OLCI calibration and characterisation

Ludovic Bourg

International Ocean Colour Science Meeting
Darmstadt, May 2013
Overview

- OLCI, successor to MERIS
- Overall calibration strategy
  - Radiometric model
  - Calibration processing chain
    - In-flight measurements
    - On-ground characterisation
    - Analysis and modelling
- Lessons learnt from MERIS
  - Calibration sequences
  - Calibration data & processing
  - On-ground Characterisation
- Conclusion
OLCI, successor to MERIS

- Push-broom imaging spectrometer, 5 fan-arranged cameras
- Radiometric calibration based on on-board diffuser(s)
- Spectral calibration using dedicated on-board diffuser

+ 12 degrees westward tilt to avoid Sun glint and increase swath to 1250km
+ number of bands increased to 21
+ technological improvements...
Overall Calibration Strategy

On-ground characterisation

+ In-flight calibration measurements

+ Processing, analysis and modelling

= Self standing absolute calibration for the EO processing chain
$X_{b,k,m,t} = NL_{b,m} \left[ A_{b,k,m}^0 \cdot \left( L_{b,k,m,t} + SL_{b,k,m,t} (L_{*,*,*}) \right) + \right]
\left[ Sm_{b,k,m,t} (L_{*,k,m,*} + SL_{*,k,m,*} (L_{*,*,*})) + \right]
\left[ g_C(T_{t}^{CCD}) \cdot C^0_{b,k,m} \right] + \epsilon$

Where:
- $b =$ band, $k / m =$ pixel / camera, $t =$ time, ($* =$ whole/partial domain)
- $X_{b,k,m,t}$ is the OLCI raw sample
- $NL_{b,m}$ is a non-linear function
- $T_{CCD}(t)$ is the temperature of the CCDs
- $g_C(T_{CCD})$ is a dimensionless temperature correction function
- $A_{b,k,m}^0$ the "absolute radiometric gain" in counts/radiance unit
- $L_{b,k,m,t}$ the spectral radiance distribution in front of OLCI
- $Sm_{b,k,m,t}$ the smear signal, due to continuous sensing of light by OLCI
- $C^0_{b,k,m}$ the calibrated dark signal (possibly including an on-board compensation)
- $SL_{b,k,m,t}$ a linear operator representing the stray light contribution to the signal
- $\epsilon$ is a random process representative of the noise and measurement errors.
Radiometric model applies to Calibration measurements

\[ X_{b,k,m,t}^{\text{Cal}} = \text{NL}_{b,m} \left[ A_{b,k,m}^0 \left( L_{b,k,m,t}^{\text{Cal}} + \text{SL}_{b,k,m,t}^{\text{Cal}} (L_{*,*,*,*}^{\text{Cal}}) \right) + \right. \\
\left. \text{Sm}_{b,k,m,t} (L_{*,k,m,*}^{\text{Cal}} + \text{SL}_{*,k,m,*}^{\text{Cal}} (L_{*,*,*,*}^{\text{Cal}})) + \right] + \varepsilon \\
\]

\[ A_{b,k,m}^0 = \left\langle \frac{\text{NL}^{-1}_{b,m} (X_{b,k,m,t}^{\text{Cal}}) - \text{Sm}_{b,k,m,t} (L_{*,k,m,*}^{\text{Cal}} + \text{SL}_{*,k,m,*}^{\text{Cal}})}{L_{b,k,m,t}^{\text{Cal}} + \text{SL}_{b,k,m,t}^{\text{Cal}}} \right\rangle_{t \in \{\text{cal}\}} \]

With:
- \( X_{\text{Cal}} \) from Sun diffuser measurements
- \( C^0 \) from dedicated measurements (with shutter)
- \( \text{Sm} \) from dedicated band (virtual, lit only during CCD frame transfer)
- \( L \) from characterised diffuser BRDF + in-flight geometry + \( E_0 \) at OLCI bands
- \( \text{SL} \) from \( L \) + characterised/modelled convolution kernels
- \( g_C \) from characterisation
- \( \text{NL}^{-1} \) from characterisation
Calibration chain summary

Spectral Calibration
- absolute wavelengths
  - Sun Irradiance model
  - Sun-View geometry
    - Diffuser ageing model

Gain Computations
- Instrument Spectral Model
  - in-band irradiances, wavelengths
  - calibration irradiances, wavelengths
    - Diffuser BRDF model
      - calibration radiance

Gain Modelling
- \( \{G(t)\} \)
  - reference gains
  - degradation model

Level 1b EQ processing
- observation counts (corrected)
- reference gains
- degradation model
  - EQ radiances

Gain computation

ACRI-ST | Author | Meeting title | Date | Slide 7 / X
Calibration chain summary (short term)

Spectral Calibration
- absolute wavelengths

Sun Irradiance model
- Sun-View geometry
- Diffuser ageing model

Instrument Spectral Model
- in-band irradiances, wavelengths

Diffuser BRDF model

Gain Computations
- calibration counts (corrected)
- Gain computation
- G(t)

Level 1b EQ processing
- observation counts (corrected)
- Gain computation
- degradation model (identity)
- EQ radiances

Gain Modelling
- reference gains
- degradation model

{G(t)}
- Gain computation
In-flight measurements

- Shutter: dark offset (calibration zero), before every diffuser acquisition (systematic) or along-orbit (infrequent)
- Radiometric diffuser: calibration gains
- Reference radiometric diffuser: ageing of nominal diffuser
- Spectral diffuser: spectral calibration at 3 wavelengths
- Specific observations in support to spectral calibration (Fraunhofer lines on diffuser, O₂ absorption over Earth) → additional wavelengths
On-ground characterisation: Key Inputs

Main inputs for radiometric calibration:

- Spectral data: central wavelengths, spectral response curves → in-band equivalent irradiance
- Diffusers characterisation: BRDF and orientation
- Integral non-linearity
- Instrument pointing vectors
- Stray light operators

- Compute radiance at instrument entrance during radiometric calibration from in-flight geometry
Processing, analysis and modelling

- From spectral calibrations: correction of spectral model, impact on central wavelengths and in-band irradiances, if required
- From radiometric diffuser: calibration gains
- From reference diffuser comparison with nominal (ageing sequences): modelling of diffusers ageing (browning)
- Analysis of calibration gains time series (mid and long term): derivation of instrument degradation model, smoothing transitions
- Back to Calibration of EO data through auxiliary files
1) Calibration sequences

In addition to “classical” sequences (radiometric, ageing and spectral diffuser), the following have been included:

- Orbital stability (along-orbit dark level stability)
- Fraunhofer lines observations on radiometric diffuser (no spectral relaxation: 1 orbit allows observing 6 lines, while 3 orbits were necessary with MERIS)
- Earth observations of O₂ atmospheric absorption using dedicated band setting (+ corresponding radiometric calibration)

- All the MERIS spectral campaigns are pre-defined on-board OLCI
2) Calibration acquisitions and processing

- All calibration measurements are sent to ground and processed on a frame by frame basis (i.e. without the temporal averaging of MERIS)
  → inputs to uncertainties, SNR evaluations, BRDF model assessment, diffuser speckle, sensitivity to geometry ...

- All calibration acquisitions are packed without spectral relaxation (i.e. in micro-bands, or sub-bands)
  → better processing, finer analysis

- Much more detailed stray-light modelling for both Radiometric Calibration and Earth Observation: full spatial 2D for Ground Imager and full across-track/spectral 2D for the spectrometer.

- accurate navigation/attitude from on-board system
3) On-ground Characterisation

- Improved spectral characterisation → spectral model
- Improved diffuser BRDF characterisation domain

- Much more detailed stray-light modelling for both Radiometric Calibration and Earth Observation: full spatial 2D for Ground Imager and full across-track/spectral 2D for the spectrometer.
Conclusion

Thanks to commonality between the two instruments:

- a successful calibration strategy is re-used,
- refined according to lessons learnt,
- embedded in an operational environment should guarantee success

Surprising instrumental behaviours cannot be excluded

- Validation from vicarious is mandatory (and adjustment if required)
- calibration team must be prepared to revise everything
Thank you for your attention