Aerosols and their impact on precipitation

Aerosols are small (ranging from a few nm to μm) and ubiquitous particles suspended in the atmosphere. They originate from natural and anthropogenic sources forming through a variety of processes which leads to a large variability in their sizes and composition. Urban areas and industrial sites may generate aerosol concentrations 10-1000 times larger than the unpolluted maritime and continental environments. The biomass burning and fossil fuel consumption are major sources of anthropogenic aerosols.

Aerosols are either of primary or secondary origin. Primary aerosols are introduced into the atmosphere (mostly from continental surface sources) and secondary aerosols are formed in the atmosphere from precursor gases, particularly SO_2. Some aerosols can act as the cloud condensation nuclei (CCN) where the formation of cloud droplets is promoted by the presence of these particles. In very cold environments part of the aerosol particles can act as substrate for heterogeneous crystal growth (ice nuclei, IN).

Aerosols have direct and indirect effects on the Earth's climate. The direct effect is related to aerosol optical properties where they scatter and/or absorb solar radiation and thus influence the warming/cooling of the planet. The indirect effect is related to the fact that aerosols modify the properties of clouds. Heterogeneous nucleation where water drops nucleate on aerosols is the main mechanism for the formation of clouds in the atmosphere. In such way, the physical and chemical properties of aerosols determine the nucleation and growth rate of the cloud droplets affecting the cloud microphysical structure and formation. Many in-situ observations support the link between high CCN concentrations and increased cloud droplet number concentrations (CNDC) as well as the change in optical properties of the clouds. Increased CCN concentrations decrease the size of droplets. However, the impact of aerosols on the precipitation is less well established. The environmental conditions (eg. humidity, atmosphere stability) play also an important role in the precipitation formation, and thus, the identification of the sole aerosol effect on precipitation has proven to be somewhat difficult.

Anthropogenic influence on clouds is most apparent in the case of so called "ship tracks", clouds which form around the exhaust released by ships. Changes in precipitation due to urban effects were observed since 1970s (METROMEX studies). Observations during the biomass burning and forest fires in Amazon showed the reduced cloud droplet size with delayed onset of precipitation. Increased aerosol concentration can lead to the invigoration of cloud updrafts, causing intense thunderstorms, large hail and higher cloud tops. As a consequence, the regional and global circulation systems are influenced. There are strong

indications that aerosols influenced the Sahelian drought as well as the weakening of the Indian monsoon and shifting the tropical rainfall in Asia toward the south.