VISITING SCIENTIST REPORT

Validation of SEVIRI/MSG vegetation products: Inter-comparison with POLDER-3/PARASOL and MODIS/Terra C4.1 products.

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Period: 6 months (October-December 2005 and March-May 2006)

Place: MEDIAS-France (Toulouse)

CONTENTS

1. BACKGROUND

1.1 EXECUTIVE SUMMARY

Vegetation Land SAF products (FVC, LAI, FAPAR) are being developed by the University of Valencia. FVC and LAI products are currently classified as Demonstration Products, which mean that these products have to demonstrate their competitiveness regarding other equivalent satellite products before become pre-operational Land SAF products. The FAPAR algorithm will be included in the next version of the code, which is expected to be operative in October 2006.

Validation of satellite products is a mandatory task before delivering them to the user community. Validation is the process of assessing the uncertainties associated to a given satellite product. In addition to the direct validation exercises, which are limited in time and space, the indirect validation or inter-comparison allow to assess the spatial and temporal consistency between equivalent products. In this way, we can evaluate in relative terms the performance of LSA SAF products.

A Visiting Scientist proposal aimed to perform an inter-comparison between MSG and PARASOL products, covering two periods, late 2005 and early 2006, was submitted by F. Camacho to the Consortium and was later approved for the Steering Group. This inter-comparison exercise includes also LAI fields derived from MODIS/Terra and ECOCLIMAP. The objectives and contents of this document are detailed in the following points.

1.2 OBJECTIVES

The objective of this work is to validate Land-SAF vegetation products, collection derived with the VEGA v1.2 algorithm, against equivalent satellite fields. POLDER-3/PARASOL products derived with the semi-empirical Lacaze-Roujean-Bréon LRB algorithm, and MODIS/TERRA collection 4.1 concomitant products were selected. In particular, the spatial and temporal consistency among these products for the period covering one year of Land-SAF data since june 2005 was evaluated.

1.3 CONTENT OF THE DOCUMENT

This document is divided in five sections plus seven annexes. This section gathers the background information. In section 2 a short introduction to the problem is given. Section 3 describes the methodological procedure, as well as datasets and ancillary information used here. In section 4 the main results are given, including histograms of the different products, histograms of the bias, statistic indicators (mean, std, RMS, bias, r) at both continental and biome scales per geographical areas, scatter-plots and temporal profiles over selected pixels representative of the different biomes. Finally, conclusions are summarized in Section 5.

In addition, annex I shows maps of MSG FVC and LAI products. Annex II shows maps of POLDER FVC and LAI LRB products. Annex III presents maps of MODIS LAI products. Annex IV shows absolute and relative difference maps between MSG and POLDER FVC and LAI products. Annex V shows absolute and relative difference maps between MSG and MODIS LAI products. Annex VI shows absolute and relative difference maps between POLDER and MODIS LAI products. Finally, annex VII includes tables with the quantitative results (mean, std, RMS, bias, r) of the inter-comparison among MSG, PARASOL and MODIS products.

1.4 RELATED DOCUMENTS

The following LSA SAF documents are closely related to this report:

- Validation Report. SAF/LAND/IM/VR/1.5. January 2006. 136 pp.
- Product User Manual Vegetation Parameters. SAF/LAND/UV/PUM_VEGA/1.0. January 2006. 42 pp.
- Product User Manual Albedo. SAF/LAND/MF/ PUM_AL/1.3. November 2006. 46 pp.
- User Requirement Document. SAF/LAND/URD/6.2. November 2003. 50 pp.

Other related documents are:

- POLDER-3/PARASOL Land Surface Algorithms Description. Issue 1.0. March 2006. Author: R. Lacaze and F. Maignan. POSTEL / Médias-France.
- Spécifications functionnelles du module de traitement scientifique Terres Emergées Niveau 3. PARASOL-ST-362-3670-MED. Authors: R. Lacaze and B. Miras. POSTEL / Médias-France.
- Report on the validation of PARASOL land products. Issue 1.0. May 2006. Author: F. Baret and K. Pavageau. POSTEL / INRA.
- MOD15_BU and MYD15_BU. Product readme. R. Myneni and W. Yang. 8 pp.
- MODIS Leaf Area Index (LAI) and Fraction of Photosynthetically Active Radiation Absorbed by Vegetation (FPAR) Product (MOD15) Algorithm Theoretical Basis Document, Knyazikhin et al. 1999.

2. INTRODUCTION

User Community of satellite-derived products requires knowing the level of uncertainty of such products, as well as details about the processing of the products or quality flag. Theoretical error estimates based on error of the input data and error propagation theory are often provided. However, the only way to evaluate the quality and the associated uncertainty of the products is by means of validation exercises. Land-SAF Users Requirements document (SAF/LAND/IM/URD/6.2) highlights the need to validate Land-SAF products for representative subsets of all geographical areas. The accuracy stated for vegetation products is on the order of 10% for FVC and 15% for LAI.

In addition, the conceptual differences in the algorithms used in the processing line of satellite products, along with inherent differences of the sensors (radiometric, spatial, temporal), as well as the different projection of the products hampers all together the inter-comparison between satellite products. This fact makes quite complex to understand the cause of the differences between products derived from different satellites and using different processing lines. Validation of global products is thus a very difficult task due to the extent of the products, its low spatial resolution, as well as the dynamic of the different vegetation cover types. Therefore, a number of different validation exercises (either direct or indirect) should be undertaken for a proper validation of global products.

Various validation exercises have been carried out in parallel to the development of the VEGA algorithm. The first version of the VEGA algorithm (v0.1) was implemented in the LandSAF system in March 2005. This preliminary version was validated at a global scale using POLDER BRDF k0 data at 7 km spatial resolution over Europe. The estimates were compared with equivalent POLDER/ADEOS reference products derived using two different retrieval algorithms (Camacho-de Coca et al., 2005; Camacho-de Coca, 2004). These two different approaches were the semi-empirical method developed by Roujean and Lacaze (2002), and the inversion of a physical-based model using a neuronal network technique (Bicheron and Leroy, 1999). However, this version of the algorithm was not properly fitted to the still preliminary SEVIRI BRDF data, thus not reliable FVC and LAI estimates were provided. Consequently, the Land-SAF VEGA v0.1 products have not been validated.

Afterwards, an improved version of the code (VEGA v1.0) (García-Haro et al., 2005) implemented in the Land-SAF system the 27th September 2005 was previously prototyped using VEGETATION (VGT) BRDF k0 data at 1 km spatial resolution over the Iberian Peninsula. The FVC and LAI estimates were thus validated against equivalent products provided by the FP5 CYCLOPES project (CYCLOPES_V1 and CYCLOPES_V2) using the same VGT input data and two different methods (Roujean and Lacaze, 2002; Baret et al., 2003). The collection 4 of the MODIS/Terra product was also considered. In addition, comparison with ground truth over the Barrax site was conducted. For details see Martinez et al. (2005) and Martinez (2006). The best correlation with ground truth in the Barrax area was found with the outcomes of the VEGA Land-SAF v1.0 algorithm.

In both prototyping exercises, either using POLDER/ADEOS or VEGETATION/SPOT data, the FVC and LAI fields retrieved using the Land-SAF algorithm showed similar overall uncertainty (RMS) with equivalent products derived using different algorithms (either semi-empirical or physically-based) of about 0.1 for FVC and 0.8 for LAI. These prototyping exercises have shown that the algorithm for retrieving vegetation parameters in Land-SAF is both physically sound and reliable.

Afterwards, Land-SAF products derived with the first version of the algorithm (VEGA v1.0) were validated. VEGA v1.0 was running in the system since October 2005 till January 2006 only over the European region. The validation of this collection v1.0 was carried out during the first part of this visiting scientist (see results in SAF/LAND/IM/VR/1.5). As POLDER/PARASOL products were not available yet, the inter-comparison of VEGA v1.0 products was carried out using coincident MODIS products, and POLDER-2/ADEOS-2 and VEGETATION/SPOT products corresponding to the same period of 2003. The inter-comparison of VEGA v1.0 products with similar products provided an overall RMS of around 0.2 for FVC and 1.2 for the LAI, slightly better than between other products. A new version (VEGA 20) including the FAPAR product, without changes in the FVC and LAI codes, is expected to be ready in October 2006.

In this work the quality of the more recent collection derived with the algorithm VEGA v1.2, which is operational in the system since January'06, is evaluated for all the SEVIRI geographical areas. Preliminary validation results of this version were also included in the SAF/LAND validation report 1.5 (January 2005). In this report, the spatial and temporal consistency of the Land-SAF VEGA 1.2 products against similar biophysical products is assessed. Coincident global MODIS LAI C4.1 at 1 km and global PARASOL FVC and LAI products at 6-km are used. Numerous validation experiments support the reliability of MODIS LAI products (operational since 2000), whereas PARASOL products were in the validation phase.

3. METHODOLOGY

3.1 IMAGERY DATASET

· SEVIRI/MSG

FVC and LAI MSG products (figure 1) are currently generated daily at the full spatial resolution of the SEVIRI instrument by using the VEGA v1.2 algorithm. These products are based on the three short-wave channels (VIS 0.6µm, NIR 0.8µm, SWIR 1.6µm) using as input the k0 parameter of a parametric BRDF (Bi-directional Reflectance Distribution Function) model (Roujean et al. 1992). The k0 parameter (normalized reflectance) provides almost cloud-free observations over the SEVIRI disk based on an iterative scheme with a characteristic time scale of five days (see details in the Albedo PUM). FVC is retrieved using an optimized Spectral Mixture Analysis (García-Haro et al., 2006). Then, the LAI product is obtained directly from the FVC product, which is corrected of anisotropy effects, using the semi-empirical approach proposed by Roujean and Lacaze (2002). A cover-dependent empirical clumping index for each of the GLC2000 classes has been adopted based on POLDER/ADEOS estimations (Chen et al., 2005). The clumping is assumed for simplicity to be homogeneous within each vegetation cover type.

In this study, FVC and LAI v1.2 fields over the SEVIRI disk from August to December 2005 were used for the spatial consistency assessment against similar products. In addition, Land-SAF vegetation fields from January to July 2006 were also used for the temporal analysis in order to have full information on the phenologycal cycle of vegetation. This dataset can be downloaded from the landsaf site (http://landsaf.meteo.pt) since January 2006. The products corresponding to 2005 were reprocessed using the VEGA v1.2 code at the University of Valencia. The official products for 2005 were derived over Europe with previous versions of the algorithm. An evaluation of the quality of v1.0 can be found in the Land-SAF Validation Report (SAF/LAND/IM/VR/1.5).

Land-SAF products are distributed in HDF5 format. The spatial coverage is the SEVIRI disk (MSG at 0º) and the products are given in the original satellite projection, the area is split in four geographical areas (Euro, North Africa, South Africa and South America). The spatial resolution is variable from 3 km at nadir up to 12 km in northern latitudes. The temporal resolution is daily, and the composite window of the BRDF is typically of 5-days. Each HDF5 VEGA file contains the product, its error and a quality flag (see details in VEGA PUM). Land-SAF products are taken as reference for the inter-comparison with POLDER and MODIS products.

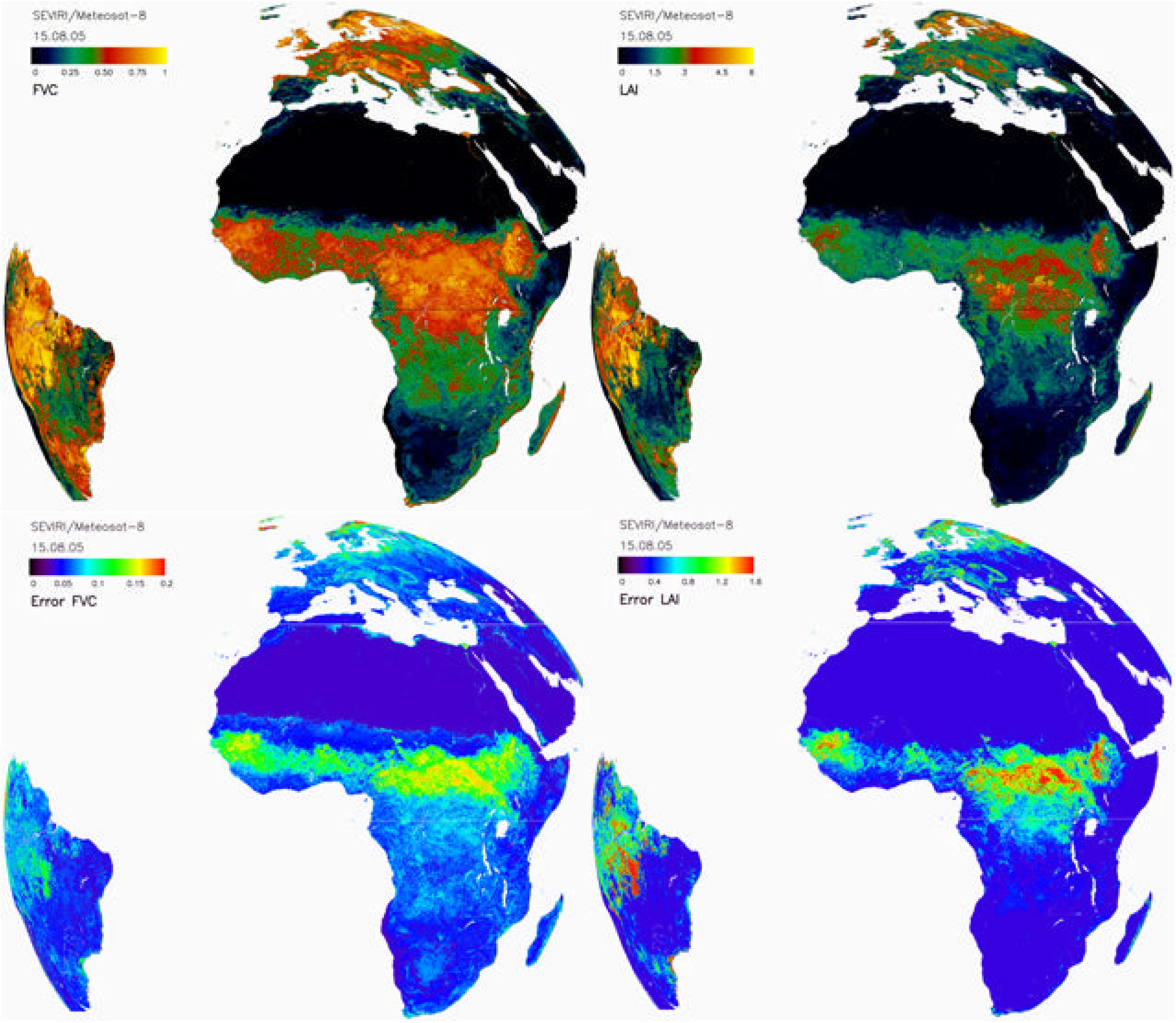


Figure 1.- FVC (left) and LAI (right) product composition of the four LSA SAF geographical areas corresponding to the 15th of August 2005. Top plots correspond to the products and bottom plots are its associated error estimates.

· POLDER / PARASOL

Two different sets of POLDER-3/ PARASOL vegetation products have been produced in the POSTEL Service Center at MEDIAS-France following two different approaches: (i) A physical-based model inversion (Bicheron and Leroy, 1999) using a Neuronal Network technique developed for POLDER/ADEOS and used also in POLDER-2/ADEOS-2 for retrieving FVC and LAI fields, and (ii) a semi-empirical relationship based on a vegetation index (DVI) (Roujean and Lacaze, 2002) to estimate FVC and LAI. For retrieving the FAPAR a linear relationship with other vegetation index (RDVI) (Roujean and Bréon, 1995) computed in an optimal geometry is used. The second approach, called LRB (Lacaze, Roujean, Bréon) is quite similar to that adopted in Land-SAF except for retrieving the FVC. Directional observations are used to fit a BRDF parametric model. The isotropic (nadir-zenith) reflectance is then used for deriving a normalized vegetation index (DVI_0). Then, the fractional vegetation cover is retrieved from a linear relationship with the DVI_0, using two different sets of coefficients for low or dense vegetation cover. The LAI is retrieved from the FVC using an exponential relationship between FVC and LAI (Roujean and Lacaze, 2002). This function takes into account the clumping effect, which is computed from the image itself using the algorithm described in Roujean and Lacaze (2002). The documentation about the algorithmic description is found in Lacaze and Maignan (2006). The technical specifications are found in Lacaze et al. (2006).

PARASOL global products (figure 2) are available at (http://postel.mediasfrance.org/) in binary format. The POLDER grid is based on the sinusoidal area projection (Sanson-Flamsted). The temporal resolution is 10-days, with a composite period of 30-days. Each PARASOL vegetation product contains its error estimates and a quality flag. PARASOL products were re-projected to the SEVIRI grid for the inter-comparison.

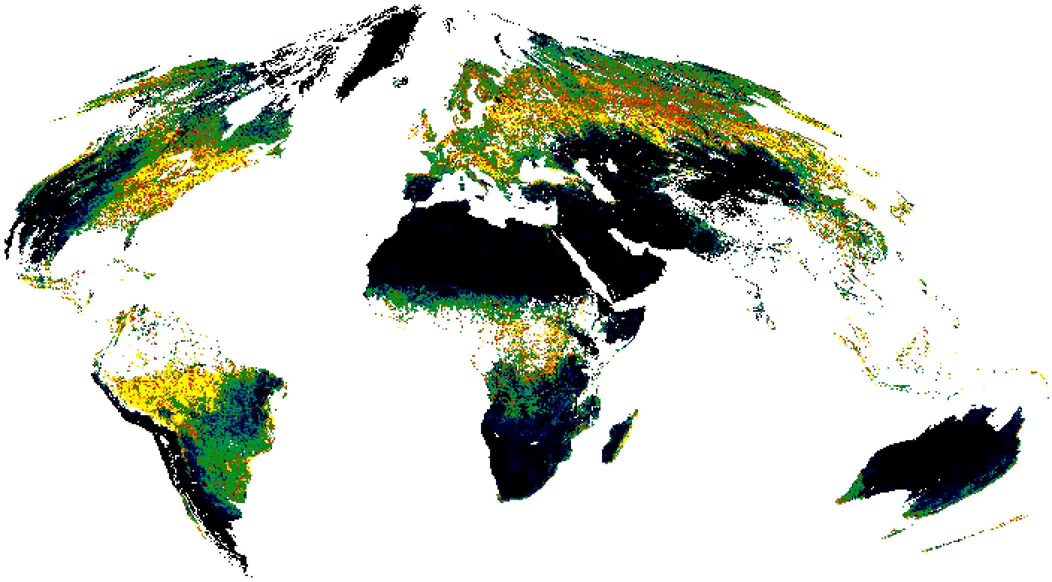


Figure 2.- LAI LRB PARASOL product of 15/08/2005. Large gap coverage is found along the Equatorial regions.

POLDER/PARASOL products were in a validation phase. The official validation of vegetation products was conducted by INRA-CSE (see Report on the validation of PARASOL land products, Baret and Pavageau (2006)). Important deficiencies in the POLDER/ PARASOL derived with the neuronal network algorithm were found. These problems are reported in Baret and Pavageau (2006). Therefore, only the LRB products were used for inter-comparison with MSG products.

Analysis of PARASOL gap fraction

One of the main problems found in the PARASOL products was the high amount of gaps. Figure 3 shows the percentage of valid pixels over land for major GLC classes and the different MSG geographical areas using the FVC LRB product as reference. The percentage of valid pixels is variable along the temporal period analyzed. In Europe, higher amount of gaps is found in December associated to the increase of cloudiness. Conversely, in North Africa, the larger proportion of gaps is found from July to September. In this case, both classes Bare and Herbaceous show very low fraction of gaps. In South Africa and South America, the fraction of gaps is related to the land cover type rather than to the period. In these areas, the cover types with major gap fraction are Broadleaved Evergreen Forest (BEF) and Tree cover: Flooded/Mosaic (TFM) (see table 1).

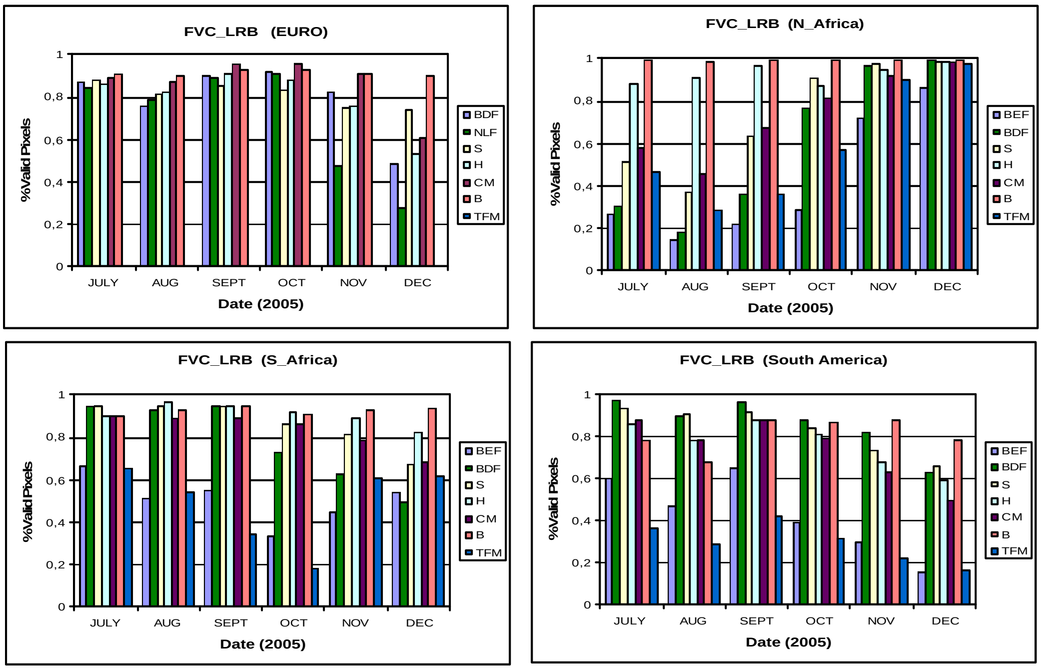


Figure 3.- Percentage of valid land pixels for major land cover classes in the four SEVIRI geographic areas. The FVC_LRB product is used as reference. BEF (Broadleaved Evergreen Forest), BDF (Broadleaved Deciduous Forest), NLF (Needle-leaved Forest), TFM (Tree cover: Flooded/Mosaic), S (Shrubs), H (Herbaceous), CM (Croplands and Mosaic), B (Bare Areas) as defined in table 1.

As a result of the above gap fraction analysis, those classes with gap fraction higher than 40%, and those months where variations in the gap fraction are higher than 20%, regarding the month with more valid pixels, are rejected for the subsequent analysis. In this way, histograms and statistics for different period are obtained using similar populations. The quantitative inter-comparison exercise has been carried out using the common area of valid pixels.

· MODIS / Terra

The MODIS products used in this exercise correspond to the global monthly LAI product, collection C4.1, derived from the TERRA platform, at 1 km resolution (MOD_15_BU). This dataset is available at the Boston University website (ftp://primavera.bu.edu/pub/).

The MODIS algorithm relies on the inversion of a 3D radiative transfer model using a look-up-table technique for 6 main biomes (Knyazikhin et al., 1998). When the algorithm fails a backup solution based on a relationship with the NDVI is used.

MODIS global products are distributed in HDF format. MODIS products present quite low amount of invalid land pixels over the globe (figure 4). The MODIS grid is the Integerized Sinusoidal (ISIN) projection. The ISIN projection is similar to the Sanson-Flamsted projection used for PARASOL products. The temporal resolution of global products is monthly. 8-days MODIS products are also available per tiles. The MODIS LAI product provides a Quality Flag but not error estimates. MODIS 1-km products were re-projected to the MSG grid. The data considered for the spatial consistency assessment spans from July to December 2005. For the temporal profiles, data from January to March 2006 was also considered.

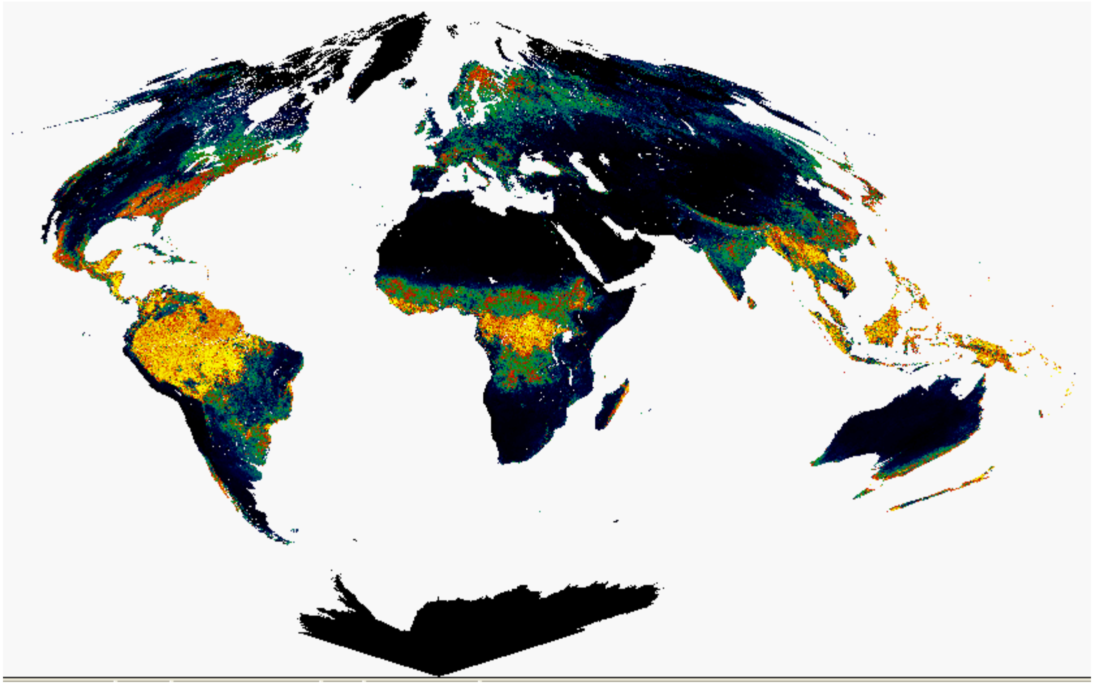


Figure 4.- Global LAI monthly MODIS product (MOD15_BU) of October 2005.

3.2 ANCILLARY DATA

· GLC-2000

The assessment of the spatial consistency among the different vegetation products is made as a function of main biomes. Here, the Global Land Cover (GLC-2000) classification re-projected over the MSG grid by Météo-France was used. GLC-2000 classification was recently validated, showing an overall accuracy of 68.6% (Mayaus et al., 2006). In this work, similar cover types were merged to reduce the number of classes. Finally, 8 main classes were identified: Broadleaved Evergreen Forest (BEF), Broadleaved Deciduous Forest (BDF), Needle-leaved Forest (NLF), Tree Cover: flooded/mosaic (TFM), Shrubs cover (S), Cultivated and Mosaic (CM) and Bare Areas (B). The spatial distribution of the merged classes is shown in figure 5. Table 1 provides the information about the original GLC classes used to form the reduced legend. Almost all types are present in the four geographical MSG areas. The exception is the biome Needle-leaved Forest - only present in Europe-. Also in Europe is not present the class Broadleaved Deciduous Forest.

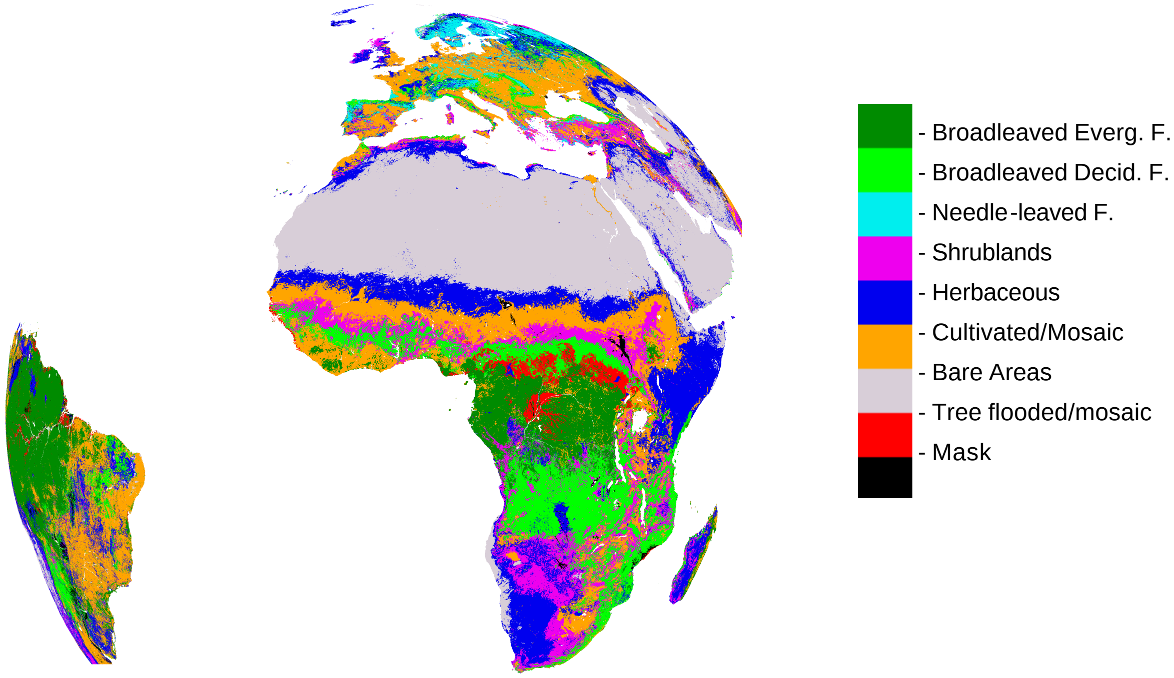


Figure 5.- Spatial distribution of the major land cover classes used based on the GLC-2000 classification re-projected to SEVIRI grid.

Tabla 1.- Composition of the reduced land cover legend used in this study as a function of the original GLC-2000 legend with the percentage of coverage in the different MSG regions.

			% of land pixels			
Reduced Legend	**Acronym**	**GLC-2000 legend**	Euro	Nafr	Safr	Same
Broadleaved Everg. Forest	**BEF**	Tree Cover, broadleaved, evergreen	0	5,4	14,3	36,3
Broadleaved Decidouos Forest	**BDF**	Tree Cover, broadleaved, deciduous, closed	10,0	5,7	31	8,2
		Tree Cover, broadleaved, deciduous, open				
Needle-leaved Forest	**NLF**	Tree Cover, needle-leaved, evergreen	10,7	0	0	0
		Tree Cover, needle-leaved, deciduous				
Tree Cover, flooded/mosaic	**TFM**	Tree Cover, regularly flooded, fresh water	2,4	2,7	0	1,5
		Tree Cover, regularly flooded, saline water				
		Mosaic: Tree Cover / Other natural vegetation				
Shrub lands	**S**	Shrub Cover, closed-open, evergreen	9,1	6,7	21,9	2,9
		Shrub Cover, closed-open, deciduous				
Herbaceous	**H**	Herbaceous Cover, closed-open	12,6	13,6	18,6	14,1
		Sparse herbaceous or sparse shrub cover				
Cultivated & Mosaic	**CM**	Cultivated and managed areas	42,7	14,8	10,4	30,9
		Mosaic: Cropland / Tree Cover / Other natural vege				
		Mosaic: Cropland / Shrub and/or grass cover				
Bare Areas	**B**	Bare Areas	6,7	50,4	2,1	1,9
Mask	**M**	Rest of GLC-2000 classes (except water bodies)	5,8	0,7	1,7	2,14

· ECOCLIMAP

ECOCLIMAP was primarily developed by Masson et al. (2003) to provide the surface variable fields required by Soil-Vegetation-Atmosphere Transfer models (SVATs) used for climate modeling. ECOCLIMAP combines two types of global classifications as shown in Figure 6 (Baret and Pavageau, 2006):

- A global biome classification corresponding to the main surfaces types , derived from the University of Maryland dataset (Hansen et al., 2000) (Figure 6-a) and the IGBP data (Loveland et al., 2000) both available at 1 km resolution. In addition, the CORINE Land Cover at 250-m resolution (Anonymous, 2003) and the Pan-European Land Cover Monitoring (PELCOM) at 1 km were used over Europe and Scandinavia in order to compensate deficiencies of the two previous global products in these areas.
- A world climate distribution map derived from the global climate map of Koeppe and De Long (1958) (Figure 6-b), improved by the Forest Information from Remote Sensing (FIRS) database over Europe (Anonymous, 1995). The combination of 15 land cover with 16 climate types enables to distinguish 240 surface classes out of which only 218 were actually represented. Note that Europe was described with larger details (93 classes) whereas the rest of the globe was described with 125 classes.

(a) (b)

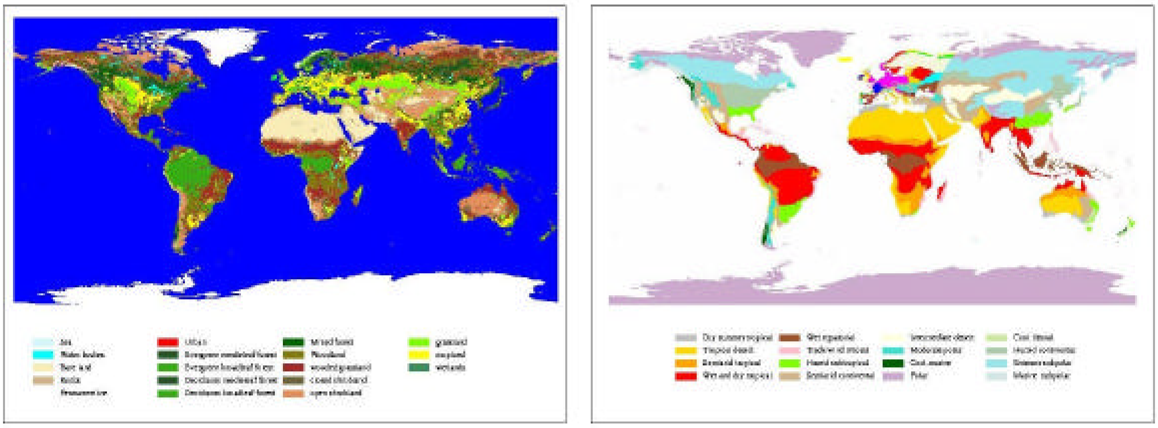


Figure 6.- (a) Land Cover Map University of Maryland, (b) Climate global map of Koeppe and De Long (1958).

The LAI range of variation for each surfaces class was computed using LAI values derived from the literature. The temporal evolution was derived using NOAA/AVHRR monthly NDVI composites at 1 km. More details can be found in Masson et al., (2003) and Baret et al., (2006). This climatology was evaluated against local measurements and POLDER LAI products (Roujean and Lacaze, 2002) showing a good level of consistency.

In this work, ECOCLIMAP_V2, currently under development at Météo-France, was used as reference of the temporal dynamic expected over selected sites. The ECOCLIMAP FVC values were derived from the LAI using the exponential function, FVC= 1-exp (-0.45*LAI), nearly the same used in POLDER LRB or Land-SAF to retrieve LAI from FVC products. As ECOCLIMAP is 1 km resolution, some sites at SEVIRI resolution included two ECOCLIMAP classes (see table 2 and table 3). In these cases, an average of the two major ECOCLIMAP classes was performed. Sites including more than two ECOCLIMAP classes were discarded. The ECOCLIMAP data was available in plate carreé projection based on the grid used for VEGETATION products.

3.3 TEST SITES

Two list of sites were selected for the spatial and temporal inter-comparison of products:

(1) For the spatial consistency assessment the CEOS-BELMANIP list of sites was used (Baret et al., 2006). These sites were compiled for validation of land biophysical products at moderate resolutions. CEOS-BELMANIP compiles sites from FLUXNET and AERONET networks, sites were direct validation exercises have been carried out, and includes additional sites up to 371 sites to improve the representativeness in latitude, longitude and surface type. In the four MSG areas the number of BELMANIP sites is: 73 for Europe, 26 for North Africa, 17 for South Africa, and 34 for South America. The distribution of the BELMANIP sites over the MSG disk is shown in figure 7.

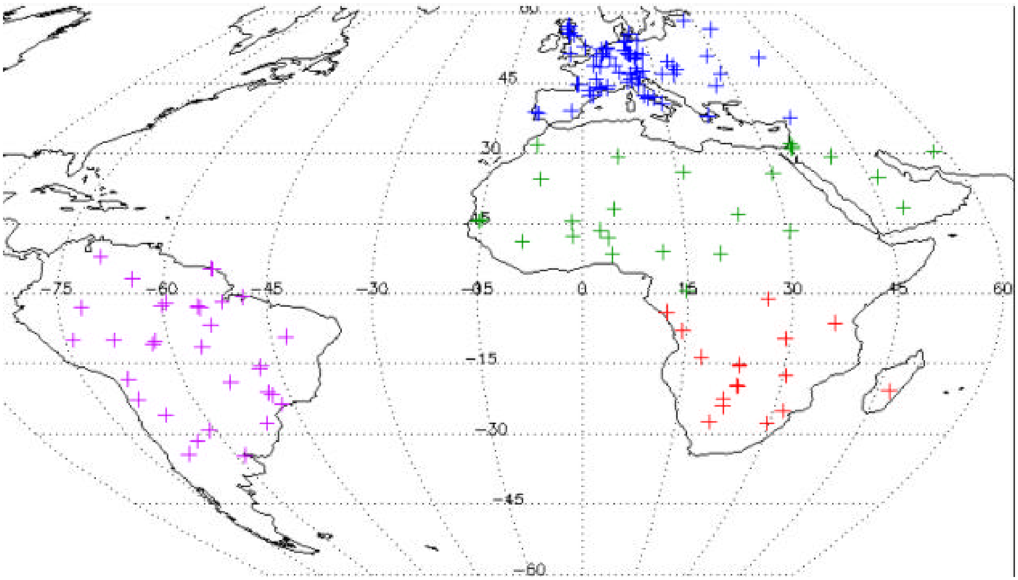


Figure 7.- Location of CEOS-BELMANIP sites over the MSG disk. A different colour is used for each Land-SAF geographical area.

(2) For the temporal consistency assessment, a reduced list of sites was used. We selected 15 sites for Europe and 14 for North Africa corresponding mostly to sites where direct validation exercises have been performed (eg., VALERI, MODLAND). Some additional well-know sites were included (eg., Rambla-Honda and Valencia AS in Spain). These sites were selected to show variability in surface and climate conditions following a North to South transect. Table 2 and 3 show the main characteristics of the selected sites.

Table 2.- Selected sites in Europe for the temporal analysis of the products. GLC acronyms are given in table 1. The ECOCLIMAP class for the given coordinate is also given. The presence of other ECOCLIMAP type in the MSG pixel is given in brackets.

SITES	Latitude	Longitude	Xmsg	Ymsg	Biome	GLC	ECOCLIMAP
HIRSIKANGAS	62.64	27.01	711	119	Evergreen needleleaf forest	NEF	11
JÄRVSELJA	58.30	27.26	777	175	Evergreen needleleaf forest	CM	217
HARWOOD	55.12	-2.02	267	203	Evergreen needleleaf forest	S	182
JALHAY	50.56	6.07	442	283	Evergreen needleleaf forest	NEF	211
ROMILLY-SUR-SEINE	48.44	3.77	396	322	Croplands	CM	168
NEZER	44.57	-1.04	282	402	Mediterranean forest	NEF	209
FUNDULEA	44.52	26.50	944	423	Croplands	CM	172
ALPILLES	44.1	4.2	414	413	Croplands	CM	188 (201)
LE LARZAC	43.94	3.12	387	417	Grassland	CM	221 (229)
COLLELONGO	41.85	13.58	664	469	Mediterranean forest	BDF	204
PUECHABON	43.44	3.35	394	428	Deciduous broadleaf forest	CM	177 (188)
BARRAX	39.04	-2.08	250	532	Croplands	CM	162
EVORA	38.5	-8.00	85	546	Mediterranean forest	H	163
VALENCIA	39.57	-1.28	273	519	Sparsely vegetation	CM	177
RAMBLA HONDA	37.13	-2.37	240	581	Sparsely vegetation	H	236 (187)

Table 3.- As in table 2 for South Africa.

SITES	Latitude	Longitude	Xmsg	Ymsg	Biome (GLC)	ECOCLIMAP
KAKAMEGA	0,25	34,82	890	1	TFM	50 (16)
KASUNGU	-12,95	33,00	808	464	S	35
CHUNGA	-14,86	25,51	582	536	BDF	51 (35)
NAMPULA	-15,03	38,39	936	530	CM	107 (51)
MONGU	-15,44	23,25	510	557	BDF	51
PANDAMATENGA	-18,65	25,50	562	664	H	51
ETOSHA	-18.68	15.45	246	673	H	69
MAUN TOWER	-19.79	23.44	494	704	H	51 (69)
MAUN MOPANE	-19,92	23,56	497	708	H	51
OKWARIVER	-22,31	21,60	424	788	S	69 (82)
GHANZI	-22,41	21,71	427	791	S	69 (82)
TSHANE	-24,16	21,76	418	847	H	82
SKUKUZA	-25,02	31,50	684	862	S	51
CHANGALA	-26.37	32.18	689	903	BDF	51 (35)

4. RESULTS

4.1 SPATIAL CONSISTENCY

4.1.1 SPATIAL DISTRIBUTION

The emphasis of this section is made on the MSG products: histograms, statistics and relative errors are shown. For PARASOL and MODIS products only some histograms are shown in this section for simplicity. The statistics (mean/std) of both products per biome and geographical area are given in Annex VII.

- **SEVIRI/MSG PRODUCTS**

Land-SAF products for the considered period are shown in Annex I. Visually, both FVC and LAI products show a good quality, with a complete spatial coverage. The spatial distribution of retrievals is consistent with the expected, presenting higher values in forest areas and lower values in arid or semi-arid regions. The existing gradient of vegetation cover with latitude is well-captured (eg., Europe, South Africa). In addition, the temporal dynamic of vegetation from August to December of 2005 can be readily observed in the four different areas.

The distributions of FVC and LAI values as well as its temporal dynamic per classes and geographical areas were analyzed using histograms (Figures 8, 10, 12, 14). Quantitative results (mean and standard deviation) are given for both products and errors (Tables 4, 5, 6, 7). In addition, an estimation of the relative error (error/mean) is also provided (Figures 9, 11, 13, 15).

Figure 8 shows the temporal variations of both FVC and LAI histograms for Europe. The histograms show a coherent behavior regarding the biome type. Broadleaved Deciduous Forest (BDF) and Needle-leaved Forest (NLF) present higher values in contrast with the Shrubs (S) or Herbaceous (H). The temporal variability can be also observed in the histograms, showing a large number of retrievals with high values in the summer period and the opposite in December. The temporal dynamic can be readily identified in Cultivated and Mosaic (CM), and also in BDF. On the contrary, H and S classes present a lower temporal variation as expected. Mean values and standard deviations are given in Table 4.

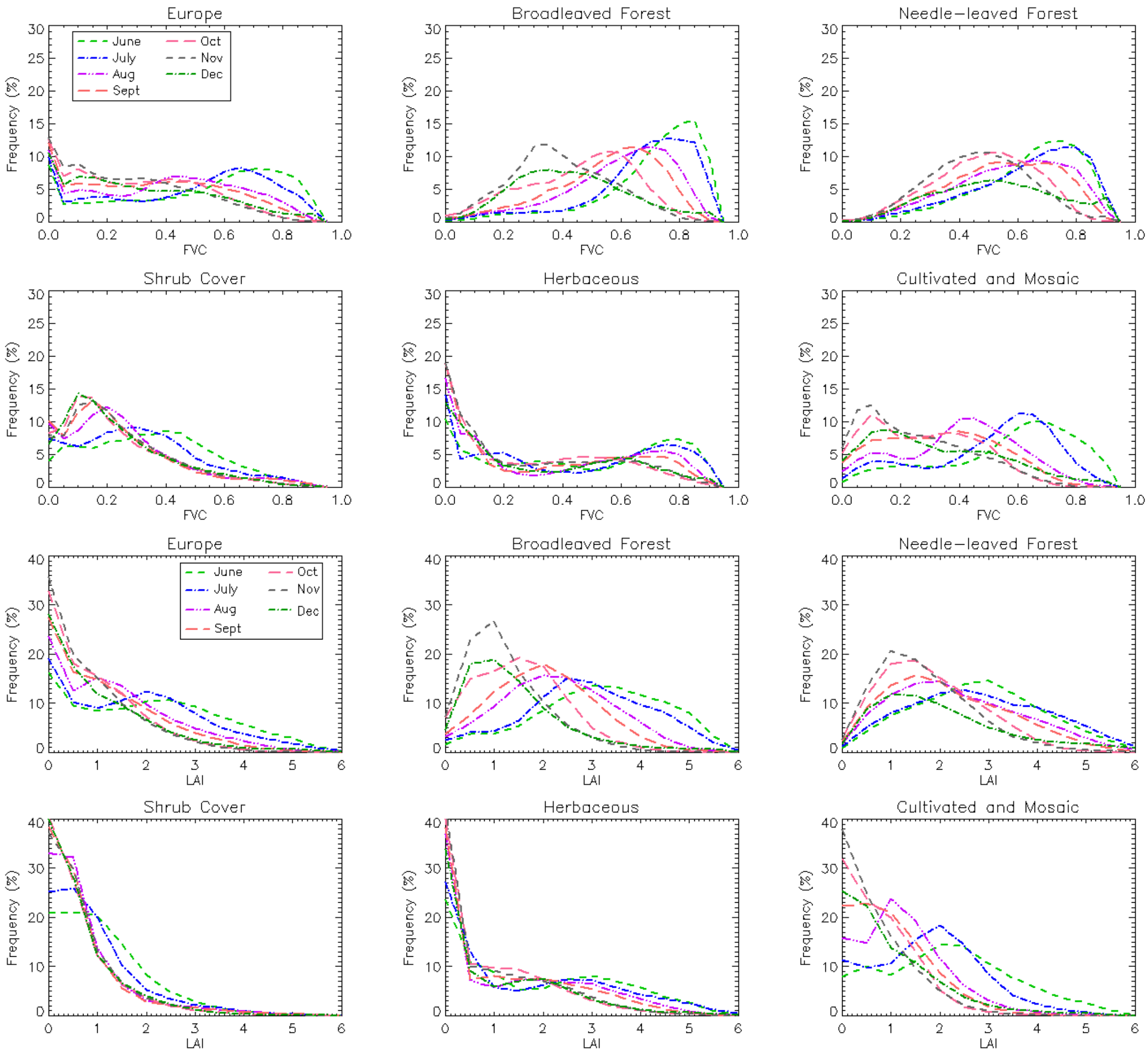


Figure 8.- Temporal variations of MSG FVC (top) and LAI (bottom) histograms for Europe and its main land cover classes. The temporal period spans from June to December 2005.

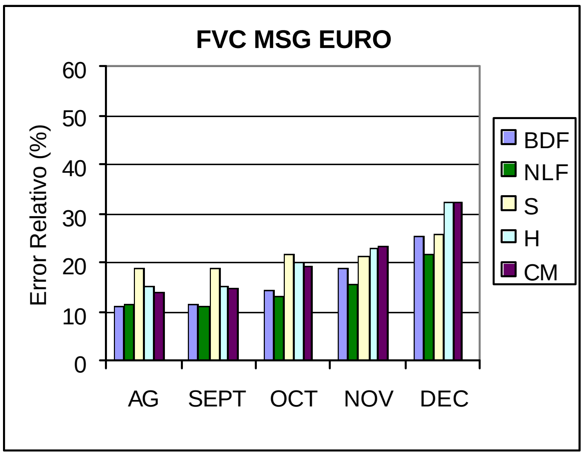
Table 4.- Statistics (mean, std) of MSG FVC product and error per main land cover classes in Europe. The temporal period spans from June to December 2005.

FVC

CLASE		JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
BDF	mean	0.69	0.66	0.58	0.54	0.46	0.40	0.36
	std	0.23	0.23	0.22	0.21	0.21	0.19	0.25
	mean error	0.00	0.00	0.06	0.06	0.07	0.07	0.09
NLF	mean	0.64	0.64	0.58	0.55	0.49	0.47	0.38
	std	0.20	0.21	0.21	0.21	0.19	0.20	0.31
	mean error	0.00	0.00	0.06	0.06	0.07	0.07	0.08
S	mean	0.36	0.32	0.27	0.26	0.25	0.25	0.25
	std	0.22	0.21	0.20	0.20	0.19	0.19	0.19
	mean error	0.00	0.00	0.05	0.05	0.05	0.05	0.07
H	mean	0.43	0.40	0.34	0.32	0.27	0.28	0.26
	std	0.32	0.33	0.31	0.30	0.26	0.27	0.28
	mean error	0.00	0.00	0.05	0.05	0.05	0.06	0.09
CM	mean	0.57	0.51	0.41	0.35	0.30	0.27	0.31
	std	0.25	0.23	0.21	0.20	0.19	0.19	0.24
	mean error	0.00	0.00	0.06	0.05	0.06	0.06	0.10
B	mean	0.02	0.02	0.02	0.02	0.02	0.01	0.02
	std	0.09	0.08	0.07	0.07	0.07	0.06	0.07
	mean error	0.00	0.00	0.03	0.03	0.03	0.03	0.03

LAI

CLASE		JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
BDF	mean	3.27	3.01	2.42	2.16	1.69	1.39	1.35
	std	1.47	1.43	1.23	1.12	0.98	0.88	1.21
	mean error	0.00	0.00	0.51	0.45	0.39	0.38	0.48
NLF	mean	2.99	3.01	2.55	2.35	1.98	1.85	1.66
	std	1.37	1.48	1.40	1.31	1.07	1.11	1.66
	mean error	0.00	0.00	0.52	0.46	0.42	0.44	0.52
S	mean	1.26	1.12	0.90	0.86	0.81	0.83	0.82
	std	0.97	0.98	0.92	0.93	0.83	0.79	0.80
	mean error	0.00	0.00	0.29	0.28	0.29	0.29	0.33
H	mean	1.80	1.69	1.38	1.23	0.99	1.01	1.00
	std	1.67	1.69	1.49	1.38	1.14	1.18	1.30
	mean error	0.00	0.00	0.37	0.33	0.32	0.35	0.44
CM	mean	2.35	1.96	1.42	1.16	0.94	0.86	1.08
	std	1.38	1.16	0.92	0.84	0.72	0.73	1.07
	mean error	0.00	0.00	0.32	0.29	0.28	0.30	0.47
B	mean	0.07	0.06	0.05	0.05	0.04	0.04	0.05
	std	0.33	0.30	0.28	0.27	0.24	0.21	0.26
	mean error	0.00	0.00	0.22	0.22	0.22	0.22	0.22



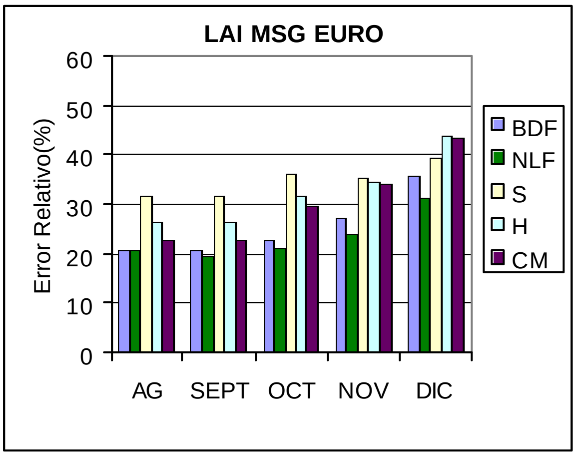


Figure 9.- Relative error (error/mean) of MSG FVC (left) and LAI (right) for main classes (see table 1) of Europe. The temporal period spans from August to December 2005.

Figure 9 shows the temporal evolution of the relative error per classes. We can observe that the error increase toward winter time, as expected by the increase of the error in the BRDF characterization due to the low sun zenith angle. For the FVC product the relative error ranges between 10% and 20 %, whereas the error in the LAI ranges between 20% and 30%. These theoretical errors are reasonable, only slightly higher than those specified by the user requirements (10% for FVC and 15% for LAI).

Same results are given for North Africa in Figure 10, Table 5 and Figure 11. Highest FVC/LAI values and lower temporal variability are found in Broadleaved Evergreen Forest (BEF), and the contrary is found for the Herbaceous (H) class. In North Africa the class Shrub (S) presents high FVC/ LAI values for August and September. It is noticeable that vegetation classified as Shrub shows histograms (mean values) and its temporal evolution quite similar to that of Broadleaved Deciduous Forest (BDF), which is very different to the results found in Europe. The spatial proximity of these two classes in North Africa (see figure 5) may result in a smooth transition between the main vegetation communities of both classes, explaining partly this similarity. In South Africa, where the Shrub class is surrounding areas classified as Herbaceous, the histograms of S and BDF classes are again quite different, as found in Europe. Relative errors are again typically of 15% for FVC and 25% for LAI. Higher values are found for Herbaceous, due to the low vegetation amount of this class.

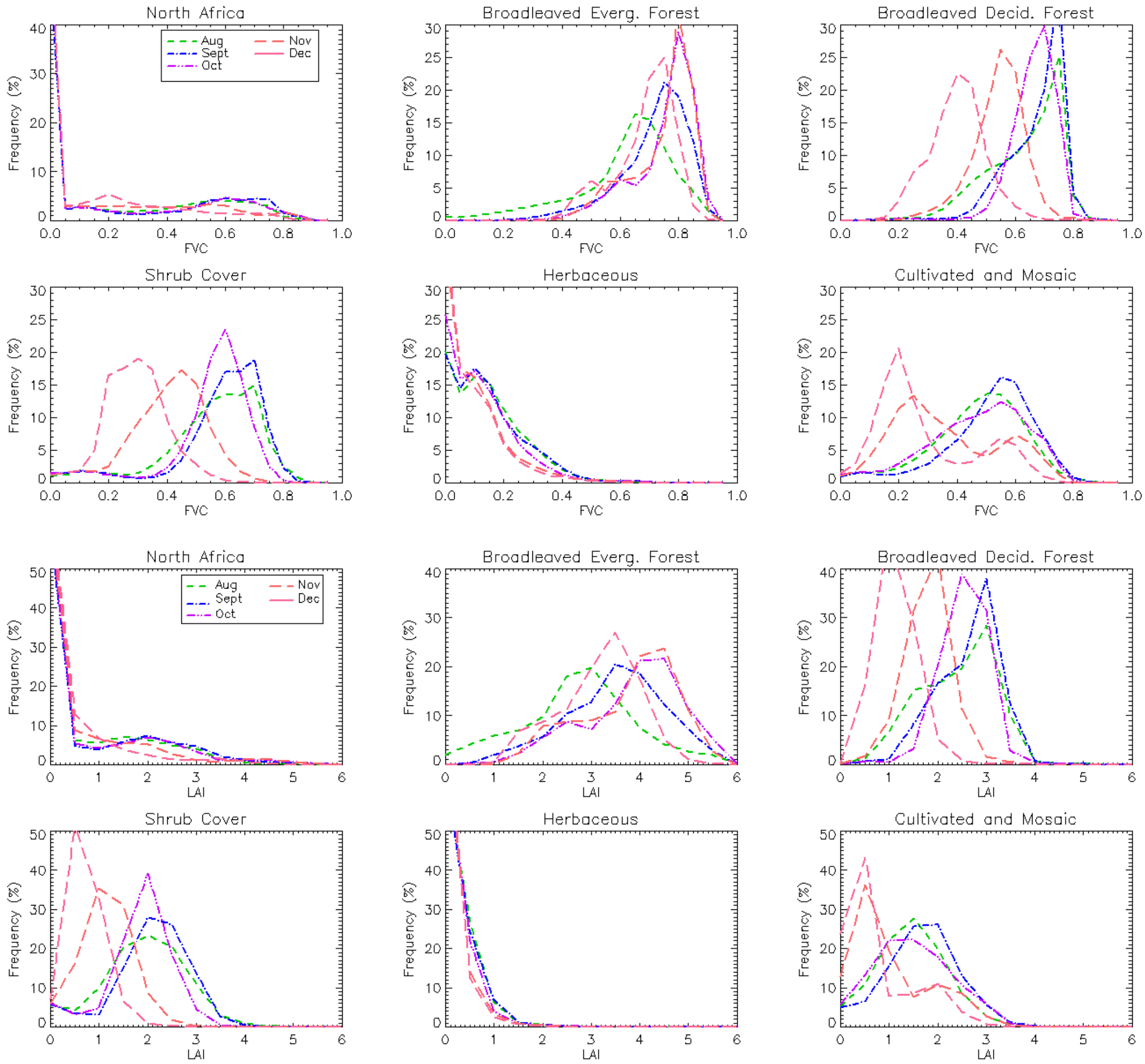
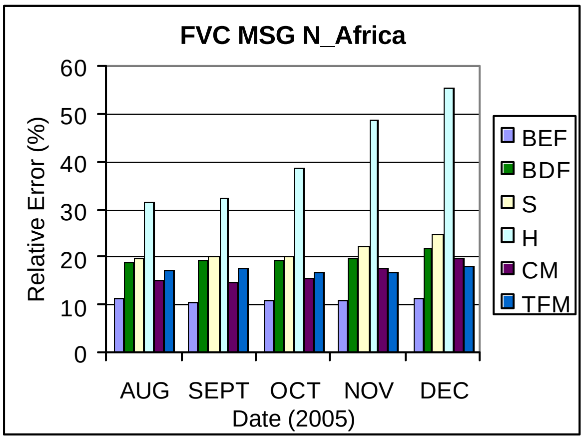


Figure 10.- Temporal variations of MSG FVC (top) and LAI (bottom) histograms for major land cover classes of North Africa. The temporal period spans from August to December 2005.

Table 6.- Statistics (mean, std) of MSG FVC (left) and LAI (right) product and its error over North Africa for main land cover classes. The temporal period spans from August to December 2005.

CLASS		AUG	SEPT	OCT	NOV	DEC
BEF	mean fvc	0.61	0.71	0.75	0.76	0.70
	std fvc	0.21	0.18	0.17	0.14	0.13
	mean efvc	0.07	0.08	0.08	0.08	0.08
BDF	mean fvc	0.65	0.69	0.68	0.56	0.42
	std fvc	0.14	0.12	0.10	0.10	0.10
	mean efvc	0.12	0.13	0.13	0.11	0.09
S	mean fvc	0.57	0.59	0.56	0.42	0.31
	std fvc	0.18	0.18	0.17	0.14	0.11
	mean efvc	0.11	0.12	0.11	0.09	0.08
H	mean fvc	0.16	0.16	0.14	0.11	0.10
	std fvc	0.13	0.13	0.12	0.11	0.10
	mean efvc	0.05	0.05	0.05	0.06	0.06
CM	mean fvc	0.49	0.53	0.49	0.38	0.31
	std fvc	0.17	0.17	0.18	0.19	0.18
	mean efvc	0.07	0.08	0.08	0.07	0.06
TFM	mean fvc	0.68	0.72	0.71	0.65	0.54
	std fvc	0.14	0.13	0.13	0.12	0.14
	mean efvc	0.12	0.13	0.12	0.11	0.10

CLASS		AUG	SEPT	OCT	NOV	DEC
BEF	mean lai	2,88	3,63	3,97	3,96	3,36
	std lai	1,27	1,20	1,21	1,08	0,91
	mean elai	0,62	0,82	0,94	0,94	0,73
BDF	mean lai	2,62	2,87	2,77	2,04	1,38
	std lai	0,81	0,69	0,56	0,51	0,45
	mean elai	0,92	1,03	0,97	0,64	0,43
S	mean lai	2,12	2,27	2,04	1,37	0,94
	std lai	0,88	0,85	0,72	0,54	0,38
	mean elai	0,73	0,79	0,69	0,44	0,32
H	mean lai	0,44	0,44	0,37	0,30	0,27
	std lai	0,39	0,40	0,36	0,34	0,30
	mean elai	0,25	0,25	0,25	0,25	0,25
CM	mean lai	1,67	1,87	1,70	1,26	1,00
	std lai	0,75	0,78	0,82	0,82	0,73
	mean elai	0,43	0,48	0,44	0,36	0,31
TFM	mean lai	2,76	3,04	2,93	2,56	1,96
	std lai	0,74	0,74	0,79	0,73	0,81
	mean elai	0,90	1,03	0,94	0,75	0,55



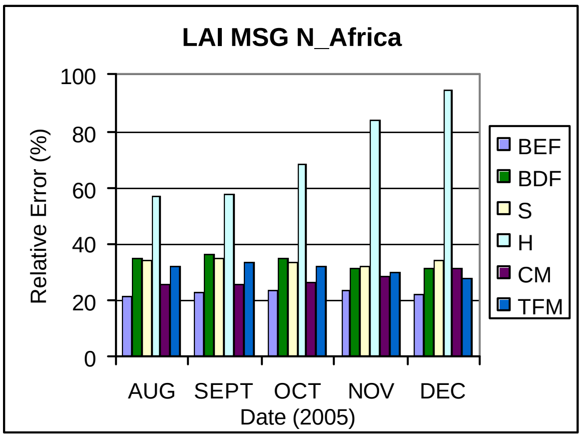


Figure 11.- As in figure 9 for North Africa.

Same results are given for South Africa in Figure 12, Table 6 and Figure 13. In the southern hemisphere we can observe how maximum values of FVC and LAI are found in November and December. Here, Herbaceous and Shrubs presents similar histograms, showing that in average over large and nearby areas both classes present similar distribution of vegetation retrieved values. The relative errors are low for densest forest (BDF, BEF, TFM) but high (around 40% or even higher for LAI) for low vegetation coverage (S, H, CM). This fact indicates that in relative terms the theoretical accuracy given for sparse vegetated areas is considerably lower than the accuracy given for densest areas.

Finally, results for South America are shown in Figure 14, Table 7 and Figure 15, showing the MSG products for this region a very similar performance than for the other areas. Note that despite the viewing configuration of SEVIRI for this area, better relative errors are obtained (below 10% for FVC and below 20% for LAI), which are now in the level of accuracy required by the users.

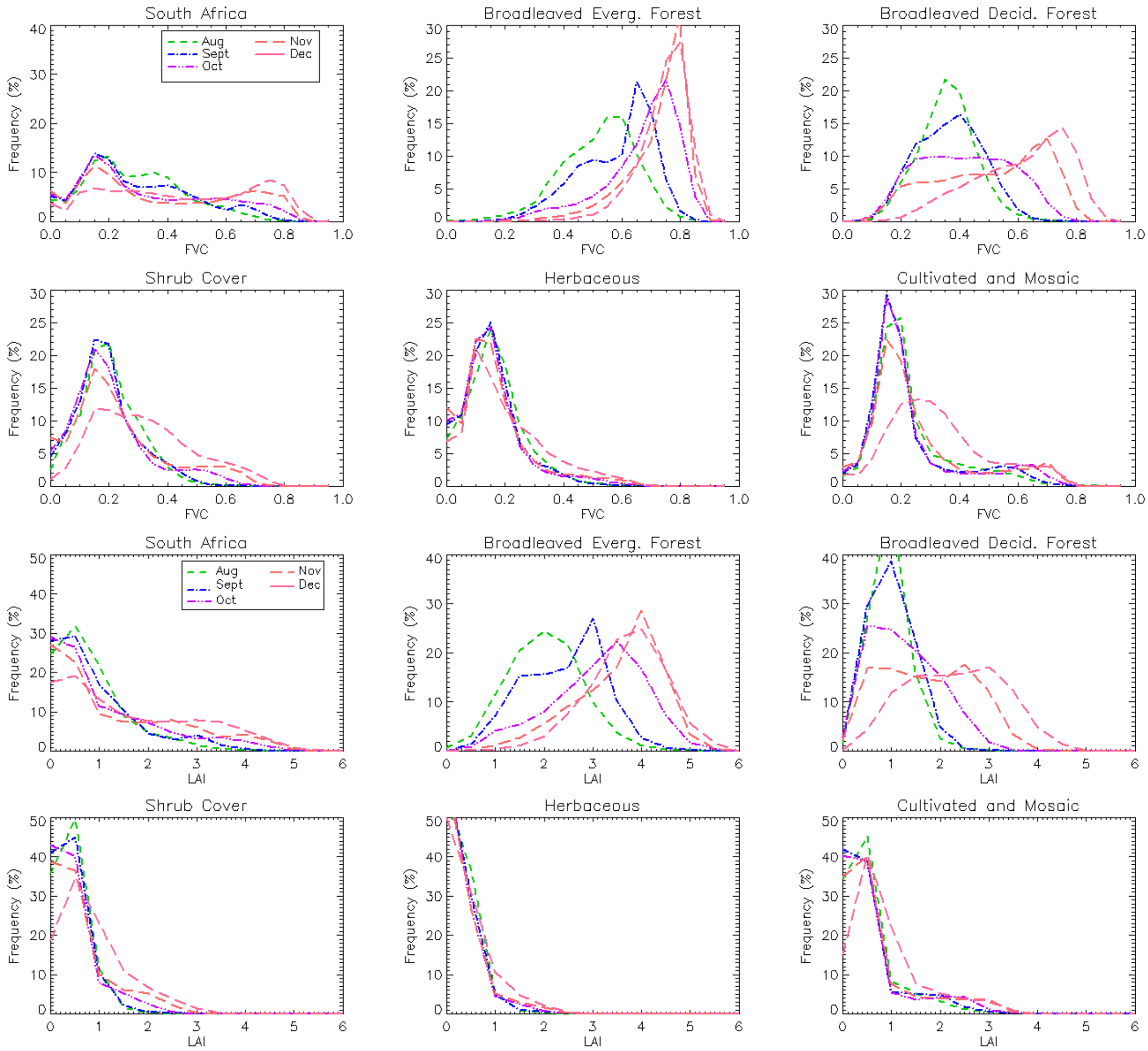


Figure 12.- As in figure 10 for South Africa.

Table 6.- Statistics (mean, std) of MSG FVC (left) and LAI (right) product and its error for main land cover classes of South Africa. The temporal period spans from August to December 2005.

CLASS		AUG	SEPT	OCT	NOV	DEC
BEF	mean fvc	0,61	0,71	0,75	0,76	0,70
	std fvc	0,21	0,18	0,17	0,14	0,13
	mean efvc	0,07	0,08	0,08	0,08	0,08
BDF	mean fvc	0,65	0,69	0,68	0,56	0,42
	std fvc	0,14	0,12	0,10	0,10	0,10
	mean efvc	0,12	0,13	0,13	0,11	0,09
S	mean fvc	0,57	0,59	0,56	0,42	0,31
	std fvc	0,18	0,18	0,17	0,14	0,11
	mean efvc	0,11	0,12	0,11	0,09	0,08
H	mean fvc	0,16	0,16	0,14	0,11	0,10
	std fvc	0,13	0,13	0,12	0,11	0,10
	mean efvc	0,05	0,05	0,05	0,06	0,06
CM	mean fvc	0,49	0,53	0,49	0,38	0,31
	std fvc	0,17	0,17	0,18	0,19	0,18
	mean efvc	0,07	0,08	0,08	0,07	0,06
TFM	mean fvc	0,68	0,72	0,71	0,65	0,54
	std fvc	0,14	0,13	0,13	0,12	0,14
	mean efvc	0,12	0,13	0,12	0,11	0,10

CLASS		AUG	SEPT	OCT	NOV	DEC
BEF	mean LAI	2,21	2,60	3,27	3,70	3,85
	std lai	0,84	0,92	1,10	1,05	0,99
	mean elai	0,45	0,53	0,70	0,84	0,89
BDF	mean LAI	1,19	1,23	1,48	1,95	2,53
	std lai	0,42	0,48	0,71	0,94	1,00
	mean elai	0,27	0,29	0,32	0,40	0,51
S	mean LAI	0,64	0,61	0,66	0,78	1,09
	std lai	0,35	0,37	0,48	0,63	0,69
	mean elai	0,26	0,26	0,27	0,29	0,32
H	mean LAI	0,50	0,47	0,48	0,51	0,63
	std lai	0,33	0,33	0,37	0,43	0,49
	mean elai	0,25	0,25	0,26	0,26	0,27
CM	mean LAI	0,74	0,73	0,78	0,88	1,10
	std lai	0,56	0,61	0,70	0,78	0,76
	mean elai	0,27	0,28	0,29	0,30	0,32
TFM	mean LAI	2,44	2,79	3,30	3,62	3,28
	std lai	0,93	1,09	1,34	1,33	1,15
	mean elai	0,46	0,55	0,68	0,79	0,68

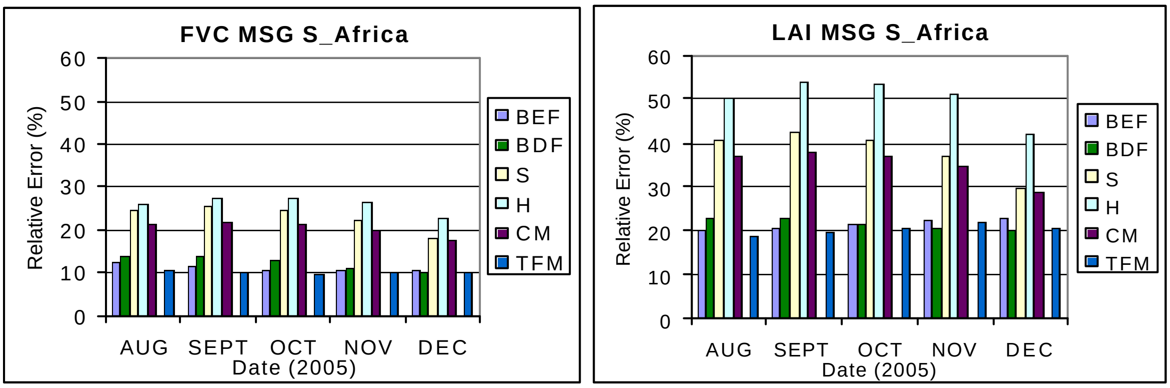


Figure 13.- As in figure 9 for South Africa.

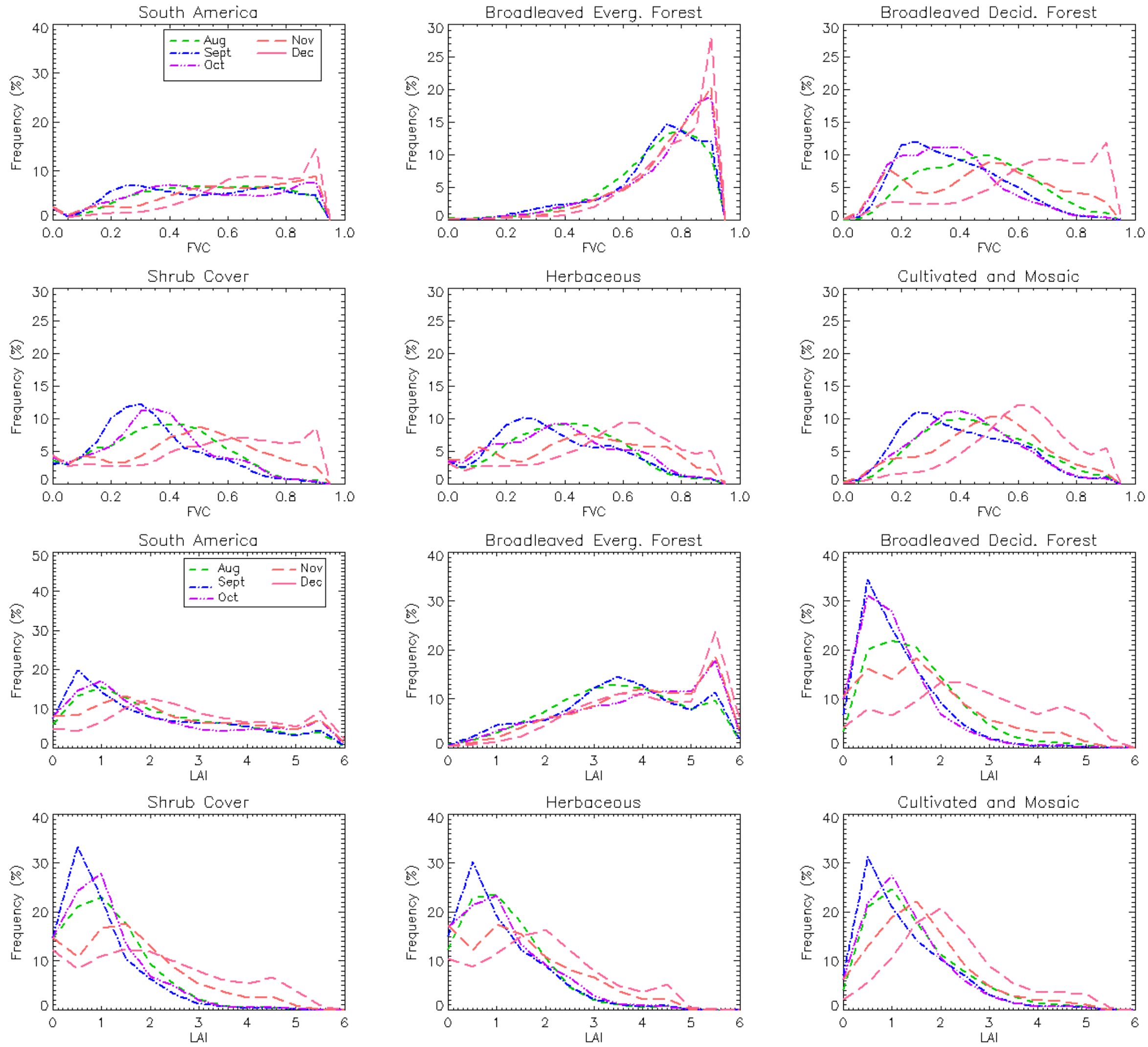


Figure 14.- As in figure 10 for South America.

Table 7.- Statistics (mean, std) of MSG FVC (left) and LAI (right) product and its error for main land cover classes of South America. The temporal period spans from August to December 2005.

CLASS		AUG	SEPT	OCT	NOV	DEC
BEF	mean fvc	0.69	0.70	0.73	0.74	0.76
	std fvc	0.22	0.21	0.21	0.21	0.20
	mean efvc	0.07	0.07	0.07	0.07	0.08
BDF	mean fvc	0.48	0.40	0.38	0.49	0.65
	std fvc	0.19	0.17	0.17	0.23	0.23
	mean efvc	0.05	0.05	0.05	0.05	0.06
S	mean fvc	0.39	0.34	0.37	0.47	0.55
	std fvc	0.21	0.19	0.20	0.25	0.28
	mean efvc	0.05	0.05	0.05	0.05	0.06
H	mean fvc	0.40	0.38	0.40	0.46	0.54
	std fvc	0.21	0.22	0.22	0.25	0.25
	mean efvc	0.05	0.05	0.05	0.05	0.06
CM	mean fvc	0.47	0.42	0.44	0.50	0.61
	std fvc	0.20	0.19	0.18	0.21	0.20
	mean efvc	0.05	0.05	0.05	0.05	0.05
TFM	mean fvc	0.62	0.64	0.66	0.65	0.65
	std fvc	0.28	0.27	0.28	0.26	0.27
	mean efvc	0.06	0.06	0.06	0.06	0.06

CLASS		AUG	SEPT	OCT	NOV	DEC
BEF	mean lai	3,57	3,65	3,96	4,04	4,24
	std lai	1,53	1,53	1,61	1,55	1,55
	mean elai	0,74	0,77	0,86	0,89	0,95
BDF	mean lai	1,73	1,33	1,28	1,89	2,84
	std lai	0,95	0,79	0,78	1,22	1,44
	mean elai	0,34	0,29	0,29	0,39	0,58
S	mean lai	1,31	1,09	1,22	1,76	2,26
	std lai	0,90	0,81	0,86	1,23	1,53
	mean elai	0,29	0,27	0,29	0,37	0,50
H	mean lai	1,33	1,24	1,32	1,66	2,08
	std lai	0,89	0,94	0,95	1,19	1,29
	mean elai	0,30	0,30	0,31	0,36	0,43
CM	mean lai	1,67	1,44	1,50	1,83	2,40
	std lai	1,02	0,94	0,90	1,07	1,18
	mean elai	0,33	0,31	0,31	0,36	0,45
TFM	mean lai	3,04	3,19	3,38	3,23	3,34
	std lai	1,62	1,62	1,73	1,62	1,72
	mean elai	0,60	0,63	0,70	0,65	0,69

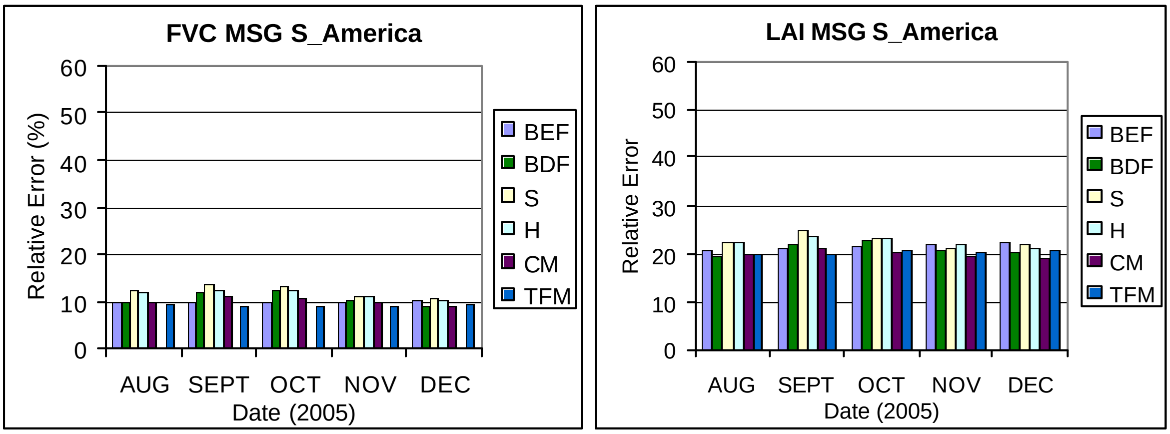


Figure 15.- As in figure 9 for South America.

• POLDER/PARASOL products

Maps of PARASOL FVC and LAI products re-projected over the SEVIRI grid for the different geographical areas are shown in annex II. For Europe, the PARASOL FVC product presents a quite high coverage from July to October, showing less spatial and temporal variability than MSG products. Concerning the LAI products, saturated values (LAI>6) are found in large areas, especially in summer time. These too high LAI values may be obtained as a consequence of a strong correction of the clumping index.

For the other geographical areas, although the spatial distribution of retrievals seems to be consistent with the expected distribution of vegetation, the usefulness of PARASOL products is very limited due to the high amount of gaps.

The analysis of the histograms allows a better interpretation about the spatial and temporal consistency of the PARASOL products for geographical areas and biomes. Figure 16 shows FVC and LAI histograms for Europe. The following features can be observed:

(1) The distribution of values presents for all the classes a strange peak, located around 0.7 for the FVC and 2.5 for LAI, for all biomes considered. It seems to be that there are two different distributions, one for low and medium vegetation coverage, and other for high vegetation amount. This effect seems to be an artifact introduced by the algorithm (Roujean and Lacaze, 2002), due to the fact that the empirical relationship between a vegetation index (DVI_0) and the FVC used in the algorithm employs different 'calibration' coefficients for high and low vegetation cover. As a consequence the histograms seems not to be very realistic.

(2) Histograms for LAI show that high LAI values (6-7) are found, especially in Broadleaved forest. As said before, these high values may be introduced by an over-estimation clumping effect in these areas.

(3) Concerning the temporal variability of the histograms, PARASOL products show a very low temporal dynamic as compared with MSG and MODIS products. A noticeable case is the Cultivated and Mosaic class, covering the largest area in Europe, whose histograms should present high temporal variation from summer to winter time. However, we can observe in figure 16 a very similar pattern for all the period, with low variations. The same low variability is found for all the biomes, showing Need-leaved forest high temporal dynamic than Cultivated and Mosaic areas. It seems to be clearly not realistic.

Relative theoretical errors (mean error/mean) have been also computed for PARASOL products. Relative errors are typically below 10% for FVC and 15% for LAI, in the level of accuracy required by the users. This good theoretical errors contrast with some unrealistic trends found in PARASOL FVC and LAI fields, showing that the real uncertainty of the products should be assessed by means of validation exercises.

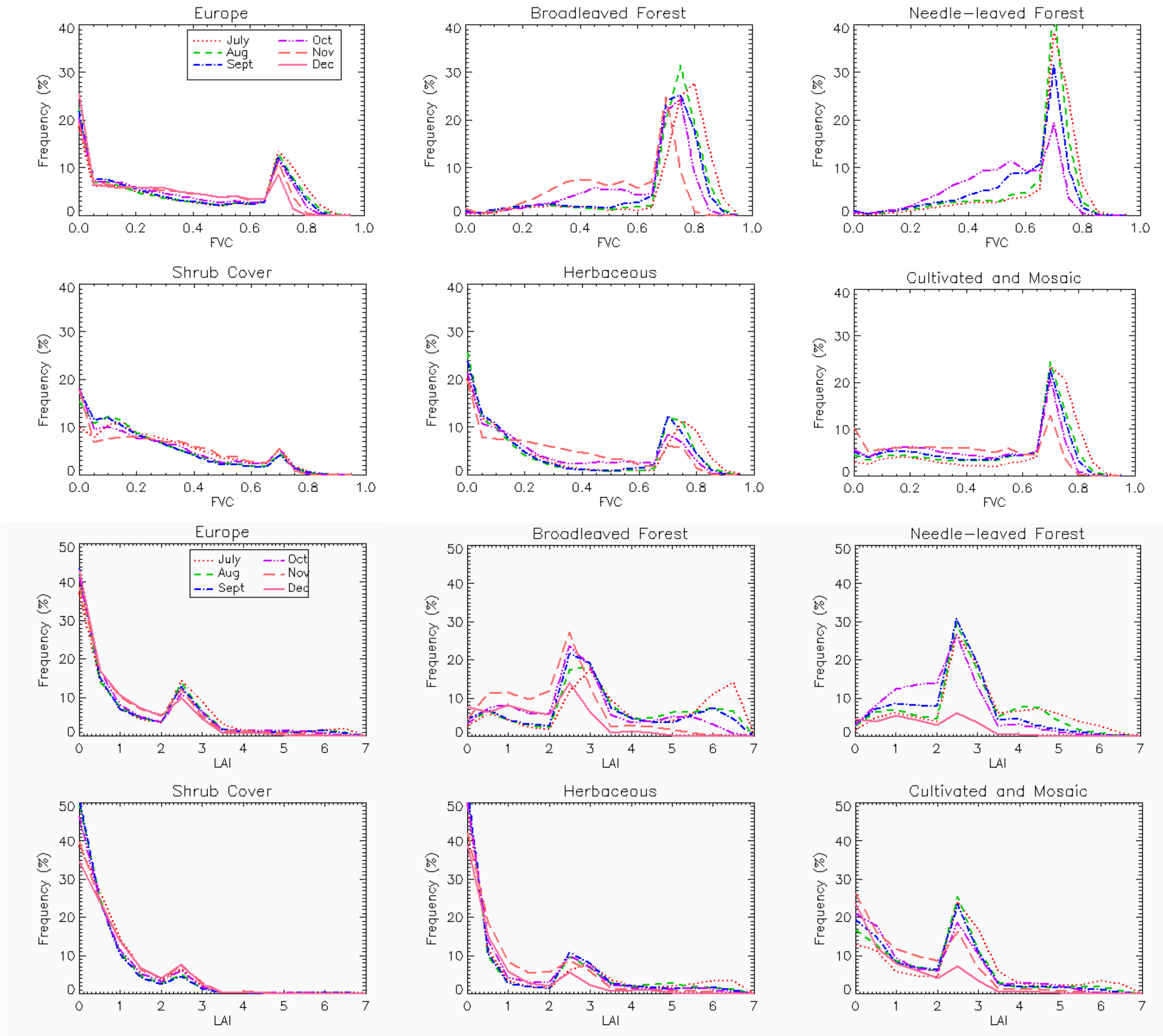


Figure 16.- Temporal variations of PARASOL FVC-LRB (top) and LAI-LRB (bottom) histograms for major land cover classes of Europe. The temporal period spans from July to December 2005.

For the other geographical areas, only the histograms for the FVC product are shown (figures 17, 18 and 19). The LAI histograms follow the same relationship with the FVC distribution as in figure 15. In general, we found the same main features that those found in Europe (figure 16). The most noticeable is the systematic peak found at 0.7 for FVC and 2.5 for LAI. And again a very low temporal variability for Cultivated and Mosaic (CM) is found in South Africa and South America. However, in North Africa very high temporal variability is found for Shrubs, CM and BDF. Note that only those dates with similar fraction of valid pixel are displayed according with the analysis of the PARASOL gaps shown in the section 3.1 (see figure 3).

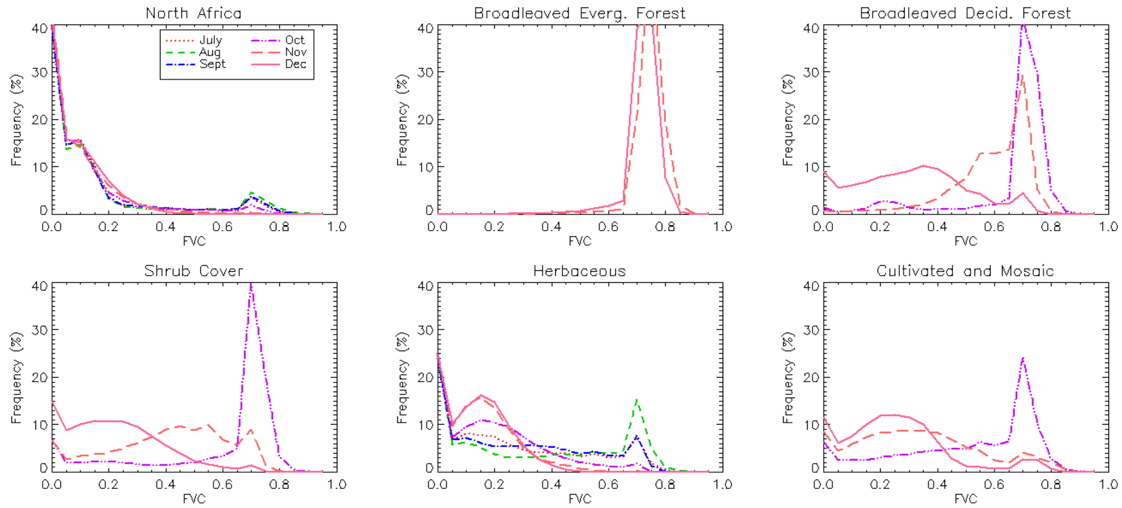


Figure 17.- Temporal variations of PARASOL FVC-LRB histograms for major land cover classes of North Africa. The temporal period spans from July to December 2005. Histograms for dates with large gap fraction have not been displayed.

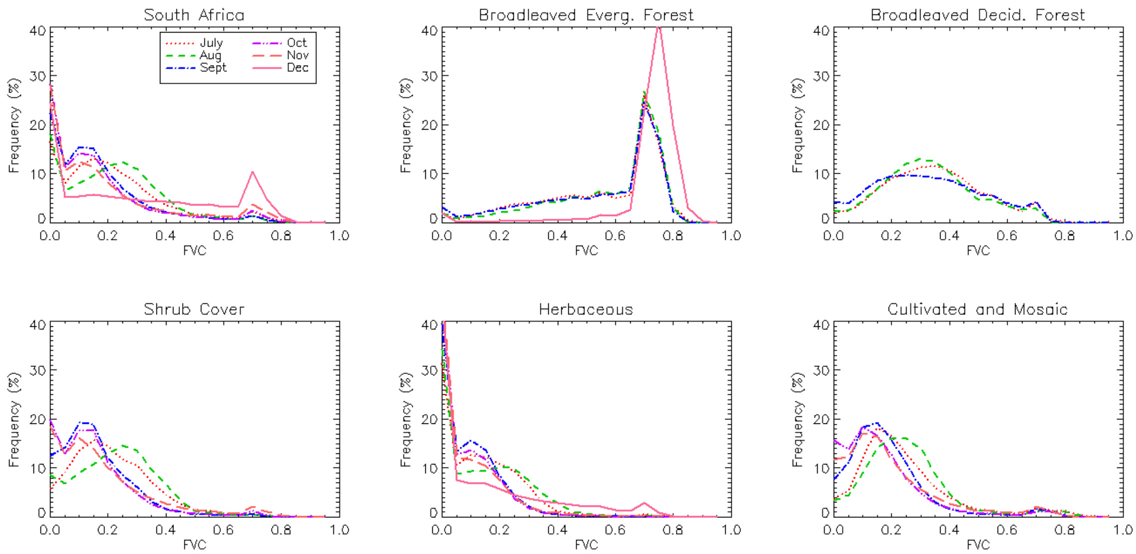


Figure 18.- As in figure 17 for South Africa.

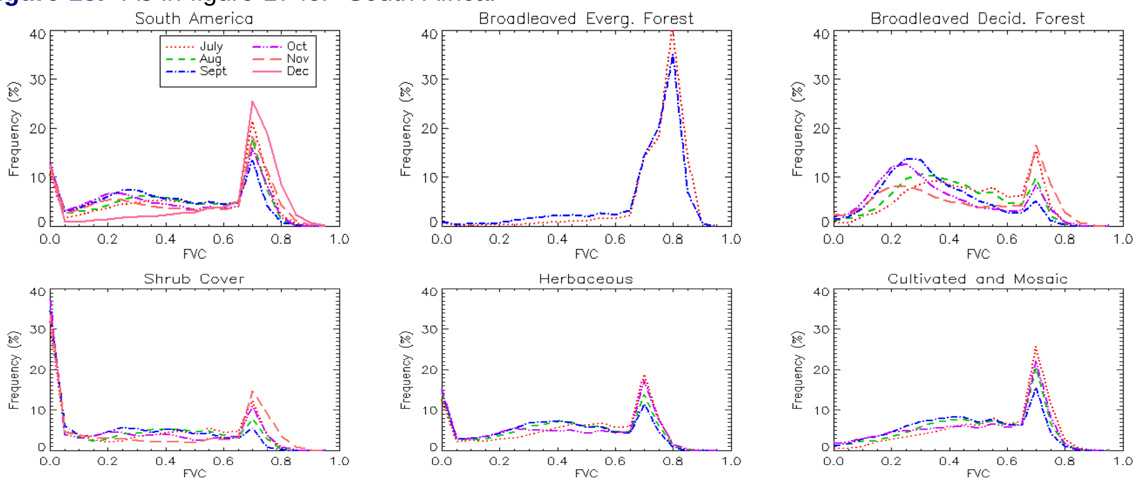


Figure 19.- As in figure 17 for South America.

• MODIS/Terra products

Annex III shows the maps of MODIS/Terra C4.1 LAI products re-projected over the SEVIRI grid for geographical areas. For Europe, MODIS LAI maps show both spatial and temporal variability, quite similar to that shown by Land-SAF products. MODIS algorithm uses a 6-biome global classification to define solutions in the Look-Up-Table accordingly. Consequently, the LAI MODIS maps are spatially consistent with the spatial distributions of main ecosystems. This can be readily observed in South Africa or South America. This also provokes in Africa a strong transition between Equatorial Forest (BEF) (LAI around 6) and the surrounding areas. MODIS 1-km monthly products present an almost complete spatial coverage, similar to MSG products. Both the good spatial coverage along with the spatial sampling and temporal resolution (8-days) make very useful the MODIS products for the Users Community. However, despite the wide extent of MODIS's catalogue, no FVC MODIS product is provided.

The histograms for geographical areas and biomes are shown in Figures 20-22. In general, the MODIS histograms for different classes and areas show similar trends to that of the Land-SAF products. The temporal variability is more evident in Europe and North Africa than in the Southern hemisphere. In both South Africa and South America regions, histograms for all the classes show a very low temporal dynamic, with the exception of Broadleaved Deciduous Forest.

As compared with MSG, MODIS products present lower temporal dynamic. For Evergreen Forest or Shrub cover the MODIS temporal stability seems to be *a priori* more realistic than the high temporal variability show in the Land-SAF products. Conversely, for Cultivated and Mosaic and Deciduous Forest is expected a higher seasonal variability as shown in the MSG products. The temporal dynamic of retrieved values seems to be an important difference between both products, and gives strength to the necessity of considering the temporal domain for the validation of biophysical products. Section 4.2 compares the temporal profiles over selected sites in northern and southern hemispheres.

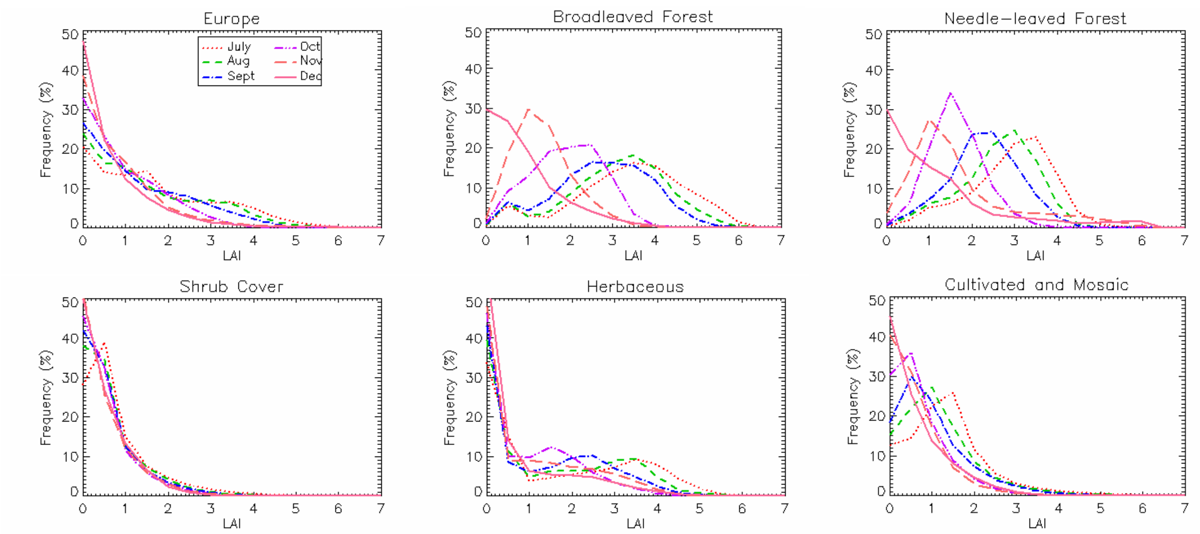


Figure 20.- Temporal variations of MODIS/Terra LAI C4.1 histograms for major land cover classes of Europe. The temporal period spans from July to December 2005.

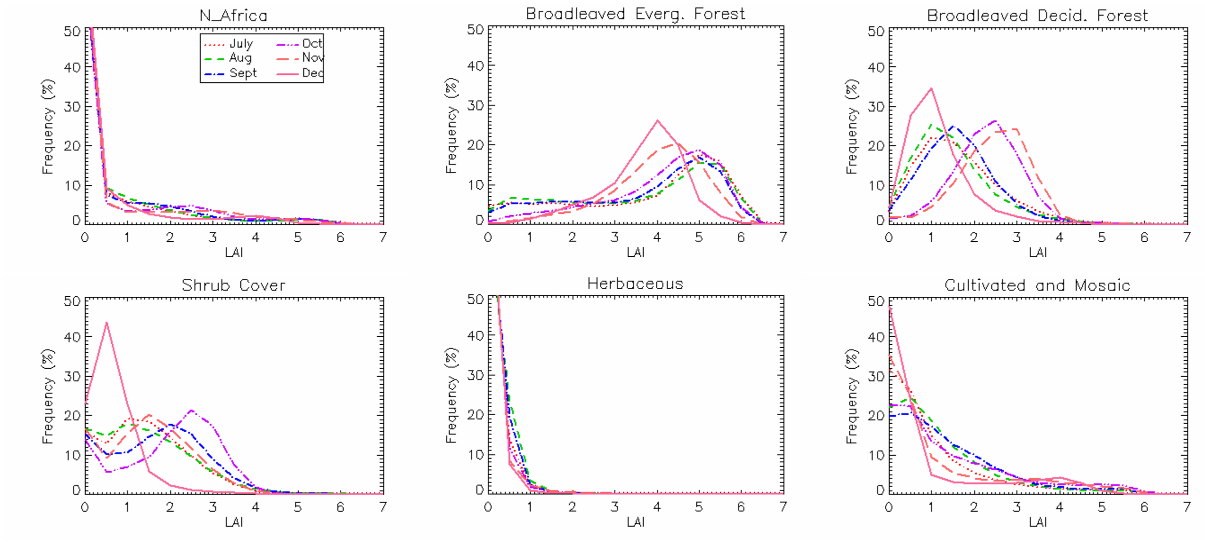


Figure 21.- As in figure 20 for North Africa.

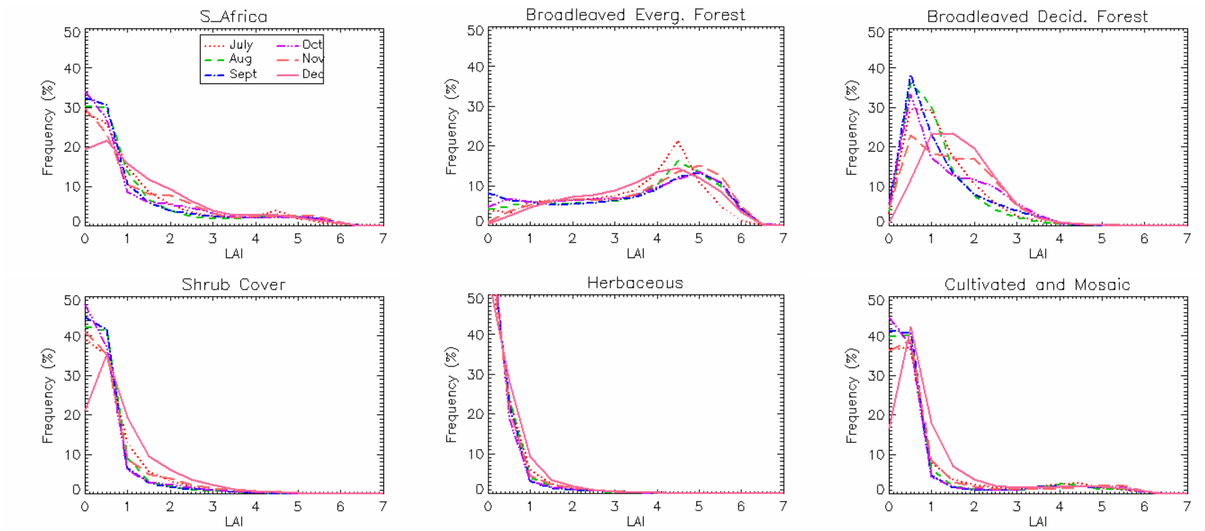


Figure 22.- As in figure 20 for South Africa.

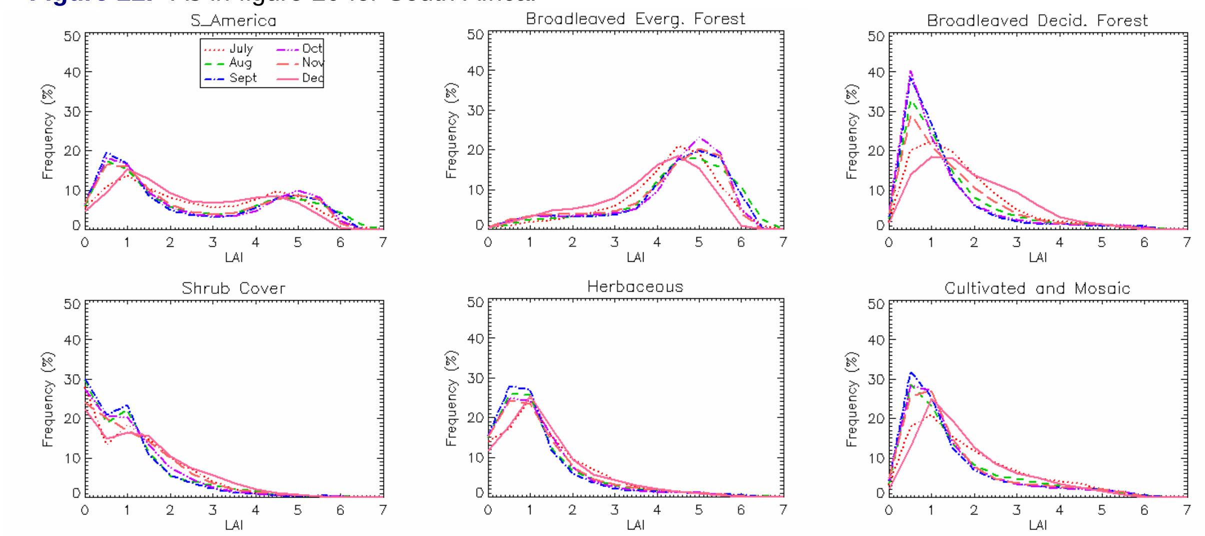


Figure 23.- As in figure 20 for South America.

4.1.2 INTER-COMPARISON EXERCISE

In this section, main results on the inter-comparison between products are provided. The inter-comparison exercise is carried out at different scales (i.e, continental-, biome- and pixel scale). First, on a continental scale, errors maps between two different products were derived. Absolute error and relative error (i.e,. 100*(A-B)/0.5*(A+B)), with A and B the different products) are provided in Annex IV (MSG-PARASOL), Annex V (MSG-MODIS) and Annex VI (PARASOL-MODIS). The statistical error indicators (overall RMS, bias and correlation) for the whole area are also given. Second, a quantitative analysis at biome scale was performed. Histograms of the bias between products are also shown, along with the temporal variation of the RMS and bias per biomes and geographical area. In those figures showing the temporal variations of the RMS and bias per biomes some data is missing, due to a large fraction of gap in POLDER data (see figure 3). All the quantitative results (mean, std, RMS, bias, r) obtained for areas, biomes and dates are given in Annex VII. Finally, scatter-plots over BELMANIP locations are also shown.

4.1.2.1 CONTINENTAL & BIOME SCALE

· ZONE EURO

Figure 24 shows an example of error maps between MSG and PARASOL FVC products for Europe. October 2005 has been selected to highlight the spatial inconsistencies between both products. A high negative bias of PARASOL with regard to MSG product, i.e. PARASOL over-estimates the MSG values, over large areas can be observed. Absolute differences go up to –0.3 in France and Eastern Europe. The opposite trend is found in Scandinavia, where MSG provides higher FVC values (difference up to 0.3). In relative terms, differences up to 100% are found in the eastern European regions. Statistical indicators for the considered period are given in table 8. The correlation between both products decreases from 0.9 in July to 0.5 in December, whereas the overall error (RMS) increases in the same period from 0.15 to 0.23. The mean POLDER over-estimation regarding MSG retrievals is typically of 0.1.

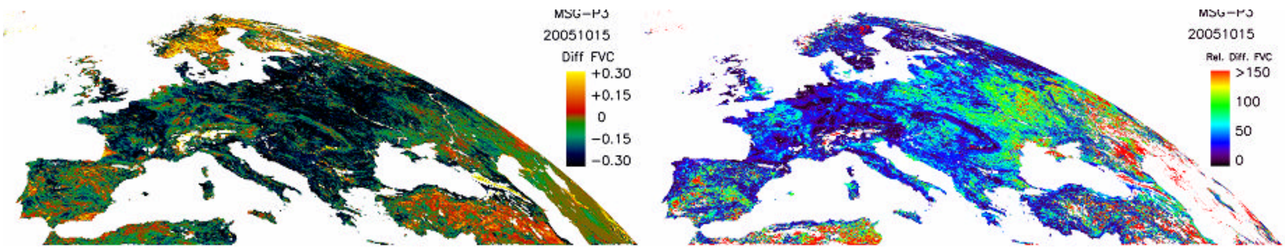


Figure 24.- Maps of the absolute (left) and relative (right) errors among FVC MSG-PARASOL (P3), products for Europe in October 2005. Relative error was not computed where FVC<0.15.

Figure 25 shows an example of the histograms of the bias for the different biomes. We can observe, with the exception of Bare areas, wide distributions spanning between +0.2 and –0.3. Similar distributions are found for the other dates. Figure 26 shows the temporal variability of the RMS and bias. Bare Areas have not been displayed due to the MSG product is constant an equal to zero in this class. The most biased biomes (bias around –0.15) are the Broadleaved Forest (BDF) and Cultivated and Mosaic (CM). These classes show also the highest RMS (higher than 0.2). However, the Evergreen Needle-leaved Forest (NLF) is the biome where the less correlation between products is found. Mean values of RMS, bias and correlation per biome and geographical area are given in Annex VIII.

Table 8. Inter-comparison between MSG and POLDER-3 (P3) FVC products over Europe. The statistical indicators are mean (std) of the products, mean RMS, mean bias and correlation coefficient (r). The period spans from July 2005 to December 2005.

EUROPE		Nº PIXELS	MEAN (STD)		RMS	bias	r
MONTH	CLASS		MSG	P3	MSG-P3		
JULY	ALL	396187	0.49 (0.28)	0.55 (0.29)	0.15	-0.07	0.89
AUG	ALL	380462	0.40 (0.26)	0.49 (0.29)	0.17	-0.09	0.87
SEP	ALL	415597	0.38 (0.25)	0.49 (0.29)	0.19	-0.11	0.83
OCT	ALL	414986	0.32 (0.23)	0.45 (0.27)	0.20	-0.13	0.79
NOV	ALL	365455	0.28 (0.21)	0.39 (0.26)	0.20	-0.12	0.77
DEC	ALL	254778	0.27 (0.22)	0.31 (0.25)	0.23	-0.04	0.55

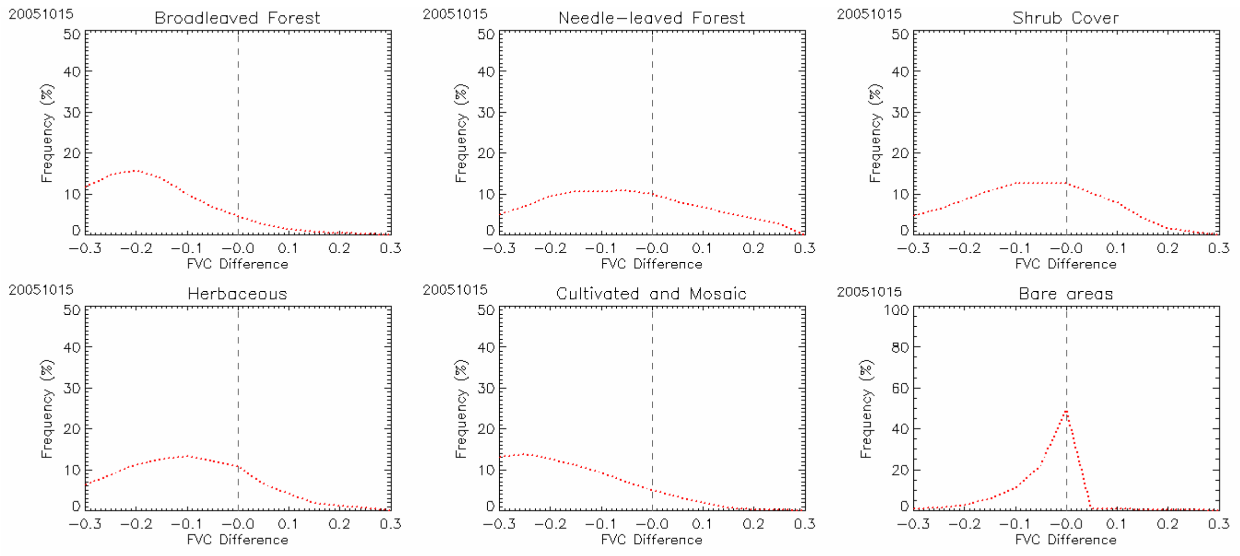


Figure 25.- Histogram of the bias between MSG and POLDER-3 (P3) FVC products for main biomes of Europe in October 2005.

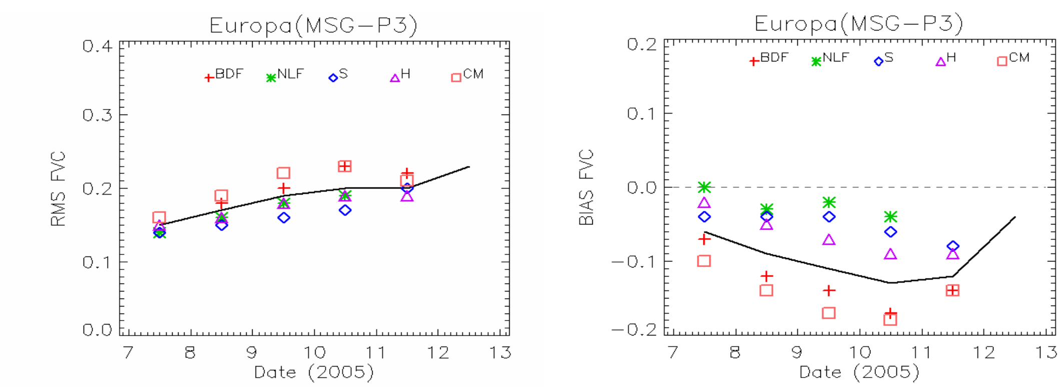


Figure 26.- Temporal evolution of RMS and Bias between MSG and POLDER FVC products for main classes of Europe. The line represents the mean value for the whole area. The period spans from July to December 2005. Data showing variations higher than 20% in the percentage of valid pixels regarding the bets case, or gap fractions higher than 40% are not plotted.

Figure 27 shows an example of the error maps between MSG and PARASOL LAI products, and between MSG and MODIS for the European region in October 2005. Differences between MSG and PARASOL (P3) LAI products are spatially distributed similarly to the distribution of the FVC difference (figure 24), as expected due to the fact that both MSG and PARASOL LAI products are generated using a similar relationship from their respective FVC fields. PARASOL LAI over-estimate the MSG LAI up to +3, with relative errors around 100% in large areas. However, MODIS and MSG LAI products are spatially more consistent, with relative differences typically below 50%. The absolute error map shows that the differences range between +1.5 and –1.5. Only for some areas (eg. United Kingdom) MODIS clearly under-estimates the MSG product up to -3. The RMS between MODIS and MSG LAI fields ranges between 0.7 and 1.0, whereas between MSG and P3 increases around a 30% (ranging between 1 and 1.3). The highest RMS is found between MODIS and P3 (ranging between 1 and 1.5). The mean bias between MSG and MODIS is close to 0, except in July (bias 0.16). However, the mean bias between MSG and P3 ranges from -0.5 to -0.8. The linear correlation between products is ranging between 0.7 and 0.8.

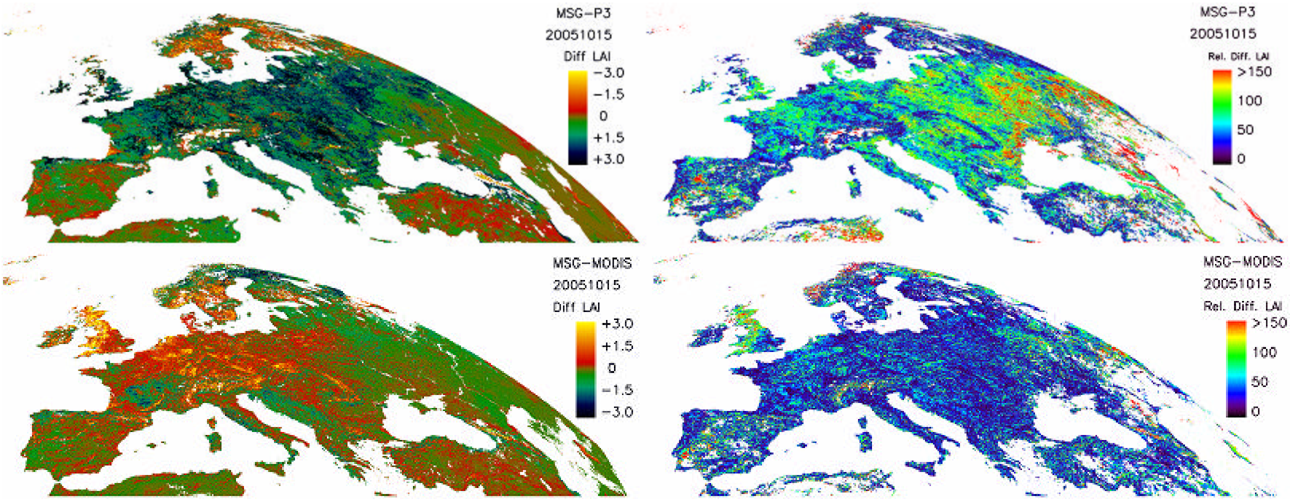


Figure 27.- Maps of the absolute (left) and relative (right) differences between MSG-PARASOL (P3) (top) and MSG-MODIS LAI products for Europe in October 2005. Relative error were not computed where LAI<0.5.

Table 9. Inter-comparison among MSG, PARASOL (P3) and MODIS LAI products for Europe. The statistical indicators are mean (standard deviation) of the products, mean RMS, mean bias and correlation coefficient (r). The period spans from July to December 2005.

EUROPE		Nº PIXELS	MEAN (STDV)			RMS	bias	r
MONTH	CLASS		MSG	MODIS	P3	MSG-MODIS / MSG-P3 / P3-MODIS		
JULY	ALL	384301	2.03 (1.50)	1.86 (1.44)	2.57 (1.97)	0.97/1.30/1.47	0.16/-0.54/0.71	0.79/0.80/0.76
AUG	ALL	367411	1.53 (1.28)	1.57(1.30)	2.16 (1.77)	0.83/1.29/1.28	-0.03/-0.63/0.59	0.79/0.77/0.77
SEP	ALL	400708	1.39 (1.19)	1.45 (1.16)	2.11 (1.71)	0.82/1.36/ 1.32	-0.05/-0.71/0.66	0.76/0.74/0.75
OCT	ALL	400754	1.13 (0.98)	1.14 (0.93)	1.93 (1.55)	0.70/1.36/1.40	-0.008/-0.79/0.79	0.73/0.70/0.66
NOV	ALL	356261	0.96 (0.89)	0.93 (0.81)	1.60 (1.31)	0.67/1.13/1.19	0.03/-0.65/0.68	0.69/0.70/0.66
DEC	ALL	248288	0.92 (0.94)	0.85 (0.79)	1.17 (1.17)	0.76/1.09/0.92	0.07/-0.25/ 0.32	0.63/0.51/0.67

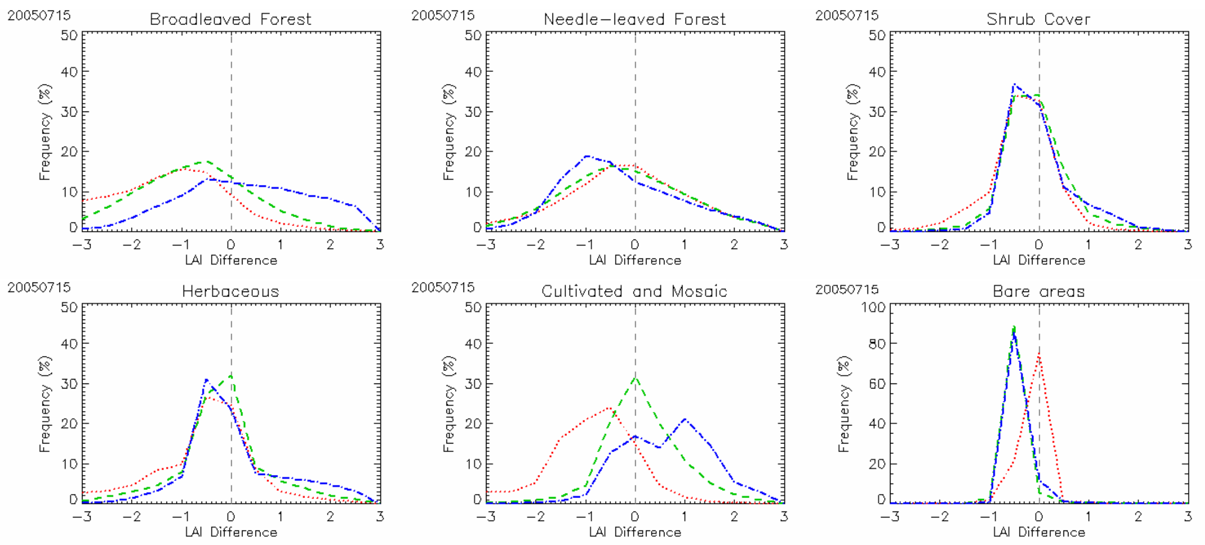


Figure 28.- Histogram of the bias among LAI products for main biomes of Europe in July 2005. MSG-PARASOL (in red), MSG -MODIS (in green) and PARASOL-MODIS (in blue).

Figure 28 shows an example of the histograms of the bias for the different biomes. Again large differences between products are clearly manifested. Shrubs, Herbaceous and Bare areas show narrower distributions with its maximum value close to zero (i.e. less biased classes). However, broad distributions for forest (both Broadleaved and Needle-leaved) and Cultivated and Mosaic are found. The CM class is where POLDER LAI presents more discrepancies with the other products.

Figure 29 shows the statistical error indicators per biomes over the studied period. Concerning the differences between POLDER and MSG, the Broadleaved Deciduous Forest (BDF) present the higher RMS (up to 2.0) and mean bias higher than –1. POLDER product over-estimates the MSG LAI values for the BDF, CM and H biomes. On the contrary, Evergreen Needle-leaved forest and S types present a mean bias close to zero. The comparison between MSG and MODIS LAI products is quite better. The RMS is scaled with the mean value of the classes, ranging between 0.5 for Shrubs and 1.4 for both forest types. The mean bias is close to zero, with the exception of BDF, where MODIS over-estimates the MSG values. Similar correlation is found among the different products. The best correlation among the different products is for Herbaceous (r>0.8) during all the period whereas the worst correlation among the products is systematically found for the Evergreen Needle-leaved Forest (r<0.4).

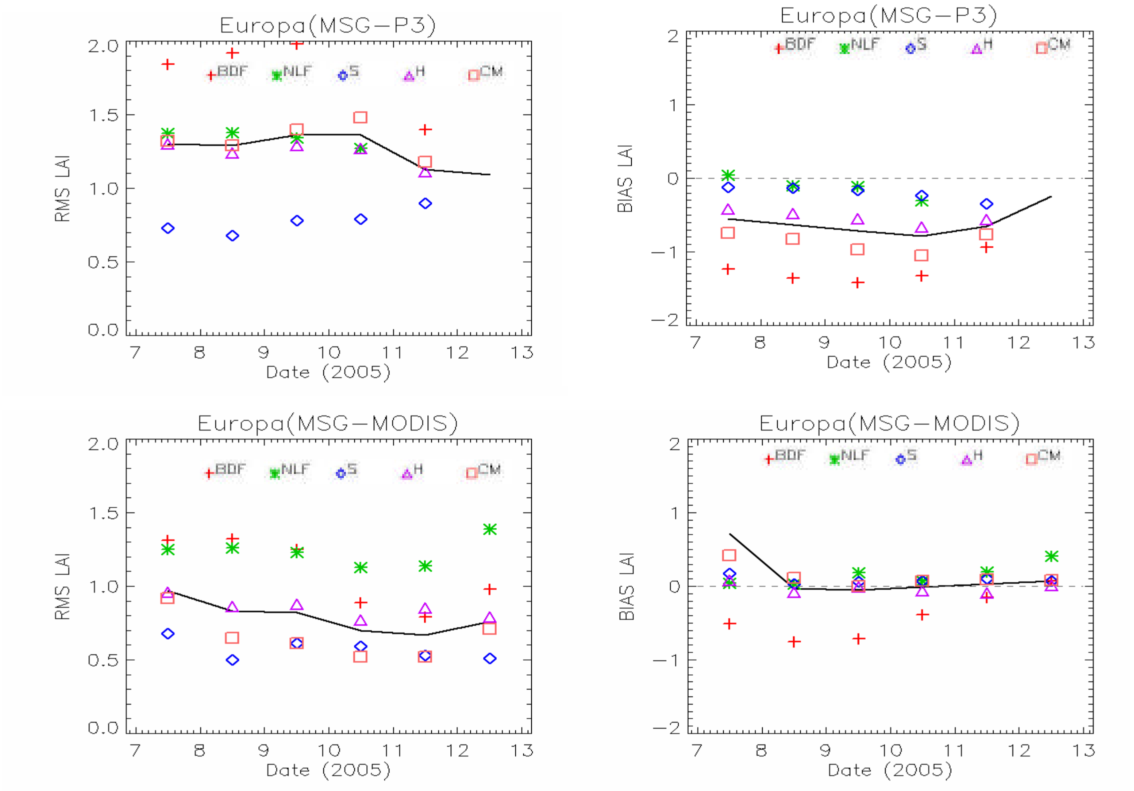


Figure 29.- Temporal evolution of the RMS (left side) and Bias (right side) between MSG and PARASOL (top) and between MSG and MODIS (bottom) LAI products for Europe and main classes. The line represents the mean value for whole area. The period spans from July to December 2005. Data showing variations higher than 20% in the percentage of valid pixels regarding the bets case, or gap fractions higher than 40% are not plotted.

· ZONE NORTH AFRICA

Figure 30 shows an example of SEVIRI and POLDER difference maps for the FVC product in December 2005 (see Annex IV for other dates). Important differences can be observed over large areas, and again the products appear to be spatially inconsistent over vegetated areas. There are an over-estimation of the POLDER FVC product over the Sahel area up to 0.3 (dark color), and the opposite trend is found in large regions of Central and Eastern Africa. This positive bias (yellow color) is not correlated with some particular ecosystem, whereas the negative bias (Sahel area) seems to affect mainly to the Herbaceous and Cultivated areas. In relative terms, differences reach 150% due to the low mean value of this class. The RMS (table 10) is around 0.15 and the mean bias for the whole area indicates an over-estimation of PARASOL products ranging between 0.1 in August and 0.05 in December. The correlation is higher than 0.8 for all the dates.

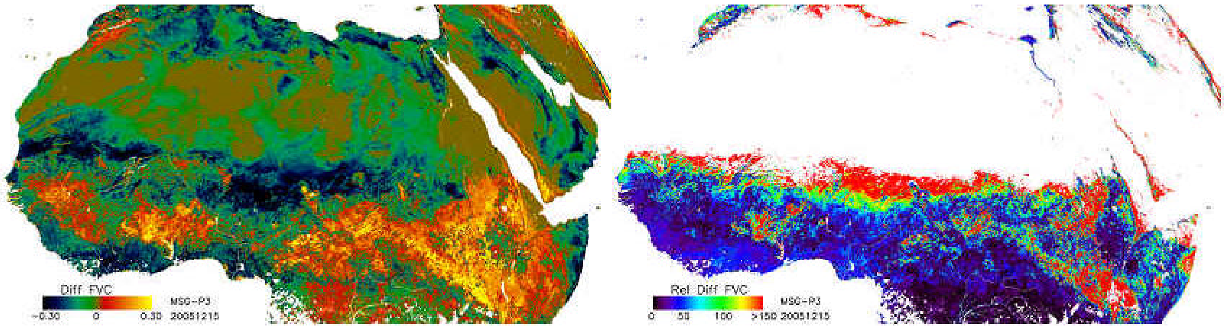


Figure 30.- Maps of the absolute (left) and relative (right) error among FVC MSG-PARASOL (P3) products for North Africa in December 2005. Relative error were not computed where FVC<0.15.

Table 10. As in table 8 for North Africa.

N_AFRICA		Nº PIXELS	MEAN FVC (STDV)		RMS	bias	r
MONTH	CLASS		MSG	P3		MSG-P3	
AUG	**ALL**	1464262	0.10 (0.21)	0.20 (0.26)	0.18	-0.10	0.81
SEP	**ALL**	1609565	0.15 (0.25)	0.23 (0.28)	0.16	-0.08	0.86
OCT	**ALL**	1716481	0.17 (0.26)	0.23 (0.27)	0.15	-0.06	0.87
NOV	**ALL**	1848765	0.17 (0.25)	0.22 (0.25)	0.12	-0.06	0.91
DEC	**ALL**	1896175	0.14 (0.21)	0.19 (0.22)	0.13	-0.05	0.85

The histograms of the difference (figure 31) show that the distribution of the bias spans over a wide range (from –0.3 to +0.3) for most biomes. The more biased classes are Bare areas, where the MSG product provides a constant zero value, and Cultivated and Mosaic (as in Europe). Statistical errors for all biomes are given in the Annex VIII. The temporal variability of RMS and bias is shown in figure 32. Highest RMS and bias are found for Herbaceous. The overall trend for the different biomes is to decrease both RMS and bias from July to December (opposite trend to that found in Europe). The worst correlation between the products is found for Broadleaved Evergreen Forest (r<0.4).

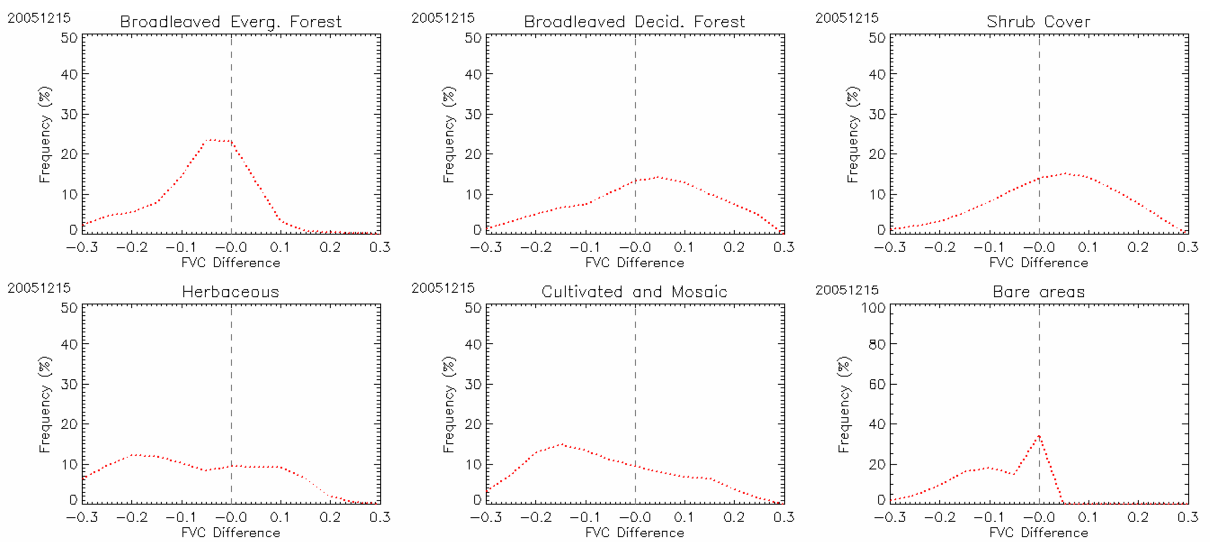


Figure 31.- Histogram of the bias between MSG and POLDER-3 FVC products for main biomes of North Africa in December 2005.

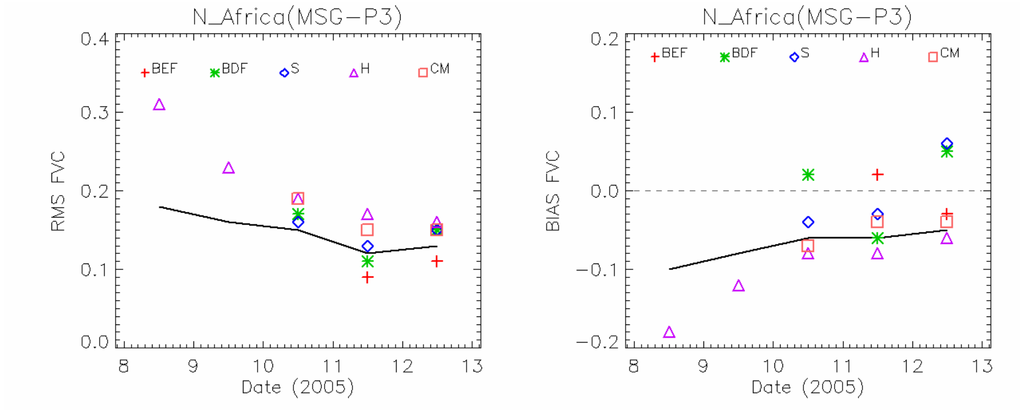


Figure 32.- As in figure 26 for North Africa.

Figure 33 shows the difference maps among LAI products for North Africa. Differences between MSG and POLDER LAI follow the same spatial pattern than in the FVC product. Absolute differences range between –3 and +1, remaining close to zero only in desert areas. The difference map between MSG and MODIS LAI fields of August 2005 reveals strong differences, showing a biome dependent pattern. There is a clear over-estimation of MODIS LAI regarding MSG LAI for Equatorial Forest (BEF), whereas for the other biomes (S, H, CM, BDF) located between desert and evergreen equatorial forest the MSG LAI product over-estimates the MODIS LAI up to near 3 in large areas. Therefore, large relative differences, between 50% and 100% and even higher (eg., Sahel), are found. However, these differences between MSG and MODIS LAI product decreases towards December, where both products are spatially quite consistent (see Annex V). The best overall RMS (table 11) is found between MSG and MODIS (RMS typically of 0.6), whereas between POLDER and MODIS the RMS is typically of 1. Mean bias between MSG and MODIS shows important temporal variations although this effect should be affected by the different percentage of valid pixels along the period. For November and December (very good coverage for the three products) MSG presents a negative bias around 0.2 with both MODIS and POLDER LAI products, whereas between MODIS and POLDER the bias is close to zero. Good correlations are found among the products (r>0.8).

Table 11.- As in table 9 for North Africa.

N_Africa		Nº PIXELS	MEAN (STDV)			RMS	bias	r
MONTH	**CLASS**		**MSG**	**MODIS**	**P3**	**MSG-MODIS / MSG-P3/ P3-MODIS**		
AUG	**ALL**	1448793	0.36 (0.80)	0.26 (0.76)	0.74 (1.25)	0.49/0.82/1.04	0.09/-0.38/0.45	0.81/0.84/0.67
SEP	**ALL**	1592781	0.54 (1.02)	0.41 (0.92)	0.85 (1.32)	0.59/0.76/1.05	0.13/-0.30/0.44	0.83/0.85/0.69
OCT	**ALL**	1698368	0.63 (1.06)	0.55 (1.06)	0.86 (1.28)	0.58/0.76/1.00	0.08/-0.30/0.31	0.85/0.85/0.68
NOV	**ALL**	1831314	0.61 (1.07)	0.76 (1.34)	0.84 (1.31)	0.62/0.64/0.79	-0.14/-0.23/0.08	0.90/0.89/0.82
DEC	**ALL**	1878197	0.51 (0.90)	0.74 (1.34)	0.68 (1.15)	0.68/0.62/0.80	-0.24/-0.17/-0.06	0.92/0.86/0.82

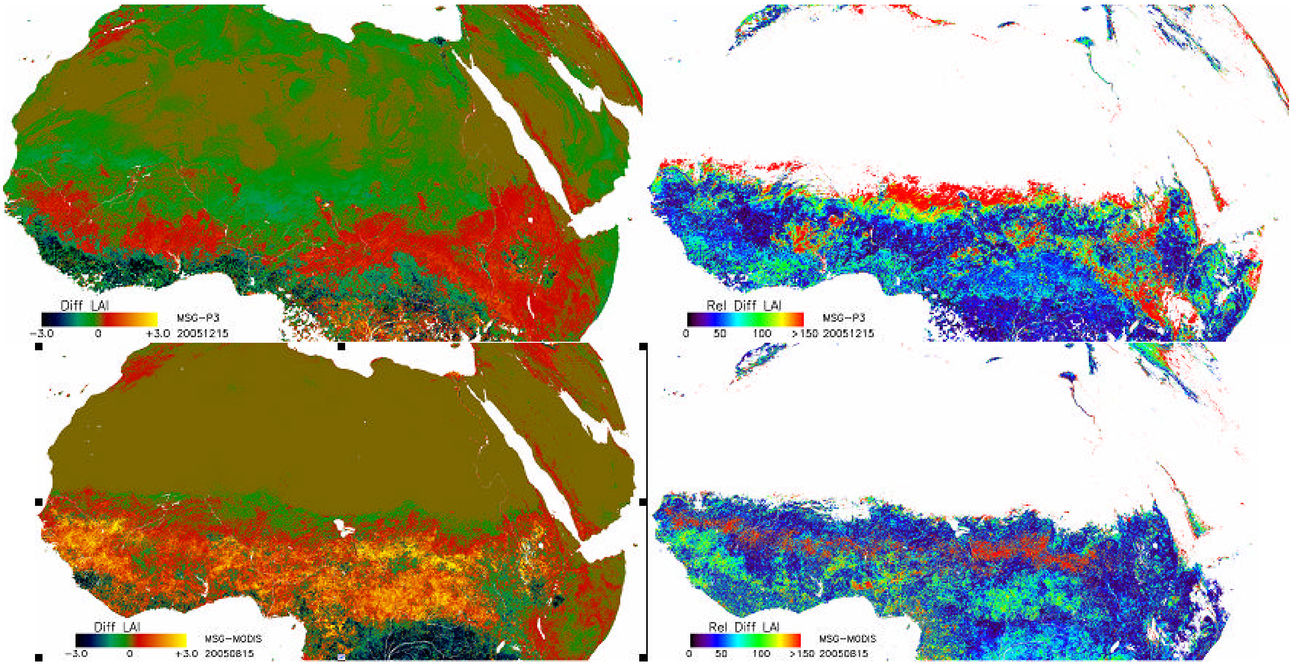


Figure 33.- Maps of the absolute (left) and relative (right) differences for North Africa between MSG-PARASOL (P3) LAI products in December 2005 (top) and MSG-MODIS LAI products in August 2005 (bottom). Relative error were not computed where LAI<0.5.

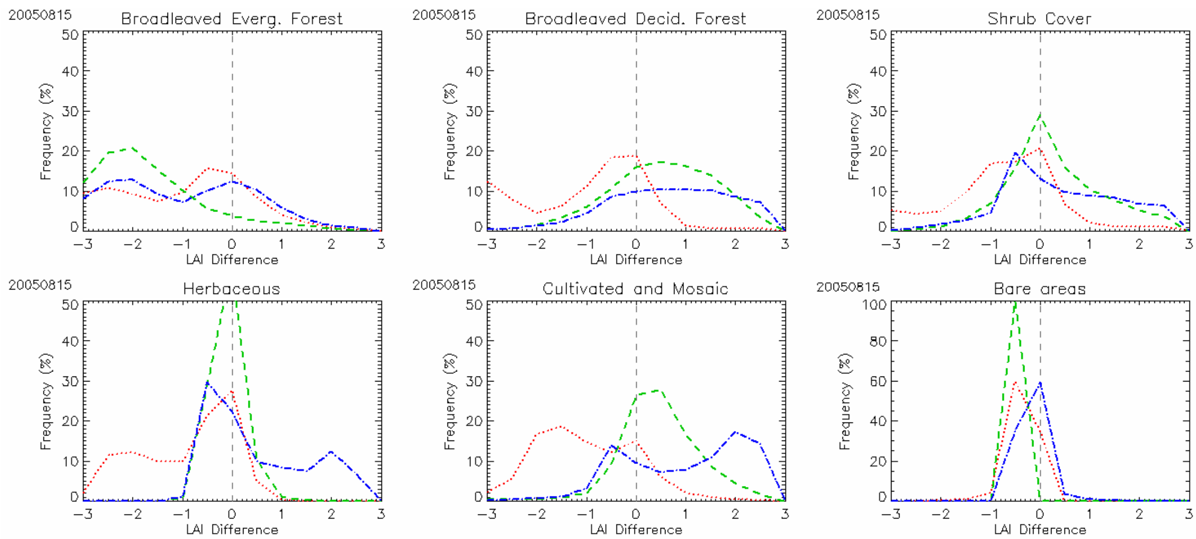


Figure 34.- Histogram of the bias among LAI products for main biomes of North Africa in August 2005. MSG-PARASOL (in red), MSG -MODIS (in green) and PARASOL-MODIS (in blue).

Figure 34 shows the histograms of the bias between different LAI estimates of North Africa in August 2005. The important bias between MSG and MODIS for the BEF class is clearly observed (maximum located around –2). However, for BDF or CM the MSG LAI product presents a positive bias regarding MODIS. Concerning POLDER products, again most of biomes (CM, BDF, BEF, H) present a negative bias. The temporal evolution of both RMS and bias is shown in Figure 35. Between MSG and MODIS LAI retrievals the RMS is quite stable, between 1.0 and 1.5 for most of biomes. The mean value for this area decreases due to the important contribution of Bare Areas. For this area PARASOL and MSG present similar RMS and mean bias than between MSG and

MODIS. The worst correlation is found for the Broadleaved Evergreen Forest class. For this class the correlation (r) is lower than 0.4 for MSG-MODIS, and still lower for MSG-POLDER (r<0.3) and MODIS-POLDER (r<0.2). However, for the other biomes correlations are higher than 0.7 for all dates. This is a clear indication of the difficulties for retrieving accurate LAI in this dense tropical forest.

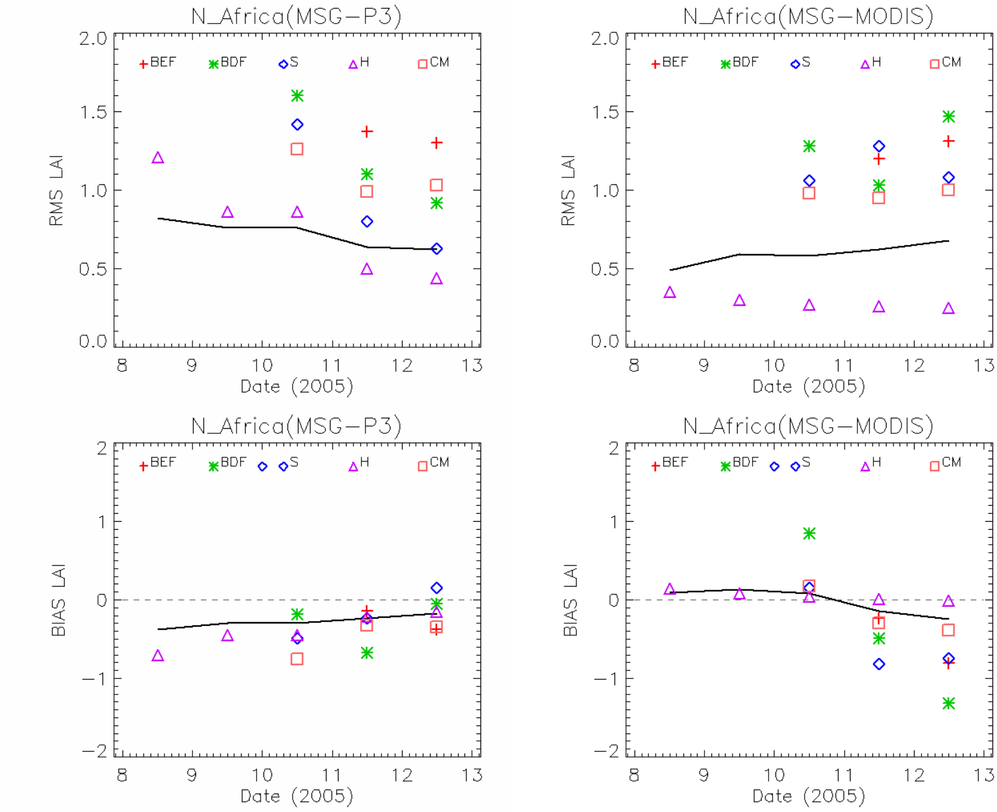


Figure 35.- As in Figure 29 for North Africa.

· ZONE SOUTH AFRICA

Figure 36 shows an example of SEVIRI and POLDER difference maps for the FVC and LAI products in August 2005 (for other dates see Annex IV). For this region, very important differences are also found for the FVC product. The absolute difference map presents either high positive values (yellow colour) or high negative values (black colour). This map shows clearly the spatial inconsistency between both products in this region, with relative errors up to 150% in the southern part (lowest vegetation coverage). Absolute differences between MSG and POLDER LAI show the same spatial pattern, with absolute difference ranging between –1 and +1. In relative terms differences between LAI products are on the same order than between FVC products. Statistical indicators for the FVC product (table 11) show an RMS typically of 0.15, mean bias close to zero and correlations higher than 0.7. These results are quite good, as compared with the large differences shown in the error maps. This fact point out the importance of monitoring the products, and the difference maps, due to the fact that statistical indicators are computed as an average over large populations, which may smooth the existing differences. However, difference maps allow us to identify areas where discrepancies are more important, and hence try to understand what is happening over such areas.

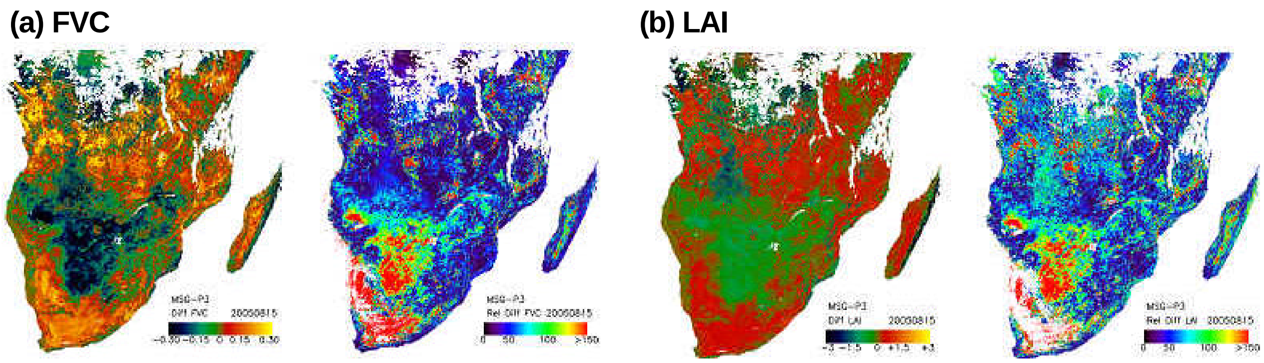


Figure 36.- Maps of the absolute (left) and relative (right) differences for South Africa between MSG-PARASOL (P3) for (a) FVC and (b) LAI products in August 2005. Relative errors were not computed where FVC<0.15 and LAI<0.5.

Table 11.- As in table 9 for North Africa.

S_AFRICA		Nº PIXELS	MEAN FVC (STDV)		RMS	bias	r
MONTH	CLASS		MSG	P3		MSG-P3	
AUG	ALL	698758	0.29 (0.16)	0.31 (0.21)	0.15	-0.02	0.69
SEP	ALL	703085	0.29 (0.18)	0.28 (0.22)	0.14	0.02	0.79
OCT	ALL	602265	0.29 (0.19)	0.25 (0.24)	0.16	0.04	0.75
NOV	ALL	570658	0.33 (0.24)	0.30 (0.27)	0.15	0.02	0.83
DEC	ALL	503397	0.41 (0.26)	0.43 (0.29)	0.17	-0.014	0.82

In Figure 37 we can observe that the difference between MSG and POLDER FVC retrievals in August is more biased for Broadleaved Evergreen Forest (BEF), where PARASOL over-estimate the MSG result. Also for CM there are more cases with negative bias up to –0.3. However is for Herbaceous where MSG provides more cases with higher FVC values. The RMS is quite stable over the period and similar for all biomes (typically 0.15), where the bias shows some temporal dynamic, especially for BEF and CM, changing from a negative bias (i.e., higher PARASOL retrievals) to a positive bias in only three months. This fact demonstrates again the impact of the different temporal dynamic shown by the different products. MSG LAI histograms for this region (figure 12) show the highest dynamic range of MSG.

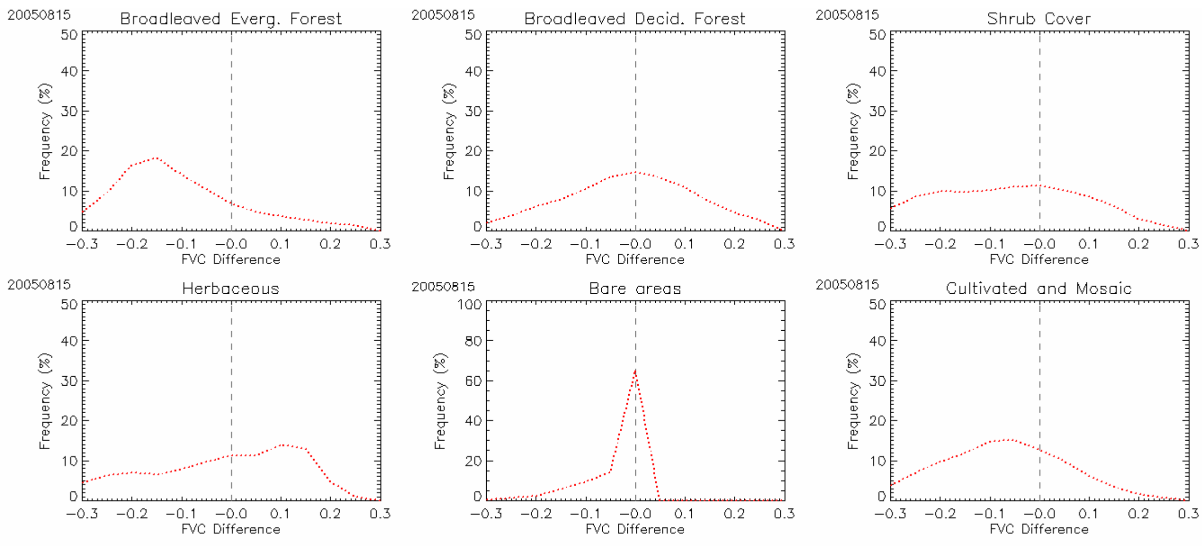


Figure 37.- Histogram of the bias between MSG and POLDER-3 (P3) FVC products for main biomes of South Africa in August 2005.

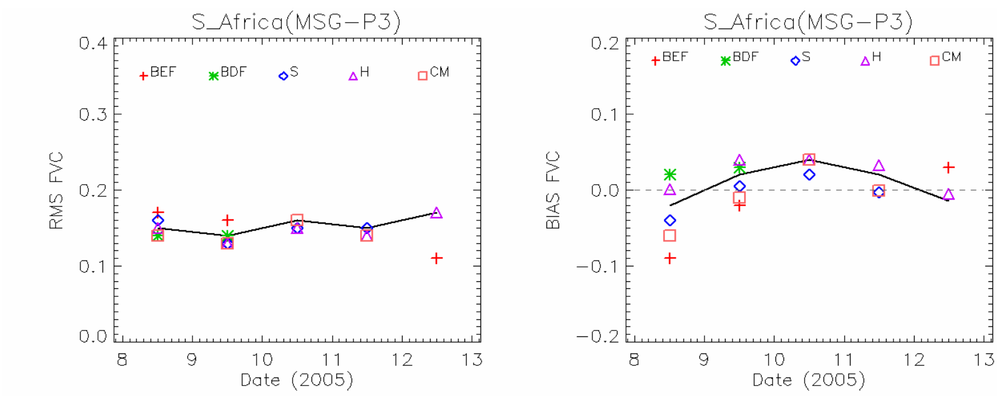


Figure 38.- As in figure 25 for North Africa.

(a) August

(b) December

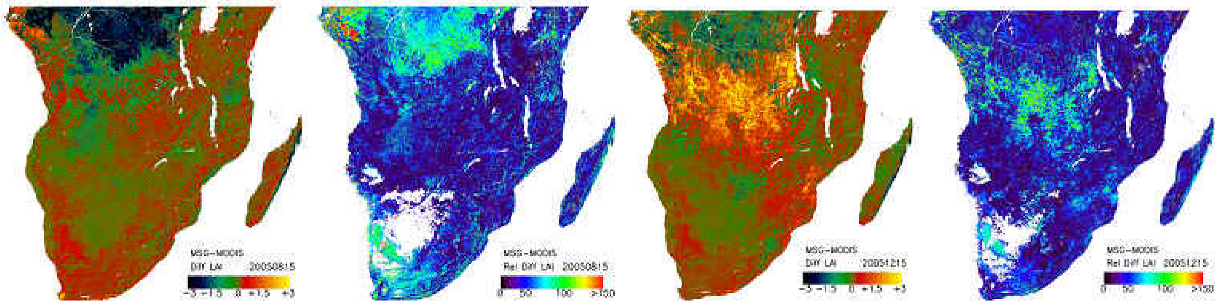


Figure 39.- Maps of the absolute (left) and relative (right) differences for South Africa between MSG-MODIS LAI for (a) August and (b) December. Relative errors were not computed for LAI<0.5.

Figure 39 show maps of the difference between MSG and MODIS LAI products. In general, MODIS and MSG LAI products are spatially more consistent that between MSG and PARASOL LAI products, especially in the southern area. The following features can be observed: First, there are an over-estimation of the MODIS LAI regarding the MSG LAI for Equatorial Forest (up to –3 in August), with relative errors around 100%, which is very high for 'dense' vegetation. The mean LAI values given by the MSG LAI product in August (2.25) seems to be quite low for this type of dense forest. Furthermore, the dynamic of the MSG product is higher than the MODIS product, with mean values ranging from 2.25 to 4 (see Annex VIII). MODIS mean LAI values are more stable, around 4, for this 'evergreen' vegetation type. This seems to point out an under-estimation of the MSG LAI during some dates, as well as a higher temporal variability than expected for this biome. In the image of December (figure 39-b) the discrepancies move toward the South. For this date, the highest difference occurs in the BDF class. MSG LAI over-estimates the MODIS LAI values between 1.5 and 3. Again the higher temporal dynamic of the MSG LAI product is responsible of this temporal variability. MODIS mean LAI values for this class is almost constant over the studied period (around 1.4, see Annex VIII), which is at least strange for a 'Deciduous' biome. The mean value for MSG ranges from 1.2 in August to 2.5 in December, which seems to be more realistic for a deciduous biome. For the Southern part of Africa the consistency between both products is pretty good, with relative errors below 50% in large areas. Table 12 shows that the bias between MSG and MODIS ranges from -0.2 to +0.2 in the studied period, which is the growing season in this hemisphere. The RMS between MODIS and MSG ranges from 0.5 (October) to 0,9 (December), and the correlation is higher than 0.8.

Table 12.- As in table 9 for South Africa.

S_Africa		Nº PIXELS	MEAN (STDV)			RMS	bias	r
MONTH	**CLASS**		**MSG**	**MODIS**	**P3**	**MSG-MODIS / MSG-P3 / P3-MODIS**		
AUG	**ALL**	697730	0.92(0.65)	1.13(1.07)	1.07(1.12)	0.69/0.78/0.82	-0.21/-0.16/-0.05	0.82/0.76/0.72
SEP	**ALL**	701826	0.96 (0.77)	1.13 (1.21)	0.97 (1.14)	0.66/0.70/0.82	-0.16/-0.01/-0.16	0.88/0.80/0.77
OCT	**ALL**	600957	0.96 (0.92)	0.97 (1.11)	0.87 (1.16)	0.51/0.77/0.89	-0.01/0.1/-0.10	0.89/0.76/0.69
NOV	**ALL**	569344	1.20 (1.22)	1.09 (1.32)	1.16 (1.45)	0.58/0.80/0.94	0.12/0.05/0.07	0.90/0.84/0.77
DEC	**ALL**	502105	1.61 (1.40)	1.33 (1.51)	1.73 (1.63)	0.86/0.96/1.29	0.28/-0.13/0.40	0.84/0.81/0.70

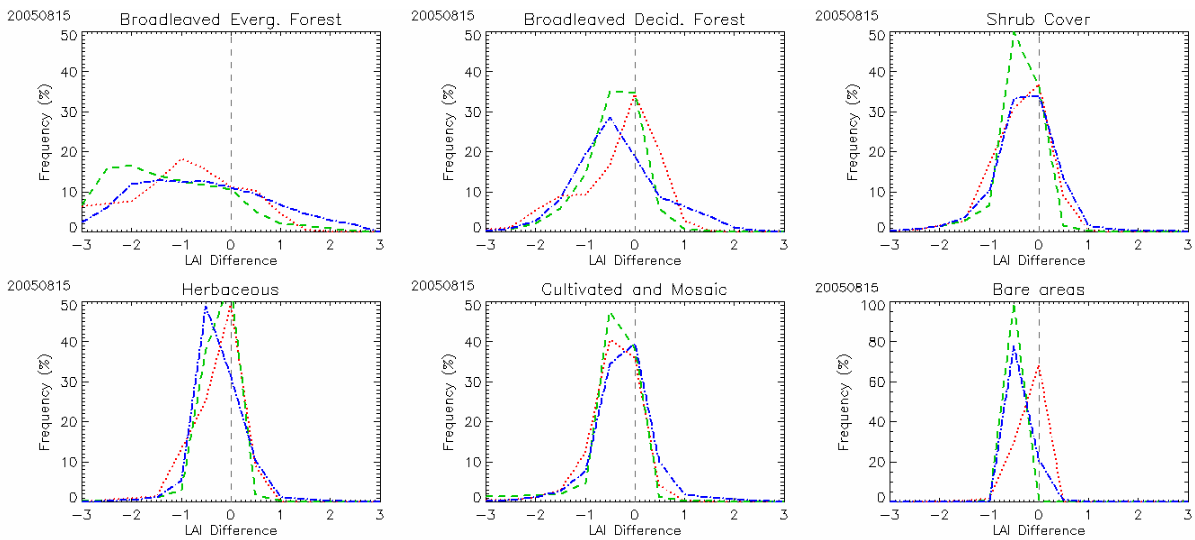


Figure 40.- Histogram of the bias among LAI products for main biomes over South Africa for August 2005. MSG-PARASOL (in red), MSG -MODIS (in green) and PARASOL-MODIS (in blue).

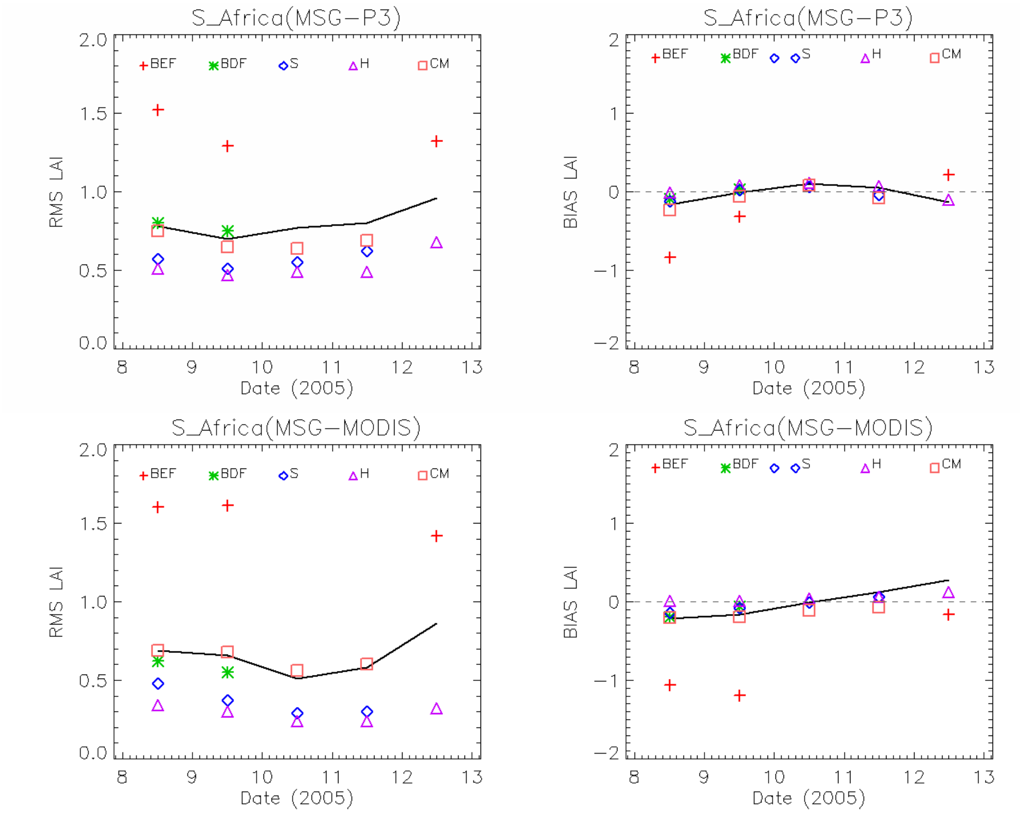


Figure 41.- As in Figure 28 for South Africa.

The temporal evolution of the error indicators (figure 41) shows the highest RMS for BEF. The bias between MSG and POLDER is quite stable, whereas the differences between MSG and MODIS are quite important for two biomes: BEF and BDF. As said before, this observed trend is explained due to the MODIS LAI product present a lower temporal dynamic than MSG. MSG values for forest areas increase with the growing season (i.e., towards winter time). The differences for Evergreen Forest (BEF) are higher in August and September (negative bias), whereas for Deciduous Forest (BDF) differences are higher in December (positive bias).

· ZONE SOUTH AMERICA

Finally, the inter-comparison for South America presents similar conclusions than those found for South Africa. Error maps between MSG and POLDER (Figure 42) show same trends found for other geographical areas, with relative error up to 100% for FVC and LAI in large regions. The mean bias however is close to zero, due to it is computed as an average of positive and negative tendencies, and the RMS is around 0.2 for FVC (table 13) and 1.2 for LAI (table 14). For biomes the bias is more important for Cultivated and Mosaic (figure 43 and 44), where again PARASOL over-estimate the MSG retrievals.

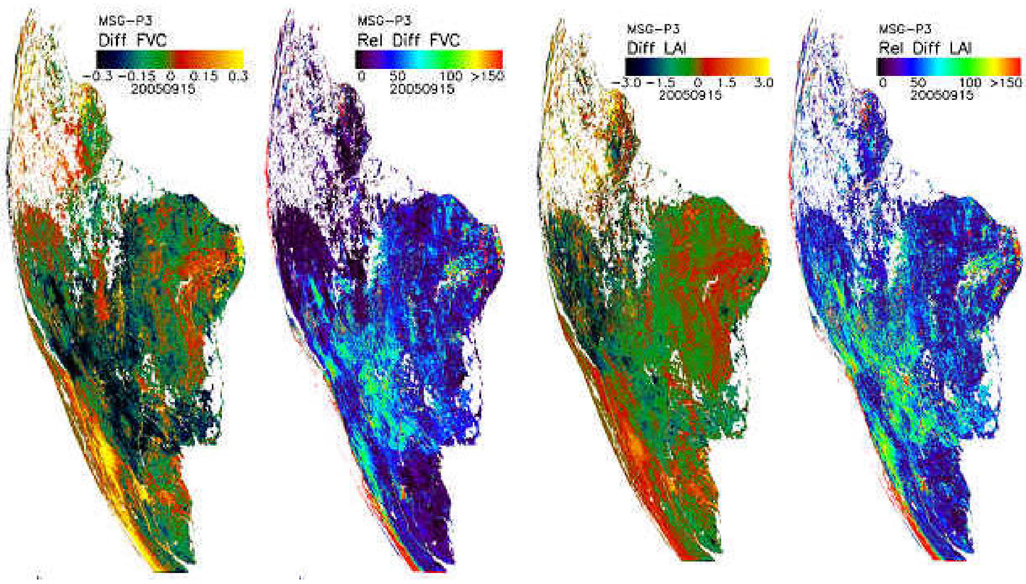


Figure 42.- Maps of the absolute (left) and relative (right) differences for South America between MSG-PARASOL (P3) for (a) FVC and (b) LAI products in September 2005. Relative errors were not computed for FVC<0.15 and LAI<0.5.

Table 13.- As in table 9 for North Africa.

S_AMERICA MONTH	CLASS	Nº PIXELS	MEAN FVC (STDV) MSG	P3	RMS	bias	r
					MSG-P3		
AUG	ALL	335102	0.51 (0.23)	0.56 (0.24)	0.17	-0.05	0.78
SEP	ALL	396394	0.48 (0.24)	0.54 (0.25)	0.18	-0.06	0.75
OCT	ALL	322469	0.47 (0.24)	0.51 (0.26)	0.19	-0.05	0.72
NOV	ALL	266368	0.52 (0.27)	0.52 (0.28)	0.18	-0.001	0.78
DEC	ALL	200179	0.61 (0.25)	0.59 (0.26)	0.22	0.009	0.65

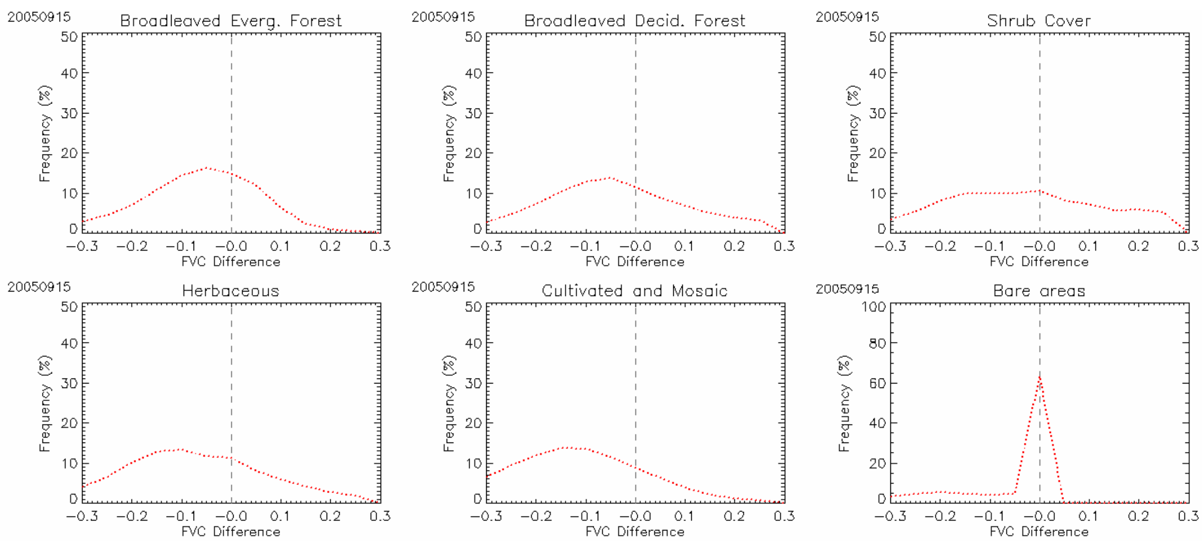


Figure 42.- Histogram of the bias between MSG and POLDER-3 (P3) FVC products for main biomes in South America for September 2005.

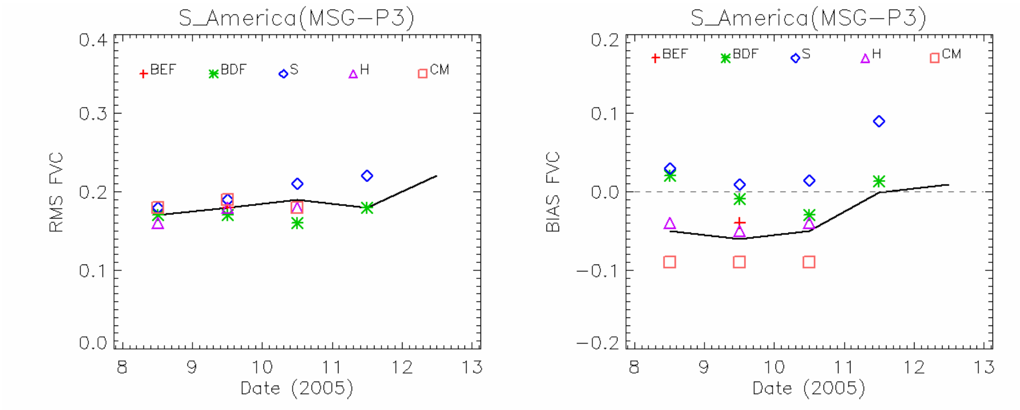


Figure 44.- As in figure 26 for South America.

The inter-comparison between MODIS and MSG LAI products for South America provides similar conclusions to that of the South Africa. As can be observed in figure 45, spatial differences between products are very dependent of the date. For August MODIS LAI product provides higher values than MSG for the Amazonian Forest, although differences are less important than in the African Equatorial Forest, with low relative errors. Conversely, in December the MSG LAI product over-estimate the MODIS retrievals in large areas, including the Amazonian Forest. The mean bias changes from a negative (-0.3) value in August to a positive (+0.8) value in December. Therefore, the spatial consistency between MSG and MODIS in this area is also highly dependent of the date. The RMS is around 1 with correlation typically of 0.8.

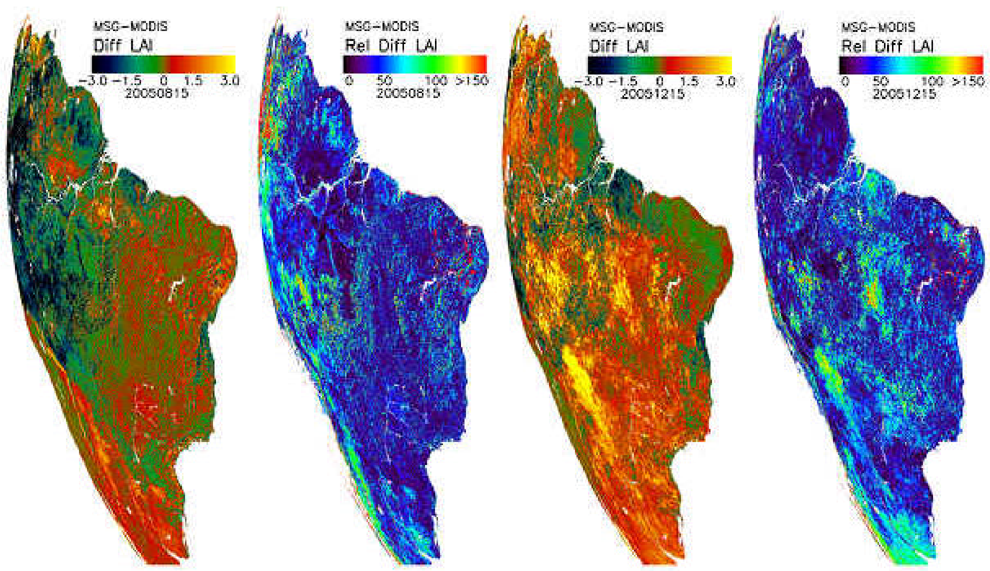


Figure 44.- Maps of the absolute (left) and relative (right) differences for South Africa between MSG-MODIS LAI for (a) August and (b) December. Relative errors were not computed where FVC<0.15 and LAI<0.5.

Table 14.- As in table 9 for South America.

S_AMERICA		Nº PIXELS	MEAN (STDV)			RMS	bias	r
MONTH	**CLASS**		**MSG**	**MODIS**	**P3**	**MSG-MODIS / MSG-P3 / P3-MODIS**		
AUG	**ALL**	332647	2.09 (1.47)	2.41 (1.67)	2.43 (1.73)	1.03/1.13/1.10	-0.31/-0.34/0.024	0.81/0.79/0.79
SEP	**ALL**	393004	1.98 (1.48)	2.48 (1.91)	2.31 (1.78)	1.23/1.21/1.18	-0.50/-0.32/-0.18	0.81/0.76/0.80
OCT	**ALL**	320011	1.86 (1.45)	1.98 (1.69)	2.07 (1.60)	0.97/1.23/1.29	-0.12/-0.21/0.09	0.83/0.69/0.69
NOV	**ALL**	263180	2.23 (1.64)	1.87 (1.59)	2.15 (1.67)	1.06/1.17/1.34	0.36/0.08/0.28	0.81/0.75 /0.68
DEC	**ALL**	197717	2.67 (1.59)	1.78 (1.43)	2.63 (1.64)	1.37/1.46/1.74	0.89/0.04/0.85	0.77/0.59/0.52

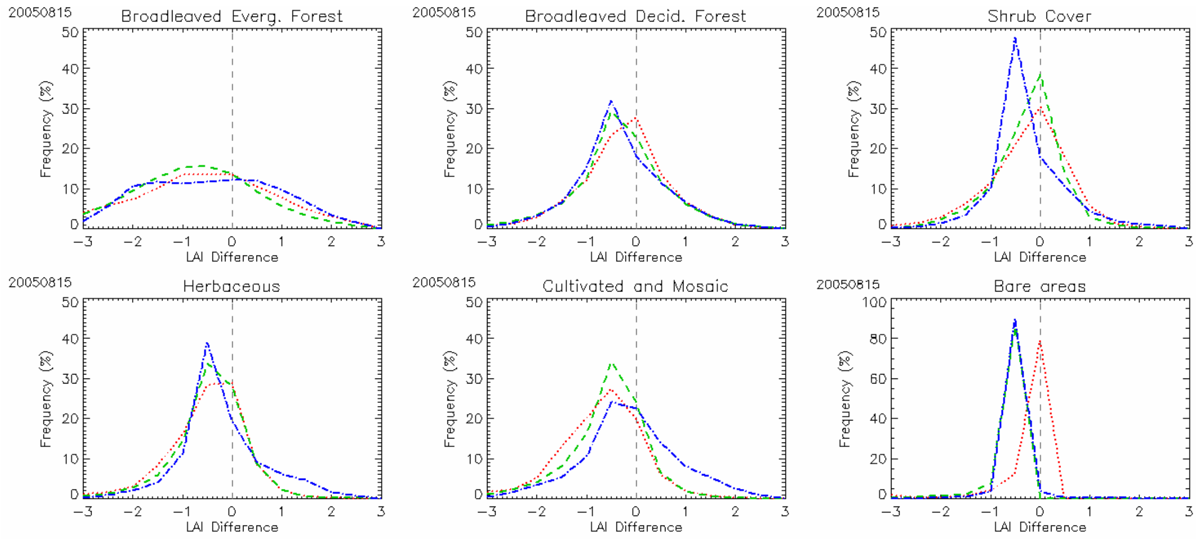


Figure 40.- Histogram of the bias among LAI products for main biomes over South America for August 2005. MSG-PARASOL (in red), MSG -MODIS (in green) and PARASOL-MODIS (in blue).

Figure 40 shows the temporal variability of the mean RMS and bias per classes. Best results are found between POLDER and MODIS. Note that the black line represents the value for the whole area. The observed tendency for the mean bias between MSG and MODIS products is quite similar for the main biomes. The main LAI values per classes are given in Annex VIII. MSG provides high variations for biomes such us Shrub (ranging from 1.1 to 2.1) or Herbaceous (ranging from 1.2 to 2), whereas MODIS LAI provides lesser variations, between 1 and 1.4 for Shrubs or between 1.2 and 1.5 for Herbaceous. The temporal variations for the PARASOL mean LAI values are closer to that of MSG, between 1.1 and 1.8 for Shrubs and between 1.4 and 2.1 for Herbaceous. The same trend is found for Deciduous Forest, where MSG and POLDER presents temporal variations of around 1.5, whereas variations in MODIS LAI is only of 0.5 in mean value. Is very difficult without additional information to say what trend is better reproducing the reality. What we can say is that MSG and PARASOL are temporally more consistent between them than MSG with MODIS, and highlight also that MODIS LAI products present a very low temporal dynamic in the growing season for South America. This seems to point out that MSG and PARASOL products capture better the temporal variability.

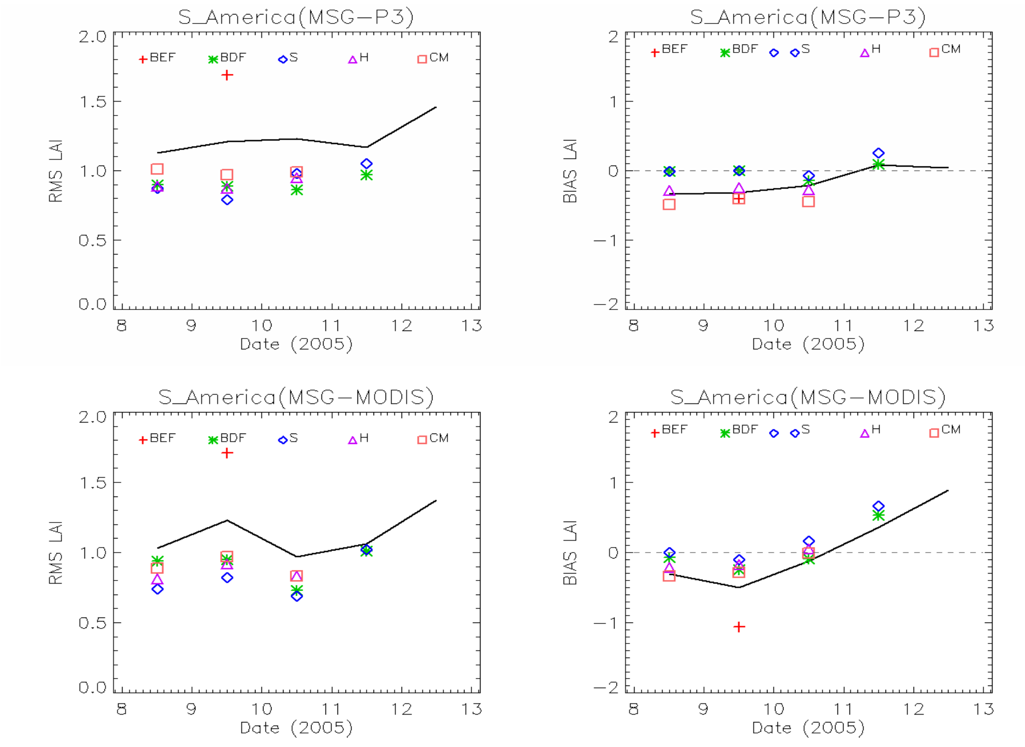


Figure 41.- As in Figure 29 for South America.

· PIXEL SCALE

Figure 42 shows the scatter-plots between the values of different products over the CEOS-BELMANIP validation sites located in the SEVIRI disk for two different dates (August 2005, October 2005). These sites are representative of vegetation global conditions, and are proposed as a benchmark for the inter-comparison of biophysical products (Baret and Pavageau, 2006).

Scatter-plots between POLDER and MSG FVC product shows a good correlation (r>0.7) with most of the data points distributed along the 1:1 line. However, we can observe most of the points showing higher values for POLDER. Hence, the over-estimation of PARASOL retrievals is also found over this limited dataset. Similar results are obtained between MSG and PARASOL LAI products at a pixel level. Now, lower values of MSG LAI are found corresponding mainly to South Africa (red crosses) and South America (magenta crosses). The scatter-plot between MSG and MODIS LAI reduces considerably the RMS (typically around 1) found between MSG and PARASOL (RMS around 2 in August and 1.2 in October). This is again indicative of the better consistency found between MODIS and MSG. This results support the idea that the scatter-plots over BELMANIP sites at a pixel level provides information of the consistency between products. Nevertheless, this information is more influenced by the impact of error in the geo-location, different projection and re-sampling.

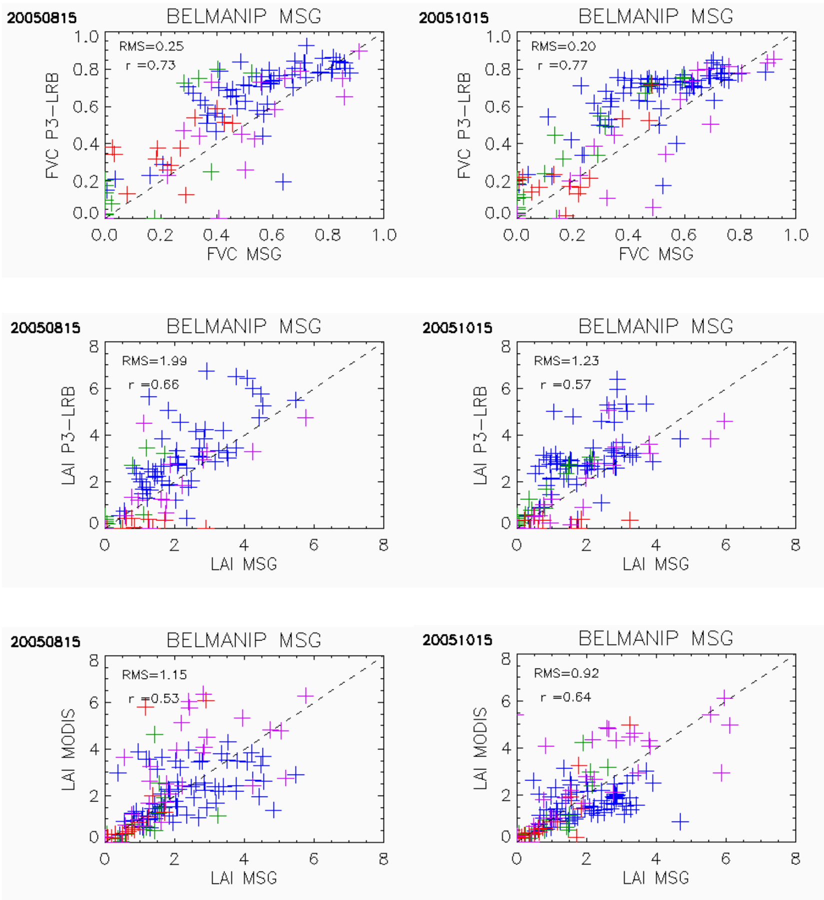


Figure 42.- Scatter-plots between different products over BELMANIP sites for August and October 2005. Blue colour is used for sites located over Europe, green for North Africa, red for South Africa and magenta for South America.

4.2. TEMPORAL CONSISTENCY

The temporal consistency among the different products was evaluated over 30 selected sites (most of them pertaining to BELMANIP) located over Europe (Table 2) and South Africa (Table 3) presenting different phenology as a function of the vegetation type and climatic conditions. The temporal profiles include MSG data since August 2005 to July 2006, PARASOL data since July 2005 to December 2005, MODIS data since June 2005 to March 2006, as well as the ECOCLIMPA temporal profiles.

Figure 43 shows the results for the sites located over Europe, figures are ordered from Northern (densest forest) to Southern latitudes (sparse vegetation). The following features can be observed for Europe:

In general, all the products are quite consistent among them and reproduce the phenology of the different test sites given by the ECOCLIMAP climatology, especially for the second part of the year. MSG and MODIS LAI temporal profiles are more consistent especially over the southern areas located below 45º (eg., see Alpilles, Fundulea, Barrax, Valencia), with some exceptions as in Nezer where MSG provides an opposite temporal trend to that of ECOCLIMAP or MODIS.

MSG products over Europe present low confidence for higher latitudes (eg., Hirsikangas, Järvselja or Harwood). For this northern latitudes two effects are observed: On one hand, an increasing error bars for winter time, which is related to the increasing error of the BRDF input data for these high latitudes when using geo-stationary satellites, especially in winter time where the sun zenith angle is low. On the other hand, the phenology shown by ECOCLIMAP is not reproduced during the winter period. For this period, MSG presents very high values for vegetation, which can be easily related to the presence of snow (see for instance the quick decrease of vegetation retrievals in spring). This effect will be corrected using a more restrictive snow mask in future versions.

POLDER products are more noisier (eg., Jahlay, Puechabon, Nezer) than MSG despite its lower temporal resolution (10-days). The temporal profiles for POLDER products present also sudden changes (eg., Harwood, Evora) that can be introduced due to the impact of a variable clumping index.

Figure 44 show the profiles for South Africa, where vegetation presents a different phenology and thus temporal curves. For the site selected the temporal consistency is really good among the different products and the ECOCLIMAP data for the different biomes. Despite its high temporal resolution, the MSG profiles are very smooth with low errors, showing the quality of the Land SAF products. The best agreement is found between MSG and MODIS. POLDER profiles are again noisier in many sites (e.g., Mongu, Maun, Okwariver), showing the low quality of PARASOL products.

Europe

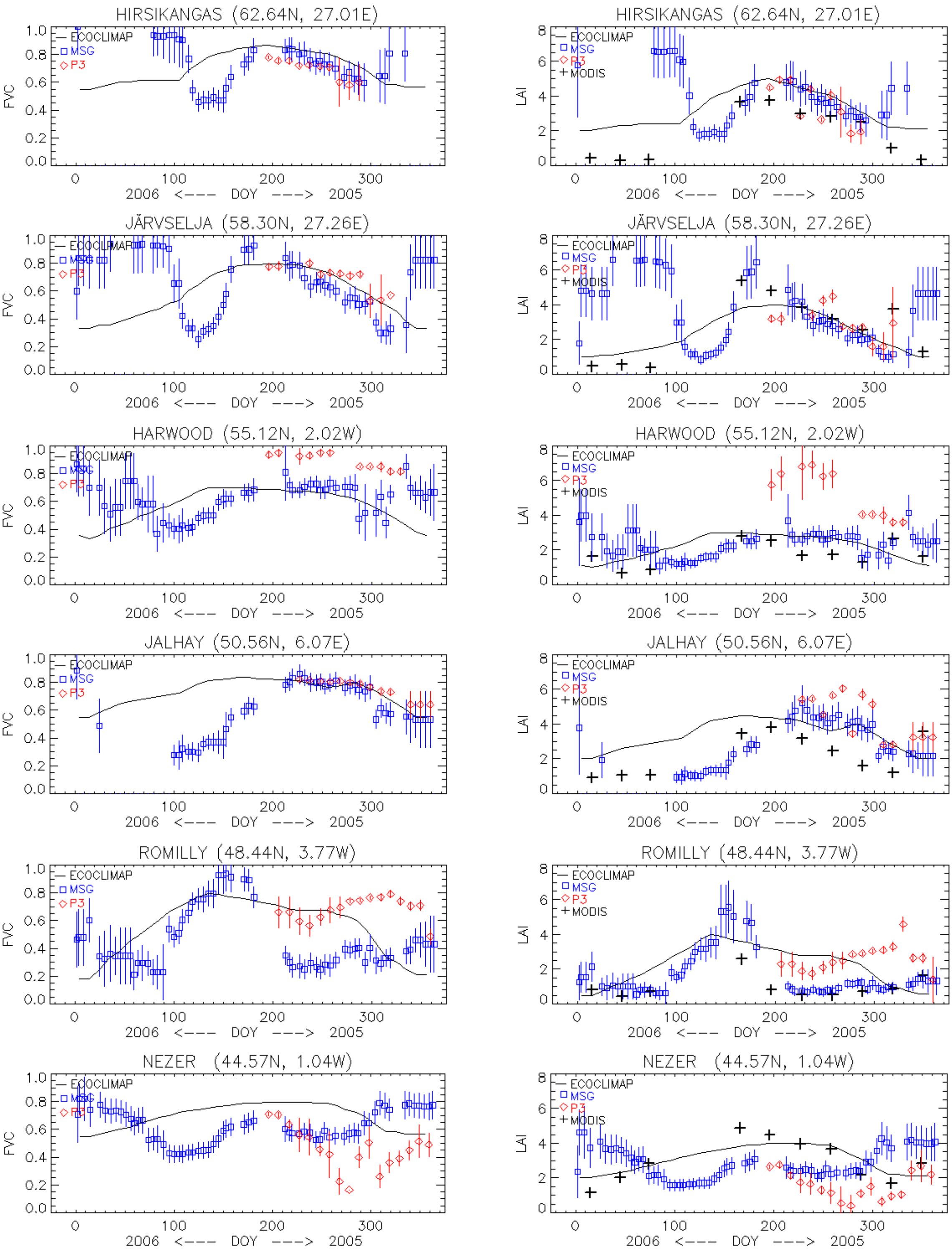


Figure 43.- Temporal profiles of FVC (left side) and LAI (right side) as a function of the Day Of the Year (DOY) for different test sites located at Europe. The data plotted correspond to the last months of 2005 and the first months of 2006.

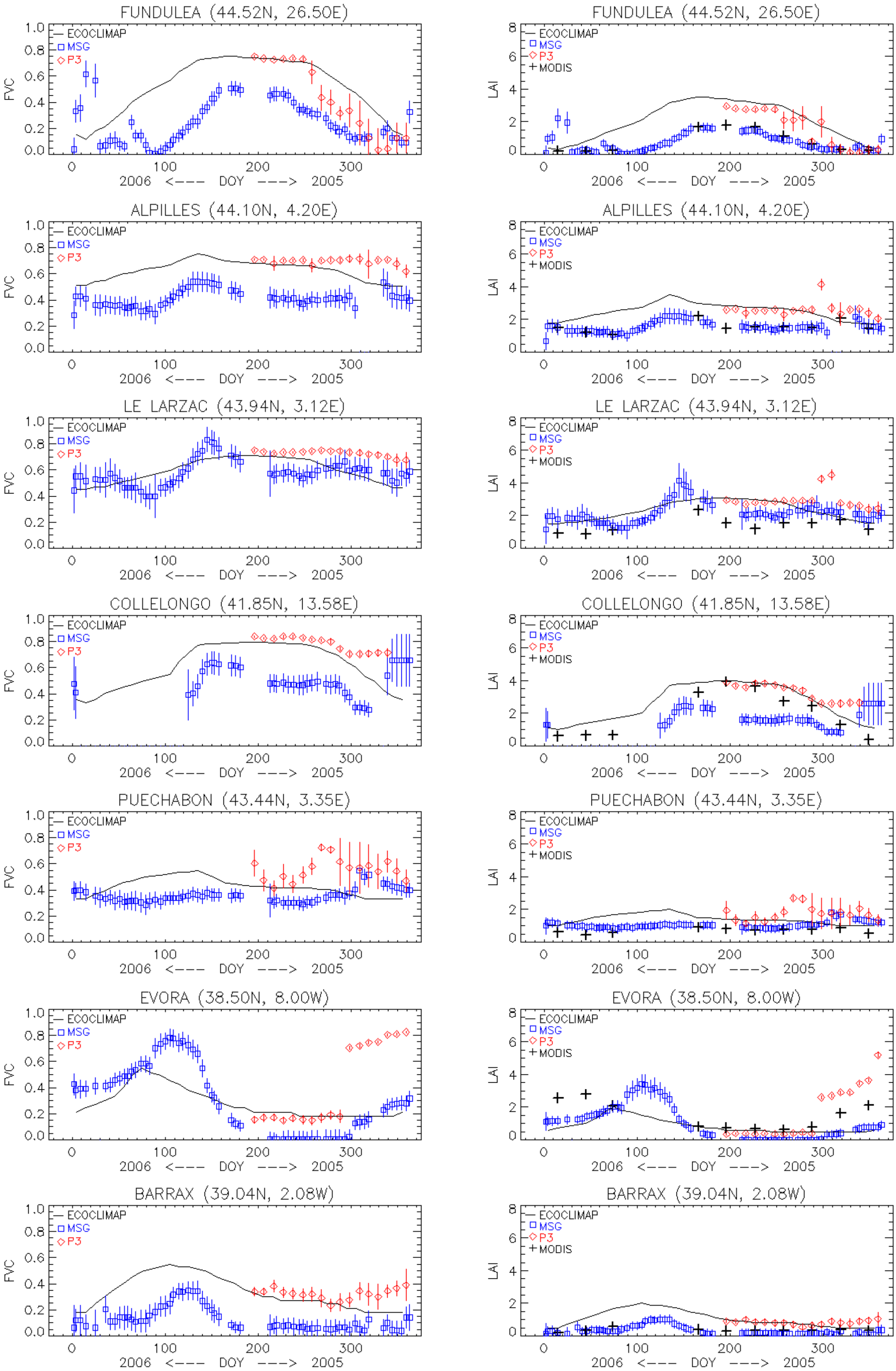


Figure 43.- Continuation

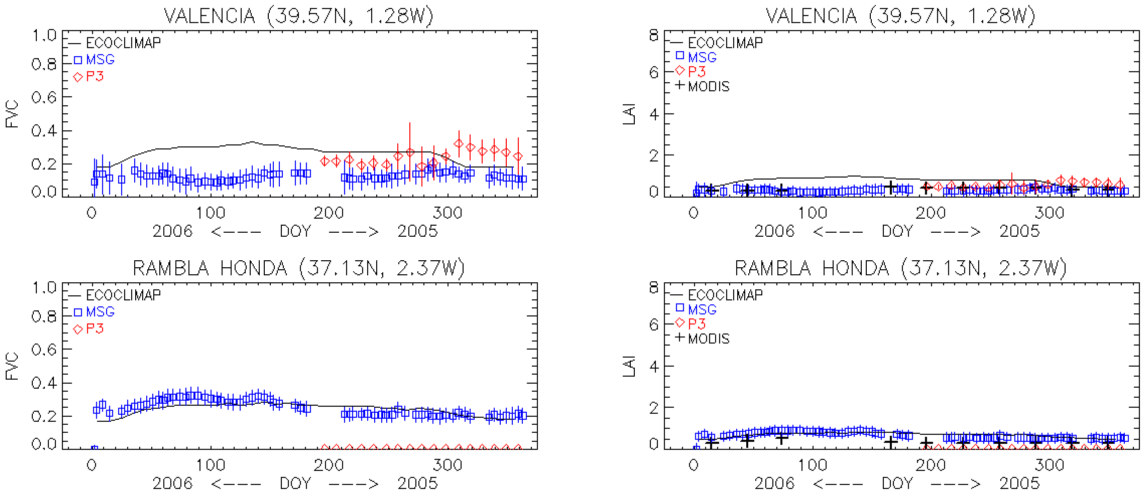


Figure 43.- Continuation

South Africa

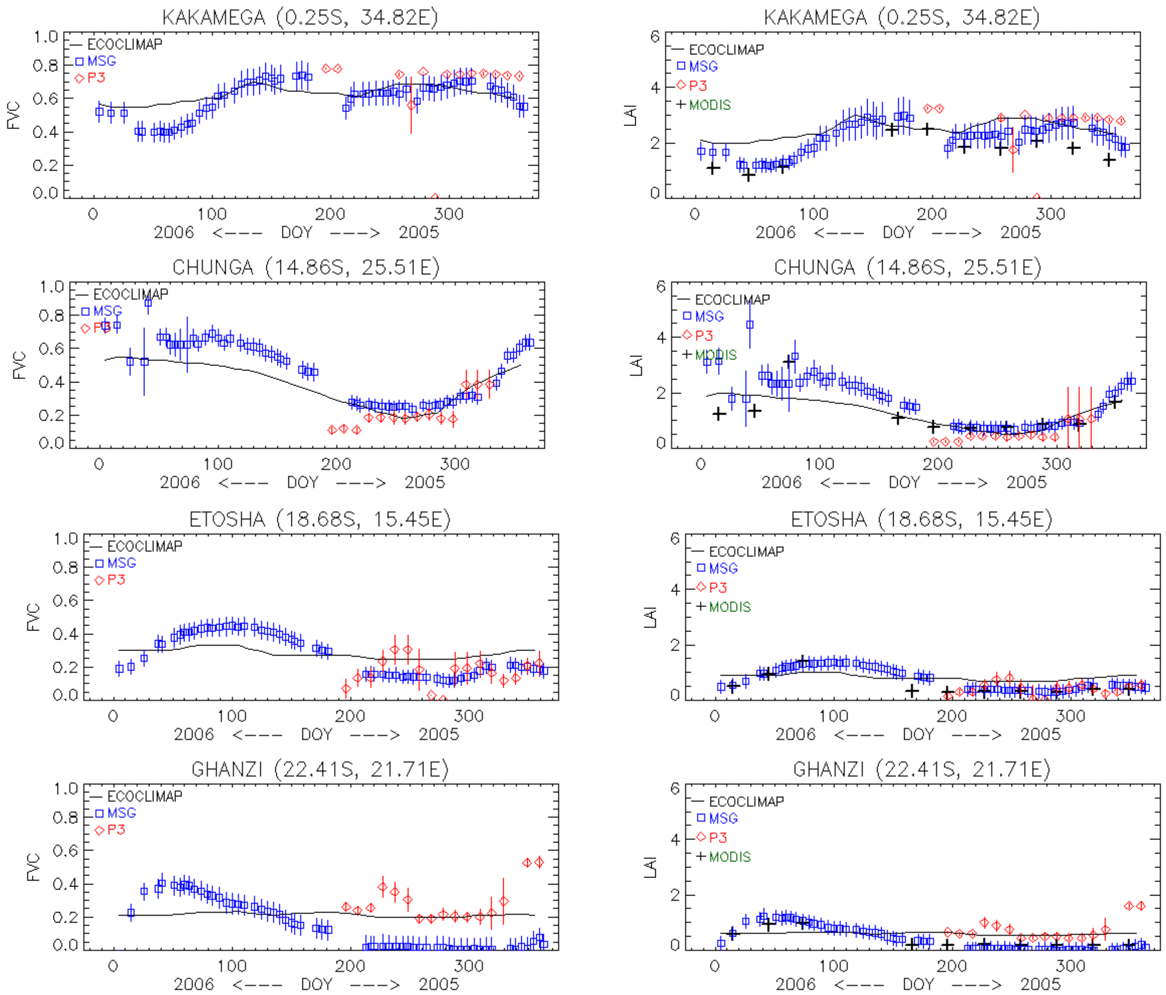


Figure 44.- Temporal profiles of FVC (left side) and LAI (right side) as a function of the Day Of the Year (DOY) for different test sites located at South Africa. The data plotted correspond to the last months of 2005 and the first months of 2006.

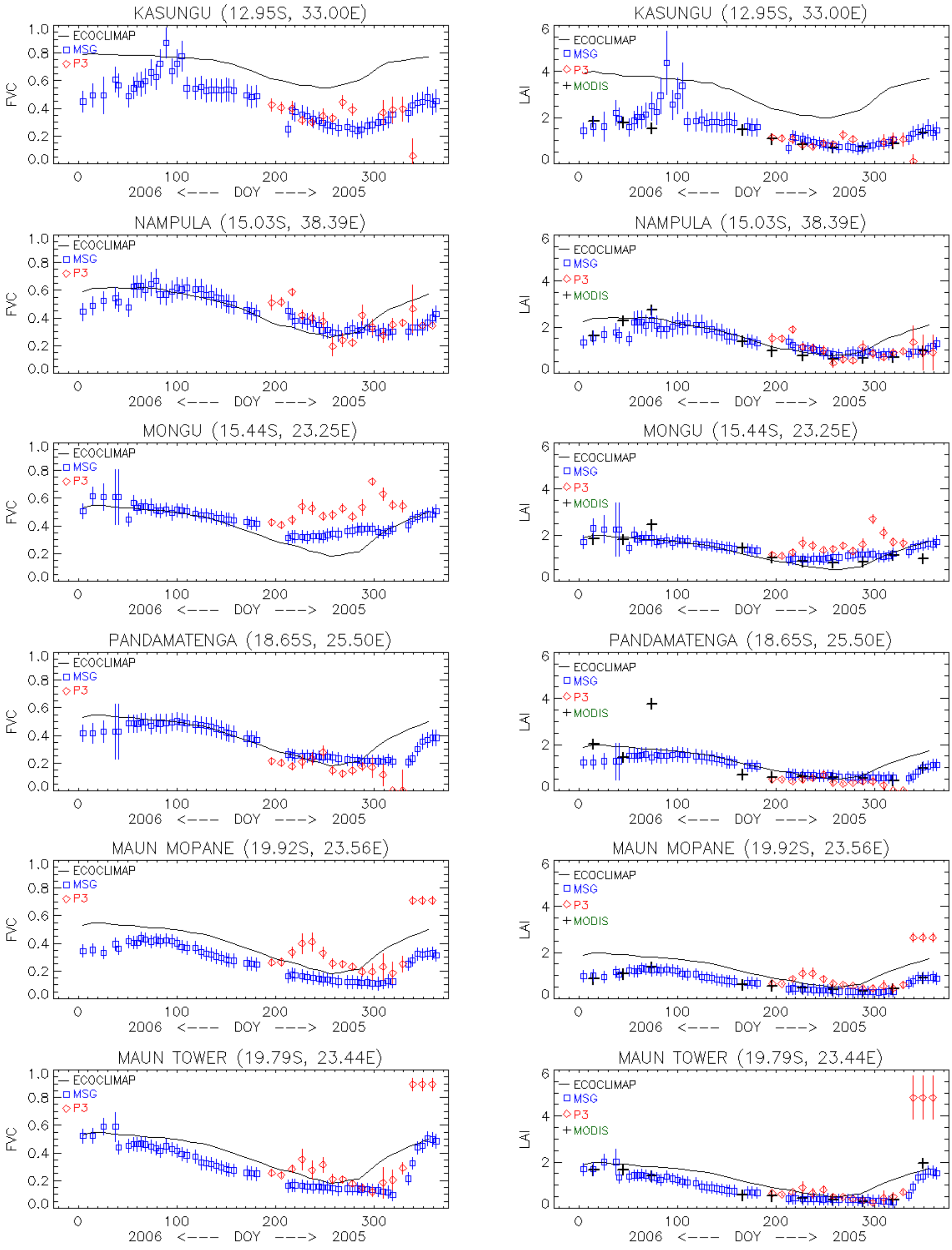


Figure 44.- Continuation.

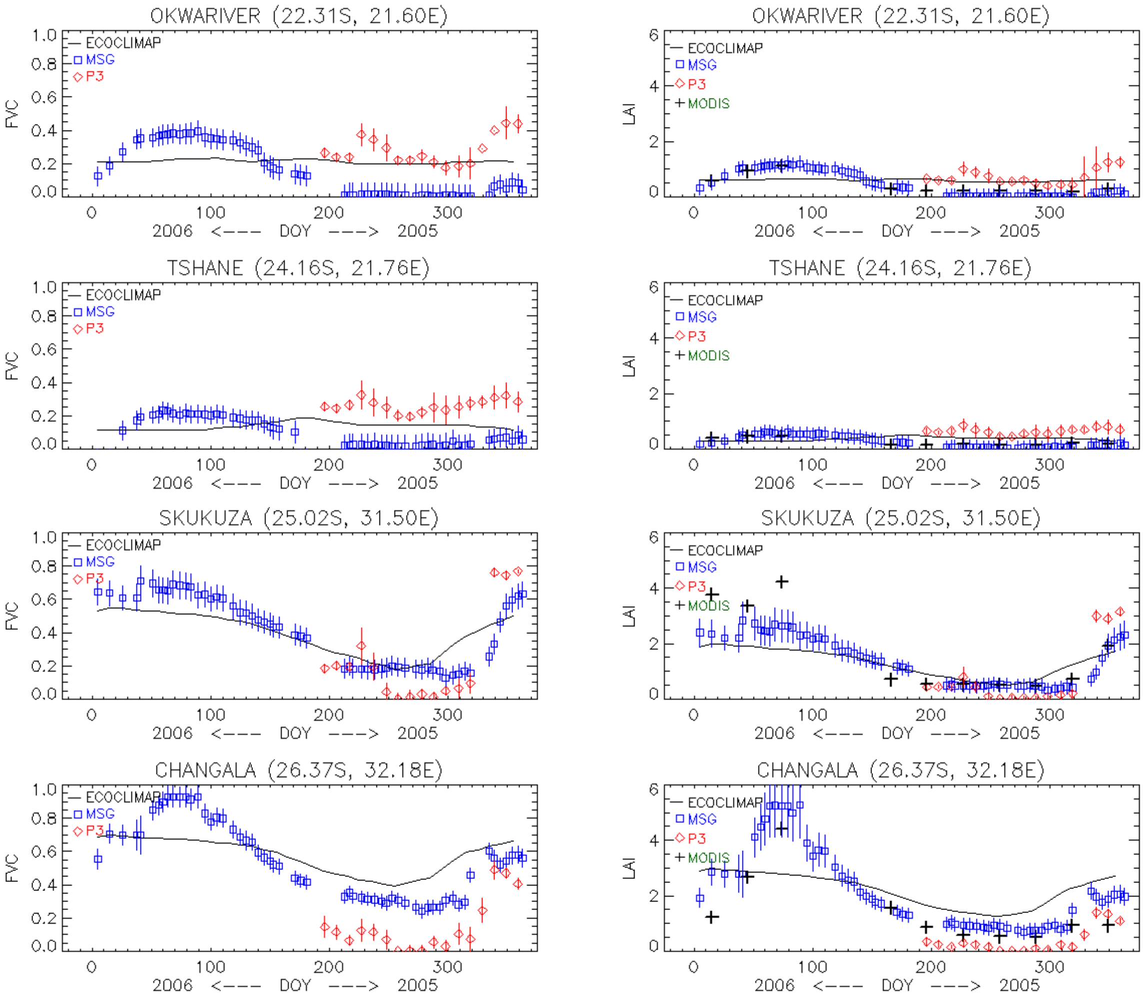


Figure 44.- Continuation.

5. CONCLUSIONS

In this work the spatial and temporal consistency between Land-SAF vegetation products (FVC and LAI) and equivalent MODIS/Terra C4.1 and PARASOL vegetation products has been evaluated. This inter-comparison exercise provides a way of evaluating the competitiveness of the Land-SAF vegetation products regarding other satellite products.

This work demonstrates the reliability and competitiveness of the Land-SAF VEGA V1.2 products. Land SAF vegetation products show consistent spatial distributions, displaying also a good temporal dynamic. Although in general the spatial consistency among MSG, MODIS and PARASOL products is not so good, the comparison between MSG and MODIS is much better (lower RMS, lower bias, higher correlation) than the comparison between PARASOL and MODIS for the SEVIRI geographical areas. The differences found between Land-SAF and MODIS or PARASOL products are less important than the discrepancies found between MODIS and PARASOL. Land-SAF products are more reliable than the PARASOL products (histograms, temporal dynamic, smooth profiles), and compares better with MODIS products. Between Land SAF and MODIS the agreement is noticeable for some areas (southern Africa, Europe), whereas for other regions (central Africa and South America) and for specific time periods important spatial differences (up to 100%) are found. MODIS LAI maps present a lower temporal dynamic than MSG products. For some biomes, such us Evergreen Forest MODIS seems to be more realistic, whereas for other biomes such us Deciduous Forest or Cultivated and Mosaic the MSG appears to be more reliable. However, with the available information we can only confirm that both products present a different dynamic range, which result in the observed spatial inconsistencies in some periods.

The following paragraphs summarize the main findings per sections:

Spatial Consistency

First the **spatial distribution** (maps, histograms) of the different products has been analyzed separately:

- **MSG** maps show a good spatial distribution and temporal dynamic as well as a good coverage. Histograms show consistent results per biomes. The temporal variation of the histograms is also quite reliable, showing large variations for Cultivated and Mosaic, and low variations for Shrubs or Herbaceous cover types. MSG products present the largest temporal variations as compared with MODIS or POLDER products. Large errors are found in Scandinavia, especially in wintertime. MSG vegetation products have thus low reliability in northern latitudes due to both the geometry of SEVIRI acquisitions at these locations as well as problems with snow not properly masked.

- **PARASOL** global products present an important fraction of invalid pixels. This is one important weakness of PARASOL products regarding MSG or MODIS. POLDER FVC and LAI maps display higher values, and lower temporal dynamic than MSG or MODIS. An abnormal peak appears systematically in all the histograms of the different biomes, for all periods and geographical areas. This peak (around 0.7 for FVC and 2.5 for LAI) seems to be an artifact introduced by the algorithm, and makes the spatial distribution of PARASOL products unreliable, at least for these values. Another observed effect is a saturated LAI values in some areas (6-7 for Broadleaved Forest in Europe), probably due to an over-estimation of the clumping index. In addition, PARASOL products present a very low temporal variation of the histograms. This seems to be clearly unrealistic, at least for biomes such us Cultivated and Mosaic. Hence, the PARASOL products are not of enough quality to be delivered to the Users Community.

- **MODIS** global products present a very low amount of invalid pixel, as well as the best spatial sampling of the three satellite products compared here. Furthermore, a wide set of MODIS/ Terra products are operative since 2000, and numerous validation exercises can be found in the literature. Therefore, MODIS products are very interesting for the global Users Community, and are obviously the best reference to validate Land-SAF vegetation products. MODIS products present similar spatial and temporal variability than MSG products in Europe. However, in South Africa or South America, MODIS histograms per biomes show less temporal variations than the MSG products. In fact, the MODIS products for these areas are very similar between them, which is strange in the studied growing season. Other characteristic of the MODIS products is the strong spatial changes in some areas, as a consequence of the biome dependent MODIS LAI algorithm (e.g., Equatorial African Forest).

Secondly, the **Inter-comparison** exercise was conducted at continental (error maps), biome (histograms) and pixel level (scatter-plots over BELMANIP sites). Statistical error indicators (RMS, bias, r) were computed for the different levels.

Difference maps show the most important inconsistencies between products, although these differences are also very dependent of the considered period. Concerning the MSG and PARASOL products, they are spatially very inconsistent, with large areas with differences up to –0.3 (over-estimation of the PARASOL product) for FVC and up to -3 for LAI. These inconsistencies can be readily observed over Europe or South Africa. In South Africa, the whole area present very high differences (either positive or negative). This can be also observed by biomes looking the histograms of the bias, which spans over a large range of difference values. In relative terms, large areas present differences up to 100% or beyond. The general conclusion is that MSG and PARASOL are 'spatially' non-consistent products. The same happens between PARASOL and MODIS LAI, where differences are still higher (see Annex VI). The analysis per biomes shows the highest differences in the Cultivated and Mosaic, and Broadleaved Forest, where POLDER over-estimates systematically the MSG products. In Europe, the Needle-leaved Forest shows the worst correlation between the products. The MSG results for this biome are less reliable due to this biome is located at northern latitudes, where MSG present large errors. However, the correlation between POLDER and MODIS for this biome is also very low. Similarly, the correlation for the Evergreen Broadleaved Forest is also very low, which show the difficulty of retrieving LAI of highly clumped forests.

Concerning MSG and MODIS LAI the results are more much better. The spatial consistency is quite good in Europe with low relative errors (typically<50%) in lager areas. However, in North Africa, South Africa and South America, MSG and MODIS presents important inconsistencies for some dates. The differences happen in large areas, covering the Sahel region, and more towards south the Broadleaved Evergreen Forest (over-estimation of MODIS regarding MSG), and Broadleaved Deciduous Forest (over-estimation of MSG regarding MODIS). These differences are quite important, with positive or negative bias up to 3, and relative errors around 100% in these areas for some dates. However, these differences are very dependent of the considered period.

Temporal Consistency

As said before, on a continental scale, the spatial distribution of LAI values shown by MSG and MODIS products presents important variations for some dates, whereas is quite consistent for other dates. Therefore, the spatial consistency between both products depends highly of the date. Conversely, the temporal consistency of the products is dependent of the region. The MSG products present a higher temporal dynamic than MODIS products in all the classes. This point deserves to be investigated deeper, in order to know which product is reproducing better nature.

At a pixel level, the study over selected sites of Europe and Southern Africa (Botswana, South Africa) shows a very good temporal consistency between MODIS and MSG. The error maps show that MSG and MODIS present a very good spatial consistency in these areas.

The MSG temporal profiles are smooth and capture the phenology shown by ECOCLIMAP. The temporal profiles show that MSG products are not reliable for northern latitudes, where large errors and unreliable values due the presence of snow (not properly masked) are found.

PARASOL product presents the noisier temporal profiles, with sudden changes associated with the estimation of the clumping index.

Comments on the methodology

This work demonstrates the complexity of the validation process at global scale, where many variables are playing a role at the same time. The differences found between the analyzed products depend highly on the spatial domain, and conversely the spatial inconsistencies are highly dependent of the considered period (eg. MODIS and MSG). The statistical error indicators are computed as an average over large areas, and thus could not reflect properly the high spatial discrepancies found between products in some regions. Also the validation on a pixel level could lead to more positive conclusions, as can be derived here from the scatter-plots and temporal profiles plots. In addition, direct validation, although necessary, is very limited in space and time.

The difference maps between products have provided the more interesting insights in order to identify inconsistencies between the products. The histograms of retrieved values per biomes have allowed us to infer interesting conclusions over the products and its temporal dynamic based on the expected results per biomes. In addition, the temporal evolution of statistical indicators (RMS, bias) has also allowed identify trends per biomes. Finally, temporal profiles and ancillary (ECOCLIMAP) data have been a very useful source of information to evaluate the quality of the products, although this evaluation is very dependent of the selected sites.

ACKNOWLEDGEMENTS

This work has been funded by the Visiting Scientist Program of EUMETSAT. I would like to thank to Marc Leroy, the POSTEL team and Médias-France for their support during this stage. To Jean-Louis Roujean and Bernhard Geiger for many discussions, and to Météo-France for hosting me this period. To Javier García-Haro for its valuable work deriving LandSAF vegetation products and to Beatriz Martinez for deriving the high-resolution LAI map of Barrax. Finally, to Frédéric Baret for providing the report on the validation of PARASOL land products in advance. ECOCLIMAP data was provided by Météo-France. PARASOL data was provided by Médias-Frances. MODIS/Terra data was downloaded from the Boston University ftp site. MSG products are from Land-SAF EUMETSAT.

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ANNEX I

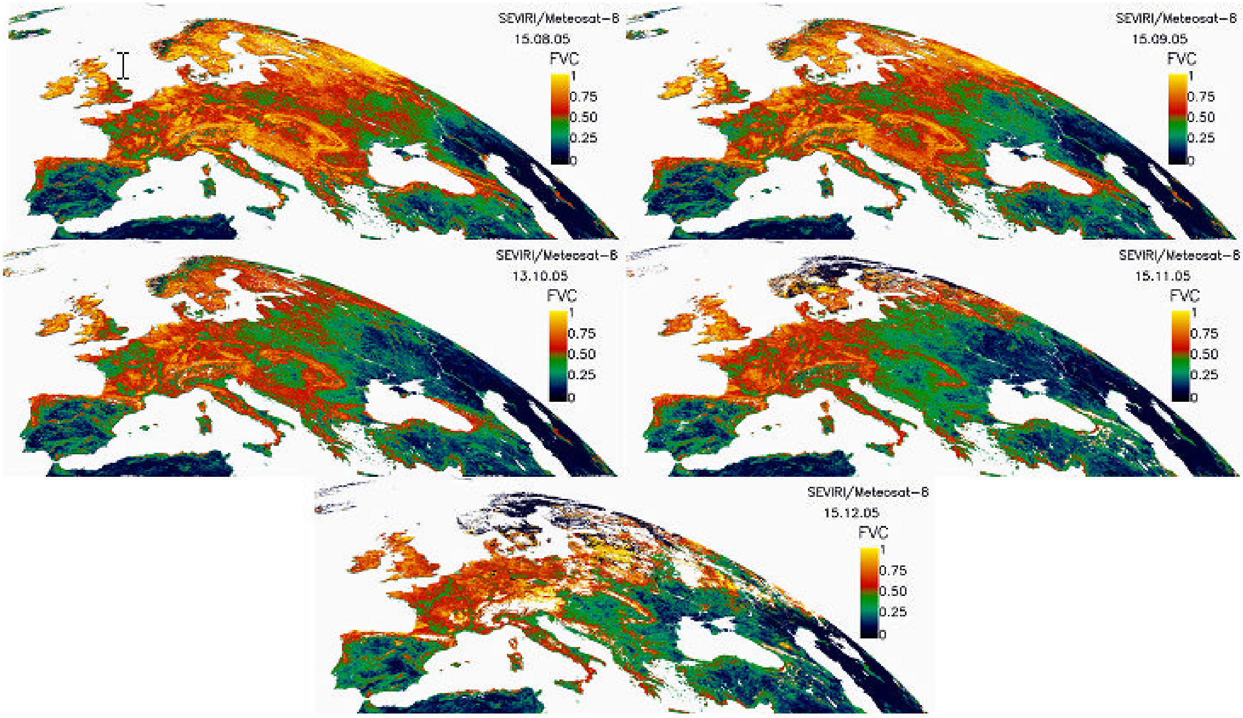
SEVIRI/MSG

FVC & LAI V1.2 MAPS

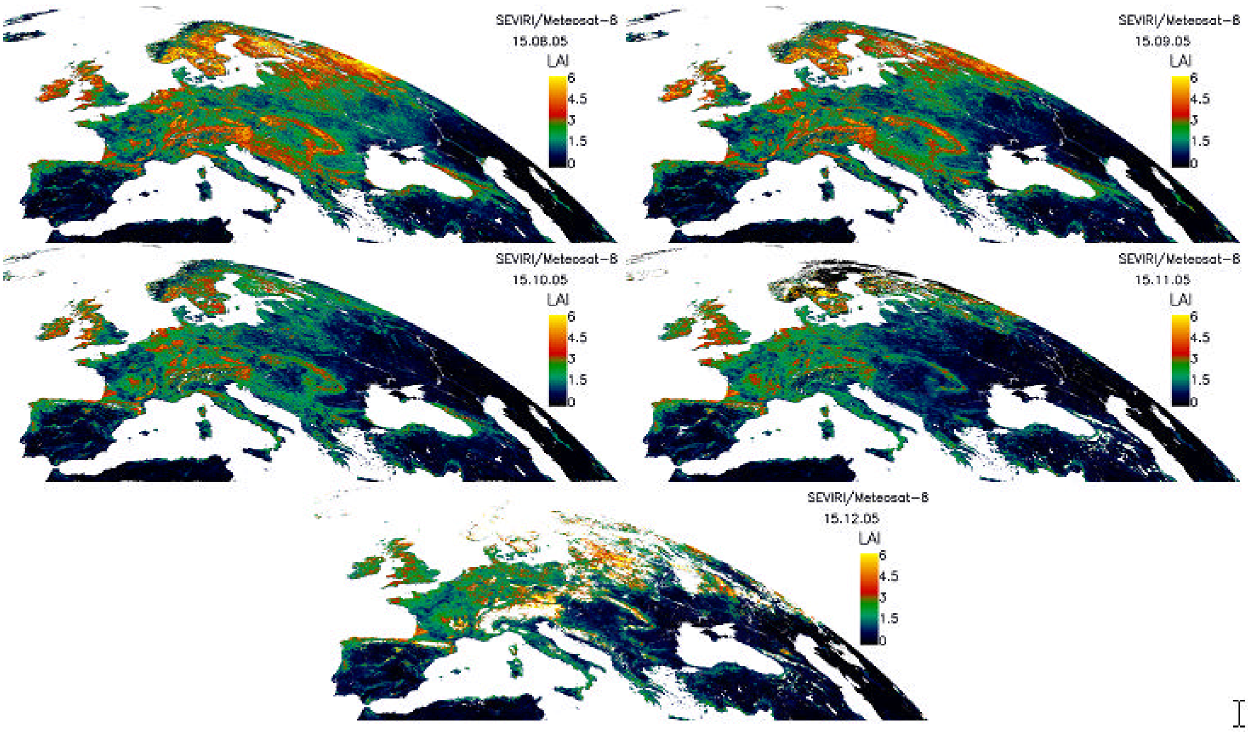
Period: August- December 2005

ZONE EURO

- FVC -

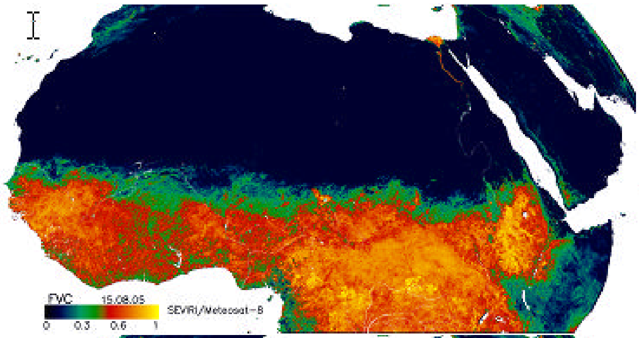


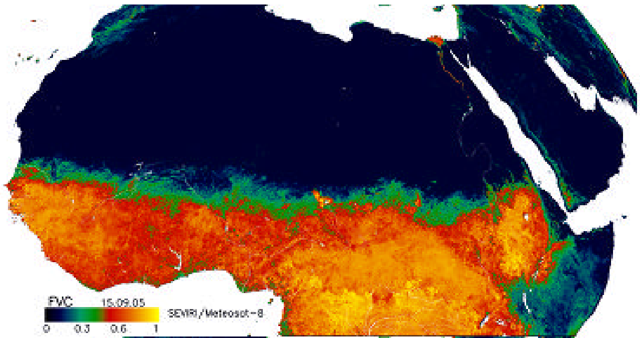
- LAI -

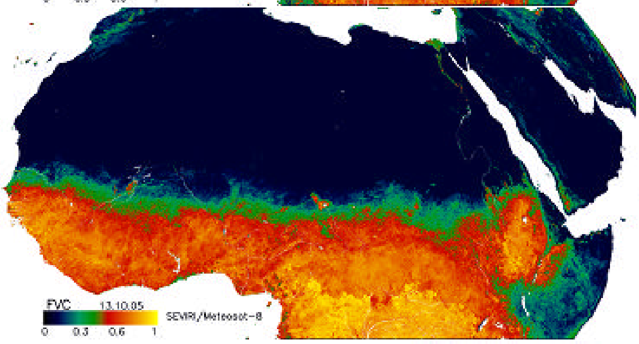


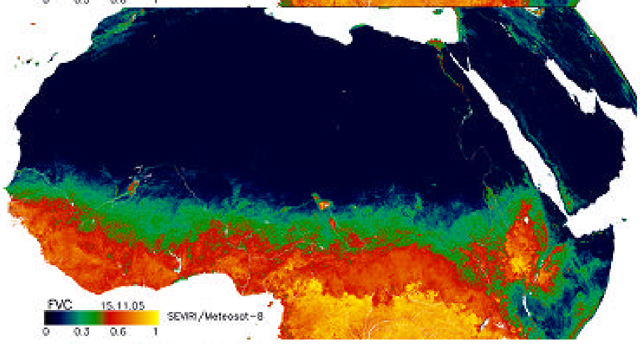
ZONE NORTH AFRICA

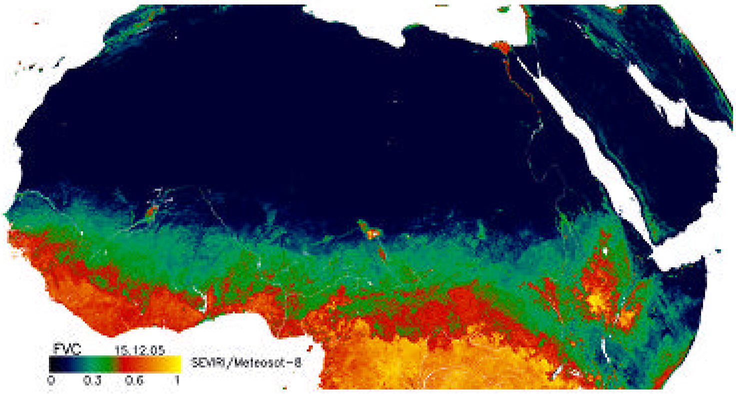
- FVC -



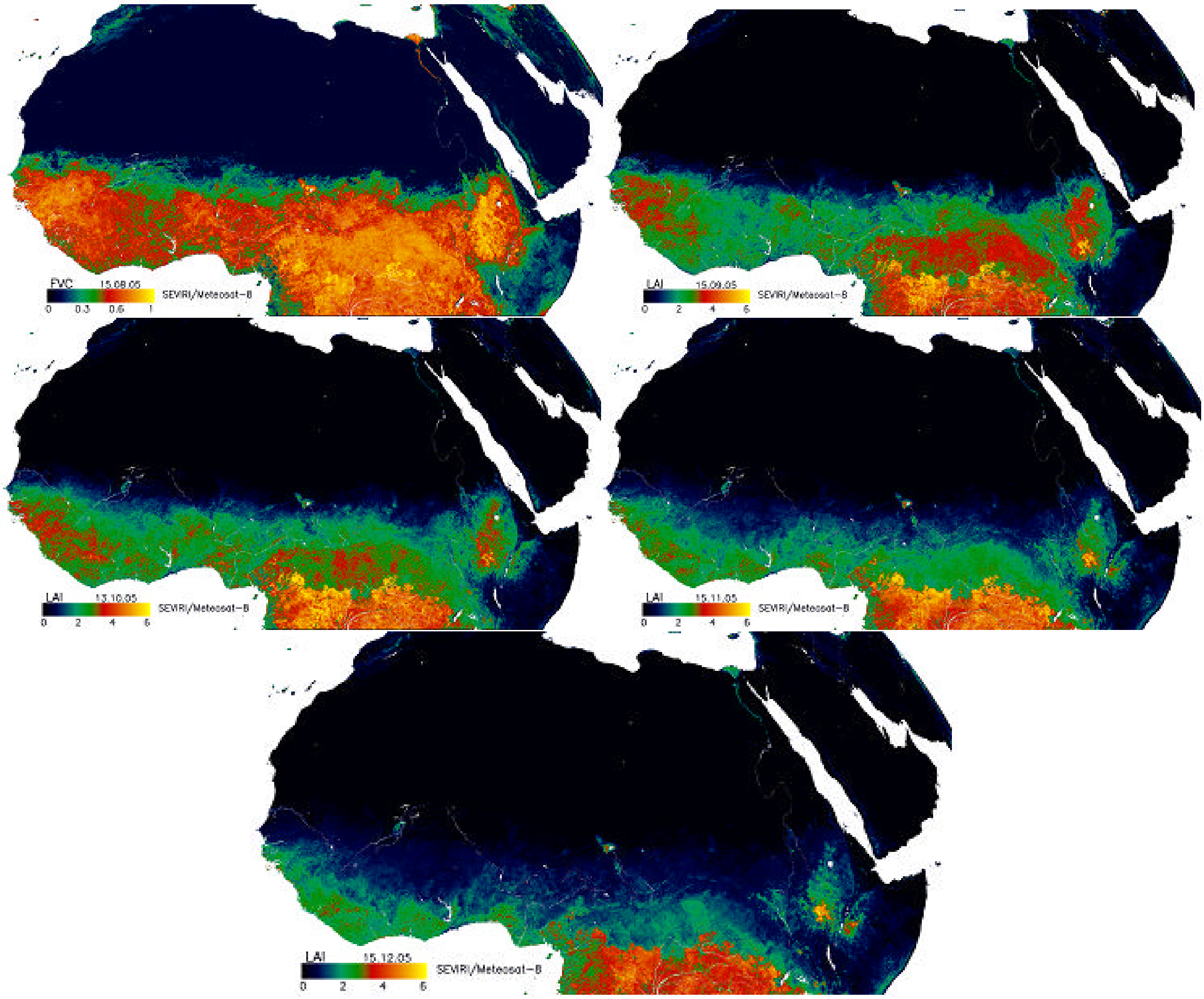








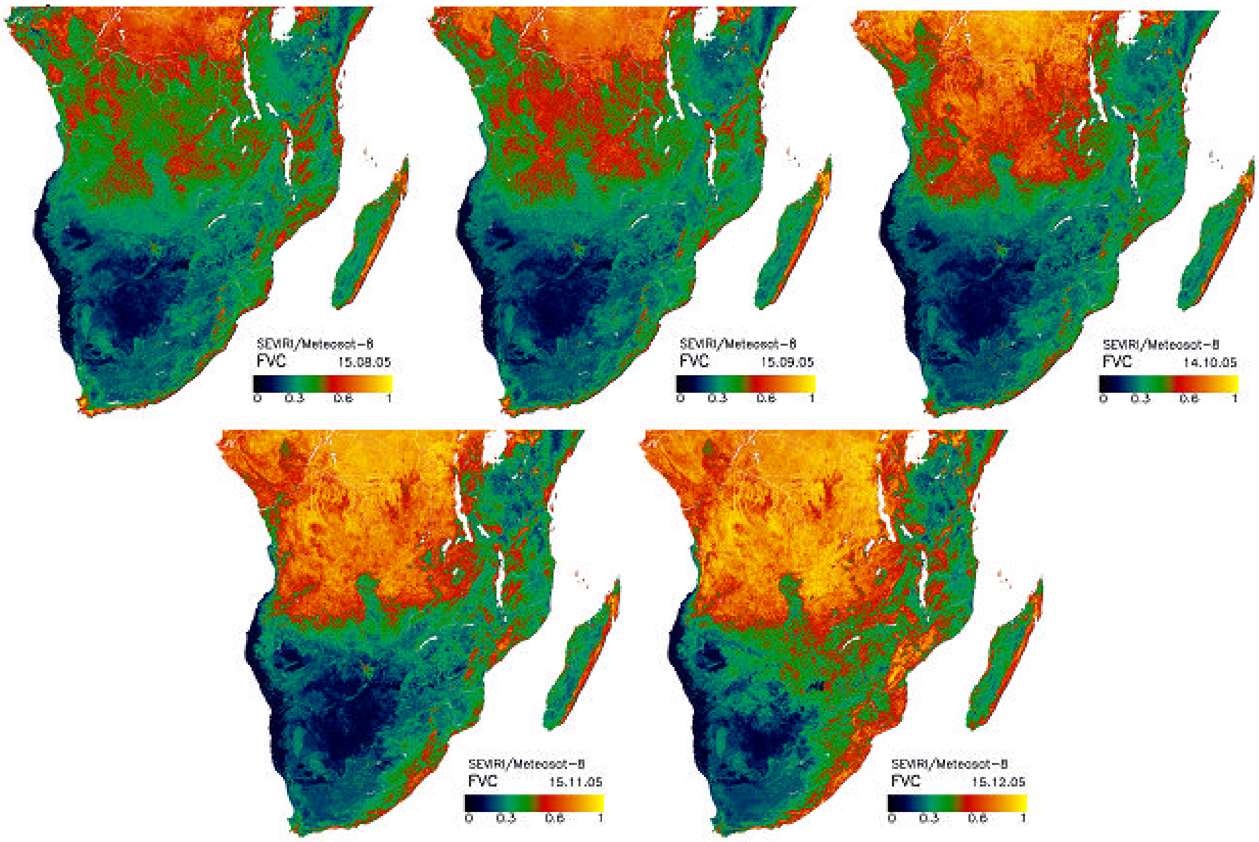
- LAI -



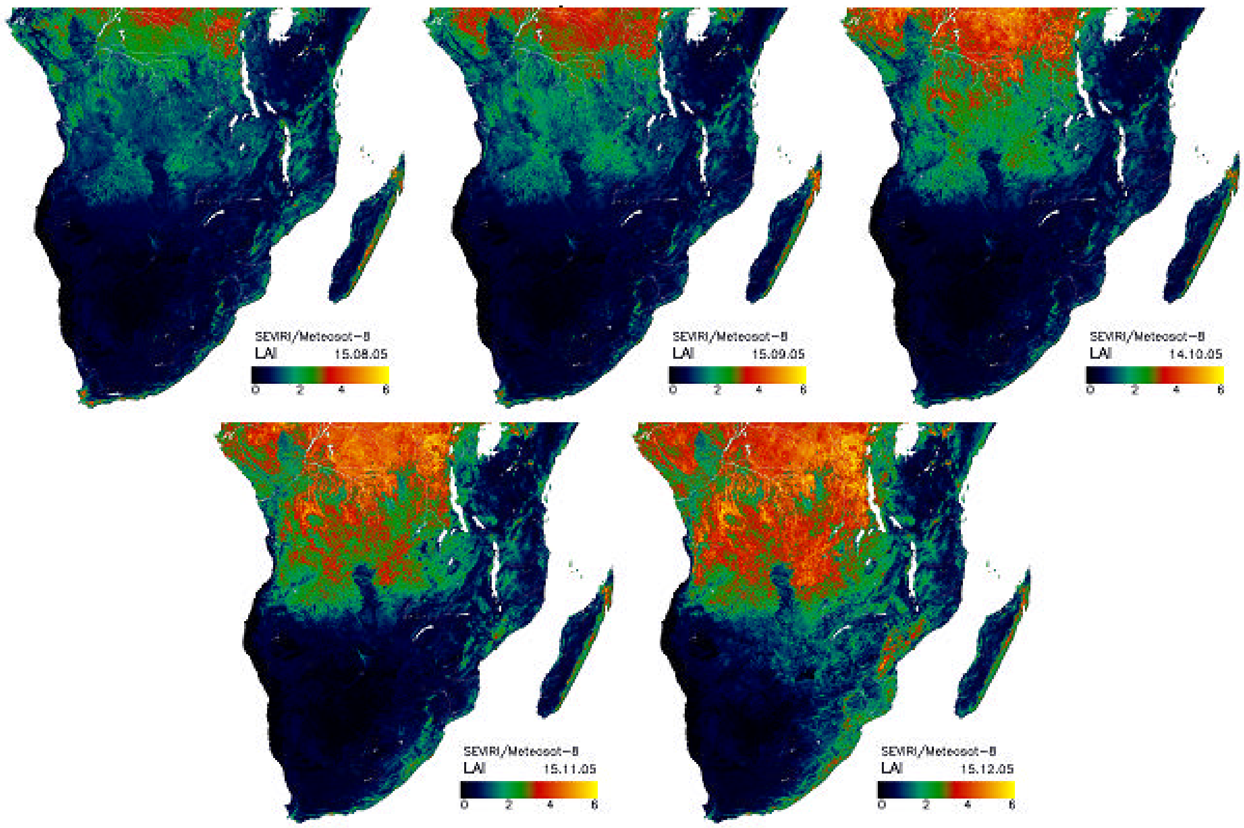
FVC
15.08.05
SEVIRI/Meteosat-8
0 0.3 0.6 1
LAI
15.09.05
SEVIRI/Meteosat-8
0 2 4 6
LAI
13.10.05
SEVIRI/Meteosat-8
0 2 4 6
LAI
15.11.05
SEVIRI/Meteosat-8
0 2 4 6
LAI
15.12.05
SEVIRI/Meteosat-8
0 2 4 6

ZONE SOUTH AFRICA

- FVC -

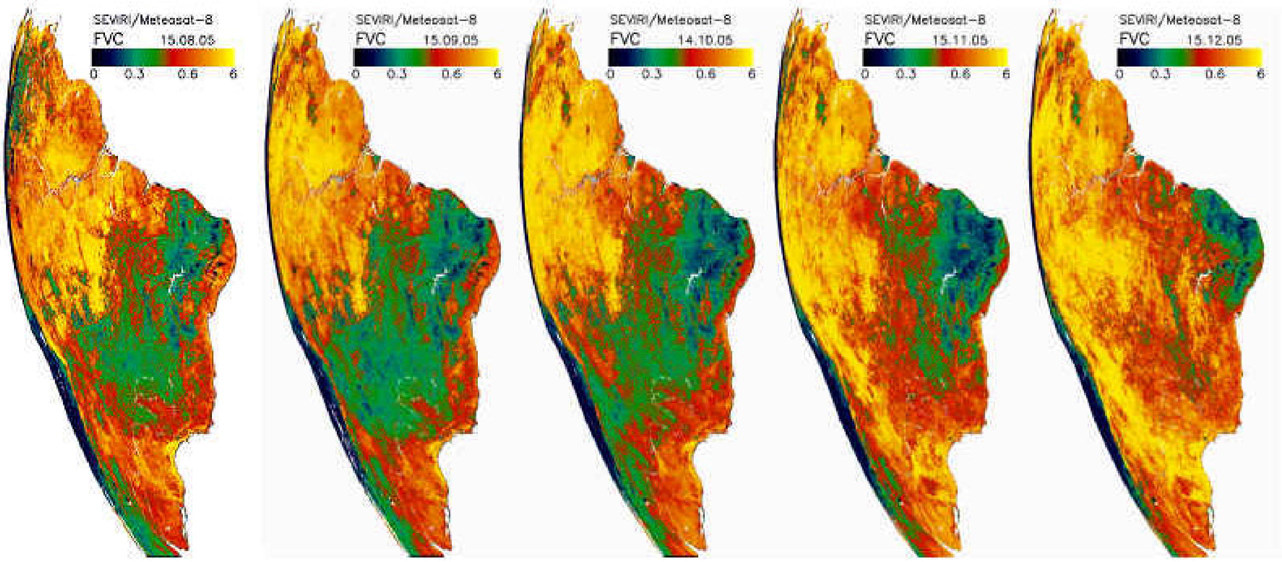


- LAI -

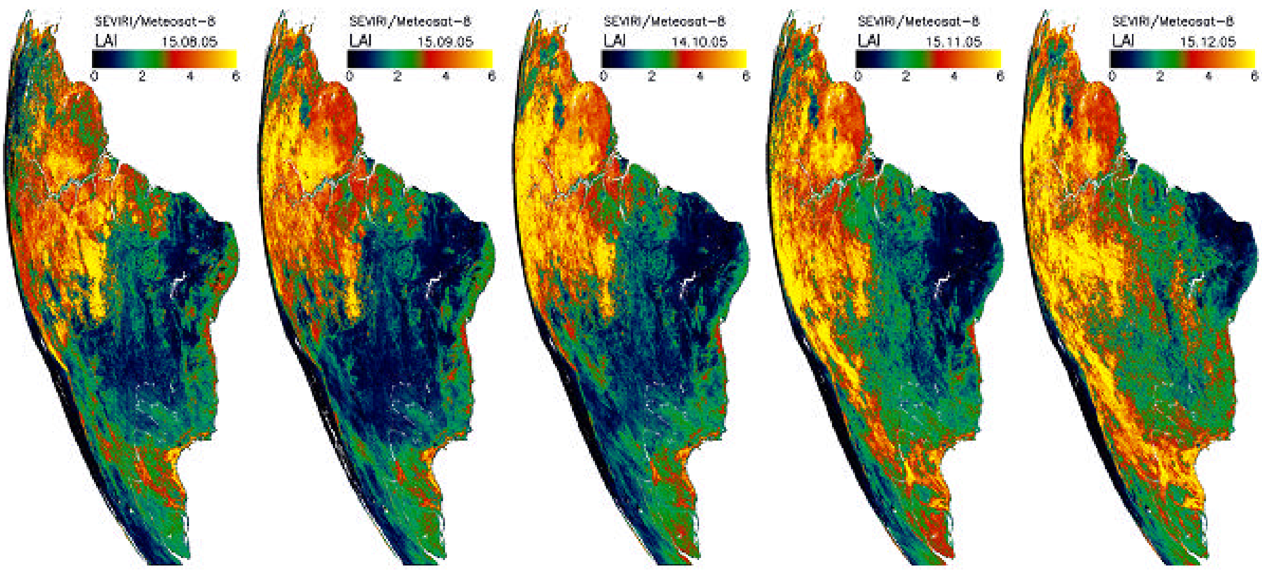


ZONE SOUTH AMERICA

- FVC -



- LAI -



ANNEX II

POLDER3/PARASOL

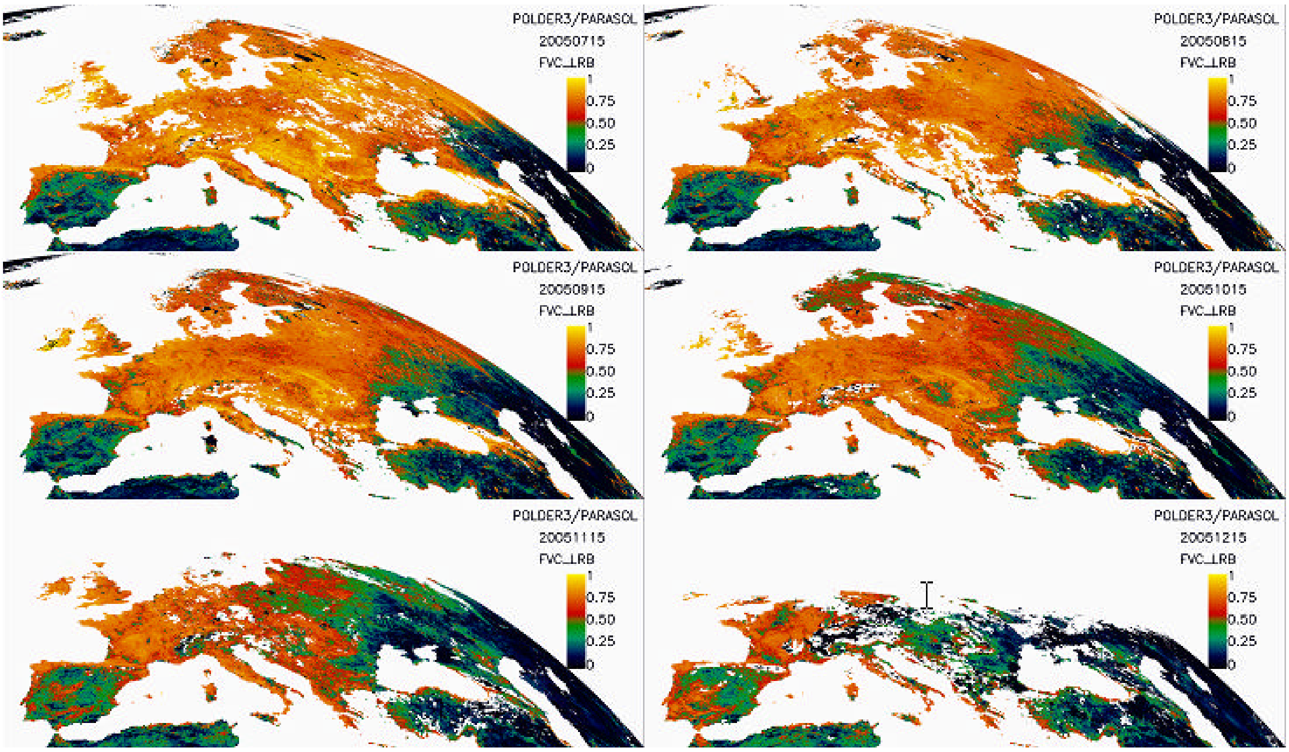
FVC & LAI LRB MAPS

(SEVIRI projection)

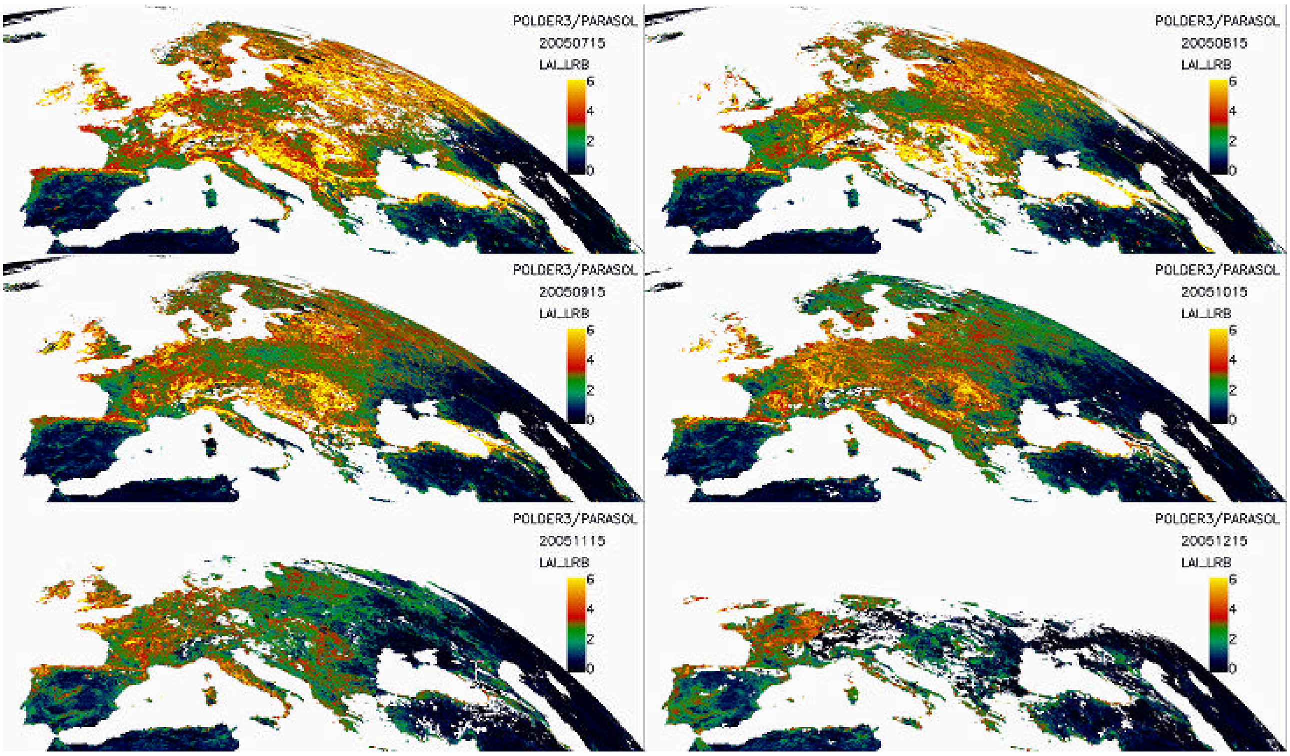
Period: July- December 2005

ZONE EURO

- FVC -

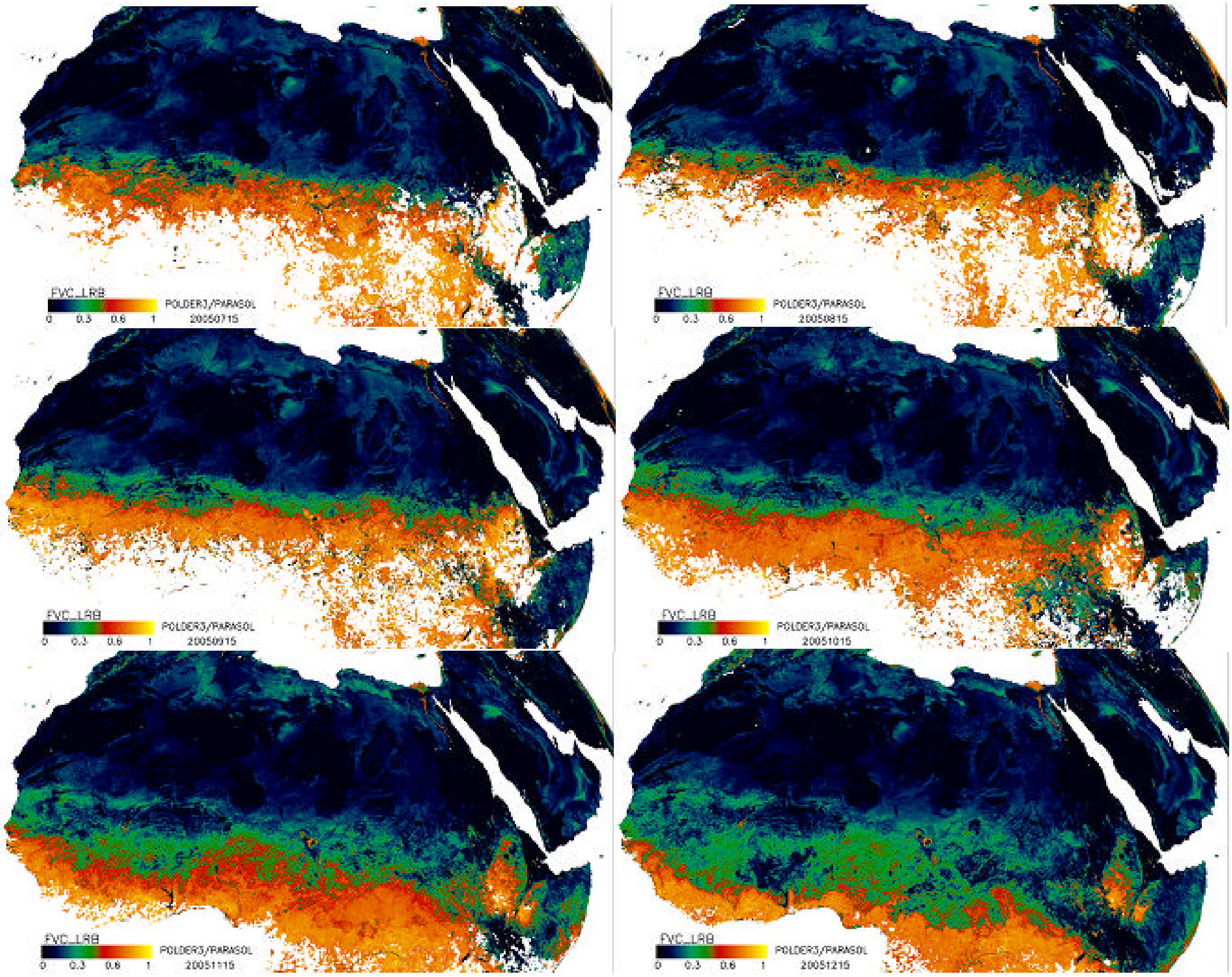


- LAI -

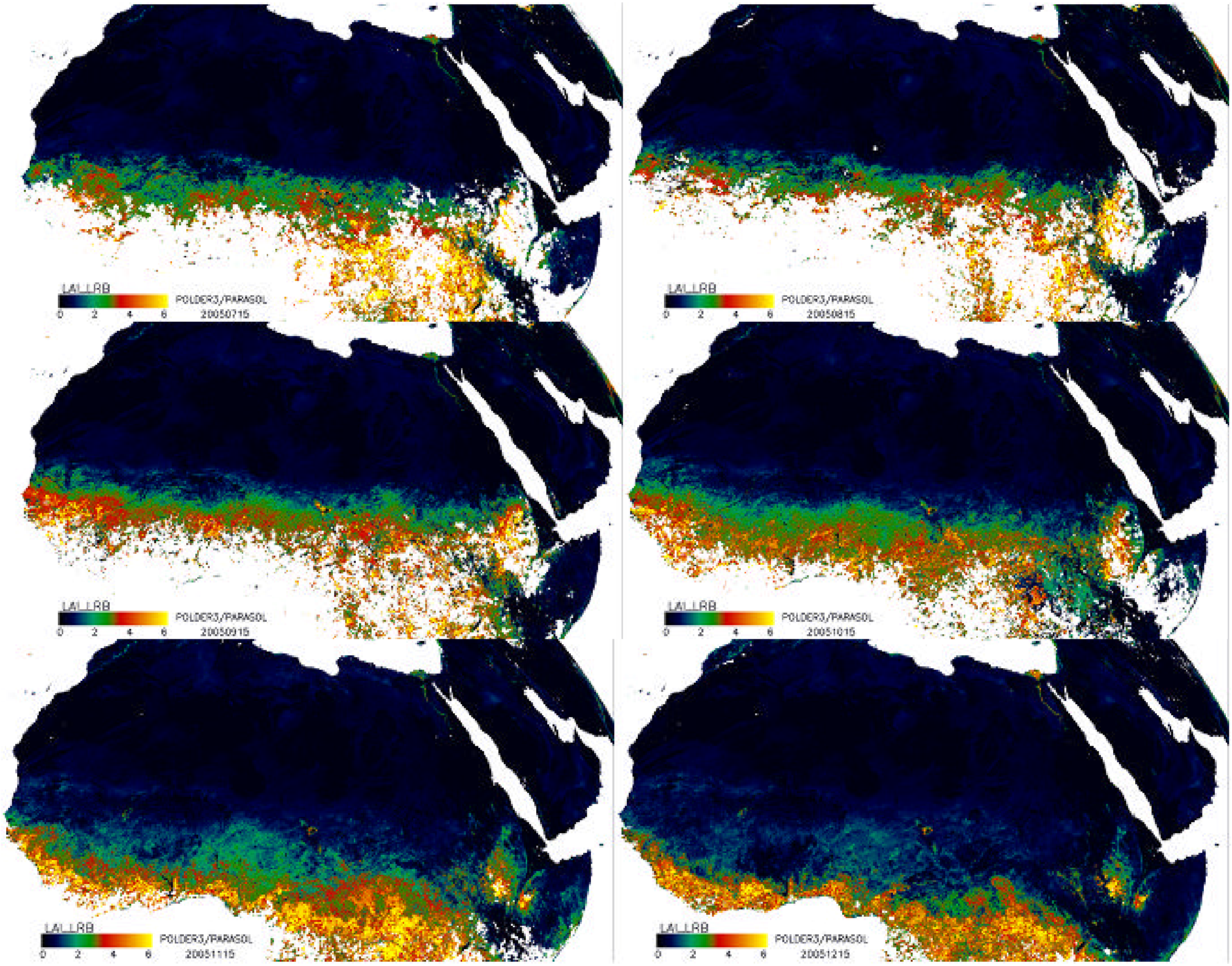


ZONE NORTH AFRICA

- FVC -



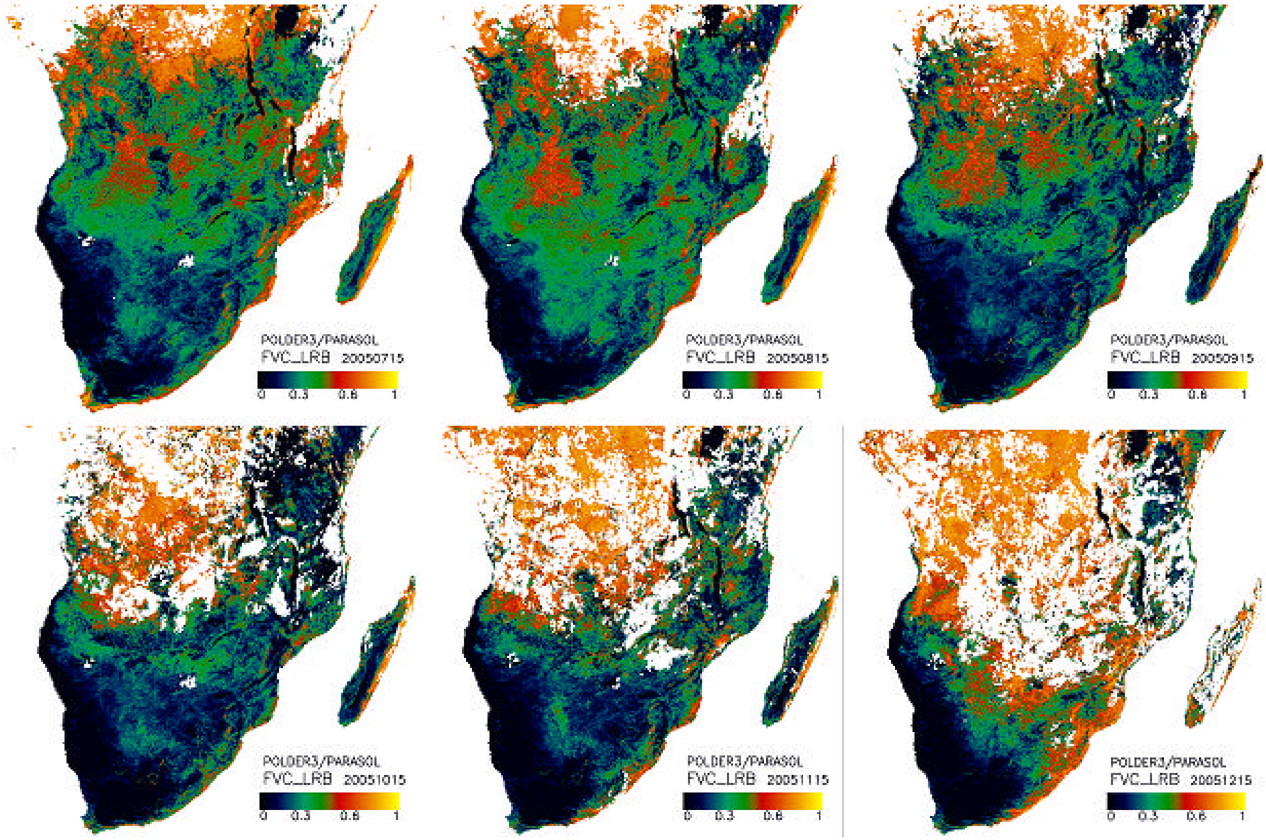
- LAI -



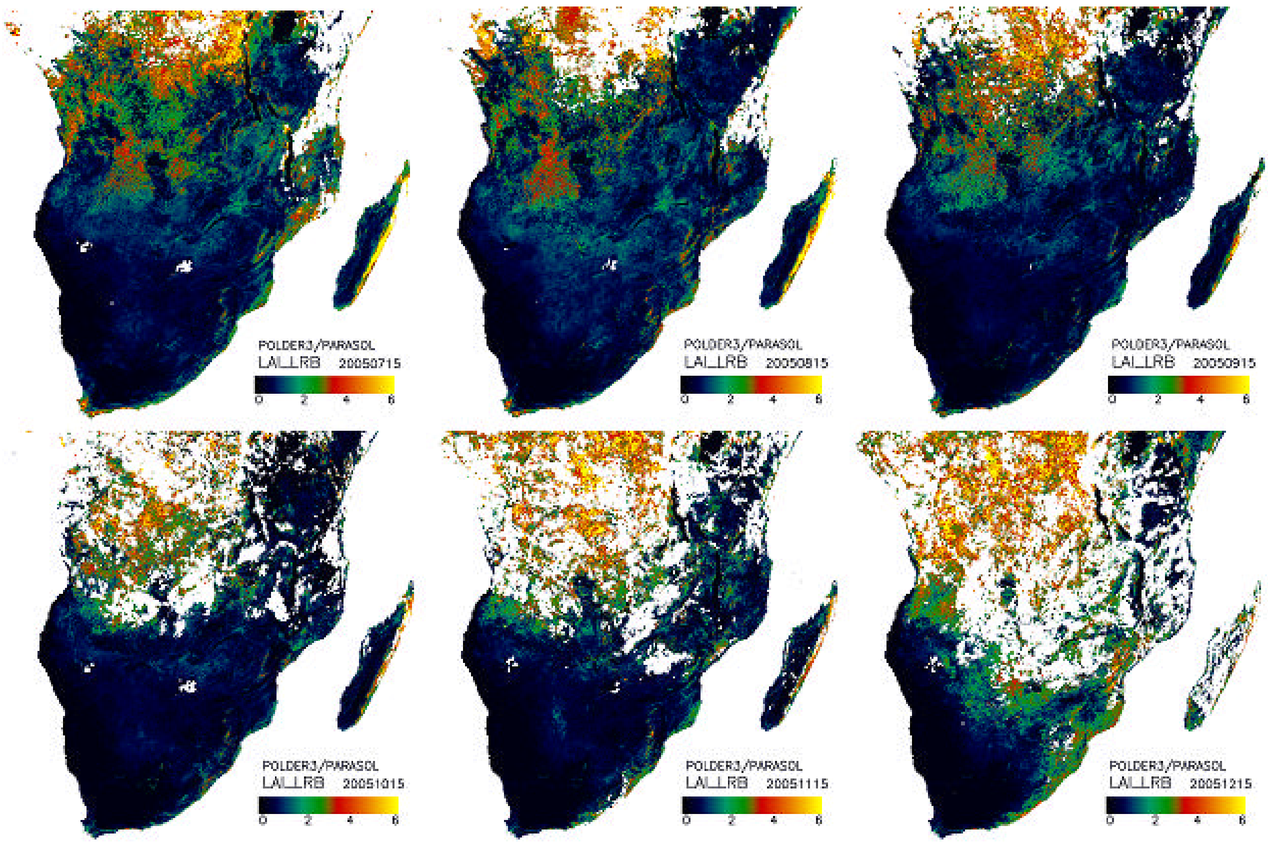
LAI_LRB
0 2 4 6
POLDER3/PARASOL
20050715
LAI_LRB
0 2 4 6
POLDER3/PARASOL
20050815
LAI_LRB
0 2 4 6
POLDER3/PARASOL
20050915
LAI_LRB
0 2 4 6
POLDER3/PARASOL
20051015
LAI_LRB
0 2 4 6
POLDER3/PARASOL
20051115
LAI_LRB
0 2 4 6
POLDER3/PARASOL
20051215

ZONE SOUTH AFRICA

- FVC -

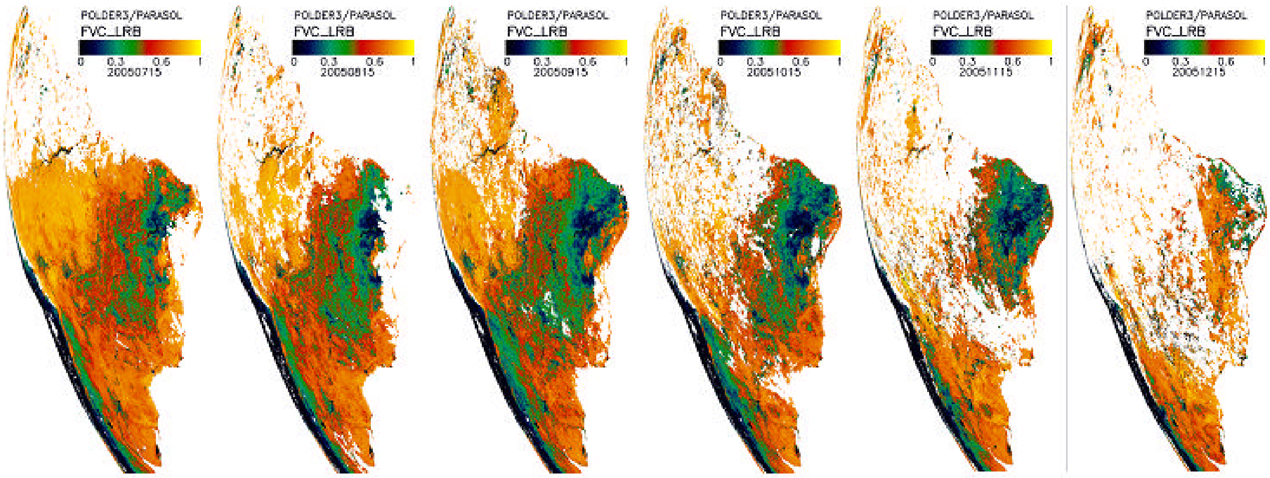


- LAI-

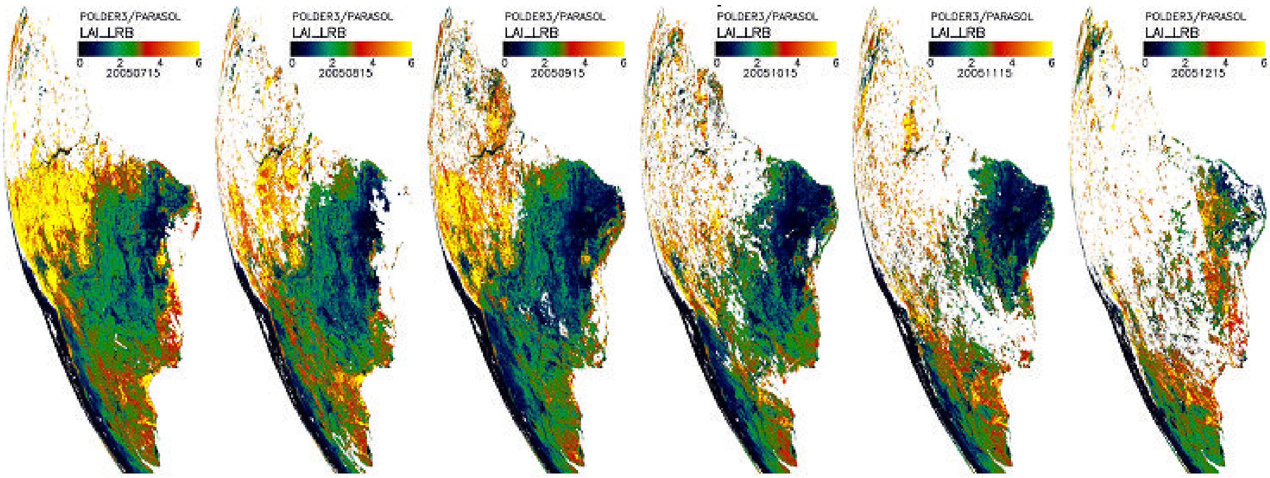


ZONE SOUTH AMERICA

- FVC -



- LAI -



ANNEX III

MODIS/TERRA

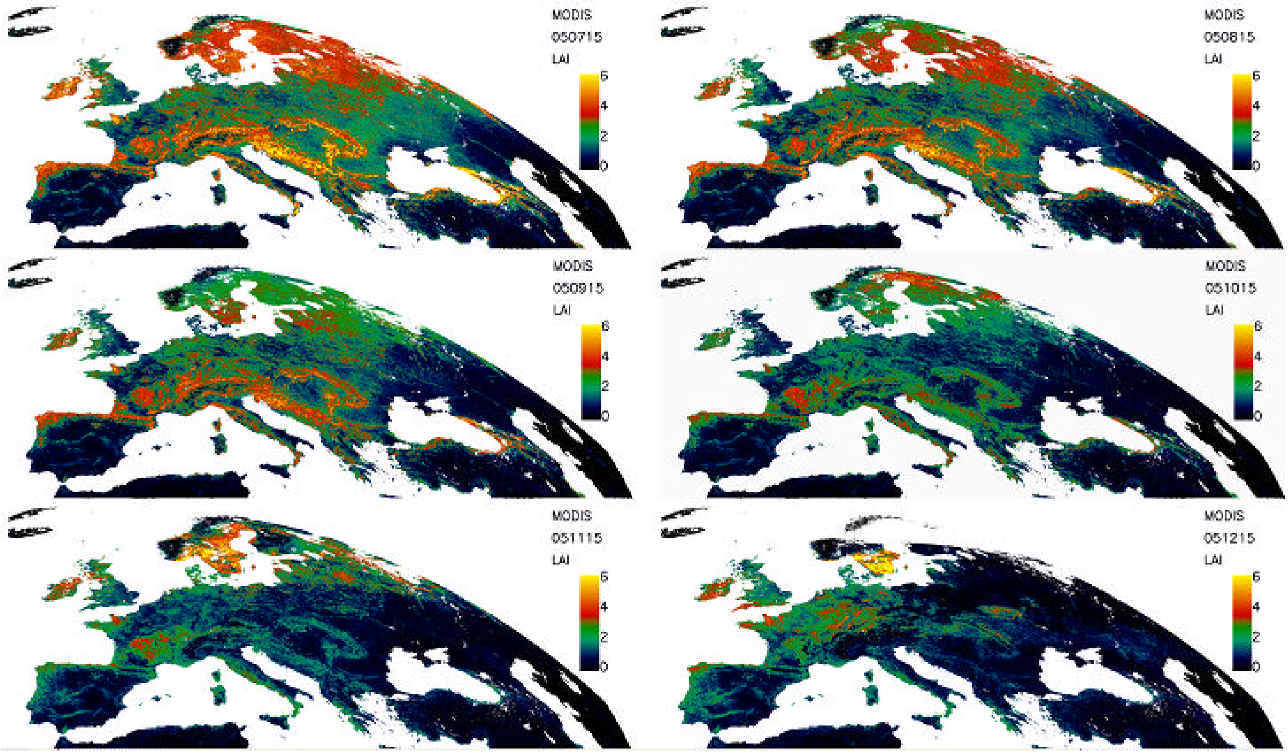
LAI C4.1 MAPS

(SEVIRI projection)

Period: July- December 2005

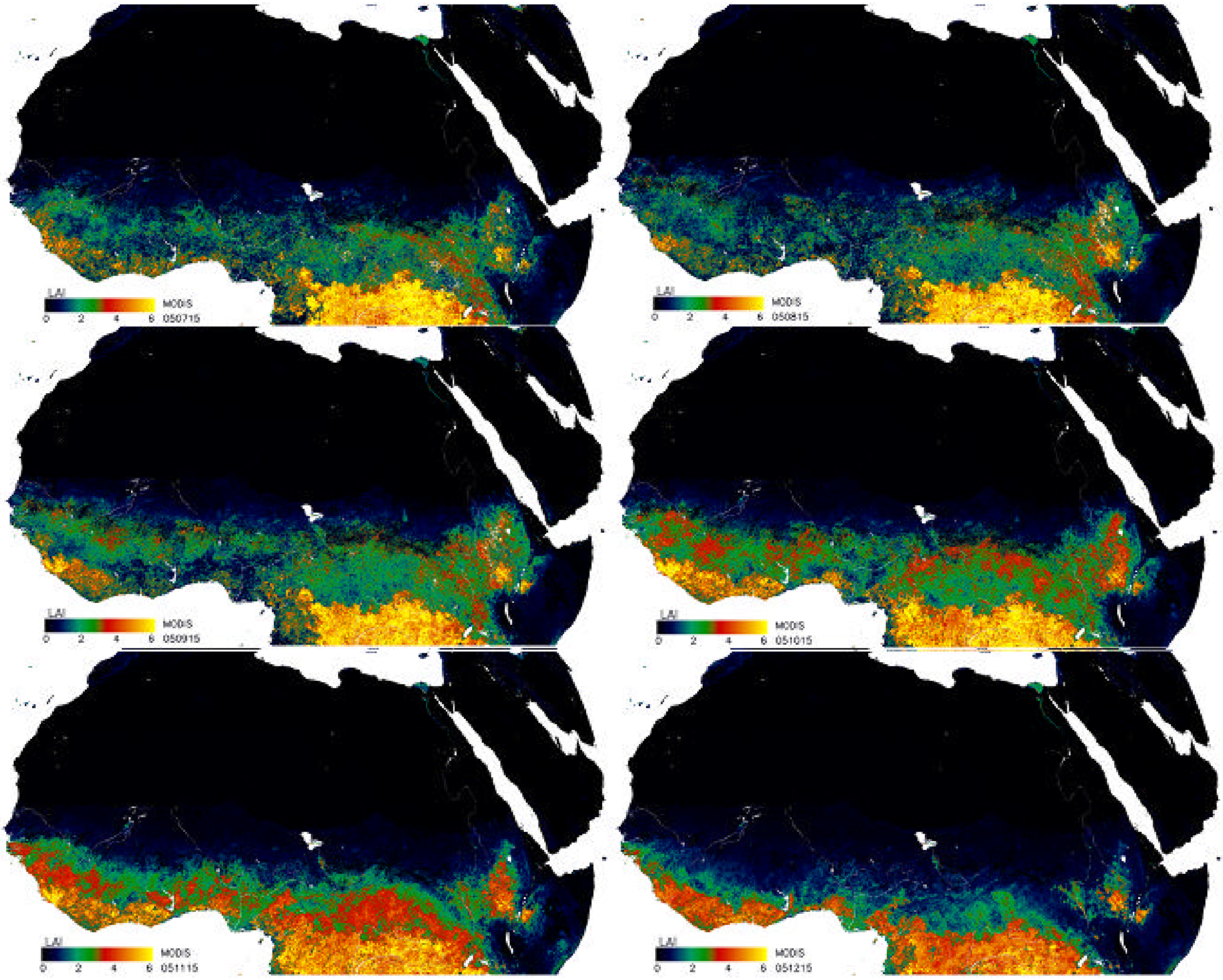
ZONE EURO

- LAI -



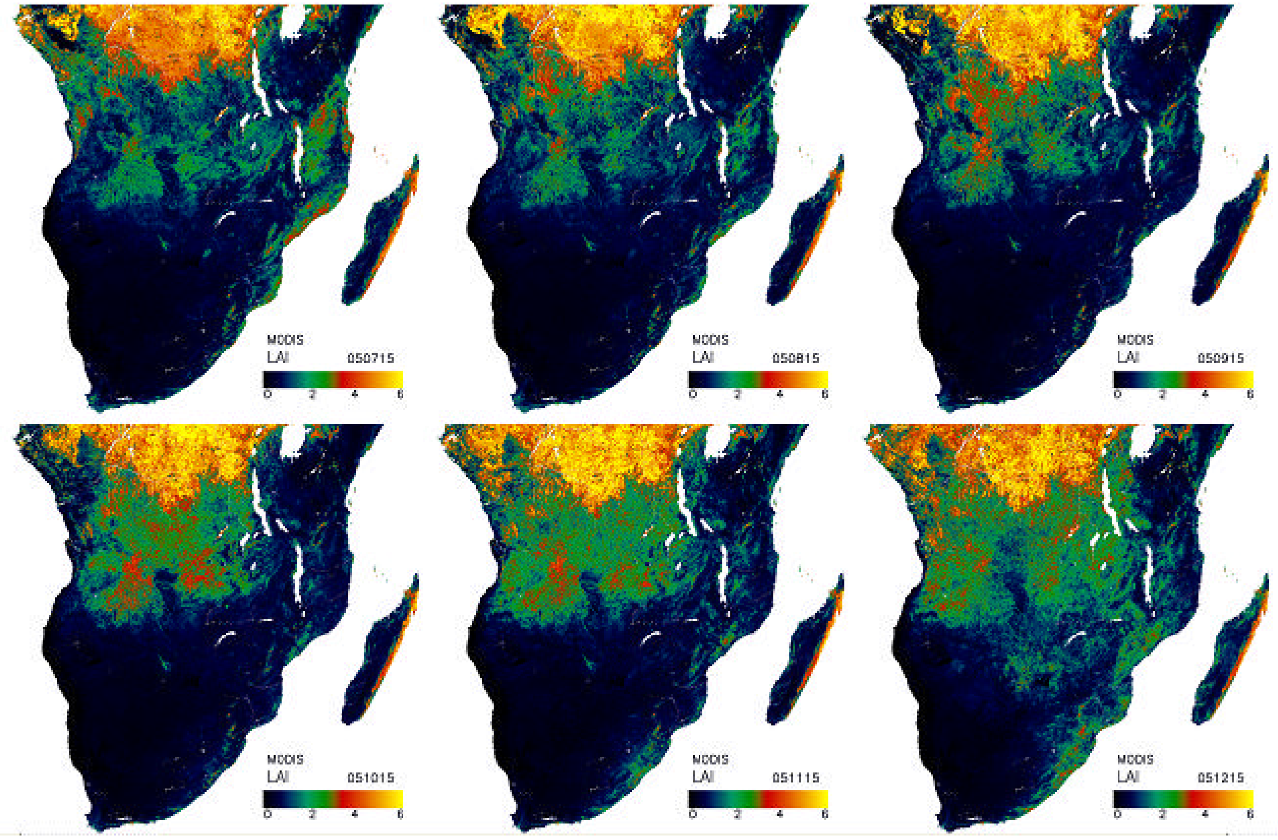
ZONE NORTH AFRICA

- LAI -



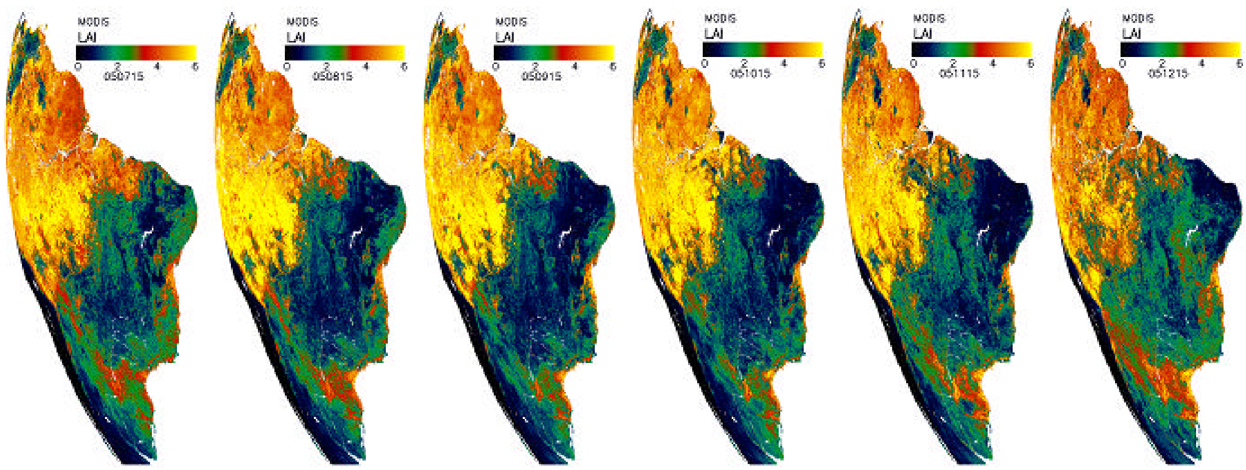
ZONE SOUTH AFRICA

- LAI -



ZONE SOUTH AMERICA

- LAI -



ANNEX IV

MSG-PARASOL

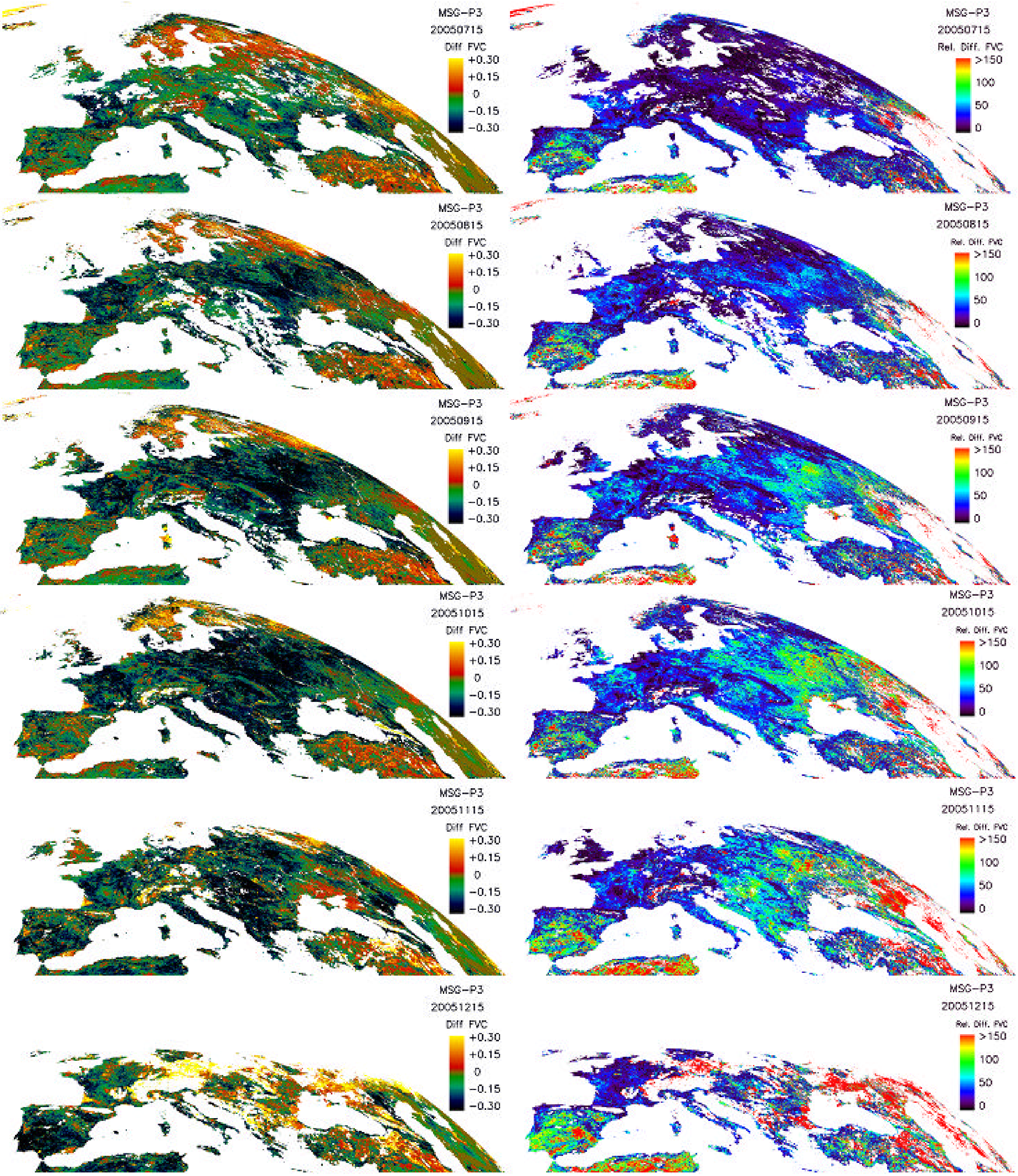
DIFFERENCE MAPS

Period: August- December 2005

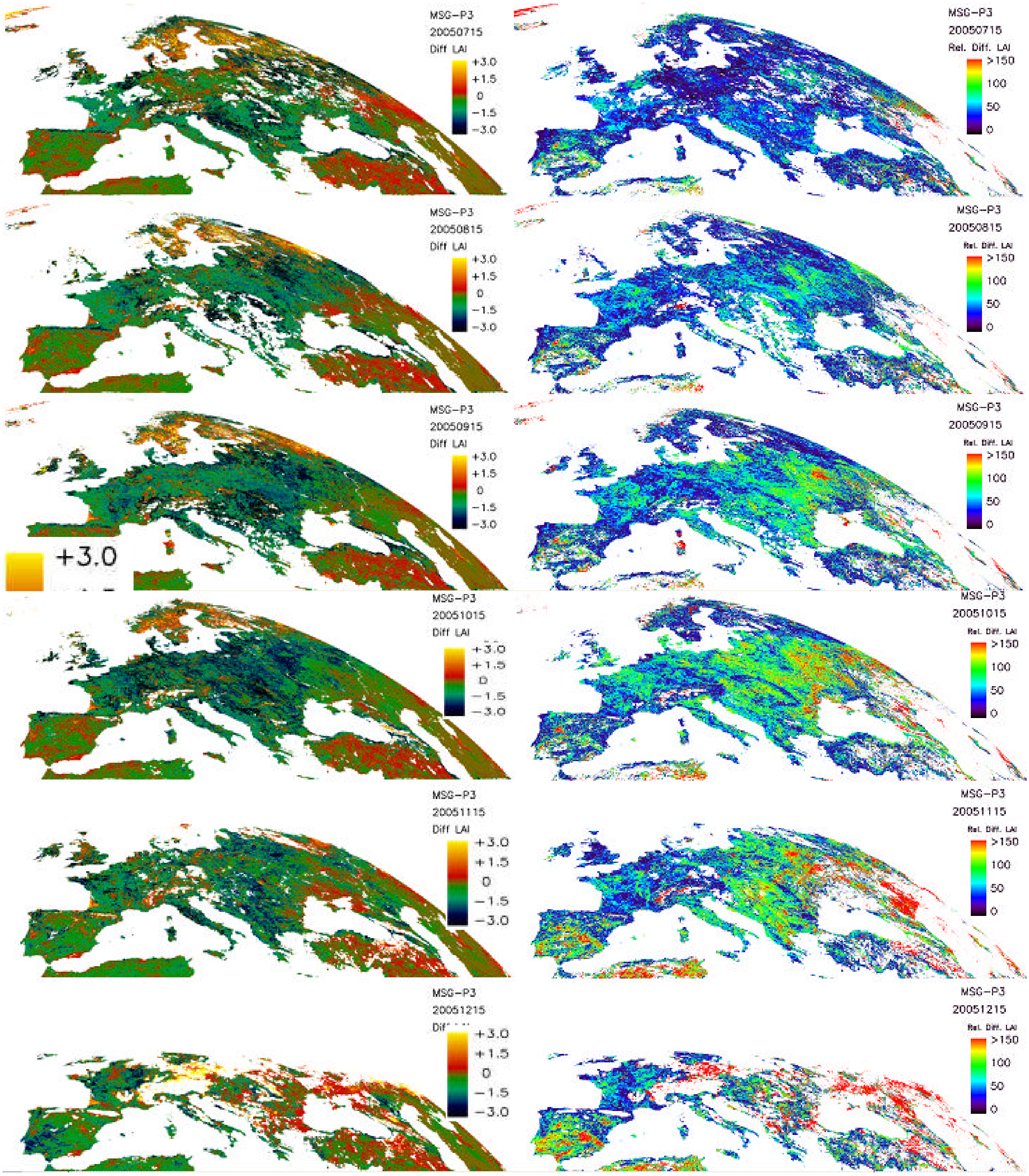
Note: Relative errors were not computed where mean FVC<0.15 or mean LAI<0.5

ZONE EURO

- FVC -



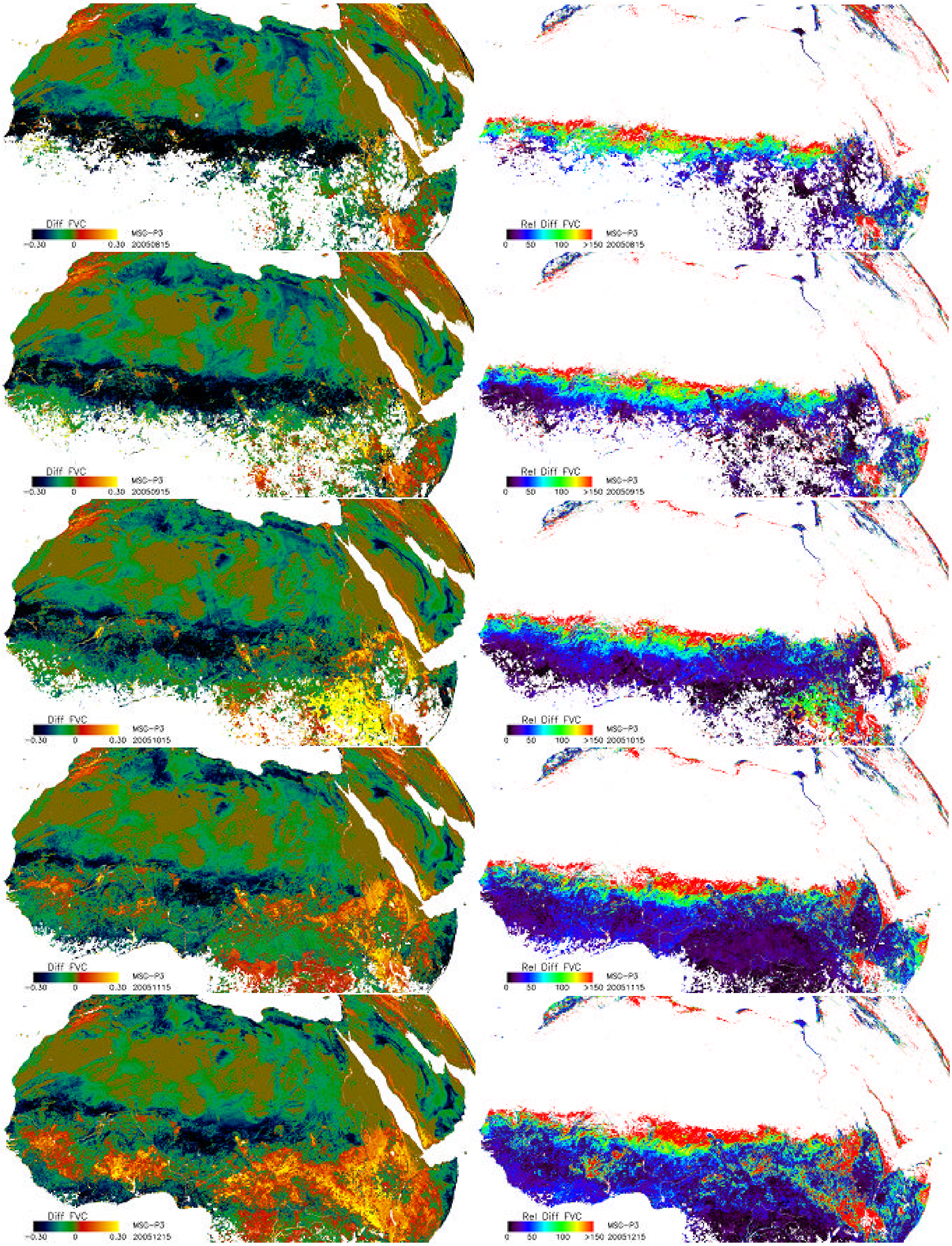
- LAI -



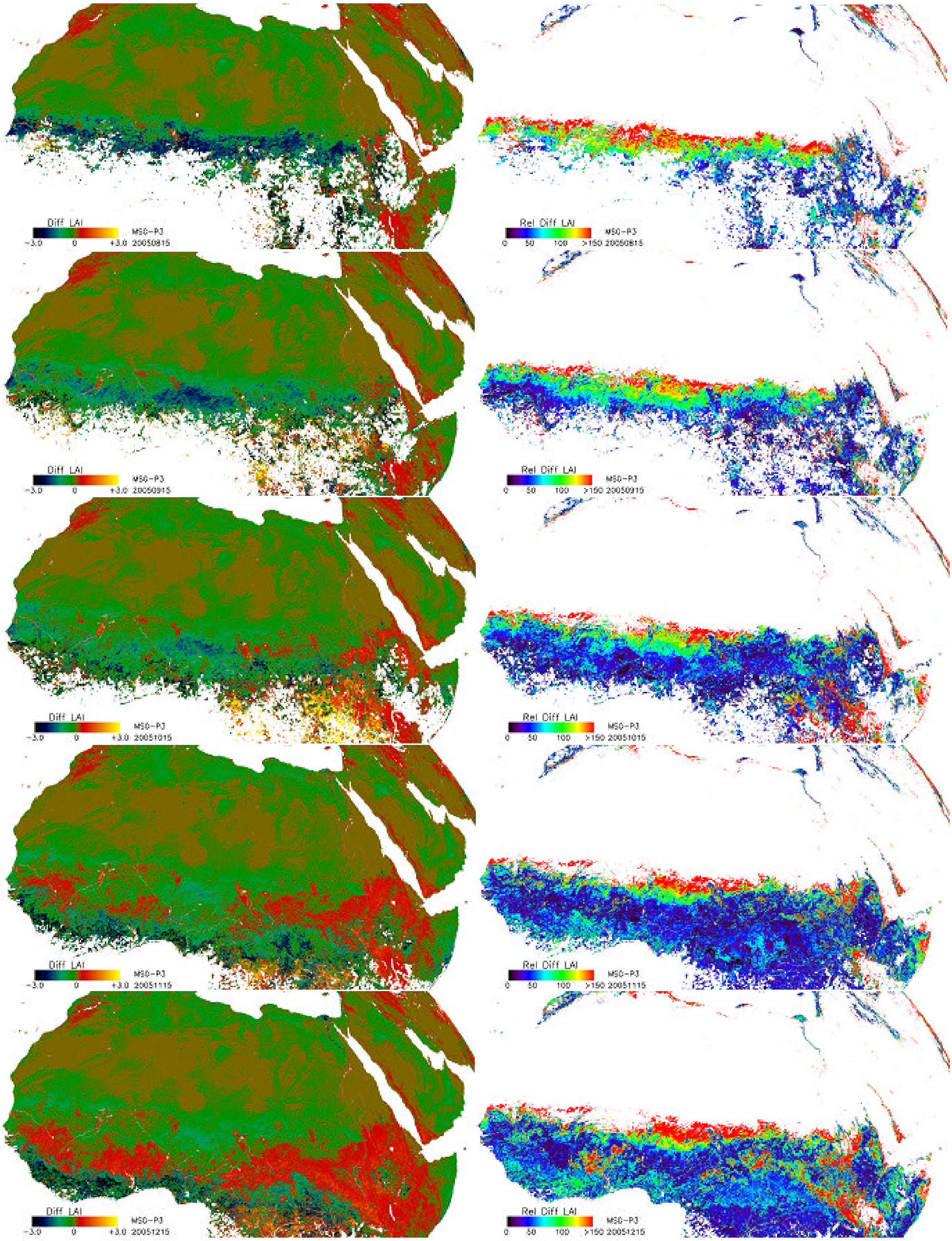
MSG–P3
20050715
Diff LAI
+3.0
+1.5
0
–1.5
–3.0
MSG–P3
20050715
Rel. Diff. LAI
>150
100
50
0
MSG–P3
20050815
Diff LAI
MSG–P3
20050815
Rel. Diff. LAI
MSG–P3
20050915
Diff LAI
MSG–P3
20050915
Rel. Diff. LAI
MSG–P3
20051015
Diff LAI
MSG–P3
20051015
Rel. Diff. LAI
MSG–P3
20051115
Diff LAI
MSG–P3
20051115
Rel. Diff. LAI
MSG–P3
20051215
MSG–P3
20051215
Rel. Diff. LAI

ZONE NORTH AFRICA

- FVC -



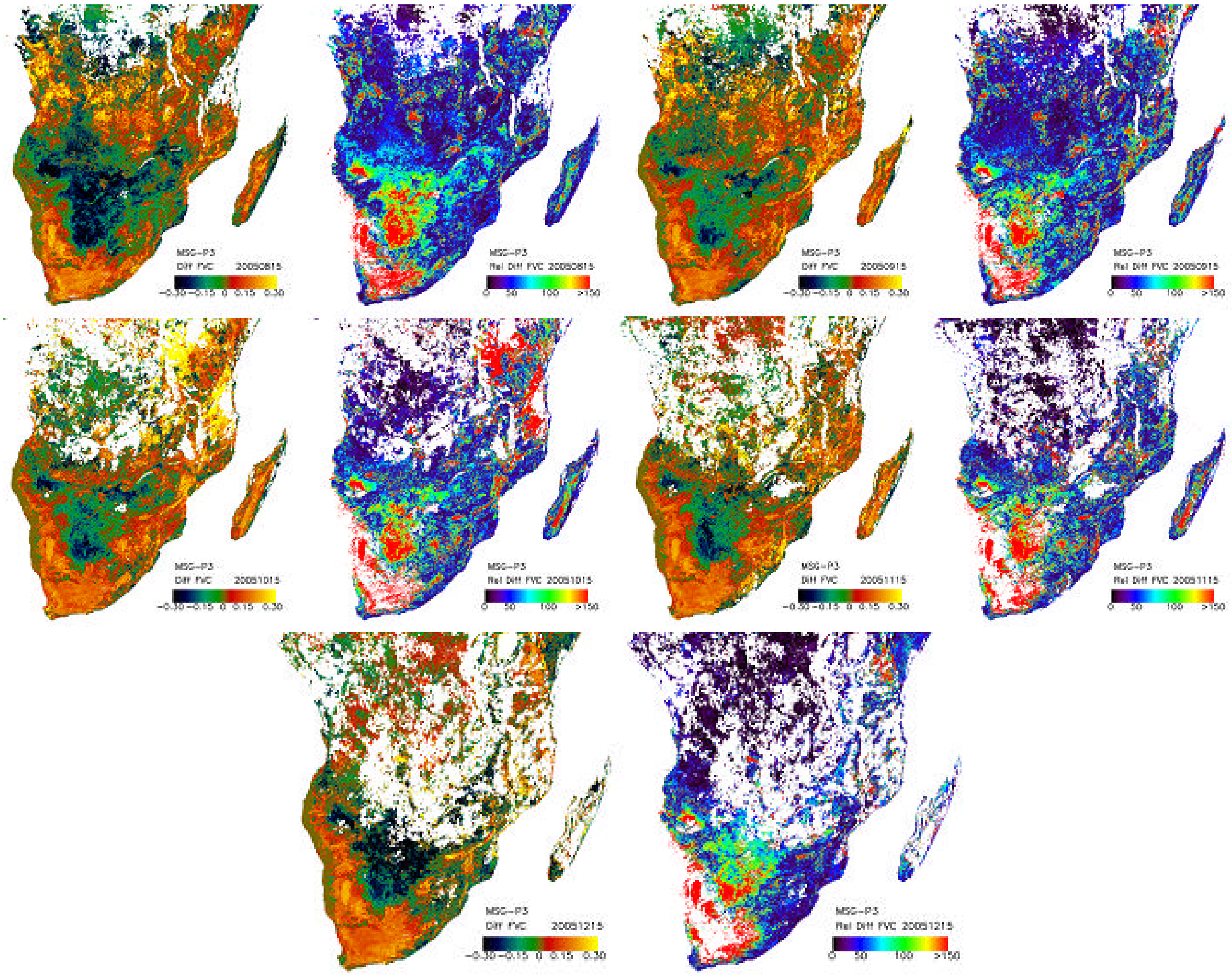
- LAI -



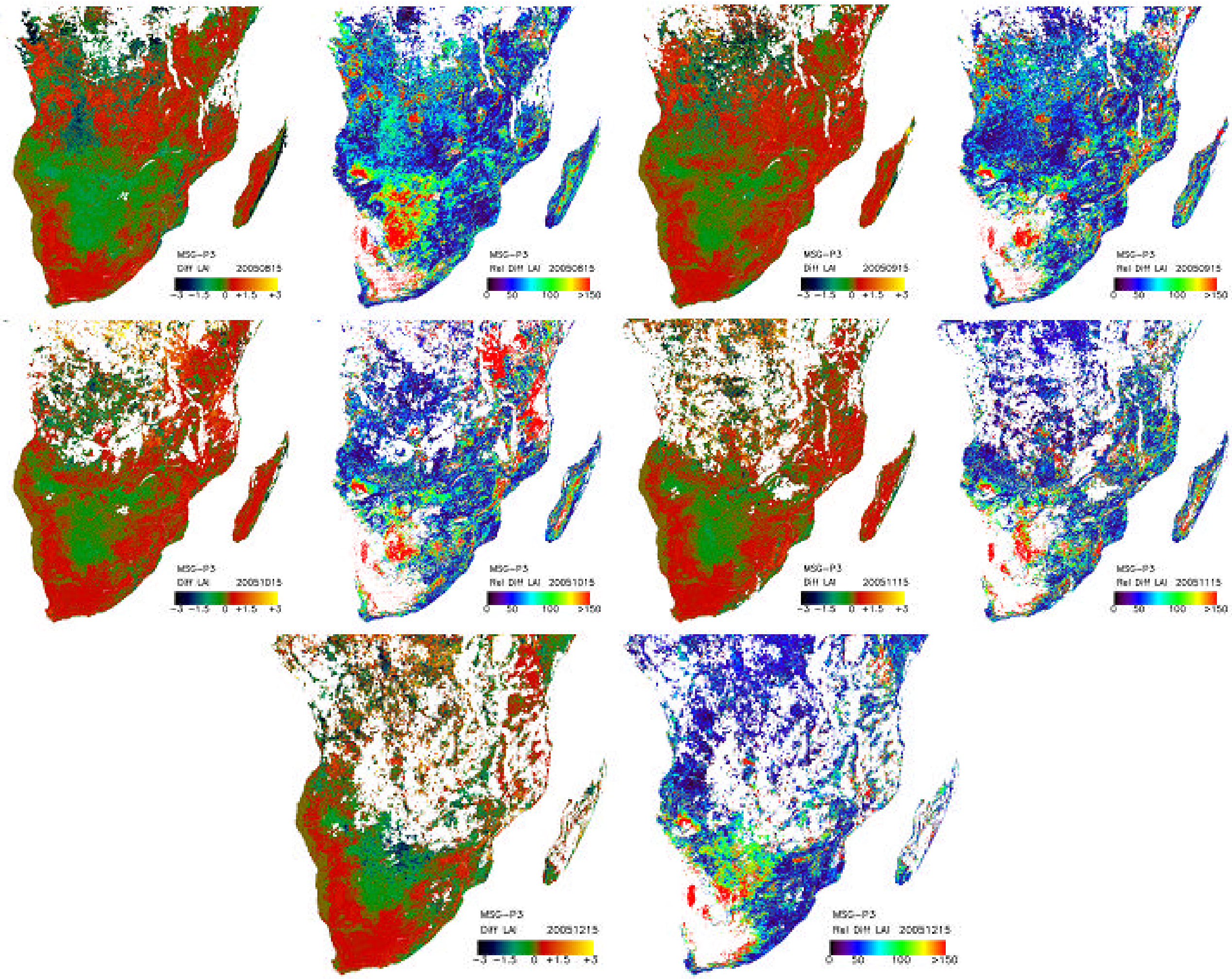
Diff LAI
-3.0 0 +3.0
MSG-P3 20050815
Rel Diff LAI
0 50 100 >150
MSG-P3 20050815
Diff LAI
-3.0 0 +3.0
MSG-P3 20050915
Rel Diff LAI
0 50 100 >150
MSG-P3 20050915
Diff LAI
-3.0 0 +3.0
MSG-P3 20051015
Rel Diff LAI
0 50 100 >150
MSG-P3 20051015
Diff LAI
-3.0 0 +3.0
MSG-P3 20051115
Rel Diff LAI
0 50 100 >150
MSG-P3 20051115
Diff LAI
-3.0 0 +3.0
MSG-P3 20051215
Rel Diff LAI
0 50 100 >150
MSG-P3 20051215

ZONE SOUTH AFRICA

-FVC -



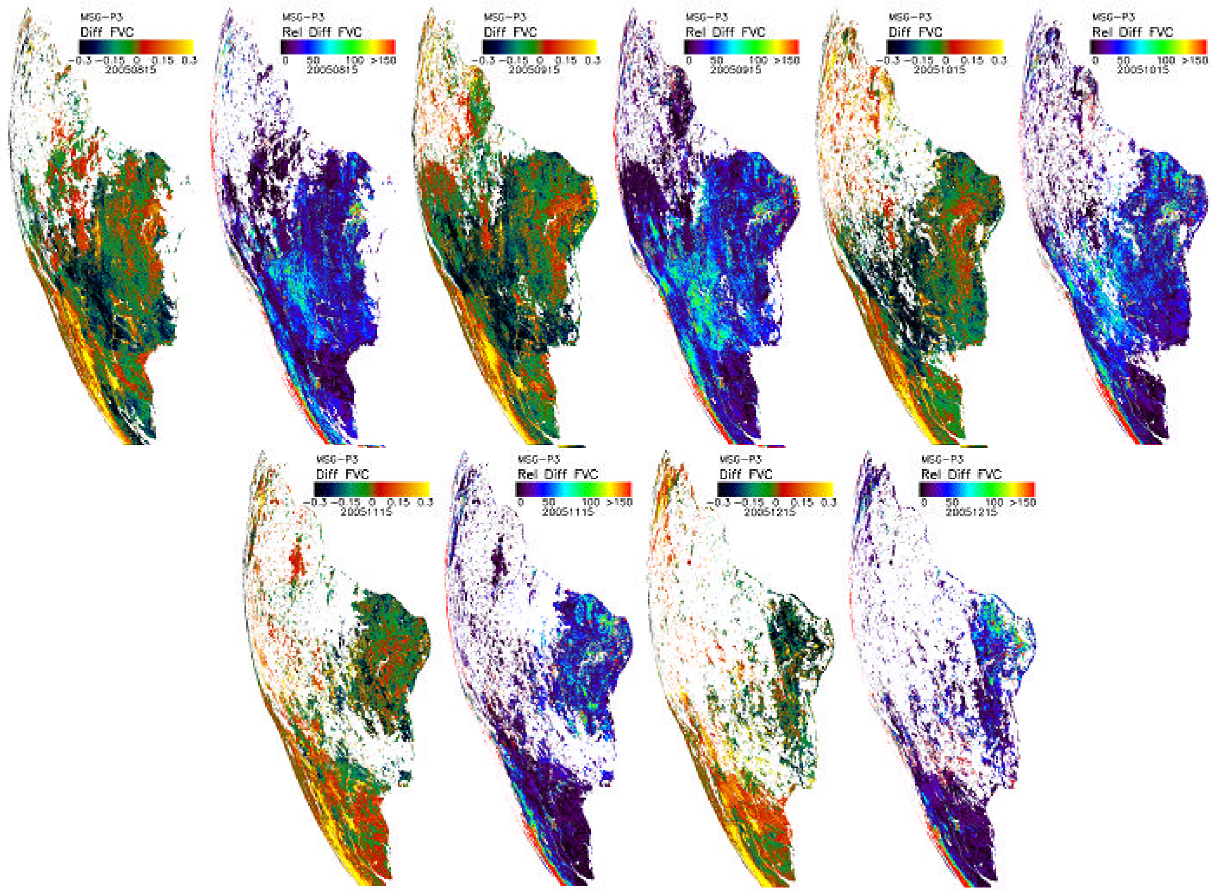
- LAI -



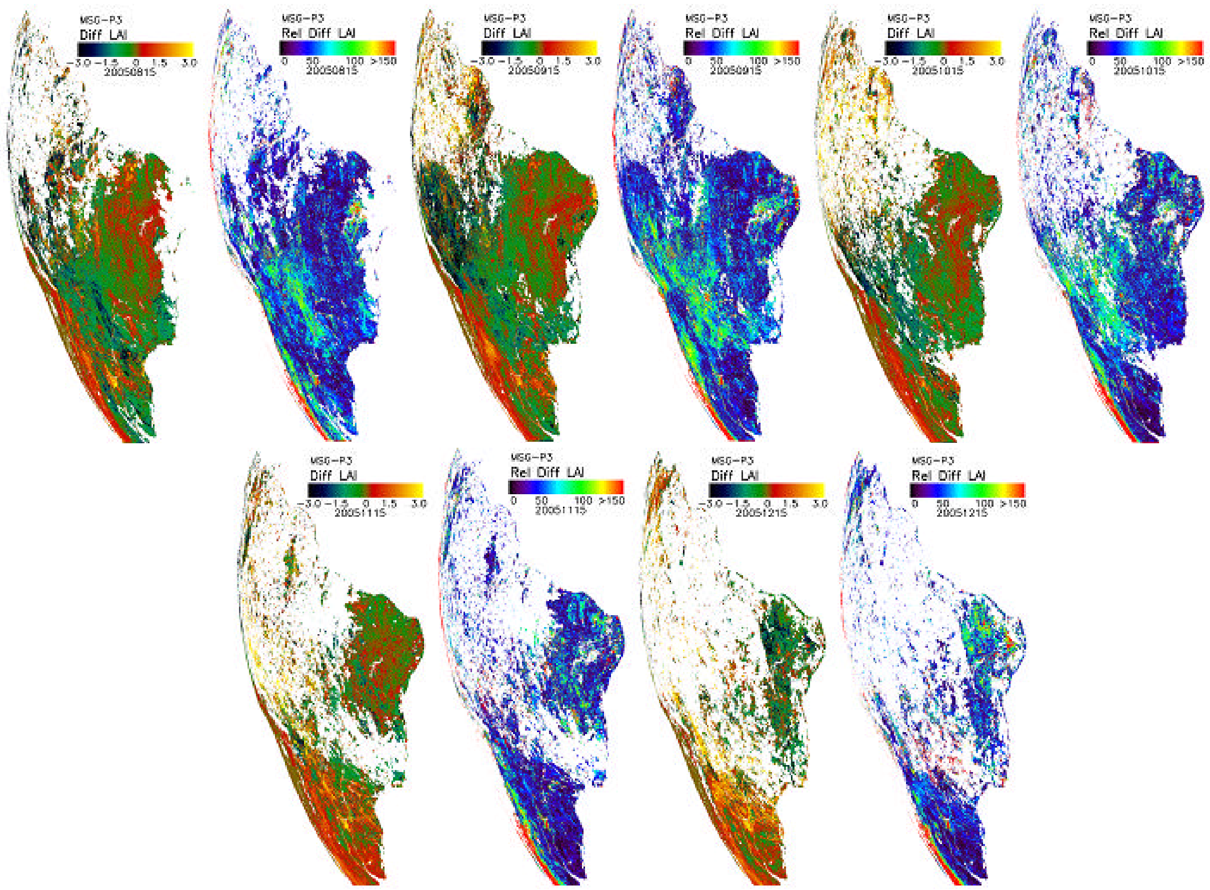
MSG-P3
Diff LAI 20050815
-3 -1.5 0 +1.5 +3
MSG-P3
Rel Diff LAI 20050815
0 50 100 >150
MSG-P3
Diff LAI 20050915
-3 -1.5 0 +1.5 +3
MSG-P3
Rel Diff LAI 20050915
0 50 100 >150
MSG-P3
Diff LAI 20051015
-3 -1.5 0 +1.5 +3
MSG-P3
Rel Diff LAI 20051015
0 50 100 >150
MSG-P3
Diff LAI 20051115
-3 -1.5 0 +1.5 +3
MSG-P3
Rel Diff LAI 20051115
0 50 100 >150
MSG-P3
Diff LAI 20051215
-3 -1.5 0 +1.5 +3
MSG-P3
Rel Diff LAI 20051215
0 50 100 >150

ZONE SOUTH AMERICA

- FVC -



- LAI -



ANNEX V

MSG-MODIS

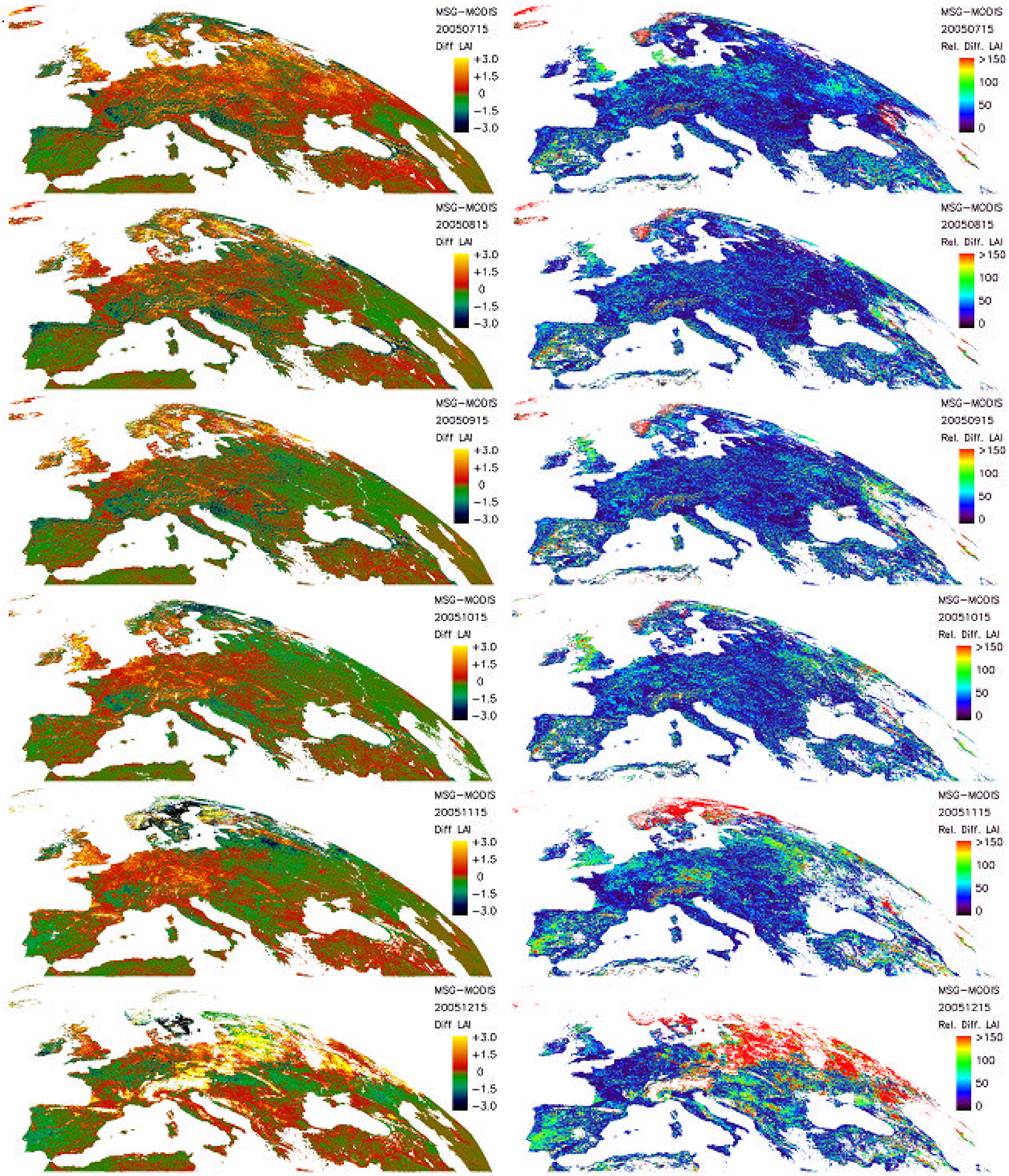
DIFFERENCE MAPS

Period: August- December 2005

Note: Relative errors were not computed if mean FVC<0.15 or mean LAI<0.5

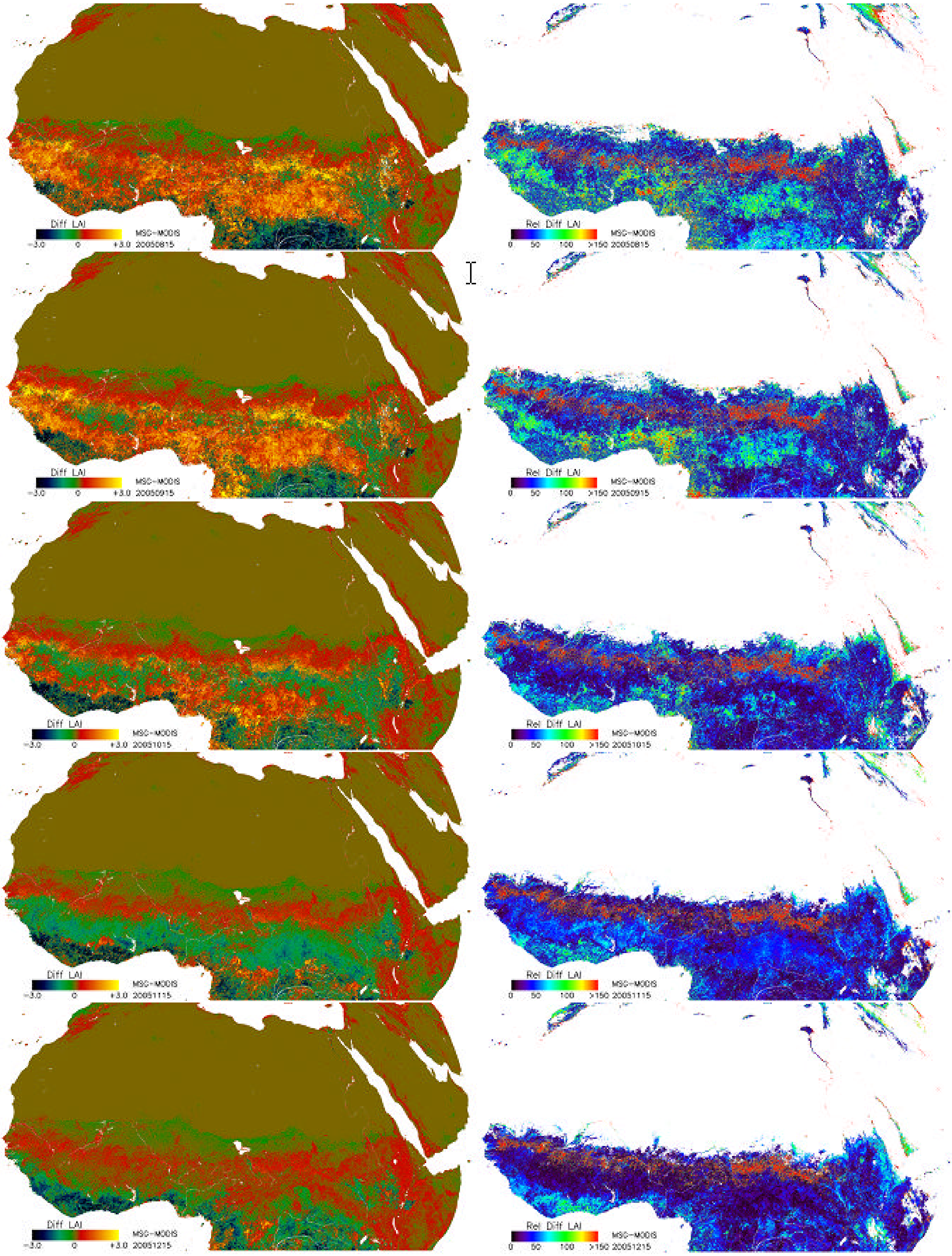
ZONE EURO

- LAI-



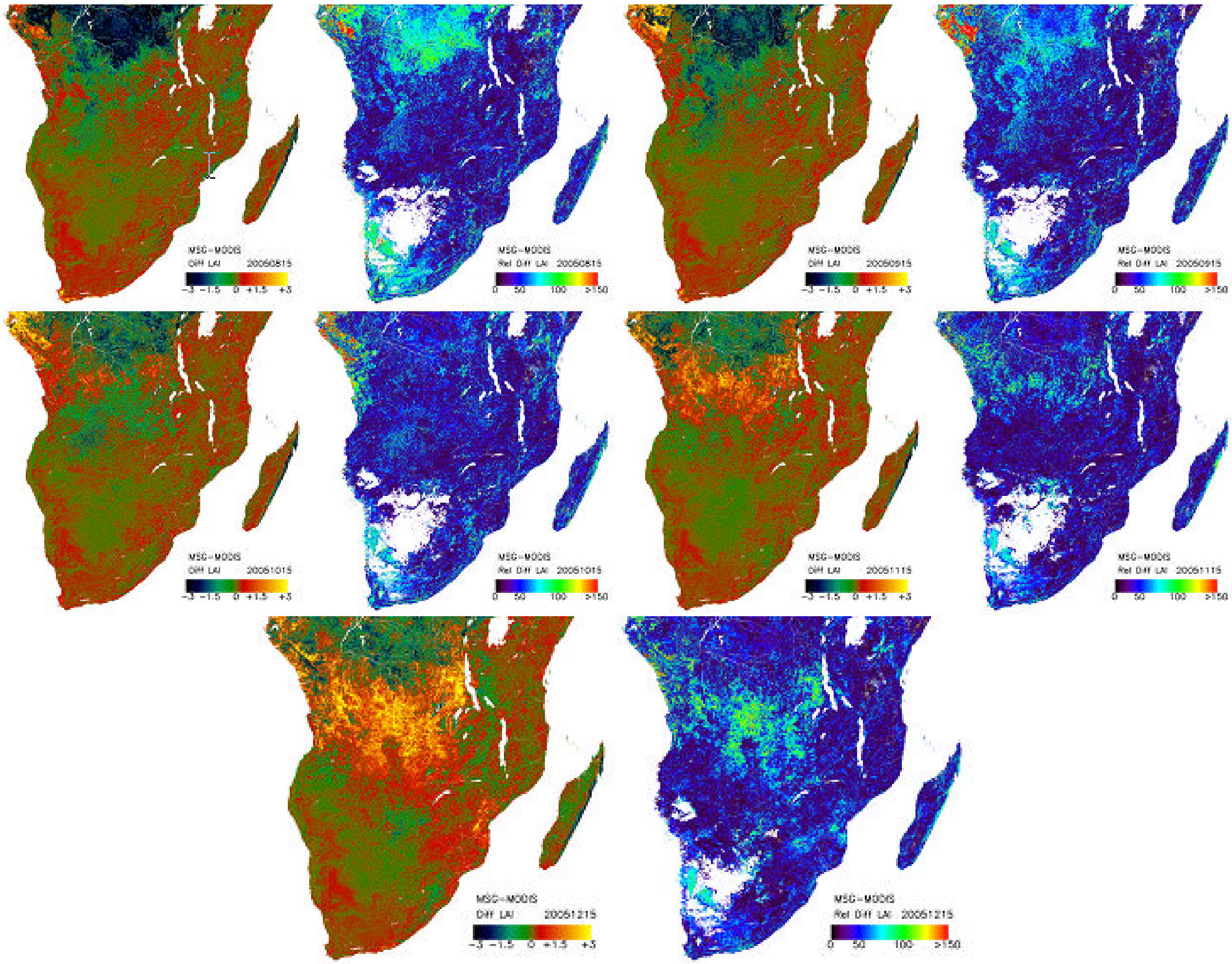
ZONE NORTH AFRICA

- LAI -



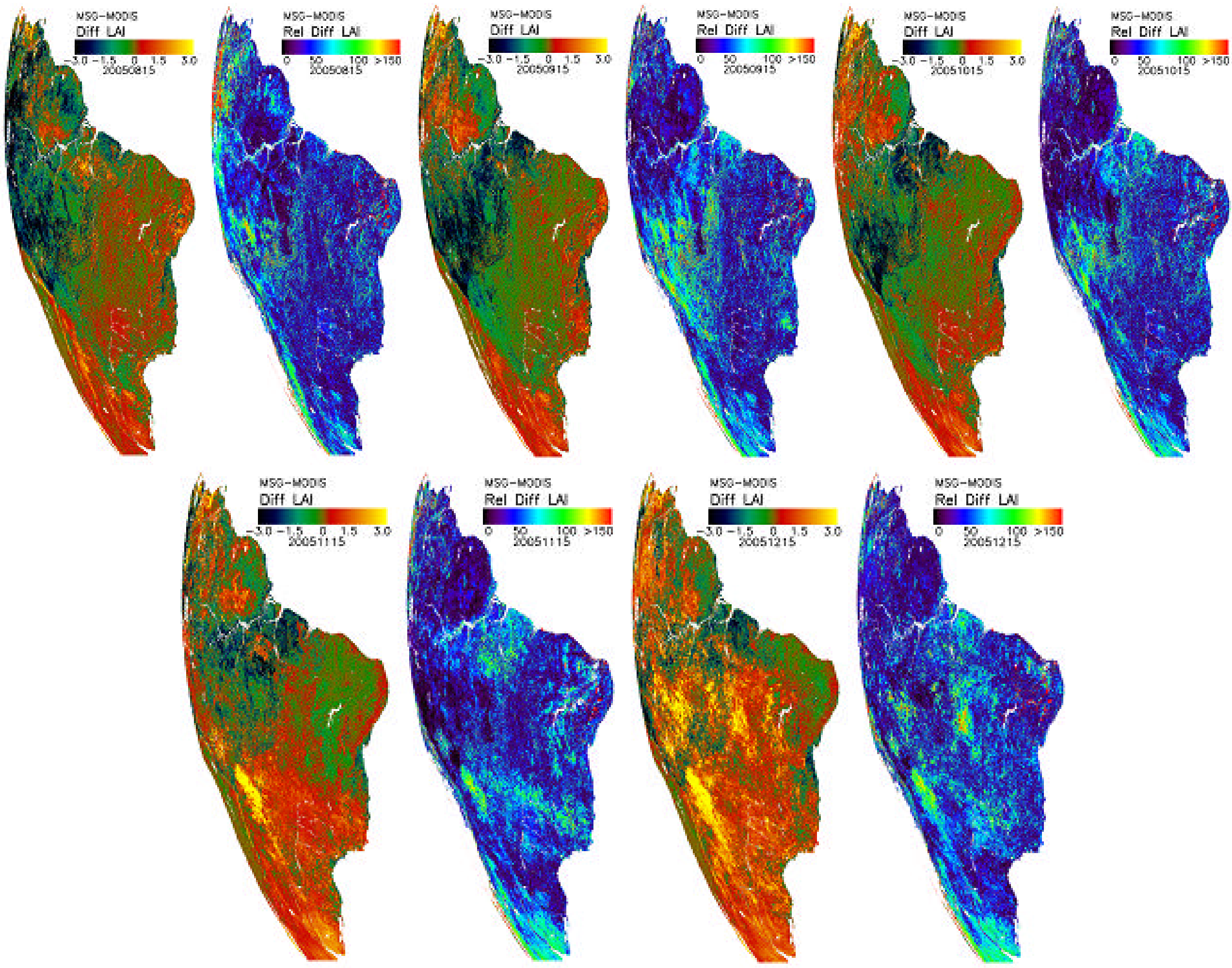
ZONE SOUTH AFRICA

- LAI -



ZONE SOUTH AMERICA

- LAI -



ANNEX VI

PARASOL-MODIS

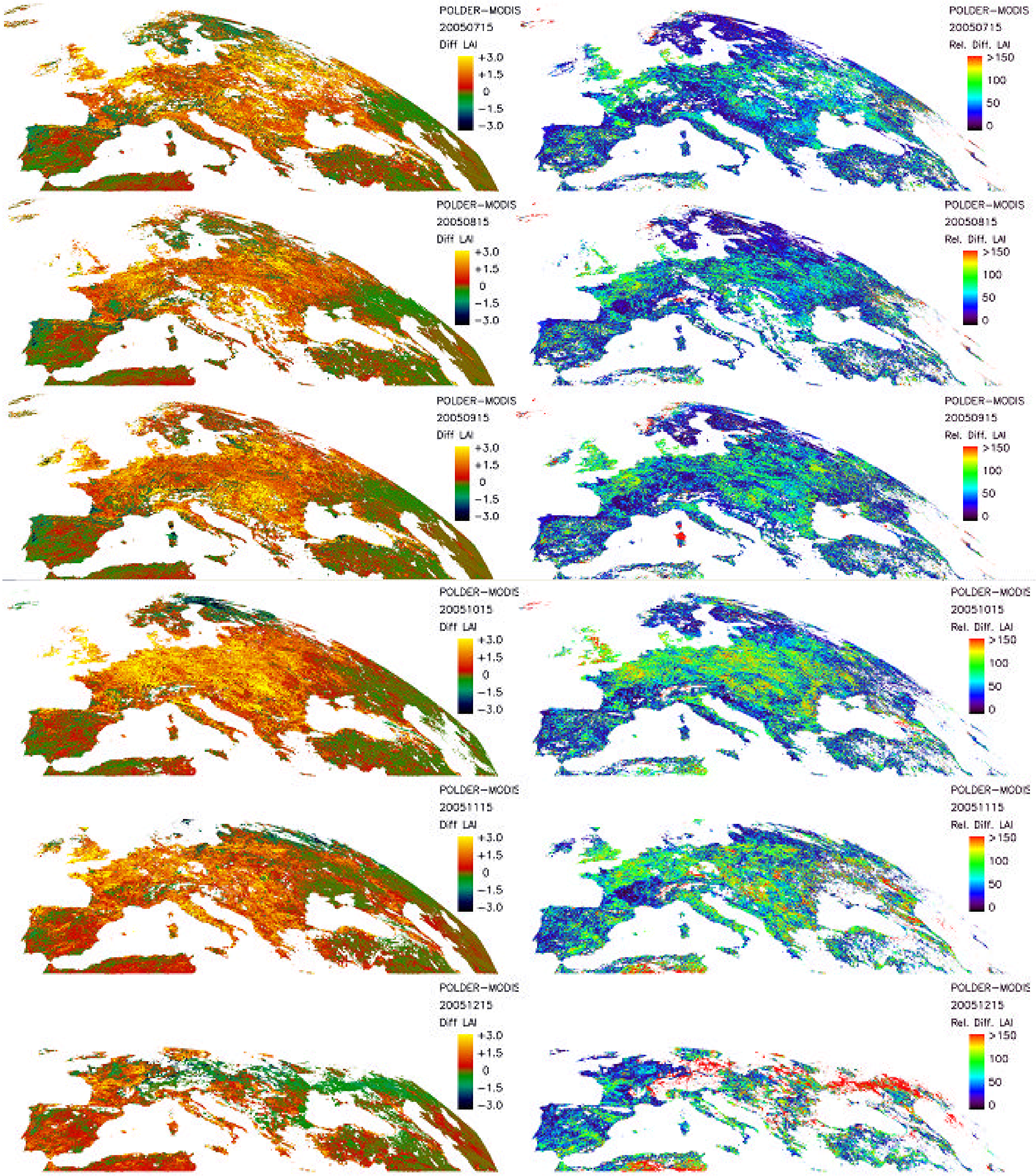
DIFFERENCE MAPS

Period: August- December 2005

Note: Relative errors were not computed where mean FVC<0.15 or mean LAI<0.5

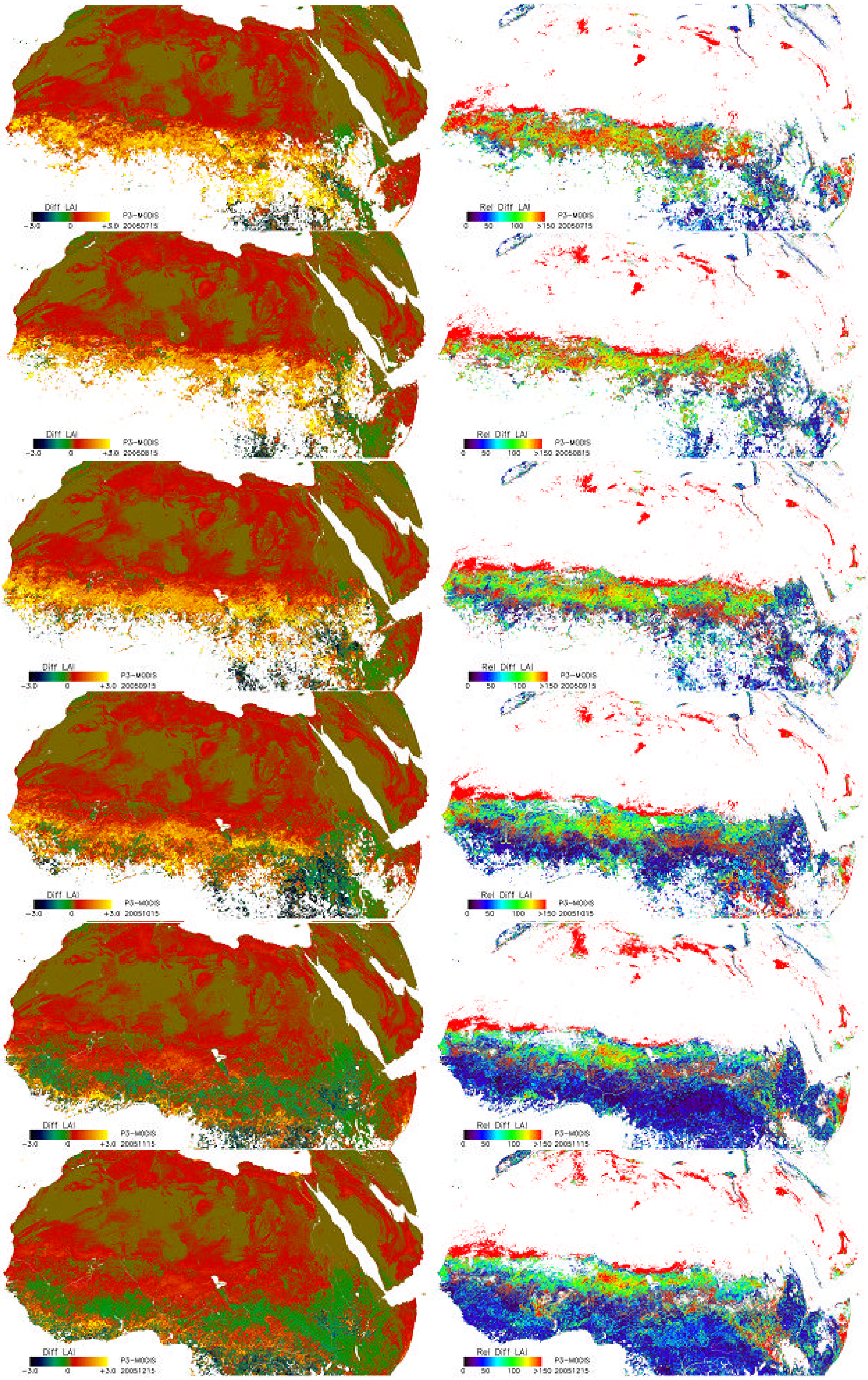
ZONE EURO

- LAI -



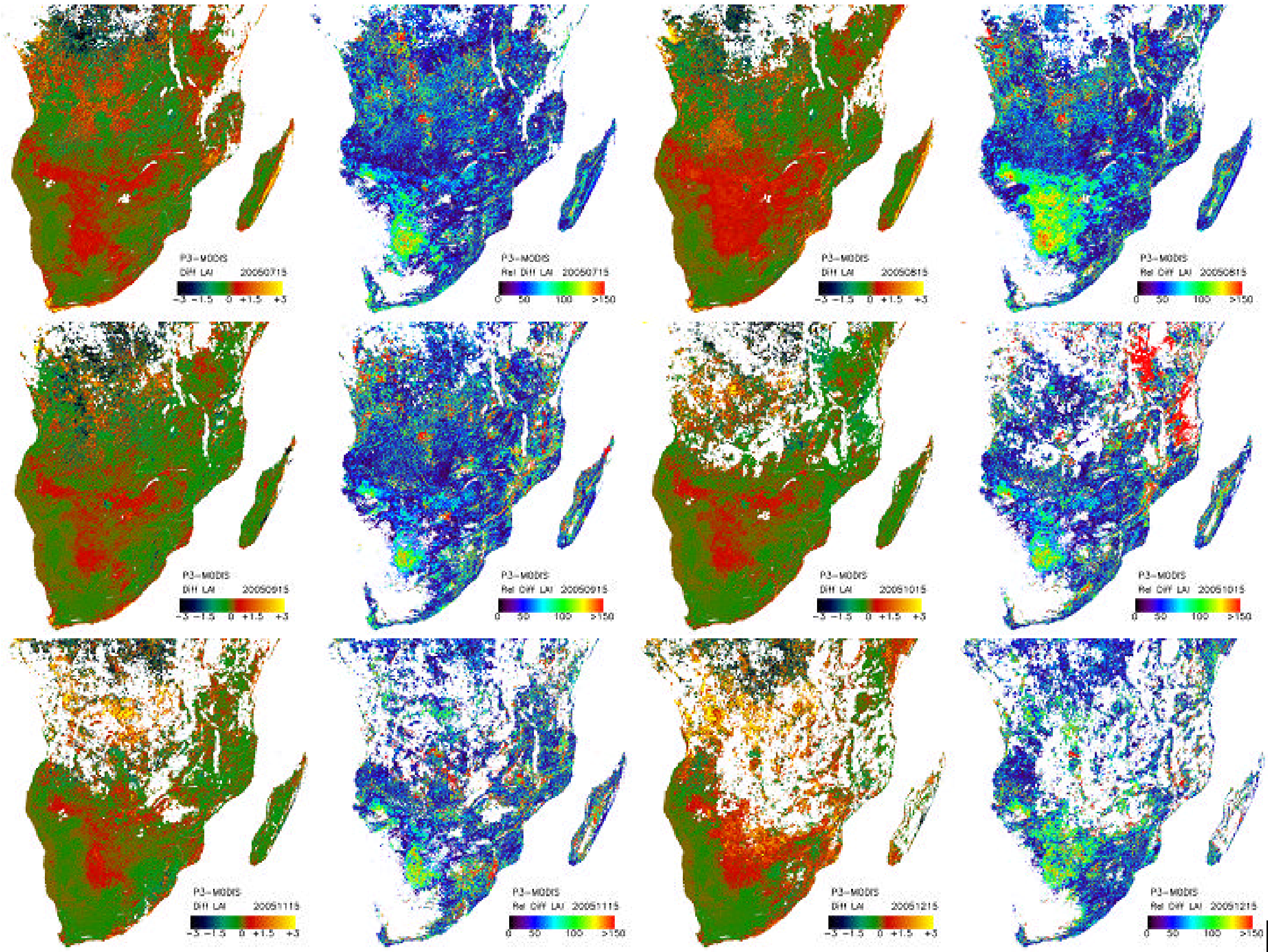
ZONE NORTH AFRICA

- LAI -



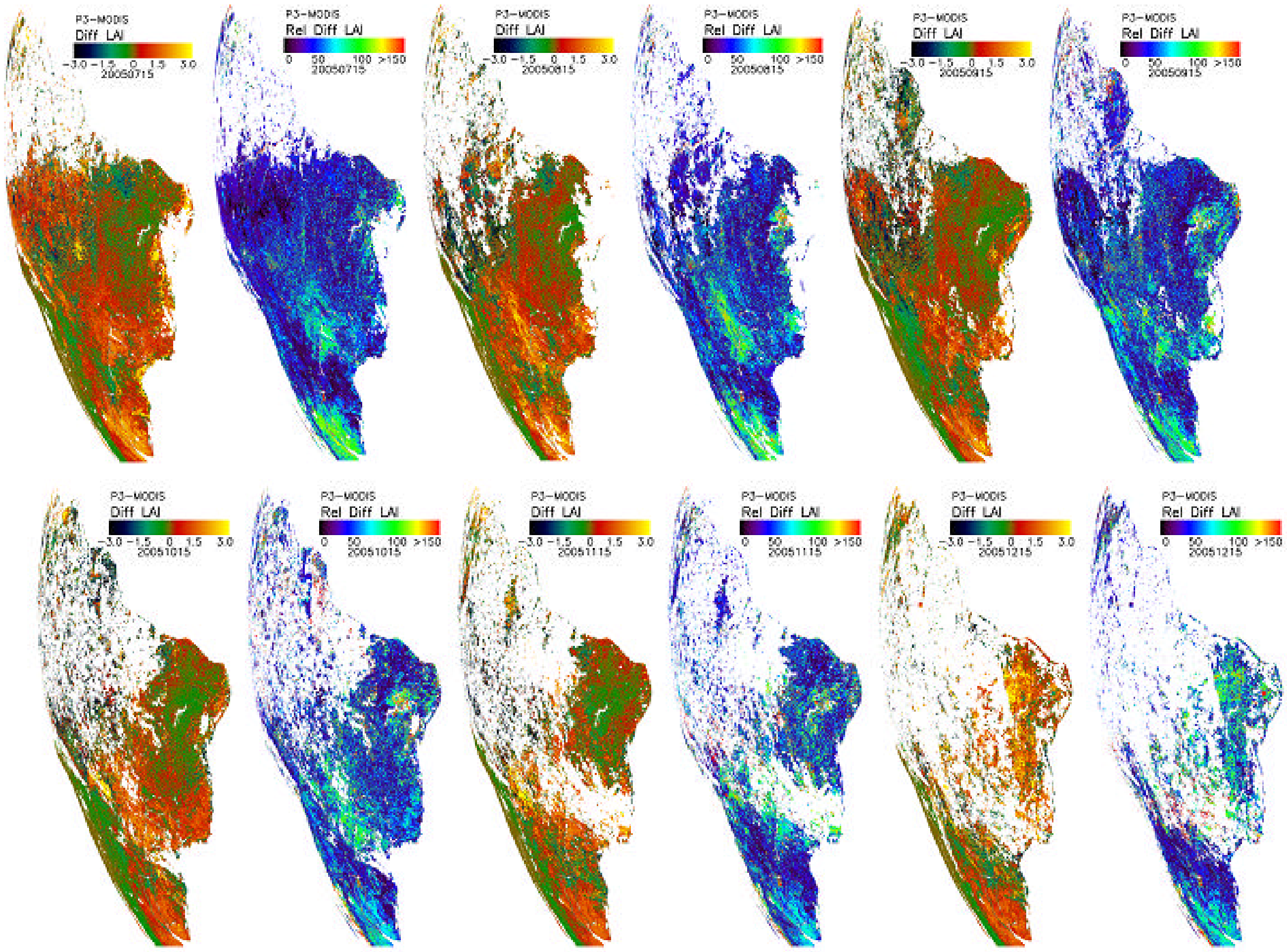
ZONE SOUTH AFRICA

- LAI -



ZONE SOUTH AMERICA

- LAI -



ANNEX VII

Inter-comparison of MSG, MODIS and POLDER:

Quantitative results (mean/std, RMS, bias, r) for biomes and geographical areas from July to December 2005.

ZONE EURO FVC

Table VII.1. Inter-comparison between MSG and POLDER-3 (P3) FVC products per main classes (see table 1) over Europe. The statistical indicators are the mean (standard deviation) of the products, the mean RMS, mean bias and the correlation coefficient (r). The period spans from July 2005 to December 2005.

EUROPE		Nº PIXELS	MEAN (STDV)		RMS	bias	r
MONTH	CLASS		MSG	P3		MSG-P3	
JULY	ALL	396187	0.49 (0.28)	0.55 (0.29)	0.15	-0.06	0.89
	BDF	41607	0.69 (0.19)	0.76 (0.16)	0.14	-0.07	0.80
	NLF	47638	0.68 (0.18)	0.68 (0.15)	0.14	0	0.64
	S	37397	0.33 (0.20)	0.37 (0.25)	0.14	-0.04	0.83
	H	66445	0.44 (0.32)	0.47 (0.34)	0.15	-0.02	0.90
	CM	175164	0.52 (0.22)	0.62 (0.25)	0.16	-0.10	0.86
	B	27936	0.02 (0.08)	0.03 (0.09)	0.08	-0.01	0.54
AUG	ALL	380462	0.40 (0.26)	0.49 (0.29)	0.17	-0.09	0.87
	BDF	37029	0.59 (0.19)	0.72 (0.17)	0.18	-0.12	0.75
	NLF	42708	0.63 (0.19)	0.65 (0.17)	0.16	-0.03	0.60
	S	34601	0.24 (0.17)	0.28 (0.23)	0.15	-0.04	0.78
	H	65121	0.37 (0.31)	0.42 (0.33)	0.16	-0.05	0.89
	CM	173520	0.41 (0.19)	0.55 (0.25)	0.19	-0.14	0.85
	B	27483	0.017 (0.07)	0.03 (0.08)	0.08	-0.01	0.49
SEP	ALL	415597	0.38 (0.25)	0.49 (0.29)	0.19	-0.11	0.83
	BDF	43272	0.57 (0.19)	0.71 (0.18)	0.20	-0.14	0.67
	NLF	49365	0.60 (0.18)	0.62 (0.17)	0.18	-0.02	0.49
	S	36467	0.25 (0.19)	0.29 (0.24)	0.16	-0.04	0.78
	H	70807	0.36 (0.30)	0.43 (0.33)	0.18	-0.07	0.86
	CM	187502	0.36 (0.19)	0.53 (0.25)	0.22	-0.17	0.83
	B	28184	0.02 (0.08)	0.04 (0.09)	0.09	-0.017	0.53
OCT	ALL	414986	0.32 (0.23)	0.45 (0.27)	0.20	-0.13	0.79
	BDF	44077	0.48 (0.19)	0.65 (0.18)	0.23	-0.17	0.68
	NLF	50388	0.53 (0.17)	0.57 (0.16)	0.19	-0.04	0.38
	S	35690	0.24 (0.17)	0.29 (0.24)	0.17	-0.06	0.76
	H	68332	0.30 (0.25)	0.39 (0.29)	0.19	-0.09	0.84
	CM	188231	0.30 (0.18)	0.49 (0.25)	0.23	-0.18	0.81
	B	28268	0.02 (0.08)	0.05 (0.09)	0.10	-0.03	0.38
NOV	ALL	365455	0.28 (0.21)	0.39 (0.26)	0.20	-0.12	0.77
	BDF	40117	0.41 (0.17)	0.56 (0.19)	0.22	-0.14	0.57
	NLF	28384	0.48 (0.16)	0.53 (0.17)	0.18	-0.06	0.48
	S	31726	0.24 (0.17)	0.32 (0.23)	0.20	-0.08	0.64
	H	58815	0.28 (0.26)	0.37 (0.27)	0.19	-0.09	0.79
	CM	178739	0.27 (0.18)	0.41 (0.24)	0.21	-0.14	0.77
	B	27674	0.012 (0.05)	0.08 (0.12)	0.14	-0.07	0.16
DEC	ALL	254778	0.27 (0.22)	0.31 (0.25)	0.23	-0.04	0.55
	BDF	22782	0.43 (0.18)	0.46 (0.23)	0.24	-0.04	0.34
	NLF	15076	0.49 (0.19)	0.45 (0.22)	0.27	0.04	0.18
	S	31775	0.22 (0.15)	0.29 (0.22)	0.22	-0.08	0.48
	H	38968	0.23 (0.24)	0.29 (026)	0.25	-0.06	0.54
	CM	119602	0.29 (0.19)	0.33 (0.25)	0.23	-0.04	0.48
	B	26575	0.017 (0.07)	0.08 (0.11)	0.14	-0.06	0.09

ZONE EURO LAI

Table VII.2. Inter-comparison among MSG, POLDER-3 (P3) and MODIS LAI products per main classes (see table 1) over Europe. The statistical indicators are the mean (standard deviation) of the products, the mean RMS, mean bias and the correlation coefficient (r). The period spans from July 2005 to December 2005.

EUROPE		Nº PIXELS	MEAN (STDV)			RMS	bias	r
MONTH	**CLASS**		**MSG**	**MODIS**	**P3**	**MSG-MODIS / MSG-P3 / P3-MODIS**		
	ALL	384301	2.03 (1.50)	1.86 (1.44)	2.57 (1.97)	0.97/1.30/1.47	0.16/-0.54/0.71	0.79/0.80/0.76
	BDF	40110	3.10 (1.33)	3.61 (1.32)	4.33 (1.88)	1.31/1.84/1.67	-0.51/-1.23/0.71	0.58/0.68/0.61
	NLF	45363	3.29 (1.44)	3.26 (0.91)	3.25 (1.42)	1.25/1.37/1.25	0.04/0.04/-0.007	0.51/0.54/0.50
JULY	**S**	36762	1.10 (0.91)	0.94 (0.75)	1.23 (1.24)	0.68/0.73/0.88	0.17/-0.12/0.29	0.70/0.81/0.76
	H	62810	1.87 (1.80)	1.78 (1.66)	2.29 (2.24)	0.96/1.30/1.36	0.08/-0.42/0.49	0.84/0.84/0.83
	CM	173342	1.99 (1.14)	1.57 (0.96)	2.74 (1.70)	0.92/1.32/1.69	0.42/-0.75/1.17	0.71/0.78/0.71
	B	25914	0.06 (0.26)	0.12 (0.19)	0.09 (0.32)	0.27/0.27/0.28	-0.06/-0.03/-0.03	0.35/0.59/0.49
	ALL	367411	1.53 (1.28)	1.57(1.30)	2.16 (1.77)	0.83/1.29/1.28	-0.03/-0.63/0.59	0.79/0.77/0.77
	BDF	35537	2.44 (1.14)	3.19 (1.20)	3.79 (1.75)	1.32/1.92/ 1.51	-0.76/-1.36/0.60	0.58/0.63/0.62
	NLF	40766	2.89 (1.41)	2.86 (0.83)	2.99 (1.36)	1.26/1.38/ 1.19	0.03/-0.10/0.14	0.46/0.51/0.51
AUG	**S**	33860	0.77 (0.67)	0.74 (0.59)	0.89 (1.02)	0.50/0.68/0.72	0.03/-0.13/0.16	0.69/0.76/0.75
	H	60408	1.48 (1.52)	1.56 (1.50)	1.96 (1.98)	0.86/1.24/1.19	-0.08/-0.48/0.39	0.84/0.82/0.83
	CM	171398	1.42 (0.88)	1.31 (0.82)	2.25 (1.51)	0.65/1.29/ 1.44	0.11/-0.83/0.95	0.72/0.78/0.72
	B	25442	0.04 (0.22)	0.10 (0.16)	0.06 (0.26)	0.25/0.24/ 0.26	-0.06/-0.02/-0.04	0.22/0.53/0.36
	ALL	400708	1.39 (1.19)	1.45 (1.16)	2.11 (1.71)	0.82/1.36/ 1.32	-0.05/-0.71/0.66	0.76/0.74/0.75
	BDF	41525	2.24 (1.05)	2.95 (1.14)	3.66 (1.72)	1.25/1.98/1.56	-0.71/-1.42/0.71	0.56/0.59/0.59
	NLF	46838	2.66 (1.25)	2.48 (0.76)	2.77 (1.25)	1.23/1.34/1.19	0.18/-0.11/0.29	0.34/0.43/0.43
SEP	**S**	35578	0.80 (0.81)	0.74 (0.60)	0.96 (1.19)	0.61/0.78/0.91	0.06/-0.16/0.22	0.66/0.78/0.70
	H	65487	1.41 (1.41)	1.42 (1.30)	1.96 (1.91)	0.88/1.29/1.30	-0.01/-0.55/0.53	0.79/0.79/0.79
	CM	185238	1.19 (0.82)	1.19 (0.80)	2.16 (1.49)	0.61/1.40/1.45	-0.003/-0.97/0.96	0.72/0.76/0.71
	B	26042	0.05 (0.26)	0.10 (0.15)	0.10 (0.34)	0.27/0.28/0.31	-0.04/-0.05/0.003	0.23/0.60/0.40
	ALL	400754	1.13 (0.98)	1.14 (0.93)	1.93 (1.55)	0.70/1.36/1.40	-0.008/-0.79/0.79	0.73/0.70/0.66
	BDF	42438	1.77 (0.93)	2.15 (0.82)	3.09 (1.45)	0.89/1.79/1.52	-0.39/-1.33/0.94	0.59/0.56/0.57
	NLF	47872	2.16 (1.02)	2.09 (0.80)	2.48(1.13)	1.13/1.27/1.38	0.07/-0.31/0.39	0.25/0.35/0.11
OCT	**S**	34869	0.76 (0.72)	0.69 (0.58)	0.98 (1.10)	0.59/0.79/0.89	0.07-/0.23/0.29	0.60/0.74/0.67
	H	63400	1.08 (1.10)	1.15 (1.07)	1.74 (1.69)	0.77/1.27/1.28	-0.06/-0.66/0.59	0.75/0.78/0.75
	CM	186034	0.96 (0.71)	0.89 (0.61)	2.01 (1.45)	0.52/1.48/1.59	0.07/-1.05/1.11	0.70/0.74/0.68
	B	26141	0.05 (0.27)	0.09 (0.15)	0.13 (0.31)	0.29/0.32/0.27	-0.04/-0.08/0.04	0.18/0.41/0.50
	ALL	356261	0.96 (0.89)	0.93 (0.81)	1.60 (1.31)	0.67/1.13/1.19	0.03/-0.65/0.68	0.69/0.70/0.66
	BDF	39258	1.45 (0.83)	1.59 (0.67)	2.39 (1.14)	0.79/1.40/1.33	-0.15/-0.94/0.79	0.48/0.48/0.40
	NLF	28189	1.84 (0.93)	1.64 (0.80)	2.17 (1.01)	1.14/1.12/1.28	0.19/-0.33/0.54	0.18/0.39/0.19
NOV	**S**	31171	0.75 (0.68)	0.65 (0.54)	1.11 (1.09)	0.53/0.90/0.90	0.10/-0.35/0.46	0.66/0.65/0.75
	H	55427	1.01 (1.14)	1.11 (1.16)	1.57 (1.52)	0.85/1.11/1.13	-0.09/-0.56/0.46	0.74/0.78/0.73
	CM	176725	0.86 (0.72)	0.77 (0.56)	1.63 (1.24)	0.52/1.18/1.29	0.09/-0.77/0.86	0.69/0.71/0.67
	B	25491	0.03 (0.14)	0.09 (0.16)	0.24 (0.47)	0.20/0.52/0.40	-0.07/-0.21/0.15	0.18/0.17/0.72
	ALL	248288	0.92 (0.94)	0.85 (0.79)	1.17 (1.17)	0.76/1.09/0.92	0.07/-0.25/ 0.32	0.63/0.51/0.67
	BDF	22513	1.51 (0.93)	1.44 (0.83)	1.89 (1.18)	0.98/1.32/1.18	0.07/-0.37/0.44	0.39/0.29/0.46
	NLF	15008	1.99 (1.23)	1.58 (0.88)	1.76 (1.13)	1.39/1.53/1.12	0.41/0.23/0.18	0.24/0.18/0.42
DEC	**S**	31214	0.66 (0.57)	0.59 (0.46)	0.95 (0.94)	0.51/0.86/0.78	0.07/-0.29/0.36	0.53/0.52/0.72
	H	36821	0.83 (0.02)	0.82 (0.98)	1.10 (1.27)	0.79/1.12/0.85	0.014/-0.27/0.29	0.69/0.57/0.78
	CM	118260	0.95 (0.81)	0.87 (0.68)	1.23 (1.16)	0.71/1.10/0.97	0.08/-0.28/0.36	0.58/0.46/0.63
	B	24472	0.04 (0.22)	0.16 (0.30)	0.24 (0.48)	0.36/0.54/0.42	-0.12/-0.19/0.08	0.16/0.09/0.51

ZONE NORTH AFRICA

FVC

Table VII.3. **As in table VII.1 for North Africa**.

N_AFRICA		Nº PIXELS	MEAN (STDV)		RMS	bias	r
MONTH	CLASS		MSG	P3	MSG-P3		
AUG	ALL	1464262	0.10 (0.21)	0.20 (0.26)	0.18	-0.10	0.81
	BEF	15699	0.68 (0.14)	0.77 (0.07)	0.17	-0.09	0.22
	BDF	20804	0.71 (0.14)	0.74 (0.18)	0.13	-0.04	0.72
	S	49948	0.54 (0.24)	0.56 (0.32)	0.18	-0.02	0.84
	H	247218	0.16 (0.12)	0.33 (0.28)	0.31	-0.18	0.47
	CM	135370	0.45 (0.19)	0.58 (0.28)	0.25	-0.13	0.66
	B	995223	0.00 (0.00)	0.08 (0.09)	NaN	-0.08	NaN
	TFM	15748	0.69 (0.09)	0.77 (0.08)	0.12	-0.08	0.41
SEP	ALL	1609565	0.15 (0.25)	0.23 (0.28)	0.16	-0.08	0.86
	BEF	23409	0.77 (0.13)	0.74 (0.14)	0.19	0.03	0.09
	BDF	40989	0.72 (0.11)	0.67 (0.25)	0.24	0.05	0.37
	S	85287	0.59 (0.21)	0.59 (0.29)	0.19	-0.005	0.77
	H	261956	0.16 (0.12)	0.28 (0.25)	0.23	-0.12	0.60
	CM	198738	0.50 (0.18)	0.62 (0.24)	0.21	-0.11	0.68
	B	999186	0.00 (0.00)	0.08 (0.08)	NaN	-0.08	NaN
	TFM	19947	0.74 (0.09)	0.69 (0.21)	0.23	0.05	0.09
OCT	ALL	1716481	0.17 (0.26)	0.23 (0.27)	0.15	-0.06	0.87
	BEF	30957	0.78 (0.13)	0.59 (0.29)	0.36	0.19	0.14
	BDF	87159	0.68 (0.08)	0.67 (0.19)	0.17	0.02	0.49
	S	122147	0.56 (0.16)	0.59 (0.259	0.16	-0.04	0.78
	H	237211	0.13 (0.12)	0.22 (0.19)	0.19	-0.08	0.44
	CM	238837	0.46 (0.17)	0.53 (0.24)	0.19	-0.07	0.69
	B	1000170	0.00 (0.00)	0.07 (0.08)	NaN	-0.07	NaN
	TFM	31974	0.71 (0.08)	0.51 (0.27)	0.33	0.19	0.31
NOV	ALL	1848765	0.17 (0.25)	0.22 (0.25)	0.12	-0.06	0.91
	BEF	77147	0.79 (0.09)	0.77 (0.06)	0.09	0.02	0.34
	BDF	110326	0.57 (0.09)	0.63 (0.14)	0.11	-0.06	0.75
	S	131861	0.43 (0.13)	0.45 (0.21)	0.13	-0.03	0.82
	H	257799	0.11 (0.11)	0.19 (0.16)	0.17	-0.08	0.40
	CM	271662	0.37 (0.18)	0.40 (0.24)	0.15	-0.04	0.83
	B	999970	0.00 (0.00)	0.07 (0.08)	NaN	-0.07	NaN
	TFM	50530	0.66 (0.08)	0.71 (0.09)	0.09	-0.05	0.52
DEC	ALL	1896175	0.14 (0.21)	0.19 (0.22)	0.13	-0.05	0.85
	BEF	92861	0.71 (0.10)	0.74 (0.08)	0.11	-0.03	0.41
	BDF	112969	0.43 (0.09)	0.37 (0.21)	0.15	0.05	0.79
	S	133526	0.32 (0.10)	0.26 (0.19)	0.15	0.06	0.71
	H	267734	0.10 (0.10)	0.16 (0.13)	0.16	-0.06	0.15
	CM	288918	0.31 (0.17)	0.35 (0.25)	0.15	-0.04	0.82
	B	1000167	0.00 (0.00)	0.07 (0.08)	NaN	-0.07	NaN
	TFM	54592	0.55 (0.12)	0.54 (0.19)	0.13	0.02	0.73

ZONE NORTH AFRICA
LAI

Table VII.4. As in table VII.2 for North Africa.

N_Africa		Nº PIXELS	MEAN (STDV)			RMS	bias	r
MONTH	CLASS		MSG	MODIS	P3	MSG-MODIS/MSG-P3/P3-MODIS		
AUG	ALL	1448793	0.36 (0.80)	0.26 (0.76)	0.74 (1.25)	0.49/0.82/1.04	0.09/-0.38/0.45	0.81/0.84/0.67
	BEF	15224	3.32 (0.71)	4.83 (1.13)	4.22 (1.33)	1.91/1.69/1.77	-1.51/-0.90/-0.61	0.25/0.12/0.09
	BDF	20440	3.02 (0.76)	2.26 (1.10)	3.97 (1.70)	1.35/1.72/2.49	0.76/-0.96/1.72	0.32/0.54/0.23
	S	47913	2.16 (1.07)	1.62 (1.17)	2.84 (2.00)	1.14/1.52/2.13	0.54/-0.68/1.22	0.60/0.77/0.50
	H	243222	0.42 (0.35)	0.27 (0.28)	1.11 (1.12)	0.35/1.21/1.35	0.14/-0.70/0.84	0.52/0.52/0.35
	CM	131300	1.52 (0.79)	0.84 (0.94)	2.43 (1.54)	1.12/1.51/2.21	0.68/-0.91/1.59	0.47/0.64/0.31
	B	990694	0,00 (0,00)	0.01 (0.04)	0.20 (0.27)	NaN/NaN /0.32	-0.01/-0.20/0.19	NaN/NaN/0.32
	TFM	15222	2.82 (0.48)	2.75 (1.54)	4.23 (1.41)	1.61/2.00/2.72	0.07/-1.40/1.47	0.01/0.14/-0.20
SEP	ALL	1592781	0.54 (1.02)	0.41 (0.92)	0.85 (1.32)	0.59/0.76/1.05	0.13/-0.30/0.44	0.83/0.85/0.69
	BEF	22936	4.12 (0.83)	4.83 (1.24)	3.79 (1.43)	1.44/1.68/2.06	-0.71/0.33/-1.04	0.31/-0.01/0.11
	BDF	40653	3.03 (0.64)	1.89 (0.99)	3.24 (1.71)	1.55/1.60/2.33	1.16/-0.18/1.34	0.28/0.36/0.08
	S	82442	2.34 (0.90)	1.69 (1.19)	2.83 (1.76)	1.26/1.42/2.15	0.64/-0.50/1.14	0.50/.0.68/0.29
	H	257930	0.43 (0.37)	0.36 (0.35)	0.88 (0.91)	0.30/0.86/0.92	0.08/-0.45/0.52	0.67/0.65/0.61
	CM	194151	1.75 (0.76)	1.14 (0.10)	2.52 (1.33)	1.14/1.26/1.98	0.62/-0.76/1.38	0.44/0.65/0.17
	B	994669	0,00 (0,00)	0.10 (0.05)	0.18 (0.21)	NaN/NaN /0.27	-0.01/-0.18/0.17	NaN/NaN/0.28
	TFM	19715	3.16 (0.53)	2.50 (1.43)	3.43 (1.58)	1.53/1.64/2.35	0.66/-0.27/0.93	0.28/0.08/-0.03
OCT	ALL	1698368	0.63 (1.06)	0.55 (1.06)	0.86 (1.28)	0.58/0.72/1.00	0.08/-0.23/0.31	0.85/0.85/0.68
	BEF	30459	4.26 (0.97)	4.37 (1.40)	2.76 (1.75)	1.29/2.41/2.74	-0.11/1.49/-1.61	0.46/0.13/0.26
	BDF	86734	2.77 (0.49)	1.91 (0.85)	3.16 (1.32)	1.28/1.26/2.07	0.85/-0.39/1.24	0.05/0.43/-0.12
	S	119251	2.06 (0.67)	1.91 (1.14)	2.67 (1.38)	1.06/1.19/1.75	0.15/-0.61/0.76	0.42/0.71/0.23
	H	233193	0.36 (0.35)	0.32 (0.32)	0.61 (0.66)	0.27/0.62/0.61	0.04/-0.25/0.29	0.69/0.52/0.57
	CM	234149	1.55 (0.73)	1.38 (1.14)	2.04 (1.31)	0.98/1.04/1.58	0.17/-0.49/0.66	0.54/0.73/0.32
	B	994582	0,00 (0,00)	0.01 (0.05)	0.17 (0.19)	NaN/NaN /0.25	-0.01/-0.18/0.16	NaN/NaN/0.17
	TFM	31698	2.85 (0.53)	2.34 (1.05)	2.40 (1.51)	1.15/1.52/1.86	0.50/0.45/0.05	0.28/0.28/-0.02
NOV	ALL	1831314	0.61 (1.07)	0.76 (1.34)	0.84 (1.31)	0.62/0.64/0.79	-0.14/-0.23/0.08	0.90/0.89/0.82
	BEF	75901	4.22 (0.92)	4.44 (1.27)	4.35 (1.30)	1.20/1.37/1.66	-0.23/-0.14/-0.09	0.46/0.28/0.17
	BDF	110183	2.05 (0.47)	2.54 (0.79)	2.72 (1.08)	1.03/1.10/1.36	-0.49/-0.67/0.18	0.04/0.61/-0.02
	S	129805	1.39 (0.51)	2.21 (1.14)	1.62 (1.07)	1.28/0.80/1.41	-0.82/-0.23/-0.59	0.50/0.75/0.33
	H	254035	0.29 (0.33)	0.28 (0.30)	0.50 (0.53)	0.26/0.50/0.49	0.012/-0.21/0.22	0.67/0.53/0.55
	CM	267151	1.19 (0.77)	1.49 (1.37)	1.52 (1.52)	0.95/0.99/1.15	-0.30/-0.33/0.02	0.79/0.86/0.68
	B	994239	0,00 (0,00)	0.01 (0.04)	0.16 (0.18)	NaN/NaN /0.24	-0.01/-0.16/0.15	NaN/NaN/0.15
	TFM	50214	2.55(0.60)	2.73 (1.04)	3.44 (1.05)	0.89/1.33/1.57	-0.18/-0.90/0.71	0.55/0.40/0.10
DEC	ALL	1878197	0.51 (0.90)	0.74 (1.34)	0.68 (1.15)	0.68/0.62/0.80	-0.24/-0.17/-0.06	0.92/0.86/0.82
	BEF	91468	3.46 (0.82)	4.27 (1.03)	3.85 (1.18)	1.31/1.30/1.52	-0.81/-0.38/-0.43	0.40/0.27/0.14
	BDF	112776	1.39 (0.42)	2.71 (0.83)	1.43 (1.18)	1.47/0.92/1.67	-1.32/-0.05/-1.27	0.65/0.72/0.46
	S	131421	0.95 (0.37)	1.71 (1.01)	0.80 (0.81)	1.08/0.63/1.30	-0.75/0.15/-0.91	0.76/0.70/0.50
	H	263795	0.27 (0.30)	0.28 (0.37)	0.42 (0.39)	0.25/0.44/0.41	-0.01/-0.15/0.14	0.74/0.29/0.48
	CM	284298	0.99 (0.72)	1.37 (1.50)	1.34 (1.50)	1.00/1.03/1.01	-0.39/-0.35/-0.04	0.89/0.85/0.77
	B	994439	0,00 (0,00)	0.01 (0.04)	0.17 (0.19)	NaN/NaN /0.24	-0.01/-0.17/0.16	NaN/NaN/0.15
	TFM	54125	1.98 (0.77)	3.53 (0.81)	2.52 (1.19)	1.69/1.15/1.53	-1.55/-0.53/-1.01	0.64/0.53/0.39

ZONE SOUTH AFRICA FVC

Table VII.5. As in table VII.1 for South Africa.

S_AFRICA		Nº PIXELS	MEAN (STDV)		RMS	bias	r
MONTH	CLASS		MSG	P3	MSG-P3		
AUG	ALL	698758	0.29 (0.16)	0.31 (0.21)	0.15	-0.02	0.69
	BEF	58594	0.54 (0.12)	0.63 (0.19)	0.17	-0.09	0.66
	BDF	234209	0.38 (0.09)	0.36 (0.17)	0.14	0.02	0.54
	S	168133	0.22 (0.10)	0.26 (0.15)	0.16	-0.04	0.32
	H	146252	0.19 (0.09)	0.19 (0.16)	0.15	0.001	0.41
	CM	75242	0.24 (0.12)	0.29 (0.18)	0.14	-0.06	0.67
	B	16328	0.00 (0.00)	0.03 (0.06)	NaN	-0.03	NaN
	TFM	3762	0.63 (0.09)	0.71 (0.13)	0.12	-0.08	0.68
SEP	ALL	703085	0.29 (0.18)	0.28 (0.22)	0.14	0.02	0.79
	BEF	62779	0.60 (0.12)	0.63 (0.21)	0.16	-0.02	0.67
	BDF	238084	0.39 (0.11)	0.36 (0.19)	0.14	0.03	0.67
	S	167335	0.21 (0.11)	0.20 (0.15)	0.13	0.005	0.56
	H	142697	0.17 (0.09)	0.14 (0.159	0.13	0.04	0.50
	CM	75526	0.23 (0.13)	0.24 (0.19)	0.13	-0.01	0.74
	B	16664	0.00 (0.00)	0.03 (0.07)	NaN	-0.03	NaN
	TFM	2385	0.65 (0.13)	0.63 (0.20)	0.15	0.02	0.69
OCT	ALL	602265	0.29 (0.19)	0.25 (0.24)	0.16	0.04	0.75
	BEF	38547	0.68 (0.14)	0.59 (0.26)	0.26	0.09	0.36
	BDF	182714	0.42 (0.16)	0.38 (0.24)	0.17	0.04	0.72
	S	153425	0.21 (0.12)	0.19 (0.17)	0.15	0.02	0.55
	H	138562	0.16 (0.09)	0.12 (0.15)	0.15	0.04	0.42
	CM	73116	0.23 (0.14)	0.19 (0.18)	0.16	0.04	0.56
	B	15901	0.00 (0.00)	0.007 (0.03)	NaN	-0.007	NaN
	TFM	1219	0.64 (0.19)	0.47 (0.29)	0.32	0.17	0.45
NOV	ALL	570658	0.33 (0.24)	0.30 (0.27)	0.15	0.02	0.83
	BEF	51240	0.76 (0.11)	0.73 (0.14)	0.12	0.03	0.62
	BDF	158443	0.49 (0.19)	0.44 (0.25)	0.19	0.05	0.70
	S	144035	0.22 (0.14)	0.22 (0.20)	0.15	-0.003	0.68
	H	134233	0.17 (0.11)	0.14 (0.17)	0.14	0.033	0.55
	CM	66368	0.25 (0.16)	0.25 (0.22)	0.14	-0.001	0.76
	B	16339	0.00 (0.00)	0.007 (0.03)	NaN	-0.007	NaN
	TFM	4272	0.77 (0.11)	0.71 (0.16)	0.13	0.06	0.68
DEC	ALL	503397	0.41 (0.26)	0.43 (0.29)	0.17	-0.014	0.82
	BEF	61489	0.78 (0.08)	0.75 (0.12)	0.11	0.03	0.52
	BDF	124621	0.62 (0.17)	0.59 (0.21)	0.16	0.03	0.67
	S	119336	0.31 (0.17)	0.38 (0.26)	0.21	-0.07	0.65
	H	123729	0.20 (0.13)	0.21 (0.23)	0.17	-0.005	0.68
	CM	57809	0.34 (0.17)	0.39 (0.24)	0.17	-0.05	0.74
	B	16413	0.00 (0.00)	0.012 (0.06)	NaN	-0.012	NaN
	TFM	4308	0.74 (0.09)	0.71 (0.14)	0.13	0.04	0.51

ZONE SOUTH AFRICA LAI

Table VII.6. As in table VII.2 for South Africa.

S_Africa		Nº PIXELS	MEAN (STDV)			RMS	bias	r
MONTH	CLASS		MSG	MODIS	P3	MSG-MODIS / MSG-P3 / P3-MODIS		
AUG	ALL	697730	0.92(0.65)	1.13(1.07)	1.07(1.12)	0.69/0.78/0.82	-0.21/-0.16/-0.05	0.82/0.76/0.72
	BEF	58406	2.25(0.73)	3.31(1.44)	3.09(1.54)	1.60/1.52/1.58	-1.06/-0.84/-0.22	0.57/0.58/0.45
	BDF	233791	1.20(0.39)	1.39(0.71)	1.28(0.94)	0.62/0.80/0.89	-0.19/-0.09/-0.10	0.56/0.56/0.45
	S	167927	0.63(0.34)	0.77(0.62)	0.75(0.64)	0.48/0.57/0.65	-0.14/-0.12/-0.02	0.69/0.49/0.47
	H	146209	0.50(0.31)	0.49(0.48)	0.51(0.61)	0.34/0.51/0.49	0.01/-0.01/-0.02	0.70/0.54/0.62
	CM	75069	0.67(0.49)	0.87(0.97)	0.90(1.03)	0.69/0.75/0.64	-0.2/-0.23/0.03	0.78/0.78/0.80
	B	16328	0.00 (0.00)	0.07(0.11)	0.07(0.15)	NaN/NaN/0.14	-0.07/-0.07/0,00	NaN/NaN/0.46
	TFM	3741	2.72(0.62)	4.21(1.05)	3.17(1.08)	1.73/1.08/1.49	-1.5/-0.46/-1.04	0.55/0.45/0.49
SEP	ALL	701826	0.96 (0.77)	1.13 (1.21)	0.97 (1.14)	0.66/0.70/0.82	-0.16/-0.01/-0.16	0.88/0.80/0.77
	BEF	62618	2.65 (0.78)	3.84 (1.53)	2.97 (1.51)	1.61/1.29/1.75	-1.19/-0.32/-0.87	0.75/0.56/0.50
	BDF	237603	1.24 (0.45)	1.30 (0.71)	1.22 (0.97)	0.55/0.75/0.85	-0.06/0.03/-0.08	0.63/0.66/0.53
	S	167000	0.59 (0.35)	0.67 (0.54)	0.57 (0.65)	0.37/0.51/0.53	-0.08/0.02/-0.10	0.75/0.63/0.63
	H	142582	0.46 (0.30)	0.45 (0.45)	0.37 (0.56)	0.30/0.47/0.43	0.01/0.08/-0.08	0.74/0.58/0.66
	CM	75360	0.66 (0.51)	0.84 (1.04)	0.74 (0.97)	0.68/0.65/0.65	-0.19/-0.08/-0.11	0.86/0.79/0.79
	B	16663	0.00 (0.00)	0.07 (0.11)	0.06 (0.18)	NaN/NaN/0.19	-0.07 0.06/-0.01	NaN/NaN/0.24
	TFM	2372	2.88 (0.88)	4.24 (1.53)	2.79 (1.39)	1.73/1.15/2.07	-1.37/0.08/-1.45	0.74/0.57/0.50
OCT	ALL	600957	0.96 (0.92)	0.97 (1.11)	0.87 (1.16)	0.51/0.77/0.89	-0.01/0.1/-0.10	0.89/0.76/0.69
	BEF	38374	3.27 (1.00)	3.67 (1.60)	2.73 (1.64)	1.19/1.70/2.19	-0.40/0.54/-0.94	0.72/0.34/0.26
	BDF	182230	1.40 (0.68)	1.30 (0.85)	1.35 (1.23)	0.56/0.86/0.99	0.10/0.04/0.06	0.75/0.74/0.60
	S	153098	0.59 (0.43)	0.60 (0.50)	0.54 (0.72)	0.29/0.55/0.57	-0.01/0.06/-0.07	0.81/0.66/0.63
	H	138442	0.44 (0.31)	0.40 (0.36)	0.33 (0.56)	0.24/0.49/0.47	0.04/0.11/-0.07	0.76/0.52/0.56
	CM	72914	0.67 (0.55)	0.78 (0.96)	0.59 (0.88)	0.56/0.64/0.72	-0.11/0.08/-0.18	0.88/0.69/0.72
	B	15899	0.00 (0.00)	0.07 (0.11)	0.02 (0.08)	NaN/NaN/0.13	-0.07/-0.02/-0.06	NaN/NaN/0.32
	TFM	1193	2.92 (1.36)	3.37 (1.86)	2.01 (1.61)	1.15/1.80/2.25	-0.45/0.91/-1.36	0.83/0.47 /0.47
NOV	ALL	569344	1.20 (1.22)	1.09 (1.32)	1.16 (1.45)	0.58/0.80/0.94	0.12/0.05/0.07	0.90/0.84/0.77
	BEF	51044	3.96 (0.86)	4.05 (1.61)	3.78 (1.48)	1.25/1.33/1.80	-0.09 /0.18/-0.27	0.64/0.46/0.34
	BDF	157974	1.76 (0.92)	1.39 (0.90)	1.65 (1.38)	0.64/0.98/1.14	0.38/0.11/0.26	0.84/0.71/0.60
	S	143717	0.65 (0.52)	0.59 (0.51)	0.68 (0.90)	0.30/0.62/0.68	0.06/-0.04/0.10	0.84/0.74/0.67
	H	134118	0.45 (0.36)	0.39 (0.39)	0.38 (0.63)	0.24/0.49/0.50	0.06/0.07/-0.01	0.81/0.65/0.62
	CM	66155	0.76 (0.67)	0.83 (1.13)	0.84 (1.14)	0.60/0.69/0.71	-0.07/-0.08/0.01	0.91/0.83/0.80
	B	16336	0.00 (0.00)	0.07 (0.10)	0.02 (0.11)	NaN/NaN/0.14	-0.07/-0.02/-0.05	NaN/NaN/0.17
	TFM	4238	3.91 (0.88)	4.45 (1.34)	3.56 (1.48)	1.06/1.35/1.78	-0.54/0.35/-0.89	0.74/0.49/0.40
DEC	ALL	502105	1.61 (1.40)	1.33 (1.51)	1.73 (1.63)	0.86/0.96/1.29	0.28/-0.13/0.40	0.84/0.81/0.70
	BEF	61266	4.06 (0.76)	4.22 (1.51)	3.86 (1.38)	1.42/1.32/1.86	-0.16/0.21/-0.37	0.37/0.37/0.21
	BDF	124164	2.51 (0.99)	1.64 (0.93)	2.54 (1.43)	1.17/1.08/1.58	0.87/-0.03/0.90	0.66/0.66/0.46
	S	119028	0.96 (0.67)	0.75 (0.77)	1.32 (1.24)	0.51/0.96/1.18	0.22/-0.36/0.58	0.80/0.72/0.56
	H	123617	0.56 (0.44)	0.43 (0.49)	0.65 (0.92)	0.32/0.68/0.79	0.12/-0.10/0.22	0.80/0.73/0.58
	CM	57619	1.07 (0.76)	1.06 (1.35)	1.38 (1.30)	0.78/0.90/1.10	0.01/-0.31/0.32	0.88/0.79/0.69
	B	16411	0.00 (0.00)	0.07 (0.11)	0.03 (0.21)	NaN/NaN/0.22	-0.07/-0.03/-0.04	NaN /NaN/0.18
	TFM	4273	3.57 (0.67)	4.54 (1.28)	3.42 (1.40)	1.38/1.32/1.87	-0.97/0.15/-1.12	0.65/0.38/0.39

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Table VII.7. As in table VII.1 for South America.

S_AMERICA		Nº PIXELS	MEAN (STDV)		RMS	bias	r
MONTH	CLASS		MSG	P3	MSG-P3		
AUG	ALL	335102	0.51 (0.23)	0.56 (0.24)	0.17	-0.05	0.78
	BEF	89943	0.72 (0.18)	0.75 (0.15)	0.16	-0.03	0.59
	BDF	39034	0.49 (0.18)	0.47 (0.19)	0.17	0.02	0.61
	S	14181	0.39 (0.19)	0.37 (0.27)	0.18	0.03	0.75
	H	56646	0.41 (0.19)	0.45 (0.25)	0.16	-0.04	0.79
	CM	128728	0.45 (0.18)	0.55 (0.19)	0.18	-0.09	0.69
	B	6570	0.00 (0.00)	0.05 (0.14)	NaN	-0.05	NaN
	TFM	2234	0.67 (0.21)	0.72 (0.18)	0.23	-0.05	0.33
SEP	ALL	396394	0.48 (0.24)	0.54 (0.25)	0.18	-0.06	0.75
	BEF	124606	0.69 (0.19)	0.73 (0.18)	0.18	-0.04	0.54
	BDF	41785	0.39 (0.179	0.40 (0.19)	0.17	-0.009	0.54
	S	14122	0.34 (0.18)	0.33 (0.26)	0.19	0.009	0.68
	H	63160	0.37 (0.19)	0.42 (0.25)	0.18	-0.05	0.73
	CM	144729	0.41 (0.18)	0.51 (0.219	0.19	-0.09	0.65
	B	7992	0.00 (0.00)	0.09 (0.18)	NaN	-0.09	NaN
	TFM	3279	0.67 (0.19)	0.70 (0.19)	0.25	-0.03	0.23
OCT	ALL	322469	0.47 (0.24)	0.51 (0.26)	0.19	-0.05	0.72
	BEF	74630	0.70 (0.20)	0.69 (0.22)	0.23	0.012	0.41
	BDF	38028	0.37 (0.16)	0.40 (0.22)	0.16	-0.03	0.67
	S	13196	0.36 (0.19)	0.35 (0.29)	0.21	0.014	0.70
	H	58679	0.39 (0.21)	0.43 (0.27)	0.18	-0.04	0.76
	CM	129455	0.43 (0.17)	0.52 (0.22)	0.18	-0.09	0.70
	B	8481	0.00 (0.00)	0.08 (0.16)	NaN	-0.08	NaN
	TFM	2443	0.72 (0.18)	0.67 (0.23)	0.26	0.04	0.24
NOV	ALL	266368	0.52 (0.27)	0.52 (0.28)	0.18	-0.001	0.78
	BEF	57177	0.75 (0.20)	0.71 (0.20)	0.21	0.04	0.48
	BDF	35427	0.48 (0.23)	0.46 (0.24)	0.18	0.013	0.73
	S	11485	0.45 (0.26)	0.37 (0.32)	0.22	0.09	0.77
	H	49371	0.45 (0.21)	0.44 (0.29)	0.17	0.01	0.82
	CM	104303	0.49 (0.22)	0.53 (0.24)	0.17	-0.04	0.74
	B	8605	0.00 (0.00)	0.08 (0.15)	NaN	-0.08	NaN
	TFM	1721	0.72 (0.16)	0.69 (0.21)	0.23	0.03	0.31
DEC	ALL	200179	0.61 (0.25)	0.59 (0.26)	0.22	0.009	0.65
	BEF	30322	0.78 (0.19)	0.73 (0.17)	0.20	0.06	0.43
	BDF	27241	0.65 (0.22)	0.64 (0.20)	0.21	0.014	0.5
	S	10375	0.52 (0.28)	0.34 (0.349	0.26	0.12	0.75
	H	43255	0.54 (0.25)	0.52 (0.28)	0.22	0.02	0.68
	CM	81359	0.63 (0.18)	0.65 (0.22)	0.22	-0.02	0.45
	B	7627	0.00 (0.00)	0.12 (0.23)	NaN	-0.12	NaN
	TFM	1336	0.71 (0.18)	0.69 (0.19)	0.22	0.02	0.29

ZONE SOUTH AMERICA LAI

S_AMERICA		Nº PIXELS	MEAN (STDV)			RMS	bias	r
MONTH	CLASS		MSG	MODIS	P3	MSG-MODIS / MSG-P3 / P3-MODIS		
AUG	ALL	332647	2.09 (1.47)	2.41 (1.67)	2.43 (1.73)	1.03/1.13/1.10	-0.31/-0.34/0.024	0.81/0.79/0.79
	BEF	88718	3.79 (1.38)	4.29 (1.41)	4.14 (1.67)	1.39/1.51/1.39	-0.50/-0.35/-0.15	0.57/0.55/0.61
	BDF	39008	1.75 (0.92)	1.83 (1.02)	1.76 (1.16)	0.94/0.90/0.90	-0.07/-0.007/-0.07	0.54/0.65/0.67
	S	13979	1.35 (0.84)	1.35 (1.04)	1.35 (1.24)	0.74/0.87/0.75	-0.004/0.006/0.002	0.71/0.71/0.79
	H	56092	1.33 (0.80)	1.54 (1.07)	1.62 (1.26)	0.81/0.89/0.94	-0.21/-0.29/0.08	0.69/0.75/0.69
	CM	128280	1.55 (0.90)	1.89 (1.17)	2.04 (1.23)	0.89/1.01/1.05	-0.34/-0.49/0.15	0.71/0.69/0.63
	B	6570	0.00 (0.00)	0.24 (0.57)	0.16 (0.54)	NaN/NaN/0.34	-0.24/-0.16/-0.08	NaN/NaN/ 0.83
	TFM	2156	3.39 (1.32)	4.13 (1.18)	3.91 (1.77)	1.44/1.74/1.62	-0.73/-0.51/-0.22	0.52/0.45/0.47
SEP	ALL	393004	1.98 (1.48)	2.48 (1.91)	2.31 (1.78)	1.23/1.21/1.18	-0.50/-0.32/-0.18	0.81/0.76/0.80
	BEF	122771	3.53 (1.39)	4.59 (1.52)	3.94 (1.81)	1.71/1.69/1.57	-1.06/-0.41/-0.65	0.58/0.50/0.65
	BDF	41764	1.32 (0.76)	1.57 (1.09)	1.33 (1.06)	0.95/0.89/ 0.85	-0.25/-0.005/-0.24	0.56/0.56/0.72
	S	13913	1.11 (0.73)	1.21 (1.04)	1.11 (1.06)	0.82/0.79/0.75	-0.10/0.00/ -0.10	0.63/0.67/0.75
	H	62537	1.19 (0.82)	1.36 (1.08)	1.44 (1.19)	0.92/0.87/0.94	-0.17/-0.25/0.08	0.58/0.71/0.67
	CM	144112	1.39 (0.87)	1.68 (1.18)	1.79 (1.14)	0.97/0.97/1.03	-0.29/-0.41/0.12	0.63/0.65/0.61
	B	7907	0.00 (0.00)	0.38 (0.64)	0.30 (0.71)	NaN/NaN /0.47	-0.38/-0.30/-0.08	NaN/NaN/0.77
	TFM	3170	3.37 (1.26)	4.45 (1.39)	3.66 (1.79)	1.69/1.79/1.79	-1.08/-0.29/-0.79	0.52/0.36/0.52
OCT	ALL	320011	1.86 (1.45)	1.98 (1.69)	2.07 (1.60)	0.97/1.23/1.29	-0.12/-0.21/0.09	0.83/0.69/0.69
	BEF	73667	3.69 (1.55)	4.16 (1.68)	3.49 (1.84)	1.38/1.88/1.89	-0.47/0.19/-0.66	0.68/0.40/0.49
	BDF	38008	1.22 (0.71)	1.31 (0.89)	1.35 (1.12)	0.73/0.86/0.90	-0.09/-0.14/0.04	0.61/0.65/0.62
	S	12960	1.21 (0.77)	1.05 (0.91)	1.28 (1.31)	0.69/0.98/0.94	0.16/-0.07/0.23	0.69/0.67/0.72
	H	58052	1.29 (0.89)	1.24 (0.99)	1.57 (1.29)	0.83/0.95/1.04	0.05/-0.28/0.33	0.62/0.71/0.66
	CM	128935	1.45 (0.81)	1.47 (1.05)	1.89 (1.19)	0.83/0.99/1.15	-0.012/-0.45/0.44	0.63/0.66/0.55
	B	8389	0.00 (0.00)	0.30 (0.52)	0.23 (0.52)	NaN/NaN /0.35	-0.30/-0.23/-0.07	NaN/NaN/0.78
	TFM	2380	3.65 (1.37)	4.39 (1.38)	3.29 (1.75)	1.56/1.88/2.09	-0.74/0.35/-1.09	0.50/0.32/0.37
NOV	ALL	263180	2.23 (1.64)	1.87 (1.59)	2.15 (1.67)	1.06/1.17/1.34	0.36/0.08/0.28	0.81/0.75 /0.68
	BEF	55955	4.19 (1.53)	3.88 (1.69)	3.60 (1.79)	1.47/1.80/1.85	0.31/0.58/-0.27	0.61/0.48/0.45
	BDF	35400	1.81 (1.22)	1.28 (0.89)	1.71 (1.35)	1.01/0.97/1.18	0.53/0.09/0.44	0.71/0.72/0.59
	S	11173	1.75 (1.28)	1.09 (0.99)	1.49 (1.59)	1.02/1.05/1.19	0.66/0.26/0.40	0.79/0.77/0.71
	H	48464	1.64 (1.22)	1.25 (0.97)	1.63 (1.38)	0.87/0.87/1.06	0.39/0.005 /0.39	0.77/0.78/0.69
	CM	103676	1.82 (1.14)	1.49 (1.07)	1.99 (1.34)	0.93/0.94/1.23	0.32/-0.17/0.49	0.69/0.73/0.58
	B	8512	0.00 (0.00)	0.26 (0.45)	0.21 (0.51)	NaN/NaN /0.34	-0.26/-0.22/-0.05	NaN/NaN/ 0.77
	TFM	1690	3.62 (1.26)	4.32 (1.44)	3.43 (1.74)	1.55/1.84 /1.93	-0.70/0.18/-0.89	0.49/0.29/0.43
DEC	ALL	197717	2.67 (1.59)	1.78 (1.43)	2.63 (1.64)	1.37/1.46/1.74	0.89/0.04/0.85	0.77/0.59/0.52
	BEF	29521	4.54 (1.47)	3.69 (1.62)	3.70 (1.65)	1.74/1.88/1.71	0.85/0.84/0.02	0.52/0.43/0.45
	BDF	27227	2.86 (1.43)	1.50 (0.96)	2.75 (1.47)	1.68/1.51/1.91	1.35/0.10/1.25	0.72/0.46/0.35
	S	10095	2.17 (1.52)	1.21 (1.08)	1.71 (1.71)	1.29/1.34/1.36	0.96/0.46/0.50	0.84/0.70/0.67
	H	42467	2.07 (1.25)	1.34 (1.03)	2.10 (1.46)	1.06/1.23/1.48	0.73/-0.03/0.76	0.79/0.59/0.53
	CM	80871	2.55 (1.48)	1.62 (1.13)	2.79 (1.47)	1.32/1.42/1.91	0.93/-0.24/1.17	0.67/0.46/0.35
	B	7536	0.00 (0.00)	0.20 (0.36)	0.43 (0.94)	NaN/NaN/0.78	-0.20/-0.43/0.23	NaN/NaN/0.66
	TFM	1278	3.65 (1.37)	3.96 (1.46)	3.33 (1.59)	1.55/1.62/1.79	-0.31/0.32/-0.63	0.42/0.43/0.39

Table VII.8. As in table VII.8 for South America

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