



Multi-decadal variability in temperature and rainfall proxy records from the Baltic Sea, the Mediterranean Sea and the Black Sea over the last 2000 years

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Records of temperature and rainfall variability across highly populated marginal seas with a decadal to multi-decadal resolution over the last millennia are precious to improve future climate projections in these highly sensitive areas. Here, we combine well-dated, quantitative surface water temperature reconstructions and qualitative rainfall-related records from the central Baltic Sea, the north-western Mediterranean Sea (Gulf of Genoa) and the south-eastern Black Sea based mainly on molecular organic proxies. The records, which cover the last 2000 years with a multi-decadal resolution, indicate that temperatures were 1-2 °C above the 2-kyr-averages during the Medieval Warm Period (MWP) and the Modern Warm Period (MoWP), while they were 1-2 °C below averages during the Dark Ages Cold Period (DACP) and the Little Ice Age (LIA). Rainfall-related proxy records suggest relatively wetter conditions during warm periods (MWP and MoWP) and drier conditions during cold periods (DACP and LIA) in the Baltic Sea realm. Conversely, relatively drier conditions prevailed during warm periods, and wetter conditions during cold periods in the NW Mediterranean Sea and the SE Black Sea. Because such an antiphase pattern is presently typical of the North Atlantic Oscillation (NAO), we suggest rainfall variability over the last 2000 years to be predominantly controlled by NAO-related shifts in the westerly winds and associated storm tracks at a multi-decadal timescale. In the Baltic Sea, warm periods were also characterized by relatively high primary production and hypoxic conditions in the deep basins of the Baltic Sea, while during cold periods relatively low primary production and oxic conditions prevailed. We suggest that shifting westerly winds are potentially the primary mechanism responsible for the oxygenation of the Baltic Sea at a multi-decadal timescale, while temperature and human impact are most probably mainly amplifiers.