Estimating surface reflectance for aerosol retrieval SYNAER Envisat and MetOp, based on analysis of ASRVN and spectrometer data

Miriam Kosmale[1]
[1]German Aerospace Center (DLR), German Remote Sensing Data Center (DFD)
contact: Miriam.Kosmale@dlr.de

Introduction

A constant factor B can be analytically defined to describe the dependency between the red and shortwave infrared channel reflectance for estimating surface albedo in the visible for aerosol retrieval treatments. This Factor is dependent on two vegetation indices, NDVI and NDII respectively and contributes for leaf area in case of vegetation, visible brightness of the surface as well as moisture within the shortwave infrared channels.

Spectral radiances of sunlight measured by satellite devices are influenced by transmission through their atmospheric path, as well as the reflected contribution from the surface. In case being able to quantify the contribution of the atmosphere the remaining radiance can be converted into reflectances. Analyzing these reflectances may help understanding and applying the surface treatment within the darkfield method in aerosol retrieval like SYNAER (Holzer-Popp et al., 2008).
Kaufman et al., 1994 described an approach evaluating the ground reflectance in the visible channel by use of mid infrared channel measurements. The advantage of these channels is based on the fact, that opacity of an aerosol layer is lower at higher wavelengths. Except for large particle like dust, the scattering efficiency as a function of Mie size parameter decreases with increasing wavelength.
An important aspect for adaptability of this approach is a similar relative spectral response signature between the RED and Mid-IR channels, depending on their vegetation type. Although for vegetation in the RED channel chlorophyll is responsible for absorption, whereas in Mid-IR liquid water within the leaves causes the typical signature, both aspects are a measure for the vegetation cover. For soil in both channels absorption by liquid water causes a decrease in reflectance.
Mid-IR or shortwave infrared channel measurements can in principle be used within the dark target approach, deriving the ground reflectance contribution in the visible for further purpose of aerosol retrieval.

The correlation between the shortwave infrared and the RED channel reflectivity of the ground is assumed to be dependent on the NDVI, a measure for vegetation content of the surface. It has kept in mind, that the NDVI itself is sensitive on aerosol-loading, and therefore distorts such a linear approach between shortwave infrared and RED surface reflectivity. On the other hand NDVI is a normalized index so aerosol influence maybe vanished or at least diminished.

It is important to note, that NDVI, or also other vegetation indices such as NDII (normalized differential infrared index), based on radiometric channel measurements are sensor specific measures.

Analysis

In SYNAER version 2.0 (Holzer-Popp, et al. 2008) surface reflectance of the RED channel is estimated by reflectance at 1.6µm with a NDVI-dependent regression function (analogous to figure 2). This function was previously calculated from 2500 AATSR dark field pixel in vicinity of an AERONET measurement, where aerosol loading could be assumed as low (AOD at 550nm < 0.1).

$$\rho(\lambda_{RED}) = A + B \cdot \rho(\lambda_{SWIR})$$
$$\Delta = \rho(\lambda_{SWIR}) - \rho(\lambda_{NIR})$$

For further analysis of the correlation between RED and SWIR channel, ASRVN, a MODIS collection 5 based validation dataset of ground reflectances was used.

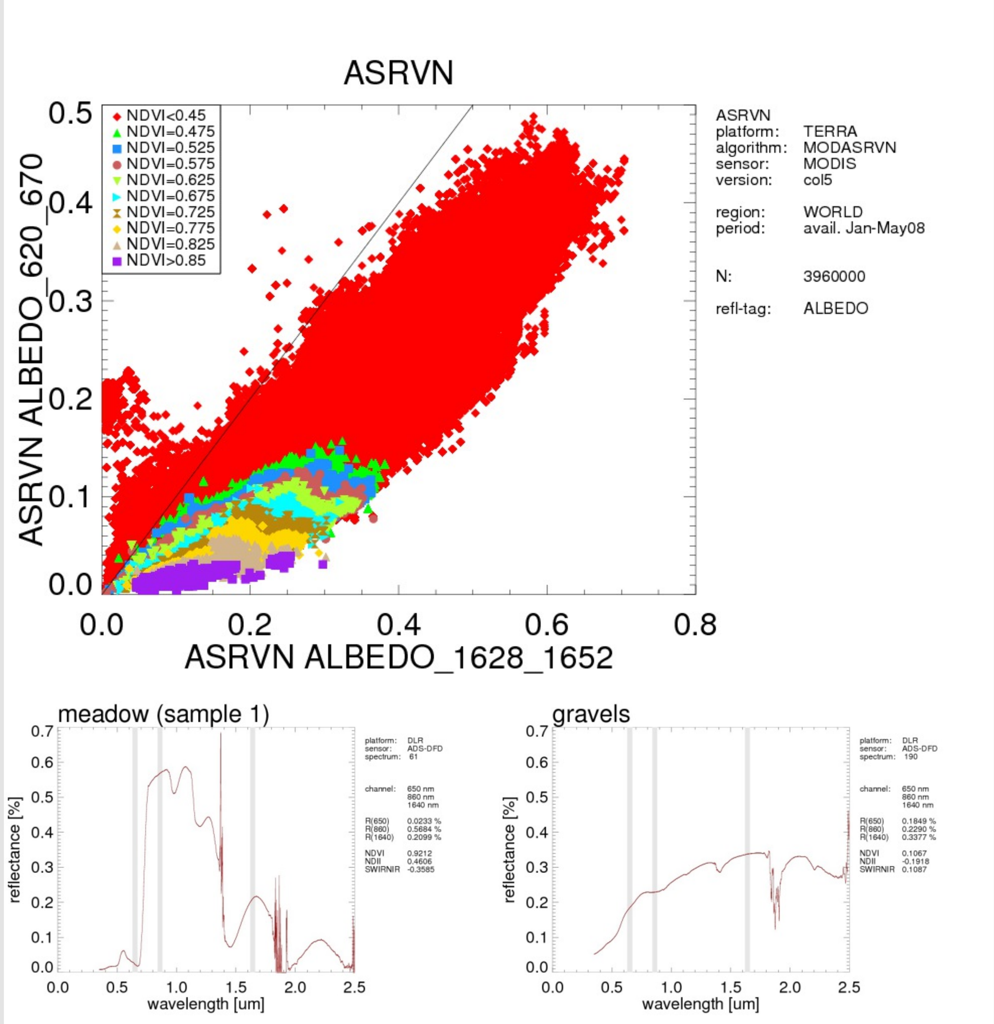

Fig. 2 above: correlation between red and shortwave infrared channel, dependent on vegetation index NDVI based on ASRVN dataset. Adding a second vegetation index NDII can yield to a much better linear fit between the two channels
Fig. 2 below: two typical measured surface spectra. In grey the location of the three channels of interest are marked.

ASRVN dataset is available at 1km resolution selections of boxes 50km surrounding AERONET measurements, which were used for atmospheric correction of the MODIS data. This dataset is globally distributed, and covers a wide range of surface types. This high resolution, atmospherically corrected and stable dataset of surface reflectances, gave a much denser dataset, than the 2500 darkfield pixels by AATSR previously used for regression analysis.
Regression analysis of ASRVN-data showed (figure 2), that the dependency between 1.6µm and 670nm surface reflectance is not only linearly with respect to NDVI (see figure 1). Another measure has to be added, to describe the dependency between these two channels properly.
In a first approach the absolute reflectance difference between 1.6µm and near infrared (870nm) was used, contributing to the water content within the surface, which influences the reflectivity in the short wave infrared.
The advantage of the latter parameterization, adding the reflectance difference between NIR and SWIR channel measurements, is the expansion to water content of the surface, and not only vegetation amount, as before.

Methodology

To avoid absolute values in a parameterization, in a second approach the NDII (normalized differential infrared index) was introduced, which is defined similarly like NDVI, but between near infrared 870nm and water affected short wave infrared channel 1.6µm, and is a measure for the water content within the surface. For sensors with absence of the 1.6µm channel, the NDII should be replaced by the VI3-Index (introduced by Kaufman et al., 1994), which is the differential difference between the near infrared channel at 870nm and the mid infrared channel at 3.7µm.

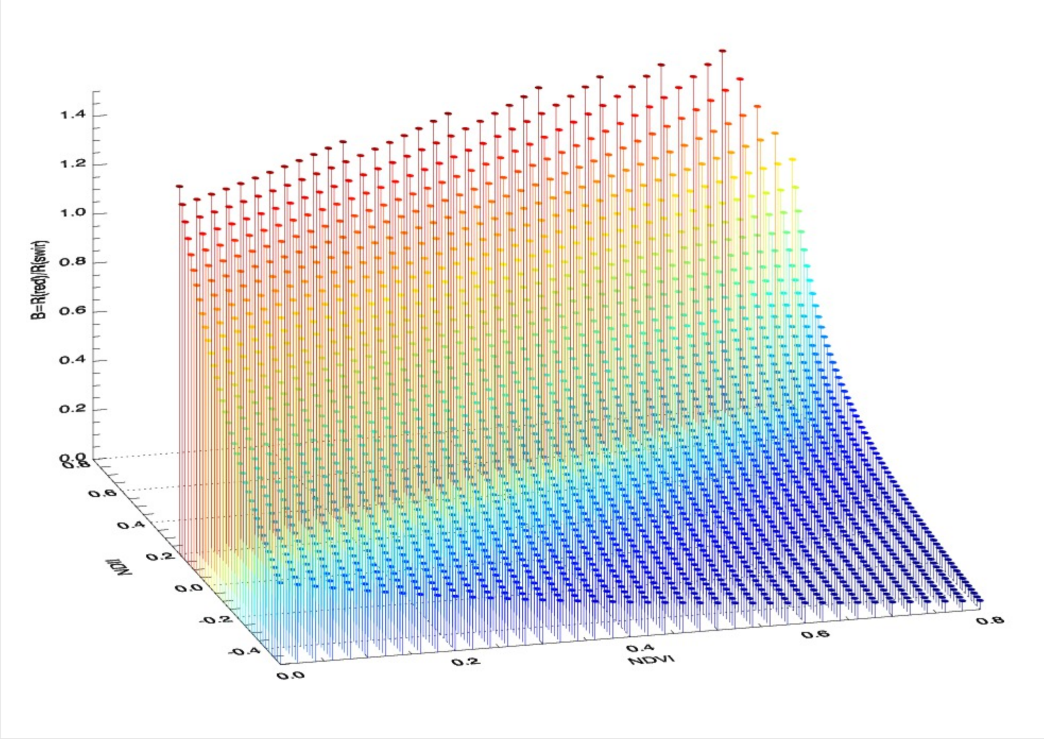

Fig. 3: analytical solution for B factor, dependent on the two vegetation indices NDVI and NDII.

$$\rho\left(\lambda_{RED}\right) = B \cdot \rho\left(\lambda_{SWIR}\right)$$
$$B = \frac{NDVI-1}{NDVI+1} \cdot \frac{NDII+1}{NDII-1}$$

A constant factor B can be analytically defined to describe the dependency between the red and shortwave infrared channel reflectance.
B is dependent of measures, which are characteristically for different surface types. Figure 3 shows the dependency as 3-dimensional plot. The higher the NDVI, as for Vegetation and the higher the NDII, describing the loss of water stress of the surface type, then the higher is the factor B. This mountainside function for B describes the dependency between RED and SWIR channel.

For satellite measurements it has kept in mind, that the NDVI and NDII are calculated from reflectances, which have contributions of aerosol loading (see also Kaufman et al., 1997). This leads to slightly different vegetation indices, than assumed in the idealized relationship. An iterative corrections scheme dependent on aerosol loading has to be implemented within the aerosol retrieval, as the B factor is going to be used.

Conclusions and outlook

The new suggestion for the surface treatment within SYNAER, with a vegetation index dependent regression from infrared to red channel, will be applied to different sensors.
For each radiometer in a first step the "B-factor" has to be tabled. This will be done by analysis of selected pixels, which were atmospheric corrected with available AERONET-measurements. The B-factor is sensor sensitive, so this analysis has to be done once per sensor.

Implementing the B-factor to the aerosol retrieval could be a way to get the surface albedo in the visible channels.

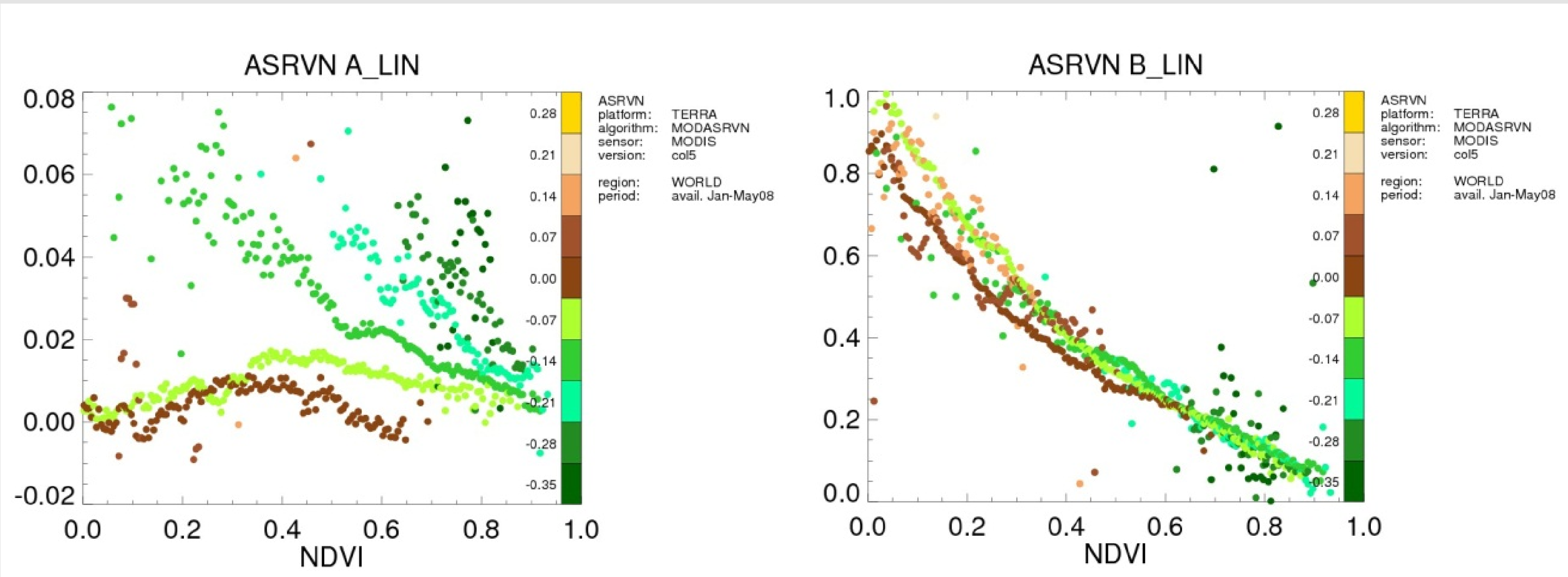

Fig. 1: Coefficients for linear fit between infrared channel at 1.6um and red channel at 670nm. color coded are the absolute differences between NIR channel 870nm and infrared channel at 1.6um, to show the dependency on moisture of the surface. The greener the dots are, the higher is the moisture of the surface, corresponding to healthier vegetation.

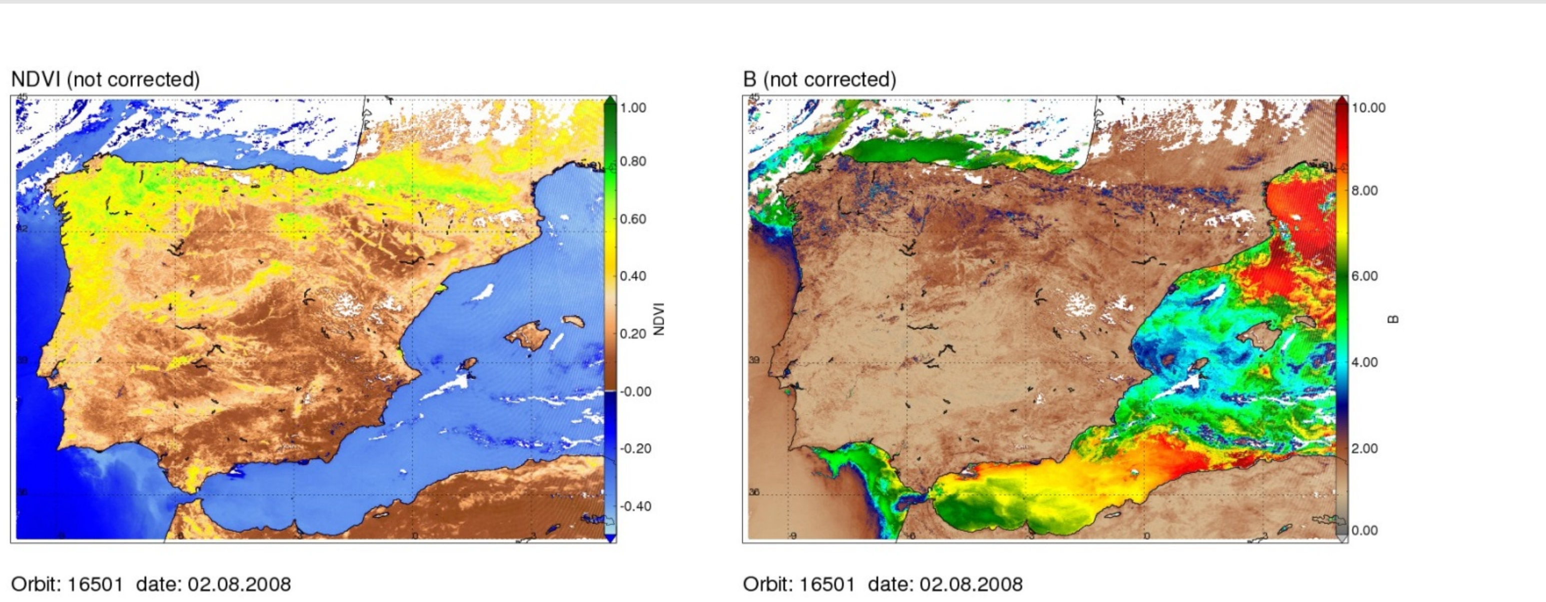

Fig. 4: NDVI and B factor top of atmosphere for Hesperian peninsula for a selected orbit of MetOp/AVHRR. B factor is a measure for vegetation and moisture of the surface. On the sea a dependency on sea roughness can be seen.

literature:
Kaufman Y., Remer L., 1994, Detection of Forests Using Mid-IR Reflectance: An Application for Aerosol Studies, IEEE Transactions on Geoscience and Remote Sensing, 32-3, 672-683
Kaufman Y., Tanre D., 1996, Strategy for direct and indirect methods for correcting the aerosol effect on remote sensing: From AVHRR to MODIS-EOS, Remote Sensing of Environment, 55, 65-79
Kaufman Y., Wald A., Remer L., Gao B., Li R., Flynn L., 1997, The MODIS 2.1-um Channel-Correlation with Visible Reflectance for Use in Remote Sensing of Aerosol, IEEE Transactions on Geoscience and Remote Sensing, 35-5, 1286-1298
Holzer-Popp T., Schroedter-Homscheidt M., Breitkreuz H., Martynenko D., Klüser L., 2008, Improvements of synergetic aerosol retrieval for ENVISAT, Atmospheric Chemistry and Physics, 8, 7651-7672
Holzer-Popp T., Schroedter-Homscheidt M., Breitkreuz H., Martynenko D., Klüser L., 2009, Benefits and limitations of synergistic aerosol retrieval SYNAER in Satellite Aerosol Remote Sensing over Land, Kokhanovsky A. and Leeuw de G. (Eds.), Springer, 227-266

DLR Deutsches Zentrum für Luft- und Raumfahrt