GNSS ellipsoidal heights to LAT and NAP
What reference frame at what epoch?

Lennard Huisman

Nederlandse Samenwerking Geodetische Infrastructuur
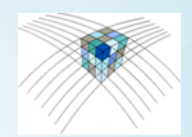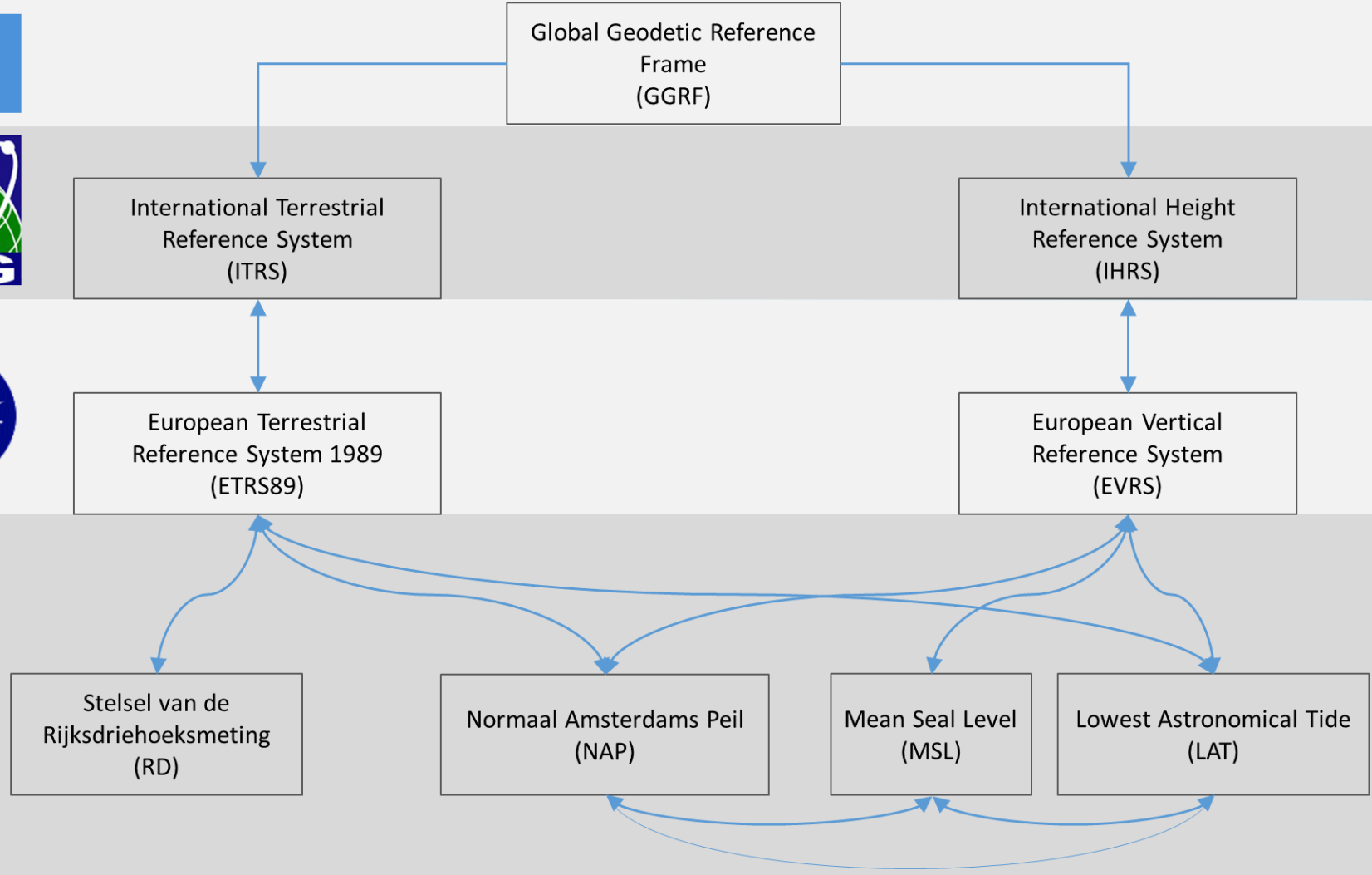
$$\mathbf{x}_R(t) = \mathbf{d}(t) + s(t)\mathbf{R}(t)\mathbf{x}_G(t)$$

TUDelft

Deltares Enabling Delta Life

STW connecting innovators

Rijkswaterstaat Ministerie van Infrastructuur en Waterstaat
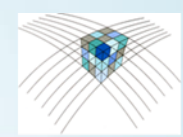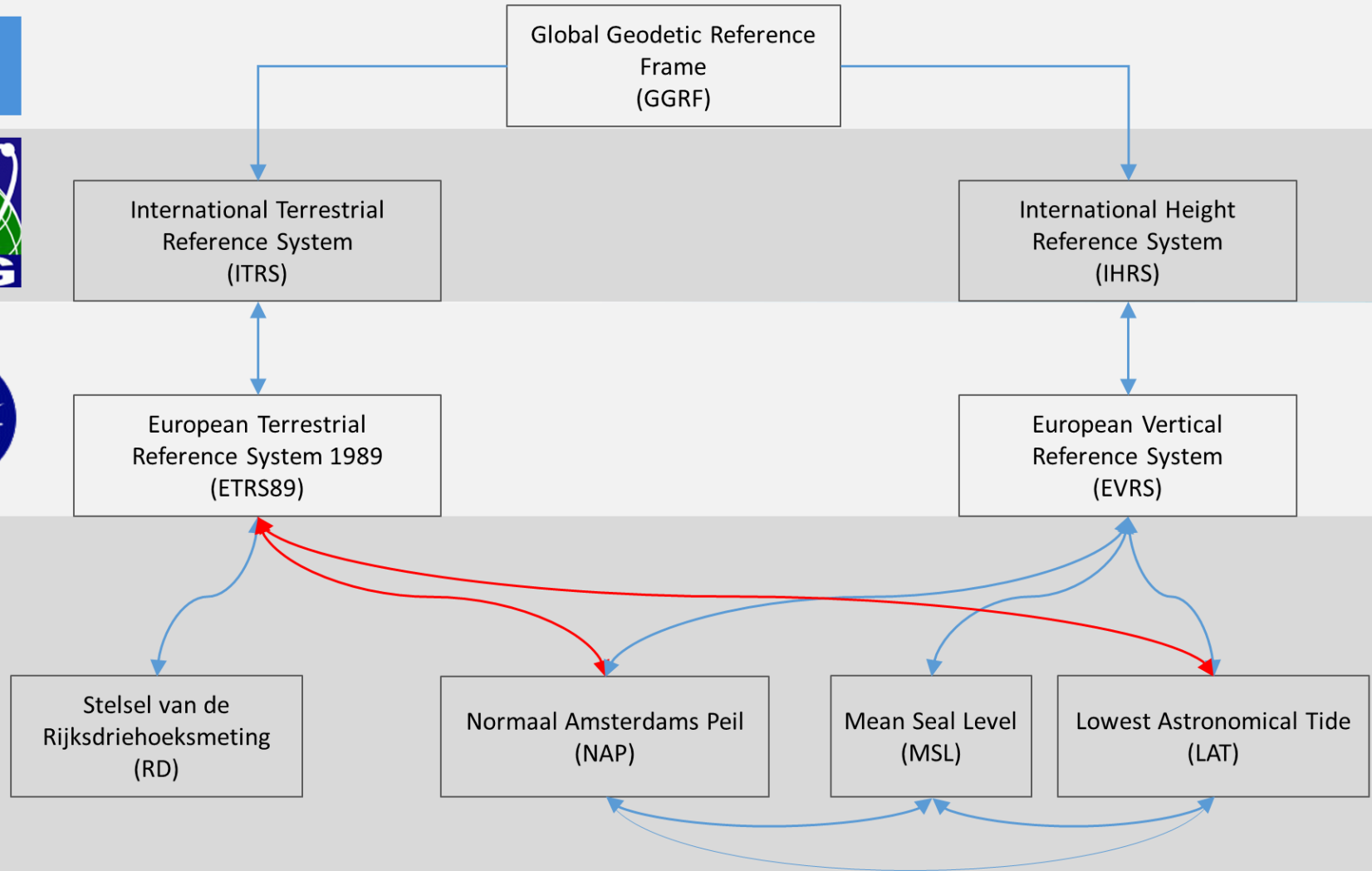
Koninklijke Marine

Outline

- Relation between reference systems
- ITRS and ETRS89
- National realisation of ETRS89
- Transformations between ITRFxx and ETRFxx
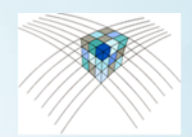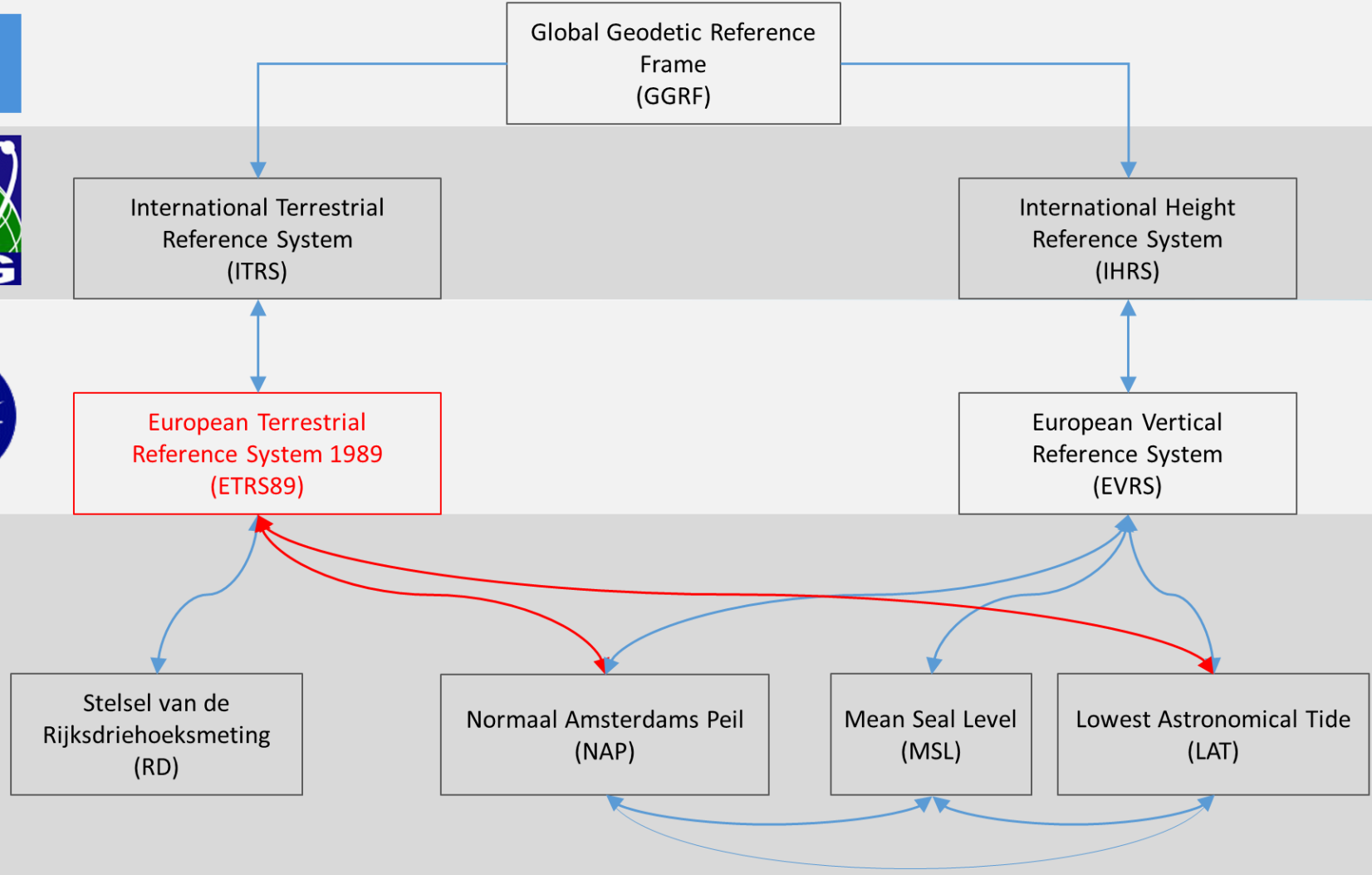
Relation between reference systems

Todays topic: NLLAT2018 and NLGEO2018
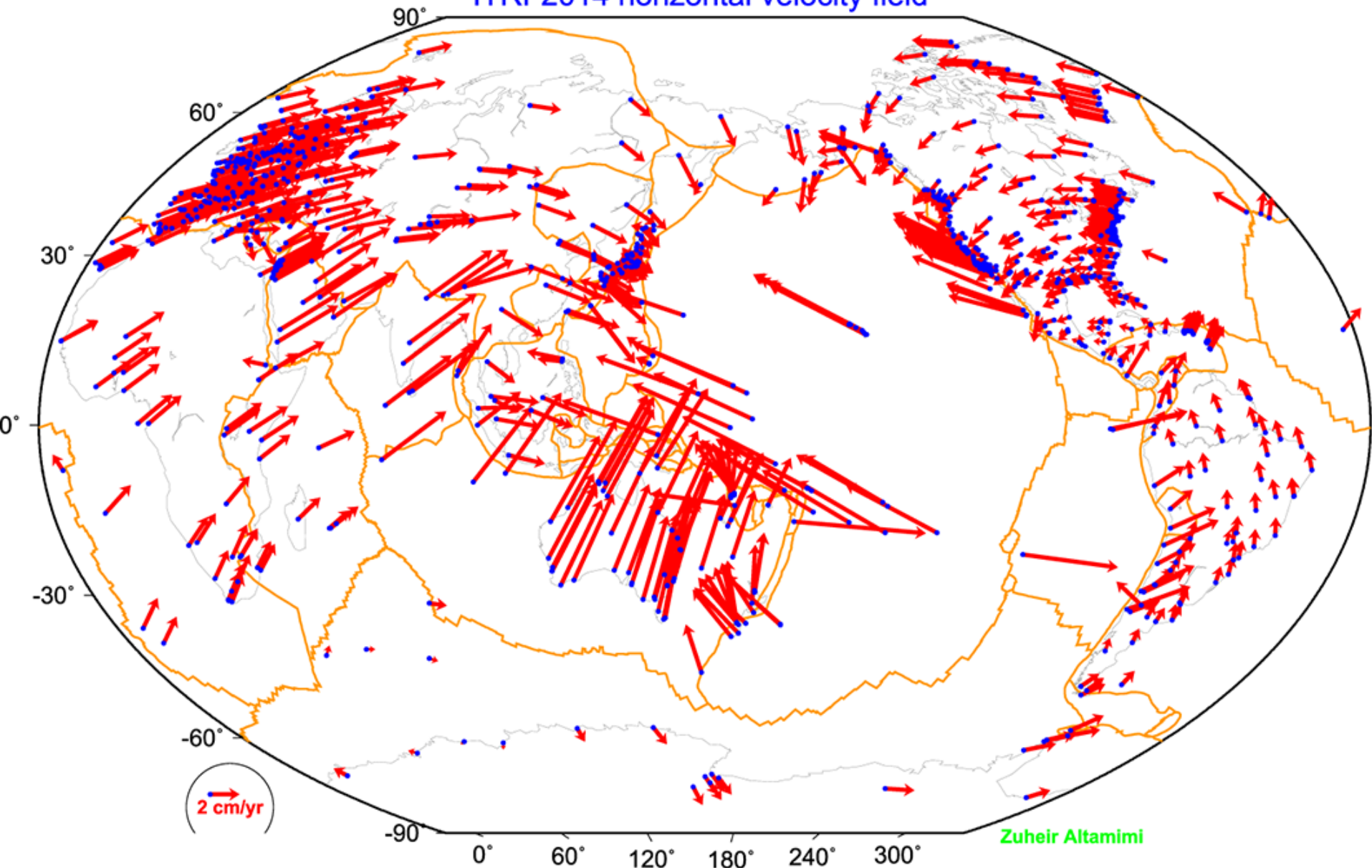
How to get an ETRS89 height?

International Terrestrial Reference System

- Basis for international reference frames
- Used to determine
    - Variations in earth rotation
    - Variations center of mass
    - Precise satellite orbits
    - Plate tectonics

ITRF2014 horizontal velocity field



2 cm/yr

Zuheir Altamimi

TUDelft   Enabling Delta Life   **Deltares**   STW connecting innovators   Rijkswaterstaat Ministerie van Infrastructuur en Waterstaat   Koninklijke Marine

European Terrestrial Reference System 1989
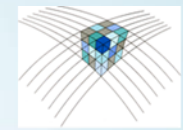
- Coincides with ITRS at epoch 1989.0: ITRF89@1989.0 = ETRF89@1989.0
- Moves with 'stable part of Europe'
- Goal: Stable coordinates in Europe
- Used for:
    – Exchange of European spatial data
    – Netherlands geo information on North Sea
    – Geodynamic studies in Europe
- Basis for precise GNSS positioning in the Netherlands (data collection for BGT, BRK, AHN, Beeldmateriaal, …)
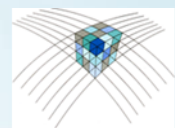
ETRF2000 horizontal velocities
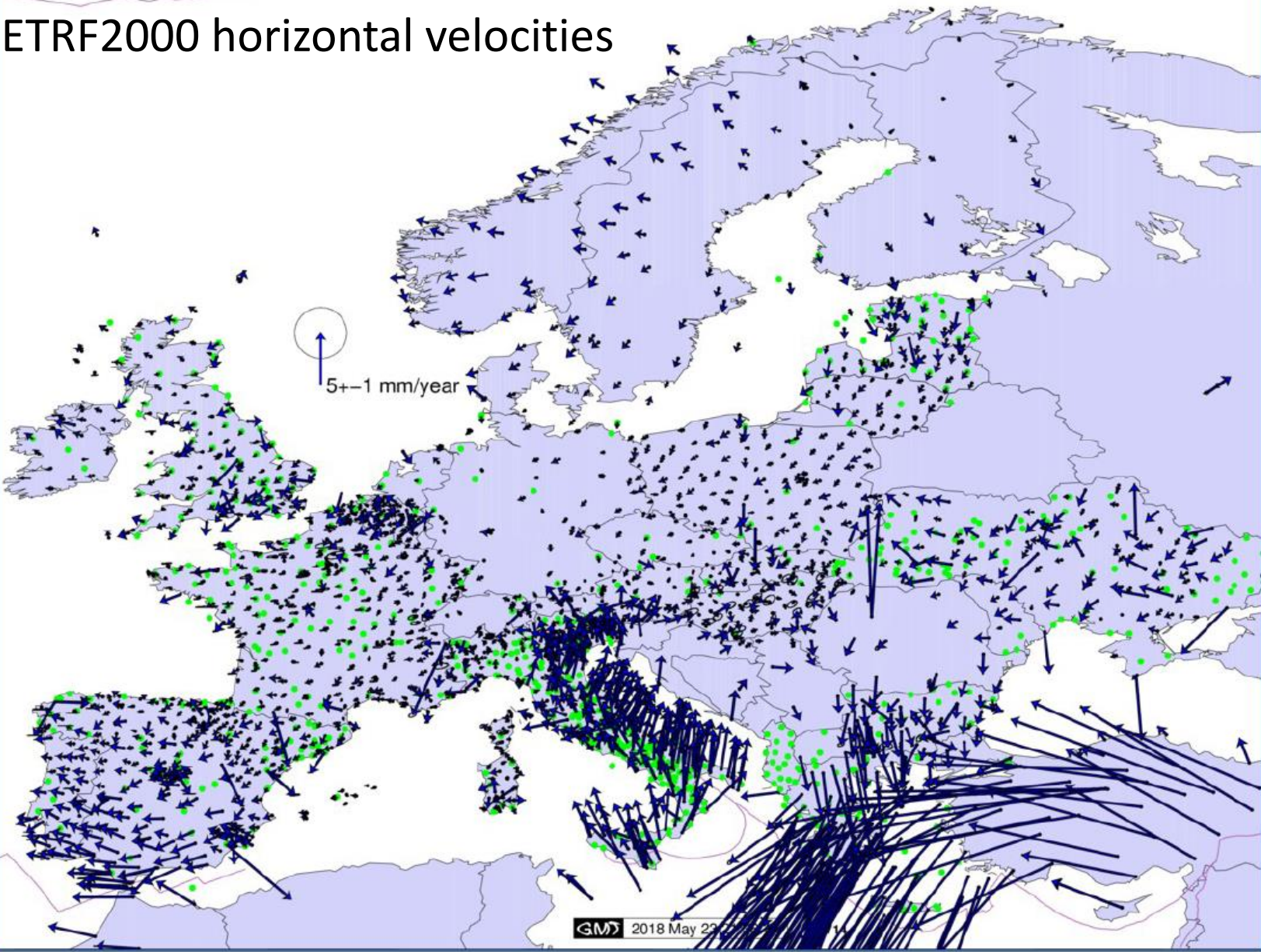
Bron: A. Kenyeres, *EPN Densification WG: Where to go?, EUREF Symposium 2018, Amsterdam, Netherlands*

Realisation of ETRS89 by GNSS: AGRS.NL

Procedure

365 x (meta)data

Daily solution using BSW52

365 x

- Coordinates and velocities IGS reference stations (IGS14)
- Models, IERS conventions
- IGS final products

Final solution: IGS2014@2017.5

Transformation from ITRF2014 to ETRF2000(R14)

Final solution: ETRF2000(R14)@2017.5
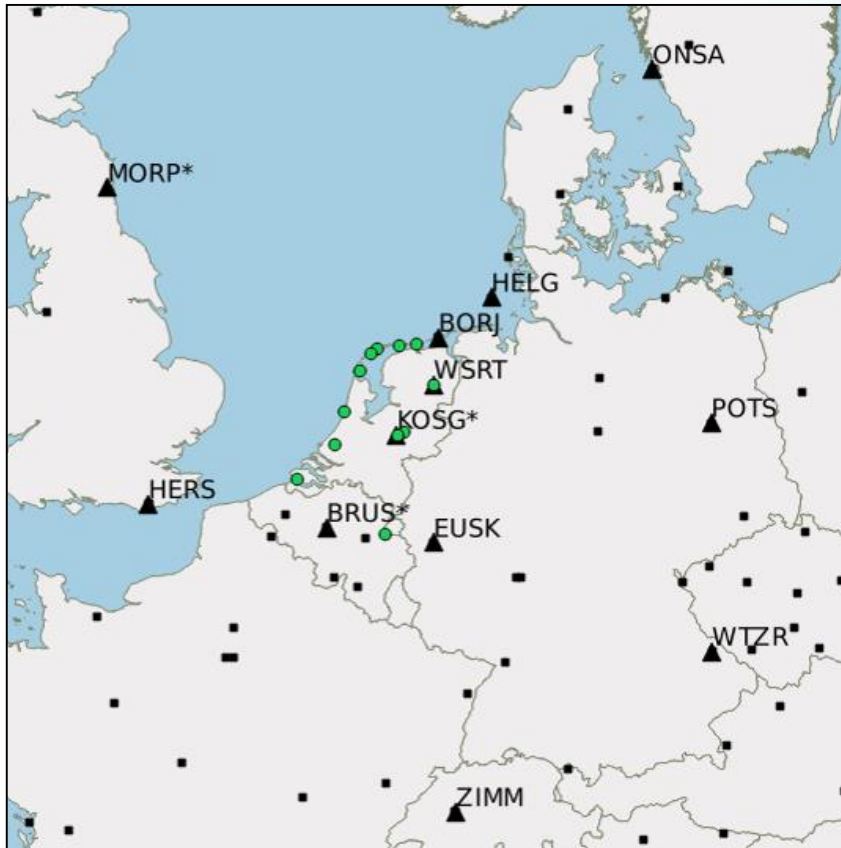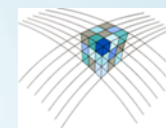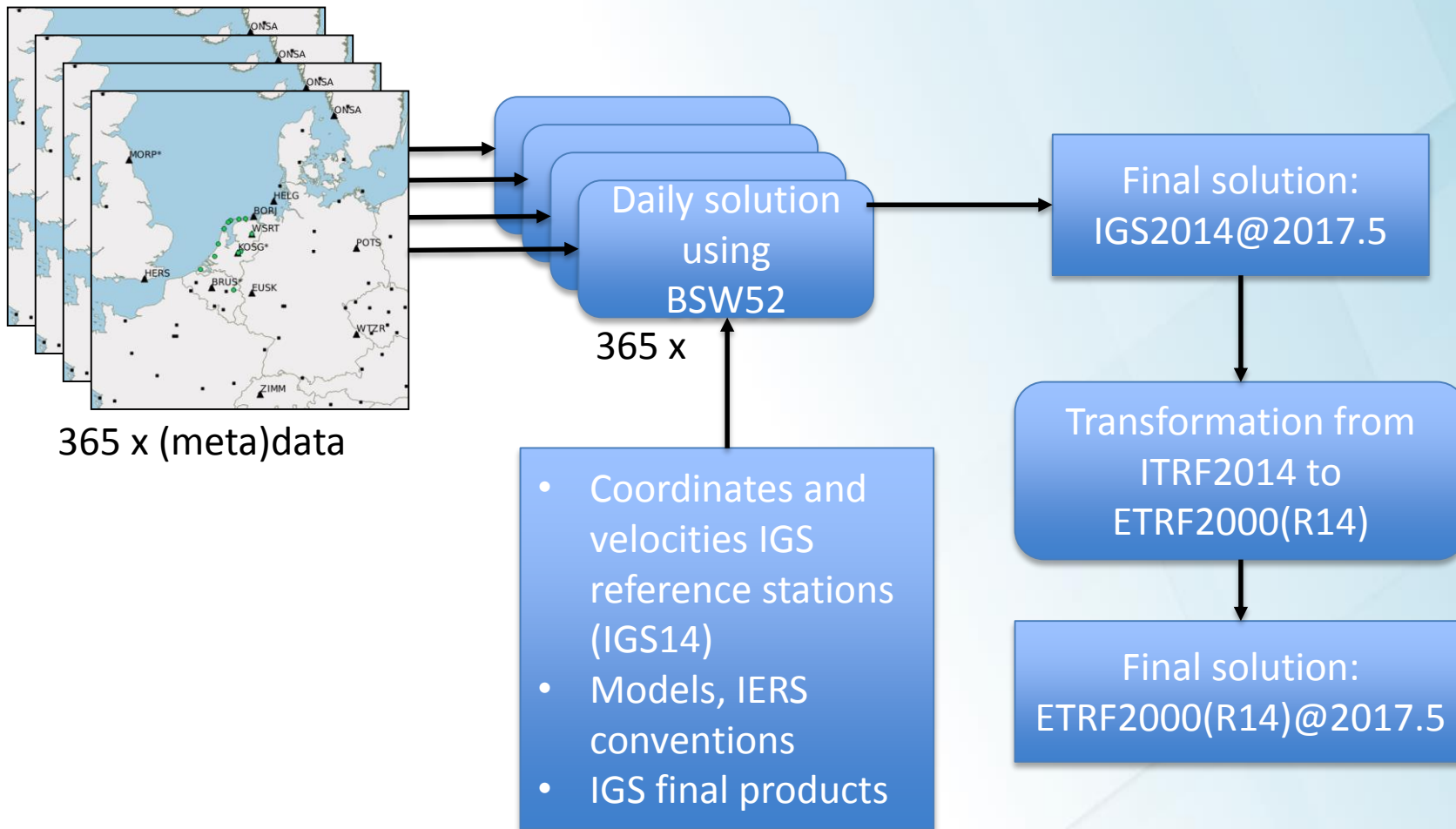
From ETRF2000(R14) into LAT and NAP using NLLAT2018 and NLGEO2018

Certification of GNSS reference stations

- Common reference frame for precise GNSS-positioning

From ITRFxxxx into LAT and NAP using NLLAT2018 and NLGEO2018

Transformation between ITRFxx and ETRF2000

- EUREF Technical Note 1: Relationship and Transformation between the International and the European Terrestrial Reference Systems
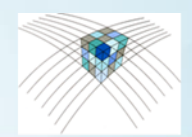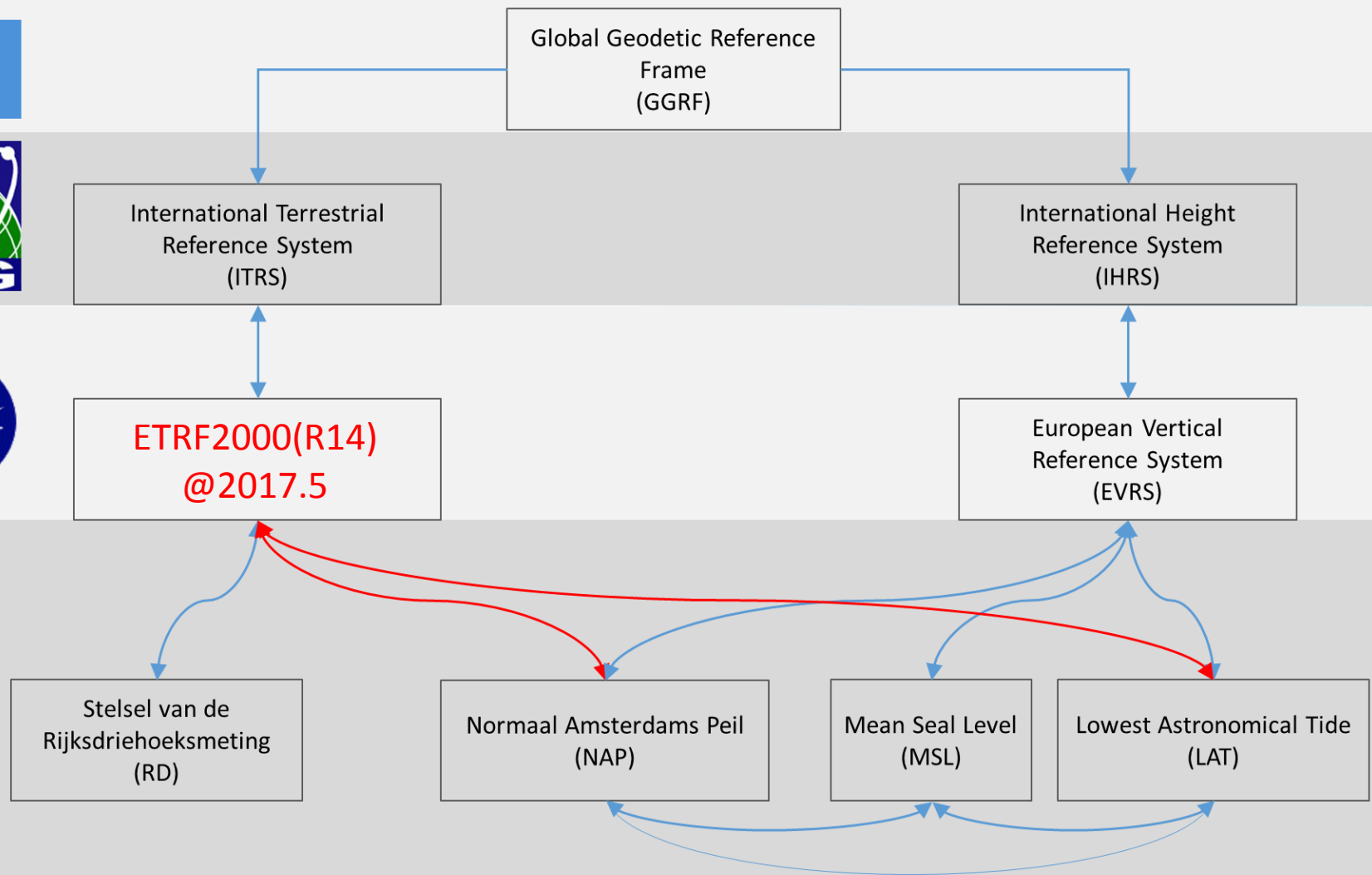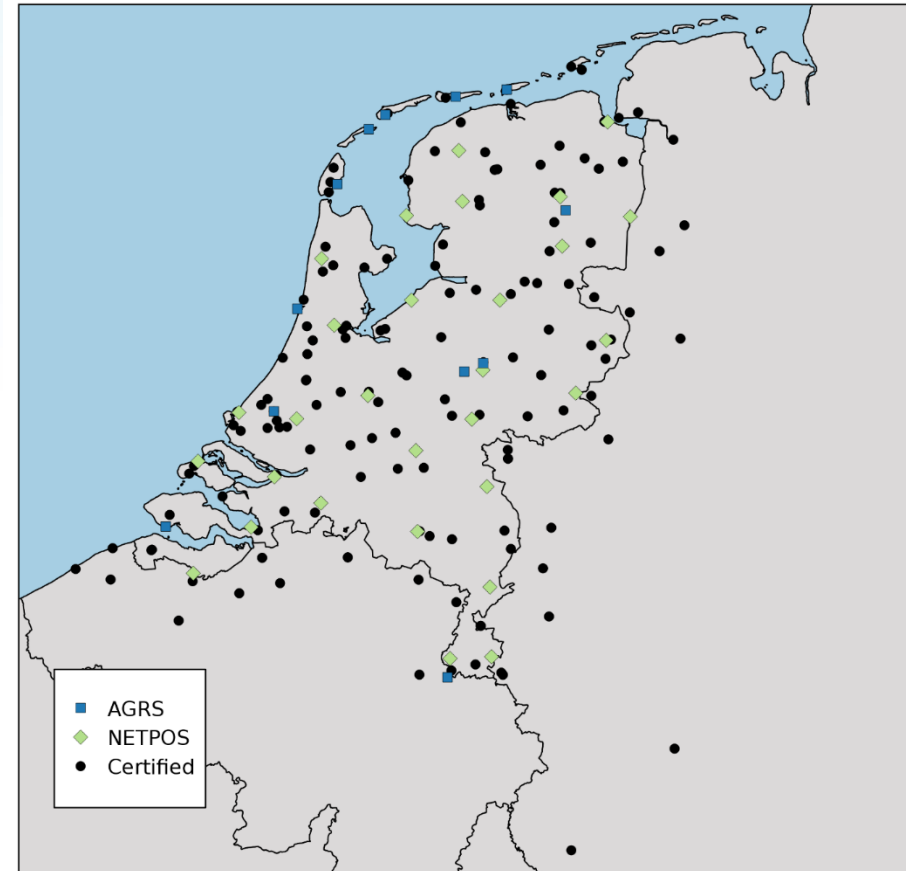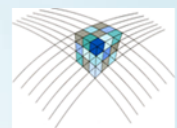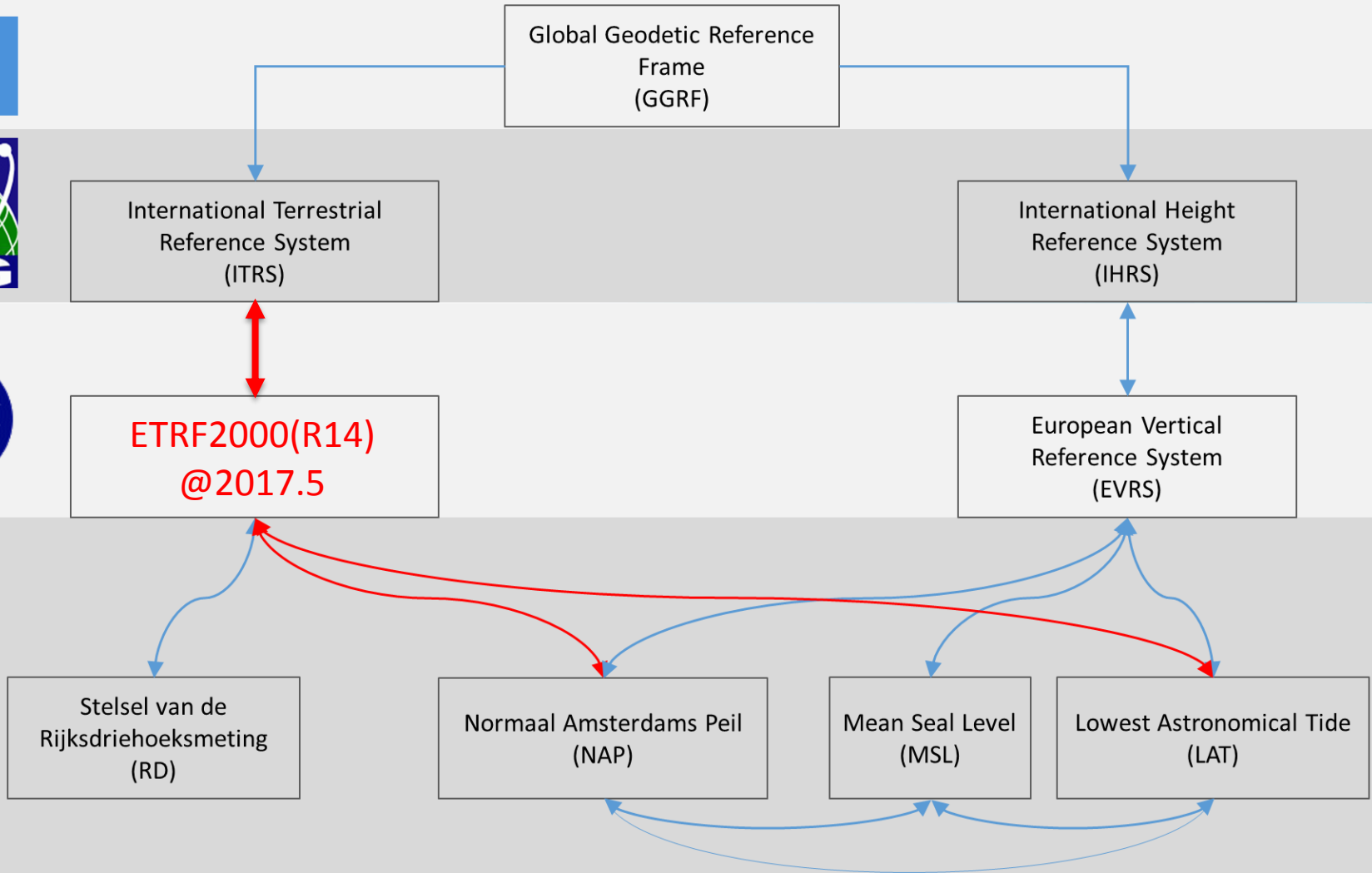
Table 3: Transformation parameters from ITRF$_{yy}$ to ETRF2000 **at epoch 2010.0** and their rates/year

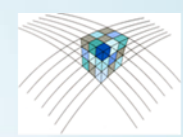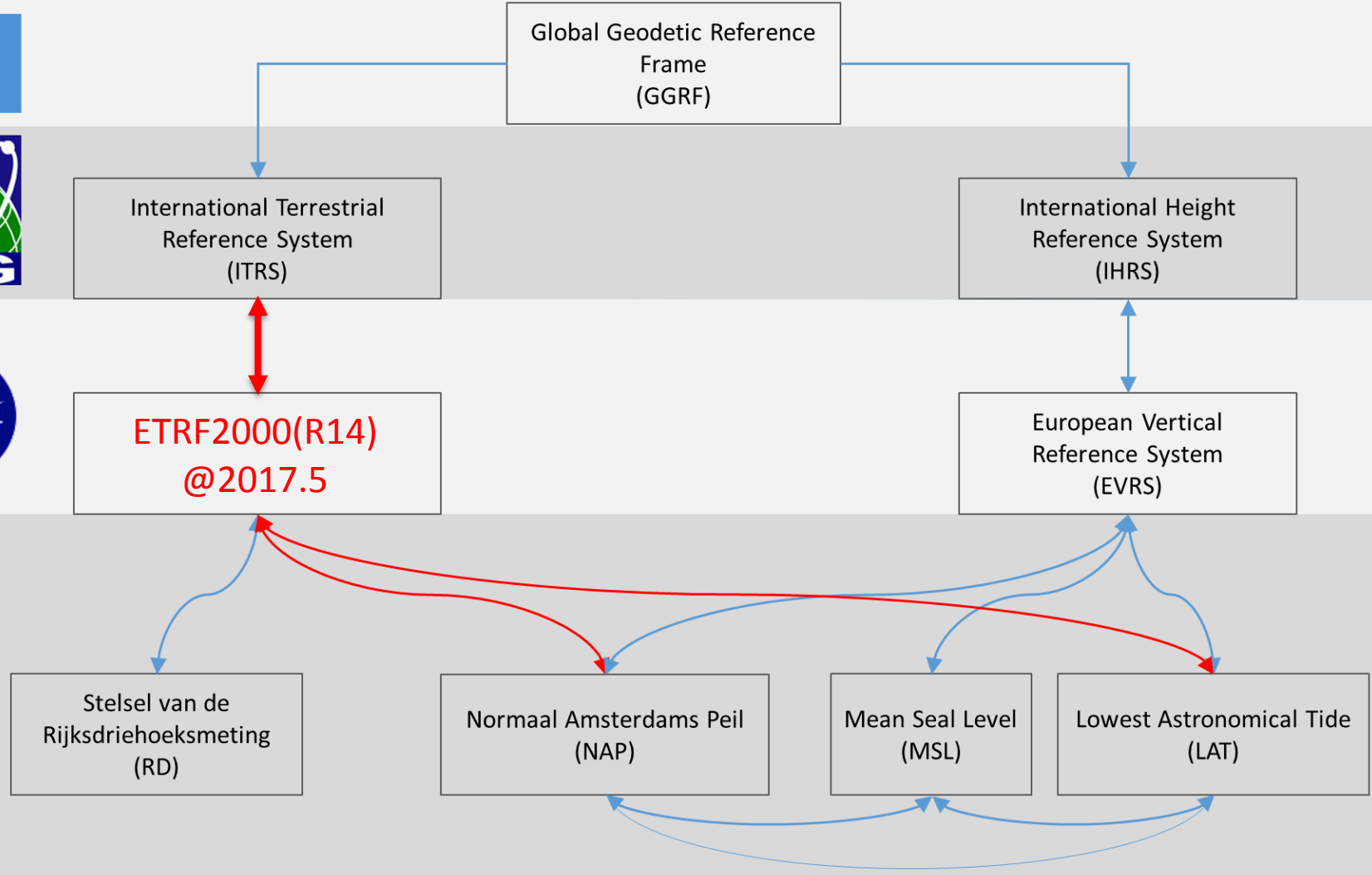| ITRF Solution	T1 mm	T2 mm	T3 mm	D 10^{-9}	R1 mas	R2 mas	R3 mas
ITRF2014	54.7	52.2	-74.1	2.12	1.701	10.290	-16.632
rates	0.1	0.1	-1.9	0.11	0.081	0.490	-0.792
ITRF2008	53.1	50.3	-76.5	2.14	1.701	10.290	-16.632
rates	0.1	0.1	-1.8	0.08	0.081	0.490	-0.792
ITRF2005	52.1	51.2	-71.8	1.20	1.701	10.290	-16.632
rates	-0.2	0.1	-1.8	0.08	0.081	0.490	-0.792
ITRF2000	54.0	51.0	-48.0	0.00	1.701	10.290	-16.632
rates	0.0	0.0	0.0	0.00	0.081	0.490	-0.792
ITRF97	47.3	52.7	-11.3	-1.68	1.701	10.290	-16.892
rates	0.0	0.6	1.4	-0.01	0.081	0.490	-0.812
ITRF96	47.3	52.7	-11.3	-1.68	1.701	10.290	-16.892
rates	0.0	0.6	1.4	-0.01	0.081	0.490	-0.812
ITRF94	47.3	52.7	-11.3	-1.68	1.701	10.290	-16.892
rates	0.0	0.6	1.4	-0.01	0.081	0.490	-0.812
ITRF93	105.1	48.9	-13.9	-2.17	4.511	13.670	-17.032
rates	2.9	0.2	0.6	-0.01	0.191	0.680	-0.862
ITRF92	39.3	50.7	-3.3	-0.97	1.701	10.290	-16.892
rates	0.0	0.6	1.4	-0.01	0.081	0.490	-0.812
ITRF91	27.3	36.7	2.7	-2.37	1.701	10.290	-16.892
rates	0.0	0.6	1.4	-0.01	0.081	0.490	-0.812
ITRF90	29.3	40.7	18.7	-2.67	1.701	10.290	-16.892
rates	0.0	0.6	1.4	-0.01	0.081	0.490	-0.812
ITRF89	24.3	16.7	56.7	-6.07	1.701	10.290	-16.892
rates	0.0	0.6	1.4	-0.01	0.081	0.490	-0.812
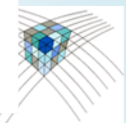
Assume constant height in NAP
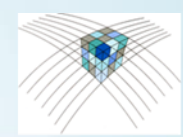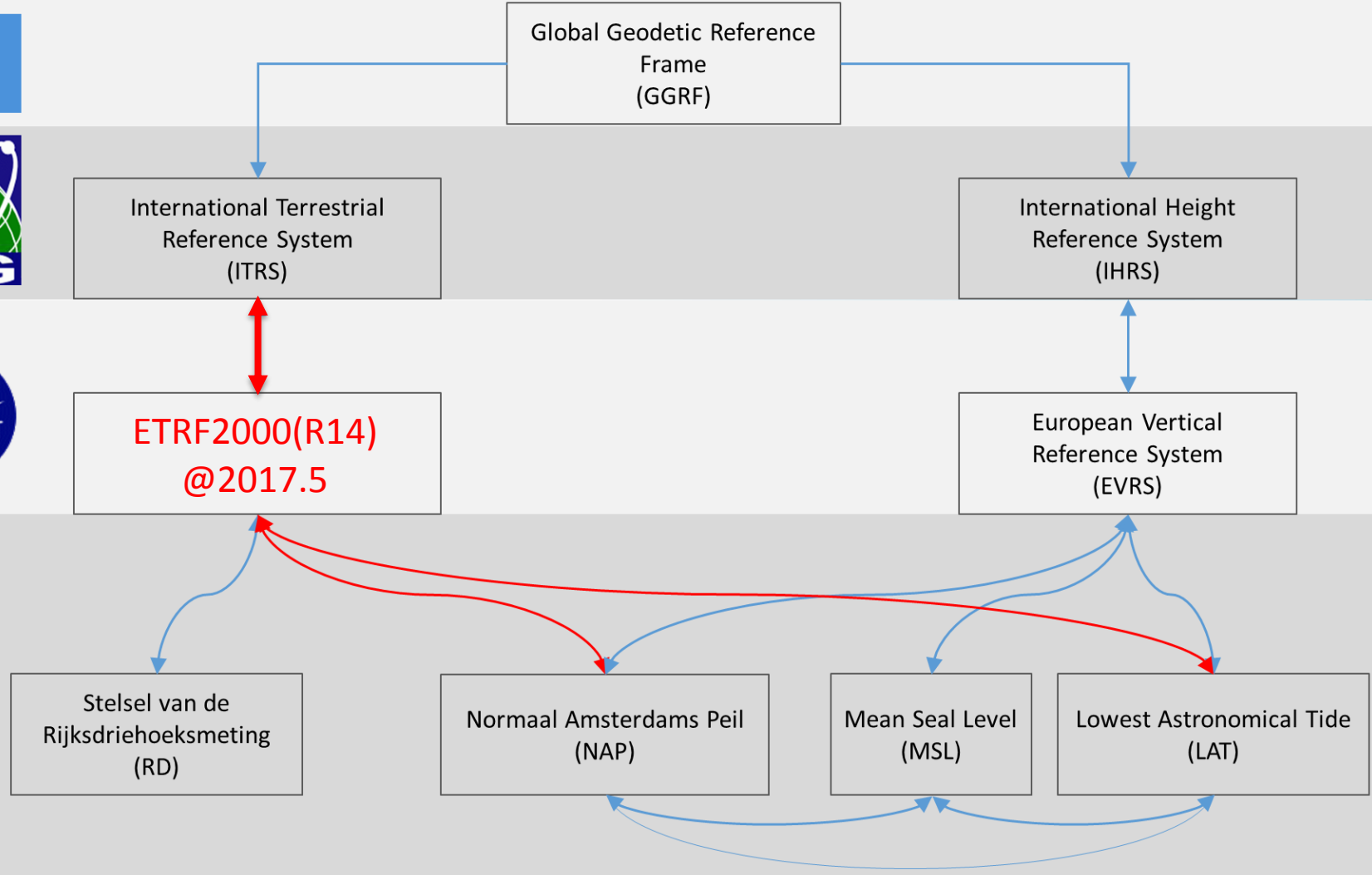
And then I received a simple question…

Geoid and LAT have been computed in ITRF2005@1997.9

- How to deliver a geoid in ETRF2000@2017.5?
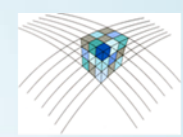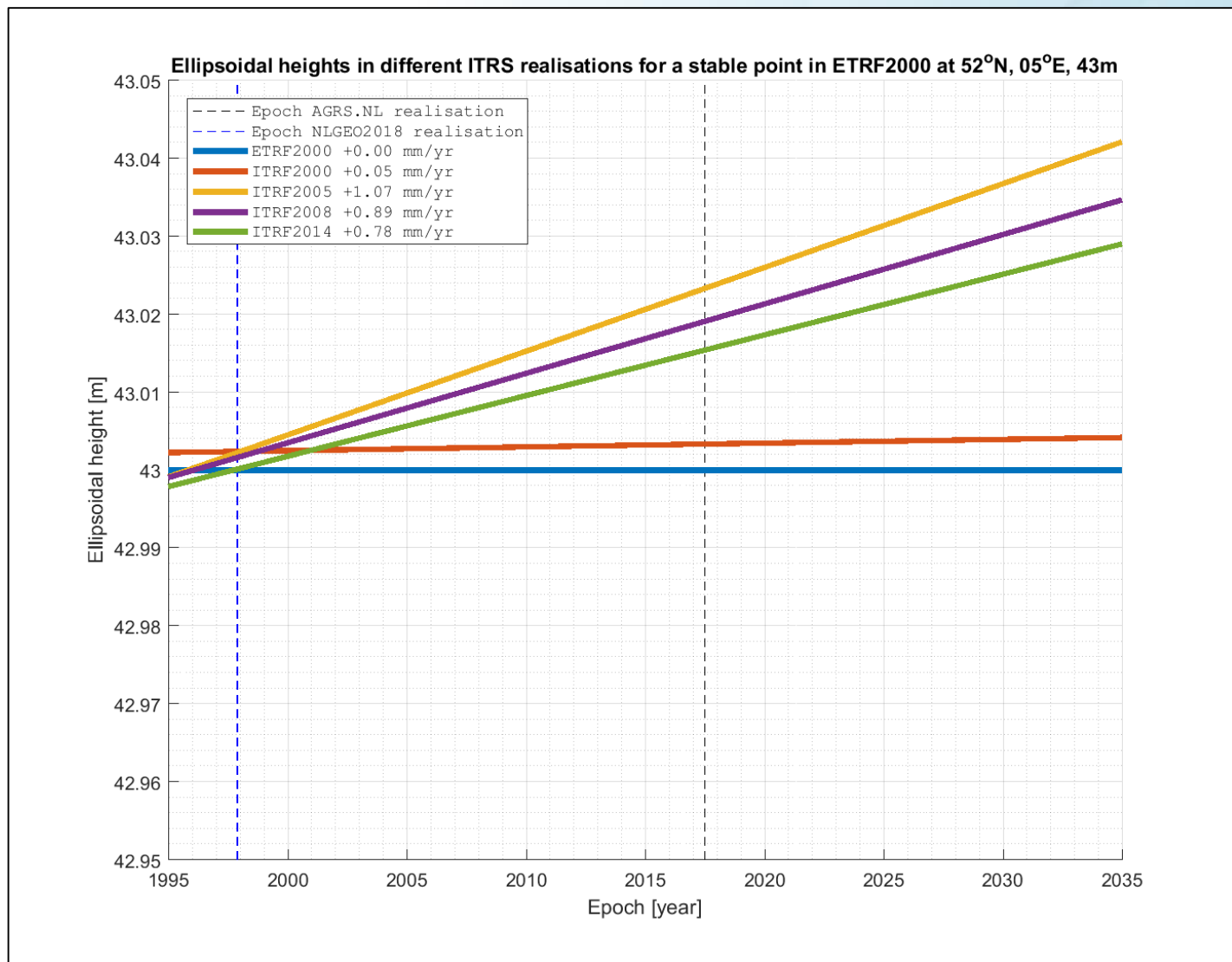- How to transform from ITRF2014@2020 to ETRF2000@2017.5?

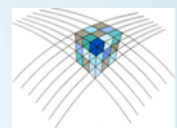# Assume constant height in NAP

Assume constant height in NAP and ETRF2000

Ellipsoidal heights in different ITRS realisations for a stable point in ETRF2000 at 52°N, 05°E, 43m

Legend:
- Epoch AGRS.NL realisation
- Epoch NLGEO2018 realisation
- ETRF2000 +0.00 mm/yr
- ITRF2000 +0.05 mm/yr
- ITRF2005 +1.07 mm/yr
- ITRF2008 +0.89 mm/yr
- ITRF2014 +0.78 mm/yr

Assume constant height in NAP and ITRF2005

Ellipsoidal heights in different ITRS realisations for a stable point in ITRF2005 at 52°N, 05°E, 43m

Legend:
- Epoch AGRS.NL realisation
- Epoch NLGEO2018 realisation
- ETRF2000 -1.07 mm/yr
- ITRF2000 -1.03 mm/yr
- ITRF2005 +0.00 mm/yr
- ITRF2008 -0.18 mm/yr
- ITRF2014 -0.30 mm/yr

Y-axis: Ellipsoidal height [m]
X-axis: Epoch [year]

Assume constant height in NAP and [I|E]TRFxxxx

- In what reference frame can we assume that h behaves the same as H?
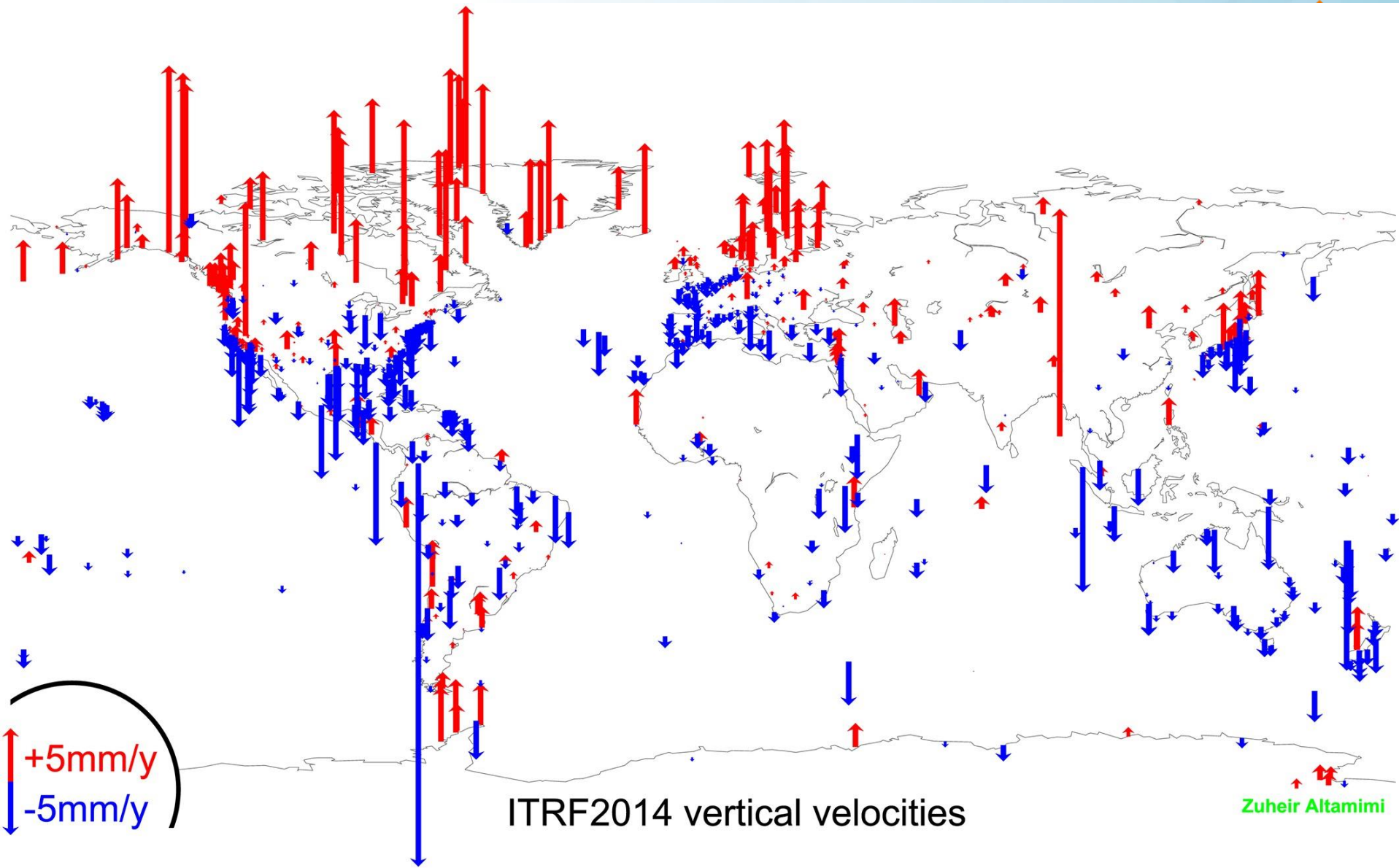
- Should corrected mean tide quasi-geoid height be time or reference frame dependent?

Ellipsoidal heights in different ITRS realisations for a stable point in ETRF2000 at 52°N, 05°E, 43m

NAP height = mean-tide ellipsoidal height – corrected mean-tide quasi-geoid height

+5mm/y
-5mm/y

ITRF2014 vertical velocities

Zuheir Altamimi

TUDelft Deltares Enabling Delta Life STW connecting innovators Rijkswaterstaat Ministerie van Infrastructuur en Waterstaat Koninklijke Marine
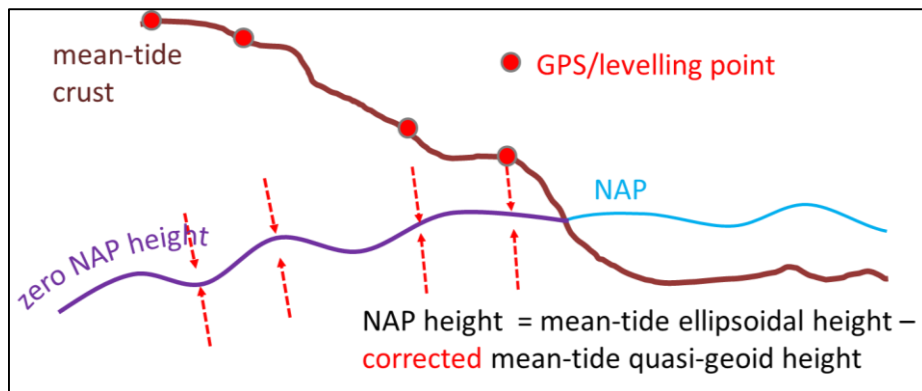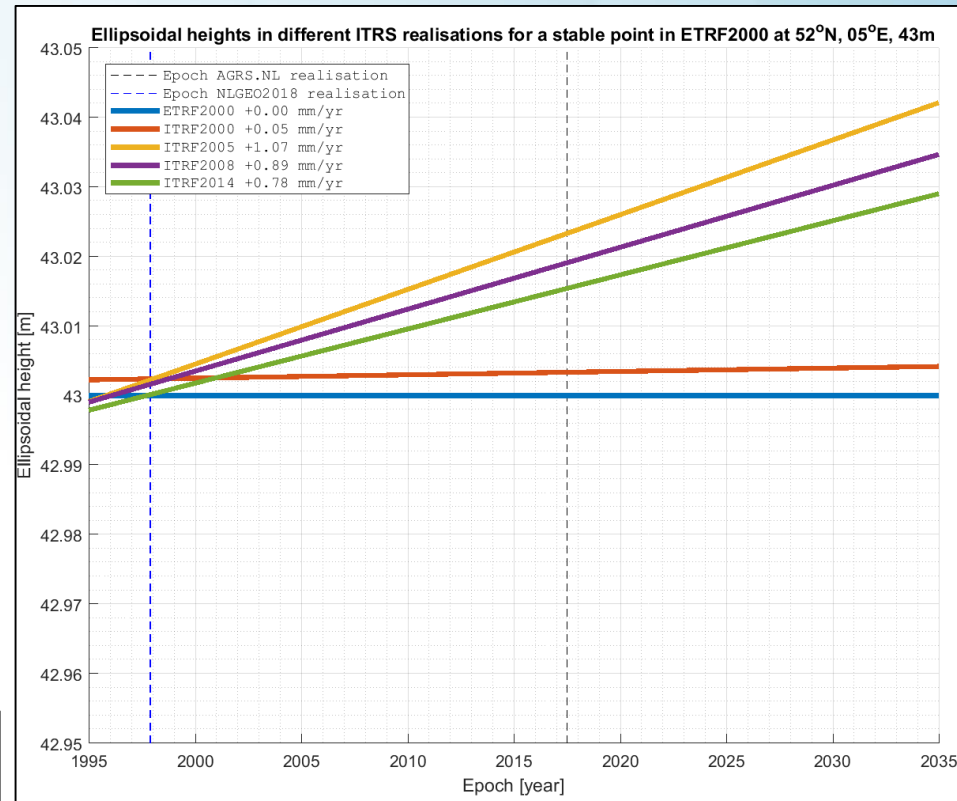
ETRF2000 vertical velocities

5+−1 mm/year

GMT 2018 May 23 21:37:22   EDV14

Bron: A. Kenyeres, *EPN Densification WG: Where to go?, EUREF Symposium 2018, Amsterdam, Netherlands*

TUDelft   **Deltares** Enabling Delta Life   STW connecting innovators   Rijkswaterstaat Ministerie van Infrastructuur en Waterstaat   Koninklijke Marine
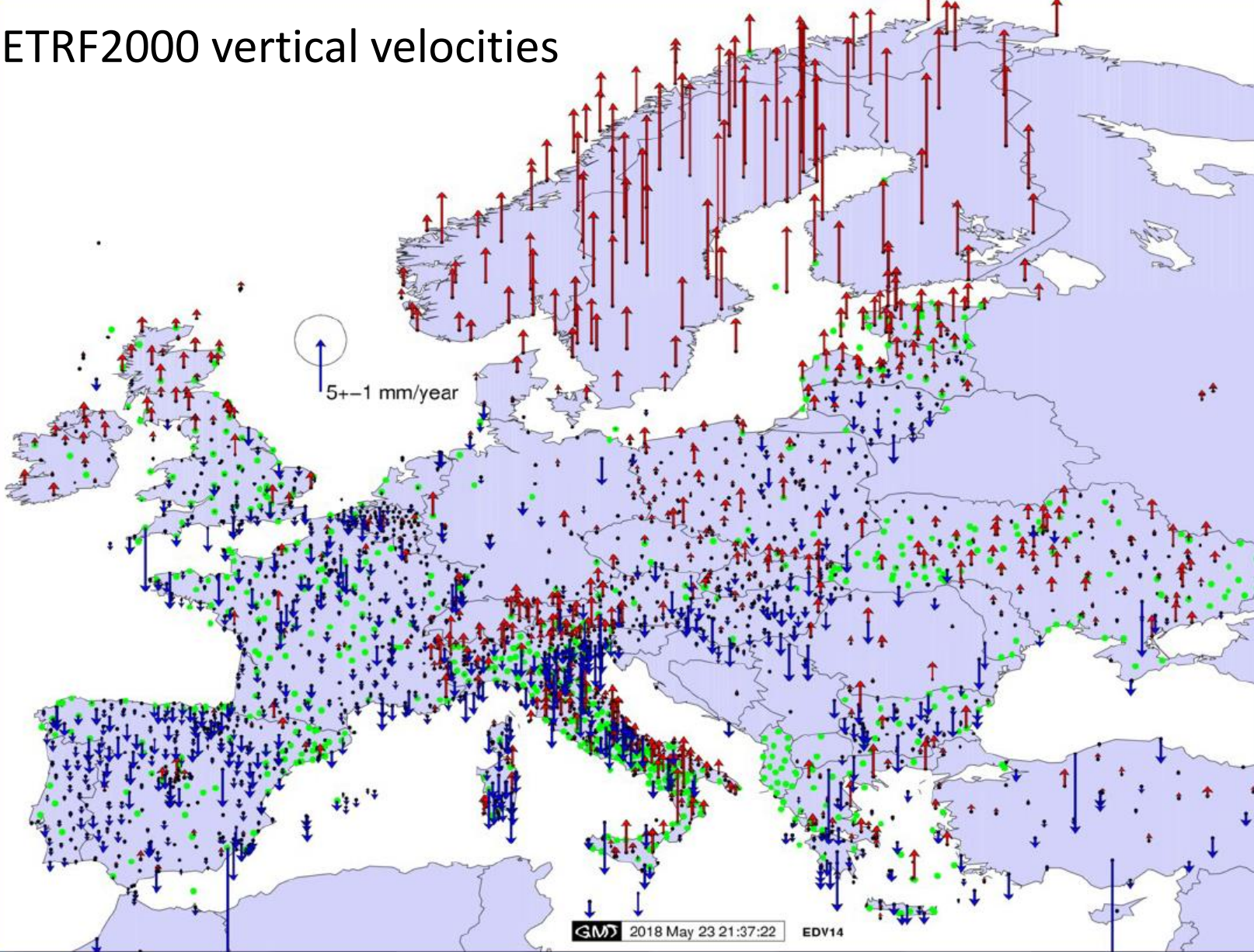
Assume constant height in NAP and [I|E]TRFxxxx

- In what reference frame can we assume that h behaves the same as H?

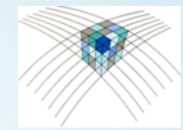- Should corrected mean tide quasi-geoid height be time or reference frame dependent?

Ellipsoidal heights in different ITRS realisations for a stable point in ETRF2000 at 52°N, 05°E, 43m

- - - Epoch AGRS.NL realisation
- - - Epoch NLGEO2018 realisation
— ETRF2000 +0.00 mm/yr
— ITRF2000 +0.05 mm/yr
— ITRF2005 +1.07 mm/yr
— ITRF2008 +0.89 mm/yr
— ITRF2014 +0.78 mm/yr

NAP height = mean-tide ellipsoidal height − corrected mean-tide quasi-geoid height

Summary

- NSGI provides ETRS89, RD, NAP and LAT

- Relation between ITRS and ETRS89 maintained by EUREF

- Certified networks (will) provide ETRF2000(R14)@2017.5

- Provide products in ITRF2014 and ETRF2000@2017.5