Unfiltering Study for the EarthCARE BBR

Almudena Velazquez, Nicolas Clerbaux, Alessandro Ipe, Luis Gonzalez, Steven Dewitte, Edward Baudrez, Ilse Decoster, Stijn Nevens, Patrick Vandermeulen (RMIB)
Jacqueline E. Russell, Helen Brindley (ICL)
Outline

• Overview: EarthCARE mission
• BBR Configuration
• Spectral Response
• Sensitivity Study
• Results:
  • Geotype database generation
  • Contaminations
  • Standalone unfiltering
  • MSI based unfiltering
• Quantification of the unfiltering error
• Recommendations on the algorithm
EarthCARE mission

EarthCARE is the sixth Earth Explorer Mission of the ESA Living Planet Program.

Objectives:
Enable advances in climate modeling by simultaneous observation of aerosol and cloud properties and the radiation and hydrological cycle parameters.

Space segment:
- Backscatter Lidar (ATLID) - ESA High-spectral resolution and depolarisation
- Cloud Profiling Radar (CPR) - JAXA/NICT -36 dBZ sensitivity, 500 m vertical range, Doppler
- Multi-Spectral Imager (MSI) - ESA 7 channels, 150 km swath, 500 m pixel
- Broadband Radiometer (BBR) - ESA 2 channels, 3 views (nadir, fore and aft)

Orbit: Sun-synchronous, DN 10:30
Height: 450 km
Lifetime: 2(+1) years
BBR Configuration

- Along track sampling: 3 telescopes
- Telescope zenith angle: $\theta = 0^\circ, \pm 55^\circ$
- Pixel: - 10 km x 10 km for all three telescopes
  - 0.1 pixel co-registration
- Two spectral channels:
  - SW: 0.2 - 4.0 $\mu$m
  - LW: 4.0 - 50 $\mu$m
- Calibration:
  - Sun calibration via diffuser
  - Deep space calibration
  - Black body calibration
- Parallax compensation by over-sampling

Mass: < 27 kg
Power: < 43 W
Data rate: < 50 kb/s

ERB Workshop 13th - 16th Sept, ECN, Paris
Study objectives

Provide the unfiltering algorithms & coefficients for the BBR

ATBD of the Unfiltering process

Generate and deliver SW and LW radiative transfer simulation databases

Provide the contamination coefficients for SW and “LW” channels.

End to end error analysis
BBR Spectral response

Single mirror telescope
Mirror coating: aluminium
Quartz filter for SW
No data at $\lambda > 50$ µm

Comparison with GERB and CERES
Better in the “blue”
Worse in the near-IR
BBR spectral response

\[ \phi_{tot}(\lambda) = \phi_{det}(\lambda) \cdot \phi_{tele}(\lambda) \]
\[ \phi_{sw}(\lambda) = \phi_{det}(\lambda) \cdot \phi_{tele}(\lambda) \cdot \phi_{quartz}(\lambda) \]

No data at \( \lambda > 50 \, \mu m \)

- the mirror reflectivity has been extrapolated at a constant value from 50\( \mu m \) to 500\( \mu m \)
- the detector is assumed to decrease in response (linearly) from 50\( \mu m \) to zero at 500\( \mu m \)
- the quartz silver transmission is set to the one from GERB for wavelengths beyond 50 \( \mu m \)
Unfiltering process

Objective: estimate the reflected solar and emitted thermal BB radiance from the BBR measurements

Method: based on theoretical simulated filtered and unfiltered radiances

Estimation of the LW as TOT - A SW

Substraction of the contaminations
Based on the BBR measurements

Unfiltering by multiplication with the “unfiltering factor” estimated from de measurements (standalone) the MSI scene identification
**SW unfiltering factor**

Estimated from RTM with SBDART

Limited range for the SW unfiltering factor

1.215 +/- 0.03

Excellent response in the blue
Limited range for the LW unfiltering factor:

- BBR: 1.05 +/- 0.006
- TRMM: 1.16 +/- 0.01
- G2: 1.09 +/- 0.01

2nd order fit on the LW measurement gives excellent results
No need for MSI information
Results Obtained. Geotype database

- 2 theoretical databases:
  - 616 scenes → 5544 solar (SW) simulations
  - 12096 thermal (LW) simulations
- ASTER surf. reflectance
- Cox and Munk ocean
- OPAC aerosol def.
- Cloud prop. From Yang parametrization
- Fine spectral resolution
  - SW sim: 0.25 to 5 µm (833 \( \lambda \))
    - 0.25 to 1.36 µm, step 0.002 µm
    - 1.36 to 2.5 µm, step 0.005 µm
    - 2.5 to 5 µm, step 0.05 µm
  - LW sim: 2.5 to 100 µm (762 \( \lambda \)) + extended up to 500 µm
    - 2.5 to 14 µm, step 0.05 µm
    - 14.1 to 50 µm, step of 0.1 µm
    - 55 to 100 µm, step of 0.5 µm

Geometry:
  - 9 Solar Zenith Angles, 0° to 80°, step 10°
  - 18 Viewing Zenith Angles: 0° to 85°, step 5°
  - 19 Relative Azimuth Angles: 0° to 180°, step 10°.

Example of CS SW simulation

Full description in “Global spectral Databases of simulated solar and thermal radiance fields at the TOA.”

Database available from RMIB or ESTEC
Database description

- **SW database (5544 scenes)**
  - Clear sky land (176)
  - Clear sky ocean (56)
  - Thick clouds (72)
  - Semi-transparent clouds (240)
  - Overlapping clouds (72)

- **LW database (12096 scenes)**
  - Clear sky land/ocean (540)
  - Thin clouds (3024)
  - “Moderate” clouds (2592)
  - Thick clouds (1080)
  - Overlapping clouds (4860)

**Time cost:**

- Simulations run in plato cluster/processor (30/192 processors)
- ~20 min SW clear sky land
- Up to 2h 30 min for ocean and overcast
- Computation time: ~20 days in 30 processors
Clear sky land simulations

• Surface reflectance from ASTER spectral library
  • VEGE: 4 vegetation types (+scaling to 0.8 1.0 1.2) → 12 spectra
  • SNOW: 4 snow types (+scaling to 0.8 0.9 1.0) → 12 spectra
  • ROCK: 48 rock types → clustering in 12 rocks using k-means algorithm → 12 spectra
  • SOIL: 48 soil types → clustering in 12 soils using k-means algorithm → 12 spectra
  • Atmospheric profiles (selection of 3: TRO, MLW, SAW)

• Aerosol
  • Type: desert and continental
  • Optical thickness: 0.2, 0.5, 1, 3.0 (desert only)
  • Over 4 surface types (vege_av, snow_av, rock_av, soil_av) and 1 atmospheric profile (MLW)

  total of 176 sim * geometry
Vegetation spectra

Snow spectra
K-means clustering for rocks and soils

The clustering has been done according to the SW unfiltering factors obtained by using RTMOM simulations.
## Aerosol properties from OPAC

<table>
<thead>
<tr>
<th>Layer Number</th>
<th>Layer Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Aerosol layer</td>
</tr>
<tr>
<td>2</td>
<td>Mineral transported layer</td>
</tr>
<tr>
<td>3</td>
<td>Free troposphere layer</td>
</tr>
<tr>
<td>4</td>
<td>Stratosphere layer</td>
</tr>
</tbody>
</table>

OPAC software is used to build the extinction coefficients, phase functions, single scattering albedo and vertical profile of aerosols considered in the simulations. It is necessary to compute the moments of the Legendre Polynomials from OPAC phase function to use the built aerosol properties of the mixed species in LibRadtran (i.e., desert, continental, maritime...)
Clear sky ocean simulations

- Cox and Munk model at 4 wind speed (1, 5, 10, 15 m/s)
- 1 Atmospheric profile enough
- 1 salinity
- 1 pigment concentration
- Aerosol:
  - Type: desert, maritime polluted and maritime clean / maritime tropical
  - Optical thickness: 0.0, 0.1, 0.3, 1, 3.0 (desert only)

total of 52 sims * geometry
Thick cloud simulations

• 2 surface types: ocean and desert
• Cloud phase: ice and water
• Cloud effective radius
  (selection according ISCCP studies, and A. Ipe statistics)
    • Water: 6 12 18 µm
    • Ice: 10, 30, 50 µm (Yang parameterization)
• Cloud optical thickness: 30, 100, 300
• Cloud altitude (considering physical thickness ~ 1 km):
  • Ice: 6km and 12 km
  • Water: 1km and 6km
• Sensibility study about importance of the dependency with ice particle shape
  Total: 72 simulations
Semi-transparent cloud simulations

- 5 surfaces type: ocean, vegetation average, soil, desert, snow
- Cloud phase: ice and water
- Cloud effective radius
  - Water: 6, 12, 18 µm
  - Ice: 10, 30, 50 µm (Yang parameterization)
- Cloud optical thickness: 0.3, 1, 3, 10
- Cloud altitude:
  - Ice: 6km and 12 km
  - Water: 1km and 6km

Total: 240 simulations
Multilayer clouds (proposal)

- 2 surface types: Ocean and desert
- Only ice cloud over water cloud
- Cloud effective radius
  - Water: 8 µm (Mie)
  - Ice: 10, 30, 50 µm (Yang parameterization)
- Cloud optical thickness of ice layer: 0.3, 1, 3, 10
- Cloud optical thickness of water layer: 10 30 (2surf) 100 (1 surf)
- Cloud altitude:
  - Ice: 12 km
  - Water: 1 km

Total: 60 simulations
Clear sky LW simulations

Atmospheric profiles → selection of 5: TRO, MLS, MLW, SAS, SAW (Anderson et al, 1986)

<table>
<thead>
<tr>
<th>Surface description</th>
<th>Standard atmosphere model</th>
<th>Surface Temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Desert/Land</td>
<td>MLS, MLW</td>
<td>$T_{\text{std}}$, $T_{\text{std}+15}$, $T_{\text{std}+30}$</td>
</tr>
<tr>
<td>Vegetation</td>
<td>TRO, MLS, MLW, SAS, SAW</td>
<td>$T_{\text{std}}$, $T_{\text{std}+5}$, $T_{\text{std}+10}$</td>
</tr>
<tr>
<td>Snow</td>
<td>SAS, SAW</td>
<td>$T_{\text{std}}$, $T_{\text{std}-5}$, $T_{\text{std}-10}$</td>
</tr>
<tr>
<td>Ocean</td>
<td>TRO, MLS, MLW</td>
<td>$T_{\text{std}}$, $T_{\text{std}-3}$, $T_{\text{std}+3}$</td>
</tr>
</tbody>
</table>

Water Vapor Content scaled to 0.6 0.8 1.0 1.2 1.4 from the profiles (according to NVAP data)

Emissivity from ASTER spectral library: $1 - \rho$ + extrapolation

Aerosols optical thickness: desert, 0 0.3 1

Total of 540 simulations for LW clear sky
Cloudy sky LW – Thin clouds

Temperature profiles and surface temperature

<table>
<thead>
<tr>
<th>Surface description</th>
<th>Standard atmosphere model</th>
<th>Surface Temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Desert/Land</td>
<td>MLS, MLW</td>
<td>$T_{std}$, $T_{std} + 15$</td>
</tr>
<tr>
<td>Vegetation</td>
<td>TRO, MLS, MLW, SAS, SAW</td>
<td>$T_{std}$, $T_{std} + 5$</td>
</tr>
<tr>
<td>Snow</td>
<td>SAS, SAW</td>
<td>$T_{std}$, $T_{std} - 5$</td>
</tr>
<tr>
<td>Ocean</td>
<td>TRO, MLS, MLW</td>
<td>$T_{std}$</td>
</tr>
</tbody>
</table>

Water Vapor Content scaled to 0.7 1.0 1.3 from the profiles (according to NVAP data)
Thin: Optical thickness < 3 [0.5 1]
Cloudy sky LW – Thin clouds (cont)

- Cloud altitude (low, medium, high) (according to WMO)
  - High: Base over 6 km [8 10 12] (ice clouds)
  - Medium: Base between 2 km and 6 km [4 6] (water)
  - Low: Base below 2 km [0.5 1 2] (water clouds)
- Emissivity (as for clear sky LW but only important for thin clouds)
- Cloud droplet effective radius
  - Water: 6, 12, 18 µm
  - Ice: 10, 30, 50 µm (yang parameterization)

3024 simulations
Cloudy sky LW – Moderate clouds

Temperature profiles and surface temperature

<table>
<thead>
<tr>
<th>Surface description</th>
<th>Standard atmosphere model</th>
<th>Surface Temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Desert/Land</td>
<td>MLS, MLW</td>
<td>$T_{\text{std}}$</td>
</tr>
<tr>
<td>Vegetation</td>
<td>TRO, MLS, MLW, SAS, SAW</td>
<td>$T_{\text{std}}$</td>
</tr>
<tr>
<td>Snow</td>
<td>SAS, SAW</td>
<td>$T_{\text{std}}$</td>
</tr>
<tr>
<td>Ocean</td>
<td>TRO, MLS, MLW</td>
<td>$T_{\text{std}}$</td>
</tr>
</tbody>
</table>

Water Vapor Content scaled to 0.7 1.0 1.3 from the profiles (according to NVAP data)
Moderate: $3 \leq \text{Optical thickness} \leq 20 \ [3 \ 6 \ 10]$
Cloudy sky LW – Moderate clouds (cont)

- Cloud altitude (low, medium, high) (according to WMO)
  - High: Base over 6 km [8 10 12] (ice clouds)
  - Medium: Base between 2 km and 6 km [4 6] (water)
  - Low: Base below 2 km [0.5 1 2] (water clouds)

- Emissivity (as for clear sky LW)

- Cloud droplet effective radius
  - Water: 6, 12, 18 µm
  - Ice: 10, 30, 50 µm (Baum parameterization)

4320 simulations
Cloudy sky LW – Thick clouds

• 5 profiles

• Water Vapor Content scaled to 0.7 1.0 1.3 from the profiles (according to NVAP data)

• Thick: Optical thickness > 20 [20 50 100]

• Cloud altitude (low, medium, high) (according to WMO)
  • High: Base over 6 km [8 10 12] (ice clouds)
  • Medium: Base between 2 km and 6 km [4 6] (water)
  • Low: Base below 2 km [0.5 1 2] (water clouds)

• Emissivity (as for clear sky LW but only important for thin clouds)

• Cloud droplet effective radius/diameter
  • Water: 6, 12, 18 μm
  • Ice: 10, 30, 90 μm (yang parameterization)

1080 simulations
Overlapping clouds

- Atmospheric profiles → selection of 5: TRO, MLS, MLW, SAS, SAW
- Surface Temperature (from the selected 5 std profiles) (5)
- Water Vapor Content scaled to 0.7 1.0 1.3 from the profiles (according to NVAP data) (3)
  - Top layer: ice cloud
    - Ice: 10, 30, 50 µm (Yang parameterization) (3)
  - Thin: Optical thickness < 3 [0.5 1] (2)
  - Bottom layer: water cloud
    - Water: 2, 8, 16 µm (3)
  - Moderate: 3 <= Optical thickness <= 20 [10] (1)
  - Thick: Optical thickness > 20 [50] (1)
- Cloud altitude (low, medium, high) (according to WMO)
  - Top > Ice: 8 10 12
  - Bottom > Water: 2 4 6 (6)
- Emissivity = 0.98

1620 simulations
Convolution of the database radiances with the BBR spectral response

As there is no longwave filter on the BBR, the longwave radiances are obtained from the total and the shortwave ones:

\[ L_{LW} = L_{tot} - A \cdot L_{SW} \]
\[ \phi_{LW}(\lambda) = \phi_{tot}(\lambda) - A \cdot \phi_{SW}(\lambda) \]

\[ A = \frac{\int L_{5800K}(\lambda) \phi_{tot}(\lambda) \, d\lambda}{\int L_{5800K}(\lambda) \phi_{SW}(\lambda) \, d\lambda} \]

Database radiances are convolved with the spectral responses for the BBR, the filters used are:

- No Filter: constant value of 1 at all wavelengths: theoretical unfiltered radiances
- BBR Total Spectral Response
- synthetic BBR LW Spectral Response → SW DB: thermal contamination  
  LW DB: filtered radiances
- SW BBR Spectral Response → SW DB: filtered radiances  
  LW DB: solar contamination

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Convolution of the database radiances with the BBR spectral response

\[
\begin{align*}
\text{sits}_\text{sw}_\text{convol}_\text{SZA}_\text{VZA}_\text{RAA}.\text{txt} & \quad \{ \begin{array}{l} 
612 \text{ different scenes} \\
3076 \text{ files} \\
(18 \text{VZA, 19 RAA, and 9 SZA}) 
\end{array} 
\} \\
\text{sits}_\text{lw}_\text{convol}_\text{VZA}.\text{txt} & \quad \{ \begin{array}{l} 
12096 \text{ different scenes} \\
18 \text{ VZA} 
\end{array} 
\} \\
\text{sits}_\text{sw}_\text{convol}_\text{SZA}_\text{flux}.\text{txt} \\
\text{sits}_\text{sw}_\text{convol}_\text{SZA}_\text{influx}.\text{txt} \\
\text{sits}_\text{lw}_\text{convol}_\text{flux}.\text{txt}
\end{align*}
\]
Results.
Solar Contamination in the LW channel

Sunglint angle < 10° + 1 m/s wind speed

Full description of the method and results in “ATBD”

\[ L_{lw, sol} = a \cdot L_{sw, sol} \]

Higher errors:
sunglint situations over flat ocean surface (low wind speed)
For sunglint cases the error estimated is about 0.5 Wm−2sr−1 for a typical ocean clear sky LW radiance of 80 Wm−2sr−1 (thus ~ 0.6 % error)

RMS error is 0.039 Wm−2sr−1
typical signal in the LW channel (~60 Wm−2sr−1)
Results.
Thermal contamination in the SW channel

Thermal contamination in SW channel VZA=55°

Full description of the method and results in “ATBD”
Results.
Thermal contamination in the SW channel

Scenes with higher temperature (bright desert scenes) + scenes with high content of water vapor in warm atmospheres (tropical and midlatitude summer) show higher errors.

Ice-phase high clouds (placed at 12 km) are also showing higher error than the rest of scenes.

RMS $L_{sw,th}$ is $0.01624 \text{ Wm}^{-2}\text{sr}^{-1}$, (0.016% relative error)
radiometric accuracy of the EarthCARE BBR SW channel ($2.5 \text{ Wm}^{-2}\text{sr}^{-1}$).

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Results.
Stand Alone SW Unfiltering

\[ L_{sol} = b + a \cdot L_{sw,sol} \]

Surface type dependent Hyperbolic fit

\[ \alpha_{sw} = a + b/L_{sw,sol} \]

Coeff. Dependent on SZA, VZA, RAA

SW unfiltering factors for all the geometries [1.17, 1.25]

Full description of the method and results in “ATBD”
Results.
Stand Alone SW Unfiltering

<table>
<thead>
<tr>
<th>Surface type</th>
<th>&lt;RMS&gt;</th>
<th>bias</th>
</tr>
</thead>
<tbody>
<tr>
<td>ocean</td>
<td>0.003528</td>
<td>0.000000</td>
</tr>
<tr>
<td>vege</td>
<td>0.003904</td>
<td>0.000000</td>
</tr>
<tr>
<td>soil</td>
<td>0.004489</td>
<td>0.000000</td>
</tr>
<tr>
<td>rock</td>
<td>0.004770</td>
<td>0.000000</td>
</tr>
<tr>
<td>snow</td>
<td>0.004865</td>
<td>0.000000</td>
</tr>
</tbody>
</table>

RMS < 0.005 W m-2 sr-1
Results.
Stand Alone SW Unfiltering.
Implementation

BBR SW Unfiltering factor for (SZA=33.15°, VZA= 54.97°, RAA=83°)

- Tri-linear interpolation SA ocean
- Tri-linear interpolation SA vege
- Tri-linear interpolation SA soil
- Tri-linear interpolation SA rock
- Tri-linear interpolation SA snow

SW unfiltering factor vs SW solar radiance (Wm\(^{-2}\)sr\(^{-1}\))
Use other databases (SBDART)
Different scene types simulated
As expected the application of the contamination and unfiltering coefficients to the validation database showed a good performance
## Results.

**Stand Alone SW Unfiltering. Validation**

<table>
<thead>
<tr>
<th>surface type</th>
<th>clear/cloudy</th>
<th>$&lt;\text{RMS}&gt;$</th>
<th>$&lt;\text{BIAS}&gt;$</th>
</tr>
</thead>
<tbody>
<tr>
<td>ocean</td>
<td>clear</td>
<td>0.004619</td>
<td>$-0.0016$</td>
</tr>
<tr>
<td>ocean</td>
<td>cloud</td>
<td>0.005092</td>
<td>$-0.0020$</td>
</tr>
<tr>
<td>vege</td>
<td>clear</td>
<td>0.005393</td>
<td>$-0.0007$</td>
</tr>
<tr>
<td>vege</td>
<td>cloud</td>
<td>0.005688</td>
<td>$-0.0034$</td>
</tr>
<tr>
<td>soil</td>
<td>clear</td>
<td>0.008369</td>
<td>$0.0012$</td>
</tr>
<tr>
<td>soil</td>
<td>cloud</td>
<td>0.005912</td>
<td>$-0.0031$</td>
</tr>
<tr>
<td>snow</td>
<td>clear</td>
<td>0.007776</td>
<td>$0.0001$</td>
</tr>
<tr>
<td>snow</td>
<td>cloud</td>
<td>0.006819</td>
<td>$-0.0034$</td>
</tr>
<tr>
<td>rock</td>
<td>clear</td>
<td>0.006857</td>
<td>$-0.0039$</td>
</tr>
<tr>
<td>rock</td>
<td>cloud</td>
<td>0.005547</td>
<td>$-0.0002$</td>
</tr>
</tbody>
</table>

RMS $< 0.009$

W m$^{-2}$ sr$^{-1}$
Results Obtained. Subtask 3.2
Stand-alone LW unfiltering

Surface type independent
Parabolic fit

\[ \alpha_{lw} = a + b \cdot L_{lw,th} + c \cdot L_{lw,th}^2 \]

Coef. Dependent on VZA
RMS error < 0.0003 W/m²/sr
Radiometric accuracy = 1.5 W/m²/sr

unfiltering_coef_lw.txt

Full description of the method and results in “ATBD”
Results Obtained.
Stand-alone LW unfiltering. Validation

RMS error < 0.0008 W/m²/sr
bias negligible

3 times higher than for the study DB

Radiometric accuracy = 1.5 W/m²/sr
Results.

MSI based unfiltering

Separate fit for every surface and clear, water and ice clouds
2 methods: linear and hyperbolic

\[ \alpha_{sw} = a + \frac{b}{L_{sw,\text{sol}}} \]  
\[ \alpha_{sw} = a + b \cdot L_{sw,\text{sol}} \]

Full description of the method and results in “ATBD”
Results.
Stand alone vs MSI based unfiltering

Geometry:
9 Solar Zenith Angles, 0° to 80°, step 10°
18 Viewing Zenith Angles: 0° to 85°, step 5°
19 Relative Azimuth Angles: 0° to 180°, step 10°.

<table>
<thead>
<tr>
<th>Surface</th>
<th>&lt;RMS&gt; stand-alone</th>
<th>MSI type</th>
<th>&lt;RMS&gt; MSI hyperbolic</th>
<th>&lt;RMS&gt; MSI linear</th>
</tr>
</thead>
<tbody>
<tr>
<td>ocean</td>
<td>0.003569</td>
<td>clear</td>
<td>0.003297</td>
<td>0.003848</td>
</tr>
<tr>
<td></td>
<td></td>
<td>wat</td>
<td>0.003056</td>
<td>0.003973</td>
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<tr>
<td></td>
<td></td>
<td>ice</td>
<td>0.003381</td>
<td>0.004216</td>
</tr>
<tr>
<td>vege</td>
<td>0.003831</td>
<td>clear</td>
<td>0.002426</td>
<td>0.002592</td>
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<tr>
<td></td>
<td></td>
<td>wat</td>
<td>0.002743</td>
<td>0.002912</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ice</td>
<td>0.003731</td>
<td>0.003989</td>
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<tr>
<td>soil</td>
<td>0.004346</td>
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<td>0.004953</td>
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<tr>
<td></td>
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<td>wat</td>
<td>0.002793</td>
<td>0.003122</td>
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<td></td>
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<td>ice</td>
<td>0.003859</td>
<td>0.004275</td>
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<tr>
<td>rock</td>
<td>0.004556</td>
<td>clear</td>
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<td>0.005609</td>
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<tr>
<td></td>
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<td>wat</td>
<td>0.002662</td>
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<tr>
<td></td>
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<td>ice</td>
<td>0.003191</td>
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<tr>
<td>snow</td>
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<td>clear</td>
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</tr>
<tr>
<td></td>
<td></td>
<td>wat</td>
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<td></td>
<td></td>
<td>ice</td>
<td>0.004072</td>
<td>0.003896</td>
</tr>
</tbody>
</table>
Results Obtained.

MSI based unfiltering. Implementation

BBR SW Unfiltering factor for (SZA=33.15°, VZA= 54.97°, RAA=83°)

- Tri-linear interpolation clear ocean
- Tri-linear interpolation clear vege
- Tri-linear interpolation clear soil
- Tri-linear interpolation clear rock
- Tri-linear interpolation clear snow

BBR SW Unfiltering factor for (SZA=33.15°, VZA= 54.97°, RAA=83°)

- Tri-linear interpolation wat ocean
- Tri-linear interpolation wat vege
- Tri-linear interpolation wat soil
- Tri-linear interpolation wat rock
- Tri-linear interpolation wat snow

BBR SW Unfiltering factor for (SZA=33.15°, VZA= 54.97°, RAA=83°)

- Tri-linear interpolation ice ocean
- Tri-linear interpolation ice vege
- Tri-linear interpolation ice soil
- Tri-linear interpolation ice rock
- Tri-linear interpolation ice snow

- 16th Sept, ECN, Paris
## Results.
### MSI based unfiltering. Validation

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\( \text{RMS} < 0.008 \ \text{W m}^{-2} \ \text{sr}^{-1} \)
Handling mixed scenes (SW)

Modeled radiances are first weighted to estimate modeled radiance for the BBR footprint

$$\tilde{L}_{sw,\text{sol}} = \sum_{i}^{n} \omega_{i} \tilde{L}_{sw,\text{sol}}^{i}$$

then, the individual radiances originated from the different scenes $i$ present in the footprint are then estimated correcting the individual model by the ratio between the modeled footprint radiance and the BBR measurement

$$L_{sw,\text{sol}}^{i} = \tilde{L}_{sw}^{i} \cdot \frac{L_{sw,\text{sol}}}{\tilde{L}_{sw,\text{sol}}}$$

$$\alpha = \frac{\sum_{i}^{n} w_{i} \alpha_{i} L_{sw,\text{sol}}^{i}}{\sum w_{i} L_{sw,\text{sol}}^{i}}$$
Ecoclimap-2 database
(Masson et al, 2003)

Database of ecosystem (252) and ecosystem properties at 1km res (250 m for Europe)

Ecosystem is a combination of:
City, water, vegetation (C3, C4, irr, Conifers, evergreen veg, grass), bare, rocks and snow

Built using land cover maps:
• GLC 2000 (1 km res)
• Corine over Europe (250 m res)
• Interannual variability from SPOT/VEGETATION
  • LAI
  • NDVI
• Surface parameters:
  • MODIS
  • SAF Land dataset
## Results.

### Error analysis. Contamination error

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<tr>
<th>Type of scene</th>
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<th>$&lt;RMSL_{sw,th}&gt;$</th>
<th>$&lt;L_{lw,th}&gt;$</th>
<th>$&lt;RMSL_{lw,sol}&gt;$</th>
<th>$&lt;\alpha_{sw}&gt;$</th>
<th>$&lt;\alpha_{lw}&gt;$</th>
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## Results

Error analysis. SA unfiltering error

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<td>0.0044</td>
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Results.
Error analysis. SA unfiltering error.
Mixed footprints

\[ L_{sw, sol}^{mixed} = w \cdot L_{sw, sol}^{clear} + (1 - w) \cdot L_{sw, sol}^{cloudy} \]
\[ L_{sol}^{mixed} = w \cdot L_{sol}^{clear} + (1 - w) \cdot L_{sol}^{cloudy} \]

Mixed footprint unfiltering error estimation

\[ \alpha_T = \frac{L_{sol}^{mixed}}{L_{sw, sol}^{mixed}} \]
\[ \alpha_{SA} = a + \frac{b}{L_{sw, sol}^{mixed}} \]

\( \omega \) is cloud free fraction in the BBR footprint

Mix: clear ocean surf 1 m/s and optically thick cloud \( \tau > 30 \) at 1km

ERB Workshop 13\textsuperscript{th} - 16\textsuperscript{th} Sept, ECN, Paris
## Results.

Error analysis. MSI unfiltering error

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Table 21: MSI unfiltering associated errors
## Results. Error analysis. Case study

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<th>Combined $\epsilon_r$ (%)</th>
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## Contamination + unfiltering

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<td>62.71</td>
<td>0.0465</td>
<td>0.074</td>
<td>1.574</td>
<td>2.5</td>
</tr>
<tr>
<td>semi high ice cloud</td>
<td>57.80</td>
<td>0.0364</td>
<td>0.063</td>
<td>1.575</td>
<td>2.7</td>
</tr>
<tr>
<td>semi low cloud</td>
<td>73.94</td>
<td>0.0414</td>
<td>0.056</td>
<td>1.571</td>
<td>2.1</td>
</tr>
<tr>
<td>thick low cloud</td>
<td>72.31</td>
<td>0.0282</td>
<td>0.039</td>
<td>1.571</td>
<td>2.1</td>
</tr>
<tr>
<td>clear dessert</td>
<td>80.84</td>
<td>0.0678</td>
<td>0.083</td>
<td>1.572</td>
<td>1.9</td>
</tr>
<tr>
<td>clear ocean</td>
<td>79.06</td>
<td>0.0608</td>
<td>0.076</td>
<td>1.571</td>
<td>1.9</td>
</tr>
<tr>
<td>clear snow</td>
<td>67.18</td>
<td>0.0382</td>
<td>0.056</td>
<td>1.572</td>
<td>2.3</td>
</tr>
<tr>
<td>clear vege</td>
<td>76.66</td>
<td>0.0377</td>
<td>0.049</td>
<td>1.571</td>
<td>2.0</td>
</tr>
</tbody>
</table>
Conclusions and recommendations

Spectral response: Any change in the spectral response will consequently lead to a change in the contamination and unfiltering coefficients.

Synthetic longwave channel: If needed for further studies, the synthetic longwave channel should be defined in the same way as in this study.

Radiative transfer code: For the study it was selected Libradtran, among other reasons because of its fine spectral resolution and flexibility, that allows the user to specify the properties of the atmosphere, including Rayleigh scattering, molecular absorption, aerosols, water and ice clouds and surface albedo. A modification in the code for ocean scenes was introduced for optimization reasons.

Parallax problem: Given the higher complexity and the difficulty to address the parallax, it is recommended to use the stand-alone methodology rather than the MSI based, at least until the MSI cloud mask and cloud phase products are available and/or validated.

MSI unfiltering method: According to the results obtained, it is recommended to use the hyperbolic unfiltering coefficients rather than the linear ones.

Geotype Database: available under request
It will be used to improve the GERB LW ADMs.
Conclusions and recommendations

For the fore and aft views, the SW unfiltering factor determined with the standalone algorithm could be corrected using the ratio of MSI-based and standalone unfiltering factors for the corresponding nadir view. This correction will allow to have homogeneous unfiltering error for the views of the BBR instrument.

**In orbit studies:**

**Night time measurements:**
Will provide a better estimation of the thermal contamination in the SW channel and of the longwave component of the SR unmeasured (longest wavelengths)

**Longwave SR beyond 50 microns:** relation for thick high clouds between L narrowband and L BBR. Iteration of the LW response can be made to improve linearity and increase knowledge of SR at longest wavelengths.

**SW degradation:** long-term monitoring of the albedo of deep convective clouds has shown to enable a check on the stability around the 1% level over the lifetime of the mission, but it doesn’t specifically check for the degradation at short wavelengths. An intercomparison between measured clear ocean radiances and an ocean colour instrument is also recommended.