PROBA--V RADIOMETRIC CALIBRATION

Sindy Sterckx, Stefan Adriaensen

Workshop on Radiometric Calibration for European Optical Missions, ESRIN, 30-31 August 2017
OUTLINE

» Introduction: the PROBA-V mission and instrument

» Overview radiometric methods

» Instrument performance

» Multi-angular calibration

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**SPOT-VGT VS PROBA-V: INSTRUMENTS ARE NOT THE SAME**

- No on-board calibration devices
- Design complexity
  - 3 Cameras
  - 2 focal planes:
    - VNIR with 3 bands
    - SWIR with 1 band but staggered strips

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**IN-FLIGHT CALIBRATION**

- **NO** on-board calibration devices

Radiometric model:

\[
L_{TOA,i}^k = \frac{DN_{i,acquired}^k}{NL(DN_{i,acquired}^k)} - dc_{im}^k
\]

**OSCAR** *(Optical Sensor Calibration with simulated Radiances)*

- Absolute REQ. 5%
- Oceans
- DC Clouds
- Interband REQ. 3%
- Temporal (3% over 6 months)

*Sterckx et al. RS, 2017, Sterckx et al. IJRS, 2014; Sterckx et al., TGARS, 2013; Govaerts et al., RSL, 2013*
IN-FLIGHT CALIBRATION

- NO on-board calibration devices

Radiometric model:

\[ L_{\text{TOA},i} = \frac{A_i}{\alpha_i} \]

- Supported by DIMITRI analyses by M. Bouvet

- Supported by Y. Govaerts: Desert BRF modelling

- 6-monthly QWG meetings

*Sterckx et al. RS, 2017, Sterckx et al. IJRS, 2014; Sterckx et al., TGARS, 2013; Govaerts et al., RSL, 2013
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OSCAR DESERT CALIBRATION APPROACH

- 6SV simulations
- Surface RPV BRF
- ECMWF (P, O3, H2O)
- Desert aerosol
- AOT(month)
**IMPROVEMENTS TO DESERT APPROACH**

Surface characterisation improvement

(MISR/MODIS ** ⇔ ORIG*: POLDER/ATSR2)

Aerosol characterisation

* Govaerts and Clerici (2004)

INSTRUMENT STABILITY : OSCAR DESERT METHOD LIBYA-4

libya4 CENTER BLUE

PROBASIM

days since launch

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INSTRUMENT STABILITY : OSCAR DESERT METHOD LIBYA-4

libya4 CENTER BLUE- seasonal modelling

[Graph showing PROBASIM vs days since launch]
INSTRUMENT STABILITY: OSCAR DESERT METHOD LIBYA-4

Libya4 CENTER BLUE linear trend: -0.40%/year

PROBAM/SIM vs. days since launch
INSTRUMENT STABILITY : OSCAR DESERT METHOD LIBYA-4

CENTER CAMERA

seasonal corrected, OSCAR Libya4 results CENTER BLUE

seasonal corrected, OSCAR Libya4 results CENTER RED

seasonal corrected, OSCAR Libya4 results CENTER NIR

seasonal corrected, OSCAR Libya4 results CENTER SWIR1

seasonal corrected, OSCAR Libya4 results CENTER SWIR2

seasonal corrected, OSCAR Libya4 results CENTER SWIR3

BLUE: -0.4% / year

RED: 0.09% / year

NIR: -0.24% / year

SWIR 1: -1.14% / year

SWIR 2: -1.11% / year

SWIR 3: -1.02% / year
INSTRUMENT STABILITY: OSCAR DESERT METHOD LIBYA-4

LEFT CAMERA

**BLUE:** -0.43 %/year

**RED:** 0.14 %/year

**NIR:** -0.15 %/year

**SWIR 1:** -0.97 %/year

**SWIR 2:** -1.21 %/year

**SWIR 3:** -1.11 %/year
INSTRUMENT STABILITY: OSCAR DESERT METHOD LIBYA-4

RIGHT CAMERA

BLUE: -0.13% / year
RED: 0.24% / year
NIR: 0.09% / year

SWIR 1: -0.92% / year
SWIR 2: -1.46% / year
SWIR 3: -0.93% / year
Observation of the moon:

- Phase angle 7° +/- 0.5 degrees (moon - observer - sun angle)
- Pitch maneuver: 360 degrees rotation at approx. 0.2 °/s
- Oversampling of +/-4.0

In-house implementation ROLO model
INSTRUMENT STABILITY: LUNAR CALIBRATION RESULTS

**BLUEST:**
- Linear trend BLUE CENTER: \(-0.32 \pm 0.03\)%/year
- Degradation trend BLUE: \(-0.32\)%/year

**RED:**
- Linear trend RED CENTER: \(0.25 \pm 0.04\)%/year
- Degradation trend RED: \(0.25\)%/year

**NIR:**
- Linear trend NIR CENTER: \(0.01 \pm 0.04\)%/year
- Degradation trend NIR: \(0.01\)%/year

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DEEP CONVECTIVE CLOUDS CALIBRATION

- LibRadtran LUT
- Ice clouds optical properties (Baum et al. 2005)
- Fixed effective ice cloud radius
- ECMWF (O3)
- Strict procedure to automatically select DCC
- Not for SWIR band
- INTERBAND

Sterckx et al. TGARS, 2013
INSTRUMENT STABILITY : DCC CALIBRATION RESULTS

LEFT camera

CENTER camera

RIGHT Camera

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### INSTRUMENT STABILITY SUMMARY TABLE

<table>
<thead>
<tr>
<th>Band</th>
<th>Camera</th>
<th>Linear trend (%/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Libya-4</td>
</tr>
<tr>
<td>BLUE</td>
<td>LEFT</td>
<td>-0.43</td>
</tr>
<tr>
<td>BLUE</td>
<td>CENTER</td>
<td>-0.40</td>
</tr>
<tr>
<td>BLUE</td>
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</tr>
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<td>LEFT</td>
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<td>SWIR2</td>
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</tr>
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<td>SWIR2</td>
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<td>SWIR3</td>
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<td>RIGHT</td>
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</tr>
</tbody>
</table>
COLLECTION 0 VS COLLECTION 1

- Uncertainty in instantaneous vicarious calibration results
- Some methods prone to seasonal dependent biases
  - Large amount of vicarious calibrations are required to distinguish an instrument related degradation trend from the ‘noise’
DEGRADATION OVER 16 DESERT SITES

NOTE: surface characterisation based on POLDER/ATSR2

Larger absolute bias, but OK for trending
leftrightarrow MISR/MODIS for Libya-4 and Niger-2
Govaerts, Sterckx & Adriaensen (2013)
Libya-4
## RadCalNet Sites

<table>
<thead>
<tr>
<th>RadCalNet Site</th>
<th>Site code</th>
<th>Latitude (°)</th>
<th>Longitude center (°)</th>
<th>Altitude (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>La Crau, France</td>
<td>LCFR</td>
<td>43.55885</td>
<td>4.864472</td>
<td>20.0</td>
</tr>
<tr>
<td>Railroad Valley Playa, United States</td>
<td>RVUS</td>
<td>38.497</td>
<td>-115.690</td>
<td>1435</td>
</tr>
<tr>
<td>Baotou, China</td>
<td>BTCN</td>
<td>40.851659</td>
<td>109.628904</td>
<td>1270</td>
</tr>
<tr>
<td>Gobabeb, Namibia</td>
<td>GBNB</td>
<td>TBD</td>
<td>TBD</td>
<td>TBD</td>
</tr>
</tbody>
</table>

<table>
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<tr>
<th>Site Name</th>
<th>Representative area</th>
</tr>
</thead>
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<tr>
<td>La Crau</td>
<td>Disk of 30 m radius</td>
</tr>
<tr>
<td>Railroad Valley Playa</td>
<td>A square of 1 km x 1km</td>
</tr>
<tr>
<td>Baotou</td>
<td>Each square is about 48 m across.</td>
</tr>
</tbody>
</table>

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RAILROAD VALLEY PLAYA

- 100 m spatial resolution
- Representative area: 1kmx1km
  ~ 10 x 10 VNIR Pixels
  ~ 3 x 3 SWIR Pixels
AVERAGE RESULTS max 10° VZA

PROBA-V - RadCalnet % diff

BLUE (0.440 – 0.487)  RED (0.614 – 0.696)  NIR (0.772 – 0.902)  SWIR (1.570 – 1.635 )

28 match-ups
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COMPLEXITY OF THE IN-FLIGHT CALIBRATION
• Commissioning improvements to the pre-flight equalisation parameters

Vignetting correction

• But, still some remaining uniformities both at the edges and the middle of the detectors (visible if stretched over uniform areas)
90 yaw acquisition (with 2.9° roll)

Same target on ground imaged by all the array detectors
YAW MANEUVER RESULTS CENTER SWIR

**CENTER SWIR 1**

**CENTER SWIR 2**

**CENTER SWIR 3**
IMPACT OF NEW EQUALISATION COEFFICIENTS

NEW CENTER SWIR1

OLD CENTER SWIR1

NEW CENTER SWIR2

OLD CENTER SWIR2

NEW CENTER SWIR3

OLD CENTER SWIR3
Thank you!

The PROBA-V team