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SURFACE ALBEDO FROM METEOSAT-4 DATA. ACCURATE ATMOSPHERIC CORRECTION USING GROUND DATA

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ABSTRACT: The diurnal evolution of surface albedo has been obtained from METEOSAT-4 data by applying an atmospheric correction based on *in situ* radiosounding ascents, and tuning up some atmospheric parameters by successively comparing the corresponding 5S radiative transfer code simulated data to ground measured global irradiance until atmospheric aerosol optical depth could be adjusted. This atmospheric correction may be considered accurate so that remote sensing radiances are more reliable to produce surface quantities.

INTRODUCTION

Surface albedo, defined as the fraction of reflected to incident shortwave radiation over a surface, is one of the important parameters of the Earth - Atmosphere System radiation balance. Thus, the difference of this property to unity permits the determination of the amount of solar radiation absorbed by the surface. During daytime the budget is mainly determined by insolation and surface albedo. Since surface albedo is characteristic of each surface, satellite monitoring of its changes is one of the main concerns of contemporary climatology from satellites.

The first step towards surface albedo reliable estimation from satellites is the accurate determination of the intervening atmosphere effects. The occasion of the broad measurement deployment in the EFEDA field campaign in Castilla-La Mancha in June 1991 [1], has put together a wealth of land surface and atmospheric data that may be used as reference for the estimation of remote sensing quantities and process studies. An example of this is the evolution of surface albedo, obtained from standard albedometers placed over different natural land surfaces, that should be reproduced from simultaneous satellite data. The deviations still found in remote sensing quantities should help us to improve some of the intermediate calculation steps (spectral correction from satellite narrow-band filtered quantities to broad-band meteorological ones, Lambertian *versus* bidirectional albedo approaches, obtention of integrated cumulative quantities from a sparse number of satellite observations, topographic correction, etc). It is also true that all the above ideas gain particular interest when concerning low spatial but in contrast high temporal resolution satellite data, where operational methodologies should not go in detriment of accuracy and reliability.

The purpose of this work has been to accurately determine the atmospheric correction of METEOSAT-4 VIS channel data to estimate surface albedo hourly evolution in the Tomelloso EFEDA Pilot area during one of the Project Golden Days on 23 June 1991.

METHODOLOGY AND SIMULATION. ACCURATE DETERMINATION OF THE ATMOSPHERIC CORRECTION

Top of the atmosphere radiance and surface irradiance have been simulated by means of the 5S radiative transfer code [2] with the aim to generating a several entry look up table (LUT). The simulation keeps fixed some of the atmospheric, geometrical and surface parameters, whereas it varies some others within certain pre-determined ranges. The parameters kept fixed are: the day (23 June 1991), position of the observed surface (the center of the EFEDA study area, latitude 39.29, longitude -2.43), atmospheric profile (US62 atmosphere model, except for water vapour which is considered variable), aerosol model (5S continental model), and a natural vegetation spectral signature from a homogeneous Castilla-La Mancha surface. The variable parameters used as LUT entrie were: precipitable water vapour (0.5-2.5 cm), atmospheric aerosol optical depth (0.1-0.7), land surface absolute albedo (0.1-0.4), and observation time (6:30 to 18:30 h G.M.T).

The utility of the LUT refers to its direct application on the EFEDA study area on 23 June 1991 of which we are analising the 24 consecutive METEOSAT slots from 6:30 to 18:30 h (G.M.T.). Interpolation by means of spline curves under tension [3] allows the LUT to reproduce the 5S code results in a fast and simple way. Thus, we selected broad band surface irradiance (0.3-2.5 μm) and planetary and surface albedo in METEOSAT-4 VIS-1 band as LUT output parameters. Additionally, we also had available some of the field campaign data contained in the EFEDA Database [4], including radiosonde data, and albedo and solar radiation from crops and other natural surfaces. It is then possible to obtain a precipitable water vapour value every two hours by integrating radiosonde data for each of the EFEDA Pilot areas in Tomelloso, Barrax and Rada de Haro. This value is then used as input data to the LUT.

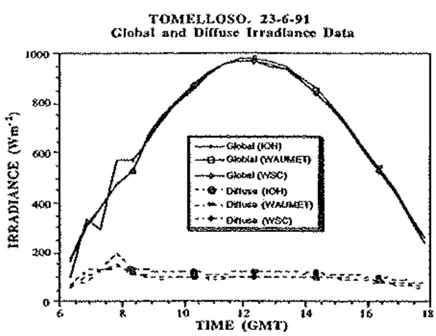

Fig.1)-Global and diffuse irradiance evolution measured at three stations in the Tomelloso area during 23 June 1991.

Fig. 1 shows surface irradiance measured at three stations in the Tomelloso area on 23 June 1991. Particularly, these three stations measured global and diffuse irradiance so that the direct component may be easily estimated from their difference between both. The remaining of the stations did not measure diffuse irradiance. Global irradiance and albedo, which were resampled to half hour data, may be used for the estimation of aerosol optical depth (AOD) by comparing measured irradiance to 5S simulated irradiance. In this sense, AOD may be indistinctly calculated either from the global or the direct irradiance component.

Fig. 2 shows AOD calculated every half hour, both from global and direct irradiance measurements for the three stations shown in Fig. 1. We may see that the differences in AODs estimated from different station data explain the small differences observed in irradiance data. However, the biggest differences are found between AODs calculated either from global irradiance or from direct irradiance. On the one hand, the former presents a higher value but it exactly reproduces the surface measured global irradiance value. On the other hand, the direct irradiance estimated AOD presents a more coherent value and, although it exactly determines the surface measured direct irradiance value, the global component is over-estimated in about 4%. Therefore, we can see that the differences observed between the different AODs lead to much smaller differences between simulated global irradiance. This may be explained in terms of the continental aerosol model scattering effect that produces a different irradiance partition between the direct and diffuse component, but keeping the global component approximately constant.

With the two-hour information on atmospheric water vapour and the half-hour information on the aerosol concentration optical depth, the simulated data LUT allows us to directly relate planetary and surface METEOSAT-band albedo as they would be observed by METEOSAT. This case-dependent relationship determines the atmospheric correction that should be applied to estimate actual surface albedo.

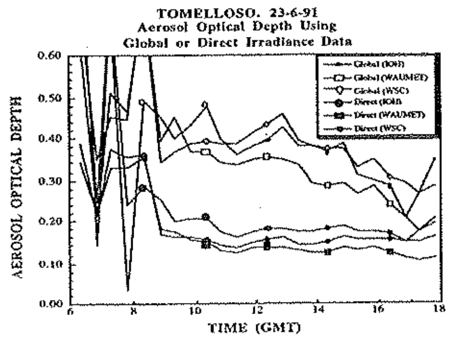

Fig.2)-Aerosol optical depth evolution retrieved from Fig.1 irradiance data.

The purpose of this work is centered on the estimation of surface albedo in the METEOSAT band by using a sequence of METEOSAT images of a particular cloudless day, 23 June 1991. The METEOSAT band albedo should then be spectrally corrected to broad band albedo [5] to make it comparable to albedometer data. Hourly albedo thus obtained may be now compared to the albedo evolution observed in the ground data.

SATELLITE AND GROUND DATA

The METEOSAT-4 VIS channel images (0.3-1.1 µm) used in this work correspond to a rectified window mainly covering the Iberian Peninsula, approximately comprising between 45.5°N and 33.4°N latitude and 8°E and 13°W longitude. The slots (13-37) correspond to half-hour intervals from 6:30 to 18:30 h G.M.T. Geographical identification of the ground measuring stations on the images have been performed by applying ESOC software [6]. Conversion to physical radiance has been done by means of a multitemporal calibration [7] that accounts for the observed drift in the sensor sensitivity for the VIS channel.

The synoptic diurnal situation for 23 June 1991 corresponds to the Las Azores high pressure influence, with a development of a thermal low over La Meseta. In the Tomelloso EFEDA Pilot area (10x10 km^2), where the ground measurements were performed, there existed some middle and high clouds early in the morning that disappeared by midday. During the rest of the day, the situation was mostly cloudless, but in the middle of the afternoon there appeared some evolution clouds in near mountain areas that did not develop vertically.

Global irradiance and albedo ground measurements used in this work were carried out in the Tomelloso area by different research groups such as the Méteo-France from the Centre National de Recherches Metéorologiques, Toulouse, France (CNRM), the University of Copenhagen, Denmark (COP), the Institute of Hidrology from Wallingford, England (IOH), the University of Reading, England (REA), the Winand Staring Center from Wageningen, The Netherlands (WSC), and the Departments of Hydrology and Meteorology from the Wageningen Agricultural University, The Netherlands (WAUMET). All of them used pyranometers and albedometers (0.3-3.0 µm) at 2 m above the surface to get diurnal evolution of shortwave radiation over different land surfaces such as vineyards, vetch and bare soil. Three out of these stations carried out simultaneous global and diffuse irradiance (IOH,WAUMET,WSC), thus permitting us now to obtain AOD either from global or from direct irradiance as mentioned earlier.

The five radiosounding ascents from which we obtained atmospheric water vapour to carry out the atmospheric correction were performed by CNRM.

The comparison between ground measured albedo and surface albedo from METEOSAT data has been performed by locating the corresponding pixel on the image. In order to account for the possible image registration error, the comparison has been made by considering the mean of a 3 x 3 pixel matrix around the pixel under consideration.

ESTIMATION OF SURFACE ALBEDO. RESULTS AND CONCLUSIONS

Fig. 3 shows METEOSAT-band surface albedo obtained from the atmospheric correction, using the different AODs shown in Fig. 2. The observed high reflectance during the first part of the morning corresponds to a cloud event over the study area. Thus, the interval of interest in this study begins from about 9:00 h G.M.T., when cloudy conditions do not show neither in the ground data nor in the METEOSAT images. As seen in Fig. 3, the differences between albedos obtained from different station data are minimal, whereas albedos obtained from AODs calculated from different irradiance components differ from each other only in about 4% at the most, and this coincides with the differences estimated in global irradiance simulated with the two AOD types. Because of these slight differences, the work was carried out with albedos obtained from AOD calculated from global irradiance which was the component generally measured in all EFEDA stations.

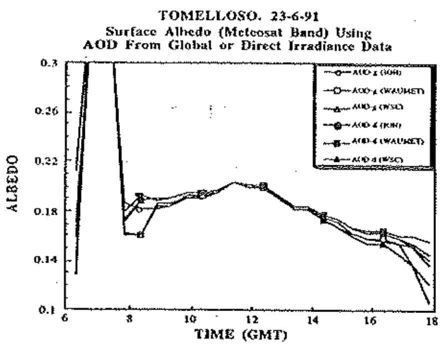

Fig.3)-METEOSAT band surface albedo using aerosol optical depth calculated from global or direct irradiance data.

The albedo spectral correction from METEOSAT band to broad band has been performed with a relationship found for a wide ensemble of natural surfaces [5]. It is preferable to use this relationship because the satellite data actually represent a large combination of surfaces and not a unique one that could be *a priori* assumed. Fig. 4 shows this transformation for our data. The error bars on the graph only refer to the standard deviation associated with the 3 x 3 pixel matrix average surrounding the central pixel. We may see that this transformation shifts the METEOSAT albedo values to about 10% higher values in broad band.

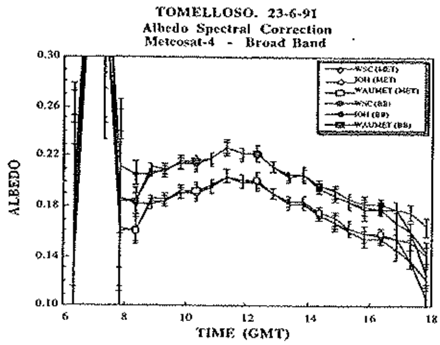

Fig.4)-METEOSAT to broad band albedo spectral correction applied.

Finally, Fig.5 shows the comparison of satellite surface albedo to ground measured albedo in the different EFEDA stations of the Tomelloso area. The points corresponding to the first part of the morning have not been shown in the calculated albedo curve because they corresponded to cloud events picked up by the satellite. Cultivated crop surfaces show a minimum albedo around midday that increases as we get away from there. Vineyards show less diurnal albedo variation due to a high percent presence of bare soil at that time of the year. In contrast, the satellite albedo presents maximum values around midday that decay in the afternoon. Additionally, this satellite albedo only takes values in the range of the measured albedo at hours around midday. In the afternoon, the satellite values are progressively under the ground-data range. This discrepancy must not be explained in terms of innacurate simulation of atmospheric effects or as a consequence of non-coinciding surfaces. The explanation could rather be found in terms of a distinct reflectivity caused by a combination of surface types that differ from the measured ones. However, this hypothesis may not hold either due to the terrain homogeneity of the Tomelloso area. It is the opinion of the authors that the discrepancy may best be explained as a consequence of bidirectionality effects in surface reflection. The assumption of Lambertian surface behaviour at the METEOSAT scale may not be entirely valid when calculating surface albedo from pixel radiance registered by the satellite. The satellite values shown in Fig. 5 should then correspond to bidirectional surface reflectance in the direction of the METEOSAT satellite due to the fixed viewing geometry and varying illumination conditions in each half-hour satellite image. The correspondence between satellite values and measured ground albedo during midday hours can be explained just by considering that bidirectional surface reflectance may be representative of ground albedo for that particular viewing and illumination geometry.

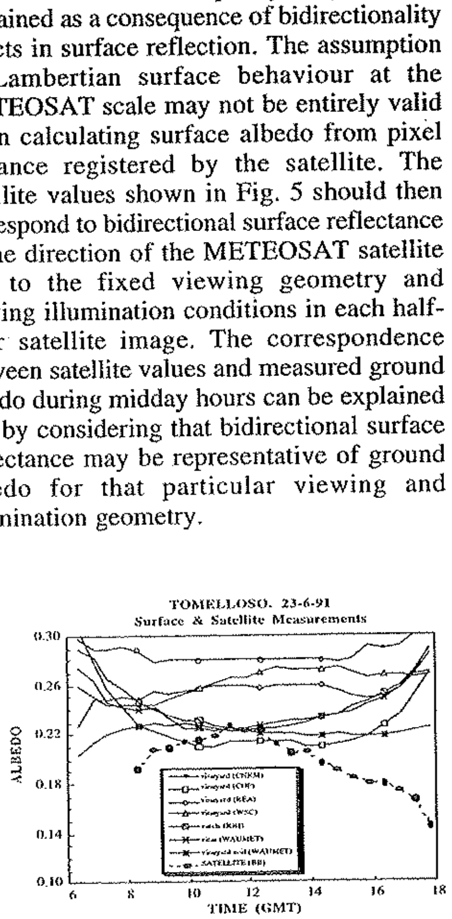

Fig.5)-Surface measurements and satellite estimated albedo for the Tomelloso area.

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