Climate Change Impact Assessment on Ocean Wave Energy and Coastal Hazards and Reducing the Uncertainties in Pursuit of Sustainable Development

Providing parts of the energy demand from renewable resources is vital for a sustainable development. Recent studies over the globe have shown that as well as the amount of energy, the sustainability and reliability of the available resources should be taken into consideration. This project will focus on the impact of climate change on ocean wave energy resources to reduce the uncertainties in wave energy potential assessment and long-term planning of wave farms development. For this purpose, long-term high-resolution wave dataset will be generated in potential areas where have been specified by spatio-temporal assessment of the global wave energy distribution in historical and future projections. Novel criteria will be proposed for locating the optimal locations for wave energy extraction based on the sustainability criteria taking into account both short-term fluctuations and long-term changes due to climate change. In addition, as well as climate change, installment of wave energy converters (WECs) will impact the sea state and coastal morphology. Hence, in this study, the combined impact of climate change and installment of WECs on sea state and coastal morphology will be investigated to reduce the uncertainties in planning for a future sustainable development.

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Background and Importance

Renewable energy resources are proper alternatives to mitigate the negative effects of fossil fuels on global warming and climate change. Marine renewable energies are massive resources to provide parts of the energy demand in areas adjacent to open water bodies. Among them, waves have the highest density and lowest visual and environmental impacts, however, the available resources are strongly affected by climate change, which alters the wind magnitude and pattern and consequently, the wave climate. In addition, development from full-scale testing to the commercialization of wave energy farms has been relatively slow, partly due to the financial risks connected to uncertainties in quantifying the wave energy resources. Moreover, installment of wave energy converters (WECs) (Fig. 1) will impact the sea state and coastal morphology in the areas where the wave energy exploitation is planned. Therefore, my research is focused on assessing the climate change impacts on wave energy resources and extreme events to ensure a reliable supply of energy and efficient use of it, as well as reducing the uncertainties in coastal hazards and investigating the combined impact of climate change and installment of WECs on sea state and coastal morphology to reduce the uncertainties in planning for a future sustainable development.

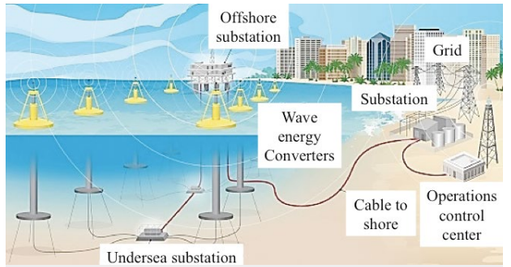

Figure 1

A typical WEC arrangement

Aims and Purposes:

1. Producing global atlas of wave climate and wave energy for historical and future projections
2. Assessment of climate changes impacts on wave energy and discussion on the relationship between simulated wave climatology and observed ocean phenomena
3. Determining potential areas for wave energy extraction considering the higher level of sustainability taking into account climate change impact as well as short-term fluctuations
4. Producing higher-resolution long-term wave energy atlas for historical and future projections in potential areas
5. Determining the optimal locations for wave energy extraction using a novel identifier taking into account both short-term fluctuations and long-term future changes
6. Suggesting optimal WECs and installment arrangement for optimal locations regarding the latest development and future wave climate and extreme values
7. Reducing the associated risks in coastal hazards and wave energy extraction by investigating the combined impact of climate change and WECs installment on sea condition and coastal morphology and developing new criteria for a sustainable usage of wave energy resources

The purposes of this study are matched with #7 affordable and clean energy, #9 industry, innovation and infrastructure and #13 climate action in United Nation's Sustainable Development Goals (SDGs).

Method

The high-resolution wind data for historical period and future projections will be obtained from Global Climate models and will be evaluated using previous reliable wind fields and satellite measurements. Global wave modeling will then be carried out using numerical wave modeling and the results will be validated using measurements to be performed for long-term periods to produce historical and future projections. The generated dataset will then be used to produce the atlas of wave climate and wave energy, globally and assess the wave climate and wave energy spatial distribution and variations in terms of short-term fluctuations and long-term changes. Moreover, the relationship between short-term fluctuations and long-term changes with observed natural phenomena and intensification of teleconnection patterns such as ENSO (El Niño-Southern Oscillation), NAO (North Atlantic Oscillation) will be discussed to clarify the relationship between climatic changes and natural phenomena. Estimation of wave power spatio-temporal propagation will specify the hotspots and potential areas with higher stability in the future for further assessments.

The wave climate in potential areas will then be assessed by higher resolution wave modeling using dynamical downscaling utilizing the boundary conditions provided by the global model. The generated dataset will then be assessed in terms of short-term fluctuations and long-term changes of the wave power in both offshore and nearshore areas in order to specify the optimal locations. A new sustainability indicator will be suggested considering the highest available wave power, highest frequency of exploitable wave powers, as well as lowest variability to reduce the associated risks due to uncertainties in the future and ensure a stable supply of wave energy. Selecting the optimal WECs will be carried out based on their efficiency considering the short and long-term variations in characteristics of the available resources and climate change impacts on extreme events.

In this study, the impact of changing wave climate in combination with the impact of WECs installment will be investigated on sea condition and coastal morphology in nearshore areas. Based on the results, novel criteria for optimal arrangement of the wave farms will be suggested considering both the highest production of energy and protection of the coast under the impact of climate change. The results of the project can be used in a variety of research subjects and industrial projects related to coastal hazards and renewable energies, and the proposed method will provide a reliable approach for the future sustainable development of wave energy exploitation projects.