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# Late Quaternary hydrology in North Africa and the Near East (Hans Oeschger Medal Lecture)

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The present-day arid-semiarid belt from North Africa to West Asia has experienced huge hydrological changes together with a long history of human civilisations. This belt straddles the boundary between a temperate domain (winter rains linked to the mid-latitude Westerlies), and a subtropical one (rare monsoonal summer precipitation). What are the timing and direction of major hydrological changes in these two domains ? How does the transitional zone migrate through time, and why ? How did human societies respond to changes in water availability ? These questions are addressed using records illustrating both long and short-term environmental changes.

At the glacial-interglacial time scale, hydrological changes broadly follow the orbitally-induced Northern Hemisphere summer insolation, but with different regional expressions. In the winter rain domain, the best-dated records come from southern Levant : stable isotope records from speleothems in Israel (120-230 ka) show a remarkable consistency with those from the Eastern Mediterranean Sea[1,2], but the prominant role of rainfall amount or of moisture source isotopic composition on inland records is still debated [1−4]; lake-level reconstructions in the Lisan-Dead Sea basin during the past 70 ka demonstrate higher winter rains during the last glacial period than during the Holocene [4,5]. However, a new multi-proxy lacustrine record (230 ka) from northern Levant (Yammoûneh, Lebanon) shows relatively wet environments during interglacial periods[6,7], suggesting temporal changes in the NS climatic gradients over the Levantine region. Extratropical rainfalls apparently remained predominant over northern Sahara, with a major period of aquifer recharge during the Late Pleistocene[8]. Conversely, south of about 25-22°N, the subtropical deserts experienced pluvial periods during interglacials, including the remarkable early-Mid Holocene wetting of the Saharan heart[8]. Older pluvial periods, precisely dated in speleothems from Arabia[9] and inferred from lake archives and nearshore marine cores for the Sahara coincide with Marine Isotopic Stages 9, 7, 5.5 and 5.3. Stable isotope and vegetation data indicate that there, precipitation is of tropical origin as a result of an intensified monsoon and a northward migration of the Intertropical Convergence zone.

These regional patterns are discussed in the light of general climatic models: roles of orbital forcing, extent/decrease of the northern ice sheet and marine ice, atmospheric content in greenhouse gases, large-scale atmospheric and oceanic circulation and related latitudinal shifts of major climatic belts.

At a shorter time-scale, several abrupt changes can also be related to climatic events in high northern latitudes. Pronounced dry spells in the Lisan basin are correlated with Heinrich events[5]. The Younger Dryas (YD) and the 8.2 ka events often coincide with arid intervals. During the Holocene, the best-resolved records suggest close relationships between solar activity, northern high-latitude temperature and rainfall intensity. The rapid Mid-Late Holocene aridification leading to modern climates affected both the temperate and subtropical domains. Its mechanisms have been intensively debated. To-date, the best explanations derive from a transient simulation of the North Africa aridification using a general circulation ocean–atmosphere–terrestrial ecosystem model[10]; it suggests that the vegetation collapse in southern Sahara is driven by a gradual monsoonal climate response to orbital forcing, increased climate variability and precipitation threshold, rather than a positive vegetation feedback as previously suggested.

Long and short-term hydrological changes have obviously induced adjustments or migrations of human societies. For exemple, in the Levant, the YD drought placed the sedentary hunter-gatherers Natufians under severe stress that they circumvented by two strategies : (i) people were forced to switch from a passive dependence on wild grains harvests to the first practices of agriculture; (ii) some populations migrated to the north up to southern Turkey, adopting a more mobile hunting and collecting way of life[11]. In NE Africa, the occupation phase around 10 ka,

the cultural development and pastoralism in the Early Holocene, and the exodus into the wetter zone of the Nile Valley at 7-5 ka clearly follow the tropical rainfall belt migrations[12].


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