Direct, semi Direct, Indirect Effect

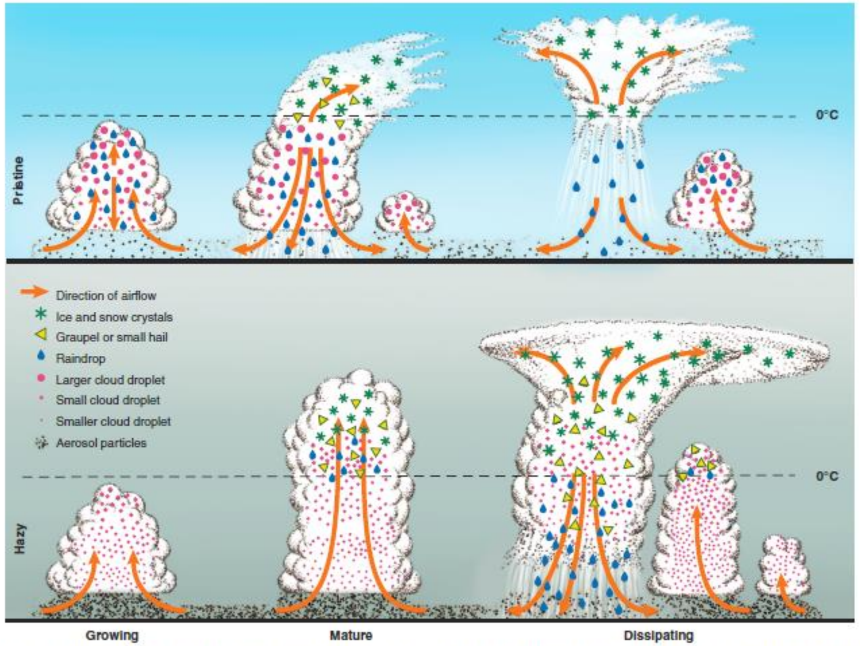


Fig. 2. Evolution of deep convective clouds developing in the pristine (top) and polluted (bottom) atmosphere. Cloud droplets coalesce into raindrops that rain out from the pristine clouds. The smaller drops in the polluted air do not precipitate before reaching the supercooled levels, where they freeze onto ice precipitation that falls and melts at lower levels. The additional release of latent heat of freezing aloft and reabsorbed heat at lower levels by the melting ice implies greater upward heat transport for the same amount of surface precipitation in the more polluted atmosphere. This means consumption of more instability for the same amount of rainfall. The inevitable result is invigoration of the convective clouds and additional rainfall, despite the slower conversion of cloud droplets to raindrops (*43*).

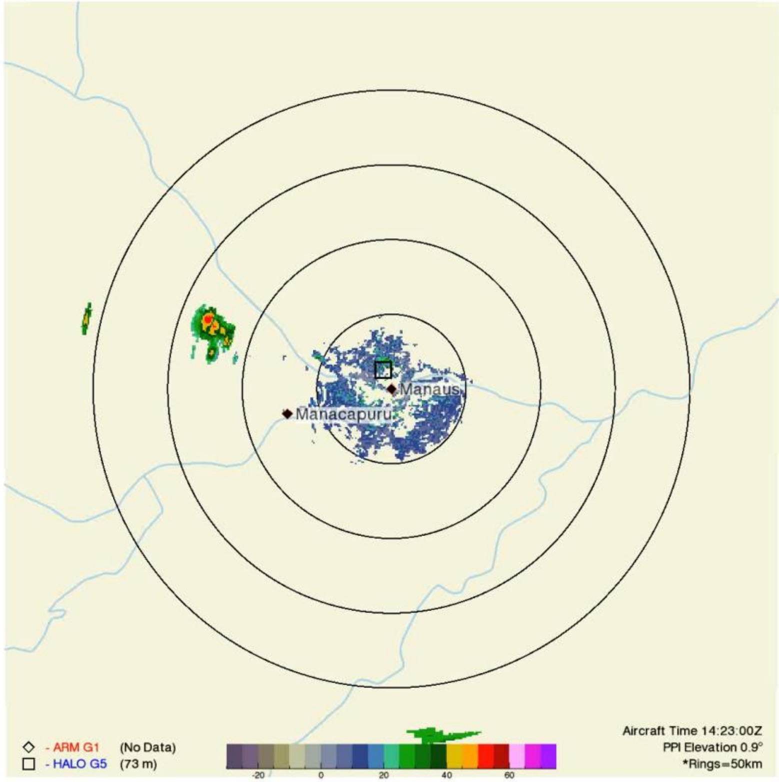
Daniel Rosenfeld, *et al. Science* **321**, 1309 (2008)

Aerosol-Cloud-Precipitation Interaction in Amazon

Luiz.Machado@inpe.br

Outline

- Convective Clouds and Aerosol feedbacks
- Manaus pollution plume in the warm rain formation
- Convective Invigoration what is new?
- Sensitivity of the updraft and aerosol concentration in the cloud processes
- Aerosol –Cloud-Precipitation Interaction in the Gamma Space
- A new microphysical parameterization perspective .



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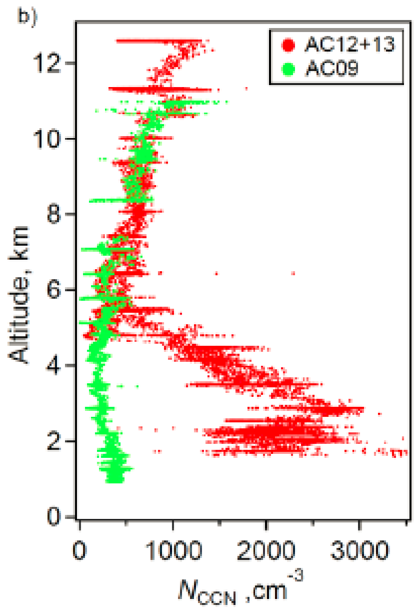
SOS CHUVA

ACRIDICON - CHUVA
Manaus 2014

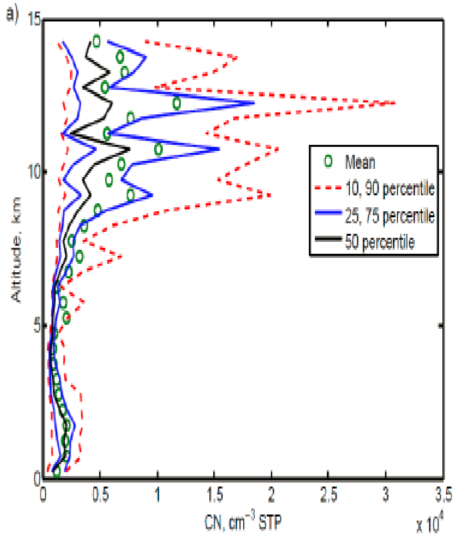
CPTEC

Convective Clouds and Aerosol feedbacks



The air in the immediate outflow of deep convective clouds was depleted in aerosol particles, whereas strongly enhanced number concentrations of small particles (<90 nm diameter)

Figure 7: Vertical profiles of CN concentrations, N_{CN}; a) overall statistics from all flights, b) examples from individual profiles on flight AC07 (segment G) and AC09 (segments A1 and A2).

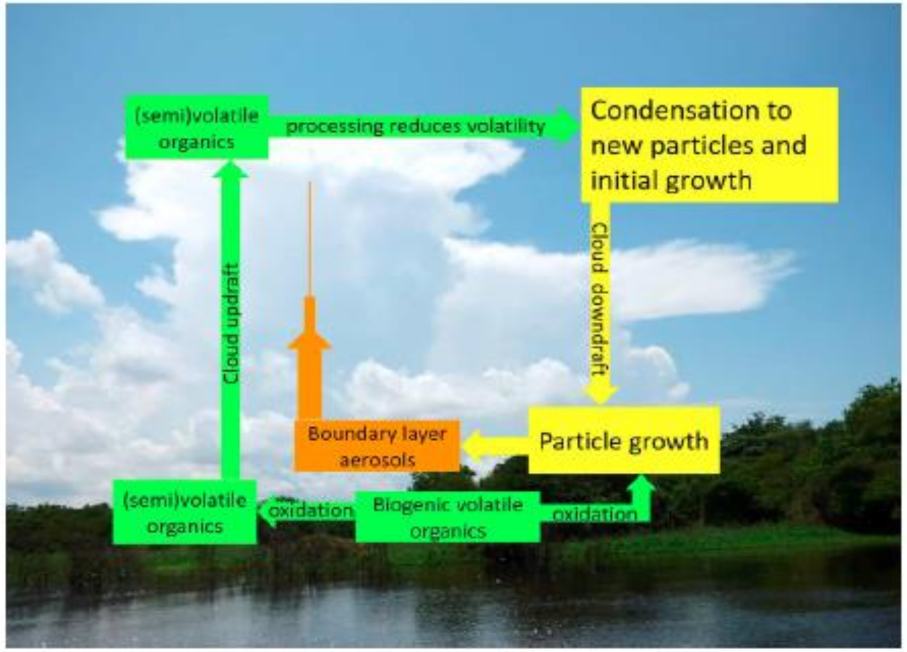


Aerosol characteristics and particle production in the upper troposphere over the Amazon Basin

Meinrat O. Andreae, Armin Afchine, Rachel Albrecht, Bruna Amorim Holanda, Paulo Artaxo, Henrique M. J. Barbosa, Stephan Borrmann, Micael A. Cecchini, Anja Costa, Maximilian Dollner, Daniel Fütterer, Emma Järvinen, Tina Jurkat, Thomas Klimach, Tobias Konemann, Christoph Knote, Martina Krämer, Trismono Krisna, Luiz A. T. Machado, Stephan Mertes, Andreas Minikin, Christopher Pöhlker, Mira L. Pöhlker, Ulrich Pöschl, Daniel Rosenfel, Daniel Sauer, Hans Schlager, Martin Schnaiter, Johannes Schneider,Christiane Schulz, Antonio Spanu, Vicinius B. Sperling, Christine Voigt, Adrian Walser, Jian Wang, Bernadett Weinzier, Manfred Wendisch, and Helmut Ziereis.

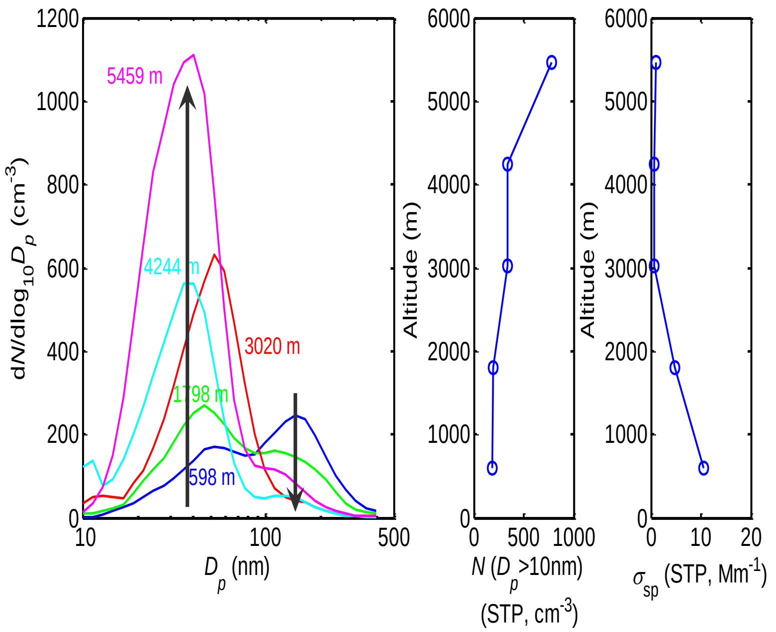
Atmos. Chem. Phys. Discuss., https://doi.org/10.5194/acp-2017-694

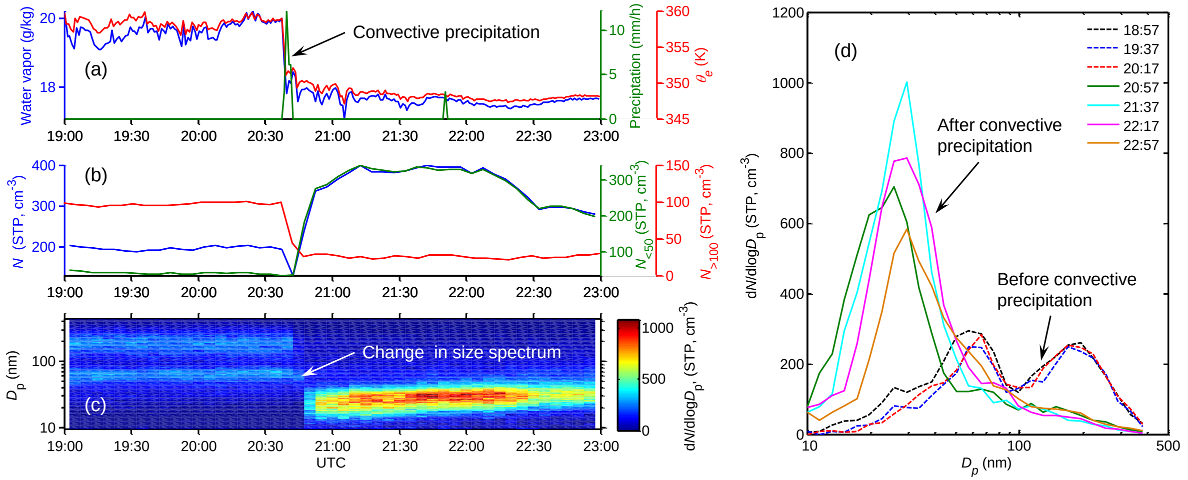
Figure 24: Conceptual model of the aerosol life cycle over the Amazon Basin



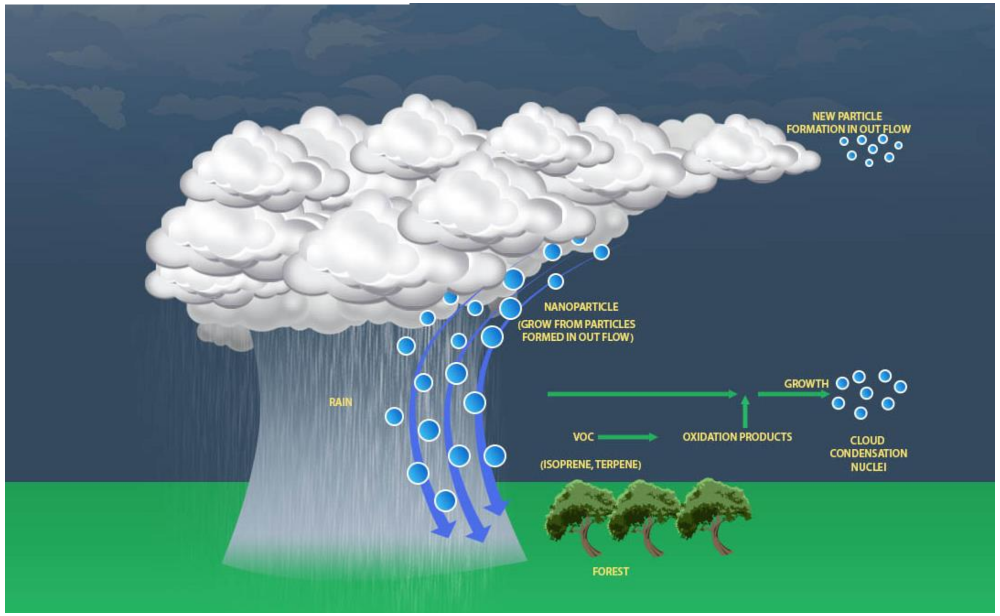
Conceptual model, where production of new aerosol particles takes place in the UT from **biogenic volatile organic material brought up by deep convection**, which is converted to condensable species in the UT. Subsequently, downward mixing and transport of upper tropospheric aerosol can be a source of particles to the PBL, where they increase in size by the condensation of biogenic volatile organic carbon (BVOC) oxidation products

Convective Clouds and Aerosol feedbacks



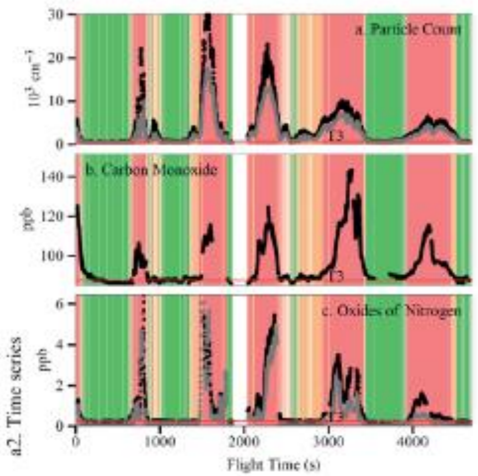


Deep convections sustain aerosol concentration in Amazon atmosphere
by *Jian Wang, Radovan Krejci, Scott Giangrande, Chongai Kuang, Hanna E. Manninen, Henrique M. J. Barbosa, Joel Brito, Jennifer Comstock, Mira Krüger, Jost Lavric, Karla Longo, Antonio O. Manzi, Fan Mei, Christopher Pöhlker, Beat Schmid, Rodrigo A. F. Souza, Steven Springston, Jason Tomlinson, David Walter, Daniela Wimmer, Jim Smith, Markku Kulmala, Luiz A. T. Machado, Paulo Artaxo, Meinrat Andreae, Scot Martin, Tuukka Petaja* – ***Nature* 2016**



INPE GOAMAZON PROJETO CHUVA SOS CHUVA ACRIDICON - CHUVA Manaus 2014 CPTEC

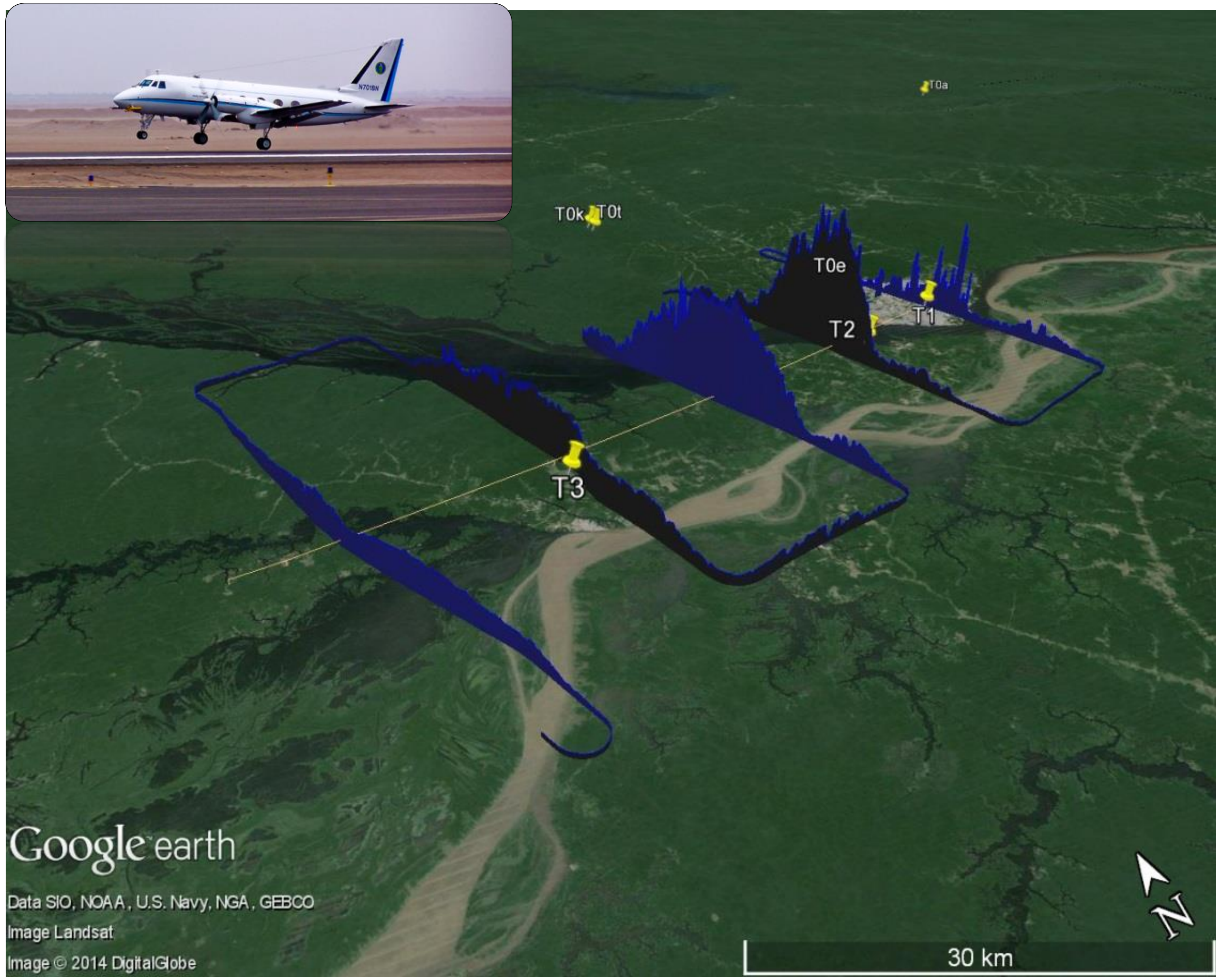
Manaus pollution plume in the warm rain formation



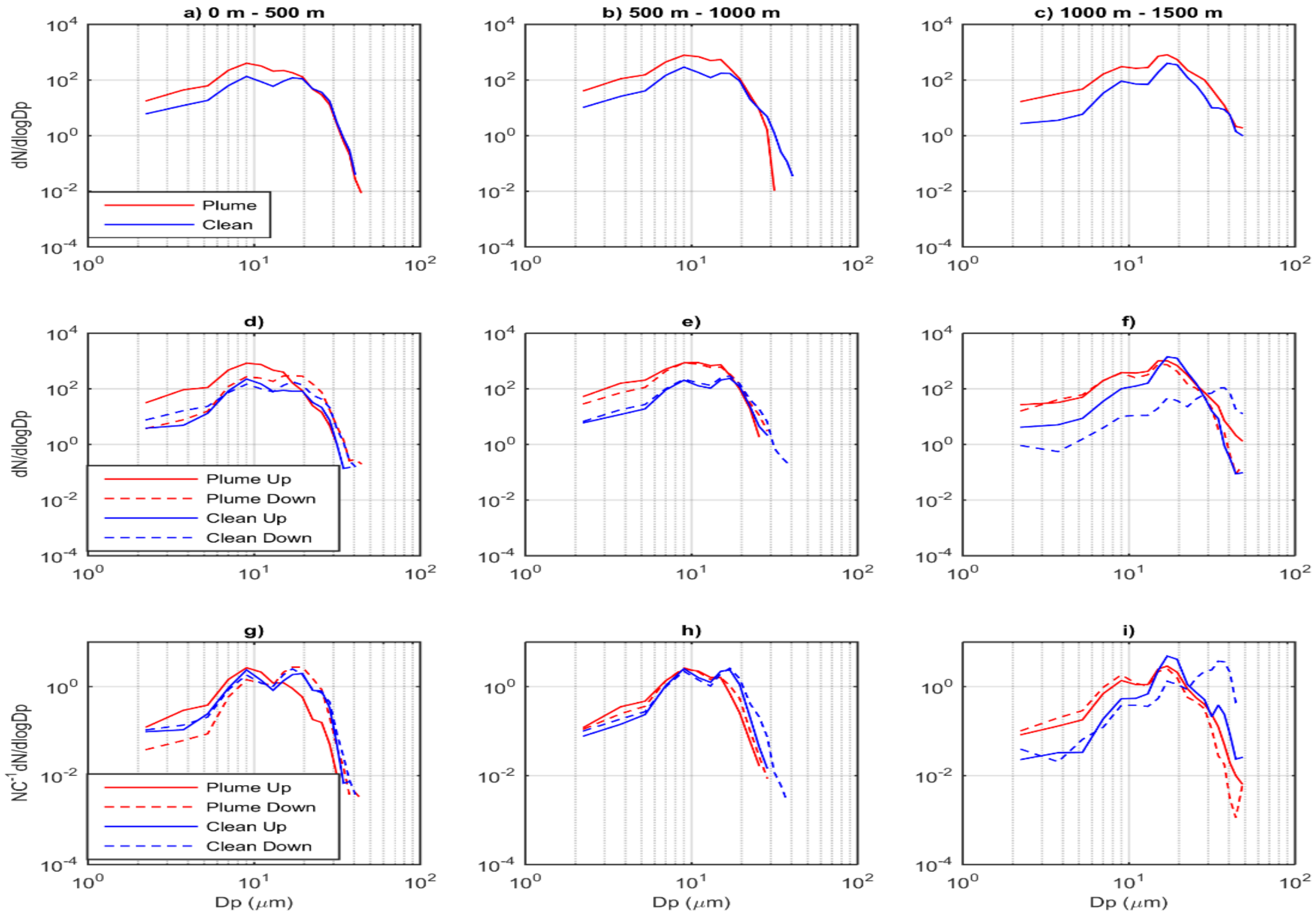
Martin, S. T and Coauthors: **The Green Ocean Amazon Experiment (GoAmazon2014/5) Observes Pollution Affecting Gases, Aerosols, Clouds, and Rainfall over the Rain Forest**, Bull. Am. Meteorol. Soc., 98, 981-997, doi:10.1175/BAMS-D-15-00221.1, 2017

Transverse Transects of Urban Plume

500 m
11 AM local
13 March 2014



Manaus pollution plume in the warm rain formation

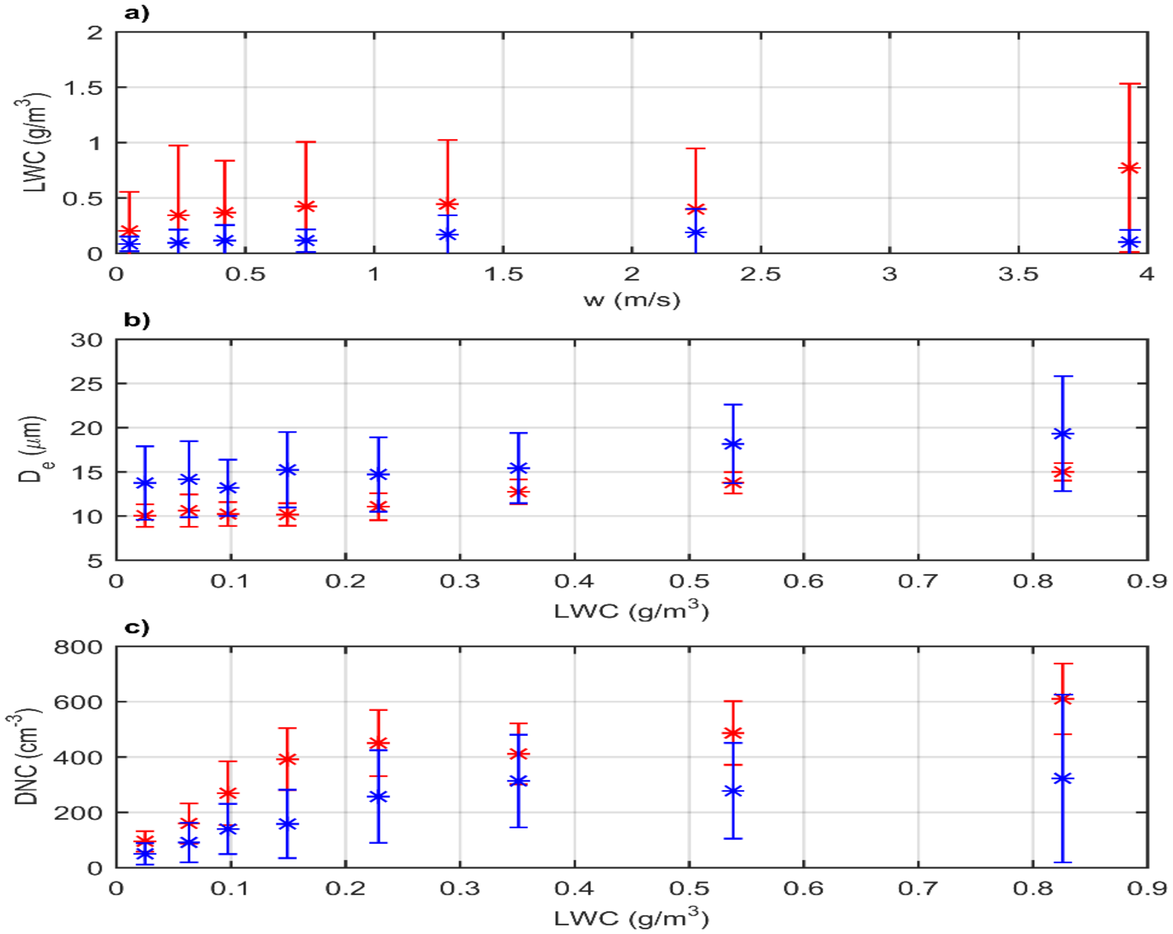


Mean DSDs for plume (red) or clean (blue) conditions as a function of altitude. Graphs a)-c) shows the mean DSDs in absolute number concentrations (cm^{-3}). d)-f) shows the mean DSDs for up- (w>1.5 m/s) and downdraft (w<-1.5 m/s) regions in cm^{-3}, while g)-i) show the NC-normalized ones.

Manaus' pollution plume impacts on cloud microphysical properties. Micael A. Cecchini[1], Luiz A.T. Machado[1], Jennifer M. Comstock[2], Fan Mei[2], John Schiling[2], Jian Wang[2], Jiwen Fan[2], Jason M. Tomlinson[2], Beat Schmid[2], Scot T. Martin[3]; Atmos. Chem. Phys. 2016

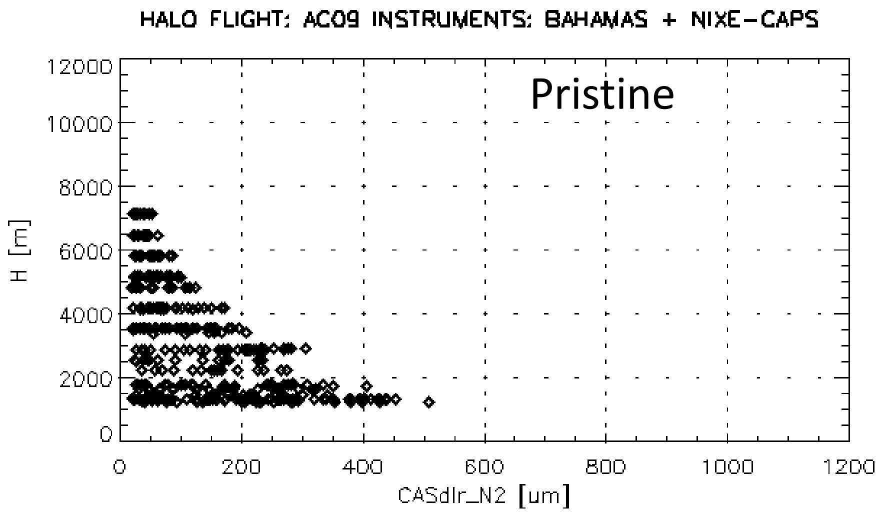
Manaus pollution plume in the warm rain formation

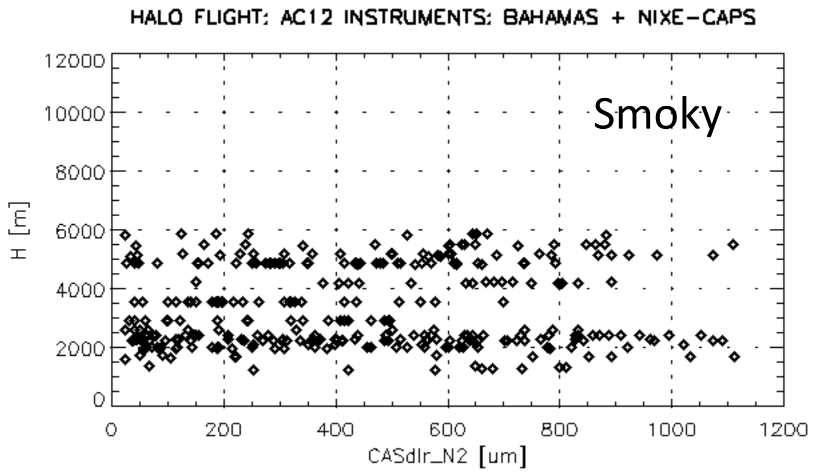
The wet season presents a clean background atmosphere characterized by frequent rain showers. The contrast between **background clouds** and those **affected by the Manaus pollution** can be observed and detailed. The **pollution-affected clouds** are found to have **smaller effective diameters and higher droplet number concentrations**. The differences range from **10 to 40 % for the effective diameter and are as high as 1000 % for droplet concentration** for the same vertical levels. The **growth rates of droplets with altitude are slower for pollution-affected clouds** This study shows that the pollution produced by Manaus significantly affects warm-phase microphysical properties of the surrounding clouds by changing the initial DSD formation.

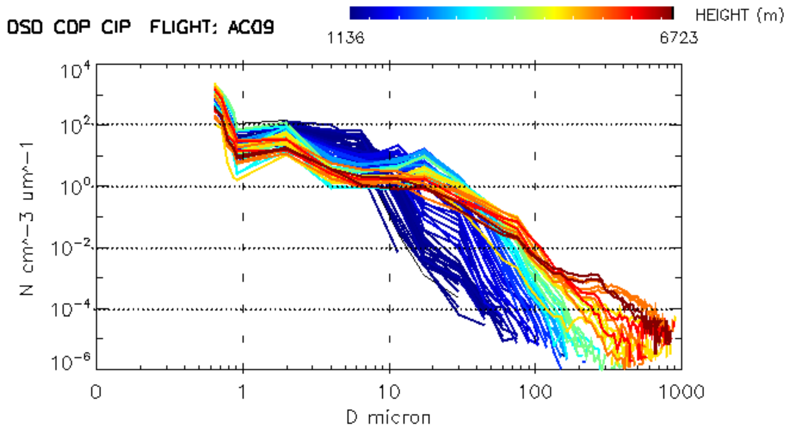


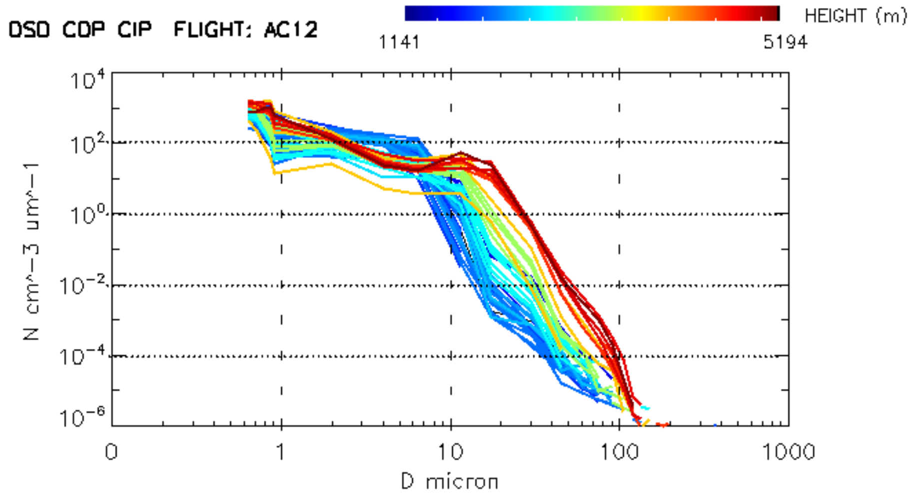
Manaus' pollution plume impacts on cloud microphysical properties. Micael A. Cecchini[1], Luiz A.T. Machado[1], Jennifer M. Comstock[2], Fan Mei[2], John Schiling[2], Jian Wang[2], Jiwen Fan[2], Jason M. Tomlinson[2], Beat Schmid[2], Scot T. Martin[3]; Atmos. Chem. Phys. 2016

Sensitivity of the updraft and aerosol concentration in the cloud processes









The ACRIDICON–CHUVA campaign to study tropical deep convective clouds and precipitation using the new German research aircraft HALO by Manfred Wendisch, Ulrich P¨oschl, Meinrat O. Andreae , Luiz A. T. Machado , Rachel Albrecht, Hans Schlager k, Daniel Rosenfeld et al. - Bulletin of American Met. Soc. 2016

Convective Invigoration what is new?

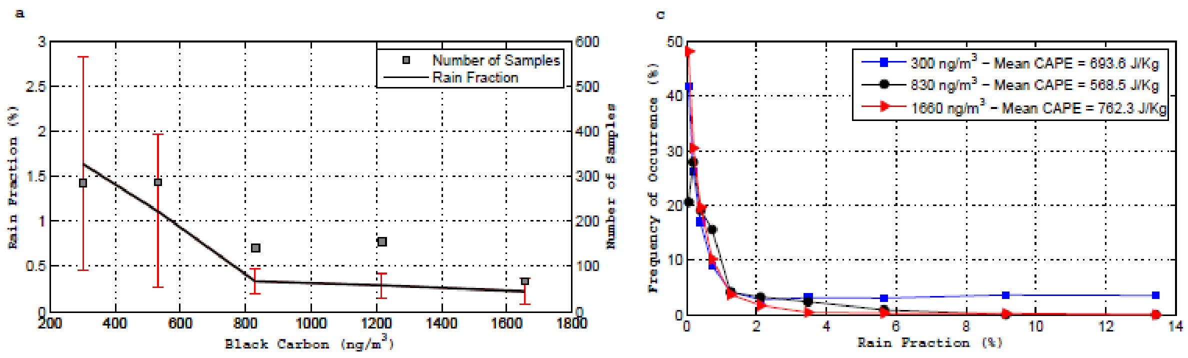


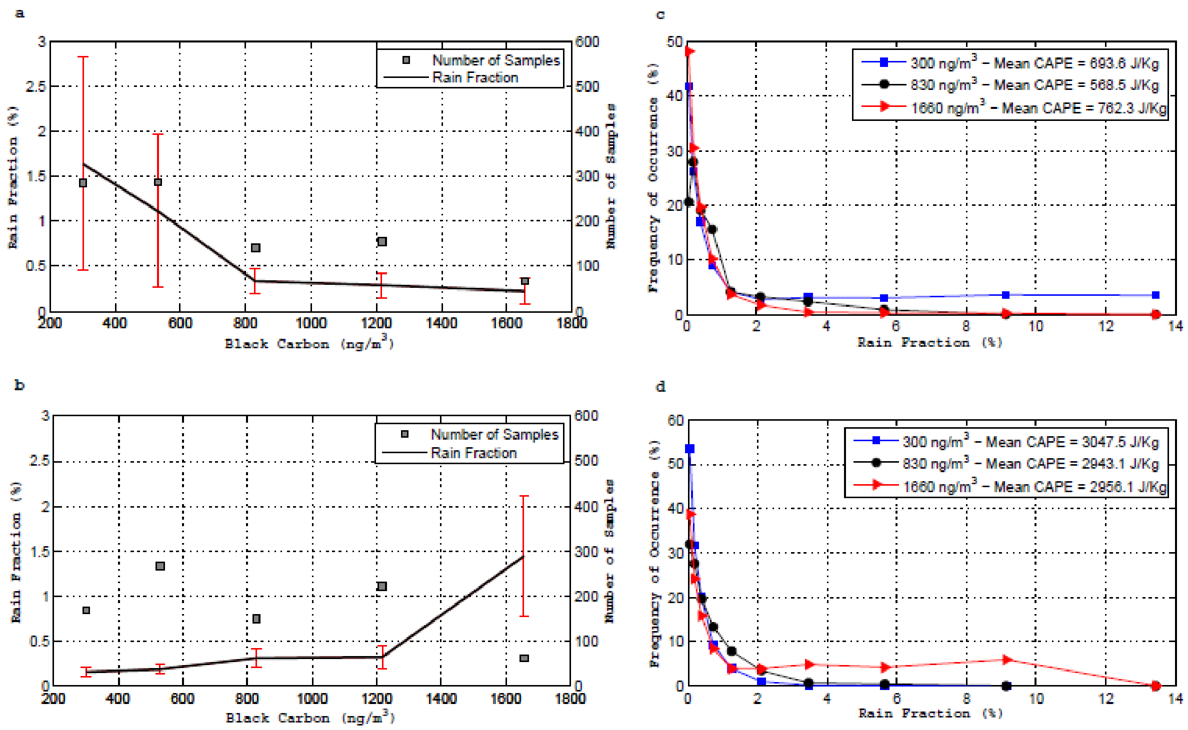
Figure 4. Mean, standard deviation, and number of samples of rain fraction (RF) for different black carbon (BC) concentrations for less unstable **(a)** and more unstable **(b)** atmospheres in the dry period. RF frequency histograms for the first, third, and fifth BC concentrations in **(a)** and **(b)**, are shown for less unstable **(c)** and more unstable **(d)** atmospheres. The first and third curves in **(c)** and **(d)** are significantly different as determined by a *t* test at the 95 % confidence level.

Gonçalves, W. A., Machado, L. A. T., and Kirstetter, P.-E.: Influence of biomass aerosol on precipitation over the Central Amazon: an observational study, Atmos. Chem. Phys., 15, 6789-6800, https://doi.org/10.5194/acp-15-6789-2015, 2015.

SOS CHUVA

ACRIDICON - CHUVA Manaus 2014

Convective Invigoration what is new?



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Convective Invigoration what is new?

Substantial Convecti
Enhance

Ultrafine Aer

Jiwen Fan[1*], Daniel Ros
Scott E. Giangrande[4], Zh
Machado[5], Scot T. Marti
Wang[4], Paulo Artaxo[8], H
Ramon C. Braga[9], Jenni
Feng[1], Wenhua Gao[1,10],
Mei[1], Christopher Pöhlk
Ulrich Pöschl[12], Rodrigo
Science 2018

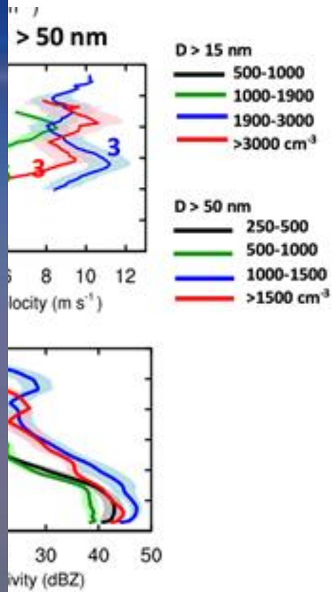
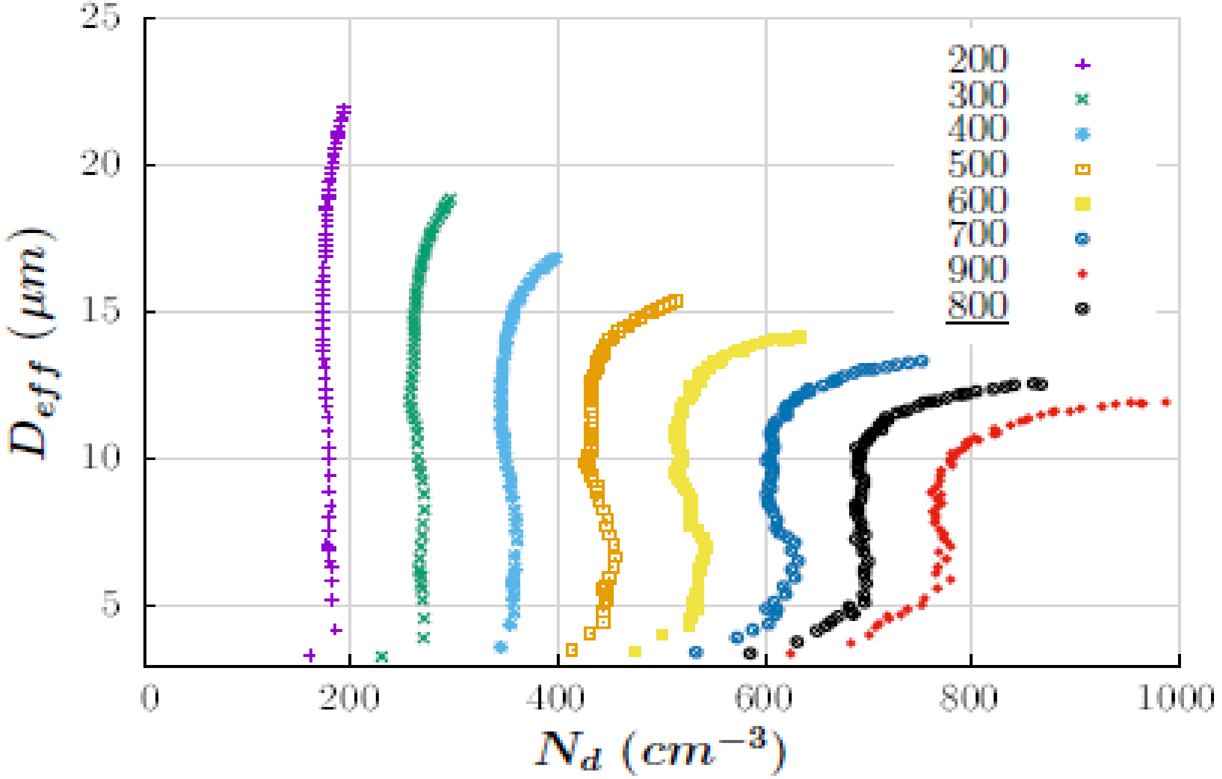


Illustration of the effect of ultra
drop coalescence that forms wa
cloud droplets are nucleated, w
convection. The additional con
increase in rate, but enhances p

Convective Invigoration what is new?

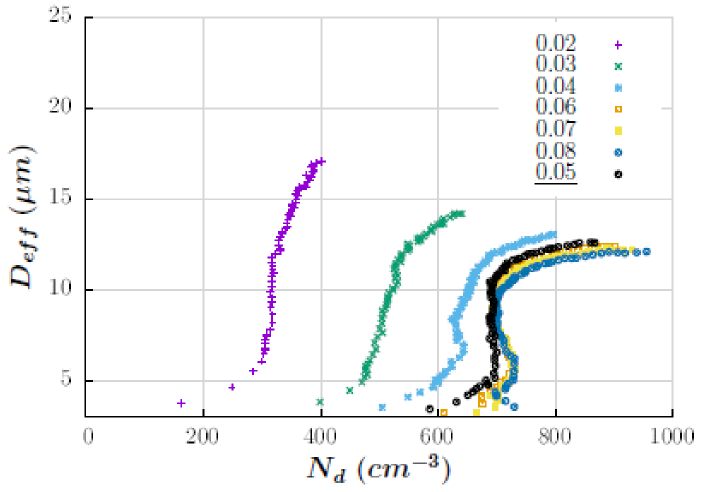
Aerosol → Concentration, Aerosol Size, Hygroscopicity, distribution width

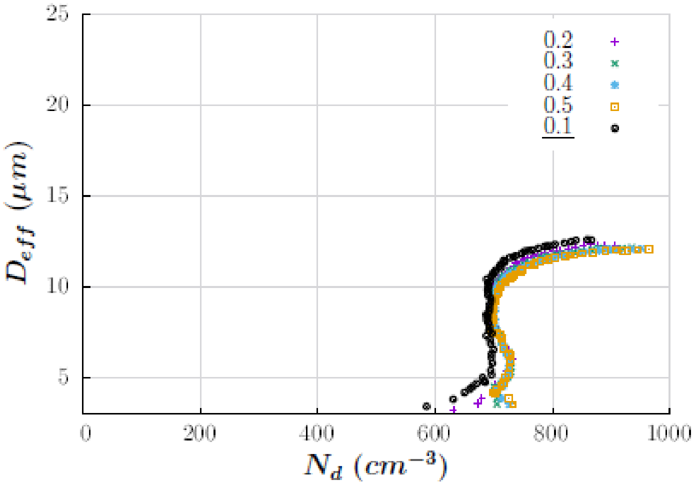


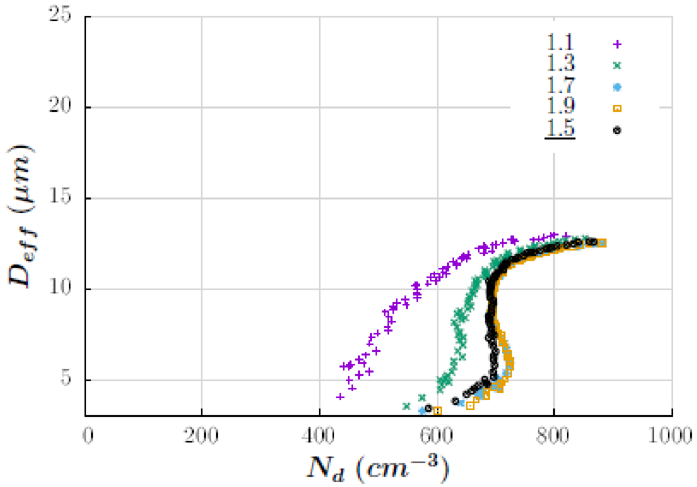
INPE GOAMAZON SOS CHUVA ACRIDICON - CHUVA Manaus 2014 CPTEC

Convective Invigoration what is new?

Aerosol → Concentration, Aerosol Size, Hygroscopicity, distribution width

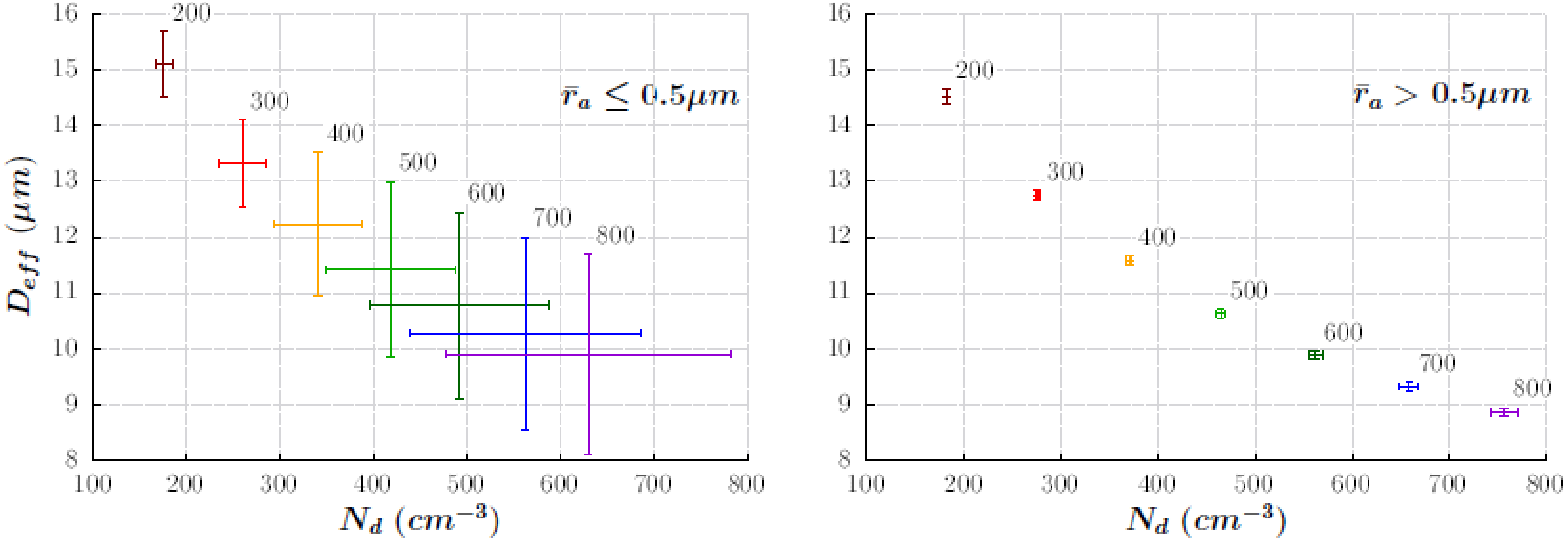






INPE GOAMAZON 2014-2015 SOS CHUVA ACRIDICON - CHUVA Manaus 2014 CPTEC

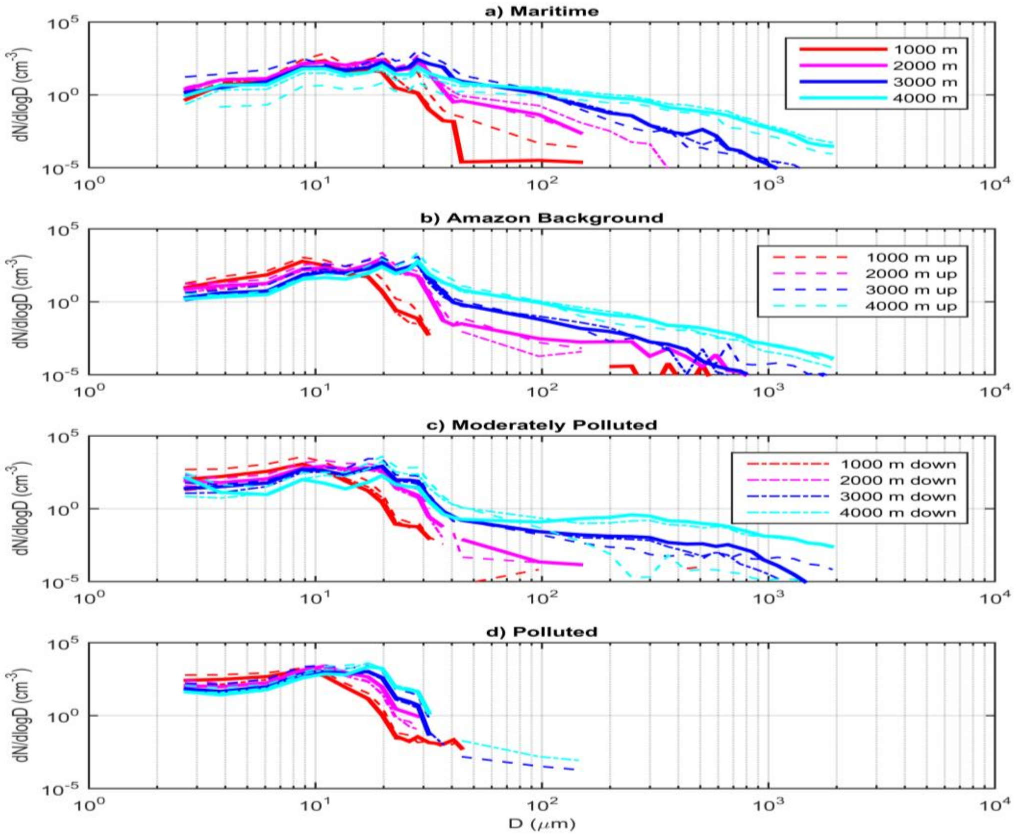
Convective Invigoration what is new?



Lianet H. Pardo[1], Luiz A. T. Machado[1], Micael A. Cecchini[1;2], Madeleine S. Gácita. Cloud Sensitivities to Aerosol Properties. In submission process to Geoph. Res. Let., 2018

Sensitivity of the updraft and aerosol concentration in the cloud processes

Particle concentration is the primary driver for the vertical profiles of effective diameter and droplet concentration in the warm phase of Amazonian convective clouds, while **updraft speeds have a modulating role in the total condensed water**. The DSD shape is crucial in understanding cloud sensitivities. The **aerosol effect on DSD shape was found to vary with altitude**, which can help models to better constrain the indirect aerosol effect on climate.



Droplet size distributions as function of altitude above cloud base, aerosol particle number concentration, and vertical wind speed, *W*. Four 1000-m-thick layers are considered in the vertical, where the legends in the graphs show the respective upper limit of each one. Solid lines represent averaged DSDs for $-1\ m\ s^{-1} \leq W \leq 1\ m\ s^{-1}$, i.e., for relatively neutral vertical movements. Dashed lines represent averaged DSDs for the updraft regions where $W > 1\ m\ s^{-1}$, and dot-dashed lines represent the downdrafts ($W < -1\ m\ s^{-1}$).

Cecchini, M. A., Machado, L. A. T., Andreae, M. O., Martin, S. T., Albrecht, R. I., Artaxo, P., Barbosa, H. M. J., Borrmann, S., Fütterer, D., Jurkat, T., Mahnke, C., Minikin, A., Molleker, S., Pöhlker, M. L., Pöschl, U., Rosenfeld, D., Voigt, C., Weinzierl, B., and Wendisch, M.: **Sensitivities of Amazonian clouds to aerosols and updraft speed**, Atmos. Chem. Phys., 17, 10037-10050, https://doi.org/10.5194/acp-17-10037-2017, 2017.

Sensitivity of the updraft and aerosol concentration in the cloud processes

$$S_{N_d}(N_a) = \left.\frac{\partial \ln N_d}{\partial \ln N_a}\right|_{w,H}, S_{N_d}(w) = \left.\frac{\partial \ln N_d}{\partial \ln w}\right|_{N_a,H}, S_{N_d}(H) = \left.\frac{\partial \ln N_d}{\partial \ln H}\right|_{w,N_a}$$

	$\overline{S_{N_d}}$	$\overline{S_{D_{eff}}}$
N_a	**0.84** ± 0.21	**-0.25** ± 0.074
	$R^2 = 0.91$	$R^2 = 0.89$
w	**0.43** ± 0.28	**0.028** ± 0.058
	$R^2 = 0.81$	$R^2 = 0.46$
H	**-0.13** ± 0.16	**0.28** ± 0.058
	$R^2 = 0.38$	$R^2 = 0.93$

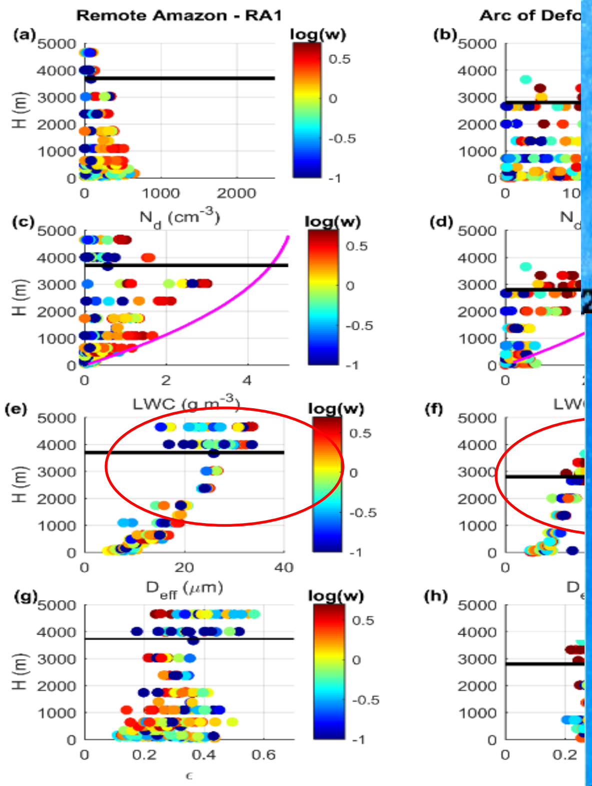
An increase of **100% in aerosol concentration** results in an **84% increase in droplet number concentration** and the **effective droplet diameter decreases 25%.**

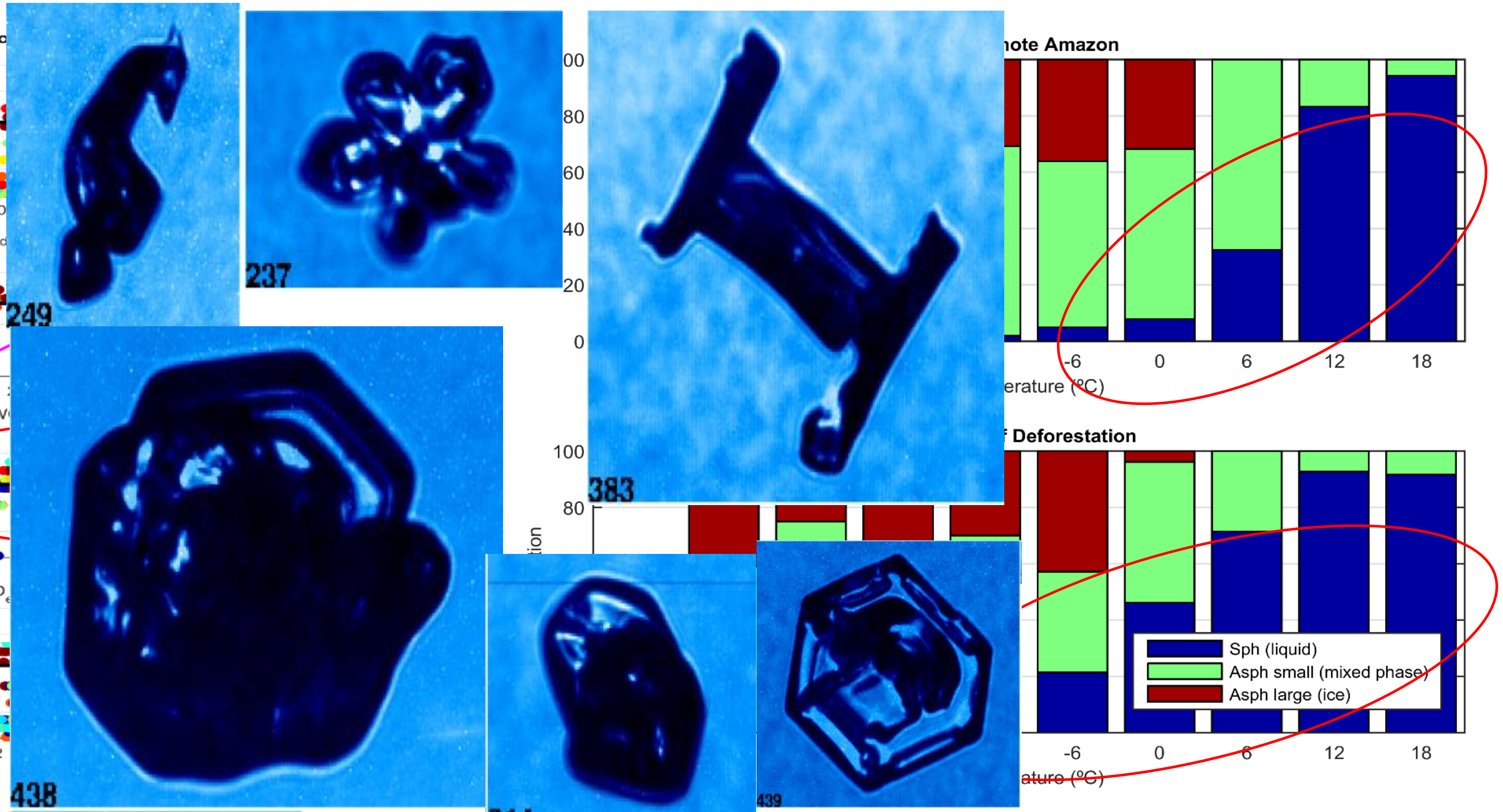
An increase of **100% in updraft wind speed** results in an **43% increase in droplet number concentration** and the **effective droplet diameter is** nearly unchanged

Aerosol concentration is the primary driver for DSD, whereas the updrafts mainly affect droplet number concentration and liquid water content.

Cecchini, M. A., Machado, L. A. T., Andreae, M. O., Martin, S. T., Albrecht, R. I., Artaxo, P., Barbosa, H. M. J., Borrmann, S., Fütterer, D., Jurkat, T., Mahnke, C., Minikin, A., Molleker, S., Pöhlker, M. L., Pöschl, U., Rosenfeld, D., Voigt, C., Weinzierl, B., and Wendisch, M.: **Sensitivities of Amazonian clouds to aerosols and updraft speed**, Atmos. Chem. Phys., 17, 10037-10050, https://doi.org/10.5194/acp-17-10037-2017, 2017.

Sensitivity of the updraft and aerosol concentration in the cloud processes





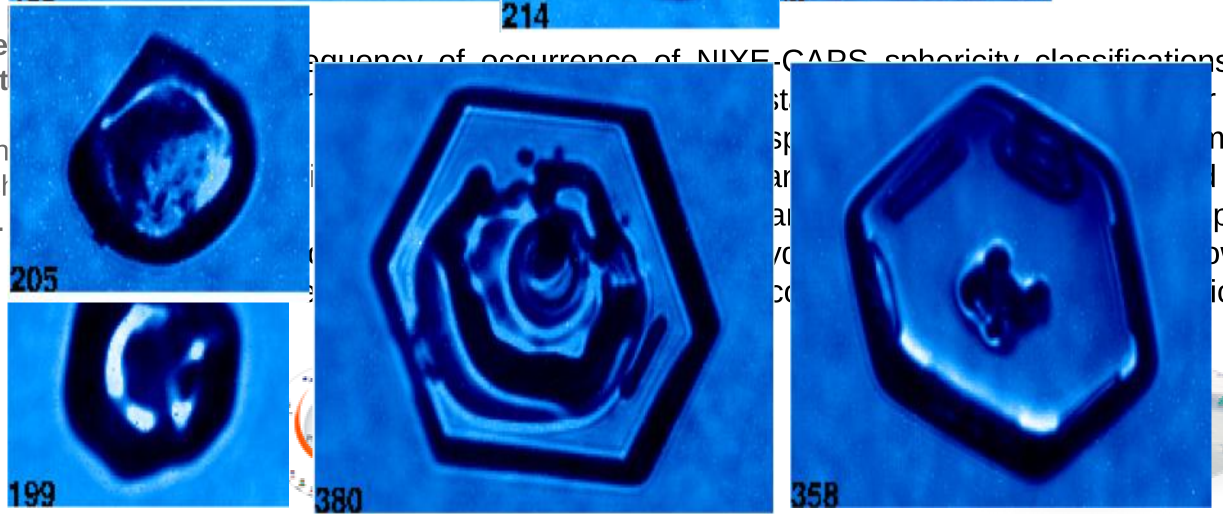
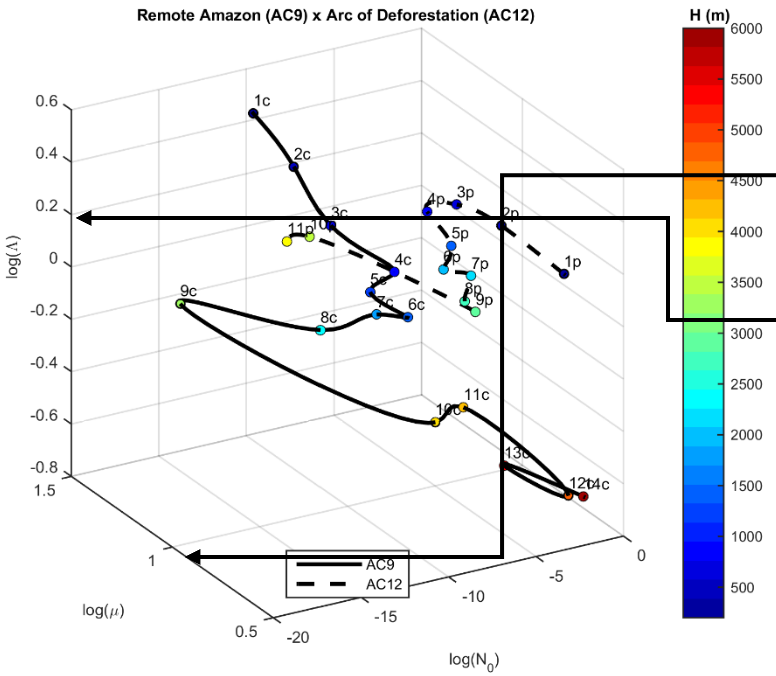


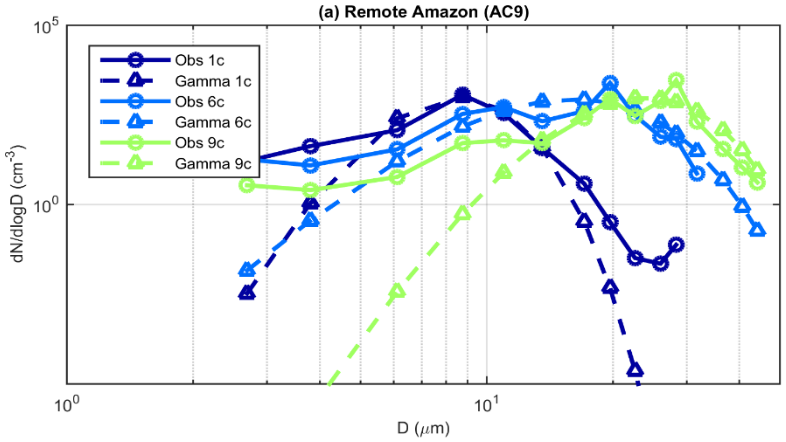
Illustration of microphysical processes in Amazonian de... convective clouds in the Gamma phase space: Introduct... and potential applications Cecchini, M. A., Machado, L. A. ... Wendisch, M., Costa, A., Krämer, M., Andreae, M. O., Afchin... Albrecht, R. I., Artaxo, P., Borrmann, S., Fütterer, D., Klimach... Mahnke, C., Martin, S. T., Minikin, A., Molleker, S., Pardo, L. ... Pöhlker, C., Pöhlker, M. L., Pöschl, U., Rosenfeld, D., and Weinzierl, B.:, Atmos. Chem. Phys. Discuss., https://doi.org/10.5194/acp-2017-185, in review, 2017.

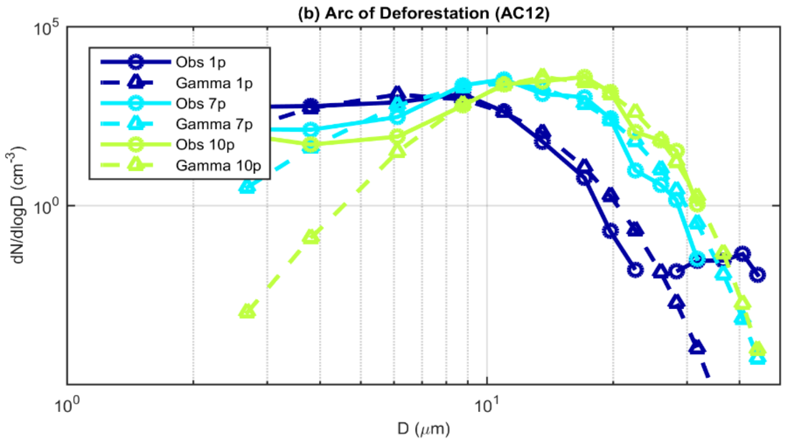
...equency of occurrence of NIXE-CAPS sphericity classifications for (a) the remote ... many only spherical ... meteors, “Asph small ... only aspherical (D > ... pherical (D < 50 µm) ... own on the x-axis are ... ick layers.

Aerosol –Cloud-Precipitation Interaction in the Gamma Space

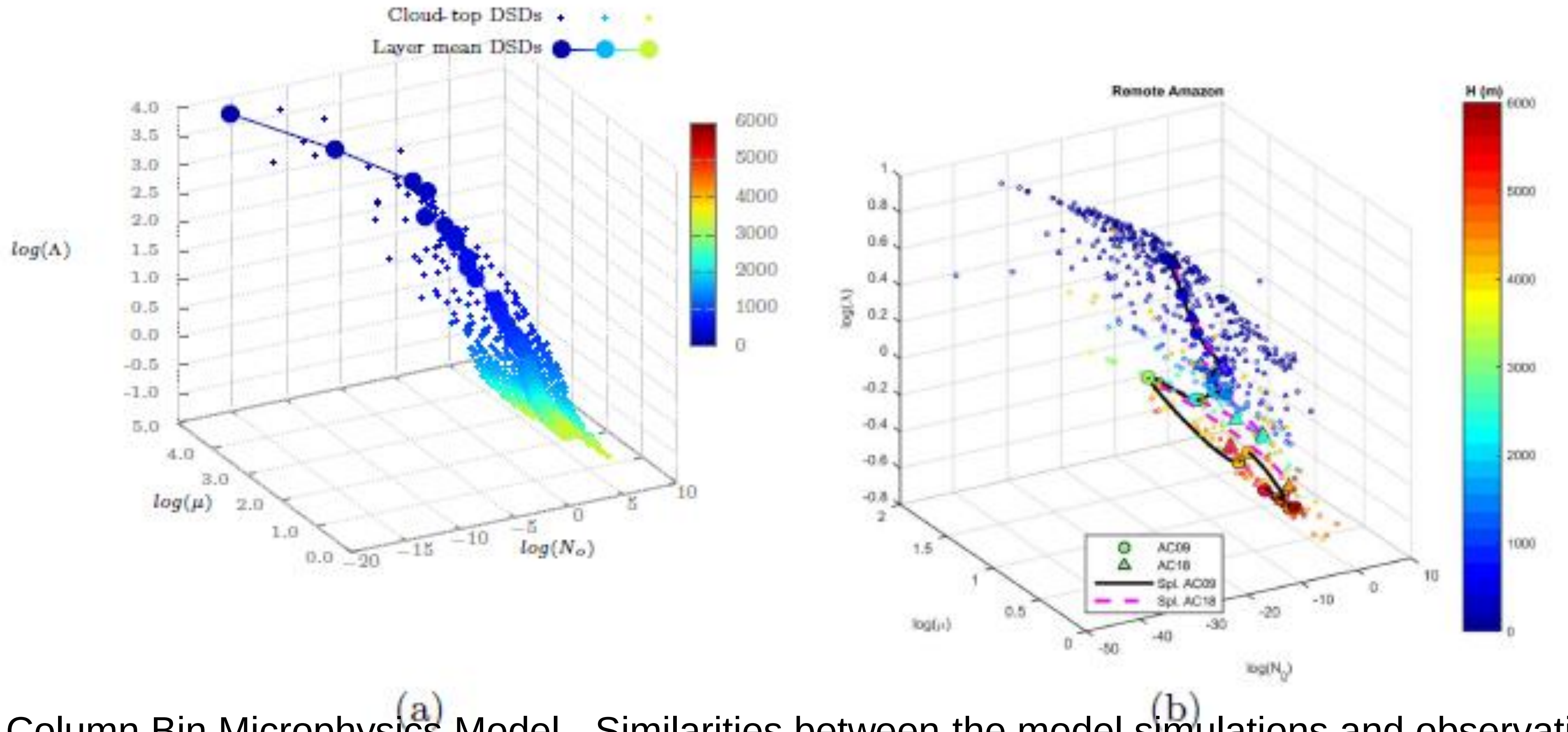


$$N(D) = N_0 D^{\mu} \exp(-\Lambda D)$$





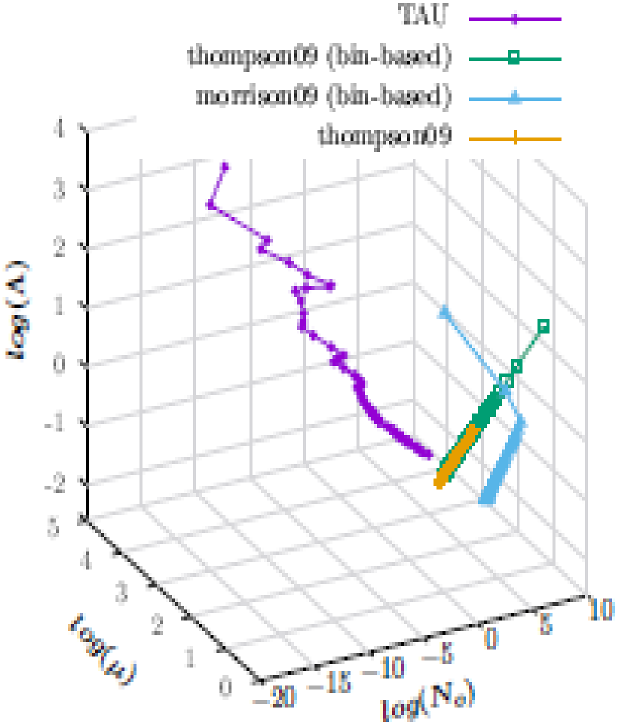
Aerosol –Cloud-Precipitation Interaction in the Gamma Space

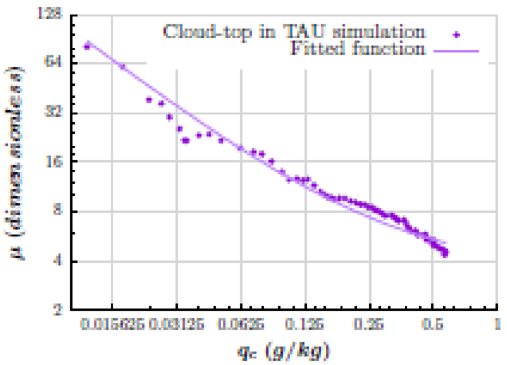


Column Bin Microphysics Model - Similarities between the model simulations and observations.

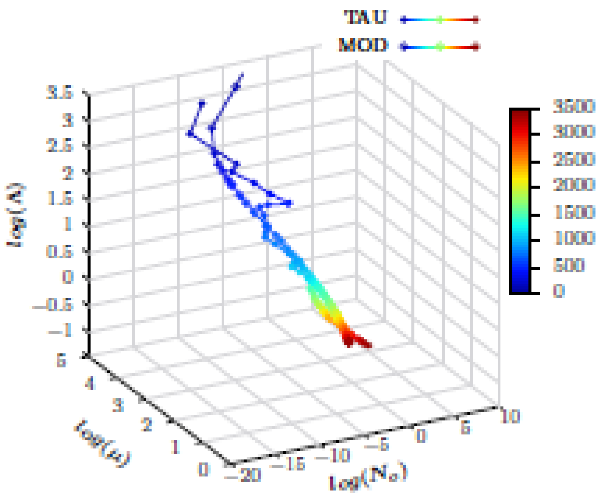
Figure 1:

Aerosol –Cloud-Precipitation Interaction in the Gamma Space





$$\mu(q_c) = \frac{1}{q_c} + \frac{1000}{N_d} + 2$$



Aerosol –Cloud-Precipitation Interaction in the Gamma Space

Conceptual drawing of the properties of the Gamma phase space in the warm layer of the clouds. The dotted gray line represents one trajectory through the phase space, representing the DSD evolution. P_1 is one DSD that grows by condensation and collision-coalescence to reach P_2. The displacement represented by the pseudo-force $\vec{F}$ is decomposed into two components - $\overrightarrow{F_{cd}}$ **(condensational pseudo-force) and** $\overrightarrow{F_{cl}}$ **(collisional pseudo-force).** Also shown are the two DSDs representative of points P_1 and P_2.

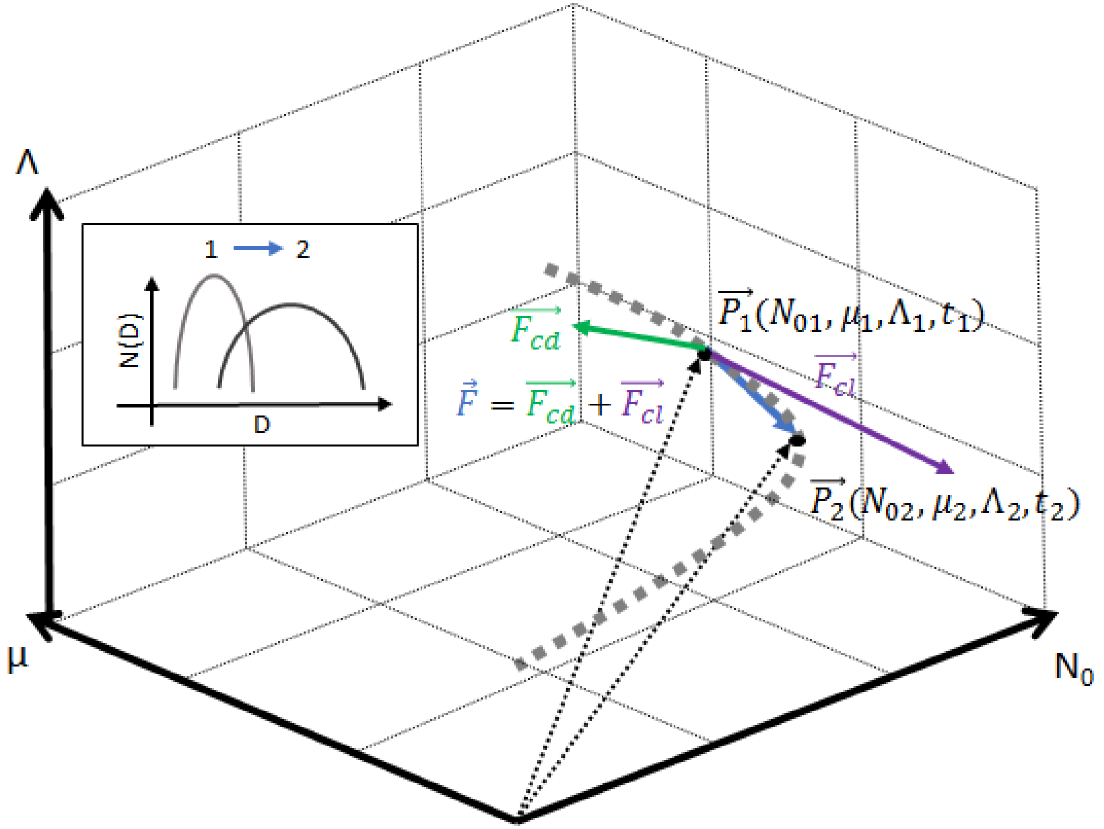
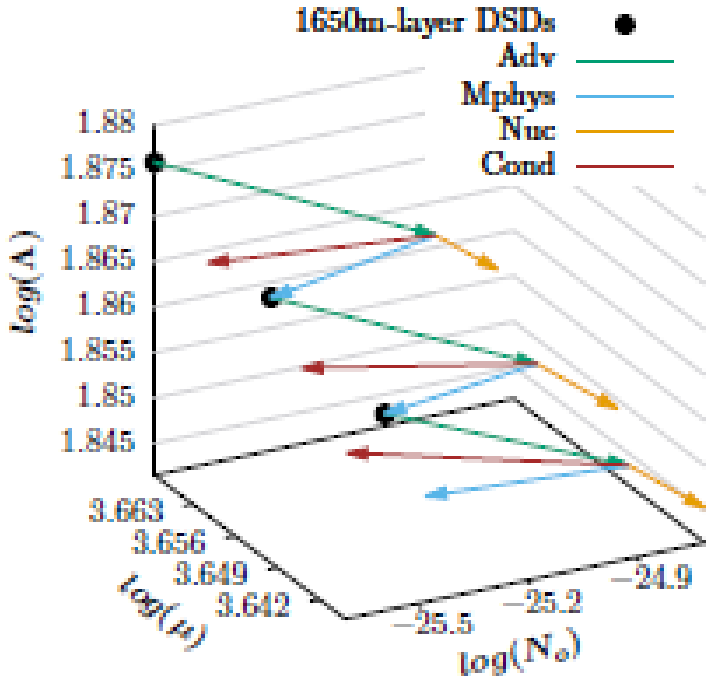
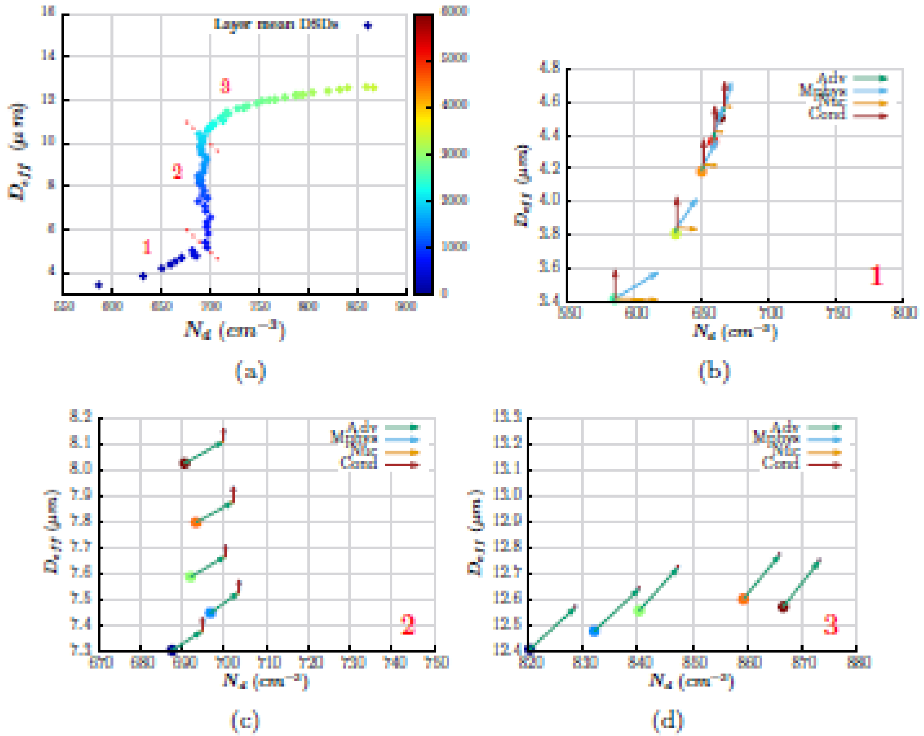


Illustration of microphysical processes in Amazonian deep convective clouds in the Gamma phase space: Introduction and potential applications Cecchini, M. A., Machado, L. A. T., Wendisch, M., Costa, A., Krämer, M., Andreae, M. O., Afchine, A., Albrecht, R. I., Artaxo, P., Borrmann, S., Fütterer, D., Klimach, T., Mahnke, C., Martin, S. T., Minikin, A., Molleker, S., Pardo, L. H., Pöhlker, C., Pöhlker, M. L., Pöschl, U., Rosenfeld, D., and Weinzierl, B.:, Atmos. Chem. Phys. Discuss., https://doi.org/10.5194/acp-2017-185, in review, 2017.

Aerosol –Cloud-Precipitation Interaction in the Gamma Space





Cloud-top microphysics evolution in the Gamma phase-space from a modelling perspective. Lianet Hernández Pardo, Luiz Augusto Toledo Machado, and Micael Amore Cecchini. In submisson process to Atmos. Chem, and Physc., 2018

Novos Experimentos


IN DEPTH

The 325-meter-high Amazon Tall Tower Observatory, a stairway to heavenly air.

ATMOSPHERIC PHYSICS

A pristine Amazon's last stand

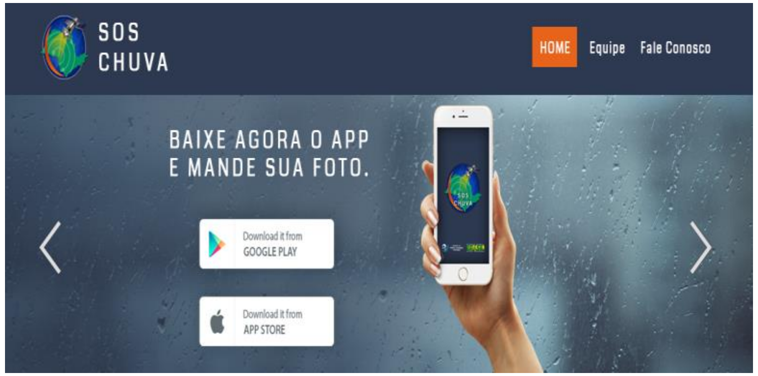
Laboratory in the sky will sample some of the last unspoiled air on the planet

By Lizzie Wade

allow scientists to sample air as close to

enough to Manaus to get there and back in a single day. The chosen location is 150 kilometers northeast—and, vitally, upwind—of the city, allowing scientists to reach the site in about 6 hours by car and boat. For the most part, the only air that reaches the tower travels from the Atlantic Ocean over 1500 kilometers of undisturbed rainforest.

One feature that sets the Amazon's pristine air apart is a dearth of aerosols—the



RELAMPAGO: Remote sensing of Electrification,Lightning, And Meso-scale/micro-scale Processes with Adaptive Ground Observations (translates to lightning flash in Spanish)

CACTI: Cloud, Aerosol, and Complex Terrain Interactions

ATTO: Amazon Tall Tower Observatory

SOS CHUVA – Cloud Processes and Nowcasting

CAFÉ-BRASIL: New HALO Mission in Amazonas 2020

Summary

- better understand of the aerosol-cloud-precipitation interaction - upper troposphere high concentration of nano-particles
- The Effect of Manaus pollution plume on cloud formation
- The quantification of the sensitivities of the cloud droplet and number concentration with the aerosol and updraft.
- The use of Gamma Space in cloud microphysics.

Thank You