THE LAND SURFACE ANALYSIS SAF: ONE YEAR OF PRE-OPERATIONAL ACTIVITY

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Abstract

The goal of this communication is to provide an overview of the main achievements of the Satellite Application Facility on Land Surface Analysis (LSA SAF), as well as presenting an account of applications of LSA SAF products already been carried out by the end user community. The LSA SAF has initiated its pre-operational phase on January 2005 and its main purpose is to develop techniques to retrieve products related with land, land-atmosphere interactions and biospheric applications, using satellite information, namely from Meteosat-8 and the forthcoming Metop-2. The LSA SAF system is fully centralized at the Portuguese Institute of Meteorology (IM) and is currently able to operationally generate, archive, and disseminate a set of pre-operational products; Surface Albedo, Land Surface Temperature, Snow Cover, and Downwelling Surface Short- and Long-wave Fluxes. Although the Numerical Weather Prediction community has been identified as having the greatest potential to fully exploit the LSA SAF products, these also provide relevant information to a wide range of applications. Some actual examples of the latter include the MARS Crop Yield Forecasting System (MCYFS), the mapping of surface components of the hydrological cycle and the planning of flights over transects of heterogeneous surface moisture in the framework of the African Monsoon Multidisciplinary Analysis (AMMA). Currently, the LSA SAF is also involved in GEOLAND, a GMES-related integrated project under the Sixth Framework Programme, whose products and services focus on the monitoring of land cover and vegetation with the purpose of helping authorities to fulfil their environmental monitoring and reporting obligations and manage their natural resources more effectively.

INTRODUCTION

As part of the Satellite Application Facility (SAF) Network, the SAF on Land Surface Analysis (LSA SAF) is a specialised development and processing centre whose aim is to take full advantage of remotely sensed data, particularly those available from EUMETSAT sensors, to describe/derive land surface properties/variables. Like other SAFs, the LSA SAF has successfully completed the Development Phase (June 1999 – December 2004) and is currently at its Initial Operational Phase (January 2005 – February 2007).

As shown in Table 1 the LSA SAF products are related with physical and biophysical properties of the land surface, and are especially relevant to estimating the surface radiative and energy budgets. Accordingly it is expected that the LSA SAF products are relevant to a wide range of applications, including weather forecasting and climate modelling, environmental management and land use, agricultural and forestry applications, renewable energy resource assessment and natural hazard management.

Currently SAF products are derived from SEVIRI/Meteosat-8 over four geographical areas – Europe, North Africa, South Africa, and South America (see Figure 1) –, covering most land pixels within the Meteosat disk.
<table>
<thead>
<tr>
<th>Product</th>
<th>Acronym</th>
<th>Type</th>
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<tbody>
<tr>
<td>Surface Albedo</td>
<td>AL</td>
<td>Pre-Operational</td>
</tr>
<tr>
<td>Bi-directional Reflectance Distribution Function</td>
<td>BRDF</td>
<td>Internal</td>
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<tr>
<td>Land Surface Temperature</td>
<td>LST</td>
<td>Pre-Operational</td>
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<tr>
<td>Land Surface Emissivity</td>
<td>EM</td>
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<tr>
<td>Downwelling Surface Short-wave Flux</td>
<td>DSSF</td>
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<td>Downwelling Surface Long-wave Flux</td>
<td>DSLF</td>
<td>Pre-Operational</td>
</tr>
<tr>
<td>Snow Cover</td>
<td>SC</td>
<td>Pre-Operational</td>
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<tr>
<td>Soil Moisture and Evapotranspiration</td>
<td>SMET</td>
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<tr>
<td>Fractional Vegetation Cover</td>
<td>FVC</td>
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</tr>
<tr>
<td>Leaf Area Index</td>
<td>LAI</td>
<td>Internal</td>
</tr>
<tr>
<td>Fraction of Absorbed Photosynthetic Active Radiation</td>
<td>IAPAR</td>
<td>Under Development</td>
</tr>
</tbody>
</table>

Table 1: The LSA SAF products.

Figure 1: The four geographical areas; Europe, North Africa, South Africa, and South America.

Figure 2: Two examples of LSA SAF products as defined over Europe; snow cover (upper panel) and evapotranspiration (bottom panel).
Figure 3: Examples of LSA SAF products as defined over the Meteosat disk; surface albedo (AL), land surface temperature (LST), downwelling surface short-wave flux (DSSF), downwelling surface long-wave flux (DSLF), fractional vegetation cover (FVC) and leaf area index (LAI).
THE LSA SAF PRODUCTS

AL and BRDF

The AL products (Figure 3) are derived on a daily basis (associated to a time-scale of the order of 3- to-5 days) as well as on a 20-day composite basis over the four geographical areas. They are currently available at the spatial resolution of the SEVIRI/Meteosat instrument and are delivered for the three short-wave channels (i.e. VIS 0.6µm, NIR 0.8µm, SWIR 1.6µm) as well as for the visible, near-infrared and total short-wave wavelength ranges. First, cloud-free reflectance observations are corrected for atmospheric effects using a simplified radiative transfer model. A linear kernel-driven BRDF model is then fitted to a daily time series of the resulting top-of-canopy (TOC) reflectance factor values. Finally albedo estimates are obtained by integrating the BRDF model functions and the generated products include the directional-hemispherical (or 'black-sky') albedo as well as the bi- hemispherical (or 'white-sky') albedo.

LST and EM

The main algorithm for LST estimation is based on a Generalized Split Window (GSW) and relies on information from the atmospheric window channels IR10.8 and IR12.0. The LST product (Figure 3) is provided every 15-minutes on a pixel-by-pixel basis over the four geographical regions, with satellite viewing angles below 57.5°. The EM algorithm is based on the so-called Vegetation Cover Method (VCM), using FVC, as its main input. The generation frequency of EM follows that of the FVC product and accordingly is derived daily and on a 10-day basis over the four geographical areas.

DSSF and DSLF

DSSF refers to the radiative energy in the wavelength interval [0.3µm, 4.0µm] reaching the Earth's surface per time and surface unit. Separate algorithms are applied for clear sky and cloudy sky situations. DSSF is strongly anti-correlated with observed TOA reflectances; the brighter the clouds, the more radiation is reflected and the less radiation reaches the surface. In the case of clear sky the DSSF estimate is directly determined by parameterising the effective transmittance of the atmosphere as a function of the concentration of atmospheric constituents. The DSLF product (Figure 3) is provided every 30-minutes on a pixel-by-pixel basis over the four geographical areas.

DSLF can only be indirectly inferred from remotely sensed data and the LSA SAF product is estimated using the signature of clouds and cloud types on IR and VIS channels, complemented with information on atmosphere water content and temperature profiles available from ECMWF forecasted fields (forecasts within ranges between 12h and 24h), that include information from atmospheric sounders and other observations, and therefore may be viewed as reflecting the best knowledge of atmospheric profiles for each time-slot. As in the case of DSSF, the LSA SAF DSLF product uses different bulk parameterization schemes applicable to clear sky or to cloudy pixels. The DSLF product (Figure 3) is generated every 30-minutes over the four geographical regions, up to viewing angles of 80°.

SC

The SC algorithm determines whether a satellite ground pixel is fully or partially snow covered, through the use of different signatures of snow, ice, and clouds on the reflectance of SWIR1.6 and SWIR3.9 SEVIRI channels. The SC product (Figure 2) is generated on a daily basis over the four geographical areas and surface pixels are classified as totally snow covered, partially snow covered, with no snow, unclassified or non-processed.

FVC, LAI and FAPAR

FVC, LAI and fAPAR constitute the LSA SAF Vegetation Products (VEGA). FVC determines the partition between soil and vegetation contributions, whereas for fully and healthy developed canopies
LAI indicates the amount of green vegetation that absorbs or scatters solar radiation. fAPAR is an indicator of the health and thereby productivity of vegetation and is generally well-correlated with LAI, particularly for healthy fully developed vegetation canopies. The generation of the three VEGA products relies on AL and BRDF parameters, making use of the vegetation signatures on (directional) reflectances of channels VIS0.6, NIR0.8 and SWIR1.6. Derivation of VEGA products is closely linked to those of AL and BRDF products and therefore FVC, LAI and fAPAR (Figure 3) are generated on a daily and on a 20-day composite basis over the four geographical areas.

SMET

In the current approach, evapotranspiration is estimated using a simplified SVAT model forced by LSA SAF radiation products (DSSF, DSLF, and AL) as well as by ECMWF meteorological parameters. The soil moisture is taken from ECMWF analysis but more realistic estimates are being envisaged e.g. based on information form ASCAT/Metop and SMOS. Evapotranspiration (Figure 2) is currently being generated on a daily basis over Europe.

THE USER COMMUNITY

As pointed out in the introduction, the LSA SAF products are relevant to a wide range of applications. Although the Numerical Weather Prediction (NWP) community has been identified as having the greatest potential to fully exploit the LSA SAF products and was therefore assigned the highest priority during the Development Phase, the LSA SAF addresses a much broader community, including amongst others:

- Weather forecasting and climate modelling, which require detailed information on the nature and properties of land.
- Environmental management and land use, which require information on land cover type and land cover changes.
- Agricultural and Forestry applications, which require information on soil and vegetation properties.
- Renewable energy resource assessment, particularly biomass, which depends on biophysical parameters, and solar energy, which highly depends on DSSF.
- Natural hazard management, which requires frequent observations of terrestrial surfaces in both the solar and thermal bands, as well as merged information from NWP models and surface characteristics.

The LSA SAF Consortium has always recognized the importance of correctly and comprehensively identifying the user community and of keeping a lively interaction between developers and users. At the end of the Development Phase a user survey focusing on the potential use of LSA SAF products was performed, inquiring a wide range of potential users that included most European National Meteorological Services (NMSs) and several European hydrological services. Several users groups were identified and approached through direct contact to be part of the LSA SAF beta-users group. Besides ECMWF and NMSs (e.g. INM, M-F, IM), the beta-user group encompasses a wide variety of research institutes such as the Joint Research Centre (JRC), VITO, the Department of Civil Engineering of the University of Florence, the Centre for Ecology and Hydrology (Wallington, UK), the Institute for Atmospheric Science at the School of the Environment of the University of Leeds (UK), Médias (France), the Department of Earth and Environmental Sciences of the University of Munich (Germany), the Wageningen University and Research Centre (The Netherlands), the Laboratoire de Météorologie Dynamique (France) and ICAT at the University of Lisbon (Portugal). The beta-user group has been providing useful information on the adequacy of product accuracy, spatial coverage and projection, and timeliness for their fields of application. In order to inform users about achievements and progress on products as well as reinforcing the links with the user community, the LSA SAF consortium has also promoted two Workshops for information and user training, that were respectively held in Lisbon from the 8th to the 10th of July 2002 and from the 8th to the 10th of March 2006.

The dialogue initiated with the end-users community during the IOP has proved to be an invaluable (indirect) mean of LSA SAF products validation since it has allowed users to appraise the reliability of
the products as well as their limitations, and based on such appraisal assist developers in the process of reviewing and improving the algorithms. Actual examples of fruitful interactions between the LSA SAF and the user community include the MARS Crop Yield Forecasting System (MCYFS), the mapping of surface components of the hydrological cycle and the planning of flights over transects of heterogeneous surface moisture in the framework of the African Monsoon Multidisciplinary Analysis (AMMA). The on-going close interaction with the NWP community (e.g., INM, M-F, and ECMWF) has also proved to be a crucial step towards acceptance of LSA SAF products by the NWP community.

Figure 4 presents two indicators of the impact of the LSA SAF products on the user community, namely the number of registered users and the monthly bandwidth of the LSA SAF web page. The positive trends observed in both indicators may be viewed as reflecting a growing interest for LSA SAF products.

![Figure 4: Number and classes of registered users of LSA SAF products (upper panel) and monthly bandwidth of the LSA SAF web page (lower panel).]

A LOOK INTO FUTURE DEVELOPMENTS

The LSA SAF Consortium is currently preparing for the next 5-year Continuous Development Operational Phase (CDOP), which will be devoted to consolidating operational activities as well as to maintaining and steering both Engineering and Scientific R&D Activities.

The consolidation of operational activities (i.e., the generation, dissemination and archiving of LSA products) include (i) the monitoring of the LSA SAF processing chain (i.e. reception of input data, product generation, archiving, dissemination); (ii) the monitoring of LSA SAF (pre-)operational products; (iii) the maintenance of the interfaces between product algorithms and the LSA SAF system;
and (iv) the maintenance of the helpdesk service, and general user support (updated website, workshops).

Engineering R&D activities will include essentially the upgrading of (i) the LSA SAF system, following the demands of new operational products and/or sensors to be processed as well as of software and/or hardware evolution; (ii) of the functionalities available at the LSA SAF website.

Science R&D activities will focus on the following aspects:

- The maintenance of existing (pre-)operational products, including (i) “fine tuning” of the algorithms, as suggested from validation and monitoring of products; (ii) the development of merged products using AVHRR and SEVIRI data; and (iii) the maintenance of Product User Manuals and other documents relevant to the description of the LSA SAF products.
- The validation of the LSA SAF products, namely (i) the comparison of LSA SAF products with similar parameters retrieved from different sensors; (ii) the comparison with in-situ measurements; (iii) the performance of sensitivity studies and the assessment of the impact of input errors on the quality of the LSA SAF products.
- The improvement of existing products following new user requirements and/or the adaptation to new sensors (e.g. MODIS), including the preparation for post-MSG (MTG), and post-EPS data.
- The development of new land surface related products, to be operational during the CDOP. New products considered encompass the domains of Fire Detection and Monitoring (FD&M) and the Mapping of Fire Risk (MFR) and, in this respect, the LSA SAF will explore in particular the capability of Meteosat/SEVIRI to detect and monitor active fires (especially in Africa) as well as to identify signals of vegetation water stress on SEVIRI channels over Europe.

The LSA SAF is also planning to reinforce its participation in programmes such as the Global Climate Observing System (GCOS) from WMO and the Global Monitoring of Environment and Security (GMES) from EC and ESA. The aim of GCOS is threefold; (i) to ensure the data needs for climate system monitoring; (ii) to improve the observing capabilities; and (iii) to integrate observation into useful products. The aim of GMES is establish a European capacity for the provision and use of operational information for global monitoring of environment and security.

Both GCOS and GMES have established important guidelines for monitoring of climate and environment, stressing the need for global, long-term, high quality and reliable products, and the LSA SAF shows up to be in a privileged position as a product/service provider for those programmes. The LSA SAF has been involved in discussions and workshops related to GCOS, and is already contributing to prototyping addressing GCOS requirements. The LSA SAF is also involved in GEOLAND, a GMES-related integrated project under the Sixth Framework Programme. GEOLAND aims to develop and integrate a range of geo-information services and products focusing on land cover and vegetation monitoring with the purpose of helping authorities to fulfil their environmental monitoring and reporting obligations and manage their natural resources more effectively. The LSA SAF Consortium is also currently involved in preliminary discussions to initiate steps towards the definition and implementation of the Global Component of the GMES Land Monitoring Service. In this respect, it is worth mentioning that requirements for producing global products will be considered through the use of EPS data; other non-EUMETSAT remote sensing data (e.g. from NPOESS satellites) may be considered subject to availability.

Last but not least the proactive relationship with the user community, already established during the IOP, will be reinforced, keeping in mind that contacts with the user community make the User Requirement Document (URD) a live document to be upgraded whenever necessary. In particular, the LSA SAF Team intends to involve the beta-user group in validation activities and will promote inquiries and organise workshops to discuss the adequacy of the LSA SAF list of products, and respective characteristics.
ACKNOWLEDGEMENTS

The present paper is an account of results from a collective work and the author is naturally indebted to the entire LSA SAF Team. Details about the presented material may be found in the two following documents, submitted to EUMETSAT by the Portuguese Institute of Meteorology (IM) on behalf of the main and associated cooperating entities of the LSA SAF:


Other useful information may be found at the LSA SAF website: http://landsaf.meteo.pt

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