SURFACE ALBEDO CDR FROM GEOSTATIONARY SATELLITES: VALIDATION AND FURTHER PROSPECTS

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Abstract

This study presents the results of an evaluation study for EUMETSAT's Meteosat Surface Albedo (MSA) Climate Data Record (CDR) that has been performed by independent researchers in Europe and the US. This CDR has been generated within the Sustained and Coordinated Processing of Environmental Satellite Data for Climate Monitoring (SCOPE-CM) activity. EUMETSAT has generated the MSA CDR that comprises up to 29 years (1982-2011) of continuous surface albedo coverage for large areas of the Earth. The MSA CDR has been evaluated in terms of its internal consistency, its compatibility to other satellite-derived surface albedo products, its validity against in-situ observations assumed to be of superior quality, and its temporal homogeneity. The evaluation of the MSA data record has revealed a number of specific strengths and weaknesses that are outlined in this paper. The study shows that the MSA data record agrees well with corresponding values from satellite-derived and ground-based observing systems under many observation conditions. The long-term consistency is very high and meets the GCOS stability requirements for desert reference sites. Some issues of the MSA CDR quality concerning cloud detection and aerosol related effects are also reported. While the strengths underline the already high value of the MSA CDR for climate applications, the weaknesses need to be considered and will be addressed in the context of a future re-processing. The recommendations devised by the independent validation experts strongly support the improvement of the MSA CDR quality and its utility.

INTRODUCTION

The Global Climate Observing System (GCOS) formulated scientific requirements for climate observations including a list of relevant parameters, the so-called Essential Climate Variables (ECVs), with associated observation requirements. One of the defined ECVs is the land surface albedo, a parameter defined as the ratio of the radiation flux reflected from the surface into the atmosphere to the incident radiation flux which depends on both the anisotropy of the surface and the atmosphere. Land surface albedo is a key forcing parameter for the climate system controlling the radiative energy budget. Thus, its monitoring is of primary importance for an understanding of the climate system. Its value changes in space and time, depending on both natural processes (vegetation growth, rain and snowfall and snow melting, wildfires, etc.) and human activities (forestation and deforestation, harvesting crops, anthropogenic fires, etc.). Ground-based measurements are of great importance for the assessment and evaluation of local and regional variability and change, while satellite remote sensing offers a unique opportunity for documenting and monitoring the spatial surface albedo distribution, its variability and change at continental scales. Observations acquired by geostationary satellites have the advantages of offering both a long-term dataset and an angular sampling of the surface as well as providing diurnal sampling of key parameters influencing the retrieval such as cloud cover and aerosol load.

RETRIEVAL OF SURFACE ALBEDO FROM GEOSTATIONARY SATELLITES

Geostationary satellites are very powerful devices for the measurement of surface albedo due to their ability to sense several times per day the same portion of the Earth's surface. On the other hand, the retrieval area is limited to a circle with a radius of ca. 65 degrees around the sub satellite point (SSP).

The MSA algorithm performs the inversion of a fast Radiative Transfer Model (RTM) ingesting reanalysis total column water vapour and total column ozone data. MSA is based on a method proposed by Pinty et al. (2000). This method relies on daily accumulation of clear sky radiances acquired in a single visible band and on the applicability of the reciprocity principle (Lattanzio et al., 2006). According to this principle the Bidirectional Reflectance Distribution Function (BRDF) does not change when incident and reflected angles are reversed. The method applied in the MSA algorithm allows for a joint retrieval of aerosol load and surface albedo. An assessment of the measurement error and an estimation of the retrieval uncertainty are performed for each pixel (Govaerts and Lattanzio, 2007). The surface albedo is retrieved as Bi-directional Hemispherical Reflectance isotropic (BHRiso or white sky albedo) and Directional Hemispherical Reflectance (DHR or black sky albedo). Those parameters can be used to estimate the real albedo (blue sky albedo) as explained in Pinty et al. (2005).

At EUMETSAT the MSA CDR has been generated from measurements of the Meteosat Visible and InfraRed Imager (MVIRI) instrument operated onboard of the Meteosat First Generation (MFG) satellites. The spatial-temporal range of the data record shown in Figure 1 covers:

1982-2006, prime 0° Sub Satellite Point (SSP) coverage (6 satellites);
1998-2011 Indian Ocean Data Coverage (IODC) at 57°E and 63°E SSPs (2 satellites);
1991-1995, (Extended) Atlantic Data Coverage at 50°W and 75°W SSPs;

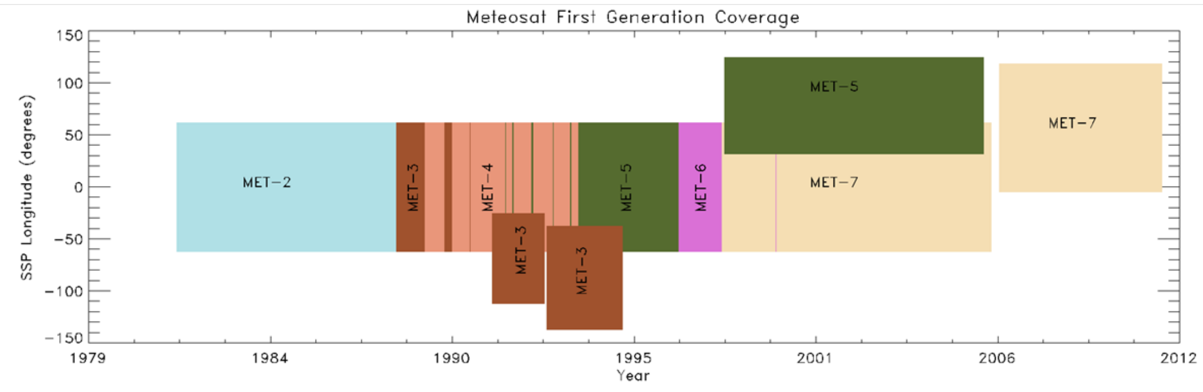

Figure 1 Spatial and temporal coverage of the MSA data record.

The product can be requested from the EUMETSAT Data Centre (https://eoportal.eumetsat.int) free of charge after registration. It can be delivered in BUFR and HDF4 formats. A complete new user documentation consisting of an Algorithm Theoretical Base Document, Product User Guide and Validation Report has been compiled and will be made available for users on the EUMETSAT web page.

VALIDATION WITHIN THE ALBEDOVAL STUDY

Recently, EUMETSAT coordinated a study for the validation of the surface albedo dataset. The study was performed by a group of independent researchers in Europe and the USA. A project report was delivered (Fell et al., 2012) and can be requested by interested users.The following sections summarise results of the validation analysis that focused on four main aspects: (1) uncertainty assessment, (2) temporal consistency, (3) validation against in-situ measurements and (4) comparison with other satellite estimates.

1 UNCERTAINTY ASSESSMENT

The uncertainty assessment concentrated on the impact of undetected clouds and aerosol retrieval. The impact of non detected clouds was assessed comparing the MVIRI based MSA products against the Spinning Enhanced Visible and Infrared Imager (SEVIRI) based surface albedo product from the

Land Surface Analysis Satellite Applications Facility (LSA SAF) in Lisbon, Portugal (Météo-France, 2012). In the current MSA implementation no external cloud mask is applied. During the first processing step, a simple procedure is applied to detect and remove cloud covered pixels. This procedure analyses statistically the daily variation of reflectance in order to detect values deviating from the expected value for clear sky. Figure 2 shows the comparison between surface albedo from the MVIRI based MSA product and the SEVIRI based (the radiometer operated onboard Meteosat Second Generation) LSA-SAF product. The red circles in Figure 2 indicate where the issue of erroneous cloud detection affects the MSA product. The results reveal that the cloud detection procedure seems not adequate for situations with almost stationary cloud cover during the day. The remaining cloud contamination is the factor which at most is hampering the retrieval quality. This is particularity true over rainforest where the cloud coverage is expected to be more frequent and stationary. Work for mitigating this issue is foreseen for the next phase of development that will include the explicit use of cloud cover information and analysis of seasonal variations of cloud cover.

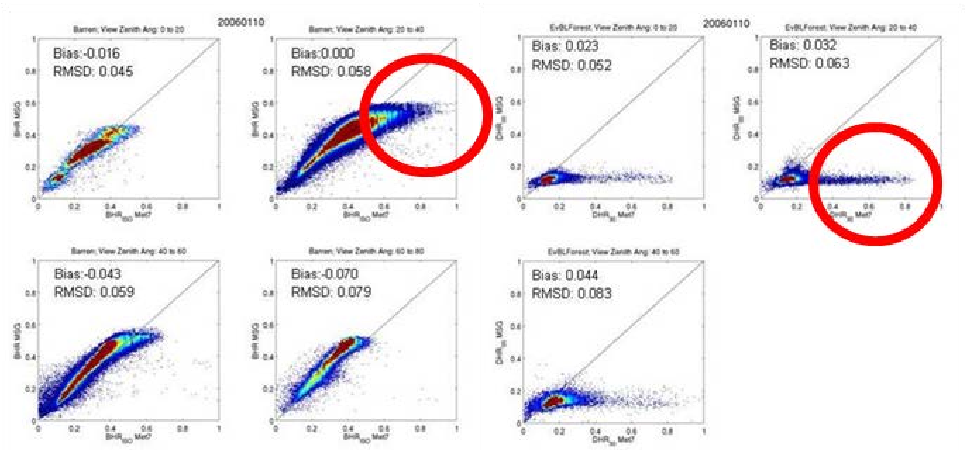

Figure 2: MSA albedo on the x-axis and SEVIRI albedo on the y-axis. Retrieval for barren soil (left) and forest (right). The red circles highlight the cloud contamination issue for the MSA. The issue is particular severe over forest.

The MSA retrieval assumes only one aerosol type that is continental aerosol and that the Aerosol Optical Thickness (AOT) varies between a minimum value of 0.1 and a maximum value of 1.0. If the real type and AOT value arel outside this range an error on the AOT (underestimation or overestimation) and consequently on the surface albedo is introduced (overestimation or underestimation). The effect is evident when comparing AOT retrieved with the MSA algorithm with the measurement from AERONET (Holben et al., 1998) stations (see Figure 3).

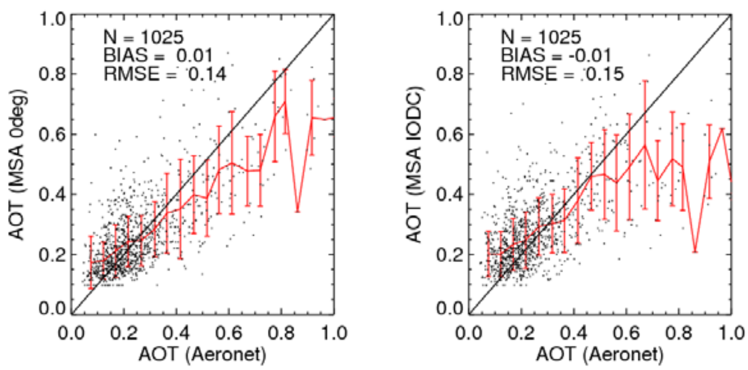

Figure 3: Comparison between MSA and Aeronet measured AOT. 0Degree mission (left) and IODC mission (right).The red bars represent the scatter value binning the data in 0.05 AOT steps. The red line is the best fit of the red bars.

2 TEMPORAL CONSISTENCY

In order to detect temporal trends of a geophysical variable one fundamental characteristic is the confidence level on the temporal stability of the data record. One way to assess this aspect is to select a set of stable targets, e.g., desert targets and analyse the BHRiso and DHR retrievals over a long time period. One typical case is shown in Figure 4. The visible bands of the MVIRI instrument on-board of the Meteosat First Generation (MFG) are slightly different between the different satellites, and a spectral conversion is necessary to compare them. In this case the method proposed by Loew and Govaerts (2010) has been applied.

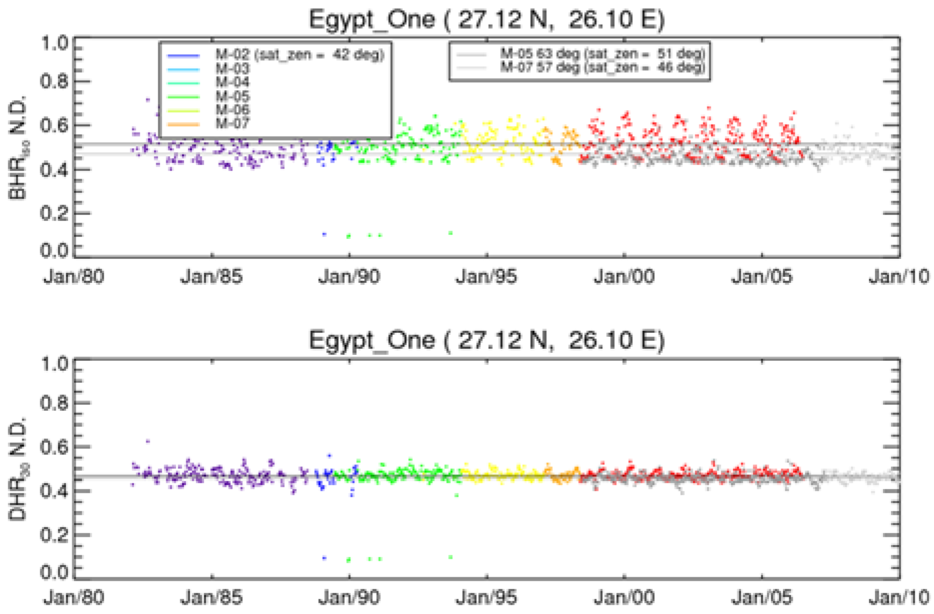

Figure 4: Time series for a pixel in Egypt. BHRiso(upper), DHR (bototm) are shown. The series enclosed all MFG for both the 0degree and IODC missions.

The following Table 1 shows the change per decade of some desert targets.

Name	0DEG		IODC	
	BHR [1/decade]	DHR [1/decade]	BHR [1/decade]	DHR [1/decade]
Murzuq desert	-0.0084	**-0.0325**	0.0102	0.0099
Libya Desert	0.0037	-0.0085	-0.0011	-0.0011
Egypt one	0.0083	0.0071	-0.0006	-0.0006
Omani desert	**0.0170**	**0.0133**	**0.0437**	**0.0421**

Table 1: regression slopes value variation/decade. In vold the values exceeding 0.01

It can be seen that the temporal consistency is good for the DHR and meets, in most of the cases, the GCOS stability requirements (Maximum 1%) for desert reference sites. Some BHRiso seasonal variations can be seen and are still under unvestigation.

3 VALIDATION AGAINST IN-SITU MEASUREMENTS

For the comparison with in-situ data the measurements from the SAFARI campaign (Privette et al., 2005) has been chosen. The years 2000, 2001 and 2002 for both MSA products derived from the 0° and IODC missions have been analysed for the a site located in Mongu (Zambia). The albedo measured by the in-situ instrument is expected to be between the BHRiso and DHR values retrieved from MVIRI. This expected behaviour is confirmed by the comparison as shown Figure 5. The decrease in accuracy and precision of the retrieval in winter, during the rainy season, can be expected and is due to the above mentioned issue of undetected clouds in the data record.

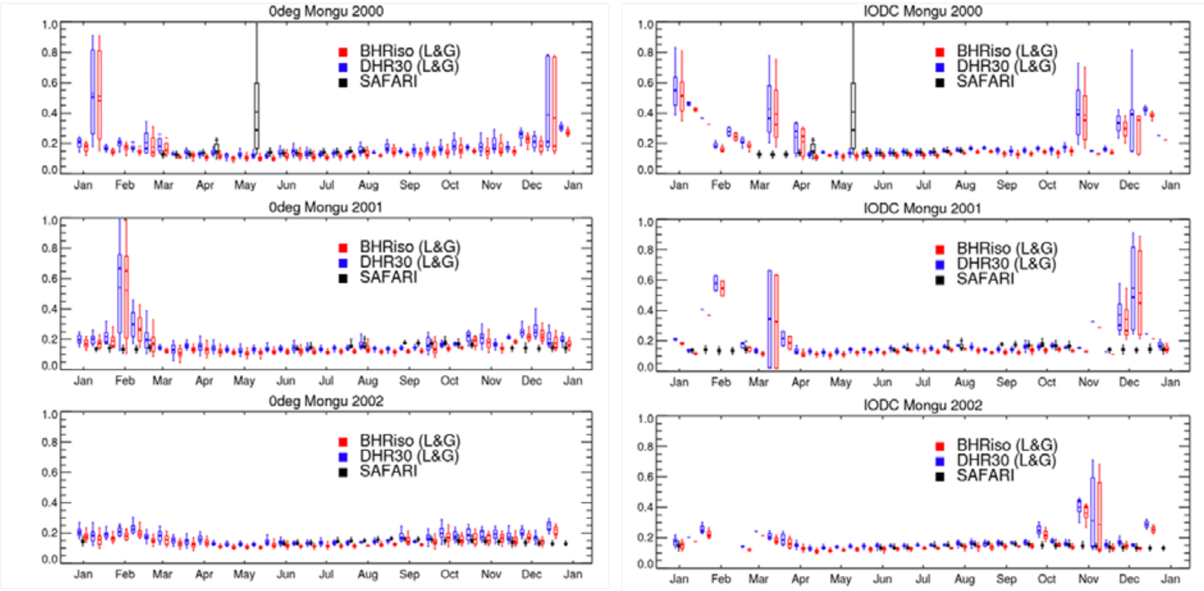

Figure 5: Comparison between MSA and in-situ measurements from the SAFARI campaign. The box-and-whisker diagrams represent the spatial variability (3x3) of the MSA observations (Loew and Govaerts, 2010 spectral conversion coefficients applied) within a 3x3 window centred at Mongu (Zambia). For the in situ observations (black), the diagrams represent the temporal variability within a ten-day observation periodThe impact of cloud contamination can be clearly seen during the rain season.

4 INTER-COMPARISON WITH OTHER SATELLITES

The blue sky albedo measured by different sensors using different retrieval schemes have been inter-compared and compared against in-situ measurements obtained from FLUXNET towers (Cescatti et al., 2012). Figure 6 shows that there is high agreement among all satellite estimates and with the FLUXNET measurement during the summer season. Large deviations exist during the winter season due to snow cover and different handling of it in the retrieval schemes. Also apparent during spring all satellite estimates deviate from the FLUXNET measurements pointing to issues with the representativeness of the tower measurement for a satellite pixel and/or to surface conditions, e.g., with melting snow, intrinsically difficult for the albedo retrieval schemes.

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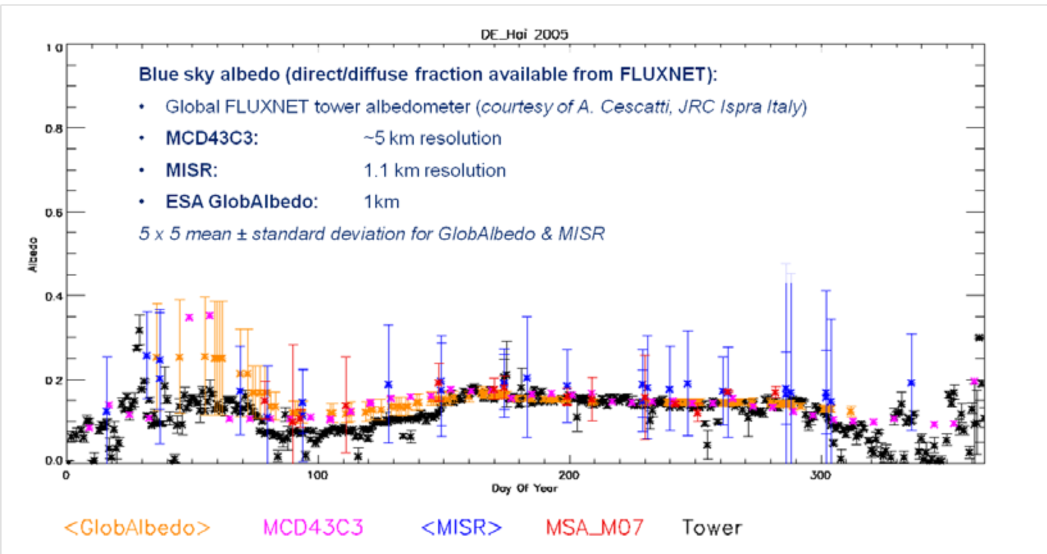

Figure 6: Typical case of comparison between MSA other products derived by different instruments and the FLUXNET ground measurements. It is shown the site Hainich (Germany) for year 2005.

FUTURE PERSPECTIVE: SCOPE-CM

A successful generation of a surface albedo product from all historic geostationary satellites requires a joint long-term international commitment from research and governmental institutions. The Global Climate Observing System (GCOS) formulated scientific requirements for the needed global observations and products including a list of relevant parameters, the so called Essential Climate Variables (ECVs). The Sustained and Coordinated Processing of Environmental Satellite Data for Climate Monitoring (SCOPE-CM) activity, is answering to these requirements by establishing an international network of facilities to ensure a continuous and sustained generation of high-quality Climate Data Records (CDR) from satellite data in compliance with the GCOS principles and guidelines. Currently, SCOPE-CM represents a partnership between operational space agencies to coordinate the generation of CDRs. As part of the SCOPE-CM activity on land surface albedo, involving the operational meteorological satellite agencies in Europe (EUMETSAT), in Japan (JMA: Japanese Meteorological Agency) and in the USA (NOAA: National Oceanic and Atmospheric Administration), the MSA CDR contributes to the creation of a global harmonised surface albedo record derived from all satellites in geostationary orbit.
A proof of concept for a geostationary combined albedo product obtained using five different geostationary satellites is shown in Figure 7 and more details about this SCOPE-CM project are described in Lattanzio et al. (2013). The issues highlighted by the presented validation results will be addressed during a new SCOPE-CM project starting in 2014

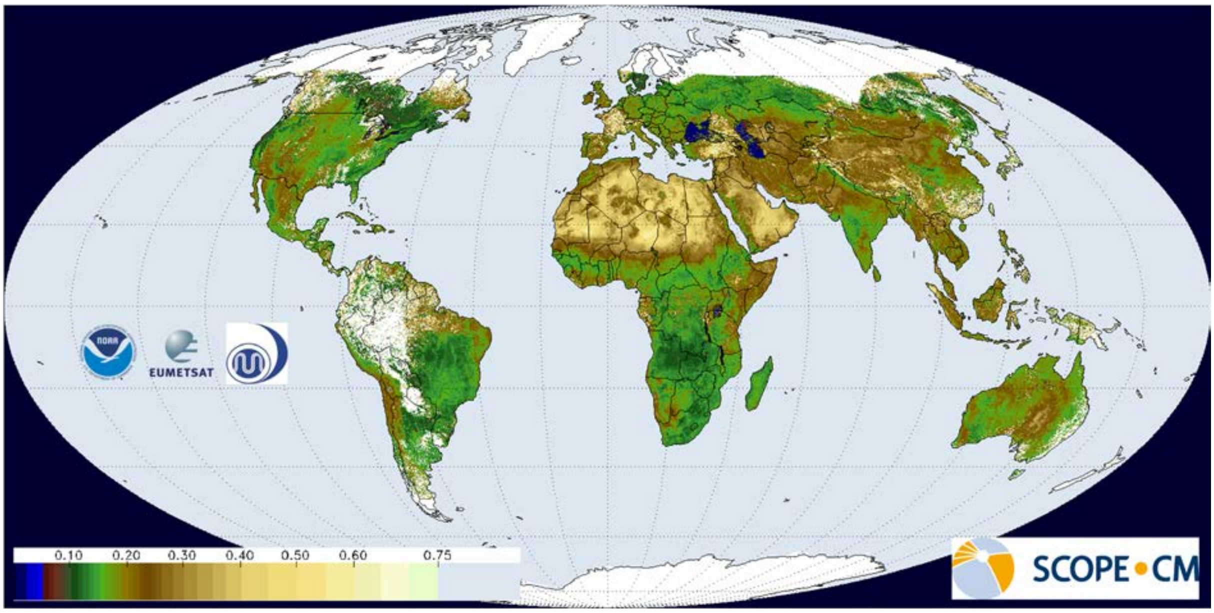

Figure 7: DHR30 (or black sky albedo BB (0.3-3.0 µm). Satellites: GMS-5, MET-5,MET-7,GOES-8, GOES-10

The federated activity performed by the agencies in Europe (EUMETSAT), United States (NOAA) and Japan (JMA) for the generation of a long term surface albedo climate data record (CDR) is described in Lattanzio et al., 2013. The activity on surface albedo retrieval within the SCOPE-CM framework will continue as of 2014. The issues highlighted by the ALBEDOVAL study will be addressed.

CONCLUSIONS

The evaluation of the MSA data record shows that it agrees well with corresponding values derived by other satellite and ground-based observing systems under many observation conditions. It also shows a high temporal stability which meets the GCOS stability requirements for desert reference sites.
Some issues of the MSA CDR quality concerning cloud detection (much larger problem over vegetated areas due to higher cloud occurrence) and aerosol related effects (model using continental aerosol only and a limited set of pre-defined values) are reported. The strengths underline the already

high value of the MSA CDR for climate applications. The weaknesses need to be considered for specific applications and will be addressed in the context of a future re-processing within SCOPE-CM. The recommendations devised by the independent experts strongly support the improvement of the MSA CDR quality and its utility.

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