Future of Reference Frames – from Static to Dynamic?

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Future of Reference Frames – from Static to ~~Dynamic~~?

kinematic

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- Consequences of increased accuracy requirements
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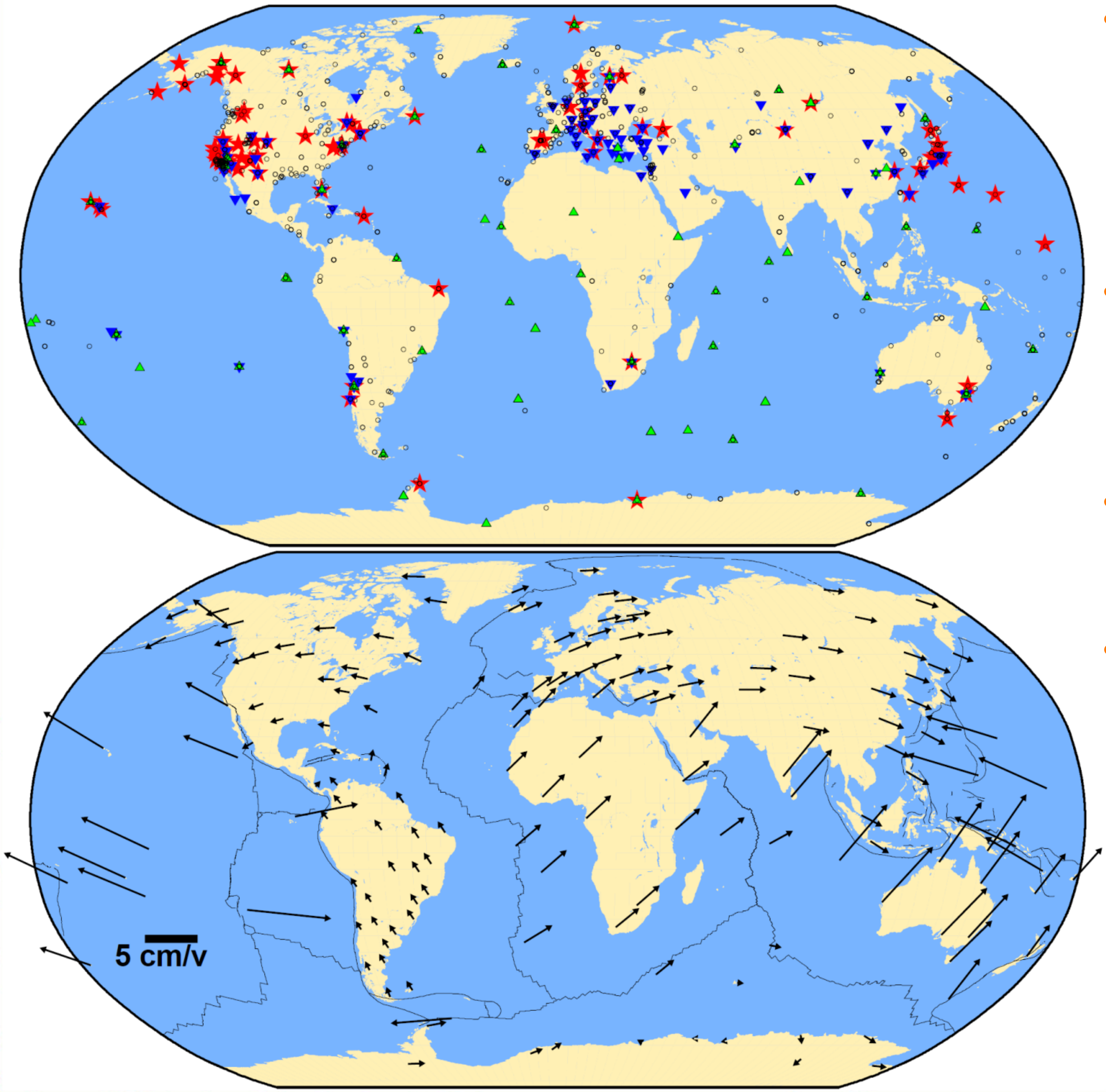
Technical development allows new ways of coordinate measurements

- *faster*
- *more cost effective*
- *more accurately*
- *in global system*

BUT: *What are the consequences? Are we ready? Do we have instructions and regulations? What legislation-related issues may arise?*

Global Reference Frame



- A reference frame is realized with a global network of permanent geodetic observing stations
- Stations defining the realization are on different continents
- Coordinates of stations are changing a few cm/year
- For practical purposes time-dependent coordinates have not been preferable

BUT: how in the future?

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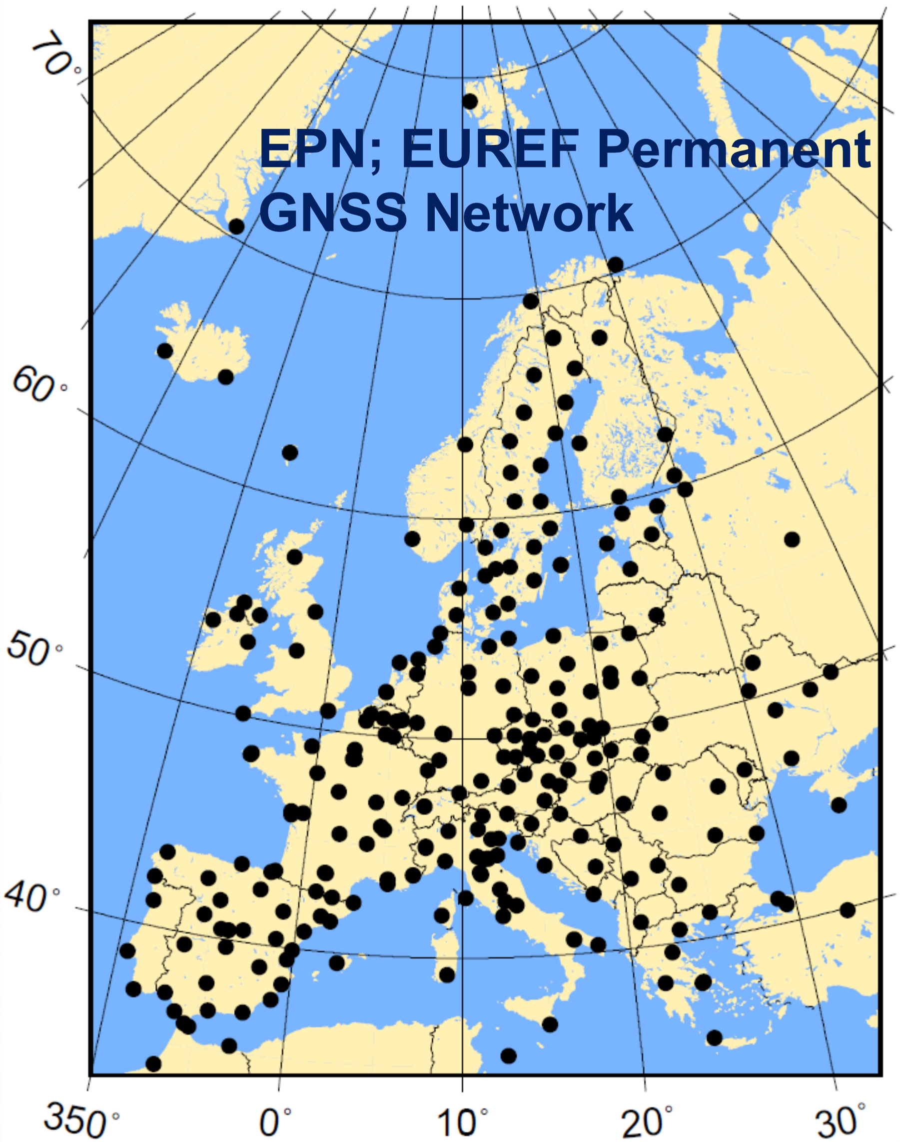
Regional Reference Frames



To overcome issues in global reference frame, regional systems / frames have been established

In Europe, ETRS89 -> ETRF2000

Fixed on and moving with the Eurasian continent

As the first approximation, station coordinates in ETRFxx will not change with time

ETRS89 based reference frames are in use in European countries;

Regulated by EU Directive INSPIRE

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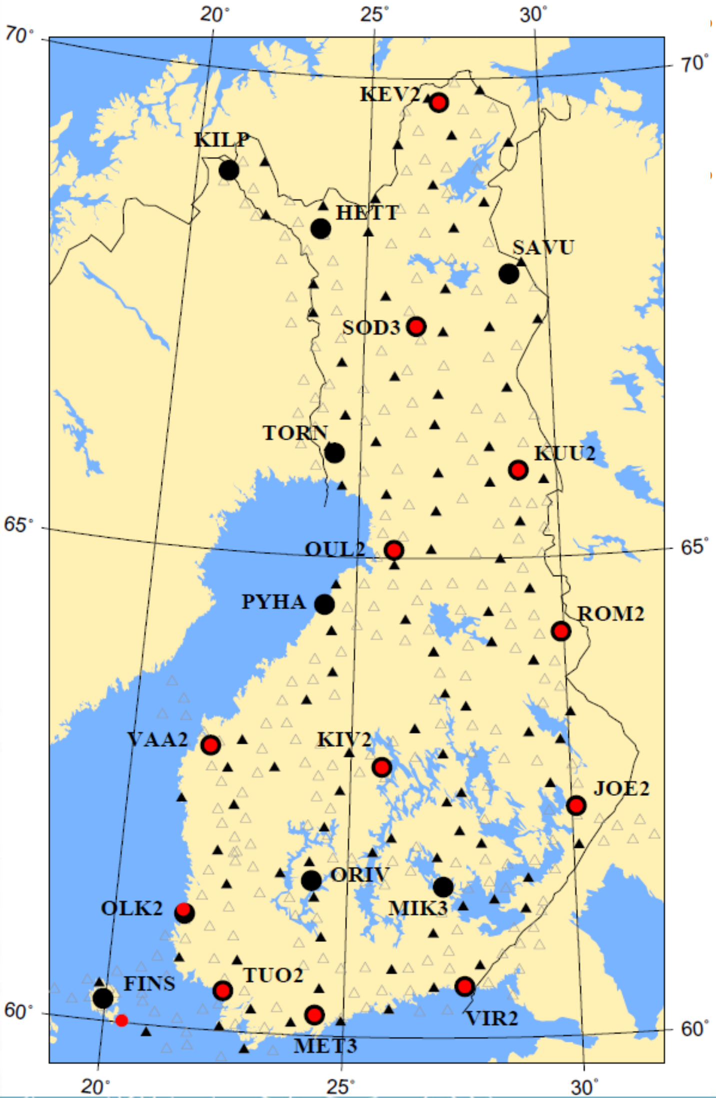
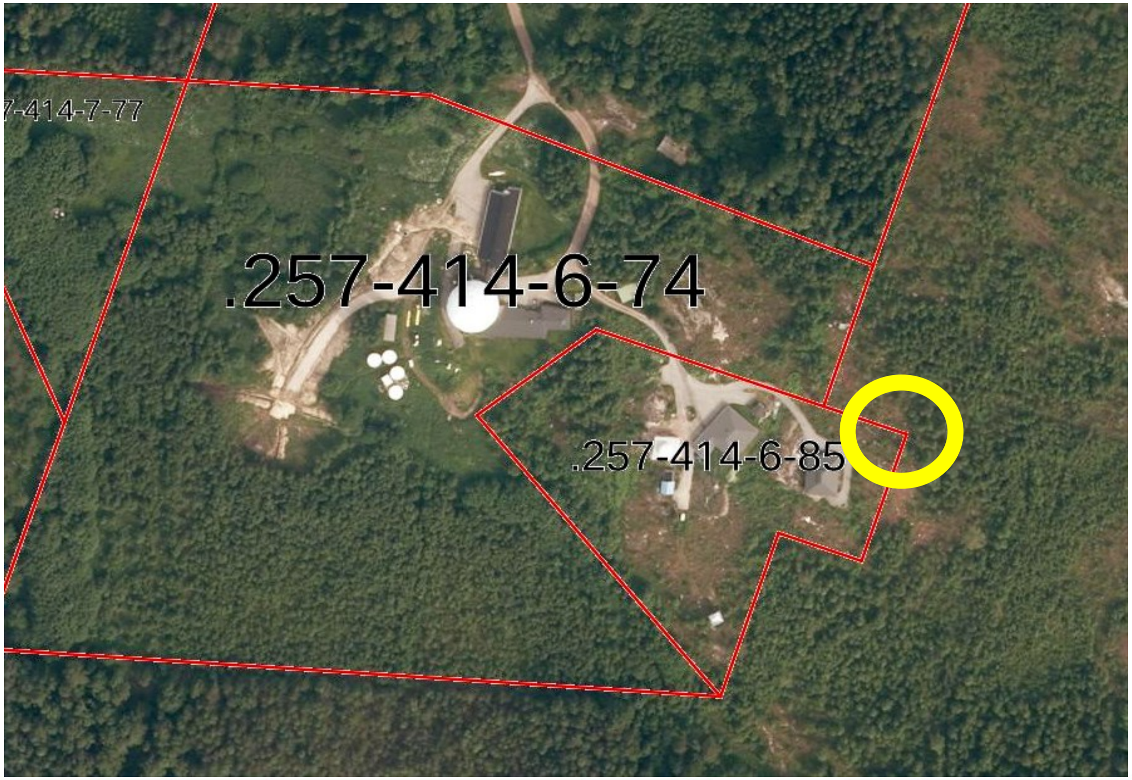
Local reference frames



- National and local reference frames are either based on ETRS89, or something else
- Traditionally, e.g. land information is based on coordinates in a local 2-D system



Crustal deformation

There are movements of reference points on several scales (excluding stability of the point itself)

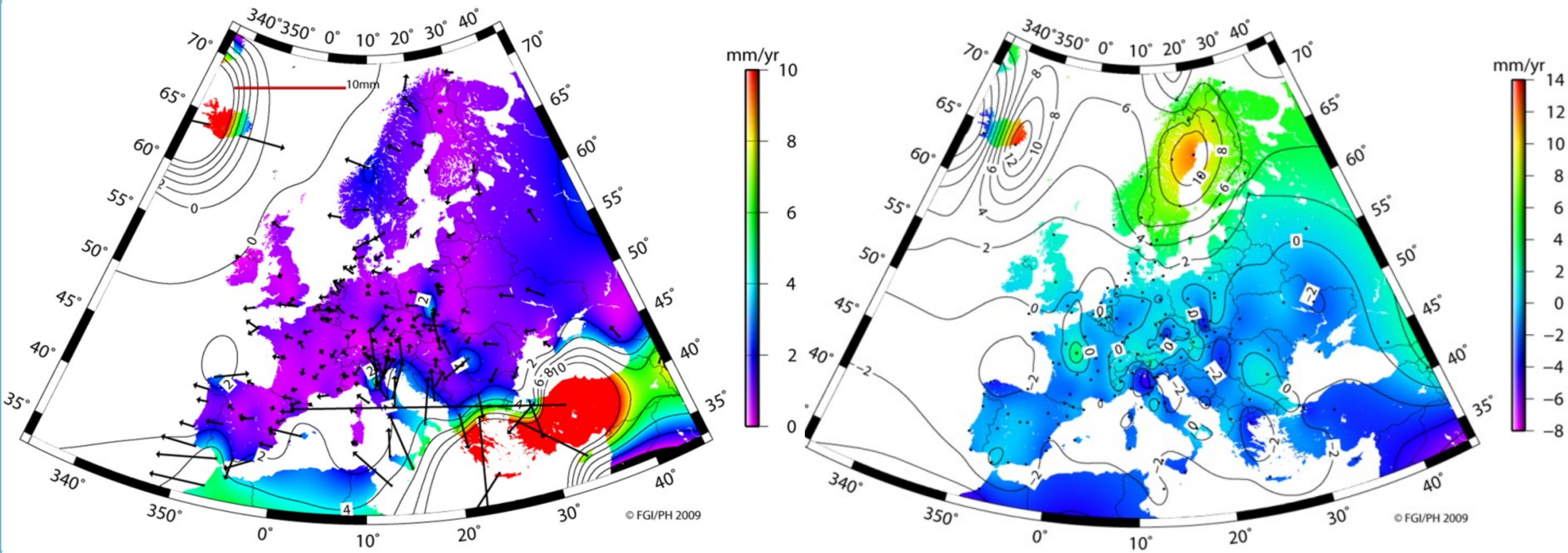
1. **Continents are moving** a few cm/year ⟶ absolute position on the Earth is changed

Since 1989 Eurasian plate has moved on Earth's surface about 80 cm

2. **Wide area movements within a continent**; as an example the post-glacial rebound in Fennoscandia and Canada or deformations at plate-margin areas
3. **Local abrupt movements**, like earthquakes or landslides
4. **Local slow movements**, like subsidence of ground, local tectonics, volcanos, … &c

To manage the temporal variation in our reference frame, we should know the movements better than 0.5 mm/year. **Only case 1 is predictable, partly case 2.**

Crustal deformation within a continent

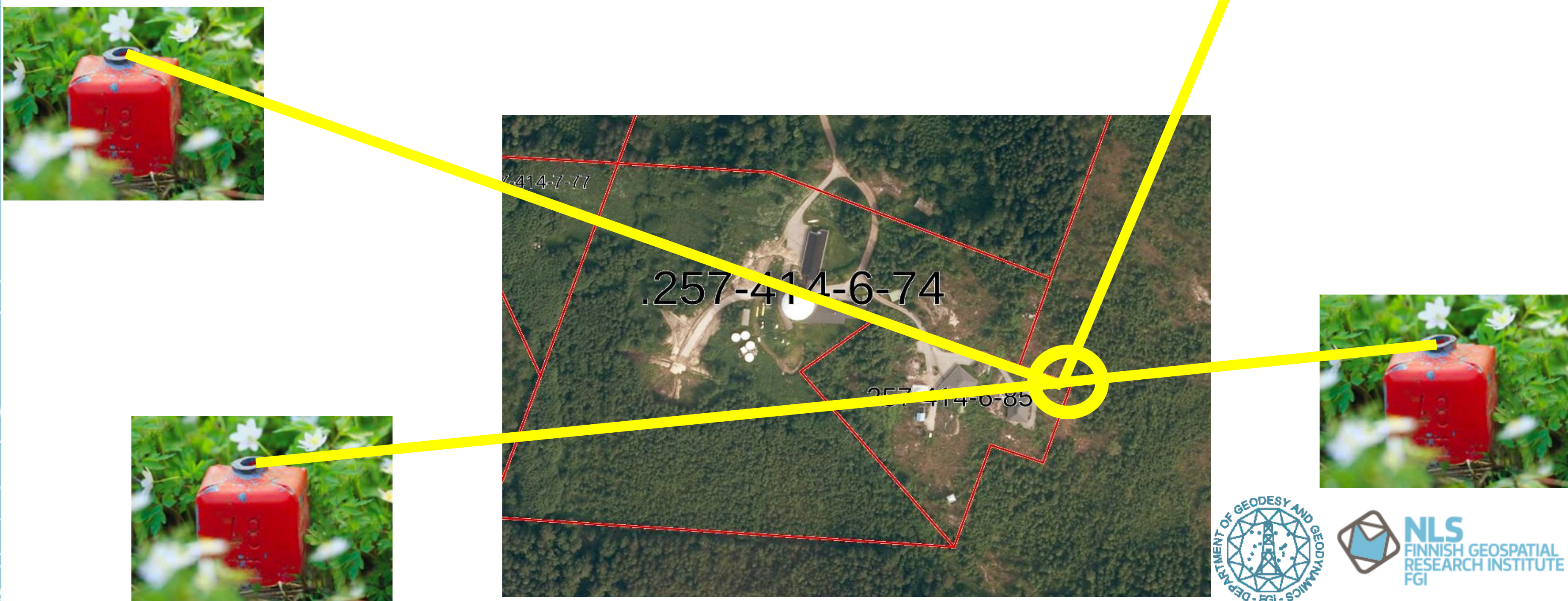


Horizontal and vertical deformation of Eurasian plate. There are large differences within the continent. No single model can describe the motion.

Continuous monitoring the motion, improving models, updating reference frames,…

Traditional way to measure

- Fixed benchmarks, relative of which measurements are made
- GNSS receivers on every point (or RTK)
- **New points are automatically in the same reference frame**
- Coordinates need update only if the whole reference frame is changed



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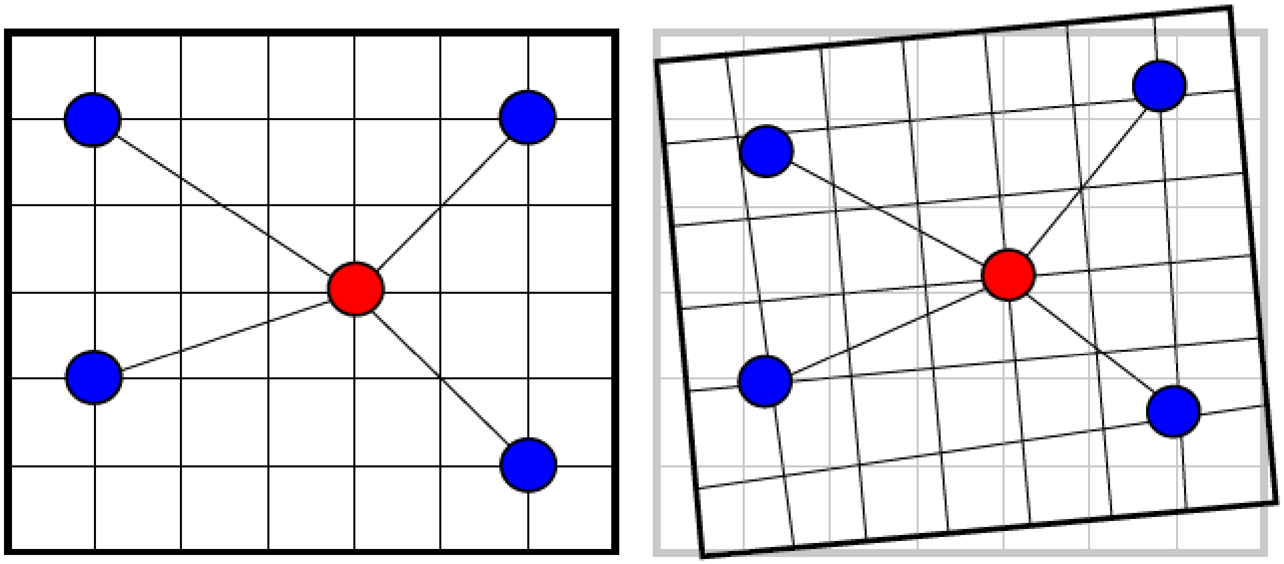
Deformations degrade coordinates



- Coordinates of fixed points are kept unaltered
- Coordinates of new points will be affected by the deformation
- One cannot apply full accuracy of GNSS measurements
- Renewal of the whole system is labourous, expensive and cannot be done very often

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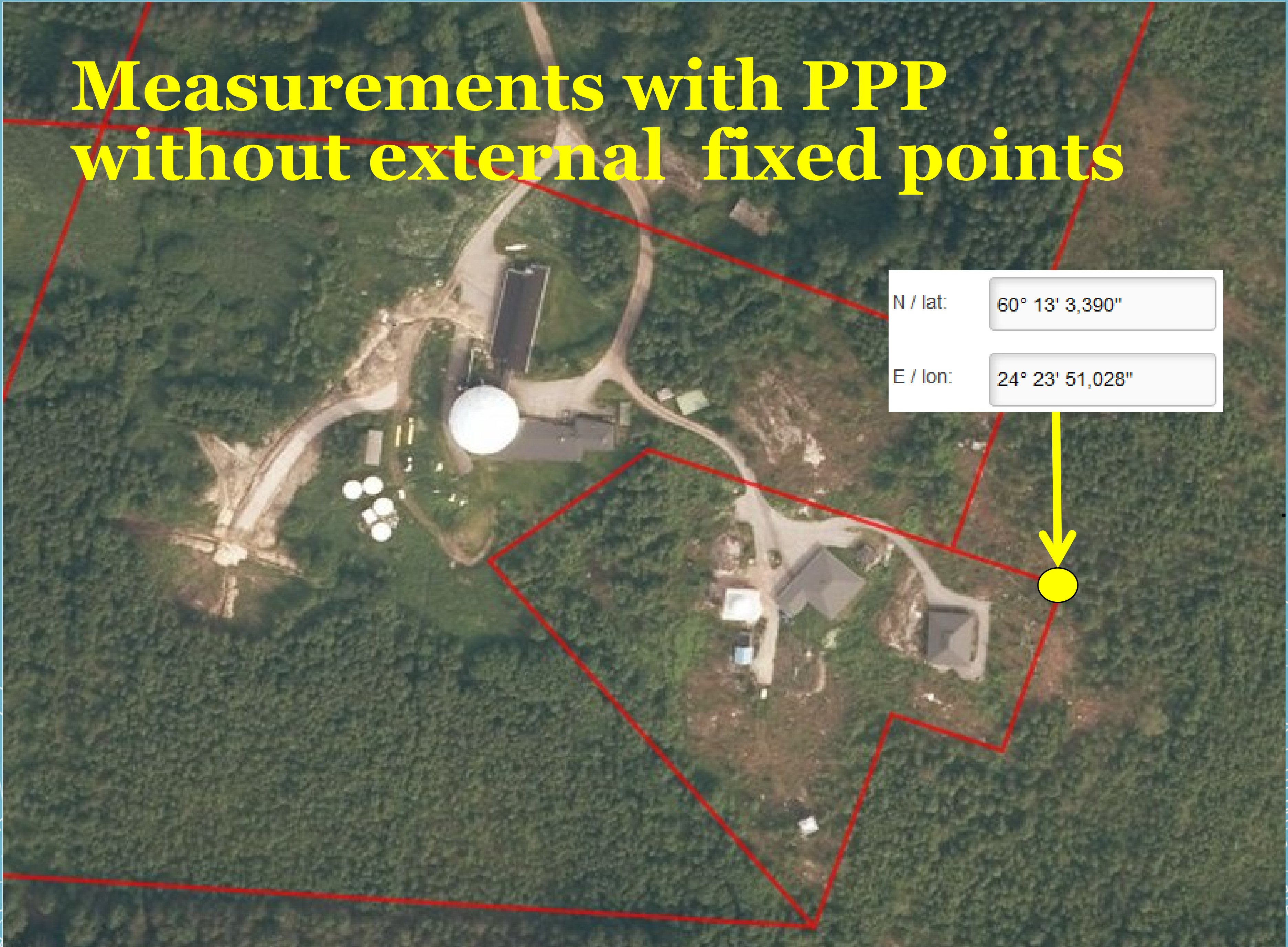
Measurements with PPP without external fixed points



Fixed coordinates point on a different place every time !

…or we keep the place fixed, every time it has different coordinates

- Coordinates are in the global reference frame at the epoch of the measurement
- Every time we get **different coordinates for the same point** due to crustal movements and deformations
- If we keep **coordinates fixed, they point to a different place**
- To get the measurement show the same point we must change the coordinates
- We should know crustal movements within 0.5 mm/yr everywhere
- But we don’t and we can’t

Passive and active reference frame

- **Passive reference frame**
  - Definition based on coordinates of **passive (fixed) benchmarks on the ground** (traditional situation)
  - Typically no velocities, just (static) coordinates
  - Challenging to maintain in case of deformations, e.g. positioning services
- **Active reference frame**
  - Definition based on coordinates of **active (CORS) stations**
  - Possible to estimate (reliable) station velocities in addition to coordinates – enables handling of deformations
  - Challenges related to instrument changes and aging, changing conventions etc.

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Static:
benefits and challenges

- Traditional situation with **passive benchmarks – all geospatial data in a (static) regional/national system** (e.g. ETRS89/EVRS-based coordinates):
  - \+ No time evolution, no need to fix an epoch
  - \+ Simple to maintain registers
  - \- The whole reference system is getting ”old”, especially in case of crustal deformations; renewal necessary in regular intervals
  - \- Technical development and new methods allow more precise measurements; uncertainties in the old system becomes visible
  - \- Establishment of benchmarks
  - \- Renewal process slow and expensive → needs to find a method to extend the lifetime of a reference system

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Semi-dynamic: benefits and challenges

- **Positioning in a global** (dynamic/kinematic) ITRS-based coordinates, **registries in national** (static) ETRS89-/EVRS-based coordinates. **Transformation, including a deformation model,** takes care of deformations and guarantees accuracy between the global and national coordinates

  + Enables accurate positioning without deformations
  + All coordinates are transformed with the same procedure and parameters, relative accuracy within the network handled through a transformation
  + Simple to maintain registers
  - Small time dependency due to uncertainties in transformation; need to add epoch information
  - One needs to know crustal deformation everywhere in the area
  - Uncertainties increase with time

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Dynamic: benefits and challenges

- **Everything in global** (dynamic/kinematic) ITRS-based **coordinates** – typically an active reference frame and access based on a positioning service (or even PPP)
  - \+ All coordinates are available in real-time (or transformable to any epoch) and thus they are accurately reflecting reality
  - \+ Cost effective, no passive benchmarks or network needed
  - \- Time dependent; every time new coordinates are given to the same point
  - \- Challenge to register maintenance; measurement epoch and 3-D velocity of the point must be known; old values must be kept as well
  - \- How to identify the same point at different epochs (e.g. land owning issues…) if no physical markers
  - \- What about physical heights? Currently no global/international dynamic/kinematic frame exist…

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Consequences and actions if we move from static reference frames to semi-dynamic or dynamic

Example: cadastre ≈ coordinate reference system + precise positioning + current registry information + legal issues

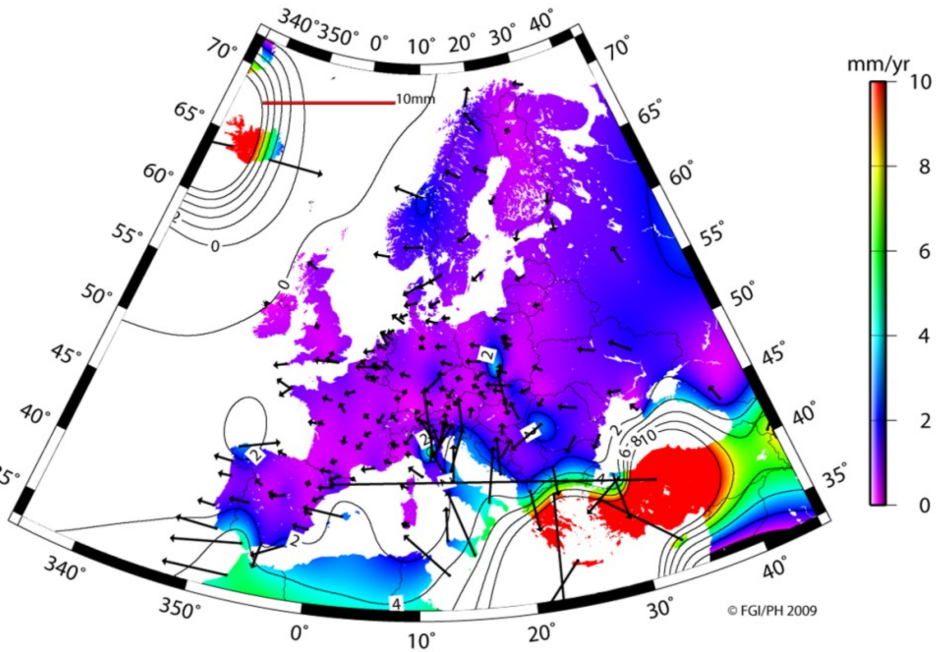
	Datum type	Precise positioning 3	Reference system in registers	Changes to current register	Legal issues
Now	Static	ETRS89 (regional)	ETRS89 EVRS 2	None	None
Near future	Semi-dynamic	ITRS (global) 1	ETRS89 EVRS 2	None	None(?)
Future?	Dynamic	ITRS (global)	ITRS, IHRS(?) 2	Positions: N,E,H →X,Y,Z,VX,VY,VZ,t 1	Changing coordinates

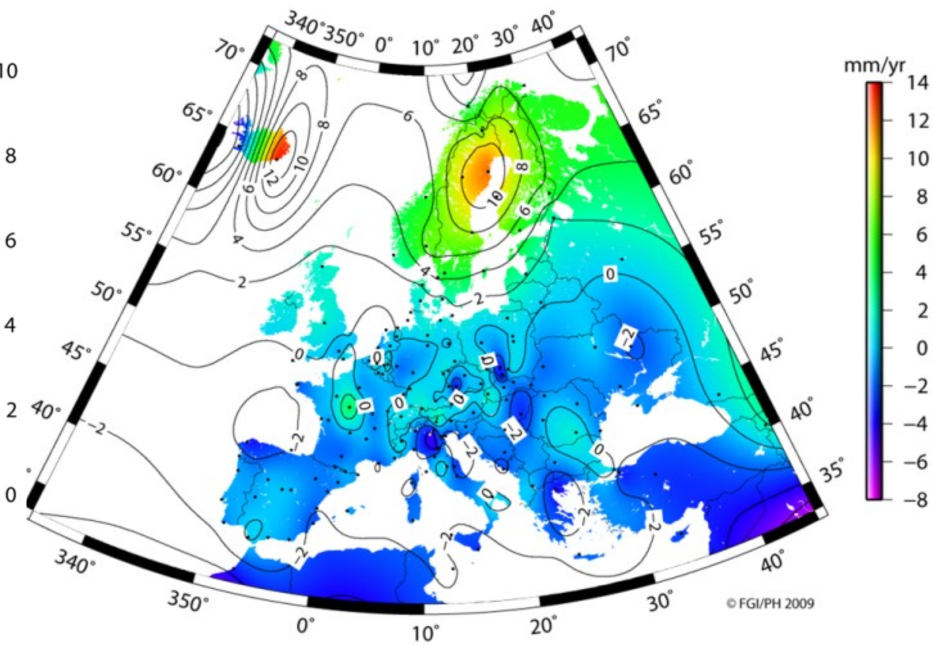
N 1 **Improved land uplift model (3D) and practices**

K 2 **Improved Geoid model (ETRS89→EVRS)**

G 3 **Improved positioning (techniques)**

Deformation models / dense velocity fields are needed





Different needs in different part of Europe
Do we have good enough information today?

EUREF WGs to study this topic

We need to do almost the same things:

- **Static**: No transformation, computation directly in a national frame; fixed coordinates at fixed place. Deformations degrade accuracy

- **Semi-dynamic**: Coordinates from positioning transformed to regional/local frame during the measurements, **velocities needed**. Users will see fixed coordinates in a regional/local frame. From users view, only a slight difference to the current situation. Active reference points (permanent GNSS stations)

- **Dynamic**: Geospatial data (in registers) transformed to current epoch if one needs to compare to positioning (or to common epoch with different data sets), **velocities needed**. Users will see changing coordinates. No passive reference points; all in the global system.

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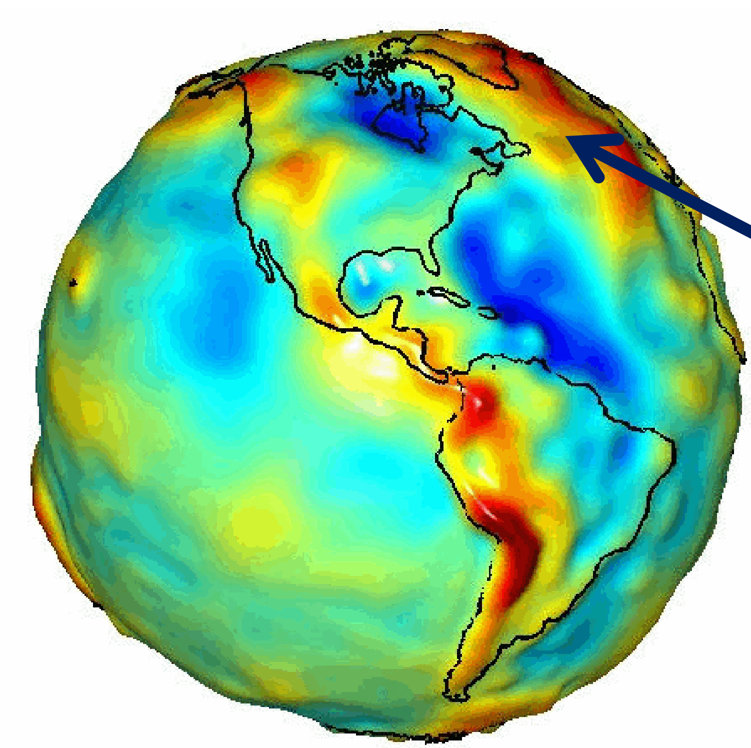
Thank you for your attention!



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