LEVELLING ASSISTED REGIONAL REALIZATIONS OF THE INTERNATIONAL HEIGHT REFERENCE SYSTEM

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LANTMÄTERIET

OUTLINE

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- International Height Reference Frame (IHRF)
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- Case study over Sweden
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  - Comparison between IHRF and RH 2000, the official Swedish realisation of EVRS
- Conclusions and future work

A GLOBAL PHYSICAL VERTICAL REFERENCE SYSTEM

A global physical vertical reference system is essential in many cases:

- To study changes caused by movements in the Earth’s mass balance
  - For example, studies of changes in sea level caused by climate change
- Exchange of height information between continents

It also enables establishment of local unified height networks, without connection by levelling to higher order height networks.

INTERNATIONAL HEIGHT REFERENCE SYSTEM, IHRS

IHRS defined by the International Association of Geodesy, IAG, in 2015:

- Fixed vertical potential reference level at the geoid,
  $$W_0 = 62\,636\,853.4\, m^2 s^{-2}$$
- The vertical coordinates of P in IHRS are defined as the potential numbers, $C(P) = W_0 - W(P)$
- Spatial 3D-positions given in ITRS
- Mean tide concept (Mäkinen, 2021)
- Units: meter (m), second (s)

INTERNATIONAL HEIGHT REFERENCE FRAME, IHRF

The IHRS realisation according to Sánchez et al. (2021):

- “Based on a worldwide homogeneously distributed set of reference stations including a **core network** and **regional/national densifications.**”
- “The regional and national densifications are to provide **local accessibility** to the global frame.”
- “If regional (“quasi-)geoid models of high resolution are available, an IHRF reference station may be installed every 50 km or 100 km.”
- ”For higher resolutions and applications requiring accuracies at the millimetre level, **high-precise levelling is recommended.**”

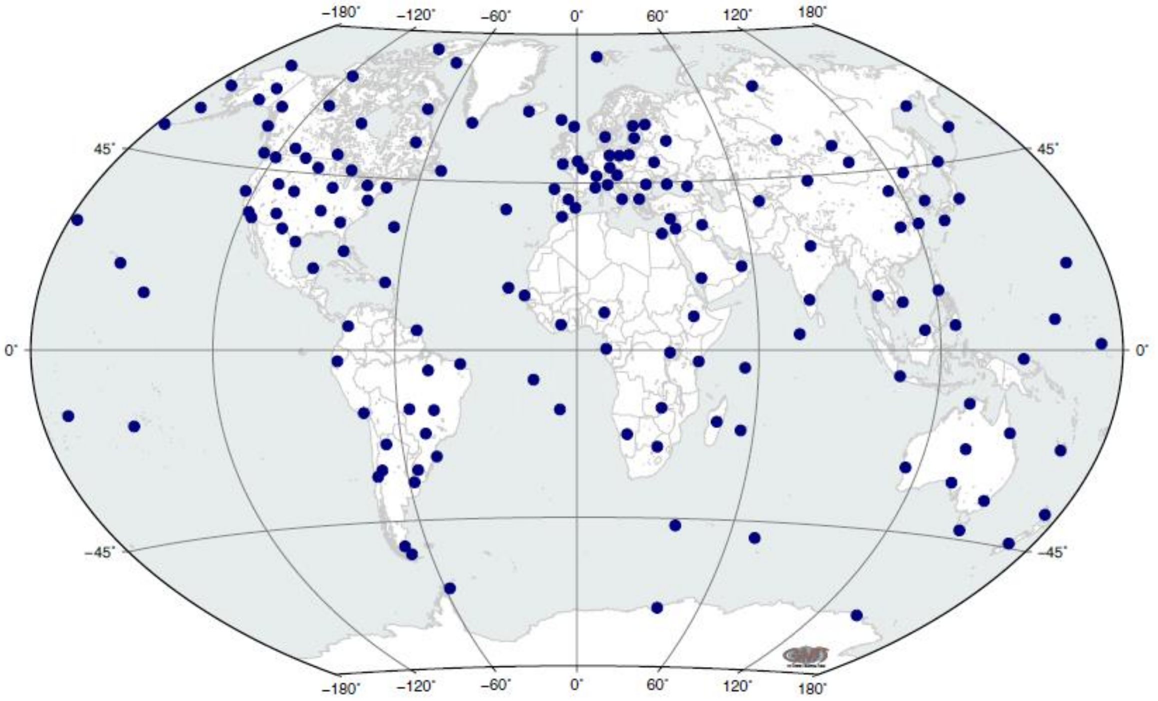


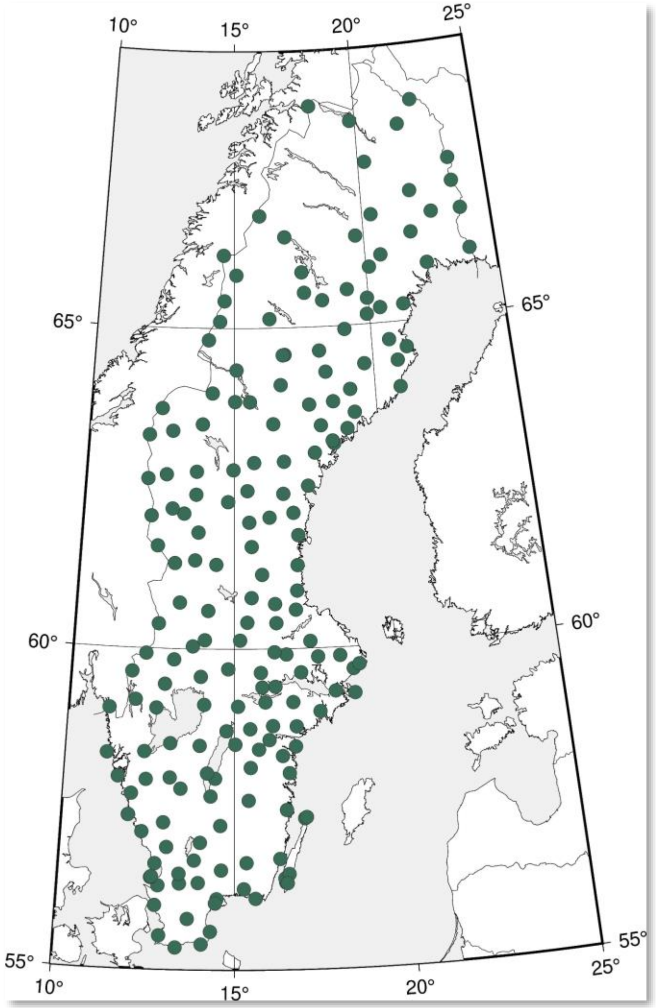
Fig. 10 IHRF reference network (as of October 2020)

INTRODUCTION TO THE CASE STUDY

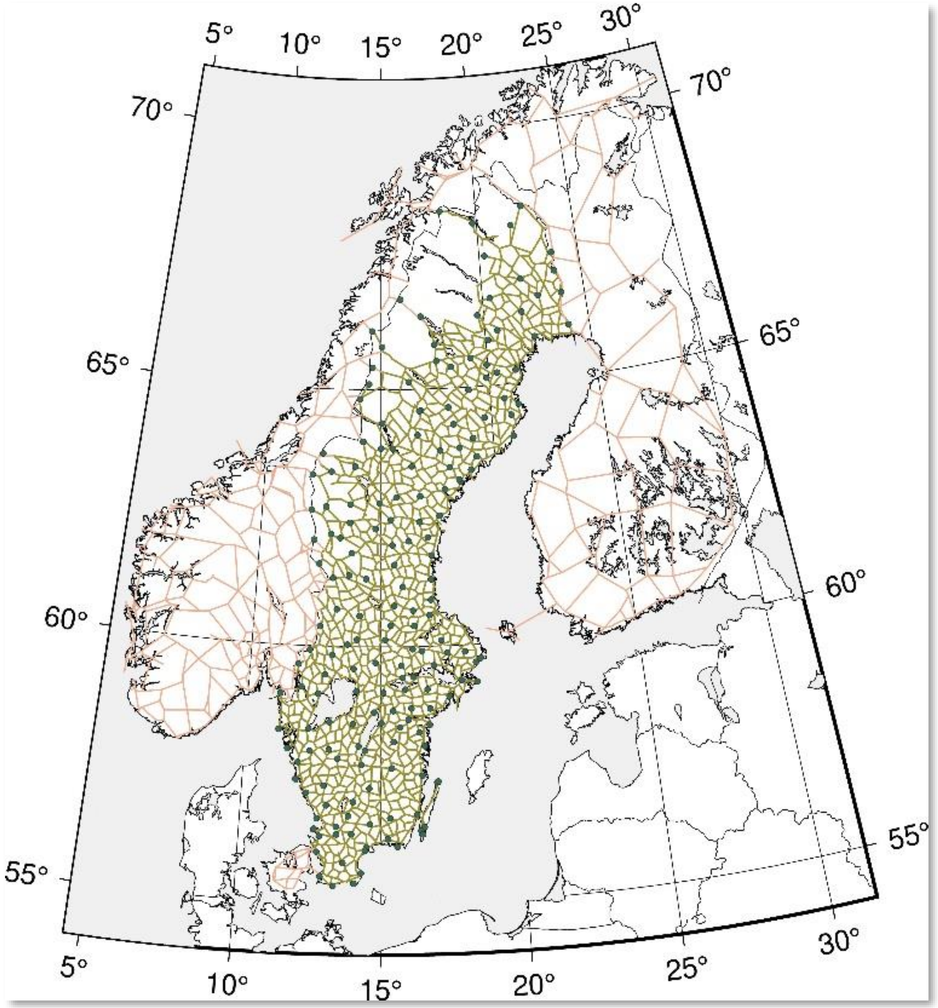
Motivation

- Investigate how a regional realisation of IHRS will benefit from the inclusion of precise levelling observations
- Utilise existing precise levelling networks to establish levelling assisted IHRS realisations
- To provide a dense IHRS realisation with known uncertainty.

GNSS STATIONS AND LEVELLING NETWORK



Initial pointwise IHRS realisation, 186 GNSS/Levelling stations



Part of the Baltic Levelling Ring with 3350 Swedish nodal benchmarks

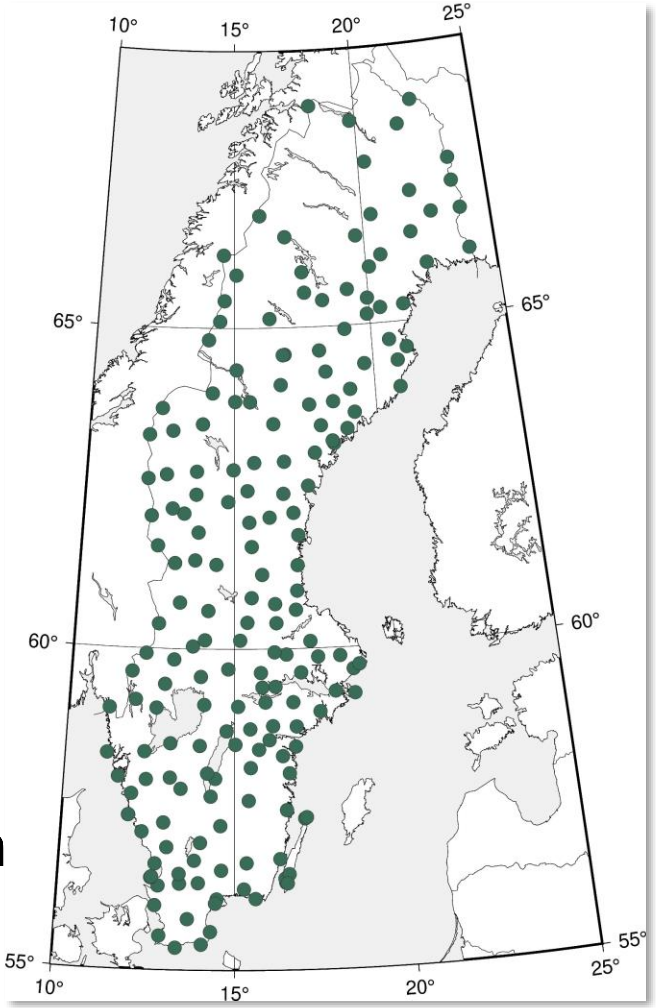
INITIAL POINTWISE IHRS REALISATION

Geopotential values, $W(P)$, were recovered from the NKG2015 gravimetric quasigeoid model (Ågren et al., 2016) according to the guidelines in Sánchez et al. (2021).

- 186 high-quality GNSS observations
- 48 hours of observations
- Dorne Margolin Antennas
- Bernese software
- Well connected to the levelling network

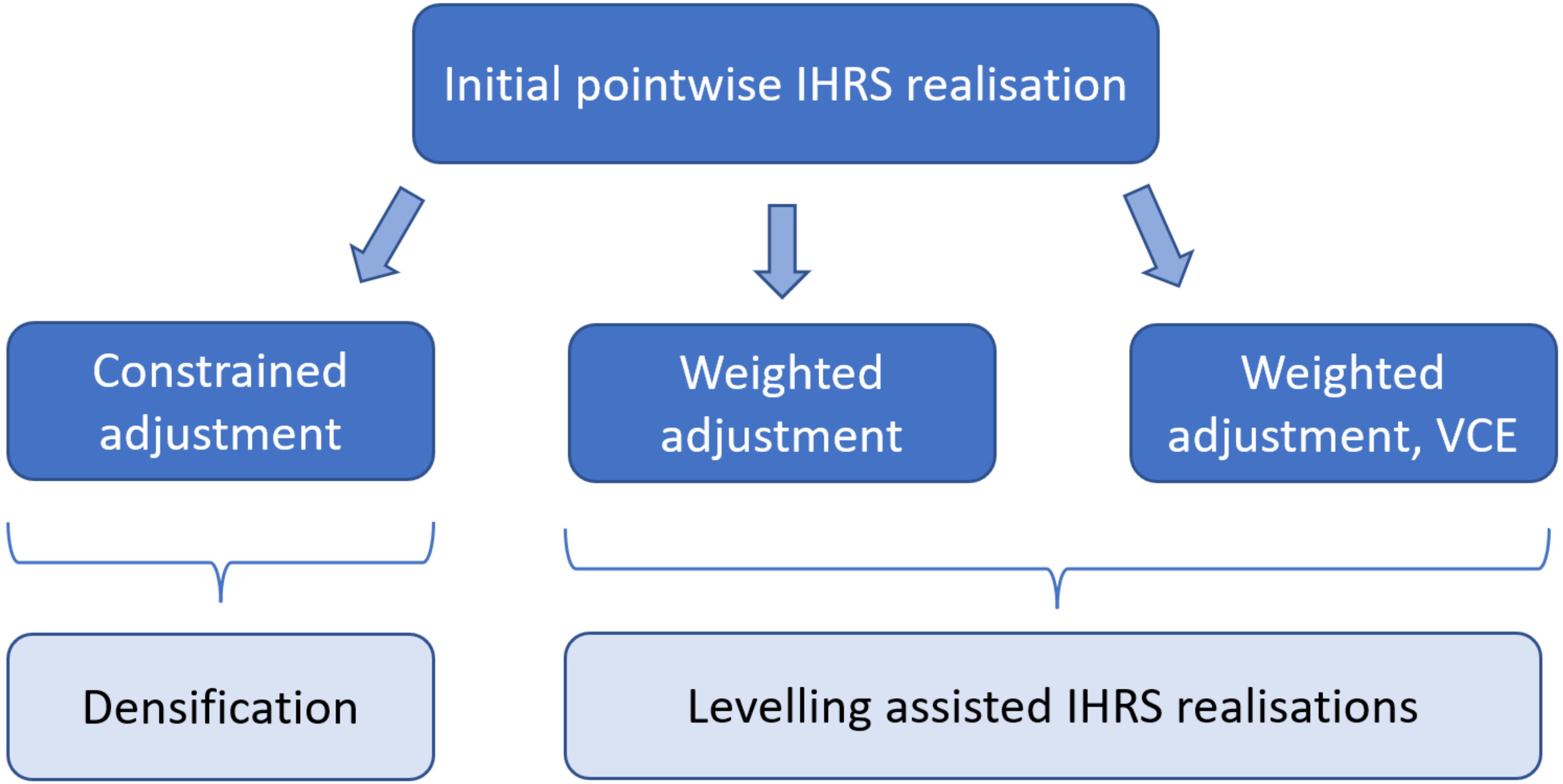
The spatial 3D-positions were converted to ITRF 2014, with the reference epoch 2021.04*.

*) *The epoch of IHRF is so far only implicitly defined by the epoch of the provided ITRF2014 coordinates for the global IHRS realisation.*



Pointwise IHRS realisation at 186 GNSS stations

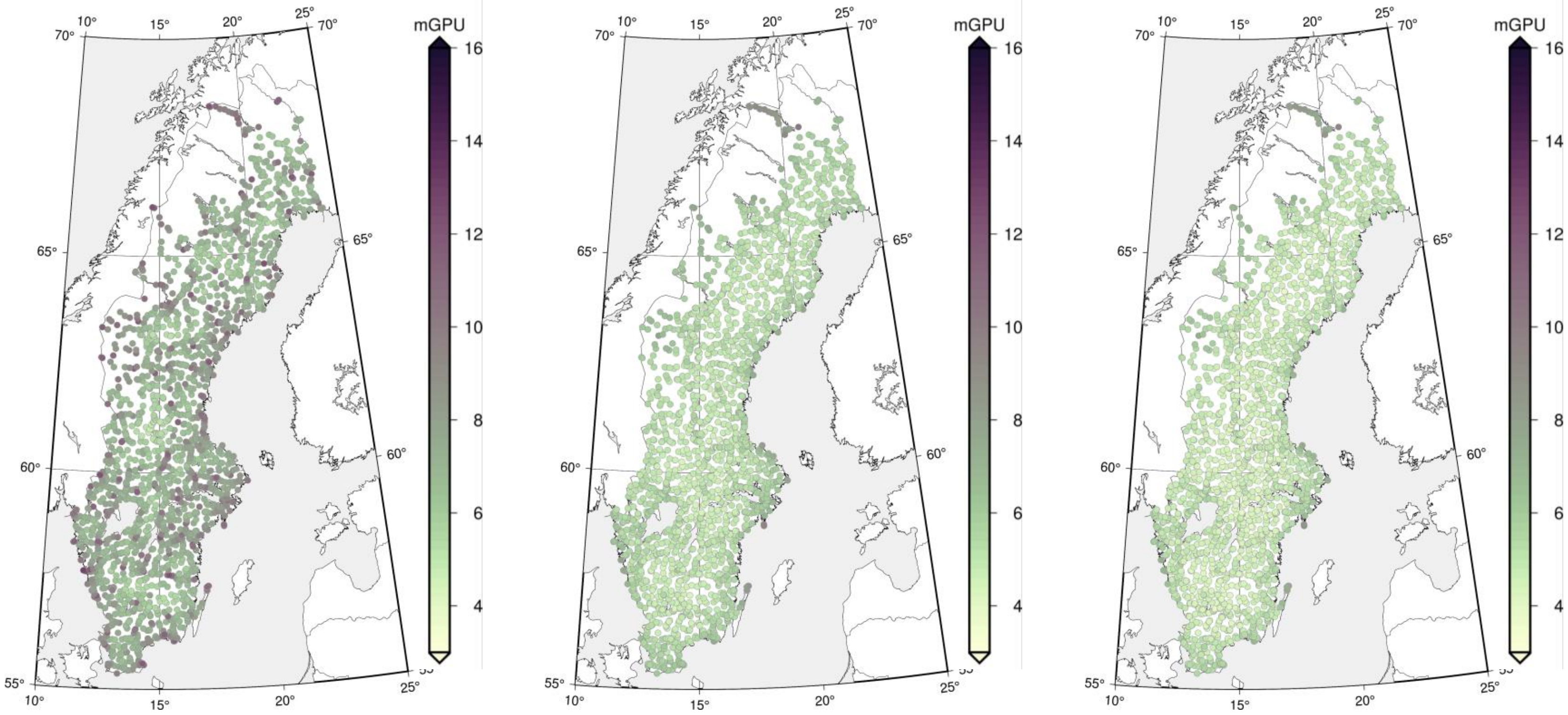
THREE APPROACHES TO THE ADJUSTMENT OF THE LEVELLING OBSERVATIONS



ESTIMATED STANDARD UNCERTAINTY

Estimated standard uncertainty for the 3350 adjusted geopotential numbers.

- Correlated uncertainty model
- Unit: mGPU (~mm)



	Constrained	Weighted	Weighted, VCE
Min	4.6	4.2	3.9
Max	12.9	10.4	9.6
Mean	7.5	5.2	4.8
StDev	1.5	0.7	0.6

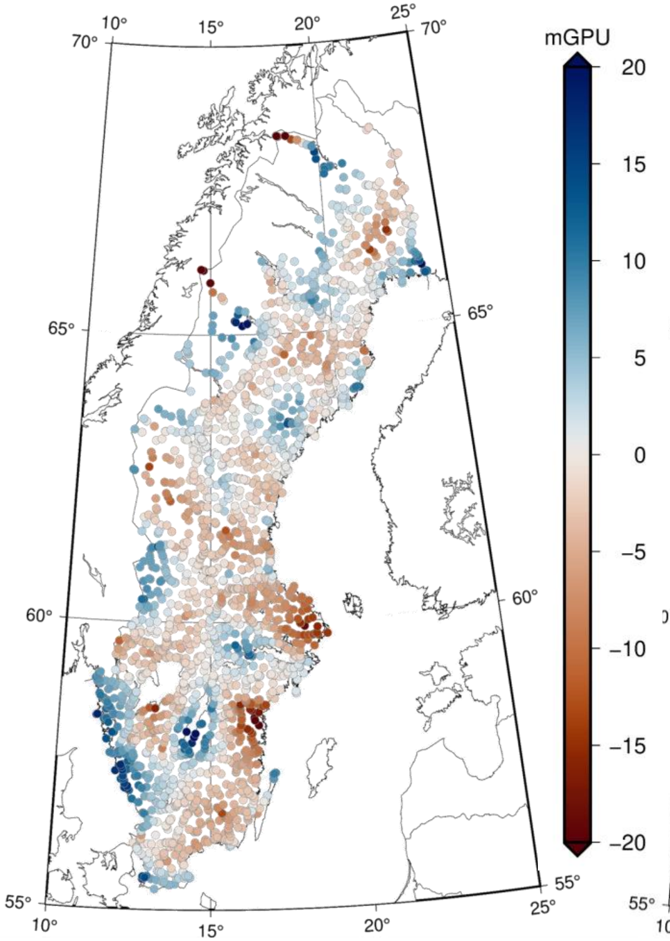
ADJUSTED IHRF GEOPOTENTIAL NUMBERS

Differences between the estimated IHRF geopotential numbers of the different approaches:

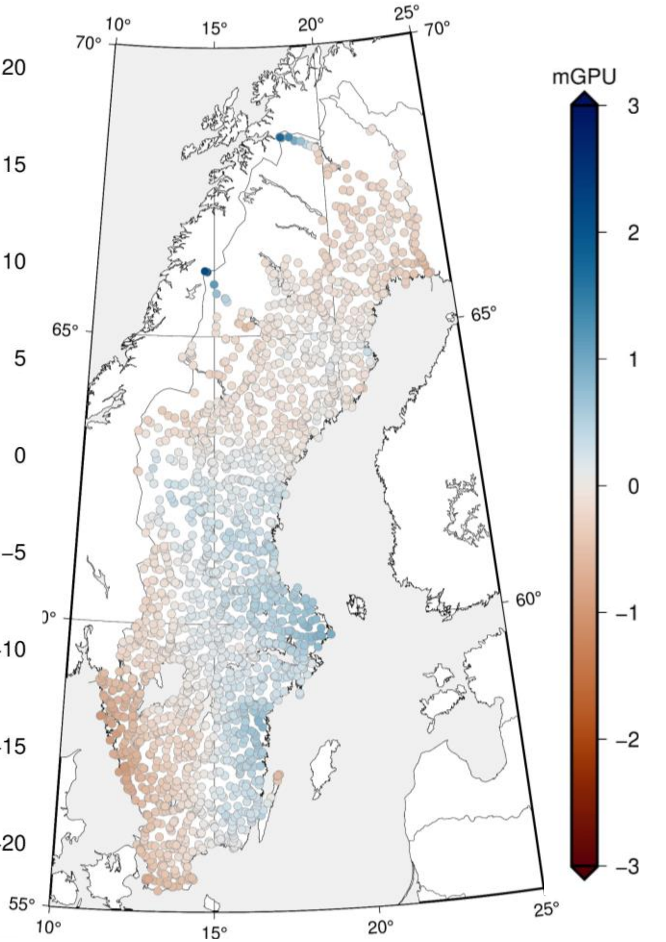
- Weighted (VCE) – constrained
- Weighted (VCE) – weighted

	VCE – Constrained	VCE – Weighted
Min	–40.8	–1.0
Max	28.2	2.2
Mean	–0.16	0.00
StDev	5.85	0.34

- Correlated uncertainty model.
- Unit: mGPU (~mm)



VCE – Constrained



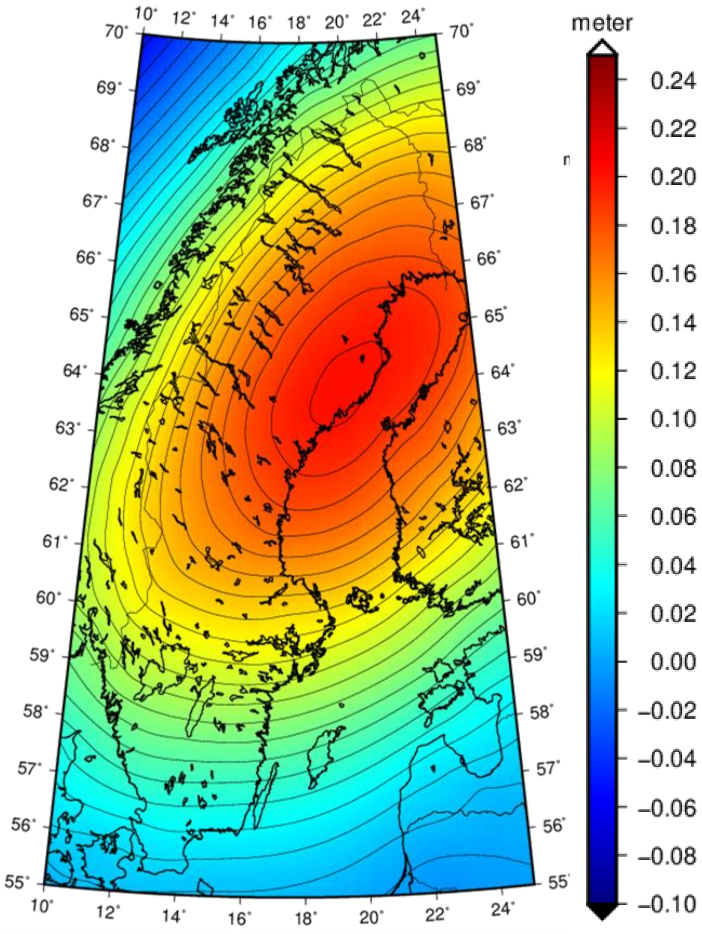
VCE – Weighted

COMPARISON OF IHRF AND RH 2000

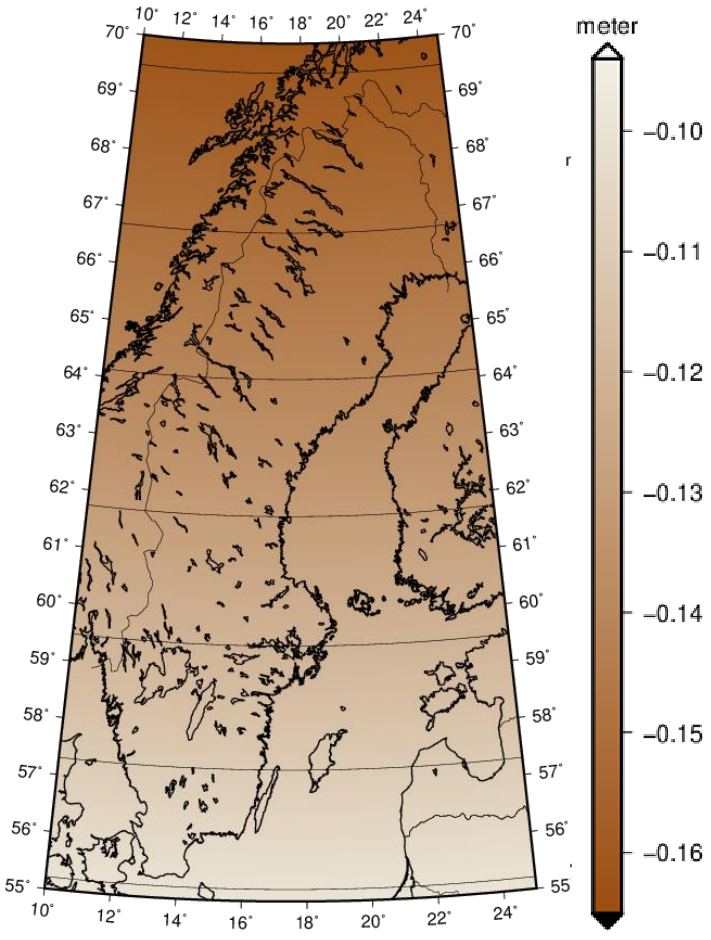
RH 2000 is the official Swedish realisation of EVRS.

Corrections due to differences of the system definitions.

- Postglacial land uplift epoch
- Permanent tide concept
- Zero-level shift



Correction of 21.04 years of postglacial land uplift.



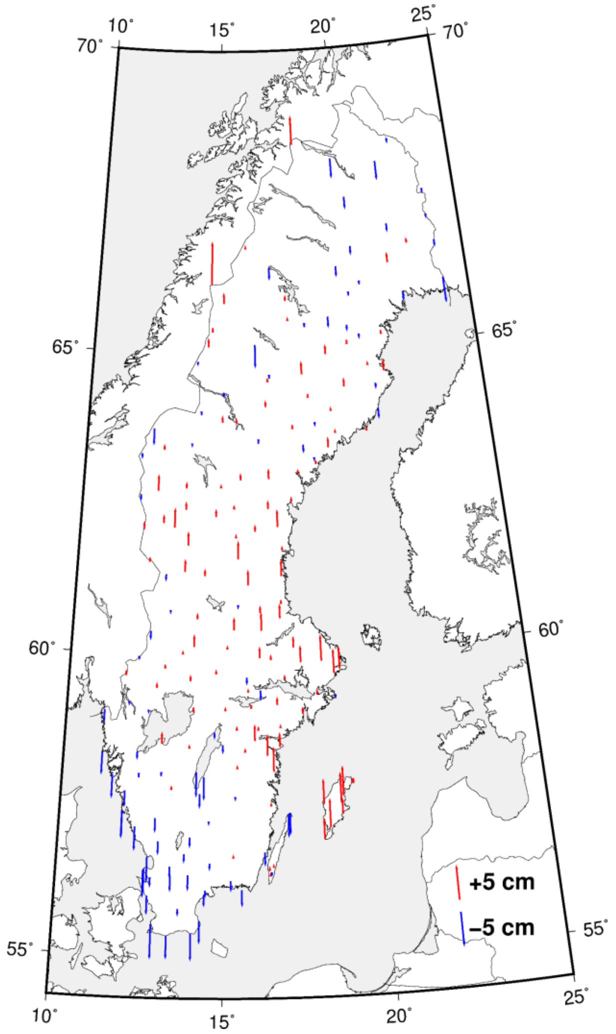
Correction between mean tide and zero tide concepts.

DIFFERENCES IHRF – RH 2000

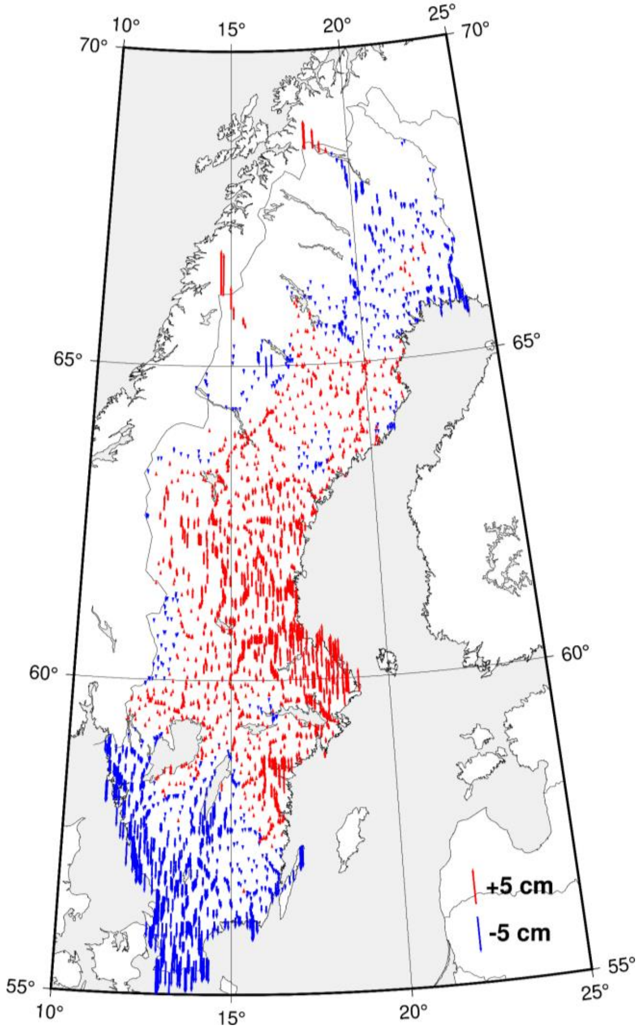
Differences between the IHRF solutions and RH 2000, after reduction of permanent tide effect, land uplift and zero level

	Initial pointwise IHRF	Levelling assisted IHRF (constrained)	Levelling assisted IHRF (weighted, VCE)
# Points	197	3308	3308
Zero-level shift	+454.7 mm	+455.8 mm	+456.0 mm
Mean	0.0	0.0	0.0
Min	–49.8	–51.6	–30.2
Max	+62.2	+63.1	+25.1
StdDev	19.2	13.5	10.4

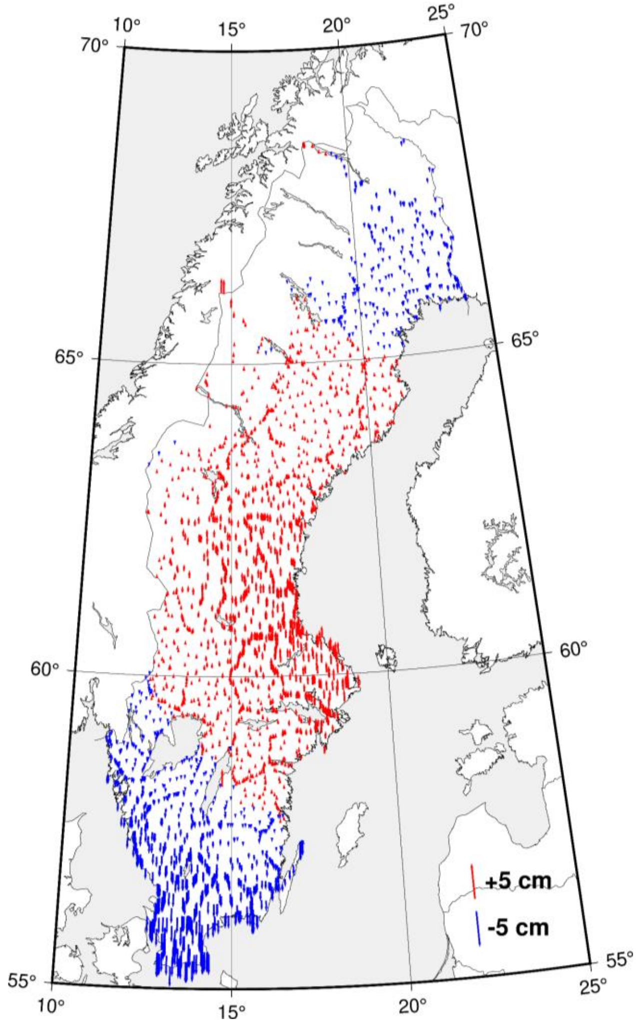
PLOTS OF THE DIFFERENCES IHRF – RH 2000



Initial pointwise IHRF solution



Levelling assisted IHRF (constrained)



Levelling assisted IHRF (weighted, VCE)

CONCLUSIONS

- A constrained adjustment is a pure densification of the initial pointwise IHRS realisation, with propagation of the GNSS station uncertainties into the levelling network.
- With the weighted adjustment, the standard uncertainties are reduced significantly. It is essential to choose a priori uncertainties carefully, though.
- Weighted adjustment with VCE yields the lowest standard uncertainty, even though the differences compared to the weighted adjustment are small.
- A clear systematic pattern is shown in the comparison to RH 2000. Due to the long wavelength pattern, the discrepancy is most likely related to the gravimetric geoid model, but other explanations shall be investigated.

FUTURE WORKS

- New initial IHRS realisation
  - Updated gravimetric quasigeoid model
  - Updated GNSS/levelling dataset
- Investigate the impact of potential systematic errors in levelling observations on a levelling-assisted IHRF solution
- Further investigations related to the long wavelength systematic shown in the comparison to RH 2000
  - Gravimetric geoid model
  - Levelling
  - GNSS
  - Corrections of known effects

THANK YOU! QUESTIONS?

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