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Abrupt changes in wave climate of regional seas caused by large-scale atmospheric forcing and teleconnections

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Climate warming is expected to change the functioning of regional seas substantially. However, it is still an open question how the global climate processes will affect in the future the regional seas, their wave climate, changes in the storm surges and, consequently, the coastal erosion, flooding risks, and coastal communities. In this study, we perform a detailed analysis of the wave climate of the Baltic Sea and the Caspian Sea based on the multi-mission satellite altimetry data in 1990 – 2017. The dataset of significant wave heights (SWH) from ten satellites was cross-validated against regional in situ buoy and echosounder measurements. In the Caspian Sea, due to the limited availability of the in-situ measurements, the satellite data were validated with visual wave measurements. After correction for systematic differences, the visual observations showed excellent correspondence with monthly averaged satellite data with a typical root mean square difference of 0.06 m. Even though several satellite pairs (ENVISAT/JASON-1, SARAL/JASON-2, ERS-1/TOPEX) exhibit substantial mutual temporal drift, and calm wave conditions are ignored, the overall picture is very consistent. The averaged over the whole basin annual mean SWH in the Baltic Sea shows an increase of 0.005 m/yr but no significant trend is detected in the Caspian Sea.

Interestingly, in both Baltic and Caspian seas, changes in the average SWH exhibit a strong spatial pattern. In the Baltic Sea, a meridional pattern is detected: an increase in the central and western parts of the sea and a decrease in the eastern part. This pattern has a timescale of ~13 yr. We also found a faster-varying region in the Baltic Proper where trends in the wave heights experience abrupt changes with a timescale of 3 years and show a strong relation to changes in the North Atlantic Oscillation. In the Caspian Sea, the wave height decreased by 0.019 ± 0.007 m/yr in the eastern segment of the central basin and by 0.04 ± 0.04 m/yr in the western segment of the southern basin when the other parts showed an increase of wave heights. These changes can be explained by an increase in the frequency of westerly winds at the expense of southerly winds. Analysing the changes in the atmospheric forcing we found that there is a cyclic behaviour with a timescale of ~12 years which result in abrupt changes in the wave climate every 12 years, causing the trends in different regions to reverse its sign.

We demonstrate that the impact on the coast and coastal community is caused by a complex chain of events, starting from changes in the wind direction due to large-scale atmospheric variability and atmospheric teleconnections, which create abrupt shifts in the wave climate of regional seas. We discuss that regional seas have a different response to the changing climate

compared to the open ocean condition, which can lead to accelerated coastal erosion and a higher risk of flooding.