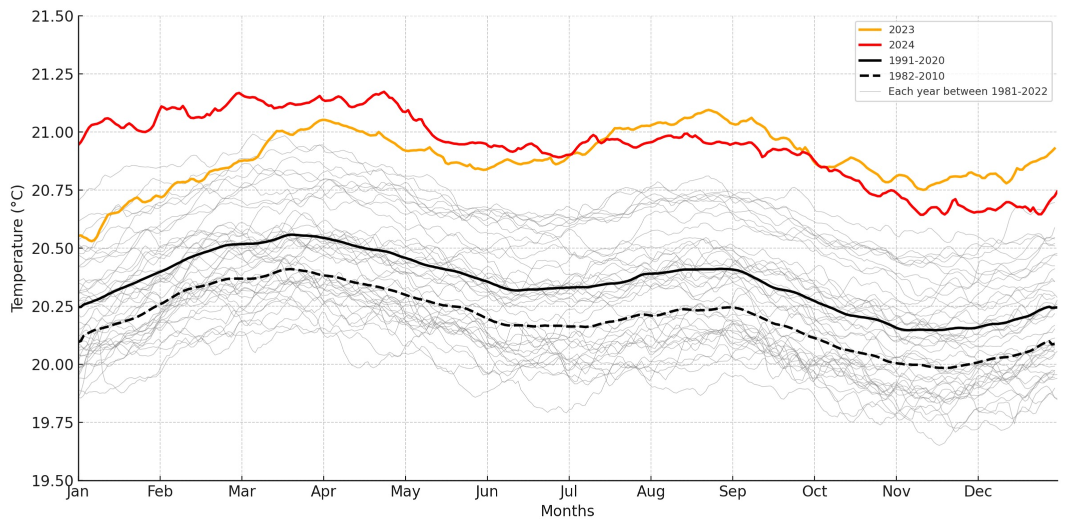
Winter is not coming: Simulating heat stress on Florida's Coral Reef

Louis Rycx[1], Thomas Dobbelaere[1], Colin Scherpereel[1], Heidi Hirsh[2], Jonathan Lambrechts[3] and Emmanuel Hanert[1,3]
[1] UCLouvain, Earth and Life Institute, Louvain-la-Neuve, Belgium, [2] Cooperative Institute for Marine and Atmospheric Studies, University of Miami, Coral Gables, USA,
[3] Institute of Mechanics, Materials and Civil Engineering, UCLouvain, Louvain-la-Neuve, Belgium

The recent heatwave devastated coral reefs

Coral reefs are very sensitive to temperature variations. Prolonged marine heatwaves can lead to bleaching, affecting their survival. In Florida, the summer of 2023 was marked by record sea temperatures. To understand the broad-scale bleaching patterns and their local variations, we have to combine the few observations available with high-resolution ocean models.

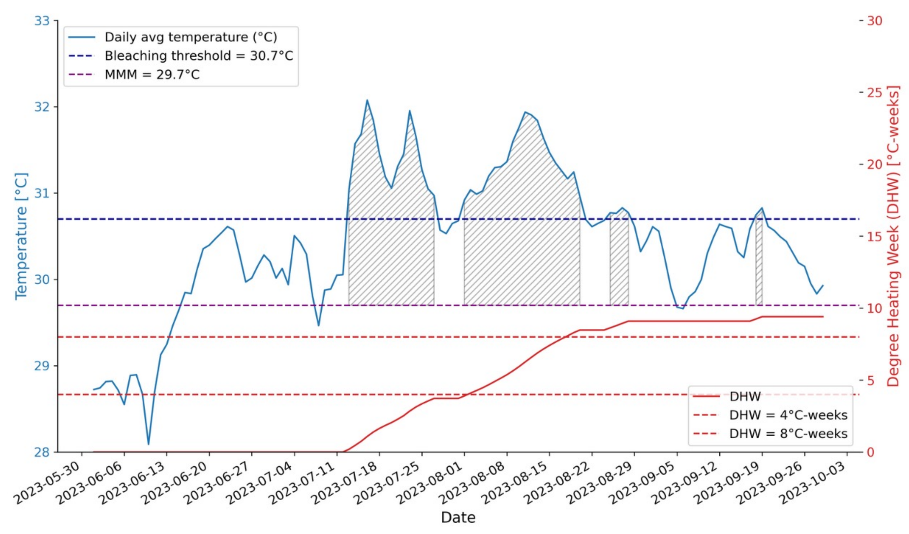


This work aims to simulate the hydrodynamics and thermal conditions of summer 2023 in the Florida's Coral Reef using hydrodynamic model. The main goals are to reproduce the vertical temperature stratification, identify spatial variations in thermal exposure between inshore and offshore reef areas, and evaluate the cumulative thermal stress experienced by coral habitats at different depths.

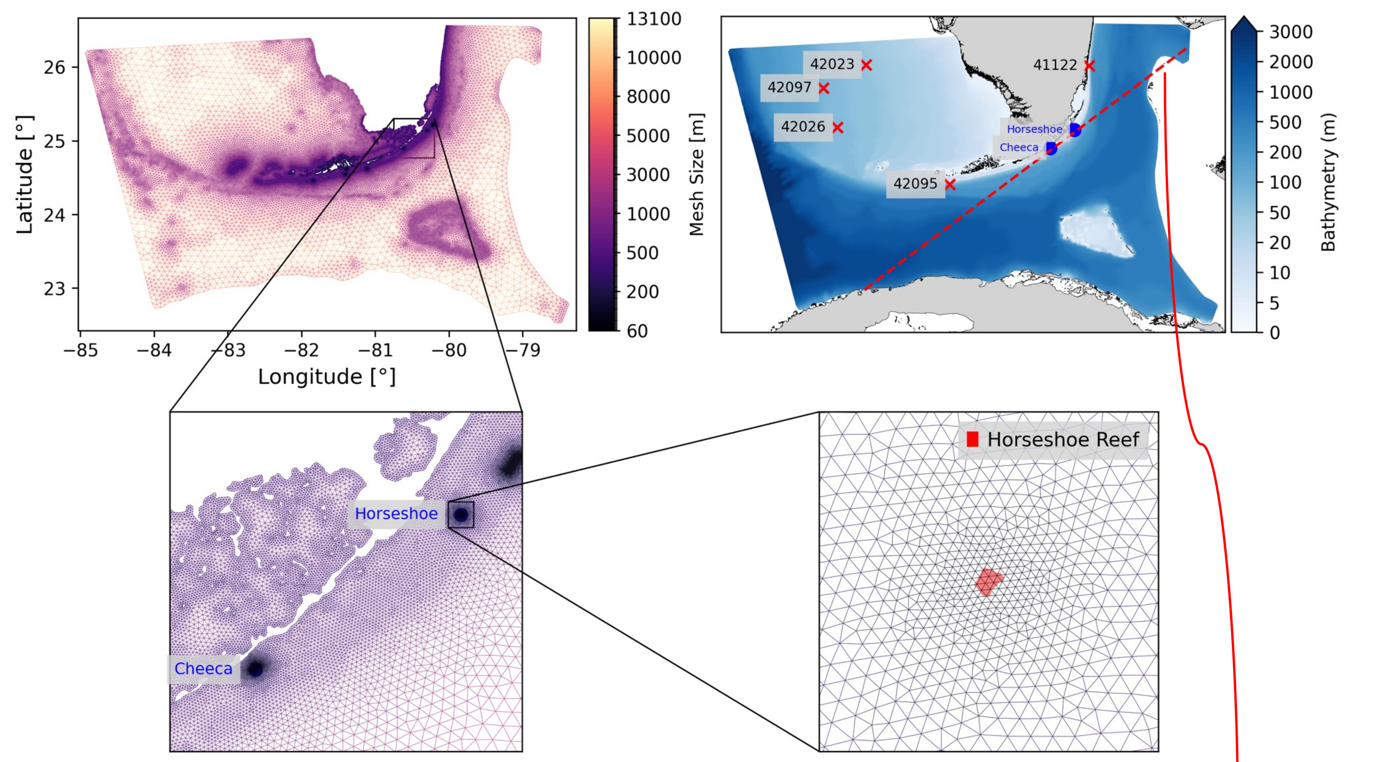
We use SLIM3D to simulate ocean dynamics and quantify thermal stress

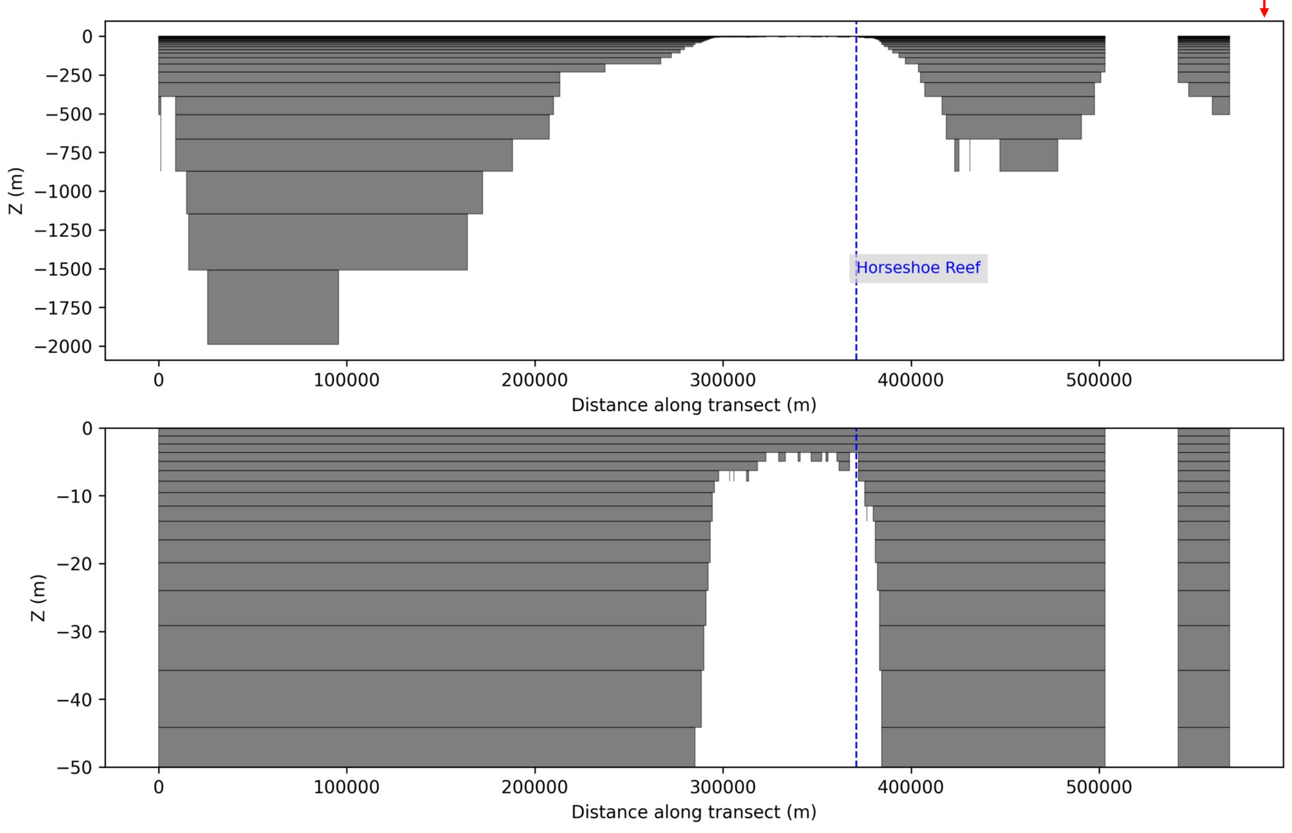
We used the unstructured-mesh ocean circulation model SLIM3D, a baroclinic ocean circulation model that can simulate fine-scale details of hydrodynamics and temperature variations.

To quantify the thermal stress experienced by corals, we use the Degree Heating Weeks (DHW) metric. It is used to quantify accumulated thermal stress over time, which is computed at each location to evaluate spatial patterns of exposure.

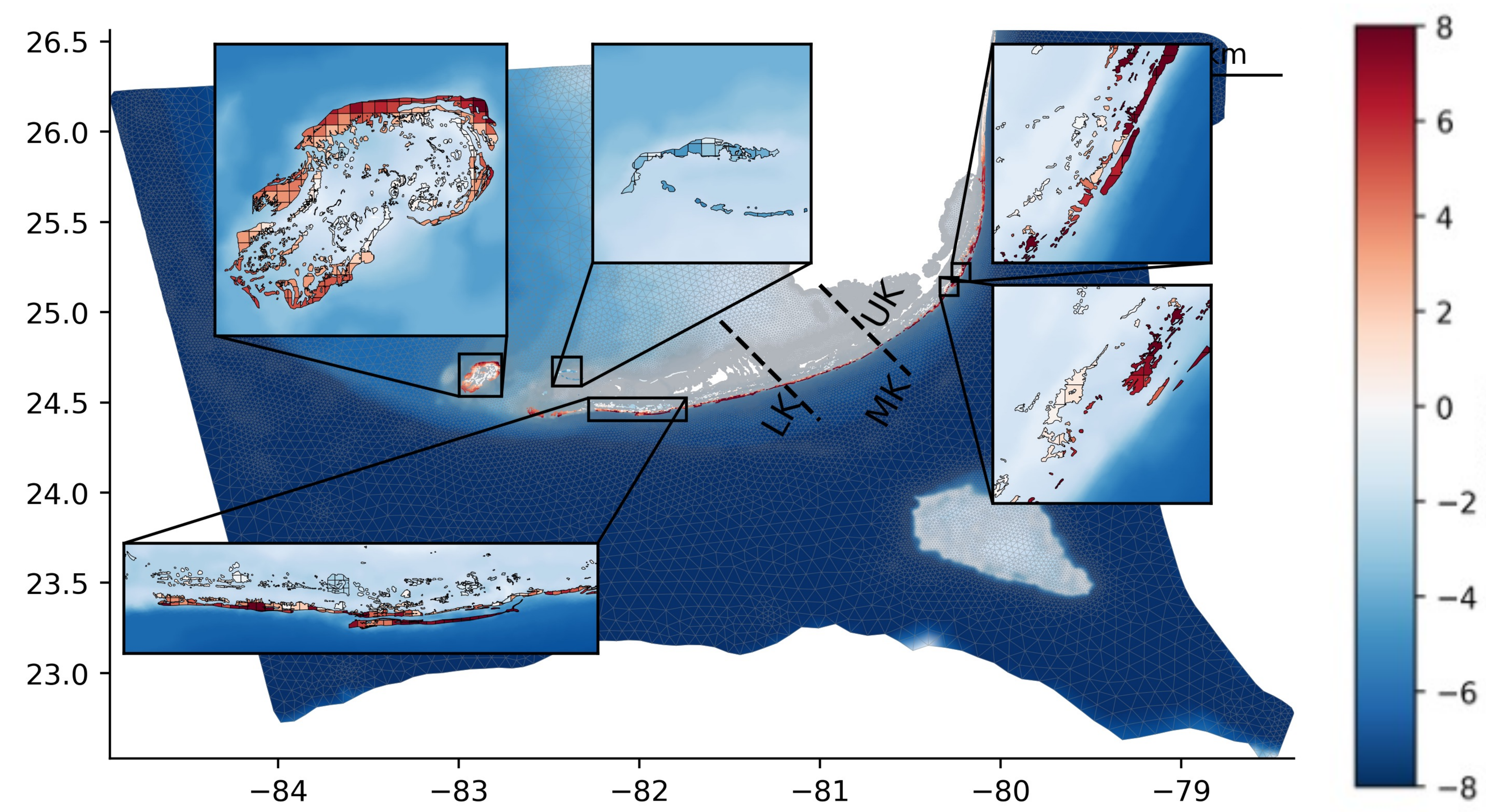


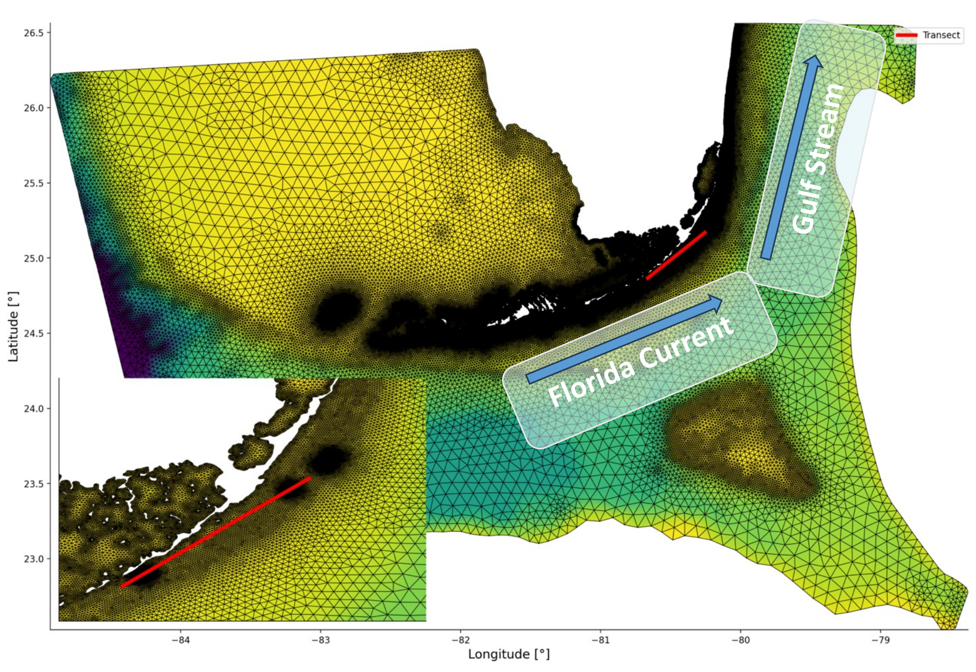
Our model setup uses a mesh with ~147,000 2D elements and 32 vertical layers. The layers are mainly concentrated near the surface with ~13 layers in the first 30 m with a thickness ranging from 1 to 4 m.

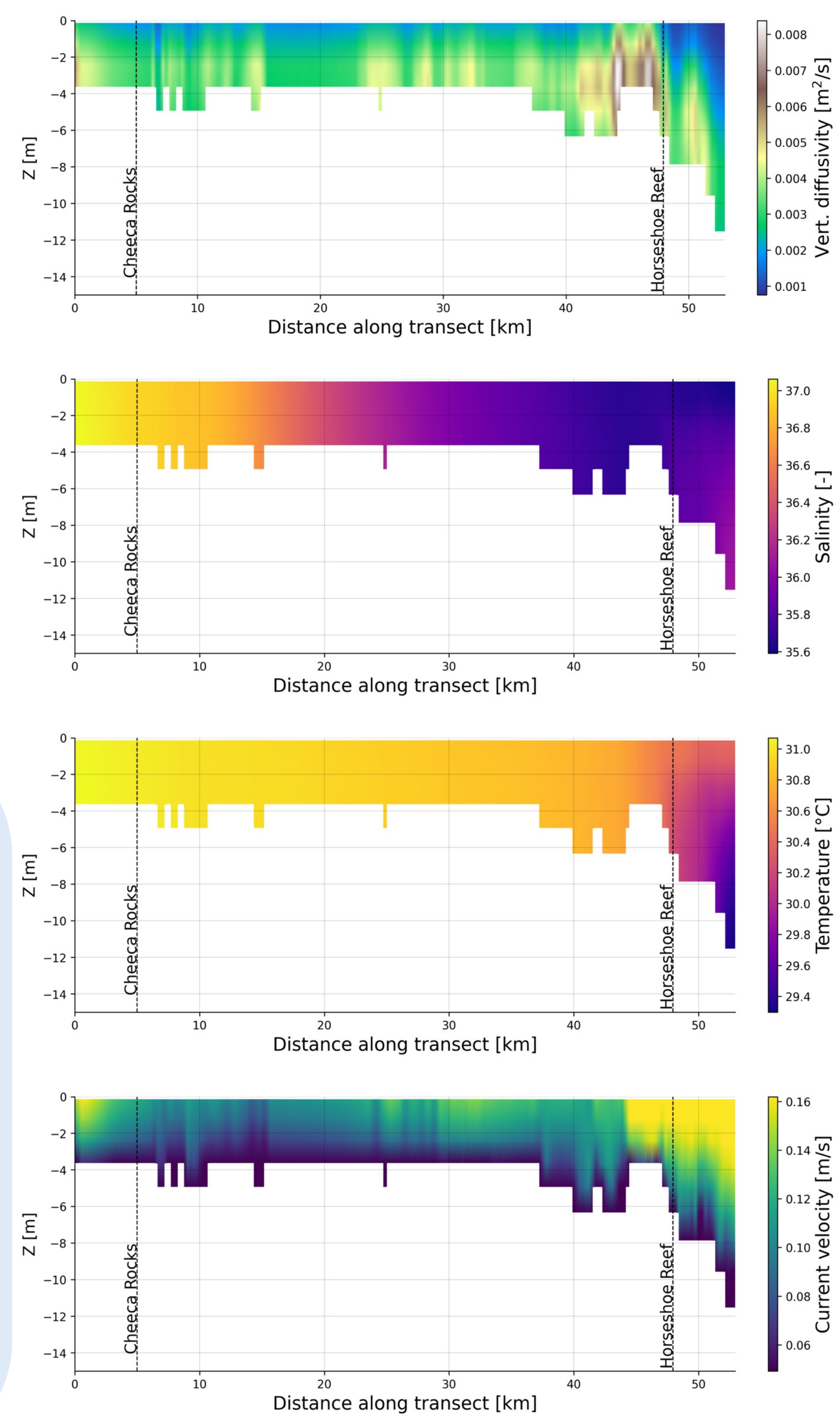


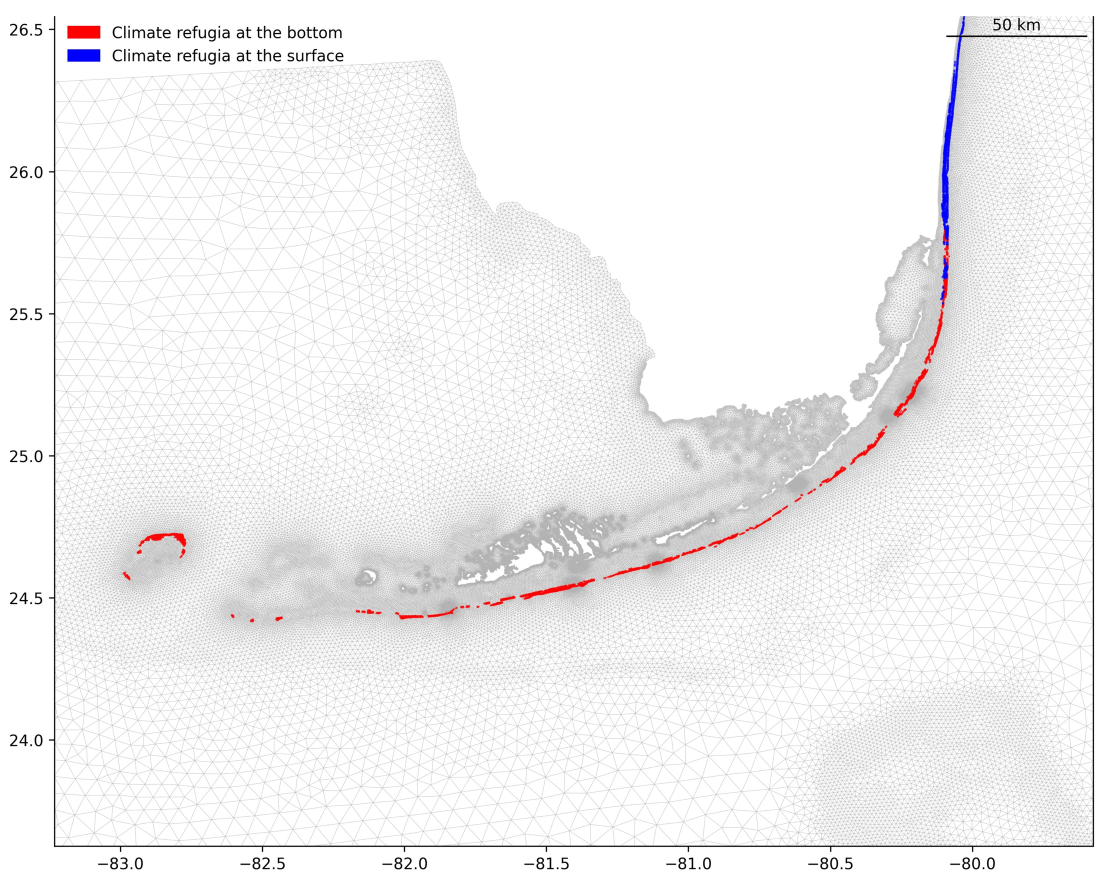


Coral reefs' thermal stress varies over very short distances, highlighting potential climate refugia









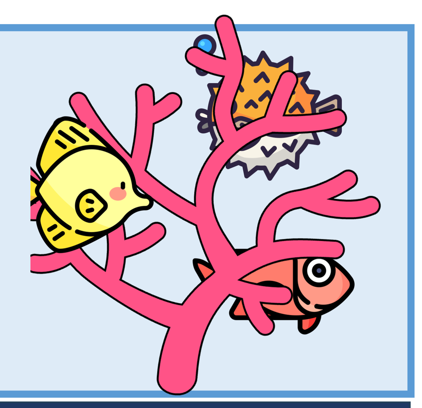
Our results highlight potential climate refugia both at the surface (in blue on the left plot) and at the bottom (in red) . DHW difference maps highlights offshore locations where reefs seems to experience less bleaching than inshore ones.

Two nearby reefs can experience large differences in bleaching due to differences in bathymetry and local hydrodynamics. Cheeca Rocks (on the right plot) is a shallow, inshore reef with weak stratification and relatively uniform temperature profiles. Heat tends to accumulate there, also because of the less dynamic environment with no major currents around. In contrast, Horseshoe Reef, located farther offshore and in deeper waters, exhibits stronger vertical stratification, which contribute to lower bottom temperatures and reduced bleaching at depth.

We identified potential climate refugia using thermal stress indicator… but that's only the first piece of the puzzle

- Some areas are less subject to bleaching than others due to hydrodynamic processes like upwelling.
- It's important to use a high-resolution ocean model like SLIM to capture small-scale temperature gradients between the surface and the reefs' depth, which can explain the bleaching variability between nearby reefs.
- Identifying climate refugia at both the bottom and surface could inform coral reef management and restoration.
- This study however does not account for biological factors, such as the variable thermal stress tolerance across different coral species.

- Simulate the summer of 2024 to observe whether the climate refugia observed in 2023 persist.
- Simulate the dispersal of different analytes from wastewater to integrate water quality in our study.



https://www.slim-ocean.be
louis.rycxlamme@uclouvain.be
https://www.linkedin.com/in/louis-rycx-58329a249/