OSIRISC: Co-Design of an Integrated Observatory to Monitor Vulnerability to Coastal Risks of Erosion and Marine Flooding in Brittany

10

Nicolas Le Dantec, Marion Jaud, Alain Henaff, Iwan Le Berre, Catherine Meur-Ferec, Quentin Ruaud, Mathias Rouan, Julie Pierson, Caroline Lummert, Manuelle Philippe, Thibaud Lami, Pauline Letortu, Elisabeth Guillou, Serge Suanez and Sylvain Lendre

10.1 Introduction

OSIRISC (French acronym for "*ObServatoire Intégré des RISques Côtiers en Bretagne*") is an integrated observatory addressing coastal risks of coastal erosion and marine flooding in Brittany.

The coastal zone has become very attractive over the last century, for the numerous amenities it offers. It now concentrates many infrastructures, economic activities, residential housing and a large population. At the same time, it is a dynamic zone, as the coastline is in constant

N. Le Dantec (✉) · M. Jaud · Q. Ruaud · C. Lummert
UMR 6538 GeoOcean, University of Brest-CNRS, Institut Universitaire Européen de La Mer, Rue Dumont d'Urville, 29280 Plouzané, France
e-mail: nicolas.ledantec@univ-brest.fr

M. Jaud
e-mail: marion.jaud@univ-brest.fr

Q. Ruaud
e-mail: quentin.ruaud@univ-brest.fr

C. Lummert
e-mail: caroline.lummert@univ-brest.fr

A. Henaff · I. Le Berre · C. Meur-Ferec · M. Rouan · J. Pierson · T. Lami · P. Letortu · S. Suanez
UMR 6554 Littoral-Environnement-Télédétection-Géomatique, University of Brest, CNRS, Institut Universitaire Européen de La Mer, Rue Dumont d'Urville, 29280 Plouzané, France
e-mail: alain.henaff@univ-brest.fr

I. Le Berre
e-mail: iwan.leberre@univ-brest.fr

C. Meur-Ferec
e-mail: catherine.meurferec@univ-brest.fr

M. Rouan
e-mail: mathias.rouan@univ-brest.fr

J. Pierson
e-mail: julie.pierson@univ-brest.fr

T. Lami
e-mail: thibaud.lami@univ-brest.fr

P. Letortu
e-mail: pauline.letortu@univ-brest.fr

S. Suanez
e-mail: serge.suanez@univ-brest.fr

M. Philippe
UMR 6308 Amure, University of Brest, CNRS, Institut Universitaire Européen de La Mer, Rue Dumont d'Urville, 29280 Plouzané, France
e-mail: manuelle.philippe@univ-brest.fr

E. Guillou
EA 1285 LP3C, University of Brest, 29238 Brest cedex 3, Brest, France
e-mail: Elisabeth.Guillou@univ-brest.fr

S. Lendre
CEREMA, Direction Eau Mer Et Fleuves, 134 Rue de Beauvais, 60280 Margny-Lès-Compiègne, France
e-mail: sylvain.lendre@cerema.fr

© The Author(s) 2025
R. C. Gomes et al. (eds.), *Citizens' Observatories on Geohazards*, Geoenvironmental Disaster Reduction,
https://doi.org/10.1007/978-3-031-53371-6_10

evolution at different time scales, from storm events to seasonal and to multi-annual (including under the effect of climate change), in addition to longer time scales of coastline evolution, in relation to sea-level change. Coastal forms are continuously being reshaped according to the geomorphological response of coastal environments subject to varying marine and subaerial conditions, and to sediment erosion and deposition dynamics. Natural coastal environments are classified into different geomorphological types depending on whether their primary features were created by erosion of land (erosional coast) or deposition of eroded material (depositional coast). Erosional coasts include the wave-cut platforms as well as rocky and soft cliffs. Cliffs can only retreat under marine erosion, subaerial weathering and continental processes, while wave-cut platforms are shaped both through the evolution of their width and the downwearing of their surface. Depositional coasts include low-lying accumulations of shingle, gravel or sand forming barrier beaches and dunes on exposed environments. Phases of retreat of the coastline can alternate with beach and dune recovery as sediments are transported in cross-shore and alongshore directions due to the action of waves and currents, as well as aeolian processes on the exposed sandy beach and dune, giving rise to circulation patterns at the spatial scale of littoral cells. Finally, finer sediments are deposited in sheltered conditions in estuaries, tidal mud-flats or lagoons. Parts of the coastlines have been artificialized, either with coastal defences to protect against the sea or with harbour infrastructures. The coastline itself, meant to represent the limit of the marine and continental domains, is usually defined according to a morphological marker such as the top of a cliff or the foot of a dune, or to an elevation with respect to a vertical reference, such as the mean sea level or the maximum astronomical tide. The unstable nature of the coastal zone brings about 3 types of geohazards: coastal erosion, marine flooding and coastal dune migration. We will only consider the first 2, as the dune migration concerns nowadays only very few areas in Brittany and is often identified as coastline retreat.

- Coastal erosion is the loss of sediment, which eventually results in the recession of the coastline and therefore a loss of land to the sea (Fig. 10.1). Approximately 1/5 of the French coastline is affected, to varying degrees, by coastal erosion (Cerema, 2018). In the long term, it is a continuous process, with periods of more or less rapid retreat. Coastal erosion can be impacted by various factors including climate (sea-level change, frequency of occurrence of storms, wind regimes), topography, vegetation, tectonic activity, but also human activity (over-frequentation, sediment extraction, river dams, sea defence structures, urbanization close to the coastline leading to surface runoff, etc.).

Fig. 10.1 Coastline recession visible by comparing two aerial images from 1952 (coastline digitized in red) and 2021 (coastline digitized in green). Location: Ploudalmézeau and Lampaul-Ploudalmézeau, Finistère department, France (modified from: « Remonter le temps » website - © IGN)

- Marine flooding is the inundation of the continental part of the coastal zone by the sea during unfavourable meteorological and oceanic conditions (low atmospheric pressure, strong landward winds, storm surge and waves, and for macrotidal seas, during high tide) (Fig. 10.2). Three modes of marine flooding are generally distinguished:
- flooding by overflows (when the sea level is higher than the crest of the sea defence structures or the natural ground);
- flooding due to wave overtopping (when the instantaneous wave height at the coastline exceeds the crest of the sea defence structures or the natural ground);
- and flooding due to failure of a sea defence system.

Coastal erosion and marine flooding hazards can cause severe damage or losses to properties and infrastructures worldwide. Human lives may also be lost in dramatic flood events, such as the Xynthia storm during winter 2010 (Vinet et al., 2012) on the French Atlantic coast. In France, risk management policies consider coastal erosion as a slow and continuous process. However, during a single intense coastal event, the coastline can retreat several metres in a few hours and even up to tens of metres locally (Hénaff et al., 2013). Unlike other natural geohazards associated with sudden processes like earthquakes—where early-warning systems and crisis response plans under the responsibility of civil protection services are a large part of risk reduction policies—prevention of coastal erosion risks focuses mainly on land-use planning and mitigation measures to control or stop coastline retreat. These risk mitigation measures take many forms, ranging from active defence with hard engineering protection (seawalls, riprap, etc.) to other approaches such as beach replenishment or sediment bypass that attempt to prevent or slow down coastal retreat without shoreline stabilization. Alternative strategies of risk reduction through adaptation, consisting in relocating exposed elements when possible, are now actively being promoted, although their application requires a change in paradigm for all stakeholders until they become accepted. Risk prevention policies against marine flooding are also relying on protection with coastal defences and regulations on urban planning, as well as the development of a risk culture as marine flooding can occur in catastrophic ways, in case of breeching of protection systems. Again, relocation strategies are considered but their implementation remains limited. While coastal erosion and marine flooding hazards are treated differently in terms of regulations framework for risk management (mainly because financial compensation of losses due to marine flooding is on public funds, which is not the case for losses

Fig. 10.2 Marine flooding by wave overtopping in Penhors (Audierne Bay, Brittany, France) in 2016

due to coastal erosion), they are often interrelated and difficult to dissociate in practice.

Risk being the combination of hazards and exposure, the main driver in the increasing trend in coastal risks is in fact coastal urbanisation and anthropic actions causing perturbations in the sediment fluxes. This is measurable through the increase of damages reported due to coastal hazards in historical records and in particular over the last decades (Hénaff et al., 2018). The appeal for coastal environments has led to a major growth of exposed elements in areas subject to coastal hazards (Fig. 10.3). The upcoming sea-level rise and changes in wave climate induced by climate change will exacerbate coastal hazards of erosion and flooding. In this context, long-term, sustainable strategies of coastal risks management are needed because the addition or reinforcement of coastal defences not only fails to address the main cause of risk, the exposure, but also to restore equilibrium in the sediment budget and even prevents the natural resilience of the coastal system through coastline recession.

Results from interdisciplinary research studies on coastal risks have led us to progressively develop an integrated approach combining natural phenomena (hazard) and structural (socio-economic, cultural, functional, institutional) factors, within a conceptual framework of systemic vulnerability (*Hénaff and Philippe (Eds), 2014*). Following prior work such as D'Ercole (1994), this approach reflects the level of fragility of a socio-economic system as a whole in the face of risk, and the ability of society to respond to potential crises through adaptation and resilience. Instead of considering vulnerability and hazards separately, systemic vulnerability is the combined outcome of 4 inter-related components: the hazards, the significance and nature of the exposed elements, the management responses to address risks and the social representations of risks (Fig. 10.4). In this approach, all 4 components are assessed independently to generate indicators. Interrelations between the components are taken into account when combining indicators into indices. Exposed elements or exposure refers to assets (human, economic, structural, etc.), measured independently of their level of exposure to the hazards. Risk management comprises the public policies of risk protection, prevention and adaptation and their application at local scale by authorities in charge of coastal risks. Social representations address the perception people have on risks (awareness, relationship to

Fig. 10.3 Evolution of the coastal urbanisation in Île-Tudy (Brittany, France) images from 1950 and 2021. (GeoBretagne 1950' website)

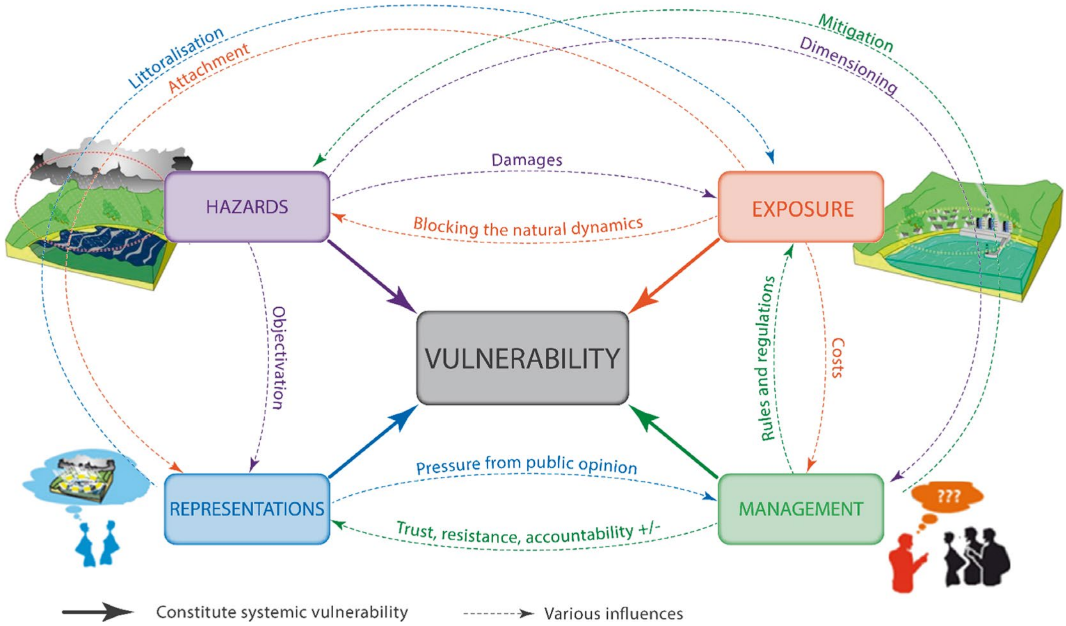

Fig. 10.4 The four components of systemic vulnerability, their interrelations and the nature of their contribution to systemic vulnerability (Meur-Ferec et al., 2020; modified)

the place they live, preferences for adaptation to risks, understanding and acceptability of management policies, etc.). These latter two components are the resources and levers available to cope with risks and its resulting impacts (Meur-Ferec et al., 2020). While increasing hazards and exposure will increase vulnerability, management is meant to reduce vulnerability. The influence of social representation on vulnerability is more difficult to characterize, as risk perception does not necessarily lead to behavioral changes acting towards reducing vulnerability. Rather, better understanding of how people who occupy a territory (as inhabitants or having activities in the territory, or being in charge of it) think about risks will bring insight on behaviors, which can help towards defining risk management strategies that may be better accepted.

As these four components evolve over time with their own temporalities, systemic vulnerability is dynamic as well. Beyond establishing systemic vulnerability diagnosis, monitoring trajectories of vulnerability over time, as a result of the evolution of the different contributing factors, through regular assessments, will improve our knowledge on coastal risks and help defining management strategies. The constitutive variables of each of the four components of vulnerability also vary over space, which raises the questions of the relevant size of territory, scale and granularity for the assessment of integrated (or systemic) vulnerability. A methodology based on indicators has been developed to evaluate systemic vulnerability (*Philippe and Hénaff, 2021*). Each of the four vulnerability components is approached using methods and tools specific to the corresponding scientific disciplines (geology, geography, law, environmental psychology…). The results can be presented in quantitative or qualitative form depending on the components. Thus, hazards and most of the elements-at-risk are measured via numerical data, whereas data on management and risk perception is collected via surveys using questionnaires and face-to-face interviews, and producing text information. Hazard, exposure and management data are converted into calibrated indicators. Results derived from social representation data are transcribed into textual form, providing contextual elements on the studied sites (*Philippe* *and Hénaff, 2021*). The production of indicators from the collected data is further described in Sect. 4.2.

This conceptual framework for an interdisciplinary monitoring system to promote integrated coastal risks management, in close relation with risks prevention stakeholders and decision-makers, was first implemented on test territories (*Philippe and Hénaff, 2021*; Le Berre et al., 2022). Following this development and experimental phase, OSIRISC observatory (Fig. 10.5) was created in Brittany in 2019, with this focus on "vulnerability" to coastal risks, and the dual goal to respond to scientific issues and societal demands through co-design and collaborative observation. In this chapter, we will first describe the territory where OSIRISC observatory is deployed, the objective of this collaborative observatory and the data handled in OSIRISC. We will then present the achievements of OSIRISC regarding the development of applications and platforms of citizen science, before discussing the interaction with stakeholders within OSIRISC observatory and the links with risk management.

Fig. 10.5 OSIRISC observatory logo

10.2 Site Description

The coastline of Brittany is 4,324 km long when including islands, islets and rias, and very convoluted. Brittany exhibits a variety of coastal types: low sandy and pebble beaches, rocky coasts, soft cliffs and deep rias (Fig. 10.6). Although 3 main provinces can be distinguished, with a low-lying Southern coast, mainly soft cliffs on the Northern coast and

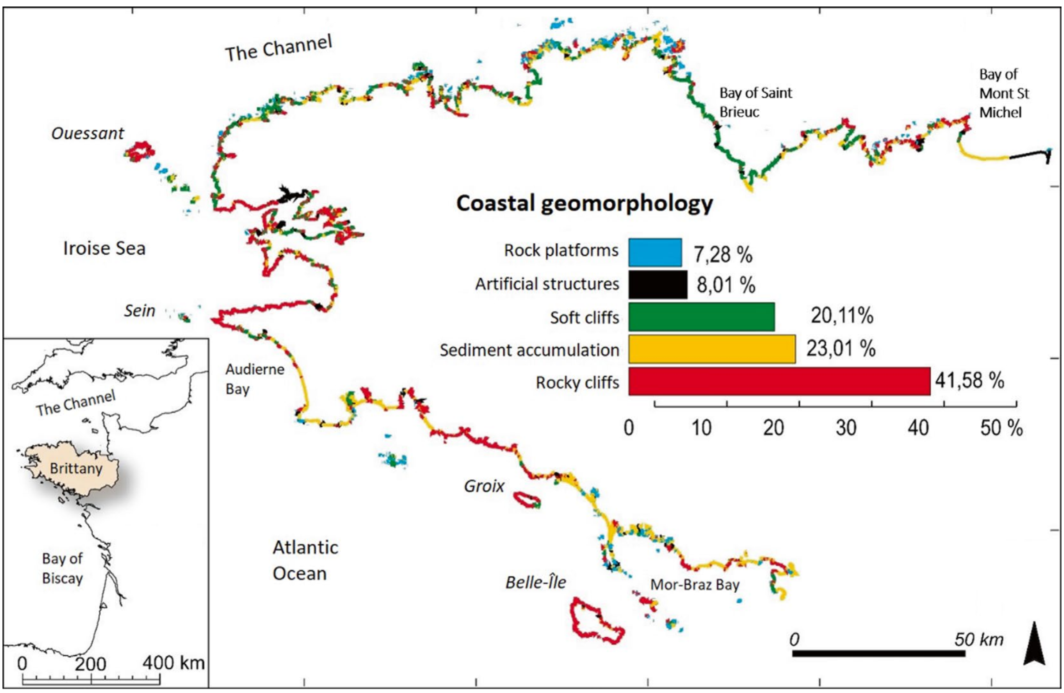

Fig. 10.6 The various coastal types in Brittany (from the Programme de recherche d'intérêt Régional «EROCOVUL»—2003)

rocky cliffs on the Western coast, the spatial heterogeneity of the coastal geomorphology is very high, with a succession of small stretches of coastline of different types. There is also a wide variety in the configurations owing to the spatial variations in coastal topography, tidal range, exposure to swells, fetch and sedimentary cover.

Overall, erosion concerns 6% of Brittany's coastline, according to a study based on diachronic analyses of ortho-photographs between 1950 and 2011 (Cerema, 2021a, b). This is lower than the national average, nevertheless, locally, some sites show retreat rates over 0.5m/year (Fig. 10.7). Accumulations of sand and pebbles represent about 24% of the region's shoreline. These are certainly the most monitored shorelines because of their relatively rapid dynamics and the many elements exposed behind. A specific analysis of changes in the shoreline of sand and pebble accumulations between 1950 and 2011 reveals that a third of them are in progradation, another third is in erosion and the remaining third is stable during the period (Fig. 10.8).

The damage produced during the historical period by coastal erosion and marine flooding (and also dune migration) on exposed territories is an indirect indicator of the growth of coastal risks in Brittany. The inventory of the damage observed since 1750 until nowadays counts some 8000 facts spread over the whole region with some coastal areas that are more frequently

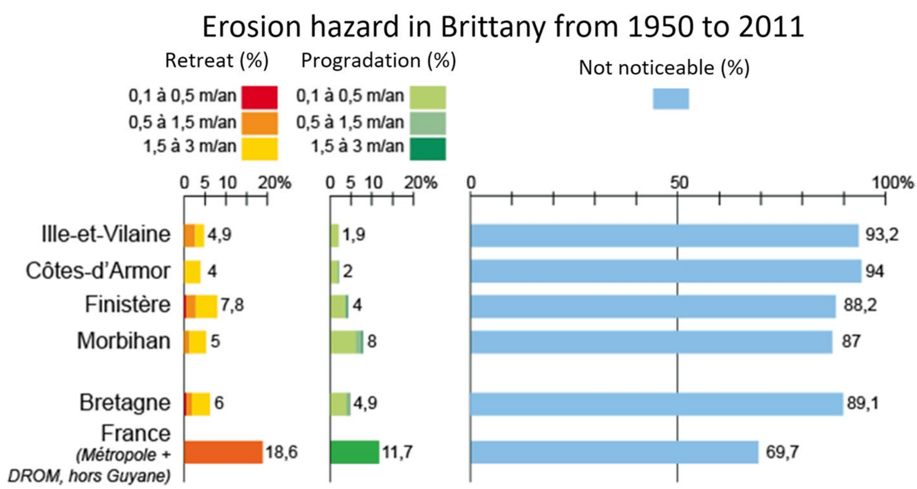

Fig. 10.7 Assessment of coastline trends in Brittany after Cerema (2021a, 2021b) and Hedou (2018)

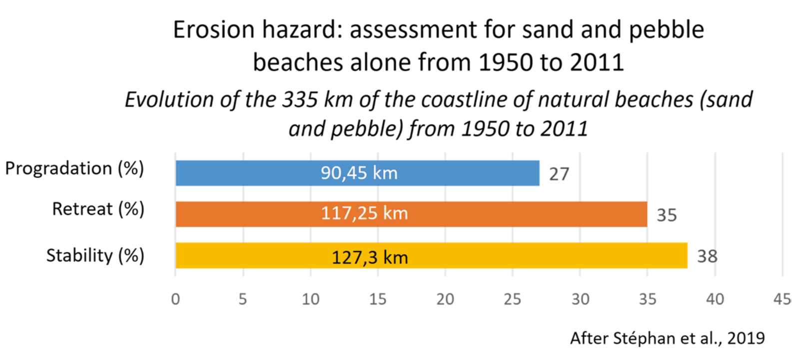

Fig. 10.8 Results of the diachronic analysis of the coastline of beaches from 1950 to 2011 in Brittany (after Stéphan et al., 2019)

affected. Diachronic analysis of hazards does not show any real growth in magnitude or frequency of occurrence of hazards during the historical period. This inventory shows periods of high occurrence of natural or anthropogenic hazards followed by quieter periods. If interannual fluctuations do exist in magnitude or frequency of hazard occurrence according to these periods, it appears that the observed increase in damage results mainly from the exposed elements that have continued to be developed in the coastal territories (Hénaff et al., 2018). The impacts of the most devastating hazards on the coasts are thus identified and they also allow to identify locally, when observed, the values of maximum shoreline retreat (Fig. 9a). Combined with the average rate of shoreline retreat, this value is crucial for predicting future coastal positions. It integrates the impacts of extreme events and allows stakeholders to obtain more reliable assessments of future positions of the shoreline than the only average rate of evolution. This is necessary in order to define a coastal risk management strategy that includes planning of prospective and future management of the coastal territory. Marine flooding mainly affects low-lying areas. Historically, an average of 8.7 incidents of marine flooding per year have been recorded from 1790 to 2021 (22% due to overtopping, 15% due to overtopping and destruction of coastal defences, 5% due to breach of the barrier beach, 45% unspecified (Chaumillon et al., 2017) (Fig. 9b).

The Breton coastline counts 257 municipalities, with a combined surface area of 4,874 km^2, or 18% of the region's surface area. According to the 2017 census by the French National Institute of Statistics and Economic Studies, the total population of coastal municipalities is 1.16 million inhabitants, representing 36% of the Breton total population. The density of the Breton coastline is 240 inhabitants per km^2, with the population of the coastal municipalities increasing by 13% from 1975 to 2012 censuses (Poupard, 2017). In addition, the coastal municipalities concentrate 74% of the 235,644 second homes in Brittany (Poupard, 2017). In addition to this population concentration, the Breton coastal municipalities also host economic (fisheries, harbours, tourist facilities,

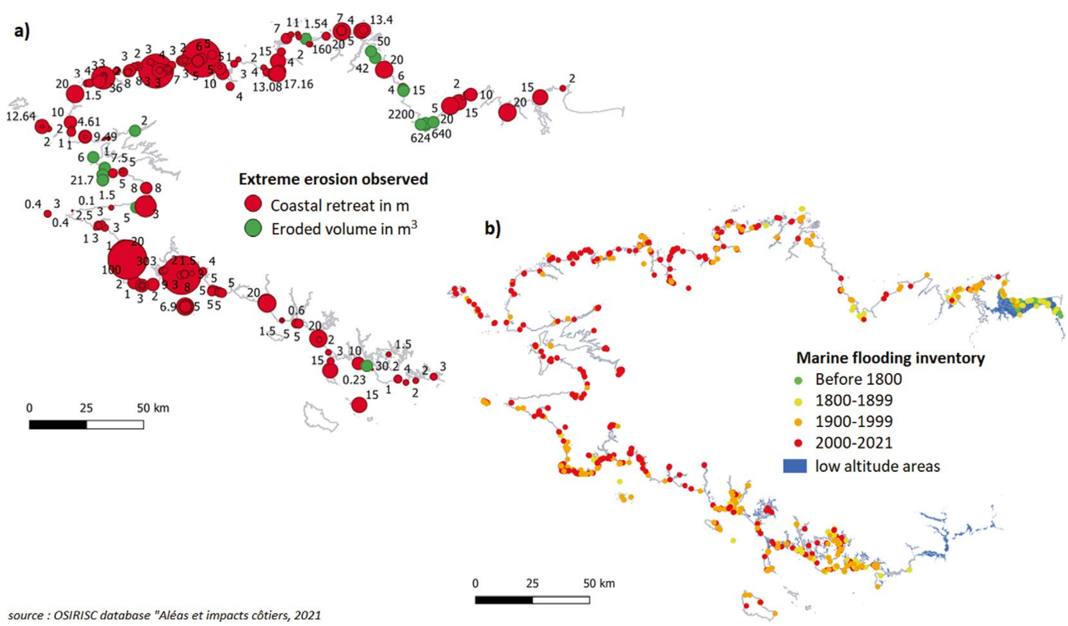

Fig. 10.9 Extreme coastal erosion observed (**a**) and recorded marine flooding events (**b**) in Brittany (source of the data: OSIRISC database "Aléas et impacts côtiers", 2021 (Chaumillon et al., 2017))

etc.) and structural assets (roads, public establishments, sea defences, etc.) as well as natural (protected areas) or patrimonial heritage (historic or prehistoric sites).

The OSIRISC observatory covers the 257 Breton coastal municipalities. The map in Fig. 10.10 shows the sites for which hazard measurements are (or have been) performed. These measurement sites were chosen either because they are particularly concerned by coastal risks or because they are representative of the evolution of a type of coastal environment. Given the diversity of coastal environments and evolution dynamics, measurement methods must be adapted to each site.

The anticipation of the long-term evolution of the shoreline is mainly based on the analysis of its present and past positions, going back to different periods quite far in time. Hence the importance of having long-term series of coastline measurements.

10.3 Objectives of OSIRISC Pilot

As previously mentioned, OSIRISC observatory aims to integrate all the dimensions of systemic vulnerability (combination of the four interdependent components: hazards, exposure, management and representations), in close relation with risks prevention stakeholders and decision-makers (*Philippe and Hénaff, 2021*). To understand the evolution of vulnerability, it is necessary to know the evolution of each of the components individually. This means "measuring" each of the components in a territory and monitoring them over time.

To achieve this, OSIRISC has carried out:

- The development of an interdisciplinary observatory methodology for coastal erosion and marine flooding risks by selecting or creating indicators and indices adapted to both research and management;

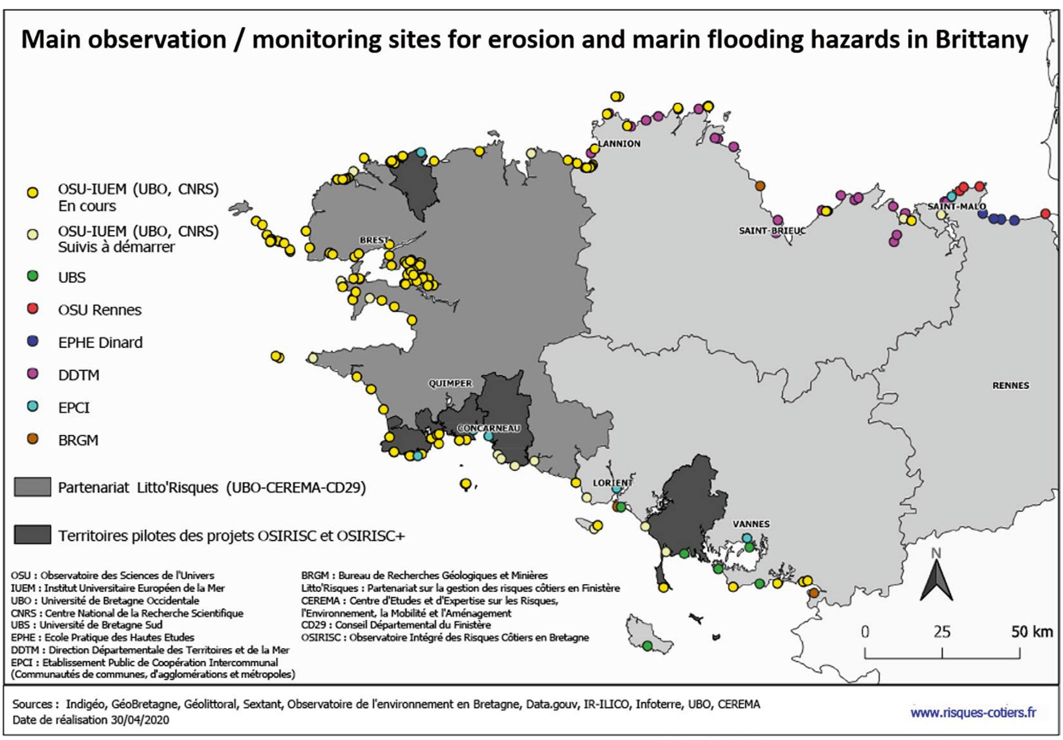

Fig. 10.10 Sites where morphologic surveys of coastal hazards are realized

- Evaluation and consolidation of this indicators approach and methodology through experimentation with local stakeholders on test sites;
- The implementation, within a Spatial Data Infrastructure (SDI), of specific tools for geographic information dissemination and sharing, as well as the study of its contributions toward scientific (improving our understanding of vulnerability to coastal risks) and applied (coastal risks management) objectives.

This approach (Fig. 10.11) is called "integrated" because it allows us to work on the different levers of vulnerability and analyse the determining factors. This will facilitate the identification of the most vulnerable areas where to focus actions, as well as the development of management strategies. This approach also allows for the monitoring of long-term trajectories in order to implement a long-term management strategy (not limited to sensitive areas).

Co-construction with local authorities implies providing technical and methodological support for coastal erosion and marine flooding risk management issues (through workshops, expertise, advanced students projects) and carrying out actions to raise awareness of coastal risks and bring together stakeholders. During the AGEO project, the OSIRISC team not only carried out in situ surveys, but also provided training and developed tools (using simple and low-cost measurement protocols, web platforms for data dissemination, etc.) to promote involvement of local authorities in coastal vulnerability observation.

Defining indicators is an essential step to make data of different types and formats compatible and accessible to a wide audience. Further details on this step are given in Sect. 4.2.

The collaboration within OSIRISC observatory between academics and local authorities is effective and was ratified by the Litto'Risques partnership between the University of Brest, the CEREMA (Centre for studies and expertise on risks, the environment, mobility and development) and the Finistère County council. Figure 10.12 shows the map of the territories involved in Litto'Risques. The OSIRISC team hopes to extend this collaboration to other territories in Brittany. Interactions with stakeholders, and specifically local authorities in charge of risk management, are presented in Sect. 10.6.

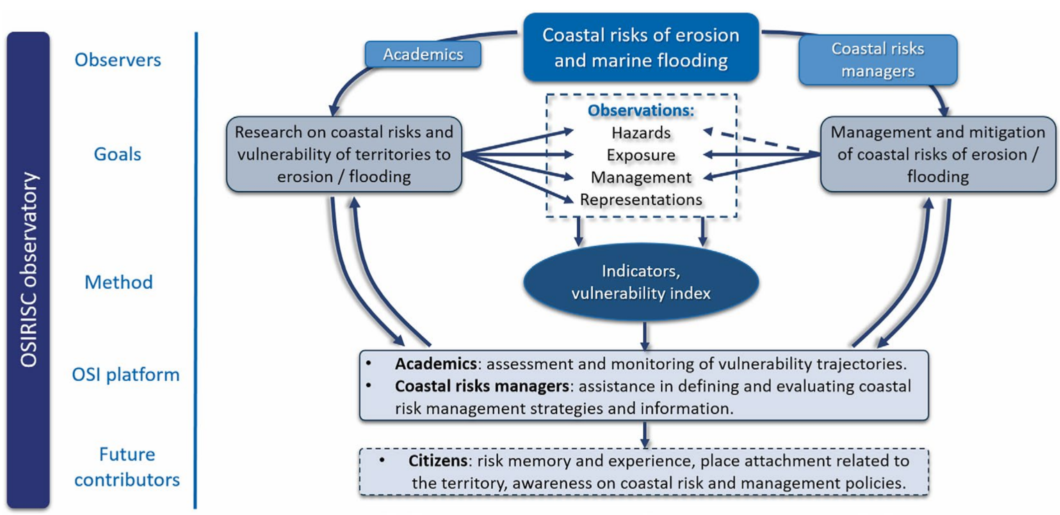

Fig. 10.11 Methodological approach developed in OSIRISC observatory

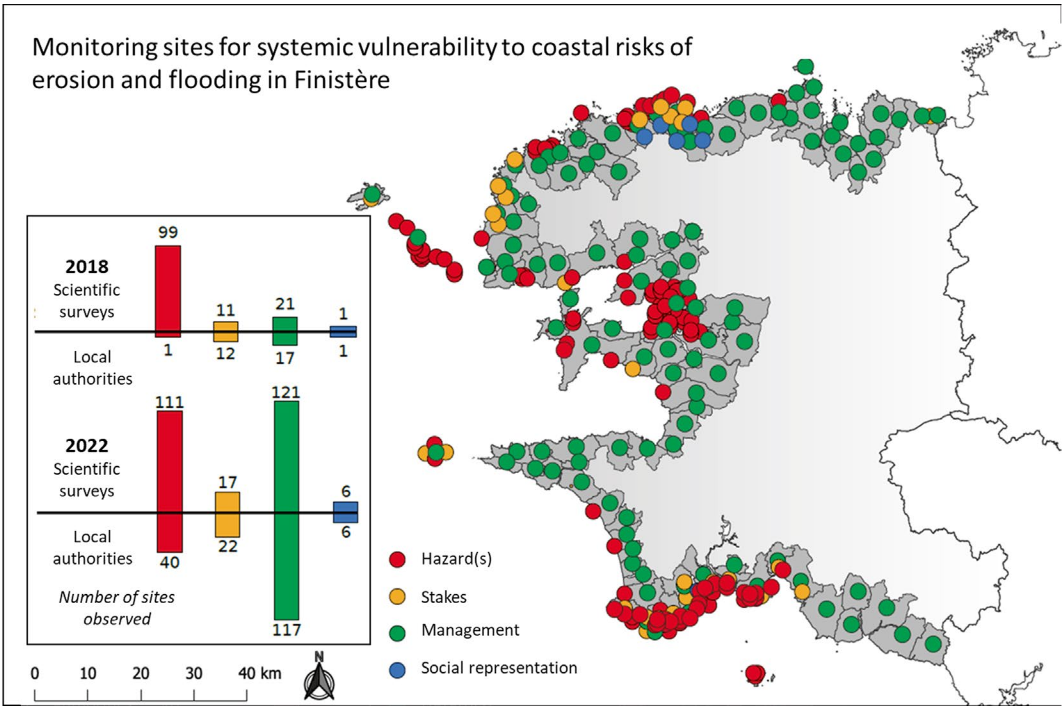

Fig. 10.12 Sites in Finistère where observations are collected on components of the systemic vulnerability to coastal risks of erosion and flooding

10.4 Data Handled by the Pilot

10.4.1 Combining Multi-Source Data

The OSIRISC observatory is based on multi-source and multi-scale data. Given the surface area of the territory concerned, data at regional level come from existing national or regional databases. Other data are collected in situ, at the local level, by academics or stakeholders. Table 10.1 summarises, for each vulnerability component, the data on which OSIRISC observatory is based.

From an academic point of view, since 2002, the marine sciences observatory of the Institut Universitaire Européen de la Mer (a Department of the University of Brest) has set up field observation data series on geomorphological evolution of the coastline. The initial objective of this monitoring is directly linked to fundamental research. The aim is to detect a signal of climatic and/or meteorological variations from the long-term morphological and sedimentary changes of the coastal fringe.

The use of modern field measurement techniques (tacheometer, Global Navigation Satellite System—GNSS, total station, Terrestrial Laser Scanner, photogrammetry, etc.) and image processing (aerial or satellite orthophotographs) has facilitated the acquisition of topo-morphological data of the coastal domain with a better accuracy, on more sites and at a higher frequency. Some of these technologies are now more widely available thanks to the emergence of low-cost instrumentation devices (Centipede collaborative GNSS network, distance meters), allowing data acquisition by managers-practitioners or student trainees (Fig. 10.13).

Observations are now collected at around 50 sites throughout Brittany, with several research laboratories contributing to the data acquisition efforts. Since 2014, some of the monitored

Table 10.1 Data handled by OSIRISC pilot

Components of vunerability to coastal risks of erosion and marine flooding				
	Hazards	Exposures	Management	Representions
OSIRISC data	**Submersion:** - Extreme water levels probabilities - Inventory from municipal archives and newspapers - Flooding benchmarks **Erosion:** - Historical aerial/satellite photo database - Inventory from municipal archives and newspapers - Topographic measurements - Photogrammetric surveys - Terrestrial Lidar surveys - Collaborative data collected by local managers	**Human exposures:** - National databases (population, housing, vulnerable populations, infrastructure...) **Economic exposures:** - National databases (jobs, economic buildings, diversity of economic activities, tourism...) **Structural exposures:** - National and regional databases (cultural heritage, coastal works, harbours, road networks, reception capacity, emergency system...) - Local studies (inventory) **Agricultural and natural exposures:** - National and regional databases (protection of natural areas, agricultural areas...)	- Information provided by the land managers on the type and progress of the management strategy implemented by the territories. (control of urbanization, crisis management, awareness rising, knowledge/expertise, local initiatives...)	**Awareness of risk:** - Interviews with citizens - Online surveys **Evaluation of institutions and collective practices:** - Interviews with citizens - Online surveys **Meaning of the place:** - Interviews with citizens - Online surveys

Data at regional scale
Data at local scale

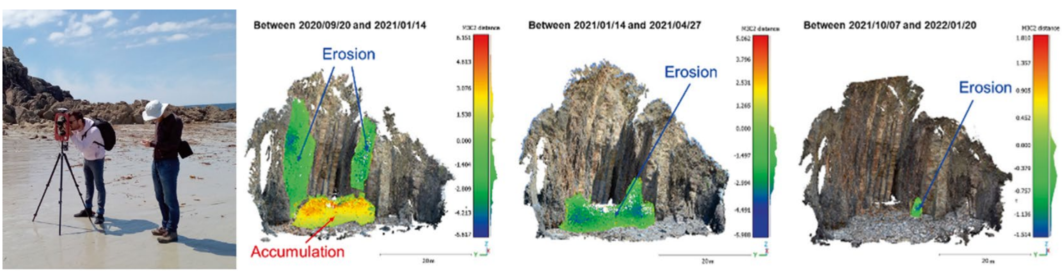

Fig. 10.13 Example of cliff erosion (between September 2020 and January 2022) measured with a photogrammetric low-cost system (Tromel cliff, Brittany, France)

sites have been integrated into the DYNALIT National Observation Service (SNO) labelled by the INSU CNRS. Similarly, several partners (local authorities, other stakeholders) produce data, either on their own or via contractors, particularly within the framework of the OSIRISC-Litto'Risques Observatory in Finistère.

Today, the aim of this monitoring program is also to meet a societal demand for applied research, especially since more than 70% of these survey operations are financed by local authorities. The aim is to compile a series of data on the evolution and morphology of the coastline to support local stakeholders in their coastal management and development policies. A final objective is to produce sufficiently long and relevant data series for the calibration of existing models in the field of engineering (1D and 2D models of beach evolution).

In France, data on exposed elements are increasingly rich and accessible via national reference databases. This makes it possible to have homogeneous information throughout the Breton territory and to reduce the very time-consuming recourse to field surveys.

Data for indicators on the management implemented in each territory are collected partly via information available on the Internet, and partly by individual surveys of technical staff in charge of risk management among local authorities. This implies close collaboration with local authorities.

Risks representation is the component for which it is most difficult to formalise information, as it involves psychosociological concepts. No pre-existing data is available for this component. Data is collected through individual surveys carried out among people who live (and work, play, …) in the studied municipalities. Several means of communication were used to encourage people to answer an online questionnaire (town hall websites, tourist offices, social networks, associations, schools, posters in the municipality bulletin boards, etc.).

10.4.2 Creating Indicators and Indices

The indicators produced within OSIRISC observatory are a harmonised, numerically rated transcription of quantitative and qualitative data, allowing for the combination of multi-source data on the different components of vulnerability (Le Berre et al., 2022). Thus, for each component of vulnerability (hazards, elements-at-risk, management and representations) and for each type of observation, the indicators were defined with a calibration to provide a rating on a scale from 1 to 5.

These indicators are calculated spatially, at the scale of the territory where the data is available (see Table 10.1), on a grid defined to be compatible with the national databases. While the initial grid cell size was 200 m, which guarantees the anonymity of personal data, many indicators are now produced on grid sizes from 50 to 800 m. Each indicator is accompanied by a descriptive datasheet specifying its role (what the indicator means), the data sources and possibly their quality, as well as the protocol for filling it in, calibrating it into five categories and the time step for updating the indicator (Le Berre et al., 2022; Meur-Ferec et al., 2020).

A high value of hazard or exposure indicator contributes to increased vulnerability. Conversely, a high value of the management indicator (corresponding to a relevant management strategy) contributes to a decrease in vulnerability. As all indicators are homogeneous since they use the same scale and same grid, aggregated "indices" (either within a component or inter-component) can also be generated by crossing several indicators in order to have a more integrated assessment of vulnerability (Fig. 10.14). Only the representation component is not integrated into indices. This component provides contextual information that will facilitate the implementation of risk management strategies.

10.5 Citizens' Involvement and Platforms

10.5.1 AGEO App

The AGEO application (see chapter 6) makes it possible to report coastal damage including identification information in order to create or enrich an inventory. The application consists of geolocated photographs, accompanied by qualitative data concerning the characterisation of the type of hazard, the estimation of the magnitude of the hazard, the elements exposed and the estimation of the date of the hazard according to the frequency of visit of the site by the participants (Fig. 10.15). This app can be used by citizens, typically residents who often visit coastal areas, or managers-practionners. Reports on coastal impacts collected with AGEO app will be added to the existing OSIRISC database "Aléas et impacts côtiers".

10.5.2 CoastAppli App

Local authorities show interest in contributing to hazards monitoring, but sometimes lack both the time and the tools and technical skills to do so.

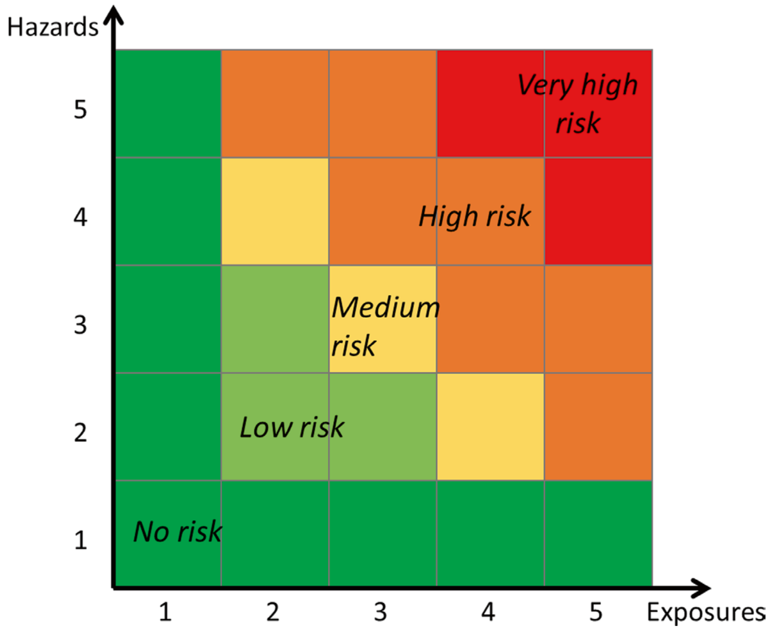

Fig. 10.14 Matrix for calculating the risk index by aggregating hazards and exposures

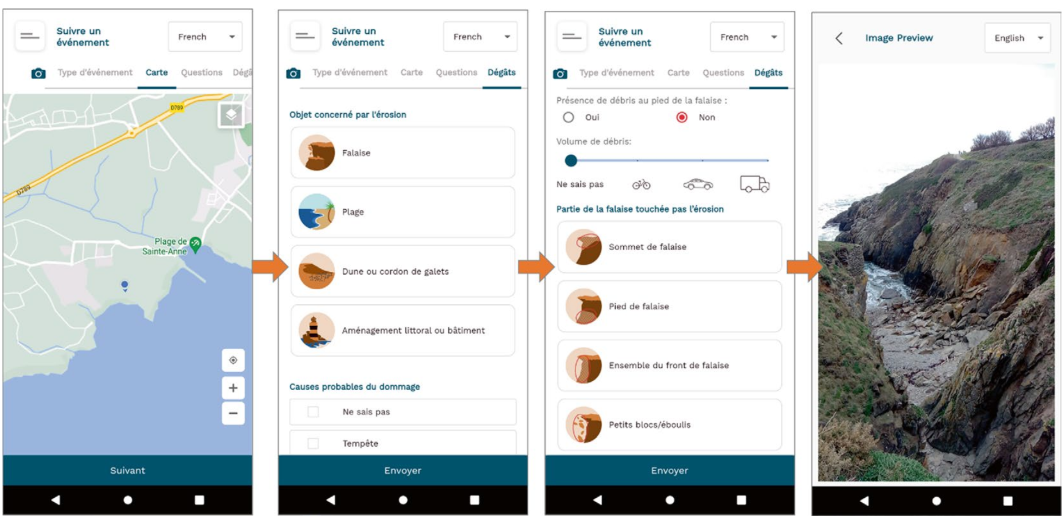

Fig. 10.15 Screenshots of the successive steps for damage reporting with AGEO app

Furthermore, the management strategies relying on adaptation measures, no longer attempting to maintain a fixed coastline position, are not always well received by the public, which make the dialogue about risk management more complicated.

The idea therefore emerged to set up an application called "CoastAppli" meant to facilitate the data acquisition for coastal surveys, to raise interest from the general public and enable its participation in monitoring programs on coastal dynamics.

This application (Fig. 10.16) was developed with the support of the EUR ISblue University Research School, the Sea-EU project and the INTERREG AGEO project. "CoastAppli" app is complementary to AGEO app. CoastAppli provides quantitative measures with resolution and accuracy close to typical positioning systems (up to ± 4 cm) for some of the protocols, using a simple approach such as measuring the size of a step and counting the number of steps, or simple tools like a measuring tape. As it relies both on quantitative and qualitative protocols, it is aimed at a targeted audience (technical staff from local authorities, trained citizens) as well as the general public, including children.

The first version of this application proposes a dozen of protocols for monitoring "erosion" and "flooding" hazards, using simple measurement tools. This version was tested and validated in the municipality of Guissény from December 2021 to October 2022, with technical staff from local authorities, schoolchildren from

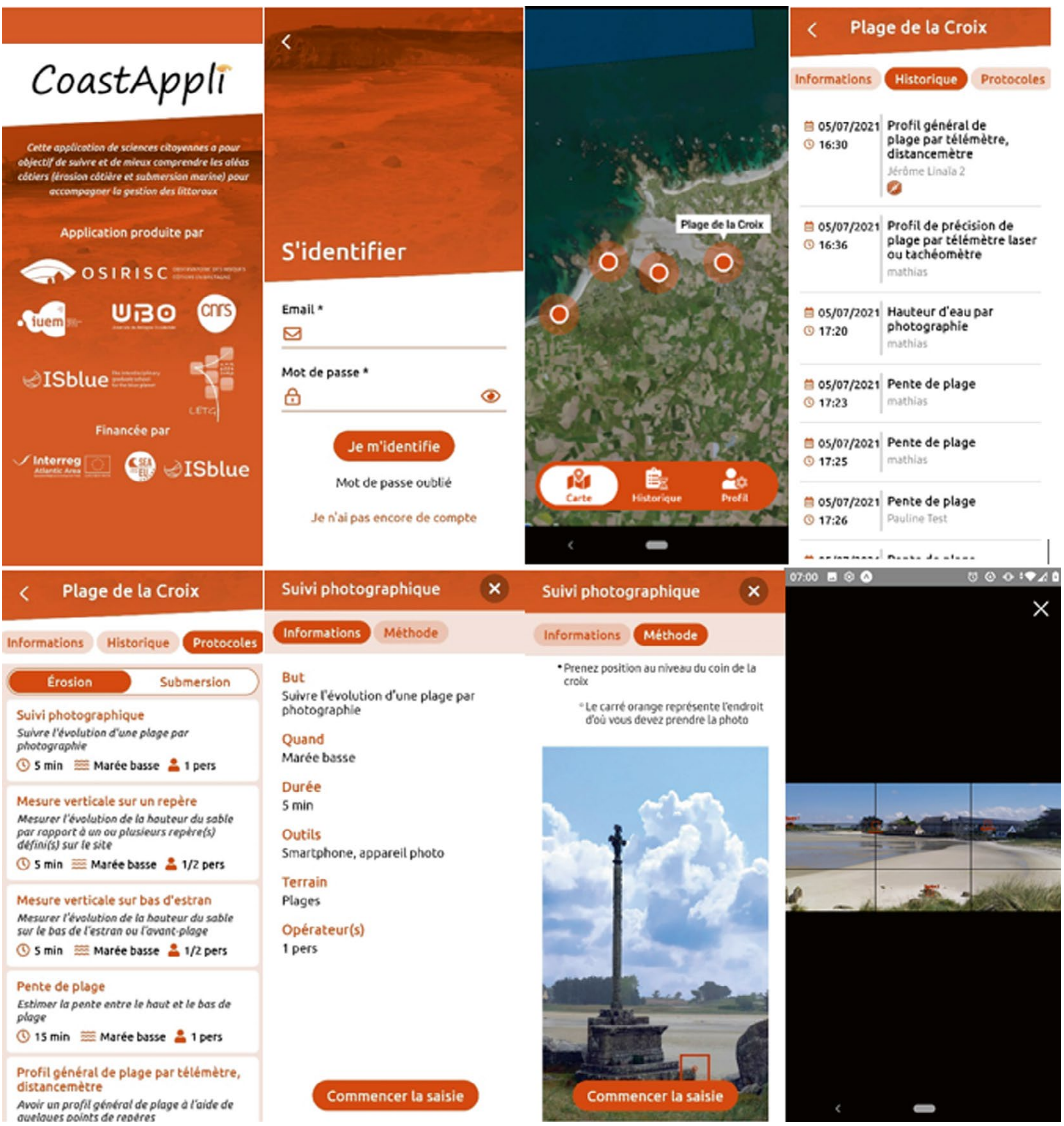

Fig. 10.16 Screenshots of the first version of CoastAppli app

Fig. 10.17 Test of data acquisition for coastal surveys using "CoastAppli" app with pupils in Guissény (R. Ruault and Q. Millière)

the Diwan Grade School and the general public. We verified the reliability of the measurements, as well as the interest and the commitment of the users (Fig. 10.17).

10.5.3 Deployment of Centipède Geolocation System

Geolocation is one of the central tools for monitoring coastal hazards (positioning of the coastline, measurement of beach profiles, 3D modelling of cliff evolution, etc.). By default, the accuracy of satellite navigation systems is only a few metres. Differential correction systems can compensate for this lack of accuracy: Real Time Kinematic (RTK) positioning can approach centimetre accuracy. However, this approach requires a reference base set-up close to the data collection site, the accessibility of its differential correction signal and very expensive equipment to process it. For some years now, developers have been actively working with open-source/open-hardware software and components to create inexpensive, reliable, lightweight and easy-to-use differential GNSS solutions.

Centipede[1] RTK (https://docs.centipede.fr/) is a collaborative network of open GNSS bases available to anyone within the coverage area. Initiated in 2019 by INRAE (French National Research Institute for Agriculture, Food and the Environment), the network is being deployed thanks to public institutes, individuals, private actors such as farmers or other public partners who voluntarily contribute by deploying GNSS base antennas to extend and densify the network. The objective of the project is to offer a complete coverage of the French metropolitan territory. Base stations are also being set-up overseas and abroad.

Deploying this system appeared to be a way of making data acquisition financially and technically more accessible, and therefore usable for collaborative science as well as student training. Within the framework of AGEO project, UBO has contributed to the Centipède base network in Brittany by installing 9 Centipede bases (Fig. 10.18). In addition, UBO has equipped the local authorities of the Litto'Risques partnership with rover antennas to carry out their own coastal measurements.

UBO supported technical staff of local authorities across the Breton territory by training

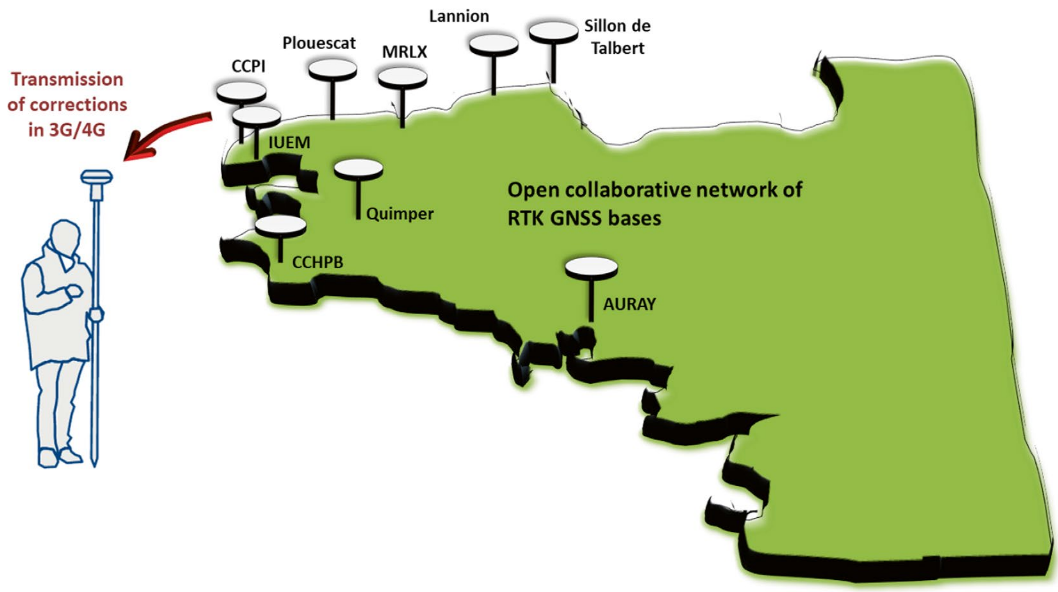

Fig. 10.18 The network of Centipède GNSS bases installed in Brittany by OSIRISC in the framework of AGEO

them in the use of this survey equipment, the measurement protocols, the choice of morphological features to survey and data processing. With involvement of local authorities, the number of measurement sites is rapidly increasing. About 40 survey sites have been added since Litto'Risques partnership was started. The data collected by local authorities using these methods and tools enrich the OSIRISC observatory databases.

10.5.4 Data cataloguing and diffusion: MADDOG and OSI Platforms

MADDOG[2], which stands for "Mise A Disposition des Données d'Observation Géomorphologique" is the OSIRISC coastline and coastal geomorphology observation data portal (https://portail.indigeo.fr/mviewer/?config=apps/maddog.xml#). It is a web platform for the visualisation of topo-morphological data series (coastline, cross-shore beach profile, Digital Terrain Model (DTM)) of the Brittany coastline: beaches, dune systems, sandbars, cliffs, river mouths.

MADDOG implements cataloguing and geographic information processing tools that allow the dissemination of these observation time series in the form of interactive databases. MADDOG also provides online interactive data processing services that allow a preliminary analysis of the morphological evolution of the coastline (Fig. 10.19). Three types of results are available on MADDOG:

- The planimetric evolution of the coastline allowing the analysis of the kinematics of the coastline by calculating a distance of shoreline retreat or advance between coastlines measured at two different dates.
- The altimetric evolution of beaches by comparing cross-sectional beach profiles measured at different dates. Morphosedimentary changes allow the calculation of the evolution of the sediment balance in m^3 per linear metre.
- The evolution of surface changes of the beaches in three dimensions (x, y and z) by comparison of digital terrain models. These data allow the calculation and mapping of the sediment budget (in m^3 per linear metre) in the form of accretion and erosion zones.

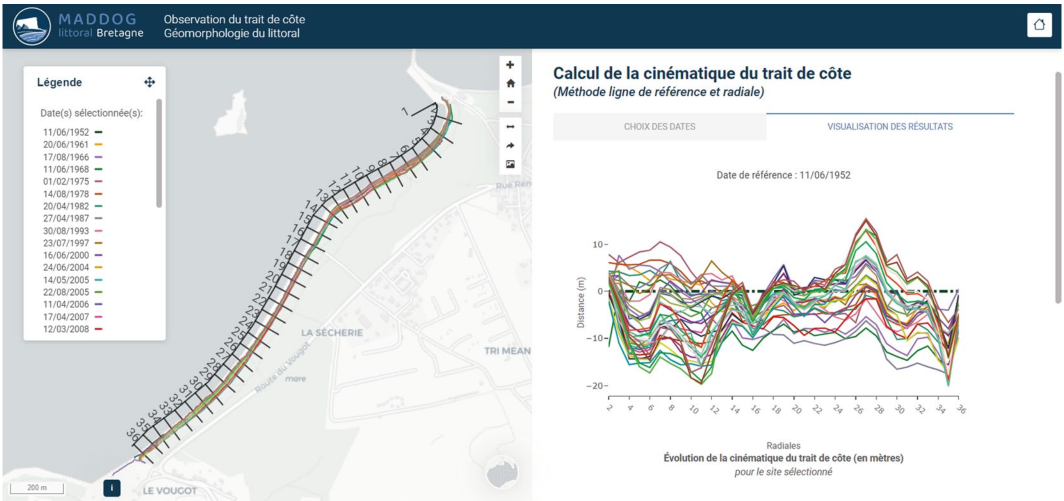

Fig. 10.19 Example of the altimetric evolution of beaches by comparing cross-sectional beach profiles on MADDOG interface (Guisseny beach, Brittany, France)

This platform is intended to be used by the scientific community as well as by managers-practitioners and citizens. It thus responds to the needs expressed by local authorities to have data readily accessible processing tools allowing preliminary exploitation of observations they carry out, and further to obtain interpreted results on geomorphological evolution of the coastline to support the definition of coastal risk management strategies (development, prevention, adaptation), as well as to raise awareness among all stakeholders.

The co-construction approach between researchers and territorial stakeholders (managers-practitioners, technicians and elected officials, and citizens) is a cornerstone of the OSIRISC regional observatory. Consistently, the data disseminated via the platform MADDOG comes from surveys carried out both by UBO research laboratories and by OSIRISC observatory partners: local authorities in charge of coastal management, State services and other public partners (the French coastal conservation agency, Natural Parks, etc.).

The European University Institute of the Sea (IUEM), which is the "marine and coastal sciences" component of UBO, runs the regional observatory OSIRISC and hosts the coastal observations database accessible via the MADDOG platform. IUEM manages (that is, hosting, archiving, maintenance, availability) the data collected by the many contributors from various marine sciences fields as part of its role as an "Observatory of the Sciences of the Universe" (OSU). The coastal monitoring data accessible on MADDOG are archived under the INDIGEO[3] Spatial Data Infrastructure (https://indigeo.fr/).

A common input data format has been defined for the series disseminated via MADDOG, in order to allow the visualisation of data collected by the various producers using different instruments.

The OSI[4] Web-GIS interface (https://osi.univ-brest.fr/) allows the visualisation of the indicators and indices developed to assess and monitor the vulnerability trajectories of coastal territories to coastal hazards. These indicators and indices are represented on an adaptive mesh ranging from 50 m to the scale of the municipality. The interoperability of data and geographic information processing tools allows for a back and forth navigation between the integrated analysis of vulnerability on the OSI interface and a more in-depth analysis of erosion and marine flooding hazard data on the MADDOG platform, where morpho-sedimentary evolutions are represented on a metric scale.

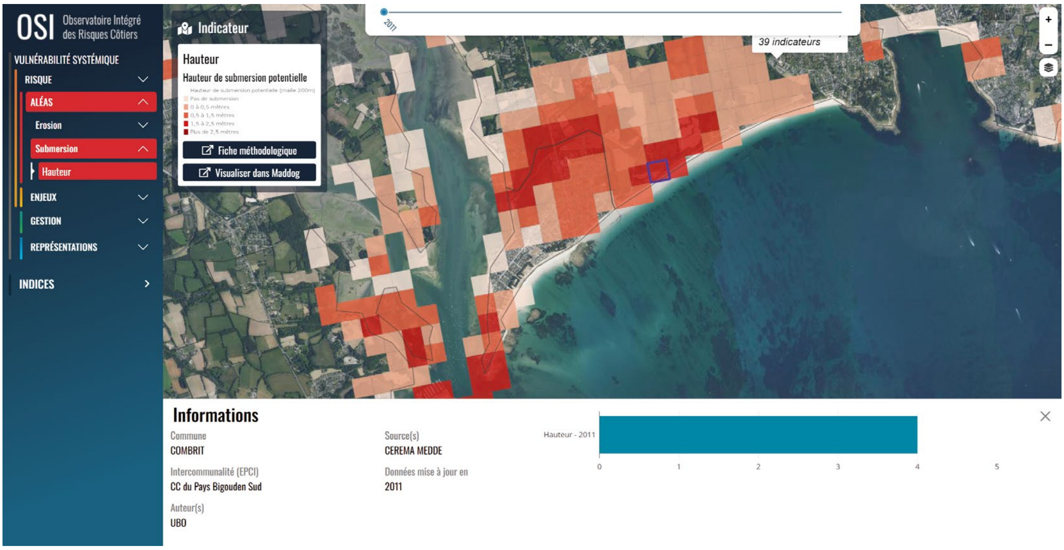

Fig. 10.20 Example of marine flooding indicator on the OSI web-platform interface (Île-Tudy, Brittany, France)

OSI displays each indicator filled in a territory for a given date (Fig. 10.20). The hot spots of high-risk territories are highlighted at both the local and regional levels. Decision-makers therefore have a general vision of the areas where risk reduction efforts should be focused. Based on these indicators, OSI calculates component indices (hazards, exposure, management and social representations). A vulnerability diagnosis can then be produced as the component(s) that most strongly influence vulnerability are highlighted. The action levers are therefore easily identifiable. Coastal risk management can then be based on this diagnosis. Once the management strategy is implemented, a new vulnerability diagnosis is obtained based on the regularly carried out measures of the indicators. This new diagnostic allows to evaluate the effectiveness of the means used to reduce the vulnerability of the coastal territory, while visualizing the evolutions of the other components. While risk management is too often aimed towards reducing hazards through the construction of sea-defences, the diagnosis can reveal the other possibilities such as reducing the exposed elements in the territories, educating citizens about risks, etc. Ultimately, these successive diagnostics define the territory's vulnerability trajectory. OSI is thus meant as a decision support tool for local authorities. OSI is also a scientific tool for geographic analysis and comparison to improve understanding of the changing vulnerability of territories and to improve coastal risks management.

10.6 Interaction with Stakeholders and Risk Management

In the framework of the OSIRISC observatory, the “Litto’Risques” partnership was signed in May 2019, aiming to strengthen the capacities of the local authorities in charge of coastal risks, in particular regarding observation of coastal vulnerability. To support coastal communities, UBO, Cerema and the County Council of Finistère have joined forces to provide methodological, scientific and technical support for the management of coastal erosion and marine flooding risks, through three main missions: coastal observation, expertise for coastline management and awareness-raising on coastal risks. Following the work carried out by the OSIRISC research teams with a co-construction approach between researchers and territorial local authorities, the scientific coordination of the OSIRISC observatory is carried out by UBO and its academic partners on coastal risks, in coordination with the stakeholders in charge of coastal risk management. This partnership aims to pool the skills of the partners in order to enable coastal communities to develop a long-term strategy for managing their coastline. The objectives of the partnership are to:

- contribute to the acquisition of data on coastal risks and to the dissemination of this data at the regional scale of the Finistère County;
- provide support to local authorities in the definition and implementation of their coastal development projects;
- support the coastal communities of Finistère in the definition of a prospective vision of their territory in order to anticipate the evolution of the coastline under the consequences of global change and coastal urbanisation;
- bring together the stakeholders in Finistère who are interested in monitoring coastal vulnerability;
- carry out dissemination and awareness-raising activities on the coastal risks.

Through this approach, there is a two-way sharing of expertise between academics and local authorities, increasing the skills of local stakeholders and disseminating the observation to decision-makers, as well as increasing the regional observation capacities and providing academics with feedback on risk management at an applied level. This is consistent with the twofold objective of addressing research questions and providing operational decision-aid tools. Coastal risk managers (from elected representatives and technical services of local authorities to government services) are both knowledge providers who contribute to monitoring the vulnerability components, and end-users of the results of the analysis of trajectories of systemic vulnerability.

Communities of municipalities can join the partnership with two levels of commitment. At a first level, they are informed of the activities and results of the observatory; they participate in the training sessions and seminars and can be assisted on coastal risk management issues. Membership is strengthened when they undertake the monitoring of vulnerability components in their territory, generally starting with hazards monitoring (Fig. 10.21).

Breton coastal territory managers can collect a certain amount of data that will improve the analysis of the systemic vulnerability of their territory. By providing them with measurement protocols, by helping them to choose appropriate methods and tools and by storing and disseminating information in the form of interactively mapped indicators, OSIRISC observatory is operated as a partnership with local authorities in charge of coastal risk management. A central requirement for the success of the partnership is to provide training on a regular basis, including:

- conceptual training to understand the observation approach, the processes involved or the consequences of a particular management strategy;
- technical training on the implementation of measurement methods and tools or the data processing.

As part of AGEO, technical staff and elected representatives from local authorities were offered several face-to-face training sessions (in classroom or on the field—Fig. 10.22). Online materials were also produced: methodological guides (Partenariat Litto'Risques, 2023a, 2023b, 2023c), video tutorials, Flot'Risco online course, etc. (Fig. 10.23). They are available through the website "Risques Côtiers"[5] (https://www.risques-cotiers.fr/).

Since OSIRISC is the result of co-design between scientists and stakeholders (at all stages, from the design of the methodology based on indicators to the implementation of collaborative monitoring), it enables capacity-building of technical staff and elected officials within local authorities in charge of coastal risks. As deployed within the Litto'Risques partnership, OSIRISC is more than an observatory.

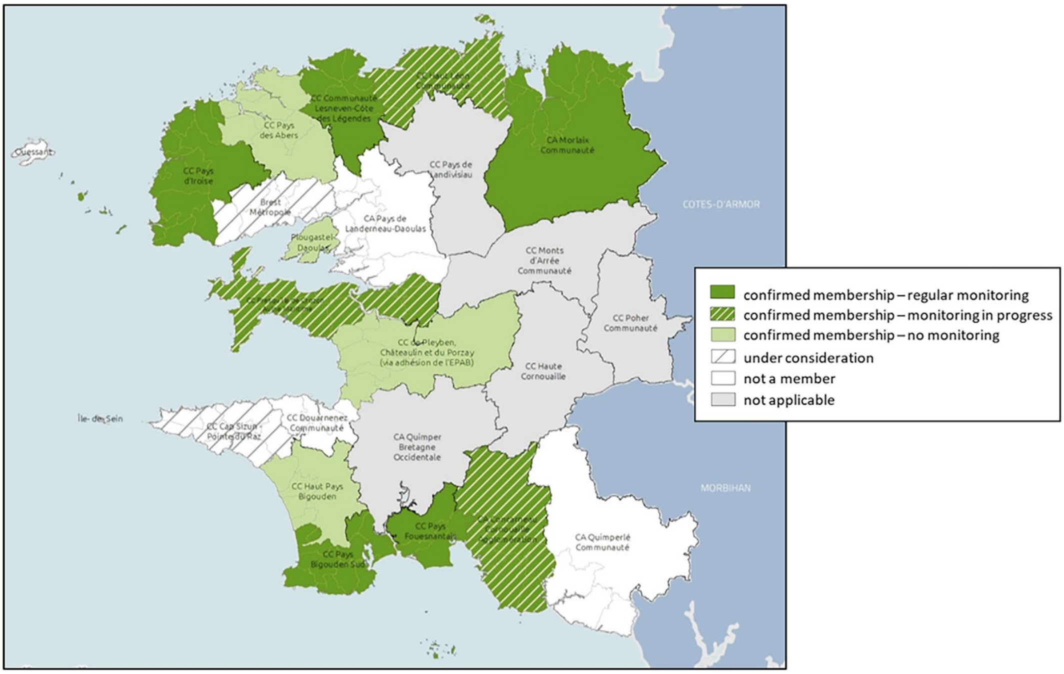

Fig. 10.21 Local authorities members of the Litto'Risques partnership

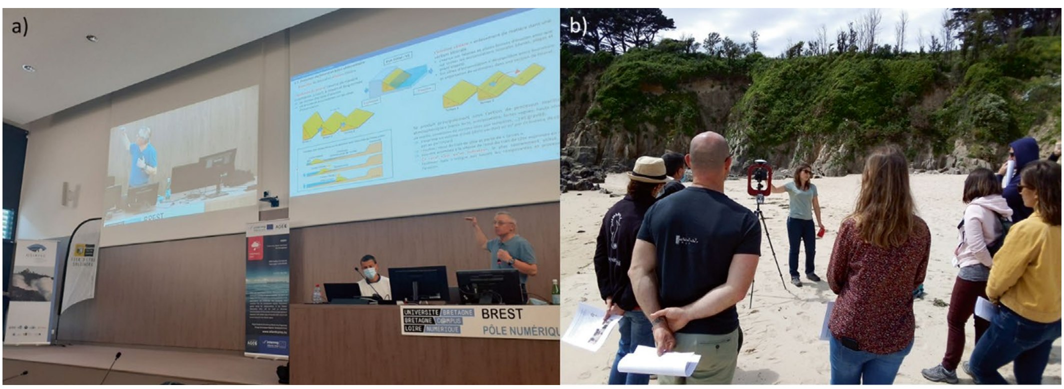

Fig. 10.22 Face-to-face training sessions with coastal risk managers

10.7 Conclusion and Recommendations

The success of OSIRISC observatory relies on the co-construction and the close interaction between academics and local authorities, which requires in-depth involvement of both parties in joint actions (data collection, sharing expertise, …), as well as political support to achieve partnership agreements and engage in long-term observation of the vulnerability of coastal territories. The OSIRISC observatory already concerns many coastal territories in Brittany, mainly in the Finistère County through Litto'Risques partnership. OSIRISC observatory is currently expanding the Litto'Risques partnership model to other coastal territories in Brittany. This approach is intended to be generalised or

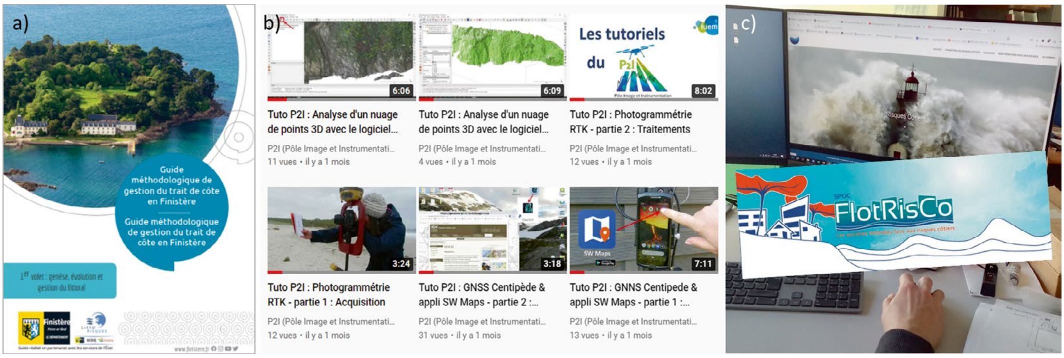

Fig. 10.23 Online training materials: methodological guide (**a**), video tutorials on measurement methods and data processing (**b**), online course on coastal risk management (**c**)

transposed to a larger territory, in Brittany and elsewhere. One of the short-term objectives is to further develop citizen observations, taking advantage of the apps developed thanks to AGEO project: AGEO App and CoastAppli.

Acknowledgements This work has been undertaken in the framework of the INTERREG Atlantic Area AGEO Project (EAPA_884/2018—AGEO).

References

Cerema, Ministère de la Transition écologique et solidaire, 2018. *Cartographie de l'indicateur national de l'érosion côtière*. http://www.geolittoral.developpement-durable.gouv.fr/indicateur-national-de-l-erosion-cotiere-r473.html.

Cerema. (2021). *Dynamiques et évolution du littoral.* Fascicule 4: Synthèse des connaissances du cap de la Hague à la pointe de Corsen. Collection: Connaissances, p. 272.

Cerema. (2021). *Dynamiques et évolution du littoral.* Fascicule 5: Synthèse des connaissances de la pointe de Corsen à la pointe de Chémoulin. Collection: Connaissances, p. 273.

Chaumillon, E., Bertin, X., Fortunato, A. B., Bajo, M., Schneider, J.-L., Dezileau, L., Walsh, J. P., Michelot, A., Chauveau, E., Créach, A., Hénaff, A., Sauzeau, T., Waeles, B., Gervais, B., Jan, G., Baumann, J., Breilh, J.-F., & Pedreros, R. (2017). Storm-induced marine flooding: Lessons from a multidisciplinary approach. *Earth-Science Reviews, 165*, 151–184.

D'Ercole, R. (1994). Les vulnérabilités des sociétés et des espaces urbanisés: concepts, typologie, modes d'analyse. *Revue de Géographie Alpine*, 4, LXXXII, 87–96.

Géoportail IGN. https://www.geoportail.gouv.fr/carte.

GeoBretagne 1950'. https://geobretagne.fr/sviewer/dual.html.

Hédou, F., Roche, A., Trmal, C., Moraud, S., & Deniaud, Y. (2018). Elaboration de l'indicateur national de l'érosion côtière. *XVe Journées Nationales Génie Côtier—Génie Civil*, La Rochelle, 29–31 mai 2018, 648–654.

Hénaff, A., Lageat, Y., Bodéré, J. -C. (2003). *PRIR "EROCOVUL", Erosion et vulnérabilité du trait de côte en Bretagne*. Rapport annuel pour la Région Bretagne, année 3, Géomer LETG UMR 6554 CNRS, p. 43.

Hénaff, A., & Philippe, M. (Eds) (2014). *Gestion des risques d'érosion et de submersion marines, guide méthodologique*. Projet-ANR-10-CEPL-0001Cocorisco, p. 156.

Hénaff, A., Le Cornec, E., Jabbar, M., Pétré, A., Corfou, J., Le Drezen, Y., & van Vliët-Lanoë, B. (2018). Caractérisation des aléas littoraux d'érosion et de submersion en Bretagne par l'approche historique. *Cybergeo: European Journal of Geography* [En ligne], Environnement, Nature, Paysage, document 847. http://journals.openedition.org/cybergeo/29000; https://doi.org/10.4000/cybergeo.29000.

Indigeo: infrastructure de données et d'informations géospatialisées sur l'environnement, UMR LETG, OSU IUEM, ZABrI: https://indigeo.fr/.

Institut Géographique National "Remonter le temps": https://remonterletemps.ign.fr.

Institut National de la Statistique et des Etudes Economiques: https://www.insee.fr

Le Berre, I., Meur-Ferec, C., Cuq, V., Guillou, E., Lami, T., Dantec, N., Letortu, P., Lummert, C., Philippe, M., Rouan, M., Noûs, C., & Hénaff, A. (2022). Systemic vulnerability of coastal territories to erosion and marine flooding: A conceptual and methodological approach applied to Brittany (France*)*. *International Journal of Disaster Risk Reduction, 78*, 103122. https://doi.org/10.1016/j.ijdrr.2022.103122

Meur-Ferec, C., Le Berre, I., Cocquempot, L., Guillou, E., Hénaff, A., Lami, T., Le Dantec, N., Letortu, P., Philippe, M., & Noûs, C. (2020). Une méthode de suivi de la vulnérabilité systémique à l'érosion et la submersion marines. *Développement Durable Et Territoires [en Ligne], 11*, 1. https://doi.org/10.4000/developpementdurable.16731

Partenariat Litto'Risques. (2023). *Guide méthodologique de gestion des risques littoraux en Finistère—Volet 1: genèse, évolution et gestion du littoral, p.* 84.

Partenariat Litto'Risques. (2023*). Guide méthodologique de gestion des risques littoraux en Finistère—Volet 2: méthodologie de gestion des risques littoraux*, p. 196.

Partenariat Litto'Risques. (2023). *Guide méthodologique de gestion des risques littoraux en Finistère—Volet 3: recensement et retours d'expérience sur les solutions mises en oeuvre sur le territoire du Finistère dans la gestion du trait de côte, p.* 216.

Philippe, M., & et Hénaff A. (coord.) (2021). *Expérimentation pour un observatoire régional de la vulnérabilité aux risques côtiers en Bretagne. Projets OSIRISC et OSIRISC+*. UBO, CNRS, Cerema. Soutenus financièrement par la Fondation de France et la DREAL Bretagne. 84 p + annexes. https://doi.org/10.48386/POPS-1519.

Poupard, G. (2017). L'urbanisation du littoral : Un essouflement?—L'exemple de la Bretagne. *Population & Avenir, 733*, 4–8.

Hénaff A, Meur-Ferec C, Lageat Y (2013) Changement climatique et dynamique géomorphologique des côtes bretonnes. Leçons pour une gestion responsable de l'imbrication des échelles spatio-temporelles. Cybergeo: European Journal of Geography [En ligne], Environnement, Nature, Paysage, document 654, http://journals.openedition.org/cybergeo/26058; https://doi.org/10.4000/cybergeo.26058

Stéphan, P., Blaise, E., Suanez, S., Fichaut, B., Autret, R., Floc'h, F., Madec-Cuq, V., Le Dantec, N., Ammann, J., David, L., Jaud, M., & Delacourt, C. (2019). Long, medium, and short-term shoreline dynamics of the Brittany coast (Western France). *Journal of Coastal Research*, SI 88, 89–109. ⟨https://doi.org/10.2112/SI88-008.1⟩.

Vinet, F., Defossez, S., Rey, T., & Boissier, L. (2012). Le processus de production du risque "submersion marine" en zone littorale : l'exemple des territoires "Xynthia." *Norois, 222*, 11–26. https://doi.org/10.4000/norois.3834

Open Access This chapter is licensed under the terms of the Creative Commons Attribution 4.0 International License (http://creativecommons.org/licenses/by/4.0/), which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons license and indicate if changes were made.

The images or other third party material in this chapter are included in the chapter's Creative Commons license, unless indicated otherwise in a credit line to the material. If material is not included in the chapter's Creative Commons license and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder.