Column-Compound Extremes: From the Global to the Southern Ocean

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Marine heatwaves (MHW) are becoming more prevalent in the oceans, posing a threat to marine organisms and ecosystems. In addition, ocean acidity extremes (OAX) and low oxygen extremes (LOX) may co-occur with MHWs in the water column, causing synergistic impacts on organisms such as increased metabolic and physiological stress. Vertically migrating organisms are particularly affected, as the compounding of these extremes constricts habitable space in the water column. We recently developed a relative threshold method to identify Column-Compound Extremes (CCX), i.e., where at least two parameters are extreme at the same time, and where each extreme type extends vertically over at least 50 m. In a global hindcast simulation of the ocean component of the Community Earth System Model (CESM) run at a relatively coarse resolution of about 100 km, we found that MHW tended to co-occur with OAX at the surface in the subtropics, and at the subsurface at higher latitudes. In the tropics and subantarctic, MHWs occurred at the surface, while OAX and LOX occurred in the subsurface. By clustering the CCXs based on vertical positions of constituent single extremes, we inferred drivers such as increased air-sea heat flux, strong diapycnal mixing, and thermocline heaving. MHWs have a propensity to co-occur with OAXs in regions without strong upwelling. On the other hand, upwelling regions see MHW induced at the surface, and OAX and LOX co-occurring below the thermocline, drastically reducing vertical habitable space. To investigate these mechanisms in more detail and to assess the role of resolution, we used daily output of a hindcast simulation (1979-2019) from the Regional Ocean Modeling System (ROMS), coupled with the Biogeochemical Elemental Cycling model (BEC) to simulate the Southern Ocean (30-80°S) at a 0.25° resolution. Applying the same CCX methodology, we expect to diagnose the drivers of specific CCXs in the hindcast, linking them to climate variations such as the El Niño Southern Oscillation or Southern Annular Mode.