Karlsruhe Institute of Technology

INUIT
Ice Nuclei Research Unit

Influence of different ice-nucleation parameterizations on orographic mixed-phase clouds

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Motivation

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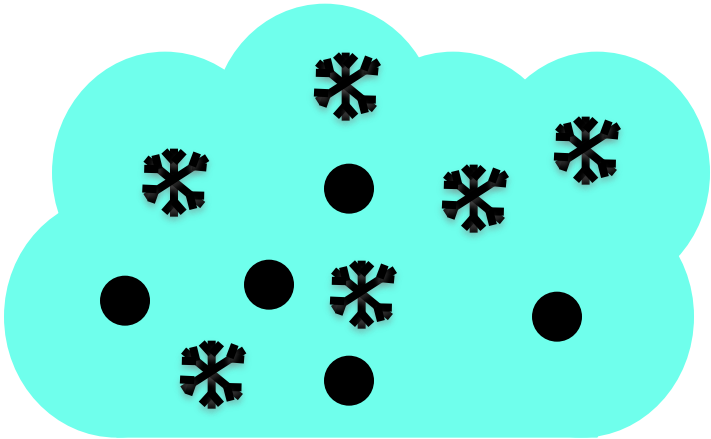


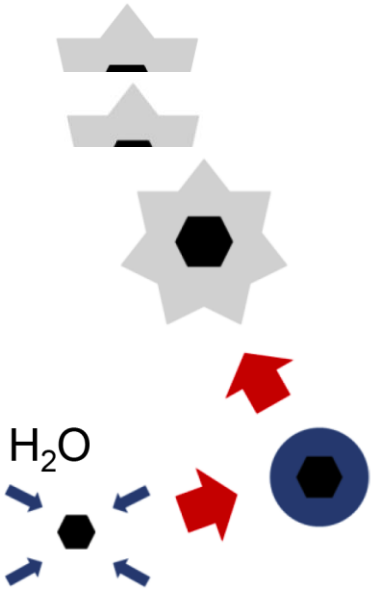
Sensitivity studies with respect to parameterization of ice nucleation with the COSMO model

- Evaluation of state-of-the-art ice nucleation parameterizations
- Quantification of the effects of some parameterizations in idealized simulations

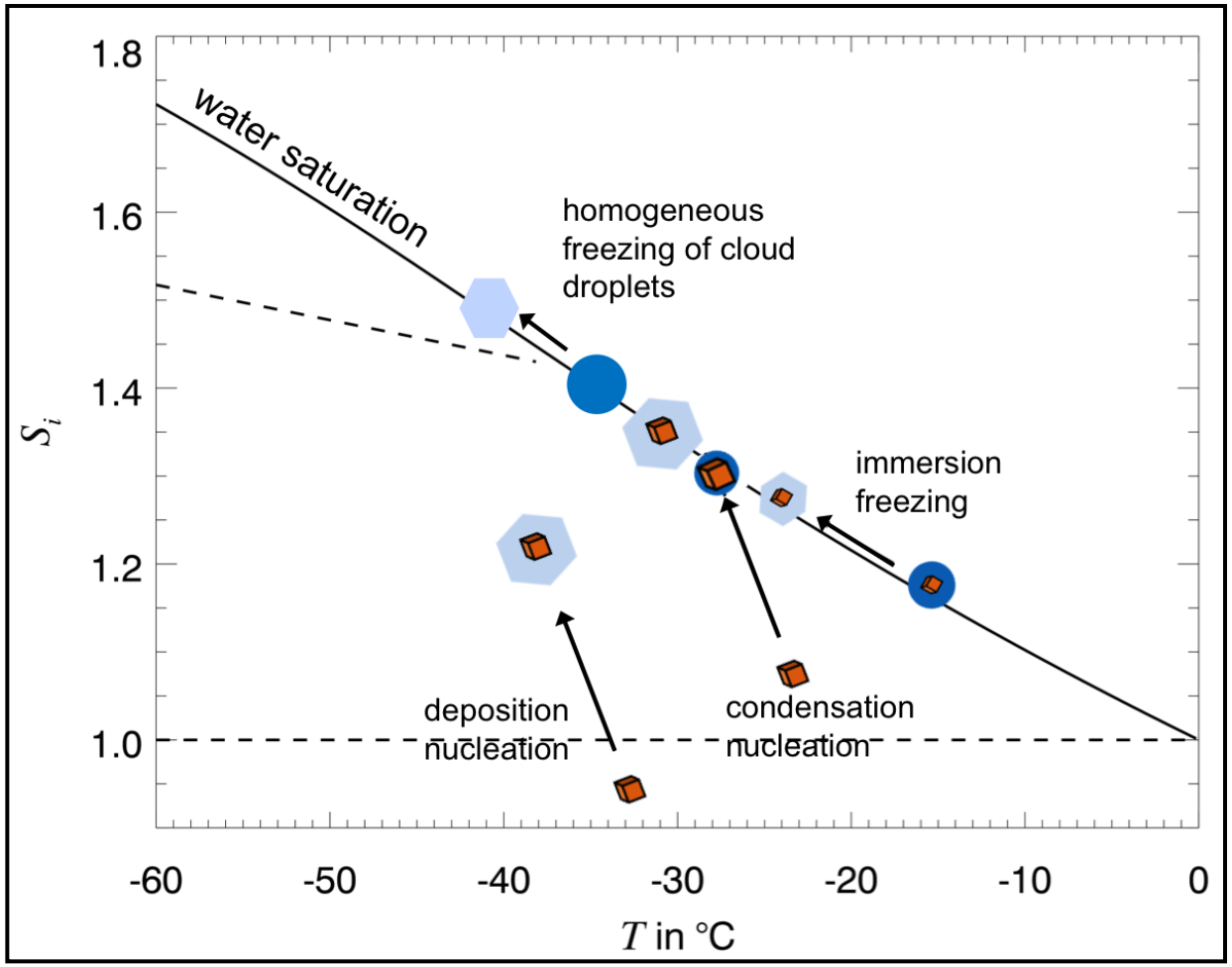
Theory of heterogeneous ice nucleation

immersion freezing

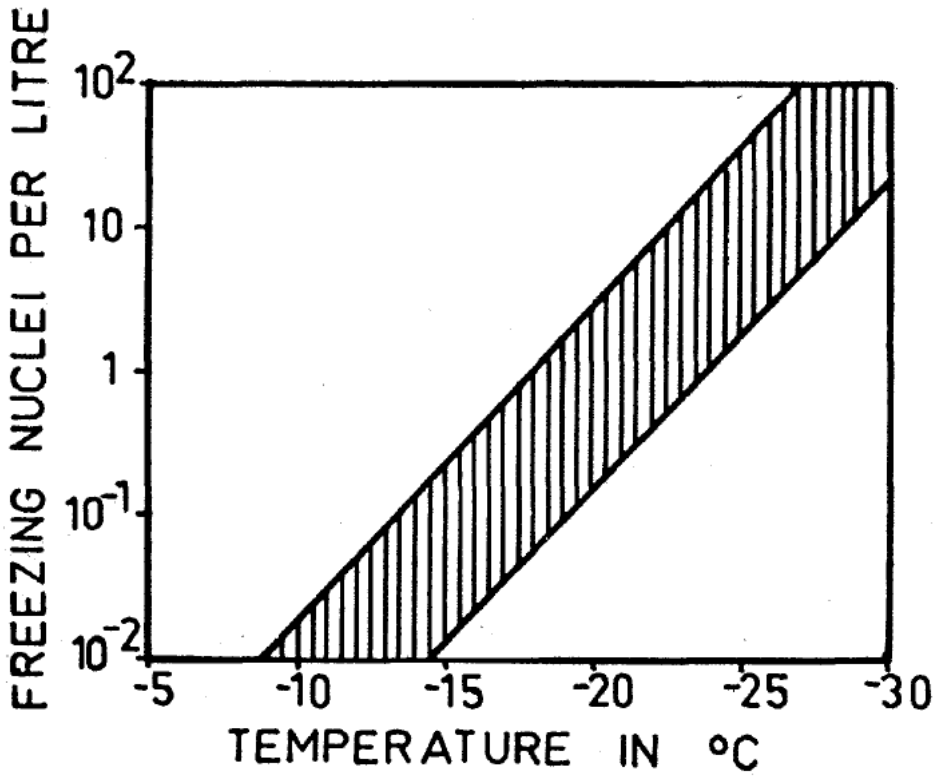
deposition nucleation



condensation nucleation



Fletcher et al. (1962)



„The activity curve varies from day to day but typically lies within the shaded region“

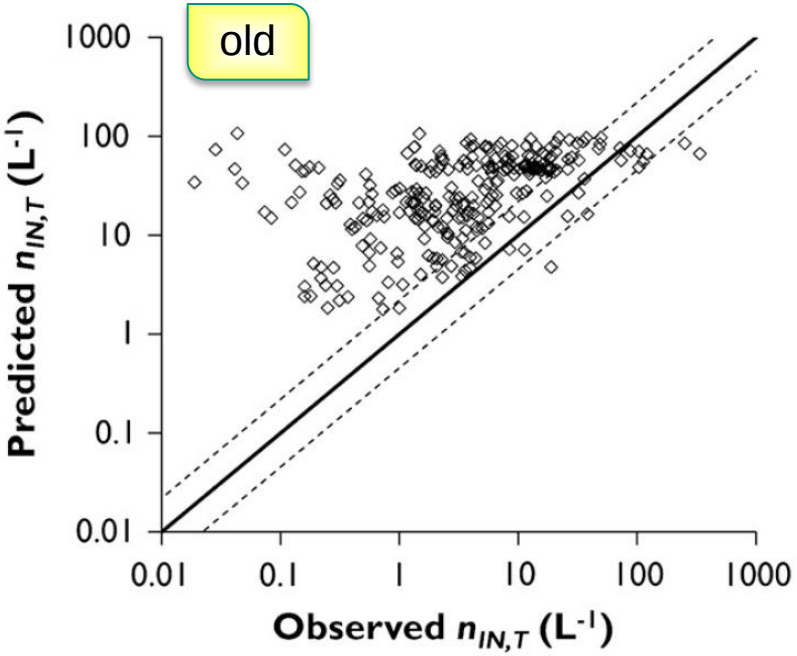
$$n_{IN} = 0.01 \exp\left[-0.6\left(\max\left(T_K, 246\right) - 273.16\right)\right]$$

Missing dependency

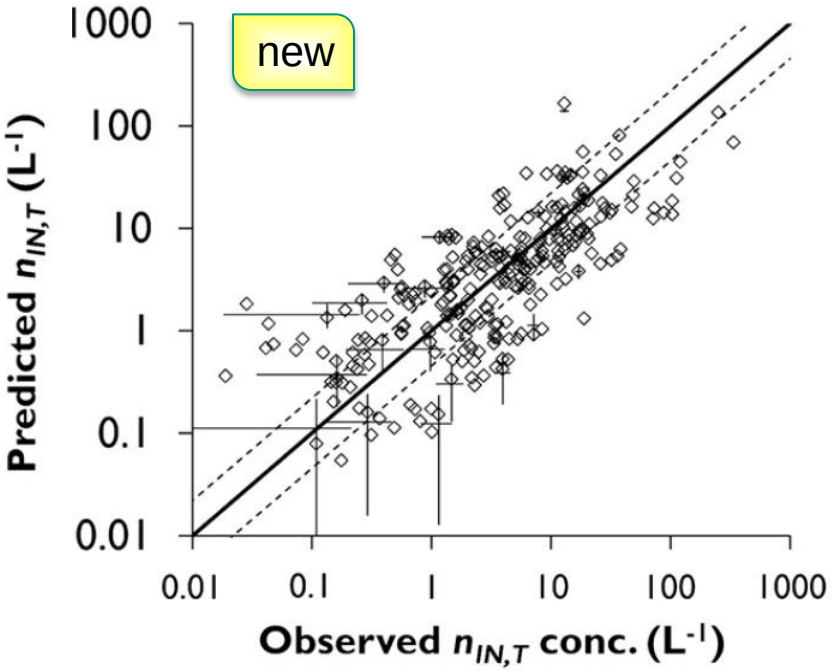
- aerosol properties
- supersaturation of water vapor

DeMott et al. (2010)

Immersion mode



- Combined field studies with ambient aerosol size distributions
- Simple link to aerosol number larger than a criticial diameter



-35° C < T < -9° C

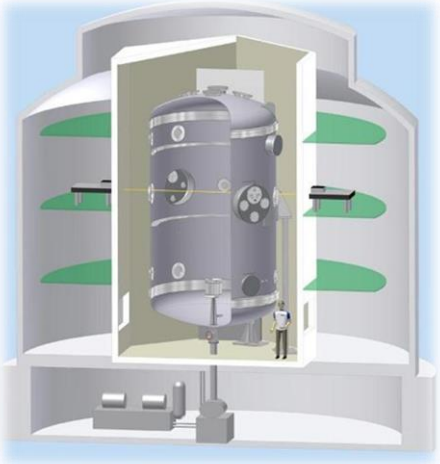
$S_w > 1$

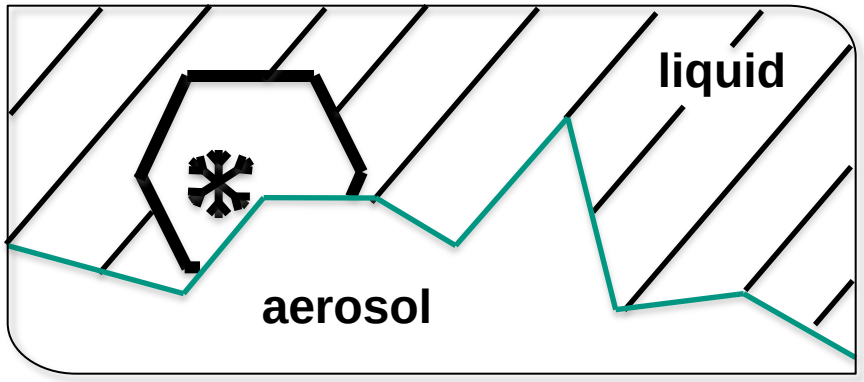
$$n_{IN} = a\left(273.16 - T_K\right)^b \left(n_{aer,0.5}\right)^{\left(c\left(273.16 - T_K\right)+d\right)}$$

a = 0.0000594	b = 3.33
c = 0.0264	d = 0.0033

Niemand et al. (2012)

Immersion mode





- Assuming only immersion freezing on dust particles
- Based on laboratory measurements in the AIDA cloud chamber

Fundamental Assumption

Number of active IN is approximatly proportional to the total surface area

-36° C < T < -12° C

$S_w > 1$

$$n_{IN} = \sum_{j=1}^{n} N_{tot,j}\left\{1 - \exp\left[-S_{ae,j}\, n_s(T)\right]\right\}$$

$$n_s(T) = \exp\left[-0.517\left(T - 273.15\right) + 8.934\right]$$

Phillips et al. (2013)

- Distinction between four different aerosol species (dust, soot, soluble organics & primary biological aerosol particles)
- Based on field and laboratory measurements (background scenario)

Fundamental assumption regarding surface site density

Background scenario

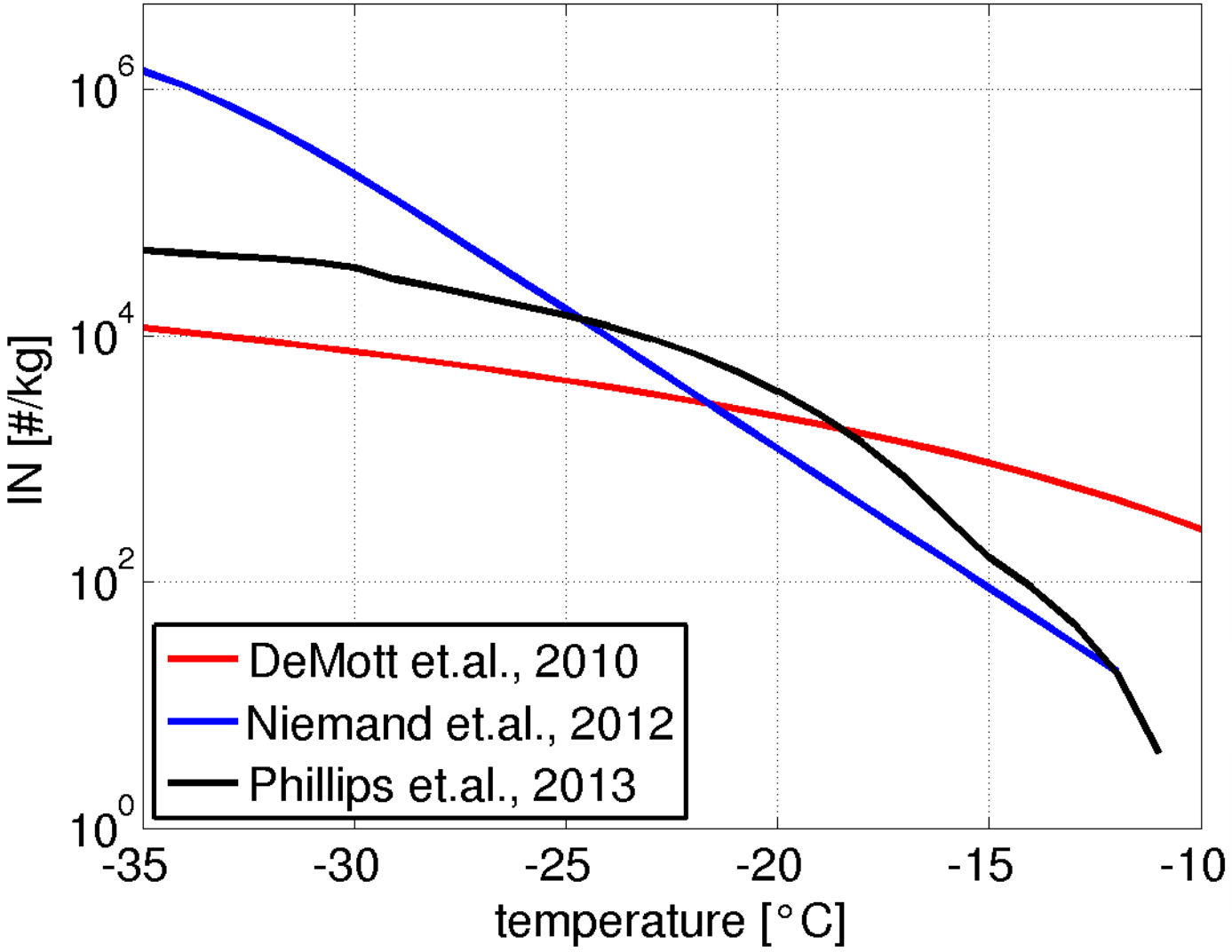
$$n_{IN,X} = \int_{\log[0.1\,\mu m]}^{\infty} \left\{1 - \exp\left[-m_X(D_X, S_i, T)\right]\right\} \cdot \frac{dn_X}{d\log D_X} d\log D_X$$

$S_i > 1$

Condensation & Immersion & deposition mode

$-70^\circ C < T < 0^\circ C$

Comparison of the parameterizations



Soot
- N=24.9 #/cm³
- D=0.14µm

Dust 1
- N=4.5 #/cm³
- D=0.52µm

Dust 2
- N=1.1 #/cm³
- D=1.13µm

from field campaign at the JFJ in 2008

Setup of the idealized simulations

Setup

- 2D simulations
  - 1 km horizontal resolution
  - 200 vertical levels
  - timestep of 5 s
- gaussian hill
  - 800m height
  - 20 km half width

Aerosol

from field campaign at the Jungfraujoch in 2008

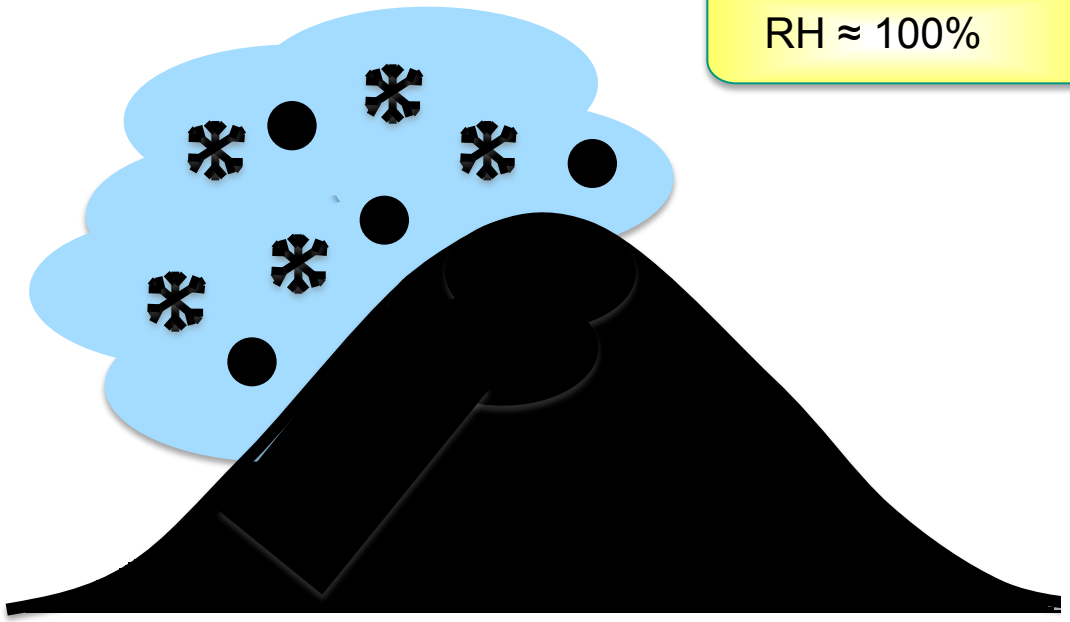
T_{ground} = 263.2 K

CONSORTIUM FOR SMALL SCALE MODELING

COSMO

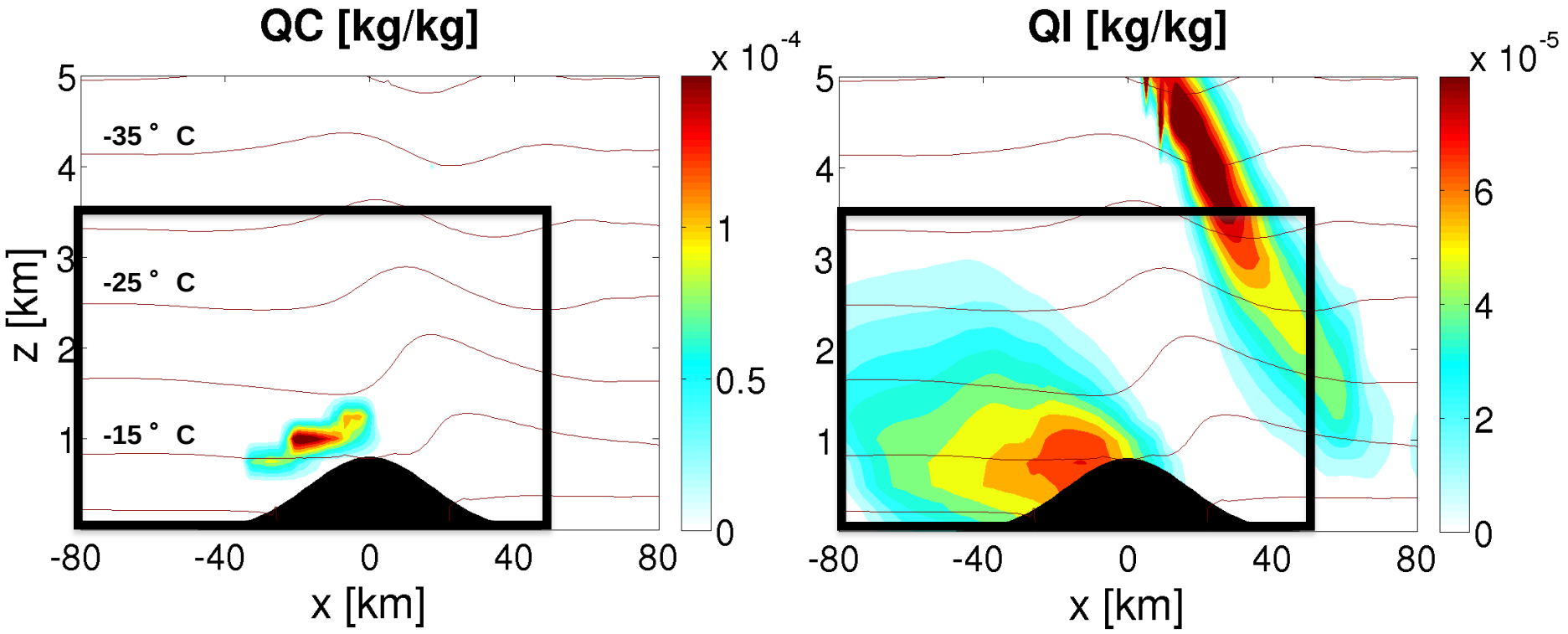
+ 2Mom-Scheme

RH ≈ 100%



Similar to Muhlbauer et al., 2009

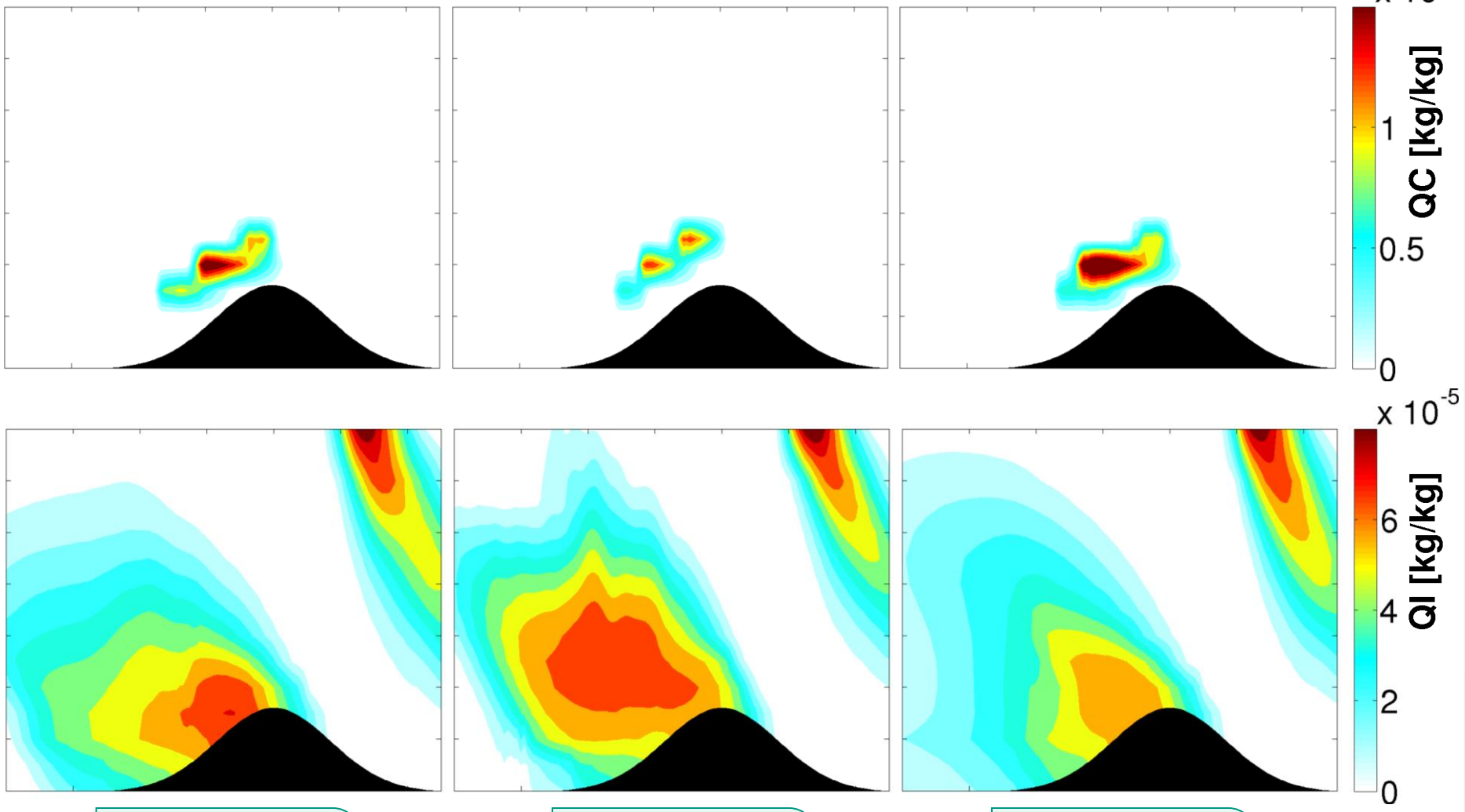
Simulation with DeMott



t = 150 min

All Parametrizations

t = 150 min



DeMott

Niemand

Phillips

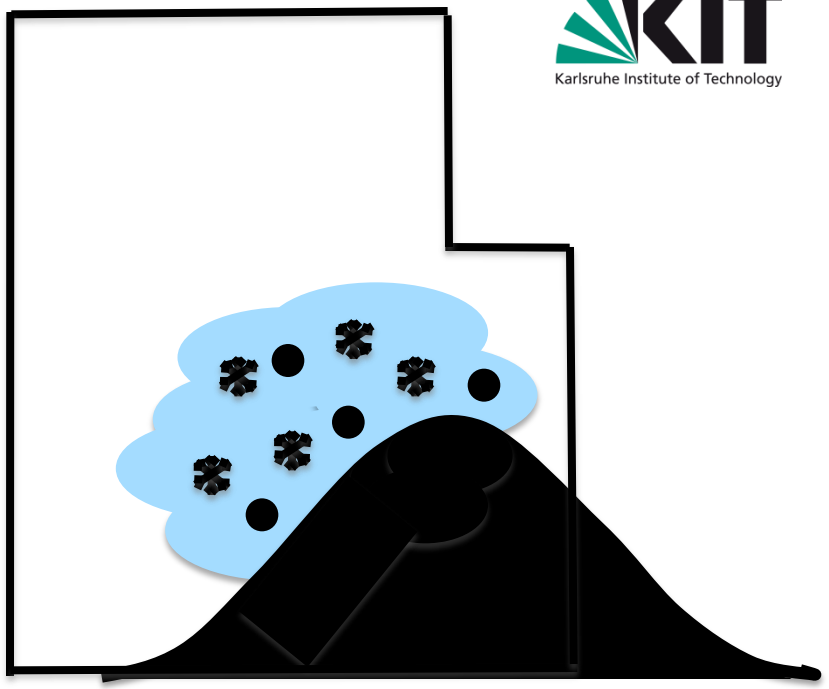
Senitivity studies

Same numerical setup

- domain & resolution
- gaussian hill

Varying surface temperature

- from 258.2K to 278.2K
- 5K steps of temperature



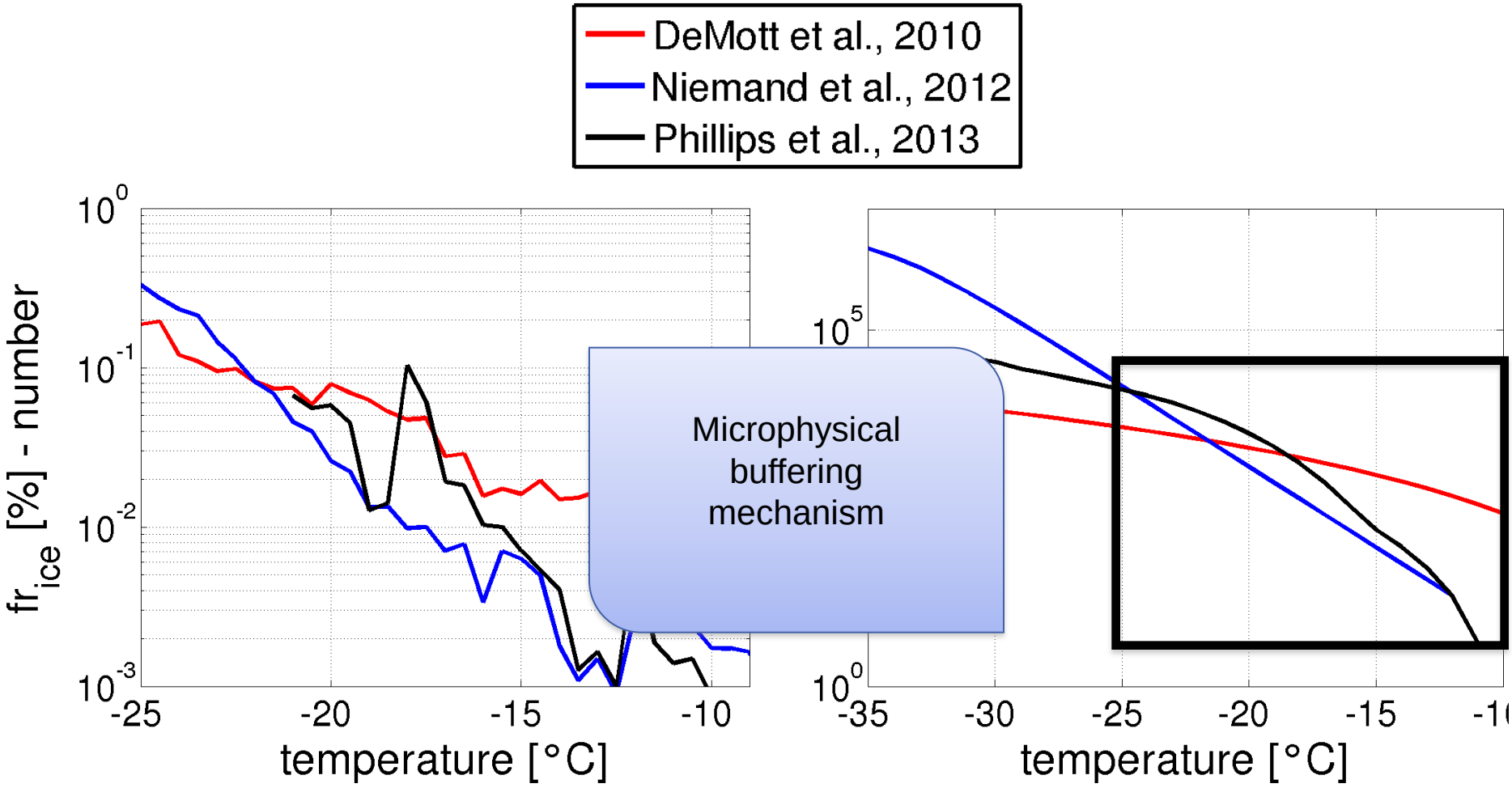
Calculation of fraction of ice

- all cloudy gridpoints of lower cloud
- over all timesteps

$$fr_{ice,\,number} = \frac{QNI}{QNI + QNC}$$

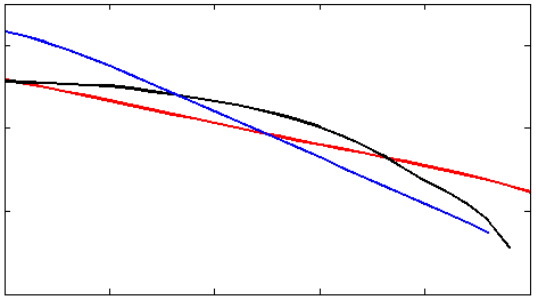
$$fr_{ice,\,mass} = \frac{QI}{QI + QC}$$

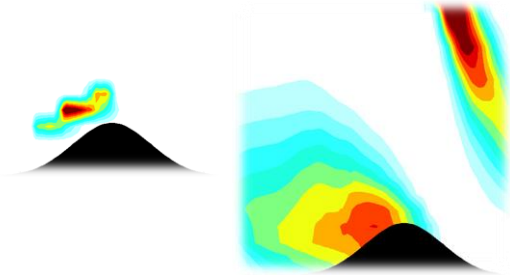
Fraction of ice from sensitivity studies



Conclusions

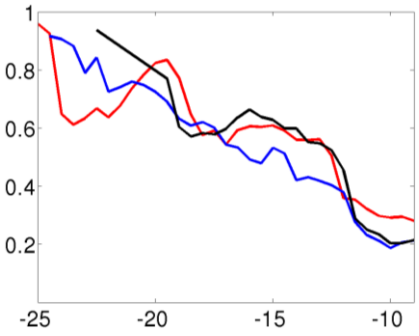
Implementation of three state-of-the-art ice nucleation parameterizations





Setup of idealized 2D simulations

Microphysical buffering mechanism



Outlook

- Implementation of more (INUIT) parameterizations
- Analysis of microphysical feedback processes
- Sensitivity studies on aerosol effects (real INUIT cases – JFJ 2013)

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Idealized simulations of mixed-phase clouds

References

Fletcher, N.H., et al., 1962: *The physics of rainclouds*

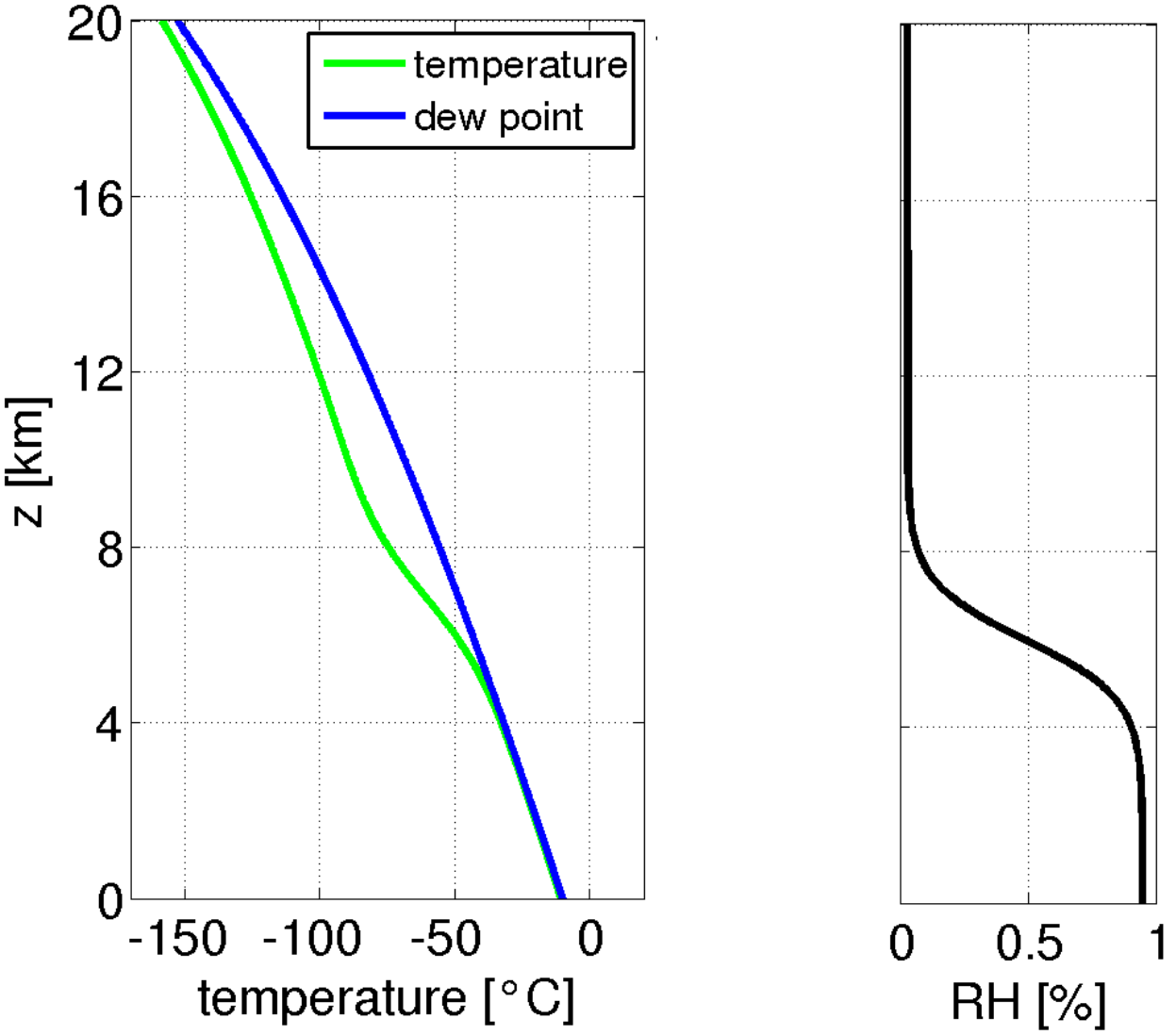
DeMott, P., et al., 2010: Predicting global atmospheric ice nuclei distributions and their impacts on climate.

Niemand, M., et al., 2012: A particle-surface-area-based parameterization of immersion freezing on desert dust particles.

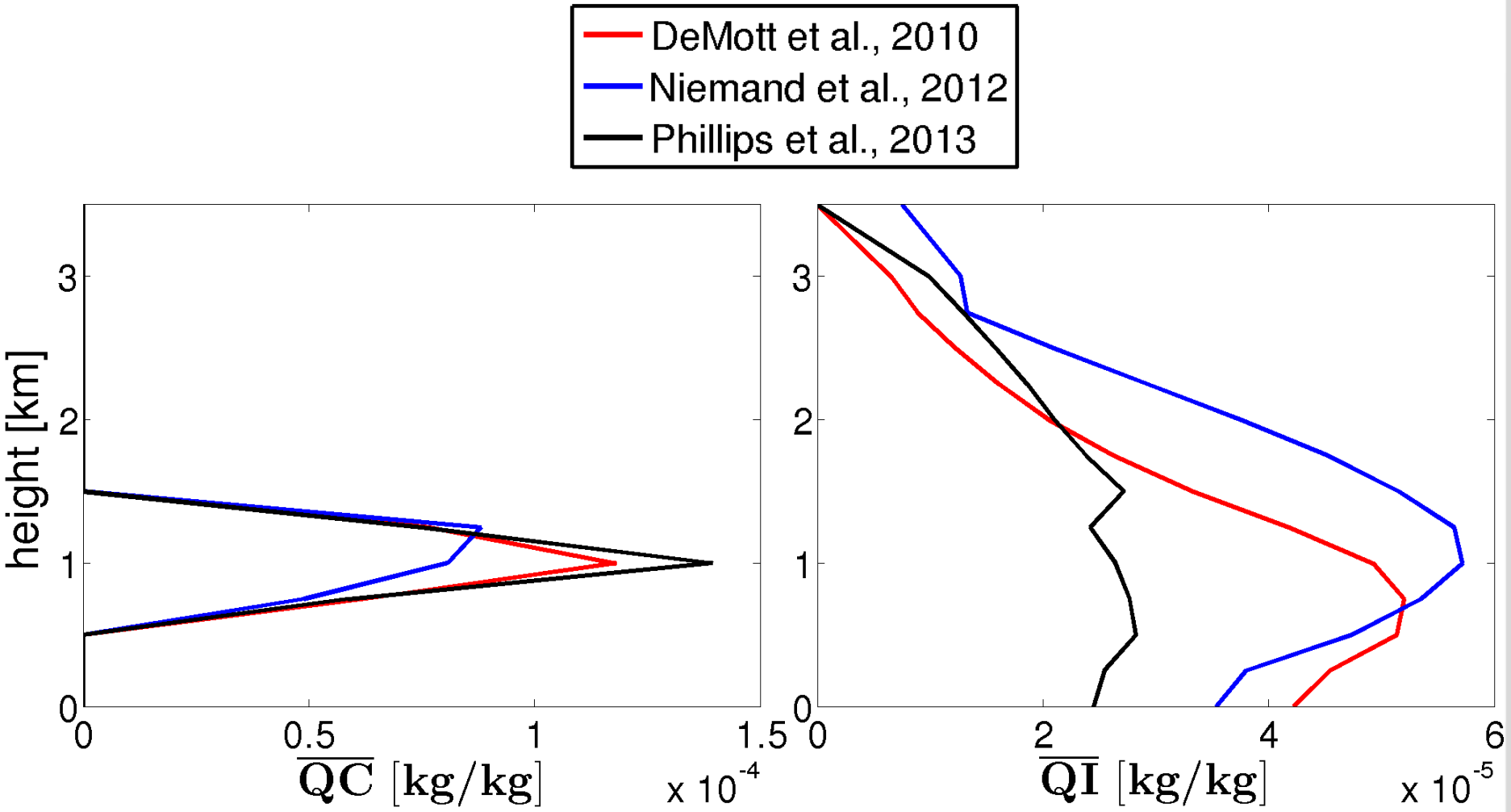
Phillips,V.T., et al., 2013: Improvements to an empirical parameterization of heterogeneous ice nucleation and its comparison with observations.

Muhlbauer, A., et al., 2009: Sensitivity studies of aerosol-cloud interactions in mixed-phase orographic precipitation.

Profiles for 263.2K



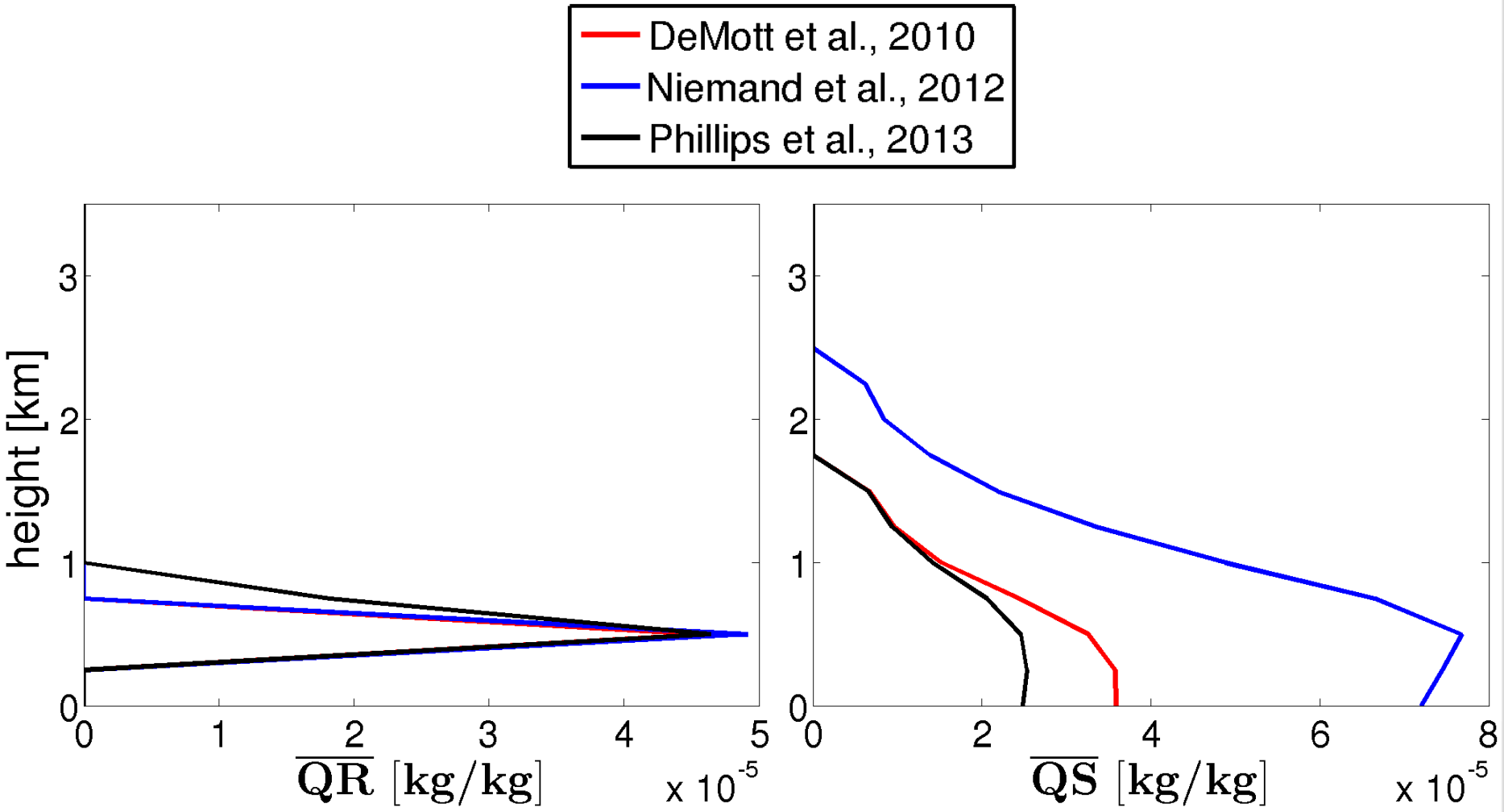
Simulations



T_s = 263.2 K

t = 150 min

Simulations



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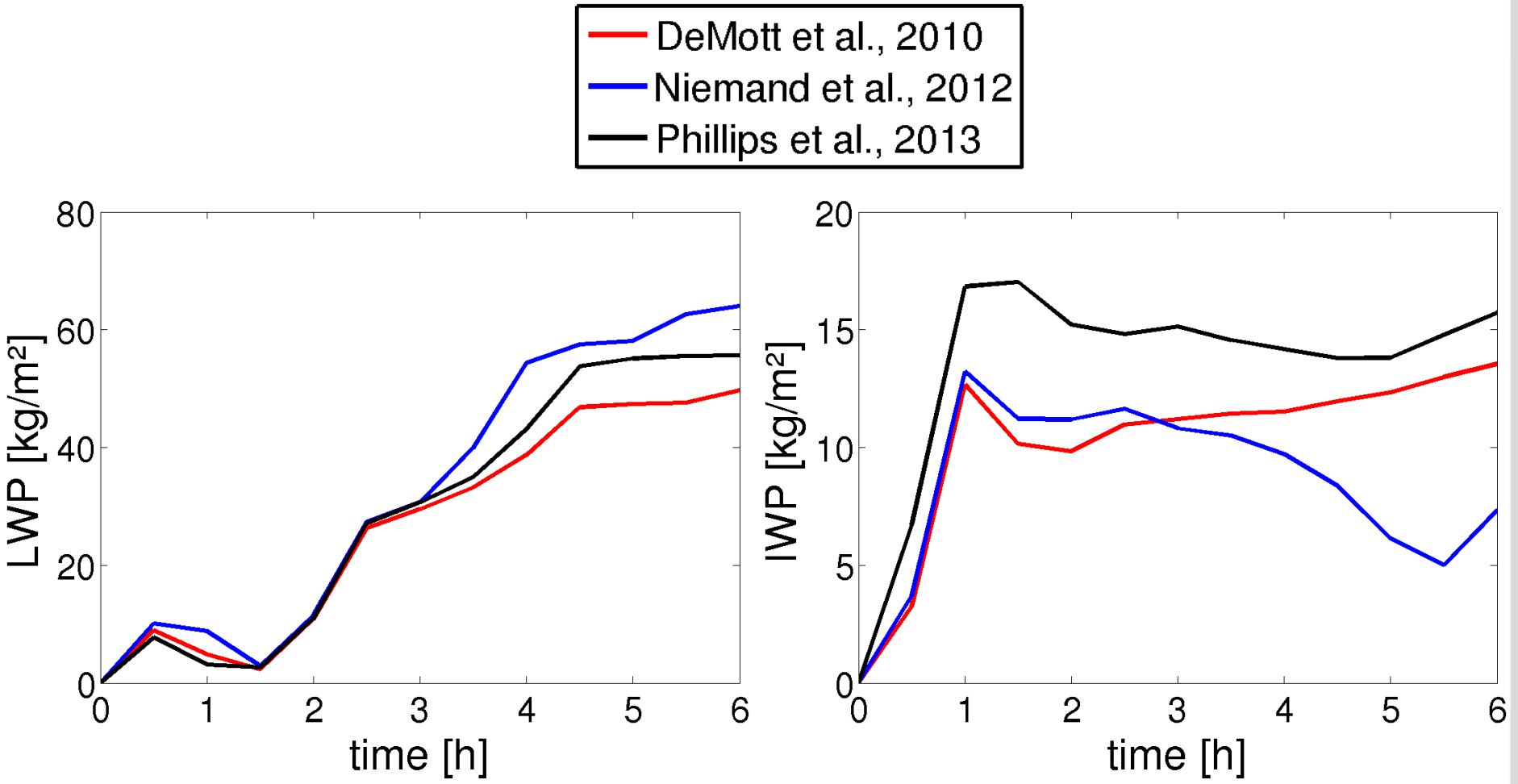

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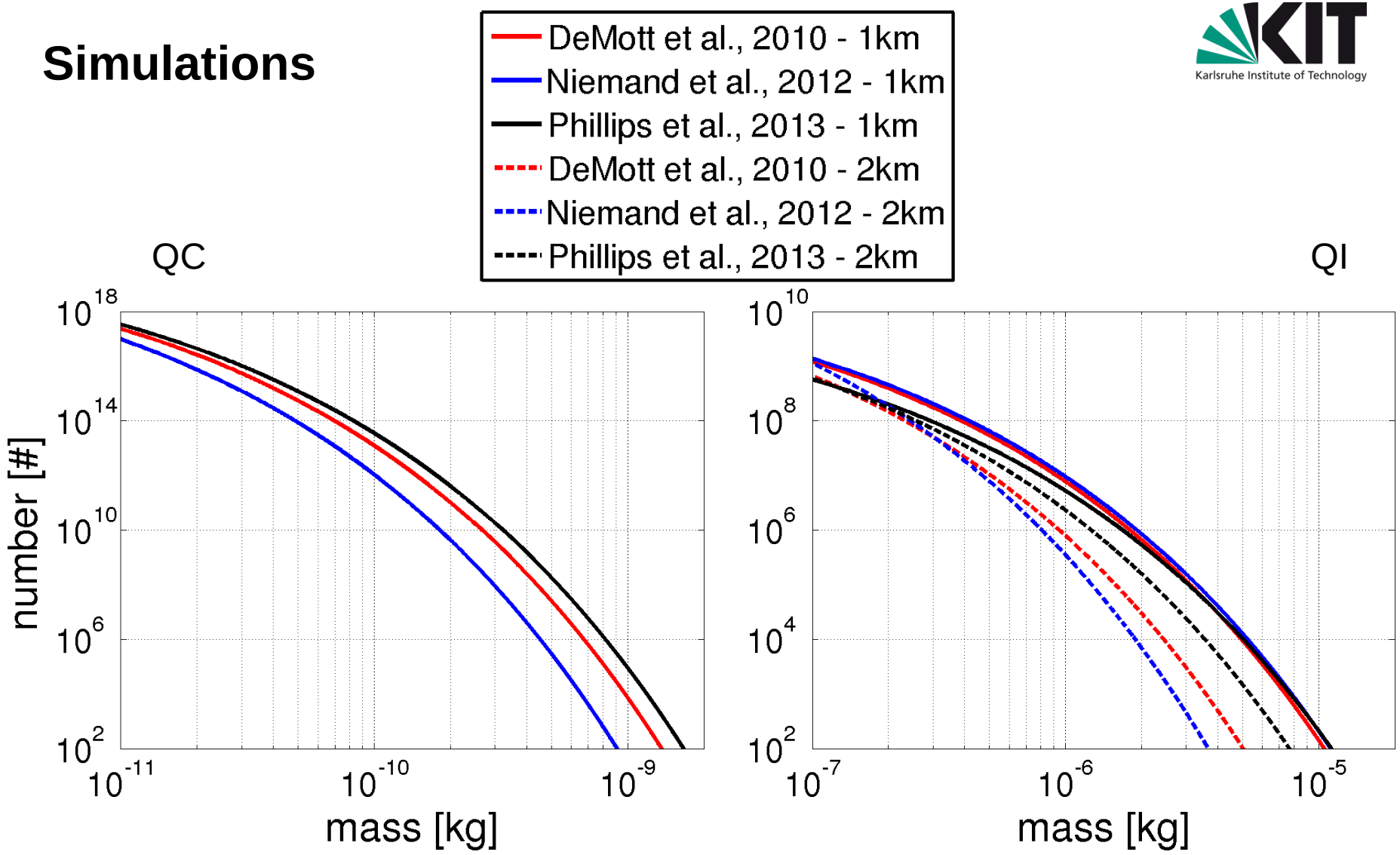

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