Nonlinear evolution of the internal tide on the Armorican Shelf

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Composante : Master Water and Wind Engineering **Nature du financement demandé** : Stage de M2
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Résumé : La campagne Solmineur du SHOM en juillet 2027 a permis obtenir un jeu de données complet (courants, stratification) sur la dynamique de la marée interne sur le Plateau Armoricain. La modélisation des ondes de gravité internes, que ce soit via des équations shallow-water, ou via une approche modale, est soit limitée à des géométries idéalisées lorsque les termes non-linéaires et non hydrostatiques sont considérés, soit à une propagation linéaire lorsqu'une topographie réaliste est introduite. L'objectif de ce stage est d'analyser la propagation de la marée interne à partir des données de terrain, et de faire évoluer les modèles idéalisés (modal ou shallow water) vers plus de réalisme.

Context

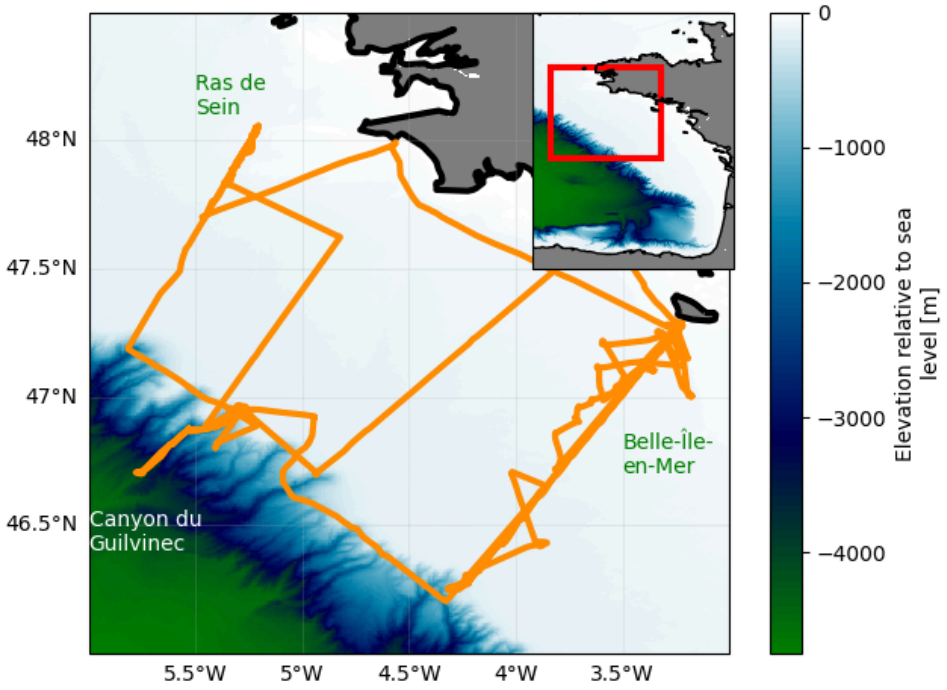
The Armorican Shelf is a 200km wide band of shallow water (200m) located between the southern coastline of Frenche Brittany, and deepest (2500m) central part of the Bay of Biscay. The interaction of the barotropic, semi-diurnal tide with the abrupt slopes at the shelfbreak generates an internal tide, that propagates northwards on the shelf.

The Solmineur campaign in summer 2026 has explored during 5 weeks a large region between the shelfbreak and the coast, between the Raz de Sein and Belle-île en Mer. Several instruments have been deployed, namely a Vessel Mounted Profiler (VMP), shipboard ADCP, drifting buoys, and CTD stations with LADCP. Several moorings also complete the dataset. The objective of the campaign was to study the fate of the internal tide, and to observe the continuum between the large scale mode 1 motion, its steepening, the generation of solitary waves of depression, and the change of polarity of these waves as they approach the coast.

These successive phenomenon are very complex to identify in this realistic configuration. Indeed, the classical linear wave propagation theory is modified by several factors, namely :

1. The interation between the baroclinic tide and the barotropic currents on the plateau
2. The non-uniformity of the stratification, and eventually the presence of fronts
3. Change of depth in the direction of propagation leading to wave steepening and polarity change
4. Change of depth in the transverse direction leaidng to diffraction and focusing of the waves
5. Coriolis dispersion
6. Nonlinearity and non-hydrostaticity of the flow

7. wave reflection at the horizontal boundaries, and stationanry waves



Recentely, realistic shallow water models have been develloped to compute the first order, baroclinic linear response of the stratified ocean to tidal and wind forcings, at a global scale with realistic stratification and bathymetry [1]. On the other hand, the non hydrostaticity and nonlinear evolution of the internal tide has been studied more intensively in idealizes, 2D-z configuration, as in the pioneering work of [2].

The objective os this internship is to explore the possibility of combining these two approaches, in order to better understand the complex propagation patterns observed on the Armorican Shelf.

Work expected

The trainee will have access to the whole dataset of the Solmineur campaign. At first, a comprehensive view of the available data is needed, as well as the understanding of the different forcings and their modelling (tides, wind). Due to the de-localization in space in time inherent to measurements along transects, it is necessary to develop tools that take into account the travelling speed of the waves with respect to the observer motion, and to the tidal phase.

Skills

The candidate should be familiar with complex data processing using Python language, have some fundamentals on fluid mechanics and wave propagation theories.

Bibliography

[1] S. M. Kelly, A. F. Waterhouse, and A. C. Savage, “Global Dynamics of the Stationary M2 Mode-1 Internal Tide,” *Geophysical Research Letters*, vol. 48, no. 11, p. e2020GL091692, Jun. 2021, doi: 10.1029/2020GL091692.

[2] T. Gerkema, “A Unified Model for the Generation and Fission of Internal Tides in a Rotating Ocean,” *Journal of Marine Research*, vol. 54, no. 3, pp. 421–450, May 1996, doi: 10.1357/0022240963213574.