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CONCLUDING RESULTS FROM EUMETSAT IR SATELLITE INTERCALIBRATION WORK

The paper provides a summary of the work performed at EUMETSAT concerning the satellite inter-calibration of the Meteosat IR window channels with corresponding channels aboard the polar orbiting NOAA and the geostationary GOES satellites.

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1 INTRODUCTION

Inter-calibration of the polar orbiting and geostationary satellite systems is necessary for consistency of data sets involving more than one sensor. CGMS XXV in St. Petersburg requested corresponding activities by satellite operators and recommended appropriate action. At that time CGMS members had started to investigate various approaches for inter-calibration of different sensors on different platforms (Gube and Schmetz, 1997; Wanzong and Menzel, 1997). Initial focus was on comparisons of infrared window (IR) radiances with the goal to achieve a relative calibration of 1 K for different IR sensors. This paper provides some concluding results of pertinent work conducted at EUMETSAT on inter-calibration for the Meteosat IR channel. EUM-WP-16 also provides relevant information addressing the importance of using clear-sky radiances and of nadir viewing on the accuracy of the inter-calibration.

2 LONG-TERM INTERCALIBRATION WITH HIRS CHANNEL 8

Figure 1 shows a comparison between the operational IR calibration of Meteosat-7 (IR) with results from an inter-calibration with channel 8 onboard NOAA-14 HIRS. 25 image pairs covering the time interval between August 1998 and May 1999 were chosen for inter-calibrations in order to cover the period of one year.

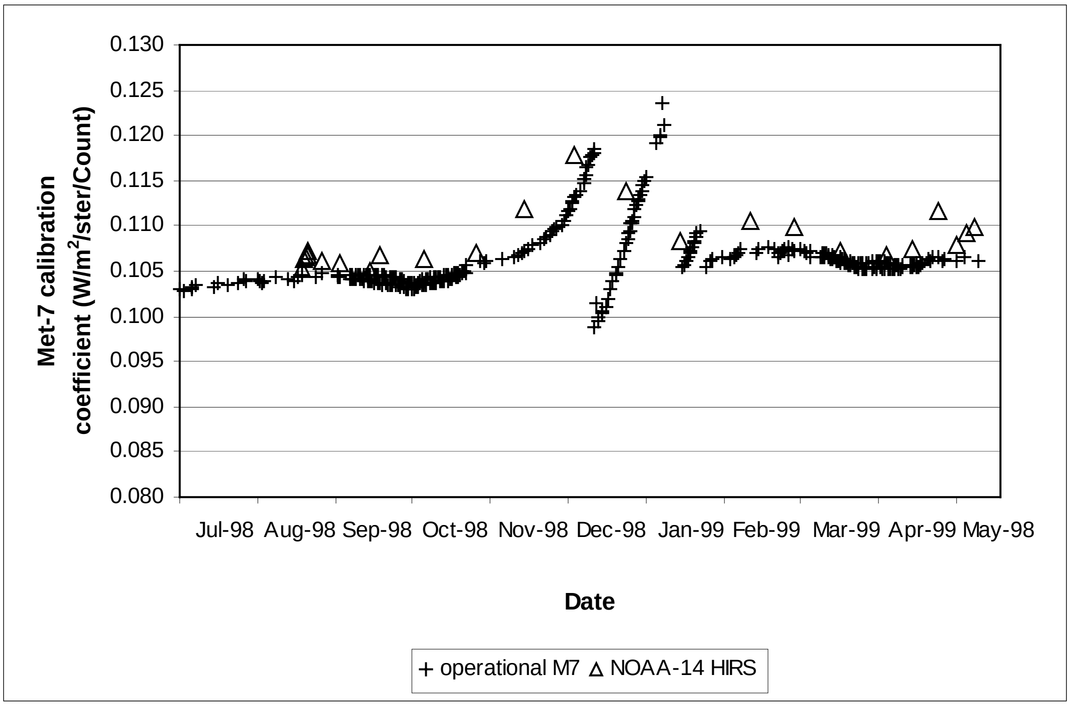

Figure 1: Comparison of the operational IR calibration coefficients of the Meteosat-7 IR channel (crosses) with results from an inter-calibration with channel 8 of HIRS on NOAA-14.

The following observations in Figure 1 are noteworthy:

(1) The differences between the cross-satellite and the operational coefficient are small between August and October 1998 (11 cases). This time period includes the autumn eclipse with the noticeable ‘variation’ of the operational calibration (which is only due to the special operation procedure during eclipse). Differences are usually within 2%, 3 cases have differences exceeding 2% with a maximum of 2.36%. The cross-calibration coefficient was always found to be higher than the operational one.

(2) During the winter months of November 1998 to January 1999, the radiometer went through the usual winter contamination which lead to a gain change in early December 1998 (jump in the operational coefficient). A decontamination was necessary by the end of January 1999 leading to another gain change. Here the cross-calibration coefficient shows larger differences to the operational coefficient (between 4-6%, again always exceeding the operational coefficient). From the figure it looks as if the cross-satellite technique picked up the contamination ahead of the operational procedure, which might be due to the special feedback and extrapolation mechanisms involved in the derivation of the operational coefficient.

(3) From February 2000 onwards, the differences between the two calibration schemes stabilises again: The analysed 9 cases are within a 2% difference in 4 instances, between 2 and 3% difference in 2 instances, between 3 and 4% difference again in 2 instances, and in one case the difference is as large as 5.1%. Again, the cross-satellite coefficient always exceeds the operational one.

(4) Due to the scatter of the data points, the cross-satellite calibration coefficient has an uncertainty of around 0.002 – 0.008 (i.e. 2 – 8%), which for most cases puts the coefficient’s error bar in the range of the operational coefficient.

Individual calibration targets were computed from a collocation of a single HIRS pixels to the respective Meteosat pixels. Only those collocations are retained for the processing which are within a 5 deg viewing angle difference of the two satellites, and where the viewing angle of neither satellite exceeds 50 deg. The radiance correction due to filter function differences is taken as

$$\text{Radiance (Meteosat-IR)} = 3.4668 + 1.0007 * \text{Radiance (HIRS, channel 8)} \quad W/m^2/ster/cm^{-1}$$

Regarding collocation in time, each pair of images is taken within 30 minutes at maximum and within 5 minutes on average.

3 INTERCALIBRATION WITH AVHRR

The IR inter-calibration between Meteosat and AVHRR channels 4 and 5 has been described in König et al. (1999) and results have been reported at previous CGMS meetings. In summary, the method uses target areas from two satellites collocated in time and space, corrects for differences in the spectral response functions, and considers the effects of different viewing geometry.

Table 1 lists the results of the inter-satellite calibration scheme to Meteosat-5 and –7 versus the split window channels onboard NOAA-14:

The Meteosat-7 results show always very good agreement between the operational calibration and the value obtained from AVHRR channel 5, the overall differences found here suggest a temperature difference of less than 0.5 K between these two instruments. The same holds for Meteosat-5 with slightly larger differences to the operational coefficient of up to 2%, which corresponds to a temperature uncertainty of 1.2 K. With channel 4, however, we are for both Meteosat satellites faced with much larger difference between 2.5 and 3.2 %. In the temperature domain this would result in a difference of 1.5 – 2 K (at 280 K), which is rather high and falls short of the expectations. These differences can be traced to the spectral response function corrections:

Using the radiation model results, the spectral response correction between the two AVHRR channels results in:

Radiance (channel 5) = 9.4751 + 1.05502 * Radiance (channel 4)

This theoretical relation, however, is not supported by the data, where data we find the relationship:

Radiance (channel 5) = 6.20540 + 1.05664 * Radiance (channel 4)

This gives an offset of roughly 3.2 $mW/m^2/ster/cm^{-1}$ versus the theoretical relation. As the theoretical relation is implicitly used in our conversion to the Meteosat spectral response, this difference is thus reflected in the derived calibration coefficients for the two channels.

Table 1: Inter-satellite calibration coefficients α obtained during August/September 1998 for Meteosat-5 and -7 IR using NOAA-14 AVHRR (GAC) channels 4 and 5. Given are also the Meteosat operational coefficients and the difference between the two coefficients (units: $W/m^2/ster/count$):

For Meteosat-7:

Date	AVHRR channel	α (oper)	α (inter-satellite)	deviation from α(oper) (%)
17 August 1998	4	0.104661	0.107498	2.71
	5		0.105623	0.92
18 August 1998	4	0.104661	0.107312	2.53
	5		0.105301	0.61
18 August 1998	4	0.104661	0.107441	2.66
	5		0.105583	0.88
19 August 1998	4	0.104661	0.107313	2.53
	5		0.105815	1.10
19 August 1998	4	0.104661	0.107472	2.69
	5		0.105430	0.73
24 August 1998	4	0.104661	0.107815	3.01
	5		0.105625	0.92
16 September 1998	4	0.104584	0.106398	1.73

	5		0.104844	0.25

For Meteosat-5:

Date	AVHRR channel	α (oper)	α (intersatellite)	deviation from α(oper) (%)
20 August 1998	4	0.072948	0.075499	3.40
	5		0.074457	2.07
21 August 1998	4	0.073152	0.075521	3.24
	5		0.074343	1.63
24 August 1998	4	0.073366	0.075388	2.76
	5		0.073540	0.24
26 August 1998	4	0.073142	0.075968	3.86
	5		0.074136	1.36
16 September 1998	4	0.072611	0.074613	2.76
	5		0.073577	1.33

In conclusion, the envisaged goal of an agreement to within 1 K is not always achieved. A caveat against the results is the systematic difference between inter-calibrations with channel-4 and –5, respectively. Further analysis will study the potential causes of the remaining bias. In particular it is necessary to understand the differences between the inter-calibration of Meteosat with AVHRR-4 and AVHRR-5, respectively.

3.1 Impact of Spatial Sampling/Resolution

Usually we use GAC (global area coverage data) for the satellite inter-calibration with AVHRR. In order to assess the impact of the reduced spatial sampling and resolution on the result, one case was analysed using the NOAA AVHRR instrument in both the GAC and the LAC resolution: The case is for 16 September 1998, and comparisons were done with the Met-7 image of 1300 UTC.

The difference between LAC (i.e. the original 1 km AVHRR resolution) and GAC is such that with the GAC resolution, pixels are sampled every three lines, and one GAC pixel is made up of the average over 4 LAC pixels out of five as shown in Figure 2.

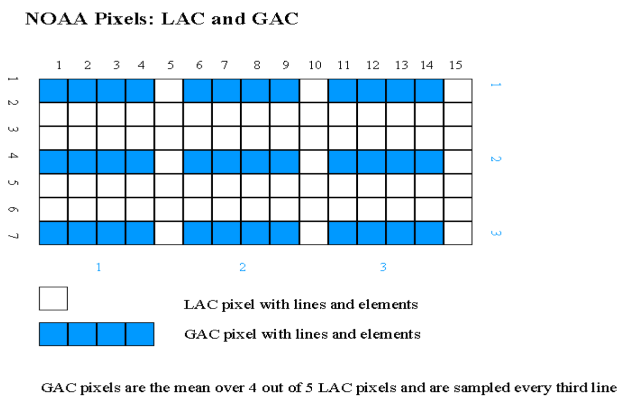

Figure 2: High resolution (LAC: local area coverage) and reduced resolution (GAC: global

area coverage) pixels from AVHRR.

For the cross-calibration, a calibration target was made up over 3*3 GAC pixels (GAC case) or over 9*9 LAC pixels (LAC case).

In summary the calibration runs showed no significant difference between the use of GAC and LAC:
The GAC cross-satellite calibration coefficient is 0.10128 +/- 0.00708, and the LAC coefficient amounts to 0.10114 +/- 0.01001. The operational coefficient is at that time 0.10363.

The example indicates that the sampling of the data is not an issue regarding cross-calibration and GAC data can be used instead of the full resolution LAC data.

4 INTER-CALIBRATION WITH GOES

Inter-calibration of the Meteosat-7 IR channel has also been performed with the split-window channels of GOES-8. So far only one case study has been done for 10 May 2000. The GOES full earth scan image of 1145 UTC was compared to the Metesoat-7 IR image of 1230 UTC. The scan directions and time conventions of the two instruments are such that the GOES scan started at 1145 UTC in the North, and the scan duration was 25 minutes, i.e. the last line was scanned at 1210 UTC. The Meteosat 1230 UTC image was started at 1200 in the South and ended at 1225 UTC in the North. This leads to time differences of up to 35 minutes in the northern part of the overlap area. Also, due to the position of the two satellites, the overlap region is seen at about 45-50 deg viewing angle (viewing angle difference is within 5 deg), which is relatively large. Calibration targets within this overlap regions are defined as 5 * 5 GOES pixels together with corresponding collocated Meteosat pixels (typically 6-8 pixels).

Visual inspection of the images reveals that there is some cloud movement within the overlap area, which will introduce large scatter in the calibration scheme. In order to minimise this effect only those calibration targets are retained where the difference in brightness temperature (10.8 µm GOES and Meteosat IR) is within 4 K. This then leads to a total of 64885 collocations, and the cross-satellite calibration coefficients are

Using GOES channel 4 (10.8 µm):
Calibration coefficient = 0.10742 (with an uncertainty due to scatter of 0.00250)
Using GOES channel 5 (12.0 µm):
Calibration coefficient = 0.10430 (with an uncertainty due to scatter of 0.0051)
while the operational Meteosat coefficient for that day is 0.10543 (Units: Wm^{-2} sr^{-1} $count^{-1}$).

Thus, as in the case of AVHRR, we are again faced with the fact that the channel 5 inter-calibration coefficient is significantly different from the inter-calibration with channel 4. The reason for this inconsistency is not clear yet. Problems with theoretical filter function corrections are the most likely explanation.

5 CONCLUSIONS

An inter-calibration of the Meteosat IR channel with HIRS channel 8 has been performed for 25 cases throughout a year. Results show an agreement to within 2 - 3% with the operational calibration coefficient for most of the period, which falls somewhat short of the expectations. Using AVHRR split window channels leads to better results (1 - 2%), however there seems to be a systematic difference between cross-calibration values obtained from channel 4 and channel 5, respectively. The most likely cause of the discrepancy is correction for different spectral response functions. A case study using the GOES split window channels confirms the conclusion drawn from the AVHRR inter-calibration. Therefore future work on the theoretical correction for different spectral filter response functions seems warranted.

6 REFERENCES

Gube and J. Schmetz, 1997: A Satellite Intercalibration Strategy: Application to Meteosat and AVHRR IR-Window Observations. Paper presented at the 25th Meeting of the Coordination Group for Meteorological Satellites held 2 - 6 June, 1997 in St. Petersburg, Russia

König, M., J. Schmetz and S. Tjemkes, 1999: Satellite intercalibration of IR window radiance observations. Adv. Space Res., 23, No. 8, 1341 – 1348.

Wanzong, S and W. P. Menzel, 1997: Intercalibration of GOES, Meteosat, and HIRS Infrared Radiances. Paper presented at 25th Meeting of the Coordination Group for Meteorological Satellites held 2 - 6 June, 1997 in St. Petersburg, Russia.