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Modulation of millennial-scale climate variability by orbital-scale forcing factors during the last 48 ka in the Atlantic-Mediterranean transition zone

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High-resolution pollen analysis of Alborán Sea core MD95-2043 (36˚8'6"N, 2˚37'3"W; 1841m water depth) provides a 48 ka continuous vegetation record which can be directly correlated with sea surface and deep-water changes. Marine Isotope Stage (MIS) 3 was characterised by fluctuations in *Quercus* forest cover in response to Dansgaard-Oeschger (D-O) climate variability and Heinrich event impacts, while MIS 2 was characterised by the dominance of semi-desert vegetation. The Bölling-Allerød (MIS 1) was marked by rapid forest development, while a re-expansion of semi-desert environments occurred during the Younger Dryas. The maximum development of mixed *Quercus* forest occurred during the early to mid-Holocene (11.1 to 5.4 ka), with forest decline related to cooling and drying after 5.4 ka. While the record is characterised by high amplitude vegetation changes in response to millennial-scale (D-O) climate variability, important orbital-scale trends are observed which reveal the modulation of vegetation response to rapid climate change by orbital-scale factors. A long-term decline of arboreal populations from MIS 3 into MIS 2 reflects high-latitude northern hemisphere summer insolation decrease in phase with the expansion of global ice-volume and atmospheric CO_2decrease. Interglacial arboreal trends reflect summer insolation patterns and contrast with atmospheric CO_2increases. Precession also had a pervasive influence on vegetation development during MIS 3, 2 and 1, influencing both the amplitude of forest development and forest composition during different interstadials. This modulation of vegetation response to millennial-scale variability may relate in part to the influence of remote atmospheric teleconnection patterns on the

Mediterranean climate, notably the strengthening of the South Asian monsoon during precession minima. The modulation of D-O interstadial forest development by orbital factors is compared and contrasted with other records from the Iberian margin, contrasting regions of stronger Atlantic and Mediterranean climate influences.