

Project to ABW 2022 session

Ivan Dias Soares

The Ocean Cleanup

Introduction

The Ocean Cleanup is a non-profit organization developing and scaling technologies to rid the oceans of plastic. To achieve this objective, our engineers and scientists are working on a combination of closing the sources of plastic pollution and cleaning up what has already accumulated in the ocean and doesn't go away by itself. That's why we have two fronts of action: the group acting in the oceans and the group acting in the rivers.

The rivers are the main source of ocean plastic pollution. They are the arteries that carry waste from land to the ocean. According to our research, 1000 rivers are responsible for roughly 80% of riverine pollution. Our main action in the rivers is to intercept the plastic before it reaches the ocean. Our engineers have developed "The Interceptor", a high-tech solution with solar-powered mechanics, smart processing, and connectivity for easy performance tracking. It is designed for series production, and in December 2020, we entered a partnership with Konecranes was signed to begin manufacturing for more locations. Due to its autonomous and large cleaning capacity, this is the primary technology we evaluate for feasibility in any new river we plan to tackle.

We currently have deployed this technology in four locations: Indonesia, Malaysia, the Dominican Republic, and Vietnam.



Figure 1: The Interceptor

For the oceans we have developed another solution. Trash in the oceans accumulates in five ocean garbage patches, which stay in the middle of immense gyres. A gyre is a large-scale circular system of wind-driven surface currents in the ocean. There are five main gyres, located in the North and South Pacific, the North and South Atlantic, and the Indian Ocean (figure 2). The largest one being the [Great Pacific Garbage Patch](#), located between Hawaii and California. To solve it, we not only need to stop more plastic from flowing into the ocean, but also clean up what is already out there. Floating plastics trapped in the patches will keep circulating until they break down into smaller and smaller pieces, becoming harder to clean up *and* increasingly easier to mistake for food by sealife. If left to circulate, the plastic will impact our ecosystems, health, and economies for decades or even centuries.

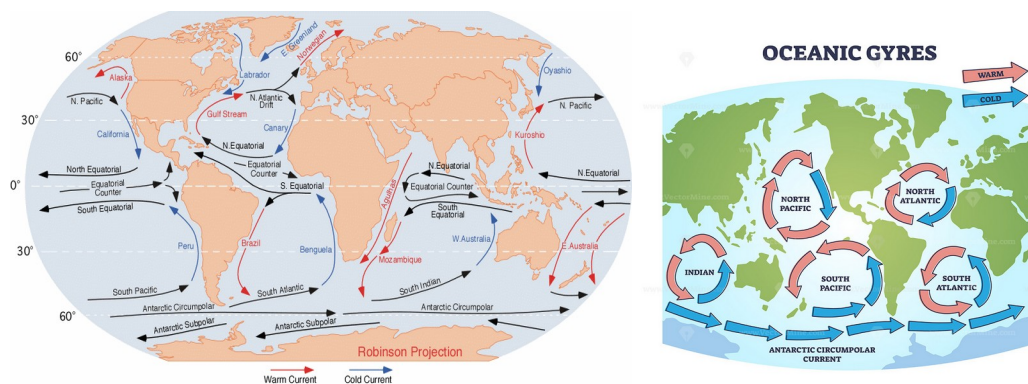


Figure 2: Large scale surface ocean currents and the 5 main oceanic gyres.

The fundamental challenge of cleaning up the ocean garbage patches is that the plastic pollution is highly diluted, spanning millions of square kilometers. Our cleanup solution is designed to first concentrate the plastic, allowing us to effectively collect and remove vast quantities.

This is how it works: With a relative speed difference maintained between the cleanup system and the plastic, we create artificial coastlines, where there are none, to concentrate the plastic. The system is comprised of a long U-shaped barrier that guides the plastic into a retention zone at its far end. Through active propulsion, we maintain a slow forward speed with the system.

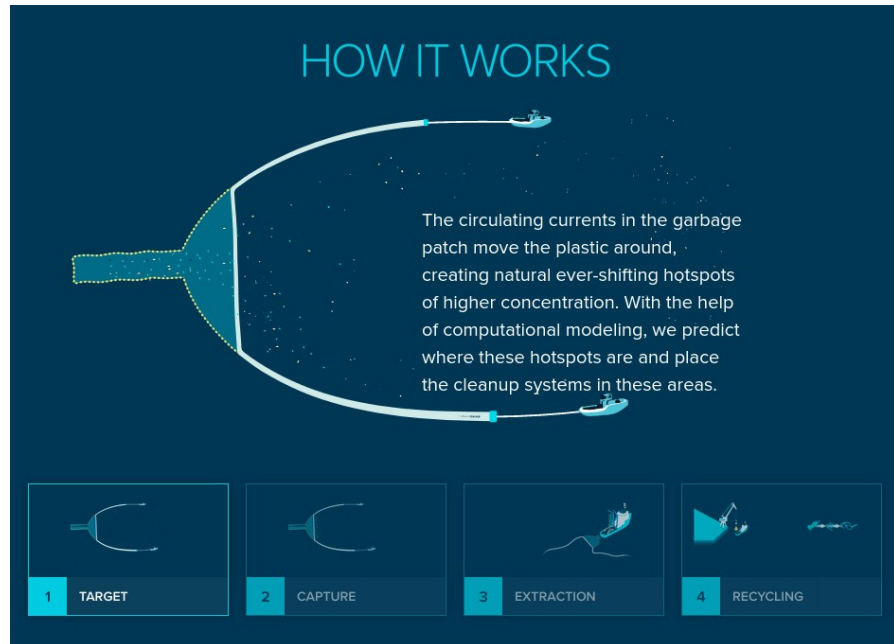


Figure 3: Oceanic cleanup system

Our work in The Ocean Cleanup is guided by the studies conducted by a few research groups, including the **Pacific Ocean Team**, the **Rivers Team** and the **Computational Modeling Team (CM Team)**, which I am part of. In the CM Team we run numerical models to simulate the behavior of the cleanup systems in the water, to understand how they interact with the winds, the ocean currents and the waves.

We also run numerical models to simulate the behavior of plastic debris in the vicinity of the net of the cleanup system to try to increase the effectiveness of the system in capturing plastic.

However, our main model is the model that simulates dispersal of plastic in the oceans, identifying areas where the plastic accumulates. This is the model that guides the offshore team when they are deploying the cleanup system in the ocean.

My job in the CM team is to run the models that simulate the ocean currents and the waves in the North Pacific Ocean.

Objective of this Project

The main objective is to implement a Data Assimilation scheme in the Wave Model that is already running in The Ocean Cleanup. The idea of using a data assimilation scheme in the model is to improve the quality of the model results and the assertiveness of the model forecast.

Two numerical models are actually running in The Ocean Cleanup, one to predict ocean currents and another to predict waves. The ocean current model already has a Data Assimilation scheme but the wave model doesn't. The data assimilation scheme used in the oceanic model is the Ensemble Optimal Interpolation (Sakov, 2015). The idea is to use a neural network to implement a data assimilation in the wave modeling

Stakeholders and Users

The main users of the oceanic forecasting are the engineers of the group who develop and deploy the cleanup system in the Great Pacific Garbage Patch.

Product

The product of the wave model is a report containing maps of wave height every 3 hours for 10 days.

The Wave Model

The Wave Watch III (WW3) model runs in The Ocean Cleanup (TOC) in two nested numerical domains (see figure 4). The larger grids has resolution of $1^\circ \times 1^\circ$, and the smaller $0.25^\circ \times 0.25^\circ$.

Simulations in the larger grid are forced with Global Forecast System (GFS) winds with time interval of 3 hours and horizontal resolution of 0.25 degrees.

Simulations in the smaller grid receive the open boundary values from the larger grid and are also forced with the same GFS winds.

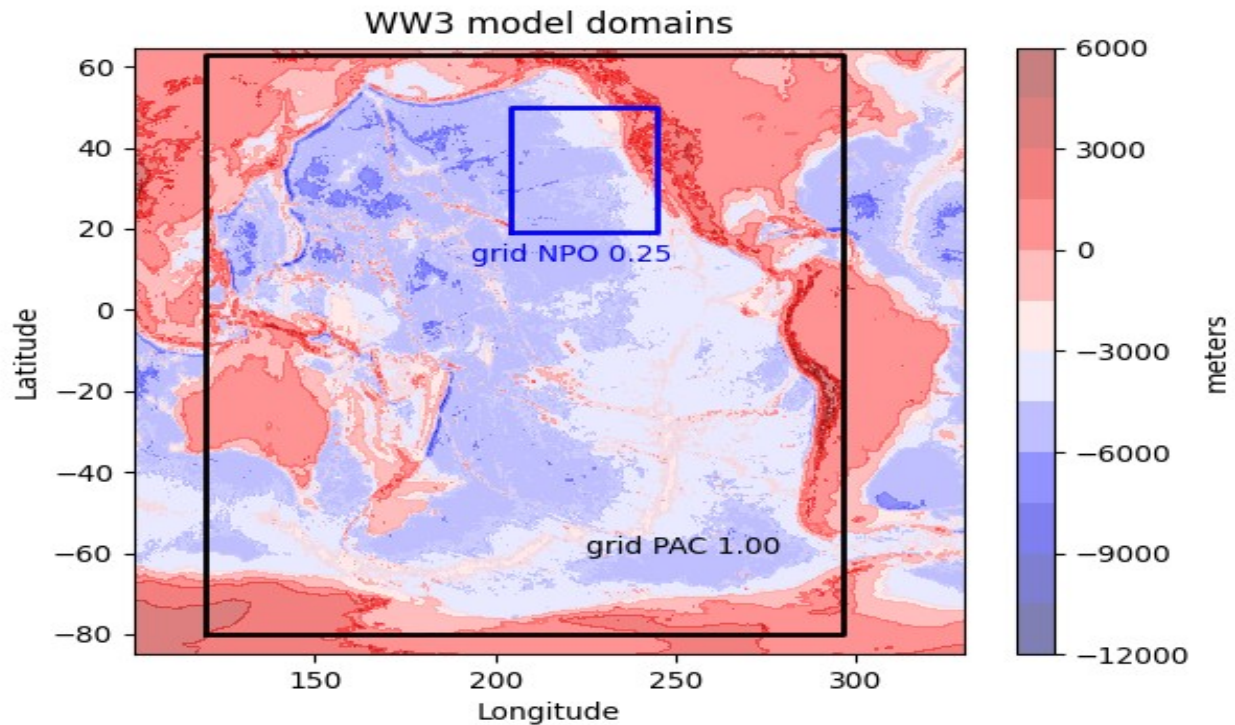


Figure 4: The Pacific Ocean topography and the WW3 numerical domains: the larger domain in black and the smaller domain in blue

The model results are validated by comparing wave significant height (H_s) and spectral density versus NOAA Buoys H_s and spectral density (see figure 5 for location of buoys). In this report we have used buoys 46002, 46006, 46059 and 51000.

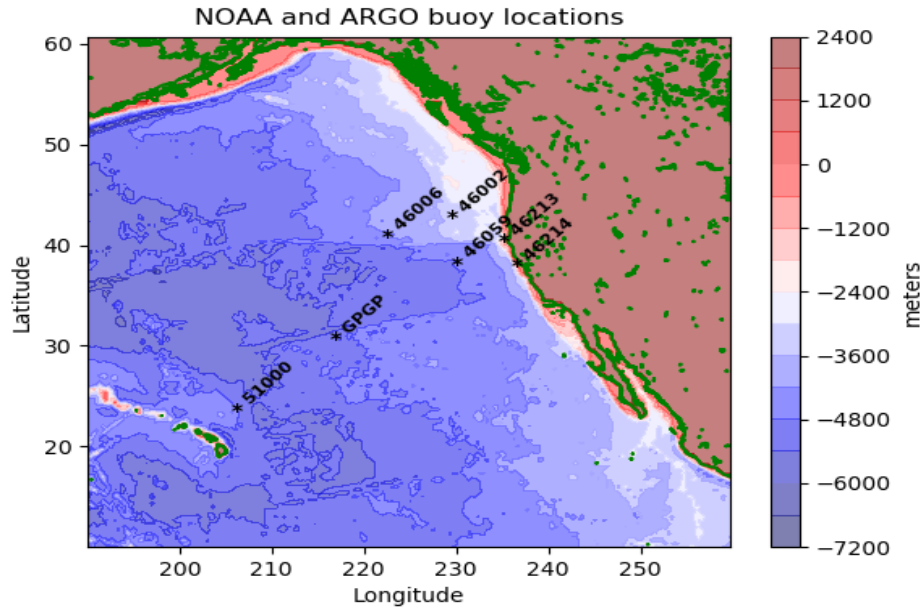


Figure 5: Locations of NOAA buoys.

My Ideas for the projects

Basically, the wave model has as input the wind velocity and wind direction and as output the wave height. The model solves the equation of energy spectral density (see Appendix I) over a numerical domain which spans part of the North Pacific Ocean (see figure 4). The model reads in the wind data, computes the time-evolution of spectral density and wave height and writes the two-dimensional array of wave height in an archive, every hour for ten days.

I have the wave height values observed in a few NOAA buoys.

My idea is to use a neural network to make the model “see” the observed data and use it to improve the quality of model forecast.

Validation of Wave Significant Height

The model was integrated over the period of 21 days starting on July 20th, 2022 and ending on August 01st, 2022. The model saves the results in netcdf format in archives containing wave height, wave period, wave length. We then compared the model results to observed data. The first validation is the comparison of wave height computed by the model and wave height observed in NOAA buoys (figure 6).

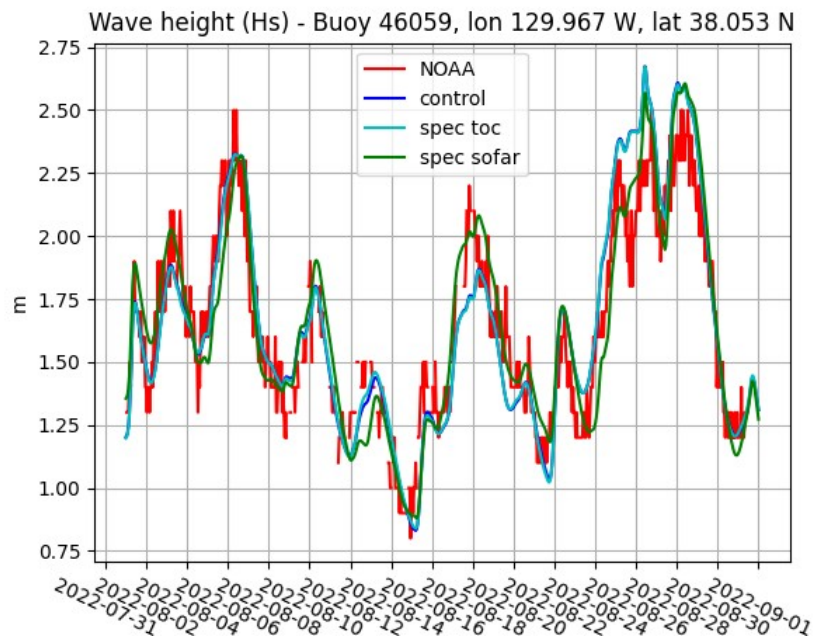


Figure 6: Time series of wave significant height (Hs) observed in NOAA buoy 46059 (red) and computed in experiments 'control' (blue), 'spec toc' (light blue) and 'spec sofar' (green).

Validation of Spectral Density

Spectral density observed in NOAA buoys were compared to those computed in both simulations of the model WW3, the one having open boundary values (OBVs) from SOFAR and the one having OBVs from the TOC model.

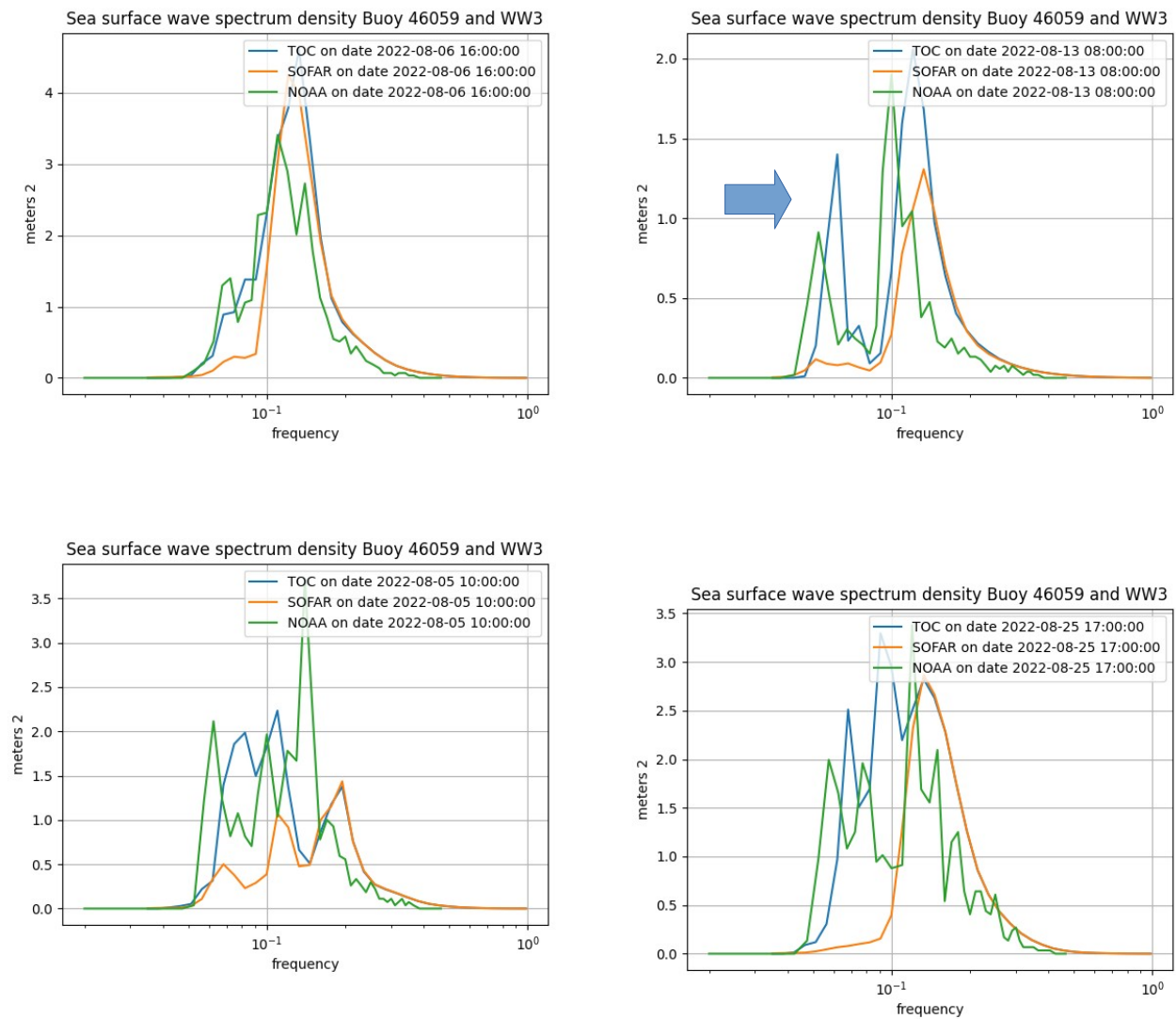
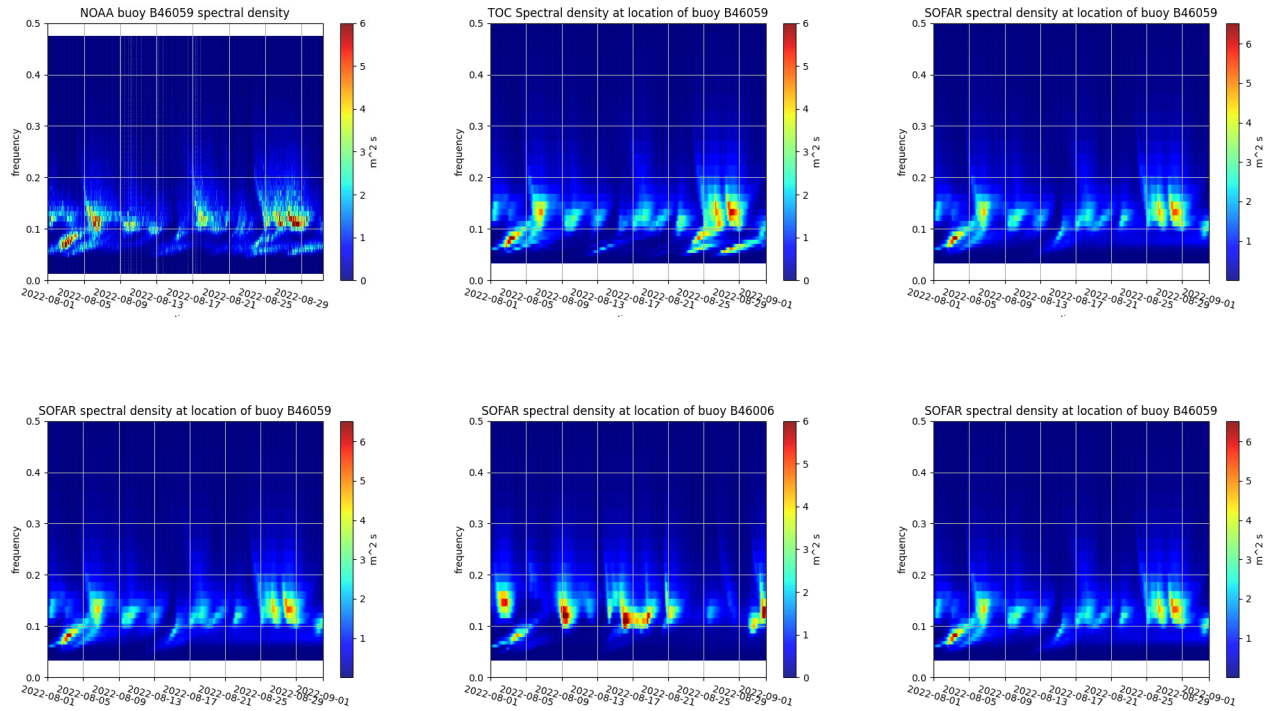
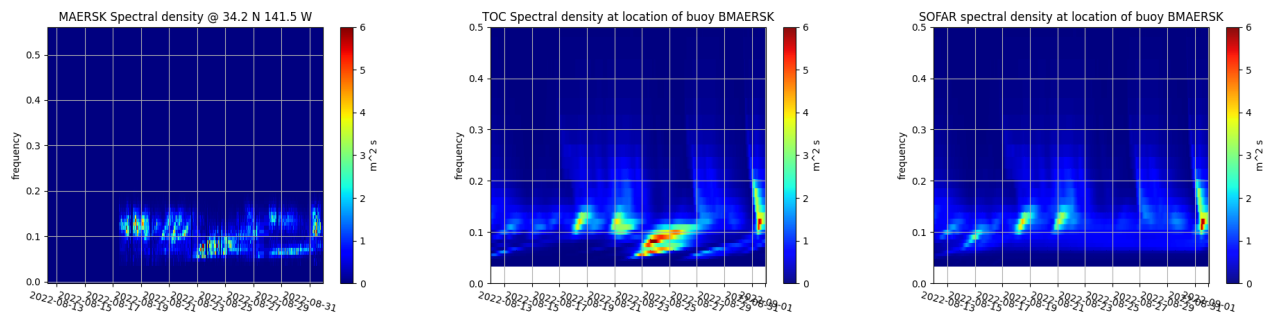


Figure 7: Spectral density observed in NOAA buoy 46059 and computed by the wave model WW3.

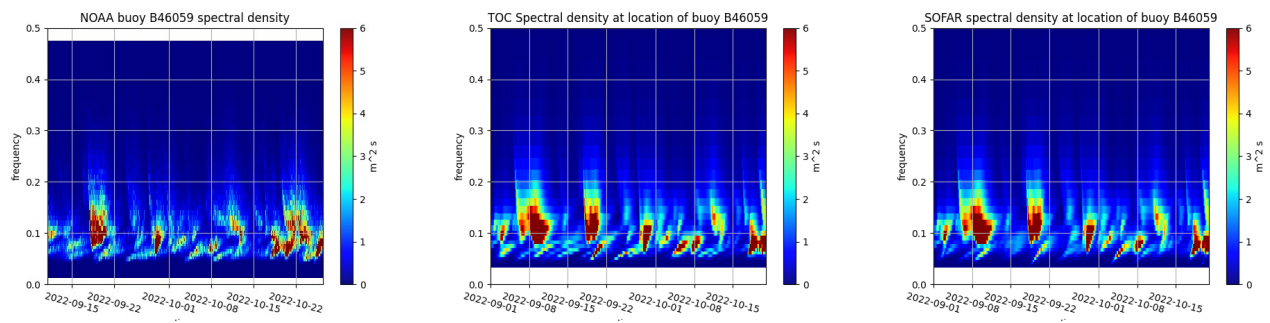
Time evolution of spectral density



Buoy B46059 spectral data in August 2022: NOAA (top left), TOC (top central), SOFAR b (top right), SOFAR c (bottom left), SOFAR d (bottom central) and SOFAR (bottom right).



MAERSK spectral data in August 2022: MAERSK (top left), TOC (top central), SOFAR (top right).



Buoy B46059 spectral data in September 2022: NOAA (left), TOC (central), SOFAR (right).