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A word from the Scientific and Technical Directors

The first Theia agreement, covering 2013-2016, is drawing to a close so we have begun planning the one for 2017-2020. The executive board of the Theia cluster has drafted a road-map for the coming few years. We shall, for example, be working hard to ensure the long-term future of infrastructures once Equipex Geosud comes to an end, to prepare in the medium term the research infrastructure for "Earth System Observation" covering the four thematic data centres, to consolidate management of regional Theia networks, extend the portfolio of products and services offered with the inclusion of airborne and *in situ* data, and ensure that Theia is firmly rooted in European systems.

Thanks to you, contributors and users, the Theia cluster is making headway in all the various strategic areas decided upon. This collective success nonetheless remains fragile and we shall therefore need to consolidate it.



Nicolas Baghdadi



Marc Leroy

LATEST NEWS

Sentinel-2

The Sentinel-2A satellite successfully passed its in-orbit checkout and data distribution began in November 2015. The Sentinel-2 system is not yet in its operational configuration, however, and only Europe and Africa are currently systematically observed whenever the satellite passes overhead, every ten days. Teething problems led to the loss of several acquisitions, but it appears that these initial difficulties are gradually being ironed out.

We shall have to wait until the summer of 2016 to reach the end of this incremental phase, the second satellite, Sentinel-2B, being scheduled for launch in late 2016 in order to offer a full system by mid- 2017.

Meanwhile, a call for proposals concerning the areas with 2A level processing by Theia (atmospheric corrections and cloud mask) was addressed to the French public community. The proposals have just been **selected and published**. The MUSCATE processing facility should start producing these data by the summer of 2016.

Oliver Hagolle (Cesbio / Cnes)

SPOT 6-7

The contract for accessing SPOT 6/7 imagery through the Geosud receiving station in Montpellier and the telemetry contract signed by six partners in June 2015 have now entered their second year. The last Theia bulletin gave an overview of the 2015 campaign.

Since being commissioned, the station has already acquired over 1,050 seg-

ments equivalent to 1,575 scenes, not only over France but the whole world. These images are mainly geared to the science community.

The 2016 acquisition campaign for annual national coverage was kicked off on 1 March. It continues to occupy the teams from IGN Espace, the Geosud station and the Airbus Defence & Space (ADS) programming department. So far, 48% of the 237 tiles covering the French territory (mainland France and Corsica) have been acquired. The IGN will also produce a mosaic of French Guiana (coastline and transboundary rivers) based on archived SPOT 6/7 images taken in 2015 by activating an additional telemetry funding tranche as authorised by the contract between the six consortium partners and ADS.

The 2016 campaign of new "tailored acquisition" requests either based on ADS image archives or by programming the SPOT 6/7 satellites is about to begin. A new version of the on-line form is available, this time designed for both Pleiades and SPOT 6/7 images (satelliteimageaccess.eu). This will make it easier for applicants to express their needs and for those processing the applications to manage the requests.

A new version of the **Geosud data and services infrastructure**, IDS, was rolled out in early 2016. It includes a new subscription system with a single means of identification that can be used for the whole Theia IDS (Geosud being just one component). The subscription database (structures, advisers and users) has just been updated and integrated in the new version. Its features include more efficient consultation of the catalogue, full-resolution image display (web mapping service flows and display) and direct downloads without having to use an FTP server. The



Sentinel-2 image of Île de Ré and La Rochelle (26 December 2015). © Copernicus data (2015) / ESA

Geosud teams are gradually integrating all the images acquired from the beginning. The long-term archiving of images at CINES should be operational by the end of 2016.

Finally, a working group jointly steered by CNES and Geosud was set up in late 2015 to link the thematic centres with the SPOT 6/7 consortium partners. It is tasked with proposing solutions to achieve a unified national system that will allow the science community and public policy players to access a bouquet of complementary images – priority being given to Pleiades and SPOT 6/7 imagery.

Pierre Maurel (Irstea)

Meeting to introduce the land use product

The Theia regional coordination network (abbreviated ART) for Languedoc-Roussillon held a meeting of the land use scientific expert centre (CES OSO) at the *Maison de la Télédétection* in Montpellier on 12 April 2016. The meeting attracted over 35 interested participants representing a broad range of regional players, including research laboratories, design offices and state organisations.

Jean-François Dejoux, research engineer at the CESBIO biosphere research centre, gave a presentation on the land use scientific expert centre. Its purpose is to design and develop automated algorithms to produce land use maps from satellite images. The goal is to produce an annual nationwide map to a 10-metre resolution with between 15 and 20 land use classes.

There were many useful discussions on the centre's purpose and its development; on which land use naming system

to choose and how it could be tailored to the special features of the Mediterranean, and on possible future enhancements. Jean-François Dejoux stressed the fact that calibrations are needed using generic national data (RPG graphical parcel-based reference frame, BD TOPO etc.) but that validation will take into account land use in the different regions.

Regional stakeholders took part, sharing their experience and describing the data currently available concerning their regions. Clara Leveque of the Languedoc-Roussillon GIS association "SIG L-R" presented the various land uses in the Languedoc-Roussillon-Midi-Pyrénées region and their distribution through the IDG regional geographic data infrastructure. Hélène Durand showed a few examples of products made using Ali-sé Géomatique for local land uses at a very small scale and with a very detailed land use nomenclature. She also demonstrated the advantages of these products for needs as varied as urban growth studies over time, the green and blue belt network or discussions on land use planning. Finally, Claire Dupaquier of the TETIS joint research unit presented the complementary aspects of remote sensing approaches (segmentation and automatic classification) and more conventional photo-interpretation approaches to achieve a very high quality land use map of the Thau lagoon near Sète in southern France.

It is this concept of complementarity that marked the meeting because the land use scientific expert centre is not meant to replace locally-produced and very detailed land use maps but add to the portfolio of tools available to help us understand our region.

To go further :

- WMS : <http://cyan.ups-tlse.fr:8080/geoserver/SudOuest/wms?%2FSudOuest%3AOSOV1%3F>

[geoserver/SudOuest/wms?%2FSudOuest%3AOSOV1%3F](http://cyan.ups-tlse.fr:8080/geoserver/SudOuest/wms?%2FSudOuest%3AOSOV1%3F)

- Nomenclature : www.cesbio.ups-tlse.fr/multitemp/wp-content/uploads/2016/02/SudOuestMosaic_France2014_V1_ColorIndexedT.html
- Metadata and information : www.cesbio.ups-tlse.fr/multitemp/wp-content/uploads/2016/01/ocs.html

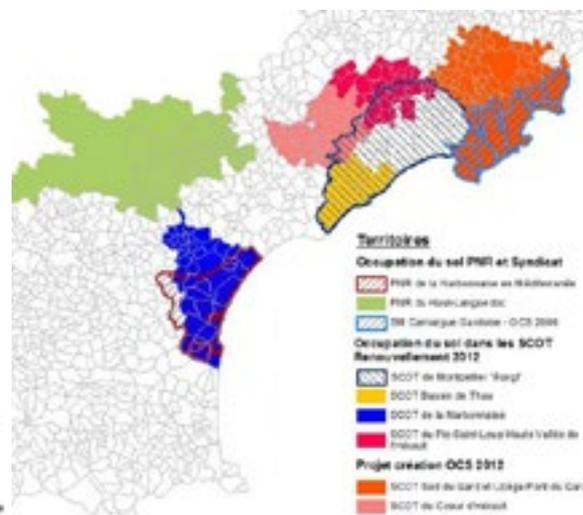
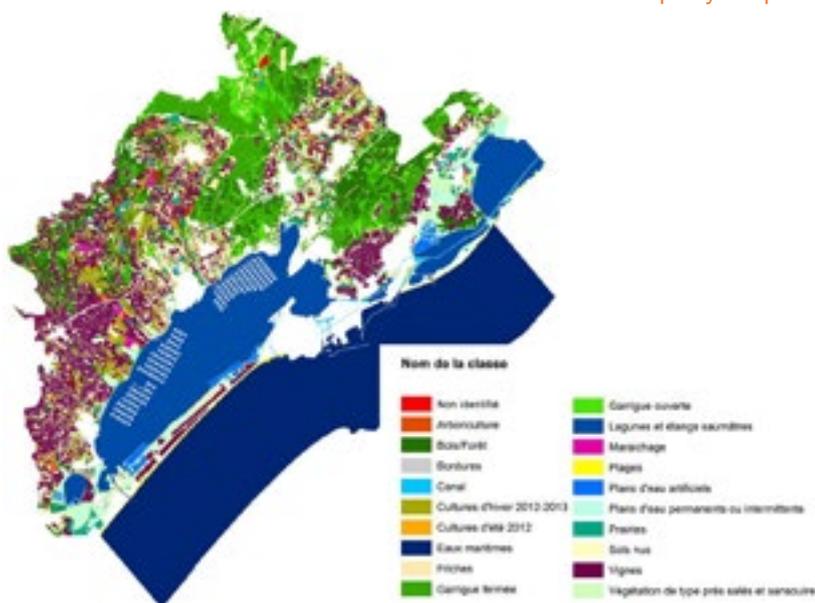
Samuel Alleaume (ART LR)

Remote sensing day in the PACA region

The PACA regional coordination network organised the Theia regional remote sensing day on 24 March 2016 at the Arbois technology park in Aix-en-Provence, in partnership with the PACA regional geographic information centre (CRIGE). The goal was to bring together public and private stakeholders to capitalise on the potential of remote sensing and create regional dynamics in order to facilitate the use of remote sensing, dialogue between users, the emergence of innovative projects, cooperation between research labs and companies, and the development of operational applications.

Some 70 people gathered for the opening session. The speakers (from bodies such as CNES, INRA, IRSTEA, Thales Alenia Space, ACRI-HE and Airbus) presented airborne and spaceborne remote sensing data, tools and applications. User needs were identified and discussed during a round table. A roadmap will soon be put forward to meet the needs of regional stakeholders. This day was also an opportunity to announce the impending creation of a "forest fires" scientific expert centre to be supported by IRSTEA.

Philippe Rossello (GeographR)



Maps of farmland and natural areas around the Thau lagoon © UMR Tetis 2012

Current or planned infra-regional land use maps in Languedoc-Roussillon © SIG L-R 2012 - IGN DREAL LR

The Pleiades Public Service Delegation

Airbus Defence & Space runs a public service delegation (DSP) on behalf of CNES to provide a preferential service to Authorised Institutional Users (UIAs) such as public or government bodies and local authorities:

- o reserved quota of 40% of the system's capacity,
- o price conditions that correspond to the system's operating costs.

UIAs can use these images for their public service missions as long as no commercial aspects are involved. A UIA can call upon a private service provider to exploit images within the framework of its public service missions.

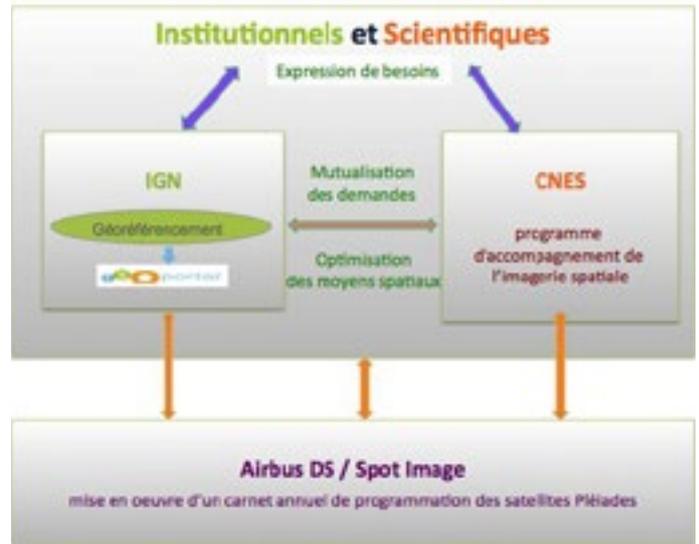
When a UIA pays a public service delegation licence for Pleiades products, the same products are free for all the other UIAs that request them as long as their signature also appears on the licence.

The DSP has geared the prices to be paid by UIAs to operating and production costs. The 2015 rates for Pleiades imagery, for example, are shown below (minimum order of 100 km²):

Product	€/ km ²
Already acquired by a UIA	free
ADS archive	4,06
Standard programming	5,22
Priority programming	5,90
Stereo	x2

Under the terms of a partnership agreement signed with CNES in early 2013, IGN is responsible for supporting French institutions wishing to use Pleiades imagery of France:

- o collecting, examining and following through user requests (<http://geosud.ign.fr/demandes>)



- o specifications, monitoring satellite programming and qualification of the images obtained
- o geo-referencing of raw products covering France for those requesting that they be aligned on the RGE®
- o managing and archiving geo-referenced products for the whole of France
- o setting up a web portal to facilitate access to these products
- o uploading these products to enable consultation in full-resolution display mode.

This support should enable public stakeholders already using the RGE® to avoid having to develop the technical expertise required to fully exploit satellite imagery. These services are free of charge, but the user must purchase the raw imagery.

IGN plays the role of national hub for collecting institutional requests through both the IGN Espace expert centre and its network of inter-regional directorates.

Jean-Paul Sempère (IGN)

ISIS offers Pleiades imagery to the scientific community

To offer the national and European scientific community reduced-cost access to satellite imagery, CNES has been running the ISIS programme since the late 90s. Initially implemented for SPOT satellites, the programme has since been extended to Pleiades imagery as a complement to the public service delegation described above.



ISIS website

An ISIS application is based on a science project requiring one or more images to meet its objectives. An ISIS application dossier goes through the following steps:

1. Definition of an application dossier comprising information on the applicant, the science project (including expected results) and the need in terms of imagery.
2. Application sent to CNES or uploaded to the satelliteimageaccess.eu website also used for SPOT 6/7 requests.
3. CNES examines the science project with the help of experts.
4. Analysis of the technical feasibility of the requested acquisitions.
5. Validation of the application or proposal of a modified acquisition plan.
6. Acquisition and delivery of imagery.
7. Feedback on project results sent to CNES.

All Pleiades images can be requested through ISIS, whether already acquired and visible in the Pleiades archives (consultable at geostore.com), or to be acquired in the future. An application may be complex, involving several acquisitions during the

same satellite pass (such as stereo or tri-stereo images to obtain 3D products) or several acquisitions over a given time. There is no maximum limit to such a request, but as CNES works on the basis of open “calls for projects”, the agency ensures it has enough resources to process applications throughout the year.

All the applications must clearly describe the project’s scientific objectives and methodology to be implemented to achieve them, along with expected results and an approximate time frame. CNES and the ISIS programme must also figure in the acknowledgements of all publications (a specific acknowledgement is provided).

For French scientists, CNES jointly funds about 80% of the costs associated with the purchase of imagery based on DSP rates. The 2016 prices are given below:

Product	€/ km ² Lab.	€/ km ² CNES
Already acquired by a UIA	Free	0
Archive	1,00	3,06
Standard programming	1,00	4,22
Stereo	2,00	x2
Tri-stereo	3,00	x3

The SPOT 1-5 image archive is still accessible via the isis-cn.es.fr website. In order to simplify matters for users, CNES and Geosud partners are trying to coordinate access to Pleiades, SPOT 6/7 and SPOT 1-5 archived imagery. Work has already begun to achieve this goal through the setting up of a joint website where



New images application filing interface (satelliteimageaccess.eu)

users can request images from Pleiades and/or SPOT 6/7, and will continue in the coming months.

Beyond CNES’s duty to make data acquired by the space systems it develops available to the scientific community (including commercially operated systems), this programme fosters new uses of space data. This second aspect often entails pushing back system boundaries and testing out new acquisition constraints that broaden the commercial operator’s experience.

Steven Hosford (Cnes)

New sites for Kalideos

Since the 2000s, CNES’s Kalideos project has sought to develop the use of Earth observation data for science and applications by distributing time series for multi-theme geographical locations while coordinating, facilitating and supporting the various thematic uses of these data.

Kalideos has just updated its list of observation sites and portfolio of sensors to include Pleiades, SPOT 6/7, the Sentinel series and more. New themes are explored: glaciers/snowfall in the Alps, urban sprawl, biodiversity in Brittany and Alsace, and global risk management in Haiti.

The objective of this second phase is to foster research that could lead to a new service offer. This represents the opening of a new chapter, with major changes in terms of stakeholders, data and infrastructure. The new Kalideos sites will benefit from some 20 or so commercial image acquisitions per year (by Pleiades, SPOT 6/7, TerraSAR-X and ALOS-2 among others) allowing multi-annual monitoring geared to user needs.

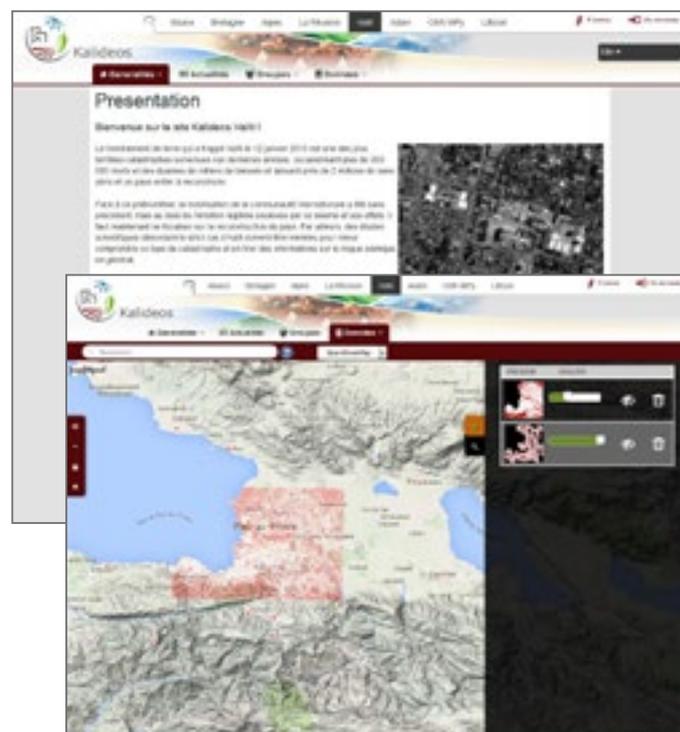
Optimal ortho-rectification will make it possible to overlay the acquired images, and radiometric processing will provide surface reflectance information.

A new cooperative data infrastructure has been set up to facilitate access to products and enable users to share their data and results in pdf, raster or vector form.

Thematic activities will be undertaken to foster dialogue within the user community, prepare grouped bids in response to calls for science projects and inspire the emergence of multidisciplinary projects.

This initiative is a CNES contribution to the thematic data and service clusters, particularly Theia and ForM@Ter, and annual Kalideos user days will be held in conjunction with the ARTs.

Catherine Proy (Cnes)



Home page and data access interface in Kalideos website

GeoDEV: the Southern countries' coordination network (ART)

The IRD (Espace-DEV joint research unit), CIRAD (TETIS joint research unit) and CNES (continental environment and hydrology programmes) have joined forces to propose a Theia regional coordination network for Southern countries. The goal is to build up a network of satellite observation centres of excellence known as GeoDEV.

GeoDEV will help Southern countries develop their satellite observation skills to better understand, govern and respond to the key challenges of environmental monitoring in the inter-tropical belt.

Network partners are encouraging three types of action:

1. Providing information, consolidating skills and jointly developing remote sensing knowledge in priority subject areas.
2. Sharing the infrastructures for data, tools and processing services geared to network regions and themes by North/South, South/North and South/South interactions.
3. Co-developing theme-based applications and products within cooperative scientific and institutional projects related to Theia CES scientific expert centres.

The first line of action - to inform, consolidate and together develop knowledge - has already begun through the GeoDEV national days, science events linked to Earth observation. Depending on the country and context, the themes investigated during these initial events have different purposes and are conducted in different ways. They depend on the support offered to help user communities express their needs, remote sensing capabilities or competencies, the consolidation of capabilities and training, data access, processing requirements, sharing solutions, research and public policy usage, the development of applications or post-processing services and the presentation of research results among others.

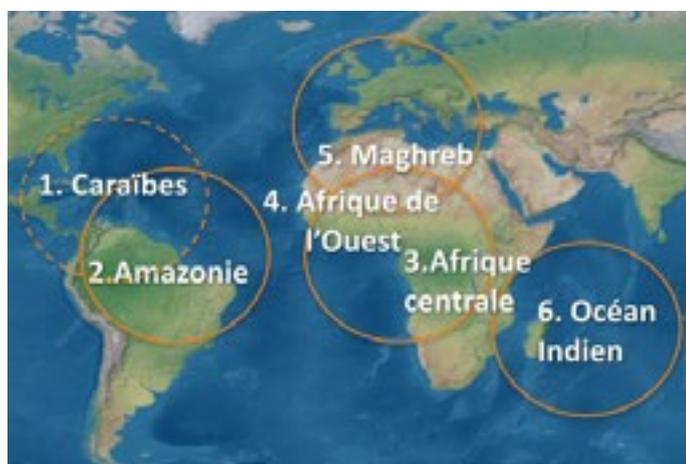
The first GeoDEV science day was held in the Ivory Coast in late January 2016. The second was held in Gabon in April 2016. Others will be planned following consultation of network partners.

Jean-François Faure, Eric Bourland (Espace Dev / IRD)



Spot 6 XS 6 m color satellite image of Port-au-prince, Haiti (9 January 2016) © ADS 2015, Distribution Airbus Defense & Space / Spot Image, France, all rights reserved. Commercial use of the product prohibited.

Network, areas and thematics



1. Caribbean

1. Water resources & Agriculture
2. Environment & Health
3. Forests

2. Amazon

1. Ressources en Eau & Agriculture
2. Environment & Health
3. Forests

3. Central Africa

1. Water resources & Agriculture
2. Environment & Health
3. Forests

4. West Africa

1. Forests (including REDD+ objectives)
2. Agriculture

5. Maghreb

1. Water resources & Agriculture
2. Dry forests

6. Indian Ocean

1. Environment & Health
2. Coastal
3. Agriculture

Planned integration of *in situ* data to expand Theia's offer

The thematic data cluster is currently composed of:

- an IDS data and services infrastructure offering the community satellite-derived products;
- CES scientific expert centres gathering together scientific communities for new thematic products such as reflectance or land use, that have been validated and add significantly to the value chain. The list of these CESs is not limited and new ones can be created following a community proposal;
- a Theia regional coordination network (ART) to coordinate and foster Theia activities in each region (aimed at scientists, public policy stakeholders and private stakeholders).

Up to now, Theia has focused on access to satellite data. Its infrastructure does not include *in situ* data. The goal of this article is to present the planned integration of *in situ* data in the Theia thematic cluster taking into consideration the efforts made by the "*in situ*" community.

Three types of *in situ* data have been identified:

1. Observatory data certified by French research institutes.
2. *In situ* data already used within the CESs to develop methods leading to new thematic products. These data are not currently available from the Theia web portal.
3. Other data from instrument-equipped sites via programmes such as ANR or TOSCA for example.

The first type of data is structured and archived, whereas the others can vary in terms of documentation (metadata, qualification) and recording media (database, USB key, hard drive etc.) depending on the investigators in charge and the policy of funding organisations (CNRS, INRA, IRSTEA, BRGM etc.).

The purpose behind this integration is to have a single portal for users of continental observation data. This would allow transparent access to data wherever they are hosted (data centre). A portal that does not store data that are already archived elsewhere, but that can propose this service for some data with a standardised description of metadata. For data that are already structured, the portal will be the link to the databases of data providers and will comply with their data charter with respect to acknowledgements and the embargo period, for example.



Measurement of the soil humidity and temperature profile in Benin © S.Galle



Measurement of the Glacier du Tour Noir: winter review based on ice cores and snow density measurements, France, April 2013 © Patrick Ginot.

The cluster will coordinate communities so as to create remote sensing and *in situ* products using basic observations (see figure below). Theia cluster data will comply with conformance and interoperability criteria, especially for metadata in relation to the INSPIRE Directive.

IDS	CES	ART
Space data <i>In situ</i> data • Certified • Calib./valid. • Other programmes	• Value-added satellite products • Other calib./valid. • 100% <i>in situ</i> products (indexes or maps etc.)	• 6-7 ART • Identify key regional data centres for <i>in situ</i> data

Theia cluster as currently being developed and the benefits and additional activities related to *in situ* data

Observatory data certified by French research bodies

The main suppliers of *in situ* data are certified to various levels according to their degree of aggregation. The basic building blocks are « national observation services » (SNO) certified by INSU. SNOs can be brought together in thematic networks known as SOEREs which are long-term observation and experimentation systems for environmental research, certified by AllEnvi. Then there are research infrastructures (IRs) which are major observation networks or instruments certified by the French Ministry of Higher Education and Research. The OZCAR infrastructure (critical zone observatory for applications and research), for example, focuses on continental surfaces. This IR was certified in December 2015.

The OZCAR IR groups SOEREs and SNOs which observe the critical zone and produce a significant proportion of long-term continental surface observations. It will be the main contact when integrating *in situ* data in Theia. Once integrated, the CES scientific expert centres will capitalise on these *in situ* data, which will not be available through the Theia portal, and finally on the *in situ* data available for continental surfaces outside the scope of the first two categories.

Sylvie Galle (IRD, CNRS - INSU)

LAND USE AND CHARACTERISTICS

Land use scientific expert centre (CES OSO)

The land use scientific expert centre (CES OSO) aims to design and develop automated algorithms to produce land use maps from satellite imagery.

In 2015, CES OSO produced prototype maps with a twofold objective. They were used to validate the algorithms' ability to process large data volumes in a time compatible with the set deadlines (availability of the land use map within three months of the end of the millennium). Secondly, they were made available to potential users to obtain feedback on product quality and usefulness when integrated in the users' standard procedures.

These prototypes were produced with the IOTA2 processing chain developed at CESBIO and to be integrated in the Theia IDS in 2016 for an initial production in early 2017.

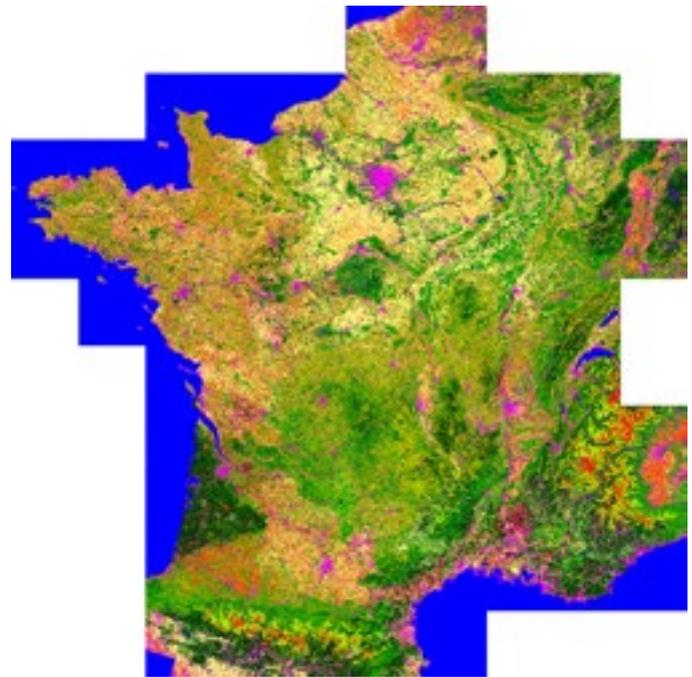
On 16 February, CES OSO held a working meeting with users. The presentations and discussions were used to:

- map out the CES OSO project context
- present the product's specifications,
- demonstrate prototype products and obtain feedback on their use,
- start discussions on the involvement of users in the validation of products in the operational phase,
- give an overview of planned product developments.

Characteristics defined with users

Despite the limitations of prototype products (developed with Landsat 8 images with a 30-metre resolution and a revisit frequency of 16 days rather than Sentinel-2's 10-metre resolution and 5-day revisit capability), user feedback has been positive. They stressed the speed of production and availability, the diversity of vegetation themes, geographical continuity with neighbouring areas and the fact that no charge was made.

Some users have requested support or training on how to use the product. The need for indicators derived from the OCS product



Land use map of France of 2014 produced by CES OSO from Landsat-8 data

was mentioned, but this type of product lies outside the scope of CES OSO activities.

Finally, it is clear that the product does not currently meet the needs of French overseas regions and communities or southern territories in general. R&D activities within CES OSO are currently addressing this issue.

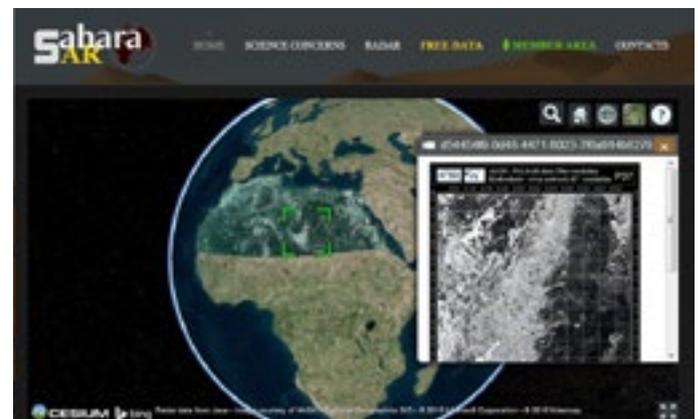
The product's final characteristics will be set in 2016 in consultation with users. CES OSO's ongoing R&D activities will continue for several years yet. The product's quality will be enhanced but continuity will be assured through re-processing if needed. Furthermore, it should be emphasised that both the data used and the processing lines are open. This means that they may be tailored to specific needs, granting users independence from Theia if they so wish.

Jordi Inglada (Cesbio / Cnes)

SaharaSAR

The SaharaSAR project was kicked off in 2008 in cooperation with Japanese aerospace agency JAXA and supported by CNES. A radar imagery mosaic using the PALSAR sensor (L-band, HH and HV polarisations, 50-metre resolution) was assembled by the Bordeaux Astrophysics Laboratory in order to study the geomorphology of North African desert regions. The PALSAR low-frequency orbital imaging radar can acquire imagery of ancient geological structures buried under a few metres of aeolian deposits. Indeed, the SaharaSAR mosaic revealed two former rivers in the Libyan Desert and the west of Mauritania. This unique dataset may be used for applications ranging from the study of the North African climate in ancient times to more modern preoccupations such as mapping fossil water resources.

Data from the SaharaSAR project are available via a dedicated website at <http://sahasar.obs.u-bordeaux1.fr>. This site allows you to display and download the geocoded PALSAR maps by 1x1-degree blocks. Using a radar image overlay, the maps indicate hydrographic HydroSHEDS information calculated on the basis of SRTM topography. Access to data is free of charge but requires the creation of an account indicating the user's



SaharaSAR website interface

contact information and the purpose of the study. PALSAR data covering the whole of the Gobi desert in Central Asia are currently being integrated.

Philippe Paillou (Université de Bordeaux)

CES on the colour of continental water

The last few months have been devoted to paving the way for the use of new satellite missions by conducting field work, modelling and analysing imagery time series, for sites with complementary characteristics. The upcoming availability of the Sentinel-2 and Sentinel-3 satellites will considerably increase the supply of satellite images for monitoring continental water. The multispectral sensor aboard Sentinel-2 will be capable of observing small water bodies (a few dozen metres wide), and thus greatly increase the number of sites observable by satellite for the « water quality » theme. The newly-acquired availability of three spectral bands in the 700-800 nm range will make it possible to exploit new inversion algorithms. The excellent spectral resolution of the OLCI sensor on board Sentinel-3 (21 bands between 400 and 1200 nm) will be capable of observing all the characteristic spectral patterns indicating the presence of photosynthetic pigments, and also the use of algorithms with multiple spectral bands in order to standardise mineralogical or granulometric effects for monitoring sediment flows.

Under surveillance by SPOT, Landsat and Sentinel

The CES on continental water colour participated in the SPOT 5 Take 5 experiment in 2015 on a selection of sites to test Sentinel-2's 5-day revisit frequency. Two lakes in particular were analysed, one in Brazil (the Paranoa reservoir) which has clear, oligotrophic water, and another in Burkina Faso (the Bagré reservoir) with hyperturbid water due to high concentrations of mineral substances in suspension. For both sites, spectroradiometric field measurements of reflectance and the attenuation coefficient were taken of the apparent optical properties at the same time as the image acquisitions. These data will serve to qualify the accuracy of atmospheric corrections (MUSCATE algorithm) on water bodies with very different characteristics (low and high albedos) and also to develop specific inversion algorithms. Additional data were acquired, including the measurement of the water absorption coefficient (dissolved and particulate phases) and of the characteristics of matter in



Landsat 8 image of the Rhone River near the city of Arles, where the Rhone Sediment Observatory (OSR) maintains a sediment flow measurement station. The data from this observatory will be used to validate satellite-based estimates and understand how the «water colour» products can supplement field observations.

Optical properties of water in a catchment area

The first synopsis of apparent optical properties ever carried out on water within the same catchment area was published in 2015 (Martinez et al. 2015, JGR) thanks to the expert centre's work. It demonstrated experimentally that the properties are sufficiently stable over time and space to obtain an inversion of the reflectance throughout the water cycle in order to monitor the concentration of material carried in suspension by rivers. This type of work is an essential step in documenting variability in the optical properties of continental water by providing a basis for the definition of generic inversion algorithms. In this case, Martinez et al. (2015) recorded the optical properties of the main rivers of the Amazon basin and demonstrated that, despite the enormous size of this catchment area, a single algorithm could be proposed for all watercourses, wherever the catchment area. This work should be reproduced in different regions of the world so as to create global databases to improve «water colour» products.

It is based at the Geosciences Environment Toulouse (GET) laboratory and backed by TOSCA funding from this year. It will use field observations and modelling to develop robust inversion algorithms and test them on time series of satellite images acquired by the new Sentinel sensors as well as the « legacy » MODIS sensors and the Landsat series for a dozen or so sites. One of the original features of this project is that it draws in the thematic teams in order to precisely calibrate/validate the estimates made by satellite, by exploiting the pre-existing field databases. In addition, it will enable each team to make full use of « water colour » products in order to understand the way specialists in each theme use them. Several laboratories in France are involved in this project, including the Geosciences joint research unit in Rennes, the LTHE, GET and IRSTEA's HHLY research unit.

At the end of 2015, the continental water colour CES was involved in many replies to the call for tender aimed at choosing Sentinel-2 sites outside France that will be processed by CNES using the MUSCATE algorithm. Study areas were thus selected on each continent in collaboration with the thematic teams in the observatories (HYBAM, Amma-Catch and MSEC) or water resource project teams such as the LTHE joint research unit, the Water Agency of Brazil or FUNCEME in various regions of the world, notably Brazil, Bolivia, Venezuela, West Africa, Vietnam and Laos. Three thematic areas stand out: (1) the study of major rivers, including issues related to sediment flows (estimation of erosion flows, siltation and navigability); (2) the study of algal blooms - especially toxic cyanobacteria in lakes and reservoirs; and (3) the relationship between health and the transport of bacteria by mineral particles.

In the coming months, new actions will be taken to help integrate « water colour » products in the hydrological modelling tools, in particular with the Soil and Water Assessment Tool (SWAT) in collaboration with the Ecolab joint research unit. The conventional networks for measuring water quality do not cover the data needs of scientists, managers and society at large, but the exploitation of satellite products is expected to improve the simulation and prediction capabilities of models.

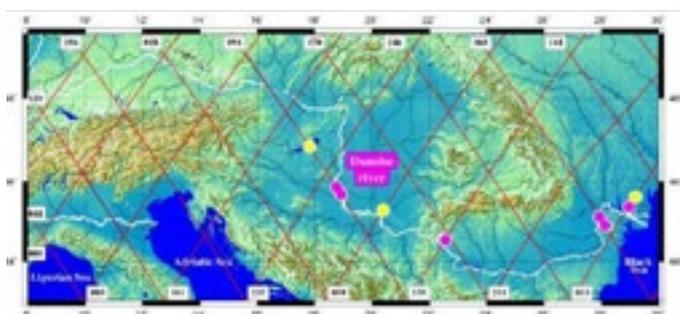
Jean-Michel Martinez (IRD)

Hydrology data accessible on Europe's Global Land platform

The Hydroweb service is tasked with disseminating products derived from satellite altimetry to the widest possible community of users in order to monitor continental water bodies such as lakes and rivers.

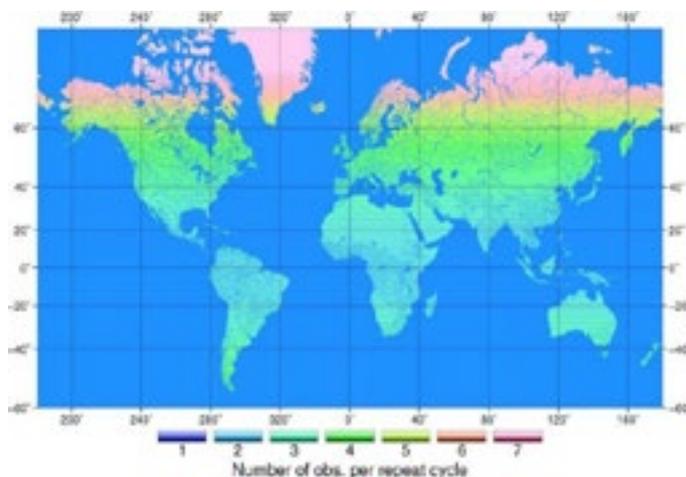
To prepare for the water resource challenges that humanity will face in the next few years, the European Commission will set up a service dedicated to water and snow issues, coordinated by CLS under the Copernicus Global Land Service.

This new European service will give online access to hydrology data derived from satellite measurements. The data acquired via satellites such as Sentinel-3 and processed by CLS and its European partners will be available on this platform, which will provide many hydrological and cryospheric parameters free of charge.



Virtual stations under Jason ground tracks

Among the key hydrological variables that will be generated are the height and variation in stocks of water in lakes, and the level of rivers (to estimate the flow rate). CNES assists with and supports the R&D undertaken by LEGOS in order to offer new products derived from the data supplied by Sentinel-3's SIRAL follow-on instrument and the Jason-3 altimeter. These products



SWOT measurements

will supplement the water levels established from past altimetry data (Topex/Poseidon, Jason-1, ERS-2) and their current successors (Jason-2, SARAL and Cryosat-2) on the Hydroweb platform. The products validated by LEGOS and CLS are likely to be integrated in the Global Land Service. In the long term, data from the SWOT satellite - which not only offers unprecedented spatial resolution and precision but also global coverage for the first time in hydrology - will be incorporated in Hydroweb.

As part of the European Copernicus programme, the Global Land Service will provide first-level variables for use in developing solutions and services relating to the management of water resources and associated risks.

These new services are the outcome of close cooperation between the European Commission, space agencies (ESA, CNES, etc.), research laboratories and companies in the industrial and service sectors. They respond to increasingly pressing societal demands in water and environmental management.

Selma Cherchali (Cnes)

EyeOnWater to monitor water quality in numerous water bodies

Since the definition of the EU's Water Framework Directive in 2000, managers of water bodies are required to monitor their ecological status. In practice, this usually means taking a few *in situ* measurements each year on certain lakes, but with the new possibilities offered by satellite imaging, managers can keep a closer eye on these indicators.

The ACRI-HE has developed a fully operational end-to-end processing system for assessing the water quality of more than 600 lakes. The system downloads the product, applies atmospheric corrections (with the LAC-ACRI algorithm), calculates water quality then publishes the results on a web interface entitled EyeOnWater (eyeonwater.eu). To achieve the required spatial resolution, Landsat 7/8 and soon Sentinel-2 data are used.

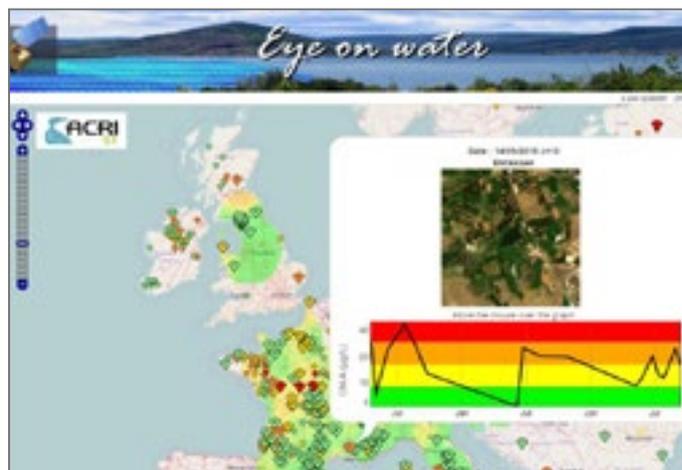
To calibrate the model, a sample set of more than 1,000 measurements of Chl-A concentrations was used (ONEMA and EDF data), giving 155 matches with the Landsat 7 images of over 110 lakes.

The result is a water quality index specific to the characteristics of each lake. This is associated with the concentration in Chl-A then synthesised using a colour code relating to the ecological status of the lake water in compliance with the directive.

By clicking on the coloured marker (see figure), the time series showing the concentration in Chl-A for the selected lake is displayed and can be analysed with support from satellite imagery (here Landsat 7) used for the calculation.

As soon as a sufficient number of *in situ* measurements become available for calibration, the data produced by Sentinel-2 will be added, offering a better spectral resolution and enhanced assessment of water quality.

Antoine Mangin, Romain Serra (ACRI-HE)



EyeOnWater website data access interface

GLOWABO for mapping water surfaces

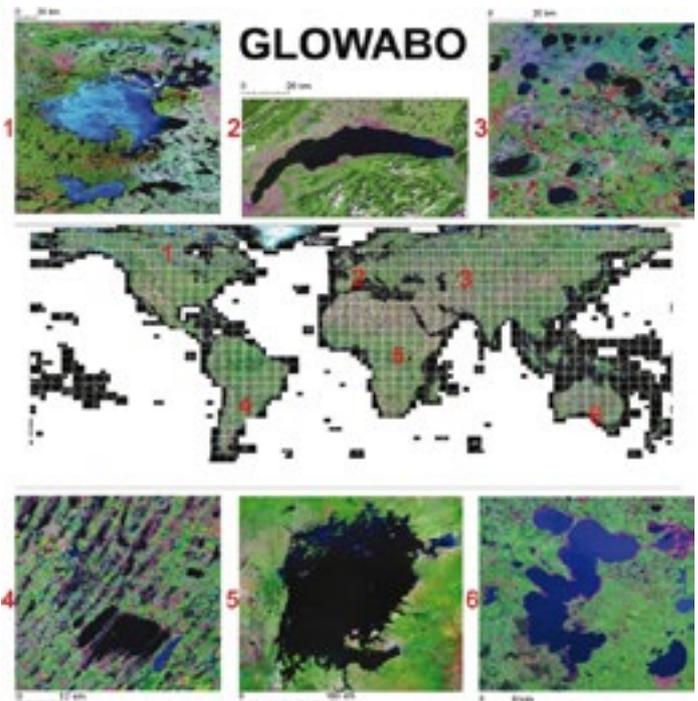
As incredible as it may seem, until 2014 nobody knew how many lakes and other water bodies there were on Earth. This is nonetheless very important information, as it is now recognised that very intense biogeochemical activity occurs at these sites. As a result, they are generally a major source of greenhouse gas emissions such as carbon dioxide or methane, which they reject into the atmosphere. However, some can absorb more carbon than they emit, thus acting as terrestrial carbon sinks.

In this context, an international study involving France, Sweden, Estonia and the United States was initiated to quantify and map the number of water bodies on our planet for the first time ever. The team mostly used satellite remote sensing combined with an algorithm to automatically detect water bodies. This study resulted in the Global Water Bodies database, commonly known as GLOWABO (Verpoorter et al., 2014, GRL).

While the Blue Planet owes its nickname primarily to the oceans, there are at least 117 million lakes of more than 2000 m² (the equivalent of two Olympic swimming pools) in the world, excluding the Caspian Sea and glaciated regions of Antarctica and the Arctic, thus calling into question previous statistics-based calculations that estimated 304 million water bodies. In all, they cover approximately five million square kilometres, which is 3.7% of the Earth's surface. The inventory collected information on the geographical distribution, abundance, size (i.e. area and perimeter), morphometric characteristics and elevation of lakes. In a context of global warming, all these parameters are essential for quantifying limnetic contributions to the carbon cycle, particularly in places where biogeochemical exchanges occur most extensively, i.e. close to shorelines. For example, if all the shorelines catalogued are added together, the result is approximately 250 times the Earth's circumference.

Available in October 2016 on Theia

The water bodies were detected by an automated algorithm which processed more than 875 mosaics of Landsat 7 ETM+ satellite images from the GeoCover Circa 2000 dataset. This method, known as the GeoCover Water Body Extraction Model, or "GWEM" (Verpoorter et al., 2012), was designed primarily for GeoCover data. The latter offer a medium spatial resolution of approximately 15 m/pixel, but only use three of the seven spectral bands available with Landsat 7 ETM+ (B2, B4 and B7). The extraction method is based in part on a supervised and prioritised classification of radiometric readings. One of the particular difficulties was how to minimise the impact of shadows caused by clouds or certain mountain slopes, which can change the radiometric values of surfaces, sometimes causing confusion with lakes, for example. Methodological developments are still under way to improve this database as regards mountainous



GeoCoverTM Circa 2000 satellite images showing several examples of lakes on different continents.

areas. The quality of Landsat 8 data opens up new horizons, as changes in detections can be taken into account by analysing multiple images of the same scene, providing an easy way of overcoming shadow effects. Unfortunately, the GeoCover dataset is basically mono-date and could not be used for this multi-temporal approach. It has been suggested that the GLOWABO database be distributed in the framework of Theia in October 2016 for water bodies covering a surface area greater than one hectare, of which there are some 28 million.

A decade ago, everybody was impressed by the first complete map of the world's lakes, which included 250,000 lakes of more than 10 hectares. It is surprising to see how the progress of space technology has highlighted the importance and number of lakes on this planet. This study has reduced the level of uncertainty compared to previous estimates and therefore constitutes a springboard for a better assessment and understanding of the influence of water bodies on large-scale biogeochemical processes and therefore on the climate.

Charles Verpoorter (ULCO)

Shadows such as those generated by mountains and clouds on the ALI satellite image complicate the detection of water surfaces. © T. Kutser.



Mapping French Guiana's forest biomass

The mapping of aboveground forest biomass is currently an important issue, in particular for the declaration of carbon stocks and their evolution over time. An approach for mapping the biomass of French Guiana's tropical forest has been developed by applying the regression-kriging technique to remote sensing data and other environmental variables such as rainfall and geology.

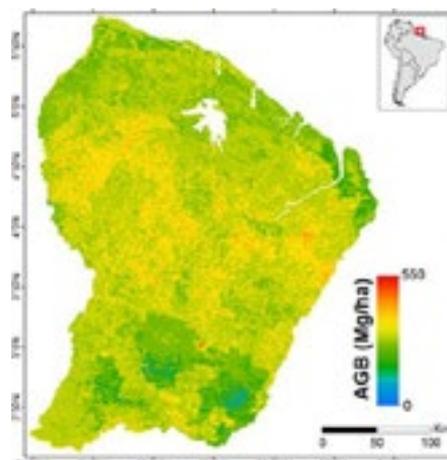
The method involves three steps :

1. Estimate the best linear regression between the metrics (variables) derived from the lidar waveforms of the GLAS/ICESat satellite (which has a footprint approximately 60 m across) and *in situ* forest aboveground biomass (AGB) data;
2. Develop a model combining the AGB data estimated from GLAS (Step 1) and the variables derived from MODIS optical imagery, the PALSAR radar, and environmental data;
3. Improve the precision of previous biomass maps by adding back the kriging residual (GLAS AGB - Map from Step 2).

A biomass map with 1 km resolution was produced with a Root

Mean Square Error (RMSE) of 51 Mg/ha ($R^2=0.66$, a mean absolute error of 12%). This map shows strong potential in the light of its precision when compared with the three global AGB maps by Saatchi, Baccini and Avitabile. Indeed, a comparison between the three world maps and the *in situ*

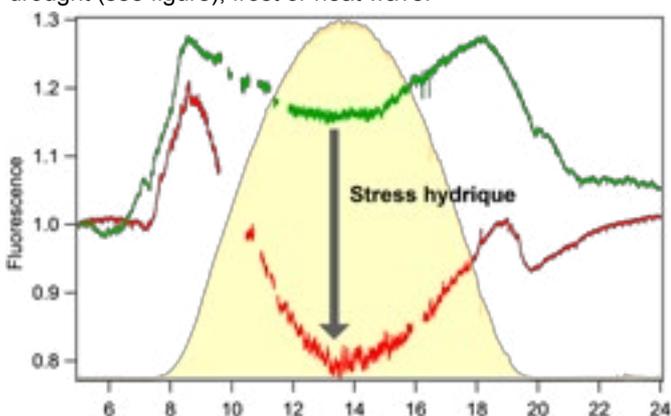
AGB data shows that the three global maps contain significant errors (discrepancies of between 45 and 70 Mg/ha and RMSEs between 70 and 100 Mg/ha).



Nicolas Baghdadi (Irstea)

FLEX : map vegetation fluorescence

On 19th November 2015, the European Space Agency (ESA) announced that the FLEX (Fluorescence Explorer) will be the 8th Earth Explorer mission in the framework of the Living Planet program. The objective of FLEX is to map vegetation fluorescence to quantify photosynthesis at the global scale. These observations will offer the opportunity to improve our understanding of the carbon and water cycles. They will also give the possibility to achieve early stress detection, in the case of drought (see figure), frost or heat wave.



Diurnal cycle of fluorescence yield upon water stress, on green peas (*Pisum sativum* L.). Upper curve (green): control. Lower curve (red): water stress. Solar irradiance is also indicated. (Credits: M.L. Lopez, I. Moya).

Vegetation fluorescence is emitted by chlorophyll, which is the leaf pigment that initiates photochemical conversion of absorbed solar energy. This energy is then used by plant to produce rich energy compounds such as sugars, which are ultimately distributed to the entire biosphere. Fluorescence is therefore intimately linked to photosynthesis, and has been used for years to quantify at leaf level.

However, this emission is very weak, and its detection from space is not possible without the analysis of the absorption bands of reflected sunlight at a very high spectral resolution. This is achieved by the FLEX mission in oxygen absorption bands at 687 nm and 760 nm. FLEX will be launched by 2022 and will fly in tandem with the Sentinel-3 mission. The two missions will provide, beside fluorescence, the biophysical parameters of vegetation (leaf area, chlorophyll content, etc), surface temperature and the photochemical reflectance index (PRI), which is linked to regulation mechanisms of photosynthesis.

French teams pioneered the development of passive methods for fluorescence detection. They are now getting structured on validation and exploitation of fluorescence data from space in support of the FLEX mission: development of an ecosystem fluorescence measuring network, validation tools for spaceborne data (ground and airborne fluorescence lidars) and fluorescence assimilation algorithms to quantify photosynthesis. Laboratories involved in remote sensing of fluorescence activities include groups from Université Paris-Saclay (LMD, LSCE, ESE, ECOSYS) as well as CESBIO and CNRM near Toulouse.

Yves Goulas (LMD / Ecole Polytechnique)

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