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Long-term variations in the South Asian monsoon annual cycle: the role of regional anthropogenic aerosol forcing

Massimo Bollasina (1) and Yi Ming (2)
(1) Program in Atmospheric and Oceanic Sciences, Princeton University, (2) Geophysical Fluid Dynamics Laboratory/NOAA

Detection and attribution of long-term variations of the South Asian monsoon is of extreme importance. Indeed, even small changes in the onset and duration of the monsoon season or in the spatial distribution of the seasonal mean precipitation may severely impact agriculture, health, water availability, ecosystems, and economy for a substantial fraction of the world's population.
In the past decades emissions of aerosols have dramatically increased over South Asia due to rapid urbanization and population growth. As a result, the study of the impact of anthropogenic aerosols on the monsoon has recently emerged as one of the topics of highest priority in the scientific community.
This study makes use of a state-of-the-art coupled climate model, the GFDL CM3, to investigate two aspects of the aerosol influence on the 20th-century changes in the monsoon. The model has fully-interactive aerosols and a representation of both direct and indirect effects.
Aerosols are responsible for the advancement of the monsoon onset over India, leading, in agreement with observations, to enhanced precipitation in June over most parts of the subcontinent. Our experiments show that the earlier onset is preceded in early spring by a strong aerosol forcing over the Bay of Bengal and Indonesia and associated atmospheric circulation anomalies. The latter triggers thermodynamical changes over the northwestern part of the Subcontinent in May and June, including enhanced surface heating, which in turn drive the movement of the monsoon to the west.
We also performed historical experiments with time-evolving radiative forcings aimed at isolating the contribution of regional versus remote anthropogenic aerosol emissions on the observed 20th century widespread drying of the Indian monsoon. Indian-only aerosol sources are found to play a predominant role in generating suppressed rainfall over the subcontinent, especially during early summer. Remote aerosols contribute, although in a minor way, to precipitation reduction over eastern India during late summer, while induce a large wettening to the west. The mechanisms and processes by which the individual aerosol impacts are realized will be discussed.