Contribution of fungi to primary biogenic aerosols in the atmosphere: Active discharge of spores, carbohydrates, and inorganic ions by Asco- and Basidiomycota

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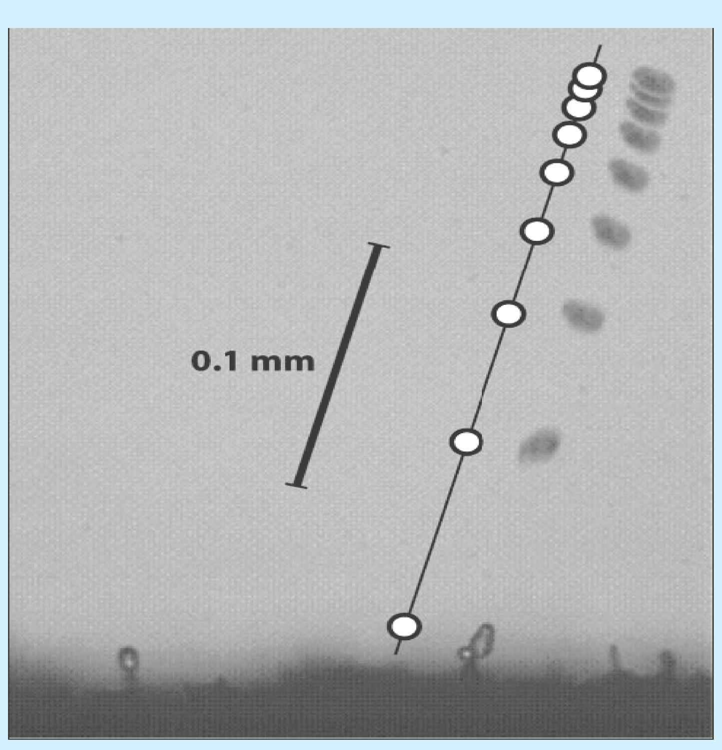
1. Motivation

Biogenic aerosols are ubiquitous in the Earth's atmosphere and they influence atmospheric chemistry and physics, the biosphere, climate, and public health. They play an important role in the spread of biological organisms and reproductive materials, and they can cause or enhance human, animal, and plant diseases. Moreover, they influence the Earth's energy budget by scattering and absorbing radiation, and they can initiate the formation of clouds and precipitation as cloud condensation nuclei (CNN) and ice nuclei (IN).

Primary biogenic aerosol (PBA) particles and components are emitted directly from the biosphere to the atmosphere. Examples of PBA particles are pollen, bacteria, fungal and fern spores, viruses, and fragments of animals and plants.

Fungi exist in terrestrial and aquatic habitats, and their reproduction proceeds via budding or sporulation, using a variety of dispersal mechanisms (Buller, 1909-1950; Ingold, 1971, 1999). Here we concentrate on those species of Ascomycota and Basidiomycota that actively discharge their spores into the air, which we designate as "actively spore-discharging Ascomycota" (AAM) and "actively spore-discharging Basidiomycota" (ABM).



Composite image of the flight of an *Auricularia auricula-judae* spore (Pringle *et al*., 2005)

Videos:

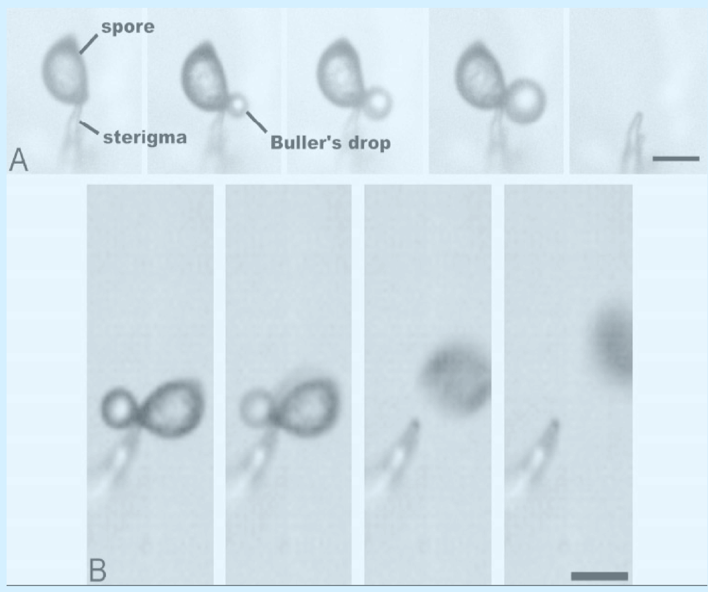
A) Ballistospores

http://www.mycologia.org/cgi/content/full/97/4/866/DC1

http://www.iwf.de/iwf/medien/infothek?Signatur=C+1993

B) Ascospores

http://www.iwf.de/iwf/medien/infothek?Signatur=C+1586



A. Mechanism of ballistospore discharge in *Itersonilia perplexans* (conventional still photomicroscopy). Suc-cessive images separated by 10 s show the growth of Buller's drop and disappearance of drop and spore from sterigma (bar 10 µm). B. Images of Buller's drop and the ballistospore using ultra high speed video. Images separated by 10 µs (bar 10 µm) (Pringle *et al*., 2005).

2. Atmospheric Contribution

Spores and related chemical compounds from AAM and ABM are primary biogenic components of air particulate matter (characteristic size range: 1–10 µm, characteristic boundary layer concentrations: ~10^3–10^4 m^{-3}). Measurement results and budget calculations based on investigations in Amazonia (Balbina, Brazil, July 2001) indicate that the forcible discharge of fungal spores may account for a large proportion of coarse air particulate matter in tropical rainforest regions during the wet season (0.7–2.3 µg m^{-3}). For the particle diameter range of 1–10 µm, the estimated proportions are ~ 25 % during day-time, ~ 45 % at night, and ~35 % on average (Figure 4).

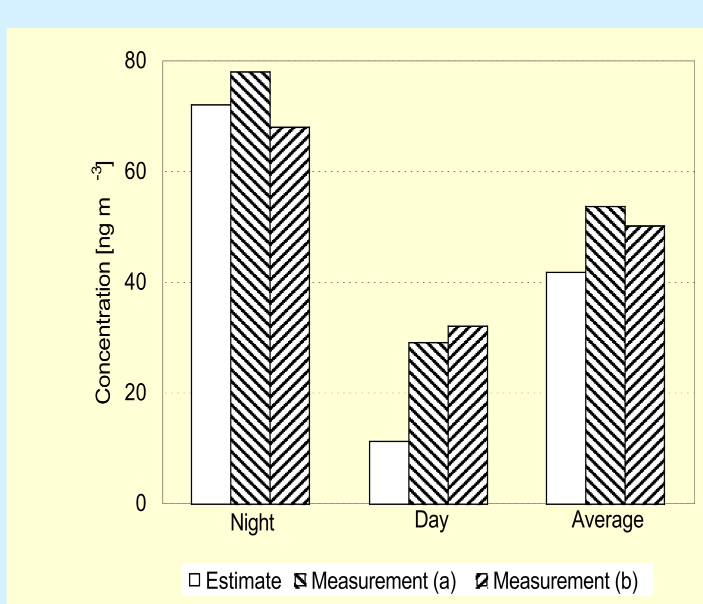


Figure 1. Mannitol concentrations in ambient air in Amazonia (Balbina, Brazil): estimate from spore counts (this study) compared to measurements of (a) Graham *et al.* (2003b) and (b) Claeys *et al.* (2004).

3. Chemical Compounds

ABM emissions may account for most of the atmospheric abundance of the sugar alcohol mannitol (10–68 ng m^{-3}), and can explain the observed diurnal cycle, i.e. higher abundance at night (Figure 1).

ABM emissions of hexose carbohydrates might also account for a significant proportion of glu-cose and fructose in air particulate matter (7–49 ng m^{-3}), but the literature-derived ratios are not consistent with the observed diurnal cycle, i.e. lower abundance at night (Figure 2).

AAM emissions appear to account for a large proportion of potassium in air particulate matter over tropical rainforest regions during the wet season (17–43 ng m^{-3}), and they can also explain the observed diurnal cycle, i.e. higher abundance at night (Figure 3).

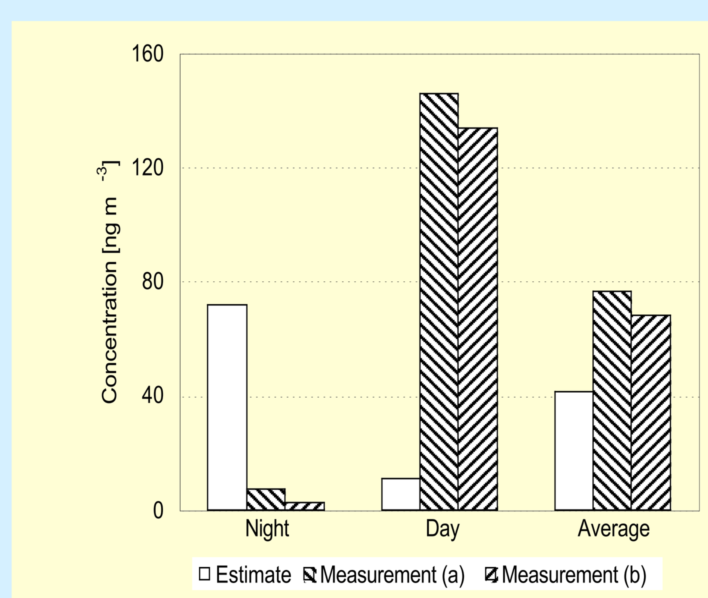
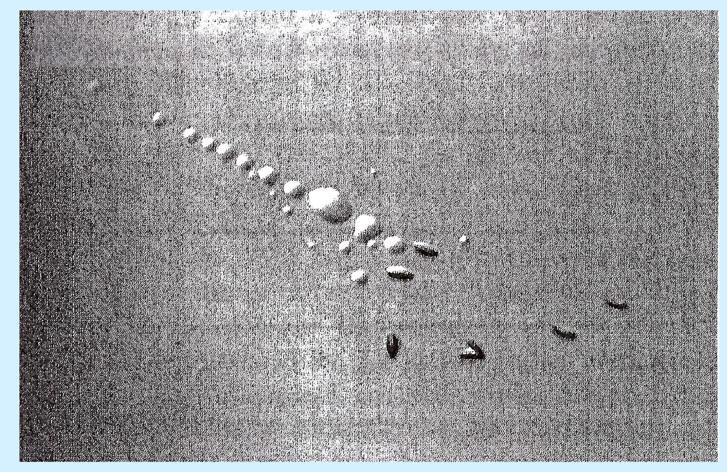


Figure 2. Hexose (glucose and fructose) concentrations in ambient air in Amazonia (Balbina, Brazil): estimate from spore counts (this study) compared to measurements of (a) Graham *et al.* (2003b) and (b) Claeys *et al.* (2004).

In vitro production of apothecia and ascospore dis-charge of *Sclerotinia sclerotiorum* (http://www.apsnet.org/education/InstructorCommunication/TeachingNotes/apothecia.html)



Ascospores and droplets exuded from a perithecium of *Gibberella zeae* (Trail *et al*., 2002)

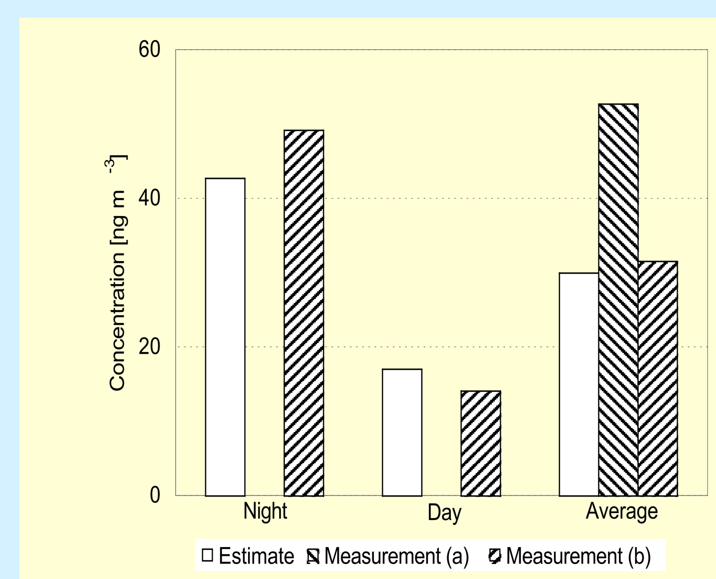


Figure 3. Potassium concentrations in ambient air in Amazonia: estimate from spore counts at Balbina (this study) compared to measurements at (a) Balbina (Graham *et al.* 2003a) and (b) FNS, Rondônia (Fuzzi *et al.* 2007).

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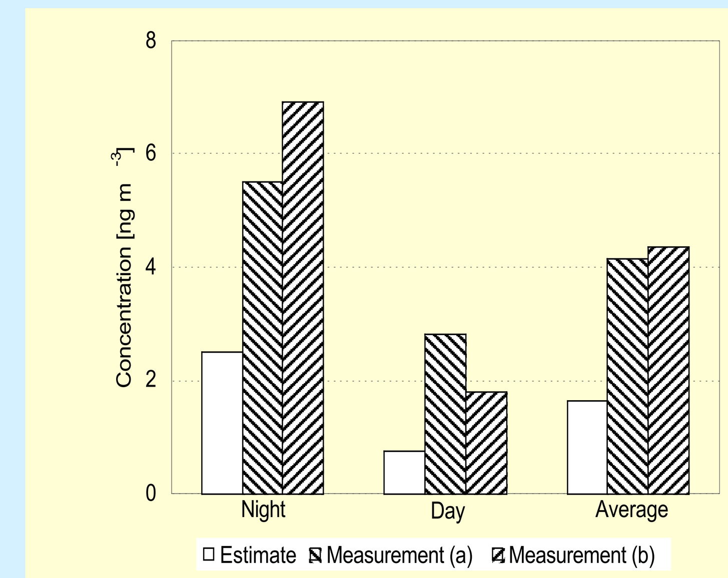

Figure 4. Aerosol mass concentration in ambient air in Amazonia: estimate from spore counts at Balbina (this study) compared to measurements at (a) Balbina (Graham *et al.* 2003a) and (b) FNS, Rondônia (Fuzzi *et al.* 2007).

4. Global Emission Estimates

Multiplication of the average number concentration of $5 \cdot 10^3$ m^{-3} with an average continental boundary layer (CBL) height of 1000 m and division by an average residence time of 1 day yields an estimate of ~ 60 m^{-2} s^{-1} for the globally averaged land surface emission flux of ABS.

By multiplication with an average spore mass of 65 pg, the global land surface area of $1.5 \cdot 10^{14}$ m^2 and the duration of one year we have calculated a value of ~ 17 Tg yr^{-1} as a first estimate for the global average emission rate of ABS over land surfaces. Comparisons with estimated rates of emission and formation of other major types of organic aerosol (~ 47 Tg yr^{-1} of anthropogenic primary organic aerosol; 12–70 Tg yr^{-1} of secondary organic aerosol) indicate that emissions from actively spore-discharging fungi should be taken into account as a significant source of organic aerosol.

Asci of *Sordaria* spp.

(http://www.mycolog.com/CHAP4b.htm)