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## ***Interactive comment on “Parameterizing the competition between homogeneous and heterogeneous freezing in ice cloud formation – polydisperse ice nuclei” by D. Barahona and A. Nenes***

**Anonymous Referee #1**

Received and published: 7 June 2009

This study presents a dynamical framework for ice cloud formation which accounts for homogeneous nucleation, heterogeneous nucleation (based on current empirical IN formulations available in the literature or on the classical nucleation theory CNT), and competition between the two mechanisms. While this study represents a step forward than their earlier studies (Barahona and Nenes, 2008; 2009) and also earlier work from theoretical point of view, I feel uncomfortable with the tones the authors uses to describe their work throughout their abstract and summary and conclusions, e.g., “any” size distribution and chemical composition; “any” form; “excellent” performance’;

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“extremely” fast”; addresses “all” the shortcomings of previous approaches. . .

The important part of their parameterization framework is the heterogeneous nucleation spectrum function. One source is based on the earlier works which were derived from the observations: Meyers et al (1992) and Phillips et al. (2008). Meyers et al.’s formulation was derived from surface measurements. Extrapolation to upper troposphere regime with lower temperature and lower aerosol concentrations has been shown to greatly overestimate IN concentrations; Although Phillips et al. formulation claims to be used in ice cloud regime ( $T < -35$  C), most data used to derive the formulation were obtained in several field campaigns in the mixed-phase cloud regime ( $T > -35$  C). Another source for the spectrum function used in this study is from the CNT. However, CNT approach is fraught with uncertainty because there are a number of unconstrained parameters (e.g., contact angle). The simplicity in this theory fails to explain the complex heterogeneous ice nucleation process. Marcolli et al. (2007) observed the quantitative agreement with measured heterogeneous immersion freezing temperatures by assuming a distribution of contact angle among the dust particles.

### Specific Comments

1. Page 9. Values for  $e_{f,j}$ ,  $sh_{,j}$ , and  $\theta_j$  used in this study (section 4.1, Table 1). . .

I don't see  $\theta_j$  in Table 1.

2. Page 11. Line 5 from bottom. Does  $s_0'$  (freezing threshold) here and also below have the same meaning as  $sh_{,j}$ ? if so, please use the same symbol.

3. Page 12. Equation (11). Is  $(s_i - s_0')$  a function of  $D_c$ , or it multiplies  $D_c$ ? The same is true in Equation (12).

4. Page 13. Equations (15), (16), and also below.

Should  $s$  be  $s_i$ ? Why do you change  $s$  in equation (15) to  $\Delta s$  in equation (16) and also in below?

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5. The title of section 3.2 is to determine  $s_{max}$ . Then how and where is  $s_{max}$  determined in section 3.2. by Equation (15)? I am not clear how you determine  $s_{max}$  there?

6. Page 19. Lines 2-3. Do you use Equation (34) together with nucleation spectrum  $N_{het}$  in Table 1 to determine  $s_{max}$ ?

7. Page 21. Equation (38) I don't know why you want to apply your equation (34) to  $T > 235$  K (mixed-phase cloud regime). In this regime, cloud microphysics and dynamics are more complicated than the ice nucleation under the dynamical framework in this study. Also what do you mean  $f_c < 0$ ? If there is only homogeneous nucleation it is  $f_c = 0$ .

8. Page 25. Comparison with existing schemes. As you note, LP parameterization used  $\alpha_d = 0.1$  and also assumed  $sh_{j,j}$  (threshold RHi)=1.2. Both of these will predict a higher ice number from heterogeneous nucleation and also limiting IN number and updraft velocity than that from this study which uses  $\alpha_d = 0.5$  and  $sh_{j,j}=1.3$ . Thus I would like the authors to present the sensitivity of their results to different  $\alpha_d$  and  $sh_{j,j}$ .

9. Why does  $s_{max}$  from LP exceeds  $sh_{om}$  when  $V > 0.2$  m/s in Figure 7?

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Interactive comment on Atmos. Chem. Phys. Discuss., 9, 10957, 2009.

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