Prototyping algorithm for retrieving FAPAR using MSG data in the context of the LSA SAF project

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Abstract—

This paper describes the prototyping algorithm developed for retrieving the Fraction of Absorbed Photosynthetically Active Radiation (FAPAR) using MSG data in the framework of Satellite Application Facility on Land Surface Analysis (LSA SAF).

The prototyping relies on the Roujean and Bréon (1995) method, which is based on simulations of visible and near infrared reflectance values in an optimal geometry. A relationship is found between a vegetation index and daily FAPAR. The algorithm has been applied to one year of MSG BRDF data since August 2005, using a temporal frequency of 5-days, and then validated against a set of operational satellite FAPAR products such as MODIS, MERIS, SeaWiFS and CYCLOPES, as well as with ground-truth information.

MSG FAPAR products present a reliable spatial and temporal distribution of retrievals. The inter-comparison of the MSG FAPAR product with different operational products shows the large existing differences among FAPAR products. However, the best consistency is found between MSG and MERIS (only July 2006 was evaluated) or between MSG and CYCLOPES (available only for 2003). At a pixel level, the RMS over selected validation sites is lower than 0.1 between MSG and MERIS or MSG and CYCLOPES products, which demonstrates the competitiveness of the proposed prototype.

Keywords - FAPAR, MSG, inter-comparison, LSA SAF.

I. INTRODUCTION

FAPAR represents the fraction of photosynthetically active radiation (400-700 nm) absorbed by the green parts of the canopy. FAPAR has been recognized as one of the fundamental terrestrial state variables in the context of the global change sciences. It is a key variable in models assessing vegetation primary productivity and, more generally, in carbon cycle models implementing up-to-date land surfaces process schemes.

Satellite Application Facility on Land Surface Analysis (LSA SAF) is aimed at developing operational products related with land, land-atmosphere interactions, and biospheric applications, using data from the new generation EUMETSAT platforms; Meteosat Second Generation (Meteosat-8 launched in August 2002), and the first Meteorological Operational Polar satellite of EUMETSAT (Metop-1, launched in October 2006). LSA SAF vegetation products are the Fraction of Vegetation Cover (FVC), the Leaf Area Index (LAI) and the FAPAR. Whereas the FVC and LAI are already demonstration products (available for beta users), the FAPAR is still in a development phase.

Reference [1] proposed an algorithm for retrieving daily FAPAR from BRDF data, corrected of surface's reflectance anisotropy and minimizing the effect of soil reflectance. The principle of the algorithm is based on simulations of visible and near infrared spectral reflectance values in optimal angular geometries identified based on numerical experiments (simulations of a 1D radiative transfer code). A pre-established relationship is then applied between a suitable directional vegetation index and daily FAPAR. The algorithm was first successfully applied and validated using different coarse spatial resolution sensors, including POLDER/ADEOS and POLDER/PARASOL, showing a good consistency with ground truth. In order to evaluate the performance of this algorithm against other methods, the algorithm described in [1] was previously applied to VEGETATION/SPOT data, and compared with the CYCLOPES and MODIS products.

Section II describes the methodology, section III describes the FAPAR product and section IV provides the main validation results. Finally main conclusions are given. A wide report concerning the development and evaluation of the FAPAR prototype for MSG can be found in [2].

II. METHODOLOGY

A. Prototyping algorithm

First, the reflectance in the SEVIRI channels C1(VIS) and C2(NIR) is computed in the optimal geometry (θ_s=45º, θ_v=60º, ϕ=0), using the three BRDF parameters (k0, k1, k2) and the Roujean's parametric model [4], as follow:

$$R_C1=k0_C1-0.240\cdot k1_C1+0.202\cdot k2_C1 \quad (1)$$

$$R_C2=k0_C2-0.240\cdot k1_C2+0.202\cdot k2_C2 \quad (2)$$

Then, the RDVI in the optimal geometry is computed as:

$$RDVI_{opt}=(R_C1-R_C2)/SQRT(R_C1+R_C2) \quad (3)$$

Finally, the FAPAR is given by:

$$FAPAR=1.81*RDVI_{opt}-0.21 \quad (4)$$

The error of the FAPAR is computed by propagation of input error through the model (see [2] for a detailed description). In addition to the error, a quality flag is provided. The FAPAR product is not processed over water (flagged as –10), traces of inland water (-20), probability of snow cover (–30), or invalid inputs (-40) in agreement with the FVC & LAI QF (see [4]). In addition, the following condition were also applied:

The FAPAR prototype algorithm sets reflectance in the optimal geometry to a maximum physical value of 1. For reflectance values grater than the maximum value, the FAPAR product is flagged with the value –40.

Input errors are very large for some areas and specific periods, particularly for the k2 parameter, which strongly correlates with a very low reliability of the FAPAR product. Hence, the FAPAR product is not computed when the Error of k2 or Error of Reflectance in the optimal geometry are larger than 1. In these cases, the FAPAR product is flagged as –50.

If the algorithm provides FAPAR values out of maximum physical range (higher than 1) then the pixel is flagged as –60. This happens only for a small fraction of land pixels (less than 1%). For values below 0 the FAPAR product is set to 0. Most of the values below 0 are located over desert areas (e.g., Sahara).

B. *Validation datasets*

The prototype has been evaluated using one year of MSG data since August 2005. The original temporal resolution of Land-SAF BRDF data was slightly reduced to 5-days in this study, which is still higher than the other FAPAR products (8-days or 10-days) used here. The spatial and temporal consistency of our product has been assessed against equivalent FAPAR satellite products (MODIS, MERIS, SeaWiFS, VGT). Below a brief description of the FAPAR reference products is given (for further details see [2]).

MODIS 1 km resolution. One year of global MODIS C4.1 FAPAR monthly products were downloaded from Boston University (ftp://primavera.bu.edu) since August 2005. The mean value of the site was computed taking into account the QF information (i.e., pixels with low quality were not considered). In addition, for temporal evaluation the main product (MOD15A2, 8-days temporal resolution) was used. MODIS ASCII subsets were downloaded from ORNL DAAC (http://daac.ornl.gov/modisl).

MERIS RR 1 km resolution. The FAPAR processor based on the MGVI algorithm [6] was applied to the MERIS_RR data -obtained through an ESA Cat-1 project- using the BEAM software. Between 15 and 20 MERIS images corresponding to different tracks over Europe and South Africa acquired during a period of 10-days centred on 12 July 2006 were re-projected to MSG and composed to cover the SEVIRI geographical area.

SeaWiFS 2 km resolution. The SeaWiFS FAPAR products [6] are available at the JRC from 1997 till 2004 (http://fapar.jrc.it). Temporal FAPAR signatures over MODIS sites were obtained corresponding to the year 2004.

VEGETATION 1 km resolution. FAPAR products derived using VEGETATION normalised reflectance data in the context of FP5 CYCLOPES project were also used. This product is derived applying the inversion of a physical model (PROSPECT+SAIL) using a neuronal network technique [7]. The temporal resolution is 10-days with a composite period of 30-days. This product is available from 1999 to 2003 through the POSTEL website (http://postel.mediasfrance.org). The data used here cover Europe and Africa and correspond to the year 2003.

Difference maps, histograms and statistics (RMS, bias, r) among products are analyzed, in addition to temporal profiles. The comparison has been performed at continental, biome and pixel level. For inter-comparison of products at pixel level, BELMANIP sites were used for spatial comparison, whereas MODLAND sites were used for temporal analysis. Finally, a direct validation exercise is carried out by using a ground-truth dataset composed of VALERI high-resolution maps based on field information.

TABLE I. VALERI SITES OVER EUROPE, NORTH AFRICA AND SOUTH AMERICA SELECTED FOR DIRECT VALIDATION.

Europe	Cover type	Date	Lat (N)	Lon (E)
Järselja	Boreal F.	26/06/2003	58.29	27.26
LeLarzac	Grassland	12/07/2002	43.93	3.12
Rovaniemi	Forest	xx/06/2004	66.44	25.35
SonianF	Forest	28/07/2004	50.76	4.41
Rovaniemi	Forest	19/06/2005	66.45	25.35
Nezer	Pine forest	21/04/2002	44.56	-1.03
Nezer	Pine forest	xx/07/2000	44.56	-1.03

Africa	Cover type	Date	Lat (N)	Lon (E)
Gourma	Grassland	09/2000	15.32	-1.55
Wankama	Grassland	27/06/2005	13.64	2.63
Dahra S	Grass savannah	01/09/2004	15.37	-15.40
Dahra S	Grass savannah	10/10/2004	15.37	-15.40

America	Cover type	Date	Lat (N)	Lon (E)
Counami	Tropical forest	01/10/2002	5.34	-53.23

III. PRODUCT DESCRIPTION

The FAPAR product contains 3 datasets, comprising the FAPAR field, their respective error estimate and the quality flag. The product and its respective error estimate are produced using the HDF5 signed 16-bit integer variable. The values are stored in their digital form with a scale-factor (gain), which is applied to transform the stored values to their biophysical counterparts for analysis. The quality control variables are 8-bit unsigned integer measures without a gain or offset.

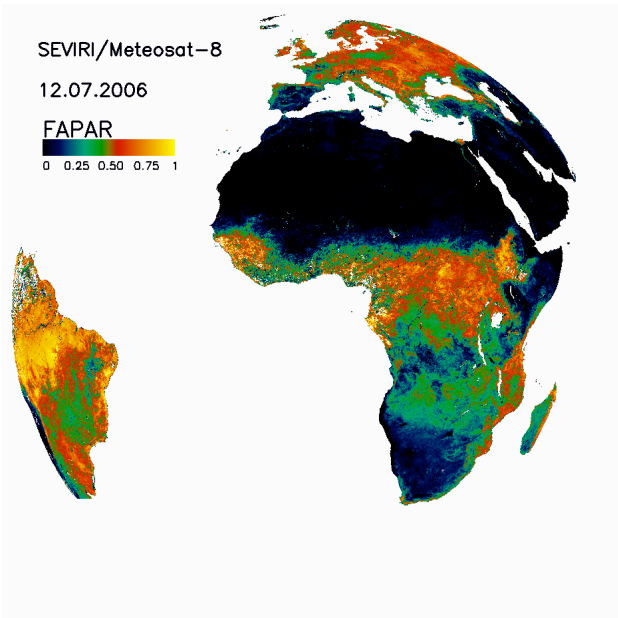

Figure 1.- SEVIRI FAPAR product for the 12th of July 2006.

Figure 1 shows an example of SEVIRI FAPAR product corresponding to summer. Figure 1 shows a coherent global spatial distribution of FAPAR retrievals, presenting highest values over equatorial forest, and zero values in desert areas. In general, the product presents good spatial coverage. The amount of gaps over Europe is important only in winter, mainly due to the presence of snow. Over Africa and South America gaps are related to unrealistic estimates associated to large BRDF errors, due to higher cloud occurrence or inadequate aerosol removal.

IV. VALIDATION

A. Inter-comparison at pixel level

In this section, results of the inter-comparison among FAPAR products at pixel level are shown (see results at global and biome level in [2]). Figure 2 shows scatter-plots of FAPAR products over BELMANIP sites located in Europe and South Africa SEVIRI geographical areas (see SEVIRI areas coverage in [4], [2]) for the 12th of July 2006. The best correlation can be observed between MSG and MERIS FAPAR products (both products are based on a statistical relationship among FAPAR and a suitable vegetation index). The RMS is of 0.08 with a correlation coefficient higher than 0.8. A positive bias of SEVIRI FAPAR estimates is found, especially for South Africa where MERIS FAPAR seems to provide low values (see [2]). The inter-comparison between MSG and CYCLOPES FAPAR products is also quite positive (RMS<0.1). However, the comparison with MODIS shows the largest discrepancies (RMS=0.15, r =0.65).

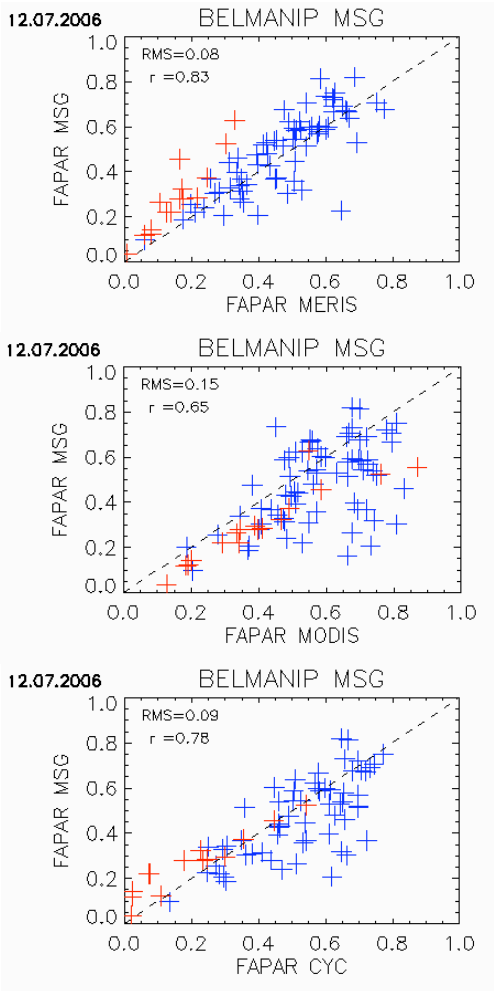

Figure 2 – Scatter-plots among different FAPAR products over BELMANIP sites for the 12th of July 2006. Blue color is used for sites of Europe, whereas red color is used for sites of South Africa.

Figure 3 shows some examples of FAPAR temporal signatures derived from differen products (MSG, MODIS, SeaWiFS and CYCLOPES). Despite the fact that only MSG and MODIS are concomitant, SeaWiFS and CYCLOPES are also displayed in order to show the phenology of the sites. As can be observed in figure 3, the MSG FAPAR prototype describes properly the phenology of the examples, in a good agreement with CYCLOPES and SeaWiFS products. However, MODIS FAPAR product is over-estimating the rest of the products, and probably the true value (e.g. Mongu site). The main drawback of the MSG products is the observed shaky profiles. This is due to short-time scale instabilities existing in the BRDF input data. In particular, in the volumetric (k2) parameter of the model. This instability can be

associated to the atmospheric correction, and thus is expected to be improved in the new version (more agresive cloud and shadow correction, better aerosol removal) as well as when merging MSG and MetOp data.

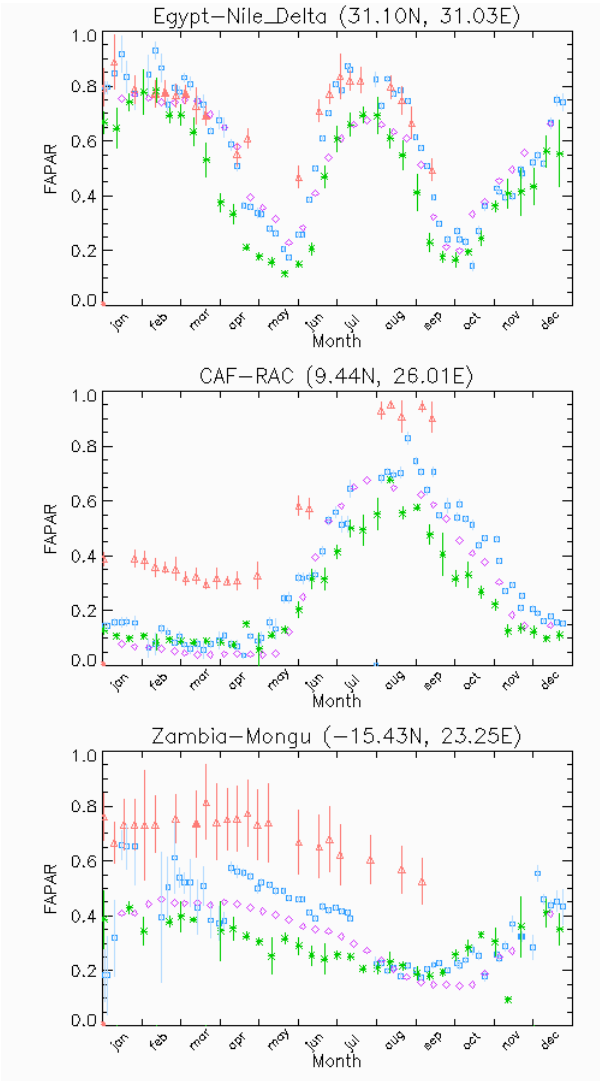

Figure 3.- FAPAR temporal signatures. Blue square for MSG (2005-2006). Red triangles for MODIS (2006). Green asterisk for SeaWiFS (2004) and violet diamond for CYCLOPES (2003).

B. Direct Validation

Finally, Figure 4 shows the result of the direct validation exercise. There is a good correlation among *in-situ* estimates and the MSG FAPAR product, with an overall accuracy of 0.2. The MSG FAPAR under-estimates the value of Nezer forest, which seems to be a problematic area. In general, there is a negative bias for MSG retrievals, which could be partly explained due to the largest size of SEVIRI footprint as compared with the VALERI sites (3x3 km).

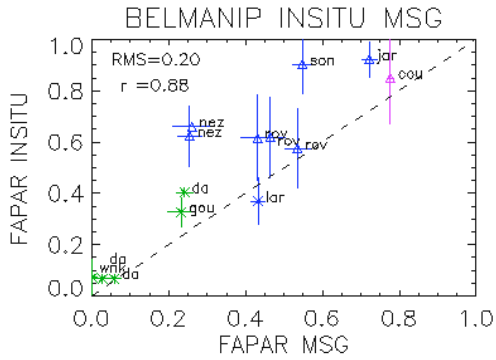

Figure 4.- Scatter-plots over VALERI sites of Europe (in Blue), North Africa (in green) and South America (in magenta). Grasslands are represented with symbol '+', forests with '⌂' and shrubs with symbol '□'. Vertical error bar is derived from the standard deviation of in-situ maps. 'da' is used for Dahra, 'gou' for Gourma, 'wnk' for wankama, 'cou' for Counami, 'nez' for Nezer, 'lar' for Larzac, 'jar' for Järvsleja, 'rou' for Rovaniemi and 'son' for Sonian forest.

CONCLUSIONS

A prototyping algorithm for retrieving FAPAR has been developed and applied to one year of MSG BRDF data since August 2005, and evaluated against a set of operational satellite FAPAR products (MODIS, MERIS, SeaWiFS, CYCLOPES), as well as with ground-truth information. MSG FAPAR temporal variations of statistic distributions show coherent results as a function of the biome type. The inter-comparison of the MSG FAPAR with different operational products shows the best consistency between MSG and MERIS. At a pixel level, the RMS over BELMANIP sites is lower than 0.1 between MSG and MERIS or CYCLOPES products, which demonstrates the competitiveness of the proposed algorithm. Thus, this method has been implemented in the LSA SAF system.

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