# Astronomical Drivers of Early Human Migration

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Our climate system varies on a wide range of timescales, from seasons to several millions of years. A large part of this variability is internally generated as a result of instabilities of the coupled atmosphere-ocean-ice-carbon cycle system. Other modes of variability, such as glacial cycles, are caused by astronomical forcings with periods of ~20, 40, 100 thousand years. These so-called Milankovitch Cycles are associated with earth's axis wobble, axis obliquity and shifts in the eccentricity of earth's orbit around the sun, respectively. If these cycles conspire, they can cause the climate system to plunge into an ice-age. This happened last time ~100,000 years ago, when Northern Hemisphere summer radiation decreased substantially and massive ice-sheets started to form as a result. Under these conditions, *Homo sapiens* started to leave Africa across vegetated corridors in Northeastern Africa and the Arabian Peninsula. This first migration wave must have been relatively weak, but it left unequivocal traces in the fossil and archaeological record. Why *Homo sapiens* embarked on its grand journey across our planet during a time of worsening climate conditions has been subject of an intense debate in various scientific communities. Moreover, the archaeological records of an early exodus around 100 thousand years ago seem to be at odds with paleo-genetic evidences, that place the first dispersal out of Africa around 70-60 thousand years ago.

To elucidate what role climate and environmental conditions played in the dispersal of Anatomically Modern Humans out of Africa, I have developed and applied one of the first integrated climate/human migration computer models. The model simulates ice-ages, abrupt climate change, the "peopling" of our planet and captures the arrival time of *Homo sapiens* in the Levant, Arabian Peninsula, Southern China and Australia in close agreement with paleo climate reconstructions, fossil and archaeological evidence.

The human dispersal model simulates multiple prominent migration waves of *Homo sapiens* across the Arabian Peninsula and the Levant region around 106-94, 89-73, 59-47 and 45-29 thousand years ago. These waves were caused by earth's axis wobble and its corresponding changes in climate seasonality and resulting large-scale shifts in vegetation in tropical/subtropical regions. Such shifts opened up green corridors between Africa, the Sinai and the Arabian Peninsula, enabling *Homo sapiens* to leave Northeastern Africa and migrate into Asia, Europe, Australia and eventually into the Americas. The model also simulates a complex pattern of human dispersal out of Africa and back flow into Africa, that challenges the more unidirectional away-from-Africa perspective that is still very prevalent in anthropology and some genetic studies.

Paleo-genetic reconstructions indicate that the first exodus out of Africa must have occurred around 70-60 thousand years ago. In contrast, our computer simulations and paleo-climate data show that northeastern Africa experienced one of its most severe long-term droughts during this time. The resulting large desert areas would have been an impenetrable natural borders for human migration.

More research needs to be done to help reconcile and synthesize genetic, archaeological, climatological and anthropological data.

*Reference: Timmermann, A. Timmermann, T. Friedrich, 2016, Late Pleistocene climate drivers of early human migration, Nature, 538, 92–95*