Unfiltering Study for the EarthCARE BBR

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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.

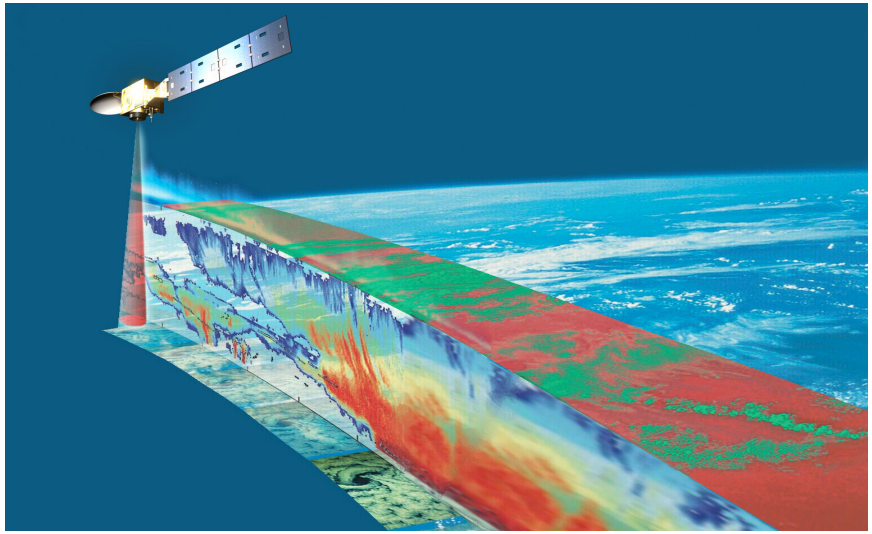
Space segment:

- 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



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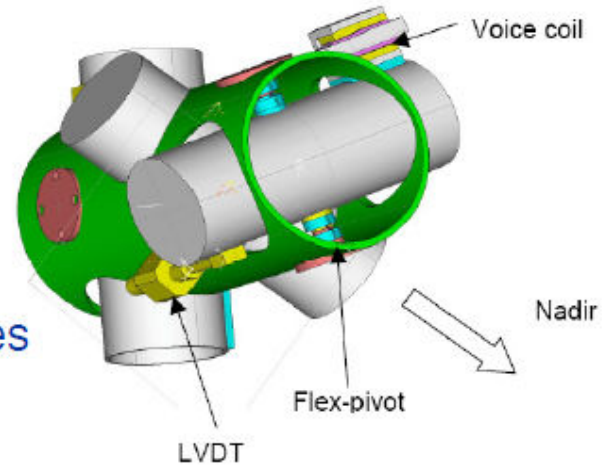
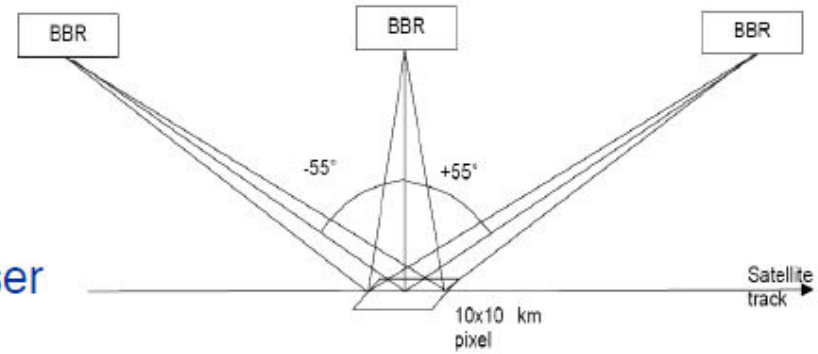
BBR Configuration

- Along track sampling: 3 telescopes
- Telescope zenith angle: $\theta = 0^o, \pm 55^o$
- Pixel : - 10 km x 10 km for all three telescopes
  - 0.1 pixel co-registration
- Two spectral channels:
  - SW: 0.2 - 4.0 μm
  - LW: 4.0 - 50 μm
- 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**

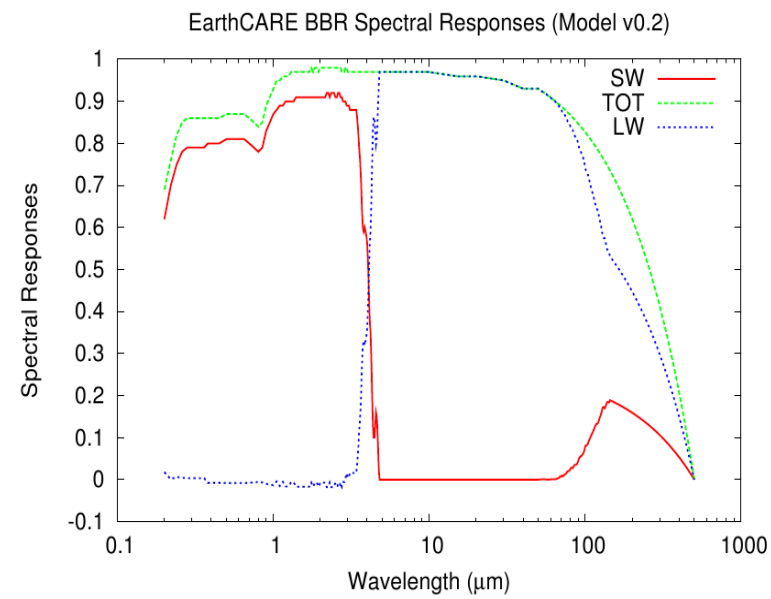
Study objectives

Provide the unfiltering algorithms & coefficients for the BBR

$$\alpha = \frac{L_{unfil}}{L_{fil}} = \frac{\int L(\lambda)\, d\lambda}{\int L(\lambda)\phi(\lambda)\, d\lambda}$$

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

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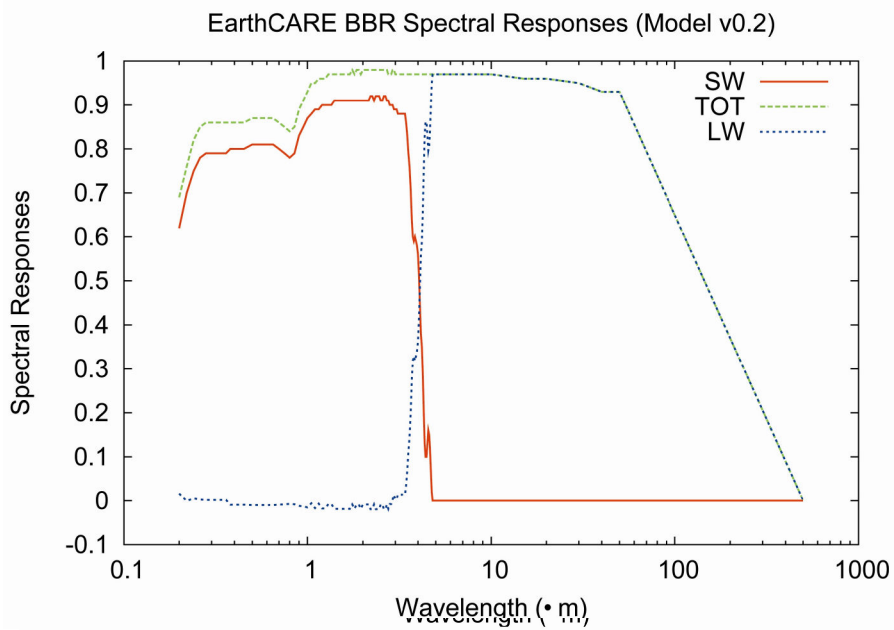
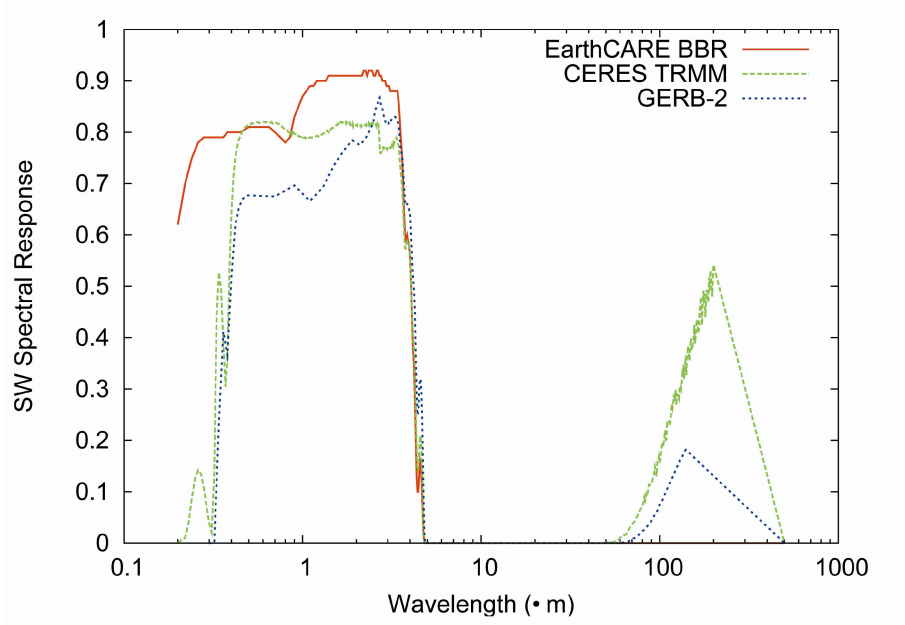
BBR Spectral response

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



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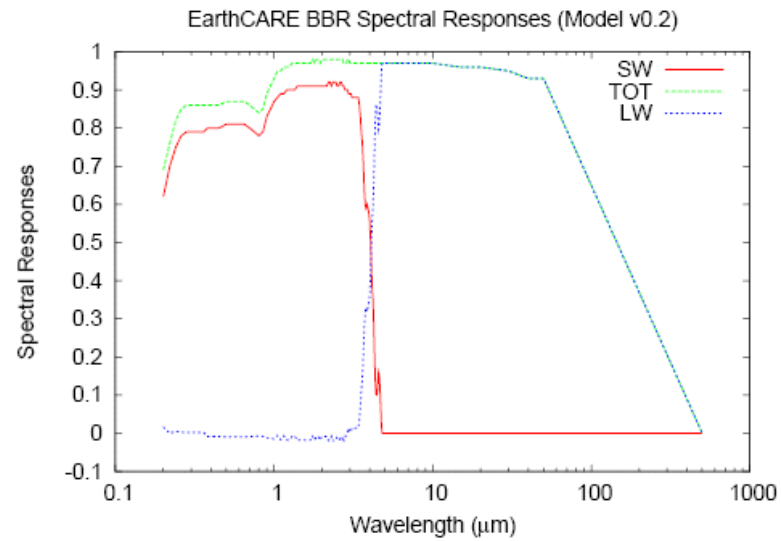
BBR spectral response

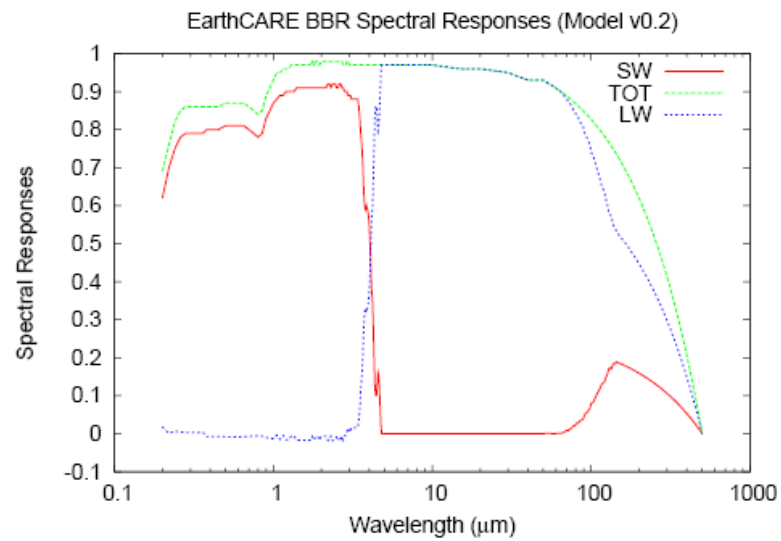
$$\phi_{tot}(\lambda) = \phi_{det}(\lambda) \cdot \phi_{tele}(\lambda)$$

$$\phi_{sw}(\lambda) = \phi_{det}(\lambda) \cdot \phi_{tele}(\lambda) \cdot \phi_{quartz}(\lambda)$$

No data at λ > 50 µm

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





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Unfiltering process

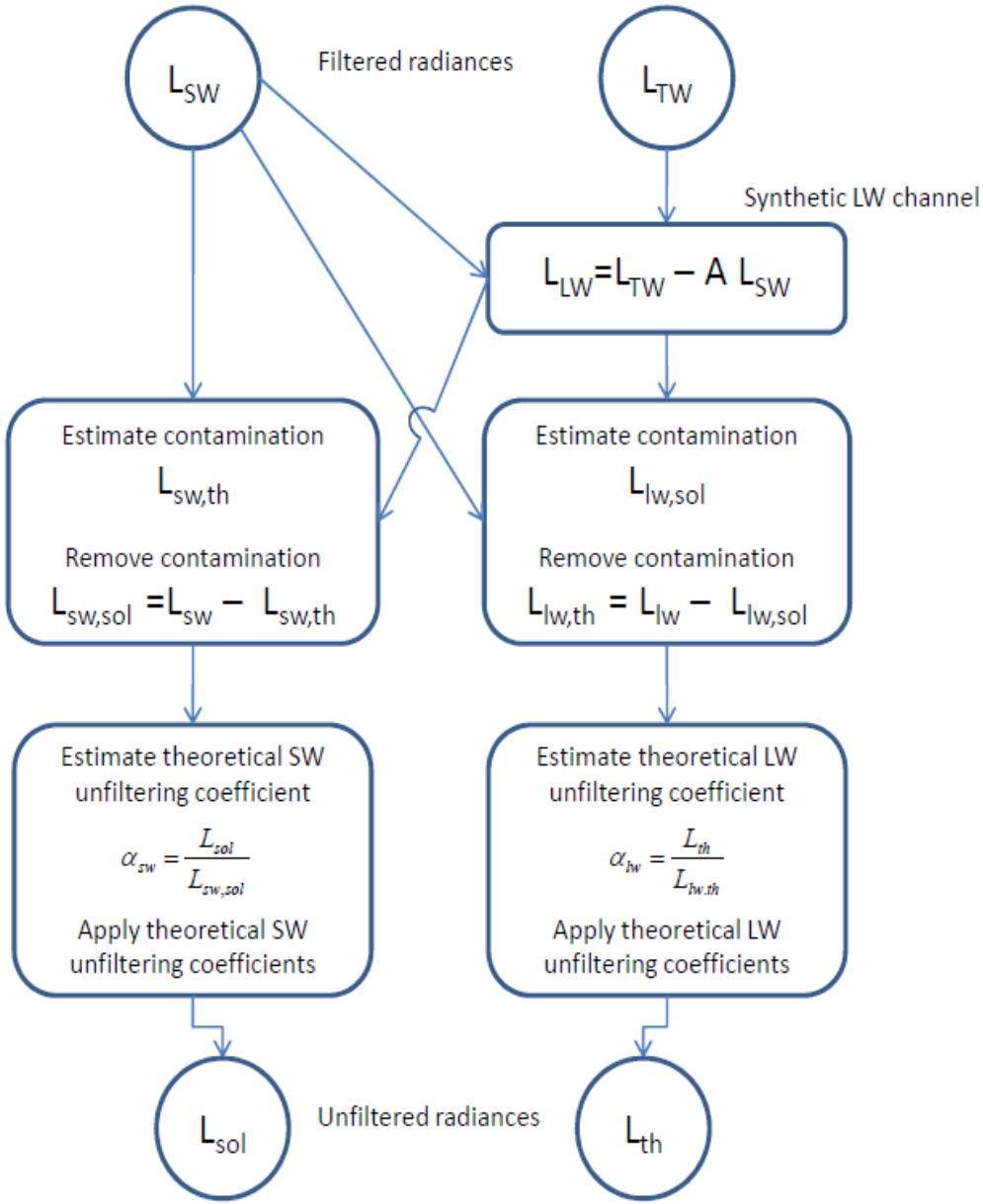
Objective: estimate the reflected solar and emitted thermal BB radiance from the BBR measurements

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



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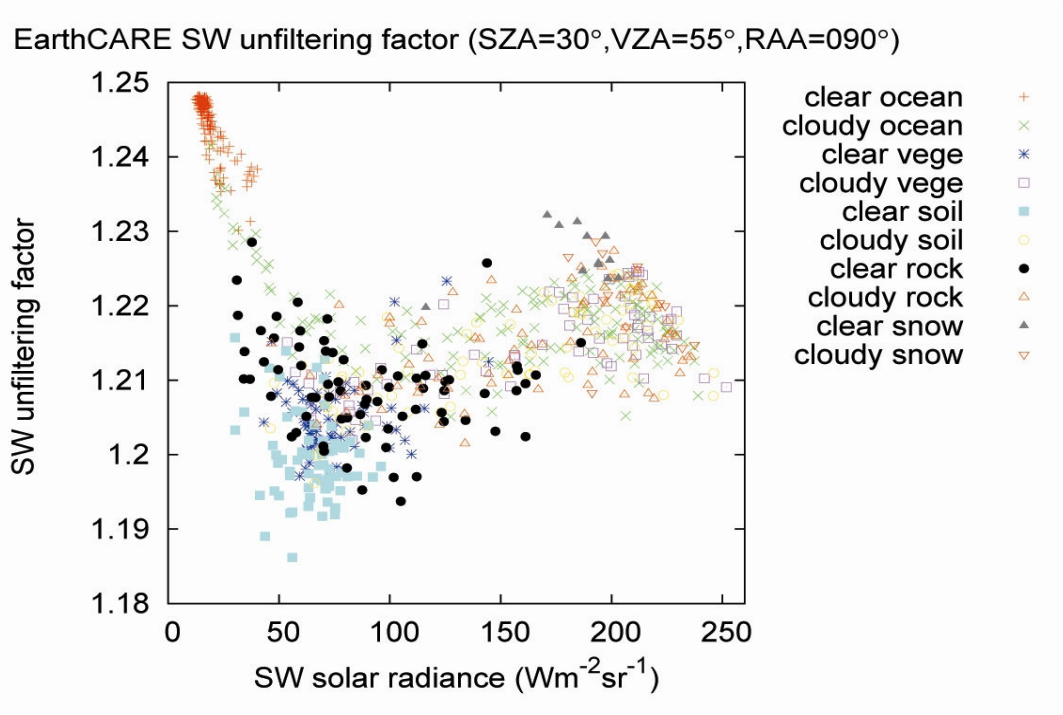
SW unfiltering factor

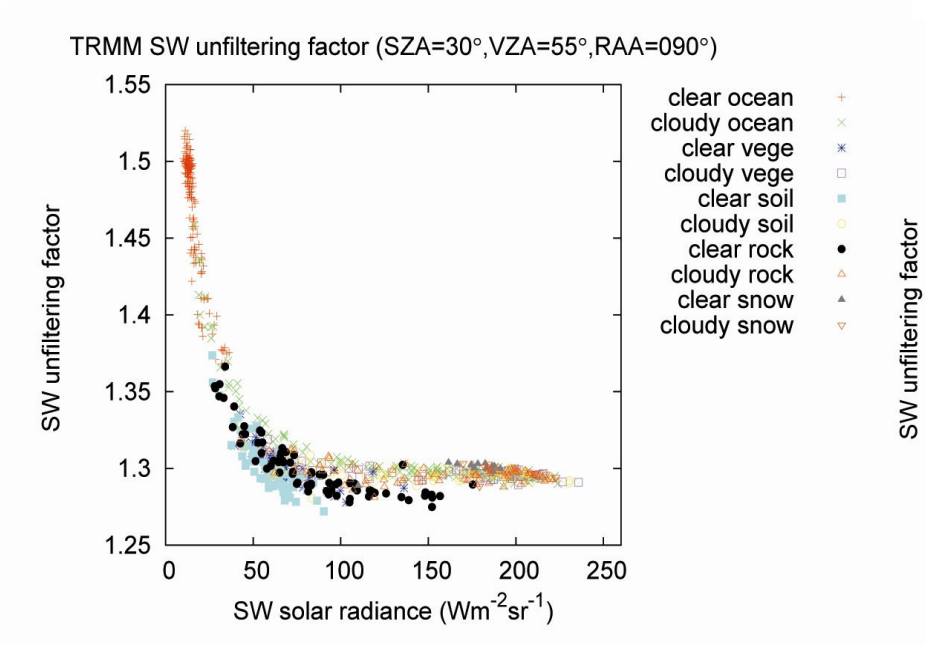
Estimated from RTM with SBDART

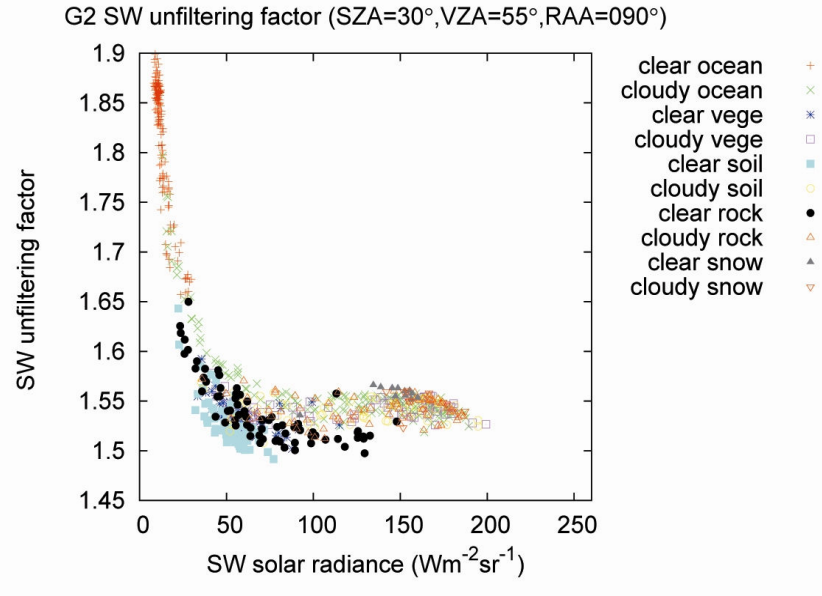
Limited range for the SW unfiltering factor

1.215 +/- 0.03



Excellent response in the blue





LW unfiltering factor

Limited range for the LW unfiltering factor :

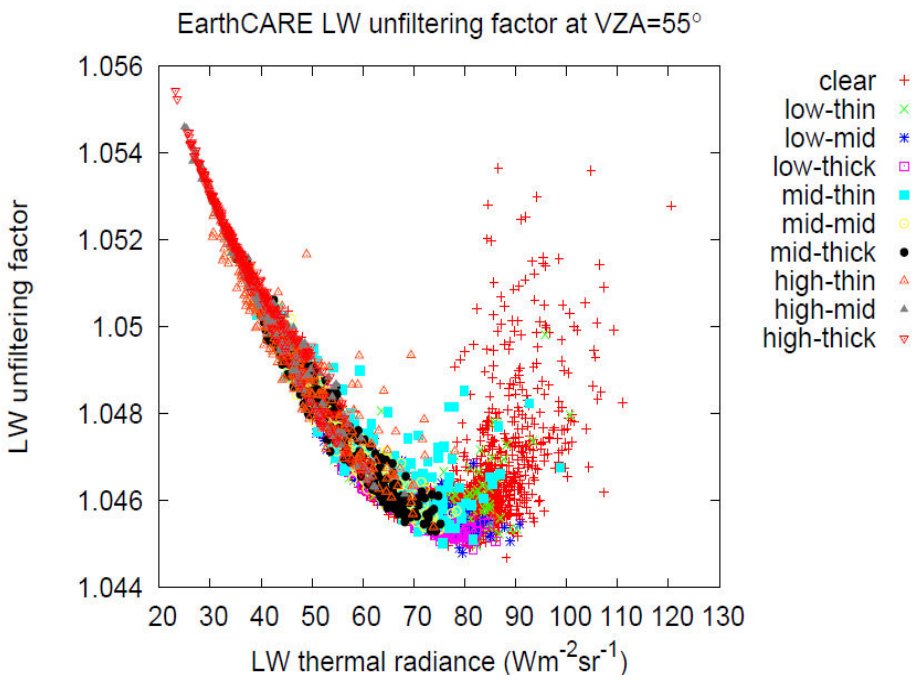
BBR: 1.05 +/- 0.006

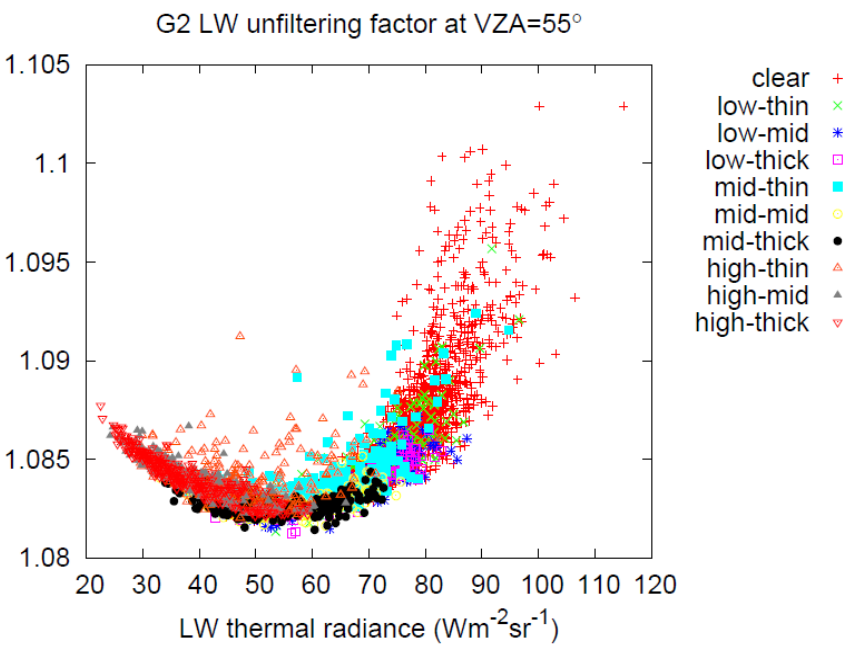
TRMM: 1.16 +/- 0.01

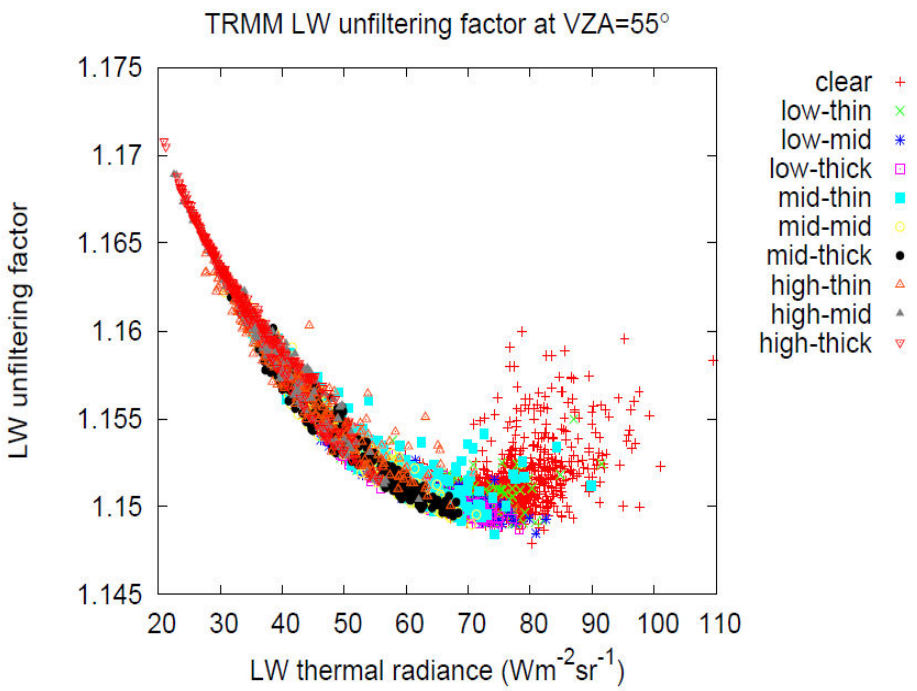
G2: 1.09+/- 0.01

2nd order fit on the LW measurement gives excellent results

No need for MSI information





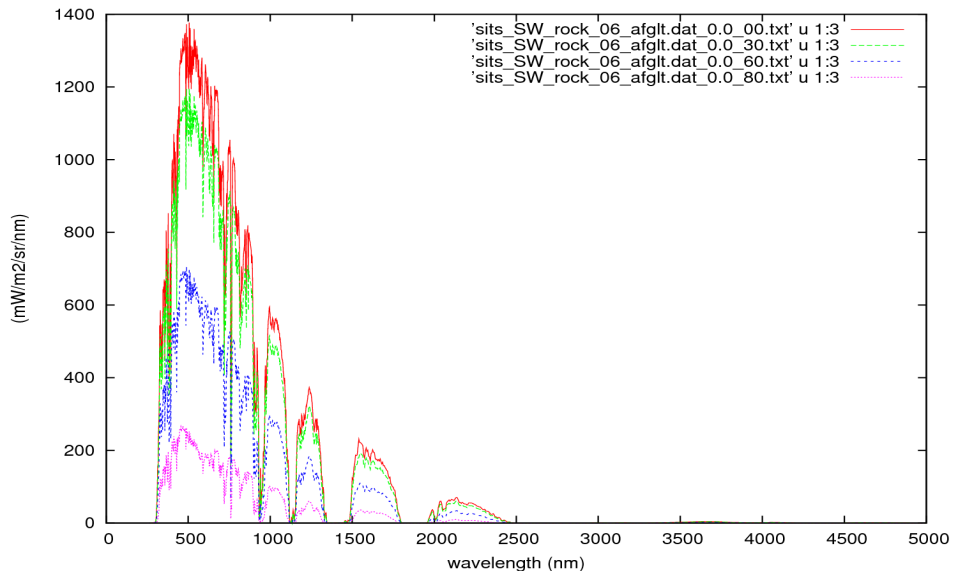


Results Obtained. Geotype database

- 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 λ)
    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 λ) + extended up to 500 μm
    2.5 to 14 μm, step0.05 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°
outputs at
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

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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

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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

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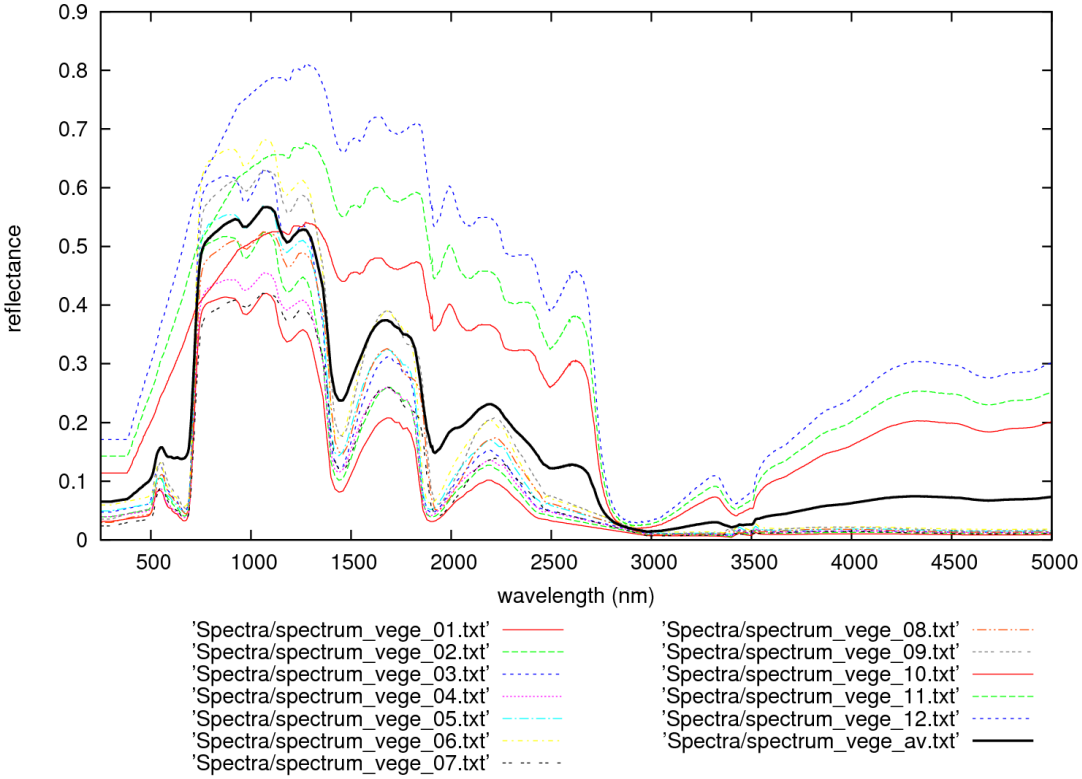
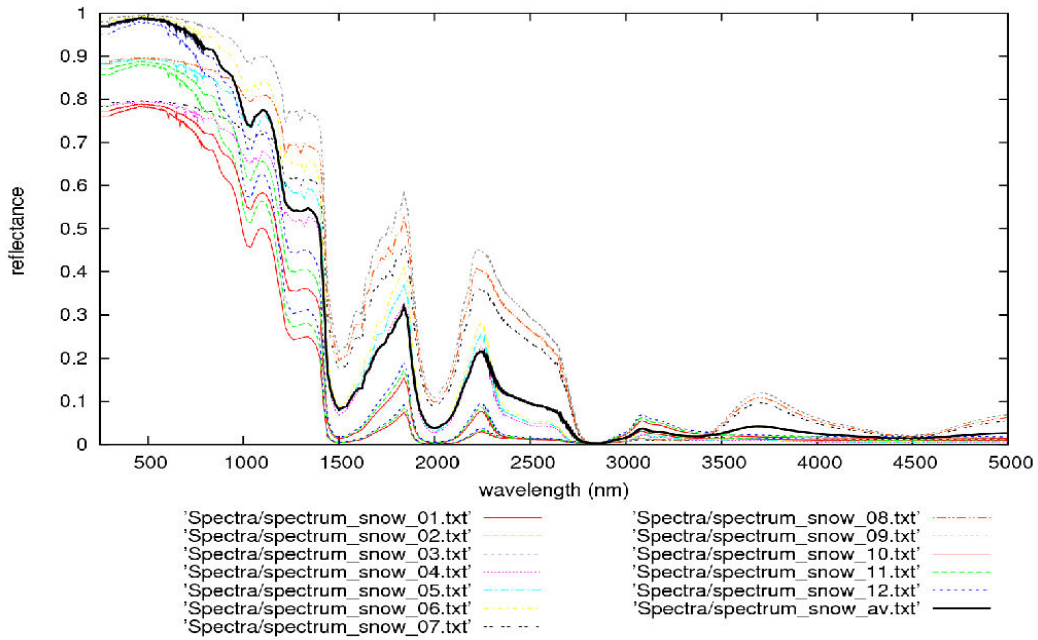
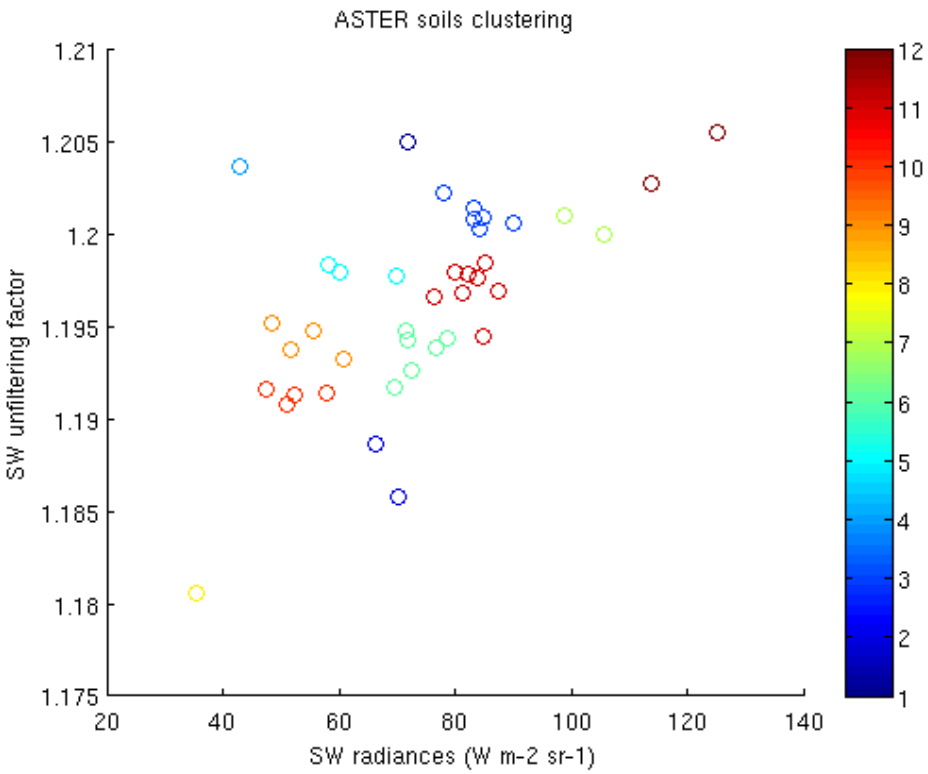


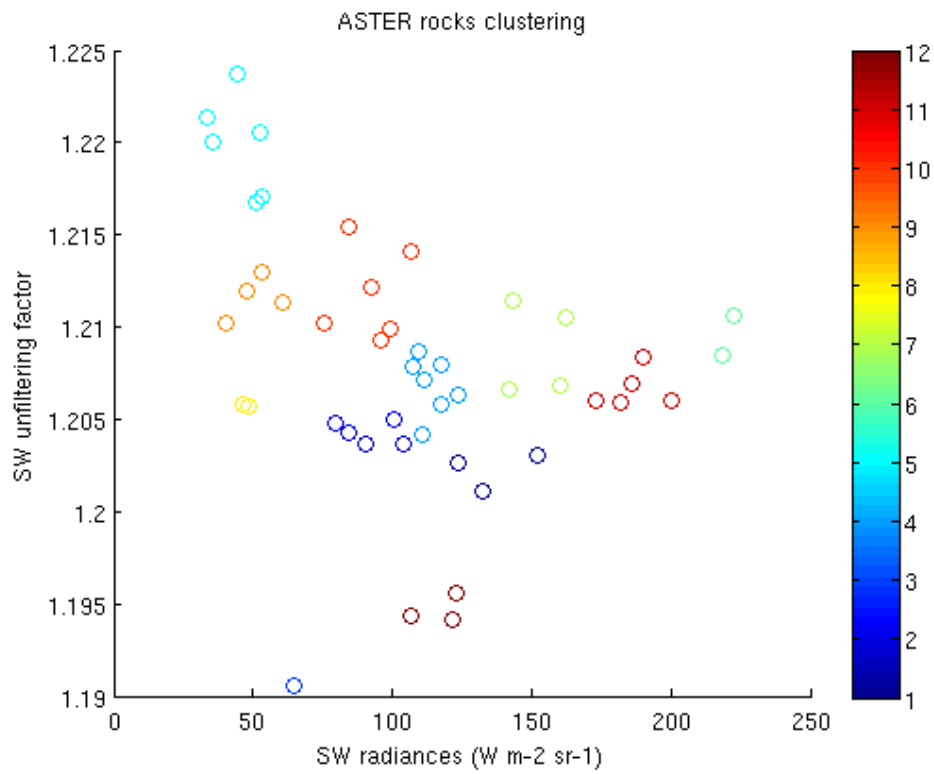
Vegetation spectra



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

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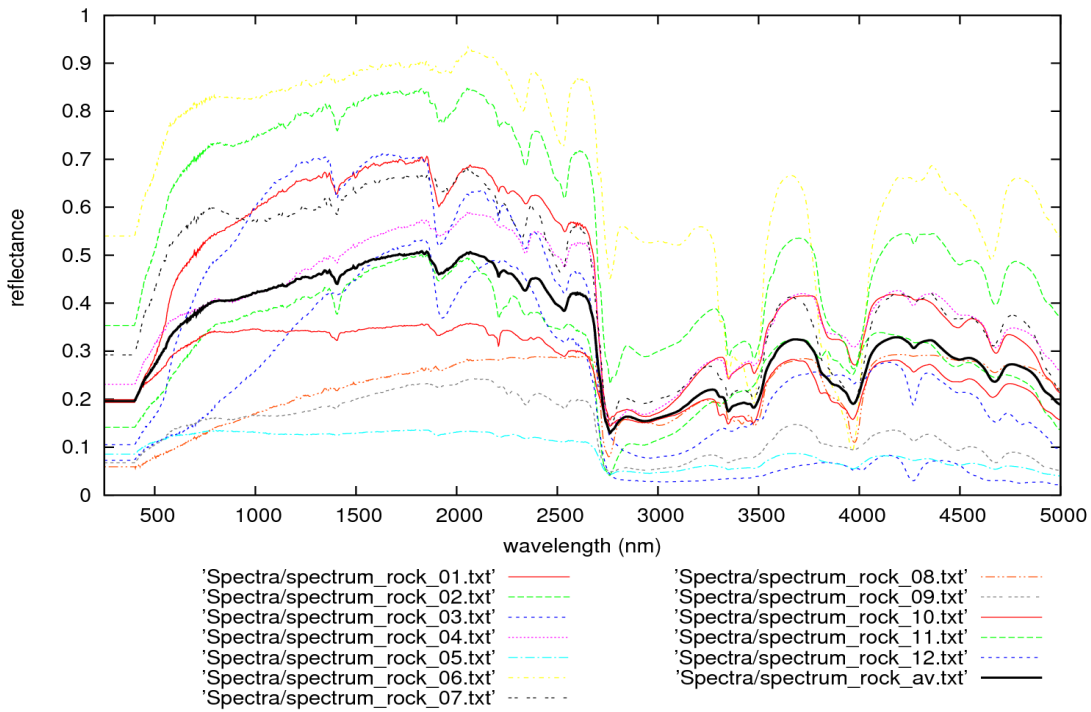
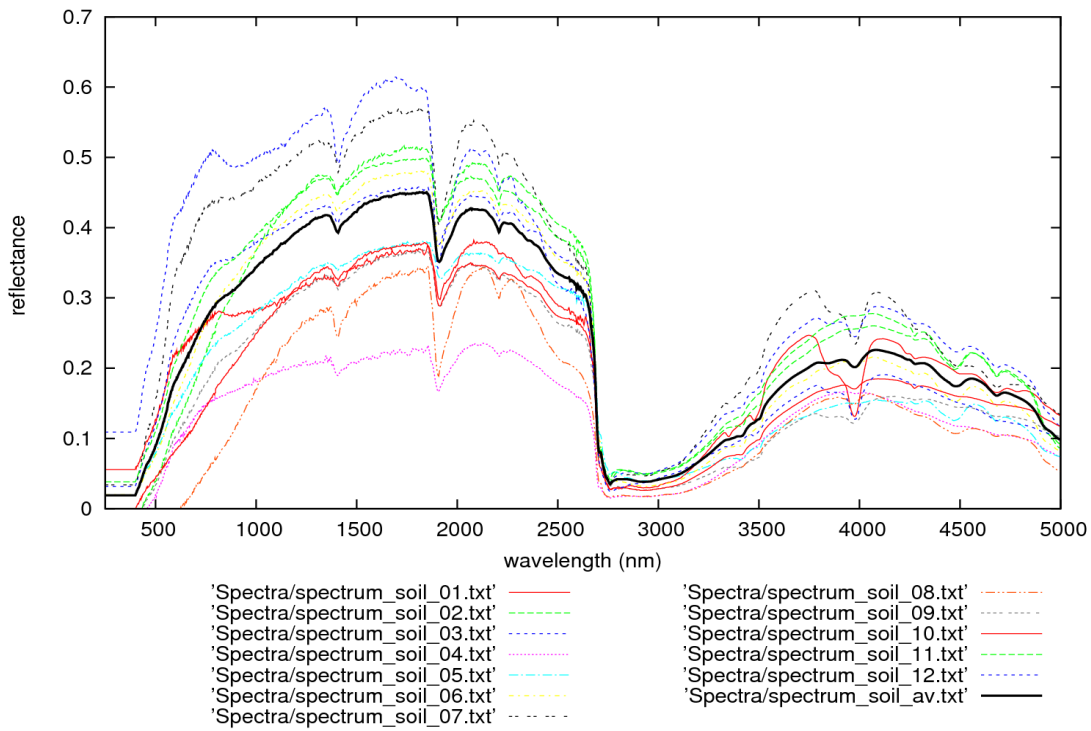


Rock spectra



Soil spectra

Aerosol properties from OPAC

4	Stratosphere layer
3	Free troposphere layer
2	Mineral transported layer
1	Aerosol layer

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...)

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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

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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: 1km

Total : 60 simulations

Clear sky LW simulations

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

Surface description	Standard atmosphere model	Surface Temperature
Desert/Land	MLS, MLW	T_{std}, T_{std}+15, T_{std}+30
Vegetation	TRO, MLS, MLW, SAS, SAW	T_{std}, T_{std} +5, T_{std}+10
Snow	SAS, SAW	T_{std}, T_{std} - 5, T_{std} -10
Ocean	TRO, MLS, MLW	T_{std}, T_{std} -3, T_{std}+3

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- ρ + extrapolation
Aerosols optical thickness: desert , 0 0.3 1
Total of 540 simulations for LW clear sky

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Cloudy sky LW – Thin clouds

Temperature profiles and surface temperature

Surface description	Standard atmosphere model	Surface Temperature
Desert/Land	MLS, MLW	T_{std}, T_{std}+15
Vegetation	TRO, MLS, MLW, SAS, SAW	T_{std}, T_{std} +5
Snow	SAS, SAW	T_{std}, T_{std} - 5
Ocean	TRO, MLS, MLW	T_{std}

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]

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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

Surface description	Standard atmosphere model	Surface Temperature
Desert/Land	MLS, MLW	T_{std}
Vegetation	TRO, MLS, MLW, SAS, SAW	T_{std}
Snow	SAS, SAW	T_{std}
Ocean	TRO, MLS, MLW	T_{std}

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

Moderate: 3 <= Optical thickness <= 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

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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

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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:

$$L_{LW} = L_{tot} - A \cdot L_{SW} \qquad \phi_{LW}(\lambda) = \phi_{tot}(\lambda) - A \cdot \phi_{SW}(\lambda)$$

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

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

`sits_sw_convol_SZA_VZA_RAA.txt`

- 612 different scenes
- 3076 files
- (18 VZA, 19 RAA, and 9 SZA)

`sits_lw_convol_VZA.txt`

- 12096 different scenes
- 18 VZA

`sits_sw_convol_SZA_flux.txt`

`sits_sw_convol_SZA_influx.txt`

`sits_lw_convol_flux.txt`

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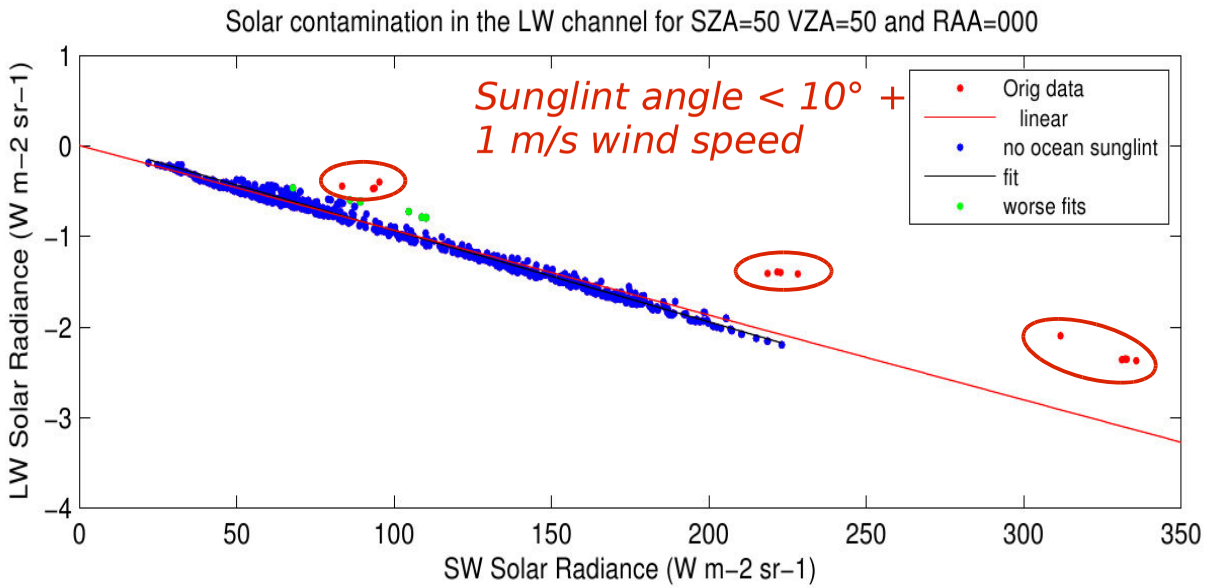
Results.
Solar Contamination in the LW channel

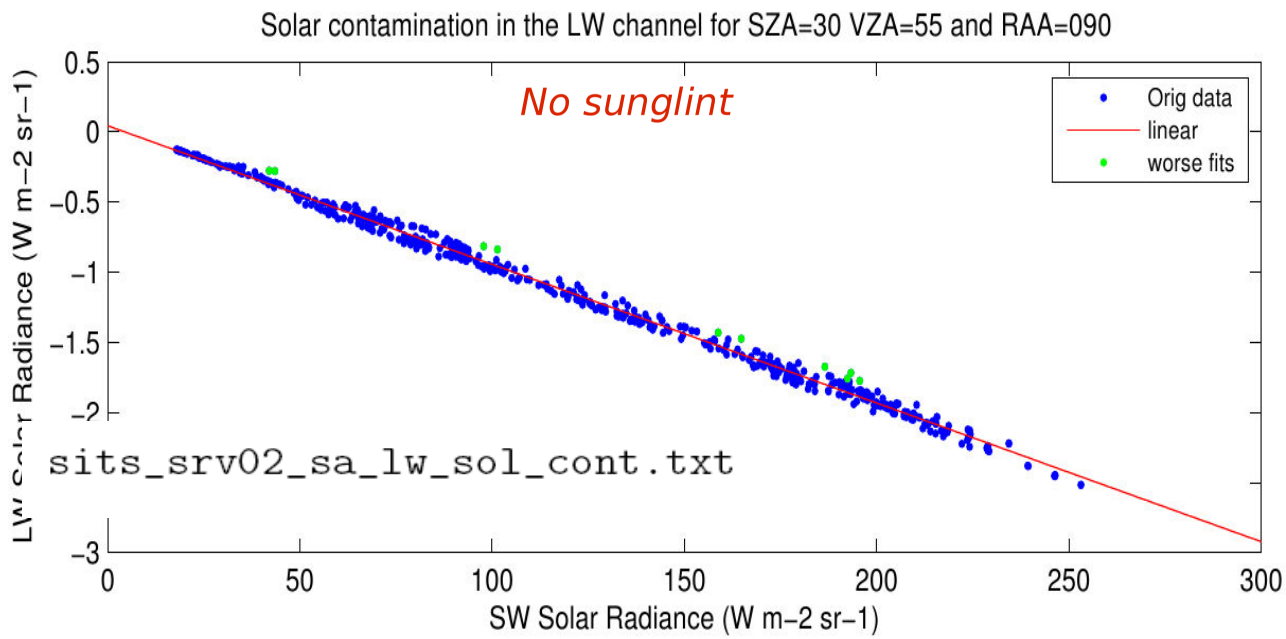


Higher errors:
sunglint situations over flat ocean surface (low wind speed)
For sunglint cases the error estimated is about 0.5 Wm−2sr−1 for a typical ocean clear sky LW radiance of 80 Wm−2sr−1 (thus ~ 0.6 % error)

RMS error is 0.039 Wm−2sr−1 typical signal in the LW channel (~60 Wm−2sr−1)

Full description of the method and results in "ATBD"

$$L_{lw,sol} = a \cdot L_{sw,sol}$$



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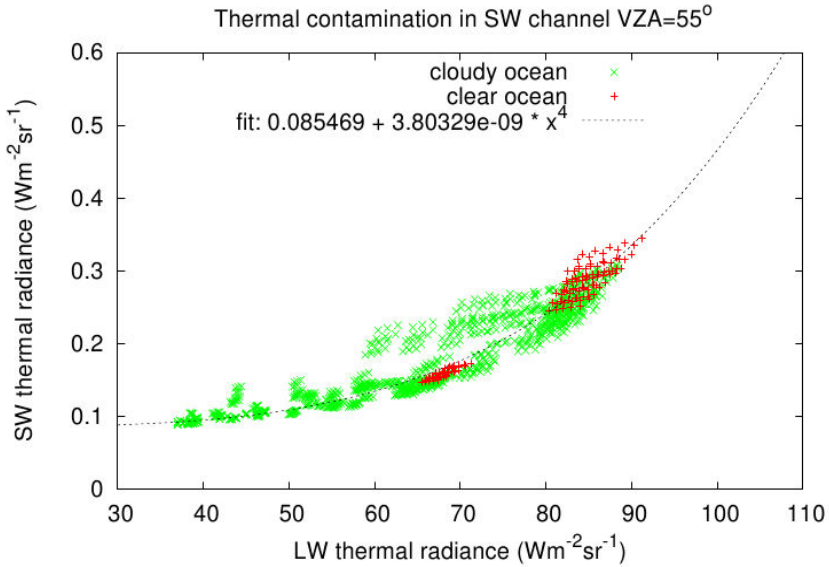
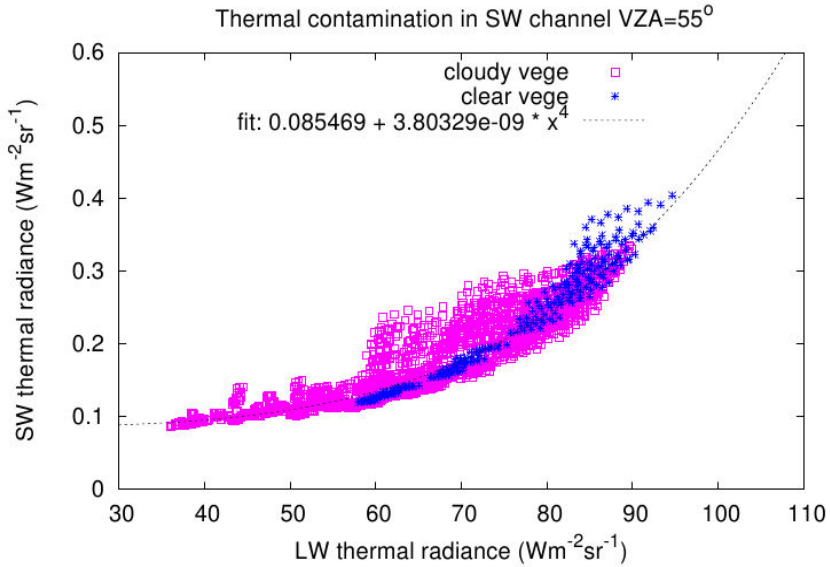
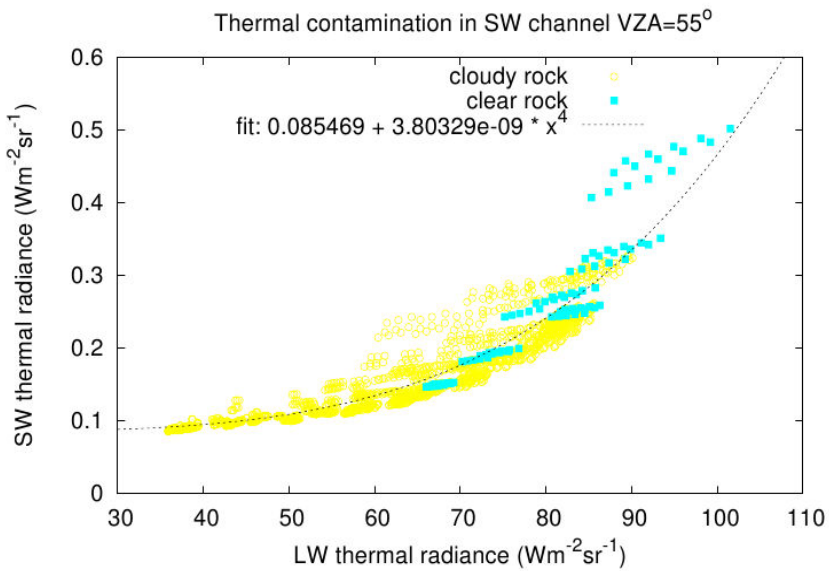
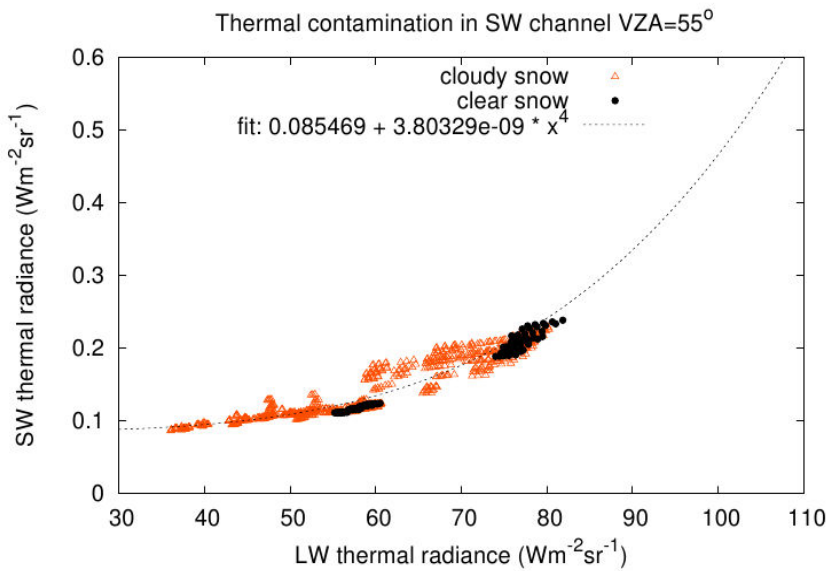
Results.
Thermal contamination in the SW channel





$$L_{sw,th} = a + b \cdot L_{lw,th}^4$$





Full description of the method and results in "ATBD"

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sits_srv02_sa_sw_th_cont.txt

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 sthan the rest of scenes.

RMS Lsw,th is 0.01624 $Wm^{-2}sr^{-1}$, (0.016% relative error)

radiometric accuracy of the EarthCARE BBR SW channel (2.5 $Wm^{-2}sr^{-1}$).

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Results.
Stand Alone SW Unfiltering

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

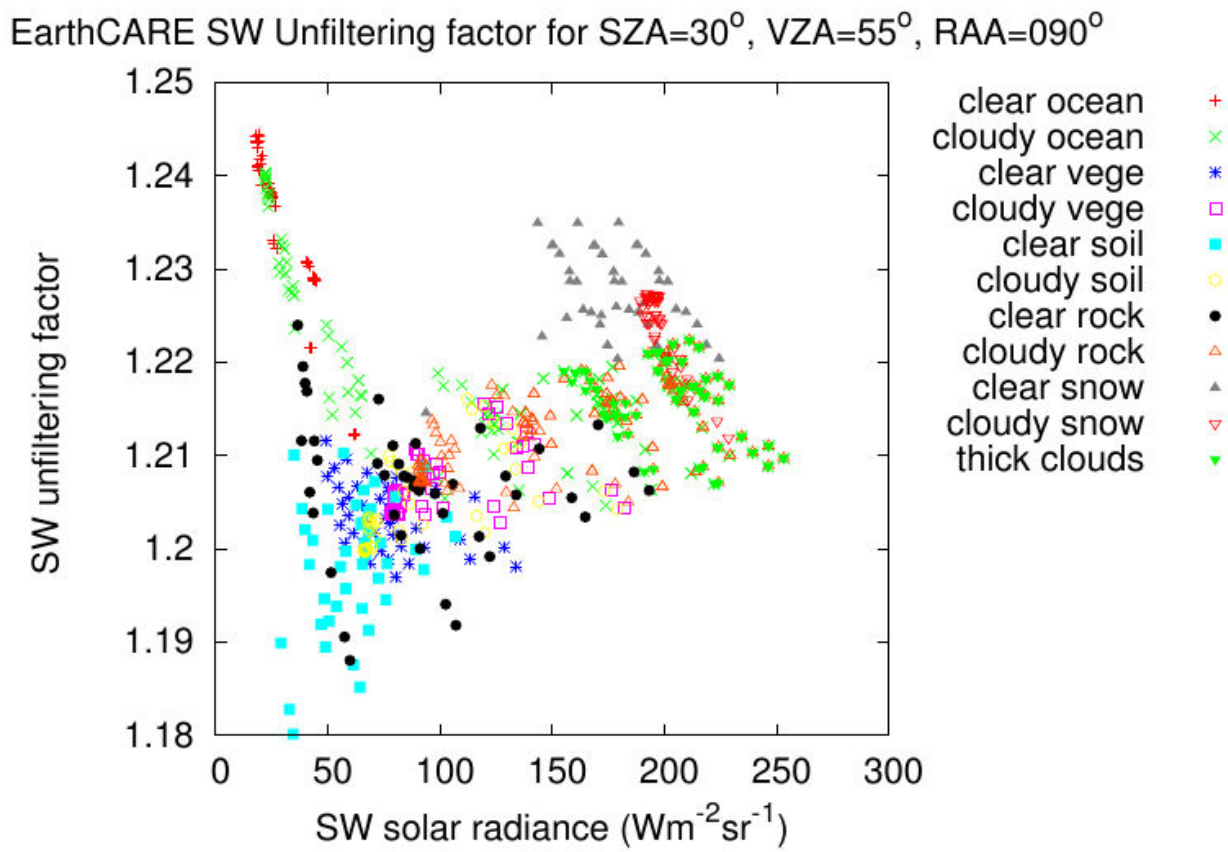
Surface type dependent Hyperbolic fit

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

Coef. Dependent on SZA, VZA, RAA

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

`unfiltering_coef_SURFACE_TYPE.txt`



Full description of the method and results in "ATBD"

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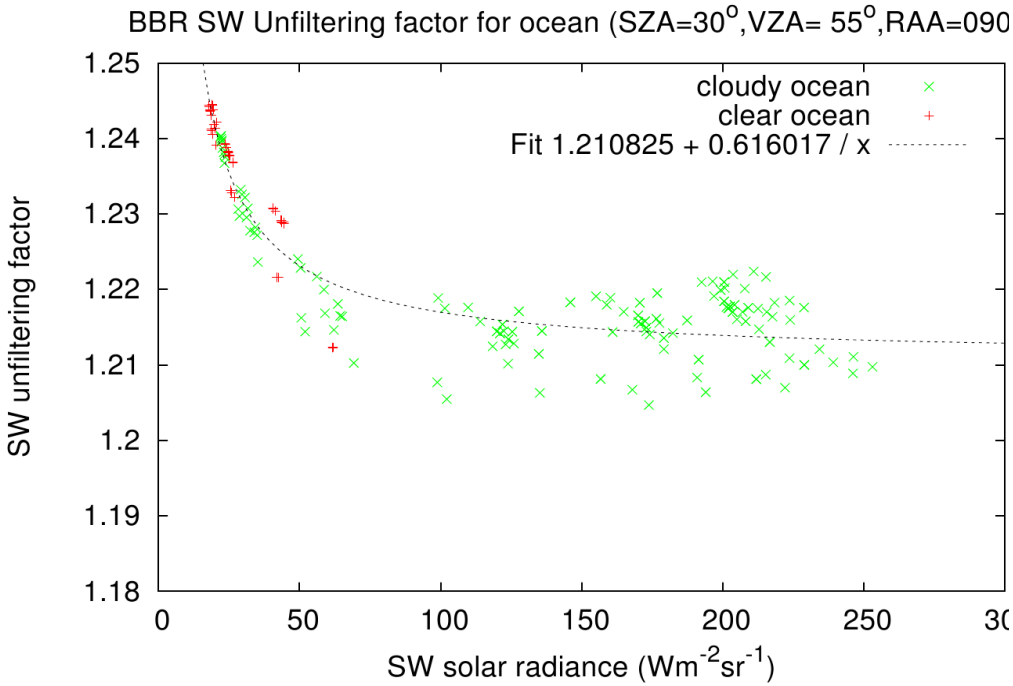
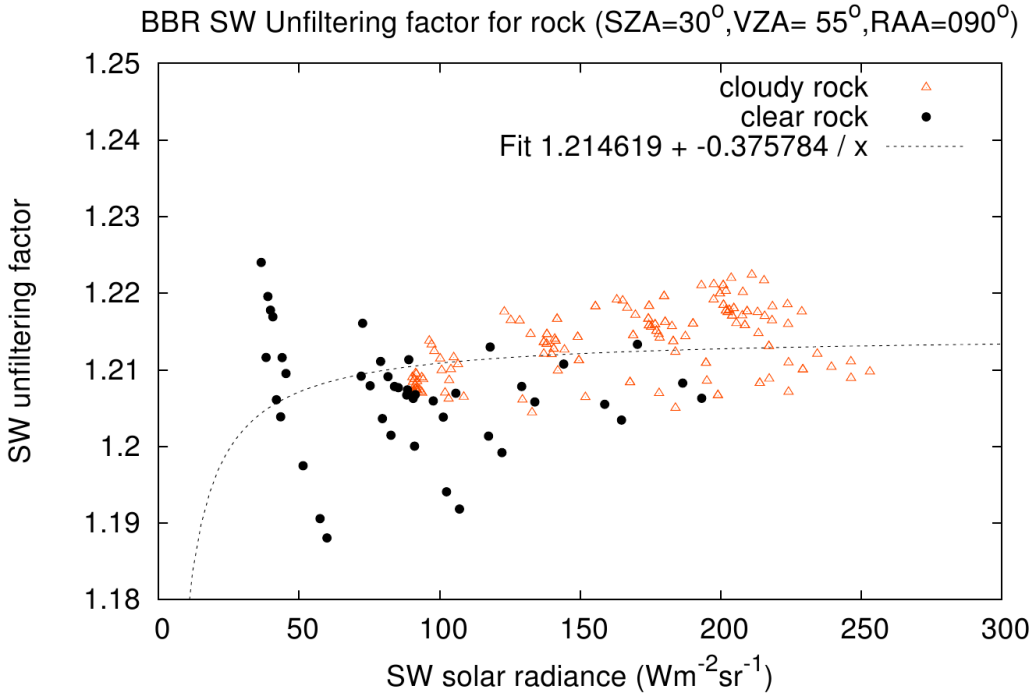
Results.
Stand Alone SW Unfiltering





Surface type	hyperbolic	
	<RMS>	bias
ocean	0.003528	0.000000
vege	0.003904	0.000000
soil	0.004489	0.000000
rock	0.004770	0.000000
snow	0.004865	0.000000

RMS < 0.005
W m-2 sr-1

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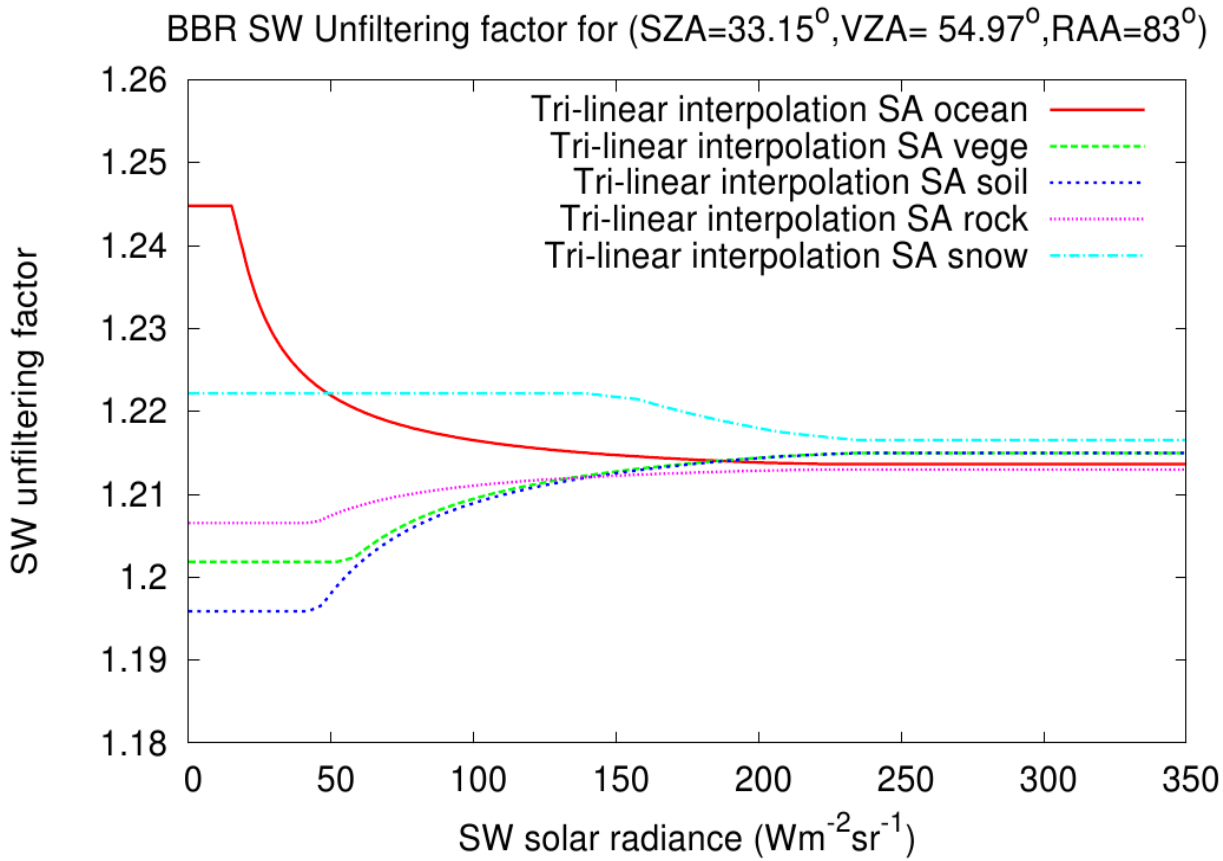
Results.
Stand Alone SW Unfiltering. Implementation



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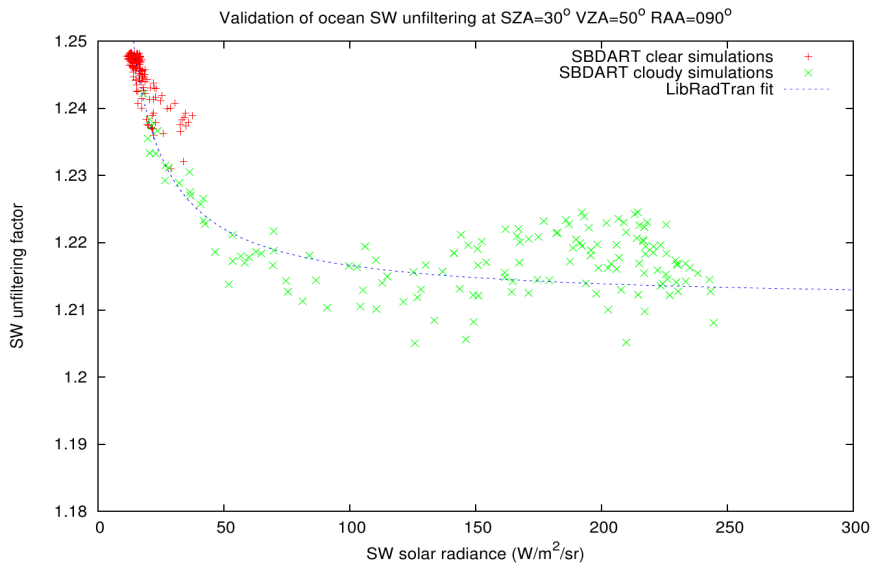
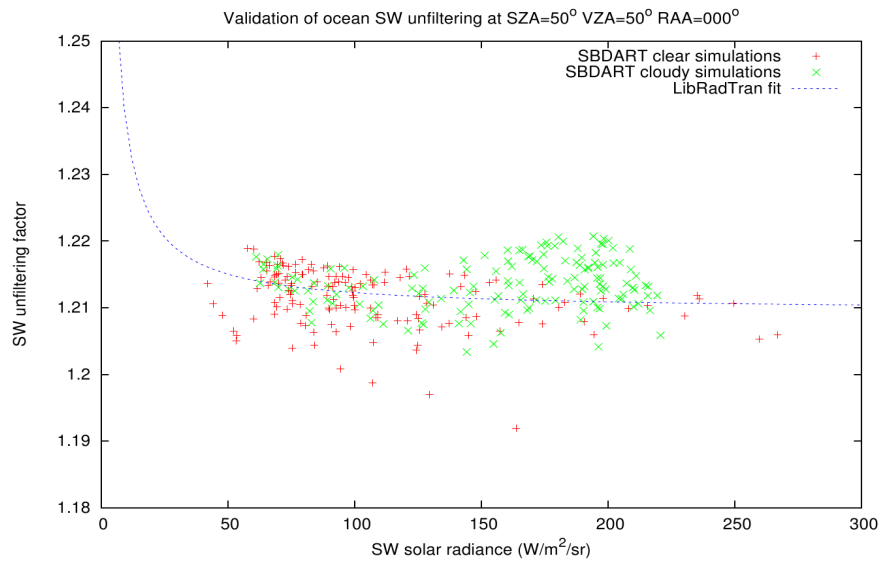
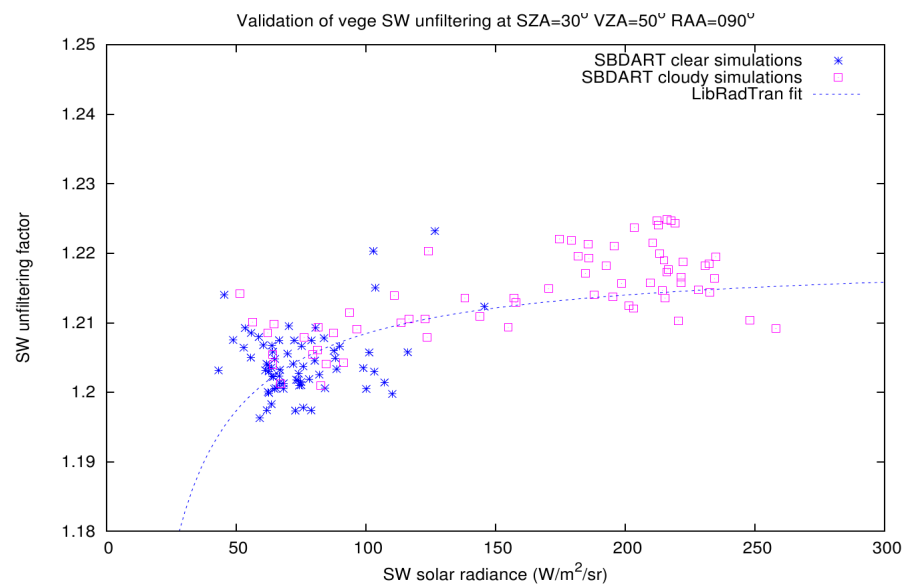
Results.
Stand Alone SW Unfiltering. Validation





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



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Results.
Stand Alone SW Unfiltering. Validation

surface type	clear/cloudy	<RMS>	<BIAS>
ocean	*clear*	0.004619	−0.0016
ocean	*cloud*	0.005092	−0.0020
vege	*clear*	0.005393	−0.0007
vege	*cloud*	0.005688	−0.0034
soil	*clear*	0.008369	0.0012
soil	*cloud*	0.005912	−0.0031
snow	*clear*	0.007776	0.0001
snow	*cloud*	0.006819	−0.0034
rock	*clear*	0.006857	−0.0039
rock	*cloud*	0.005547	−0.0002

RMS < 0.009
W m-2 sr-1

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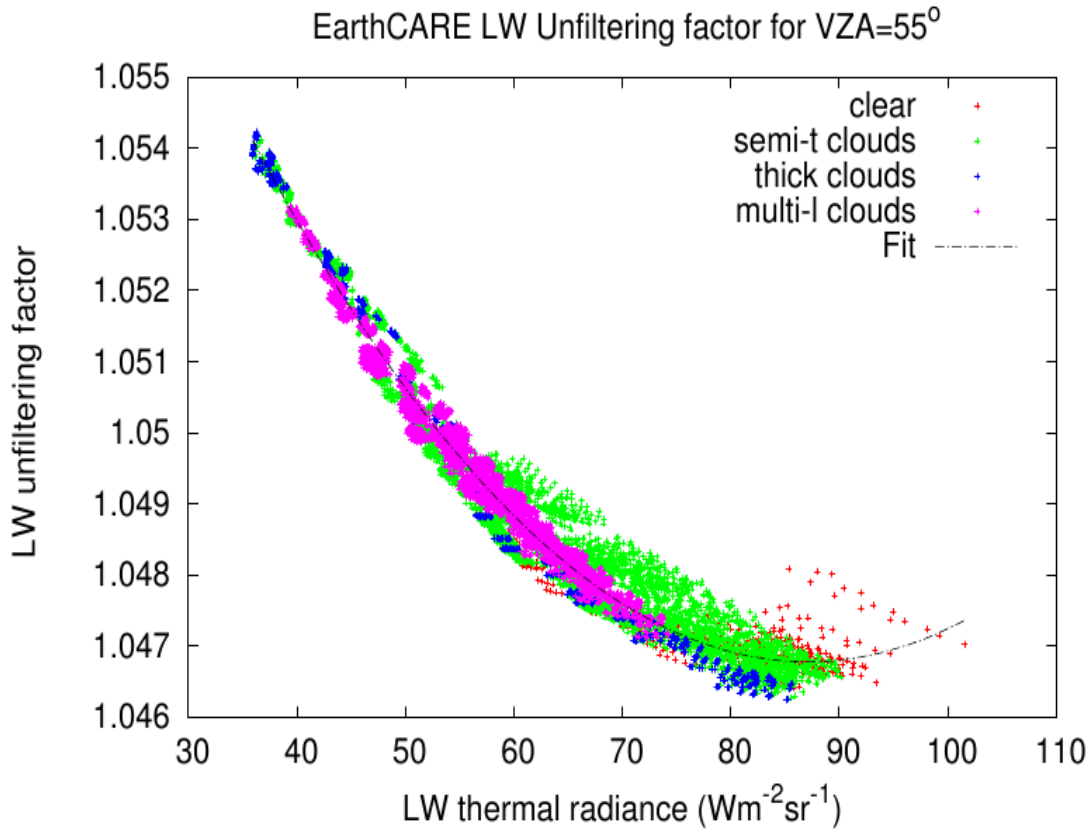
Results Obtained. Subtask 3.2
Stand-alone LW unfiltering

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"

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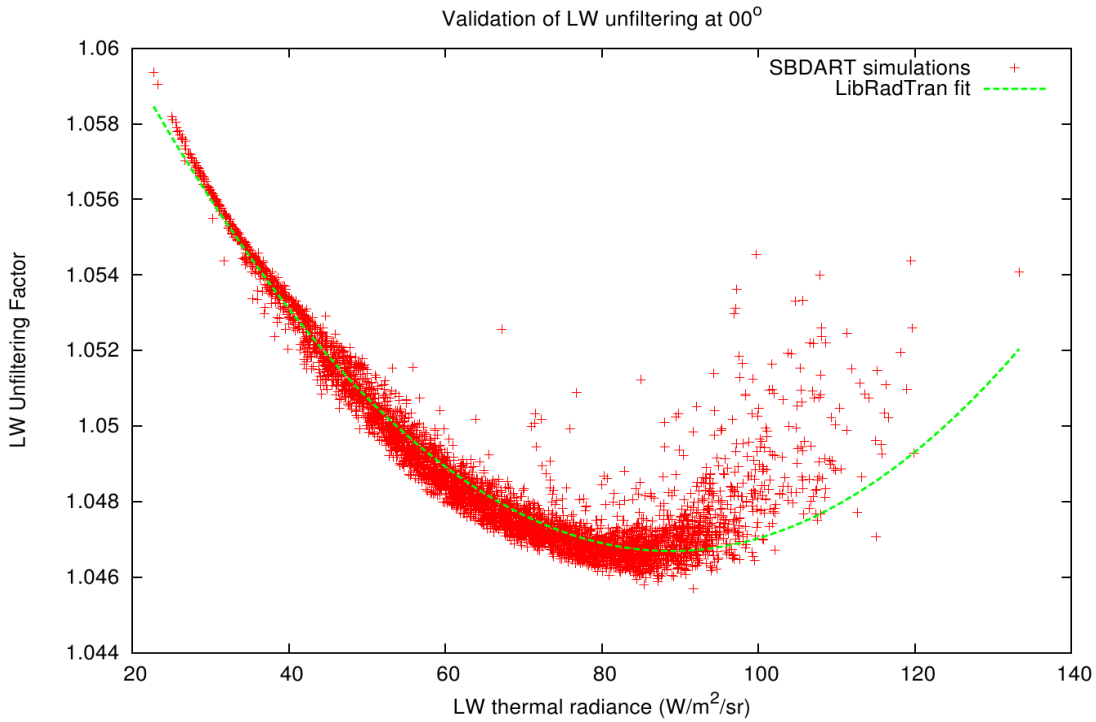
Results Obtained.
Stand-alone LW unfiltering. Validation



RMS error < 0.0008 W/m2/sr
bias negligible

3 times higher than for the study DB

Radiometric accuracy = 1.5 W/m2/sr

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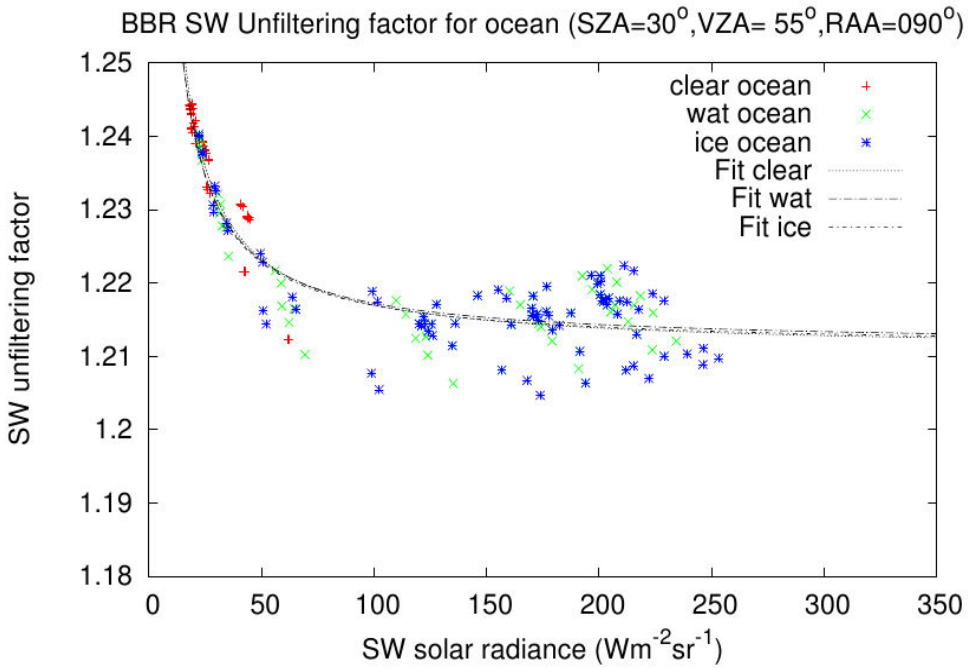
Results.
MSI based unfiltering

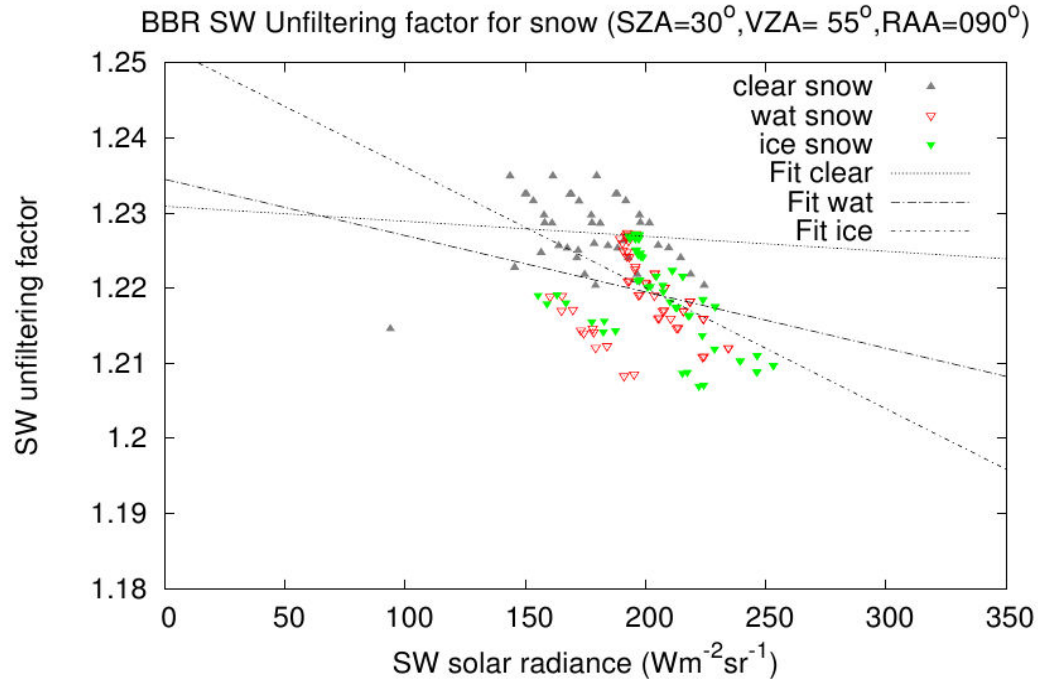
Separate fit for every surface and clear, water and ice clouds
2 methods: linear and hyperbolic

`MSI_unfiltering_coef_SURFACE_TYPE.txt`

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

$$\alpha_{sw} = a + b \cdot L_{sw,sol}$$





Full description of the method and results in "ATBD"

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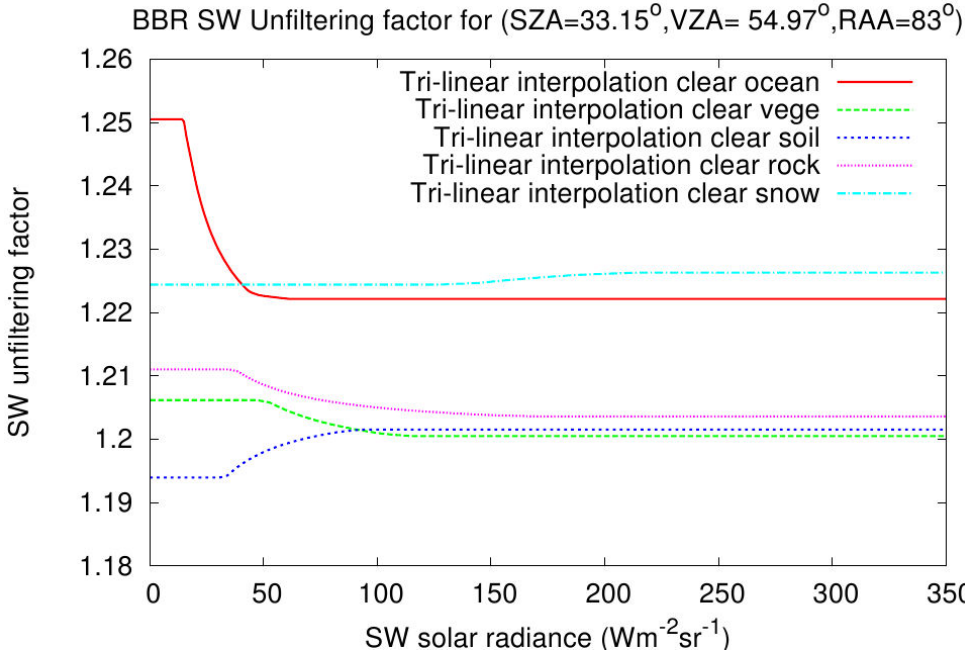
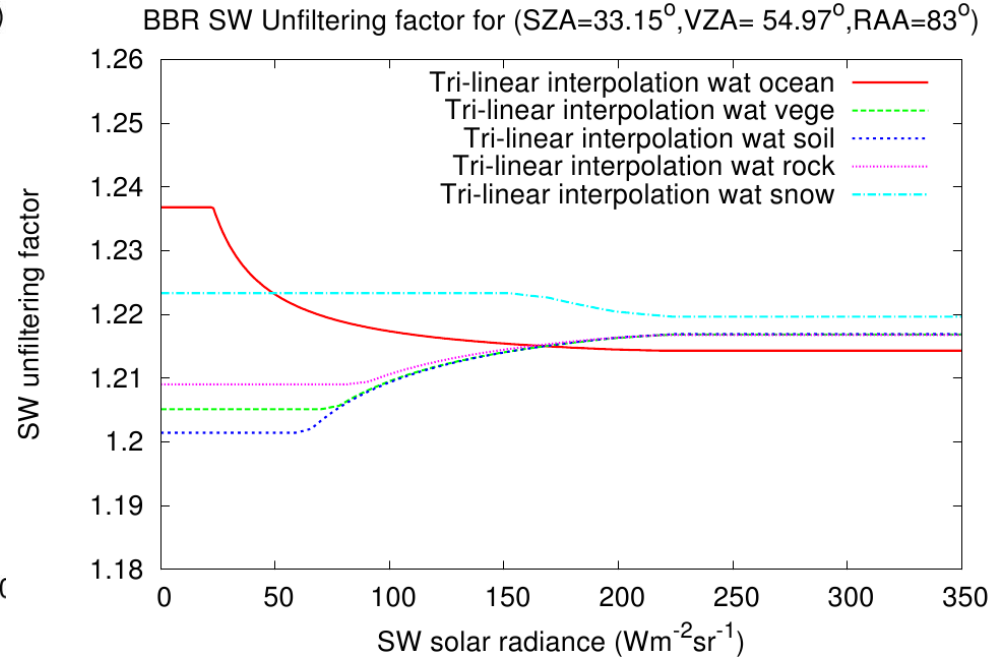
Results.
Stand alone vs MSI based unfiltering

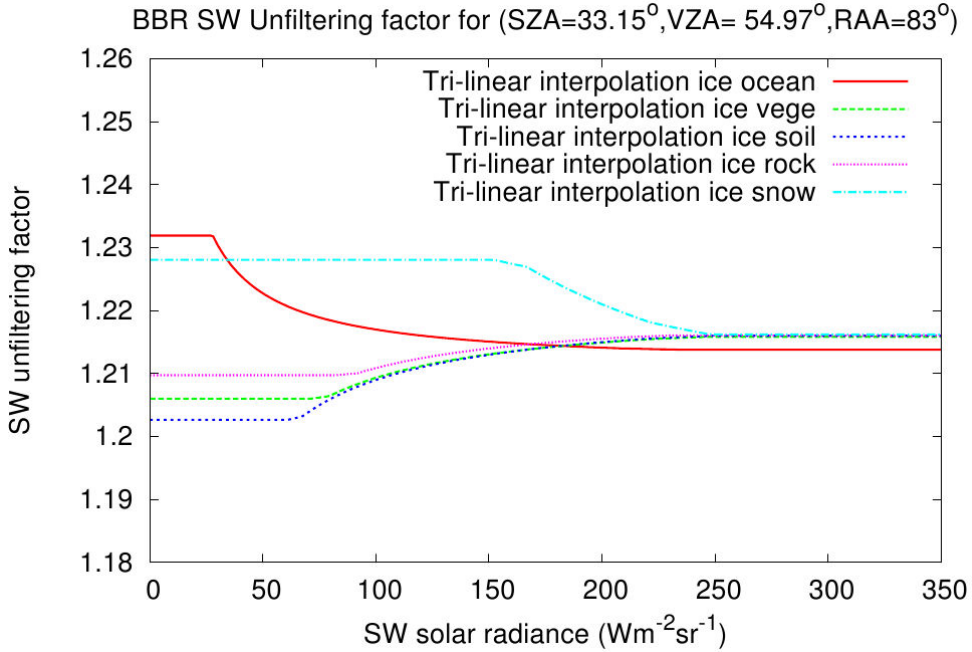
Geometry:
9 Solar Zenith Angles, 0° to 80°, step 10°
18 Viewing Zenith Angles: 0° to 85°, step 5°
19 Relative Azimuth Angles: 0° to 180°, step 10°.

Surface	<RMS> stand-alone	MSI type	<RMS> MSI hyperbolic	<RMS> MSI linear
ocean	0.003569	*clear*	0.003297	0.003848
		wat	0.003056	0.003973
		ice	0.003381	0.004216
vege	0.003831	*clear*	0.002426	0.002526
		wat	0.002743	0.002912
		ice	0.003731	0.003989
soil	0.004346	*clear*	0.004953	0.004991
		wat	0.002793	0.003122
		ice	0.003859	0.004275
rock	0.004556	*clear*	0.005281	0.005609
		wat	0.002662	0.002779
		ice	0.003191	0.003300
snow	0.004848	*clear*	0.003745	0.003773
		wat	0.003887	0.003857
		ice	0.004072	0.003896

Results Obtained.
MSI based unfiltering. Implementation







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Results.
MSI based unfiltering. Validation

surface type	cl_ph	method	<RMS>	<BIAS>
ocean	*clear*	*linear*	0.0049	−0.0026
ocean	*wat*	*linear*	0.0058	0.0001
ocean	*ice*	*linear*	0.0059	−0.0035
ocean	*clear*	*hyperb*	0.0055	−0.0009
ocean	*wat*	*hyperb*	0.0041	0.0002
ocean	*ice*	*hyperb*	0.0058	−0.0040
vege	*clear*	*linear*	0.0055	−0.0015
vege	*wat*	*linear*	0.0044	0.0006
vege	*ice*	*linear*	0.0070	0.0057
vege	*clear*	*hyperb*	0.0055	−0.0016
vege	*wat*	*hyperb*	0.0046	−0.0010
vege	*ice*	*hyperb*	0.0076	−0.0061
soil	*clear*	*linear*	0.0061	0.0009
soil	*wat*	*linear*	0.0051	0.0004
soil	*ice*	*linear*	0.0069	0.0059
soil	*clear*	*hyperb*	0.0063	0.0007
soil	*wat*	*hyperb*	0.0053	0.0003
soil	*ice*	*hyperb*	0.0074	0.0061
rock	*clear*	*linear*	0.0068	−0.0025
rock	*wat*	*linear*	0.0048	0.0010
rock	*ice*	*linear*	0.0072	−0.0055
rock	*clear*	*hyperb*	0.0065	−0.0026
rock	*wat*	*hyperb*	0.0049	0.0007
rock	*ice*	*hyperb*	0.0079	−0.0062
snow	*clear*	*linear*	0.0037	0.0003
snow	*wat*	*linear*	0.0060	0.0011
snow	*ice*	*linear*	0.0056	−0.0045
snow	*clear*	*hyperb*	0.0035	0.0005
snow	*wat*	*hyperb*	0.0061	0.0012
snow	*ice*	*hyperb*	0.0057	−0.0044

RMS < 0.008
W m-2 sr-1

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Handling mixed scenes (SW)

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

$$\tilde{L}_{sw,sol} = \sum_{i}^{n} \omega_i \tilde{L}^i_{sw,sol}$$

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

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

$$\alpha = \frac{\sum_i^n w_i \alpha_i L^i_{sw,sol}}{\sum w_i L^i_{sw,sol}}$$

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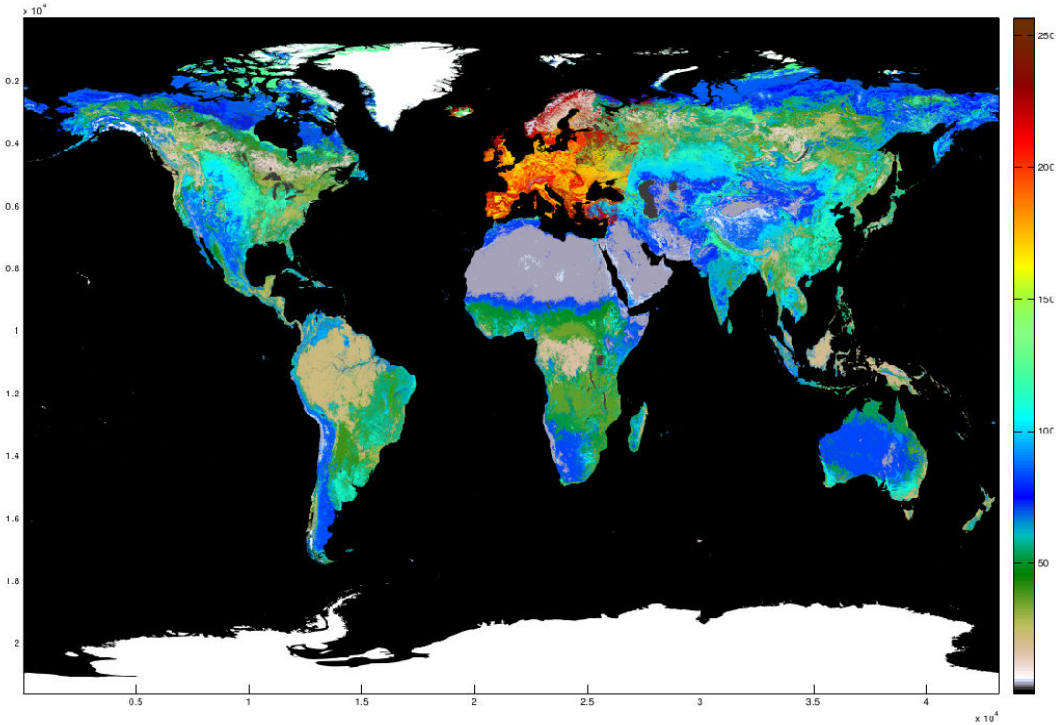
Ecoclimap-2 database
(Masson et al, 2003)

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

Type of scene	$<L_{sw,sol}>$	$< RMSL_{sw,th} >$	$<L_{lw,th}>$	$< RMSL_{lw,sol} >$	$< \alpha_{sw} >$	$< \alpha_{lw} >$
thick high cloud	171.98	0.012	55.13	0.038	1.214	1.049
semi high cloud	96.71	0.017	62.71	0.036	1.212	1.048
semi high water cloud	97.13	0.017	62.71	0.041	1.212	1.048
semi high ice cloud	96.29	0.020	57.80	0.030	1.213	1.049
semi low cloud	92.55	0.015	73.94	0.034	1.215	1.047
thick low cloud	159.71	0.022	72.31	0.018	1.218	1.047
clear dessert	74.31	0.037	80.84	0.061	1.209	1.047
clear ocean	32.16	0.014	79.06	0.054	1.230	1.047
clear snow	140.37	0.011	67.18	0.029	1.227	1.048
clear vege	62.65	0.020	76.66	0.026	1.206	1.047

Results.
Error analysis. SA unfiltering error

Surface type	<RMS α_{sw} >	$E_{5\%}$	$E_{95\%}$
ocean	0.0043	0.0036	0.0051
vege	0.0046	0.0035	0.0051
soil	0.0056	0.0040	0.0065
rock	0.0055	0.0039	0.0063
snow	0.0059	0.0044	0.0069

Type of surface	<RMS α_{lw} >	$E_{5\%}$	$E_{95\%}$
ocean	0.00028	0.00023	0.00030
vege	0.00034	0.00032	0.00035
rock	0.00028	0.00027	0.00030
snow	0.00034	0.00033	0.00037

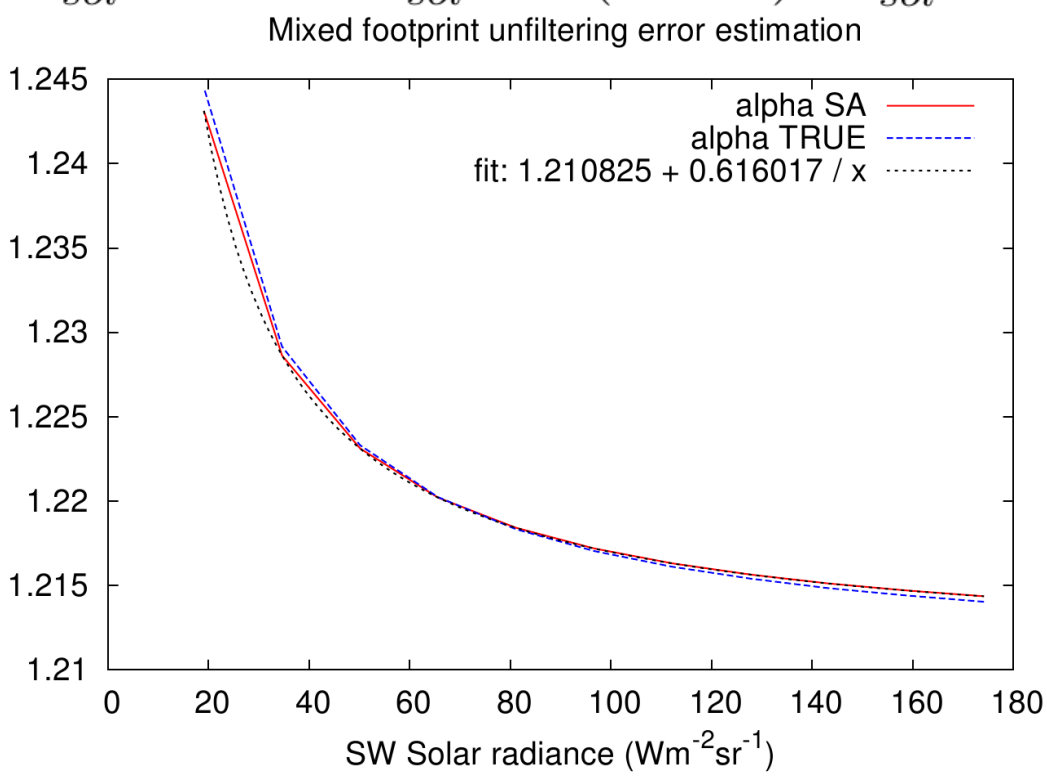
Results.
Error analysis. SA unfiltering error.
Mixed footprints

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

$$\alpha_T = L_{sol}^{mixed} / L_{sw,sol}^{mixed}$$

$$L_{sol}^{mixed} = w \cdot L_{sol}^{clear} + (1-w) \cdot L_{sol}^{cloudy}$$

$$\alpha_{SA} = a + b / L_{sw,sol}^{mixed}$$



ω is cloud free fraction in the BBR footprint

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

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Results.
Error analysis. MSI unfiltering error

Type of surface	phase	method	<RMS α_{MSI}>	$E_{5\%}$	$E_{95\%}$
ocean	*clear*	*hyperb*	0.0040	0.0027	0.0055
ocean	*clear*	*linear*	0.0046	0.0024	0.0052
ocean	*wat*	*hyperb*	0.0037	0.0030	0.0043
ocean	*wat*	*linear*	0.0048	0.0031	0.0059
ocean	*ice*	*hyperb*	0.0041	0.0034	0.0046
ocean	*ice*	*linear*	0.0051	0.0035	0.0061
vege	*clear*	*hyperb*	0.0029	0.0024	0.0034
vege	*clear*	*linear*	0.0030	0.0025	0.0035
vege	*wat*	*hyperb*	0.0026	0.0020	0.0035
vege	*wat*	*linear*	0.0026	0.0021	0.0035
vege	*ice*	*hyperb*	0.0037	0.0030	0.0044
vege	*ice*	*linear*	0.0038	0.0031	0.0044
soil	*clear*	*hyperb*	0.0059	0.0039	0.0068
soil	*clear*	*linear*	0.0059	0.0040	0.0069
soil	*wat*	*hyperb*	0.0028	0.0021	0.0036
soil	*wat*	*linear*	0.0031	0.0025	0.0037
soil	*ice*	*hyperb*	0.0041	0.0032	0.0048
soil	*ice*	*linear*	0.0045	0.0034	0.0052
rock	*clear*	*hyperb*	0.0063	0.0044	0.0072
rock	*clear*	*linear*	0.0067	0.0050	0.0074
rock	*wat*	*hyperb*	0.0032	0.0028	0.0040
rock	*wat*	*linear*	0.0033	0.0030	0.0040
rock	*ice*	*hyperb*	0.0038	0.0031	0.0044
rock	*ice*	*linear*	0.0040	0.0031	0.0045
snow	*clear*	*hyperb*	0.0045	0.0042	0.0051
snow	*clear*	*linear*	0.0046	0.0041	0.0052
snow	*wat*	*hyperb*	0.0049	0.0013	0.0059
snow	*wat*	*linear*	0.0048	0.0013	0.0059
snow	*ice*	*hyperb*	0.0049	0.0014	0.0058
snow	*ice*	*linear*	0.0045	0.0017	0.0054

Table 21: MSI unfiltering associated errors

Results. Error analysis. Case study

Error cont+unfil+rad.accuracy

Type of scene	$<L_{sw,sol}>$ $Wm^{-2}sr-1$	Error L_{sol} $Wm^{-2}sr^{-1}$	ϵ_r (%)	Combined Error L_{sol} $Wm^{-2}sr^{-1}$	Combined $\epsilon_r(\%)$
thick high cloud	171.98	0.75	0.44	3.12	1.82
semi high cloud	96.71	0.42	0.44	3.06	3.17
semi high water cloud	97.13	0.42	0.44	3.06	3.15
semi high ice cloud	96.29	0.42	0.44	3.06	3.18
semi low cloud	92.55	0.40	0.44	3.06	3.31
thick low cloud	159.71	0.70	0.44	3.12	1.96
clear dessert	74.31	0.41	0.55	3.05	4.11
clear ocean	32.16	0.13	0.43	3.07	9.57
clear snow	140.37	0.82	0.59	3.17	2.26
clear vege	62.65	0.28	0.46	3.03	4.84

Contamination + unfiltering

Type of scene	$<L_{lw,th}>$ $Wm^{-2}sr-1$	Error L_{th} $Wm^{-2}sr-1$	$\epsilon_r(\%)$	Combined Error L_{th} $Wm^{-2}sr-1$	Combined $\epsilon_r(\%)$
thick high cloud	55.13	0.0432	0.078	1.575	2.8
semi high cloud	62.71	0.0422	0.067	1.574	2.5
semi high water cloud	62.71	0.0465	0.074	1.574	2.5
semi high ice cloud	57.80	0.0364	0.063	1.575	2.7
semi low cloud	73.94	0.0414	0.056	1.571	2.1
thick low cloud	72.31	0.0282	0.039	1.571	2.1
clear dessert	80.84	0.0678	0.083	1.572	1.9
clear ocean	79.06	0.0608	0.076	1.571	1.9
clear snow	67.18	0.0382	0.056	1.572	2.3
clear vege	76.66	0.0377	0.049	1.571	2.0

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 doesnt specifically check for the degradation at short wavelengths. An intercomparison between measured clear ocean radiances and an ocean colour instrument is also recommended.