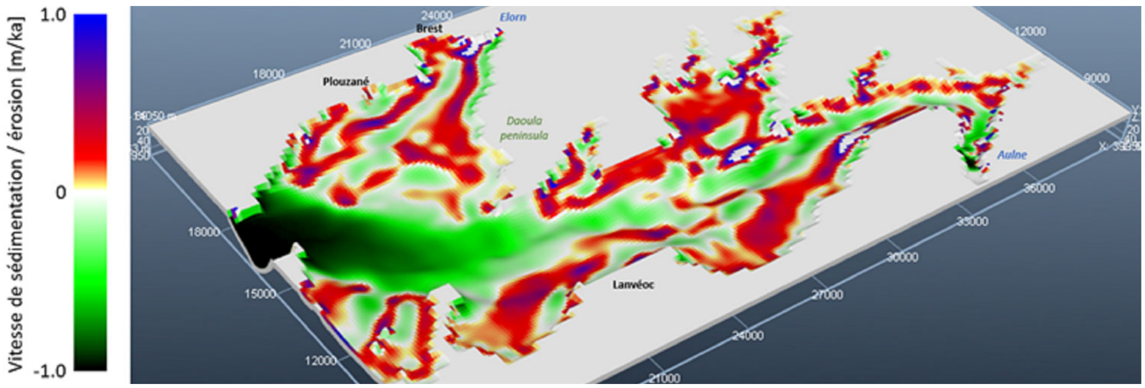

Written on 26 September 2022

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News

Fundamental Research

Geosciences

Coastal areas and particularly estuaries are exposed to tidal currents and waves that have a significant influence on erosion and sedimentary transport and consequently the evolution of their morphology over centuries and millennia. These phenomena depend on the sea level, which can vary, particularly during periods of climate change such as the one we are currently experiencing. A PhD thesis applied to the Bay of Brest provides a better understanding of these different processes and details their long-term effects on coastal dynamics and morphology.

High-resolution but short-term scale hydro-sedimentary models

In the 1990s, a number of 3D hydro-sedimentary numerical models were developed to simulate **the impact of the tide and waves on coastal areas**, quantifying the movements of water masses as well as sedimentary erosion, transport and deposit. These simulations are conducted for time steps of about an hour and for a spatial resolution of around one hundred meters. They provide a detailed description of the evolution of coastlines, ports and estuaries over periods of time ranging from a few months to a few years, but **they cannot be applied for longer periods beyond around ten years**. That is because these high-resolution numerical models were built **on the basis of the time stationarity of sedimentary systems** and so they are not valid for large time-scales. While coasts are sensitive zones in the current context of climate change, their long-term morphodynamic evolutions (from a few decades to several millennia) and interactions with the tide remain poorly understood and poorly modeled.

A combination of different modeling approaches to understand the long-term impact of tides

The question of **the long-term impact (9,000 years) of the tide** on currents, sedimentary transport and dynamics and topography at estuary level was the focus of a doctoral thesis [1]. The impact of tide was studied by using **a combination of hydrodynamic and hydro-sedimentary modeling**, with reconstitutions of the geological evolution of the bay considered.
The principal aim of the thesis was to provide **a better description of an estuary's evolution over centuries, or even millennia**. The focus of the study and modeling was the Bay of Brest, a macrotidal [1] estuary protected from waves, where the tidal range can currently be as much as 7 m (figure 1). Moreover, 9,000 years ago, the sea level was 25 meters lower than it is currently and a fluviatile[2] system covered the entire bay area. Over the course of the past 9,000 years, the Bay of Brest has been gradually submerged and a system of marine terraces has progressively become established. Examination of the sediments deposited over the course of the last glacial cycle therefore provided an opportunity to understand **the interaction between sea level, tide and sedimentary dynamics**.

[1] Qualifies a coastal zone environment exposed to significant tidal ranges (in excess of 4 meters)
[2] Relating to rivers and water courses

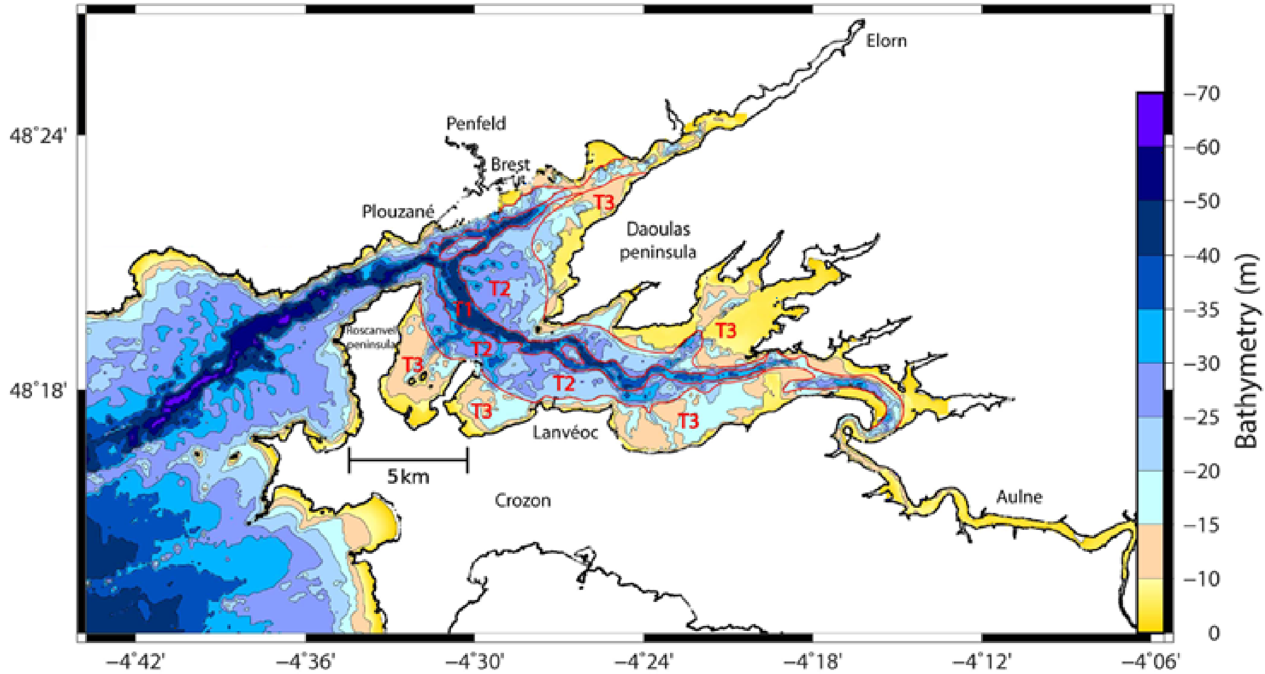

Figure 1: Current bathymetry of the Bay of Brest [1]

A three-step methodology

Three steps were required to produce a detailed model of the evolution of the Bay of Brest:

1/ The evolution of the Bay of Brest during the last Holocene glaciation was described by recreating its morphology and the deposit environments at four key stages of its submersion and that of the marine terraces [2]. To do so, a detailed sedimentary analysis was conducted using seismic data and coring.

2/ The ocean currents induced by the tide and their impacts on sedimentary erosion, transport and deposit were simulated for each stage with Mars 3D hydrodynamic models (figure 2), followed by Mustang hydro-sedimentary models, both developed by Ifremer; each simulation was conducted for time steps of 30 minutes for a total simulated period of 2 years, and with a spatial resolution of 250 meters [2].

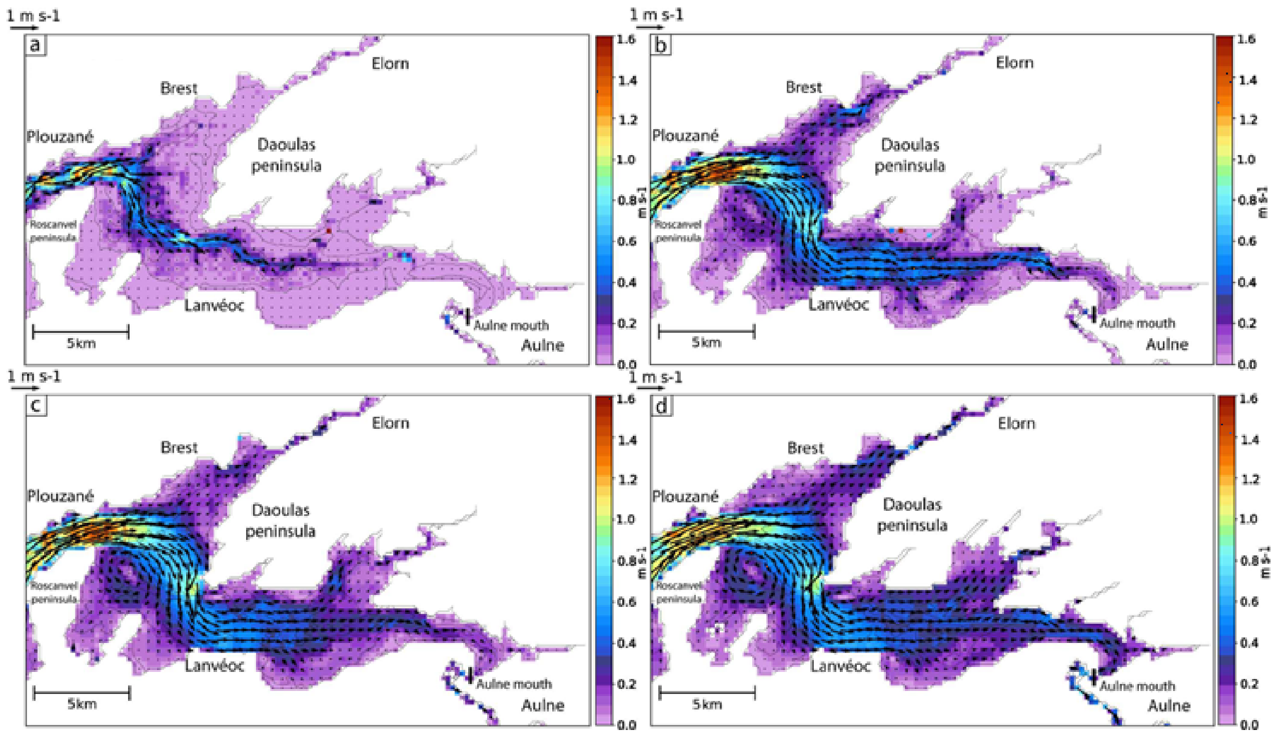

Figure 2: Hydro-sedimentary numerical modeling of flow currents conducted with Mars 3D (Ifremer software), with four key stages of the submersion of the Bay of Brest [2]: (a) 9,000 years BP (before present), sea level = -26 m compared to current level; (b) 7,500 years BP, sea level = -10 m; (c) 7,000 years BP, sea level = - 5 m; (d) today.

3/ A spectral analysis of the evolution of the seabed of the bay was then carried out in order to identify the characteristics of **extreme events, known as morphogenetic tides, primarily responsible for sedimentary dynamics** [1]. The identification of these morphogenetic tides made it easier to take into account the temporal evolution of tides, and to replace its hourly evolution by the definition of the scale and frequency of these extreme events. The ocean currents induced by these morphogenetic tides were then used in the DionisosFlow stratigraphic model, developed by IFPEN, in order to simulate the bay's evolution over a period of several years. These low-resolution stratigraphic simulations (time step = 1 year, spatial resolution = 250 m) are essential for studying an estuary's evolution over long periods (from a few decades to several centuries), and being able to compare the results of hydrodynamic simulations with sedimentary records.

An evolving model of the Bay of Brest that takes into account climate variability

LThe results of this comparison between hydro-sedimentary modeling and sedimentary observations are very encouraging and led to **the first stratigraphic simulation of the evolution of the Bay of Brest seabed** [3]. By drawing on the results of Mars 3D and Mustang hydro-sedimentary modeling, and assuming a constant climate over a period of 10,000 years, the PhD thesis research made it possible to estimate the erosion or sedimentation speed in the bay (figure 3). This first combined hydro-sedimentary and stratigraphic simulation shows the potential of the approach adopted **for evaluating the long-term evolution of an estuary as a function of climate scenarios**.

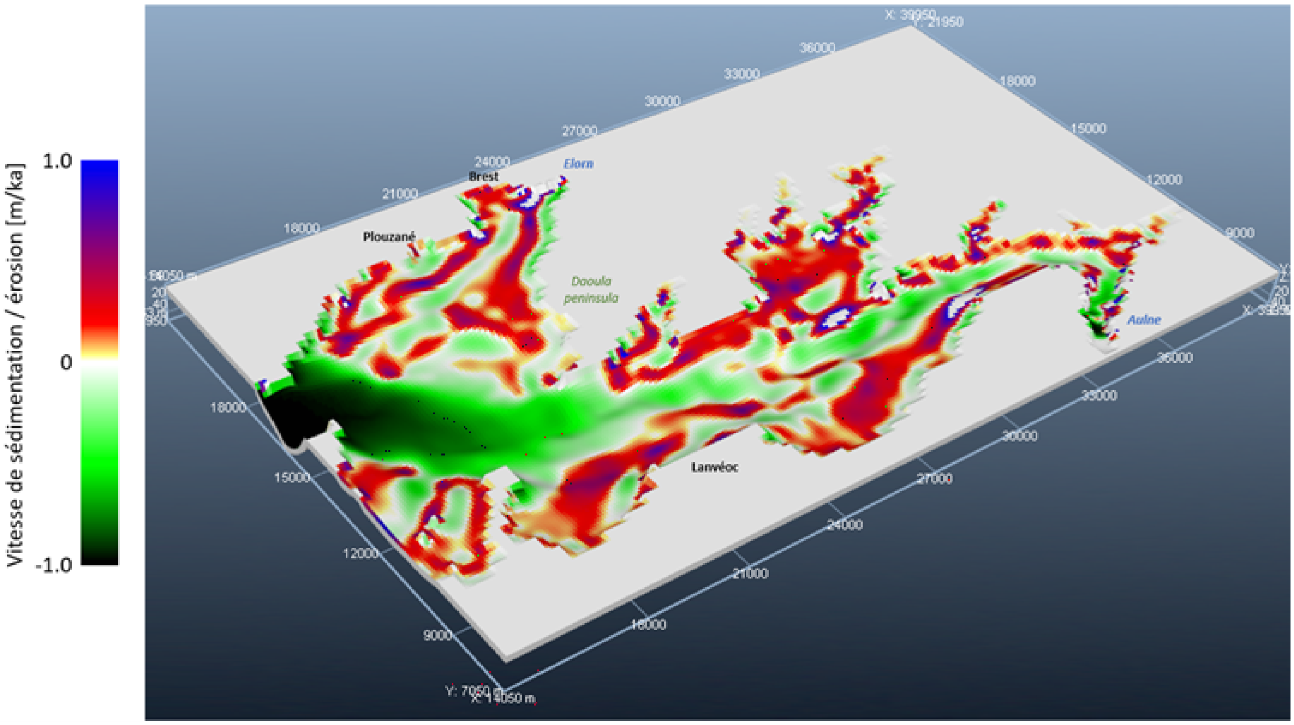

Figure 3: Stratigraphic numerical modeling of the evolution of the seabed at the Bay of Brest conducted with DionisosFlow (IFPEN software), based on numerical ocean current modeling [3]

Références:

[1] M. Olivier, Numerical modelling of the impact of tidal currents over the long-term: application to Holocene sedimentary records from the bay of Brest, thèse de doctorat soutenue à l'Université de Bretagne Ouest (UBO) le 10 mai 2022. Co-encadrée par IFREMER, IFPEN et UBO.

[2] M. Olivier, E. Leroux, M. Rabineau, P. Le Hir, D. Granjeon, T. Chataignier, A. Beudin, H. Muller, (2021), Numerical modelling of a Macrotidal Bay over the last 9,000 years: An interdisciplinary methodology to understand the influence of sea-level variations on tidal currents in the Bay of Brest. Continental Shelf Research 231, 104595. https://doi.org/10.1016/j.csr.2021.104595

[3] M. Olivier, E. Leroux, P. Le Hir, M. Rabineau, D. Granjeon, H. Muller, (soumis) Numerical Modelling of Tidal Sediment Dynamics in the Bay of Brest over the Holocene: How the Use of a Process-Based Model over Paleoenvironmental Reconstitutions can Help to Understand Long-term Tidal Deposits ?

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