Report on the validation of MERIS TOA_VEG land products

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1. Introduction

1.1. Objectives of the validation process

The objective of this study is to provide some validation elements of the LAI, fAPAR and fCover products derived from the TOA_VEG algorithm {Baret, 2006 #4085}. The algorithm accepts as inputs the top of atmosphere reflectance values as derived from MERIS L1b images.

The validation is the process of assessing by independent means the accuracy of data products derived from the system outputs (Justice, Starr et al., 1998). This will provide the confidence intervals that ire mandatory for the users in a number of applications, including those based on a data assimilation approach. However, the validation is a very difficult task particularly regarding the extent of the products (the globe), the spatial resolution (from 300m to 1km), as well as the dynamics of the vegetation. Therefore, the results that will be presented here after could only be considered as a preliminary step before a more rigorous validation exercise. However, the results presented here after, although limited because of the restricted resources available, are approaching those acquired through the validation activity around the MODIS products which beneficiate from a far larger amount of support…

The validation is generally achieved through two main approaches:

- ***Direct validation*** which consists in the comparison of the products to ground measured values of the corresponding biophysical variables. Direct comparison with ground measurements have been achieved over a limited number of sites and dates. The few sites and dates that have been sampled during these last years provide high spatial resolution maps of the biophysical variables considered as derived from local ground measurements that have been up-scaled thanks to SPOT or TM high spatial resolution images. However, in addition to the question of the proper uncertainty associated to this ground validation exercise, the necessary small number of sites sampled questions the representativity of this sampling with regards to the global extent targeted. The same applies to the temporal sampling, particularly regarding the large seasonal variation observed for some vegetation types. In this study, we focused on three different sets of ground measurements that took place over a relatively wide range of situations.
- ***Indirect validation*** that should rather be termed 'evaluation' because it provides only insight into the relative values (from date to date, from place to place, from product to product) of the products. Inter-comparison would be very useful to complement the direct validation exercise by providing a far better sampling, both in space and time because it does not require any ground measurements. In addition, inspection of the smoothness of the time course of the biophysical products at a given site would also yield key information on the sensor and the performances of the algorithms with regards to cloud screening, atmospheric correction, BRDF effects, and soil background possible variations. In this study, we mainly focused on the comparison of our MERIS products to the corresponding ones derived from MODIS, CYCLOPES, ECOCLIMAP, and MERIS-MGVI products. Concurrently, when possible, the spatial and temporal consistency of the products will be also discussed.

1.2. The MERIS products considered

Because of the very little full resolution images available, most of this validation exercise was achieved over reduced resolution MERIS images. The report will thus be organized according to the several validation exercises completed, grouped into direct and indirect approaches. Table 1 shows the several validation exercises considered with the associated MERIS level data, resolution and atmospheric correction scheme.

MERIS level	Atmosphere correction	Input to the Biophysical algorithm	MERIS resolution	Use of BEAM	Direct validation	Indirect evaluation
L1b	coupled	TOA	RR	no	VALERI	BELMANIP
L1b	coupled	TOA	FR	no	Barrax	-

Table 1. The different products evaluated over the several validation exercises considered.

2. Direct validation

Two series of data sets have been used for this exercise. They will be described successively.

2.1. Validation over the Barrax site based on MERIS L1b FR data

2.1.1. The site

The study area selected for validation purposes in Spain is situated within a larger area in Albacete (Castilla-La Mancha), in which different validation activities have been developed (Martinez, Baret et al., 2004; Martinez, Garcia-Haro et al., 2004). Figure 1 shows the different scales used in the validation approach which comprise: (1) a small area selected (approx. 5□5 km^2) in order to achieve the ground measurements (Barrax test site and HyMAP flight lines) and (2) a larger area (SPOT image) appropriate to derive the high-resolution vegetation products.

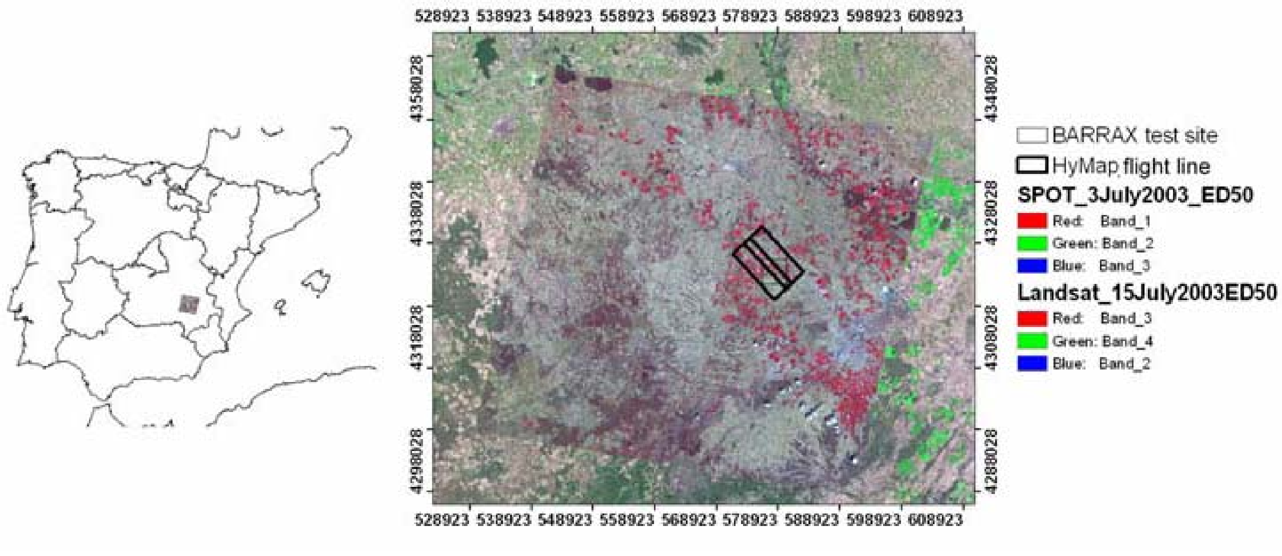


Figure 1. **Different scales used in the methodology. A Landsat-5 scene corresponding to 15th July is presented as background image, followed by a SPOT scene acquired on 3rd July, which agrees with the size of the high-**

resolution vegetation products. The HyMAP area and the Barrax test site, in which different ground measurements were collected, are also overlaid.

2.1.2. Ground measurements

The ground measurements were performed using the LAI2000 instrument. The Barrax site is made of fields irrigated with pivot systems that are large enough to contain at least one 'pure' full resolution pixel. The crops sampled included Corn, Alfalfa, Maize, Potatoes, vine, garlic, onions. Rather than using a scaling up method based on the use of a high spatial resolution image such as SPOT/HRV or Landsat, the 'pure' MERIS pixels were directly compared to the LAI2000 ground measurements performed over the corresponding fields.

2.1.3. MERIS products

Three L1b MERIS full resolution images from July were received for validation: one the 14^{th} of July 2003, the second the 14^{th} of July 2004, and the last one the 17^{th} of July 2004. The TOA_VEG algorithm was used here to estimate LAI values directly from the TOA reflectances.

2.1.4. Results

2.1.4.1. Range of values

The range of retrieved values for LAI, FCOVER, fAPAR and LAIxCab are shown in Table 1. Histograms of those parameters for the three images under study are shown in Figures 1, 2, 3 and 4.

The range of values is the expected. However for the 4 retrieved parameters, we can found negative values that are properly flagged as "out of range". In the case of LAI, FCOVER, and LAI.C_{ab} the number of negative values in the images is low (<1%). In the case of Fraction of Vegetation Cover retrievals there number of pixels with FCOVER < 0 is considerable. For instance, see Figure 5, which shows the negative values of FCOVER in the image of 2004_07_14.

	LAI_min	LAI_max	LAI Mean
2003_07_14	-0.20	6.48	0.64
2004_07_14	-0.17	6.51	0.69
2004_07_17	-0.11	6.62	0.65
	FCOVER min	FCOVER max	FCOVER Mean
2003_07_14	-0.17	0.92	0.12
2004_07_14	-0.31	0.94	0.15
2004_07_17	-0.08	0.87	0.13
	fAPAR min	fAPAR max	fAPAR Mean
2003_07_14	-0.09	0.90	0.24
2004_07_14	-0.08	0.92	0.29
2004_07_17	-0.07	0.89	0.26
	LAIxCab min	LAIxCab max	LAIxCab Mean
2003_07_14	-33.90	466.09	30.09
2004_07_14	-40.41	552.41	32.83
2004_07_17	-28.51	517.43	33.07

Table 2 LAI range retrieved vegetation parameters for the three images under study.

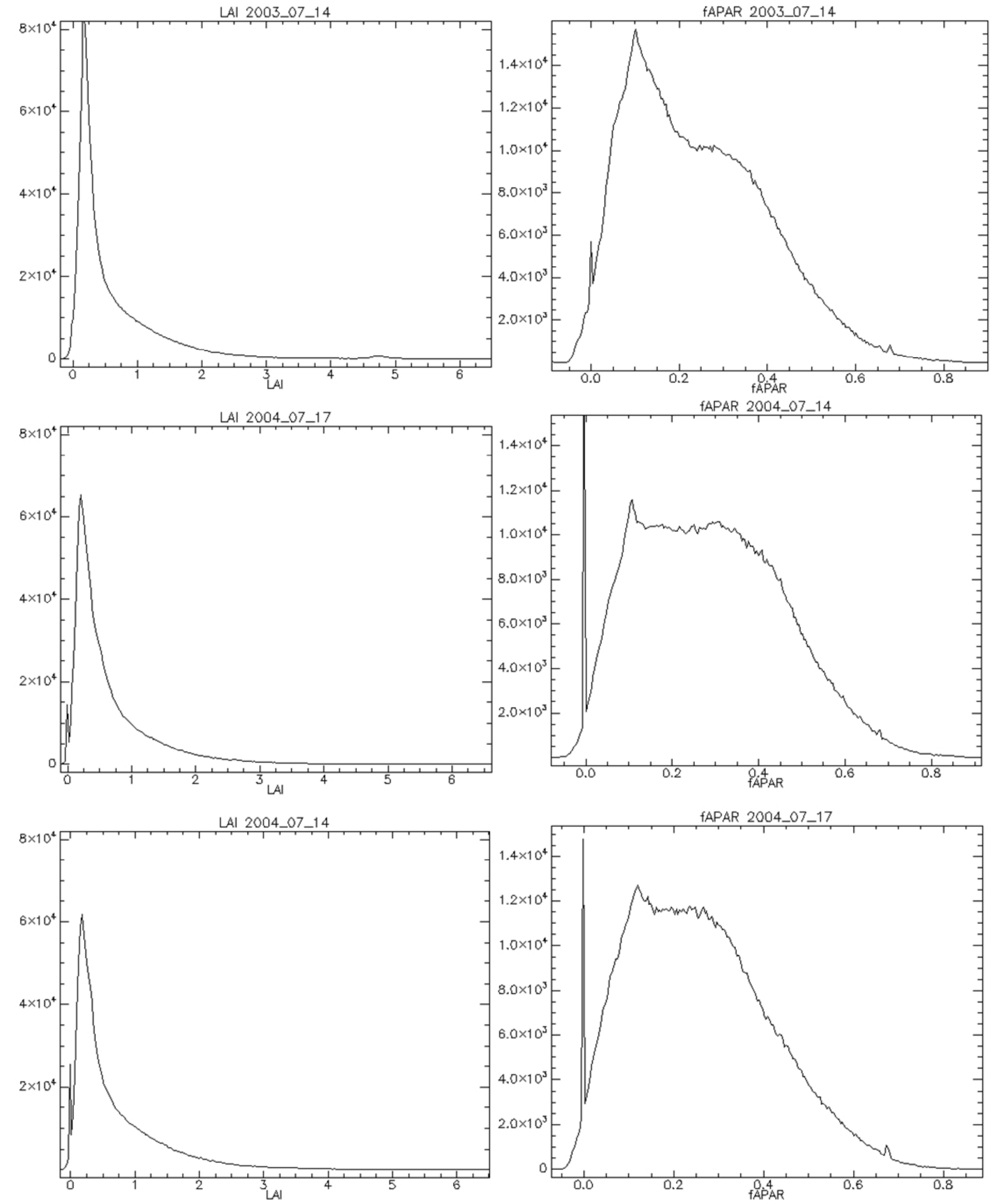


Figure 2. . LAI and fAPAR histograms

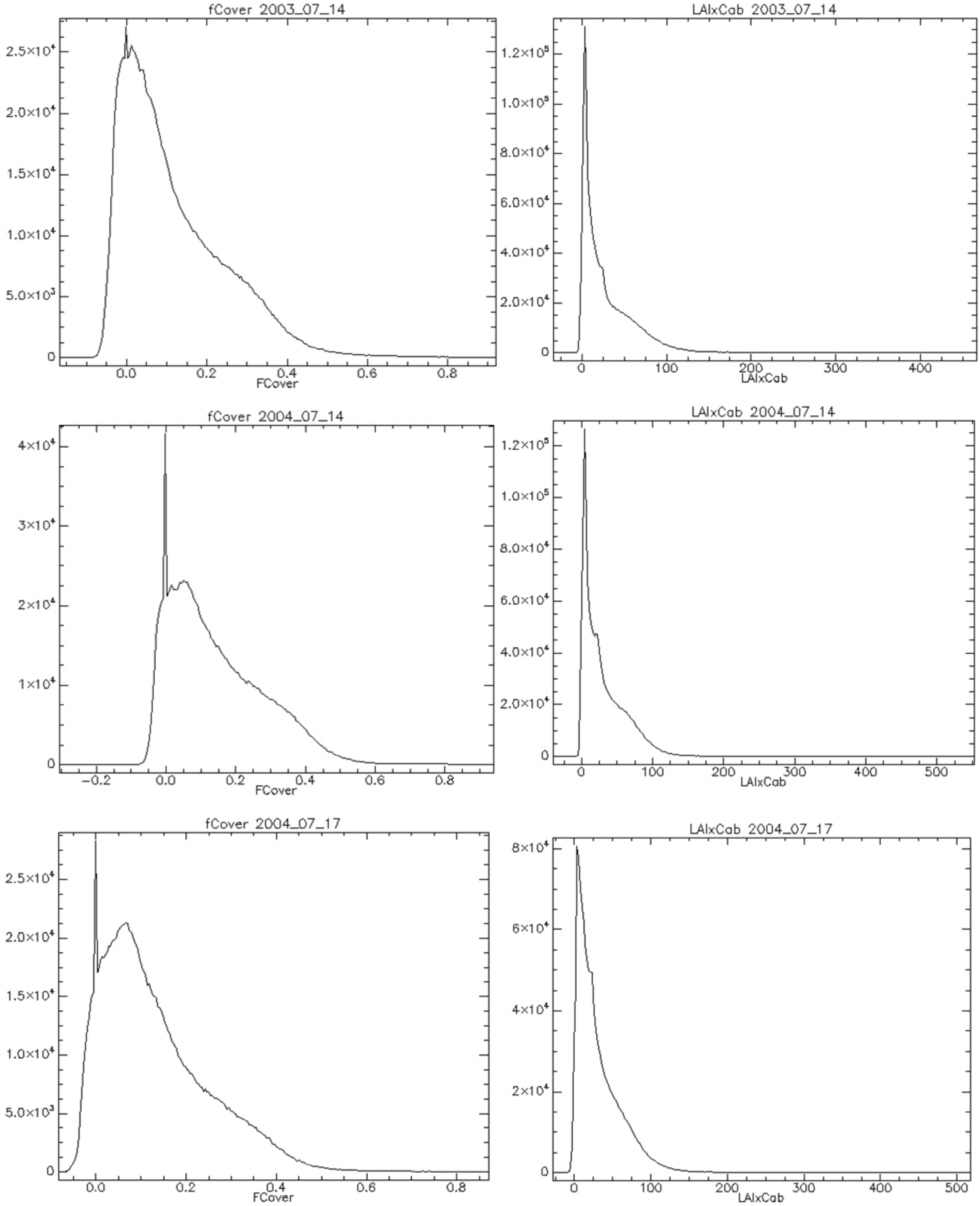
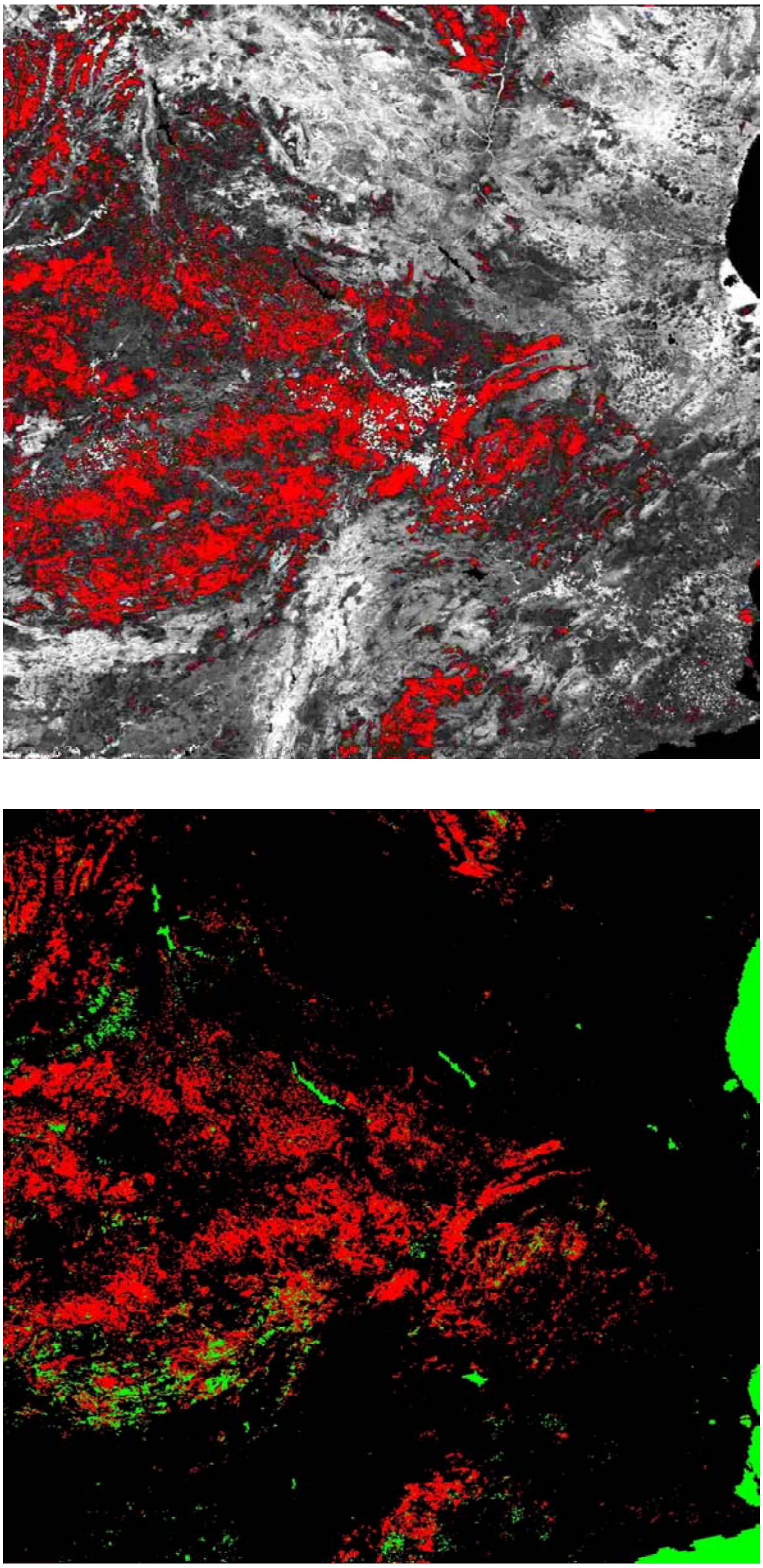


Figure 3. . fCover and LAI.C_{ab} histograms



A

B

Figure 4. A) Negative values of FCOVER for the image 2004_07_14. B) TOAVEG Flags for the image 2004_07_14. Red pixels correspond to flag value 16, “FCOVER out of range”.

2.1.4.2. Flags

The following table resumes the statistics of TOAVEG_FLAGS.

	FLAG VALUE	2003_07_14 % pixels	2004_07_14 % pixels	2004_07_17 % pixels
INVALID_INPUT	3	0.16	1.52	0.91
LAI_OUT_RANGE	8	0.02	0.03	0.01
FCOVER OUT OF RANGE	16	14.65	9.83	7.45
LAI AND FCOVER OUT RANGE	24	0.18	0.21	0.01
LAIxCAB OUT OF RANGE	32	0.04	0.06	0.07
LAI AND LAIxCAB_OUT_RANGE	40	0.00	0.00	0.00
FCOVER AND LAIxCAB OUT RANGE	48	0.67	0.44	0.69
LAI LAI.CAB AND FCOVER OUT OF RANGE	56	0.43	0.23	0.11
FPAR OUT OF RANGE	64	0.62	0.26	0.47
FCOVER AND FPAR OUT OF RANGE	80	0.57	0.28	0.32
LAI FCOVER AND FAPAR OUT OF RANGE	88	0.03	0.01	0.00
LAI.CAB AND FPAR OUT OF RANGE	96	0.01	0.00	0.02
FCOVER LAI.CAB AND FAPAR OUT OF RANGE	112	0.01	0.01	0.03
LAI FCOVER LAI.CAB AND FAPAR OUT OF RANGE	120	0.06	0.02	0.01
TOTAL FLAGGED PIXELS (%)		**17.46**	**12.91**	**10.11**
TOTAL LAI FLAGGED PIXELS (%)		**0.72**	**0.50**	**0.14**

Table 3. TOAVEG Flags

It is considerable the number of pixels for which Fraction Cover of Vegetation is out of range. In fact, almost all flagged pixels correspond to this case.

2.1.4.3. Spatial and Temporal consistence

No significant differences are expected among the three dates under study as all of them are acquisitions in mid-July. Figures 6 and Figure 7 show this temporal and spatial consistence between the three products for LAI and fAPAR respectively.

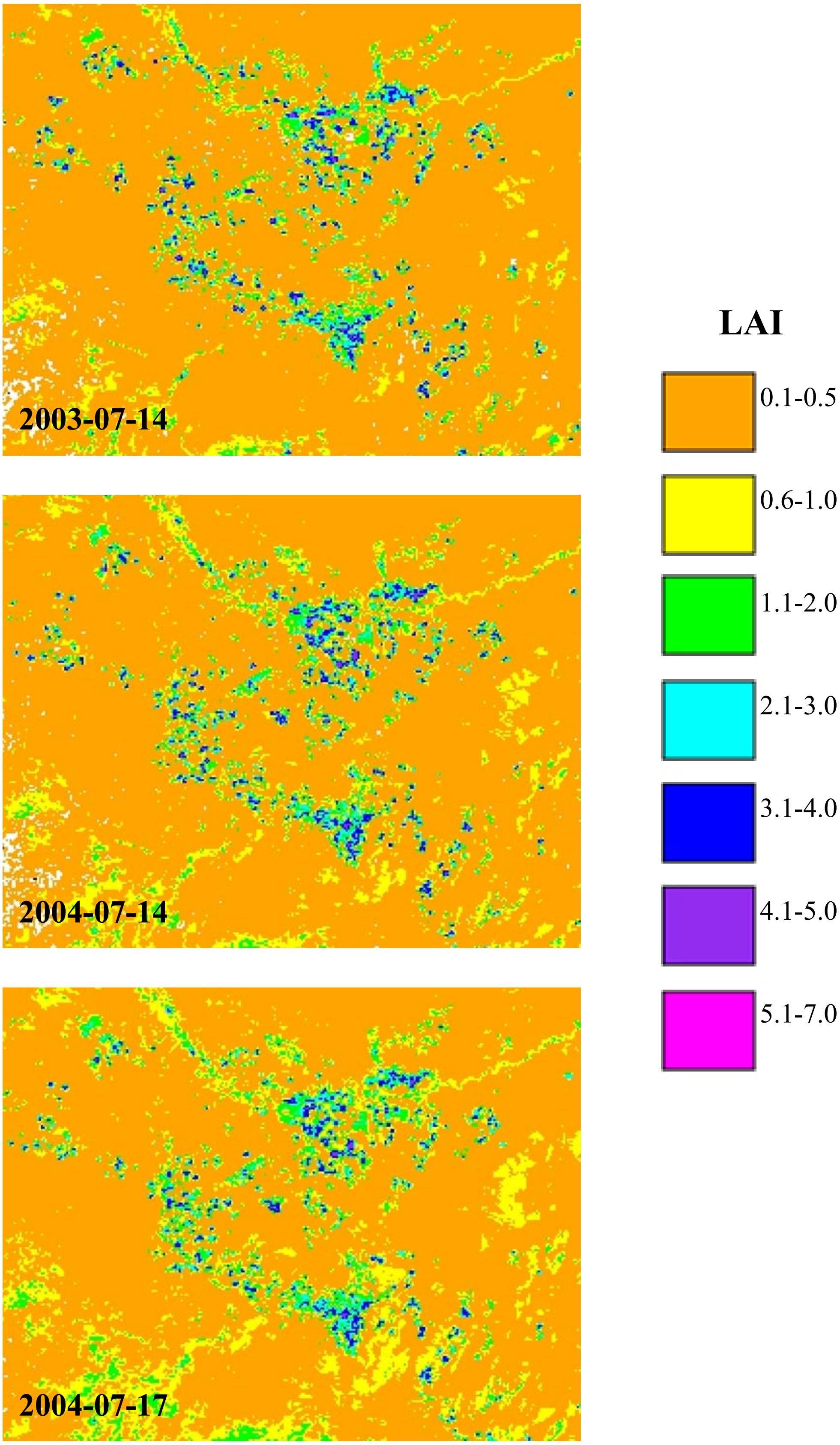


Figure 5. LAI maps for the area of Barrax

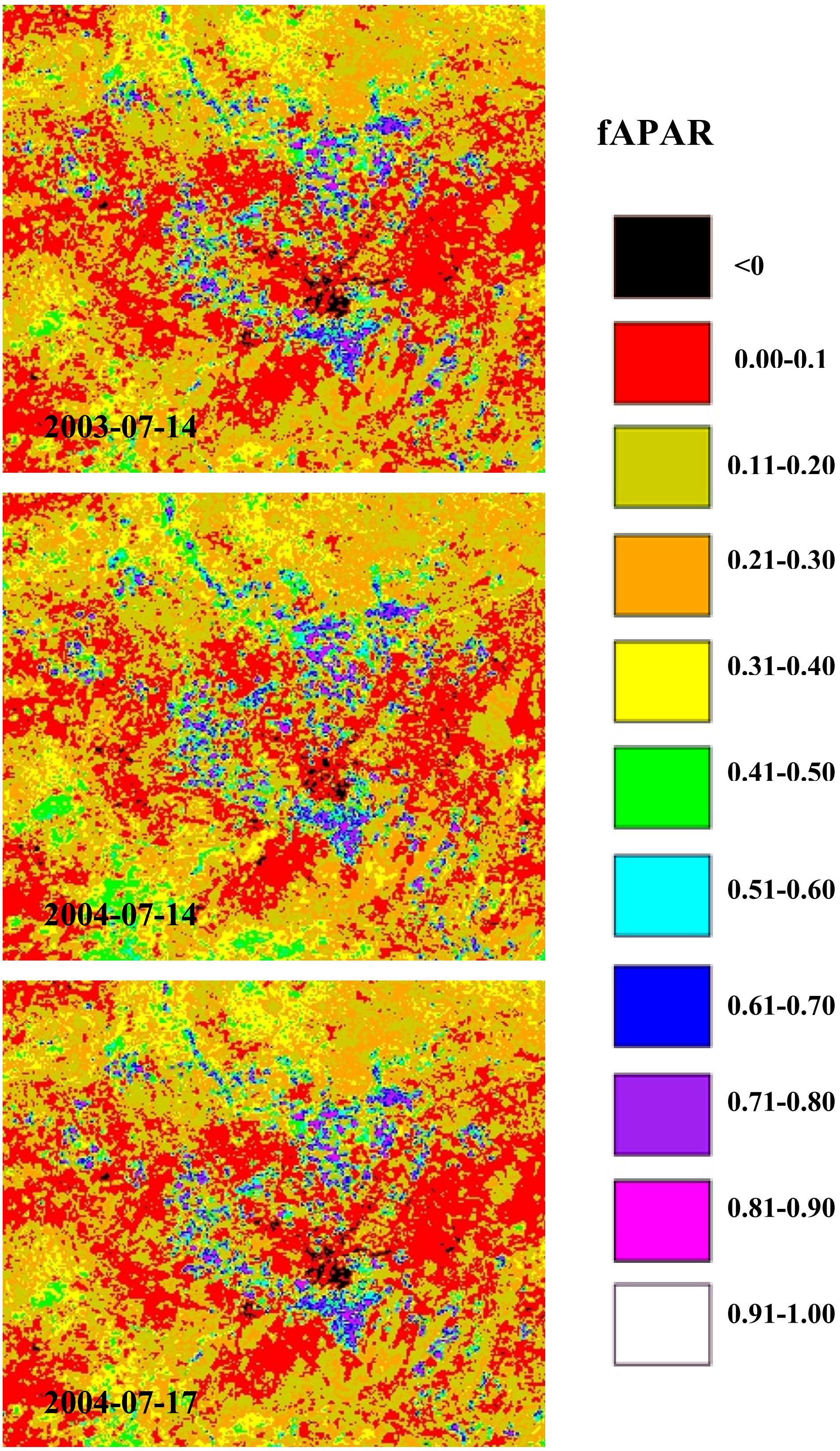


Figure 6. fAPAR maps for the area of Barrax

2.1.4.4. Relationships between parameters:

Figure 8 shows the relationships between the TOAVEG products.

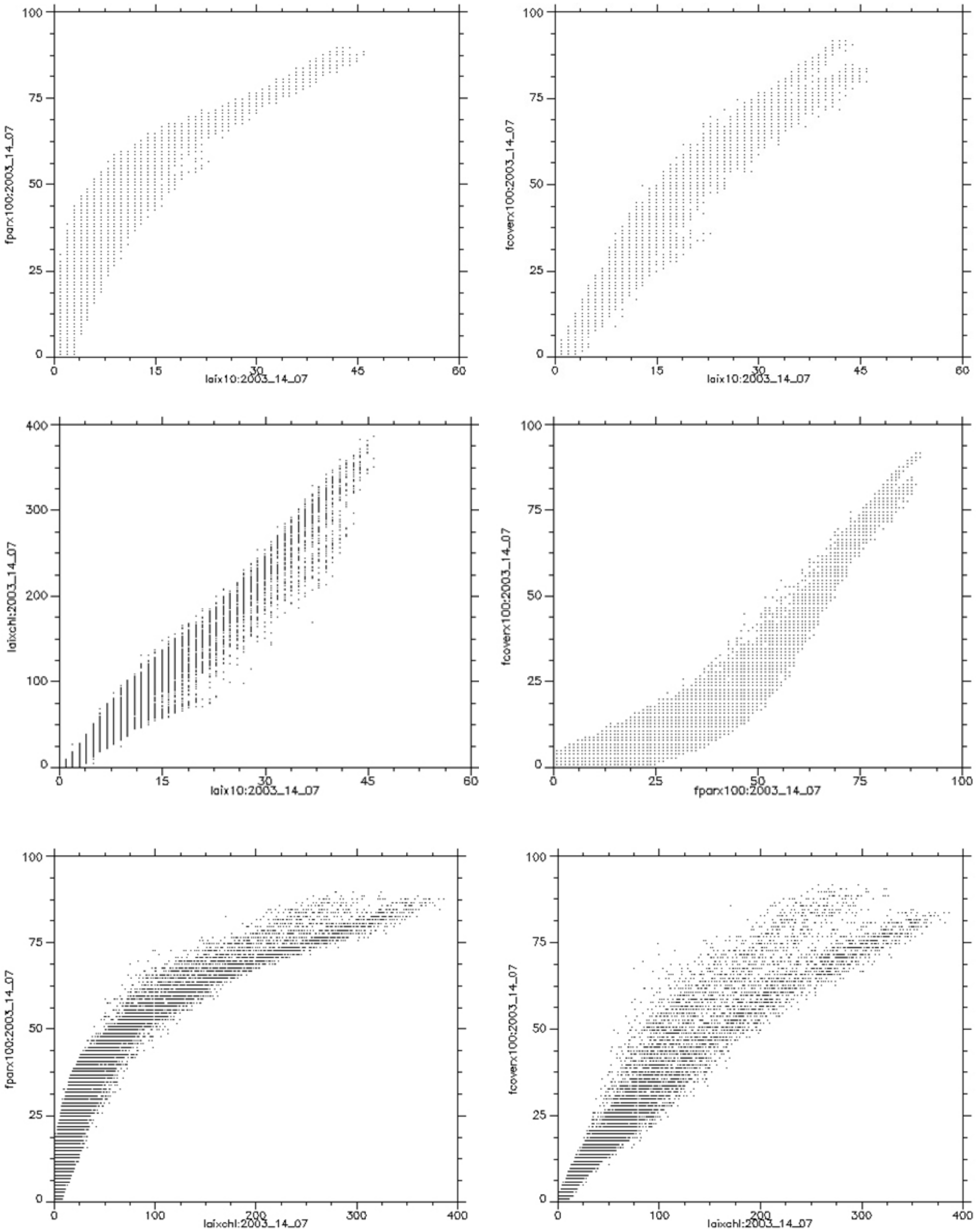


Figure 7. Relationships between the TOA_VEG products for the image 2003_14_07 in the area of Barrax

2.1.4.5. Validation with ground data

Data from the SPARC-2003 field campaign have been used to validate LAI and FCOVER products. Pixels have been manually extracted from the images for this preliminary validation. Methods for up-scaling field measurements should be use in order to do a more accurate validation.

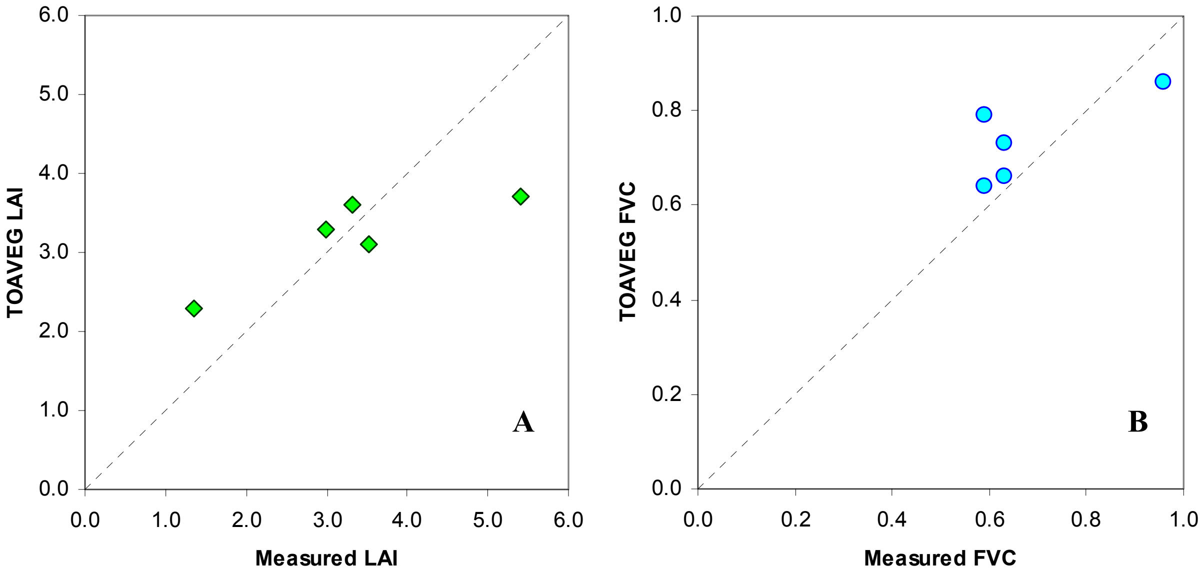


Figure 8. Validation with in-situ measurements a) LAI, b) FCOVER.

2.1.4.6. Validation with other products / other dates

A comparison has been done with MODIS product in July and the MERIS image in July 14, both during the year 2003. To this aim MERIS FR products have been degraded to MODIS resolution. TOAVEG LAI flagged pixels have been masked in MERIS LAI product. Pixels flagged as "bright" in MERIS image have been masked in both MERIS and MODIS products.

In this area the two products are globally consistent (see Figure 10), however some differences between are found:

a) In the Barrax area MERIS products gives higher values of LAI. This can be due to the differences in the spatial resolution of the product and also that we are comparing with MODIS monthly product.
b) In some regions MODIS product gives higher values (see Figure 11). Using the CORINE land use map (Figure 12) those pixels have been identified mainly as forest classes (Table 3). This should be further investigated in other regions.

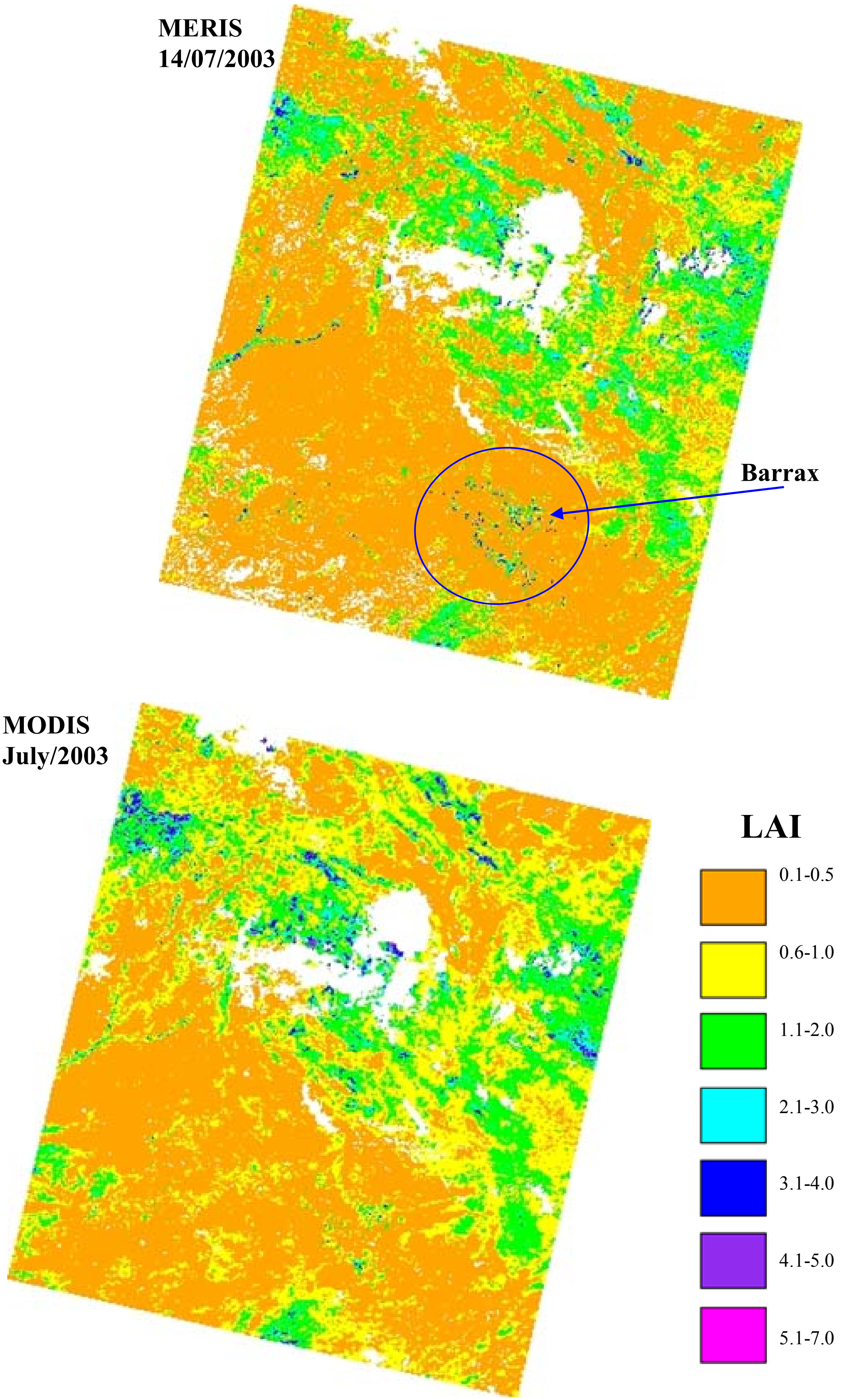


Figure 9. Comparison between MERIS (14/07/2003) and MODIS (July) LAI products**.**

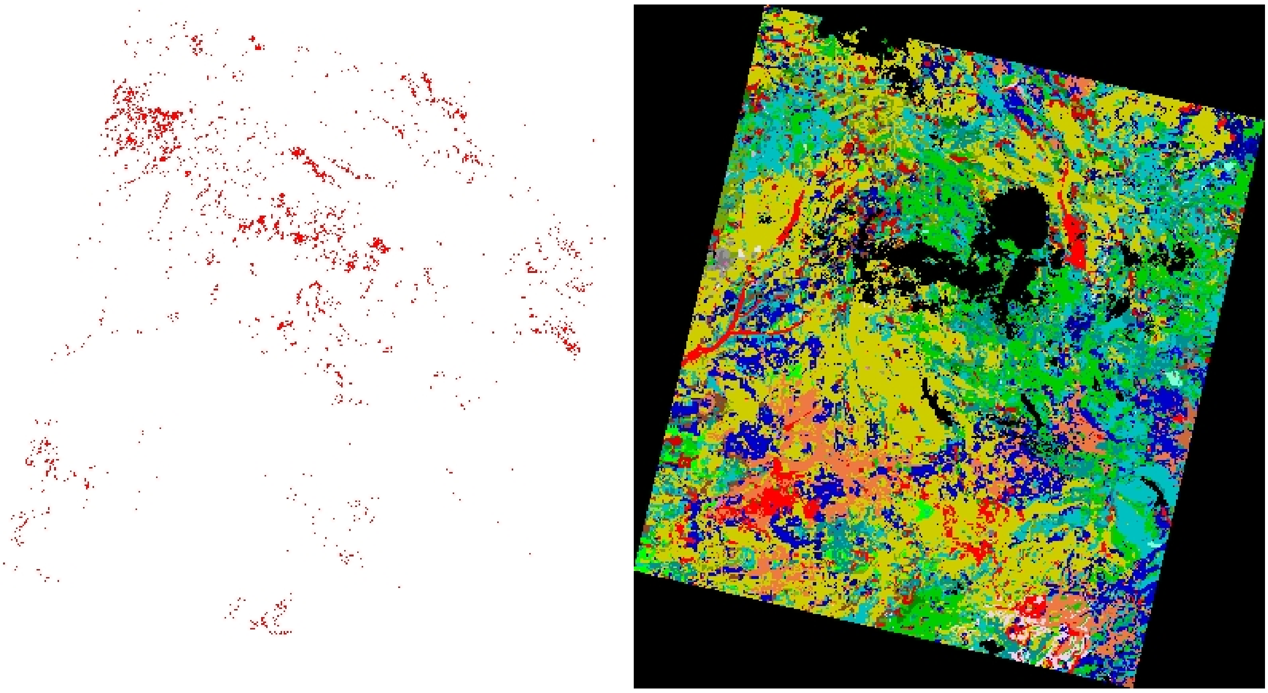


Figure 10. Pixels where MODIS July product is higher than MERIS 14/07 product (left). CORINE land use map (right)

CORINE CLASS	% pixels
Non-irrigated arable land	6
Permanently irrigated land	3
Broad-leaved forest	14
Coniferous forest	42
Mixed forest	4
Natural grassland	2
Sclerophyllous vegetation	14
Transitional woodland-scrub	12

Table 4. Classes where MODIS LAI is higher than MERIS LAI (between 1 and 5).

2.2. Validation over the VALERI sites based on MERIS L1b RR data

VALERI is a validation activity coordinated by INRA Avignon and mainly funded by CNES. It mainly consists in the development of a network of sites that will be sampled according to a dedicated methodology to derive high spatial resolution maps of the corresponding biophysical variables: LAI, fAPAR and fCover. A description of the sites, methods and high spatial resolution biophysical maps are available at the following web site: www.avignon.inra.fr/valeri. In this validation exercise, only the sites sampled in 2003 will be considered.

2.2.1. The sites

The selected sites must fulfill a number of criteria to enable the provision of accurate estimates of biophysical variables from ground measurements:

- ***Size***: The spatial resolution of the sensors considered ranges from few hundred of meters (MODIS, MERIS) to a few kilometers (MSG) with most of the sensors being around 1 km² (AVHRR, VEGETATION, SEAWIFS). Therefore, the validation sites must cover at least a 3×3 km² area.
- ***Homogeneity***: it should be relatively homogeneous at the kilometer scale, i.e. the biophysical variable value as well as the corresponding radiometric values may change only marginally when shifting the position of a 1km² pixel within the 3×3 km² square.
- ***Topography***: the area should be relatively flat to simplify the interpretation both of the ground measurements and the satellite data.
- ***Biome type***: the selection of sites is made in order to sample the variability of biomes and conditions encountered over the Earth's surface. Obviously this is also governed by the availability of local support for the measurements.

The VALERI sites that are used in this validation exercise correspond to 2003 campaigns, which are concomitant with the presence of the MERIS sensors (Table 5). They correspond to a relatively large range of variation in terms of vegetation type and amount.

Site	Country	Vegetation Type	Latitude	Longitude	LAI	fAPAR	fCover
Barrax	Spain	Cropland	39.057173	-2.104382	0.82	0.22	0.21
Concepcion	Chili	Mixed Forest	-37.463833	-73.468057	3.10	0.77	-
Fundulea	Romania	Cropland	44.405563	26.585521	1.06	0.64	0.29
Haouz	Morocco	Cropland	31.661545	-7.601216	1.16	0.49	0.36
Hirsikangas	Finland	Boreal forest	62.644175	27.011225	2.55	-	0.65
Larose	Canada	Boreal forest	45.380646	-75.217258	3.36	0.89	0.86
Turco	Bolivia	Sparse vegetation	-18.235766	-68.191440	0.06	0.04	0.04

Table 5. VALERI sites used for the MERIS product validation. The average value of each biophysical variable (level 1 VALERI map) is provided. Some data are missing due to problems in the processing.

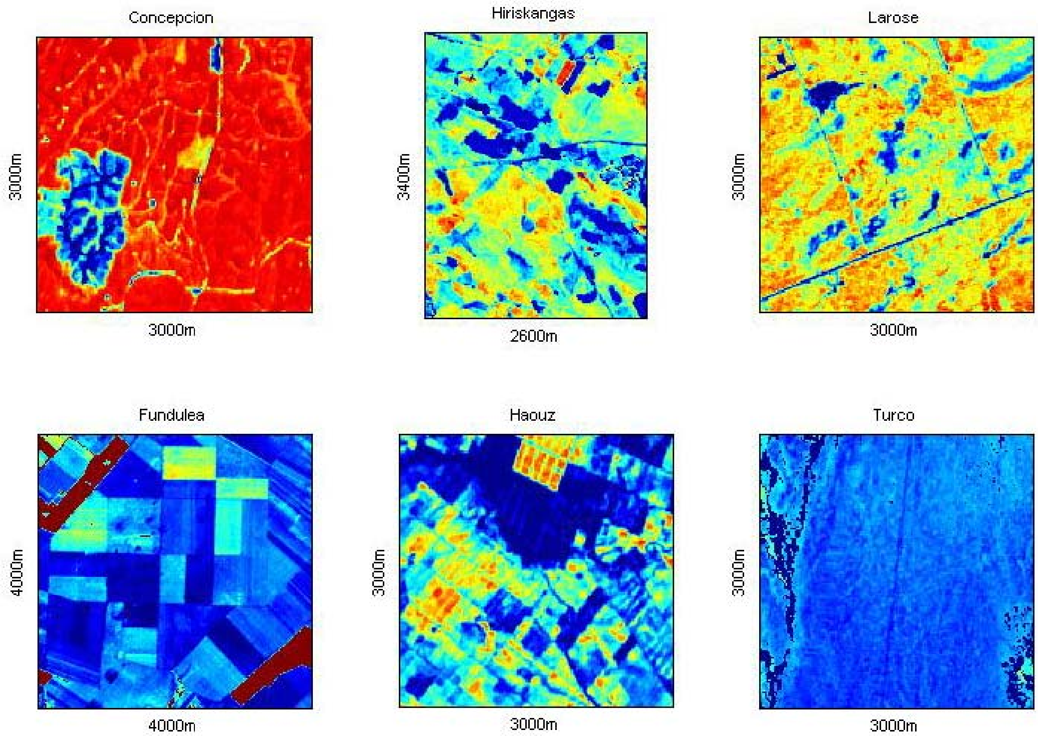


Figure 11. LAI maps obtained for 6 VALERI sites in 2003. For the three upper graphs (forest sites), blue corresponds to LAI=0, Dark Red to LAI=6. For the two crop sites (Haouz, Fundulea), blue corresponds to LAI=0, red to LAI=4. For Turco (very sparse vegetation), LAI varies between 0 and 0.3.

2.2.2. The ground measurements

The sites are approximately 3×3 km² area and preferentially located on relatively flat terrain. The VALERI field sampling approach at a site is based on a nested sampling design. At the site level, 30 to 50 elementary sampling units (ESU) are distributed using an adaptative sampling scheme with the objective to provide a good representativity of the variability of surface types (first order criterion), while ensuring (second order criterion) a relatively even spatial distribution allowing the computation of geo-statistics. The ESU represents an area of few tenths of meters, well geo-referenced, to be associated with few pixels of high spatial resolution images acquired by Landsat, SPOT or IKONOS sensors. The ESU is sampled by taking 10 to 24 measurements organized either in a fixed "square" or "cross" pattern within a 20m diameter area. Local measurements are generally performed using gap fraction measurements either based on the LAI2000 instrument or on hemispherical photography (Weiss, Baret et al., 2004). The up-scaling process is mainly based on the calibration of empirical transfer functions. They are statistical relationships established over all or part of the ESUs, and relating directly the top of atmosphere high spatial resolution signal to the average LAI value of the corresponding ESU. An automatic classification is applied to the high spatial resolution satellite image to possibly separate very different surface types. A number of transfer functions are computed, based on multiple linear regressions applied to the combinations of the bands available, with or without log transformation to possibly capture non linearities. Classical vegetation indices such as NDVI and SR are also used. Robust regression is employed to discard or give a small weigh to possible outliers. The performances of each transfer function are evaluated by cross validation, allowing to eventually select the best one. Finally, collocated cokriging is applied to account for the actual position of the measurements. Although this final process did not modify dramatically the resulting LAI high spatial resolution image, it allows computing some error terms associated to the LAI values aggregated at the medium spatial resolution of the satellites to be validated. The whole process from ground measurements to the final high spatial resolution map is made within a traceable way. All intermediate results and steps are described within the ground measurement. The full methodology of VALERI is fully described in (Baret, Weiss et al., 2005). For each site, a processing report is available at http://www.avignon.inra.fr/valeri.

Figure 11 shows the different VALERI level 1 LAI maps at high resolution (SPOT=20m) for all the sites except Barrax. The range of LAI values and thus heterogeneity for each site is very different from site to site: Concepcion, Barrax, Haouz, low: Turco. Figure 12 presents an example of the results obtained for the three variables obtained on the Barrax site.

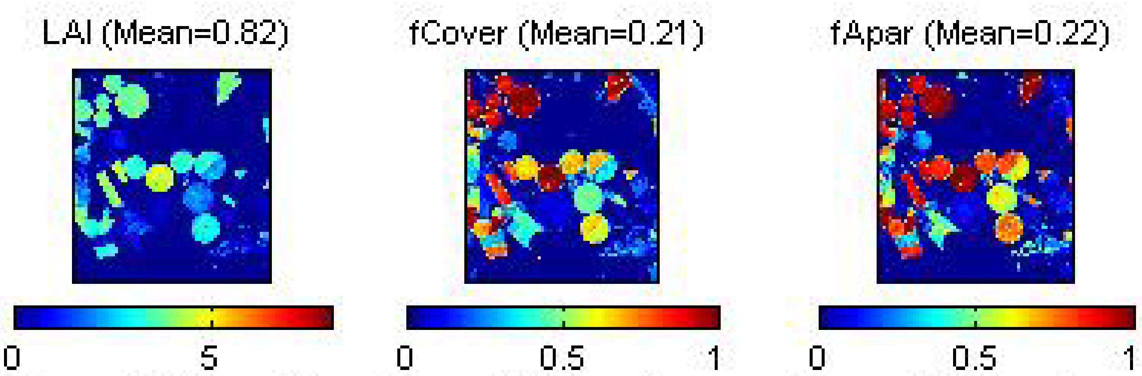


Figure 12. VALERI biophysical variable maps obtained on the Barrax site (cropland).

2.2.3. Satellite products considered

In this direct validation exercise, we included the products coming from several sensors and algorithms:

- **MERIS_TOA_VEG.** This corresponds to our algorithm based on the fully coupled approach using L1B RR TOA reflectance values (Baret, Pavageau et al., 2004).
- **MODIS**. This corresponds to Collection 4 of MODIS 1km 8 day composite products (Knyazikhin, Martonchik et al., 1998).
- **CYCLOPES**. This corresponds to the products derived from the VEGETATION sensor. Version 2 of the algorithm is shown.
- **ECOCLIMAP**. This corresponds to a climatology of LAI values derived by (Masson, Champeaux et al., 2003).
- **MERIS MGVI**. This is an estimate of fAPAR values proposed by (Gobron, Pinty et al., 2000) and computed directly from the L1B RR products.

For all these products, linear interpolation was applied to get the product values corresponding to the date of the ground measurements. In most cases the interval between the closest actual satellite product and the date of ground measurements was smaller than 10 days.

Although it would have been possible to achieve a comparison at the pixel level, the uncertainties in co-registration as well as the poorly known point spread function makes this exercise quite difficult. In this preliminary validation process, we thus used the average LAI, fAPAR or fCover values over the 3×3 km² area.

2.2.4. Results

The LAI products will first be investigated. The MERIS_TOA_VEG_V3 product shows a reasonable agreement with the ground measurements. Some underestimation is however noticed for the coniferous forests characterized by a higher LAI value. The MODIS products seems to show the opposite behaviour, where the LAI for these coniferous sites are overestimated. The same applies to the climatology values derived from ECOCLIMAP.

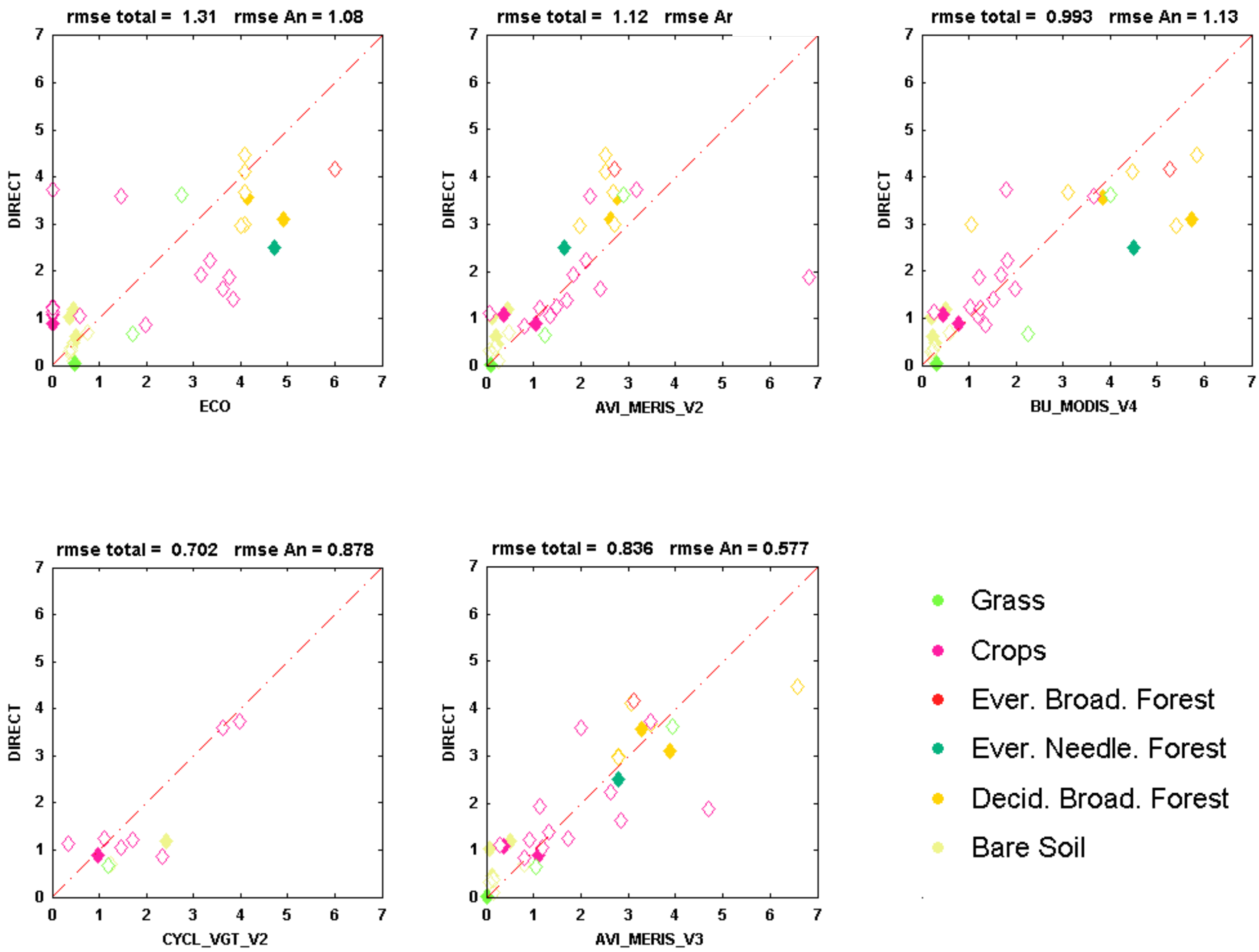


Figure 13. Comparison between the LAI values derived from ground measurements (DIRECT) to the corresponding satellite products. It includes ECOCLIMAP, MODIS (1km collection 4 8 days composite), CYCLOPES (V2 VEGETATION, 1 km, 10 days composite), and our MERIS_TOA_VEG_V3 algorithm. Several VALERI and BIGFOOT sites are used.

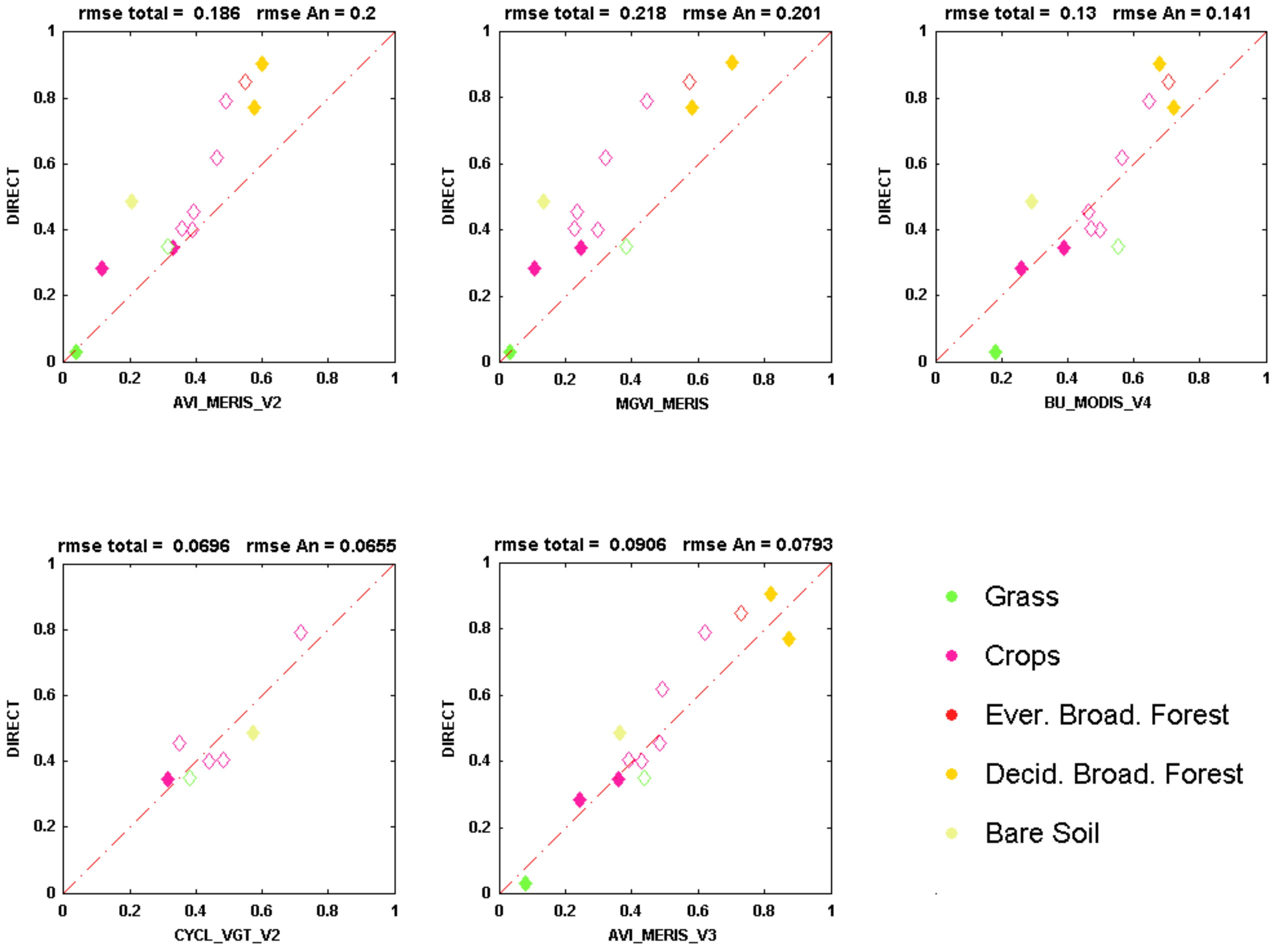


Figure 14. Comparison between the fAPAR values derived from ground measurements (DIRECT) to the corresponding satellite products. It includes MODIS (1km collection 4 8 days composite), CYCLOPES (V2 VEGETATION, 1 km, 10 days composite), MGVI and our MERIS_TOA_VEG_V3 algorithm. Several VALERI and BIGFOOT sites are used.

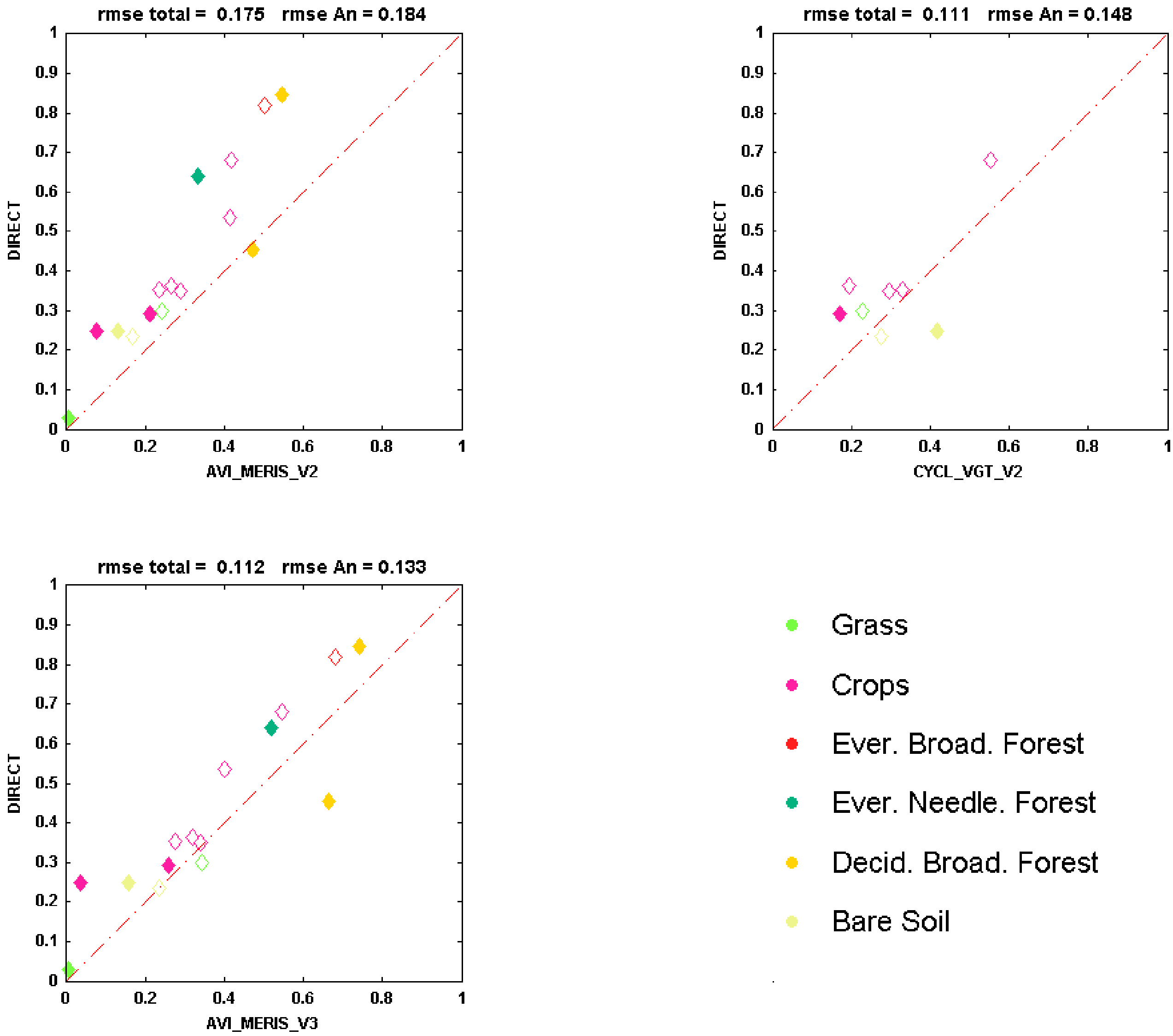


Figure 15. Comparison between the fCover values derived from ground measurements (DIRECT) to the corresponding satellite products. It includes CYCLOPES (V2 VEGETATION, 1 km, 10 days composite), and our MERIS_TOA_VEG_V3 algorithm. Several VALERI sites are used.

PRODUCTS	LAI	fAPAR	fCover
ECOCLIMAP	1.31	-	-
MERIS TOA_VEG_V2	1.12	0.19	0.18
MODIS	0.99	0.13	-
CYCLOPES_V2	0.70	0.07	0.11
MERIS TOA_VEG_V3	**0.84**	**0.09**	**0.11**
MGVI	-	0.22	-

Table 6. Comparison of the RMSE of the several products to VALERI ground measurements.

The RMSE values characterizing the agreement between VALERI ground level derived LAI and fAPAR values and the satellite products were computed (Table 6). It shows that our TOA algorithm performs reasonably well as compared to standard other products. However, this validation exercise, although significant, does not include a sufficiently large enough set of sites to draw clear conclusions. In addition, the ground measurements are also associated with some error, presumably around 0.1 for fAPAR and 15% for LAI (relative values). These results show however that the MERIS_TOA_VEG products are in the same accuracy range as the MODIS one, and apparently better than the MERIS MGVI product, which is the official MERIS product that has actually received very little direct validation.

3. Indirect evaluation methods

3.1. Inter-comparison over BELMANIP based on MERIS L1b RR data

3.1.1. The sites used

Several sites (26) have been selected for this inter-comparison. They span over very different locations, vegetation types and amount (Table 7). The 26 sites selected belong to the BELMANIP network of sites established by CEOS and dedicated to the sensor inter-comparison (Baret, Morissette et al., 2005). Our 26 sites correspond to the VALERI 2001, 2002 and 2003 sites as well as to the AERONET network of sites that are used by D. Béal to validate the aerosol optical thickness algorithm which is developed for MERIS at INRA. In this inter-comparison exercise, the size of the sites considered was 3×3 km².

# Name	Origine	Latitude	Longitude
Concepcion	VALERI2003	-37.4700	-73.4700
Larose	VALERI2003	45.3800	-75.2200
Haouz	VALERI2003	31.6600	-7.6000
Turco	VALERI2003	-18.2400	-68.2000
Barrax	VALERI2003	39.06	-2.10
Fundulea	VALERI2003	44.4100	26.5700
Hirsikangas	VALERI2003	62.5200	27.0300
Banizoumbou	AERONET	13.5333	2.6500
Columbia_sc	AERONET	34.0167	-81.0333
Bordeaux	AERONET	44.7171	-0.7693
Jabiru	AERONET	-12.6500	132.8833
Ouagadougou	AERONET	12.1833	-1.3833
Moldova	AERONET	47.0167	28.7500
Avignon-Alpilles	AERONET	43.8000	4.7000
Fontainebleau	AERONET	48.4000	2.6667
Counami	VALERI2002	5.3400	-53.2400
SierraCincua	VALERI2002	19.6700	-100.2800
Laprida	VALERI2002	-36.9900	-60.5500
Gourma	VALERI2001	15.3333	-1.5333
ZhangBei	VALERI2002	41.2800	114.6800
AekLoba	VALERI2001	2.6333	99.5800
Sud-Ouest	VALERI2002	43.5000	1.2300
Romilly	VALERI2000	48.3300	3.8000
Gilching	VALERI2002	48.0500	11.2000
Larzac	VALERI2002	43.9500	3.1333
Puechabon	VALERI2001	43.7167	3.6500

Table 7. Sites used for the inter-comparison of the products derived from different sensors. Latitude and longitude are provided in the plate carrée projection (WGS84 datum)

3.1.2. The products

3.1.2.1. MERIS

The global archive of MERIS L1b RR products delivered by ESA to MEDIAS-France within the CYCLOPES project was exploited for this purpose. Extracts over 26 sites was achieved for all the images available during year 2003. The L1B RR products were computed at the pixel level, and then projected over a reference grid (the CYCLOPES plate carrée grid). Then, LAI, fAPAR and fCover products were computed using our TOA_VEG algorithm based on the fully coupled approach (Baret, Bacour et al., 2005). Finally, the values were averaged over the 3×3 km² area for each sites.

3.1.2.2. MERIS fAPAR/MGVI

MERIS MGVI. This is an estimate of fAPAR values proposed by (Gobron et al., 2000) and computed directly from the L1B RR products.

3.1.2.3. MODIS

The MODIS products that are used in this validation exercise are the ones issued from collection 4: LAI-fAPAR weekly data (MOD15 product), acquired from the terra platform. The spatial resolution is 1km. The MODIS algorithm consists of a main procedure based on the inversion of 3D radiative transfer models using look-up-tables. If this algorithm fails, a back-up algorithm is triggered to estimate LAI and fAPAR using vegetation indices. The algorithm is based on land cover classification.

The data have been ordered on the EOS MODIS gateway for year 2003 to be concomitant with MERIS data availability (http://edcimswww.cr.usgs.gov/pub/imswelcome/). The flagged values, as well as the use of the back-up algorithm or main algorithm have been pointed out in the extraction of the data. The data have been re-projected in the lat-lon/WGS84 projection (plate-carrée) using the MODIS re-projection tool available at http://edcdaac.usgs.gov/landdaac/tools/modis/index.asp .

3.1.2.4. CYCLOPES

The CYCLOPES project funded by the European Commission and the French Ministry of research aims at providing high level biophysical products (albedo, LAI, fAPAR, fCover) to users from the fusion of coarse resolution sensors data (VEGETATION, POLDER, MERIS, MSG, AVHRR) (www.avignon.inra.fr/cyclopes). Among the several products available, we used the 1km 10 day composite LAI, fAPAR and fCover products derived from the VEGETATION sensor during 2003. The products considered here correspond to the first version. The principles of the algorithm are briefly described in the following:

- Radiometric calibration and geometric projection onto a plate carrée grid of 1/112° resolution
- Cloud screening using the basic thresholds used in the official VGT algorithm
- Atmospheric correction based on climatology for water vapour, pressure and aerosol type and optical thickness
- BRDF normalization based on the Roujean model over a temporal window of ±15 days with more weight on the central values, a procedure to eliminate outliers, and accounting for prior knowledge on the kernel coefficients.

- A biophysical algorithm based on the approach proposed by (Roujean and Lacaze, 2002). The fCover is derived from the difference vegetation index computed from the first kernel coefficients (reflectance at nadir with a sun at nadir). The LAI is derived from the fCover assuming a spherical distribution of the leaf inclination. fAPAR is derived from the NDVI vegetation index computed from the reflectances as observed in the back-ward direction.

The data were provided thanks to MEDIAS-France by extraction of the sites over the CYTTARES network (Derive, Bacour et al., 2003) for year 2003 which was the starting point of the BELMANIP network of sites (Baret, Morissette et al., 2005). However, at the one kilometre resolution, only Europe was available within this first version of the products.

3.1.2.5. ECOCLIMAP

ECOCLIMAP was primarily developed by (Masson, Champeaux et al., 2003) to provide the surface variables fields that are required by the Soil-Vegetation-Atmosphere Transfer models (SVATs) used for climate modelling: *LAI*, *fCover*, surface albedo, the roughness length, the minimal stomatal resistance and the surface emissivity. ECOCLIMAP combines two types of global classifications:

- A global biome classification corresponding to the main land surface types. Both the University of Maryland dataset (Hansen, Defries et al., 2000) and the International Geosphere-Biosphere Program Data and Information System (Loveland, Reed et al., 2000) were used. These classifications are available at a 1-km sampling interval and registered over a Digital Chart of the World for the water mask. However, both the CORINE Land Cover at a 250-m sampling interval (anonymous, 1993) and the Pan-European Land COver Monitoring (PELCOM) at a 1-km resolution (Mucher, Champeaux et al., 2001) maps were respectively privileged over Europe and Scandinavia, in order to compensate the deficiencies of the two previous global classifications in these areas.
- A world climate distribution map derived from the climate map of (Koeppe and De Long, 1958) over the globe, improved by the FIRS database (Forest Information from Remote Sensing) using a higher spatial resolution over Europe (Anonymous, 1995).

The combination of the 15 land cover with the 16 climate types enables to distinguish 240 potential surface classes out of which only 208 were actually represented. Classes were sometimes merged together when their biome composition and NDVI profile derived from AVHRR were similar. Note that Europe was described here with larger details and corresponds to 93 classes as compared to the 125 used for the rest of the world. Each of the 218 classes was assumed to be a mixture of 15 elementary components. For sake of simplicity, we proposed to group them into 7 main components: (1) water bodies (including inland water, seas and oceans), (2) bare surface (including dense urban built up, rocks, deserts and permanent snow and ice), (3) conifers, (4) evergreen-broadleaf, (5) deciduous broadleaf, (6) crops, and (7) grass. This distinction of surface and vegetation type is important for validation and inter-comparison purposes because it is strongly related to canopy structure.

The *LAI* range of variation for each surface class was computed using the composition of elementary components and the corresponding *LAI* values derived from the literature. The temporal evolution was derived thanks to NOAA/AVHRR monthly NDVI composite at 1 km resolution for year 1992-1993 over the globe, and 1997 for Europe. More details could be found in (Masson, Champeaux et al., 2003). This climatology was evaluated by comparison to local *LAI* measurements reported in the literature, as well as to POLDER *LAI* products (Roujean and Lacaze, 2002) and ISLSCP *LAI* data. Results showed reasonable level of consistency for the ECOCLIMAP *LAI* climatology.

3.1.3. Results

3.1.3.1. Temporal consistency between products

The temporal consistency as described by the smoothness of the LAI or fAPAR temporal profiles is a good way to asses the performances of a product. The temporal profiles of LAI, fAPAR and fCover products from several sensors were plotted for each of the 26 sites considered here. shows an example of such temporal profiles, the other 26 profiles being posted in the annexe. It would have been tedious to comment each individual profile, because apart from the smoothness character of the profile, other criterions could have been used particularly looking at the phasing and amplitude of the vegetation dynamics.

We therefore preferred to concentrate on the temporal smoothness aspect. For this purpose, a classification of each profile was done into 4 categories according to their visual aspect: smooth profile, ½ smooth, shaky, and profile with few 'accidents'. Although this classification is subjective, it gives some indication of the general trends. Table 8 presents the results obtained over the 26 sites (MERIS), 24 (MODIS) and 10 (CYCLOPES) available. The CYCLOPES products are the smoothest ones. However, the dynamics for some sites is not very credible with generally a shorter vegetation season presumably due to its underestimation of vegetation amount. MERIS LAI and fAPAR appeared to be the other smoothest products, along with MGVI. Then the MODIS product shows in about half the cases either ½ shaky to shaky profiles, with some accidents from time to time. The same applied to the fCover MERIS product which appears to be more sensitive to artifacts than the other products. It can thus be concluded that our MERIS product is reasonably smooth as compared to other available products.

	LAI			fAPAR				fCover	
	MERIS	MODIS	CYCLOPES	MERIS	MODIS	CYCLOPES	MGVI	MERIS	CYCLOPES
Smooth	88	42	100	96	50	100	85	50	80
1/2 smooth	4	25	0	0	21	0	4	42	20
shaky	4	29	0	0	17	0	4	8	0
accident	4	4	0	4	13	0	8	0	0

Table 8. Frequency (in %) of smooth, ½ smooth, shaky or accidental temporal profiles as observed for the sites considered for MERIS (26 sites), MODIS (24 sites) and CYCLOPES (10 sites).

As a matter of facts, canopy develops its structure in a relatively continuous process that should express smooth LAI and fAPAR temporal profiles. However, the comparison was achieved here between level 3 products derived from a temporal compositing process (MODIS, CYCLOPES) with level 2 products which are instantaneous estimates of the biophysical variables (MERIS and MGVI). These later products will obviously be more 'shaky' as compared to MODIS and CYCLOPES products that are smoothed out through the temporal compositing process. For this reason, we proposed to smooth the temporal profiles of LAI, fAPAR and fCover as well as MGVI using a sampling interval of 10 days, and a temporal window of $\pm$15 days with a Gaussian weighing (**Erreur ! Source du renvoi introuvable.**). Inspection of the smoothed profiles for the 26 sites available confirms the good performances of our algorithm regarding the temporal consistency (see **Erreur ! Source du renvoi introuvable.** as an example of the 26 sites that are available in the annexe).

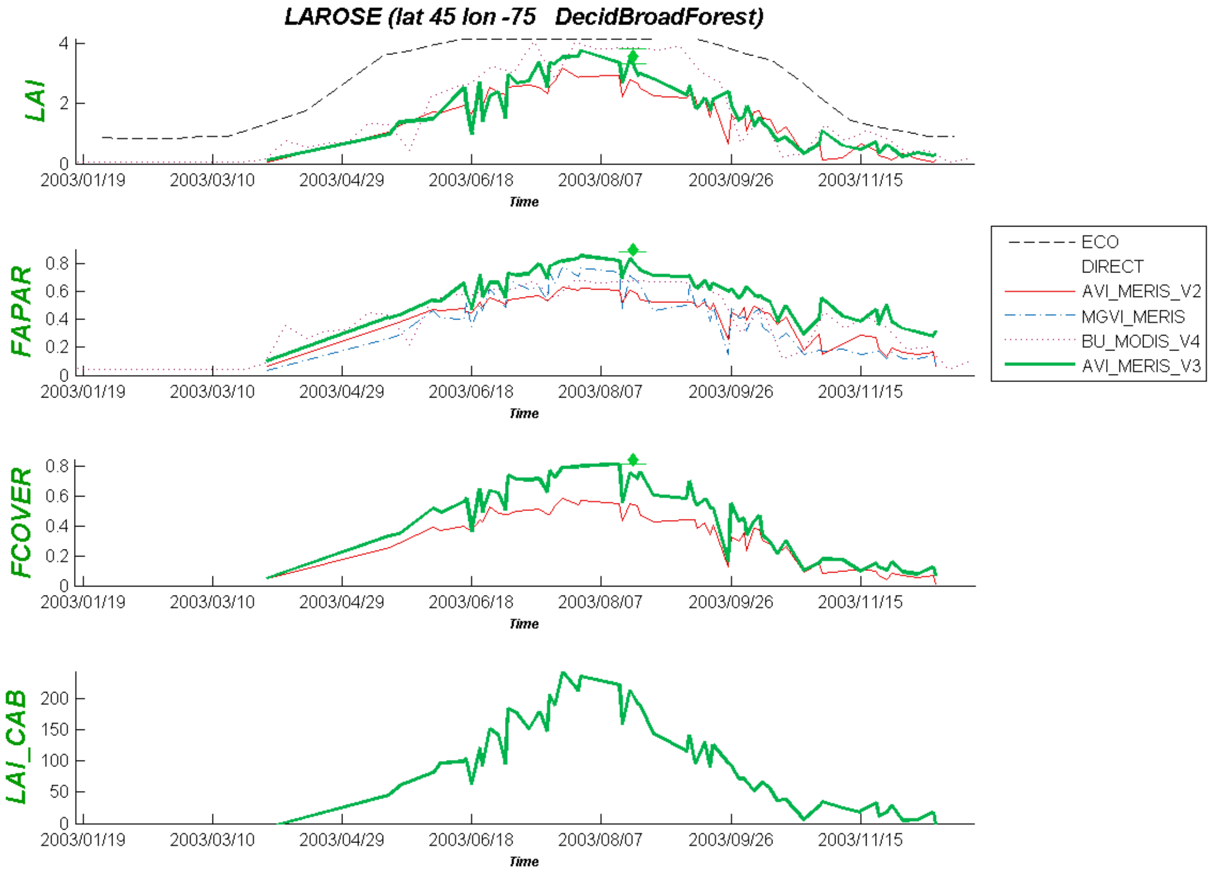


Figure 16. Temporal profiles of LAI, fAPAR, and fCover and LAI.Cab products as derived from MERIS TOAV_VEG_V3, CYCLOPES V2, MGVI, ECOCLIMAP and MODIS. Plein circle indicate that the main algorithm is used, while empty circles indicate that the back-up algorithm was used. This figure corresponds to the Larose site, where the dark square corresponds to the values derived from ground measurements performed within the VALERI activity.

3.1.3.2. Global comparison

A date to date global comparison was achieved to assess possible differences in magnitude between the several products. It consists mainly in estimating the values of all products at the MODIS observation dates thanks to linear interpolation. Note that here the smoothed MERIS (including MGVI) products were used. Then, a scatter plot is generated using MERIS products as the abscissa, and distinguishing the several vegetation types from their dominant component provided by ECOCLIMAP. A RMSE value is also computed to quantify the departure from the 1:1 line. Figure 17 shows these scatterplots.

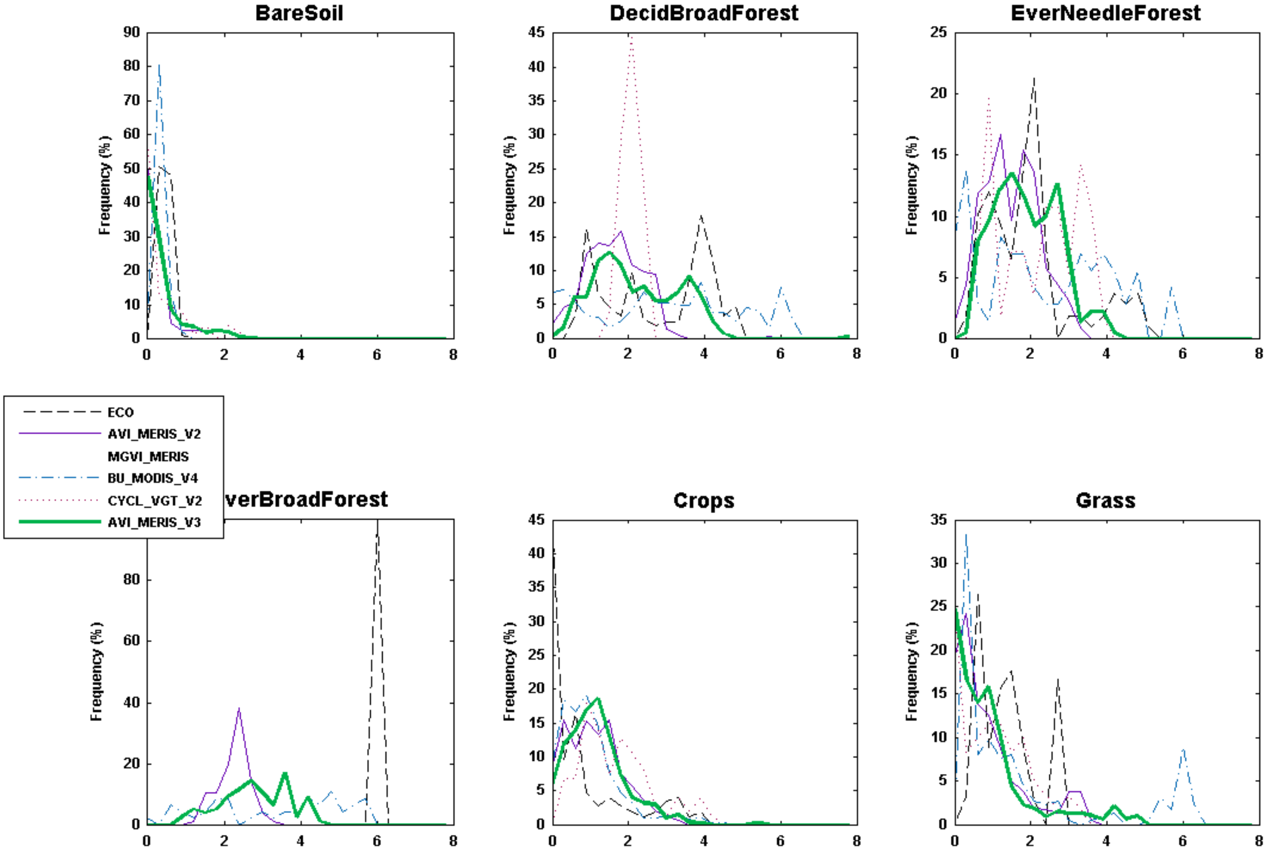


Figure 17. Comparison of LAI products distribution per land surface type.

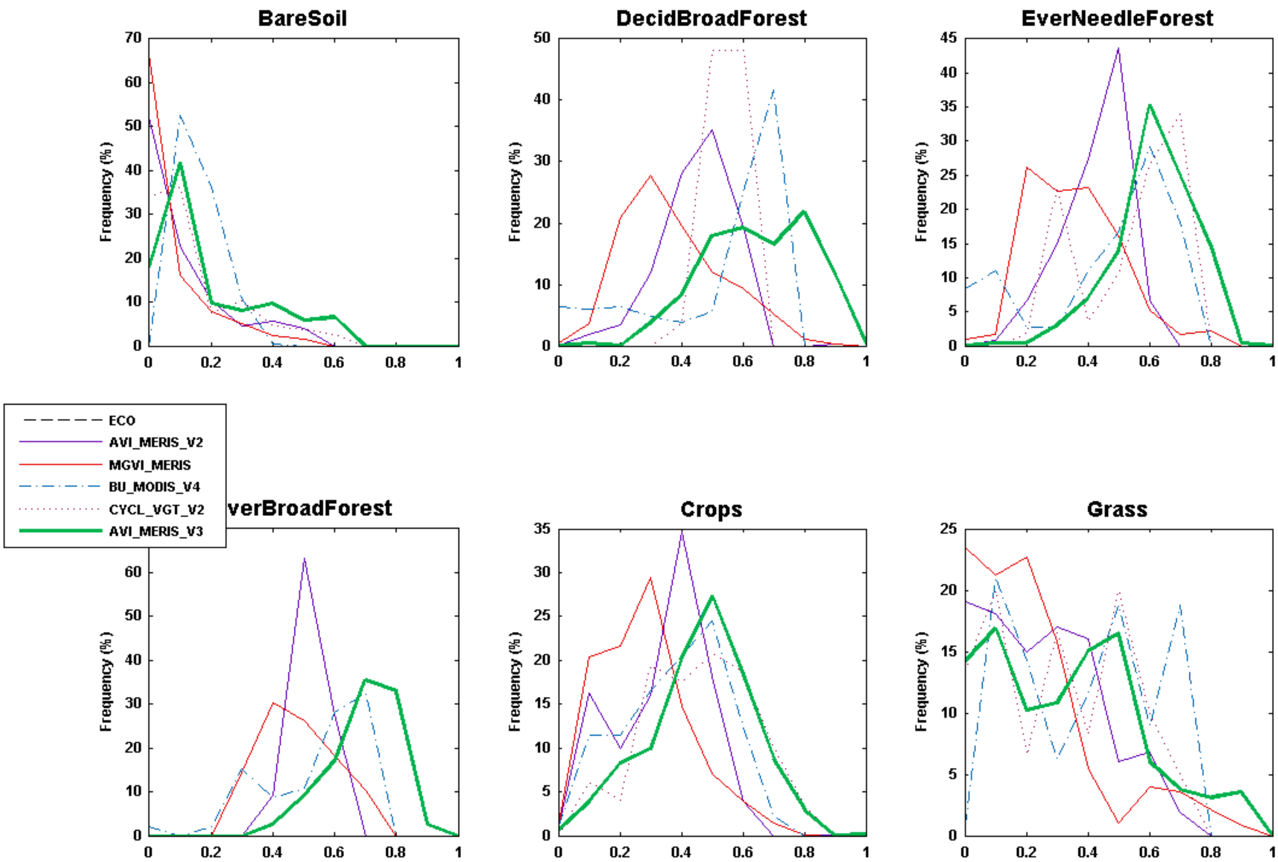


Figure 18. Comparison of fAPAR products distribution per land surface type.

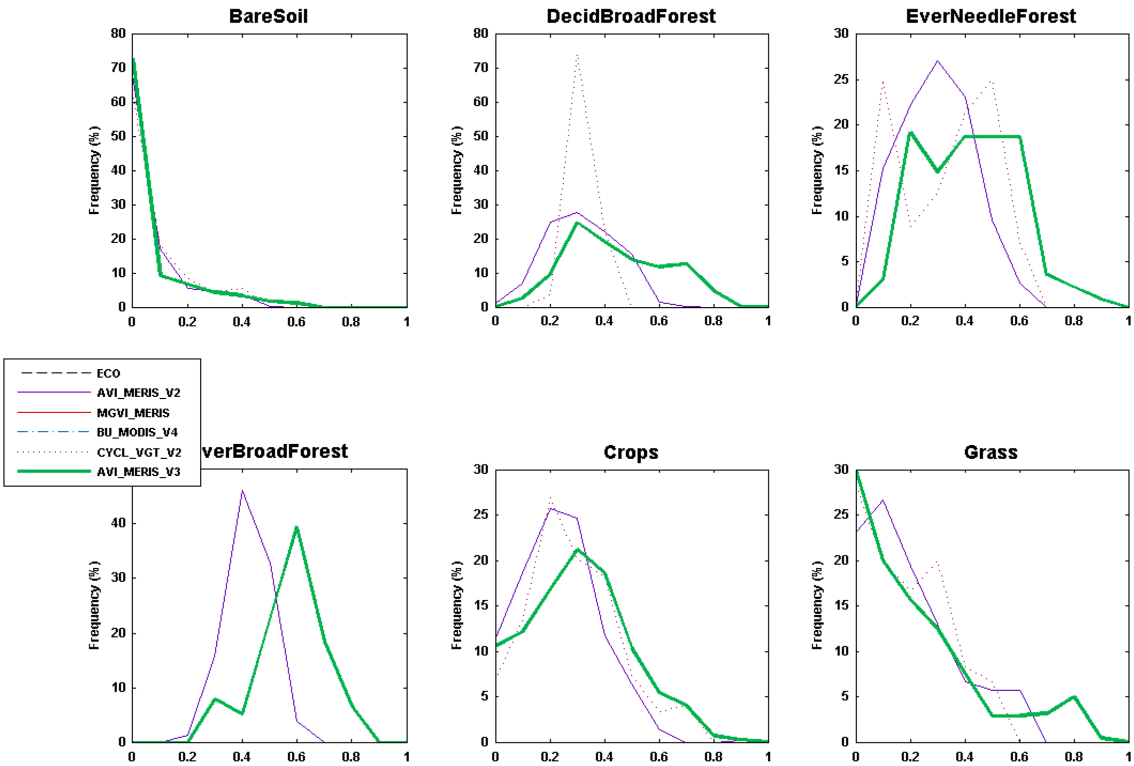


Figure 19. Comparison of fCover products distribution per land surface type.

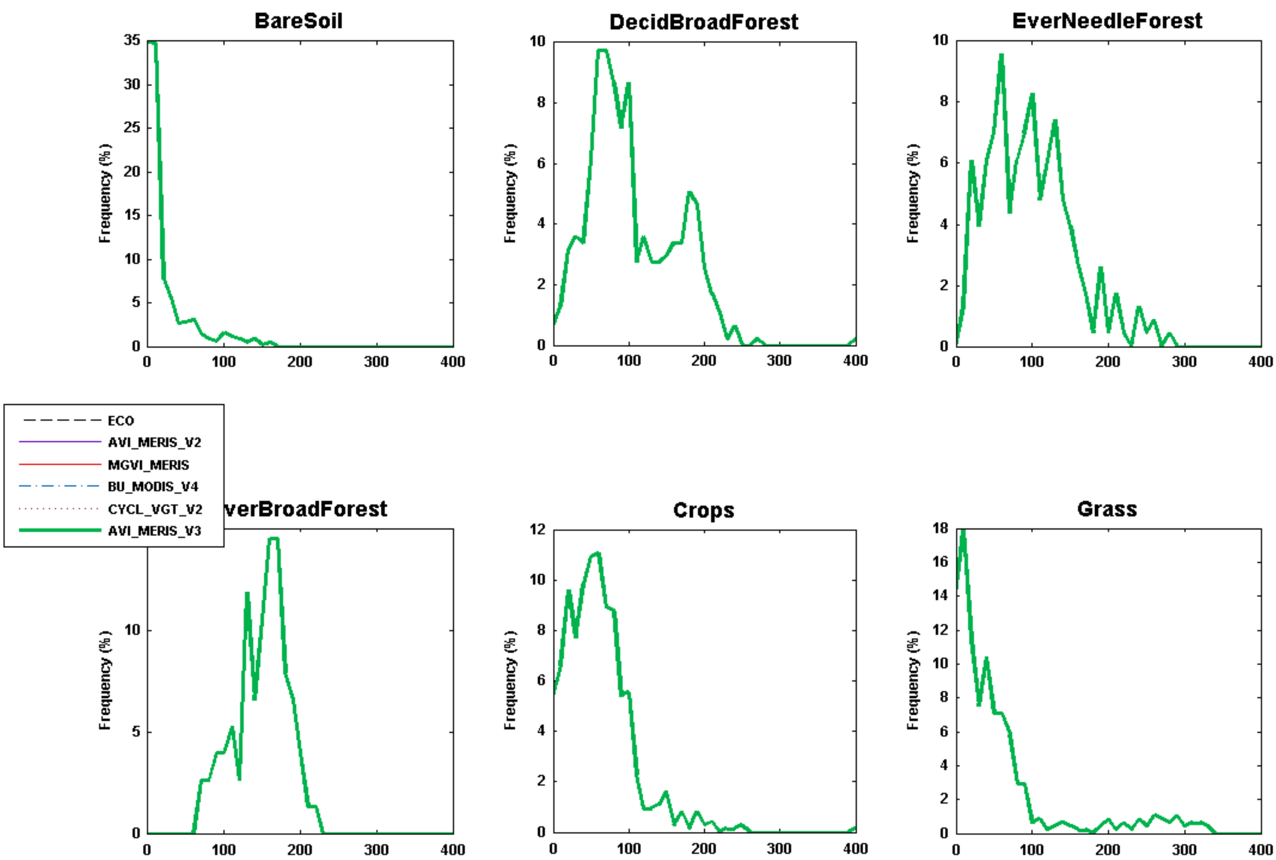


Figure 20. Comparison of LAI.C_{ab} products distribution per land surface type.

The following observations are made:

- **MODIS LAI.** The MERIS products show a relatively good agreement with the MODIS products for LAI below 2.0. This is particularly true for the grasslands. Above LAI of 2.0, MODIS LAI is systematically higher than that of MERIS, which confirms the previous results. This is enhanced for the forest sites. We observe also some scattering for the crops for the whole LAI range of values.
- **CYCLOPES LAI.** A better agreement is observed with our MERIS products for all the cover types. However, for low LAI values, the CYCLOPES product seems to lack some sensitivity, with values that are close to 0 up to LAI=1.0, leading to some underestimation. Oppositely, larger CYCLOPES LAI values are observed for LAI larger than 2.0. Note however, that the comparison is limited here to the European sites. Therefore, sites with very small LAI values are poorly represented.
- **MODIS fAPAR.** The scatter is relatively large, with MODIS fAPAR being quasi systematically higher than the MERIS fAPAR.
- **CYCLOPES fAPAR.** The scatter is smaller, and CYCLOPES fAPAR values are slightly smaller than those of MERIS. Note again that the comparison is limited here to the European sites. Therefore, sites with very small fAPAR values are poorly represented.
- **MERIS MGVI fAPAR.** The scatter is quite large, with values being quasi systematically smaller than those of our MERIS fAPAR values.

3.1.3.3. Consistency between LAI and fAPAR products

The fraction of photosynthetically active radiation absorbed by the canopy (fAPAR) results from the radiative transfer within canopies. It thus depends on canopy structural variables, among which LAI is certainly the most important one. Therefore, relatively strong relationships are expected between LAI and fAPAR products for a given canopy type. This is illustrated in Figure 21 for the VALERI sites.

To evaluate the internal consistency of the products, we investigated these relationships over the same data set as previously: the 26 sites of 3×3km², over the whole 2003 year. Figure 21 shows these relationships for all the products considered. Note that here again the smoothed MERIS products were used.

- **MERIS.** Our products show a relatively strong relationship between LAI and fAPAR. Among the several vegetation types, the crops show a lower fAPAR than the forests for a given LAI which is what is expected according to the level of clumping frequently observed for forests. However, the grasslands that should behave closer to the crops are actually closer to the forests.
- **MODIS.** The most prominent feature of the MODIS LAI products, is the larger range of variation of LAI values as already pointed out previously. The relationship between LAI and fAPAR is stronger than that observed for MERIS which is a good sign (up to a certain point!). However, the crops show smaller fAPAR values than forests for the same LAI level, which was not expected due to the clumping in the forest as discussed previously.
- **CYCLOPES.** The relationship between LAI and fAPAR is not very good, with some kind of offset of the relationship around 0.2 fAPAR value. Then the relationship appears very linear which is not actually expected.

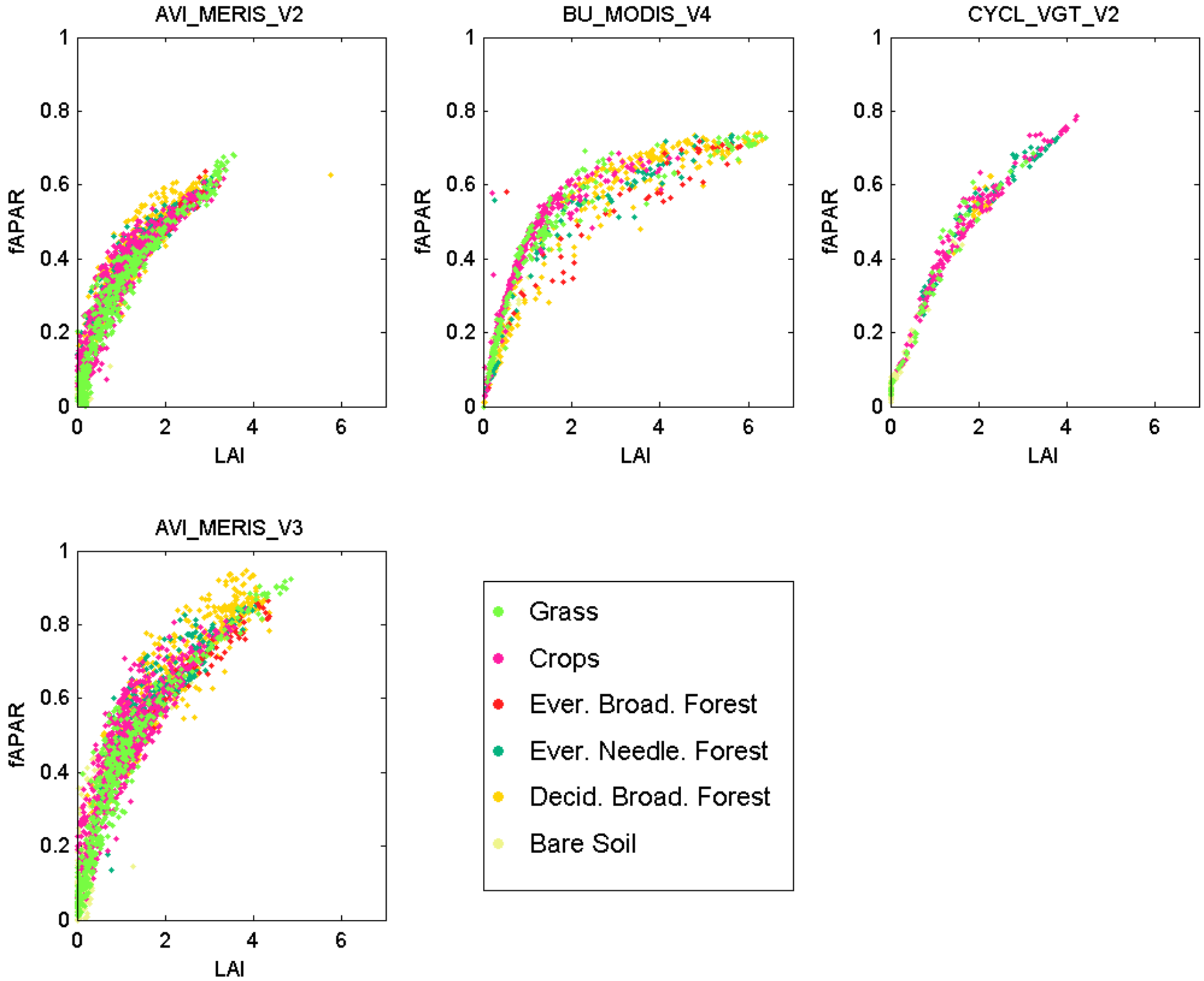


Figure 21. Relationships between LAI and fAPAR for the different products considered. The 26 sites and all the cloudless MERIS observations dates are considered for year 2003. The colours correspond to the dominant surface type as derived from ECOCLIMAP.

4. Conclusion

4.1. Difficulties encountered

- The various ***flags indicating the quality of the MERIS products did not seem to be very reliable***, and even worse, they seem lacking consistency between them (see the Barrax and Changbai test cases).
- The ***cloud filtering is poorly achieved*** with the current MERIS L2 products. Important efforts should be directed towards this critical step before producing accurate surface characteristics.
- We encountered ***few bugs in the BEAM toolbox*** for the manipulation of the images, particularly regarding the projection module. These were reported to Brockman and will be corrected.
- We got ***difficulties getting the right information from the current MERIS documentation*** on several aspects. This needs a very strong improvement. The same is also true for the MGVI ATBD that is not apparently up-dated.

4.2. Actual performances of the algorithms

Despite these difficulties, ***this validation exercise yielded very promising results*** on the performances of our algorithms. The TOA_VEG algorithm is one of the algorithms that appears to perform the best. However, we suspect here also some ***possible underestimation of LAI for the larger LAI values***.

From this preliminary validation exercise, we could conclude that ***the current TOA product could be released to the user community***, since other products that are official MERIS ESA products have been already released without a true validation process!

4.3. Possible ways to improve the products

This validation exercise allowed identifying problems that needed a proper solution to improve the accuracy and robustness of the products. The following issues will have therefore to investigated

- **Cloud screening.** Because fully cloudless images are very scarce, and because most of the users are also interested in the dynamics of the vegetation, clouds should be efficiently detected and flagged. This is currently not the case, even for L2 products. A dedicated study should therefore be conducted to design an efficient cloud screening algorithm. This algorithm should apply at the L1b level, and if possible provides also screening of snow and water surfaces. This algorithm should yield 'probabilities of occurrence or fraction' of cloud, snow and water surfaces that would indicate the level of confidence associated to this detection. For cloud flagged pixels, the corresponding cloud shadow should be also computed, probably using a standard altitude of the clouds, or (to be investigated), that derived from the retrieved oxygen pressure.

- **Biophysical algorithm.**

  In the current TOA_VEG algorithm, the ***atmospheric pressure*** is not explicitly used as an input in the neural network. This simplification was done for sake of simplicity, because the atmospheric pressure product does not exist at L1b. However, we showed that using explicitly the atmospheric pressure as an additional input should contribute to improve the performances of the algorithm, while the other atmospheric characteristics (water vapour and ozone) had an insignificant role. Work should be therefore directed towards the derivation of the atmospheric pressure at level L1b, and training networks to account for this additional input.

Learning on actual MERIS data. In the current version of the algorithm, the network is trained over simulated data sets. Although we have shown through the reflectance mismatch test that the simulations were able to accurately describe the MERIS TOA reflectance measurements, the structure of the uncertainties is not accounted for. This is very important, particularly regarding the selection of the inputs, and the reduction of the size and complexity of the network to improve its robustness. For the next versions of this algorithm, the two steps scheme proposed earlier should be implemented. It mainly consists in computing the 'best estimates' over a wide range of situations (the CYTTARES network of sites) thanks to iterative optimization algorithm. Then, the temporally smoothed biophysical retrieved variables will be used along with the corresponding MERIS L1b TOA reflectances and atmospheric pressure and geometry of observation to train the network.

We observed that the current version of the algorithm tends to ***underestimate LAI values for the larger LAI values***. This is presumably to the way the learning data base was generated, with fewer examples for the larger LAI values. This could be easily corrected by adapting the learning data base. However, we should recognize that saturation of reflectance with LAI is a well known problem, and that there is actually little hope to get very accurate estimate of LAI for the larger LAI values! This problem should be reflected in the quality assessment criterion: the associated uncertainties will be higher in these situations.

The current radiative transfer model used is based on a turbid medium description of the canopy structure. This is obviously an oversimplification of the actual canopy structure. It would be desirable to ***use a more realistic canopy structure description*** that at least accounts for the first order features such as the leaf clumping. Although these types of models require more input variables to describe this more complex architecture, the learning on actual CYTTARES sites will help because for each site, prior distribution of the variables will be roughly known.

The inspection of the ***relationships between LAI, fAPAR and fCover*** showed that the consistency could be improved. This could be simply achieved by using the fAPAR estimates as an additional input to the LAI network. The same could be done for the fCover, since we observed that it was more 'shaky' and needed some regularization. The same could be also achieved for the LAI.Cab product.

- **Level 3: temporal compositing.** Most of the users will exploit the dynamics of the biophysical variables either as inputs to their process models (climate, carbon, production) or as proxy for classification and land cover change detection. This clearly calls for the development of proper level 3 biophysical products derived from the composition of the biophysical products over a given time period. This could exploit efficiently the specific angular (relatively small angular excursion) and spectral (possibility to perform (transparent!) atmospheric correction) features of MERIS while compensating for slightly smaller revisit frequency (three days). A fixed sampling interval of 10 days for which all the MERIS observations available within ±10 days with a proper weighing according to the uncertainties associated to each instantaneous product and distance to the centre of the interval would be relatively easy to design and implement. However, this requires obviously to be implemented within an operational processing chain because of the large amount of data to be manipulated.

4.4. Extension of the validation exercise

This validation exercise was limited in time and resources, although already significant results have been derived. It should be more formally supported to be able to acquire and exploit more ground measurements. We should also acknowledge the role of CEOS around which a community is aggregated and active. This should make available a larger number of ground measurements, as well as provides some benchmark set of cases from which metrics could be computed to evaluate the actual performances of the products. The following activities should be undertaken to further the validation exercise:

For the direct validation, ***more sites are required***, covering a larger range of situations. This is very important since the uncertainties associated to the ground measurements are significant, and could only be smoothed out by the number! The VALERI activity is one of the main contributors of this validation exercise for Europe, but also for the Globe. However, ESA still does not support this activity although it beneficiates strongly from it!

The direct validation was mainly achieved based on the average over the 3×3 km² sites. More detailed validation could be achieved at the original resolution of the products, but this requires a significant effort in accurate co-registration of the images, and proper knowledge of the PSF. The use of the full resolution images could also help a lot for this pixel level validation as illustrated over the Barrax site.

The inter-comparison exercise is very important since it allows evaluating the spatial, temporal and internal products consistencies (relations between LAI, fAPAR and fCover). It also allows inter-comparing different products, which is a very interesting exercise when no absolute truth is known. However, this needs to be properly organized to be efficient. This is the purpose of the BELMANIP network of sites proposed by CEOS (Baret, Morissette et al., 2005) over which the products could be inter-compared.

Finally, very little attention was paid to the LAI.Cab product validation. The difficulty of measurement of the chlorophyll content explains this situation. However, it would be possible to validate this product over few agricultural sites where chlorophyll content was measured: Barrax and Fundulea. Additional sites could be possible added if resources are available, with the objective to focus on forests sites.

These results allowed concluding that the MERIS instrument seems to provide quite good measurements, but lacks of consolidated land products. This includes the flagging of MERIS data, cloud filtering, atmospheric correction and obviously validated biophysical products. The proposed algorithm, although still perfectible seemed to outperform on most cases the other currently available products. Therefore, efforts should be directed concurrently to:

- The distribution of these products to the user community (including the ‘level 3 products, with better cloud filtering and smoothing process)
- The extension of the validation activity in synergy with the CEOS/LPV activities
- The improvement of these products according to the proposed directions

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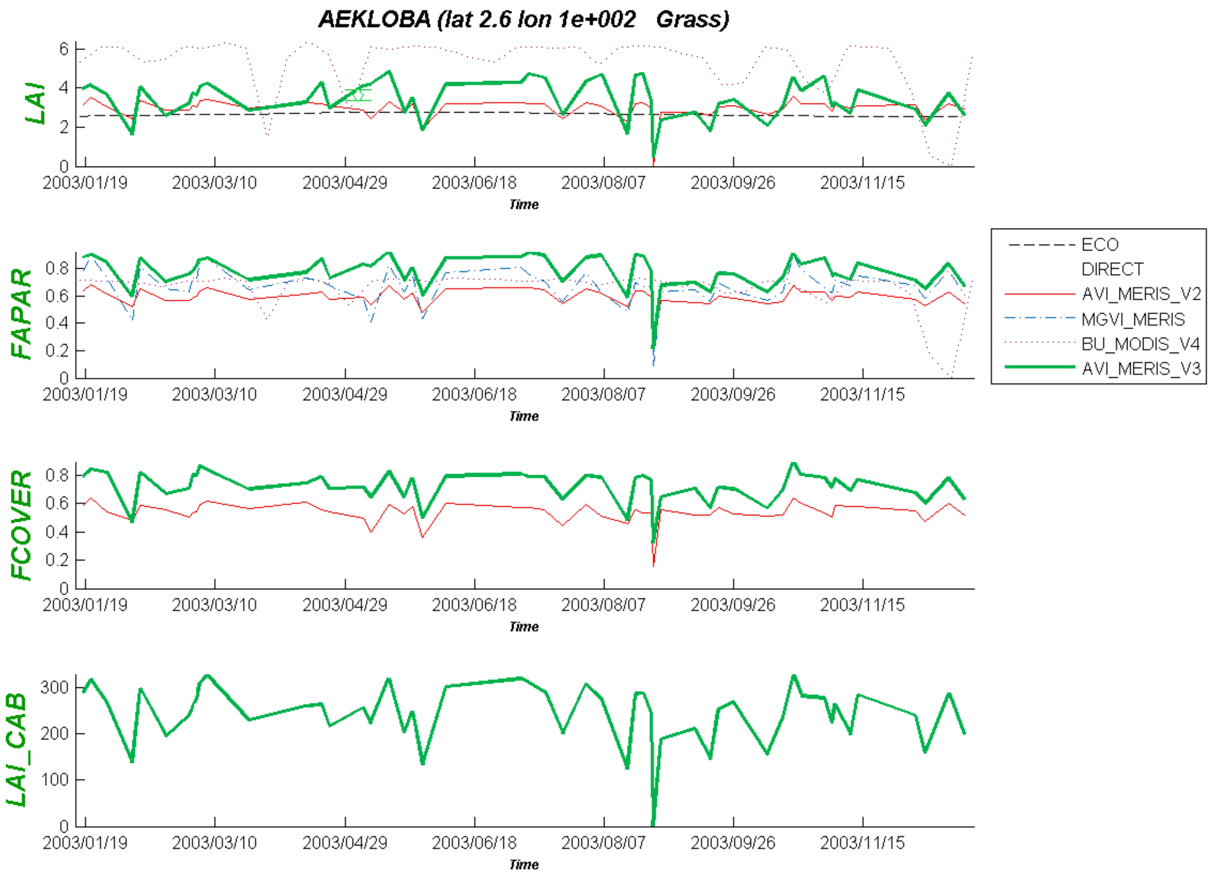
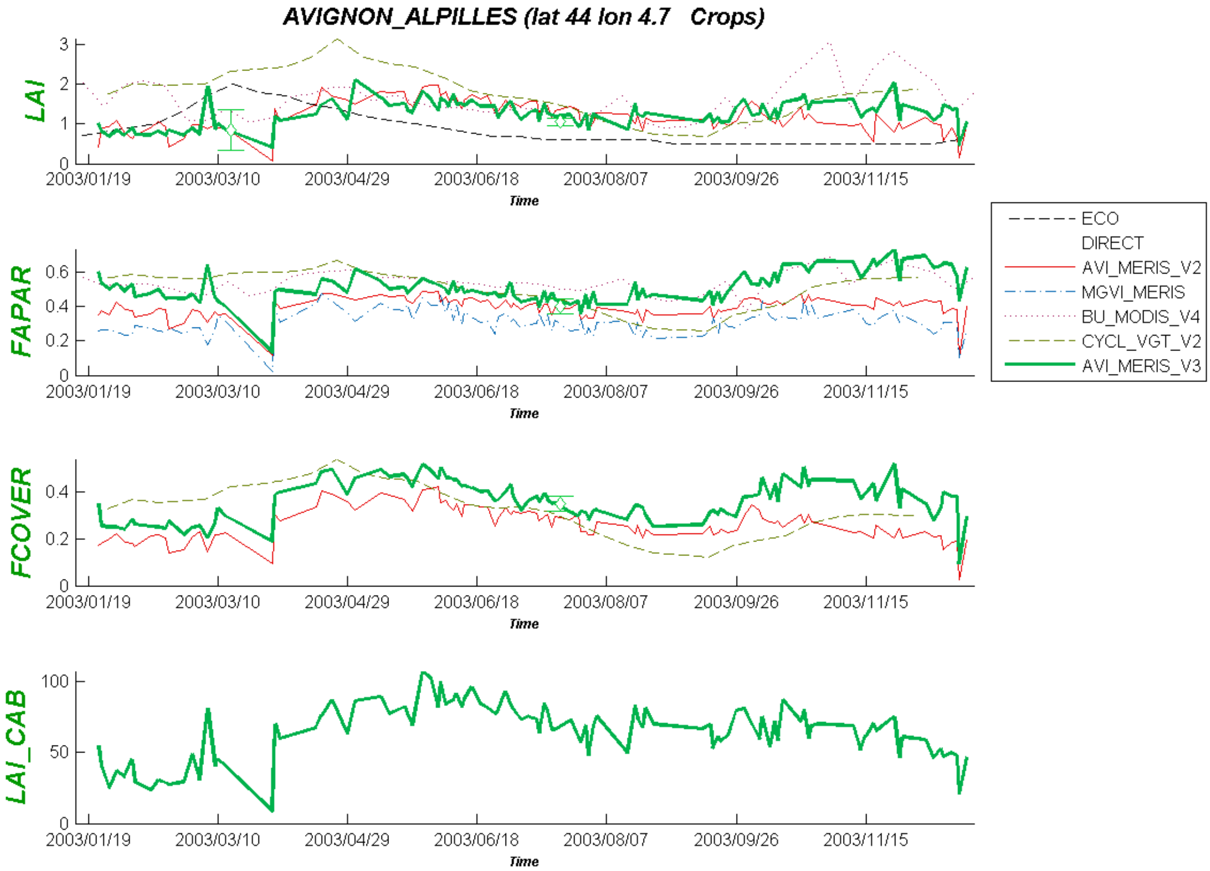
6. Annexe

6.1. Temporal variation over the BELMANIP sites

Temporal profiles of LAI (top), fAPAR (middle), and fCover (bottom) products as derived from MERIS (solid blue line: smoothed profile; filled diamonds: individual products used; empty diamonds: cloudy products not considered),CYCLOPES (solid red line), MGVI (dotted blue line: smoothed profile), ECOCLIMAP (dotted black line) and MODIS (dotted green line. Filled circle indicate that the main algorithm is used, while empty circles indicate that the back-up algorithm was used. The black square corresponds to the values derived from ground measurements performed within the VALERI activity.

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FAPAR
FCOVER
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Time
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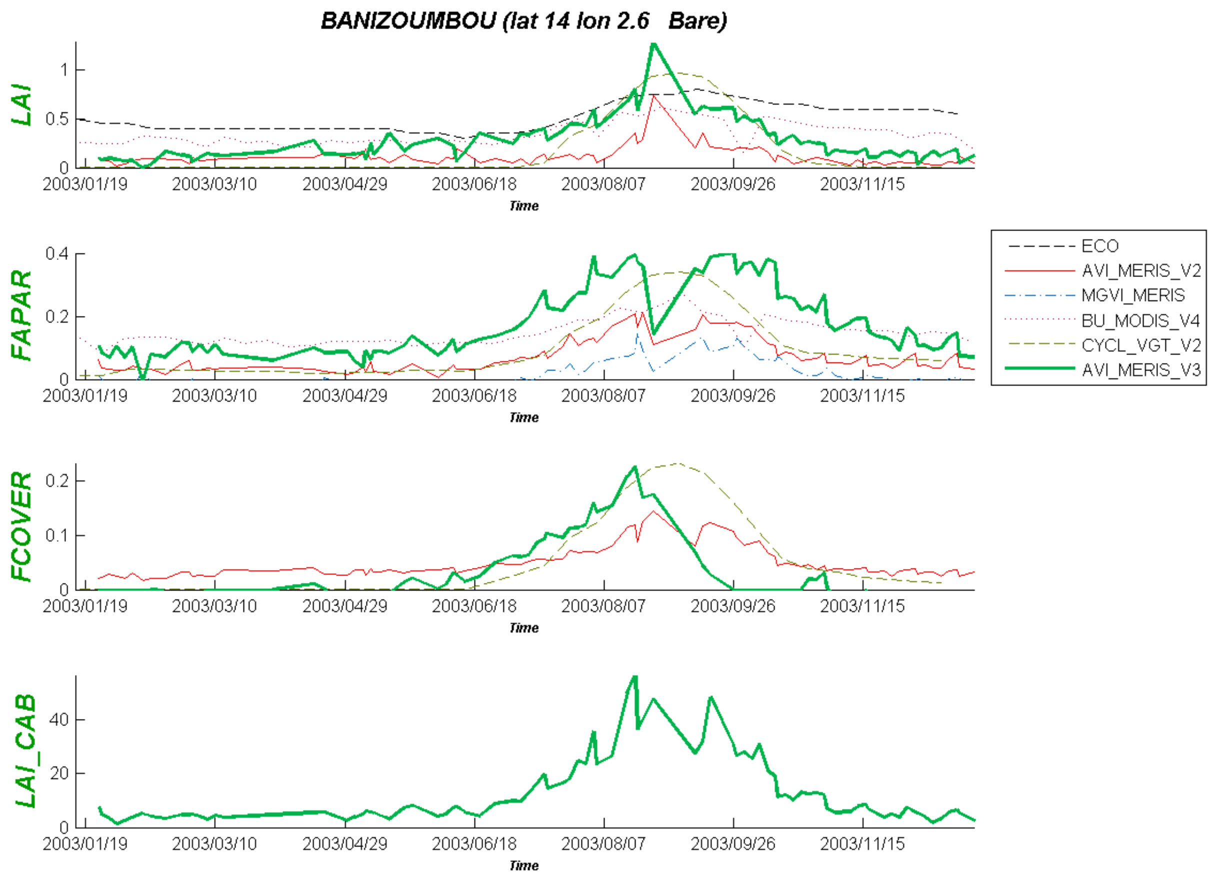
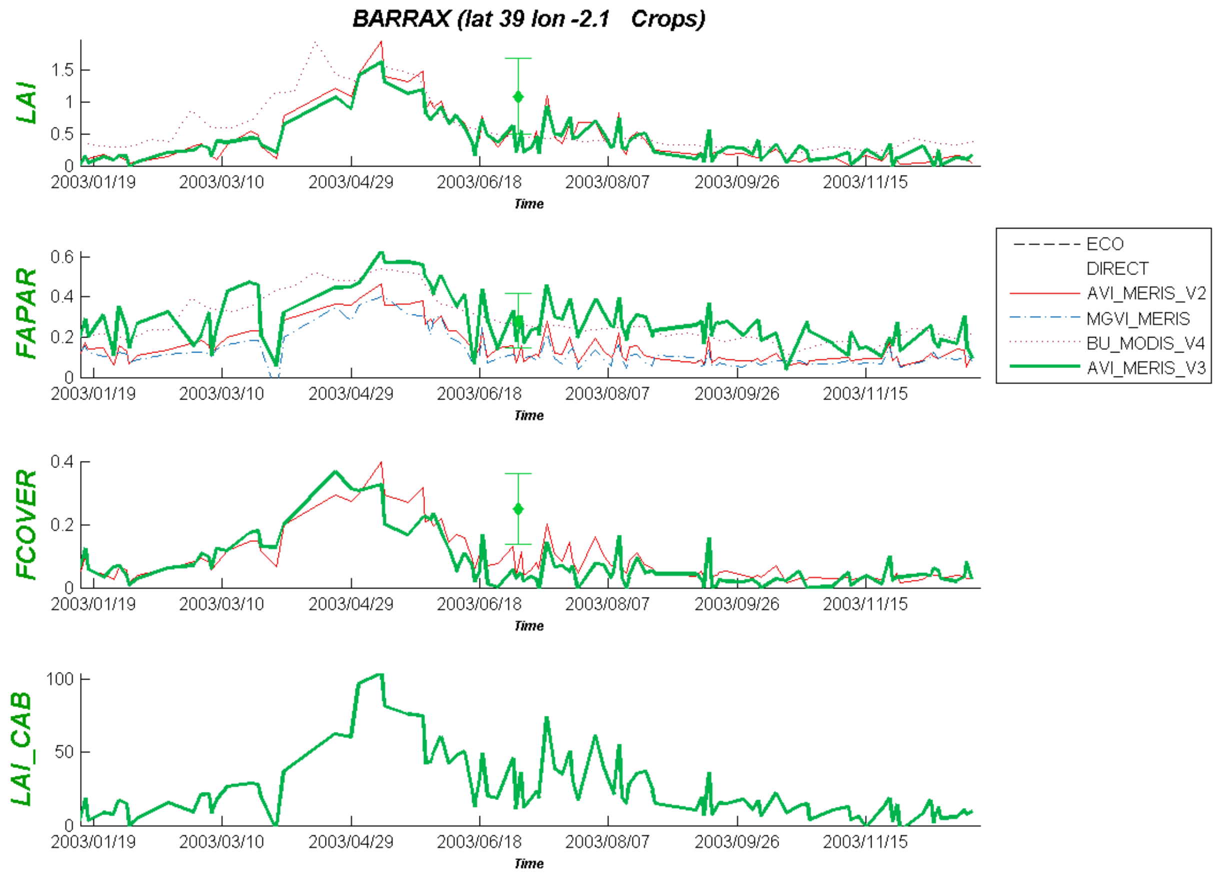
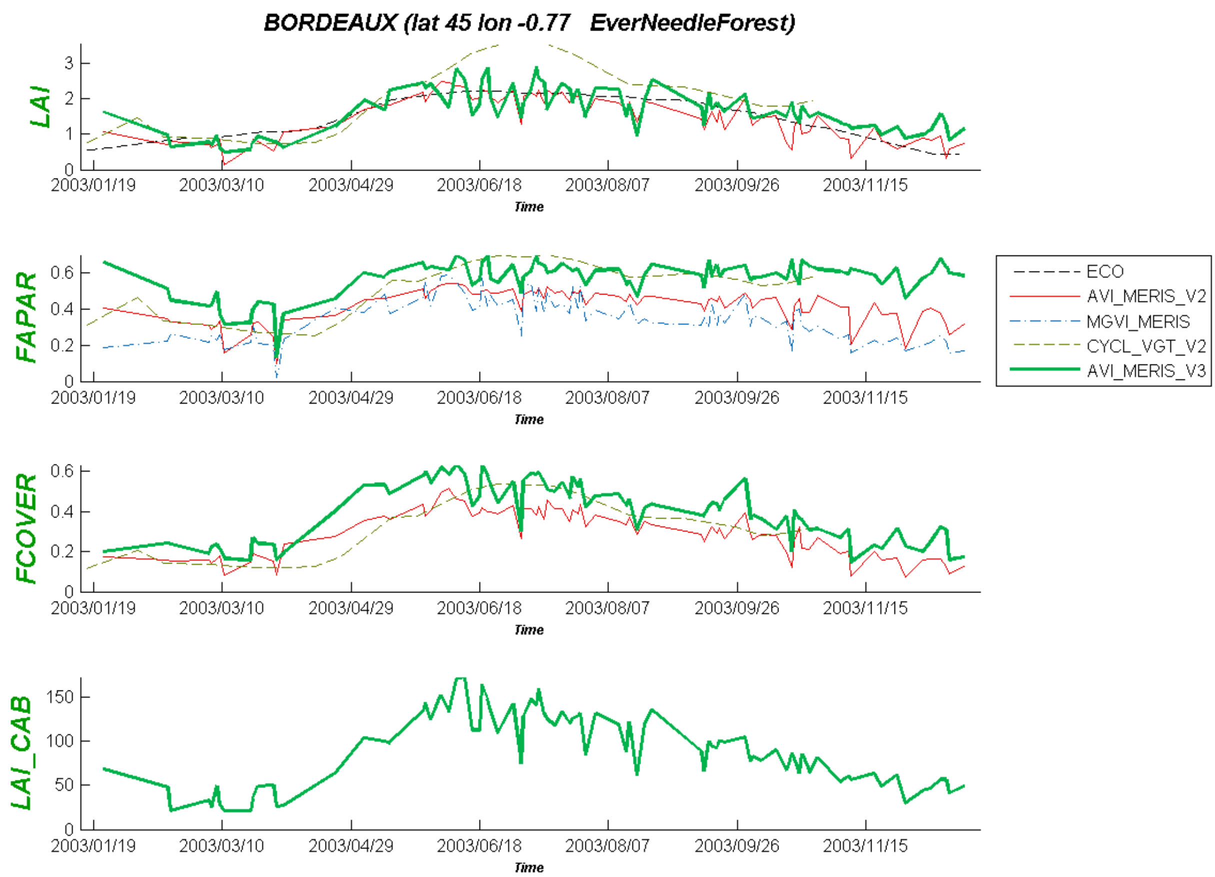
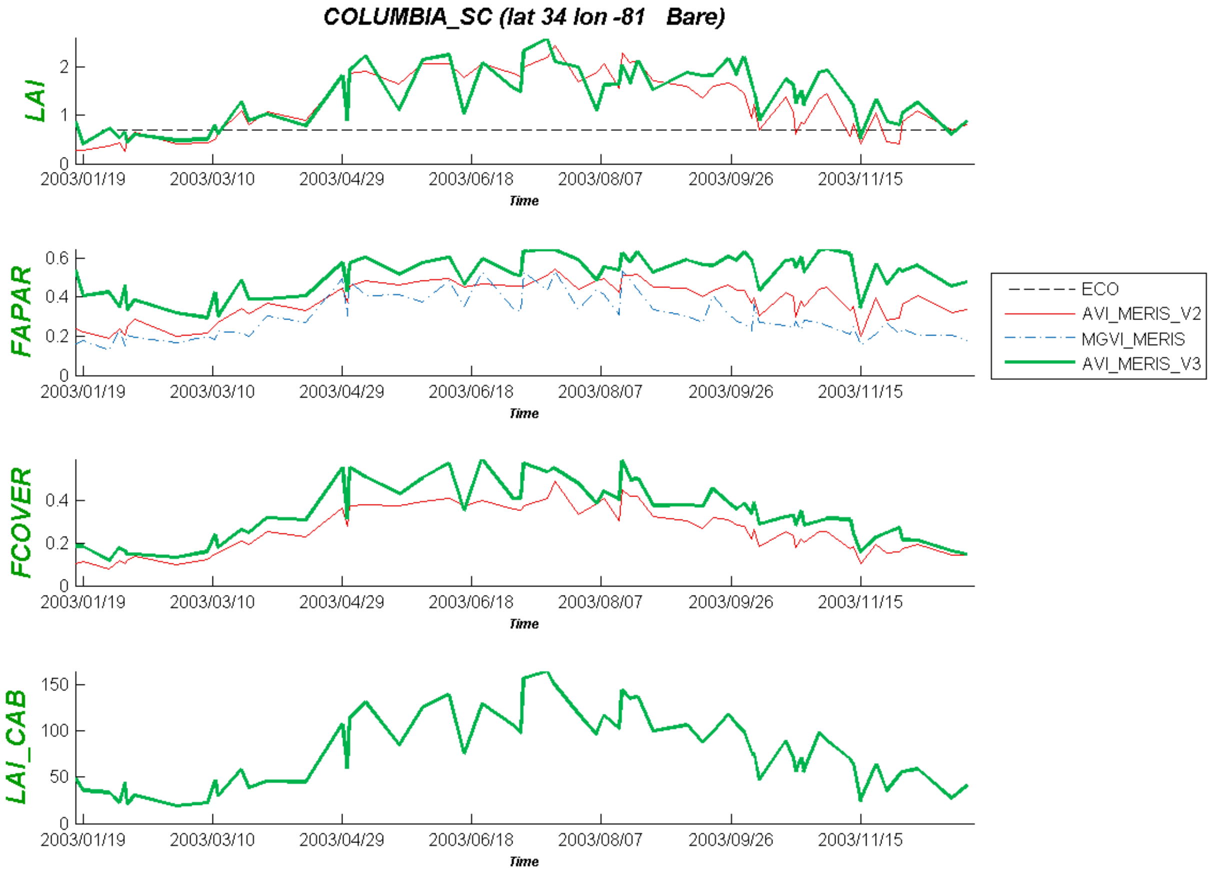
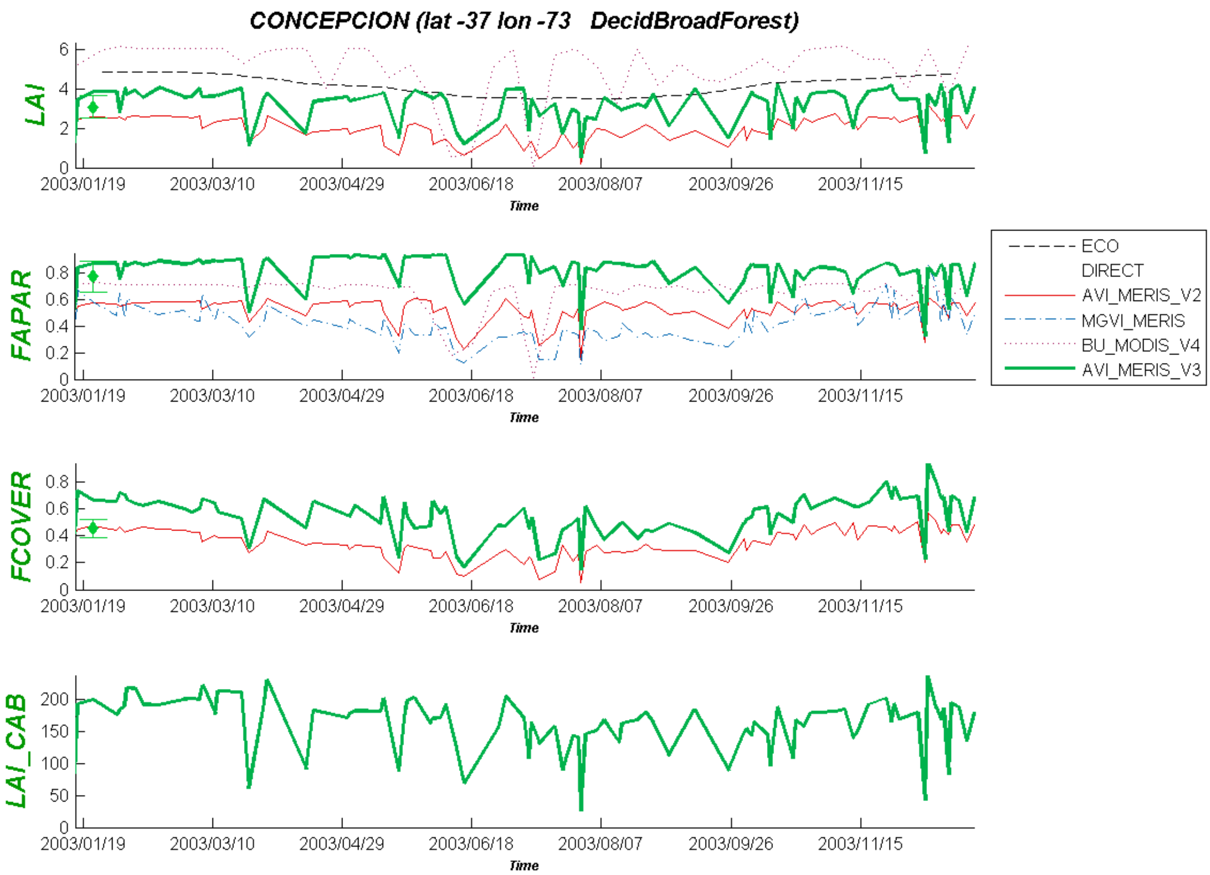
2003/06/18
2003/08/07
2003/09/26
2003/11/15
ECO
DIRECT
AVI_MERIS_V2
MGVI_MERIS
BU_MODIS_V4
CYCL_VGT_V2
AVI_MERIS_V3

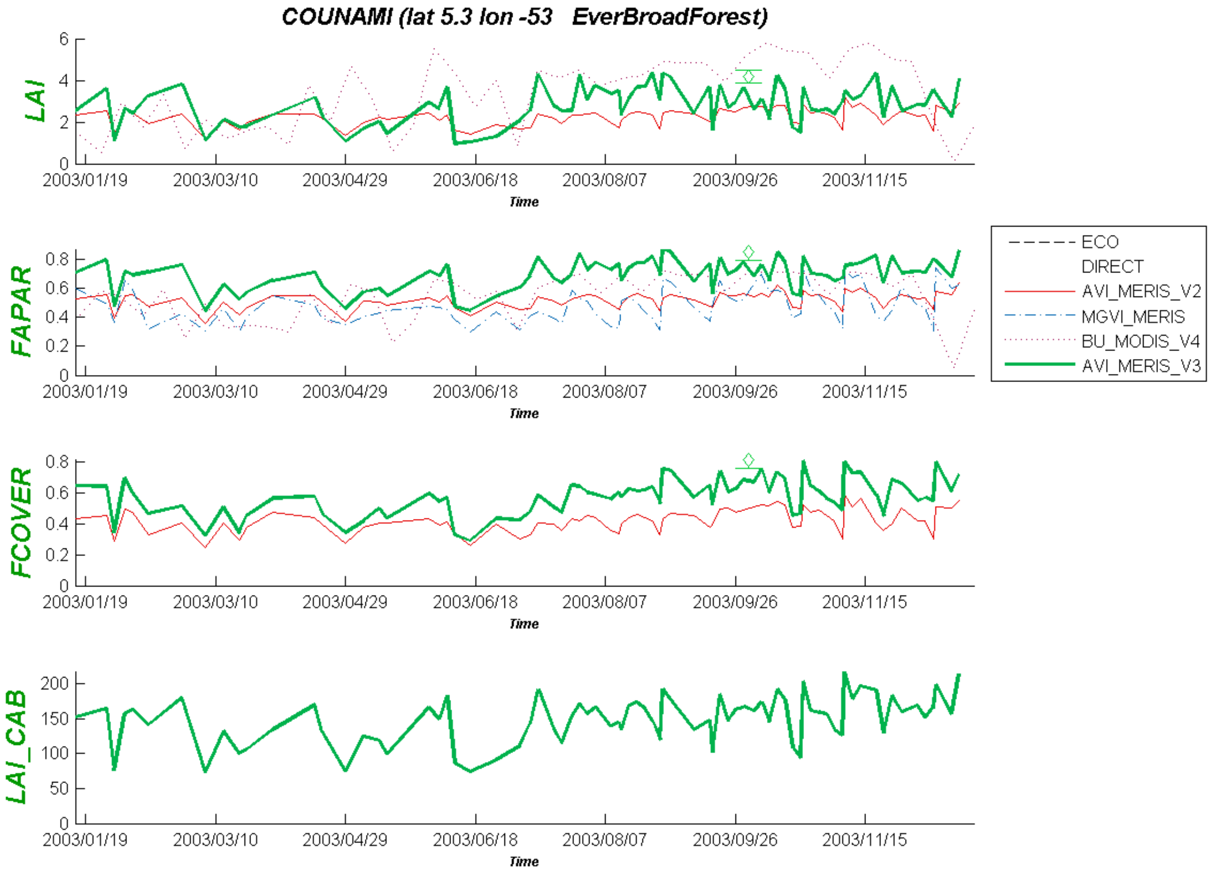

BANIZOUMBOU (lat 14 lon 2.6 Bare)
LAI
FAPAR
FCOVER
LAI_CAB
Time
2003/01/19
2003/03/10
2003/04/29
2003/06/18
2003/08/07
2003/09/26
2003/11/15
ECO
AVI_MERIS_V2
MGVI_MERIS
BU_MODIS_V4
CYCL_VGT_V2
AVI_MERIS_V3


BARRAX (lat 39 lon -2.1 Crops)
LAI
FAPAR
FCOVER
LAI_CAB
Time
2003/01/19
2003/03/10
2003/04/29
2003/06/18
2003/08/07
2003/09/26
2003/11/15
ECO
DIRECT
AVI_MERIS_V2
MGVI_MERIS
BU_MODIS_V4
AVI_MERIS_V3

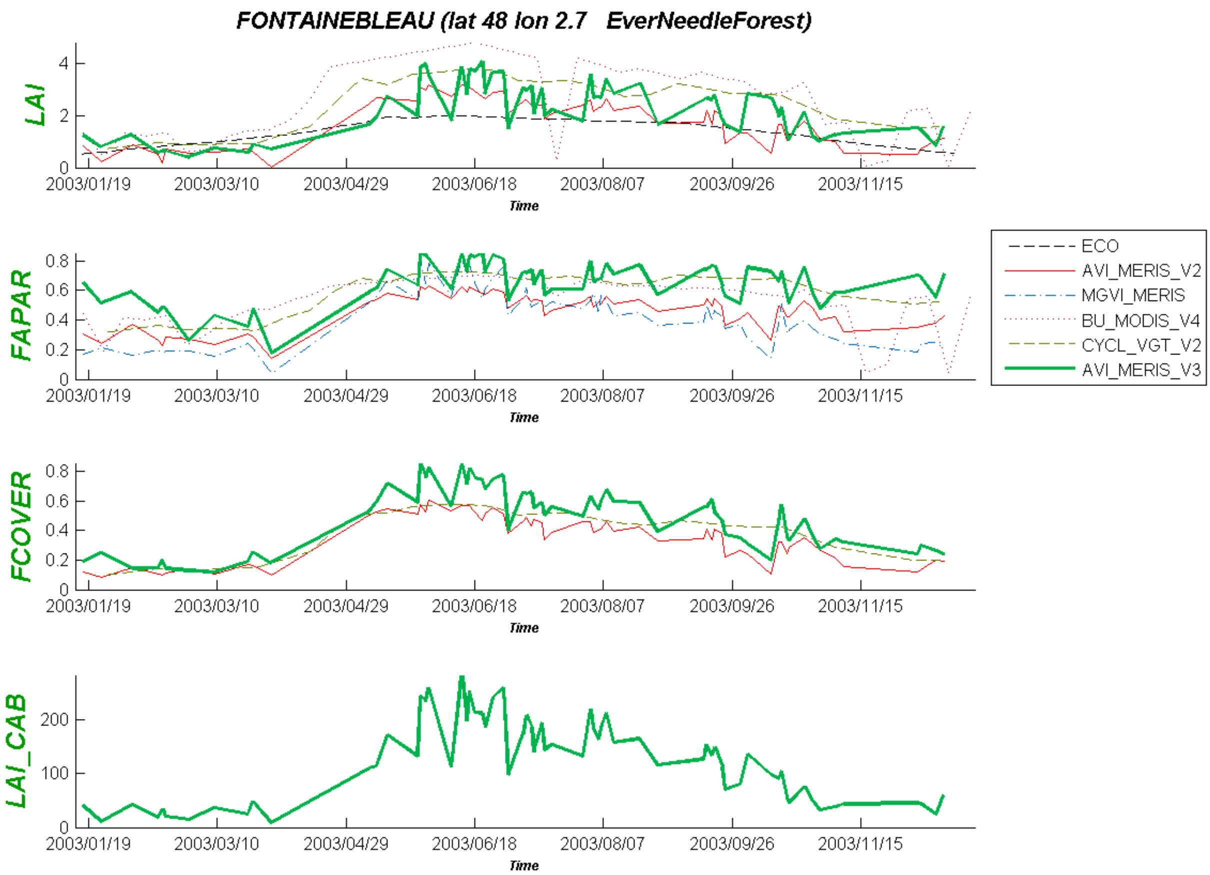

BORDEAUX (lat 45 lon -0.77 EverNeedleForest)
LAI
FAPAR
FCOVER
LAI_CAB
Time
2003/01/19
2003/03/10
2003/04/29
2003/06/18
2003/08/07
2003/09/26
2003/11/15
ECO
AVI_MERIS_V2
MGVI_MERIS
CYCL_VGT_V2
AVI_MERIS_V3


COLUMBIA_SC (lat 34 lon -81 Bare)
LAI
FAPAR
FCOVER
LAI_CAB
Time
ECO
AVI_MERIS_V2
MGVI_MERIS
AVI_MERIS_V3
2003/01/19
2003/03/10
2003/04/29
2003/06/18
2003/08/07
2003/09/26
2003/11/15

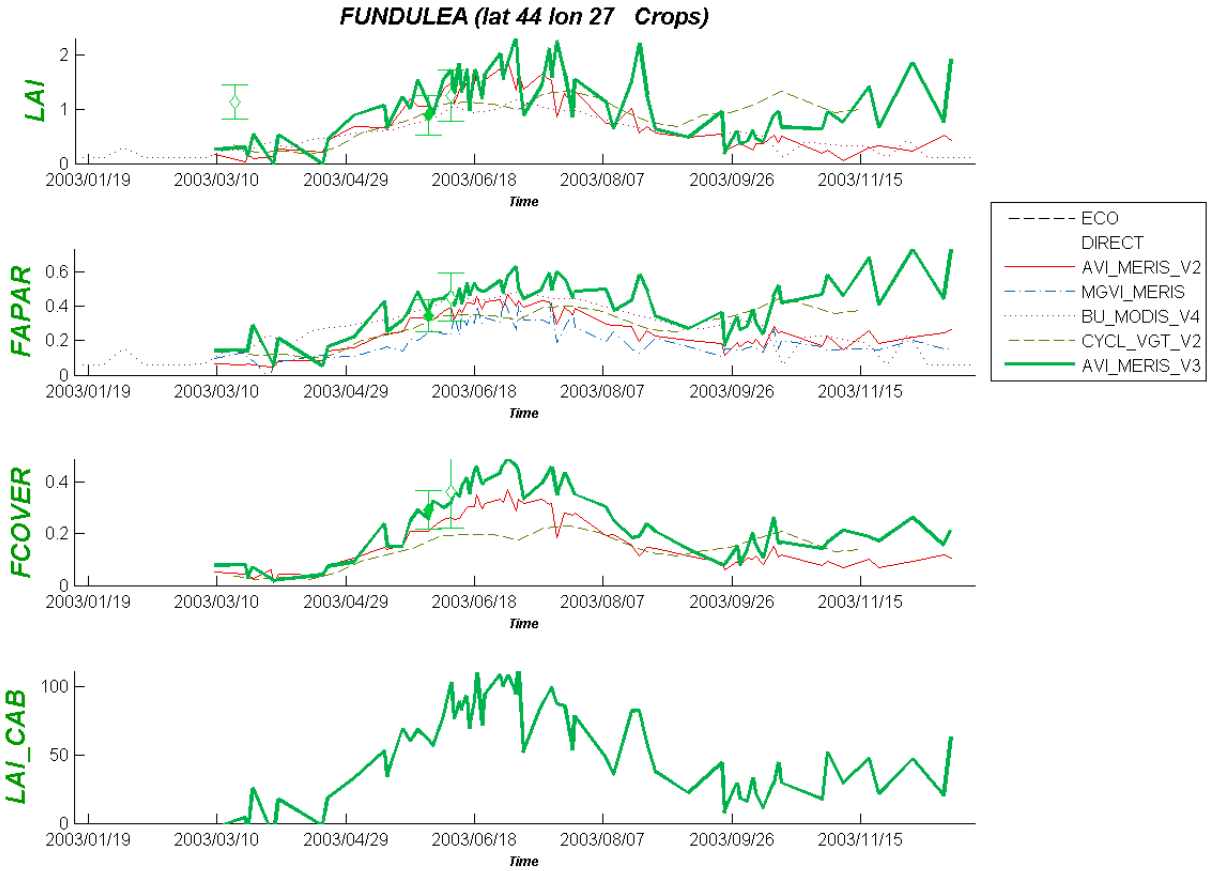

CONCEPCION (lat -37 lon -73 DecidBroadForest)
LAI
FAPAR
FCOVER
LAI_CAB
Time
ECO
DIRECT
AVI_MERIS_V2
MGVI_MERIS
BU_MODIS_V4
AVI_MERIS_V3
2003/01/19
2003/03/10
2003/04/29
2003/06/18
2003/08/07
2003/09/26
2003/11/15

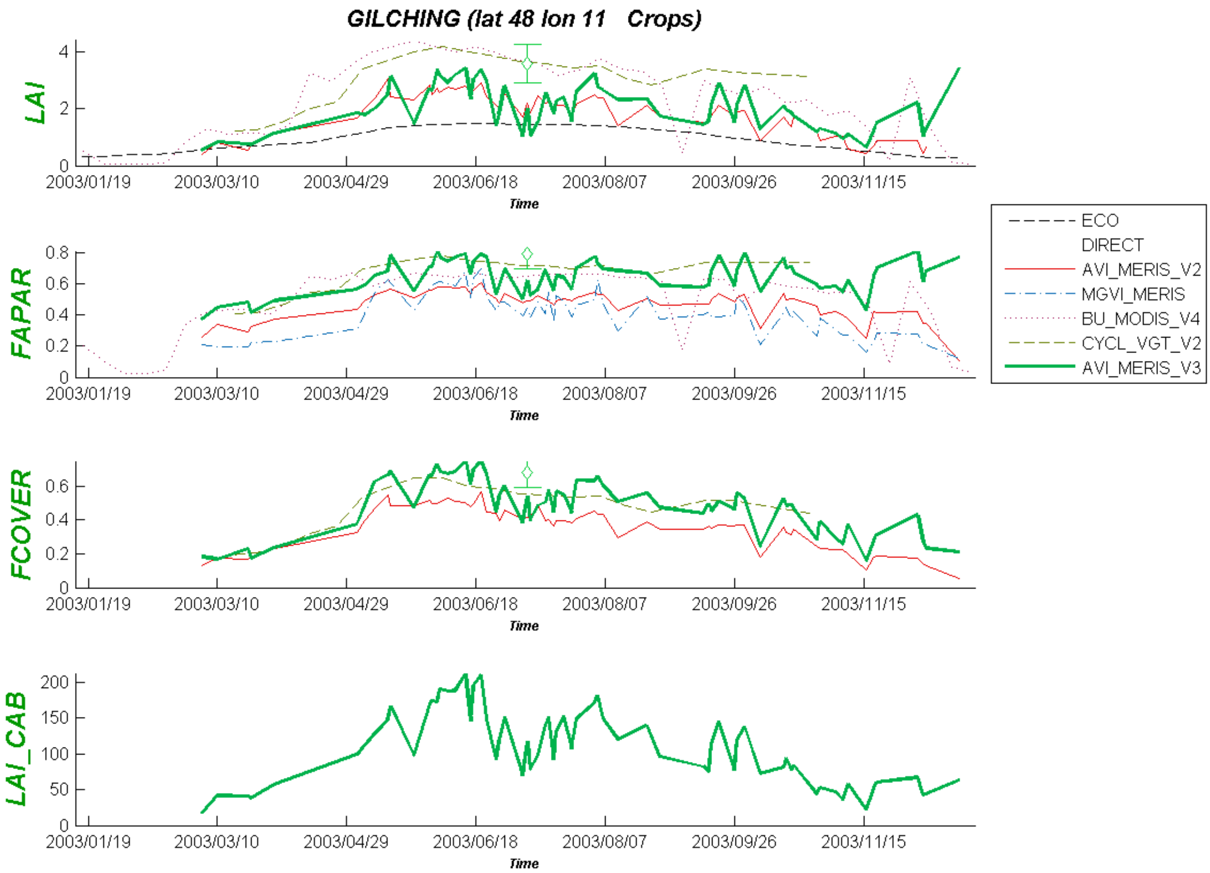


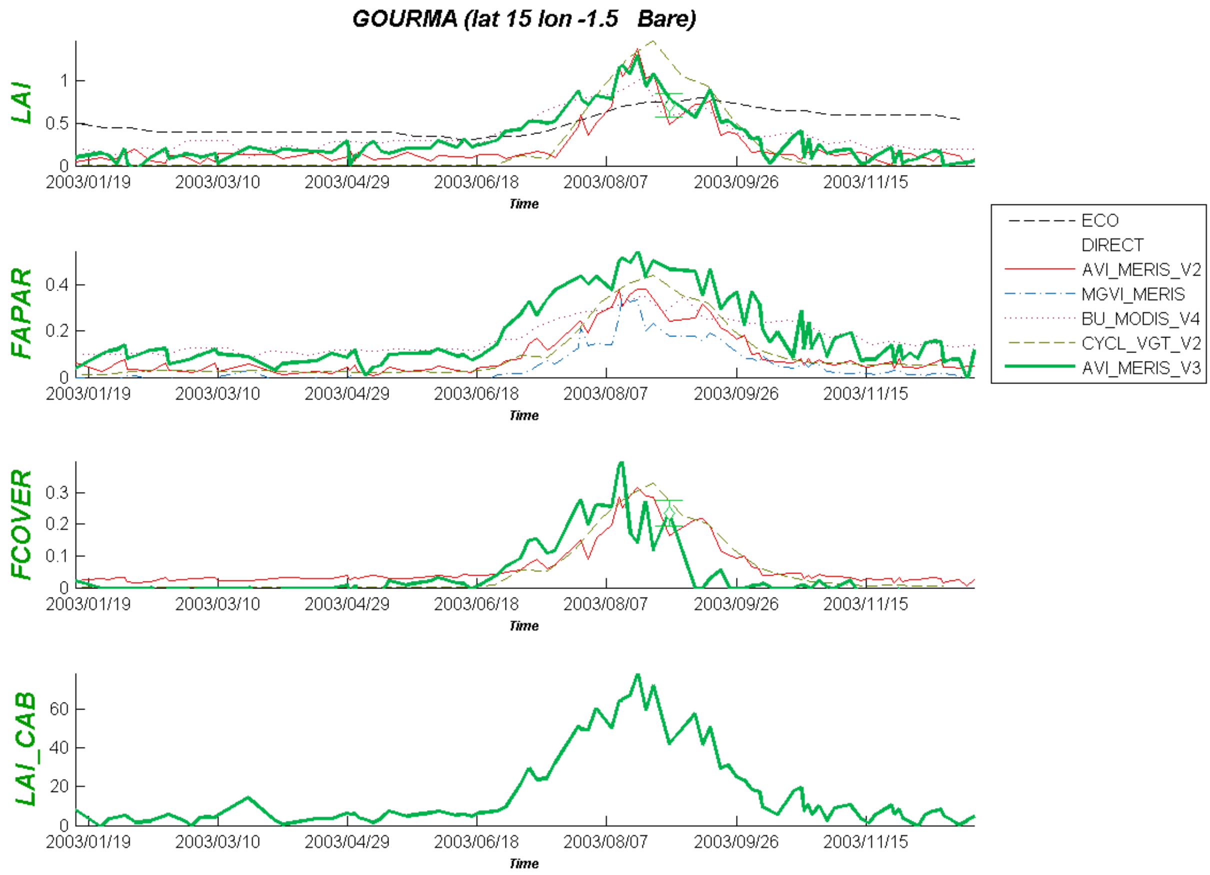
COUNAMI (lat 5.3 lon -53 EverBroadForest)
LAI
FAPAR
FCOVER
LAI_CAB
Time
2003/01/19
2003/03/10
2003/04/29
2003/06/18
2003/08/07
2003/09/26
2003/11/15
ECO
DIRECT
AVI_MERIS_V2
MGVI_MERIS
BU_MODIS_V4
AVI_MERIS_V3

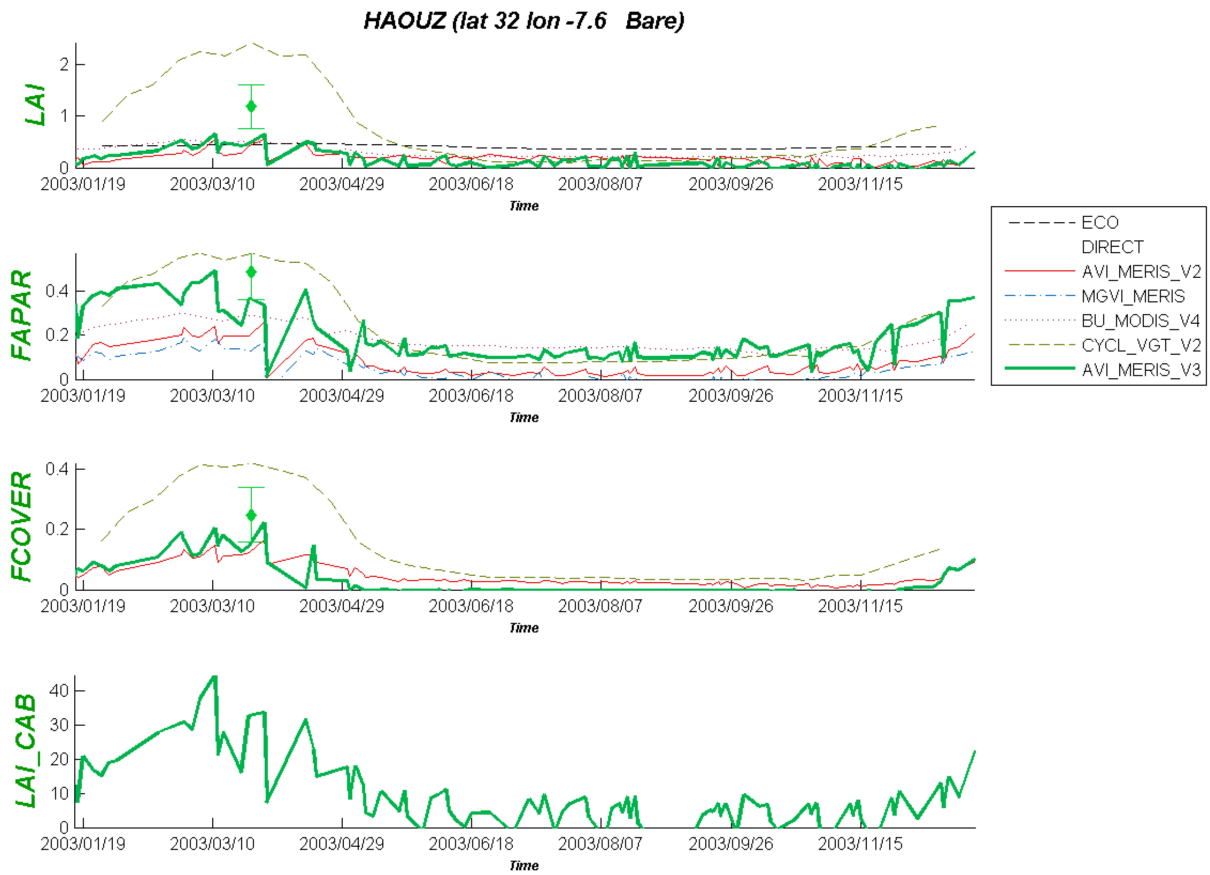


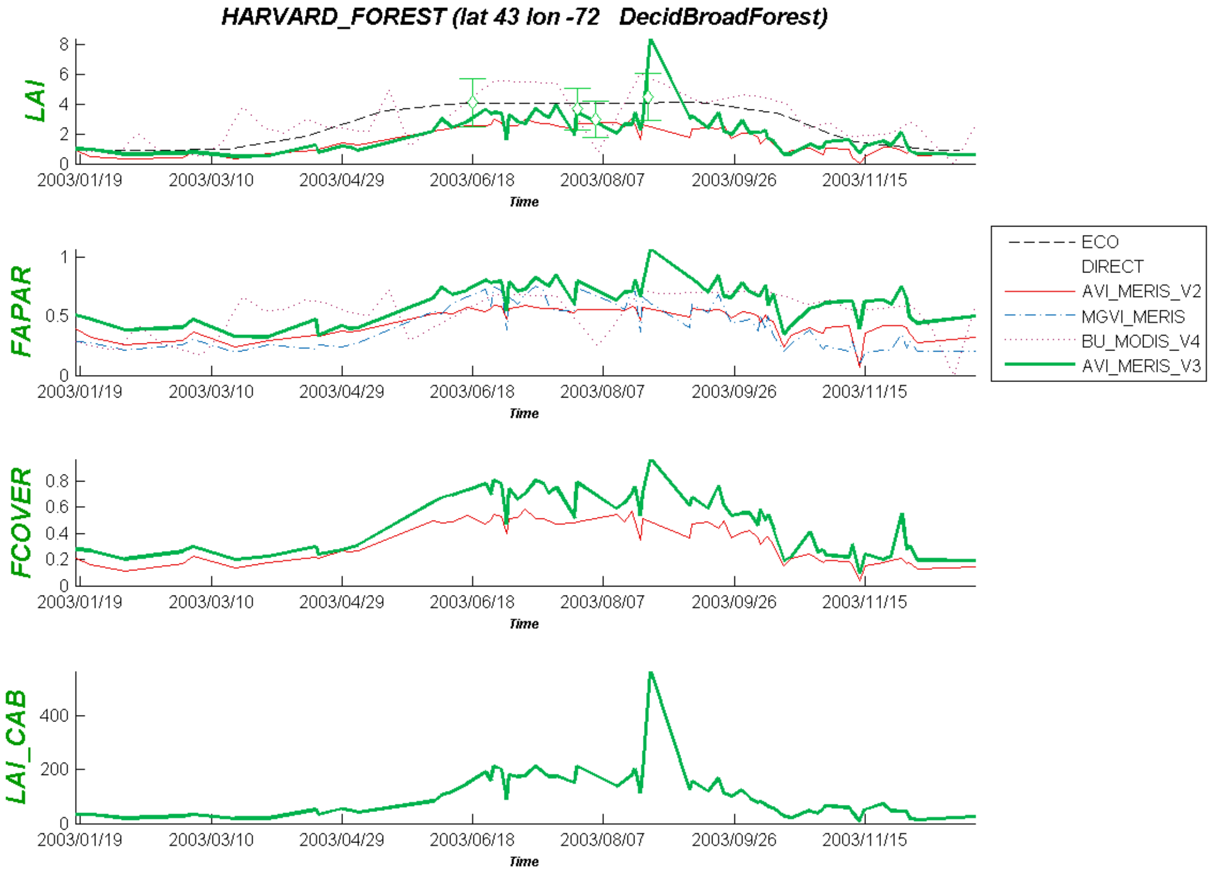
FONTAINEBLEAU (lat 48 lon 2.7 EverNeedleForest)
LAI
FAPAR
FCOVER
LAI_CAB
Time
2003/01/19
2003/03/10
2003/04/29
2003/06/18
2003/08/07
2003/09/26
2003/11/15
ECO
AVI_MERIS_V2
MGVI_MERIS
BU_MODIS_V4
CYCL_VGT_V2
AVI_MERIS_V3

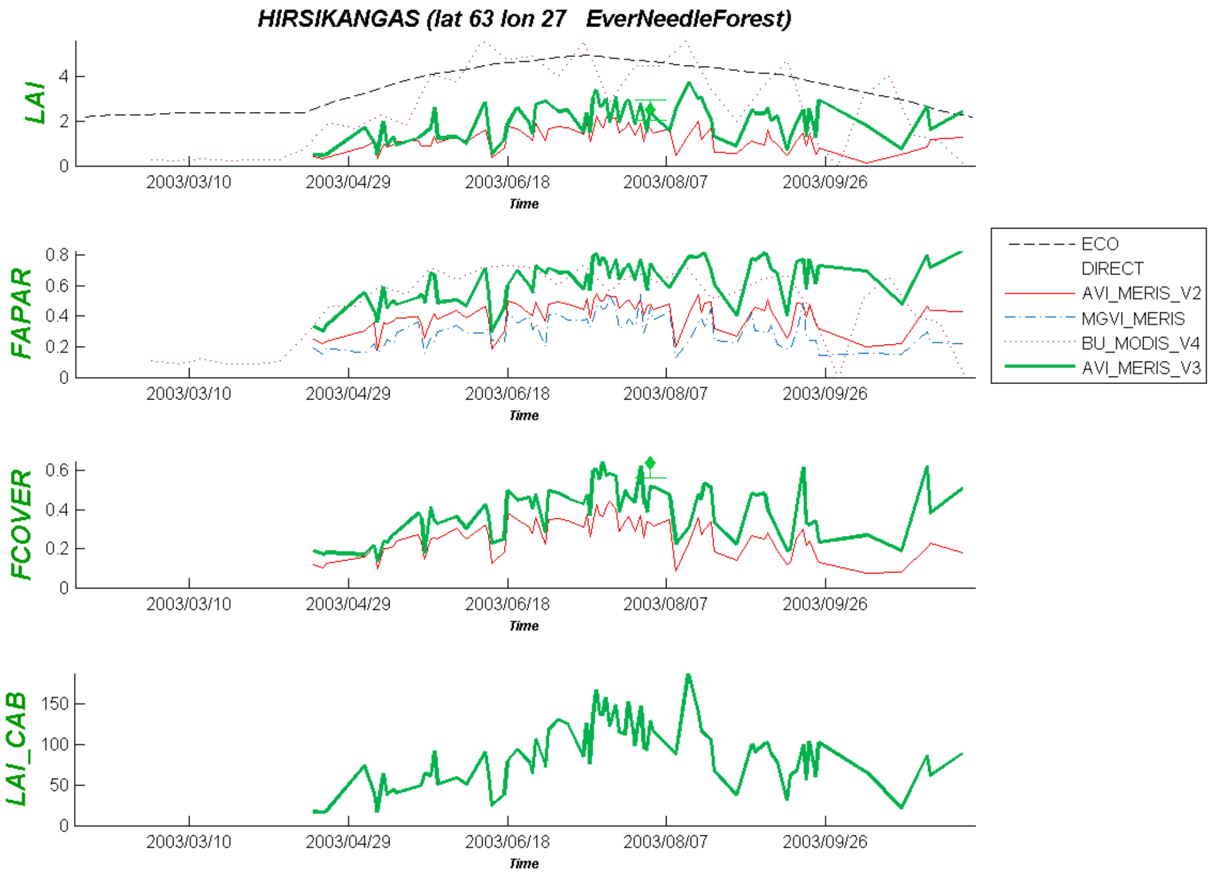

FUNDULEA (lat 44 lon 27 Crops)
LAI
FAPAR
FCOVER
LAI_CAB
Time
2003/01/19
2003/03/10
2003/04/29
2003/06/18
2003/08/07
2003/09/26
2003/11/15
ECO
DIRECT
AVI_MERIS_V2
MGVI_MERIS
BU_MODIS_V4
CYCL_VGT_V2
AVI_MERIS_V3

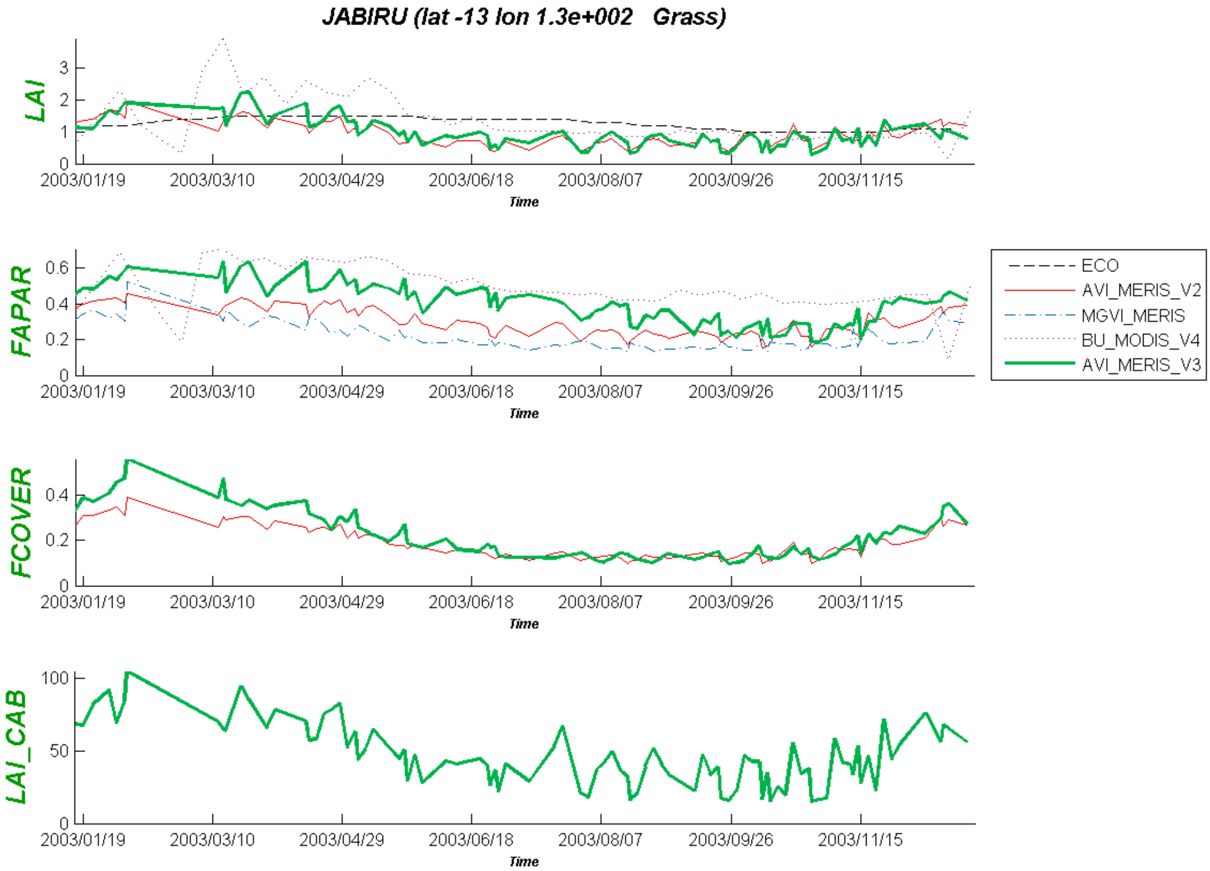

GILCHING (lat 48 lon 11 Crops)
LAI
FAPAR
FCOVER
LAI_CAB
Time
2003/01/19
2003/03/10
2003/04/29
2003/06/18
2003/08/07
2003/09/26
2003/11/15
ECO
DIRECT
AVI_MERIS_V2
MGVI_MERIS
BU_MODIS_V4
CYCL_VGT_V2
AVI_MERIS_V3

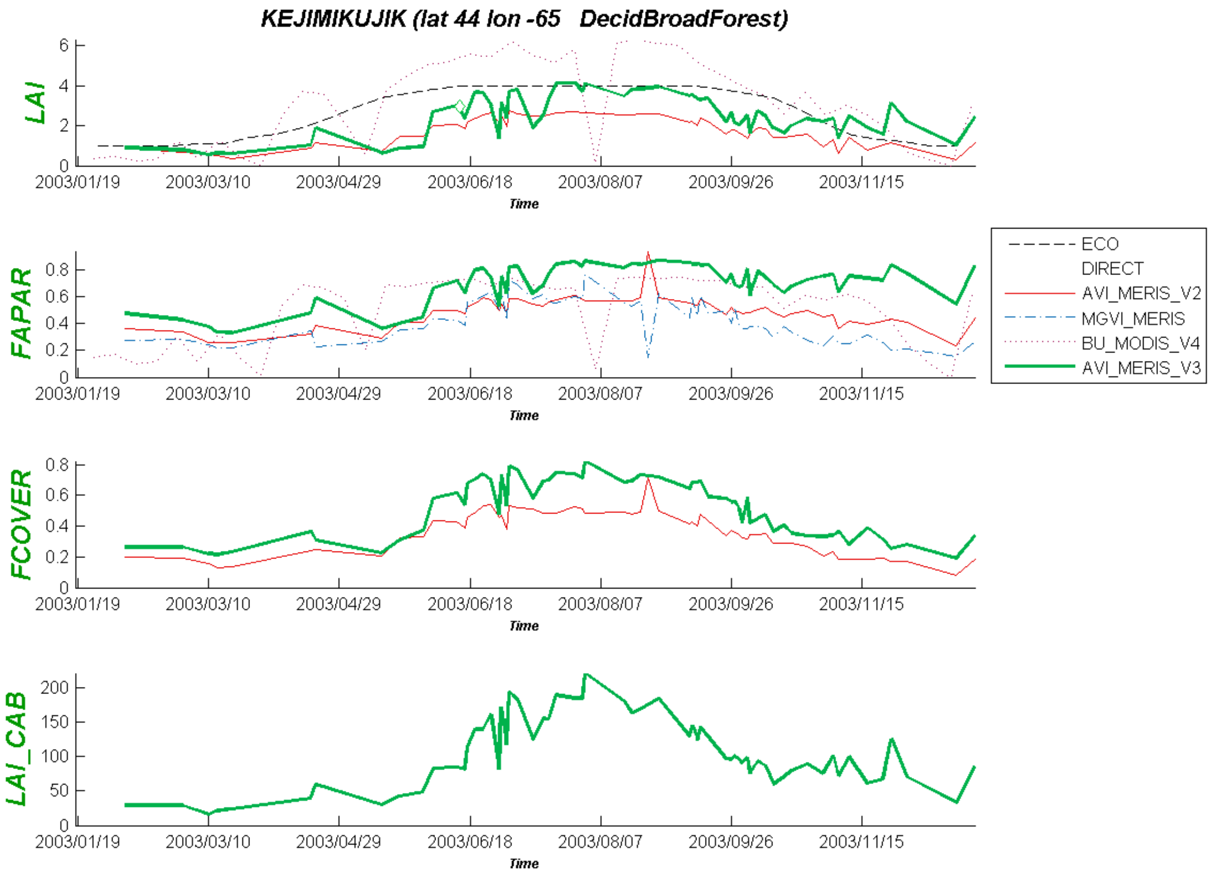

GOURMA (lat 15 lon -1.5 Bare)
LAI
FAPAR
FCOVER
LAI_CAB
Time
2003/01/19
2003/03/10
2003/04/29
2003/06/18
2003/08/07
2003/09/26
2003/11/15
ECO
DIRECT
AVI_MERIS_V2
MGVI_MERIS
BU_MODIS_V4
CYCL_VGT_V2
AVI_MERIS_V3

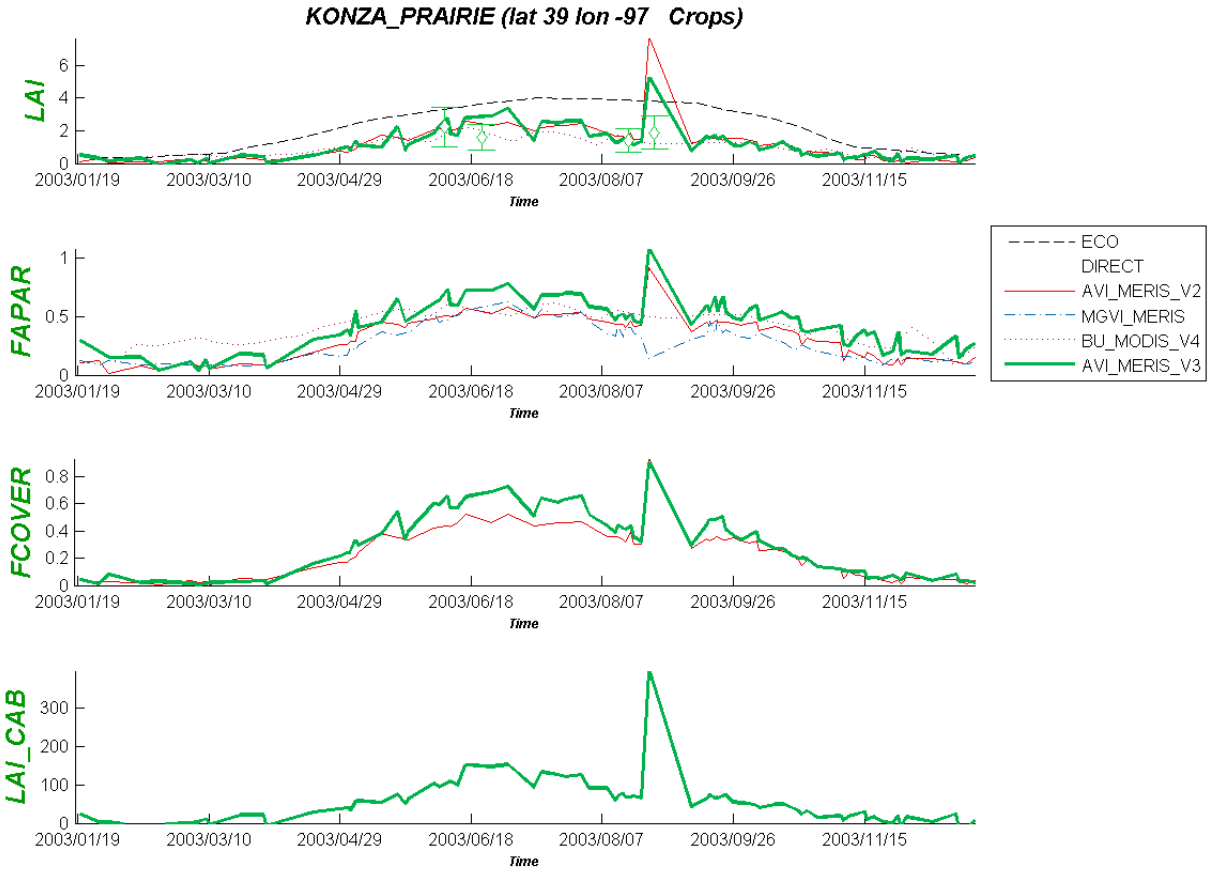

HAOUZ (lat 32 lon -7.6 Bare)
LAI
FAPAR
FCOVER
LAI_CAB
Time
2003/01/19
2003/03/10
2003/04/29
2003/06/18
2003/08/07
2003/09/26
2003/11/15
ECO
DIRECT
AVI_MERIS_V2
MGVI_MERIS
BU_MODIS_V4
CYCL_VGT_V2
AVI_MERIS_V3

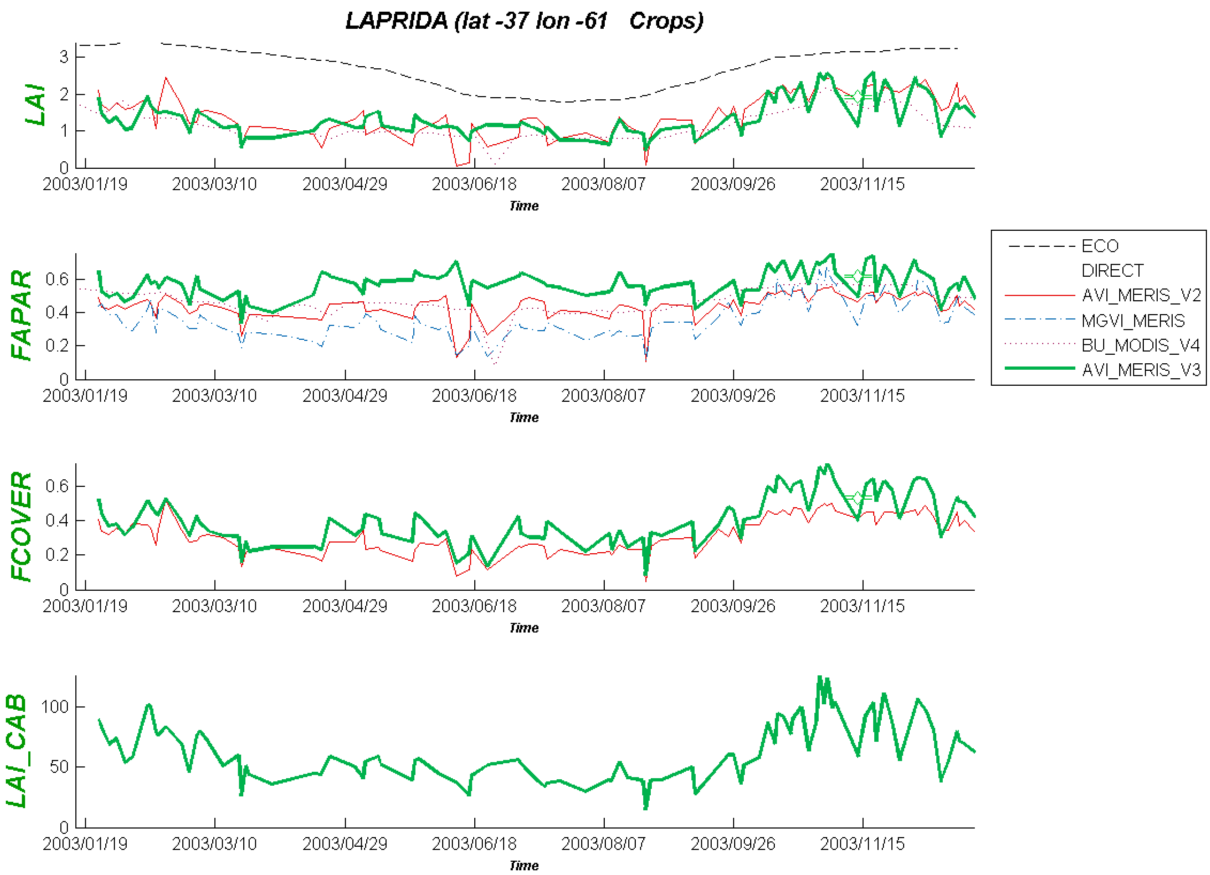

HARVARD_FOREST (lat 43 lon -72 DecidBroadForest)
LAI
FAPAR
FCOVER
LAI_CAB
Time
2003/01/19
2003/03/10
2003/04/29
2003/06/18
2003/08/07
2003/09/26
2003/11/15
ECO
DIRECT
AVI_MERIS_V2
MGVI_MERIS
BU_MODIS_V4
AVI_MERIS_V3

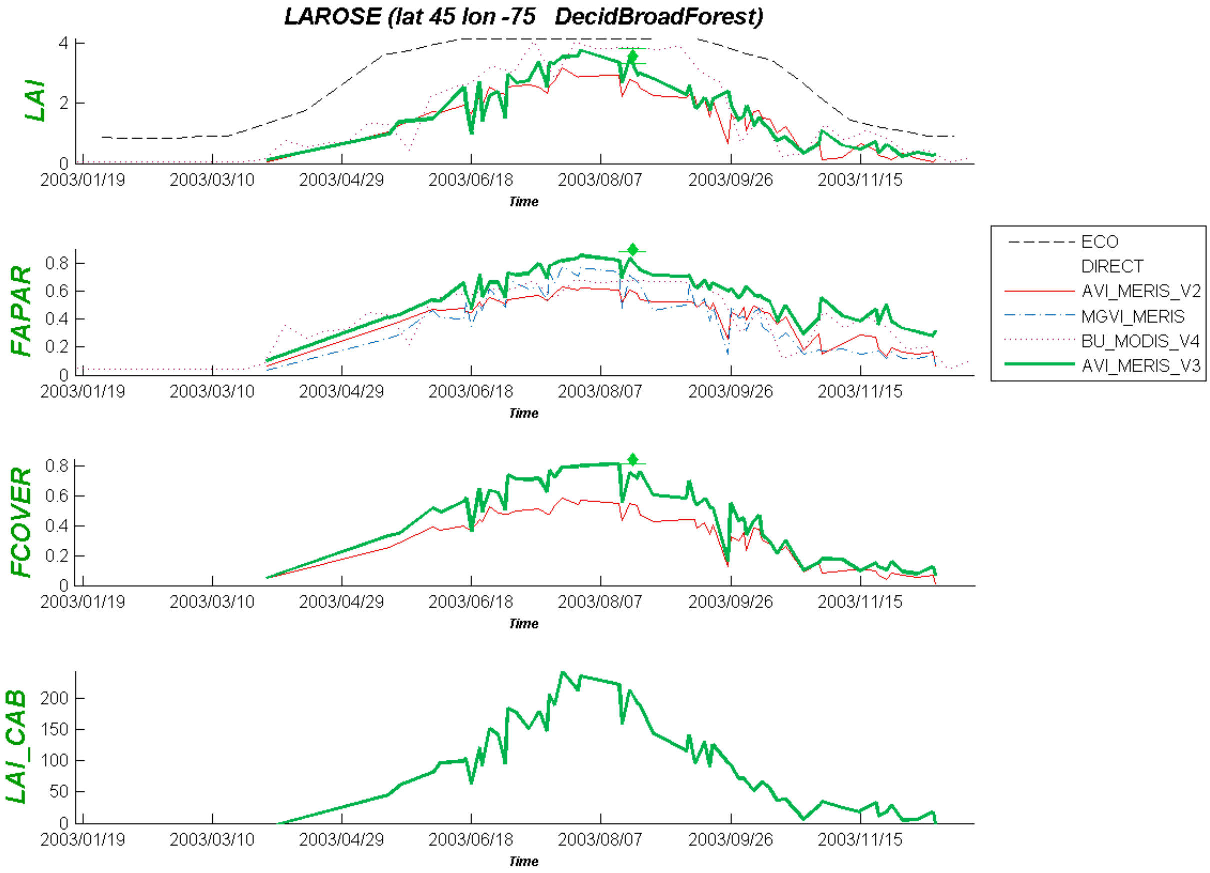

HIRSIKANGAS (lat 63 lon 27 EverNeedleForest)
LAI
FAPAR
FCOVER
LAI_CAB
Time
2003/03/10
2003/04/29
2003/06/18
2003/08/07
2003/09/26
ECO
DIRECT
AVI_MERIS_V2
MGVI_MERIS
BU_MODIS_V4
AVI_MERIS_V3

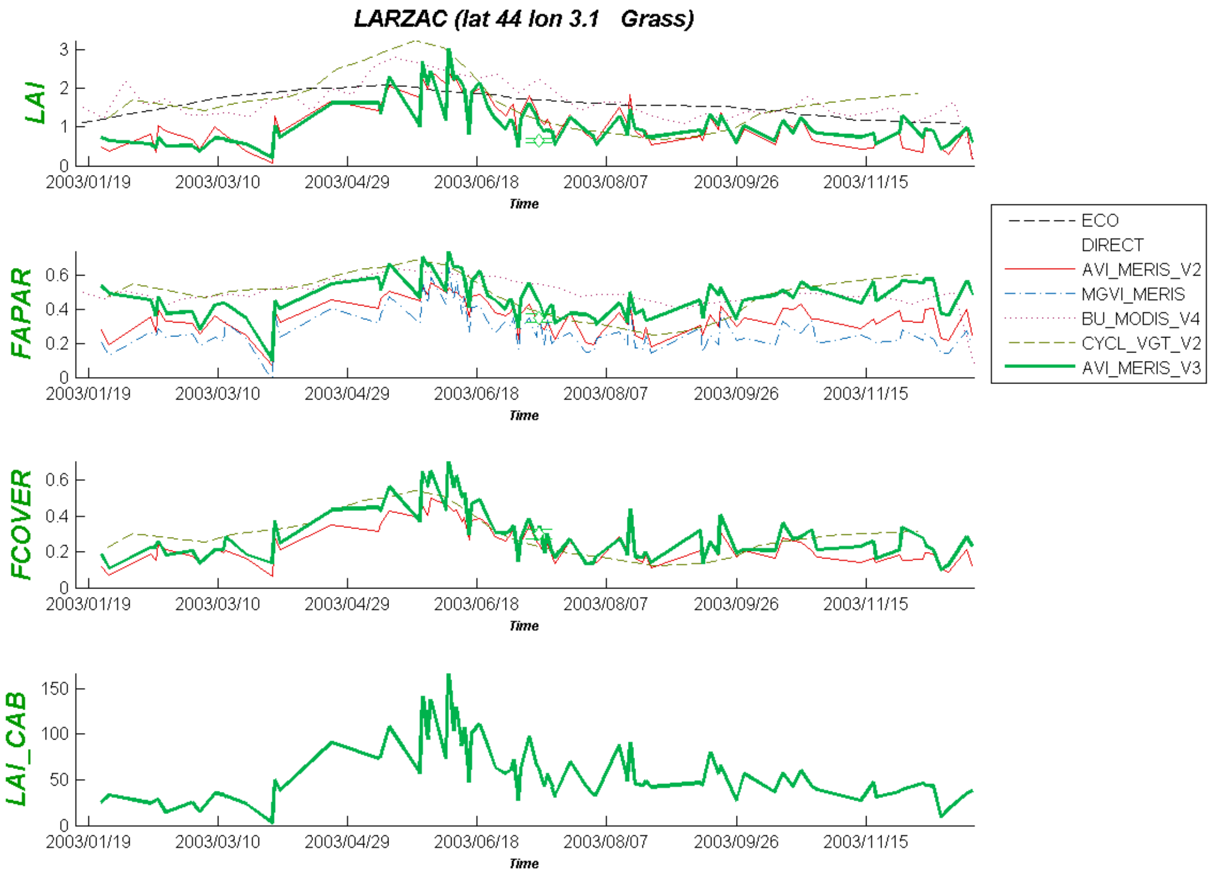

JABIRU (lat -13 lon 1.3e+002 Grass)
LAI
FAPAR
FCOVER
LAI_CAB
Time
2003/01/19
2003/03/10
2003/04/29
2003/06/18
2003/08/07
2003/09/26
2003/11/15
ECO
AVI_MERIS_V2
MGVI_MERIS
BU_MODIS_V4
AVI_MERIS_V3

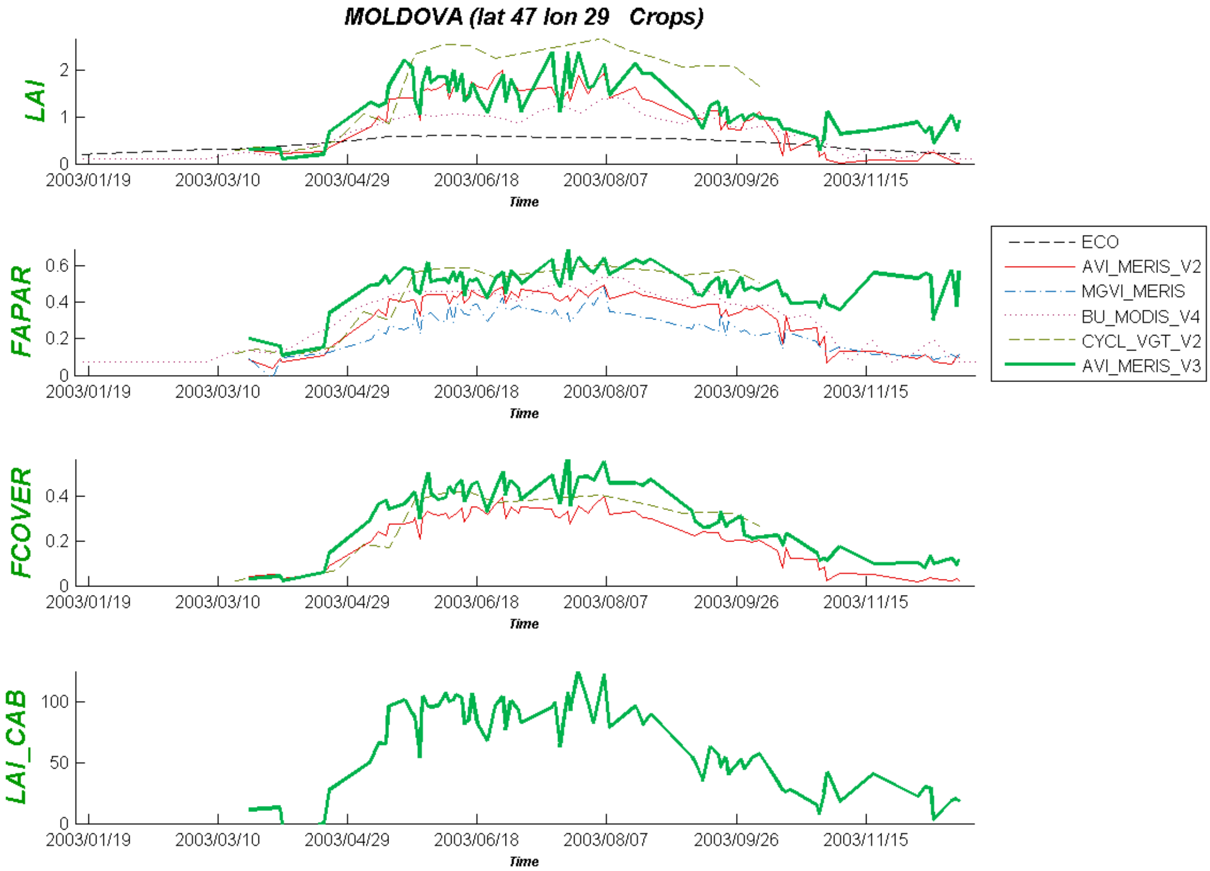

KEJIMIKUJIK (lat 44 lon -65 DecidBroadForest)
LAI
FAPAR
FCOVER
LAI_CAB
Time
2003/01/19
2003/03/10
2003/04/29
2003/06/18
2003/08/07
2003/09/26
2003/11/15
ECO
DIRECT
AVI_MERIS_V2
MGVI_MERIS
BU_MODIS_V4
AVI_MERIS_V3

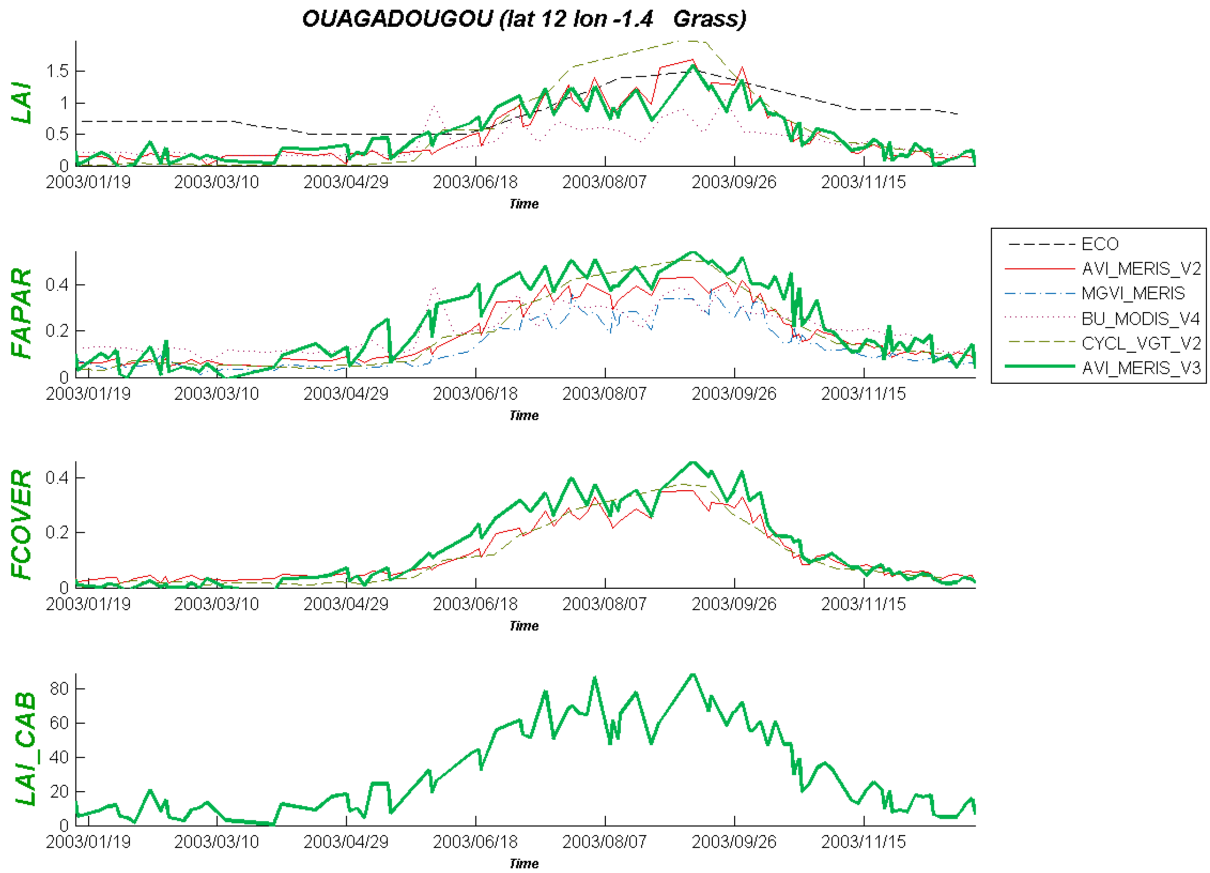

KONZA_PRAIRIE (lat 39 lon -97 Crops)
LAI
FAPAR
FCOVER
LAI_CAB
Time
2003/01/19
2003/03/10
2003/04/29
2003/06/18
2003/08/07
2003/09/26
2003/11/15
ECO
DIRECT
AVI_MERIS_V2
MGVI_MERIS
BU_MODIS_V4
AVI_MERIS_V3

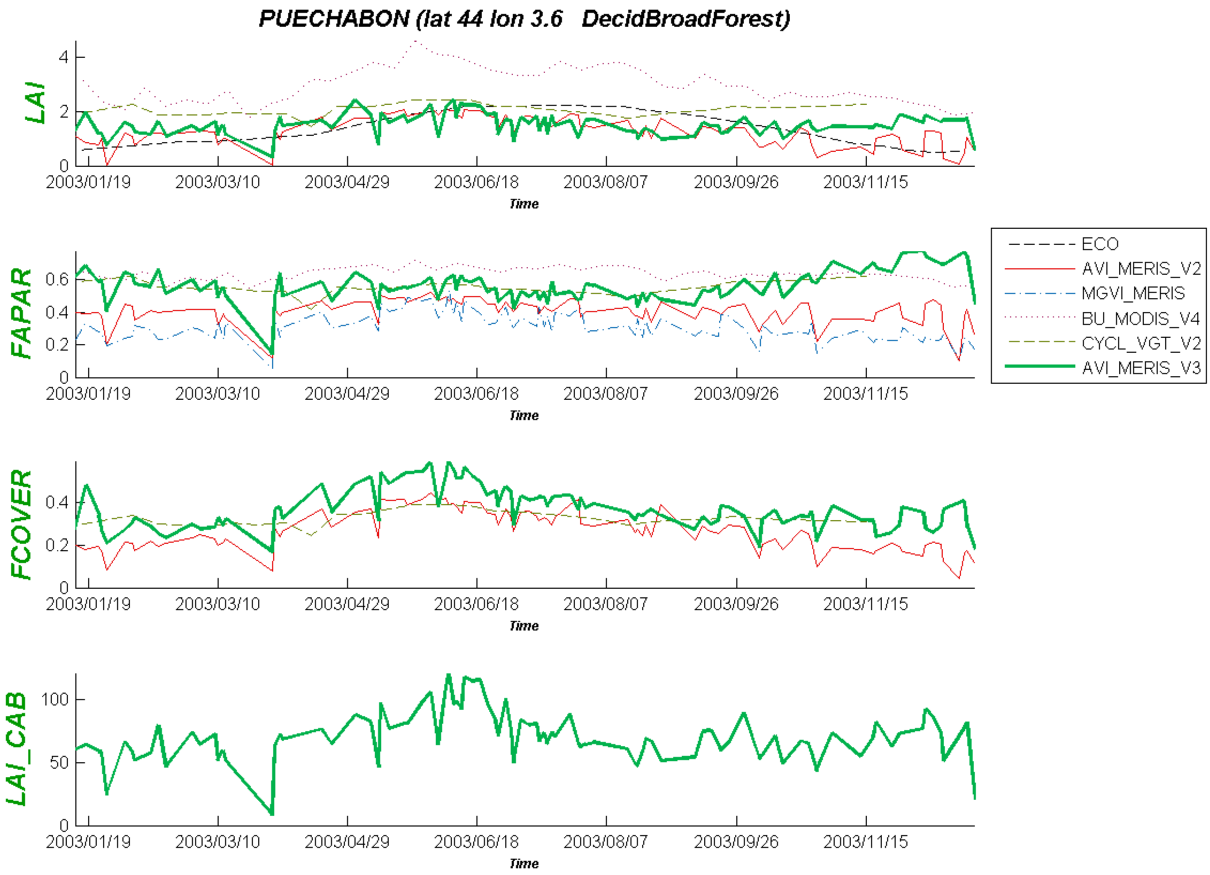

LAPRIDA (lat -37 lon -61 Crops)
LAI
FAPAR
FCOVER
LAI_CAB
Time
2003/01/19
2003/03/10
2003/04/29
2003/06/18
2003/08/07
2003/09/26
2003/11/15
ECO
DIRECT
AVI_MERIS_V2
MGVI_MERIS
BU_MODIS_V4
AVI_MERIS_V3

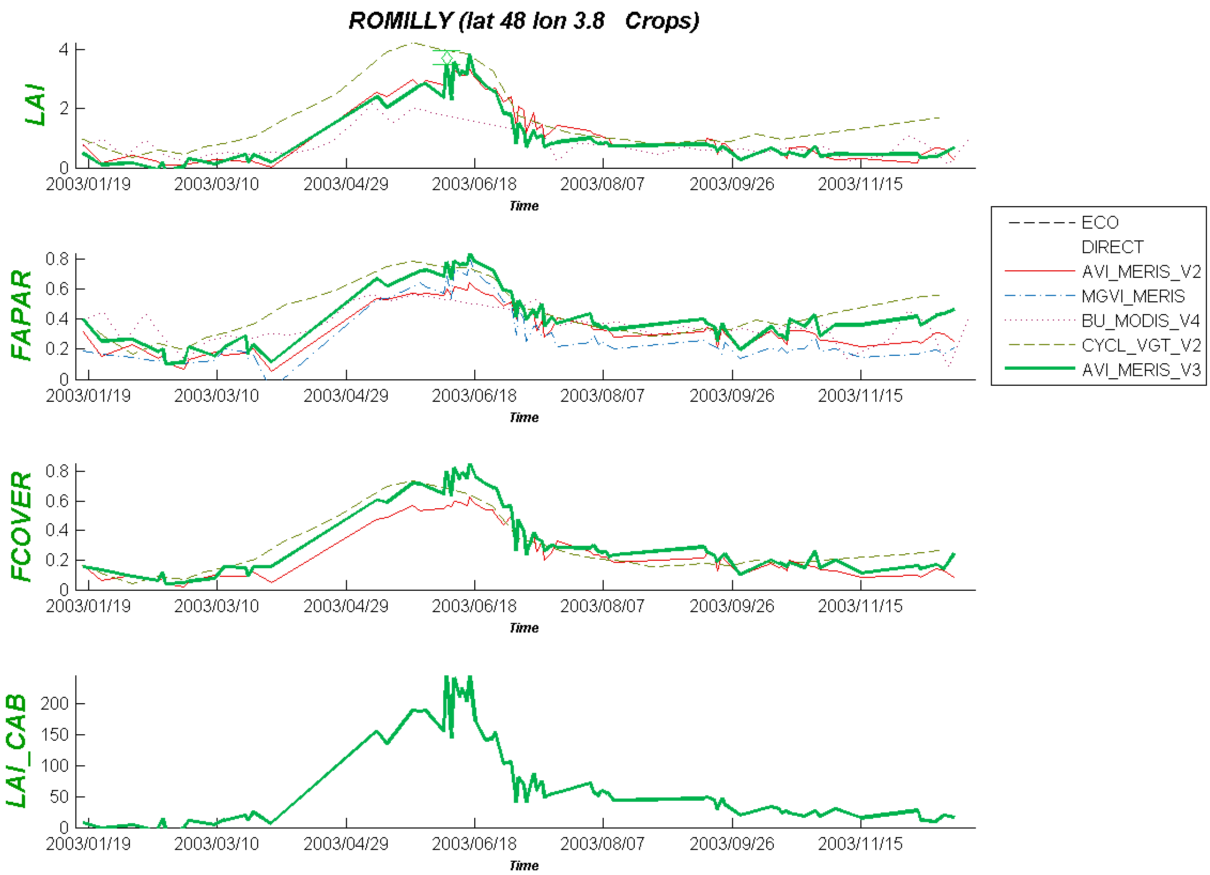

LAROSE (lat 45 lon -75 DecidBroadForest)
LAI
FAPAR
FCOVER
LAI_CAB
Time
2003/01/19
2003/03/10
2003/04/29
2003/06/18
2003/08/07
2003/09/26
2003/11/15
ECO
DIRECT
AVI_MERIS_V2
MGVI_MERIS
BU_MODIS_V4
AVI_MERIS_V3


LARZAC (lat 44 lon 3.1 Grass)
LAI
FAPAR
FCOVER
LAI_CAB
Time
2003/01/19
2003/03/10
2003/04/29
2003/06/18
2003/08/07
2003/09/26
2003/11/15
ECO
DIRECT
AVI_MERIS_V2
MGVI_MERIS
BU_MODIS_V4
CYCL_VGT_V2
AVI_MERIS_V3

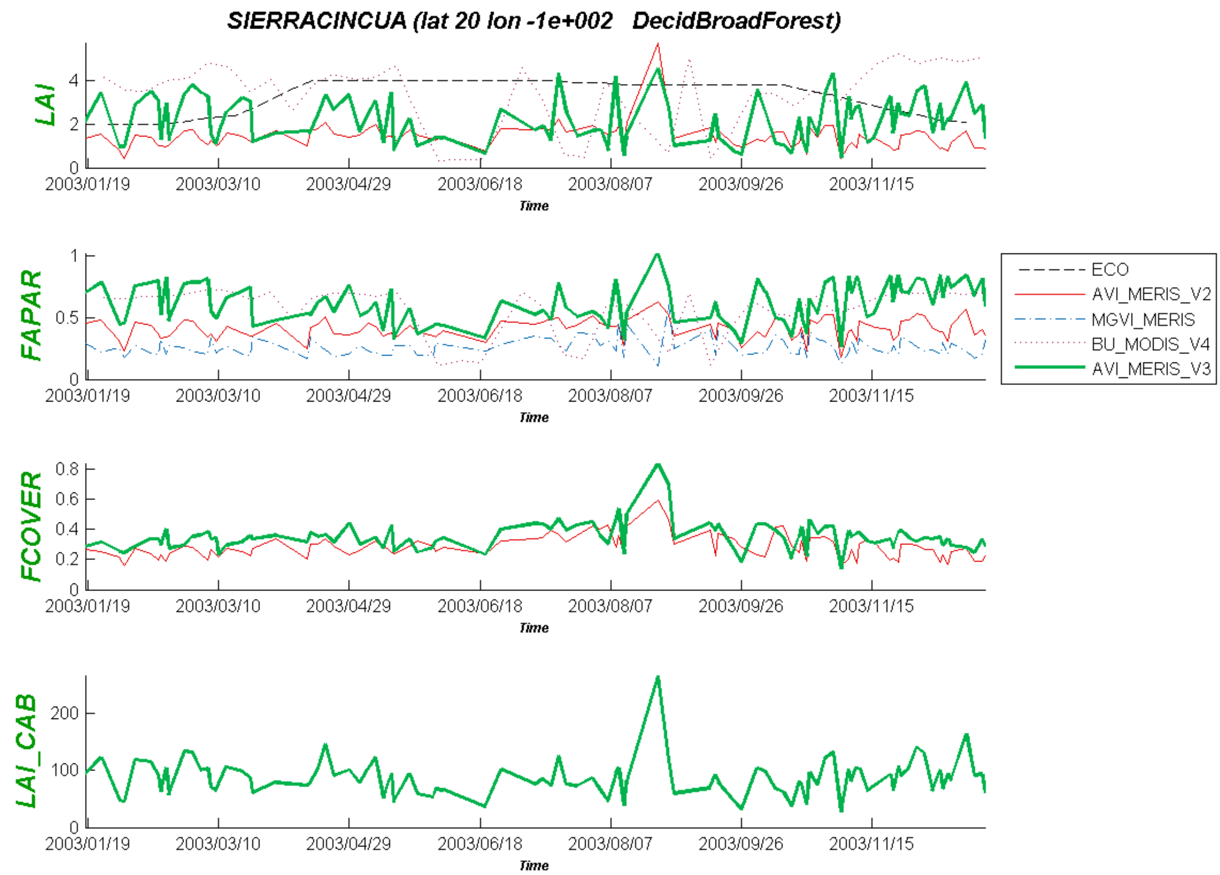

MOLDOVA (lat 47 lon 29 Crops)
LAI
FAPAR
FCOVER
LAI_CAB
Time
2003/01/19
2003/03/10
2003/04/29
2003/06/18
2003/08/07
2003/09/26
2003/11/15
ECO
AVI_MERIS_V2
MGVI_MERIS
BU_MODIS_V4
CYCL_VGT_V2
AVI_MERIS_V3

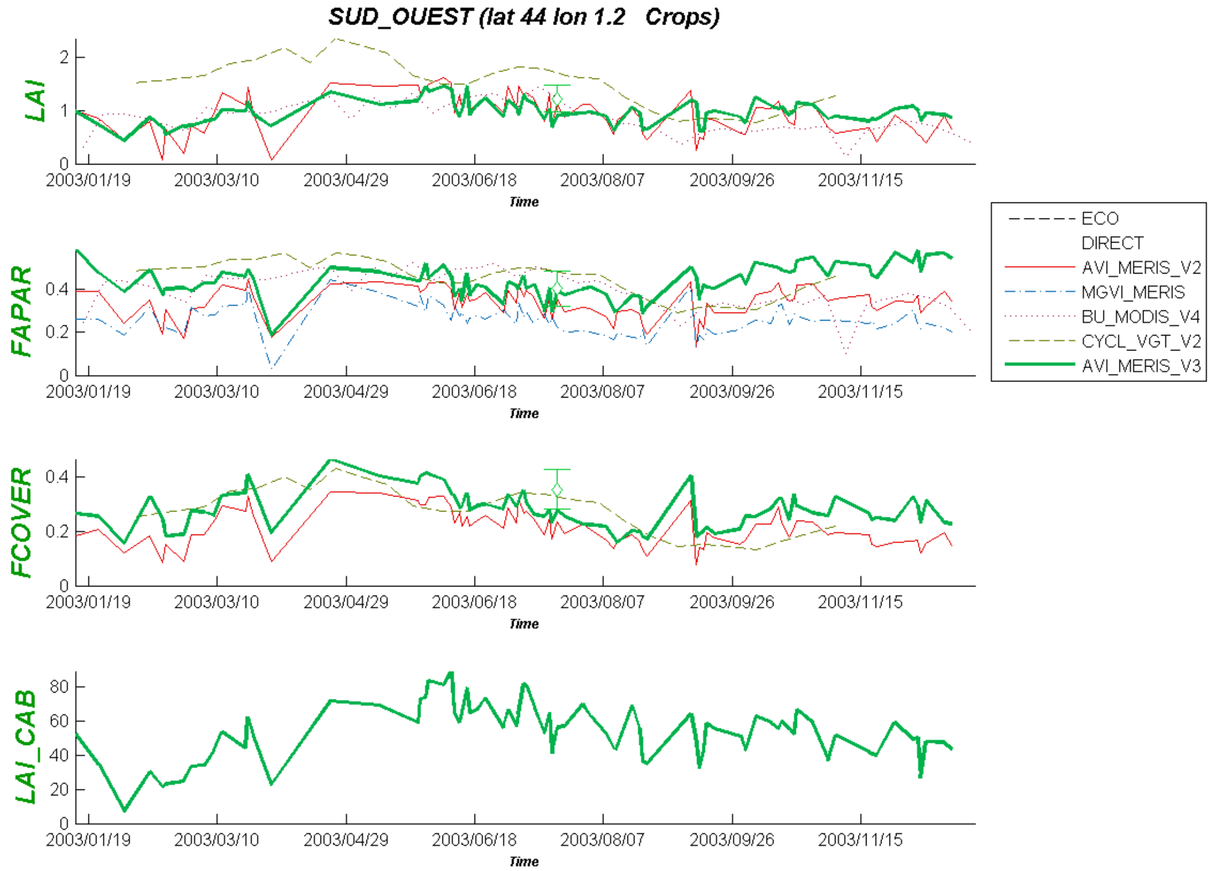

OUAGADOUGOU (lat 12 lon -1.4 Grass)
LAI
FAPAR
FCOVER
LAI_CAB
Time
2003/01/19
2003/03/10
2003/04/29
2003/06/18
2003/08/07
2003/09/26
2003/11/15
ECO
AVI_MERIS_V2
MGVI_MERIS
BU_MODIS_V4
CYCL_VGT_V2
AVI_MERIS_V3

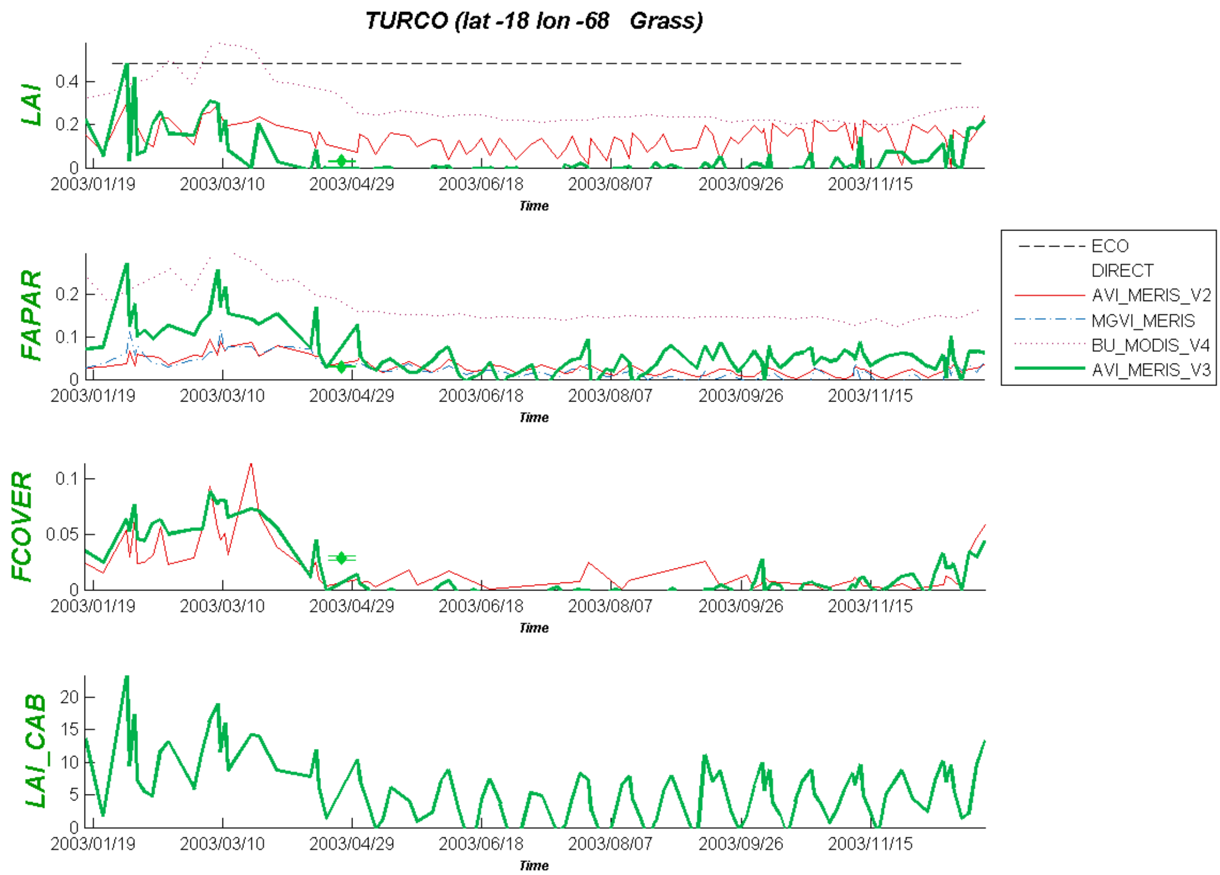

PUECHABON (lat 44 lon 3.6 DecidBroadForest)
LAI
FAPAR
FCOVER
LAI_CAB
Time
2003/01/19
2003/03/10
2003/04/29
2003/06/18
2003/08/07
2003/09/26
2003/11/15
ECO
AVI_MERIS_V2
MGVI_MERIS
BU_MODIS_V4
CYCL_VGT_V2
AVI_MERIS_V3

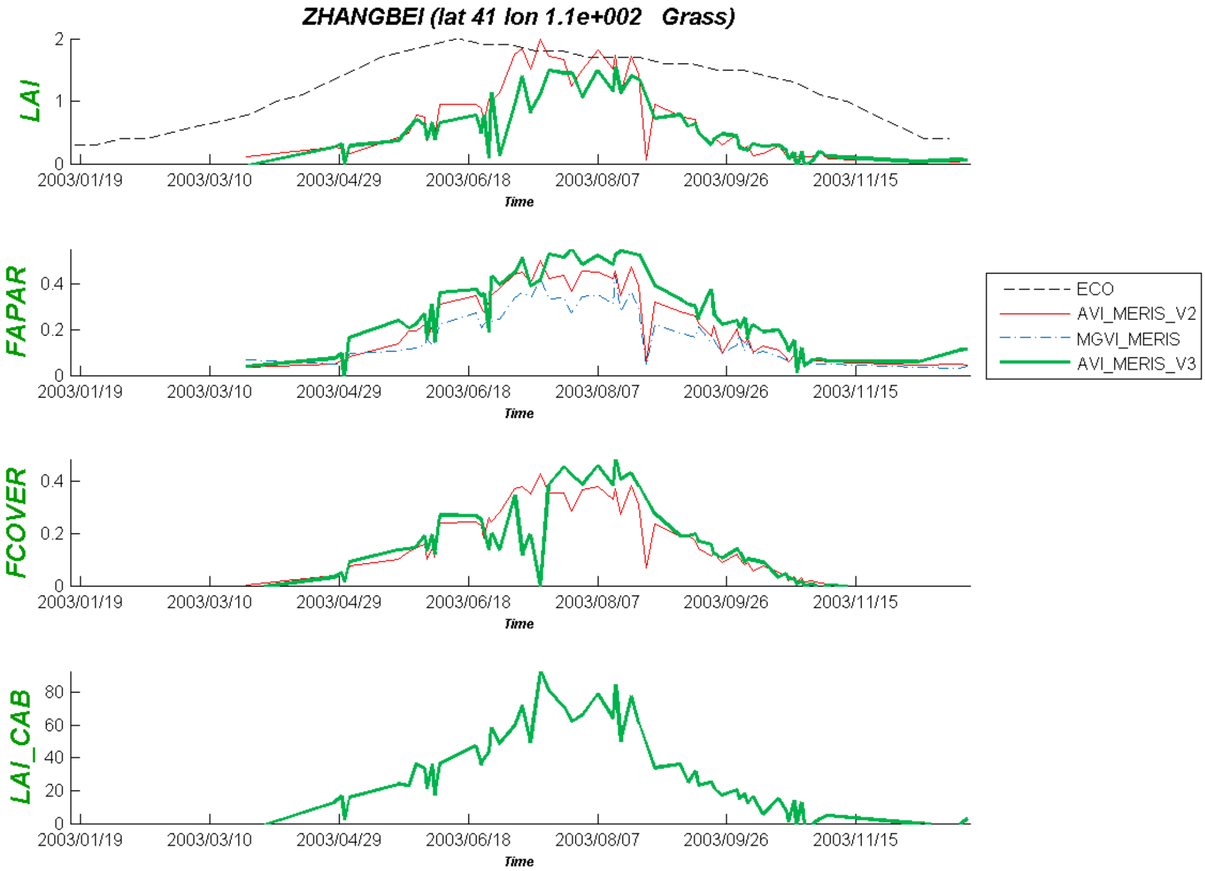

ROMILLY (lat 48 lon 3.8 Crops)
LAI
FAPAR
FCOVER
LAI_CAB
Time
2003/01/19
2003/03/10
2003/04/29
2003/06/18
2003/08/07
2003/09/26
2003/11/15
ECO
DIRECT
AVI_MERIS_V2
MGVI_MERIS
BU_MODIS_V4
CYCL_VGT_V2
AVI_MERIS_V3


SEVILLETA (lat 34 lon -1.1e+002 Bare)
LAI
FAPAR
FCOVER
LAI_CAB
Time
2003/01/19
2003/03/10
2003/04/29
2003/06/18
2003/08/07
2003/09/26
2003/11/15
ECO
DIRECT
AVI_MERIS_V2
MGVI_MERIS
BU_MODIS_V4
AVI_MERIS_V3


SIERRACINCUA (lat 20 lon -1e+002 DecidBroadForest)
LAI
FAPAR
FCOVER
LAI_CAB
Time
2003/01/19
2003/03/10
2003/04/29
2003/06/18
2003/08/07
2003/09/26
2003/11/15
ECO
AVI_MERIS_V2
MGVI_MERIS
BU_MODIS_V4
AVI_MERIS_V3


SUD_OUEST (lat 44 lon 1.2 Crops)
LAI
FAPAR
FCOVER
LAI_CAB
Time
2003/01/19
2003/03/10
2003/04/29
2003/06/18
2003/08/07
2003/09/26
2003/11/15
ECO
DIRECT
AVI_MERIS_V2
MGVI_MERIS
BU_MODIS_V4
CYCL_VGT_V2
AVI_MERIS_V3


TURCO (lat -18 lon -68 Grass)
LAI
FAPAR
FCOVER
LAI_CAB
Time
2003/01/19
2003/03/10
2003/04/29
2003/06/18
2003/08/07
2003/09/26
2003/11/15
ECO
DIRECT
AVI_MERIS_V2
MGVI_MERIS
BU_MODIS_V4
AVI_MERIS_V3



ZHANGBEI (lat 41 lon 1.1e+002 Grass)
LAI
FAPAR
FCOVER
LAI_CAB
Time
2003/01/19
2003/03/10
2003/04/29
2003/06/18
2003/08/07
2003/09/26
2003/11/15
ECO
AVI_MERIS_V2
MGVI_MERIS
AVI_MERIS_V3