Ice nucleation ability of mineral dust particles mixed with biological substances

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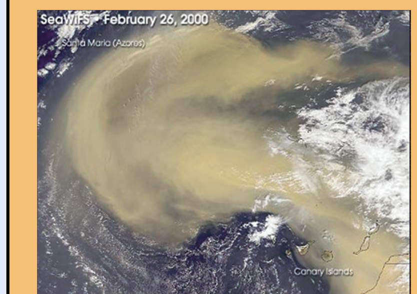
Introduction – mineral dust and biological ice nuclei (IN)

Mineral Dust

- Mineral dust is **thought to be the most abundant and thus the most important IN** in the atmosphere (Murray et al., 2012)
- **Ice nucleating active sites on the surface** of the dust particles catalyze freezing
- **The larger the particle surface, the higher the chance to have an active site**
- Observed freezing temperatures: < -20° C (Reviews by Murray et al., 2012 and Hoose and Möhler, 2012, Atkinson et al., 2013)



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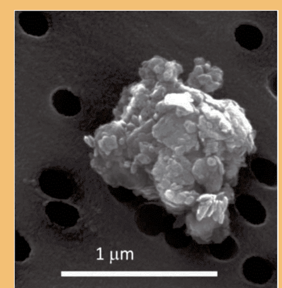
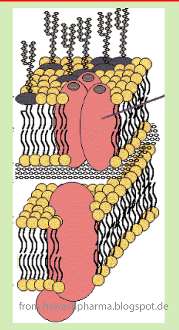


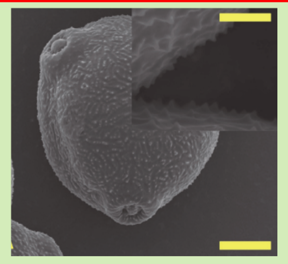
large illite particle Hoffmann et al., 2013

Biological IN

- **Atmospheric relevance was expected to be rather low** because of their small number (Hoose et al., 2010)
- Freezing is induced by small single **ice nucleating active (INA) macromolecules** (around 20 nm) e.g. proteins (bacteria, fungi) or sugars (pollen) (e.g. Wolber et al., 1986, Pummer et al., 2012)
- Very efficient IN (Maki et al. (1974) observed **freezing at -2° C**)
- Still ice **active if original carrier** (e.g. bacteria or pollen grain) **is detached or already dead** (Pummer et al. (2012), Hartmann et al. (2013), Augustin et al., 2013)

Pseudomonas syringae, foto by G. Vrdoljak, U.C. Berkeley



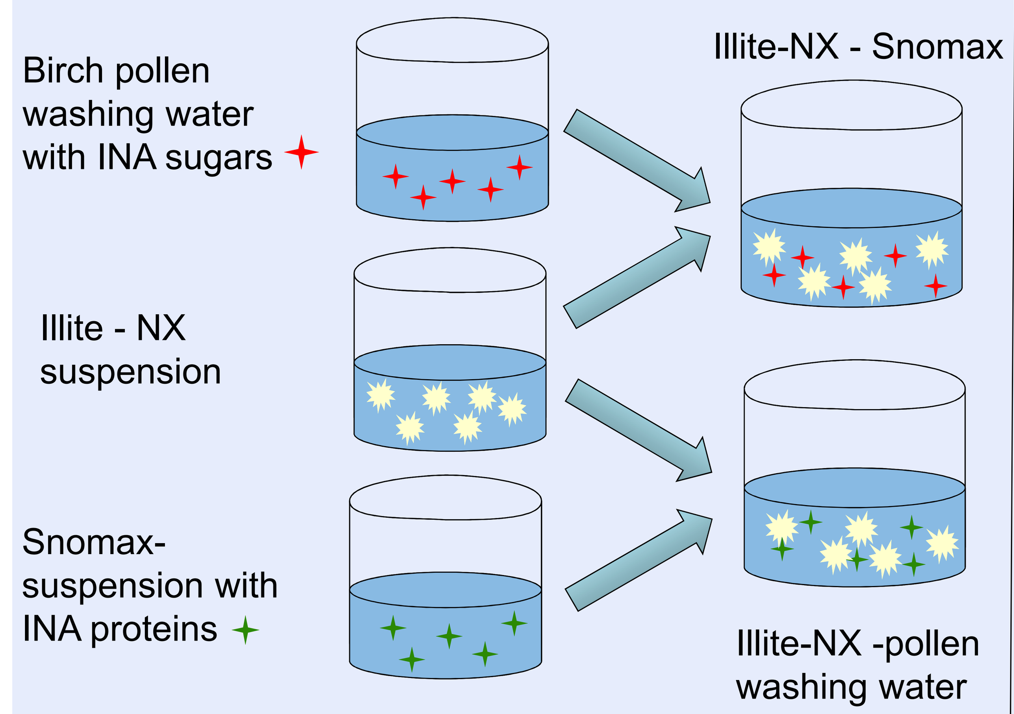


Birch pollen grain, Pummer et al. , 2012

- **Up to now this fact is not considered in atmospheric models**
- **There might be a lot of ice active submicron particles, which have a much longer residence time in the atmosphere than their original carriers**
- **They may accumulate in the ground and come in contact with other particles**
- **Mineral dust particles may act as "inert" carriers for biological material (Schnell and Vali, 1976)**
- **Soil/natural dusts are more efficient ice nuclei than pure dust, biological residues may be the reason for that (Conen et al., 2011, Sullivan et al., 2013)**

Methods

Mixing a suspension of illite-NX with either birch pollen washing water or Snomax-suspension



Leipzig Aerosol Cloud Interaction Simulator (LACIS)

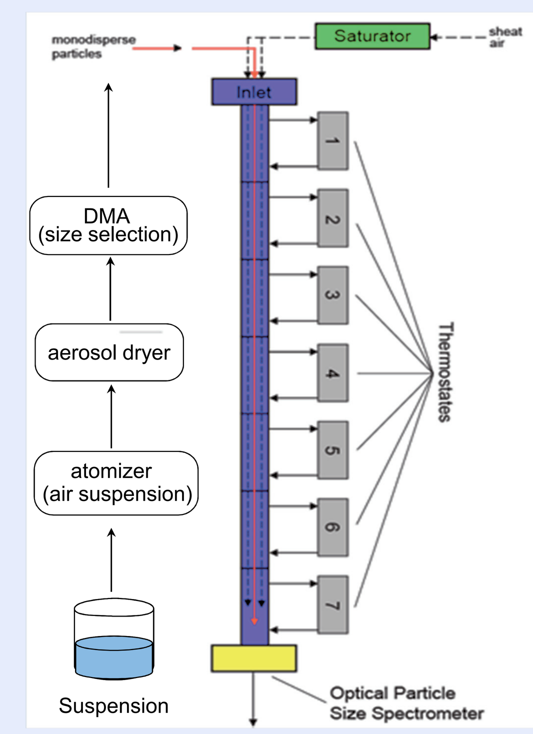
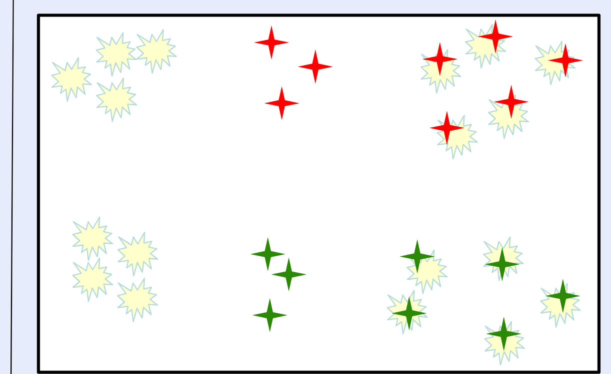
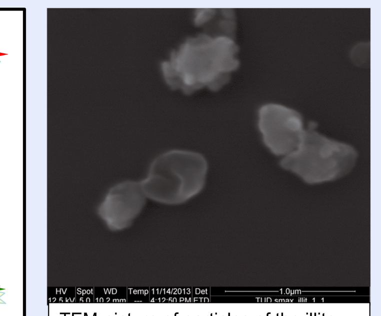


Fig.1: LACIS, Stratmann et al., 2004, Hartmann et al., 2011.

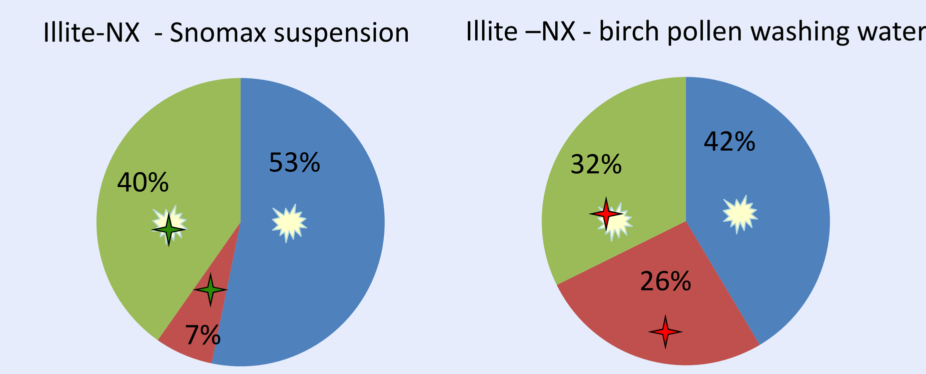
Characterizing the particles





TEM-picture of particles of the illite-SNOMAX suspension

Single particle mass spectrometry – SPLAT



Results I - Measurements

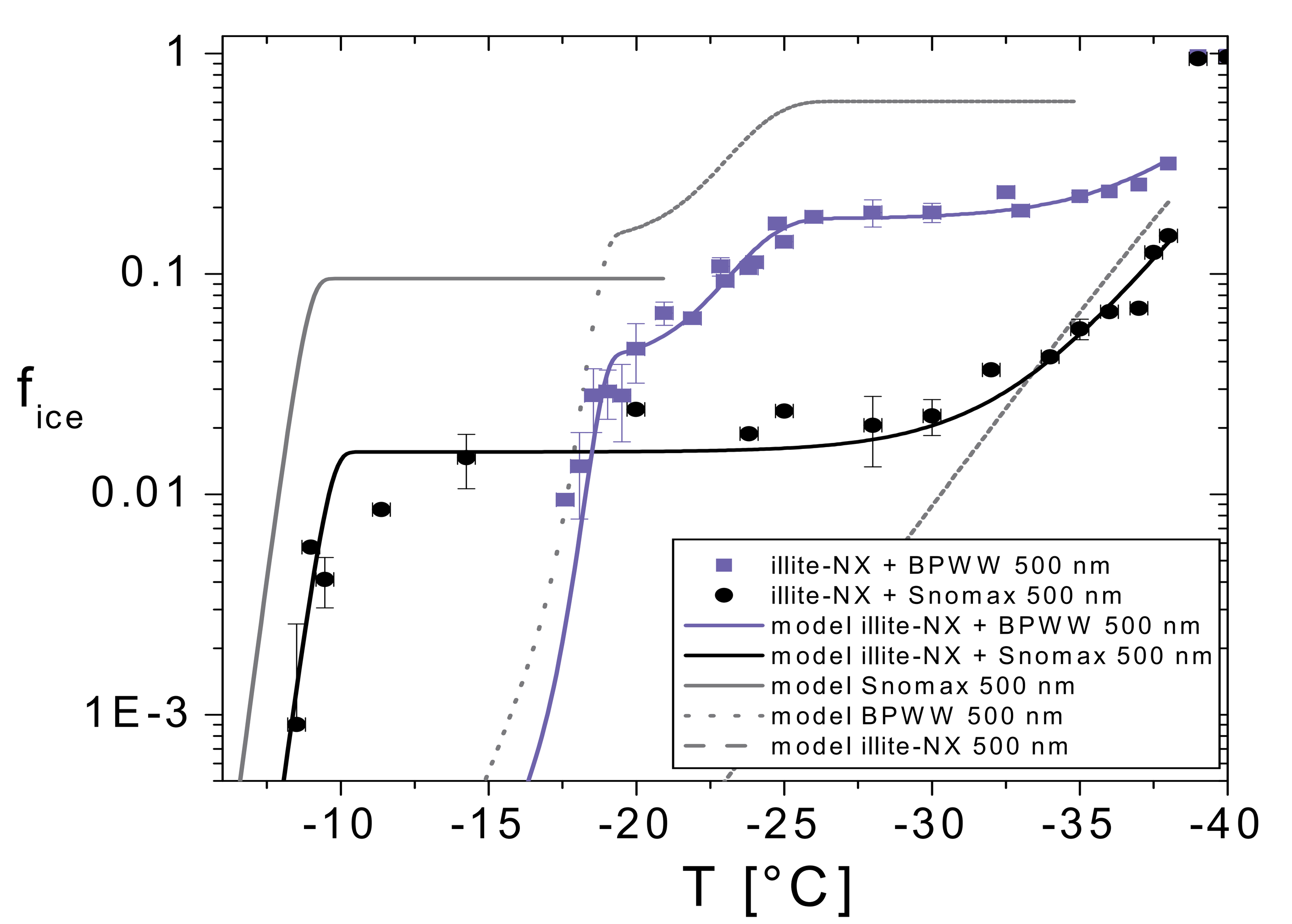


Fig.2: Results of the Immersion freezing experiments of the illit-NX-Snomax (black) and the illite-NX-pollen washing water (blue) mixtures. The modeled ice fractions of the dust bio mixtures are plotted as black and blue lines (Eq.1). Additionally, parameterizations derived from nucleation rates determined in former measurements considering pure substances are shown as grey lines.

Results II – Parameterization

1. **Combining the three present particle types taking into account the determined mixing state** ($A1$, $A2$ and $A3$ symbolize the amount of pure illite-NX, pure pollen washing water and internally mixed particles, respectively, determined with mass spectrometry)

$$
\begin{aligned}
f_{ice} = &\ A1 \cdot [1-\exp(S_{site} j_{het}(illite)\ t)] \\
&+ A2 \cdot [1-\exp(-\lambda\cdot(1-\exp(J_{het}(bio)\ t)))] \\
&+ A3 \cdot [1-(\exp(S_{site} j_{het}(illite)\ t)\cdot\exp(-\lambda\cdot(1-\exp(J_{het}(bio)\ t))))]
\end{aligned}
\quad \text{(Eq.1)}
$$

2. **Using known parameters from former investigations**

$J_{het}(bio)$ nucleation rate of the biological particles (Hartmann et al., 2013 for SNOMAX, Augustin et al., 2013 for birch pollen washing water)

$j_{het}(illite)$ nucleation rate coefficient of illite-NX (unpublished)

3. **Correct the data to account for the internally mixed particles only**

$$
\begin{aligned}
f_{ice} &- A1 \cdot [1-\exp(S_{site} j_{het}(illite)\ t)] \\
&- A2 \cdot [1-\exp(-\lambda\cdot(1-\exp(J_{het}(bio)\ t)))] \\
&\boxed{= A3 \cdot [1-(\exp(S_{site} j_{het}(illite)\ t)\cdot\exp(-\lambda\cdot(1-\exp(J_{het}(bio)\ t))))]}
\end{aligned}
\quad \text{(Eq.2)}
$$

Results III – Internally mixed particles

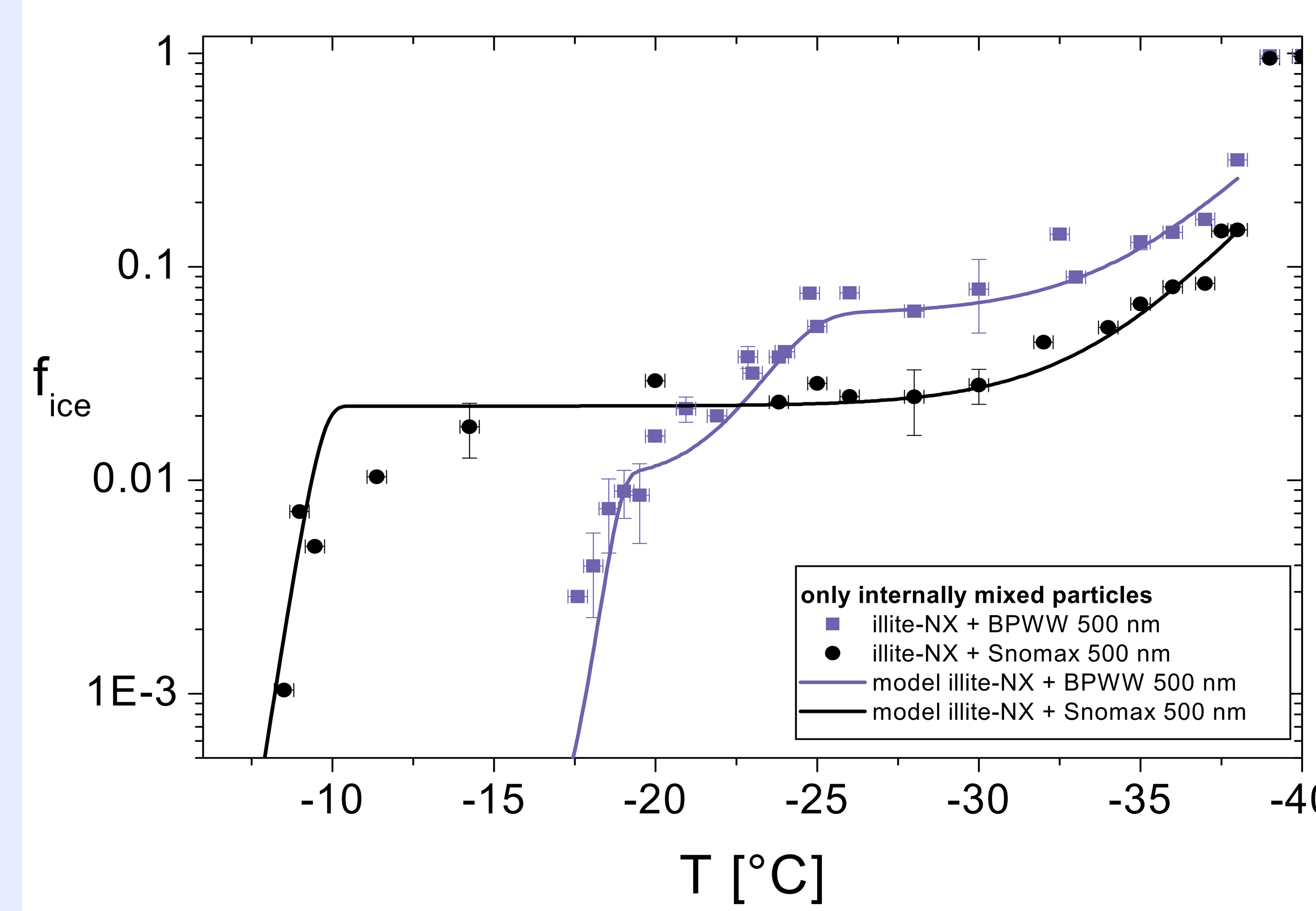


Fig.3: Results concerning the immersion freezing behavior of the internally mixed particles only: black: illit-NX-Snomax mixture and blue: illite-NX-pollen washing water mixtures. The modeled ice fractions of the dust bio mixtures are plotted as black and blue lines.

Summary and Conclusion

- **Biological IN (macromolecules) can retain their ice activity** detached from their original carrier or if their carrier is non-vial → possible accumulation in soils and in the atmosphere
- **Mineral dust particles may act as "inert" carriers of biological substances** which may be ice nucleating active → how does such a particle behave in terms of ice nucleation?
- We produced mixtures of illite-NX with either SNOMAX (INA proteins) or birch pollen washing water (INA sugars) → **mixed aerosol consisting of pure NX-illite, pure biological and internally mixed particles.**
- **LACIS freezing experiments could be consistently described based on measured mixing states and experimentally determined single component nucleation rates for the single substances.**
- **Internally mixed** particles showed nearly the **same freezing behavior as pure biological particles**

→Dust-bio-mixtures should be treated like biological particles

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