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Megha Tropiques Validation plan

Part 3 :

Calibration/Validation of ScaRaB and ERB TOA product

This document summarizes the CAL/VAL plan for ScaRaB and the Earth Radiative Budget (ERB) at the Top Of the Atmosphere (TOA). These important activities do not require a specific ground deployment.

First we are going to describe the calibration processes and then the validation part. ScaRaB validation activities will be focused on two aspects:

i) verification of the radiances.
ii) verification of the radiance to flux conversion scheme.

SCARAB is an optical scanning radiometer devoted to the measurements of radiative fluxes at the top of the atmosphere. The optical radiometer is composed of 4 parallel and independent telescopes focusing the reflected solar and emitted thermal radiation of the earth atmosphere on 4 detection channels (see Table hereafter).

Channel	Description	Spectral Interval
1	VIS (visible)	0.5 – 0.7
2	SW (or solar)	0.2 – 4
3	T (total)	0.2 – 50
4	IR (infrared)	10.5 – 12.5

Table : The four ScaRaB channels

Channels 1 and 4 are the narrowband channels and are principally used for scene identification. Channels 2 and 3 are the broadband channels. Channel 2, or solar channel directly provides the solar energy reflected by the Earth-atmosphere (SW radiances). Channel 3 measures the total energy (solar and thermal between 0.2 and 50 µm). So we don't directly have the daytime LW radiances as channel 3 is a total channel. During nighttime, the LW radiance is directly given by channel 3. On the other hand, the daytime LW radiance is obtained by difference between the total and the SW channels ($L_{LW\ (daytime)} = L_T - A' \times L_{SW}$). In this equation, the A' coefficient is a constant and is equal to 0.9142 for ScaRaB on MT.

1 – ScaRaB Radiometry Check before and after launch

1.1 – Spectral characterization and gain determination

The following list of verifications and recording is needed to ensure the radiometric quality:

1. In preparing the instrument, one must
   i) characterize all optical components: FOV (Field Of View), and channel coregistration, spectral responses, components of calibration module (emissivity of the blackbodies, radiances of SW sources, temperature measurement chains).
   ii) minimize or assess the effects parasites: reflection parasite, polarization, diffraction, thermal pollution.
   iii) therefore develop an optical and thermal model of the instrument.

2. Before launch, complete tests are required
   i) in the 'lab' environment: a set of functional tests .
   ii) in vacuum chamber estimations of the gains, of their temperature dependence, etc…
   iii) comparisons with the optics characterization (previous phase); consistency at 1% must be found.

3. After launch, one needs
   i) an initial phase during which the consistency of all methods of in-flight calibration are checked and compared to the gain estimations made on ground. Note there are three in-flight calibration modes (Calibration, Solar and Total) which allow more possibilities then the ones in the two previous ScaRaB instruments (Viollier et Raberanto, 2010).
   ii) to control regularly this nominal on-board calibration, including the search for possible degradation of optical correction and their impacts; cross-checking with all the independent methods which are described below

Any error or time degradation of these radiometric characteristics will yield discrepancies at all the levels of validation activity as well as from the comparisons with other ERB instruments.

1.2 – Three-channel consistency

This useful method for validating the SW response was developed by Duvel and Raberanto (2000) for ScaRaB. The principle is to compare the SW radiance to the SW part of the total channel radiance. To isolate that part, we use the observations over deep convective clouds (DCC) in the Tropics. DCC are selected from cloud-top temperature colder than 205 K. Over these clouds, very bright and cold, the SW radiance constitutes the major part of the signal. The LW radiance is small, non negligible, but can be estimated by the IR window channel with sufficient accuracy since the DCC altitudes are > 10 km and then both channels mostly are not affected by the atmospheric absorption and emission.
Consequently, this target of spectrum covering all the solar wavelengths has a known SW radiance, without involving atmospheric modelling. It makes a perfect reference source to compute channel 2 gain and to check the unfiltering process.

This approach already applied to ScaRaB-2 measurements gave cross-calibration parameters with accuracy better than 1%. We can summarize this approach by saying that this method transfers the reliable channel 3 calibration to the SW channel. However, the SW calibration is assessed by this method only if the SW spectral responses of the total and SW channels are well characterized and not degraded. Any change can arise from either an error in the absolute accuracy of the SW channel gain or from the SW part of the Total channel. This illustrates the importance for cross-checking the numerous CAL/VAL proposed in this report.

2 – Radiances and Flux Comparison with other ERB spaceborne instruments

The most direct radiance and flux comparisons will be with other simultaneous ERB satellite measurements. All these missions have the same specification: to provide an accuracy of 1% to 2% in the measurement of broad-band radiances SW and LW (in the case SW, this objective is difficult to realize). Comparing ScaRaB with these missions is therefore imperative. We must find consistency at the 1% or 2% level.

Note that these comparisons are consistency-checks and do not show what mission is the most accurate.

Radiances measured from ERB instruments and ScaRaB scanners are sensitive to viewing and illumination geometries (viewing zenith for LW and SW and solar zenith and relative azimuth angles for SW) as well as spatial and temporal heterogeneities of the radiative fields used in the comparisons.

ERB instruments and ScaRaB measurements can be compared directly, without bi-directional models or temporal interpolation schemes, if the two instruments observe the same scene at the same time with the same viewing geometry (as mentioned in the preceding paragraph, we have more restrictive angular conditions for SW radiances so in this case, comparisons will be more “problematic”).

We are going to have two different approaches to compare ScaRaB with other instruments (especially with CERES).
The first one is called “systematic” and is planned to be made all along the Megha-Tropiques mission.
The second one is called “occasional”.

2.1 – Systematic approach

These comparisons are planned with the following instruments:

1. CERES

   The first comparison between two ERB scanners was between CERES/TRMM and ScaRaB-2/Resurs (sur quell sat ?) during simultaneous operations in January and March 1999 (Haeffelin et al., 2001). They showed that the differences are independent of the scene type, which largely valid the spectral corrections. The instruments were found to be consistent to within 0.5% and 1.5% in the LW and SW domains.

   In 2012, comparisons are planned to be made with CERES in cross-track mode on Terra and Aqua (Flash Flux products). CERES on NPP (NPOESS Preparatory Project), (sun-synchronous orbit) was launched recently (on October 28, 2011), it will then be possible to compare ScaRaB products with those from NPP as soon as data from NPP will be released.

   When CERES operates in cross-track mode and because of the very different orbit inclination between Megha-Tropiques and Terra (or Aqua), the number of colocalized pixels between the two instruments is very small (a few dozen a day for the SW case). We need then to accumulate data for several months in order to have reliable statistics.

   The Figure below shows the occurrence of simultaneous observations in the normal cross-track scan mode for a 52 days period and for a conical angle of 10° between CERES and ScaRaB directions of observation. Concerning the temporal matching, we have used ± 10 minutes criteria between observations.

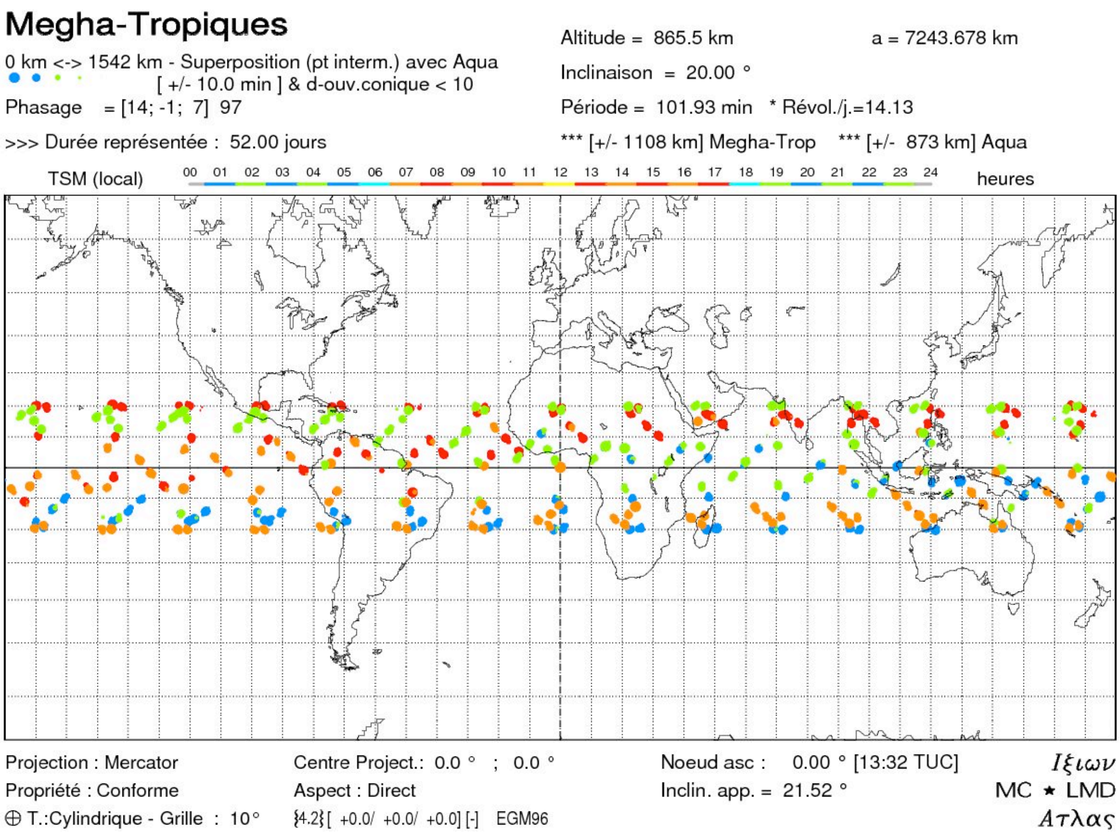

Figure above : Simulation of coincidences (±10 mn) between Megha-Tropiques and CERES/Aqua during two days, with an angular conditions of 10° (conical angle between the tow instruments).

2. GERB

Two 'Geostationary Earth Radiation Budget' GERB instruments are already in space and two other are programmed to be launched in the coming years. Therefore we are going to have, at least, one GERB instrument operating in space with ScaRaB.

GERB provides broad-band shortwave and longwave fluxes every 15 minutes at about 50 km resolution within the Meteosat field of view (Harries et al., 2005). Therefore there will be a common ScaRaB/Megha-Tropiques and GERB spatial coverage, between 30°S to 30° N, and 50° W to 50° E.

Comparisons between both instruments will be made at different spatial and temporal scales, for radiances and fluxes and classified by region and scene type. Comparing radiances requires that observations be made under the same geometric view. A previous GERB/ScaRaB study was presented at the meeting GERB of Valencia in January 2008.

This simulation of GERB and ScaRaB/Megha-Tropiques observation shows that co-angled comparisons will occur but only near the 0° longitude (GERB detectors ~100 to 150). However, since GERB observations are available each 15 minutes, the matching dataset will be quite considerable.

2.2 – Occasional approach

The particularity of CERES instrument is to operate it in different acquisition modes. In addition to the cross-track mode, it's possible to change the scanning mode to RAPS (Rotating Azimuth Plan), to FAPS (Fixed Azimuth Programming Scan) to PAPS (Programmable Azimuth Plane Scan) and also to Along-Track.
To increase the coincidences between ScaRaB and CERES, Haeffelin et al. (2001) have used this feature of the CERES instruments.

After discussion with the CERES team, it is planned to change the scan mode of one of the CERES instrument (cross-track to PAPS mode) to have more co-location between CERES and ScaRaB. With this mode, it would be possible to align CERES measurements with ScaRaB measurements when the two instruments overpass (the angle between the two will be fixed for each overpass). This effort is planned to be made around March 2012 and for 51 days (the precessing cycle of Megha-Tropiques).

Using the PAPS mode to compare SW radiances between CERES and ScaRaB increases the number of coincidences by a factor close to 10 (over a 51 days period), see Chomette et al. (2012).

These modes were found responsible for instrument degradations (Matthews et al, 2005) so, to be sure to have at least one operational instrument on each satellite, it has been decided to use CERES FM1 on Terra (both FM1 and FM2 are still operating correctly today on TERRA, on AQUA, FM3 is operating correctly but this is not the case for FM4 which presents anomalies on the SW channel).

3 – Internal and climatological consistency check

3.1 – Comparison with historical data

The tropical means (zone between 20°S and 20°N) of nadir IR radiances is considered as a relatively constant non-varying source (Thomas et al, 2004) to be used as a reference source. Statistics of the ScaRaB radiances will be compared with his reference data set, to check if they fit in the mean and if day/night differences are respected (Thomas et al. 2002).

Other useful information for validation of the spectral and angular corrections could be found by examining the tropical means of data classified according the cloudiness and geotype.

3.2 – Histogram and map visualization

Probability density function (PDF) and histogram are efficient method to detect any discrepancy in the data. Histograms will be plotted on data classified according to the SZA and type of scene identification.

Visualization and animation of orbits and maps are also efficient means to detect anomalies in the data, as well as differences between the current maps and historical data.

3.3 – Monitoring the stability

Given the difficulties in achieving absolute accurate calibration especially in the visible, many remote sensing experiments have used indirect methods to double check the calibration and to monitor the instrument stability over time.

To monitor the stability, the principle is to substitute, as a reference source, terrestrial targets with reflectance assumed stable over time or being known with precision (from measurement of reflectance of the surface, of aerosol content, etc…). Among these targets, the most used are the deserts (used for SPOT, Meteosat), Rayleigh scattering (for ocean color sensors) and thick clouds. For climate applications, the use of these methods cannot be absolutely recommended, since the stability of ground targets may itself be affected by climate change then by changes in surface and properties or the atmosphere.

After many theoretical and empirical studies, the CERES team (Hu et al., 2004) has recommended, however, to use the "deep convective clouds" (DCC). Indeed, these DCC have such optical thicknesses they give a reflection high, stable and isotropic. They can be regarded as stable, because changes in the absorption by ozone are not expected in the tropics, as well as variations in size and shape of ice crystals, as the DCC crystals are composed of fresh and small crystals.

The on-board calibration will be compared to these vicarious methods, especially the DCC method.

3.4 – Validation of the Geolocalisation

The location of the pixels depends on the platform attitude (roll, yaw, pitch), on the instrument and optics alignment and on the instrument pointing accuracy.

By selecting clear sky pixels, the strong contrast between land and ocean radiances, especially in the SW domain, can be compared to the coast line for assess the accuracy of the location. Similar calculations carried out with ScaRaB-2 data show that the location of the pixel centre can be assessed with an uncertainty of about 5 km.

4 – Cloud cover characterization comparison

In one of the Level-2 algorithm (SEL), a necessary step to compute the TOA fluxes is to determine the cloud cover characterization of the scene with the MLE (Maximum Likelihood Estimates) method. It would be interested to compare this cloud cover characterization with a product determined with the help of geostationary satellites (or with a combined Megha-Tropiques product)..

5 – ScaRaB CALVAL Summary

The ScaRaB calibration and data validation rely on a multitude of independent cross-checking analyses. This is true for CAL activities where several methods are compared (section 2), and also for VAL where the ScaRaB results are compared to:

- external ERB and meteorological satellites
- historical radiance and flux datasets and internal consistency checks
- well-documented benchmark test targets.

The geolocalisation validation requires comparisons with digitalised maps of coast lines or with other satellite data.

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