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Interactive comment on "Nitric acid trihydrate (NAT) formation at low NAT supersaturations" *by* C. Voigt et al.

C. Voigt et al.

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We thank the referee for the insightfull review and helpful and positive comments.

We answer the suggestions as follows:

Concerning the concept of heterogeneous freezing: we took out section 6.5 as it obviously was not clear. On the other hand we detail in the discussion new important lab measurements showing that heterogeneous freezing of ice on mineral test dust occurs over a wide range of ice supersaturations (Mangold et al., 2005). Similar behaviour is expected for NAT nucleation on ice. We further mention laboratory results from Bogdan et al., (2003) and in situ measurements of meteoritic material in cirrus (Cziczo et al., 2004)

Specific comments

Title has been changed to:

In situ observations of nitric acid trihydrate (NAT) clouds in the Arctic stratosphere - evidence for particle formation at low NAT supersaturations

P8584 L11

Enhanced fluctuations are fluctuations, that exceed the background instrument noise. We now added a panel (A) in Fig.3 comparing the background instrument noise to measurements in the PSCs.

P8584 L14

Thanks for that comment. In the first version of the paper, we assumed HNO3 to be 100% of NOy. We now changed it to more realistic values of 80% in the stratosphere. This also changes the actual values for TNAT, T-TNAT and SNAT throughout the paper.

P8585

We now give the nitric acid content of the NAT and the STS particles. The STS particles are important, they basically shift the delta NOy instrument background distribution from 0 to 0.3 ppbv (new Fig.3). The NAT particles account for the difference between the background distrubution and the measurements at higher delta NOy. Particles $<0.2\mu$m only contain 15% of the condensed STS HNO3, therefore we can neglect that. In addition the particle enhacement factor increases with increasing particle diameter, therefore we are more sensitive to larger NAT particles. The conservative estimate of the detection limit of 0.3 ppbv NOy means that particle spikes >0.3 ppbv can be resolved as individual particles. Additionally we labelled NAT and STS in Fig.3. And we extended the STS particle size distribution to larger diameters in Fig. 3.

P8586 L8

We now calculate the volume depolarization and backscatter ratio of the observed NAT

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cloud, which is significantly below the detection limit of the optical instruments.

P8587 L6

The sentence has been changed to: At temperatures few K above the the ice frost point, the NAT particle growth is reduced due to HNO3 uptake into ternary solution particles.

P8587 L17

We did not want to give that number here, because it is discussed later at an appropriate place in the paper. However, we changed that now according to the referees suggestions.

P8587 L28

The difference between the simulated and the measured NAT aera can partially be explained by the different resolutions of model and measurements. Thank you for that comment.

P8588 L3

variation of the air masses has been changed to composition of the air masses

P8588 L5

could has been changed to might

P8588 section 4.4

Thanks for that suggestion. We now emphasize the important role and the detection difficulties of small NAT number densities.

P8590 L20

We include the best case of Grooss et al (2004).

P8591 L26

Fig.4 is the correct reference.

P8592 L2

Summarized has been changed to therefore

P8594 L1-5

We changed the sequence in the discussion of the Biermann et al. results. We now additionally explain the Bogdan measurements and AIDA measurements of ice nucleation on mineral test dust (Mangold et al., 2005), which support our data.

P8594 L4

Thank you, we changed it to SNAT$>$25.

P8594 L16

We changed must to can

P8594 L19

Has been changed to: Assuming temperatures below TNAT for more than 3 days (instead of 1day as during EUPLEX), the estimated rate can produce NAT particle number densities up to few times 1e-4 cm-3 as observed by Fahey et al.(2001).

P8595 L25

We changed that sentence to: For the late Arctic winter 2002/2003 calculations with the effective nucleation rate of 8e-6 cm-3 h-1 as derived in the present study reasonably reproduce our observations of NAT particle number density, size distribution and additionally of denitrification (Grooss et al., 2004).

Fig.1

We now explain the NAT contour in the figure caption.

Fig.4

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For small NAT particle number densities, gas phase NOy is assumed to be constant in this calculation.

Fig.5

Thanks for the suggestions, we hope the plot is more instructive now. We now show the temperature histories of the backtrajectories ending on the flight track. Those trajectories are also shown in Fig.1. The trajectories ending in PSCs have encontered lower temperautres and the trajectories ending outside the PSC region on the flight track have encountered slightly higher temperatures.

References: Cziczo, D. J., Murphy, D. M. , Hudson, P. K. and Thomson, D. S.: Single particle measurements of the chemical composition of cirrus ice residue during Crystal Face, J. Geophys. Res., 109 (D4210), 4517, doi:10.1029/2003JD004032, 2004.

Mangold, A., R. Wagner, H. Saathoff, U. Schurath, C. Giesemann, V. Ebert, M. Kraemer, and O. Moehler, Experimental investigation of ice nucleation by different types of aerosols in the aerosol chamber AIDA: implications to microphysics of cirrus clouds, Meteorol. Z., in press, 2005.

Interactive comment on Atmos. Chem. Phys. Discuss., 4, 8579, 2004.