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Earth's Dynamic Systems: Monsoons

The Seasonal Rains

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Conclusion

This free sample contains the Introduction and Chapter 1. The complete book contains the full contents above.

Introduction

A monsoon is traditionally a seasonal reversing wind accompanied by corresponding changes in precipitation, but now used to describe seasonal changes in atmospheric circulation and precipitation associated with annual latitudinal oscillation of the Intertropical Convergence Zone, specifically between its limits to the north and south of the equator. Usually, the term monsoon is used to refer to the rainy phase of a seasonally changing pattern, although technically there is a dry phase. The term is also used to describe locally heavy but short-term rains.

What follows is the whole story of the phenomenon: how it was discovered and understood, the physics that drives it, the instruments that watch it, its features and its famous vagaries, its place in culture and history, and the research frontier of a world trying to forecast it and adapt to it. A closing pair of chapters looks forward to the science of the coming decades and asks what the monsoon finally means, to the planet and to the people who wait for it.

The major monsoon systems of the world consist of the West African, South Asian-Australian, North American, and South American monsoons. The term was first used in English in British India and neighbouring countries, referring to big seasonal winds blowing from the Bay of Bengal and Arabian Sea in the southwest that brought heavy rainfall to the area. The etymology of the word monsoon is not wholly certain.

The English monsoon came from Portuguese monção, ultimately from Arabic

موسم (mawsim, "season"), "but partly via early modern Dutch monson".

Strengthening of the Asian monsoon has been linked to the uplift of the Tibetan Plateau after the collision of the Indian subcontinent and Asia around 50 million years ago. Because of studies of records from the Arabian Sea and that of the wind-blown dust in the Loess Plateau of China, many geologists believe the monsoon first became strong around 8 million years ago.

The monsoon is old enough to have fossils.

Its antiquity also makes the monsoon a geological agent. The rains the system delivers have built the floodplains of the Ganges, the Brahmaputra and the Mekong, rivers whose sediment loads are the monsoon's eroded footprint; the same winds that water the continent carry dust from the Thar and the Sahel out over the ocean, fertilizing its surface waters with iron; and the monsoon's own past, read from seabed cores and cave stone, is one of the longest continuous records of how a climate system responds when the world warms

or cools. To study the monsoon is to study a machine the planet has been running, and tuning, for tens of millions of years.

Its record is written in the sediments it delivered: the dust bands of the Chinese loess plateau alternate with monsoon-soil layers like tree rings, the Arabian Sea's seabed preserves bursts of windblown mineral grains from the same summers, and the plant fossils of Yunnan record when the rains first settled into a seasonal rhythm. Reading that archive, geologists can date a wind, which is a strange and satisfying kind of history.

More recently, studies of plant fossils in China and new long-duration sediment records from the South China Sea led to a timing of the monsoon beginning 15-20 million years ago and linked to early Tibetan uplift. Testing of this hypothesis awaits deep ocean sampling by the Integrated Ocean Drilling Program. The monsoon has varied significantly in strength since this time, largely linked to global climate change, especially the cycle of the Pleistocene ice ages.

It is believed that the resulting increase in sea surface temperatures in the Indian Ocean increased the intensity of monsoons. In 2018, a study of the SAM's variability over the past million years found that precipitation resulting from the monsoon was significantly reduced during glacial periods compared to interglacial periods like the present day.

Chapter 1: The Discovery of Monsoons

The Indian Summer Monsoon (ISM) underwent several intensifications during the warming following the Last Glacial Maximum, specifically during the time intervals corresponding to 16,100-14,600 BP, 13,600-13,000 BP, and 12,400-10,400 BP as indicated by vegetation changes in the Tibetan Plateau displaying increases in humidity brought by an intensifying ISM. Though the ISM was relatively weak for much of the Late Holocene, significant glacial accumulation in the Himalayas still occurred due to cold temperatures brought by westerlies from the west.

During the Middle Miocene, the July ITCZ, the zone of rainfall maximum, migrated northwards, increasing precipitation over southern China during the East Asian Summer Monsoon (EASM) while making Indochina drier. During the Late Miocene Global Cooling (LMCG), from 7.9 to 5.8 million years ago, the East Asian Winter Monsoon (EAWM) became stronger as the subarctic front shifted southwards. An abrupt intensification of the EAWM occurred 5.5 million years ago.

The EAWM was still significantly weaker relative to today between 4.3 and 3.8 million years ago but abruptly became more intense around 3.8 million years ago as crustal stretching widened the Tsushima Strait and enabled greater inflow of the warm Tsushima Current into the Sea of Japan. Circa 3.0 million years ago, the EAWM became more stable, having previously been more variable and inconsistent, in addition to being enhanced further amidst a period of global cooling and sea level fall.

The EASM was weaker during cold intervals of glacial periods such as the Last Glacial Maximum (LGM) and stronger during interglacials and warm intervals of glacial periods. Another EAWM intensification event occurred 2.6 million years ago, followed by yet another one around 1.0 million years ago. During Dansgaard-Oeschger events, the EASM grew in strength, but it has been suggested to have decreased in strength during Heinrich events.

The EASM expanded its influence deeper into the interior of Asia as sea levels rose following the LGM; it also underwent a period of intensification during the Middle Holocene, around 6,000 years ago, due to orbital forcing made more intense by the fact that the Sahara at the time was much more vegetated and emitted less dust. This Middle Holocene interval of maximum EASM was associated with an expansion of temperate deciduous forest steppe and temperate mixed forest steppe in northern China.

By around 5,000 to 4,500 BP, the East Asian monsoon's strength began to wane, weakening from that point until the present day. A particularly notable

weakening took place ~3,000 BP. The location of the EASM shifted multiple times over the course of the Holocene: first, it moved southward between 12,000 and 8,000 BP, followed by an expansion to the north between approximately 8,000 and 4,000 BP, and most recently retreated southward once more between 4,000 and 0 BP.

The January ITCZ migrated further south to its present location during the Middle Miocene, strengthening the summer monsoon of Australia that had previously been weaker. Five episodes during the Quaternary at 2.22 Ma (PL-1), 1.83 Ma (PL-2), 0.68 Ma (PL-3), 0.45 Ma (PL-4) and 0.04 Ma (PL-5) were identified which showed a weakening of the Leeuwin Current (LC).

The weakening of the LC would have an effect on the sea surface temperature (SST) field in the Indian Ocean, as the Indonesian Throughflow generally warms the Indian Ocean. Thus these five intervals could probably be those of considerable lowering of SST in the Indian Ocean and would have influenced Indian monsoon intensity.

During the weak LC, there is the possibility of reduced intensity of the Indian winter monsoon and strong summer monsoon, because of change in the Indian Ocean dipole due to reduction in net heat input to the Indian Ocean through the Indonesian Throughflow.

Thus a better understanding of the possible links between El Niño, Western Pacific Warm Pool, Indonesian Throughflow, wind pattern off western Australia, and ice volume expansion and contraction can be obtained by studying the behaviour of the LC during Quaternary at close stratigraphic intervals. The South American summer monsoon (SASM) is known to have become weakened during Dansgaard-Oeschger events. The SASM has been suggested to have been enhanced during Heinrich events.

Monsoons were once considered as a large-scale sea breeze caused by higher temperature over land than in the ocean.

The idea that the monsoon was more than a big sea breeze took a century to settle. Henry Blanford, the first head of the India Meteorological Department, tied the rains to Himalayan snow cover in the 1880s, launching the world's first institutional seasonal forecasting; Gilbert Walker, hunting the oscillation that bears his name, showed in the 1920s that the monsoon was one dial in a planet-wide seesaw of pressure and rain; and the jet-stream and Tibetan Plateau theories of the mid-twentieth century explained why the burst is abrupt rather than gradual. Each step widened the frame, from a breeze off the sea to a circulation the size of a hemisphere.

This is no longer considered the cause. The monsoon is now considered a

planetary-scale phenomenon involving the annual migration of the Intertropical Convergence Zone between its northern and southern limits. The limits of the ITCZ vary according to the land-sea heating contrast and it is thought that the northern extent of the monsoon in South Asia is influenced by the high Tibetan Plateau.

A study of Asian monsoonal climate cycles from 123,200 to 121,210 years BP, during the Eemian interglacial, suggests that they had an average duration of around 64 years, with the minimum duration being around 50 years and the maximum approximately 80 years, similar to today. A study of marine plankton suggested that the South Asian Monsoon (SAM) strengthened around 5 million years ago. Then, during ice periods, the sea level fell and the Indonesian Seaway closed.

When this happened, cold waters in the Pacific were impeded from flowing into the Indian Ocean.

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ABOUT THE AUTHOR

Aira Astralis is a science writer specializing in astronomy and space exploration. Her work spans the full breadth of humanity's relationship with the cosmos -- from the earliest naked-eye observations to the engineering marvels of modern space missions.

Her books are built on a foundation of primary sources: peer-reviewed research, mission archives, and direct engagement with the scientific community. She writes for readers who want to understand not just what we know about the universe, but how we came to know it.

She believes that the most important frontier is not out there but in the gap between what scientists discover and what the public understands. Her books exist to close that gap.