lower mantle[12–15]. It is known that standard theoretical methods can fail to predict the correct electronic structure of iron-bearing minerals, and this appears to be the case for silicate perovskite and post-perovskite. Or the problem could be that what is calculated does not represent what is measured in the experiment. It remains to be seen if, when given the correct spin state, such methods will be able to predict the correct elastic properties.

The experiments of Lin and McCammon and their colleagues mark a significant advance in our understanding of iron in the lower mantle, and should motivate new experiments and calculations to determine the properties of silicate perovskite and post-perovskite containing iron in the intermediate spin-state. However, their results regarding the spin state of ferrous iron present only half of the story. Much work needs to be done to ascertain the electronic configuration of ferric iron, which could make up as much as 50% of the total, in the phases at high temperatures and pressures.

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PALAEOCLIMATE

Africa on the edge

Saharan humidity has varied dramatically throughout the Pleistocene era. A new deep-sea sediment record reveals large and rapid hydrological shifts that are linked to the competing influences of low- and high-latitude climate processes.

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Like the ice ages, the deserts of the Sahara also come and go. The slow wobble of the Earth's orbit periodically increases and decreases the amount of summer seasonal radiation over North Africa with a roughly 20,000-year beat. This orbital precession has paced the strength and northward penetration of African monsoonal rains for many millions of years. During the most recent wet phase, about 10,000–5,000 years ago, the modern Sahara Desert was covered with lush tropical grasslands and forests, with large permanent lakes — some as large as the United Kingdom — and abundant fauna[1]. However, the rapidity of northwest African climate changes cannot be explained without an influence from the far field. On page 670 of this issue, Tjallingii and co-authors[2] use proxy measurements of both local and remote climate signals in the same sediment core, and thus directly assess their relative impacts on African climate.

Palaeoclimate records from terrestrial and marine sequences clearly show that orbital precession has been the pacemaker of North African palaeohydrologic changes. However, some detailed records have revealed arid–humid transitions that were much faster than would be expected from orbital forcing alone[1–5]. During glacial periods, surges of large continental ice sheets periodically launched armadas of icebergs into the North Atlantic Ocean. These iceberg surges are known as Heinrich events, and abruptly chilled the oceans for roughly a millennium[6]. Despite their distance from the tropics, the most detailed records suggest that these high-latitude cooling events affected African climate with concurrent abrupt shifts to drier conditions[3,5]. Together, these observations have led to the conclusion that northwest African climate history has been driven by both high- and low-latitude influences.

Tjallingii and co-authors document these dual high- and low-latitude controls on northwest African climate with unprecedented clarity, using detailed analyses of a marine sediment core taken off the coast of Mauritania. Their data capture several precessional wet–dry cycles as well as millennial-scale arid events associated with the Heinrich events. To estimate the near- and far-field contributions to past changes in African climate, they performed detailed measurements of the sediment grain-size spectrum of the marine sediment siliciclastic mineral fraction, which is delivered to the ocean through rivers and as wind-borne dust. Northwest Africa is one of the world's largest exporters of aeolian dust, which is characteristically coarse and clearly distinguishable from the much finer fluvial sediments. By measuring the particle size distribution for each sample, and using a clever method to quantify the relative proportions of aeolian and fluvial grains, the authors developed a 'humidity index' where positive values indicate wetter conditions (Fig. 1).

Their humidity index shows that northwest Africa has been a very variable place over the past 100,000 years. The region was subject to a succession of wetter and drier phases, each lasting 1–10 kyr in duration, with rapid century-scale transitions between these states. At first glance African climate appears to have chaotically flip-flopped between wet and dry extremes, but Tjallingii and co-authors make a compelling case that each of the wet and dry phases can be linked to specific responses to either high- or low-latitude climate forcing events.

The reconstructed wet periods stand out as prominent and persistent fine-grained intervals, reflecting reduced aeolian sedimentation and increased supply of fluvial sediments. The intervals coincide with the largest orbital precession peaks in African monsoonal forcing, centred near 10 kyr, 80 kyr and 105 kyr BP (Fig. 1). However, the onset and termination of these humid phases were consistently more abrupt than would be expected from gradual insolation forcing alone. This observation is consistent with other palaeoclimate records[1–5], but in disagreement with the gradual transition noted in a recent exceptional lake record from northern Chad[8]. Using a low-resolution but fully coupled climate model, Tjallingii and co-authors found that African climate only exhibits such non-linear behaviour when the vegetation feedback is switched on in the model. They conclude that the climate-driven advance and retreat of vegetation amplifies African climate sensitivity to the orbital monsoonal forcing and introduces the non-linear positive feedback responsible for the abrupt climate transitions.

The orbitally driven intervals are punctuated by shorter millennial-scale drying events. They are represented by step-like increases in sediment grain size reflecting enhanced aeolian supply. Tjallingii and co-authors unequivocally link these African dusty periods to North Atlantic cooling events by noting the close match between the humidity index and a proxy for North Atlantic deep-water circulation from the same core. Earlier studies have amply demonstrated that most North Atlantic cooling events were accompanied by sharp reductions in North Atlantic deep-water ventilation[9]. The excellent match between these two proxies measured in the same core provides strong evidence that the millennial-scale African dry events were indeed paced by climate changes originating in the far North Atlantic Ocean[10] (Fig. 1).

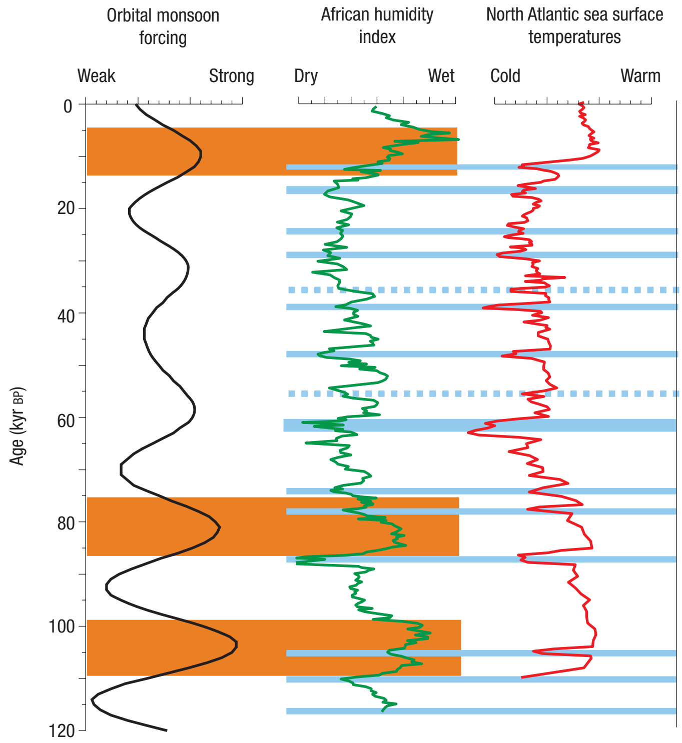

Figure 1 Past controls on African climate. Left: Reconstructed summer-season solar irradiance forcing for 30° N latitude[2]. Middle: The Tjallingii *et al.* African Humidity Index record derived from siliciclastic grain size variations in a deep-sea sediment core off Cap Blanc, Mauritania[2]. Right: Rapid variations in ocean temperatures near the Portuguese margin associated with North Atlantic cooling events[10]. The competing influences of local orbital insolation monsoonal forcing (orange bars) and remote high-latitude cooling events (blue bars) on African climate are both reflected in the humidity record.

But how did these distant events spur the drying of northwest Africa? Their model results lead Tjallingii and co-authors to two possible candidates: an atmospheric response to cooler ocean temperatures near coastal West Africa or an oceanic transmission of the high-latitude cooling by the North Atlantic overturning circulation. Their grain-size record is an important constraint. Whatever physical process is linking high- and low-latitude climates, it must be fast and efficient: cooling in the North Atlantic Ocean quickly shifts the North African monsoonal rainbelt southward, drying the region[11].

One promising oceanic mechanism that could be fast enough involves the shallow wind-driven ocean circulation cells that can link high- and low-latitude climate. Surface waters at mid-latitudes are subducted to depths of several hundred metres before resurfacing in the tropics within a few years to decades. A recent high-resolution modelling study by Chang *et al.*[12] emphasizes the importance of this shallow ocean conduit in linking changes in North Atlantic overturning circulation to rapid widespread aridification of North Africa. Their simulations show that the weakening and shifting of tropical subsurface currents caused by slowing meridional overturning circulation in the North Atlantic Ocean decreases monsoonal winds, reducing moisture supply to northwest Africa.

The remarkable implication of the study by Tjallingi and co-authors is that northwest Africa has repeatedly swung between wetter and drier extremes, often in a matter of centuries. The Sahara imbues a sense of majesty and permanence, and it's instructive to return to the earliest accounts of a once lush and verdant Green Sahara.

As he crossed by caravan from Tripoli to Timbuktu in the mid 1800s, the German explorer Heinrich Barth became the first European to discover the then-mysterious prehistoric Saharan rock paintings and engravings, which we now know date back to the African Humid Period, between 9,000 and 6,000 years ago. The frescoes and carvings adorn rocky nooks and outcrops poking through the desert sands, depicting pastoral scenes with abundant elephants, giraffe, hippos, long-horn cattle and antelope, occasionally chased by bands of hunters. The incongruence of these lively images in such lifeless settings intrigued Barth. He observed[13] "[They] have nothing in them of a Roman character", and noted that the art work "bears testimony to a state of life very different from that which we are accustomed to see now in these regions".

If the work by Tjallingii and co-authors can be shown to represent the broader northwest African domain[1–5], if not the eastern Sahara[8], it is indeed impressive to consider just how rapidly this very different world dried up and disappeared.

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