A modelling study of the impact of bacteria on cloud development

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1. Introduction

The INSU-DFG bilateral BIOCLOUDS project aimed at investigating and quantifying the role of bioaerosols in tropospheric clouds, focussing in the studies on microorganisms, mainly bacteria. To reach our objectives, we:

1. isolated and identified ice nuclei active (INA) bacterial strains in cloud water sampled on the Puy de Dôme mountain station,
2. studied in more details ice nuclei (IN) and cloud condensation nuclei (CCN) properties of bacteria isolated from cloud water in the laboratory and in cloud chambers
3. used the new data as input to cloud models.

Two posters present the work, one on the experimental part and this one dedicated to the modelling studies.

2. The DESCAM Model

DESCAM (Detailed SCAvenging Model, Flossmann et al, 1985) is a detailed microphysics model with the specificity of following explicitly the evolution of the mass of the aerosol population (*Fig. 1a*). This allows to study separately background and bioaerosol.

In this study DESCAM is coupled with a 1D cylindrical dynamical model with lateral exchange (Asai and Kasahara, 1967, *Fig. 1b*).

The dynamics were initiated from the CCOPE experiment (Dye *et al*, 1986), a strong storm well studied since the 1990s, regularly used as reference case for convective model studies.

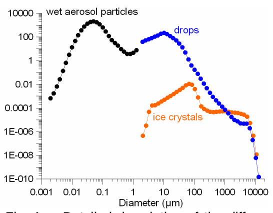

Fig. 1a : Detailed description of the different hydrometeor class in DESCAM (Planche *et al*,2010)

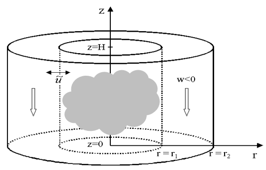

Fig. 1b: Schematic model configuration

3. Parameterization

The first measurement campaigns in the AIDA Chamber (IMK-AAF, FZK) showed that bacteria act as good cloud condensation nuclei, partly because of their size. Thus, they initiate ice acting as condensation freezing nuclei.

The ice nucleation activity was parameterized as following:

$$N_{bact,ice} = J_{bact} * N_{bact,tot}$$

To consider INA bacteria in the model, we used the IN properties measured for the most efficient bacterial strain (Andraud) and those measured by the ICCF (Joly et al, 2012), *Fig. 2a*, and we first assumed that they represent all of the bioaerosol population present.

We then used in another study results from the ICCF (Joly et al, 2013) to consider a realistic amount of INA bioaerosol (*Fig.2b*).

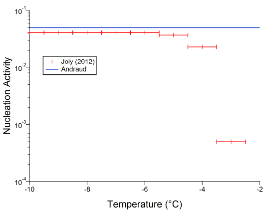

Fig. 2a : Ice Nucleation Activity of bacteria for the highest possible rate (Andraud) and as measured by Joly *et al*, 2012.

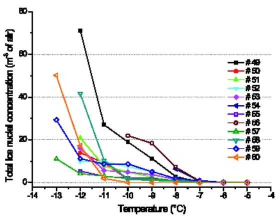

Fig. 2b : Concentration of INA bioaerosol at the Puy de Dôme as a function of temperature (taken from Joly et al, 2013)

4. Impact of INA bacteria

Based on the parameterizations, we performed sensitivity studies by varying the bacteria concentration in the troposphere.

We observed an optimum value in the precipitation amount for a concentration classified as high followed by a fast decrease. (*Fig. 3a*)

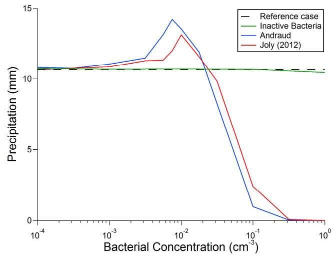

Fig. 3a : Evolution of the precipitation amount as a function of the INA bacteria concentration for the two different parameterizations of *Fig.2a*.

A recent study (Hiron et al., 2013) demonstrated that condensation freezing in general plays a very important role in the development of the cloud as it forms ice at warm temperatures, having therefore a major dynamical feedback, even though it forms only small amounts of ice.

The impact of the INA bacteria is due to their activity at these warm temperatures as can be seen in *Fig. 3b*.

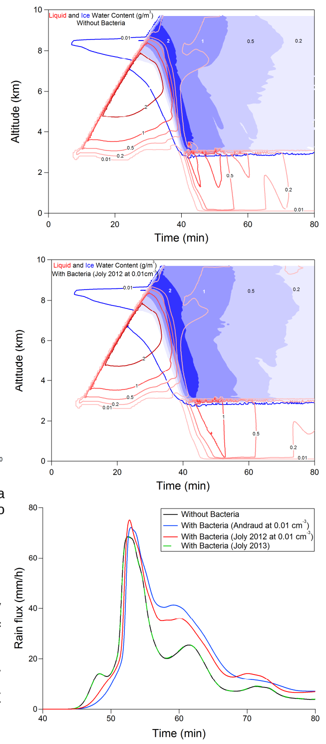

Fig. 3b : Liquid and ice water content in the atmospheric column as a function of time with (top) and without (middle) bacteria. Bottom graph gives the resulting rain flux on the ground.

5. Impact of INA bacteria in realistic concentrations

To improve the estimates on the impact of INA bacteria we also used the results from Joly et al. (2013) where the concentration of INA bacteria was directly measured as a function of temperature *(Fig.2b)*.

The impact on the then simulated cloud is quite small which is in agreement with the concentration estimations derived from the sensitivity study (over one order of magnitude below the optimum: ≈ 0.001 cm^{-3}).

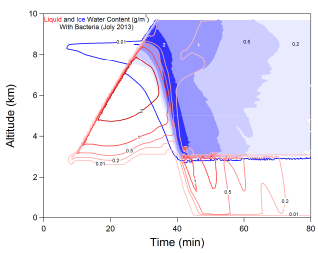

Fig. 4 : Liquid and ice water content in the atmospheric column as a function of time bacteria in a realistic concentration.

6. Conclusions and perspectives

INA bacteria can potentially have a large impact on the development of a storm if present in high concentrations although it seems that often their actual concentration is too low.

Further development of this study will need to consider a 3D dynamical framework and stratiform clouds where the time scales are longer.

Ref: Hiron, Th., M. Andraud, M. Monier and A. I. Flossmann, 2013: A study of the role of different modes of heterogeneous ice nucleation for the microphysics and precipitation of a convective cloud. To be submitted

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