# Importance of secondary ice production over a large temperature range in Arctic mixed-phase clouds

This presentation participates in OSPP

Outstanding Student & PhD candidate Presentation contest

**EGU General Assembly**

26/05/2022


**Julie T. Pasquier**

julie.pasquier@env.ethz.ch

J. Henneberger, F. Ramelli, A. Lauber, R. O. David, J. Wieder, T. Carlsen, R. Gierens, M. Maturilli, and U. Lohmann

IAC Institute for Atmospheric and Climate Science ETH zürich

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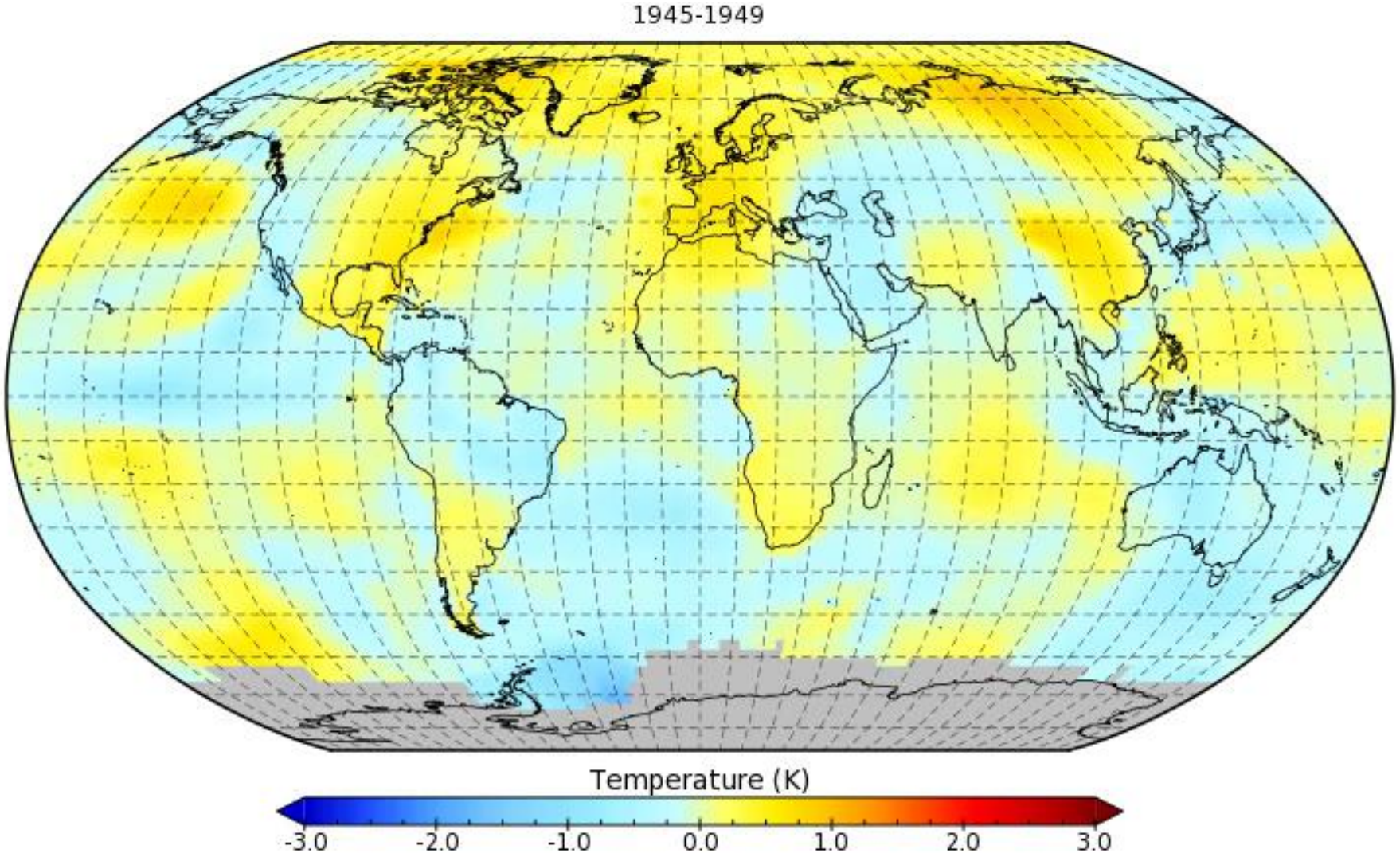
# Arctic amplification




Annual Surface Temperature Anomaly
(Base 1951 – 1980)

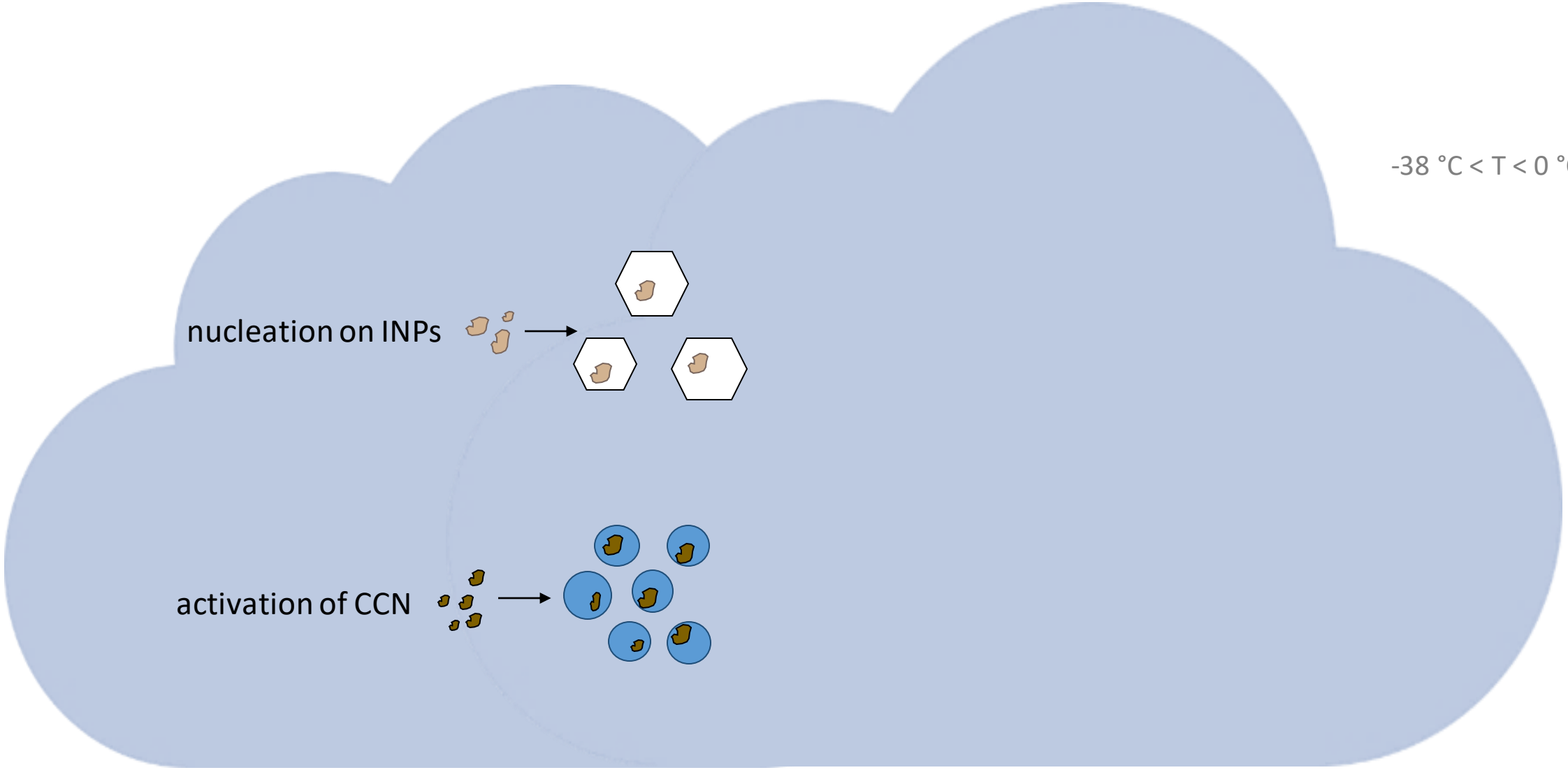
NASA and Goddard Space Flight Center (2021)

*“Cloud feedbacks are the most uncertain of all the radiative feedbacks in the polar regions…”*

Goosse et al., Nature communication, (2018)

# Cloud particle formation in mixed-phase clouds

Formation on aerosols

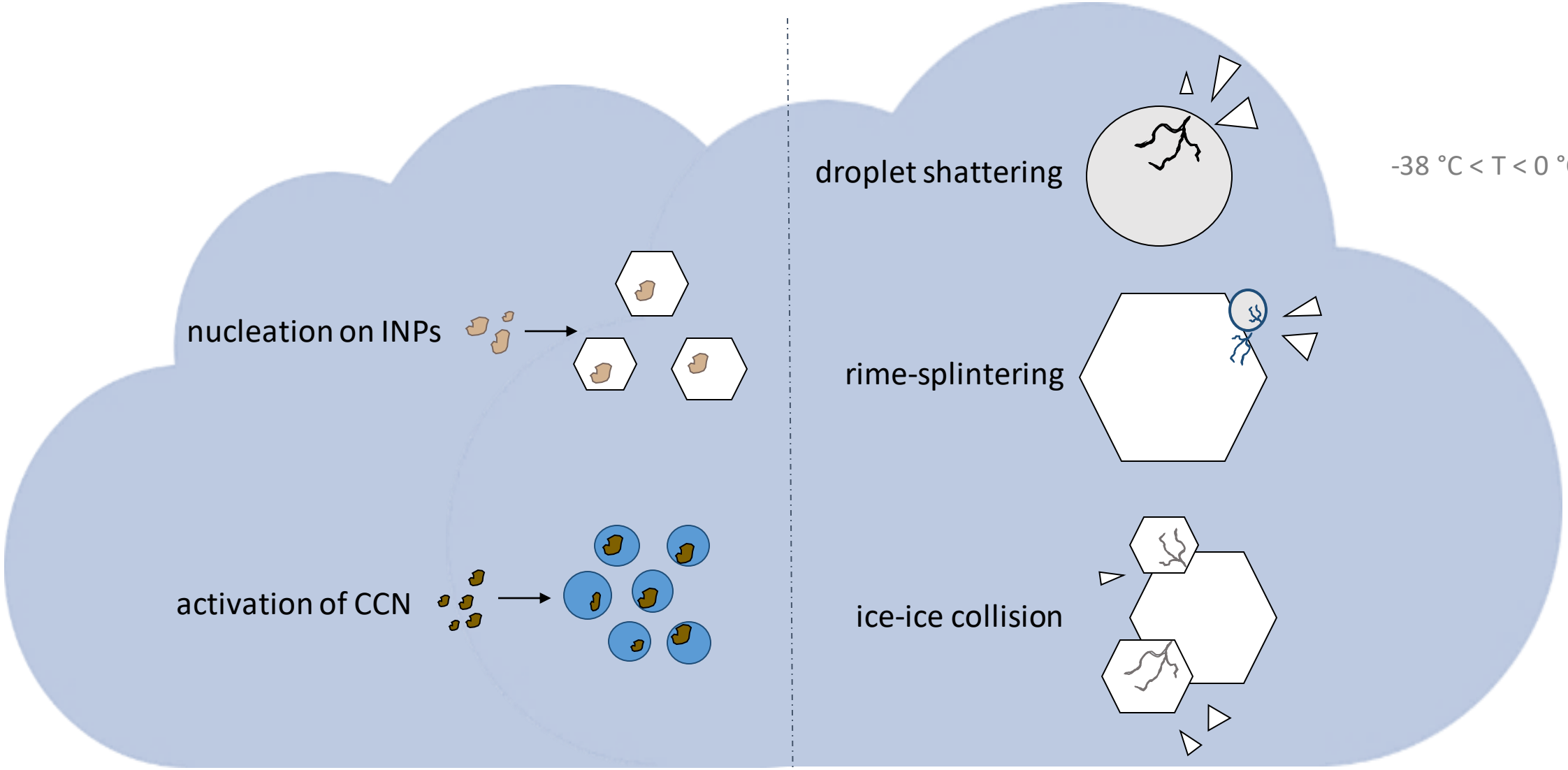



-38 °C < T < 0 °C

INPs: ice nucleating particles

CCN: cloud condensation nuclei

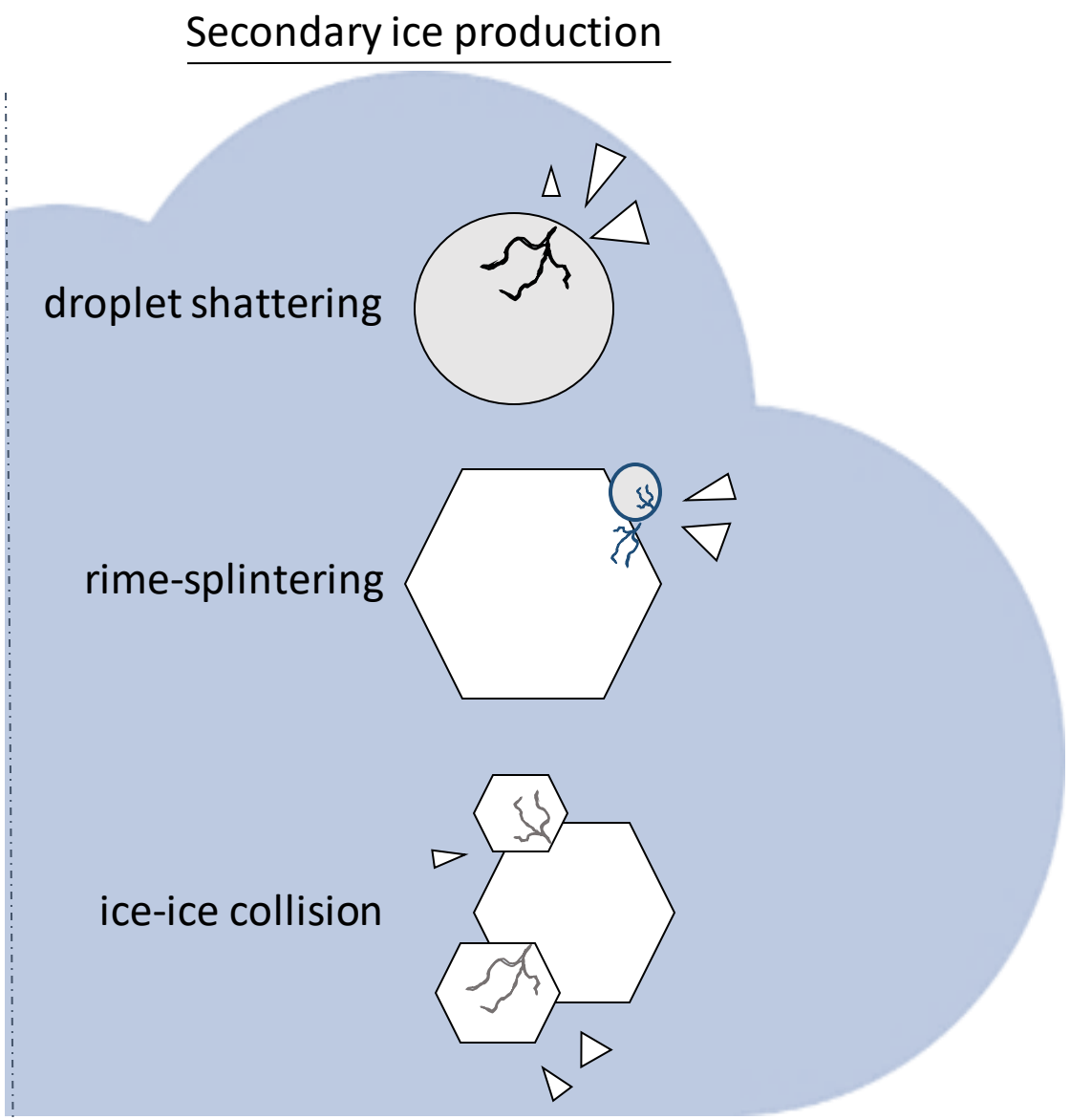
# Cloud particle formation in mixed-phase clouds




INPs: ice nucleating particles CCN: cloud condensation nuclei

# Secondary ice production (SIP) in Arctic mixed-phase clouds

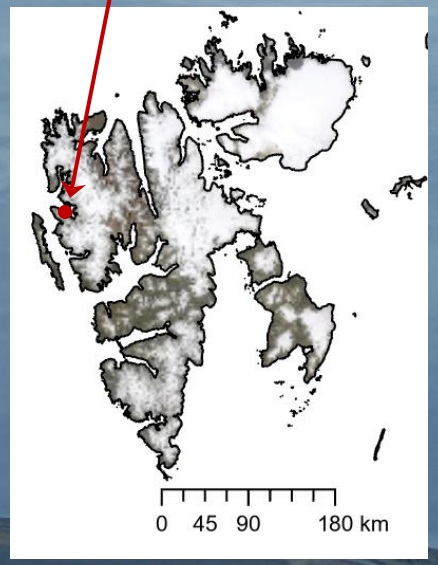
- How frequent is SIP in Arctic mixed-phase clouds?
- Under which conditions does SIP occur in Arctic mixed-phase clouds?




INPs: ice nucleating particles

CCN: cloud condensation nuclei

# The Ny-Ålesund AeroSol Cloud ExperimeNT




AWIPEV Observatory

Cloud radar

Radiosondes

HoloBalloon

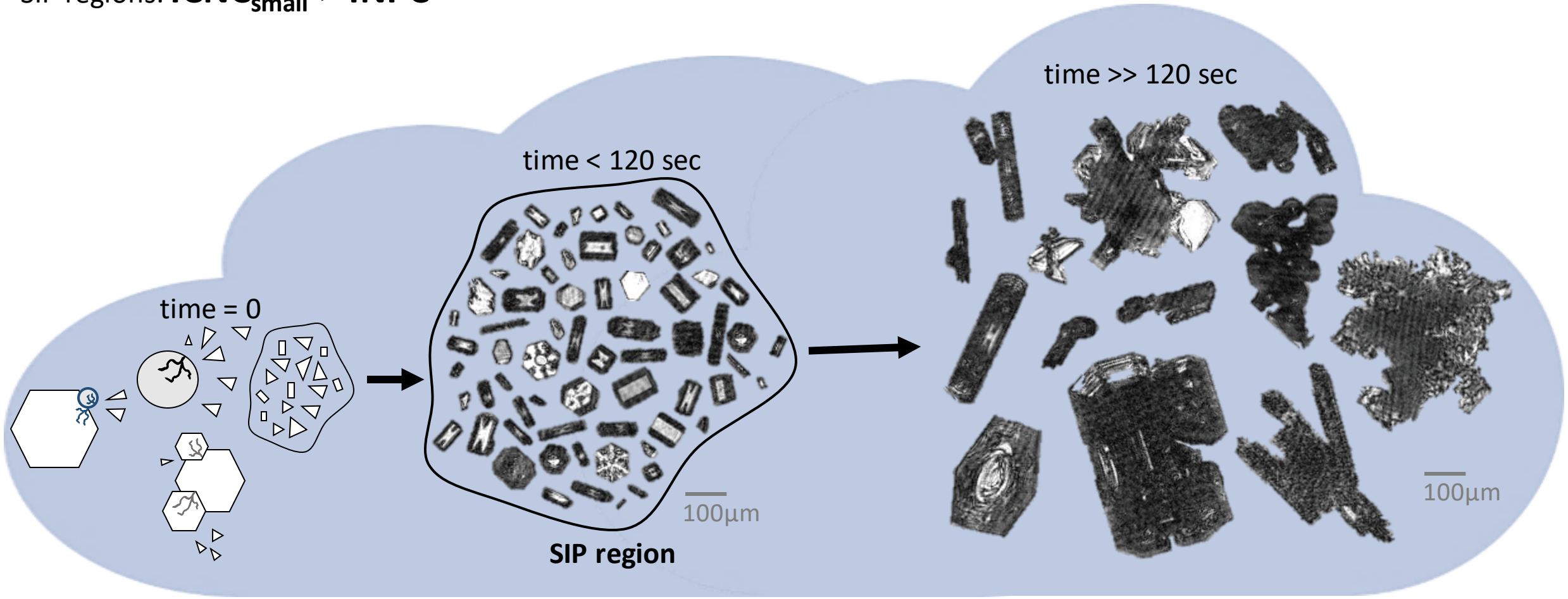
Aerosol container

*October – November 2019*
*March – April 2020*

**Overview paper:**
Pasquier et al., BAMS, in revision

# Identification of regions with SIP

- SIP regions: **$ICNC_{small}$ > INPC**

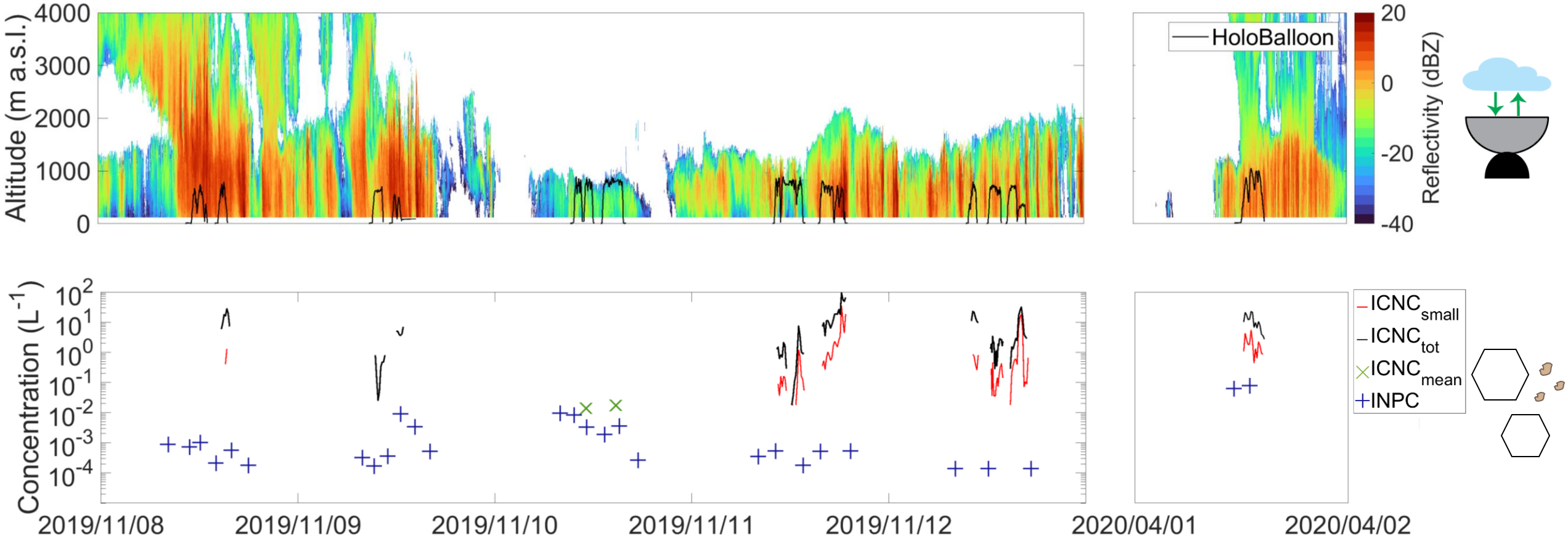



SIP: secondary ice production INPC: ice nucleating particle concentration $ICNC_{small}$: ice crystal number concentration of ice particles smaller 100 µm



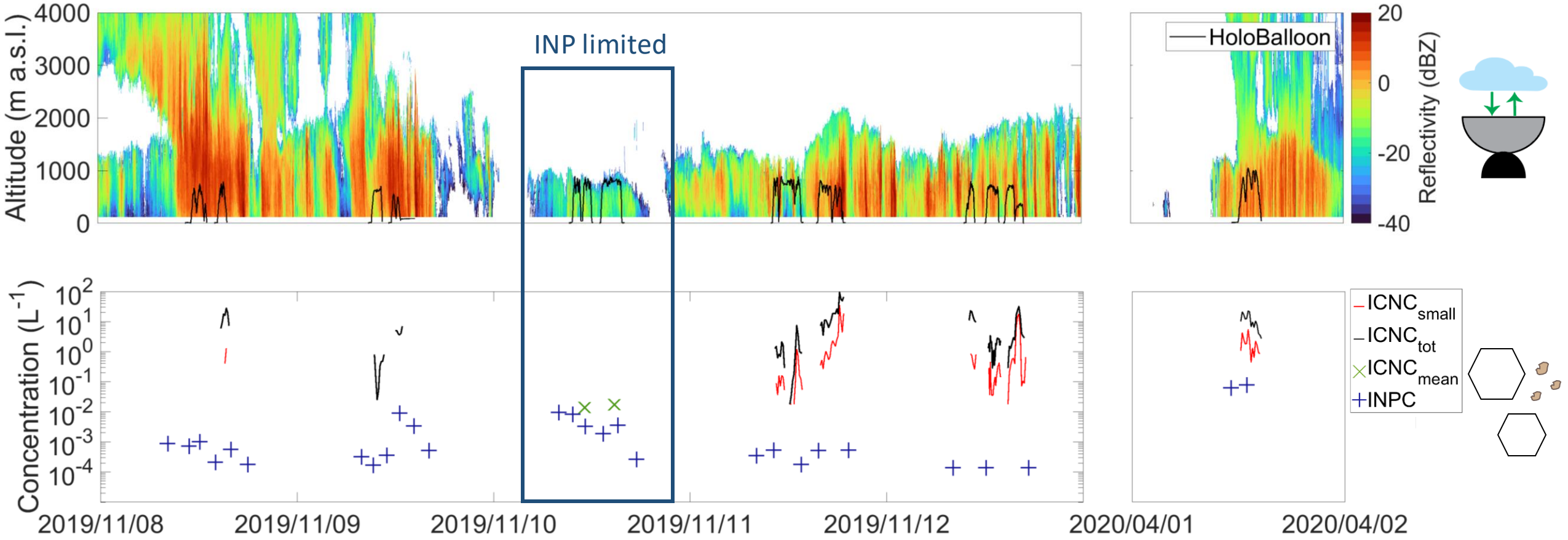
Approach adapted from Korolev et al., ACP, 2020

# Measurements in mixed-phase clouds



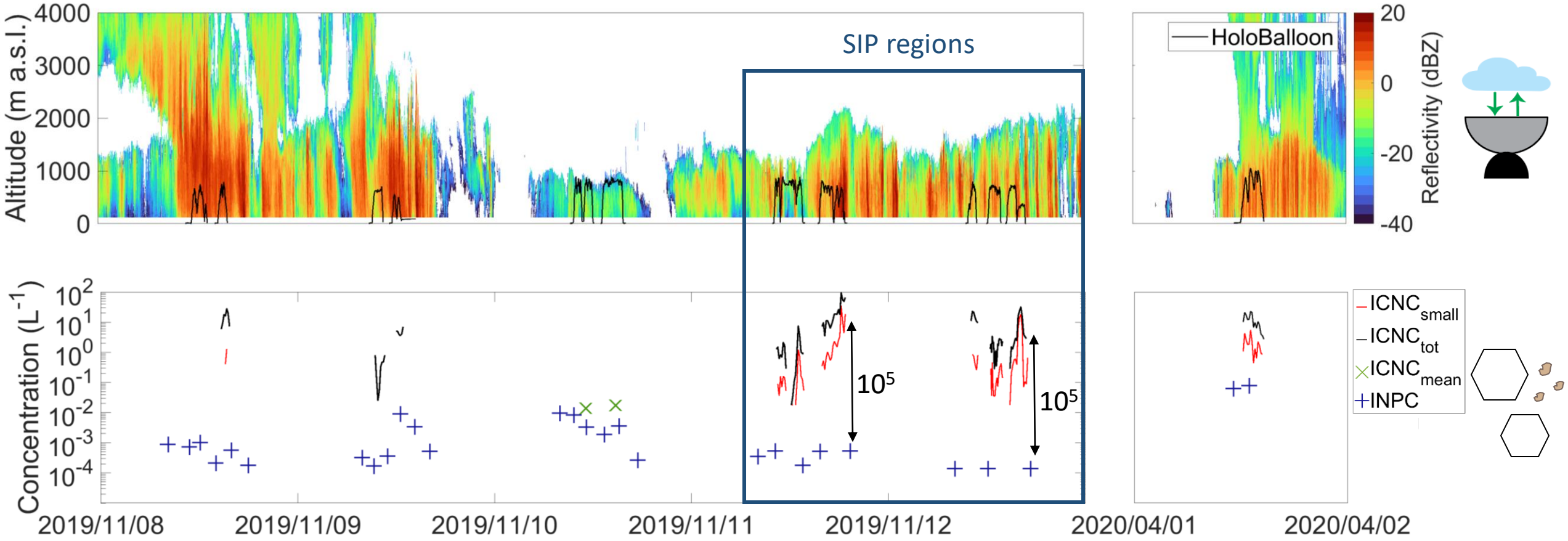

Pasquier et al., ACPD, 2022

# Primary ice formation dominates




Pasquier et al., ACPD, 2022

# Secondary ice formation dominates




Pasquier et al., ACPD, 2022

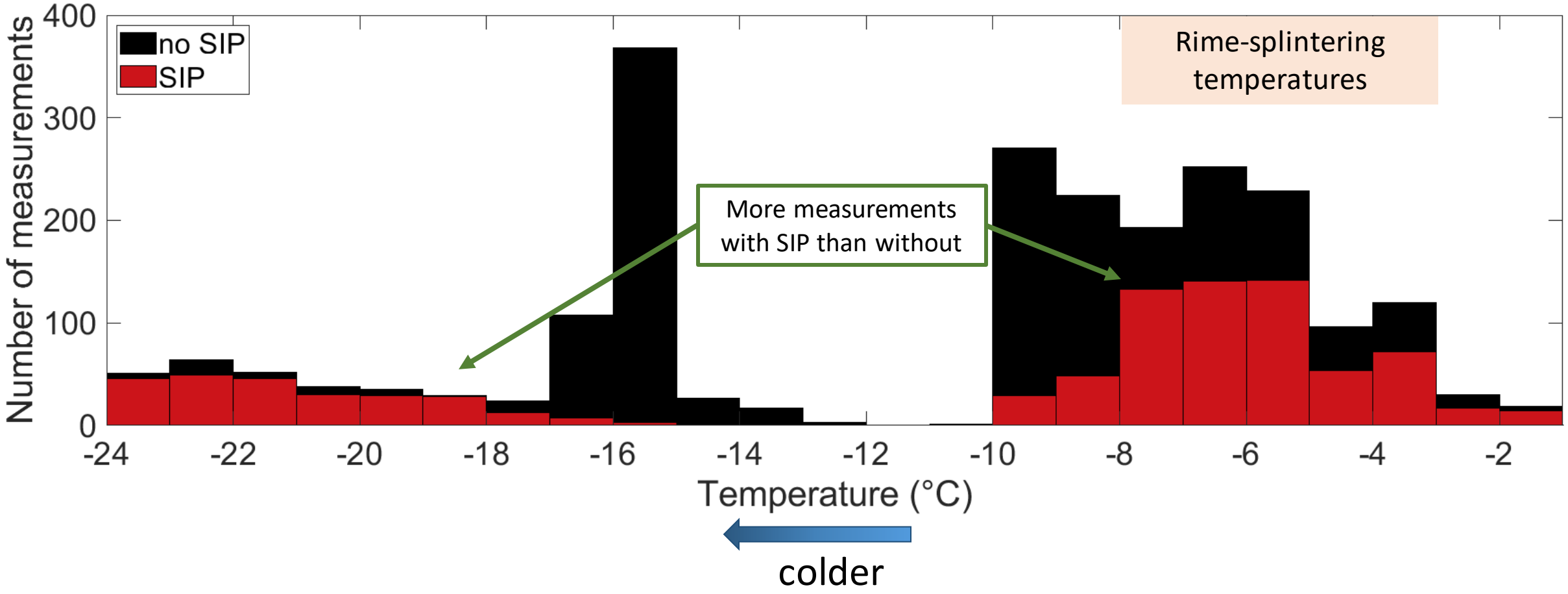
**How frequent is SIP in Arctic mixed-phase clouds?**

Evidence for secondary ice production was observed in **40%** of the in-cloud measurements

**Under which conditions does SIP occur in Arctic mixed-phase clouds?**

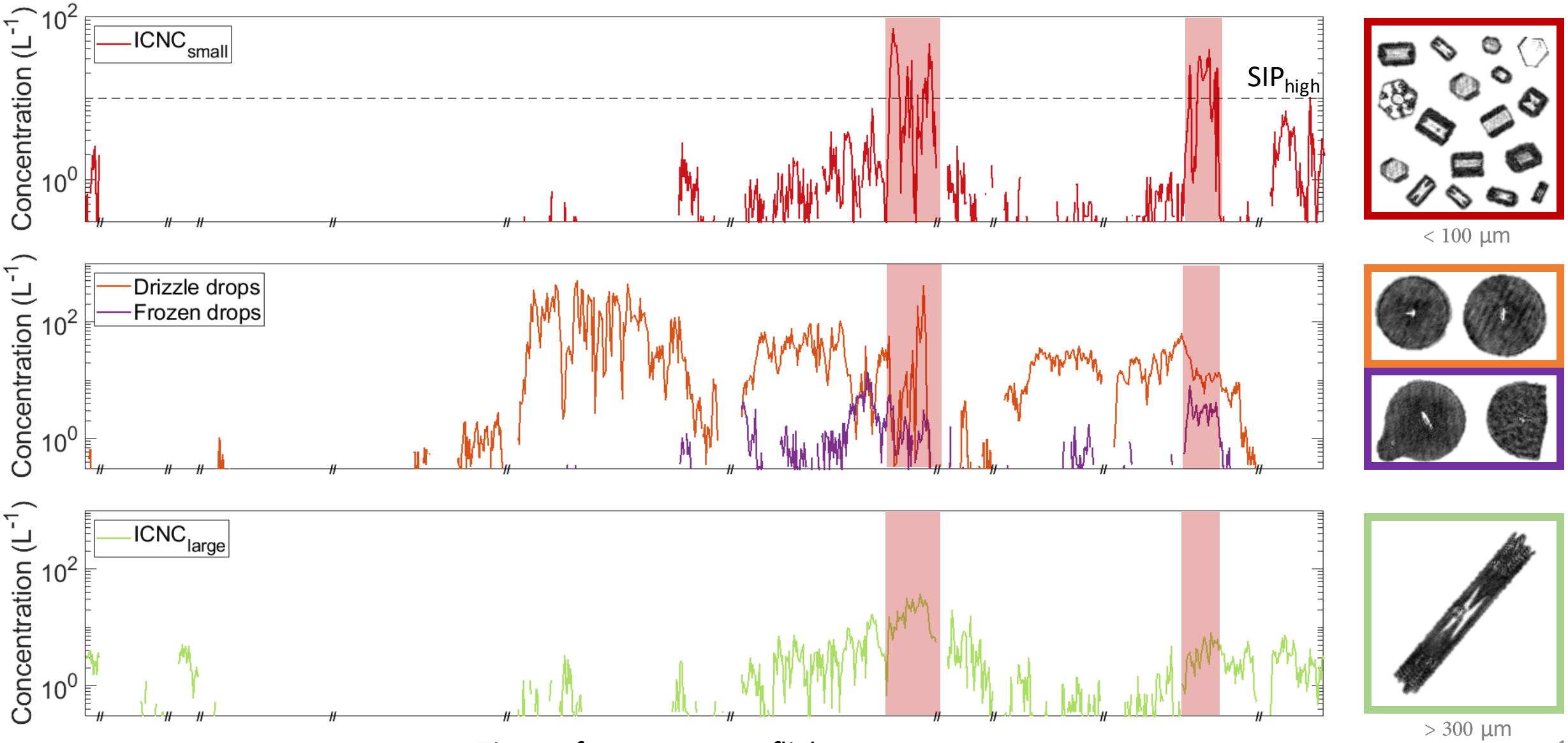
# Ambient temperature during SIP

SIP occurred over a large temperature range



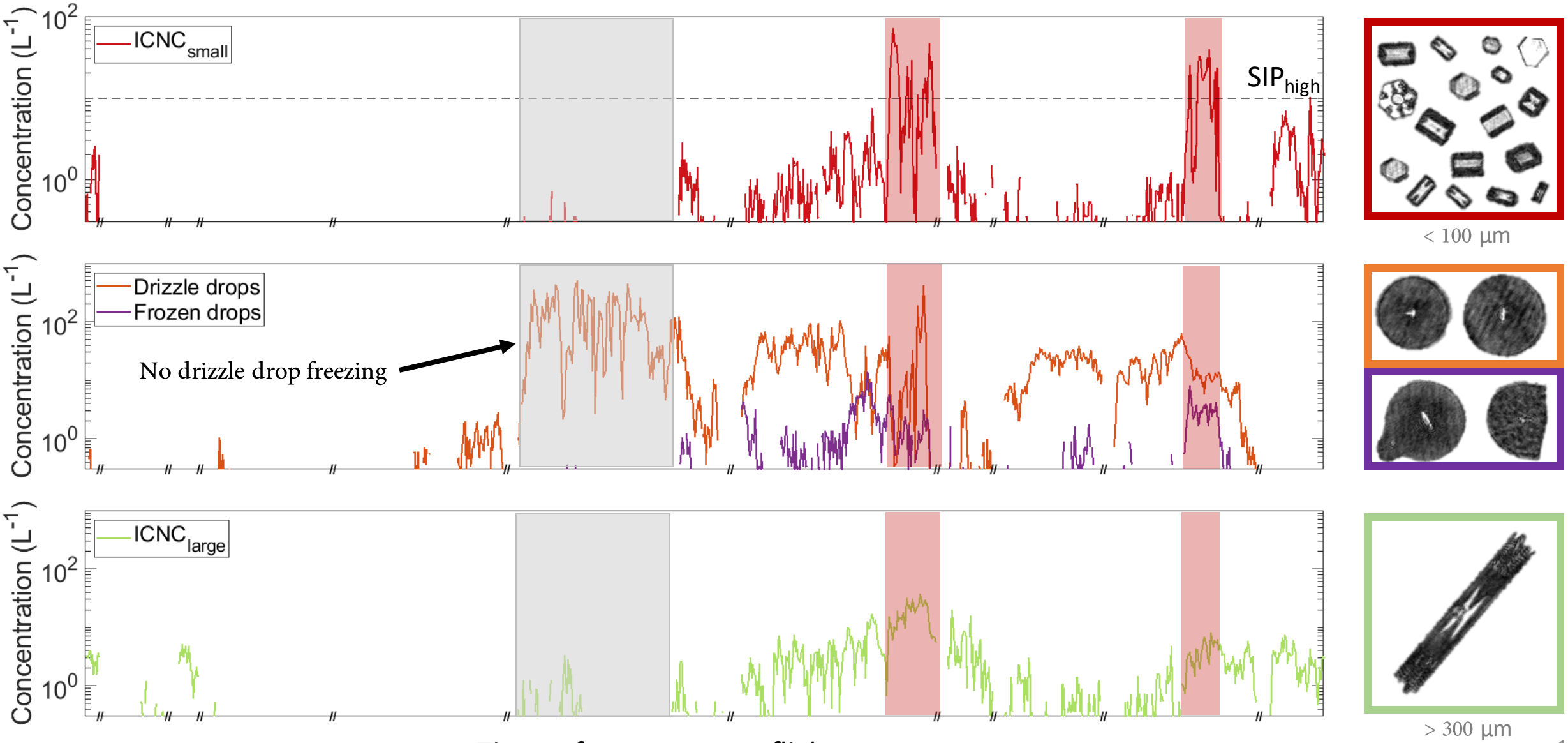

Pasquier et al., ACPD, 2022

# SIP from droplet shattering




Pasquier et al., ACPD, 2022

# SIP from droplet shattering






< 100 µm





> 300 µm

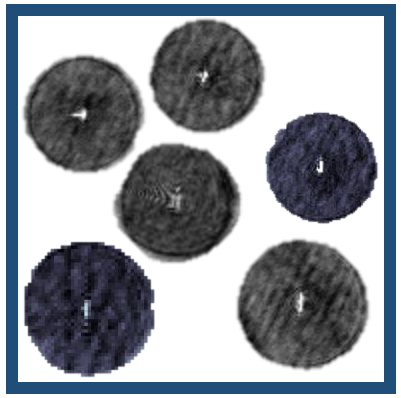


Pasquier et al., ACPD, 2022

# A roadmap for high SIP in Arctic mixed-phase clouds

Low **CCN** concentrations & sufficient updrafts

Drizzle drops



Freezing drops

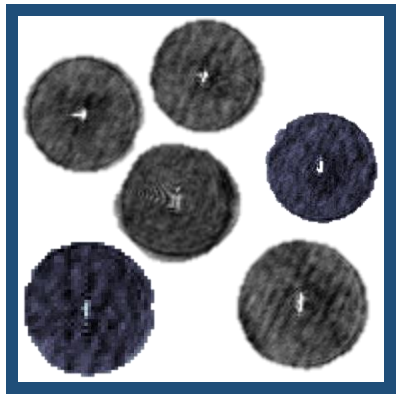
**INP**

Ice crystals

# A roadmap for high SIP in Arctic mixed-phase clouds

Low **CCN** concentrations & sufficient updrafts

Drizzle drops



Low CCN and sufficient INP concentrations increase SIP

**INP**

Ice crystals

Freezing drops

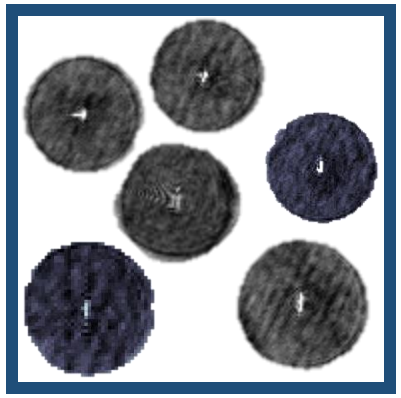
High concentration of small ice crystals

100µm

# A roadmap for high SIP in Arctic mixed-phase clouds

Low **CCN** concentrations & sufficient updrafts

Drizzle drops



Ice crystals

**INP**

Freezing drops

High concentration of small ice crystals

100µm

Positive feedback enhances droplet shattering

# Conclusions

## How frequent is SIP?

- Evidence for secondary ice production was observed in **40%** of the measurements in the Arctic mixed-phase clouds

## Which conditions are favorable for SIP?

- SIP occured over a temperature range between **-1 °C** and **-24 °C**
- **Droplet shattering** was found to be responsible for the high SIP

# Thank you for your attention

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