Algorithm development for gross primary production (GPP) in LSA-SAF

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ABSTRACT

GPP can be modelled (Monteith, 1977) as the product of the incident photosynthetically active radiation (PAR), the fraction of PAR absorbed by vegetation f_{APAR} and the light use efficiency (LUE). In this work the PAR relies on the daily MSG down-welling surface short-wave radiation flux (DIDSSF) product. The PAR is considered as the 46% of the DIDSSF. For the fAPAR input, the daily MSG f_{APAR} (MDFAPAR) product has been used. A refinement of the above approach consist in an optimal definition of the LUE constrains on GPP over a pilot area (Spain). In order to characterize and quantify, by means of remote sensing data, the impact of water stress in GPP three different water stress factors were tested: using only meteorological data, combining meteorological data and the LSA-SAF evapotranspiration (ET) product, and using SMOS-derived soil moisture product. Advanced statistical methods, such as partial and semi-partial correlations and LASSO for hierarchical interactions with an optimal cross validation strategy, allows to detect and quantify the influence of the factors mentioned above on LUE in different EC sites covering in Mediterranean ecosystems. Our results show the higher explanatory power of the fraction of diffuse radiation and the water stress on LUE when using both semi-partial correlations and LASSO for hierarchical interactions.

LSA-SAF GPP algorithm

- **Production Efficiency Model: Monteith (1972)**

$$GPP = \varepsilon_{\max}\varepsilon(T, W, f_{Dif}, \ldots)\ PAR\ f_{APAR}$$

- Maximum light use efficiency from Garbulsky *et al.* (2010)
- Factors that regulate LUE for water stress, temperature, diffuse fraction, etc.
- Photosynthetically active radiation from MSG/SEVIRI DIDSSF as its 46 %
- Fraction of absorbed PAR from the daily MSG f_{APAR} (MDFAPAR) product (Roujean & Bréon (1995))

- In a preliminary approach (Figure 1) a constant light use efficiency (ε) was used since it has been shown to be the most significant contribution of PAR and f_{APAR}.
- The comparison with EC data has revealed that seasonality has been captured well but GPP was overestimated specifically on the dry season.
- Further improvements on the MSG GPP by a better parameterization of the light use efficiency (below) are currently being analyzed.

Figure 1: Annual GPP image (kg m^{-2} yr^{-1}) for 2008.

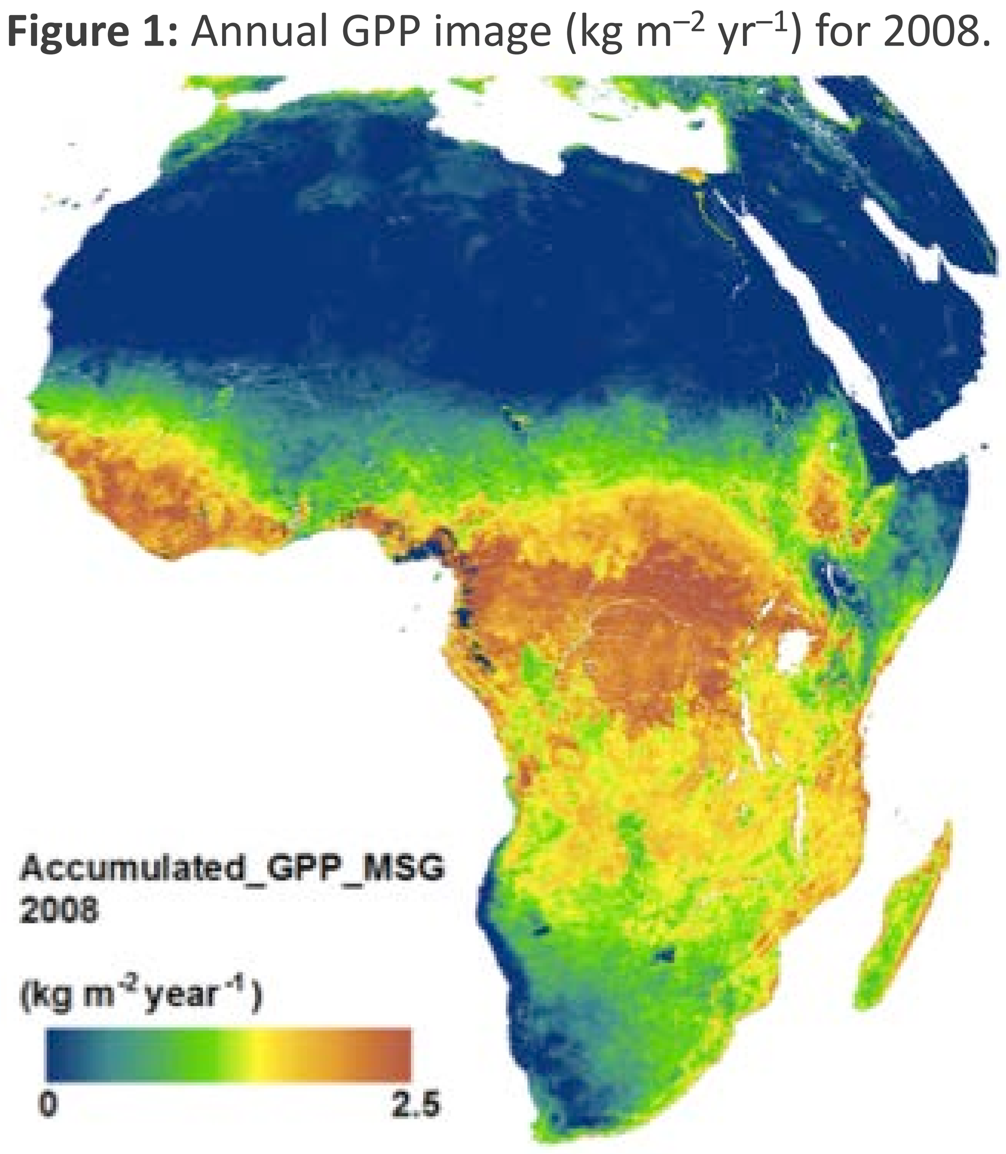

Table 1: MBE, RMSE and R for MSG GPP as compared to EC data for the two sites considered (g m^{-2} day^{-1}).

Site	*MBE*	*RMSE*	*R*
Demokeya	0.03	0.90	0.90
Mongu	-0.02	1.8	0.59

Ongoing refinements of the GPP algorithm

Impact of water stress on ε

- Three alternatives for the calculation of the water stress factor (ε(w)) have been considered:

$$\varepsilon(W):\quad C_{ws}^{1} = (1 + P/PET)/2,\quad C_{ws}^{2} = (1 + AET/PET)/2,\quad C_{ws}^{3} = (1 + SM)/2$$

- Precipitation (*P*) from AEMet by kriging
- Potential evapotranspiration (PET) from AEMet by kriging , MSG/SEVIRI DIDSSF, and Jensen & Haise (1965)-
- Actual evapotranspiration (AET) from MSG/SEVIRI DMET
- Soil moisture (SM) from SMOS-BEC.

	Las Majadas del Tiétar			
	R^2	MBE	MAE	RMSE
ε(w)=1	0.77	0.6	1.1	1.4
ε(w)=C^1_{ws}	0.86	-0.09	0.8	1.0
ε(w)=C^2_{ws}	0.83	-0.4	1.0	1.3
ε(w)=C^{3a}_{ws}	0.89	-0.8	1.2	1.8
ε(w)=C^{3b}_{ws}	0.86	-0.8	1.2	1.7

Table 2. Statistics for the different water stress factors included in the PEM (year 2011). The *m* and *a indices* indicate morning and afternoon orbits respectively.

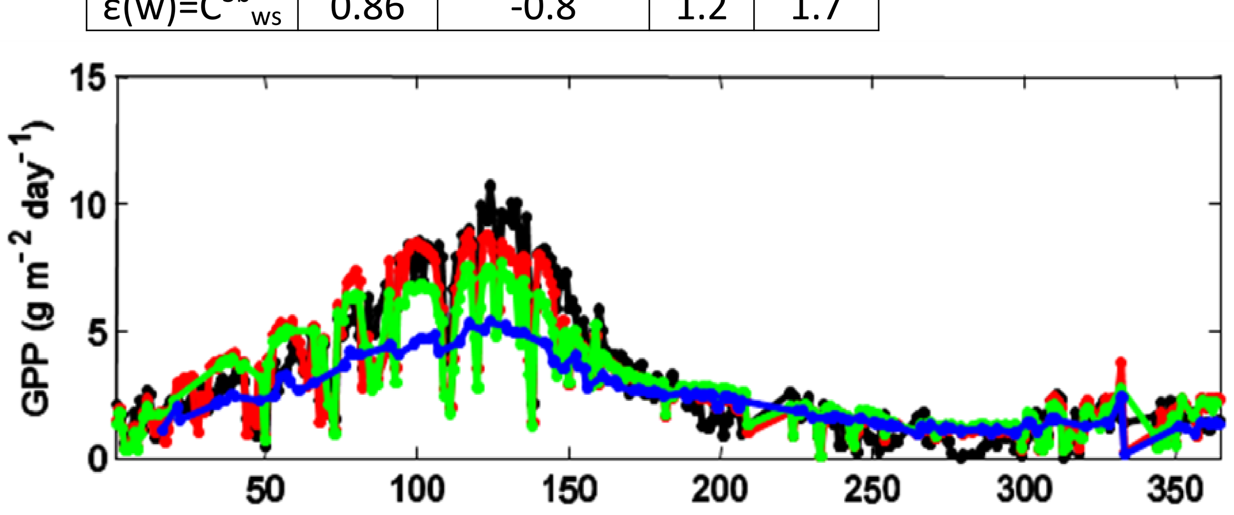

Figure 2. Temporal variation of GPP estimated with EC data (black) and PEM models considering C^1_{ws} (red), C^2_{ws} (green) and C^{3m}_{ws} (blue) as water stress factors (ε(w)).

- The inclusion of any of the considered water stress factors increases model accuracy.
- C^1_{ws} obtained the highest accuracy, but it relies only on ground measurements.
- C^2_{ws} performs well and reduces the needed ground data to temperature.
- C^3_{ws} outperforms the other approaches in terms of correlation but presents a significant bias.

Impact of diffuse fraction of PAR on ε

- The analysis of the explanatory power of water stress (ε(w)), minimum temperatures (ε(T)) and fraction of diffuse radiation (ε(f_{Dif})) have been considered.
- ε has been estimated with GPP EC data as: $\varepsilon = GPP_{EC} / (PAR\ f_{APAR})$
- ε(w) has been modeled as C^1_{ws}.
- ε(T) has been modeled using the MODIS approach (Heinsch *et al.*, 2003)
- ε(f_{Dif}) has been modeled using the equation proposed by Collares-Pereira & Rabl (1979).

Table 3. Assessment of the explanatory power of the three factors over the light use efficiency (ε) in two EC ground stations.

Las Majadas del Tiétar	*ε(T)*	*ε(w)*	*ε(f_{Dif})*
Partial corelations	0.06	0.34	0.52
Semi-partial corelations	0.04	0.27	0.45

Cortes de Pallás	*ε(T)*	*ε(w)*	*ε(f_{Dif})*
Partial corelations	0.32	0.34	0.48
Semi-partial corelations	0.27	0.28	0.43

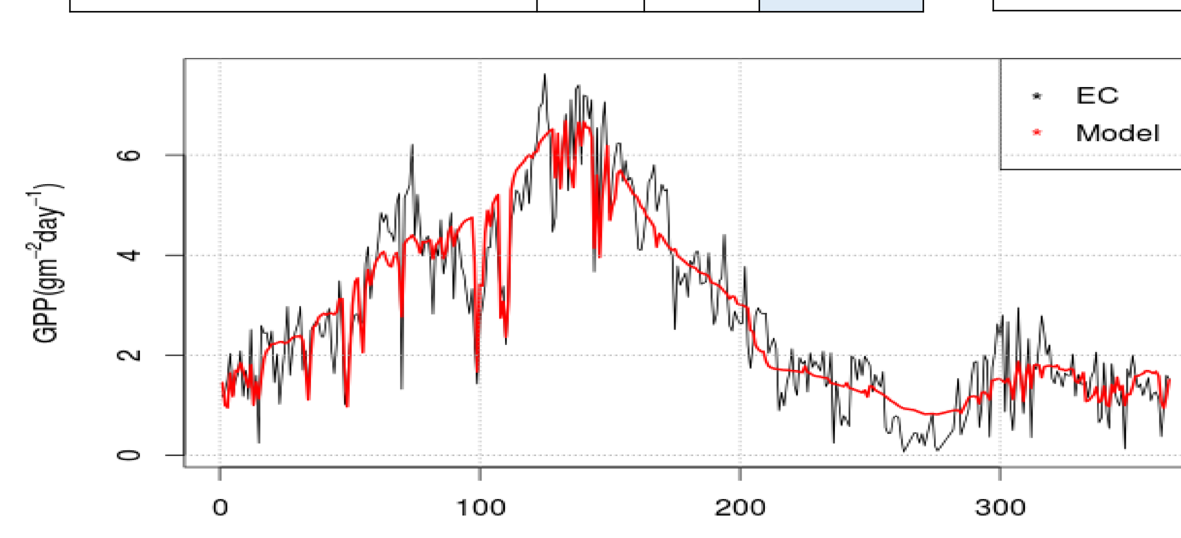

Figure 3. Estimated and modeled GPP using the LASSO for hierarchical interactions approach. All down regulating factors have been considered by the model.

- LASSO for hierarchical interactions allowed to detect and quantify the influence of the factors mentioned above on ε.
- The ranking in order of importance provided by the model for both sites is : ε(f_{Dif}) , ε(w) and ε(T).

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