ATMOSPHERIC SCIENCE

Desert dust and monsoon rain

The climate regimes of monsoon regions and deserts are connected. Satellite data and numerical experiments reveal that an increase in dust aerosol loading over the Arabian Sea and West Asia can lead to enhanced summer monsoon rainfall over central India on timescales of days to weeks.

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For centuries, inhabitants of the Indian subcontinent have known that heavy dust events brought on by strong winds occur frequently in the pre-monsoon season, before the onset of heavy rain. Yet scientists have never seriously considered the possibility that natural dust can affect monsoon rainfall. Up to now, most studies of the impacts of aerosols on Indian monsoon rainfall have focused on anthropogenic aerosols in the context of climate change. However, a few recent studies have shown that aerosols from anthropogenic and natural sources over the Indian subcontinent may affect the transition from break to active monsoon phases[1,2] on short timescales of days to weeks. Writing in *Nature Geoscience*, Vinoj and colleagues[3] describe how they have shown that desert dust aerosols over the Arabian Sea and West Asia can strengthen the summer monsoon over the Indian subcontinent in a matter of days.

Prevailing low-level winds carry dust particles from the deserts of West Asia, the Middle East and North Africa across the Arabian Sea to the Indian subcontinent each year, before the onset of the summer monsoon[4] (Fig. 1). As the monsoon develops, these low-level winds strengthen and transport more dust from the desert regions. As a result, dust levels over the Arabian Sea, northwestern India, the Indo-Gangetic Plain and the Himalaya foothills peak during the late boreal spring and early summer months. As the monsoon season progresses, atmospheric dust loading diminishes over India because of wash-out by heavy rainfall and weakening winds.

Airborne dust particles can cool the underlying surface by reducing the total sunlight reaching the surface by scattering and absorbing incoming solar radiation. The solar radiation absorbed by dust will heat the ambient atmosphere. Increasing concentrations of aerosols over the Arabian Sea during the pre-monsoon and the early monsoon season (May–June) — primarily composed of desert dust and sea salt — have been estimated to warm the atmosphere by 10 to 15 W m^{-2}, far exceeding the warming attributed to greenhouse gases[5].

Figure 1 | Desert dust over the Arabian Sea. A giant dust plume stretched across the Arabian Sea from the coast of Oman to India on 20 March 2012. This extensive plume followed days of dust-storm activity over the Arabian Peninsula and southwestern Asia. Vinoj and colleagues[3] show that desert dust over West Asia and the Arabian Sea enhances summer monsoon rainfall in central India within a few days.

Vinoj and colleagues[3] show that warming of the atmosphere by dust aerosols over the Arabian Sea can induce atmospheric feedback processes, resulting in enhanced summer monsoon rainfall over central India. Using satellite data, they document a positive correlation between dust aerosol levels over the Arabian Sea and the rainfall amount over central India during the monsoon season. A similar correlation pattern is reproduced in their numerical simulations with an atmospheric global climate model. According to these simulations, dust aerosols can warm the atmosphere over West Asia and the Arabian Sea by as much as 36 W m^{-2} on short timescales. This aerosol-induced warming strengthens the southwesterly monsoon winds, thereby increasing moisture convergence north and west of the region of maximum dust loading over the Arabian Sea, eventually leading to increased rainfall over central India.

To focus on the short-term effects of aerosols on monsoon rainfall, Vinoj *et al.*[3] ignore the cooling effect of dust aerosols on sea surface temperature in their model simulations. Over longer timescales, this cooling effect may reduce the north–south temperature gradient, suppressing monsoon rainfall over the Indian subcontinent[6]. Additional model simulations including both dust effects and interactive sea surface temperatures need to be carried out to investigate [Au:OK?] how monsoon rainfall will respond to dust forcing over longer timescales.

The dust-induced enhancement of the Indian summer monsoon rainfall suggested by Vinoj *et al.*[3] could increase with regional population growth and climate change. Emissions of black carbon aerosols — highly absorptive particles released from industrial activities, residential cooking and heating — have risen with population growth in India in recent decades[7]. If emissions continue to rise, dust particles transported across India will become increasingly coated in black carbon aerosols[8]. The resultant rise in dust-induced warming could further strengthen aerosol–monsoon interactions. Furthermore, the expected expansion of desert and arid regions under global warming[9] could enhance dust transport from the deserts of the Middle East and North Africa to the Asian monsoon regions, further enhancing monsoon rainfall.

Vinoj and colleagues[3] identify a mechanism by which atmospheric warming over the Arabian Sea by desert dust strengthens monsoon rains over central India on short timescales. Their findings add to a growing body of evidence[10–12] that aerosols, both natural and anthropogenic, constitute a key component of the monsoon climate system. ❐

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References

1. Manoj, M. G., Devara, P. C. S., Safai, P. D. & Goswami, B. N. *Clim. Dyn.* **37**, 2181–2198 (2011).
2. Hazra, A., Goswami, B. N. & Chen, J-P. *J. Atmos. Sci.* **70**, 2073–2087 (2013).
3. Vinoj, V. *et al. Nature Geosci.* http://dx.doi.org/10.1038/ngeo2107 (2014).
4. Pease, P. P., Tchakerian, V. P. & Tindale, N. W. *J. Arid Environ.* **39**, 477–496 (1998).
5. Satheesh, S. K. & Srinivasan, J. *Geophys. Res. Lett.* **29**, 1874 (2002).
6. Chung, C. E. & Ramanathan, V. *J. Clim.* **19**, 2036–2045 (2006).
7. Prasad, A. K., Singh, R. P. & Kafatos, M. *Geophys. Res. Lett.* **33**, L05805 (2006).
8. Dey, S., Tripathi, S. N. & Mishra, S. K. *Geophys. Res. Lett.* **35**, L03808 (2008).
9. IPCC *Climate Change 2013: The Physical Science Basis* (eds Stocker, T. F. *et al.*) (Cambridge Univ. Press, 2013).
10. Lau, K. M., Kim, M. K. & Kim, K. M. *Clim. Dyn.* **26**, 855–864 (2006).
11. Ramanathan, V. *et al. Nature* **448**, 575–578 (2007).
12. Wang, C. *et al. Geophys. Res. Lett.* **36**, L21704 (2009).