New Particle Formation in Arctic-
The knowns and the unknowns

SIOS access Call (2021) Funded Project:

Molecular steps of New Particle Formation in the Arctic atmosphere part II - long-term measurements (NPFARCTIC-II)

RIS-ID: 11031

Roseline Thakur,

Post Doc, INAR

(Principle Investigator)

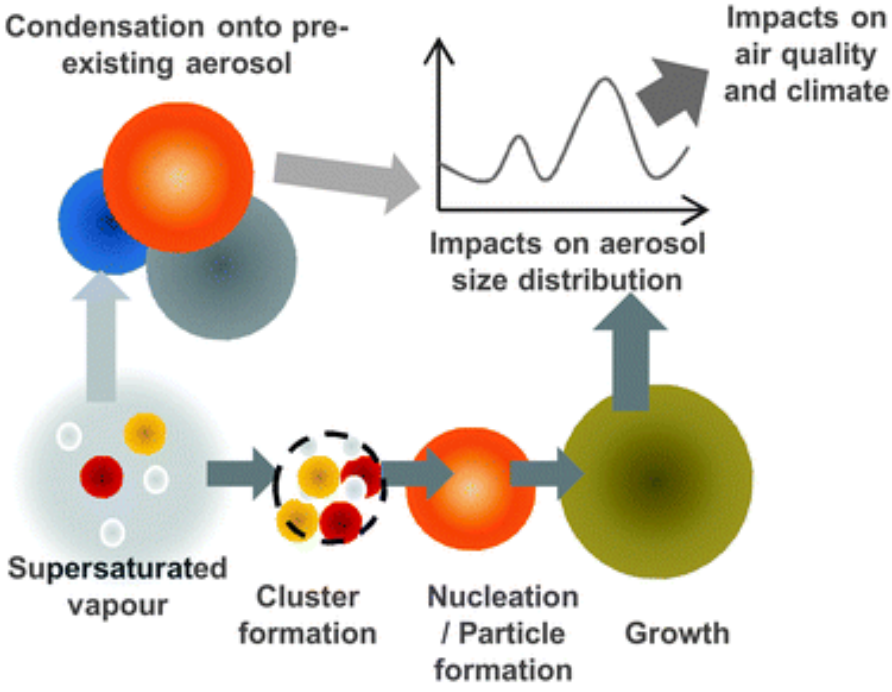
Group: Polar and Arctic Atmospheric Research (PANDA)

https://www.helsinki.fi/en/researchgroups/polar-and-arctic-atmospheric-research

Project Head: Mikko Sipilä

Introduction

- Aerosols act as cloud condensation nuclei (CCN) and ice nuclei, aerosols also play an important role in controlling cloud formation/development, albedo, frequency, and lifetime of clouds
- Aerosol particles are either emitted directly into the atmosphere (referred to as primary particles) or produced in the atmosphere via gas-to-particle conversion
- New particle formation (NPF), involves formation of high concentrations of subnanometer-sized (1–3 nm) particles in the atmosphere followed by their growth (Kulmala et al., 2014).
- Atmospheric observations show that about 10% to 60% of the NPF events lead to CCN formation



Gas-to-particle conversion processes and the impacts of particle formation and growth from atmospheric vapours (Vehkamäki and Riipinen, 2012)

What we know of this process in Arctic

The Arctic Ocean emits a variety of precursor gases for new particle formation (NPF) particle growth to the sizes of cloud condensation nuclei (CCN).

These gases include:

- Dimethylsulfide (DMS) (Levasseur, 2013),
- Organic compounds (OVOCs in Canadian Arctic) (Mungall et al., 2017)
- Biogenic organic compounds (Western Greenland) (Wester-Larsen et al., 2020)
- Iodine species (Cuevas et al., 2018; Raso et al., 2017).
- Coastal bird colonies form a primary source of Ammonia (NH_3) (Croft et al., 2016)
- Arctic tundra is a source of volatile organic compounds (VOC) (Lindwall et al., 2016).

- The NPF (through particle number size distributions) frequency in the Arctic atmosphere was found to be correlated with the diminishing sea ice extent (Dall'Osto et al., 2017, 2018)
- NPF may contribute to a large fraction of the high Arctic CCN number concentration (Gordon et al., 2017).
- Over the Central Arctic Ocean Iodine driven NPF was observed (Baccarini et al., 2020).
- NPF processes are highly different in two Arctic sites, Greenland and Ny-Ålesund (Beck et al., 2020)

Some unknowns…….

The absence of detailed chemical understanding down to molecular scale observations (Lee et al., 2019).

Baccarini et al., 2020

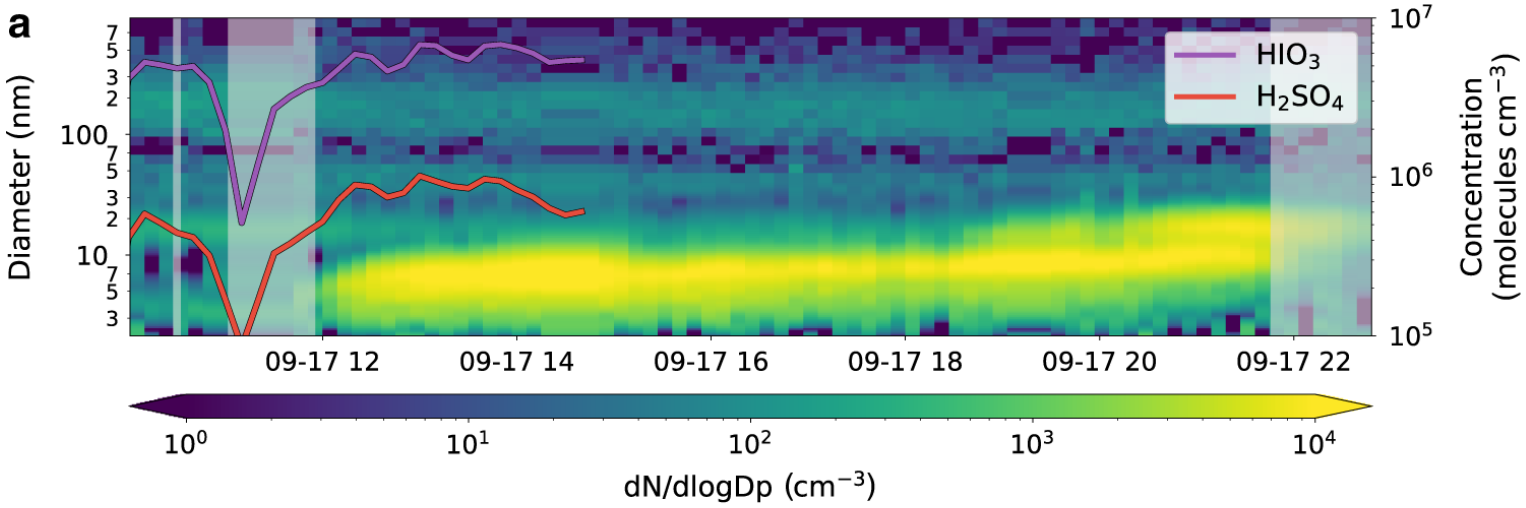
the contribution of gaseous precursors to Arctic marine SOA remain poorly defined" (Abbatt et al., 2019).

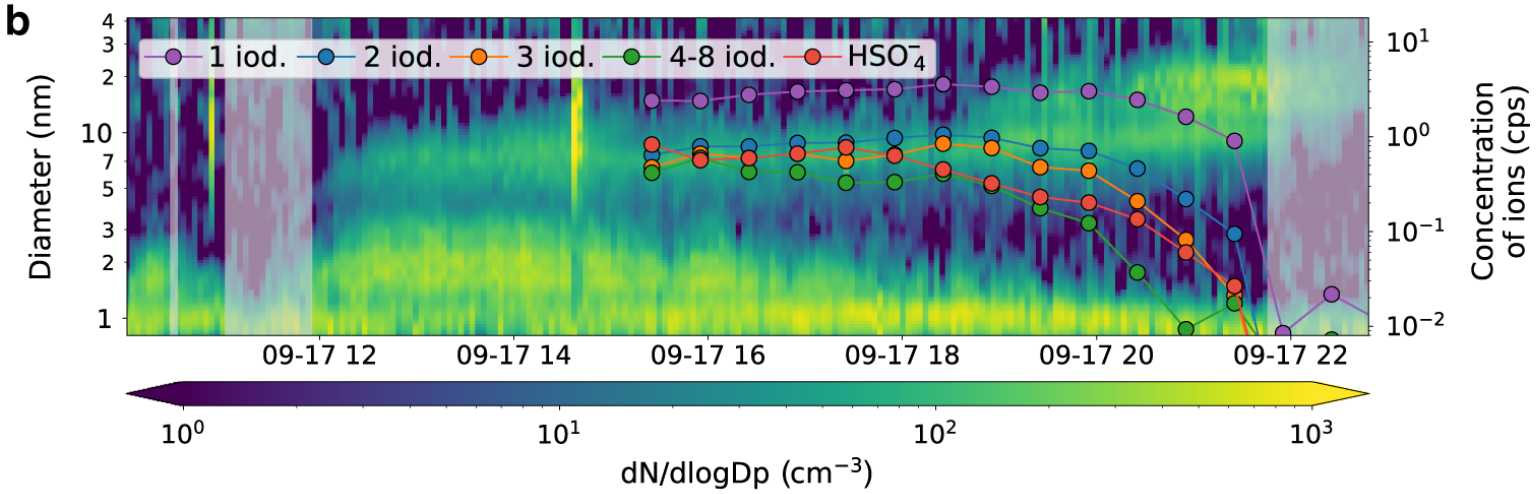
Baccarini et al., 2020

The details of chemical driven mechanisms of NPF and CCN production over ice-covered and open Arctic waters have remained largely unknown"

Beck et al., 2020

Baccarini et al., 2020, Nature Comm.





11 major NPF events over the pack ice in total, all driven by HIO_3 (iodic acid) insignificant contribution from sulfuric acid or other compounds

Increase of HIO_3 and NPF linked to sea ice freezing onset

nature COMMUNICATIONS

ARTICLE

https://doi.org/10.1038/s41467-020-18551-0 OPEN

Frequent new particle formation over the high Arctic pack ice by enhanced iodine emissions

Andrea Baccarini[1], Linn Karlsson[2], Josef Dommen[1], Patrick Duplessis[3], Jutta Vüllers[4], Ian M. Brooks[4], Alfonso Saiz-Lopez[5], Matthew Salter[2], Michael Tjernström[6], Urs Baltensperger[1], Paul Zieger[2] & Julia Schmale[1,7]

Iodic acid concentration : >8 × 10^6 molecules cm^{-3}, the sulfuric acid concentration remains six to ten times lower.

The negatively charged clusters are composed of iodine oxides with a maximum of eight iodine atoms per cluster, whereas the largest pure sulfuric acid cluster detected is only the trimer

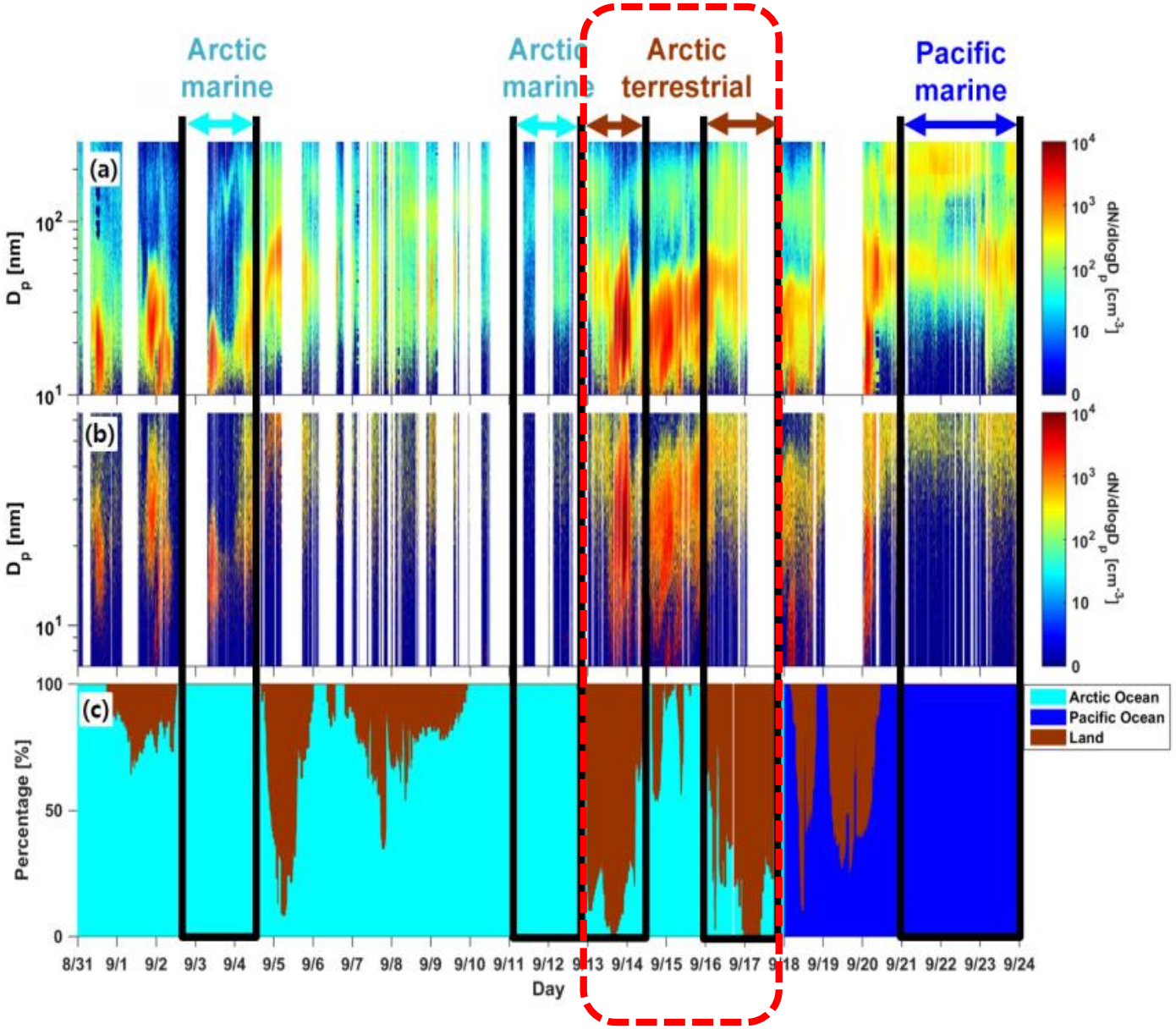
Atmos. Chem. Phys., 20, 5573–5590, 2020
https://doi.org/10.5194/acp-20-5573-2020

Atmospheric Chemistry and Physics
Open Access
EGU

Shipborne observations reveal contrasting Arctic marine, Arctic terrestrial and Pacific marine aerosol properties

Jiyeon Park[1], Manuel Dall'Osto[2], Kihong Park[3], Yeontae Gim[1], Hyo Jin Kang[1,4], Eunho Jang[1,4], Ki-Tae Park[1], Minsu Park[5], Seong Soo Yum[5], Jinyoung Jung[1], Bang Yong Lee[1], and Young Jun Yoon[1]

- Terrestrial ecosystems in the Arctic coastal area - including river outflows and tundra strongly affects aerosol emissions, **possibly more than anthropogenic Arctic emissions**
- The increased river discharge, tundra emissions and melting sea ice should be considered in future Arctic atmospheric composition and climate simulations



Beck et al., 2020, GRL.

At Villum, the lower concentration of SA and MSA compared to Ny-Ålesund, IA alone seems insufficient to grow particles effectively into CCN size regimes, unlike over the Arctic Ocean.

Suprisingly High concentration of HOMs in Ny-Ålesund!

HOMs generally are oxidation products of VOCs (autooxidation of peroxy radiacls, Bianchi et al., 2019) released by plants/forests. HOM concentrations in excess of 10^8 molecules cm^{-3} are typical for forests (Ehn et al., 2014)

The terrestrial biomass in the Ny-Ålesund area is scarce.

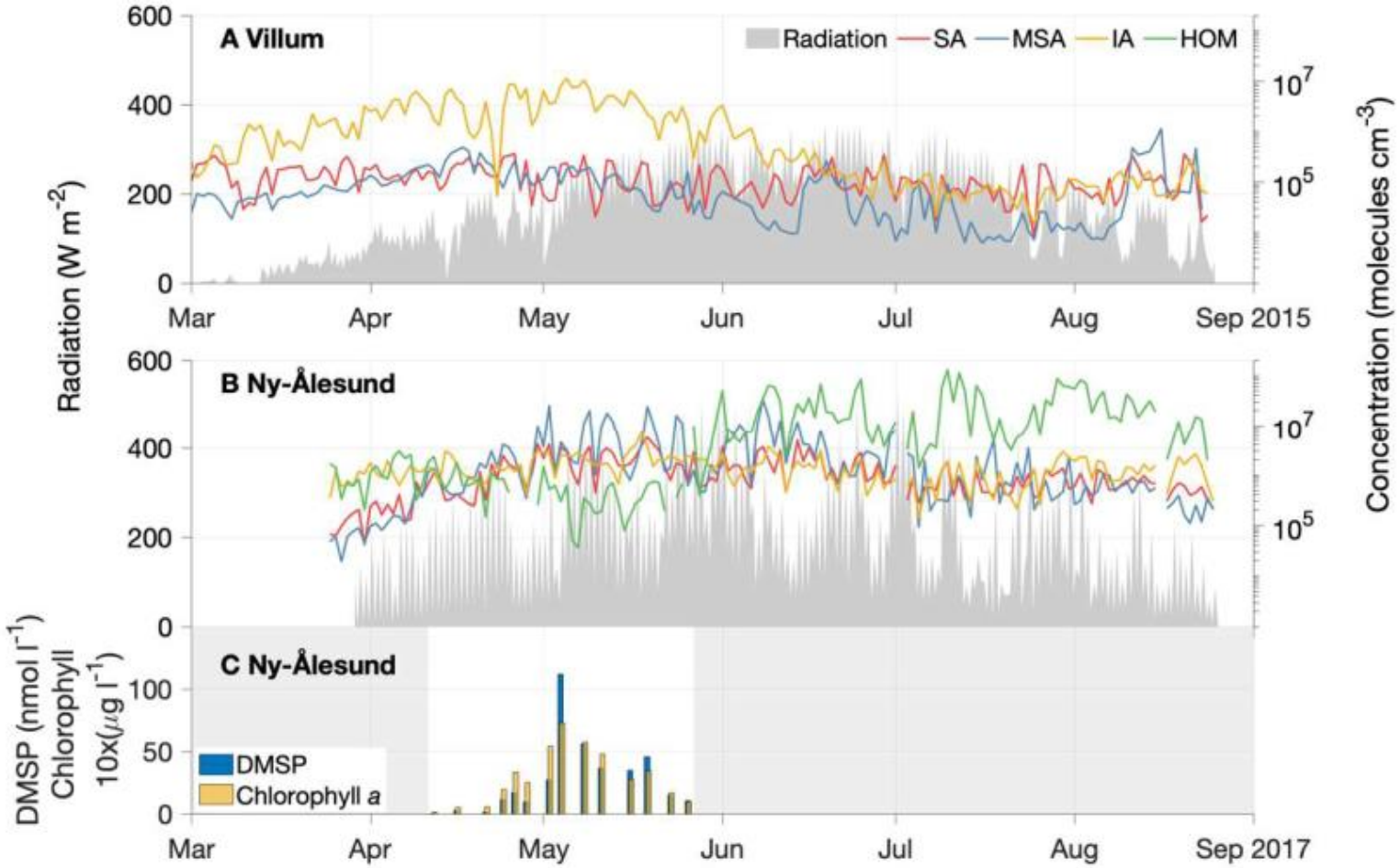
Geophysical Research Letters

Research Letter | Open Access

Differing mechanisms of new particle formation at two Arctic sites.

Lisa J. Beck, Nina Sarnela, Heikki Junninen, Clara J. M. Hoppe, Olga Garmash, Federico Bianchi, Matthieu Riva, Clemence Rose, Otso Peräkylä, Daniela Wimmer, Oskari Kausiala ... See all authors

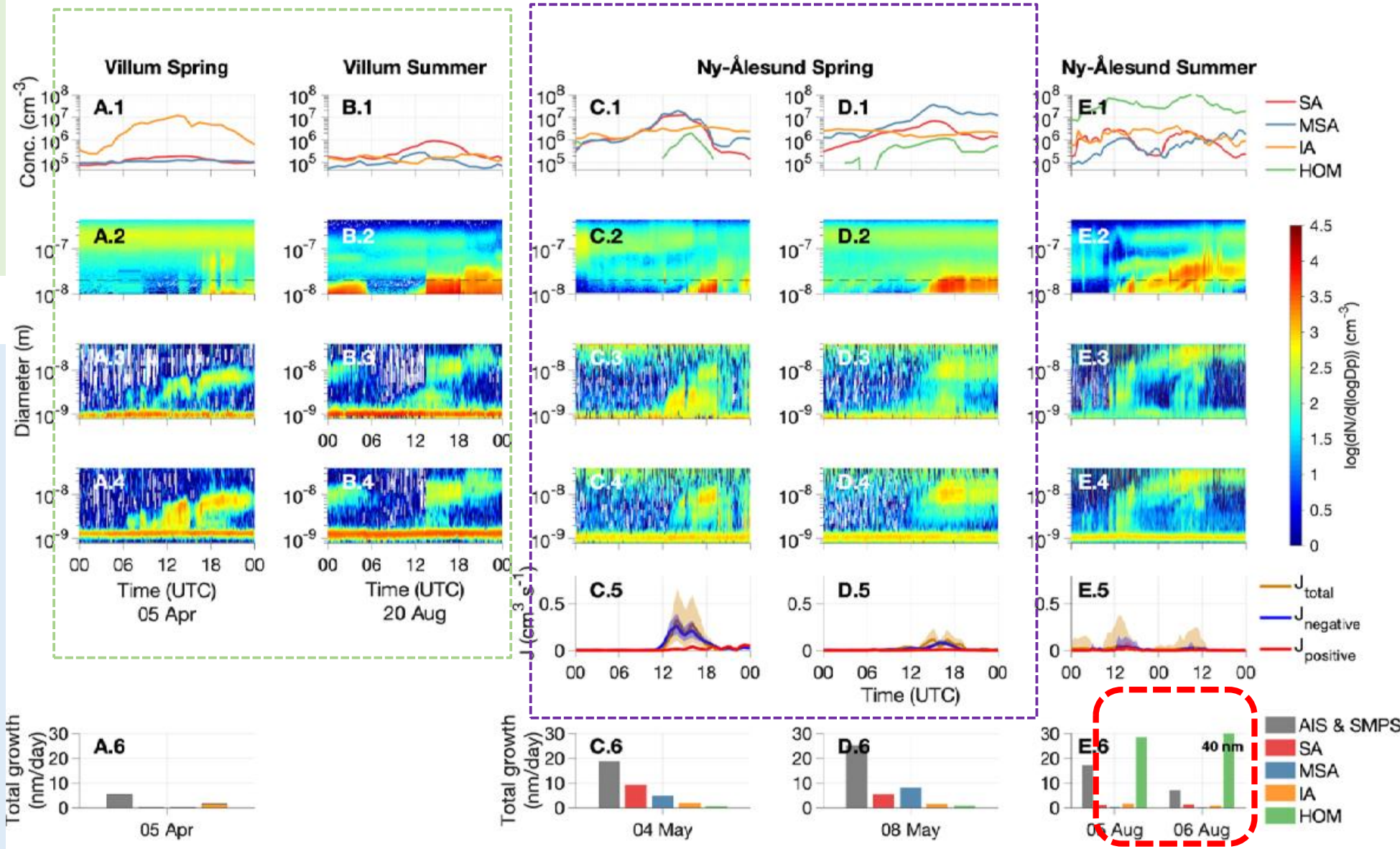
First published: 28 December 2020 | https://doi.org/10.1029/2020GL091334



Villum: weaker particle growth.
Springtime: pure iodic acid nucleation; summertime: weak SA-NH_3 nucleation

Ny-Ålesund: ion-induced nucleation of SA and NH_3 is an important pathway for secondary aerosol formation during the Arctic spring

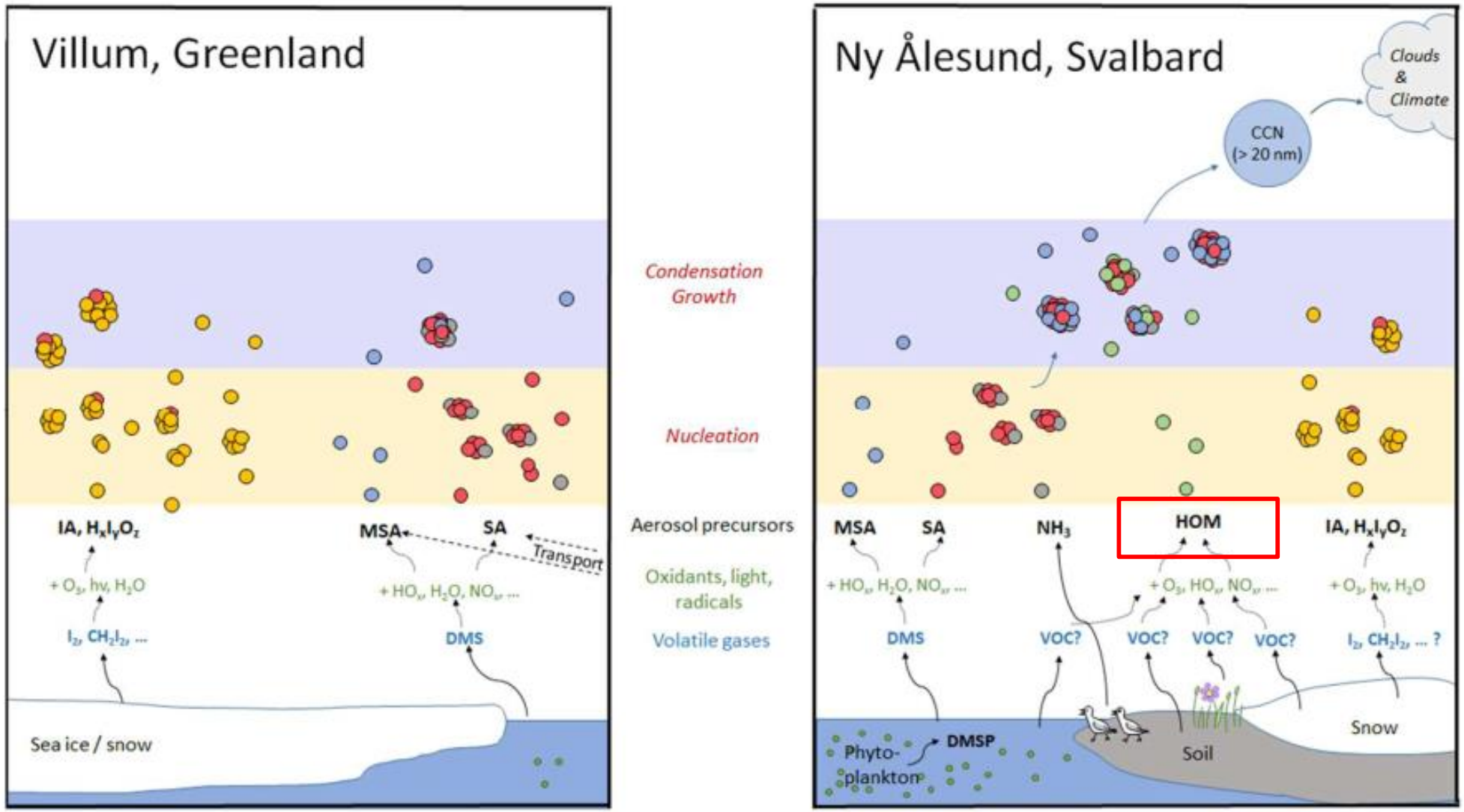
High HOM concentrations during summertime: likely involved in nucleation, dominant contribution to particle growth



IA: Iodic acid, SA: Sulphuric acid, MSA: Methanesulphonic acid, HOM: Highly Oxygenated molecules, NH3: Ammonia

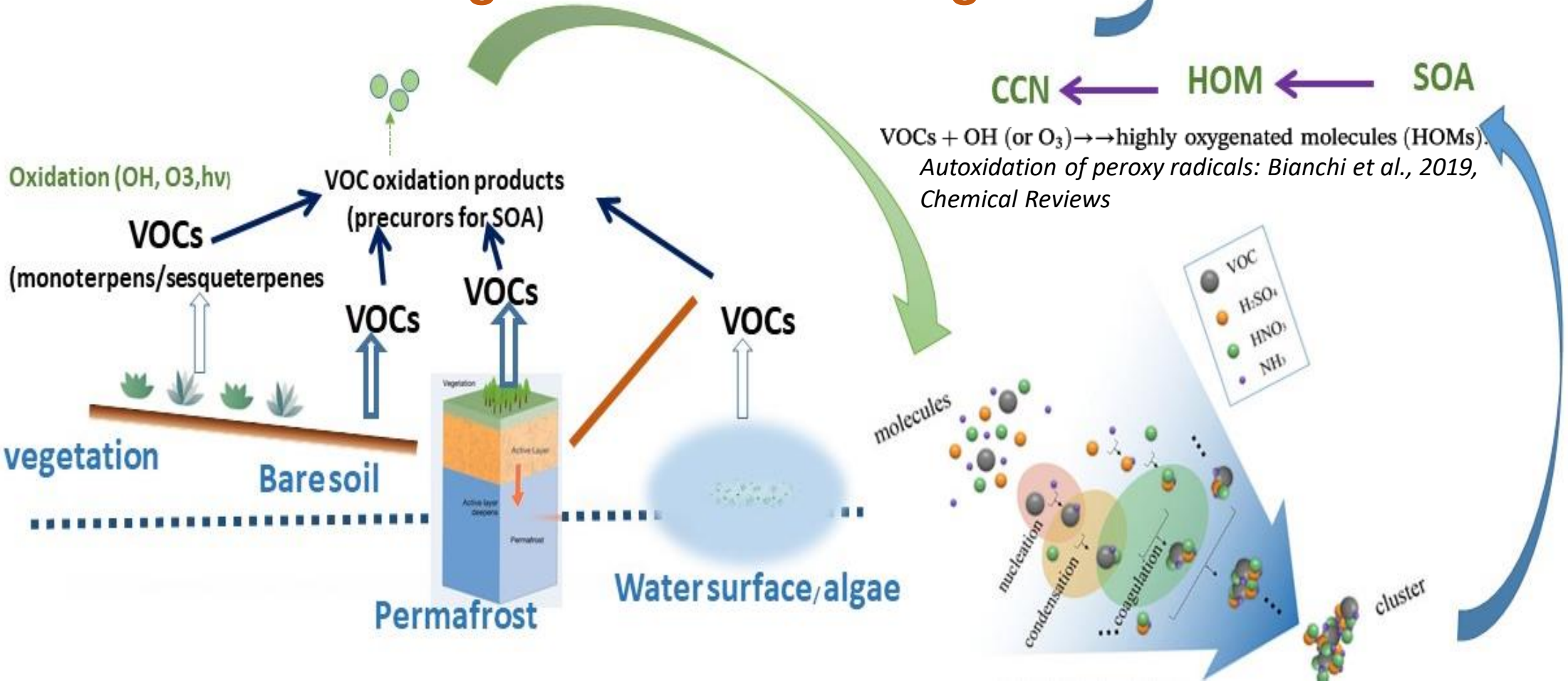
What we do not know…..

Sources of HOMs in Ny-Ålesund



VOCs? Why study them?

A small increase in the CCN concentration can lead to a pronounced increase in surface warming due to the longwave cloud forcing



Jiang et al., 2018, Sci.Tot.Environ.

Aims of the Project

long-term research program

1. Understanding the role of Biogenic Volatile Organic compounds oxidation products (HOMs),DMS oxidation products, Iodine compounds in aerosol formation and growth processes in Ny-Ålesund.

Campaign based: short term

2. Tracing source of HOMs in Ny-Ålesund.

3. Understanding the effect of changes in temperature, snow cover and vegetation cover on the emissions of BVOC.

AREA OF STUDY: Ny-Ålesund, Svalbard

Research Facilities and Collaboration

Research Facility in Ny-Ålesund: Dirigibile Italia

Faculty of Agriculture and Forestry, University of Helsinki, Helsinki, for VOCs flux chamber equipment and microbiological analysis of soil samples.

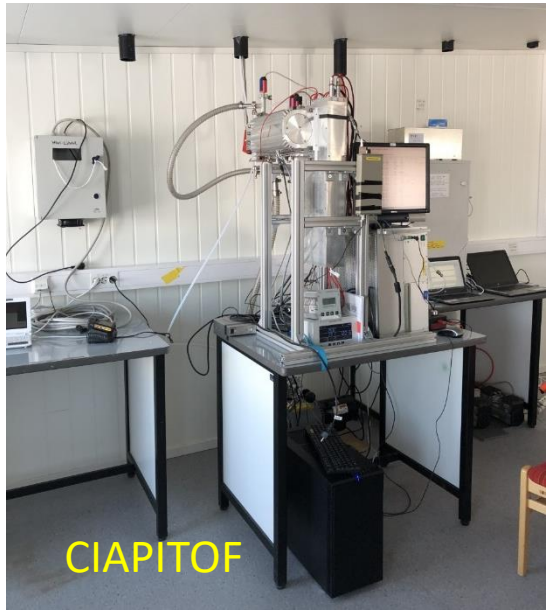
Finnish Meteorological Institute for providing Gas chromatography analysis of the samples (brought back from Arctic).

National Research Council of Italy (CNR) for obtaining meteorological and other particle data. CNR also provides facilities for INAR equipment at Ny-Ålesund.

Institute of Geosciences and Earth resources, CNR Italy for collaborative field work for soil cores collection from the active layer of the Permafrost site in Ny-Ålesund Arctic.

Methodology and instrumentation

- **The BVOCs fluxes**: measured manual steady-state flow-through flux chambers and Tenax tubes.
- **Online Analysis of VOCs**: A proton transfer reaction mass spectrometer
- **Offline Analysis**: Thermal desorption-Gas Chromatography- Mass Spectrometery,TD-GC-MS (Finnish Meteorological Institute).
- **Laboratory experiment**: short soil cores from Bayelva catchment (Permafrost areas) would be collected to study VOC release from thawing active layer

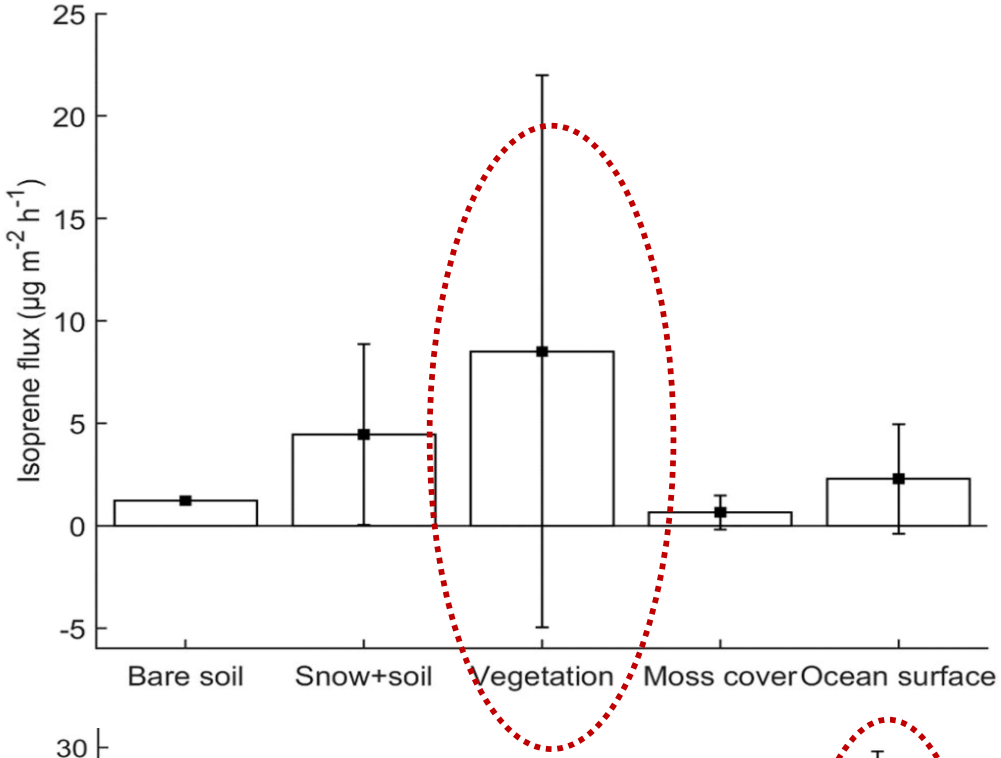


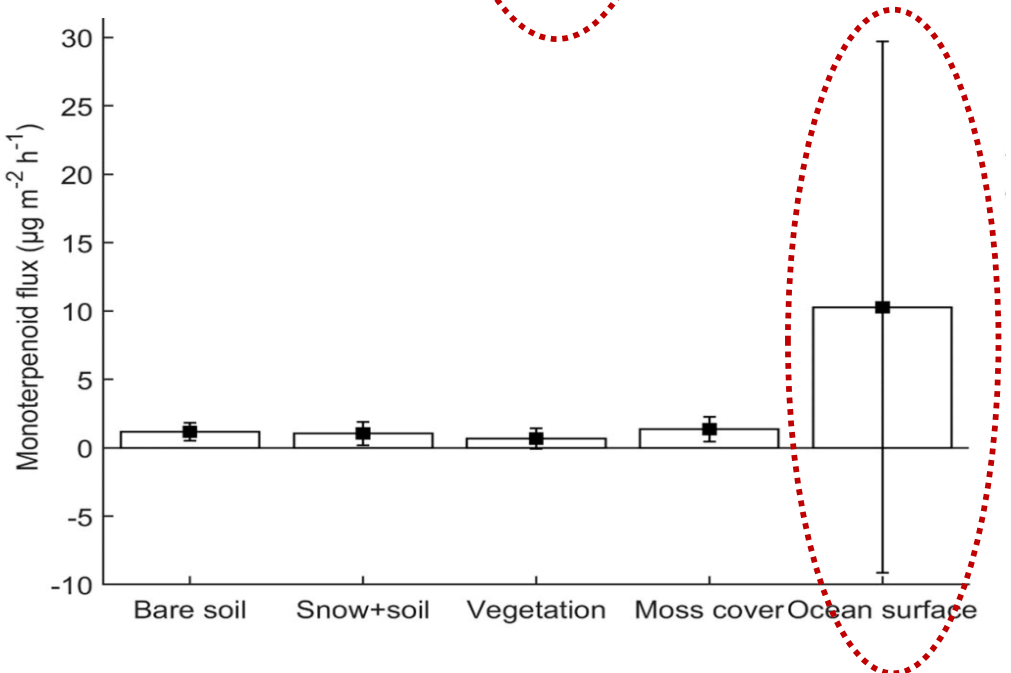
- **Gaseous Precursors and molecular clusters**: were detected through Chemical Ionization- Atmospheric Pressure Interface-Mass spectrometry ,CI-APITOF

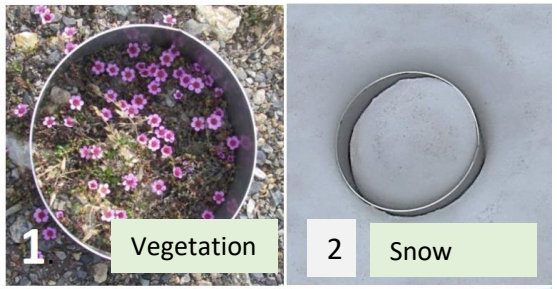
- **Particle (charged and neutral) number size distribution** measured with a Neutral cluster and Air Ion Spectrometer (NAIS)

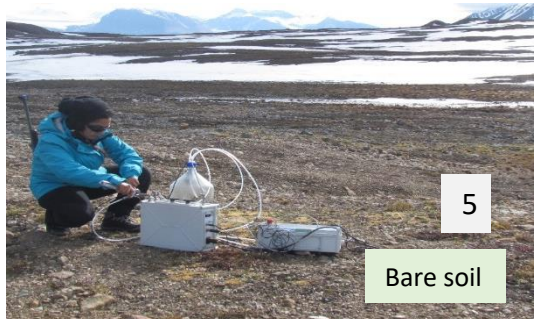
VOC fluxes from different ecosystems in Ny-Ålesund

Very Prelimnary Results from Summer campaign, 2019
25th June-15th July 2019

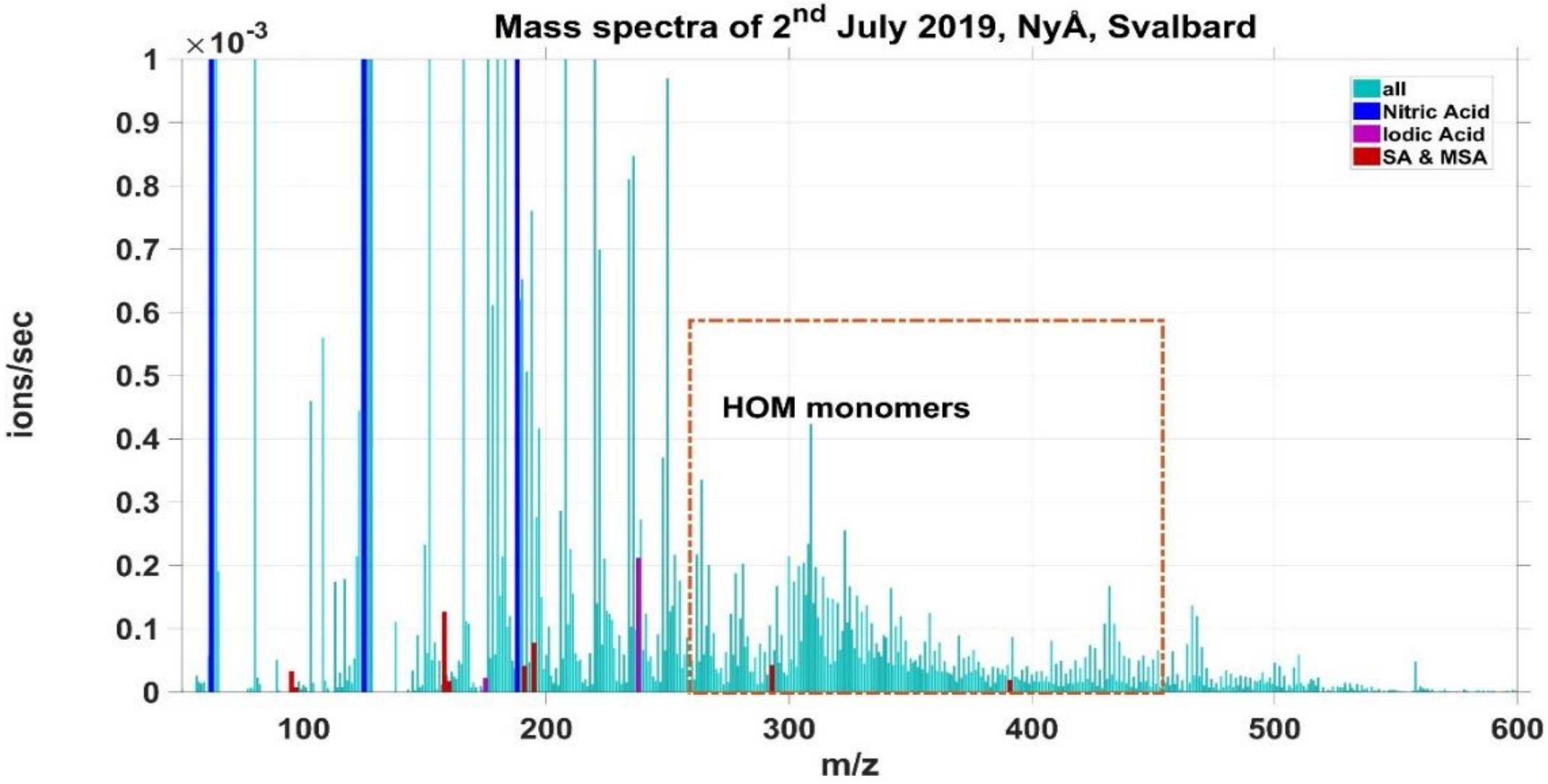








Mass spectra : CI-ApiTOF



Campaigns planned (current year, 2021)

- April 2021- Early May: Melt season
- June 2021: snow cover melted, onset of Tundra vegetation.
- Mid July-early August 2021: Peak summer.
- Mid September: Autumn

Implications of the study

- Characterization and quantification of the HOMs found in this study (m/Z 260-600). Baseline Data from Ny-Ålesund!
- Comparison of the calculated yield of HOM from monoterpernes and hemiterpens found in this study to the measured HOM. Tracing the source!
- Understanding the process of the formation of HOM, SOA from the local VOC emission and their implications on new particle formation and CCN in the arctic atmosphere. : Less Uncertainity in Models!
- Increasing temperature in Arctic may accelerate the release of the BVOCs which would effect the SOA yield and thus impact new particle formation: Baseline Data from Ny-Ålesund!

This project is supported by, SIOS, ERC-StG: GASPARCON – 714621 and the European Union’s Horizon2020 research and innovation programme under grant agreements No 654109 and 739530 (ACTRIS).

We thank logistic support by AWIPEV and the staff of the Arctic Station "Dirigibile Italia" for extending support the past campaigns and hosting us for the future campaigns at Ny-Ålesund

Thankyou for your attention
Stay Safe!