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New Aerosol Particle Formation in Amazonia

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Abstract. Particle nucleation in Amazonia has been an enigma throughout decades of active scrutiny of natural nucleation processes; however, measurements have so far been thought to fail capturing an actual new particle formation (NPF) event. In this study we have analyzed latest measurements of ultra-fine particle size distributions alongside with air ion spectra and revealed a diurnal pattern of ultra-fine particle apparent growth. The revealed growth pattern is preceded by diurnal precipitation probability maxima, and simultaneous abundant ion production as detected by Neutral cluster and Air Ion Spectrometer (NAIS) data. Thus, we claim that by implementing statistical analysis of scanning mobility particle sizer (SMPS) data and combining with independent observations from Neutral cluster and Air Ion Spectrometer (NAIS) we can observe a consistent signal of NPF events in Amazonia.

Keywords: Nucleation, NPF, Amazonia, Particle growth, cluster analysis
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INTRODUCTION

Events of new particle formation (NPF) in tropical boundary layer followed by consecutive growth towards Aitken mode size range are sparse compared to mid-latitudes Kulmala et al. (2004). This is also the case for rainforest environment. More often short episodes of elevated ultra-fine and Aitken mode aerosol particle concentrations are observed. Their origin and the processes governing these episodes however remain unclear. Based on observations performed in the Amazonian rainforest environment combined with statistical analysis we present a mechanism explaining the erratic appearance of ultrafine aerosol in tropical boundary layer of the rainforest.

MEASUREMENT SITE

The measurement site is located in Cuieras forest reserve TT34 (2.6 S, 60.2 W) tower, 60 km NNW from the city of Manaus, Brazil. Engulfed by Rio Negro from the

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west and low traffic intensity highway 174 from the east the station is an excellent representative for a primary rainforest with an outlook on anthropogenic influence in the region. Also, annual shift cycle between dry and rainy seasons ensures excellent conditions to evaluate human influence on climatic patters in the Amazon River basin. During the dry season easterly winds prevail and during the rainy season northeasterly winds provide majority of air mass transport over the pristine rainforest to the site with a fraction of air masses brought over the Manaus city. A detailed description of the measurement size is provided in Martin et al. (2010).

INSTRUMENTATION

In this study we used data acquired by Scanning Mobility Particle Sizer (SMPS) and Neutral cluster and Air Ion Spectrometer (NAIS). Measured particle size range of the SMPS is 10-500 nm distributed over 22 channels. The time resolution is 10 minutes. The instrument was situated in a container below the canopy height with an inlet mounted above the canopy height (details in Martin et al., 2010).

The NAIS observes mobility distributions of both negative and positive air ions simultaneously in the mobility diameter range of 0.8 - 42 nm. It consists of two parallel cylindrical Differential Mobility Analyzers, one for classifying negative ions and the other for positive ions. The ions are classified according to their electrical mobility with differential radial electric field and collected to 21 electrically isolated electrometers to measure the currents carried by the ions.

DATA MINING METHOD

We chose to analyze the SMPS data using a statistical method based on kmeans cluster analysis technique. MacQueen (1967) described kmeans cluster analysis in detail. Prior to our study cluster analysis has been implement in aerosol science for other purposes, such as principle meteorological component analysis in particle nucleation day classification (Hyvönen et al., 2005) and investigation of processes controlling the evolution of aerosol particle size distribution properties (Tunved et al., 2004). We introduce a method that allows for mining ultra fine particle statistics by analyzing particle size distributions selectively.

Each scan was normalized to its maximum number concentration; thus, we are focusing on different shapes of particle size distributions instead of absolute number concentrations. Only size distributions having a local a maximum between 10 to 80 nm were considered further analysis. This was achieved by discarding size distributions in abovementioned size range whose second order derivative of number size distribution curve was greater than 0. Applied thresholds and input parameters have been compiled in the Table 1.

TABLE 1. Cluster analysis thresholds and input parameters.

Parameter	Value	Comments
Number of clusters	50	
Method run repetitions	30	

Particle number size distribution normalization		To maximum number concentration value of corresponding size distribution
Curvature cutoff threshold	0	Only convex distributions considered
Lower particle size cutoff	10 nm	Instrumentation limit
Upper particle size cutoff	80 nm	Empirically chosen limit that minimizes analysis bias by Aitken/accumulation mode particles.

RESULTS AND DISCUSSION

By extrapolating the apparent growth of the particles (Figure 1.) we estimate the time of formation to around 6 - 7 am, which coincides with a morning precipitation maximum as well as elevated ion burst probability. Abundance of afternoon nucleation mode particle cluster type frequency is also preceded by a similar but much stronger pattern of ion bursts and afternoon rain showers. For in depth description of possible mechanisms controlling ion production by rain or waterfall see Hõrrak et al. (2005) and Hirsikko et al. (2011).

We also used CALM model (Tunved et al. 2010) to evaluate ion production rate based on maximum values of ion concentration of ~10^5 cm^{-3}. Model predicted a 100 $cm^{-3}s^{-1}$ production rate, which equilibrates with self-coagulation sink. Such concentration of 4 nm ions, considering only self-coagulation, would deplete to 800 cm^{-3} in 5 hours, whilst D_p would grow to 20 nm. However, our reconstructed apparent growth rate of 5 nm/h takes on the order of 3 hours to do just the same. It is likely that also other processes, mainly growth by condensation of biogenic volatile organic compounds contribute to observed aerosol growth.

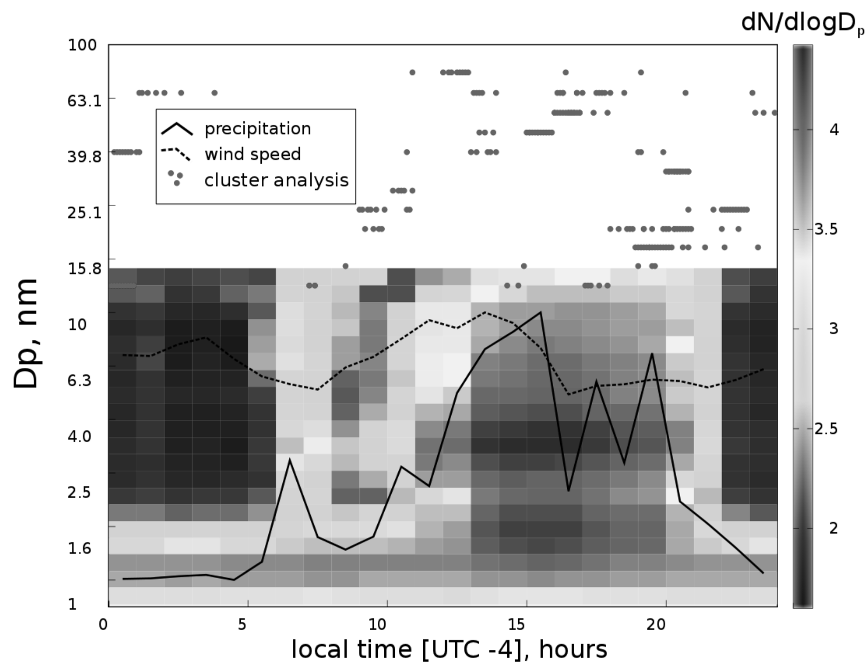

FIGURE 1. NAIS negative ion concentration 95th percentile diurnal pattern combined with cluster analysis method results (red dots). Mean meteorological parameters are given in arbitrary units.

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REFERENCES

1. A. Hirsikko, T. Nieminen, S. Gagné, K. Lehtipalo, H. Manninen, M. Ehn, U. Horrak, V. Kerminen, L. Laakso, P. McMurry, et al.: Atmospheric ions and nucleation: a review of observations, Atmos. Chem. Phys, 11, 767–798, 2011.
2. U. Horrak, H. Tammet, P. Aalto, M. Vana, A. Hirsikko, L. Laakso, and M. Kulmala: Formation of charged nanometer aerosol particles associated with rainfall: atmospheric measurements and lab experiment, Proceedings of BACCI, NECC and FCoE activities, pp. 180–185, 2005.
3. M. Kulmala, H. Vehkamäki, T. Petäjä, M. Dal Maso, A. Lauri, V. Kerminen, W. Birmili, and P. McMurry: Formation and growth rates of ultrafine atmospheric particles: a review of ob- servations, Journal of Aerosol Science, 35, 143–176, 2004.
4. J. MacQueen: Some methods for classification and analysis of mul- tivariate observations, in: Proceedings of the fifth Berkeley sym- posium on mathematical statistics and probability, vol. 1, p. 14, California, USA, 1967.
5. S. Martin, M. Andreae, D. Althausen, P. Artaxo, H. Baars, S. Borrmann, Q. Chen, D. Farmer, A. Guenther, S. Gunthe, et al.: An overview of the Amazonian Aerosol Characterization Experiment 2008 (AMAZE-08), Atmospheric Chemistry & Physics Discussions, 10, 18 139–18 195, 2010.
6. P. Tunved, J. Ström, H. Hansson, et al.: An investigation of processes controlling the evolution of the boundary layer aerosol size distribution properties at the Swedish background station Aspvreten, Atmospheric Chemistry and Physics Discussions, 4, 4507–4543, 2004.
7. Tunved, P., Partridge, D., and Korhonen, H.: New trajectory driven aerosol and chemical process model Chemical and Aerosol Lagrangian Model (CALM), Atmos. Chem. Phys, 10, 10161– 10 185, 2010.