New ice nucleation parameterizations in EC-Earth3

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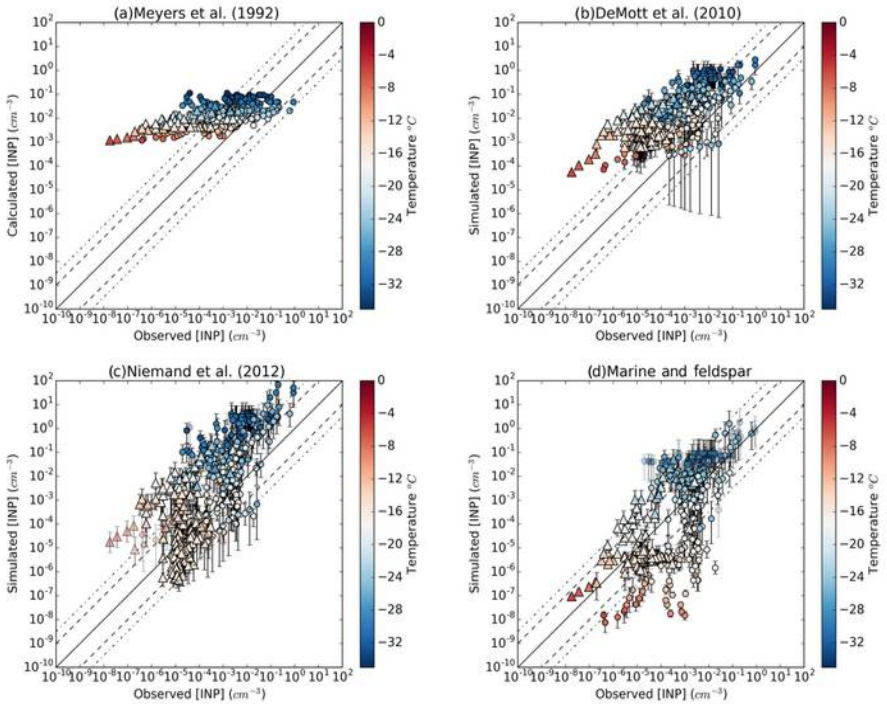
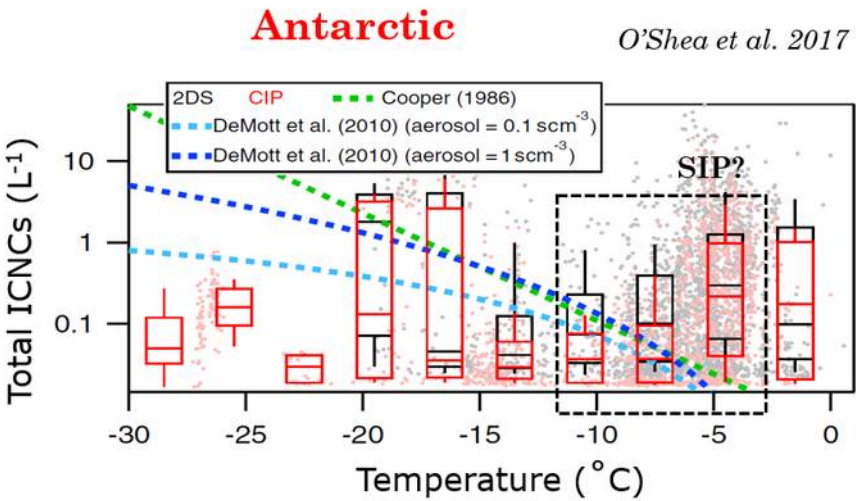
Motivation

Investigate the effect of modeled dust mineralogy upon heterogeneous ice nucleation in mixed-phase clouds by implementing new ice nucleation parameterizations in EC-Earth3-AerChem dependent of aerosols, and the effect of the secondary ice production (SIP) in a global model by implementing a new SIP parameterization based on a Random Forest regressor (RaFSIP) in the EC-Earth3-AerChem.



Vergara-Temprado et al., 2017

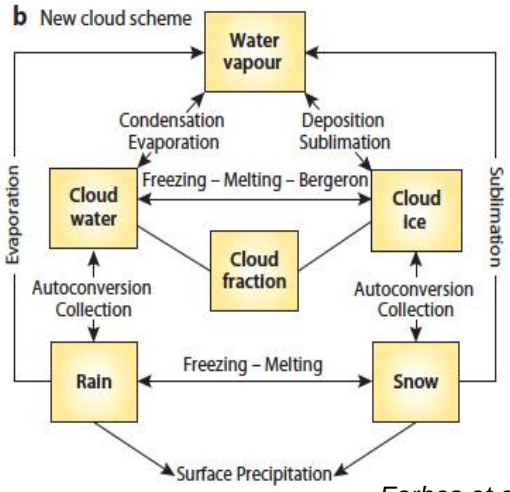


Before and after implementing aerosol mineralogy from TM5 interactively with IFS

Meyers et al. (1992) deposition-condensation freezing nucleation parametrization

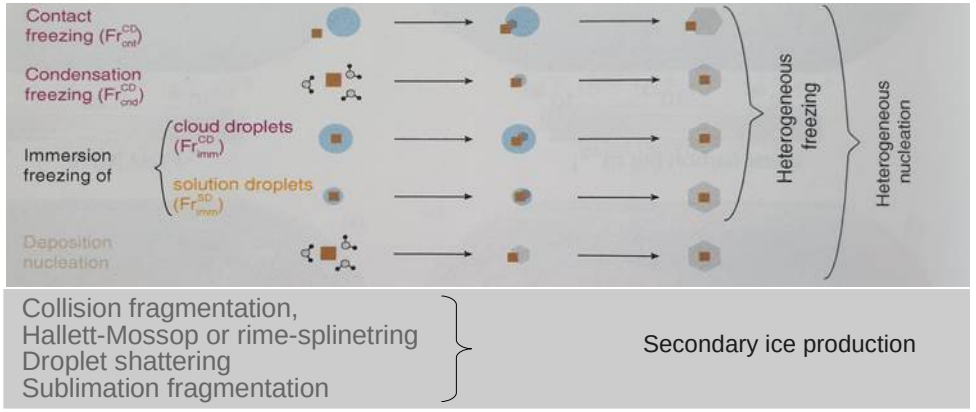
$$N_i = 1000exp[12.96(e_{sl} - e_{si})/e_{si} - 0.639]$$

N_i: ice crystal number concentration
e_{sl}: saturation vapor pressure with respect to liquid water
e_{si}: saturation vapor pressure with respect to ice



Forbes et al., 2011

Aerosol/Mineralogy dependent parameterization + Secondary ice production



Lohmann et al., 2016

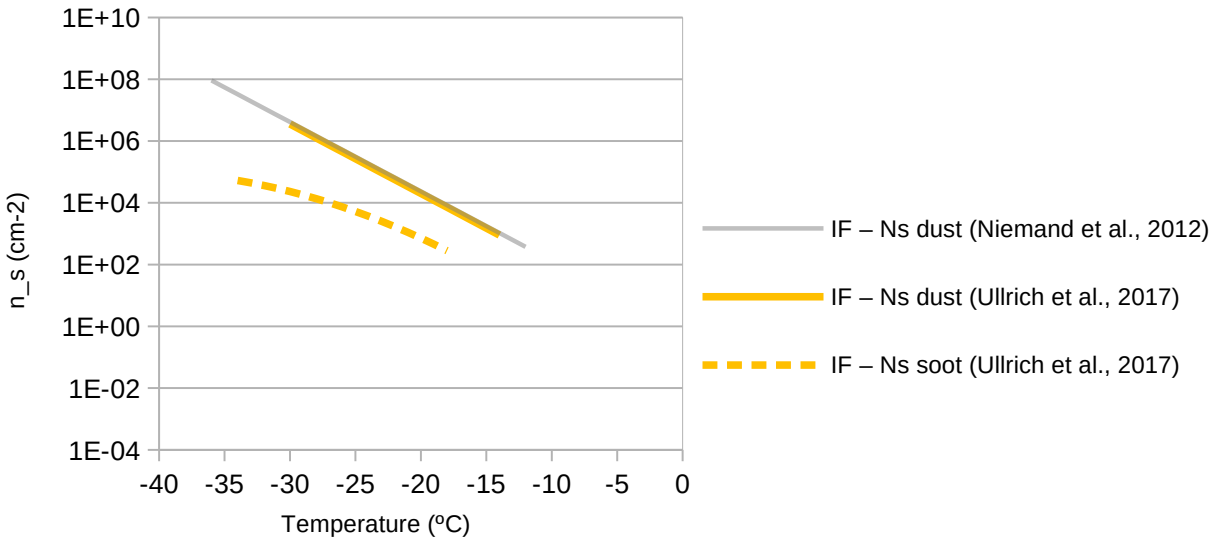
Atmospheric Chemistry **TM5** ⟷ Atmospheric Dynamics **IFS**

Feldspar
Quartz
Marine organic
[...]

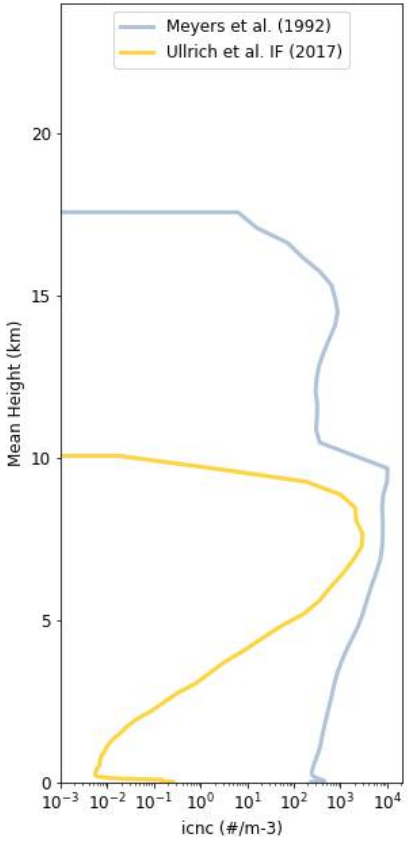
IN immersion freezing parameterizations

Ullrich et al. (2017):
- Dust (accum. and coarse soluble and insoluble), and soot mass (accum. and coarse soluble modes)
- Dust: [-30, -14] ºC, and soot: [-34.15, -18.15] ºC
- External mixing (for insoluble) and internal mixing (for soluble) assumptions.

Number of nucleation sites per unit surface area



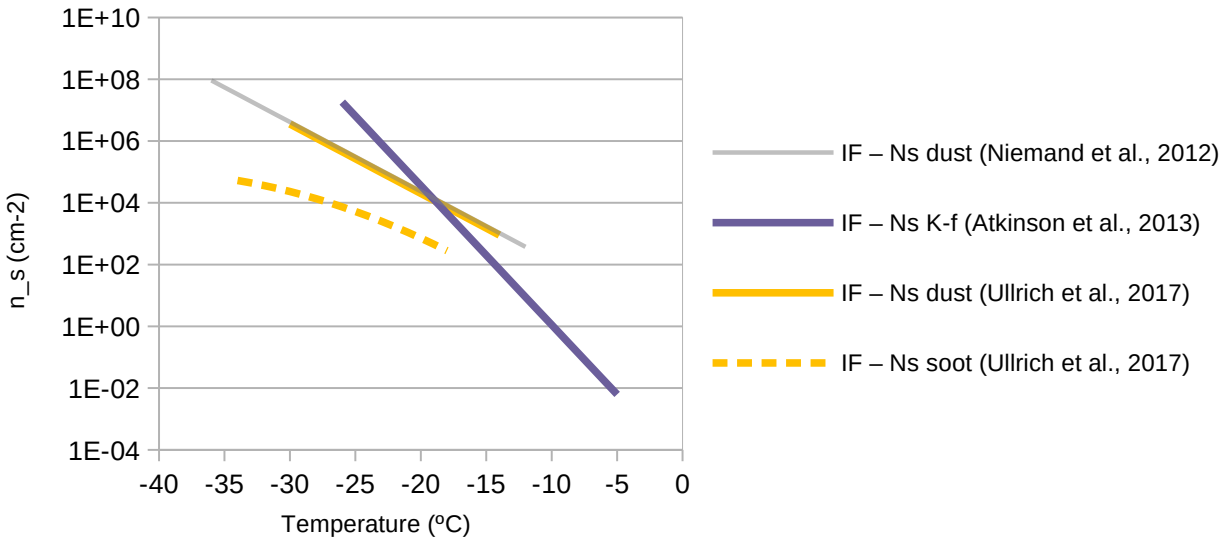
Free runs from January to June 1990, showing results for June 1990



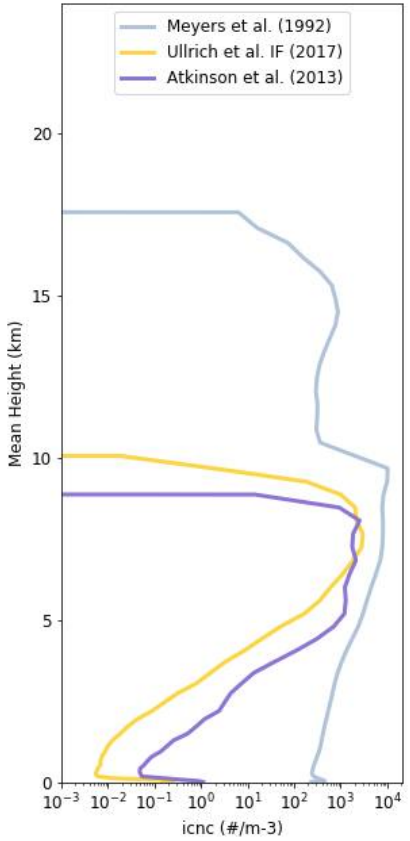
IN immersion freezing parameterizations

Atkinson et al. (2013):
- K-feldspar mass (acc. and coarse insoluble modes)
- [-25.15, -5.15] ºC
- External mixing assumption

Number of nucleation sites per unit surface area



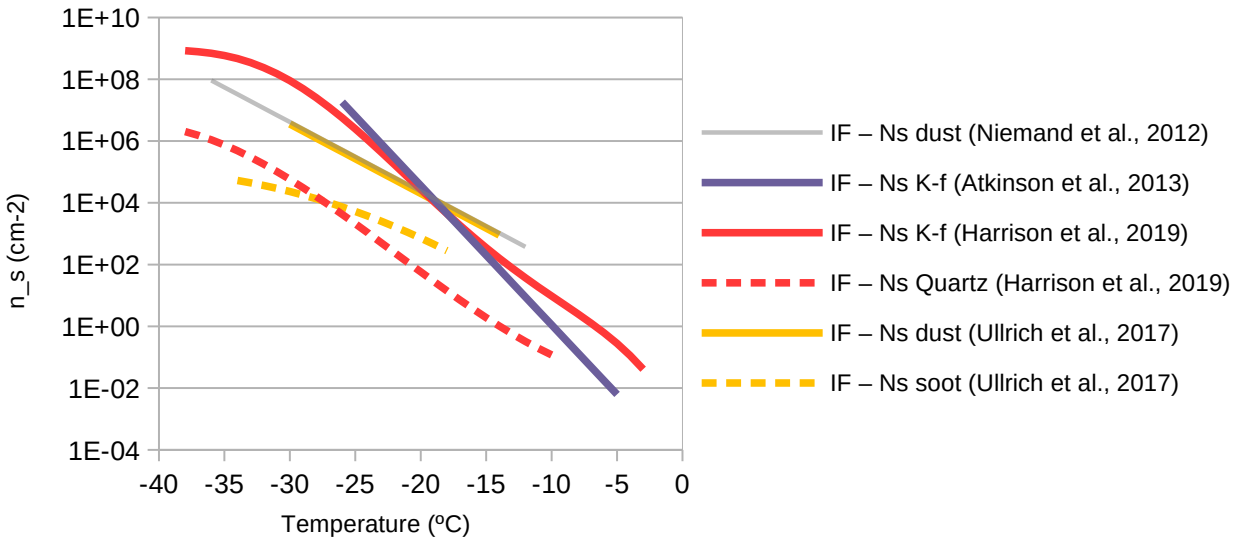
Free runs from January to June 1990, showing results for June 1990



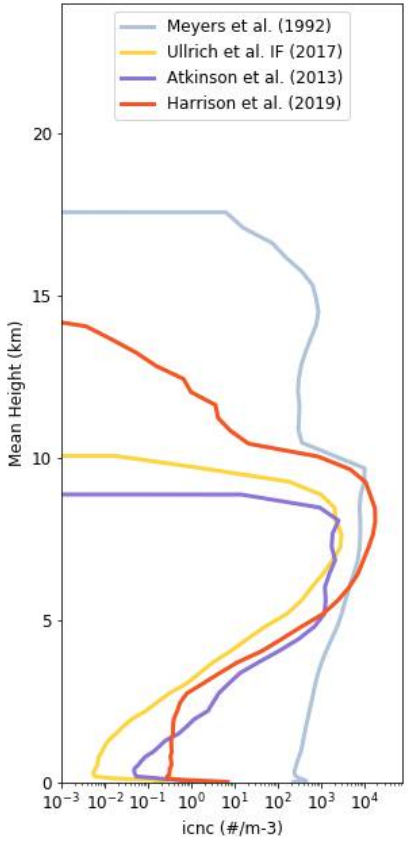
IN immersion freezing parameterizations

Harrison et al. (2019):
- K-feldspar and quartz mass (acc. and coarse insoluble modes).
- K-f: [-37.51, -3.5] ºC, quartz: [-37.51, -10.5ºC]
- External mixing assumption

Number of nucleation sites per unit surface area



Free runs from January to June 1990, showing results for June 1990



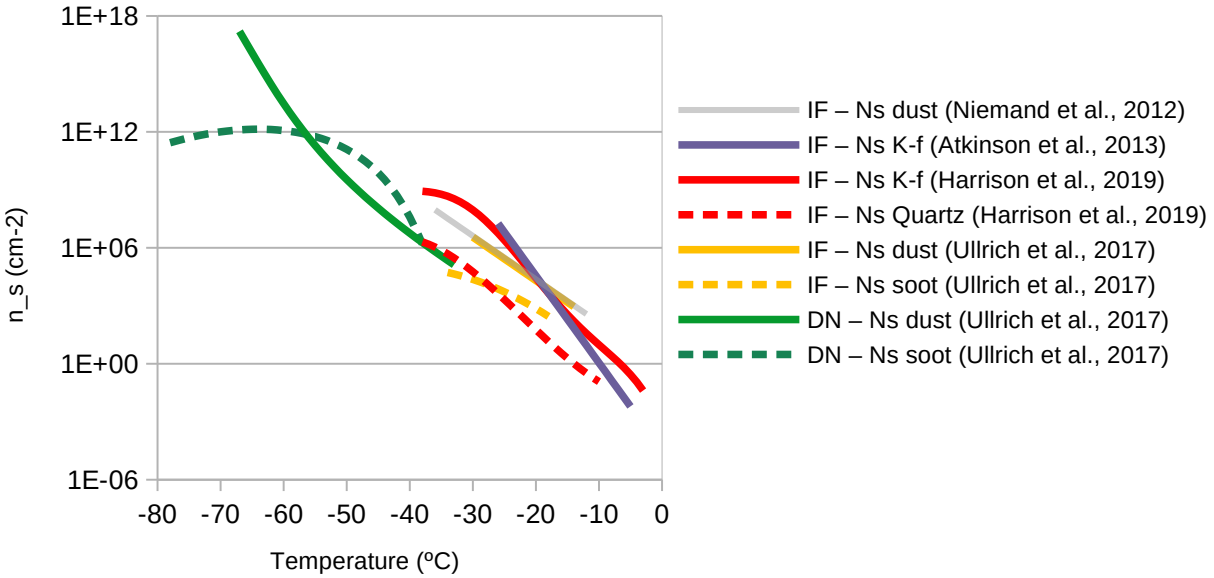
Need to take into account other processes and other aerosols, e.g.:

- For the upper levels: include Ullrich et al. (2017) **deposition nucleation** parameterization
- Include parameterization depending on immersion freezing of **marine organic aerosols**: will improve lower levels ice formation in the oceanic regions (e.g. Wilson et al., 2015) → input needed
- **Secondary ice production**

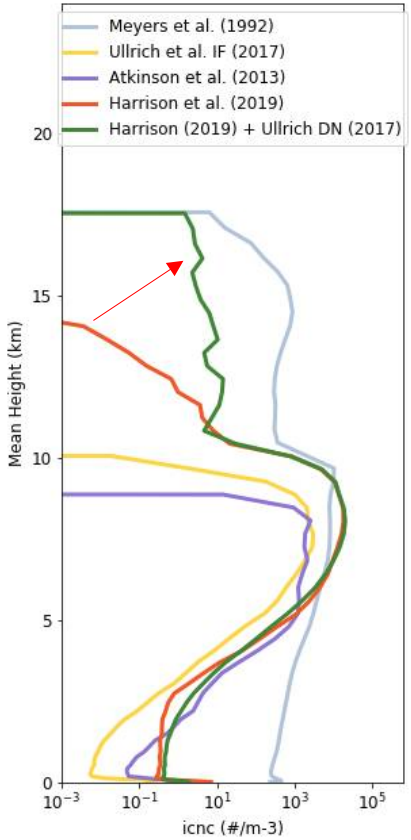
IN deposition nucleation parameterization

Ullrich et al. (2017):
- Dust (accum. and coarse soluble and insoluble), and soot mass (accum. and coarse soluble modes), and ice saturation ratio.
- Dust: [-67.15, -33.15] ºC, and soot: [-78.15, -38.15] ºC
- External mixing (insoluble) and internal mixing (soluble) assumptions.

Number of nucleation sites per unit surface area



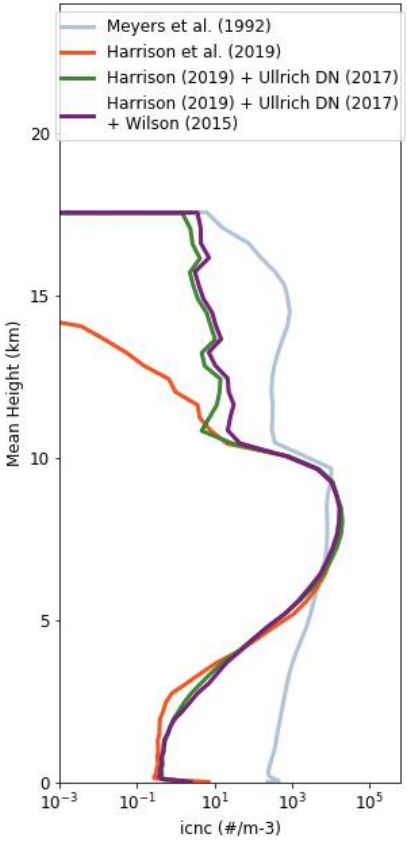
Free runs from January to June 1990, showing results for June 1990



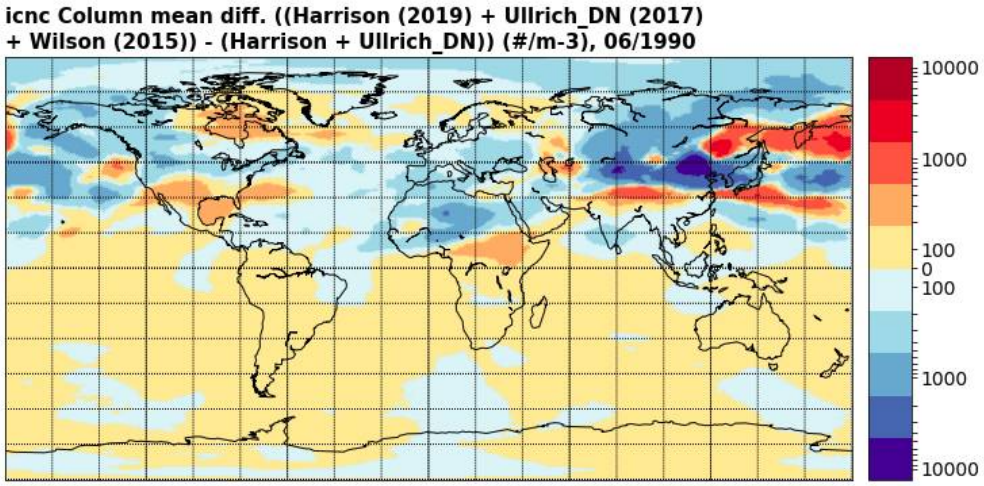
Immersion freezing of marine organic aerosols

Wilson et al. (2015):

- Marine organic aerosol particles (acc. soluble)
- [-28, -6.5] ºC



Collaboration with M. Kanakidou and M. Chatziparaschos (University of Crete/CSTACC), who parameterized the marine organic aerosols in TM5 to be used as an input to IFS.



WIP: still refining the parametrization of marine organics emission and other immersion freezing parameterizations will be tested (e.g. McKluskey et al., 2017). Also, the results will be validated with long time observations from BACCHUS and Wex (2019) data bases.

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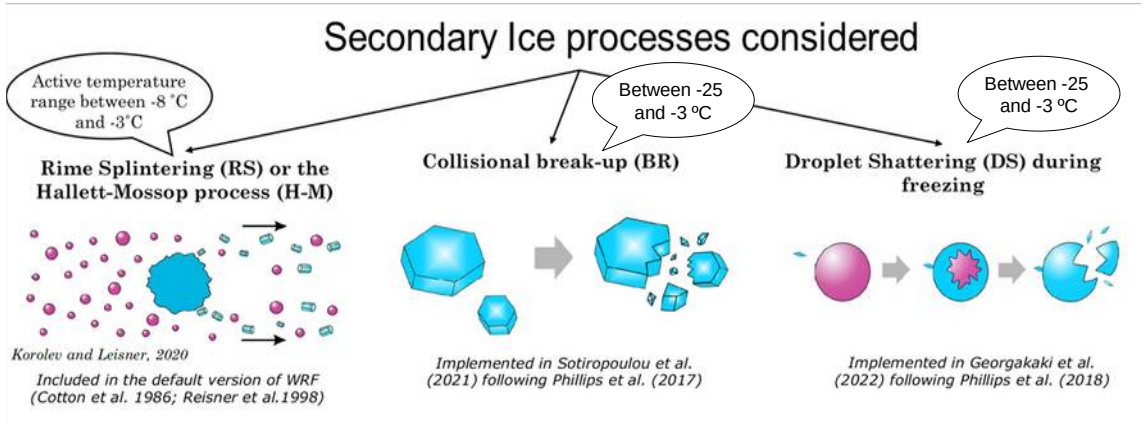
Secondary ice production

Georgakaki et al. (in prep.):
Parameterization developed from 2 years of simulation data with WRF that includes secondary ice microphysics:



The methodology has been tested in the NorESM and Polar-WRF models and now implemented in the EC-Earth3-AerChem.

Approach (developed by Georgaki et al.): multiply the primary ice in each grid cell for each time step with an **Ice Enhancement Factor (IEF)** that accounts for SIP effects.

Total ice crystal number = **Primary ice** × **Ice Enhancement Factor (IEF)**

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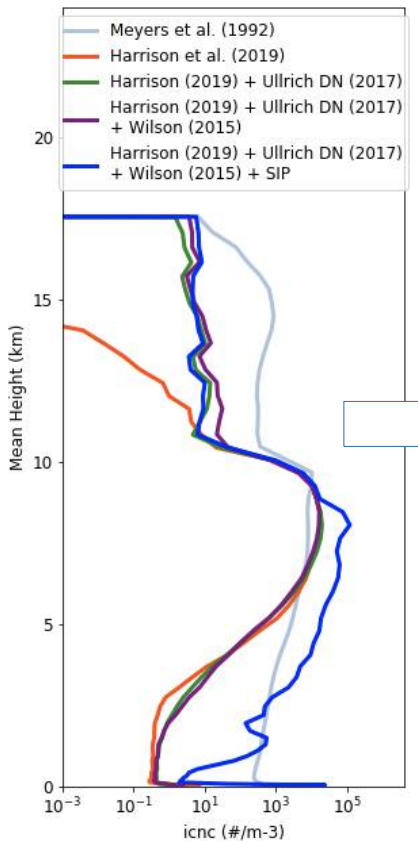
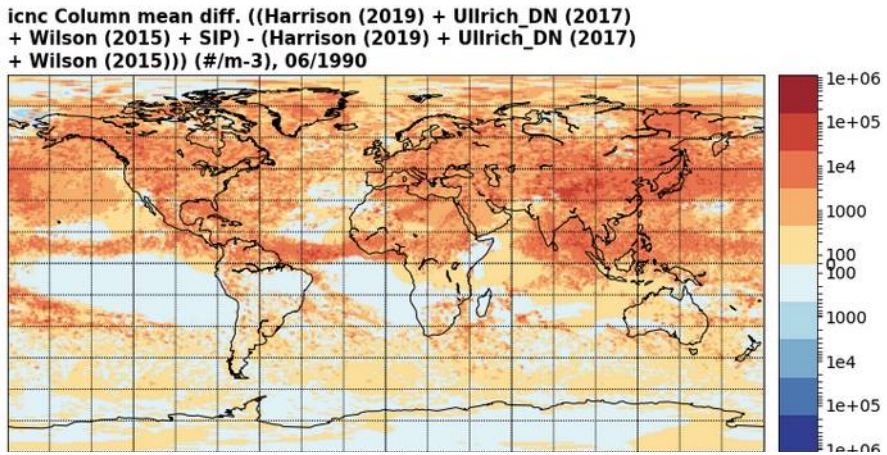
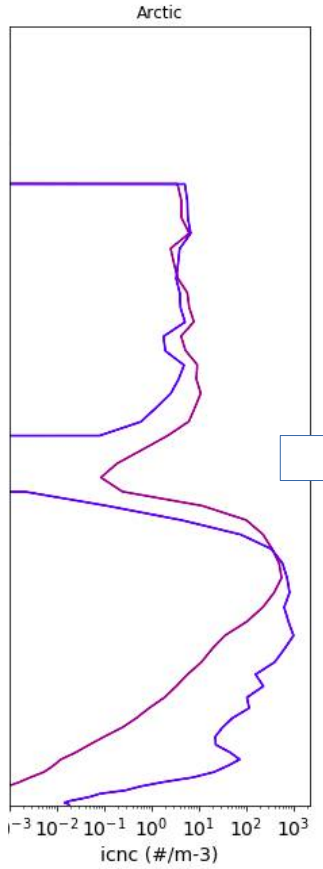
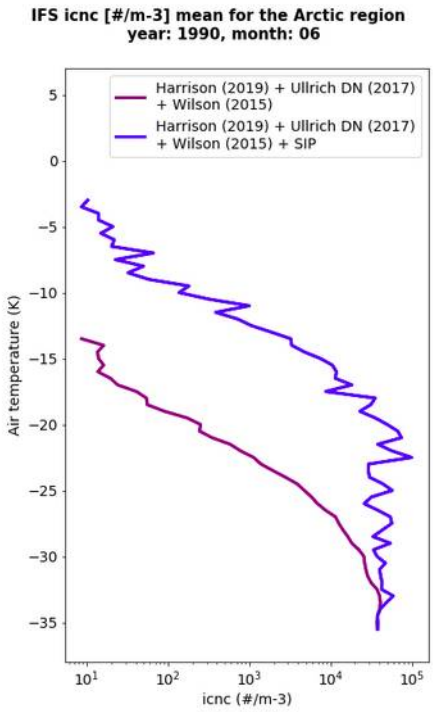
Preliminary results with SIP parameterization:







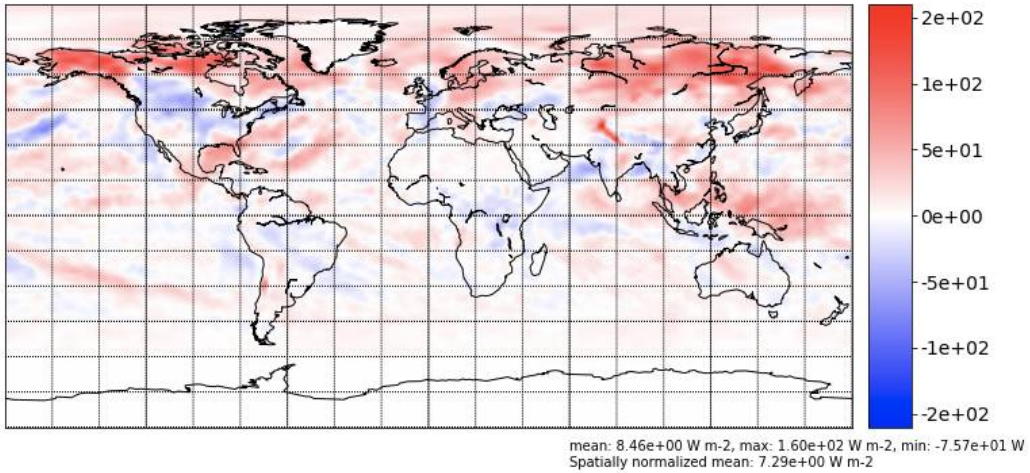


WIP: still working on SIP parametrization, final results may change

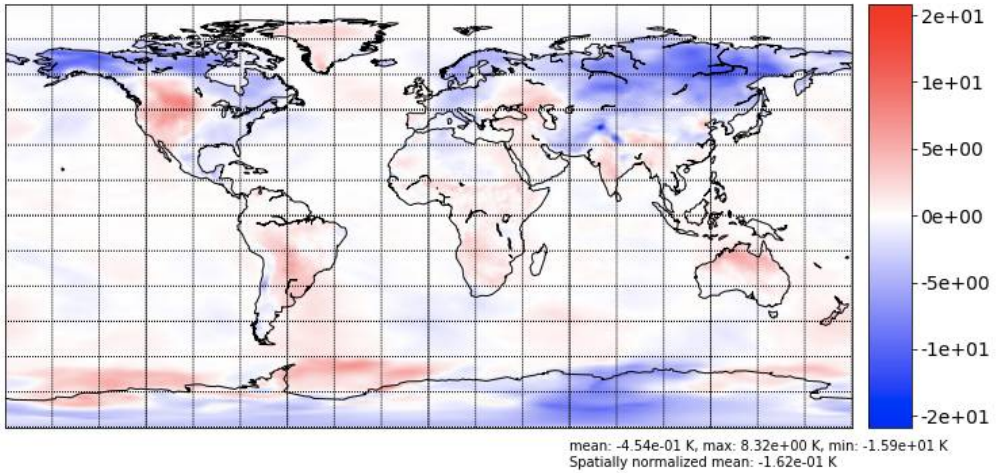
Climate imapacts:

Difference between
Aerosol dependent IN parameterization and Meyers et al. (1992)

TOA Outgoing Shortwave Radiation



Near-Surface Air Temperature



WIP: still working on the parametrizations, final results may change

Conclusions and future plans:

- Some **immersion freezing** parameterizations that have been tested show an underestimation in comparison to Meyers (Atkinson et al. (2013) and Ullrich et al. (2017)) or an overestimation (Harrison et al., 2019). We will **refine K-f proportions** of the mineralogy-dependent parameterizations and test other combinations (e.g. Atkinson et al. (2013) + Ullrich et al. DN (2917) + Wilson et al. (2015) + SIP).
- The **marine organic** aerosol parameterization that has been implemented provides more ice cristals to the SH, as expected. However, to keep improving it we will consider **other mixing assumptions** (collaboration with M. Kanakidou and M. Chatziparaschos, U. Crete/CSTACC) **and immersion freezing** parameterizations (e.g. McKluskey et al., 2017).
- The **secondary ice production** parameterization increases the ice crystal concentrations on average globally by one or two orders of magnitude, mainly below 8 km. The SIP parameterization will be tested further with other primary IN parameterizations to see its behaviour (collaboration with A. Nenes and P. Georgakaki, EPFL/CSTACC).
- We will run **longer simulations** to have robust results to analyze the cloud fields, radiative variables, etc.

The aerosol-dependent implementation will be integrated into the **EC-Earth3-FORCeS** version together with other groups' developments to improve the aerosol forcing representation.

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FORCeS

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