Atmos. Chem. Phys. Discuss., 9, C5223–C5226, 2009
www.atmos-chem-phys-discuss.net/9/C5223/2009/

Atmospheric
Chemistry
and Physics
Discussions

Interactive comment on “Ice nucleation properties of mineral dust particles: Determination of onset RH_i, IN active fraction, nucleation time-lag, and the effect of active sites on contact angles” *by* G. Kulkarni and S. Dobbie

G. Kulkarni and S. Dobbie

Gourihar.Kulkarni@pnl.gov

Received and published: 25 September 2009

We also thank the anonymous referee 2 for providing constructive comments in improving the contents of this paper. Please read our comments as follows, and the corresponding changes are included in the revised manuscript.

Specific remarks:

All changes are incorporated in the revised manuscript.

Pg. 11309, line 25 remark: We agree with the referee that elemental composition might influence both onset of ice formation and activated fraction. However, we surmise that there might be a possibility of observing a special type of mineralogical compounds (formed when 2 or more elements are combined) over the dust surface and these surfaces only activates after exposure to longer time. In short these special dust particles require longer time to nucleate in comparison to other particles at similar temperature and RHi. Please note that we terminate the onset RHi experiments once we observe the first ice formation event, whereas during IN active fraction experiments we terminate the experiments when no further ice formation events are observed. Thus the exposure (or experimental) time for onset RHi is smaller compared to IN active fraction experiments. Currently we do not have any tools to understand these special types of mineralogical compounds that influence ice nucleation and formation, but in future time we would like to investigate these ideas and assumptions. We will modify the manuscript accordingly.

Pg. 11310, line 11 remark: We agree with the referee that time lag could be due to the equilibrium of particles to the respective temperature. To understand this time lag we performed simple heat transfer analysis. Here we calculated the time required for the particle (original at room temperature 20 deg C) to equilibrate when exposed to ice chamber temperature (-30 deg C).

Following equation equates the rate of change of internal energy of the dust particle to the rate of heat transfer from the particle to the surrounding at any instant of time.

$\rho.C_p.V.\frac{dT}{dt} = h.A.\Delta T$

OR in words,

density x specific heat capacity x dust volume x rate of temperature change in time=

natural heat transfer convection coefficient x dust particle surface area x temperature difference (final – initial)

Assuming dust particle as a sphere (mean diameter of 20 micron) and other thermodynamic properties for standard dust particle, we integrate the above equation to calculate the ‘t’. The time calculated is approximately 3.3 seconds. We will put these comments in the revised manuscript.

Pg. 11310, line 19-21 remark: At this time we are unsure why the lower limit of the time lag is longer for warmer temperatures. But we think may be at 110% RHi the vapor density is low enough such that there in no influence of temperature on the lower time lag limits. At higher vapor density as temperature changes the effect of vapor diffusion rate might become significant and this was observed at 116% RHi. We will mention this note in the revised manuscript.

Pg. 11311, line 5 remark: Surface tension is assumed as kind of surface force acting at the interface between the dust surface and ice embryo.

Pg. 11315, beginning of the page remark: The active site theory used here is independent of thermodynamic variables, such as temperature and RHi. This theory predicts only fraction of surface area which consists of active sites (size of active site is assumed). The next question is the efficiency of these active sites, which depends upon the above thermodynamic variables. Current knowledge regarding ice nucleation is inadequate to determine how these variables might influence the active site efficiency, and therefore we assume probability, P = 0.5. It is quite possible that at lower temperatures the efficiency might be higher or P is closer to unity and vice versa. To investigate these microphysical ice nucleation problems is beyond the scope of this paper. We will revise the manuscript accordingly.

Pg. 11316, line 1 remark: We agree with the referee that if experimental uncertainties are considered then the lower limits of the onset RHi between Saharan and Spanish dust particles diminishes. We would like to highlight that spread in the onset RHi for Saharan particles is higher compared to Spanish. We will revise the particular sentence accordingly.

However in ideal world if there are no experimental uncertainties then the onset RHi lower limits for these particles are different. Then question we would ask is why Spanish dust particles have higher lower limit onset RHi than Saharan. One reason we think of is the higher Ca element associated with Spanish dust might be affecting the onsets. It should be noted that we have not performed any special experiments to understand this observation, and would be beyond the scope of this work to understand the role of individual elements in the ice nucleation and formation processes. In future molecular dynamics based simulations could be carried out for understanding these theoretical questions, and are important to advance the ice nucleation field.

Interactive comment on Atmos. Chem. Phys. Discuss., 9, 11299, 2009.