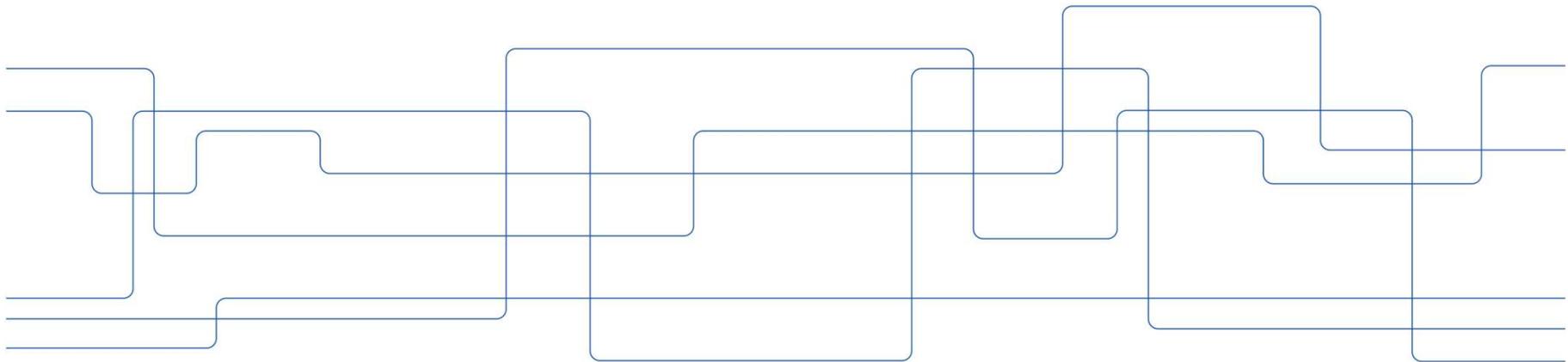# Report from the Nordic Countries

by Anna Jensen, KTH – Royal Institute of Technology

with input from Dan Norin, Kjell Arne Aarmo, Sarang Thombre and Thorarinn Sigurdsson

Outline

- Cooperation and trends in the Nordic countries
- Activities and status in Norway
- Activities and status in Finland
- Activities and status in Iceland
- Activities and status in Denmark
- Activities and status in Sweden
- Concluding remarks and acknowledgements

Cooperation between the Nordic countries

- Long tradition for cooperation between the Nordic countries
    - Since the age of the Vikings (or even before)

- Many cultural similarities (and differences) between the countries

- Nordic cooperation often includes also the Baltic countries; Estonia, Latvia, Lithuania

- Several formal bodies for cooperation, for instance:
    - Nordic Institute of Navigation and Nordic Geodetic Commission

Photo by Werner Karrasch the Viking Ship Museum in Roskilde

Trends in the Nordic countries

- Number of continuously operating reference stations (CORS) increasing in all countries

- Number of users of high-accuracy GNSS positioning services increasing, especially within building & construction and farming

- Strong development towards high-accuracy use of GNSS in "new" fields such as autonomous vehicles and mass-market applications (mobile phones etc.)

- Many GNSS-related research and development (R&D) activities

Activities and status in Norway

- Norwegian Mapping Authority (NMA) CORS network:

  SATREF

- Approx. 270 stations owned by the government capable of tracking GPS, GLONASS, Galileo and BeiDou

- Both public (NMA's CPOS) and private RTK-services (from Hexagon, Topcon, Trimble, Sapcorda) use NMA's reference stations
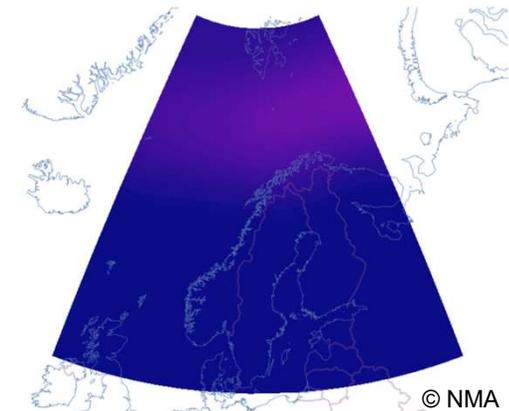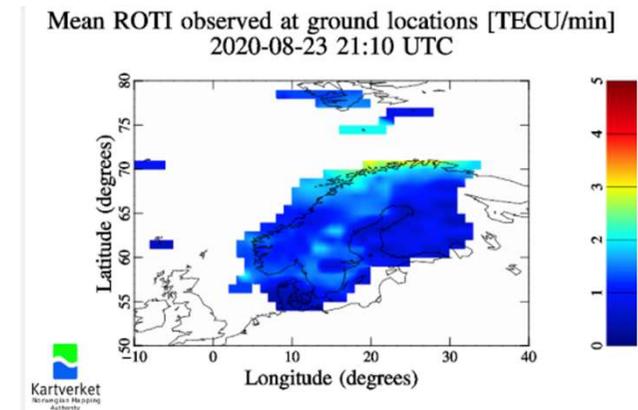
Activities and status in Norway

A few examples of projects and activities:

- Monitoring of space weather (ionosphere) carried out by NMA

- Two stations (Stavanger, Ny Ålesund) for monitoring radio noise from the sun. Data available in real time, and contributes to the international network e-Callisto

- Joint project of NMA, CNES, ONERA and Norwegian Space Agency to predict the ionosphere at northern latitudes: **HAPEE** (**H**igh l**A**titude scintillation **P**ositioning **E**rror **E**stimator). A beta implementation is around the corner

Mean ROTI observed at ground locations [TECU/min]
2020-08-23 21:10 UTC

© NMA

Activities and status in Norway

- NMA carry out performance monitoring of:
  - Galileo
    - > GRC MS – Galileo Reference Centre member state support
  - EGNOS
    - > SPMS – Service Performance Monitoring Support

- Permanent monitor station to monitor radio frequency interference along a Norwegian main road
→ presentation at ION GNSS+ 2020 session F4a

- Performance monitoring of Galileo in urban areas using a tram in Oslo
→ presentation of results at ENC 2020
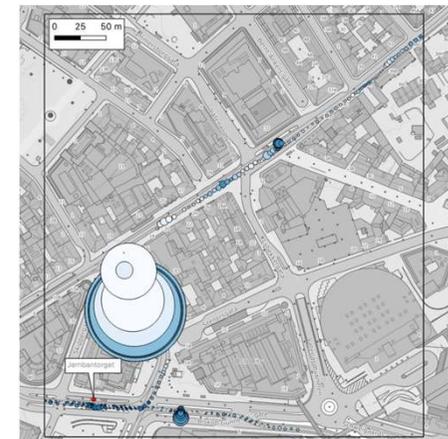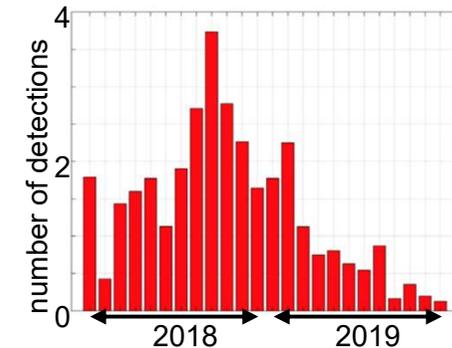
Activities and status in Finland

Continuously operating reference stations (CORS):

- FinnRef network being densified

- Network RTK services offered by private companies
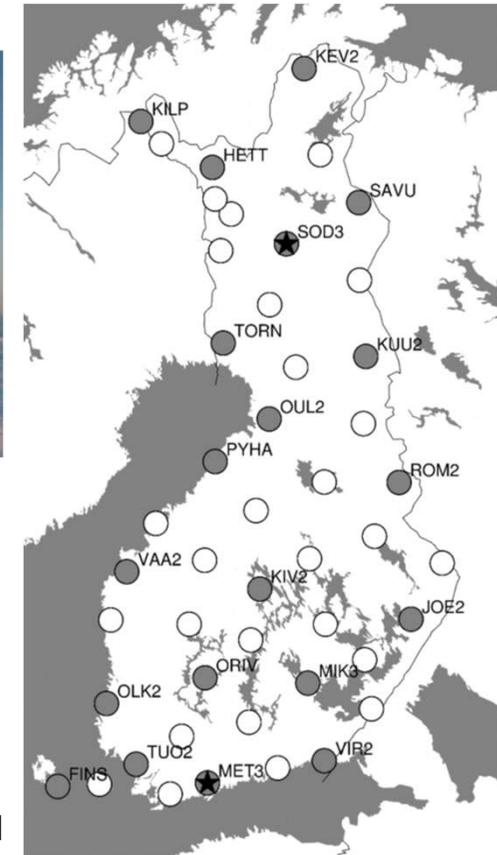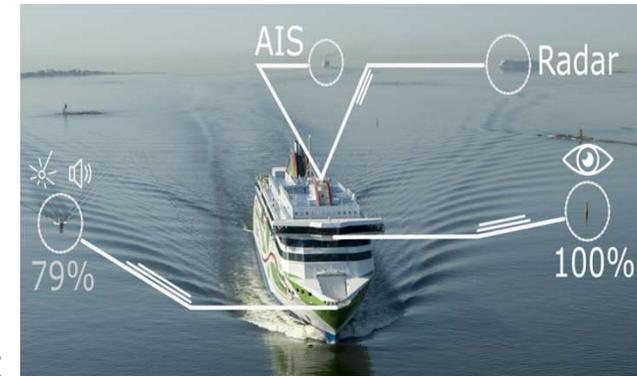

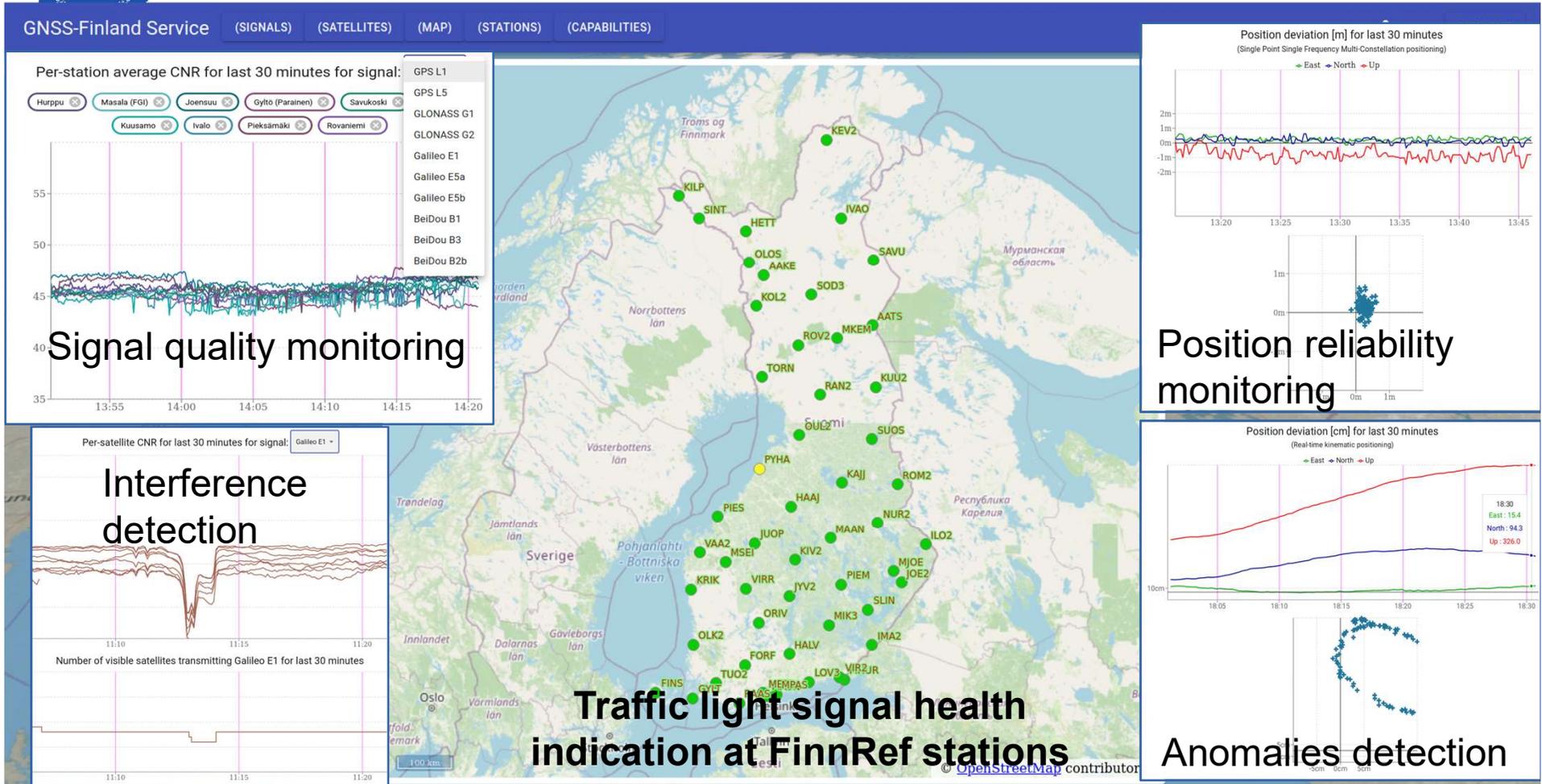Images from National Land Survey, Finland

Activities and status in Finland

- Maritime AI-NAV (ESA), ENHANCE (ESA)
  - Sensor integration and AI machine learning for autonomous maritime situational awareness
  - Twitter: @ai_maritime, www.maritimeai.org/
- PrestigeFin (Finnish Transport Infra. Agency)
  - Review of GNSS augmentation resources available in Finnish waterways for improving accuracy of vessel height (sea-floor clearance) estimation
  - https://prestigefin.org/
- GEARS (GSA)
  - Designing a resilient Galileo Timing receiver for critical infrastructures
  - www.gears-gsa-project.eu
- RAGE (Business Finland)
  - Automatic mineral detection based on indoor positioning, AI, and hyperspectral sensing
  - www.FGI.fi>>Dept. of Navi>>RAGE

GNSS Signal Quality Monitoring

@GNSSfinland

Signal quality monitoring

Interference detection

Position reliability monitoring

Traffic light signal health indication at FinnRef stations

Anomalies detection

Activities and status in Iceland

National Land Survey of Iceland, major use of GNSS:

- IceCORS, 25 stations established by

  the government. Of these:
  - 2 IGS stations
  - 2 EPN stations

- Used for:
  - Geodesy and geodynamic applications
  - Monitoring and maintains the semi-dynamic datum in Iceland
  - RTK positioning free of charge

- Network RTK services offered by private companies: Trimble and Topcon

Activities and status in Iceland

University of Iceland, major use of GNSS:

- Crustal deformation research
    - Volcanoes
    - Earthquakes
    - Plate motion
    - Glacio-isostatic-adjustment
    - Geothermal production response
    - Earthquake triggering
    - Landslides
    - GNSS – seismometry: using GNSS to measure seismic waves from large earthquakes

- Glacial applications
    - Subglacial lake level and flood research
    - Ice motion

- Mapping purposes
    - Faults and fissures, lava flow outlines, sample locations

- Timing: seismometer time-tags

- And of course for navigation ☺

Activities and status in Iceland

Icelandic Met Office, major use of GNSS:

- Volcano monitoring
- Seismic monitoring
- Tracking glacial movements, especially for monitoring the onset of floods from subglacial lakes that form at geothermal areas beneath glaciers
- Monitoring of unstable slopes
- Meteorological applications

Activities and status in Denmark

CORS stations:

- Stations for geodetic and geodynamic applications operated by the government

- Stations for high-accuracy real-time kinematic (RTK) positioning services operated by private companies i.e. Trimble, Leica and Topcon affiliates

- GNET: Greenland GPS Network
 - Established for geodesy and geodynamics, increasing use for other applications

Green: Stations planned for 2019/2020

HIRS
SULD/SUL5
FER5
SKEJ
HABY
Ringkoebing_2019?
BUDP/BUDD
SMID/SMI2
ESBC/ESBH
Nyborg_2019?
TEJH
MOJN
FYHA
GESR

Activities and status in Denmark

A few examples of projects and activities:

- TAPAS: Testbed in Aarhus for Precision Positioning and Autonomous Systems
  - GNSS-based infrastructure for R&D in autonomy and smart city applications
  - Presentation ION GNSS+ 2020 session D4

- DANGO: Danish National Galileo Overlay
  - R&D project on coordinate transformations and monitoring of Galileo performance

- GNSS-based space weather monitoring in Greenland, several R&D activities
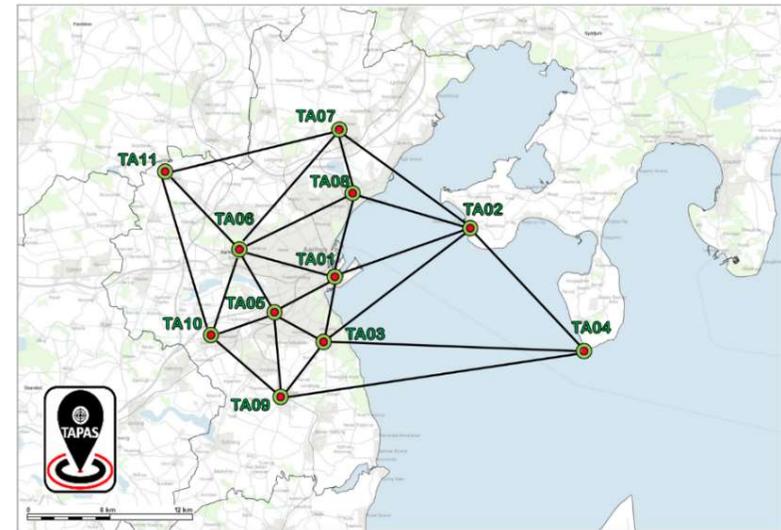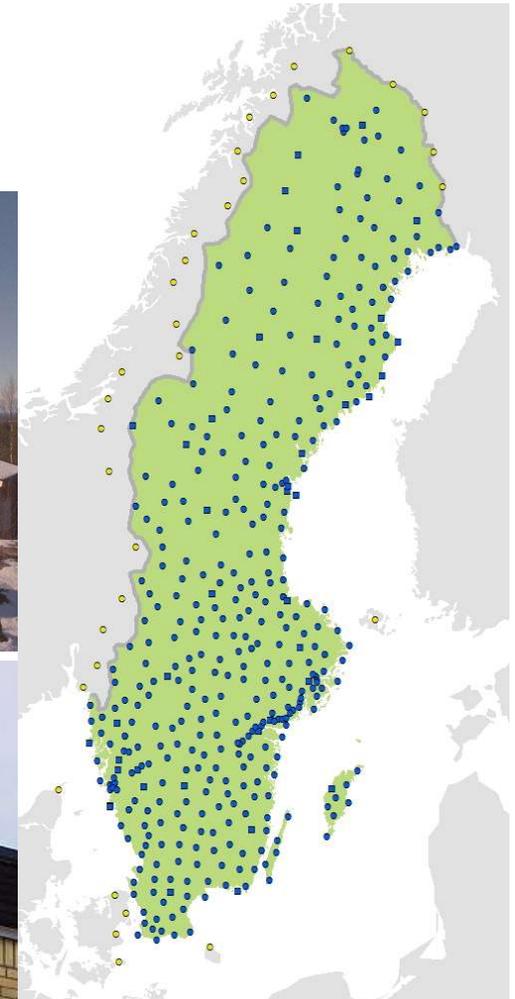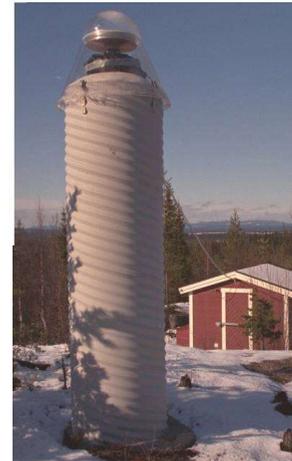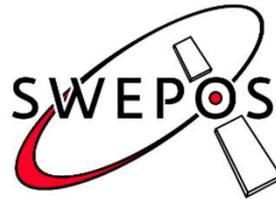
Activities and status in Denmark

- Galileo Forum established by the Danish government for information on GNSS. Both public and private organisations participate

- Analysis by London Economics in 2019 revealed:

  23% of Danish GDP is created in businesses dependent on GNSS

- Open and free use of data from the GNSS stations in Denmark and Greenland (GNET) which are owned by the Danish government

- Many R&D activities regarding GNSS applications within autonomy, digitalisation, smart city, logistics and shipping

Activities and status in Sweden

CORS stations:

- 454 SWEPOS stations
  - Operated by Lantmäteriet
- SWEPOS Network RTK, service with 6200 paying subscriptions
  - Use of Galileo since February 2018
  - The major commercial network RTK services are also available, using SWEPOS stations (common geodetic infrastructure)

Images from: *Lantmäteriet*

Activities and status in Sweden

A few examples of projects and activities:

- *SWEPOS project adaption*
  - Supports construction of new infrastructure through a dense GNSS station network

- *Stomnät i Luften 2.0* (Reference Network in the Air)
  - Funded by Swedish Transport Administration
  - R&D project on high-accuracy positioning in construction

Images from:

Lantmäteriet and the Swedish Transport Administration
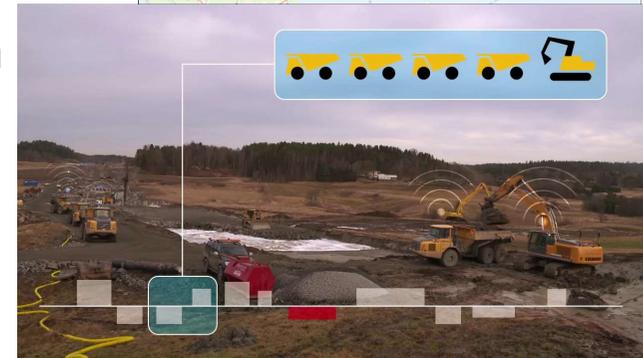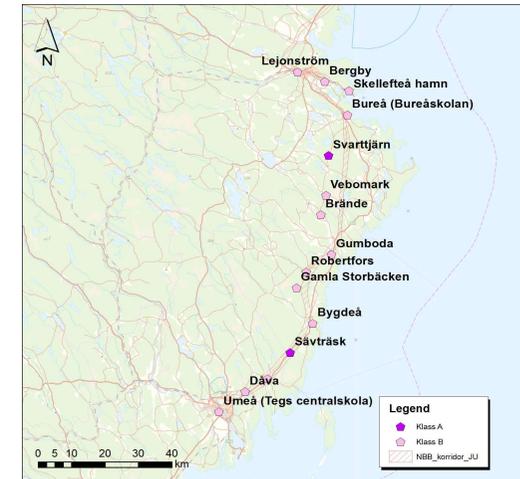
Activities and status in Sweden

- *Prepare Ships*
  - Funded by Horizon 2020
  - Using EGNSS, to allow vessels to navigate safely in close proximity to each other and to stationary objects, and creating structure for autonomous maritime navigation

- *Network RTK Positioning for automated driving (NPAD)*
  - Funded by Vinnova
  - Objective to enable network RTK positioning for automated vehicles or other mobile platforms on land by applying the standard developed by 3GPP and adapting the existing SWEPOS infrastructure
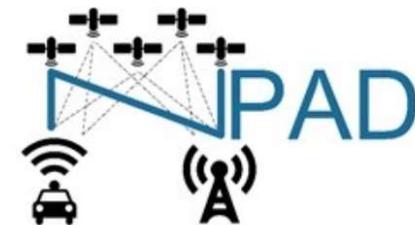
Concluding remarks

- Good cooperation as well as exchange of experiences around GNSS between the Nordic countries

- A lot of GNSS-related research and development activities in the Nordic countries
  - At universities, public organisations and private companies

- Much focus on high-accuracy and increased robustness in applications

- More information in the White paper: "Future Positioning Services", written by Nordic Geodetic Commission:
  - http://www.nordicgeodeticcommission.com/wp-content/uploads/2019/12/NKG-White-Paper-on-Future-Positioning-Services-2019.pdf

Acknowledgements

This presentation was prepared by:

- Anna Jensen, KTH Royal Institute of Technology, Sweden (abjensen@kth.se) and DTU Space, National Space Institute, Denmark
  - https://www.kth.se/en and https://www.space.dtu.dk/english

- Dan Norin, Lantmäteriet, Sweden
  - https://www.lantmateriet.se/en/

- Kjell Arne Aarmo, Norwegian Space Centre, Norway
  - https://www.romsenter.no/eng/

- Sarang Thombre, Finnish Geospatial Research Institute, Finland
  - https://www.maanmittauslaitos.fi/en/research

- Thorarinn Sigurdsson, The National Land Survey of Iceland, Iceland
  - https://www.lmi.is/en/