Effect of mineral dust on cloud microphysics and precipitation of mesoscale convective systems

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Introduction

Mineral dust & aerosol indirect effect

As giant CCN, dusts may enhance the collision and coalescence of droplets and therefore increase warm precipitation formation and decrease cloud's albedo.

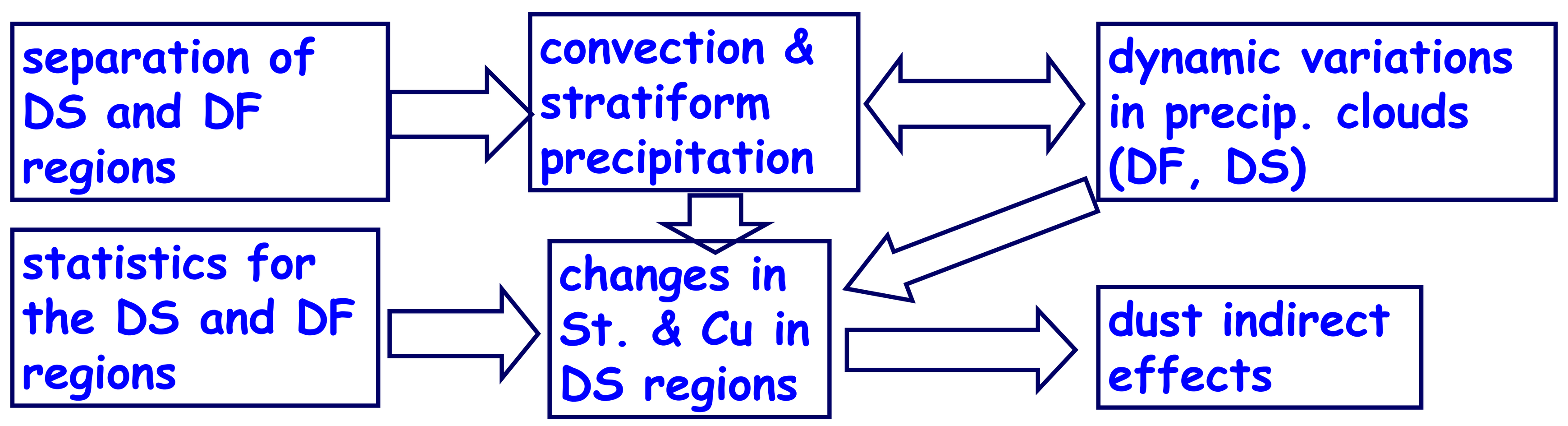
But they may also reduce ice particle sizes due to abundant ice nuclei (IN), thus increase lifetime and amount of ice clouds.

Some observations show that dusts suppress clouds and precipitation.

Objectives

There are inconsistent evidences of aerosol indirect effects (AIE) on clouds and precipitation, and not enough observations of the impacts of dusts on rainfall internal structures. This study uses multi-platform and multi-sensor measurements to investigate detailed physical processes of cloud microphysics and precipitation that are affected by mineral dusts in a case of mesoscale convective systems.

Approach



Data

Terra

MODIS: Aerosol and cloud optical properties

CERES: Radiation and climate forcing

TRMM

TMI: Cloud water and precipitation

PR: Precipitation

VIRS: Aerosol and cloud optical properties

CERES: Radiation

Aqua, GOES and METSAT

Selected case

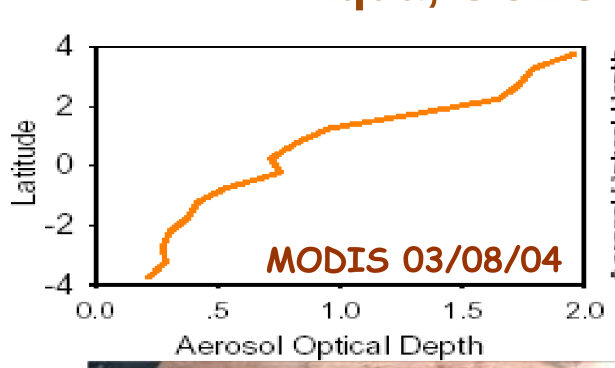
early March 2004

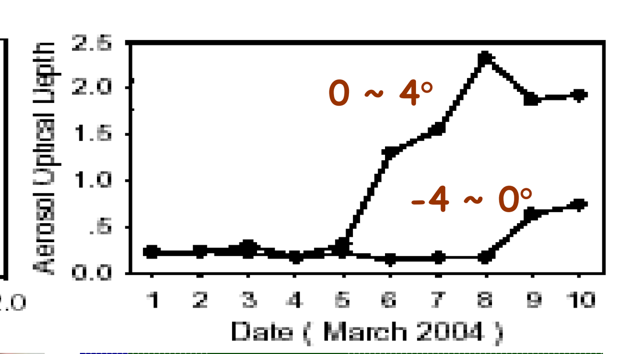
Sahara dust storm

mesoscale convection

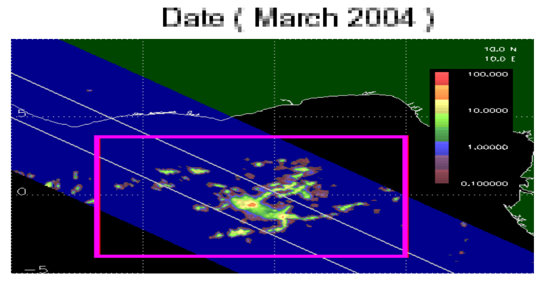
dust-free (DF) and dusty (DS) regions (or sectors)

Surface network: AMMA and AERNET

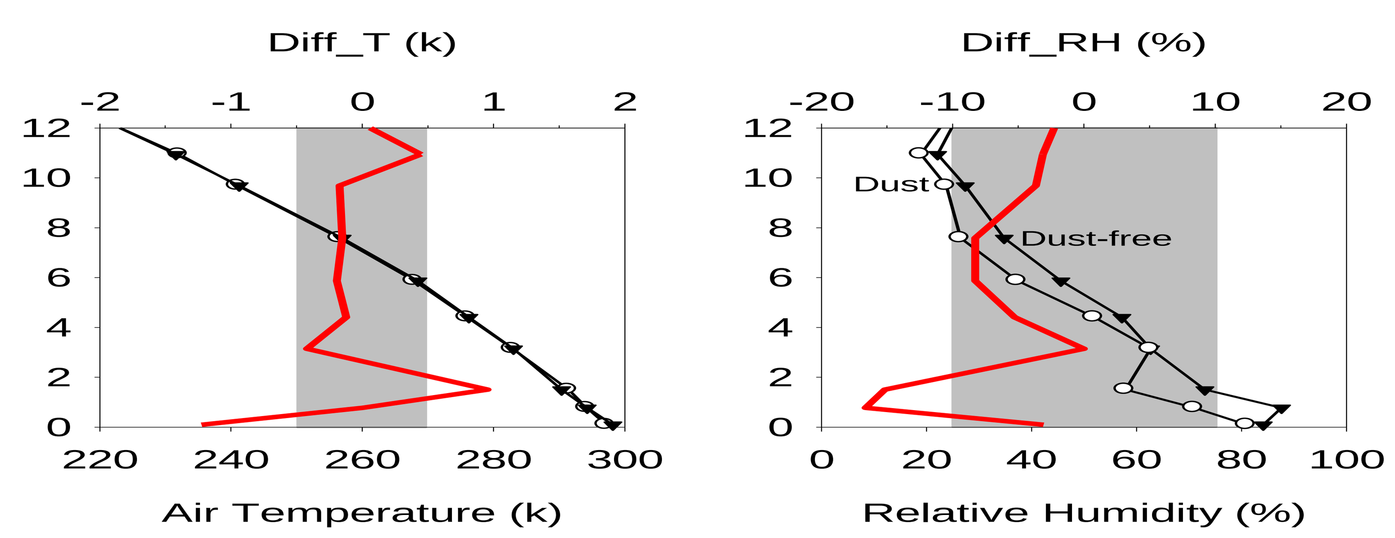




Meteosat-8 RGB composite visible image at 09:12UTC

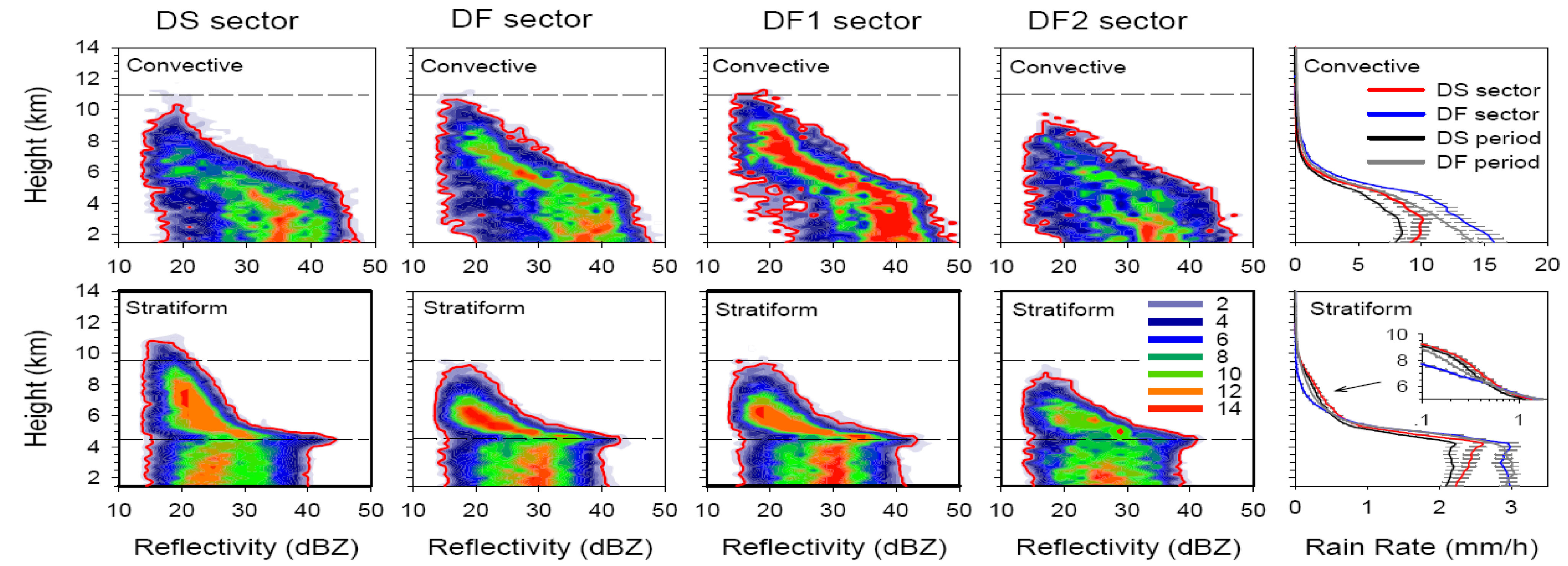


TMI precipitation image on at 09:11 UTC

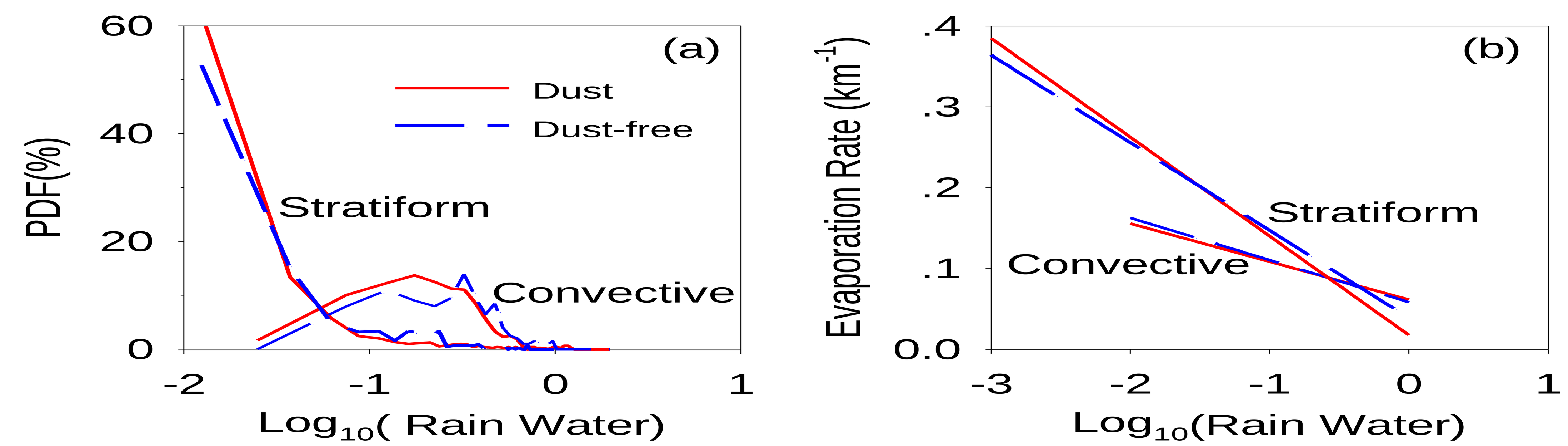


Air temperature and relative humidity profiles in dusty and dust-free sectors derived form AQUA AIRS/AMSU on March 8 about 2:00 UTC

Results



sector:	dusty (DS)	dust-free (DF)
convective clouds:	weaker	strong, variable
stratiform aloft:	stronger	weak, variable
bottom:	similar	more variable



The probability density functions of rain water in convective and stratiform precipitation regions for both dusty and dust-free sectors (a), and corresponding evaporation rates (b).

Summary

❖ Dusts transported up by the strong convection updraft acted as additional ice nuclei. Some of ice particles grown under this dusty condition were carried up to upper levels by the strong convective updraft and contributed to convective precipitation, and others were entered into the neighboring stratiform region and slowly settled downward in the upper layer of the cloud system until they reach the melting level.

❖ Consequences of microphysical effects of dusts were shifting precipitation size spectrum from heavy precipitation to light precipitation and suppressing precipitation. Dusts also enhanced evaporation processes, which further reduced the precipitation reaching surfaces.

❖ The microphysical processes of dust-cloud interaction had strong feedbacks to cloud thermodynamics and altered the vertical gradient of heating profiles in both convective and stratiform regions.

❖ Cloud system adjusted itself for IN changes and resulted in a weak but long lasting cloud system with increasing convective precipitation fraction and decreasing stratiform precipitation fraction.