From the surface to the deep-sea: characteristics and drivers of marine heatwaves in the Atlantic Ocean

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Marine heatwaves (MHWs) were shown to have devastating impacts on marine ecosystems across the Atlantic Ocean. While various studies utilise model and observational based datasets to detect MHWs at the surface, little is known about the characteristics and drivers of MHWs at depth. Detecting MHWs requires continuous daily temperature records over a multi-year time period, which are only scarcely available from observations, in particular in the deep ocean. Although models provide such a temporally and spatially coherent dataset, a basin-wide detection of MHWs is challenging, especially for high-resolution models with realistic mesoscale activity and boundary current systems, due to the large number of grid points. We fill this major gap by identifying MHWs over the course of more than 40 years at all 100 million three-dimensional grid points of an eddy-rich (1/20°) ocean model, covering the entire Atlantic Ocean from 34.5°S to approximately 65°N.

We find that MHWs at depth frequently occur along the pathways of highly variable currents, such as the Gulf Stream, North Atlantic Current, or Deep Western Boundary Current. Although their appearance is more frequent along the boundary of the Atlantic, MHWs last longer in the interior ocean. By comparing different experiments in the same model that only differ in their initialisation, we show that a potential pitfall of detecting sub-surface MHWs is a drift in model temperature, particularly at depth. While MHWs statistics are robust at the surface, their duration at depth strongly depends on the magnitude of the temperature drift in the experiments. As a consequence, detecting MHWs at depth requires a model spin-up of at least a few 100 years to allow the deep ocean to equilibrate. Such a long spin-up is often not feasible in eddy-rich models. Furthermore, we show that changes in MHW statistics at the surface are mostly explained by ocean-atmosphere heat fluxes. In contrast, the occurrence of sub-surface MHWs is closely linked to variability of the large-scale circulation, including the Atlantic Meridional Overturning Circulation.