THE SCARAB INSTRUMENT ON THE MEGHA-TROPIQUES MISSION

Olivier Chomette*, Patrick Raberanto and Rémy Roca
LMD, Palaiseau, France

1. INTRODUCTION

ScaRaB (Scanner for Radiation Budget) is an Earth Radiation Budget (ERB) instrument which provides top of the atmosphere (TOA) fluxes in both longwave and shortwave domain (Kandel et al., 1998 ; Duvel et al., 2001). This instrument will be on board the Megha-Tropiques satellite, an Indo-French mission built by the the Centre National d'Etudes Spatiales (CNES) and the Indian Space Research Organisation (ISRO) and due to launch in 2011. Megha means cloud in Sanskrit and Tropiques is the French for tropics. The scientific objective of this mission is focused on the tropical latitudes.

2. SCARAB ON MEGHA-TROPIQUES

This section will be focusing on the ScaRaB instrument and his specificity within the Megha-Tropiques mission.

2.1 The instrument characteristics

It is a wide band instrument with four channels, a cross track scanning and a 40 km pixel resolution at nadir. Figure 1 represents the instrument while it was assembled. Each ScaRaB channel has its own telescope. The locations of the telescopes are in red in Figure 1. The black box is the calibration module with the blackbodies and a lamp. ScaRaB mass is 22 kg without the electronic part (13kg) for a 40 W power consumption. ScaRaB dimensions are 52cm width, 23cm high and 23cm depth.

Figure 1 : the ScaRaB instrument

The ScaRaB goal is to determine the longwave (LW) and shortwave (SW) outgoing fluxes observations at the TOA.

* *Corresponding author address:* Olivier Chomette, CNRS/IPSL/LMD, Ecole Polytechnique, Route de Saclay, 91128 Palaiseau, France; e-mail: chomette@lmd.polytechnique.fr.

Table 1 shows the characteristics of the four 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. Channel 3 measures the total energy (solar and thermal between 0.2 and 100 µm). No filter is used on this channel.

Channel	Description	Spectral Interval	Filter
1	VIS (visible)	0.55 – 0.65	Interferential
2	SW (or solar)	0.2 – 4	Silice filter
3	T (total)	0.2 – 100	No filter
4	IR (infrared)	10.5 – 12.5	Interferential

Table 1 : the four ScaRaB channels

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 (see equation 1). In this equation, the A' coefficient is a constant and is approximately equal to 0.910 for this instrument. A' depends on the spectral response of the total and the SW channels, see Viollier and Raberanto (2010) for more details.

$$L_{LW\ (daytime)} = L_T - A^{'} \times L_{SW} \qquad (1)$$

The general concept of the instrument remains unchanged and is based on the two previous ScaRaB models (see Kandel et al. (1994), Kandel et al. (1998) and Duvel et al. (2001)) whose flown on Meteor and Resurs satellites in 1994 and 1998, but most of the components (detectors, optics, mechanisms and electronics) have been updated. The only major change concerns the calibration onboard procedure, Viollier and Raberanto (2010).

2.2 The on-board calibration procedure

The on-board calibration procedures have been modified for this ScaRaB (Viollier and Raberanto, 2010). The solar filter can be switched from the SW to the T channel, which allows checking calibration and balance of the SW responses of both channels and also calibrating channel 2 by viewing a blackbody. With this new design, there are 3 in-flight calibration modes:

In Figure 2, (1) represents the position for the measurements mode, (2) represents the solar mode (or S-mode) in which it's possible to compare measurements from geophysical scenes obtained from channel 2 and channel 3 as solar channels. (3)

represents the calibration mode (or C-mode) where the detectors are looking for the calibration module (CALM) to check gain stability of all channels using internal blackbodies and a lamp for the channel 1 and (3) also represents the position for the total mode (or T-mode) in which it's possible to compare measurements from geophysical scenes obtained from channel 2 and channel 3 as total channels. Note that the blackbodies for channels 2, 3 and 4 have an emissivity of 0.997±0.002 between 2 and 14 µm and a mass of 80g for each one. For channel 1, there is a lamp on the CALM.

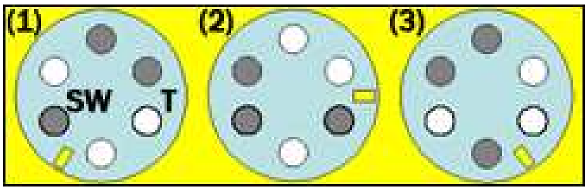

Figure 2 : ScaRaB different modes. In grey, the filters. In white no filter inside the channel. SW is for channel 2, T is for channel 3.

Each cycle of the Earth measurement mode includes an Earth scan of ± 48.91° and a space look (idem for S-mode & T-mode).

The ScaRaB calibration process consists of computing the gain with the measured radiances (i.e. the filtered radiances, see equation (2)).

$$L_K^f = \int_0^\infty L(\lambda) \cdot r_K(\lambda) \cdot d\lambda \quad (2)$$

Where, r is the instrument's spectral response function, L the incoming radiance of the observed scene, K the channel number and N the instrument output (i.e. the scene signal subtracted from the space signal). The gain is then given by equation (3).

$$G_K = \frac{N_K}{L_K^f} \quad (3)$$

The first guesses for each G_K and the A' coefficient are determined during the ground pre-flight calibration (integrated sphere for the SW and thermal vacuum for the LW).

2.3 The Megha-Tropiques mission

The major innovation of Megha-Tropiques is to bring together a suite of complementary instruments on a dedicated orbit (see a 7 days representation of this orbit on Figure 3) that strongly improves the sampling of the water cycle elements. Indeed the low inclination on the equator (20°) combined with the elevated height of the orbit (865 km) provides unique observing capabilities with up to 6 over-passes per day in the best cases (see Figure 4).

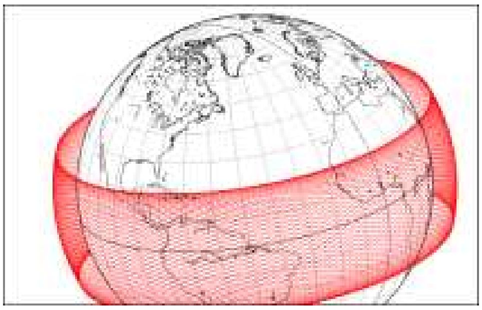

Figure 3 : The Megha-Tropiques orbit

The scientific objective of the mission concerns i) Atmospheric energy budget in the inter-tropical zone and at system scale (radiation, latent heat, …) ii) Life cycle of Mesoscale Convective Complexes in the Tropics (over Oceans and Continents) and iii) Monitoring and assimilation for Cyclones, Monsoons, Mesoscale Convective Systems forecasting. These scientific objectives are achieved besides ScaRaB thanks to the following payload: SAPHIR, a microwave sounder for water vapour sounding with 6 channels in the WV absorption band at 183.31 GHz (cross track, 10 km) and MADRAS, a microwave imager for precipitation with channels at 18, 23, 37, 89 and 157 GHz, H and V polarisations (conical swath, <10 km to 40 km).). More details are available in Desbois et al. (2007).

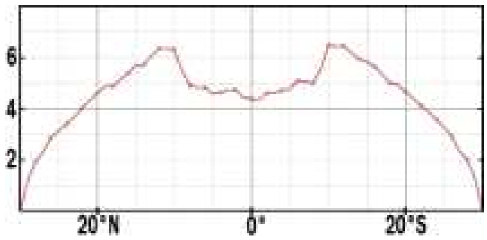

Figure 4 : statistics on overpasses for ScaRaB between 30°N and 30°S

2.4 ScaRaB on Megha-Tropiques

We have two objectives for ScaRaB in this mission.

The first one is to obtain a time series of regional monthly means fluxes with an accuracy of 5 $W.m^{-2}$. To obtain this value on regional means, the accuracy on instantaneous fluxes has to be approximately 20 $W.m^{-2}$. The algorithm used for this objective is called SEL for ScaRaB ERBE-Like, Viollier et al. (1995).

The second objective is to observe simultaneously the radiation fluxes and the water cycle components. To achieve this goal, the accuracy needed on instantaneous fluxes has to be better than with SEL. A second algorithm has been developed to obtain this accuracy and is called SANN (ScaRaB Artificial Neural Network) because it's a neuronal network approach, Viollier et al. (2009).

3. THE SCARAB PRODUCTS

ScaRaB measures radiances at TOA. The level 1 consists of calibrated radiances, geolocated with latitudes and longitudes for the center of each pixel. The nadir pixel resolution is 40 km (1600 km^2 surface) and the last pixel of the swath (the 25^{th}) has a surface 5.6 times more important than the nadir pixel. ScaRaB's goal is to determine the instantaneous fluxes (level 2) and also regional means fluxes (level 3). These level 3 products are planned to be improved using data from geostationary (Young et al. (1998)). The high sampling with Megha-Tropiques will certainly improve the narrowband to broadband transition.
All theses fluxes will be at TOA, fixed at 20 km height.

4. THE SCARAB CAL/VAL PLAN

Calibration and validation are major concerns when measuring ERB. General definitions of the CAL/VAL activities are the following. Calibration is the process of quantitatively defining the instrument's response to known radiances. Validation is the process of assessing, by independent means, the quality of the data products derived from the instrument outputs. However, compared to remote sensing techniques used for observing climate variables (clouds, precipitation, atmospheric profiles...), the estimation of the ERB at TOA is specific and requires careful re-examination of the CAL/VAL operations. The double specificities are (i) there is actually no 'in-situ truth' to be compared to the satellite observations and (ii) the estimate flux results from almost direct radiance measurement with algorithms much simpler than those used for other remote sensing purposes.

The CAL/VAL activities therefore are first focus on the radiance accuracy. This accuracy is so critical than the CAL activities are tightly associated to VAL activities because both are based on various comparisons of independent quantities from internal calibration sources to external observations.

In the CAL/VAL plan, we will have the following:

i. The on-board calibration (see §2.2).
ii. The vicarious calibration (using direct Earth observations).
iii. The comparison with other ERB instruments such as CERES or GERB (broadband channels radiances comparison and fluxes comparison).
iv. The comparison with other radiometers (narrowband channels radiances comparison).

5. CONCLUSION

Except for the new calibration processes, ScaRaB general concept is identical to the two former ScaRaBs. But most of the components have been updated. The radiances to fluxes conversion (level-2) has been improved for ScaRaB-3 on Megha-Tropiques with the development of a new algorithm based on a neural network approach, to reach the scientific requests.

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