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Holocene dust dynamics: Introduction to the special issue

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Abstract

This article is a brief introduction to the Special Issue on *Holocene Dust Dynamics*, which brings together recent research on a key aspect of the Earth's changing climate through its effects on radiative balance, cloud cover and biogeochemical cycles. The aim of the Special Issue is to contribute to a better understanding of the role of dust aerosols by analysing the evolution and climatic impact of atmospheric dust over long and short timescales within the Holocene. Here, we introduce the rationale behind the Special Issue and the eight research papers, which include long-term records of dust deposition from different types of natural archive (e.g. peatlands, ice, loess and lake sediments) as well as present-day multi-annual dust trap records and process studies from various climatic regimes that have global implications.

Keywords

aerosols, atmospheric dust, climate change, Holocene, natural archives

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Atmospheric dust is a key player in Earth's climate. It affects the planet's radiative balance directly by reflecting incoming shortwave solar radiation and absorbing outgoing longwave radiation (e.g. Miller et al., 2014). It also influences the climate indirectly by acting as condensation nuclei for clouds (e.g. Lohmann and Feichter, 2005) and by affecting biogeochemical cycles through micronutrient supply to the terrestrial and marine biospheres (Boy and Wilcke, 2008; Mahowald, 2011; Yu et al., 2015). Unlike greenhouse gases, whose effect on climate is relatively well constrained, the uncertainty of aerosols, and mineral dust in particular, on climate change is comparatively large (Huneeus et al., 2011; Myhre et al., 2013). This is true for both current and past large-scale climatic changes.

The processes of emission, transport and deposition of atmospheric dust and its climatic impacts vary with past and current climate and environmental changes. Atmospheric dust is intimately linked to global paleoclimatic change, with exponentially higher and lower atmospheric dust loads during colder and warmer periods, respectively (e.g. Lambert et al., 2013; Maher et al., 2010). Increased or reduced dust concentrations also feed back on the climate system through dust's direct and indirect effects. Shaffer and Lambert (2018) recently showed that dust loads during glacial maxima may be responsible for a global cooling of 1°C due to combined dust–climate feedbacks. The latest Intergovernmental Panel on Climate Change (IPCC) reports suggest a global negative radiative forcing of atmospheric dust on global climate and also point out to a relative uncertainty in the calculation of that budget (IPCC, 2014). Conversely, Ellis and Palmer (2016) argue that dust deposition during glacial times may have triggered accelerated melting of ice globally through decreasing the earth's albedo.

Atmospheric dust deposition/flux is also an indicator for aridity and wind system changes. Higher precipitation will wash out more dust from the atmosphere (Yung et al., 1996), while stronger winds will entrain more and coarser-grained particles from the surface (McGee et al., 2010; Van der Does et al., 2016). Therefore, dust deposition records can be used to reconstruct past wind and atmospheric dynamics as well as the activity of dust sources (i.e. deserts) (e.g. Albani et al., 2015; De Vleeschouwer et al., 2014). High uncertainties in reconstructing past dust fluxes, however, limit our knowledge of the relative contributions of dust source changes, wind changes and hydrological cycle changes during past times, which translates into highly variable estimates of dust deposition. Moreover, in modern times, dust emissions have at least doubled over the past two centuries due to

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anthropogenic influence (Hooper and Marx, 2018; IPCC, 2014; Mahowald et al., 2010; Mulitza et al., 2010), with consequences that are still uncertain (Kok et al., 2018).

To summarize, climate and dust have mutual interactions and one will alter the other in many ways, resulting in a feedback paradigm: global climate is affected by atmospheric dust variations and the generation, transport and deposition of atmospheric dust is itself modulated by climate. Studying past and present atmospheric dust behaviour and understanding those climate–dust feedbacks may therefore help forecasting future climate–dust interactions. The broad aim of this special issue is to contribute to the general goal of a better understanding of dust aerosols by analysing in detail the evolution and climatic impact of atmospheric dust during to the Holocene. It follows the DICE working group initiative and guidelines (http://www.pages-igbp.org/working-groups/global-monsoon/143-working-group/dice/861-dice) in compiling a series of past and present-day atmospheric dust records from various areas. The first part of the special issue is dedicated to the most prominent archives of atmospheric dust that are used nowadays: peatlands, ice and loess. Those first papers show how it is possible to reconstruct dust deposition fluxes and sources and decipher climatic information such as wind regimes, positions and intensities in various climatic conditions from seasonal to monsoonal regimes (Hooper et al., 2020; Martínez Cortizas et al., 2020; Pratte et al., 2020). While peatlands provide detailed and high-resolution chronologies, they are generally limited to the Holocene or the last glacial termination, whereas loess and ice provide a longer prospective. The two papers presented in this issue are a perfect example of the source to sink transport of dust. Loess from South American Pampas do not only provide a reconstruction of past climatic conditions over several MIS (Torre et al., 2020), but also provide source characterizations to dust deposited in Antarctica (Delmonte et al., 2020). When those archives are not available in a given geographical area, lake sediments can provide an alternative, given specific conditions, to disentangle the atmospheric signal from the watershed erosion (Arcusa et al., 2020). These contributions about past atmospheric dust are closely dependent on present-day dust studies as while 'the past is the key to understand our future', present-day studies help validate hypothesis made from past dust archives. They also greatly help understanding the processes behind the dust cycle in terms of climatic feedbacks, transport and effects on living organisms and ecosystems. The last two contributions of this special issue perfectly illustrate those aspects. Cosentino et al. (2020) present a very detailed study of the dust deposition in Southern South America over the last 14 years and greatly help understanding how dust is generated, transported and deposited over a continent, whereas Bigelow et al. (2020) contribute to our understanding of the importance of atmospheric dust as fertilizer in environments where nutrients are limited as well as on the availability and degradability of dust components that may play an important role on metabolic functions of bacteria, at the base of the trophic chain of some ecosystems.

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