EarthCARE BBR level 2 Products and Algorithms : BM-RAD, BMA-FLX

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Content

- A single-slide introduction to the EarthCARE mission
- An introduction to the EarthCARE BroadBand Radiometer (BBR) instrument.
  - Configuration of the 3 views
  - Telescope and acquisition mechanism
- The BBR level 1 products
  - Concept of “integration domains”
- Processing toward level 2
  - The radiances unfiltering
  - The fluxes estimation (focus on LW, SW to be detailed tomorrow by Florian Tornow)
  - Weighting of the 3 LW fluxes: study based on CERES TAT data
- Summary

The ESA/JAXA EarthCARE Mission

Launch Date: official 2018/Q4

Duration: 3 years, (incl. 6 months commissioning).

The scientific objectives of the mission are:

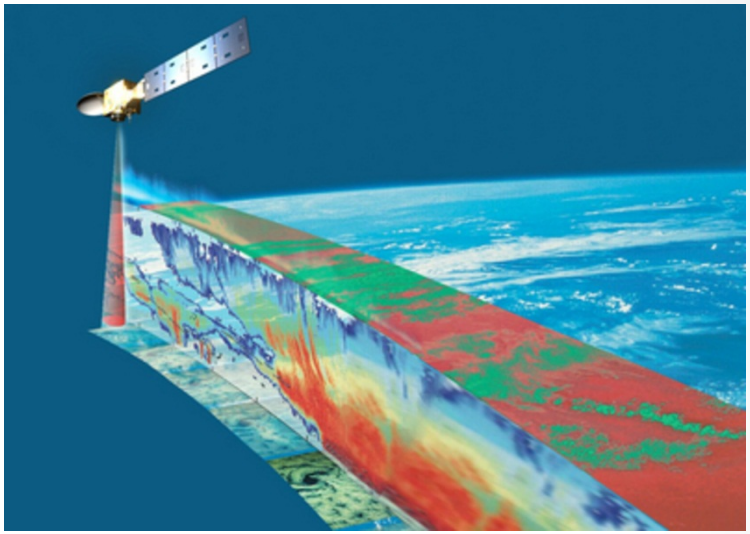
- To observe vertical profiles of natural and anthropogenic aerosols on a global scale, their radiative properties and interaction with clouds
- To observe vertical distributions of atmospheric liquid water and ice on a global scale, their transport by clouds and their radiative impact
- To observe cloud distribution, cloud-precipitation interactions and the characteristics of vertical motions within clouds
- To retrieve profiles of atmospheric radiative heating and cooling through the combination of the retrieved aerosol and cloud properties

Mission orbit:

- **Orbit:** Sun-synchronous
- **Mean solar local time:** 14:00
- **Mean spherical altitude:** 393.14 km
- **Inclination:** 97.05 degrees
- **Repeat cycle:** 25 days/389 orbits 9 days/140 orbits
- **Orbital duration:** 5552.7 sec 5554.3 sec

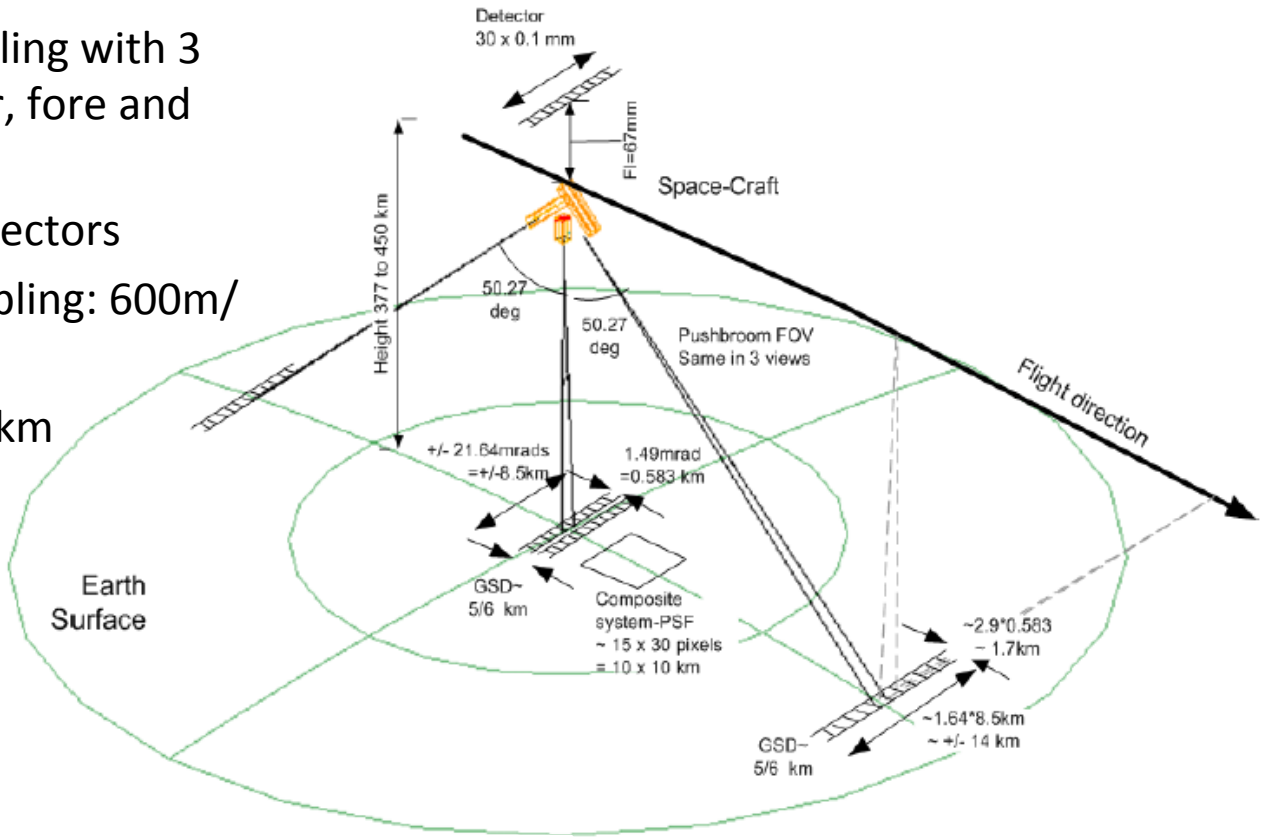
Payload:

- The **Atmospheric Lidar** (ATLID) provides vertical profiles of aerosols and thin clouds. It operates at a wavelength of 355nm and has a high-spectral resolution receiver and depolarisation channel.
- The **Cloud Profiling Radar** (CPR) provides vertical profiles measurements of clouds and has the capability to observe vertical velocities of cloud particles through Doppler measurements. It operates at 94GHz.
- The **Multi-Spectral Imager** (MSI) provides across-track information on clouds and aerosols with channels in the visible, near infrared, shortwave- and thermal infrared.
- The **Broad-Band Radiometer** (BBR) provides measurements of top-of-the-atmosphere radiances and fluxes. It has one short-wave and one long-wave channel with three fixed viewing directions pointing in nadir and aft-directions.



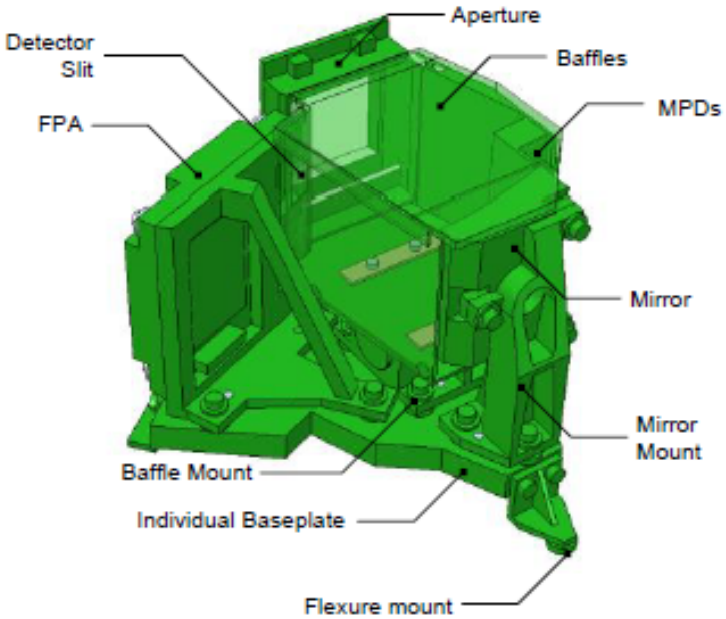
BBR Viewing Configuration

- Along track sampling with 3 telescopes : nadir, fore and back (@55° VZA)
- Array of 30x1 detectors
- Across track sampling: 600m/ 1000m
- Swath : 18km/30km



Viewing geometry

Telescope detail and assembly



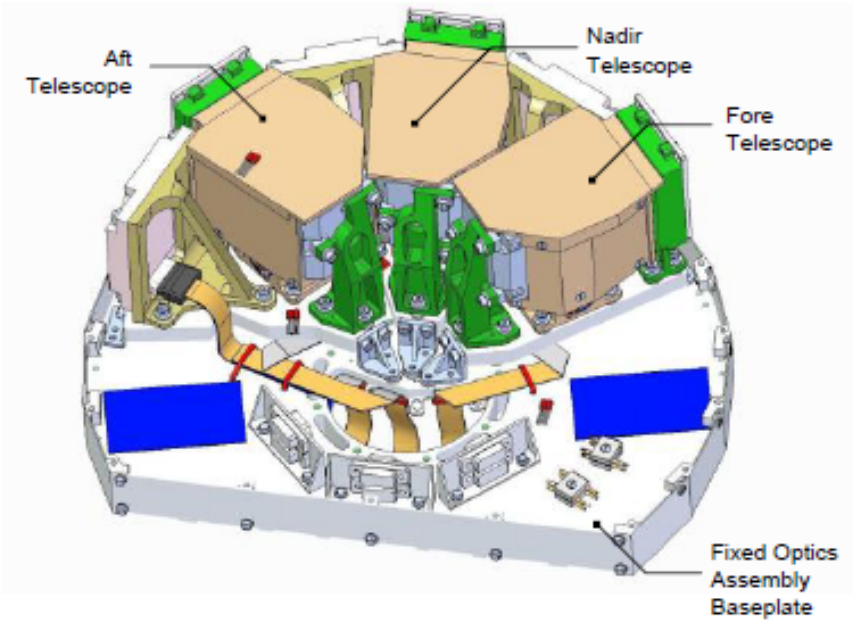
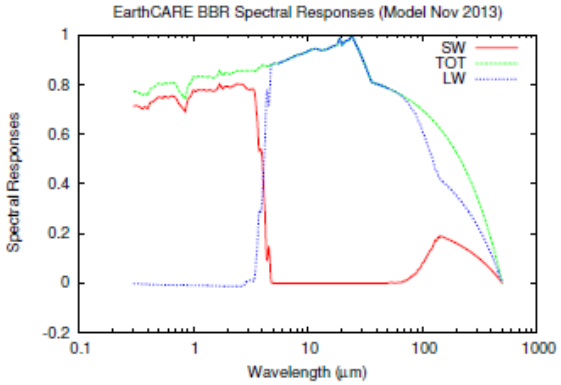
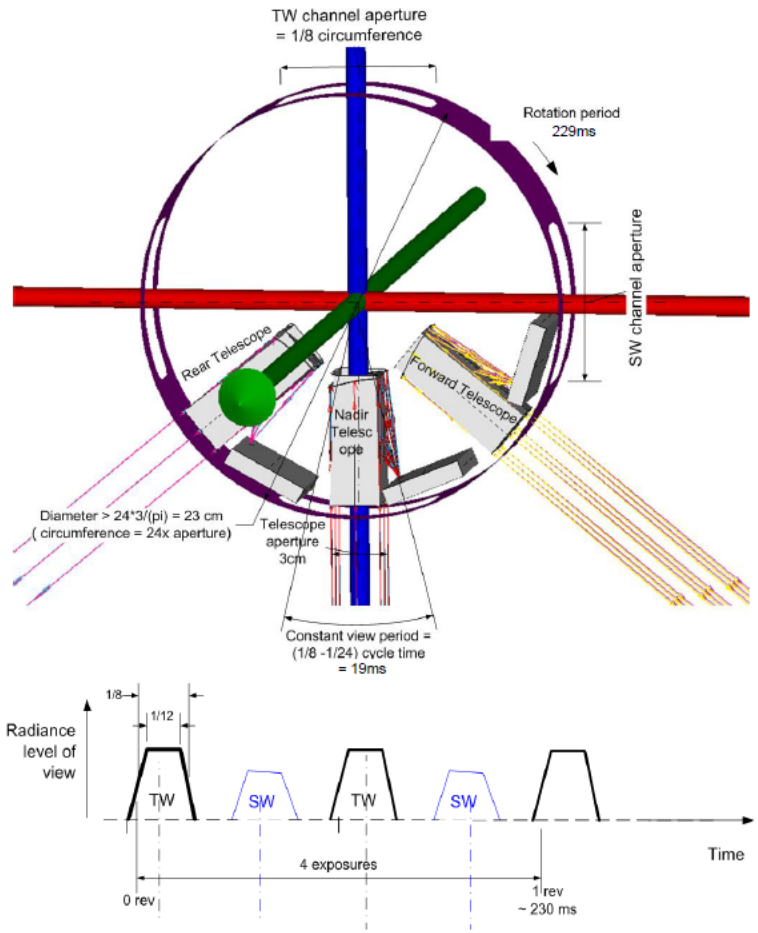


Figure 1-2 : Telescope and Fixed Optics Assembly

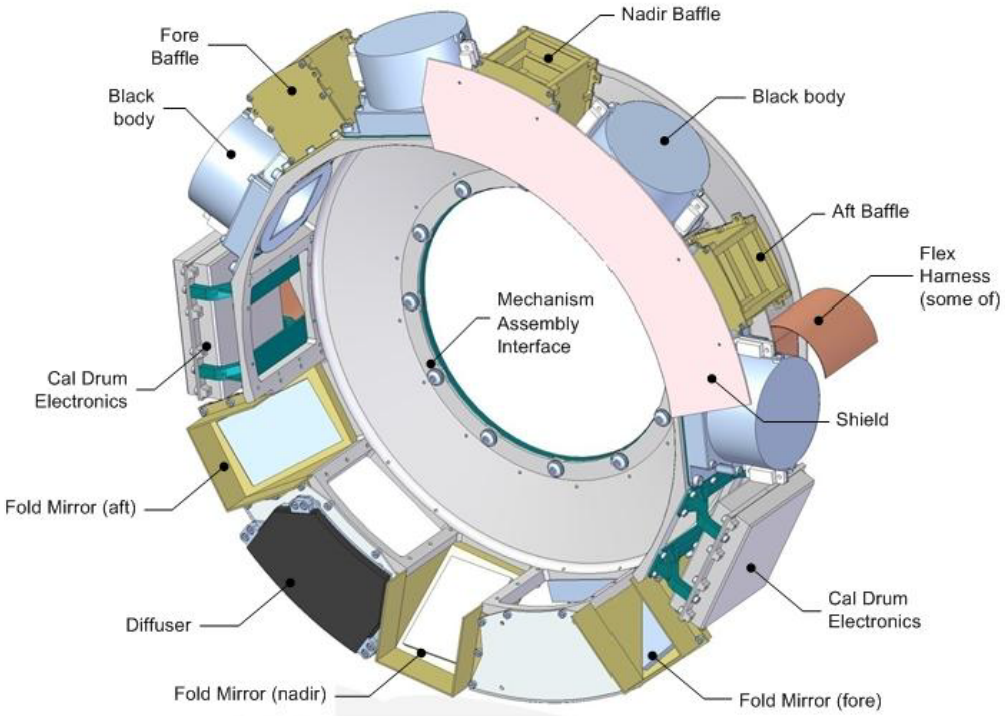
- Detectors : 30 x 1 Vanadium Oxide microbolometer array
- Single mirror optics (Aluminium coating)
- Two spectral channels: TW (0.2 – 50 µm) & SW (0.2 – 4 µm)
- Radiometric accuracy : SW : 2.5 W/m²/sr & LW : 1.5 W/m²/sr



Chopper and Calibration Drums



Chopper and chopper operation

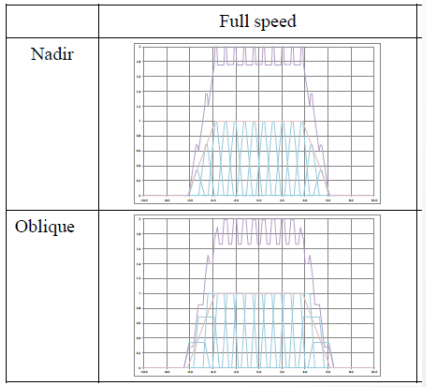


: Calibration Drum Layout.

Level 1 integration areas (PSF)

Level 1 PSF	Size (across x along track)	ref	Level 2 unfil. rad	Level 2 fluxes	Level 2 combined flux
Standard	10x10km	BBR	x	x	x
Small	5x10km	BBR	x	x	x
Full	18 x 10km 30 x 10km	BBR	x	x	
Assessment Domain	5 x 21 km	JSG	x	x	x
JSG	1 x 1 km	JSG	x		

10 km along-track integration



Notes

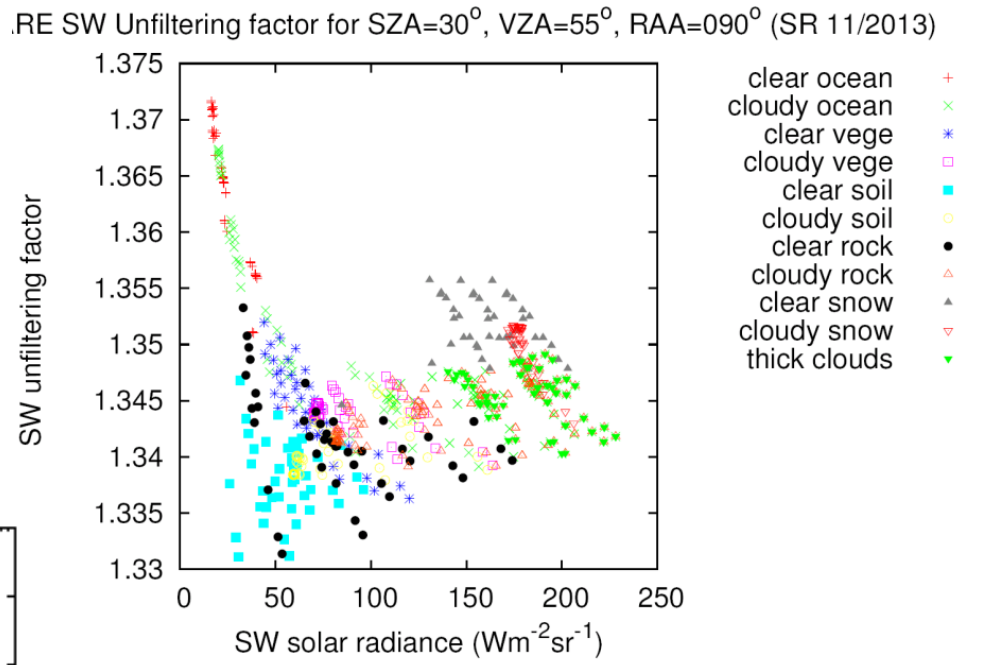
- all regions sampled @ 1km
- all dimensions are configurable

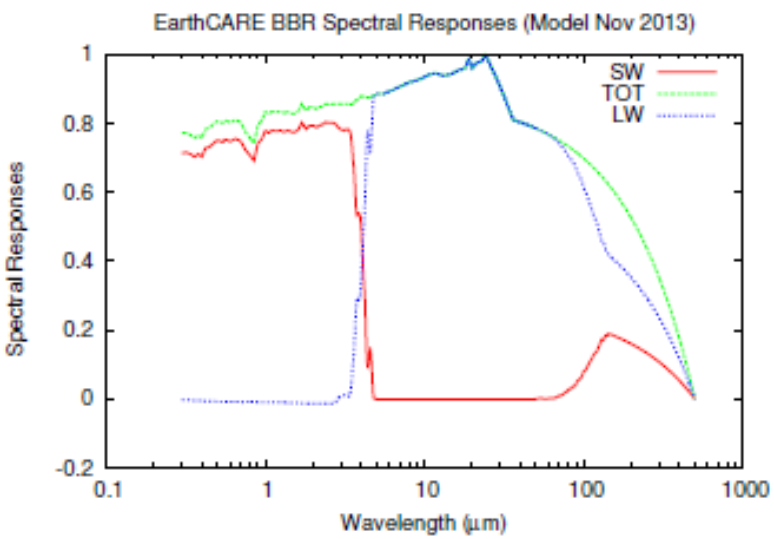
BBR instrument SW channel unfiltering

Surface type dependent Hyperbolic fit

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

Coeffcients *a*,*b* dependent on geometry (SZA, VZA, RAA).

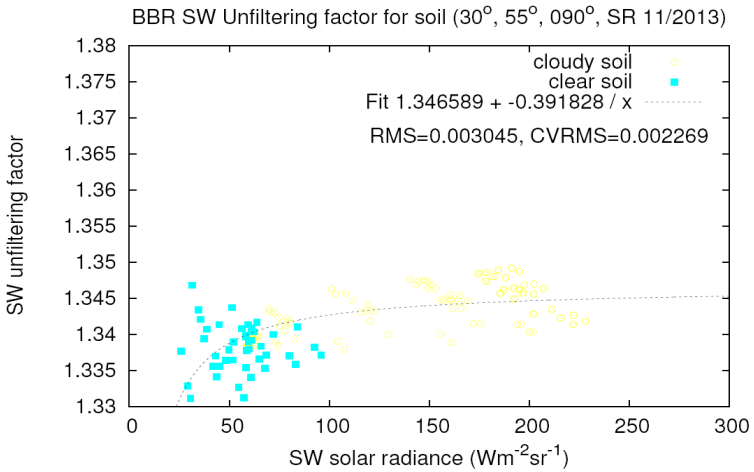


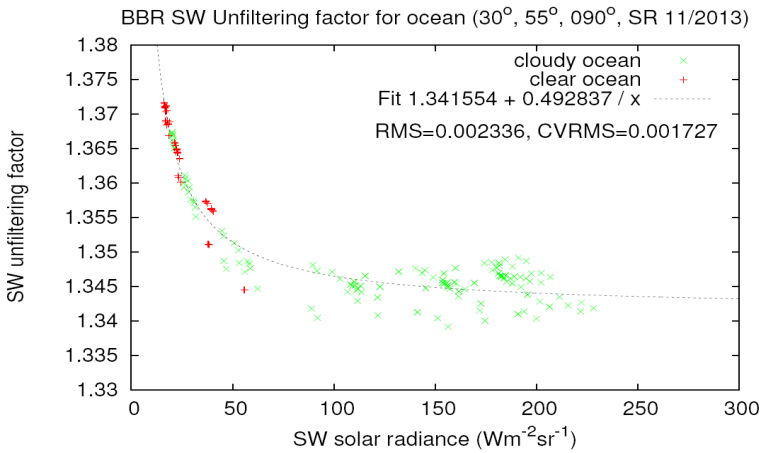


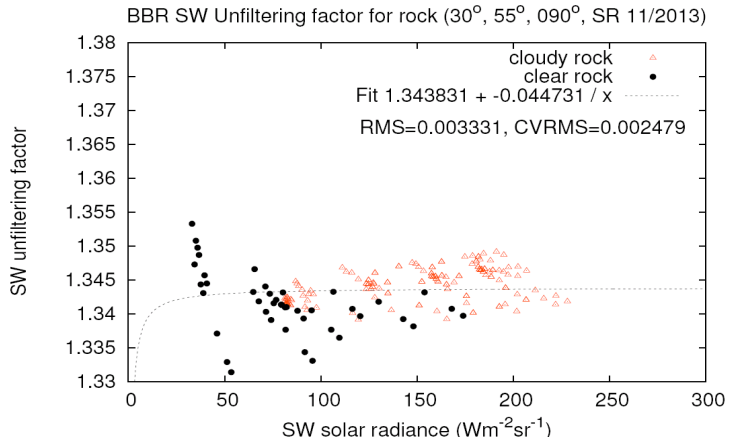
Surface type	<RMS α_{sw} >	$E_{5\%}$	$E_{95\%}$
ocean	0.0043	0.0036	0.0051
vege	0.0046	0.0035	0.0051
soil	0.0056	0.0040	0.0065
rock	0.0055	0.0039	0.0063
snow	0.0059	0.0044	0.0069

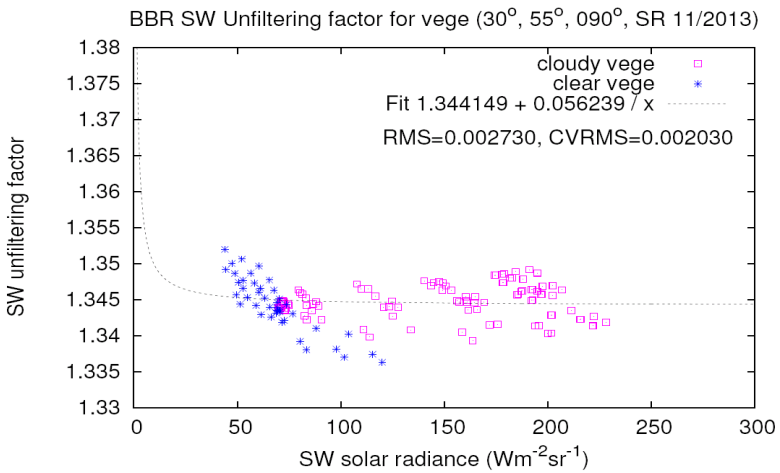
Note : Full description of the method and results in

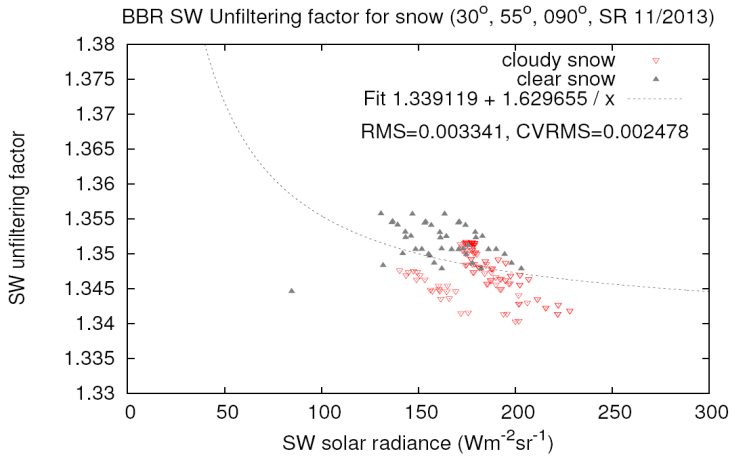
SW unfiltering by scene type









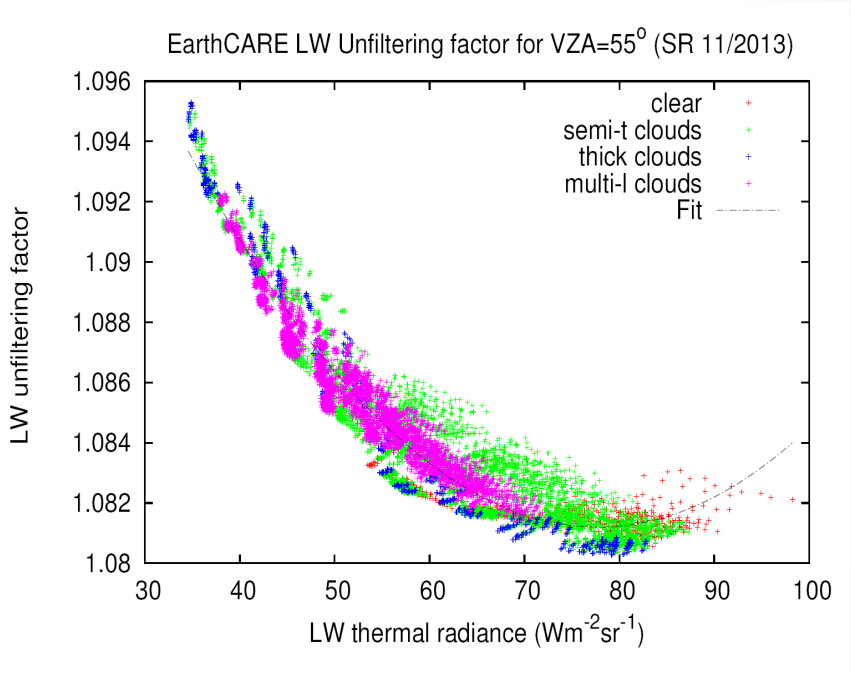


BBR instrument LW channel unfiltering

Surface type independent parabolic fit

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

RMS error on factor ~ 0.0008
RMS error on radiance ~ 0.05 W/m²/sr



Full description of the unfiltering method and results in the "ATBD", including the subtraction of the "contaminations".

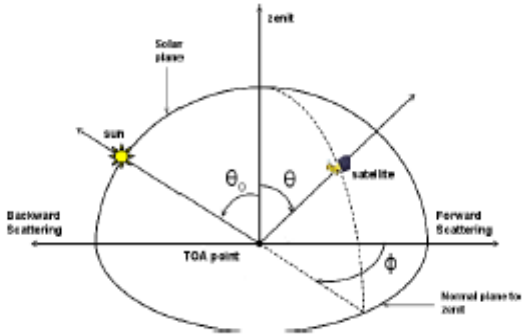
BBR LW Flux Estimation

- BBR measure radiances $L(\theta, \phi)$ $[Wm^{-2}sr^{-1}]$ at the TOA but flux is

$$F = \int_{\theta=0}^{\frac{\pi}{2}} \int_{\phi=0}^{2\pi} L(\theta, \phi) cos(\theta) sin(\theta) d\theta d\phi$$

- Need of Angular Dependency Models (R)

$$F = \frac{\pi L(\theta, \phi)}{R(\theta, \phi)}$$



- In the LW (from FLURB ESA Study 2014):

$$R(\theta) = a_0 + a_1 \cdot z_1 + a_2 \cdot z_2 + a_3 \cdot z_1^2 + a_4 \cdot z_1 \cdot z_2 + a_5 \cdot z_2^2$$

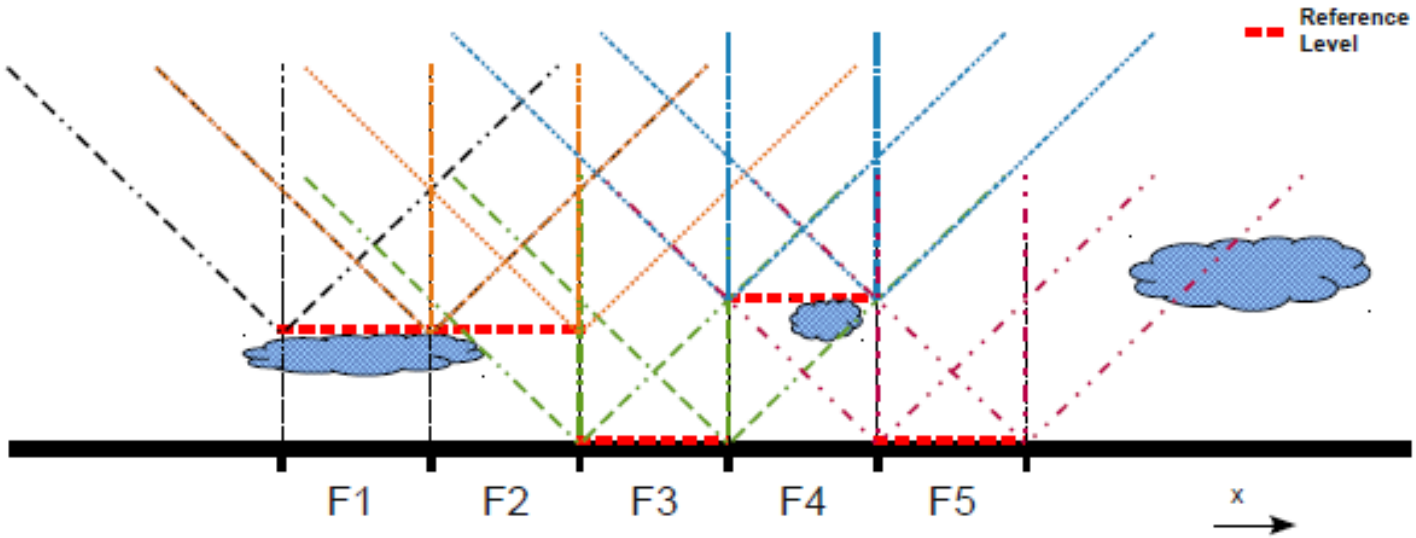
$$z_1 = BT_{10.8\mu m}, z_2 = BT_{12\mu m} - BT_{10.8\mu m}$$

- Need a geophysical database to obtain a_i: Use of SITS Database
- BBR 3 views flux is estimated as:

$$F = \frac{1-\alpha}{2} F_{fore} + \frac{1-\alpha}{2} F_{aft} + \alpha F_{nadir}$$

BBR LW Flux Estimation : Reference level for fluxes co-registration

- Important to define Flux reference level for the collocation of the views to avoid parallax
- The reference level will be placed at the altitude of the highest cloud in the footprint (using statistics on the MSI cloud top height product in nadir)



BBR LW Flux Estimation : Radiative Transfer database

SITS LibRadtran database improved for warm scenes (270)

- 12096 thermal (LW) simulations, 540 are clear sky
- Outputs at: 18 VZA: 0° to 85°, step 5°
- ASTER surface emission
- OPAC aerosol definition
- Standard atmospheric profiles + wv scaled
- Cloud properties from Yang parametrization
- LW sim: 2.5 to 100 μm (762 λ) + extended up to 500 μm
- Surface Temperature from profile + ΔT
- DB and description available at: *ftp://gerb.oma.be/almudena/SITS_DB_compressed*

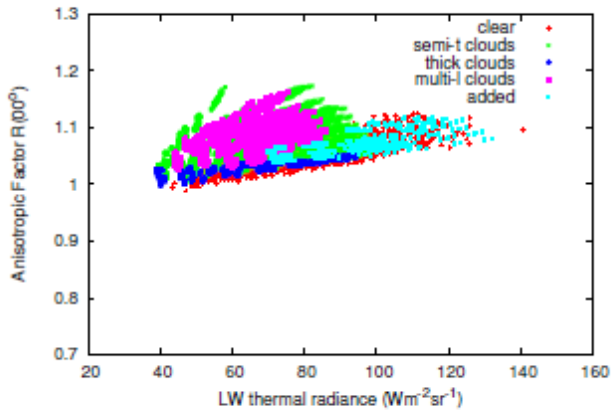
SBDART database

- 4622 thermal (LW) simulations, only used clear sky ones (2311)
- Outputs at: 18 VZA: 0° to 85°, step 5°
- Atmospheric profiles from TIGR-3 database
- LW sim: 2.5 to 100 μm (431 λ) + extended up to 500 μm
- Emissivity generated randomly between 0.85 and 1
- Surface Temperature generated randomly with values close to the lowest in the atmospheric profile

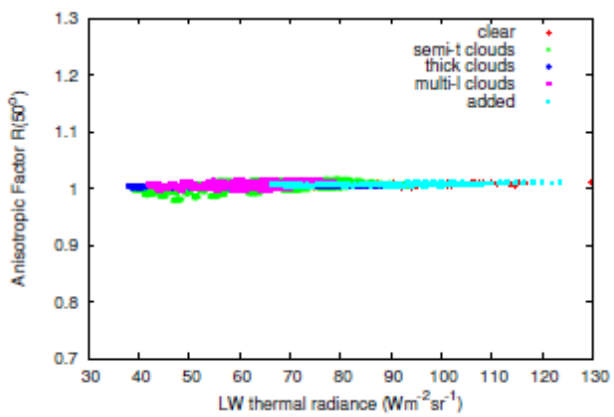
BBR LW Flux Estimation : Radiative Transfer database

LibRadtran SITS DB + clear sky SBDART DB + improved SITS warm scenes

NADIR

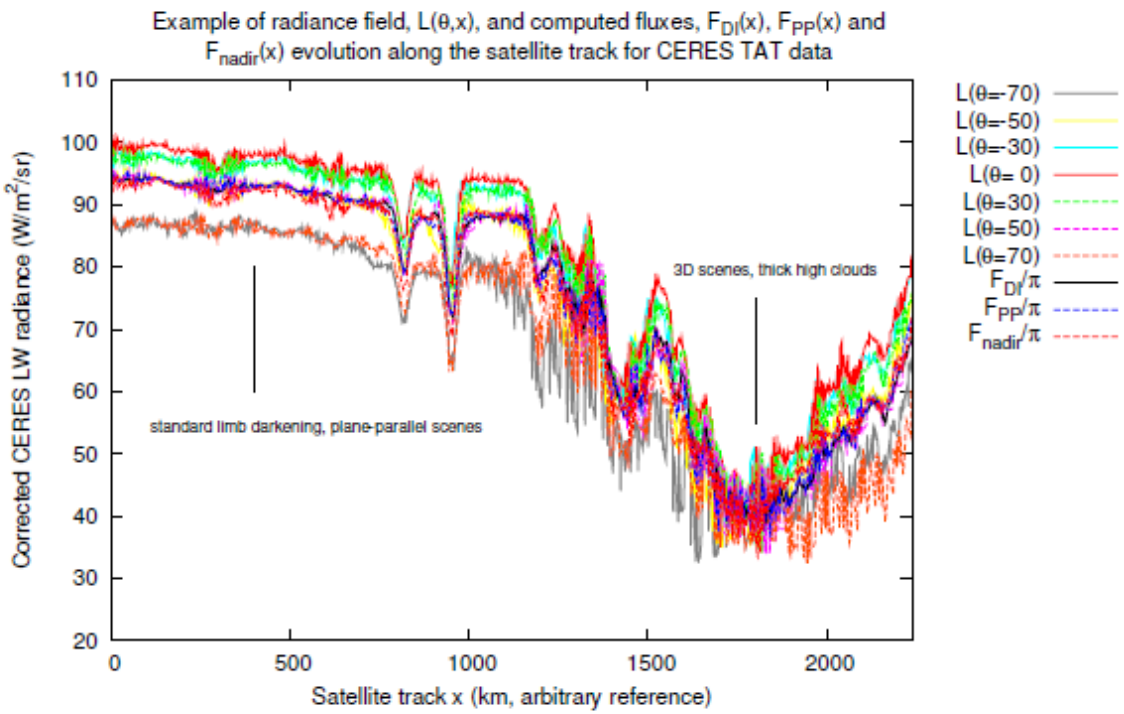


OFF-NADIR



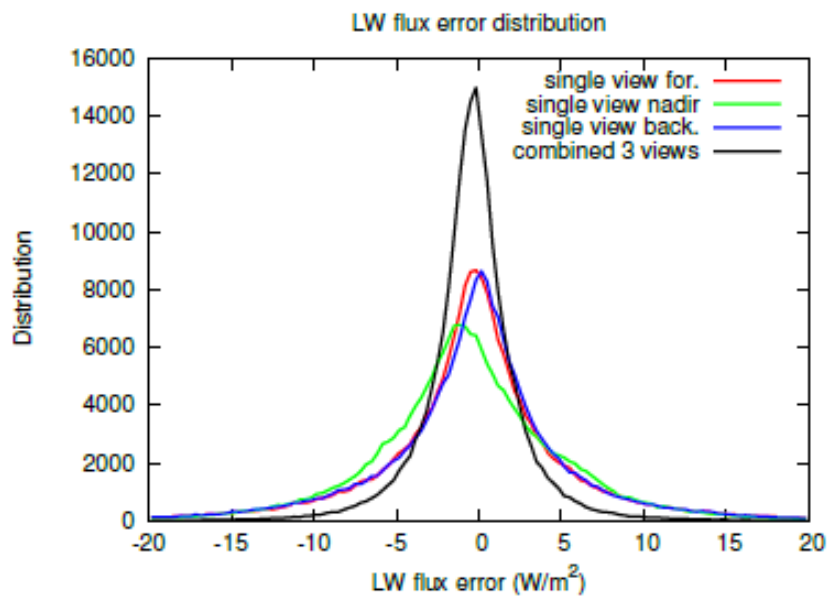
BBR LW Flux Estimation : best weighting of the 3 views ?

- Study based on CERES TAT data, allowing to estimate the true flux (Direct Integration)
- Best weigthing using real data: $\alpha \sim 1/3$
- 3D effects are important and the three views should be considered



BBR LW Flux Estimation : verification based on TAT data

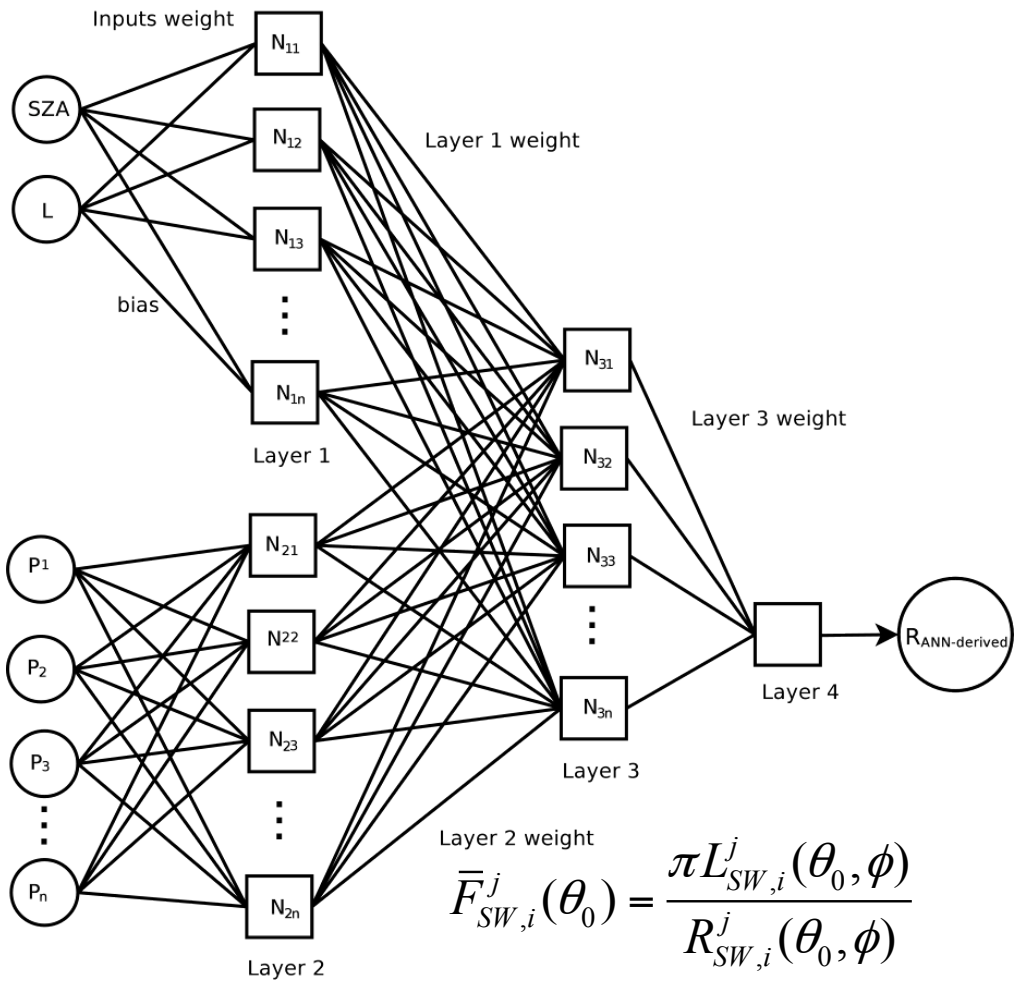
Averaged magnitude	Value
Flux CERES	241.75 W/m²
Flux Direct Integration	241.23 W/m²
Flux BBR	240.85 W/m²
Forward Flux	240.91 W/m²
Backward Flux	240.96 W/m²
Nadir Flux	240.65 W/m²
Reference Level	1.91 Km
Reference level variability	0.75 km
Forward Radiance	77.13 W/m²/sr
Backward radiance	77.14 W/m²/sr
Nadir radiance	81.37 W/m²/sr



Type	Equation	RMS error	Prob (err>10W/m²)
Forward view only	F_DI = 1.0005 F_for	6.51 W/m²	10.2%
Backward view only	F_DI = 1.0003 F_aft	6.56 W/m²	9.8%
Nadir view only	F_DI = 1.0012 F_nadir	6.87 W/m²	10.5%
Linear combination of the 3 views	F_DI = 0.3735 F_for + 0.3685 F_aft + 0.2590 F_nadir	3.14 W/m²	1.4%

SW radiance-to-flux conversion
(see detail in talk of Florian Tornow)

SW BMA-FLX algorithm is an ADM that employs a feed-forward back-propagation artificial neural network (ANN) technique trained with radiative fluxes from CERES instrument



$$\bar{F}^{j}_{SW,i}(\theta_0) = \frac{\pi L^{j}_{SW,i}(\theta_0,\phi)}{R^{j}_{SW,i}(\theta_0,\phi)}$$

BBR inputs: BM-RAD
- BBR SW unfiltered radiances
- Illumination and viewing geometry

MSI inputs: M-NOM, M-CM, M-COP
- PSF-weighted MSI radiances/ Tb over clear/cloudy pixels
- PSF-weighted CTH
- PSF-weighted cloud fraction

Aux. inputs: X-MET, IGBP, Alb. clim.
- Surface parameter descriptors

It outputs the 3 SW BBR TOA radiances co-registered at a reference level.

Summary

- Similitudes and differences of the BBR wrt current ERB instruments.
- Unfiltering and radiance-to-flux algorithms have been developed
- Currently under implementation in the ground segment, still room for scientific improvements
- The 10 W/m^2 instantaneous error is achieved in the LW for most (98.5%) of the 10x10km observations.

Thank you!