Topics

- Uncertainty Budget Development
  - Examples - Status of Copernicus Missions, Landsat
- Standards for Storage & Distribution

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Uncertainty Budget Development

Steps to an FDR / TDP or FRM Uncertainty budget

MEASURAND 01

Define the measurand and measurement function

TRACEABILITY 02

Establish the traceability with a diagram

UNCERTAINTY 03

Evaluate each source of uncertainty and fill out an effects table

CALCULATE 04

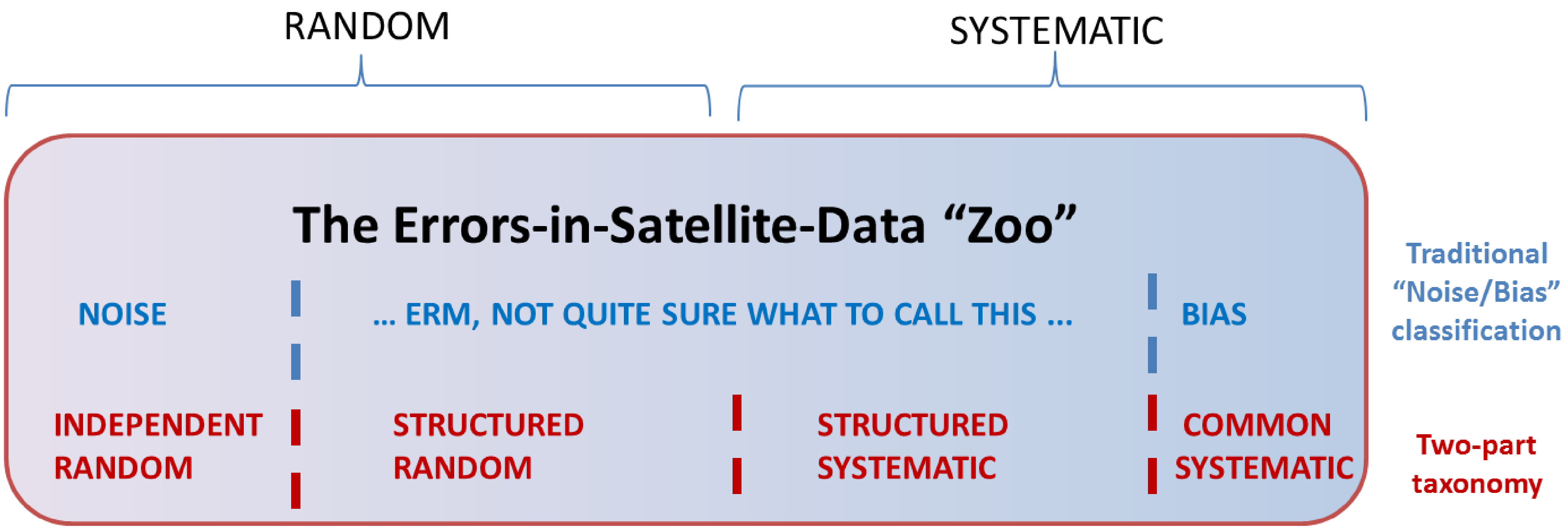
Calculate the product and its uncertainty

STORE 05

Store relevant information for future users

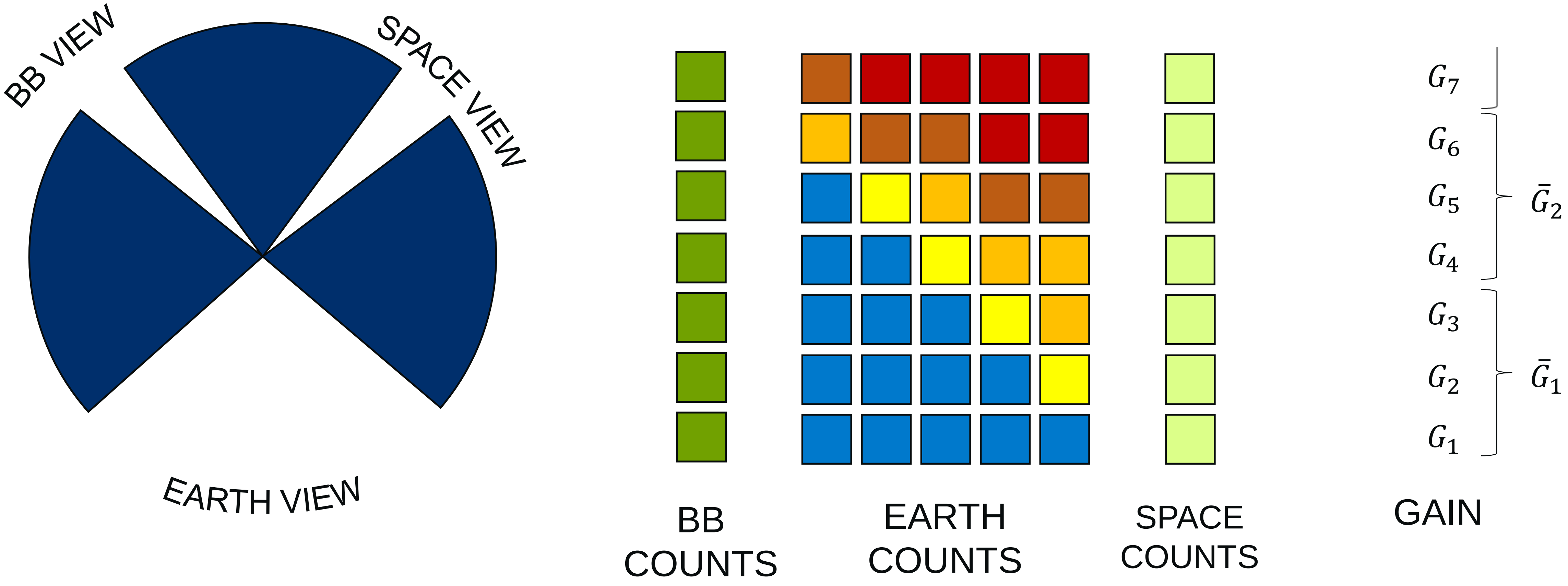
Guidance documentation and training materials available at www.qa4eo.org

Error-Correlation in EO Datasets

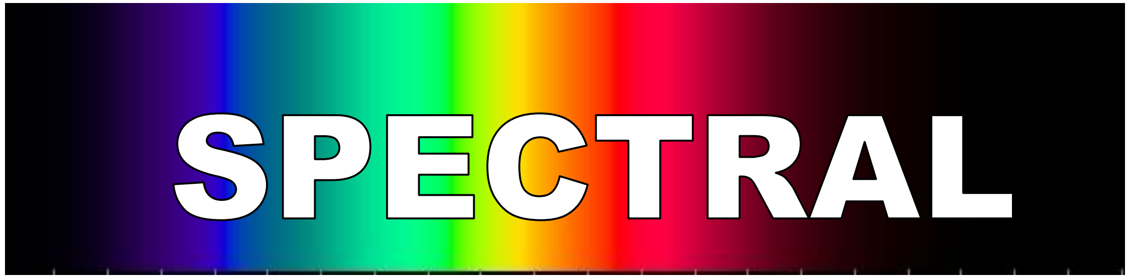


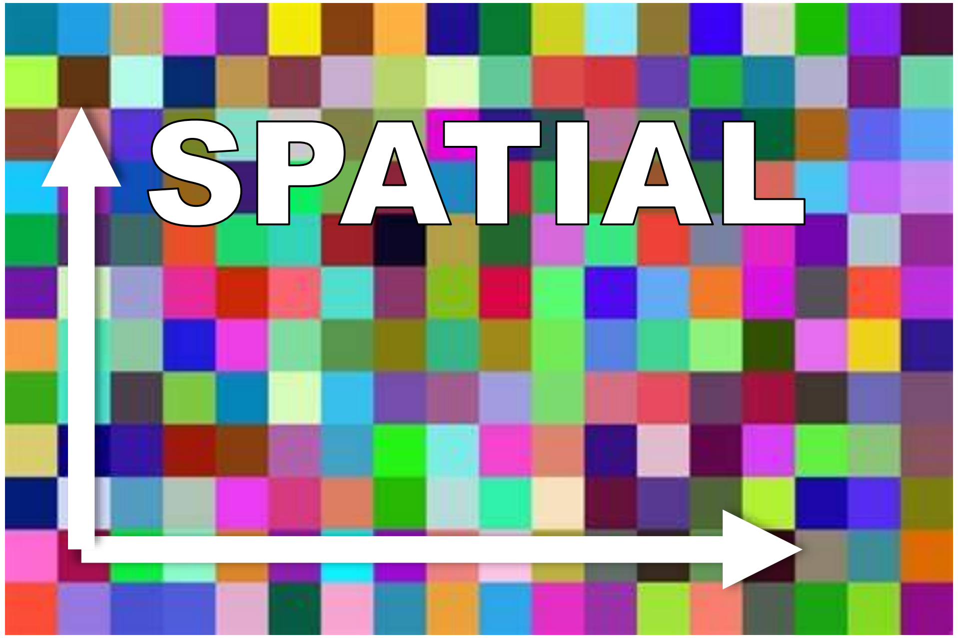
Example of a Sea Surface Temperature Radiometer

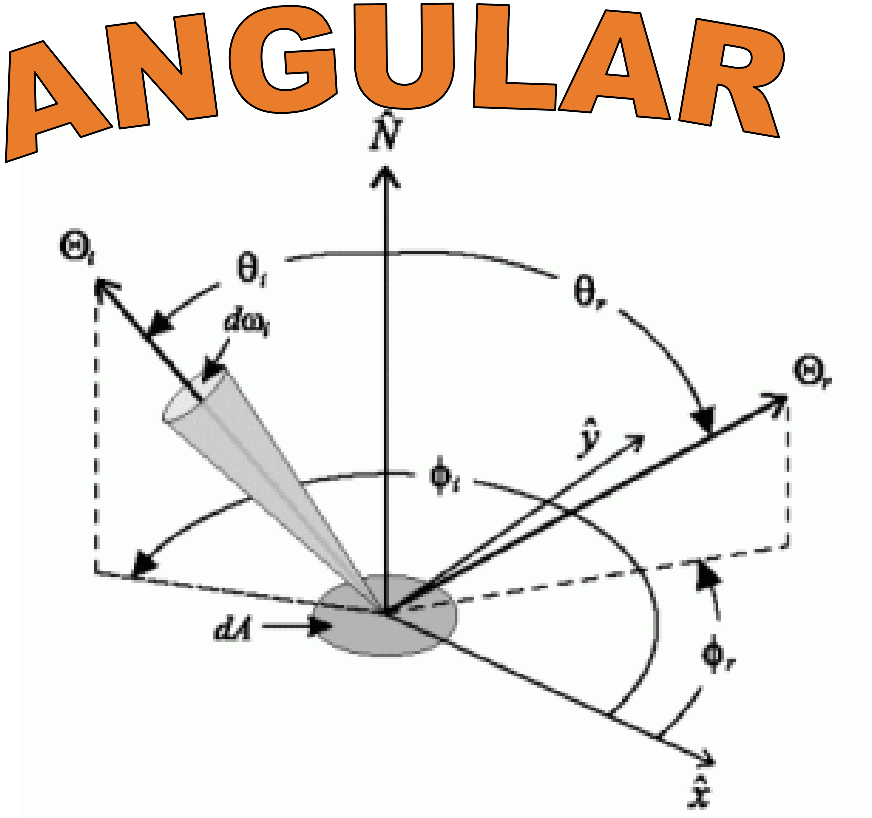
Sea surface temperature – TIR Radiometer – Example



Which dimensions matter?
(Radiometric examples)





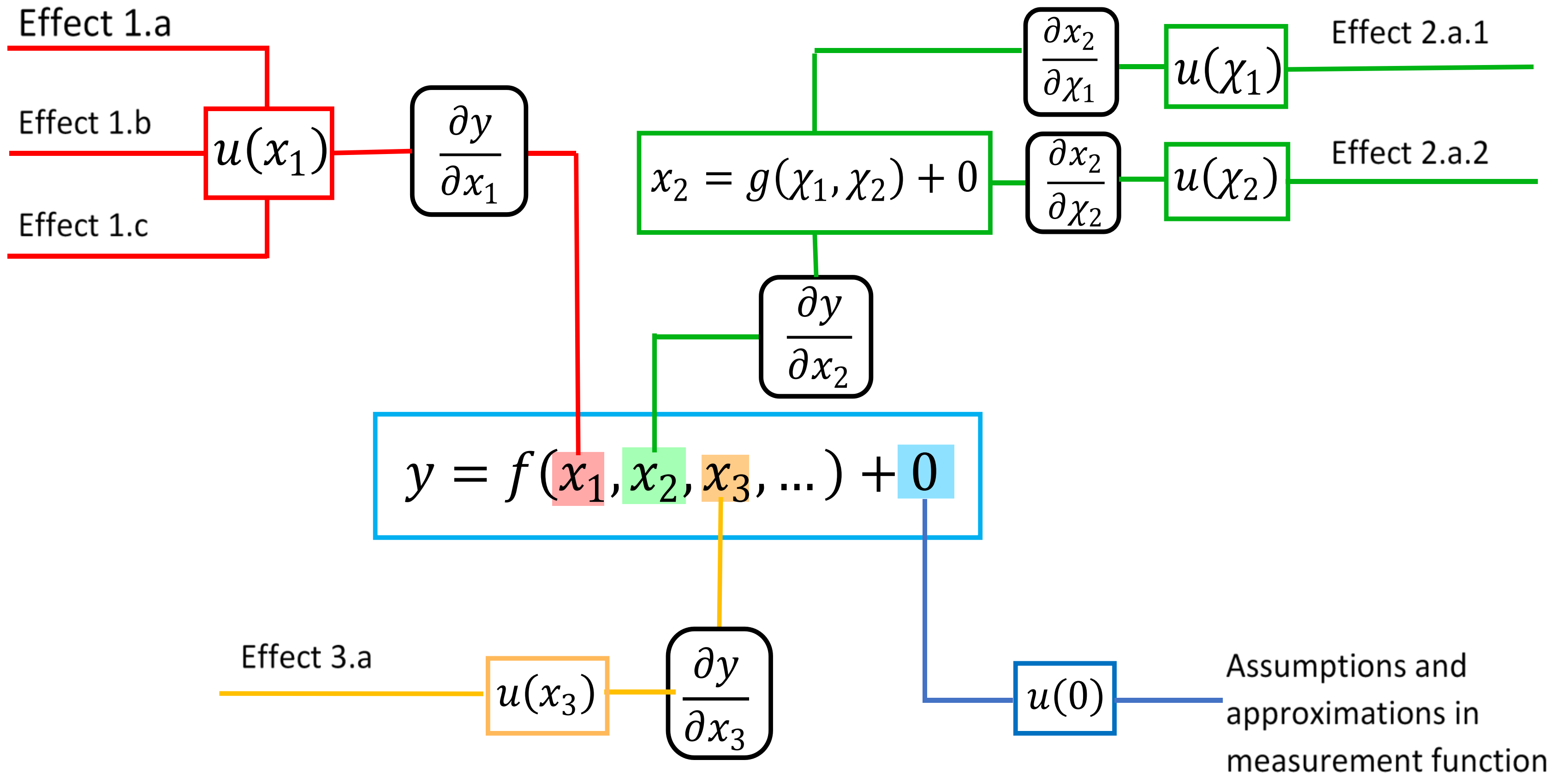


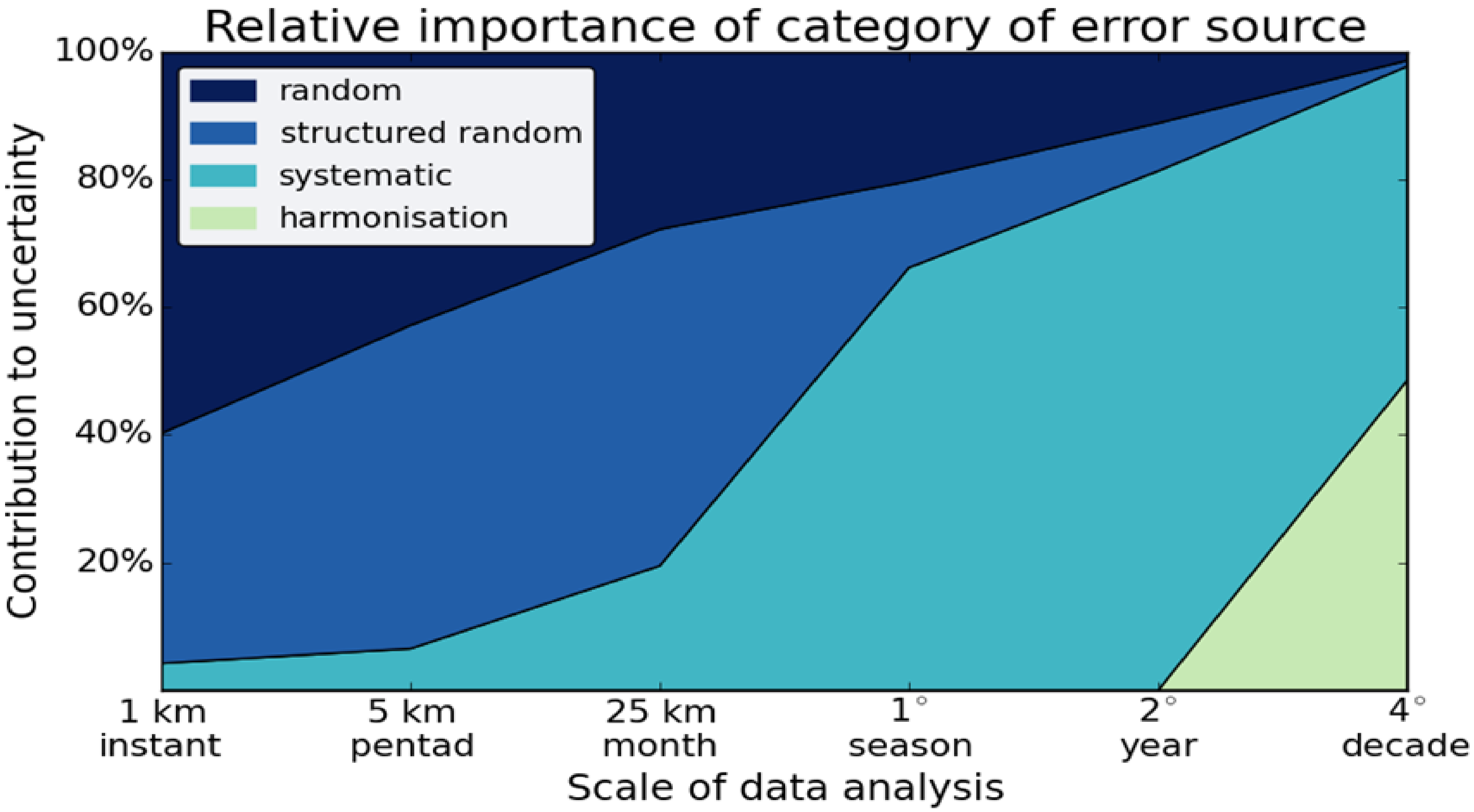
Artefact to artefact
Run to run
Site to site
Etc…

Establish traceability with a diagram

TRACEABILITY 02

Establish the traceability with a diagram





Relative importance of category of error source
100%
80%
60%
40%
20%
Contribution to uncertainty
random
structured random
systematic
harmonisation
1 km
instant
5 km
pentad
25 km
month
1°
season
2°
year
4°
decade
Scale of data analysis

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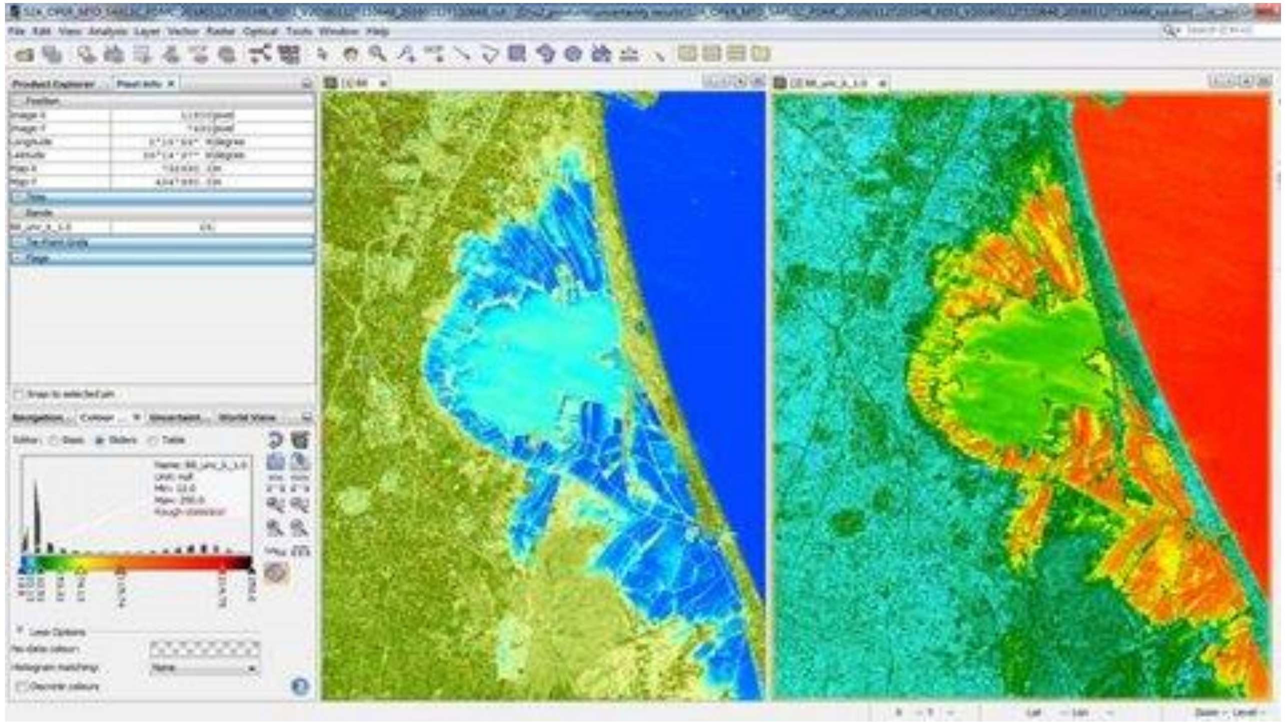
Copernicus Missions

Uncertainty Analysis for Copernicus Sensors

- Uncertainty information now available for all Copernicus optical imaging sensors at L1
  - Sentinel-2/MSI – on-the-fly tool (S2-RUT)
  - Sentinel-3/SLSTR – on-the-fly tool
  - Sentinel-3/OLCI – now embedded in the product

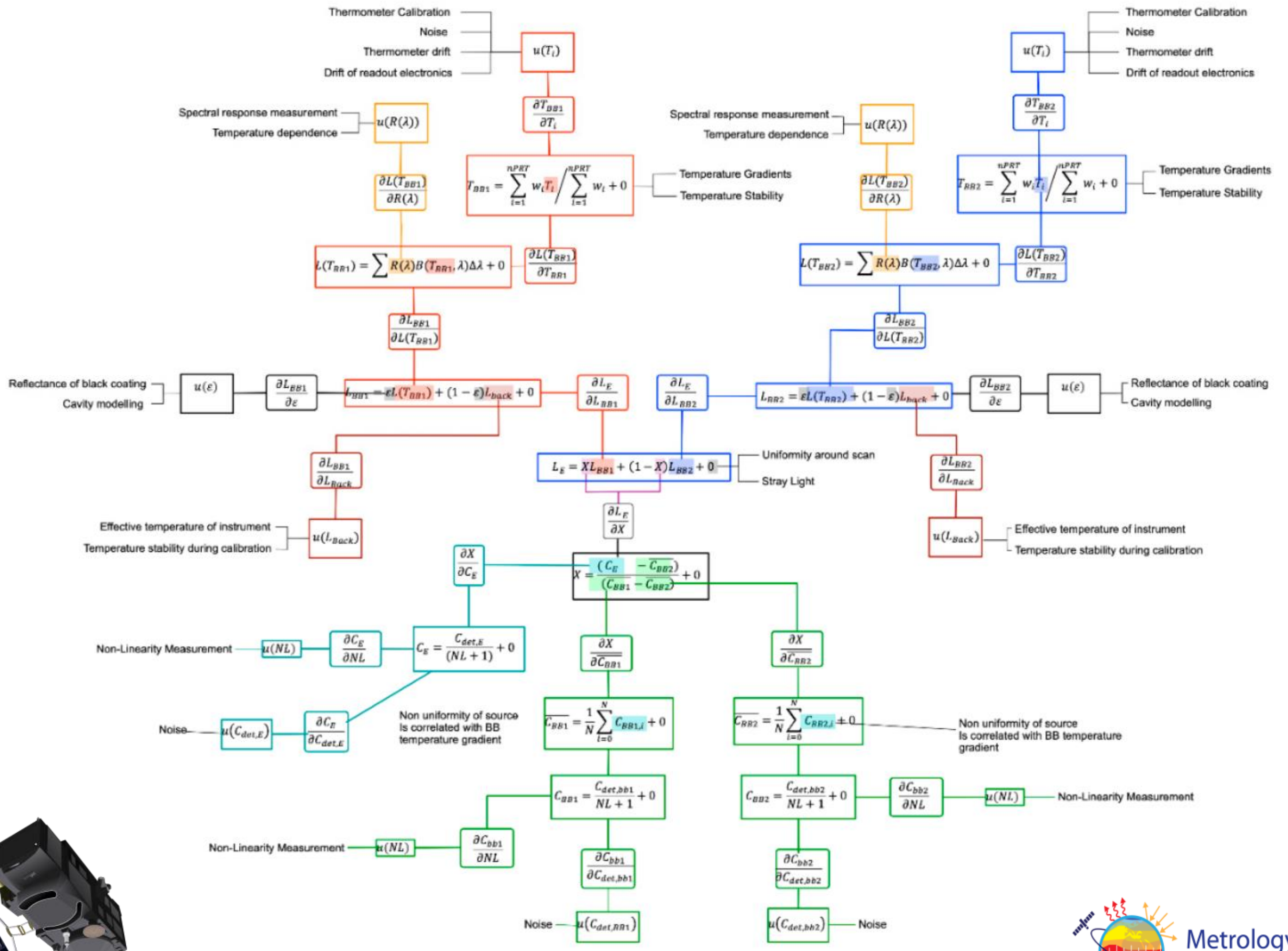
Sentinel-2 Radiometric Uncertainty Tool

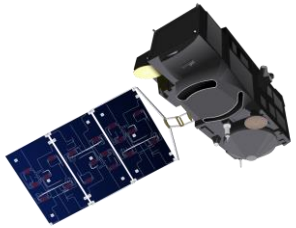
- S2-RUT plugin developed for SNAP to allow users to evaluate uncertainties for the products they are analysing on the fly
- Based on uncertainty model developed following GUM model
- On-going development to extend to L2A products



SLSTR Uncertainty Analysis

- Uncertainty budget developed in MetEOC
- Delivered by an on-the-fly tool MapNoiS3
- Validation activity via tandem phase analysis





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Standards for Storage & Distribution

Interactive mission documentation

- Interactive uncertainty tree diagram to store information about algorithms and as “educational resource” for mission
- Quantitative information about uncertainties included in metadata for products
- Documentation on data traceability and any harmonisation applied (e.g. Sentinel 2A/B harmonisation discussed yesterday). (Raw data also available?)
- CEOS to agree standardised approach so users can understand different missions and analyses

Standardised Error-Covariance Metadata: Digital Effects Tables (with NPL CoMet software)

		Comments
Name of effect		A unique name
Affected term in measurement function		Name and standard symbol
Instruments in the series affected		List names
Correlation type and form	Pixel-to-pixel [pixels]	From a set of defined correlation forms
	from scanline to scanline [scanlines]	
	between images [images]	
	Between orbits [orbit]	
	Over time [time]	
Correlation scale	Pixel-to-pixel [pixels]	As needed to define type
	from scanline to scanline [scanlines]	
	between images [images]	
	Between orbits [orbit]	
	Over time [time]	
Channels/bands	List of channels / bands affected	Channel names
	Error correlation coefficient matrix	A matrix
Uncertainty	PDF shape	Functional form
	units	Units
	magnitude	
Sensitivity coefficient		Value, equation or parameterisation of sensitivity of measurand to term

FIduceo Effects Table

```
double u_str_temperature(x=2, y=2, time=3);
  :_FillValue = 9.969209968386869E36; // double
  :err_corr_1_dim = "x";
  :err_corr_1_form = "custom";
  :err_corr_1_units = ; // double
  :err_corr_1_params = "err_corr_str_temperature_x";
  :err_corr_2_dim = "y";
  :err_corr_2_form = "systematic";
  :err_corr_2_units = ; // double
  :err_corr_2_params = ; // double
  :err_corr_3_dim = "time";
  :err_corr_3_form = "systematic";
  :err_corr_3_units = ; // double
  :err_corr_3_params = ; // double
  :pdf_shape = "gaussian";
```

Print out of uncertainty variable attributes for netCDF file

Digital Effects Table

Tools for uncertainty propagation

- NPL's CoMet toolkit can be used to simplify uncertainty propagation
  - Open-source python toolkit aligned to QA4EO approach
  - Enable easy handling and processing of dataset error-covariance
  - Implements Law of Propagation of Uncertainties & Monte Carlo methods
  - Allow the user to rely on quality-assured code, rather than having to reinvent the wheel, and lower the barrier to entry for users new to handling uncertainties.

www.comet-toolkit.org
github.com/comet-toolkit

The CoMet toolkit in practice

These digital effects tables (DET) can be used to propagate uncertainties while automatically taking into account the error correlation information

```
from punpy import MeasurementFunction

# Define your measurement function inside a subclass of MeasurementFunction
class IdealGasLaw(MeasurementFunction):
    def meas_function(self, pres, temp, n):
        return (n *temp * 8.134)/pres

# create object of the measurement function class and specify the variable names
gl = IdealGasLaw(["pressure", "temperature", "n_moles"], "volume", yunit="m^3")

# propagate uncertainties on the input quantities in ds to measurand in ds_y
ds_y = gl.propagate_ds(ds)
```

ds_y will contain DET with propagated random, systematic and structured uncertainties, taking into account error_correlation in ds (input DET)

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Discussion Topics

Discussion Topics

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- Building an uncertainty budget
  - Design
  - Pre-Launch Characterization
  - Transfer to Orbit
  - Monitoring
  - How can expand the uptake of uncertainty best practices
    - At space agencies?
    - At commercial companies?
      - What are the minimum viable implementations?
  - Already on-orbit sensors

Discussion Topics

NPL

- Coordination Between Active Groups
- Standardization/Best Practices
- Generalizations/Simplifications
- Constellation Normalization
- Tools/Processing/Data Storage
- References/Traceability/Uncertainty "Transfer"
- Metadata

- How can we progress with these topics?