BIOAEROSOLS AND BIOLOGICAL INP IN THE ARCTIC

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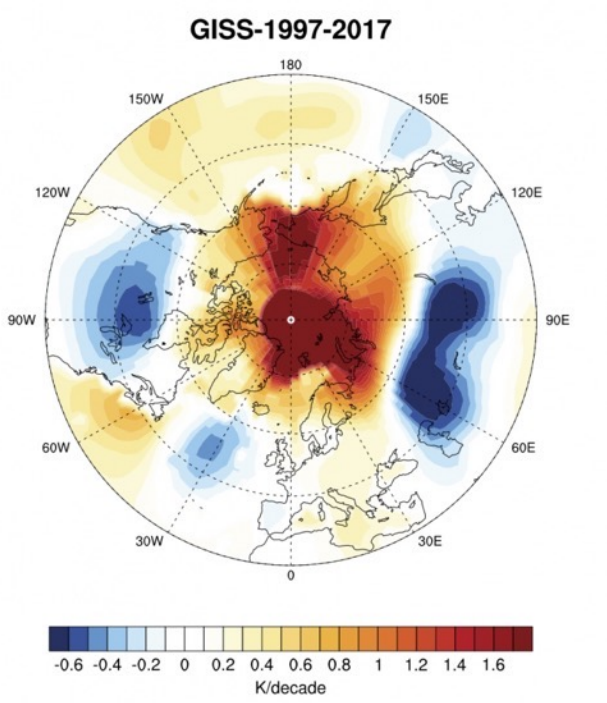
STELLAR ASTROPHYSICS CENTRE

THE ARCTIC – AN AREA OF PARTICULAR INTEREST FOR BIOAEROSOL RESEARCH

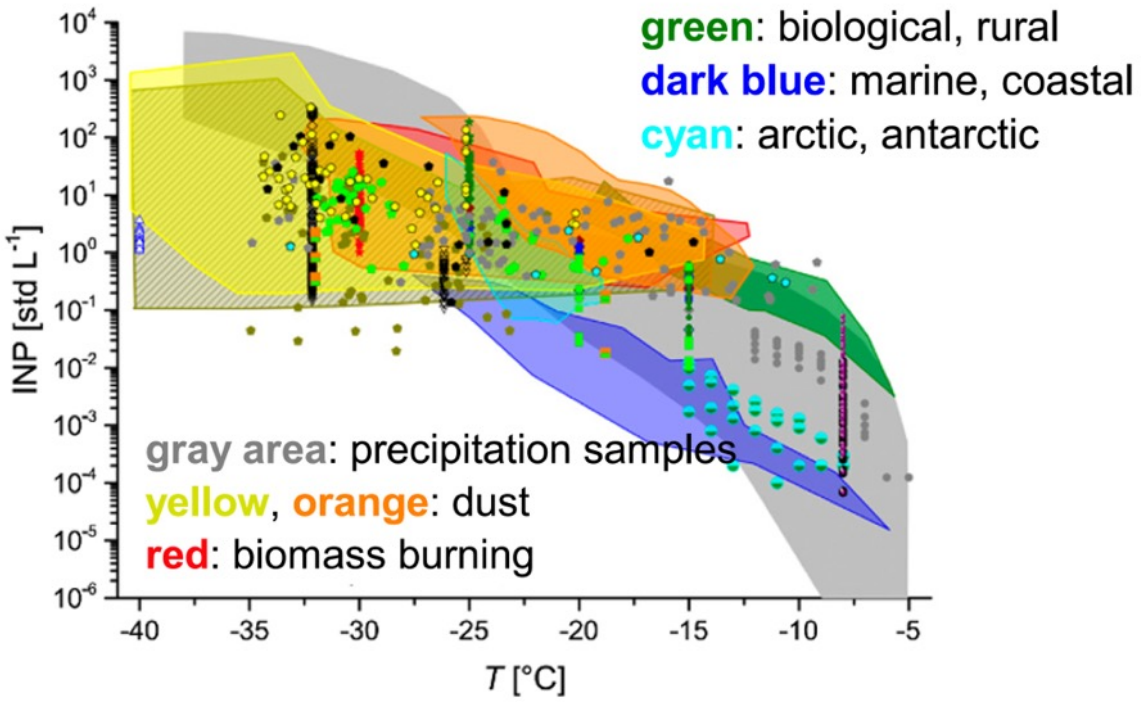
Accelerated warming



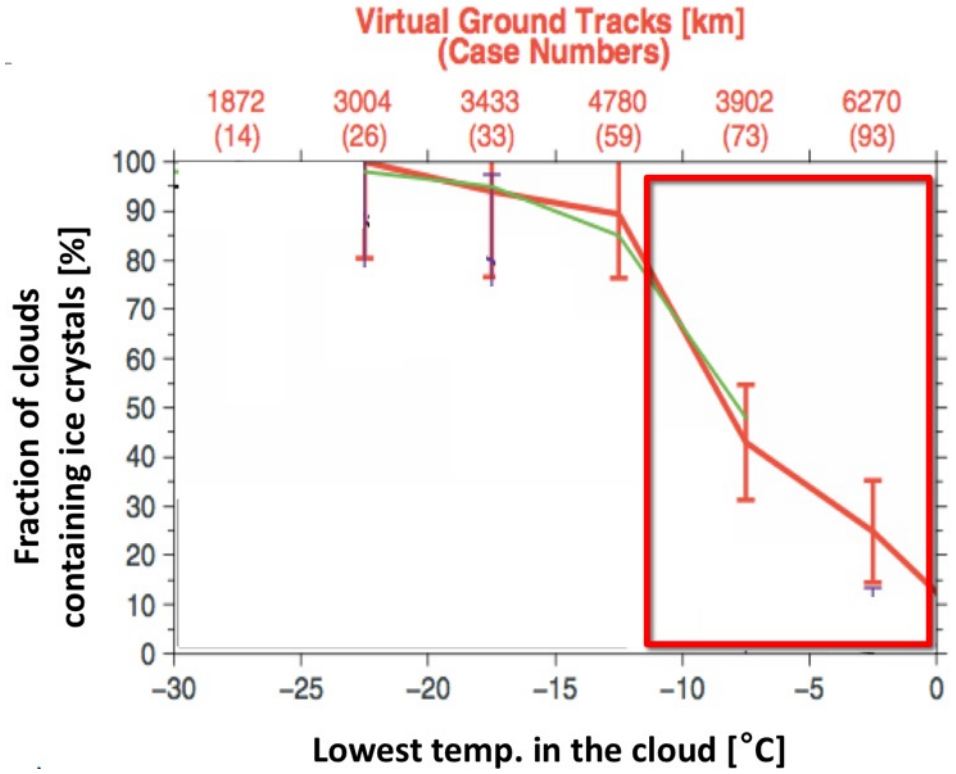
Melting processes and climate feedbacks

Šantl-Temkiv et al. (2020) AST.

PROTEINACEOUS INP AND CLOUDS

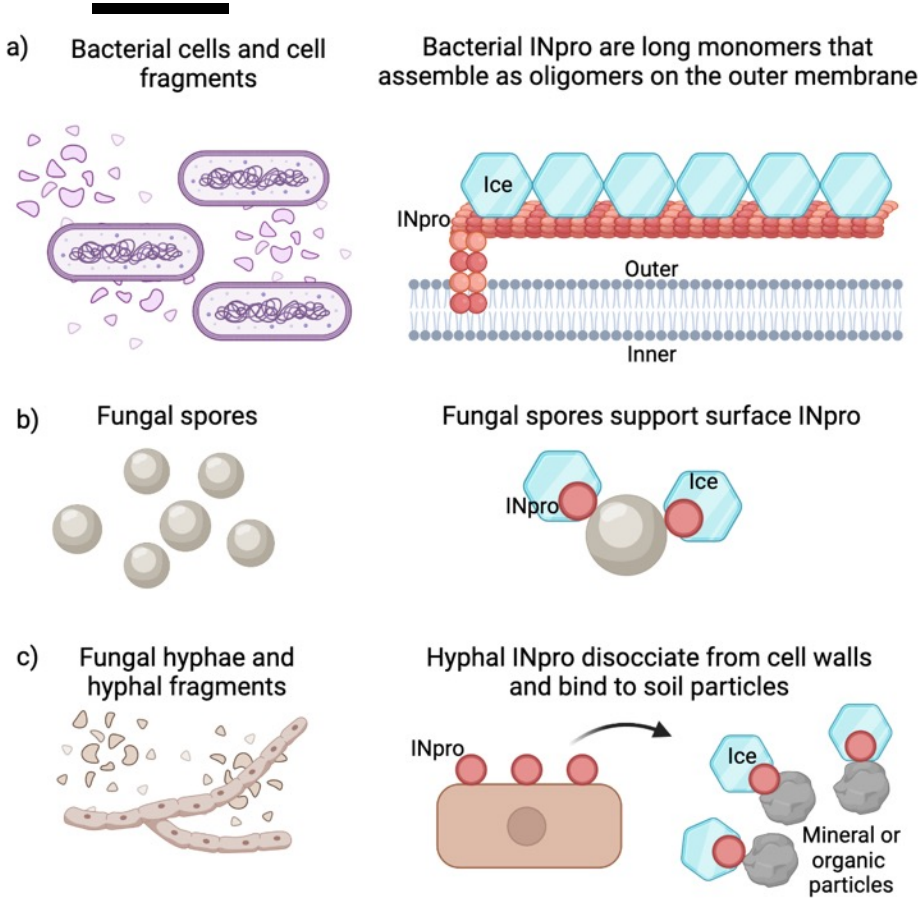


Adapted from Kanji et al. (2017), Meteorological Monographs

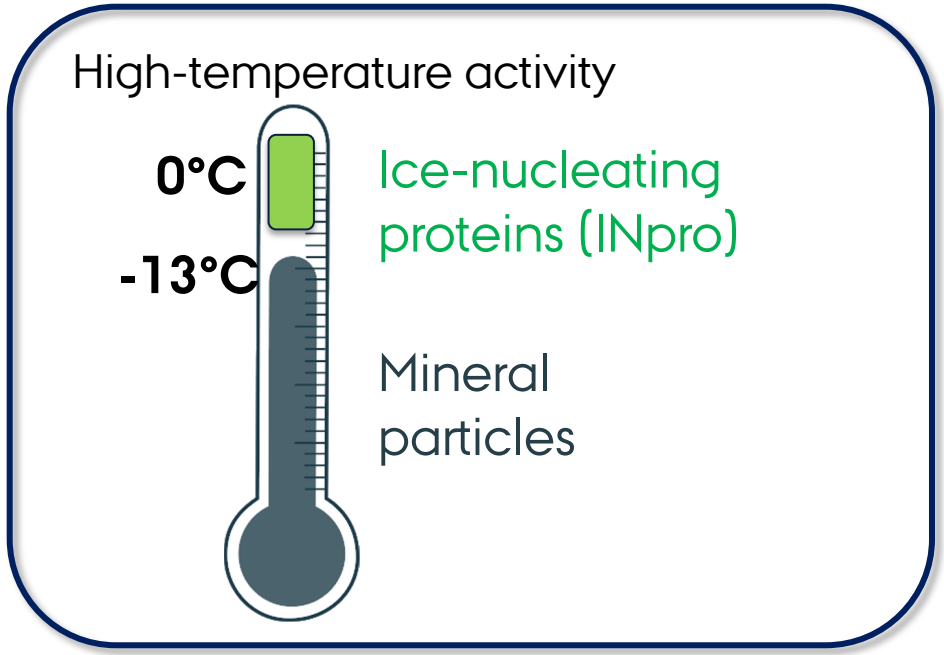


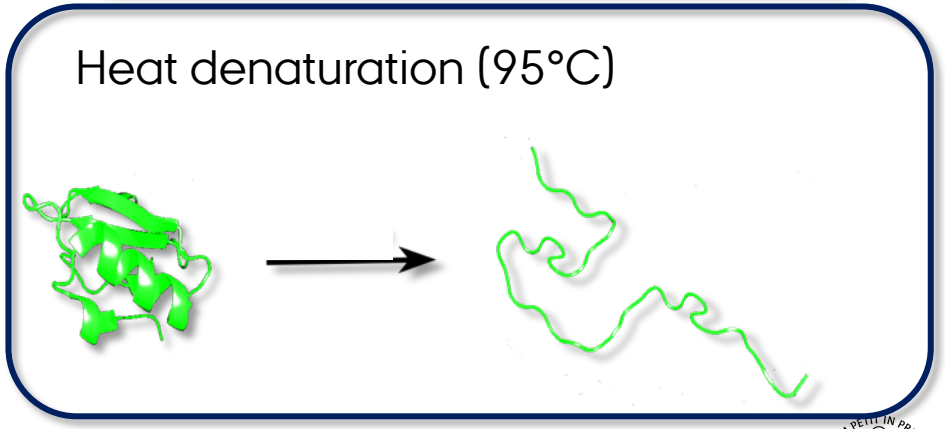
Adapted from Bühl et al (2013), GRL

ICE NUCLEATING BIOAEROSOLS

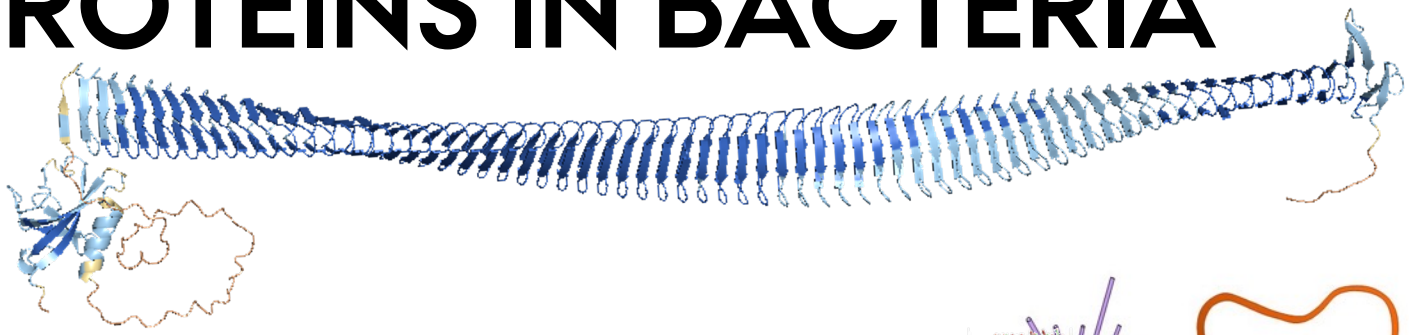


Šantl-Temkiv T, Amato P, Casamayor E, Lee P and Pointing S (in review), FEMS Reviews

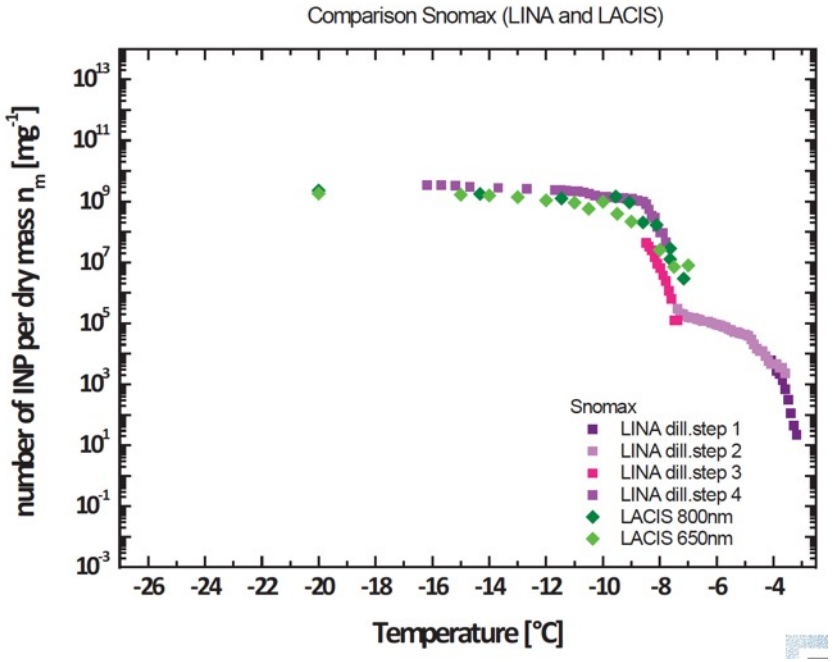


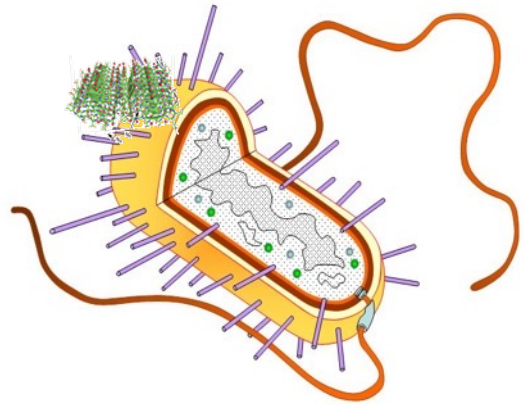


ICE-NUCLEATING PROTEINS IN BACTERIA



- Very large proteins encoded by a single *ina* gene
- Protein sequence is known, but little understanding of the structure
- Central repeat domain: "16-amino acid repeats" 50-80
- Associated with membrane
- INprot forms oligomers –> nucleation temperature

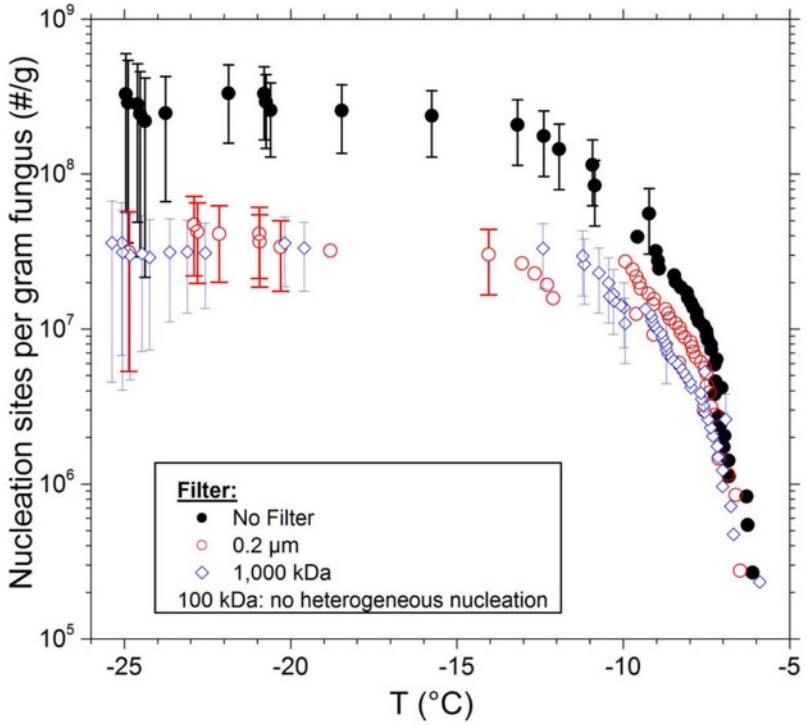


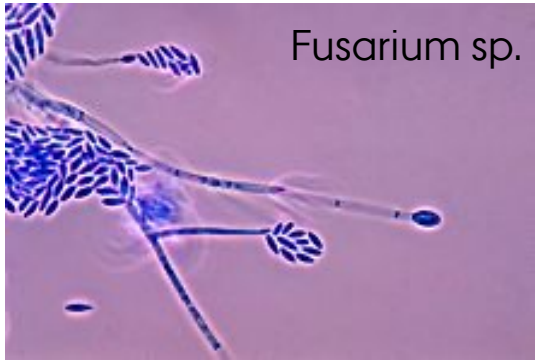


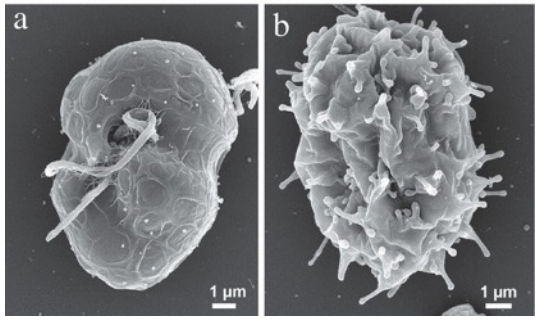
Wex et al. (2015), ACP.
Hartmann S, Ling M, **Dreyer LSE,** Zipori A, (...), Wex H, Rudich Y, **Boesen T,** and Šantl-Temkiv T (in preparation).

ICE-NUCLEATING PROTEINS IN FUNGI AND MICOALGAE

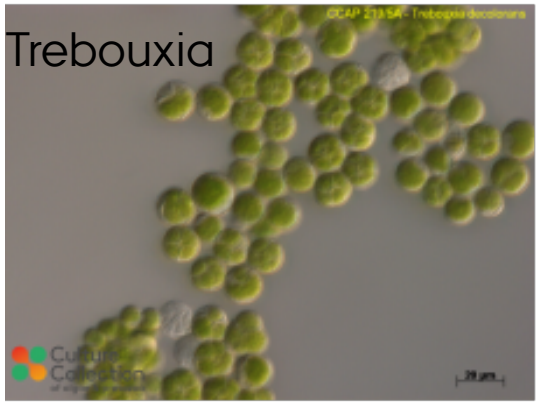
- Different types of terrestrial and aquatic microorganisms
- Genes are not known
- Proteinaceous INP, that often gets secreted into the environment







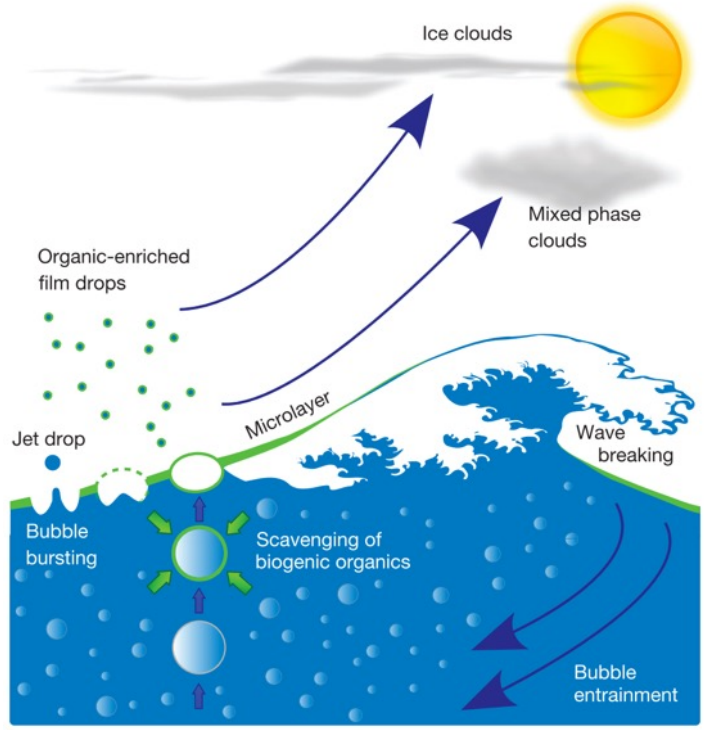
Polarella glacialis

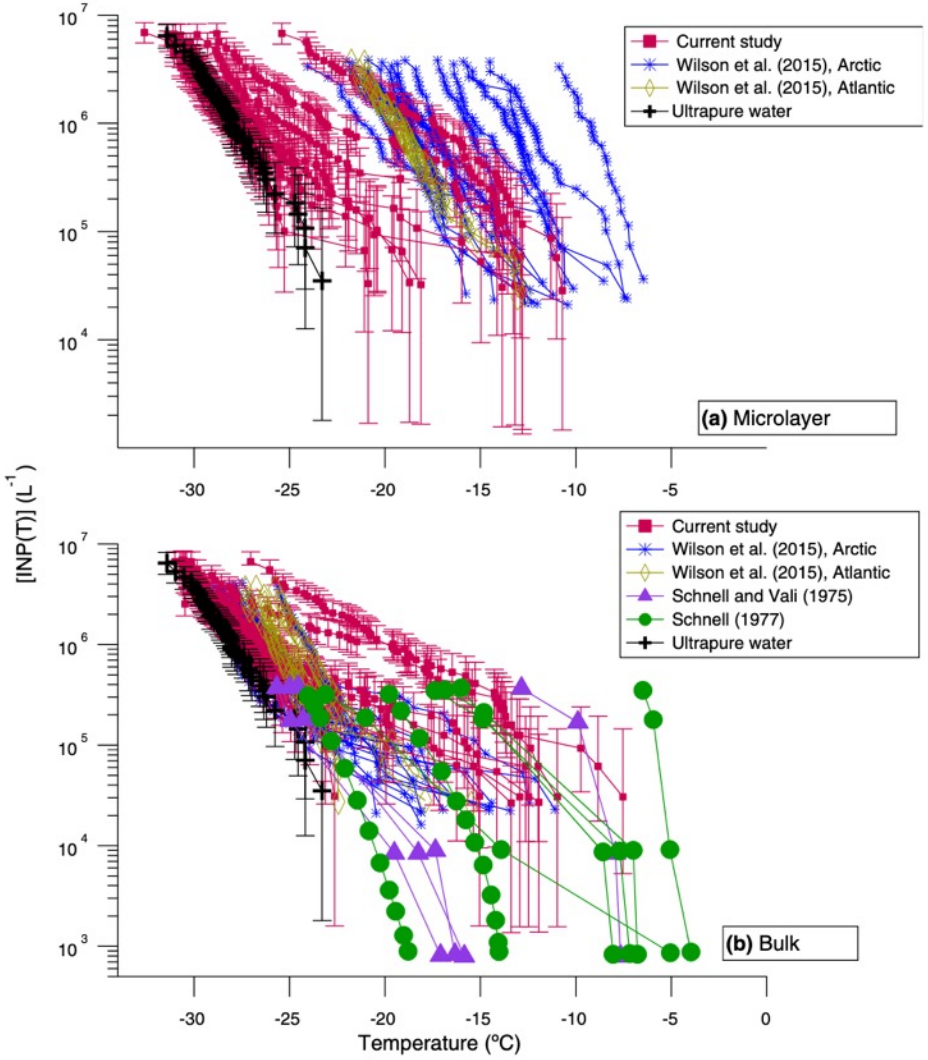


Pouleur S at al. (1992) Appl Envir Microbiol
Fröhlich-Nowoisky J et a (2015) Biogeosciences.
O'Sullivan et al (2015)
Tesson S and Šantl-Temkiv T (2018) Frontiers in Microbiology

PROTEINACEOUS INP IN THE ARCTIC

Marine environments

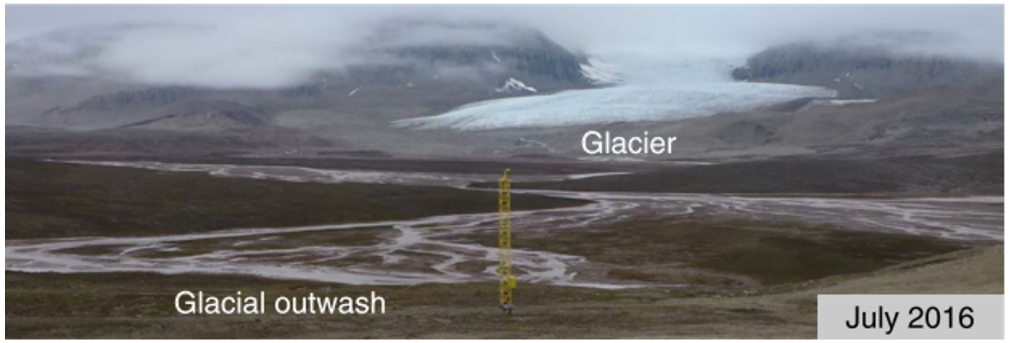


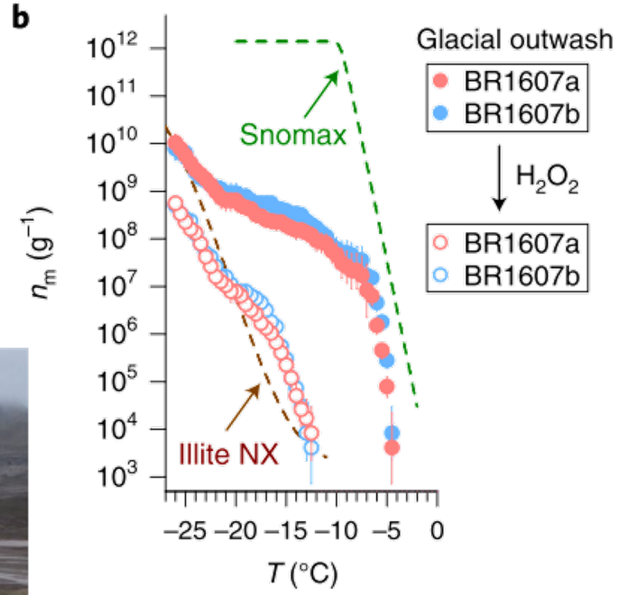


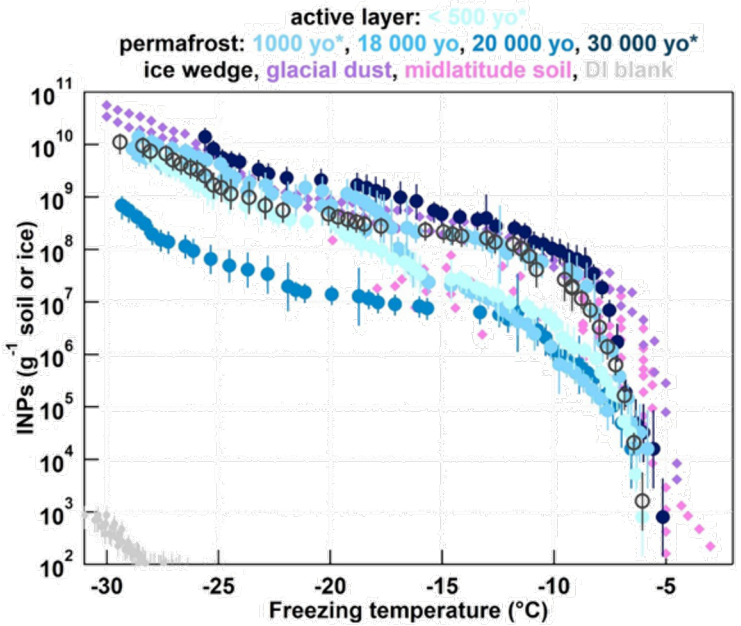
Wilson TW et al (2015). Nature.
Irish et al (2017 and 2018). ACP

PROTEINACEOUS INP IN THE ARCTIC

Terrestrial environments





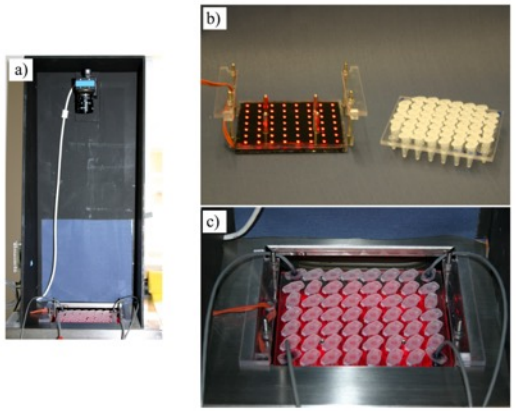


Conen et al (2016) Atmospheric Environment.
Tobo Y et al (2019). Nat Geosci.
Creamean et al (2020) Environ Res Lett.

SAMPLE ANALYSIS

Sample analysis

INP Quantification: Droplet-freezing assays

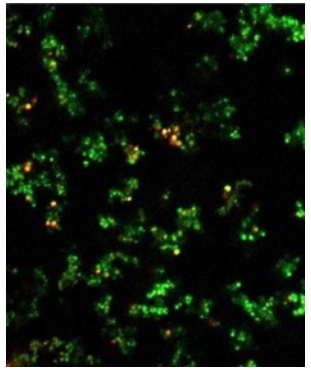


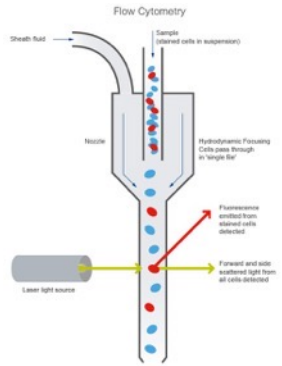
Cell quantification

DNA staining

Fluorescent microscopy

Flow cytometry





DNA/RNA co-extraction

Quantification of specific microbial groups

Library Preparation

Barcoding and mixing with other samples

Sequencing

Illumina MiSeq
~4*10^7 reads of 300bp/run
Accurate (99.9%) reads

TROPOS

University of Basel

BIOLOGICAL INP IN THE HIGH ARCTIC

Villum Research Station, Station Nord:

Super-site: infrastructure for studying atmospheric processes in the high Arctic.

Sample collection during 3 campaigns spanning over 71 days:

—15 fresh surface snow samples and

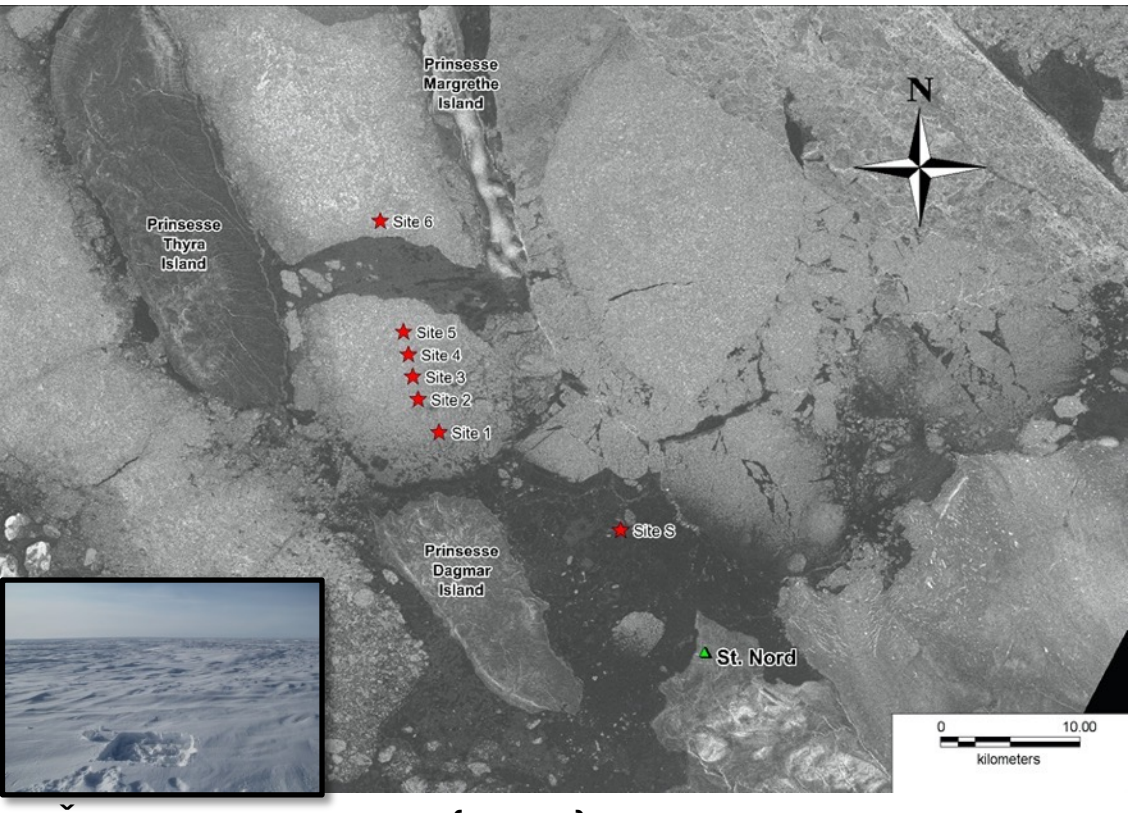
—51 air samples

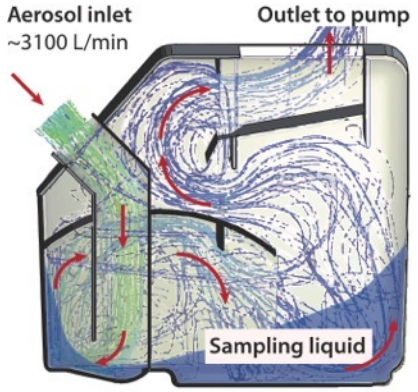
Apr – May 2015, Apr, Aug 2016

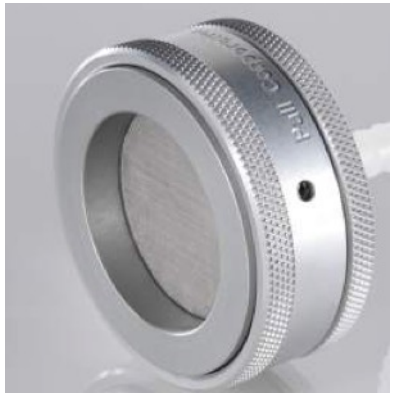
Šantl-Temkiv et al. (2019) EST.

BIOLOGICAL INP IN THE HIGH ARCTIC

Sample collection

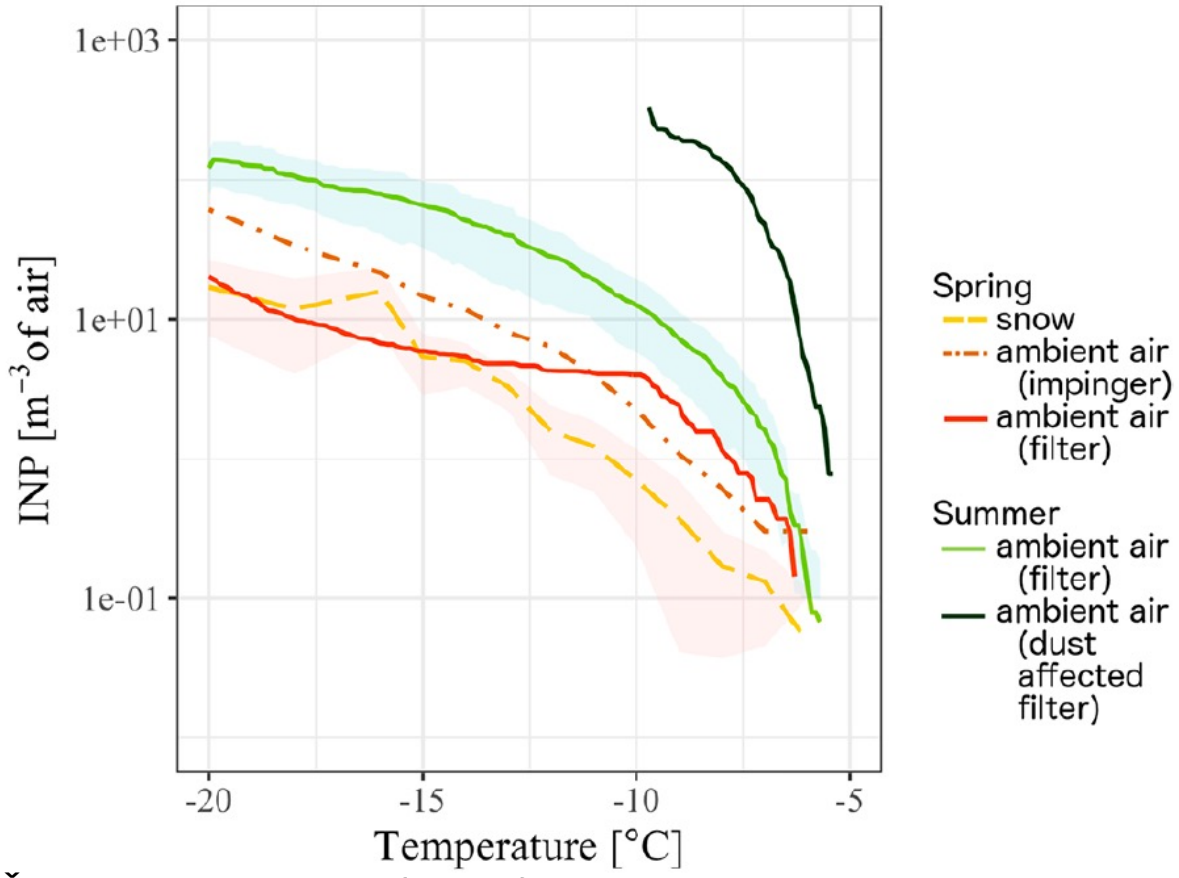






Šantl-Temkiv et al. (2019) EST.

BIOLOGICAL INP IN THE HIGH ARCTIC



Šantl-Temkiv et al. (2019) EST.

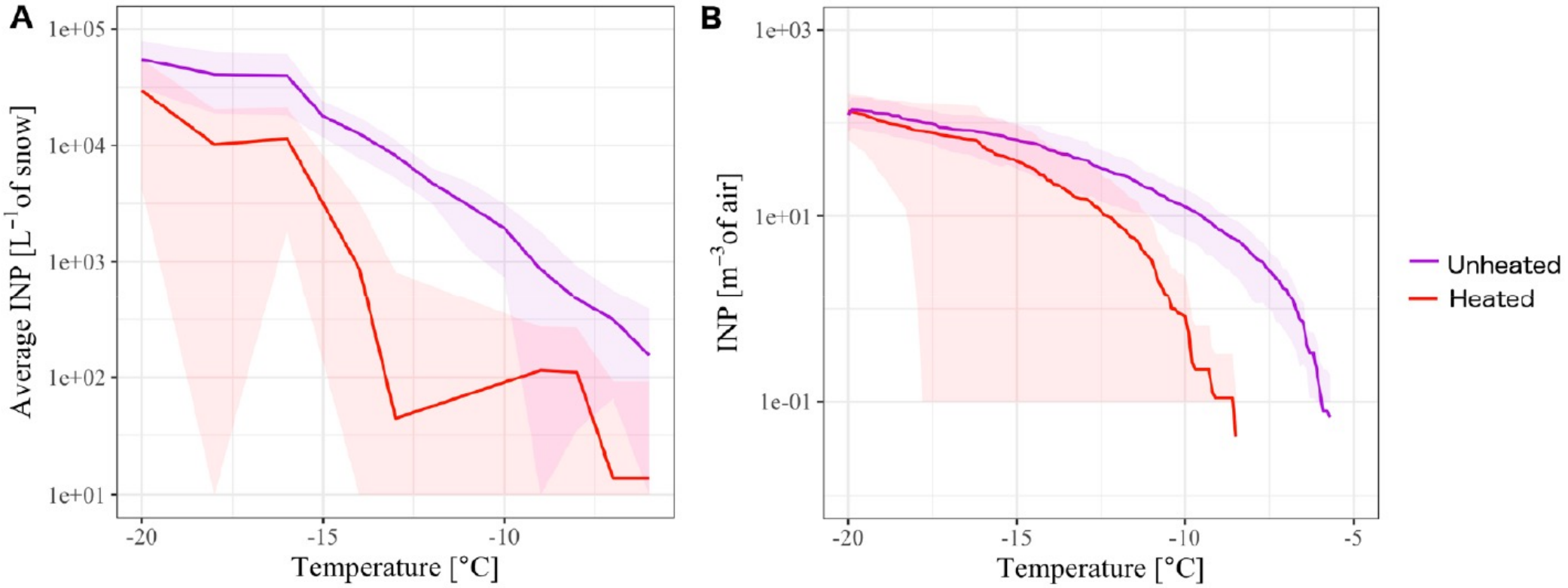
- Summer air concentrations were estimated from filter samples
- Spring air concentrations on filter samples were bellow the detection limit –> max value was determined
- Spring air concentration calculated from snow concentrations (liquid water content of 0.4 g m^{-3}, Petters and Wright, 2015)

TROPOS

BIOLOGICAL INP IN THE HIGH ARCTIC

Spring: snow samples

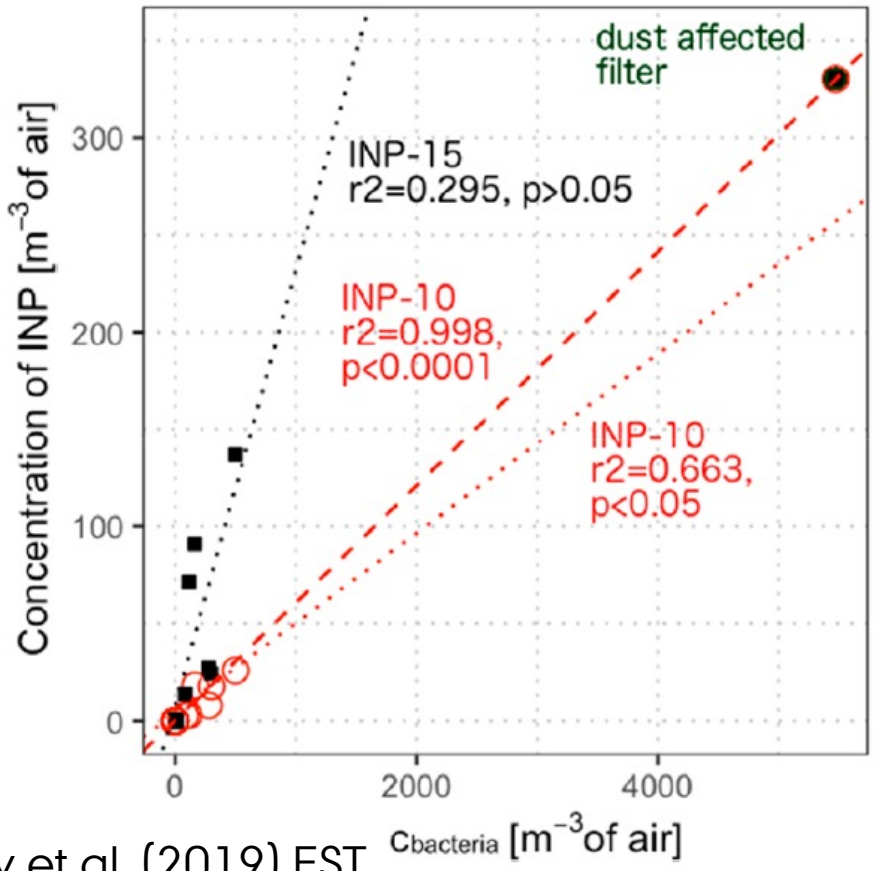
Summer: filter samples



Šantl-Temkiv et al. (2019) EST.

BIOLOGICAL INP IN THE HIGH ARCTIC

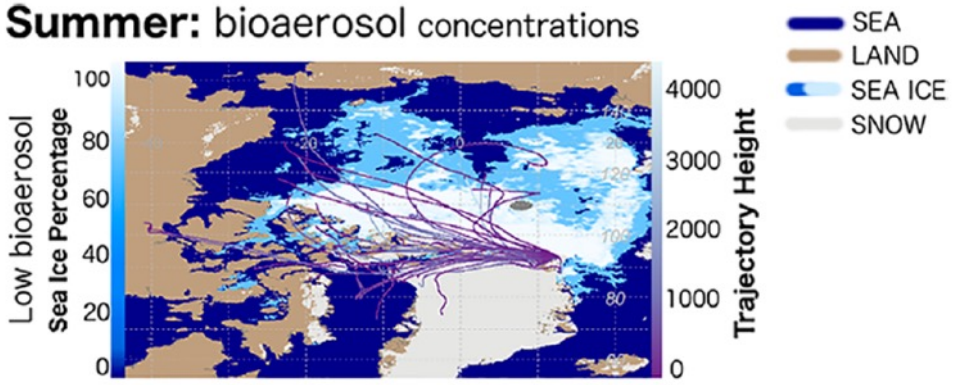
Summer: filter samples

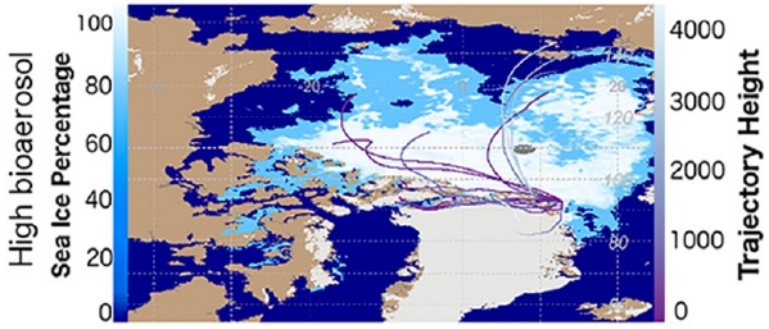


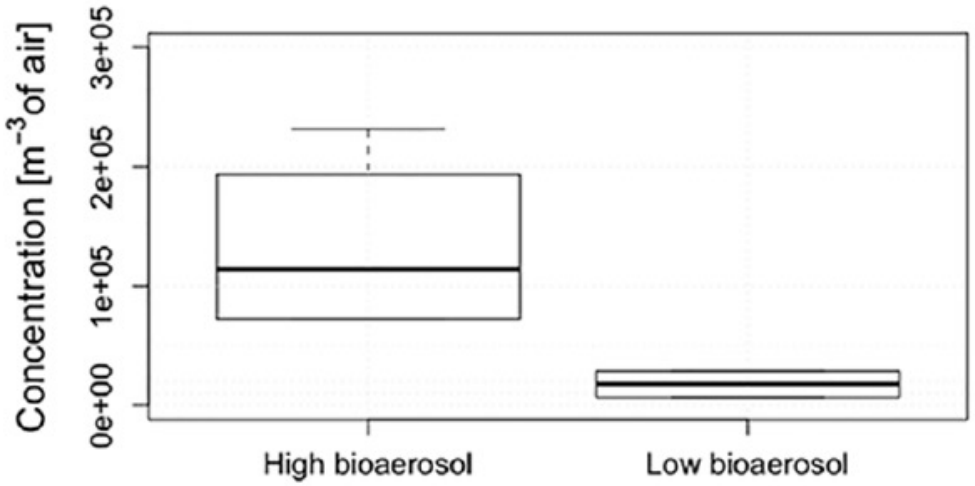
Šantl-Temkiv et al. (2019) EST.

- A significant correlation between **INP-10**, and bacterial concentrations in summer
- No correlation for spring snow samples.

BIOLOGICAL INP IN THE HIGH ARCTIC



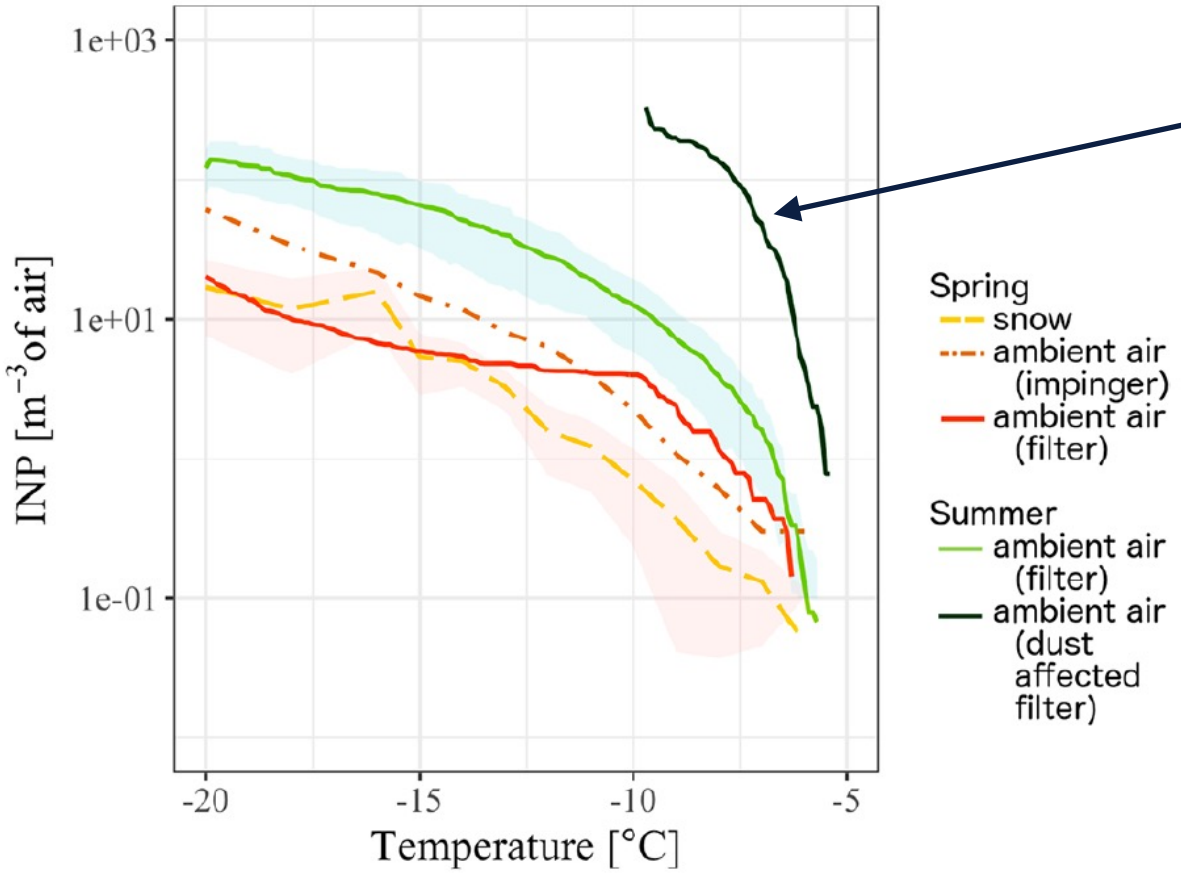




— Air masses traveling over terrestrial and marine environments in W Greenland
— Trajectories during high-bioaerosol periods spent more time over open sea surfaces and open land.

Šantl-Temkiv et al. (2019) EST.

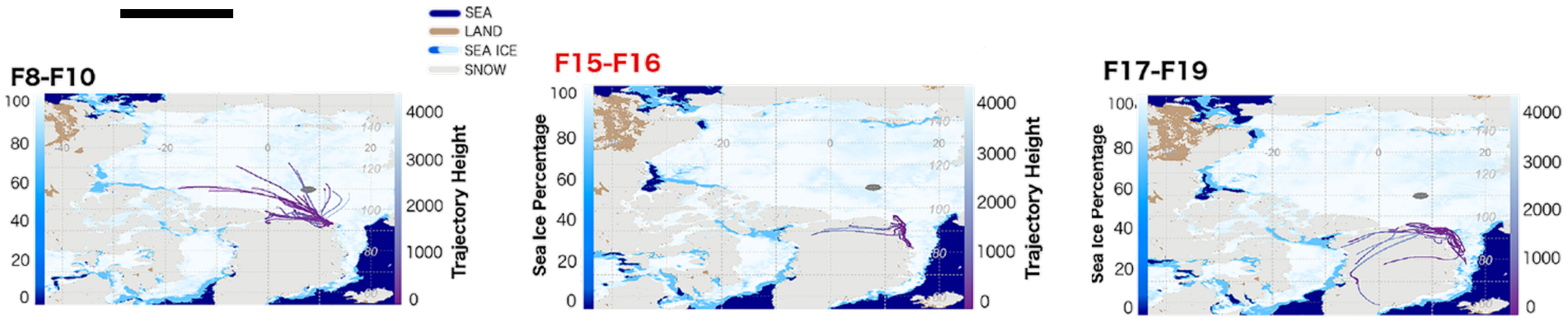
BIOLOGICAL INP IN THE HIGH ARCTIC

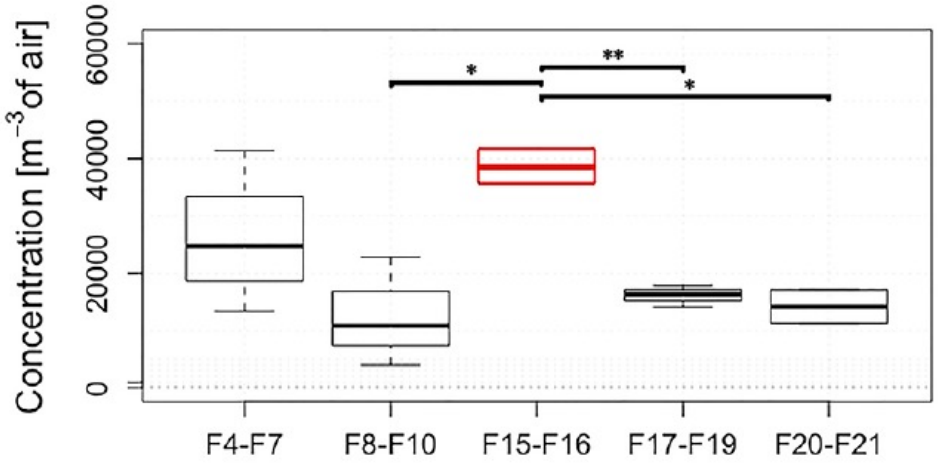


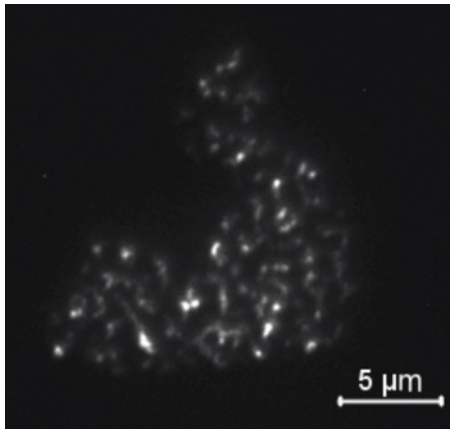
Local terrestrial sources: "soil" dust

Šantl-Temkiv et al. (2019) EST.

BIOLOGICAL INP IN THE HIGH ARCTIC



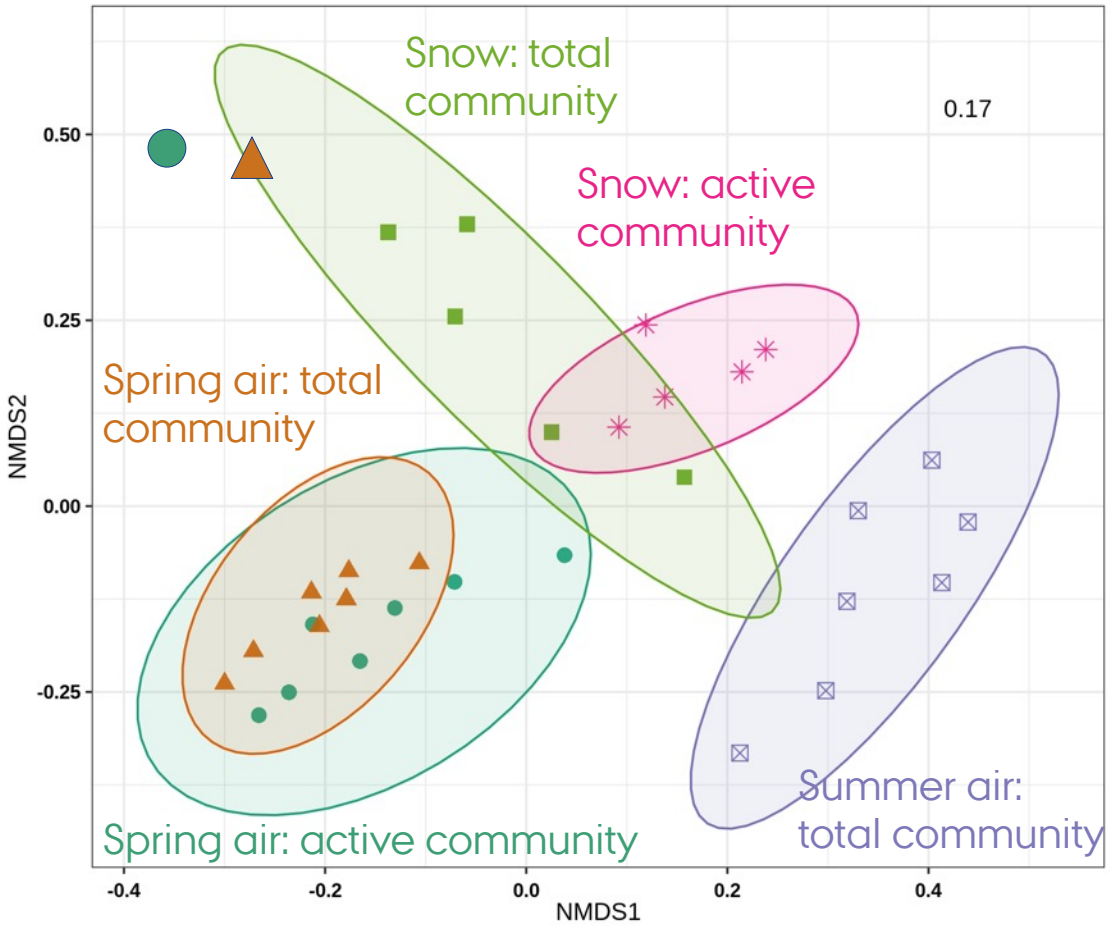




— Trajectories did not pass any snow-free land but spent 1-10% of the time over open sea and pack ice.
— Extra sources: sea ice, frost flowers, and snow known to contribute to sea salt aerosols.

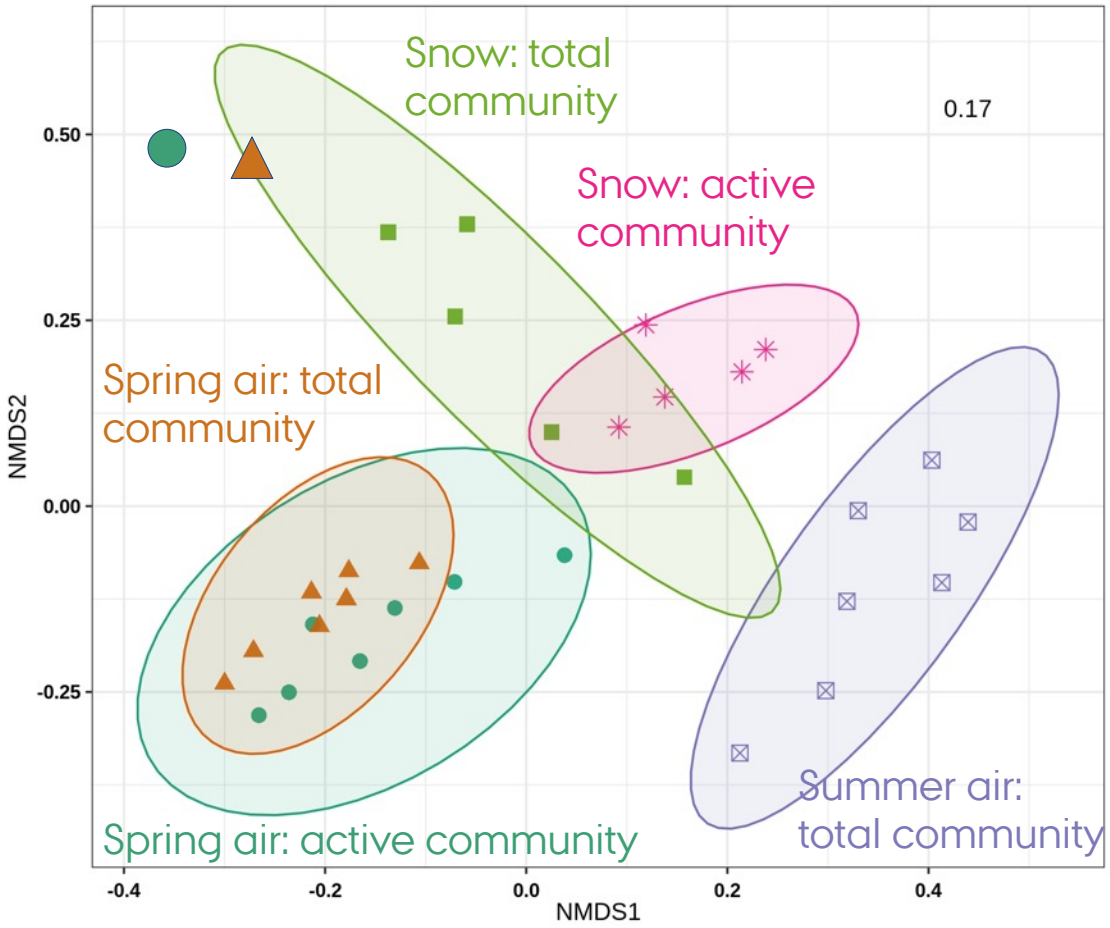
Šantl-Temkiv et al. (2019) EST.

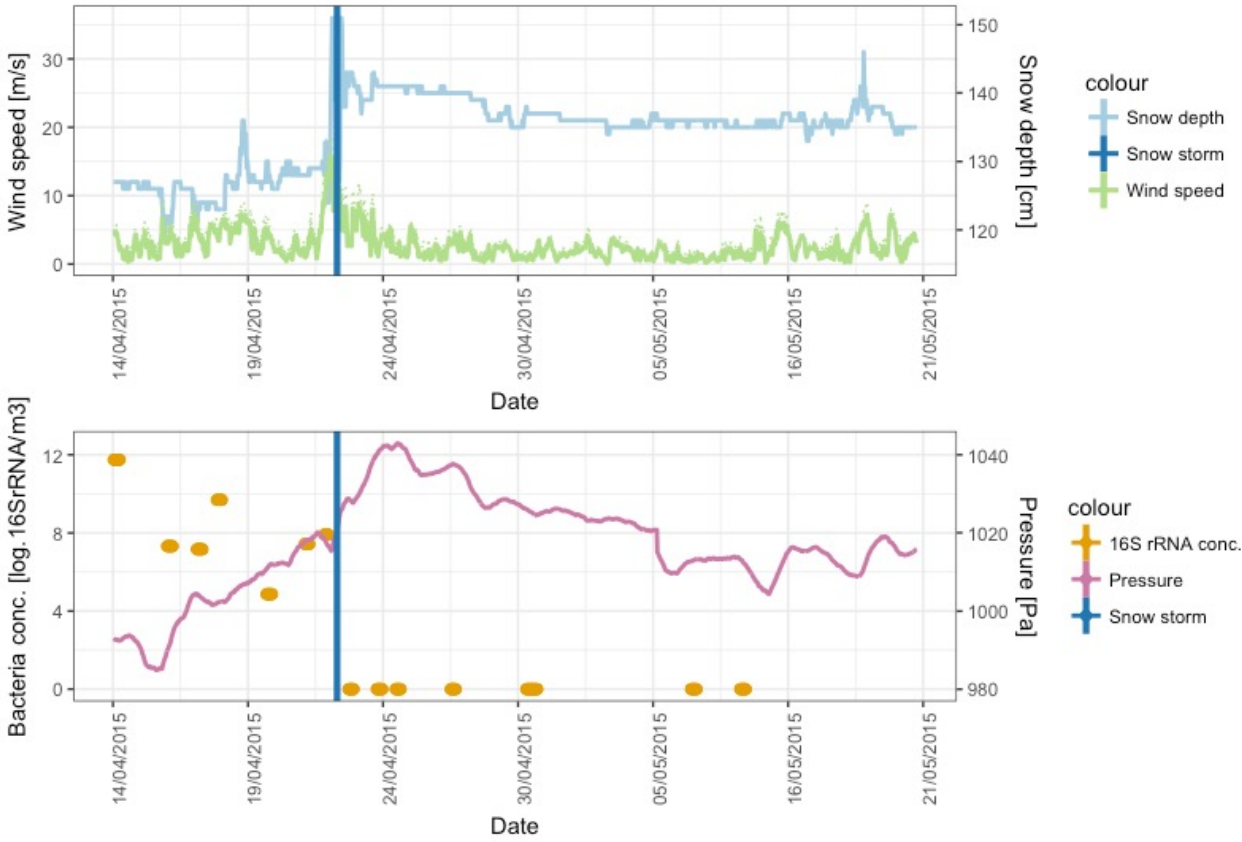
BIOAEROSOLS AND PRECIPITATION IN THE HIGH ARCTIC



Jensen ZL, Finster K and Šantl-Temkiv T. (in preparation) Frontiers in Microbiology

BIOAEROSOLS AND PRECIPITATION IN THE HIGH ARCTIC





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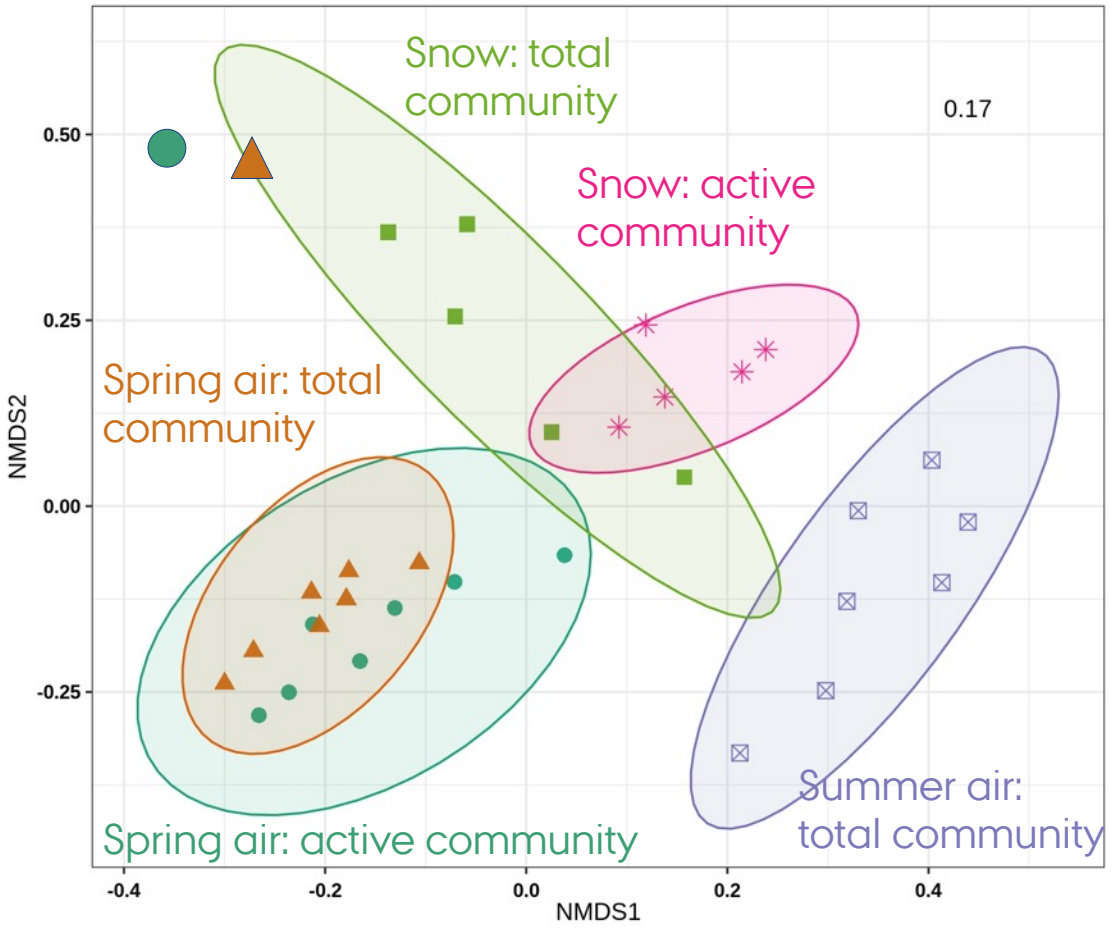

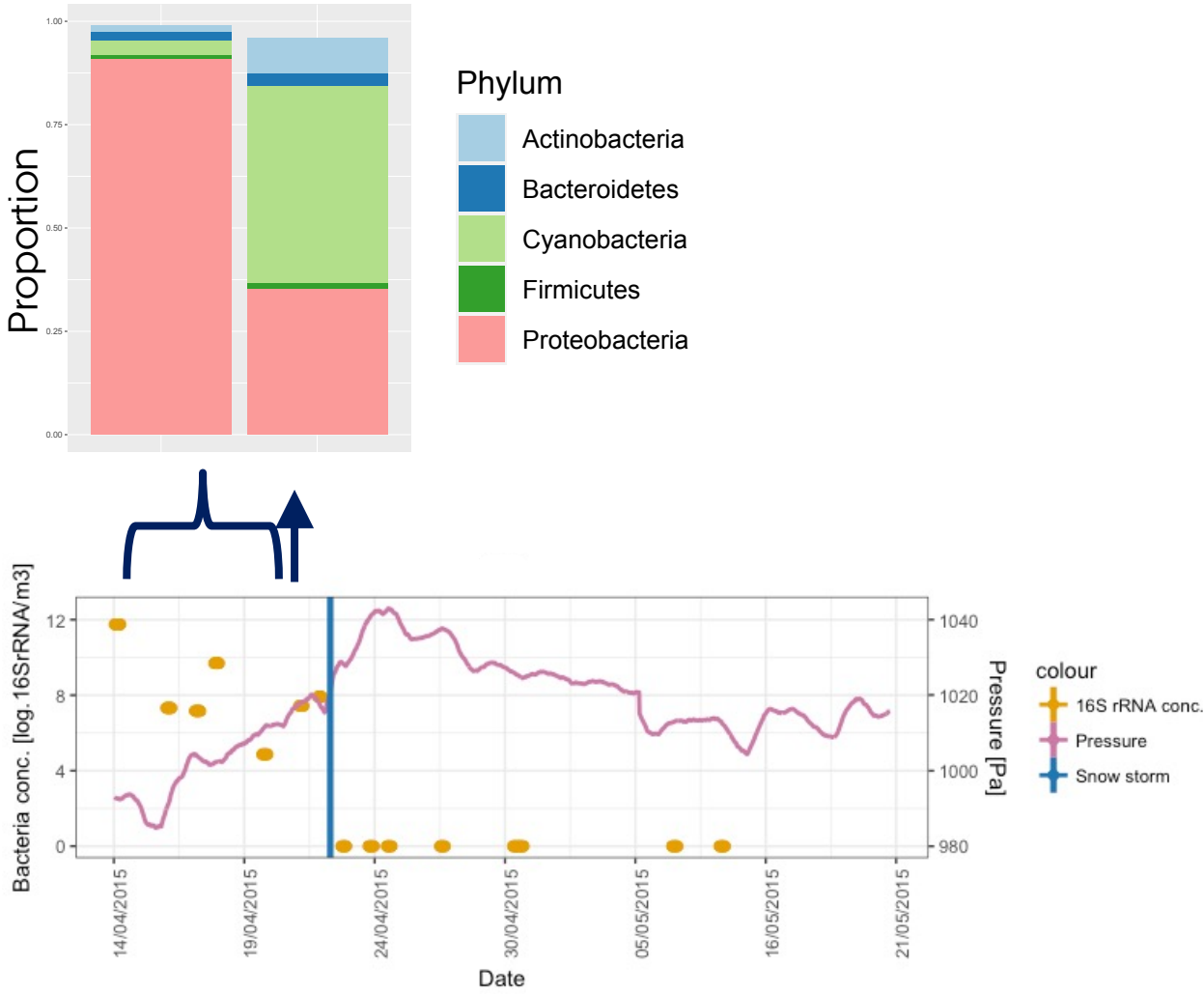

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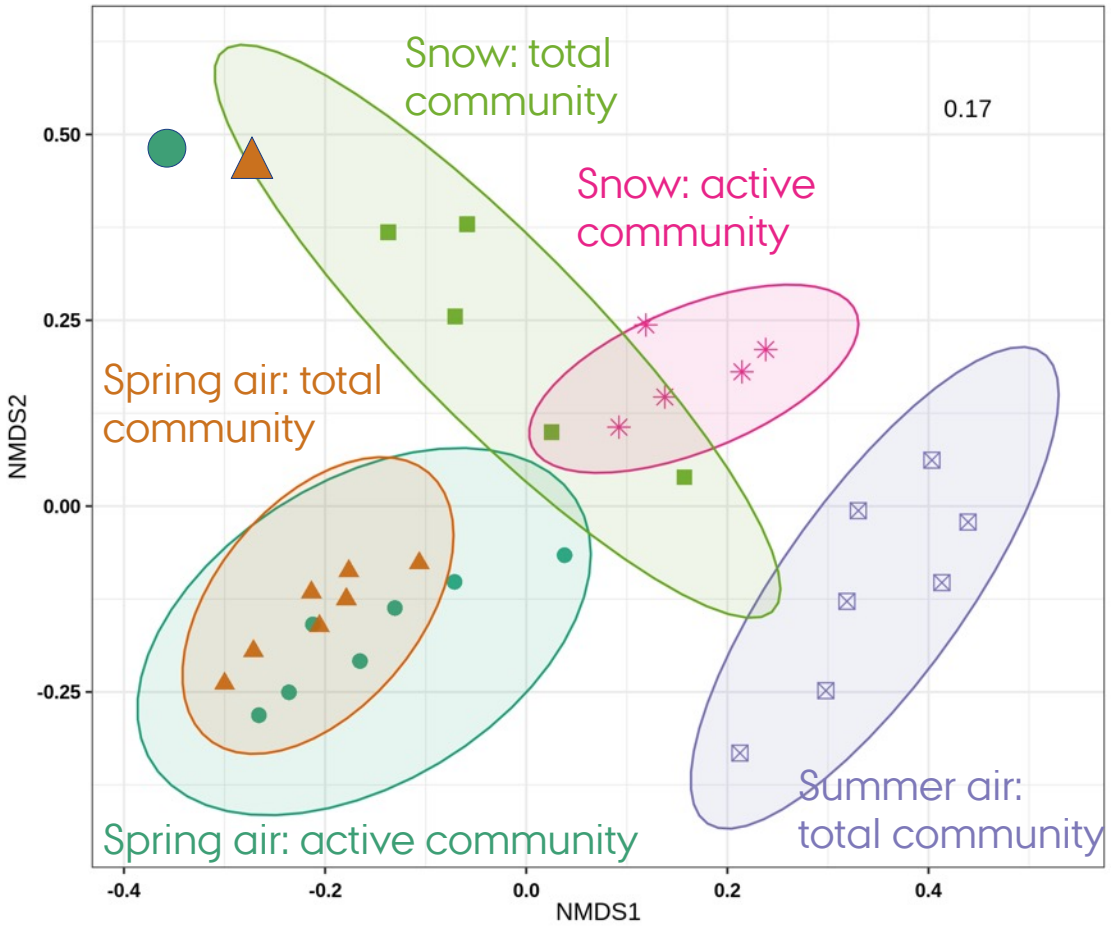
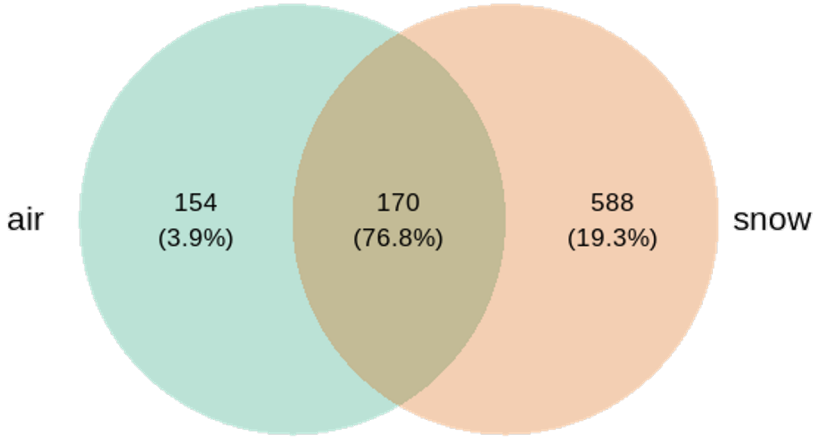


Shared "species" Between the last air sample and the snow samples



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CONCLUSIONS AND OPEN QUESTIONS

INP and bioaerosol concentration:

- High-temperature INP are likely proteinaceous and correlate with bacterial concentrations in the summer;
- Summer concentrations of INP are about an order of magnitude higher than spring concentrations;
- Open sea surfaces may contribute to bioaerosol population both in summer and in spring;
- Open land and local dust sources may contribute to bioaerosol population in summer.

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- Open sea surfaces may contribute to bioaerosol population both in summer and in spring;
- Open land and local dust sources may contribute to bioaerosol population in summer.

Microbial community:

- Generally, there are distinct bacterial communities present in snow, and in sping and summer air;
- A snow storm caused a washout event of airborne bacterial cells;
- A shift in bacterial community correlated with the onset of the snow storm.

Open questions:

1. Where do the active Cyanobacteria come from?
2. Are they involved in cloud formation?

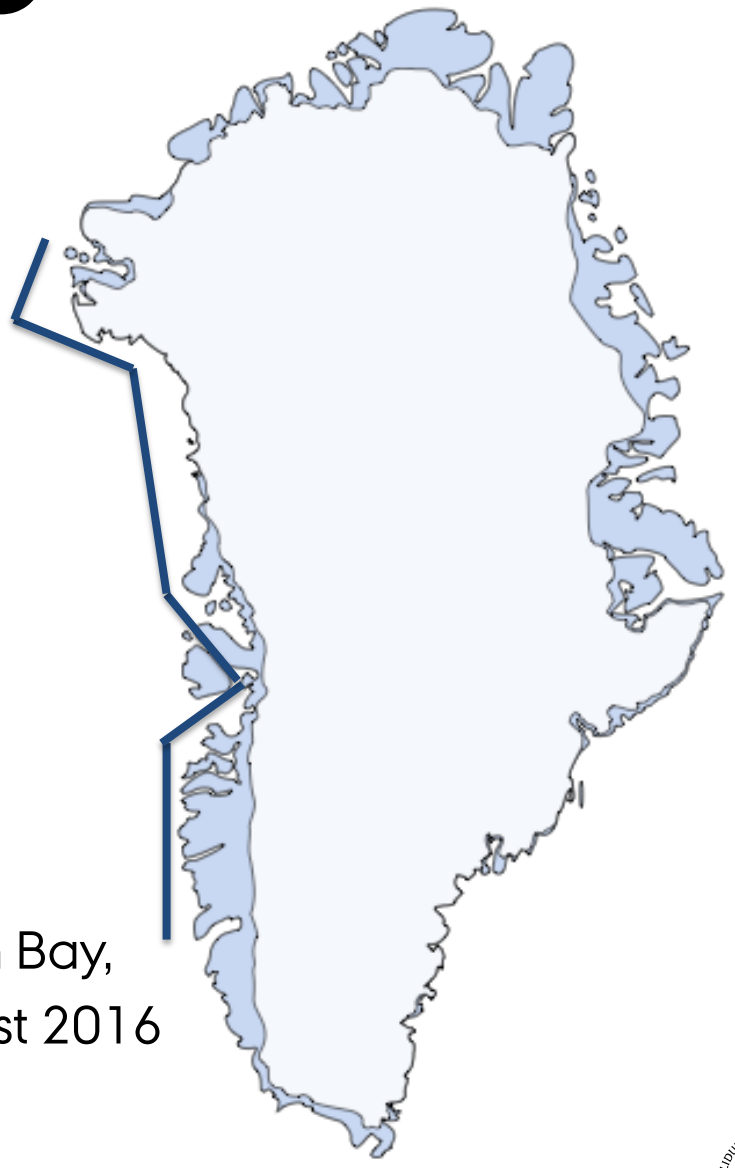
MARINE SOURCES OF ARCTIC BIOAEROSOLS AND INP

Sample collection during 10 days:

—42 samples of sea bulk water and surface microlayer

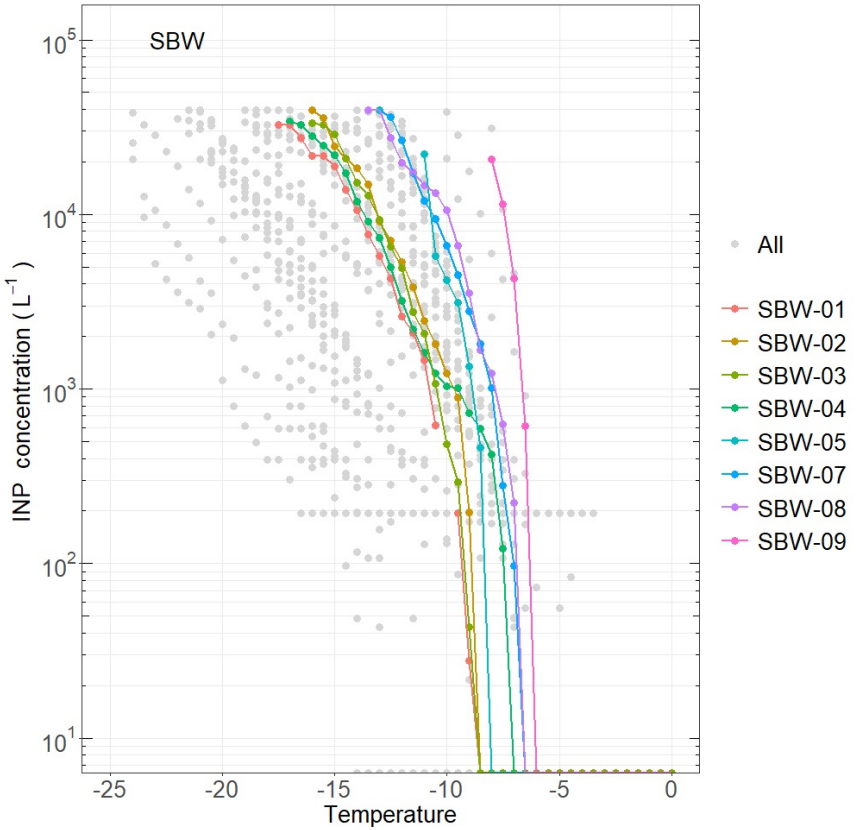
—36 air samples

Royal Danish Navy patrol vessel Ejnar Mikkelsen



Baffin Bay, August 2016

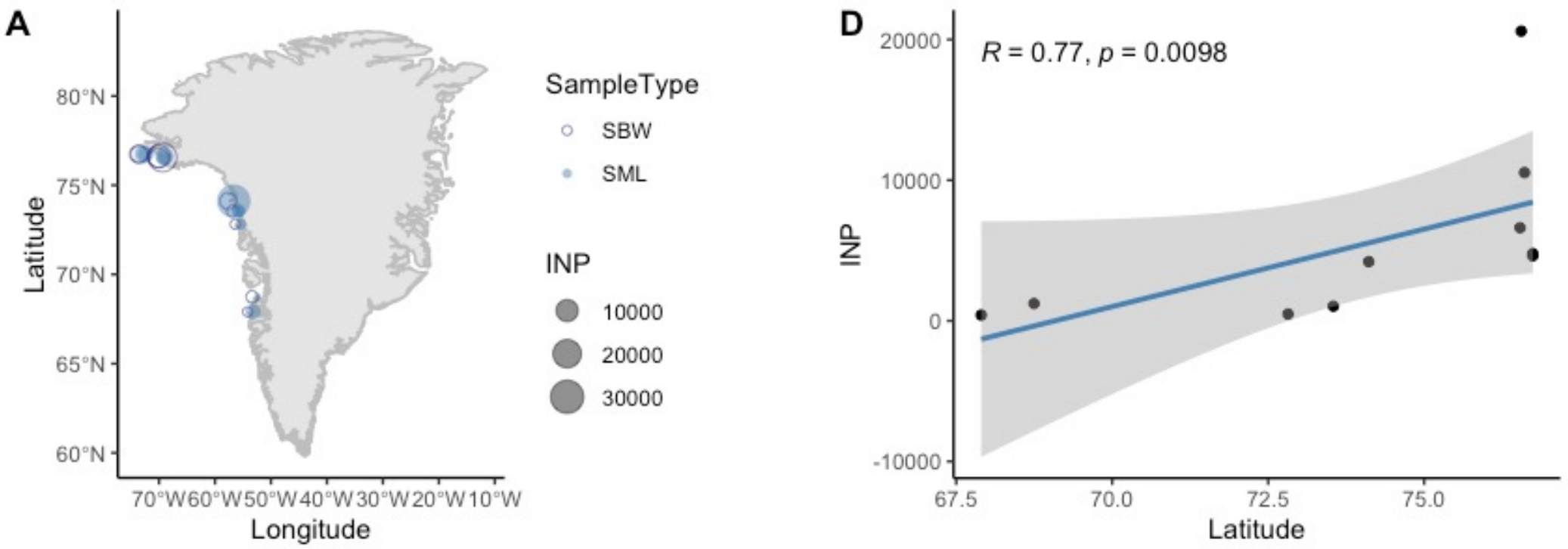
MARINE SOURCES OF ARCTIC BIOAEROSOLS AND INP



- High-temperature INP detected in all sea bulk water and surface microlayer samples;
- We observed no clear upconcentration in the sea surface microlayer.

Tesson S, **Mignani C**, Christiansen S, Bilde M, Finster K (...) and Šantl-Temkiv T. (in preparation) Frontiers in Microbiology

MARINE SOURCES OF ARCTIC BIOAEROSOLS AND INP



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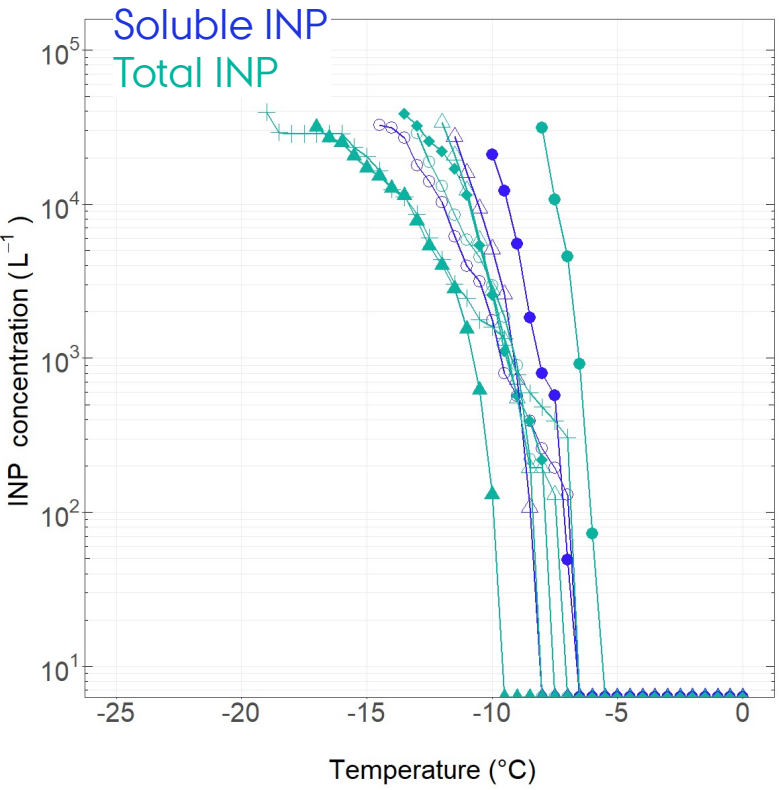
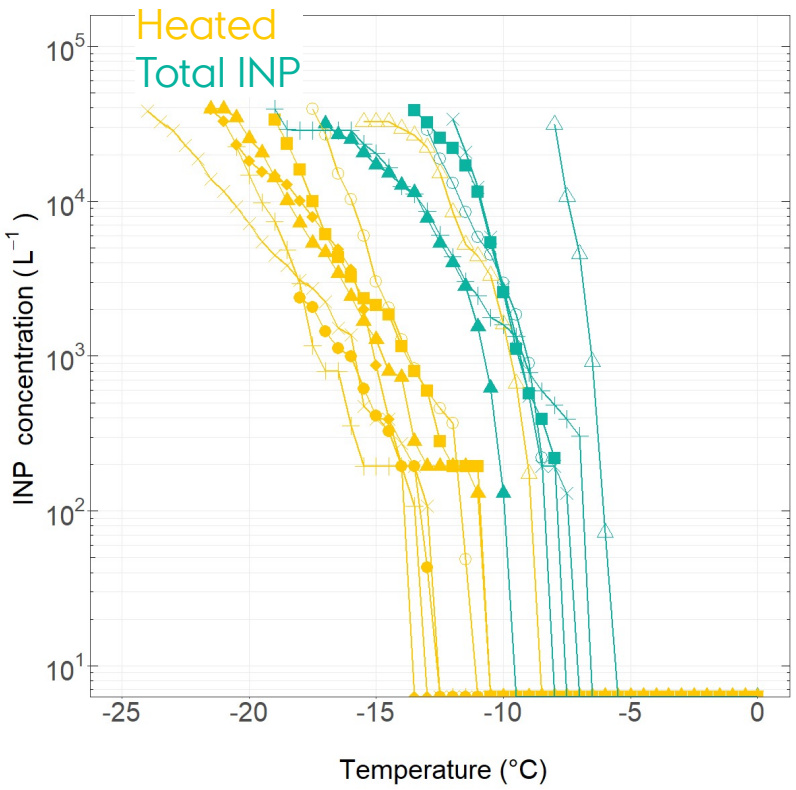
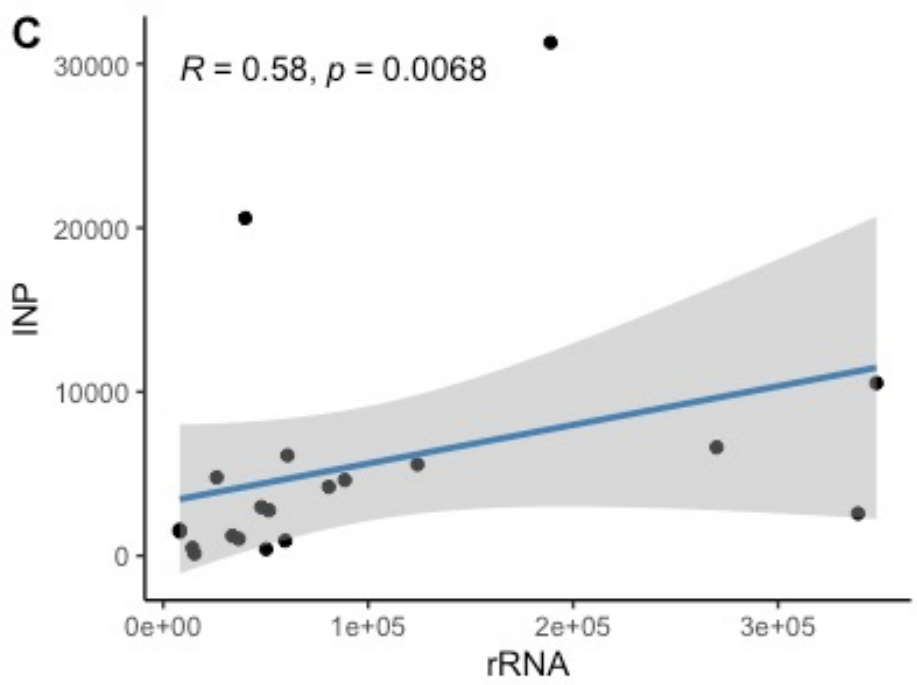
MARINE SOURCES OF ARCTIC BIOAEROSOLS AND INP

University of Basel







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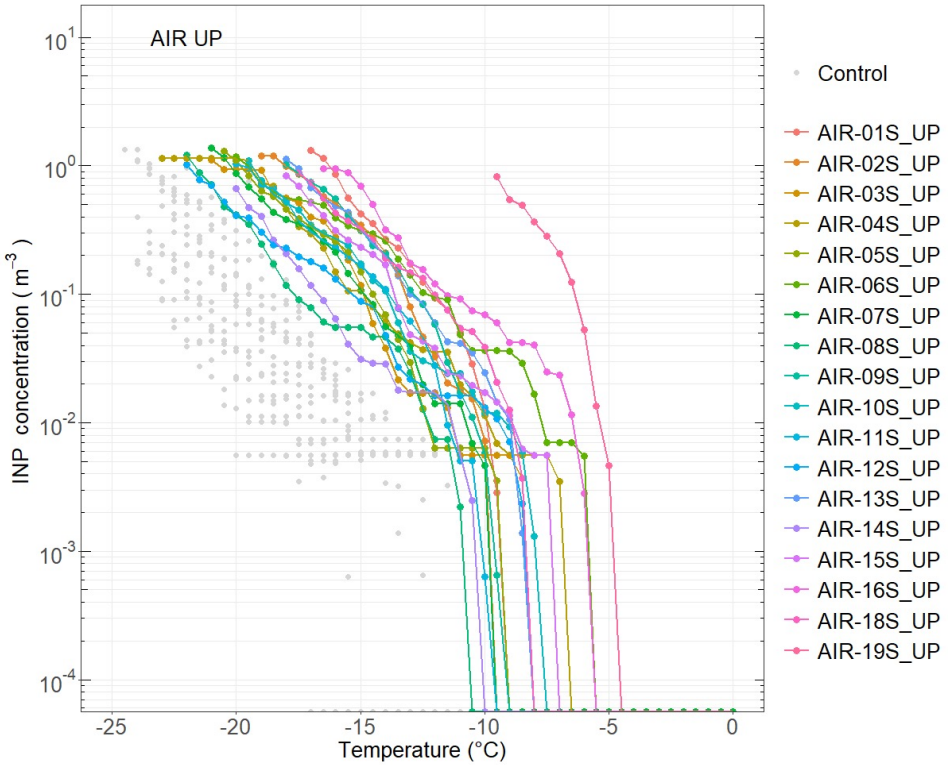
MARINE SOURCES OF ARCTIC BIOAEROSOLS AND INP



- We could quantify INP in all air samples and could observe roughly the same trend with latitude as in sea samples
- The INP were present at very low concentrations of on average 0.018± 0.018 INP_{-10} m^{-3} (min-max: 0,0006-0,07 INP_{-10} m^{-3})

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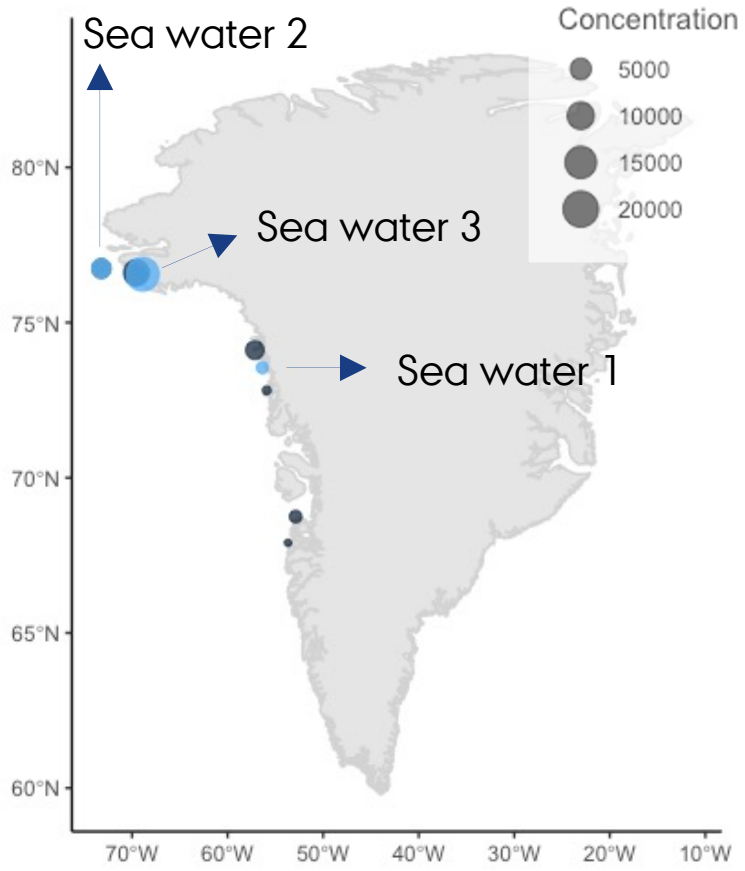
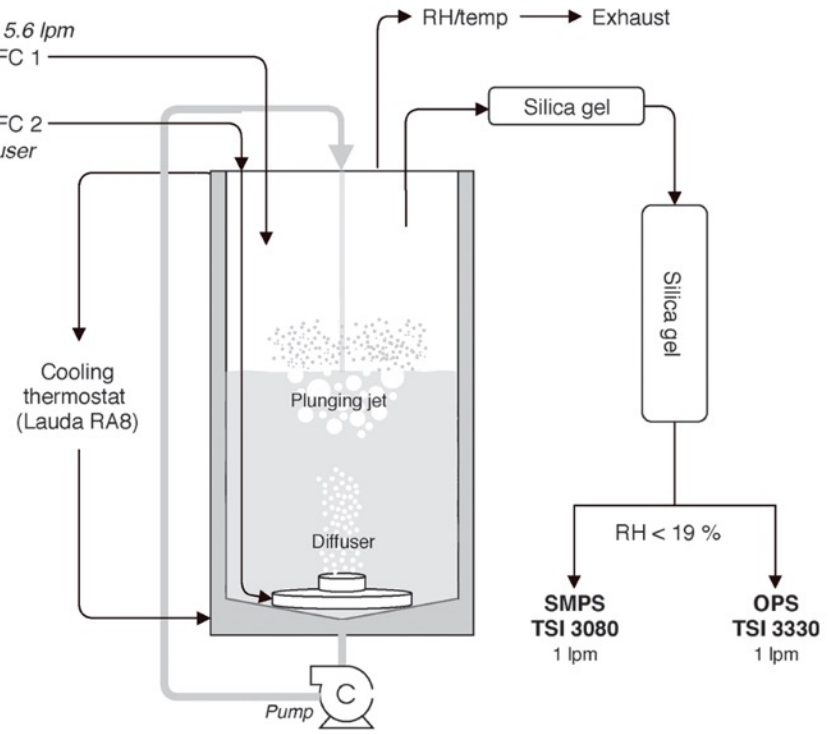
SEA SPRAY EXPERIMENTS



Temperature controlled sea-spray tank



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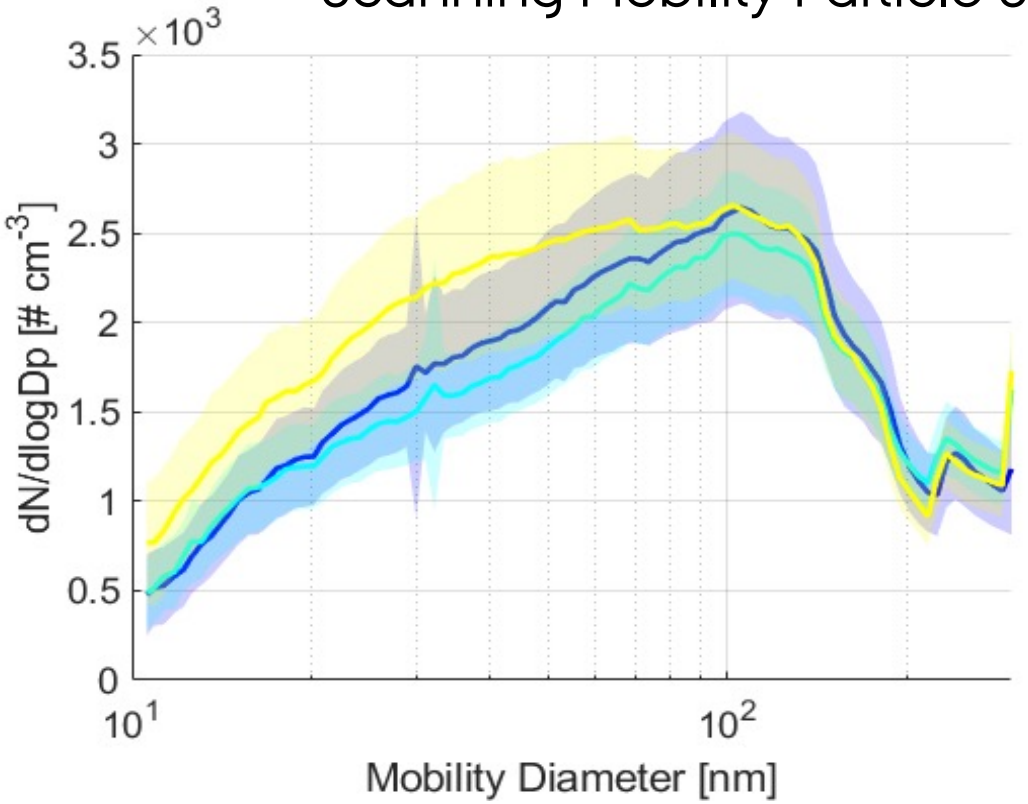
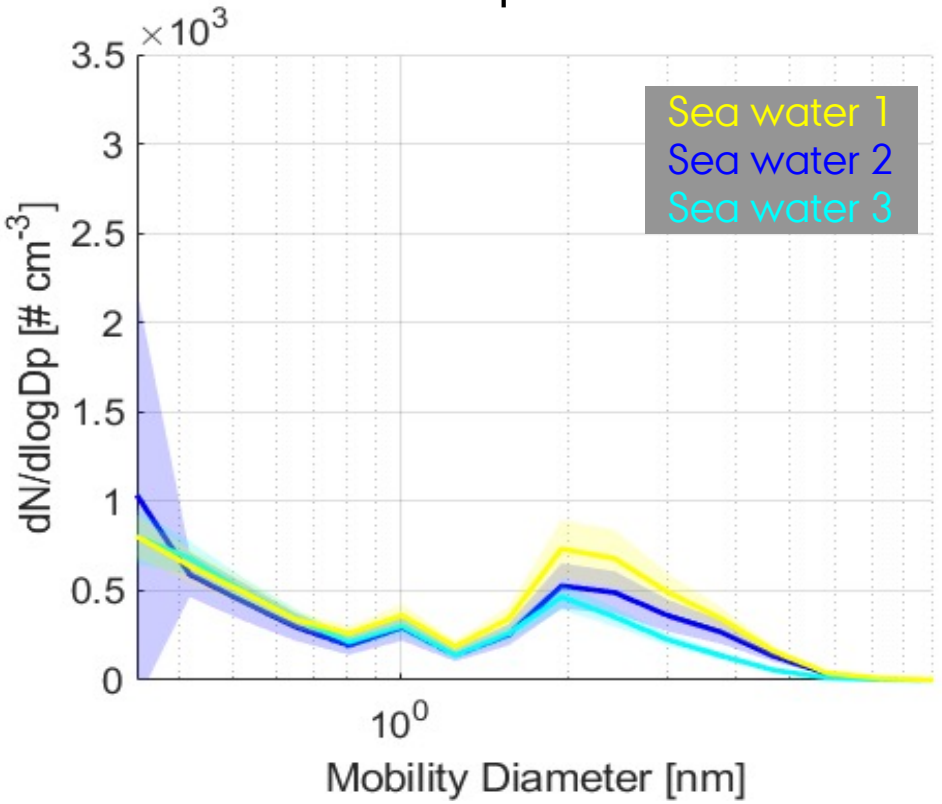
SEA SPRAY EXPERIMENTS

Scanning Mobility Particle Sizer



Optical Particle Sizer



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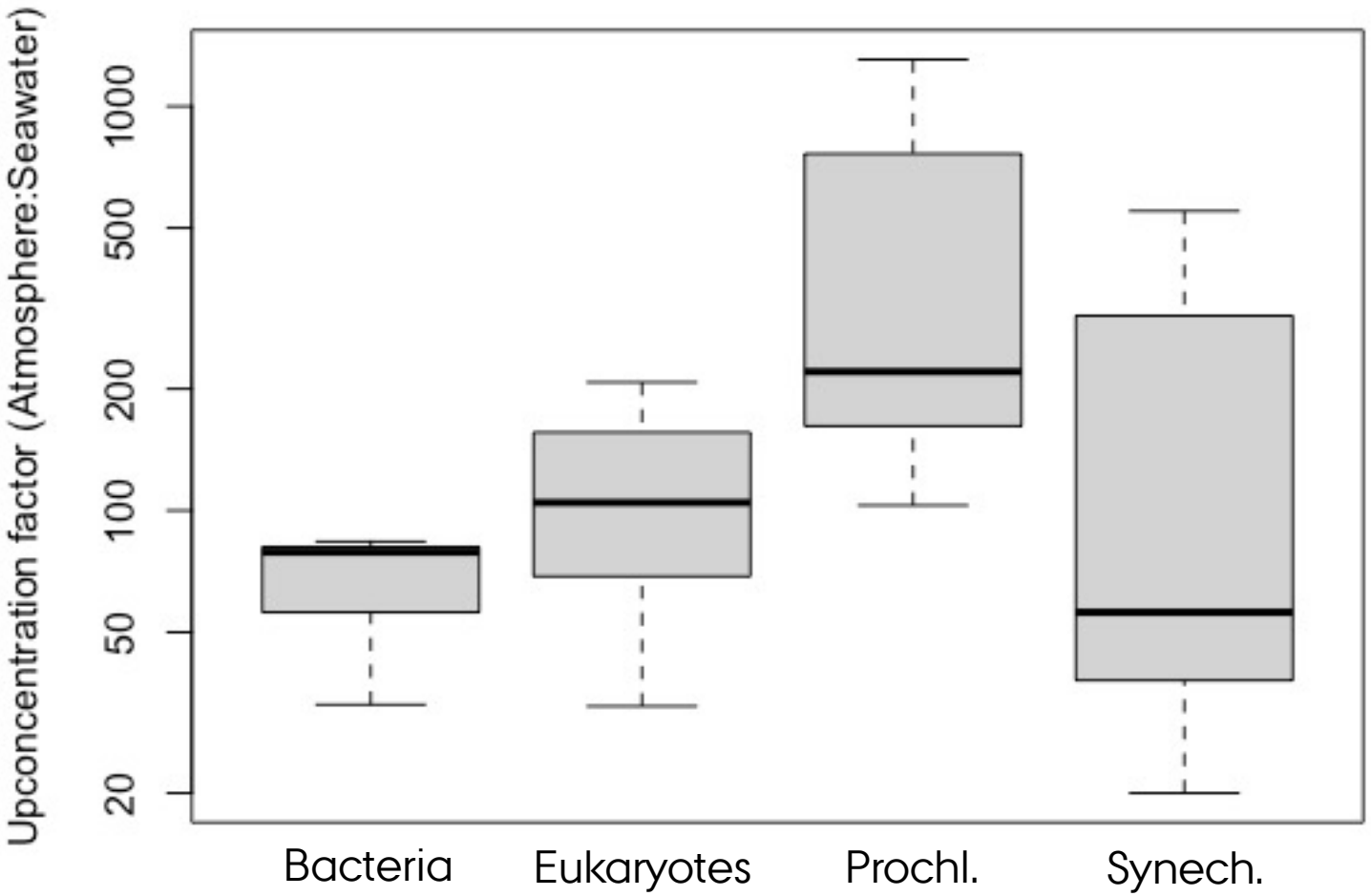
SEA SPRAY EXPERIMENTS

Biosampler



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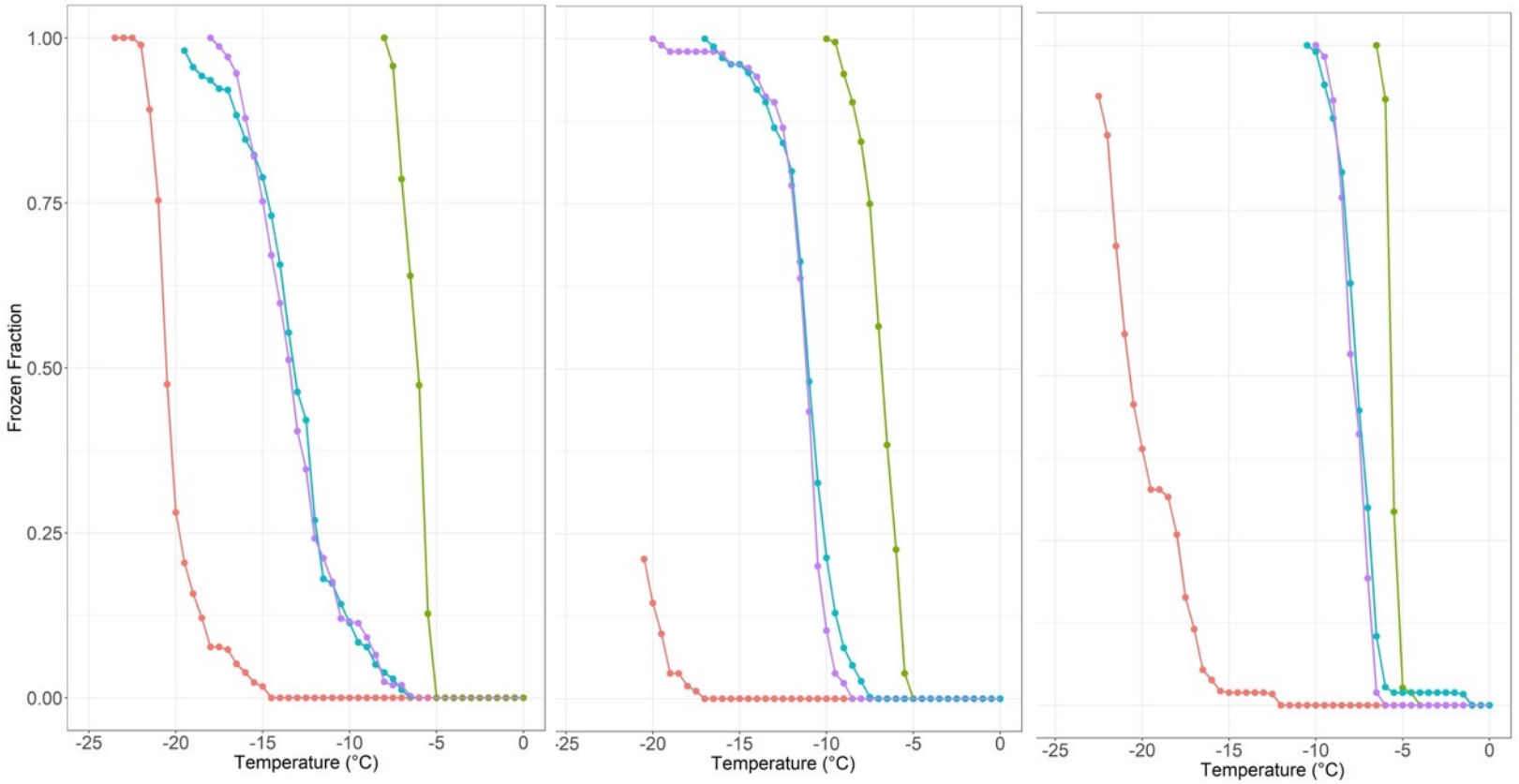
SEA SPRAY EXPERIMENTS

Sea water 1 | Sea water 2 | Sea water 3



Air samples
Sea water
Neg control

- We observe an up-concentration of INP in the air
- The air-concentrations of INP_{-7} were 34-923 INP m^{-3}, which is 3-5 orders of magnitude higher than measured during the field campaign.

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CONCLUSIONS AND OPEN QUESTIONS

Field study

- We observe high-temperature INP in sea bulk water and surface microlayer samples;
- Marine INP are soluble, heat sensitive and correlate with bacterial concentrations;
- We could detect high-temperature INP in the atmosphere at very low concentrations;
- The marine INP concentration increase with latitiude in the sea and in the atmosphere.

CONCLUSIONS AND OPEN QUESTIONS

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- We observe high-temperature INP in sea bulk water and surface microlayer samples;
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- The marine INP concentration increase with latitiude in the sea and in the atmosphere.

Sea-spray study

- We observed a preferential aerosolization of certain microbial taxa;
- We observed an efficient aerosolization of high-temperature INP resulting in 3-5 orders of magnitude higher concentration of INP_{-7} than in situ.

Open questions:

1. How does air entrainment / wind speed relate to bioaerosol and INP emission?
2. Why does latitude matter?
3. Which microorganisms are producing proteinaceous INP in these marine samples?

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