



**TRE**  
**ALTAMIRA**  
A CLS Group Company

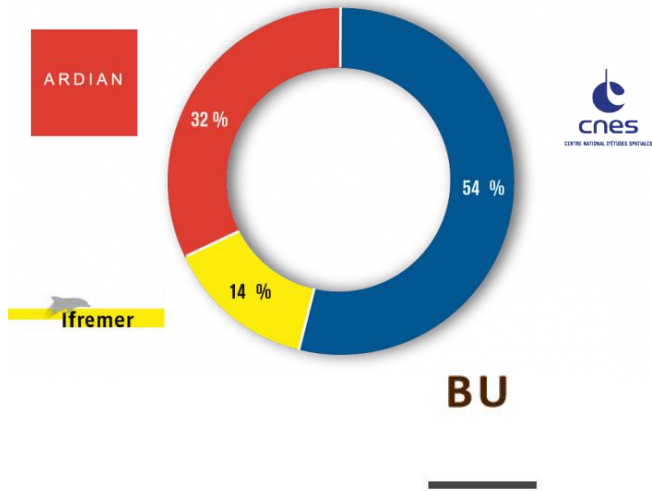
# National InSAR coverage – EGMS perspective French metropolitan territory

INFORMATION FROM SPACE

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# Presentation of TRE ALTAMIRA – CLS Group

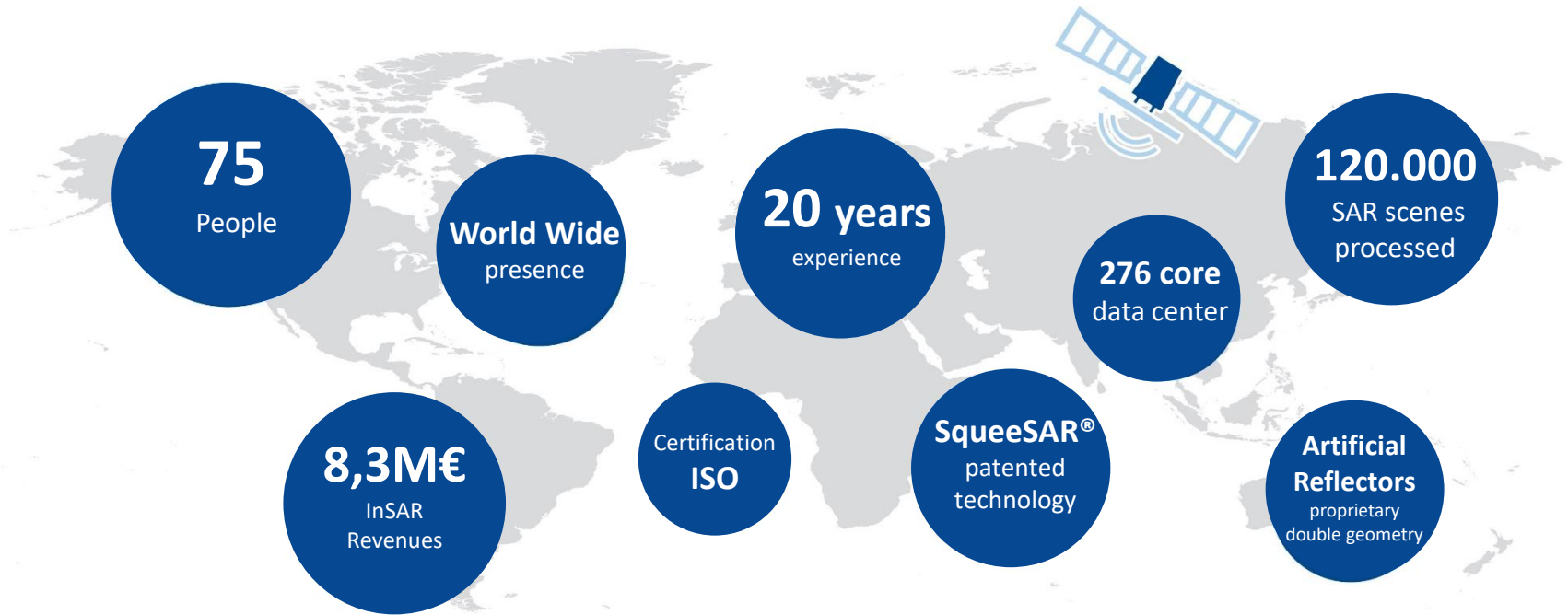
The CLS Group



# Introduction to TRE ALTAMIRA – CLS Group

InSAR leader

TRE ALTAMIRA is the largest InSAR group worldwide.



TRE ALTAMIRA, world leader in ground motion monitoring services  
with satellite radar data.

- » With the launch by European Space Agency of the Sentinel-1 mission, which offers free access to radar satellite data, initiatives are emerging in order to propose ground motion measurements into the Copernicus service portfolio.
- » The development of a European Ground Motion Service (EGMS) is proposed as part of the Copernicus Land Service.
- » As a precursor of such a service, the French Space Agency CNES - Centre National d'Etudes Spatiales - launched the first pilot project over the whole metropolitan French Territory.
- » In this framework, TRE ALTAMIRA has processed 4-year ascending and descending Sentinel-1 data (2015-2018).

# The context of the study

## French initiative towards EGMS

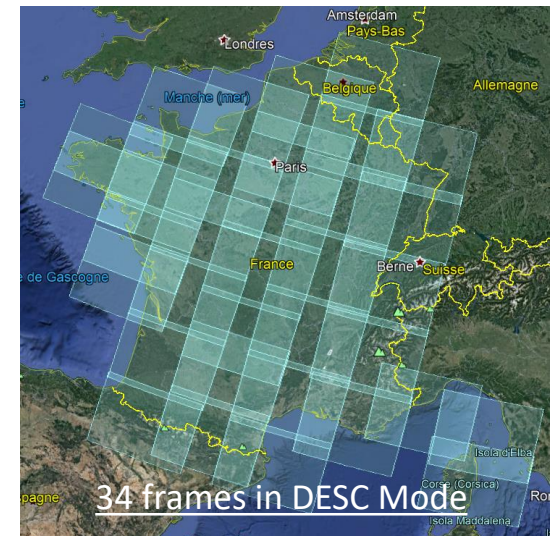
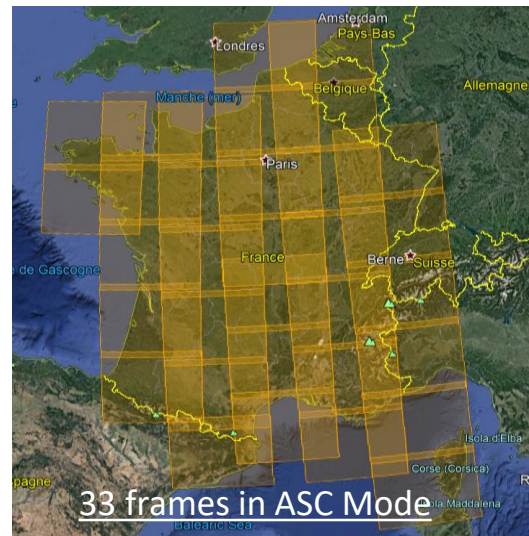
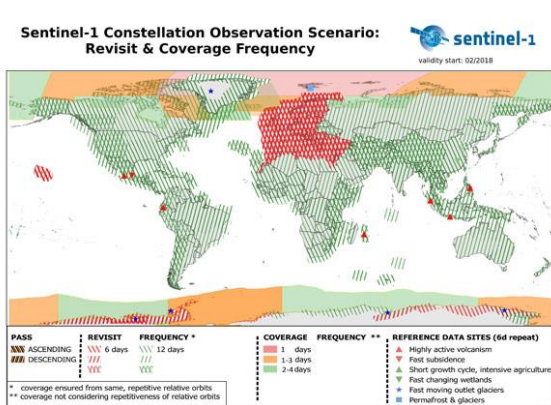
- » The study considers the totality of the French Territory.
- » It extends over about 550 000 Km<sup>2</sup>.
- » Project complexity is related to the size of the study area, the diversity of its land cover and the topography.
- » **The challenge lies in the need to optimize the processing time while guaranteeing high quality results.**



# The context of the study

## The Sentinel-1 coverage

- » Sentinel-1 is the first of the five missions that ESA is developing for the Copernicus initiative.
- » The mission ensures continuity of C-band SAR data to applications and builds on ESA's heritage and experience with the ERS and Envisat SAR instruments.
- » Ascending and descending archives are considered in order to minimize the impact of geometric distortion and guarantee an optimal visibility also in mountainous areas.



# The context of the study

## Defining processing areas

- » To optimize the satellite coverage (due to the specific S1 burst acquisition), France metropolitan has been divided in several zones.
- » 31 zones have been defined in ascending and descending modes.

Ascending mode



Descending mode



- » The study considers a period of almost 4 years, from November 2014 until September 2018.
- » Since October 2016, the update frequency is 6 days.
- » Thanks to the combination of S1-A/-B, an optimal data set in terms of temporal distribution is now available.
- » 9566 S1 images were processed

Track	Nb of processing areas	Periode d'étude		Nb d'images par track	Nb d'images total
T30	8	2015-03-12	2018-09-28	155	1240
T59	6	2015-05-01	2018-09-30	147	882
T88	5	2014-11-16	2018-09-26	165	825
T103	3	2015-05-04	2018-09-27	145	435
T132	5	2015-03-07	2018-09-29	131	655
T161	5	2015-02-13	2018-09-25	154	770
<b>TOTAL_ASC</b>	<b>32</b>			<b>897</b>	<b>4807</b>

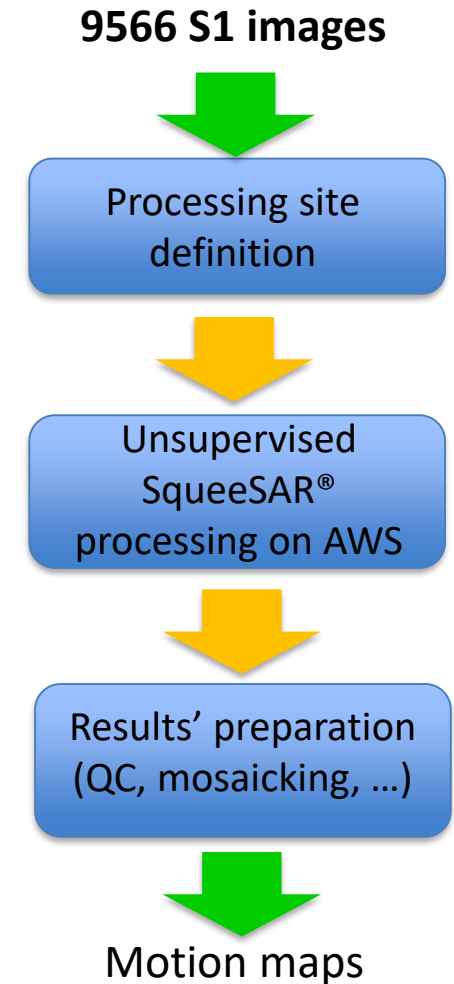
Track	Nb of processing areas	Periode d'étude		Nb d'images par track	Nb d'images total
T8	7	2014-11-11	2018-09-27	157	1099
T37	5	2015-02-05	2018-09-29	157	785
T52	1	2015-05-01	2018-09-30	156	156
T66	1	2014-11-03	2018-09-25	175	175
T81	3	2014-11-16	2018-09-26	157	471
T110	6	2014-11-18	2018-09-28	158	948
T139	4	2015-03-20	2018-09-30	123	492
T154	3	2015-05-08	2018-09-25	155	465
T168	1	2014-11-10	2018-09-26	168	168
<b>TOTAL_DESC</b>	<b>31</b>			<b>1406</b>	<b>4759</b>



# Methodology for ground motion measurement

## The processing strategy




- » TRE ALTAMIRA's strategy takes advantage almost unlimited parallel computing capacity offered on the cloud environment.
- » An adapted SqueeSAR<sup>®</sup> chain has been developed in order to allow an unsupervised processing to be carried.
- » **The objective is to guarantee high quality and reliable results while limiting the need for interaction.**

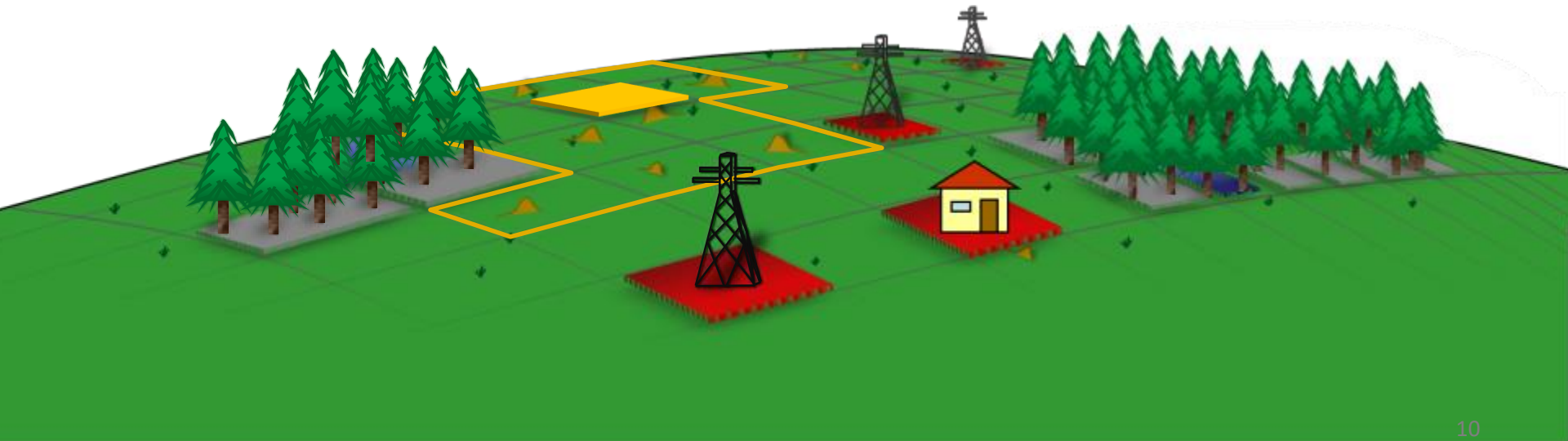
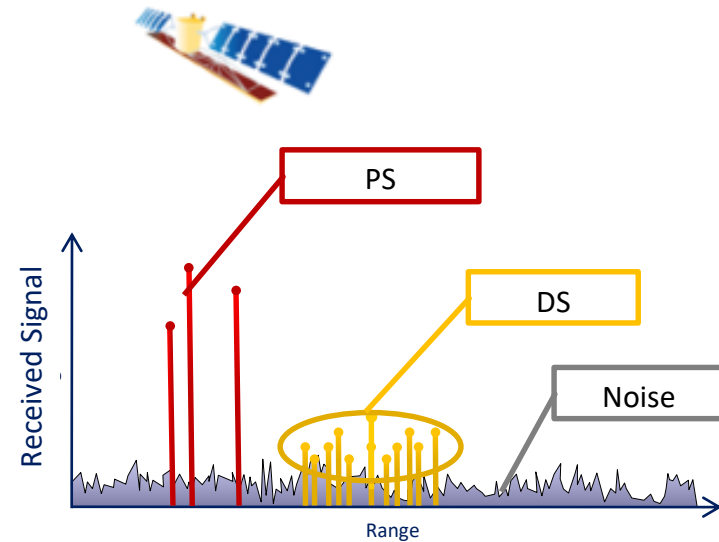


# SqueeSAR<sup>®</sup> for ground motion measurement

## The SqueeSAR<sup>®</sup> algorithm

- » SqueeSAR<sup>®</sup> is the latest and most advanced interferometric algorithm.
- » It identifies two sets of radar targets (measurement points) on the ground:

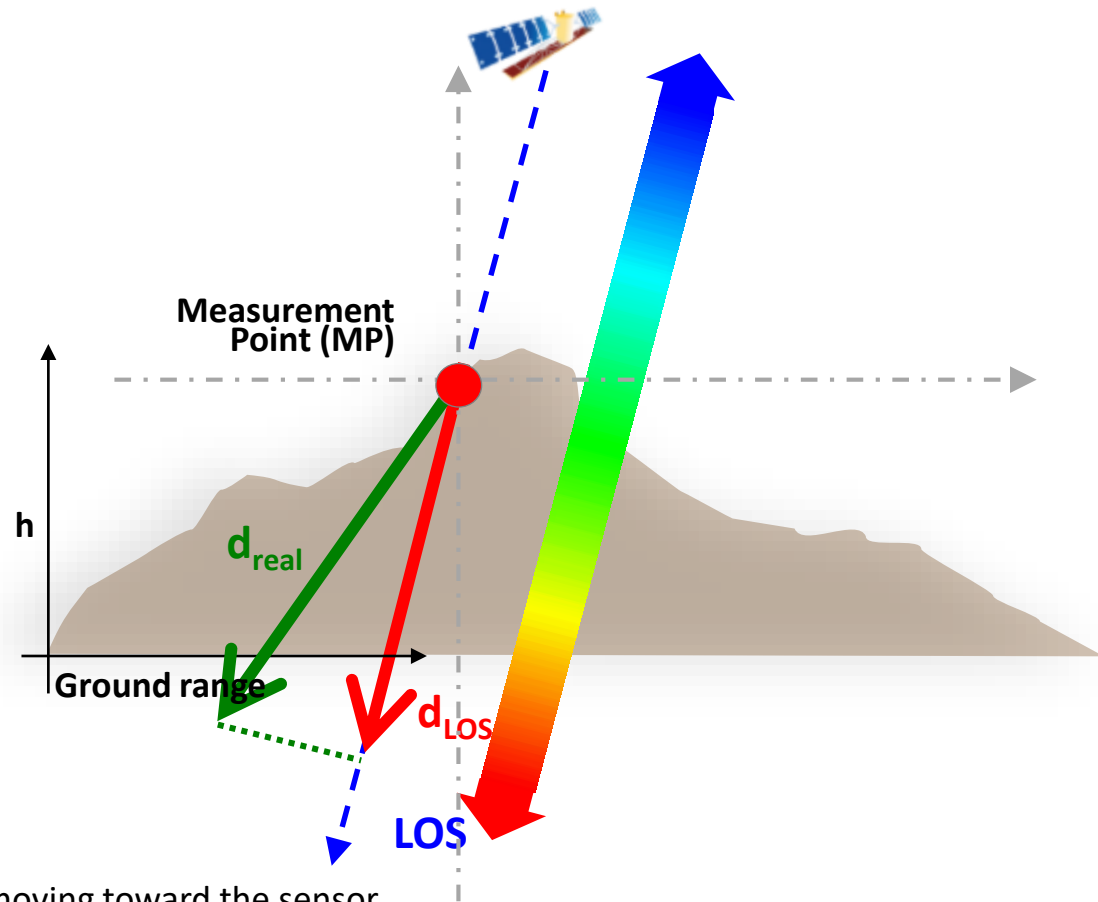
-  Permanent Scatterers ou PS
-  Distributed Scatterer ou DS
-  No data



# SqueeSAR<sup>®</sup> for ground motion measurement

Measurement in the radar LOS direction

- » Radar satellites measure the motion in the radar image plane, i.e. in the Line of Sight (or LOS) direction.
- » LOS is the direction in which the sensor looks at the Earth's surface.

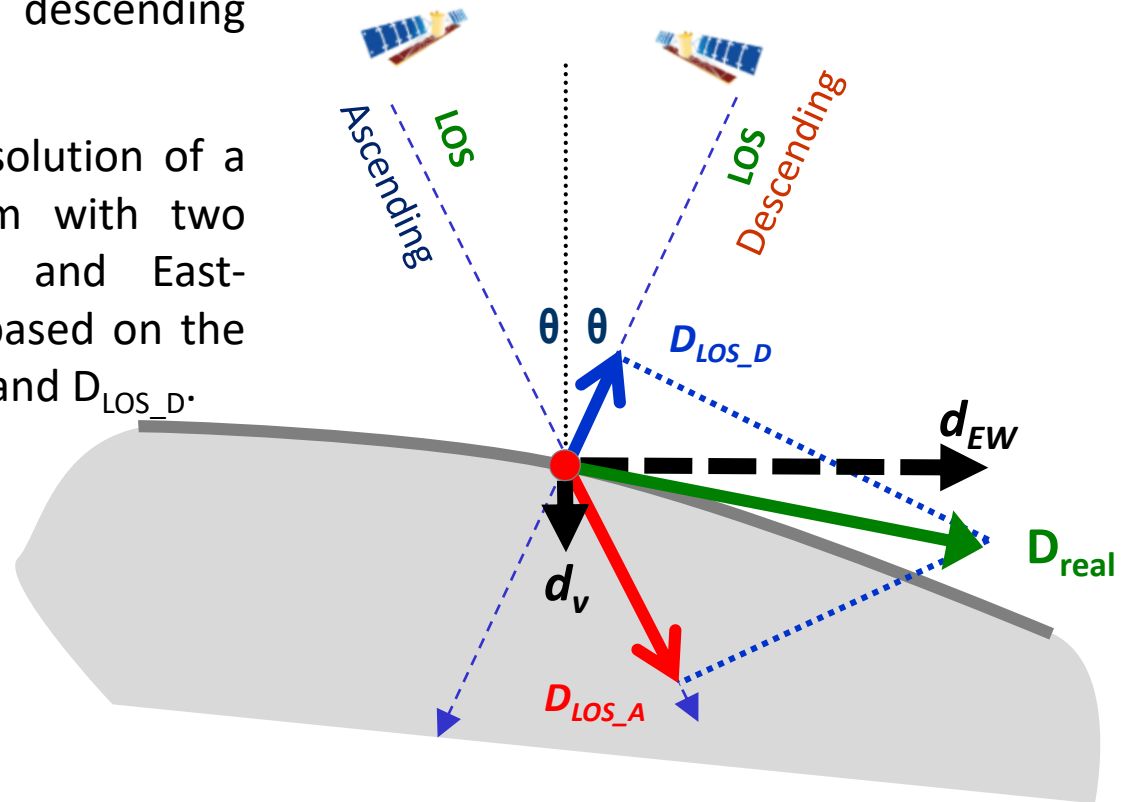


- The cyan to dark blue color identifies MP moving toward the sensor.
- The green color identifies stable MP.
- The yellow to red color identifies MP moving away from the sensor.

# SqueeSAR® for ground motion measurement

Combining Ascending and Descending

- » The total decomposition of the motion can be done by combining measurement in ascending and descending modes.
- » It consists in the resolution of a trigonometric system with two unknowns (vertical and East-West components) based on the knowledge of  $D_{LOS\_A}$  and  $D_{LOS\_D}$ .



# SqueeSAR<sup>®</sup> for ground motion measurement

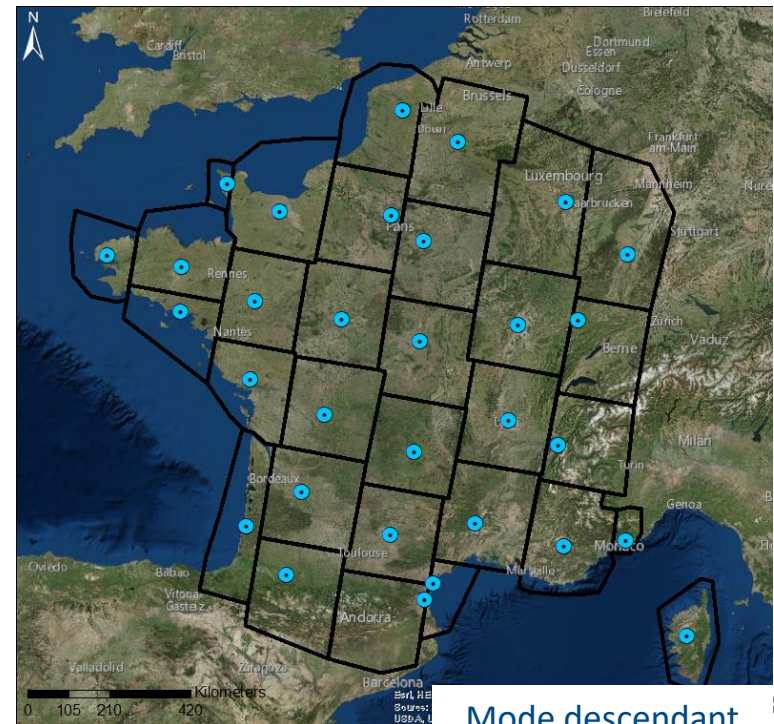
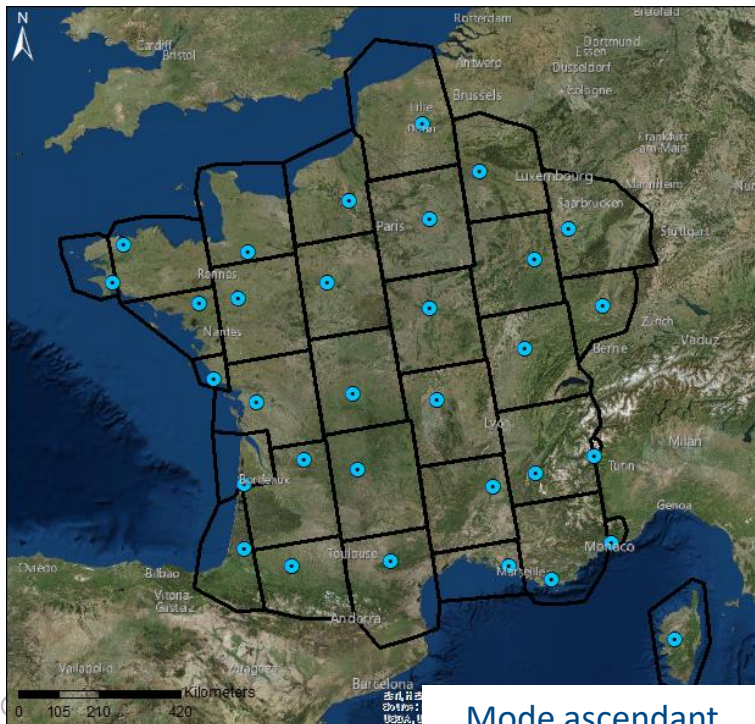
## Data combination approach (1/4)

- » Data combination requires that the same target is identifiable from either the ascending and descending geometry but in general different geometries see different object over the ground.



1. The area is divided into small patches of terrain (a grid of 80x80 m cell is used) and it is assumed that the MP contained into the same cell are affected by similar motion.
2. The measurements of all the MP located in the same cell are averaged and referred to a *pseudo-MP*. This is performed for each geometry separately.
3. Data combination for 2D estimation is performed for all the cells containing *pseudo-MP* from both geometries.

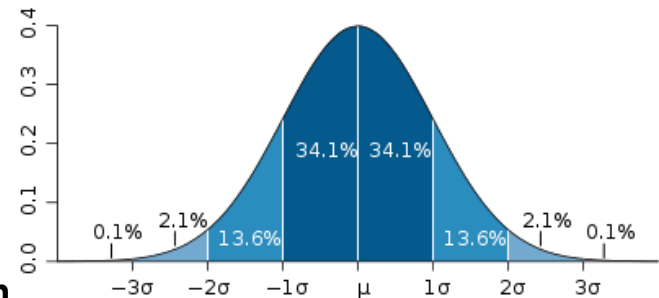
- » SqueeSAR® measurements are relative to a Reference Point (REF), assumed to be motionless.
- » REF is selected by its radar characteristics and motion behaviour in the monitored period:
  - High radar quality of the target: It has to be affected by a low phase noise in all the images of the processed dataset.
  - Not affected by displacement rate variations (no-linear movement or seasonality) in the monitored period.
- » One REF has been taken for each of the 31 zones processed independly.



# SqueeSAR® for ground motion measurement

## Precision of the ground motion measurement

- » The precision of the ground motion measurement is given by the **standard deviation**.
- » It depends on:
  - Distance to the REF
  - Quality of the processed dataset
  - Quality of the radar targets
  - Quality of the atmospheric noise estimation
- » Standard deviation values are not provided for each measure of the time series but only for the average displacement rate.



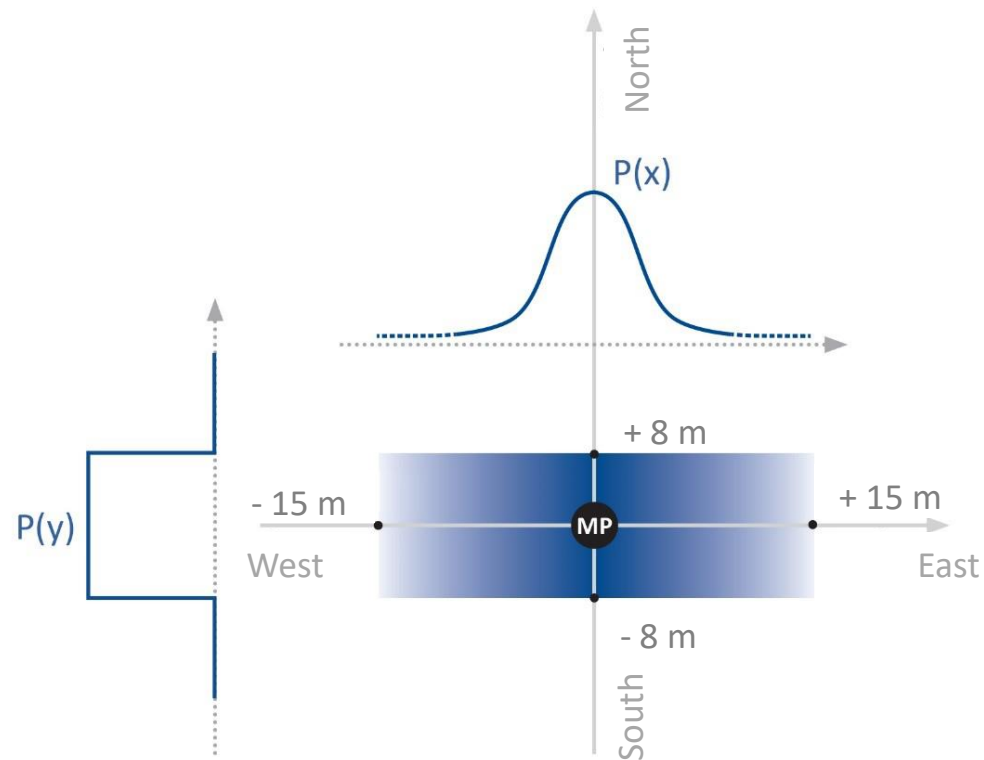
Motion component	Measurement direction	Spatial resolution	Standard deviation
Annual displacement rate	LOS	≈ 20 m	2-3 mm/year
	Vertical	80 m	3-4 mm/year
	East-West	80 m	5-6 mm/year

Typical values of precision for a MP less than 1 km from the REF using a dataset of at least 30 scenes covering a 2-year period

# SqueeSAR® for ground motion measurement

## Geolocalisation precision

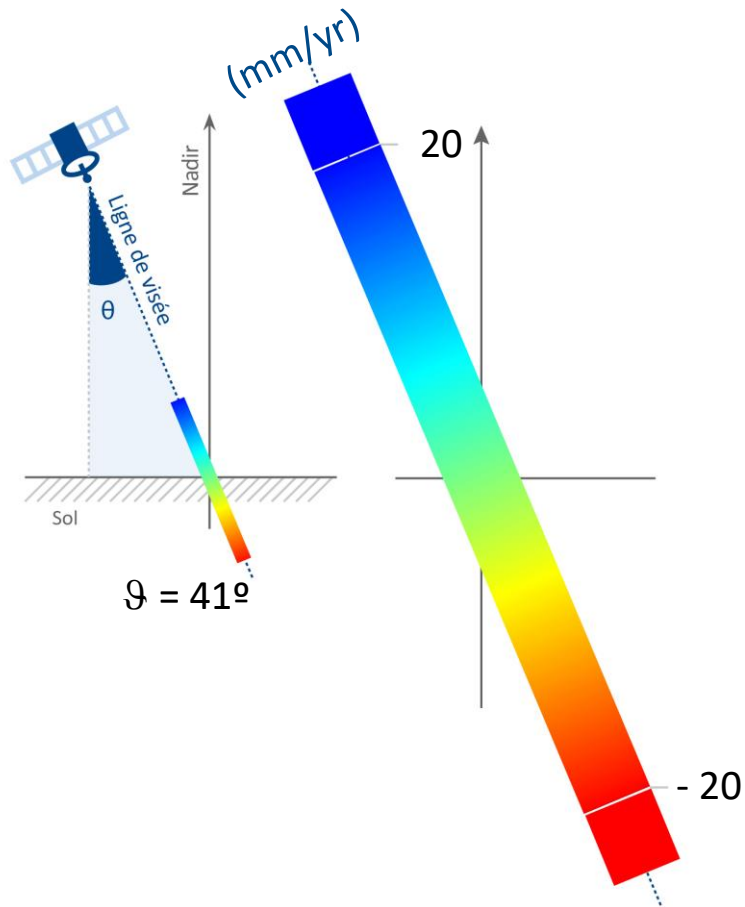
Localisation of the MP	North	East	Ellipsoidal Height
Sentinel-1	$\pm 8$ m	$\pm 15$ m	$\pm 5$ m



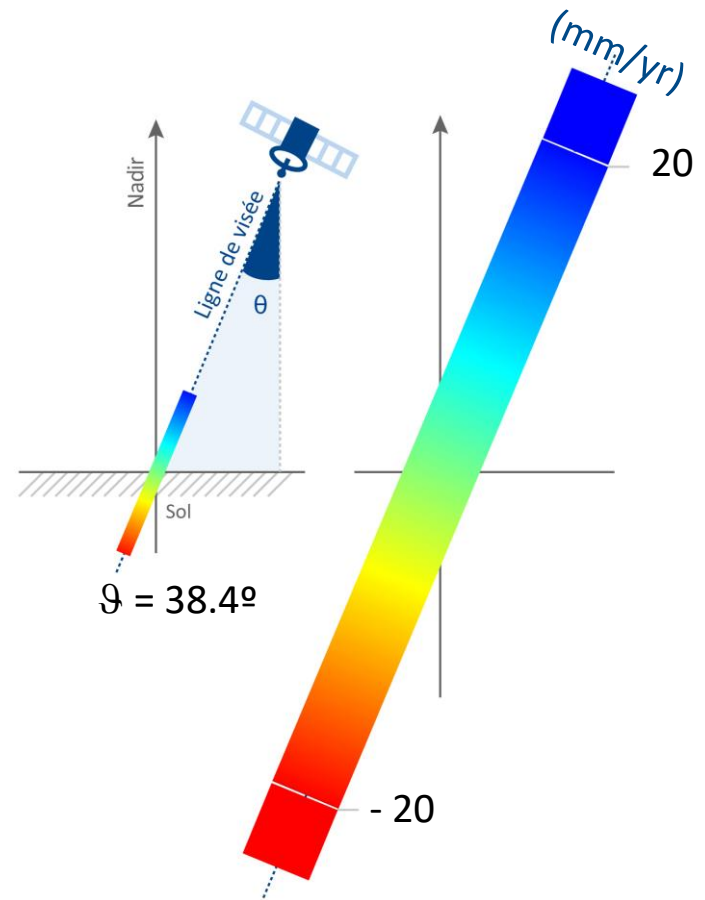


# The results of the study

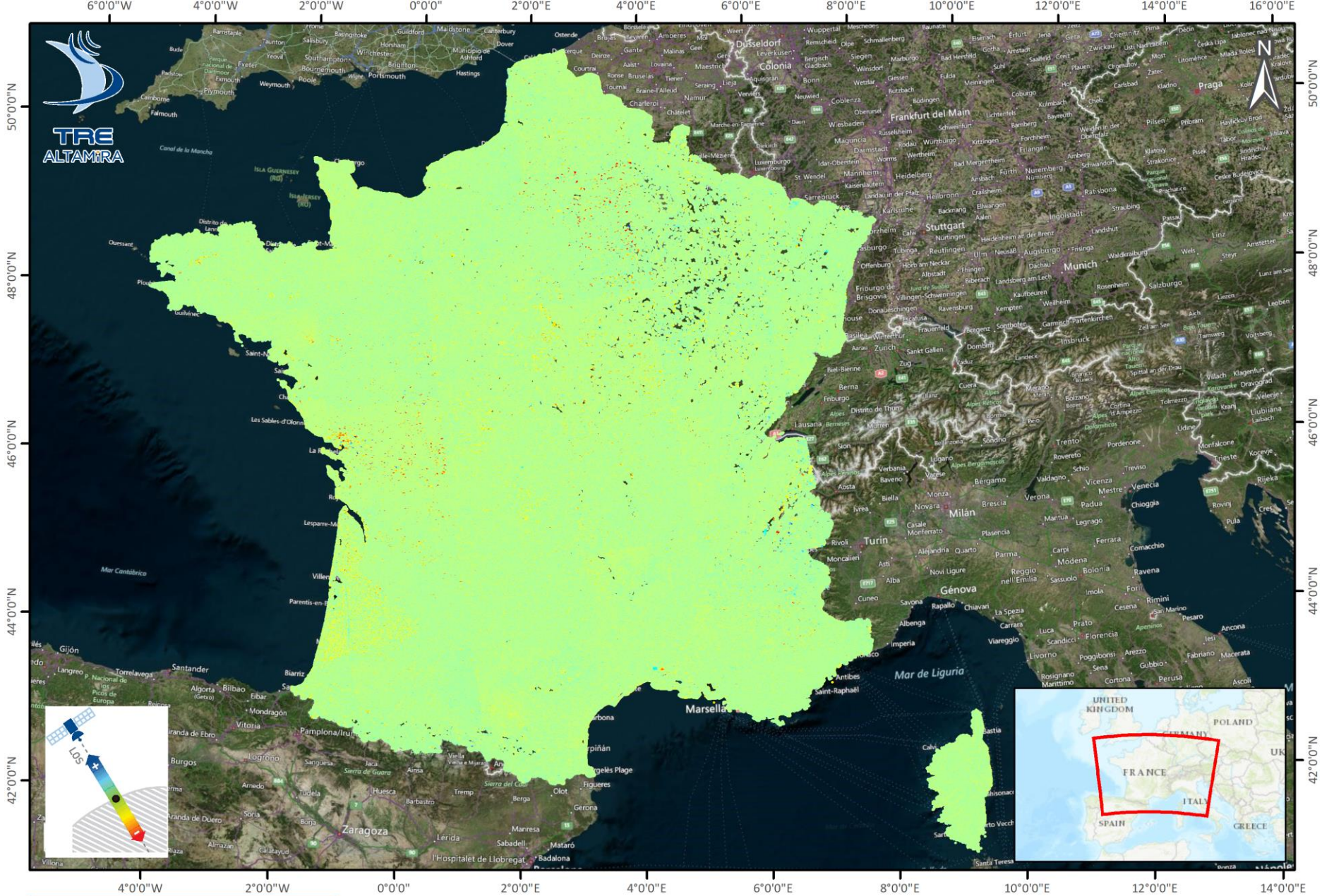
## The display scales of LOS ground motion



**Ascending mode**



**Descending mode**

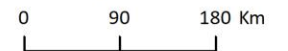


SqueeSAR® Analysis

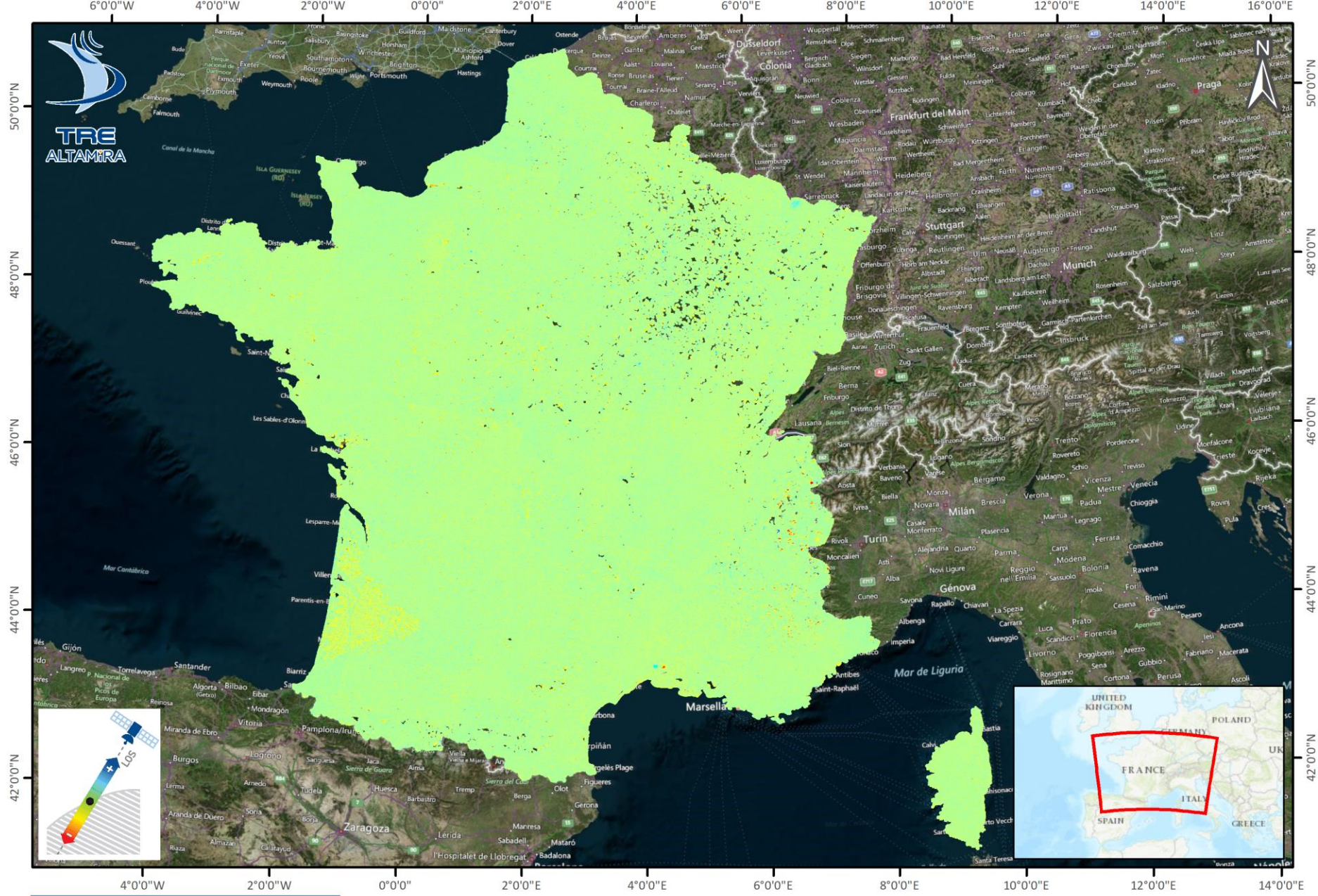
## France Métropolitaine Sentinel-1 2014-2018

Satellite	Sentinel-1
Géométrie	Ascendant
N. d'images	4807
Période	nov. 14 - sept. 19

Vitesse moyenne de déplacement [mm/an]



Background: Microsoft® Bing Maps  
Map Projection: RGF 1993 Lambert 93



**SqueeSAR® Analysis**

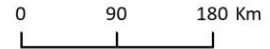
**France Métropolitaine  
Sentinel-1 2014-2018**

Satellite	Sentinel-1
Géométrie	Descendant
N. d'images	4759
Période	nov. 14 - sept. 19

Vitesse moyenne de déplacement [mm/an]



≤ -20      0      ≥ +20  
\*mouvement mesuré dans la ligne de visée du satellite



Background: Microsoft® Bing Maps  
Map Projection: RGF 1993 Lambert 93

- » More than 15 millions Measurement Points were detected in each mode
- » Points are not distributed in the same way throughout the territory. PS and DS distribution is related to the ground coverage.
- » Point density is around 22.5% PS/km<sup>2</sup> in ascending mode and 20.75% PS/km<sup>2</sup> in descending mode.

Track	Nb de pts de mesure	Surface analysée	Densité
T30	2929622	152729.5	19.2
T59	4319438	153270.8	28.2
T88	1287368	53835	23.9
T103	939466	43319.8	21.7
T132	2877055	133809.2	21.5
T161	2724468	132318.6	20.6
<b>TOTAL_ASC</b>	<b>15077417</b>	<b>669282.9</b>	<b>22.53</b>

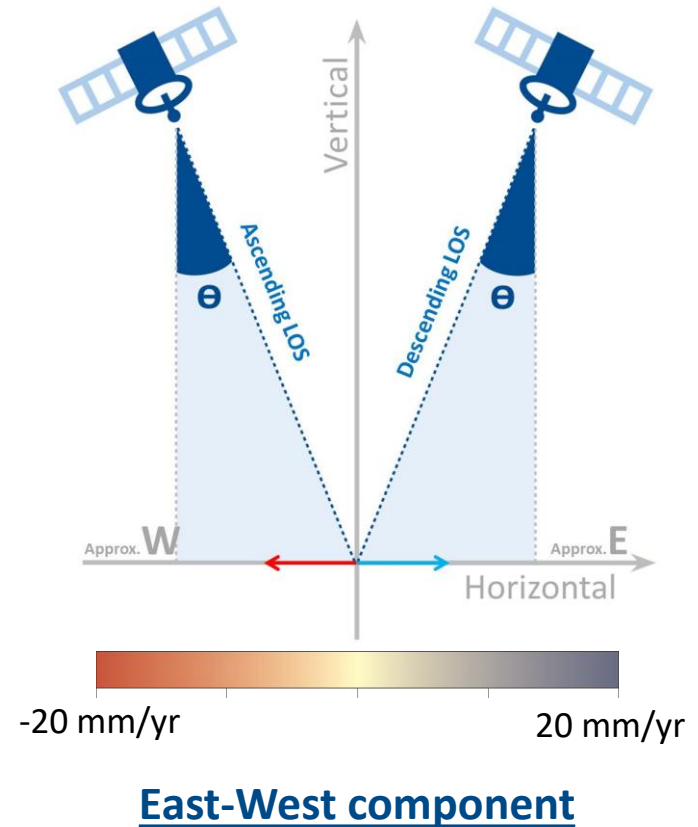
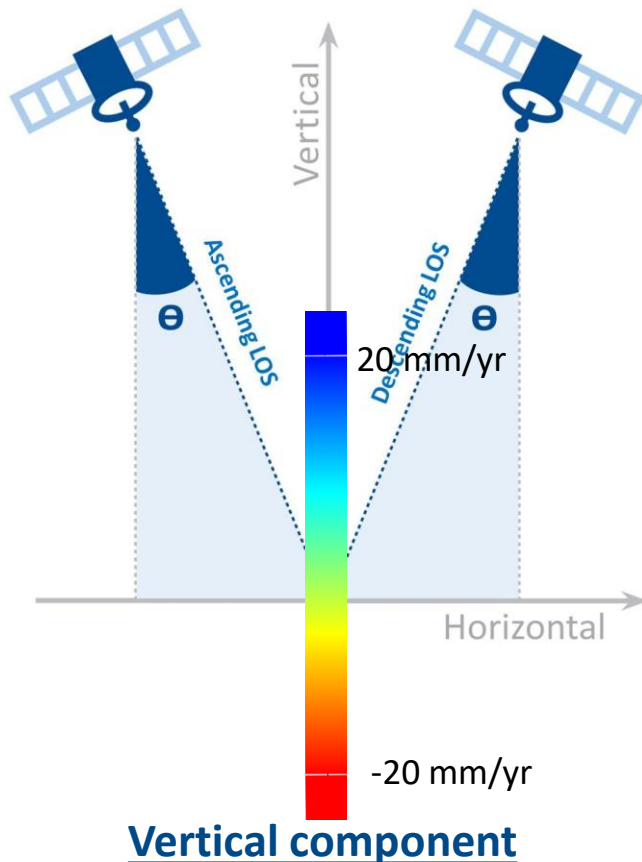
Track	Nb de pts de mesure	Surface analysée	Densité
T8	3211091	179625.8	17.9
T37	3526003	132663.6	26.6
T52	197655	13513.1	14.6
T66	72740	3804.1	19.1
T81	1526233	73363.1	20.8
T110	3148404	164548.5	19.1
T139	2251845	112751.5	20
T154	710743	43010.8	16.5
T168	623504	12406.8	50.3
<b>TOTAL_DESC</b>	<b>15268218</b>	<b>735687.3</b>	<b>20.75</b>

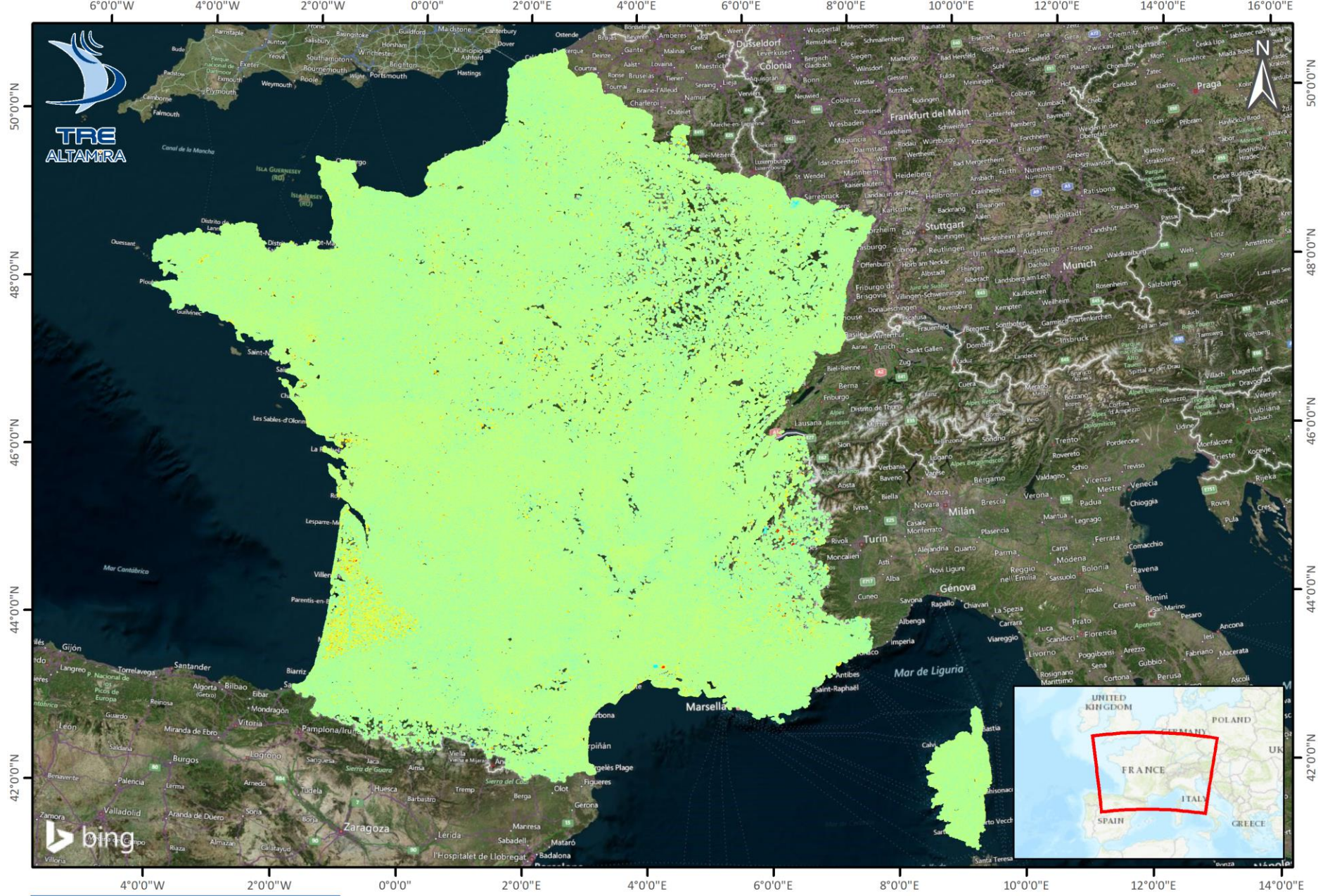


# The results of the study

## The display scales of Vertical and East-West ground motion

- » The asc and desc results are combined in order to derive the Vertical and East-West components of the displacement.





**SqueeSAR® Analysis**

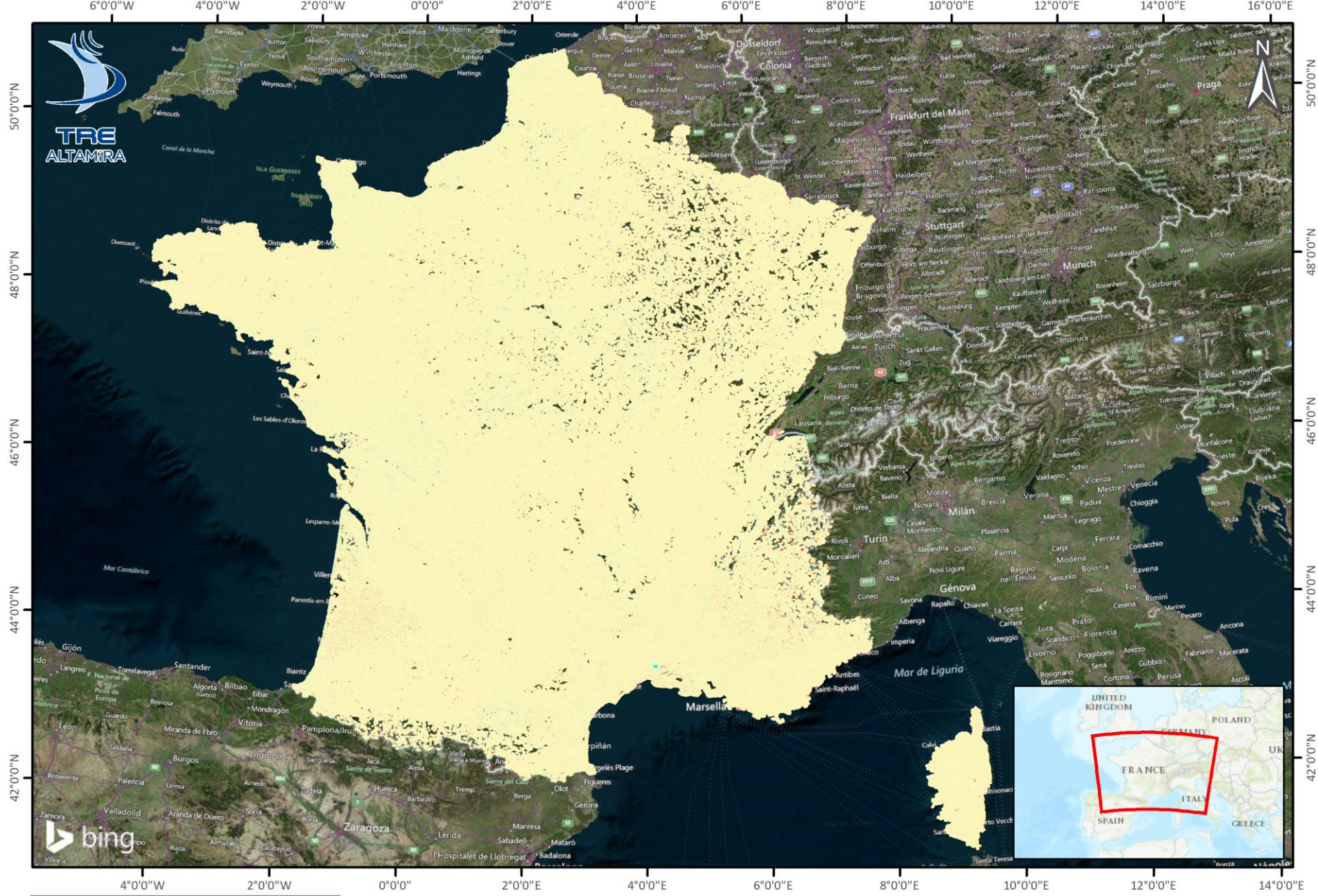
**France Métropolitaine  
Sentinel-1 2014-2018**

Satellite	Sentinel-1
Géométrie	Composante VERT
N. d'images	4807 (ASC) + 4759 (DESC)
Période	nov. 14 - sept. 19

Composante VERT du déplacement [mm/an]



Background: Microsoft® Bing Maps  
Map Projection: RGF 1993 Lambert 93

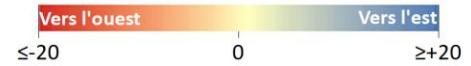


**SqueeSAR® Analysis**

**France Métropolitaine  
Sentinel-1 2014-2018**

Satellite	Sentinel-1
Géométrie	Composante E-W
N. d'images	4807 (ASC) + 4759 (DESC)
Période	nov. 14 - sept. 19

Composante EW du déplacement [mm/an]



Background: Microsoft® Bing Maps  
Map Projection: RGF 1993 Lambert 93



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