Are ship-based GNSS measurements precise enough to detect ionospheric phase scintillation at solar minimum?

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Photo Polarstern: Peter Lemke, AWI

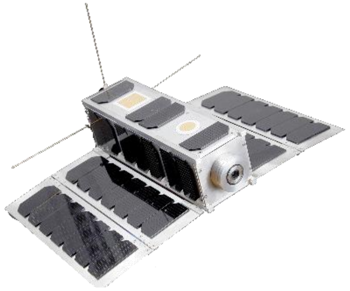
Outline

- Precise GNSS for Remote Sensing
- MOSAiC: Opportunity and Challenge
- Preliminary Scintillation Results
- Conclusions

Precise GNSS for Remote Sensing

- A: Low Earth Orbiter

  Wickert et al. 2016
  Semmling et al. 2016



- B: Aircraft

  Semmling et al. 2014
  Moreno et al. 2021

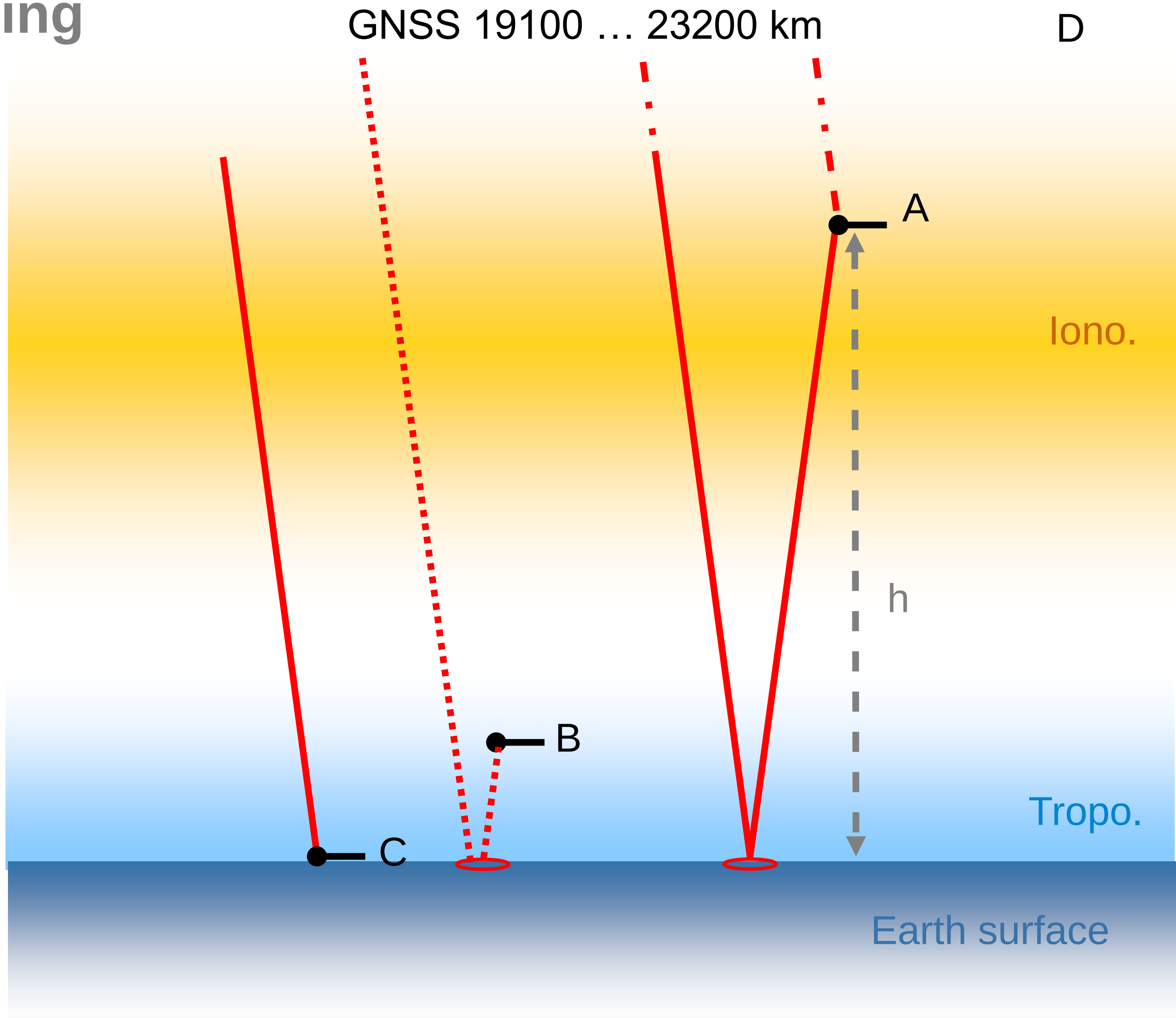
- C: Research Vessels

  Wang et al. 2019
  Semmling et al. 2019, 2022
  Semmling et al. 2023 (accepted)

- Application

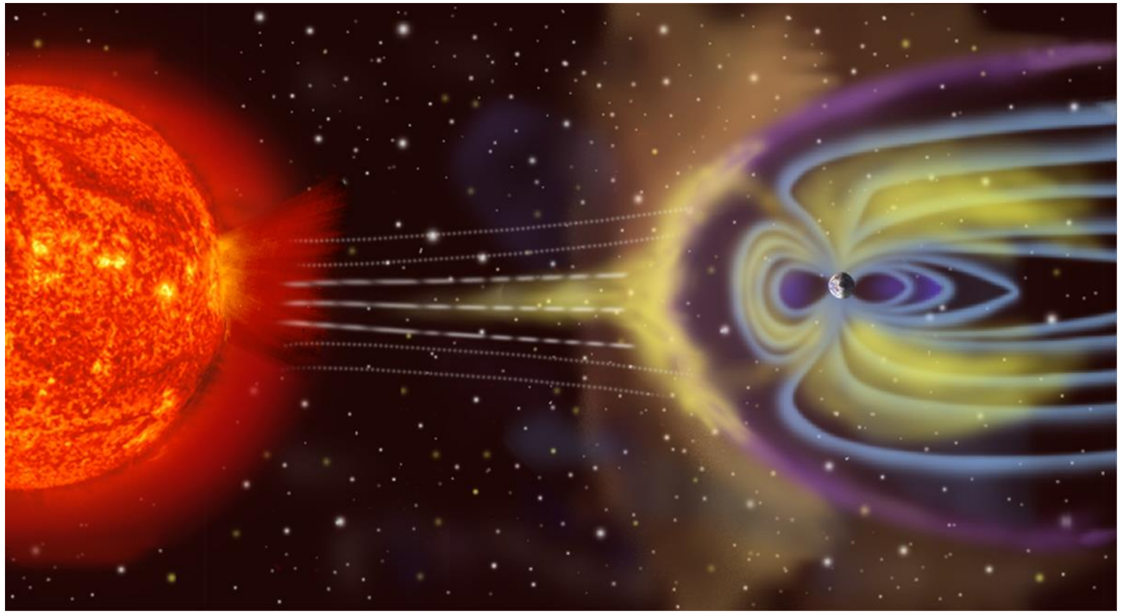
sea surface altimetry
sea state estimation
sea-ice detection

water vapor estimation
iono. scintillation detection



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

Potential Impact of Space Weather



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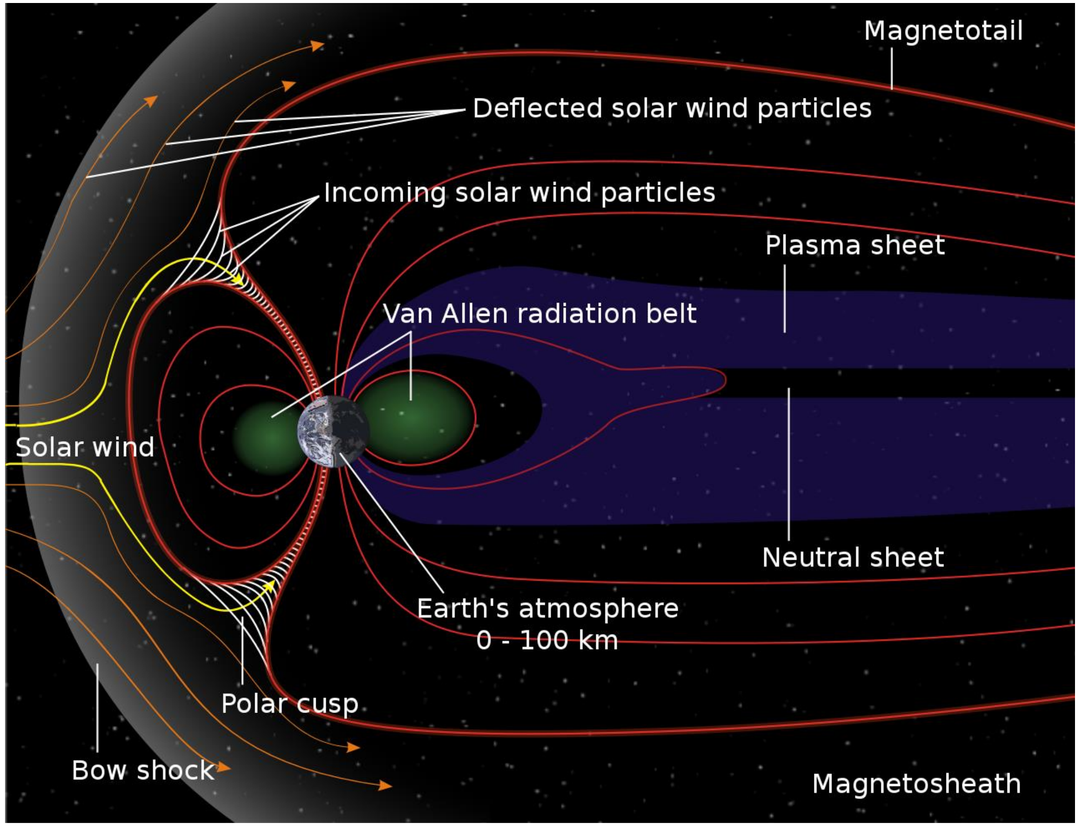

Original: NASA Vector: Aaron Kaase, Medium69,
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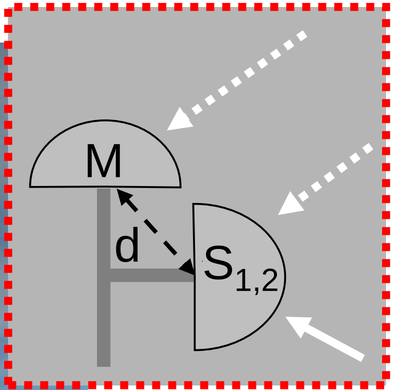
Solar wind particles can disturb polar ionsphere

can cause scintillation of GNSS signals

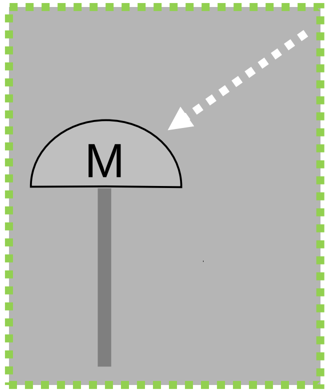
MOSAiC: Opportunity and Challenge

MOSAiC: Opportunity

* GFZ GNSS-R setup * DLR GNSS setup



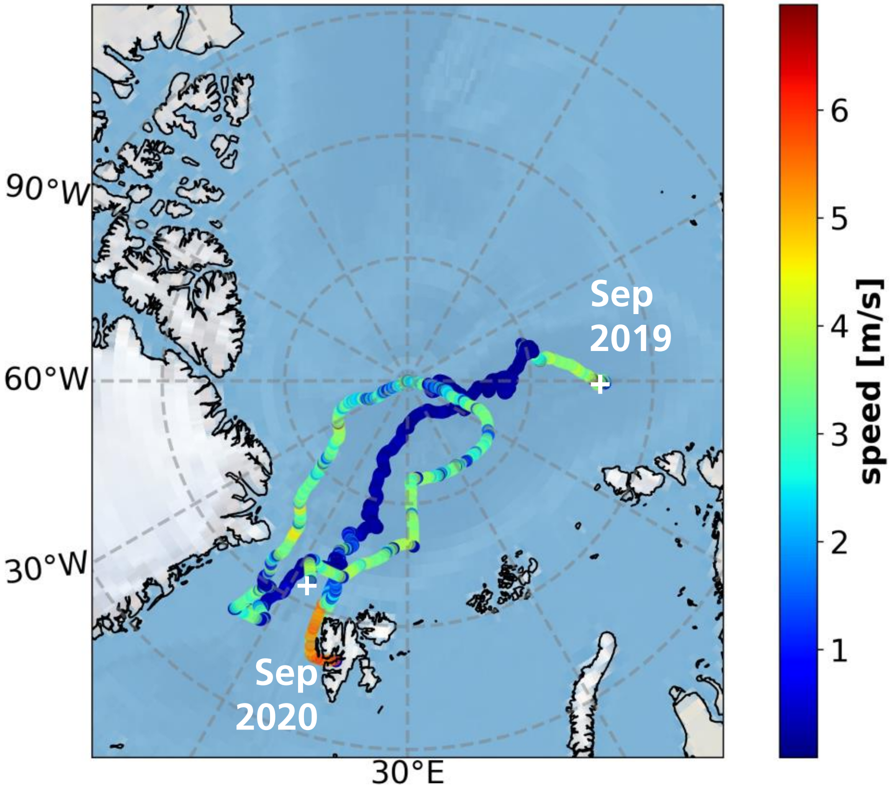
h = 22 m
d = 20 cm



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

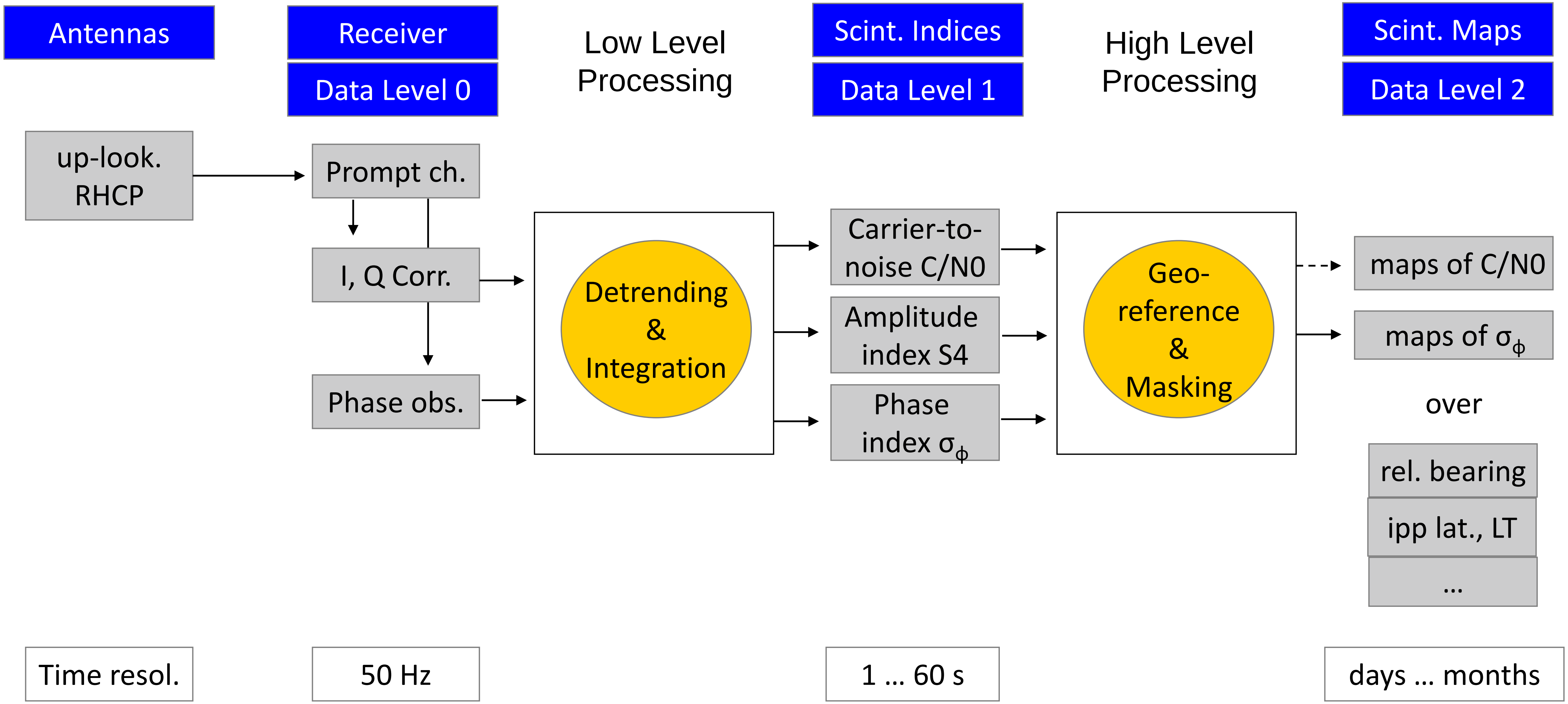
Master link (M): up-looking ant.
Slave links ($S_{1,2}$): side-looking ant.

MOSAiC expedition: Sep 2019 - Sep 2020

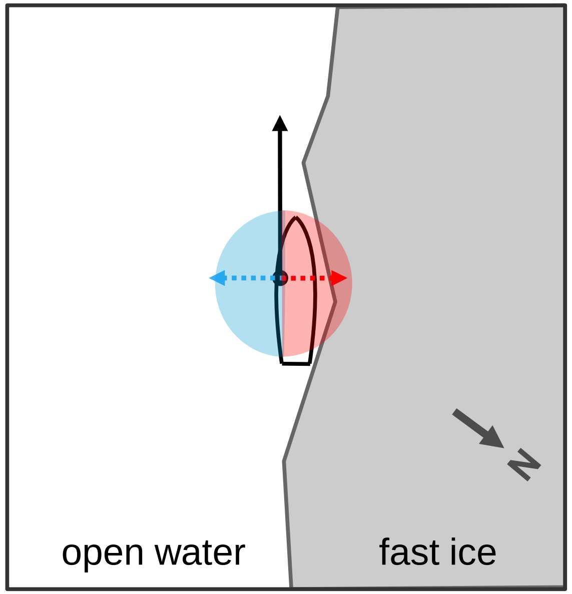


Cruising Periods: speed > 1 m/s
Drifting Period: speed < 1 m/s

Scintillation Data Processing

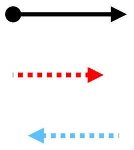


Challenges: Visibility and Background Noise



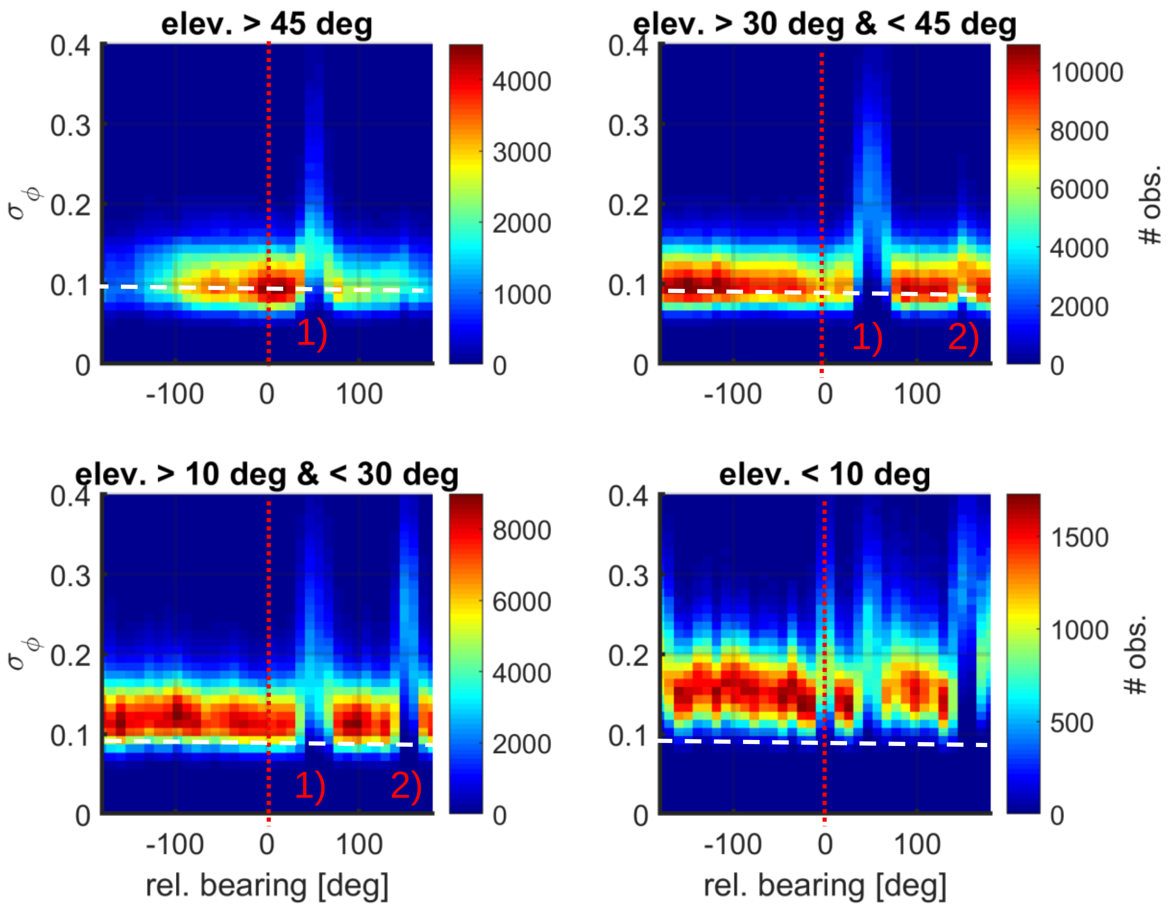
clear view
to port-side

left rel. Bearing:
-180° to 0°



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

σ_φ over rel. bearing



1) ship's main mast
2) ship's chimney

Sep 2019 … Sep 2020

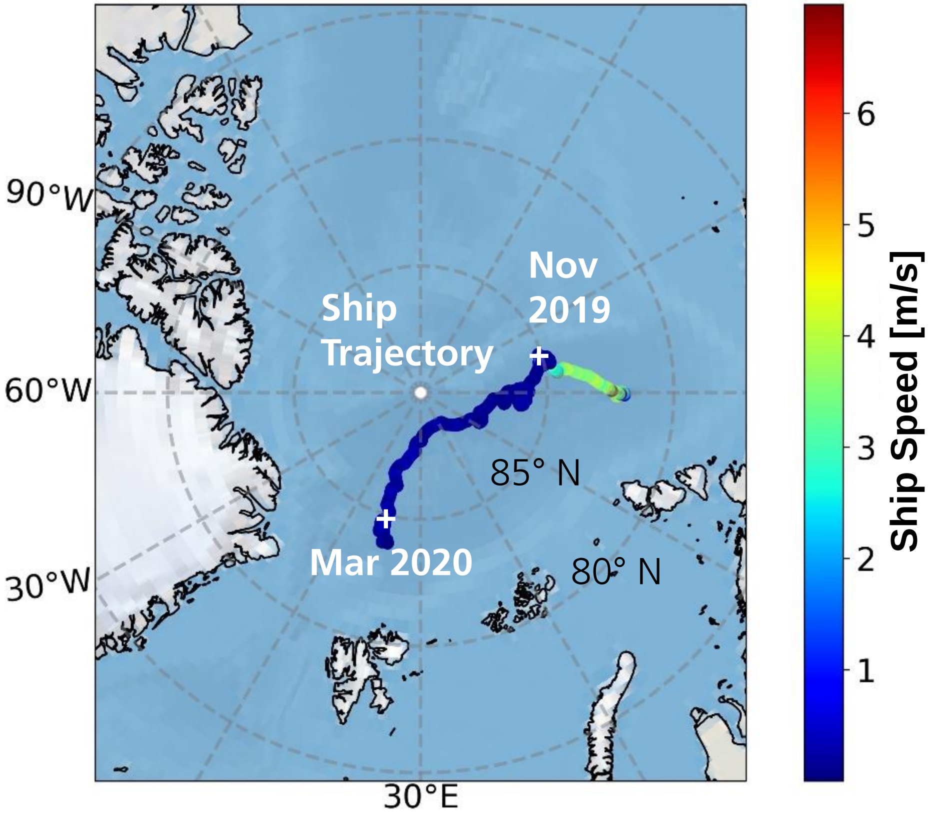
Normal threshold
$\sigma_\varphi < 0.1$ rad

Semmling et al. 2023
(accepted)

Preliminary Scintillation Results

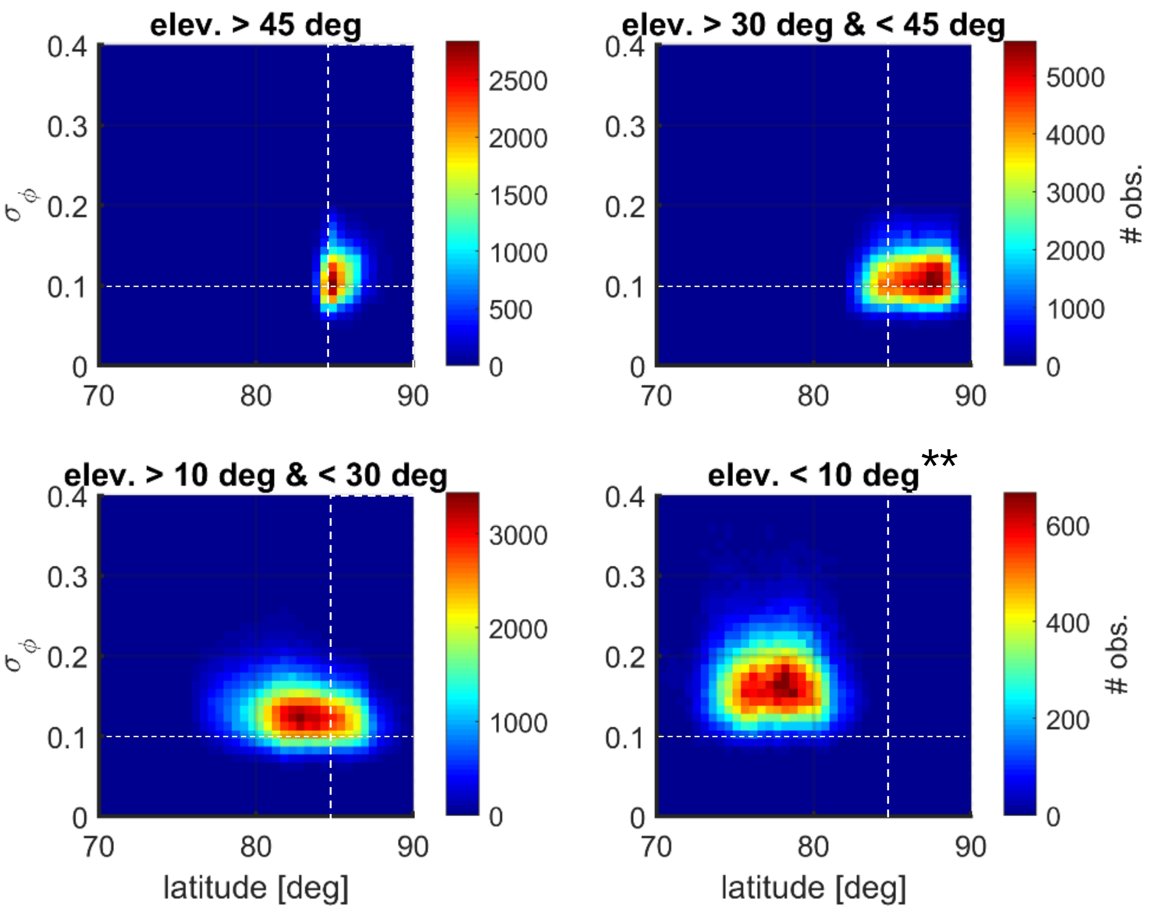
High Arctic Winter

GNSS obs. in the Central Arctic



Nov 2019 … Mar 2020

σ_φ over lat. at IPP (height 350 km)



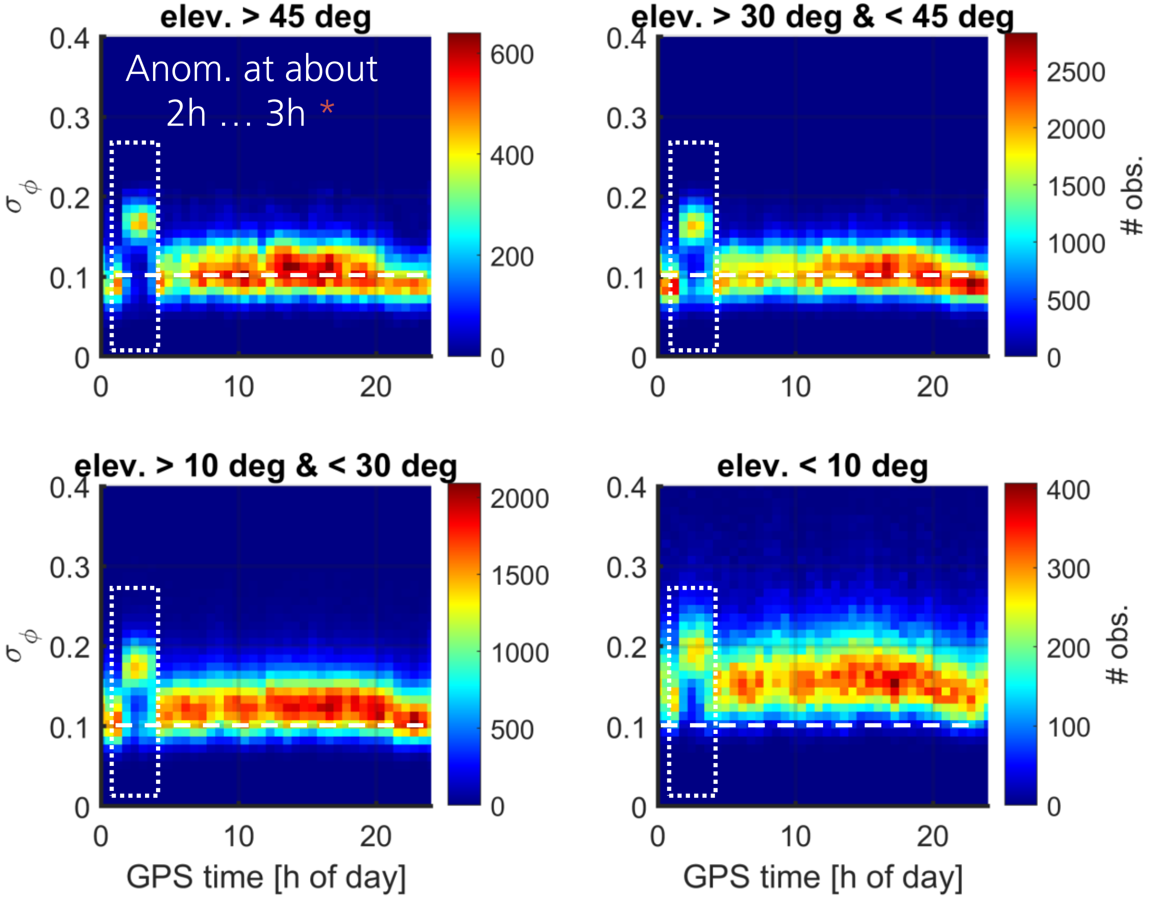
** at low elev.:

multipath cause offset in σ_φ

ionospheric piercing points (IPP) rather south

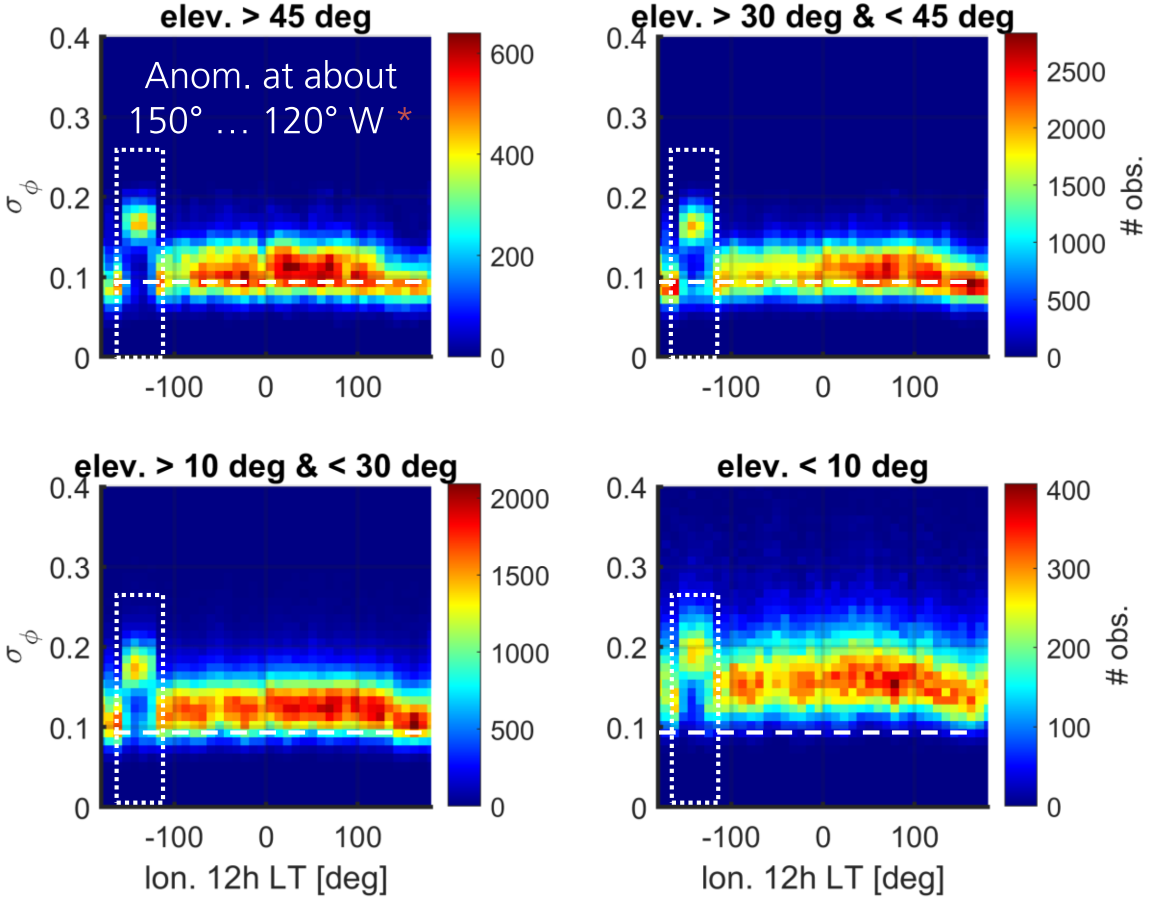
High Arctic Winter

σ_φ over GPS time at PS (~ UTC)



Nov 2019 … Mar 2020

σ_φ over longitude of local noon



Nov 2019 … Mar 2020

* Scintillation with cusp influence ?
Only high Arctic Winter

Conclusions

- GNSS remote sensing can be precise from a ship
  requires adapted processing (ship disturbance, multipath)
- Baseline phase noise is higher than for station obs. (about 0.1 rad)
  still significant anomalies are resolved in high Arctic winter data
- cusp influence is expected at given latitudes, still need to be verified

Acknowledgements

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Werkstatt and IT staff at DLR and GFZ

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Thank you for your attention.

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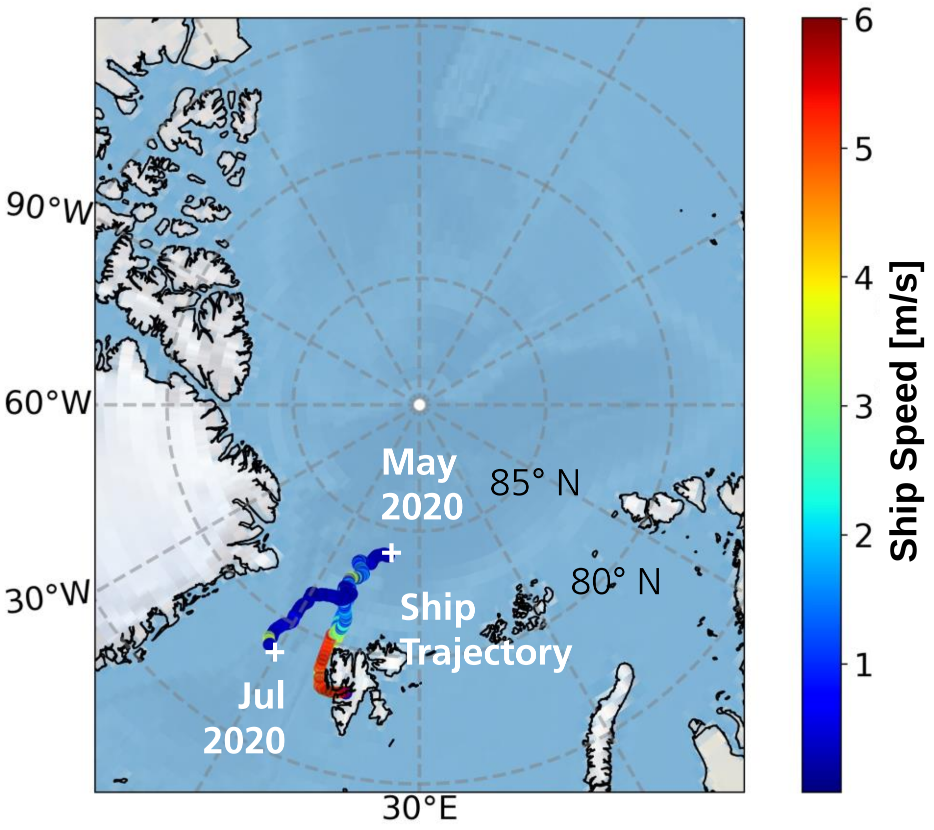
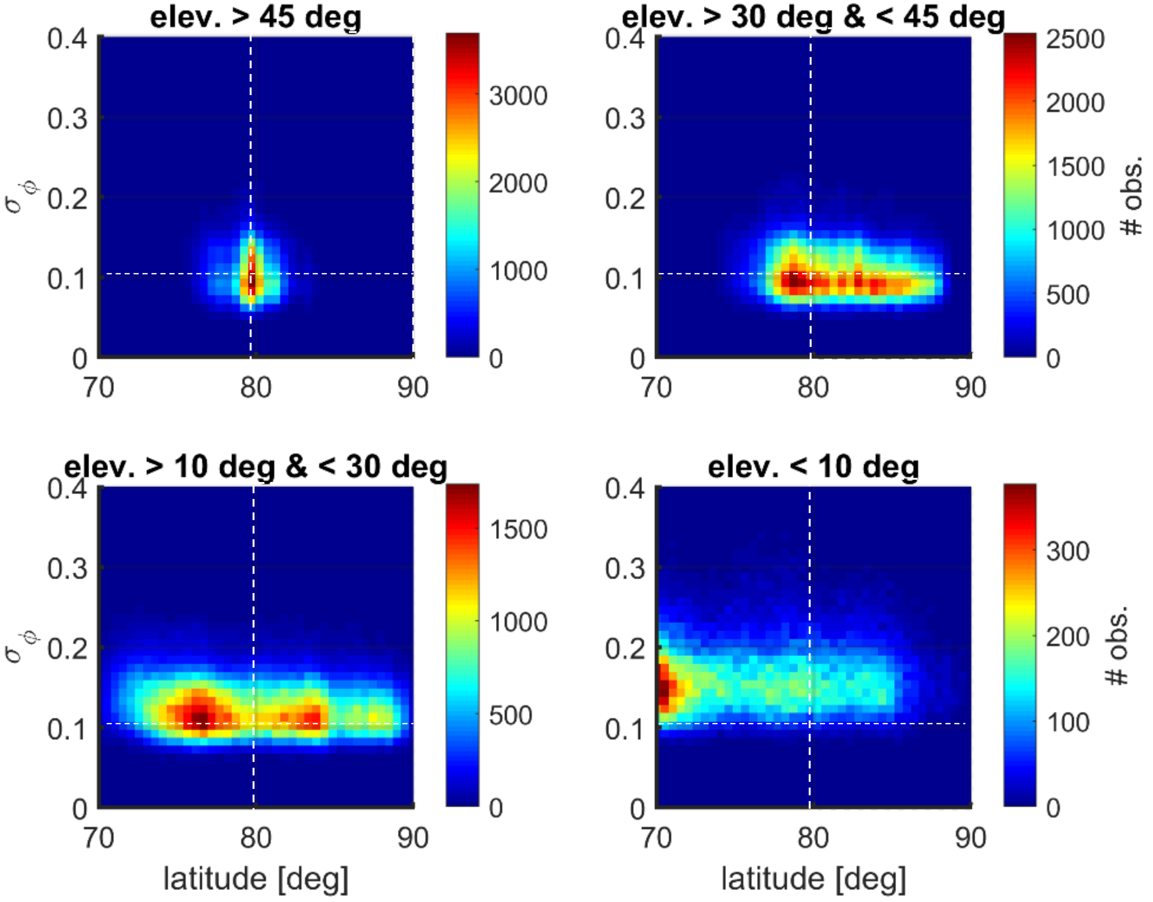
  URSI Radio Science Letters (accepted)

Spring & Summer in Fram Strait

GNSS obs. in the Central Arctic



σ_φ over lat. at IPP (height 350 km)

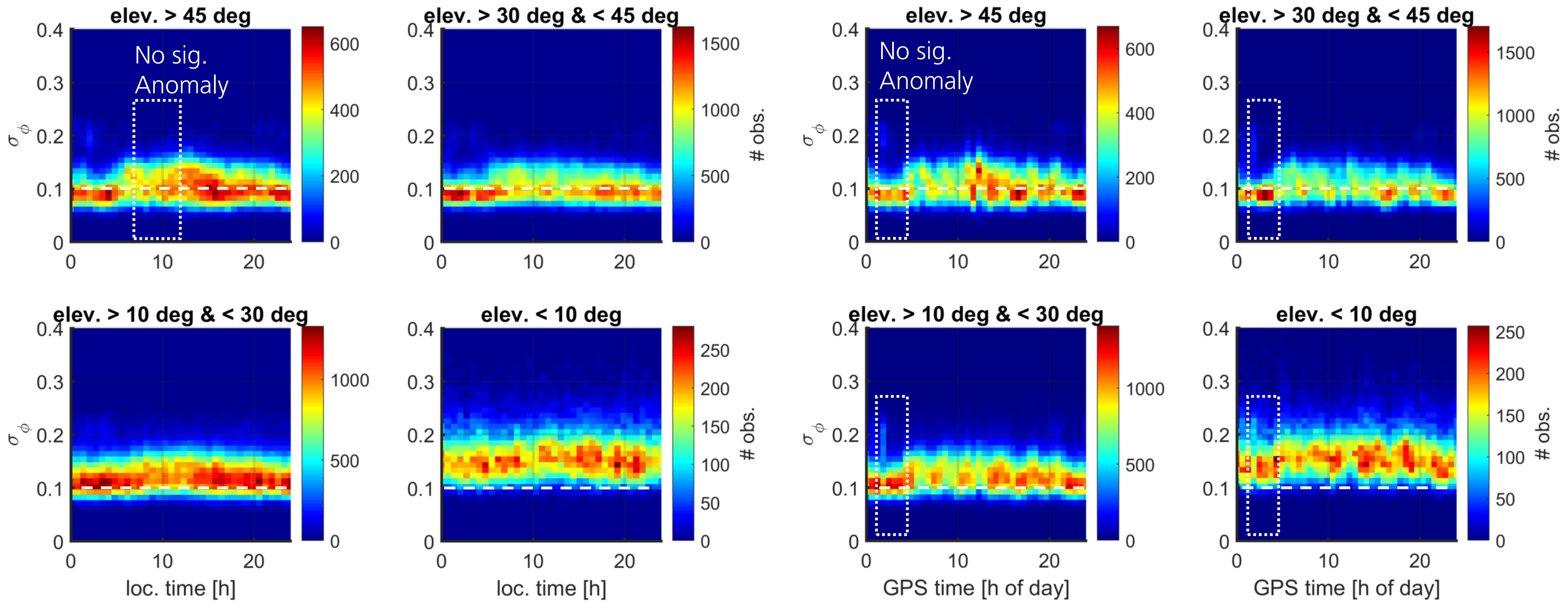


May 2020 … Jul 2020

Spring & Summer in Fram Strait

σ_φ over local time at IPP (height 350 km)

σ_φ over GPS time at PS (~ UTC)



May 2020 … Jul 2020

* cusp influence ?

May 2020 … Jul 2020

Findings & Next steps

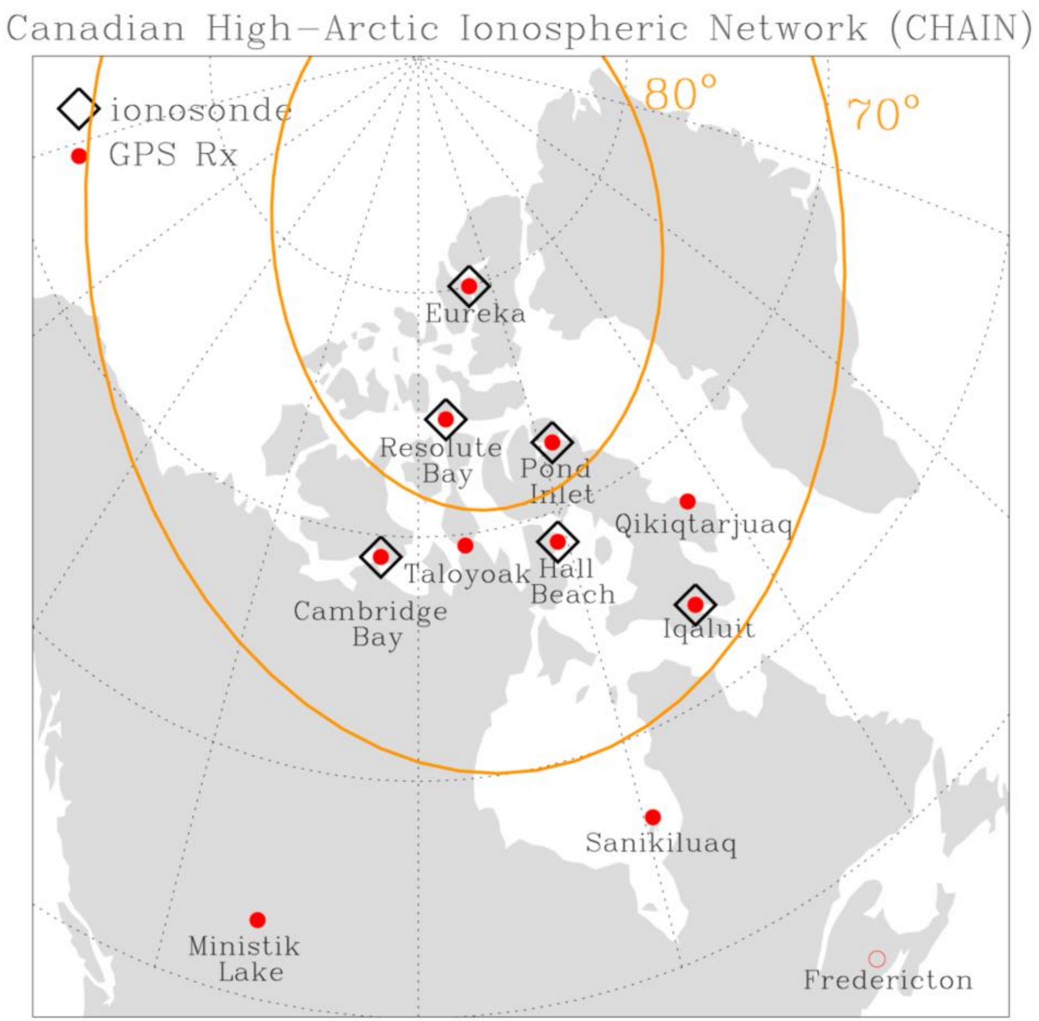
- We found: most significant anomaly in σ_φ at about 2h to 3h UTC in high arctic winter for almost all elevation angles

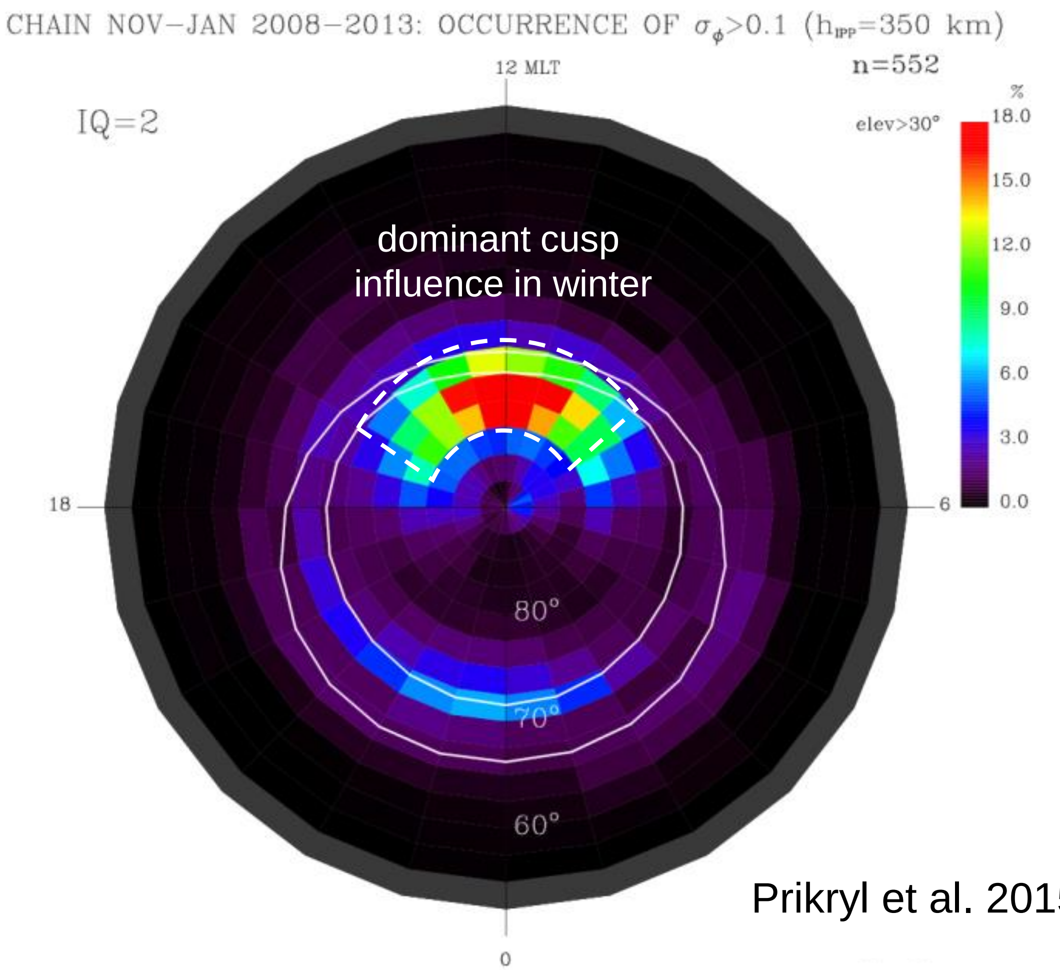
  -> expect relation to cusp influence

- 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