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Distinguishing climatic from direct anthropogenic influences during the past 400 years in varved sediments from Lake Holzmaar (Eifel, Germany)

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A 336-year floating varve chronology covering the period AD 1607-1942 from Lake Holzmaar (Eifel, W-Germany) has been established using microfacies analysis of thin sections. Varve microfacies analysis revealed 13 different sublaminae based on their lithology, fabric, and microfossil content. Element mapping (μXRF scanning) resulted in count rates of Al, Si, S, K, Ca, Ti, Mn and Fe above the background level. The influences of climatic variability and anthropogenic activities in the lake's catchment (e.g., forestry, agriculture) on the combination of the sublaminae in the varves and their thickness and on the element chemistry could be discriminated by applying statistical analyses (ordination and fuzzy c-means clustering). The obtained clusters characterize four different states during the studied sequence. Colder phases during the Maunder Minimum and the Dalton Minimum are accompanied by transitional phases marked by vigorous and prolonged spring circulation (clusters 1 and 2). In contrast, samples assigned to clusters 3 and 4 show the imprint of anthropogenic influences. Cluster 3 (AD 1795-1815 and AD 1825-1885), characterized by above-average VT due to high detritus input throughout the year, can be linked to anthropogenic deforestation at the end of the 18th century. This external input, with increased count rates of detrital elements, biases the signal of a colder climate during the Dalton Minimum. At about AD 1890, cluster 4 conditions with increased nutrient concentrations, enhanced S count rates, low detritus input, and longer periods of stable summer stratification, become the stable state in Lake Holzmaar. They indicate the response of the lake to natural reforestation and the use of artificial fertilizers in the catchment. The prolonged, stable summer stratification periods may be the first indication of the modern warming trend.