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Trends on atmospheric new particle formation — 16 years of observations in boreal forest

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Research on new particle formation (NPF) in the atmosphere has been very active during the last two decades. This phenomenon has been observed in various environments around the world [1]. One of the longest and most comprehensive data sets of atmospheric aerosol properties is available from the University of Helsinki SMEAR II station in Hyytiälä, southern Finland [2]. Ambient aerosol size distributions have been measured at Hyytiälä since January 1996 with a DMPS system covering particle size range 3 – 1000 nm (3 – 500 nm until end of 2004; see Aalto et al., 2001 [3]). Aerosol measurements are complemented by measurements of basic meteorological variables, trace gas concentrations (SO_2, O_3, CO, CO_2, NO, NO_x), and quantities related to the soil and forest surrounding the station.

Until end of 2011 we have observed 1337 days with regional NPF events, i.e. formation of new 3 nm particles followed by particle growth to sizes of 30–50 nm typically within 10–20 hours. The number of nucleation events detected at Hyytiälä varies from year to year in the range 60 – 120 per year. The reasons behind this quite substantial variation are not yet found. We have, however, established that the variation of the galactic cosmic ray intensity due to the 11 year solar cycle is not connected to the particle formation intensity at Hyytiälä [4].

Mean values and observed trends in the quantities relative to NPF are listed in Table 1. There is no significant trend in the formation rates of 3 nm particles. In contrast, the growth rates are increasing by 3% per year relative to their 16 year mean value. Concentrations of sulphuric acid, which is the most important precursor vapor in atmospheric NPF, can be approximated with a simple proxy model [5]. This proxy takes into account the source from SO_2 and the condensation sink by pre-existing particles. Both the SO_2 concentration and CS are decreasing in Hyytiälä, but the relative change in SO_2 is larger. This leads to a decreasing trend of 4% per year also in the H_2SO_4 proxy concentration, and suggests that the observed increase in the particle growth rates could be caused by increased concentrations of organic compounds and their oxidation products. As the emissions of these biogenic organic compounds are highly temperature dependent, increasing global temperatures can lead to a larger fraction of newly formed particles reaching cloud condensation nuclei sizes and this way NPF becoming more significant to climate.

Table 1: Mean values and trends of gas and particle quantities related to new particle formation in Hyytiälä during 1996–2011. Trend is calculated from linear least-squares fit to all the measurement data.

	1996 – 2011 mean value	**Trend**	
		absolute value	**relative to 1996 – 2011 mean**
SO_2	0.38 ppb	-0.02 ppb/year	-5.0%/year
Condensation sink	$5.1 \cdot 10^{-3}$ s^{-1}	$-1.5 \cdot 10^{-4}$ s^{-1}	-2.9%/year
H_2SO_4 proxy	$3.8 \cdot 10^{5}$ cm^{-3}	$-1.7 \cdot 10^{4}$ cm^{-3}	-4.3%/year
Formation rate	0.84 cm^{-3} s^{-1}	no trend	—
Growth rate	3.1 nm/h	$+0.1$ nm/h	$+3.2$%/year

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