Sources and processes governing the annual cycle of aerosol chemical composition in the central Arctic

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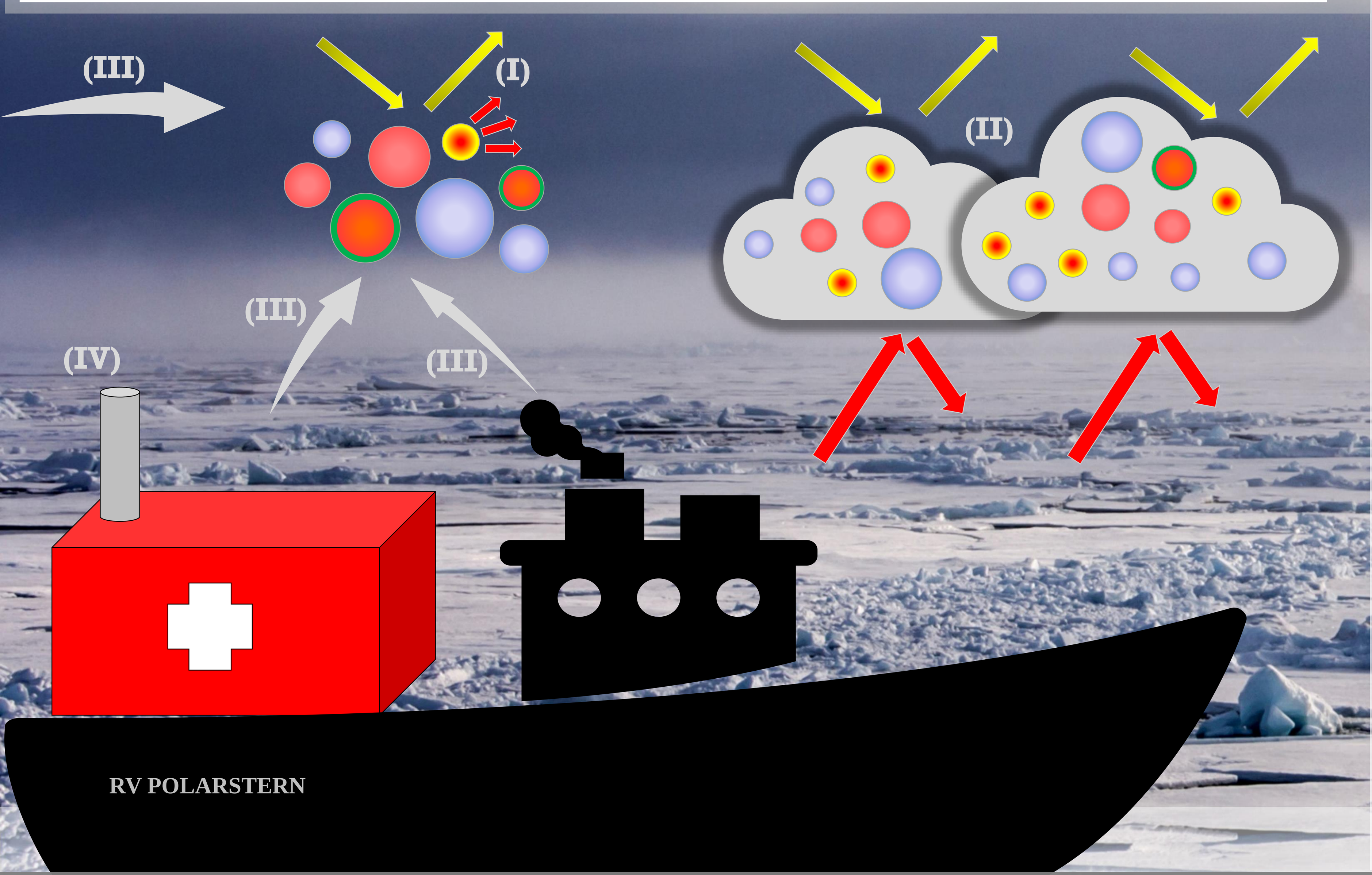
WHAT ARE AEROSOLS AND WHY ARE THEY IMPORTANT?



Aerosols:

- Fine solid or liquid particles suspended in the air (nm → µm).

Climate relevance:

- **(I)** Directly scatter (cooling) or absorb (warming) incoming shortwave radiation.
- **(II)** Indirectly modulate cloud formation, lifetime, and radiative properties.

→ Effect depends on aerosol **abundance**, **size**, **chemical composition** (physicochemical prop.).

What about the Arctic?

- Arctic warming ~ x4[1] compared to global average.
- Physicochemical properties depend on **sources** and emission/aging **processes (III)**.

- Strong seasonality in the Arctic: higher concentration in winter/spring, lower in summer/autumn.
- Challenge to discern **remote vs. local** sources and **natural vs. anthropogenic** sources.

Instrument & method:

- Ship-based year-long expedition in the central Arctic[2] (Fig. 1).
- Suite of aerosol high-time resolution instrumentation in the "*Swiss* container"[3] **(IV).** Cleaned from local contamination[4].
- Statistical models to evaluate aerosol sources (PMF) and back trajectories.

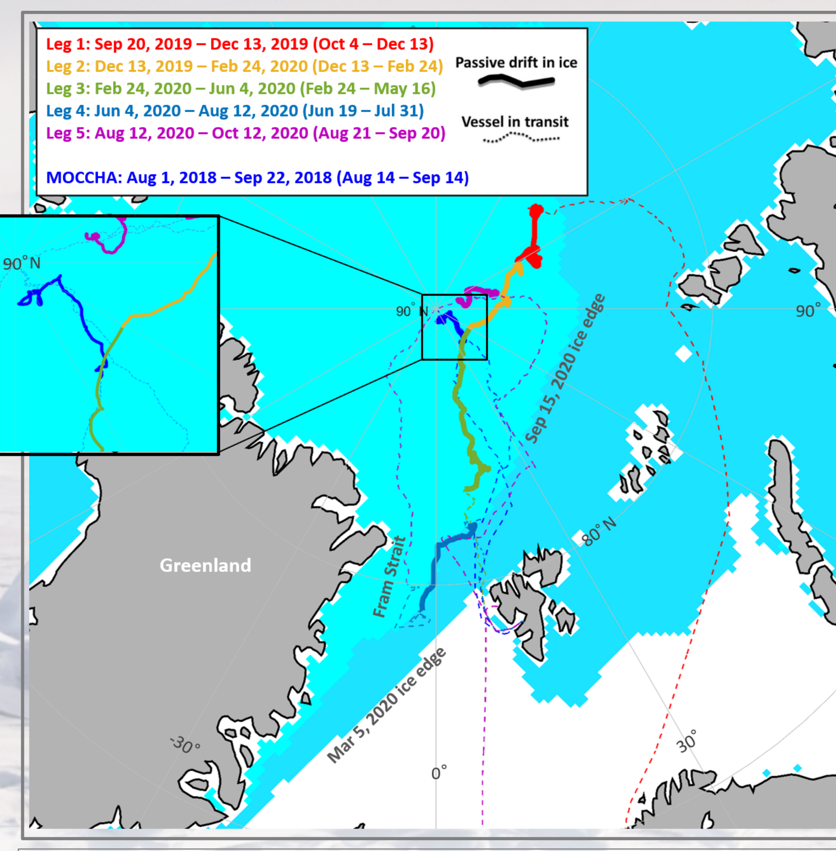


Fig. 1: Expedition track from MOSAiC and MOCCHA[5].

AEROSOL CHEMICAL COMPOSITION: SHORT TIMESCALE PROCESSES & SOURCES

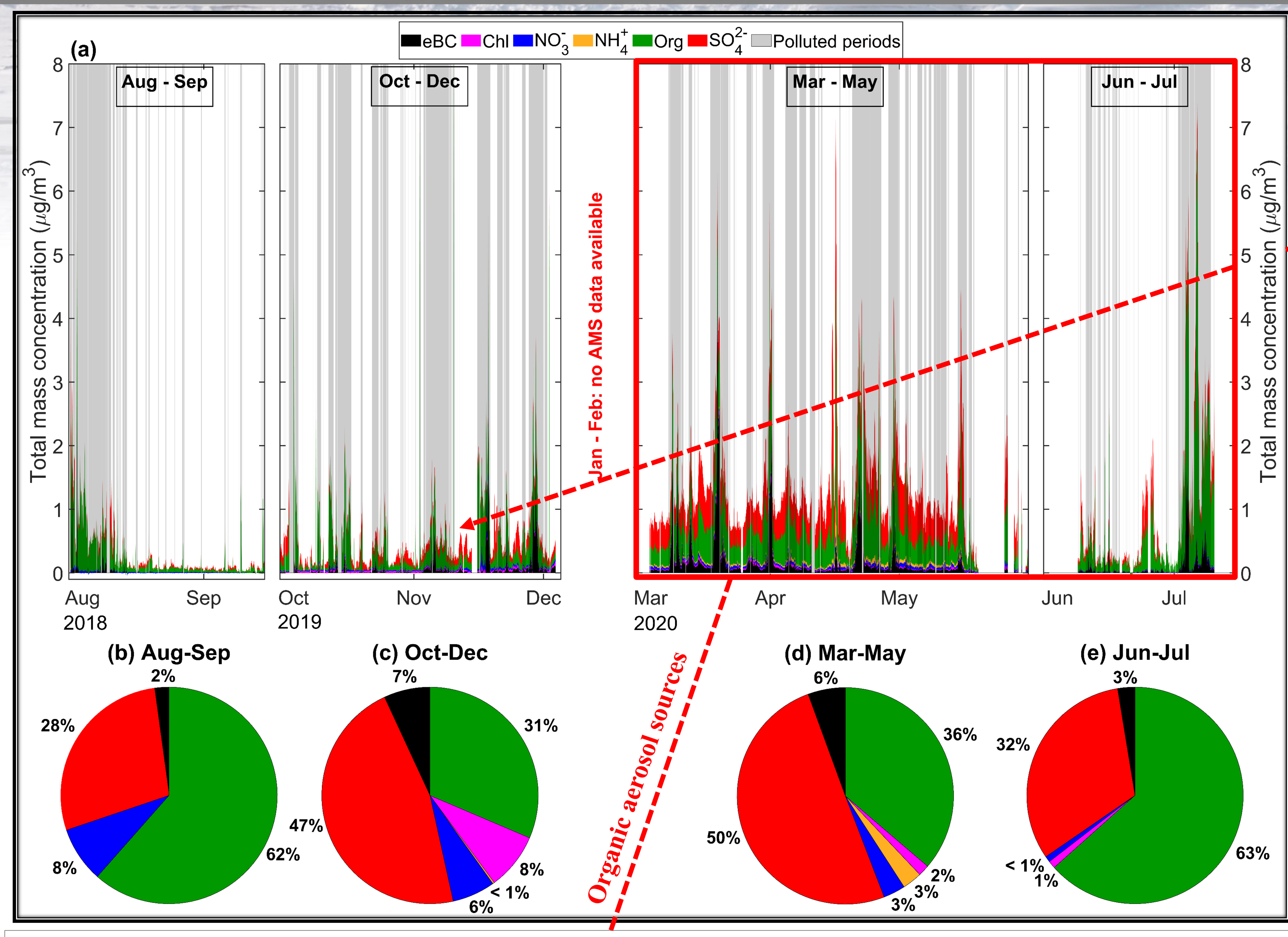


Fig. 2: Bulk submicron (<1 µm) aerosol mass composition during MOCCHA and MOSAiC. Measurements averaged to 1h time resolution (a) and relative contribution to total summed mass (PM_1) concentration (b-e). Data identified as affected by local pollution (from the ship) are indicated with shaded grey area in (a) and excluded in (b-e). Figure adapted from Heutte et al. (2024)[5].

Short-term variability: case study of storm in autumn 2019

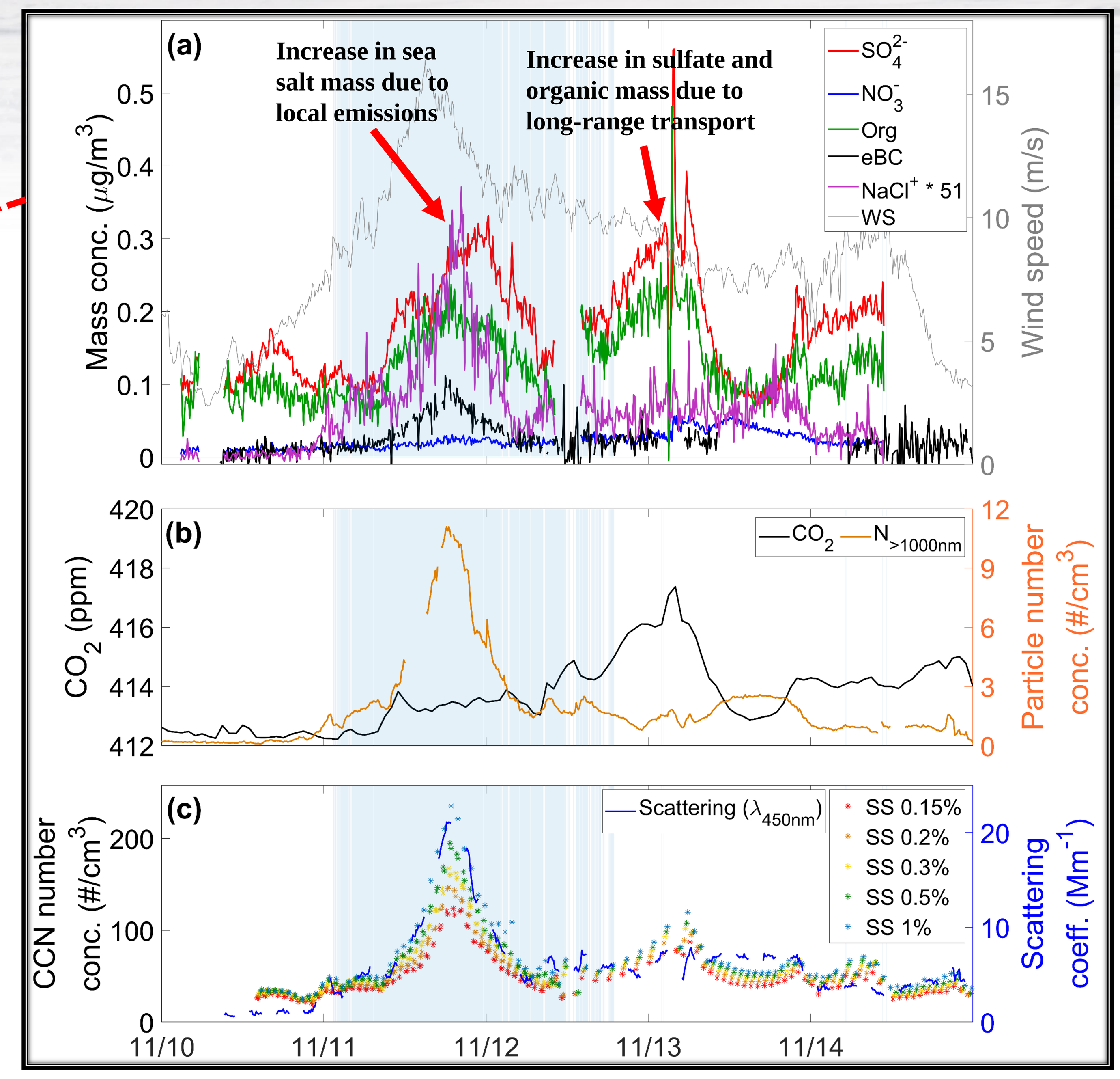


Fig. 3: High-time resolution case study of a storm in November 2019. The wind speed and chemical composition are shown in (a). CO_2 dry air mole fraction and supermicron (>1 µm) particle number concentrations are shown in (b). Cloud condensation nuclei (CCN) concentrations and total light scattering coefficient (blue wavelength) are shown in (c). The blue shaded region corresponds to the period when blowing/drifting snow was detected. Figure adapted from Heutte et al. (2024)[5].

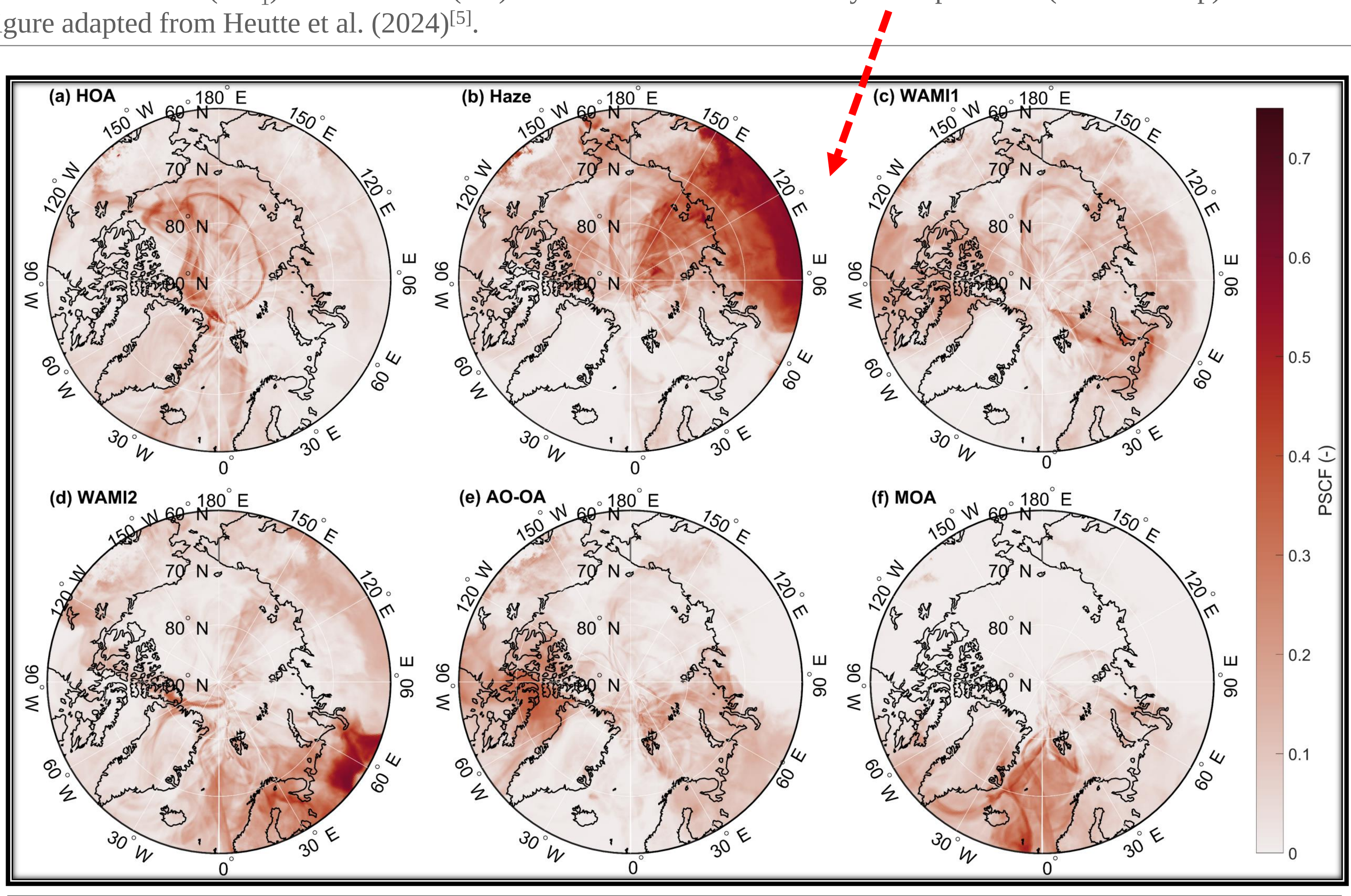


Fig. 4: Source regions for the six speciated OA factors from Positive Matrix Factorization applied on organics between March and July 2020. (HOA = Hydrocarbon-like Organic Aerosol; WAMI = Warm Air Mass Intrusion; AO-OA = Arctic Oxygenated OA; MOA = Marine OA). Figure adapted from Heutte et al. (in prep.).

SUMMARY & OUTLOOK

- **1st year-long observations of aerosol chemical composition in central Arctic (Fig. 2).**
  → Similar to what was observed at lower latitudes of the Arctic ([NH_4^+] much lower): possible to extrapolate.
- **Cyclonic activity (storms) influence aerosol variability in autumn and spring: increase in emissions from local sources and transport of remote aerosols (Fig. 3).**
  → Locally wind-generated particles contributed up to 80% (20%) of the cloud condensation nuclei (CCN) population in autumn (spring).
- **Organics dominate the pristine summer (> 60% PM_1 mass). Sources of OA in spring-summer (Fig. 4) related to large scale atmospheric dynamics, shortwave radiation, and marine biological activity.**

- **What is the impact of OA speciation on CCN activation potential?**
- **Opportunity to study ship pollution in the Arctic (increasingly relevant).**
- **Need to include wind-generated particles in climate simulations (specifically in scenarios with declining anthropogenic haze).**

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