Monitoring of GNSS Scintillation Indices during the MOSAiC Expedition: Preliminary Results of Ship-borne and Station-based Observations in the Arctic

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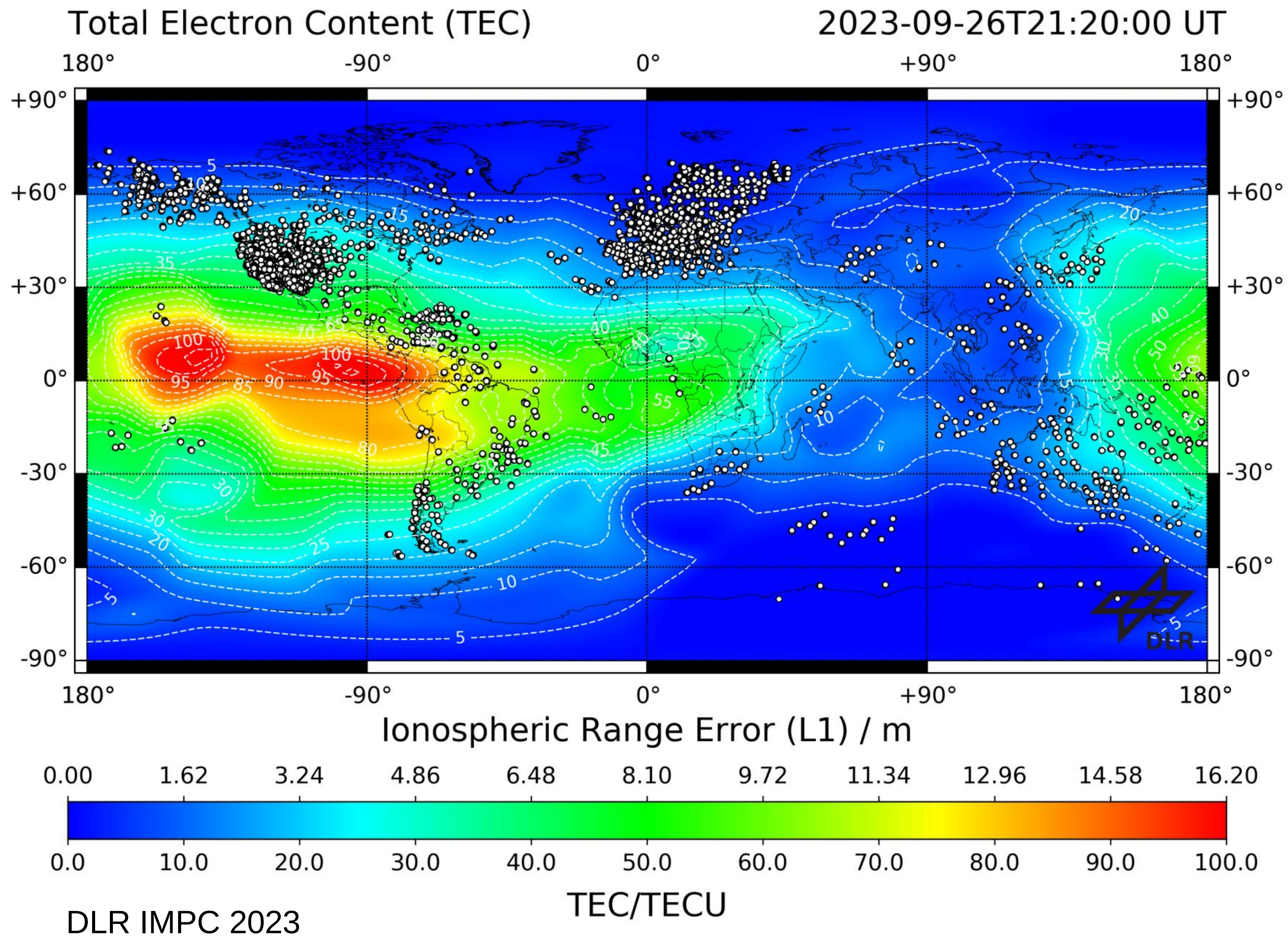
URSI Kleinheubacher Tagung, Miltenberg, September 2023

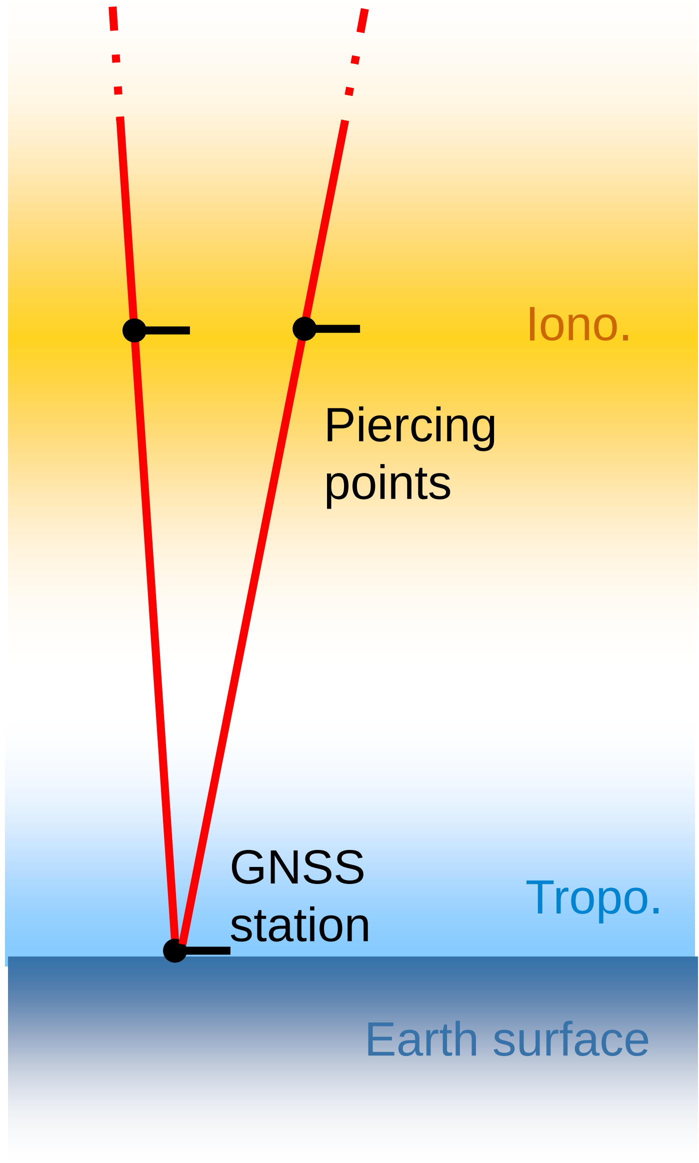
Photo Polarstern: Peter Lemke, AWI

Outline

- GNSS Remote Sensing for Ionospheric Monitoring
- MOSAiC Expedition and Polarstern Setup
- Processing and Masking of Ship-based Data
- Preliminary Scintillation Results
- Conclusions

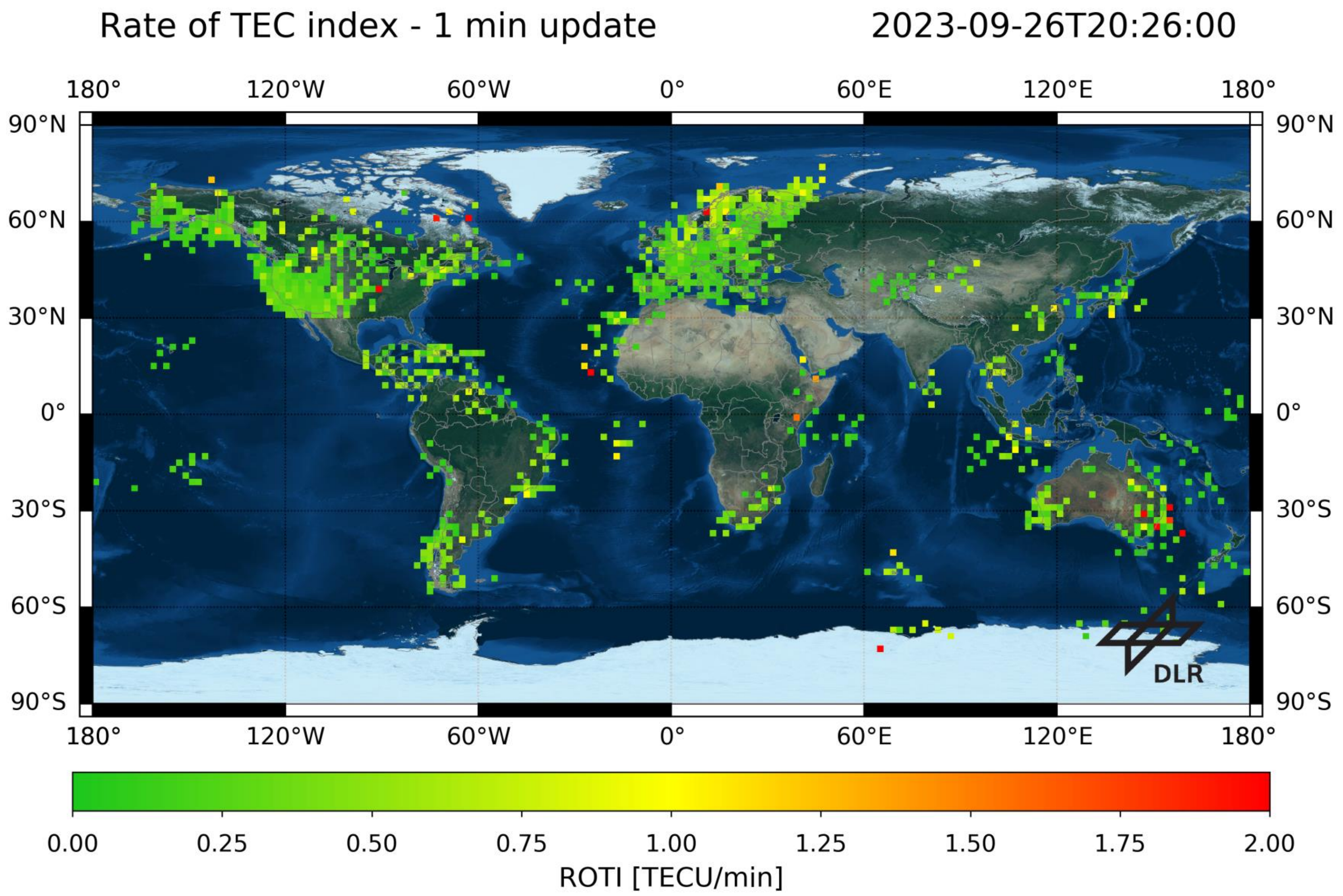
Ionosphere TEC Monitoring with GNSS





DLR IMPC 2023

Ionosphere Disturbance Monitoring with GNSS



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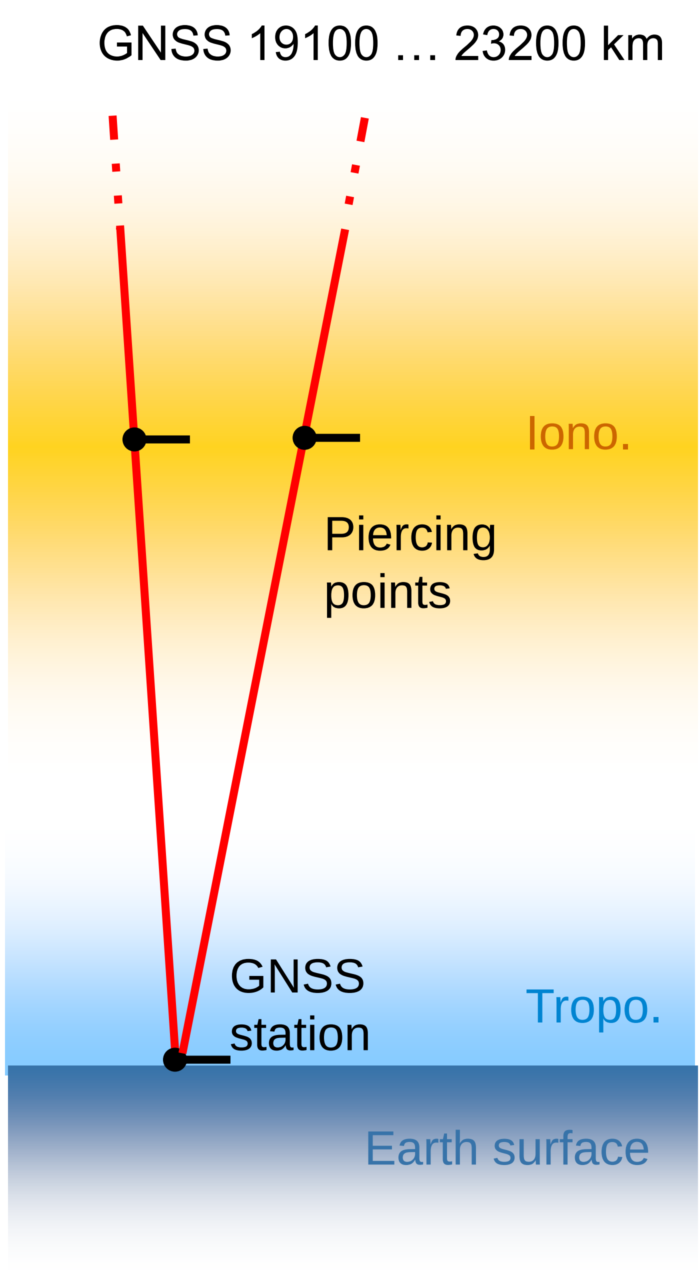
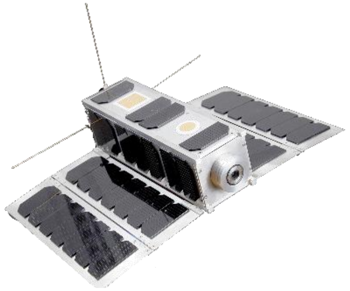


Motivation GNSS Remote Sensing

- A: Low Earth Orbiter



Wickert et al. 2016
Semmling et al. 2016

- B: Aircraft

Semmling et al. 2014
Moreno et al. 2021

- C: Research Vessels

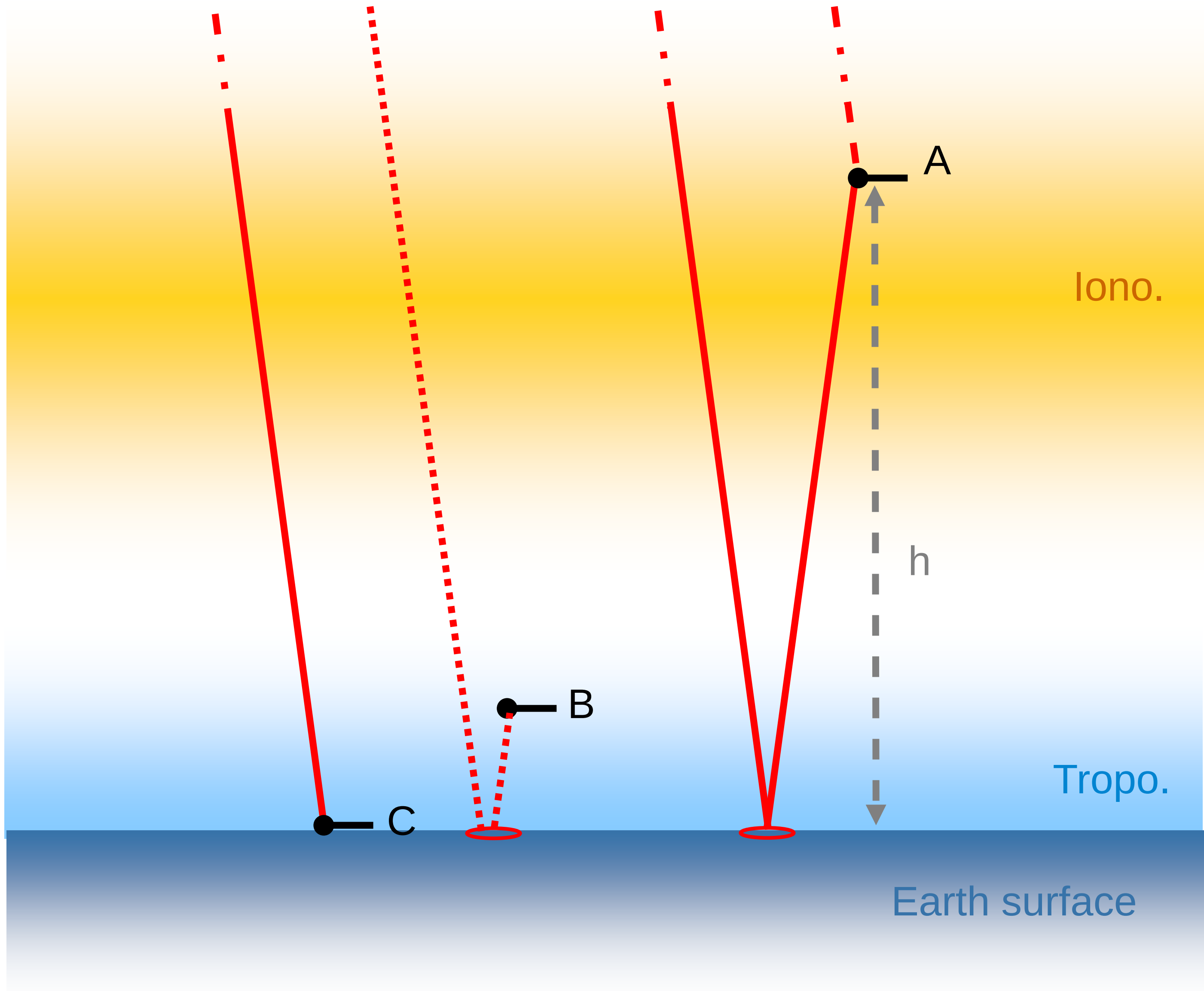
Wang et al. 2019
Semmling et al. 2019, 2022
Semmling et al. 2023

- Application

sea surface altimetry
sea state estimation
sea-ice detection

water vapor estimation
iono. scintillation detection

GNSS 19100 … 23200 km

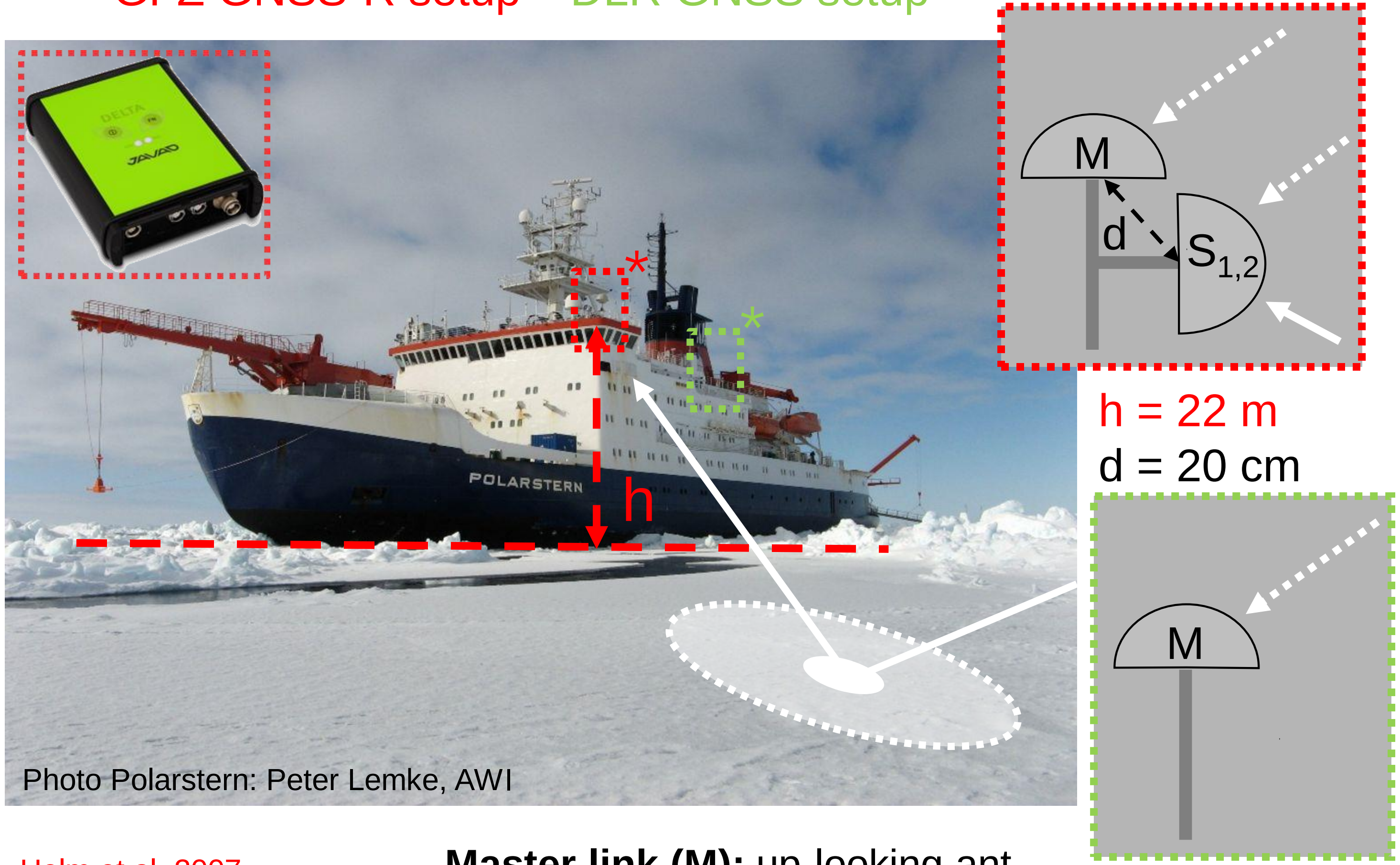


A: e.g. ISS, h ~ 400 km
B: e.g. HALO, h ~ 3500 m
C: e.g. Polarstern, h ~ 25 m

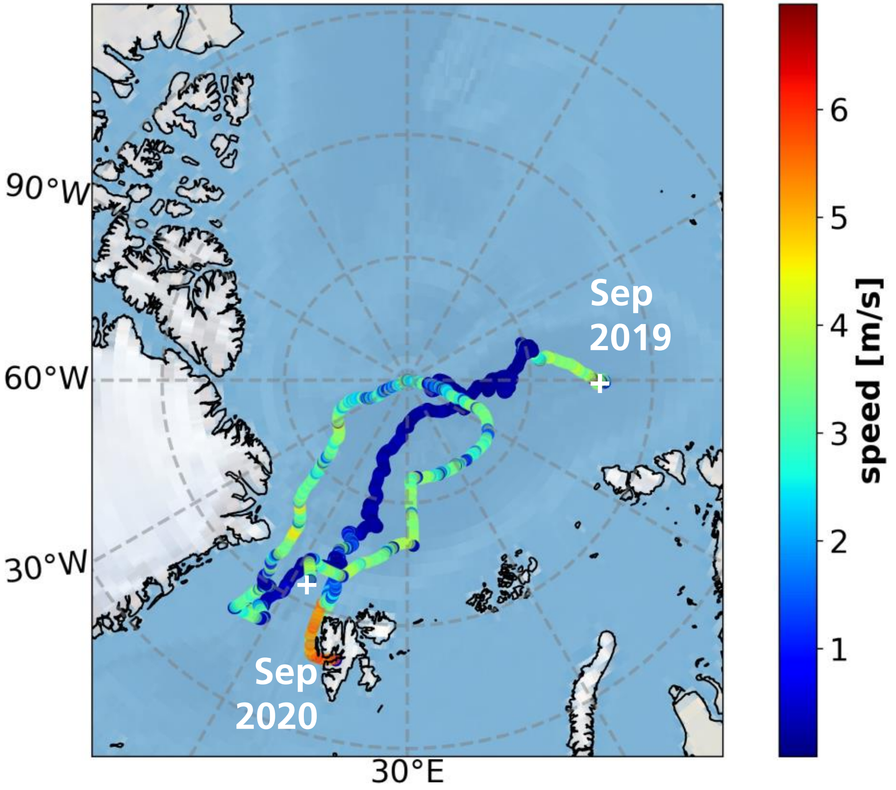
MOSAiC Expedition and Polarstern Setup

MOSAiC Expedition and Polarstern Setup

* GFZ GNSS-R setup * DLR GNSS setup



MOSAiC expedition: Sep 2019 - Sep 2020

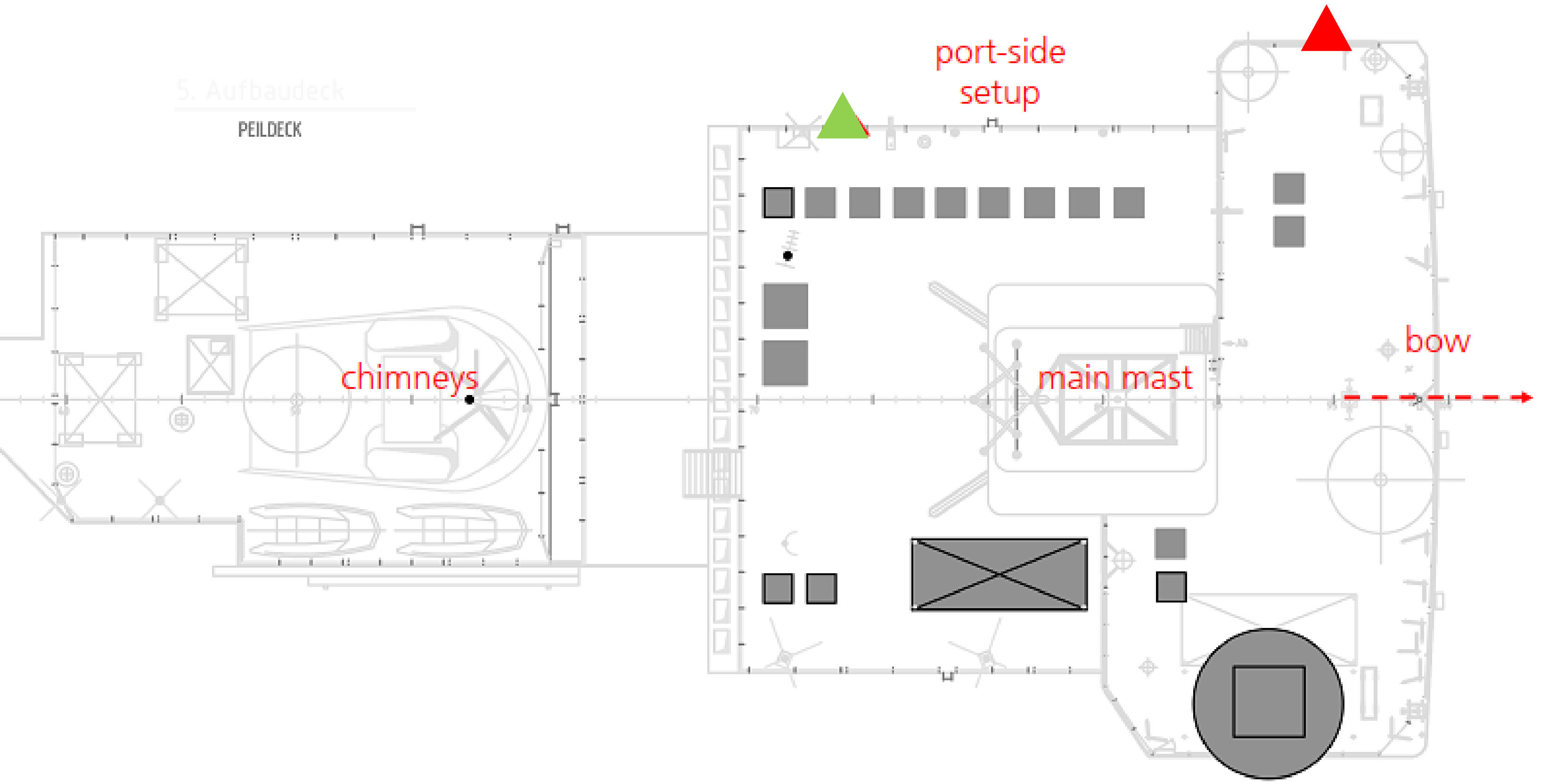


Helm et al. 2007
Semmling et al. 2013
Kriegel et al. 2017

Master link (M): up-looking ant.
Slave links ($S_{1,2}$): side-looking ant.

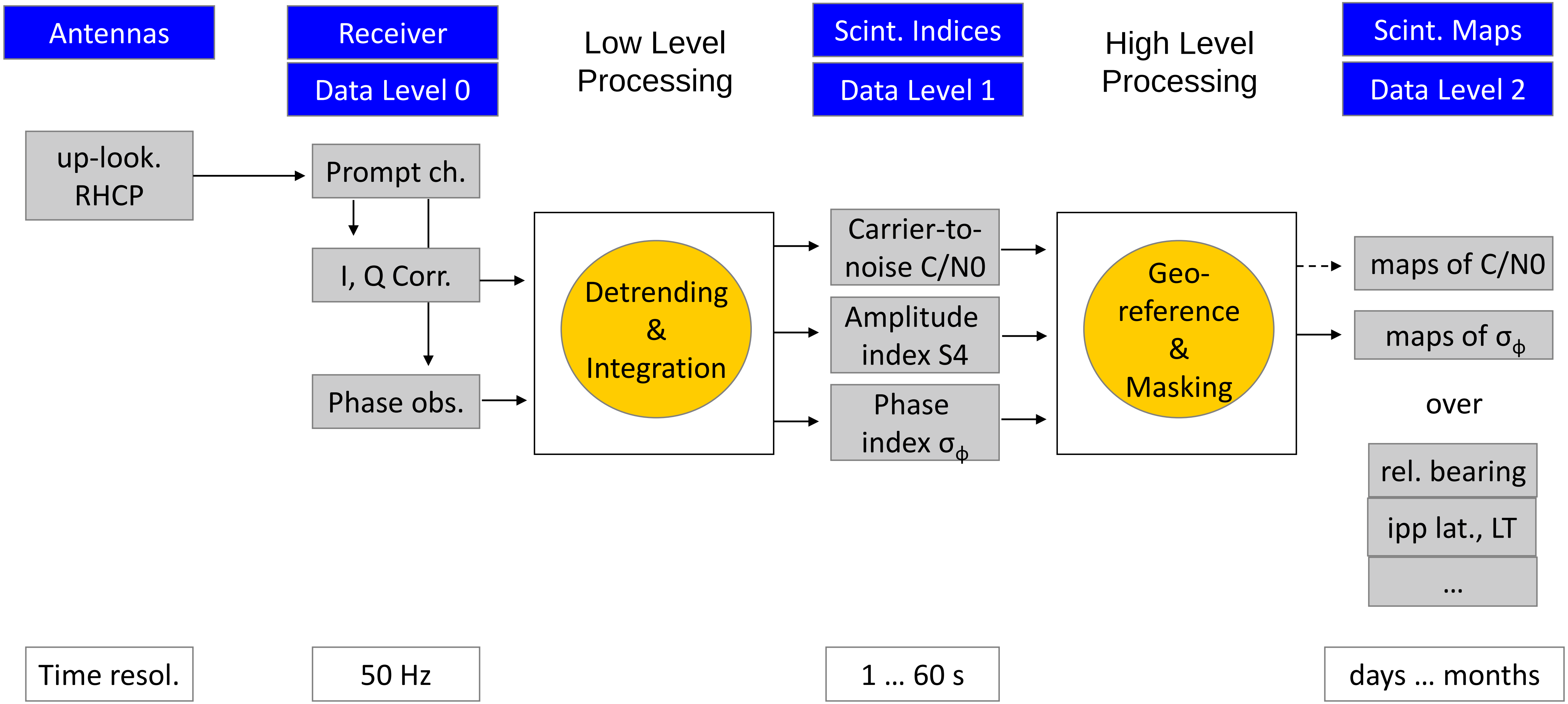
Cruising Periods: speed > 1 m/s
Drifting Period: speed < 1 m/s

MOSAiC Expedition and Polarstern Setup

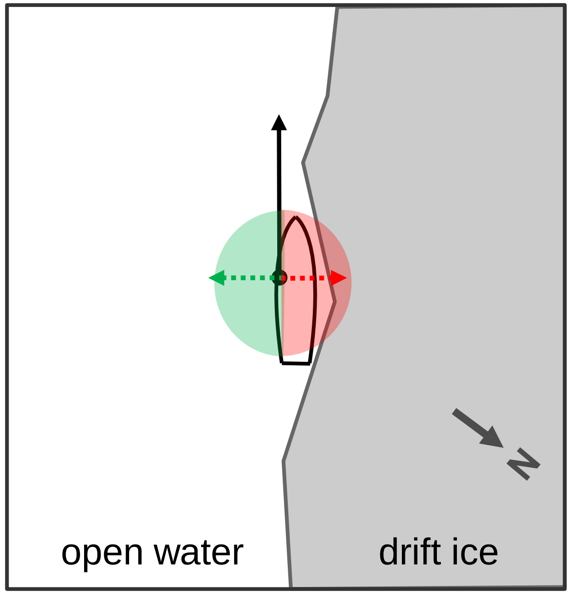


Processing and Masking of Ship-based Data

Scintillation Data Processing



Limits of Visibility from the Ship

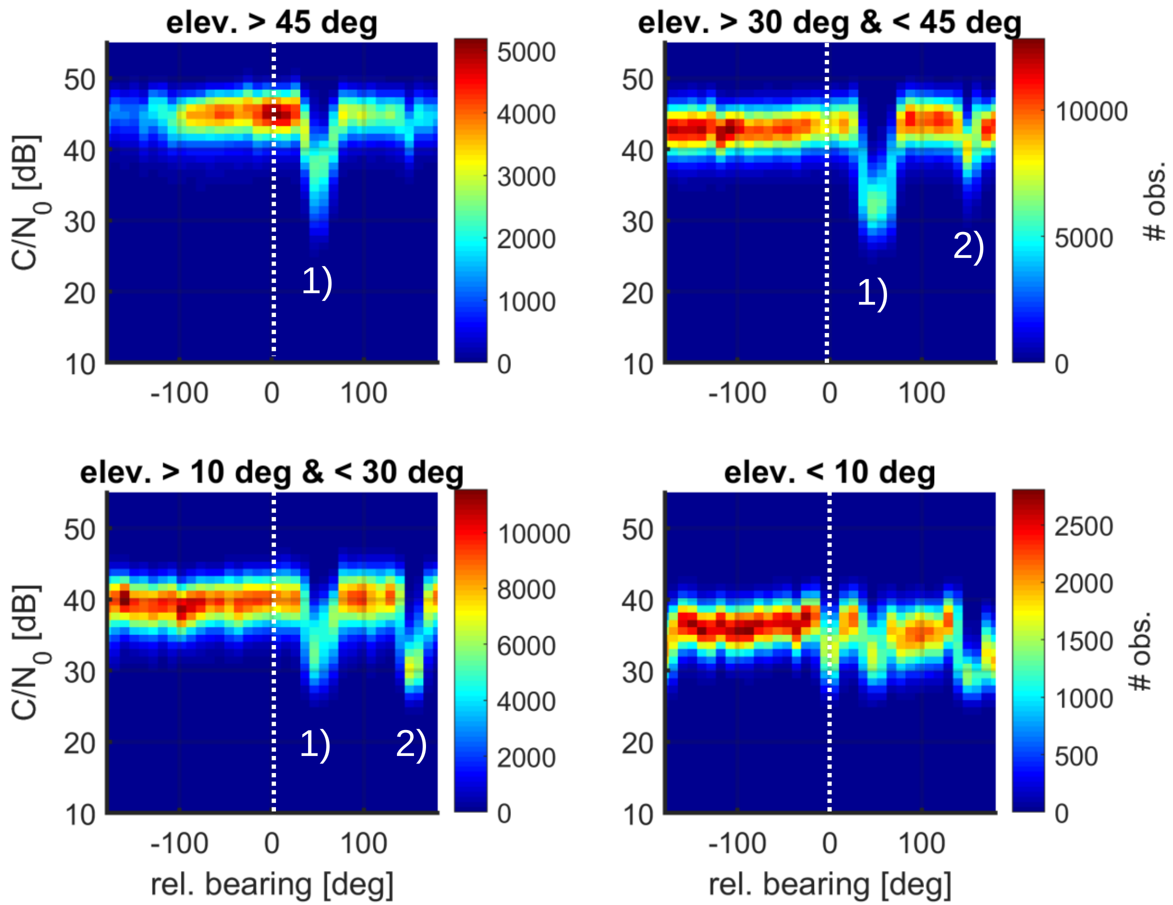


clear view
to port-side

left rel. Bearing:
-180° to 0°

heading of the ship
right rel. bearing (blocked)
left rel. bearing (clear)

C/N0 over rel. bearing

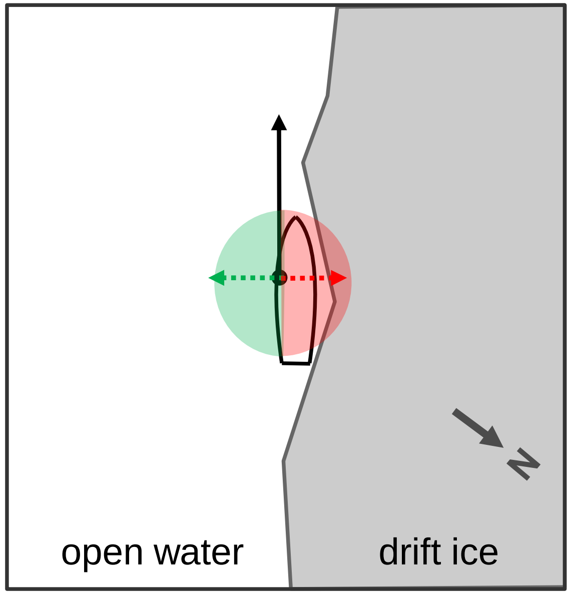


1) ship‘s main mast
2) ship‘s chimney

Sep 2019 … Sep 2020

Semmling et al. 2023

Limits of Visibility from the Ship

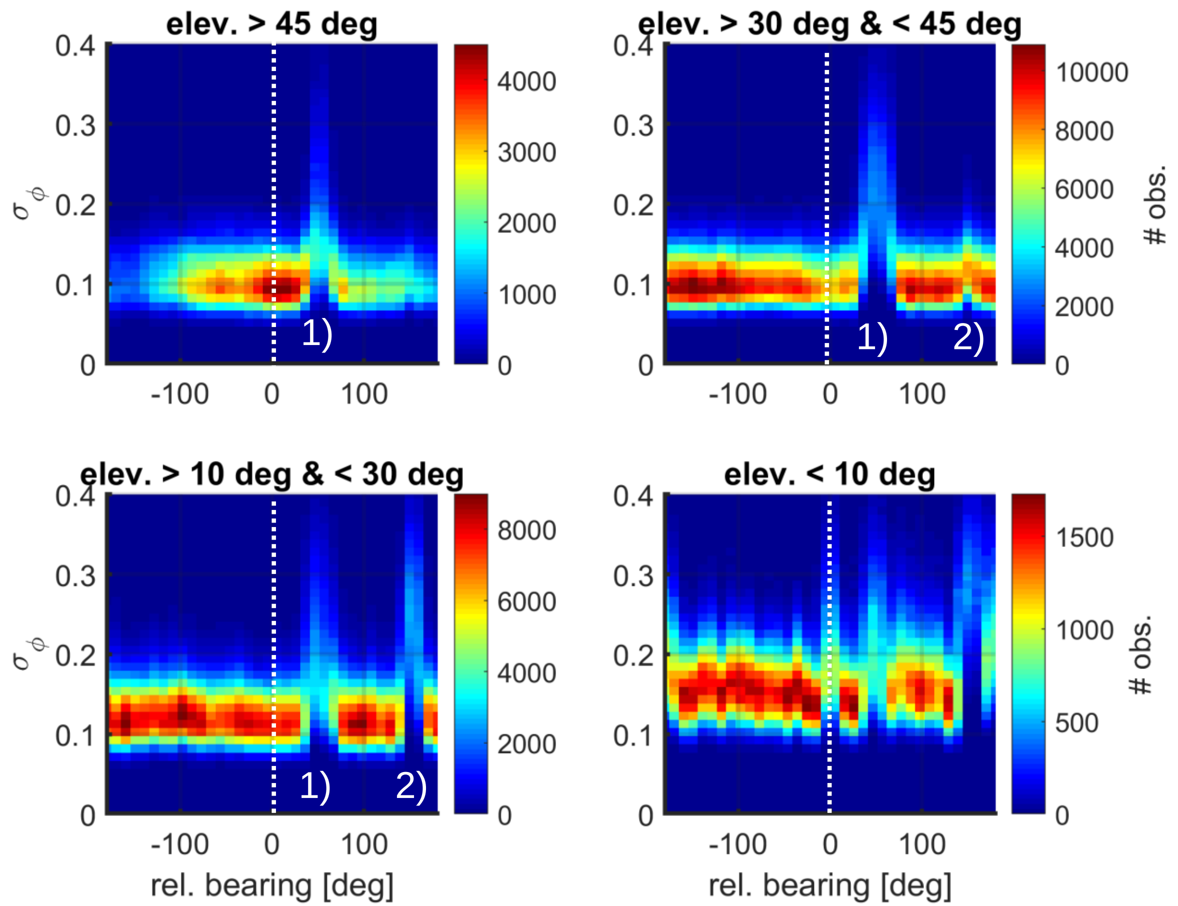


clear view
to port-side

left rel. Bearing:
-180° to 0°

heading of the ship
right rel. bearing (blocked)
left rel. bearing (clear)

σ_φ over rel. bearing



1) ship‘s main mast
2) ship‘s chimney

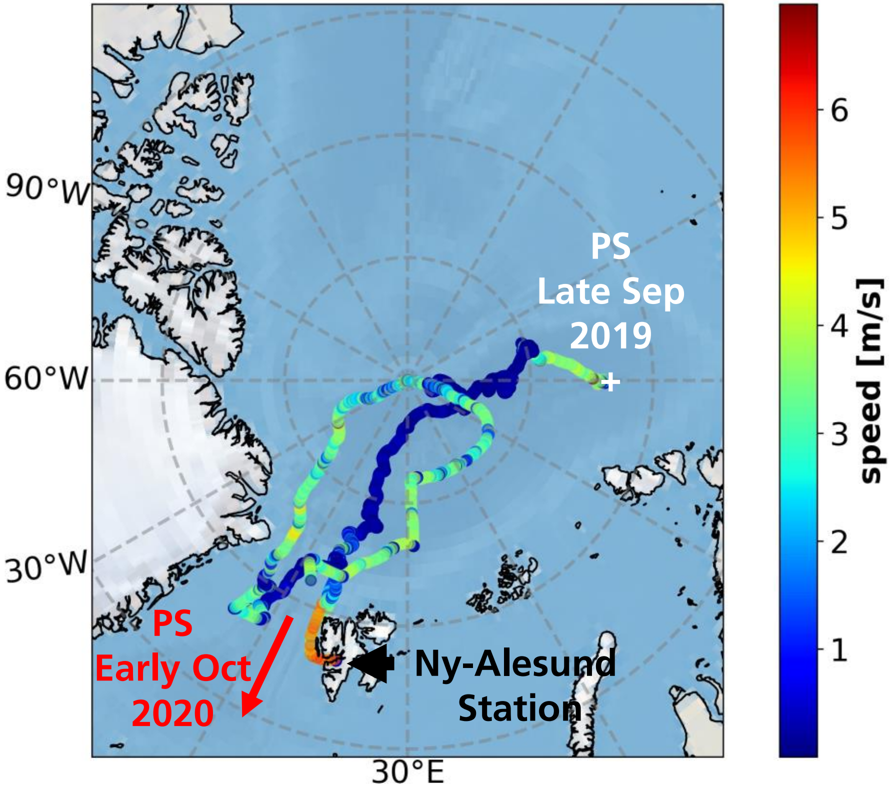
Sep 2019 … Sep 2020

Preliminary Scintillation Results

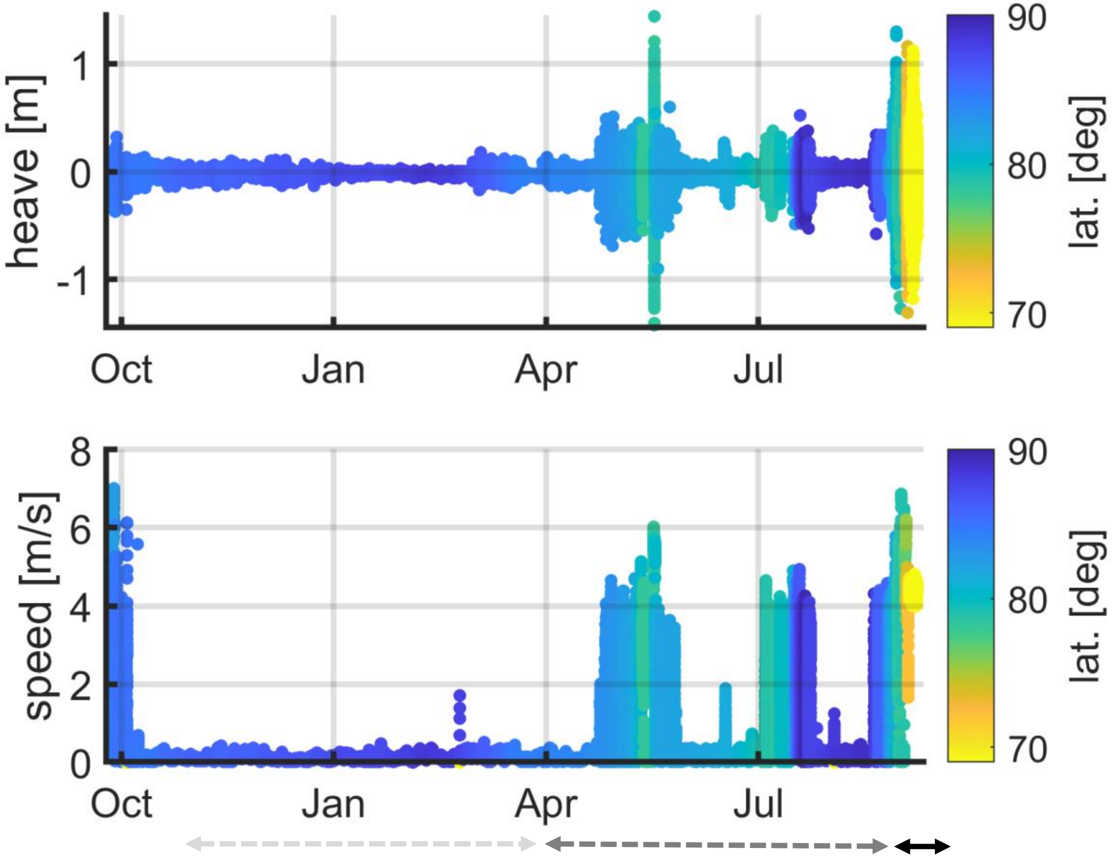
How does a ship-based setup perform compared to a station setup?

Observation Periods & Conditions

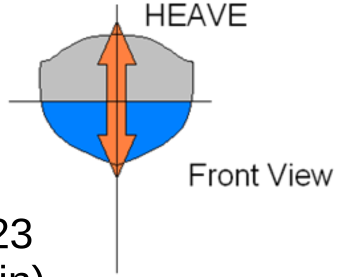
MOSAiC expedition: Sep 2019 - Sep 2020



MOSAiC expedition: Polarstern 2019/2020



Cruising Periods: speed > 1 m/s
Drifting Period: speed < 1 m/s

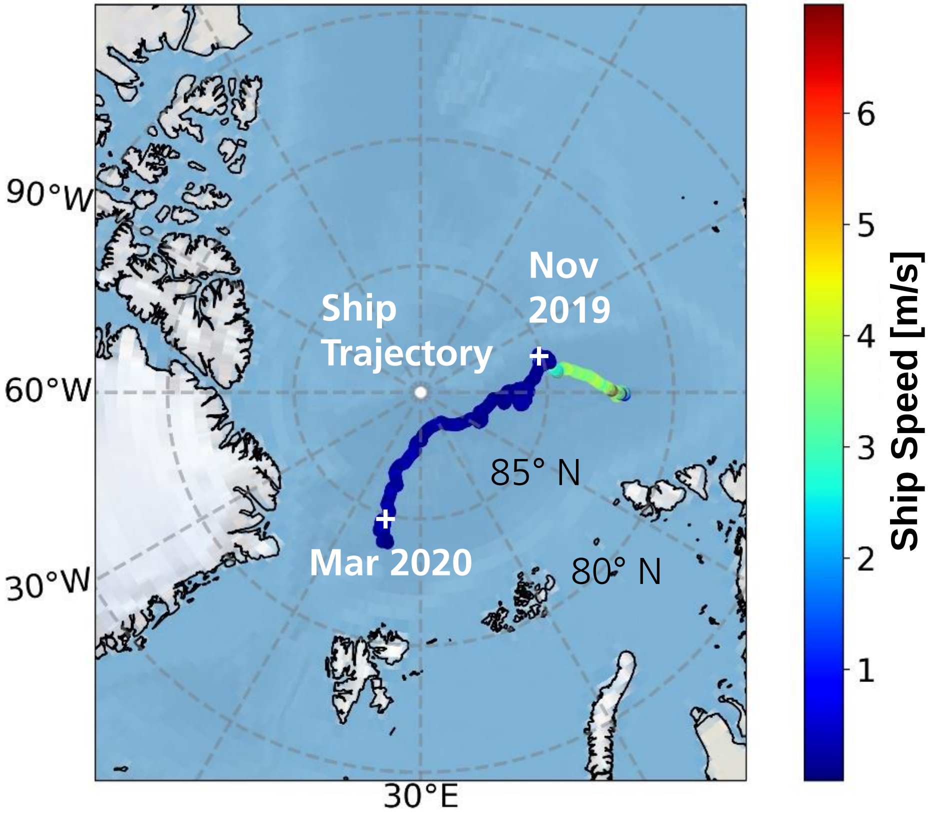


Wikipedia 2023
(Public Domain)

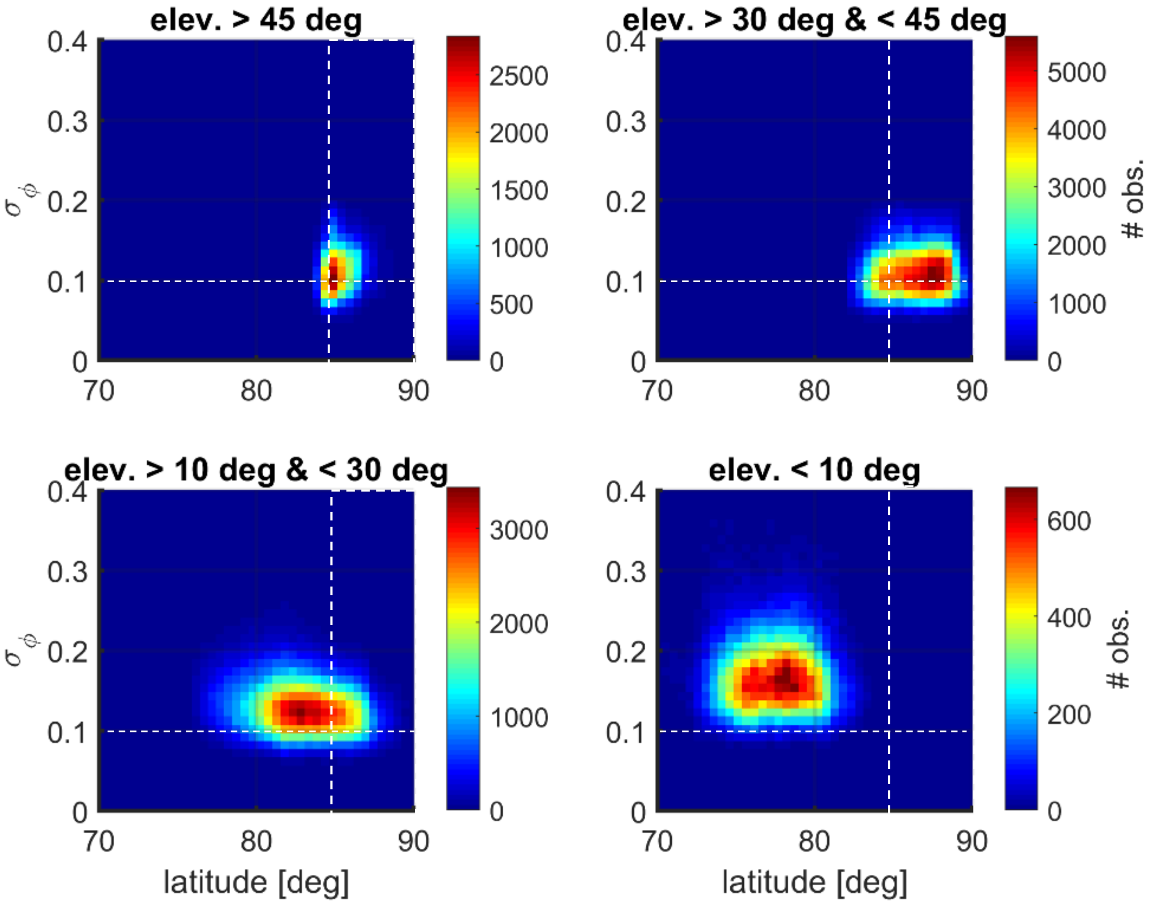
Drift (small heave)	Nov 2019 – Mar 2020
Drift & cruise (var. heave)	Apr 2020 – Sep 2020
Cruise (larger heave)	**Oct 2020**

Drift - High Arctic - Winter

GNSS obs. in the Central Arctic



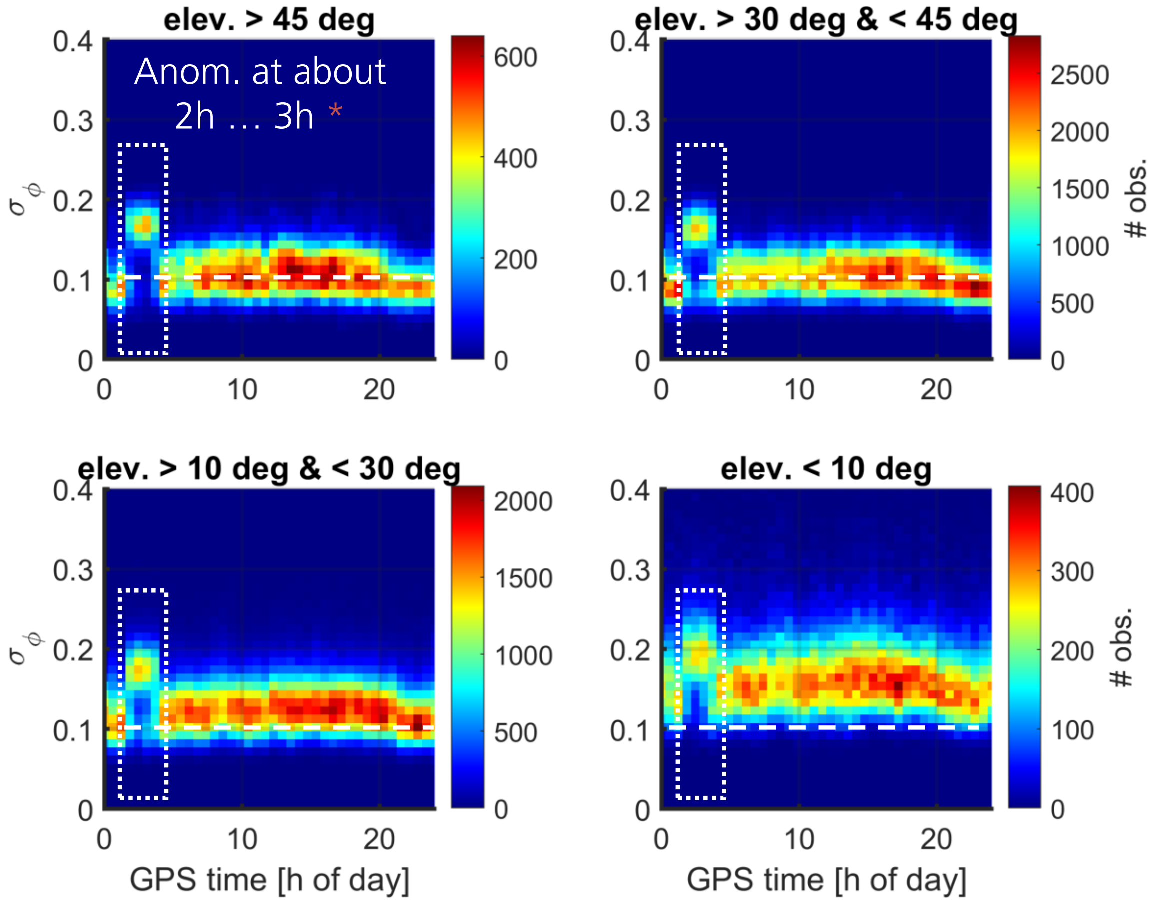
σ_φ over lat. at IPP (height 350 km)



Nov 2019 … Mar 2020

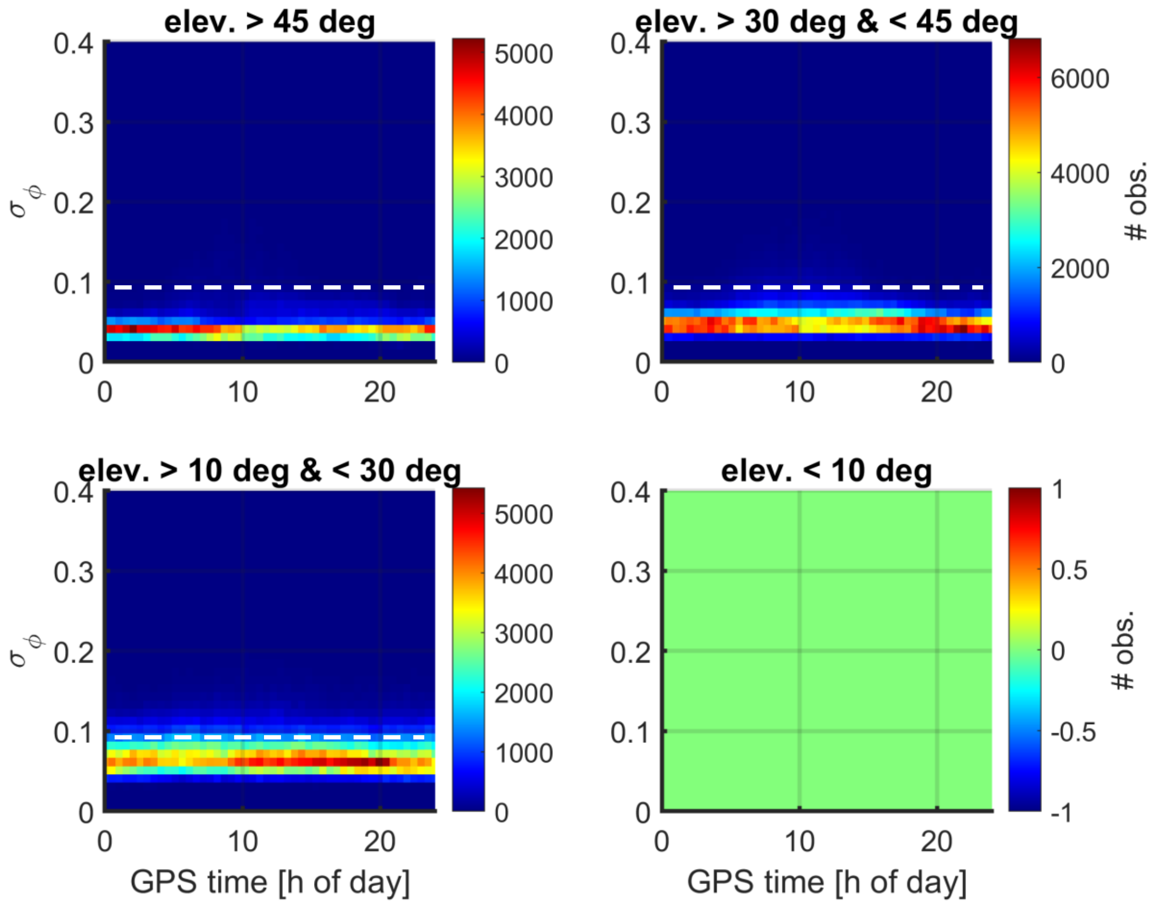
Drift - High Arctic - Winter

σ_φ over hour of day at PS



Nov 2019 … Mar 2020

σ_φ over hour of day at NyA station

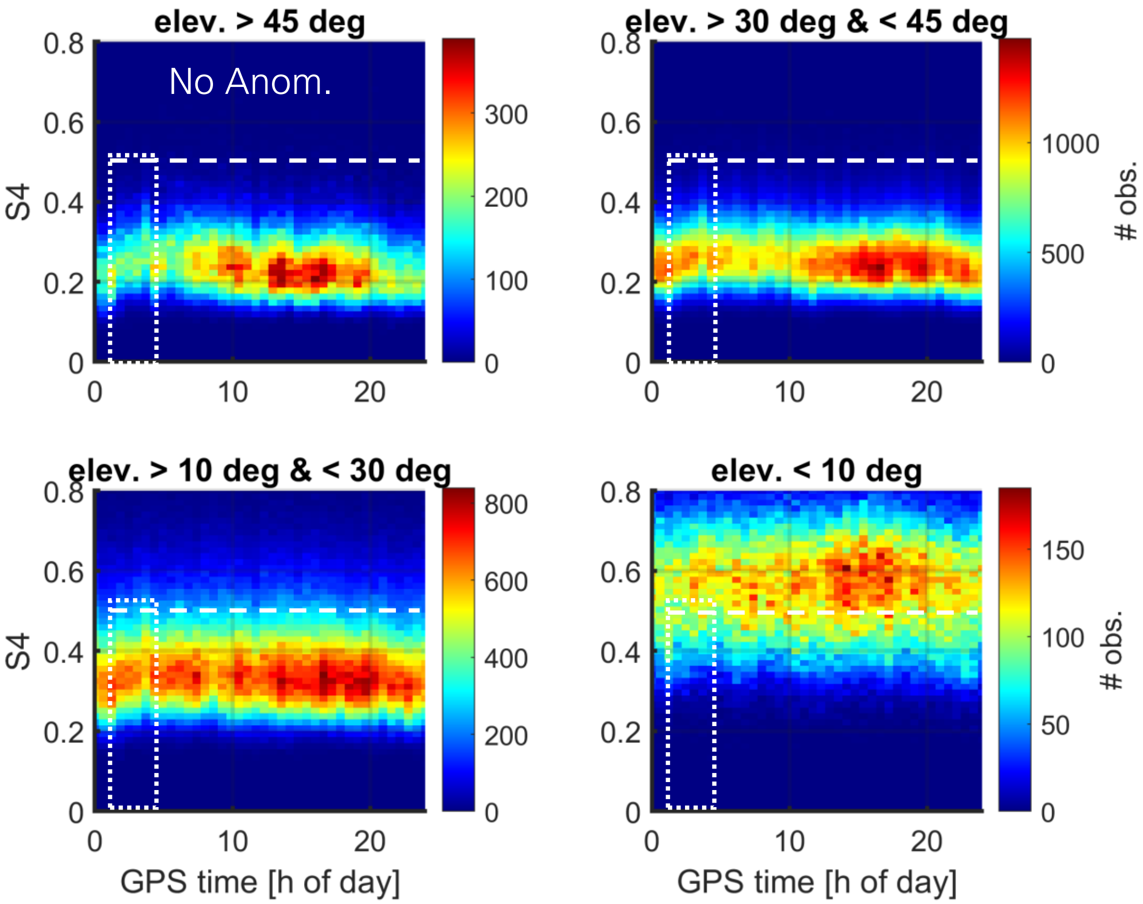


Nov 2019 … Mar 2020

* cusp
influence ?

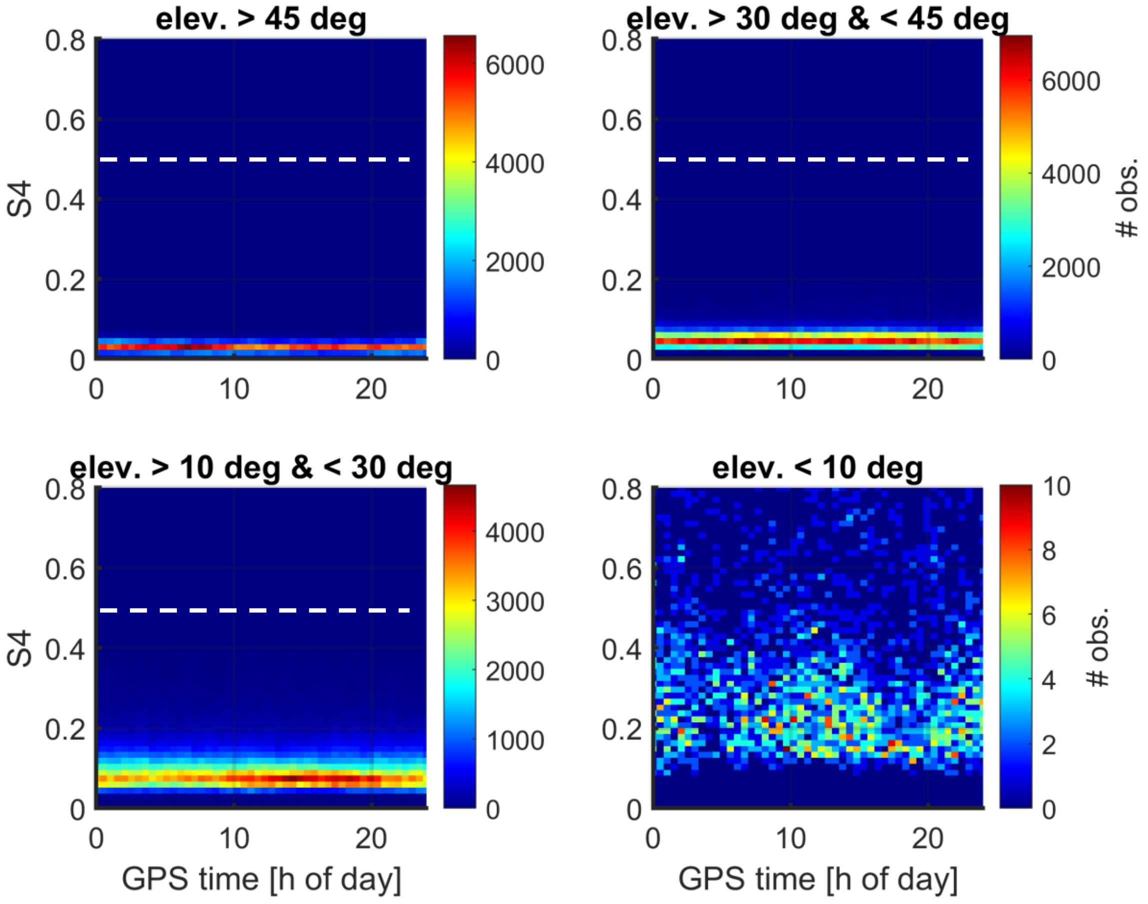
Drift - High Arctic - Winter

S4 over hour of day at PS



Nov 2019 … Mar 2020

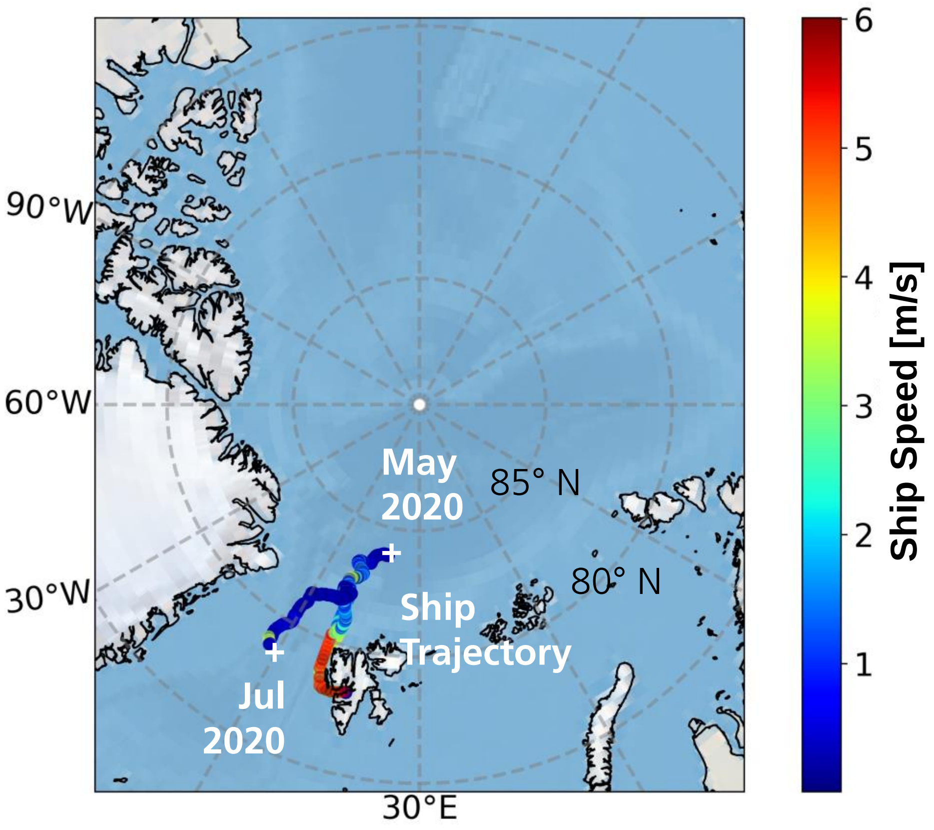
S4 over hour of day at NyA station



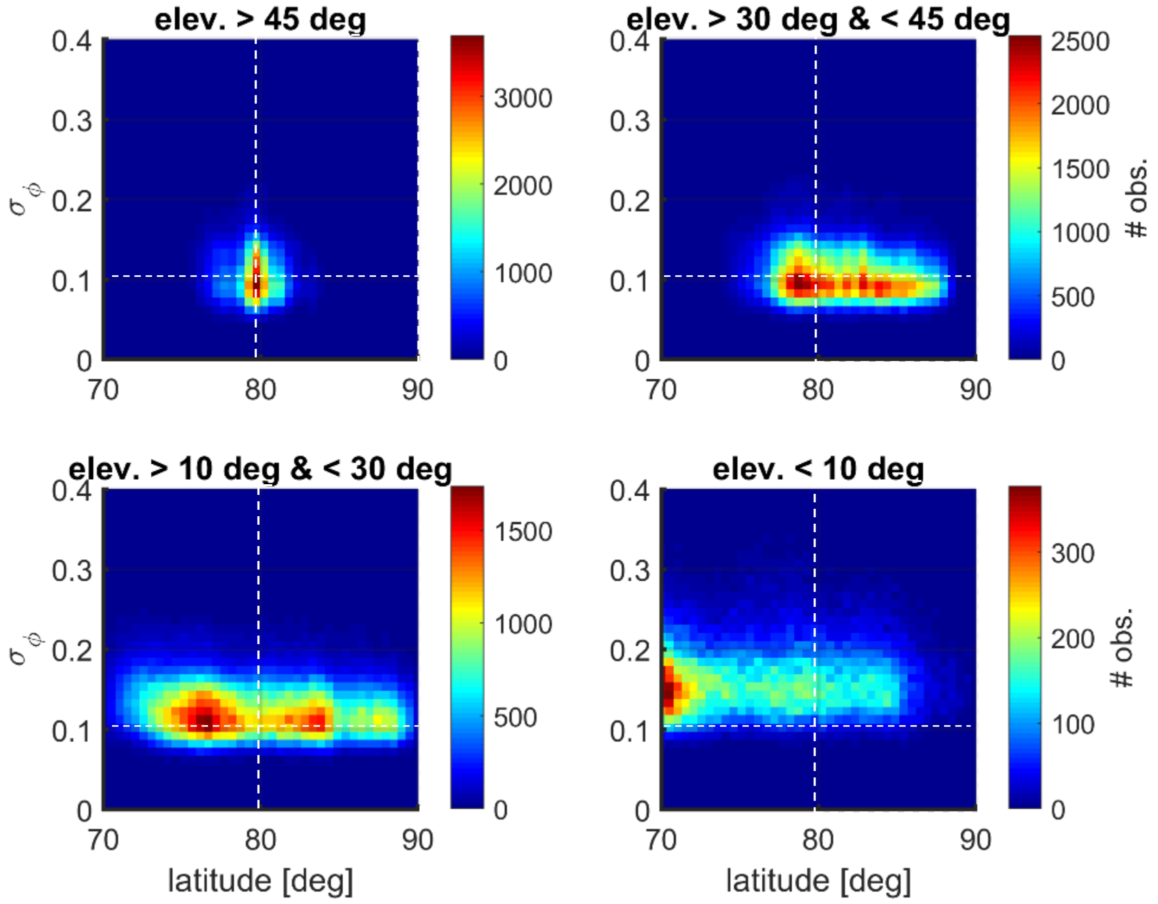
Nov 2019 … Mar 2020

Drift & Cruise - Spring & Summer - Fram Strait

GNSS obs. in the Central Arctic



σ_φ over lat. at IPP (height 350 km)

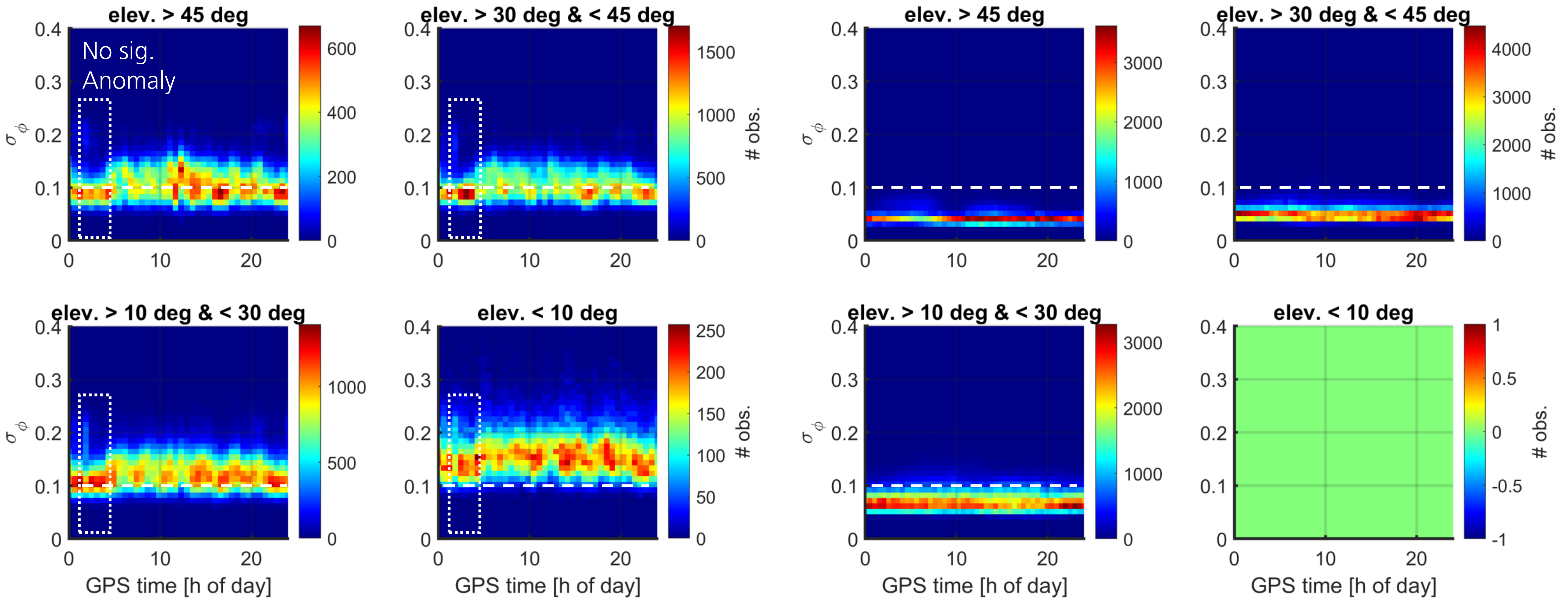


May 2020 … Jul 2020

Drift & Cruise - Spring & Summer - Fram Strait

σ_φ over hour of day at PS

σ_φ over hour of day at NyA station

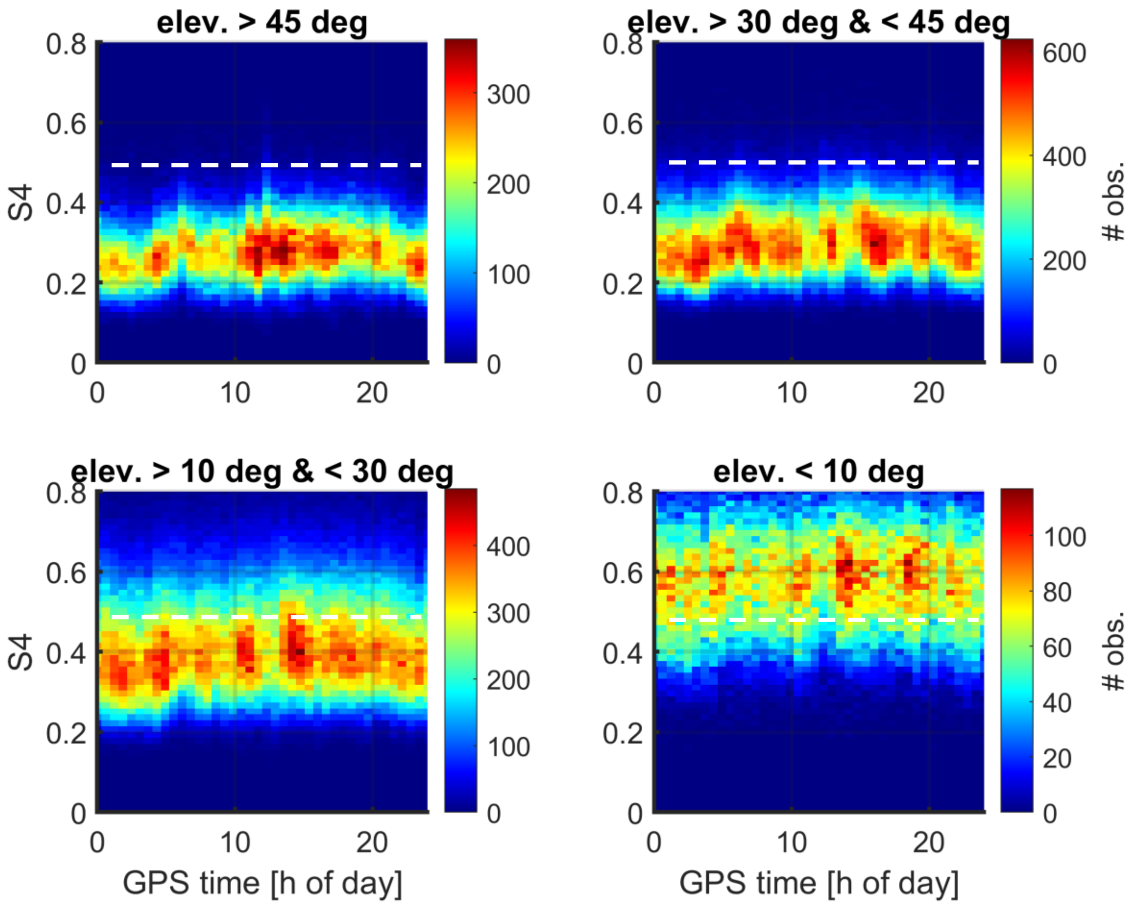


May 2020 … Jul 2020

May 2020 … Jul 2020

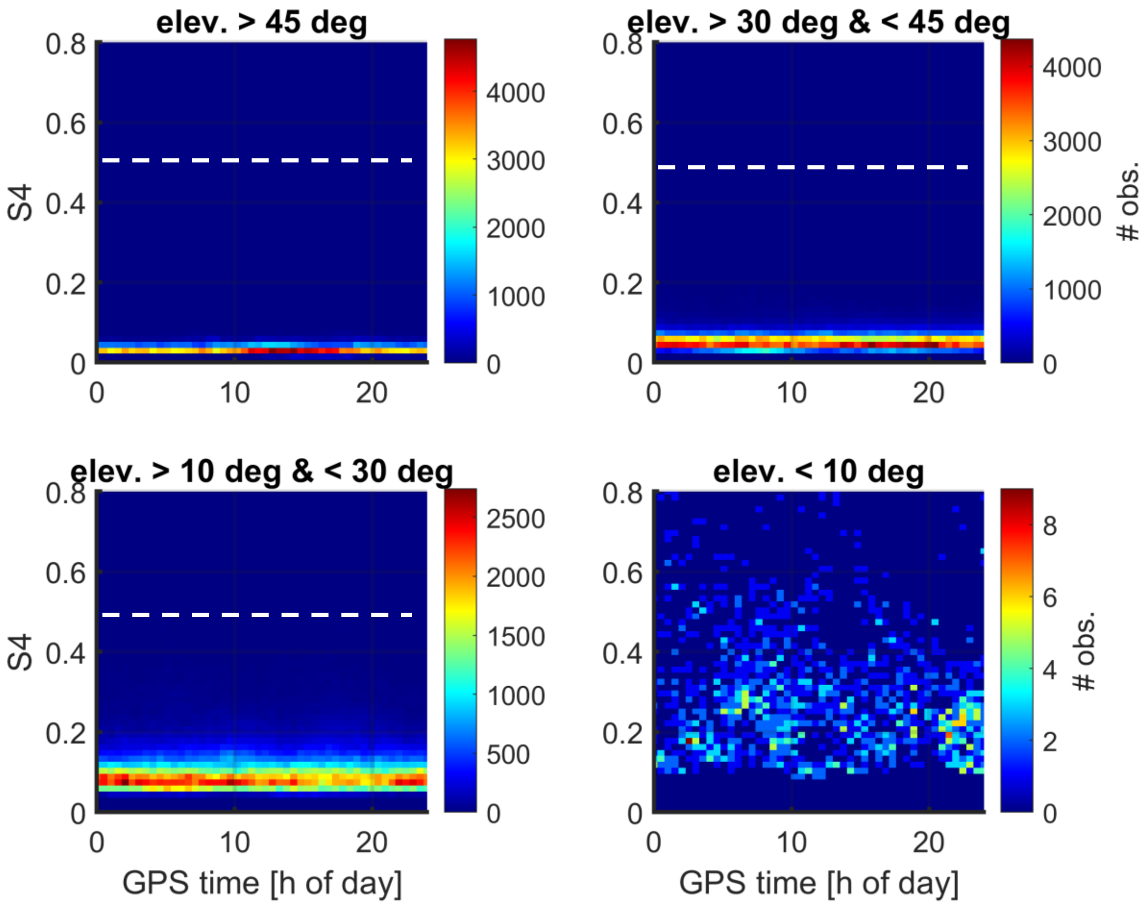
Drift & Cruise - Spring & Summer - Fram Strait

S4 over hour of day at PS



May 2020 … Jul 2020

S4 over hour of day at NyA station



May 2020 … Jul 2020

Summary of Results at High Elevations

	Feb 2020	Mar 2020	Jun 2020	Sep 2020	Oct 2020	Mar 2020	Jun 2020
Days of obs.	28	31	30	30	5	31	30
Av. Speed [m/s]	0.1+-0.1	0.2+-0.1	0.7+-1.2	0.9+-1.3	4.4+-0.3	-	-
Av. Heave [dm]	-0.2+-0.1	-0.1+-0.4	-0.1+-0.8	0.0+-0.5	-0.5+-2.3	-	-
High elev. Indices							
Av. S4 (% to ref.)	0.26 (100)	0.25 (95)	0.29 (113)	0.32 (122)	0.31 (120)	0.04 (15)	0.04 (16)
Av. σ(φ) [rad] (%)	0.12 (100)	0.11 (92)	0.11 (93)	0.11 (92)	0.12 (99)	0.05 (41)	0.05 (38)
Av. C/N0 [dBHz]	43+-2	44+-2	44+-3	43+-3	44+-3	51+-1	50+-1

Polarstern Setup during MOSAiC

Ny-Alesund Station on Svalbard

S4 scint. is …
Weak 0 … 0.5
Moderate 0.5 … 0.8
Strong > 0.8

σ(φ) [rad] scint. is …
Weak 0 … 0.4
Moderate 0.4 … 0.7
Strong > 0.7

Conclusions

DLR

- GNSS remote sensing from a ship requires adapted processing (ship disturbs scint. index)
- Baseline phase noise (σ_φ) and amplitude fluct. (S4) are increased compared to station obs., however, not to severe level
- A significant impact of ship vertical motion (heave) on σ_φ is not found here, there is a small impact on S4 (all still for moderate heave < 2m)
- Ship-based detection is possible recurrent anomaly at 2h-3h UTC during drift in high arctic winter (cusp influence or polar patches? origin still needs to be verified)

Acknowledgements

Support from MOSAiC team
G. Spreen, L. Kaleschke, R. Ricker, A. Tavri
Logistics at AWI & Crew of R/V Polarstern
Werkstatt and IT staff at DLR and GFZ

Data used here were produced as part of MOSAiC project.

Thank you for your attention.

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  URSI Radio Science Letters
- DLR IMPC 2023: Ionosphere Monitoring and Prediction Center
  https://impc.dlr.de/products/

Appendix

Findings & Next steps

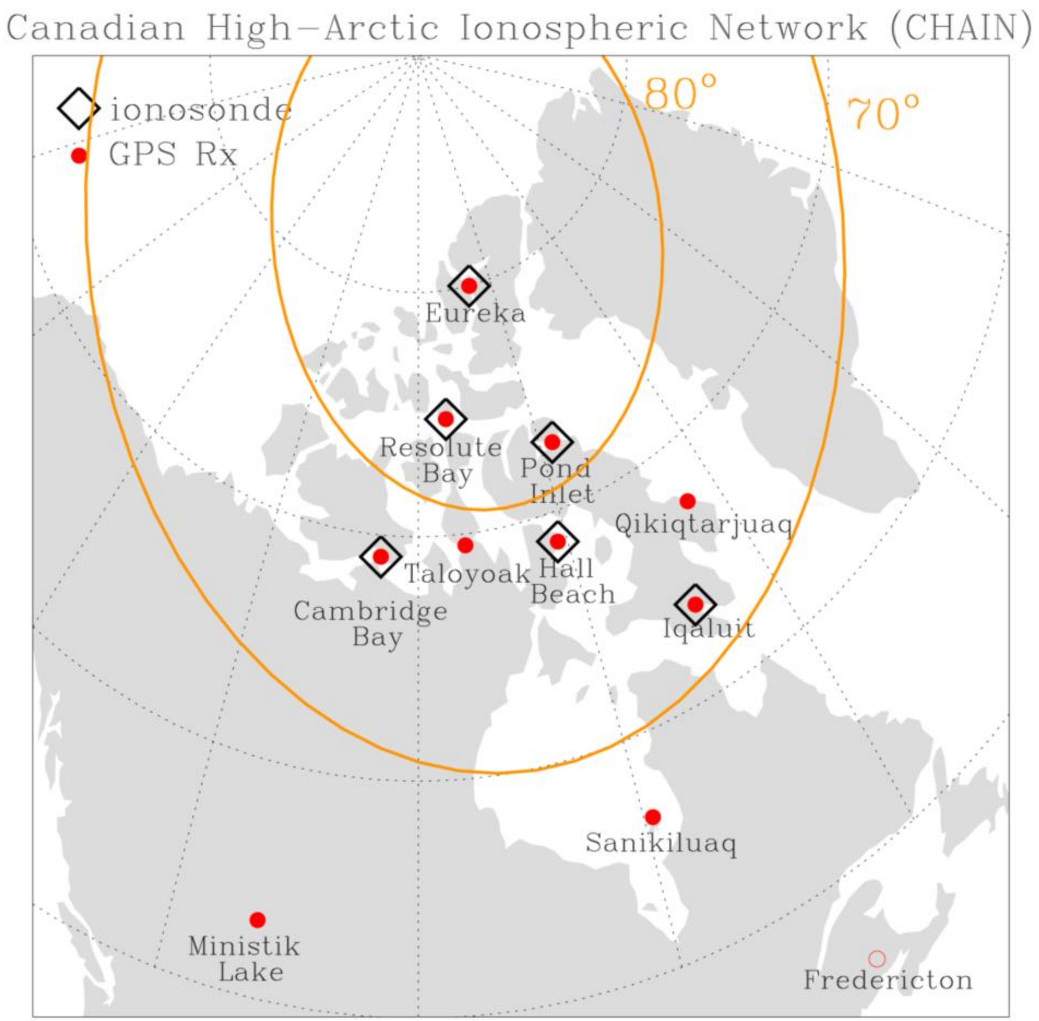
- We found: most significant anomaly in σ_φ at about 2h to 3h UTC in high arctic winter for almost all elevation angles

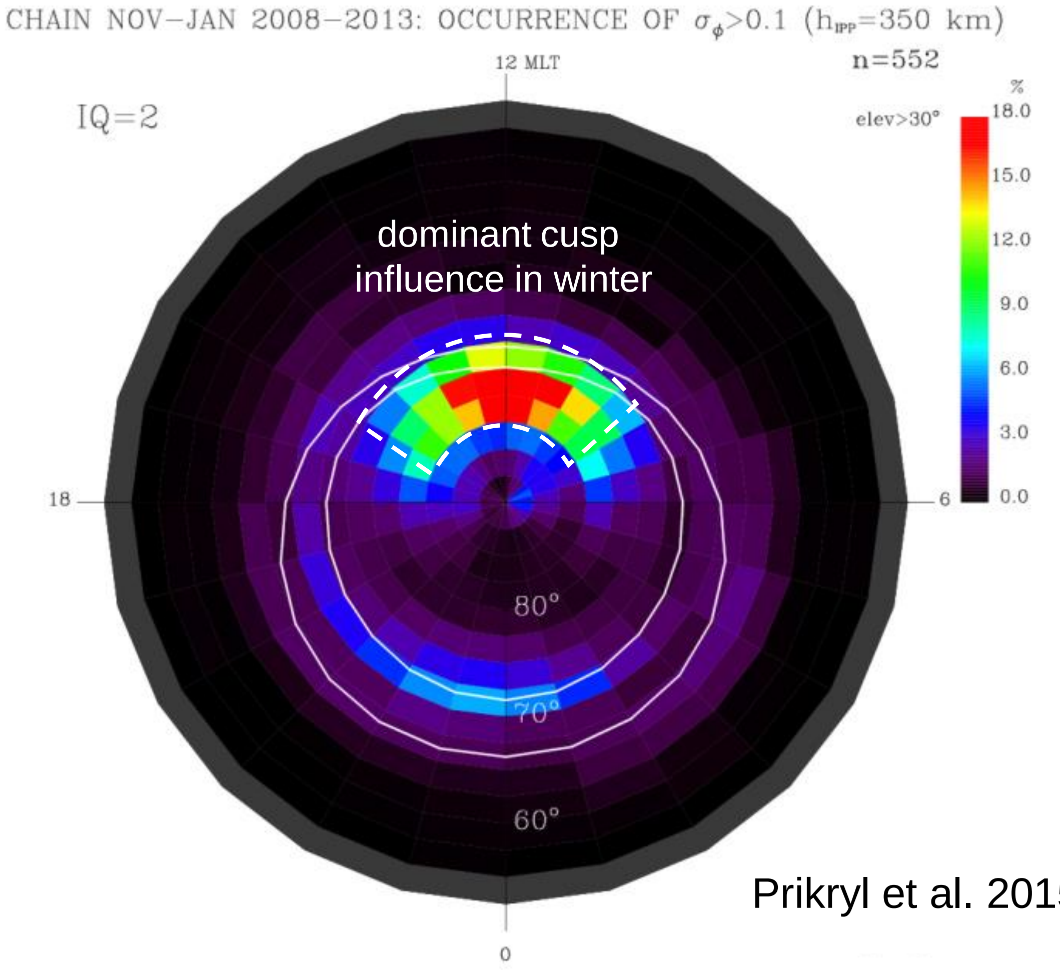
  ->	expect relation to cusp influence

- In a next step: identify cusp influence by range of corr. geomag. latitude (CGM lat.) and mag. Local time (MLT) according to Prikryl et al. [2015]

  ->	CGM lat.: 72.5° N … 80.0° N
  MLT: 9 h … 15 h

Climatology of scintillation based on GNSS station data





Prikryl et al. 2015