MULTI-DECADAL VARIABILITY IN GLOBAL WIND AND WAVE CLIMATE: AN ANALYSIS BASED ON MIROC6 DATASET

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ABSTRACT

Assessing the long-term variation/change of wind and wave climate is vital for sustainable development purposes. The long-term variability includes both global warming impacts and natural fluctuations. Typically, spatio-temporal assessment of wind and wave climate is carried out in inter and intra-annual scales, and decadal analysis does not exceed a few decades due to the lack of availability of long-term dataset. The sixth version of the Model for Interdisciplinary Research on Climate (MIROC6) simulates the internal variations on daily-to-multi-decadal timescales that are generated due to the model's dynamics containing both signals of global warming and internal variations. This study utilized 160 years of historical simulation of the wind field obtained from MIROC6 to analyze the decadal variability of wind and wave, globally, to investigate the rate of change in different time slices. Decadal variation was obtained in terms of the rate of change per decade in order to specify the areas with higher climate stability.

Keywords: wind climate, wave climate, MIROC6, decadal change

1. INTRODUCTION

Investigating the variability of wind and wave parameters is necessary not only in short-term (e.g., monthly, seasonal, inter-annual), but also in long-term (e.g., decadal) in order to define the stability of them for different purposes such as the design of coastal structures, installation of wave farms, etc. The recent trend in assessing the impact of climate change of sea state highlights the importance of long-term variation on wind and wave climate. For this purpose, various Global Climate Models (GCMs) with different characteristics have been developed. One of the most recently developed models is the sixth version of the Model for Interdisciplinary Research on Climate (MIROC6) (Tatebe et al., 2019) which covers the time spans of 1850-2014 for historical and 2015-2100 for future projections. In this study, we examine the reliability of MIROC6 in generating the wave climate on a global scale. In addition, we assess the long-term change of historical wind dataset on MIROC6 in 40-yearly time spans in the whole globe.

2. METHOD

MIROC6 wind data with spatial and temporal resolutions of 150 km and 3 hourly, respectively were utilized to force SWAN (Simulating WAves Nearshore) numerical wave model (Booij et al., 1999) Cycle III version 41.31 covering the whole globe. MIROC6 historical dataset including the wind components from 1850 to 2014 with spatial resolutions of approximately 1.4°× 1.4° and temporal resolution of 3-hourly was used as wave model input. Bathymetry information obtained from GEBCO with a 30 arc-sec spatial resolution was also used as a model input (Figure 1). The computational domain covering the whole globe (0° E-360° E in longitude and 90°S–90°N in latitude) has 1° spatial resolution with temporal resolution of 30 mins. The outputs parameters were generated in 6-hourly temporal resolution. The frequency domain of the computational grid ranges from 0.03 to 1 Hz with 36 bins on a logarithmic scale, and the directional computational grid was divided into 36 bins of 10°.

The modeled wave characteristics using MIROC6 wind dataset were verified in comparison with the near-real time gridded (1°x1°, regular grid) satellite wave data obtained from Aviso (http://www.aviso.oceanobs.com/), a global hindcast using SWAN model and JRA-55 wind dataset (Kobayashi et a., 2015) and reanalysis wave dataset obtained from European Center for Medium-Range Weather Forecasts (ECMWF) ERA5 wave dataset ((C3S) CCCS, 2017) for an overlapping period of 2010 to 2012.

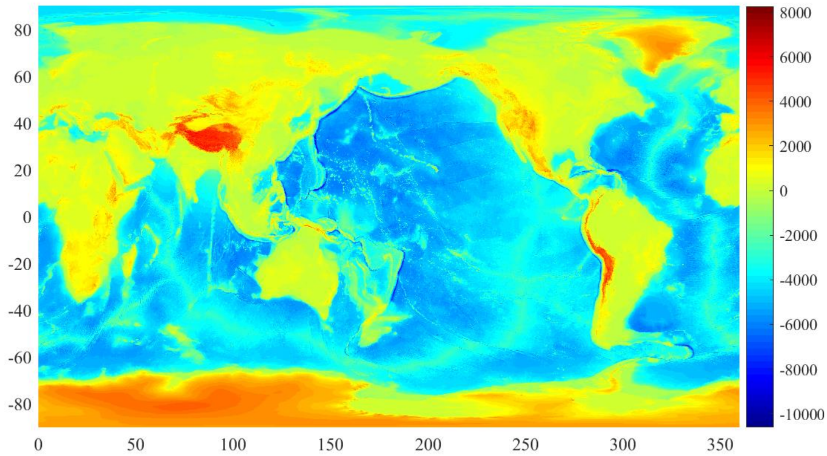

Fig. 1. Bathymetry of the Globe obtained from GEBCO, used an model input.

3. RESULTS AND DISCUSSION

The model reliability in generation of the wave characteristics was evaluated comparing to satellite wave measurements, SWAN generated waves using JRA-55 wind dataset, and ERA5 wave data. Figure 2 indicates the spatial distribution of mean annual significant wave height (H_s) in the whole globe obtained from different resources. According to this figure, MIROC6 driven model shows a similar spatial distribution of Hs comparing to other sources. It seems that the MIROC6 driven model overestimates in the northern Pacific Ocean and Equatorial regions in comparison with satellite and ERA5 data. However, this overestimation can be found in JRA-55 driven model results, as well. In the southern hemisphere, MIROC6 driven model shows more consistency than JRA-55 driven model, compared to satellite measurements and ERA5 re-analysis. Hence, further downscaling on a regional scale is required in order to tune the modeling parameters in various regions, differently.

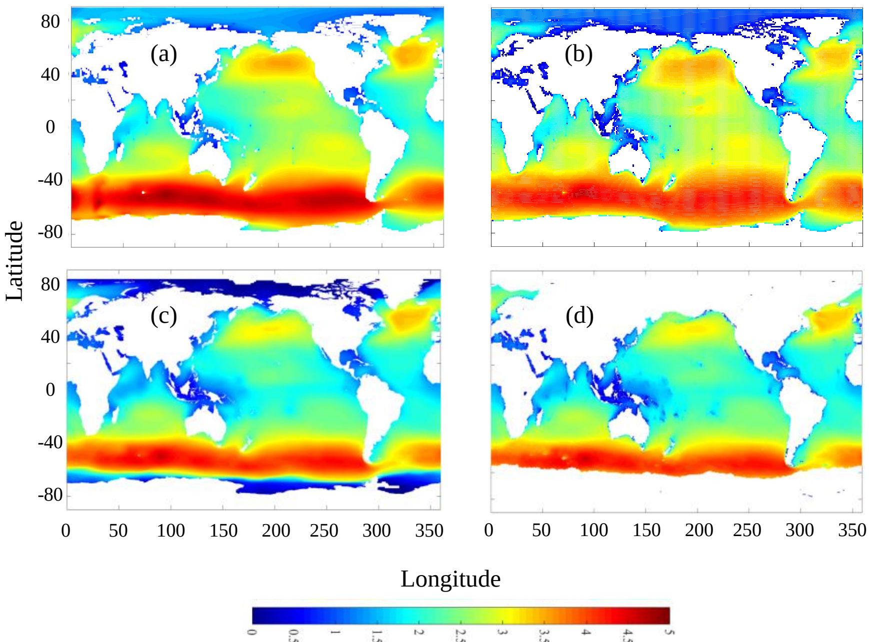

Fig. 2. Annual mean H_s (m), (a) SWAN using JRA-55 wind field, (b) SWAN using MIROC6 wind field, (c) satellite wave data (d) ERA5.

Figure 3 shows the annual rate of change during four 40-yearly periods which has been calculated based on the slope of the best fitting line to yearly mean wind speed in each grid point. According to figure 3, in the first 40-yearly period, there has been both increase and decrease of up to 3% per year in wind speed in Equatorial region. It seems that the wind speed has had a drastic increase in north and south of Australia during that period. In addition, the southern Pacific has experienced a decrease while southern Indian Ocean has experienced mainly increase in wind speed. The second period, i.e., 1890-1929 represents a lower change in the whole globe, while the third period (1930-1969) illustrates a nearly similar pattern to the first period, except for mainly northwest of Australia and south of South America. The changing pattern remains similar in the fourth period except for northern Pacific, Arctic and south of south America. Hence, it is important to consider a suitable period for assessing the impact of climate change. Depending on the purpose of the variability assessment and by diving the periods into shorter time spans, relation between the changing pattern and other natural phenomena can be described.

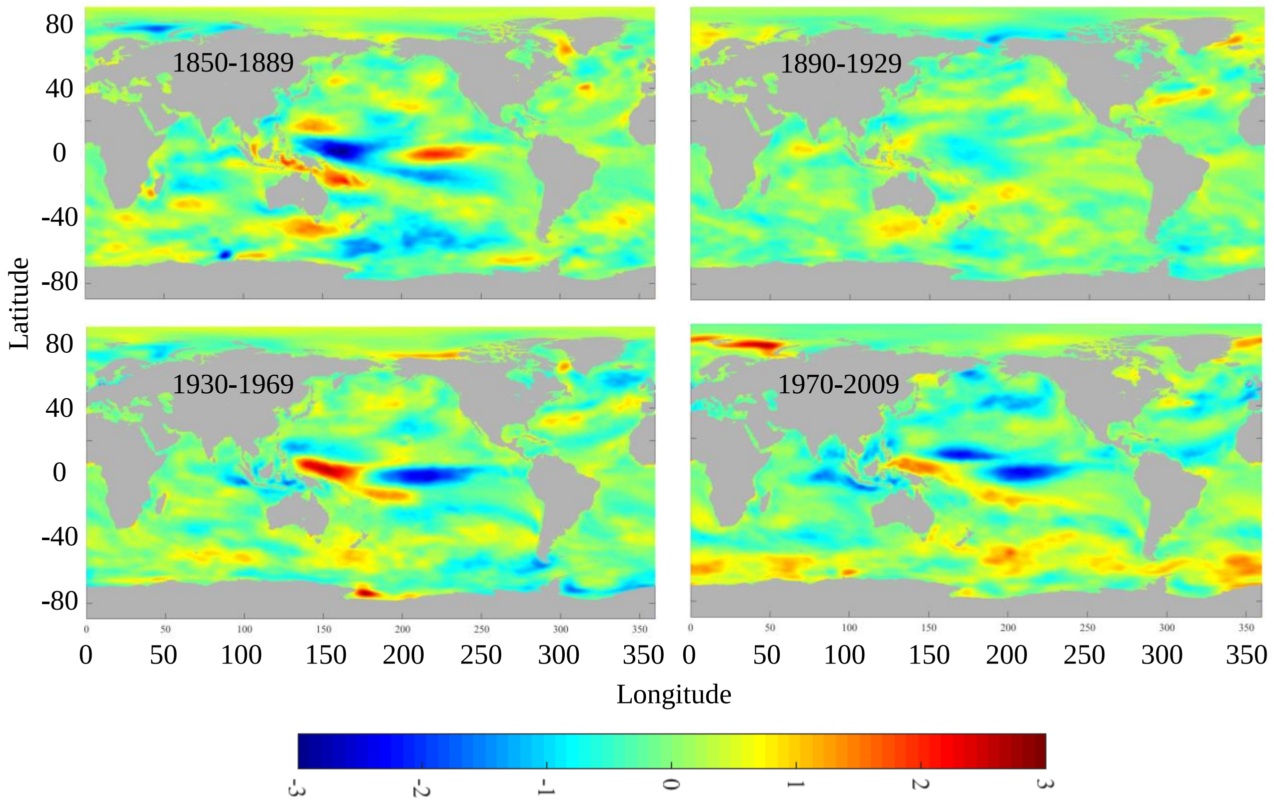

Fig. 3. Annual rate of change during four 40-yearly periods.

4. CONCLUSIONS

The achievements of this study emphasize the importance of considering the appropriate time span for analyzing the wind and wave climate for different targets such as extreme value analysis and wave energy assessment. Hence, the outcome of this research can be used in various applications considering the likely change in estimated values due to long-term variability which can be useful for the target relevant to sustainable development.

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