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Tesis doctoral

A model to estimate daily albedo from remote sensing data.
Accuracy assessment of MODIS MCD43 product

Autora: Belen Franch Gras
Director: Jose A. Sobrino
Lugar: Parc Cientific, Universitat de Valencia
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Land surface albedo is a physical parameter that affects the Earth´s climate and, also, supposes one of the greatest radiative uncertainties in the current climate modeling. This parameter is highly variable both spatially and temporally. It changes naturally with solar insolation angle, seasonally with vegetation changes and stochastically with rain or snowfall. It can also be changed directly via human activity or indirectly. Consequently, climate studies require a daily temporal resolution. Additionally, the increasing spatial resolution of climate models require the study of the albedo spatial distribution at global scale. Therefore, remote sensing supposes the only practical way to determine the global surface albedo accurately and with high temporal and spatial resolution.

Due to its acquisition geometry and frequency of satellite pass, the MODerate Resolution Imaging Spectroradiometer (MODIS) sensor onboard Terra and Aqua satellites allows the estimation of the surface albedo. The official albedo product (MCD43) is estimated through the Bi-directional Reflectance Distribution Function (BRDF) model inversion from surface reflectance images. In this way several assumptions are made in order to derive the surface albedo. First, the surface reflectance, which is the basis to obtain the albedo, is estimated considering that the surface is Lambertian, that is, it reflects radiance equally into all directions. However, it is well known that natural surfaces are anisotropic. Then, the first objective of the thesis is the study of how the Lambertian assumption impacts on the albedo estimation. We analyzed MODIS Climate Modeling Grid (CMG) daily data from both Aqua and Terra platforms between 2003 and 2006 at four different Aeronet sites (each one of them corresponded to one CMG pixel) located in the United States of America. Secondly, the BRDF model considered in the albedo official product does not take into account the hot spot effect. This effect consists on a maximum of reflectance values when the view and illumination angles coincide. Taking advantage of the Earth Observation: optical Data calibration and Information eXtraction (EODIX) field campaign which was developed in an agricultural area in Barrax (Albacete) where several flights were achieved with the Airborne Hyperspectral Scanner (AHS), the next objective of this thesis is the comparison of in situ measurements with airborne albedo derived with the MODIS BRDF model and with the BRDF model that considers the Hot Spot effect correction. Additionally, we evaluate the MODIS albedo product by comparing satellite albedo images to airborne albedo estimations. This study is achieved through pixel aggregation in order to get to the same spatial resolution to the satellite images. Finally, looking for an improvement in the MODIS albedo temporal resolution and

following Vermote *et al*. (2009) method (VJB) which allows the instantaneous estimation of the albedo, we have improved this methodology presenting a more robust method. Therefore, the last objective of this thesis is the comparison of the MODIS official product with the results obtained with the VJB method and with the improvement presented. Every method was applied to MODIS CMG daily data from both Aqua and Terra platforms over a European scene from 2002 through 2011.

Additionally, we present two applications derived from the previous studies. Considering the airborne albedo obtained and studied during the EODIX campaign we analyze the influence of its accuracy on the evapotranspiration estimation. Finally, taking advantage of all the CMG MODIS dataset processed we study the albedo temporal evolution over the European scene considered and we examine its influence on the land surface temperature and air temperature.

First of all, the influence study of including the BRDF coupling in the atmospheric correction showed that the Lambertian assumption can be used satisfactorily in the derivation of surface reflectance and surface albedo. In fact, the obtained RMS of 1% in case of the surface albedo estimation meets the accuracy requirement of 5% suggested by the Global Climate Observing System. However, it should be used carefully for high aerosol amounts since this can result in a significant error in the surface reflectance estimation.

Regarding the MODIS BRDF/albedo product evaluation over an agricultural heterogeneous area in the framework of the EODIX campaign, we obtained good results when comparing airborne albedo to in situ data with a RMSE of 0.018 both using the same BRDF model than MODIS (RTLSR model) and using the Hot Spot correction (RTLSR-HS model). However, the comparison between airborne and satellite data led to a RMSE of 0.04 for both models which can be consequence of the different methodology applied to estimate the BRDF. While MODIS BRDF/albedo algorithm considers that the surface does not change during 16 days (a coarse approach when working with agricultural sites), the AHS BRDF corresponded to a single day composition. Nevertheless, since airborne images presented a good agreement with in situ data, the RMSE of 0.04 proves that MODIS BRDF/albedo product meets the required accuracy of 0.02-0.05 in the surface albedo estimation.

We compared the MCD43 MODIS product with different BRDF inversion methods through the white sky albedo analysis. The VJB method and the proposed methods provide equivalent results to the MCD43 MODIS product (with errors around 5% along the dataset considered) but with the advantage of a daily versus a 16-day basis temporal resolution. The proposed method suppose an alternative method to the VJB that shows equivalent results, is more robust and reduce significantly the processing time needed for the retrieval of BRDF parameters.

We analyzed the error committed by many evapotranspiration studies that assume the surface as Lambertian and estimate the albedo from a surface reflectance weighted average. The results show that this approximation lead to relative errors in sensible heat flux, latent heat flux and daily evapotranspiration ranging between 23-39%, 6-18% and 5-15% respectively. We observed higher errors for view zenith angles higher than 35º and along the hot spot region. Therefore, for future evapotranspiration studies we suggest the appropriate use of the RTLSR-HS modeled albedo.

Finally, we localized the pixels which suffered the highest albedo changes from 2002 to 2011 through a Europe and northern Africa scene, dividing the study into four categories of hazards responsible of the albedo increase: forest fires, wind storms, floods and droughts. Forest fires, located in the Iberian Peninsula, led to the highest albedo increases ranging from 0.02 to 0.05. After most of these events we detected an increase of the seasonal extreme LST proportional to the albedo increase which lasts three to four years after the fire event while the albedo reestablishment takes longer. During the studied period a wind storm hit Bordeaux region of Les Landes damaging large forest areas which increased the albedo by 0.02. We observed an increase of the yearly average LST of 6K and of 2K in case of the air temperature during the year of the wind storm. We did not observe any influence of the albedo

increase on the temperature caused by the other hazards. This study showed that natural hazards that origin surface albedo alteration may impact LST depending on the location of the event (showing more impact on temperature Southern Europe sites) the magnitude of the hazard and the regional climate.