Toward a COPERNICUS service for ground displacements from PS/INSAR Sentinel-1 data. Example from a pilot project in South West France

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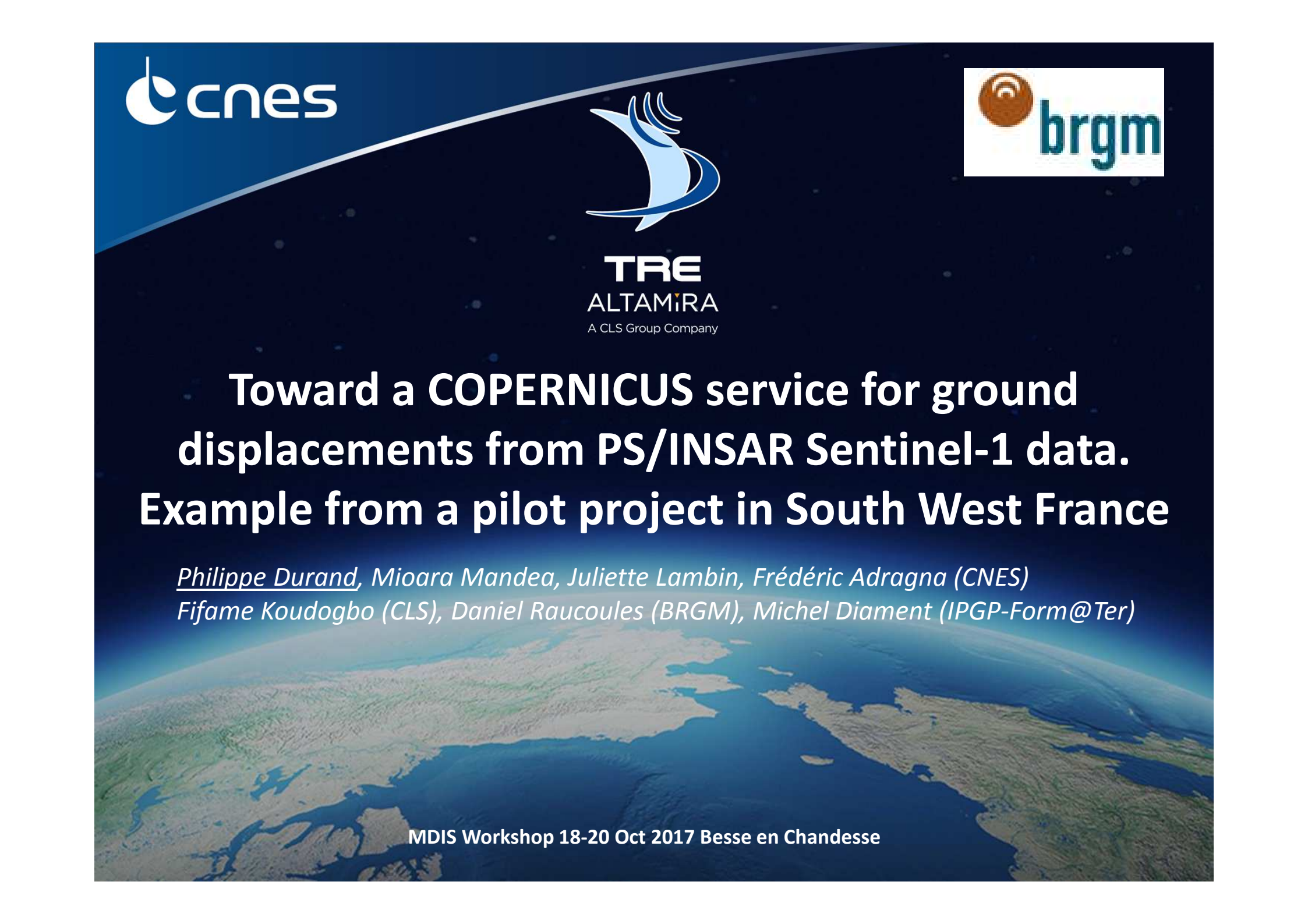

MDIS Workshop 18-20 Oct 2017 Besse en Chandesse

OUTLINE

- Copernicus services and background
- A EU-Ground Motion Service for Copernicus ?
- French analyse and initiative
- Pilot project in SW France


FULL, FREE AND OPEN
ACCESS TO DATA
ATMOSPHERE MONITORING
MARINE ENVIRONMENT MONITORING
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CLIMATE CHANGE
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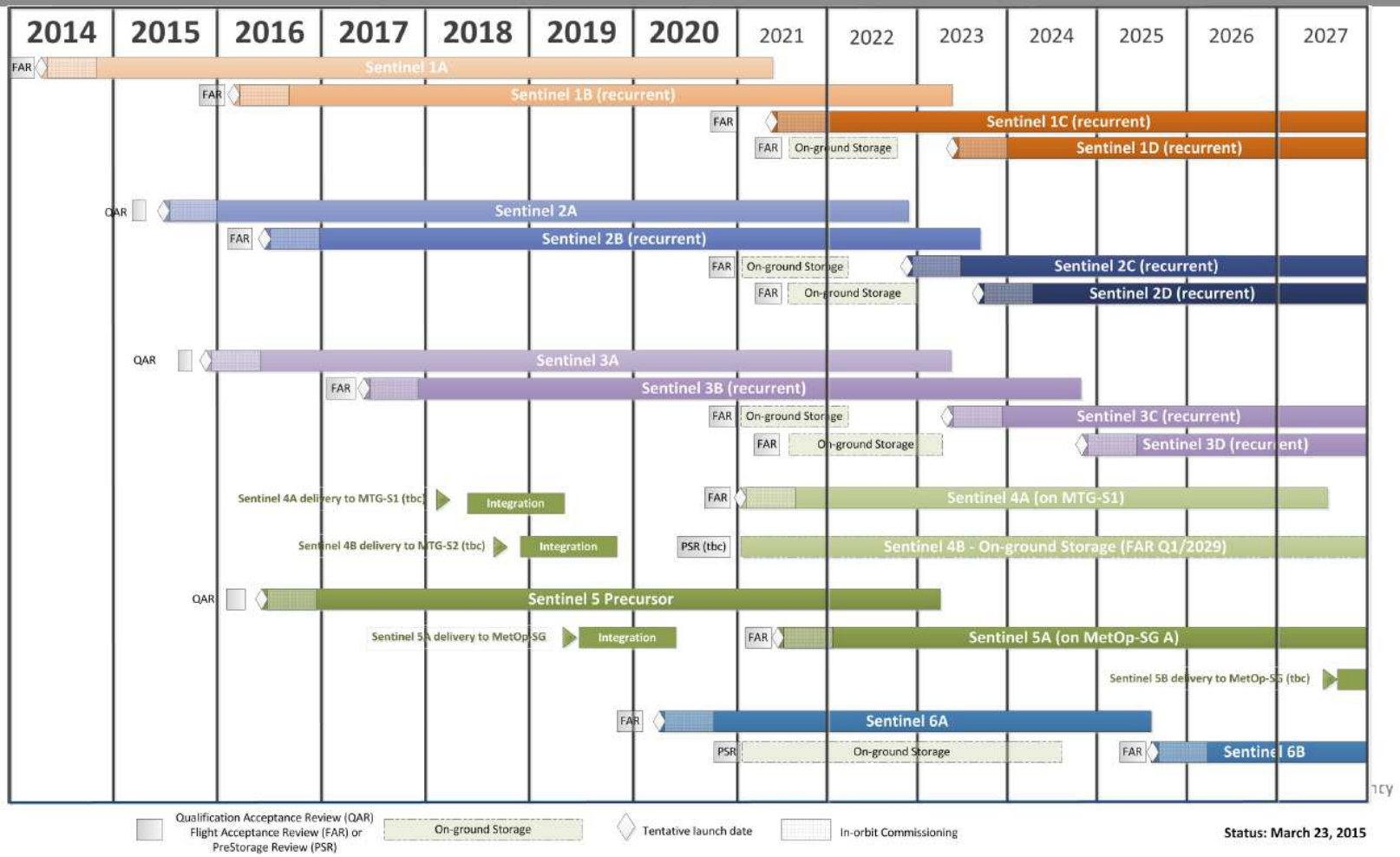
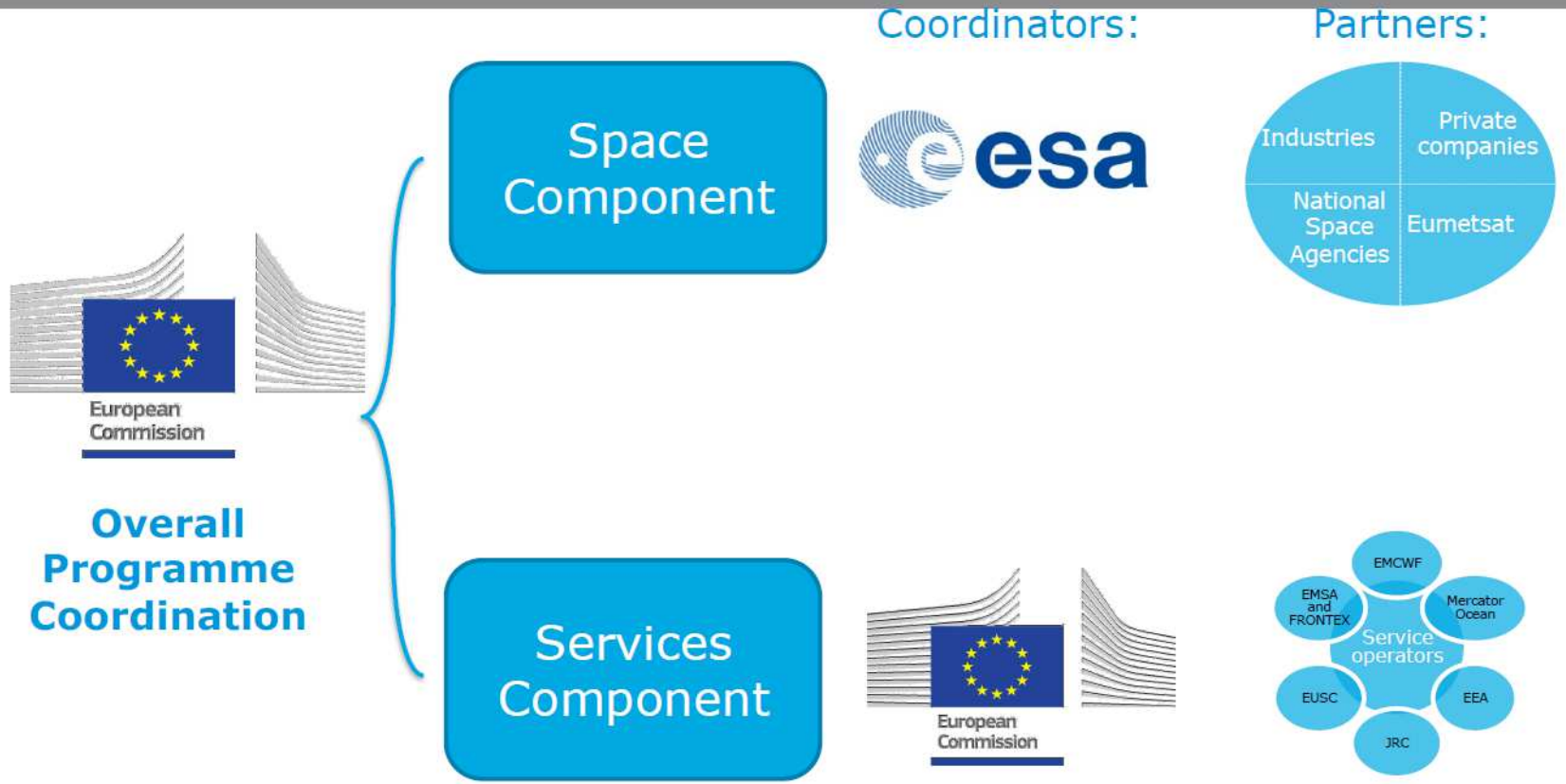
… with a long-term operational perspective



Components & Competences



In-situ data are supporting the Space and Services Components

European Space Agency

6

ESA PS Journal

Meeting 2015 Collaborative GS WS #10 & #11
The 'Sentinel-1 European WW Persistent Scatterers (PS)', with an overarching objective to prepare and maintain a European datasets and database of World Wide Persistent Scatters (PS) for public usage.

ESA **dedicated technical note** including a proposal for the PS Journal scope and implementation approach.

Recommendation : preparing a presentation to the Copernicus User forum addressing how the Journal could support the generation of value-added products and services as well as research activities in public/private sector.

ESA UNCLASSIFIED – For Official Use

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DOCUMENT

Towards a European Integrated CSC GS: Sentinel-1 World Wide Persistent Scatterers Journal

Technical Note

Prepared by	CSC Mission Management Team
Reference	ESA-EOPGS-CSCGS-TN-0012
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Revision	0
Date of Issue	27-11-2015
Status	Authorised
Document Type	

European Space Agency
Agence spatiale européenne

A European Ground Motion Service for Copernicus ?

Under in the impulse of BGR (German Geological Survey),

3 meetings at a European level, including 13 Copernicus participating states, were held in Nov 2016, March and July 2017.

The objective of these meetings was to **discuss and consolidate user needs and to scope key specifications for a European Ground Motion Service (EU-GMS).**
(France representatives : CNES, IPGP, BRGM, CLS)

A white paper was proposed to the stakeholders in summer 2017 :

> following slides are exposing the main content of a proposed EU-GMS

What is EU-GMS ?

EU-GMS is a service that aims at providing consistent, regular, standardized, harmonized and reliable information regarding natural and anthropogenic **ground motion phenomena over Europe and across national borders, with millimeter accuracy**.

Main objective :

Measure **ground displacements, including landslides and subsidence,** as well as **deformation of infrastructure.**

Derive Ground motion from **time series analyses of Copernicus Sentinel-1 data using PS** (Persistent Scatterers) **and DS** (Distributed Scatterers) **radar interferometry approach**.

Complement GNSS and other in-situ observations.

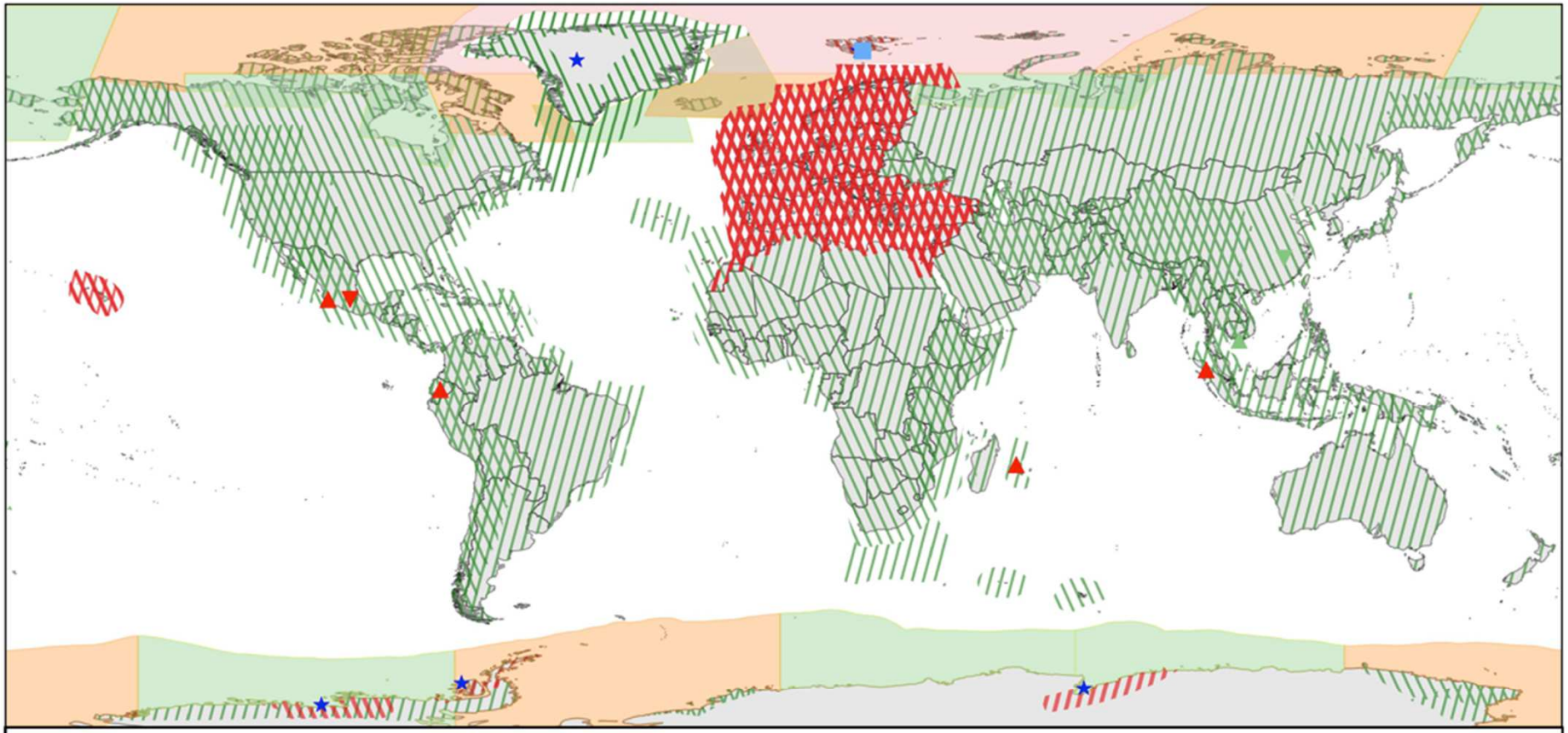
Provide tools for visualization, interactive data exploration and user uptake elements **for further ground investigations**

ESA High Level Operation Plan : MAY 2017 UPDATE

Sentinel-1 Constellation Observation Scenario: Revisit & Coverage Frequency

sentinel-1

validity start: 05/2017



A Pan-European Service

Processing at a European scale is efficient, providing a uniform product for large and small countries.

Pan-European service is needed to reach :

- **public users**
- **commercial downstream service providers,**

Several Copernicus Participating States have already or are in the process of implementing national ground motion services.

All these services will both benefit from and complement the EU-GMS.

EU-GMS can provide the opportunity to uniform and standardize national service components.

Target Applications

- Natural and man-induced geohazard assessment
- Geodesy
- Land management, urban and rural planning
- Climate services
- Infrastructure development and management
- Mining and other natural resources extraction
- Dam and groundwater monitoring
- Insurance topics and mitigations
- Structural and civil engineering
- The property market
- Railway and road management

Targeted users

Direct Users of EU-GMS :

- **Geological and geodetic surveys**
- **Public authorities at European, national, regional and municipal levels**
- **Academia**

Downstream Services Users :

- **Road, railway and mining administrations**
- **Regulators and planners**
- **Citizens of Copernicus participating states**
- **Industry**
- **Academia**

Service definition 1/3

EU-GMS provide ground motion time-series information with **full spatial and temporal resolution based on interferometric analysis of Sentinel-1 time-series.**

Area covered
Copernicus participating states.
Frequency of product updates
Updated every 12 months.
Updates should be generated incrementally, i.e. by processing newly acquired images rather than the whole data inventory from scratch.
Data processed and archived in epochs of e.g. 5 years in order to monitor the temporal evolution of deformation patterns.
Spatial resolution
The InSAR processing of time series in EU-GMS shall be based on using the Sentinel-1 IW mode **SLC products at 5x20 meter resolution.**
Expected scaterrer density :
thousands points per km2 for urban areas
hundreds points per km2 for non-urban areas
Full spatial resolution not degraded or down sampled

Service definition 2/3

Temporal resolution
Ascending + Descending every six days.

Methodology
From these data, ground motion can be derived using InSAR time series analyses. There are many different InSAR processing concepts, and common to all is an end product consisting of a set of ground motion time series valid for specific points or pixels, with a corresponding quality measure.

In order to provide a seamless and consistent EU-wide ground motion base map, the processing method in the **EU-GMS will be standardized using state-of-the-art algorithms**.

The final products and intermediate auxiliary data will be made available, so that local deformation phenomena can be processed with special user or specific algorithms.

Service definition 3/3 – Main products

(Level 1 Single Look Complex data : input data only)

Level 2a – an intermediate product
Basic displacement information provided in the satellite line-of-sight (LOS), projected to ground geometry and quality measures per measurement point. Community best practices and state-of-the art algorithms shall be used in data processing and analysis.

Level 2b
Level 2a products integrated into a standardized reference frame using external information such as GNSS network measurements and mosaicked.
For products integration and mosaicking, best geodetic practices will use EUREF network for georeferencing.

Level 3
East-West and Up-Down deformation rates produced by combining Level 2 data stemming from ascending and descending orbits.
Granularity of level 3 product, i.e. maximum granularity, sampling grid size, depends on the area of interest, and the deformation signal.

Identified Links to services and other initiatives in Europe

Copernicus Land Monitoring Service: http://land.copernicus.eu

Copernicus Emergency Management Service (EMS): http://emergency.copernicus.eu

Copernicus Climate Change Service (C3S): http://climate.copernicus.eu

OneGeology: http://www.onegeology.org/

European Plate Observing System (EPOS): https://www.epos-ip.org/

European Soil Data Centre (ESDAC): http://esdac.jrc.ec.europa.eu/

Reference frame Subcommission for Europe (EUREF): http://www.euref.eu

Foreseen schedule for EU-GMS

2017/18 Preparation Phase
technical definition of product content, format, quality indicators, metadata, etc.; service implementation concept; preparation of the tender; setting up validation group.

2018 Tender for initial production/operation

2019 Initial Production Phase

2020 production, service setup, delivery of products, first validation activities

2020+ Tender for Routine Operations Phase: regular updates and validation activities

Need for a EC approval

French analyse and initiative

French actors

» Governemental Institutions

BRGM (French Geological Survey) expertises in InSAR and PS at European level (TerraFirma, PSIC4, Pangeo…)
CNES (French Space Agency) expertises and InSAR promoter (DIAPASON…)
…also InSAR & POLinSAR activities in **CEA**, **ONERA**

» Private compagnies

CLS/TRE-ALTAMIRA with well known expertise
1999 Altamira spin off creation
2010-2015 Altamira and TRE integrate CLS group

» Scientific Community

Research laboratories (from CNRS, ENS, IPGP, IRD, Universities …) are very active in the use and development of InSAR and PS new methods of analysis supported by national fundings (from ANR, CNES,…) as european ones (such ESA). They are federated in the **ForM@Ter** data and services pole that also represents the French scientific community in the dedicated EPOS Thematic Core Service and various National Research infrastructure for acquiring complementarity in situ data.

Past projects based on extended PSI where BRGM (French Geological Survey) contributed

-**Terrafirma** (EU funded)

BRGM role : *validate the relevance of the output from PSI processing as a geological and engineering product, to identify causes for the observed ground motion and produce hazard related products of use to end-users*

-**PSIC-4** (ESA funded)

BRGM role : Persistent Scatterer Interferometry Codes Cross-Comparison And Certification - validation and cross comparison with ground truth.

-**Pangeo** (EU funded)

BRGM role : provide information coupling the stability of the ground on which we live to Geological information already held by the National Geological Survey

Exemple: Combination with ancillary data (e. g. geology) / interpretation :

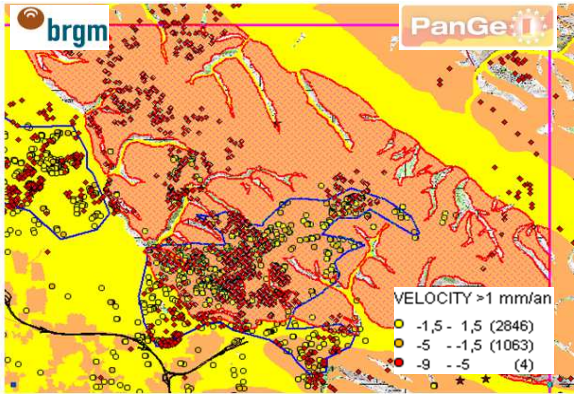


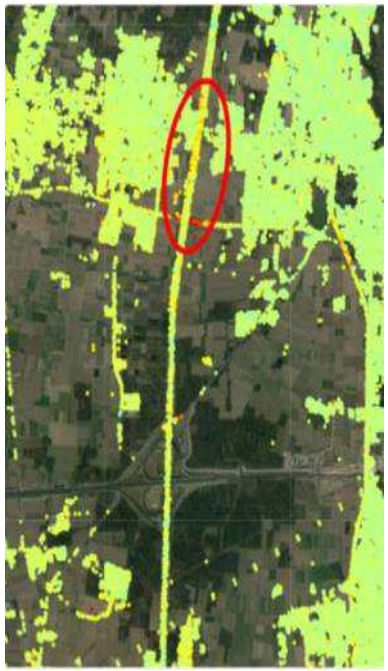
Image :
PSI results on clay shrink-swell hazard map (Toulouse area). Source (pangeo/brgm/altamira)

Possible ancillary data from BRGM:

- Hazard maps
- Ground motion database (BD MVT)
- Ground cavities database (BD Cavités)
- Geological maps
- Hydrogeological informations

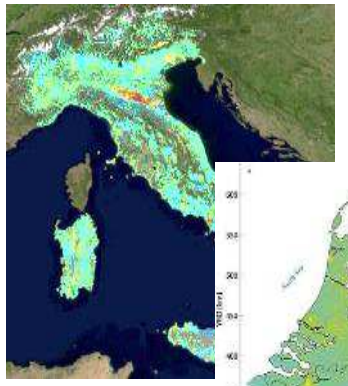
What products - National or European products ? (1/2)

- Precise displacement data can provide "***sensitive information***" which should be managed with care
- InSAR data would be published on the web with no interpretation; make them accessible to the general public **can be misleading**.
- Displacement data and velocity maps **are not risk maps**, however, they can cause concern and cause "false alarms" within uninformed public.
- Precise displacement maps can provide conclusive data to Public Administration and Governmental agencies about whether or not some local or national regulations are followed (e.g. maximum subsidence rates over O&G reservoirs or coastal areas, illegal water pumping, etc.).

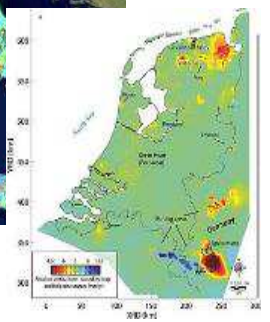


What products - National or European products ? (2/2)

- High-Resolution (HR) displacement data over a whole country should be managed **by individual member states**.
- There are, however, InSAR services which have a broader (transnational) scope and for which a **European service** could be envisaged (e.g. subsidence along coastal areas all over Europe or the generation of water vapor maps from InSAR data).
- Copernicus products should not kill the InSAR market. Free downloadable HR InSAR can be a threat for any commercial applications (+ potentially misleading if not interpreted), medium resolution data can create awareness and foster the adoption of the technology.
- New Copernicus products must be "**in phase"** with other UE/ESA initiatives EPOS/GTEP/etc. and **their end-users have to be defined/identified in detail**



The Italian PS database



InSAR results over The Netherlands

BGS SubCoast page

Step-by-step approach

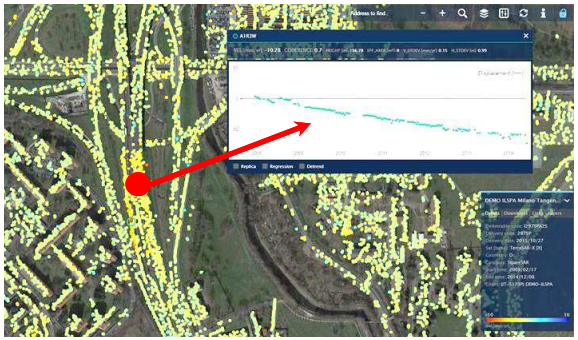
To come up with a national InSAR service, we recommend a step-by-step approach to carefully evaluate all aspects of the project.

STARTED 2016

- **Proof Of Concept** – an area of about 20,000 km^2 has been selected. On this area, all products/deliverables foreseen for the national service will be generated and evaluated with potential users.

FORESEEN

- Creation of the so called «**baseline**» - all data acquired by Sentinel-1A/B over France are processed, geocoded and the geo-database is created. The processing chain is tuned for a national service and the web-based platform is optimized for quick and reliable queries and early warning.

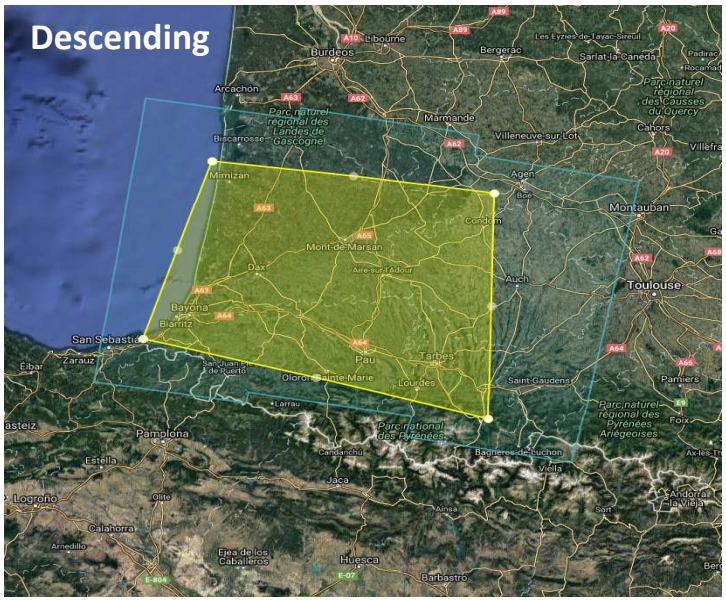


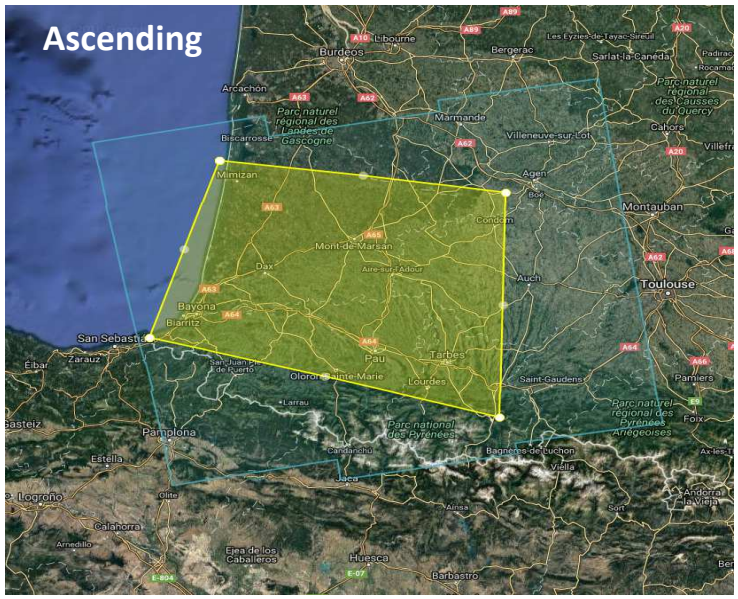
FORESEEN

- Start of the **monitoring service** on a national scale – here the key parameter, impacting also on the cost of service, is the frequency of update of the information

Pilot Project in SW France - Introduction

- The pilot project focussed on a 2 year duration of Sentinel1 IW SLC data.
- More than 50 images acquired in each mode have been processed to provide deformation data over the area of interest.



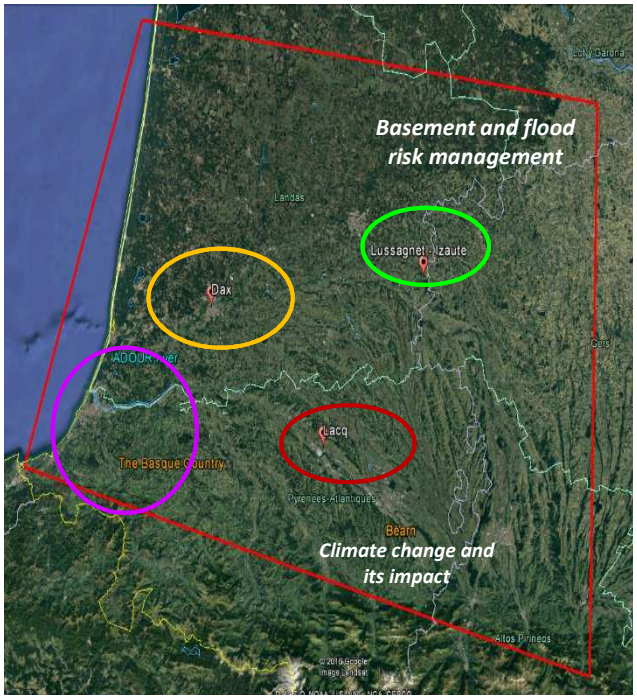


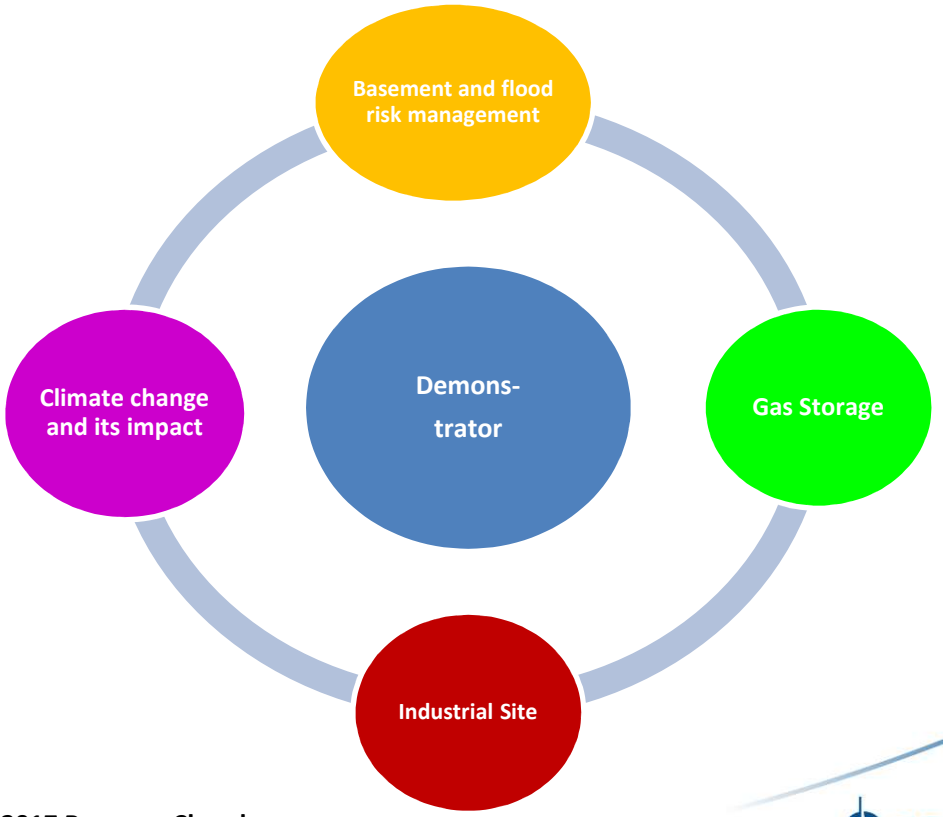
Descending IW Mode, 51 images : 2014/10/18 - 2016/10/19

Ascending IW Mode, 54 images : 2014/10/19 - 2016/10/19

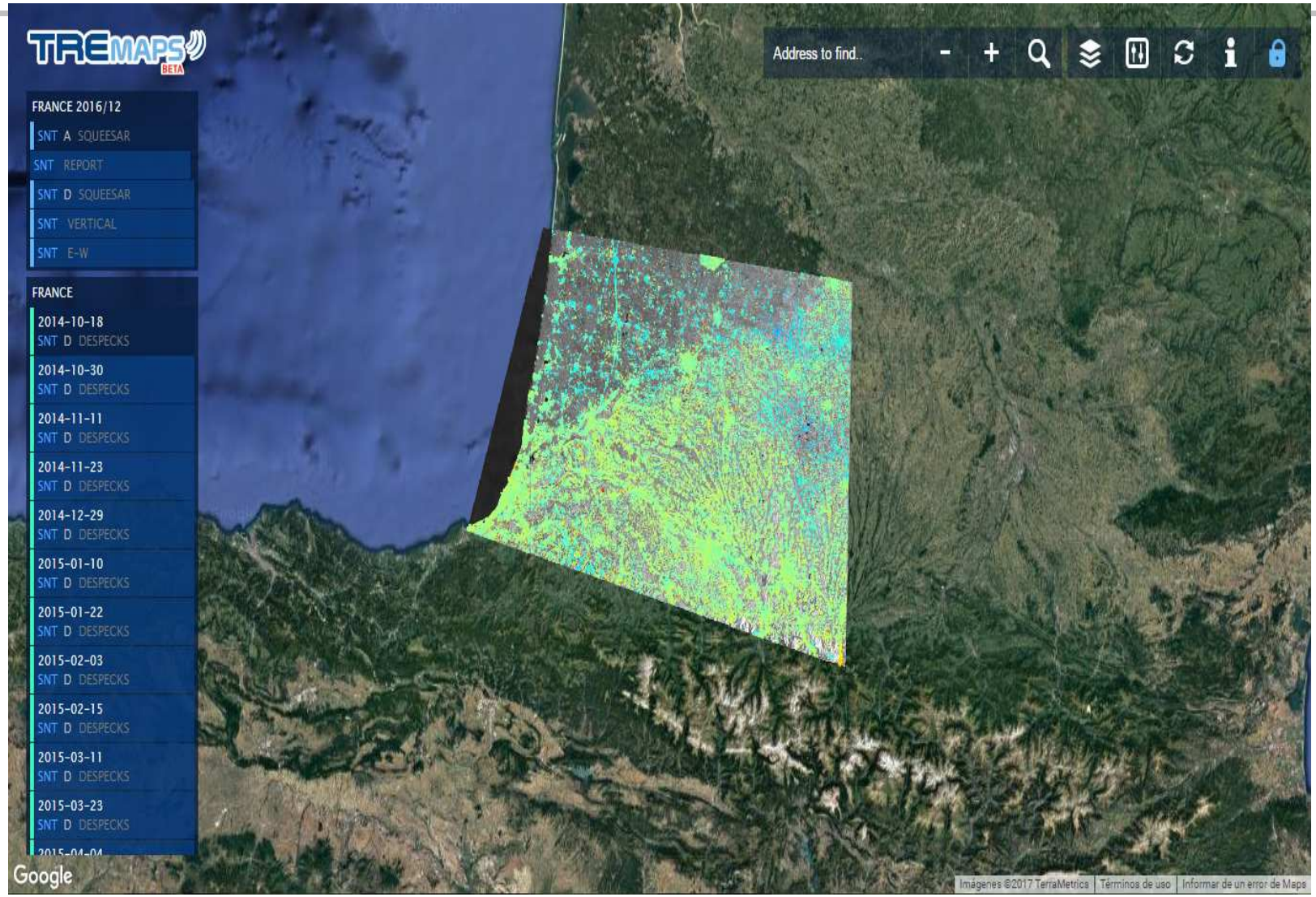
Pilot project – The possible applications

- Various themes that can be addressed within the pilot area to serve as a demonstrator.
- The results will make it possible to evaluate the interest of the information provided and the possible upgrade of the service at national or European level.

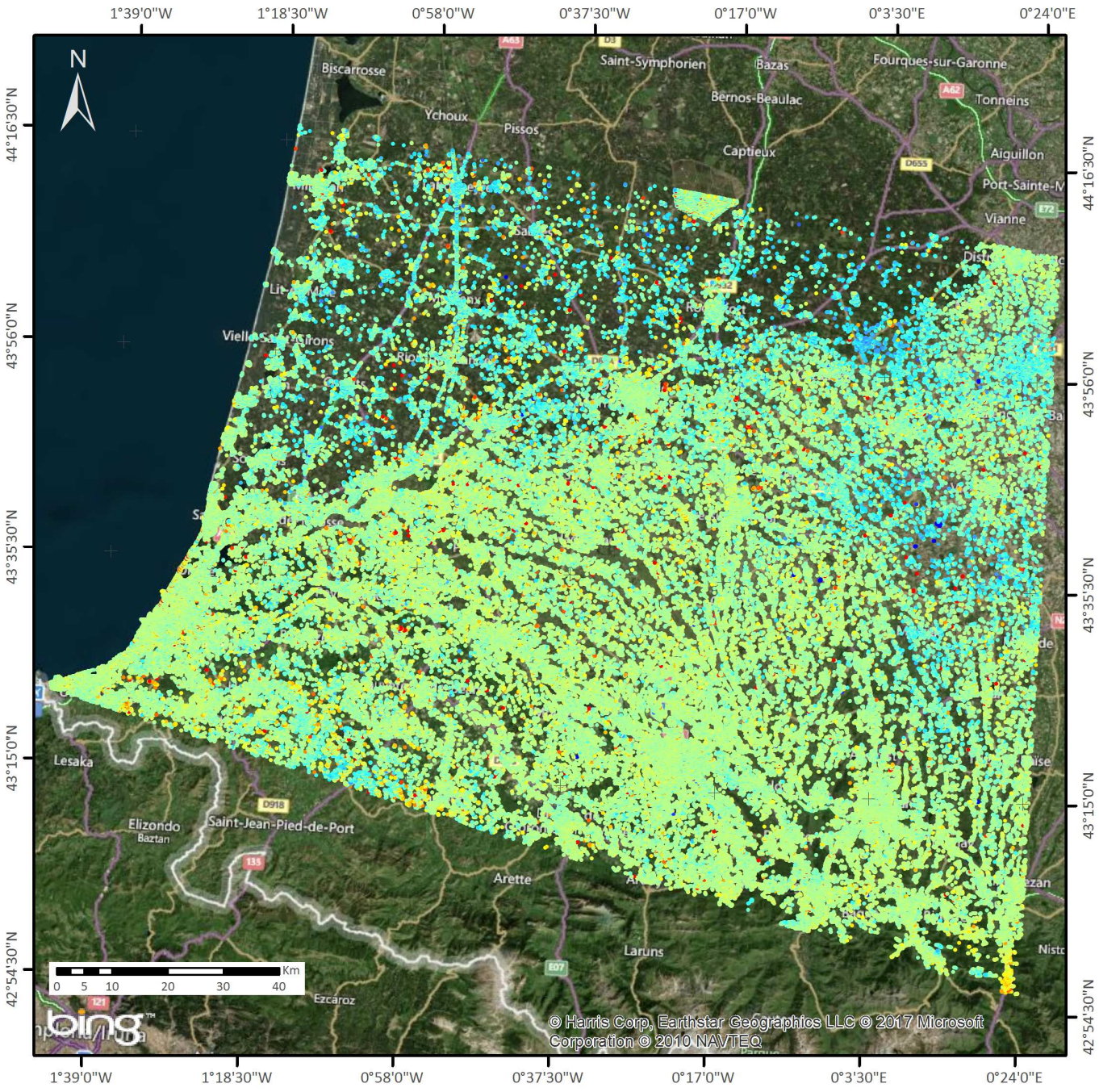




Pilot Project – The results

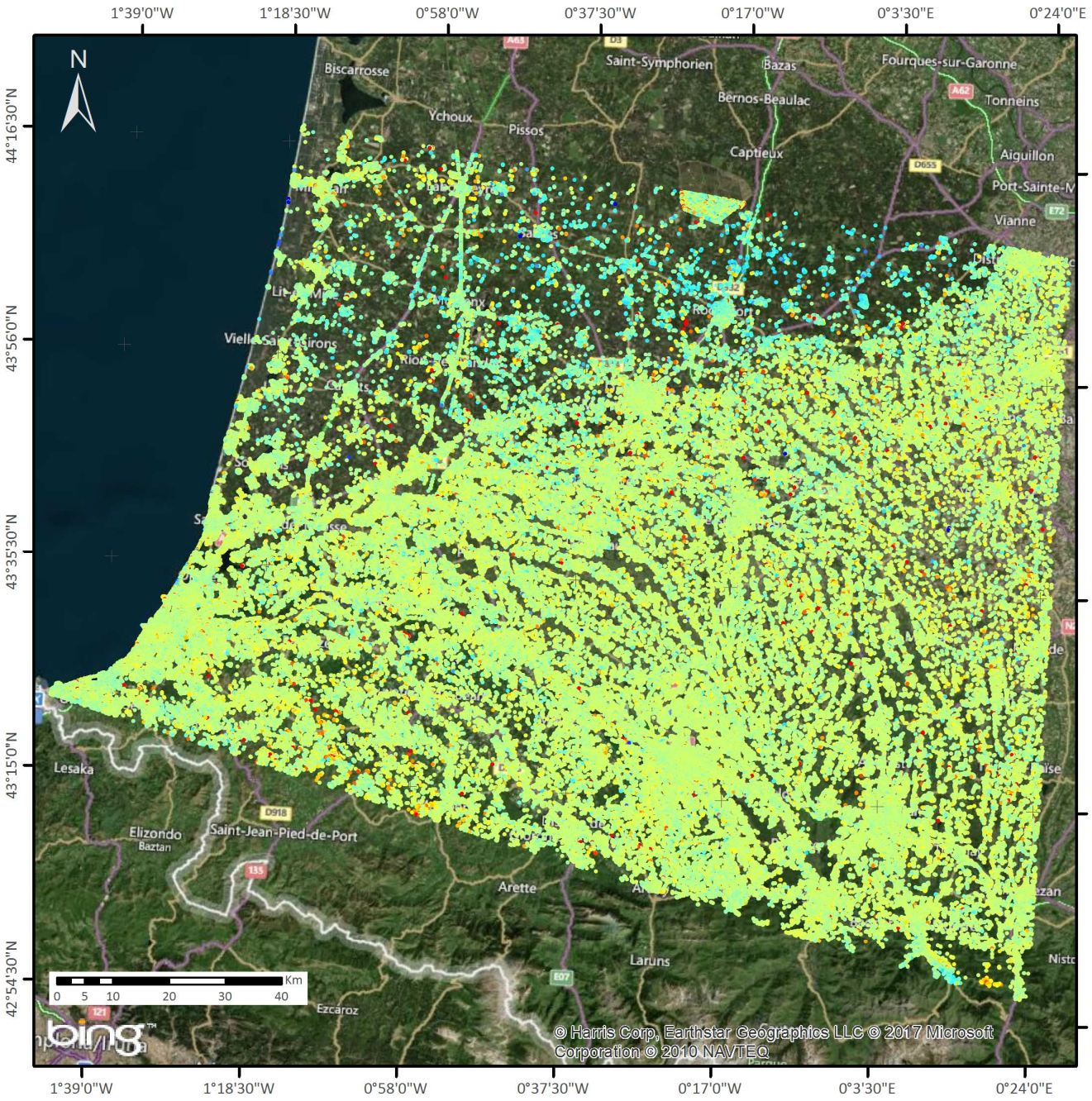


Ascending
LOS 20m

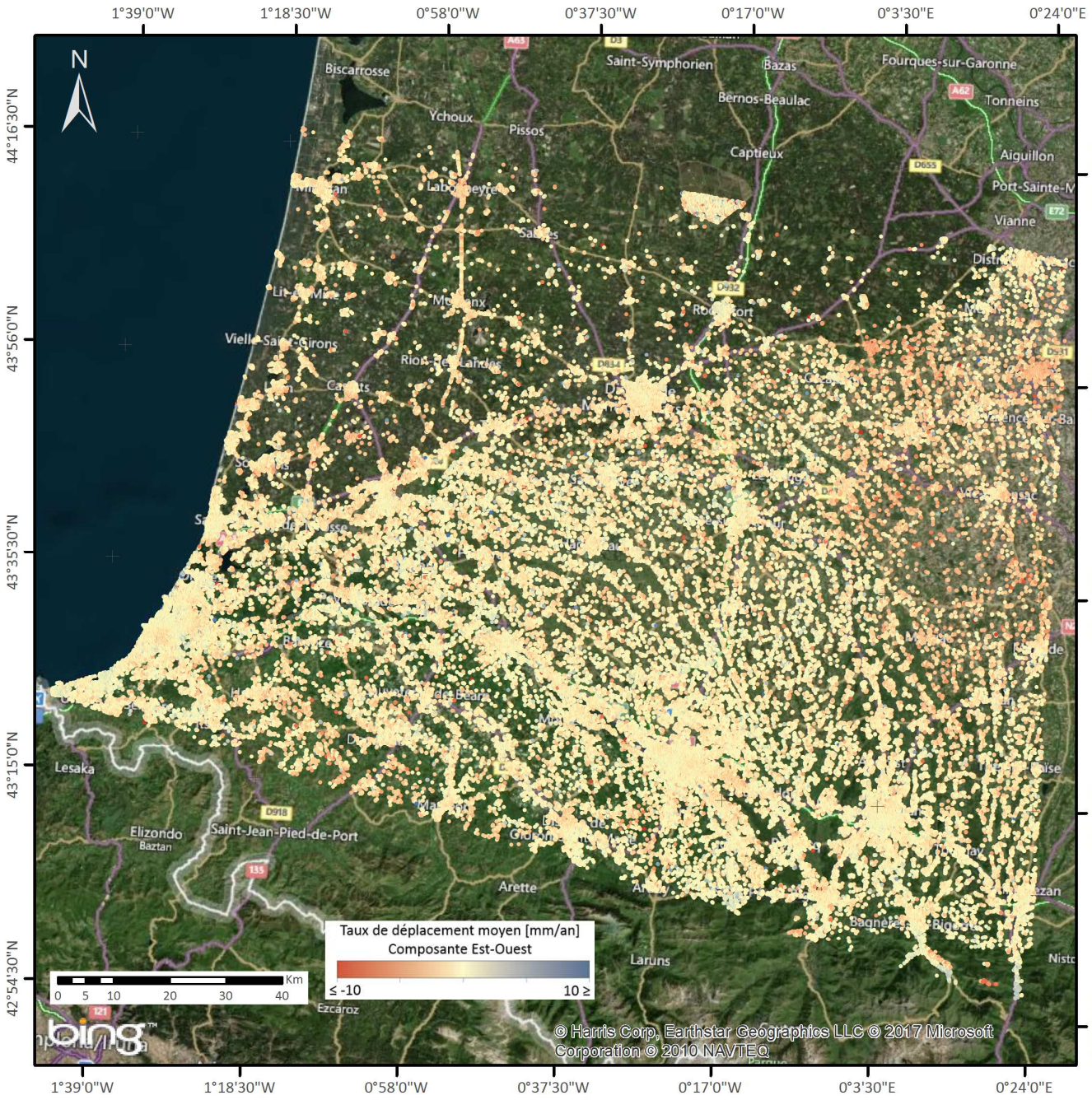


Descending

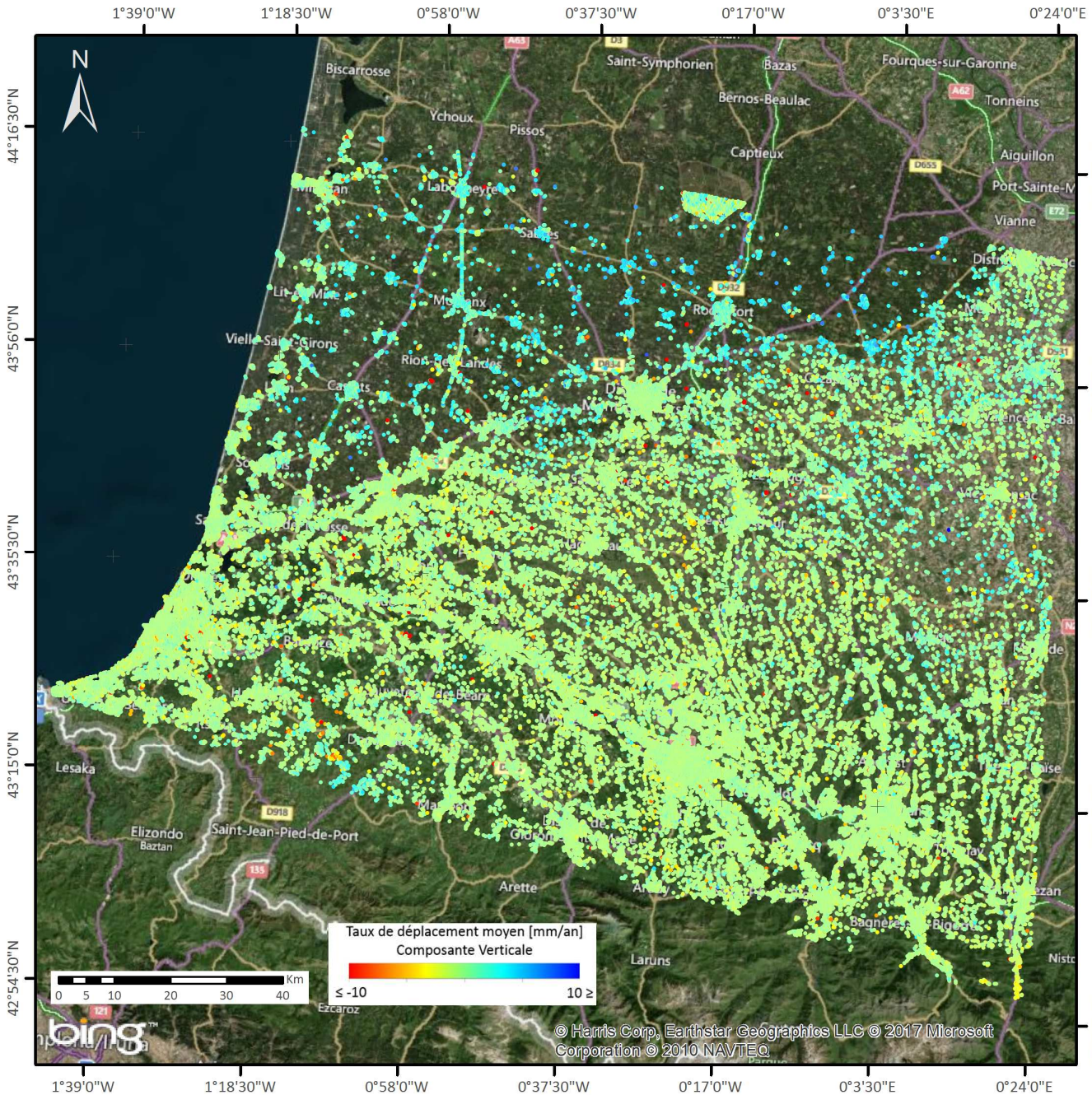
LOS 20m



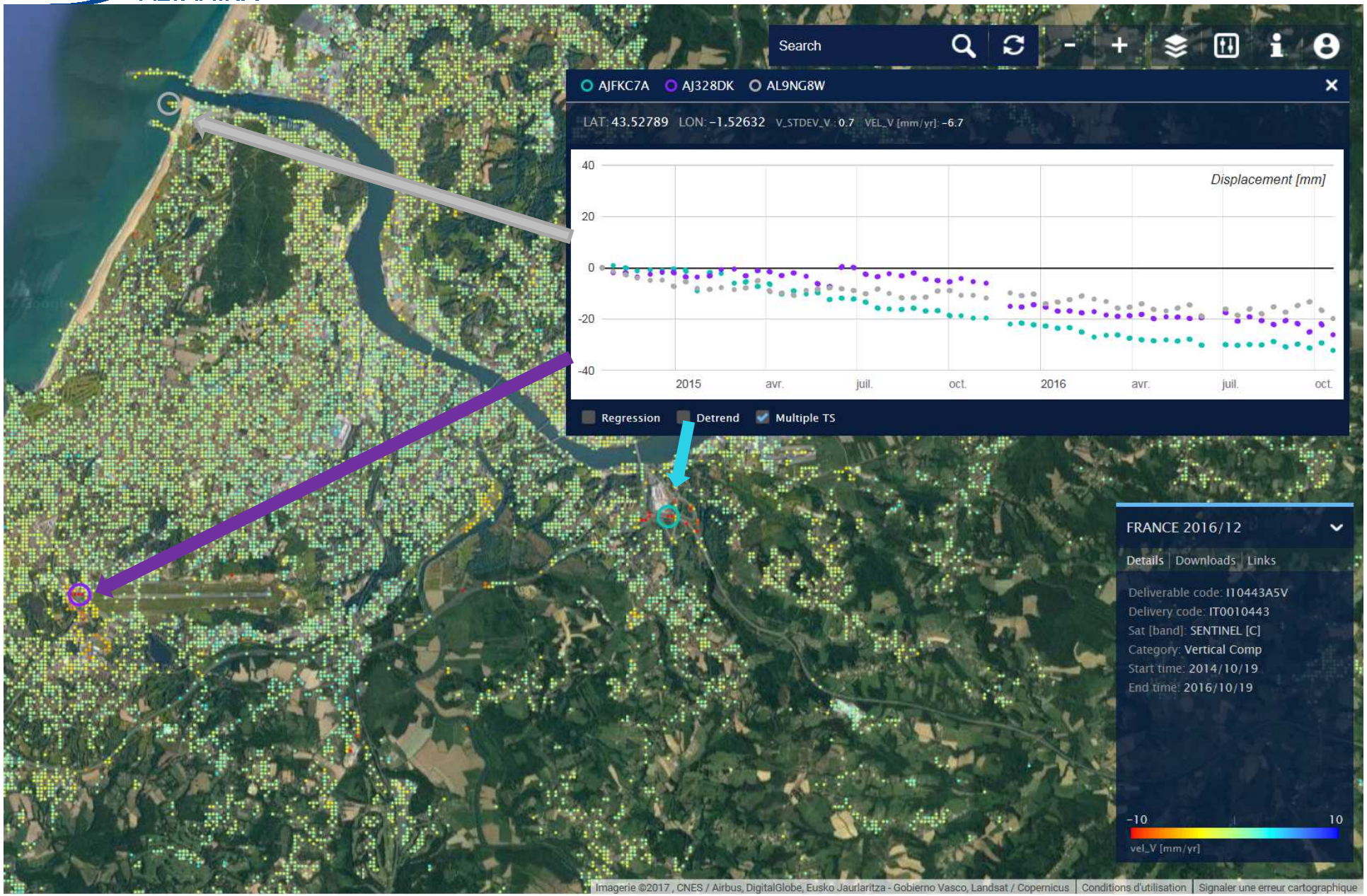
East-West
Component
40m



Vertical Component 40m



Pilot Project – Focus result



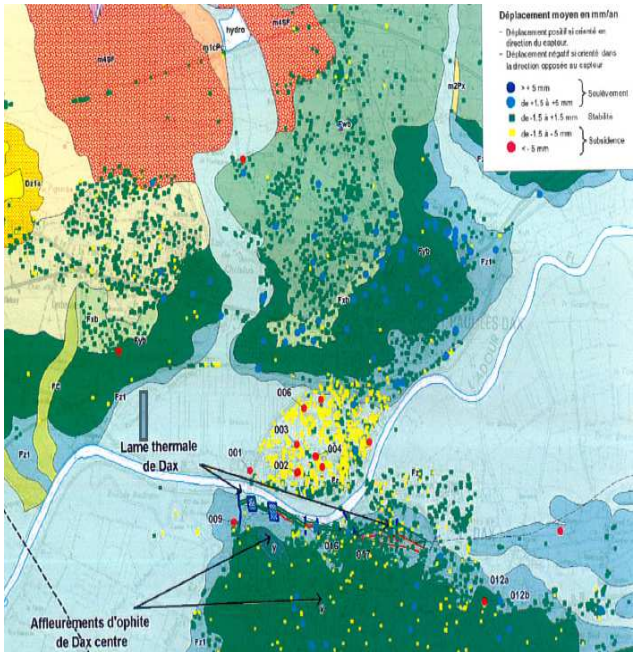
City of DAX : a unique experience

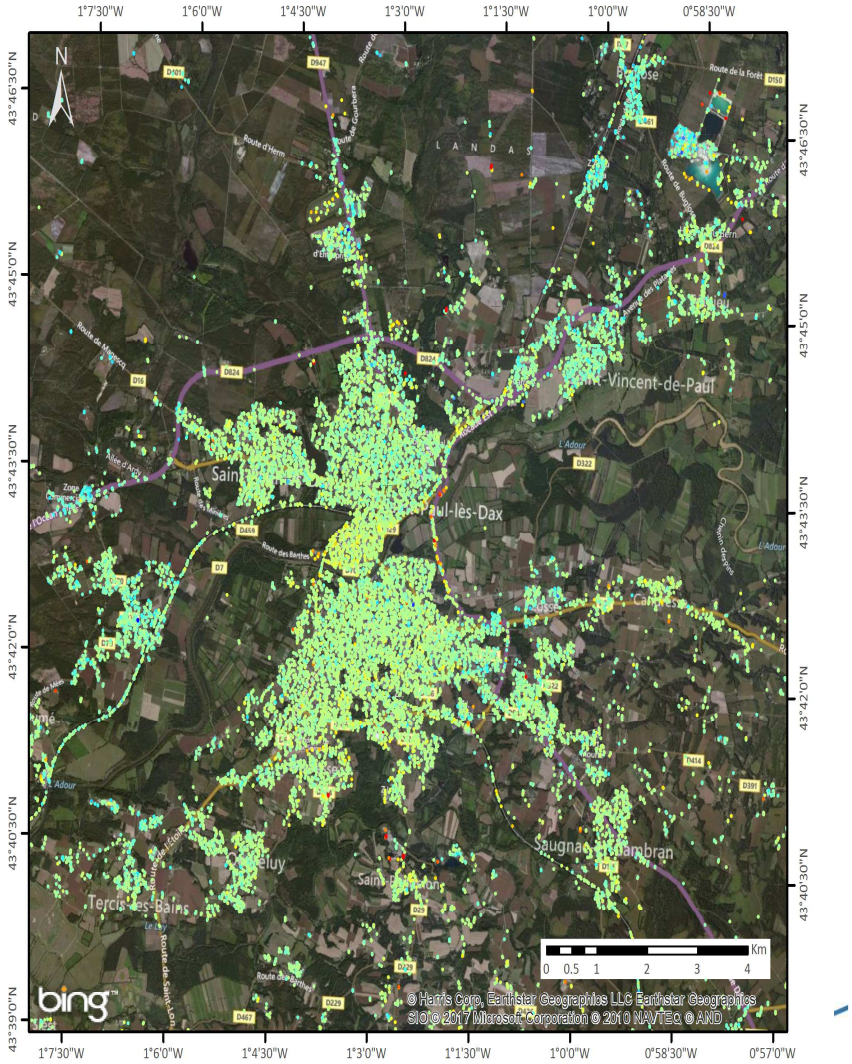
» a community that finances itself long term HR InSAR studies

- The 2010 study, based on ASAR (2003-2010) data, allowed the InSAR potential to be demonstrated. Antea's interpretation of the source of the subsidence measured on the Sablar district was decisive.
- The 2013 study made it possible to validate the contribution of this solution by considerably densifying the number of measurement points with the use of High Resolution. A Corner Reflector network was installed.
- The 2016 study was dedicated to the analyse of ground motion over the whole Dax agglomeration using 2012-2015 HR data stack.

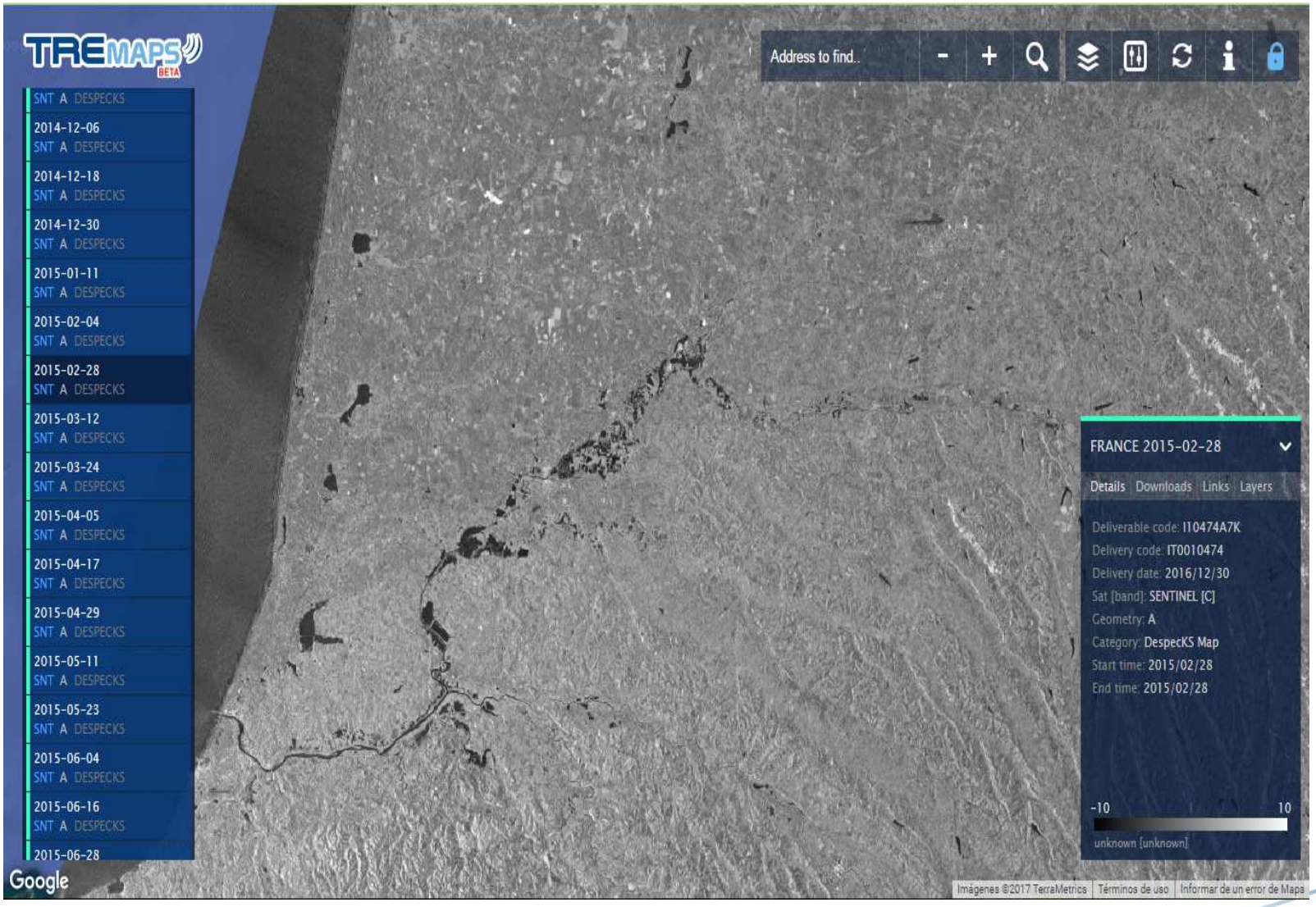
Pilot project – The Sablar district in DAX

» Despite the short duration of the analysed period, the generalised subsidence on Sablar is visible with IW S1 data

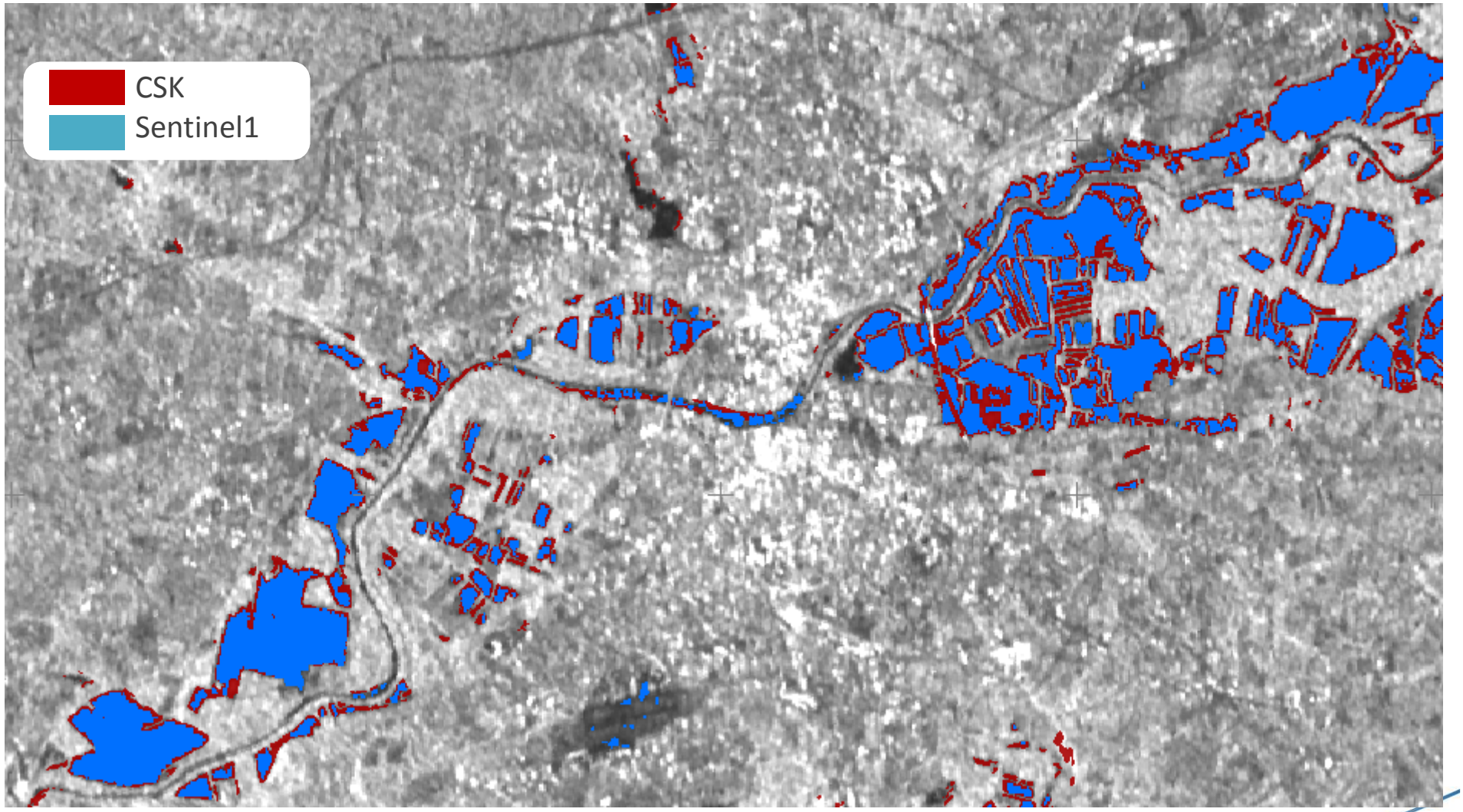




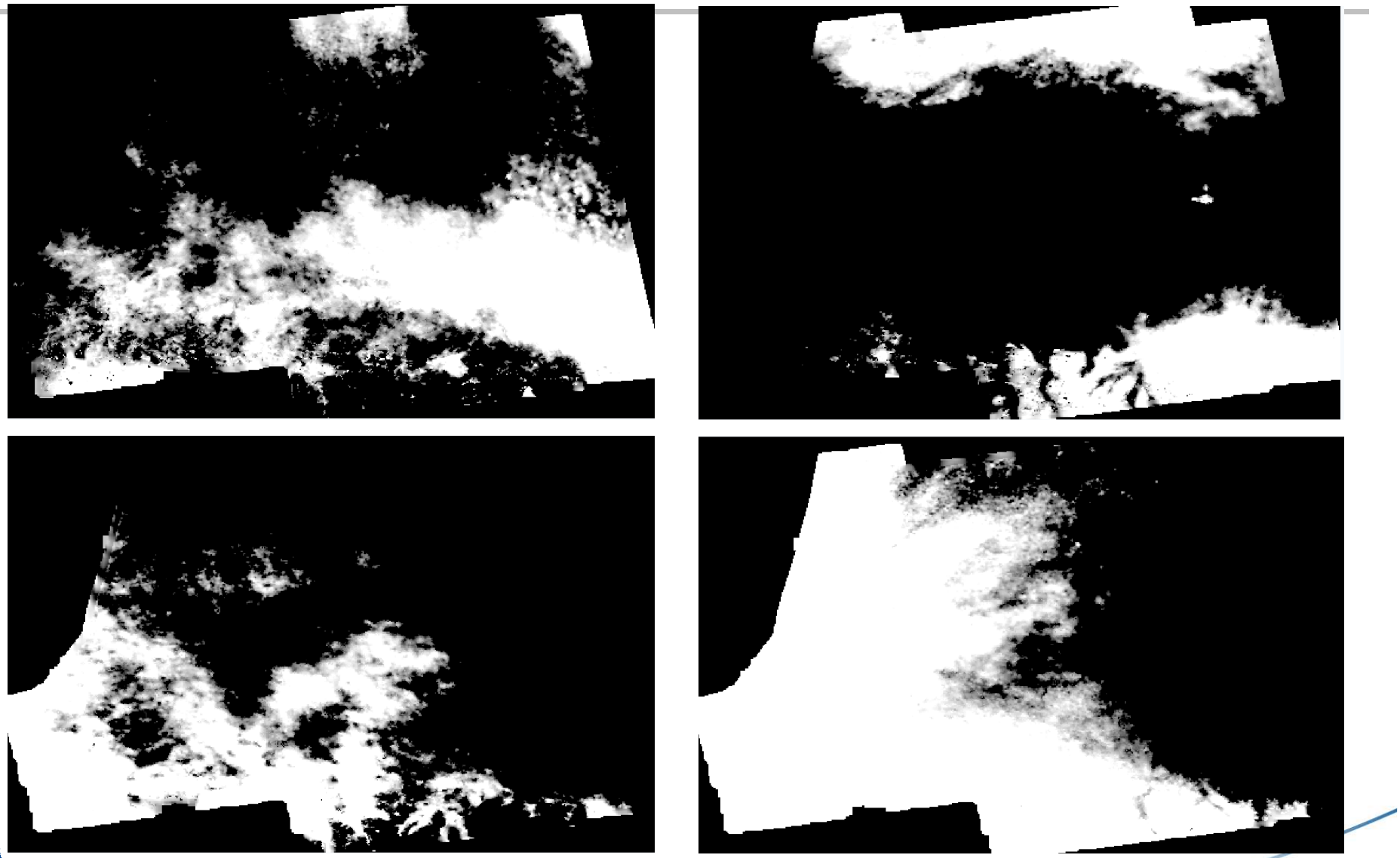
Not define as EU-GMS product – The SAR image analysis



Climate change (floods)



Not define as EU-GMS product : Atmospheric Phase Screen for each pass



Conclusions

- **Sentinel-1** data can play a **key role** in fostering the adoption of InSAR data.
- InSAR results should be treated with **care**. They provide **sensitive**, though extremely useful, **information**.
- Individual **member states** should look after the data of their **own territory**, taking into account also local and national regulations to tune the service accordingly.
- There are **information layers** based on InSAR data which could be considered **of «*European interest*»** (e.g. motion along coastal areas). In this case, we recommend an international management.
- CNES is well aware of the potential of the InSAR technology and the Copernicus program, and has already planned a set of activities aiming at a **national service** based on Sentinel-1 data.
- Key features for any national service are: **data usability, reliability, regular update** as well as a **training program** for all potential users.
- The **planned service** is **nationally** based for the reasons above mentioned and is **viewed as a brick** (element) for the building of a EU-GMS service in the Copernicus framework

B/U SLIDES

Initiative

Main potential applications/limitations in France for a 100mx100m gridded product : BRGM feedback

- **Urban vertical motions** (phenomena size > few hundreds of m): different origins (workings, fluid extraction, cavities, salt/gypsum dissolution, urban landsliding)

- **Gas storage/ Geothermal exploitation**. The 6 days repeat cycle will allow full injection/extraction cycles monitoring. The expected size of deformation is appropriate for 100x100m cell product. In certain cases new/future regulation could require InSAR monitoring.

- **Post-Mining** (there are no more active mines in France). The monitoring is focused on the evolution of areas of past underground mining. The product can be useful (except for sudden or very localized ground motion).

- **Coastal management**. Increase of coastal vulnerability due to combination of sea level rise and land motion . In certain cases, the 6 days repeat cycle would allow succesfull PSI processing on short periods. In other cases, best targets are the coastal urbanizations. BRGM is developing services on climate changes (i. e. ERANET ERA4CS). Such applications could integrate the PSI product.

- **Landslides**. In France, 100m grid resolution is a major limitation to landsliding monitoring as most of threatening slides are smaller than that. The 6 days repeat cycle is interesting for targeted rates, from cm/yr to dm/yr. This is the application for which ascending+descending processing is essential as there is an important horizontal component of the displacement.

- **Clay Shrink-Swell hazard**. The 100m grid could be a limitation as there is strong local motion variability.

Projet Pilote – précisions

Mesures	Direction de la mesure	Résolution spatiale	Ecart-type
Vitesse moyenne de déplacement	LOS	20 m	± 1 mm/an
	Vertical	40 m	± 3-4 mm/an
	Est-Ouest	40 m	± 6-7 mm/an
Mesure individuelle de déplacement	LOS	20 m	± 5 mm

Localisation du point de mesure	
Position Nord	± 8
Position Est	± 15 m
Hauteur ellipsoïdale	± 8 m

Précisions théoriques à 1 km du point de reference

Valeurs obtenues à partir de l'analyse d'un jeu de 55 images S1 acquises sur une période de 24 mois.

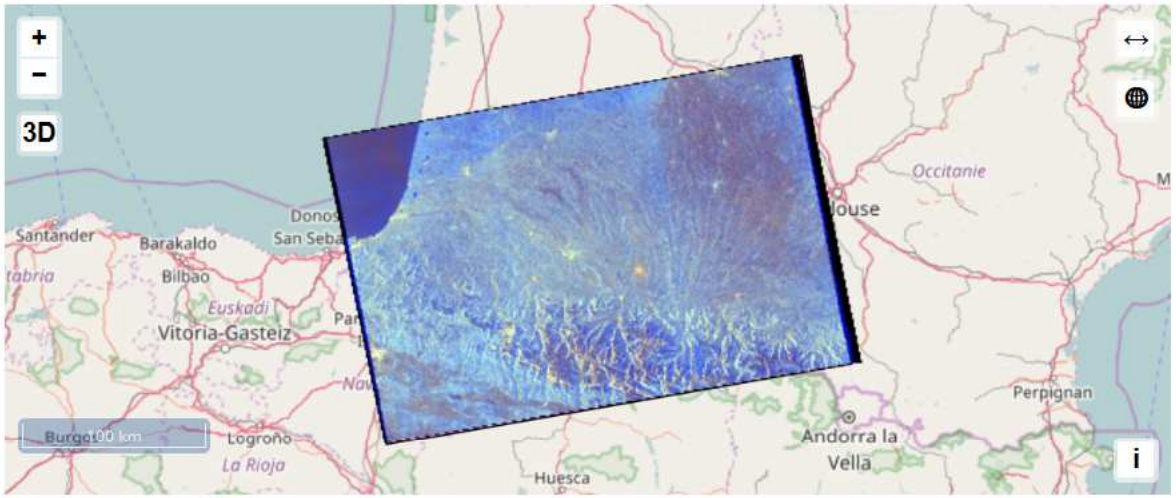
PEPS

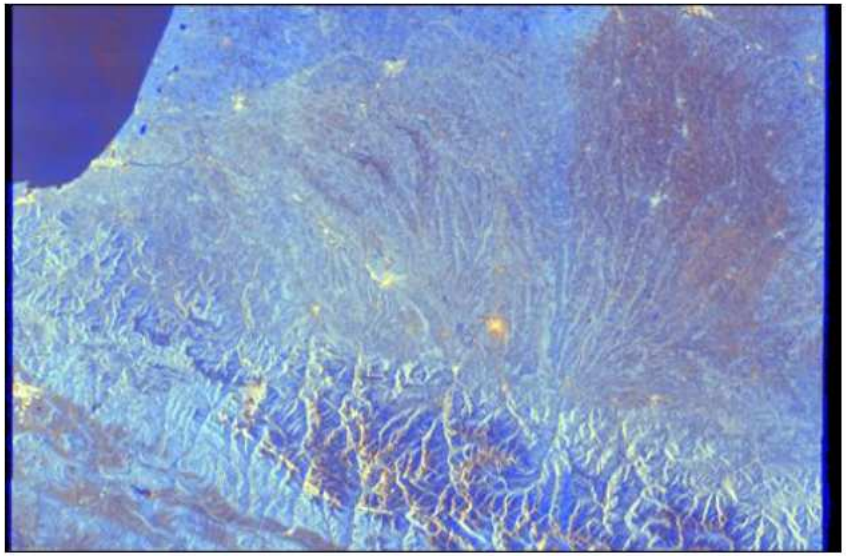
https://peps.cnes.fr/rocket/#/collections/S1/5f0d4e43-a4b0-5e58-8349-7a6c6055078d

Search

cnes peps

Accueil Explorer PEPS-RSS





France

Général

Collection	S
Identifiant du produit	S
Date de publication	2

Satellite

Plateforme	S
Instrument	S
Type de produit	G
Niveau de traitement	L
Mode du capteur	I

Caractéristiques

Date de début	2
Couverture neigeuse	0
Couverture nuageuse	0
Polarisation	V
Sens de l'orbite	A
Numéro d'orbite	-

PEPS

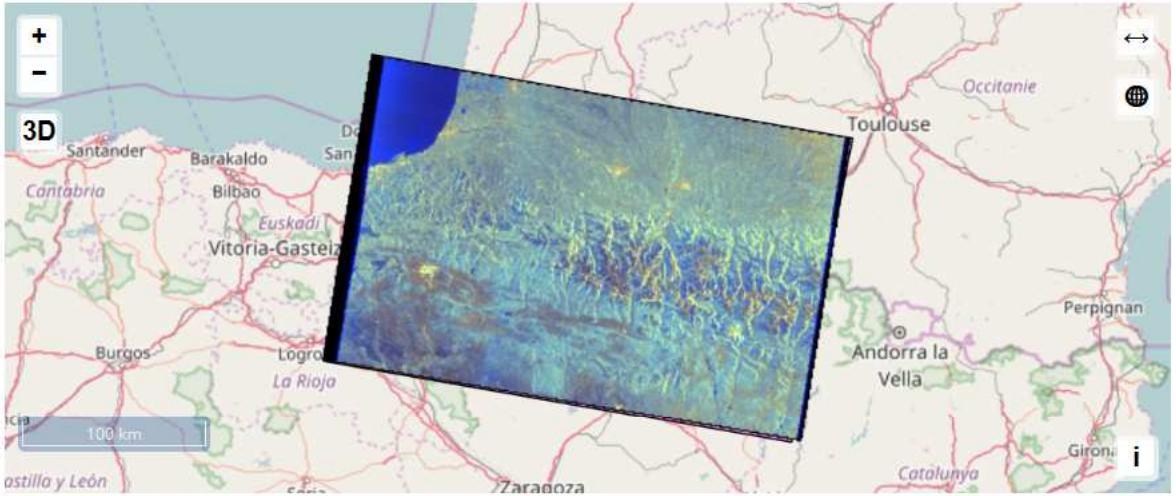
https://peps.cnes.fr/rocket/#/collections/S1/8d71ff02-1ca0-5692-8357-ab82c0c1d7a5

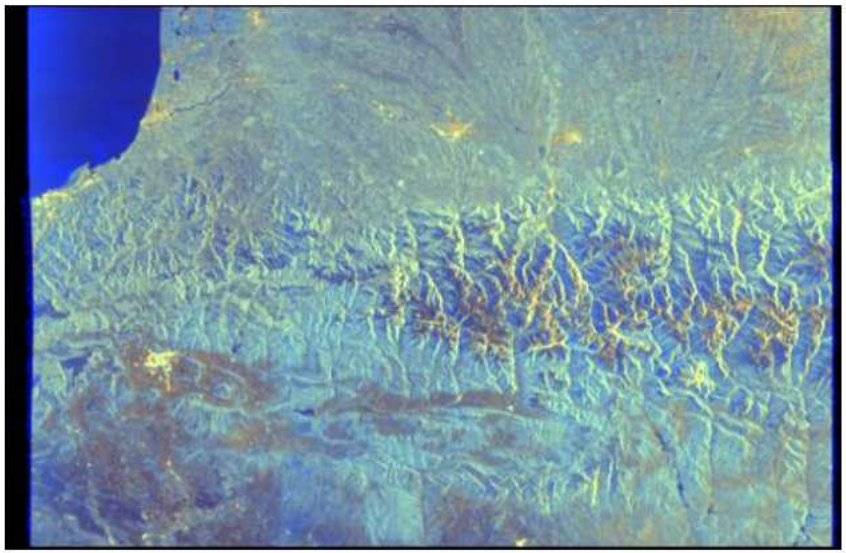
Search

cnes peps

Accueil Explorer PEPS-RSS

S1A_IW_GRDH_1SDV_20161019T060853_20161019T060918_013555_015B30_EB91





Espagne

Général

Collection	
Identifiant du produit	
Date de publication	

Satellite

Plateforme	
Instrument	
Type de produit	
Niveau de traitement	
Mode du capteur	

Caractéristiques

Date de début	
Couverture neigeuse	
Couverture nuageuse	
Polarisation	
Sens de l'orbite	