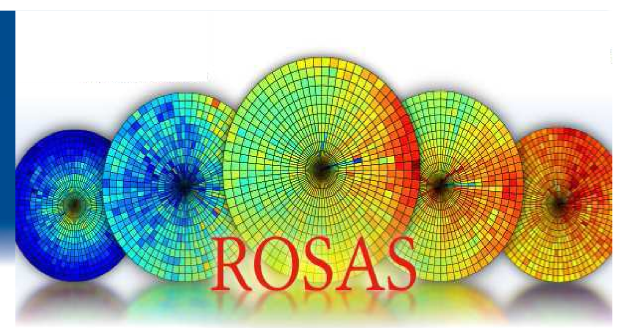

A ROBotic Station for Atmosphere and Surface characterization dedicated to on-orbit calibration and L2a products validation

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ABSTRACT

Crau test site has been used by CNES since 1987 for the vicarious calibration of SPOT cameras. Former calibration activities were conducted during field campaigns devoted to the characterization of the atmosphere and the site reflectance. In 1997 an automatic photometric station (ROSAS) was set up on the site on top of a 10m-high post. This station measures at different wavelengths, the solar extinction and the sky radiance to fully characterize the optical properties of the atmosphere. It also measures the upwelling radiance over the ground to derive the surface reflectance.

The photometer samples the spectrum from 380nm to 1600nm with 9 narrow bands. Every non cloudy day the photometer automatically and sequentially performs its measurements. Data are transmitted by GSM (Global System for Mobile communications) to CNES and processed here. The photometer calibration is performed in situ using the sun measurements for irradiance and cross-band calibration, and over the Rayleigh scattering for the short wavelengths radiance calibration.

The data are processed by an operational software which calibrates the photometer, estimates the atmosphere properties and computes the bidirectional reflectance distribution function of the site. This bidirectional reflectance can be used to simulate the top of atmosphere radiance seen by any sensor over-passing the site and calibrates it or to validate the retrieved surface reflectance product from this sensor.

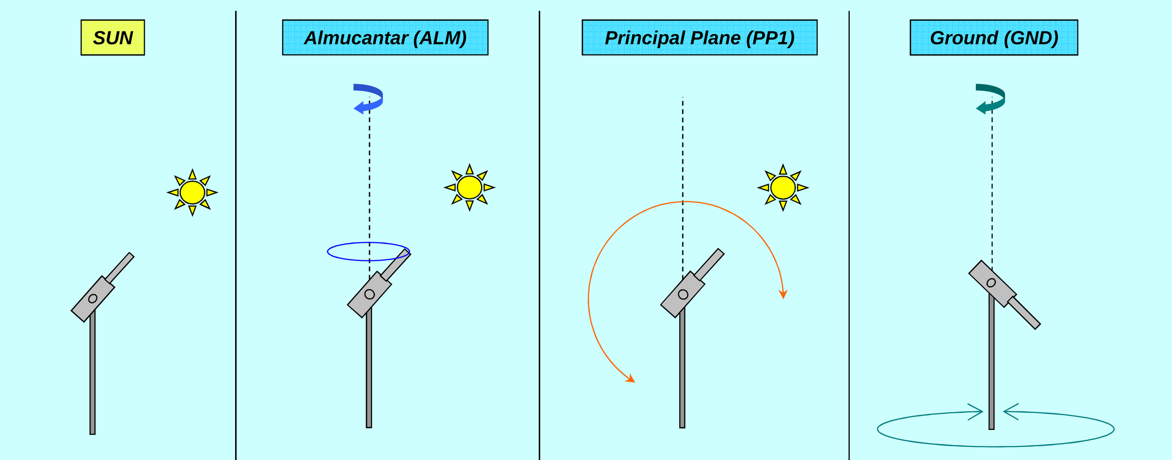
This poster describes the instrument, its measurement protocol and its calibration principle. It details the surface reflectance characterization and presents SPOT4 Take 5 surface reflectance validation results. This station will be used for SENTINEL-2 calibration during the commissionning phase but also for level 2A products validation. To reach this objective, the current photometer will be updated to increase the number of spectral bands and a similar instrument will be installed on an ESA/CNES calibration site within CEOS RADCALNET calibration activities.
Both La Crau and ESA/CNES sites will then be used to provide vicarious calibration references for SENTINEL-2 and validate surface reflectance products during the routine phase.

The instrument: CIMEL photometer

Band	λ (nm)
1	1020Si
2	1600 InGaAs
3	870 Si
4	670 Si
5	440 Si
6	550 Si
7	1020 InGaAs
8	937 Si
9	380 Si
10	740 Si

Crau (South East of France, near Marseille), flat plain of 20 km diameter, covered with white pebbles and grass

Measurement protocols



Irradiance measurements pointing the Sun in each band

Sky radiances measurement according to 2 half cones around vertical axis for 30 azimuth observation angles for all bands except 937 nm

Sky radiances measurement in the vertical plane containing the Sun for 40 zenith observation angles for all bands except 937 nm

Surface radiances measurement for 12 zenith angles up to 60 degrees and 72 azimuth observation angles for 6 bands

Every non cloudy day, 4 measurements scenarios are automatically and continuously performed. The acquisitions starts when air mass > 5 and stops when air mass < 5.

A complete set of measurement every 90mn: *SUN + ALM + PP1 + GND (1st elevation) + SUN + GND (2nd elevation) + … + GND (12th elevation) + SUN*

In situ photometer calibration

- Irradiance calibration based on Bouguer-Langley extinction formula (Sun mode)

$$E_k = E_{0k} \cdot \left(\frac{d_0}{d}\right)^2 \cdot \exp\left(\frac{-\tau_k}{\cos\theta_s}\right) \cdot T_g$$

$$CN_k = A_k \cdot Gu_k \cdot E_k$$

$$\ln(CN_k) = -\tau_k \cdot m + \ln\left(A_k Gu_k E_{0k} T_g (d_0/d)^2\right)$$

- Radiance calibration Based on the Rayleigh scattering ascendency at short wavelength (Principal Plane and Almucantar modes):

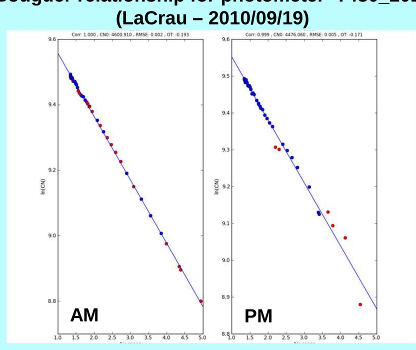
$$CN_k = B_k \times Gk_k \times L_k$$

- Estimation of the aerosol optical properties using Sun measurements
- Use of a radiative transfer code (SOS) to predict the radiance L_k seen by the photometer
  - Hypothesis: B_k is independent of τ_{aer}: $B_k=B_k(\tau_{aer}=0)$, case of a pure atmosphere
  - Derivation of $\Omega = B_k/A_k$ (photometer FOV)

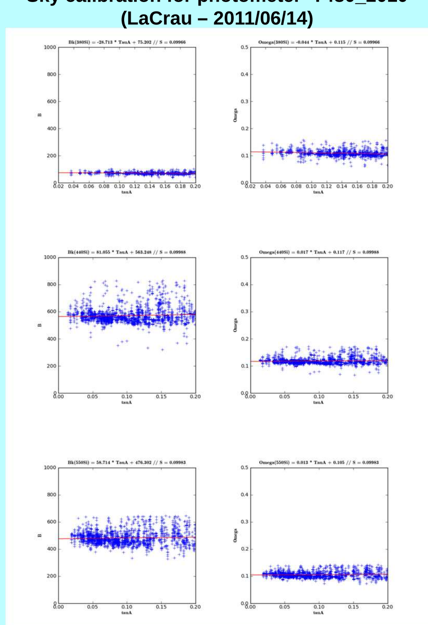
Ω (380)	Ω (440)	Ω (550)	Ω (labo)
0.115	0.117	0.105	0.115

➔ Good consistency between « laboratory » and in situ radiance calibration for 380 and 440nm

Bouguer relationship for photometer T480_2010 (LaCrau – 2010/09/19)



Sky calibration for photometer T480_2010 (LaCrau – 2011/06/14)



Surface reflectance

$$\rho_k(\theta_s,\theta_v,\Delta\varphi) = \frac{\pi.CN_{gnd,k}(\theta_s,\theta_v,\Delta\varphi)}{Gg_k} \cdot \frac{1}{\Omega.\frac{CN_{sun,k}.\mu_s}{Gu_k.d} + \int_0^{2\pi}\int_0^1 \frac{CN_{ciel,k}.\mu_v}{G_k}.\mu_v.d\mu_v.d(\Delta\varphi)}$$

Upwelling flow

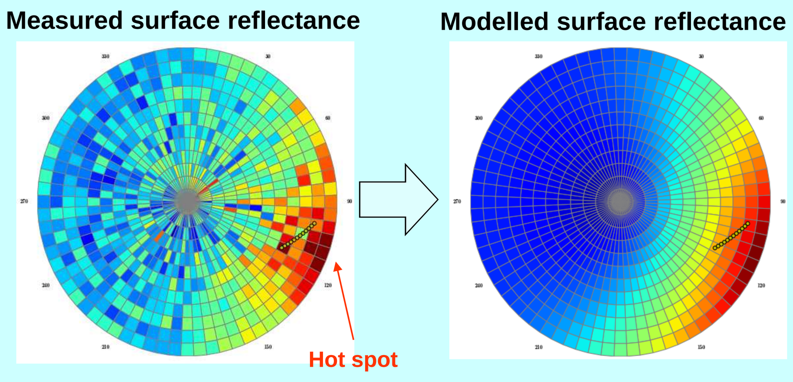
surface upwelling flow

Photometer FOV

Direct downwelling flow

Diffuse downwelling flow

BRDF model fitting: Roujean model
⇒ Semi empirical approach applicable to heterogeneous surfaces

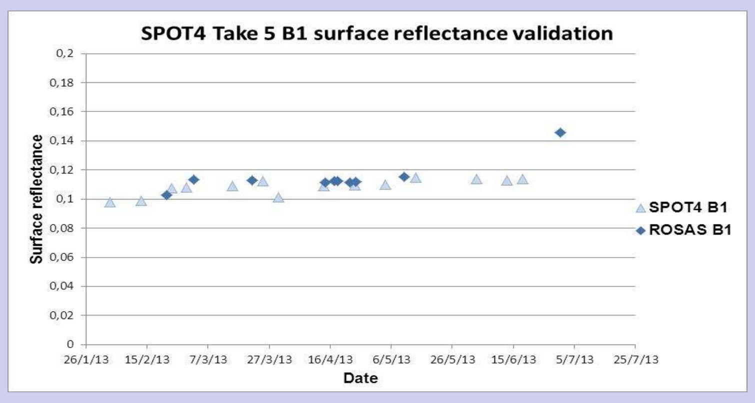


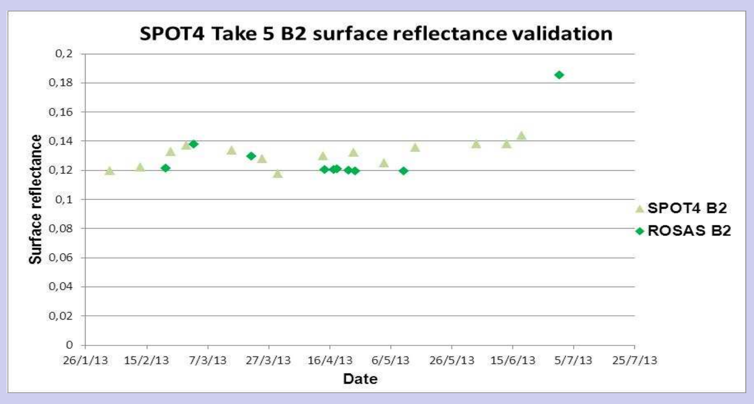
SPOT4/Take5 experiment: surface reflectance validation

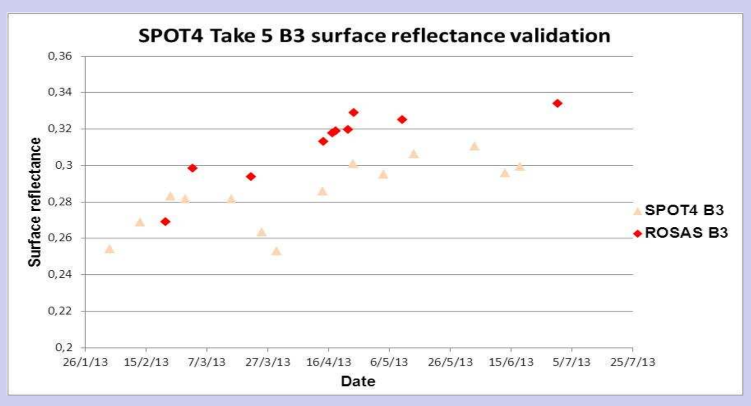
At the end of life of each satellite, CNES issues a call for ideas for short-term experiments taking place before de-orbiting the satellite. CNES/CESBIO took the opportunity to set up the Take 5 experiment at the end of SPOT4 life : this experiment used SPOT4 as a simulator of the time series that ESA's SENTINEL-2 mission will provide. To do so, on January 29, SPOT4's orbit was lowered by 3 kilometers to put it on a 5 days repeat cycle orbit. On this new orbit, the satellite has flown over the same places with the same viewing conditions every 5 days. SPOT4 followed this orbit until June the 19th, 2013. During this period, 45 sites have been observed every 5 days, with the same repetitiveness as Sentinel-2 mission.
The data have been processed and distributed by the THEIA Land data center and distributed to users in mid July 2013. Two product levels are provided :

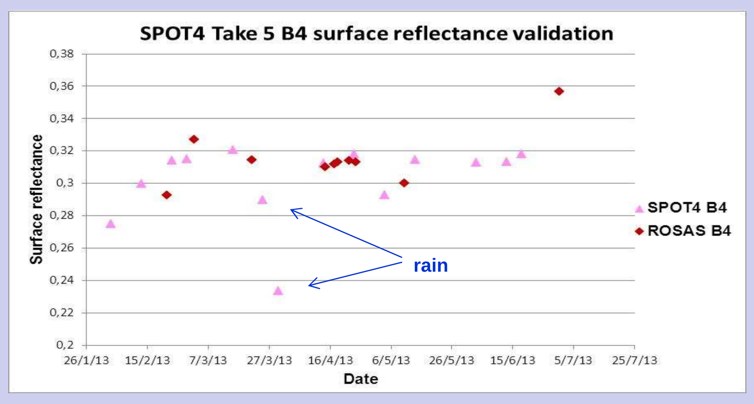
- Level 1C (Top Of Atmosphere orthorectified reflectance)
- Level 2A (Bottom Of Atmosphere orthorectified reflectance, along with a mask of clouds and their shadows, as well as a mask of water and snow).

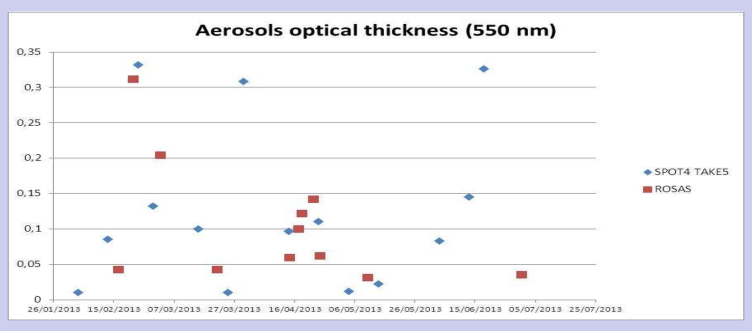
Surface reflectance and aerosol optical thickness validation results using ROSAS are shown below. These results are very good (less than 5%) for bands B1 (550nm), B2 (670nm) and B4 (1650 nm). A small bias (7-8%) for band B3 (840nm) could be explained by the photometer FOV knowledge for the visible and NIR bands which weights the direct downwelling flow in the reflectance estimation (see reflectance formula); the direct downwelling flow is the main contributor to the total downwelling flow for high wavelengths.

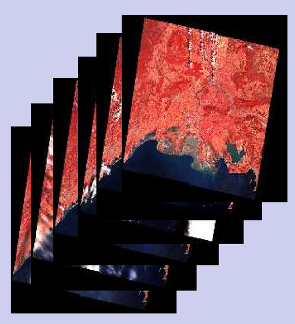












More on the experiment and data processing
www.cesbio.ups-tlse.fr/multitemp

THEIA Land Data Center, Spot4/Take5 data download
www.ptsc.fr