Rentrée 2021

PROPOSITION DE SUJET DE THESE

Formulaire demande de financement : ARED - ISblue - ETABLISSEMENTS - …

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Identification du projet

Acronyme du projet *(8 caractères maximum)* **:** CICERO

Intitulé du projet *en langue française* : ContrIbution de la télédétection spatiale multiangulaire au suivi et à la Compréhension de l'ÉROsion des falaises

Intitulé du projet en langue anglaise: ContributIon of multi-angle spatial remote sensing to the monitoring and understanding of Cliff EROsion

Présentation de l'établissement porteur (bénéficiaire de l'aide régionale)

Établissement porteur du projet : Université de Bretagne Occidentale

Ecole Doctorale : EDSML ☒ SP ou MATHSTIC pour les projets ISblue ☐

Identification du responsable du projet (futur directeur de thèse)

Nom du laboratoire d'accueil : Laboratoire Géosciences Océan (LGO)
Code du laboratoire (U/UMR/USR/EA/JE/…) : UMR 6538
Directeur[1] du Laboratoire : Marc-André Gutscher
Nom de l'équipe de recherche : DYNELI

Nombre HDR dans le laboratoire : 27 Nombre de thèses en cours : 27 Nombre de post-docs en cours : 7

Nom et prénom du directeur* de thèse (HDR), porteur du projet : DELACOURT Christophe

- **e-mail :** christophe.delacourt@univ-brest.fr
- **Téléphone :** 02-98-49-87-42
- **Publications récentes du directeur de thèse** *(nb total et 5 références max au cours des 5 dernières années)* **:** 92 publications sur Publons (https://publons.com/researcher/2892209/christophe-delacourt/publications/)

Letortu, P., Taouki, R., Jaud, M., Costa, S., Maquaire, O., **Delacourt, C.**, accepté. 3D reconstructions of the coastal cliff face in Normandy (France) based on oblique Pléiades imagery: assessment of ASP® and MicMac® processing chains. *International Journal of Remote Sensing*.

Jaud M., **Delacourt C.**, Le Dantec N, Ammann J., Grandjean P., Allemand P., Cocquempot L., 2021. « Potential of Imaging UAVs for Coastal Monitoring ». In Remote Detection and Maritime Pollution, édité par Stéphane Le Floch et Frédéric Muttin, 1re éd., 133 42. Wiley. https://doi.org/10.1002/9781119801849.ch10

Jaud M., Bertin S., Beauverger M., Augereau E., **Delacourt C.**, 2020. RTK GNSS-Assisted Terrestrial SfM Photogrammetry without GCP: Application to Coastal Morphodynamics Monitoring. Remote sensing 12(11), 1889. https://doi.org/10.3390/rs12111889

Costa, S., Maquaire, O., Letortu, P., Thirard, G., Compain, V., Roulland, T., Medjkane, M., Davidson, R., Graff, K., Lissak, C., **Delacourt, C.**, Duguet, T., Fauchard, C., Antoine, R., 2019. Sedimentary Coastal Cliffs of Normandy:

[1] Ce formulaire est rédigé en style épicène

Modalities and Quantification of Retreat. Journal of Coastal Research 88, 46–60. https://doi.org/10.2112/SI88-005.1

Letortu, P., Jaud, M., Grandjean, P., Ammann, J., Costa, S., Maquaire, O., Davidson, R., Le Dantec, N., **Delacourt, C.,** 2018. Examining high-resolution survey methods for monitoring cliff erosion at an operational scale. *GIScience & Remote Sensing* 55, 457–476. https://doi.org/10.1080/15481603.2017.1408931

- Expériences d'encadrement et co-encadrement de doctorants (passées et en cours)

(nom des doctorants dirigés et en cours et antérieurement, sur les 6 années passées : sujet, financement, date de soutenance, et situation professionnelle actuelle si connue)

Docteurs ayant soutenu depuis 2014 :

NOM **prénom**	**% d'encadrement et nom du co-directeur ou co-encadrant**	**Type d'allocation**	**Date d'inscription**	**Date de** **soutenance**	**Insertion Professionnelle**
MAZUEL Aude	20% N. Babonneau 50% S. Jorry 30%	Labex Mer – Brest + Ministère	01/10/2010	10/04/2014	Post Doctorant
FROMANT Guillaume	30% N. Le Dantec 30% F. Floc'h 40%	DGA – Brest + Ministère	01/10/2012	09/11/2015	Enseignant-chercheur à l'Université du Littoral Côte d'Opale
PETIT Tristan	40% T. Bajouk 60%	IFREMER + Labex Mer	01/10/2013	07/03/2017	Ingénieur de Recherche à Actimar Brest
LE BIVIC Réjanne	30% P. Allemand 40 % A. Quiquerez 30 %	CNES + Ministère	01/10/2013	05/07/2017	Enseignante-chercheure à l'Université du Maryland
VARING Audrey	30% J.F. Filipot 70%	ANR + FEM	01/11/2016	01/11/2019	Post Doctorant France Energies Marines (FEM)

Doctorants en cours de formation :

NOM **prénom**	**% d'encadrement et nom du co-directeur ou co-encadrant**	**Type d'allocation**	**Date d'inscription**
VIENT Jean-Marie	30%, R. Fablet 40 % F. Jourdin 30 %	CNES + ISblue	01/10/2019
HAYOUN Clarisse	30%, France Floc'h 70%	ISblue + Ministère	01/10/2019

Co-directeur de thèse (HDR ou équivalent étranger) éventuel :

Laboratoire de recherche : (nom + code U/UMR/USR/EA/JE/…)

- **e-mail :**
- **Téléphone :**
- **Expériences d'encadrement et co-encadrement de doctorants (passées et en cours)**
  (nom des doctorants dirigés et en cours et antérieurement, sur les 6 années passées : sujet, financement, date de soutenance, et situation professionnelle actuelle si connue)

Et/ou co-encadrant-e scientifique :

LETORTU Pauline

Laboratoire de recherche co-encadrant (nom + code U/UMR/USR/EA/JE/…) : LETG (Littoral, Environnement, Télédétection, Géomatique) UMR 6554

- **e-mail :** pauline.letortu@univ-brest.fr
- **Téléphone :** 02-90-91-55-88
- **Expériences d'encadrement et co-encadrement de doctorants (passées et en cours)**
  Pas d'expérience d'encadrement doctoral.

JAUD Marion

Laboratoire de recherche co-encadrant (nom + code U/UMR/USR/EA/JE/…) : UMS 3113

- **e-mail :** marion.jaud@univ-brest.fr
- **Téléphone :** 02-98-49-88-91
  Pas d'expérience d'encadrement doctoral.

Le cas échéant, autres collaborations (co-encadrant et laboratoire concerné) :
EVELPIDOU Niki (professeure, laboratoire de géo-environnement, université nationale et kapodistrienne d'Athènes, Grèce).

Financement du projet de thèse

En cas de financement à 50 %, le cofinancement est-il déjà identifié *(oui/non)* **:** oui

Si oui, préciser la nature du cofinancement (*ANR, partenaire privé, Ademe, etc.*) : GIS BreTel (1/2 ARED Bretagne)

Si le cofinancement n'est pas encore confirmé, date prévue de réponse du cofinanceur : semaine du 25 janvier 2021

En cas de non-obtention du cofinancement demandé, une autre source de cofinancement est-elle identifiée *(oui/non)* **:** oui

Si oui, laquelle : DGA

Sollicitez-vous un co-financement Is-Blue (y compris ARED Is-Blue) *(oui/non)* **?** oui

Projet de thèse en cotutelle internationale

S'agit-il d'un projet de thèse en cotutelle internationale dans le cadre d'une convention *(oui/non)* **:** non

Si oui, préciser l'établissement pressenti (*et le pays de rattachement*) :

Ce projet de thèse fera-t-il l'objet d'un cofinancement international *(oui/non)* **:** non

(Rémunération du doctorant par l'établissement implanté sur le territoire régional (18 mois sur 36 mois), et l'établissement étranger, qui s'engage également à rémunérer le doctorant dans le cadre de son séjour à l'étranger, soit durant 18 mois -a minima-)

En cas de cofinancement international, préciser -*si vous en avez connaissance*- **l'organisation du calendrier des périodes de séjour :**

Préciser quel est le stade du projet international (joindre une lettre d'engagement du partenaire)

Présentation du projet (en langue française ou anglaise, 2 à 3 pages)

Résumé du projet *(4000 caractères maxi espaces compris) :*

The PhD thesis deals with the contribution of multi-angle spatial remote sensing (Pléiades and Pléiades Neo) to the monitoring and understanding of coastal cliff erosion. This PhD thesis will analyse different types of cliffs (soft and rocky), located in different regions. Soft cliffs in Brittany (which represent 20% of the Brittany coastline) and rocky limestone cliffs in Normandy and on the island of Zakynthos (Greece) will be studied. On these three sites, the cliffs are retreating rapidly (> 10 cm/year) and are threatening issues located close to the cliff (people, property, activities, networks, etc.). This raises scientific, societal and political questions about coastal management and development in a context of global change. The synoptic scale of the satellite images (consistent with the scale of coastal management, which ranges from a few km to hundreds of km), the increasing number of satellites and the repetitiveness of the acquisitions (appropriate to seasonal and event-based monitoring), as well as the very high resolution (VHR) of the images and the great agility of the satellites (capable of acquiring various oblique images) are all criteria that offer new perspectives for monitoring changes in cliff coasts, and in particular in the cliff face, proxy which until now has been impossible to study from images acquired at nadir. The EROFALITT project (Erosion of the coastal cliffs in Normandy), funded by the National Centre for Space Studies (CNES) and coordinated between 2016 and 2020 by P. Letortu, has demonstrated the potential of VHR and agile space imagery in monitoring and understanding cliff erosion. The PhD subject proposed here will enable this contribution to be developed by studying (1) the multi-decennial monitoring of the cliff-top retreat rates by aerial and spatial VHR imagery under GIS (Geographic Information Systems); (2) the semi-automatic detection of rockfalls by statistical learning (as Machine Learning) in order to monitor their rhythms and modalities; (3) 3D reconstruction by stereorestitution of potential change areas in order to calculate the erosion of the cliff face (retreat rates complementary to those measured at the cliff top, information on the spatial and temporal diffusion of the cliff face instability); (4) comparison of erosion dynamics between the different studied sites and the proposal of hypotheses to explain these differences. Moreover, particular attention will be focused on disseminating methods and results to elected officials and stakeholders in order to integrate the spatial imaging dataset into a toolbox for sustainable management of coastal territories. It will also be a main objective of improving the use of satellite data in the framework of observation services dedicated to the coastline (e.g. Service National d'Observation Dynalit), labelled by national and European research organizations.

Présentation détaillée du projet :

1 - Hypothèse et questions posées, état de l'art, identification des points de blocages scientifiques (4000 caractères maxi espaces compris)

The erosion of cliffs (which represent 52% of the world's coastline, Young and Carilli, 2019) is the result of marine (mean sea level, waves…), continental (rainfall, temperature variations…) and anthropogenic factors (artificialisation, modification of the sedimentary stock…). Their multiplicity and interconnection currently make it impossible to identify the respective contributions of these factors to the triggering of rockfalls (Naylor et al., 2010; Letortu et al., 2015). Thus, the unpredictability of the time and place of erosion remains, posing a problem of risk management (with sometimes fatalities). To achieve this major objective, research requires 3D data from the cliff face (CF, from the foot to the top of the cliff, the best proxy for observing all rockfalls), at spatial VHR (< 1 m), with short revisit time (from season to day), on long coastlines in order to respect the management scale that is the hydro-sedimentary cell[2].

However, monitoring this sub-vertical proxy is problematic because "classic" satellite imagery (at nadir) only allows cliff top monitoring. VHR measurement of the CF is possible to use in situ methods, such as photogrammetry or laser

[2] Scale at which sedimentary phenomena and dynamics take place. The hydro-sedimentary cell is thus a concept that makes it possible to identify, at a given scale, coastal compartments that can be described and analyzed autonomously in terms of sediment transport. The purpose of this division of the coastline is to enable the establishment of sediment exchange balances within each cell and to help define the right geographical scale for decision-making in terms of coastal development. It enables all the factors that influence the evolution of the coastline in a given geographical sector to be taken into account (https://www.ecologique-solidaire.gouv.fr).

scanning (Lim et al., 2010; Jaud et al., 2019), but without meeting the criteria of short revisit time and surface coverage. However, today, the new generations of VHR satellites (70 cm for Pléiades and 30 cm for Pléiades Neo (Airbus Defence and Space, 2017) and highly agile (tracking up to 40° for Pléiades (ASTRIUM, 2012)) make it possible to consider a cliff face monitoring strategy that meets all these criteria. Based on panchromatic Pléiades images, a 3D reconstruction method was proposed for monitoring the face of calcareous cliffs in Normandy (Letortu et al., 2020, EROFALITT). Planimetric accuracy can reach 10 cm with a point density of 2 pts/m² on the CF allowing good monitoring of any erosion greater than 100 m^3 (Letortu et al., accepted), i.e. 70% of the rockfalls observed in this sector.

Some problems persist, such as the dependence of the 3D restitution on environmental parameters (weather, exposure of the cliff face) and the difficulty in optimizing the processing parameters over the whole area. Furthermore, the volumes of data involved mean that suitable semi-automatic analysis methods must be developed, such as Machine Learning. Here again, a bottleneck will have to be overcome to adapt these methods to oblique images (non-orthorectified). Finally, another lever consists of working on sites with similar geological characteristics but with varied environmental constraints in order to better understand the role of environmental factors in erosion.

Thus, this PhD thesis will allow to improve the monitoring and understanding of cliff behaviour thanks to VHR and multi-angle satellite imagery. This implies making the most of satellite imagery by developing adequate, intelligible and transposable processing chains for the monitoring and sustainable management of cliffs.

2 - Approche méthodologique et techniques envisagées : (4000 caractères maxi espaces compris)

This PhD thesis will focus on three sites: Pléneuf-Val-André (soft cliffs, Brittany), Varengeville-sur-Mer (limestone rocky cliffs, Normandy) and Keri on the island of Zakynthos (limestone rocky cliffs, Greece). These cliffs, having a sub-vertical and multi-decametric CF, are retreating rapidly (>10 cm/year), maximizing the occurrence probability of rockfalls. Considering two different bioclimatic contexts (oceanic temperate climate and Mediterranean one) will make it possible to benefit from different meteorological contexts for the acquisition of satellite images and to assess the role of meteorological factors (among others) in the erosion dynamics of the limestone cliffs. Moreover, the varied orientations of the cliffs (North in Normandy, North-West in Brittany, and South-West in Zakynthos) will make it possible to test different configurations for satellite image acquisition. These three sites have been studied for several decades and it will be possible to carry out photogrammetric surveys that will serve as ground truth. The variety of sites will make it possible to assess the transferability of the method, so that other actors in the scientific community and civil society can benefit from it.

The collection of VHR satellite images and validation data is financed by the CNES HIRACLES project (HIgh Resolution imAgery for CLiff Erosion Studies), coordinated by P. Letortu (2021-2023). Based on these images, the envisaged methodology combines classical approaches and innovative aspects that are explained in more detail below:

- a classic diachronic monitoring of the position of the cliff top under GIS (from images acquired for the thesis and from archives) to obtain annual erosion rates;

- a “cliff face” oriented approach, with the implementation of semi-automatic detection of rockfalls thanks to statistical learning. Indeed, satellite images of a CF prove to be a massively multivariate data set, whether according to the characteristics of the site (colour, texture, height, cliff orientation) or the characteristics of the acquisition (satellite trajectography in relation to the site, time of passage, season, weather). Machine Learning methods will also be used to identify rockfalls areas (and more generally areas with common characteristics), as the diversity of the sites should make it possible to create a training data set that is sufficiently varied to cover all possible configurations;

- from these segmentation results and from stereoscopic pairs, a 3D reconstruction will be carried out. For the restitution of the CF, one of the results of the EROFALITT project emphasized the importance of optimizing the processing parameters according to the characteristics of the area. The quality of the reconstructions should therefore be improved by working in a more targeted way on these rockfall areas. As the ASP, Micmac and ERDAS Imagine processing chains have been tested, these routines can be reused. In addition, the new possibilities offered by Agisoft Metashape software or the CARS processing chain from CNES will also be tested;

- the previous stages will provide information on the rhythms and modalities of erosion (size of rockfalls, kinematics, duration of evacuation of the rockfalls by the sea…). An analysis of the erosion data will be carried out in order to explain the differences obtained between the study sites;

- the dissemination of our methods and results to elected representatives and stakeholders will be facilitated by the special relationships maintained by the scientific team with these interlocutors within the framework of regional and interregional coastal observatories (OSIRISC, ROL…).

3 - Positionnement et environnement scientifique dans le contexte régional, national et international :

At the regional level, the improved knowledge thanks to this PhD thesis will contribute to strengthen the regional expertise in monitoring and understanding erosion hazard on the cliff coasts of EUR ISblue (which belongs to the Strategic Innovation Domain (DIS) 1: Maritime economy for blue growth) and in remote sensing expertise of GIS BreTel (which belongs to DIS 3: Secure and responsible digital economy). Ultimately, this expertise is intended to feed the consulting sector for elected officials and managers of local authorities faced with the erosion risk, the environmental studies sector as well as work for the sustainable development of coasts. The objectives assigned to the PhD thesis also justify its attachment to the transversal axis "energy and ecological transitions". This transversality in the DIS underlines that this PhD project is fully on Breton fields of excellence and promising fields. In addition, our strong willingness to transfer knowledge and dialogue between academic research, elected officials, coastal managers, and actors in economic development and innovation will accelerate the transition to a frugal and sustainable economy. In addition, the PhD project responds to the flagship project 8 "améliorer la sauvegarde de la vie humaine et la gestion des risques environnementaux en zone côtière" of the charter for Breton coastal areas. Finally, this PhD project would make it possible to make progress on the proposals put forward by the Atlantic CESER Association and the study on "Submersion marine et erosion côtière : Connaître, prévenir et gérer les risques naturels littoraux sur la façade atlantique" (2015).

At the national level, this PhD project is part of the national strategy for integrated management of coastline. In particular, it echoes the report by MP S. Buchou's report "Quel littoral pour demain ? Vers un nouvel aménagement des territoires côtiers adapté au changement climatique" (2019). Our project is in line with many of the report's recommendations, such as the need for knowledge associated with the need to share it, in order to move towards the crucial issue of transition (adapting the existing and anticipating the future and sustainable implementation of goods and activities).

At the international level, our collaboration with N. Evelpidou (Univ. Athens), whose expertise is recognized in the geomorphology of the limestone cliffs of the Ionian Islands, allows us to extend our research towards an environment favourable to the acquisition of satellite images (low cloud cover in the Mediterranean) and where, despite a similar geology of the Normandy limestone cliffs, the continental and marine forcings are different. This collaboration, formalized by the HIRACLES project, is continuing in this PhD project in order to compare the contribution of meteorological and marine factors to the erosion of limestone cliffs between a Mediterranean climate and an oceanic climate (Normandy). Thanks to the worldwide coverage of the satellite network and our network of international researchers studying cliffs (coll. with Canada, UK, New Zealand, United States (submission last September of a Marie Curie postdoc project related to these countries)), our work will be easily transferable. Eventually, international research projects (e.g. ERC) on the spatial and temporal VHR monitoring of cliff erosion on a global scale along a North/South transect will be developed thanks to the complementarity of VHR tools (satellite images, mobile LiDAR...) of which we have a good expertise. In addition, our project is fully in line with the United Nations' Sustainable Development Goal 9 "Industry, innovation and infrastructure" by seeking sustainable solutions to environmental challenges.

References:

Airbus Defence and Space, 2017. Airbus révolutionne le marché de l'observation de la Terre avec sa constellation Pléiades Neo, les premiers satellites optiques commerciaux utilisant le SpaceDataHighway [WWW Document]. Airbus. URL https://www.airbus.com/newsroom/press-releases/fr/2017/09/Press-release-SpaceDataHighway.html (accessed 9.24.20).

Association des CESER de l'Atlantique, 2015. Submersion marine et érosion côtière - Connaître, prévenir et gérer les

risques naturels littoraux sur la façade atlantique.
ASTRIUM, 2012. Pléiades Imagery - User Guide (Technical report No. USRPHR-DT-125-SPOT-2.0).
Basara, N., 2019. L'érosion des littoraux à falaises meubles en Bretagne : aléa, enjeux et gestion du risque. Université de Bretagne Occidentale.
Buchou, S., 2019. Quel littoral pour demain ? Vers un nouvel aménagement des territoires côtiers adapté au changement climatique (Rapport parlementaire).
Jaud, M., Letortu, P., Théry, C., Grandjean, P., Costa, S., Maquaire, O., Davidson, R., Le Dantec, N., 2019. UAV survey of a coastal cliff face - Selection of the best imaging angle. Measurement 139, 10–20. https://doi.org/10.1016/j.measurement.2019.02.024
Letortu, P., Costa, S., Cador, J.-M., Coinaud, C., Cantat, O., 2015. Statistical and empirical analyses of the triggers of coastal chalk cliff failure. Earth Surface Processes and Landforms 40, 1371–1386. https://doi.org/10.1002/esp.3741
Letortu, P., Jaud, M., Théry, C., Nabucet, J., Taouki, R., Passot, S., Augereau, E., 2020. The potential of Pléiades images with high angle of incidence for reconstructing the coastal cliff face in Normandy (France). International Journal of Applied Earth Observation and Geoinformation 84, 101976.
Letortu, P., Taouki, R., Jaud, M., Costa, S., Maquaire, O., Delacourt, C., accepté. 3D reconstructions of the coastal cliff face in Normandy (France) based on oblique Pléiades imagery: assessment of ASP® and MicMac® processing chains. International Journal of Remote Sensing.
Lim, M., Rosser, N.J., Allison, R.J., Petley, D.N., 2010. Erosional processes in the hard rock coastal cliffs at Staithes, North Yorkshire. Geomorphology 114, 12–21. https://doi.org/10.1016/j.geomorph.2009.02.011
Naylor, L.A., Stephenson, W.J., Trenhaile, A.S., 2010. Rock coast geomorphology: Recent advances and future research directions. Geomorphology 114, 3–11. https://doi.org/10.1016/j.geomorph.2009.02.004
Young, A.P., Carilli, J.E., 2019. Global distribution of coastal cliffs. Earth Surface Processes and Landforms 44, 1309–1316. https://doi.org/10.1002/esp.4574

4 - Contexte scientifique et partenarial : éléments généraux (ERC, CPER, FEDER, Breizhcop …) (4000 caractères maxi espaces compris)

Due to its interdisciplinarity, both thematic and methodological, this PhD project reinforces collaborations between several research and service units within ISblue, the Brittany region and beyond.

Concerning the scientific context, the PhD student will be integrated at the same time at the LGO (UMR 6538, C. Delacourt, N. Le Dantec), at the LETG (UMR 6554, P. Letortu, A. Hénaff, S. Costa, T. Corpetti, J. Nabucet, S. Niculescu) and at the P2I (Pôle Image et Instrumentation – UMS 3113, M. Jaud). "Littoral" and "Remote sensing" are part of the research axes of the LGO and the LETG. The P2I is a transversal platform in imagery and instrumentation within the OSU IUEM, pooling instruments and knowledge and conducting technological and methodological research in remote sensing for coastal monitoring. The P2i will also provide access to software tools and computer resources adapted for Machine Learning. In addition to benefiting from the CNES HIRACLES project (2021-2023), obtained by the team proposing this PhD subject, providing him/her satellite image acquisitions, field missions, and the necessary computing resources, the student will also benefit from the ISblue network, facilitating exchanges with academic members of the ISblue consortium or with companies (ISblue Hub) and guaranteeing logistical support, for example access to the DATARMOR Computing Pole. In addition, on Machine Learning themes, the student will be helped by S. Lefèvre's team at IRISA (UBS) (possible immersion in the OBELIX team) and/or T. Corpetti (LETG - Univ. Rennes 2), thus allowing the initiation of interdisciplinary collaborations on a regional scale around innovative themes for coastal observation at VHR.

Concerning the partnership context, the PhD subject is integrated in a favourable regional context with:

- the CNES-Brittany Region framework convention and the GIS BreTel, which underline the will of the Brittany Region to position its territory as a precursor in the use of space technologies and their applications;

- the CPER Glaz meta-project on the continental and coastal environment in Brittany (2021-2027), which aims to build a world-class research infrastructure able to detect, anticipate and accompany the socio-environmental transitions that terrestrial and coastal ecosystems will undergo in the coming decades, notably via the inter-regional coordination platform for observation (AAA project);

- Recommendation 6 of the Breizh COP, which advocates a strong commitment to innovation (to adapt to climate change), research (to be able to innovate and better prevent the effects of climate change), and education and training (in particular to support elected officials and territorial actors in the implementation of the necessary policies and strategies).

In addition, the Jean Monnet European Chair "European Spatial Studies of Sea and Coastal Zones", obtained by S. Niculescu (LETG, 2018-2021), will enable to benefit the space expertise on the sea and coast of the J. Monnet Chair network and from links with space research centers in Europe and around the world. Moreover, the objective being to obtain an observation method that can be reproduced independently of the study sites, the method can be extended to other areas. We are thinking in particular of regional and interregional observatories (OSIRISC, ROL Normandie – Hauts-de-France) or national sites of the DYNALIT network (four cliff sites), but also on international scale, via our research network (Greece, Canada, Malta, Brazil...) and that of the European J. Monnet Chair.

Vous sollicitez un financement ISblue, ou une ARED ISblue :

Précisez le lien du sujet avec les thèmes ISblue

Thème ISblue	**Thème principal**	**Thème secondaire** (si nécessaire)	**Autre** (si nécessaire)
la régulation du climat par l'océan			
les interactions entre la Terre et l'océan			
la durabilité des systèmes côtiers	x		
l'océan vivant et les services écosystémiques			
les systèmes d'observation à long terme		x	

Expliquez/précisez <u>en quelques lignes</u> dans quelle mesure votre demande correspond à l'un ou plusieurs des critères ISblue ci-dessous :

1- Originalité, impact potentiel du projet (4 lignes maxi)
This subject is innovative and promising because there is little research on cliffs and 157 communes in Brittany are concerned by the erosion of soft cliffs (Basara, 2019); only our team is working on the 3D restitution of the cliff face by multi-angle spatial remote sensing; the interdisciplinarity of the project will allow the development of original methods (including Machine Learning ones) and the proposal of monitoring methods to managers.

2- Positionnement international du sujet, cotutelle ou co-encadrement international (4 lignes maxi)
The subject is international through the spatial coverage of cliff coasts (52% of the world's coastline), the global coverage of satellites and the collaboration with N. Evelpidou (Univ. of Athens), started in 2018. Together, we have submitted several projects: the European project COST COAST ENGAGE (COASTal Evolution and adaptation: climate chaNGe And GEohazards, 2020) and the HIRACLES project (accepted in 2020, funded from 2021 to 2023).

3- Effet intégrateur entre unités de recherche et / ou interdisciplinarités (4 lignes maxi)
The PhD project which combines geomorphology, remote sensing and computer science will allow the integration: (1) within IUEM-UBO, UMR 6538 LGO (C. Delacourt), UMR 6554 LETG (P. Letortu) and UMS 3113 (M. Jaud); (2) at ISblue, UBO, UBS (IRISA, S. Lefèvre) and IMTA (P. Tandeo, who accepts that the PhD student attends his courses); (4) at the geo-environmental laboratory of the National and Kapodistrian University of Athens (N. Evelpidou).

4- Potentiel d'insertion à un haut niveau dans la communauté académique ou non académique du docteur (4 lignes maxi)
The thematic (cliff erosion and risk management) and methodological (photogrammetry, 3D data processing and analysis, GIS, Machine Learning) skills acquired by the future doctor will enable him to move either into academic research, or into jobs in local authorities or government services, or in the private domain of design offices or

companies providing Earth observation and monitoring solutions.

Le candidat

Profil souhaité du candidat (spécialité/discipline principale, compétences scientifiques et techniques requises) :

- Master 2 in geography or geoscience or remote sensing or programming or equivalent engineering degree;

- Skills in coastal environment;

- Skills in photogrammetry (MicMac, ASP, ERDAS Imagine, Agisoft Metashape, CARS);

- Skills in Geographical Information Systems (ArcGIS ou QGIS);

- Skills in programming;

- Skills in point cloud processing and 3D data analysis (e.g. CloudCompare).