Spectral ageing model for the Meteosat First Generation visible band

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Vrije Universiteit Brussel

Royal Meteorological Institute of Belgium

March 2014

Outline

Introduction – Meteosat First Generation

- Meteosat Visible and Infrared Imager (MVIRI)
  - 6 instruments (02/1982 – 07/2006)

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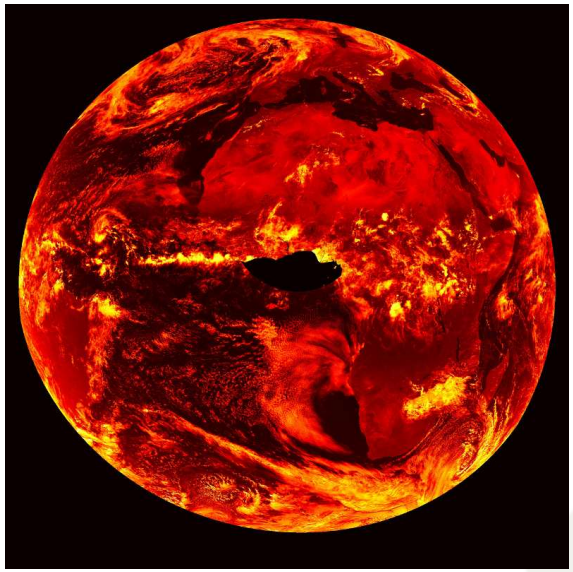

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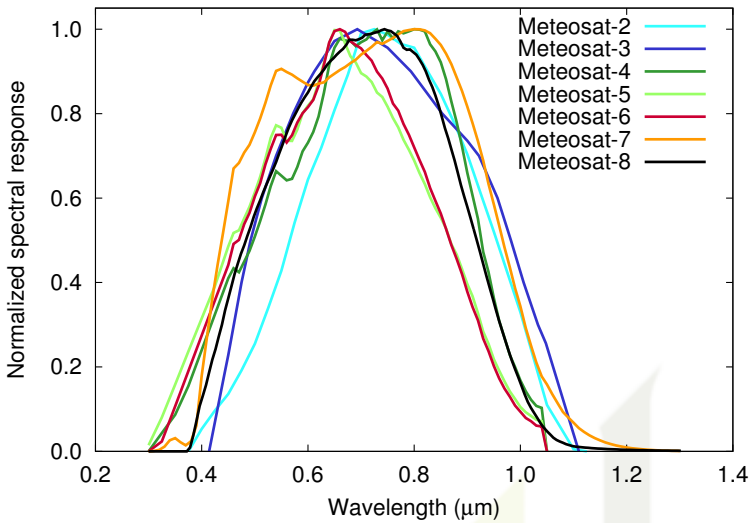
  - Visible channel (0.3 – 1.2 µm)



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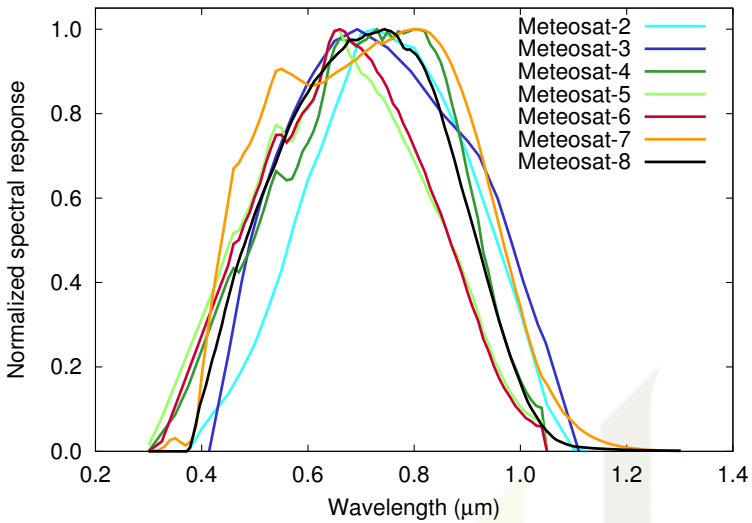

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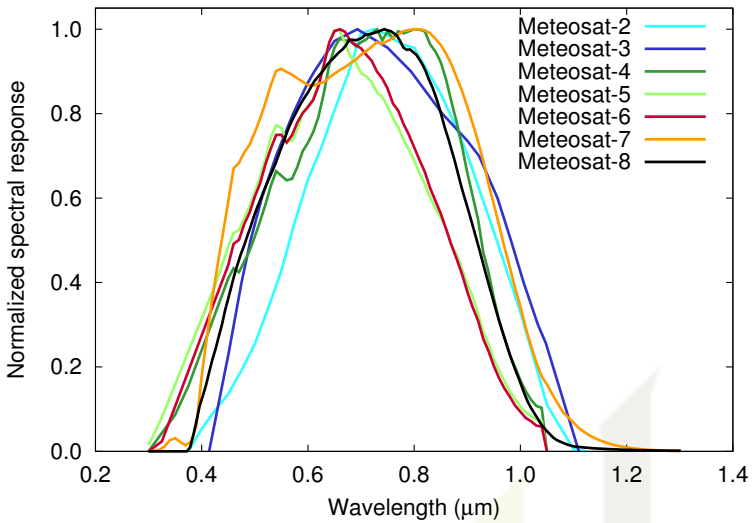

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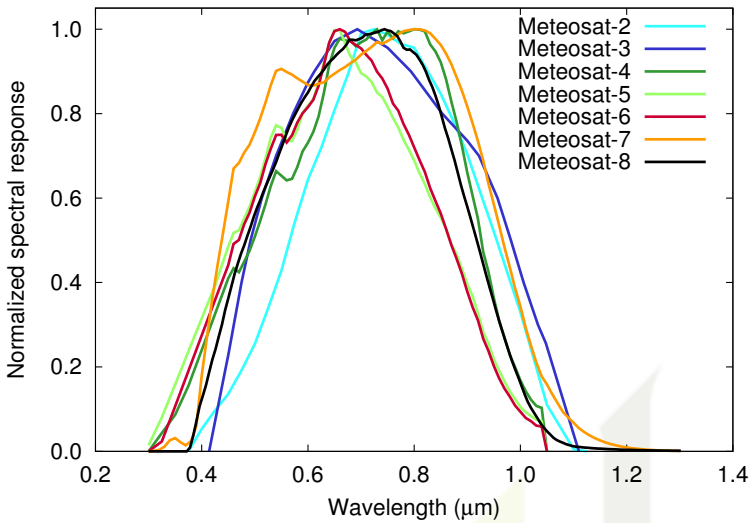

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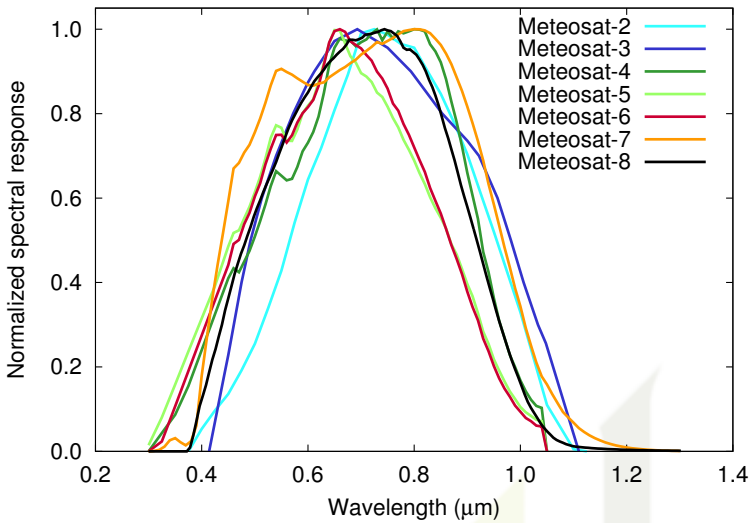

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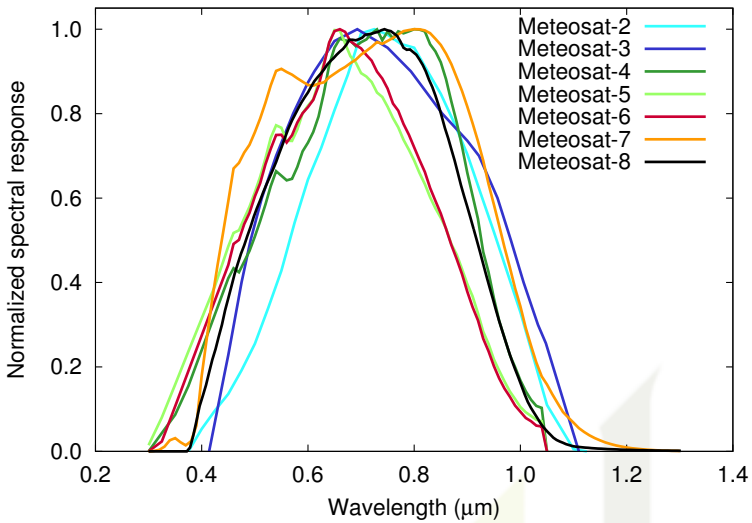

Introduction – In-flight degradation

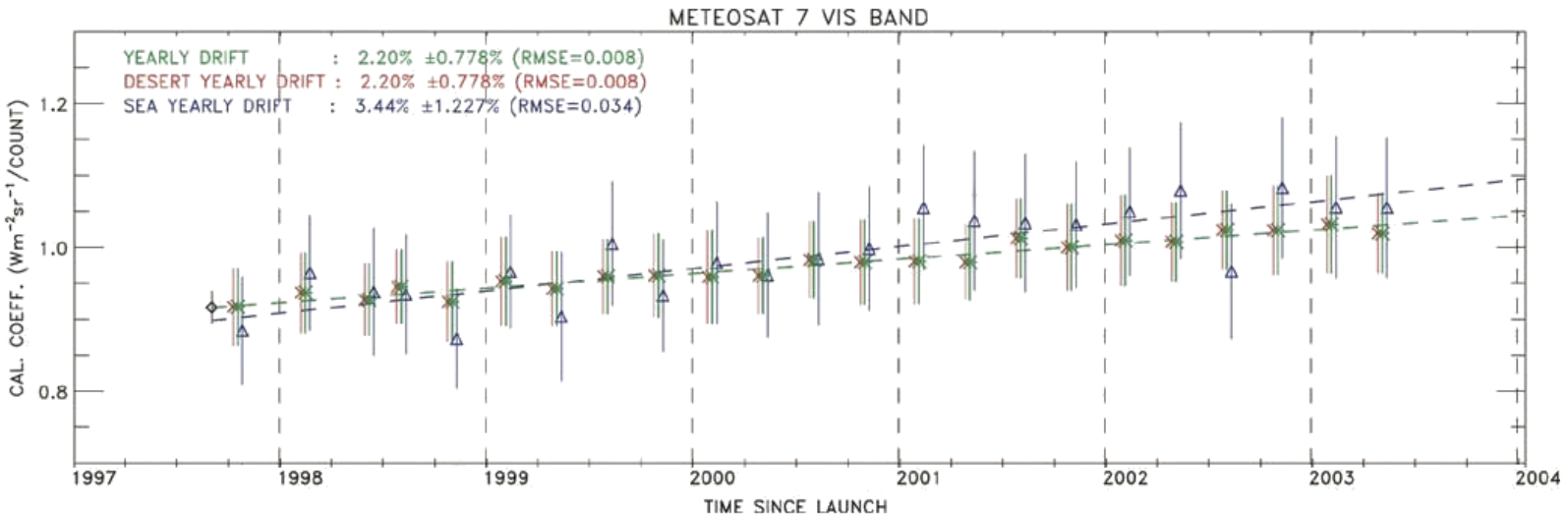

Figure : *VIS calibration coefficients for Meteosat-7 (Govaerts et al. 2004).*

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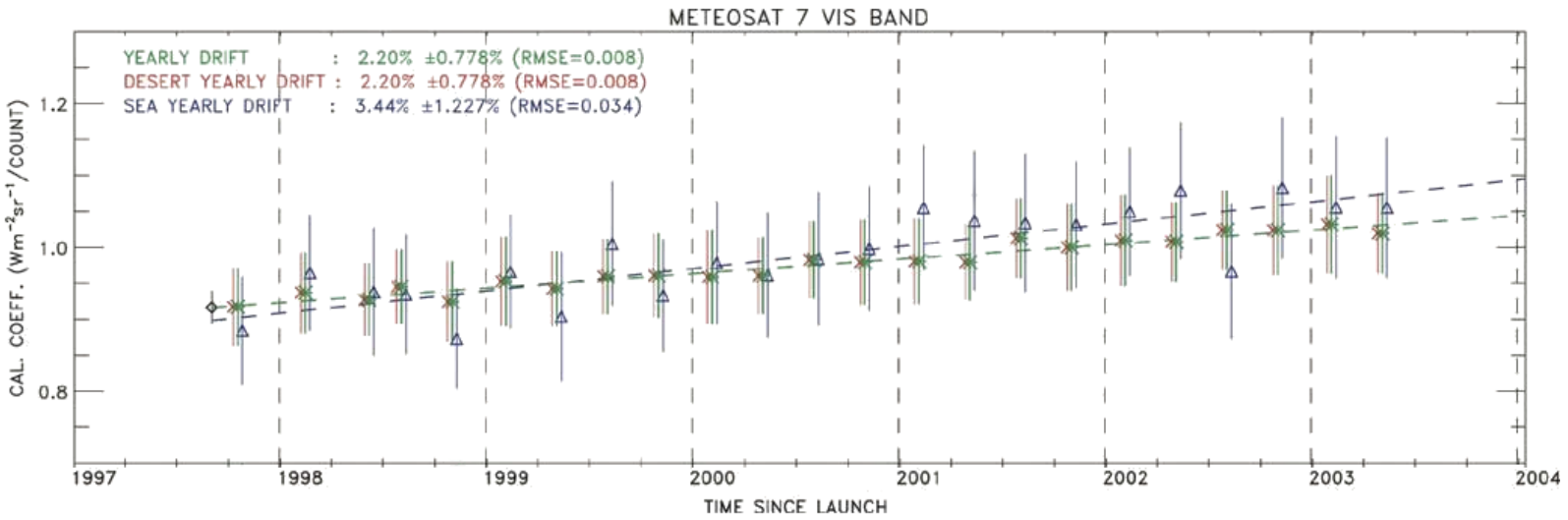

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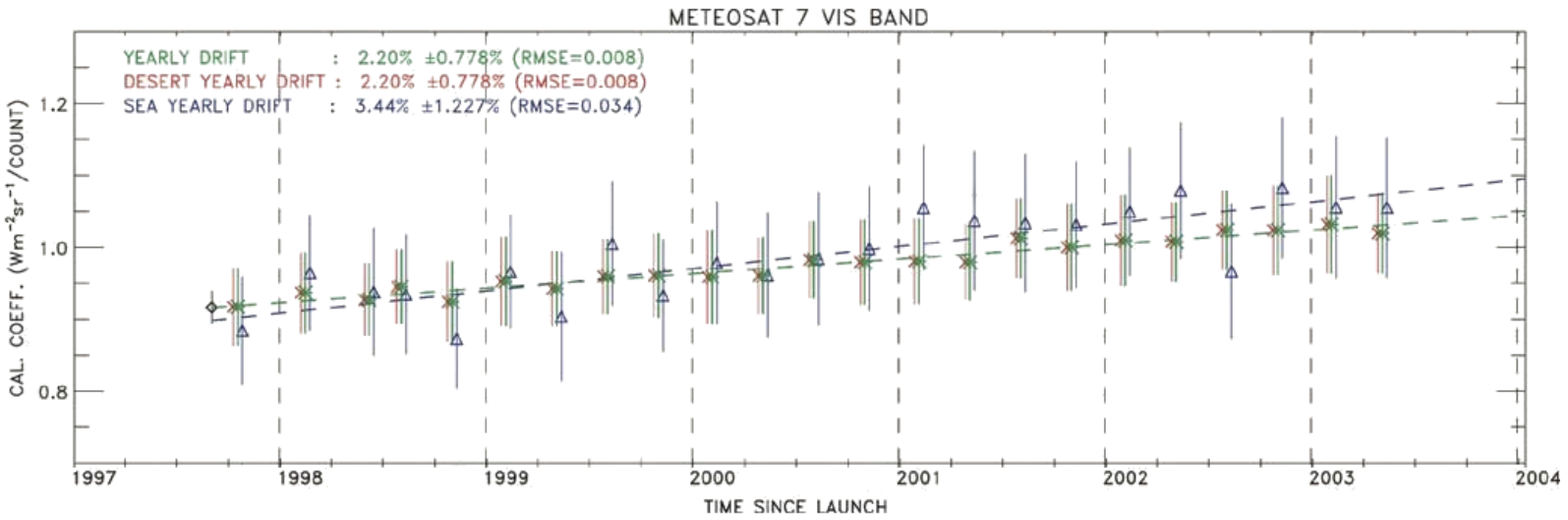

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- Saturation of the drift

Outline

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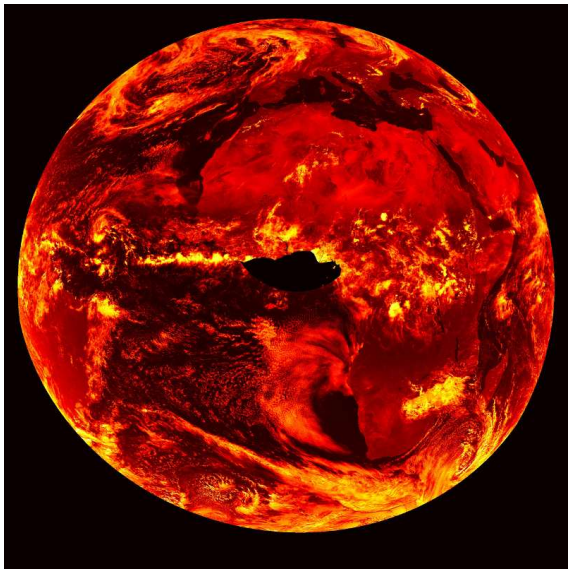
- 1200 UTC images: converted from DC to reflectance



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- 1200 UTC images: converted from DC to reflectance
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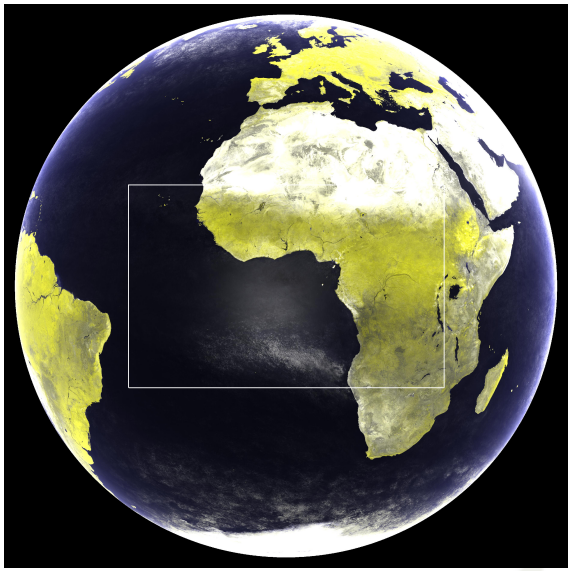

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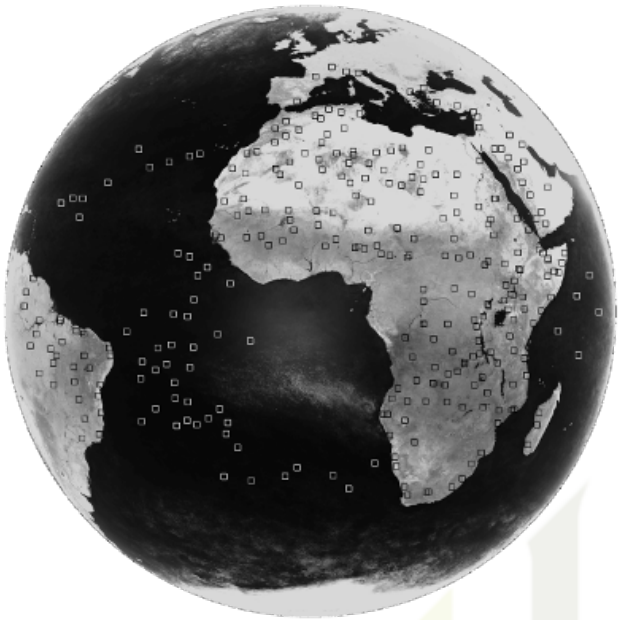

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- 1200 UTC images: converted from DC to reflectance
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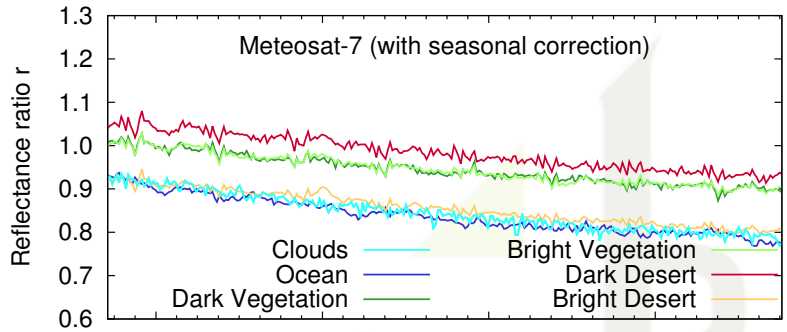

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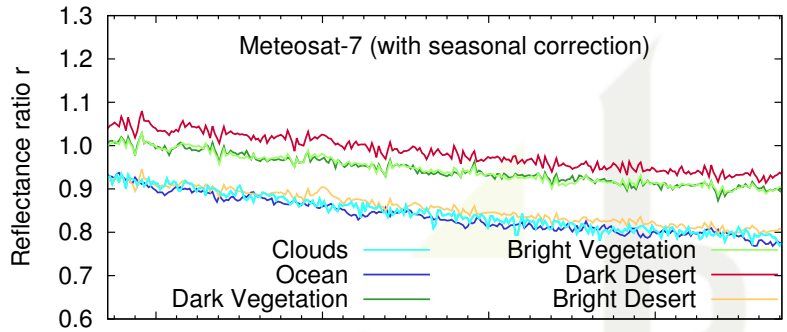

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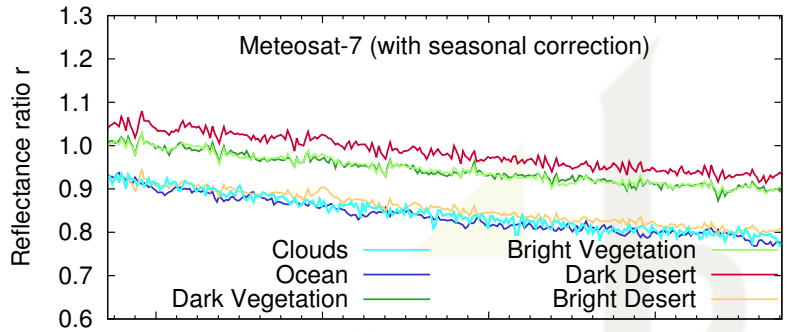

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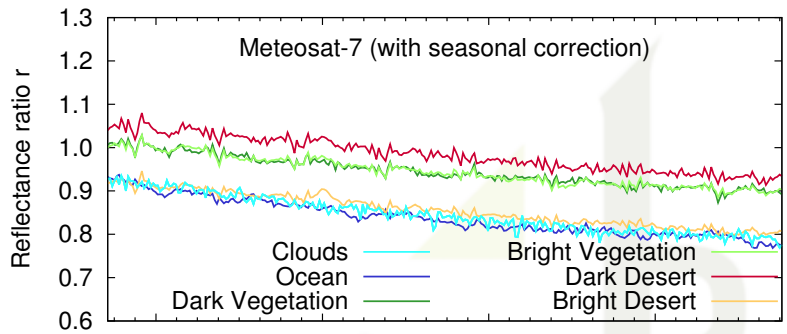

(1) Spectral ageing model – mathematical formula

- Semi-empirical model of spectral response curve $\phi(\lambda, t)$

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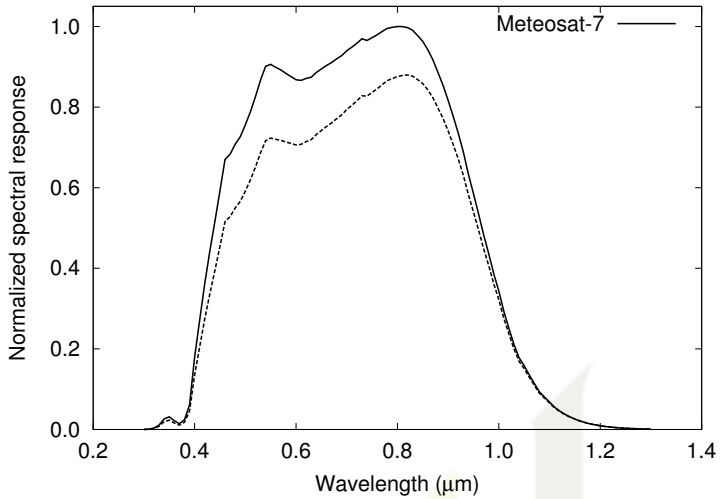

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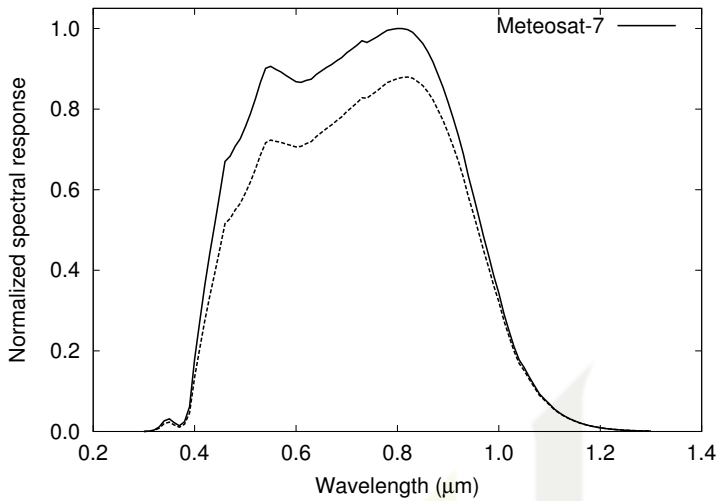

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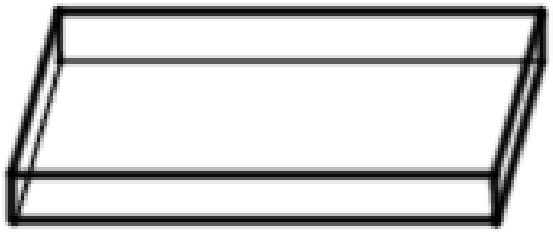

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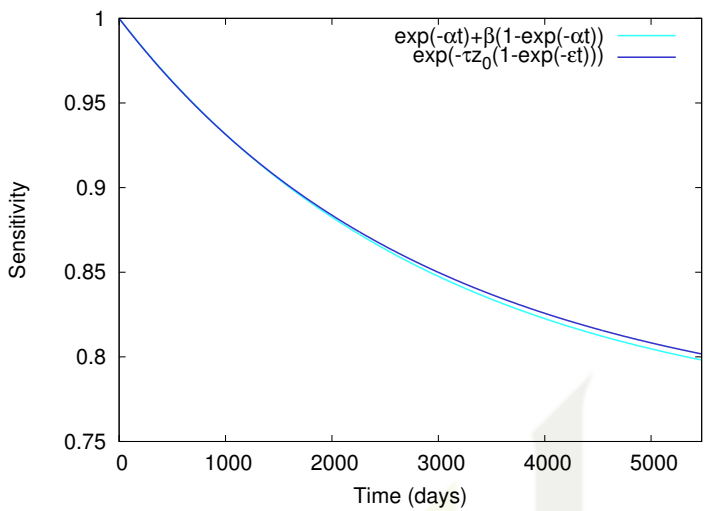

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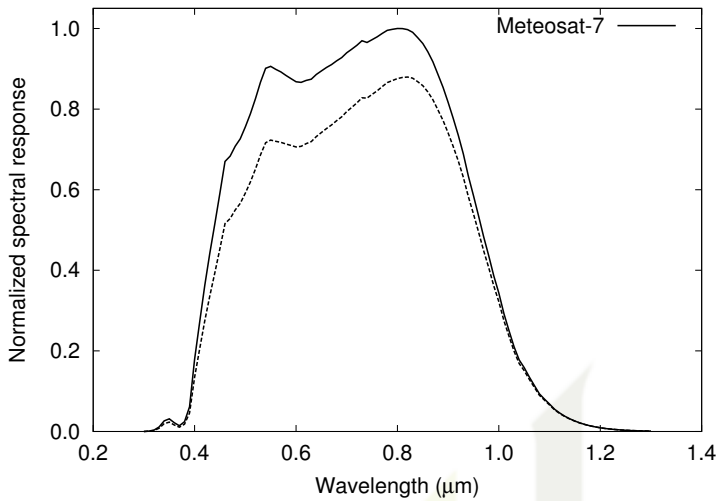

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- Parameter fitting
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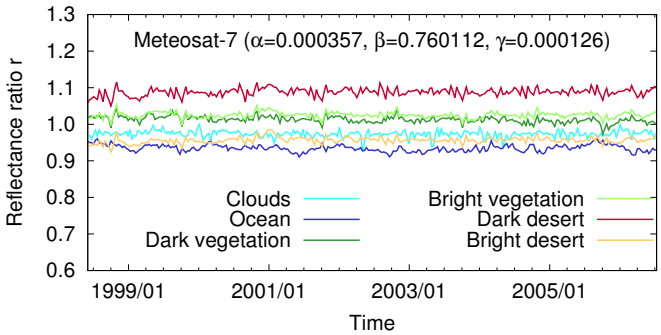

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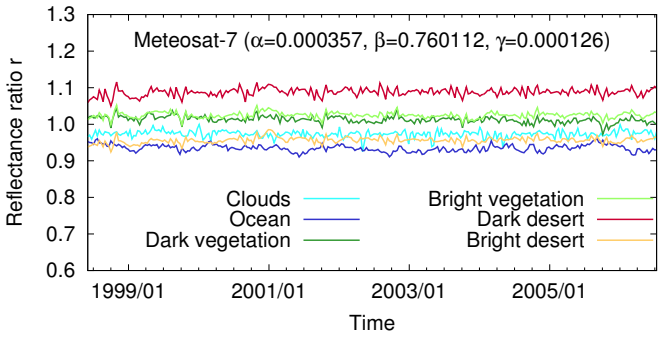

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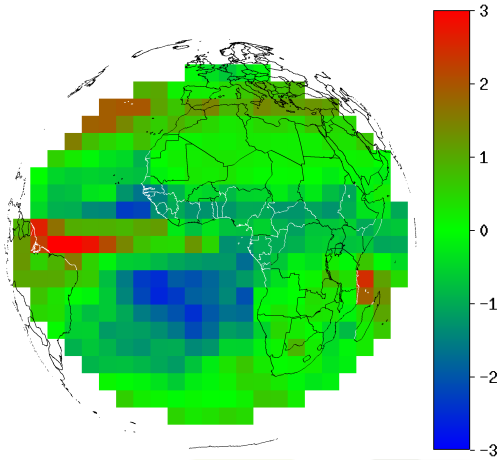

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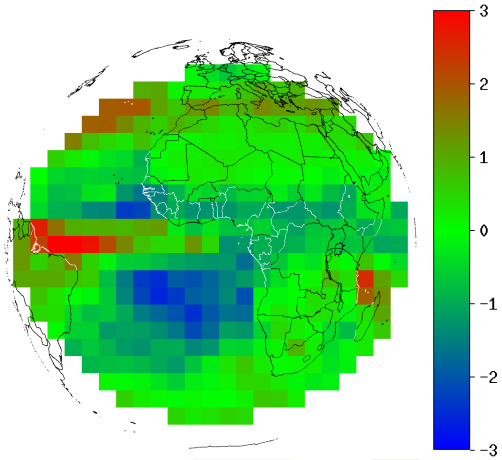

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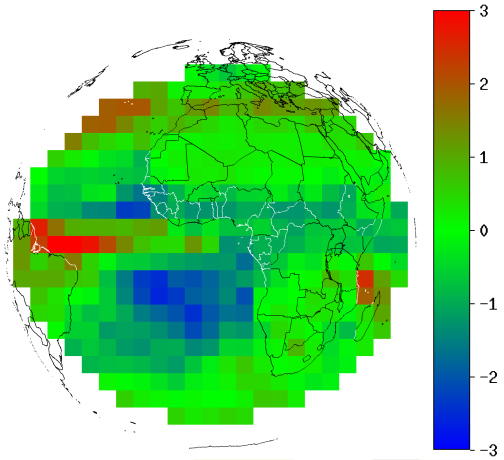

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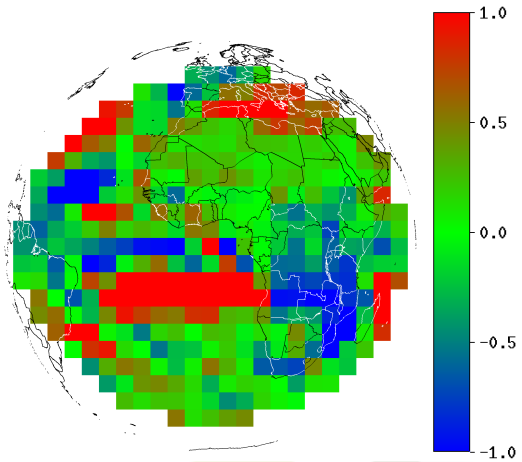
  - all-sky images (01/99–12/05): $\sigma = 0.6\%\text{yr}^{-1}$



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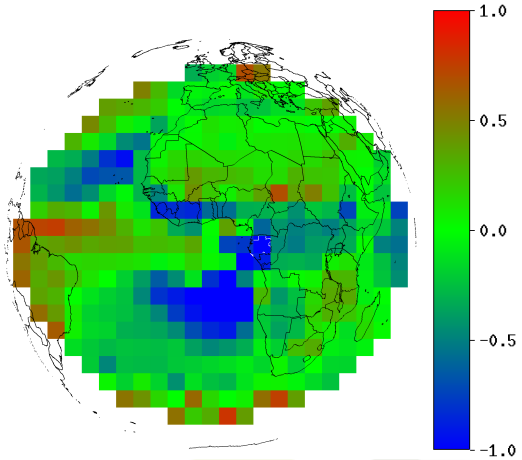

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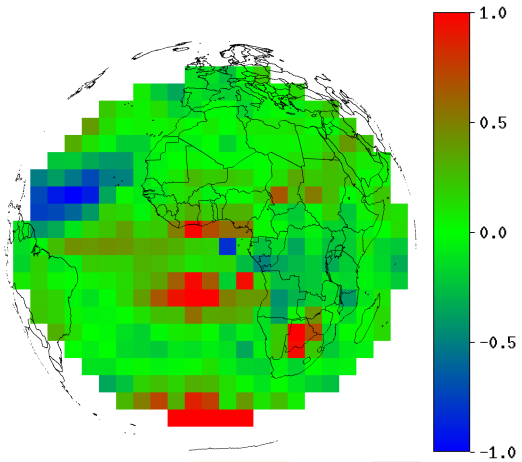

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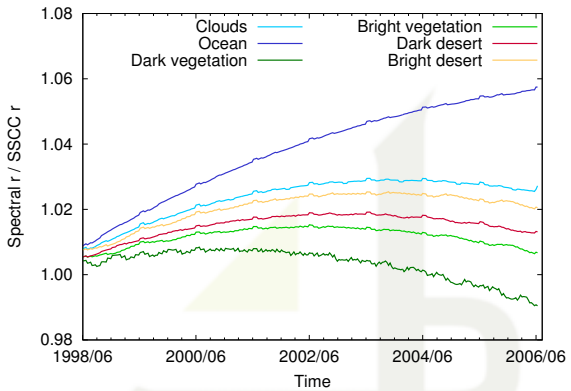

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- Apply linear calibration increase
- Published in March 2013

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ABSTRACT

For more than 30 years, the Meteosat satellites have been in a geostationary orbit around the earth. Because of the high temporal frequency of the data and the long time period, this database is an excellent candidate for fundamental climate data records (FCDRs). One of the prerequisites to create FCDRs is an accurate and stable calibration over the full data period. Because of the presence of contamination on the instrument in space, a degradation of the visible band of the instruments has been observed. Previous work on the Meteosat First Generation satellites, together with results from other spaceborne instruments, led to the idea that there is a spectral component to this degradation. This paper describes the model that was created to correct the *Meteosat-7* visible (VIS) channel for these spectral aging effects. The model assumes an exponential temporal decay for the gray part of the degradation and a linear temporal decay for the wavelength-dependent part. The effect of these two parts of the model is tuned according to three parameters; 253 clear-sky stable earth targets with different surface types are used together with deep convective cloud measurements to fit these parameters. The validation of the model leads to an overall stability of the *Meteosat-7* reflected solar radiation data record of about 0.66 W m^{-2} $decade^{-1}$.

1. Introduction

One of the primary goals of satellites in the twentieth century was to observe weather, ocean, and land for forecasting purposes (Szekielda 1988). When the data records became sufficiently long, the usefulness of these satellites for climatological studies was recognized. This led to the creation of the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) Climate Monitoring Satellite Application Facility (CM SAF) in 1999. From the satellite data, fundamental climate data records (FCDRs) were generated. These are time series that cover different instruments and have been extensively tested and calibrated to ensure consistency over the entire record (WMO 2006). Geophysical variables [essential climate variables (ECVs)] such as cloud properties, precipitation, ozone, albedo, etc., were derived from these FCDRs, forming thematic climate date records (TCDRs). Stability requirements for such TCDRs are very strict. For example, the Global Climate Observing System (GCOS) requires a stability of 0.2 W m^{-2} $decade^{-1}$ for the top-of-atmosphere earth radiation budget (WMO 2006).

These requirements are, however, usually not met using the original data. Postprocessing and intercalibrations are done to meet the criteria. An example of this is the work done by Yang et al. (2011), who demonstrate the impact and importance of the Special Sensor Microwave Imager (SSM/I) intersensor calibration for the improved FCDRs and TCDRs. Satellites in geostationary orbit provide information on a fixed viewing geometry throughout the whole day, which allows the creation of quite accurate and stable FCDRs and TCDRs.

The Meteosat First Generation (MFG) program consists of seven geostationary satellites, *Meteosat-1* through

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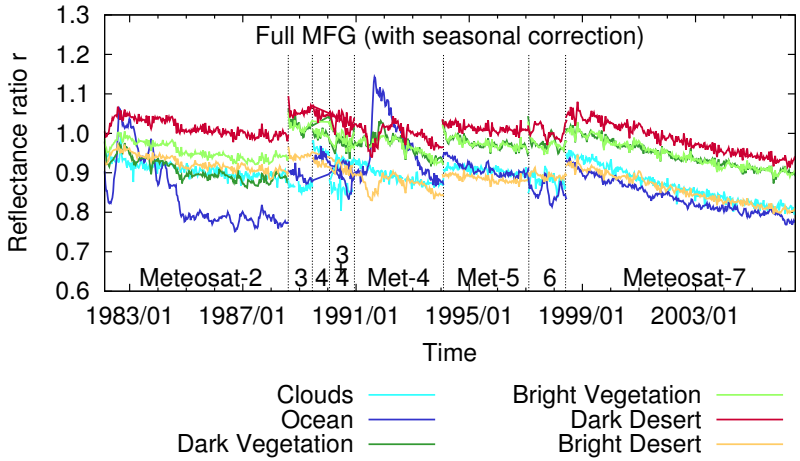
Outline

(3) Full MFG – spectral ageing correction

- Problems in original time series



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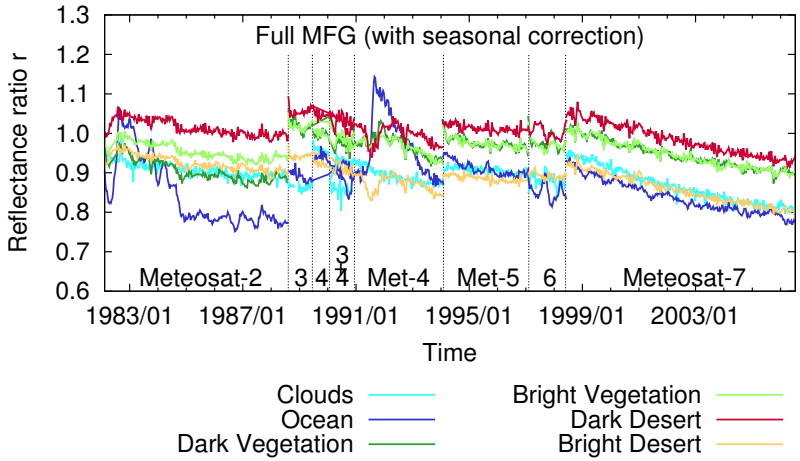
  - volcanic eruptions corrected through least-squares fitting with GACP AOD dataset



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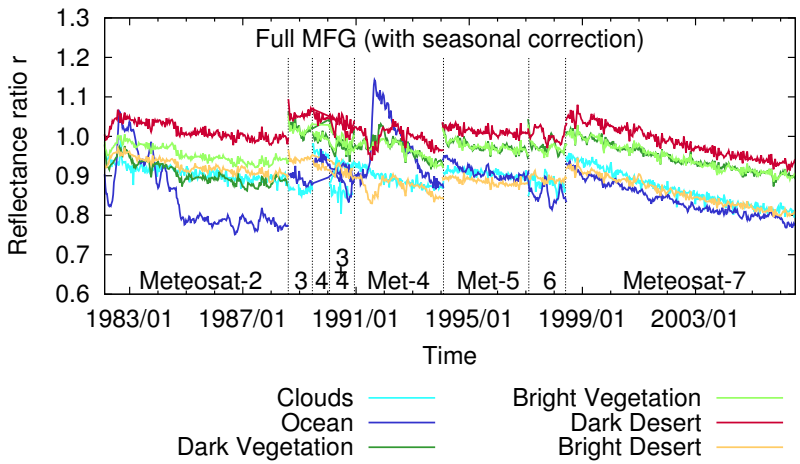
  - 6-bit digitisation



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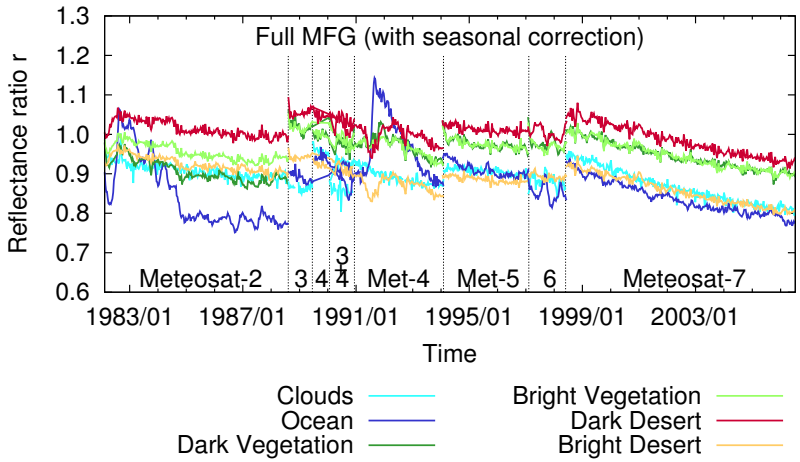
  - saturation



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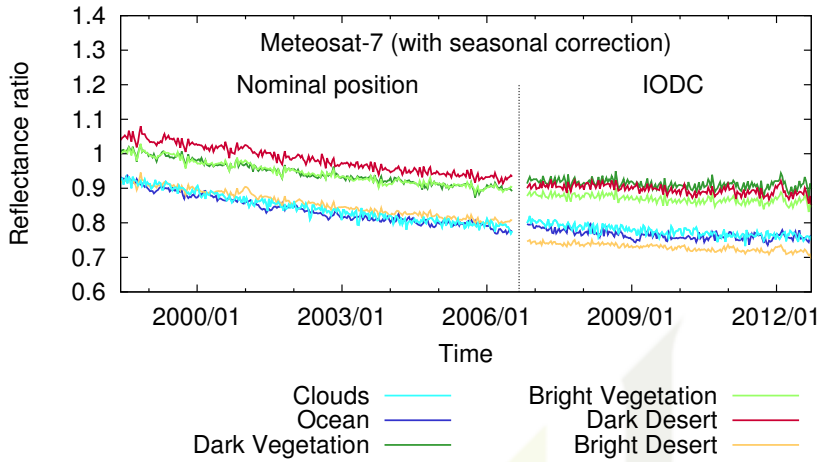
  - saturation
- Used ADC/XADC and IODC to improve model parameters



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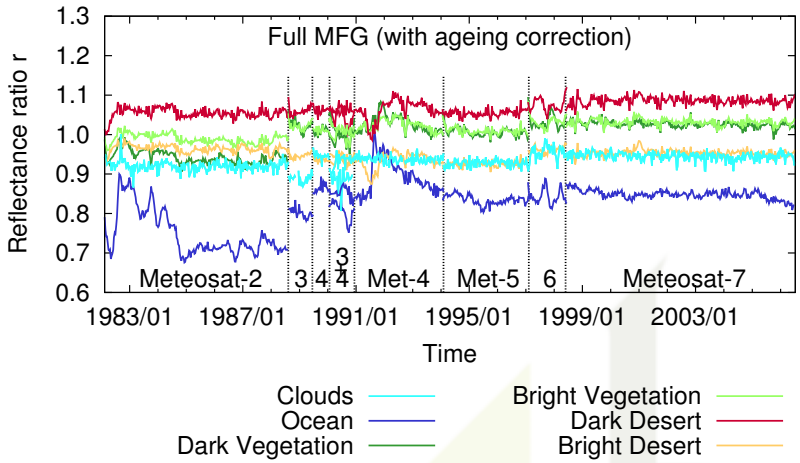
  - parameter fitting through minimisation



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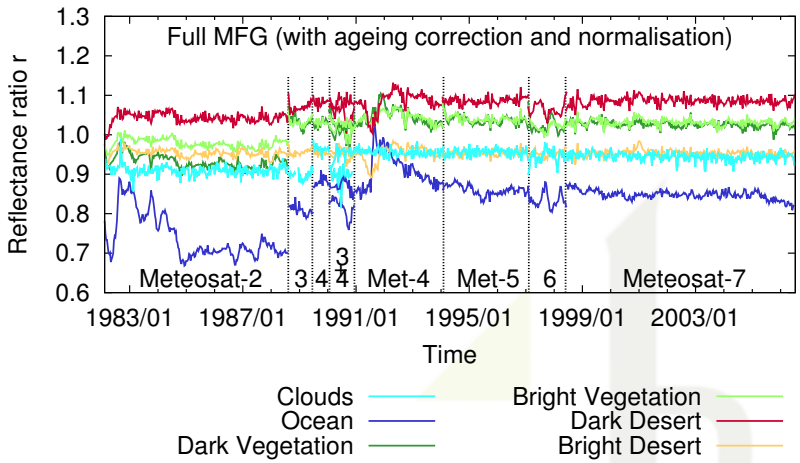
  - normalisation with respect to Meteosat-7 bright desert



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- Long-term stability

Surface type	Met-4 – 7 (17 yrs)	Met-2 – 7 (24 yrs)
Clouds	0.0123	0.0239
Ocean	0.0167	0.0611
Dark vegetation	0.0140	0.0437
Bright vegetation	0.0120	0.0266
Dark desert	0.0142	0.0230
Bright desert	0.0098	0.0099

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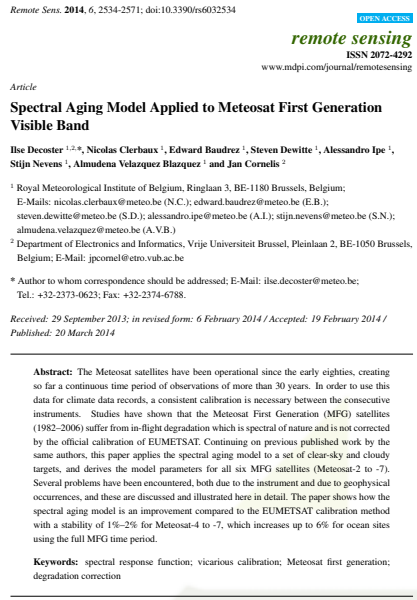
- Long-term stability
- Published in March 2014



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Article

Spectral Aging Model Applied to Meteosat First Generation Visible Band

Ilse Decoster [1,2,*], Nicolas Clerbaux [1], Edward Baudrez [1], Steven Dewitte [1], Alessandro Ipe [1], Stijn Nevens [1], Almudena Velazquez Blazquez [1] and Jan Cornelis [2]

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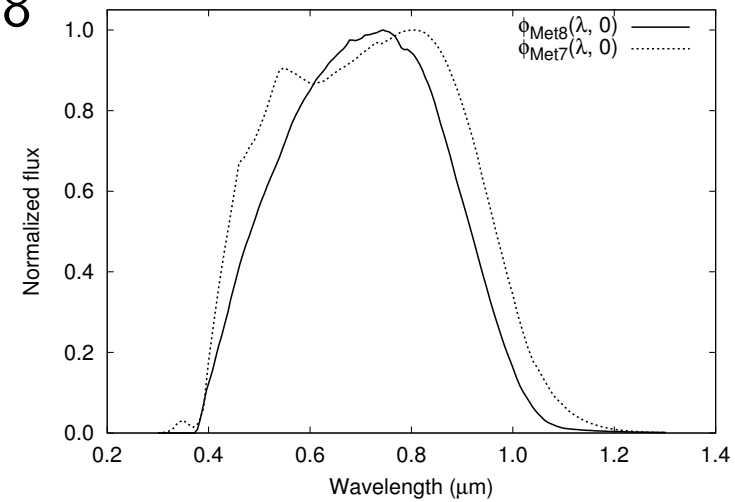
Abstract: The Meteosat satellites have been operational since the early eighties, creating so far a continuous time period of observations of more than 30 years. In order to use this data for climate data records, a consistent calibration is necessary between the consecutive instruments. Studies have shown that the Meteosat First Generation (MFG) satellites (1982–2006) suffer from in-flight degradation which is spectral of nature and is not corrected by the official calibration of EUMETSAT. Continuing on previous published work by the same authors, this paper applies the spectral aging model to a set of clear-sky and cloudy targets, and derives the model parameters for all six MFG satellites (Meteosat-2 to -7). Several problems have been encountered, both due to the instrument and due to geophysical occurrences, and these are discussed and illustrated here in detail. The paper shows how the spectral aging model is an improvement compared to the EUMETSAT calibration method with a stability of 1%–2% for Meteosat-4 to -7, which increases up to 6% for ocean sites using the full MFG time period.

Keywords: spectral response function; vicarious calibration; Meteosat first generation; degradation correction

Outline

(4) Pre-launch characterisation problem

- Using the SEVIRI HRV data of Meteosat-8 in the overlap period 2004–2006
  - Successor channel of MVIRI VIS
  - Comparable spectral response curves



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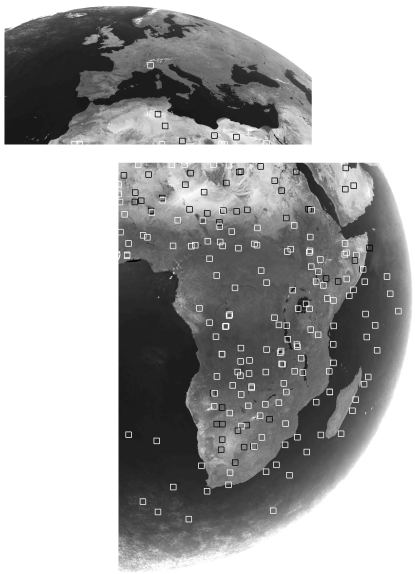

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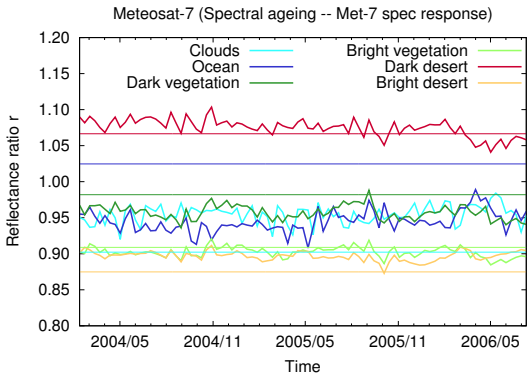
- Relative intercept differences



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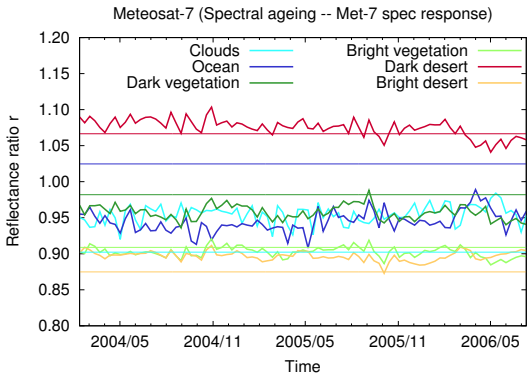
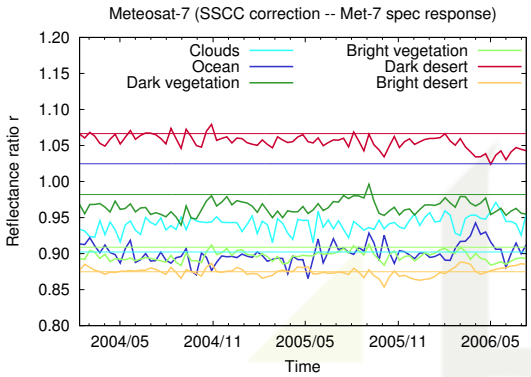
- Relative intercept differences
  - Validation of spectral ageing model





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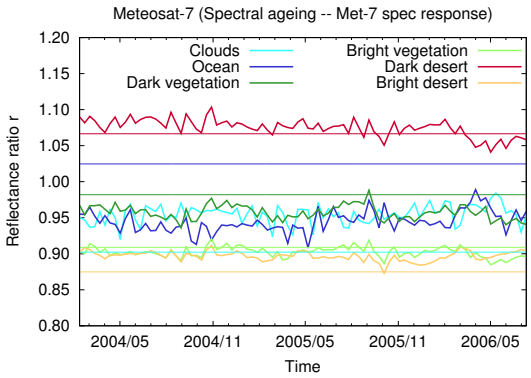
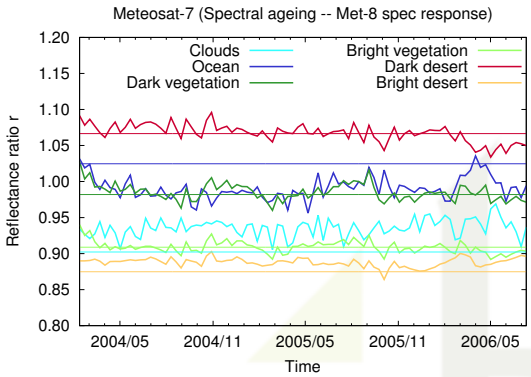
  - Improvement using Meteosat-8 HRV curve from 4.5% to 2.1% RMS





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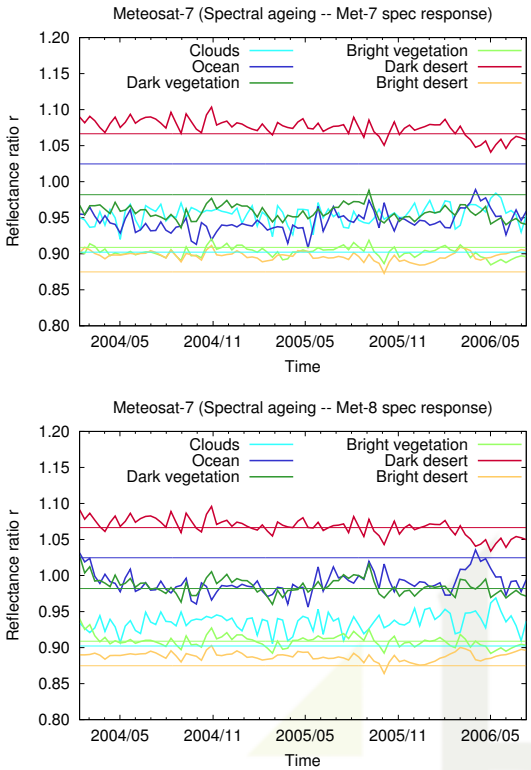

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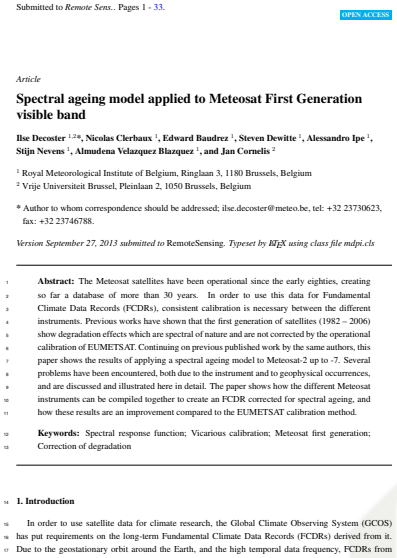
- Published in August 2013



Submitted to *Remote Sens.*. Pages 1 - 33.

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Article

Spectral ageing model applied to Meteosat First Generation visible band

Ilse Decoster [1,2,*], Nicolas Clerbaux [1], Edward Baudrez [1], Steven Dewitte [1], Alessandro Ipe [1], Stijn Nevens [1], Almudena Velazquez Blazquez [1], and Jan Cornelis [2]

[1] Royal Meteorological Institute of Belgium, Ringlaan 3, 1180 Brussels, Belgium
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* Author to whom correspondence should be addressed; ilse.decoster@meteo.be, tel: +32 23730623, fax: +32 23746788.

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Abstract: The Meteosat satellites have been operational since the early eighties, creating so far a database of more than 30 years. In order to use this data for Fundamental Climate Data Records (FCDRs), consistent calibration is necessary between the different instruments. Previous works have shown that the first generation of satellites (1982 – 2006) show degradation effects which are spectral of nature and are not corrected by the operational calibration of EUMETSAT. Continuing on previous published work by the same authors, this paper shows the results of applying a spectral ageing model to Meteosat-2 up to -7. Several problems have been encountered, both due to the instrument and to geophysical occurrences, and are discussed and illustrated here in detail. The paper shows how the different Meteosat instruments can be compiled together to create an FCDR corrected for spectral ageing, and how these results are an improvement compared to the EUMETSAT calibration method.

Keywords: Spectral response function; Vicarious calibration; Meteosat first generation; Correction of degradation

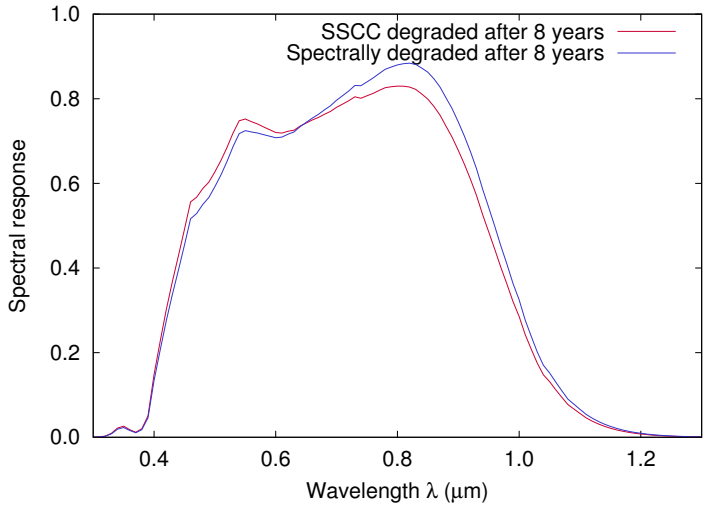
1. Introduction

In order to use satellite data for climate research, the Global Climate Observing System (GCOS) has put requirements on the long-term Fundamental Climate Data Records (FCDRs) derived from it. Due to the geostationary orbit around the Earth, and the high temporal data frequency, FCDRs from

Outline

(U-1) Sensitivity study – ΔECV

- Simulate degraded radiances after 8 year using both spectral and linear modeled spectral response curves



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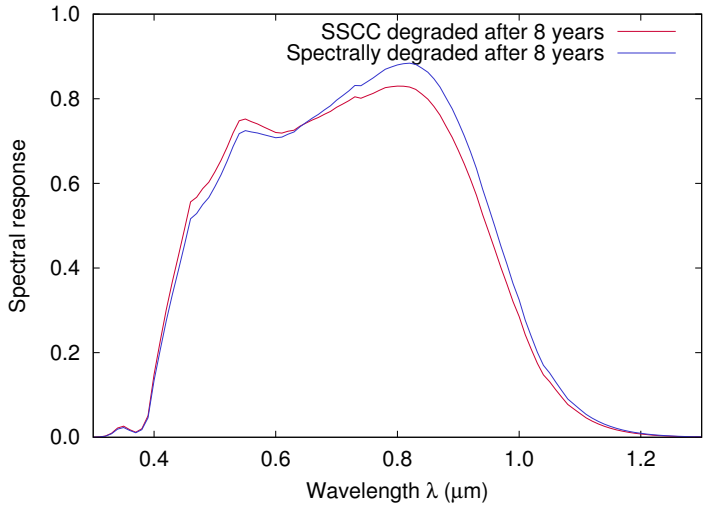

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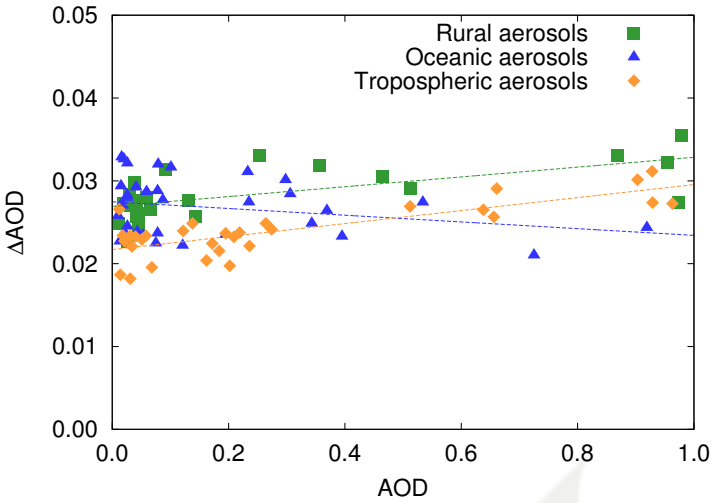
    $\Rightarrow \sim$ background aerosols



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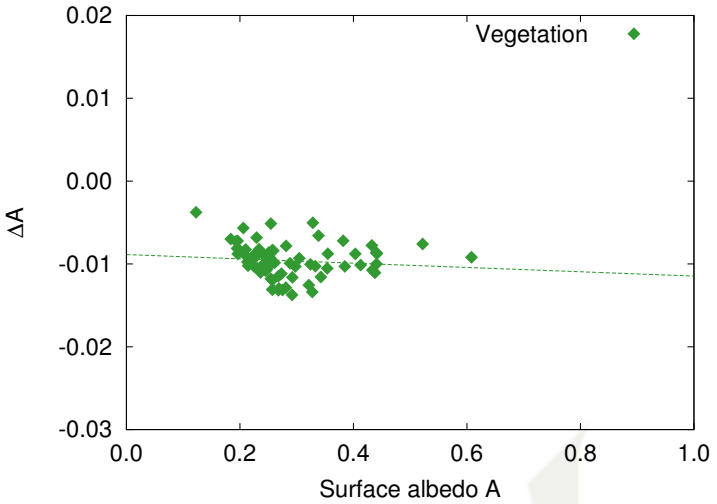
  - Land surface albedo
    $\Rightarrow$ 5% over vegetation



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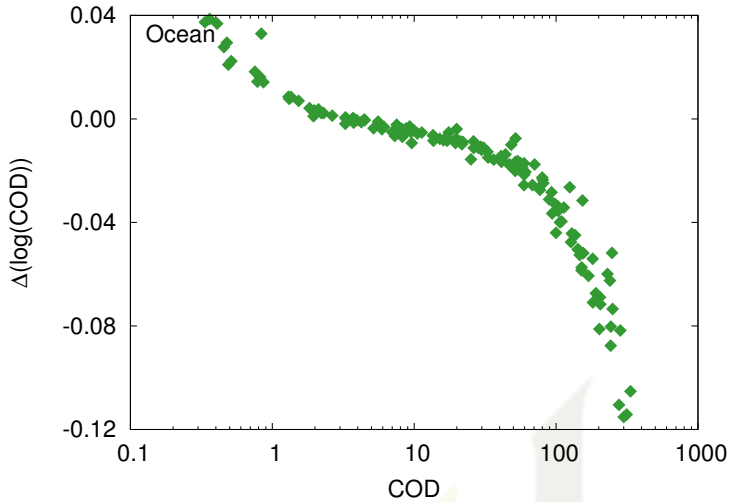
    $\Rightarrow$ 10% over ocean



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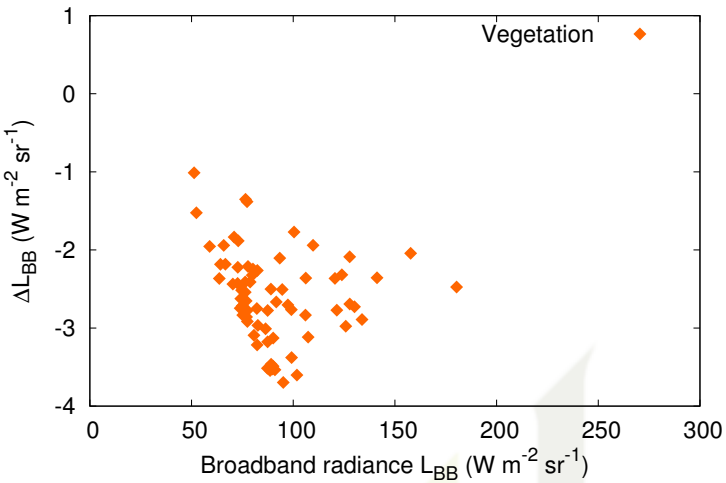
    $\Rightarrow$ 10% over ocean
  - TOA outgoing VIS BB-radiation
    $\Rightarrow$ 4% over vegetation



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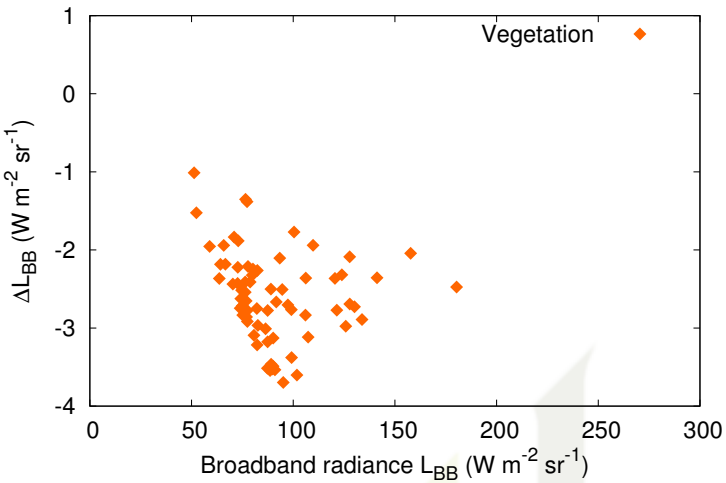
    $\Rightarrow$ 4% over vegetation
- Decrease in difference with self-calibration



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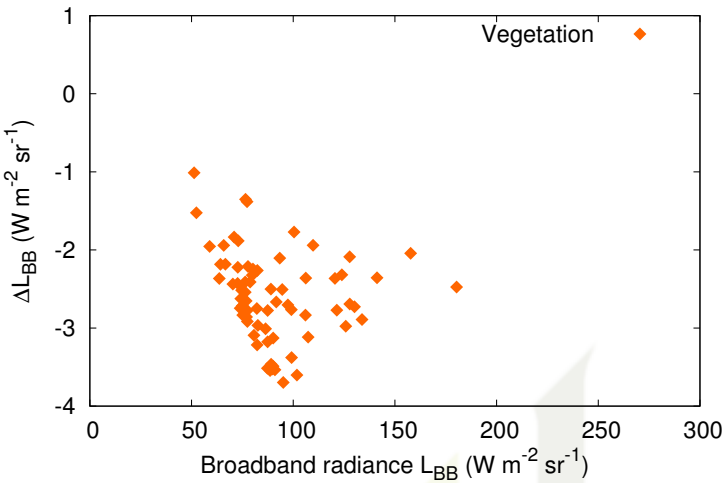


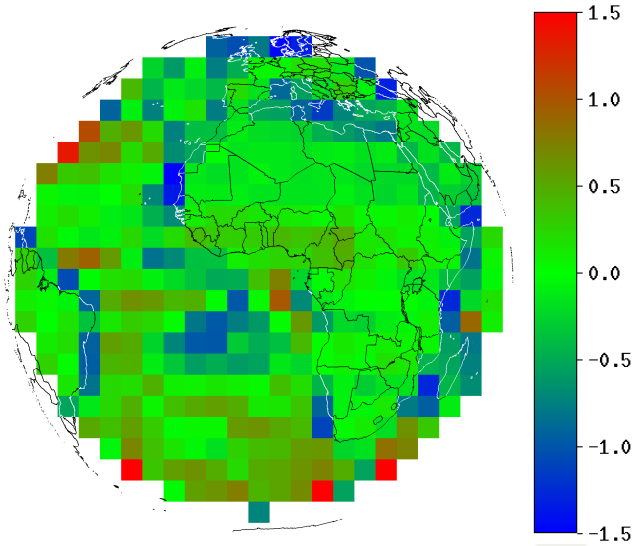
- Decrease in difference with self-calibration

$\Rightarrow$ It is worth to consider the spectral ageing model for most ECVs

Outline

(U-2) Full MFG Regional validation

- All-sky images Meteosat-2 – 7
  $\sigma = 0.7\%\text{yr}^{-1}$



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- All-sky images Meteosat-2 – 7
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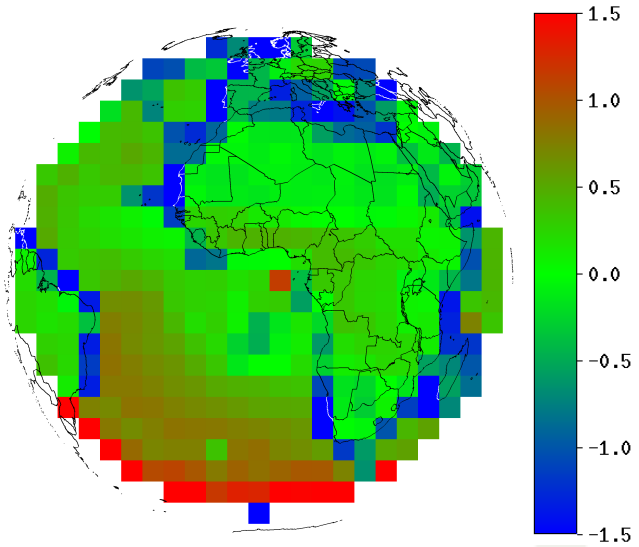

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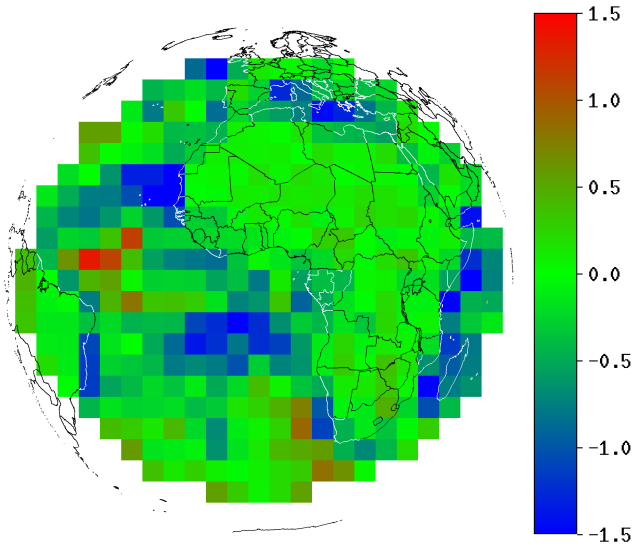
- Clear-sky images Meteosat-2 – 7
  $\sigma = 1.7\%\text{yr}^{-1}$
- All-sky images Meteosat-4 – 7
  $\sigma = 0.5\%\text{yr}^{-1}$



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  $\sigma = 1.7\%\text{yr}^{-1}$
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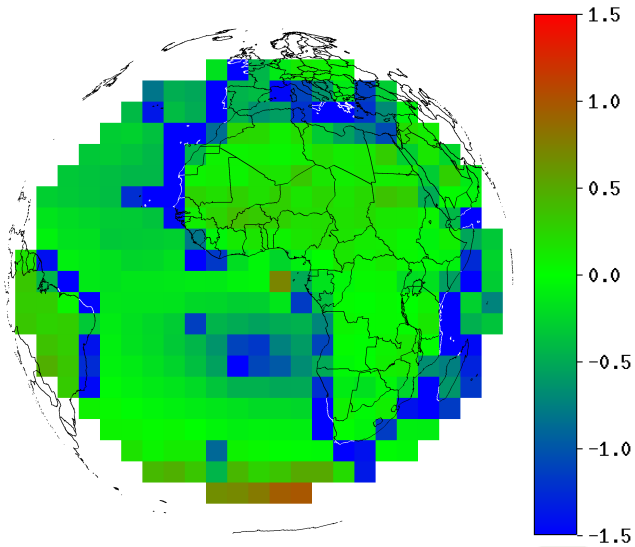
  $\sigma = 0.5\%\text{yr}^{-1}$
- Clear-sky images Meteosat-4 – 7
  $\sigma = 0.6\%\text{yr}^{-1}$



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- Achievements and accompanying problems were presented:
  - scientific papers in peer-reviewed journals
  - oral presentations at international conferences and meetings
  - personal communication and visit with EUMETSAT team working on calibration of MVIRI VIS channel

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Future prospects – Correcting spectral response curve

- Problems with Meteosat-2 and -3
  - 6-bit digitisation: decrease offset slightly
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  - characterisation issue of spectral response curve: replace or mathematically adjust the spectral response curves
- Use of Sciamachy to correct spectral response curve of Meteosat-5, -6, and -7
  - use spectra of Sciamachy and observations from MVIRI to derive spectral response curve
  - based on current response curve or starting from gaussian curve
  - need co-angular data (limited!)

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  - theoretical unfiltering to a reference spectral response curve (e.g. Meteosat-7 at launch)
- Mathematical formula and parameters
  - useful for LUTs of AOD, COD, ...

Thank you