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Physical processes of desert dust in the atmosphere

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Abstract. Dust particles play an important role in several atmospheric processes with significant contribution to climate change considerations. Dust affects the radiation budget of the atmosphere by both direct and indirect aerosol effects. The direct effects refer to the reflection and absorption of solar and terrestrial radiation by the dust particles while the indirect effects refer to their role in cloud formation. Atmospheric studies regarding the dust emission and transport started in the late 60's and corresponding research continues until now, with increasing complexity on the specific particle properties and atmospheric processes. In this work we describe the main factors that affect several physical processes of dust in nature based on observational and modeling studies, including a retrospective of dust science efforts in the previous decades.

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1. Introduction

Mineral dust is one of the most important aerosol types in terms of mass and optical depth. It affects radiation and alters liquid and ice cloud properties, as well as precipitation processes. Once dust particles are deposited at the surface, they provide micronutrients to the ocean or to land ecosystems, affecting fishery and agriculture activities. Moreover, very high concentrations of dust are often transported away from Sahara Desert towards Europe. Under such conditions, the smaller PM2.5 particles can be easily inhaled and deposited on the lungs and are related to human health disorders. For these reasons, mineral dust and the associated uncertainties in climate projections are key topics for atmospheric physics research. This is particularly true for the highly dust-affected area of Eastern Mediterranean where the largest climate change effects are also expected in the decades to come.

2. Results

Early theoretical and modeling studies have defined the primary physical processes that lead to dust mobilization, long range transfer and deposition processes [1,2]. These atmospheric models are being constantly improved with the inclusion of more detailed physical schemes and with the assimilation of in-situ and remote sensing data. This effort results in more detailed representations of the atmospheric physical processes, in accordance with the in-situ (surface stations and airborne) and remote sensing (surface and satellite observations). In general, the most crucial parameter for the emission of dust is the near-surface wind. Increased wind speeds may occur due to synoptic wind forcing, topographic effects (e.g., valley channeling), low-level jets (LLJ) squall lines and storm downdrafts [3]. Most of the above processes result in detached elevated dust plumes over the Mediterranean. Most dust layers in the area are observed at heights of 4–5 km in the troposphere and are associated either with Mediterranean low-pressure systems or with the summer anticyclonic circulation over north Africa. The dust plumes travel over very long distances often crossing the Atlantic Ocean to reach America and under certain circumstances enhanced cloud icing due to mineral dust may impact aviation safety [4]. When the plumes reach mainland, their transport over complex terrain can be strongly affected by local wind patterns such as Foehn flows [5]. The description of surface dust emissions also plays a major role in mineral dust research. The development of assimilation methods for including satellite observations in model fields replaces the earlier static dust source maps with dynamic satellite-based emissions maps, allowing a physically based representation of seasonal and annual variations of dust-source strength [6]. Additionally, 3D-Var assimilation of dust Aerosol Optical Depth from satellite retrievals is also used for nudging the simulated fields towards the observational satellite values. An overview of the aforementioned physical processes and associated theoretical model developments, as well as the current status of knowledge regarding dust physics in the atmosphere will be discussed.

3. Conclusions

The significant role of dust aerosols in physical processes has been identified since the late 60's. In this work we present a retrospective of theoretical and observational studies on this field as well as typical examples of atmospheric dust processes (Figure 1). The significant scientific progress in the fields of atmospheric and aerosol physics is expected to minimize the uncertainty in climate change projections and improve our understanding on fundamental atmospheric physics.

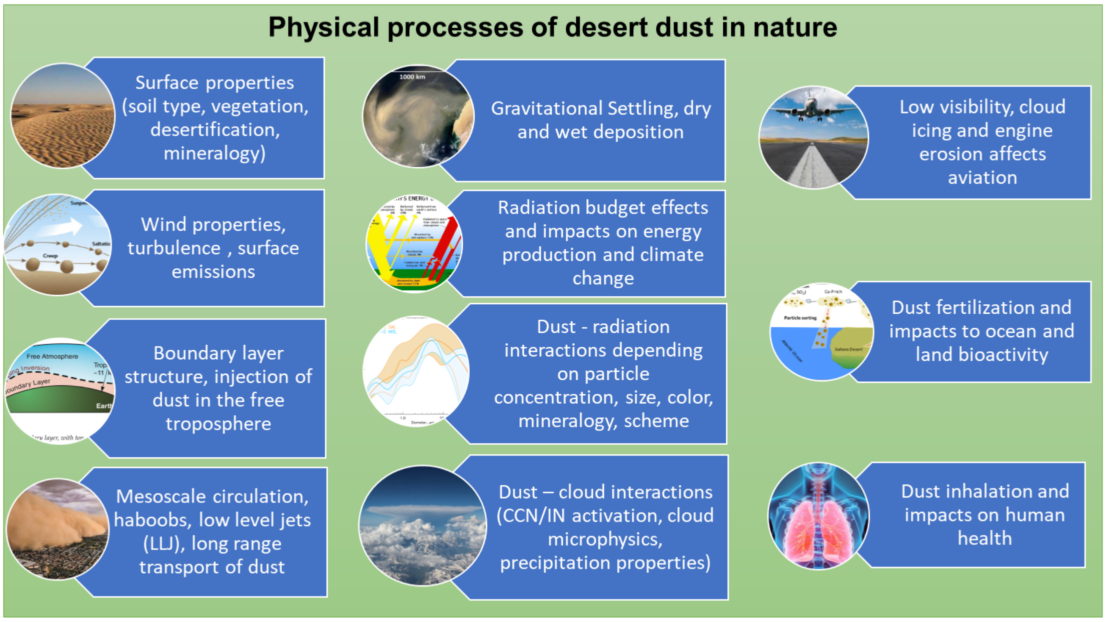

Figure 1. Examples of physical processes of dust in nature

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