Observations of increased new-particle formation along horizontal roll vortices

J. Lampilahti[1], H. Manninen[1], R. Väänänen[1], K. Leino[1], A. Manninen[1], S. Buenrostro Mazon[1], T. Nieminen[2], M. Leskinen[1], T. Petäjä[1] and M. Kulmala[1]

[1]Department of Physics, University of Helsinki, Helsinki, FI-00560, Finland
[2]Department of Applied Physics, University of Eastern Finland, Kuopio, FI-70211, Finland
Keywords: new-particle formation, roll vortices, planetary boundary layer, airborne measurements
Presenting author email: riikka.vaananen@helsinki.fi

New particle formation (NPF) is a frequent phenomenon and a major source of climatically relevant aerosol particles in the atmosphere (e.g. Kulmala et al., 2013). The degree of spatial variation in particle production in the lower troposphere during NPF is still unclear. Previous numerical investigations and field measurements have indicated that different mixing processes including roll vortices could be favourable for NPF (Nilsson et al. 2001; Easter and Peters, 1994).

We have done airborne measurements of aerosol particles in the lower troposphere using a light airplane and a zeppelin. The airplane measured the particle concentration (>3 nm) and particle-size distribution (10...400 nm) in separate intensive campaigns between 2013-2015 that took place between spring and autumn. The zeppelin measured particle-size distribution down to 2 nm during the spring 2013.

The airplane measurements consisted of ~30 km long flight legs flown perpendicular to mean wind, while the zeppelin measured over a smaller area of ~5 km in diameter. All airborne measurements were done in the vicinity of the SMEAR II field station in Hyytiälä southern Finland (61°51'N, 24°17'E), and were complemented by the station's own aerosol particle measurements.

Large helical circulations in the planetary boundary layer (PBL), known as roll vortices (e.g. Etling and Brown, 1998), were identified using tower and airborne wind measurements, satellite images as well as radar.

The observations suggest that NPF could be enhanced, or exclusively take place, in some locally limited regions of the mixed PBL. These enhancement regions, where the sub-10-nm particle concentration can increase by almost an order of magnitude compared to the background, appear to be connected to roll vortices. The enhanced NPF regions seem to be spatio-temporally linked to rolls, but only some of the rolls are able to enhance NPF significantly.

An example case (Aug 21, 2015) is presented in Figure 1, where part of the flight track is coloured by averaged vertical wind and 3...10 nm particle concentration. The parallel convective band structure in Fig. 1a was caused by rolls. The rolls were also visible in radar. The region of increased 3...10 nm particle concentration is shown in Fig. 1b. The particles were also observed from the field station (marked by +), where the particle flux measurements indicate that the particles had an elevated source.

On another measurement day (May 8, 2013) we could observe the rolls and the particle region to move across the measurement area in a similar way and the particles showed clear growth.

These kinds of long lines of small sub-10-nm aerosol particles were observed on roughly 40 % of the days when NPF was observed. Further studies need to be carried out in order to determine the importance of the phenomenon.

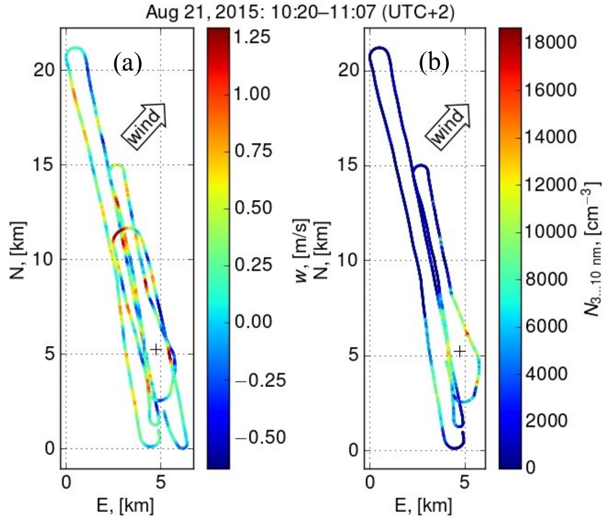

Figure 1. Flight track coloured by (a) averaged vertical wind and (b) 3...10 nm particle concentration.

Acknowledgements. This work was supported by the Office of Science (BER), U.S. Department of Energy. This research has been funded by the ERC-Advanced "ATM-NUCLE" (grant no. 227463), the Academy of Finland (Center of Excellence project no. 272041), the Eurostars Programme under contract no. E!6911 and the European Commission under the Framework Programme 7 (FP7-ENV-2010-265148), and the European Union's FP7 capacities programme under ACTRIS (grant no. 262254), and Horizon 2020 research and innovation programme under ACTRIS-2 (grant no. 654109). In addition, this work was supported by CRAICC and the Swedish Research Councils.

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