AXELSPACE

Surface Reflectance Product Guide

Terminology

BOA - Bottom-of-atmosphere reflectance
TOA - Top-of-atmosphere reflectance
Surface Reflectance (SR) - Reflectance without atmospheric interference (i.e. BOA)
NDVI - Normalised Difference Vegetation Index
LAI - Leaf Area Index
LUT - Look up table

Description

The GRUS Surface Reflectance product is generated for every GRUS tile on AxelGlobe. The values contained in the surface reflectance product have been corrected with respect to the atmospheric conditions at the time of acquisition. The process of atmospheric correction converts top-of-atmosphere reflectance (TOA) to bottom-of-atmosphere reflectance (BOA).

We expect this product to improve radiometric consistency and produce more accurate multispectral indices, especially when working with multi-temporal datasets and calculating real-world attributes such as biomass or LAI. This is achieved by removing atmospheric bias which can affect reflectance values according to the conditions at the time the data is acquired.

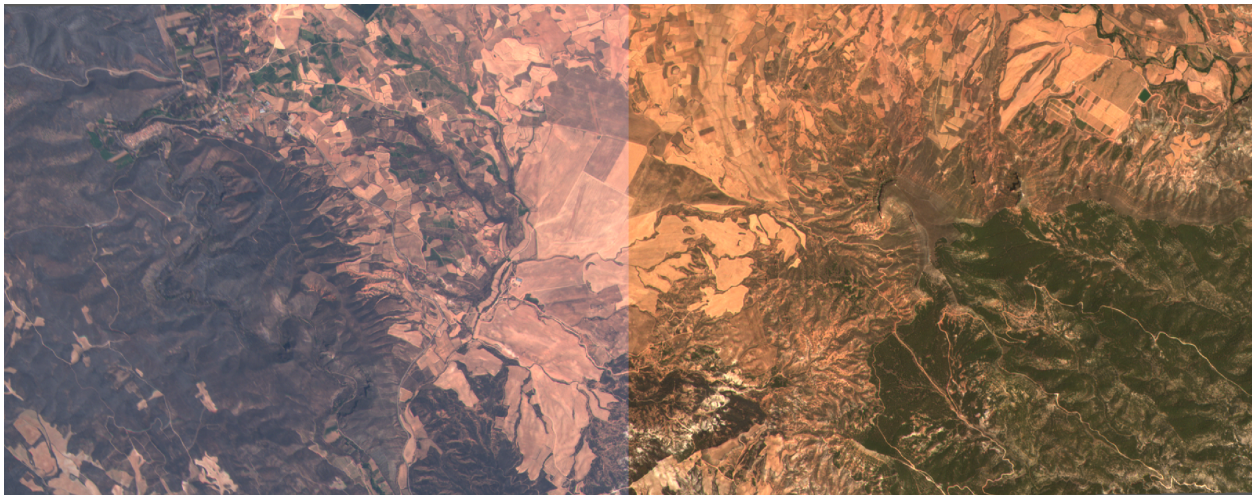


Figure 1: Comparison of TOA (left) and BOA (right) image products captured by GRUS-1E Zaragoza, Spain

How to Access

Surface reflectance data is available for all GRUS tiles and can be accessed by request to the AxelGlobe Sales team.

Product Generation

The process of atmospheric correction and converting GRUS Analytic product into the Surface Reflectance product is done using the 6S radiative transfer code (6SV1.1 https://salsa.umd.edu/). The 6S model requires GRUS TOA values along with a number of atmospheric parameters specific to the conditions when the acquisition took place. Here is a detailed list of the input parameters including their origin and example values for each.

These data are distributed alongside the Surface Reflectance product in a JSON file where the actual parameters used in the atmospheric correction process are listed.

Table 1: Input parameters used by the 6S model to generate bottom-of-atmosphere data

Input Parameter	Description	Example value	Unit	Product Code or Version	Source
TOA	Top-of-atmosphere reflectance	0.5 (scaled by 10,000 from Uint16)	N/A	N/A	GRUS Multispectral product
AOT (Aerosol Optical Thickness)	Thickness of aerosol at 550nm	0.4	N/A	MOD08 & MOD04	MODIS[1]
Water Vapour	Total amount of water in atmosphere vertical path	3	g/cm^2	MOD08 & MOD07	MODIS
Ozone	Total amount of ozone in atmosphere vertical path	0.3	cm-atm	MOD08 & MOD07	MODIS
Elevation	Average height above sea level	0.84	km	SRTMGL1Nv003	SRTM[2]
Satellite zenith	Angle of satellite inclination	5.11	degrees	N/A	GRUS Multispectral product
Satellite azimuth	Angle of satellite viewing	76.5	degrees	N/A	GRUS Multispectral product
Solar zenith	Angle of sun inclination	58.0	degrees	N/A	GRUS Multispectral

					product
Solar azimuth	Angle of sun viewing	156.25	degrees	N/A	Multispectral product

Axelspace Implementation of 6S

Surface reflectance values are calculated for each multispectral GRUS product using the input data shown in Table 1, however the values do slightly change depending on the time of acquisition. All recently acquired GRUS acquisitions will use the MODIS NRT (Near Real Time) products, and captures being processed that are more than 5 days old use an archival MODIS product.
Using 6S to estimate surface reflectance from TOA reflectance is a time consuming calculation which would not be practical to apply to every pixel in a GRUS image tile. Lookup tables (LUT) are generated for each new capture and contain a model for a range of conditions and TOA reflectances. The LUT model is used to rapidly convert every TOA pixel into a BOA reflectance value with a 2nd order polynomial.

Product Validation

To confirm the quality of the Surface Reflectance product, we compare GRUS data with reliable 3rd party data.

Because surface reflectance data has had atmospheric bias removed, it can be more easily compared with other datasets than the TOA data.
This also includes comparisons made between surface reflectance data from different sensors, although in this case care must be taken to account for differences in spectral response curves. For example, although two sensors may have “red” bands, the exact width and centres of these bands may be different. The relative spectral responses for each GRUS band can be found on the AxelGlobe Image Specification sheet (https://docs.axelglobe.com/en/image-specifications).

For validation of GRUS Surface Reflectance data we have chosen to compare it with RadCalNet[3] sites (https://www.radcalnet.org/), where reliable surface reflectance measurements are made on a daily basis. RadCalNet measurements are acquired by sensors on ground and are also taken for a large number of spectral wavelengths with good overlap with GRUS bands; this ensures that the data is not affected by the atmosphere and can be more reliably compared with GRUS.

The figures below show the locations of different RadCalNet sites used for validation, as well as comparisons between the spectral response of TOA and BOA measurements at each site. The benefit of atmospheric correction is demonstrated here by illustrating the close similarity between the GRUS and RadCalNet surface reflectance values.

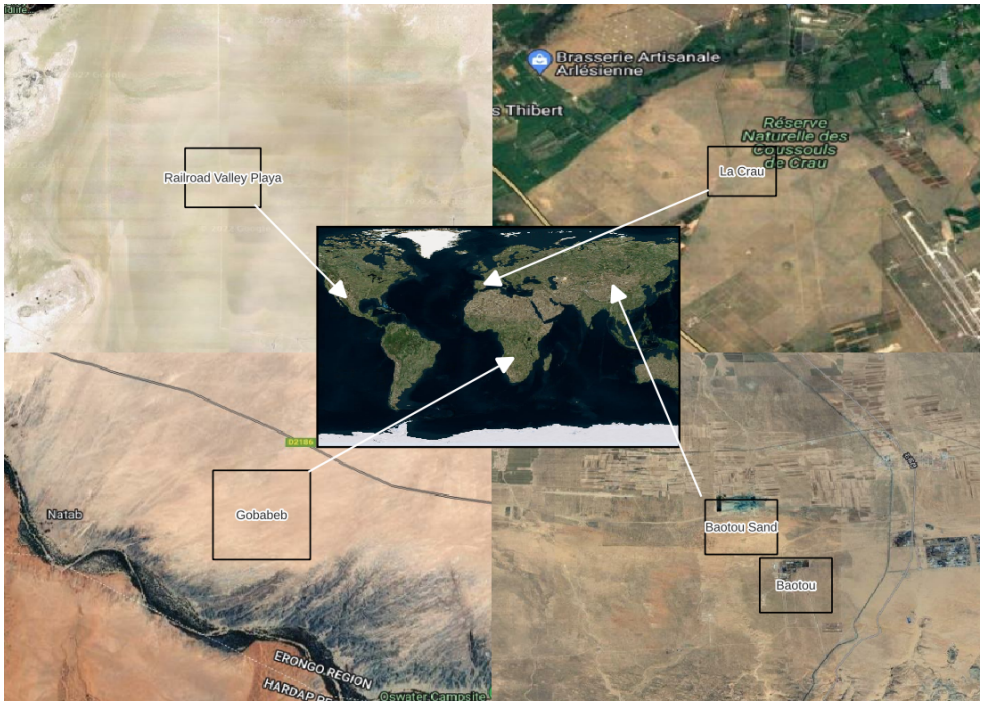
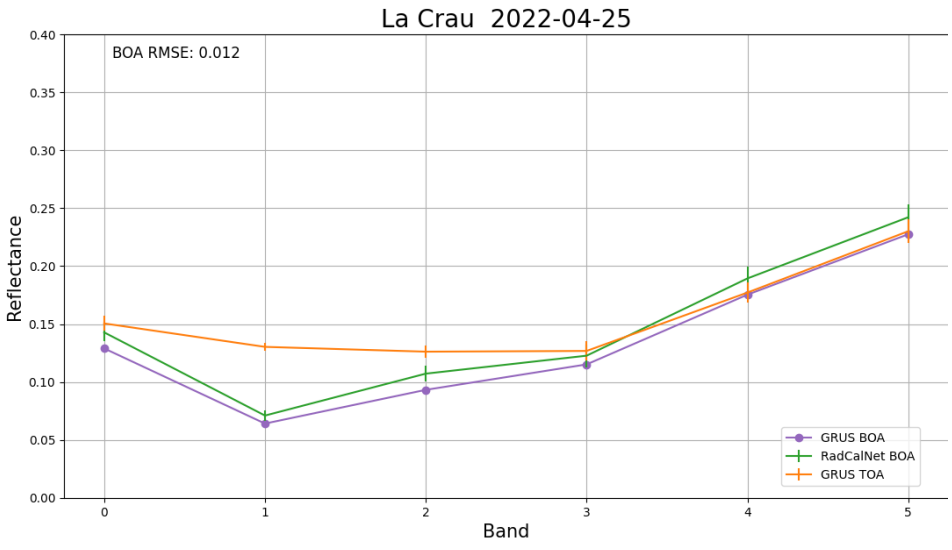


Figure 2: Visualisation of RadCalNet site locations



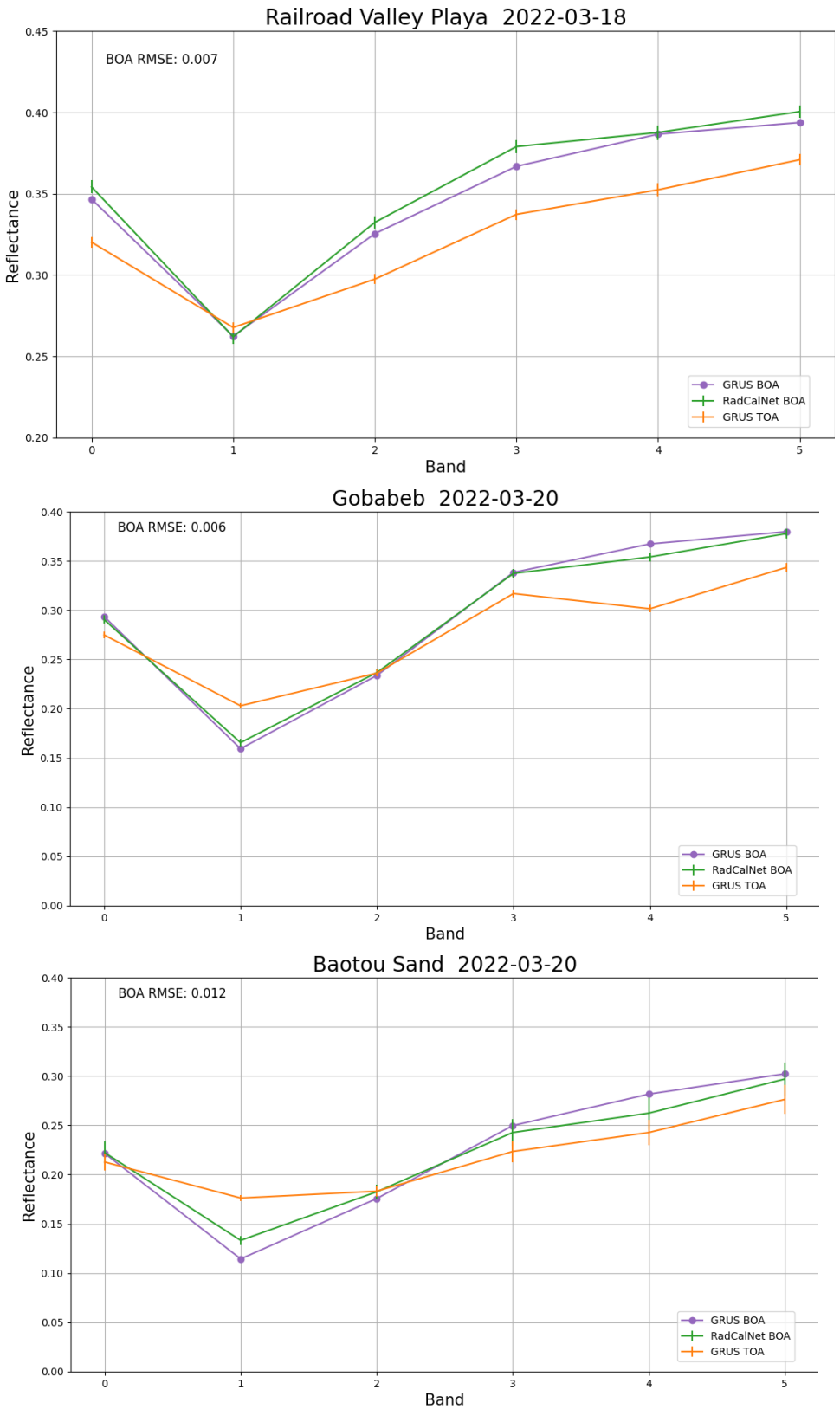


Figure 3: Comparison of TOA & BOA reflectance values measured at different RadCalNet sites with GRUS. Band ordering: 0=Pan; 1=Blue; 2=Green; 3=Red; 4=Red Edge; 5=Near Infrared.

In addition to comparisons between RadCalNet and GRUS surface reflectance data, we have made similar comparisons with the Sentinel-2 surface reflectance product[4]. Sentinel-2 imagery is widely used, but it must be taken into account when viewing that this is not a perfect comparison due to the differences between GRUS and Sentinel-2 (L2A) spectral responses.

Figure 4: Comparison of GRUS (left) acquired at 2021-07-08 and Sentinel-2 acquired at 2021-07-07 (right) RGB composites using surface reflectance.

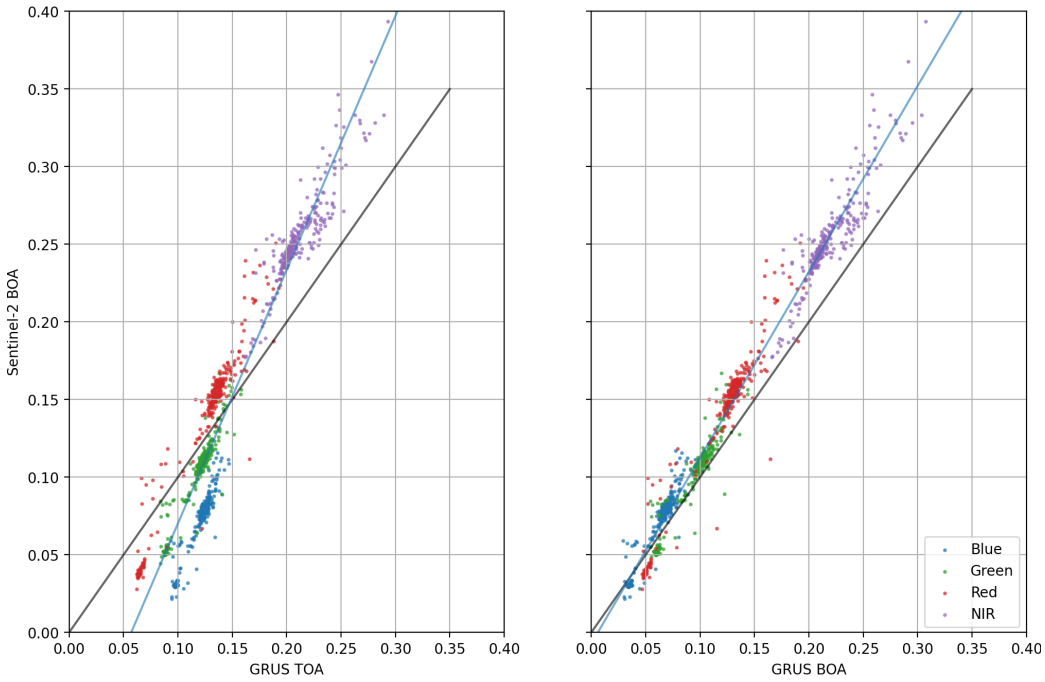


Figure 5: Comparison of BOA (right) and TOA (left) reflectance values for GRUS-1C and Sentinel-2. Atmospheric correction improves closeness between the two datasets with R^2=0.89 compared to before atmospheric correction when R^2=0.57.

Specification Versioning

Table 2: Versioning history of the GRUS Surface Reflectance Product Guide

Version No.	**Date**	**Remarks**
1.0.0	01-03-2023	Initial version

Acknowledgements

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References

1 https://www.earthdata.nasa.gov/learn/find-data/near-real-time/modis

2 https://lpdaac.usgs.gov/products/srtmgl1nv003/

3 https://www.radcalnet.org/#!/

4 https://sentinel.esa.int/web/sentinel/missions/sentinel-2