The effect of dynamic reference systems on formats for real-time data distribution

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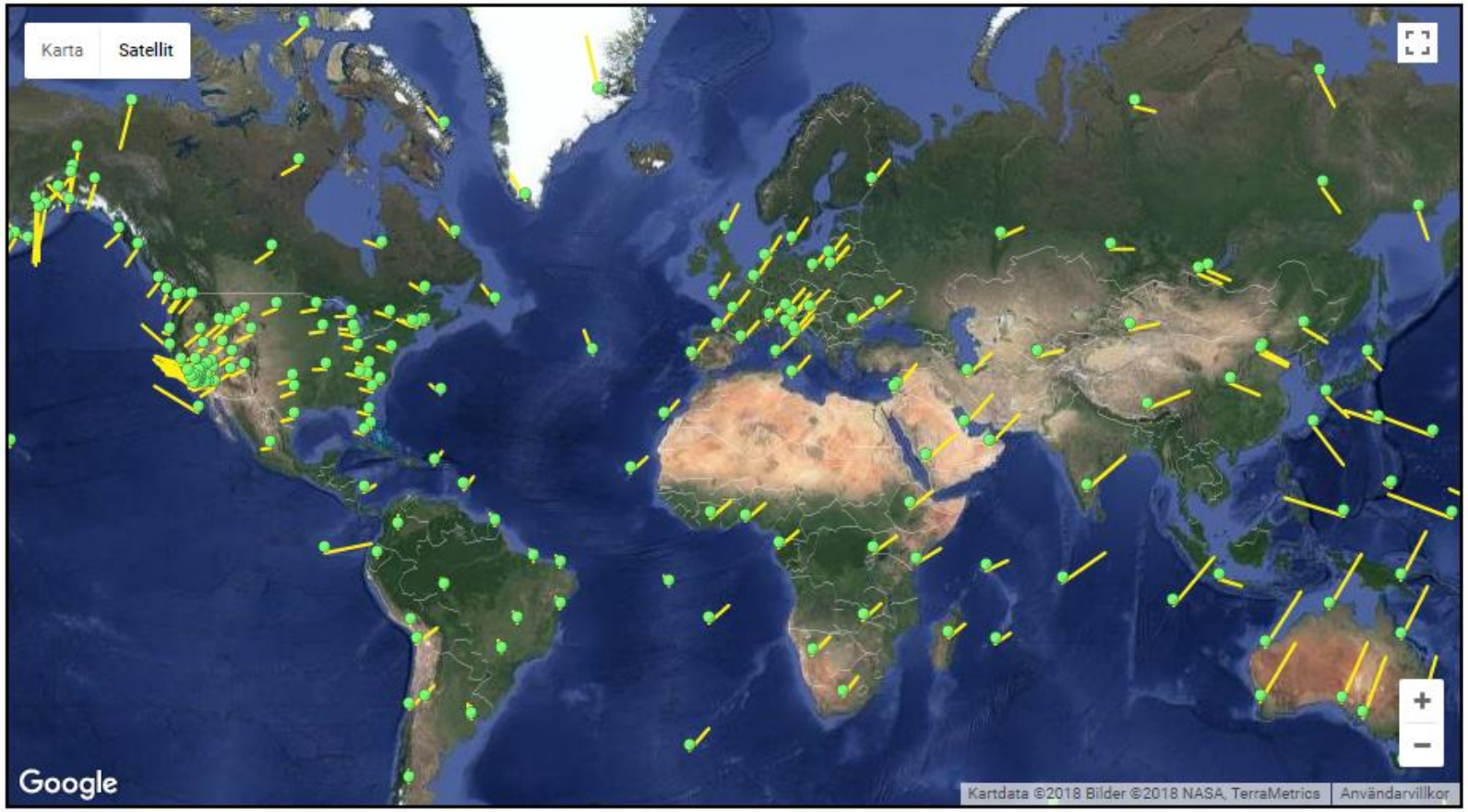
Assumed scenario

Within 3 yr?

- **Precise positioning services** available for the wider consumer market
  - e.g. using PPP from Galileo Commercial Service
  - or initiatives like Sapcorda Joint Venture (Bosch, Geo++, Mitsubishi Electric and u-blox)
  - Work in progress to incorporate precise GNSS services in the standards for mobile phone communication (3GPP)
- These services will be consumed together with **precise spatial information** (geodata)
- The spatial information will be streamed in real-time to the user
- Position and data must be in the same Geodetic Reference Frame!

Geodetic Reference Frames and the dynamic earth



- Plate tectonic motions usually at **some cm/yr**
- Earth quake events, **meter** level deformations locally/regionally

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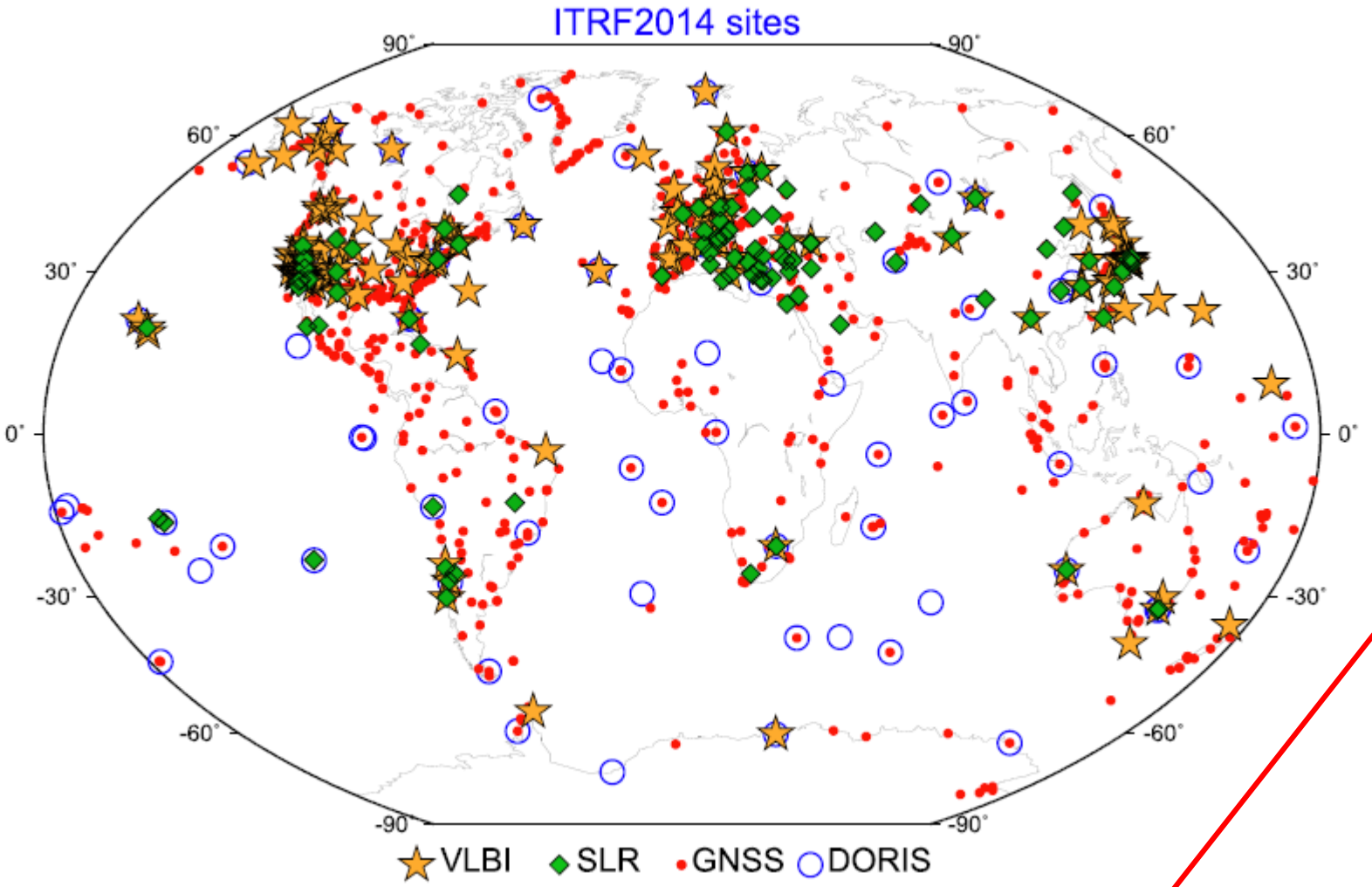
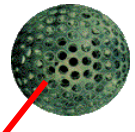
ITRS and ITRF2014



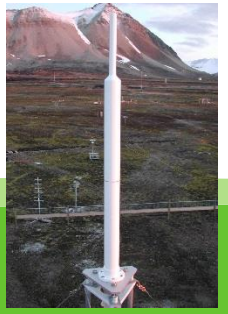


ITRF2014 map from:
Altamimi, Z., P. Rebischung, L. Métivier, and C. Xavier (2016), ITRF2014: A new release of the International Terrestrial Reference Frame modeling nonlinear station motions, *J. Geophys. Res. Solid Earth*, *121*, doi:10.1002/2016JB013098

⇒ VLBI sites ⇐

SLR/LLR laser ⇒

GPS station



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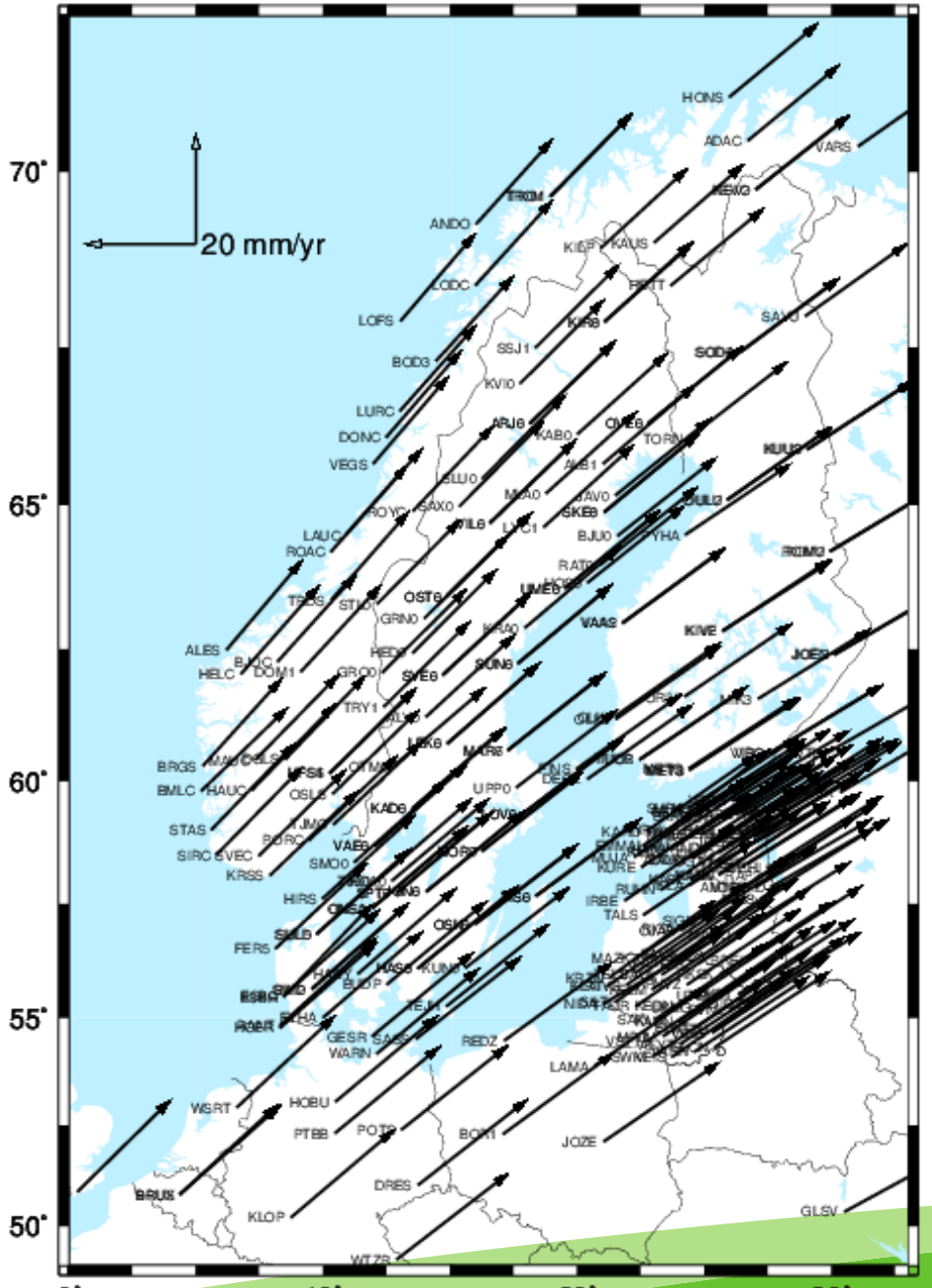
Earth dynamics in northern Europe

The earth crust moves ~2.5 cm/yr towards NE when expressed in "the global geodetic reference frame"

ITRS - International Terrestrial Reference System

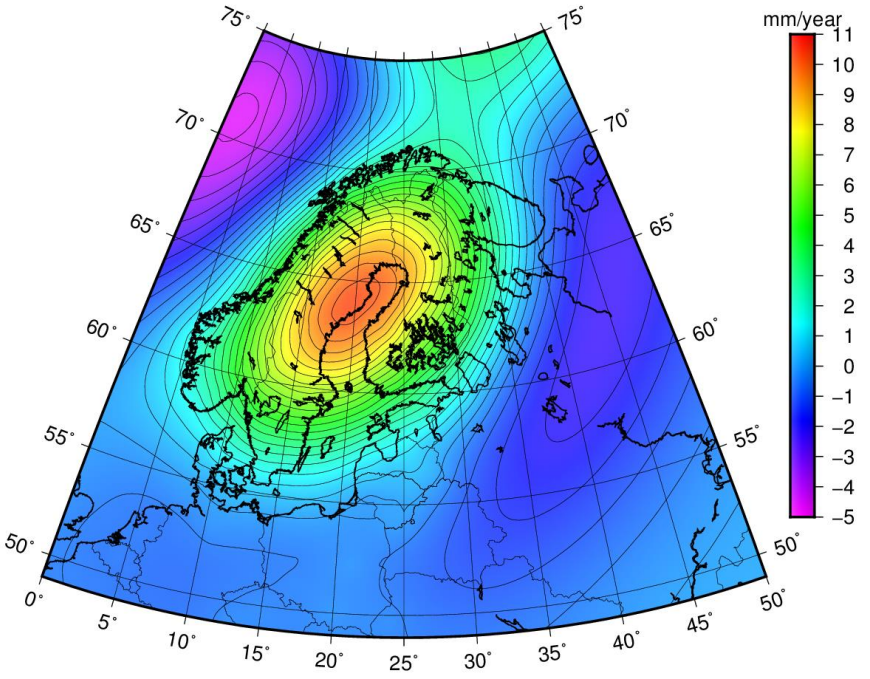
ITRF – International Terrestrial Reference Frame

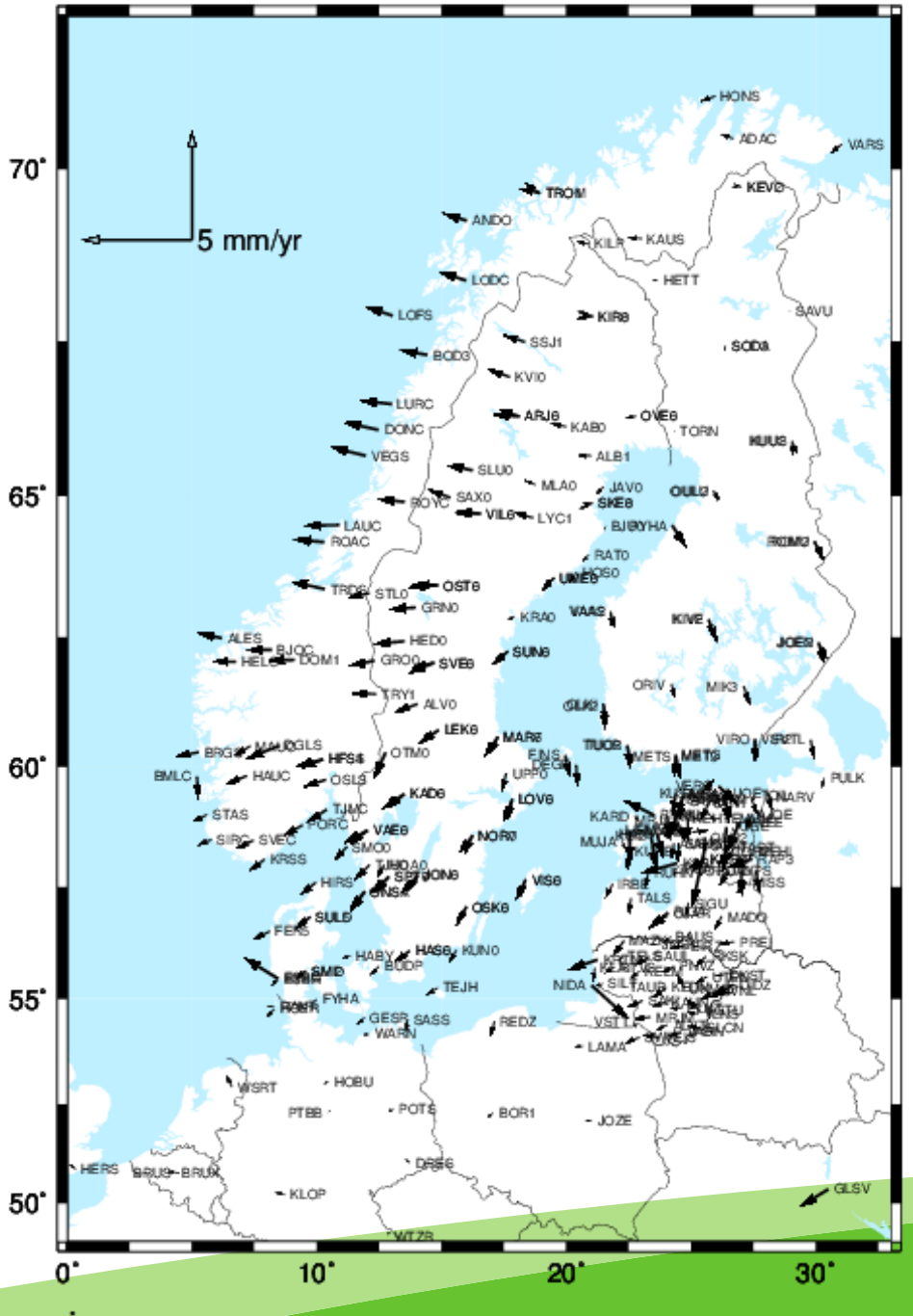


The Fennoscandia post glacial rebound

~0-10 mm/yr

NKG2016LU_abs





Deformations relative to the Eurasia tectonic plate

- Velocities usually <2 mm/yr.
- ETRS89 - The European Terrestrial Reference System 1989
- ETRS89 is mandatory for data exchange under the INSPIRE Directive 2007/2/EC, within EU member countries
- Most countries have realizations of ETRS89 as national reference frame
- In Sweden we have SWEREF 99

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Two principles

In presence of crustal deformations

Time tag everything! *(Mäkinen et al 2003)*

Whatever concept for geodetic reference frame we implement,

The knowledge of the crustal deformations are crucial!

Choice of appropriate Reference Frame

Dynamic, semi-dynamic, or static reference frame?

…well..

- Use recent ITRF in current epoch (dynamic/kinematic frame)

  This is how dynamic reference frames are realized in practice
  the position is dependent on the epoch (X,Y,Z,t) – the 2.5 cm/yr …

or

- A frame “fixed” to a part of the earth crust or a tectonic plate

  Positions much less dependent on the epoch – the <2mm/yr…
  This is part of the motivation behind ETRS89
  SWEREF 99 and other countries realization of ETRS89 are usually “**static frames**” at a specific epoch. Positions is e.g. (X,Y,Z) in SWEREF 99.

The transition from “current” to “future”

- The currently used geodetic reference frames are usually somehow “fixed to the ground” or an epoch realization of ITRF (“static” frames)
- *(Although ETRS89 is a secular frame, the national realizations are usually at a specific epoch)*
- We have enormous amount of important spatial related information that are based on the existing reference frames

- Message to geodetic authorities – make sure that the **precise relation** between the **existing frames** and recent **ITRF** (ITRF2014) are known (through transformations and deformation models)

Handling of Reference frame in SWEPOS

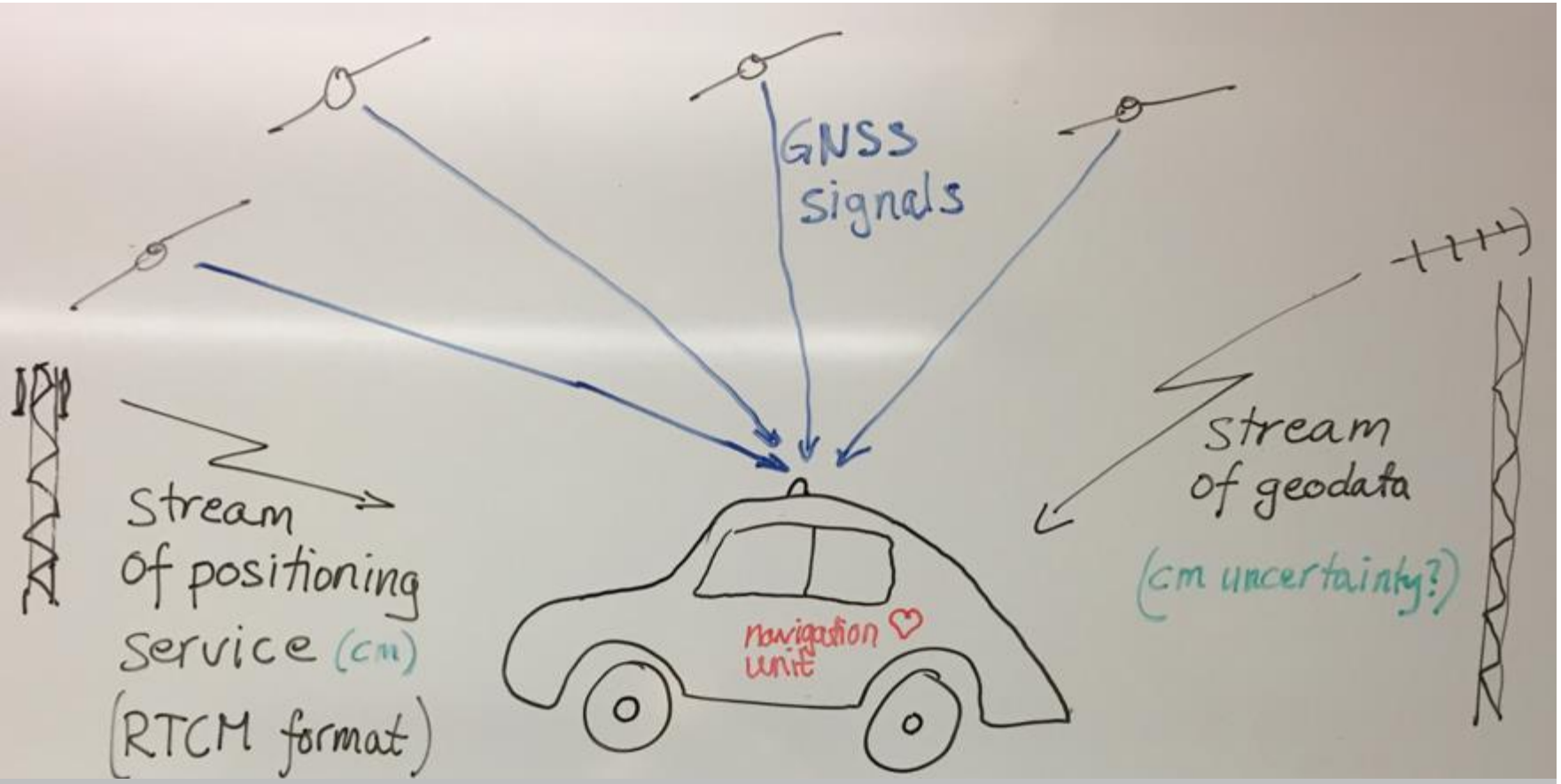
- short version

- The user get the position in SWEREF 99
- All permanent GNSS reference stations in the SWEPOS network have precise coordinates in SWEREF 99
- However, internally in the “network RTK software” at the SWEPOS operational center, we use precise satellite orbits in the “global reference frame” (from the International GNSS service, IGS). So the relation between SWEREF 99 and ITRF are used
- Similar situation in practically all countries in Europe.

Reference frames from GNSS??

- The GNSS providers (GPS, GLONASS, Galileo, BeiDou, QZSS, some more..) meet regularly within the UN International committee on Global Navigation Satellite Systems - ICG
- And have agreed to align their internally used reference frame to the realizations of ITRS, (where ITRF2014 is the most recent)
- Thus, they operate and provide positions to users in the "global geodetic reference frame" - at some uncertainty level
- E.g. WGS84 agree to ITRF at the sub-dm level
- Since **absolute positions** directly from GNSS are at the **"some meter level",** this has not been a major important topic from the user perspective
- But, if e.g. Galileo (and others?) provide precise real-time services at the sub-dm uncertainty level directly from the satellites, details of the reference frame will be important!

Standardization issues!



"Autonomous Navigation Integrity Monitoring"

The navigation unit needs to be able to verify that geodata and positioning service use the same reference frame!

Therefore we need reference frame information in the data streams.

And we need to include this possibility in our standards!

Thank you for your attention!

Discussions?