A Geophysical Cross-Calibration Approach for Broadband Channels: Application to the ScaRaB Experiment

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(Manuscript received 28 October 1999, in final form 25 February 2000)

ABSTRACT

For the determination of the earth radiation budget (ERB) from space, the reflected solar flux and the emitted longwave (LW: 4–100 μm) fluxes are estimated using radiance measurements made in shortwave (SW: 0.2–4.5 μm) and ''total'' (TW: 0.2–100 μm) channels. An accurate (1%) calibration and cross-calibration of these two channels is required for the determination of the ERB and for daylight determination of the LW radiance based on differences between the TW and the SW radiances. This paper presents an approach to calibrate the SW channel by using a cross-calibration between the SW channel and the SW part of the TW channel. This approach is applied and validated using data from the Scanner for Radiation Budget (ScaRaB) experiment.

The principle of this cross-calibration is to estimate the LW radiance from the infrared window (IR: 10.5–12.5 μm) radiance measurements over deep convective cloudiness in the Tropics. This estimate makes it possible to subtract the LW signal from the TW radiance measurement during daylight and thus to compare directly the SW radiances measured by the SW and the TW channels. An IR channel is already implemented on ScaRaB and on the Cloud and the Earth's Radiant Energy System (CERES) instruments. Using ScaRaB data, it is shown that it is possible to estimate the LW radiance over deep convective cloudiness in the Tropics from IR radiance measurement with accuracy better than 1 W m^{-2} sr^{-1}. The method applied to ScaRaB measurements gives calibration and cross-calibration parameters with accuracy better than 1%.

1. Introduction

The earth radiation budget (ERB) at the top of the atmosphere may be estimated from space using broadband measurements of reflected solar or shortwave (SW: 0.2–4.5 μm) radiation and of outgoing infrared or longwave (LW: 4–100 μm) radiation. Due to technical limitation on spectral response flatness, direct broadband LW radiance measurement is not practical. The LW radiance is estimated from an unfiltered ''total'' (TW) channel integrating the spectral radiance between 0.2 and 100 μm. This is the case for the Earth Radiation Budget Experiment (ERBE) instruments (Lee at al. 1989), for the Scanner for Radiation Budget (ScaRaB) instruments (Monge et al. 1991) and for the Cloud and the Earth's Radiant Energy System (CERES) instruments (Lee at al. 1993). The calibration of the LW portion of the TW channel is relatively straightforward using measurements of an onboard blackbody simulator. Such a device can have an emittance very close to unity, and the temperature can be determined with high accuracy using platinum resistance temperature sensors. An in-flight absolute calibration in the SW domain is much more difficult, because the instruments used to observe the earth cannot be used to observe the Sun directly. The onboard lamps used are not very good simulators of the 5800-K blackbody that should be better suited for a good calibration. In addition, these lamps are far from being as stable as an onboard blackbody simulator. It is very difficult to find an absolute source of calibration in the SW domain and even solar diffusers, such as the mirror attenuator mosaic of CERES, are only relative calibration systems (Lee et al. 1996). This calibration problem, together with uncertainties in the spectral correction process, is a source of bias in the determination of the SW flux. This gives inconsistencies between the SW measurements of different instruments (CERES, ERBE, ScaRaB), as was shown by Currey and Green (1999) by comparing the SW signature of different selected geophysical targets. During nighttime, TW measurements directly give the outgoing LW radiance but during daylight, the LW radiance must be estimated by a difference between TW and SW radiance measurements. It is thus necessary to cross-calibrate SW and TW channels accurately, not only in order to have a correct estimate of the earth radiation balance, but also to correctly estimate the LW radiance during daylight. This cross-calibration is indeed a known possible source of uncertainty in the determination of the LW radiative

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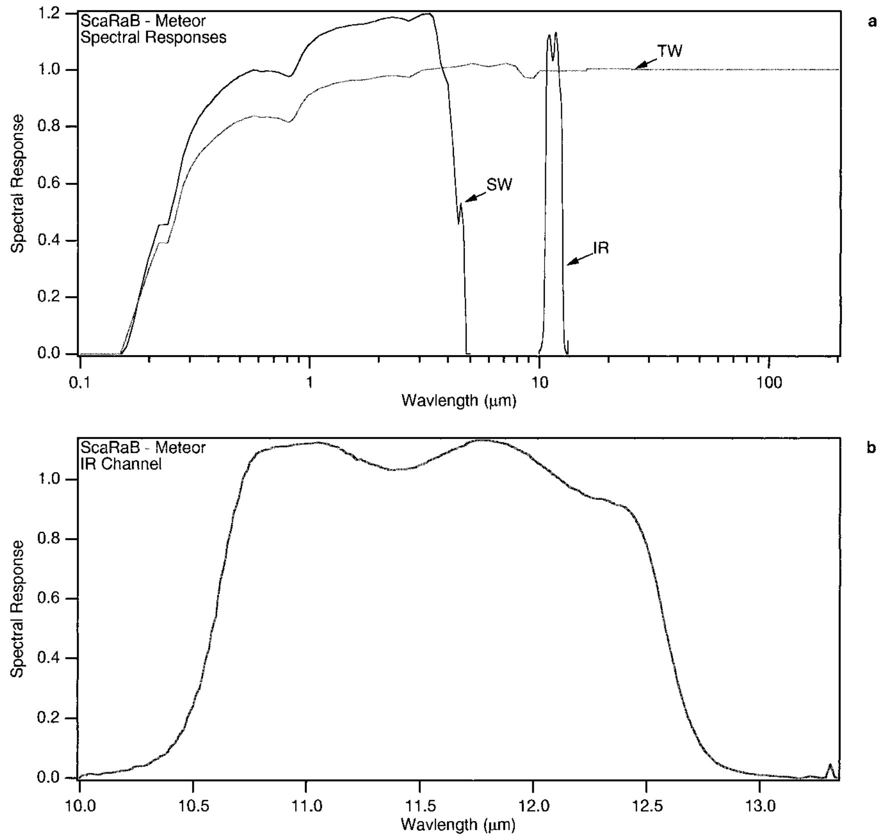

FIG. 1. (a) Normalized spectral response of the shortwave (SW), the "total" (TW), and the infrared (IR) window channels of ScaRaB-Meteor. The response of the SW channel is normalized to give a filtered radiance equal to the actual radiance for a blackbody at 5800 K. The response of the TW channel is normalized to give a filtered radiance equal to the actual radiance for a blackbody at 310 K. The response of the IR channel is normalized to give a filtered radiance equal to the actual radiance for a blackbody at 310 K integrated between 10 and 12 μm. (b) Detail of the normalized spectral response for the IR channel only.

fluxes at the top of the atmosphere (Thomas et al. 1995; Green and Avis 1996).

By construction, the shapes of the response of the SW and TW channel are very similar in the SW spectral domain (Fig. 1). Note that for the ScaRaB instrument, a particular normalization of the spectral response is done that may give a value larger than one for some wavelengths. Indeed, the response of the SW channel is normalized to give a filtered radiance equal to the actual radiance for a blackbody at 5800 K. The response of the TW channel is normalized to give a filtered radiance equal to the actual radiance for a blackbody at 310 K. The response of the IR channel is normalized to give a filtered radiance equal to the actual radiance for a blackbody at 310 K integrated between 10 and 12 μm. This particular procedure gives filtered radiances that are close to actual radiances for the two broadband channels. The SW channel differs from the TW channel by a silica filter that modifies only slightly the shape of the spectral response for wavelength smaller than 4 μm (Monge et al. 1991). The spectral correction required to compensate for the nonflatness of this spectral response is thus very similar for both channels. Consequently, a cross-calibration obtained from a direct comparison between the SW signal and the SW part of the TW signal will be applicable on all scene types.

The knowledge of the LW part of the TW radiance for a set of daylight measurements makes it possible to do such comparison, giving a cross-calibration coefficient between the TW and the SW channels. This cross-calibration gives thus a calibration of the SW channel based on the accurate calibration of the TW channel on onboard blackbody simulator. To estimate the LW radiance, it is possible to use a radiance measurement in the infrared window (IR: 10.5–12.5 μm) for particular scene types. We show in this paper that IR measurements over deep convective cloudiness in the Tropics make it possible to estimate precisely the LW radiance. Measurements of IR, TW, and SW radiances over these scene types may thus be used to cross-calibrate the SW channel and the SW part of the TW channel. This SW–TW cross-calibration is very efficient to verify or determine the calibration of the SW channel since the TW channel is reliably calibrated by the onboard blackbody

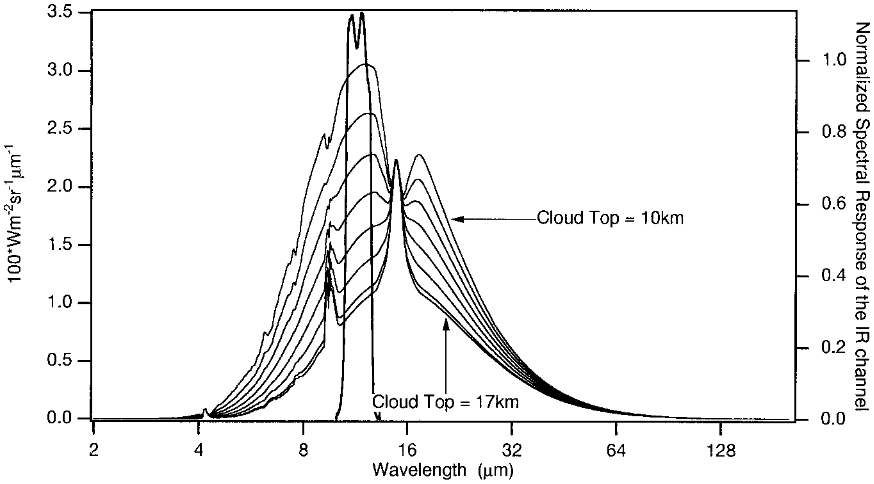

FIG. 2. Longwave radiance spectrum at the top of the atmosphere computed using the LOWTRAN (Kneizys et al. 1980) radiative transfer model with a tropical standard atmosphere and with cloud top simulated as blackbodies at the temperature of the environmental air at the corresponding altitude. The altitude of the cloud top is set between 10 and 17 km with a step of 1 km. The response of the IR channel of ScaRaB is superimposed (right axis).

simulator. A similar approach applied to CERES measurements is described in Kratz et al (1999) and revealed a shortwave inconsistency of 0.8% compared to the operational SW calibration.

The description of the method is reported in section 2. The method is applied to both ScaRaB-Meteor (Kandel et al. 1998) and ScaRaB-Resurs experiments. ScaRaB-Meteor, the first flight model of ScaRaB, was integrated on the Russian operational satellite *Meteor-3/7* and launched on 24 January 1994 from the Plesetsk spaceport. ScaRaB-Meteor gave data during one year between March 1994 and March 1995. Since there were some data missing during April and October 1994, only 10 months of data are used in this paper. ScaRaB-Resurs, the second flight model of the ScaRaB instrument, was launched from Baïkonour on board the Russian *Resurs-01/4* platform on 10 July 1998. Due to various data transmission problems, ScaRaB-Resurs data are available only between November 1998 and March 1999 with much data missing. The results of the geophysical cross-calibration are reported in section 3 for both ScaRaB experiments.

2. The geophysical cross-calibration approach

This geophysical method is based on the estimation of the LW radiance from an IR window radiance measurement. To make the approach more physically interpretable, it is convenient to define a pseudo–LW radiance from the IR window measurement as

$$L_{IR} = \frac{\sigma T_{IR}^4}{\pi}, \qquad (1)$$

where T_{IR} is the equivalent blackbody temperature (EBBT) corresponding to the measured IR window radiance.

For this geophysical cross-calibration approach to be valid, it must exist in specific scene types for which the LW radiance may be estimated from L_{IR} with a small error. The scatter of the relation between LW and L_{IR} is mainly due to variability of atmospheric absorption and emission. By considering the very cold top of deep convective cloud in the Tropics, we expect to minimize this scatter because the atmosphere above the cloud top has only little absorption mainly due to CO_2 and O_3. In fact, as illustrated in Fig. 2, these bands may even be in emission because of the warmer stratosphere above the very cold and high cloud top. In addition, these clouds are very bright and cold and give potentially a small LW radiance compared to the SW radiance if the measurement is done around noon. In such a case, the error due to the estimate of the LW radiance from the IR measurement is further minimized in regard to the large signal in the SW spectral domain on which the cross-calibration is done.

a. Relation between LW and L_{IR} using nighttime measurements

The first step of the method is to compute the relation between the IR and the LW radiances for these cold scenes. This relation is established by considering nighttime measurements for scenes with an EBBT in the IR window lower than 230 K. A smaller EBBT is not considered here in order to obtain a number of measurements sufficiently large to construct a statistical relation between IR and LW radiances at night and to apply the cross-calibration procedure during daylight. Figure 3

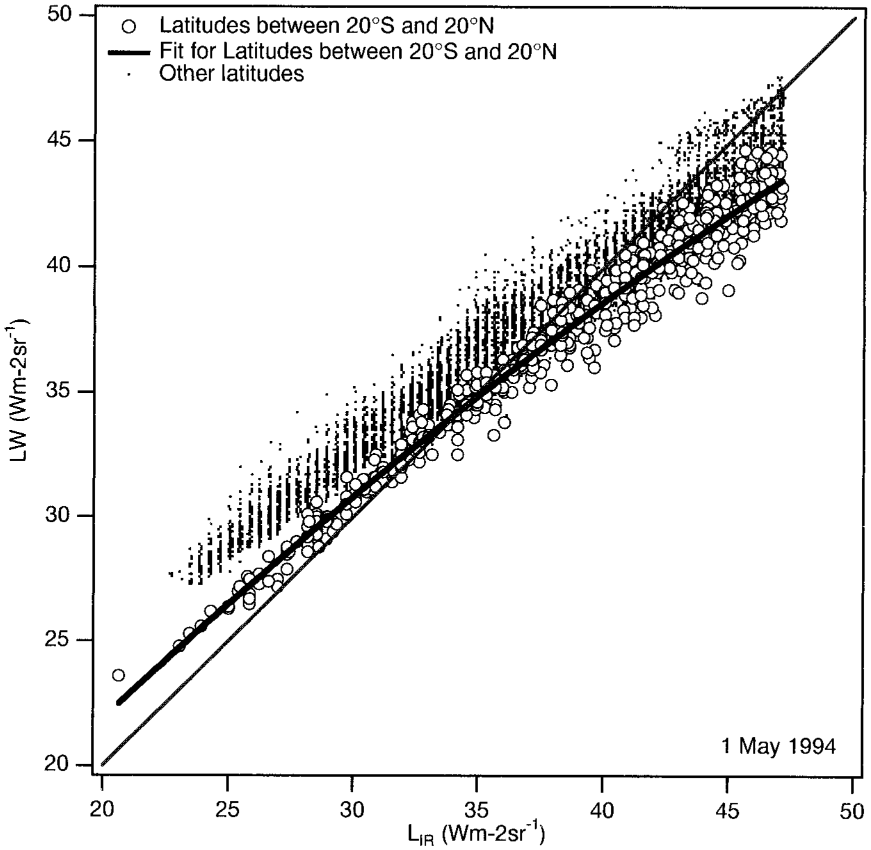

FIG. 3. Longwave radiance (LW) as a function of the pseudo LW radiance L_{IR} for one day of ScaRaB-Meteor measurements (1 May 1994) and for infrared window equivalent blackbody temperature (EBBT) lower than 230 K. The circles are measurements in tropical regions between 20°N and 20°S and the dots are for all the other regions. The bold line represents the mean quadratic regression for this day and for tropical regions only.

shows that the consideration of only cold scenes for tropical regions (20°S to 20°N) strongly reduces the scatter of the relation between LW and L_{IR}. This is because the atmospheric content and the atmospheric temperature structure above the deep convective cloud are relatively homogeneous for tropical regions. Note that, due to atmospheric absorption, the LW radiance is smaller than L_{IR} for LW values larger than 35 W m^{-2} sr^{-1}. As noted above, the LW radiance is larger than L_{IR} for very cold scenes because the cloud top is colder than the stratosphere (see also Fig. 2). The scatter increases with the L_{IR} signal because warmer (thinner or lower) clouds correspond to more variable absorption. For

TABLE 1. Values of the regression coefficients between the LW radiance and the L_{IR} radiance estimate [Eq. (2)].

	ScaRaB-Meteor		ScaRaB-Resurs	
	a_n	b_n	a_n	b_n
$n = 0$	5.850	−4.951	6.220	−5.166
$n = 1$	9.321e–01	1.900e–01	9.365e–01	1.892e-01
$n = 2$	−3.646e–03	−7.034e–04	−3.653e-03	−6.542e-04

these relatively warmer clouds, the atmospheric content has potentially a greater impact on the L_{IR} to LW conversion since the LW radiance is more sensible than L_{IR} to the atmospheric path. In addition, since the atmospheric path depends on the cosine of the viewing zenith angle (θ_v), this parameter must be considered in the regression between LW and L_{IR}.

On the average, over the 10 months of ScaRaB-Meteor data, there is as expected a larger difference between LW and L_{IR} for larger viewing zenith angle (Fig. 4a), and this difference is larger for large values of L_{IR}. For L_{IR} smaller than 30 W m^{-2} sr^{-1}, there is almost no influence of the viewing angle (Fig. 4a). Note that, for the swath of ScaRaB, the number of measurements is far larger for cosine of the viewing zenith angle between 0.9 and 1 (Fig. 4b) so that regression coefficients between LW and L_{IR} computed from this dataset will be more strongly weighted by these angular configurations. The monthly mean relation between the LW radiance measured by the TW channel and L_{IR} is very stable all along the ScaRaB-Meteor experiment for any viewing angle (Figs. 5a,b). This shows that the seasonal variation

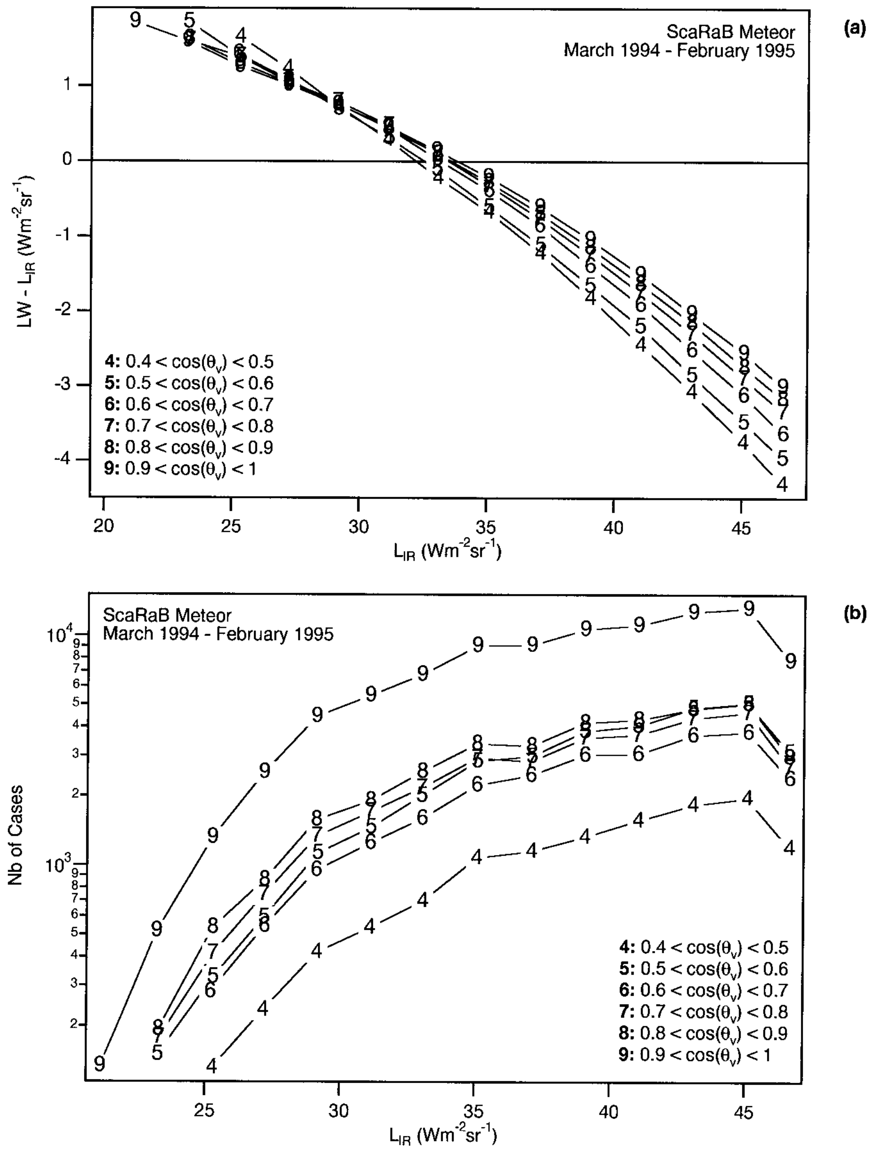

FIG. 4. (a) Mean difference between the longwave radiance LW and the pseudo–LW radiance L_{IR} for the 10 months of ScaRaB-Meteor measurements. The average differences are computed in intervals of 2 W m^{-2} sr^{-1} of L_{IR} and in different intervals of the cosine of the viewing zenith angle. (b) Corresponding number of measurements in each interval.

of the meteorological conditions in the Tropics (i.e., mainly the latitudinal migration of the intertropical convergence zone) has almost no influence on the relation between LW and L_{IR}. This shows also the long-term stability of the spectral response of the LW part of the TW channel and of the IR channel.

Due to the large amount of missing data, the results for ScaRaB-Resurs reported here are the average over the whole experiment. The relation obtained for ScaRaB-Resurs measurements is very similar to the relation obtained for ScaRaB-Meteor. The small discrepancy between Meteor and Resurs is due to small differences in the LW spectral response of the TW channels of the two instruments. The standard deviation of the difference between LW measurements and L_{IR} in each interval of θ_v and L_{IR} is generally smaller than 1 W m^{-2} sr^{-1} (not shown). The scatter between the ScaRaB-Meteor monthly means is larger for small values of L_{IR} and for large viewing angles, mainly because there are fewer measurements for these categories (Fig. 4b).

For this interval of L_{IR} (20–45 W m^{-2}sr^{-1}), the LW radiances are estimated by a quadratic regression:

$$\mathrm{LW_{est}} = \sum_{n=0}^{2} [a_n + b_n \cos(\theta_v)]L_{\mathrm{IR}}^n. \quad (2)$$

The values of the coefficients a_n and b_n are reported in

Table 1 for both ScaRaB-Meteor and ScaRaB-Resurs. The root-mean-square regression error is smaller than 1 W m^{-2} sr^{-1}. The corresponding regression curves for two values of the cosine of the viewing zenith angle are reported on Fig. 5.

b. Cross-calibration using daytime measurements

During day, the count N_{tw} measured by the TW channel for a given geophysical scene may be expressed as

$$N_{tw} = G_{tw}\left[\int_0^\infty L_{geo}^{sw}(\lambda)r_{tw}(\lambda)\,d\lambda + \int_0^\infty L_{geo}^{lw}(\lambda)r_{tw}(\lambda)\,d\lambda\right], \tag{3}$$

where G_{tw} is the gain of the TW channel, r_{tw} is its spectral response, and L_{geo}^{sw} and L_{geo}^{lw} are, respectively, the reflected SW radiance and the emitted LW radiance of the scene. In the following this relation is noted as

$$N_{tw} = G_{tw}SW_{tw} + G_{tw}LW_{tw}, \tag{4}$$

where SW_{tw} and LW_{tw} thus represent radiances in the SW and in the LW spectral domain, filtered by the spectral response of the TW channel. An equivalent relation may be written for the SW channel:

$$N_{sw} = G_{sw}SW_{sw} + G_{sw}LW_{sw}, \tag{5}$$

where LW_{sw} is a "thermal leak" of the SW channel due to the part of the LW radiance for wavelength shorter than 4.5 μm and to LW radiance beyond 50 μm where the silica filter is not entirely opaque (see Lee et al. 1996). For this geophysical cross-calibration, the LW radiance is small for the deep convective cloud and we will neglect this thermal leak so that

$$SW_{sw} = \frac{N_{sw}}{G_{sw}}. \tag{6}$$

Replacing LW_{tw} by LW_{est} in Eq. (4) gives

$$SW_{tw} = \frac{N_{tw} - G_{tw}LW_{est}}{G_{tw}}. \tag{7}$$

For any daytime cross-calibration measurement (i) over a tropical deep convective cloud, we thus compute a gain of the SW channel by combining Eqs. (6) and (7):

$$G_{sw}^i = \frac{A'N_{sw}^i G_{tw}}{N_{tw}^i - G_{tw}LW_{est}^i}. \tag{8}$$

The right-hand side of Eq. (8) is either measured or estimated. The ratio

$$A' = \frac{SW_{tw}}{SW_{sw}} \tag{9}$$

is computed using ground calibration parameters (Mueller et al. 1993) and is not supposed to vary significantly with time. In addition, since shapes of the spectral response of the SW and the TW channels are very similar in the SW spectral domain this ratio A' is supposed to be constant for any type of reflected SW spectral signature. The value A' essentially depends on the normalization procedure of the spectral responses of SW and TW channels. With the ScaRaB particular normalization principle, the ratio A' is equal to 0.8449

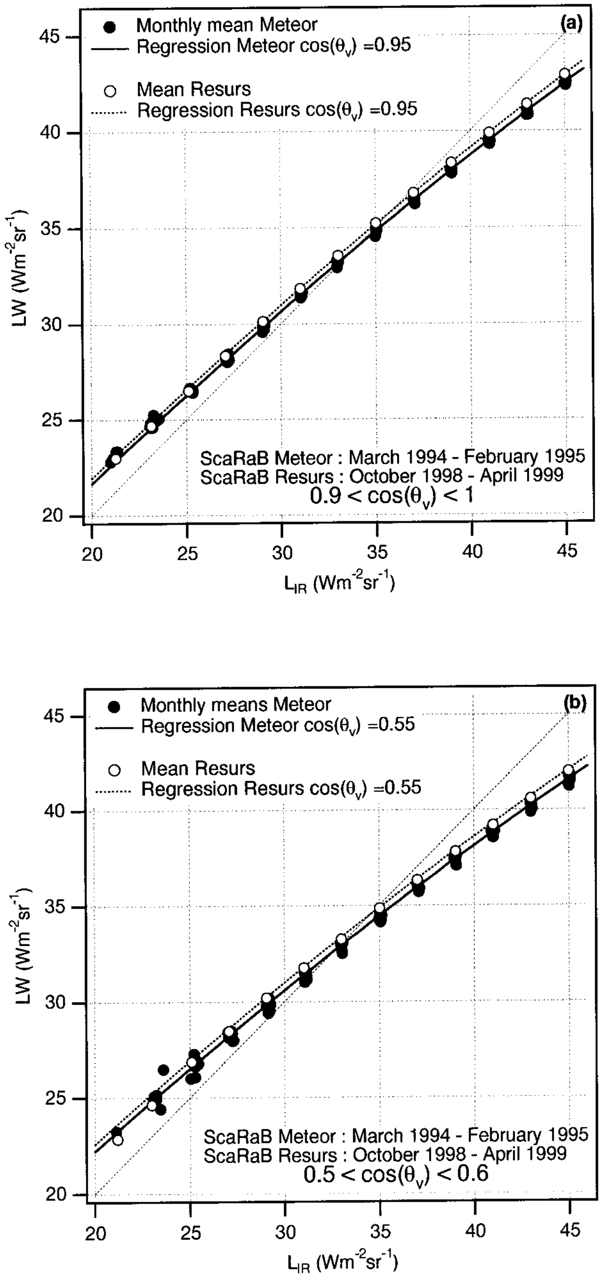

FIG. 5. Mean longwave radiance in intervals of 2 W m^{-2} sr^{-1} of pseudo–LW radiance L_{IR} for each of the 10 months of ScaRaB-Meteor measurements and for all the ScaRaB-Resurs measurements. The corresponding regression between LW and L_{IR} is superimposed. (a) Mean relation for the cosine of the viewing zenith angle between 0.9 and 1. (b) Mean relation for the cosine of the viewing zenith angle between 0.5 and 0.6.

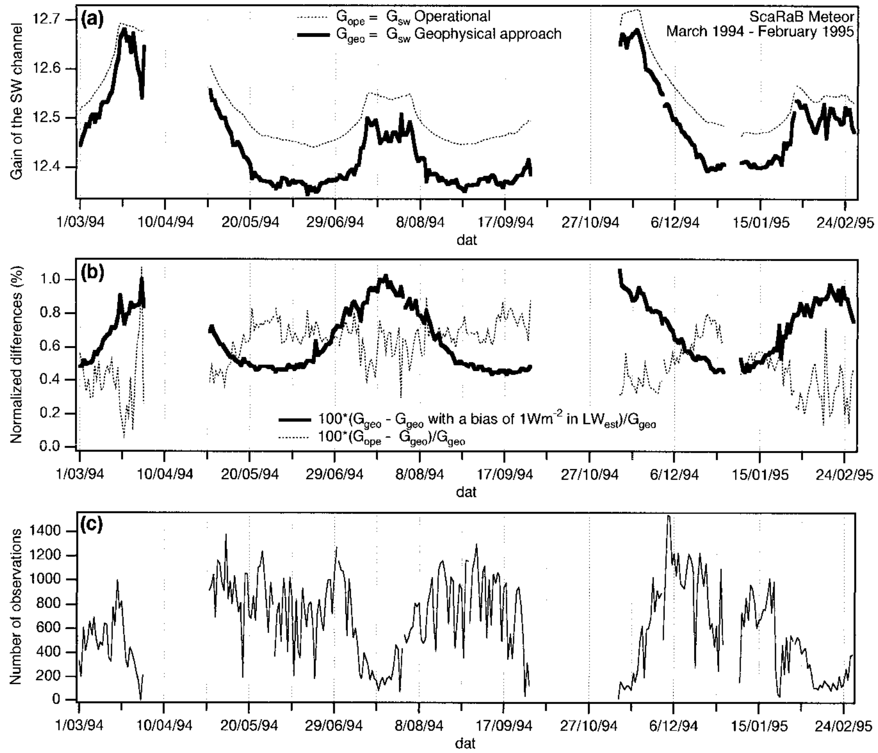

FIG. 6. (a) Time evolution of the operational gain (W m^{-2} sr^{-1} per digital count) of the SW channel of ScaRaB (dotted line) compared to the gain obtained from the geophysical cross-calibration approach (solid line). (b) Normalized difference between the operational gain and the gain derived from the geophysical cross-calibration approach (dotted line) and normalized difference for a bias of 1 W m^{-2} sr^{-1} in the estimate LW_{est} [in Eq. (8)] of the LW radiance from the IR radiance measurement (solid line). (c) Daily number of measurements considered for the cross-calibration.

for ScaRaB-Meteor and to 0.8945 for ScaRaB-Resurs. The knowledge of this ratio A' is very important and is needed all along the ground and in-flight calibration procedures.

In order to average the noise due to the scatter of LW_{est}, it is convenient to determine average values of G_{sw}. For the ScaRaB instrument, the gain of the total channel (G_{tw}) is estimated every four scans (of 6 s each) using the onboard blackbody simulator. In fact, this gain and the gain of the other channels vary mainly as a function of the temperature of the instrument (T_{inst}) given by a temperature sensor located on the TW channel. The operational calibration of the different channels of ScaRaB is based on the periodic verification of a linear relation between the gain and T_{inst}. The gain values applied to either ScaRaB-Meteor or ScaRaB-Resurs measurements are deduced from this linear relation. For the cross-calibration, it is thus appropriate to compute an average relation between G_{sw} and the temperature of the instrument (T_{inst}). Such a relation may be established and tested on a monthly basis. By using the two linear relations $G_{tw}(T_{inst})$ and $G_{sw}(T_{inst})$, the LW radiance may thus be estimated for a measurement (m) over any scene type by

$$LW_{tw}^{m} = \frac{N_{tw}^{m}}{G_{tw}(T_{inst})} - \frac{A'N_{sw}^{m}}{G_{sw}(T_{inst})} + A'LW_{sw}^{m}. \qquad (10)$$

Here, the thermal leak LW_{sw} is not always negligible. This thermal leak may also be estimated by using regression between LW_{sw} and the signal in the IR channel that is established using nighttime measurements.

3. Application to the ScaRaB experiments

The time evolution of the gain G_{sw} of the SW channel of the ScaRaB-Meteor instrument between March 1994 and February 1995 is computed with a time step of one day. The average daily value of G_{sw} is simply the average value of the G_{sw}^{i} [Eq. (8)]. In order to improve the precision of the cross-calibration, we consider only the cold tropical cloud scenes with a TW radiance (i.e., LW + SW) larger than 100 W m^{-2} sr^{-1} and with an IR EBBT smaller than 230 K.

The time evolution of the daily mean gain of the SW channel obtained from the geophysical approach is very consistent with the gain used in the operational ScaRaB processing (Fig. 6a). This operational gain is obtained from a mean linear relation between the gain and the

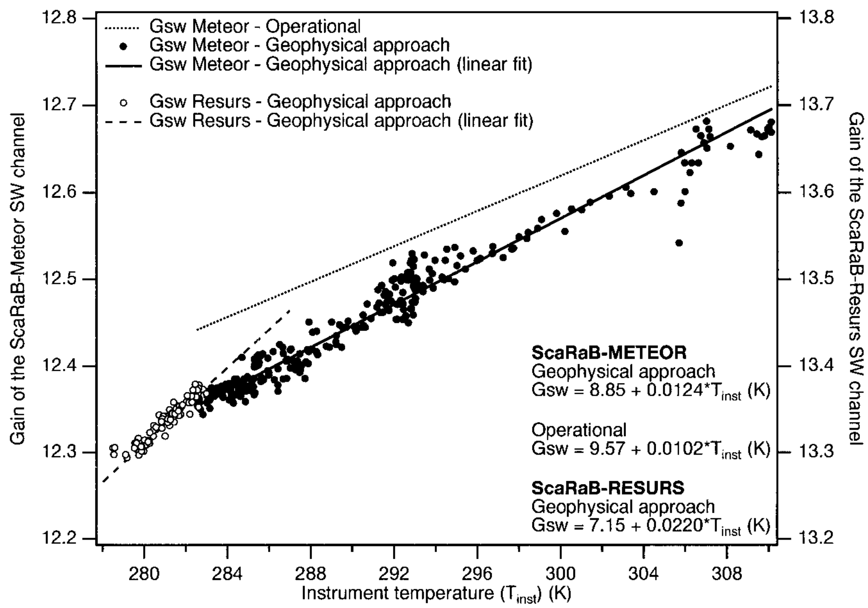

FIG. 7. Relation between the gain (W m^{-2} sr^{-1} per digital count) of the SW channel of ScaRaB (Meteor and Resurs) and the temperature of the instrument (T_{inst}). The relations are shown for the operational gain of ScaRaB-Meteor (dotted line) and for daily mean estimate of the gain with the geophysical cross-calibration approach for ScaRaB-Meteor (solid circle) and for ScaRaB-Resurs (open circle). Regressions are computed using all relevant radiance measurements over deep convective clouds in the Tropics.

instrument temperature that was established using an onboard calibration lamp every 15 days. This lamp was supposed to be fairly stable all along the ScaRaB-Meteor experiment. The time evolution of the operational gain thus reflects the time evolution of the temperature of the instrument. This temperature evolution is related to the progressive change of the equator crossing time of the instrument (see Kandel et al. 1998). The number of daily measurements on cold tropical clouds (Fig. 6c) varies with the equator crossing time with more than 1400 measurements for near-noon orbit to less than 200 for orbits near the terminator. This variation of the number of measurements is due to the threshold of 100 W m^{-2} sr^{-1} in the TW radiance.

The main potential shortcoming of this approach is due to the estimate of the LW radiance (LW_{est}) from the measurement in the infrared window radiance. For nighttime measurement, this relation appears to be very stable with a standard deviation of individual measurements of less than 1 W m^{-2} sr^{-1}. However, in order to test the sensitivity of the method to possible bias in this relation, we have introduced a bias of 1 W m^{-2} sr^{-1} in the value of LW_{est} in Eq. (8). This value of 1 W m^{-2} sr^{-1} is larger than the variation of the relation between LW_{est} and L_{IR} from one month to another (Fig. 5). The resulting error in the determination of G_{sw} (Fig. 6b) is nevertheless generally less than 1%, even for the very unfavorable terminator orbits. For measurement around noon, the resulting error is smaller than 0.5%.

The deviation with respect to the operational gain is smaller than 1% (Fig. 6b). For ScaRaB-Meteor the linear relation between the gain and the instrument temperature has a slightly larger slope value for the geophysical approach than for the operational approach (Fig. 7). This small disagreement may be due to different instrumental factors such as small variations in the lamp radiance with the instrument temperature or to slightly different temperature structure within the instrument during calibration modes (there is a temperature sensor only on the TW channel).

The same cross-calibration approach was also applied to the ScaRaB-Resurs instrument. For ScaRaB-Resurs, there is a very small set of calibration modes (on internal lamps) available. In addition, there were some discrepancies between the different ground calibration approaches tested for this second flight model (Dinguirard et al. 1998). For these reasons, it was decided to use the gain of the SW channel deduced from the geophysical cross-calibration. This gain is determined using a linear regression established using the ensemble of G^i_{sw} (all relevant measurements between November 1998 and March 1999) and a measure of the temperature T_{inst} of the instrument. The obtained mean linear relation shows that the sensitivity of the gain G_{sw} to the temperature is larger for ScaRaB-Resurs than for ScaRaB-Meteor (Fig. 7). However, it should be noted that the temperature variation of ScaRaB-Resurs (sun-synchronous orbit) is small compared to the temperature variation of ScaRaB-Meteor (5 K compared to 28 K).

4. Conclusions

This paper presents an approach to derive the gain of a broadband SW channel using a geophysical cross-calibration with a total channel on very cold tropical clouds. To be rigorous, this geophysical cross-calibration approach should be considered only as a verification of the absolute SW channel gain since a true calibration should be based on a real understanding of the instrument behavior. However, the verification with the ScaRaB-Meteor measurements shows that this approach may well be used to calibrate the SW channel with a precision better than 1%, even for near-terminator orbits. This method is independent of any onboard SW calibration sources. This is a great advantage since these SW calibration sources are known to be unreliable. In particular, the spectrum of a lamp does not cover the full SW solar spectrum, giving a strong uncertainty for the ultraviolet part of the SW spectral response.

Since the TW channel is calibrated using a blackbody simulator in the infrared, the ratio A' (that characterizes the difference between the LW and the SW response of the TW channel) must be known accurately to estimate the gain of the SW channel from the geophysical cross-calibration approach. This ratio A' must be, however, also known accurately for any calibration or cross-calibration approach. This is thus not a limitation of the geophysical approach. The SW gain deduced from the geophysical cross-calibration gives a reliable basis for the computation of the LW signal during daylight by a difference between TW and SW radiance measurements. This computation may be done simply for scene types with various spectral signatures because, for ERB instruments such as ScaRaB or CERES, the shape of the spectral response of the SW part of the TW channel is very similar to the shape of the spectral response of the SW channel. No additional spectral correction is thus needed to deduce the LW radiance during daylight.

This cross-calibration approach requires that an infrared (IR) window channel be implemented on the ERB instrument with a good coregistration with the TW channel, as is the case for CERES. The IR channel of the CERES instrument has, however, a broader spectral response than the IR channel of ScaRaB (8–12 μm instead of 10.5–12.5 μm). This may cause some problem for the estimate of the LW radiance from the IR radiance because of the variable ozone layer above the deep tropical convective clouds. This aspect has to be tested before an eventual application of the approach to the CERES measurements, while some preliminary results (Kratz et al. 1999) have already revealed interesting shortwave inconsistency of 0.8% by comparing similar geophysical cross-calibration to the operational SW calibration. For future ERB instruments, it should be more straightforward to be able to remove the silica filter on the SW channel during calibration modes, giving a possibility to directly estimate the SW channel gain on a blackbody simulator. Also, a new instrument should offer the possibility to do some scans with a silica filter in front of the TW channel. This will give direct SW cross-calibrations between the two channels for various geophysical scene types. The variety of the spectral signatures of the various geophysical scenes is probably not required for a correct cross-calibration (see above). However, for long-lived instruments, this cross-calibration approach will offer a chance to detect eventual difference in the temporal drifts of the spectral signature of the two broadband channels, primarily in the ultraviolet part of the spectrum.

Acknowledgments. The ScaRaB experiment is a cooperation between France, Russia, and Germany. This experiment was supported by the French space agency CNES (Centre National d'Études Spatiales). We would like to thank Leonid Pakhomov, Vladimir Golovko, Johannes Mueller, and Thierry Trémas for interesting discussions about this cross-calibration approach.

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