Effects of the mirror in the SW Unfiltering

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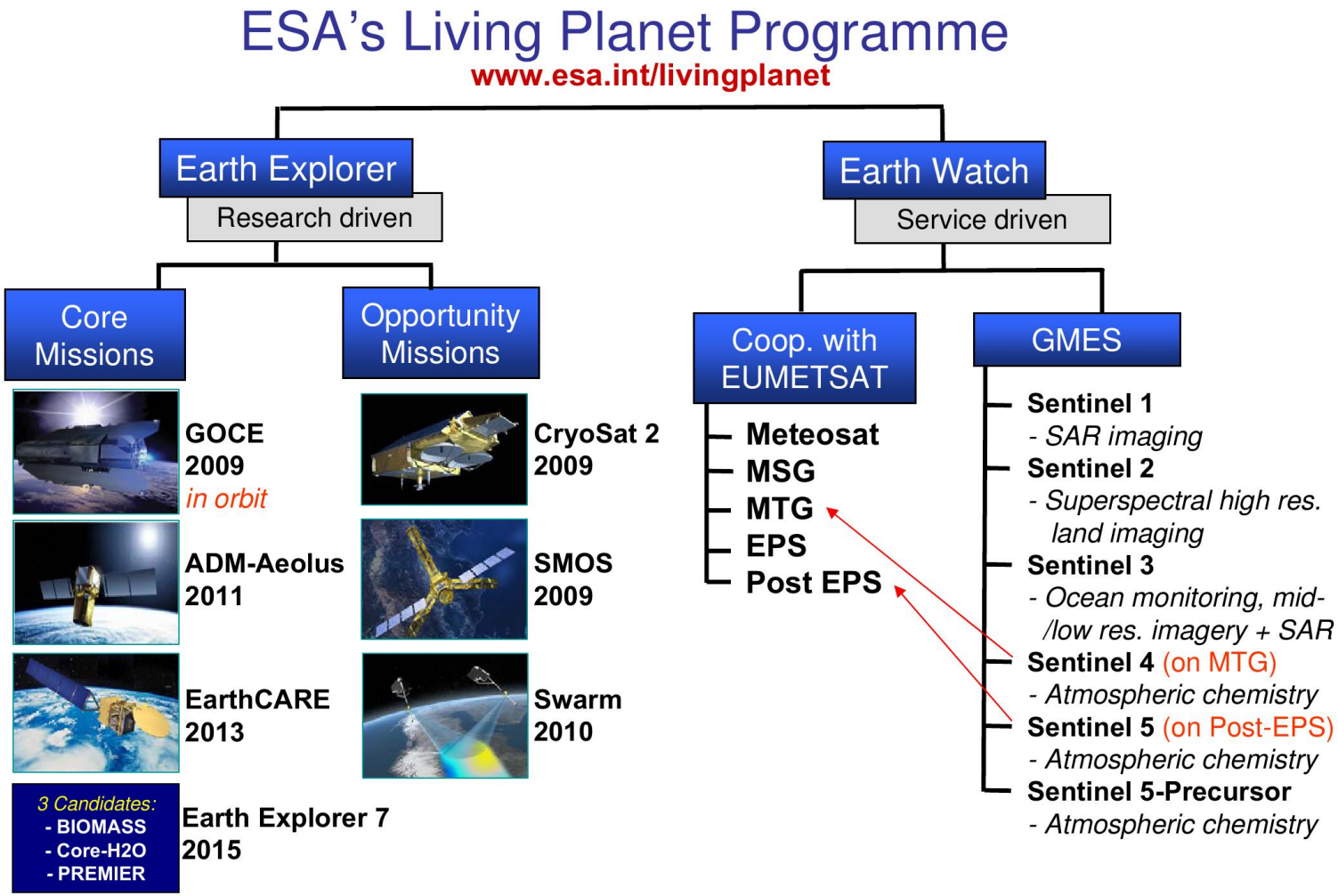
Royal Meteorological Institute of Belgium (RMIB)

CERES Science Team Meeting
Newport News, VA USA - April 26-28, 2011

Outline

Outline

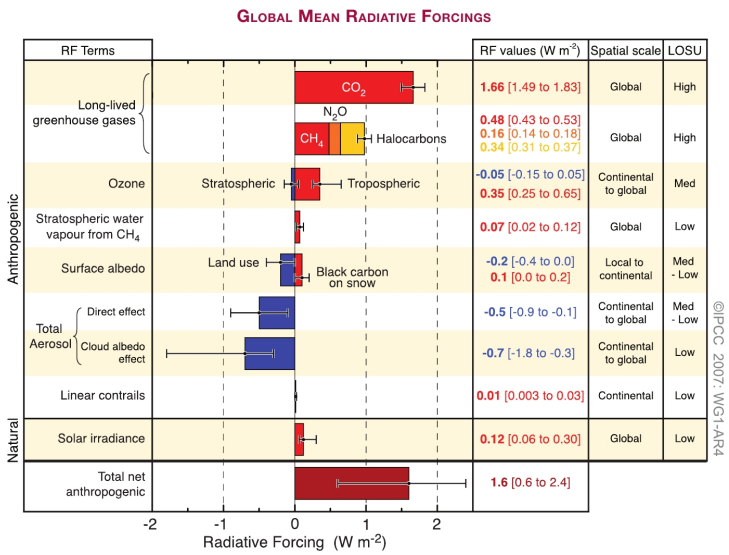
The EarthCARE mission



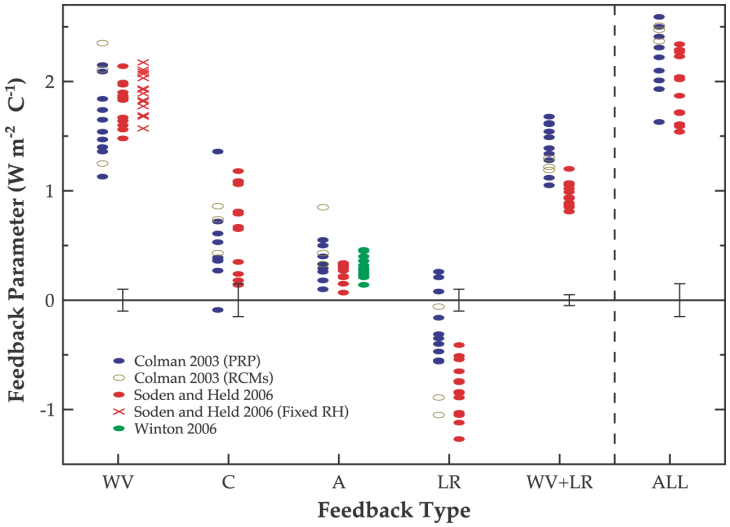
The EarthCARE mission

- EarthCARE objective: reduce current uncertainties related to aerosol - clouds - radiation interactions to provide correct and reliable datasets to be used in climate and Numerical Weather Prediction models.

Uncertainties in radiative forcing: Aerosol effects



Uncertainties in climate response: Cloud radiative feedback



WV: Water Vapour, C: Clouds, A: Aerosol, LR: Lapse Rate

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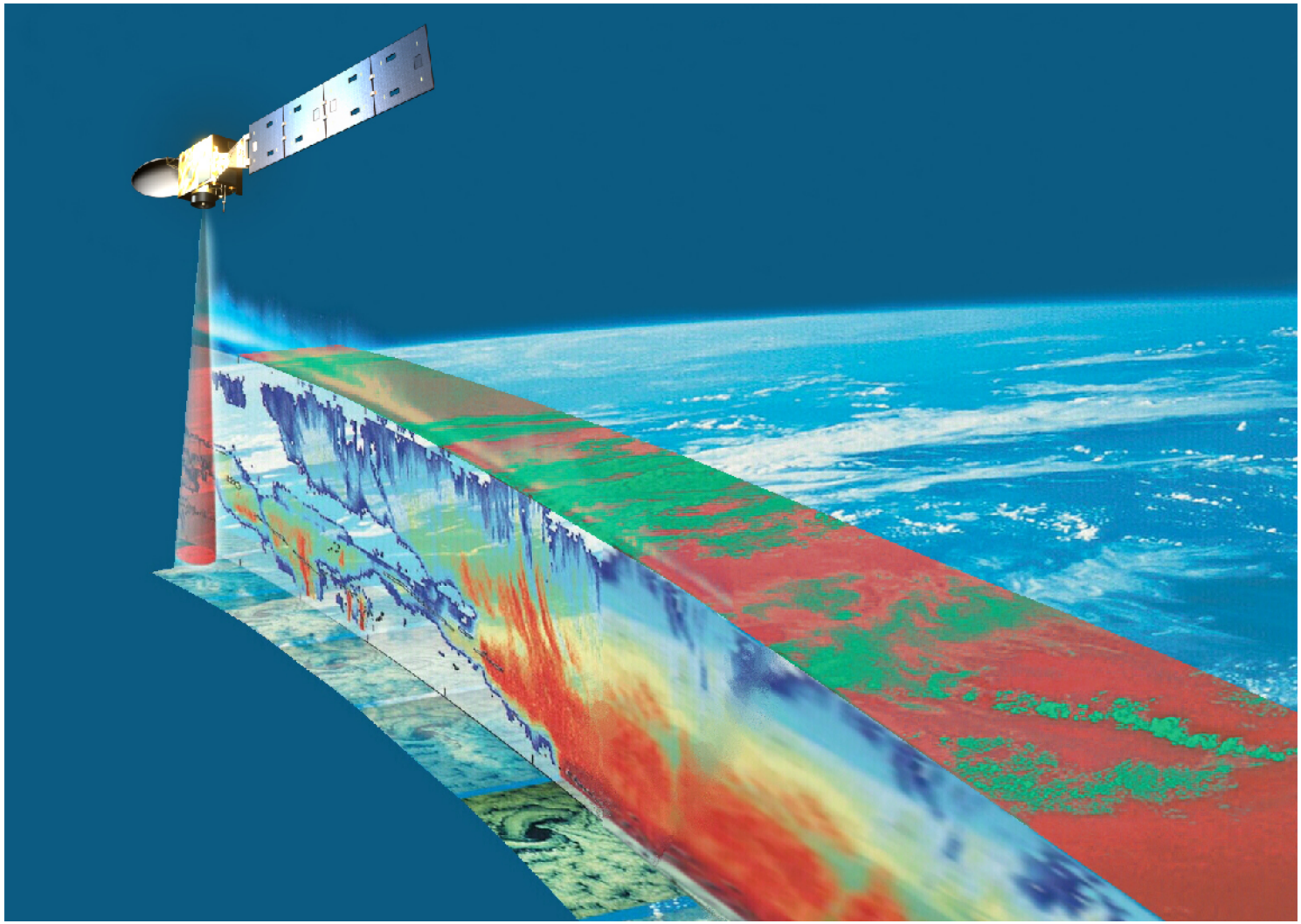

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- Objectives: Enable advances in climate modeling by simultaneous observation of aerosol and cloud properties and the radiation and hydrological cycle parameters.
- Space segment:
  - Backscatter Lidar (ATLID) - ESA High-spectral resolution and depolarisation
  - 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

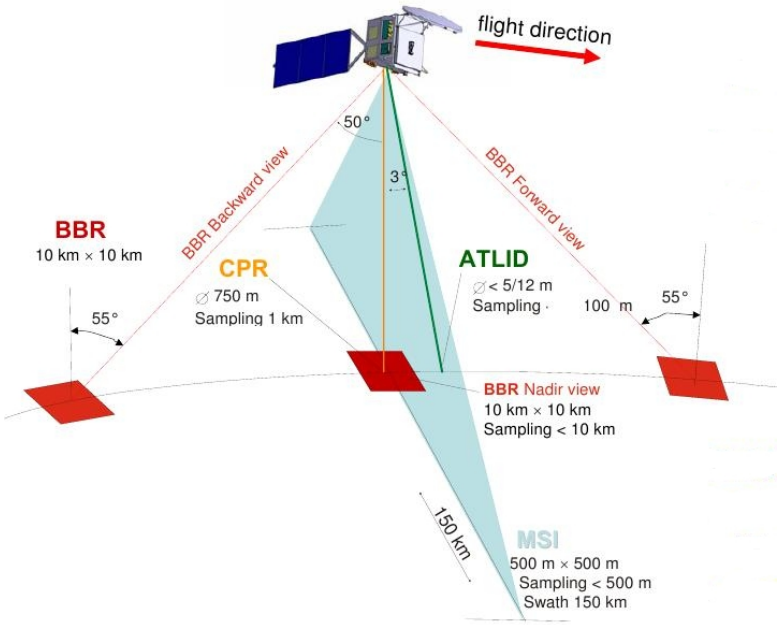
- Along track sampling: 3 telescopes (nadir 0°, fore +55°, aft -55°)
- Two spectral channels:

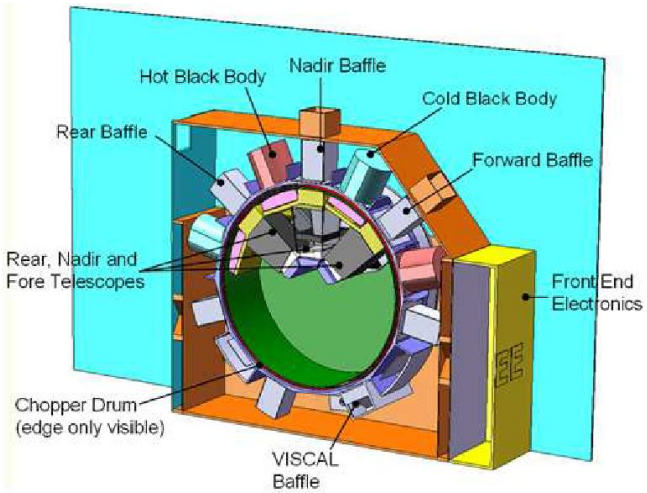
  SW (0.2 - 4 μ m)
  TOT (0.2 - 50 μ m)

- Radiometric accuracy:

  SW 2.5 $\mathrm{Wm^{-2}sr^{-1}}$
  LW 1.5 $\mathrm{Wm^{-2}sr^{-1}}$

- Pixel:
  - 10 x 10 km for the 3 telescopes
  - 0.1 pixel co-registration





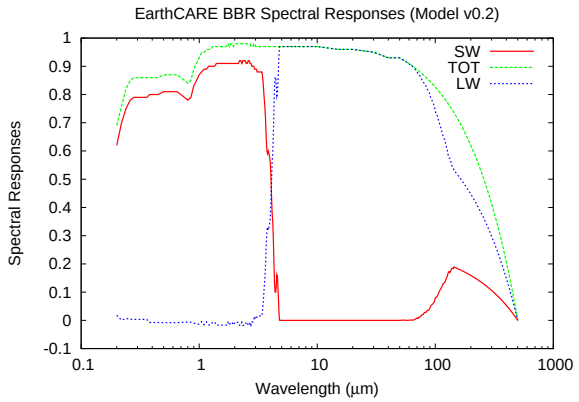
SITS

SITS: Sensitivity Study of the Influence of a Target Spectral Signature in the Unfiltering Process for Broadband Radiometers.

Objectives and deliverables of the study:

- study of the best technology to be used for the mirror (based in range of α)
- Generation of the Geotype database $\Rightarrow$ Radiative Transfer SW and LW databases
- Estimation of the Interchannel Contamination
- Stand-alone Unfiltering Algorithm (SW and LW)

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



- Scene Dependent Unfiltering Algorithm (SW)
- ATBD (Algorithm Theoretical Basis Document of the unfiltering)
- Error Analysis

$\Rightarrow$ Implementation to be done by the Ground Segment

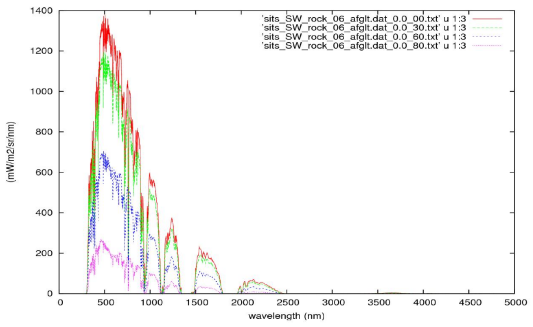
Outline

Geotype database

- Radiative tranfer code ⇒ LibRadTran v 1.4 (Mayer et al.)
- 2 theoretical databases:

  SW: 616 scenes ⇒ 5544 solar simulations
  - clear sky land: 176 scenes
  - clear sky ocean: 56 scenes
  - thick clouds: 72 scenes
  - semi-transparent clouds: 240 scenes
  - overlapping clouds: 72 scenes

  LW: 12096 thermal simulations
  - clear sky land/ocean: 540 scenes
  - thin clouds: 3024 scenes
  - "moderate clouds": 2592 scenes
  - thick clouds: 1080 scenes
  - overlapping clouds: 4860 scenes



- Time cost: Simulations run @ *plato* cluster/processor
  - 20' for SW clear sky land up to 2h 30' for ocean & overcast
  - Computation time: 20 days using 30 / 192 processors
- 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

Geotype database (2) - Surface Reflectance

- ASTER surf. reflectance

VEGE: 4 types (+ scaling to 0.8 1.0 1.2) $\Rightarrow$ 12 spectra

SNOW: 4 types (+ scaling to 0.8 1.0 1.2) $\Rightarrow$ 12 spectra

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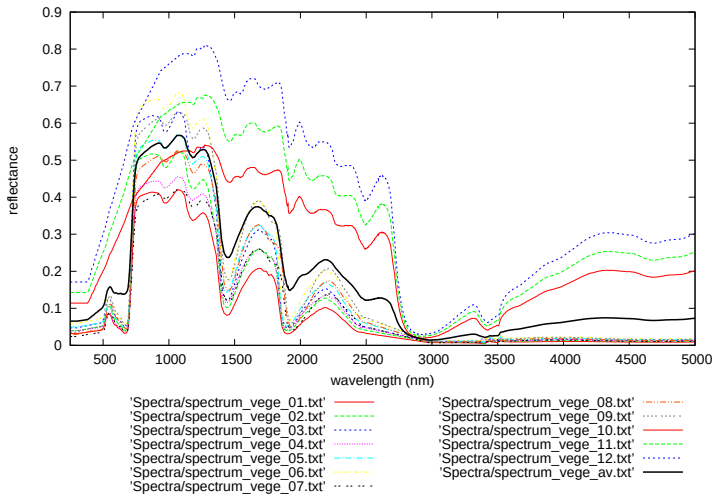

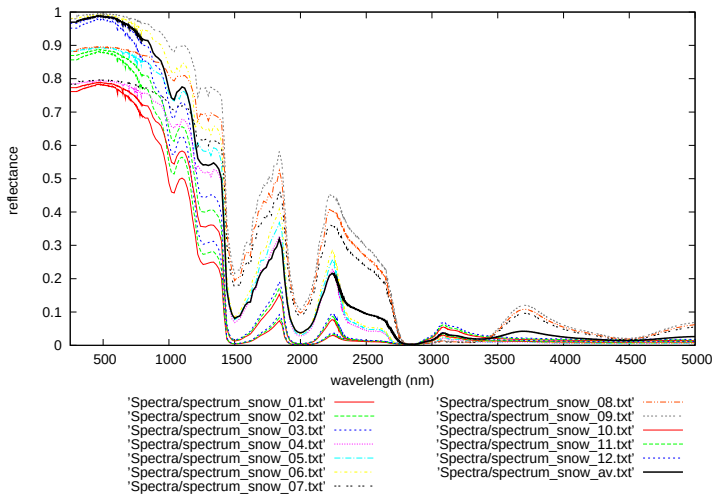

Geotype database (2) - Surface Reflectance

- ASTER surf. reflectance

ROCK: 48 types ⇒ clustering in 12 rock spectra using k-means algorithm

SOIL: 48 types ⇒ clustering in 12 soil spectra using k-means algorithm

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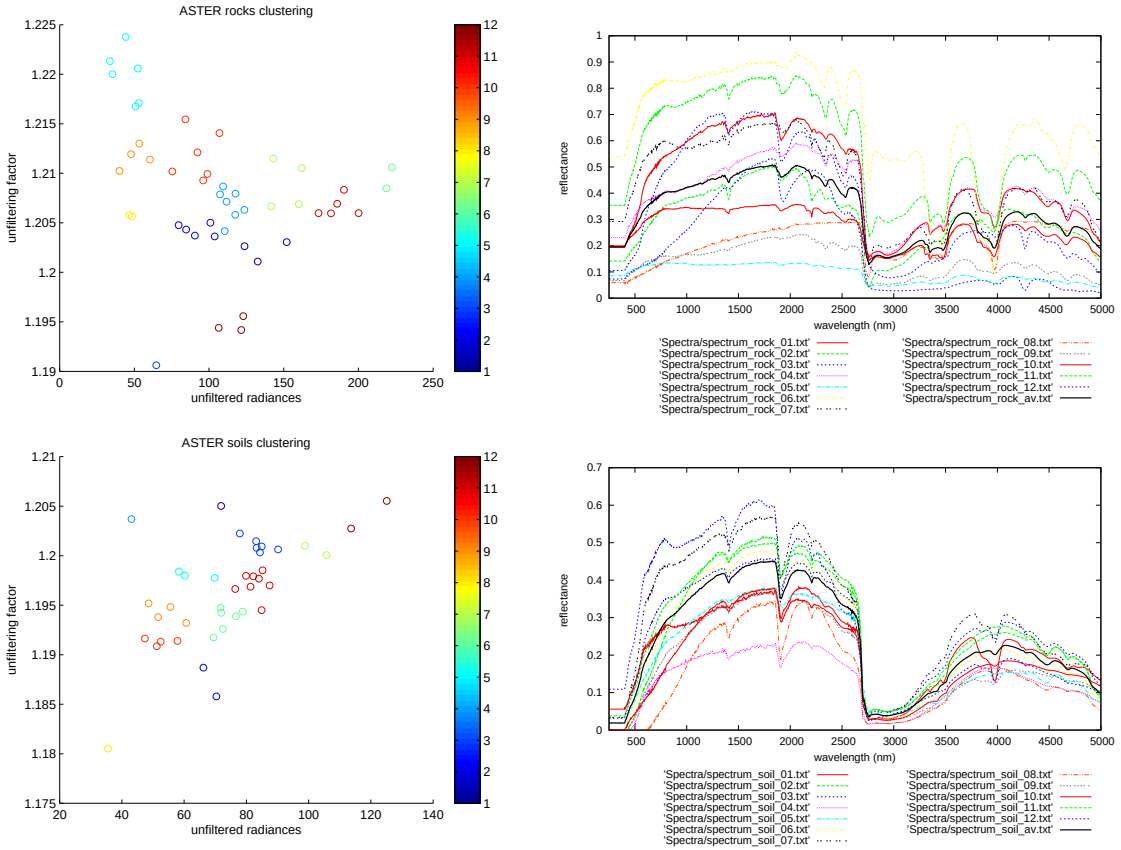


Geotype database (3)

- Ocean BRDF: Cox and Munk
- Aerosol properties computed with OPAC software:
  - extinction coefficient
  - phase function
  - single scattering albedo
  - vertical profile

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

$\Rightarrow$ Moments of the Legendre Polynomials had to be computed from OPAC phase function to use the aerosol properties built with OPAC software in LibRadTran (i.e, desert, continental, maritime, ...)

- 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

ERB missions mirror characteristics

- Earth's Radiation Budget can only be accurately determined at a global scale by means of TOA broadband radiance satellite observations.
- Different missions have been dedicated to its measurement over the last 30 years.

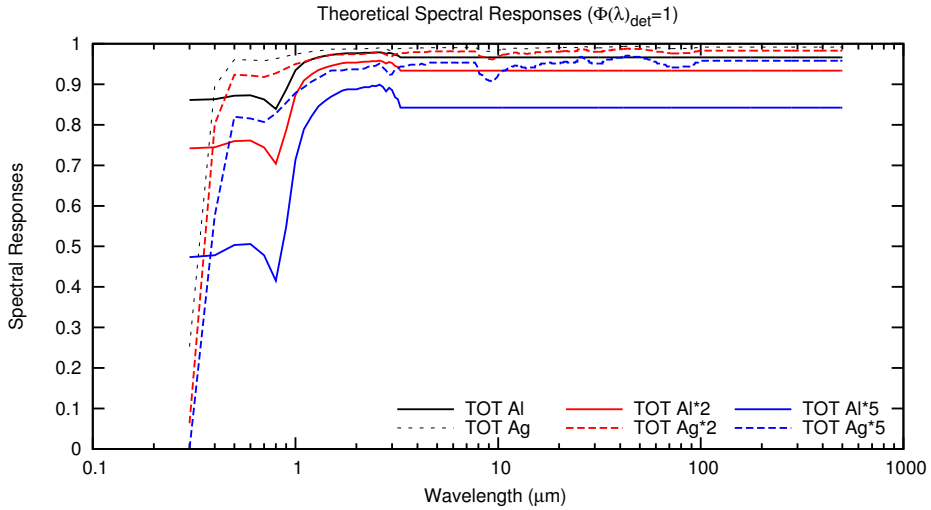
Platform	Radiometer	year	Type of mirror	N mirrors
ERBS	ERBE WFOV	1984	no mirror	0
NOAA 9 & NOAA 10	ERBE Scanners	1984 & 1986	Al	2
TRMM	CERES	1997	Ag	2
Meteor 3/7 & RESURS O1/4	SCARAB-1/2	1994 & 1998	Al	1
Terra	CERES FM1 FM2	1999	Ag	2
Aqua	CERES FM3 FM4	2002	Ag	2
Meteosat 8	GERB 2	2002	Ag	5
Meteosat 9	GERB 1	2005	Ag	5
Meghatropics	SCARAB	2011	Al	1
NPP	CERES FM5	2011	Al	2
EarthCARE	BBR	2013?	Al	1

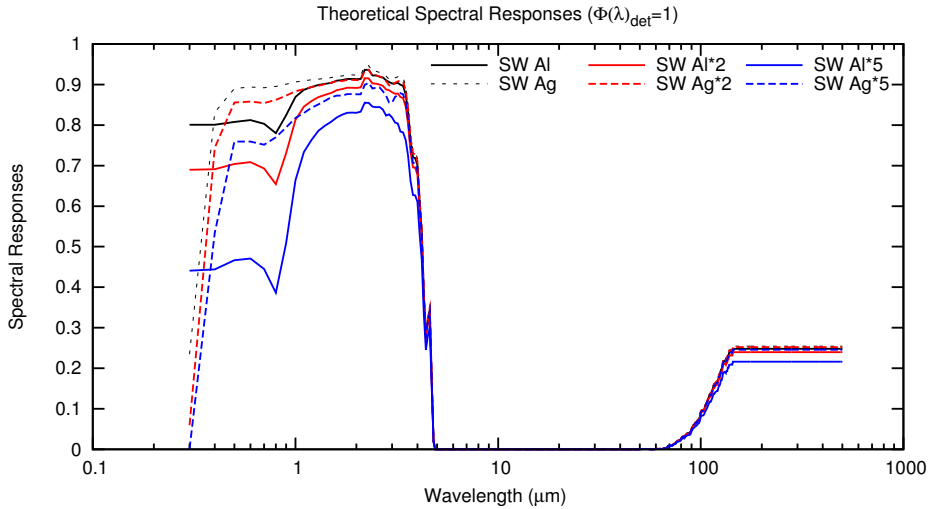
- Same spectral range:
  - SW: 0.2-4.0 μm
  - TW: 0.2-100 μm
- Different optical design

Theoretical Spectral Responses

$$\phi_{tot}(\lambda) = \phi_{det}(\lambda) \cdot \phi^n_{mirror}(\lambda)$$

$$\phi_{sw}(\lambda) = \phi_{det}(\lambda) \cdot \phi^n_{mirror}(\lambda) \cdot \phi_{quartz}(\lambda)$$





- $\phi_{det}(\lambda) = 1$ to evaluate the effect of the mirrors in the unfiltering
- GERB quartz filter transmission data has been used.

Weighting of the database radiances with the Spectral response

Spectral database radiances are weighted with the theoretical spectral responses and integrated in the band in order to compute theoretical filtered and unfiltered radiances.
The SR used are:

- $\phi_{SW} = 1$: constant value of 1 at all wavelengths $\rightarrow$ theoretical unfiltered radiances

$$L_{sol} = \int L_{sol}(\lambda) d\lambda$$

- Spectral responses for SW $\rightarrow$ theoretical filtered radiances for the cases:

$$L_{sol} = \int L_{sol} \phi_{SW}(\lambda) d\lambda$$

  - No mirror
  - 1 Aluminum mirror
  - 1 Silver mirror
  - ...
  - 5 Aluminum mirrors
  - 5 Silver mirrors

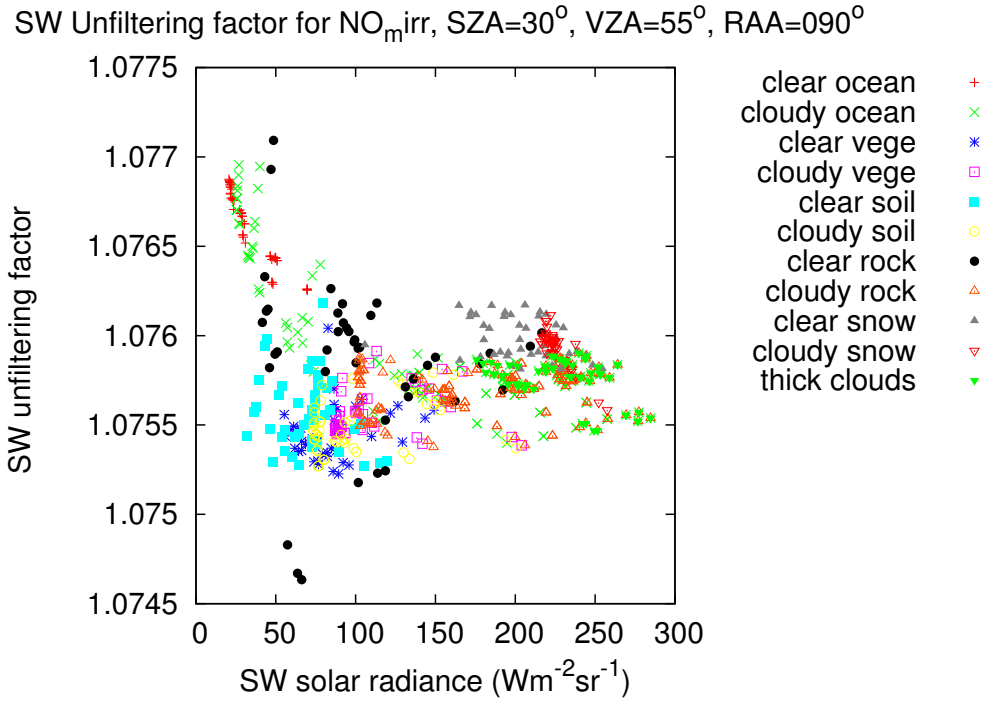
Stand-Alone SW Unfiltering

$$L_{sol} = a \cdot L_{sw,sol} + b \qquad L_{sol} = b + a \cdot L_{sw,sol} + c \cdot L^2_{sw,sol}$$

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

Coefficients dependent on SZA, VZA, RAA.

SW unfiltering factors range increase with number of mirrors



Full description of the method and results in "ATBD"

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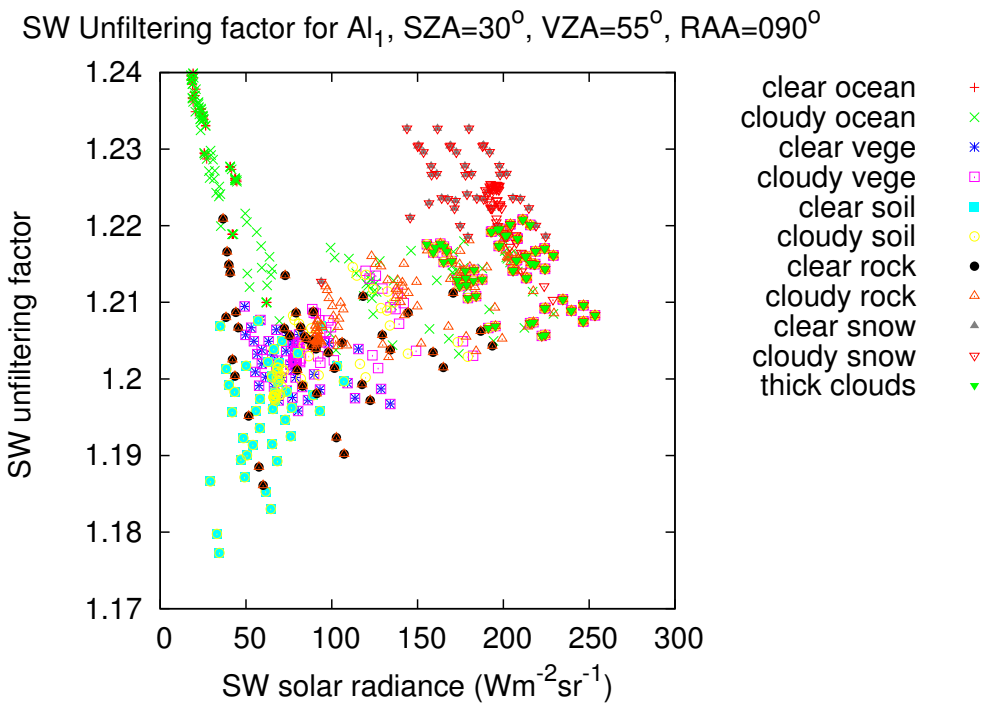

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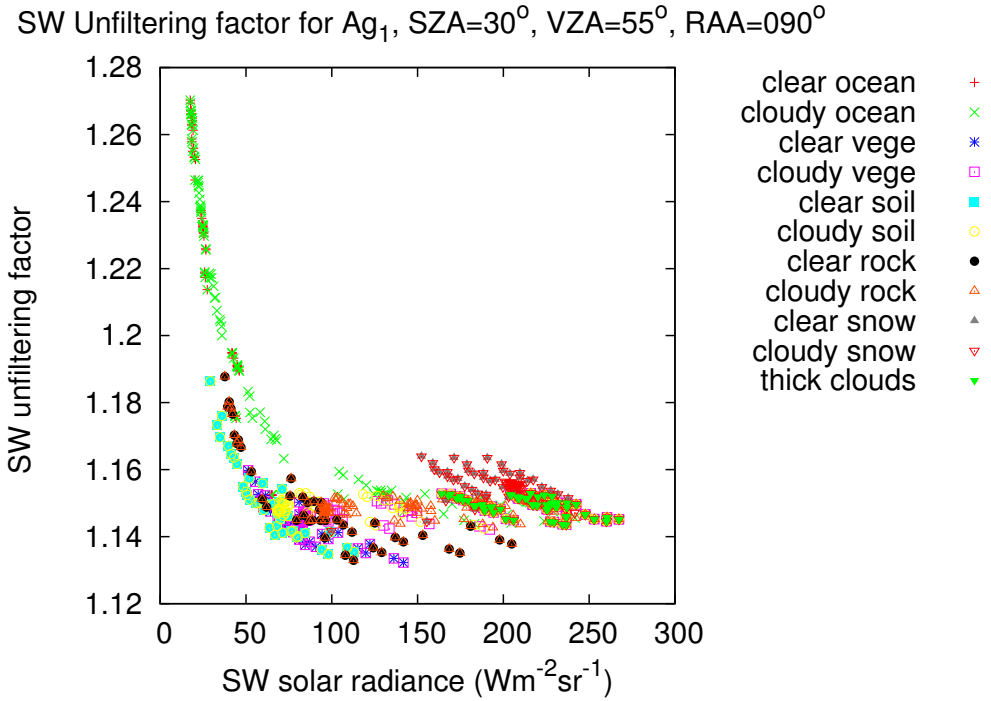

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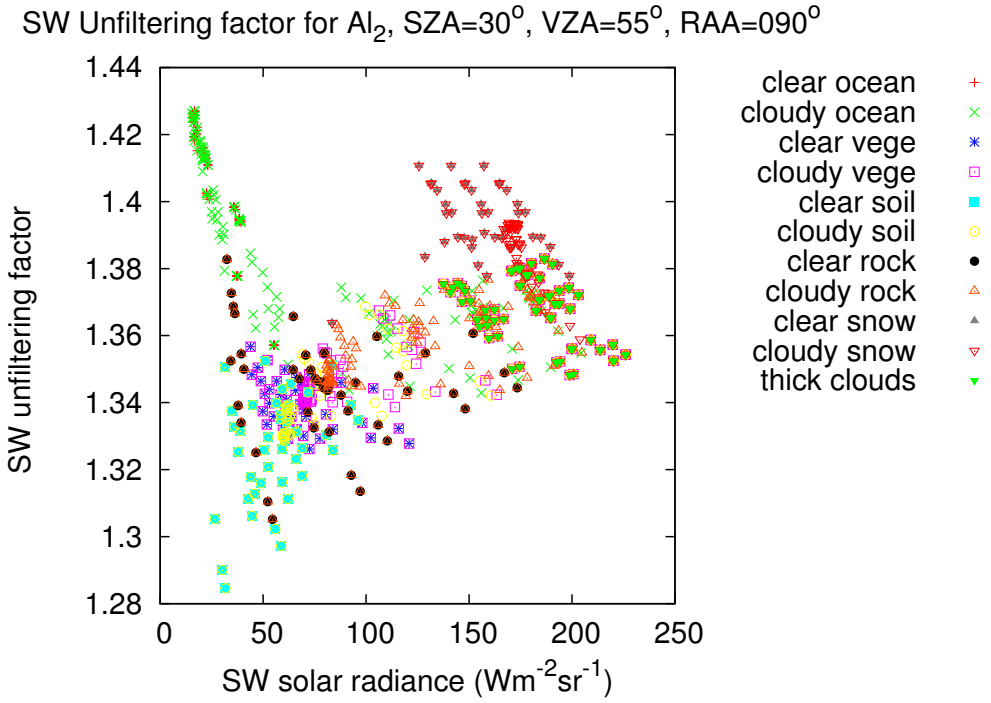

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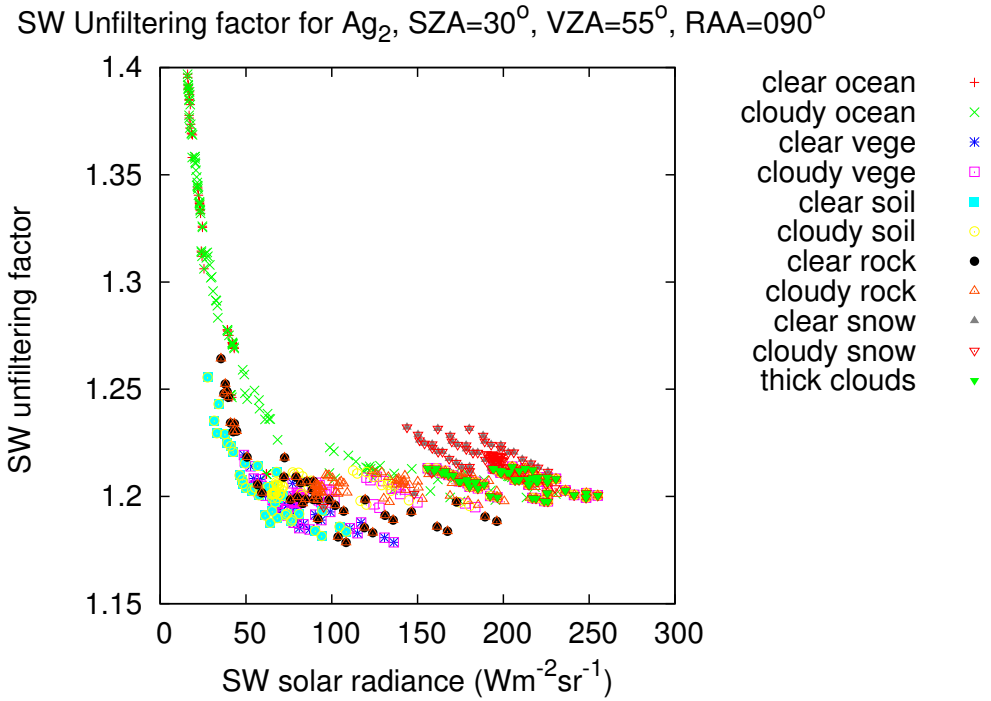

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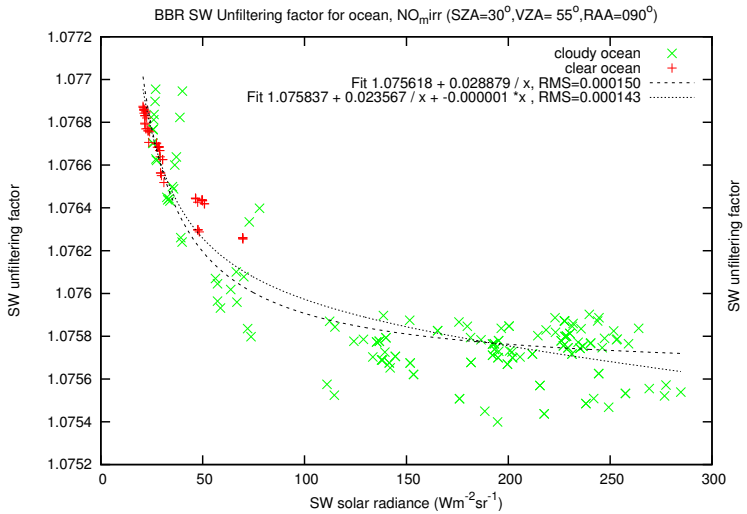
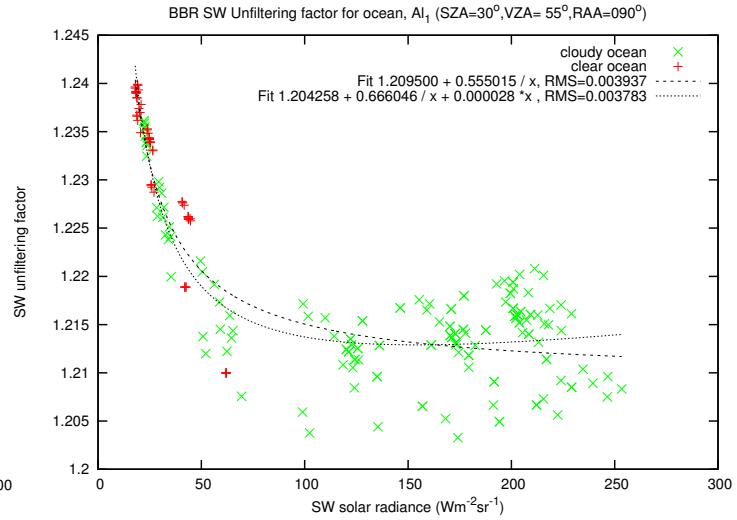
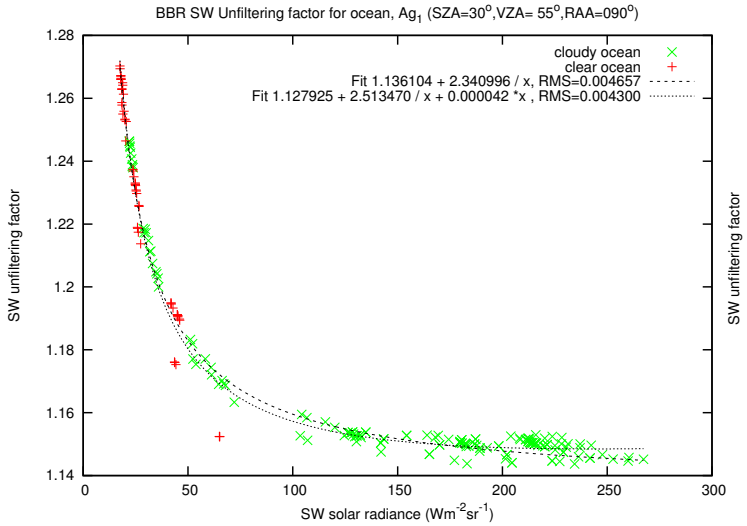
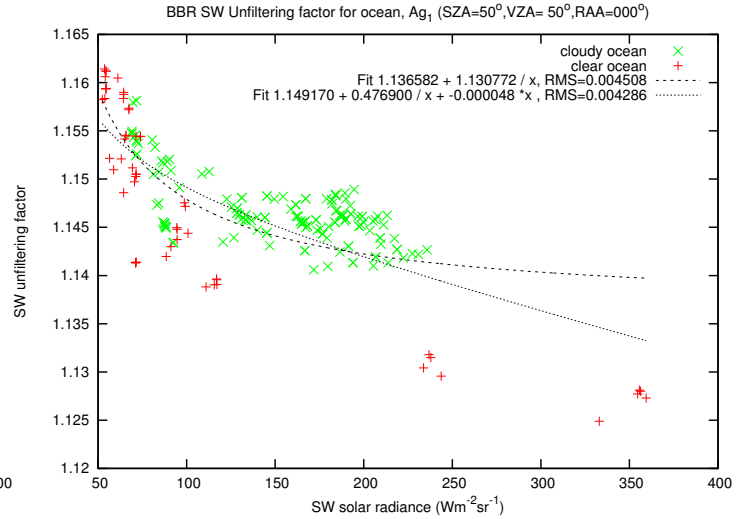
Stand-Alone SW Unfiltering(2)









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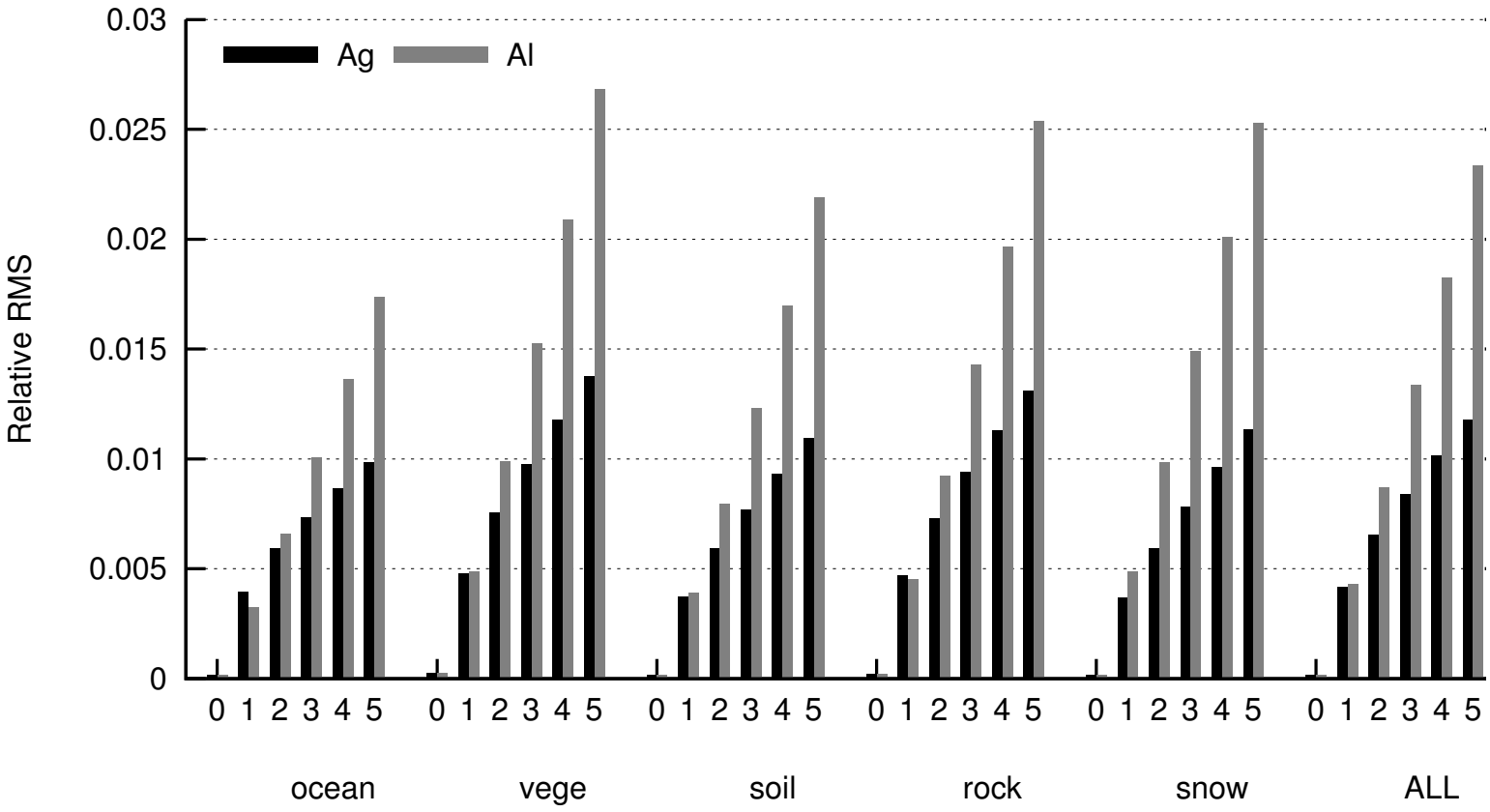
Relative RMS



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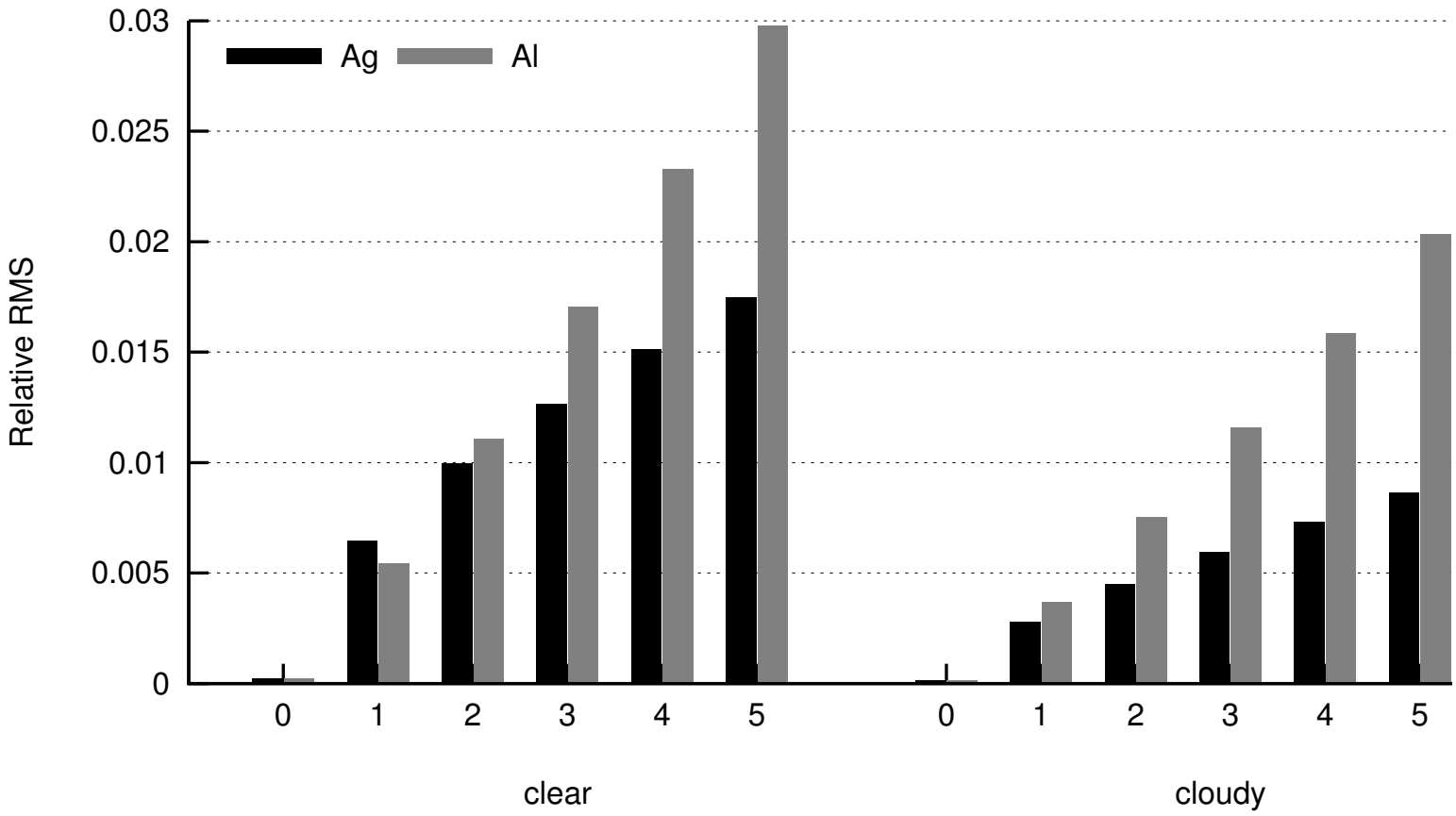

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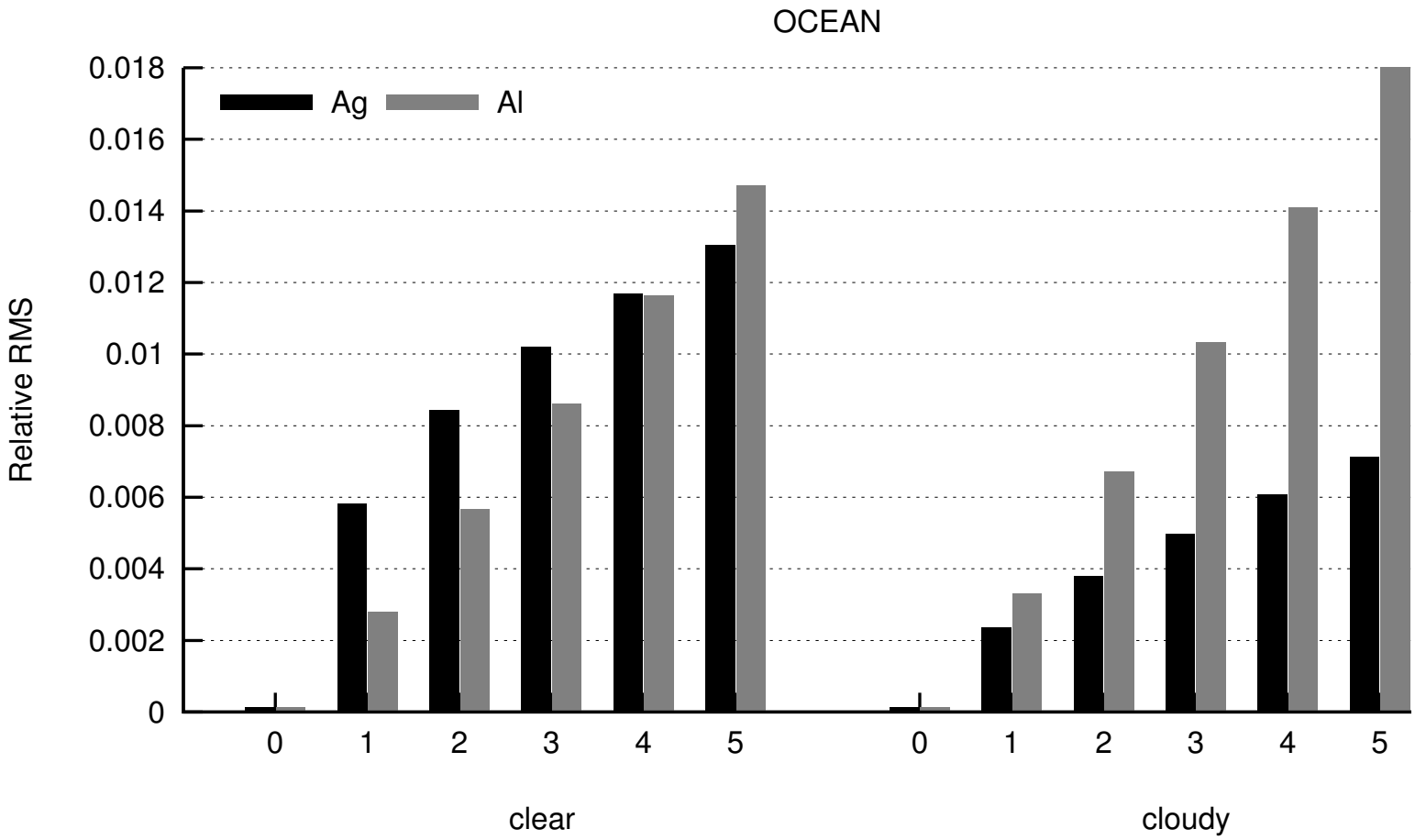

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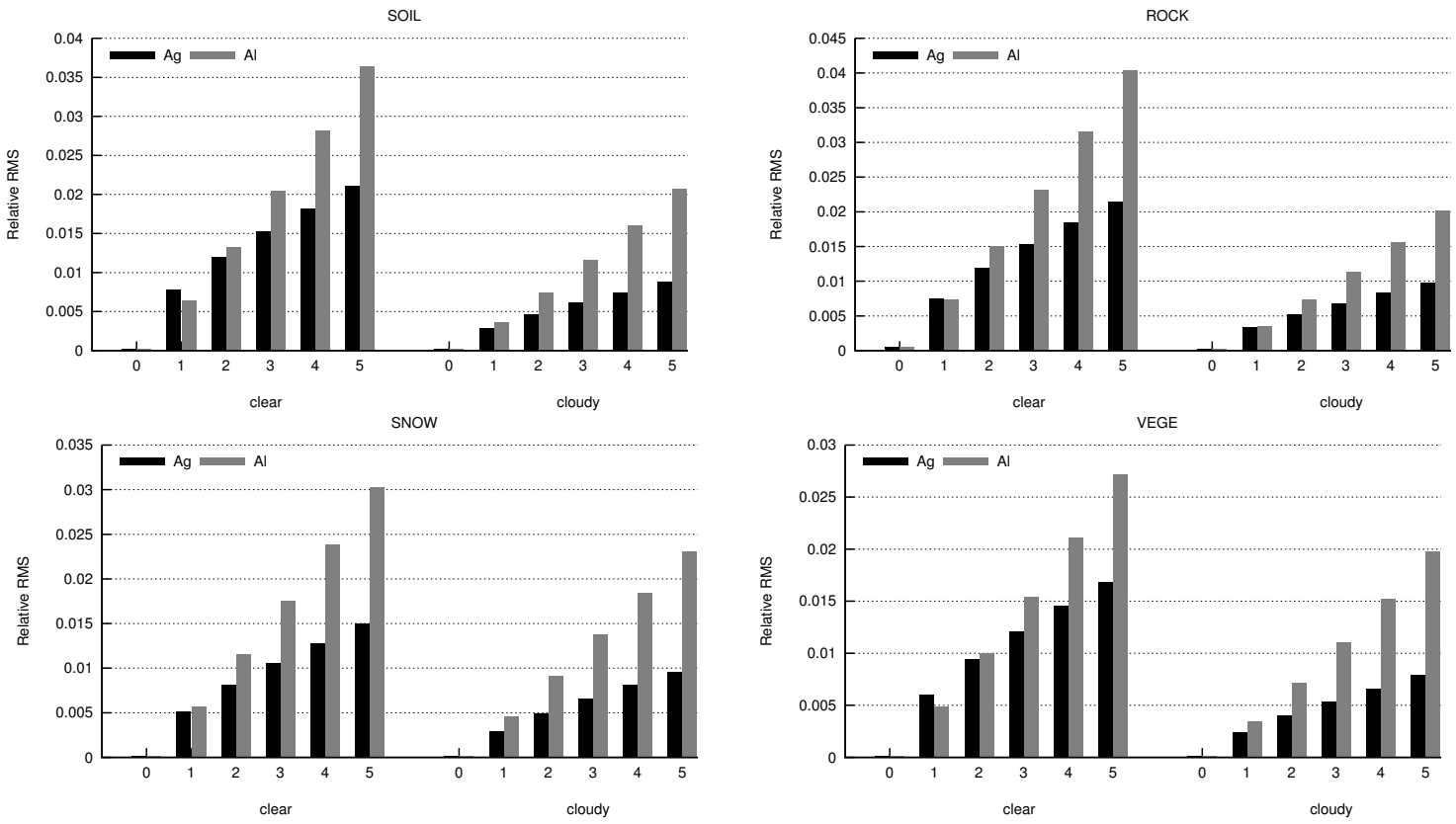

Outline

Conclusions

- Geotype database available under request.
- Geotype database definition is physically more representative than the GERB database ⇒ could be used to improve the GERB LW ADM's
- Variability in Spectral Response increase with the number of mirrors
- Unfiltering factor range increase as number of mirror increase
- Al enhanced UV response mirrors performs better than Ag when observing clear ocean scenes (with or without aerosols) up to 3 mirrors
- Cloudy scenes shows similar relative errors (probably different for semi-t clouds)
- In general, as from 2 mirrors, Ag introduce less error than Aluminum
- Thermal contamination in the reflected solar channel has not been considered ($\tilde{0}.05\%$ for EC BBR). It could be estimated with night time measurements, as the measure in the SW channel will correspond to the thermal contamination.