Technical Note on Quality Assessment for GomX-4B HyperScout-1

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AMENDMENT RECORD SHEET

The Amendment Record Sheet below records the history and issue status of this document.

ISSUE	DATE	REASON
0.1	15/12/2020	First draft version for review.
1.0	03/06/2021	Second draft version for review. Included updated version of Figure 4-10 with TOA NDVI comparison included.
1.0	23/03/2022	First issue

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1. INTRODUCTION

This technical note details the results of the (preliminary) mission data quality assessments (including geometric calibration, radiometric calibration and image quality) performed on a sample of two HyperScout-1 (GomX-4B satellite) Land Level 1C products provided by Cosine Measurement Systems, the instrument developer who is based in the Netherlands.

The aforementioned mission data quality assessments are performed in accordance with the assessment guidelines, detailed in [RD.1] and [RD.2] that constitute the European Space Agency (**ESA**) Earthnet Data Assessment Pilot (**EDAP**) Project's *EO Mission Data Quality Assessment Framework*. An important representation of the latter framework, constructed by the National Physical Laboratory (**NPL**), is what is known as the *maturity matrix*. It is a diagrammatic summary of the following:

- ***Documentation Review****: the EDAP Optical team reviews materials (e.g. data and documentation) provided by the data provider or operator, some of which may not be publicly available, or even the scientific community (e.g. published papers). The results are detailed in Section 2 (covering the first four columns of the maturity matrix).*
- ***Data Quality Assessments:*** *the EDAP Optical team performs the data quality assessments (i.e. validation assessments), independently of any validation assessments performed by the data provider and / or operator. The results are detailed in Section 3 (covering the last column, 'Validation', of the maturity matrix).*

The above assessments are performed by the EDAP Optical team using the appropriate in-house and open-source ad-hoc scripts / tools.

It is important to note the purpose of the EDAP EO Mission Data Quality Assessment Framework is to ensure that the delivered commercial mission data is fit for purpose and that all decisions regarding the inclusion of the commercial mission as an ESA third party mission can be made fairly and with confidence.

1.1 Reference Documents

The following is a list of documents with a direct bearing on the content of this report. Where referenced in the text, these are identified as RD.n, where 'n' is the number in the list below:

[RD.1] EDAP Mission Quality Assessment Guidelines, Issue 1.2, 19 July 2019.

[RD.2] Earth Observation Mission Quality Assessment Framework – Optical Guidelines, EDAP.REP.002, v2.0, December 2020.

[RD.3] GomX-4 overview: https://directory.eoportal.org/web/eoportal/satellite-missions/g/gomx-4

[RD.4] Bouvet, M.; Thome, K.; Berthelot, B.; Bialek, A.; Czapla-Myers, J.; Fox, N.P.; Goryl, P.; Henry, P.; Ma, L.; Marcq, S.; Meygret, A.; Wenny, B.N.; Woolliams, E.R. 2019. RadCalNet: A Radiometric Calibration Network for Earth Observing Imagers Operating in the Visible to Shortwave Infrared Spectral Range. *Remote Sens.*, https://doi.org/10.3390/rs11202401

[RD.5] COSINE. 2020. HyperScout VNIR Level-1C data product specification, CR-HSTPM-SP01, August 2020.

[RD.6] Esposito M. and Zuccaro Marchi A. 2019. In-Orbit Demonstration of the first hyperspectral imager for nanosatellites, *International Conference on Space Optics*, https://doi.org/10.1117/12.2535991

[RD.7] Sentinel-2 Radiometric Resolution: Radiometric - Resolutions - Sentinel-2 MSI - User Guides - Sentinel Online (esa.int)

[RD.8] PRISMA Specification: PRISMA (Hyperspectral) - eoPortal Directory

[RD.9] Barducci et al. 2005. CHRIS-Proba Performance Evaluation: Signal-To-Noise Ratio, Instrument Efficiency and Data Quality From Acquisitions Over San Rossore (Italy) Test Site, 3rd ESA CHRIS/Proba Workshop

[RD.10] RadCalNet Working Group, The 2020 data collection – changes, improvements and quality, Version 1.0, 07 March 2020. https://www.radcalnet.org/documentation/RadCalNetProcessing/2020_Data_Collection_Changes_Improvements_Quality_v20200317.pdf

[RD.11] Roy, D.P.; Li, J.; Zhang, H.K.; Yan, L.; Huang, H. 2017. Examination of Sentinel-2A multispectral instrument (MSI) reflectance anisotropy and the suitability of a general method to normalise MSI reflectance to nadir BRDF adjusted reflectance. *Remote Sens. Environ.*, 199, 25–38.

[RD.12] CEOS, 2020. RadCalNet Quick Start Guide: https://www.radcalnet.org/resources/RadCalNetQuickstartGuide_20180702.pdf

[RD.13] Lavender et al. 2020 (Submitted) CHRIS/Proba-1 Radiometric Calibration Assessment, *WHISPERS 2021*.

1.2 Glossary

The following acronyms and abbreviations have been used in this report:

ATBD	Algorithm Theoretical Basis Document
BRDF	Bidirectional Reflectance Distribution Function
CEOS	Committee on Earth Observation Satellites
DDALO	Danish Defence Acquisition and Logistics Organization
EDAP	Earthnet Data Assessment Pilot
ESA	European Space Agency
GCP	Ground Control Points
L1C	Level 1C
NBAR	Nadir BRDF-Adjusted Reflectance
NPL	National Physical Laboratory
PUG	Product User Guide
RadCalNet	Radiometric Calibration Network
RD	Reference Document
SNR	Signal-to-Noise Ratio
TOA	Top of Atmosphere

VNIR	Visible and Near-InfraRed

2. EXECUTIVE SUMMARY

The aim is to perform the following data quality assessments of the HyperScout-1 data provided:

- Assessment (review) of documentation (EDAP Maturity Matrix);
- Assessment of geometric and radiometric calibration quality, using **Level 1C** products;
- Assessment of product suitability for applications through the preliminary application of applying Level 2 algorithms.

2.1 EDAP Maturity Matrix

Note with each iteration of this report, the available documentation has been checked and updated where necessary.

Product Details	Product Generation	Ancillary Information	Uncertainty Characterisation	Validation
Product Information	Sensor Calibration & Characterisation Pre-Flight	Product Flags	Uncertainty Characterisation Method	Reference Data Representativeness
Availability & Accessibility	Sensor Calibration & Characterisation Post-Launch	Additional Information	Uncertainty Sources Included	Reference Data Quality
Product Format			Uncertainty Values Provided	Validation Method
User Documentation			Geolocation Uncertainty	Validation Results
Metrological Traceability Documentation				

Key
Not Assessed
Not Assessable
Basic
Intermediate
Good
Excellent
Information Not Public

Figure 2-1 – HyperScout-1 Quality Evaluation Matrix

2.2 Summary of Quality Assessment

The two HyperScout-1 Level 1C (**L1C**) products supplied have been used to perform preliminary data quality assessments of the product's radiometric accuracy, geometric accuracy, and suitability for applications. The products were assessed using a combination of Jupyter notebooks for the radiometric calibration assessment and remote sensing / geographic information system packages for the geometric calibration and application assessments. Overall, the results were positive but as the data was limited in scope and had been vicariously adjusted using one of the sites supplied then the results are considered as preliminary.

3. DETAILED EDAP QUALITY ASSESSMENT

3.1 Product Details

Product Information	
Grade: Basic	
Product Name	VNIR Level -1C
Sensor Name	HyperScout-1
Sensor Type	Hyperspectral imager
Product Version Number	Only schema version quoted in HDF header
Product ID	N/A
Processing level of product	Level 1C (**L1C**) - Level 2 (**L2**) is mentioned in [RD.3], but was not provided for independent assessment
Measured Quantity Name	Reflectance
Measured Quantity Units	Unitless
Stated Measurement Quality	Radiometric and geometric assessment provided in the supplied technical note
Spatial Resolution	Ground Sample Distance (GSD) @500 km altitude is 70 m
Spatial Coverage	200 km @500 km altitude
Temporal Resolution	Acquisition on-demand
Temporal Coverage	Acquisition on-demand
Mission coverage	Global
Point of Contact	COSINE Measurement Systems
Product locator (DOI/URL)	N/A
Conditions for access and use	Data provided privately under the restrictions of an NDA
Limitations on public access	No public access
Product Abstract	N/A

Product Availability & Accessibility	
Grade: Not Assessable	
Compliant with FAIR principles	Examples provided for review, dataset not free-to-access
Data Management Plan	Not provided
Availability Status	Size of overall archive unknown

Product Format
Grade: Basic

Product File Format	HDF
Metadata Conventions	Not stated
Analysis Ready Data?	Not as provided

Product User Documentation		
Grade: Not Assessable		
Document	*Reference*	*QA4ECV Compliant*
Product User Guide (**PUG**)	For the assessment, EDAP were provided with a technical note [RD.5]	
Algorithm Theoretical Basis Document (**ATBD**)	N/A	

Metrological Traceability Documentation	
Grade: Not Assessable	
Document Reference	Not provided
Traceability Chain / Uncertainty Tree Diagram Available	Not provided

3.2 Product Generation

Sensor Calibration & Characterisation – Pre-Flight	
Grade: Not Assessable	
Summary	Not provided / found from online search
References	N/A

Sensor Calibration & Characterisation – Post-Launch	
Grade: Not Assessable	
Summary	Limited information available publicly
References	• Provided within the supplied technical note [RD.5] • In-Orbit Demonstration of the first hyperspectral imager for nanosatellites [RD.6]

3.3 Ancillary Information

Product Flags	
Grade: Not Assessable	
Product Flag Documentation	Product has no flags
Comprehensiveness of Flags	N/A

Additional Information

Grade: Not Assessable	
Ancillary Data Documentation	None provided
Comprehensiveness of Data	N/A
Uncertainty Quantified	N/A

3.4 Uncertainty Characterisation

Uncertainty Characterisation Method	
Grade: Not Assessable	
Summary	No relevant documentation has been found.
Reference	N/A

Uncertainty Sources Included	
Grade: Not Assessable	
Summary	No relevant documentation has been found.
Reference	N/A

Uncertainty Values Provided	
Grade: Not Assessable	
Summary	No relevant documentation has been found.
Reference	N/A
Analysis Ready Data?	N/A

Geolocation Uncertainty	
Grade: Basic	
Summary	Not provided / No relevant documentation has been found.
Reference	N/A

3.5 Validation

Validation Activity #1	
Independently Assessed?	Limited analysis by EDAP within this report, no other examples found.
Reference Data Representativeness	
Grade: Basic	
Summary	Overall, the results were positive but as the data was limited in scope and had been adjusted using one of the sites supplied then the results are considered as preliminary.
Reference	Section 4

Reference Data Quality & Suitability	
Grade: Basic	
Summary	RadCalNet for the radiometric analysis
Reference	[RD.4] RadCalNet: A Radiometric Calibration Network for Earth Observing Imagers Operating in the Visible to Shortwave Infrared Spectral Range
Validation Method	
Grade: Basic	
Summary	As described in Section 4
Reference	N/A
Validation Results	
Grade: Basic	
Summary	As described in Section 4
Reference	N/A

4. DETAILED HYPERSCOUT-1 QUALITY ASSESSMENT

4.1 Goals

GomX-4 is a research and development mission developed by GomSpace ApS (Denmark) [RD.3]. The mission includes two 6U CubeSats, launched on 2 February 2018:

- GomX-4A was sponsored by the Danish Defence Acquisition and Logistics Organization (**DALO**) with a focus on surveillance of the Arctic.
- GomX-4B is an ESA satellite, intending to demonstrate inter-satellite linking and station keeping capabilities, which are both key enabling technologies for future nanosatellite constellations.

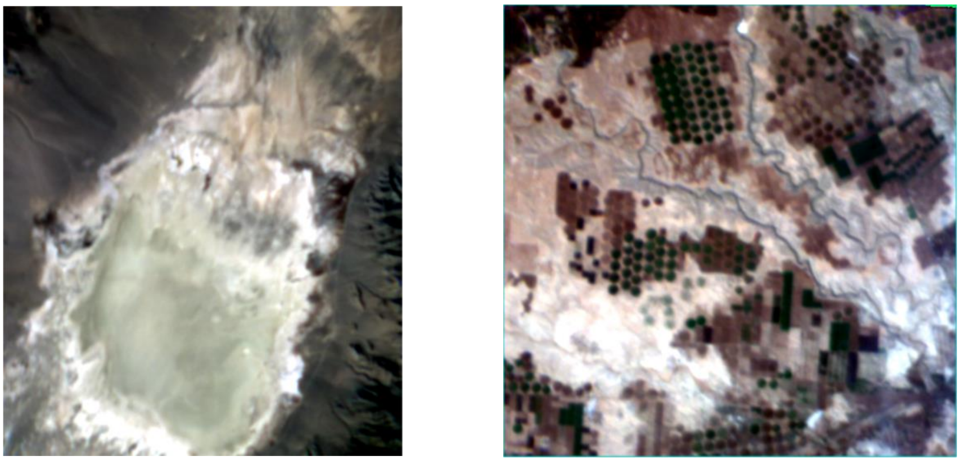
HyperScout-1 is carried onboard GomX-4B and is a hyperspectral imager with 45 spectral bands within the 400-1000 nm wavelength range. The maximum size of an image is 4096 x 1850 pixels.

This report includes inspections regarding image quality, radiometric calibration, and geometric calibration, as follows:

- The radiometric calibration consistency and calibration is essential for temporal analysis. The measured radiance depends on the sensor and changing viewing conditions (sun sensor view angle). The assessment is based on a comparison to in-situ measurements from the Radiometric Calibration Network (**RadCalNet**) [RD.4].
- The geometry is assessed to understand the quality of ortho-processing, which is often based on both a sensor model and Ground Control Points (**GCP**). The products are compared to Sentinel-2. Temporal geometric registration accuracy is required for time-series analysis. As only a single HyperScout-1 image has been supplied over a location where this can be assessed, the aim is to understand whether users would have to perform additional processing for the data to be applicable, i.e. whether the geometric accuracy is sufficient to be immediately usable of if further processing using GCPs is needed first.

4.2 Image Quality

Two images were provided for assessment, see Figure 4-1. The L1C data Visible and Near-InfraRed (**VNIR**) product is composed of a Top of Atmosphere (**TOA**) reflectance hyperspectral cube. Images can be generated up to a size of 4000 x 4000 pixels, but downlink limitations result in smaller images being available to analyse on-ground. The supplied images are from (Figure 4-1a) Railroad Valley, USA, and (Figure 4-1b) Ceylanpinar, Turkey.



(a) **(b)**

Figure 4-1: HyperScout-1 images from (a) Railroad Valley, USA, and (b) Ceylanpinar, Turkey, shown as pseudo colour composites (651, 551 and 450 nm as RGB).

The specifications of the two images are shown in Table 4-1, both have 40 bands and are subsets of the larger possible acquisitions.

Table 4-1. GCOM-C Image Specifications

Specification	Railroad Valley	Ceylanpinar
Filename	HS-L1C-FA-16f57-00.hdf5	HS-L1C-FA-166db-00.hdf5
Date of Acquisition	07 November 2018	01 November 2018
Dimensions (columns x rows)	390 x 440	440 x 440
No. of Bands	40	40

4.2.1 Data Quality Flags or Mask

The HDF file contains no data flags or mask bands to indicate data quality.

4.2.2 Surface Reflectance

The data is supplied as TOA reflectance data resampled to a cartesian map projection:

- Railroad Valley: UTM zone 11N (EPSG:32611)
- Ceylanpinar: UTM zone 37N (EPSG:32637)

4.2.3 Signal-to-Noise Ratio

The Signal-to-Noise Ratio (**SNR**) is a vital image quality indicator to assess the potential of data. Visual interpretation of an image does not require high SNR data; even in the presence of noise, an operator can identify an object. However, multispectral image processing requires high SNR values to control, as much as possible, uncertainties in the measurement.

The quoted [RD.5] SNR for the HyperScout-1 data is a single figure of 50. As a comparison, Sentinel-2 has an SNR ranging from 142 to 174 for the 10 m resolution VNIR bands [RD.6] and for the PRISMA (Hyperspectral Precursor and Application Mission) the value is estimated to be around 200 [RD.8].

For CHRIS/Proba-1, the 'forward motion compensation' boosts its overall integration time per image, giving CHRIS an imaging performance and SNR equivalent to that of an instrument with an aperture area five times larger. A scientific investigation [RD.9] indicated that the SNR varies across the VNIR spectrum, decreasing with increasing wavelength; Figure 4-2.

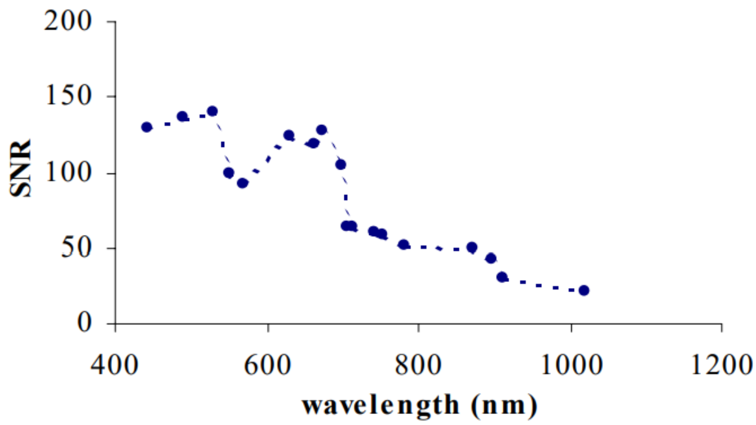


Figure 4-2: Plot of the estimated CHRIS/Proba-1SNR [RD.9].

4.3 Validation of the Radiometric Calibration

RadCalNet is an initiative of the Working Group on Calibration and Validation of the Committee on Earth Observation Satellites (**CEOS**). The RadCalNet service provides SI-traceable TOA spectrally-resolved reflectances to aid in the post-launch radiometric calibration and validation of optical imaging sensor data [RD.4].

The free and open access service provides a continuously updated archive of TOA reflectances derived over a network of sites, with associated uncertainties, at a 10 nm spectral sampling interval, in the spectral range from 380 nm to 2500 nm and at 30-minute intervals.

4.3.1 Methods and Data

The method used for this exercise consists of different processing stages, as shown in Figure 4-3. The approach was implemented in a series of Jupyter notebooks so that the assessment can easily be rerun.

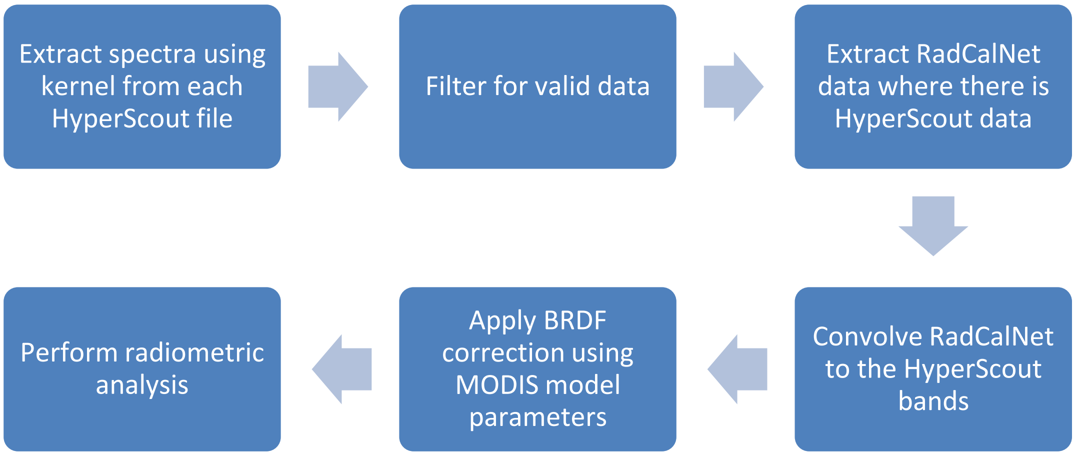


Figure 4-3: The workflow of the radiometric calibration assessment using RadCalNet data.

These different processing stages can be summarised as follows:

1. Extract multispectral TOA measurements from the HyperScout-1 product collected over the Railroad Valley (Nevada, U.S.A) RadCalNet station.
2. The measurement is spatially integrated over a 3 x 3 pixel kernel, which is a window of size of 210 by 210 m, where there is valid data.
3. Extract the RadCalNet 2020 data collection [RD.5] TOA measurements where there is valid HyperScout-1 data. It is not possible to get exact observation time of the HyperScout-1 product, so temporal interpolation is performed to overcome this.
4. Convolve the RadCalNet 10 nm TOA spectrum with the HyperScout-1 spectral band pass to get the reference measurements for each sensor spectral band.
5. Application of the Bidirectional Reflectance Distribution Function (BRDF) correction to the HyperScout-1 data using the model parameters in the MODIS albedo/BRDF product (MCD43A1) using the c-factor method as defined in [RD.11]:

$$NBAR = c_\lambda * \rho_\lambda\left(\theta_v = \theta_v^{HyperScout}, \theta_s = \theta_s^{HyperScout}\right)$$

$$c_\lambda = \frac{\rho_\lambda^{MODIS}(\theta_v = 0, \theta_s = k)}{\rho_\lambda^{MODIS}\left(\theta_v = \theta_v^{HyperScout}, \theta_s = \theta_s^{HyperScout}\right)}$$

   where θ_v is the view zenith angle, θ_s is the solar zenith angle and k is the average solar zenith angle of the pair of forward and backward scattering observations. The MODIS reflectances are calculated from the model parameters in the MODIS product using the view and solar zenith and azimuth angles.

6. Plot the convolved RadCalNet data against the HyperScout-1 data.
7. Compute the calibration ratio between HyperScout-1 mean TOA reflectance and RadCalNet TOA reflectance, then compute the percent difference as follows:

$$\%Difference = \frac{100 * (TOA\_Measure - TOA\_Reference)}{TOA\_Reference}$$

Where $TOA\_Measure$ is the measurement processed from the HyperScout-1 product and $TOA\_Reference$ is the measurement processed from RadCalNet data.

As detailed in [RD.12], the TOA reflectance spectra over the Railroad Valley Playa RadCalNet site are representative of a square of 1 km x 1 km centred on 38.497° Latitude and -115.690° Longitude. This assessment is using the TOA nadir-observed surface reflectance data, and the HyperScout-1 pixels are 70 m in resolution, so we are assuming there is homogeneity between the original point TOA measurement and 3 x 3 HyperScout-1 kernel being investigated.

From Figure 4-4, it can be seen that the site is in the middle of the Playa where there is limited variation, although a road does run through the marked yellow square.

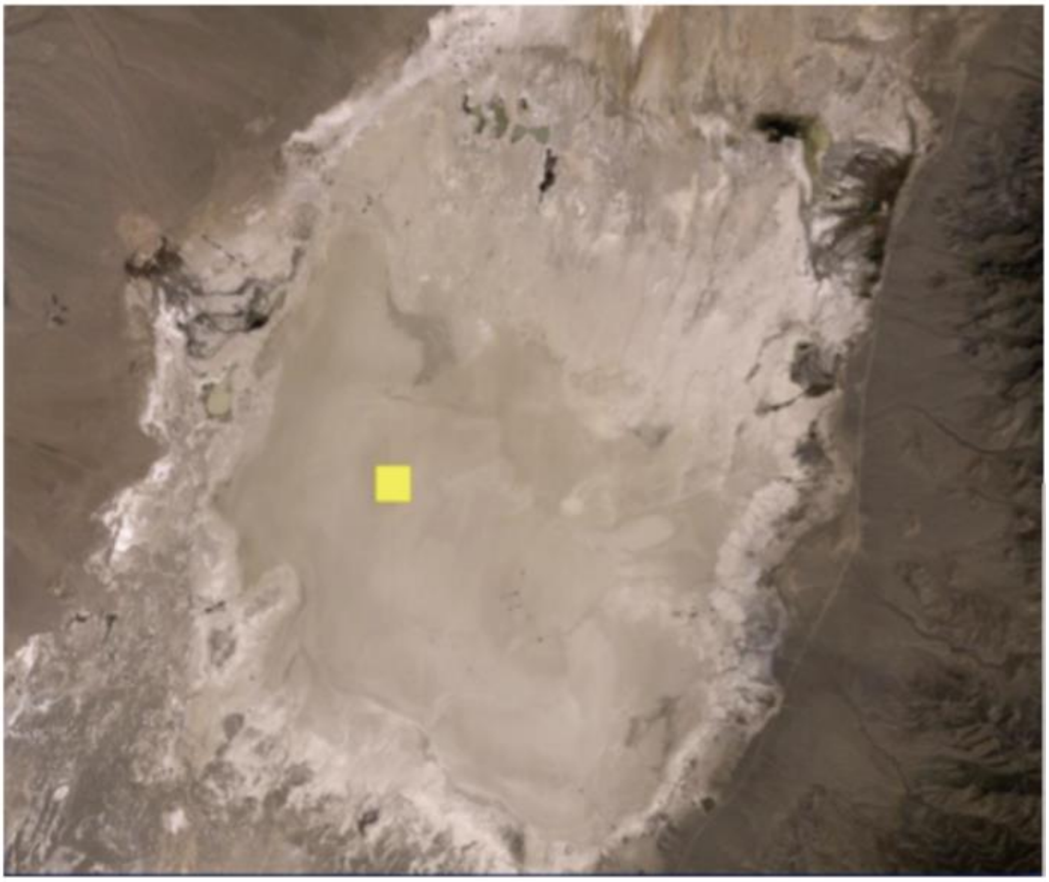


Figure 4-4: Railroad Valley location, with the RadCalNet site validity in yellow [RD.12].

4.3.2 Results

The calibration results based on in- situ RadCalNet data are described by showing the steps involved, which have been implemented within a series of Jupyter notebooks. Figure 4-5 shows a plot of the TOA RadCalNet reflectance spectra for Railroad Valley (RVUS) and the spectra convolved to the HyperScout-1 bands for the 07 November 2018 (day of year 311).

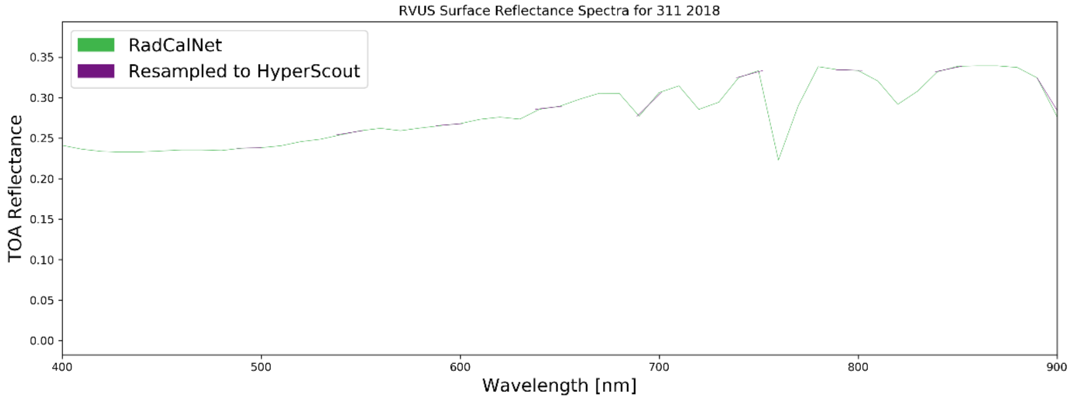


Figure 4-5: Convolution of the RadCalNet reflectance spectra into the HyperScout-1 bands.

For each date in the RadCalNet series, an input HyperScout-1 file is looked for and the data extracted with the two spectra being compared (Figure 4-6). The actual HyperScout-1 data is plotted as the mean of the kernel with the vertical error bars showing the standard deviation. For this dataset, there is only one HyperScout-1 image, and so the plot shows two versions of that data – before the Bidirectional Reflectance Distribution Function (**BRDF**) correction was applied and afterwards as the Nadir BRDF-Adjusted Reflectance (**NBAR**).

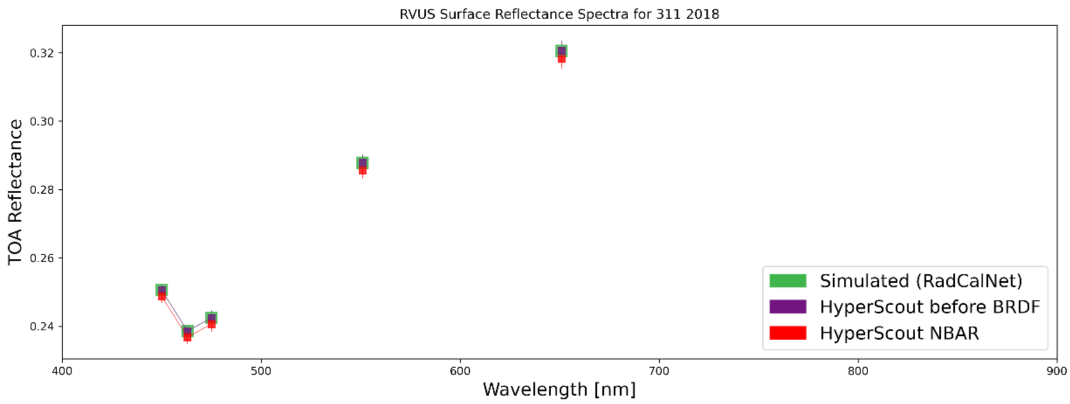


Figure 4-6: Comparison of HyperScout-1 data (with and without BRDF correction) and RadCalNet convolved to the HyperScout-1 bands. The marker size for the RadCalNet data has been made larger so it can be seen underneath the purple HyperScout-1 marker.

Figure 4-7 shows a plot for all the HyperScout-1 bands with valid data as a correlation plot.

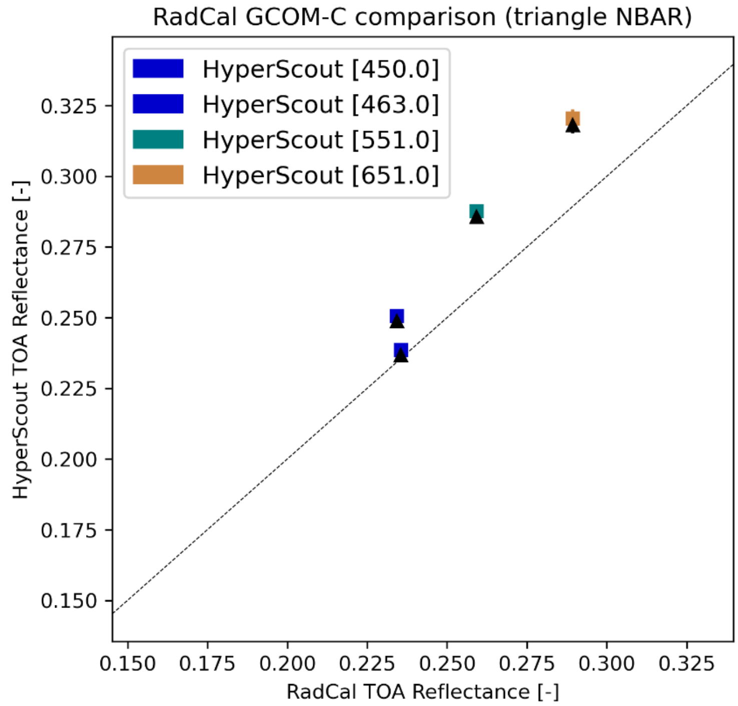


Figure 4-7: Comparison of HyperScout-1 data with RadCalNet convolved to HyperScout-1 for all dates.

Figure 4-8 shows the calculated percentage difference between the HyperScout-1 and convolved RadCalNet data. As is also evident in Figure 4-7, all the bands have higher radiometric values than the RadCalNet data but with the second blue (463 nm) band being much closer in agreement. The values after BRDF correction (triangles) have a closer agreement to the data without a BRDF correction, indicating that this may be improving the accuracy of the results.

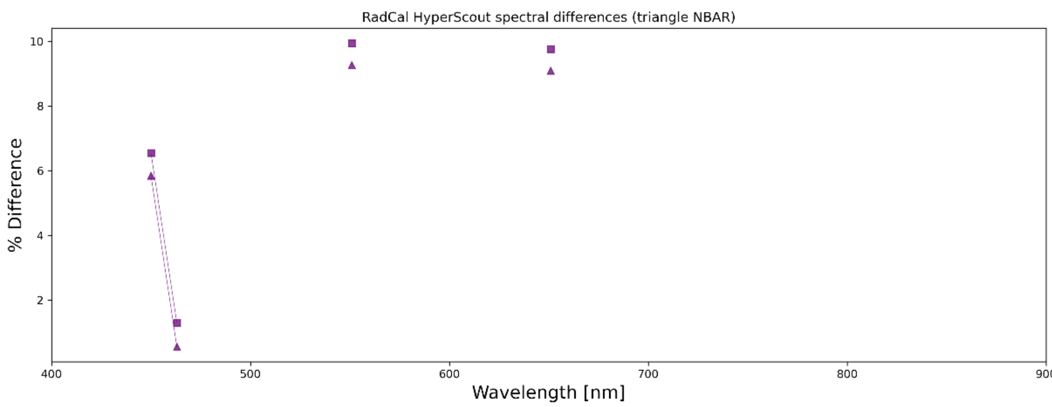


Figure 4-8: Spectral plot of the percentage differences between HyperScout-1 and convolved RadCalNet data; squared are before BRDF correction and triangles are after.

4.4 Validation of the Geometric Calibration

In this section dedicated to the analysis of geometry, for which three accuracy assessments can be performed; absolute accuracy, temporal accuracy and interband accuracy. For HyperScout-1, we have only a limited (single) image over each of the two sites and so have focused on the absolute accuracy using the Ceylanpinar as Railroad Valley has more difficult to distinguish features.

4.4.1 Methods

For the absolute geometric accuracy, the approach consists of visual comparison using a Sentinel-2 Level 2 image acquired on the 30 October 2018, so close in time. The results from a band in the red part of the electromagnetic spectrum (651 nm for HyperScout-1 and 665 nm for Sentinel-2) are reported.

Note this assessment was performed using ENVI instead of ESA's SNAP as HyperScout-1 HDF products could only be partially read in SNAP (e.g. bands displayed were not recognised as having specific wavelengths and band measurements not given in radiometric units, geometry information could not be read and applied, etc.).

The product HDF files were imported into ENVI, and then the header was manually updated to contain the missing information. The Sentinel-2 data was read into SNAP and then exported as a GeoTIFF. Then, the combined Sentinel-2 / HyperScout-1 products were visualised in QGIS alongside a Google Earth Web Mapping Service feed.

4.4.2 Results

Figure 4-9 shows a comparison of the same areas (at three zoom settings from the whole image down to a small region) for Sentinel-2 and HyperScout-1. The effects of the different spatial resolutions, 10 m versus 70 m, can be seen but no significant displacement was visible.

4.5 Preliminary Product Assessment

For data over Ceylanpinar, a common vegetation indicator, known as Normalized Difference Vegetation Index (**NDVI**) was calculated using bands 17 and 34 (651 and 865 nm) and bands 4 and 8 (685 and 842 nm) for HyperScout-1 and Sentinel-2, respectively. The HyperScout-1 data is a TOA reflectance product and the Sentinel-2 data used is both the L1C TOA and L2A Bottom of Atmosphere (**BOA**) reflectance product, so there is a variation in the output due to the different processing levels (primarily the application of the atmospheric correction).

Accepting that an atmospheric correction is not applied, the HyperScout-1 calculated NDVI values are reasonable (see Figure 4-10), and the overall spectral shape (see Figure 4-11) is also realistic for TOA reflectance data. The HyperScout-1 values appear to be within the envelope of the Sentinel-2 L1C and L2A data for the lower values resulting from the bare soil/low vegetation regions, and provide an underestimate for the high vegetation regions.

As a comparison to the HyperScout-1 spectra, bare soil spectra acquired by CHRIS/Proba-1 over the Barrax test site in Spain [RD.13] are also shown. CHRIS has a broader spectral range, and a higher number of bands (62) for the operating mode shown and so has an increased spectral sampling frequency. Still, both instruments see the increase in reflectance from the blue towards the NIR and then drop-off in reflectance after 850 nm. The TOA reflectance values are also of the same order of magnitude.

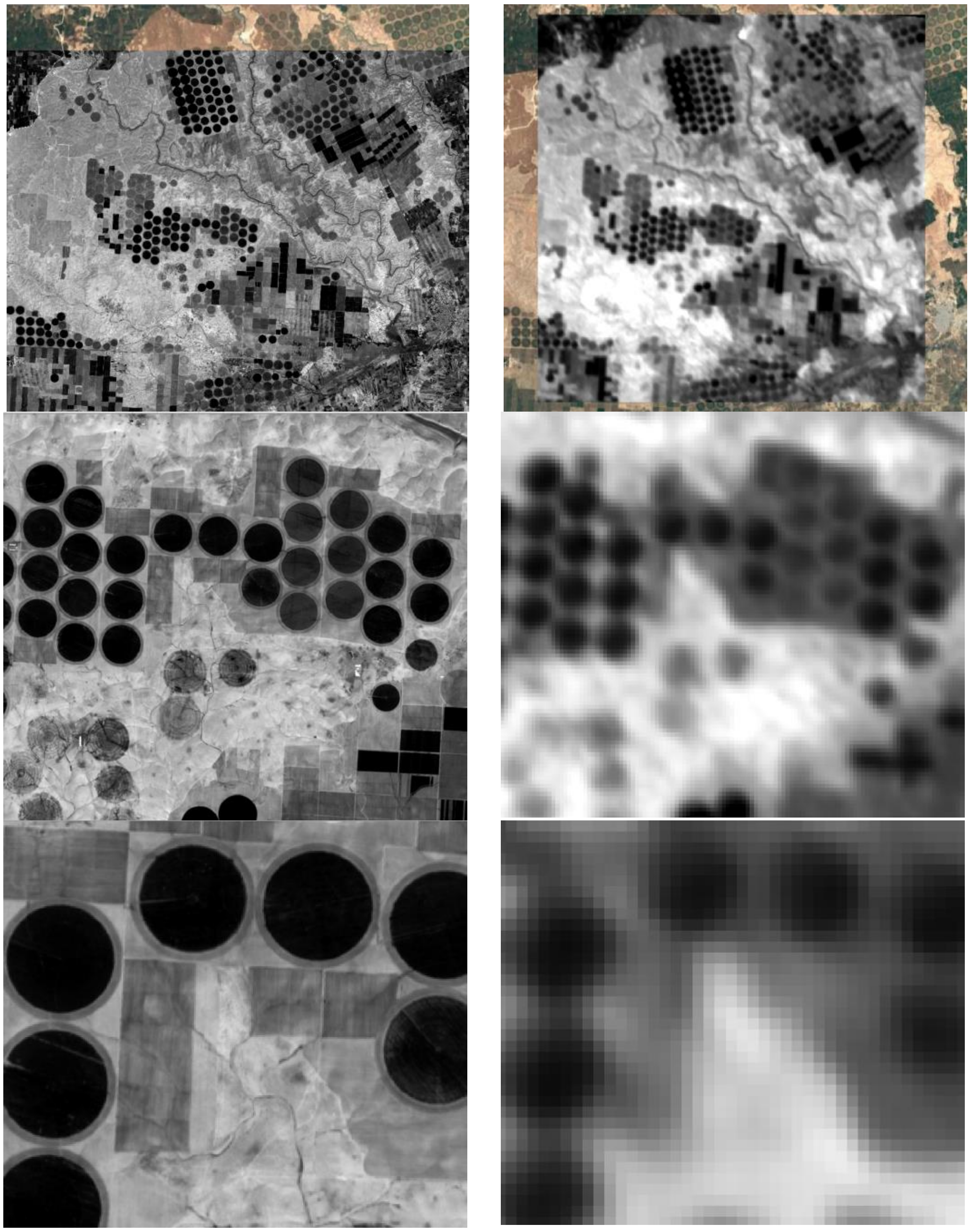


Figure 4-9: Comparison of (left) Sentinel-2 and (right) HyperScout-1 red bands for Ceylanpinar at various zoom settings: zooming in going from top to bottom with coloured backdrop from Google Earth.

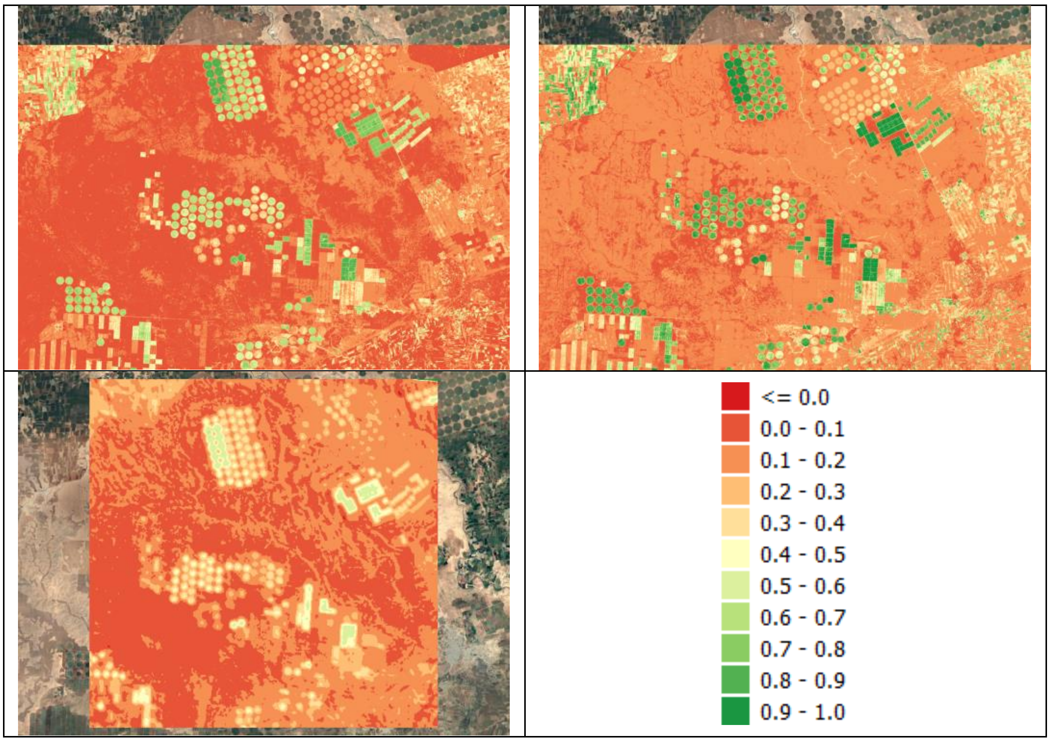


Figure 4-10: Comparison of Sentinel-2 (top left) L1 (top right) L2 and (bottom left) HyperScout-1 L1C calculated NDVI with the same (bottom right) red to green colour palette applied.

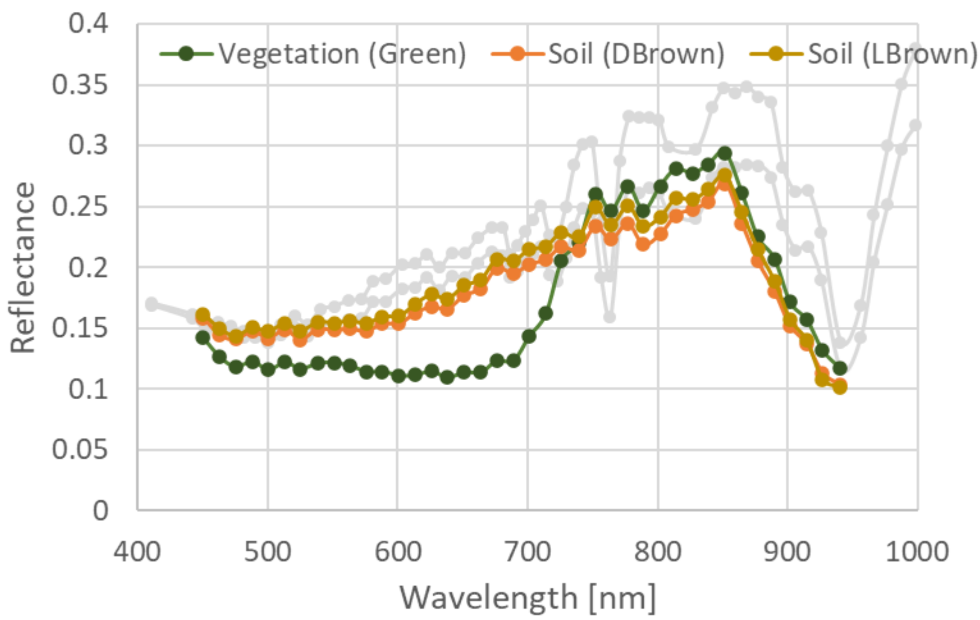


Figure 4-11: HyperScout-1 L1C spectral plots for the circular agricultural plots; in grey are spectra from CHRIS/Proba-1 L1 data taken over the Barrax (Spain) site for soil sites [RD.13].

4.6 Conclusions

The conclusions from this Quality Assessment report for the HyperScout-1 land products are:

- Image Quality:
  - The HDF files have no quality flags or masks and, overall, the HDF file contains limited metadata. It is recommended to improve this information to improve the overall usability of the products.
  - For users of ESA's SNAP tool, it would be useful for the HyperScout-1 format to be explicitly recognised so that the geometry is recognised, and the data can be analysed using, for example, spectral profiles.
  - The SNR is quoted as a single number in [RD.5] that is lower than the quoted value ranges for other hyperspectral missions. It would be useful for users to have further information on the spectral variability to better understand the impact on potential applications.

- Radiometric assessment:
  - The assessment results showed a close matchup between the HyperScout-1 and RadCalNet data for the Railroad Valley site, with the differences being less than 10% across the matching bands. This result is not unexpected as Railroad Valley is used as a vicarious calibration site, so is not an independent dataset.
  - Discussions with Cosine revealed that the TOA reflectance is not BRDF corrected, but that HyperScout-1 is considered as a nadir viewing instrument. To improve the data's usefulness, e.g. in support of an atmospheric correction, the L1C HDF files should contain the satellite geometry information as part of the metadata if not as ancillary bands.

- Geometric assessment:
  - The results showed that the HyperScout-1 image over Ceylanpinar is aligned with Sentinel-2.

- Preliminary product suitability assessment for applications:
  - The results showed that the spectra extracted over Ceylanpinar are similar to the CHRIS/Proba-1 spectra in terms of both reflectance order of magnitude and expected shape.
  - The NDVI product comparison between Sentinel-2 and HyperScout-1 also showed similar results, with a lower estimated vegetation cover from HyperScout-1.

[End of Document]