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Consistency of surface anisotropy characterization with meteosat observations

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Abstract

The purpose of this paper is to present the results of the evaluation of the Meteosat Surface Albedo (MSA) product, including the effects due to instrument changes and associated calibration uncertainties. To this end, observations acquired by two adjacent geostationary spacecrafts, Meteosat-7 and Meteosat-5 have been processed with the MSA algorithm. These satellites are located, respectively, at 0° and 63° East. Data acquired by these two instruments overlap over a large area encompassing most of Africa and the Arabian peninsula. The consistency of the surface anisotropy retrieval is evaluated through a reconstruction of the Meteosat-5 (-7) observations with the Meteosat-7 (-5) surface anisotropy characterization. Some differences slightly higher than the calibration accuracy have been found. This effect has no significant impact on the albedo retrieval which indicates that MSA is a reliable algorithm to produce albedo datasets.

Keywords: Albedo; Reciprocity principle; Surface anisotropy

1. Introduction

Surface albedo retrieval requires an angular sampling of the analyzed area for the characterization of the reflectance fields anisotropy controlled by the coupled surface-atmosphere system (Verstraete and Pinty, 2001) and the sun. Geostationary satellites as the Meteosat series have not been conceived to derive such geophysical quantity but Pinty et al. (2000a) proposed a reliable method for the estimation of the land surface albedo exploiting their high temporal sampling (30 min). Assuming that the Helmholtz reciprocity principle can be applied to Meteosat observations, the Meteosat surface Albedo (MSA) algorithm proposed by these authors relies on a daily accumulation of geostationary observations acquired under constant viewing conditions but different positions of the sun to document the surface anisotropy.

The objective of this paper is to evaluate the assumption of the reciprocity principle to characterize the surface anisotropy from Meteosat observations and its impact on the reliability of the surface albedo retrieval. The approach consists in comparing contemporaneous albedo products generated from two satellites, Meteosat-7 located at a nominal position of 0° and Meteosat-5 located at 63° East, originally in support to the INDOEX experiment (Ramanathan et al., 1995, 1996) since July 1998. These two satellites observe a large common area enclosing almost all the African continent and the arabic peninsula (Fig. 1).

The statement of the problem is given in Section 2 and the adopted method is described in Section 3. The consistency of the surface albedo derived from both radiometers is analyzed in Section 4 and conclusions are drawn in Section 5.

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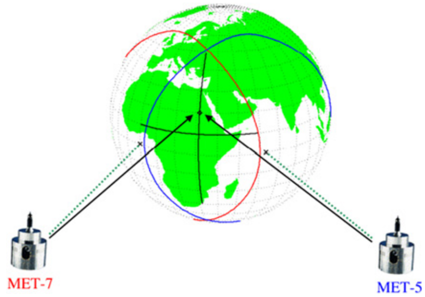

Fig. 1. Satellites geometry. Meteosat-5 (-7) processed area is enclosed by a blue (red) line. The two profiles at longitude 31.5° East, 10° North and the pixel at latitude 20° North and longitude 31.5° East exploited for the evaluation are plotted in black. The green dashed lines indicate the nominal sub satellites points.

2. Statement of the problem

The approach followed in the MSA algorithm relies on the daily accumulation of observations for each pixel acquired under different illumination conditions inverted against a fast Radiative Transfer model (Pinty et al., 2000a) and on the applicability of some assumptions described in detail in Govaerts et al. (2004b). The more relevant among all those assumptions is the validity of the reciprocity principle. For each pixel MSA algorithm derives three parameters accounting for the surface anisotropy and the mean reflectance level plus a forth one, the aerosol optical thickness, characterizing the atmosphere, as described in Pinty et al. (2000a).

The present paper focuses on the evaluation of the characterization of the surface anisotropy as derived if the assumptions are correct. In particular we want to assess the applicability of the key assumption, i.e., the reciprocity principle. This principle has been probably proposed for the first time by Helmholtz in the second half of the XIX century (Helmholtz, 1867). According to this principle the Bidirectional Reflectance Distribution Function (BRDF) is reciprocal, i.e. it is not changing when the incident and reflected angles are reversed (Hapke, 1993). Strictly speaking, this principle is valid in turbid medium such as the atmosphere where the so called ''far-field approximation'' is valid (Snyder, 2002), as it is applicable only when the distance R between the scattering elements is much larger than their size D^2 normalized by the wavelength λ ($R \gg D^2/\lambda$). Such condition does not hold in case of light propagation in the vegetation where the size of the scatter elements, leaves or brunches, is often bigger than their distance. As the size of the observed area increases the contribution of each single scattering element to the reflected radiance of the scene is becoming less critical (Widlowski, 2002). When the field of view reaches several kilometers, as in the case with the Meteosat instruments, it can be anticipated that the reciprocity principle still holds due to the statistical arrangement of the elementary surface scatterers. A method to evaluate the applicability of this principle in the MSA scheme is presented in the next section.

3. Surface anisotropy characterization

The common area observed by Meteosat-5 and -7 offers a unique opportunity to evaluate the impact of the reciprocity principle on the surface anisotropy retrieval. Each pixel belonging to the common area is seen with a different viewing angle from the two spacecrafts. The proposed approach to evaluate the impact of the reciprocity principle consists in comparing contemporaneous MSA products over the common area generated by Meteosat-5 and -7.

A pre-requisite to such comparison is to verify the consistency of the observed top of atmosphere (TOA) reflectances between the two radiometers. A previous study has demonstrated that these radiances agree relatively well within 3% but exhibit some non-linearity in case of low value of radiance (Govaerts et al., 2004a).

3.1. Description of the method

Surface anisotropy retrieval is a critical step in the process of estimating surface albedo from space observations. Red curves on Fig. 2 illustrate typical daily cycles of observed TOA BRF (Bidirectional Reflectance Factor) for a single pixel at latitude 20° North and longitude 31.5° East with Meteosat-5 (-7) on the bottom (top) panel. Both time series are acquired with identical illumination conditions but different viewing angles. If the surface anisotropy, as derived from the inversion of one time series, is correctly characterized, it should be possible to reconstruct the other time series acquired with a different viewing condition. On the top (bottom) panel the red line represents the observation acquired by the sensor on-board Meteosat-5 (-7). The solution derived from the inversion of

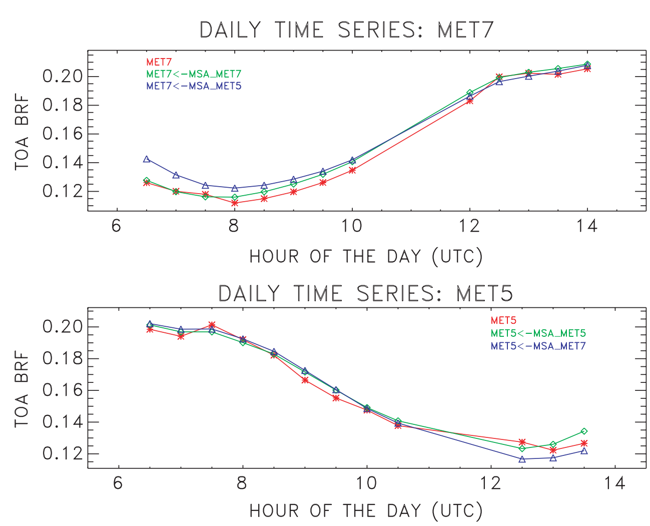

Fig. 2. Bottom (top) panel: Meteosat-5 (-7) TOA daily time series (day 121 of year 1999) is shown for a pixel at longitude 31.5° East and latitude 20° North. The TOA BRF observed by Meteosat-5 (-7) (red line) is compared with the signal reconstructed using the MSA solution derived from Meteosat-5 (-7) (green line) and with the one reconstructed using the MSA solution derived from Meteosat-7 (-5) (blue line) as described in the text.