The first global picture of observation-based estimate on continental boundary layer new particle formation

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Atmospheric aerosols have a large impact on air quality, human health and on global climate. One of the largest uncertainties related to climate change is the magnitude of the cooling effect of aerosols that counteracts the warming caused by greenhouse gases (IPCC, 2013). Formation of secondary aerosol particles is a major source of atmospheric aerosols (Merikanto et al., 2009), and a subject of active research during the past two decades. Regional events of new particle formation (NPF) have been observed worldwide (Kulmala et al., 2004), but in the literature reports of the seasonality of the NPF related parameters are still rather sparse.

The aim of this study is to present a global picture on the relevance of aerosol formation. We gathered observations of the annual cycle of NPF events from sites with at least one year of total particle size distribution measurements available. As the number of such sites is rather limited, we also included sites, which offered shorter campaign-wise data coverage, but what could be parsed into a full seasonal cycle. As the published peer-reviewed articles about the data do not always provide all the climate-relevant NPF characteristics (event frequencies, particle formation rates and growth rates), we collected the observational data of sub-micron aerosol number size distribution, and performed a standardized analysis (using the methods described by Kulmala et al. 2012) to reveal the characteristic features of the NPF events at different sites.

Aerosol number concentration size distribution data was obtained from the EBAS database (http://ebas.nilu.no/) and from several research groups running long-term aerosol measurements. The Differential Mobility Particle Sizer (DMPS) or Scanning Mobility Particle Sizer (SMPS) instruments typically had lower detection limits varying between 3 and 10 nm. In order to have comparable results between different sites, a common size range of 10–25 nm was used for nucleation mode particles in this study. Altogether we identified 35 measurement sites worldwide where aerosol size distributions have been measured for at least one year (either continuously, or in separate campaigns covering a full annual cycle). The sites included in this study range from arctic and remote areas to heavily polluted megacities.

The size distribution data was classified into NPF event, non-event and undefined days according to the guidelines presented by Kulmala et al. (2012). We used the criteria originally introduced by Dal Maso et al. (2005) for identifying regional NPF events, where the formation and subsequent growth is distinguishable for several hours.

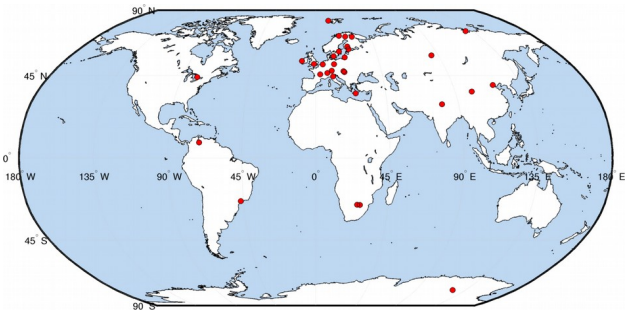

Figure 1. The locations of the 35 measurement sites included in this study.

Regional NPF events were observed at all the sites throughout the year. The global average NPF frequencies were ranging from 12% of days during December–February to 31% of days in March–May. The smallest NPF frequencies occurred in the polar areas (NPF occurring in less than 20% of days), and the highest in the African savannah area (NPF occurring in more than 60% of days).

The particle formation rates did not, on average, show large seasonal variation, but there exist large differences between different environments. The highest formation rates that are over 1 cm^{-3} s^{-1} occur inside cities and other anthropogenically heavily influenced areas. In these areas the SO_2 concentrations are typically high leading to high concentrations of sulphuric acid, which is one of the key precursor species in atmospheric NPF. On the other hand, the highest particle growth rates do not occur in these same areas of high formation rates, pointing to the decoupling of the mechanisms leading to the initial particle formation and the later growth of the particles.

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