

Sea level determination with GNSS-IR by using Norwegian GNSS positioning network stations

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Photo: Torbjørn Taskjelle

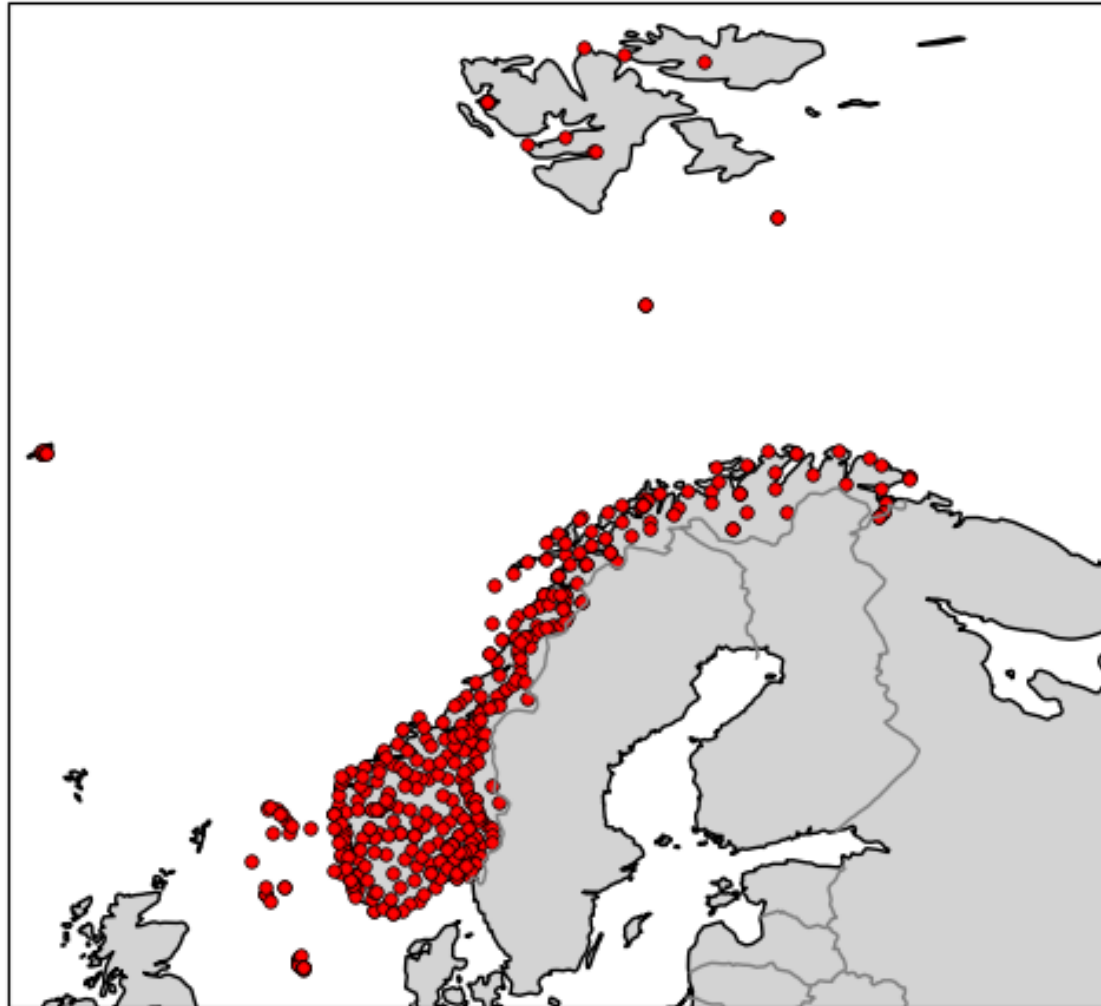
Part 1

**What is GNSS-IR and how
can it be used for sea level
determination?**

Motivation

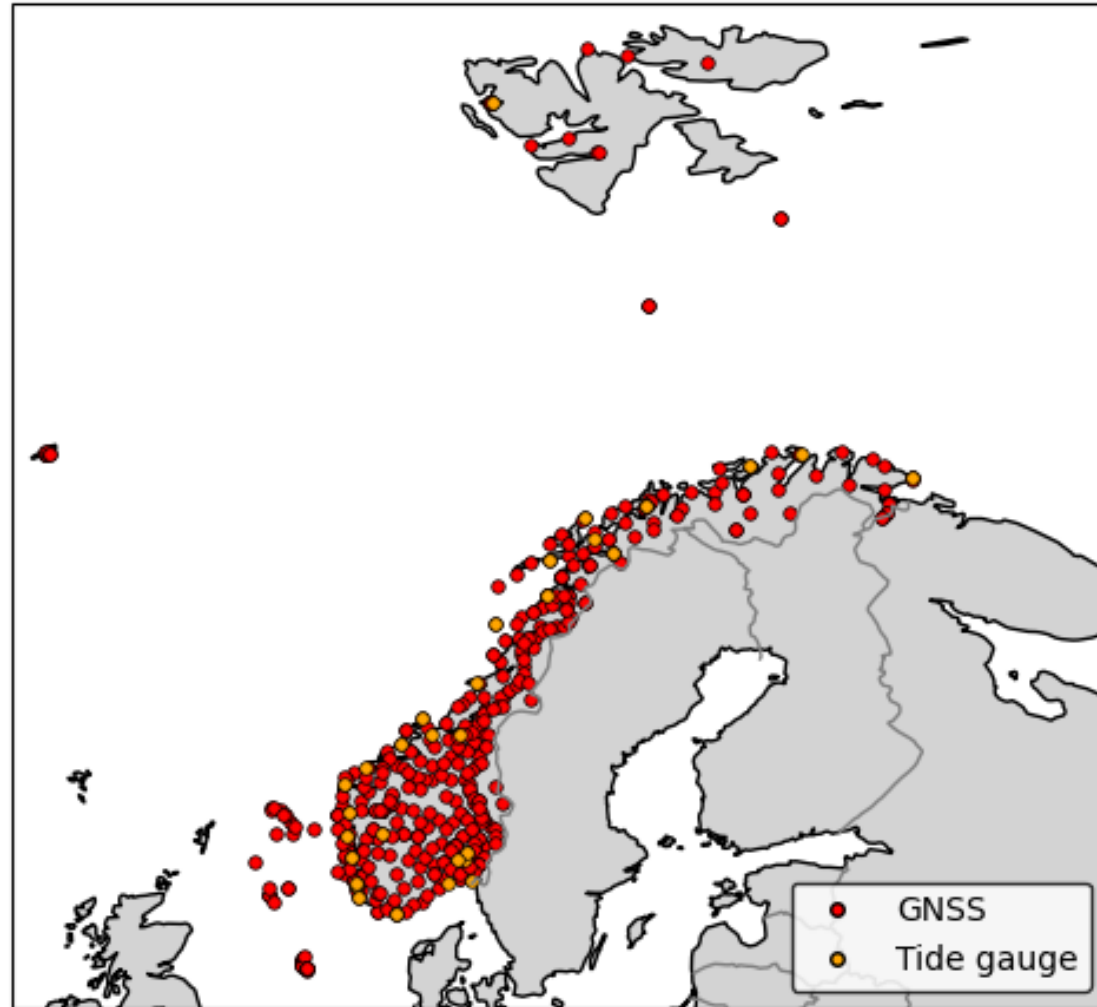
Motivation

- GNSS station network:
 - More than 300 GNSS stations
 - Mainly established for positioning service and national reference frame realization



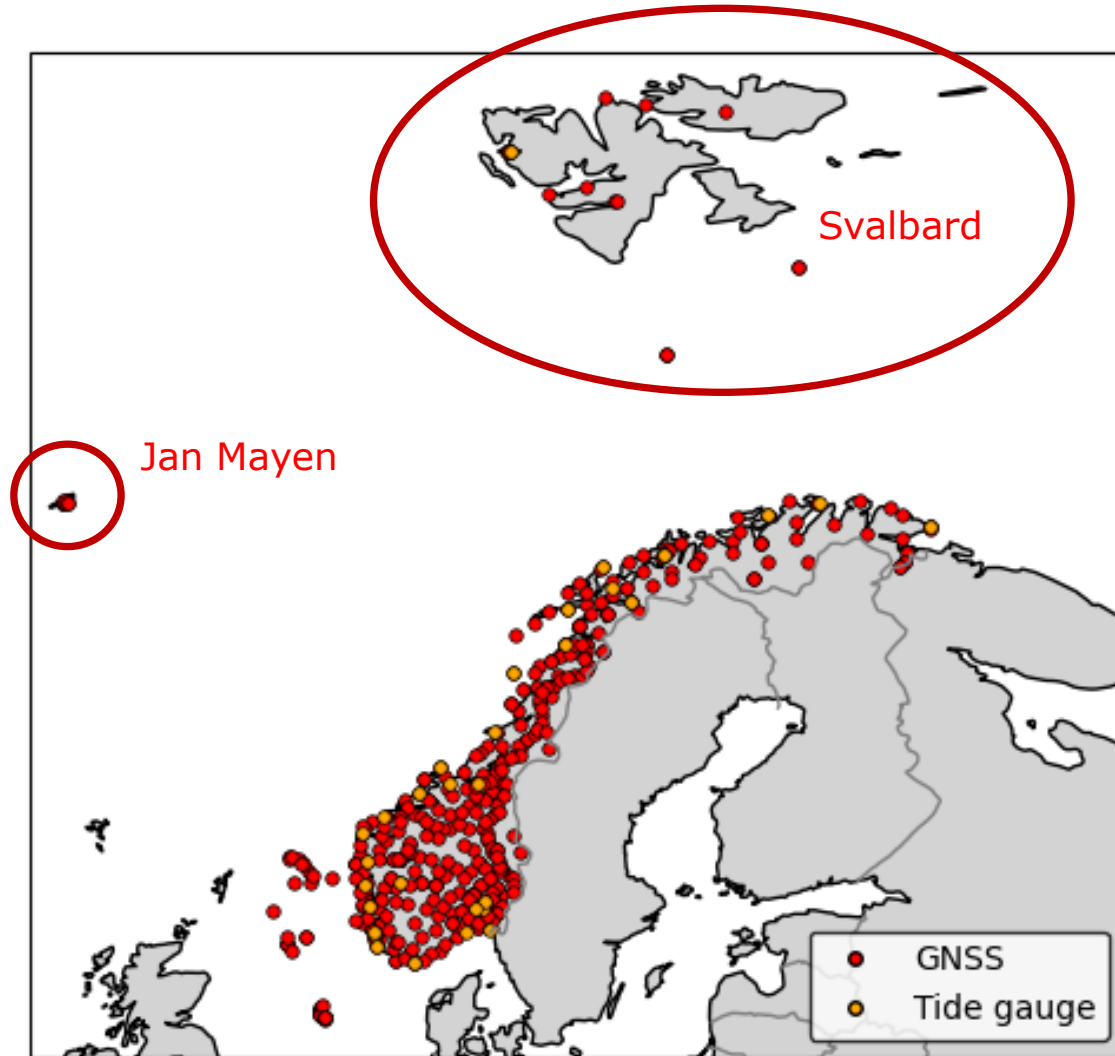
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- Tide gauge network
 - More than 30 permanent tide gauges
 - Norwegian Hydrographic Service division at NMA responsible for sea level determination



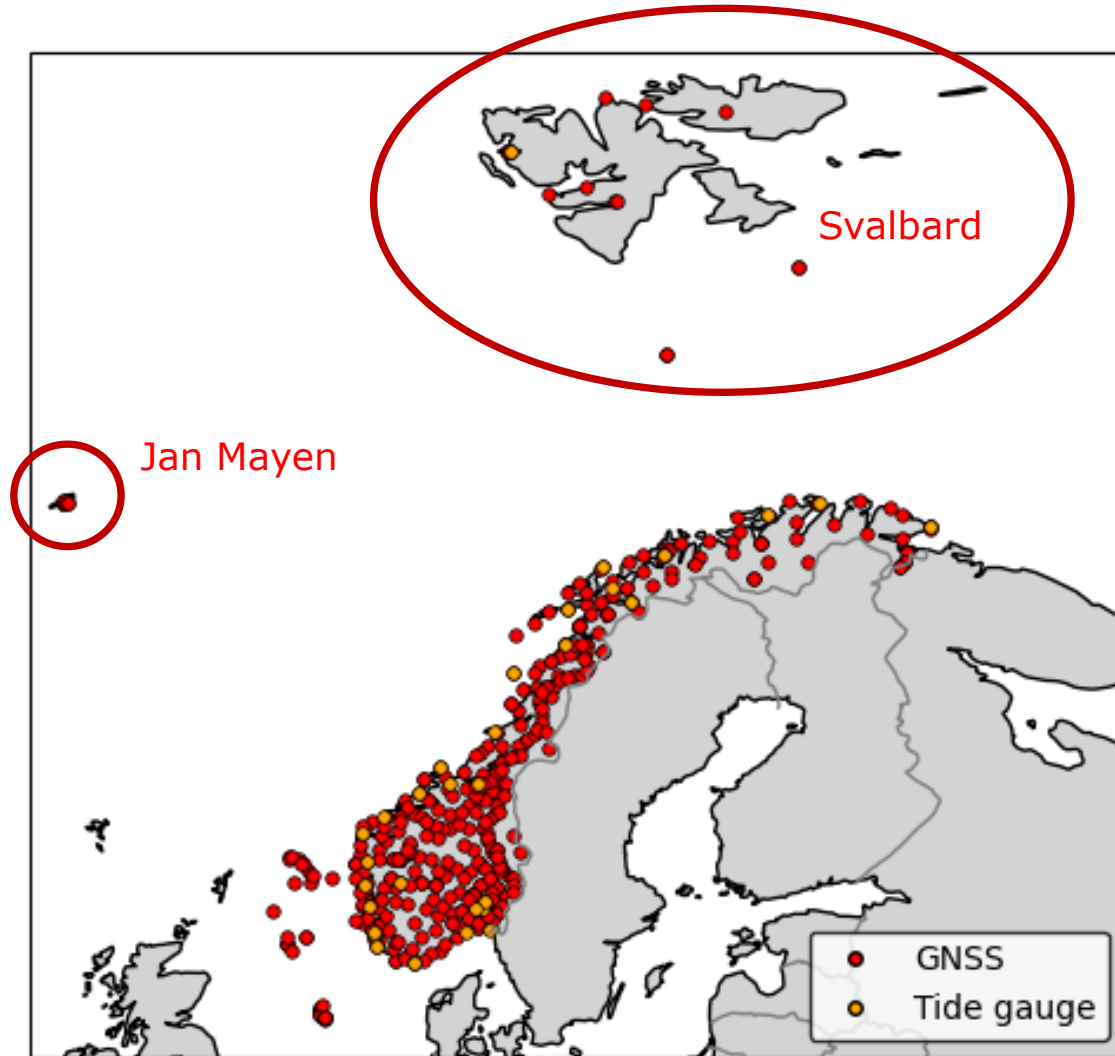
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 - Challenges to establish permanent tide gauges on remote areas
- **What is the potential from GNSS-IR for sea level determination? How could GNSS-IR contribute to NMA sea level products?**

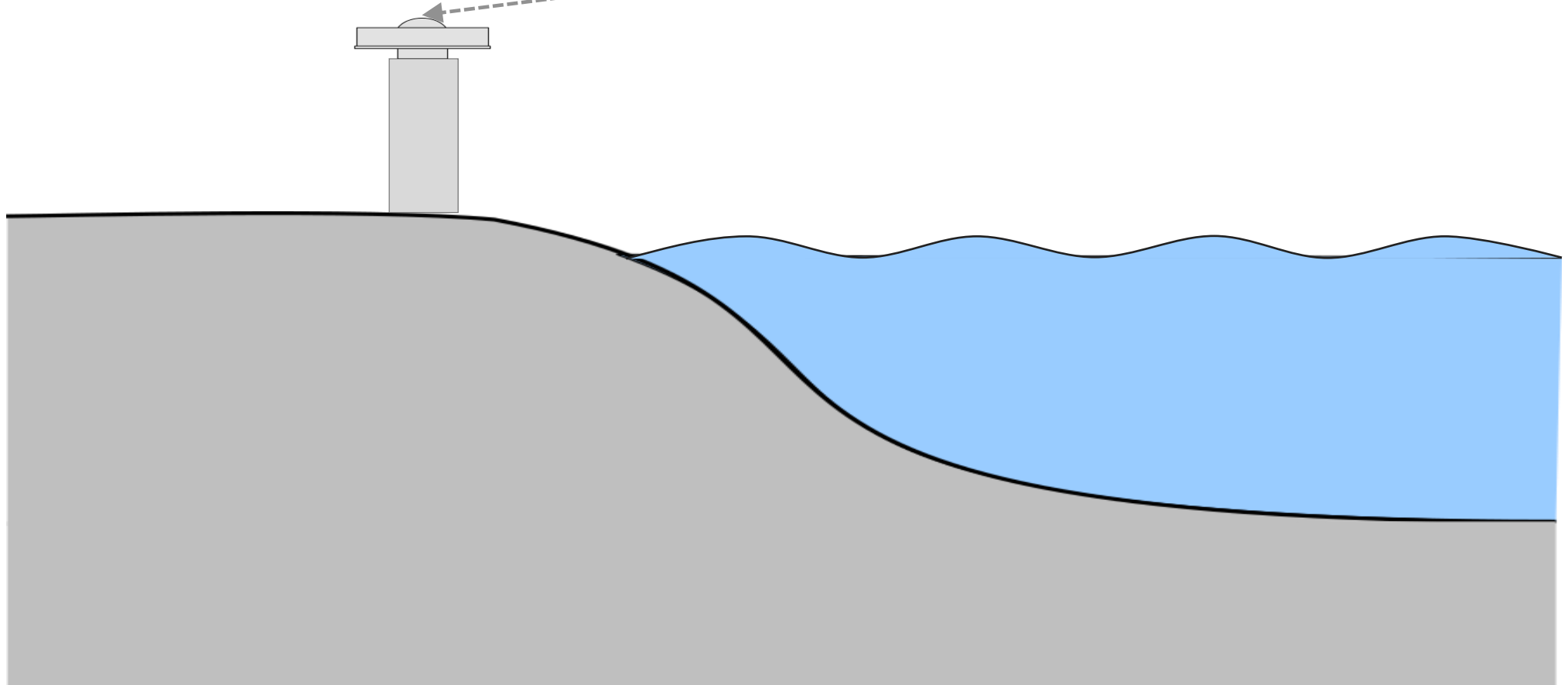


What is GNSS interferometric
reflectometry (GNSS-IR)?

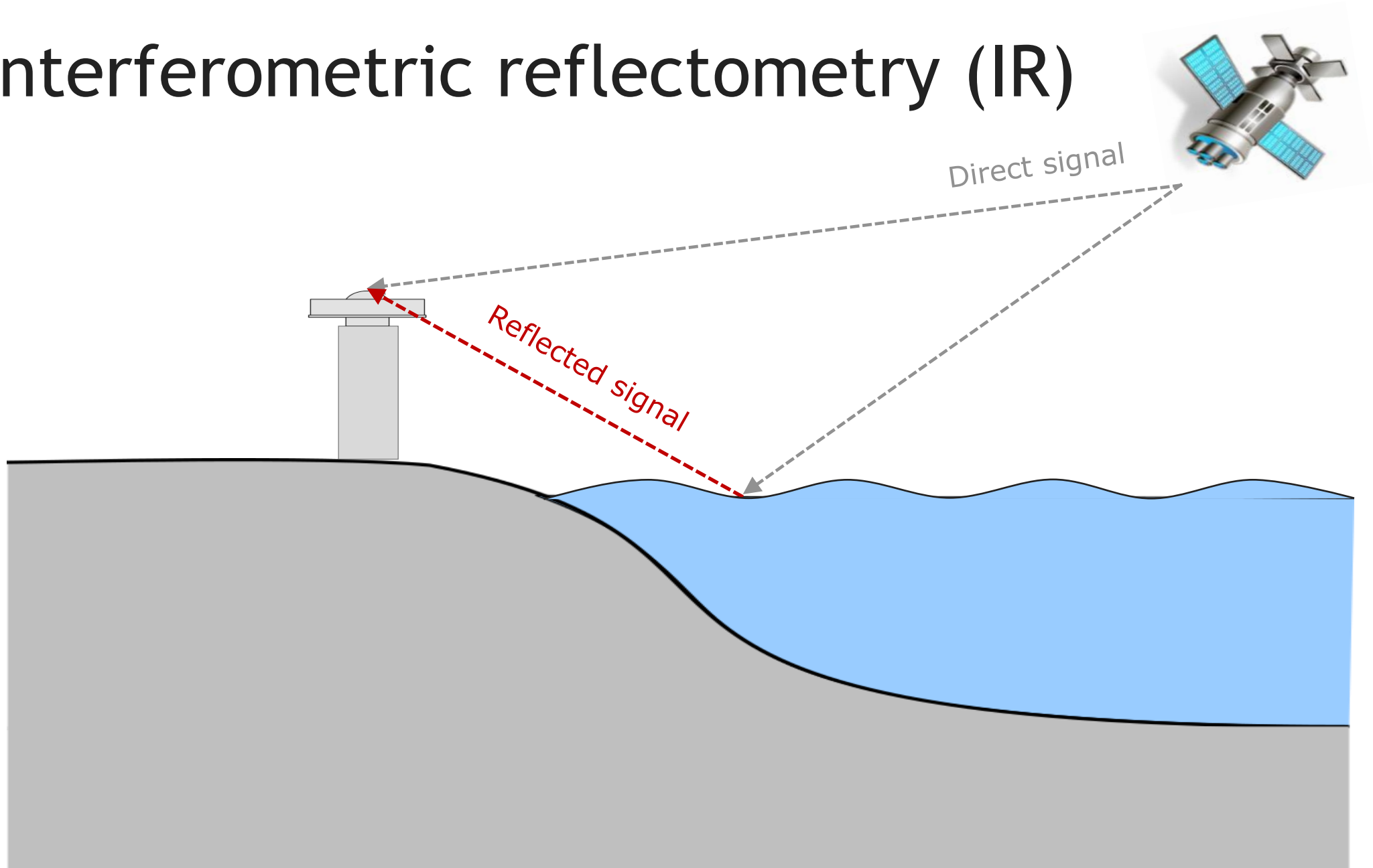
GNSS interferometric reflectometry (IR)



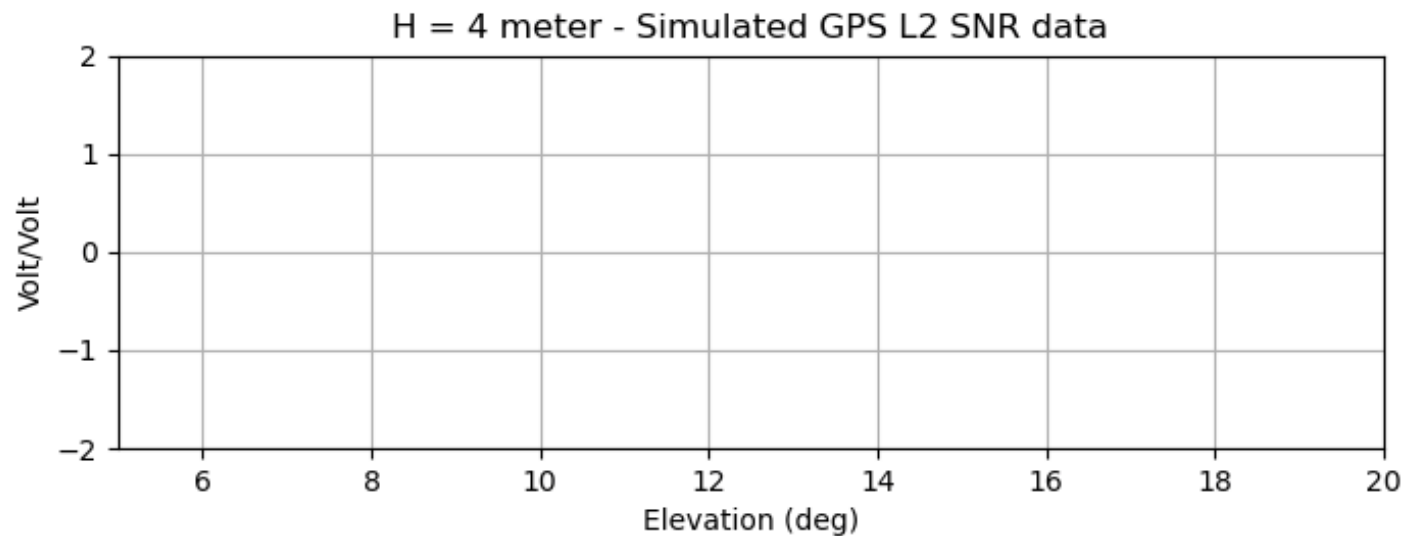
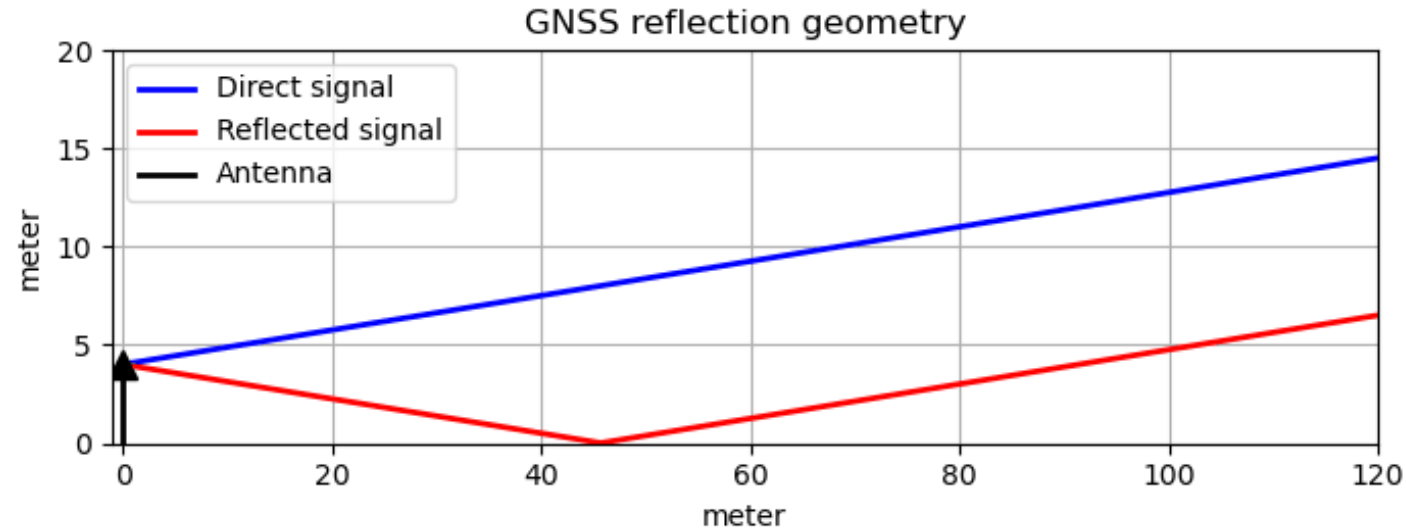
Direct signal



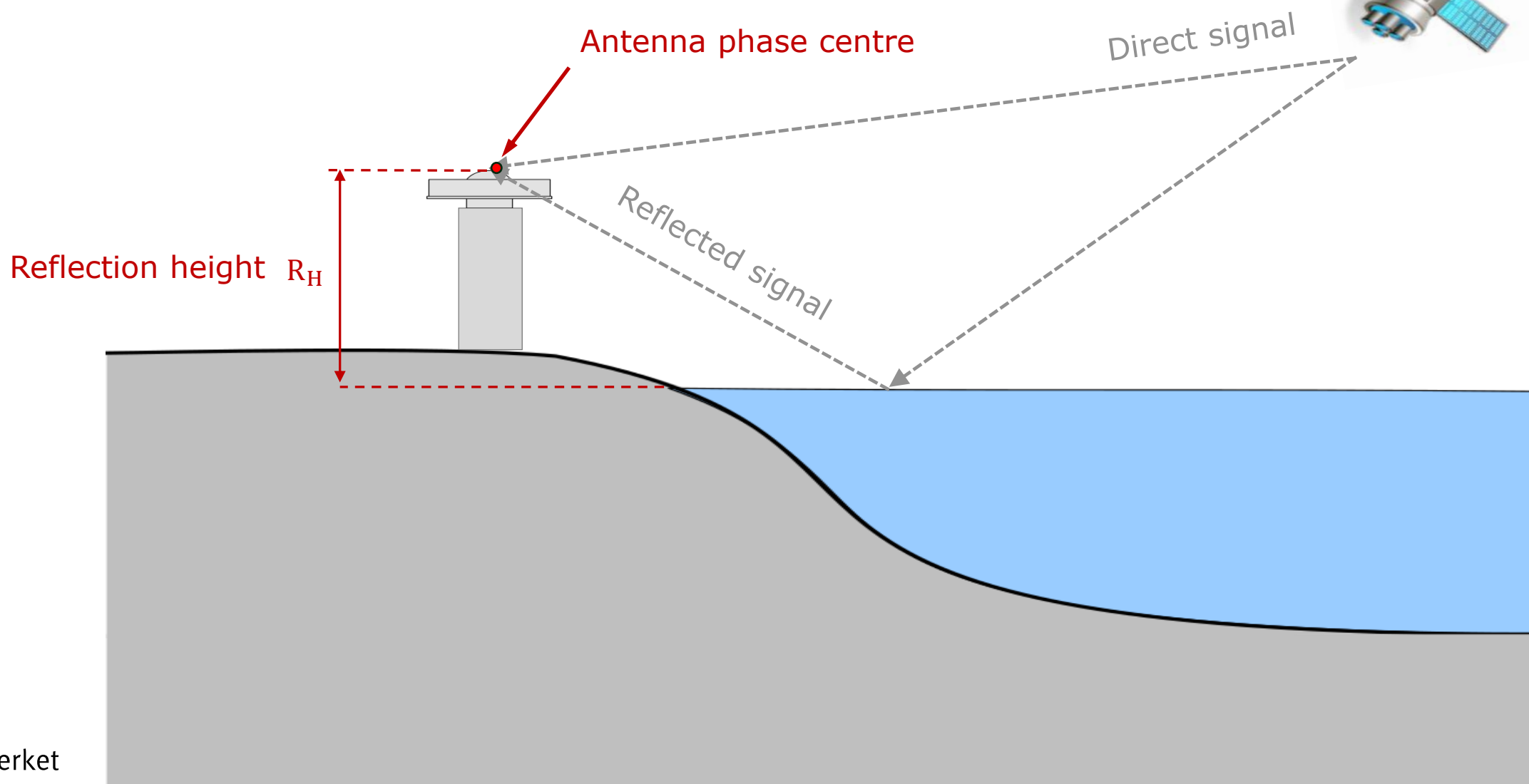
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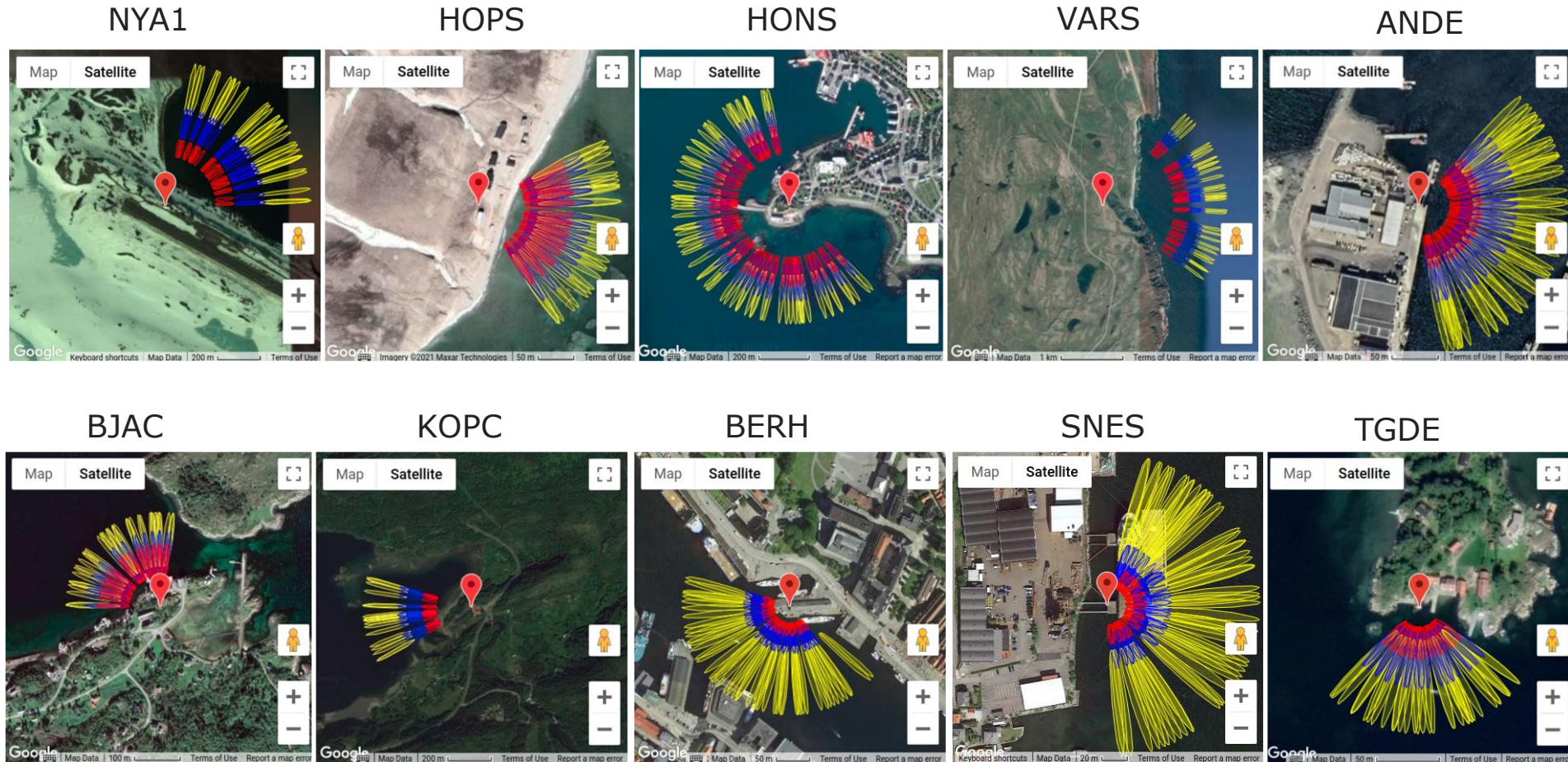


GNSS interferometric reflectometry (IR)



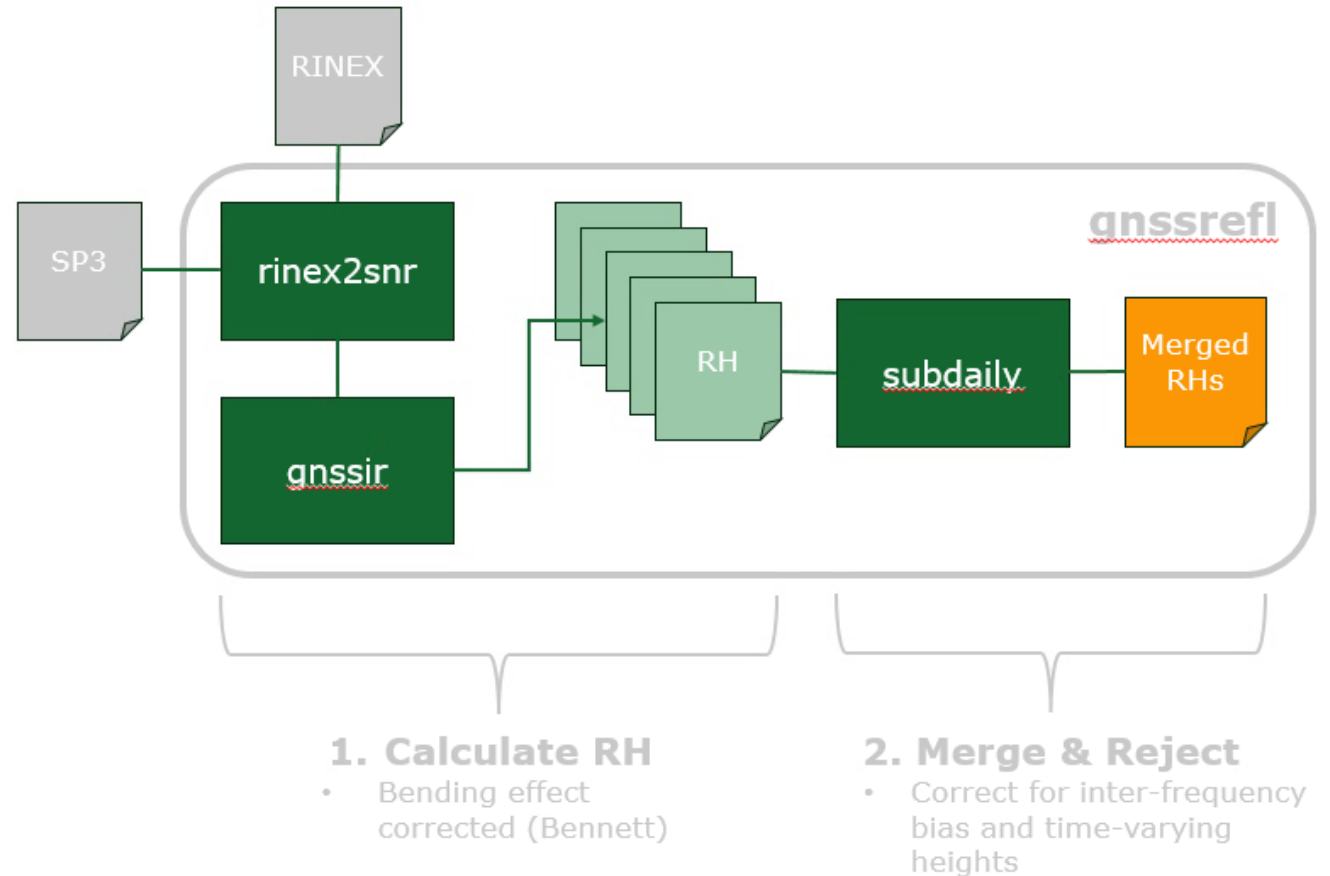
How can GNSS-IR be used for
sea level determination?

Which GNSS stations can be used for GNSS-IR?

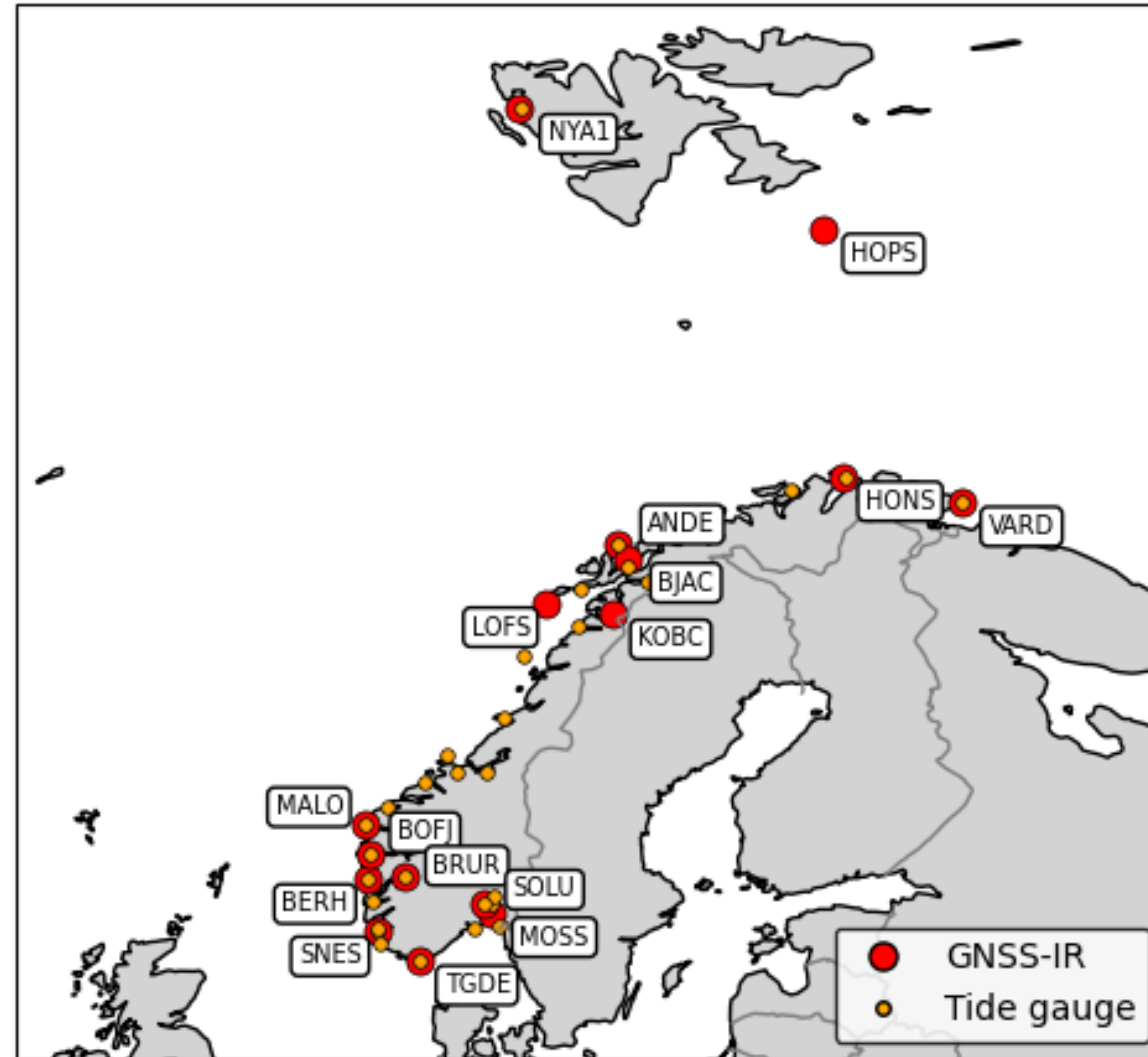


GNSS-IR processing

- Use of open-source program **gnssrefl**
- Available on GitHub:
<https://github.com/kristinemlarson/gnssrefl>
- Determination of reflection height – distance between antenna phase centre and sea surface

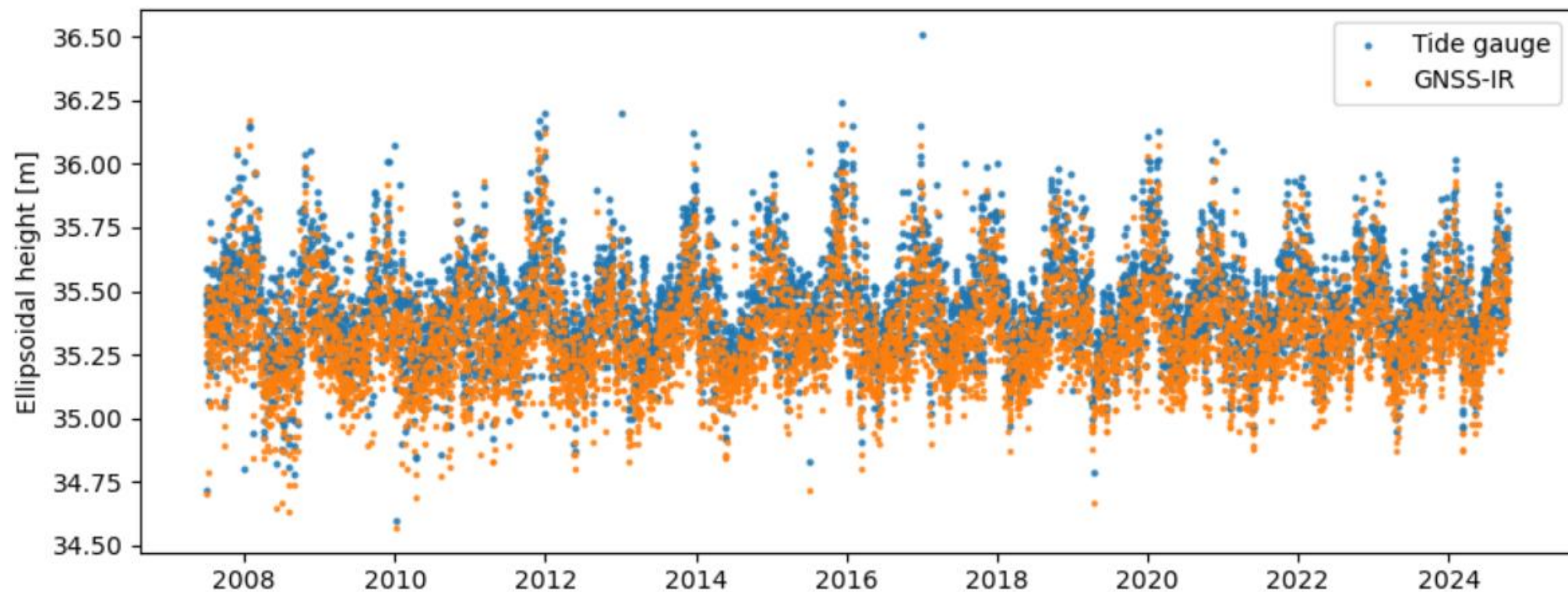


GNSS-IR network for sea level determination



GNSS-IR vs. tide gauge results

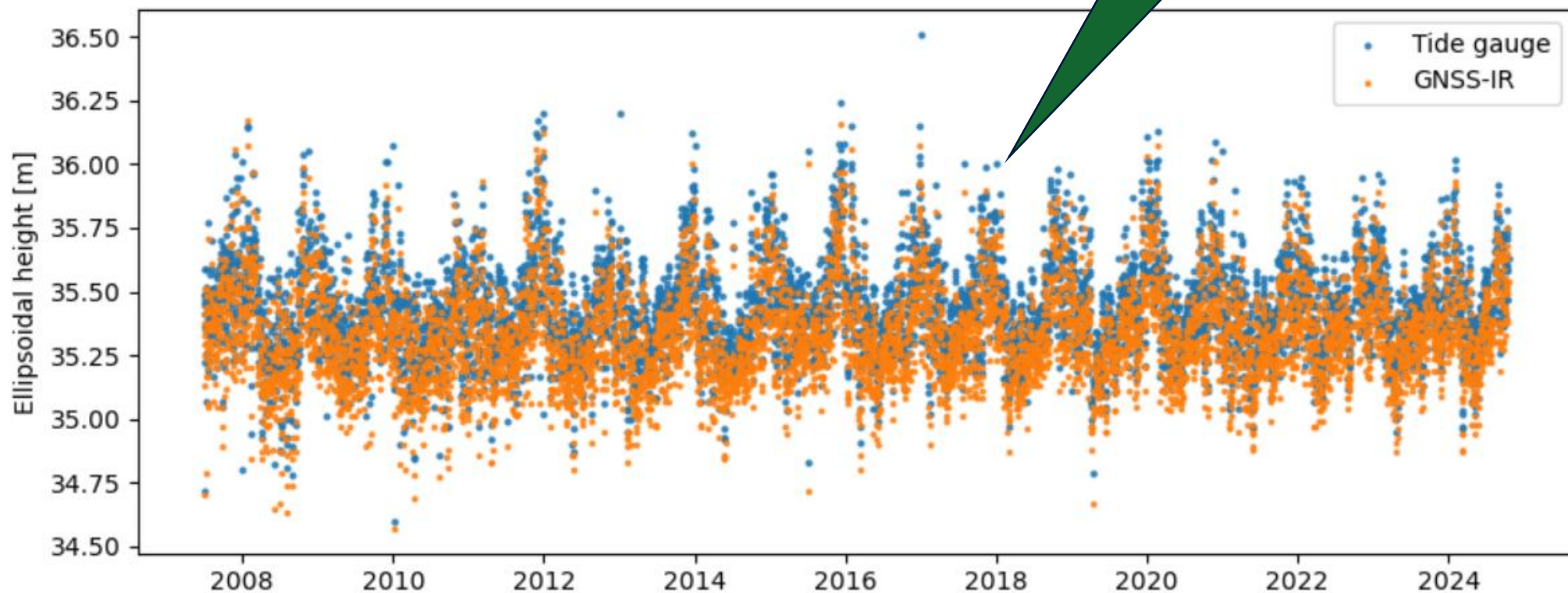
Andenes (ANDE)



GNSS-IR vs. tide gauge results

Andenes (ANDE)

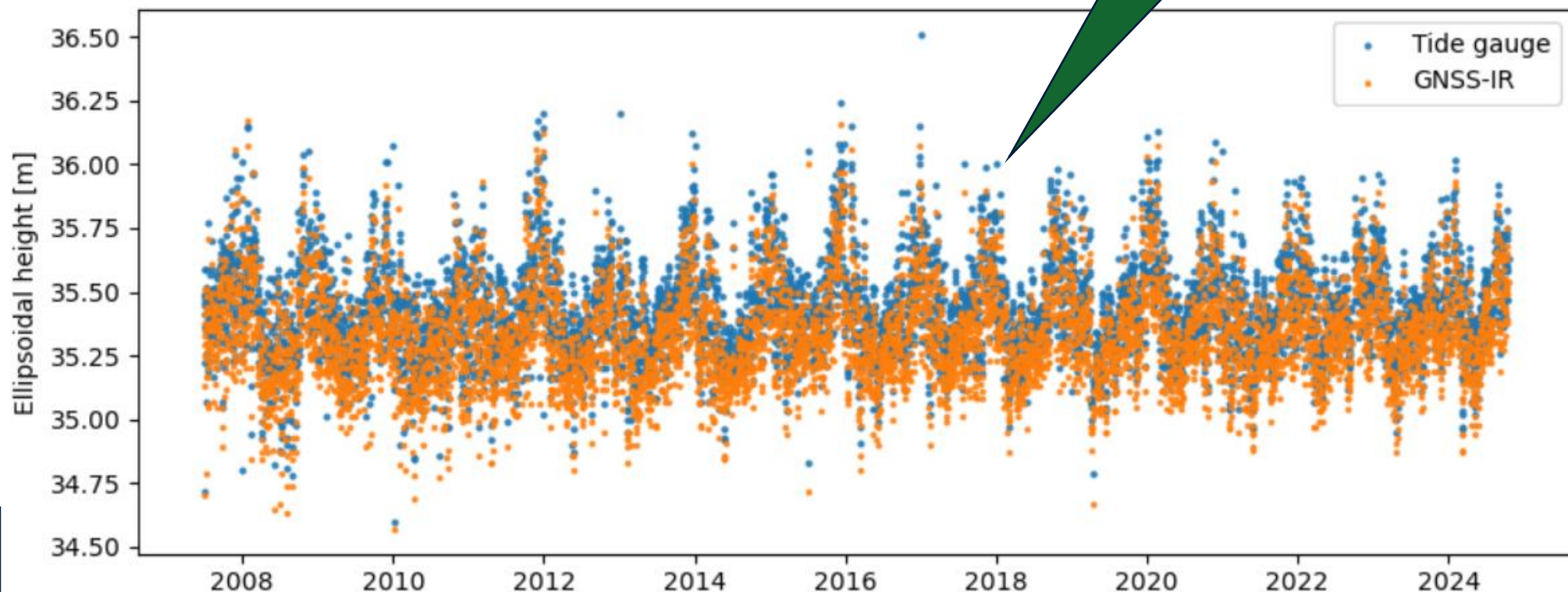
Daily average
are determined



GNSS-IR vs. tide gauge results

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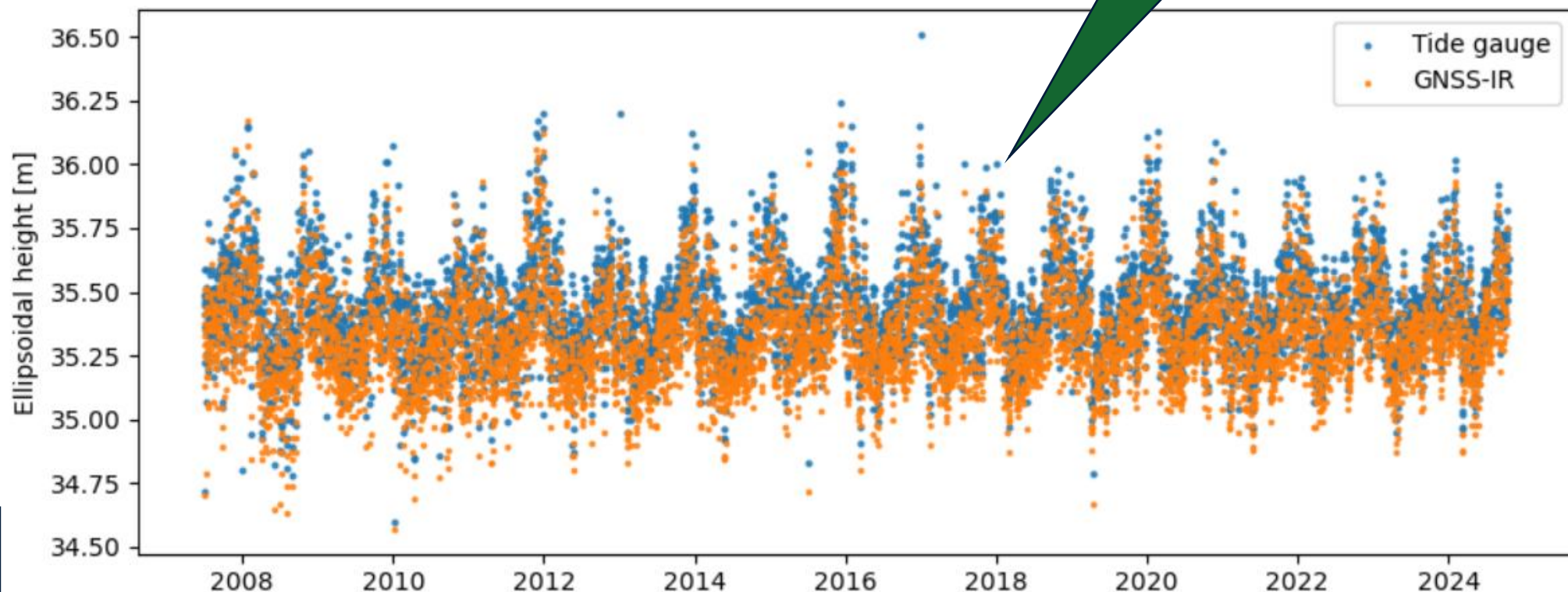


Referenced to
ellipsoid

GNSS-IR vs. tide gauge results

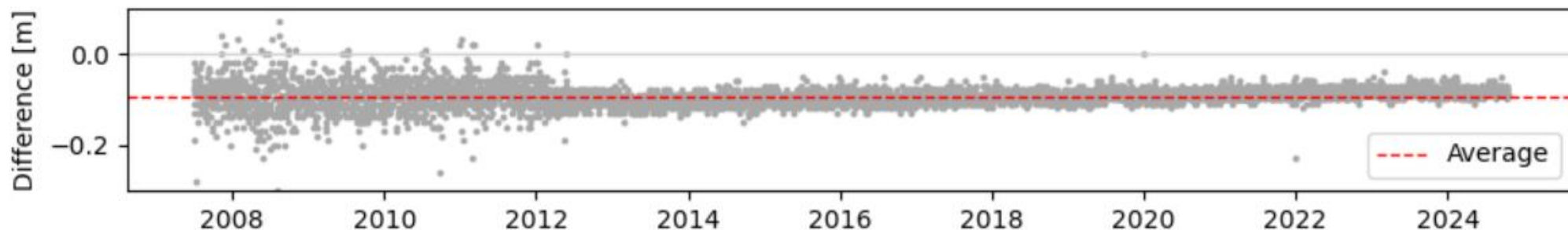
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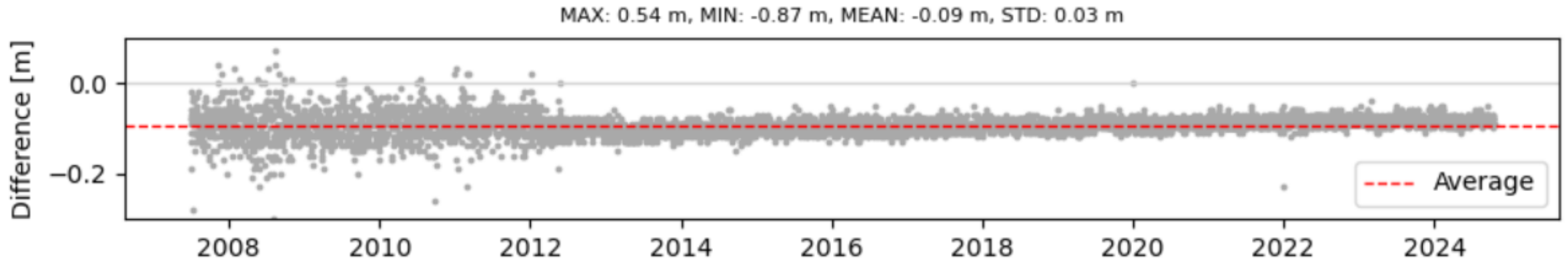
Referenced to
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MAX: 0.54 m, MIN: -0.87 m, MEAN: -0.09 m, STD: 0.03 m

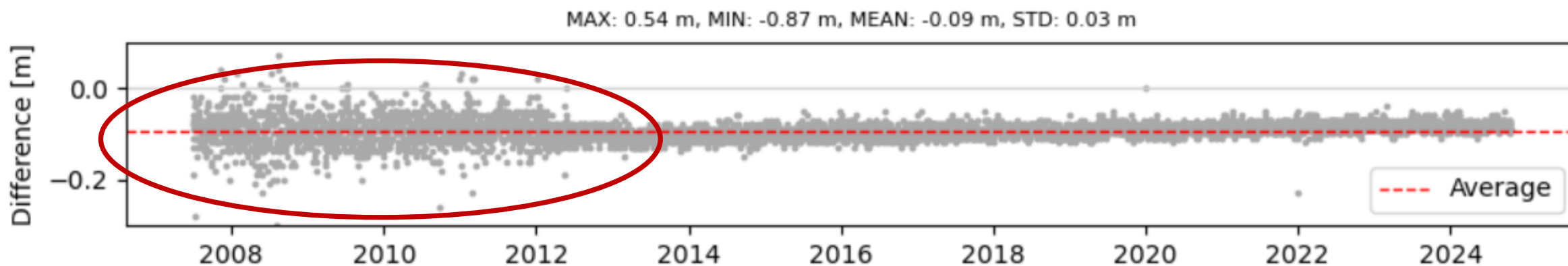


Kartverket

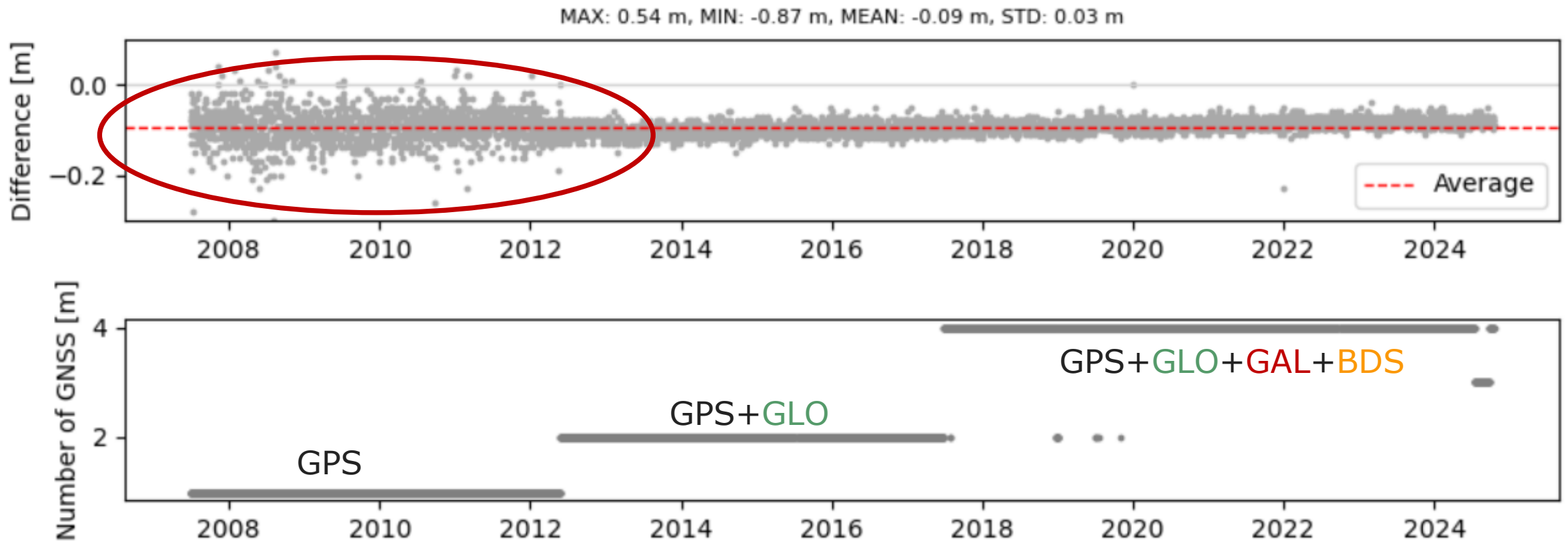
GNSS-IR vs. tide gauge results



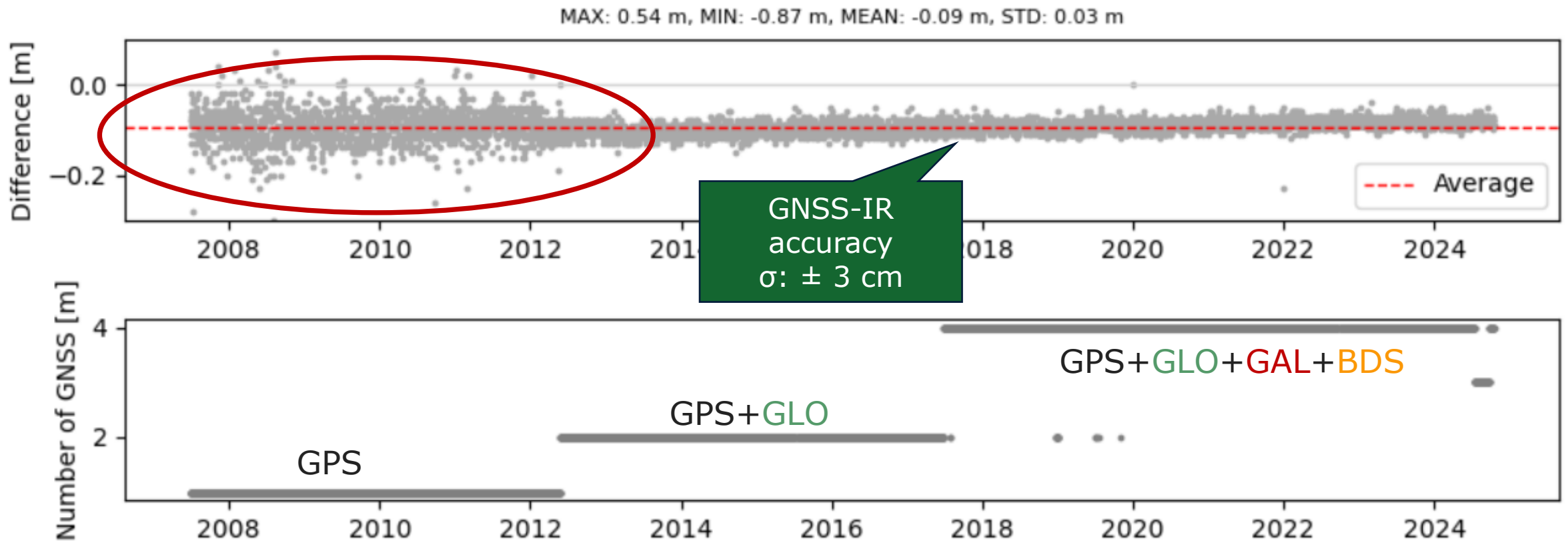
GNSS-IR vs. tide gauge results



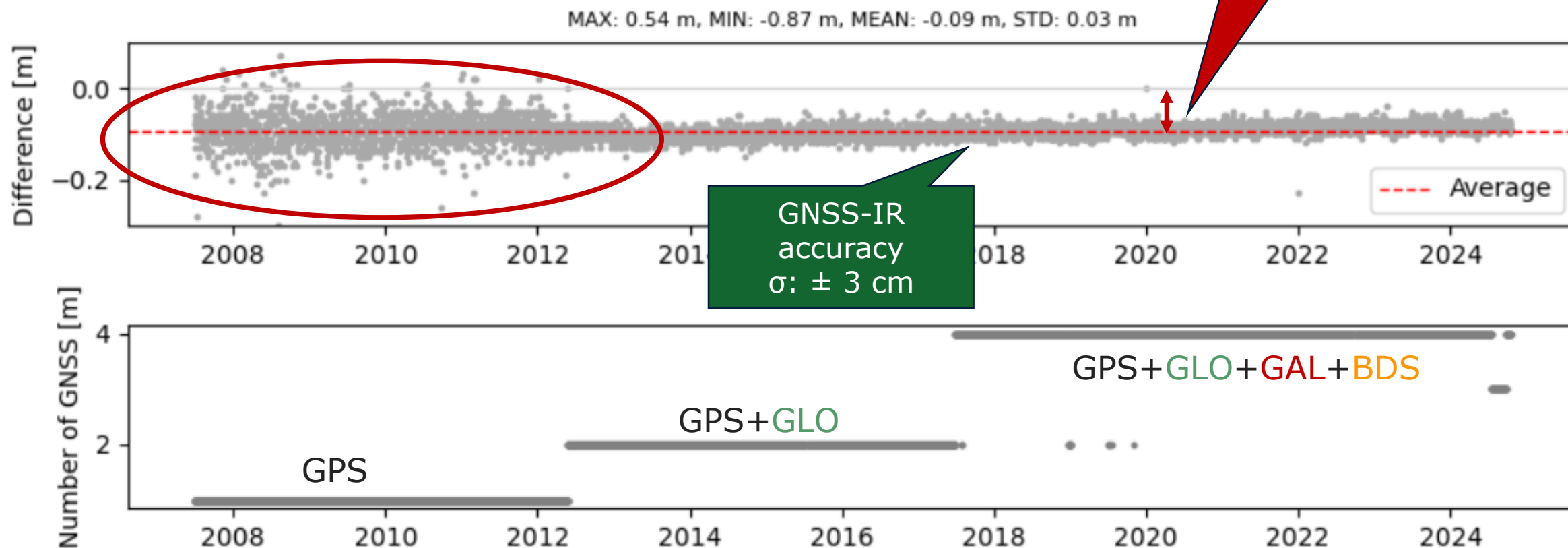
GNSS-IR vs. tide gauge results



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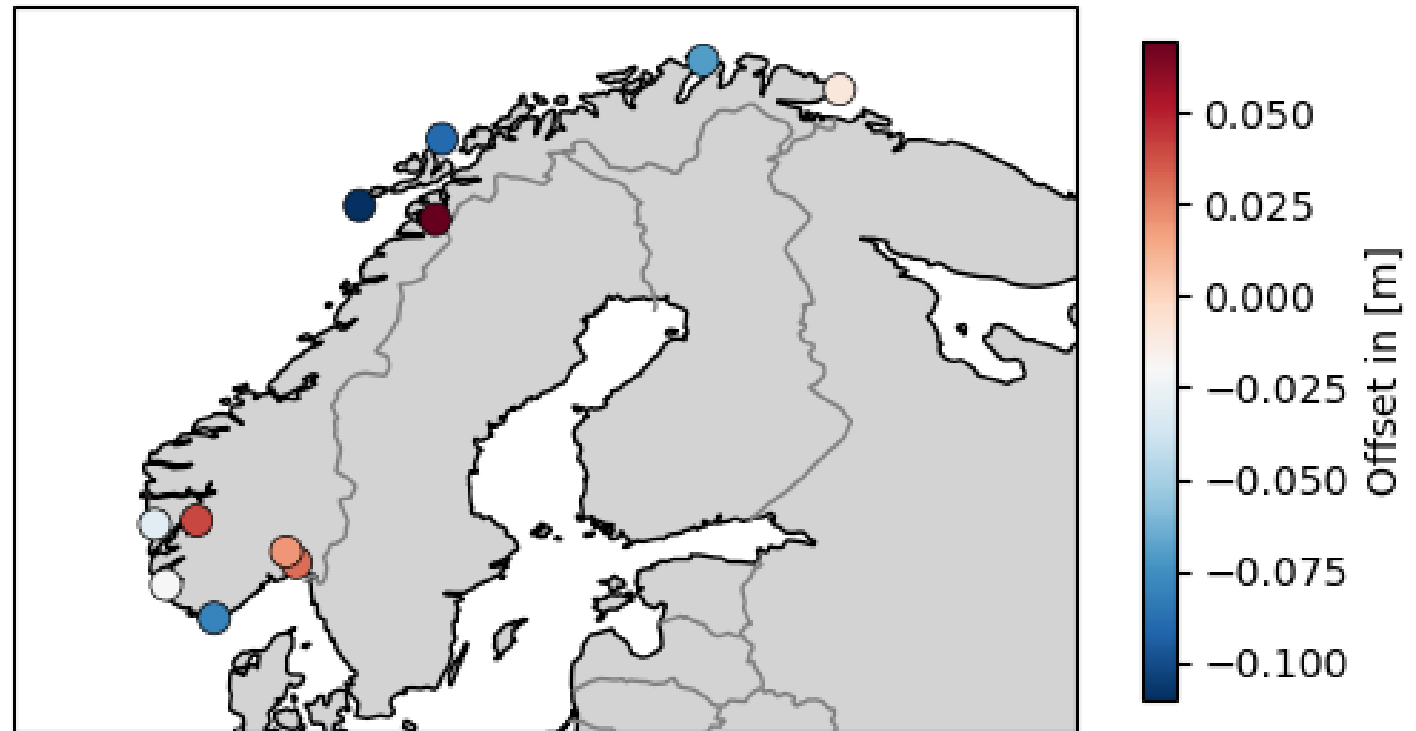


GNSS-IR vs. tide gauge results



Challenge - Offset between GNSS-IR and tide gauge

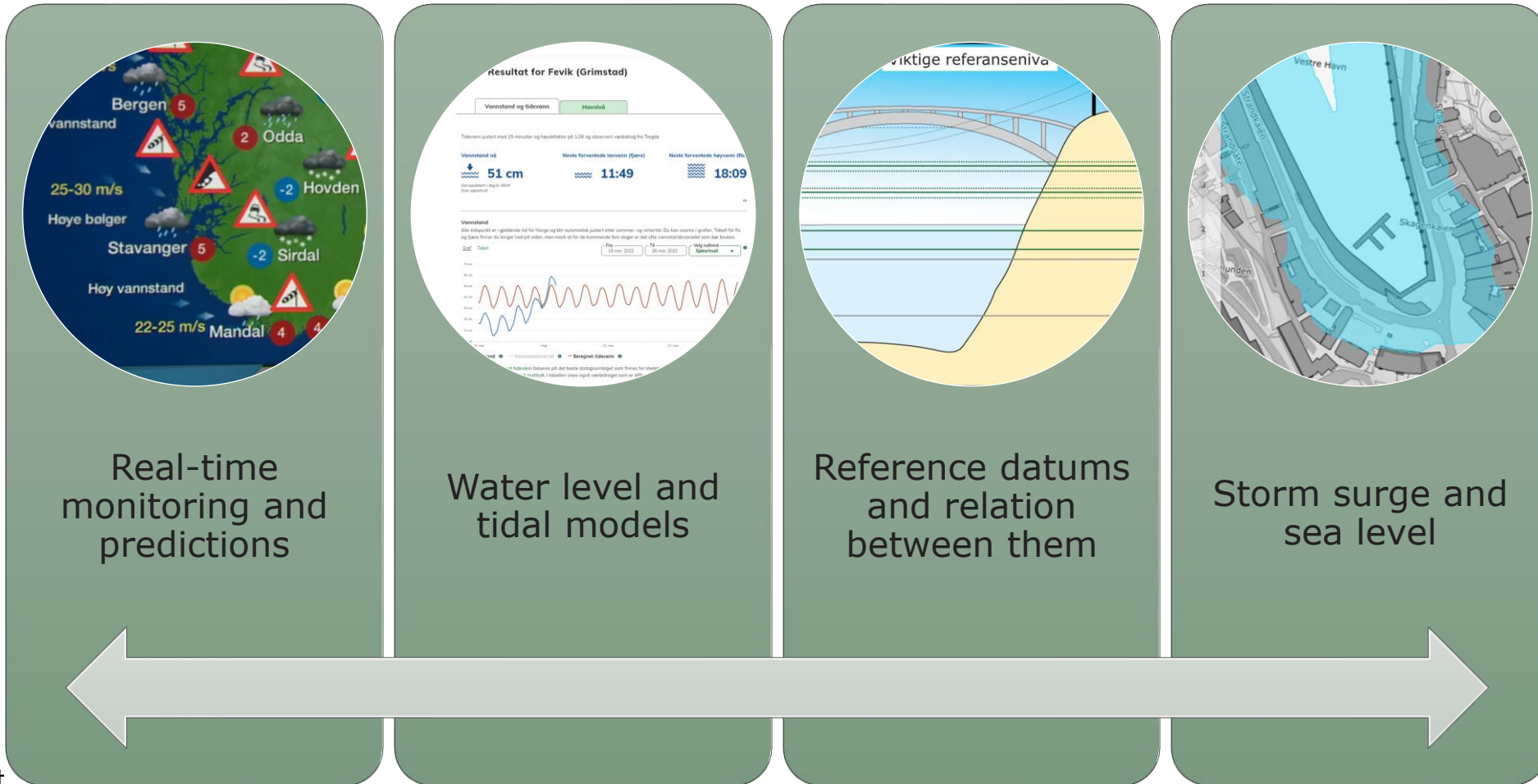
- Offset: Average of difference between GNSS-IR and tide gauge
- What is the cause of the offset?
- Solving of offset issue is crucial for connecting GNSS-IR results to water level products, which are related to mean sea level
 - Especially important if no tide gauge is nearby GNSS-IR station



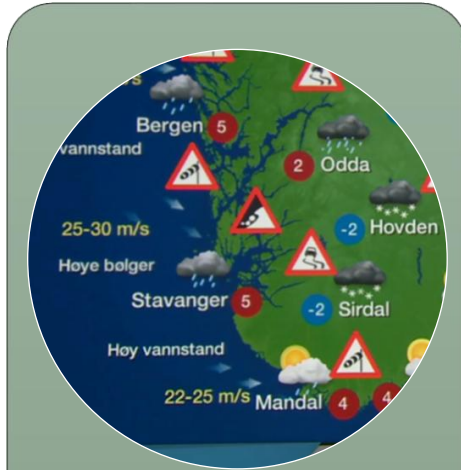
Part 2

How useful is GNSS-IR for sea level products?

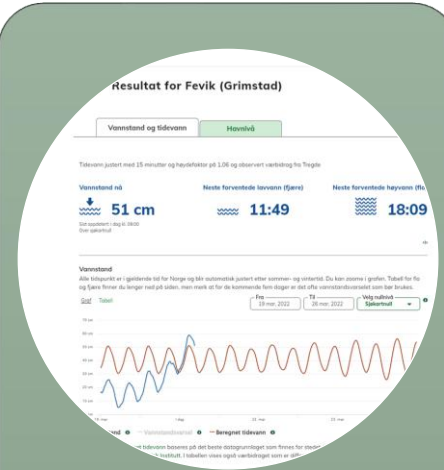
NMA products and services related to sea level



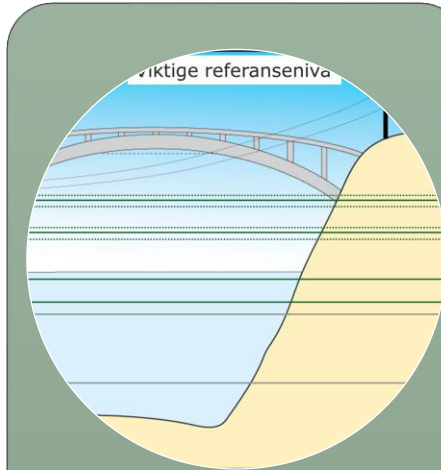
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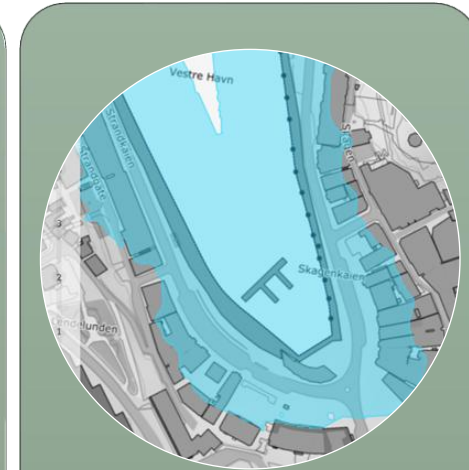
Real-time
monitoring and
predictions



Water level and
tidal models



Reference datums
and relation
between them

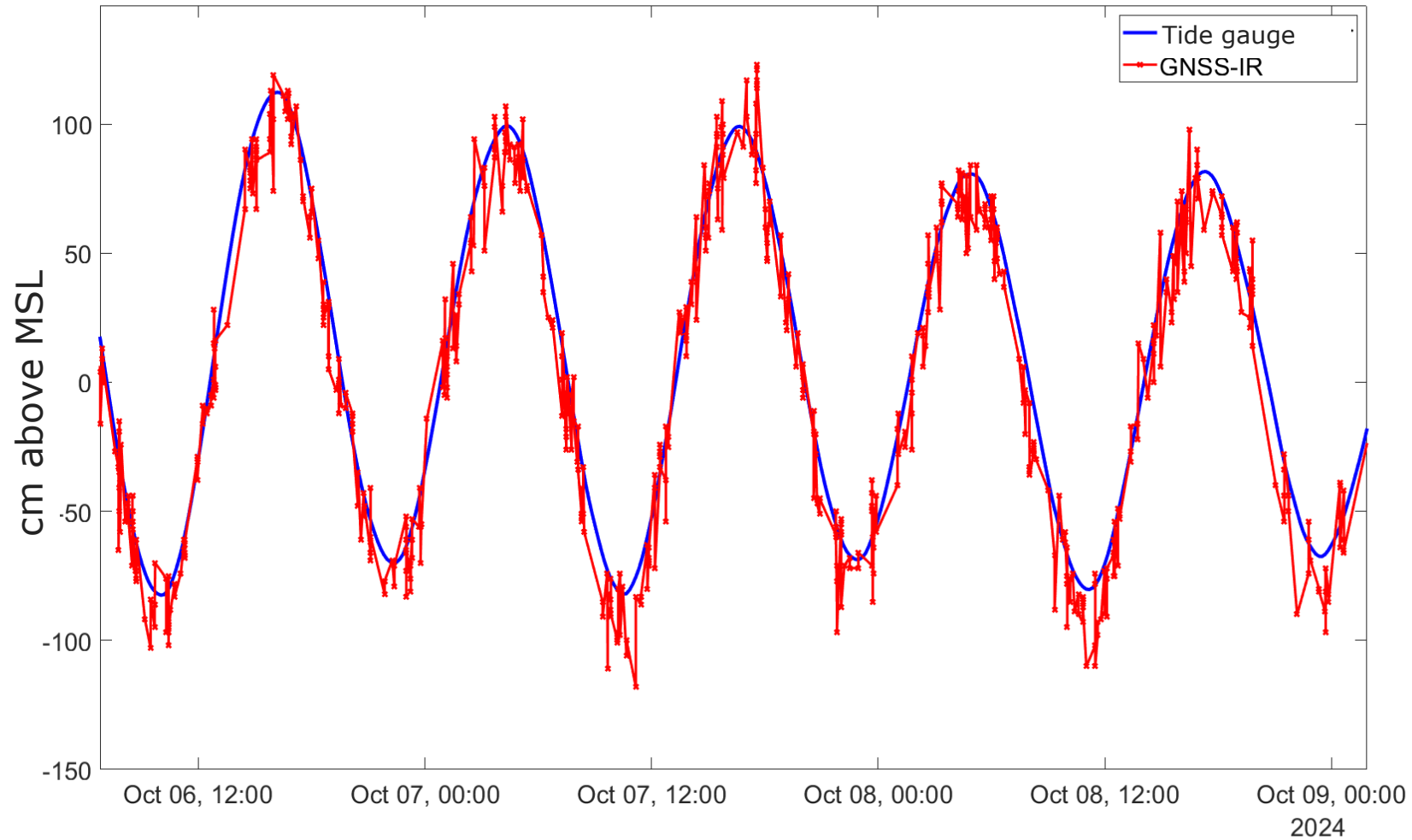


Storm surge and
sea level

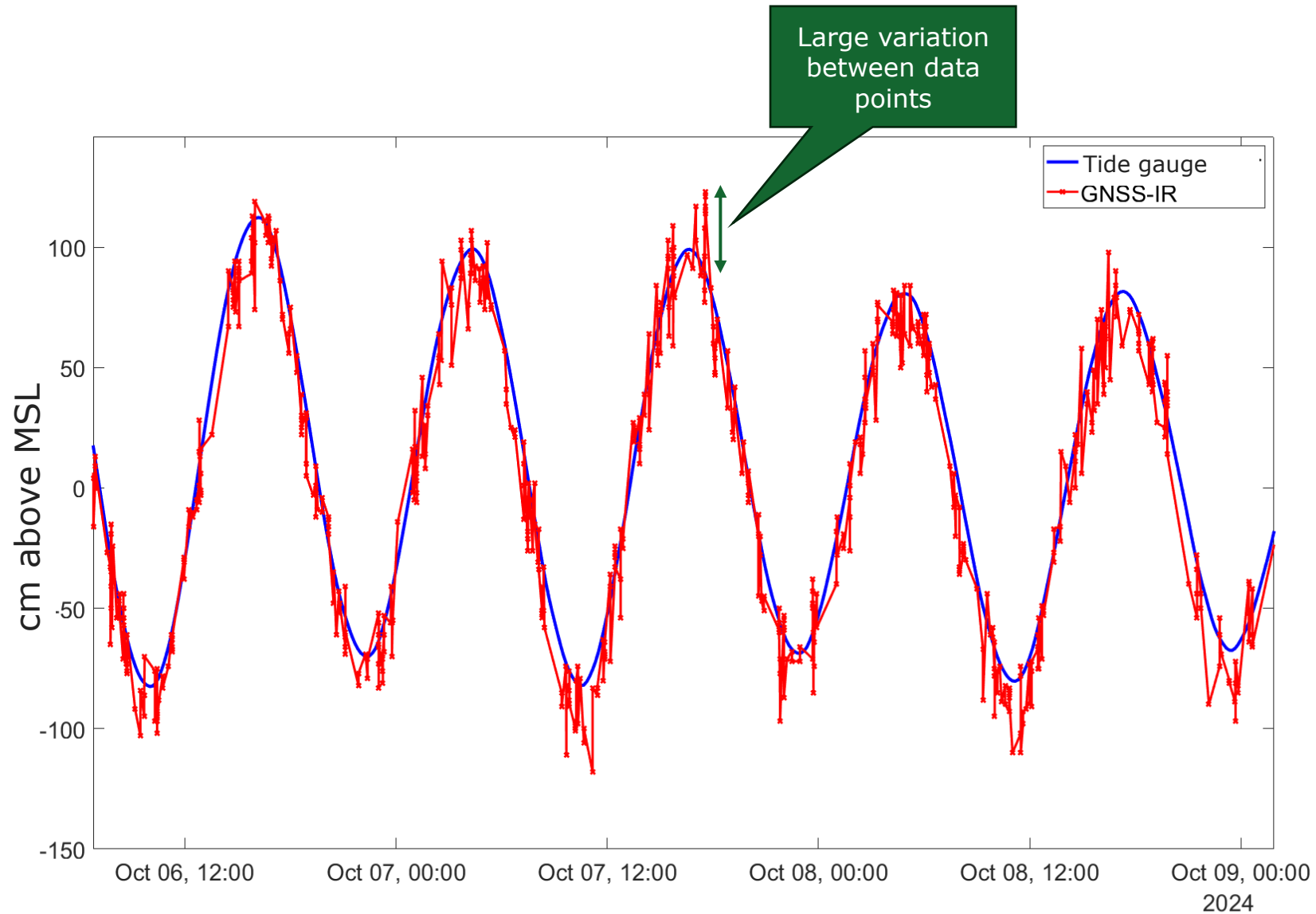
How can GNSS-IR contribute to the data basis, products and services?

Can GNSS-IR be applied as
ordinary tide gauge?

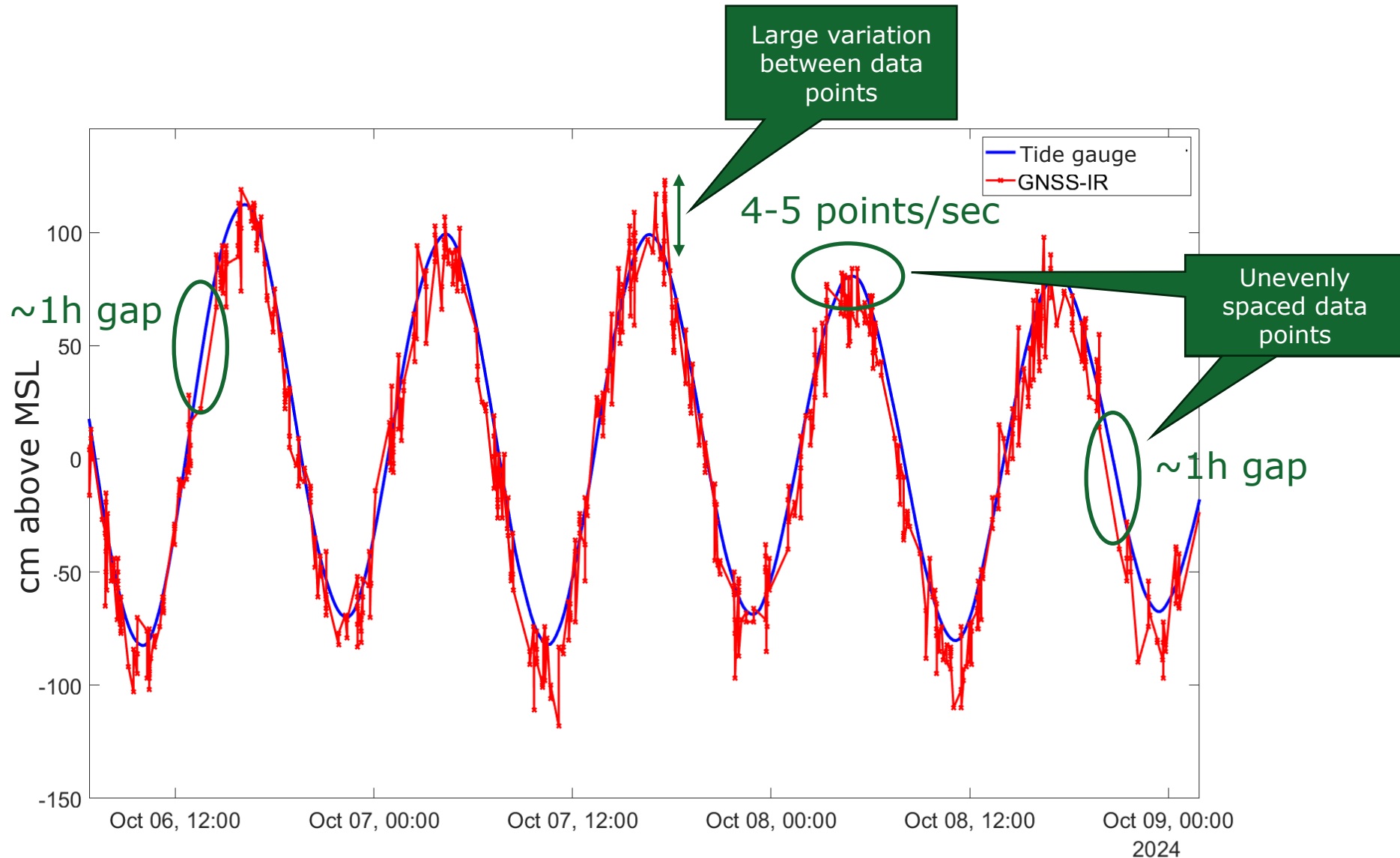
Challenges with GNSS-IR observations (e.g. Honningsvåg)



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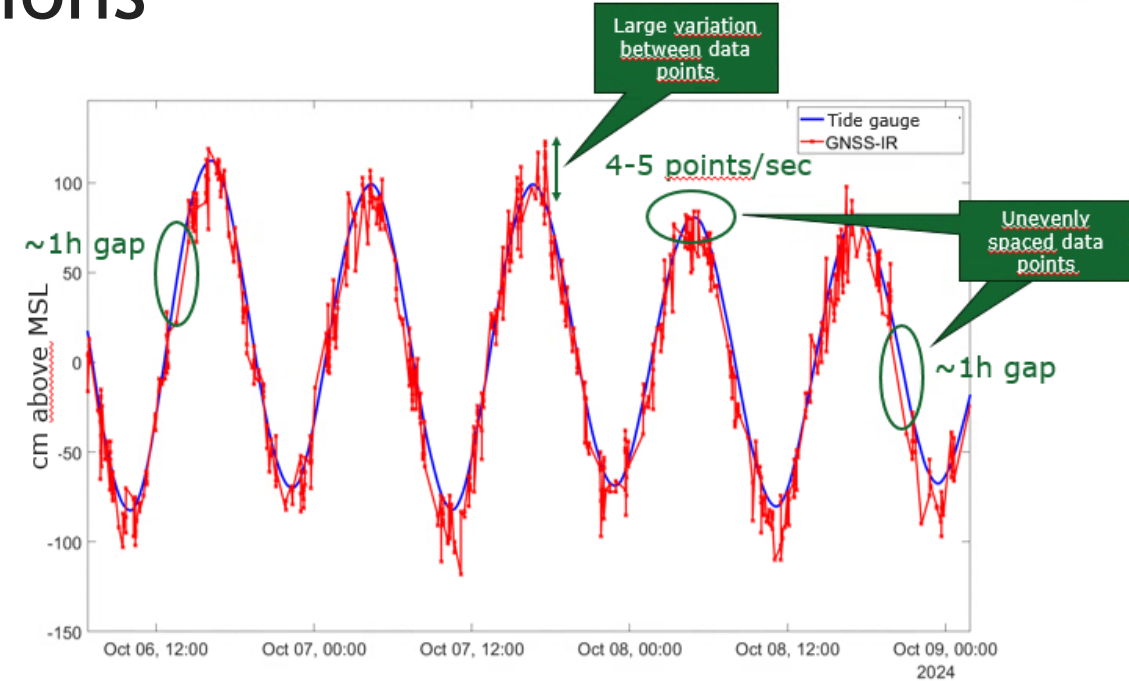


Challenges with GNSS-IR observations (e.g. Honningsvåg)



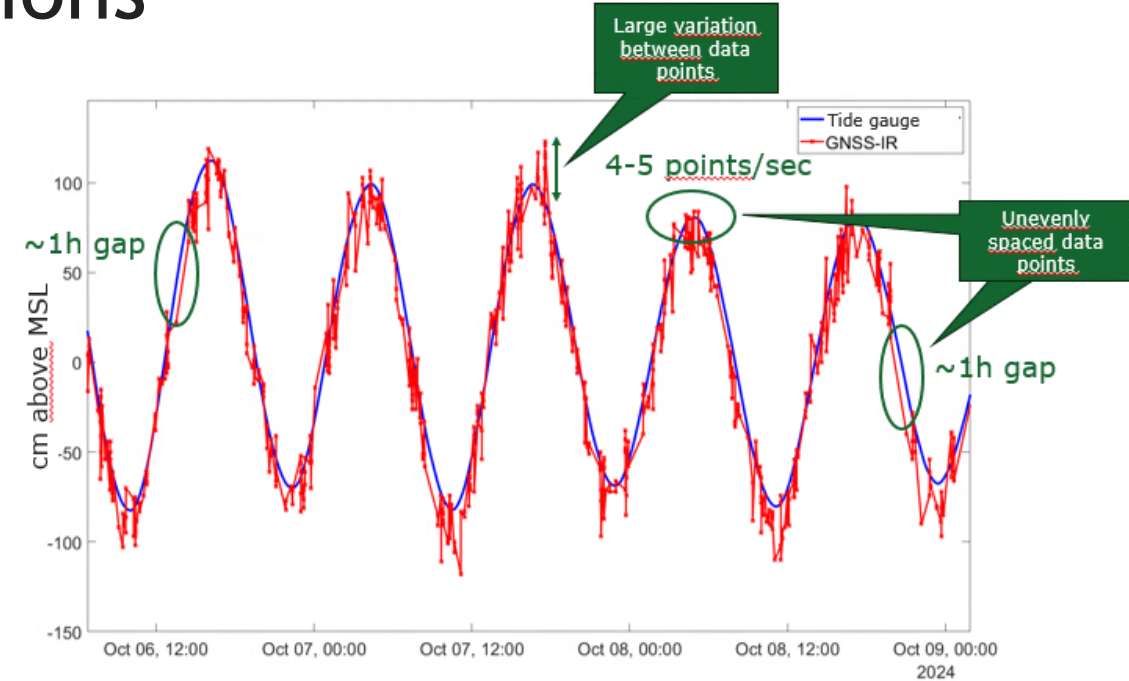
Challenges with GNSS-IR observations

- If GNSS-IR data should be applied for sea level products, then analysis strategies has to be adapted for the shown issues



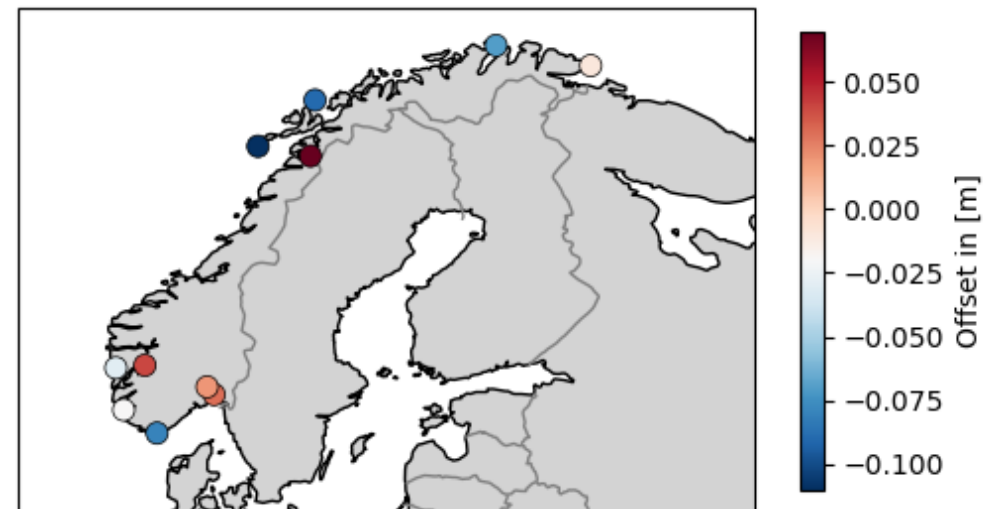
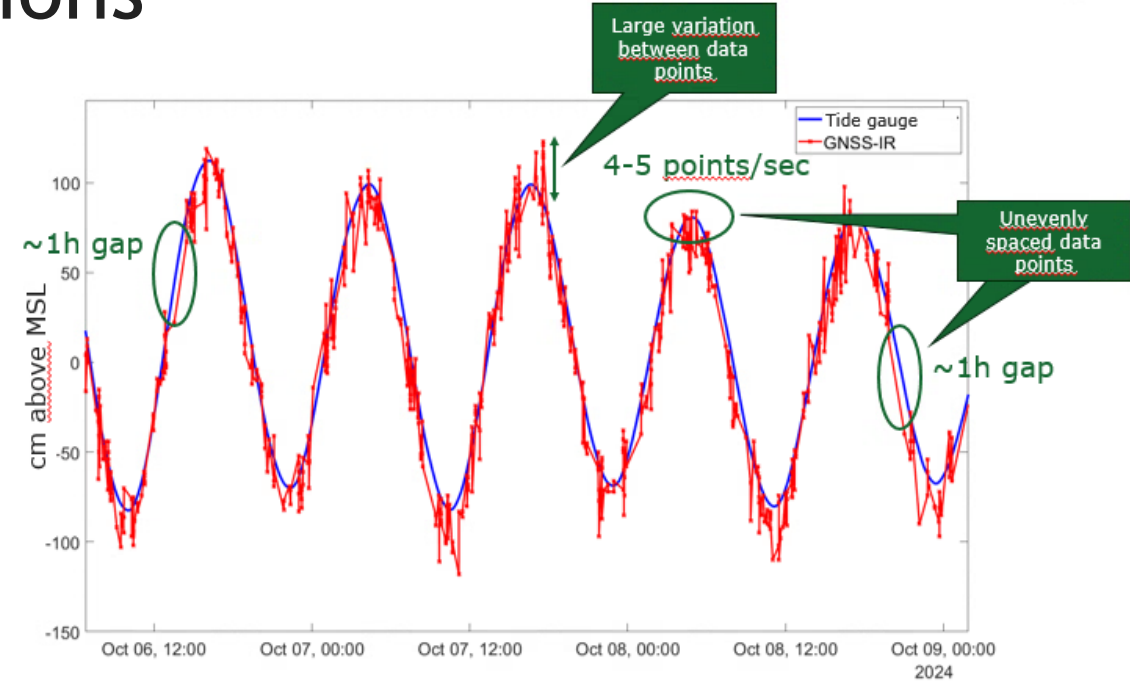
Challenges with GNSS-IR observations

- If GNSS-IR data should be applied for sea level products, then analysis strategies has to be adapted for the shown issues
- Challenging to use GNSS-IR for extreme events (e.g. storm surge, tsunami) and real-time applications

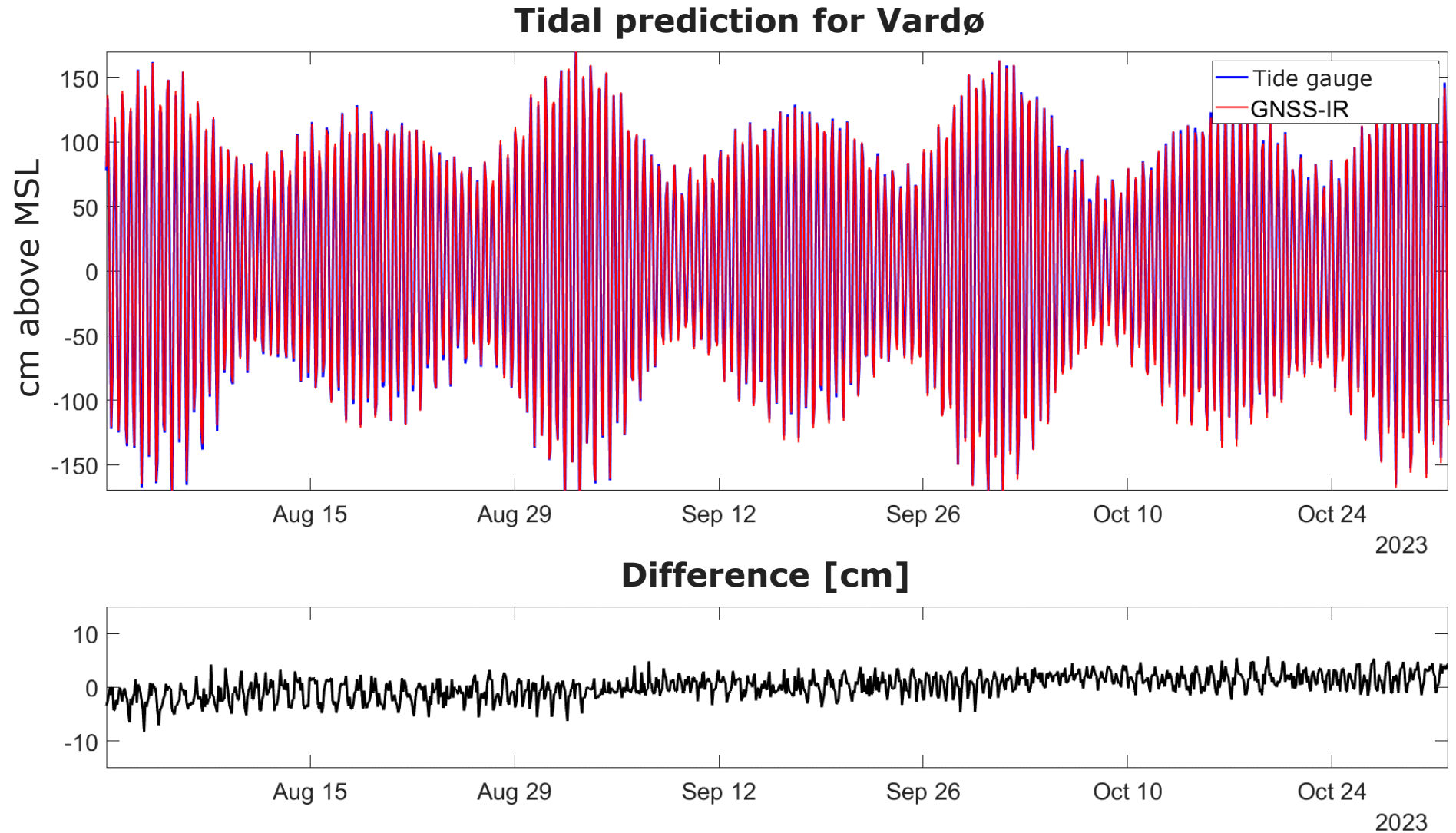


Challenges with GNSS-IR observations

- If GNSS-IR data should be applied for sea level products, then analysis strategies has to be adapted for the shown issues
- Challenging to use GNSS-IR for extreme events (e.g. storm surge, tsunami) and real-time applications
- Offset issue makes it difficult to use GNSS-IR for determination of mean sea level (MSL)



GNSS-IR for tides and tidal modelling

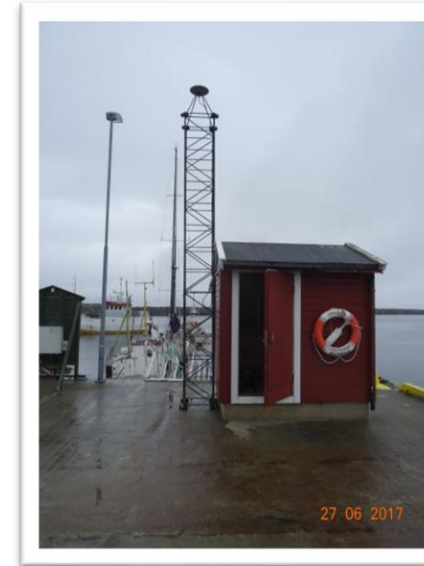
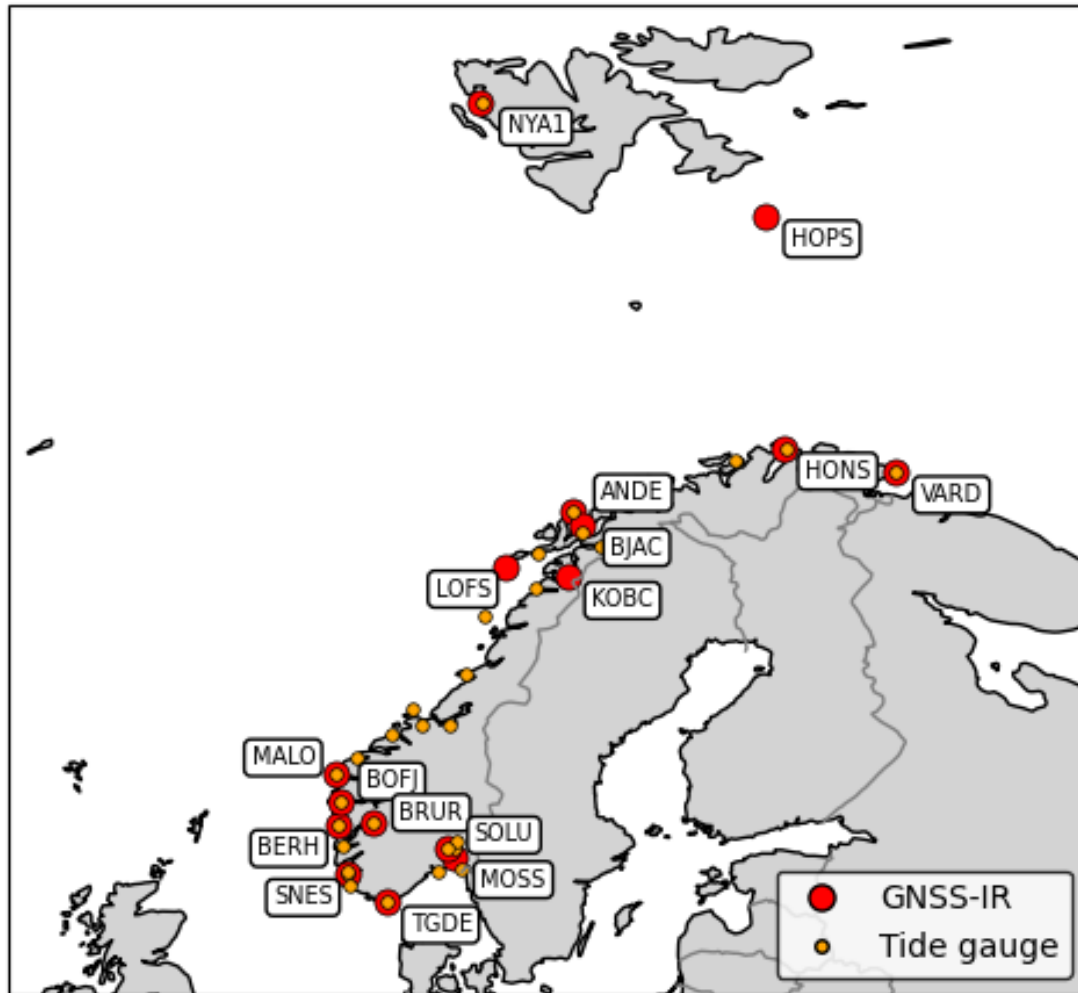


GNSS-IR for determination of Lowest Astronomical Tide (LAT) in relation to Mean Sea Level (MSL)

Location	MSL-LAT from tide gauge	MSL-LAT from GNSS-IR
Vardø	197 cm	196 cm
Andenes	135 cm	134 cm
Bruravik	89 cm	86 cm
Tregde	29 cm	29 cm

Can GNSS-IR be applied as
secondary sensor?

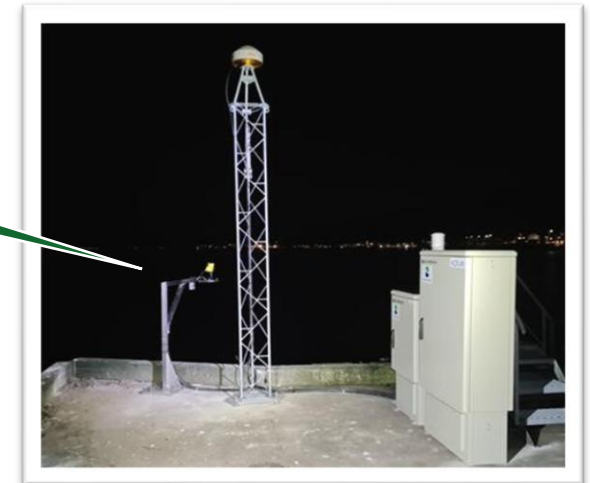
Secondary sensor for co-located sites



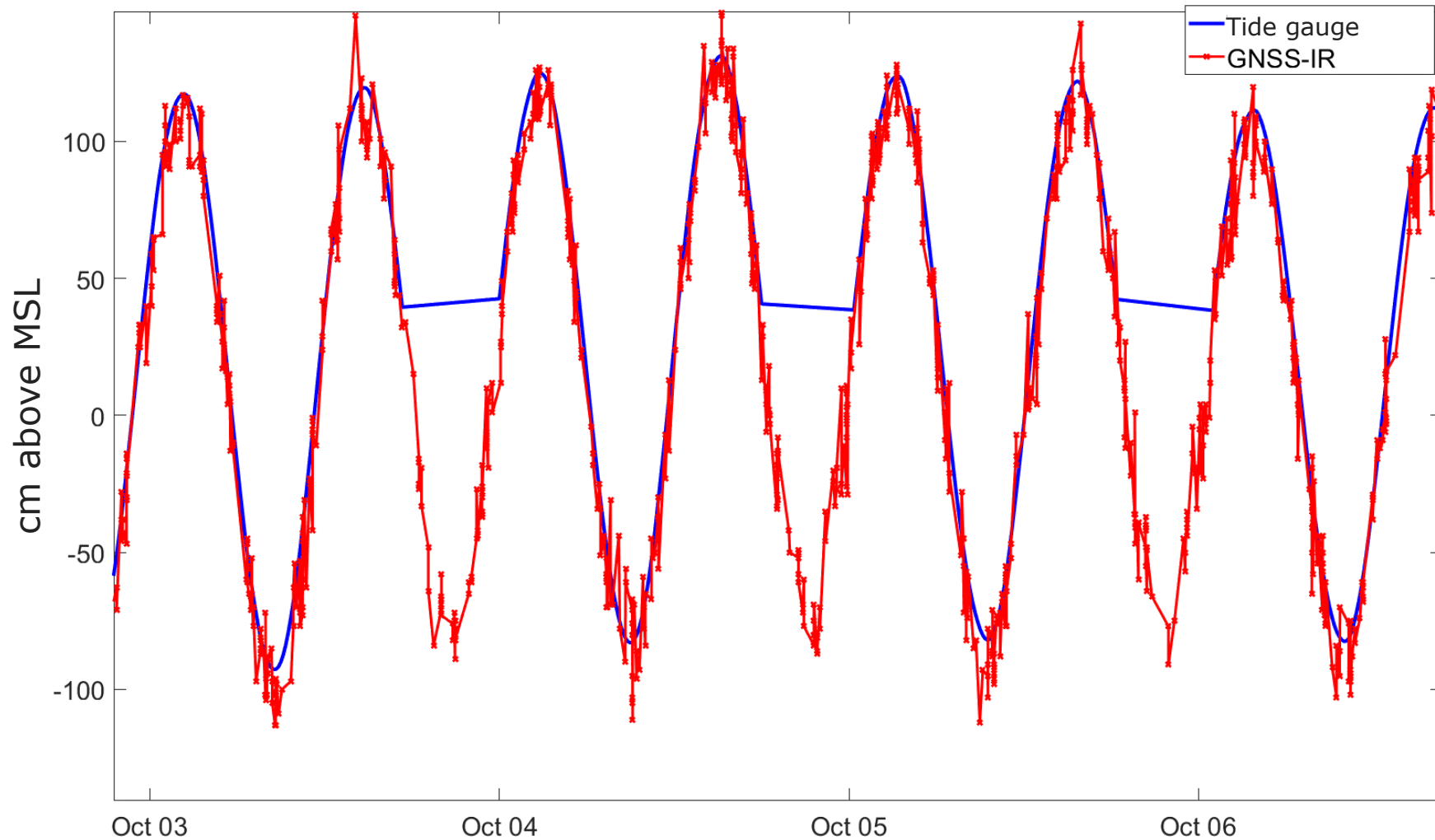
Float gauge



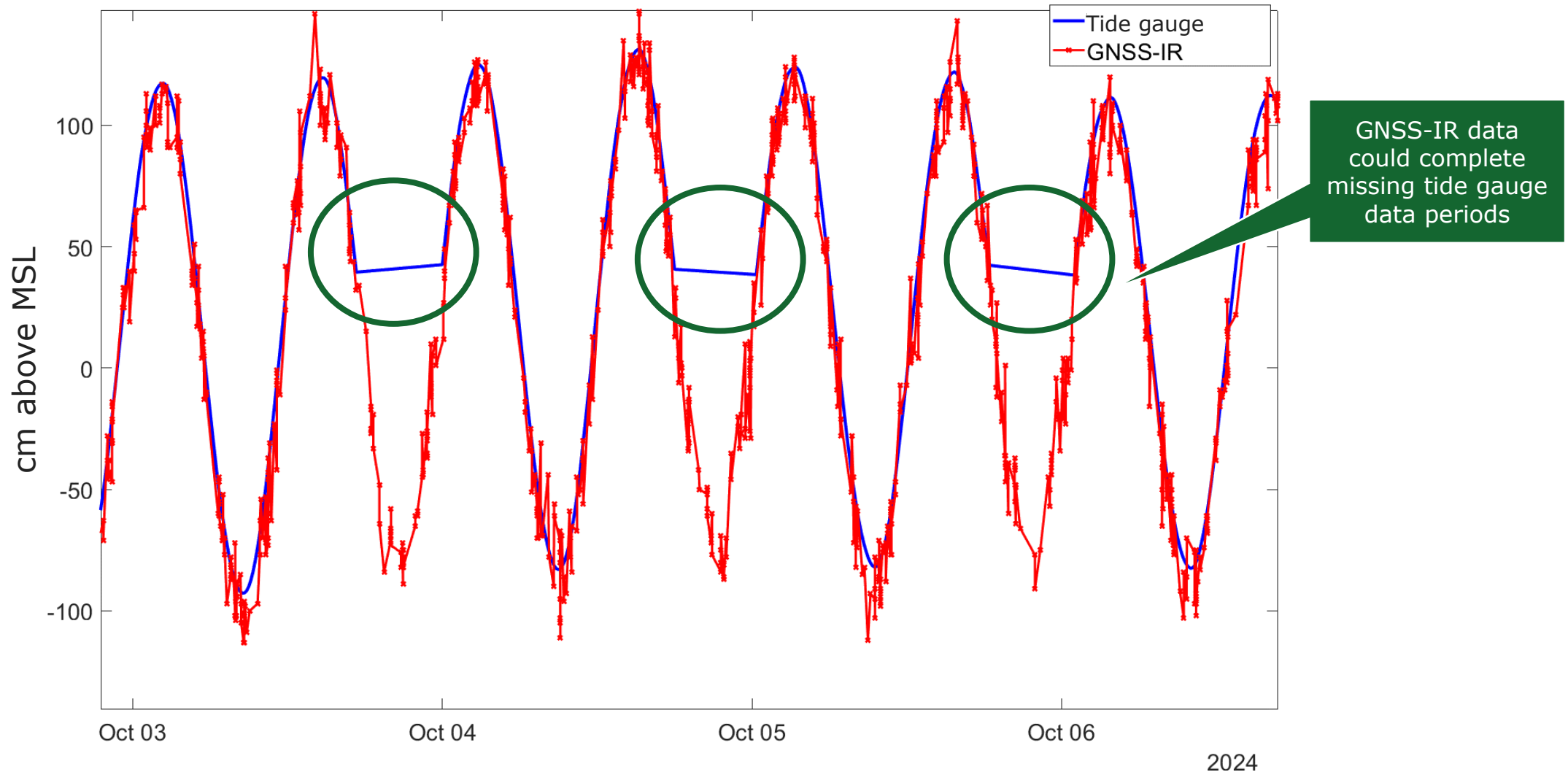
Radar gauge



Secondary sensor for co-located sites (e.g. Honningsvåg)



Secondary sensor for co-located sites (e.g. Honningsvåg)



Can GNSS-IR be applied for
calibration and control?

Calibration and control of pressure sensors

- Working with a concept for an autonomous pressure sensor (e.g. to be used on Svalbard)
- Challenges with a pressure sensor:
 - Water density needed to convert from pressure to water level
 - Pressure sensor drift
 - A long-term station on Svalbard must be retrieved at regular intervals
 - The water level can become inconsistent.
 - Stands on the sea ground, exposed to currents, sediments, biofouling...
- **GNSS-IR can be used to calibrate and control pressure sensor behaviour**



Conclusion

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- Existing GNSS network can be used for sea level determination with GNSS-IR
 - Similar GNSS-IR results compared to tide gauges (few cm for Andenes example)
- GNSS-IR will not replace ordinary tide gauges, but ...
 - can be installed at areas, where it is challenging to place tide gauges
 - can be useful for:
 - improving tidal models
 - as secondary sensor
 - calibration and control especially for pressure gauges
 - improving the connection between sea level and ellipsoid (only if offset issue can be solved)





Question?

Contact

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→ oda.ravndal@kartverket.no



Kartverket

Outlook

- Interest to investigate
 - How the offset issue (up to dm-level) could be solved?
 - To what extent can low-cost/low power consumption GNSS equipment be used?
 - Particularly interesting for GNSS-IR installations on Svalbard
 - How GNSS-IR could be operational used for ordinary water level products?
- International community associated with the Global Sea Level Observing System (GLOSS) are interested in operational use of GNSS-IR
 - plan to establish/integrate this topic in a working group

