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# Assessment of the wave spectral characteristics offshore Portugal

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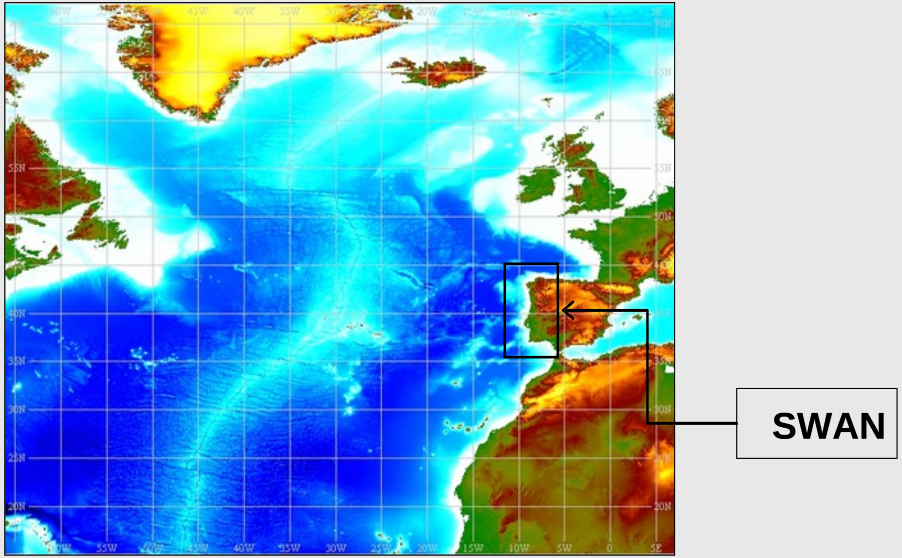
# Objectives

- Characterize the different sea states occurrences in **eight** locations in different water depths: **Aguçadoura**, **Leixões (2), Nazaré (2)**, **Peniche, Sines** and **Faro**

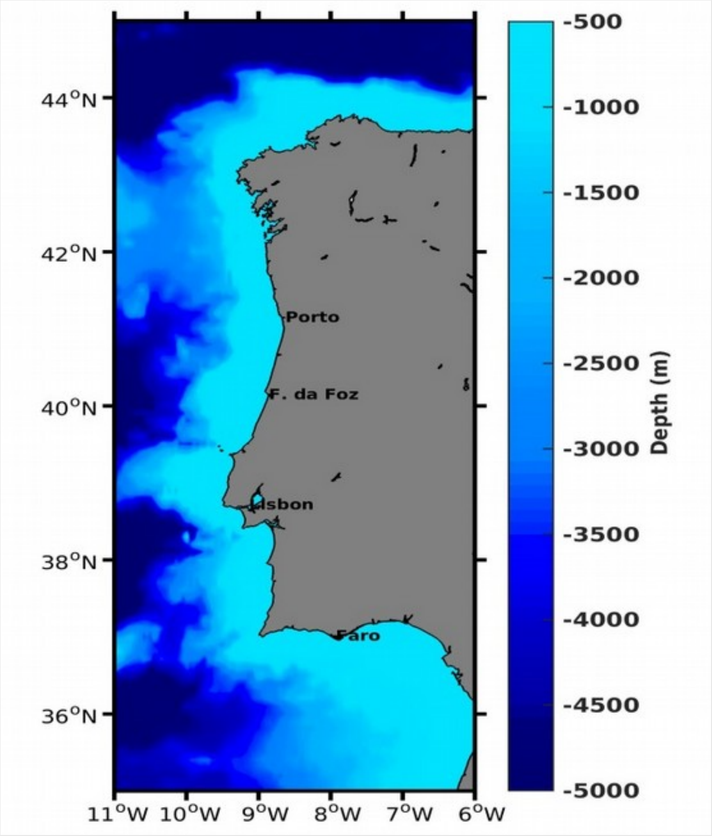
- Provide a statistical and a spectral analysis using a **21 years hindcast** dataset provided by the **SWAN** model:
  - statistics of the wave parameters **Hs** and **Tp.**
  - statistics on the different classes of **directional spectra**

- **Parametric approach** which allows to obtain the **type** of **wave systems** present and its **spectral parameters**.

# Spectral wave models



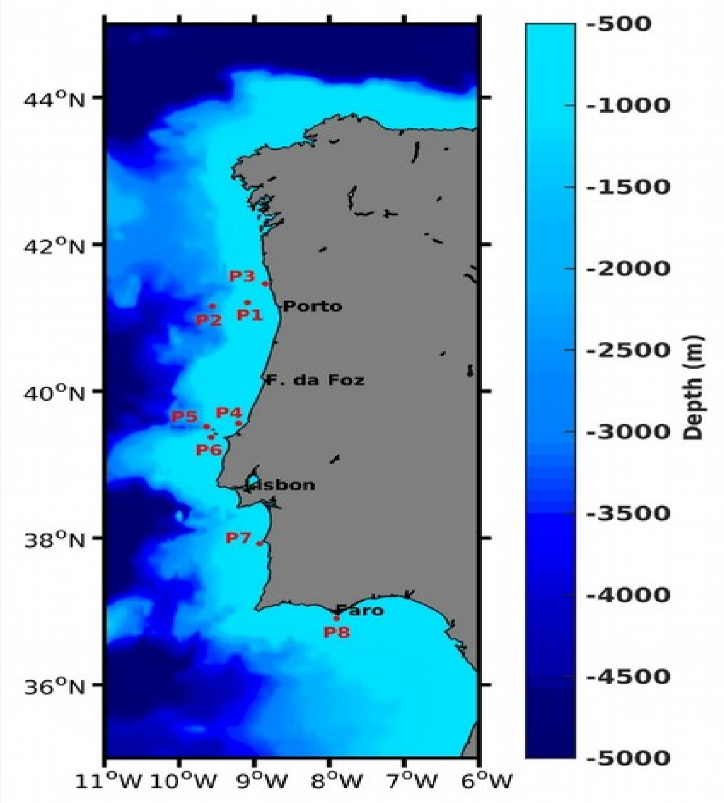

**ERA – INTERIM (WAM)** and **SWAN** area of implementation




Regional **SWAN** area

# Spectral wave models

- **SWAN** for the nearshore physical processes (**21-year** hindcast dataset (1990 to 2010))




**P1** – Leixões (106.7m)

**P2** – Leixões Ocean (1935.6m)

**P3** – Aguçadoura (34.6m)

**P4** – Nazaré (109.5m)

**P5** – Nazaré ocean (1624.8m)

**P6** – Peniche (362.8m)

**P7** – Sines (809.9m)

**P8** – Faro (113.9m)

➢ Analysis of the wave regime was performed in all the water points

# **Spectral wave models:** descriptive statistics of the wave parameters

Time step of 6h

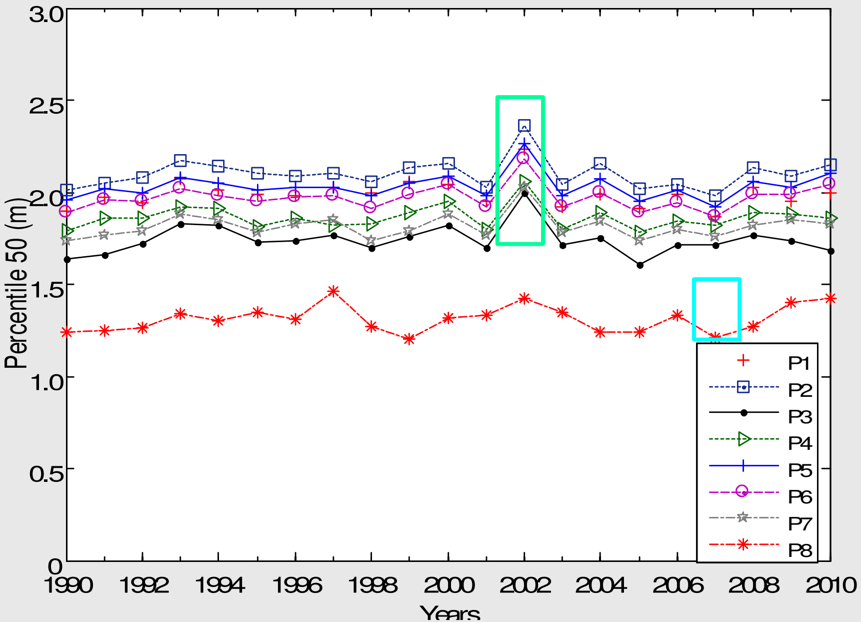
**Hs** (1990 to 2010)

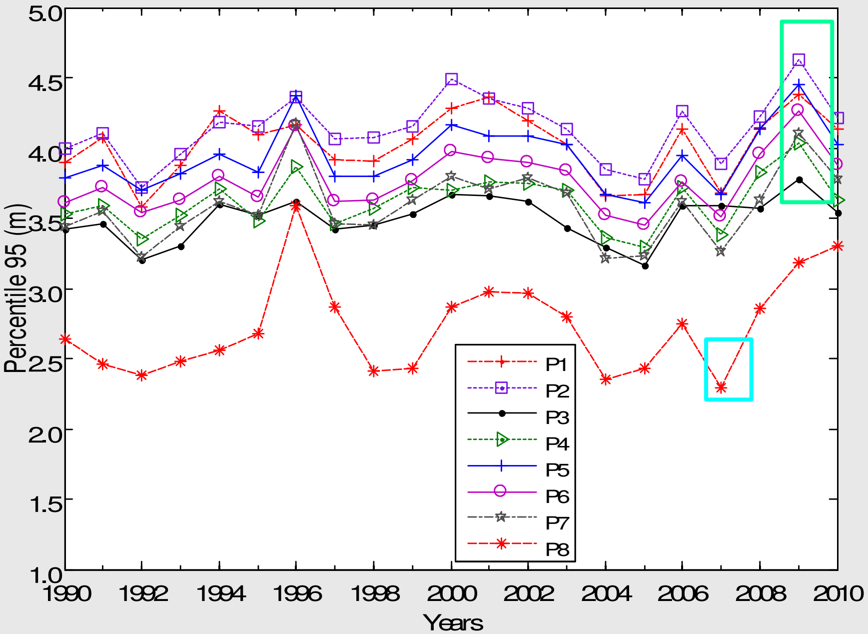
| | Leixões | Leixões Ocean | Aguçadoura | Nazaré | Nazaré Ocean | Peniche | Sines | Faro |
|---|---|---|---|---|---|---|---|---|
| | **P1** | **P2** | **P3** | **P4** | **P5** | **P6** | **P7** | **P8** |
| **Mean** | 2.18 | 2.28 | 1.91 | 2.03 | 2.21 | 2.14 | 2.00 | 1.46 |
| **Median** | 1.99 | 2.09 | 1.74 | 1.86 | 2.03 | 1.97 | 1.81 | 1.30 |
| **Std. dev** | 0.95 | 0.96 | 0.83 | 0.82 | 0.90 | 0.85 | 0.81 | 0.67 |
| **Minimum** | 0.43 | 0.50 | 0.35 | 0.46 | 0.61 | 0.61 | 0.54 | 0.35 |
| **Maximum** | 6.97 | **8.03** | 6.23 | 6.67 | **7.04** | 6.65 | 6.14 | 6.03 |
| **Skewness** | 1.05 | 1.05 | 0.83 | 1.10 | 1.09 | 1.09 | 1.14 | 1.53 |
| **Nº obs** | 30681 | 30681 | 30681 | 30681 | 30681 | 30681 | 30681 | 30681 |

**Deepest points**

# **Spectral wave models:** descriptive statistics of the wave parameters

## The **50th** and the **95th** Percentile profile




- **50th** percentile: highest waves in **2002** (**P2 - Leixões Ocean**) and the lowest in **2007** (**P8 – Faro**)
- **95th** percentile: highest values for the **Hs** in **2009** (**P2 – Leixões Ocean**), lowest in **2007** (**P8 – Faro**)

# Modelling the climatic variability of directional wave spectra

- An **approach** for **statistical analysis** and **modelling of directional wave spectra is** used to perform an description of the **sea wave** climate **offshore Portuguese waters**.

- It is based on a **parametric description** of the directional wave spectrum and adopts a **numerical optimization** procedure, to **identify the spectral type and parameters** (Boukhanovsky et al. 2007; Boukhanovsky and Guedes Soares , 2009).

  - **estimation of the number of peaks** and the **set of spectral parameters**;
  - **classification** of the **directional wave spectra** on **the genetic classes** ➡ **sea state conditions**;
  - the **occurrences** of the **spectral classes (5 classes** of **climatic wave spectra)**.

- The concept of adjusting **five different classes** is introduced as a **way of summarising** the **characteristics** of **hindcast sea states** over large areas and long time periods.

# Modelling the climatic variability of directional wave spectra

**Classification of the directional spectrum** in **5 classes** of **climatic wave spectra:**

→ based on two types of characteristics: **number** of the **wave systems** and their **separation in frequency and direction**.

Number of types is **5 (M):** wind waves, swell, wind waves and one swell, two swells, complex multipeaked spectrum.

→ **class I, II (One-peaked spectra):** wind waves (**class I**) or swell (**class II**).

→ **classes III, IV (Double-peaked spectra):** two wave systems. Two sub-classes are separated with respect to the wave-making conditions, associated with wave fetch and time of wave propagation: **"matured"** sea and the **complex** sea:

- **class III - "matured"** sea class: double-peaked spectra with two swells. Generally, one of the swell systems belongs to local wave conditions, and the second one to the swell propagating from distant storm.
- **class IV - Complex** sea class, mainly consists of two wave systems – **wind waves** and **swell**.

→ **class V (Multipeaked spectra)**: complicated wave fields with **2** or more **swells**.
- spectrum with more than **2** promounced peaks.

# Modelling the climatic variability of directional wave spectra

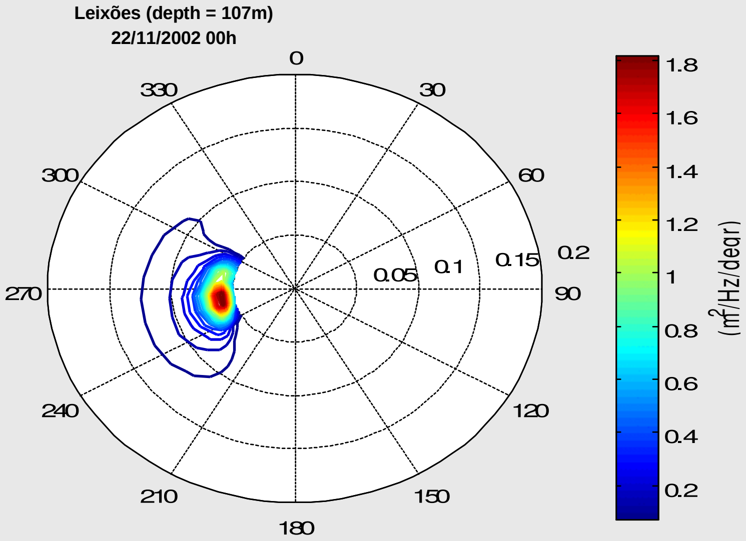
Classification of the **directional spectra** in **classes** of general **wave types**

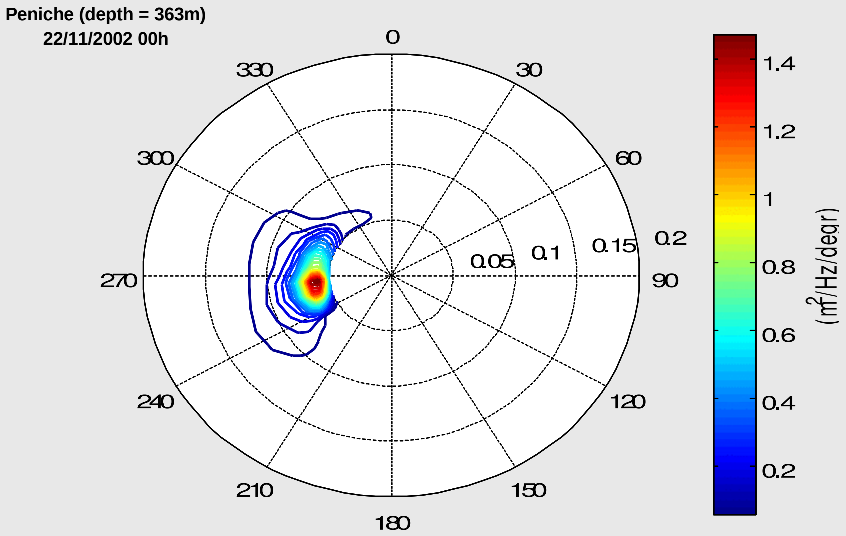
| | Depth (m) | One-peaked spectra (%) | Double- peaked spectra (%) | Multipeaked spectra (%) |
|---|---|---|---|---|
| **Leixões (P1)** | 106.7 | 63.0 | 32.1 | 4.9 |
| **Leixões Ocean (P2)** | 1935.6 | 58.5 | 32.6 | 8.9 |
| **Aguçadoura (P3)** | 34.6 | 71.8 | 25.6 | 2.6 |
| **Nazaré (P4)** | 109.5 | 66.9 | 30.0 | 3.1 |
| **Nazaré Ocean (P5)** | 1624.8 | 59.6 | 31.6 | 8.7 |
| **Peniche (P6)** | 362.8 | 60.2 | 32.4 | 7.4 |
| **Sines (P7)** | 80.9 | 74.2 | 23.5 | 2.3 |
| **Faro (P8)** | 114.0 | 52.7 | 42.2 | 5.1 |
| | | **I, II** | **III, IV** | **V** |

- The classification in **classes allows** for the **association** of **each directional spectrum** $S(f,\theta, t)$ with certain **classes** $c$.

# Modelling the climatic variability of directional wave spectra

## Wave spectra variance - Time frame: 2002.11.22 00:00 h




- **Hs** in Leixões and Peniche (≈ 7m)
- Classification of the directional spectra: **wind wave** and **swell**

# Modelling the climatic variability of directional wave spectra:
## variability of directional spectral classes

→ Each **class** corresponds to a **stable state c** (**c = 1…M**) - **synoptic variability** of the **waves** can be described by a **Markov chain**, **c = c(t)**, with a **matrix of transition probabilities** allowing to compute the **probabilities** of all **transitions** and **jump**s between the **classes**.

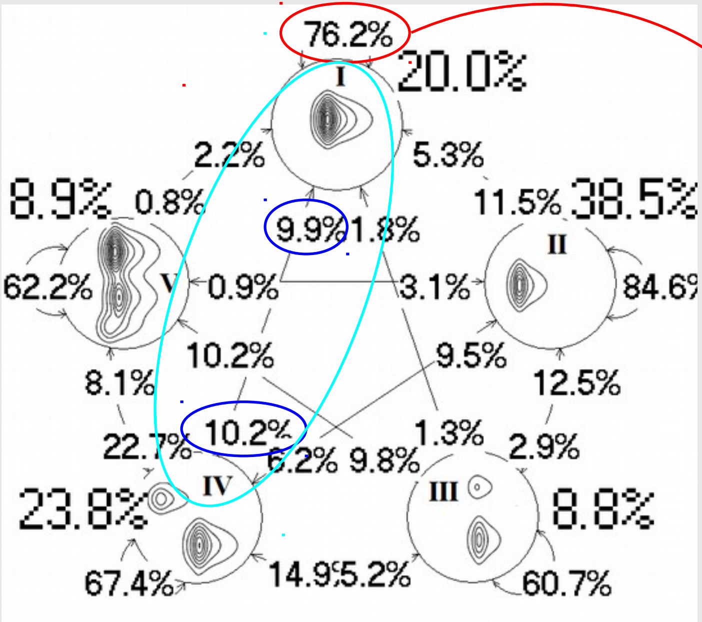
→ The **variability of directional spectra (**e.g.,**21-year hindcast data) classes** were estimated based on the **transitions** and **jumps** probabilities (**Markov chain)**.

→ **Transition:** the event when the wave spectrum changes the **class** during **1** synoptic term (e.g., **3** hours).

→ **Jump:** the event when the wave spectrum changes the **class** and comes back during **2** synoptic terms (e.g., **3+3**hours).

→ **Transition I** : if in the present time type **I** is observed, the conditional probability for the spectrum of type **IV** to occur in the next step is 10.2%, and to return back in the following time step is 9.9% (**P5**).

Transition



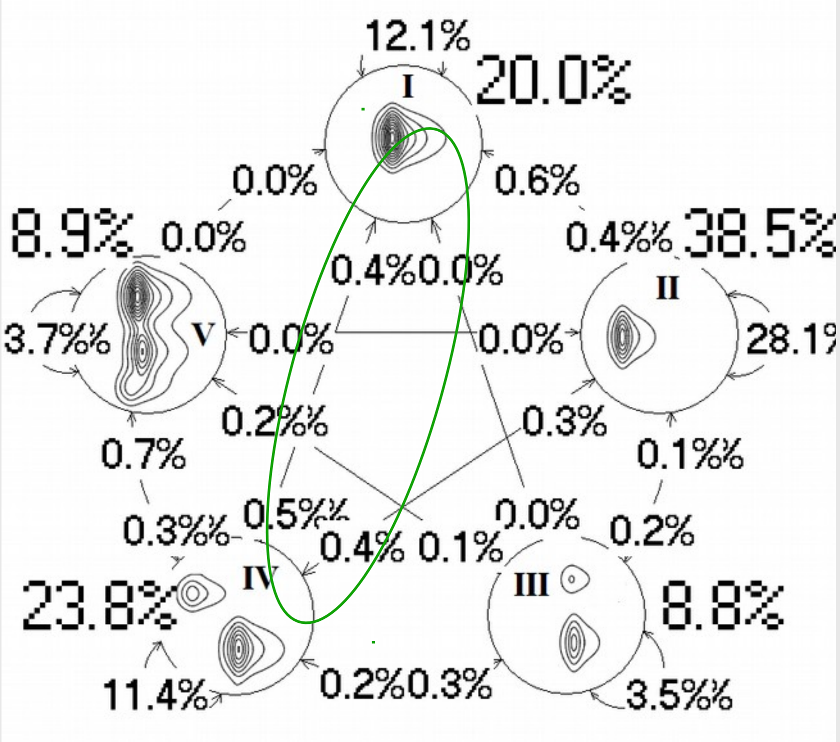

remain in the type **I** in the next step (3h)

**P5 – 1624.8 m (Nazaré Ocean)**

# Modelling the climatic variability of directional wave spectra:
## variability of directional spectral classes

→ **Jump:** the absolute probability of occurrence of the spectral jump **I-IV-I** is 0.5% and **IV-I-IV** is 0.4% (**P5**).

Jump




→ The **5** main **types of spectra** (**P5**):

- wind waves (**I**, 20.0%);
- decaying waves or swell (**II**, 38.5%);
- two swell systems of different ages (**III**, 8.8%);
- wind waves and the swell (**IV**, 23.8%);
- complex multipeaked spectra (**V**, 8.9%).

# Conclusions

→ The statistical analysis shows that it is in the deep water points where the **Hs** is higher.

- The **50th** and the **95th** for the **Hs** present a variation of **1** m to **2.5** m and **2.4** m to **4.8** m, respectively, from shallow to deep water points.

- **50th:** 2002 had the highest waves and 2007 the lowest ones
- **95th:** 2009 had the highest waves and 2007 the lowest ones

→ The polar representation for the **wave spectra variance densities** shows the main direction of the waves, from **W** to **NW**, from **240º** to **330º**.

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# Conclusions

→ The directional spectra processed for each location, were classified in **5 classes of climatic wave spectra** (wind waves – **I**, swell – **II**, two swells - **III**, wind waves and one swell – **IV**, complex multipeaked spectrum – **V**).

→ **Classification** of the **directional spectra** in **classes** of **general wave types:**

- **% one-peaked** spectra is greater for **Sines** (**P7**) and lower for **Faro** (**P8**).
- **% double-peaked** spectra is greater for **Peniche** (**P6**) and lower for **Sines** (**P7**)
- **% multipeaked** spectra is greater for **Leixões Ocean** (**P2**) and lower for **Nazaré** (**P4**).

# Conclusions

- Provides statistics of the main spectral parameter and statistics on the different classes of directional spectra that occur offshore Portugal

↓

detailed picture about how the wave conditions change

↓

characterization of the **wave conditions** in the **8** locations (**Leixões**, **Leixões Ocean**, **Aguçadoura**, **Nazaré**, **Nazaré Ocean**, **Peniche**, **Sines** and **Faro**

- The **characterizations** of the **environmental conditions** are extremely important for all the **marine activities**:

→ **planning the operability and safety of shipping;**
→ **construction of coastal structures;**
→ **implementation of Wave Energy Converts (WEC).**

# Acknowledgements


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