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CHANGE OF NEARSHORE EXTREME WIND AND WAVE CLIMATE IN SOUTHEAST AFRICA

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EXTENDED ABSTRACT

L'uso eccessivo di combustibili fossili sta causando la riduzione delle riserve di carbone, oltre ad un aumento delle emissioni di gas "effetto serra" esacerbando i cambiamenti climatici. Tali condizioni alterano la circolazione dei venti sugli oceani e, di conseguenza, il clima ondoso, con effetti non solo sui regimi medi, ma anche sugli eventi estremi, la cui determinazione risulta di fondamentale importanza per una accurata gestione delle coste e per la riduzione del rischio costiero. L'Oceano Indiano è interessato da intensi cicloni tropicali sia nella zona settentrionale che meridionale (Gray, 1985; DuBe *et alii*, 1977) ed in quest'ultimo si registrano eventi estremi soprattutto nelle stagioni di dicembre-gennaio-febbraio (DJF) e marzo-aprile-maggio (MAM). Tuttavia, non è ancora chiaro come nelle aree costiere dell'Oceano Indiano meridionale i cicloni tropicali possano evolvere e quale sia l'impatto di tali alterazioni sul regime dei venti e sul clima ondoso. Nel presente studio, sono stati valutati gli eventi estremi sulle aree costiere dell'Africa sud-orientale considerando le proiezioni future secondo uno scenario RCP (Rappresentative Concentration Pathway) 8.5 della quinta fase del modello CMIP5 (Coupled Model Inter-comparative Project). L'analisi è stata effettuata sulla base della variazione stagionale degli eventi estremi sotto costa, al fine di determinare le variazioni nel breve e nel lungo periodo. I risultati indicano che la maggior parte delle aree vicino alla costa africana nel nord e nel sud del Canale del Mozambico, a est e sud-ovest del Madagascar e le coste di Reunion e Mauritius sono soggette ad eventi estremi specialmente durante le stagioni DJF e MAM.

Le proiezioni dei cambiamenti del clima meteomarino mostrano una maggiore intensità degli eventi estremi sotto costa quasi in tutte le stagioni. I risultati (Tabella 1) indicano, inoltre, che i valori massimi di velocità del vento nelle aree costiere dell'Africa sud-orientale aumenteranno dell'1% e del 16% nei mesi di settembre-ottobre-novembre (SON) e giugno-luglio-agosto (JJA), mentre durante le stagioni dei cicloni tropicali (DJF e MAM), aumenteranno, rispettivamente, dell'11% e del 4%. Di conseguenza, le altezze significative delle onde estreme aumenteranno in media del 10% durante DJF, JJA e SON. Durante i mesi MAM, nonostante le previsioni mostrino un incremento degli eventi estremi al largo dell'Oceano Indiano meridionale, si osserva una riduzione dell'intensità degli eventi estremi sotto costa, a causa del cambiamento delle traiettorie dei tifoni.

ABSTRACT

Climate change impact assessment is vital in order to investigate not only the change of average wind and wave climate, but also the extreme events. Such kind of events can affect the activities in nearshore areas such as marine operation, as well as on design of coastal and marine structures. In this research, long-term assessment of wind and wave data has been conducted to determine the effect of climate change by comparing the dataset for historical and future projections. The analysis has been done mainly in nearshore areas and the results were discussed in order to evaluate the impact of climate change, quantitatively.

Keywords: extreme events, wind, wave, Indian Ocean.

INTRODUCTION

Excessive use of fossil fuels has caused negative impacts such as decrease in carbon reserves and increase in greenhouse gases emission and global warming. Climate change alters the wind patterns blowing over the ocean and consequently, the wave patterns and climate. However, changing climate affects not only the average wind and wave regime but also extreme events. For instance, Zhang *et alii* (2019) assessed the climate change impact on extreme conditions of wind. Vanem (2015, 2017) also considered the impact of climate change on extreme value analysis. Taking into account that extreme events play a vital role in coastal management and disaster risk reduction, it is important to consider their variation/change in a changing climate.

The Indian Ocean encounters intense tropical cyclones in both northern and southern parts (Gray 1985; Dube *et alii*, 1977) while extreme conditions in the Southern Indian Ocean exist, especially during December-January-February (DJF) and March-April-May (MAM) seasons. However, it is still unclear how the tropical cyclones will change in the future and what is the impact of their change on wind and wave climates, in nearshore areas of the southern Indian Ocean. Hence, in this study, the extreme events in nearshore areas of southeast Africa have been assessed using a super-high-resolution Global Climate Model (GCM) with 20 km spatial resolution and the future change based on RCP8.5 scenario of a CMIP5 model has been investigated for the first time. The analysis has been done based on seasonal variation of the extreme events in nearshore areas in order to determine short-term variations, as well as long-term change.

METHODS

The study area is Indian Ocean, which has been less investigated for the impact of climate change on wind and wave characteristics. Indian Ocean experiences intense tropical cyclones in both northern and southern parts. The Northern Indian Ocean includes 7% of the global tropical cyclones, which results in generating severe wave climate during the extreme events. The cyclone seasons in the Northern Indian Ocean are divided by pre-monsoon (especially May) and northeast monsoon (October - December). Moreover, there are few cyclones form the southwest monsoon during June and September. In the Southern Indian Ocean the tropical cyclone seasons, start from November 1 until the end of April, with peaks in mid-February to early March.

The wave characteristics in southeast Africa were modeled using SWAN (Simulating WAves Nearshore) (Booji *et alii*, 1999). SWAN is a third generation mode developed by Delft University of Technology mainly to simulate the nearshore wave characteristics. However, it has been used to simulate the wave characteristics in oceanic scale, as well (e.g., Yang *et alii,* 2017). The wind dataset of MRI-AGCM3.2S by Japan Meteorological Agency (JMA) for two periods (historical 1979-2003, and future: 2075 - 2099) was used as forcing (Mizuta *et alii*. 2012) (Fig. 1).

The wind dataset has the spatial and temporal resolution of 20 km and 1 hour, respectively. For the future projections, RCP8.5 of CMIP5 has been considered. The computational domain was considered longitudes between 30° E and 60° E and latitudes between 30°S - 5°N with spatial resolution of (1/6)°×(1/6)°.

The boundary conditions were obtained from a model covering the Indian Ocean developed by Kamranzad & Mori (2019) in which, the wave climate in the Indian Ocean has been generated using the same wind dataset.

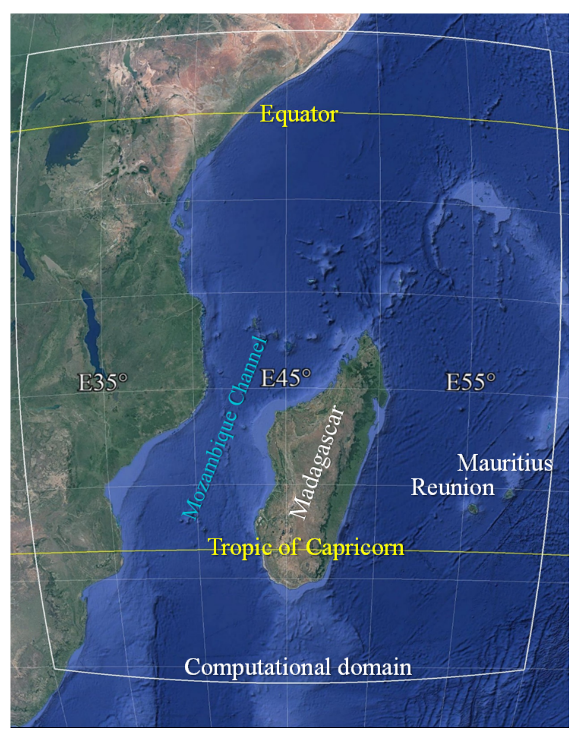

Fig. 1 - Computational domain in the study area.

The model has been validated using near-real-time merged gridded satellite data (Kamranzad & Mori, 2019). The wave model for southeast Africa covers the domain from 30° E to 60° E and 30° S to 5° N with spatial resolution of 1/6° in both directions for both computational and output grids. The comparisons will focus mainly on the change of annual and seasonal extreme events in nearshore areas of southeast Africa.

RESULTS AND DISCUSSION

The model was performed to generate the wave characteristics in southeast Africa for two 25-yearly periods (historical and future projections) and the outputs were used to estimate the nearshore extreme events. Figure 2 shows the extreme wind speed and significant wave height for the whole period of simulations.

According to this figure, east Madagascar, Reunion and Mauritius and Africa's nearshore in the north and south of Mozambique Channel will have higher values in both historical and future periods.

Moreover, there seems to be no considerable change in hotspots in the future compared to the historical period.

The highest waves exist in Reunion and Mauritius in both periods. However, the west of Mozambique Channel is exposed to high wind speeds, it is not affected by high waves as Madagascar acts like a natural barrier causing a sheltering effect on waves.

Assessing seasonal variations (Figures 3 and 4) indicate that extreme waves can be found mostly in Africa's nearshore in the north and south of the Mozambique Channel, east and southwest of Madagascar and the whole coastlines of Reunion and Mauritius, especially during DJF and MAM.

Future changes in wind/wave climate show that the extreme

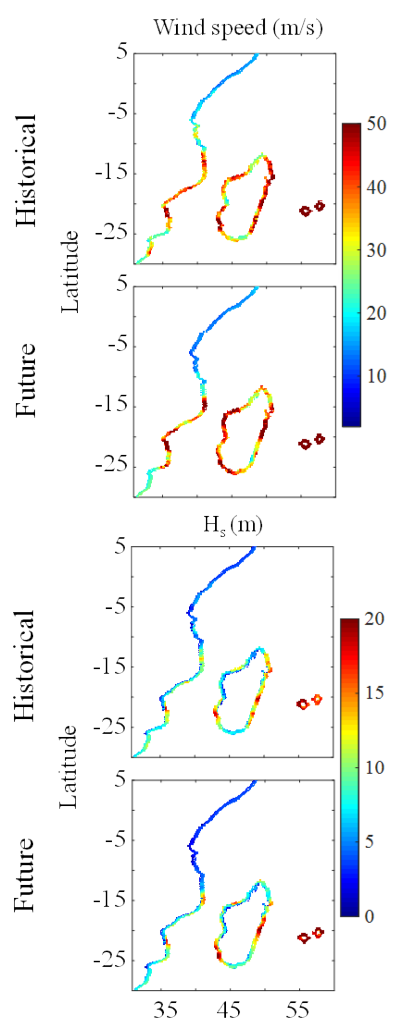

Fig. 2 - Maximum wind speed and significant wave height in southeast Africa.

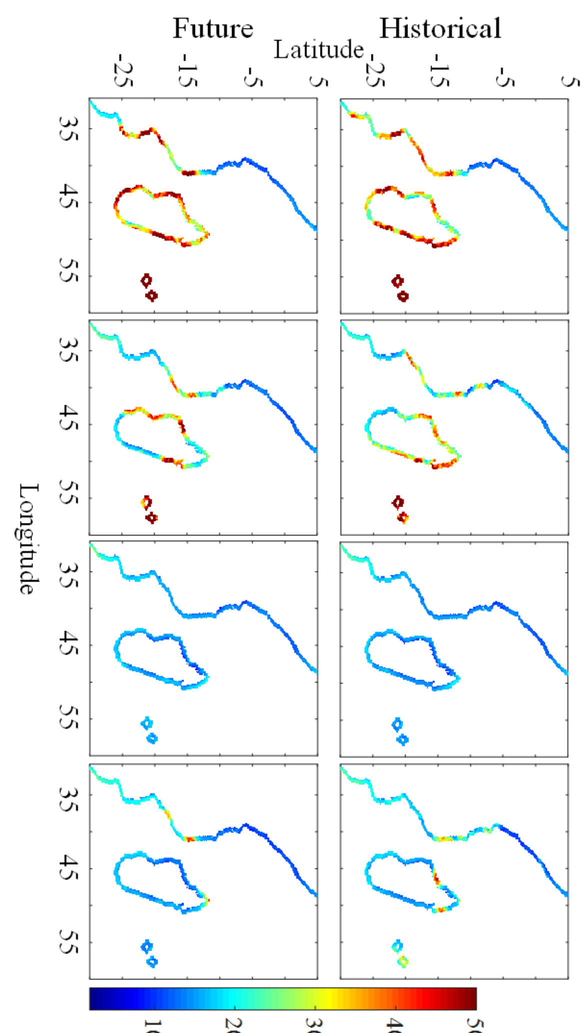

Fig. 3 - Seasonal maximum wind speed (m/s) in southeast Africa.

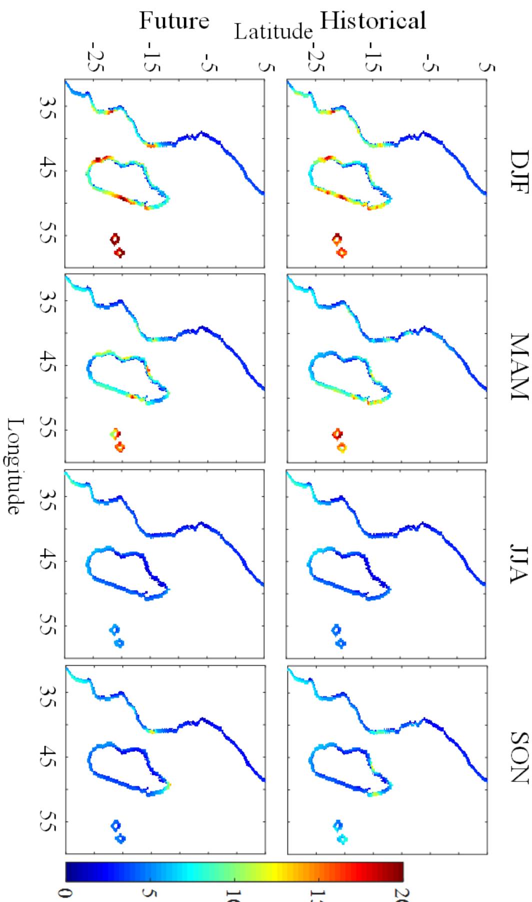

Fig. 4 - Seasonal maximum significant wave height (m) in southeast Africa

		DJF	MAM	JJA	SON
Wind speed	*Historical (m/s)*	*66.1*	*66.6*	*22.6*	*46.7*
	Relative change (%)	*11*	*4*	*16*	*1*
Significant wave height	*Historical (m/s)*	*20.7*	*21*	*8.62*	*13.2*
	Relative change (%)	*11*	*-3*	*10*	*8*

Tab. 1 - Maximum values of wind and wave parameters and their future change.

events will be more intense in the nearshore areas almost in all seasons. Comparing Figures 3 and 4 indicates that the areas with the highest values are almost the same even on seasonal scale, with the exception of the western Mozambique Channel, especially during DJF due to sheltering effect as discussed before.

The results indicated in Table 1 also represent that the maximum values of the wind speed in the nearshore areas of southeast Africa will increase by 1% and 16% during the September-October-November (SON) and June-July-August (JJA), respectively while during the tropical cyclone seasons (DJF and MAM), it will increase 11% and 4%, respectively. Consequently, the extreme significant wave heights will increase 10% on average during DJF, JJA and SON. During MAM, however, the intensity of extreme events will increase in the offshore of the southern Indian Ocean, due to the change in typhoon tracks, the nearshore areas will have lower future extreme events.

SUMMARY AND CONCLUSIONS

Historical and future projections of maximum events in nearshore southeast Africa were compared and the results showed that the extreme events will be most intense in the nearshore areas almost in all seasons. However, during MAM, the intensity of extreme events will increase at the offshore of the southern Indian Ocean, due to the change in typhoon tracks, the nearshore areas will contain lower future extreme events. The spatial distribution of future maximum events will not be different from the historical period. The sheltering effect of Madagascar was also discussed on lowering the wave height in the west of Mozambique Channel despite showing high wind speeds.

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