To Rain or Not to Rain...Aerosols May Be the Answer

Research Highlight

Many studies have shown that aerosols suppress rainfall through indirect effects. Recent studies have also suggested that this suppression of warm rain by aerosols may allow more cloud particles to ascend above the freezing level, initiating an ice process in which more latent heat is released, thus invigorating convection. The theory (Rosenfeld et al. 2008) was verified by an analysis of long-term ARM ground-based measurements (Li et al. 2011), which is now reinforced with global satellite data collected by active and passive sensors aboard the A-Train constellation.

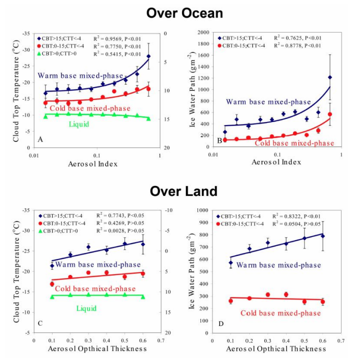
A large ensemble of satellite data acquired by the Moderate Resolution Imaging Spectro-radiometer aboard the Earth Observing System's Aqua platform, the CloudSat cloud profiling radar, and the Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations satellite over the tropical oceans during 2007 was analyzed, and two distinct relationships between clouds/precipitation rate and aerosol loading were found. Cloud-top temperatures were significantly negatively correlated with increasing aerosol index (AI) over oceans and aerosol optical thickness (AOT) over land for deep mixed-phase clouds with liquid droplets near the warm bases and ice crystals near the cold tops; no such significant relationship was seen in uniformly liquid clouds. Precipitation rates were positively correlated with the AI for mixed-phase clouds, but negatively correlated with the AI for liquid clouds.

These distinct correlations might be a manifestation of two potential mechanisms: the invigoration effect (which enhances convection and precipitation) and the micro-physical effect (which suppresses precipitation). Tests checking whether column water vapor and lower tropospheric static stability depended on AI/AOT show that the above results cannot be explained by any changes in meteorological conditions. The authors note that the highly limited information garnered from satellite products cannot unequivocally support the causal relationships between cloud-top temperature/ precipitation rate and aerosol loading. But the fact that the findings of this paper are in good agreement with those from an earlier study using long-term ground-based data and the fact that they can be simulated with a cloud-resolving model lends confidence to the authors' explanations of their results.

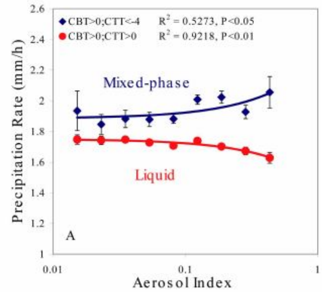
Important implications for studying both the Earth's radiation budget and the global hydrological cycle arise if aerosol loading truly has that great an impact on cloud top temperature and precipitation rate. Aerosols may change the overall distribution of precipitation, leading to a more extreme and unfavorable rainfall pattern of suppressing light rains and fostering heavy rains.

Li, Z, F Niu, J Fan, Y Liu, D Rosenfeld, and Y Ding. 2011. "The long-term impacts of aerosols on the vertical development of clouds and precipitation." Nature-Geoscience: doi: 10.1038/NGEO1313.

Rosenfeld, D, et al. 2008. "Flood or drought: How do aerosols affect precipitation?" Science 321: 1309–1313.



Cloud-top temperature (A, C) and ice water path (B, D) as functions of AI/AOT for warm (blue dots) and cold (red dots) base mixed-phase clouds and liquid clouds (green dots) over the ocean (upper panels) and land (lower panels). The right-hand axes of (A) and (C) are for liquid clouds.



Precipitation rate as a function of AI for mixed-phase (blue dots) and liquid clouds (red dots) over the ocean.

Reference(s)

Niu F and Z Li. 2012. "Systematic variations of cloud top temperature and precipitation rate with aerosols over the global tropics." Atmospheric Chemistry and Physics, 12, doi:10.5194/acp-12-8491-2012.

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Cloud-Aerosol-Precipitation Interactions