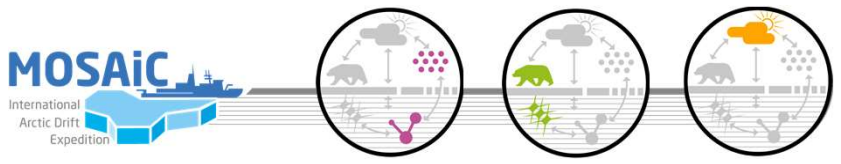
Marine carbohydrates in surface seawater during the MOSAiC expedition

Sebastian Zeppenfeld, Manuela van Pinxteren, and Hartmut Herrmann

Leibniz Institute for Tropospheric Research (TROPOS), Atmospheric Chemistry Department (ACD) Permoserstraße 15, 04318 Leipzig, Germany
Contact: zeppenfeld@tropos.de, +49 341 2717 7360



Scientific background

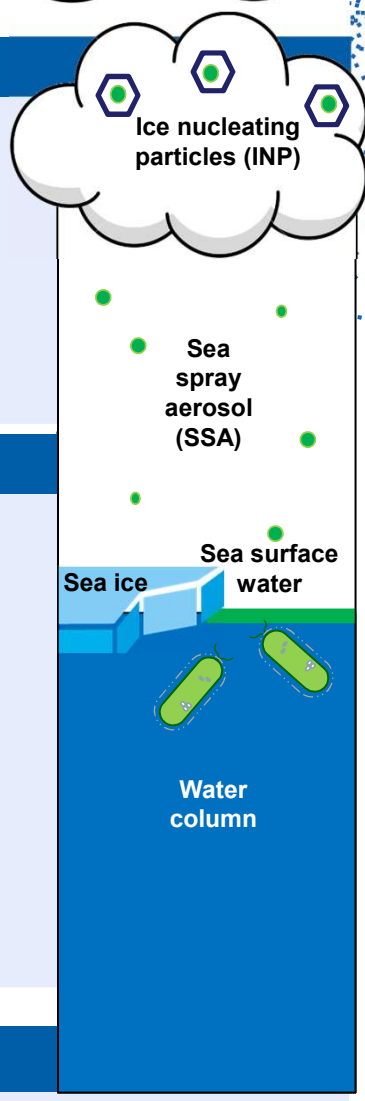
Marine polysaccharides involved in many biogeochemical and atmospheric processes

The transfer of organic matter from the ocean to the atmosphere is a possible key process for the formation of aerosol particles that may impact cloud processes (e.g. droplet activation and freezing) and cloud properties (e.g. Russell et al., 2010).

Marine carbohydrates (CHO) serve as structural elements and energy storage in marine macro- and microorganisms, and are released as protective films during environmental stress. They are present in the diverse environmental compartments in the Arctic, such as the oceanic water column, sea ice, sea spray aerosol (SSA) particles and fog (Zeppenfeld et al. 2020, 2023). Recent findings suggest that low-level cloud formation and properties above the Arctic Ocean may be influenced by marine carbohydrates (e.g. Orellana et al., 2011; Galgani et al. 2016, Hartmann et al. 2024 *submit*).

However, a detailed understanding of the seasonality of the CHO in the water column and the aerosol particles within the Arctic, their transfer processes from the sea surface to the atmosphere, and the linkage to cloud and fog formation and properties are extremely limited.

Thanks to our many partners on board of the RV Polarstern, we have obtained CTD seawater samples at various depths, sea ice cores, aerosol particle samples, and snow from several legs during the MOSAiC expedition. Here, we present initial findings from the ongoing CHO analyses focused on sea surface water collected at a depth of approximately 2 meters.



Chemical structure of marine carbohydrates (CHO)

Marine carbohydrates (CHO) appear either as

Dissolved free carbohydrates (dFCHO),

Dissolved combined carbohydrates (dCCHO, <0.2µm) or

Particulate combined carbohydrates (pCCHO, >0.2µm).

Through acid hydrolysis, dCCHO and pCCHO undergo degradation into their individual monosaccharide units, facilitating their subsequent chromatographic analysis.

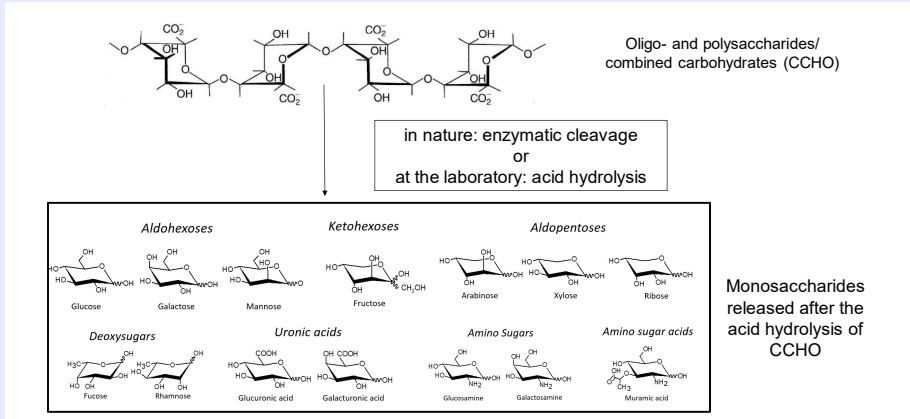


Figure 1: *Marine polysaccharides (CCHO) and their monomeric units*

First MOSAiC results from surface seawater at 2m depth

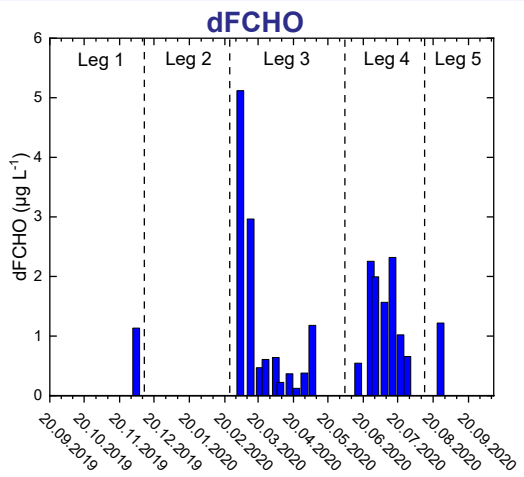


Figure 2: *dFCHO in surface seawater during MOSAiC*

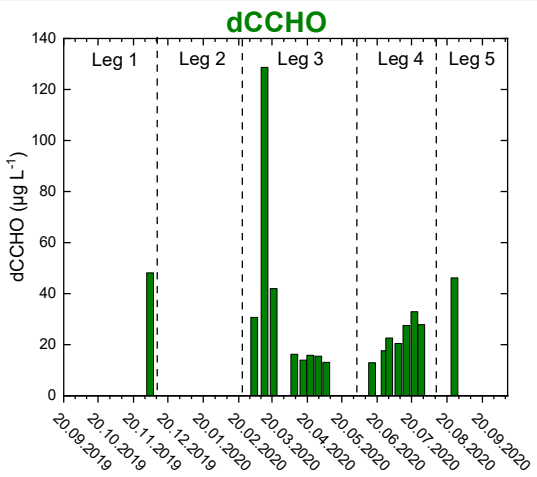


Figure 3: *dCCHO in surface seawater during MOSAiC*

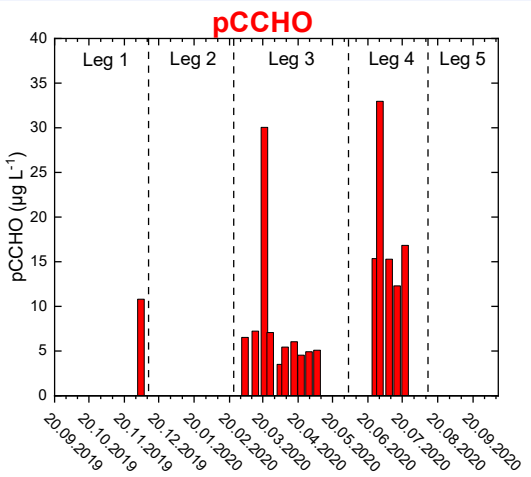


Figure 4: *pCCHO in surface seawater during MOSAiC*

dFCHO, dCCHO and pCCHO as the sums of their individual monosaccharides are influenced by a complex interplay between several environmental conditions and biological activities.

Seasonality and influence of environmental factors might not be obvious. Individual monosaccharides might reveal more information.

Free glucose and ice nucleation

dFCHO are usually utilized by heterotrophic bacteria quickly and hence appear in very low concentrations.

However, in some Arctic regions, they can be higher (e.g. marginal ice zone or aged melt ponds during summer months)

Previous study (Zeppenfeld et al., 2019) showed that free glucose seems to be related with ice nucleating activity in surface seawater, especially the sea surface microlayer (SML).

From Zeppenfeld et al. (2019):

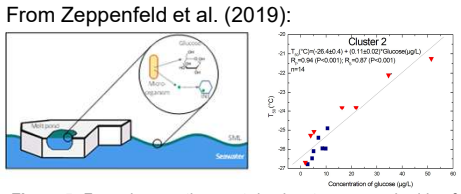


Figure 5: *Free glucose, the most dominant monosaccharide of dFCHO, correlates well with ice nucleating activity represented by the T_{50} value.*

dCCHO rather recalcitrant

dCCHO represents a mix of freshly formed polysaccharides (mostly $glucose_{dCCHO}$) and old, more persistent polysaccharides. During MOSAiC, $glucose_{dCCHO}$ was very variable, while the relative compositions (Figure 6) and absolute concentration of other dCCHO monosaccharides changed hardly.

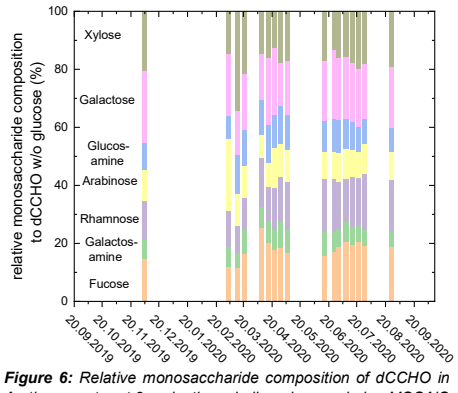


Figure 6: *Relative monosaccharide composition of dCCHO in Arctic seawater at 2 m depth excluding glucose during MOSAiC*

pCCHO rather freshly formed

pCCHO primarily reflects a direct response of local microbiota to recent environmental changes. Certain pCCHO monosaccharides, such as $fucose_{dCCHO}$, directly correlate with the biological parameter Chl-a* and exhibit distinct seasonality patterns (Figure 7).

*Chl-a data downloaded from https://doi.org/10.1594/PANGAEA.963277 (Hoppe et al. 2023)

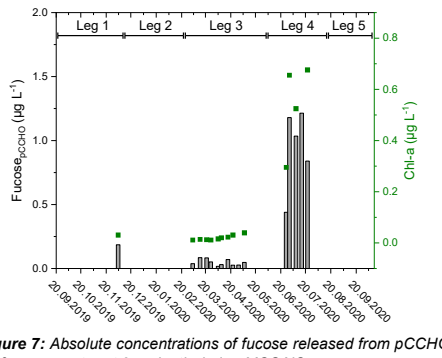


Figure 7: *Absolute concentrations of fucose released from pCCHO in surface seawater at 2 m depth during MOSAiC*

References

Galgani et al. *Scientific Reports* (2016), Hartmann et al. currently *submitted to Nature Geoscience* (2024), Hoppe et al. *PANGAEA* (2023), Orellana et al. *PNAS* (2011), Russel et al. *PNAS* (2010), Zeppenfeld et al. *ES&T* (2019), Zeppenfeld et al. *Ocean Science* (2020), Zeppenfeld et al. *ACP*(2023),

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Summary and Outlook

→ Marine polysaccharides are dominated by several formation, aging and degradation processes. Different carbohydrates may be influenced by different environmental factors.
→ CCHO may serve as an important biochemical parameter for the interpretation of biological data

Currently, we are completing MOSAiC seawater samples and will continue with atmospheric carbohydrate concentrations (be welcome to the talk by Manuela van Pinxteren in Session: Aerosol and Clouds).
Please reach out to Sebastian Zeppenfeld for inquiries regarding CCHO analysis in other matrices, such as sea ice, snow,…

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