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Intercomparison of FAPAR products derived from various optical sensors over terrestrial surfaces

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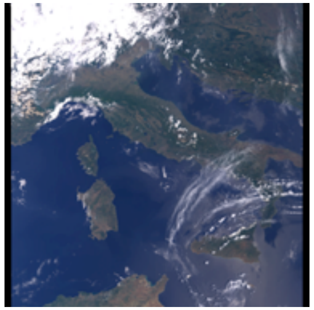
Institute for Environment and Sustainability

12 - 14 October 2004

RS Products

- Modern Remote Sensing algorithms are physically-based & designed to retrieve **biophysical surface parameters** such as surface albedo, FAPAR, LAI, surfaces roughness, etc …
- Physically-based algorithms can be prototyped for a variety of instruments, this approach allows product inter-comparisons.
- These parameters correspond to physical quantities that can be:
  - measured independently from RS data, and
  - compared against other sources of information (e.g., field in-situ measurements and simulations).
  - used for both delivered long time series of products or merged together for larger spatial samples.

MERIS FAPAR algorithm



Satellite Data

BRF TOA | View angles | Sun angles

Angular/Atmospheric `Rectification'

$$\tilde{\rho}(\lambda_i) = \frac{\rho^{TOA}(\Omega_0,\Omega_v,\lambda_i)}{F(\Omega_0,\Omega_v,k_{\lambda i},\Omega_{\lambda i}^{HG},\rho_{\lambda ic})}$$

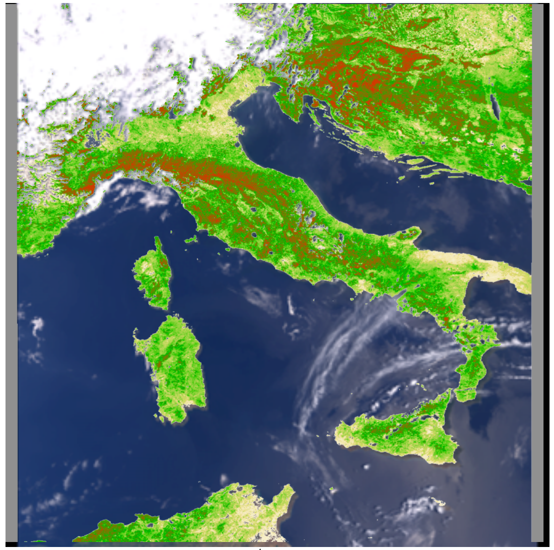
Rectified Red

$$\rho_{Rred} = g_1[\tilde{\rho}(\lambda_{blu}),\tilde{\rho}(\lambda_{red})]$$

Rectified NIR

$$\rho_{Rnir} = g_2[\tilde{\rho}(\lambda_{blu}),\tilde{\rho}(\lambda_{nir})]$$

$$\mathrm{FAPAR} = g_0(\rho_{Rred},\rho_{Rnir})$$



Govaerts, Y. et. al. (1999) 'Designing Optimal Spectral Indices: A Feasibility and Proof of Concept Study', *International Journal of Remote Sensing*, **20**, 1853-1873.
Gobron, N. et. al. (1999) 'The MERIS Global Vegetation Index (MGVI): Description and Preliminary Application', *International Journal of Remote Sensing*, **20**, 1917-1927.

FAPAR products

- Equivalent physically based algorithms have been developed for optical sensors (MERIS, SeaWiFS, GLI, MODIS & MISR/Terra).

- SeaWiFS processing chain has been designed for delivering time series products at global scale.
- It serves as a prototype for the MERIS FAPAR product at Level 2 and further Level 3.

Gobron, N., F. Mélin, B. Pinty, M. M. Verstraete, J.-L. Widlowski, and G. Bucini (2001) 'A Global Vegetation Index for SeaWiFS: Design and Applications', *Remote Sensing and Climate Modeling: Synergies and Limitations*, Edited by M. Beniston and M. M. Verstraete, Kluwer Academic Publishers, Dordrecht, 5-21.

Gobron, N. et al. (2002) 'Medium Resolution Imaging Spectrometer (MERIS) - Level 2 Land Surface Products - Algorithm Theoretical Basis Document, Institute for Environment and Sustainability, EUR Report No. 20143 EN

Mélin, F., C. Steinich, N. Gobron, B. Pinty, and M. M. Verstraete (2002) 'Optimal merging of LAC and GAC data from SeaWiFS', *International Journal of Remote Sensing*, 23, 801-807.

Taberner, M., N. Gobron, F. Mélin, B. Pinty, and M. M. Verstraete (2002) 'The STARS FAPAR Algorithm: A Consolidated and Generalized Software Package', *Institute for Environment and Sustainability*, EUR Report No. 20145 EN, 75 pp.

Requirements for intercomparison

✓ Intercomparison of large scale (spatial and temporal) data of terrestrial products implies for each sensor products to be analyzed …

- from sensor nominal resolution scale of daily products to larger spatial/temporal scale

→ Temporal composite and re-gridding algorithms:

- Daily to time composite products
- Degradation of nominal spatial resolution to large scale.

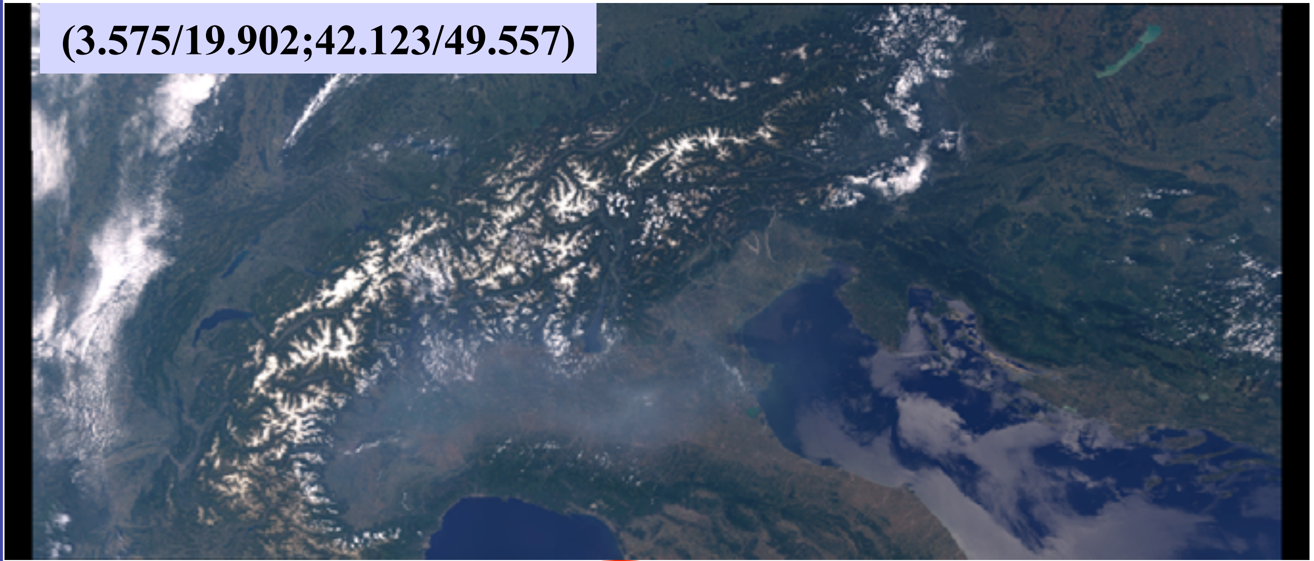
Results of Intercomparison

- ✓ Daily FAPAR of similar algorithm are inter-compared over the same region using various instruments.
- Request to remap data/products from both sensors into geographical projection using nearest-neighbor techniques.
- ✓ Large temporal scale inter-comparison

→ time series of daily profiles

→ time period-composite

MERIS & SeaWiFS data - 19 June 2002



Orbit 1579

@ 09:48

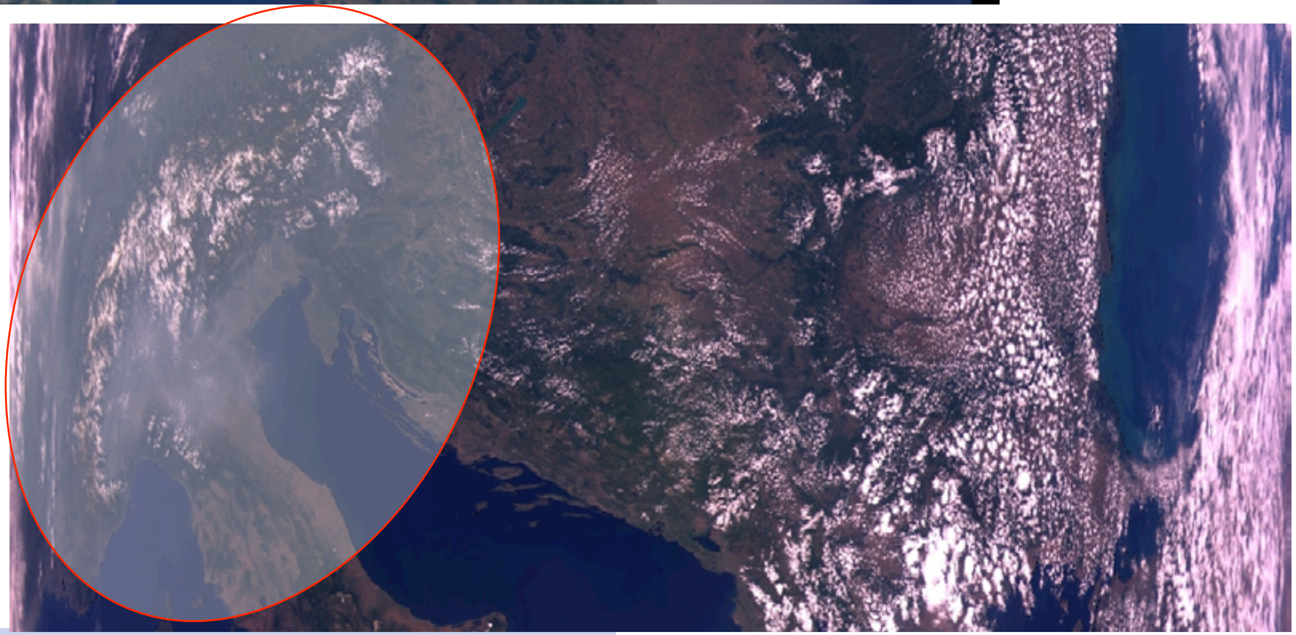
(Push-broom)

ENVISAT
CARING FOR THE EARTH

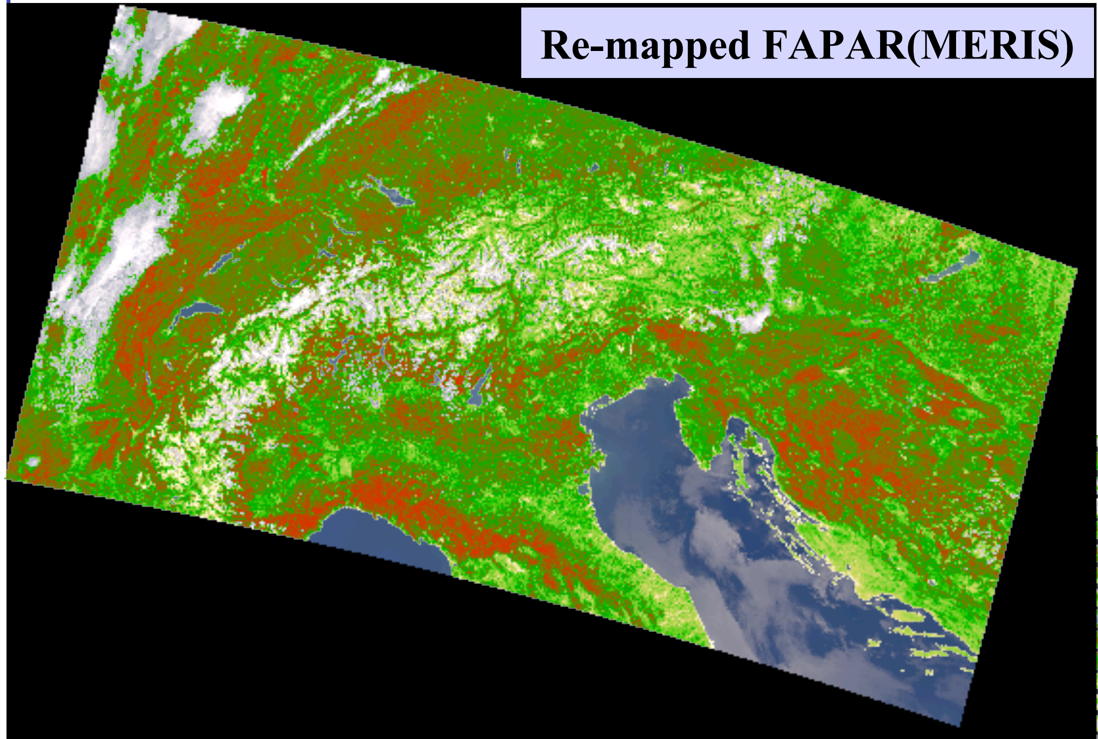
SeaWiFS

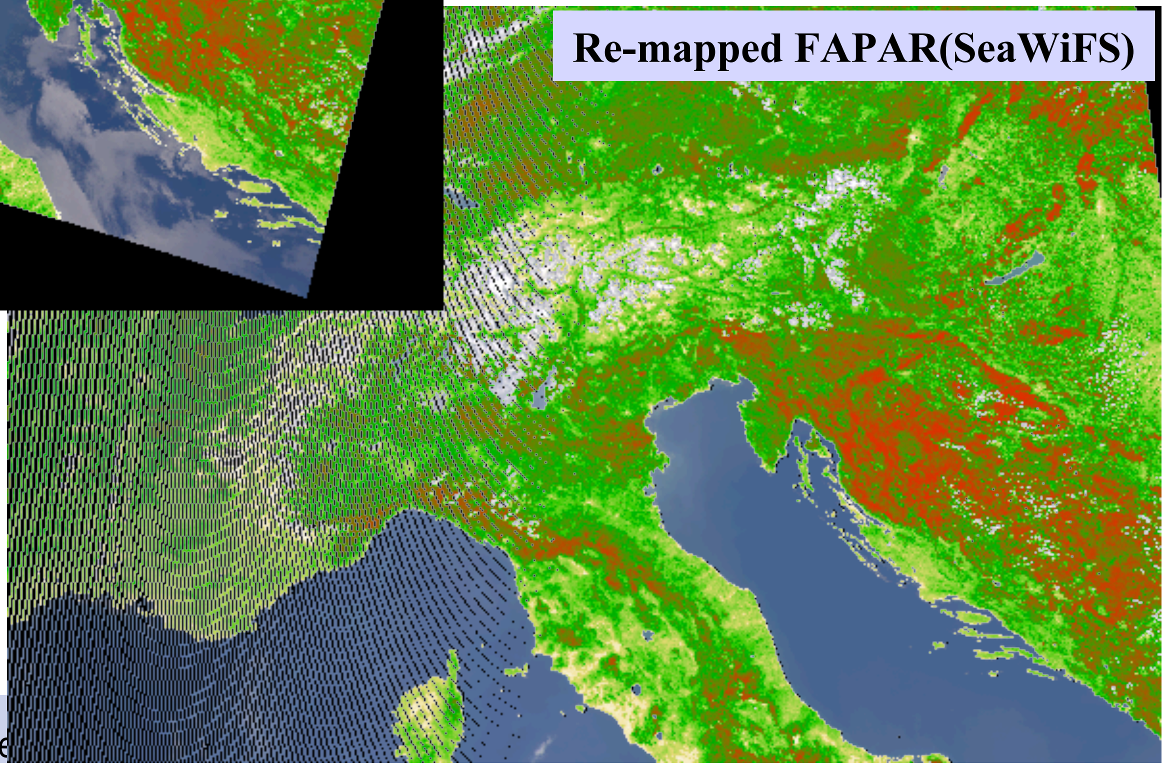
@ 11:17

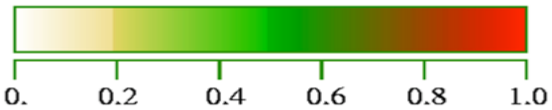
(Scanner)



Re-mapping FAPAR derived from MERIS and SeaWiFS into Global Sinusoidal projection @2.17 km

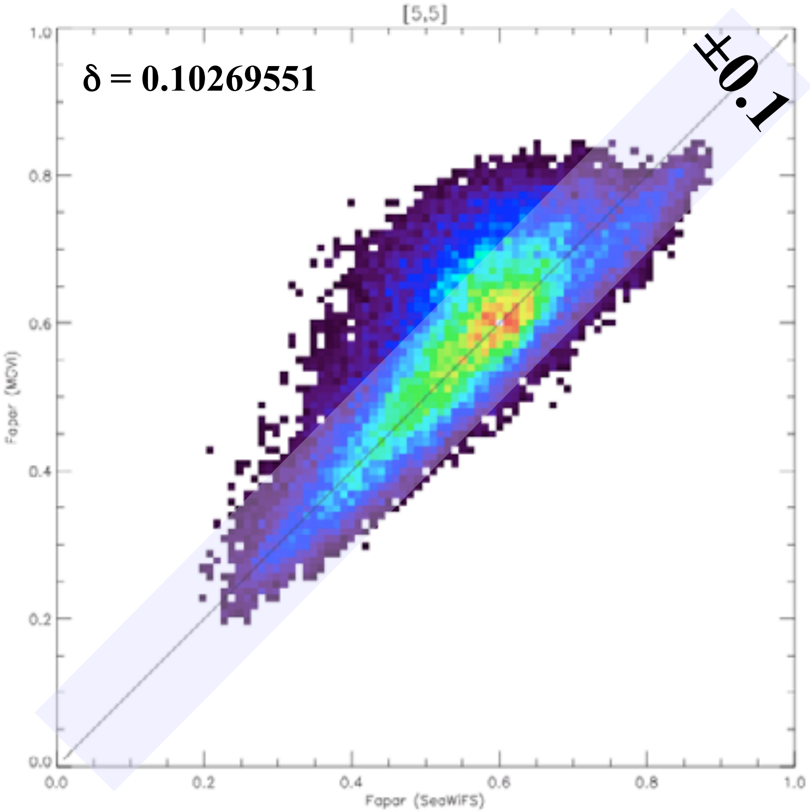




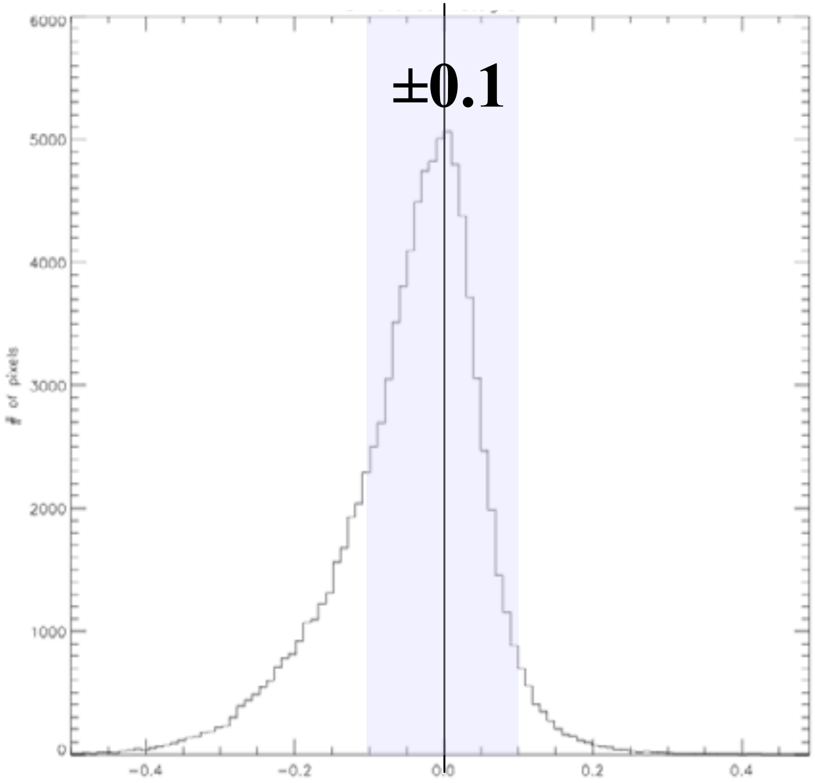


2002/06/19

Comparing FAPAR derived from MERIS and SeaWiFS



FAPAR (SeaWiFS) – FAPAR (MERIS)



2002/06/19

Gobron, N. et al. (2002) 'MERIS Land Algorithm: preliminary results', *Proceedings of the ENVISAT Validation Workshop*, Frascati, Italy, 09-13 December, 2002, European Space Agency **SP 531**.

Results of Intercomparison

- ✓ Daily FAPAR of similar algorithm are inter-compared over the same region using various instruments.
- Request to remap data/products from both sensors into geographical projection using nearest-neighbors techniques.
- ✓ Large temporal scale inter-comparison

→ time series of daily profiles

→ time period-composite

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Soröe (Denmark); Hardwood forest - Fagus sylvatica

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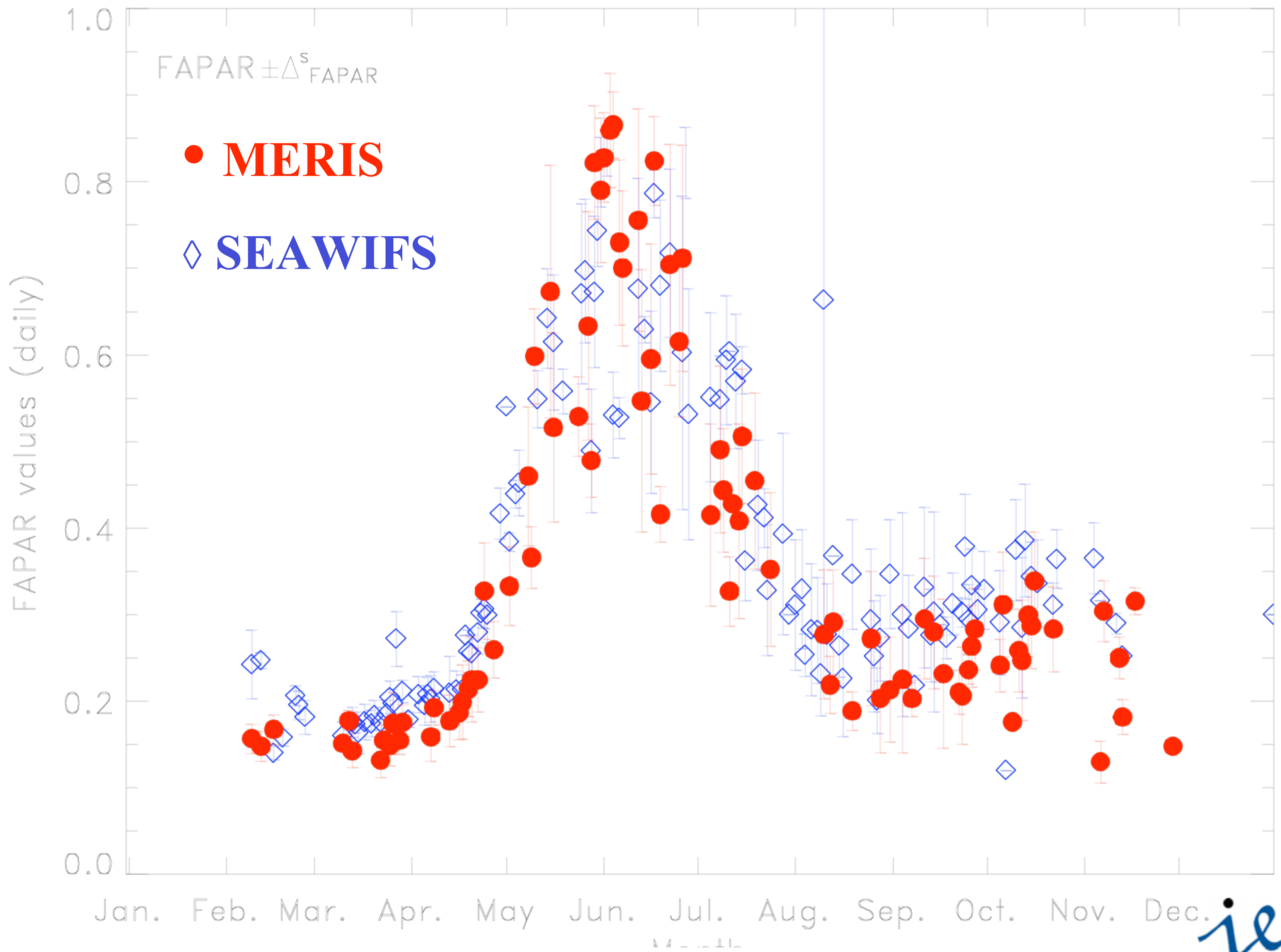

Gobron, N. et al. (2003) 'Evaluation of the MERIS Global Vegetation Index: Methodology and Initial Results', *Proceedings of the MERIS and ATSR Calibration and Geophysical Validation (MAVT),* Frascati, Italy, 20-23 October, 2003, European Space Agency **SP 541**.

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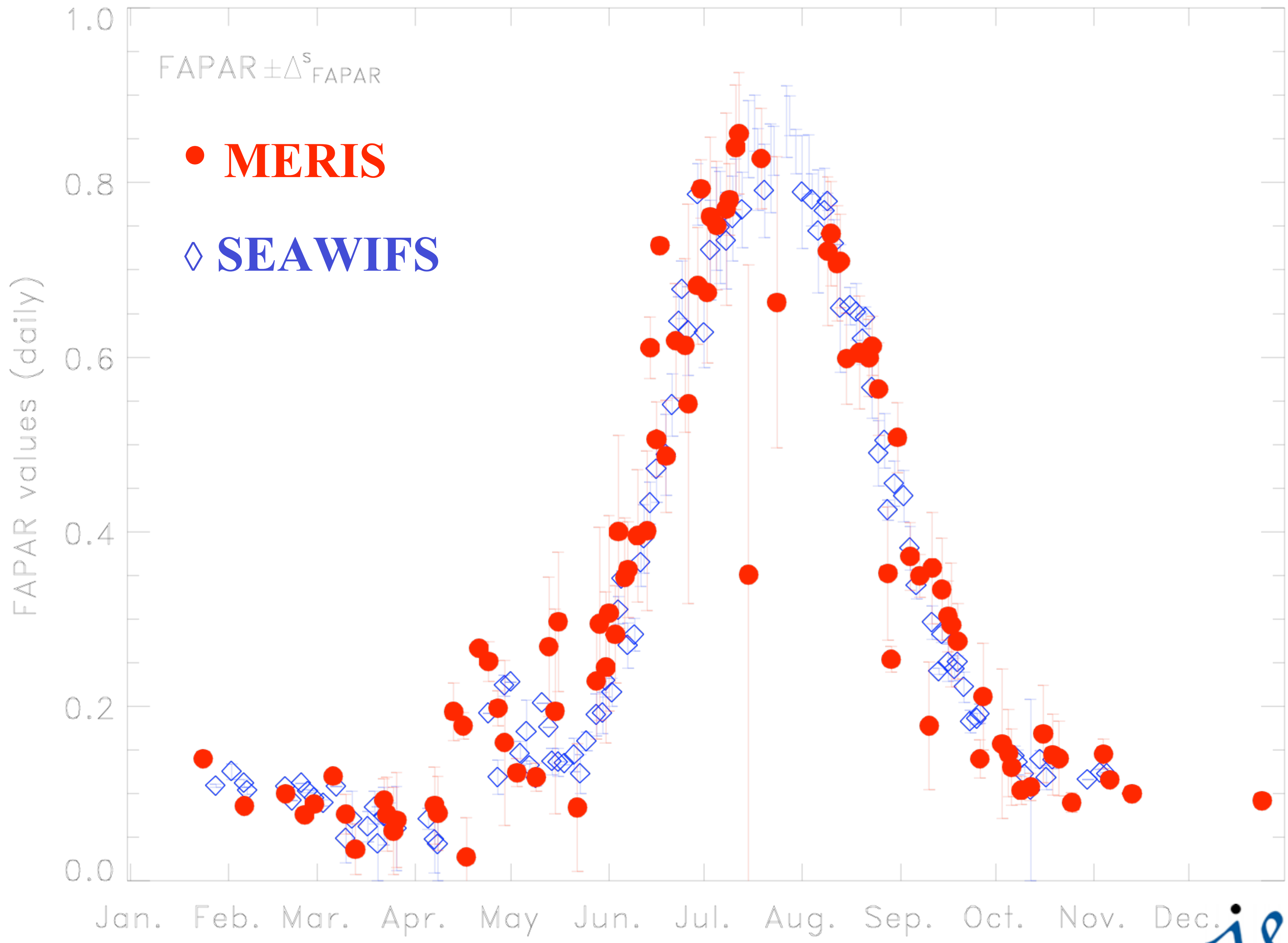
Pavia (Italy); Agricultural Fields – Rice



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Gobron, N. et al. (2003) 'Evaluation of the MERIS Global Vegetation Index: Methodology and Initial Results', *Proceedings of the MERIS and ATSR Calibration and Geophysical Validation (MAVT),* Frascati, Italy, 20-23 October, 2003, European Space Agency **SP 541**.

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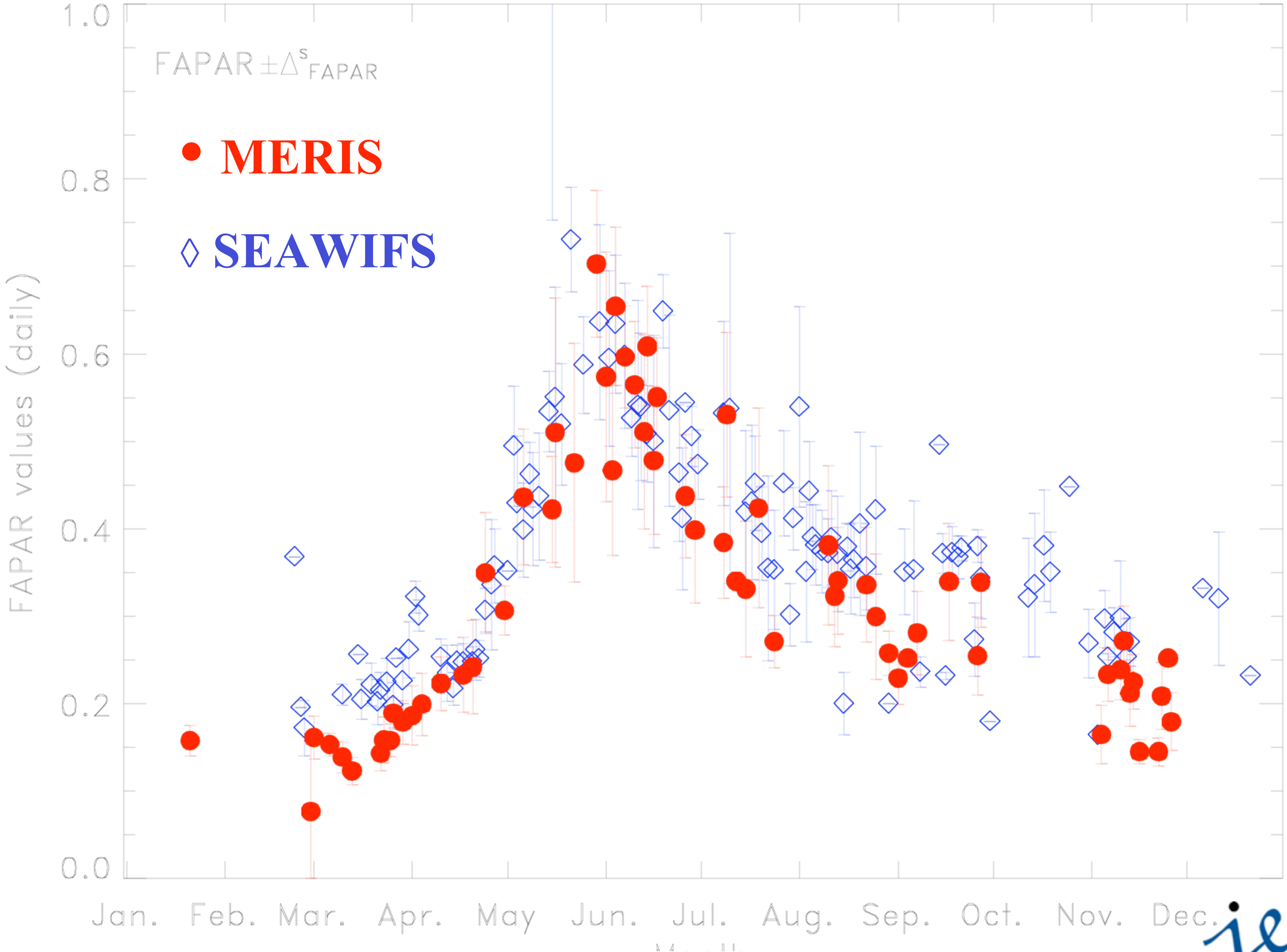
Tharandt (Germany); Conifereous Forest - Pices Abies



Gobron, N. et al. (2003) 'Evaluation of the MERIS Global Vegetation Index: Methodology and Initial Results', *Proceedings of the MERIS and ATSR Calibration and Geophysical Validation (MAVT),* Frascati, Italy, 20-23 October, 2003, European Space Agency **SP 541**.

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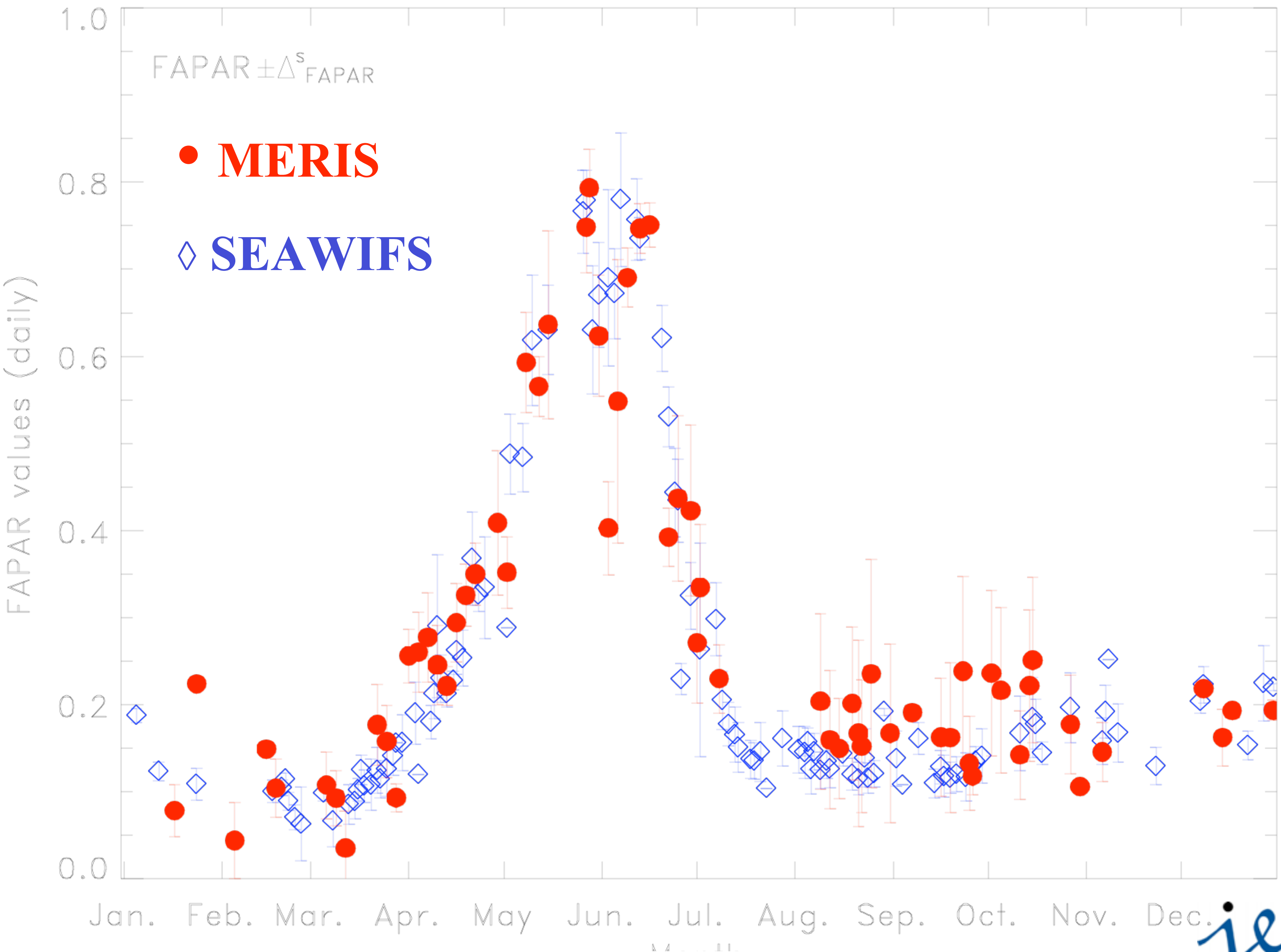
Chartres (France); Agricultural - Rape flowers and wheat



Gobron, N. et al. (2003) 'Evaluation of the MERIS Global Vegetation Index: Methodology and Initial Results', *Proceedings of the MERIS and ATSR Calibration and Geophysical Validation (MAVT),* Frascati, Italy, 20-23 October, 2003, European Space Agency **SP 541**.

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Scatter-plot of daily FAPAR values

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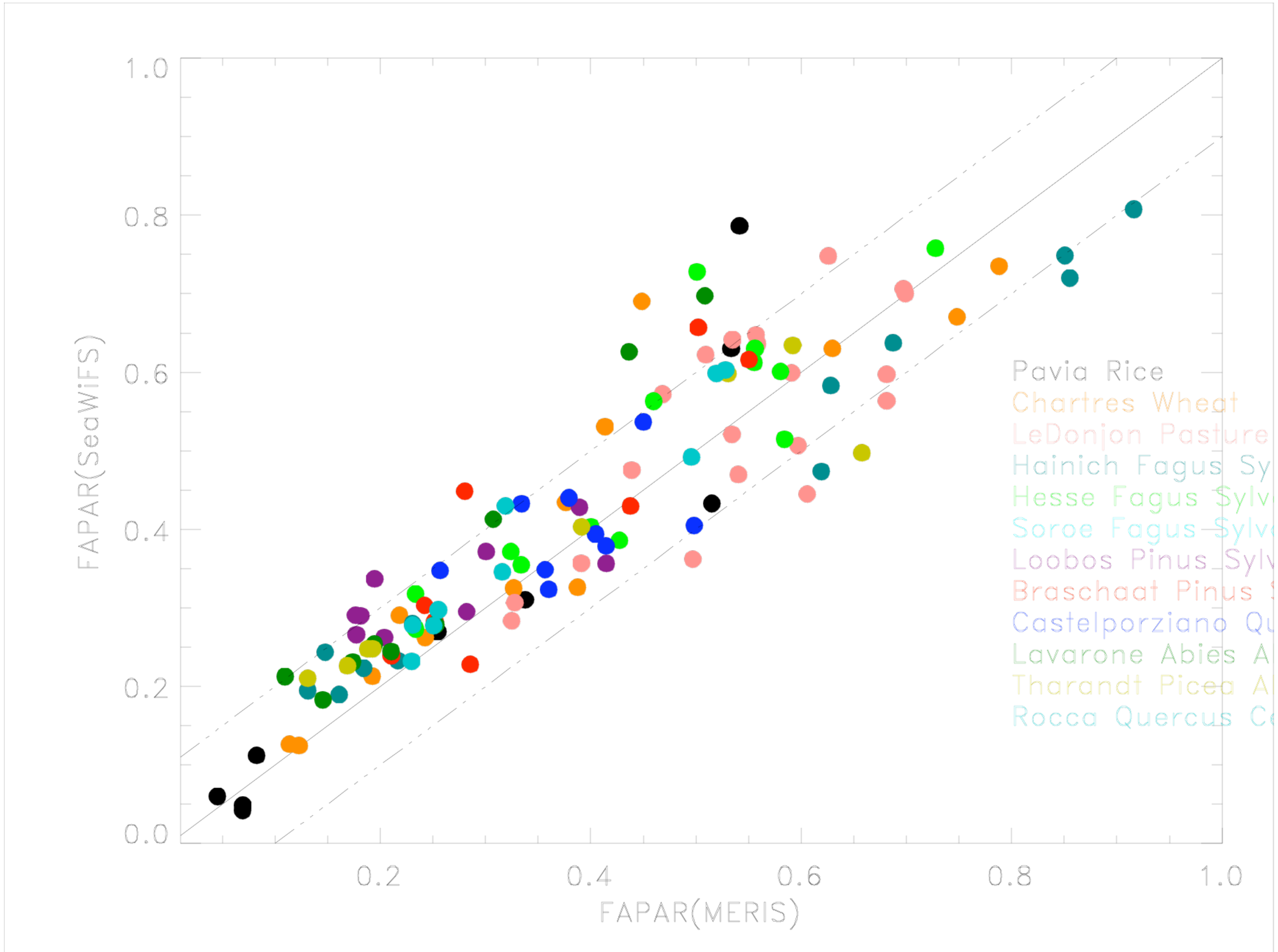

Gobron, N. et al. (2003) 'Evaluation of the MERIS Global Vegetation Index: Methodology and Initial Results', *Proceedings of the MERIS and ATSR Calibration and Geophysical Validation (MAVT),* Frascati, Italy, 20-23 October, 2003, European Space Agency **SP 541**.

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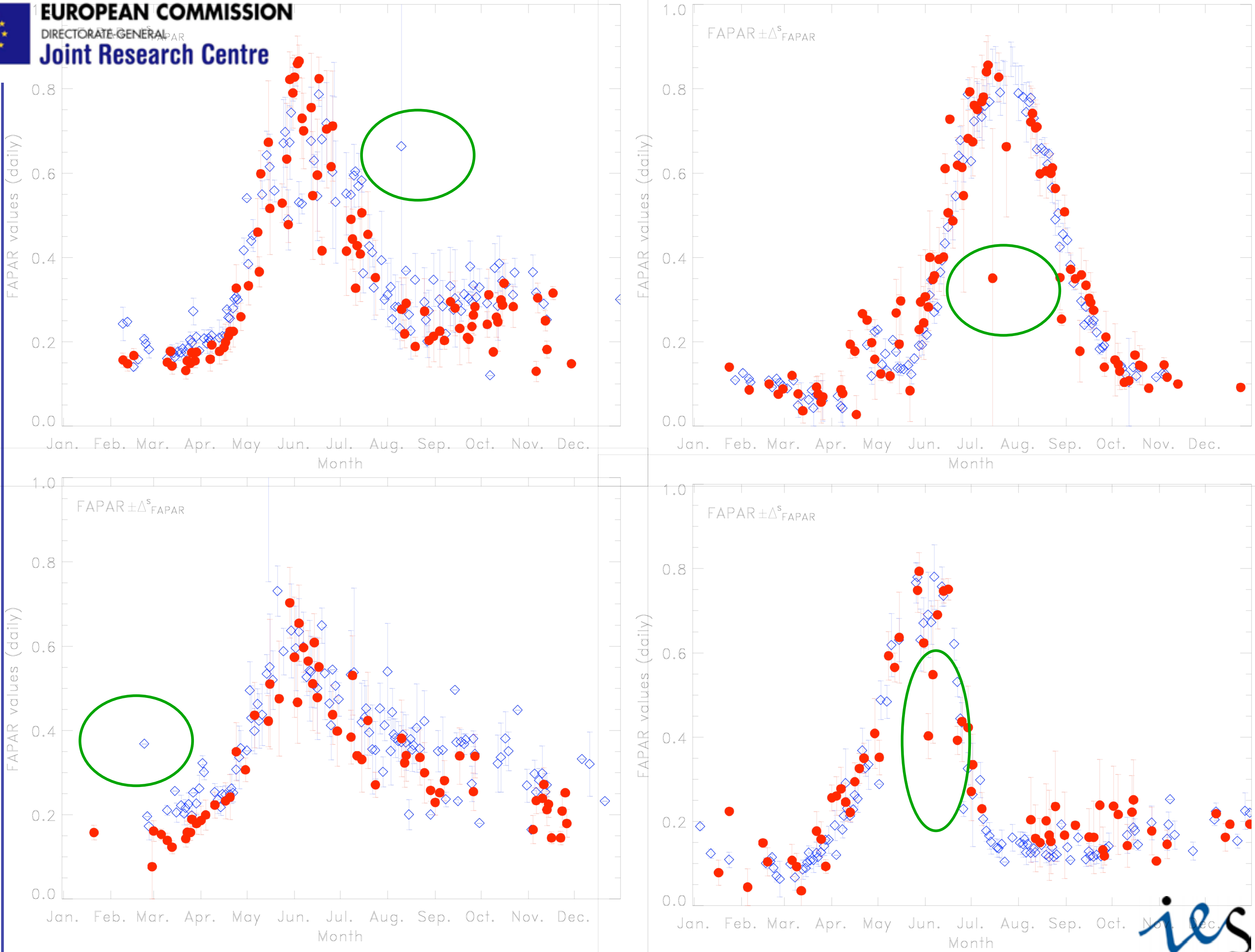

The time composite algorithm

1) Compute the temporal average and corresponding deviation of product S, e.g. FAPAR, over the N-day period:

$$\overline{S} = \tfrac{1}{T}\sum_{t=1}^{T} S(t) \qquad \Delta_S^T = \frac{1}{T}\sum_{t=1}^{T} |\, S(t) - \overline{S}\,|$$

T is the number of valid days during the N-day period

2) Select the "most representative day" in the N-days time series such that it corresponds to the value which minimizes $|\, S(t) - \overline{S}\,|$

NB: the procedure is applied twice sequentially to reject values outside the range $\overline{S} \pm \Delta_S^T$

Pinty, B., N. Gobron, F. Mélin and M. M. Verstraete (2002) 'A Time Composite Algorithm Theoretical Basis Document', Institute for Environment and Sustainability, EUR Report No. 20150 EN, 8 pp.

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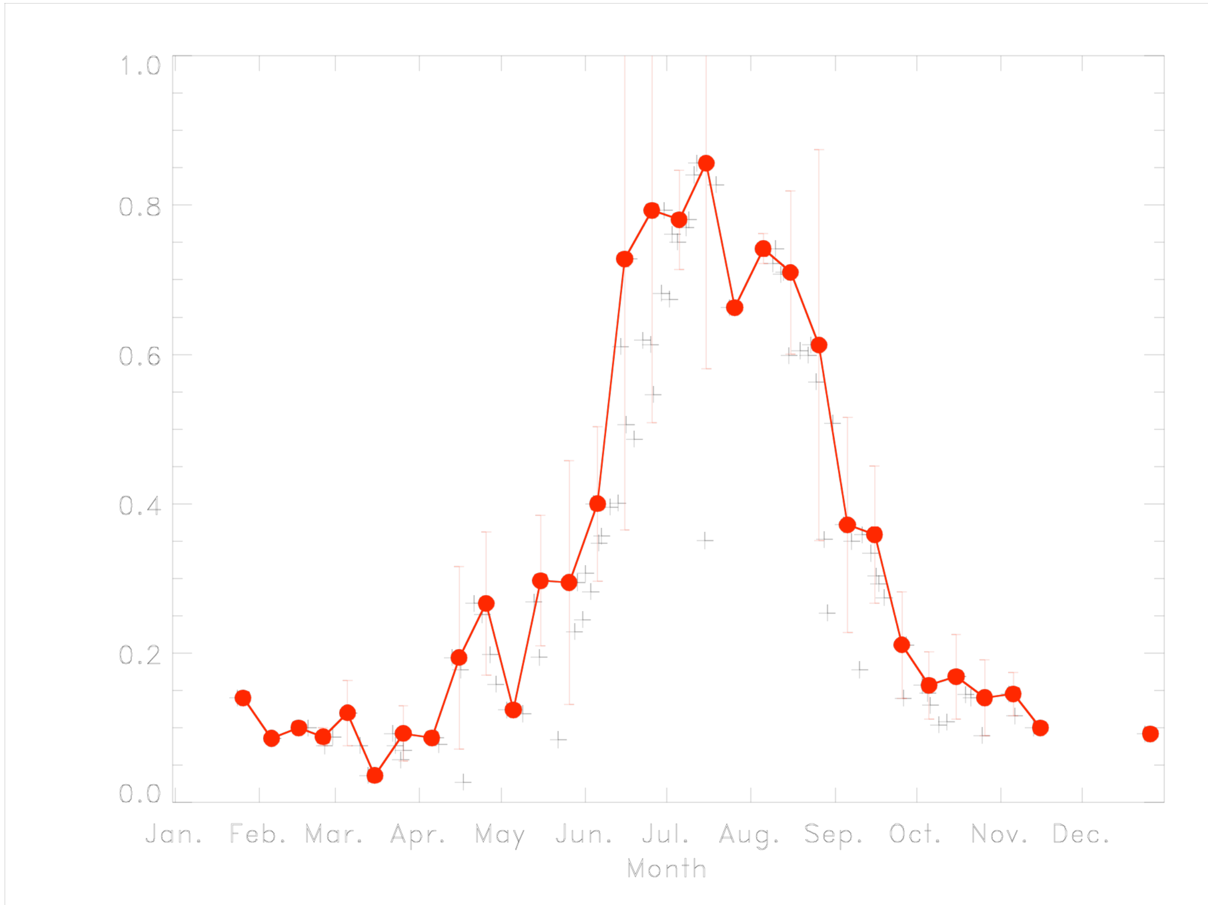
Ten-days MERIS/FAPAR time series



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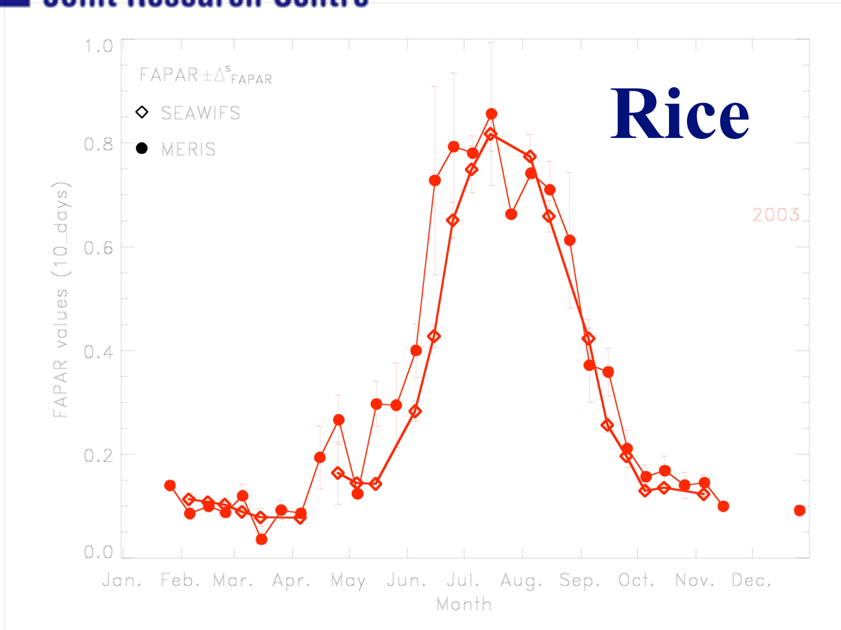
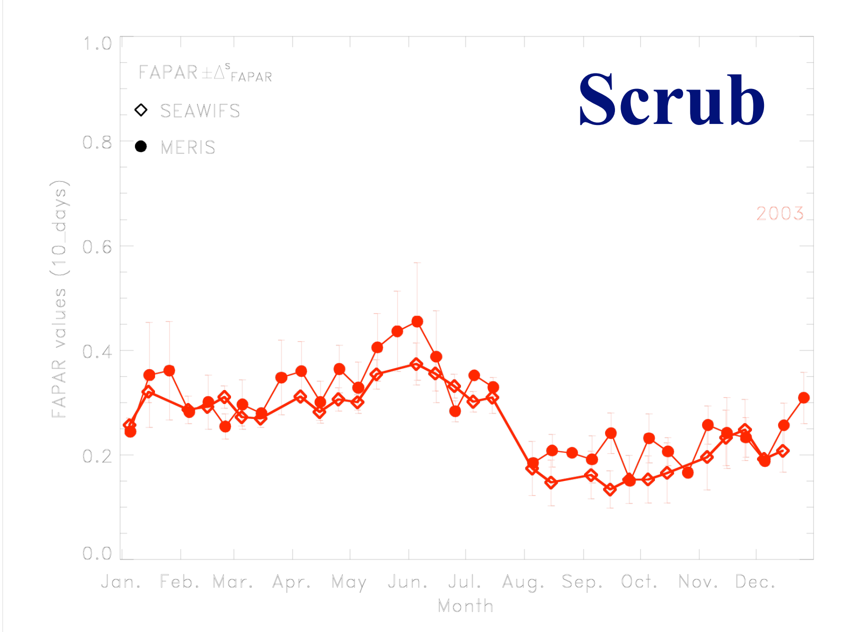
Preliminary Intercomparison

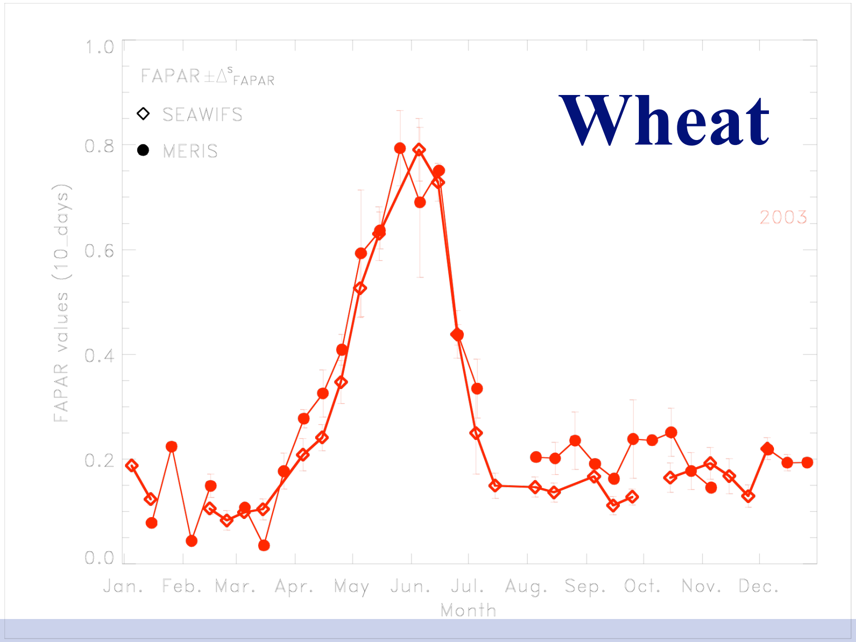
- ✓ Daily products are inter-compared over the same region using various instruments.
- Request to remap data/products from both sensors into geographical projection using nearest-neighbors techniques.
- ✓ Large temporal scale inter-comparison

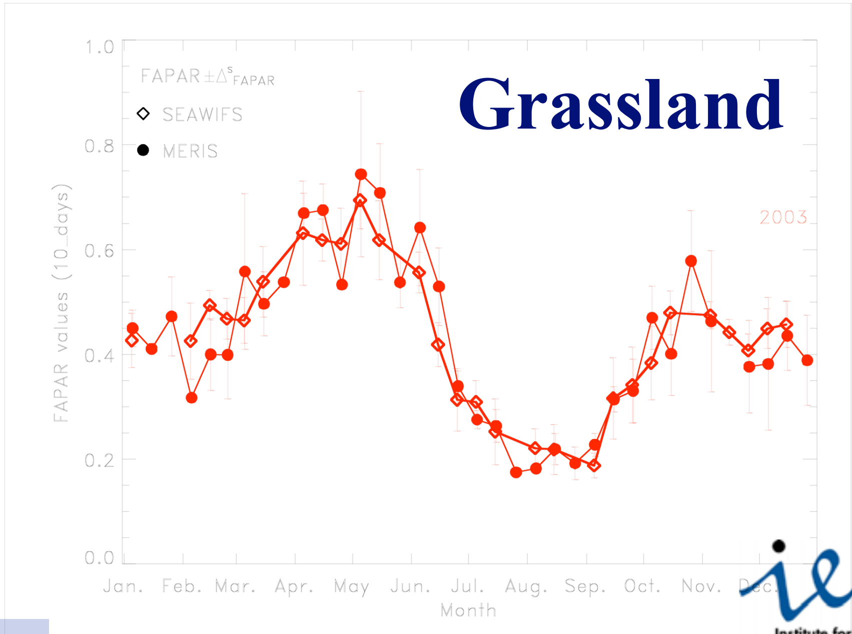
  → time series of daily profiles

  → time period-composite

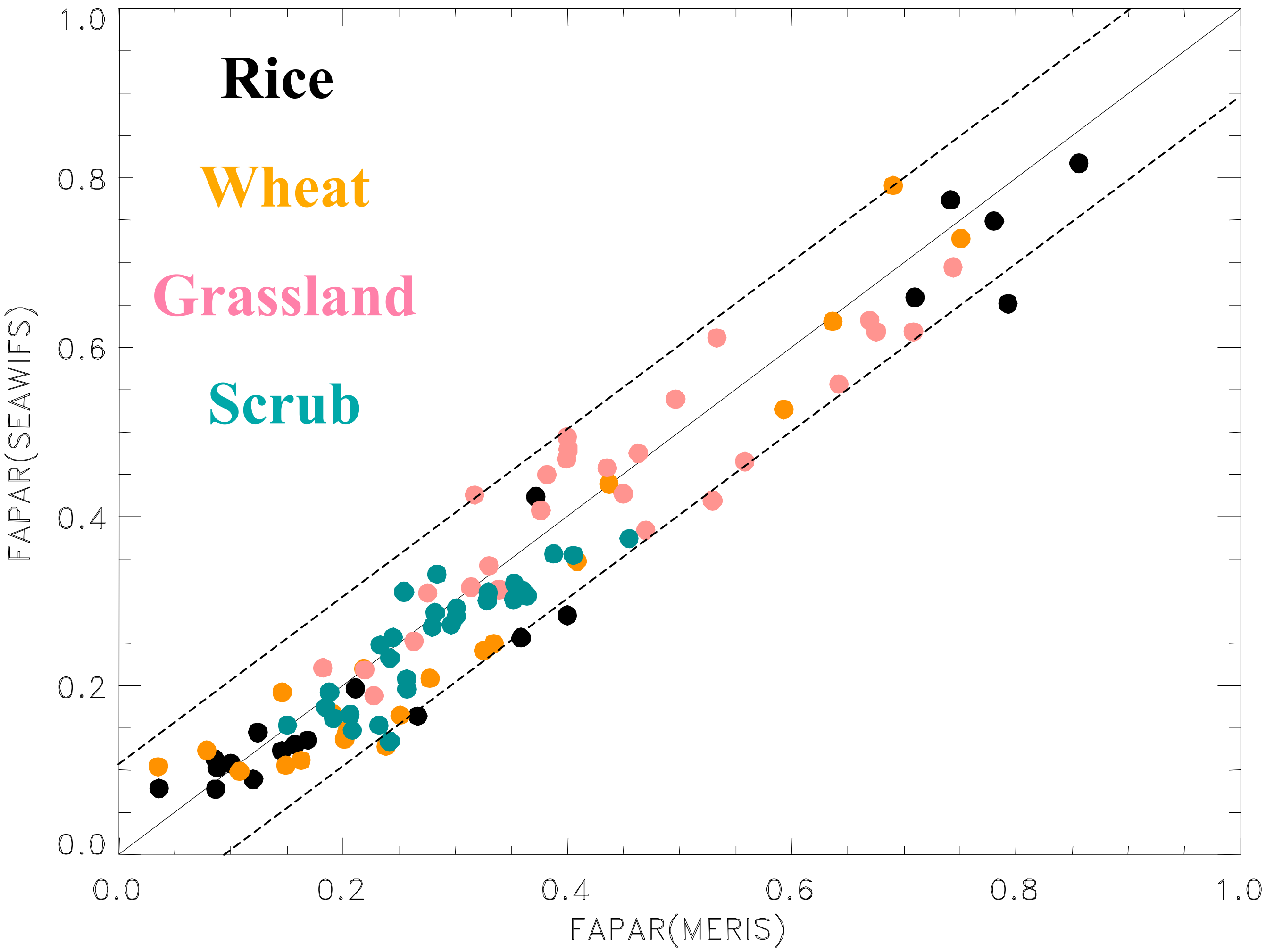

Rice
FAPAR ±Δ^s FAPAR
SEAWIFS
MERIS
2003
FAPAR values (10_days)
1.0
0.8
0.6
0.4
0.2
0.0
Jan. Feb. Mar. Apr. May Jun. Jul. Aug. Sep. Oct. Nov. Dec.
Month


Scrub
FAPAR ±Δ^s FAPAR
SEAWIFS
MERIS
2003
FAPAR values (10_days)
1.0
0.8
0.6
0.4
0.2
0.0
Jan. Feb. Mar. Apr. May Jun. Jul. Aug. Sep. Oct. Nov. Dec.
Month


Wheat
FAPAR ±Δ^s FAPAR
SEAWIFS
MERIS
2003
FAPAR values (10_days)
1.0
0.8
0.6
0.4
0.2
0.0
Jan. Feb. Mar. Apr. May Jun. Jul. Aug. Sep. Oct. Nov. Dec.
Month


Grassland
FAPAR ±Δ^s FAPAR
SEAWIFS
MERIS
2003
FAPAR values (10_days)
1.0
0.8
0.6
0.4
0.2
0.0
Jan. Feb. Mar. Apr. May Jun. Jul. Aug. Sep. Oct. Nov. Dec.
Month

Scatter-plot of 10-days FAPAR values



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Application using both FAPAR sensor products

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Wheat - Chartres (48° 20’ N;2° 0’ E)

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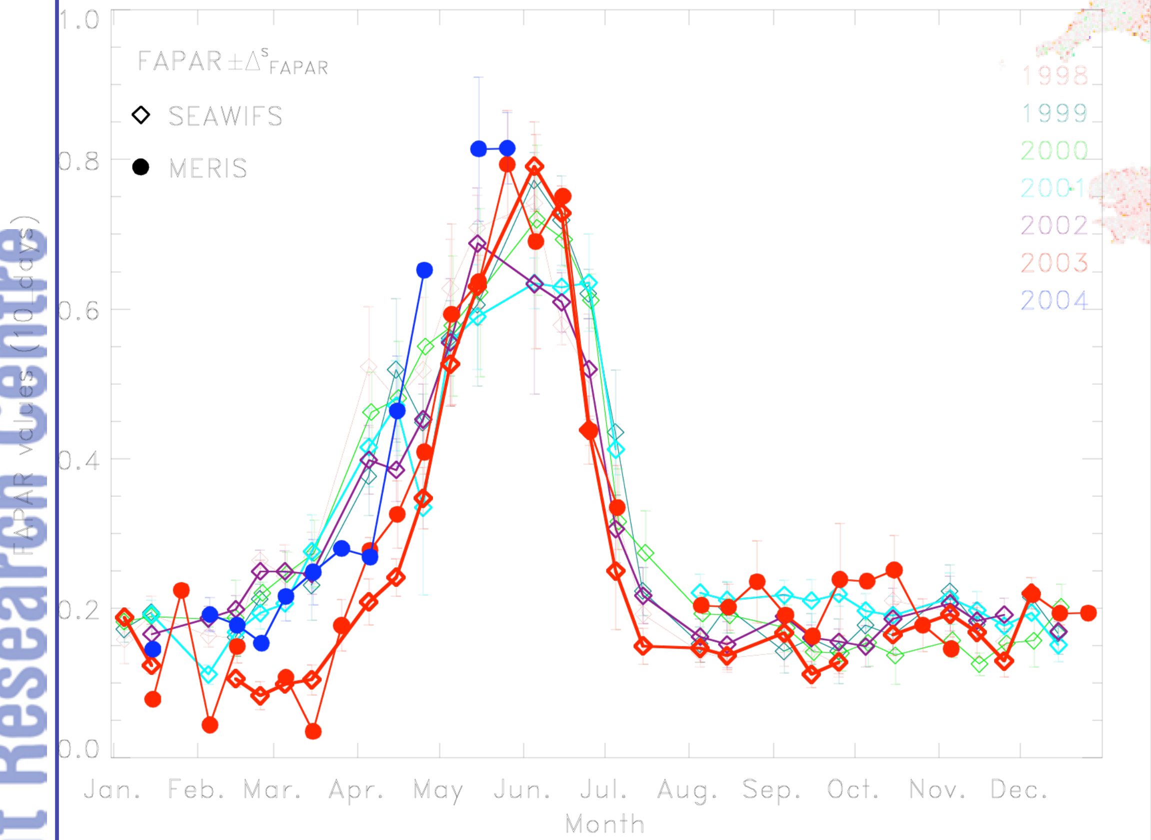

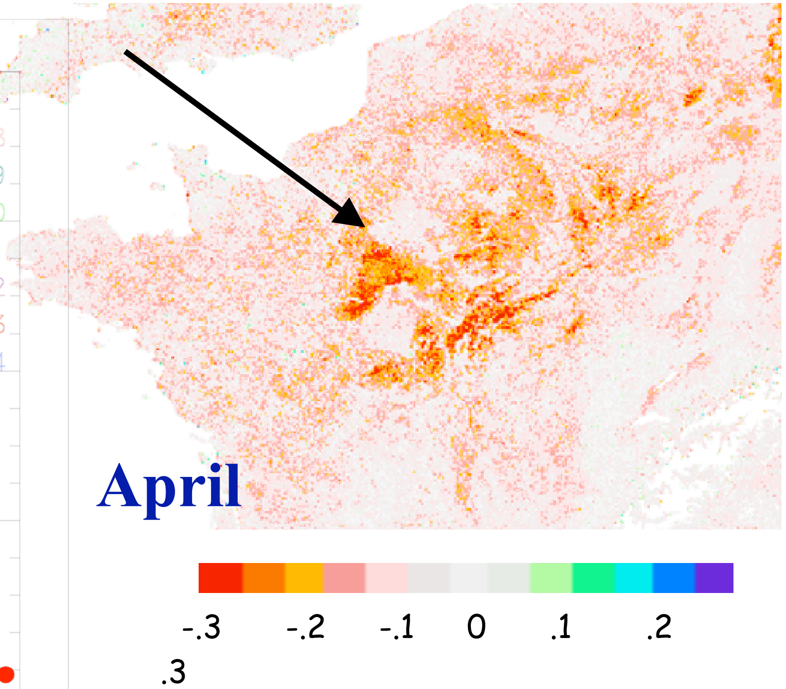

The seasonal evolutions of FAPAR during the period 1998 to 2003 (estimated from SeaWiFs data), as well as that for 2003 and 2004 (derived from MERIS data), for an area close to Chartres (France). The impact of the drought on the vegetation is clearly noticeable as early as March in this under-irrigated area.

- **2004 MGVI values indicate that the situation is back to normal this year at this location.**

Gobron, N., B. Pinty , F. Mélin, M. Taberner , M. M. Verstraete, A. Belward , T. Lavergne and J.-L. Widlowski (2004) 'The state of vegetation in Europe following the 2003 drought', *International Journal of Remote Sensing Letters*, submitted.

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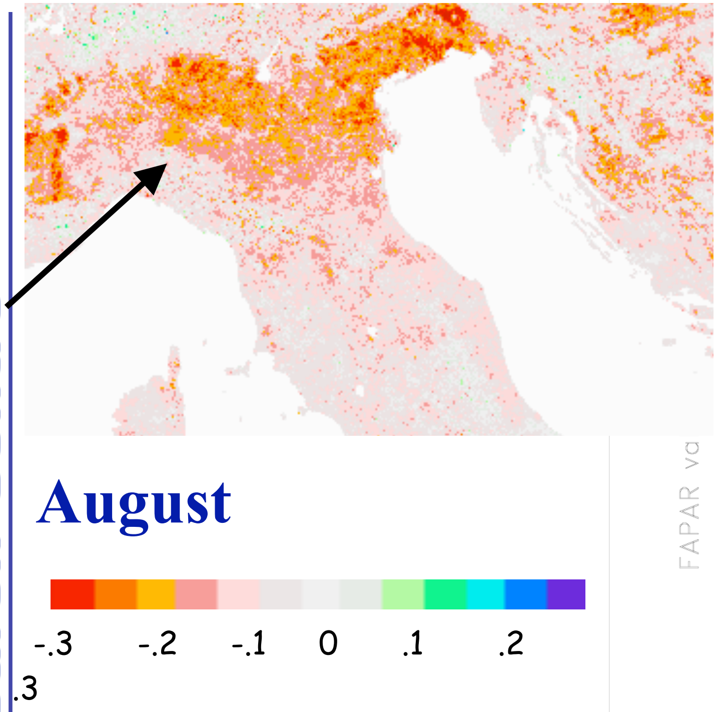
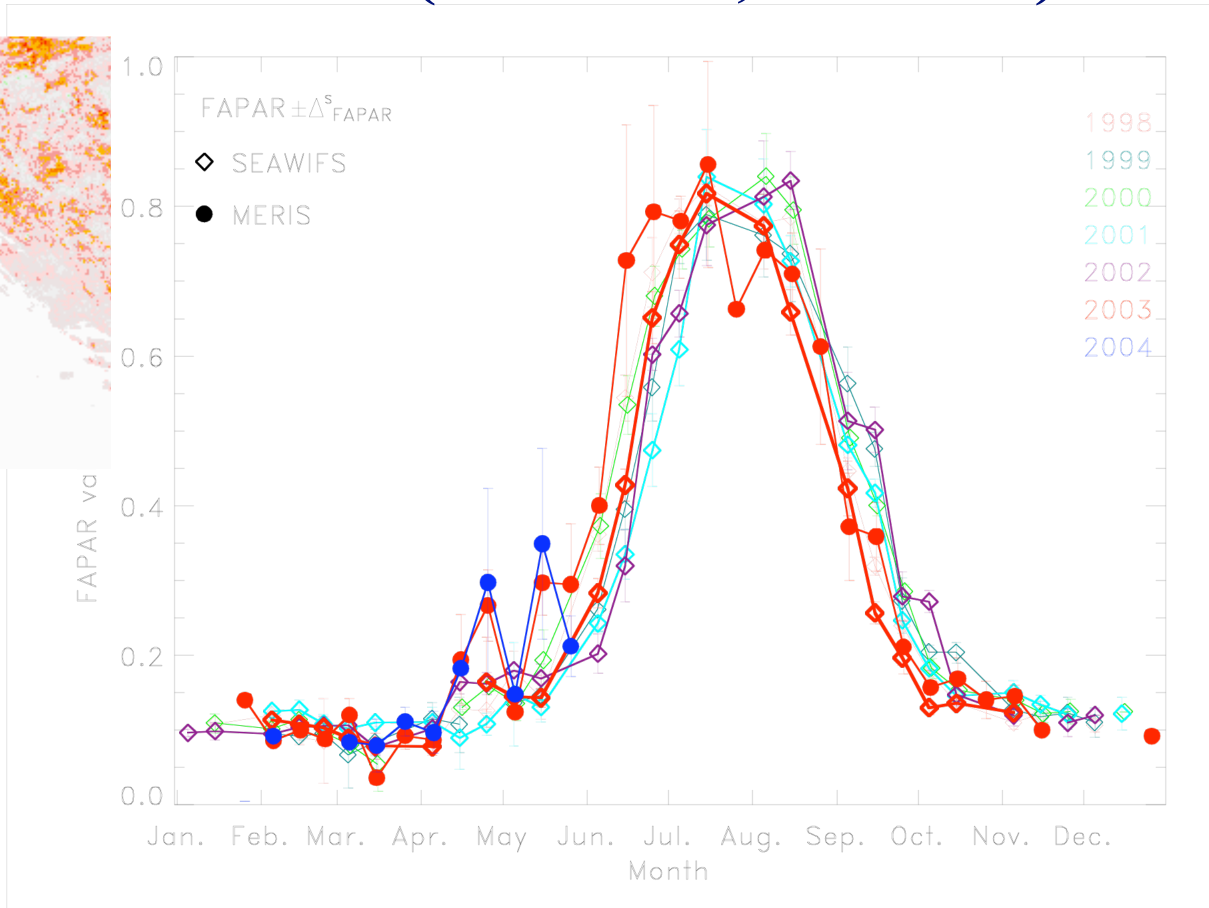
Rice - Pavia (45° 17’ N; 8° 23’W)





We have the same 6 (almost indistinguishable) annual vegetation cycles.

This rice-growing area was regularly irrigated throughout the period and was unaffected by the drought.

Gobron, N., B. Pinty , F. Mélin, M. Taberner , M. M. Verstraete, A. Belward , T. Lavergne and J.-L. Widlowski (2004) 'The state of vegetation in Europe following the 2003 drought', *International Journal of Remote Sensing Letters*, submitted.

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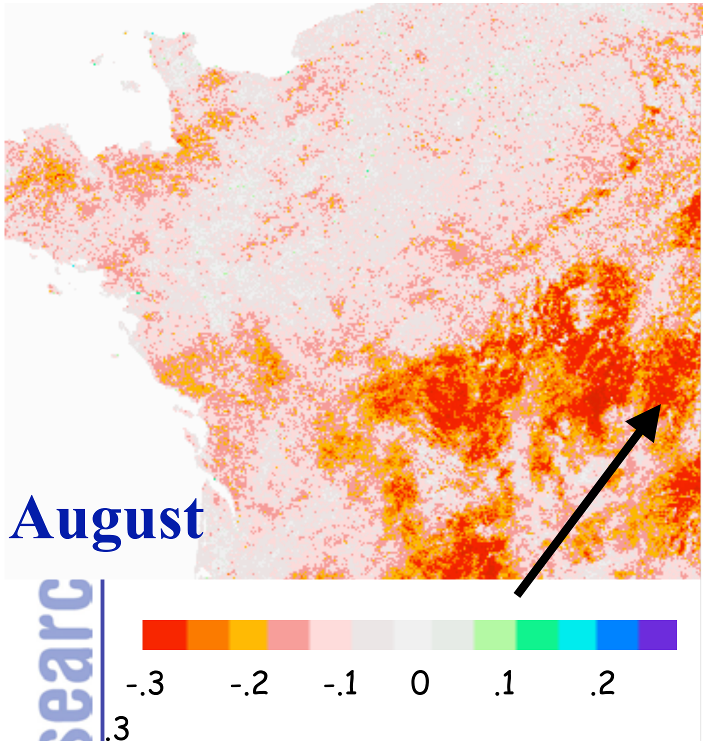
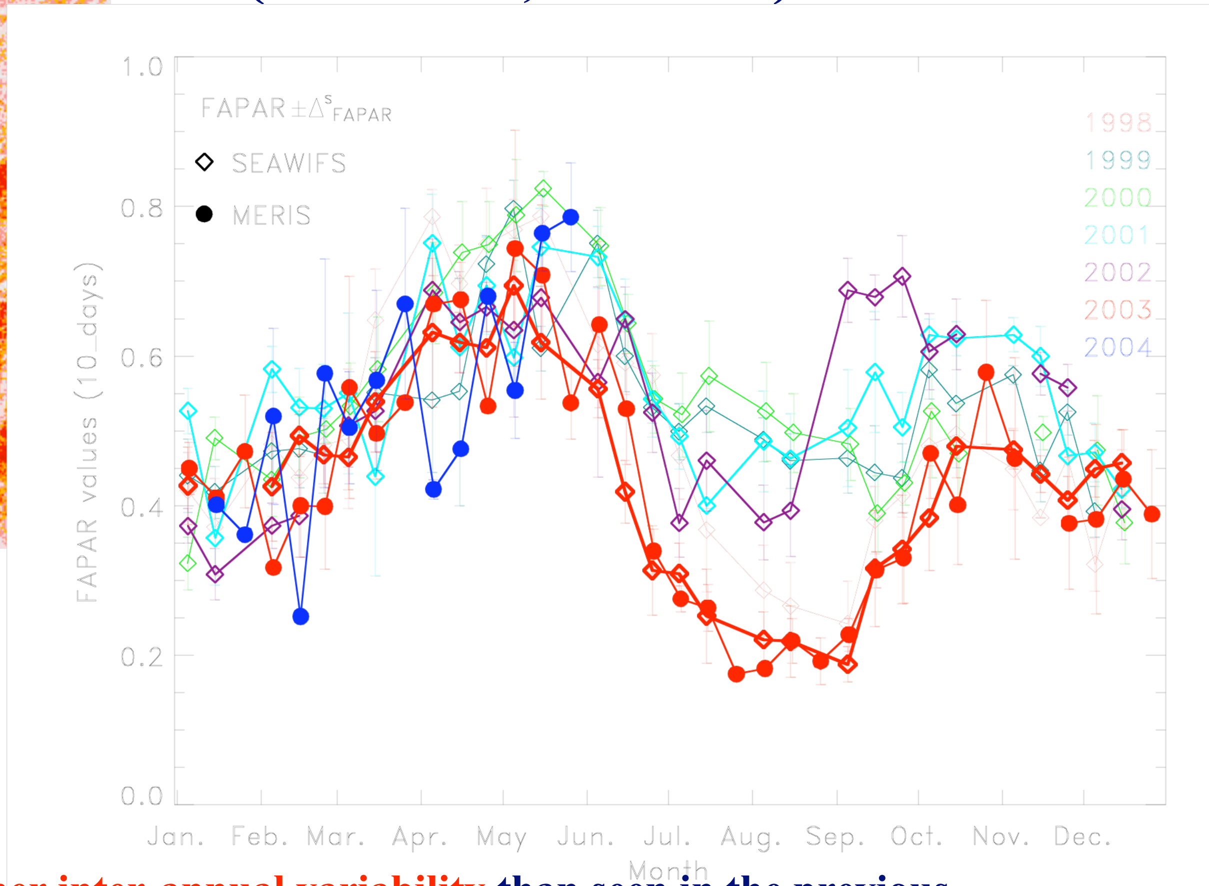
Mixed grassland/cultivated area - Le Paradis (46° 30’ N; 3° 40’ E)





- **This site exhibits a much higher inter-annual variability than seen in the previous examples, especially for 1998 and 2002. Although the potential impact of the 2003 drought is not yet noticeable in early spring, the measured FAPAR shows a significant reduction in productivity from June onwards.**

- **This delay in the vegetation response may be due to a better adaptation of this type of ecosystem to such stresses**

Gobron, N., B. Pinty , F. Mélin, M. Taberner , M. M. Verstraete, A. Belward , T. Lavergne and J.-L. Widlowski (2004) 'The state of vegetation in Europe following the 2003 drought', *International Journal of Remote Sensing Letters*, submitted.

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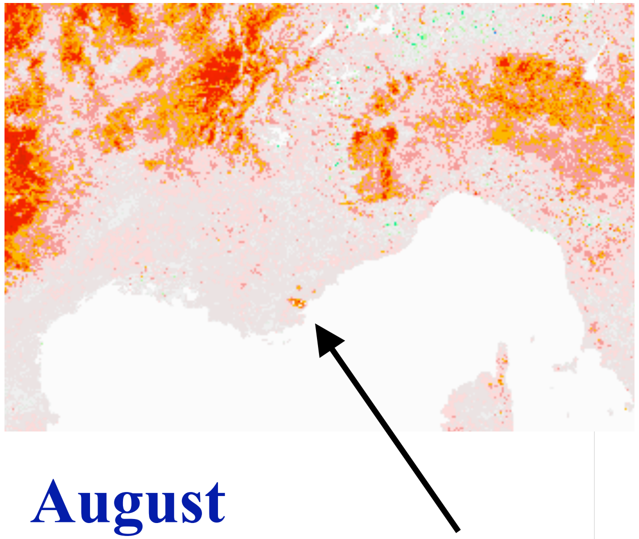
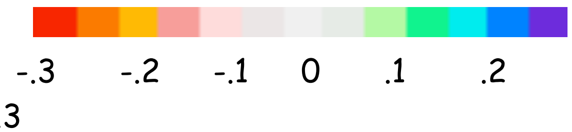
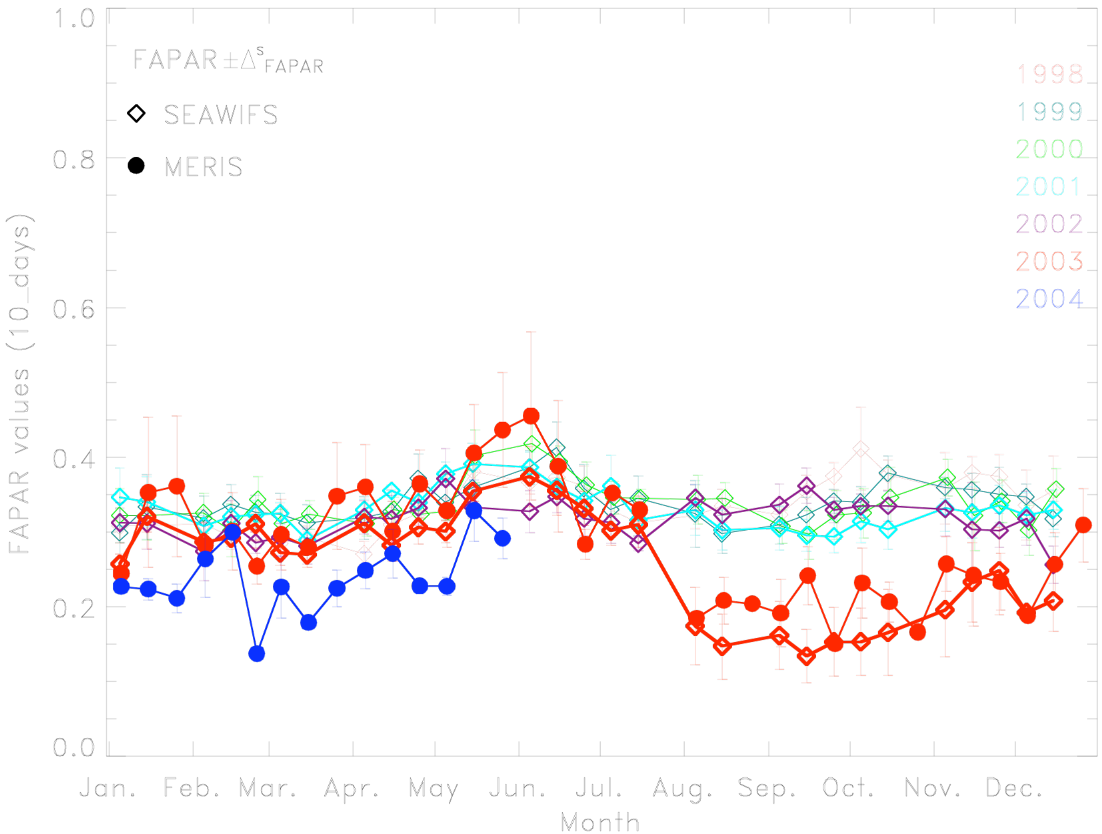
Scrub -Plan de la Tour (43° 21’N;6° 35’E)



August

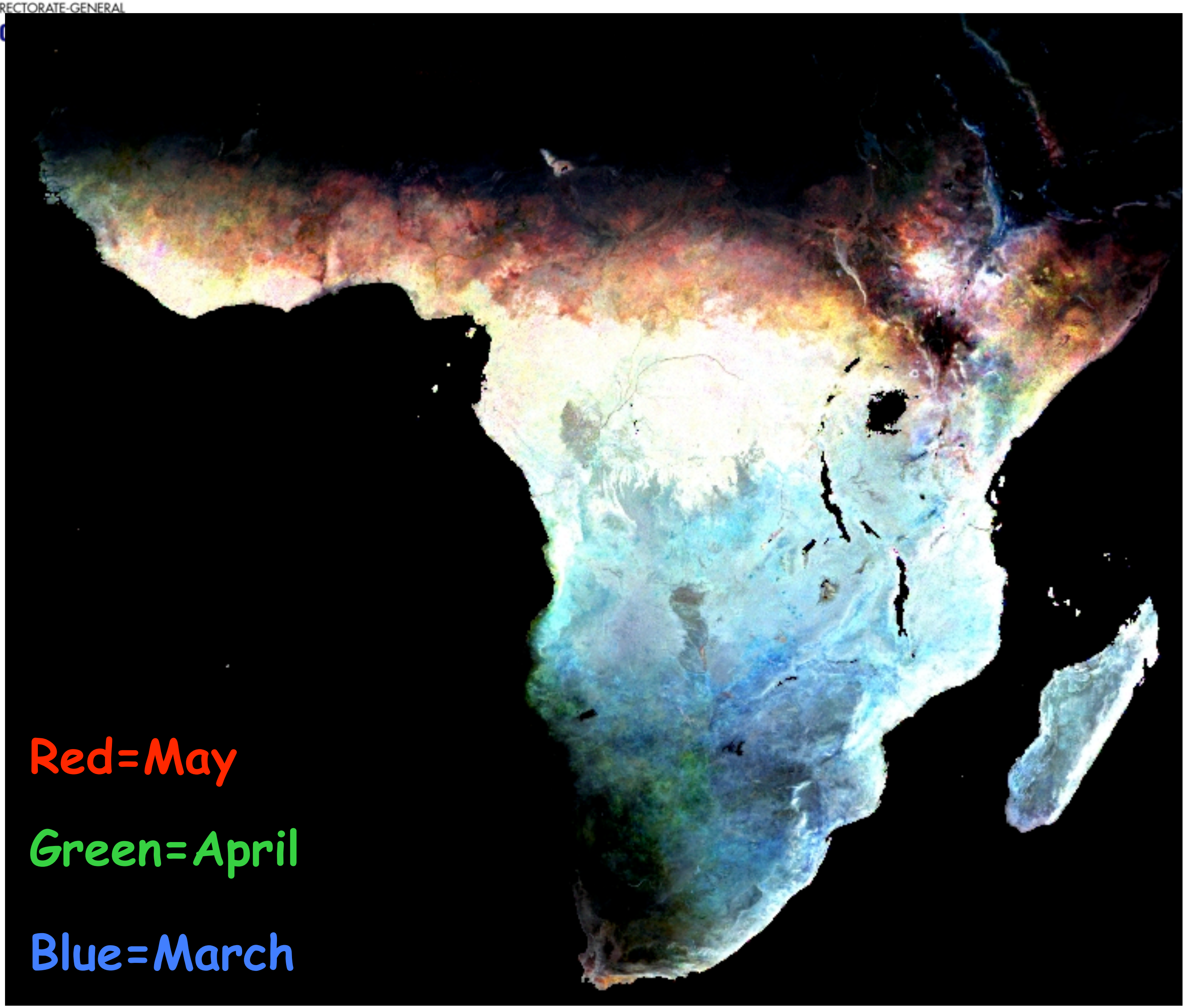




- **•The most extreme illustration of the 2003 drought impact: Plan de La Tour (France) experienced intense fires in August 2003. The FAPAR values suddenly decline after the summer fire events and keep relatively low values, by comparison to those obtained for the period 1998-2002, until the end of 2003.**

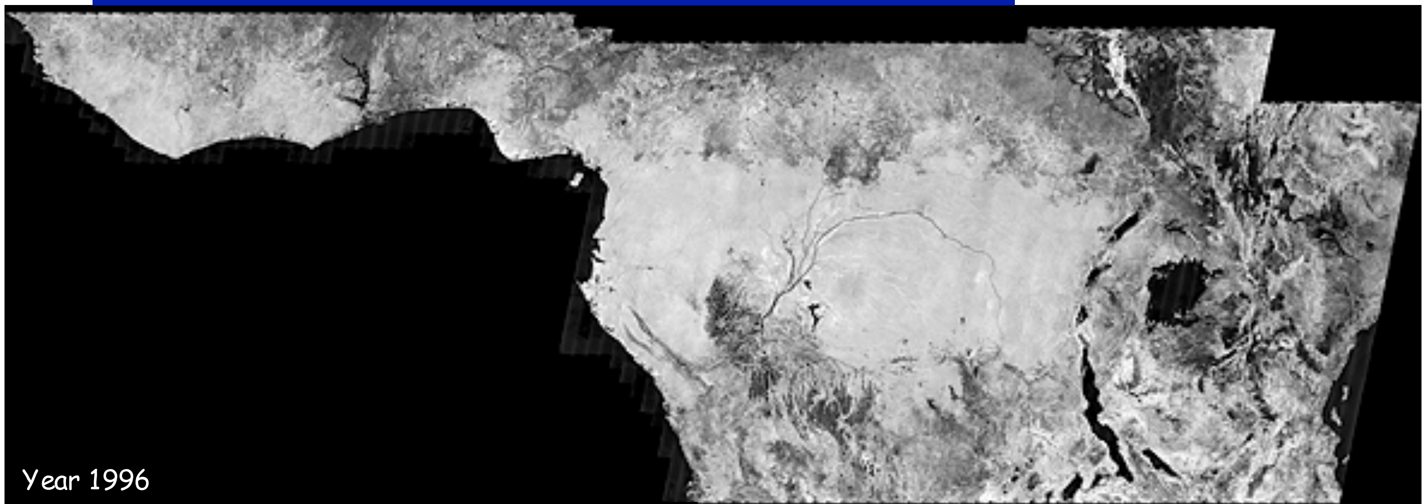
- **•The 2004 spring FAPAR estimations suggest that the vegetation has not recovered from the 2003 fire stress.**

Gobron, N., B. Pinty , F. Mélin, M. Taberner , M. M. Verstraete, A. Belward , T. Lavergne and J.-L. Widlowski (2004) 'The state of vegetation in Europe following the 2003 drought', *International Journal of Remote Sensing Letters*, submitted.


Red=May
Green=April
Blue=March

SeaWiFS FAPAR Monthly Variations

Data from JERS-1 SAR radar



Source: De Grandi et al., 2000, IEEE, TGRS

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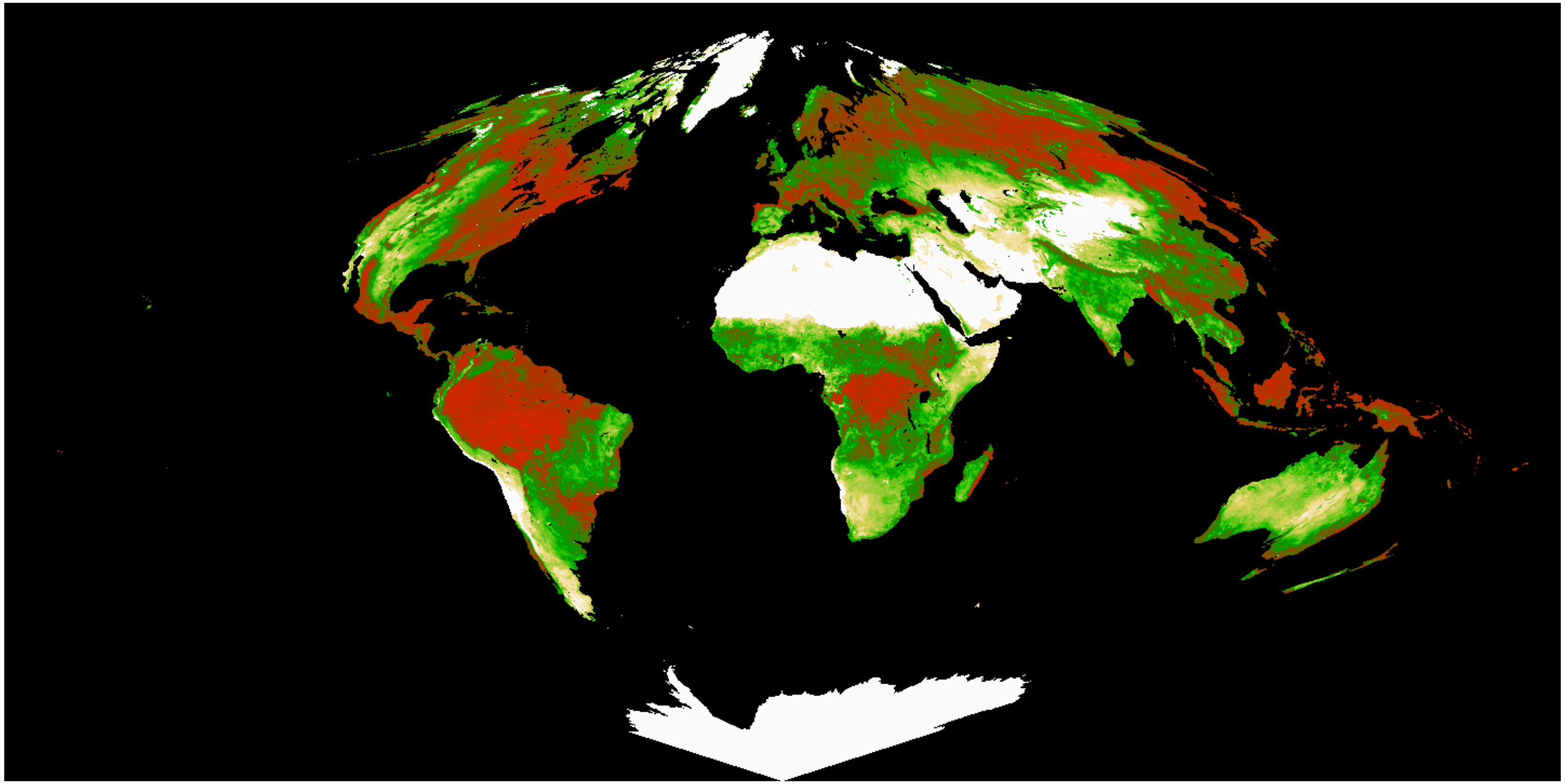
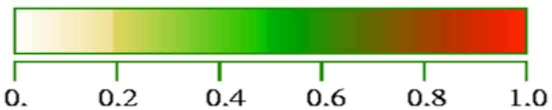
Global MODIS FAPAR Products

July 2001 @0.25°

MODIS products





Source: ftp://crsa.bu.edu/pub/rmyneni/myneniproducts/datasets

Ref: Knyazikhin *et. al.*, JGR, 1998

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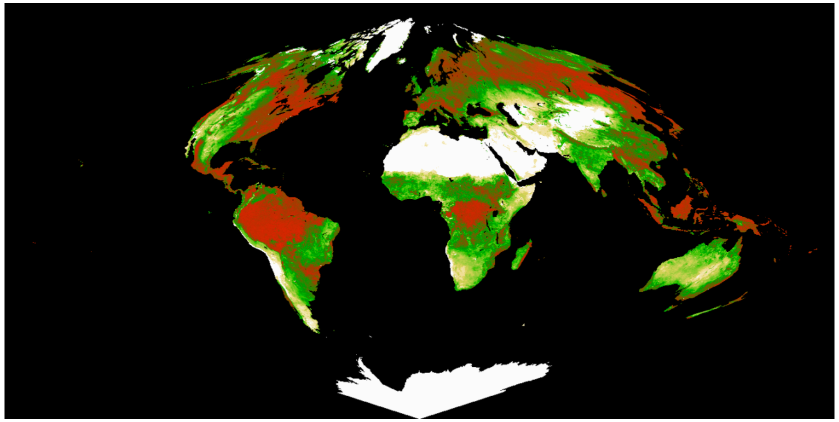
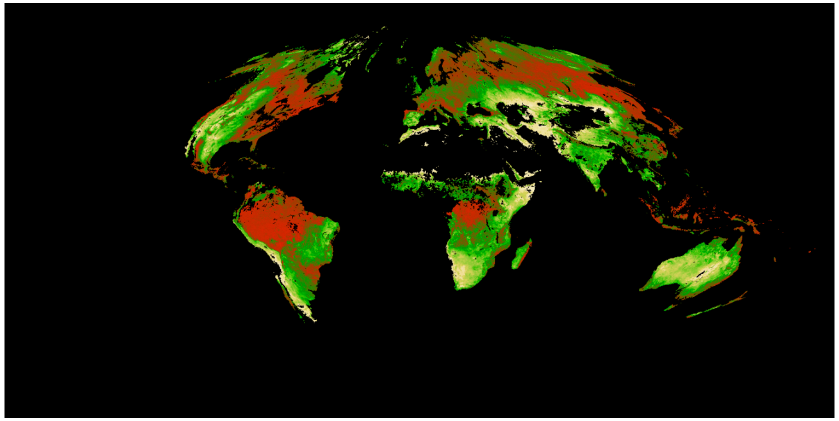
Comparisons - July 2001

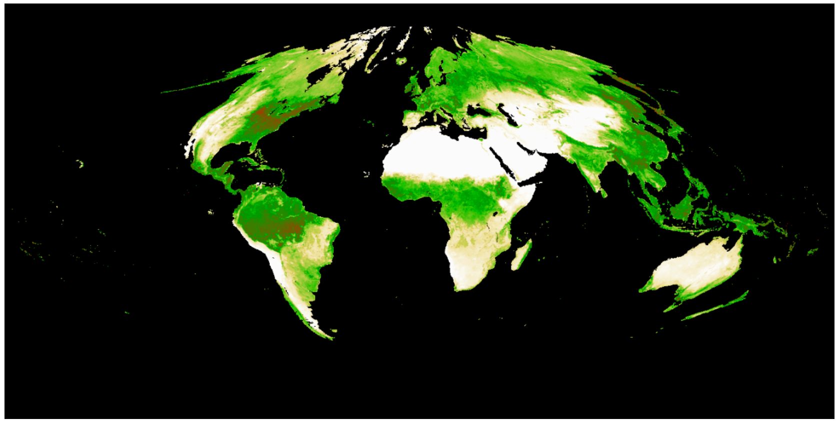
MOD 15 – 0.25 X 0.25 – FPAR

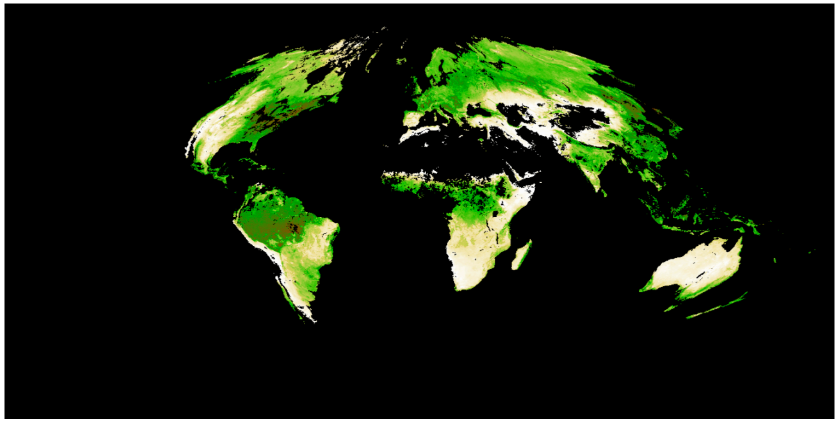




QA_MODIS > 75 &
50 % vegetation pixels in SeaWiFS grid cell

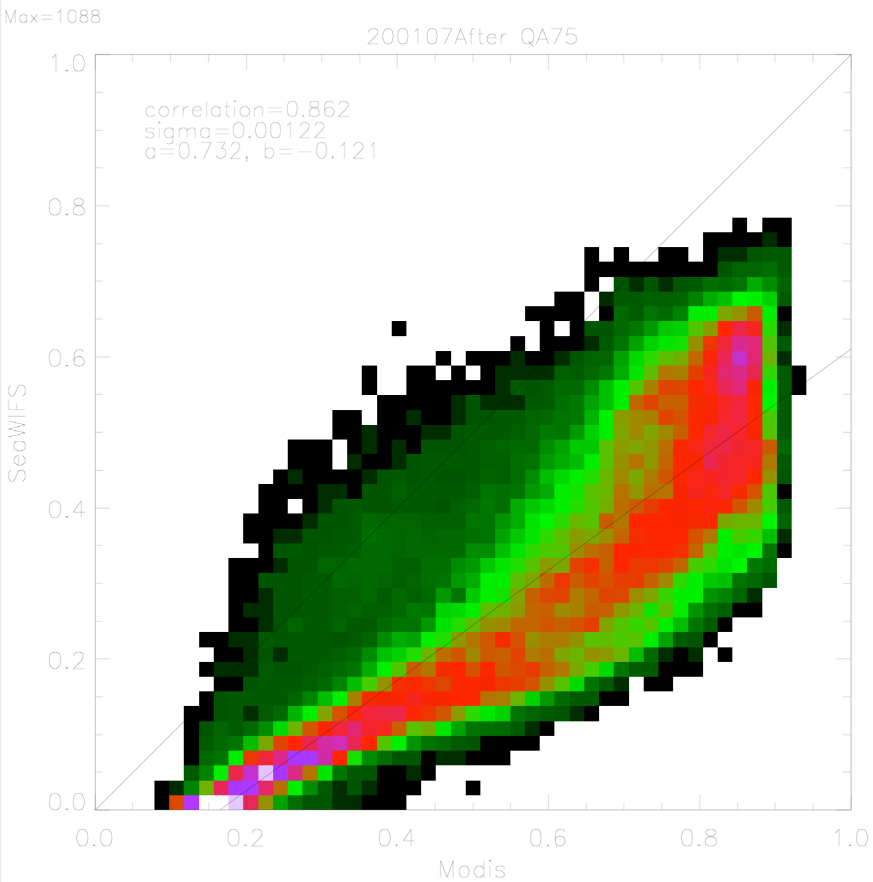
SeaWiFS – 0.25 x 0.25 - FAPAR

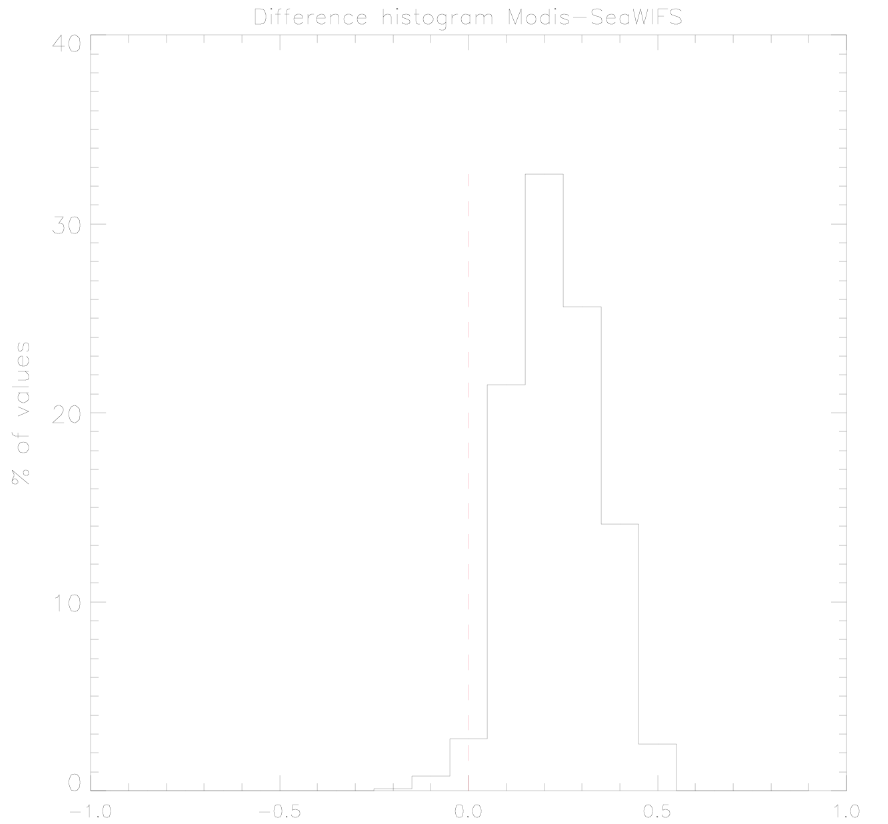




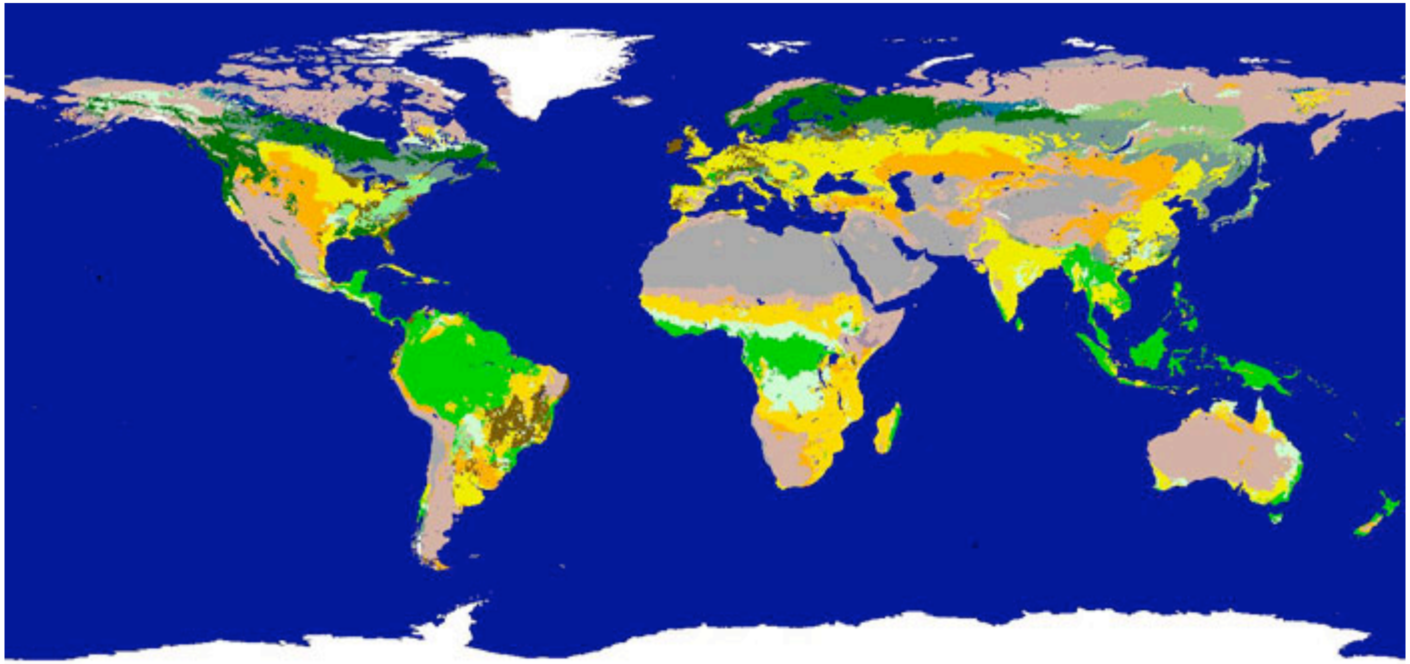
Comparisons - July 2001

QA_MODIS > 75 &
50 % vegetation pixels in SeaWiFS grid cell



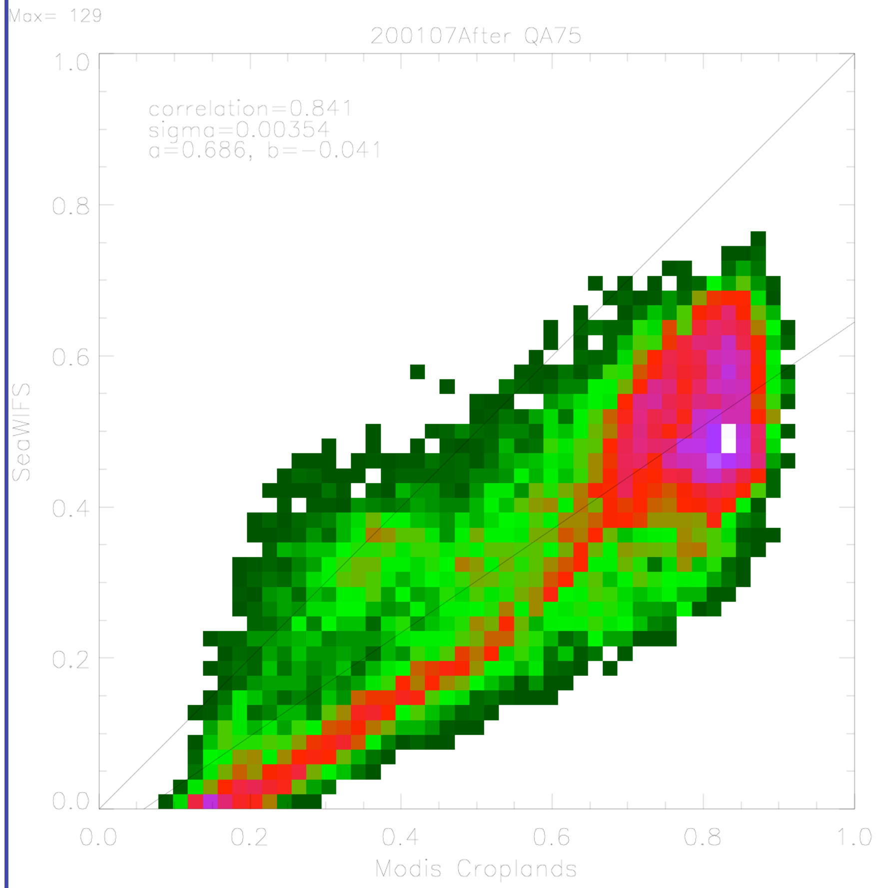


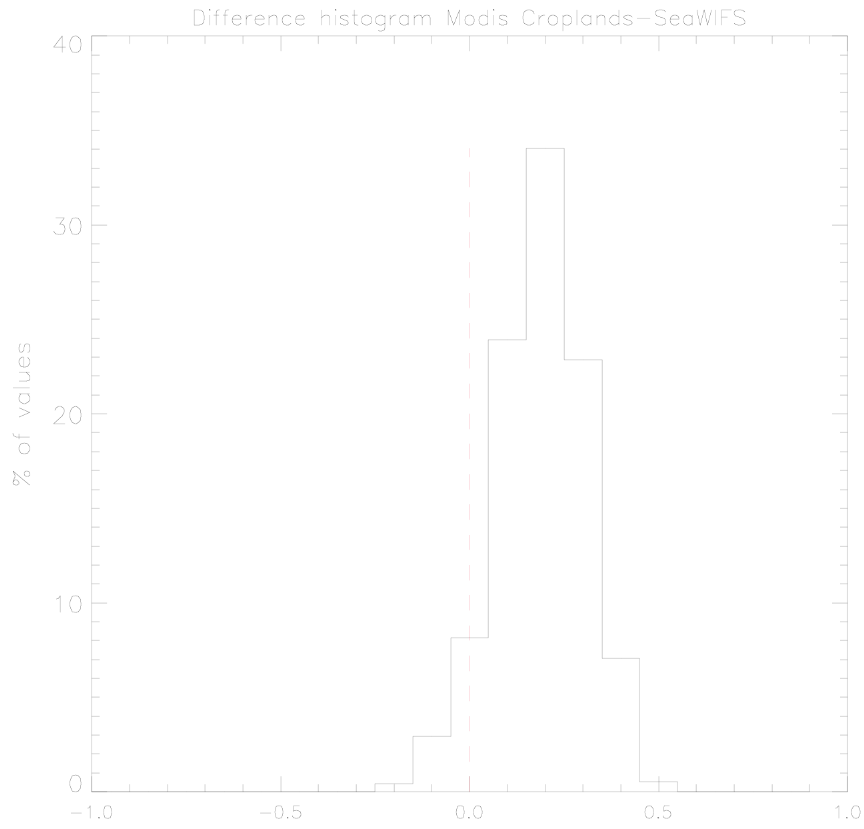
MOD 12 - Land Cover 0.25 x 0.25 degrees



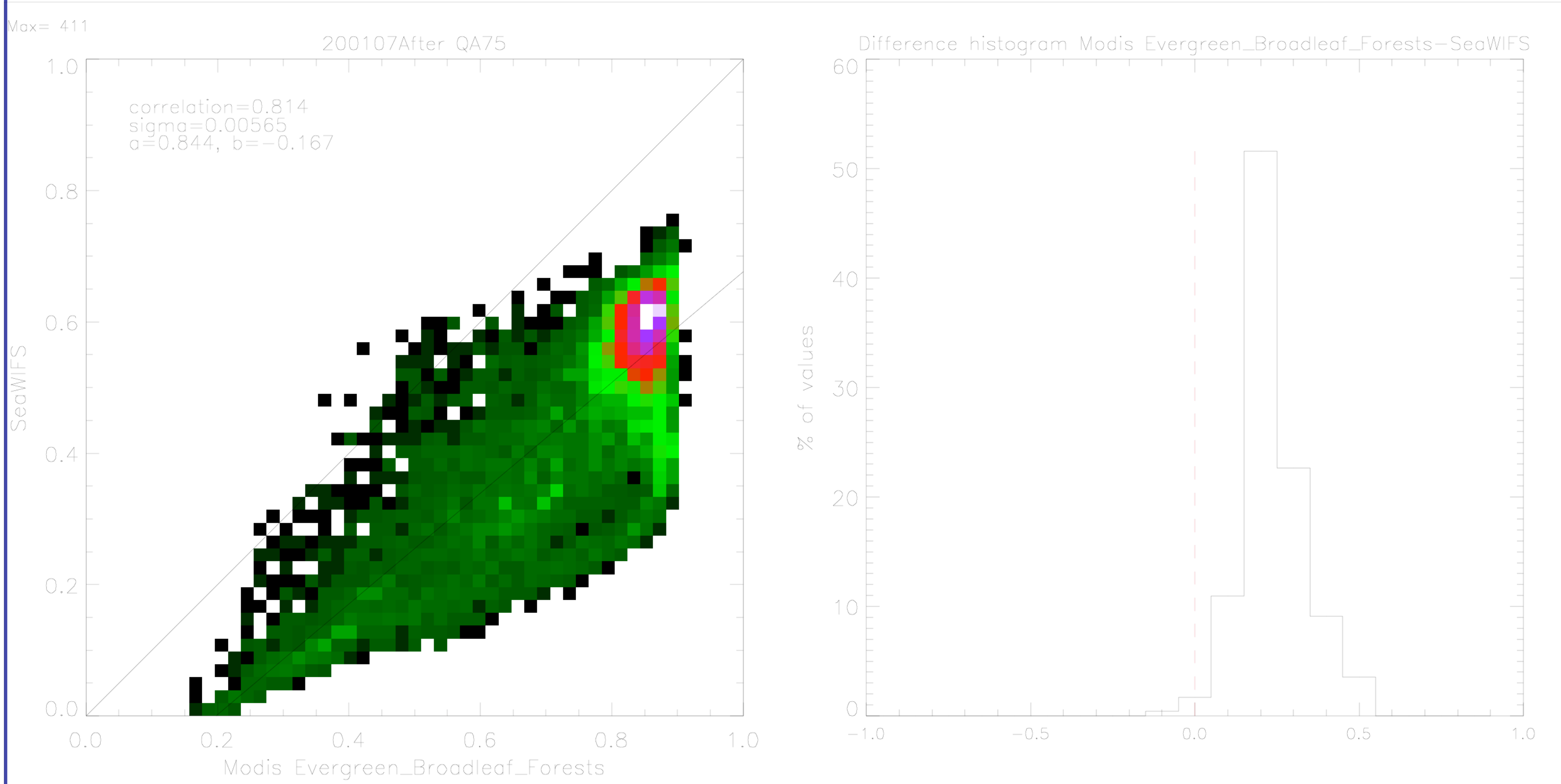
CLASSIFICATION	INDEX	COLOR
Majority Land Cover Type 1		
water	0	
evergreen needleleaf forests	1	
evergreen broadleaf forests	2	
deciduous needleleaf forests	3	
deciduous broadleaf forests	4	
mixed forests	5	
closed shrublands	6	
open shrublands	7	
woody savannas	8	
savannas	9	
grasslands	10	
permanent wetlands	11	
croplands	12	
urban and built-up	13	
cropland/natural vegetation mosaic	14	
snow and ice	15	
barren or sparsely vegetated	16	
unclassified	254	

Croplands/Broadleaf crops





Evergreen Broadleaf Forests



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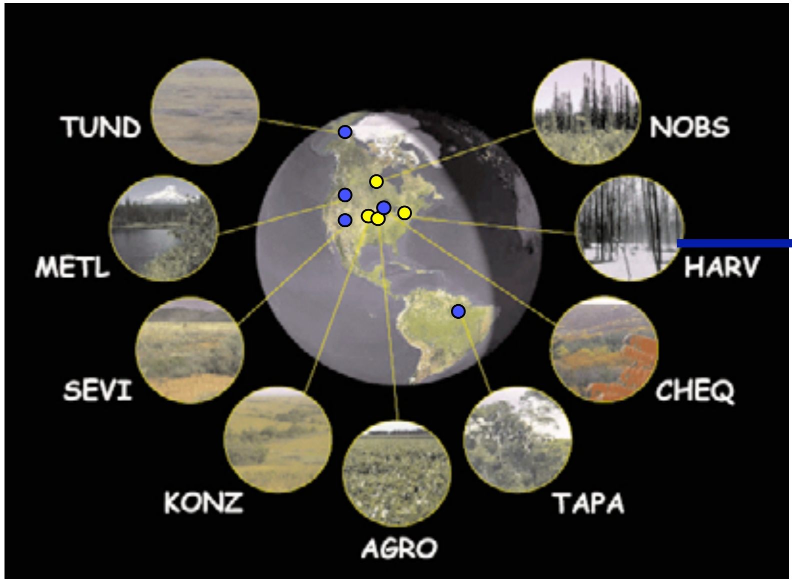
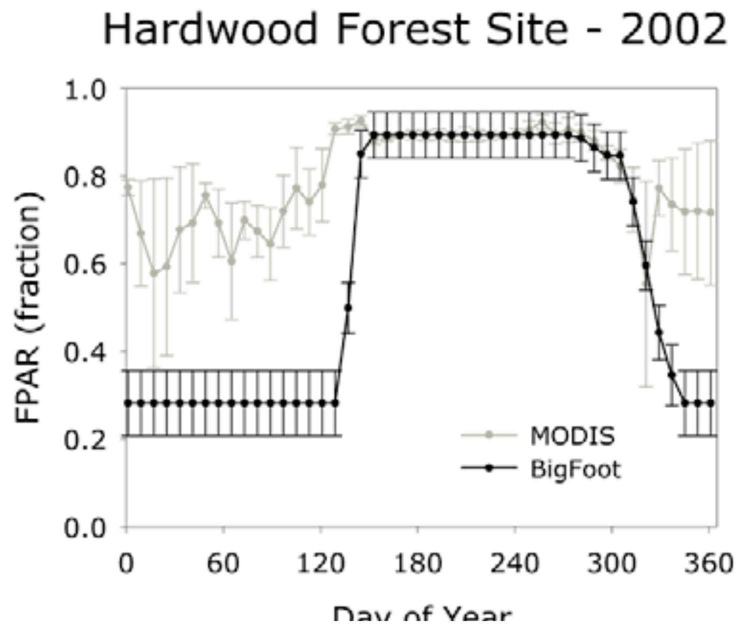
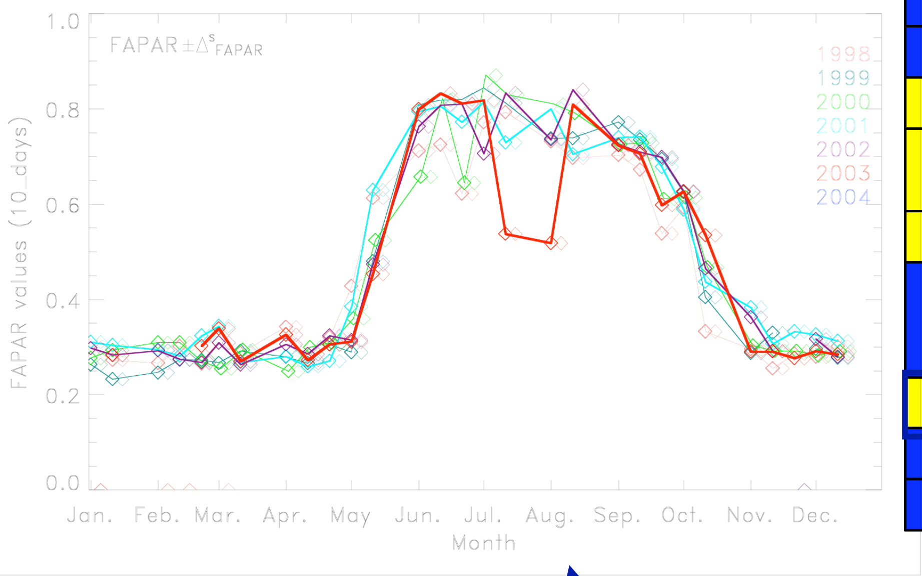
Name	Vegetation	Climate	Location
TUND	tundra (grass)	Arctic	Alaska
SEVI	short grass	desert	New Mexico
KONZ	tall grass	temperate	Kansas
AGRO	cropland (corn/soybeans)	temperate	Illinois
NOBS	black spruce	northern boreal	Manitoba
CHEQ	mixed forest	southern boreal / northern temperate	Wisconsin
HARV	mixed forest	moist temperate	Massachus etts
METL	ponderosa pine	dry temperate	Oregon
TAPA	broadleaf forest	moist tropical	Brazil





Ref: Cohen et al, 2003, RSE. Source: www.fsl.orst.edu/larse/bigfoot



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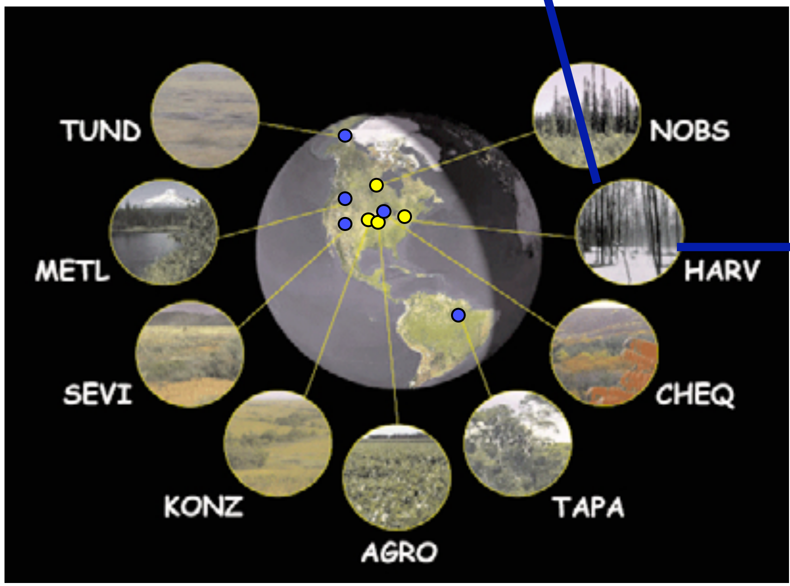

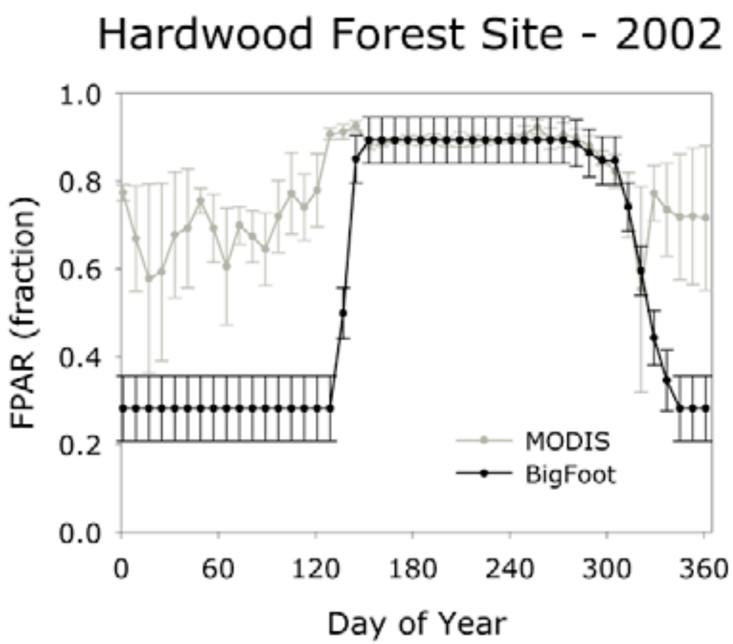

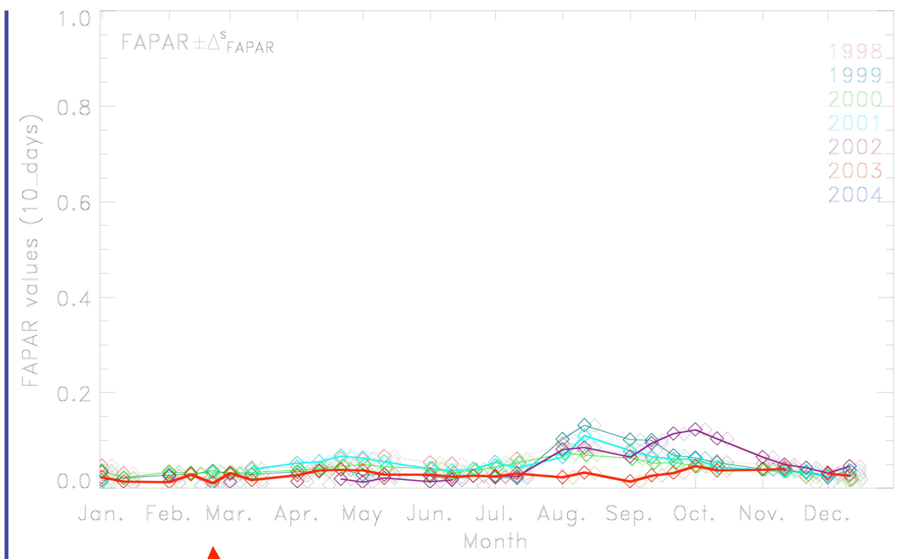

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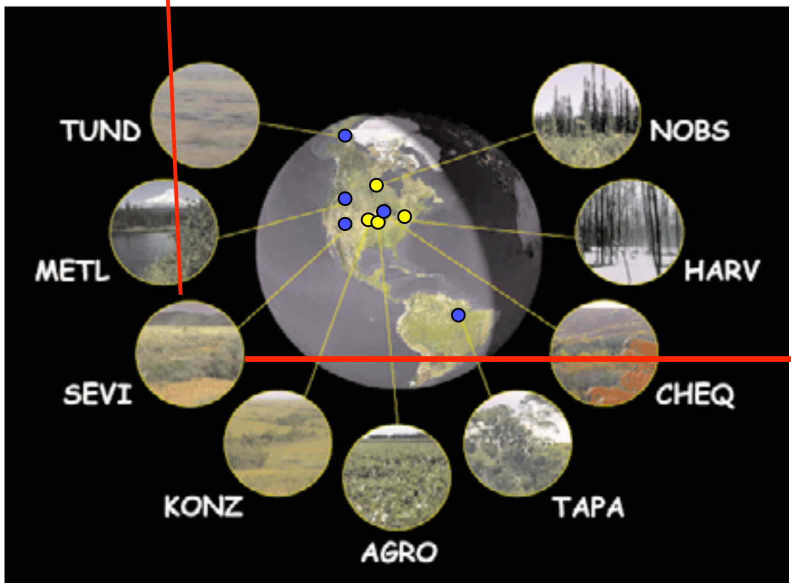

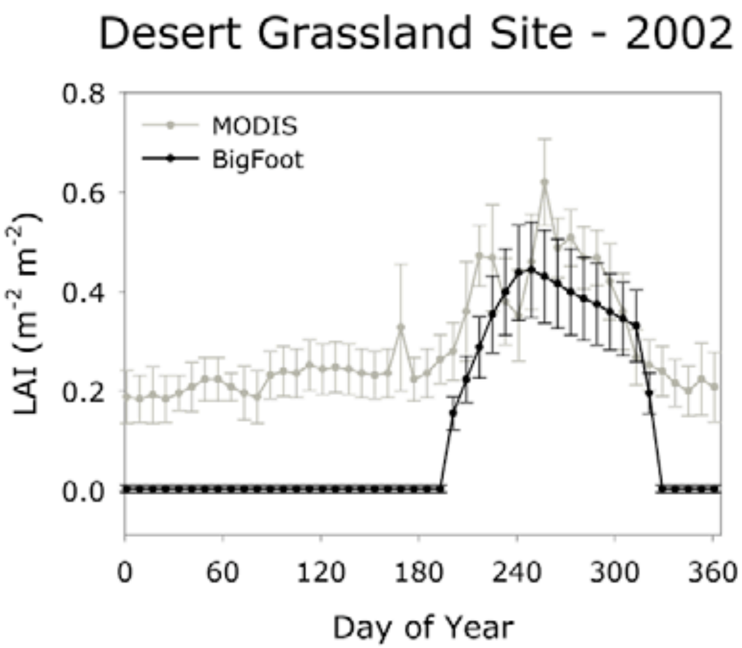

CONCLUSIONS

- FAPAR products from MERIS and SeaWiFS are platform-independent thanks to physical-based approach.
- Seasonal variations over time series represent well the state and evolution of vegetated surfaces:
  - able to catch stress events (drought or fire)
- The FAPAR algorithm is mostly insensitive to the geometry of illumination and observation (not shown)
- The built-in "atmospheric removal" procedure seems efficient

- There is a systematic bias of 0.2 between MOD15 and JRC-ESA-FAPAR products for year 2001 at global scale:
  - Retrieval Algorithms are different !
  - Time composites are different !
  - Re-gridding at global scale seems to be the same ;-)

Perspectives

- The comparison of daily MODIS product and ESA-JRC-FAPAR products.
- Regional in-situ measurements of FAPAR.
- Inter-comparison with MISR global land products.

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