1. Title

Study of the impacts of extreme events on morphosedimentary changes of sandy/gravel coasts of the Western Iceland

2. Research unit

LETG UMR 6554 CNRS

3. Supervision

Co-supervision 50/50 % : Serge SUANEZ (Université de Bretagne Occidentale) and David DIDIER (Université du Québec à Rimouski)

4. Coordinates of thesis co-directors

Serge SUANEZ, laboratory LETG UMR 6554 CNRS, Institut Universitaire Européen de la Mer (Université de Bretagne Occidentale), rue Dumont d'Urville, 29280 Plouzané, France. Email : serge.suanez@univ-brest.fr ; Telephone : +33 (0)2 98 49 86 10

David DIDIER, Université du Québec à Rimouski, Department of Biology, Chemistry and Geography, 300 allée des Ursulines, C. P. 3300, succ. A, Rimouski (Canada). Email : David_Didier@uqar.ca ; Telephone : 1-418-318-0143

5. Scientific context, objectives and interest

This proposal for a thesis topic entitled "Study of the impacts of extreme events on morphosedimentary changes of sandy/gravel coasts of the Western Iceland", is led by researchers from three laboratories with long-standing collaborations: Serge Suanez from LETG UMR 6554 CNRS-UBO (co-direction), David Didier from the Department of Biology, Chemistry and Geography of the Université du Québec à Rimouski - UQAR (co-direction), Guillaume Dodet from LOPS UMR 6523 CNRS-UBO/IFREMER/IRD (scientific supervision), Pierre Stéphan from LETG UMR 6554 CNRS (scientific supervision). It is a continuation of three research projects: (i) PROTEVS (2013-2018) led by SHOM, and the two UMRs LETG and LOPS, whose objective was to improve the knowledge of oceanic and coastal marine environments from the coupling between sea state (waves) and ocean circulation on a larger scale, (ii) EXTREMEVENT started in 2014 with funding from LabexMER and the Institut Paul Emile Victor (IPEV), led in particular by UBO and UQAR, whose objective is to study the coastal morphodynamic processes of the Reykjanes peninsula (SW Iceland), and (iii) Sea state Climate Change Initiative (2018-2021) funded by the European Space Agency and piloted by LOPS, whose objective is to exploit the archive of satellite observations to study the climate variability of sea states over the last three decades.

Iceland is located in the zone of influence of extra-tropical storms in the North Atlantic, and is regularly impacted by strong waves developing from the cyclo-genesis zone in the northwest Atlantic (Betts et al., 2004). This strong tempetuosity is at the origin of particularly virulent coastal morphogenic dynamics, especially along the southern and western coasts (Etienne and Paris, 2010; Autret, 2018). In recent years, the combination of extreme waves (e.g., significant height > 15 m) with particularly high water levels in the passage of atmospheric depressions have caused major damage, forcing evacuations in some cases (Geirsdóttir et al., 2014; Viggósson et al., 2016). However, meteo-marine extreme events are still poorly known due to the low number of *in situ* observations available. As a consequence, the parameterizations of numerical sea state forecasting models - indispensable tools

for coastal management - are relatively unconstrained for these conditions and still present significant margins of uncertainty (Ardhuin et al., 2019). Spatial altimetry, which has been collecting sea state measurements with near-global coverage since the 1990s, thus represents a tremendous opportunity to complete existing databases and improve the prediction of extreme sea states (Dodet et al., 2020). This context thus offers a very stimulating study framework both from the point of view of the study of extreme hydrodynamic forcing and from the point of view of extreme morphosedimentary dynamics, especially since these aspects have never before been studied at the scale of the Icelandic sandy/gravel coasts.

The area of study selected for this thesis extends over the two regions of Vesturland and Vestfirðir located in the west of Iceland, between 64°20' and 65°30' N. The specificity of this area lies in the fact that it is made up of large sand and gravel barriers and/or spits directly exposed to the oceanic flows from west to southwest. These forms of accumulation extend from Akranes to Arnarstapi (Snæfells peninsula), including the southern coast of the Western Fiords Peninsula located further north. The high mobility of these sandy/gravel coasts is therefore a good indicator for the study of extreme events in these sub-polar latitudes, especially since the absence of anthropization that characterizes them makes them subject only to natural dynamics.

This thesis project is concerned by three main objectives. The first objective will focus on the study of the conditions of extreme sea states off Iceland. The first objective will be to identify, from satellite archives and in situ data, the major storms that have potentially had a morphogenic impact on the Icelandic sandy/gravel coasts. For this purpose, the *in situ* and satellite databases recently developed at LOPS in the framework of the Sea State CCI project will be exploited and will make it possible to catalog the most energetic sea state conditions observed off Iceland over the period 1992-2020. In a second step, these observations will be compared with numerical simulation results and the analysis of the validated model results will allow to precisely characterize the hydrodynamic conditions at stake during the main morphogenic events observed in the field during the thesis period. For this purpose, the retrospective wind and wave simulations produced by the European Centre for Medium-Range Weather Forecasts (ECMWF) and Ifremer will be exploited.

The second objective will concern the study of long-term morpho-sedimentary changes in response to hydrodynamic forcing and will be based on the multi-decadal analysis of the kinematics of the shoreline by photo-interpretation. The objective is to reconstruct historical changes in morphological indicators (such as the position of the shoreline) using digital processing of documents (maps), aerial photographs, and high-resolution satellite imagery. For the recent period, this work will be based on higher frequency topo-morphological monitoring carried out on certain sites representative of the diversity of morphological and sedimentological conditions, and of exposure to hydrodynamic forcing. These field surveys will be carried out within the framework of annual missions carried out by the PhD student; it will also involve the use of "local forces" (master's internships and others) within the framework of collaborations established with the University of the Western Fjords in order to increase the frequency of observations.

The third and last objective will concern the study of the coastal hydrological dynamics in order to make the link with the observed morphological changes, in particular over the observation period of the thesis. This work will be carried out from comparative analyses of *in situ* (site-scale) measurements of water levels and waves at the coast from submerged instruments (pressure sensors, ADCP, etc.), and from tide gauge and wave recordings made continuously by the Icelandic Road and Coastal Administration along the west coast of Iceland. This work will also be based on the deployment of video systems on very dynamic sites selected in advance with the local authorities, in order to study the dynamic processes acting from the surf zone to the swash zone (wave runup and setup). The analysis of the control of these forcings in the morphosedimentary dynamics of the studied beaches will constitute an important point in the understanding of the processes acting at the episodic scale, in particular of the stormy event.

Reférences

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6. Project Summary

The thesis project entitled « Study of the impacts of extreme events on morphosedimentary changes of sandy/gravel coasts of the Western Iceland » is part of a research project entitled EXTREMEVENT started in 2014 with funding from LabexMER (ANR-10-LABX-19-01) and the Institut Paul Emile Victor (IPEV), bringing together the universities of “Bretagne Occidentale” and “du Québec à Rimouski”. The study of the morphodynamic processes of the sandy/gravel coasts of the Western Iceland is of great scientific interest because (i) Iceland is on the trajectory of a large part of the extra-tropical storms of the North Atlantic, and generally undergoes the impact of highly developed sea states from their generation zone along the western margin of the Atlantic, (ii) the study area extends from Akranes to Arnarstapi (Snæfells peninsula), including the southern coast of the Western Fiords Peninsula located further north, is made up of large sand and gravel barriers and/or spits that are extremely mobile under the action of extreme stormy events, (iii) the absence of anthropization of these sandy/gravel coasts means that they are only subject to natural dynamics, and finally (iv) the whole of this coast area, and more generally, this problem applied to Icelandic sandy/gravel coasts, has never yet been studied. This thesis project is concerned by three main objectives. (i) The study of long-term morpho-sedimentary changes in response to hydrodynamic forcing will be based on the multi-decadal analysis of the kinematics of the shoreline by photo-interpretation. It will also be based on higher frequency topo-morphological monitoring carried out on certain sites representative of the diversity of morphological and sedimentological conditions and exposure to hydrodynamic forcing. (ii) The study of coastal hydrological dynamics, particularly stormy ones, will be carried out through a combination of *in situ* measurements of water levels and waves at the coast, and through the instrumentation of video cameras on very dynamic sites previously selected with the local authorities. Analyses of the control of offshore forcing on the dynamic processes on the beaches (wave runup and setup) will be carried out in order to better understand the conditions controlling the observed morphological changes. (iii) Finally, the work will aim at defining in a more relevant way the extreme stormy conditions of offshore sea which intervene in the morphodynamics of the sandy/gravel beaches studied. It will be a question of exploiting the satellite observation databases of sea states, in conjunction with the measurements of the wave record buoys in operation along the south and west coasts of Iceland. Comparisons will also have to be carried out with retrospective wave and wind simulations obtained by modelling. This thesis work will benefit from local collaborations already established in the framework of the EXTREMEVENT project with the University Centre Of The Westfjords and the public service Vegagerdin (Icelandic Road and Coastal Administration) located in Reykjavik.

7. Partnership

As previously mentioned, this thesis project is carried by the two laboratories LETG UMR 6554 CNRS (Serge Suanez and Pierre Stéphan) and LOPS UMR 6523 CNRS-UBO/IFREMER/IRD (Guillaume Dodet) of the Université de Bretagne Occidentale, and the Department of Biology, Chemistry and Geography of the Université du Québec à Rimouski - UQAR (David Didier). To this partnership is added the LGO UMR 6538 CNRS, in the person of Jérôme Ammann, who participates since 2018 in the EXTREMEVENT project as a research engineer specialized in the piloting of airborne platforms (UAVs) and stereoscopic image data processing. This thesis project is also part of the partnership established for several years with Icelandic academic and/or public organizations such as the University Centre Of The Westfjords, in the person of Bjoern Erlingsson, specialized on meteorological and marine submersion aspects, and the public service Vegagerdin (Icelandic Road and Coastal Administration) of Reykjavik, in the person of Sigurður Sigurðarson, in charge of the management of coastal hydrological measurements (wave and tide).