for aquatic ecosystems, but if we are to fully understand the behaviour of countless rivers across the planet many more measurements are needed. Global land-use data sets do not yet allow us to distinguish the effects of different kinds of human activities, and we cannot conclusively rule out effects of intrinsic factors. For example, rivers that export old DOC could also be also those with dry, deep, permeable soils that have proved conducive to human settlement.

Experimental studies targeted on drained and undrained peatlands indicate that the interpretation by Butman *et al.* is correct[7], but similar studies that compare croplands, grasslands and forests on mineral soils in a rigorous and controlled way are needed. Finally, we need to know what happens to the aged DOC in our rivers — in particular, whether it is reactive. The so-called active pipe theory of river carbon transport suggests that it is, with freshwaters functioning as zones of active carbon cycling rather than as passive conduits from land to ocean[8]. But further work is needed to quantify the influence of old carbon on the operation of aquatic ecosystems, and the proportion of aged DOC that is ultimately emitted to the atmosphere as CO_2.

The work of Butman and colleagues[3] provides a foundation on which to build a better understanding of human influence on riverine carbon, and of the role of this carbon in the global carbon cycle. ❐

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PALAEOCLIMATE

End of the African Humid Period

The Sahara was more humid and habitable thousands of years ago. Reconstructions of North African hydroclimate show that the onset of aridity started in the north, with the monsoon rains weakening progressively later at lower latitudes.

Peter B. de Menocal

Roughly ten thousand years ago, the now barren Sahara Desert was a verdant landscape covered with grasslands and trees[1], dotted with numerous lakes[2,3], and incised by large river networks[4]. Petroglyph art and engravings on rocky outcrops capture a rich and diverse mammalian fauna including hippos, crocodiles, giraffes, elephants and antelopes, the latter often pursued by bands of hunters. But by about five thousand years ago, this North African paradise was lost as dry, shifting sands spread across the subcontinent[2,4–6]. There has been considerable debate about whether this termination occurred gradually as a linear response to orbital changes or whether nonlinear climate feedback processes acted to accelerate this change in climate. Writing in *Nature Geoscience*, Shanahan and co-authors[7] show that both processes occurred, with the end of the African Humid Period occurring progressively later at lower latitudes across North Africa, as expected from orbital climate theory[8].

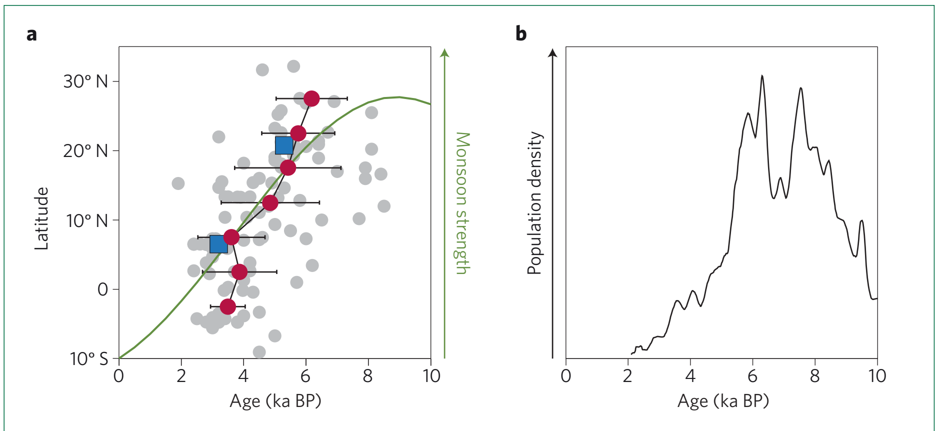

Figure 1 | The time-transgressive end of the African Humid Period. **a**, Shanahan and co-authors[7] generated and compiled proxy records (grey circles) to show that the African Humid Period ended progressively later with decreasing latitude. This progressive termination (better seen in the zonally binned records shown in red) matches what would be expected from the orbital forcing of the African monsoon circulation (green line). The end of the humid period at Lake Bosumtwi (6.5° N) occurred near 3 ka BP, significantly later than observed in sediment cores off Mauritania (5 ka BP at 20° N; blue squares). **b**, Despite the gradual decline in humidity, North Africa was rapidly depopulated between 6,300 and 5,200 years ago based on a recent compilation of radiocarbon dates from North African human settlements[14].

The wet and verdant early Holocene conditions in North Africa — and elsewhere across the northern subtropics — were a consequence of slow changes in the precession of the Earth's orbit. Incoming solar radiation (insolation) during summer peaked about 10,000 years ago in the tropics, strengthening the intensity and northward penetration of the African monsoonal rains during the peak of the African Humid Period. The basic mechanism linking orbital forcing and monsoonal climate response is robust and well-documented, but considerable debate has developed around the details of this linkage. Conflicting records suggest that termination of the humid period either occurred quickly, within a matter of centuries[9,10], or occurred over the course of millennia[5,11,12]. It is similarly unclear whether the termination was uniform or varied spatially and temporally. At the heart of this debate is whether non-linear climate feedback processes act to accelerate climate change, or whether a more simple linear theory linking climate and the Earth's orbit is sufficient.

Shanahan and co-authors[7] generated a record of palaeo-precipitation during the African Humid Period from Lake Bosumtwi, located at about 6° N. They measured the hydrogen isotope composition of leaf waxes preserved in the lake sediments over the past 20,000 years, which reflects the overall amount of precipitation in the lake's catchment region, and compared these data with the dating of the ancient shorelines that record the expansion and contraction of this lake.

In this area, the onset of humid conditions occurred just under 15,000 years ago, as seen elsewhere in Africa[6,9,10,13]. By 10,000 years ago the lake level had risen by nearly 100 metres. Lake levels and the leaf-wax isotopes indicate that humid conditions persisted until about 3,000 years ago. After that, both proxies gradually fell to modern values. In this tropical region, the termination occurred much later than in sites located further to the north, where the humid conditions generally ended 5,000 to 6,000 years ago[6].

Suspecting a latitudinal trend, Shanahan and co-authors then compiled available North African palaeoclimate records from 9° S to 32° N to constrain the timing of the end of the humid phase (Fig. 1a). The conclusion from this analysis is clear: the end of the African Humid Period progressed from north to south, and closely matches what would be expected from orbital forcing[8]. Specifically, the monsoon rains were reduced first in the north, and then progressively later with decreasing latitude.

However, the end of the African Humid Period was locally abrupt at many sites, transitioning from wet to dry conditions much faster than expected from this simple linear theory. Hence some additional, nonlinear mechanism must have been active at these specific sites. Shanahan *et al.* propose that these locally abrupt transitions were the result of soil moisture and vegetation responses to the gradually retreating monsoon: with diminishing rain, soils rapidly become desiccated and barren, and the loose, sandy soils are subject to rapid wind deflation and transport.

Radiocarbon dating of over 1,000 archaeological sites across North Africa reveals how profoundly the end of the humid phase affected human populations[14]. These dates, which record human occupation at these sites, indicate that North Africa was rapidly depopulated between 6,300 and 5,200 years ago as dry conditions set in (Fig. 1b). Within centuries, sedentary populations appeared along the Nile, marking the emergence of urban and socially stratified Pharaonic culture and construction of the first pyramids[12,14].

Shanahan and co-authors[7] show that the end of the African Humid Period occurred gradually with latitude but changes were quite abrupt locally in many places. It is noteworthy that most of the North African population decline occurred in less than a millennium, suggesting that people, like local climate, can respond nonlinearly to climate change. ❐

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CLIMATE SCIENCE

Pacemakers of warming

In the first decades of the twentieth century, the Earth warmed rapidly. A coral-based climate proxy record of westerly winds over the equatorial Pacific suggests that wind strength and warming rate were linked, as they are today.

Stefan Brönnimann

Whenever climate takes an unexpected turn, a look at the past is warranted. The slowdown of global warming since around 2000 thus prompts analyses of previous episodes of slow or accelerated warming. Among these phases is the early twentieth-century warming, a poorly understood period of relatively rapid warming of global average temperatures between about 1900 and 1945. Writing in *Nature Geoscience*, Thompson *et al.*[1] suggest that this early phase of fast warming was closely linked to frequent strong bursts of westerly winds over the equatorial Pacific, a pattern opposite in sign to that diagnosed for the early 2000s when global warming slowed down unexpectedly.

The warming during the early twentieth century was larger than can be explained solely by changes in incoming radiation as a result of increasing greenhouse-gas concentrations, increasing solar irradiance, or a muting of volcanic activity. An "unusually large realization of internal variability" is additionally required[2]. Traditionally, scientists have searched for this unusual variability in the North Atlantic Ocean[3,4], whose surface temperature increased steeply in the 1920s, accompanied by rapid warming in the European sector of the Arctic. This Atlantic warming is often seen as part of a multidecadal mode of the Atlantic Ocean circulation. However, warming was pronounced over the North American continent, too, as well as in the tropical oceans. Therefore, a broader view of concurrent warming mechanisms is required[5].

Thompson and co-authors[1] suggest instead that the tropical Pacific may have played an important role in the early twentieth-century warming. The authors base their claim on the study of corals from Tarawa, Kiribati, a v-shaped coral atoll in the central equatorial Pacific that opens to the west. Through physical mixing, westerly winds at Tarawa remobilize manganese (Mn) from