Implications of Mineral dust particles for Clouds, Precipitation and Hydrological Cycle

Source:

Natural sources such as arid areas (deserts, dry lake beds) and anthropogenic activities such as grazing and cultivation, exposure and disruption of topsoil, enhances dust emissions from the surface. It is estimated that approximately 360 to 1500 Tg of mineral dust is deposited into oceans with about 50% of the total deposition occurring in the North Atlantic Ocean. Dust particles when first emitted can be composed of soluble or insoluble components depending on the source. While transported dust may react with gaseous species or get coated with other soluble aerosols, which can potentially enhance its ability to serve as a CCN. The surfaces of mineral dust particles provide a medium in the atmosphere for heterogeneous chemistry to occur which has a tendency to affect the way the dust particles respond to change in the atmosphere

Size Distribution:

Dust particles have been found to be of variable sizes and can thus be can be categorized into both fine and course mode. The activation of dust to form a cloud droplet is a strong function of its dry particle size. Dust particles can act as CCN or GCCN (giant CCN) depending on their size. Studies suggest that for certain conditions, all dust particles with diameters greater that 2 microns (GCCN) can activate regardless of their composition But for dust particles with sizes between 0.6 and 2.0 microns, the presence of slightly soluble components can induce activation of dust particles that would not activate if entirely insoluble. For dust particles with sizes less than 0.6 microns in diameters, highly soluble substances are required except under highly supersaturated conditions for activation to occur. Also since this size corresponds to fine mode, they may have less carbonate that the coarse dust thereby by reducing the extent of forward heterogeneous chemical reactions that can made dust more hygroscopic. Studies have suggested that for adiabatic parcels with low updraft velocities and high concentration of reacted dust, coarse dust particles can significantly reduce parcel supersaturation and hence the number of particles that activate.

Existing mechanisms of dust particles-cloud-precipitation relations:

Category	***Mechanism***		***Details***	***Spatial and temporal scales***
Radiative Effects	Dust in the atmosphere	Negative or Positive TOA Forcing	Absorbing and scattering have opposing effects upon solar forcing at TOA.	Local Regional and Global scales Hours to weeks
		Atmospheric Net Heating	Dust absorption cause atmospheric heating, and alter the thermodynamic structure of the atmosphere, which further affect the boundary layer growth, and cloud and precipitation formation.	Shorten cloud lifetime
		Surface Cooling in the solar and heating in long wave.	Less solar radiation reaches the ground, thus reducing the available energy for sensible and latent heat fluxes, which drives the boundary layer growth and cloud formation.	Regional to global scale
	Dust Precipitation Positive Feedback		Reduction in the energy that reaches the surface causes a reduction in the evaporation which ultimately leads to reduced precipitation. This causes an increase in the drier climate and more dust.	**Global** effects 1. Reduced precipitation and increased arid regions. 2. Decreased wet removal 3. Longer left time of dust particles. 4. Decrease in SST (water vapor feedback).
	Dust-cloud Radiation Effects [indirect effect] Dust cloud precipitation effects		Dust acts as CCN/IN, changing cloud properties (e.g., coverage, lifetime, height) and consequently have cloud radiation effects.	
Dynamic Effects [radiative-convective coupling]	Atmospheric Stabilization [semi-direct effect; reduced surface sensible heat]		Dust in lower troposphere (by advective or convective transport) absorbs sunlight, changing the atmospheric temperature profile (e.g., temperature inversion) and reduces surface sensible heat, inhibiting buoyant convection and **decreasing** cloud fraction and rainfall.	

	Reduced surface latent heat (or evapotranspiration)	Latent heat associated with evaportranspiration provides moisture for the atmosphere, and also affects the atmospheric temperature profile (e.g., level of free convection), thus reduction of latent heat due to surface cooling can **decrease** atmospheric humidity and influence the boundary layer convection.	
Microphysical Effects Convective Mixing Mechanism [Dust as CCN/IN]	Dust as CCN/GCCN	Dust particles can also aggregate with soluble species to provide a surface on which water condense thereby making them into a CCN. Dust particles when first emitted are composed of insoluble components however over the course of transport of dust; it reacts with gases which increases its ability to serve as a CCN. The surfaces of mineral dust particles provide a medium in the atmosphere for heterogeneous chemistry to occur which has a tendency to affect the way the dust particles respond to change in the atmosphere. Fine particles can activate and suppress precipitation according to first indirect effect while the larger particles can serve as a GCCN and promote precipitation. Opposing Tendencies with unknown net effect.	Interaction between individual dust particles and cloud droplets happen on scale of micro-meters. Time Scales: Order of seconds Activation of dust particles also controlled by the updraft velocity of the parcel resulting in increased time scale.
	Dust as IN	The insoluble part of the dust particles has a tendency to act as efficient IN.	
	Heating within the dust layer (semi-indirect effect)	Due to changes in the heating cooling rate.	

Contrasting BC and Dust

	BC	Dust
Solubility	Insoluble	Can be soluble or insoluble
Size	Fine mode	Fine/Coarse mode
CCN	No	YES, CCN/GCCN
IN	No for fresh BC and Yes for aged BC	YES
Optical properties	Very effective absorber in shortwave. Not efficient absorber in the longwave	Can absorb and scatter in shortwave and longwave
TOA forcing	Positive	Negative or Positive but net effect is negative
SFC forcing	Negative	Negative in shortwave, positive in longwave
Effect on precipitation and hydrological cycle	The net effect on precipitation is still unclear and depends on number of factors such as: 1. Type of Aerosol 2. Cloud Type 3. Meteorological conditions	