Unraveling hypoxia events in a context of climate change in the Bay of Vilaine, France

Coline Poppeschi[1], *Anne Daniel*[2] *and* Guillaume Charria[1]

[1] *Ifremer, Univ. Brest, CNRS, IRD, Laboratoire d'Océanographie Physique et Spatiale (LOPS), IUEM, Brest, France.*
[2] *Ifremer, DYNECO, Pelagic Ecology Laboratory (PELAGOS), 29280 Brest, France*

AIMS

- To detect hypoxia events at high frequency with a low-tech instrumentation during 4 years
- To determine the physical conditions that can lead to hypoxia events with a high resolution numerical simulation
- To study interaction between surface phytoplankton blooms, stratification and hypoxia

1. INTRODUCTION

This study explores the physical processes that promote episodic hypoxia in a shallow coastal ecosystem under the influence or river plumes with high nutrient inputs.
The bay of Vilaine is known for recurrent hypoxic events since the 1980s[1] and as France's main shellfish-growing region[2]. Massive algal blooms are observed in recent years[3] in the bay.
By using high frequency measurements on subsurface and bottom waters with 3D simulations, stratification implementation is describe in the bay.

2. METHODOLOGY

- **Ocean *in situ* high-frequency observations**[4,5]

COAST-HF MOLIT buoy: 20min sampling of physical & biogeochemical parameters
Mastodons: 10min sampling of physical, biogeochemical & biological parameters

- **Rivers *in situ* observations**

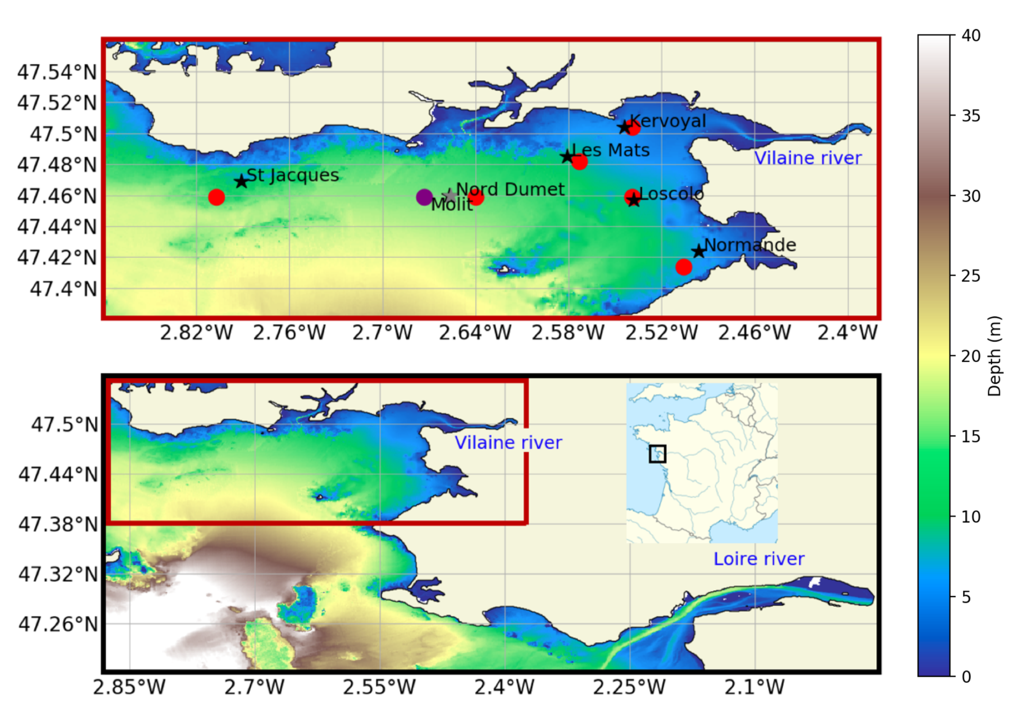
Average discharge: Vilaine & Loire rivers (HydroFrance)

- **Meteorological *in situ* observations**

Mean daily wind: Guipavas station (Météo-France)

- **3D Numerical model simulation – CROCO**[3] ★

GAMAR configuration[6,7] – 1km resolution



Location of the sampling sites

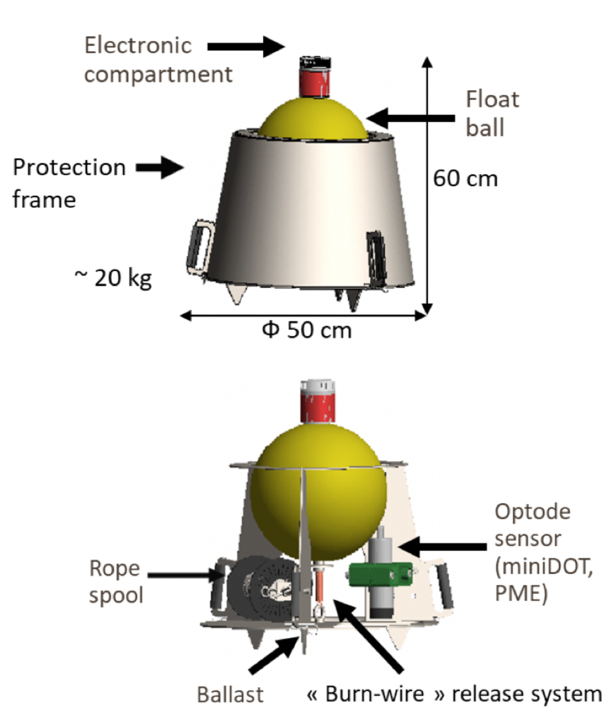


Illustration of Mastodon oxygen mooring system

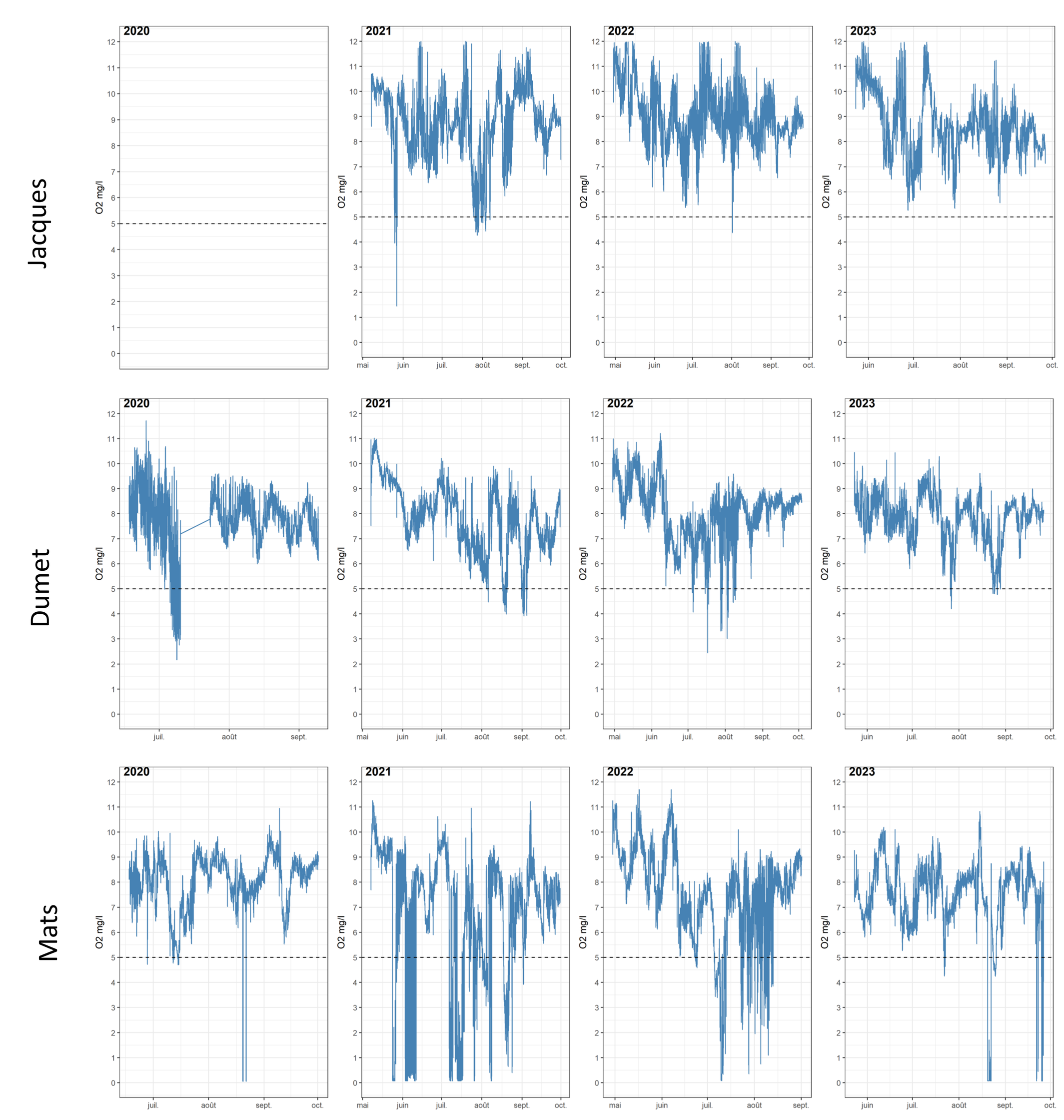
The **Mastodon Oxygen mooring systems** are low-cost instruments, equipped with PME miniDOT® loggers to measure **dissolved oxygen concentrations at 15 cm above the sediment**. Deployed in the Bay of Vilaine from **2020 to 2023** on **6 sites** located along a dilution gradient of the Vilaine plume, with 3 of them very close to shellfish farms, measurements are taken every **10 minutes** from **May to September**.

The stratification index is calculated as follows:

$$\text{Stratification index} = \frac{\rho_{bottom} - \rho_{surface}}{\rho_{bottom}}$$

To evaluate the stratification driver (temperature or salinity gradients), density is computed considering a constant temperature (summer mean surface temperature over the whole time period 2001-2023) to compute density variations due to salinity gradients and considering a constant salinity (summer mean surface salinity over the whole time period 2001-2023) to compute density variations due to temperature gradients.

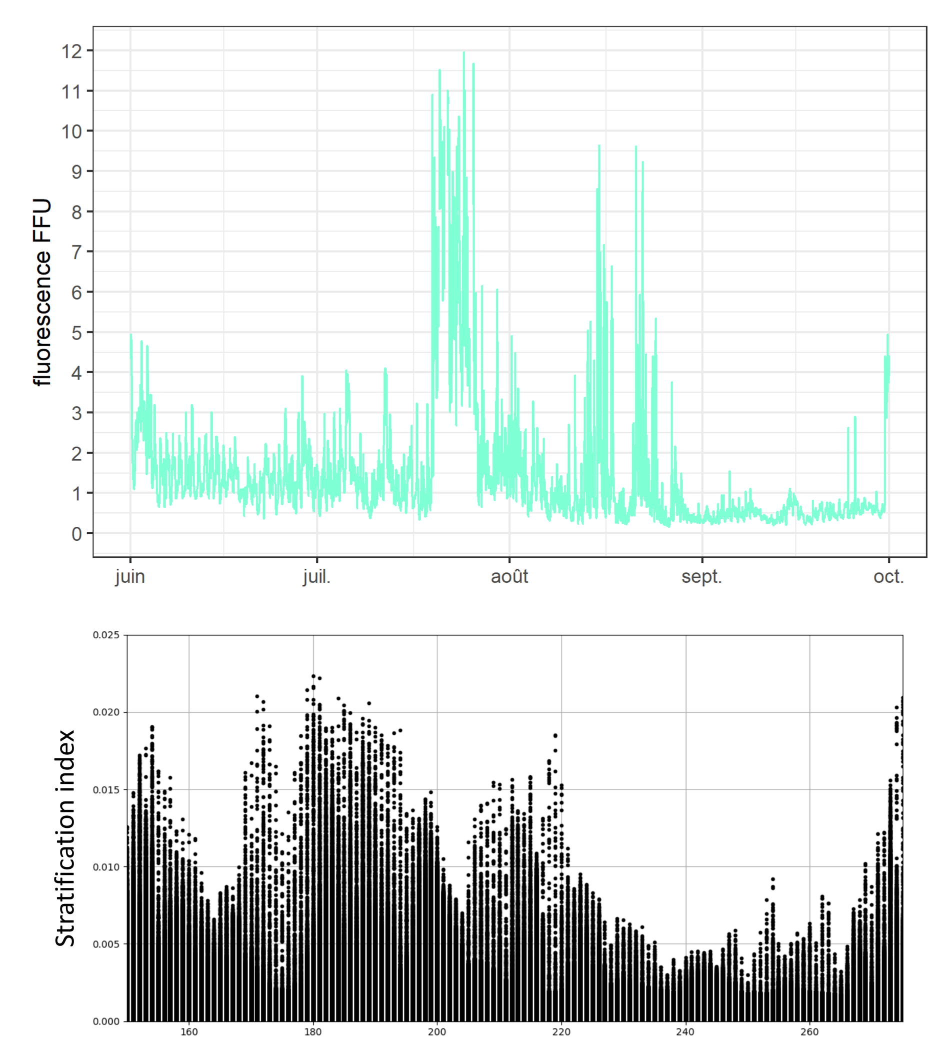
3. HYPOXIA EVENTS in the Bay of Vilaine



Oxygen time series from three mastodon moorings located on the Vilaine plume (bottom = estuary, top = large) between 2020 and 2023

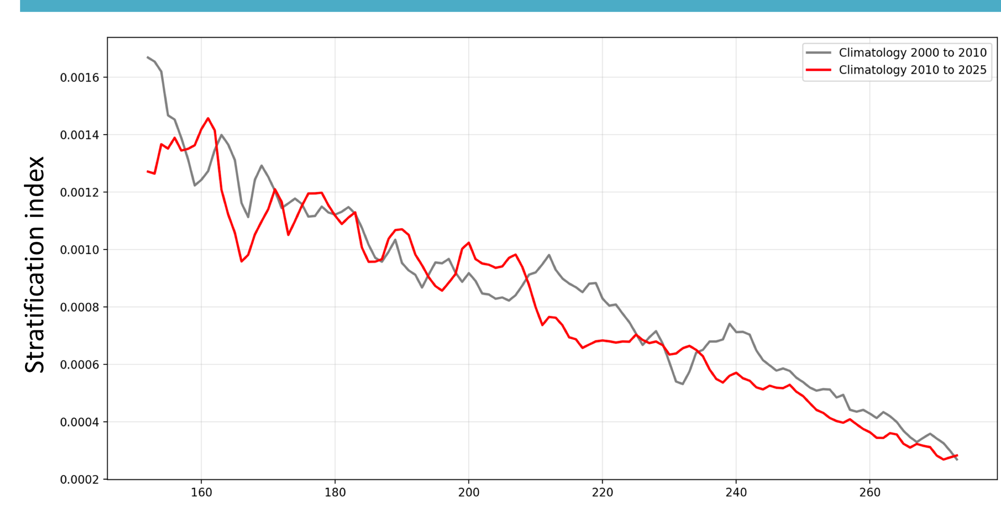
4. STRATIFICATION

❖ Interaction between fluorescence and stratification at the MOLIT buoy



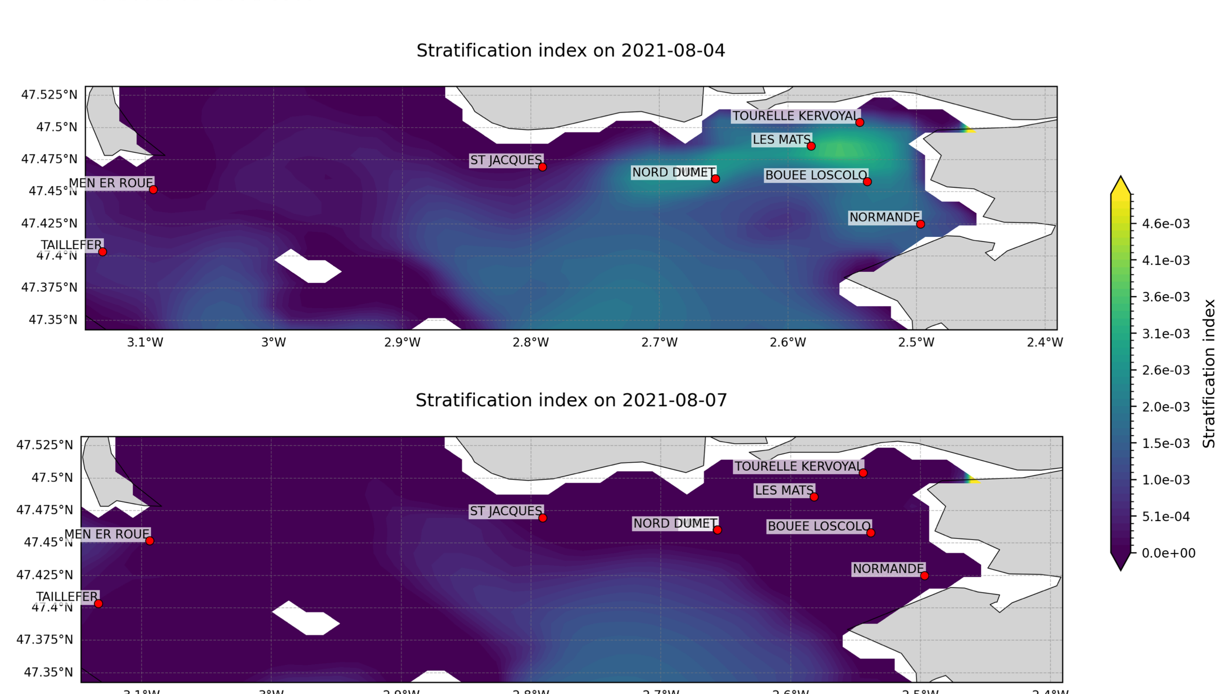
Fluorescence data at MOLIT buoy (top) and stratification index in summer 2021 (bottom)

5. TEMPORAL AND SPATIAL EVOLUTION OF STRATIFICATION



Stratification index evolution from one decade to another

- Variability of stratification in the last two decades are similar so no trend is shown

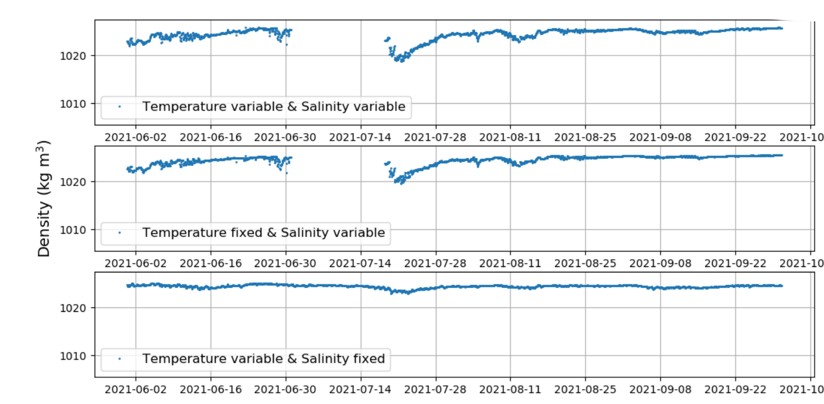


Stratification index during hypoxic event of early August 2021 during the event (top) and after (bottom)

- Shifting stratification during hypoxic events: the example of the early August 2021 event and highlighting preferential stratification zones in the bay

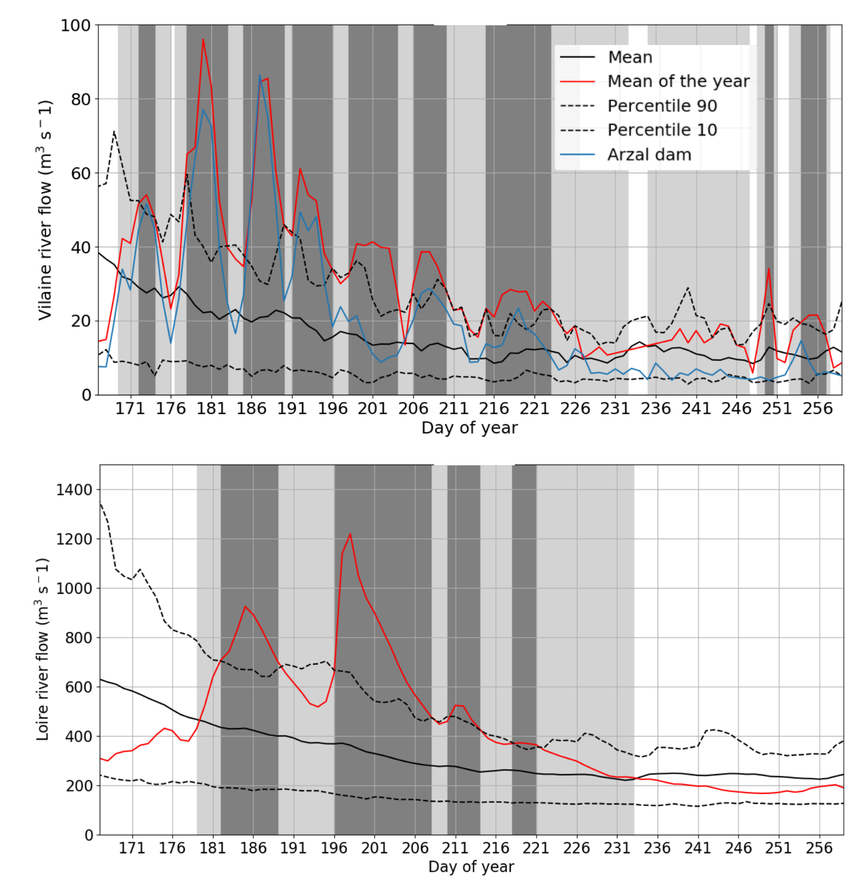
6. Which parameters are responsible for stratification in the Bay of Vilaine ?

- Salinity is the principal parameter driving salinity in the bay



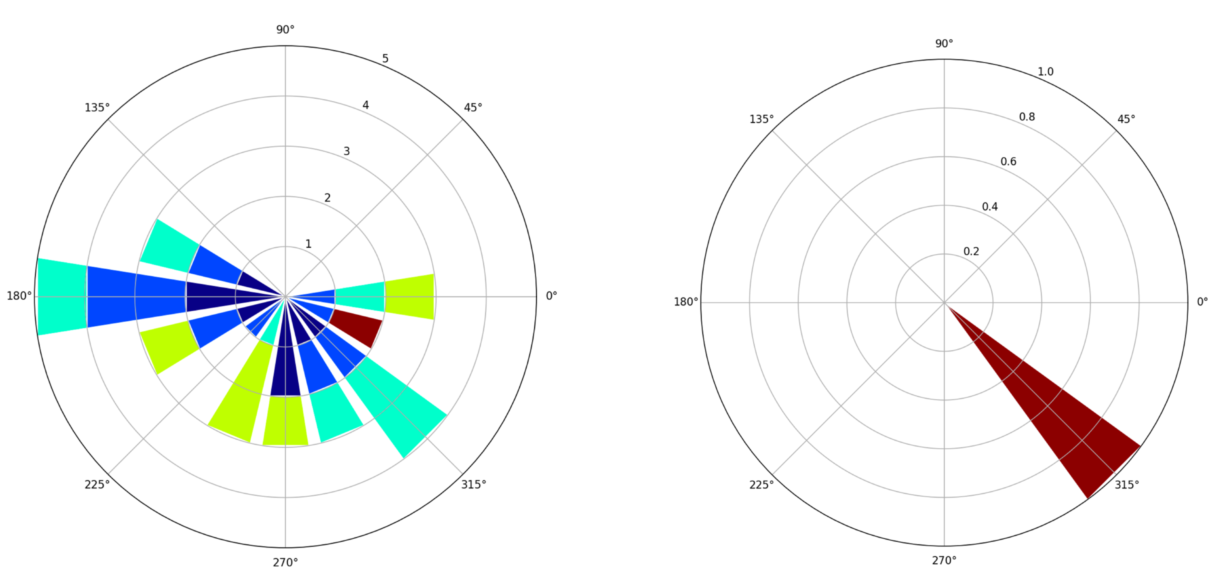
Tests of temperature and salinity impacts on density at the surface at MOLIT buoy

- Rivers and wind play a role too by increasing salinity stratification



Vilaine (top) and Loire (bottom) rivers during mean conditions and during the summer 2021 as example

❖ The influence of the Loire and Vilaine rivers, with flooding during the summer of 2021, has enabled the haline stratification to take place



Wind conditions for all summers (left) and during the week before the early August 2021 event (right)

❖ The average wind direction is between 180 and 315 degrees, whereas during the early August 2021 event it is only at 315 degrees, allowing the freshwater plume to spread out in the bay and extend the stratification especially over the northern zones

CONCLUSION

- **Combined study of high frequency low cost measurements with high resolution modelling allow inferring Bay of Vilaine oxygen dynamics**
- **Stratification plays a key role on hypoxic events**
- **Salinity is the most important parameter for stratification in the Bay of Vilaine**
- **Wind drive spatial repartition of stratification in the bay**

Acknowledgments and References:

In situ observations were provided by the COAST-HF (http://www.coast-hf.fr) network from the ILICO research infrastructure. Data processing and figures have been partly performed using the open-source Python library VACUMM (http://www.ifremer.fr/vacumm/) and the Geographical Information System (QGIS - http://www.qgis.org). We also thank Météo-France as well as HydroFrance for provided wind and river data.

[1] Merceron, M. 1984. Baie de Vilaine: juillet 1982 mortalité massive de poisons. Equinoxe 21.
[2] Chapelle, A., Lazure, P., Menesguen, A. 1994. Modelling eutrophication events in a coastal ecosystem. Sensivity analysis. Est. Coast & Shelf Sci. 39(6). https://doi.org/10.1016/S0272-7714(06)80008-9
[3] Mertens, K., Retho, M., Manach, S. et al. 2023. An unprecedented bloom of Lingulodinium polyedra on the French Atlantic coast during summer2021. Harmful Algae 125 (102426). https://doi.org/10.1016/j.hal.2023.102426
[4] Farcy, P., Durand, D., Charria, G. et al. 2019. Toward a European coastal observing network to provide better answers to science and to societal challenges; the JERICO research infrastructure. Front. Mar. Sci. 6 (529). https://doi.org/10.3389/fmars.2019.00529
[5] Lazure, P., Le Berre, D., Laurent, G. 2015. Mastodon Mooring System To Measure Seabed Temperature Data Logger With Ballast, Release Device at European Continental Shelf. Sea Technology. http://archimer.ifremer.fr/doc/00292/40319/
[6] Auclair, F., Benshila, R., Bordois, L. et al. 2024. Coastal and Regional Ocean Community model. Zenodo.
[7] Martinez Almoyna, M., Charria, G., Sourisseau, M. et al. 2025. Temporal scales of variability in Regions of Freshwater Influence on the French continental shelf over two decades. J. Mar. Syst. 24. https://doi.org/10.1016/j.jmarsys.2025.104068