Project: **1002**

Project title: **Forcing in the long-wave spectrum due to aerosol-cloud interactions: satellite and climate modelling vs. HALO (FLASH)**

Project lead: **Johannes Quaas**

Report period: **1.7.2017 – 30.6.2018**

In the report period, we were not yet able to make use of the ICON model (this is now planned for the next allocation period, please see request), but we assessed in a thorough manner the simulated ice crystal number concentration in the ECHAM-HAM aerosol-climate model (Stevens et al., 2013; Zhang et al., 2012) using satellite observations DARDAR-LIM (Sourdeval et al., 2018; Gryspeerdt et al., 2018). Various sensitivity studies were conducted to investigate the processes that are relevant to match the observed characteristics. Notably the Ice crystal number concentration (N_i) relationship with temperature is a characteristic feature that the model should reproduce.

Results from a set of sensitivity studies are shown in Fig. 1 in comparison to the newly-derived satellite retrievals for N_i based on active remote sensing (Sourdeval et al., 2018; black curve), and in comparison to parameterisations proposed in earlier literature. It is clear that previous approaches show far too strong a dependency of N_i on temperature (Chen, 2017). In turn, the model does not show enough sensitivity. None of the sensitivity studies, indeed, shows the negative relationship of N_i with temperature, calling for further investigation.

Results of model intercomparison are included in the submitted publication of Sourdeval et al. (2018), and the sensitivity simulations will be part of a publication in preparation. The ICON studies are now planned for the next allocation period.

References

Cheng, H., Simulation and Evaluation of the cloud ice number concentration in global atmospheric model ECHAM6-HAM2, Master's thesis, available at *http://research.uni-leipzig.de/climate/cheng_hanmi__masterarbeit__2017.pdf*, 2017.

Delanoë, J., and R. J. Hogan, Combined CloudSat-CALIPSO-MODIS retrievals of the properties of ice clouds, J. Geophys. Res., 115, D00H29, doi:10.1029/2009JD012346, 2010.

Fletcher, N. H. et al.: The physics of rainclouds, Cambridge University Press, 1962.

Gryspeerdt, E., **O. Sourdeval, J. Quaas**, J. Delanoë, and P. Kühne, Ice crystal number concentration estimates from lidar-radar satellite retrievals. Part 2: Controls on the ice crystal number concentration, Atmos. Chem. Phys. Discuss., in review, doi:10.5194/acp-2018-21.

Heinze, R., A. Dipankar, C. Carbajal Henken, C. Moseley, O. Sourdeval, S. Trömel, X. Xie, P. Adamidis, F. Ament, H. Baars, C. Barthlott, A. Behrendt, U. Blahak, S. Bley, Slavko Brdar, M. Brueck, Susanne Crewell, H. Deneke, P. Di Girolamo, R. Evaristo, J. Fischer, C. Frank, P. Friederichs, T. Göcke, K. Gorges, L. Hande, M. Hanke, A. Hansen, H.-C. Hege, C. Hoose, T. Jahns, N. Kalthoff, D. Klocke, S. Kneifel, P. Knippertz, A. Kuhn, T. Laar, Andreas Macke, V. Maurer, B. Mayer, C. I. Meyer, S. K. Muppa, R. A. J. Neggers, E. Orlandi, F. Pantillon, B. Pospichal, N. Röber, L. Scheck, A. Seifert, P. Seifert, F. Senf, P. Siligam, C. Simmer, S. Steinke, B. Stevens, K. Wapler, M. Weniger, V. Wulfmeyer, G. Zängl, D. Zhang, and **J. Quaas**, Large-eddy simulations over Germany using ICON: A comprehensive evaluation, Quart. J. Roy. Meteorol. Soc., 143, 69-100, doi:10.1002/qj.2947, 2017.

Lohmann, U., P. Stier, C. Hoose, S. Ferrachat, S. Kloster, E. Roeckner, J. and Zhang, Cloud microphysics and aerosol indirect effects in the global climate model ECHAM5-HAM, Atmos. Chem. Phys., 7, 3425-3446, 2007.

Meyers, M. P., DeMott, P. J., and Cotton, W. R.: New primary ice-nucleation parameterizations in an explicit cloud model, Journal of Applied Meteorology, 31, 708–721, 1992.

Sourdeval, O., E. Gryspeerdt, M. Krämer, T. Goren, J. Delanoë, A. Afchine, F. Hemmer, and **J. Quaas**, Ice crystal number concentration estimates from lidar-radar satellite remote sensing. Part 1: Method and evaluation, Atmos. Chem. Phys. Discuss., in review, doi:10.5194/acp-2018-20.

Stevens, B., M. A. Giorgetta, M. Esch, T. Mauritsen, T. Crueger, S. Rast, M. Salzmann, H. Schmidt, J. Bader, K. Block, R. Brokopf, I. Fast, S. Kinne, L. Kornblueh, U. Lohmann, R. Pincus, T. Reichler, and E. Roeckner, Atmospheric component of the MPI-M Earth System Model: ECHAM6. J. Adv. Model. Earth Syst., 5, 146-172. doi:10.1002/jame.20015, 2013.

Zhang, K., D. O'Donnell, J. Kazil, P. Stier, S. Kinne, U. Lohmann, S. Ferrachat, B. Croft, **J. Quaas**, H. Wan, S. Rast, and J. Feichter, The global aerosol-climate model ECHAM5-HAM, version 2: sensitivity to improvements in process representations, Atmos. Chem. Phys., 12, 8911-8949, doi:10.5194/acp-12-8911-2012, 2012.

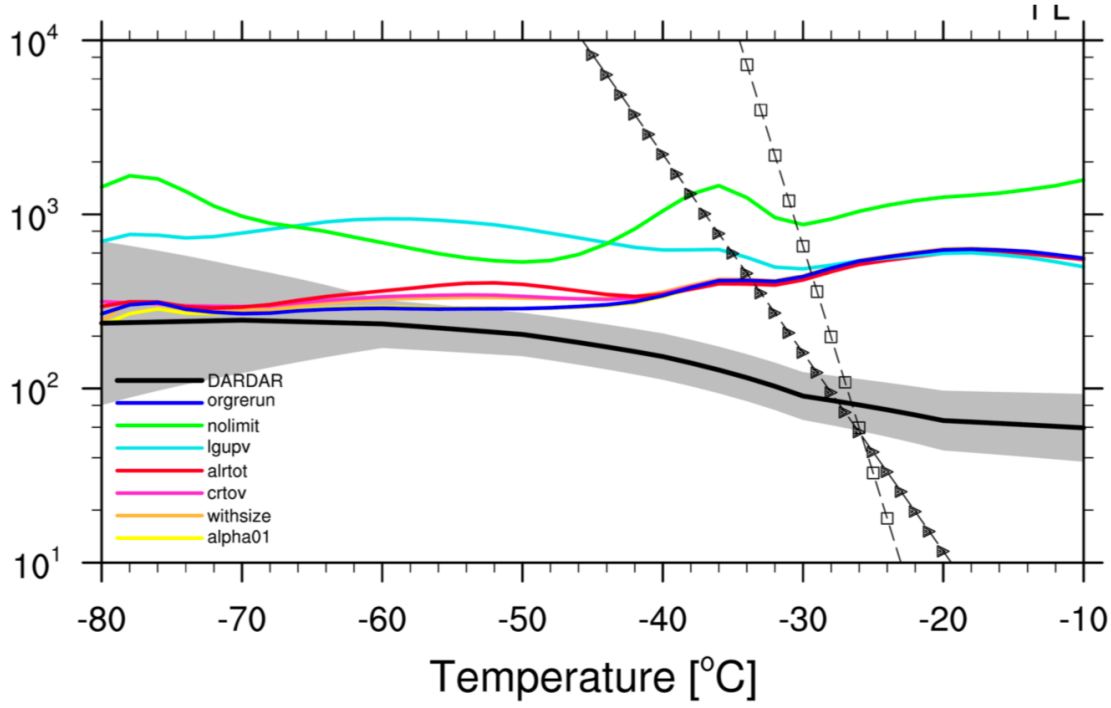

Fig. 1: Ice crystal number concentration (N_i, l^{-1}, y-axis) vs. temperature (°C, x-axis). The solid black curve represents the mean N_i from satellite retrieved data using DARDAR algorithm (Sourdeval et al., 2018) with the gray shaded area representing mean value plus/minus one standard deviation (N_i interpolated onto isothermal surfaces from −10◦ C to −80◦ C with 10◦ C spacing). The dashed black curves with triangular and square marks represent the parameterization from Meyers et al. (1992) and Fletcher et al. (1962), respectively. Curves with other colors are correspondent to different simulations with a temperature spacing of 2 K."orgrerun" is the control simulation with standard settings (Lohmann et al., 2007). "nolimit" removes the min-max statements that limit the plausible range of N_i in the model. "lgupv" introduces a stronger contribution to subgrid-scale updraft velocity by turbulence. "alrtot" implements a temperature-dependent deposition coefficient for ice. "crtov" includes a stronger dependency of nucleation on updraft velocity."withsize" adds a dependency of the ice nucleation on the aerosol size distribution. "alpha01" finally sets the deposition coefficient to a constant value of 0.1.