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Simulating the Development of the Eastern Tropical Pacific Oxygen Minimum Zone during the Holocene

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Oxygen minimum zones (OMZs) in the ocean are areas of severely low oxygen concentrations, caused by low rates of oxygen delivery (ventilation) and/or high rates of oxygen consumption due to the degradation of organic matter. OMZs are of major importance, for example on regional economies due to their impact on higher trophic level organisms in the water column, with expanding OMZs potentially reducing fishery yields. OMZs are potentially triggering ocean denitrification, which causes a loss of nitrogen, the major limiting nutrient on short time scales, thereby reducing the oceans ability to sequester (anthropogenic) carbon. Denitrification also results in the production of N2O, a potent greenhouse gas, and therefore, OMZs are also of relevance for the global climate. In recent decades an expansion and intensification of the major OMZs in the world oceans has been observed, probably caused by ongoing global warming.

In the present study transient climate and ocean biogeochemical model simulations of the Holocene (last 10 kyrs) have been carried out to assess the natural variability of OMZs, especially with regard to anticipated future climate change. The Holocene is characterized by rather stable annual mean global climate conditions with only moderate variations, for example a mid-Holocene climate optimum which is mostly manifested in land proxy records. At the seasonal time scale, however, some larger reorganisations have occurred due to the effect of orbital insolation forcing (mostly precession). We find that, even in the absence of strong external climate forcing, the OMZ of the Eastern Tropical Pacific (ETP) underwent significant variations with better-oxygenated conditions during the mid-Holocene. The late Holocene expansion of the ETP OMZ is accompanied by an increasing age of water masses entering the deep Pacific, which cannot immediately be linked to any climate forcing factor, highlighting the slow response time of the sub surface ocean. The recently observed trend of the ETP OMZ may thus be part of a still ongoing adjustment of the sub surface ocean to Holocene climate change, potentially amplified by anthropogenic forcing.