Federal Agency for Cartography and Geodesy

BKG
Wir geben Orientierung.

Status and future of the European Vertical Reference Frame

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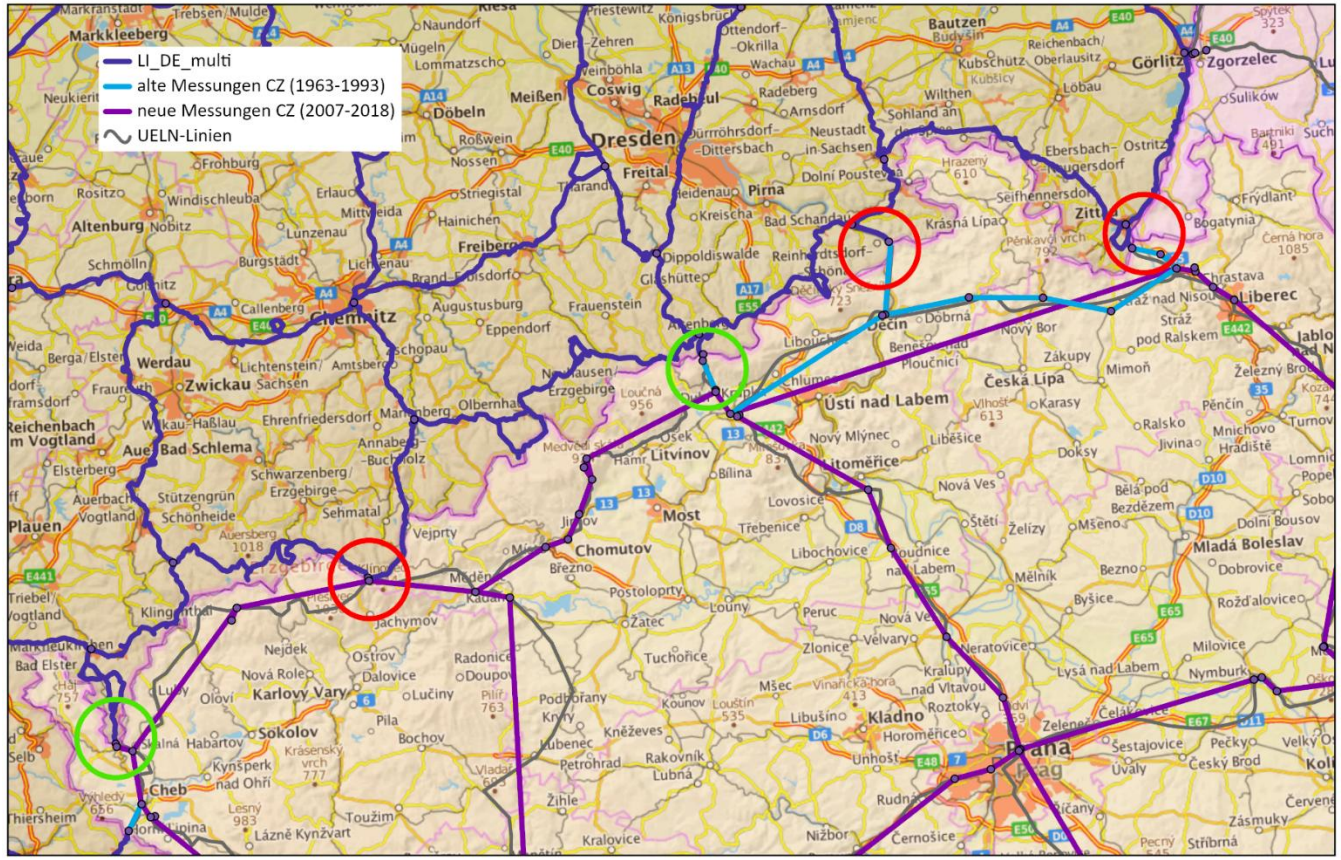
   - Connections between Germany and Czech Republic
   - National Leveling Network of Serbia
2. Test of new strategies for EVRS realization
   - Inclusion of hydrodynamic connections
   - Inclusion of GNSS observations

Leveling connections between Czech Republic and Germany (Saxony)

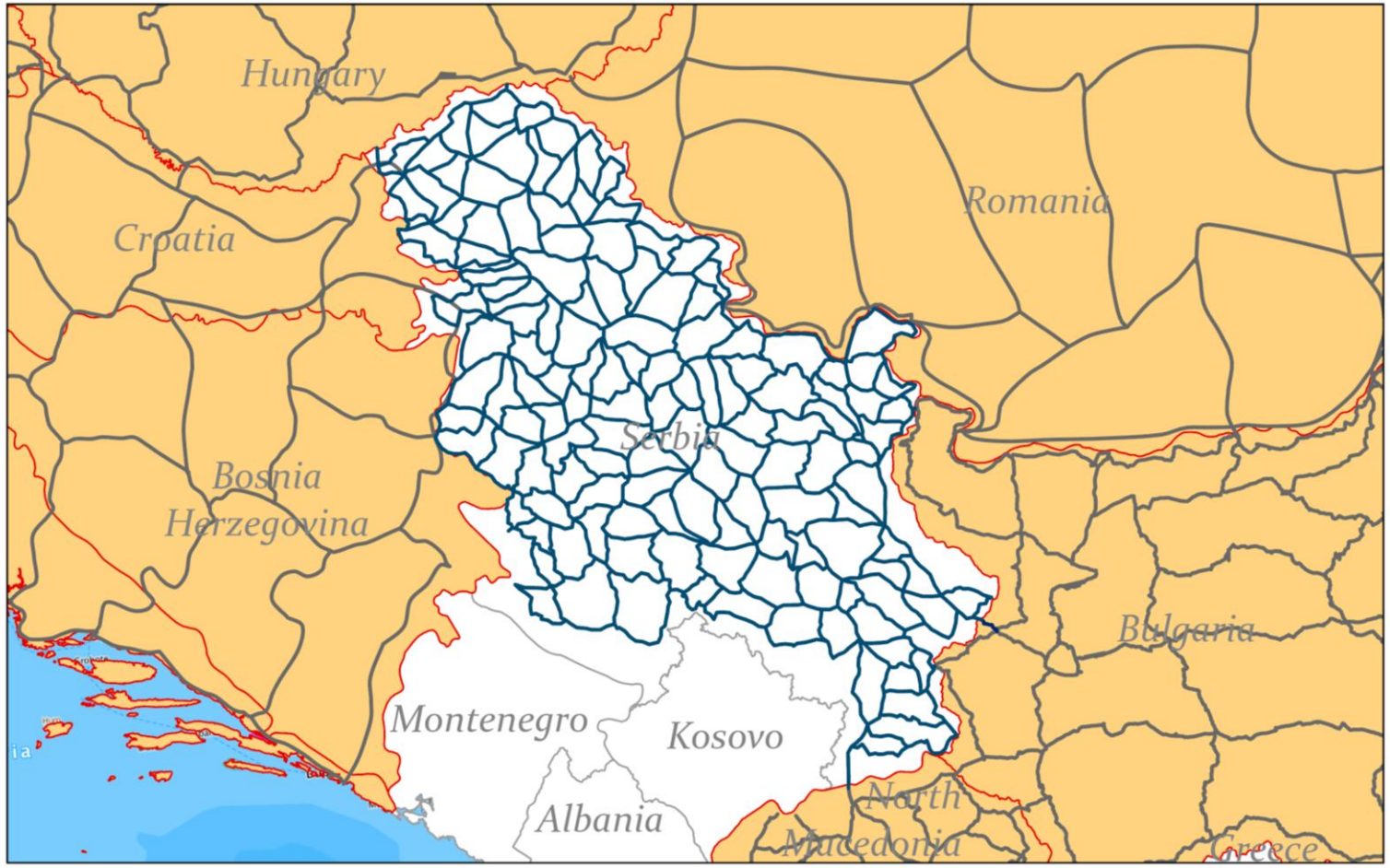


- Green: contained in EVRF2019
- Red: in EVRF2019 deleted as an outlier or not usable because of missing points

- Border connections between Czech Republic and Saxony are old
- Only 2 (of 4) connections were usable in EVRF2019
- BKG contacted the regional authority for surveying in Saxony and Czech Colleagues
- Czech colleagues
  - started inspection of their leveling points at the border
  - sent an update of their whole leveling network (status 2023) → data have been included to UELN, but some old measurements on connection lines are remaining
  - decided to re-measure all 4 connections between Saxony and Czech republic + 1 additional connection in autumn 2025

Data of Serbia

- Serbia provided data of national leveling network in March 2025
- Measurements between 2013 and 2023
- Single adjustment:
  - 260 nodal points
  - 399 observations
  - S_0 = 1.77mm / km
- Serbia provided connections to the borders with Bulgaria (3), North Macedonia (1) and Hungary (2)
- The data of the 2 border connections on the side of Hungary are still under preparation



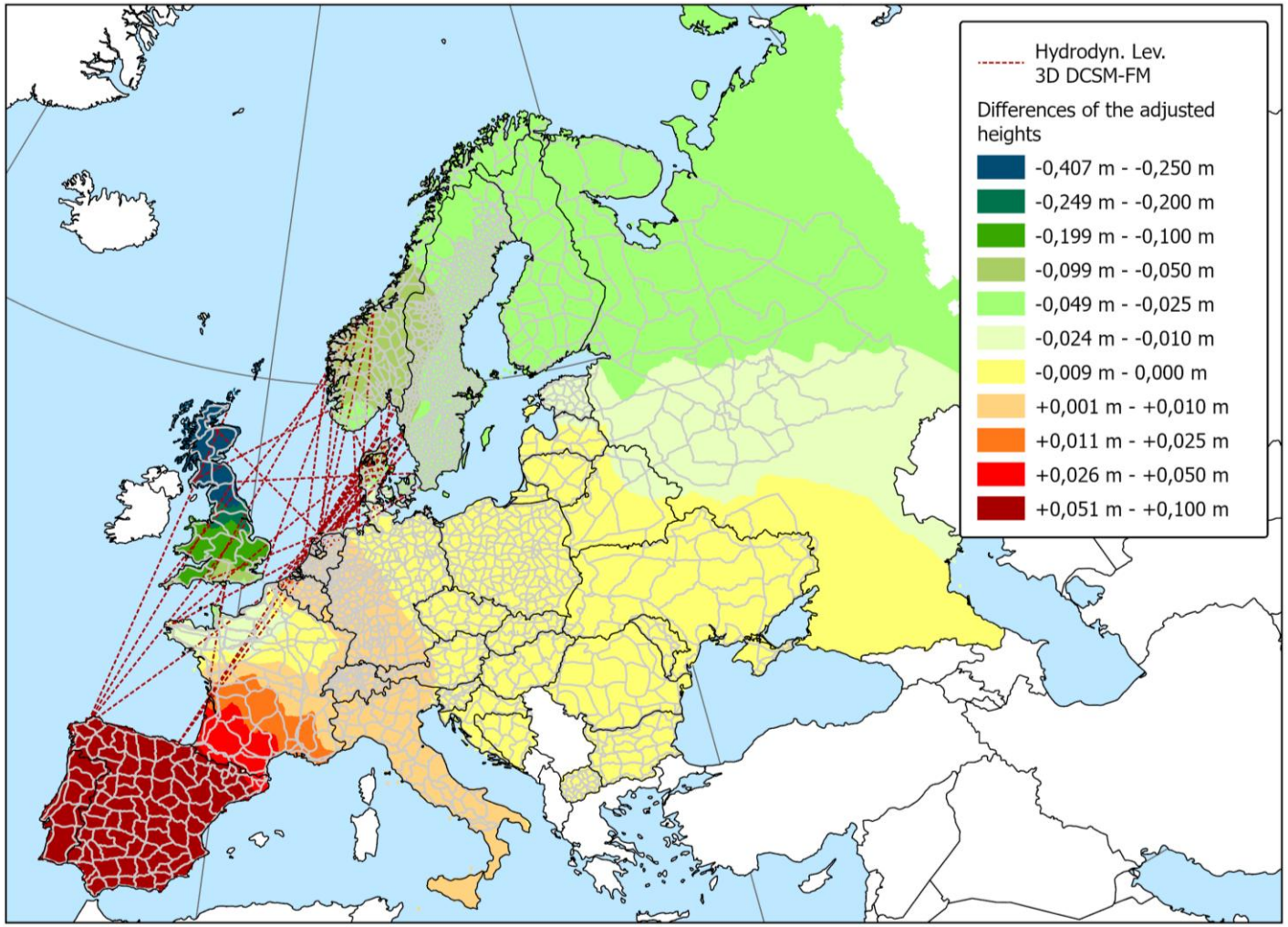
Test of new strategies for EVRF realization

- Adjustment of current UELN data (status 2025) **EVRF25_Lev_only**
  - Including measurements of 3rd leveling epoch of GB (in EVRF2019 only use of a constant offset)
  - Updated data of France (Please note: variance factor 100 for observations of IGN69)
  - Additional network part of Moldova
  - Additional border connections to Austria, minor changes in the data of Czech Republic
- EVRF25 + hydrodynamic connections **EVRF25_HY25**
  - Availability of hydrodynamic models and tide gauge data
  - Results depend on the choice of the connections
- EVRF25 + GNSS observations **EVRF25_GNSS**
  - Absolute “measured” heights h(ell)- ζ(EGG15)
- EVRF25 + height differences from GNSS observations **EVRF25_GNSSdif**
  - Results depend on the choice of the connections
- EVRF25 + hydrodynamic connections + GNSS observations (heights) **EVRF25_HY25_GNSS**

Inclusion of hydrodynamic connections

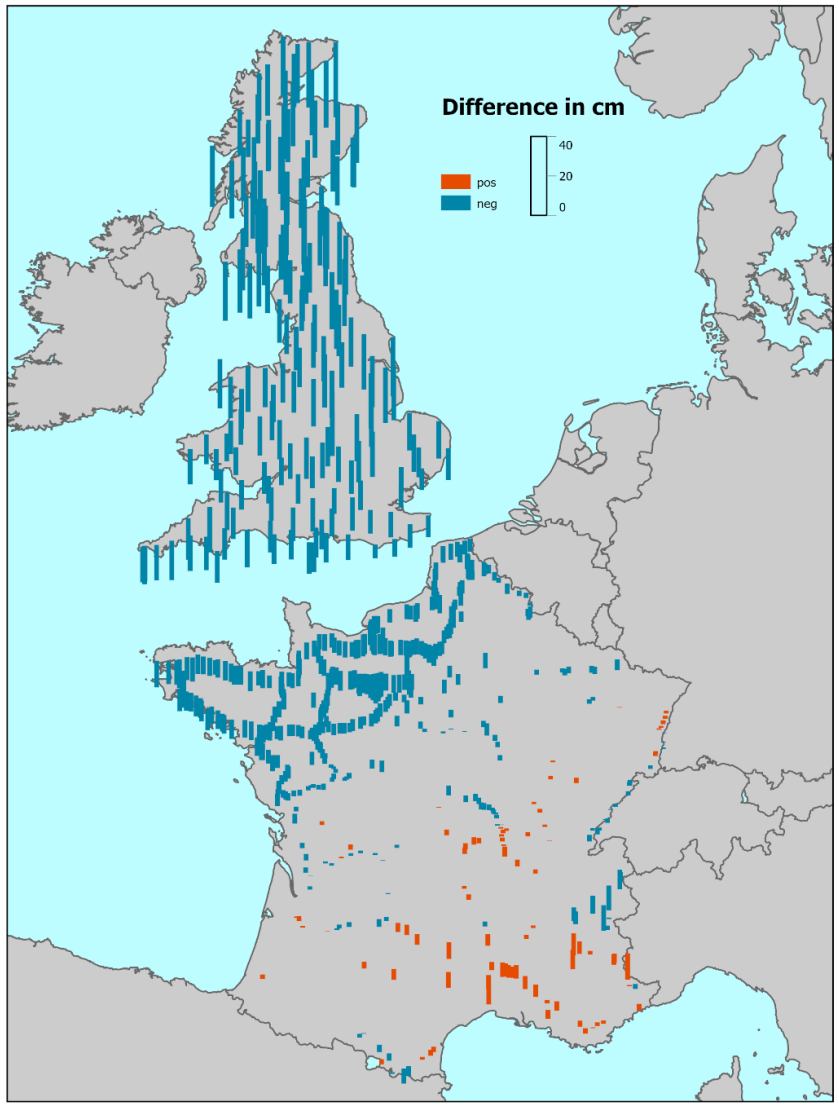
- Versatile Hydrodynamics – Project of Delft University of Technology (2018-2023)
  - Deltares (independent institute for applied research in the field of water, subsurface and infrastructure) and Federal Agency for Cartography and Geodesy (BKG) were involved as external advisors
- One part of the project: Dissertation Yosra Afrasteh: "**Model based Hydrodynamic leveling – an impact study on the European Vertical Reference Frame"** (Afrasteh 2023)
- Combining spirit leveling data with model based hydrodynamic leveling data
  - Regional, high-resolution hydrodynamic model
  - Tide gauge observations
  - Connections between tide gauges and UELN benchmarks
- Hydrodynamic model: 3D DCSM-FM ("Dutch Continental Shelf Model – Flexible Mesh")
  - Developed by Deltares (on request of Rijkswaterstaat (RWS))
  - Covers North-East Atlantic Ocean including the North Sea

Height differences between adjustments of leveling data only and of leveling data + additional hydrodynamic connections

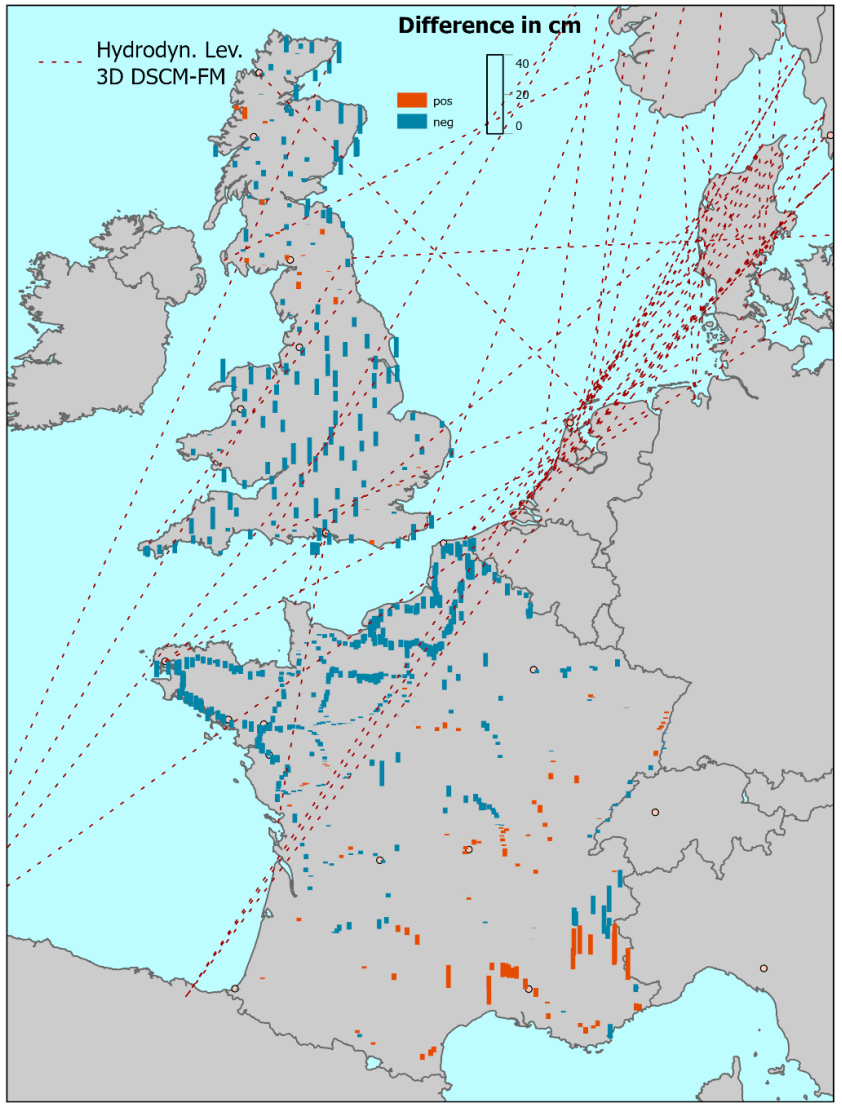


- Presentation at EUREF symposium 2024:
  - use of selection of 74 hydrodynamic connections using 3D DSCM model
  - Selection criterion: minimization of the standard deviation of the adjusted heights in EVRF
- Cornelis Slobbe in the scope of the WG "European Unified Height Reference":
  - New choice of connections using the same model
  - Selection criterion: minimization of systematic errors, checked with GNSS/leveling points (EHRS_CP)

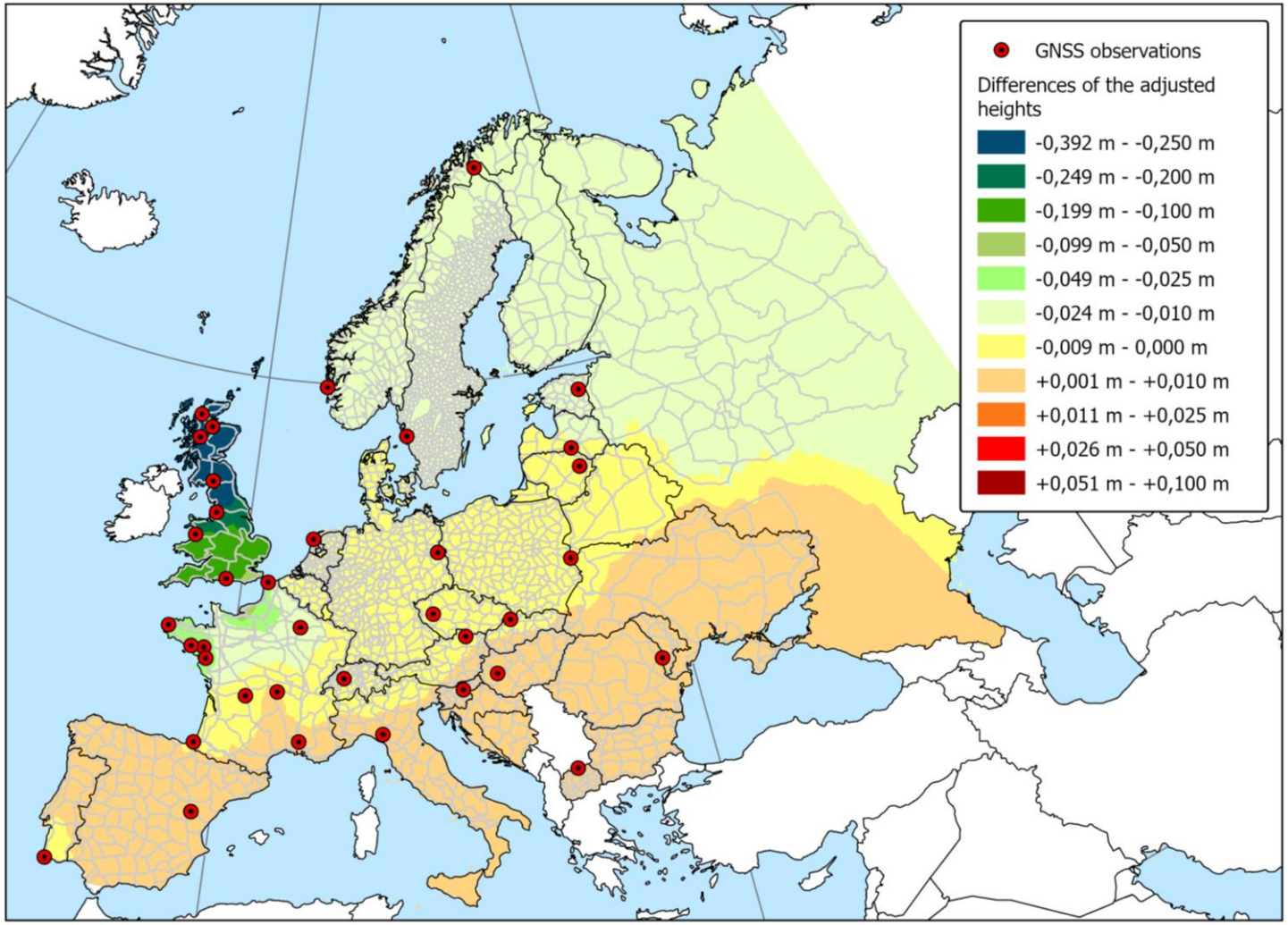
Differences h(ell)-H(EVRF_lev_only)-EGG2015 in cm



Differences h(ell)-H(EVRF_HY25)-EGG2015 in cm

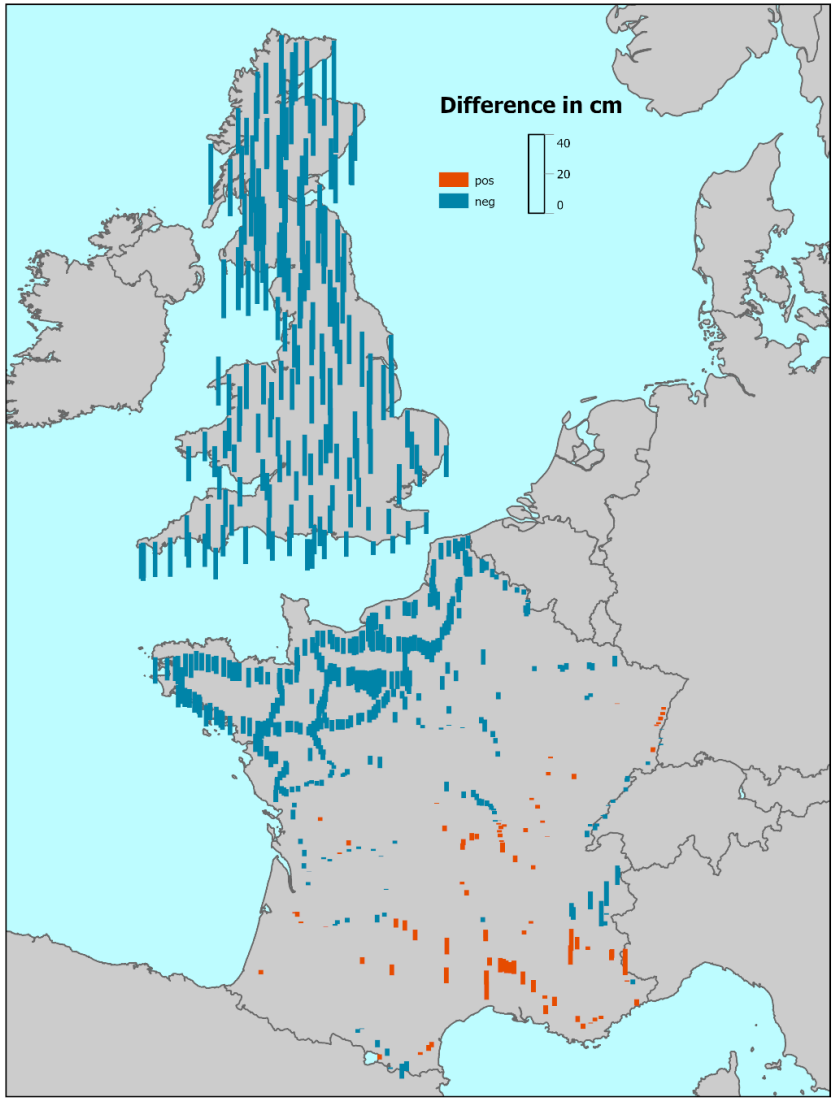


Height differences between adjustments of leveling data only and of leveling data + GNSS observations

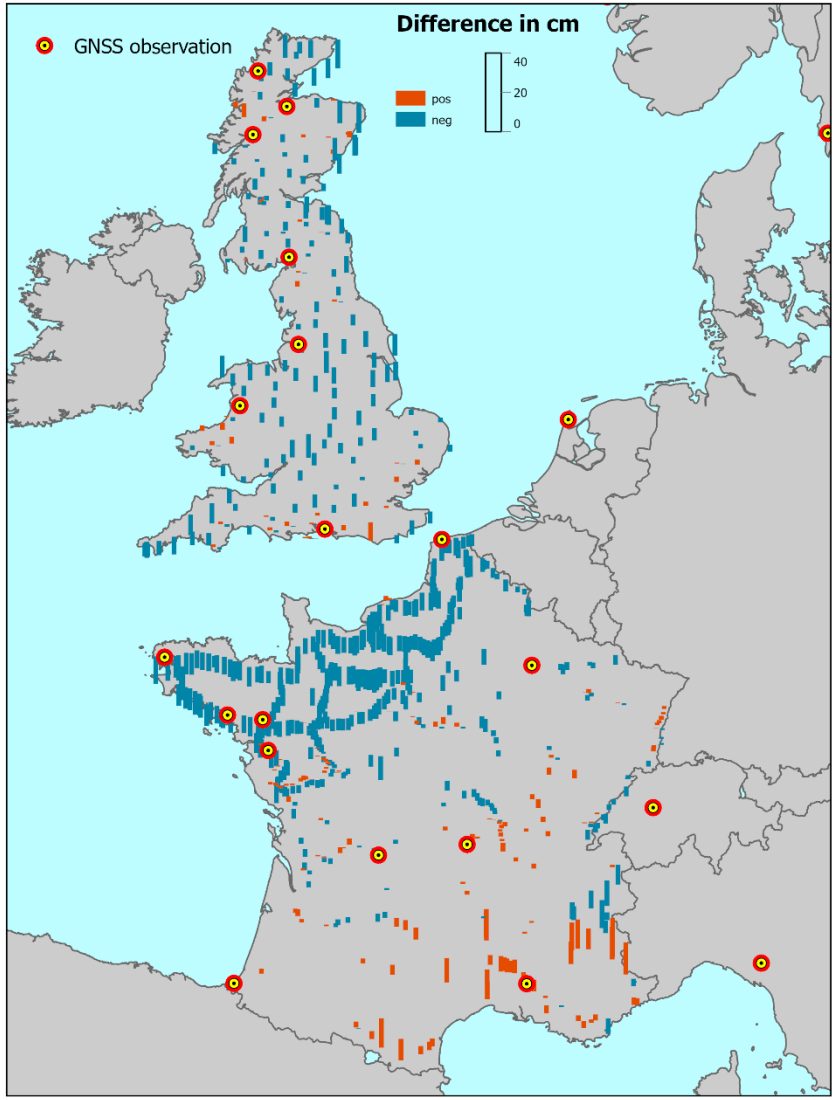


- In the following, we introduce GNSS-based heights computed as $H = h + \zeta_{EGG2015}$
- Preliminary choice of EHRS_CP
- Particular attention to the tilt in GB and FR (more points in GB and FR)

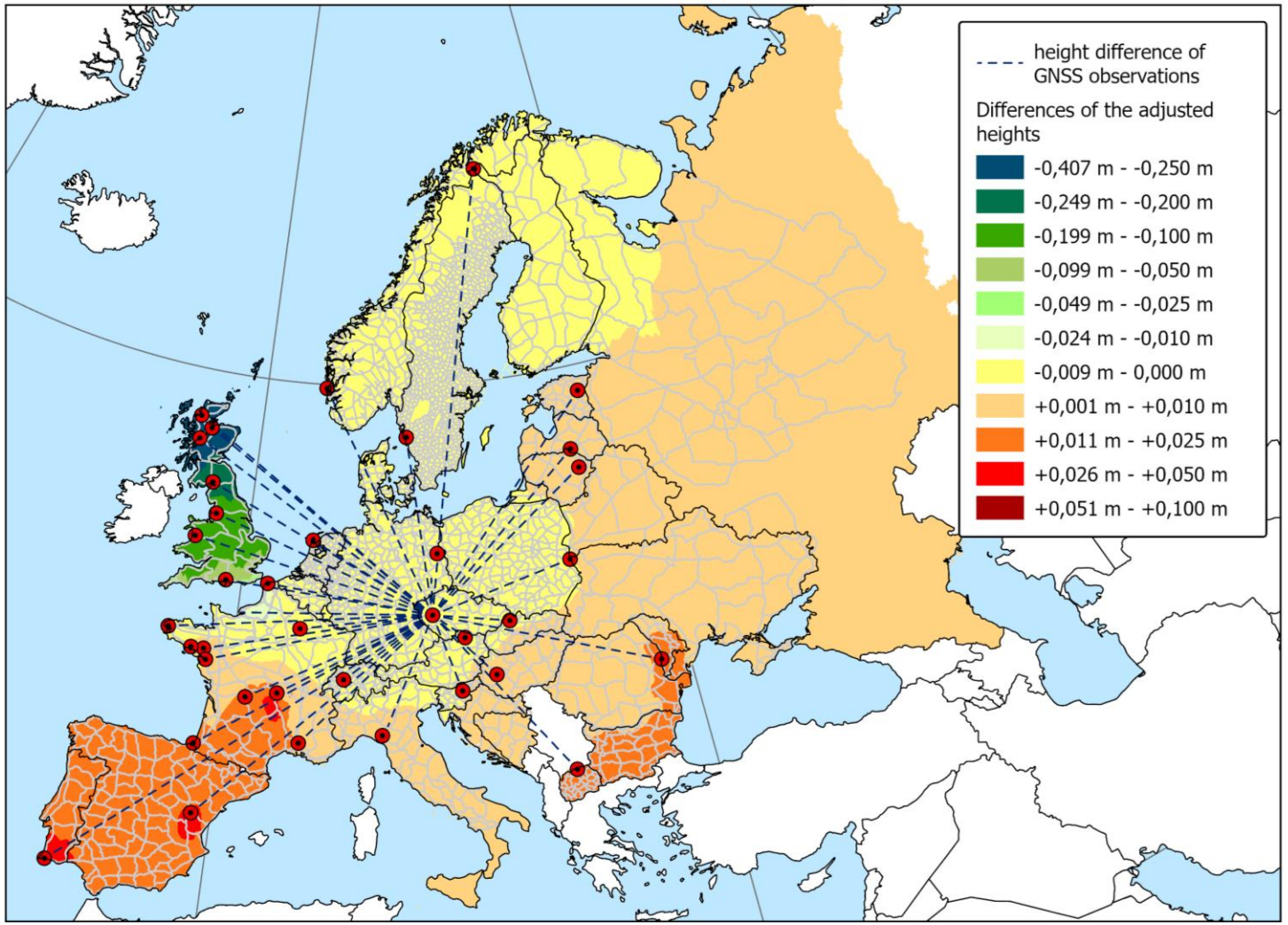
Differences h(ell)-H(EVRF_lev_only)-EGG2015 in cm



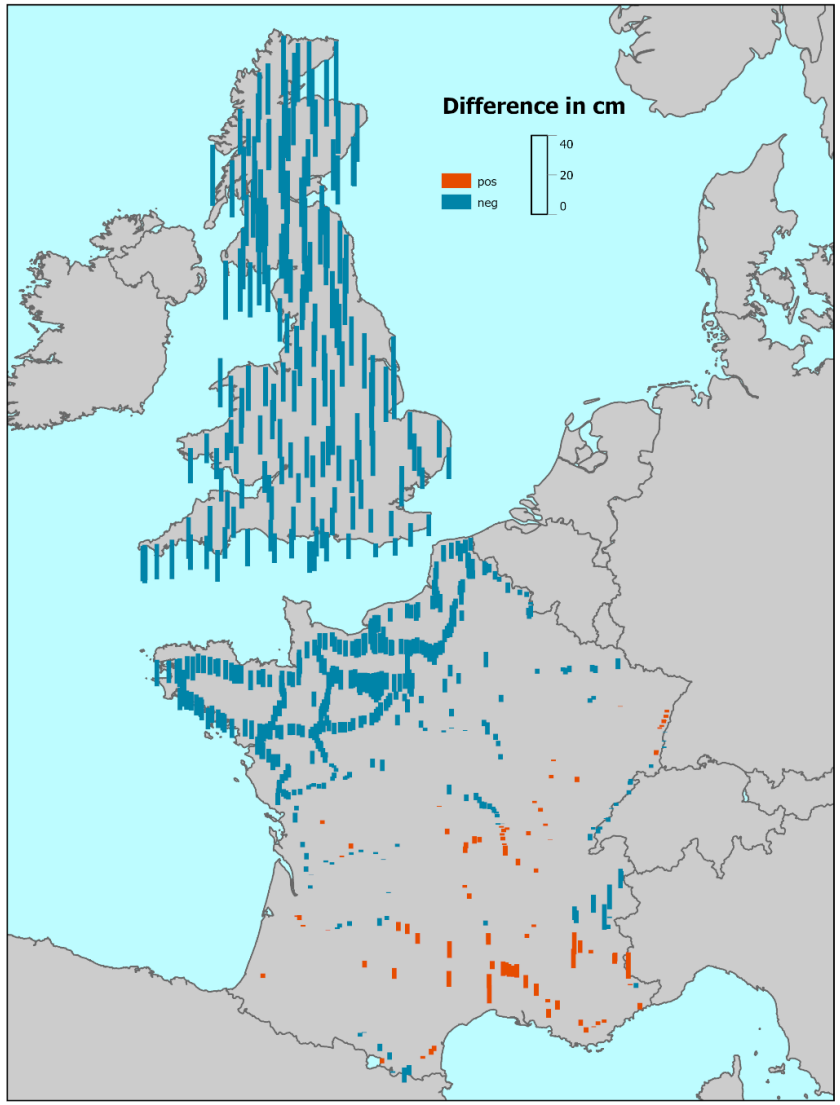
Differences h(ell)-H(EVRF_GNSS)-EGG2015 in cm



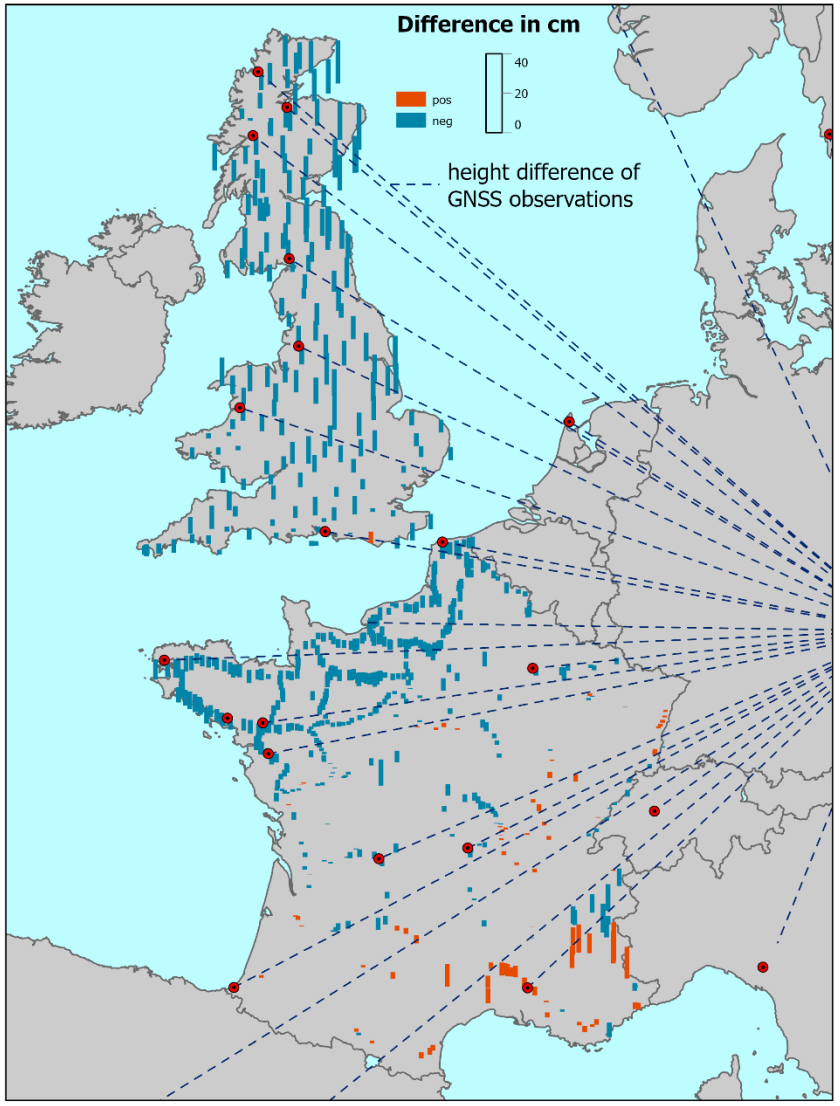
Height differences between adjustments of leveling data only and of leveling data + height differences from GNSS observations



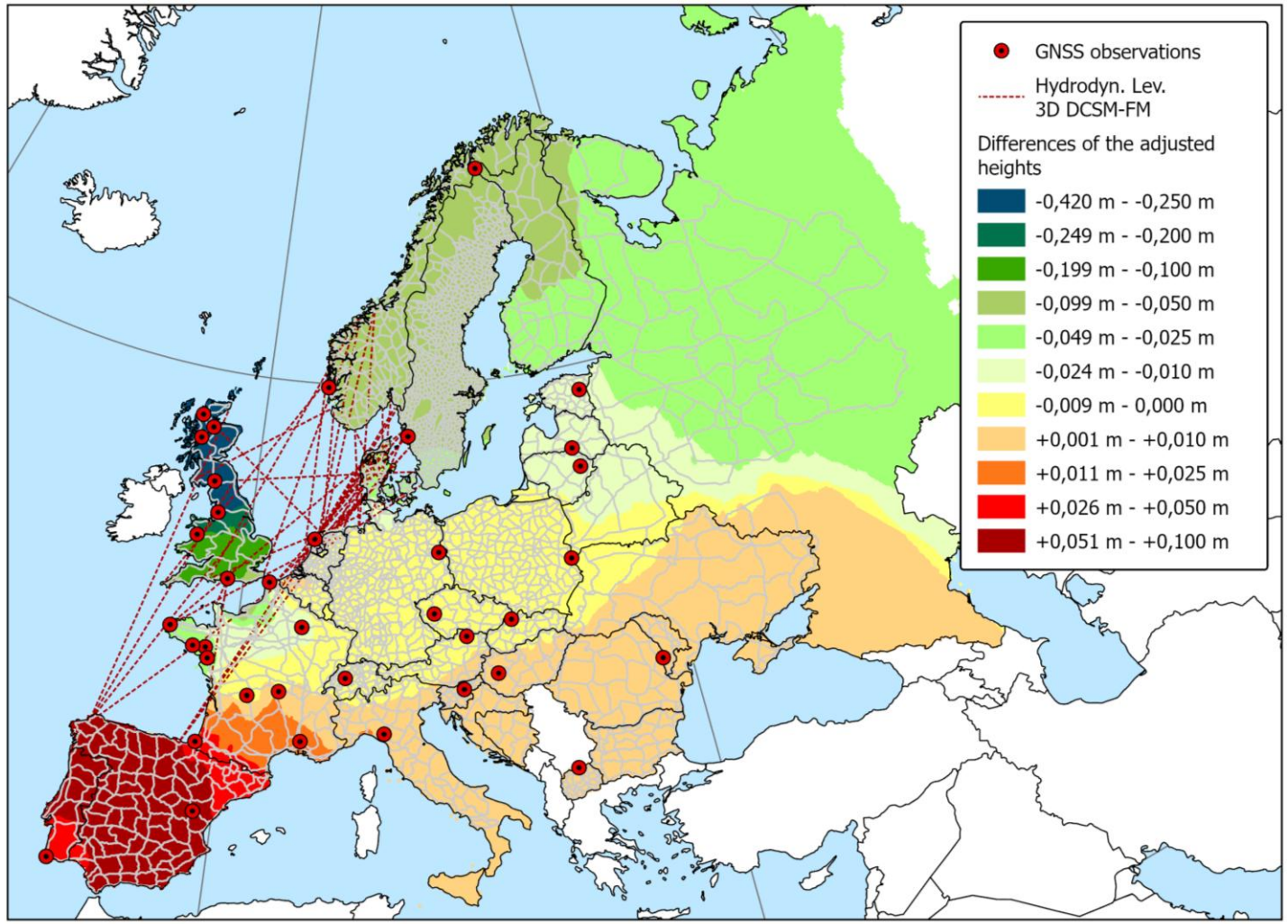
Differences h(ell)-H(EVRF_lev_only)-EGG2015 in cm



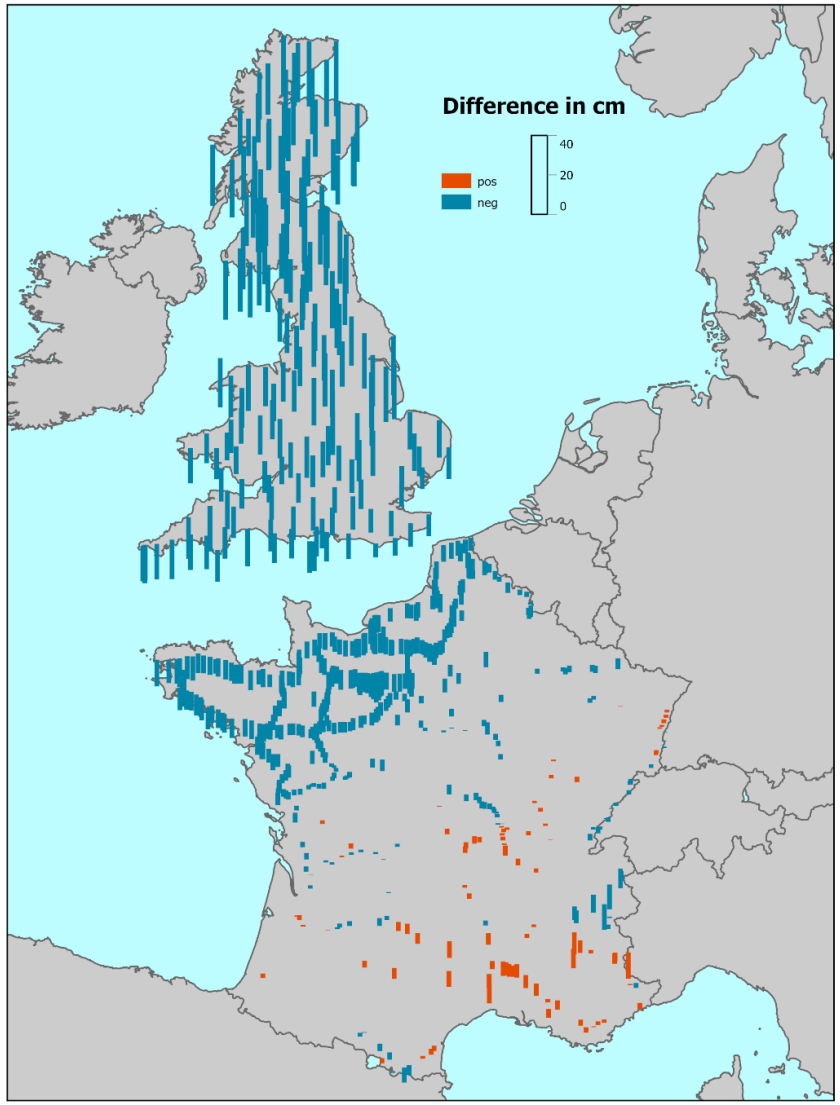
Differences h(ell)-H(EVRF_GNSSdif)-EGG2015 in cm



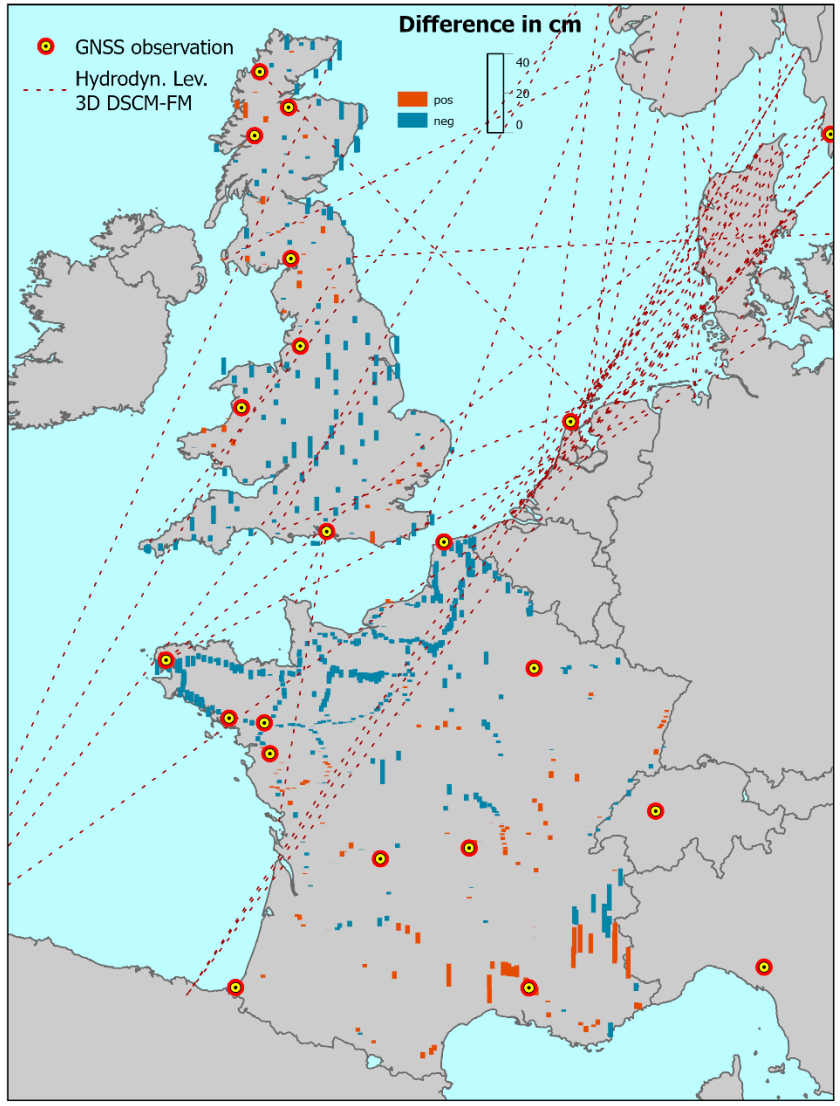
Height differences between adjustments of leveling data only and of leveling data + additional combination of hydrodynamic connections and GNSS observations



Differences h(ell)-H(EVRF_lev_only)-EGG2015 in cm

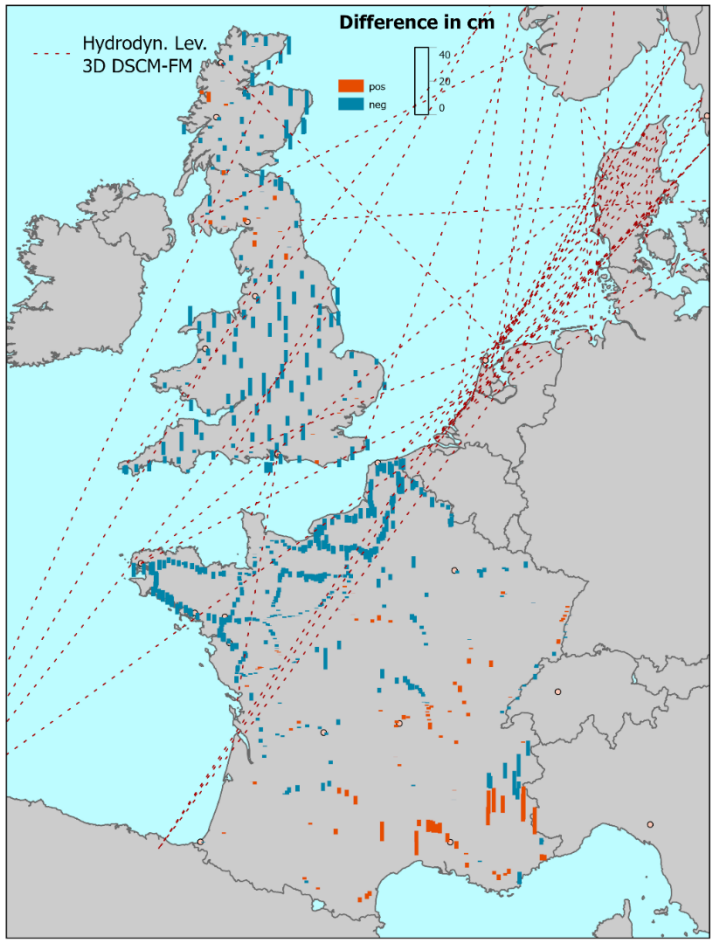


Differences h(ell)-H(EVRF_HY25_GNSS)-EGG2015 in cm

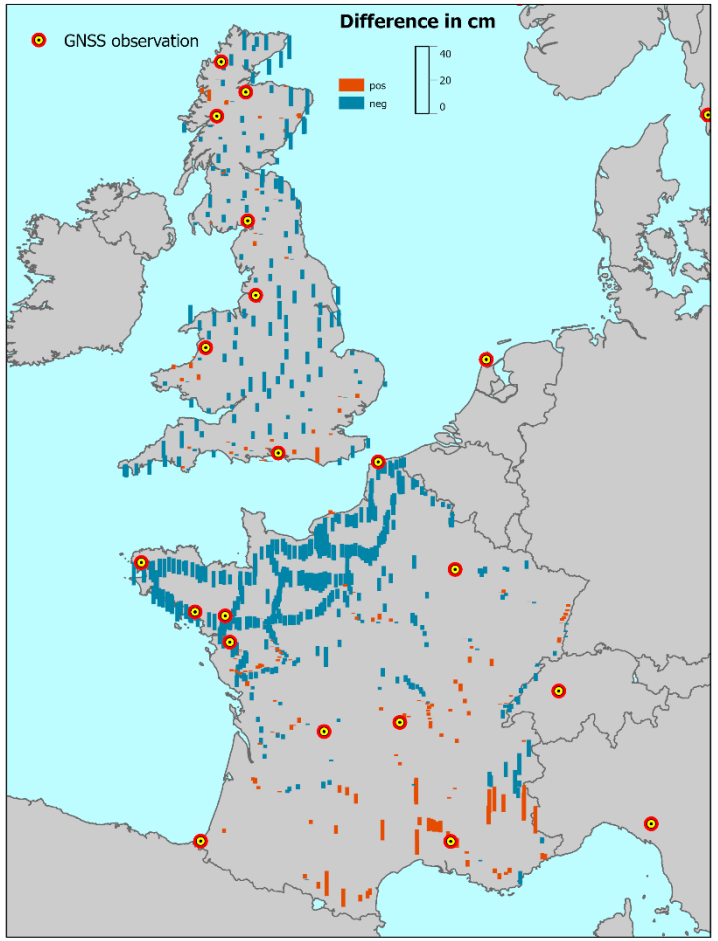


Comparison EVRF25 + HY25, +GNSS, + HY25/GNSS

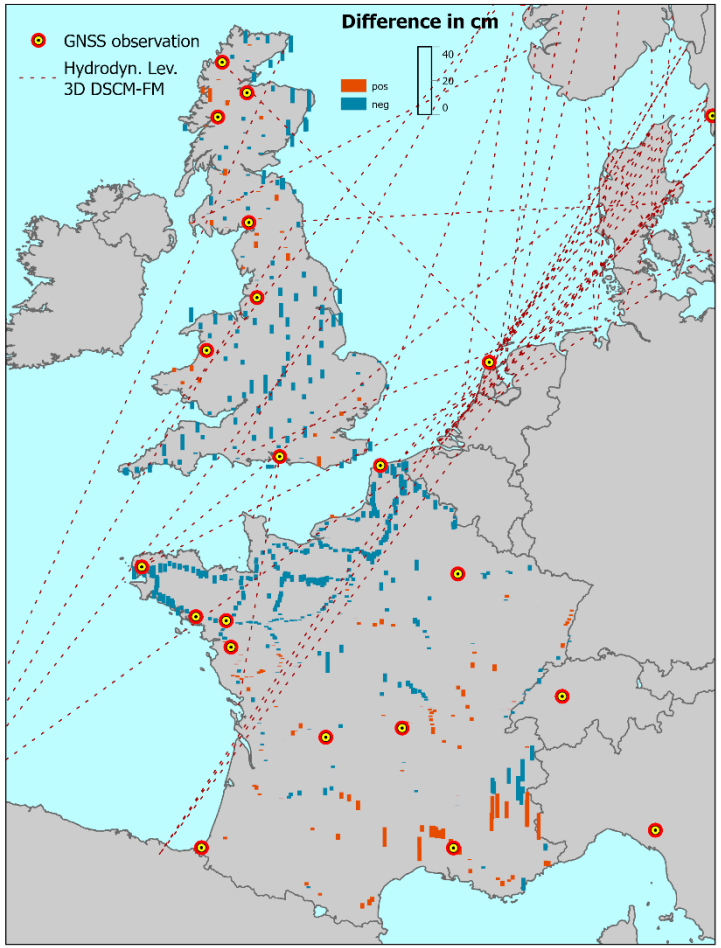
Differences h(ell)-H(EVRF_HY25)-EGG2015 in cm



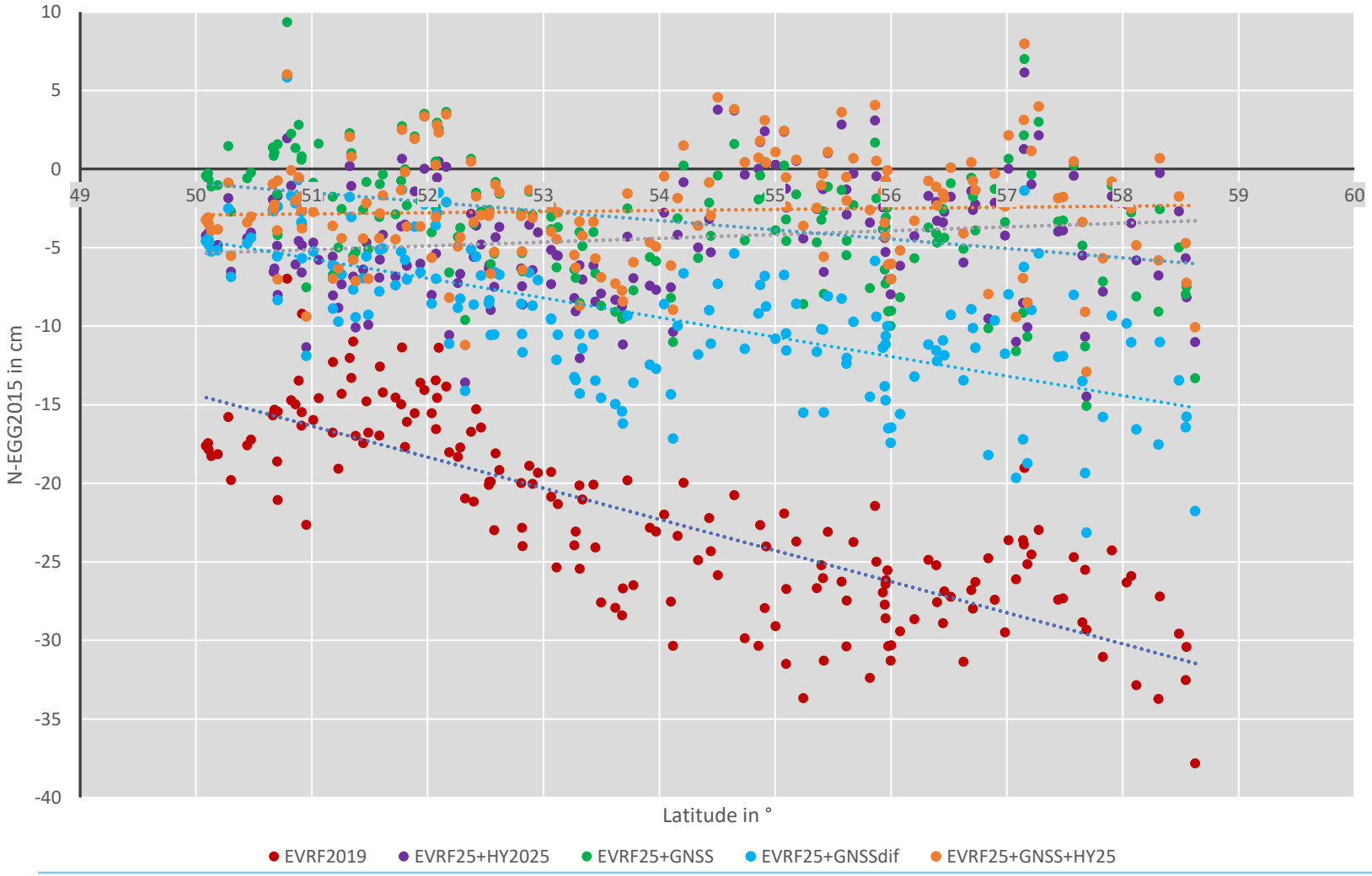
Differences h(ell)-H(EVRF_GNSS)-EGG2015 in cm



Differences h(ell)-H(EVRF_HY25_GNSS)-EGG2015 in cm



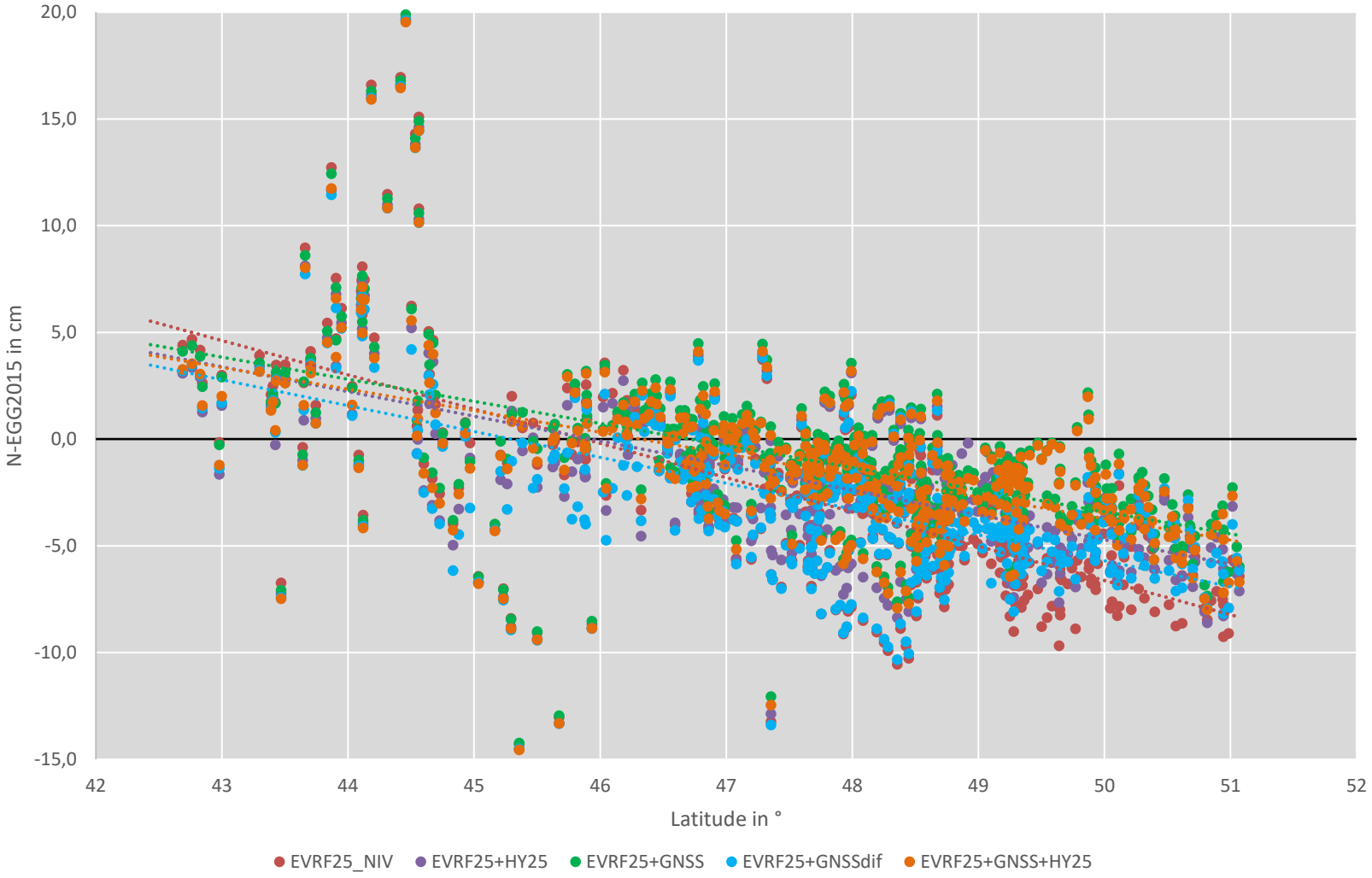
Great Britain – Differences between N (GNSS/lev points) and EGG2015, as a function of latitude



Linear equations:

EVRF2019:	y= -1.98x+84.65
EVRF25_HY25:	y= +0.22x-16.53
EVRF25_GNSSabs:	y= -0.59x+28.73
EVRF25_GNSSdif:	y= -1.24x+57.77
EVRF25_GNSS+HY25:	y=+0.07x+ 6.37

France - Differences N (GNSS/lev points) and EGG2015, as a function of latitude



Linear equations:

EVRF25_lev_only: y= -1.60x+73.62

EVRF25_HY25: y= -1.16x+53.08

EVRF25_GNSS: y= -1.04x+48.38

EVRF25_GNSSdif: y= -1.21x+54.83

EVRF25_GNSS+HY25: y= -1.01x+46.83

French EHRS_CP:

- minimum 3 hours of observation
- No direct connection to UELN point

Conclusion

additional observations	pros	cons
hydrodynamic connections		
GNSS observations+ gravimetric quasi-geoid (introduced as **heights**)		
GNSS observations + gravimetric quasigeoid (introduced as **height differences**)		

Next activity: comparison of h(ell)-H(EVRF…) with ζ(EGG2015) in all participating European countries

Goodbye

I (Martina Sacher) will retire at the end of September 2025.
For the time being, the work at the topic UELN/EVRS will be continued by my colleague Tobias Bauer.
From October onwards, e-mails to my personal mailbox will be forwarded to

heights@bkg.bund.de

This functional mailbox can already be used.

It was a pleasure to work with you!

Federal Agency for Cartography and Geodesy

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Thank you for your kind attention!

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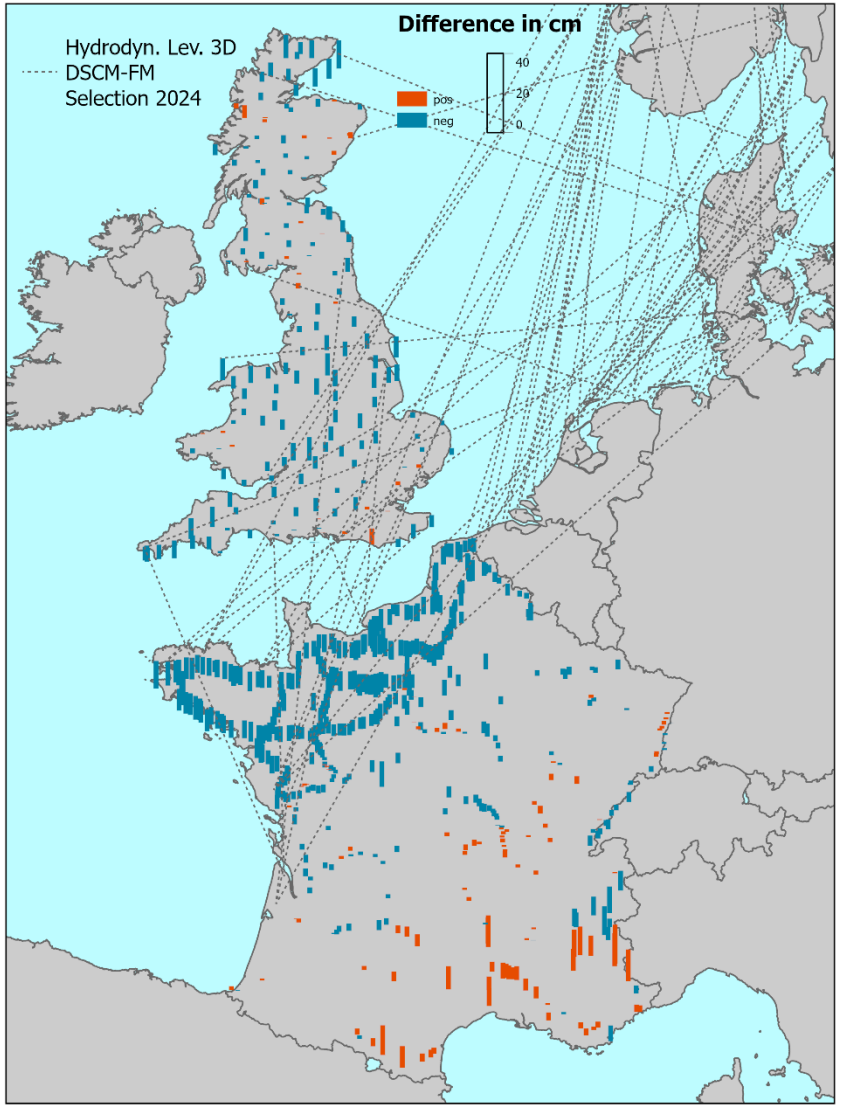
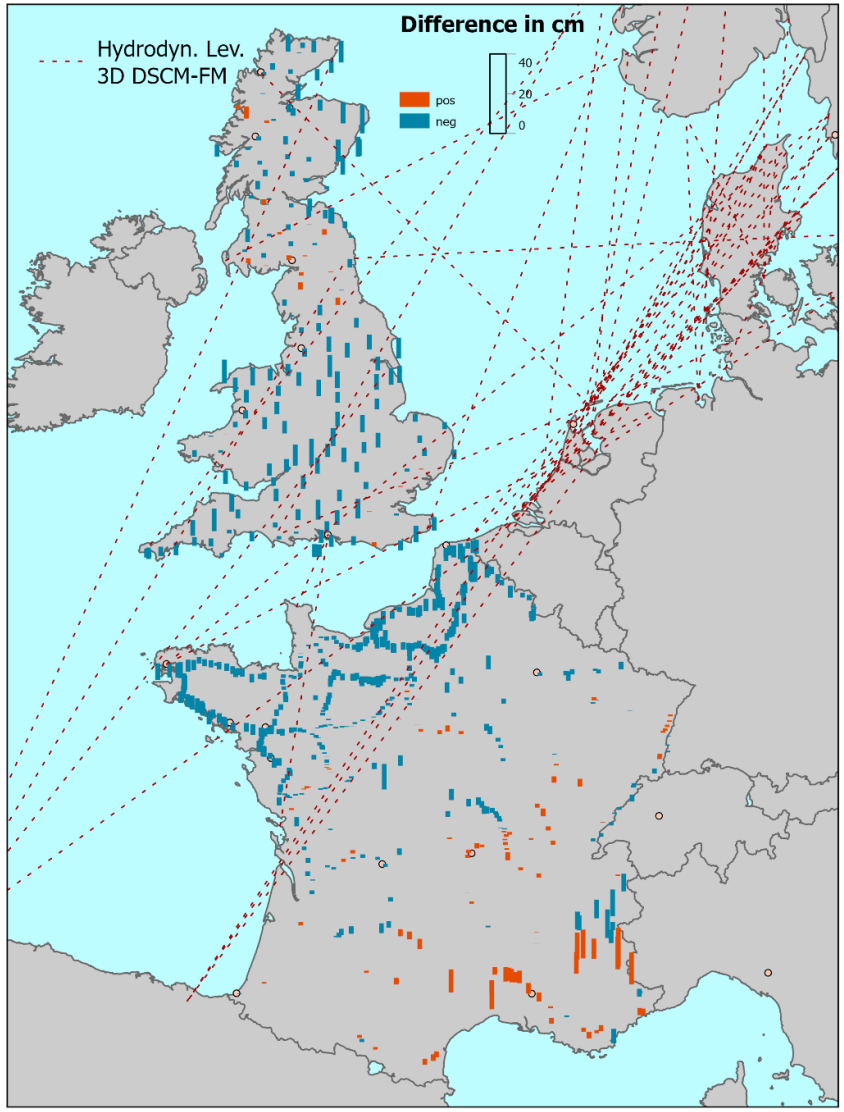
Differences h(ell)-H(EVRF_HY24)-EGG2015 in cm



Differences h(ell)-H(EVRF_HY25)-EGG2015 in cm



Mean standard deviation of the adjusted heights in kgal*mm

Variant	Country		
	FR	GB	UELN
EVRF2025	**47.6**	**38.9**	**24.4**
EVRF2025_HY25	46.5	**29.9**	23.3
EVRF2025_GNSS_abs	**44.4**	35.9	**22.7**
EVRF2025_GNSS_diff	45.3	37.7	23.3
EVRF2025_HY25_GNSSabs	**43.4**	**24.4**	**21.7**

Please note:
The data of IGN69 in FR got the variance factor 100 in the variance component estimation.