Satellite Application Facility on Climate Monitoring

Scientific Report

Validation of Surface Radiation Fluxes using MSG data

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	Name	Function	Signature	Date
Author	Rainer Hollmann Richard Müller	Project scientists		28.06.2005
Approval	Richard Müller	WP manager		28.06.2005
Approval	Annegret Gratzki	Science co-ordinator		28.06.2005
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1 INTRODUCTION

This report describes first validation results of CM-SAF surface radiation fluxes using MSG data as input. It is based on the comparison of satellite derived data with independent ground based measurements, obtained from selected locations and time periods,.

The algorithms applied to derive surface radiation fluxes (surface incoming shortwave radiation flux and surface downward longwave radiation flux) require cloud information as input. In order to have consistency between CM-SAF cloud and radiation products CM-SAF cloud products are used to derive the surface radiation fluxes.

Beside cloud information the top of atmosphere albedo retrieved from MSG data have been used as input for the surface flux calculations.

<u>Added validation results and modifications in comparison to Issue 1.0 of the report:</u>

-Added validation results for December 2004 (respective subsections of Section 4.1) .

-Added initial comparison of the different aerosol climatologies (Subsection 4.1.3).

-Added “results” of initial SOL/SDL bias analysis (Subsection 4.1.2).

-Comparison of NOAA and MSG based products for July 2004 (Subsection 4.3.1) and March 2005 (SAL only, Subsection 4.3.2)

-Initial comparison of the monthly mean diurnal cycle (Subsection 4.2)

-Modification of the Conclusion, consideration of the added validation results.

2 INPUT DATA

2.1 MSG cloud data

The cloud data has been retrieved with the nowcasting-SAF software using MSG-SEVIRI data as input. For the validation of the radiation products cloud data for the month July and Octobre 2004 have been retrieved. For the calculation of SDL the cloud fraction together with the cloud height have been used. For the calculation of SIS only the information of the cloud mask is needed.

2.2 Top of atmosphere albedo.

The top of atmosphere albedo is based on GERB and SEVIRI data and has been processed and provided by RMIB. The validation of the data will be done and reported by RMIB.

2.3 Aerosol data

Based on the results of a comparison study performed by CM-SAF the GADS/OPAC climatology has been used, which has a coarse spatial and temporal resolution. Yet, it has been worked out that this climatology seems still to be the most accurate on market, at least for Europe. Within a comparison study GADS/OPAC has shown a much better agreement with Aeronet ground based data than MODIS derived aerosol data and a slight better agreement than aerosol data from a model median (AEROCOM project; http://nansen.ipsl.jussieu.fr/AEROCOM/).

2.4 Temperature and water vapour

The required temperature and humidity profiles were taken from the global GME analysis data, in detail 3-hourly data from the GME assimilation scheme were used. The reason to use GME analysis data instead of forecast data is that analysis data have a better accuracy. The GME model grid is an icosahedral–hexagonal grid with an average mesh size of about 40 km. The flux algorithms use as input GME data mapped to a regular 0.5°x0.5° longitude-latitude grid. The model has 40 layers with the highest layer in 10 hPa.

3 VALIDATION DATA

For this validation study surface radiation data have been used from BSRN sites and the Lindenberg and Cabauw (Beljaars and Bosveld,1997) measurements sites. The radiation data from the BSRN sites were received directly from the station operators (courtesy of MeteoSwiss, MeteoFrance) as there is a significant time delay between measurement and availability of the data in the BSRN archive. The nonsystematic errors for the BSRN data are estimated to be 10 W/m^2 for the longwave measurements and 5 W/m^2 for solar irradiance measurements (Ohmura et al., 1998).

Station	Latitude	Longitude	elevation (m)
Payerne	46.81° N	6.94° E	491
Carpentras	44.05° N	5.03° E	100
Lindenberg	52.22° N	14.12° N	125
Cabauw	51.97° N	4.93° E	2

Table 3-1: Geographical coordinates and elevation of validation sites.

For the validation hourly surface radiation measurements were used. Satellite data were extracted from an area of 15 km x 15 km around the surface station and averaged. The chosen area size reflects the spatial resolution of the CM-SAF end products.

Choosing an area average compensates partly for the fact that instantaneous satellite values are being compared with time integrated values of surface measurements. Improvements in validation results of instantaneous SIS values are expected to be achieved if the surface measurements are integrated over smaller time scales and centered around the satellite measurement time. However, comparing monthly and daily SIS means directly will also resolve this handicap.

4 VALIDATION RESULTS

4.1 CM-SAF surface radiation end products

CM-SAF plans to provide monthly means of all surface radiation flux components and additionally daily means for shortwave fluxes. The comparisons with surface measurements provided here are based on instantaneous and daily/monthly data for SIS comparison. The comparison of instantaneous data allows a meaningful evaluation of the expected accuracy of the monthly means for the longwave radiation. The monthly mean and the monthly average of the instantaneous values (SOL, SDL) are almost identical.

SIS is characterised by very high variations and values of zero in the night. Consequently, the monthly mean and the monthly average of the instantaneous values are by no ways identical. In order to get a meaningful evaluation of the expected accuracy of the monthly SIS means, daily and monthly means have been compared directly, in addition to the instantaneous comparison.

4.1.1 Surface downward longwave fluxes - SDL

The comparison of satellite derived SDL values with in situ measurements (Table 4-1, Table 4-3), performed on instantaneous data, shows average RMS deviations of 7.6 % for October 2004, 6 % for July 2004 and 10 % for December 2004.

The average absolute bias is 3 % for October 2004, 2.5 % for July 2004 and 3 % for December 2004, or 10.1 W/m², 8.9 W/m² and 8.9 W/m², respectively.

These are quite good results, taking into account that the evaluated bias is in the same range as the uncertainty of the ground based measurements, being 10 W/m² (Ohmura et al. 1998) . In this context even the relative high bias obtained for Payerne is tolerable. However, since the Alpine region can be seen as climate indicator small bias values are very important. In this context further investigation of the reason for the bias are discussed in section 4.1.2. A previous study (SAF/CM/DWD/PR/1.2A2_2) based on METEOSAT ISCCP-DX (3 hour time resolution) and ECMWF data showed an RMS error of 10.8 W/m^2 for monthly means based on a 5 month study covering different seasons.

Summarising, it can be expected that the target accuracy of 10 W/m^2 can be in general achieved for monthly mean values. The bias in the Alpine region has to investigated and monitored in more detail.

				[W/ m^2]	[W/ m^2]		[W/ m^2]	[%]	[W/ m^2]	[%]
LOCATION	YEAR	MONTH	NVAL	MA_MS	MA_CA	COR	BIAS	BIAS	RMS	RMS
Lindenberg	2004	12	673	296.1	294.0	0.63	- 2.1	- 0.7	29.2	9.9
Cabauw	2004	12	689	302.5	298.6	0.74	- 4.0	- 1.3	27.4	9.1
Payerne	2004	12	692	299.9	279.2	0.59	- 20.7	- 6.9	33.1	11.0
Mean absolute BIAS over all stations: 8.9 W/m² or 3 %							Mean RMS: 29.9 [W/m2] or 10 %			
Lindenberg	2005	03	642	274.9	268.0	0.83	- 6.8	- 2.5	25.9	9.4
Payerne	2005	03	655	281.8	257.8	0.86	- 24.0	-8.5	33.9	12.0

Table 4-1: Comparison of instantaneous satellite derived and hourly in situ surface downward longwave fluxes for December 2004. MA_MS: Measured monthly average. MA_CA.: Calculated (satellite derived) monthly average, COR: correlation coefficient, RMS: root mean square error, BIAS calculated - measured value in W/m² and % related to the measured average. Also some results for March 2005 are added.

				[W/ m^2]	[W/ m^2]		[W/ m^2]	[%]	[W/ m^2]	[%]
LOCATION	YEAR	MONTH	NVAL	MA_MS	MA_CA	COR	BIAS	BIAS	RMS	RMS
Lindenberg	2004	10	585	308.4	311.3	0.79	2.8	0.9	25.1	8.1
Cabauw	2004	10	530	328.9	319.5	0.74	- 9.4	- 2.9	23.9	7.3
Carpentras	2004	10	584	350.5	337.8	0.75	- 12.6	-3.6	23.9	6.8
Payerne	2004	10	589	333.5	317.9	0.65	- 15.6	-4.7	26.7	8.0
Mean absolute BIAS over all stations: 10.1 W/m² or 3 %							Mean RMS: 24.9 [W/m2] or 7.6%			

Table 4-2: Comparison of instantaneous satellite derived and hourly in situ surface downward longwave fluxes for October 2004. MA_MS: Measured monthly average. MA_CA.: Calculated (satellite derived) monthly average, COR: correlation coefficient, RMS: root mean square error, BIAS calculated - measured value in W/m² and % related to the measured average.

				[W/m^2]	[W/m^2]		[W/m^2]	[%]	[W/m^2]	[%]
LOCATION	YEAR	MONTH	NVAL	MA_MS	MA_CA	COR	BIAS	BIAS	RMS	RMS
Lindenberg	2004	07	674	349.7	355.1	0.76	5.4	1.6	22.3	6.4
Cabauw	2004	07	609	363.5	352.5	0.77	-11.0	3.0	23.4	6.4
Carpentras	2004	07	699	358.8	350.4	0.87	- 8.4	-2.4	19.1	5.3
Payerne	2004	07	700	349.2	338.3	0.82	-10.9	-3.1	20.7	5.9
Mean absolute BIAS over all stations: 8.9 W/m² or 2.5 %							Mean RMS: 21.4 [W/m2] or 6 %			

Table 4-3: Comparison of instantaneous satellite derived and hourly in situ surface downward longwave fluxes for July 2004. For legend see table 4-1

Figure 4-1 shows the monthly mean of SDL for July 2004 for Europe. This data set has been produced based on MSG data by the CM-SAF pre-operational processing chain. For this image at least 3 images per day and at least 20 images per month had to be available to calculate the time integrated values.

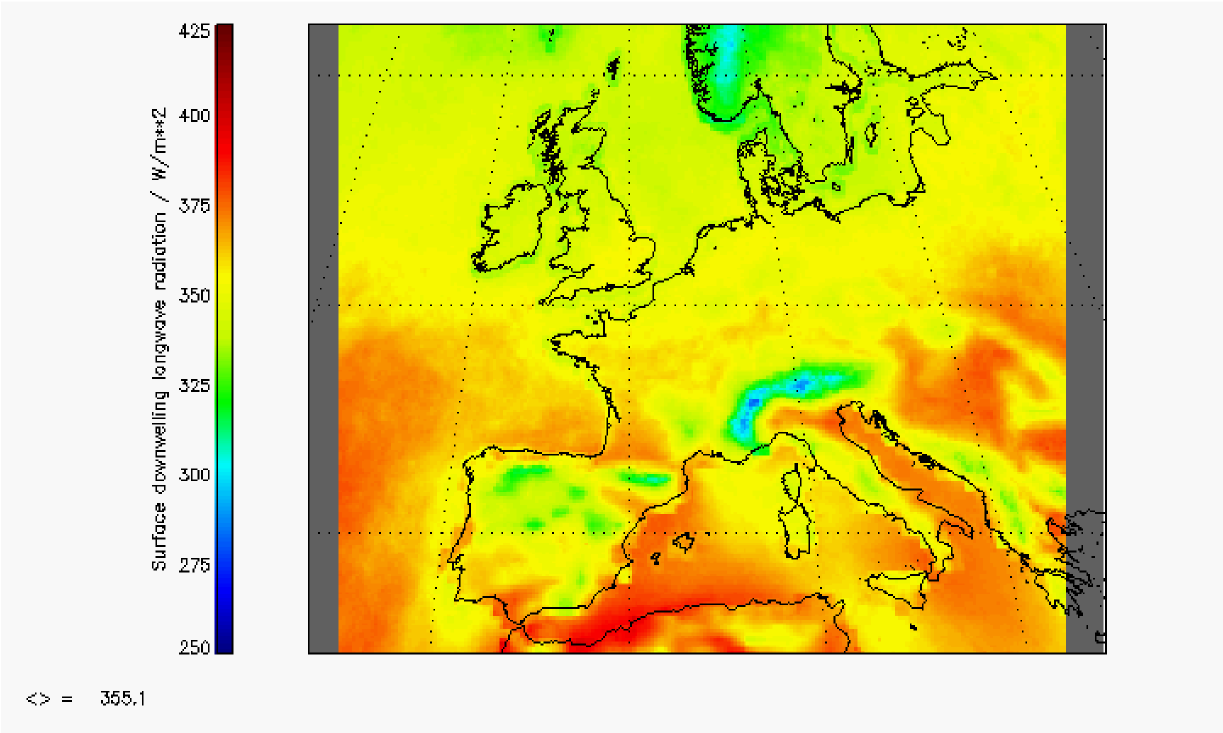

Figure 4-1: Monthly mean of surface downward longwave radiation for July 2004.

4.1.2 Surface outgoing longwave fluxes - SOL

Surface outgoing longwave radiation is measured at Lindenberg, Payerne and Cabauw, but not in Carpentras. Measurements at 1.5 and 2 m height above ground have been used for the SOL validation . Radiation measurements at this height only see a small surface area, which is usually grass covered. They do not represent well the area seen by the satellite pixel. Measurements at higher altitudes are better suited to validate outgoing fluxes. At the Lindenberg and Payerne site measurements at larger heights are also available (Lindenberg 100 m above ground, Payerne 30 m above ground). It will be useful to compare validation results for outgoing radiation fluxes derived from different measurement heights at a later stage.

The surface outgoing longwave fluxes are presently purely based on GME analysis data. However the GME surface model have been improved. It seems that this leads to lower bias values than reported before (see validation report SAF/CM/DWD/SR/SFCFLX/1).

The average RMS error of the instantaneous fluxes is 3.5 % for October 2004, 4.6 % for July 2004 and 4.8 % for December 2004.

The average absolute bias is 1.9 % for October 2004, 2 % for July 2004 and 3.3 % for December 2004 or 7 W/m², 8.4 W/m², and 10.6 W/m² respectively. These are quite good results.

The RMS and bias is the largest at the Payerne site. This site is dominated by Alpine climate and seems to be the worst to estimate. Taking into account the complexity of the Alps region and that the uncertainty of ground based measurements is 10 W/m² (Ohmura et al. 1998) the bias obtained for Payerne is not as bad as it seems at the first glance. Large bias in SOL, hence in the surface temperature, affects also SDL.

				[W/m2]	[W/m2]		[W/m2]	[%]	[W/m2]	[%]
LOCATION	YEAR	MONTH	NVAL	MA_MS	MA_CA	COR	BIAS	BIAS	RMS	RMS
Lindenberg	2004	12	704	318.8	326.2	0.79	7.4	2.3	9.3	2.9
Cabauw	2004	12	697	331.5	336.3	0.75	4.9	1.5	13.5	4.1
Payerne	2004	12	700	320.4	300.9	0.72	- 19.5	-6.1	23.3	7.3
Mean absolute BIAS over all stations: 10.6 W/m² or 3.3 %							Mean RMS: 15.4 [W/m2] or 4.8 %			

Table 4-4: Comparison of instantaneous satellite derived and hourly in situ surface outgoing longwave fluxes for December 2004. For legend see table 4-1

				[W/m2]	[W/m2]		[W/m2]	[%]	[W/m2]	[%]
LOCATION	YEAR	MONTH	NVAL	MA_MS	MA_CA	COR	BIAS	BIAS	RMS	RMS
Lindenberg	2004	10	589	357.9	362.0	0.89	4.2	1.2	11.5	3.2
Cabauw	2004	10	530	365.7	369.8	0.88	4.2	1.1	10.2	2.8
Payerne	2004	10	589	372.2	359.6	0.87	-12.6	-3.4	16.7	4.5
Mean absolute BIAS over all stations: 7 W/m² or 1.9 %							Mean RMS: 12.8 [W/m2] or 3.5 %			

Table 4-5: Comparison of instantaneous satellite derived and hourly in situ surface outgoing longwave fluxes for October 2004. For legend see table 4-1

				[W/m2]	[W/m2]		[W/m2]	[%]	[W/m2]	[%]
LOCATION	YEAR	MONTH	NVAL	MA_MS	MA_CA	COR	BIAS	BIAS	RMS	RMS
Lindenberg	2004	07	676	418.9	411.9	0.90	- 7.1	- 1.7	21.7	5.2
Cabauw	2004	07	687	405.3	405.7	0.91	0.4	0.1	10.7	2.6
Payerne	2004	07	700	416.0	398.1	0.91	-17.8	-4.3	24.8	6.0
Mean absolute BIAS over all stations: 8.4 W/m² or 2 %							Mean RMS: 19.0 [W/m²] or 4.6 %			

Table 4-6: Comparison of instantaneous satellite derived and hourly in situ surface outgoing longwave fluxes for July 2004. For legend see table 4-1

One reason for the comparatively large bias of the SOL and SDL for Payerne is related to the resolution of the GME analysis data. The GME model resolution and satellite resolution are quite different (GME: app. 40 km, MSG: at sub-satellite point 3 km). Each GME grid box represents an average altitude and and average soil type. The surface temperature for each MSG pixel is estimated by linear interpolation of GME grid boxes and does not account for altitude effects. The measurement station of Payerne is 500 m high. The average altitude of a 40x40 km box around the measurement station is 700 m. For a first guess a change in the temperature of about 0.6 Kelvin per 100 m altitude difference can be assumed. Applying such an rough altitude correction would increase the calculated SOL by 5-7 W/m² for Payerne (see figure 4-2) ,reducing the bias significantly.

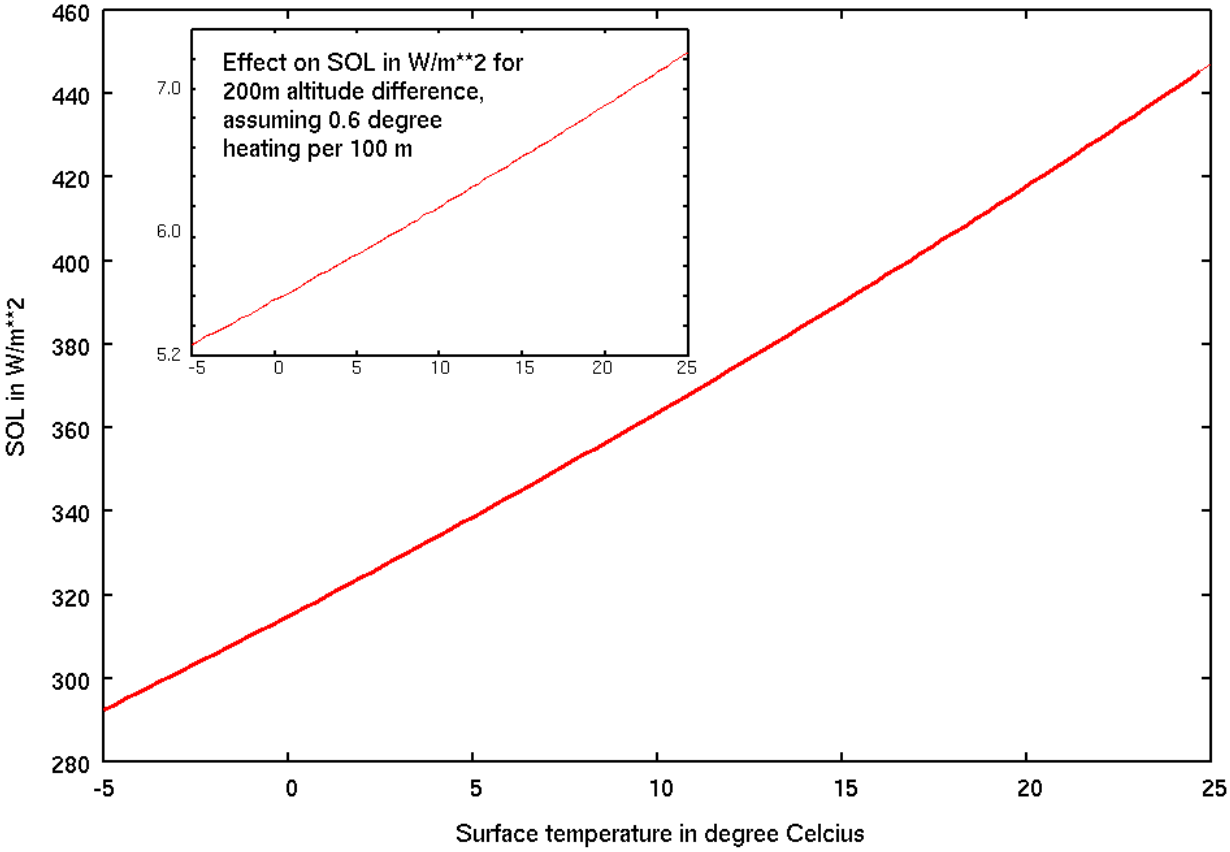

Figure 4-2: The effect of the surface temperature on SOL

Also the average soil type effects the temperature due to different heat capacities. The soil type within a 40x40 km box around Payerne is very different. In addition, the GME model does not taken into account the effect of large lakes. This might also lead to a higher bias in the Payerne case. The Lac de Neuchatel is nearby Payerne and acts as energy (heat) storage.

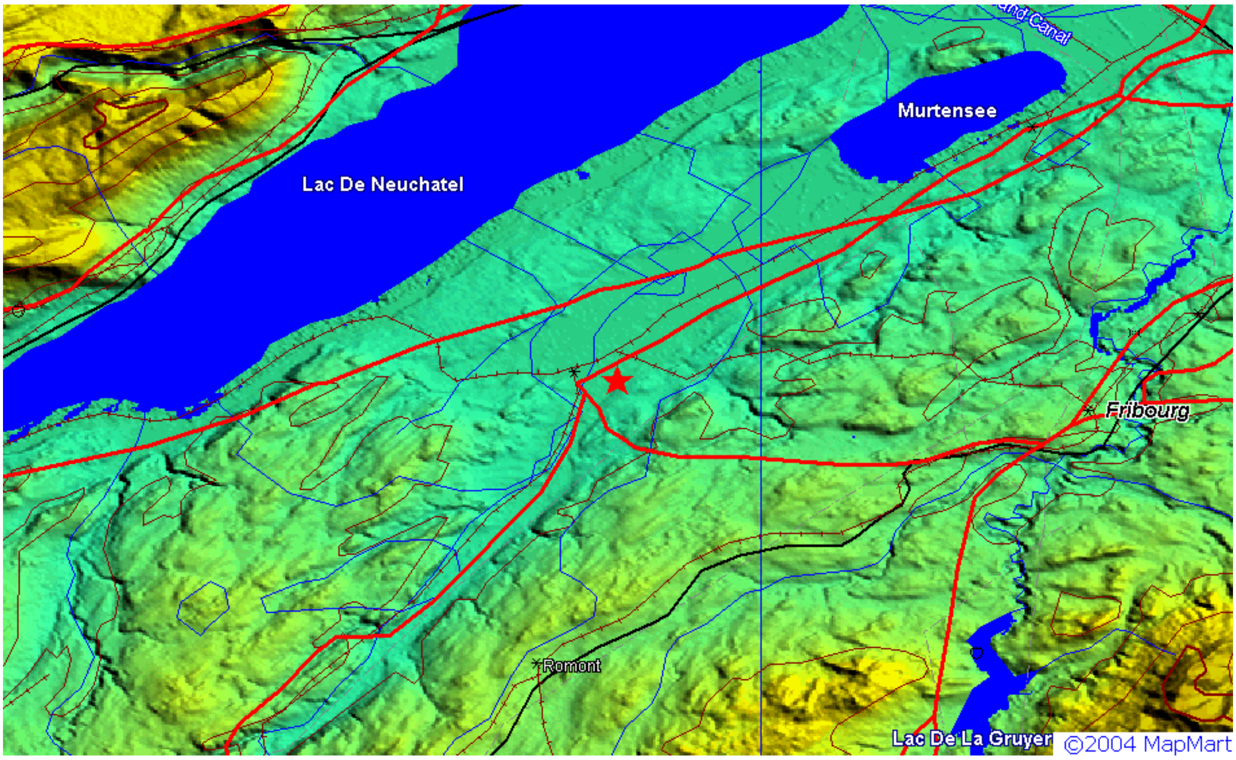

Figure 4-3: Map of the region around Payerne. The width of the map is 25 miles. The red star is Payerne.

As a consequence of the things mentioned above the bias between point measurements and area averaged is expected to increase in heterogeneous regions, where large differences in the altitude and the soil type occurs. In such cases the bias describes not the error in the calculated SOL ore SDL values, since the calculated values are area values (SOL:40x40 km box, SDL: effected by 40x40 km box by temperature) while the ground based measurements are point measurements. In such cases the monthly means are not completely comparable, since the bias characterises both, errors in the calculation and differences due to principle drawbacks by comparing point measurements with area values.

In addition the resolution also affects the physical processes captured by the model. UK-MET has demonstrated this effect on the precipitation amount, see Figure 4-5 (http://www.metoffice.com/research/apr/wms.html).

Figure 4-4 shows the mean of SDL for July 2004 for a European area. This data set has been produced by the CM-SAF pre-operational processing chain. The image is based on GME data.

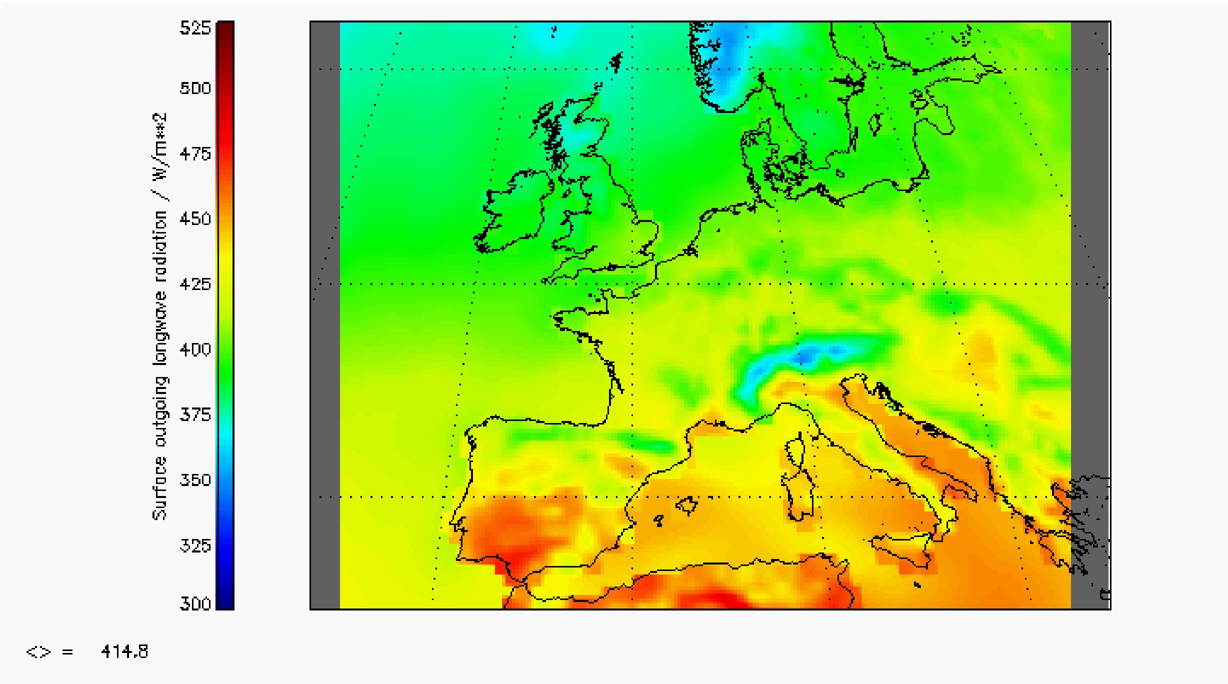

Figure 4-4: Monthly mean of surface outgoing longwave radiation for July 2004.

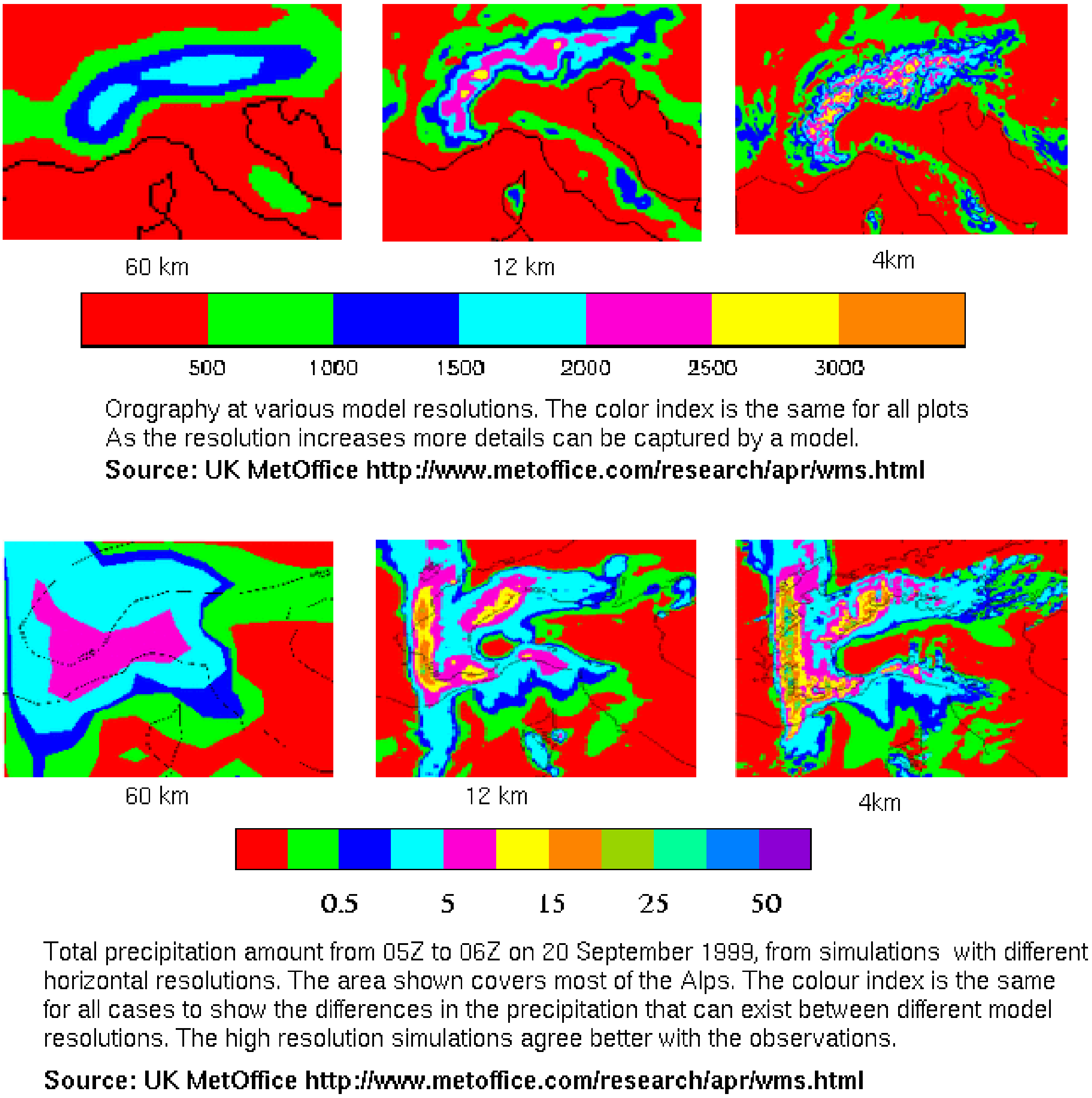

Figure 4-5: Example for the effect of orography resolution.

4.1.3 Surface incoming shortwave fluxes - SIS

The algorithms for the calculation of SIS are identical for the MSG and AVHHR processing. The average RMS error of the instantaneous fluxes is 35.1% (October 2004) and 28.5 % (July 2004). The RMS is much higher than for the longwave radiation because clouds are very dynamical in time and space. They have a larger effect on SIS than on SDL. SDL and SOL are dominated by temperature. Variations in temperature, especially that of the surface, are compared to the variations of cloud patterns very dull. Consequently, variations in instantaneous SIS values are much higher than that of SOL or SDL. This leads in a natural manner to a higher RMS. Additionally hourly values of the ground based measurements have been compared with instantaneous satellite based SIS values, which forces the effect of cloud variations on the RMS value. This effect is reduced if daily or monthly means are compared.

The average absolute bias is 2.93 % (October 2004) and 4.65 % (July 2004). It is a little bit surprising, that the summer month has a higher bias. However, in contrast to the validation of the AHVRR derived SIS (SAF/CM/DWD/SR/SFCFLX/1) for both seasons (summer and autumn month) quite good results are obtained. It is important to note that the average values of the instantaneous SIS is different to the monthly mean.

The monthly mean is much smaller, because it is calculated including the night hours with SIS values of zero. Additionally the RMS and the bias should decrease by decreasing the "sampling error", especially since only one MSG-Image per hour is currently used in the processing. The scanning time is in contrast to the AVHRR processing always at the same times of day. This might lead also to an increased bias in case of comparing the instantaneous SIS values with hourly means of ground based measurements. For these reasons monthly and daily means has been calculated and compared directly in case of SIS, in addition.

The results are presented in table 4-9, 4-10 and 4-11. For SIS these tables contains the relevant information for the target accuracy. The mean absolute bias for the monthly means is 2.75 W/m² or 1.1 % for July 2004, 3.05 W/m² or 3.9 % for October 2004 and 2.6 W/m² or 11.6 % for December 2004. This is far below the target accuracy. Also the individual bias values are below the target accuracy for all investigated stations and months. The only exception is Lindenberg in October 2004, but even these results are very close to the target accuracy (0.8 W/m² for monthly means and 1.6 % for daily means above target accuracy).

The increase of the bias values in percent with comparable bias in W/m² is typical for SIS. The SIS monthly and daily means are very small in winter months. Hence, even small absolute bias values lead to a large relative bias values in %. This is the reason why a target accuracy of 15 % for daily means is not reasonable for the winter time. The mean absolute deviation is 10.9 % for October and July, but 40 % for December. The MAD in W/m² is 18.4 for July, 11,5 for October and 8,6 for December.

				[W/m2]	[W/m2]		[W/m2]	[%]	[W/m2]	[%]
LOCATION	YEAR	MONTH	NVAL	MA_MS	MA_CA	COR	BIAS	BIAS	RMS	RMS
Lindenberg	2004	10	195	190.5	175.4	0.90	-15.1	-7.9	64.4	33.8
Cabauw	2004	10	178	185.3	185.0	0.91	-0.3	-0.2	57.2	30.9
Carpentras	2004	10	204	233.4	241.3	0.89	8.0	3.4	83.4	35.7
Payerne	2004	10	208	189.8	189.4	0.88	-0.4	-0.2	75.9	40.0

Mean absolute BIAS over all stations: 5.95 W/m² or 2.93 % Mean RMS: 70.2 [W/m2] or 35.1%

Table 4-7: Comparison of instantaneous satellite derived and hourly in situ surface downward shortwave fluxes for October 2004. For legend see table 4-1

				[W/m2]	[W/m2]		[W/m2]	[%]	[W/m2]	[%]
LOCATION	YEAR	MONTH	NVAL	MA_MS	MA_CA	COR	BIAS	BIAS	RMS	RMS
Lindenberg	2004	07	429	327.7	345.3	0.93	17.6	5.4	90.5	27.6
Cabauw	2004	07	392	304.1	324.8	0.90	20.7	6.8	106.0	34.9
Carpentras	2004	07	418	494.3	510.4	0.95	16.1	3.2	96.7	19.6
Payerne	2004	07	424	378.3	390.2	0.91	12.0	3.2	120.9	32.0

Mean absolute BIAS over all stations: 16.6 W/m² or 4.65 % Mean RMS: 103.5 [W/m^2] or 28.5%

Table 4-8: Comparison of instantaneous satellite derived and hourly in situ surface downward shortwave fluxes for July 2004. For legend see table 4-1.

COMPARISON OF MONTHLY AND DAILY MEANS

			[W/m^2]	[W/m^2]	[W/m^2]	[%]		[W/m^2]	[W/m^2]	[W/m^2]	[%]
LOCATION	YEAR	MONTH	MM_MS	MM_CA	BIAS	BIAS	MONTH	MM_MS	MM_CA	BIAS	BIAS
Lindenberg	2004	07	216.3	218.0	1.7	0.8	10	76.2	68.0	-8.2	-10.8
Cabauw	2004	07	207.2	209.1	1.9	1.0	10	73.7	74.0	0.7	1.0
Carpentras	2004	07	311.2	307.0	4.2	-1.4	10	101.5	100.3	-1.3	-1.2
Payerne	2004	07	242.4	239.2	-3.2	1.3	10	82.2	80.3	-2.0	-2.4

Mean absolute bias over all stations and months is 2.9 W/m² or 2.5 %.

Table 4-9: Comparison of monthly means calculated from daily means. MM_MS: Measured monthly mean. MM_CA.: Satellite derived monthly mean, COR: correlation coefficient, BIAS=calculated – satellite derived value in W/m² and % related to the measured average.

			[W/m²]	[W/m²]	[W/m²]	[%]		[W/m²]	[%]
LOCATION	YEAR	MONTH	MM_MS	MM_CA	BIAS	BIAS	COR	MAD_DM	MAD
Lindenberg	2004	12	15.1	16.6	1.5	9.6	0.64	5.8	38.4
Cabauw	2004	12	19.4	20.5	1.1	5.5	0.92	5.4	27.7
Payerne	2004	12	27.0	32.3	5.3	19.7	0.63	14.6	54.0
Mean absolute bias over all stations is 2.6 W/m² or 11.6 %. The mean absolute deviation of the daily means is 8.6 W/m² or 40 %.									
Payerne	2005	03	144.1	134.9	-9.1	-6.3	0.95	17.7	12.3

Table 4-10: Comparison of monthly means calculated from daily means. MM_MS: Measured monthly mean. MM_CA.: Satellite derived monthly mean, COR: correlation coefficient, BIAS=calculated – satellite derived value in W/m² and % related to the measured average.

				[W/m²]	[%]			[W/m²]	[%]
LOCATION	YEAR	MONTH	COR	MAD_DM	MAD_DS	MONTH	COR	MAD_DM	MAD_DS
Lindenberg	2004	07	0.97	16.0	7.4	10	0.94	12.7	16.6
Cabauw	2004	07	0.93	20.5	9.9	10	0.95	10.4	14.1
Carpentras	2004	07	0.94	15.0	4.8	10	0.96	10.2	10.1
Payerne	2004	07	0.93	22.1	9.1	10	0.94	12.8	15.5
Mean absolute deviation over all months and stations is 10.9 %. The MAD is 18.4 for July 2004 and 11.5 W/m² for October 2004.									

Table 4-11: Comparison of daily means. COR: correlation coefficient, MAD: mean absolute deviation DM measured daily means. DS satellite derived daily means..

Absorbing aerosols:

The RTM based look-up tables used for the validation considers the effect of aerosols only by approximation. A visiting scientist activity is taking place in summer 2005 in order to overcome this problem. However the more critical point is not the approximated consideration of aerosols in cloud situations, but the availability of an accurate input.

Information about the aerosol type and the aerosol optical depth is up to now not available with a high accuracy and a large spatial coverage. AERONET provides accurate aerosol information, yet only for specific sites. GADS/OPAC (Koepke et al., 1997; Hess et al., 1998) provides the aerosol type and optical depth with a global coverage, but the spatial and temporal resolution (5X5 degree, seasonal) is too coarse to resolve regional patterns. MODIS provides aerosol optical depth (AOD) values in a spatial coverage and temporal coverage which is well suited for the calculation of irradiance within the scope of climate applications. Yet, MODIS provides no aerosol type and the aerosol optical depth is currently “not accurate enough”. E.g. for June 2003 differences of about 0.2 in the AOD occur between MODIS and the AERONET stations Hamburg, Cabauw and The Hague. The differences are higher than the official stated uncertainty of 0.05+0.2*AOD. They are most probably due to general problems of the retrieval described on the MODIS web page (see http://modis-atmos.gsfc.nasa.gov/MOD04_L2/qa.html) and due to the redundant information of the aerosol type used in the MODIS AOD retrieval over land. For the AERONET stations Carpentras and Leipzig the differences in the AOD are in the range of the provided uncertainty.

GADS/OPAC provides as aerosol type urban aerosols for the regions, where the validation stations are located. The AOD for the respective regions provided by GADS are in the range of 0.14 to 0.22 for a relative humidity of 50 %, see Table 4-12. The GADS AOD values are in a better agreement with the AOD June values of the investigated AERONET stations Hamburg, The Hague and Cabauw than the MODIS values. However, the temporal and spatial resolution of GADS is very coarse; hence the GADS values can only be seen as a "best-guess". To overcome this problem and to improve the used aerosol climatology map a contract for services has been assigned with MPI-Hamburg in order to derive a better climatology by merging of different data sources. The new climatology will be ready for use end of May 2005 latest. For the operational chain and the validation efforts discussed in this paper, the GADS/OPAC climatology has been used, because it fits best with the AERONET measurements.

In order to illustrate the effect of different aerosols on SIS RTM results, Figure 4-6 shows the relationship between the top of atmosphere flux and the surface incoming flux for different cloud optical thickness and different aerosol types with an aerosol optical thickness of 0.2. The RTM model libRadtran (www.libradtran.org) has been used for the calculations. The differences between the relation of the global irradiance and the flux at the top of the atmosphere are very small in case of rural and maritime aerosols, whereas they are significant for urban aerosols. This demonstrates the importance of accurate aerosol information, also for cloud situations.

Latitude	Longitude	Aerosol optical depth (550 nm)	Aerosol type
45	5	0.14	Urban
45	10	0.18	Urban
45	15	0.16	Urban
50	5	0.22	Urban
50	10	0.18	Urban
50	15	0.21	Urban

Table 4-12: Aerosol type and optical depth at a relative humidity of 50 % for different regions, summer values.

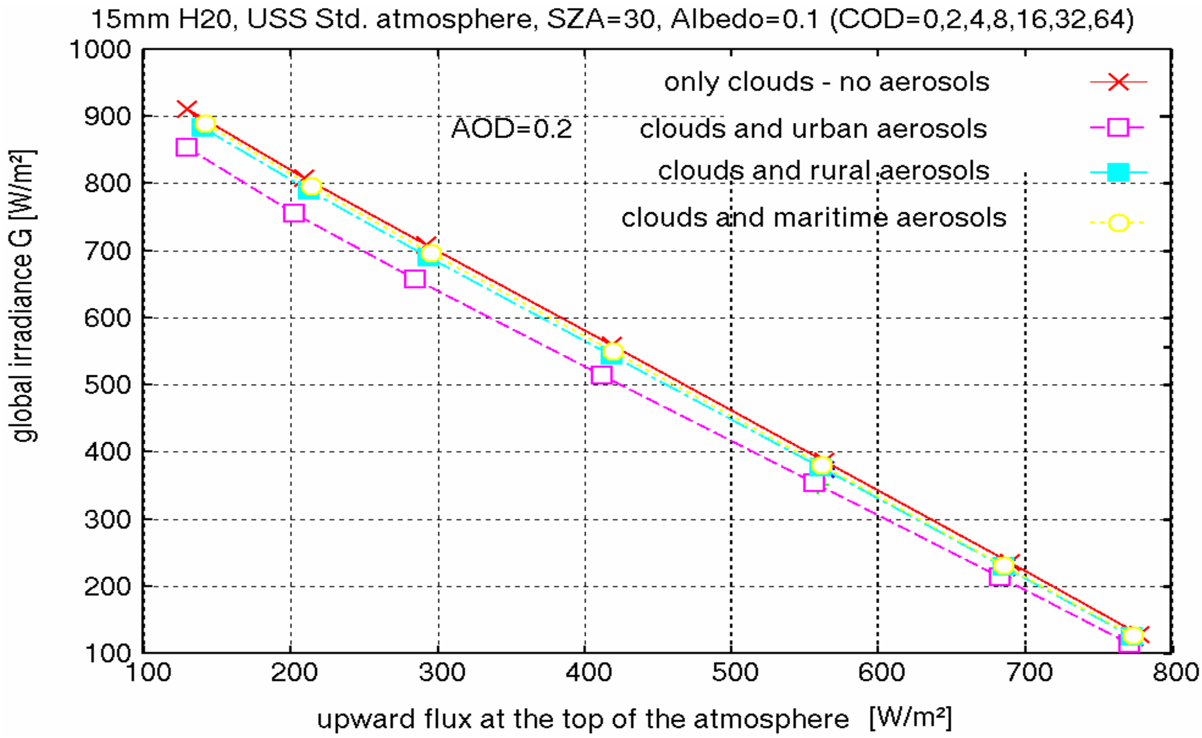

Figure 4-6: Relationship top of atmosphere flux – solar irradiance for different aerosol types.

<u>Initial Comparison of MPI aerosol climatology with GADS/OPAC</u>

Within a work contract with MPI-Hamburg a global aerosol climatology has been derived using ground based Aeronet data together with AERCOM data. The climatology provides monthly values of aerosol optical thickness, single scattering albedo and asymmetry parameter in a spatial resolution of 100x100 km.

As initial comparison SIS has been computed with the different aerosol climatologies for March 2004 and the station Payerne, Lindenberg, Cabauw and Carpentras. The mean absolute bias in the calculated SIS was 5 % using the GADS/OPAC climatology and 8.2 using a merged Aeronet/Aerocom climatology. Hence, the initial comparison shows no urgent need to replace the GADS/OPAC climatology by the merged MPI climatology. Yet, a more extended comparison is needed before final conclusions can be drawn.

<u>Effect of surface albedo:</u>

Since the relation of G-Toa-Albedo is used for the calculation of SIS in cloudy situations, the effect of incorrect surface albedo values on SIS is significant. In order to investigate this effect the surface albedo has changed compared to the albedo provided by the used albedo map. An increase of the surface albedo from 0.2 to 0.25 increases the bias for July 2004 from 4.65 to 7.45 % for the monthly average of instantaneous SIS. In contrast, a reduction of the surface albedo reduces the bias. The magnitude of the effect depends on the cloud climate and depends therefore on the location and time.

Effect of 3-D clouds on RMS:

The effect of 3-D clouds on the accuracy of calculated SIS and possible corrections of those effects have been discussed in several publications, (e.g. Girodo 2005). It will be investigated if the adaptation of such approaches is possible and advisable for the CM-SAF SIS algorithm and end products.

Procedure for the calculation of daily averages

Daily averages are calculated following a method by Möser (1983) (also published in Diekmann et al., 1988).

$$SIS_{DA} = SIS_{CLSDA} \frac{\sum_{i=1}^{n} SIS_i}{\sum_{i=1}^{n} SIS_{CLS\,i}}$$

SIS_{DA} is the daily average of SIS. SIS_{CLSDA} is the daily averaged clear sky SIS, SIS_i the calculated SIS for satellite image *i* and SIS_{CLS_i} the corresponding calculated clear sky SIS. n is the number of images available during a day.

The larger the number of available images per day, the better the daily cycle of the cloud coverage can be approximated and the better the calculated daily average.

With NOAA data, the diurnal cycle cannot be resolved as well compared to using geostationary data like METEOSAT. Comparison of the validation results provided in this report with AVHRR validation results indicates that the daily values are improved by the use of MSG.

Olseth and Skartveit (2001) have shown that RMS errors of solar irradiance values derived from Meteosat data at northern latitudes (Bergen, 60°N) compare with RMS errors derived at other (lower) latitudes. Therefore it might be favourable to use METEOSAT data even in higher northern latitudes (although the viewing geometry is less favourable) instead of using NOAA images to compensate for the low number of available images per day when using NOAA data. This needs to be evaluated further once more MSG validation results are available.

The monthly mean of SIS for July 2004 is shown in Figure 4-7. In order to investigate the effect of increased albedo values on the calculated SIS values we did calculations with different albedo maps. The origin albedo map is derived from USGS land-cover map. The albedo values of this map has been increased by a factor of 1.25 (25 %) for a comparison run (e.g for green vegetation the albedo is 0.25 instead of 0.2 then) Figure 4-7 is from the comparison run with increased albedo values compared to the origin albedo map used for for the validation.

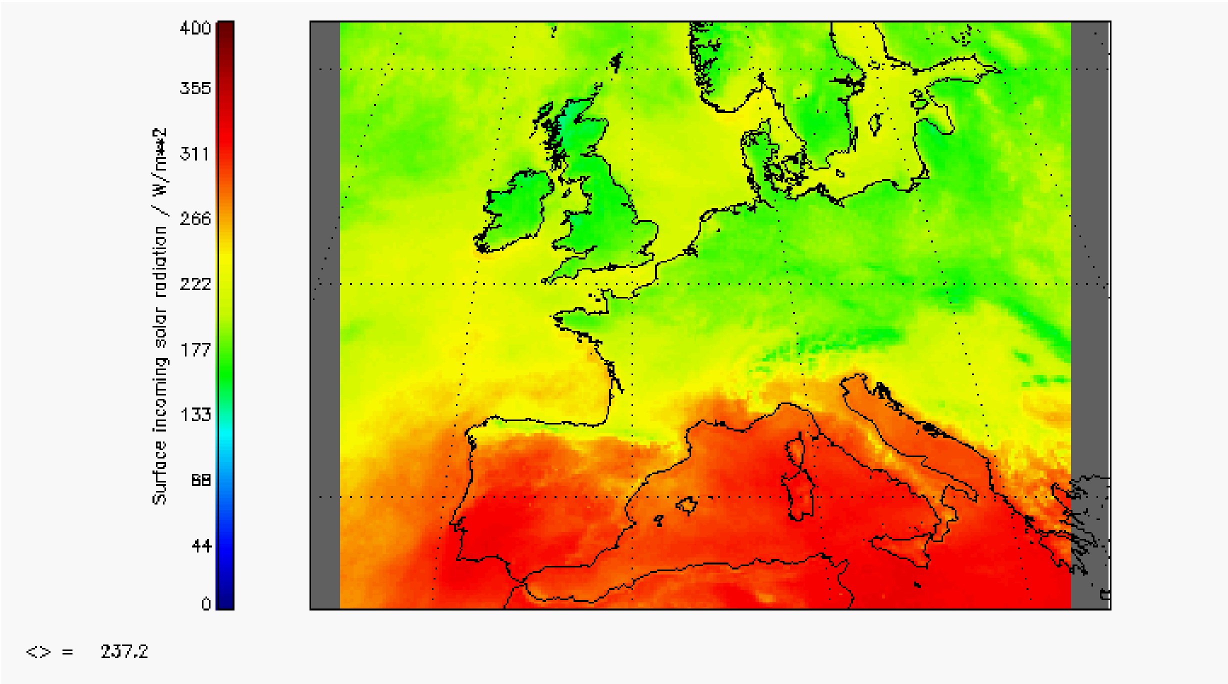

Figure 4-7: Monthly mean of surface incoming shortwave radiation for July 2004.

4.1.4 Net fluxes

The longwave net fluxes can be calculated from SDL and SOL, since SNL is defined as the difference between SDL and SOL. Consequently, the bias of SNL is the difference of the bias of SDL and SOL.

The bias calculated is for all investigated stations and months within the target accuracy of 15 W/m², see table 4-10.

			[W/m^2]	[W/m^2]	[W/m^2]		[W/m^2]	[W/m^2]	[W/m^2]
LOCATION	YEAR	MONTH	MA_MS	MA_CA	BIAS	MONTH	MA_MS	MA_CA	BIAS
Lindenberg	2004	07	-69.2	-56.8	-12.4	10	-49.5	-50.7	1.2
Cabauw	2004	07	-41.8	-53.3	11.7	10	-36.8	-50.3	13.5
Payerne	2004	07	-66.8	-59.8	-6.9	10	-38.7	-41.7	3.0
Lindenberg	2004	12	-22.7	-32.2	-9.7				
Cabauw	2004	12	-29.0	-37.7	-8.7				
Payerne	2004	12	-20.5	-21.7	1.2				

Mean absolute bias over all stations and months is 7.2 W/m².

Table 4-13: Comparison of monthly SNL averages calculated with SNL=SDL-SOL. MA_MS: Measured monthly mean. MA_CA.: Satellite derived monthly average, COR: correlation coefficient, BIAS=satellite derived - measured value in W/m² related to the measured average.

The shortwave net fluxes have not been validated yet. The focus has been on validating the basic flux components first and improving them if necessary. Once the individual flux components are within the target accuracies, it can be expected that net fluxes will also show reasonable values. Especially, since the surface albedo is a significant input to the calculation of SIS. This validation will be performed at locations where validation data (SIS net flux measurements or measurements of SIS and SAL) are available.

4.2 Initial comparison for the monthly mean diurnal cycle.

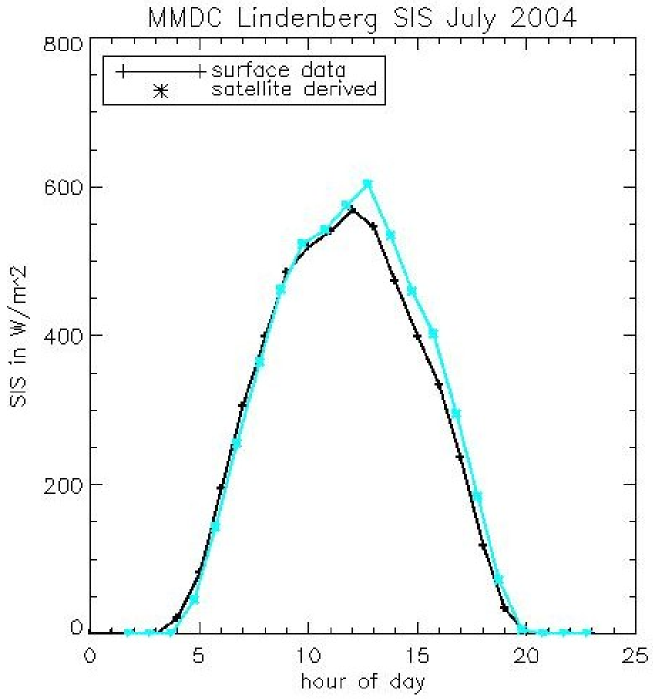

Figure 4-8: Comparison between the monthly mean diurnal cycle of SIS, Lindenberg.

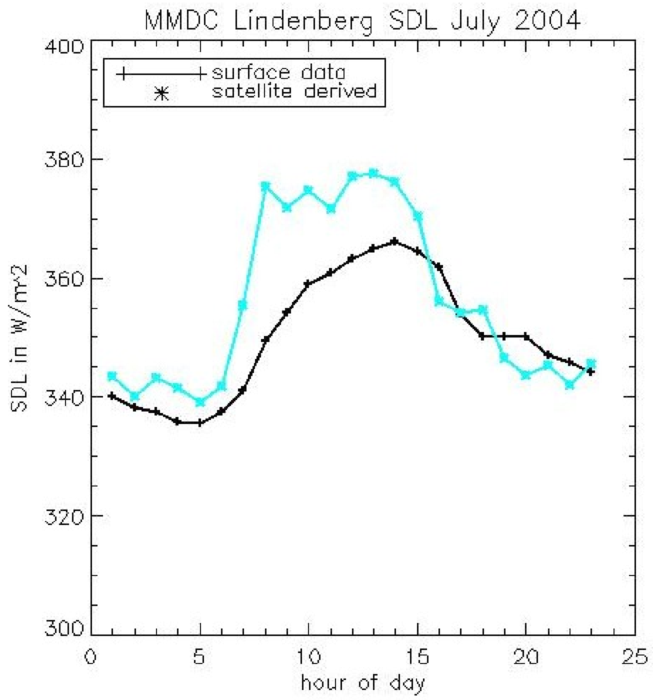

Figure 4-9: Comparison of the monthly mean diurnal cycle for SDL, Lindenberg.

While the SIS monthly mean diurnal cycle (MMDC) shows a relative good agreement with the measurements, the SDL MMDC shows differences in the order of 15 W/m² depending on the observation time. In addition, also the SIS MMDC shows significant differences in the afternoon. One reason for the differences could be the temporal resolution of the satellite data, as well as -in the case of SDL- the GME data. Currently, only one satellite image per hour is used in order to derive the SIS and SDL MMDC product. This resolution is pretty high enough for the calculation of monthly means, but it can be expected that it leads to significant differences in the case of MMDC and daily means.

For the satellite derived SDL product important input data are provided by the GME model (surface temperature, water vapour and air temperature). The GME model has a temporal resolution of 3 hours. Currently the nearest neighbour in time from GME is used as input date to calculate SDL. An interpolation between the 3 hourly steps would be obviously of benefit for the quality of MMDC. However, the comparable large differences around noon cannot be explained by the temporal resolution. This effect is probably based on a mismatch in the physics within the GME-model, especially in the morning after sunrise. It has also to investigated if this comes from a systematic overestimation of cloud fractional cover or cloud top pressure in the morning.

The MMDC has to be analysed in more detail. Analysing the MMDC would help to increase the understanding of atmospheric processes. Differences and features occur and can be analysed which are not visible in monthly or daily means.

4.3 Initial Comparison of MSG and NOAA based products

4.3.1 Comparison of NOAA and MSG results.

Product	MSG: Mean absolute bias in %	NOAA Mean absolute bias in %	Number of stations
SOL	2	3.8	3
SDL	2.5	2.8	4
SIS	4.7	4.2	4

Mean absolute bias of instantaneous values for July 2004 over all stations.

Product	MSG: Mean of bias in %	NOAA Mean of bias in %	Number of stations
SOL	-2	-1.2	3
SDL	-0.9	-1.1	4
SIS	4.7	4.2	4

Mean bias of instantus values for July 2004 over all stations.

The results of the monthly means matches very well. MSG and NOAA based results has to be monitored in more detail during the next months. The result of the comparison provides significant information for the merging concept.

4.3.2 Comparison of SAL for March 2005, related to RID53

Comparison for equally normalized SAL has been performed for July 2004 by FMI as requested in RID53. The results are described in the ORR-V2 report SAF_CM_FMI_SR_SFCSAL_1.1.

Yet, due to a bug in the processing of the SAL data at DWD pre-operational chain the differences discussed in SAF_CM_DWD_SR_SFCSAL_1 are not only due to different normalisation with respect to the solar zenith angle, but also due to different coefficients for the atmospheric correction. In order to compare SAL with equal SZA normalisation and correct coefficients for the atmospheric correction MSG based SAL has been reprocessed and compared to NOAA based SAL for March 2005. The SAL values shows on average systematic differences of 4 % for March 2005, but in general they are in line. The remaining differences in SAL can be due to different viewing geometries, different cloud masking algorithms and due to differences in the NIR channel of SEVIRI and AVHRR (calibration). Consequently differences between MSG and AVHRR based SAL might be different for different seasons. As mentioned in the radiation validation plan an extended comparison between MSG based and AVHRR based SAL values will be performed within the scope of ORR-V3.

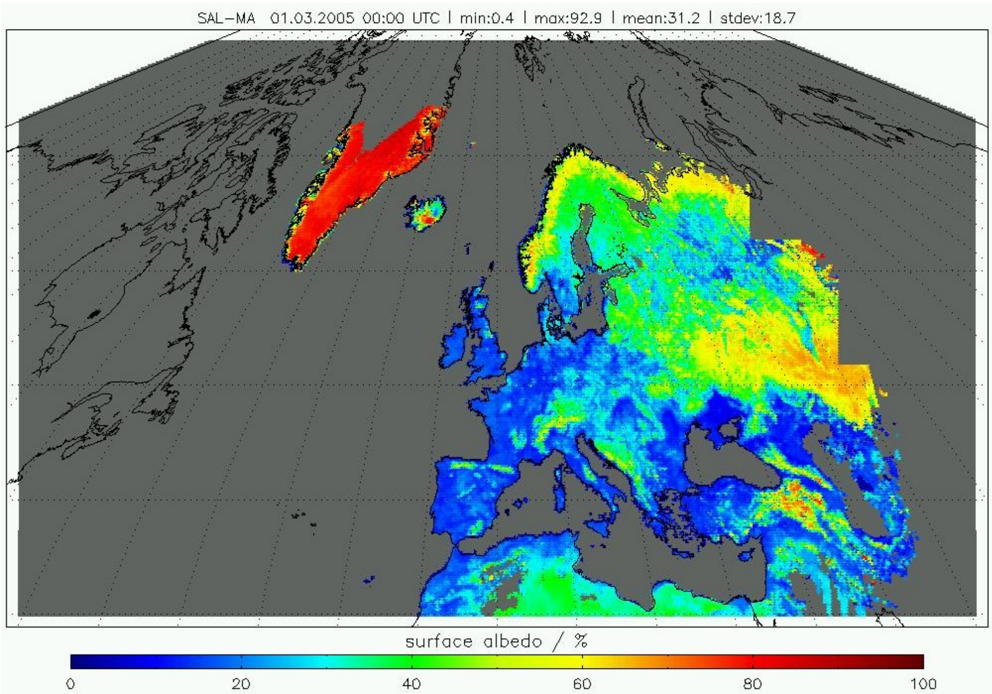

Figure 4-10: Surface albedo retrieved from AVHRR for March 2005.

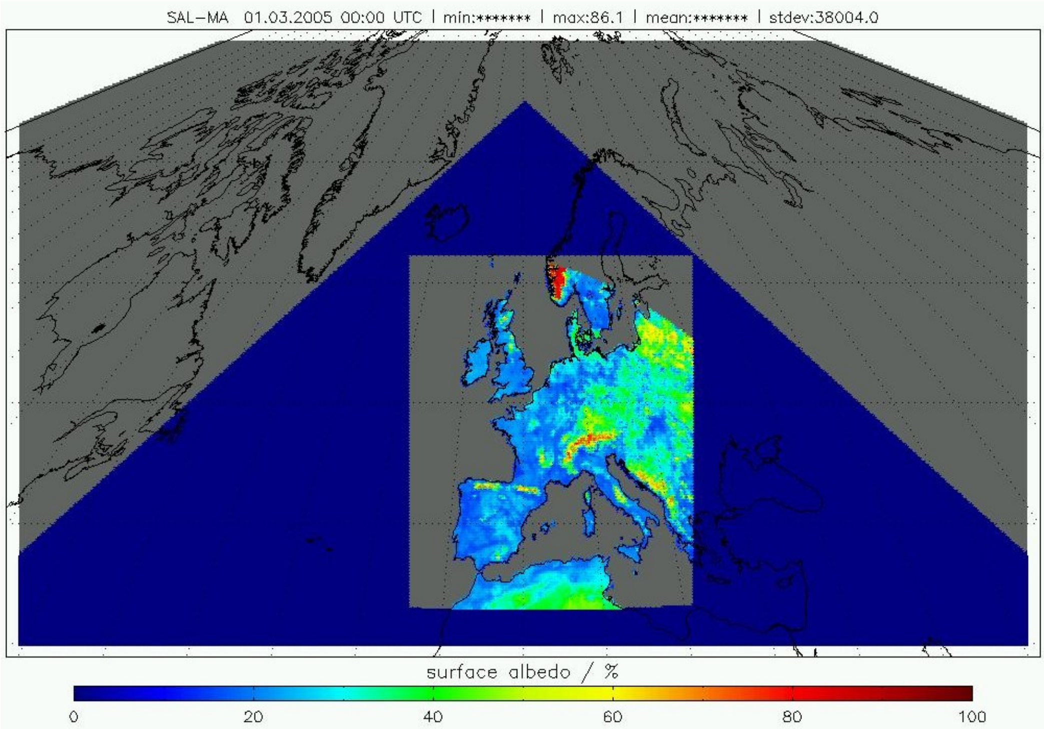

Figure 4-11: Surface Albedo retrieved from MSG/SEVIRI for March 2005.

5 CONCLUSIONS

The performed validation provides a good insight in the accuracy of the surface radiation products. Yet, because of the early stage of the MSG processing , the validation of MSG based products allows currently no final conclusion on accuracy. The validation of MSG based products will be continued as more processed data from the pre-operational/operational processing becomes available.

The mean absolute bias (over all stations and months) is below the target accuracy of 10 W/m² for SOL and SDL monthly means. Hence, it can be expected that the target accuracies can be achieved in general. Yet, the target accuracy has been not achieved for the Payerne site in the Alpine region. It seems to be difficult to obtain the target accuracy for the Alpine region without further improvement of the algorithms. But, taking into account the uncertainty of the ground based measurements the results for Payerne (Alpine region) are also quite good. Possible reasons for the comparable high bias in Payerne have been discussed in this report, but they have to be investigated in more detail, with the aim to find solutions to reduce the bias.

SNL is within the target accuracy for all investigated sites and months. The bias of SOL in the Alpine region is partly cancelled by the bias of SDL in that region. Since SDL and SOL are, with respect to the temperature information, driven by the GME analysis, a cancellation of GME introduced errors seems to take place.

The SIS monthly and daily means derived from MSG are almost all within the target accuracy for the investigated stations and months. This is a quite good result in this early stage of the CM-SAF

MSG processing. The only exception is Lindenberg in October 2004, but even these results are very close to the target accuracy (0.8 W/m² for monthly means and 1.6 % for daily means away).

Also the AVHRR validation results for June 2003 (described in validation report SAF/CM/DWD/SR/SFCFLX/1) demonstrates that the SIS algorithm is able to achieve the target accuracy for monthly and daily values provided that accurate top of atmosphere fluxes are available as input. In this context the October 2002 results (SAF/CM/DWD/SR/SFCFLX/1) of the AVHHR validation, characterised by a relative large bias, seems to be untypical.

The mean absolute bias over all investigated stations and month demonstrates that in general the target accuracies of the listed product has been achieved.

Product	MSG: Mean absolute bias in W/m²	Target accuracy	Number of month	Number of stations
SOL	9.3	10	3	3
SDL	8.7	10	3	4
SIS	2.8	10	3	4
SNL	7.2	15	3	3

SNS, SRB: The budgets are only the difference of the basic products (SIS, SAL). Because of the quite good validation results for these basic products, it can be expected that also SNS and SRB will be within the target accuracy for the investigated regions and months.

6 ACKNOWLEDGMENTS

The validation data-sets have kindly been provided by KNMI (Cabauw), MeteoSwiss (Payerne), DWD (Lindenberg) and MeteoFrance (Carpentras).

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8 GLOSSARY

Definitions, acronyms and abbreviations:

This section provides a table of acronyms, abbreviations and terms used throughout this document.

ACRIM	Active Cavity Radiometer Irradiance Monitor
ADM	Angular Distribution Model
AVHRR	Advanced Very High Resolution Radiometer
BRDF	Bi-directional Reflectivity Function
BSRN	Basis Surface Radiation Network
BUFR	Binary Universal Form for the Representation of Meteorological Data
CERES	Clouds and the Earth's Radiant Energy System
CFC	Fractional cloud cover
CM-SAF	SAF on Climate Monitoring
COT	Optical depth
CPH	Cloud phase
CTH	Cloud top height
CTT	Cloud top temperature
CTY	Cloud type
CWP	Cloud water path
DWD	Deutscher Wetterdienst
ECMWF	European Centre for Medium-Range Weather Forecasting
EPS	European polar system
ERB	Earth Radiation Budget
ERBE	Earth Radiation Budget Experiment
ERS-2	European Remote-sensing Satellite - 2
FMI	Finnish Meteorological Institute
FTP	File Transfer Protocol
GERB	Geostationary Earth Radiation Budget Instrument
GEWEX	Global Energy and Water cycle EXperiment
GME	Global Model Extended (global NWP model to be used operationally at DWD in 2000)
ISCCP	International Satellite Cloud Climatology Project
LUT	LookUp Table (data from RTMs)
MSG	Meteosat Second Generation
NCEP	National Center for Environmental Prediction
NetCDF	Network Common Data Form
NOAA	National Oceanic & Atmospheric Administration
NWP	Numerical Weather Prediction
RMIB	Royal Meteorological Institute of Belgium
RTM	Radiation Transfer Model

SAF	Satellite Application Facility
SAL	Surface albedo
SDL	Surface downward longwave radiation
SEVIRI	Spinning Enhanced Visible and InfraRed Imager
SIS	Surface incoming shortwave radiation
SNL	Surface net longwave radiation
SNS	Surface net shortwave radiation
SOL	Surface outgoing longwave radiation
SRB	Surface Radiation Budget
SRD	Software Requirement Document
SZA	Solar Zenith Angle
TBC	to be confirmed
TBD	to be defined/determined
TIS	Incoming solar radiative flux at the top of the atmosphere
TPW	Total Precipitable Water
TRS	Reflected solar radiative flux at the top of the atmosphere
TOA	Top of the Atmosphere