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Proba-V, a SPOT-VGT Successor Mission, Product Definition and Specifications

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Abstract. Proba-V is a new global vegetation monitoring mission, designed to ensure the continuity of SPOT-VGT 1km resolution data. SPOT-VGT has provided the world-wide remote sensing community with daily global vegetation products for more than 10 years, and is scheduled to end its services in 2013. Developed in the frame of the ESA In Orbit Demonstration (IOD) technological program, ProbaV adds a new 1/3 km resolution product to fulfill the evolving needs of the end-users. To allow the continuation of time-series studies, Proba-V specifications are targeted to align closely to SPOT-VGT. With a polar orbit at 820 km altitude and a LTDN between 10:30-11:30 AM, a daily coverage is obtained for land masses at latitudes from +75° to -56° (acquisition frequency decreases for latitudes less than 35°). Spectral responses are in accordance with SPOT-VGT, differences amount to the same order of magnitude as seen between SPOT-VGT1 and SPOT-VGT2. Based on the characteristics of the platform/instrument and user segment, this paper discusses the expected 1 km and 1/3 km product definitions and specifications, and how they compare to SPOT-VGT. The 1/3 km product should have the same order of magnitude SNR and MTF as SPOT VGT, while the 1km product should be much better. Geometrical accuracies are well met for the 1 km product, while the biggest challenge for the 1/3 km product lies in guaranteeing the multi-temporal accuracies due to the thermo-elastic behaviour of the platform and instrument. This requires a careful in-flight calibration to monitor periodic and seasonal changes. Proba-V data delivery will be similar to SPOT VGT: 1-day and 10-day synthesis products are available in 4 bands (Blue, Red, NIR and SWIR), derived indices and quality indicators. On top of that, similarly to SPOT-VGT, unprojected P-products in raw resolution can be ordered by the user.

Keywords. Proba-V, global vegetation monitoring, SPOT-VGT, low resolution.

1. Introduction

PROBA-V is a new global vegetation monitoring mission, expected to be launched using Vega in the 1st Quarter of 2013. PROBA-V is capable of global coverage and designed to deliver user quality products at 1/3 km and 1km resolution.

PROBA-V has been developed against user requirements which ensure continuity to the heritage VEGETATION mission. Aside from the better spatial resolution, PROBA-V is designed to achieve a similar performance to VEGETATION, while having more constraints on power, mass and volume. Development of the PROBA-V instrument and spacecraft is on track and under test; its expected image quality and performance will be reported here.

To support the existing VEGETATION user community, the data products for PROBA-V continue to provide daily TOC synthesis (S1) and ten days synthesis products (S10). In addition, a new daily synthesis product providing TOA reflectance data is foreseen, and an unprojected P product for each camera and sensor strip separately.

2. Platform specifications

After its successful maiden launch on February 13 2012 [1], Vega has been confirmed as the launcher for PROBA-V scheduled for early 2013. This settles the orbital specifications for the mission as recorded in Table 1. PROBA-V will follow a sun-synchronous orbit at 820km, allowing a daily global coverage under like illumination conditions, aside from the equatorial region where coverage is guaranteed every 2 days.

Table 1. Space segment specifications: satellite, payload and orbit.

Platform & Instrument	
Altitude	820 km
LTDN	10.30h-11.30h
Inclination	SSO + 0.1°
Coverage	90% daily, 100% every 2 days
Payload Mass	33.3 kg (including maturity margin)
Payload Dimensions	0.2 x 0.8 x 0.35 m³ payload
Payload Power	43.2 W (including maturity margin)
Lifetime	2.5-5 years
Mass memory	16 Gbit
Data rate	7.15 Mbps (after compression)

PROBA-V takes advantage of the advanced small satellite technology of the PROBA series developed by Qinetiq Space NV, which allows it to perform as required with a limited budget for mass, volume and power. These constraints also limit the memory budget; therefore, data is compressed on-board using CCSDS lossy compression software [2].

The payload consists of three cameras placed next to each other to achieve the swath necessary for global coverage. Each camera has a set of 1 VNIR and 3 SWIR detectors. The VNIR detector contains 4 lines, 3of which are used to capture a Blue band, a Red band and a NIR band. The SWIR detectors are 1-line detectors which are placed in a staggered configuration to achieve the same coverage as the VNIR detector. Every such line, 3 of the VNIR and 3 of the SWIR, is considered as a ‘strip’, an independent stream of data to be processed.

3. User products

The products of PROBA-V are very similar to the standard VEGETATION products, to ensure continuity of data towards the user community. These heritage standard products are graphically illustrated in Figure 1.

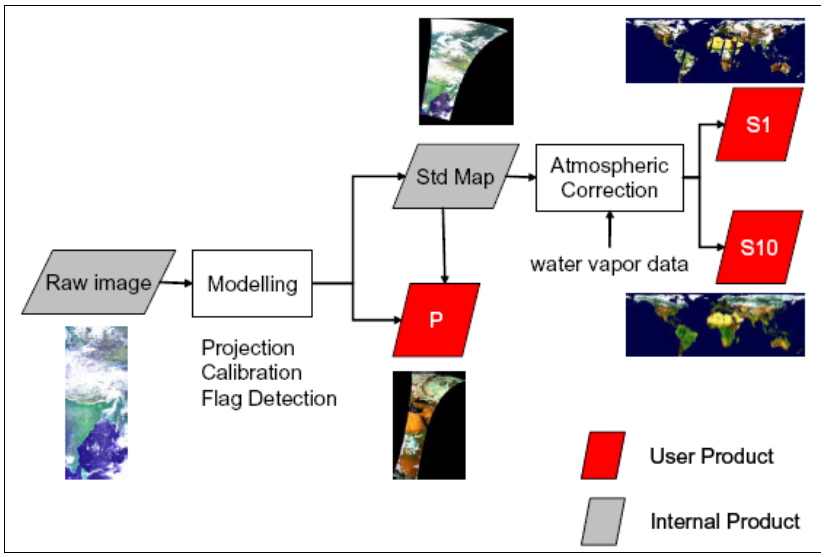

Figure 1: Structure of VEGETATION products.

VGT-P products (P=physical) are adapted for scientific applications requiring highly accurate physical measurements. The pixel brightness count is the ground area's apparent reflectance as seen at the top of atmosphere (TOA).

VGT-S1 products (daily synthesis) are corrected for atmospheric effects and then composed of the “best” ground reflectance measurements of all segments received during one day for the entire surface of the Earth. This is done for each of the images covering the same geographical area.

VGT-S10 products (ten day synthesis) are compiled by merging segments (data strips) acquired in ten days. All the segments of this period are compared again pixel by pixel to pick out the highest quality ground reflectance values.

With its collection of standard products, PROBA-V continues to provide daily synthesis (S1) and ten days synthesis (S10) products. These are both available with ground reflectance (TOC, Top of Canopy) values. In addition, daily synthesis S1-TOA products are foreseen, containing values with no atmospheric correction applied. All these products are available at two spatial resolutions: a lower resolution of 1km as in VEGETATION products, and a higher resolution of 1/3 km.

L1C products include the correction for system errors, and contain geo-positioned TOA reflectance values. It is given in raw geometry, i.e. about 100/200m nadir to 350/660m at the swath edge for VNIR and SWIR respectively, and provided with all metadata. Presented in this way, it allows the user to define a specifically defined geographic projection and atmospheric correction. Because it is given in raw geometry, data is delivered for each of the three PROBA-V cameras and strips.

Table 2. Variable spatial resolution for L1C data products.

Raw Spatial Resolution (m)			
	center pixel	camera crossing	edge of swath
VNIR	97	103	354
SWIR	185	191	666

The S1-TOA product and L1C product are proposed as the standard alternatives for VGT-P products. Demands for other products will be handled on request and by maintaining an archive of L1C data.

4. Geometric specifications

With its three cameras scanning the earth surface, PROBA-V is a wide Field-of-View satellite. This ensures a sufficient swath for the global coverage PROBA-V aspires. To achieve a 1/3 km higher resolution (HR) product, PROBA-V has targeted geometric specifications which are in par with this product. Table 3 shows these specifications for the 1/3km HR and 1km LR product.

Table 3: Geometric specifications for 300m HR, 1km LR product.

Geometric specifications	
FOV and swath	102.4° and 2295km
GSD	1/3km x 1/3km HR, 1km x 1km LR
MTF @ Nyquist	> 0,3 @ Nyquist
absolute geolocation accuracy	<1 HR GSD
inter-band geolocation accuracy	<1/3 HR GSD
multitemporal geolocation accuracy	< 1/2 HR GSD

To guarantee geolocation performance for the 1km product, the requirement analysis shows that a basic in-flight geometric calibration is sufficient. However, to guarantee performance for the 1/3km product, additional effort is necessary to reduce geolocation errors over time. For this reason, a detailed in-flight geometric calibration is put in place, with the main goal being to model systematically varying errors by correlating it with seasonal and orbital time variations.

5. Continuity of spectral responses

PROBA-V aims to continue supply of global vegetation data for the very active international community of users currently working with SPOT-VGT data [3]. To achieve this, a similarity in the spectral response of both missions should be guaranteed to allow continuity in use of data.

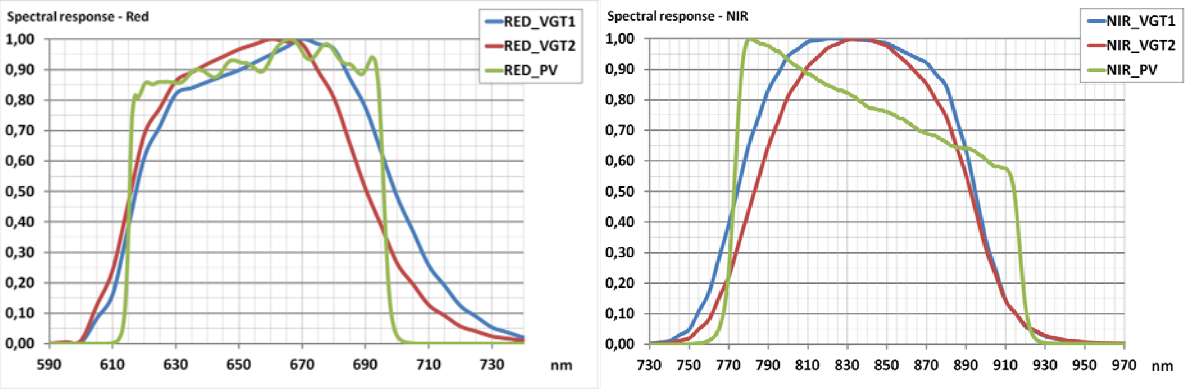

Figure 2: Comparison of NIR and RED bands for SPOT-VGT 1 & 2, and PROBA-V.

Comparing the spectral responses of the current PROBA-V design with the SPOT-VGT bands (for instance the RED and NIR band in Figure 2), it is clear that a straightforward similarity between the two is not the case. However, a detailed study has been done to show that important user derived products such as NDVI remain sufficiently similar on vegetation land covers, with differences on the same order as between SPOT-VGT 1 and SPOT-VGT 2.

Even the strongly asymmetric NIR band will not show a significant discrepancy when imaging typical land covers for vegetation studies.

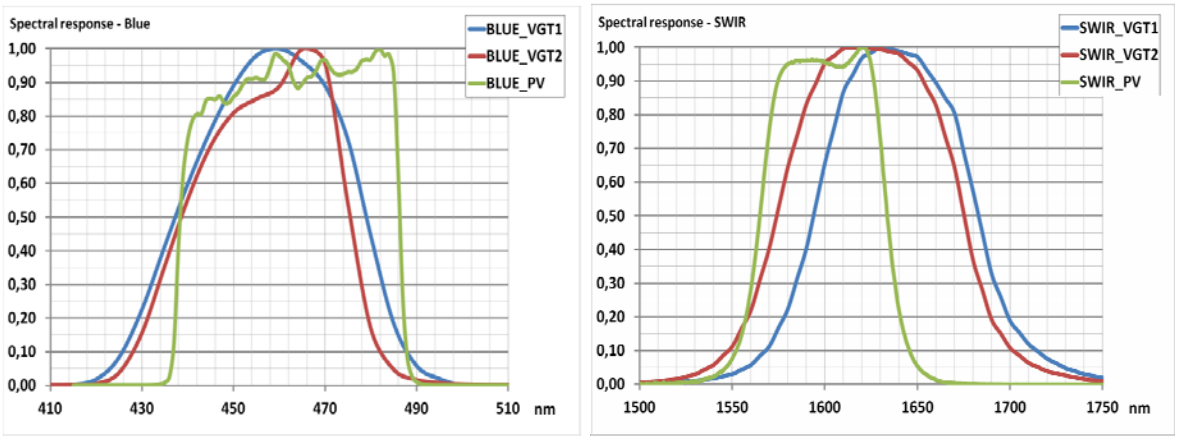

Figure 3: Comparison of BLUE and SWIR bands for SPOT-VGT 1 & 2, and PROBA-V.

Still, differences are sufficiently significant to require calibration of image data over time to ensure long-term continuity, when moving from SPOT-VGT data to PROBA-V. It's important to note as well that the contrast values for NDVI are better for PROBA-V than for SPOT-VGT 1 and 2, which is considered an advantage for user applications. Similarly, the PROBA-V SWIR, which is different with a peak wavelength shifted to lower wavelengths (Figure 3), results in higher contrast for NDWI applications.

6. Radiometric specifications

As a multispectral vegetation mission, PROBA-V has its most important specifications for the Red band around 655nm and the NIR band around 845nm. These are the bands used to determine the red-edge response of vegetation and the popular NDVI metric. The Blue band is used for atmospheric correction, the SWIR band for an estimation of water content.

Table 4. Radiometric specifications for HR product.

Radiometric specifications		
Band centre (nm)	Bandwidth (nm)	SNR @Lref(W/m².sr.um)
463	46	155 @111
655	79	430 @110
845	144	529 @106
1600	73	475 @20
Radiometric performance		
absolute acc.	5%	
inter-channel acc.	3%	
stability	3%	
spectral misregistration	0.9 nm VNIR, 2nm SWIR	
polarization sensitivity	4% Blue, 1% others	

Specifications are given for the HR product in Table 4. Compared to SPOT-VGT requirements, PROBA-V has better SNR for all of its bands except the Blue, which will allow a good discrimination of reflectance differences.

The Blue band is also more sensitive to polarization differences: this is a consequence of the reflective mirror design and is an important contributor to the radiometric accuracy budget for this band. The radiometric accuracy is still in line compared with SPOT-VGT requirements. The reflective mirror design also results in a straylight effect at the border of bright targets such as clouds; this effect will be characterized pre-flight and if necessary addressed in the operational processing of data.

Due to the limited memory budget, data must be compressed on-board using CCSDS compression (as noted in section 2) and later decompressed on-ground. Such compression can be lossy, depending on the image content; worst-case analysis has shown that this can degrade the SNR budget by a factor of 2, making the HR product slightly below, the LR product comfortably above SPOT-VGT requirements.

7. Conclusions

As the intended gapfiller mission between SPOT-VGT and the upcoming Sentinel-3 platform, PROBA-V comfortably meets the requirements for a 1km-product while maintaining good performance for a 1/3km product. Due to constraints set by its smaller platform, on-board CCSDS lossy compression is needed which impacts SNR but to an acceptable degree. Spectral bands are not entirely identical, requiring careful cross-sensor calibration when comparing SPOT-VGT data to PROBA-V. These differences are however sufficiently small to guarantee continuity for derived products like NDVI and NDWI.

Standard products for PROBA-V are similar to those of SPOT-VGT, with the daily and ten day synthesis being retained, and delivered for 1km and 1/3km resolution. As a double alternative for the VGT-P product, a 1/3km/1km S1 TOA product and a L1C product at raw spatial resolution are proposed. To accommodate non-standard processing requests, an archive of L1C data will be maintained.

Acknowledgements

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This paper is dedicated to the memory of ***Gilbert Saint*** who passed away in Toulouse on May 3rd 2012. Gilbert has been one of the key players in the development of the Vegetation Instrument on the SPOT satellites and more recently in the setting up of the PROBA-Vegetation mission.

References

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