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Climatic variability in the Mediterranean region over the last 130 ka, sapropel formation and teleconnection with the North Atlantic and monsoon systems

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Since the identification of millennial-scale climatic variability in Greenland and the North Atlantic (Dansgaard-Oeschger (D-O) and Heinrich (H) events) several questions remain open regarding the expression of this variability in the Mediterranean region, the oceanic and atmospheric mechanisms involved and how other forcings such as orbital parameters affect this variability. Several high-resolution pollen-rich marine cores retrieved in the framework of the IMAGES and ODP programs and covering at least the last 50,000 years have been analysed in the last decade. An array of terrestrial and marine micropalaeontological (pollen, foraminifer), sedimentary (microcharcoal, ice rafted detritus) and geochemical (d18O and d13C) tracers from the same sample set has allowed us to establish a direct correlation between the evolution of the atmospheric and oceanic reservoirs. All the D-O events have a counterpart in western Mediterranean terrestrial and marine ecosystems. Cold sea surface temperatures (SST) were synchronous with the expansion of semi-desert landscapes indicating a decrease in winter precipitation likely related with the northward displacement of the westerlies. SST increases were contemporaneous with the expansion of this forest and, therefore, the establishment of the Mediterranean climate, i.e. wet and mild winters with warm and dry summers. The best expression of the Mediterranean climate occurred during the Eemian, D-O 24, 21, 17-16, 8-7, 1 and the Holocene. These maxima occurred always during precession minima (seasonality maxima). The comparison of Mediterranean and Atlantic terrestrial and marine palaeoclimatic records of the last glacial period with Greenland temperature changes reveals that the Mediterranean region is distinctly impacted by precession. The comparison of this contrasting latitudinal climatic scenario with the global methane record which is also modulated by precession during the last climatic cycle reveals that the amplitude of methane peaks parallels the magnitude of forest cover expansion in the western Mediterranean region, in particular during the glacial interval (from 74 to 13 ka), and suggests the existence of an underlying common mechanism also affected by precession, namely the Asian monsoon, which determines both the strength of Mediterranean climate and methane emission. Precession minima would trigger, on the one hand, strongest summer monsoon which, in turn, produce maxima in Mediterranean summer dryness and increase of winter precipitation and, on the other hand, the largest Asian wetland expansion reaching 40°N. Besides, peaks in the Mediterranean forest coincide with precipitation maxima in the eastern Mediterranean region as detected by the Soreq cave d18O speleothem record. These periods of maximum rainfall, likely occurring during winter as concomitant expansion of the summer dry tolerant sclerophyllous plants are detected, are chronologically associated with sapropel S5 to S1. Therefore, sapropel formation would coincide with periods of maxima in both winter rainfall and summer monsoon which led to strong freshwater discharges over the entire year. In winter these discharges arrived by the rivers of the Mediterranean borderlands and in summer trough the strong Nile floods which distinctly affected the eastern Mediterranean basin. This work suggests that several apparently unrelated phenomena, namely the amplitude of the Mediterranean forest expansion, of monsoon enhancement and of methane emissions, and sapropel formation are all modulated by the same orbital forcing (precession).