New RadCalNet Instrumented Site at Gobabeb, Namibia: Installation Field Campaign and First Absolute Calibration Results

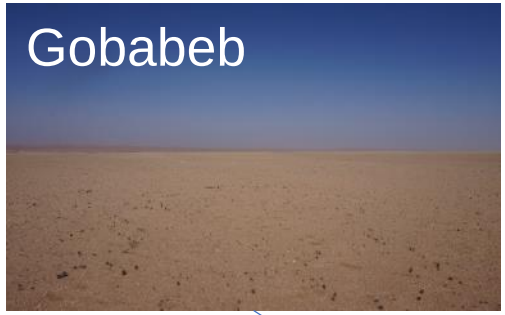
Sébastien Marcq, Aimé Meygret – Centre National d'Etudes Spatiales (CNES); Agnieszka Bialek, Claire Greenwell, Barry Scott, Nigel Fox – National Physical Laboratory (NPL); Marc Bouvet – European Space Agency (ESA); Beatrice Berthelot – Magellium; Bahaiddin Damiri – CIMEL

CALCON Aug 22-25 2017

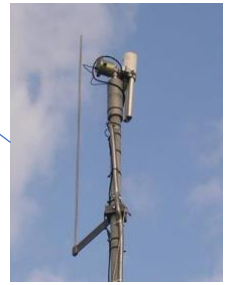
Outline

- Context:
  - Radcalnet
  - Instrumentation/Station description
- Gobabeb
  - Search for site/Characterization campaign
  - Installation
- First results

RadCalNet (Radiometric Calibration Network) – CEOS/WGCV IVOS



- **Automatic field instrumentation**
- **Data will be accessible to the public**



Baotou (AOE, China)

La Crau (CNES, France)

Railroad Valley (NASA/University of Arizona, USA)

Already operational

Gobabeb (ESA/CNES, Namibia)

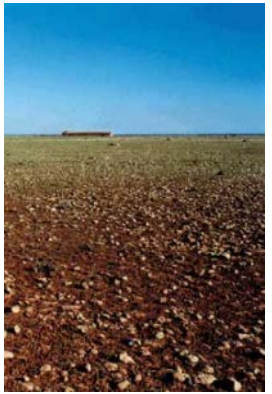
Installed in July 2017

La Crau and Gobabeb Sites

La Crau (France)

43.5589N, 4.8644E

- Flat plain of a few square kilometers, covered with white pebbles and grass
- Used since 1987 (SPOT), automated since 1997



Gobabeb desert, Namibia

23.6002S, 15.1196E

- Arid desert, tens of square kilometers
- Very low cloud coverage
- Instrumented in 2017

Station description: Instrument

ROSAS automated photometric station

A ***RO****botic* ***S****tation for* ***A****tmosphere and* ***S****urface* characterization dedicated to on-orbit calibration and L2a products validation

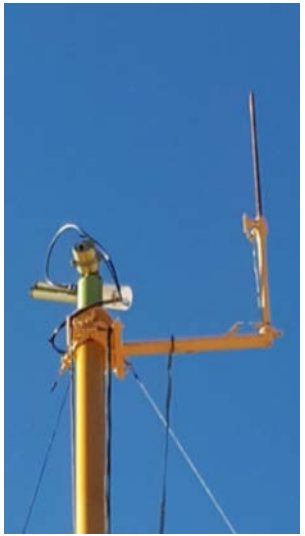
Photometer:

- Made by CIMEL
- AERONET concept (AErosol RObotoc NETwork) dedicated to atmosphere characterization
- Optical head: 2 collimators
- 2 detectors:
  - Silicium (visible and NIR)
  - InGaAs detector (SWIR)

Configuration:

12 filters:
414, 440, 500, 555, 675, 702, 740, 782, 870, 937, 1020, 1640 nm

Mounted on top of a 10m-high post .



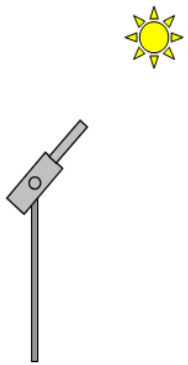
La Crau and Gobabeb stations share the same:

- **Instrument**
- **Protocol**
- **Processing**

Station description: Protocol

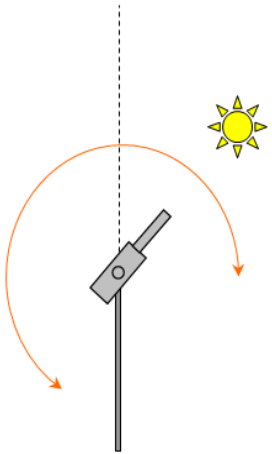
Automatic acquisitions every non cloudy day

Sun Irradiance



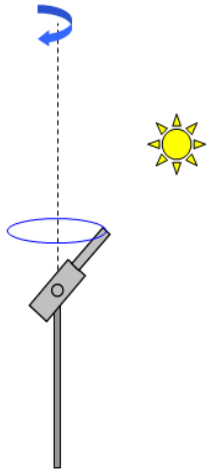
Irradiance measurements pointing the Sun in each band

Principal Plane



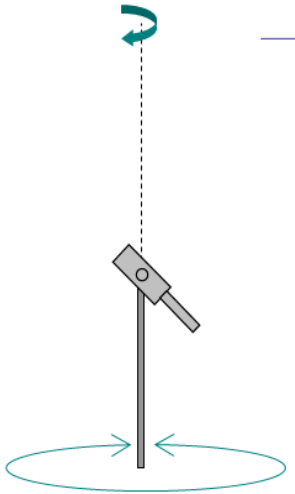
Sky radiances measurement in the vertical plane containing the Sun for 40 zenith observation angles for all bands except 937 nm

Almucantar

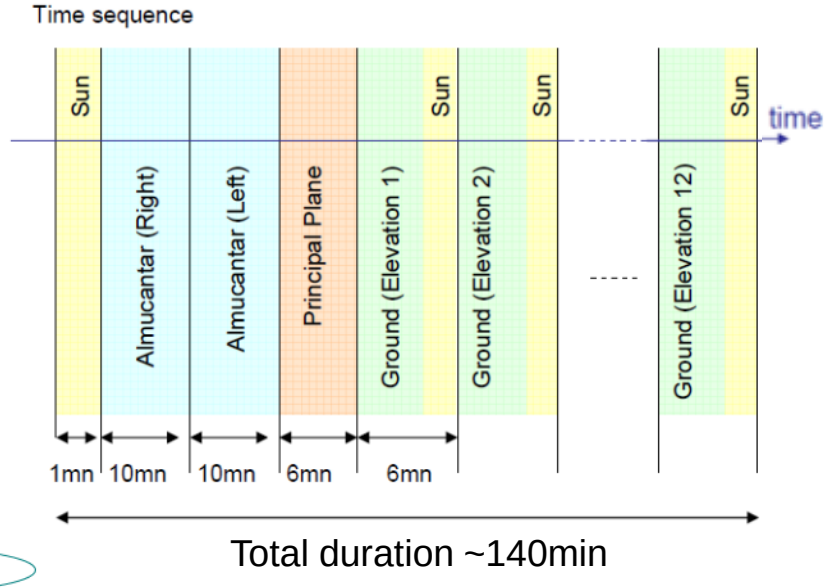


Sky radiances measurement according to 2 half cones around vertical axis for 30 azimuth observation angles for all bands except 937 nm

Ground



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



Station description: In situ Calibration

The SUN and SKY data can be used for an in-situ calibration of the photometer itself!

Irradiance Calibration

→ **Solar irradiance extinction: Bouguer-Langley Law**

Radiance Calibration

→ **Molecular scattering for short wavelengths and propagated to other bands using irradiance cross-calibration**

Station description: Radcalnet Processing

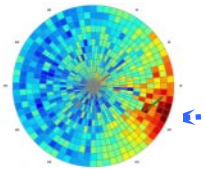
Sun Irradiance | *Principal Plane* | *Almucantar* | *Ground* — *Photometer measurement protocol*

Sun direct flux

Atm. diffuse flux

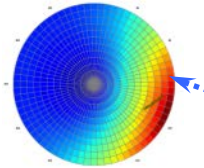
Total downwelling radiance

Upwelling radiance



Directional surface reflectance
(photometer bands)

- TOA Solar Irradiance
- Photometer spectral responses
- Masks computation
- Temperature correction (1020)



Directional surface reflectance
Roujean model
(photometer bands)

Semi empirical approach applicable to heterogeneous surfaces (Linear 3 parameter model)

Spectral interpolation // **Surface spectral response** ← From field spectroradiometer

Directional surface reflectance
(hyperspectral, 10nm resolution)

→ **Radcalnet input**

Meteo
Pressure
Water vapor
Ozone

NCEP
TOMS

Aerosols
Optical thickness
Angström coef

Station description: Satellite Calibration

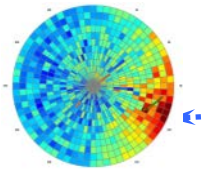
Sun Irradiance | *Principal Plane* | *Almucantar* | *Ground* — *Photometer measurement protocol*

Sun direct flux

Atm. diffuse flux

Total downwelling radiance

Upwelling radiance



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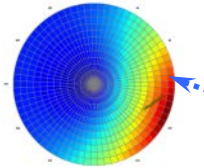

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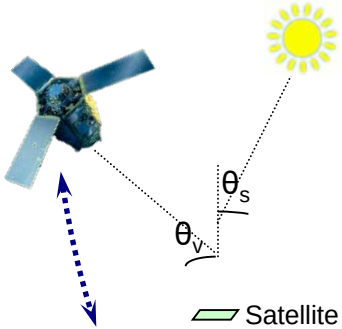


Spectral interpolation // **Surface spectral response** ← From field spectroradiometer

Satellite Sensor spectral bands

Directional surface reflectance
(hyperspectral)

Radcalnet input

Satellite acquisition
Geometrical conditions

Radiative Transfer with 6S (*)

Meteo
Pressure
Water vapor
Ozone

NCEP
TOMS

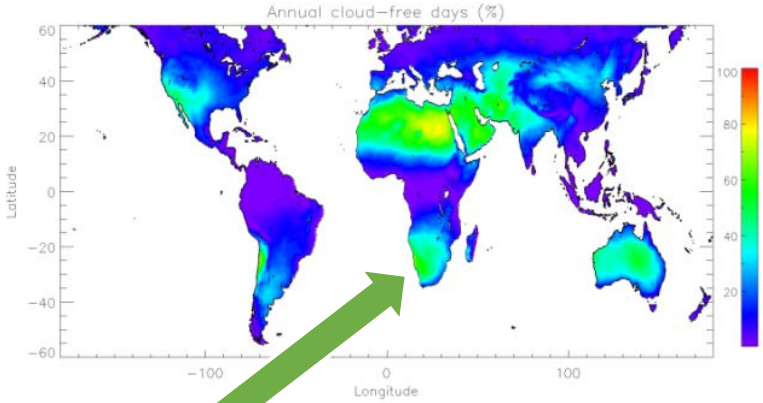
Aerosols
Optical thickness
Angström coef

Satellite TOA reflectance ⟷ **Calibration** ⟷ Top-of-Atmosphere reflectance
(sensor bands)

(*) Second Simulation of the Satellite Signal in the Solar Spectrum

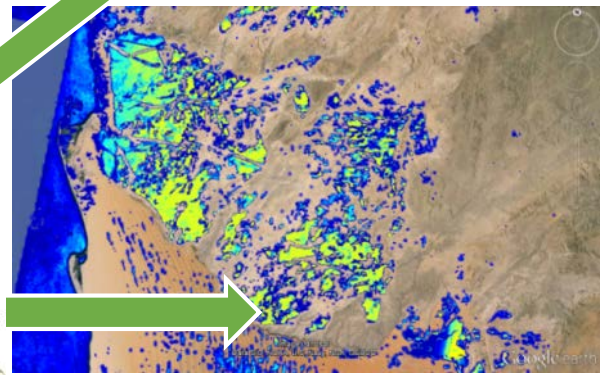
Gobabeb: Global search for a new site

⇒ **look for a new site (ESA+CNES) as part of RadCalNet (2013-2014)**



⇒ **Criteria of <u>global</u> analysis:**

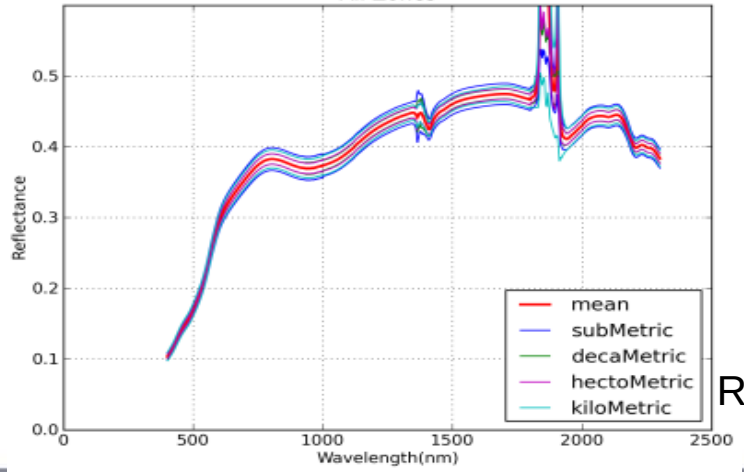
- Low Cloud coverage
- High Spatial homogeneity at several scales (10s of meters to 100s of meters)
- Stability (no vegetation)
- Atmospheric changes (atmospheric particles, water wapor…)
- Pratical reasons (access, GSM)



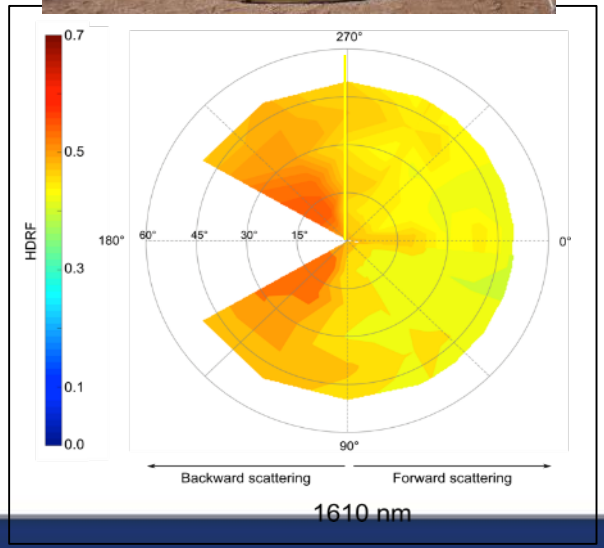
GOBABEB
RESEARCH & TRAINING CENTRE

Gobabeb: 2015 Characterization Field Campaign

Validation of satellite data analysis : very good spatial homogeneity from very high to coarse resolution



Reflectance

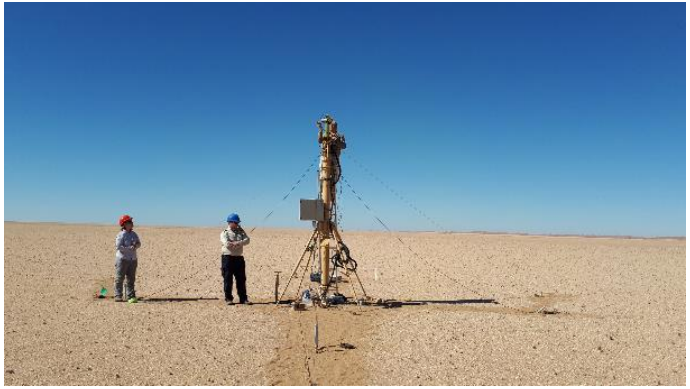


BRDF

Gobabeb: 2017 Installation

1 week field campaign for installation in July 2017

Photometer mounted on 10m telescopic mast from Clarks Masts UK



Gobabeb: 2017 Installation

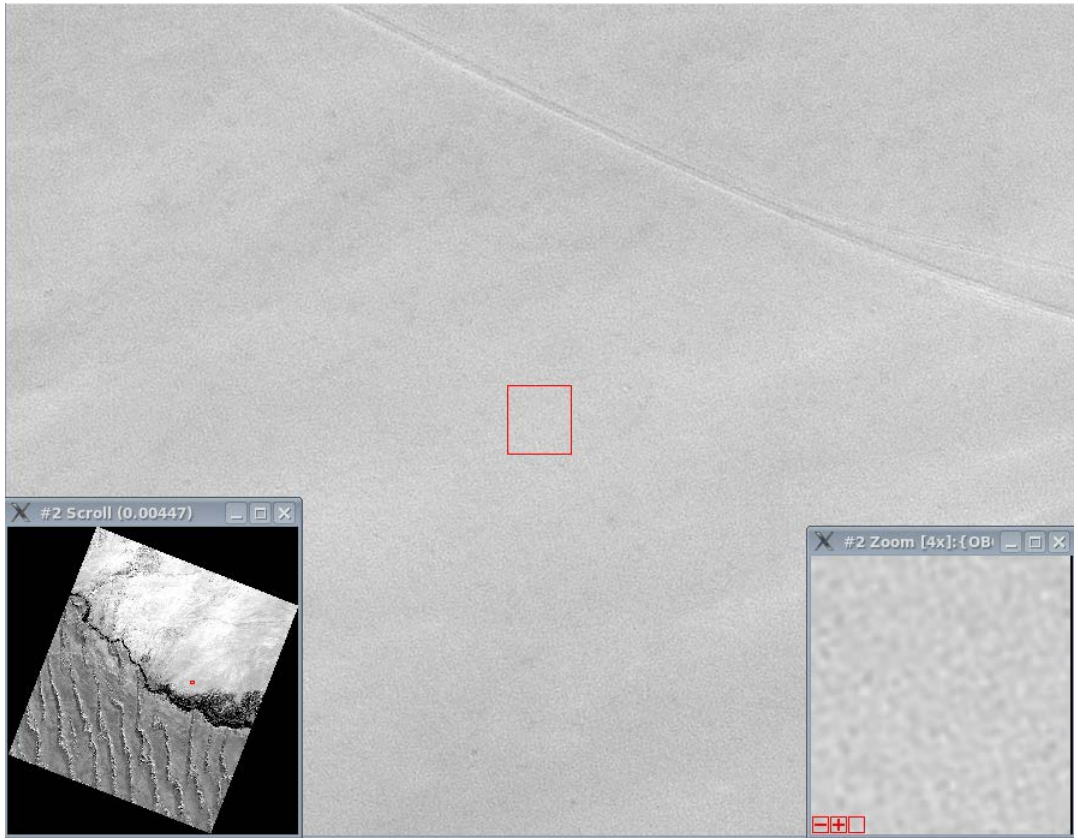
In addition to sunphotometer, weather station measuring pressure, humidity, wind speed/direction and global downwelling irradiance

Gobabeb: 2017 Installation

06/07/2017 PLEIADES PHR1A

70 cm PAN

Before installation



Gobabeb: 2017 Installation

25/07/2017 PLEIADES PHR1A

70 cm resolution PAN

After installation

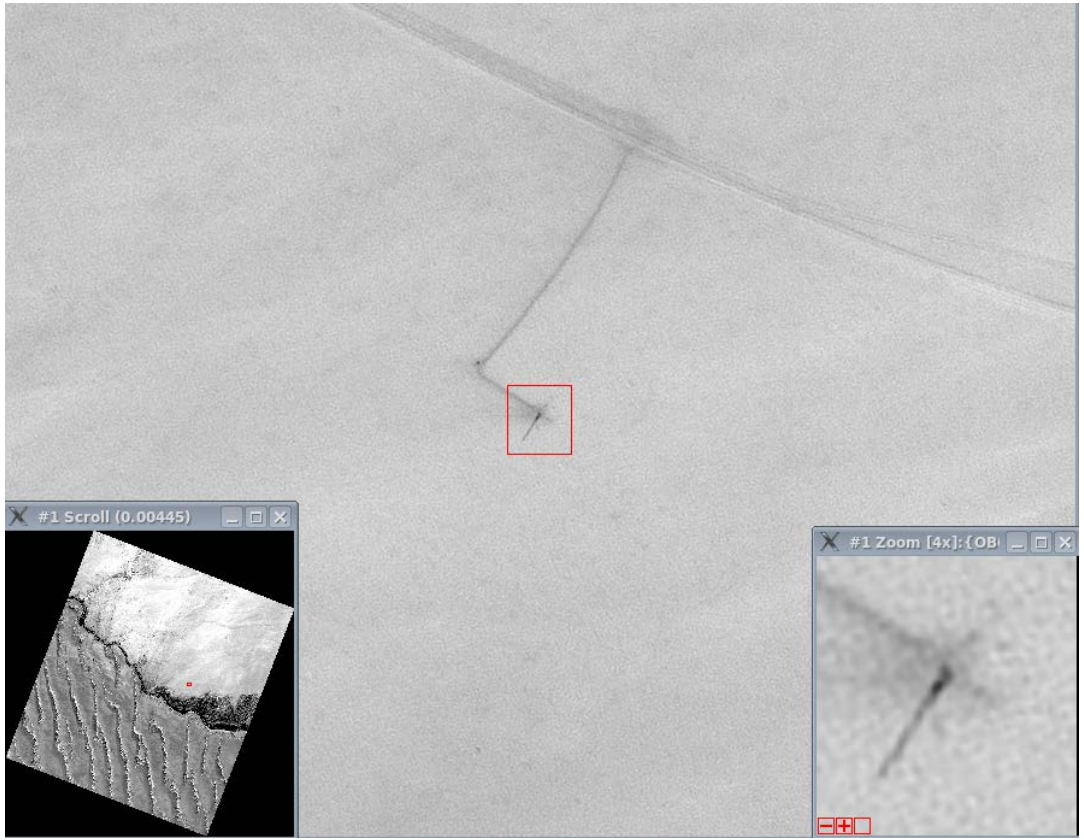
Footprints filtered in the processing (such as mast shadow)

Impact

~10% at 70cm resolution with adjacent pixels

~2% at 70cm on image extraction (30x30m²)

…and fading away (wind)



Gobabeb: 2017 Installation

19/07/2017 Sentinel2A

10 m resolution RGB

After installation

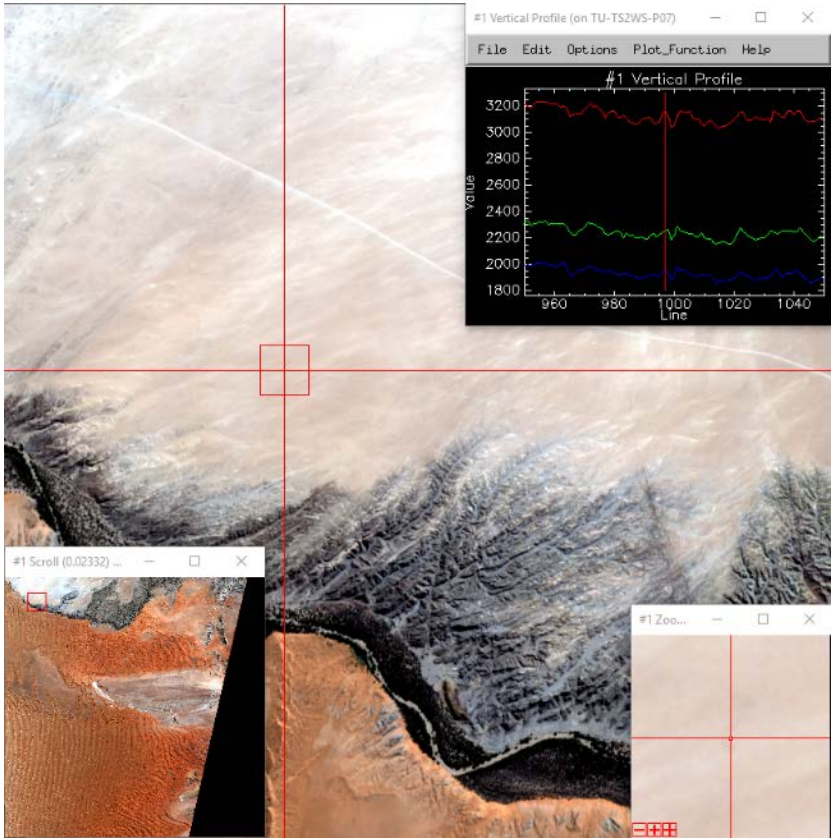
Footprints filtered in the processing (such as mast shadow)

Impact

~3% at 10m resolution with adjacent pixels

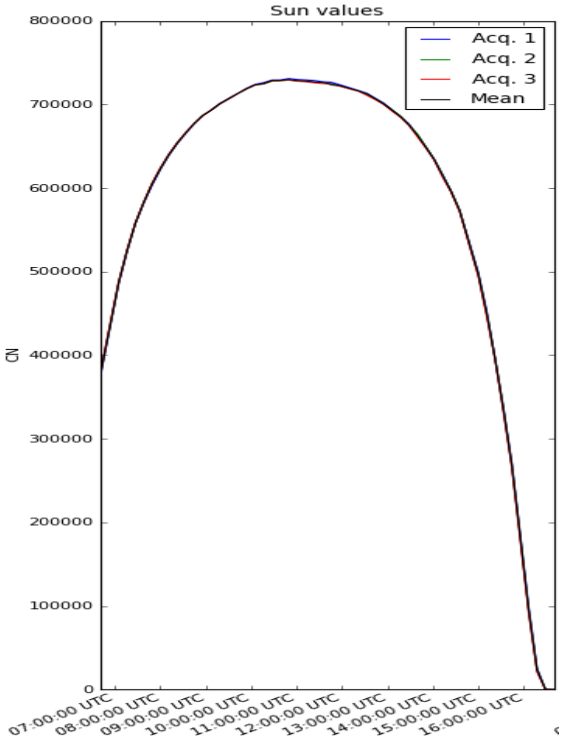
~<1% at 10m on image extraction (30x30m²)

…and fading away (wind)

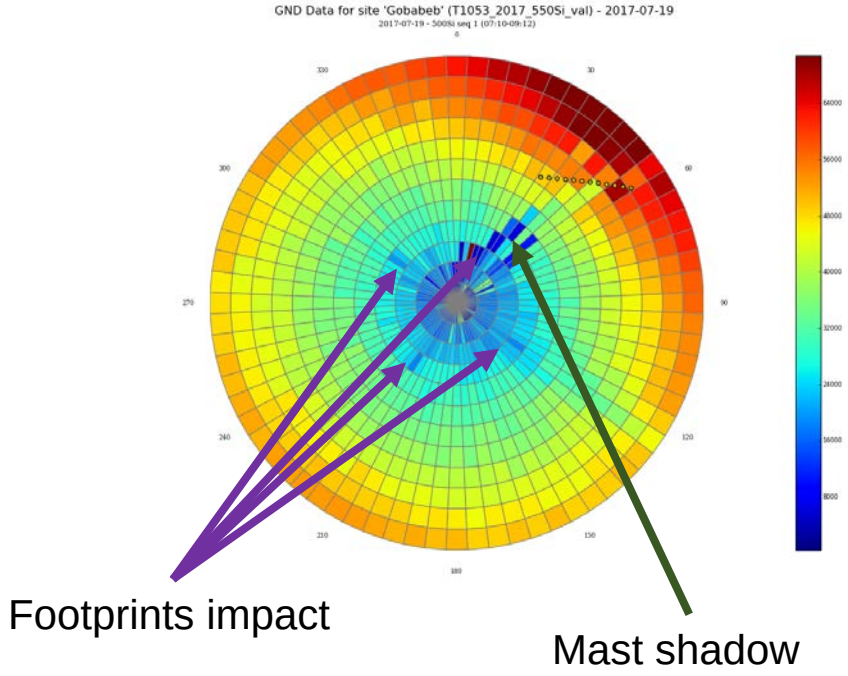


Gobabeb: Very first acquired data 2017/07/19

SUN 550 nm

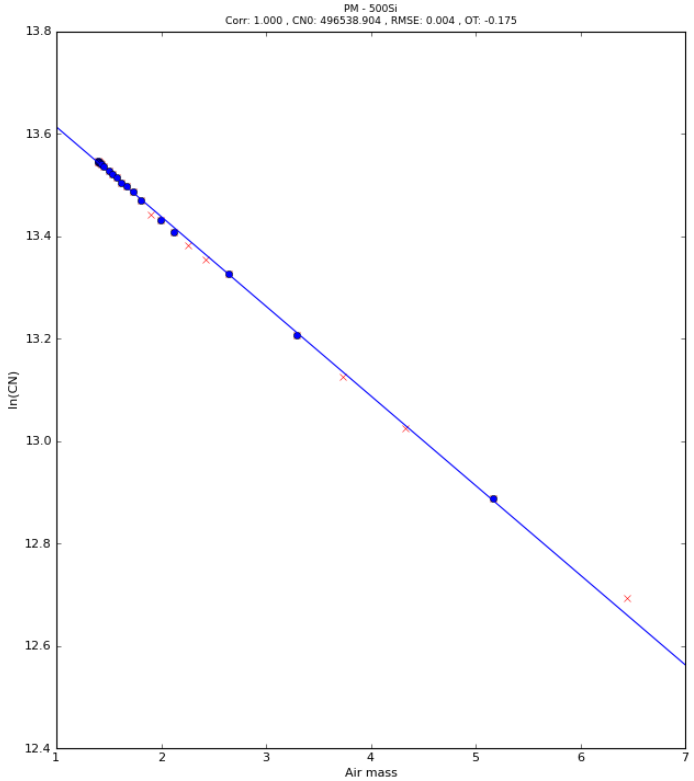


Ground Radiance 550 nm



Gobabeb: In situ Irradiance Calibration of the station

In progress: almost no clouds, but aerosol load varies slightly

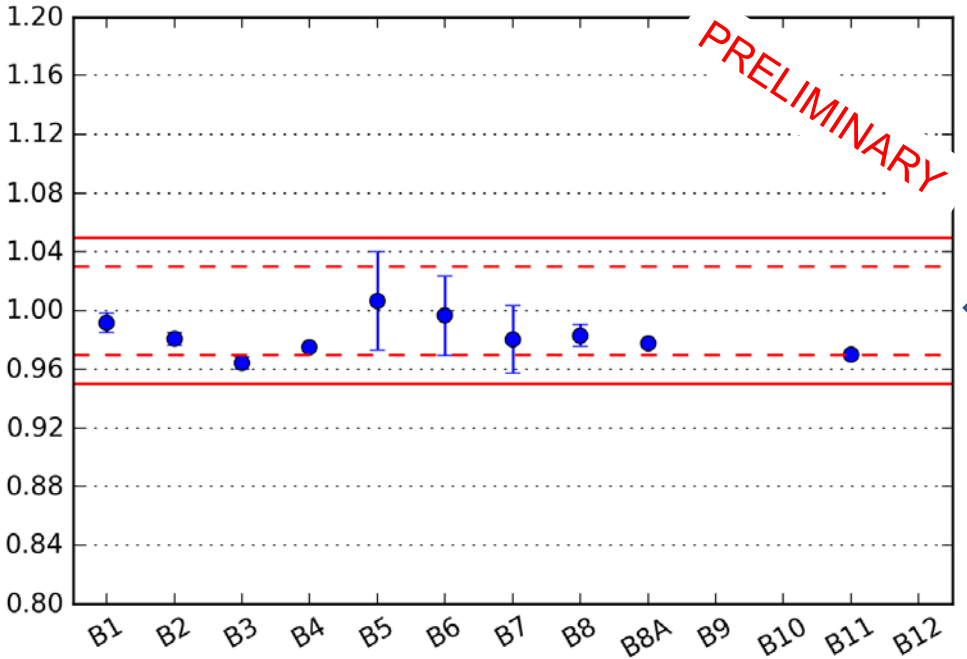


Spectral band	Irr. Calibration Coefficient	Difference to lab calibration
414	217061.8	2.5%
440	434262	1.8%
500	498934.8	1.3%
555	690851.4	1.4%
675	706242.8	0.3%
702	852989.2	0.3%
740	986128	0.0%
782	844668.7	0.7%
870	1008585.9	-0.2%
1020i	636907	-0.1%
1020	785585	-0.8%
1640	4191630	-0.7%

Results are very similar to lab calibration

Gobabeb: Sentinel 2A Absolute Calibration

1st absolute calibration results using Gobabeb station (3 S2A images)



S2A official calibration

- **Overall bias (simulated reflectance is too high)**
- **Very good repeatability (except one date around 700 nm)**

On-going analysis

(photometer calibration, aerosols …)

Conclusion

- **Gobabeb Radcalnet station has been installed in July 2017**
- **The instrument is now operational and has been used for Sentinel 2A calibration validation**
- **Quality assessment and tuning of processing parameters are currently underway**
- **First Gobabeb Beta data should flow to Radcalnet portal in the fall**

Thank you for your attention!

BACKUP SLIDES

Photometer in-situ irradiance calibration

k	Spectral band index

Langley-Bouguer principle:

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

E_k	Irradiance measured at ground level
E_{0k}	Top of atmosphere solar irradiance
d_0/d	Earth-Sun distance variation
τ	Total optical thickness
θ_s	Sun zenith angle
T_g	Total gaseous transmission

Radiometric model for Sun measurements:

$$DC_k = A_k . Gu_k . E_k$$

DC	Digital Count
Gu	Electronic Gain
A_k	Irradiance Calibration coefficient

Bouguer line:

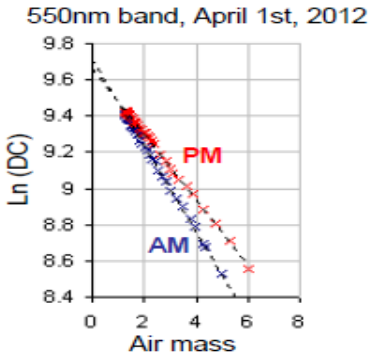
$$\ln(DC_k) = -\tau_k \, . \, m \quad + \quad \ln\left(A_k . Gu_k . E_{0k} . (d/d_0)^2\right)$$

m	Air mass = $1/\cos(\theta_s)$
T_g	is assumed ≈1 except for 937 band

Fitting of Bouguer line (least squares method) over each non cloudy half-day

- ✓ Air mass=0 → Irradiance Calibration coefficient A_k
- ✓ Slope of the line → Total optical thickness τ_k for the period

The Irradiance Calibration coefficient obtained in situ is compared to laboratoy results



Radiance Radiometric model: $DC_k = B_k.Gk_k.L_k$

DC	Digital Count
Gk	Gain for radiance measurements
B_k	Radiance Calibration coefficient

At shorter wavelenghts (380, 440, 550nm), the top of atmosphere radiance is dominated by Rayleigh scattering, and to a lesser extent by scattering from aerosols and surface →The total radiance L_k can be estimated for these wavelengths from Principal Plane measurements, using a radiative transfer code

→ B_k can be estimated in shorter wavelengths

Radiance / Irradiance relationship:

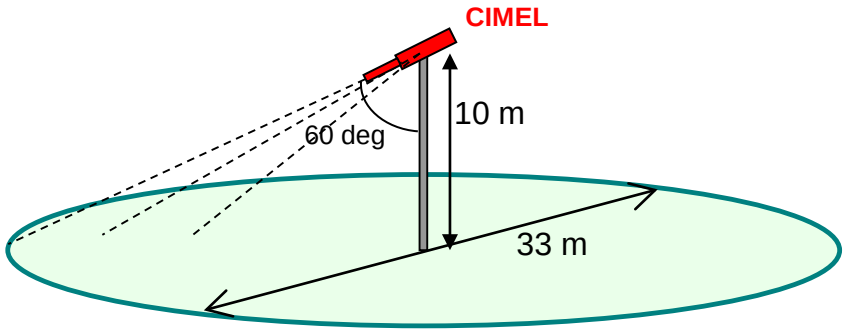
$$E_k = \Omega.L_k \qquad \Omega = \frac{B_k}{A_k}$$

Ω	Photometer solid angle (not wavelength dependent)
A_k	Irradiance Calibration coefficient
B_k	Radiance Calibration coefficient

B_k estimated in shorter wavelengths by radiance calibration
A_k already calculated in all bands by irradiance calibration

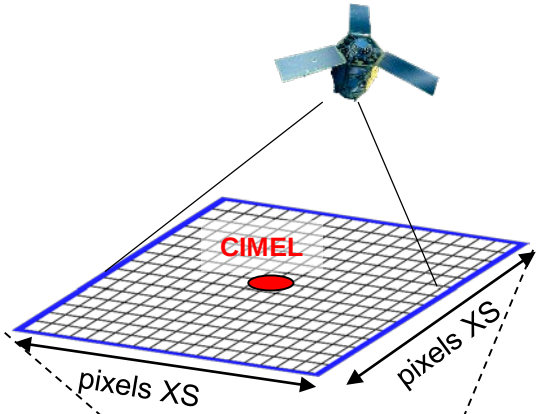
→ Estimation of Ω → B_k in all bands

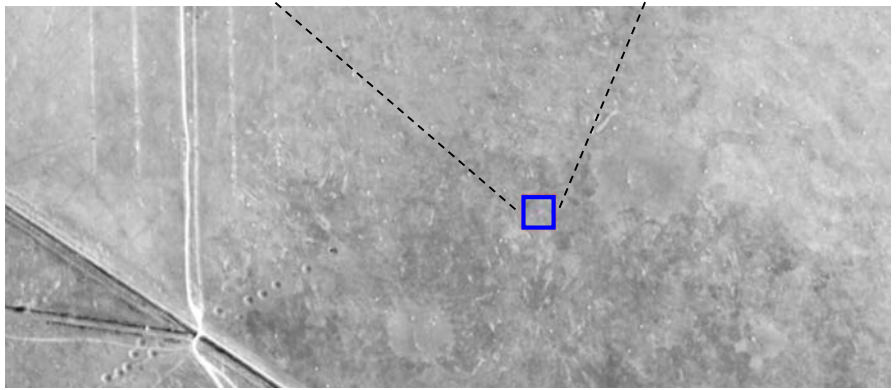
Ground measurement protocol



The Ground measurement protocol uses zenithal observation angles up to 60 degrees, which correspond to a **33m diameter** circular zone.

Satellite Acquisitions over instrumented site





PHR1A Feb 21, 2012 (PAN Image)

Each satellite measurement is averaged over X pixels around the photometer in order to form a squared area of 33m, and can be associated to a top-of-atmosphere reflectance