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Marine heatwaves in the Red Sea: a study of their spatial characteristics, trends and relationships to climate modes

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Episodes of very warm sea surface temperatures (SST), known as marine heatwaves (MHWs), can potentially alter ocean ecosystems with far-reaching ecological and socio-economic consequences. In this work, we focused on the Red Sea (RS), a region of outstanding socio-economic importance, and investigated its spatio-temporal MHW variability between 1982 and 2021. In addition, the relationship between MHWs and different climate teleconnection patterns was investigated. Our results show that during the study period (1982-2021), the highest frequencies of MHWs were in the southern Red Sea (SRS), while the prolonged and more intense ones were in the northern Red Sea (NRS). By analyzing satellite-derived sea surface temperatures (SST), we identified a warming trend in the RS that began from the mid-1990s, and has intensified since 2016. This temperature increase was accompanied by an increase in the MHW frequency and total days. 78 MHW events with a total of 1016 heat days occurred in the RS between 1982 and 2021, of which 36 events (46%) and 590 days (58%) were recorded in the last decade. In the NRS, the annual MHW frequency was highest in 2010, 2018, 2019 and 2021, while in the SRS it was highest in 1998 and from 2017 to 2021. In cold years, characterized by a negative average SST anomaly, MHWs were mainly found in the NRS. In contrast, in warm years characterized by a positive average SST anomaly, MHWs mainly affected the SRS. However, an exception was observed in 2010, which is considered one of the warmest years in the last four decades. In this year, MHWs were predominantly localized in the NRS, deviating from the typical pattern observed in warm years. The MHW frequency showed a strong positive correlation (> 0.7) with the Atlantic Multidecadal Oscillation (AMO) over the entire RS and a positive correlation (> 0.4) with the Indian Ocean Dipole Index (IOD), which was more pronounced in the SRS, whereas it had a negative correlation (< -0.5) with the East Atlantic/Western Russia (EATL/WRUS) pattern, particularly in the NRS. It was noted that 2010 was also an exceptional year for the climate modes as the AMO and IOD were in strong positive phases, and the EATL/WRUS was in its highest negative phase, both of which may have contributed to the increased MHWs in that year. This study highlights the link between climate patterns and the occurrence of marine heatwaves in the Red Sea and provides valuable insights into this important aspect of climate change.