



Ground microdeformation over coastal cliffs: early warning indicators?

L3 Harris Geospatial Solutions – Imanol Echave
Harokopio University of Athens - Issaak Parcharidis



An exhaustive review of end-users' requests

WHO



Conservatoire
du littoral



WHY

Potential interest in products indicating terrestrial vertical movements within low-lying sandy deltas to quantify the subsidence effect inherent to such areas or at cliff top to detect cliff instability development and to anticipate large landslides and rockfalls

HOW

	Revisit	Horizontal accuracy
France	n/a	n/a

WHERE

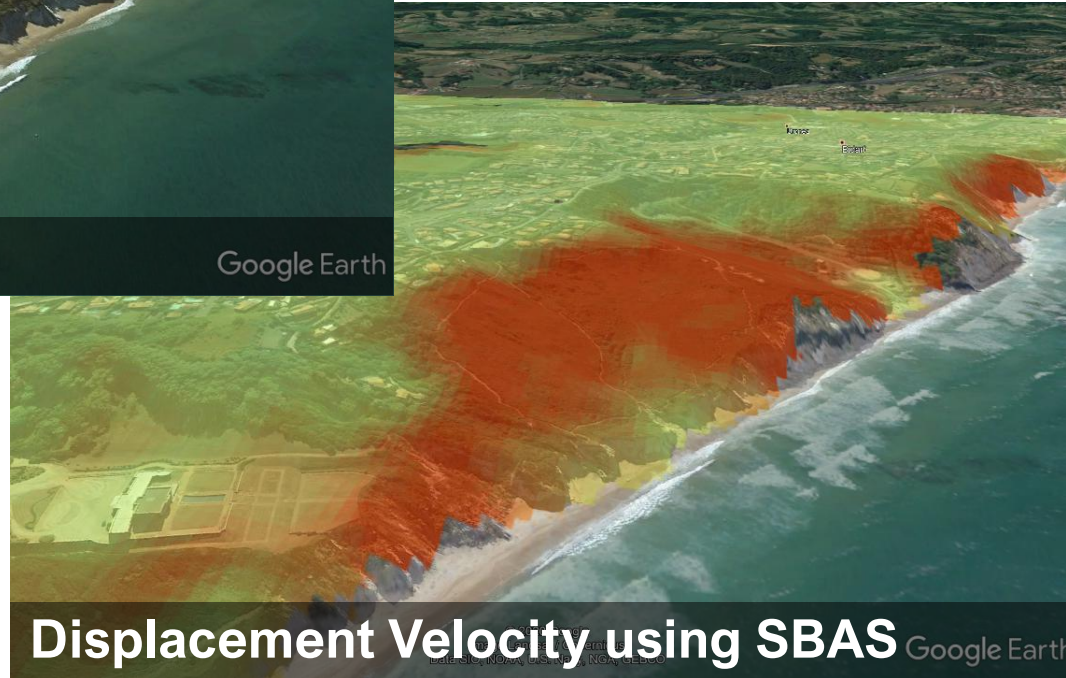
Requested in
Phase 2





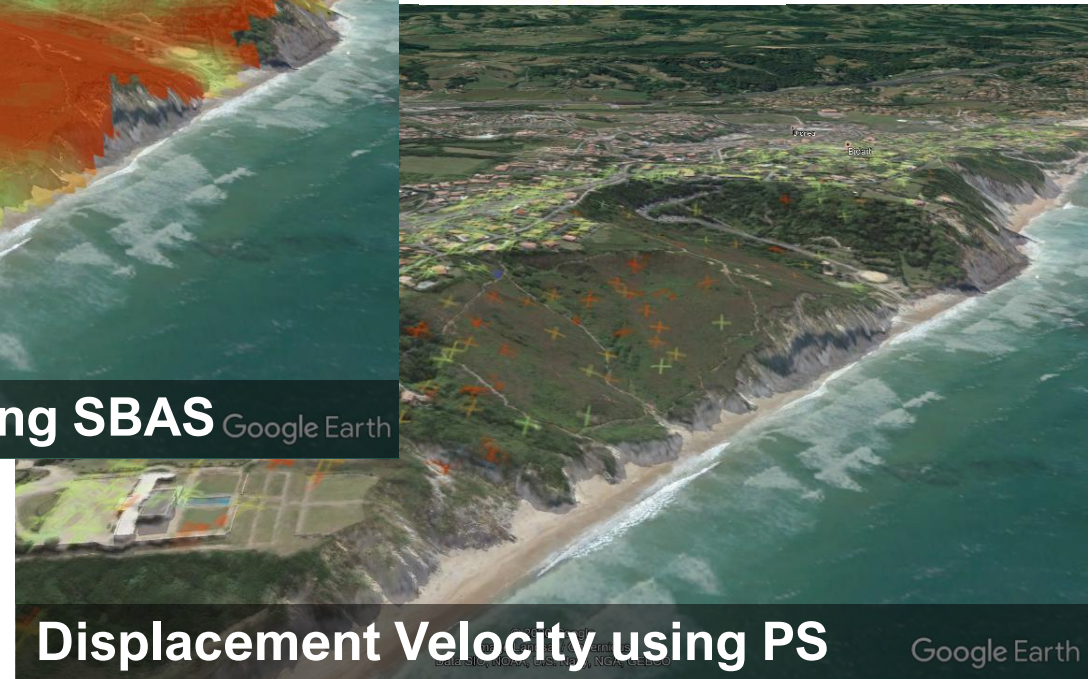
3D View of Erretega Cliffs

Google Earth



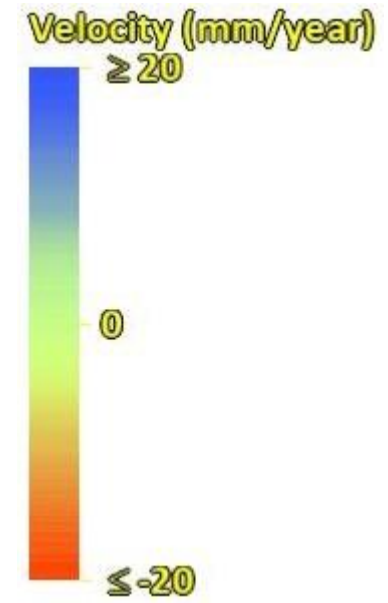
Displacement Velocity using SBAS

Google Earth

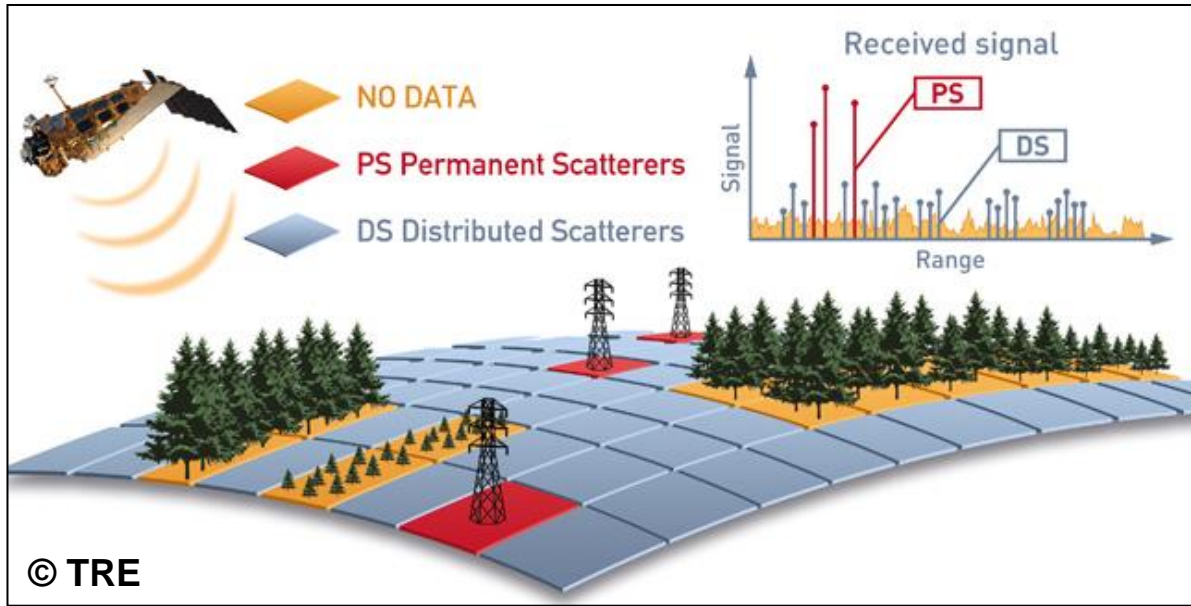


Displacement Velocity using PS

Google Earth



Method



Two algorithms

- PS
 - Used by Harokopio University
 - Modified version (hybrid PS+DS)
 - Software: Gamma (Gamma RS)
- SBAS
 - Used by L3 Harris
 - Software: SARscape (SARMap)

Multi Temporal InSAR analysis

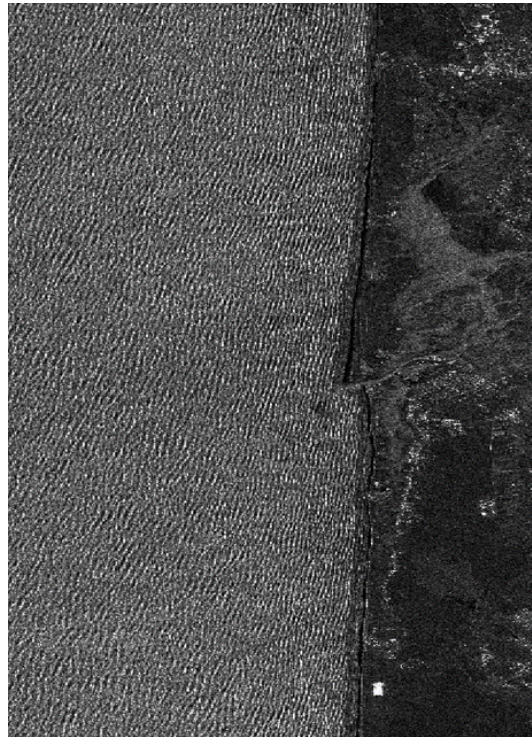
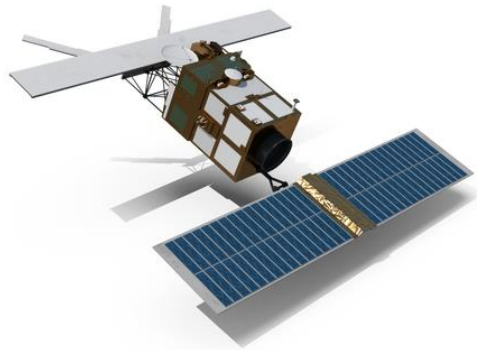
- SAR Interferogram phase differences mapped to ground displacements
- Ground displacements detected are in the order of millimeters

PS - Point-based	SBAS - Area-based
Independent, uncorrelated motions	At best spatially correlated motions
Pixelwise continuous time series	Possibility of handling time series with temporal holes
Time interval between two acquisitions limited by displacement rate	Time interval between two acquisitions limited by temporal decorrelation
Very accurate on PS	Slightly less accurate
Linear displacements favoured	Parametric models possible Non-parametric modeling possible

Databases exploited

ERS-1 AND ERS-2 (resolution 12.5 m)

- 16 images - Descending orbit (track 280, frame 2727)
- 19 images – Ascending orbit Cabourg
- 35 images- Ascending orbit Calvados-Seine-Maritime



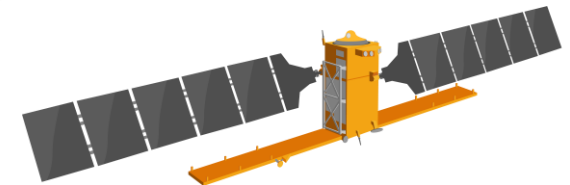
ENVISAT (resolution 10 m)

- 13 images - Descending orbit (track 280, frame 2727)
- 27 images – Ascending orbit Cabourg
- 24 images – Ascending orbit Calvados-Seine-Maritime



Sentinel-1 (resolution 10 m)

- 104 images - Descending orbit (relative orbit 8)



European Space Agency's (ESA) Online Dissemination platform. (<https://esar-ds.eo.esa.int/oads/access/>)
Sentinel-1 from the Copernicus Open Access Hub platform. (<https://scihub.copernicus.eu/>)

Demonstration areas and periods



New Aquitaine Region

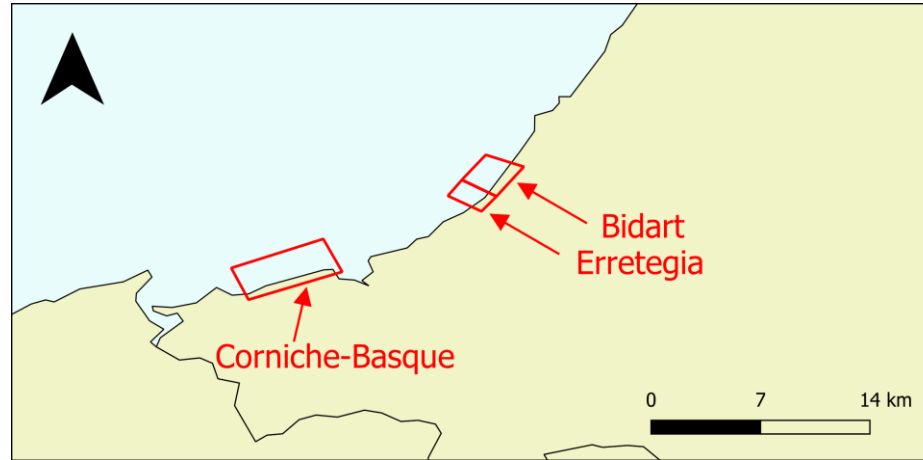
 ~ 10 km²

 1995 – 2020

 Varying

 8 products

 Using 354 images



Normandy Region

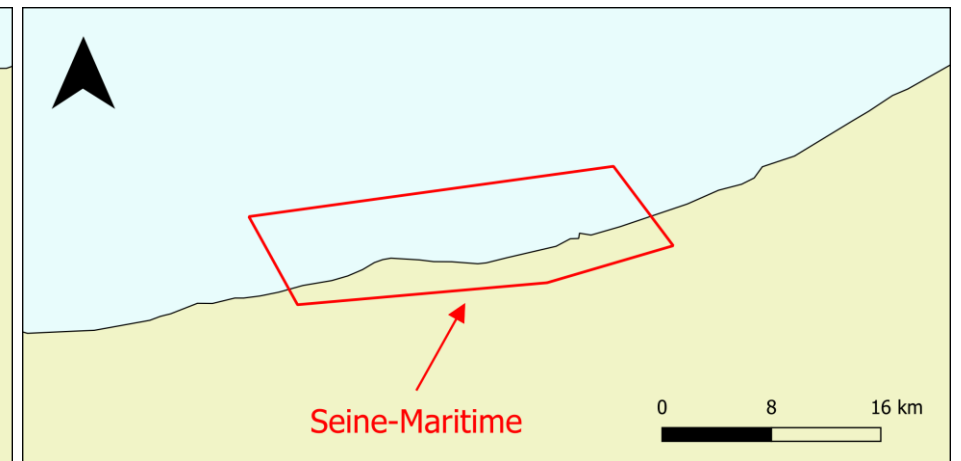
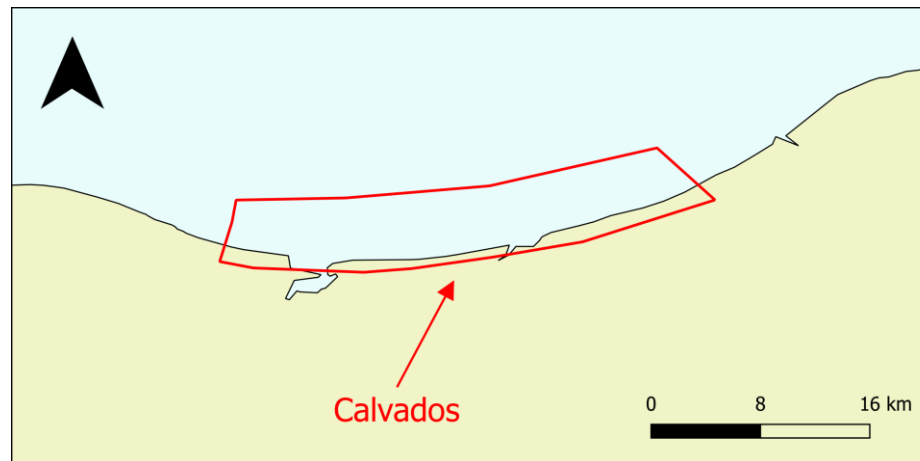
 ~ 19 km²

 1995 – 2020

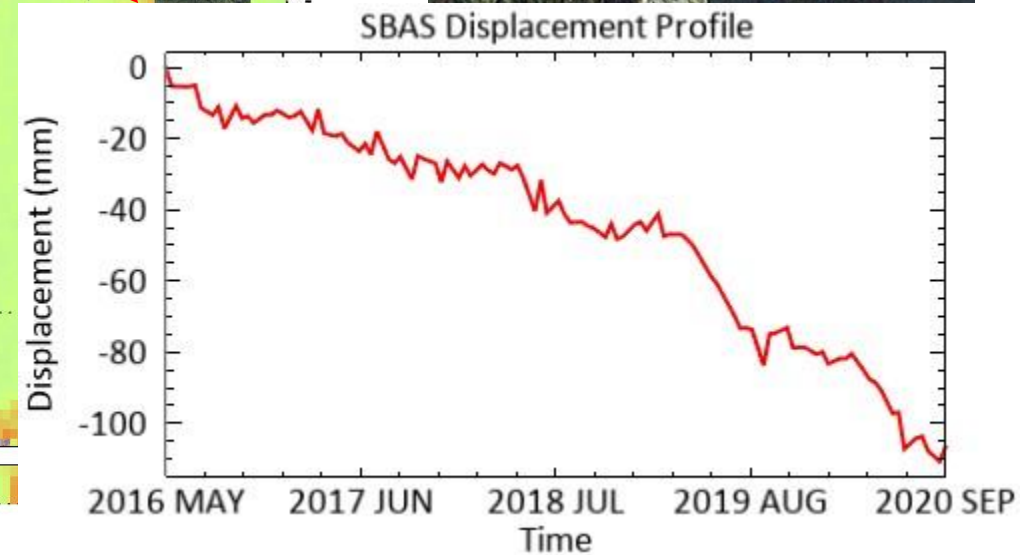
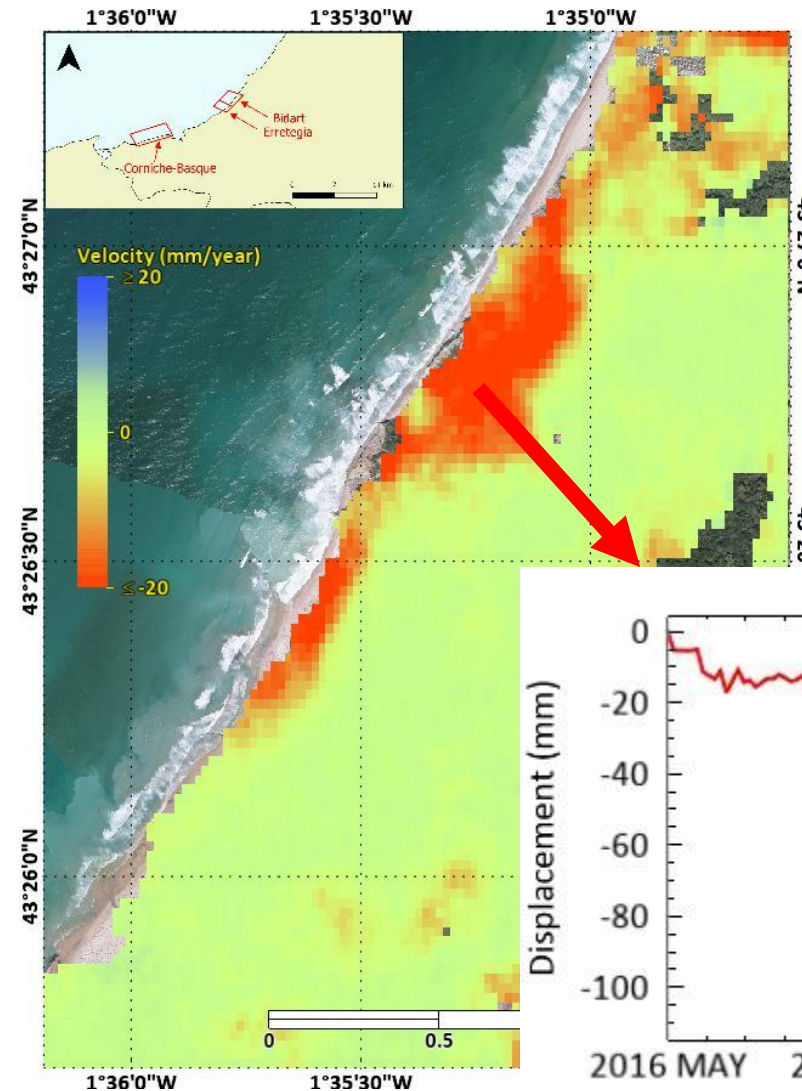
 Varying

 6 products

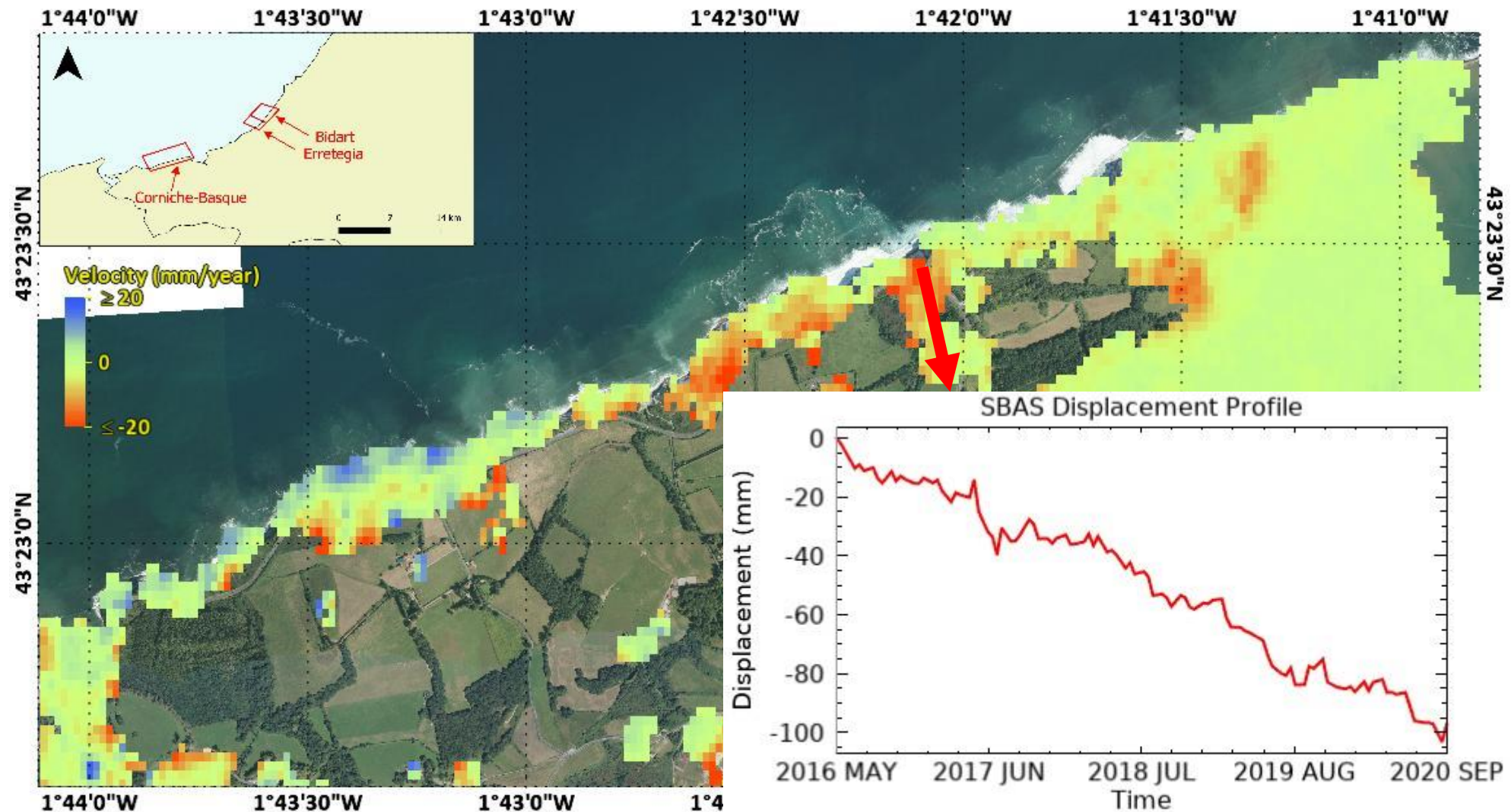
 Using 440 images



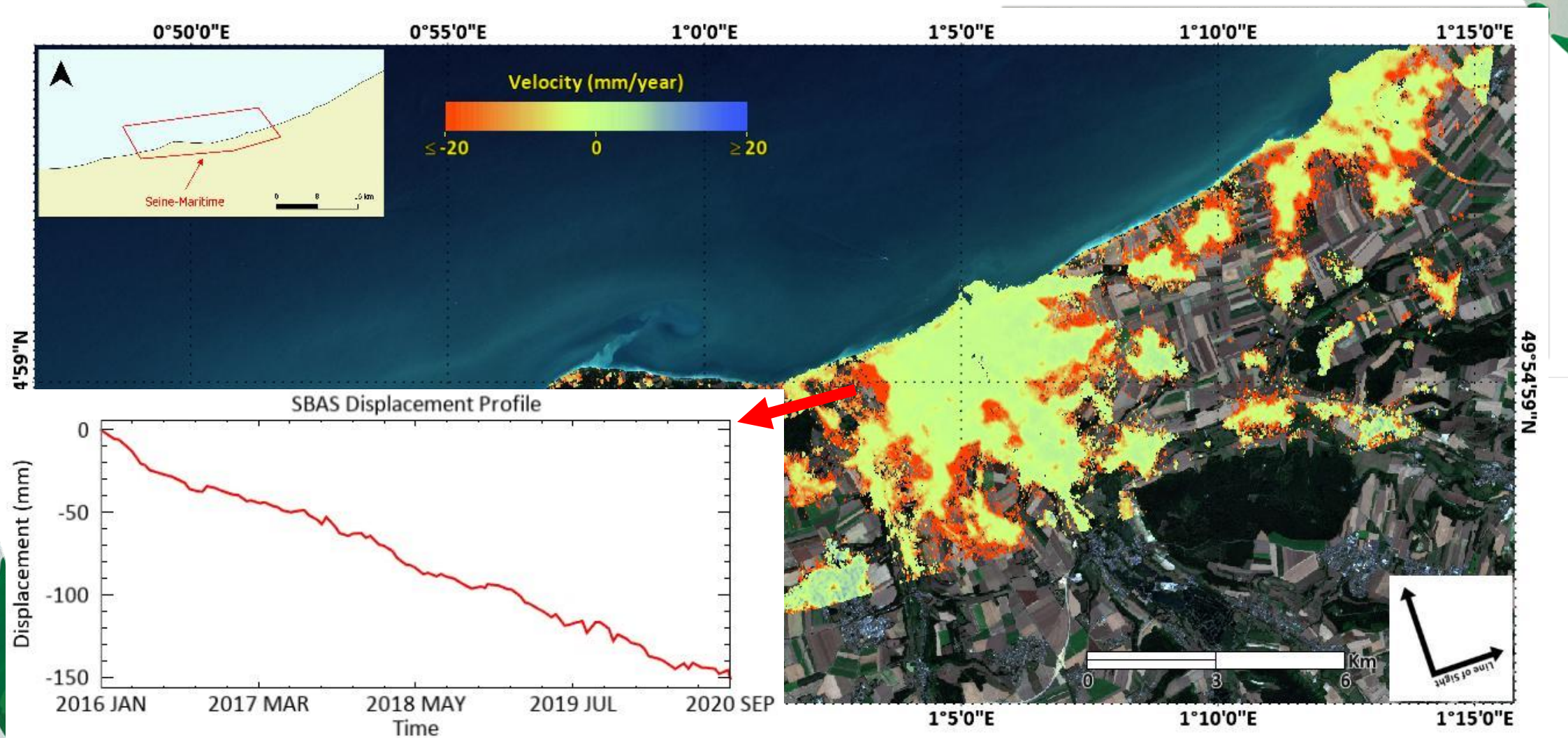
Product display – Bidart-Erretegia 2014-2019



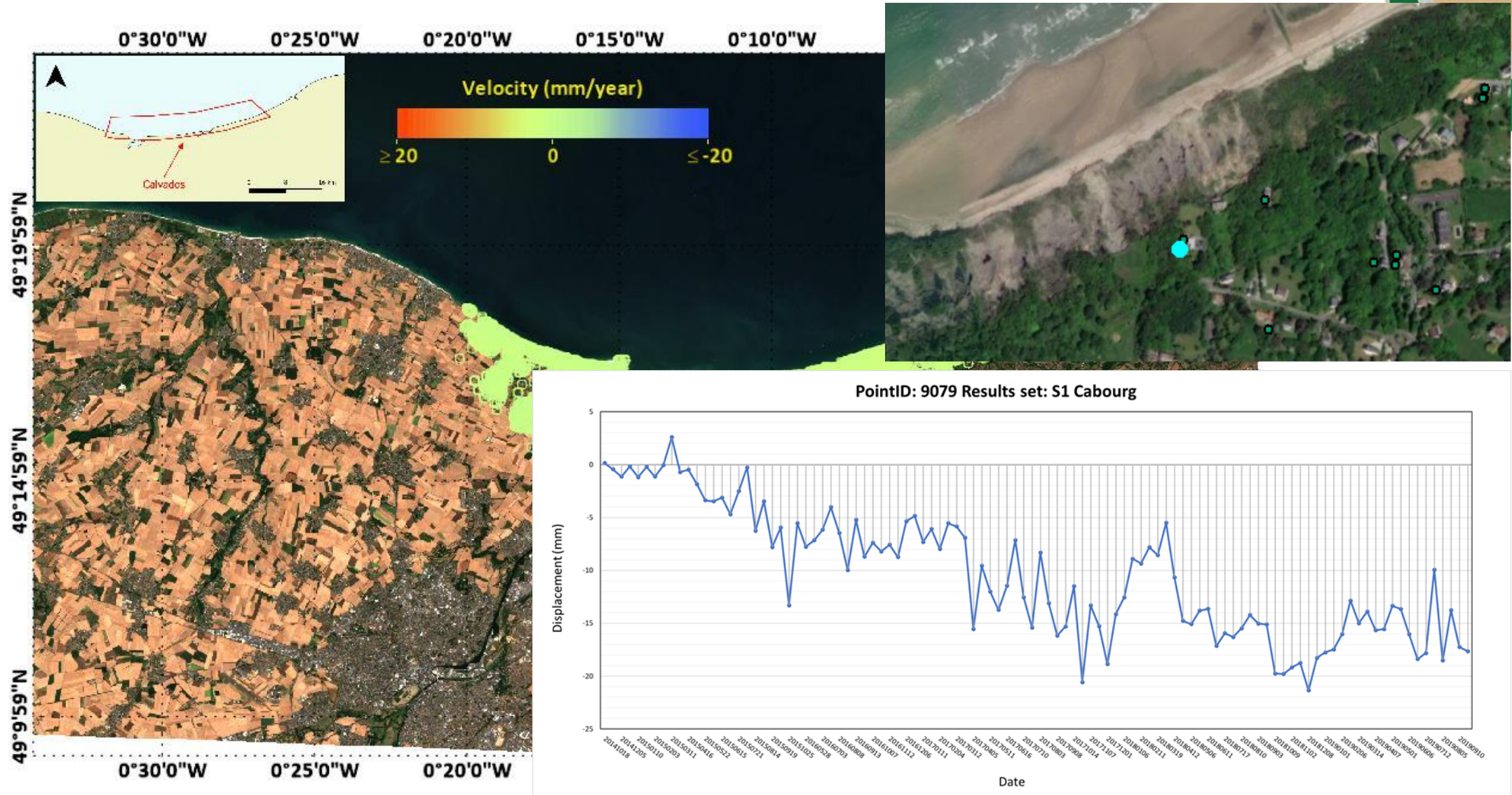
Product display – Corniche 2014-2019



Product display – PS Seine-Maritime 2014-2019



Product display – Calvados 2014-2019



Validation experiment and results

- No ground truth available for validation
- Cross-validation performed between PS and SBAS results
- Absolute difference of deformation velocities obtained by both methods

$$error = |v_{PS} - v_{SBAS}|$$

	Bidart-Ertegia	Corniche	Seine-Maritime
Mean error	2.2881	5.6742	4.3478
% of points under 1 mm/year error	44.61%	12.48%	7.39%
% of points under 2 mm/year error	67.19%	26.68%	15.86%
% of points under 3 mm/year error	79.48%	42.94%	26.46%
% of points under 4 mm/year error	86.66%	56.90%	42.44%
% of points under 5 mm/year error	90.30%	66.09%	61.60%

Approval from scientists



ΧΑΡΟΚΟΠΕΙΟ ΠΑΝΕΠΙΣΤΗΜΙΟ
HAROKOPIO UNIVERSITY

*E. Karympalis (Harokopio University): "The Permanent Scatterers Interferometric SAR technique (PSInSAR) has a **high sensitivity to small deformations** and an unmatched capability is given by the **ability to measure past deformation phenomena by using the SAR image historical archives**. This unique aspect means that it is possible to study deformation phenomena that occurred in the past and for which no other survey data are available. This interferometric synthetic aperture radar (SAR) technique has been proven to be an effective methodology for detecting and monitoring soil displacement with millimeter accuracy and also, improving our understanding of the current deformations in the study areas. The method was used for these products provides really interesting results which, however, **should be examined in detail in combination with GNSS data** (for example) from the study areas."*

UNICAEN
UNIVERSITÉ
CAEN
NORMANDIE



*S. Costa (Caen univ. / LETG): "We need to **know the accuracy** values of these products and to **define most relevant type of signal** for identifying the precursors of cliff collapse over the time series line of the recorded ground vertical change."*

End-users' testimonies



S. Costa (Caen Univ. LETG): "It can have considerable applications such as setting up a warning platform on the cliffs, maybe we put our finger on something interesting in terms of foresight... It is absolutely fascinating! "



C. Sarrade (Communauté d'Agglomération Pays Basque): "It is necessary to continue the investigations, in particular to understand if we can anticipate the ground movements , to know the processing time, the link between measured quantities and this anticipation, the cost of the treatments as well ..."

ESA's expectation achievement level

- A 25-year production achieved using PS approach that shows long term ground deformation in coastal zones
- Ground displacement production cannot be fully automatized right now (neither for PS nor SBAS) as some steps need to be done manually:
 - Selection of ground control points
 - Parameter fine tuning for specific terrain conditions
- PS and SBAS may be relevant to anticipate cliff erosion: further development is needed to clearly demonstrate this final application and there is still a gap between ground deformation measurement and the delivery of indicators useful for coastal management.

Publications & conference presentations

Workshop and conference presentations:

- **Bantouvaki K.**, “Earth Observation For Coastal Erosion Monitoring in Europe: the Space for Shore Project” 7th International Conference on Civil Protection & New Technologies Safe Greece 2020 on-line (October 2020)
Oral presentation entitled
- **Bantouvaki K.**, Fylaktos A., Kalousi G., Mytakidis K., Fryganiotis E., Parcharidis I., Coastline Mapping Methods using SAR Sentinel-1 Copernicus data validated with GNSS measurements 2nd Meeting of the Remote Sensing and Space Applications Committee (ETDE) of the OAG (March 2020)
Oral presentation entitled



Next Stop...

Overall Synthesis