Parametrization of Surface Albedo for Nadir Aerosol Retrieval SYNAER

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Introduction

Aerosol retrieval working in the visible channels has to deal with an ill-posed problem. AOD and surface albedo are both unknown parameters within a nadir-only aerosol retrieval as the synergistic aerosol retrieval SYNAER. SYNAER is a retrieval algorithm using a combination of radiometer and spectrometer measurements onboard the same satellite platform. In a first step the aerosol amount can only be estimated with the knowledge of the surface albedo within the visible channel. Kaufman, et al. introduced a linear parametrization of the albedo, which is dependent on the shortwave infrared radiometer measurement. This parametrization is a common way in the so called dark field method for aerosol retrievals2.

For a general understanding of the dependences between red, near and shortwave infrared channels ASRVN datasets were analyzed. ASRVN is a MODIS based dataset of surface albedo, atmospheric corrected with adjacent AERONET aerosol measurements. Additionally measured surface spectra were investigated on synthetic radiometer channels. A linear relationship between shortwave infrared (1.6 um) and red (670 nm) can be determined as Kaufman suggested, but the relationship is not constant. As suggested by Holzer-Popp, et al. for AATSR and by Mei et al. for AVHRR these linear relationship can be related to the NDVI (normalized differential vegetation index). By analyzing the ASRVN and spectrometer measurements it turned out that a simple linear relationship only by using the NDVI is not sufficient for a larger variety of surface types. In order to describe the SWIR to RED dependence an additional vegetation index has to be introduced. This index accounts not only for the vegetation amount of the surface as the NDVI does, but also allows a measure for the water amount of the surface, which affects the NIR and SWIR channels of a radiometer. Introducing the NDII (normalized differential infrared index) promises a more accurate determination of the RED surface reflectance based on the SWIR channel reflectance. Additionally, an analytical equation for the SWIR to RED reflectance can be derived including both vegetation indices NDVI and NDII.

Nevertheless it has to be considered that the vegetation indices themselves are affected by the aerosol amount, so the approach needs their iterative correction for the aerosol impact. The extended parametrization of surface albedo is used in the synergistic aerosol retrieval.

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).

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

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

$$\Delta = \rho(\lambda_{SWIR}) - \rho(\lambda_{NIR})$$

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.

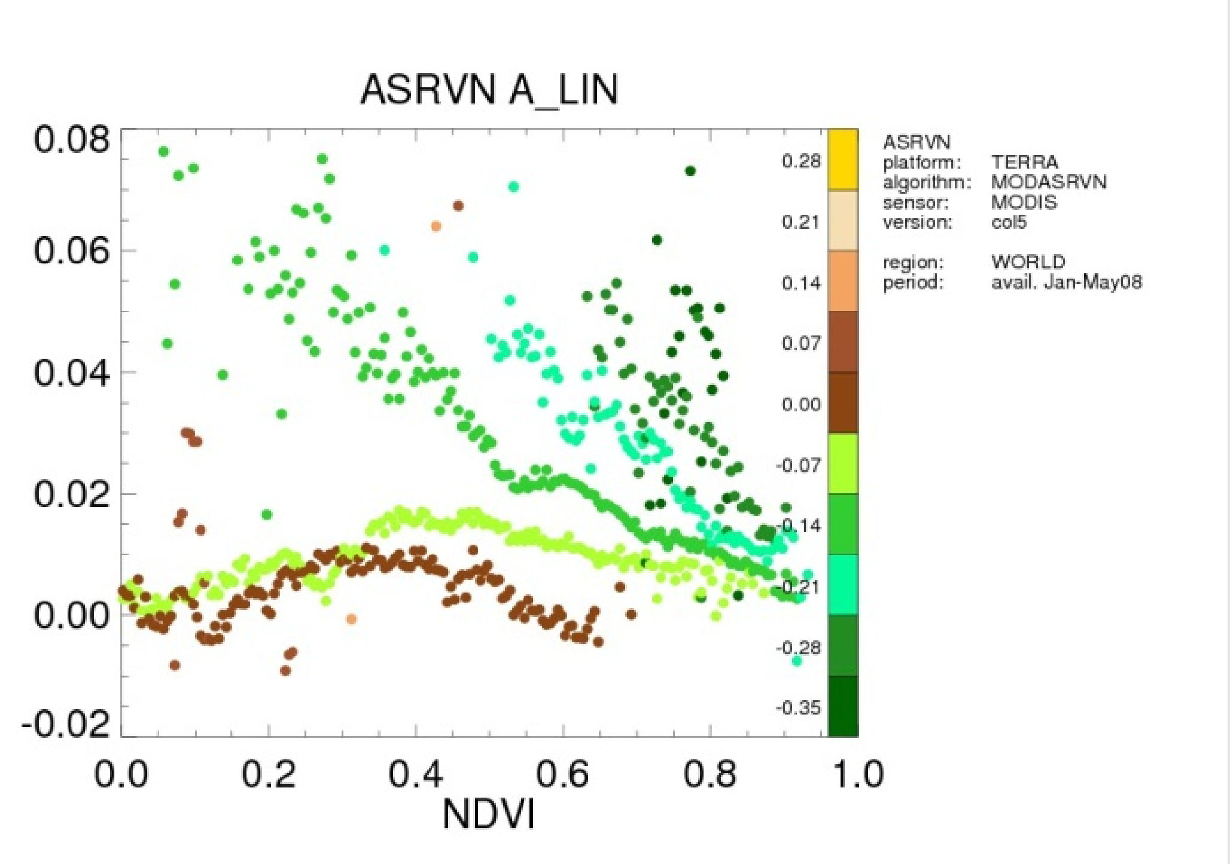

Fig. 1: Coefficients for linear fit between infrared channel at 1.6um and red channel at 670nm. color coded are the absolute differences between NIR channel 870nm and infrared channel at 1.6um, to show the dependency on moisture of the surface. The greener the dots are, the higher is the moisture of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

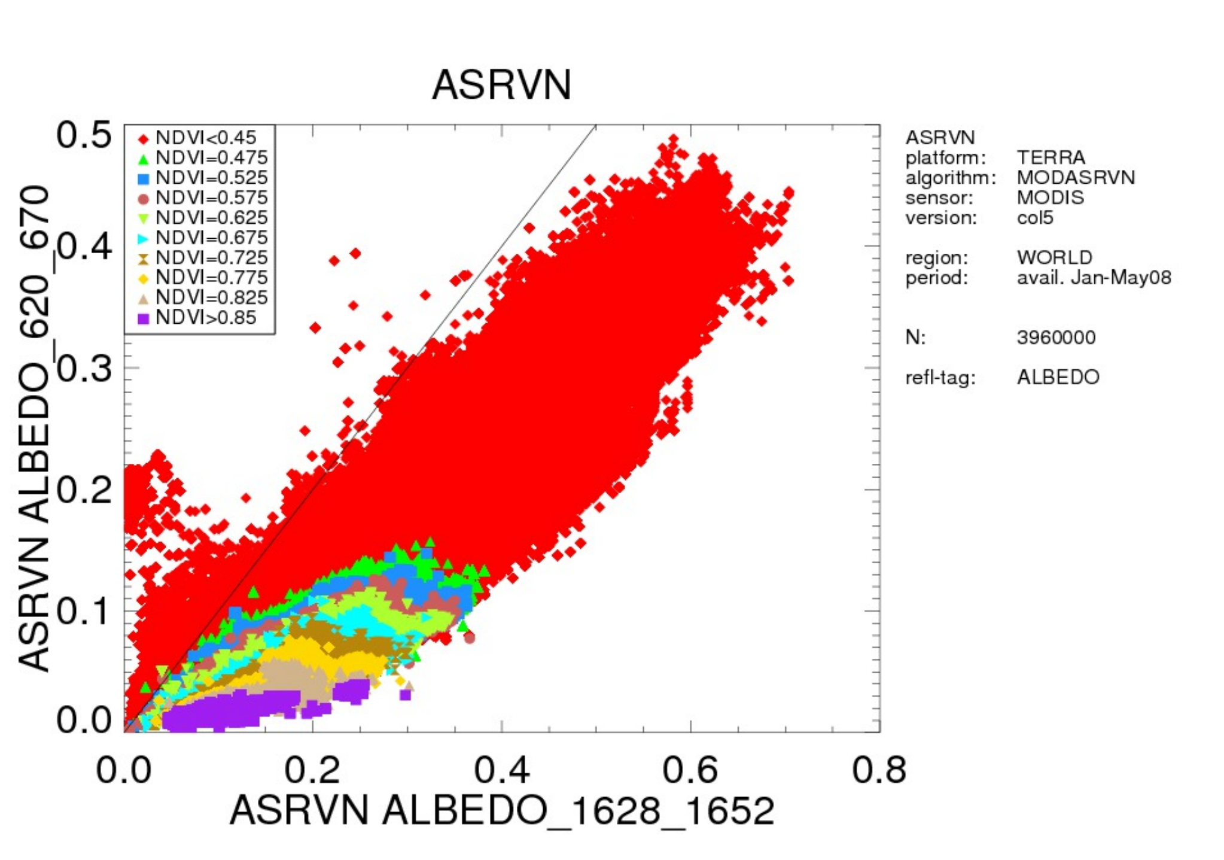

Fig. 2 above: correlation between red and shortwave infrared channel, dependent on vegetation index NDVI based on ASRVN dataset. Adding a second vegetation index NDII can yield to a much better linear fit between the two channels

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.

$$\rho\left(\lambda_{RED}\right) = B \cdot \rho\left(\lambda_{SWIR}\right)$$

$$B = \frac{NDVI-1}{NDVI+1} \cdot \frac{NDII+1}{NDII-1}$$

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.

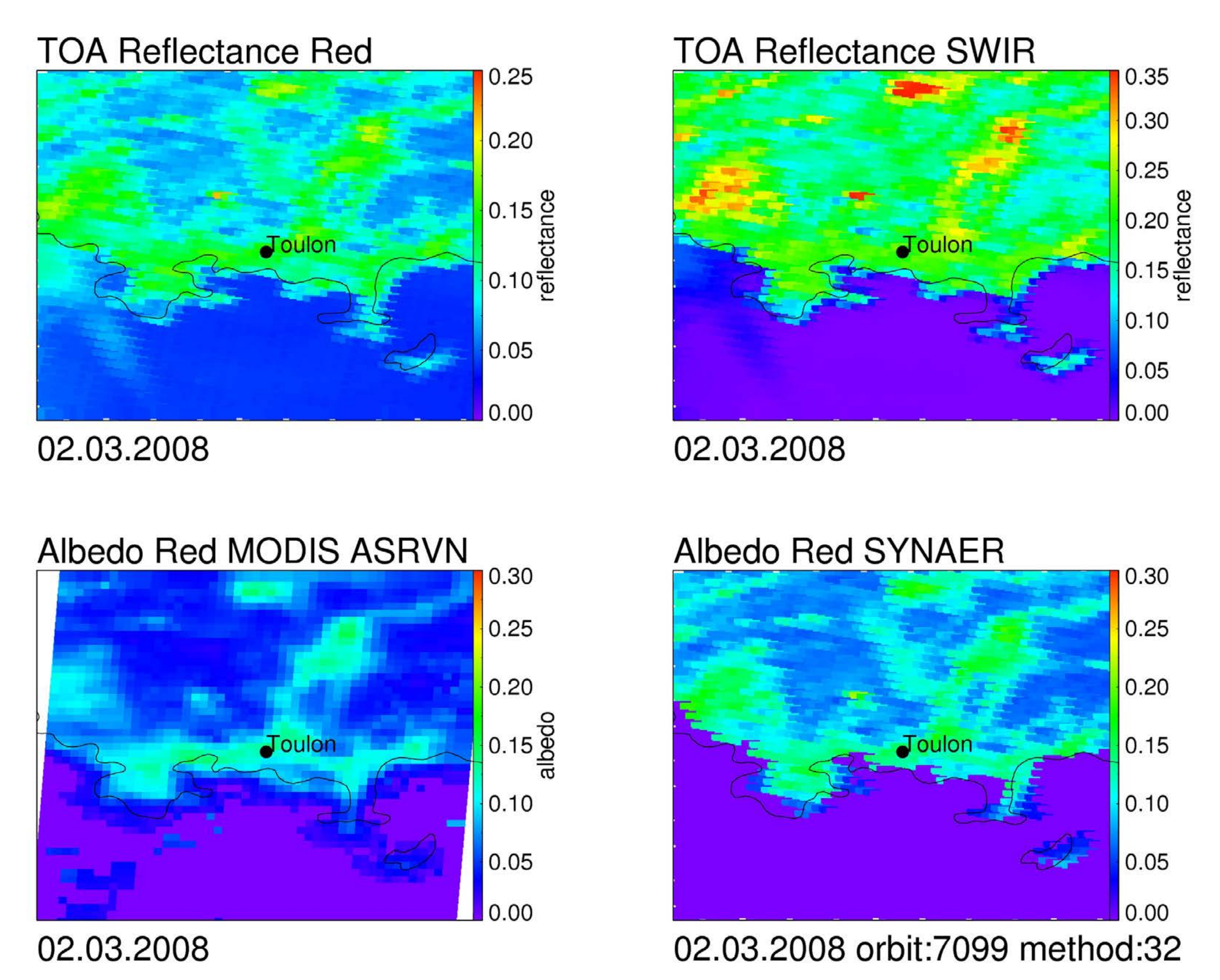

Fig. 3 : Comparison of MODIS ASRVN albedo and SYNAER with B-factor method retrievt albedo values for the same date and location. Sensor was MetOp AVHRR. Above the Red and 1.6um channel reflectance of MetOp AVHRR are plotted.

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

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