# Glucose may serve as a potential chemical marker for ice nucleating activity in Arctic seawater samples

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## Introduction

### The Arctic SML contains ice nucleating particles (INP)

The **sea surface microlayer (SML)**, as the direct interface between the ocean and the atmosphere, plays an important role as a source of organic matter in marine aerosol. Its thickness typically ranges between 1 to 1000 µm.[1] Recent studies showed the abundance of efficient **ice nucleating particles (INP)**, especially in the Arctic SML, which implies its importance as a potential source for atmospheric INP for the formation of ice crystals in Arctic clouds.[2,3,4] However, detailed chemical characterizations of INP within the Arctic SML are very sparse.

So far, this IN activity has been attributed to proteins and carbohydrates. These large biomolecules offer a lot of active sites for structuring water molecules and supporting the formation of ice embryos at temperatures higher than -38°C. For this work, we focused on finding relationships between marine sugars (e.g. **free glucose**) and the IN activity in Arctic seawater samples. Samples from different environments (ice pack, marginal ice zone, ice-free ocean, melt ponds) were analyzed.

The following results were acquired during the field campaign PS106 (PASCAL/ SiPCA) on board the German research vessel *Polarstern* from May to July 2017.

## Sampling methods

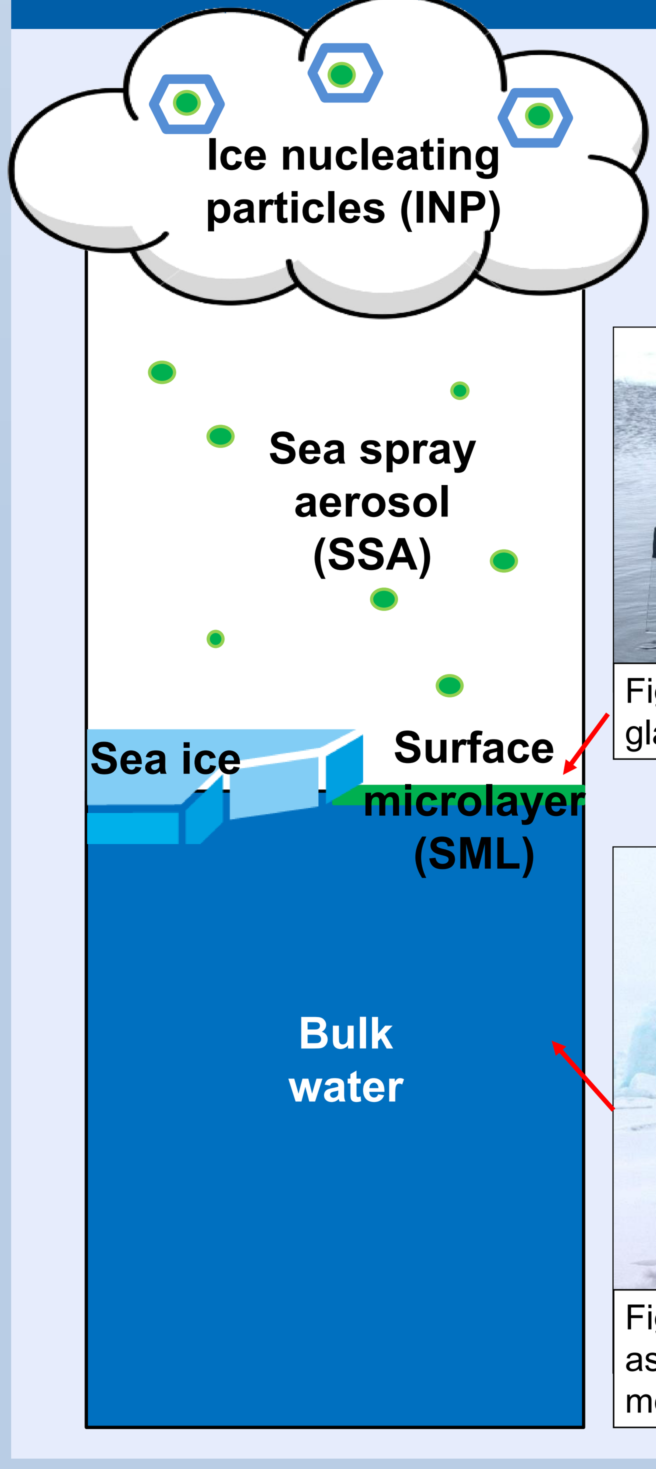
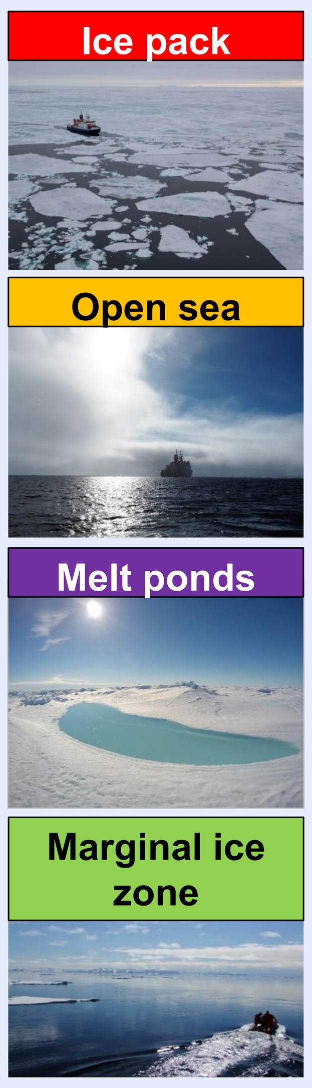



Fig 1: SML sampling via glass plate technique

Fig 2: Bulk water sampling as reference water at 1 meter depth

## Sampling locations



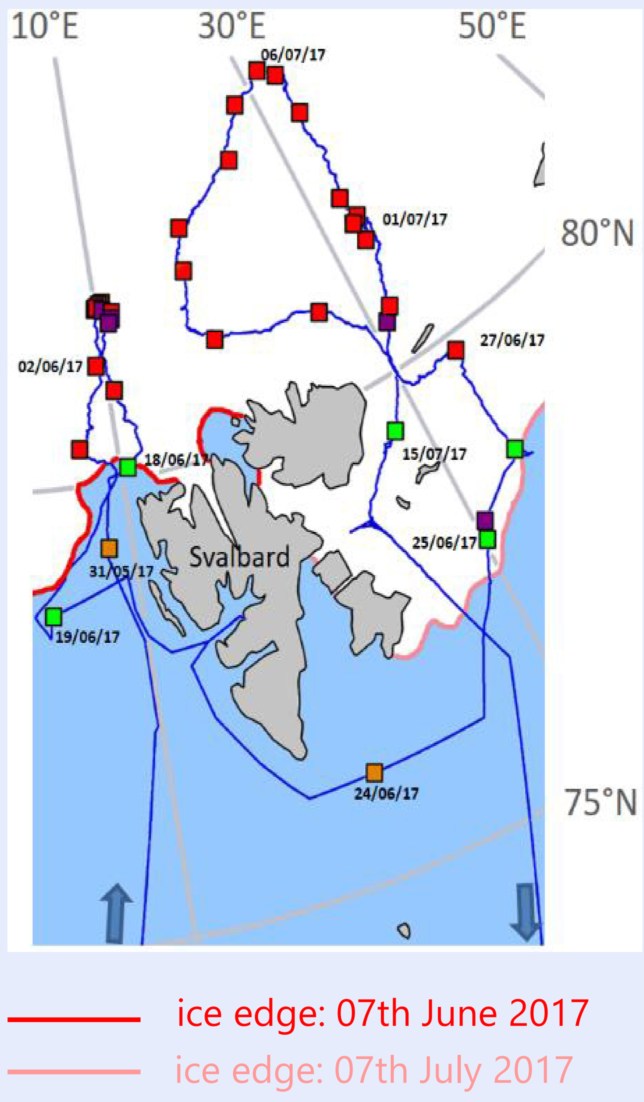




Fig 3: Sampling locations of seawater during PS 106.

- Water samples were collected from four different Arctic environments: ice pack, ice-free open sea, marginal ice zone, melt ponds

## Method for sugar analysis in seawater

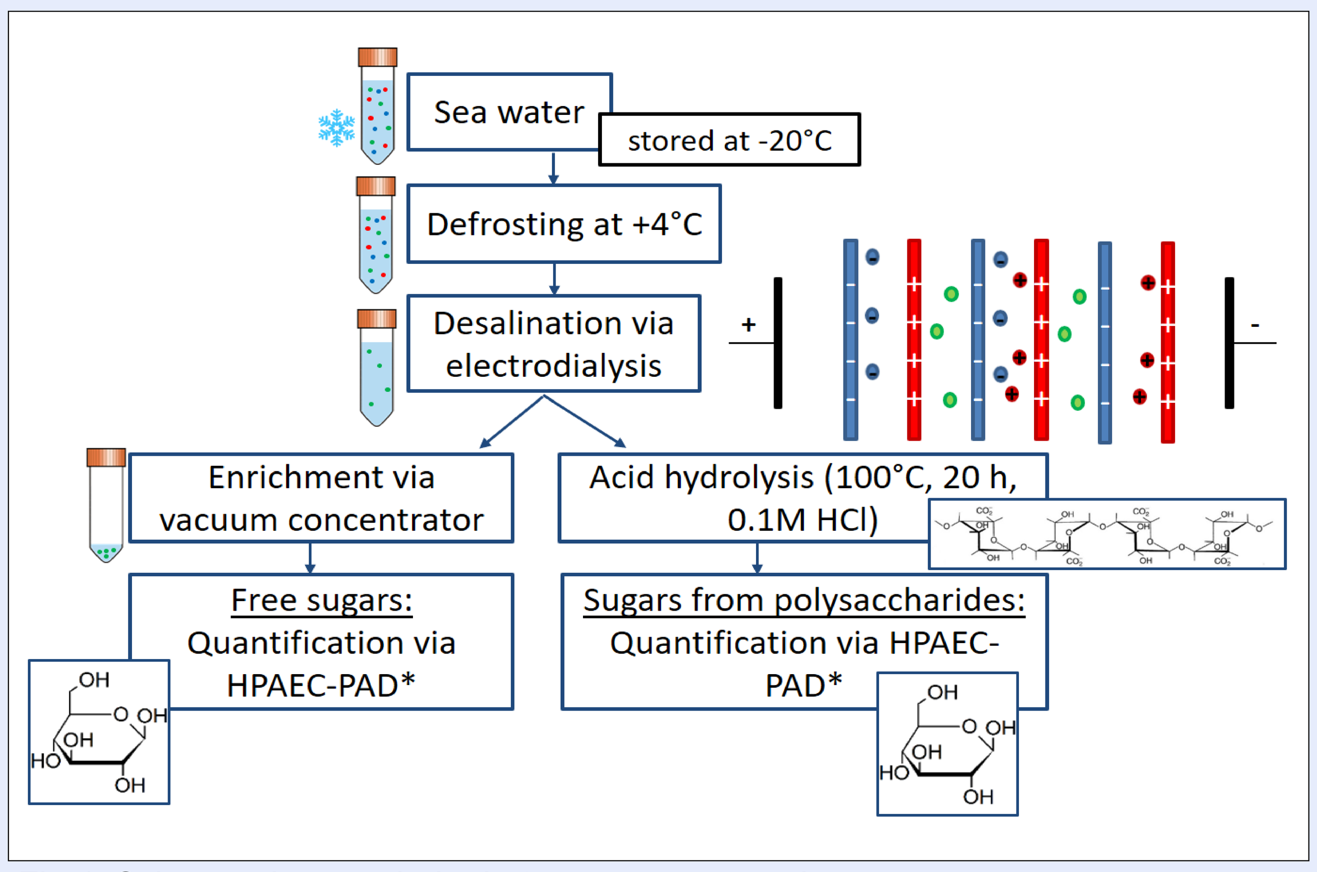



Fig 4: Scheme about carbohydrate measurements in seawater

- High Performance Anionic Exchange Chromatography coupled to Pulsed Amperometric Detection (HPAEC-PAD) for the quantification of free monosaccharides and combined sugars (polysaccharides) in seawater
- Sea salt disturbs reproducible analysis → removal of sea salt via electrodialysis (high recovery for neutral sugars and large polysaccharides)
- Enrichment procedure via vacuum concentrator for samples with low concentrations (Limit of detection for glucose=500 ng/L)

## Results: Free glucose concentration and IN activity ($T_{50}$)

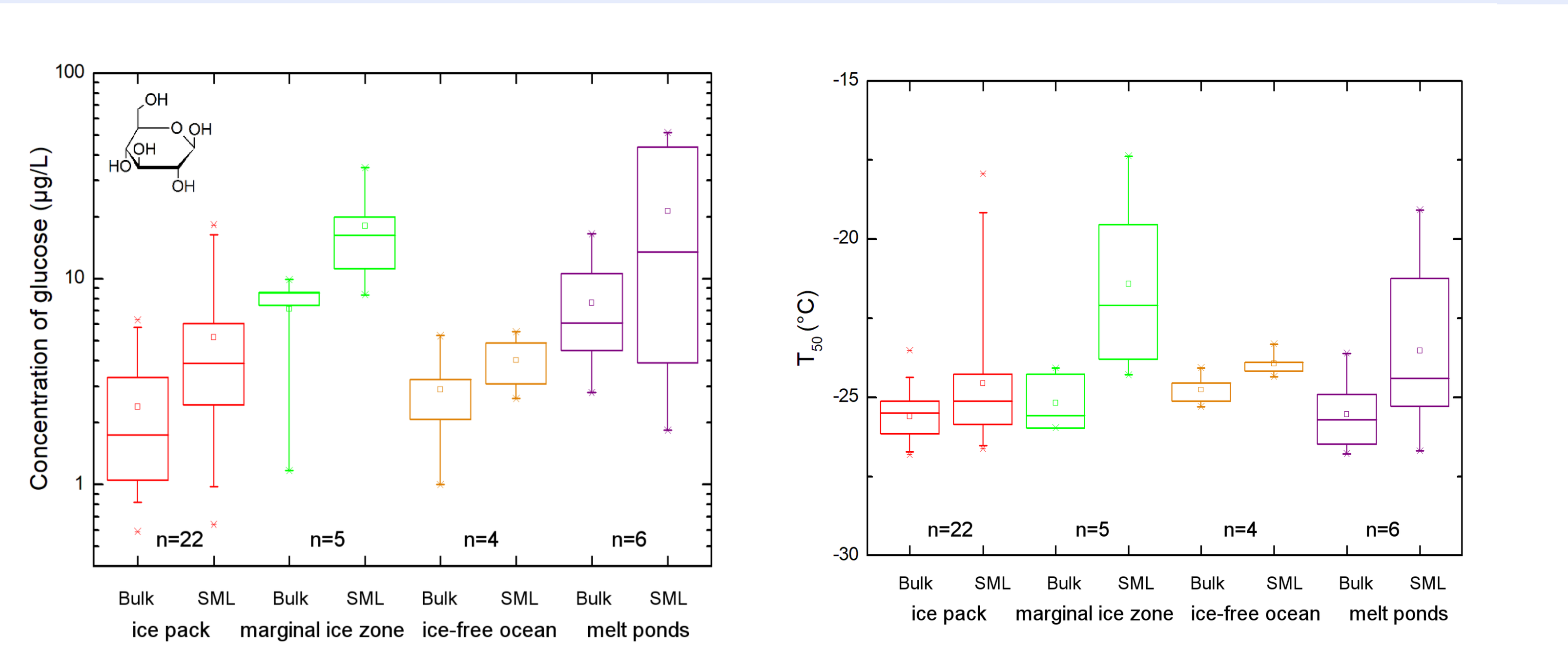



Fig 6: Free glucose concentrations (left) and IN activity - represented as $T_{50}$ values (right) in Arctic water samples. $T_{50}$ represent temperature were 50% of all wells were frozen in Leipzig Ice Nucleation Array (LINA)

- Free glucose concentrations and IN activity always higher in SML samples than corresponding bulk water samples
- SML samples from **marginal ice zone** and aged **melt ponds** show very high amounts of free glucose and efficient INP

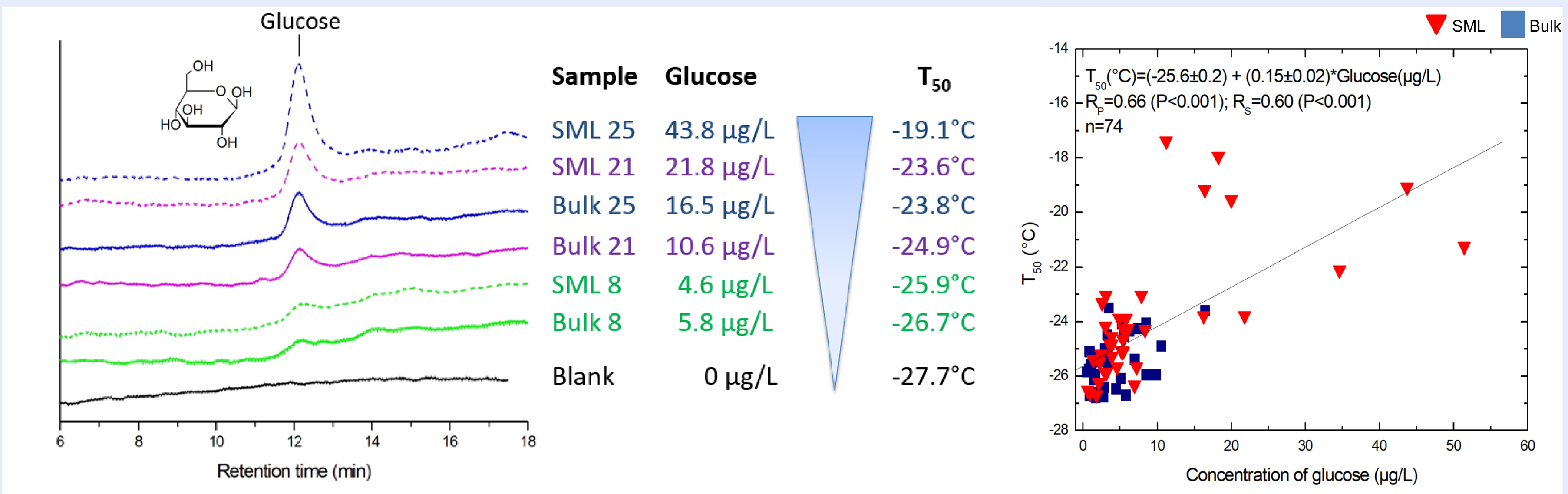



Fig 7: Signal of free glucose in HPAEC-PAD chromatogram (left) and $T_{50}$ plotted against free glucose concentration of all water samples (right)

- Correlation between free glucose concentrations and $T_{50}$ including **ALL** (quite heterogeneous) Arctic seawater samples

Hierarchical cluster analysis based on phytoplankton information (24 pigment concentrations analyzed for filtered water samples with High Performance Liquid Chromatography) for grouping into phytoplankton communities

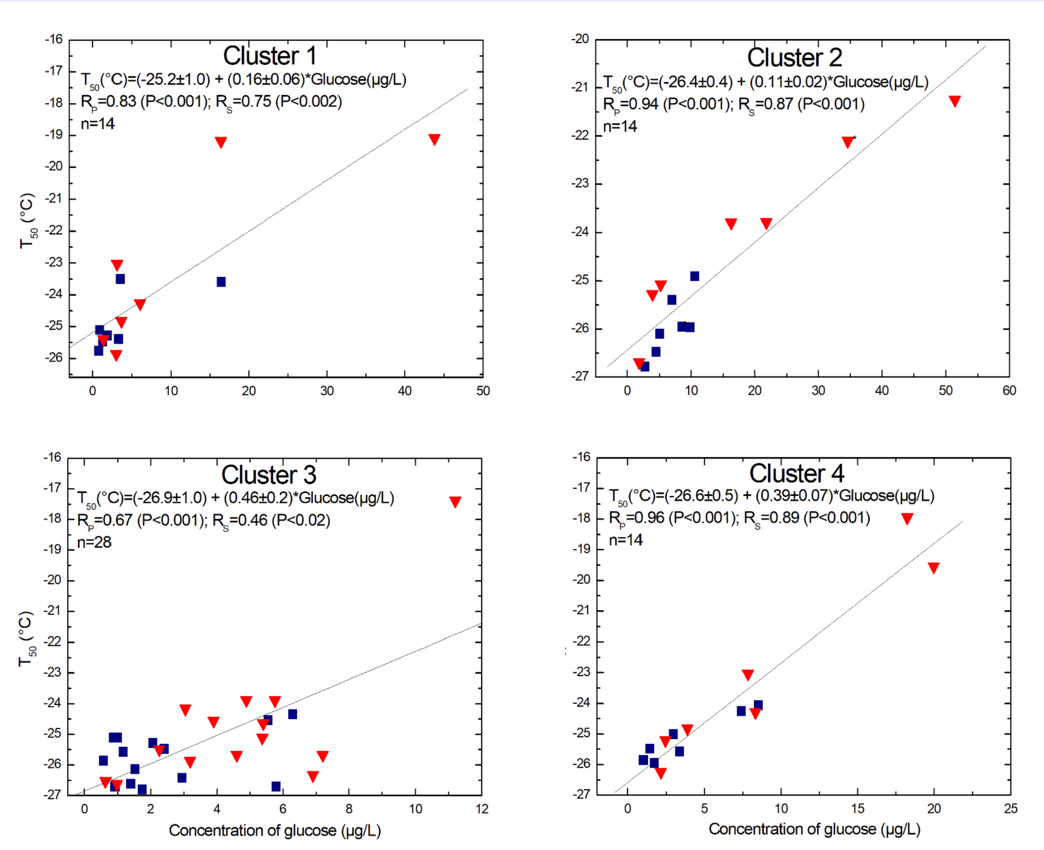



Fig 8: Glucose/$T_{50}$ correlations within 4 clusters.

- Cluster analysis based on pigment concentrations identifies 4 clusters of water samples
- Strong **linear correlations between free glucose and IN activity** within each phytoplankton cluster
- Glucose does not show significant IN activity (experiments with standard solutions)
- Still unclear how free glucose is connected to INP biochemically (degradation of polysaccharides?)

→Glucose is no IN substance, but may serve as an **INP tracer**

## Summary and Outlook

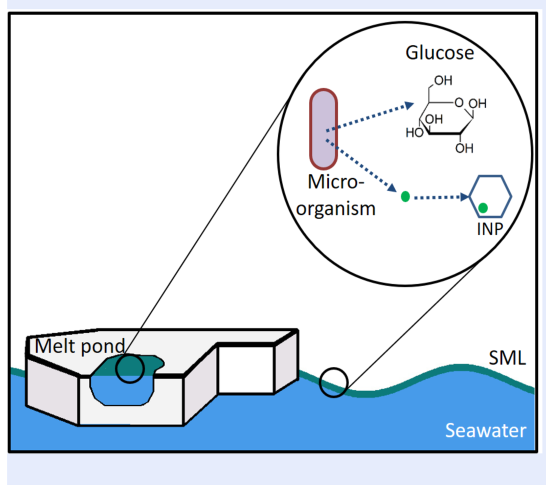
**Summary**

Glucose and IN activity in Arctic seawater samples are correlated:

- Highest concentrations in melt ponds and in the marginal ice zone
- Glucose might be released together with biological INP
- Phytoplankton composition and physiological state need to be considered

**Outlook:**

- Measurements of polysaccharides in seawater and aerosol particles
- Comparison Glucose/INP activity in other regions (Cape Verde, Antarctica)
- Systematic investigation of Arctic melt ponds (MOSAiC campaign)




These results were recently submitted at *Environmental Science and Technology*.

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References: [1] Liss&Duce (1997); [2] Wilson et al. *Nature* (2015); [3] Irish et al. *ACP* (2017); [4] Chance et al. *ES&T* (2018)