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Marine heatwaves in the Baltic Sea: IOW researchers investigate causes and effects

Marine heatwaves – periods in which the upper water layers in the sea temporarily become exceptionally warm – are occurring with increasing frequency worldwide. Recent studies by the Leibniz Institute for Baltic Sea Research Warnemünde (IOW) have now confirmed this trend also for the Baltic Sea. IOW researchers analysed very large meteorological and hydrographic data sets and identified the specific wind and weather conditions that cause Baltic Sea heatwaves. They also analysed for the first time the extent to which heatwaves reach the Baltic Sea floor and discovered that they can lead to severe oxygen depletion even in usually well-aerated coastal waters.

It is clearer than ever that the global climate is heating up – seemingly unstoppable: In this year alone, previous record temperatures were exceeded every month and just recently, on July 21, the European Copernicus Climate Service reported the warmest day ever recorded on Earth. Global warming is not stopping at the oceans either and the Baltic Sea in particular is one of the fastest warming marine regions in the world, having warmed by more than 1 °C in the last three and a half decades.

In addition to general ocean warming, marine ecosystems are also affected by marine heatwaves. These are limited periods in which the temperature of the upper water layers exceeds a threshold value typical for the respective region and season for at least five days. In the last century, such heatwaves have increased worldwide: An international study shows that since 1925 they have occurred more frequently and lasted longer, resulting in over 50 % more marine heatwave days per year.

To understand the occurrence of heat waves in marginal and inland seas in general, and in the Baltic Sea in particular, an IOW research team led by Baltic Sea climate experts Matthias Gröger and Markus Meier evaluated enormous meteorological data sets from the European Weather Center spanning more than three decades, which they incorporated into high-resolution ocean models. They identified distinctive characteristics in the large air pressure patterns and wind systems over the North Atlantic and Europe that lead to heatwaves in the Baltic Sea: In the summer months, it is the stable high-pressure systems over Scandinavia that cause the heatwaves – not only due to strong solar radiation and high air temperatures, but above all due to the exceptionally weak winds under such conditions. The latter prevents the increasingly warming surface water from mixing with cold water from the depths, leading to a heat build-up in the upper water layers.

Baltic Sea heatwaves can also occur in winter: They develop whenever strong, persistent westerly winds transport warm, humid air masses from the Atlantic to Europe, which means that the Baltic Sea does not cool down as much as usual at this time of year. Such warm, persistent winter winds occur when a particularly high difference in air pressure builds up over the Atlantic between the Icelandic low and the subtropical high-pressure belt. The dataset covering the period between 1980 and 2016 that was analysed in the study also shows that both summer and winter heatwaves in the Baltic Sea are becoming more frequent, last longer and affect increasingly larger areas.

Another recent study by the IOW shows that heatwaves in the Baltic Sea can have a significant impact on vital environmental parameters. Researchers working with Gröger and Meier analysed model data from five decades (1970 to 2020) from the European Copernicus service for monitoring the marine environment. The data take into account a large number of parameters in high temporal and spatial resolution that are important for temperature and matter exchange processes in the Baltic Sea. The research team also investigated for the first time how deep summer heatwaves spread into the water column, with a particular focus on the shallow coastal areas of the Baltic Sea, which are normally considered to be permanently well “aerated” and therefore robust against oxygen deficits.

The results of this study were surprising and alarming: The analyses demonstrated that heatwaves in summer often penetrate to a water depth of about 20 meters and reach the sea floor, where they can

locally reduce the oxygen content of the water substantially. Summer oxygen concentrations can generally be very low at the bottom of the sea in coastal areas, sometimes falling below 2 ml / litre, a critical threshold value, below which life is no longer possible for more highly developed organisms such as mussels, worms, crabs and fish. The oxygen-depleted areas at the bottom of the sea are also increasingly located above the stable thermocline, which in summer forms at a water depth of around 20 metres in the Baltic Sea and above which wind-driven mixing should normally ensure sufficient aeration. As the Baltic Sea is one of the fastest warming regions in the world's oceans, there is a high risk that marine heatwaves, together with further climate warming, will more and more cause critical oxygen deficits for the bottom fauna with far-reaching consequences for the entire ecosystem.

Original publications:

Gröger, M., Dutheil, C., Börgel, F., Meier, H. E. M. (2024): *Drivers of marine heatwaves in a stratified marginal sea.* Climate Dynamics 7062, DOI:10.1007/s00382-023-07062-5

Safonova, K., Meier, H. E. M., Gröger, M. (2024): *Summer heatwaves on the Baltic Sea seabed contribute to oxygen deficiency in shallow areas.* Commun Earth Environ 5, 106. DOI:10.1038/s43247-024-01268-z

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