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Two models of the ScaRaB radiometer (Scanner for Radiation Budget) have operated in space aboard the Russian satellites Meteor-3-7 and Resurs 1. The main objectives of radiation budget missions are 1) to contribute to the long time series of regional observations of radiative fluxes at TOA 2) to check or correct models (radiative transfer, thermodynamic processes, climate). In the future, the payload of the Megha-Tropiques mission is planned to include a similar ScaRaB instrument.

Two models of the ScaRaB radiometer (Scanner for Radiation Budget) have operated in space aboard the Russian satellites Meteor-3-7 (February 1994 to March 1995) and Resurs 1-4 (August 1998 to April 1999). These missions (Kandel et al, 1998 , Duvel et al, 2001) were the result of a co-operative project between France, Russia and Germany, with the following main contributions: instrument design development, construction and data processing by France (LMD/CNRS and CNES) with flight calibration module supplied by Russia; infrared ground calibration by France; satellite launch and data reception by Russia; solar ground calibration by Germany. As for the NASA ERBE scanners (Barkstrom et al., 1989) and CERES (Wielicki et al., 1996), ScaRaB estimates the solar reflected flux and the longwave emitted flux of the Earth. It looks for the maximum accuracy both in the measurement and in the data processing (angular and space and time averaging). These estimations are fundamental parameters of the Earth environment and climate, and their regional and monthly means have been determined with great accuracy by ERBE and ScaRaB (mean Earth albedo =0.297, global annual mean of the outgoing longwave radiation = 238 $Wm^{-2}$). The main objectives of ERBE/ScaRaB missions are 1) to contribute to the long time series of regional observations of radiative fluxes at TOA 2) to check or correct models (radiative transfer, thermodynamic processes, climate). Comparisons between experimental and theoretical determinations have led to refine assumptions of climate models, specifically the radiative properties of clouds (Ramanhathan et al., 1989, Bony et al., 1995,...).

The keys to the ERB determination are:
1 broadband channels with well determined spectral response (covering SW and LW domain)
2 accurate radiometric calibration, 1% LW, 2% SW (compared to 5%, for most other space SW radiometers vicarious method)
3 need of a robust and qualified secondary -level 2 & 3 - processing to solve the triple sampling issue (angular, space and time averaging)
4 scene identification (for this third point and cloud forcing studies)

Brief descriptions of missions and instrument are given in sections 2. Principles of calibration, instrument updates and data processing are described in other sections.

Table 1 positions ScaRaB among other ERB scanner missions. It can be seen that the ERBE provided the major contribution with at least two instruments in space for more than four years (1985-89) and three instruments during December 1986. It also shows that we are in the EOS/CERES epoch.

| Instrument | Satellite | Altitude (km) | Resolution nadir (km) | Inclination (°) | Precessing Period | From | To |
|---|---|---|---|---|---|---|---|
| ERB | Nimbus 7 | 955 | 90 | 99.3 | Sunsync. | Nov 1978 | Jun 1980 |
| ERBE | ERBS | 610 | 30 | 57 | 72 days | Nov 84 | Feb 90 |
| ,, | NOAA 9 | 812 | 45 | 99 | Suns. 14:30 | Feb 85 | Jan 87 |
| ,, | NOAA10 | 830 | 45 | 99 | Suns. 07:30 | Oct 86 | May 89 |
| ScaRaB | Meteor | 1200 | 60 | 82.6 | 209 days | Feb 94 | Mar 95 |
| ,, | Resurs | 830 | ≈45 | 99 | Suns 22 :15 | Aug 98 | Apr 99 |
| CERES | TRMM | 350 | 10 | 35 | | Dec 97 | |
| ,, | EOS-Terra | 705 | ≈25 | 99 | Suns. 10:30 | March 2000 | |
| ,, | EOS-Aqua | 705 | ≈25 | 99 | Suns. 13:00 | 2002 | |

cylinder (stator, figure 1) mounted on the spacecraft. The four channels (Table 1) include two broad spectral bands (figure 2) from which the reflected SW and emitted LW radiances are derived, and two narrower bands, one corresponding to the infrared atmospheric window, the other to the visible (green to red) portion of the solar spectrum.

General designs of the ERBE and ScaRaB scanners are quite different: DC thermistor bolometer for ERBE, AC pyroelectric detector with 16 Hz frequency chopping against an internal blackbody for ScaRaB; telescope with two mirrors for ERBE and one for ScaRaB.

| | | | |
|---|---|---|---|
| 1 | Visible (VIS) | 0.55 — 0.65 µm | Interference |
| 2 | Solar (SW) | 0.2 — 4 µm | Fused silica |
| 3 | Total (TW) | 0.2 — 50 µm | Unfiltered |
| 4 | IR window (IRW) | 10.5 — 12.5 µm | Interference |

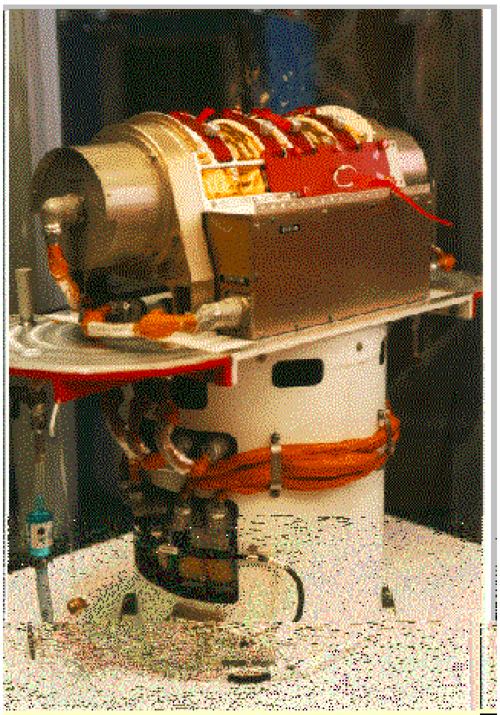
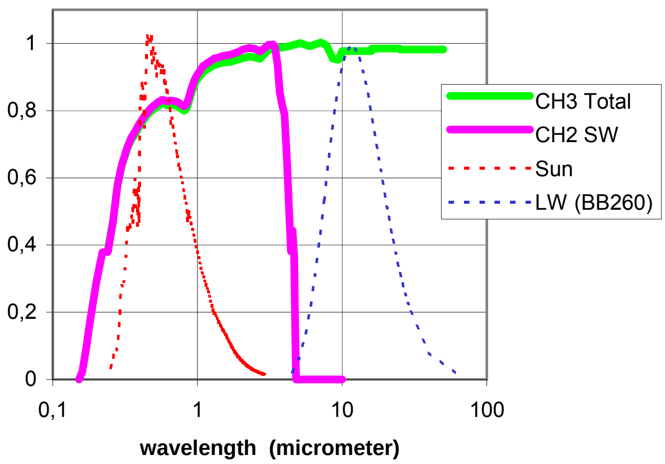


**Figure 2 : Spectral Response of ScaRaB/Meteor · Main Channels**




: ScaRaB instrument. In the upper part: the stator with the 4 channel windows looking to the Earth, the rectangular calibration module on the left. In the lower part, the cylindrical structure contains the electronic parts. Weight: about 40 kg.

Radiometric performances are first estimated on the ground (Sirou et al., 1997). In a vacuum chamber, ScaRaB was tested with an actively-controlled-temperature blackbody. These operations established the linearity of response and provided radiometric calibration of the temperature and emissivity of the on-board calibration blackbodies, and calibration of the temperature dependence of detector gains. On-board shortwave sources were calibrated at high-altitude sites (Mueller et al, 1997) against sunilluminated diffusor with incoming solar flux measured by high-standard calibrated pyrheliometer and in laboratory against calibrated integrating sphere.

In flight, the temperature of the reference blackbody (emissivity = 0.993) for channel 3 is measured by a platinum resistance thermometric sonde and included in the scientific telemetry. For the SW domain, the calibration system was designed with 3 sets of preaged incandescent lamp source (Tremas et al.,1997).

Because of the channel stability (0.1% stability was measured in flight on channel 3), the inter-channel consistency can also be used for complementary cross-checking operations. Analysis of very cold bright daytime cloud scenes over tropical convective regimes, for which the TW signal is dominated by SW reflection and the LW component can be estimated independently from the IRW radiance, yields agreement at the 1% level (Duvel and Raberanto, 2000).

Finally intercomparisons between ScaRaB and ERBE WFOV (Bess *et al.* 1997) and between ScaRaB and CERES (Haeffelin et al., 2001) also have been carried out.

According the results of all these operations the accuracy of the radiances is estimated to be 1% in the longwave and 2% in the shortwave domains.

The Megha-Tropiques ScaRaB model will benefit from the lessons of the two preceding flight models. The first lesson: the gain dependence as a function of the instrument temperature has been shown very stable (0.1% per degree). The second lesson: from the eleven months of ScaRaB-1 an excellent agreement (<1%) was found between the operational calibration of the SW channel and the geophysic-based method described by Duvel and Raberanto (2000). Radiometric stability and additional calibration method allow to simplify the original calibration system. The number of lamps is then planned to be reduced to two. An improvement is also planned in order to detect long term drift of the relative spectral responses of the SW and total channels in the SW domain. It consists in in-flight direct inter-comparisons of both channels by switching the silicate filters, owing to a new definition of the filter wheel. Except these slight modifications, the optical device is unchanged.

The electronic device has to be re-designed to improve the weight and electric power performances, to increase the component quality and to adapt the interfaces to the PLUTEUS platform.

The archive A1 files contain geographically located pixel radiances in physical units. From A1 files, the inversion processor produces the archive A2 file equivalent to the ERBE-CERES S8 product containing estimated SW and LW radiant fluxes as well as scene identifications. Each A1 and A2 file (about 10 and 20 Mbytes respectively) contains a full day's data from one satellite. Then using the same geographical grid as ERBE, the radiant fluxes are space-averaged over areas of 2.5 by 2.5 degrees in latitude and longitude. For each region, daily and monthly mean radiant fluxes are computed, using the same model for time interpolation as ERBE. The result is the family of A3 products: A3-MRI (Instantaneous Regional averaging) and A3-MRJ, A3-MRH, A3-MRMJ: daily regional means, the monthly regional mean diurnal cycles, and the monthly regional means obtained from the daily means.

The ERBE-like version is based on ERBE algorithms according to published descriptions: Smith *et al.* (1986), Wielicki and Green (1989), and Suttles *et al.* (1988a, 1988b) for Inversion, Brooks *et al* (1986) for the Monthly Time Space Averaging. However, the spectral corrections have had to be adjusted (Viollier et al, 1995) to the ScaRaB characteristics. An advanced version is proposed based on different studies (Stubenrauch et al.,1993, Standfuss et al. 2001).

There are many reasons to determine the components of the Earth Radiation Budget from Space. They are the ultimate constraints of the Earth Environment and constitute a major contribution to monitor and to study climate (year-to-year monthly means variability). At small temporal scale, ERB measurement must help to understand meteorological processes. Furthermore they can be done only from space and they are direct radiometric measurements (in spite of the triple sampling issue). Two ScaRaB instruments have provided 16 months (11+ 5) of ERB data on 2 different payloads and they have contributed to the radiometric calibration challenge, for long time series of ERB observations and for climate model tests. In the future, the payload of the Megha-Tropiques mission is planned to include a similar ScaRaB instrument. The objective of Megha-Tropiques is focused on the tropical zone and on processes at a scale of 100 km and between a few hours to a few days. In this context, the instantaneous flux estimates are the most important dataset, and studies related to the scene identification and to the angular corrections have to be pursued in order to improve their accuracy.

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