Satellite Application Facility on Climate Monitoring

Scientific Report

Initial Validation of MSG based Surface Radiation Fluxes for the extended area

Version 300 products:

Surface incoming shortwave radiation SIS

Broadband surface albedo SAL

Surface net shortwave radiation SNS

Surface outgoing longwave radiation SOL

Surface downward longwave radiation SDL

Surface net longwave radiation SNL

Surface radiation budget SRB

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Table of Contents

List of Tables

List of Figures

1 INTRODUCTION

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

The algorithms applied to derive surface radiation fluxes (with the exception of the surface outgoing longwave 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.

2 INPUT DATA

MSG cloud data

The cloud data has been retrieved with the NWC-SAF software using MSG-SEVIRI data as input. 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.

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 TOA data will be done and reported by RMIB.

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/).

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

The focus of this report is the validation of the V3 products. Consequently this report focuses on the initial validation results for the extended region of the MSG full disk, described in more detail in section 3.2. However, in order to provide an example of the outcome of the ongoing validation, the results of the comparison between in-situ data and satellite derived data are presented in the next section

3.1 Operational validation of the V2 results

The algorithms of V2 and V3 are identical. In order to assure the quality and stability of the radiation products an ongoing validation (beyond the validation events in conjunction with the reviews) is performed. For the ongoing V2 validation of the CM-SAF surface radiation products mainly data from the BSRN sites within the baseline region are used. Table 3-1 provides a list of the stations currently considered for the ongoing validation. The radiation data from the BSRN sites were received directly from the station operators (courtesy of MeteoSwiss, MeteoFrance) as there is usually 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 used for the operational validation.

Results of the comparison between in-situ data and satellite derived data are diagrammed in Figure 3-1 for Lindenberg for an eighteen month period. Since the V2 and V3 algorithms are identical this example provides also an impression about the expected stability and quality of the V3 products. Most of the values are within the expected accuracy of 10 W/m^2.

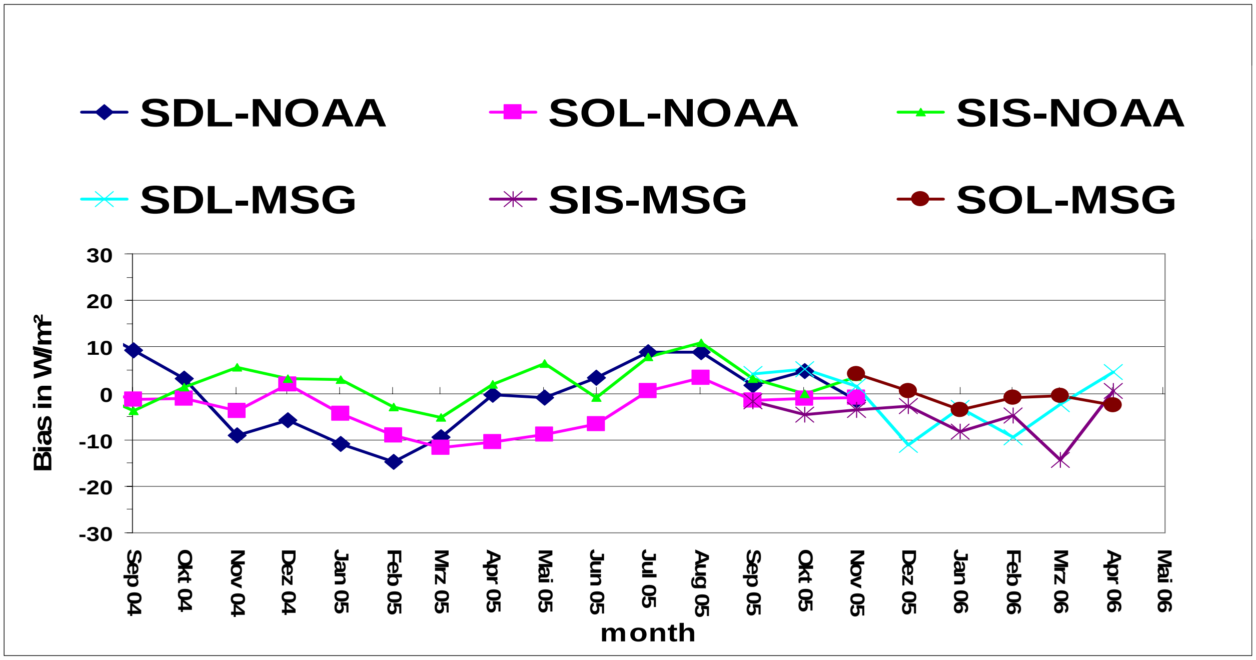

Figure 3-1: Bias (In-situ data minus Satellite derived value) for monthly means at the validation site of Lindenberg.

3.2 Validation activities for the extended area within the scope of V3 development.

For the initial validation of the extended area available in-situ data has been compared with instantaneous satellite derived values, whereby the nearest neighbour in space has been extracted from the respective product images. The nearest neighbour in time of the in-situ data has then be compared with the extracted satellite based value. For the initial validation CM-SAF V3 data starting with June 2006 as well as for July and October have been available. Unfortunately, it is quite difficult to get accurate in-situ data for Africa. The existing BSRN stations provide the data with a large temporal delay [1]. For this reason it was only possible to compare the July and October 2004 data with in-situ data for the African BSRN stations.

In order to get more validation results, data from the “Plataforma Solar de Almeria” has been used. This region in the South of Spain is characterised by arid climate, with a large amount of clear sky days (of course, since it is a test platform for solar power plants needing direct sunlight). It provides therefore hints for the accuracy of the data in arid regions in Africa, dominated by clear sky situations. Figure 3-2 shows the Plataforma Solar de Almeria together with the surrounding landscape.

[1] CM-SAF will contact the station operator in order to get the data with a smaller time delay.

None of the used stations are located within the tropical convergence region. Since this regions is quite important for climate monitoring, data from the AMMA project has been used for ORR-V3 validation issues.

In order to start validation over sea, data from the offshore platform FINO and the meteorological station onboard the METEOR research vessel has been used. Yet, the focus of the FINO platform is related to the planning of offshore wind farms, accuracy of the lonesome pyranometer data can not be expected a priori. The lack of data over ocean has already be addressed by the BSRN community and there might be more data available in the near future. A working group, leaded by Ken Rutledge from AS&M, has already started with the work by compilation of user requirements.

Figure 3-2: The "Plataforma Almeria", located in an arid region in Southern Spain.

Station	Latitude	Longitude	Country	elevation (m)
Tamanrasset	22.78° N	5.52° E	Algeria	?
Sede Boger	30.87° N	34.77° E	Israel	?
De Aar	30.68° S	24.00° E	South Africa	?
Almeria	37.08° N	2.35° W	Spain	?
Fino	54.01° N	6.59° E	North-Sea	0
ARM - Niamey	13.52° N	2.63° E	Benin	228

Table 3-2: Geographical coordinates and elevation of validation sites used for the extended area validation.

4 VALIDATION RESULTS

4.1 Introduction

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 for the initial validation of the products in the extended area are based on instantaneous values. The comparison of instantaneous data allows a direct 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 the bias in per cent is the more relevant quantity in this case. With respect to the absolute bias in W/m² it has to be considered that the bias for the monthly mean can be expected to be about 50 % lower.

Definition: target accuracy reached.

Initial validation: Mean absolute bias over stations and month is below 10 W/m². No site show a significant from the target accuracy.

CDOP - Phase1: After enough validation results for statistical interpretation at each site are available, the target accuracy is reached if 90% of the cases are below the target accuracy.

CDOP – Phase2: In heterogeneous regions, e.g. the Alps, the CM-SAF target accuracy will be adapted to topographically induced increase of natural global shortwave irradiance field variability. More generally the target accuracy is scaled related to the variability of the parameter within the 15x15 km grid box. Variability studies will lead to an assessment of the attainable performance of current validation procedures as a function of regional terrain complexity.

4.2 Surface downward longwave fluxes – SDL

The comparison of satellite derived SDL values with in situ measurements (Table 4-1), provides a Mean Absolute Bias (MAB) of 9 W/m² or 2.7 % averaged over all stations, which is below the target accuracy. However for almost all African stations the MAB is negative, an indicator that the satellite derived SDL has a cold bias in Africa. For the interpretation of the results and in order to avoid misleading conclusion it is important to consider that the nonsystematic errors for BSRN data are estimated to be 10 W/m^2 for the longwave measurements (Ohmura et al., 1998), and that they could be also higher dependent on the maintenance of the station.

Consequently, a final conclusion is not possible due to the limited amount of comparison results in combination with the uncertainty of the in-situ data. But, the initial validation provides satisfactory results, taking into account the uncertainty of the in-situ measurements. However it has to be further investigated if a target accuracy of 10 W/m^2 can be achieved in Africa. Further validations will also address the question if a cold bias in Africa exists.

Table 4-1 shows the validations results. Figure 4-1 the preliminary validation results for the ARM site in Benin.

Location	Year	Month	MA	MA_SAT	COR	Bias	Bias	RMS	RMS
			W/ m^2	W/ m^2		W/ m^2	%	W/ m^2	%
Tamanrasset	2004	07	367	352	0.85	-14.9	-4.1	23.1	6.3
	2004	10	322	314	0.72	-8.4	-2.6	16.9	5.2
Sede Boqer	2004	07	364.8	353.4	0.77	-11.4	-3.1	22.4	6.1
	2004	10	357.6	346.8	0.70	-10.9	-3.1	22.1	6.2
De Aar	2004	07	262.4	253.8	0.56	-8.55	-3.3	26.7	10.2
	2004	10	324.3	324.6	0.82	0.4	0.1	23.5	7.3

Mean absolute BIAS over all stations: 8.98 W/m² or 2.7 %

Table 4-1: Comparison of instantaneous satellite derived and hourly in situ surface downward longwave fluxes for July 2004. MA: In-situ measured monthly average. MA_SAT.: Monthly Average derived from satellite data. COR: correlation coefficient, RMS: root mean square error, BIAS calculated - measured value in W/m² and % related to the measured average

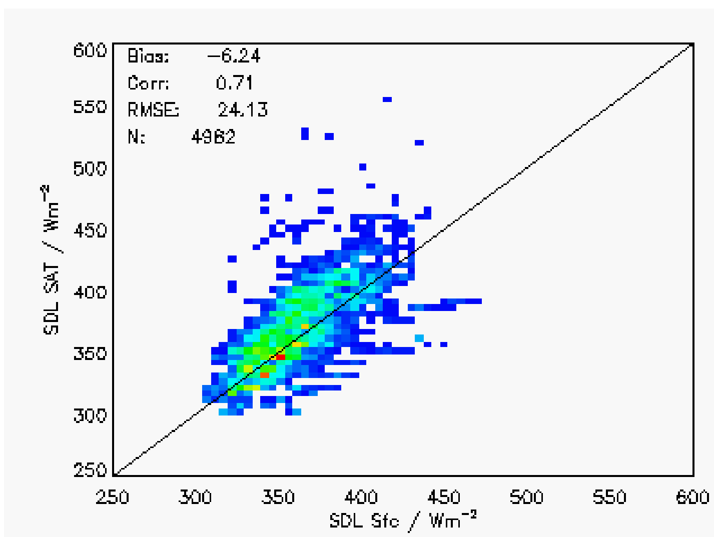

Figure 4-1:Results of the comparison of the surface downward longwave radiation at the ARM site in Benin, data from January to March 2006 .

Figure 4-2 shows as an example of SDL for the full disk area. This data set has been produced based on MSG data by the CM-SAF pre-operational processing chain. The Figure shows a typical feature, a large amount of undefined pixel especially in the tropical convergence region. The reason for this are cloud contaminated pixel. It has to be investigated if this might lead to an bias in the monthly means, due to statistical overrepresentation of the clear sky situations, since many partly cloudy situations occur but can so far be not considered due to missing cloud height. Information about the cloud height is needed for the calculation of SDL in case of cloudy situations.

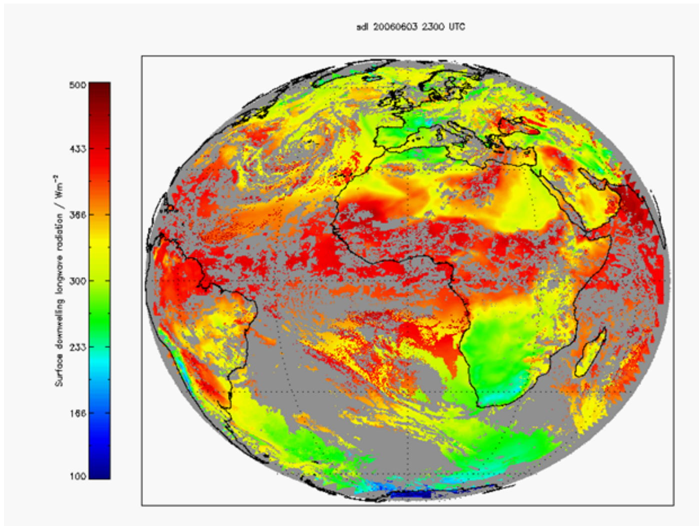

Figure 4-2: Instantaneous surface downward longwave radiation in W/m² for 3rd June 2006, 23 UTC .

4.3 Surface outgoing longwave fluxes - SOL

Surface outgoing longwave radiation is measured only at plataforma Almeria. The other stations provide no SOL measurements. Sede Boqer and De Aar provide measurements of air temperature at the height of SDL measurement. Tamanrasset not even that. In order to get a first impression of the SOL accuracy in Africa, SOL has been derived from the measured air temperature and has been compared with the CM-SAF SOL. However, due to the great vertical gradient in temperature and the neglected emissivity, this comparison has to be interpreted carefully.

In addition to the stations over land data from the Offshore platform FINO has been used. SOL or skin temperature is not measured their as well, but the water temperature at -6 m and the air temperature at 30 m. SOL has been calculated from this temperature information. As the mean skin temperature in the summertime can be expected to be somewhere in between the values for 30 m air and 6m water temperature the “real” SOL should be also in between the SOL derived from the available temperature measurements.

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

The average RMS error and the MAB is good (7.6 W/m², 1.8 %) for the plataforma Almeria comparison. The results for FINO indicate that the MAB for this month might be quite low.

For the African BSRN stations no SOL measurements have been available. SOL has been calculated from the ~2m air temperature (height of the SDL measurement) for the stations De Aar and Sede Boqer, where at least measurements of air temperature were available. (For Tamanrasset no temperature measurements are available). The validation results indicate that the CM-SAF SOL provides reasonable results with no extensive failure in the CM-SAF SOL product. Any further quantitative statement concerning the target accuracy is not reasonable, because of missing measured in-situ SOL or skin temperature data and the update of the GME model. The SOL CM-SAF data of 2004 has to be derived with the "old" model version, since data from the improved GME-model are not available.

All SOL validation results are listed in table 4-2:

			[W/m2]	[W/m2]		[W/m2]	[%]	[W/m2]	[%]
LOCATION	YEAR	MONTH	MA	MA_SAT	COR	BIAS	BIAS	RMS	RMS
Tamanrasset			------------	------------	------------	------------	------------	------------	------------
Sede Boqer	2004	07	440.9	467.3	0.47	26.4	6.0	56.0	12.7
	2004	10	422.7	440.7	0.32	17.9	4.3	47	11.1
De Aar	2004	07	356.5	352.9	0.57	-3.6	1.0	31.1	8.7
	2004	10	419.1	434.9	0.61	15.8	3.8	41.1	9.8
FINO (h=30m)	2006	06	383.6	386.6	0.59	3.1	0.8	14.6	3.8
FINO (h=-6m)	2006	06	373.3	386.6	0.63	13.3	3.6	14.5	3.9
Almeria	2006	06	416.7	418.9	0.24	2.1	0.5	39.6	9.5
	2006	07	437.7	446.9	-0.15	9.2	2.1	52.3	12.0
	2006	08	431.0	443.4	0	12.5	-2.9	50.5	11.7
	2006	09	429.4	436.0	0	6.5	-1.5	42.9	10.0

Mean absolute BIAS for Almeria : 7.58 W/m² or 1.75 %   Mean RMS, Almeria: 46.3 [W/m2] or 10.8 %

Table 4-2: Comparison of instantaneous satellite derived and in situ surface outgoing longwave fluxes. For legend see table 4-1

Figure 4-2 shows an example of the SOL product for the full disk area. This data set has been produced by the CM-SAF pre-operational processing chain. The SOL values are based on GME skin temperature data.

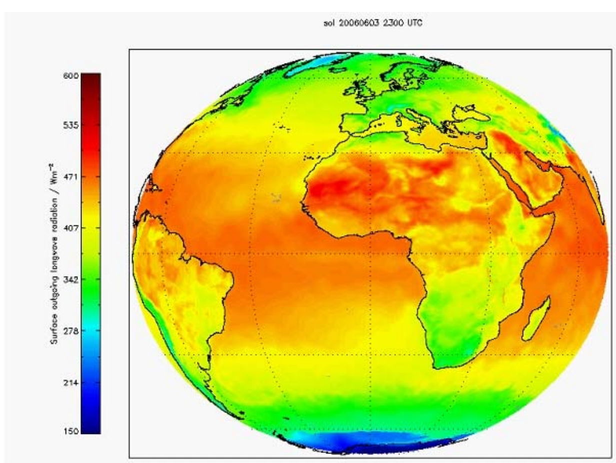

Figure 4-3: Instantaneous Surface outgoing longwave in W/m¹ for 3rd June 2006, 23 UTC.

4.4 Surface incoming shortwave fluxes – SIS

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 the bias in per cent is the more relevant quantity in the interpretation of the SIS validation results. With respect to the absolute bias in W/m² it has to be considered that the bias for the monthly mean can be expected to be about 50 % lower. Of course the “real value” depends of the amount of night hours.

SIS data are available for the African BSRN stations. CM-SAF data have been processed from June 2006 onwards in a semi-operational manner. In addition June and October 2004 have been processed “off-line”. Due to the large temporal delay in the data supply of the African BSRN stations only data from July and October 2004 were available for the initial validation. In order to get more validation results data from the “plataforma de Solar de Almeria” have been used. This region in Spain is characterised by an arid climate, with a large amount of clear sky days. It provides therefore hints for the accuracy of the data in arid regions in Africa, dominated by clear sky situations. Unfortunately data for July 2004 were not available hence recent data for June to November 2006 have been used.

None of the stations discussed so far are located within the tropical convergence region. As this region is quite important for climate monitoring, data from the AMMA project have been downloaded and used within the current validation study.

The MAB for the African stations is with 3.4 % very small. The MAB for the plataforma Almeria is with 2.7 % even lower. Also the mean RMSE 17.6 and 21.3 % are quite good. In addition the preliminary comparison for the ARM site in Benin is promising (see sub-section 4.4.1).The investigated sites and periods in this study are dominated by clear sky situations, hence uncertainties introduced by the treatment of clouds are smaller as in Northern Europe. However, the GADS/OPAC Aerosol climatology used as input for the SIS calculation is based on a quite thin data basis in Africa, therefore errors introduced by the Aerosol climatology are not well known, but the validation results indicates that the used Aerosol climatology provides reasonable values for Africa. Taking into account the uncertainties and the non-systematic errors of the in-situ measurements the validation results clearly indicates that it can be expected to reach the target accuracy, with the exception for specific dust storm and biomass burning events (see sub-section 4.1.1).

In addition to the stations over land, data from radiation measurements onboard the METEOR research vessel and from the Offshore platform FINO have been used.

To compare the ship based data, a daily average of all 10-minute measurements during the day have been assigned to the Midday position of the METEOR vessel. These daily means have then been compared to the daily mean extracted from satellite. It is planned to extend this validation exercise using the nearest instantaneous satellite measurement to the ship measurement. The results with very small differences in SIS for the METEOR comparison are very good.

For FINO quite large bias occur (50 W/m²). Based on the strength of the existing extensive validation of the SIS product our confidence in the quality of the CM-SAF SIS product is high. Hence, the quite large differences between in-situ measurements and CM-SAF SIS indicate that the in-situ measurements seems not to be correct. To underpin this, first comparisons with results from radiative transfer calculations for clear sky indicate that the in-situ measurements are probably not correct or well enough maintained. Only if a large amount of absorbing aerosols is considered the measured clear sky values can be matched. However, a high aerosol load is quite unrealistic for the investigated location and period. More probably the instrument is polluted, e.g. coated with sea salt.

These arguments are supported by the very good results of the METEOR comparison. The METEOR measurements are more reliable, because they have been performed within a well maintained meteorological station onboard the research vessel.

All SIS validation results are shown in table 4-3:

			[W/m2]	[W/m2]		[W/m2]	[%]	[W/m2]	[%]
LOCATION	YEAR	MONTH	MA	MA_CA	COR	BIAS	BIAS	RMS	RMS
Tamanrasset	2004	07	564.7	554.9	0.94	-9.8	-1.7	129.6	22.9
	2004	10	514.0	482.8	0.99	-31.3	-6.1	57.2	11.1
Sede Boqer	2004	07	619.5	605.5	0.99	-13.9	-2.2	62.8	10.1
	2004	10	428.3	445.1	0.92	16.8	3.9	104.2	24.3
De Aar	2004	07	387.1	399.6	0.93	12.4	3.2	76.8	19.8
	2004	10	525.4	541.2	0.92	15.8	3.0	135.5	25.8
Almeria	2006	06	507.3	503.2	0.94	-4.1	-0.8	117.6	23.2
		07	559.6	571.0	0.94	11.4	2.0	108.3	19.4
		08	530.9	531.9	0.96	1.1	0.2	87.5	16.5
		09	463.1	447.5	0.91	-15.6	-3.4	121.3	26.2
		10	332.5	316.7	0.92	-15.8	-4.7	93.8	28.2
		11	288.5	272.7	0.93	-15.7	-5.4	70.2	24.3

Mean absolute BIAS over all African stations: 16.6 W/m² or 3.4 %, Mean RMS: 17.6%

Mean absolute BIAS for Almeria: 10.6 W/m² or 2.7 % , Mean RMS: 21.3%

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

4.4.1 SIS Validation in the tropical convergence zone – effect of dust storms

In order to get information of the accuracy of the CM-SAF products within the tropical convergence zone a comparison of CM-SAF SIS with measurements from the ARM site at Niamey have been performed. The location of the ARM site is depicted in figure 4-4. The preliminary comparison leads to quite low bias for January and February 2006, see figure 4-5. However the bias in March 2006 increases dramatically, see figure 4-6. The reason for this behaviour is a desert storm in North Africa, starting at the beginning of March and reaching Niamey on the 7/8. March. Going ahead with the desert storm the aerosol optical thickness increases dramatically, as illustrated in figure 4-7 (Photograph taken by A. Slingo, ESSC, Slingo et. al. 2006). So far CM-SAF uses as input for the aerosol information a static climatology, which describes the background aerosols better as satellite product (e.g Kinne 2005). But, of course this climatology does not catch specific desert storm or biomass burning events. If such events occur the assumed aerosol optical thickness is below the real one, leading to an significant over-estimation of the SIS derived from the satellite. It is planned to investigate this dramatic effect in further detail, taking into account the measured values of aerosol optical thickness.

Within the CDOP phase satellite based aerosol retrieval will be implemented. As desert storms and biomass burning leads to relative large aerosol optical thickness the events can be seen and monitored by satellites. Consequently, merging the current background aerosol information with a satellite desert storm and biomass burning product is expected to improve the accuracy of the retrieved solar irradiance.

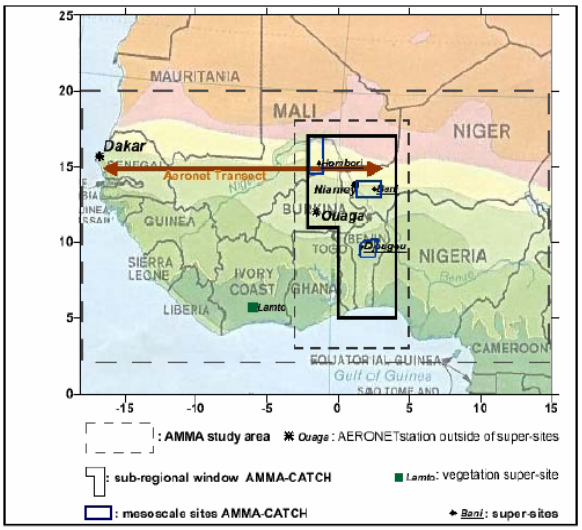

Figure 4-4: Location of the ARM site in Benin and the AMMA investigation area.

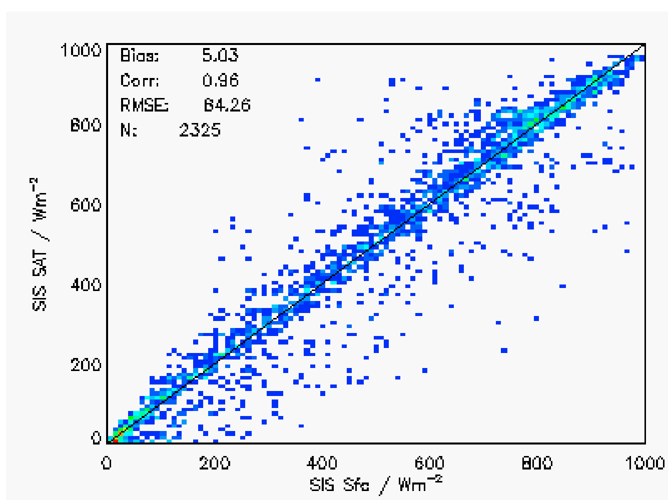

Figure 4-5: Comparison of instantaneous surface measurements and satellite derived SIS values for Niamey, only from January and February 2006.

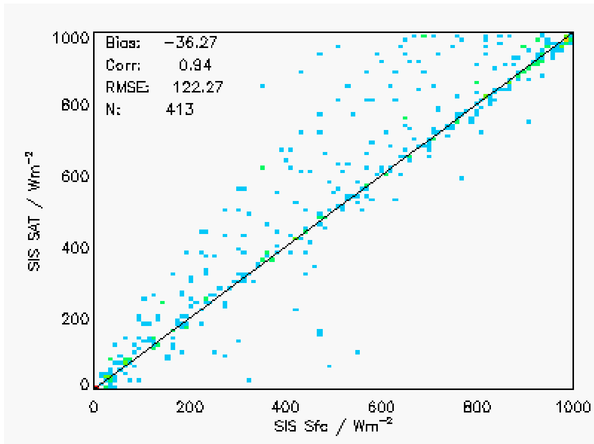

Figure 4-6: Same as Figure 4-4 but for the first 10 days of March 2006.

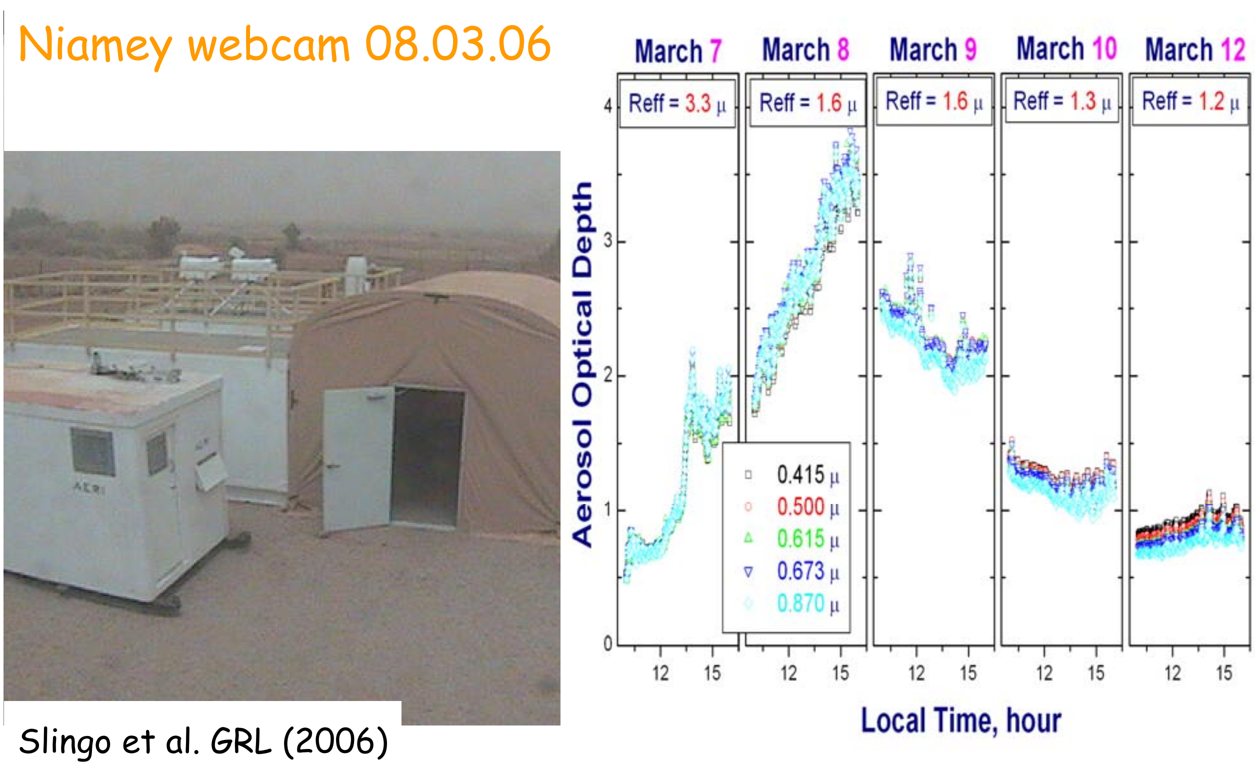

Figure 4-7: The Aerosol optical depth with time. The desert storm leads to an steep increase in the aerosol optical thickness. (Photograph by A. Slingo, ESSC).

4.4.2 Validation over ocean

The research vessel METEOR serves basic German open sea research worldwide, in collaboration with other countries active in this area. Their investigations span interdisciplinary research topics that scientists from universities and federal and state research institutions jointly conduct. These topics include maritime meteorology and aerology, physical oceanography, applied physics, marine chemistry, marine botany, zoology, bacteriology, mycology, marine geology, sedimentology and marine geophysics. The DWD operates a meteorological station on board of METEOR, ensuring well maintained measurement series. The global irradiance data measured by this station has been used for a initial validation of SIS over ocean. Due to the changing location of the ship, diagrammed in figure 4-7 the validation is a bit more complicated relative to comparison with data from “fixed” ground based stations .The validation results are very encouraging, in particular is the bias of daily means below 5 W/m², as illustrated in figure 4-8. Unfortunately, due to a satellite failure it was not possible to retrieve CM-SAF products from end of September to mid of October, leading to a gap in the validation for this period.

It is planned to proceed with the validation activities for ocean areas.

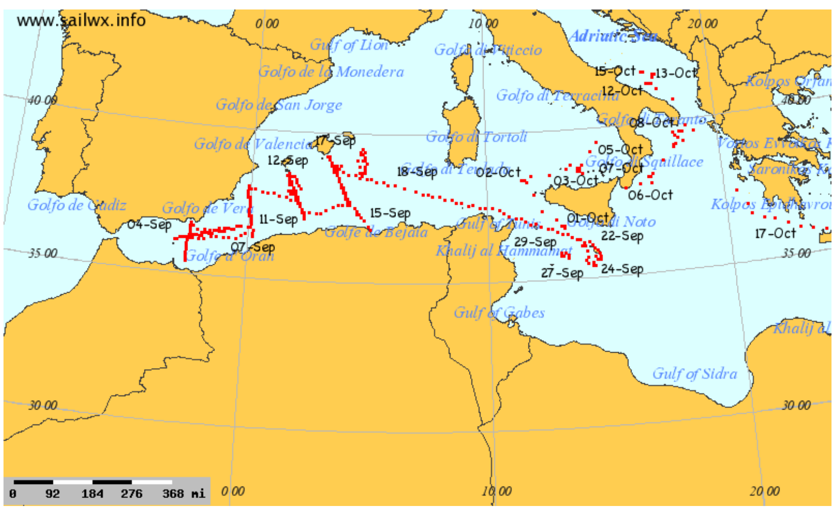

Figure 4-8: The cruise of the METEOR

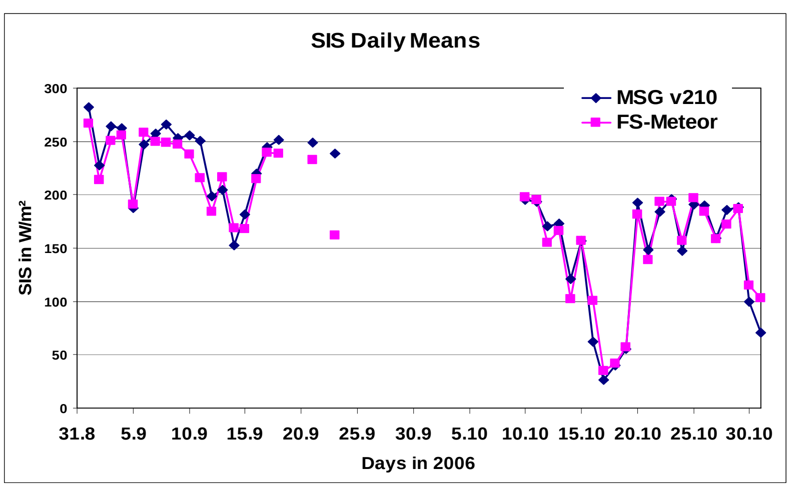

Figure 4-9: Validation results. Mean of METEOR is 182.1 W/m² and of SM-SAF 186.6

Figure 4-10 shows an example of SIS for the full disk area. This data set has been produced by the CM-SAF pre-operational processing chain. In the South a horizontal strip of comparable high SIS values is visible. Due to the damaged GERB detector elements no top of atmosphere flux is available for the region covered by the erroneous detector elements. In the early days of the pre-processing the data has been processed due to a mismatch of provided and expected no data value. This bug has been fixed (Analogous problems has occurred and have been fixed for the masked sun glint and twilight regions).

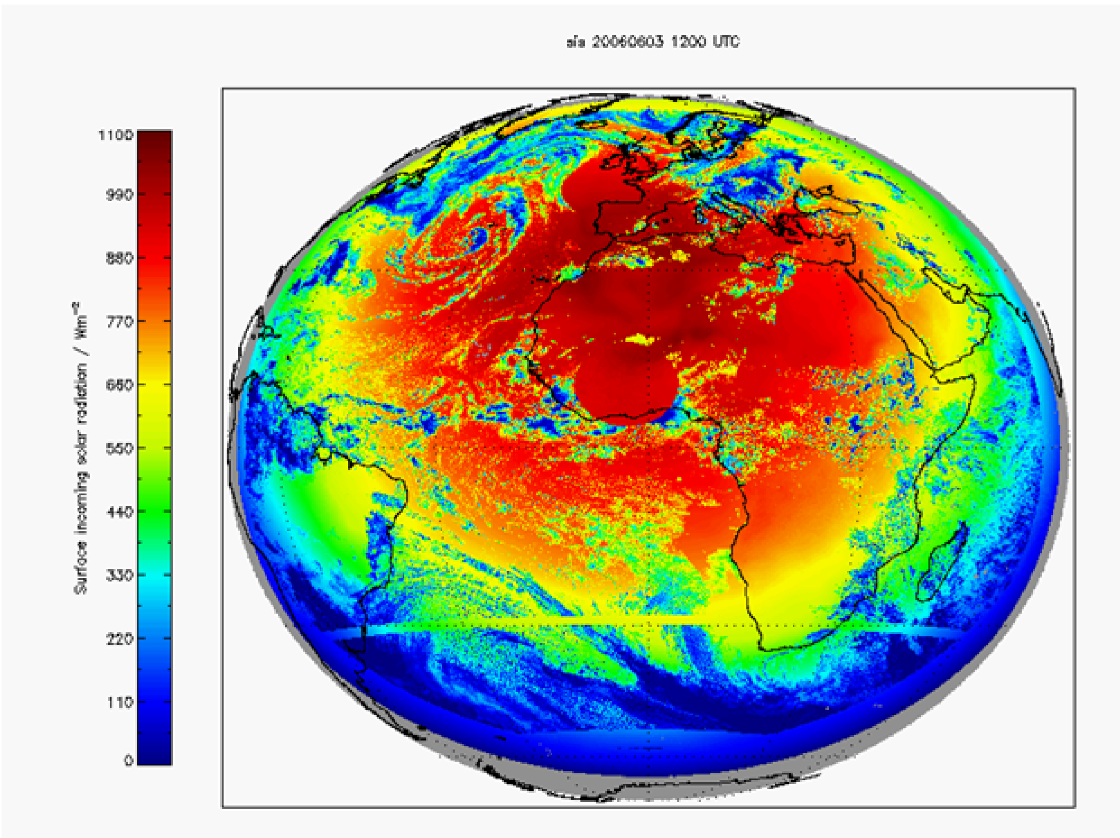

Figure 4-10: Instantaneous Surface incoming shortwave radiation in W/m² for 3rd June 2006, 12 UTC.

Effect of surface albedo on SIS:

Since the relation between the solar irradiance and the 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 validation results provided in this report (figure 4-11) 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, (Figure 4-11). This needs to be evaluated further on once more MSG validation results are available.

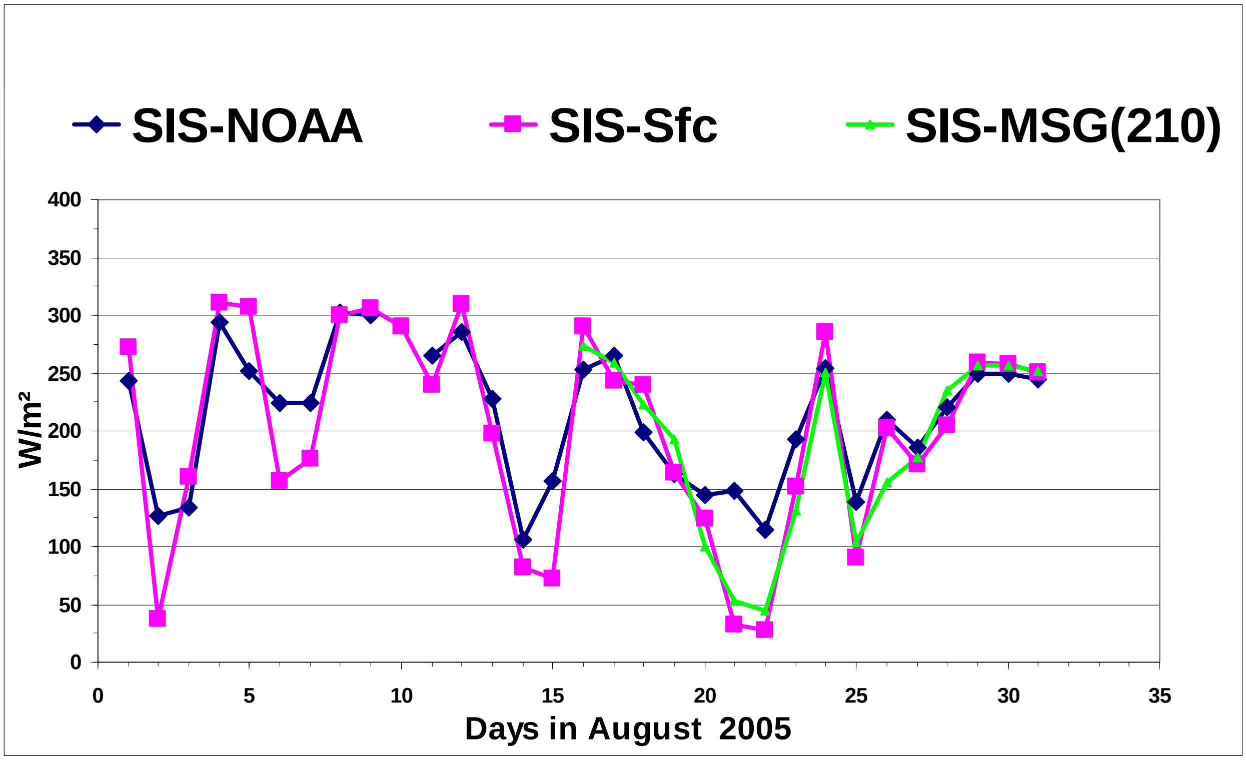

Figure 4-11: Illustration of the effect of higher resolution in space-time. Comparison between in-situ solar irradiance data measured at the Lindenberg station (green line) and satellite retrieved solar irradinace (NOAA based :blue, MSG based violet). The agreement of NOAA and MSG based daily mean irradiance data with the ground based data is in general satisfying. However, in the period from day 20 to day 23 the MSG based irradiance data matches the in-situ measurements much better than the NOAA based. For days with specific weather patterns 3-5 overpasses are not enough to map the changes in weather conditions, leading to an increased error in the daily means. MSG with it´s higher resolution in space-time is able to scan the weather patterns better.

4.5 Broadband Surface Albedo - SAL

Due to the observed differences of several percent between MSG and NOAA based SAL albedo, reported in detail the last validation report (SAF_CM_FMI_SR_SFCSAL_1.1), large amount of work has been invested to investigate the reason for the differences. LSA-SAF as well as MODIS derived surface broadband albedo has been compared with CM-SAF albedo product retrieved from MSG. In addition spectral albedo and TOA reflectance have been compared. The results of these studies can be summarised as follows:

- CM-SAF AVHRR based albedo resembles Land-SAF and MODIS albedo products.
- The CM-SAF MSG TOA reflectance and spectral albedo are very close to those of Land-SAF. Small differences are caused mainly by different spatial resolution and different processing algorithms (e.g. different averaging method before retrieval is performed). Hence, the differences is most probably not due to the applied angular distribution model.

- The observed difference of the CM-SAF MSG based albedo and the MODIS and LSA-SAF albedo is probably due to the broad band conversion method used. CM-SAF as well as LSA-SAF uses the broadband conversion by van Leeuwen and Roujean, but while the CM-SAF conversion is based on VIS0.6 and VIS0.8 channels, the LSA-SAF conversion is based on the VIS0.6, VIS0.8 and in addition on the NIR1.6 channel. This leads to significant differences in the retrieved surface albedo, e.g. the differences for February the 20th are in the range -4% to +8% in absolute units. Figure 4-12 and 4-13 show the differences if the van Leeuwen and Roujean broadband conversion method is applied to two and three channels, using identical spectral albedos from the LSA-SAF. While the differences are comparable low in Europe (blue color) significant differences in Africa up to +8% occur (red colour).
- In contrast to the MSG VIS0.8 channel the NOAA VIS0.8 channel covers more information in the NIR, hence the reason for the difference in the NOAA and MSG based SAL product could be due to the different information content in the NIR contained in the two VIS channels using NOAA two channel approach and MSG two channel approach.
- Yet, comparison with the SARB/CERES data indicates that the MSG based SAL values over desert are to high. Hence, the 3 channel approach would increase the differences between MSG based SAL and SARB/CERES SAL.
- So far no technical or implementation error in the processing has been found, that would explain the differences in the NOAA and MSG based SAL

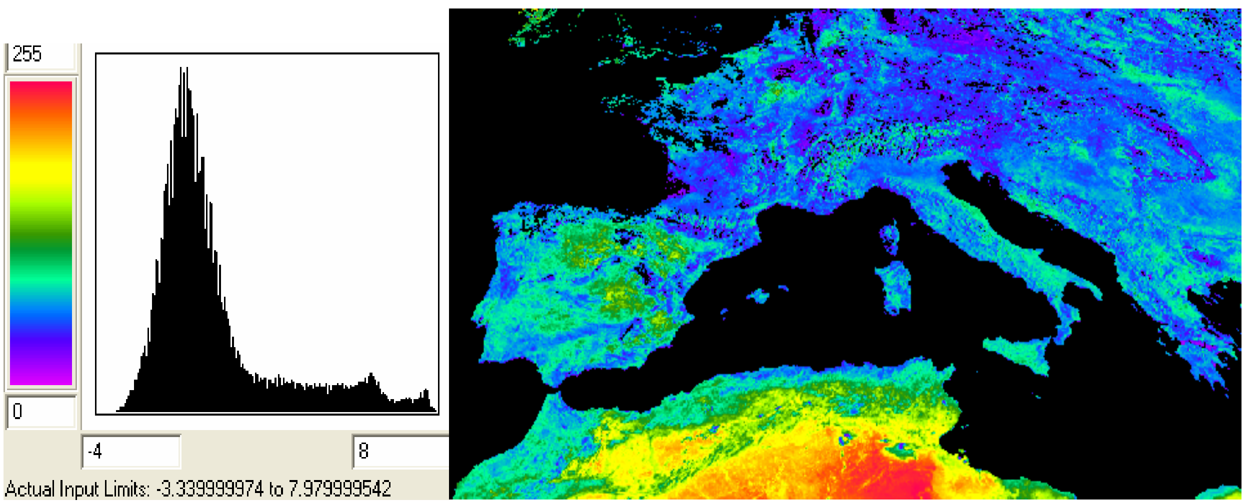

Figure 4-12: *Difference in the surface Albedo due to the additional use of the NIR 1.6 channel for the narrow to broadband conversion. 3 channel (VIS0.6, VIS0.8, NIR1.6) based albedo – 2 channel based albedo calculated using Land-SAF spectral albedo values. Image from Feb. 20th, 2006. The differences ranges from -4 % (violet/blue colour) to 8 % (red colour) in absolute units.*

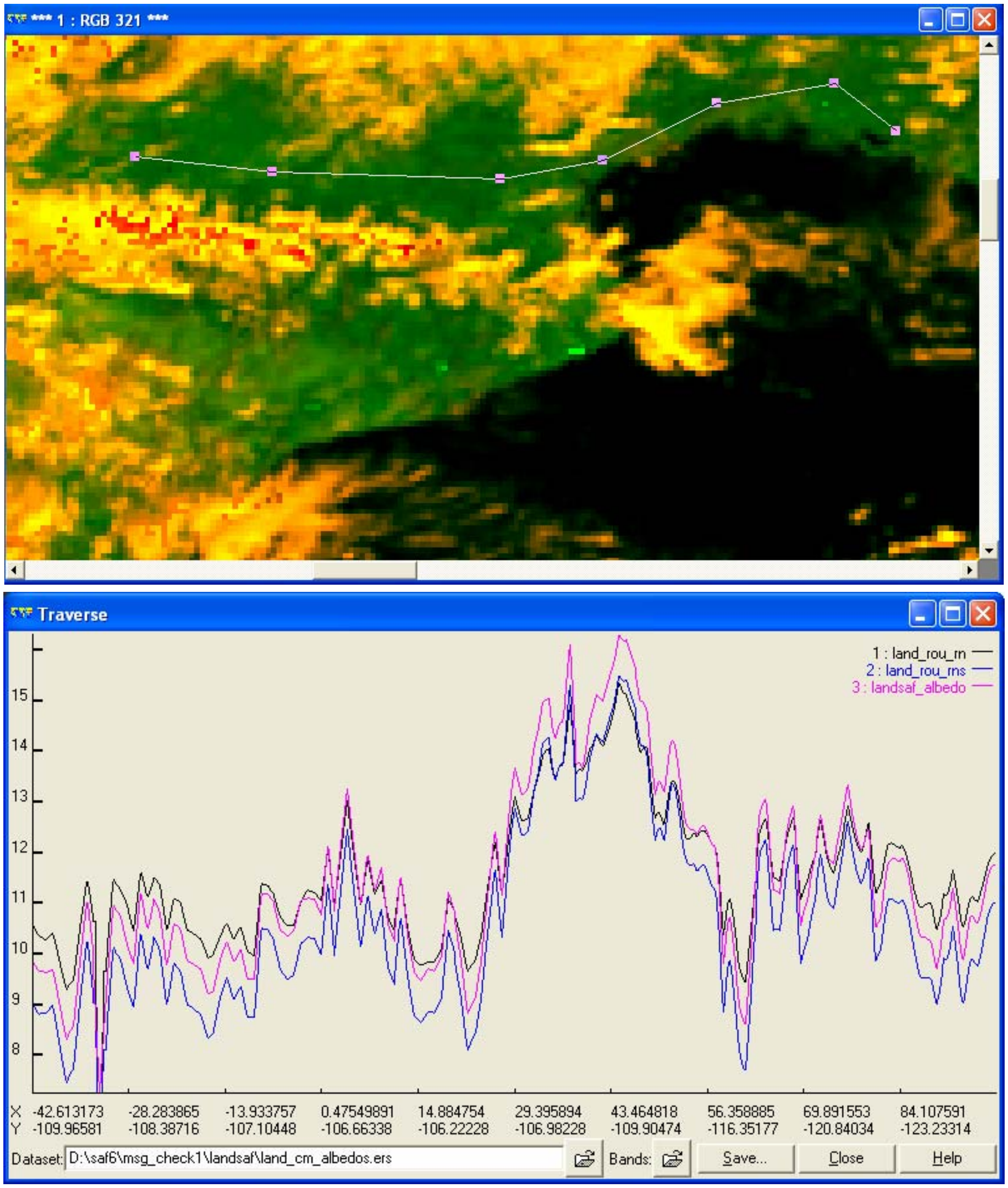

Figure 4-13: *Top: Traverse plot from Southern France, 20th Feb. 2006. Bottom: Broadband albedo of the 3 (blue line) and 2 channel conversion (black line) is used for the traverse. Official LandSAF albedo (red line) is between these values. The surface albedo value is in %, e.g. 10 % SAL means that 10 % of the incoming solar irradiance is reflected by the surface.*

Comparison with surface measurements in arid regions

The African BSRN stations, used for the validation of SIS and SDL, do not measure the shortwave reflected radiation. Hence a comparison with in-situ data was not possible for the African BSRN sites. In order to get some impression about the accuracy in arid regions a comparison with in-situ data from the plataforma de Almeria has been performed. The result of this comparison is shown in Table 4-4. Figure 4-14 shows the diurnal dependence of the bias.

			[W/ m^2]	[W/ m^2]		[% abs]	[% rel]	[abs]	[%]
LOCATION	YEAR	MONTH	MA	MA_SAT	COR	BIAS	BIAS	RMS	RMS
Almeria	2006	06	12.3	15.2	0.42	2.9	23 .9	3.3	26.7
Almeria	2006	07	13.2	15.5	0.54	2.3	17.0	2.5	19.0
Almeria	2006	08	13.4	15.9	0.53	2.5	18.6	2.7	20.0
Almeria	2006	09	13.2	16.3	0.42	3.1	25.6	3.3	25.1

Mean absolute BIAS over four month: 2.6 absolute and 20.45 % relative.

Table 4-4: Comparison of instantaneous satellite derived and hourly in situ surface albedo values.

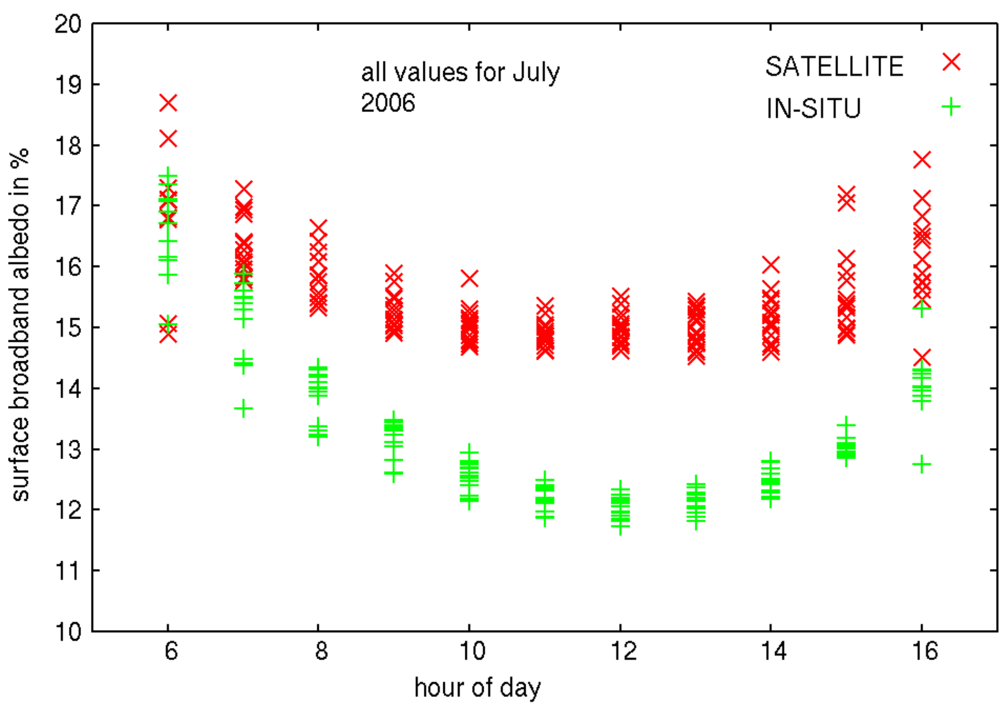

Figure 4-14: The broadband surface albedo plotted against the hour of day for all values in July 2006. The bias between the data increases towards the local noon, hence towards lower SZA. The result for June shows similar behaviour of the bias in terms of diurnal variation.

Comparison with SARB-CERES broadband surface albedo

As a consequence of the missing SAL measurements in the desert region a comparison with SARB-CERES satellite based surface albdedo has been performed. For the interpretation of the comparison results it has to be considered that SARB-CERES like other satellite based albedo products can not be seen as an absolute validation reference. Only well maintained ground based measurements can act as absolute reference, if the land cover at the measurement site is representative for the respective satellite pixel. Hence the comparison provides information if the CM-SAF SAL is in line with the SARB-CERES satellite based product over the desert, especially with respect to the spatial patterns. Figure 4-15 provides the SAL values over North-Africa, focussing on the desert region. The spatial patterns matches well, however CM-SAF shows significant higher values. In Figure 4-16 the difference between CM-SAF SAL and SARB-CERES surface albedo is plotted, providing quantitative numbers of the difference.

Because of missing in-situ data the results provides no quantitative information about the accuracy of the CM-SAF data itself, but, in line with the findings already presented in the previous sub-section, it demonstrate the inconsistency with other satellite based SAL data. This in turn forces the need for further investigations and validation activities for the MSG based SAL product especially in Afrika, including a comparison between the 2 channel and 3 channel approach for the retrieval of MSG based SAL.

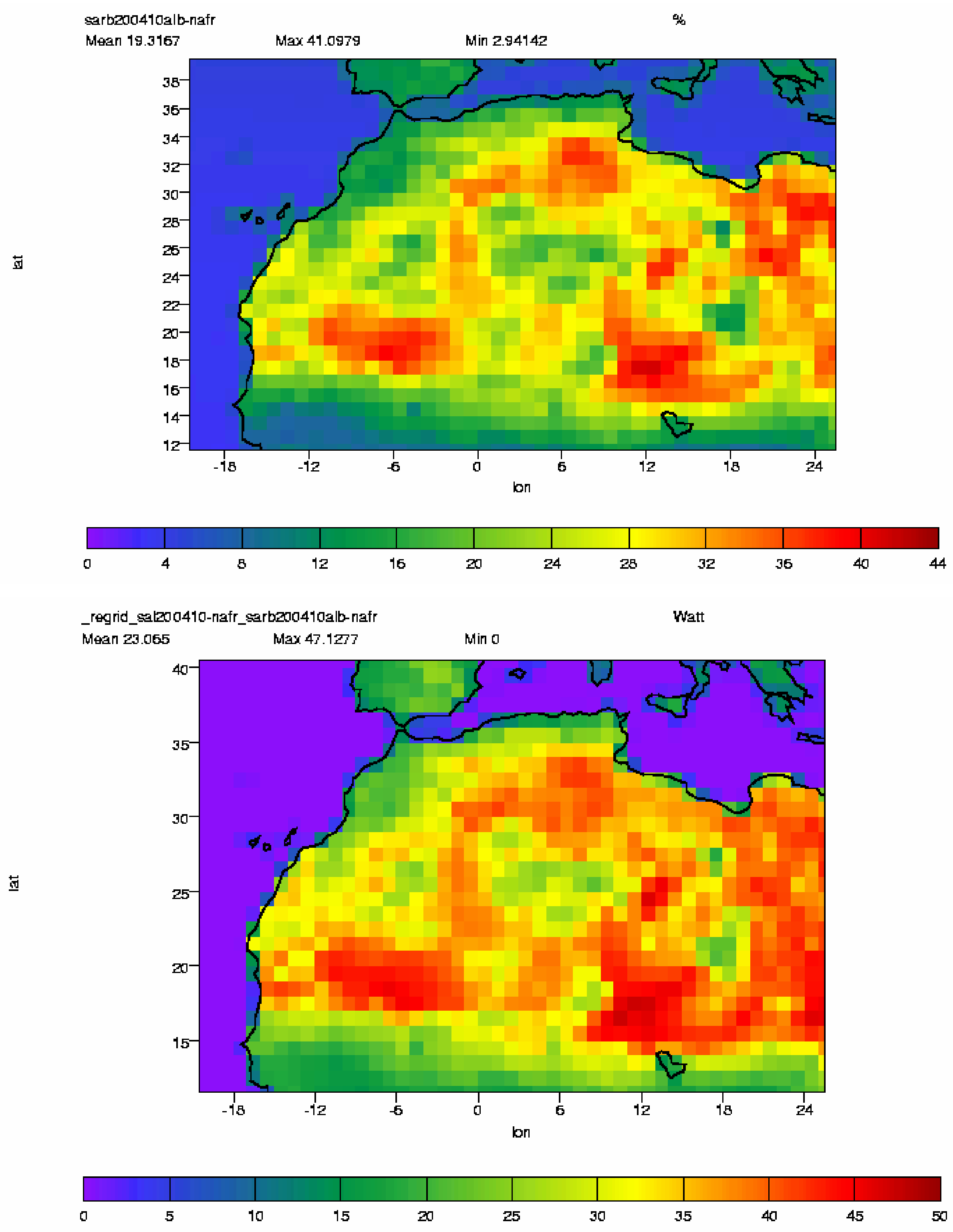

Figure 4-15: Monthly mean of broadband surface broadband normalised to 60 degree solar zenith angle. Top: the SARB/CERES SAL values. Bottom: CM-SAF values for October 2004 on the SARB/CERES grid.

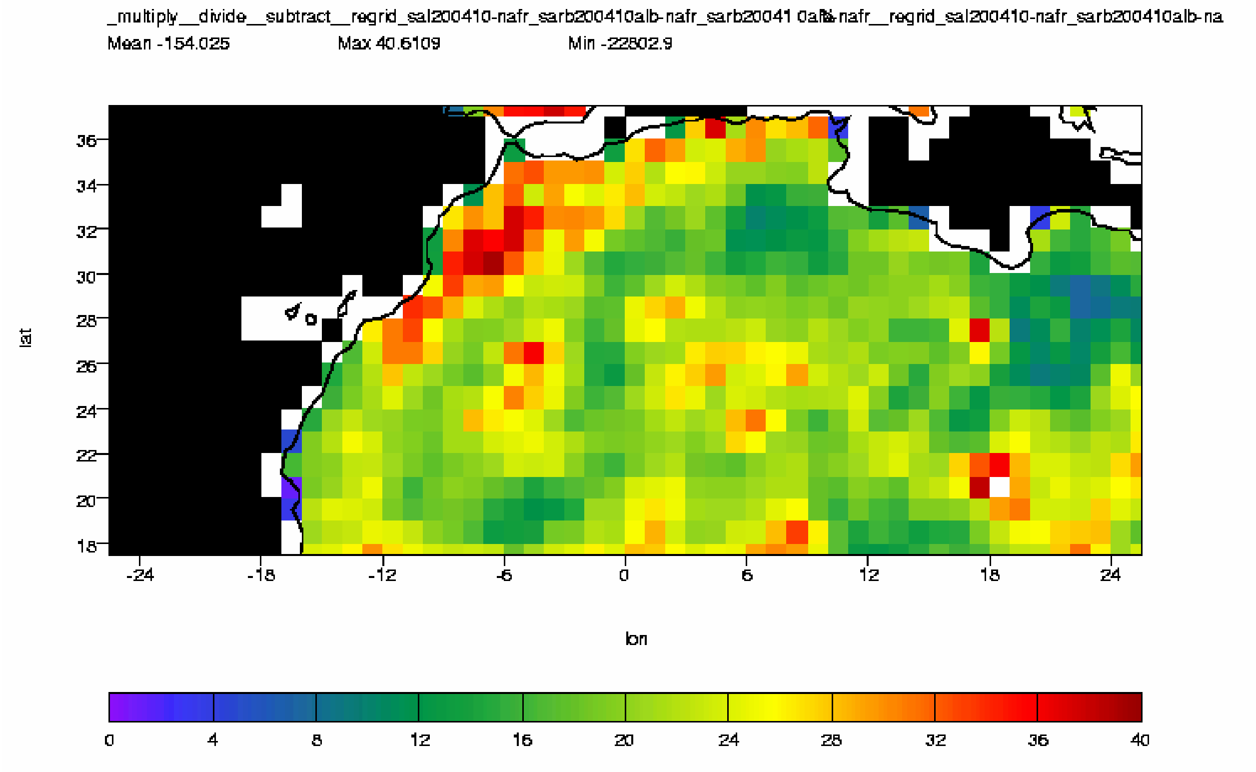

Figure 4-16: Relative Differences in SAL between SARB/CERES and CM-SAF. The CM-SAF monthly means are for the whole region higher as the SARB/CERES monthly means.

SAL Conclusion:

- The bias for Almeria is below the target accuracy (25 % relative accuracy for weekly and monthly mean). However a significant dependency of the bias with the solar zenith angle has been found. This SZA dependency of the bias might be reduced by the switch to the 3 channel approach.
- CM-SAF Albedo is significant higher as the SARB-CERES broadband albedo over the desert region in Africa. However comparison with in-situ data would be necessary to quantify the accuracy of both data sets over the desert, no explicit validation of SARB-CERES over desert is known. The use of the 3 channel approach probably increases the differences over desert, but this has to be investigated in more detail.
- In order to improve the CM-SAF MSG based albedo quality it might be necessary to start using also the IR1.6 channel for the broad band conversion. However, since LSA-SAF and MODIS SAL products are not validated sufficiently against in-situ data in Africa, validation of the MSG based SAL product (both 3 channel and 2 channel approach) with in-situ data is a prerequisite in order to guarantee that higher SAL values in Africa, which would be the consequence of the 3 channel approach, matches the reality. As long as validation with in-situ data is not completed in Africa the MSG based V3 SAL product should be seen and labelled as pre-operational.
- Also problems in the calibration of the satellite date might affect the accuracy of the CM-SAF SAL products. This has to be investigated in more details, especially if the 3 channel approach fails to increase the accuracy.

5 CONCLUSION AND SUMMARY

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

- **SOL and SDL**: The validation results for SOL and SDL provides so far no evidence that the derived products are significantly away from the target accuracy in the extended area. However, a final conclusion is not possible due to the limited amount of comparison results in combination with the uncertainty of the in-situ data. It has to be further investigated if a target accuracy of 10 W/m^2 can be achieved in Africa. **Therefore the SOL and SDL products should be labelled pre-operational in the extended area.** Further validations will also address the question if a cold bias in Africa exists.
- **SIS:** For SIS the result indicates that the V3 products are within the target accuracy in the extended area. However for some regions and periods dust storm events, as demonstrated, and likely also biomass burning events introduces a significant higher error in SIS. In 90% of the cases it can be expected that the target accuracy is fulfilled, thus SIS can be labelled operational.
- **SAL**: The current V3 SAL is within the target accuracy (25 % in relative units) for the "plataforma Almeria" located in an arid region in South of Spain. Comparison with in-situ data in Africa was not possible, because of the lack of in-situ measurement data. For that reason SAL has also been compared with other satellite derived products. The V3 SAL shows significant differences compared to LSA-SAF, MODIS and SARB-CERES Albedo in Africa. Unfortunately, LSA-SAF as well as MODIS and SARB-CERES broadband albedo values are currently not well validated over desert regions and in general for the African continent. Therefore a further comparison with in-situ data is needed before conclusions on the accuracy of the V3 SAL product can be drawn. **As long as no validation with in-situ data can be performed in Africa, especially in desert regions (e.g. due to the problems of getting accurate in-situ data) the MSG based V3 SAL product should be labelled as pre-operational**. The effects of the 3 channel approach (using in addition the NIR16 channel) on the validation and comparison results have to be investigated in more detail.

The target accuracy is defined as described in section 4.1 in order to provide the user an easy to understand and transparent definition of the accuracy. As stated their, the definition of target accuracy and its values will be improved within the CDOP. Of course, the definition of the target accuracy will be reviewed regularly taking into account emerging user demands.

6 ACKNOWLEDGMENTS

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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