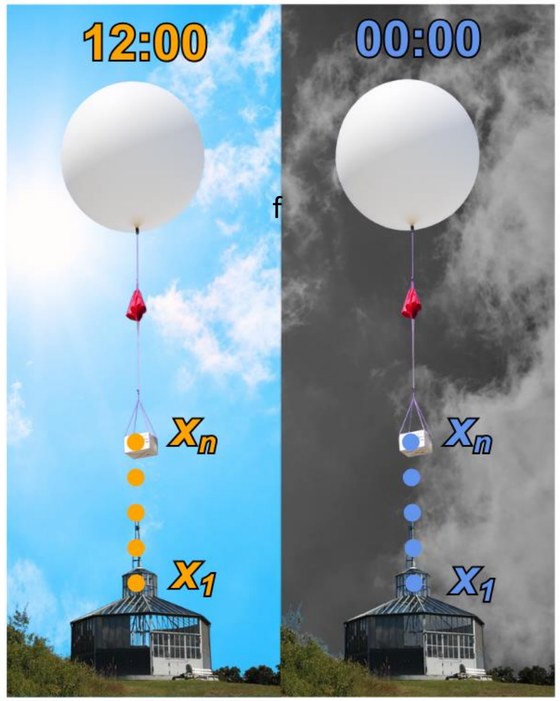
Uncorrelated u_{ucor}

Individual point uncertainties are treated as **random**.



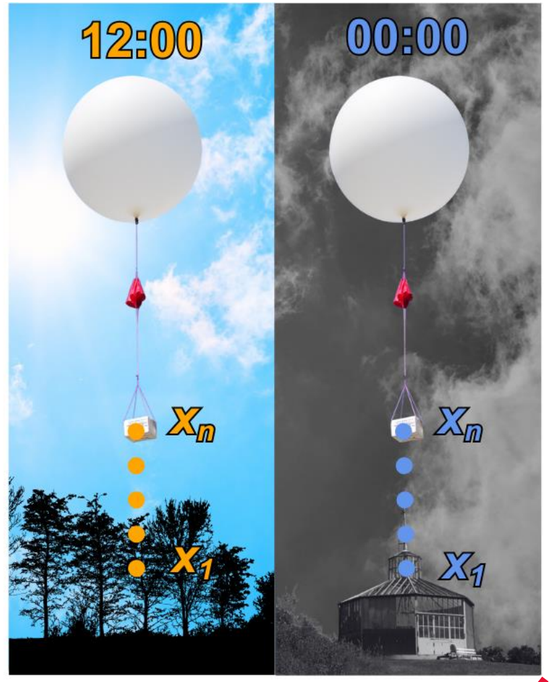
Spatially correlated u_{scor}

Uncertainties in a **single sounding profile** that are correlated (r=1). No correlation with other soundings.



Temporally correlated u_{tcor}

Correlated uncertainties between profiles measured at **different times and/or locations** (r = 1).



CoMet Toolkit

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Community Metrology (CoMet) **Toolkit**: a set of python modules that *handle*, *process*, and *store* measurement data uncertainties.

Obsarray: store uncertainty information

```
if 'ucor' in uc:
    uc_form_type = 'random'
elif 'tcor' in uc:
    uc_form_type = 'systematic'
elif 'scor' in uc:
    uc_form_type = 'systematic'
```

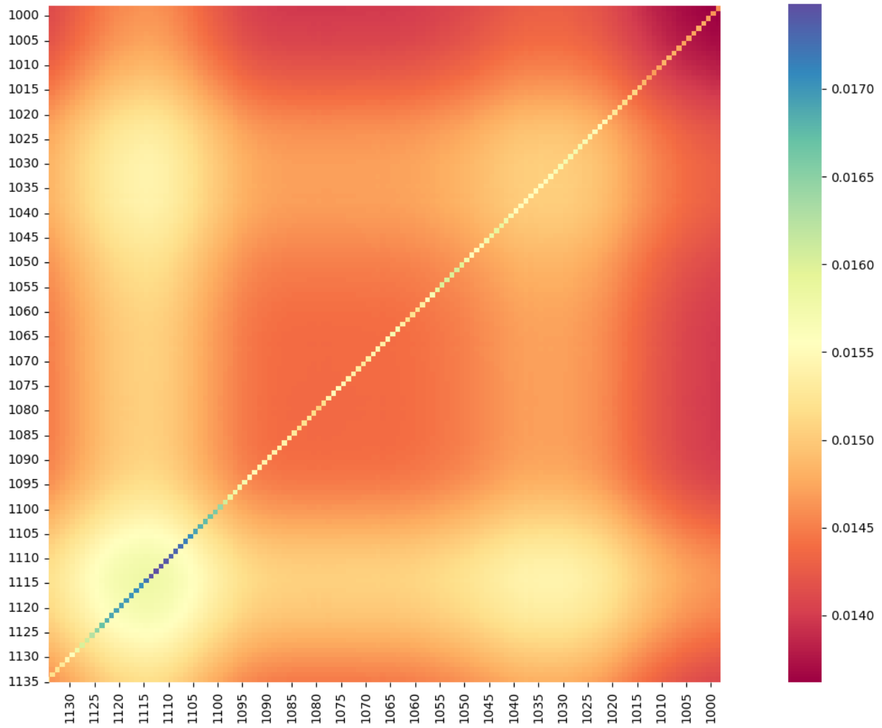
Comet_maths: performs matrix operations

```
# Obtain the covariance matrix for provided uncertainties
cov = ds.unc['rh'].total_err_cov_matrix()
# Obtain the correlation matrix for provided uncertainties
corr = ds.unc['rh'].total_err_corr_matrix()
```

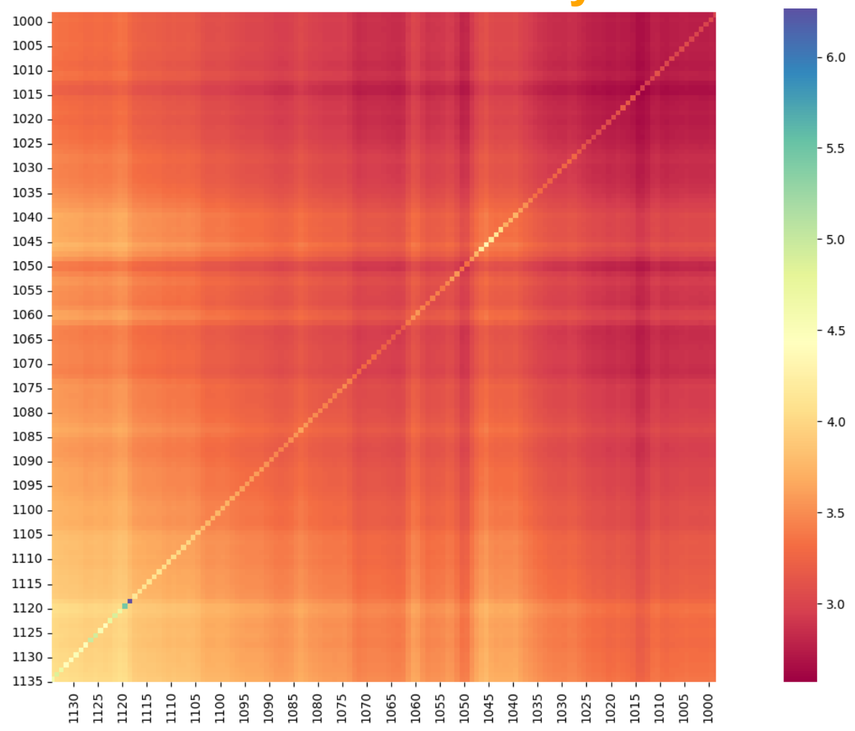
CoMet Outputs (12:00) NPL

Raw GRUAN data, 1000th to 1137th points (out of 6,864)

Temperature



Relative Humidity



Diagonals → variance, random uncertainties

Non-diagonals → systematic uncertainties

Temperature (12:00)

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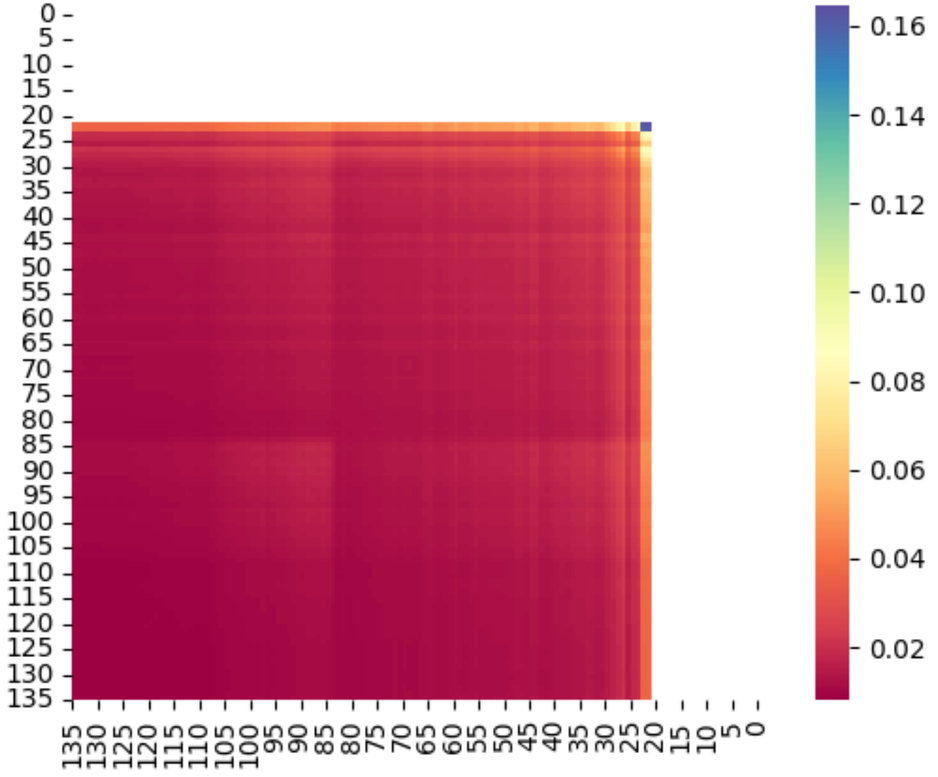
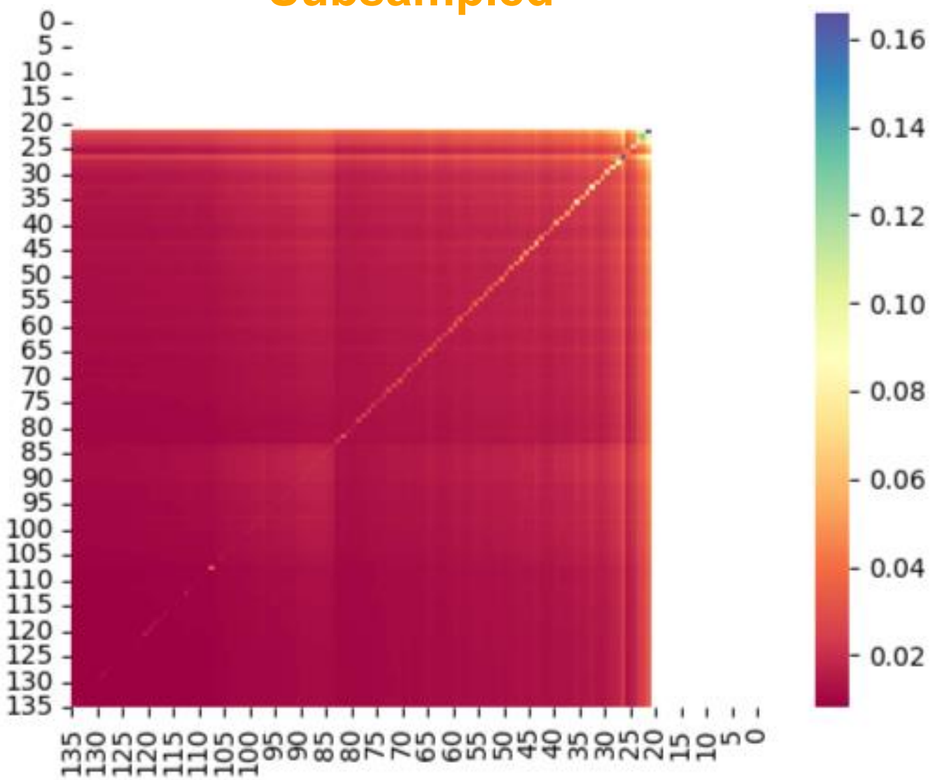
Layered mean vs subsampled 137 layers of **ECMWF**

Mean



Subsampled



Mean layers **reduce** random uncertainties (and combined uncertainty) and **minimise** variance (diagonal)

Relative Humidity (12:00)

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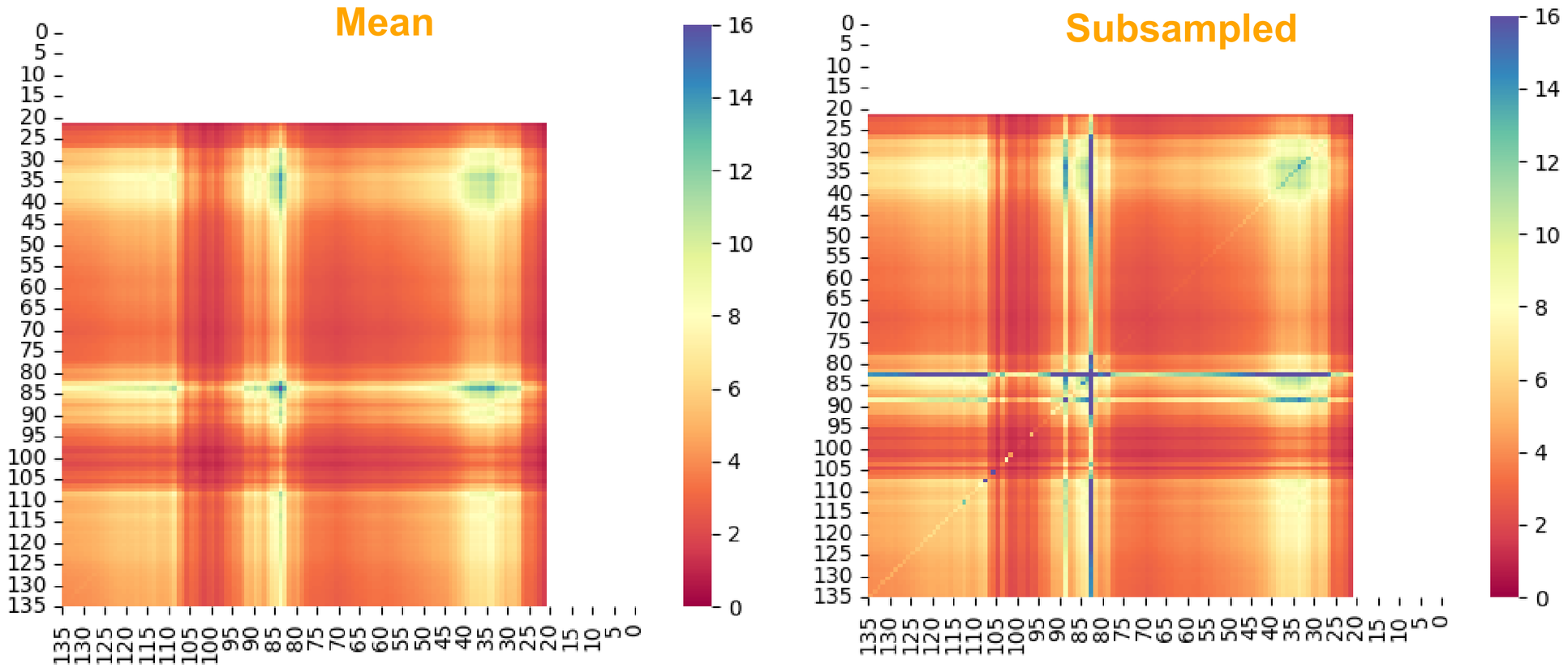
Layered mean vs subsampled 137 layers of **ECMWF**



Subsampling reduces thousands of points into a small subset, potentially **misrepresenting** the bigger picture

Conclusions

- ✓ Developed a method for calculating **covariance matrices** for *Vaisala RS-41* GRUAN Data Products using CoMet Toolkit.
- ✓ Tested it together with different **data processing methods** (layering, averaging, subsampling).
- ✓ Conducted a set of **metrological case studies** for temperature and RH.

Next Steps

- ❑ Respond to LC comments on **Technical Note (Nov 25).**
- ❑ Further Understanding of the uncertainty information of Vaisala RS-41.
  - ❑ **Tier 2** uncertainty breakdown and covariance information.
  - ❑ Account for the **partial correlations** of parameters.
- ❑ **Other parameters** beyond temperature and relative humidity.

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Thank you for your attention!