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Ocean biogeochemical modeling of scenarios leading to eastern Mediterranean sapropel formation during the early Holocene

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During the early Holocene, a series of changes in the conditions of the Mediterranean hydrography, and correspondingly its biogeochemistry, occurred. This led to the formation of an organic rich sediment layer, the so called sapropel S1, which has been attributed to a better preservation of organic carbon in oxygen depleted deep water masses. The absence of oxygen in the deep water (anoxia) might be the result of a stagnating deep-water circulation, which prevents the ventilation of the deep water column, or an enhancement of the surface primary production, which would lead to an enhanced oxygen utilization rate, or a combination of a stagnating deep-water circulation and enhanced oxygen utilization. The aim of this study is to identify plausible scenarios leading to the sapropel S1 formation.

For this purpose, we set up a regional version of the general ocean circulation model MPI-OM for the Mediterranean (20 km horizontal resolution, 29 levels) coupled to the biogeochemical model HAMOCC. The model is forced with atmospheric data derived from equilibrium time slice simulations for pre-industrial conditions and 9 kyr BP with the atmosphere-ocean-dynamical vegetation model ECHAM5/MPI-OM/LPJ. To identify the plausible scenarios leading to sapropel formation we conducted several experiments with a stagnating deep-water circulation and/or enhanced primary productivity.

Results show that an 3 times increase in riverine nutrient input within a well ventilated ocean does not lead to deep water anoxia, since the continuous oxygen supply through deep-water ventilation compensates the higher oxygen utilization rates from the higher primary productivity. On the other hand, a stagnating deep-water circulation without an enhancement of the primary productivity does not lead to deep water anoxia neither. In the experiments with a stagnating deep-water circulation upwelling processes are strongly reduced and diffusion is the main supplier of regenerated nutrients to the euphotic zone. Consequently, primary production is reduced to around 2/3 of the original primary production in a well ventilated state. This leads us to the conclusion that a stagnating deep water circulation in combination with an enhanced external nutrient supply are prerequisites for the sapropel formation in the eastern Mediterranean during the early Holocene.