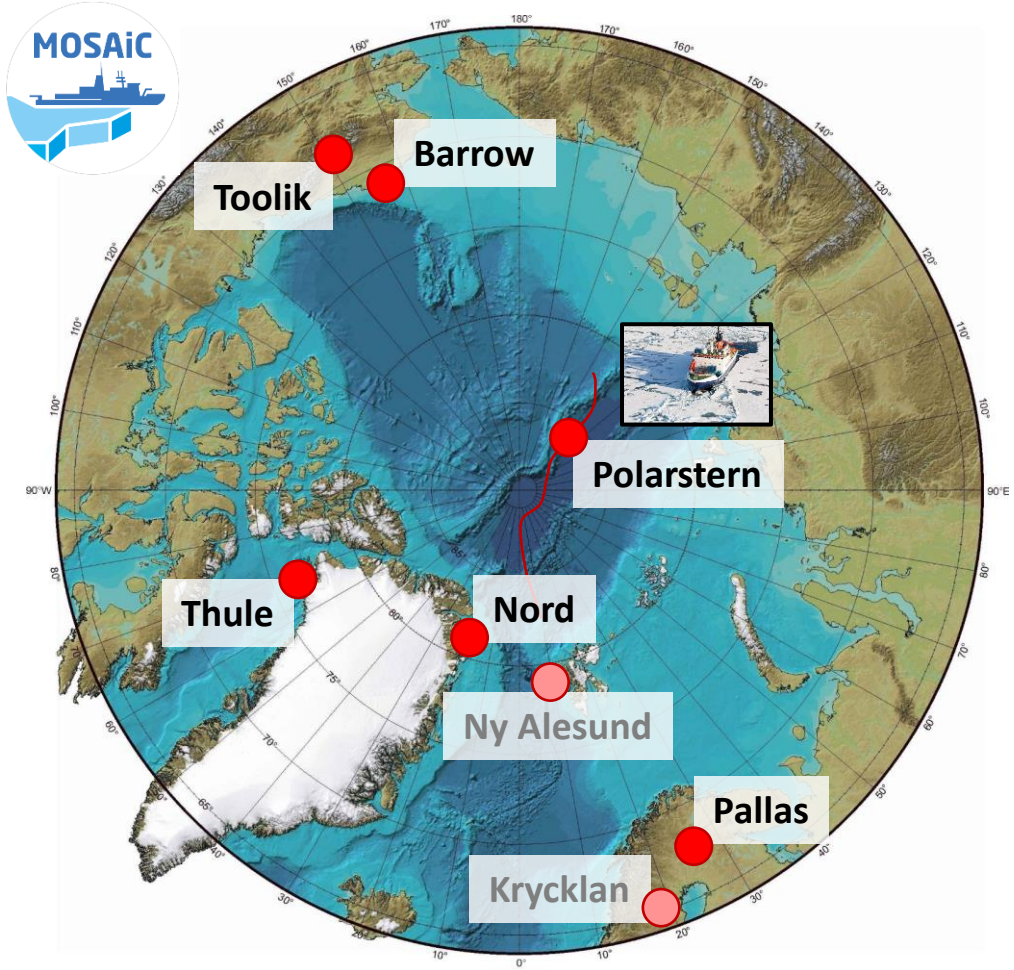
Sea ice controls on Arctic water vapor content and transport: Discoveries from MOSAiC's pan Arctic Water Isotope Network (AWIN)

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mosaic-expedition.org/

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Objectives of study:

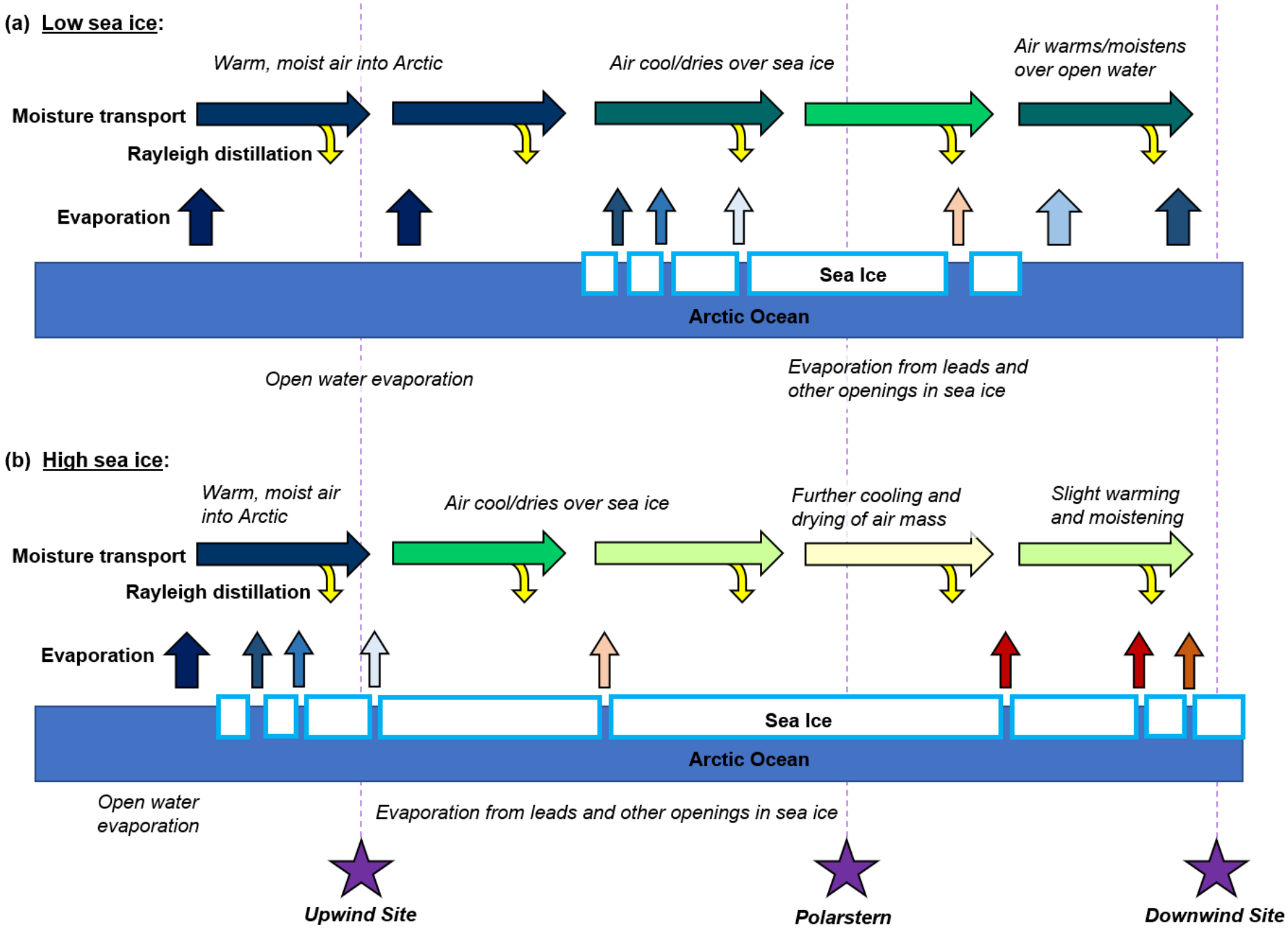
We present coordinated water vapor isotope measurements from a network of land-based stations that surround the Arctic Ocean in Barrow, Nord, Pallas, Thule, and Toolik, and on-board the Polarstern during September – November 2019 (early MOSAiC). This configuration provides the basis on which to quantify how variations in sea ice extent and distribution affect moisture content, water vapor isotope traits, and transport along several critical storm tracks.

Examining isotopic changes between sites has allowed us to:

1) Identify the distinct isotopic fingerprints of moisture sourced by evaporation from Arctic seas that is dependent on variable sea ice
2) Trace moisture additions into critical storm tracks across the Arctic
3) Examine spatial variability of the incorporation of Arctic-sourced vapor into these storms tracks

Conceptual model:

Roles of sea ice in the Arctic hydrologic cycle



Arrow colors represent those used in upcoming maps:

Moisture transport = Integrated Vapor Transport (IVT); blue is high IVT, yellow is low IVT

Evaporation = d-excess; blue is low d-excess, red is high d-excess

Evaporation and the Arctic d-excess signal

Low sea ice:

- Evaporation occurring from cold Arctic seas with low sea ice coverage into relatively warm humid air masses (*warm mode evaporation*)
- Low kinetic fractionation during evaporation produces moisture with a **low d-excess**
- D-excess difference (downwind – upwind) between sites is relatively lower (more negative)

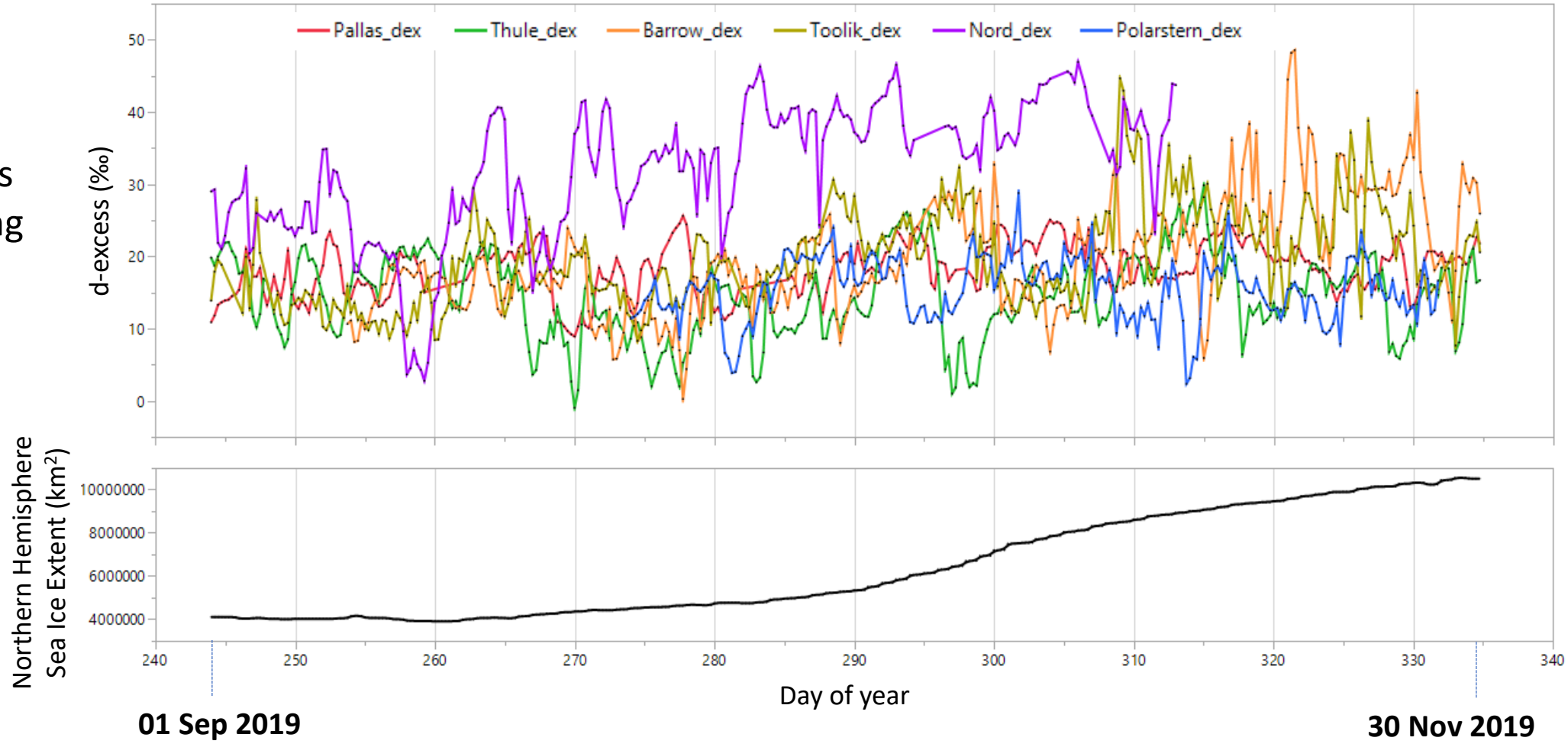
High sea ice:

- Evaporation occurring from cold Arctic seas with high sea ice coverage into relatively cold dry air masses (*cold mode evaporation*)
- High kinetic fractionation during evaporation produces moisture with a **high d-excess**
- D-excess difference (downwind – upwind) between sites is relatively higher (more positive)

Observational data:

Coordinated d-excess measurements during Sep-Nov 2019 (early MOSAiC)

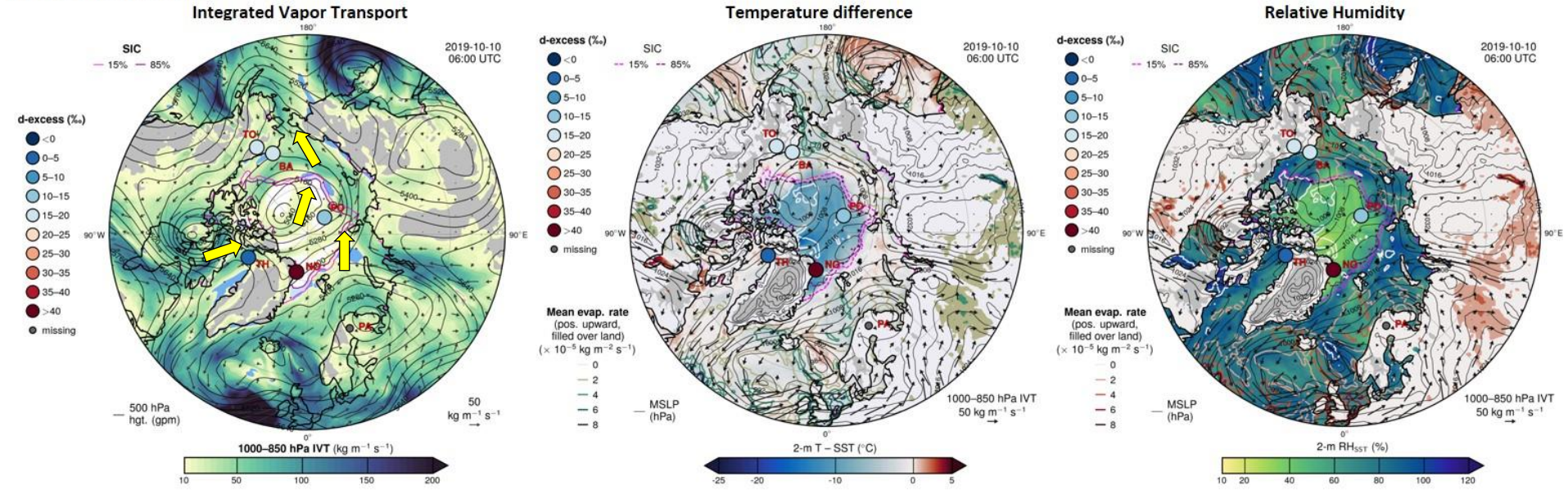
6-hour averages displayed



Data processing conducted following methods described in: Bonne et al., 2019; Akers et al., 2020; Bailey et al., 2021

Case study events showcase hypothesized d-excess changes along moisture storm tracks linking multiple AWIN sites

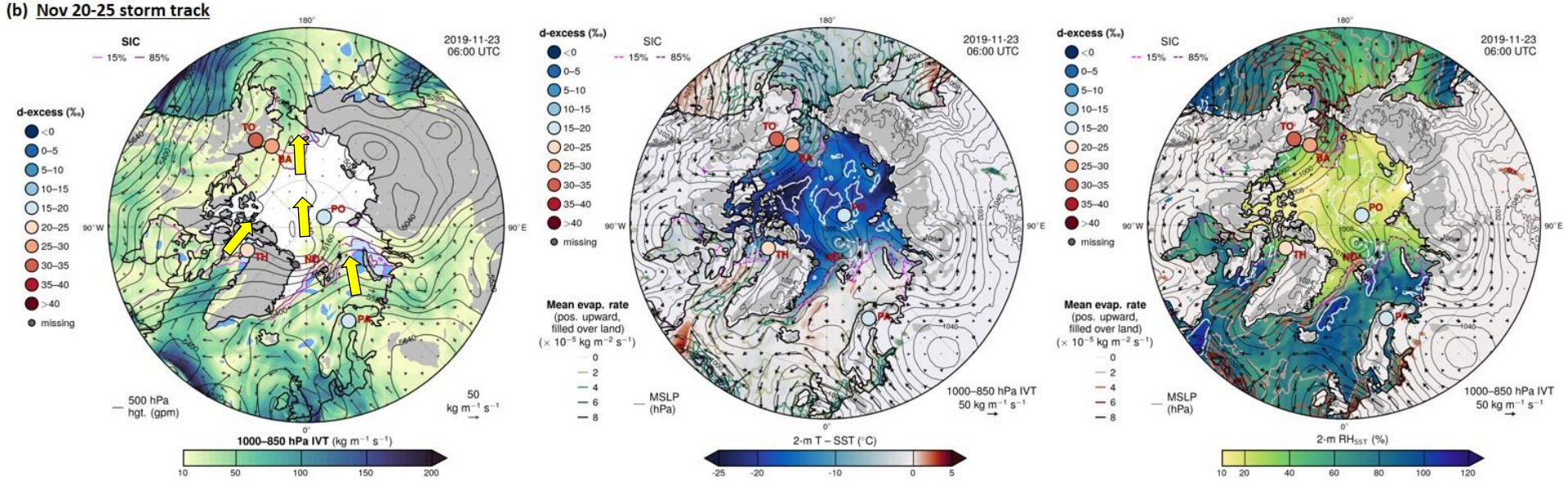
(a) Oct 7-12 storm track



Site differences:
(from 2019-10-10 06:00 UTC)

Pallas to Barrow = +3‰
Pallas to Toolik = +5
Thule to Barrow = -1
Thule to Toolik = +1
Pallas to Polarstern = -2
Thule to Polarstern = -6
Polarstern to Barrow = +5
Polarstern to Toolik = +7
Nord to Barrow = -12
Nord to Toolik = -10
Nord to Polarstern = -17

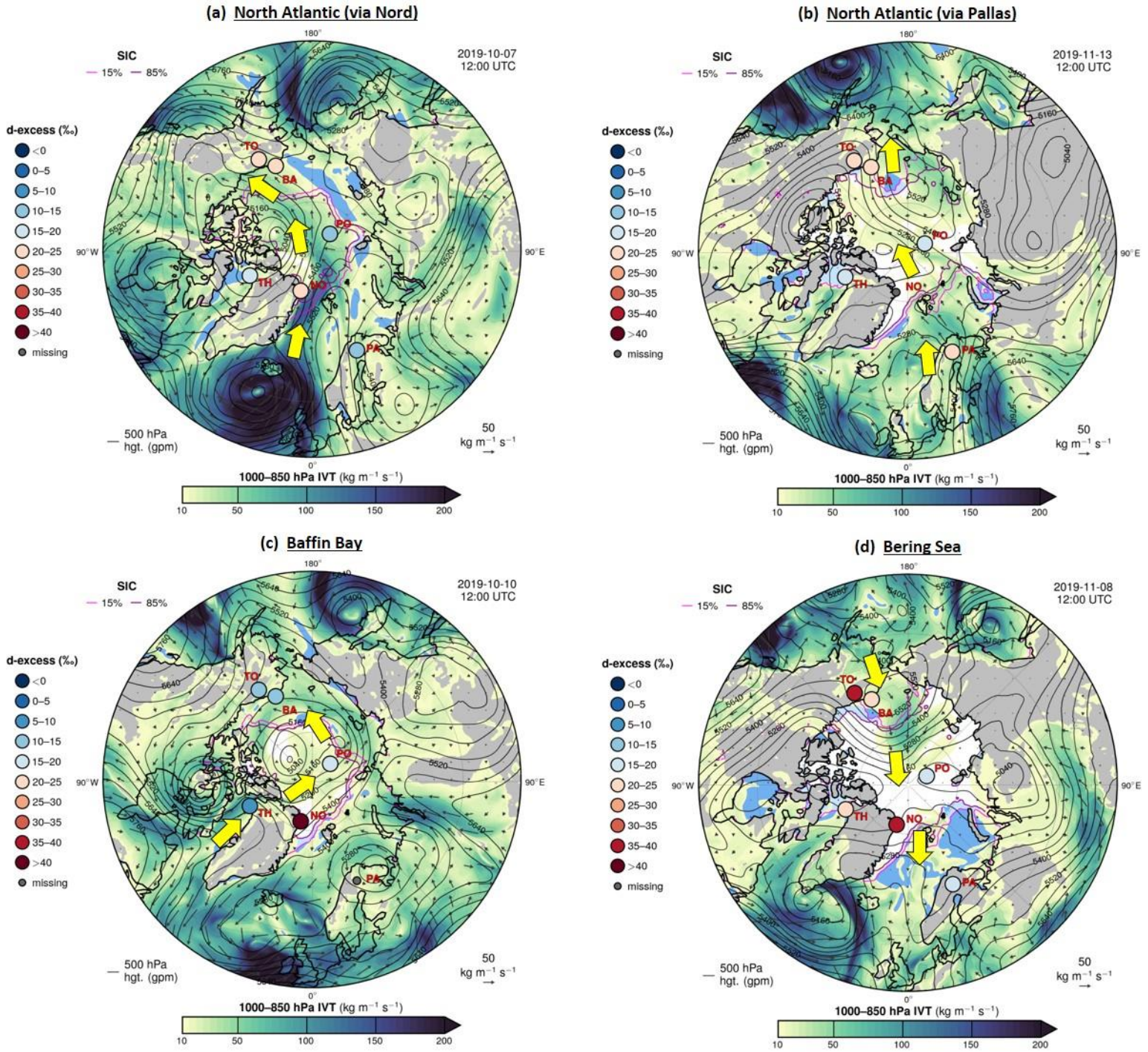
(b) Nov 20-25 storm track



Site differences:
(from 2019-11-23 06:00 UTC)

Pallas to Barrow = +14‰
Pallas to Toolik = +11
Thule to Barrow = +13
Thule to Toolik = +10
Pallas to Polarstern = +3
Thule to Polarstern = +4
Polarstern to Barrow = +10
Polarstern to Toolik = +7

Storm tracks: Examine common repeating tracks to determine d-excess changes along pathway over a range of sea ice conditions

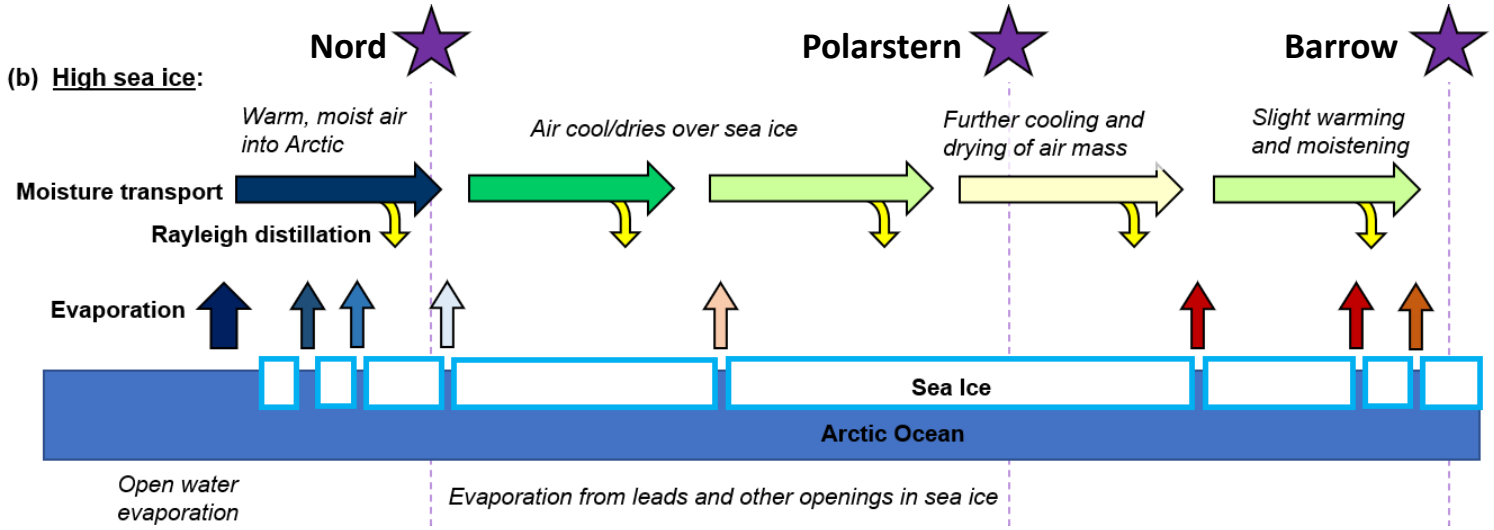


Site connections during repeated storm tracks to determine influence of sea ice

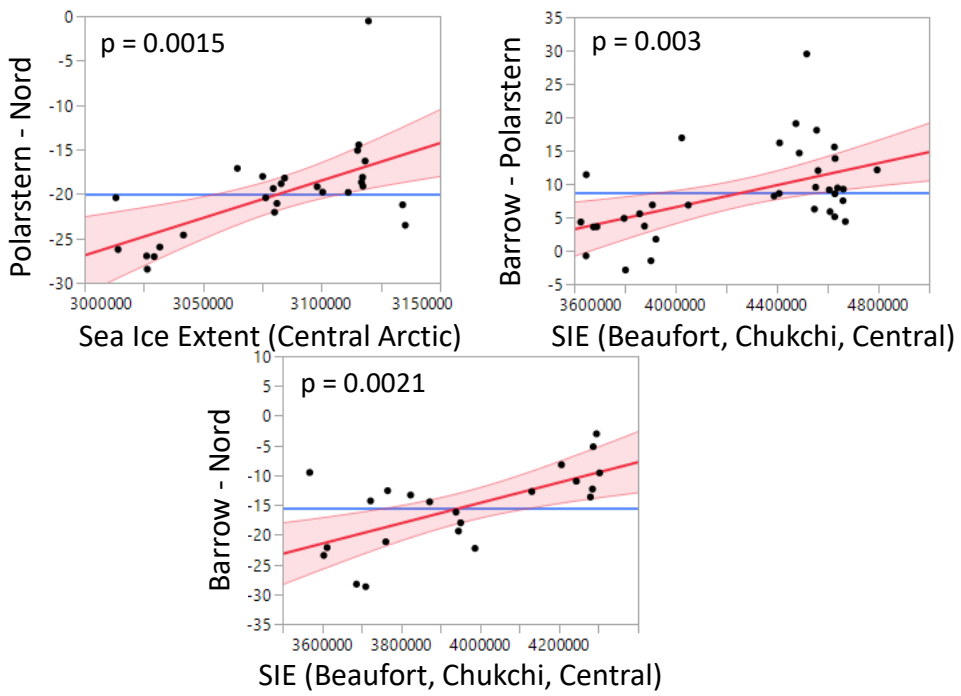
Compute d-excess difference between sites (downwind – upwind) when connected under common storm track; lag applied to account for transport time

Multiple regression model: d-excess difference against sea ice extent and IVT (at upwind and downwind site)

Sea ice extent summed for primary basins (NSIDC MASIE) the storm track crosses between sites



Example **partial regression** results for North Atlantic (via Nord) storm track for **d-excess difference** (downwind – upwind) **against sea ice extent**



Next slide: 20 site combinations over the 4 storm tracks to show consistent relationship between sea ice and d-excess

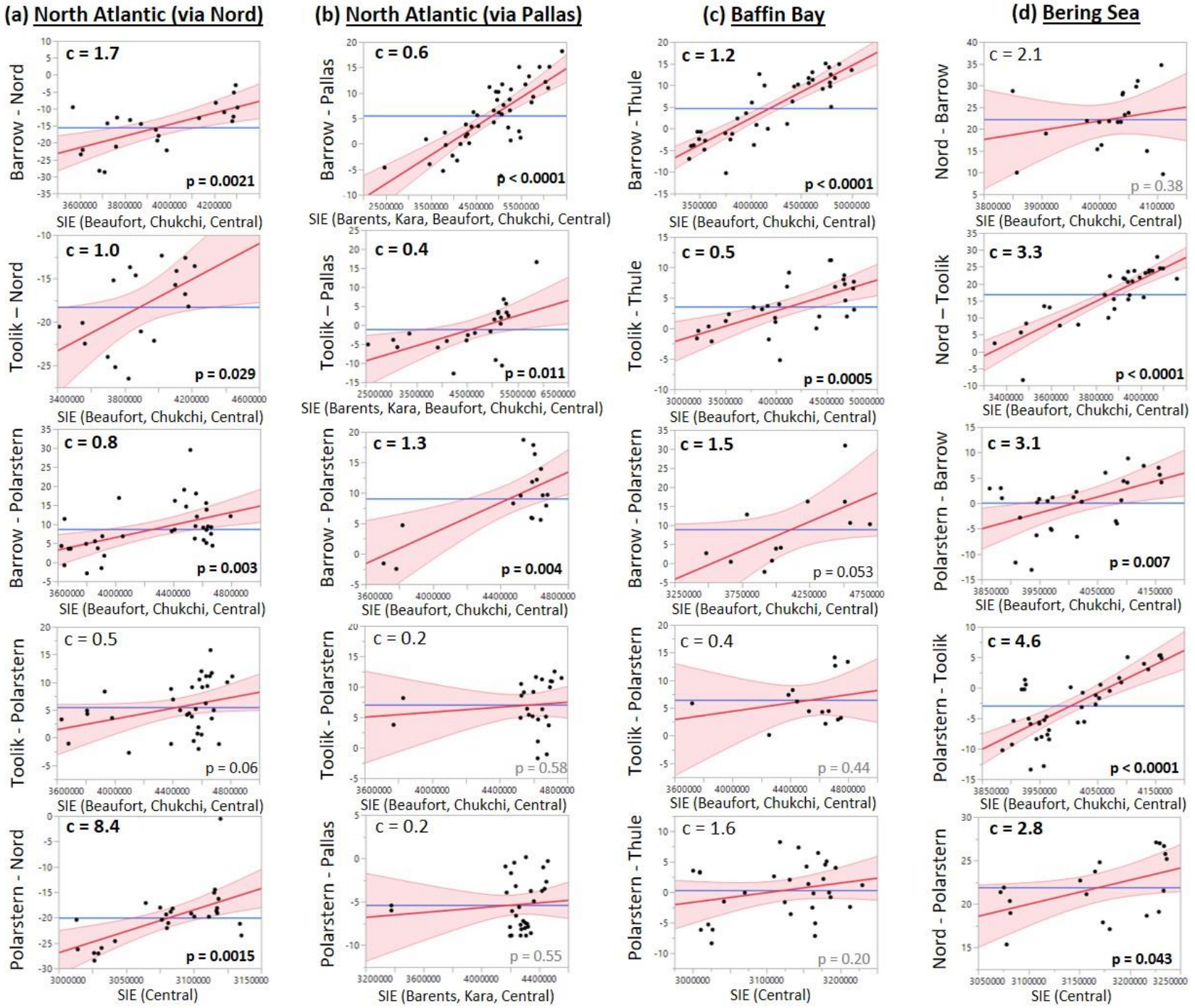
Sea ice vs d-excess difference

All partial regressions of sea ice against the d-excess difference have positive relationships (13 of 20 has $p<0.05$, 15 of 20 has $p\leq0.1$)

Consistent shift from warm to cold mode evaporation as sea ice increases

Other key takeaways:

1) Bering Sea storm track most influenced by sea ice
2) North Atlantic via Pallas track least influenced
3) Moisture reaching inland locations (Toolik) influenced by sea ice (i.e. not just a coastal effect)



Conclusions and Implications:

We demonstrate that sea ice coverage limits the total amount of evaporation, where less sea ice along a storm track results in increased evaporation and incorporation of that moisture into that storm track

This has many important consequences; most notably, that a reduction in sea ice leads to higher water vapor content in the atmosphere [Boisvert et al., 2015] and ultimately increased precipitation [Bintanja & Selton, 2014]

These hydrologic cycle changes are associated with numerous critical climate feedbacks including, the warming effect of increased water vapor, changing surface energy balance due to increased rain or snow [Kopec et al., 2016; Bintanja & Andry, 2017], among others