CEOS CAL/VAL NEWSLETTER Issue 3

Committee on Earth Observation Satellites
Working Group on Cal/Val

Contents:

CEOS WORKING GROUP ON CALIBRATION AND VALIDATION WGCV - STATUS REPORT

Dr S. M. Till (CCRS), Chair WGCV

The Committee on Earth Observation Satellites (CEOS) Working Group on Calibration and Validation (WGCV) held its seventh meeting in Italy, from June 2-4, 1993, hosted by the Joint Research Centre (JRC), Commission of the European Communities. The meeting was chaired by Susan M. Till (CCRS). Members were present from Australia, Belgium, Canada, China, ESA, France, Germany, Japan, Norway, Sweden, United Kingdom, USA/NOAA, USA/NASA, CEC, IGBP and GCOS. The four CEOS WGCV Subgroups were represented (SAR Calibration, Infrared and Visible Optical Sensors, Terrain Mapping and Passive Microwaves).

In addition to the usual business of the working group, there were two excellent special sessions on JERS-1 SAR/OPS calibration/validation results and on Topex/Poseidon calibration and validation results. These were presented by NASDA and CNES respectively.

I am pleased to report that the presentation of the WGCV activities was well received by the CEOS members at the 1993 Plenary meeting. This was held from November 16 - 18, at Tsukuba City, Japan. I presented the activities of the Working Group and Subgroups.

The six recommendations from WGCV7 were essentially accepted by the Plenary, with some minor modification of wording. The recommendations were endorsed by the Plenary as follows:

Recommendation #1:

WGCV has defined the content of the new calibration/validation section of Volume 3 of the CEOS Dossier. WGCV recommends that CEOS secretariat now proceed to commission this cal/val section of the dossier.

Recommendation #1 was approved; however resources were not identified and the Secretariat was given the job of working with the CEOS members to find resources.

Recommendation #2:

WGCV has determined specifications and costs on proposed ground test sites for calibration/validation. WGCV recommends that CEOS member agencies support identification, characterisation and maintenance of ground test sites for the verification of on-board calibration systems, in-flight calibration and subsequent cross-calibration of instruments, and support the establishment of a comprehensive data base on selected test sites.

Recommendation #2 was approved; however the words "within resources available" were added.

Recommendation #3:

WGCV recommends to CEOS Plenary that ESA, NASA, NASDA, NOAA and other suppliers of earth observation instruments should acquire common transfer standards and co-ordinate frequent intercomparisions of standards and techniques to ensure accurate cross-calibration of all earth observation sensors. All agencies should make available information on technologies employed for the use of standards (including transfer standards).

Recommendation #3 was approved, with words added "to maximum extent possible".

Recommendation #4:

Recognising that in the future, earth observation satellites will be able to produce DEMs with an accuracy of 1-2m from optical sensors and from missions designed for SAR interferometry, WGCV recommends that space agencies within CEOS recognise the importance of sound validation of DEMs and support:

- the establishment of test sites for validating DEMs
- provision of data (satellite, airborne and ground) over the test sites free of charge to organisations wishing to demonstrate the quality of algorithms for DEM generation
- the archiving, maintenance and open distribution of test site data

Recommendation #4 was approved in principle but more information was requested on the parameters since this has cost implications.

Recommendation #5:

In discussing the technology for producing DEMs from repeat track SAR interferometry, the WGCV subgroup on terrain mapping has recognised the importance of obtaining ERS-1/ERS-2 data with a minimum possible repeat interval and urges ESA to consider such a mission with a 30 minute interval. [The group recognises the problem associated with this and notes that a 1 day separation would be acceptable although work is at present going on to clarify the optimum separation].
The group also notes that a tandem ERS-1/ERS-2 mission would be useful for other cal/val activities.

Recommendation #5 was noted - ESA reported that this possibility is being considered (ERS-1/ERS-2 data with a repeat interval).

Recommendation #6:

WGCV (recognising the CEOS Dossier as a valuable source of information) recommends wider distribution/availability of the CEOS Dossier.

Recommendation #6 was approved.

WGCV was given one action item, to prepare a strategic plan - I was able to report that this is underway.

The recent Working Group meeting, WGCV8, was hosted by NOAA and was held at the Pacific Marine Environmental Laboratory (PMEL), at Sand Point, Seattle, Washington, USA, on February 23 to 25, 1994. The meeting was chaired by Susan M. Till (CCRS). Members were present from Australia, Canada, China, ESA, France, Germany, Japan, Norway, Russia, Sweden, United Kingdom, USA/NOAA, USA/NASA, CEC, and IGBP. The four CEOS WGCV Subgroups were represented (SAR Calibration, Infrared and Visible Optical Sensors, Terrain Mapping and Passive Microwaves).

In addition, meetings of the subgroups on terrain mapping and infrared and visible optical sensors were held on February 22 to 23, 1994 at the same location.

The regular business of the Working Group meeting included reports from the four subgroups on their status and activities, and the review and production of the Working
Group's strategic five year plan. We also had a special session on the NOAA programs, with emphasis on some of the current calibration and validation programs at NOAA and a short tour of the PMEL facilities.

The next Working Group meeting, WGCV9, is intended to be hosted by CSIRO and will be held in Canberra, Australia during the week 5-9 December 1994. WGCV10 is expected to be hosted by the Russian Space Agency in Moscow, Russia, in June 1995.

Further information on the WGCV can be obtained from myself (as Chair of the WGCV) Dr Susan M. Till, Canada Centre for Remote Sensing, 588 Booth Street, Ottawa, Canada, K1A OY7.
Fax: 1 613 993 5022
email: till@ccrss.emr.ca or S.TILL/OMNET.

TERRAIN MAPPING SUBGROUP

Prof. Ian Dowman (email idowman@ps.ucl.ac.uk
fax 44 71 380 0453)

Since the 2nd meeting of the group at JRC, Ispra, data has been assembled on test sites for DEMs. At present it is clear that there are a number of potential sites in Europe and North America. It is hoped that data for at least one site will be collected ready for distribution in the near future.

The 3rd meeting of the group was held immediately before the WGCV8 meeting in Seattle, WA, USA on 22-23 February 1994. At this meeting in addition to the continuing discussions on suitable test sites the main topics discussed were methodology for testing and specification of accuracy.

THE MICROWAVE SENSORS SUBGROUP

Dr James C. Shiue, NASA Goddard Space Flight Center (email jcshiue@meneg.gsfc.nasa.gov.)
Tel 1 301 286 6716 or 1 301 2861762

The newly formed Microwave Sensors Subgroup (MSSG), of the CEOS WGCV, held its first meeting on October 7-8, 1993, at the Phillips Laboratory, Hanscom Air Force Base, Bedford, Massachusetts, U.S.A. The meeting was convened by Dr. James C. Shiue of NASA Goddard Space Flight Center, and it was graciously hosted by Dr. Vincent Falcone of the Phillips Laboratory.

The meeting began with a review of the status of several major spaceborne passive microwave sensor systems, and their calibration and validation practices and issues. Microwave radiometers such as the SSM/I, AMSU-A, AMSU-B, TMI, MIMR and AMSR were reviewed. The Terms of Reference for the MSSG was discussed, and an outline of it was drafted.

The original name of this new group was to be Passive Microwave Sensors Group, however during the WGCV8 meeting on February 23-25, 1994, in Seattle, Washington, U.S.A., it was agreed that the name of this new Sub Group be changed to MSSG. This change is a part of the long-term vision of the WGCV adopted in WGCV8, so that the MSSG can accommodate not only the passive but also some of the active microwave sensors, exclusive of the SARs, which are covered by the SAR calibration subgroup. Thus the MSSG will be the future (Cal/Val) home-base for the scatterometers, altimeters, and real aperture radars etc.

The next MSSG meeting will be held on August 15-16, 1994, to be held at the Jet Propulsion Laboratory (JPL), Pasadena, California. During the meeting a tour will be arranged to see the latest microwave hardwares at JPL and/or Aerojet.

SAR CALIBRATION SUBGROUP

Dr Tony Freeman, JPL (email:
tony_freeman@radar-email.jpl.nasa.gov Fax: 1 818 393 5285)

The SAR calibration subgroup held its 6th general meeting from September 20-24 1994 at the ESA ESTEC Conference Centre in Noordwijk, the Netherlands. The meeting was co-hosted by the ESA Technical Directorate and the ESA Directorate of Earth Observation and its Environment.

The meeting was attended by approximately 120 participants and took the form of a workshop at which the topics of calibration requirements, calibration devices, polarimetric calibration, interferometric SAR calibration, radiometric calibration, SAR processor calibration, Spaceborne SAR calibration, and SCANSAR calibration were discussed. During the course of the meeting numerous interesting and fruitful discussions on the many aspects of SAR calibration were held and significant progress was made on furthering our understanding of the various issues on SAR calibration.

The proceedings of the meeting have been published in the ESA Workshop Preliminary Proceedings series (ESA-WPP-048).

A summary of the subgroups recommendations was presented at the WGCV meeting held at Seattle in February. Two papers from the last workshop (one on radar brightness or β^o, the other on the general form of the radar equation) are to be presented at the IGARSS '94 conference in Pasadena, California, this August.
The next meeting of SAR calibration subgroup will be in the form of another workshop to be held at the University of Michigan, Ann Arbor, MI on September 28-30, 1994. For more information o this workshop. Please contact Dr K Sarabandi at the Radiation Laboratory, University of Michigan, 1301 Beal, Box 2122, 3225 ECCS Building, Ann Arbor, MI 48109-2122. Email

saraband@engin.umich.edu or fax 1 313 936 3492.

Further information on the SAR calibration subgroup may be obtained from Dr Anthony Freeman, Jet Propulsion Laboratory, M/S 300-325, Pasadena, CA 91109. Tel 1 818 354 1887 Fax: 1 818 393 5285 email tony_freeman@radar-email.jpl.nasa.gov.

IVOS SUBGROUP

Dr Ian Barton, CISRO, Australia.
(email: barton@larry.dar.csiro.au
Fax 61 3586 7600)

The CEOS sub-group on Infrared and Visible Optical Sensors (IVOS) held its third meeting at NOAA's Pacific Marine Environmental Laboratory, Seattle just preceding the WGCV Meeting #8. There were two major topics discussed at the meeting - contributions to the CEOS WGCV dossier, and formulation of a five-year plan.

The questionnaire for obtaining information about on-board calibration techniques has been completed and applied to EOS-AM and UARS instruments. The form will now be distributed to instrument project scientists for completion. A list of recipients with knowledge of visible and NIR sensors had been compiled at IVOS's previous meeting and this was updated to include those scientists concerned with infrared instruments.

A questionnaire has also been developed for collecting information on test sites and this has been distributed to many CEOS members. A wider distribution is planned and CEOS members should ensure that details of test sites in their countries are made available for this valuable document. To date there have already been 117 accesses to the data base - an indication that the dossier will develop into a valuable resource.

There was much discussion at the meeting on the importance of cross calibration between instruments - both those destined for space, and those used for calibration and validation at the earth's surface. The development of transfer standards, test facilities, and techniques for use of these standards was seen as high priority in the future activities of WGCV and IVOS. The other major activity over the coming years is the development and maintenance of the dossier. This resource is to be expanded to include details of test and calibration facilities that can be used for calibration and cross-calibration of instruments.

Some members of IVOS were concerned at the poor quality of information that is available on the spectral solar irradiance at the top of the atmosphere. This concern has also been raised at two recent meetings in France and the USA. The WGCV will investigate to determine if more accurate information is available on this parameter.

Other discussions were held on the desirability of improved satellite instrument calibration coefficients and their wider and more prompt dissemination. This includes the addition of calibration coefficients to direct broadcast data streams, and the inclusion of coefficients in the headers of off-line data sets.

IVOS also was concerned at the lack of technical information available in the open literature. More publications on subjects including test sites, test facilities, calibration programs and techniques would greatly assist the implementation of future satellite calibration programs.

The discussions held at the IVOS meeting were conveyed to the WGCV and will be used in the imminent development of the WGCV Five-Year plan.

GLOBESAR - PREPARATION FOR RADARSAT

Canada, through the Canada Centre for Remote Sensing (CCRS), in co-operation with the Canadian Space Agency, the International Development Research Centre, Intera Information Technologies (Canada) Ltd., Innotech Aviation, and Radarsat International Inc., is conducting a project in which airborne SAR imagery has been collected in Europe, the Middle East, Africa and the Asia/Pacific region. Countries participating include China, East Africa, France, Jordan, Malaysia, Morocco, Taiwan, Thailand, Tunisia, the United Kingdom, and Vietnam . The project has been named GlobeSAR. The primary purpose of the project is to increase the capability of the participating countries to use radar data in resource applications for planning for development and land use management. The initial stage of the program is the data collection flights, and this was successfully completed in late 1993.

The CCRS Convair-580 airborne radar is used to simulate RADARSAT data and thus familiarise users with the capabilities of the Canadian satellite, to be launched in 1995. The creation of expertise and awareness in clients will enable them to take advantage of the information in

RADARSAT imagery as soon as possible after the satellite is operational.

Participating countries have committed resources, and suitable research sites, have been selected through CCRS-host country co-operation. The test sites cover important terrain and vegetation conditions and represent research priorities for the countries involved. All of the areas selected are important to the host countries for future development and land use management. From a technical perspective, the areas are well delineated and contain the mixture of types of terrain and land use variability that is most productive from a radar analysis view point. These will be used to validate radar data products and applications under a variety of environmental and site conditions.

Technology transfer and skills development are primary components of this project. The program includes both joint applications development between Canada and host country, and a multi-year training program based on a series of workshops. The first workshops were combined with the initial planning missions in June-July 1993. Successive workshops will become progressively oriented towards image processing and analysis. At the conclusion of this 3-4 year program, there will be a broad base of well-trained users in each country.

Should you require further information or clarification on GlobeSAR, please contact:

Dr. F.H.A. Campbell
Canada Centre for Remote Sensing

Tel: 1 613 947 1227
fax: 1 613 947 1382.

ERS ANNOUNCEMENT OF OPPORTUNITY

The European Space Agency (ESA) has issued an opportunity to conduct scientific research using data from the first and second European Remote Sensing (ERS) satellites, ERS-1 and ERS-2. This opportunity is intended to complement the Announcement of Opportunity for ERS-1 which was issued in May 1986.

This is a "world-wide" call open to the full international community of Earth Observation scientists. It is not restricted to scientists from ESA member states.

This Announcement of Opportunity sort two types of proposal, namely:-

a) Innovative scientific proposals exploiting ERS (i.e. both satellites) data either alone or in synergism with other data.

b) Proposals for the calibration and geophysical validation of the new ERS-2 instruments i.e. the GOME, PRARE and the visible channels on ATSR-2.

The synergetic use of ERS data covers not only the use of data from more than one instrument on either of the ERS satellites but also the possible synergetic use of "simultaneous" data from ERS-1 and ERS-2. Subject to the agreement by ESA member states, limited parallel operation of both satellites is being considered.

Letters of intent from interested parties have been provided to ESA at the beginning of January 1994. The closing date for the receipt of proposals was 15 March 1994. It is expected that the announcement of selections will be made by ESA in July 1994.

Further information on the ERS Announcement of Opportunity may be obtained from Dr C. J. Readings, ESTEC, PO Box 299, 2200 AG Noordwijk, The Netherlands.

JERS-1 CAL/VAL ACTIVITIES

Dr Masanobu Shimada/Earth Observation Center/NASDA/(Fax: 81 492 96 0217)

PI Meeting

The first Principal Investigators (PI) meeting was held at Kogakuin University, Tokyo on August 16 and 17 with 290 participants. The meeting consisted of two plenary sessions and four parallel sessions. At the plenary session, NASDA-MITI introduced the JERS-1 program status, covering such items as the status of the satellite, operation anomalies, SAR and OPS characterisations, image quality and data distribution. At the time of the meeting only 30% of the requested images had been distributed to PIs. NASDA and MITI promised to accelerate the distribution of the data and to provide the information on JERS-1 to PIs. In the parallel sessions, 30 valuable papers were presented. It was also confirmed that SAR and OPS showed good sensitivity for monitoring the earth surface especially for land classification and forest monitoring.

STATUS OF JERS-1 AND ITS OPERATION

Introduction

JERS-1 was launched successfully on February 11 1992 by Japanese H-I launcher. The initial check of JERS-1 satellite bus and four mission instruments, SAR, Synthetic Aperture Radar, OPS, Optical Sensor System, MDT, Mission Data Transmitter, and MDR, Mission Data Recorder was finished at the end of May 1992. The JERS-1 system then entered the operational phase to acquire global data and to support the JERS-1 verification program. During both of these phases, several experiments were added to understand and recover from some anomalous conditions of the mission instruments.

The information on the status of JERS-1 and mission instruments as well as the data acquisition and distribution for PIs are summarised below.

Check results of the satellite bus and its present condition

Following JERS-1 launch, mission check was started for the satellite bus and mission instruments except the SAR whose antenna failed to deploy. As shown in table 1, the summary of the mission check results confirmed that the satellite bus was in good condition and within the designed specification. Since then, satellite bus has been in its operational phase without any degradation. JERS-1 has sufficient fuel remaining to maintain its orbit for more than eight years.

Short history of the anomalies

There have been some image degradation and data acquisition failure due to the mission instruments' anomalies. The history of these failures is summarised in this section.

SAR

i) Antenna deployment failure (February 11 1992 - April 3 1992)
ii) Arcing of the transmission pulse in the antenna cable and resultant large azimuth ambiguity ratio in SAR image
iii) Lower SAR transmission power (April 1992 and from September 18 1992)
iv) Failure of A transmitter, which happened on October 31 1993 from which time B transmitter has been used for SAR operations OPS
v) Horizontal noise in VNIR (any time)
vi) Vertical noise in SWIR (any time)
vii) DN value degradation in VNIR in calibration mode (from the beginning of mission life)
viii) Cooling failure in SWIR (several stops are confirmed)

MDR

ix) Unsuccessful MDR dump (Nov '92)

Orbit Manoeuvring

The orbit maintenance has been routinely conducted every week since November 1992 to keep the accuracy within around 7.5 Km. The satellite state vector is determined within 80 m on average, while the prediction accuracy is less than 0.32 sec at two days' propagation. Orbit determination was conducted daily using three or four data sets acquired by NASDA's four ground stations, Katsuura, Okinawa, Masuda in Tanegashima, and Kiruna, the last of which is a transportable ground station in Kiruna, Sweden. Then, the determined orbital data are interpolated every minute and provided to Hatoyama Earth Observation Center and foreign ground stations for further data acquisition and processing.

Data Acquisition

Priority of the data acquisition requests: Data acquisition planning is initiated by the acquisition requests, which are categorised as (1) sensor Cal/Val by NASDA and MITI, (2) PI activity support, (3) global data acquisition for land, forest, etc.

Amount of data acquisition: The amount of data acquired by JERS-1 is far from the original data acquisition plan of one whole coverage by SAR and OPS. 77249 SAR images and 27901 OPS images (of which 10451 OPS images were cloud free) have been acquired (as of August 6 1993).

Image Quality of SAR/OPS

SAR Cal/Val

SAR products are calibrated on a routine basis using several 2.4 m corner reflectors and active radar calibrators. These activities are conducted for the SAR's two operation modes, these are: single transmitter standard operation and two transmitters' operation mode. The conversion factors from DN of the SAR and SAR products are given in Table 2. Degradation of the SAR performance is mainly in the reduced transmission power and the saturation of the signal in the 3 bit AD converter. Even degraded, the image quality is confirmed as almost as good as the design specification. A summary of SAR image quality is presented in Table 3.

OPS Cal/Val

OPS Cal/Val is under way especially for the formulation of DN to input radiance. The level of input radiance is made by the adaptation of the atmospheric model to the AVIRIS data which is acquired by the simultaneous underflight. The comparison of the input radiance and OPS DN provides the conversion formula. By now, we have conducted these experiments four times as NASDA-NASA joint research. The documentation for OPS summarises the relationship.

Ground truth experiment

SAR: Using the point target instruments, ground truth experiments are under way. The test sites are located near Hatoyama Earth Observation Center, and in the Niigata and Shizuoka prefectures. The major one is in Niigata, where there is no interference from the ground and no signal saturation has occurred, while Hatoyama is affected by interference and Shizuoka site is affected by signal saturation.

OPS: OPS test sites are at Rogers Dry Lake, Ivanpah Lunar Lake and White Sands, USA. Additional test sites are in the Nevada desert and Atacama high land in Chile

Product summary and Image co-ordinates:

See the documents "User's Guide to NASDA's SAR products/ HE-93014"

Conversion of the DN to physical value SAR

$$\sigma^0 = \overline{I^2} + CF[dB]$$

OPS: See document "Conversion formula for OPS DN to input radiance / HE 93066"

Table 1 Results of the Satellite bus check

Orbit		
- Local solar time	10:34:43 at May 17 '92	10:30 - 11:00
- Revolution per day	15 - 1/44	15 - 1/44
- Altitude	568.5 Km	568 Km
- Inclination	97.71 deg	97.7 deg
- Eccentricity	0.0015	0.0011
Satellite Weight	1339.5 Kg	1340 Kg
Attitude uncertainty	<0.11 deg in roll	<0.3 deg
	<0.17 deg in pitch	<0.3 deg
	<0.10 deg in yaw	<0.3 deg
Attitude rate (3s)	<0.00044 deg/sec	<0.003 deg/sec
	<0.00050 deg/sec	<0.003 deg/sec
	<0.00035 deg/sec	<0.003 deg/sec
Remain thrust fuel	< 6 years	2 years as mission life
Transmission power (S band)	16.211 dBm	14.00 - 16.99 dBm
Frequency	2220.0030 MHz	2220.00 MHz + - 44.4 kHz
Satellite G/T	-31.3 dB/K	>= -46.8 dB/K
Satellite EIRP	16.75 dBm	>= 8.1 dBm
Solar Array Power	2304 W	2053 W (End of Life)

Table 2 Conversion Factor

CF[dB]	reception date	process date
-68.5	Until end of April 92, Sept 1 '92, and since Sept 18 '92	Since Feb 15 '93
-70.0	Until end of April 92 Sept 1 '92, since Sept 18 '92	Until Feb 14 '93

Available documents

Following are the available documents for PIs:

i) CCT format description for SAR and OPS

ii) User's Guide to NASDA's SAR products/HE 93014

iii) Conversion formula for OPS DN to input radiance/HE 93066

Contact Points

Following contact points are available for the PI's inquiry

- Data request and distribution
Yasuhiko Kataoko, Team Leader, Order Handling team, Operations Planning Section, Operations Dept
RESTEC Hatoyama Division
1401 Numanoue Ohashi Hatoyama Hiki Saitama Japan 350-03
81-492-98-1303 (tel).,
81-492-98-1398 (Fax)

- Product information, handling, satellite

M Shimada/NASDA/EOC/Office of JERS-1 verification program
1401 Numanoue Ohashi Hatoyama Hiki
81-492-98-1215 (tel), 81-492-98-1001 or 81-492-96-0217(Fax)

Table 3 Summary of image quality

Item	Condition		Reference	No of Trans
Resolution	21.39m(Az)	21.01m(Rg)	23.6m	1
	20.06(Az)	21.34m(Rg)		2
PSLR	-15.67 dB(Az)	-15.55 dB(Rg)		1
	-8.16 dB(Az)	- 13.33 B(Rg)		2
ISLR	-8.70 dB			1
	-0.97 dB			2
Ambiguity	-22 dB		-20.0 dB	1
	-10 dB			2
Looks 1.8	NA	3.0		
G Error	-40.0m	-104.0 m	(1 sigma)	
R Error	1.86 dB		(1 sigma)	
Saturation				

CALIBRATION IN TERMS OF RADIANCE: SOLAR PRE-FLIGHT CALIBRATION OF SCARAB

J. Mueller, R. Stuhlmann, and E Raschke (email: joaannes.mueller@gkss.de)

The SCARAB EXPERIMENT

The very successful NASA project ERBE (Earth Radiation Budget Experiment) provided the scientific community with very accurate earth radiation budget (ERB) data[1]. There is a large demand for ERB measurements from space beyond the ERBE project. With this background the ScaRaB (Scanner for Radiation Budget) project has

been established within the French-Soviet (now French-Russian) space co-operation. Germany has taken part in the project since 1988.

Russian authorities are now responsible for the satellite and the on-board calibration system of the ScaRaB. The French group is responsible for the opto-mechanical parts as well as the electronics for the instrument.

The German group contributes the ground calibration facility for the solar spectral channels. The French, German and Russian groups are involved in the data inversion process. The first model of the ScaRaB (FM1) will be launched in December 1993 on a Russian METEOR3 satellite.

The Radiometer

The ScaRaB radiometer consists of four parallel telescopes. These are identical except for the optical filters. Each telescope represents one spectral channel: visible, solar, total and atmospheric window (Table 4 and Table 5). The ERB parameters are derived from the measurements of the total and solar channel. The visible channel and the atmospheric window are used for scene identification which is needed in the data procedures[2].

Table 4 Spectral channels of ScaRaB

No.	Channel	Spectral range (µm)	Filter
1	visible	0.5-0.7	interference
2	solar	0.2-4	fused silica
3	total	0.2-50	none
4	atm. window	10.5-12.5	interference

Table 5 Survey of the characteristics of ScaRaB (TM=Technology Model; FM1=Flight Model 1)

No. of channels (Table 4)	4
Dynamic Range	solar up to 425 $W/m^2/sr$
	total up to 500 $W/m^2/sr$
Instantaneous field of view (square)	48*48 $mrad^2$
	at nadir 60*60 Km^2
Scan Angle	100 degrees
Pixels/scan	51
Sampling interval 34 mrad	
Sampling period	62.5 ms
Scan period	6 s
useful scan time	3.18 s
Relative accuracy $\pm$ 0.25 $W/m^2/sr$	
NERR (total channel)	0.1 $W/m^2/sr$ (measured on TM)
	0.07 $W/m^2/sr$ (expected on FM1)
Mass	40 Kg
Power	42 W
Size	614 * 512 * 320 mm

Table 6 On-board calibration sources for ScaRaB (L=lamp; subscript=(number of lamp set, number of channel); B= blackbody simulator, subscript= number of channel)

No.	Channel	Usage:	1/1 month	1/12 hours	1/20 min	continuous
1	visible		L11			
2	solar		L32	L12	L22	
3	total		L33		L23	B3
4	atm. window					B4

On-board calibration

Various calibration sources are available. Table 6 shows the purposes of the various sources. The chosen procedure allows the cross checks between different sources.

The thermal channels will be calibrated with black body simulators (B3 and B4) of 310 K temperature.

Calibration sources L22 and L23 consists of a tungsten filament lamps. Their light is distributed by an optical fibre on both the solar and total channel. Each channel receives light from all filament lamps so that possible degradation will affect both channels to the same extent. This allows a calibration of the solar channel by the means of blackbody B3 via the total channel.

Assuming that the ratio between L22 and L23 remains constant, the ratio between the gains of the solar and total channel can be measured by the means of the calibration lamp sources.

Calibration lamps L12, L32, and L33 are used for test purposes and stability checks. These sources consist of filament lamps too. The visible channel is checked once a month by L11. The channel will not be calibrated. This is acceptable because this channel is used for scene identification only.

Space provides a dark reference for total and the window channel. The blackened instrument cover is dark reference for the visible and solar channel.

All on board sources have to be calibrated themselves before launch. The basic idea of a ground calibration is to use the ScaRaB instrument as a transfer radiometer in order to link the on-board sources to a ground based standard[3]. Since the radiation from the earth-atmosphere system is divided into the reflected solar light (˜ 0.2-4 µm) and the thermal emission (˜ 4-100 µm), the pre-flight calibration is divided into a solar and thermal spectral domain. The thermal spectrum of the earth can be simulated easily by blackbodies. Thus, the on-board black body simulators were calibrated by the means of the standard cavity radiators.

Standard calibration sources with a spectrum comparable to the sun are not available. Therefore, it was decided to use the sun itself as a calibration source. The solar ground calibration is performed in the Ground Calibration Unit (GCU) developed by Germany. The GCU consists of a reference diffuser that is illuminated by the sun. The thermal radiation of the diffuser is cancelled by a silica filter. The absolute transmission of this filter is measured during the calibration procedure. In front of the diffuser is a baffle which is similar to the baffle of an Eppley pyrheliometer. The pyrheliometer measures the incoming solar flux density. The actual solar spectrum is measured by a spectrometer in relative units. Knowing the solar irradiance, the solar spectrum and the spectral reflectivity of the diffuser, one can easily calculate the absolute spectral radiance of the diffuser. This allows for the determination of the absolute gain of the ScaRaB instrument. Then, the ScaRaB instrument is used to calibrate the internal solar on-board sources of the ScaRaB instrument. The diffuser-baffle system can be moved in front of the solar, visible and the total ScaRaB channel. The complete GCU points continuously to the sun by the means of a heliostat.

Some results of solar calibration

The measurements were performed at the Solar Observatory in Ianzana/Tenerife Kiepenheuer Institut fuer Sonnenphysik/ Germany) during the second half of February 1993[4]. The gain of the ScaRaB turned out to be very stable (better than one permille) within the period of one measurement cycle (approx. 30 minutes). It changed significantly on time scale of days due to temperature effects. This did not affect calibration accuracy because the gain is monitored by the means of the diffuser measurements. The variations of solar spectra were very small. Therefore, the spectral correction terms were very constant during the calibration measurement. The spectral correction term for the solar channel had a rms of 0.4 permille within the measurement cycles. Some of the lamp-sources (L22/L23 showed a significant drift during the calibration campaign. Others (L32) turned out to be very stable. The accuracy of the lamp sources is better than 2% (except lamp L11(4%), which is for auxiliary channel 1 only). This number does not include possible lamp drifts. Preliminary results have been presented recently at the SPIE'S conference on 'Passive Infrared remote Sensing of Clouds and the Atmosphere', April 1993, Orlando/USA and at the IAMP-IAHS joint symposium, July 1993, Yokohama, Japan.

Conclusions

The GCU was tested for the first time during the campaign in Ianzana. The stability of the filtered lamp radiances proves that the GCU performs reproducible measurements of a good quality. The effect of the change in the gain of the radiometer due to the temperature can be removed. The influence of the atmosphere on the measurements is very small if the sky is clear, but even thin cirrus causes a high noise on the pyrheliometer so a proper link between ScaRaB and pyrheliometer is difficult.

The GCU is an accurate and cheap tool for broad band radiometric calibration in the solar spectrum domain. A comparison with other calibration sources has not been performed yet. A comparison with the calibration facilities of the USA CERES experiment has been discussed between the responsible agencies NASA, CNES and DARA. Due to the problems of the schedule of both experiments, a joint campaign could not be fixed up to now. Proposals for comparison between GCU and other calibration facilities are very welcome.

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FUTURE MEETING DATES

WGCV9: December 5-9, 1994, Canberra, Australia.

WGCV10: June, 1994, Moscow, Russia.

SAR Calibration: September 28-30, 1994, University of Michigan, Ann Arbor, MI, USA.

Microwave Sensors Subgroup: August 15-16, 1994, Jet Propulsion Laboratory (JPL), Pasadena, California, USA.

Terrain Mapping: December 5-6, 1994, Canberra, Australia.

IVOS: December 5-6, Canberra, Australia.

REMINDER

Issue 4 of the CVWG Newsletter is intended to be completed in December 1994. Contributions for inclusion in the next issue should be submitted to the Newsletter editor Mark Hutchins preferably by email to markh@raesp-farn.mod.uk or by fax. to +44 252 522959 by 15 November 1994.

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