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Assessment of five global satellite products of fraction of absorbed photosynthetically active radiation: Intercomparison and direct validation against ground-based data

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ABSTRACT

The fraction of absorbed photosynthetically active radiation (FAPAR) is a critical input parameter in many climate and ecological models. The accuracy of satellite FAPAR products directly influences estimates of ecosystem productivity and carbon stocks. The targeted accuracy of FAPAR products is 10%, or 0.05, for many applications. It is important to evaluate satellite FAPAR products and understand differences between the products to effectively use them in carbon cycling models. In this study, five global FAPAR products, namely MODIS, MISR, MERIS, SeaWiFS, and GEOV1 are intercompared over different land covers and directly validated with ground-based measurements at VAlidation of Land European Remote sensing Instruments (VALERI) and AmeriFlux sites. Intercomparison results show that MODIS, MISR, and GEOV1 agree well with each other and so do MERIS and SeaWiFS, but the difference between these two groups can be as large as 0.1. The temporal trends of these products agree better with each other in the Northern Hemisphere than in the Southern Hemisphere. The trends in the Northern Hemisphere are similar to those globally. However, the conclusions from the northern hemispheric scale could not be extended to the global scale for land covers such as savannahs and broadleaf evergreen forests. The differences between the products are consistent throughout the year over most of the land cover types, except over the forests, because of the different assumptions in the retrieval algorithms and the differences between green and total FAPAR products over forests. Direct validation results show that MERIS, MODIS, MISR, and GEOV1 FAPAR products have an uncertainty of 0.14 when validating with total FAPAR measurements, and 0.09 when validating with green FAPAR measurements. Overall, current FAPAR products are close to, but have not fulfilled, the accuracy requirement, and further improvements are still needed.

1. Introduction

The fraction of absorbed photosynthetically active radiation (FAPAR) is the fraction of incoming solar radiation in the spectral range of 400 nm to 700 nm that is absorbed by plants (Liang, Li, & Wang, 2012). FAPAR is one of the 50 Essential Climate Variables (ECVs) recognized by the UN Global Climate Observing System (GCOS, 2011). FAPAR is a critical input parameter in the biogeophysical and biogeochemical processes described by many climate and ecological models (e.g., Community Land Model, Community Earth System Model, and crop growth models) (Bonan et al., 2002; Kaminski et al., 2012; Maselli, Chiesi, Fibbi, & Moriondo, 2008; Tian et al., 2004).

The accuracy of the satellite FAPAR products directly influences estimates of ecosystem productivity and carbon stocks. A relative accuracy of 10%, or absolute accuracy of 0.05, in FAPAR is considered acceptable in agronomical and other applications (GCOS, 2011). MODIS Collection 4 FAPAR product is validated with ground-based measurements in early studies (Baret et al., 2007; Fensholt, Sandholt, & Rasmussen, 2004; Huemmrich, Privette, Mukelabai, Myneni, & Knyazikhin, 2005; Olofsson & Eklundh, 2007; Steinberg, Goetz, & Hyer, 2006; Turner et al., 2005; Weiss, Baret, Garrigues, & Lacaze, 2007; Yang et al., 2006). The improved performance of Collection 5 over Collection 4 LAI/FAPAR products is demonstrated before the public release by Shabanov et al. (2005). Recently, the MODIS Collection 5 FAPAR product is assessed or compared with other products and has been shown to improve accuracy over Collection 4 from 0.2 to 0.1 (Baret et al., 2013; Camacho, Cemicharo, Lacaze, Baret, & Weiss, 2013; Martinez, Camacho, Verger, Garcia-Haro, & Gilabert, 2013; McCallum et al., 2010; Pickett-Heaps et al., 2014). An intermediate MODIS FAPAR Collection 4.1 product fixes the bug that existed in Collection 4, and its performance is assessed to have improved over Collection 4 but not as good as Collection 5 (Seixas, Carvalhais, Nunes, & Benali, 2009; Serbin, Ahl, & Gower, 2013). The MERIS FAPAR product has been assessed or compared with other FAPAR products and validated to show an accuracy

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Table 1
The AmeriFlux and VALERI experimental sites used in this study.

Site	State, Country	Latitude (°)	Longitude (°)	Land Cover
Mead Irrigated	Nebraska, US	41.1651	−96.4766	Crops
Mead Irrigated Rotation	Nebraska, US	41.1649	−96.4701	Crops
Mead Rainfed	Nebraska, US	41.1797	−96.4396	Crops
Bartlett	New Hampshire, US	44.0646	−71.2881	Deciduous broadleaf forests
Laprida	Argentina	−36.9904	−60.5527	Grass
Camerons	Australia	−32.5983	116.2542	Evergreen broadleaf forests
Gnangara	Australia	−31.5339	115.8824	Deciduous broadleaf forests
Sonian forest	Belgium	50.7682	4.4111	Needleleaf forests
Donga	Benin	9.7701	1.7784	Grass
Turco	Bolivia	−18.2395	−68.1933	Shrubland
Larose	Canada	45.3805	−75.2170	Needleleaf forests
Concepción	Chile	−37.4672	−73.4704	Deciduous needleleaf forests
Zhangbei	China	41.2787	114.6878	Grass
Les Alpilles	France	43.8104	4.7146	Crops
Larzac	France	43.9375	3.1230	Grass
Nezer	France	44.5680	−1.0382	Needleleaf forests
Plan-de-Dieu	France	44.1987	4.9481	Crops
Puéchabon	France	43.7246	3.6519	Mediterranean forests
Sud-Ouest	France	43.5063	1.2375	Crops
Counami	French Guiana	5.3471	−53.2378	Evergreen broadleaf forests
Demmin	Germany	53.8921	13.2072	Crops
Gilching	Germany	48.0819	11.3205	Crops
Hombori	Mali	15.3310	−1.4751	Grass
Haouz	Morocco	31.6592	−7.6003	Crops
Wankama	Niger	13.6450	2.6353	Grass
Fundulea	Romania	44.4061	26.5831	Crops
Barrax	Spain	39.0570	−2.1042	Crops

The first four sites are AmeriFlux sites, others are VALERI sites.

of 0.1 to 0.12 (D'Odorico et al., 2014; Gobron et al., 2008; Martinez et al., 2013; Pickett-Heaps et al., 2014; Seixas et al., 2009). The Sea-Viewing Wide Field-of-View Sensor (SeaWiFS) FAPAR product has been compared with other FAPAR products and evaluated to have an accuracy of 0.1 to 0.23 in the studies by Wang et al. (2001), Gobron et al. (2006), McCallum et al. (2010), Camacho et al. (2013), and Pickett-Heaps et al. (2014). The GEOV1 FAPAR is intercompared against MODIS Collection 5 and SeaWiFS products and validated to have the best performance with an accuracy of 0.08 (Baret et al., 2013; Camacho et al., 2013). However, few studies have evaluated the Multi-Angle Imaging SpectroRadiometer (MISR) FAPAR product (Hu et al., 2007). Currently, no intercomparison studies of MISR FAPAR product and other FAPAR products exist. The intercomparison of the products at various scales would help to understand and reduce large systematic biases among the magnitudes of existing products. In consideration of the need to evaluate current FAPAR products, this study focuses on a comprehensive evaluation of the performances of MISR, MODIS, SeaWiFS, MERIS, and GEOV1 FAPAR products at the global scale.

The remainder of this paper is organized as follows. Section 2 presents the satellite FAPAR products and the validation data as well as the data processing and ground-based measurement methods. Section 3 intercompares FAPAR products globally and over different land cover types. Section 4 directly validates the FAPAR products with ground-based measurements. The findings are discussed and concluded in Sections 5 and 6, respectively.

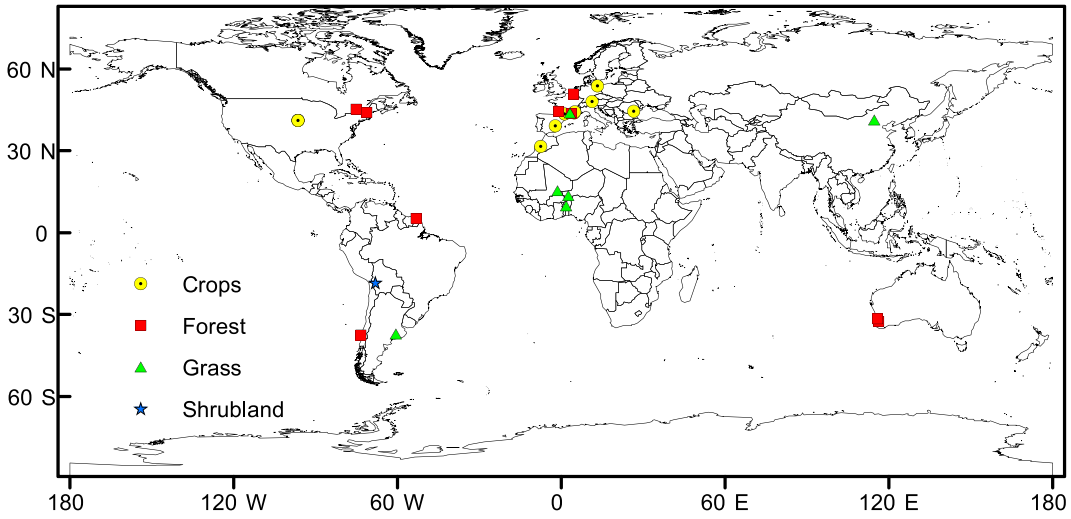

Fig. 1. The distribution of the 27 VALERI and AmeriFlux sites. There are 3 AmeriFlux and 3 VALERI sites close to each other, which may not be distinguishable from each other at a global scale here.