The Asian Monsoon: Causes, History and Effects

The Asian monsoon is one of the most dramatic climatic phenomena on Earth today, with far reaching environmental and societal effects. But why does the monsoon exist? What are its driving factors? How does it influence the climate and geology of Asia? How has it evolved over long periods of geologic time?

Almost two-thirds of humanity lives within regions influenced by the monsoon. With the emerging economies of China, Vietnam and India now adding to those of Japan, South Korea and Taiwan, the importance of the region to the global economy has never been greater. Monsoon strength and variability have been and will continue to be crucial to the past and future prosperity of the region.

The Asian Monsoon describes the evolution of the monsoon on short and long timescales, presenting and evaluating models that propose a connection between the tectonic evolution of the solid Earth and monsoon intensity. The authors explain how the monsoon has been linked to orbital processes and thus to other parts of the global climate system, especially Northern Hemispheric Glaciation. Finally, they summarize what is known of the monsoon evolution since the last ice age and note how this has impacted human societies, as well as commenting on the potential impact of future climate change.

This book presents a multi-disciplinary overview of the monsoon for advanced students and researchers in atmospheric science, climatology, oceanography, geophysics and geomorphology.

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Causes, History and Effects

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Preface

The Asian monsoon is one of the most dramatic climatic phenomena on Earth today, with far-reaching environmental and societal effects. Almost two thirds of humanity live within regions influenced by the monsoon. Monsoon strength and variability have been and will continue to be crucial to the past and future prosperity of the region. With the emerging economies of China, Vietnam and India now adding to those of Japan, South Korea and Taiwan the importance of the region to the global economy has never been greater. Continuation of this growth is dependent on the climate and environment. Recent detailed climate reconstructions now show that the development and collapse of civilizations in both South and East Asia have been controlled in large measure by monsoon intensity. Modern technology now allows society to respond more effectively to environmental stresses, yet in the face of the destructive powers of typhoons or long duration droughts there is still little man can do when environmental catastrophe strikes.

As a result, understanding what controls the Asian monsoon and how it has changed in the past is important not only to scientists but also to the general population. In this book we present a multi-disciplinary overview of the monsoon for advanced students and researchers, spanning recent advances in atmospheric sciences, climatology, oceanography and geology. Finally we consider how the evolving monsoon has both helped and hindered the development of human civilizations since the Last Glacial Maximum, 20 000 years ago. The monsoon represents a large-scale seasonal reversal of the normal atmospheric circulation pattern. In this model, low-pressure systems develop in the tropics owing to rising hot air masses that cool and descend in the subtropics, which are thus characteristically arid regions. In contrast, summer heating of the Asian continent, especially around the Tibetan Plateau, generates low-pressure cells and thus summer rains in South and East Asia. In the winter a reversed high-pressure system is established, with dry, cold winds blowing out of Asia.

The links between the Tibetan Plateau and monsoon intensity have formed the basis of a long-running debate because this proposed relationship would appear to be one of the strongest examples of how the solid Earth, which is being continuously deformed and remodeled by plate tectonic forces, may be influencing the global climate system. The intensity of the modern monsoon likely reflects the fact that Tibet is the largest mountain chain seen on Earth for more than 500 million years and has correspondingly made a particularly large impact on the planet's atmospheric systems. Progress has been made in establishing links between the relatively slow growth of the plateau and monsoon strength, yet until the developing altitude of Tibet is better established and a truly long-scale climate history for the monsoon has been reconstructed it will remain impossible to test the linkages definitely. In particular, climatologists need an appropriate, long-duration sedimentary record dating back to the collision of the Indian and Asian plates that generated Tibet in the first place. In practice this means around 50 million years. Such a record exists in the oceans and continental margins around Asia, but has yet to be sampled.

While recognizing that the monsoon has strengthened over periods of millions or tens of millions of years, research focus over the past 10–15 years has demonstrated that not only does monsoon intensity vary dramatically on much shorter timescales, but that these are often linked to other parts of the global climate system. In particular, the detailed climate records now available for the past few million years show coherent, if sometimes lagged, development of the monsoon with the glaciation of the northern hemisphere. Clearly the monsoon cannot be studied in isolation from other systems, especially the oceanic–atmospheric systems of the North Atlantic (Gulf Stream and North Atlantic Deep Water) and the El Niño Southern Oscillation system of the Pacific Ocean. Indeed, it has been suggested not only that these systems control monsoon strength, but also that the monsoon can affect their evolution. A general pattern has emerged of summer monsoons being strong and winter monsoons generally weaker during warm, interglacial periods, and the reverse situation dominating during glacial times. As a result monsoon strength varies on the 21, 40 and 100 thousand year timescales that control periods of glacial advance and retreat. In detail, however, the situation is complicated by lags in the climate system that offset the response of the monsoon to solar forcing. In addition, there continues to be debate regarding how the monsoon differs in South and East Asia over various timescales. Current data suggest a generally coherent development between the two systems over millions of years but differences at the orbital and sub-millennial scale. Determining how and why they differ requires more high-resolution climate reconstructions from across the entire geographic range of the monsoon, involving both the "core area"

of monsoon activity, such as the Bay of Bengal, and the "far-field" regions, such as the Sea of Japan and the Gulf of Oman, which may be more sensitive to modest changes in strength. Observations alone are not enough and a deep understanding of how the monsoon evolves and what the key controls are will require better climate models, ground-truthed with both oceanic and continental climate records.

The interactions of monsoon and society are a particularly fertile area of recent and future research. This field has developed as better climate records have been reconstructed over the past 8000 years or so. In particular the resolution permitted by ice cores and some high accumulation rate sediments in the oceans and lakes allows changes in monsoon intensity to be compared with human history. Indeed the ^{14}C dating used to constrain these records is the same method used to date archaeological sites, allowing a robust comparison to be made. Global warming, as a result of human activities, as well as natural processes, would tend to favor a stronger summer monsoon in the long term, yet in detail there is much potential complexity. Melting of the Greenland ice sheet may disrupt the overturn of waters in the North Atlantic and result in a cooling of that region. Comparison with similar natural events in the past suggests that such an event would result in weaker summer monsoons. Not only the strength of the monsoon can be affected by climate change but also its variability. Historical records indicate that the number and intensity of summer typhoons striking the densely populated coast of southern China have increased significantly over the past 200 years. If that trend were to continue, its economic and humanitarian effects could be disastrous.

Whatever part of the Earth we live in, the Asian monsoon is of significance to our lives and understanding of how the planet and society operates. Much work remains to be done in quantifying the monsoon and how it functions at a variety of timescales. Despite this great progress has been made in understanding this system. In this book we have attempted to synthesize what is now known and highlight those areas where significant research remains to be done.

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