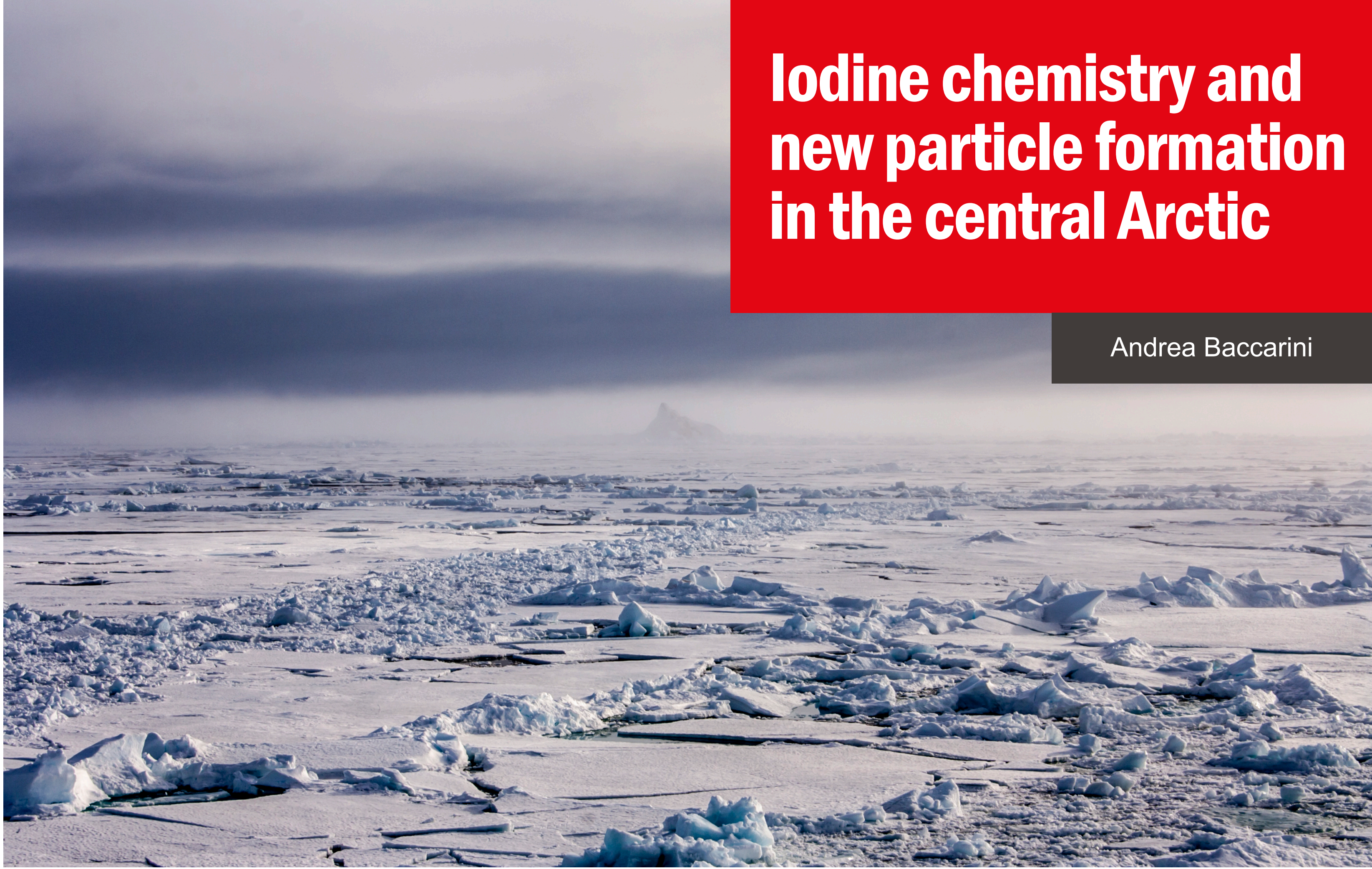
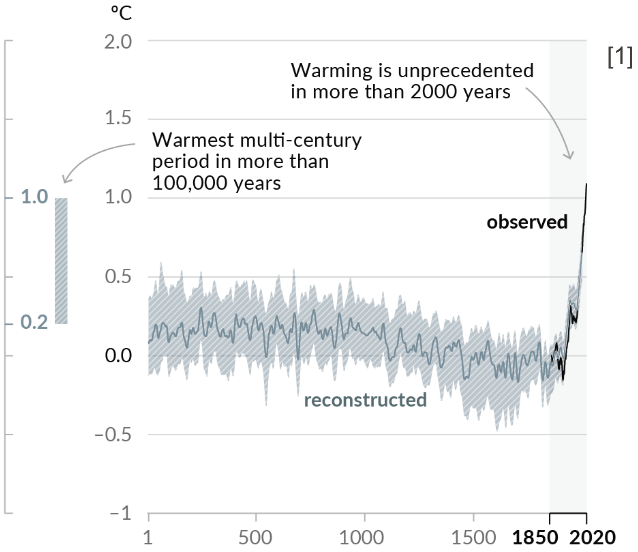
Iodine chemistry and new particle formation in the central Arctic

Andrea Baccarini

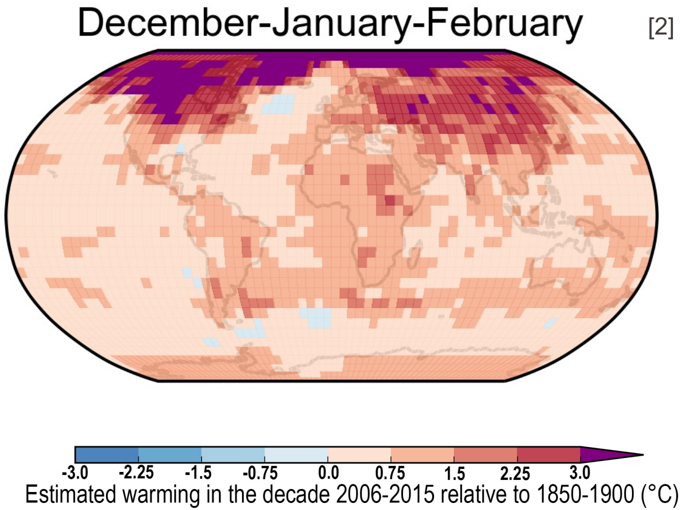


Prix de Quervain 2022

Global warming



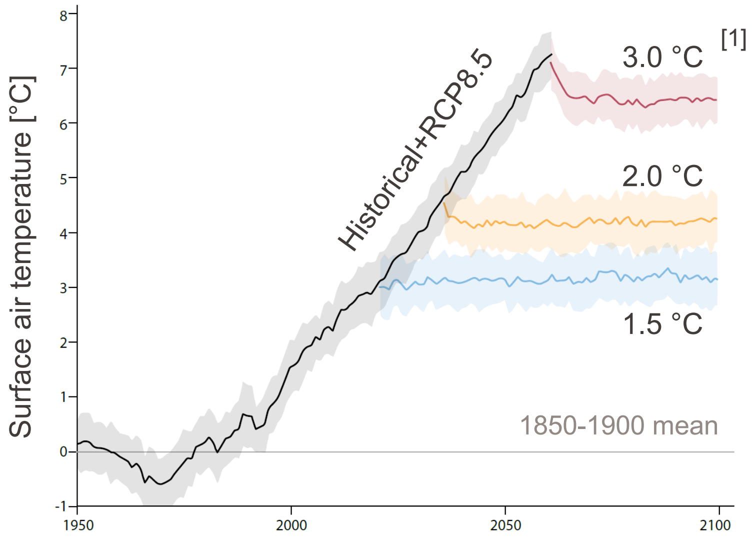
Changes in global surface temperature relative to 1850-1900

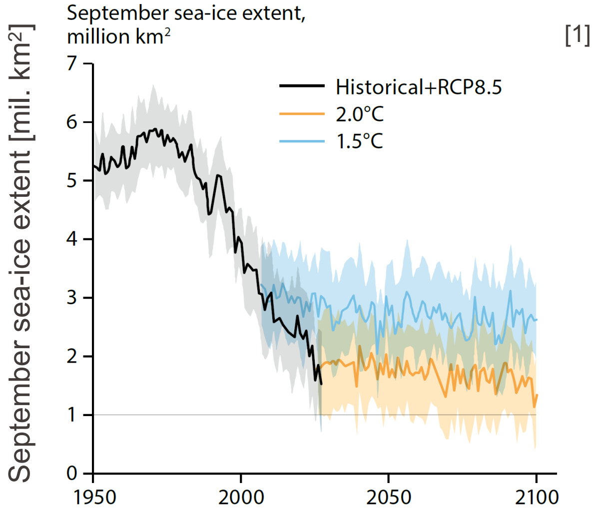


[1] IPCC, 2021: Summary for Policymakers
[2] IPCC, 2018: Global Warming of 1.5°C

The Arctic in a warming climate

Arctic annual mean warming

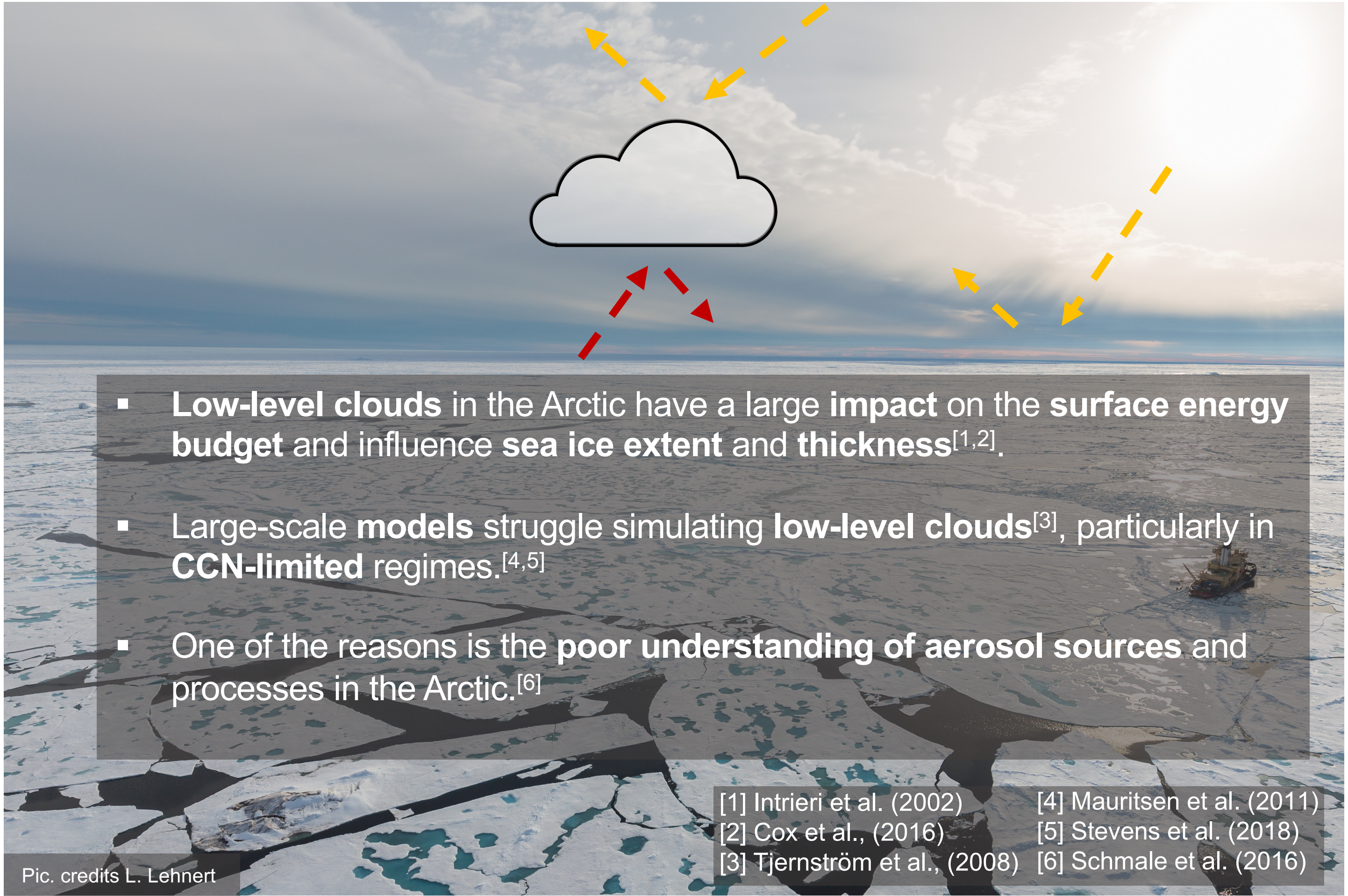




The Arctic is warming twice as fast as the global average (Arctic amplification)[2] and the sea ice extent is constantly decreasing.[3]

[1] AMAP, 2021.
[2] Serreze et al. (2011)
[3] Screen et al. (2010)

Clouds in the Arctic



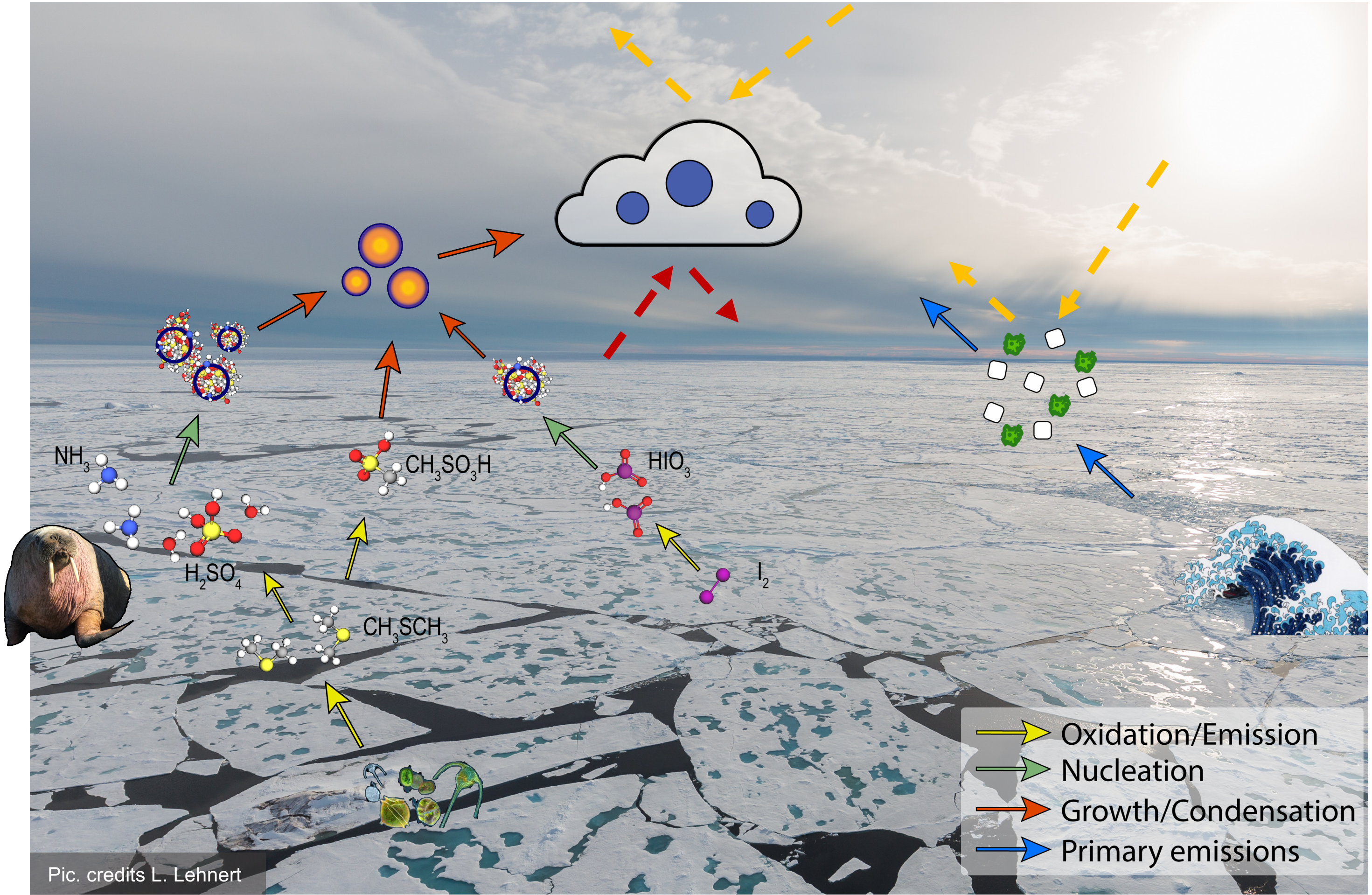
- **Low-level clouds** in the Arctic have a large **impact** on the **surface energy budget** and influence **sea ice extent** and **thickness**[1,2].
- Large-scale **models** struggle simulating **low-level clouds**[3], particularly in **CCN-limited** regimes.[4,5]
- One of the reasons is the **poor understanding of aerosol sources** and processes in the Arctic.[6]

Pic. credits L. Lehnert

[1] Intrieri et al. (2002)
[2] Cox et al., (2016)
[3] Tjernström et al., (2008)
[4] Mauritsen et al. (2011)
[5] Stevens et al. (2018)
[6] Schmale et al. (2016)

Aerosols in the Arctic

Models estimate that globally about 38-66% of the CCN by number are coming from NPF [1]



A. Baccarini

[1] Gordon, et al. (2017)

New particle formation in the central Arctic Ocean

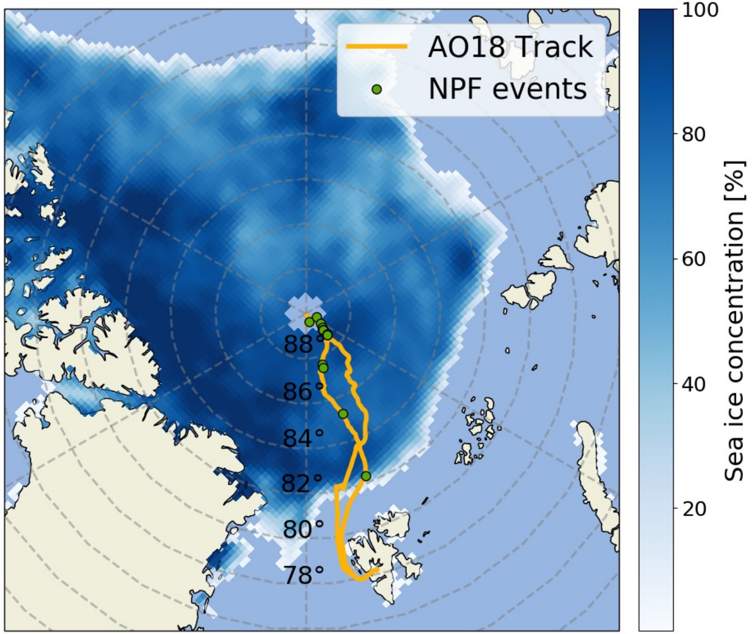
1991
1996
2001
2008
2014
2018

First aerosol measurements in the region, the occurrence of NPF events was reported[1].

Successive field campaigns **confirmed** the **occurrence of NPF** but could not identify the responsible mechanism. Estimated **sulfuric acid** concentrations were **too low** to explain observations[2,3] .

Modelling study showing that an artificially **high NPF rate** is required to **reproduce observations**[4].

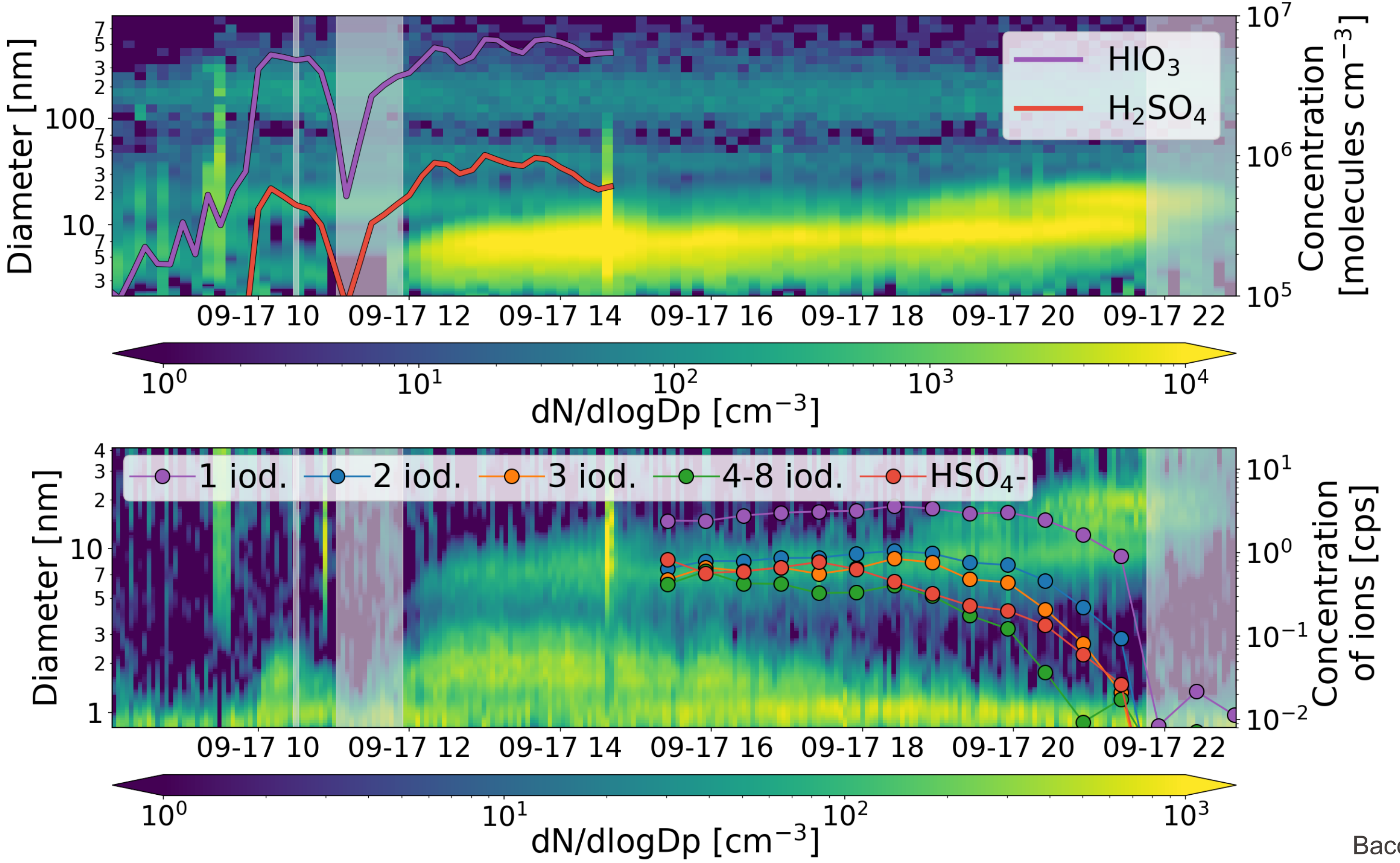
Arctic Ocean 2018 (AO18) expedition



Sea Ice data: Maslanik and Stroeve (1999)

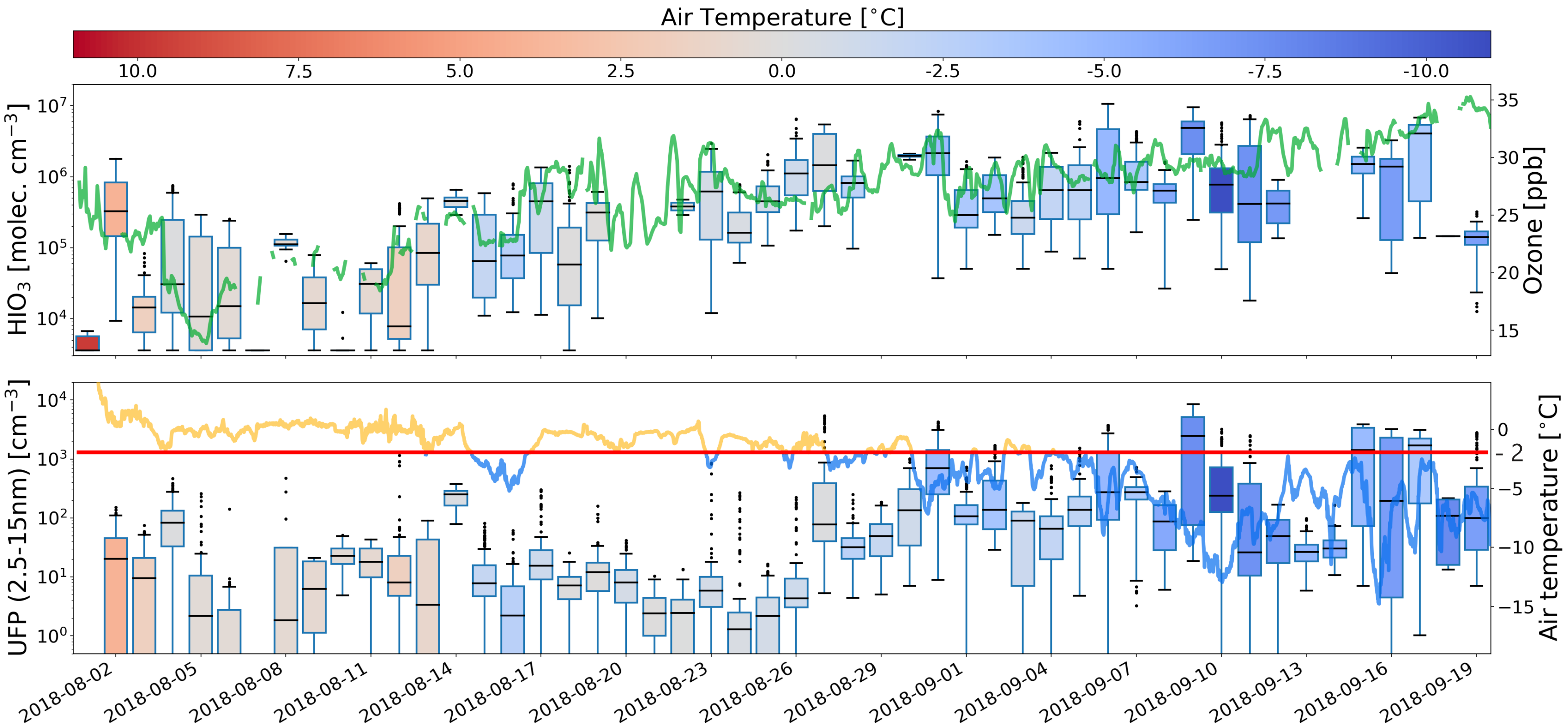
[1] Covert et al. (1996)
[2] Karl et al. (2012)
[3] Heintzenberg et al. (2015)
[4] Browse et al. (2014)

Iodic acid drives new particle formation



Baccarini et al. 2020

Iodic acid seasonality

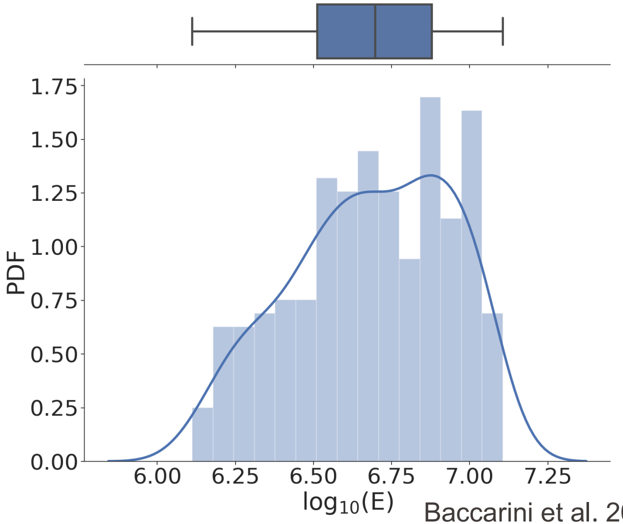


Baccarini et al. 2020

Iodic acid formation

- Globally, the reaction of O_3 with I^-_{aq} in the oceans is the main source of atmospheric iodine[1].
- From sea ice and snow-covered surfaces, biotic[2] and abiotic[3] mechanisms have been proposed.
- HIO_3 is formed from the iodine radical via reaction with O_3 and water vapor[4].
- The main sink for HIO_3 over the central Arctic Ocean is fog.
- During the freeze-up, HIO_3 concentration can be simply modelled considering condensation sink (CS), boundary layer height (h) and deposition velocity (v_d):

$$\frac{d[HIO_3]}{dt} = \frac{E}{h} - \left(\frac{v_d}{h} - CS\right)[HIO_3]$$



Baccarini et al. 2020

[1] Carpenter et al. (2013)
[2] Saiz-Lopez et al. (2015)
[3] Raso et al. (2017)
[4] Finkenzeller et al. (2022)

Modelling IA NPF in the Arctic

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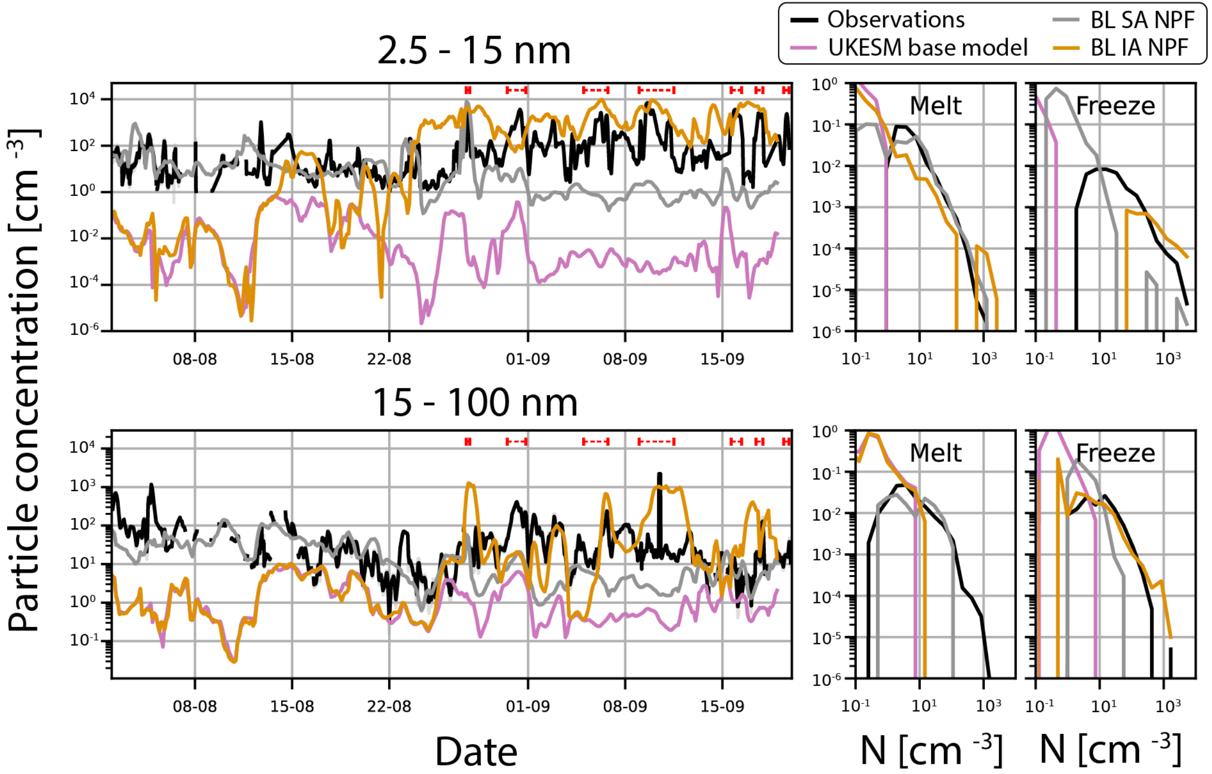
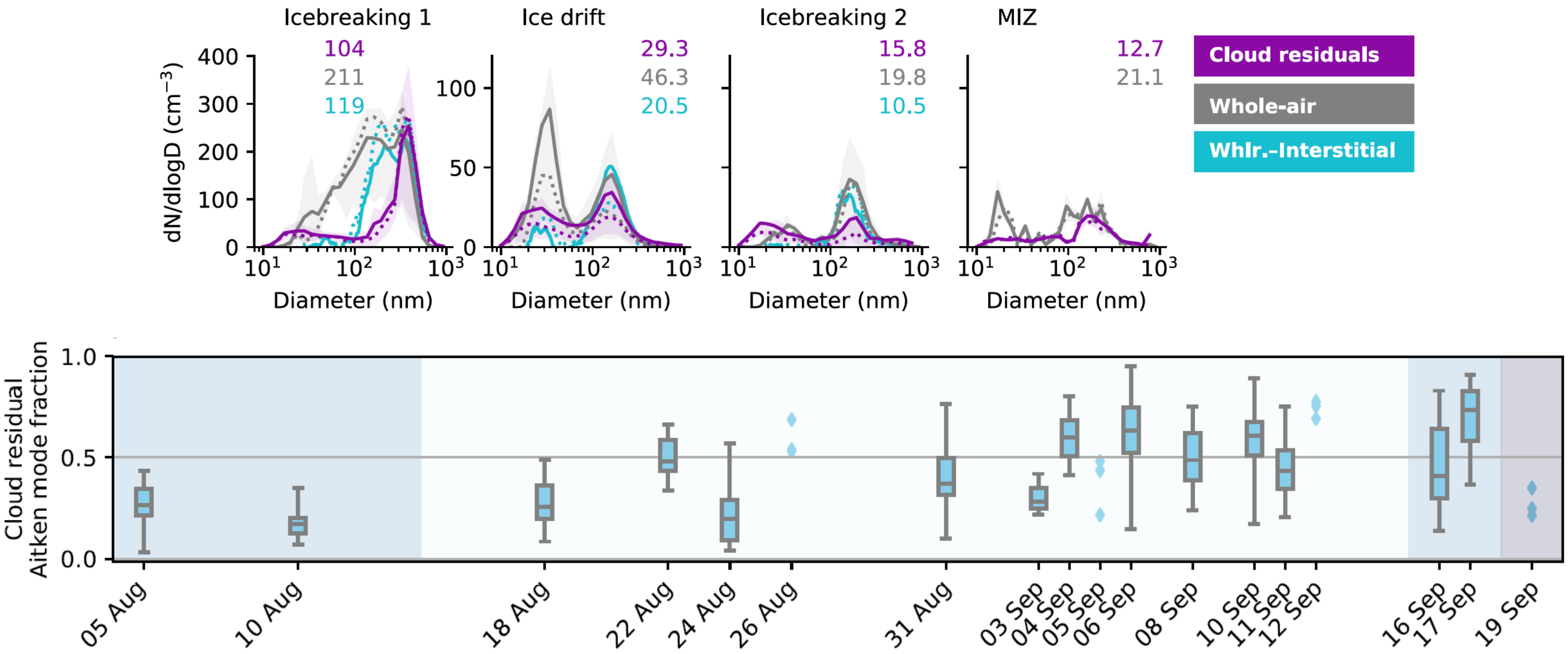


Iodic acid modelled using: $$\frac{d[HIO_3]}{dt} = \frac{E}{h} - \left(\frac{v_d}{h} - CS\right)[HIO_3]$$

Price, Baccarini et al. in review

NPF and cloud residuals

A. Baccarini



Aitken mode defined as particles with diameter < 70 nm

Karlsson, Baccarini et al. (2022)

Conclusions

- **Iodic acid (IA) shows a marked seasonal cycle** with a > 5 time increase from summer to autumn. This seasonality is reflected by the **occurrence of NPF events and the concentration of nucleation mode particles**.
- The **concentration of IA** is primarily **driven by meteorology and condensation sink**. We developed a simple model providing a **net iodine emission flux.**
- We successfully **implemented IA NPF in a global model**, obtaining a reasonable agreement with observations.
- **Aitken mode particles** significantly **contribute to cloud condensation nuclei,** supporting the **importance of NPF as a source of CCN** in the region.

Acknowledgments:
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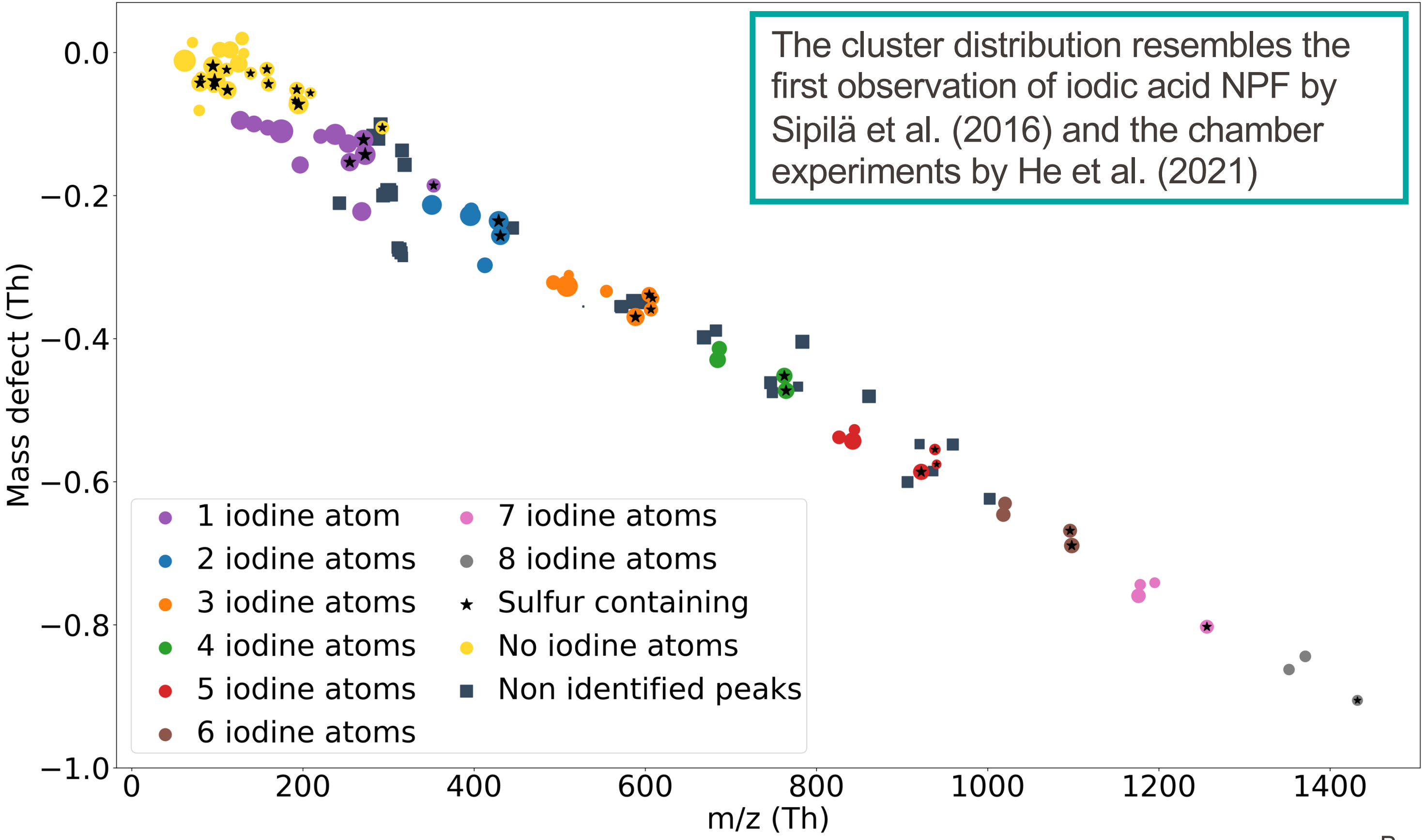
All coauthors and collaborators for the work together and their invaluable contributions.
The Swiss National Science Foundation and the Swiss Polar Institute for funding.

Back-up slides

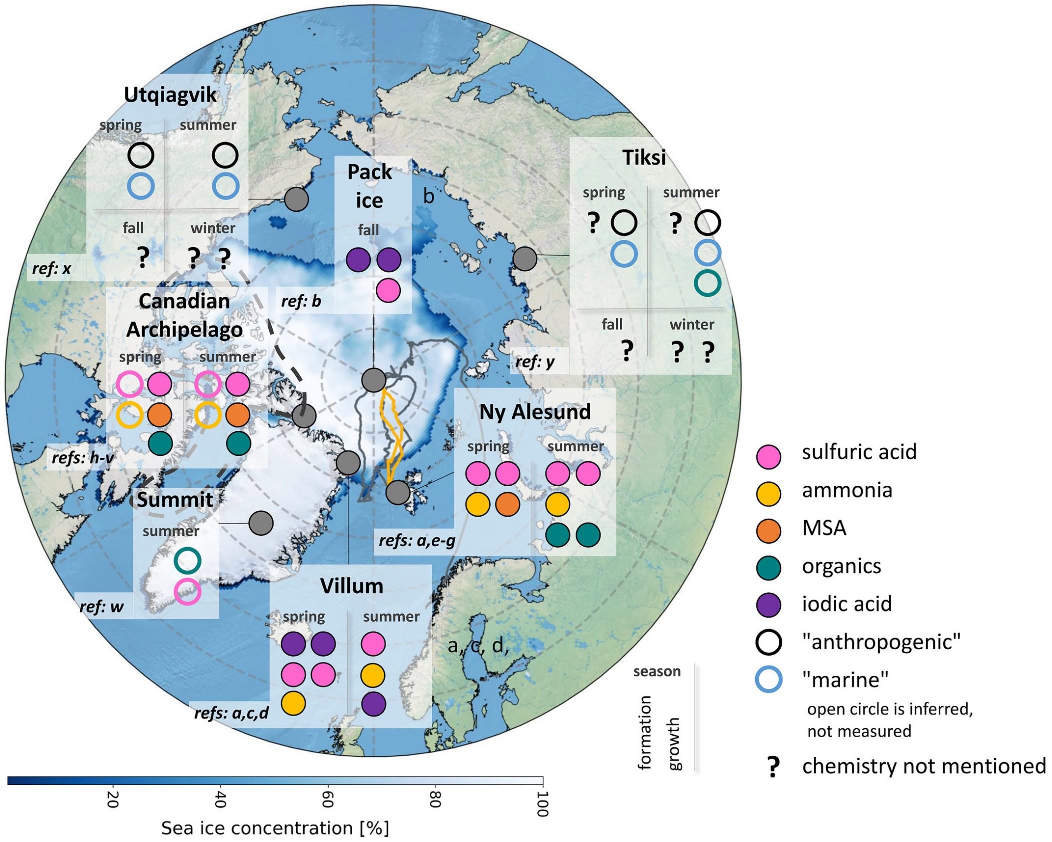
Iodic acid drives new particle formation



The cluster distribution resembles the first observation of iodic acid NPF by Sipilä et al. (2016) and the chamber experiments by He et al. (2021)

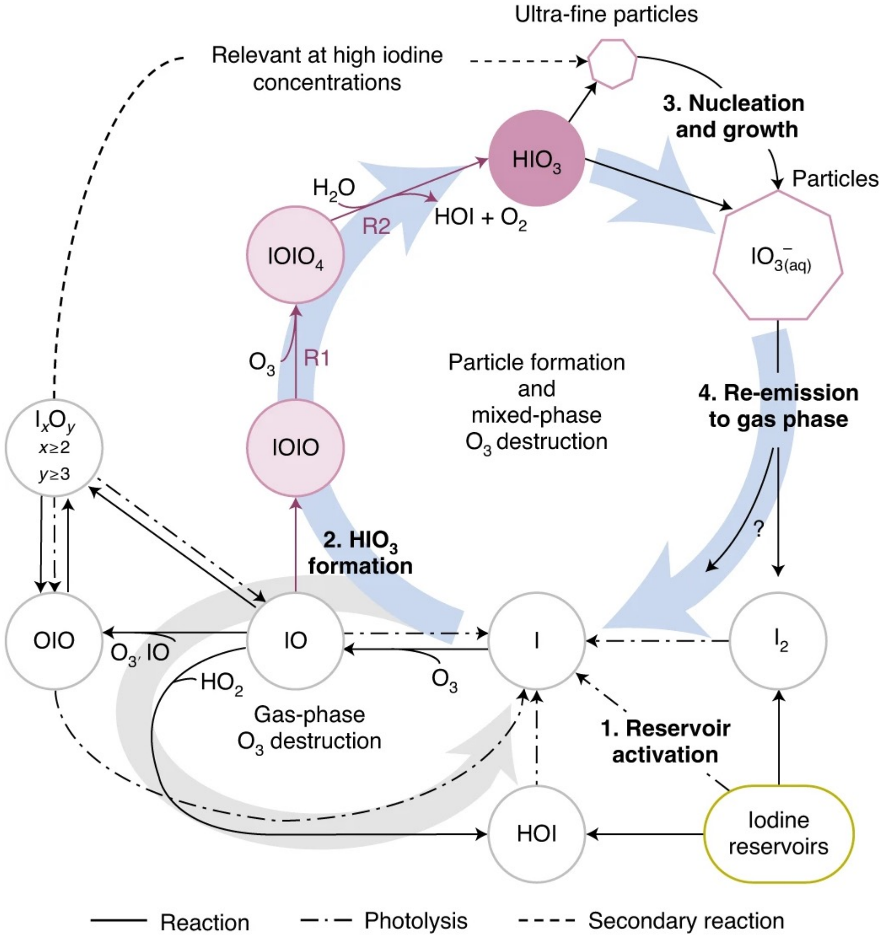
Baccarini et al. 2020

Arctic NPF



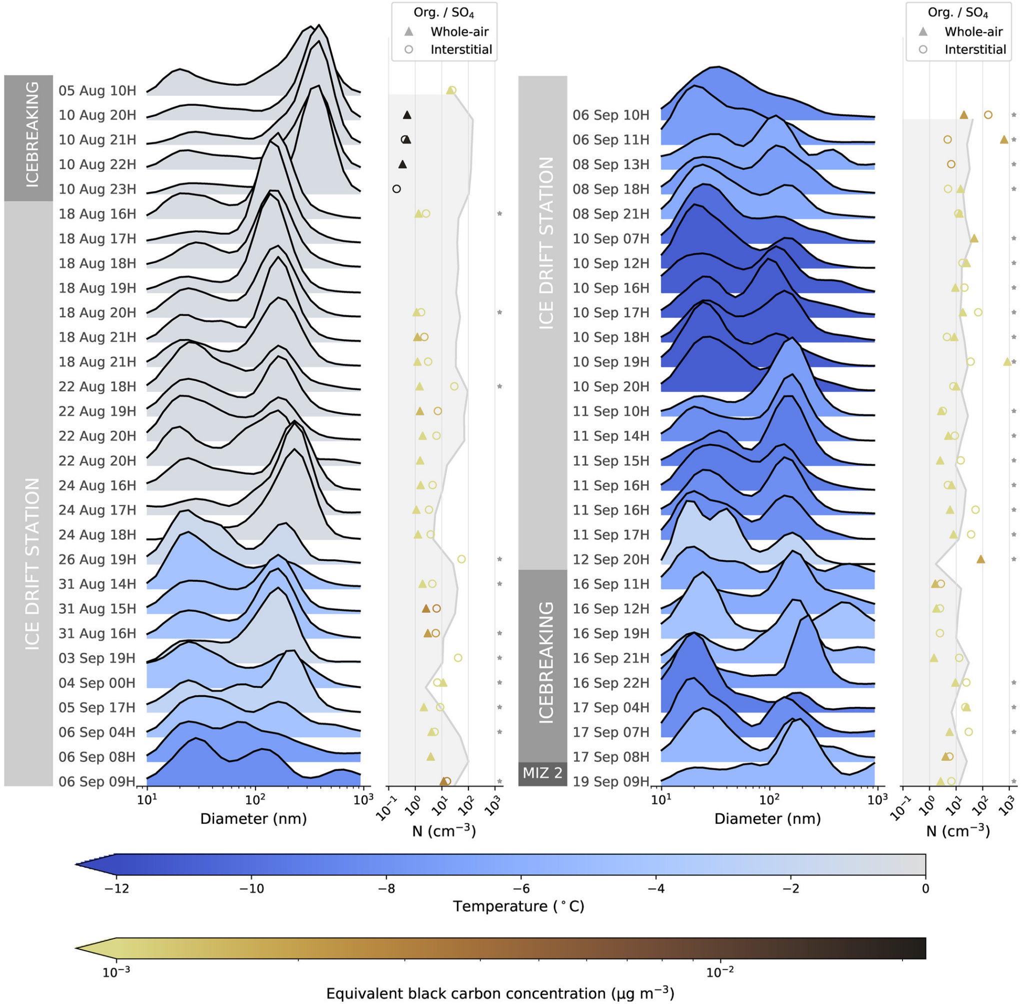
Schmale and Baccarini (2021)

Iodic acid formation



Finkenzeller et al. (2022)

Cloud residuals



Karlsson et al. (2022)

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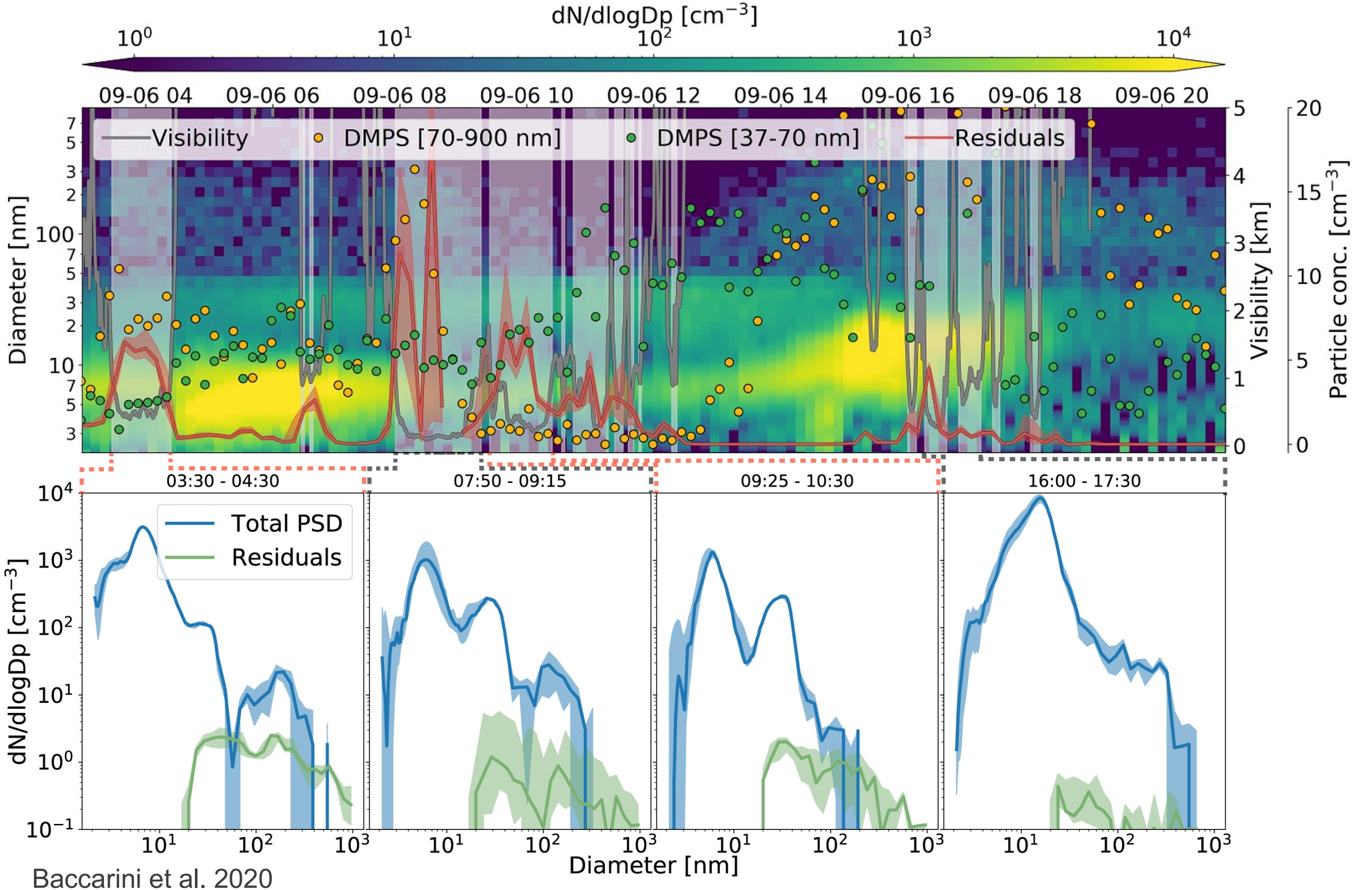
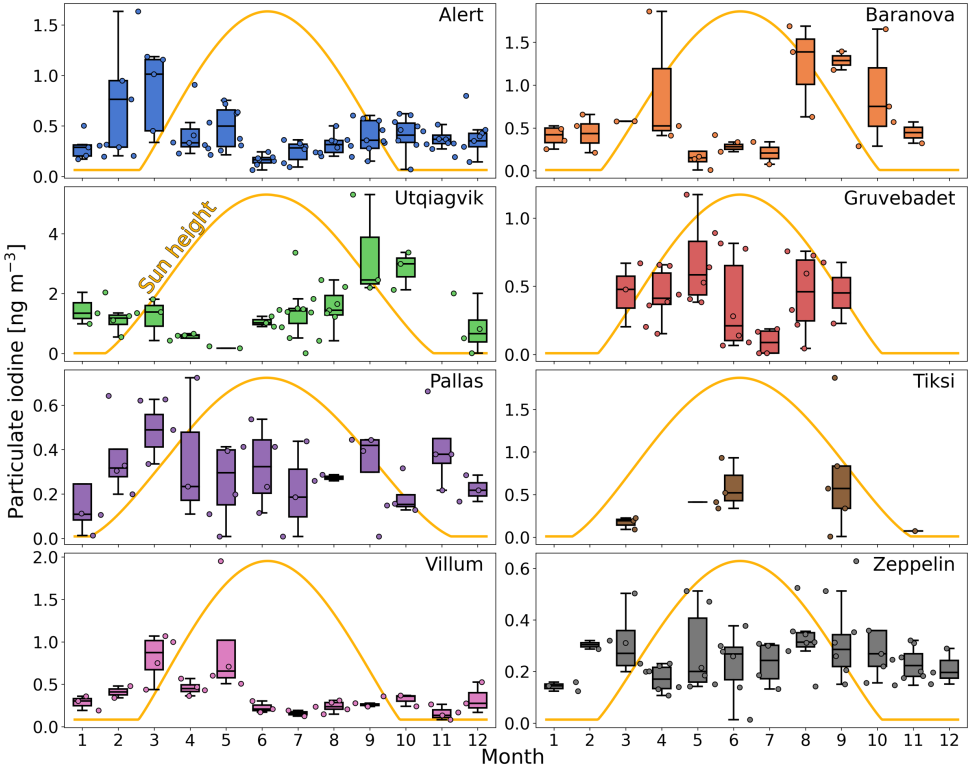
NPF and CCN activation

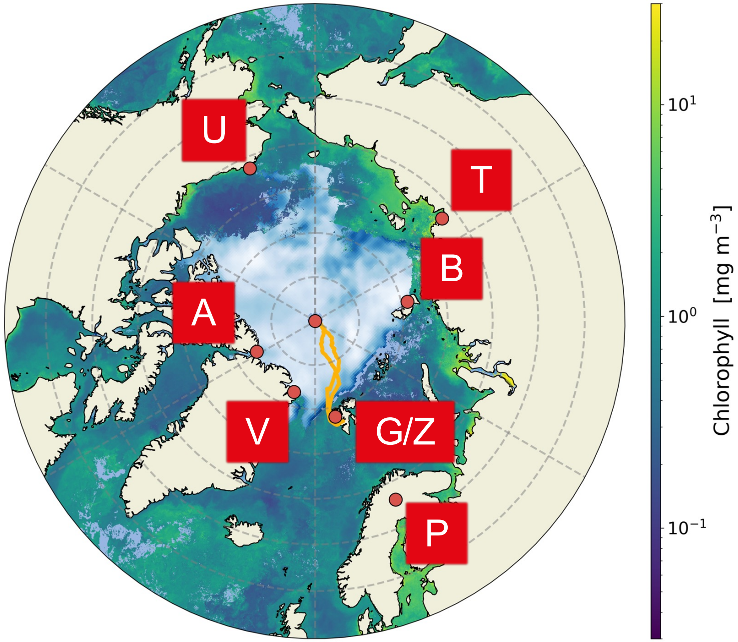
*Residuals measured with a Counter-flow virtual impactor inlet



Baccarini et al. 2020

Particulate iodine across the Arctic





Baccarini et al. in prep