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Emerging contaminants during Arctic Rain-On-Snow events: insights from the 2023-24 Ny-Ålesund campaign

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Emerging contaminants during arctic rain-on-snow events: A case study from the 2023-24 Ny-Ålesund campaign☆

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WHAT ARE RAIN-ON-SNOW (ROS) EVENTS?

WHY ARE THEY SO IMPORTANT?

THE GRUVEBADET ATMOSPHERIC LABORATORY

WHAT ABOUT THE CHEMICAL CHARACTERISATION OF ROS-ASSOCIATED LIQUID PRECIPITATIONS?

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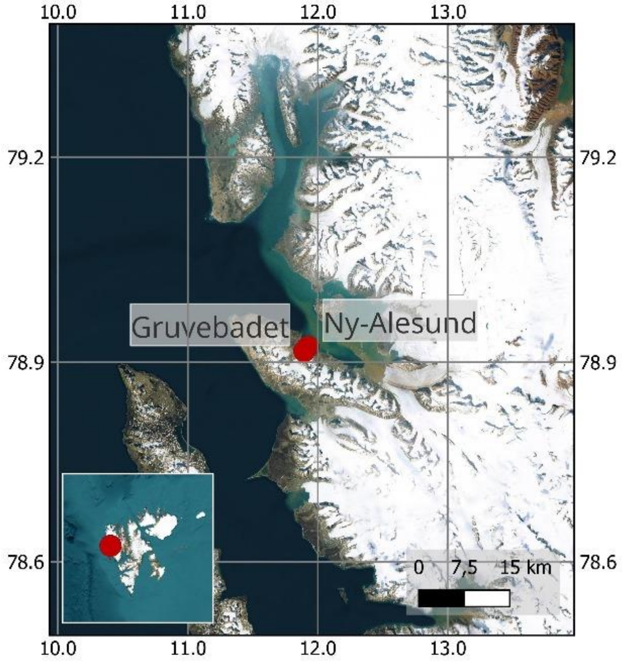
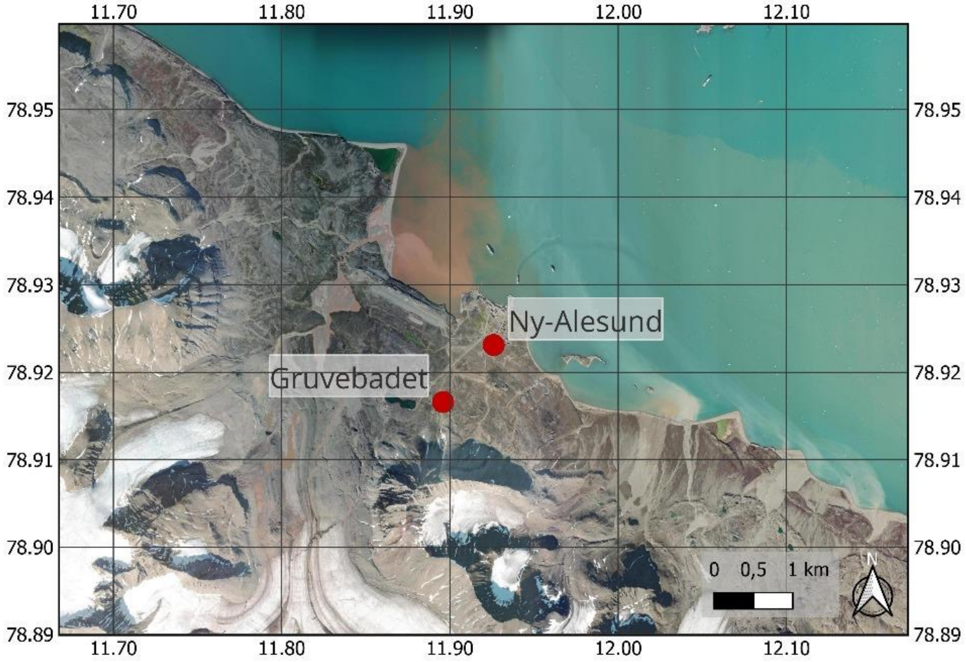
VIDEO: COURTESY OF DR. ELENA BARBARO

WHAT ARE RAIN-ON-SNOW (ROS) EVENTS?

Rainfall on an existing snowpack, known as rain-on-snow (ROS), is a significant consequence of climate change, with the potential to disrupt the environment by altering the hydrological cycle and influencing snow albedo.

GRUVEBADET ATMOSPHERIC LABORATORY





Svalbard is experiencing a notable increase in the frequency of ROS events due to warming climate, resulting from the interplay between **increasing near-surface air temperature**, **wet deposition type and intensity, and existing ground snowpack.**

ROS events are defined inconsistently across the literature:

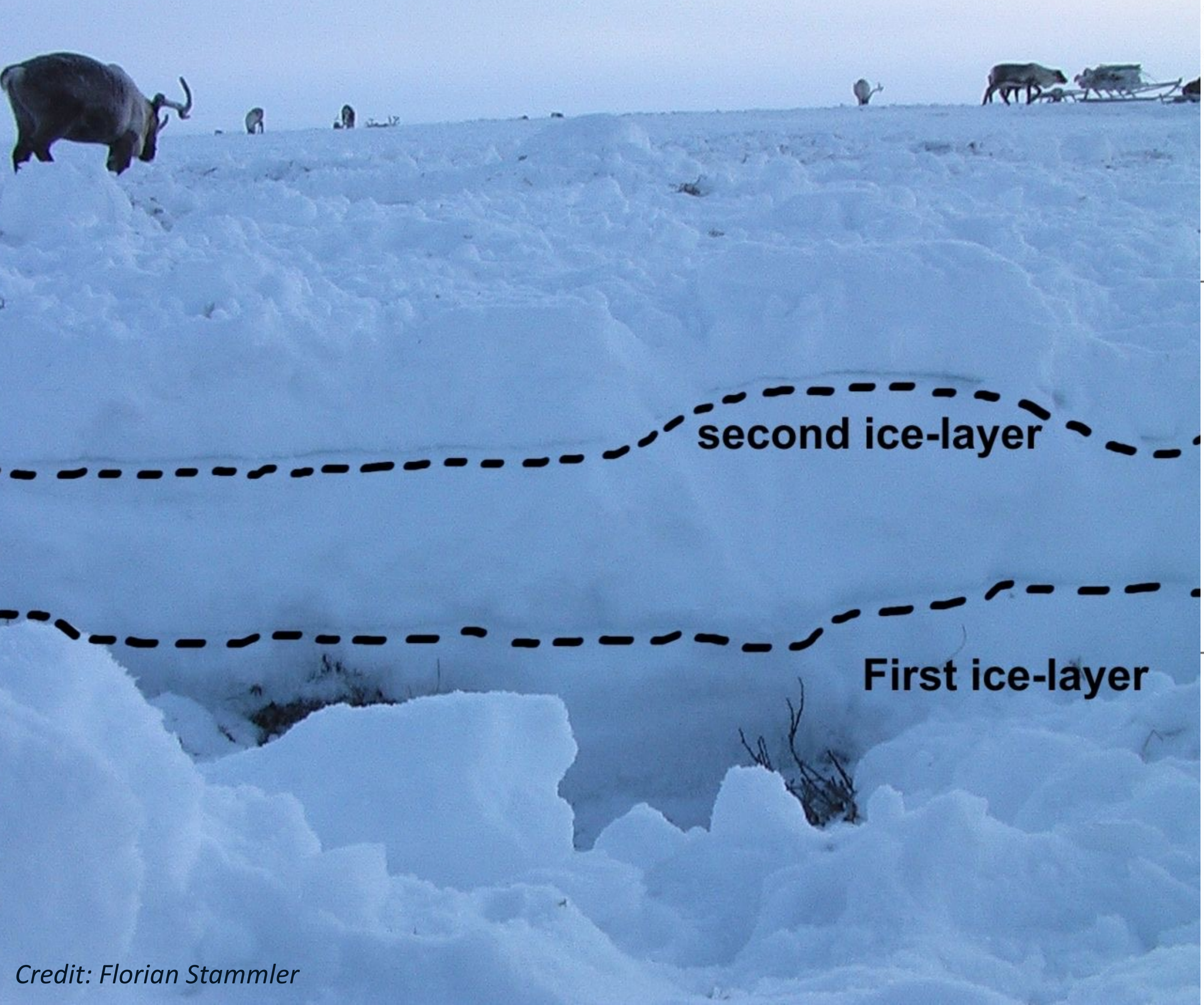
- Temperature thresholds ranging from 0°C (Wickström et al., 2020) to > 0.5°C (e.g., Sobota et al., 2020; Vickers et al., 2024),

- Minimum precipitation spanning from > 1 mm (Wickström et al., 2020) to > 10 mm (Putkonen et al., 2009),

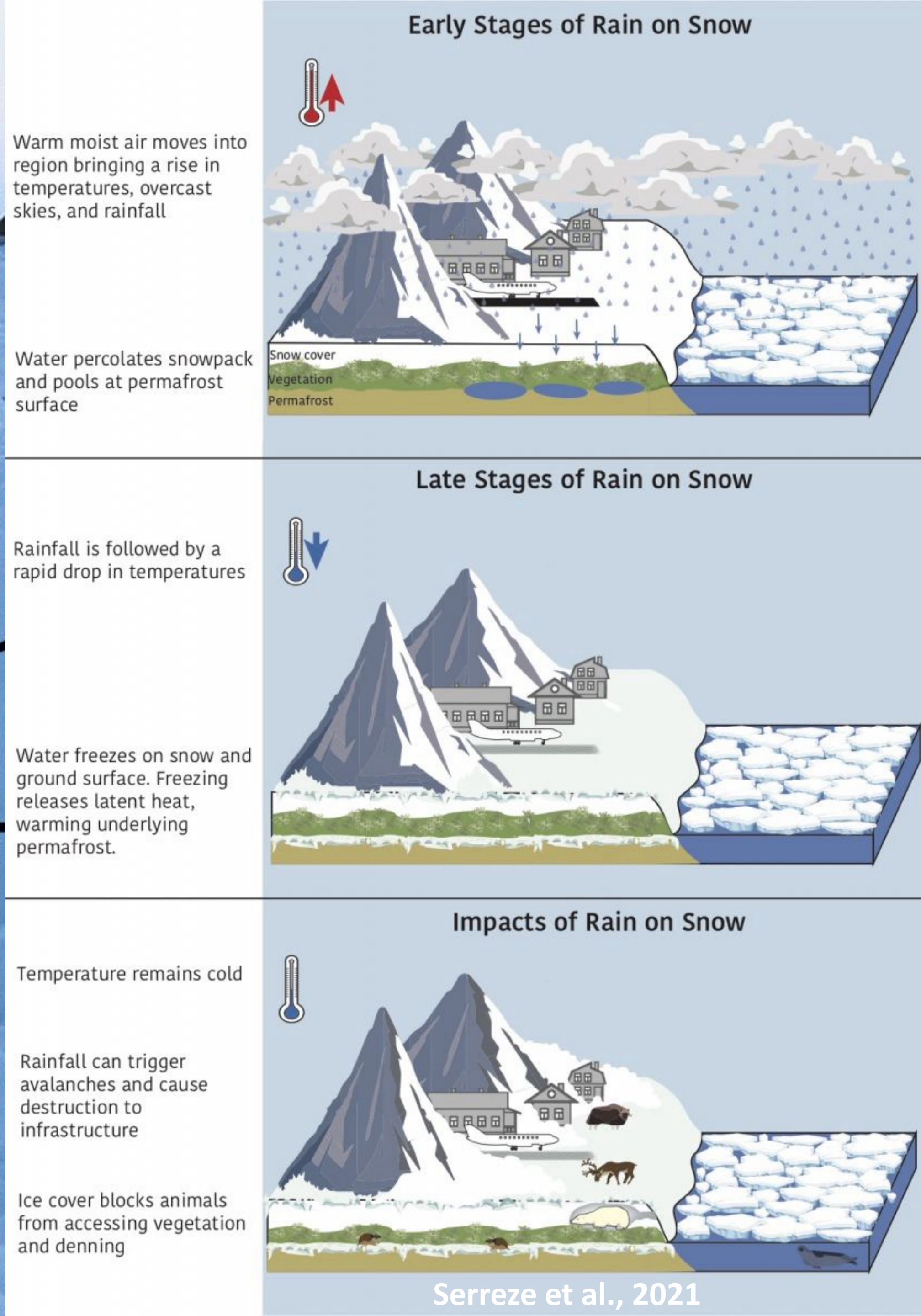
- Snow water equivalent (SWE) thresholds ranging from 3 mm (Pall et al., 2019) to 5-10 mm (Freudiger et al., 2013; Cohen et al., 2015).

- **Mean daily temperature** and cumulative precipitation thresholds **over 24 hours of 1°C** and 1 mm. At this temperature, precipitation occurs as rain and snow with equal frequency, while **above the threshold precipitation is primarily rain** and below primarily snow (Jennings et al., 2018).

WHY ARE THEY SO IMPORTANT?



Credit: Florian Stammler



Serreze et al., 2021

GAP IN THE KNOWLEDGE

AI generated image

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PM_{10}

Sampler: Tecora ECHO

Filters: 90-mm QFF

Flow rate: 150 L/min

Period: 2023-2024

Resolution: 7 days

Wet depositions

Sampler: Wet & Dry (MTX)

Containers: polypropylene bags

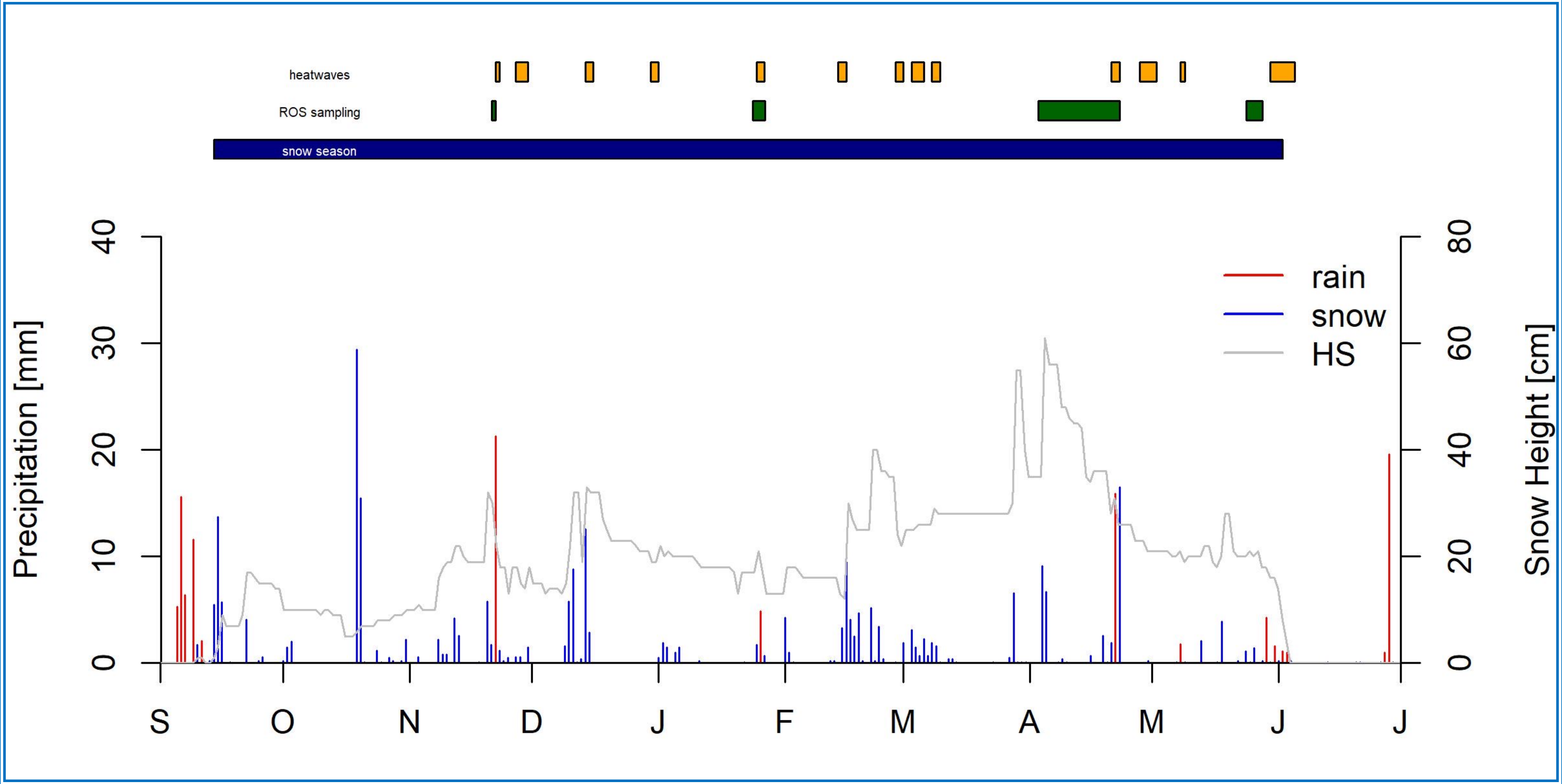
Period: 21 Nov 2023-12 Jun 2024

Samples: 36

- 7 rains
- 3 rains and snows mixed
- 24 snow samples

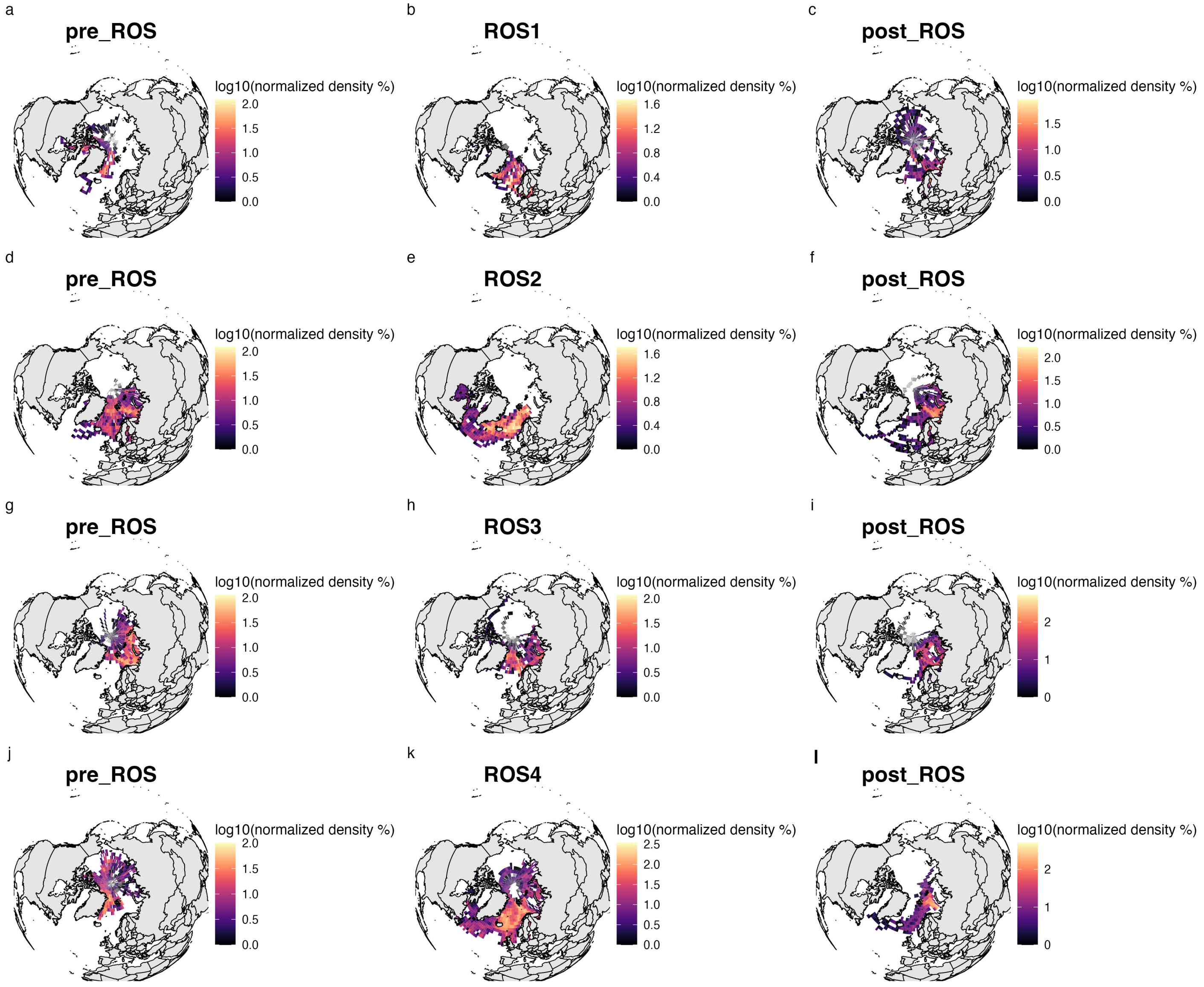
PICTURES: COURTESY OF DR. ELENA BARBARO

METEOROLOGICAL ANALYSIS



Pre-ROS and post-ROS periods are defined as the three days preceding and following each ROS event

BT obtained with Lagranto



ROS 1 = November 21st-22nd, 2023

It is characterised by a **moderately high-density air mass centred over the Greenland Sea.** It was primarily driven by the advection of moisture-laden maritime air, which favoured precipitation in the form of rain.

ROS 2 = January 26th-27th, 2024

It was dominated by a high-density **air mass extending from western Russia and eastern Europe towards Scandinavia**, with a gradual descent in altitude. **Warm, moist continental air intrusions** initially **enhanced the likelihood of liquid precipitation**, with drier and colder post-event air masses from North that reduced the moisture supply.

ROS 3 = April 21st-22nd, 2024

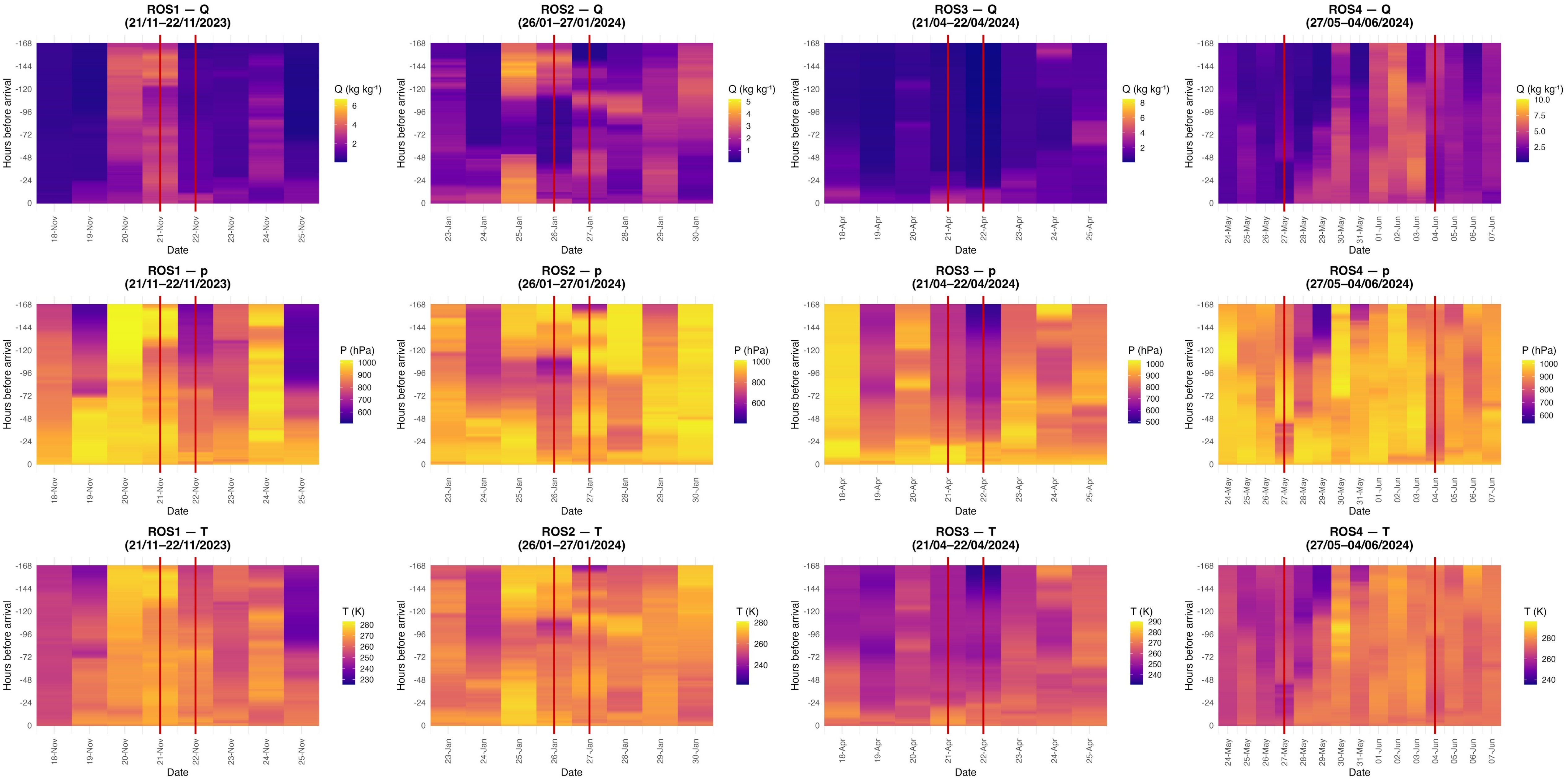
a **high-density air mass was confined to the Arctic region**, associated with **low atmospheric pressure**.

ROS 4 = May 27th-4th, 2024

It was characterized by the **intrusion of mixed low-pressure air masses originating from both SW and SE. The combined influence of maritime and continental sources is reflected in elevated specific humidity levels.**

Locally and cyclonic-dominated systems in the cold season

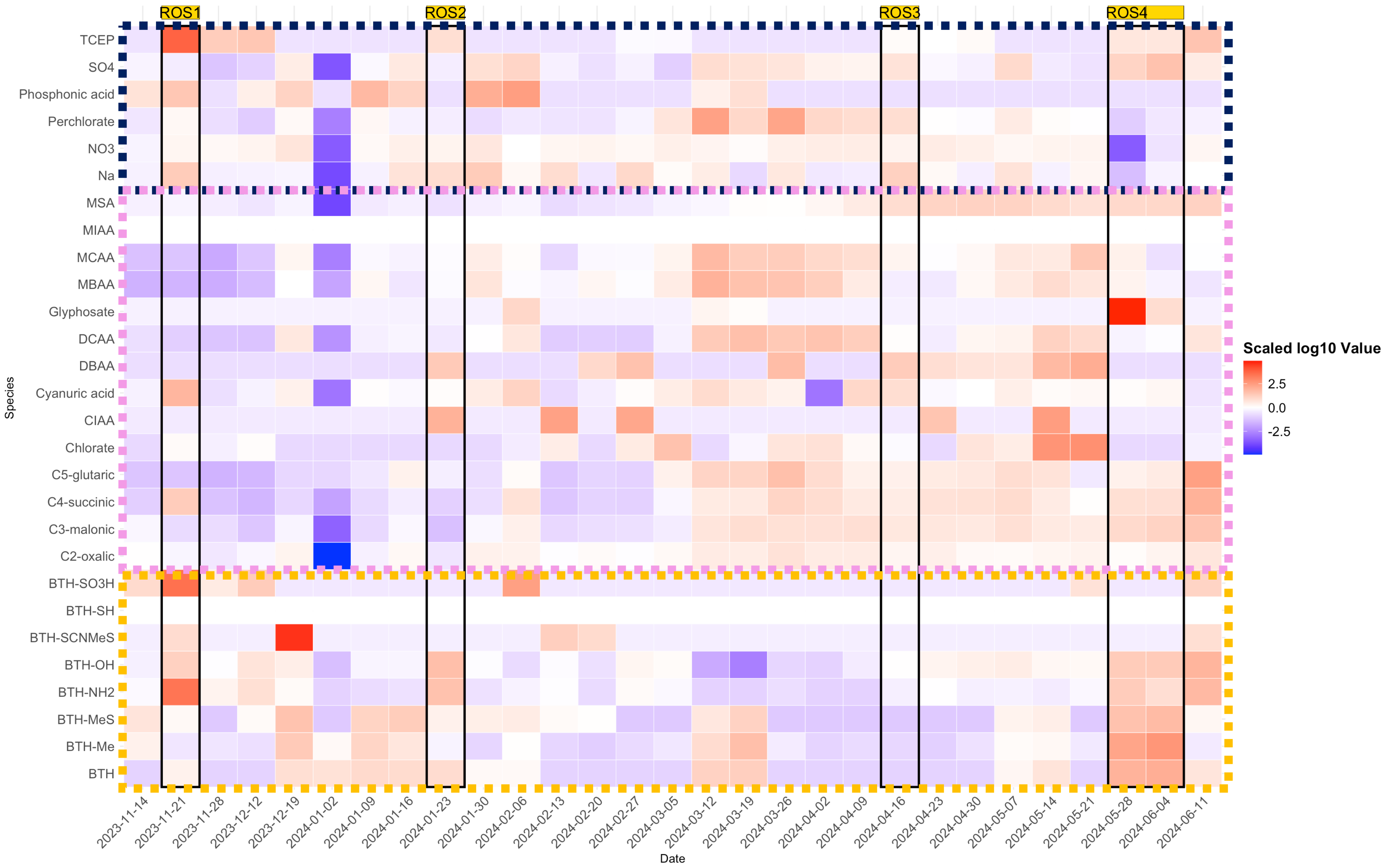
Dominated by mid-latitude mixed marine-continental systems



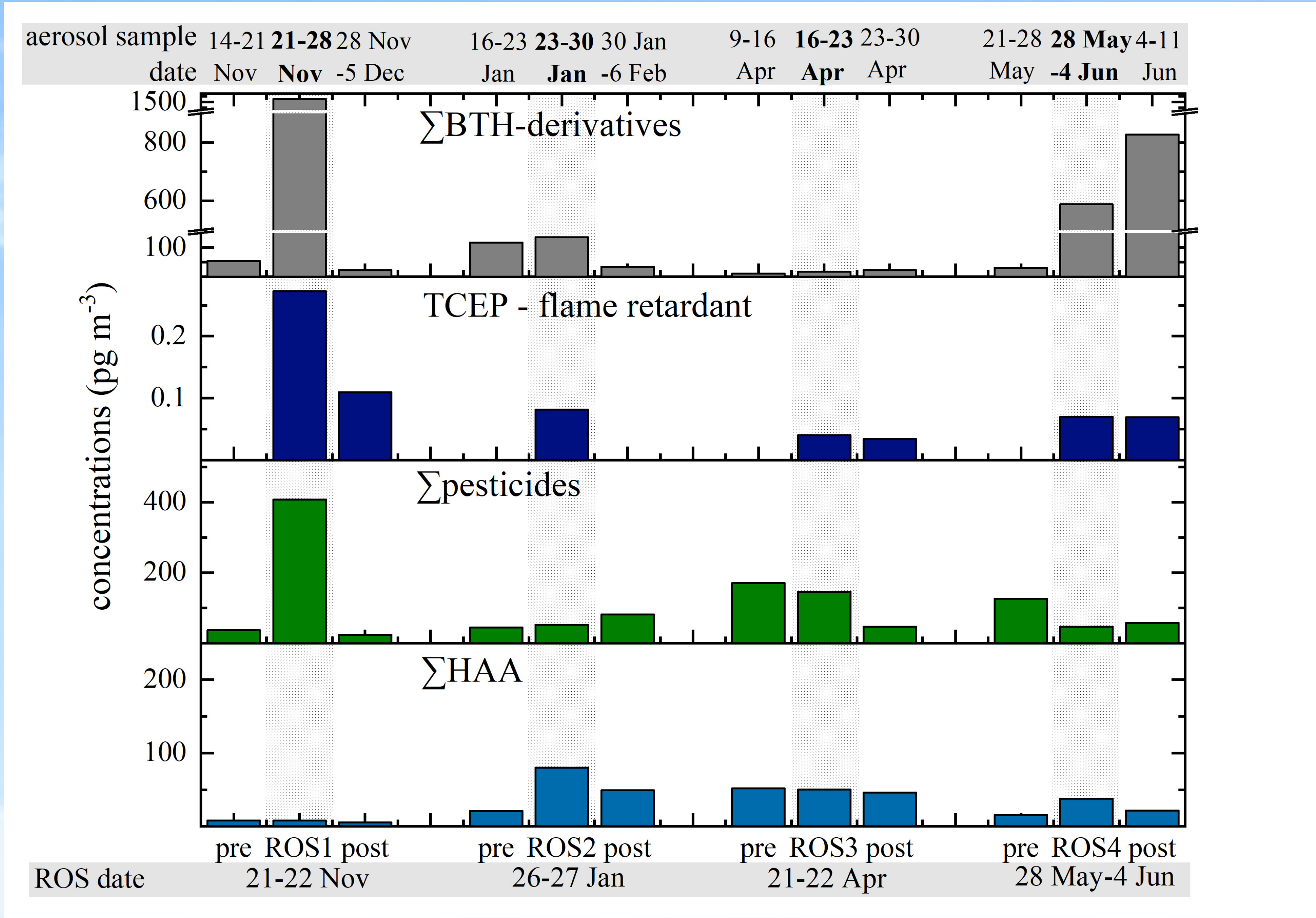
Heatmap of anomalies of the analysed emerging contaminants in AEROSOL samples

MSA, pesticides (chlorate and glyphosate), carboxylic acids (C2-oxalic, C3-malonic, C4-succinic, C5-glutaric), and haloacetic acids (MCAA, MBAA, DCAA, DBAA), presents positive anomalies mainly concentrated in the spring season = **seasonal reactivation of biological processes** and **increase in solar radiation** during spring enhances photochemical oxidation.

Benzothiazoles and their derivatives, which display similar patterns of positive anomalies, mainly occurring during the fall–winter period and late spring = coexistence of **enhanced LRAT** and accumulation of polluted air masses during the colder months and the **secondary release or transformation processes** in late spring

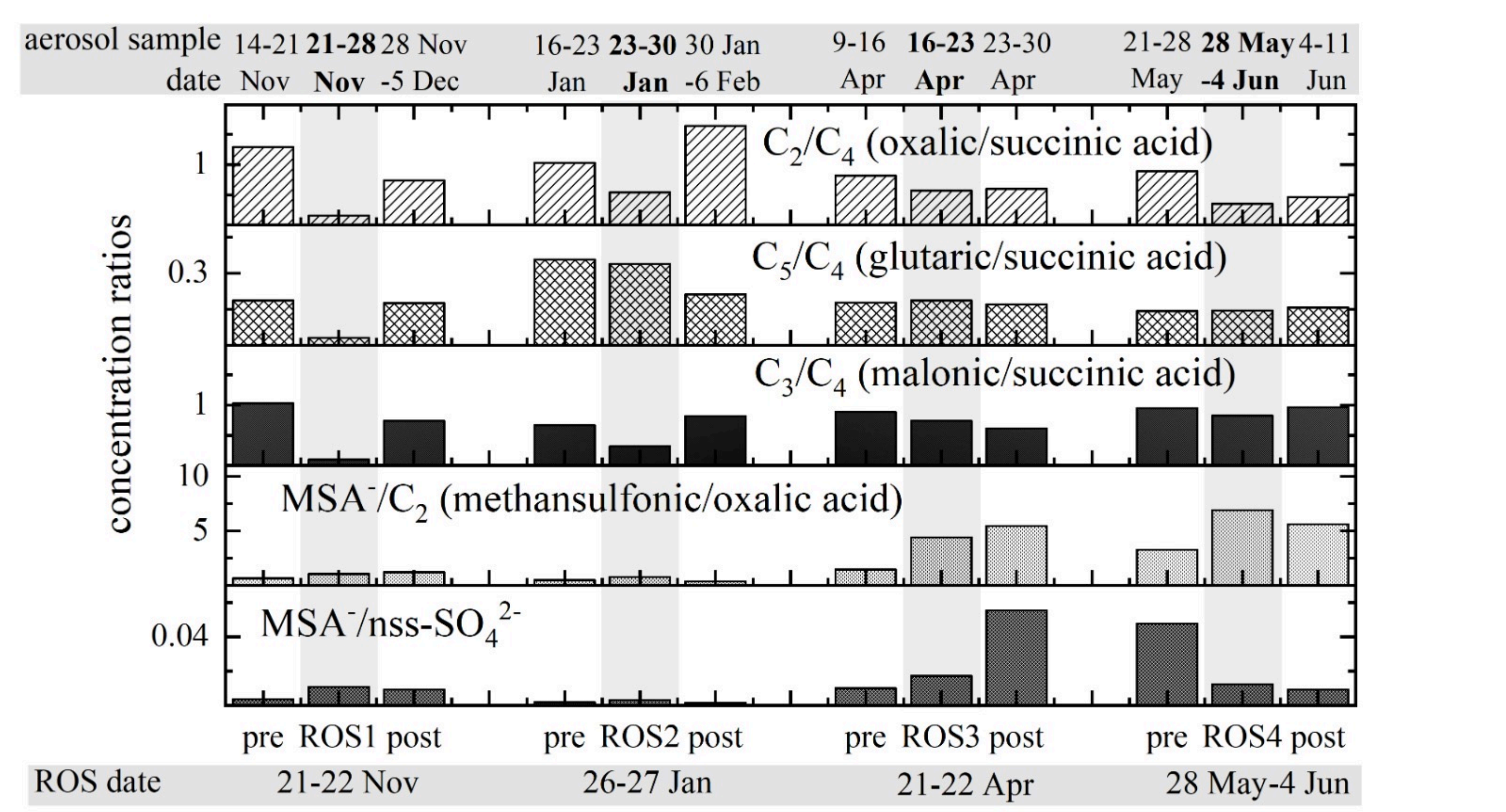


Trend of emerging contaminants in AEROSOL across pre-, during, and post-ROS events

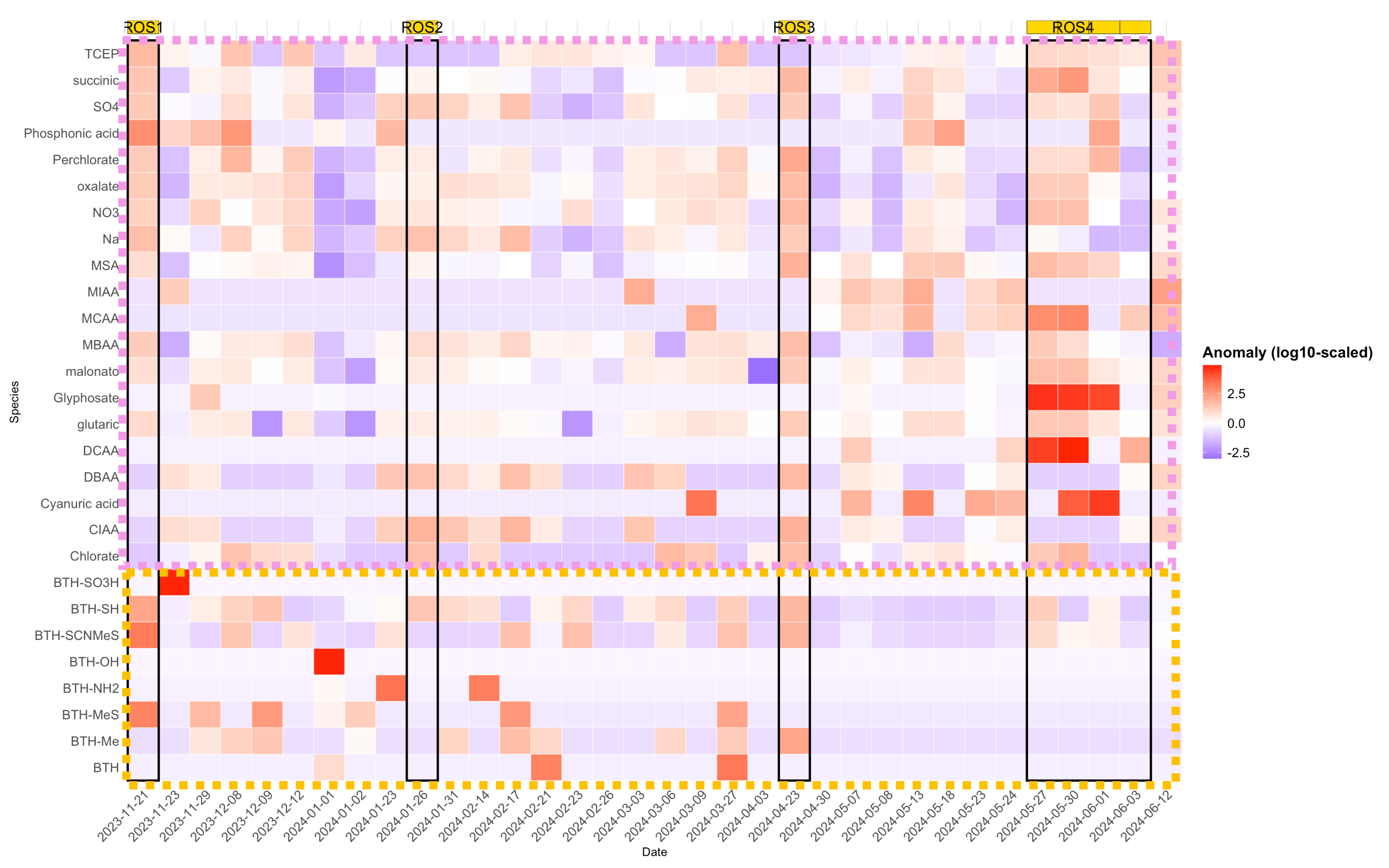


DIAGNOSTIC RATIOS

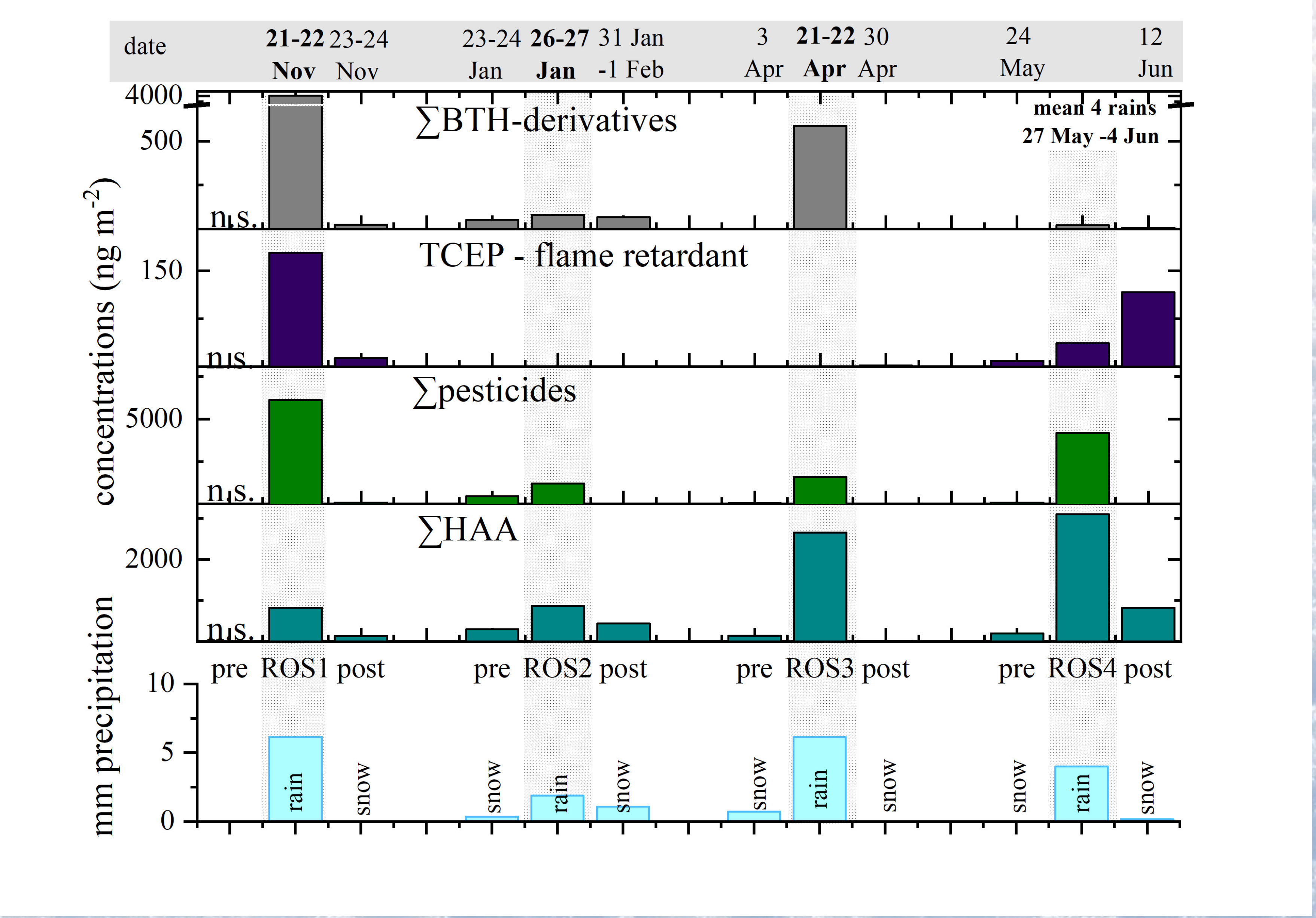
		ROS1	ROS2	ROS3	ROS4
Indicators	diacid ratios	low	low	low	low
	MSA^-/C_2	low	low	high	high
	$MSA^-/$ $nss\text{-}SO_4^{2-}$	low	low	moderate	moderate
Integrated interpretation		Combined fresh-biogenic/ marine and long-range continental sources	Combined fresh-biogenic/ marine and long-range continental sources	Dry continental air mass combined with newly advected moist, marine-biogenic air	Mixing of continental and marine-biogenic air masses with secondary formation processes in humid or cloudy conditions



Heatmap of anomalies of the analysed emerging contaminants in WET DEPOSITIONS



Trend of emerging contaminants in WET DEPOSITIONS across pre-, during, and post-ROS events



CONCLUSIONS

Overall, meteorological and chemical tracers suggest that the **interplay** between **synoptic-scale advection**, **local moisture**, and **seasonal release of emerging contaminants** from lower latitudes **governs the composition and transport of aerosols during ROS events**.

Each ROS event appears to be characterised by specific local and synoptic meteorological conditions.

Our findings highlight the importance of considering ROS events as distinct meteorological regime when interpreting Arctic aerosol and deposition observations, while also underscoring the need for future studies combining higher temporal resolution measurements with atmospheric parameters and modelling approaches to characterise transport and deposition processes.

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THANKS TO ALL AUTHORS

PRIN ROSETTA

THANKS FOR YOUR ATTENTION!

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