Atmospheric nucleation: highlights of the EUCAARI project and future directions

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Within the project EUCAARI (European Integrated project on Aerosol Cloud Climate and Air Quality interactions), atmospheric nucleation was studied by (i) developing and testing new air ion and cluster spectrometers, (ii) conducting homogeneous nucleation experiments for sulphate and organic systems in the laboratory, (iii) investigating atmospheric nucleation mechanism under field conditions, and (iv) applying new theoretical and modelling tools for data interpretation and development of parameterisations. The current paper provides a synthesis of the obtained results and identifies the remaining major knowledge gaps related to atmospheric nucleation. The most important technical achievement of the project was the development of new instruments for measuring sub-3 nm particle populations, along with the extensive application of these instruments in both the laboratory and the field. All the results obtained during EUCAARI indicate that sulphuric acid plays a central role in atmospheric nucleation. However, also vapours other than sulphuric acid are needed to explain the nucleation and the subsequent growth processes, at least in continental boundary layers. Candidate vapours in this respect are some organic compounds, ammonia, and especially amines. Both our field and laboratory data demonstrate that the nucleation rate scales to the first or second power of the nucleating vapour concentration(s). This agrees with the few earlier field observations, but is in stark contrast with classical thermodynamic nucleation theories. The average formation rates of 2-nm particles were found to vary by almost two orders of magnitude between the different EUCAARI sites, whereas the formation rates of charged 2-nm particles varied very little between the sites. Overall, our observations are indicative of frequent, yet moderate, ion-induced nucleation usually outweighed by much stronger neutral nucleation events in the continental lower troposphere. The most concrete outcome of the EUCAARI nucleation studies are the new semi-empirical nucleation rate parameterizations based on field observations, along with updated aerosol formation parameterizations.

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