FUNGI SPORES AS ICE NUCLEI AND THEIR IMPACTS ON RAINFALL AMOUNT OVER SÃO PAULO CITY

Gonçalves, F. L.T.[1]; Martins, J. A.[2]; Silva Dias, M. A. F.[1,3], Cardoso, M.R.A.[4]
Bauer, H.[5]
[1]Dept. of Atmospheric Sciences, IAG/USP/Brazil
[2] Universidade Tecnológica Federal do Paraná, 86300-000, Cornélio Procópio, Paraná,
[3] Center for Weather Forecasting and Climate Studies – CPTEC/INPE – Cachoeira Paulista, 12630-000, SP, Brazil
[4]Faculty of Public Health, USP/Brazil.
[5] Institute for Analytical Chemistry, Vienna University of Technology, Vienna, Austria

Abstract

Airborne bacteria can act as cloud condensation nuclei and some airborne bacterial and fungal species are able to act as ice nuclei and therefore induce rainfall in moderate climates. Preliminary results show that São Paulo City area presents high number of atmospheric fungi, reaching values over 30,000 spores per cubic meter. São Paulo City presents an increase in number of thunderstorms during last few decades, which is associated primarily with the heat island. However, there are indications that air pollutants, such as Vanadium, may contribute to this storm enhancements through ice nuclei increase, releasing latent heat. Fungal spores could also play a role in that enhancement, as well, acting as ice nuclei. Numerical modeling may help the understanding of how ice nuclei affect rainfall amounts. Therefore, the impact of these high scores is under investigation, in order to evaluate their effect on cloud microphysics through numerical modeling, using, BRAMS, Brazilian version of RAMS. The first modeling results show that modified ice nuclei distribution can increase the maximum condensed water by a factor of 2%, comparing with normal distribution. However, the results also present smaller average concentration, indicating a non-linear effect on microphysics variables. That means an interesting impact on rainfall distribution which must be better investigation.

1. Introduction

Airborne microorganisms have been found in the atmosphere for the first time at the end of XIX century. Since then, many studies on airborne fungi have been carried out to investigate atmospheric concentrations and compositions and their impact on the environment which cloud physic processes are involved. Airborne bacteria can act as cloud condensation nuclei and some airborne bacterial and fungal species are able to act as ice nuclei and therefore induce rainfall in moderate climates.

Microbiology as well as atmosphere physicists have been shown that certain types of plant-associated bacteria and fungi, in the atmosphere, could be important to rainfall formation (Morris, C.E. et al. 2004; Bauer, H. et al. 2003; Szyrmer, W. and Zawadzki, I., 1997). The physicists came to this conclusion because these bacteria produce a protein on their outer membrane that is one of the most active of the naturally-occurring ice nuclei (compounds capable of catalyzing the freezing of water- Jaenicke, R. 2005), and because freezing of cloud water is a critical step for rainfall over major parts of the earth (Sattler, B. et al. 2002; Ariya

P.A. and Amyot M. 2004; Diehl, K. et al. 2000 and, Hamilton, W.D. and Lenton, T.M. 1998). These bacteria are widely distributed across the planet, multiply readily, survive airborne dissemination up to the clouds and fall out with precipitation. If these fungi and bacteria play a catalyzing role in the formation of precipitation, is under investigation toward applications as drought mitigation. Fungi as IN is reported in Pouler et al. (1992), where the species *Fusarium* can behave as IN around -1.0^{o}C and -2.5^{o}C.

To understand the ice nuclei formation processes could also give important insight into the role of other biological ice nuclei, such as pollen and fungi, in atmospheric processes.

Many of those cited authors agree that, in spite of its critical importance, research on this question has been on the back burner for several decades. The forum for the needed intersection of competence does not exist. For example, the impact of aerosol particles, in general, on clouds and climate is a poorly quantified forcing process (Morris, C.E. et al., 2004). The global climate models are presently being improved to ingest such details and predict the impacts on clouds and precipitation. Furthermore, the impact of biological particles on clouds extends beyond potentially affecting precipitation alone. Impacts on the phase of clouds and on precipitation feed into the global energy and water cycle. This alone is motivation for understanding the role of biological aerosols(Morris et al., 2007).

To understand how biological materials contribute to climate forcing will require knowledge of source and dispersal functions, dependence on meteorological conditions, differences among the types of bacteria produced in different areas, and implementing such knowledge into regional and global climate models that are presently being improved to ingest such details and predict the impacts on clouds and precipitation. Much of the groundwork being done for other aerosol types can be utilized for describing biological aerosol impacts. Furthermore, the impact of biological particles on clouds extends beyond potentially affecting precipitation alone. Impacts on the phase of clouds and on precipitation feed into the global energy and water cycle. This alone is motivation for understanding the role of biological aerosols (Hamilton, W.D., Lenton, T.M. 1998; Ariya P.A. and Amyot M. 2004 and Morris et al., 2007). Therefore, numerical modeling seems to play an important role in order to understanding these processes.

In this investigation, we used a high-resolution configuration of the Brazilian Regional Atmospheric Modeling System (BRAMS). The RAMS model utilizes the full set of non-hydrostatic, Reynolds-averaged primitive equations (Tripoli and Cotton, 1982). The model solution is advanced in time by using a hybrid time-stepping scheme in which the momentum and scalar fields are integrated using a second-order accurate leapfrog scheme and a forward scheme, respectively. The RAMS uses a terrain-following coordinate designated sigma-z in the vertical scheme, and numerous options are available for the boundary conditions, turbulence parameterization, radiation schemes, microphysical parameterizations and surface schemes. The present study addresses only cloud microphysical parameterization. For a more general discussion of the numerous options available in the model, readers are referred to Pielke et al. (1992) and Cotton et al. (2003). The Brazilian version of the model (BRAMS) is the result of changes incorporated by Brazilian users in recent years, which include a simple photochemical and a soil moisture scheme. Validation of the BRAMS for use in Amazon region simulations was presented by Freitas et al. (2007).

2. Methodology

The methodology is divided in 2.1 Input data; 2.2 Fungi concentration calculus and 2.3 Numerical modeling through BRAMS.

2.1 Input data

The data were obtained as it follows:

It was sampled *Coffea arabica* leaves from the trees, mature leaves. The leaves were cut and placed at agar-agar media with two kinds of medium: with meat for bacteria and with potato for fungi. The fungi, resulting from the media growing, were analyzed and some species were identified as it follows with *Penicillium sp*. the chosen species.

The fungi of spores from above species were submitted to freezing as it follows: 30 droplets of 20 µl with fungi spores and suspended bacteria were submitted to a lyophylizator and the frezzing point was observed for each droplet. Two tests were performed, totalizing around 60 droplets with 60 freezing points; b- A curve of droplet freezing distribution was calculated from each fungi and bacteria species and c) Salt and bi-distilled water tests were also performed in order to have a blank freezing point distribution. Salty droplets were saturated. The result is shown in Figure 1.

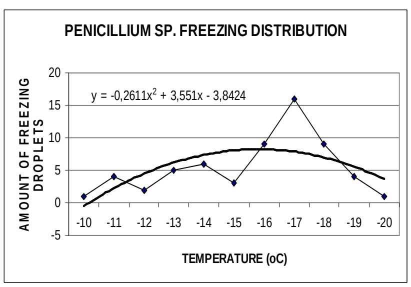

Figure 1. Freezing points of sterilized water with Penicillium sp. suspension.

2.2 Fungi spores air concentration

The air concentration of spores was developed according to Gonçalves et al. (2008). The samplings were performed indoors and outdoors of different homes scattered through the São Paulo City. The obtained concentrations were from 3000 spores per cubic meter up to 36000 spores. Around 10% were viable spores. Therefore, viable spores present an average of 300 spores per cubic meter.

These were the input data, freezing points as well as total concentrations, as ice nuclei to BRAMS, according to the following section.

2.3 RAMS modeling

The numerical simulations were developed in order to investigate the effect on the total amount of rainwater intergrated on column and raifnall amount as function of IN concentrations. Homogeneous initializations were performed and simulations carried for a time interval of 3 hrs. Heating and wetting at the central area were introduced after 10 minutes in order to develop a convective cell. The chosen radiosonde data is the day March 3 of 2003, typical summertime, at São Paulo City (43.66 long and -23.59 lat)

With the purpose of testing the sensitivity of microphysical parameters, the wet and hot bubble was activated without topography, wind and surface characteristics, emphasizing the cloud microphysical aspects.

The objective of the simulations is to analyze effect of the IN concentrations on the RAMS modeled cloud properties and precipitation. The model setup was:

- Horizontal grid spacing (x, y): 100 km $\times$ 100 km; Vertical grid spacing: 43 levels with variable stretching factor (70 m for the finest resolution in the lowest levels) and sponge upper boundary condition;
- Shape parameter 2 and CCN is set as 300 cm^{-3}
- ice nuclei concentrations are: IN-0 (default), IN-1 (305 cm^{-3}), IN-2 (3050 cm^{-3}) and IN-3 (30500 cm^{-3}).

[a1] Comentário: O espaçamento é esse mesmo??? Sera que não é 1km??

The simulation was a simple running with a moist and heat bubble based on Walko et al. (1995), using one single sounding as cited above and with no topography and wind.

2. Results

Preliminarly numerical modeling results are shown in Table 1, using BRAMS with different fungi concentrations as explained in Section 2.2.

Table 1 Total water integrated on column and rainfall amount at the surface using different IN concentrations.

	IN-0	IN-1	IN-2	IN-3
M_{cloud}	2.42	2.42	2.42	2.42
$M_{pristine}$	0.58	0.96	1.36	2.11
M_{snow}	0.57	0.10	0.00	0.00
$M_{aggregates}$	1.16	2.54	3.28	2.93
$M_{graupel}$	0.84	0.13	0.04	0.01
M_{hail}	9.19	11.76	11.66	11.65
M_{cond}	54.15	55.22	54.82	54.36
Av_{cond}	0.70	0.73	0.73	0.73
M_{pcp}	19.50	17.02	16.28	15.89
Av_{pcp}	0.42	0.35	0.33	0.32
Ice_{200mb}	4.51	6.36	6.53	6.47

M_{cloud} is maximum cloud water ($g.kg^{-1}$); $M_{pristine}$ is maximum pristine ice ($g.kg^{-1}$); M_{snow} is maximum snow crystals ($g.kg^{-1}$); $M_{aggregates}$ is maximum aggregates ice ($g.kg^{-1}$); $M_{graupel}$ is maximum graupel ($g.kg^{-1}$); M_{hail} is maximum hail ($g.kg^{-1}$); M_{cond} is maximum column integrated condensed water (mm); Av_{cond} is average column integrated condensed water (mm); M_{pcp} is maximum accumulated precipitation (mm); Av_{pcp} is average precipitation ($mm.grid^{-1}$); Ice_{200mb} is maximum ice at 200 mb level.

Table 1 shows modeling results with all kind of hydrometeors with differen secnario from no modification (IN-0) to IN concentration of 30500 cm^{-3} (IN-3). comparing with normal distribution.

The first modeling results show that modified ice nuclei distribution have a non-linear response in the average total rainfall and other microphysics variables, comparing with the normal distribution. The maximum condensed water, for example, presents the smallest amount at IN-0, increasing by a factor of 2% with IN-1 and decreasing with the other two forcing factors. However, they present values still higher than the IN-0 simulation.

On the other hand, Av_{pcp}, the average precipitation ($mm.grid^{-1}$) as well as M_{pcp} (maximum accumalated precipitation) present an steady decrease along the simulations, with the highest at IN-0 and the lowest at IN-3.

For their turn, ice parameters (aggregates, snow, pristine, graupel and hail) present each particular variability where pristine shows increasing values, according to the fungi spores concentrations (from IN-0 to IN-3). Aggregates present similar result. On the other hand, graupel and snow present the opposite behavior, probably because the higher temperature during freezing processes for these variables.

3. Conclusions

Therefore, previous works presents results where São Paulo City area shows high number of atmospheric fungi, reaching values over 30,000 spores per cubic meter. However, there are indications that air pollutants, such as Vanadium, may contribute to the ice nuclei formation, releasing latent heat and enhacing thunderstorms. Fungal spores could also play a role in that enhancement, as well, acting as ice nuclei around -10 and -15^{o}C , such as *Penicillium sp*. .As a possible consequence, São Paulo City presents an increase in number of thunderstorms during last few decades, which is associated primarily with the heat island, but it could be also indicated to the ice nuclei amount.

Anyway, it is quite clear that different patterns are presented when we change the IN concentrations based on fungi spores concentrations and freezing distributions. That means an interesting impact on rainfall and other variables which must be better investigation.

4. References

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