remote sensing

Article

Climate data records of vegetation variables from geostationary SEVIRI/MSG data: products, algorithms and applications

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Supplementary Material

S1. Products uncertainty estimation

The uncertainties due to the BRDF parameters correspond with the diagonal elements of the uncertainty covariance matrix (C00, C11 and C22 fields of the AL-C_i-CK product) obtained for the three model parameters (SAF/LAND/MF/PUM_AL/1.4).

The absolute uncertainty of FVC takes into account the uncertainty due to the propagation of the input errors (σ_{k_0}) and model selection (σ_{model}):

$$\sigma_{\mathrm{FVC}} = \sqrt{\sigma_{\mathrm{k_0}}^2 + \sigma_{\mathrm{model}}^2}. \tag{1}$$

The impact of input errors for k_0 BRDF product (σ_{k_0}) is assessed using the closed formulation of the Lagrange method [49]. The σ_{model} term is quantified from the dispersion (variance) caused by the model selection, which is related with the fact that each SEVIRI pixel may arise from various linear mixture models:

$$\sigma_{model} = \sqrt{\sum_K p(M_K|\mathbf{r}) \cdot (\mathrm{FVC}(M_K) - \mathrm{FVC})^2}. \tag{2}$$

This error is primarily due to the stochastic intraclass variability of the soil and vegetation subclasses. The theoretical uncertainty of LAI, σ_{LAI}, combines uncertainties attached to the FVC estimate and parameters a_0 and b:

$$\sigma_{\mathrm{LAI}}^2 = \left(\frac{\sigma_{\mathrm{FVC}}}{a_1(a_0-\mathrm{FVC})}\right)^2 + \left(\frac{\mathrm{LAI}\cdot\sigma_{a_1}}{a_1}\right)^2 + \left(\frac{\mathrm{FVC}\cdot\sigma_{a_0}}{a_0 a_1(a_0-\mathrm{FVC})}\right)^2. \tag{3}$$

where $a_1 = b \cdot \Omega$. Typical uncertainty values adopted for the model parameters are σ_{a_0}= 0.03 and σ_{a_1}= 0.04.

The theoretical FAPAR uncertainty is assessed by propagating input error through the model, which mainly depends in turn on the errors in the reflectance computed in the optimal geometry for red and NIR channels.

$$\sigma_{FAPAR} = 1.81 \cdot Err(\mathrm{RDVI}). \tag{4}$$

The RDVI can be written as:

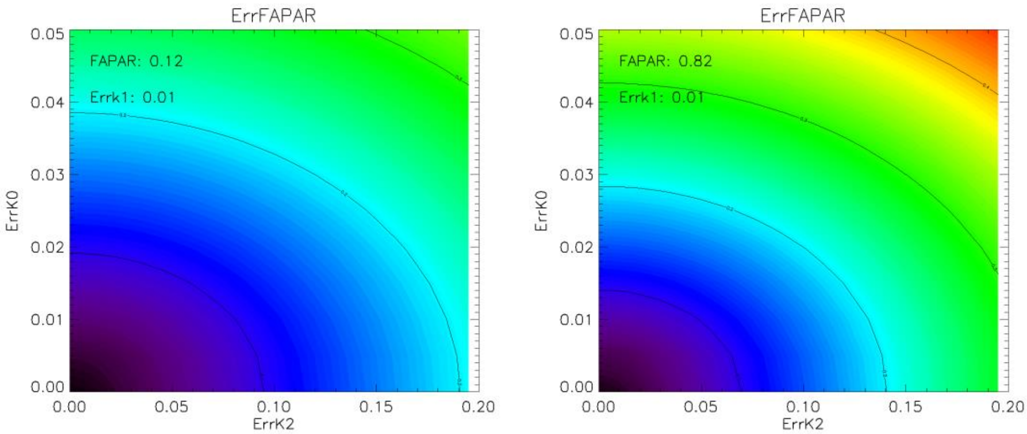
$$Err(\mathrm{RDVI}) = [Err(R(C2)) + Err(R(C1))] \cdot \left[\frac{1}{\sqrt{R(C1)+R(C2)}} + \frac{1}{2}\frac{(R(C2)-R(C1))}{(R(C1)+R(C2))^{\frac{3}{2}}}\right], \tag{5}$$

where Err(R(Ci)) in the optimal geometry used for retrieving the FAPAR is computed as:

$$Err(R) = Err(k_0) + 0.240Err(k_1) + 0.202Err(k_2), \quad (6)$$

and the theoretical uncertainty of the directional error is given in the C00, C11 and C22 fields of the HDF5_LSASAF_MSG_AL-C_i-CK product.

Figure S1 shows the FAPAR uncertainty computed as explained above with respect to the uncertainties of the k_0 and k_2 directional parameters for a fixed uncertainty of 0.01 in the k_1 parameter, and for both low and high FAPAR values. The variations of the input errors are in agreement with the range of uncertainties found in the BRDF product [55]. A threshold based on the error of k_2 equal to 0.25 has been used to blind unreliable FAPAR areas (with FAPAR error estimate larger than 0.2).



(**a**) (**b**)

Figure S1. Theoretical FAPAR error as a function of input k_0 and k_2 errors for a given k_1 error of 0.01. Two different cases have been considered: Low FAPAR values (**a**) and high FAPAR values (**b**).

Table S1: Cover-dependent clumping index values for LAI algorithm based on the GLC2000 land cover classification based on values obtained in [51].

GLC2000 Class	Global Class name (according to LCCS terminology)	Clumping Index
1	Tree Cover, broadleaved, evergreen	0.68
2	Tree Cover, broadleaved, deciduous, closed	0.79
3	Tree Cover, broadleaved, deciduous, open	0.78
4	Tree Cover, needle-leaved, evergreen	0.68
5	Tree Cover, needle-leaved, deciduous	0.77
6	Tree Cover, mixed leaf type	0.79
7	Tree Cover, regularly flooded, fresh water	0.69
8	Tree Cover, regularly flooded, saline water,	0.79
9	Mosaic: Tree cover / Other natural vegetation	0.82
10	Tree Cover, burnt	0.86
11	Shrub Cover, closed-open, evergreen	0.80
12	Shrub Cover, closed-open, deciduous	0.80
13	Herbaceous Cover, closed-open	0.83
14	Sparse Herbaceous or sparse Shrub Cover	0.84
15	Regularly flooded Shrub and/or Herbaceous Cover	0.85
16	Cultivated and managed areas	0.83
17	Mosaic: Cropland / Tree Cover / Other natural vegetation	0.76
18	Mosaic: Cropland / Shrub or Grass Cover	0.81
19	Bare Areas	0.99
20	Water Bodies	---
21	Snow and Ice	---
22	Artificial surfaces and associated areas	---

Table S2. VEGA products Q-Flag information. The default missing value for the product fields is -10. The associated error estimate fields for unprocessed pixels take different negative values, depending on the identified problem (default missing value =–10).

Bit	Bit information	Binary Code	Description	Products are processed
Bits 0-1	Land Sea Mask(*)	00	Ocean	No
		01	Land	Yes
		10	Space (Outside of MSG disk)	No
		11	Continental water	No (errors set to –20)
Bit 2	MSG(*)	0	No MSG Observations	Yes
		1	Including MSG Observations	Yes
Bit 3	Traces of inland water	0	No	Yes
		1	High Probability	Yes
Bit 4	Traces of snow cover	0	No	Yes
		1	High Probability	No (errors set to –31)
Bit 5	Snow(*)	0	No Snow	Yes
		1	Snow	No (errors set to –30)
Bit 6	Unrealistic Input ranges	0	Reliable	Yes
		1	Unreliable	No (errors set to –40)
Bit 7	Failure(*)	0	Input Normally Processed	Yes
		1	Input Algorithm Failed	No

(*) This information is reported from the BRDF product quality flag to the VEGA product quality flag.

Table S3. Main identified problems in the VEGA products and empirical thresholds used to blind problematic areas. Note that although the missing value for the product fields is unique (-10), associated error estimate fields for unprocessed pixels take different negative values, depending on the identified problem (default missing value =–10).

Identified problem	**Condition**	**Products are processed**
Traces of snow	$k_0(\lambda_1) - k_0(\lambda_3) > 0$ or $k_0(\lambda_1) > k_{0,\max}(\lambda_1) + 0.06$ or $\left(k_0(\lambda_1) > k_{0,\max}(\lambda_1) + 0.02 \text{ and } k_0(\lambda_3) < k_{0,\min}(\lambda_3)\right)$	No (bit 4 set to 1, Errors set to –31)
Unrealistic input ranges (*)	$k_0(\lambda_2) < 0.03 \text{ or } k_0(\lambda_3) < 0.03 \text{ or } \sum_{i=1}^{3} k_0(\lambda_i) < 0.03$	No (bit 6 set to 1, errors set to –40)
Traces of inland water(**)	$\sum_{i=1}^{3} k_0(\lambda_i) < 0.09$	Yes (bit 3 set to 1)
Large k_0 errors	$\frac{1}{3}\sum_{i=1}^{3} Err(k_0(\lambda_i)) < 0.10$	No (Errors set to –15)
Large k_2 errors	$Err(k_2(\lambda_1)) > 0.25 \; or \; Err(k_2(\lambda_2)) > 0.25$	Yes (FVC, LAI) No (FAPAR) FAPAR_err=–50
Large BRDF errors in optimal geometry	$Err(R_{opt}(\lambda_1)) > 1.0 \; or \; Err(R_{opt}(\lambda_2) > 1.0$	Yes (FVC, LAI) No (FAPAR) FAPAR_err=–50
Unrealistic input in optimal geometry	$R_{opt}(\lambda_2) < 0.03 \; or \; (R_{opt}(\lambda_1) + R_{opt}(\lambda_2)) < 0.06$	Yes (FVC,LAI) No (FAPAR) FAPAR_err=–40
Out of FAPAR physical range (***)	FAPAR >1	Yes (FVC,LAI) No (FAPAR) FAPAR_err=–60 FAPAR=–60

(*) The BRDF algorithm produces values out of the physical ranges in a few areas (i.e. less than 1% of land surface). Typical examples correspond to high reflectance values (e.g. for NIR reflectance at high latitudes) or negative values (e.g., for red reflectance at high view zenith angle geometries). Very dark reflectance pixels are discarded, whereas abnormally bright pixels are set to a reflectance to a maximum value (typically 0.70, 0.80 and 0.90 for the red, NIR and MIR bands, respectively).

(**) These areas should be taken with special caution by the user, since the reliability of the product may be low. This problem affects, however, to less than 0.5% of land surface pixels and is mainly located in the SAme geographical zone.

(***) FAPAR retrieval values out of maximum physical range are blinded (this problem affects only to less than 1% of land pixels). For values below 0 the FAPAR product is set to 0; this affects only to desert areas (eg. Sahara).