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AN IMPROVED CALIBRATION MECHANISM FOR THE METEOSAT-7 INFRARED CHANNELS USING ON-BOARD BLACK BODY CALIBRATION MECHANISM

On 29th May 2000 a new calibration method for the Meteosat-7 infrared channels was introduced, using the on-board black body observations. The method replaces the vicarious calibration method to calibrate the infrared channels in the atmospheric window and the water vapour absorption band. The new method can only be used on Meteosat-7 due to problems with the black body observations on the other spacecraft.

AN IMPROVED CALIBRATION MECHANISM FOR THE METEOSAT-7 INFRARED CHANNELS USING ON-BOARD BLACK BODY CALIBRATION MECHANISM

1 INTRODUCTION

On 29th May 2000 a new calibration method for the Meteosat-7 infrared channels was introduced, using the on-board black body observations. A black body calibration coefficient is derived which is corrected both for the missing effect of the front optics when viewing the black body and for the difference in the rest of the viewing geometry when compared to the Earth imaging mode. The method replaces the vicarious calibration method using NCEP sea surface temperatures and radiosonde observations to calibrate the infrared channels in the atmospheric window and the water vapour absorption band. The new method can only be used on Meteosat-7 due to problems with the black body observations on the other spacecraft.

2 THE BLACK BODY CALIBRATION METHOD

The black body calibration method uses the two black bodies, of which one has the ambient spacecraft temperature and the other is heated to about 50 K above the former. Within the black body calibration the colder black body is viewed first by the infrared detectors and is used as reference. The warmer black body is then viewed, and the observed analogue signal is converted into digital value (black body count).

From the known temperatures of the black bodies and the observed counts in both channels, a black body calibration coefficient (gain) can be deduced using a linear relationship between the known radiances (through the Planck law) and the observed counts, similar to the one used for the vicarious calibration. In principle, this can then be used to deduce the total gain of the system and applied to Earth scans to calibrate images. However, there are two aspects of the system arising from differences between the Earth scanning and black body viewing configurations that need to be corrected for:

- The front optics are not part of the optical path of the black body observations while they are part of the optical path for Earth scans
- The viewing geometry of a black body observation differs from the viewing geometry of an Earth scan.

3 THE CORRECTION MODEL

These two differences are taken into account using a calibration model (reference). The model uses the description of the flux incident on the detectors during an Earth and black body view. For the Earth view the flux (Φ_{scn}) received at the detectors depends on the detector surface (a^2), the spectral irradiance ($L(\lambda,T)$ in $Wm^{-2}sr^{-1}\mu m^{-1}$), the transmission of the total optical system ($\tau(\lambda)$) and the viewing geometry defined by the first mirror, which is partly occulted by the second mirror:

$\phi_{scn} = 2\,\pi\,a^2\,(\cos\theta_1 - \cos\theta_2)\quad \int L\,(\lambda\ T)\ \tau(\lambda)\ d\lambda$

For the black body view the flux (ϕ_{bb}) depends on a different viewing geometry limited by the pupil of the optical block and a factor ($K = 1 / (0.98)^6$) for removal of the response function of the front mirrors that are not viewed during a black body scan:

$\phi_{bb} = 2\,\pi\,a^2\,(1 - \cos\theta_3)\quad \int L\,(\lambda, T)\ K\ \tau(\lambda)\ d\lambda$

The following geometry angles were determined from prelaunch measurements (ref):

- θ_1 = The half angle of the occultation area as seen by the detector ($\theta_1 = 9^0\ 30'$)
- θ_2 = The half angle of the first mirror as seen by the detector ($\theta_2 = 21^0\ 50'$)
- θ_3 = The maximum angle under which the detector can see the black body, which is determined by the pupil of the optical block ($\theta_3 = 23^0\ 20'$)

Assuming that the total system is linear and the response function $\tau(\lambda)$ and spectral density of illumination, $L(\lambda, T)$, are approximate constant over the relevant frequency range, then the relation between the radiance and the observed count is linear. For the Earth and black body scans this gives:

$C_{scn} = G_{total}\ L(\lambda, T) + C_{off}$

$C_{bb} = G_{bb}\ (L_{bb1}\ - L_{bb2}) + C_{off}$

With:

C_{scn}, C_{bb} = Observed Earth view and black body view counts

G_{total} = Total gain of the optical system

C_{off} = a constant added in the conversion of the analogue signal to the digital count.

L_{bb1} and L_{bb2} = the radiances of both black bodies.

From here a relationship is found between the gain of the total optical system and the part of the system used for black body calibration:

$G_{total} = G_{bb}\ (\cos\theta_1 - \cos\theta_2) / (K\ (1 - \cos\theta_3))$

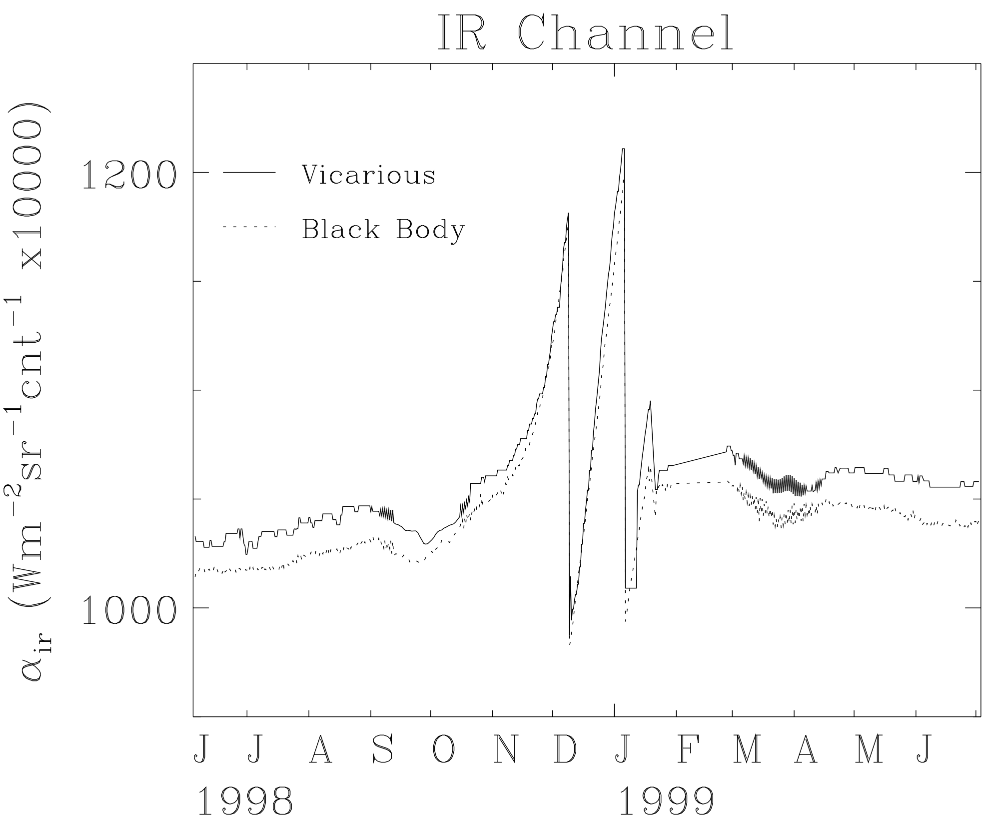
Note that the gain defined here relates radiance and counts as $C = G * L$, while the EUMETSAT calibration coefficient is defined as $L = \alpha\ C$. Hence, for the EUMETSAT calibration coefficients the model reads as:

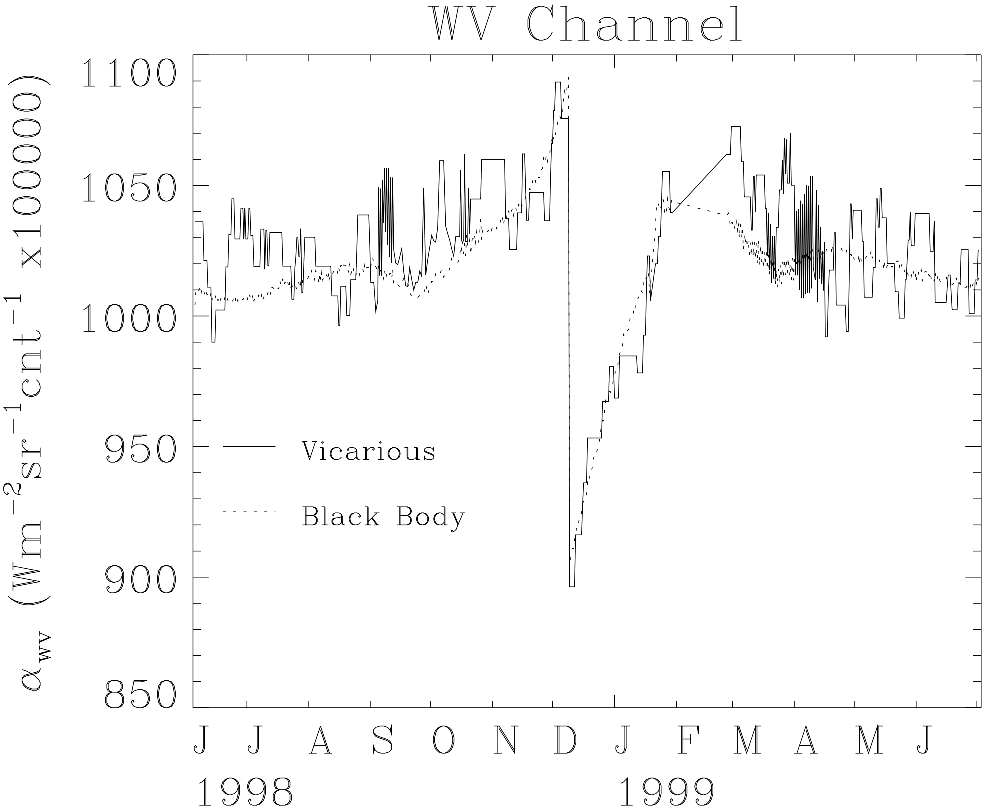
$\alpha_{total} = \alpha_{bb}\ K\ (1 - \cos\theta_3) / (\cos\theta_1 - \cos\theta_2)$

4 RESULTS

An extended study was performed where the vicarious and the black body calibration were derived for a period of 13 months (from June 1998 till July 1999). The resulting calibration data are presented in the following two figures for both infrared channels. The large variations starting late in 1998 in both calibration data show the contamination of the detectors and the subsequent gain changes and decontamination exercises of the detectors. For the channel in the atmospheric window an averaged bias of about 1 % between both methods was found, with the lower values for the black body calibration. The bias between the calibration data for the channel in the absorption band is even less (about 0.7 %), but the fluctuation on time scales of about two weeks have disappeared in the black body calibration.

This two week fluctuation was an artefact of the vicarious calibration using radiosonde observations. Within the vicarious calibration of the channel in the water vapour absorption band only observations in areas free of clouds above 700 hPa could be used. This implies, that changing synoptic situations resulted in taking different subsets of the available radiosonde observations. Using different subsets of observations means not only that the number of observations varies in time, but also their geographical area and consequently the radiosonde type, as different national meteorological services use radiosondes from different manufactures. The use of the black body calibration clearly stabilises the calibration in the water vapour absorption band.




WV Channel
α_{WV} (Wm^{-2}sr^{-1}cnt^{-1} x100000)
1100
1050
1000
950
900
850
Vicarious
Black Body
J J A S O N D J F M A M J
1998
1999