Sentinel-2 Radiometric Uncertainty Tool (S2 RUT): towards an operational version

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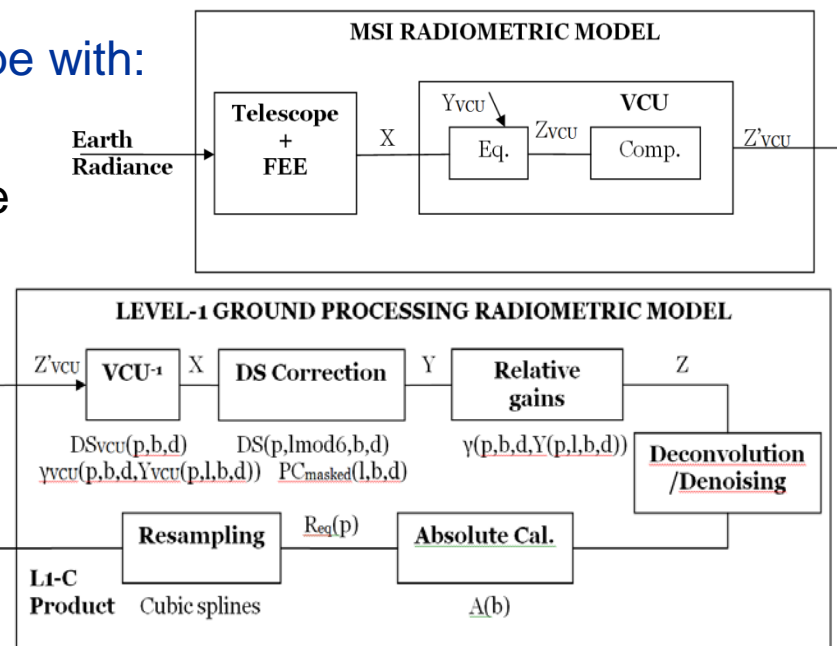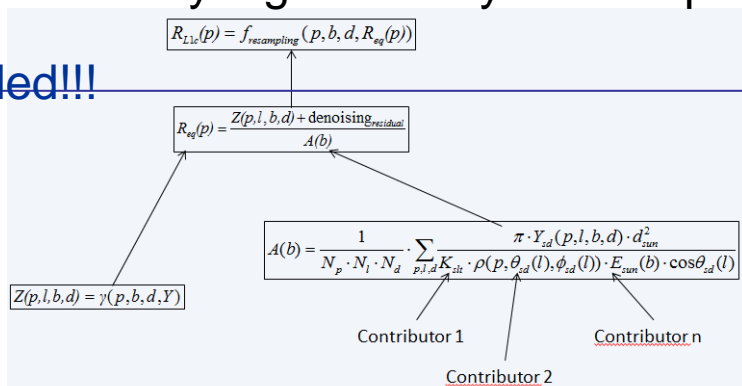Work to-date largely carried out at ESA

S2-RUT: What is it?

- **A software tool that allows a user (at their location) to determine the radiometric uncertainty at pixel level of a Sentinel-2 Level-1C product (TOA reflectance/radiance image)**

    - **minimising file transmission size:**

  - Rigorous uncertainty analysis and combination following QA4EO principles
  - Accounting for multiple Variables, both sensor and scene dependent: stray-light, On-board calibrator, detector noise, cross-talk, polarisation..
  - Based on establishment and coding of mathematical model of sensor & ground segment radiometry & resultant uncertainty model.

- Version 1 offers a first fully functional prototype with:
  Basic uncertainty analysis and combination
  Multi-variable uncertainty based on Radiance
  But with relatively high memory consumption

- V2 needed!!!

MSI RADIOMETRIC MODEL

Earth Radiance → Telescope + FEE → X → VCU (Eq. → Comp.) → Z'VCU

LEVEL-1 GROUND PROCESSING RADIOMETRIC MODEL

Z'VCU → VCU⁻¹ → X → DS Correction → Y → Relative gains → Z → Deconvolution/Denoising

$DS_{VCU}(p,b,d)$ $DS(p,lmod6,b,d)$ $\gamma(p,b,d,Y(p,l,b,d))$
$\gamma_{VCU}(p,b,d,Y_{VCU}(p,l,b,d))$ $PC_{masked}(l,b,d)$

L1-C Product Cubic splines

Resampling ← $R_{eq}(p)$ ← Absolute Cal. ← $\underline{A}(b)$

$$R_{L1c}(p) = f_{resampling}(p,b,d,R_{eq}(p))$$

$$R_{eq}(p) = \frac{Z(p,l,b,d) + \text{denoising}_{residual}}{A(b)}$$

$$A(b) = \frac{1}{N_p \cdot N_l \cdot N_d} \cdot \sum_{p,l,d} K_{slt} \cdot \frac{\pi \cdot Y_{sd}(p,l,b,d) \cdot d_{sun}^2}{\rho(p,\theta_{sd}(l),\phi_{sd}(l)) \cdot E_{sun}(b) \cdot \cos\theta_{sd}(l)}$$

$Z(p,l,b,d) = \gamma(p,b,d,Y)$

Contributor 1   Contributor n

Contributor 2

S2-RUT: Potential example Applications

- Toolbox supplied for user to choose to evaluate uncertainty at level required

- S2-RUT output to ingest higher level products uncertainty (Uncertainty propagation):

  e.g. Possibility of similar approach and its extension for Atm. Correction and L2.

- Case-2 water automated solutions:

  e.g. Average random uncertainty in a ROI can provide a "fit-for-purpose" binning in case2 water applications.

- Different performance over different scenes:

  e.g. Land vs. Case2 waters
  Boreal vs. Amazon forest

Level 1 C reflectance
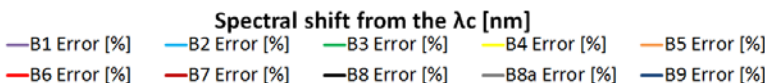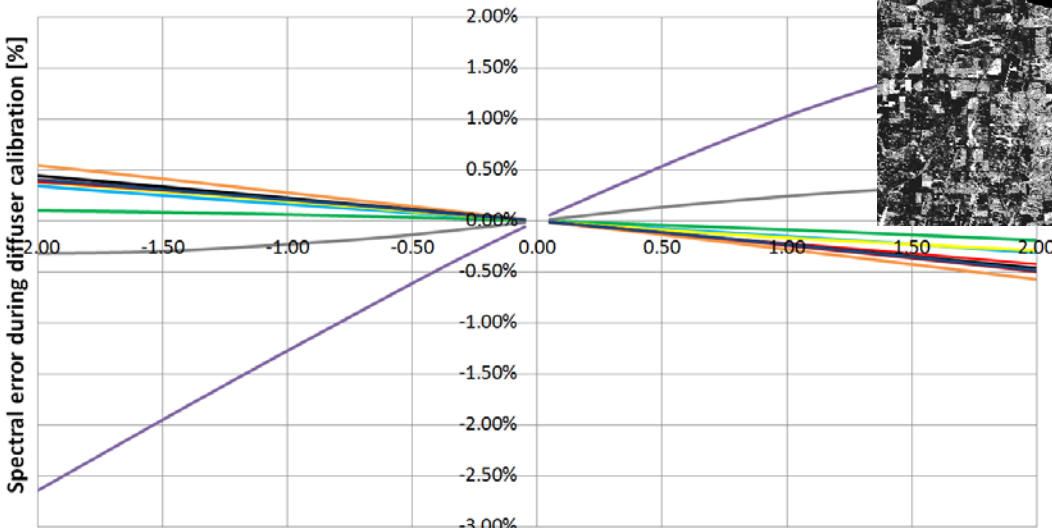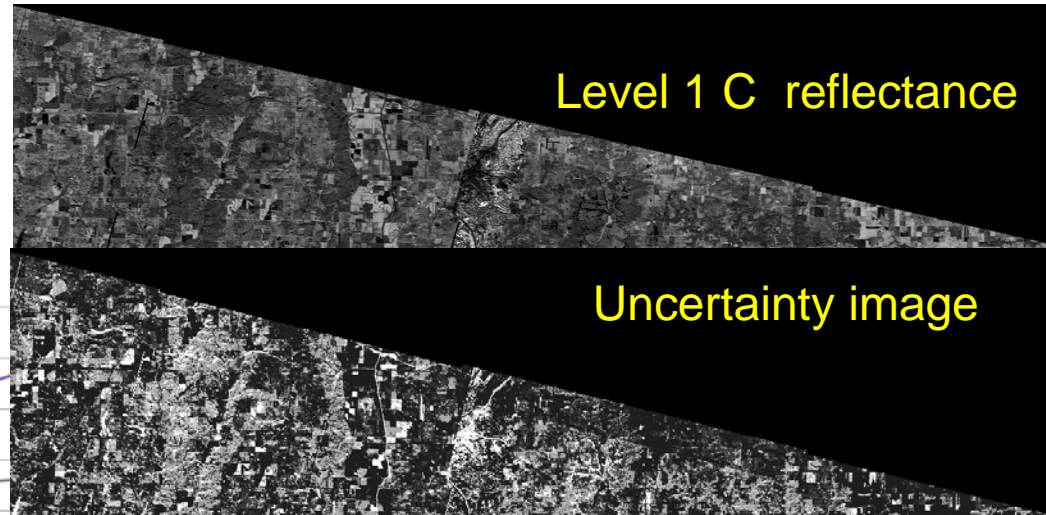
Uncertainty image

- Uncertainty analysis to monitor MSI:
  e.g. Radiometric impact of spectral error for in-flight Diffuser calibration

Spectral error during diffuser calibration [%]

Spectral shift from the λc [nm]

— B1 Error [%] — B2 Error [%] — B3 Error [%] — B4 Error [%] — B5 Error [%]
— B6 Error [%] — B7 Error [%] — B8 Error [%] — B8a Error [%] — B9 Error [%]

S2-RUT: towards a v2- next steps

NPL
National Physical Laboratory

- **Uncertainty analysis refinement**

  Analysis at detector level and propagation to L1C (effects of resampling): optical crosstalk-largely depends on angle of incidence between odd/even detectors

  Radiometric impact of spectral error: interference Across-track of passivation layers, filter stability, Fraunhofer line impact…

- **Uncertainty combination improvement**

  Montecarlo vs. GUM model validation (Supplement 1 to GUM)

  Study of the covariance: 2nd order

  $$2\sum_{i=1}^{N-1}\sum_{j=i+1}^{N}\frac{\partial f}{\partial x_i}\frac{\partial f}{\partial x_j}u(x_i)u(x_j)r(x_i,x_j)$$

- **Code design- efficiency**

  JPEG-2000 codification optimisation: OPENJPEG decoder

  Latency vs. memory trade-off: Radiance conversion per pixel

  rather than per image

- **Basis for other aspects and sensors?**

  Geometry, Atmospheric correction, Sentinel 3