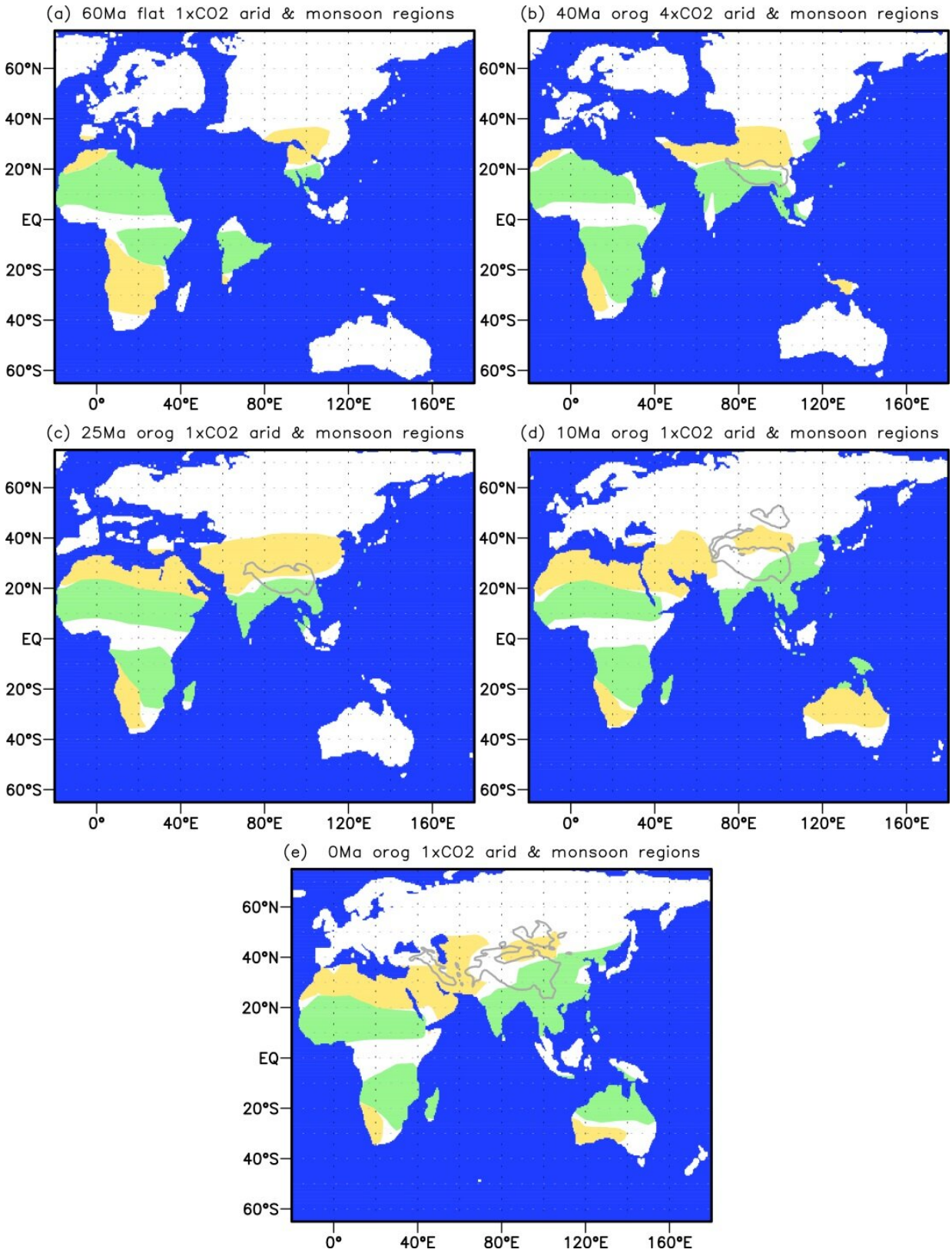
Uncovering the evolution of monsoon and arid regions in Asia, Africa and Australia

May 29 2019


(a) 60Ma flat 1xCO2 arid & monsoon regions
(b) 40Ma orog 4xCO2 arid & monsoon regions
(c) 25Ma orog 1xCO2 arid & monsoon regions
(d) 10Ma orog 1xCO2 arid & monsoon regions
(e) 0Ma orog 1xCO2 arid & monsoon regions
60°N
40°N
20°N
EQ
20°S
40°S
60°S
0°
40°E
80°E
120°E
160°E

Distribution patterns of the Asian-African-Australian monsoon regions (green) and arid regions (yellow) in five geological periods during the Cenozoic. (a) mid-Paleocene (~60Ma); (b) late-Eocene (~40Ma); (c) late-Oligocene (~25Ma); (d) late-Miocene (~10Ma); (e) present-day (0Ma). The blue shade represents oceans or lakes, and the grey outlines indicate the 1500m elevation contour of the Tibetan Plateau and its vicinity. Credit: Science China Press

Monsoon and arid climates are two climate types commonly seen in mid- and low-latitudes of the Earth. These climate types have sculpted the corresponding landforms, ecosystems and the living environments of human society. The present-day most well-known monsoon and arid regions are found in Africa, Asia and Australia. When did they originate? How have they evolved over time? What were the factors that determined their formations and evolutions? Have there been regional differences in their evolutions? These questions have been the subjects of research for the scientific community, but there is currently no consensus on them yet. A new study may shed some light on the answers to these questions.

In an article titled "Continental drift, plateau uplift, and the evolutions of monsoon and arid regions in Asia, Africa, and Australia during the Cenozoic," just published in *Science China Earth Sciences*, the formation and evolution of the Asia-Africa-Australia monsoon and arid regions and their controlling factors are investigated by an international team of scholars from China, the U.K. and the U.S.

Geological evidence has shown that major changes have occurred to the monsoon and arid environments in the Asia-Africa-Australia realm, accompanying continental drift, uplift of the Tibetan Plateau, and changes in the atmospheric CO_2 concentration since the beginning of the Cenozoic (about 65 million years ago abbreviated as Ma). Based on

reconstructed boundary conditions for 5 typical geological periods during the Cenozoic, including the mid-Paleocene (~60 Ma), late-Eocene (~40 Ma), late-Oligocene (~25 Ma), late-Miocene (~10 Ma), and the present-day (~0 Ma), the researchers performed a series of well-designed climate simulation experiments using a coupled ocean-atmosphere model by changing the land-sea distribution, topography, and CO_2 concentration over time. The following figure shows the simulated distribution patterns of the Asian-African-Australian monsoon and arid regions in the five geological periods during the Cenozoic.

"Results of our numerical experiments indicate that the timings and causes of the formations of monsoon and arid regions in Asia, Africa and Australia were very different," says Dr. Xiaodong Liu, the lead author from the Institute of Earth Environment, Chinese Academy of Sciences. Specifically, the northern and southern African monsoons existed during the mid-Paleocene, while the South Asian monsoon appeared in the Eocene after the Indian Subcontinent moved into the tropical Northern Hemisphere. The probable South Asian monsoon during the mid-Paleocene (~56Ma), previously inferred from plant fossils, and originally thought to cover the region from India to the most southern coast of China, was actually two different geographic regions, located in the Southern Hemisphere and Northern Hemisphere tropical latitudes separated by the equator at ~60Ma. In contrast, the East Asian monsoon and northern Australian monsoon were established much later in the Miocene.

"The main controlling factors of different monsoon regions during the geological periods are also different," he said. For example, the establishments of the tropical monsoons in northern and southern Africa, South Asia, and Australia were determined by both continental drift and the seasonal migration of the Inter-Tropical Convergence Zone, while the position and height of the Tibetan Plateau were the key factors for the establishment of the East Asian monsoon.

"The evolutionary mechanisms of arid regions also varied from place to place," he further explained. The presence of the subtropical arid regions in northern and southern Africa, Asia, and Australia depended on the positions of the continents and the control of the planetary scale subtropical high pressure zones, while the arid regions in the Arabian Peninsula and West Asia were closely related to the retreat of the Paratethys Sea. The formation of the mid-latitude arid region in the Asian interior, on the other hand, was the consequence of the uplift of the Tibetan Plateau.

"Although we used a low-resolution model, it still performed well in describing the distribution of monsoon and arid regions," added Dr. Robin Smith, a co-author from the National Centre for Atmospheric Science, University of Reading. "This study reveals for the first time the regional differences and the importance of tectonic boundary conditions or geographical patterns in the formation and evolution of the Asia-Africa-Australia monsoon and arid regions during the Cenozoic."

Dr. Zhi-Yong Yin, another coauthor from the Department of Environmental and Ocean Sciences, University of San Diego, stated that "although our simulations are consistent with certain paleoclimate proxies available, more geological evidence is needed to further verify these modeling results, due to the limitations of time and spatial scales of geological records."

More information: Xiaodong Liu et al, Continental drift, plateau uplift, and the evolutions of monsoon and arid regions in Asia, Africa, and Australia during the Cenozoic, *Science China Earth Sciences* (2019). DOI: 10.1007/s11430-018-9337-8

Provided by Science China Press