FUTURE PREDICTION OF WIND VELOCITY AND SIGNIFICANT WAVE HEIGHT IN THE COMPLETELY ICE-FREE ARCTIC OCEAN UNDER RCP8.5 SCENARIO

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INTRODUCTION

The summer sea ice extent in the Arctic Ocean has decreased by several million square kilometers over the past decades highly likely due to anthropogenic global warming (Walsh, 2014). In the Arctic Ocean, the decrease in sea ice increases the open water area (and period), which potentially leads to the development of more energetic wave conditions (Wang et al., 2015). In the summertime Arctic Ocean, the maximum wind speed and the maximum significant wave height have been on a long-term upward trend as the sea ice extent has decreased (Waseda et al., 2018). In addition, changes in wind speed will contribute significantly to changes in the wave height in the future Arctic Ocean (Khon et al., 2014). Thus, it is becoming more important to study the sea surface wave heights in the Arctic area under possible future scenarios. The aim of this study is (1) to develop a method to assess wind and wave conditions over the Arctic Ocean and (2) to predict them under global warming considering the RCP 8.5 scenario.

METHODOLOGY

The Polar Weather Research and Forecasting (PWRF) Model (Hines et al., 2011) and the unstructured-grid finite-volume surface wave model (FVCOM-SWAVE) (Qi et al., 2009) were used to simulate the meteorological and wave fields, respectively. Figure 1 shows an overview of the method developed in this study to assess surface wind, air pressure and wave conditions over the Arctic Ocean. PWRF was used to simulate wind speed and atmospheric pressure. These were used to force the FVCOM-SWAVE to simulate significant wave height under completely sea ice-free conditions. In Figure 1 ((1) and (2)), wind speed and significant wave height were calculated under the current climate conditions. The simulation results were compared with satellite observations of E.U. Copernicus Marine Service Information to verify the accuracy of the simulation framework developed in this study. In Figure 1 ((3) and (4)), a pseudo-warming field, whose methodology followed Nakamura et al. (2016) and Mäll et al. (2017), was constructed to predict wind speed and significant wave height in the future.

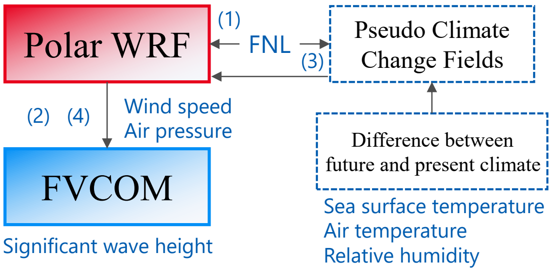


Figure 1 - An overview of the method developed to assess meteorological and wave conditions

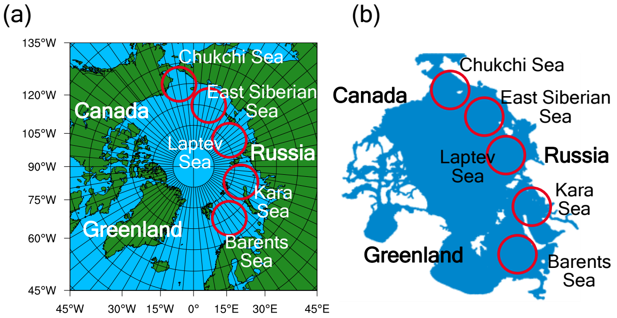


Figure 2 - Computational domain of PWRF (a), unstructured gridded computational domain of FVCOM (b)

Figure 2 shows the simulation domains. The calculation domain was set to include the entire Arctic Ocean. For the PWRF calculations, the grid spacing of the domain was set to 24 km. For the FVCOM calculations, the grid size was set to a maximum of 17 km and a minimum of 2 km. The simulation period was from 00:00 UTC on June 1st to 00:00 UTC on December 1st, 2020. NCEP Final Operational Global Analysis data (FNL) was used to provide initial and lateral boundary conditions for the PWRF. Ice parameters were obtained from Pan-Arctic Ice Ocean Modeling and Assimilation System (PIOMAS) and interpolated into the meteorological grid data. The open boundary condition for FVCOM was set to the astronomical tide predicted by the tidal model NAO.99b (Matsumoto et al., 2000). Future simulation was run by modifying sea surface temperature, air temperature, and relative humidity from 14 General Circulation Models under the RCP8.5 scenario in CMIP5 (Mäll et al., 2020; Nakamura & Mäll, 2021). The future scenario considered the 2081-2100 timeframe.

RESULTS

Figure 3 compares calculated and observed wind speed and significant wave height at a single node point in the Barents Sea (Latitude: 80 degrees north; Longitude: 45 degrees east). In this study, the accuracy of the method developed was verified in the Barents Sea, where the largest number of observed values were obtained. The observed wind speed and significant wave height tended to increase from June to November, and the calculated values also showed the same trend.

Figure 4 shows the correlation between 95th percentile wind speed and significant wave height in the Arctic Ocean under present and future climate conditions. There is a correlation between wind speed and significant wave height for both present and future climate conditions. The intensity of wind speed and significant wave height was greater under future climate conditions than under present climate conditions. This suggests that wind speed will be stronger in the future than at present and that stronger winds will cause higher waves.

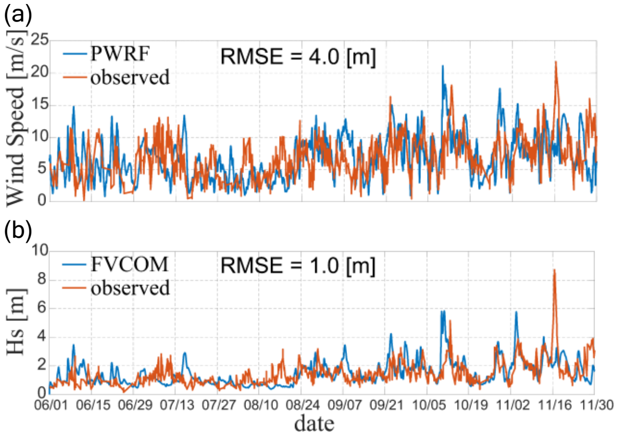


Figure 3 - Comparison of calculated and observed wind speed (a) and significant wave height Hs (b) in the Barents Sea. Blue lines are calculated values and red lines are observed values.

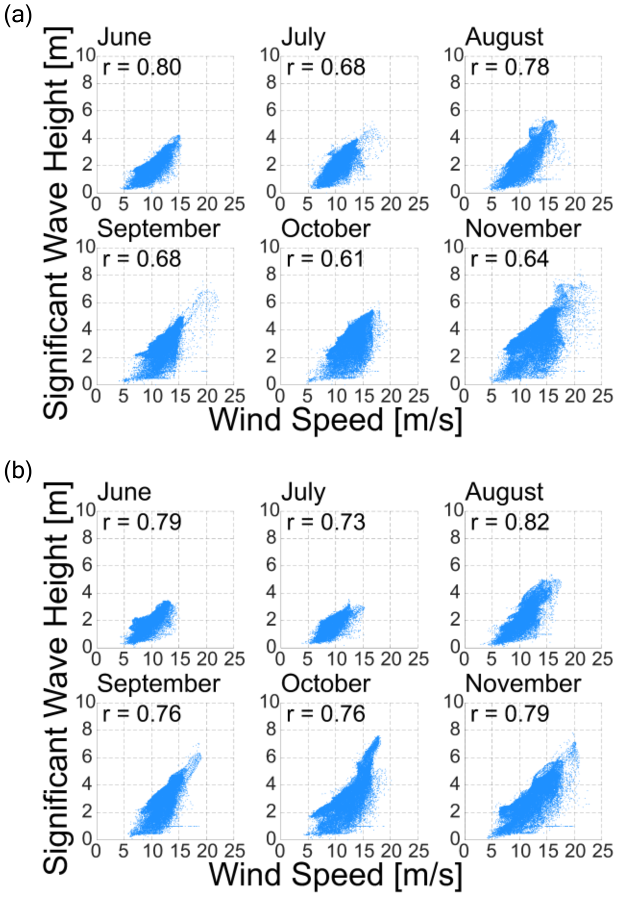
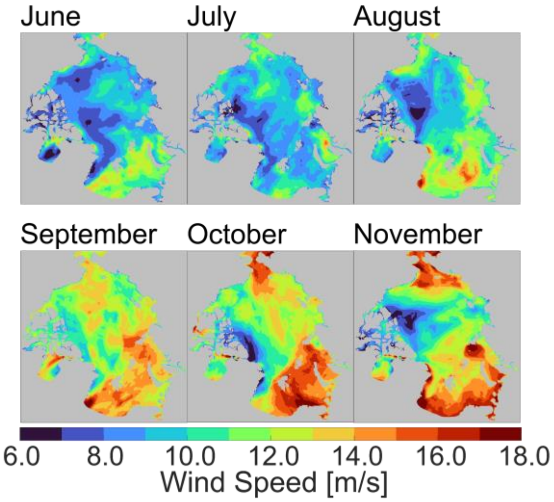


Figure 4 - Correlation between 95th percentile wind speed and significant wave height, where (a) is present and (b) is future.

Figure 5 shows spatial distribution of wind speed and significant wave height in the future Arctic Ocean. In the Chukchi Sea, Kara Sea, and Barents Sea, wind speed and significant wave height were higher than in other areas. On the other hand, wind speed and significant wave height were smaller in the continental side of North America than in other areas.

Figure 6 shows the future changes in wind speed and significant wave height. The wind speed and significant wave height tend to increase in the Chukchi Sea, Kara Sea, and the Barents Sea, and decrease in the East Siberian Sea and Laptev Sea. In September, wind speed and significant wave height showed an increasing trend throughout the Arctic Ocean.

(a) Wind Speed



(b) Significant Wave Height

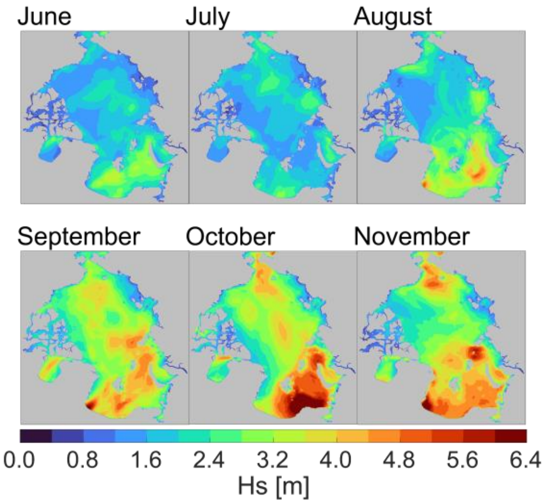
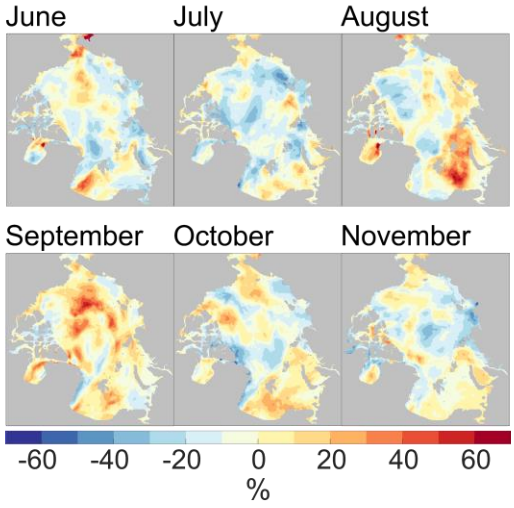


Figure 5 - 95th percentile wind speed (a), significant wave height Hs (b) in the future Arctic Ocean.

(a) Wind Speed



(b) Significant Wave Height

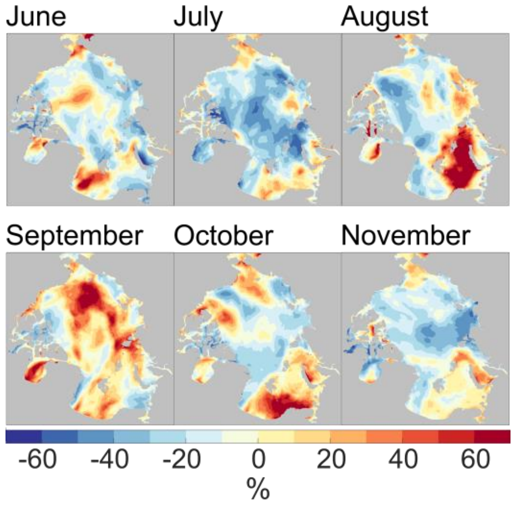


Figure 6 - Future changes in 95th percentile wind speed (a), future changes in significant wave height (b).

CONCLUSION

In this study, we developed a method to assess potential meteorological and wave climate fields in the Arctic Ocean under pseudo global warming experiments using the RCP8.5 scenario.

PWRF Model and FVCOM-SWAVE were used to simulate the meteorological and wave fields, respectively. FVCOM-SWAVE simulated significant wave height under completely sea ice-free conditions.

The results indicate that there is a correlation between wind speed and significant wave height in the Arctic Ocean. The intensity of wind speed and significant wave height is greater under future climate conditions than under present climate conditions. This suggests that wind speed will be stronger in the future than at present and that stronger winds will cause higher waves.

The results also suggest that wind speed and significant wave height may increase in the Chukchi Sea, Kara Sea, and the Barents Sea, and decrease in the East Siberian Sea, Laptev Sea, and the continental side of North America toward the end of 21 century.

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