

# ANALYSIS OF DIRECTIONAL WAVE SYSTEMS AND CROSSING SEAS IN THE MEDITERRANEAN SEA

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## INTRODUCTION

We present a methodology for the detection of directional wave systems at given locations. The methodology relies on image processing algorithms used to extract relevant features from time-series of integral parameters of spectral partitions. A case study is developed in the Mediterranean Sea (MS); the wave systems extracted are next used to assess the frequency of occurrence of crossing seas in the area, which may be dangerous for the safety of navigation.

## DATA & METHODS

We employ hindcast data reconstructed in the MS at a  $\approx 10$  km lon/lat resolution over 19879-2021, providing integral and peak parameters for up to three spectral partitions. For a single node, a 2-D frequency matrix is built up by pooling together all  $(T_m, \theta_m)$  pairs of each spectral partition. This matrix is next treated as an image, i.e., frequency bins can be thought of as pixels whose intensity depends on the number of embedded data. The Otsu (1979) algorithm is applied to detect the “background” and the “foreground” of the matrix; the latter is next split in different clusters (i.e., the wave systems) based on pixel contiguity in the  $(T_m, \theta_m)$  space, detecting in turn clusters centroids which identify the relevant fetches from which waves are originated.

Next, time series of spectral partitions are grouped according to the wave systems based on their direction of propagation (that is, the reference system minimizes the Euclidean distance between the partition’s  $\theta_m$  and the system’s centroid). It follows that, for each hindcast time-step, beside the integral and peak parameters the three spectral partitions are associated to a flag indicating the wave system they belong to. This way, it becomes straightforward to assess the most frequent systems combination, said  $f$  the frequency of occurrence:

$$f_{X,Y}(i,j) = \frac{n_{X=i,Y=j}}{N_y} \quad (1)$$

Where  $N_y$  is the number of years of the time-series and  $X = i, Y = j$  denote the number of occurrences where the  $X^{th}$  and  $Y^{th}$  spectral partitions belong to the  $i$  and  $j$  systems, respectively. Equation (1) can be computed for all possible  $m$  pairs of wave systems:

$$m = n + \frac{n!}{2!(n-2)!} \quad (2)$$

With  $n$  denoting the number of wave systems (for example, in case of 2 systems there are 3 possible permutations, that is 1-1, 1-2, 2-2) . From equation (2) it follows that also repeated systems are accounted for, indicating partitions characterized by directions of

propagation close to one another, which is in fact the most dangerous case for navigation (Zhang and Li, 2017).

## RESULTS

Figure 1 shows the systems detected at the study site within the mid Tyrrhenian Sea (west coast of Italy). Here, four main systems and as many centroids are clearly visible. Table 1 reports the most frequent permutations, 1-2 being the most probable one (that is, waves travelling N and E at the same time).

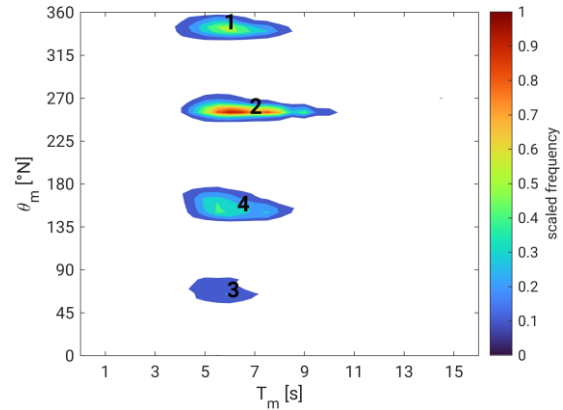


Figure 1 - Wave systems detected at the test node. Respective centroids are highlighted through black labels. Directions  $\theta_m$  are defined according to the Nautical convention.

$S_1/S_2$	1	2	3	4
1	2	527	185	84
2		31	116	562
3			14	140
4				7

Table 1 - frequencies [h/y] of all possible systems permutation at the study site (only time steps yielding  $H_s > 1$  m are accounted for).

## REFERENCES

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