REVIEW AND UPDATE OF SWEREF 99

NKG WG REFERENCE FRAMES

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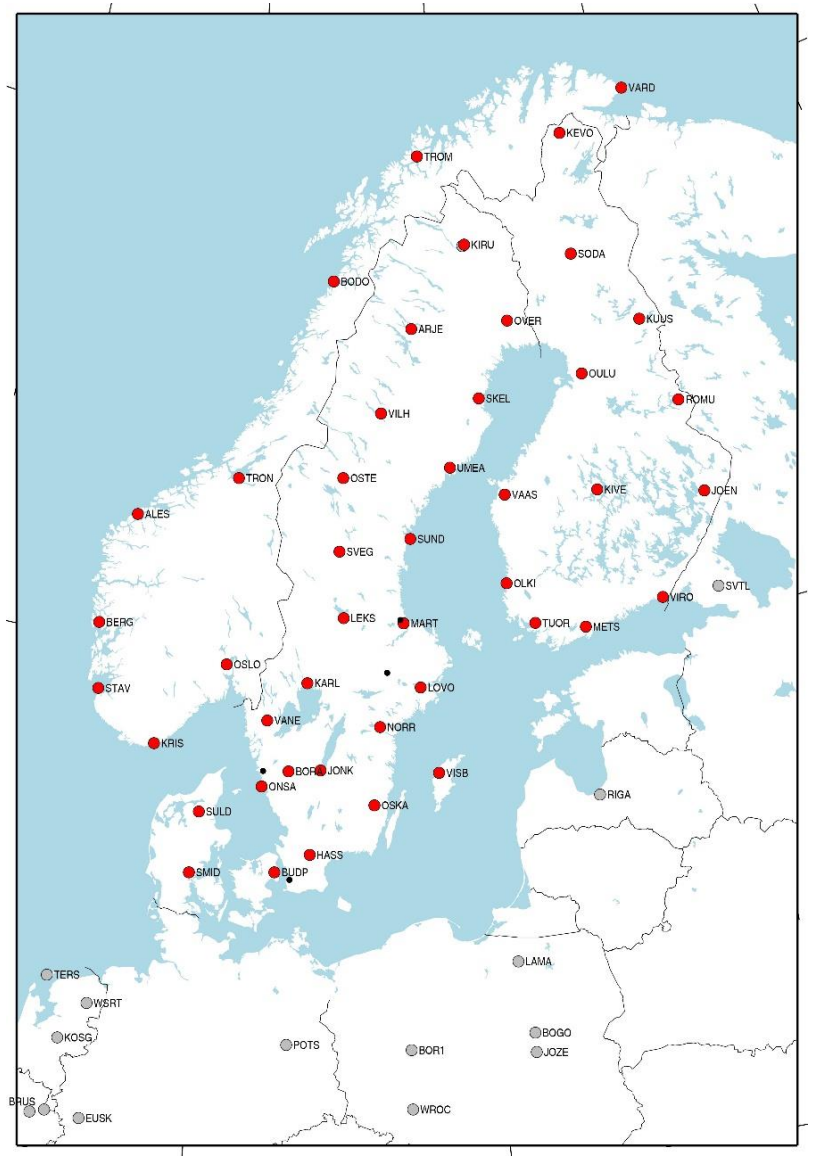
BACKGROUND

SWEREF 99, ETRS 89 IN SWEDEN, EPOK 1999.5



Defined by fundamental stations in Sweden, Norway, Denmark and Finland. SWEREF 99 is mainly accessed through SWEPOS services (realtime or postprocessing)

6 weeks in the summer of 1999

- ITRF 97
- Bernese GNSS Software ver 4.2
- igs_01.atx (relative antenna models)
- 15° elevation cut-off
- DM Chokering antennas

Motivation for the review and update:
We have experienced degradation when we determine new stations in SWEREF 99, especially in northern Sweden, and at the same time the demand on the precision from SWEPOS is increasing.

SINCE 1999

- Relative deformations within Sweden up to 4 cm in north and east and 20 cm in height
- Antenna changes in Denmark and Norway soon after the campaign in 1999 (but Finnish stations remained until 2016)
- Antenna changes
- Antenna model changes (relative → 108 → 114)
- Elevation cut-off 15° → 10° → 3°
- Other model changes for the processing
- Glonass and later Galileo were added

OBJECTIVE OF THE SWEREF 99 REVIEW

- Analyse the present SWERF99 coordinates (just replaced in Feb. 2021!) and quantify the uncertainty from different contributors:
  - Corrections for antenna model changes (relative → I08 → I14)
  - Difference between using different satellite systems
  - Geodynamic deformations – differences to used models

- Compute a new set of coordinates for all stations used in SWEPOS services and for the definition of SWEREF 99, which are
  - Consistent with present observations and processing models
  - Agree with present coordinates within the uncertainty limits of the SWEPOS services

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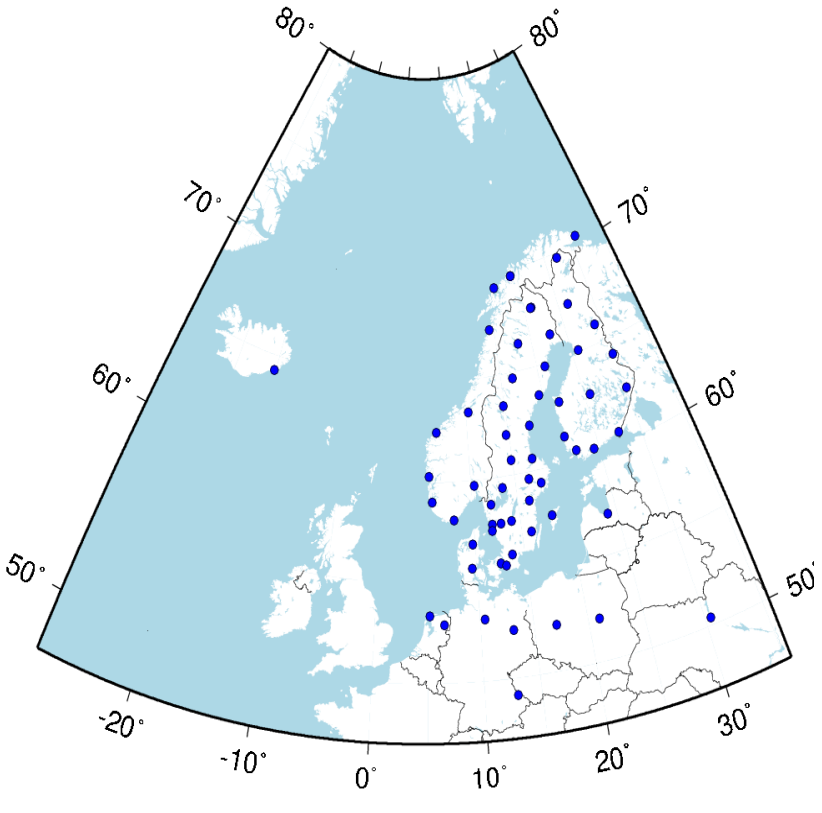
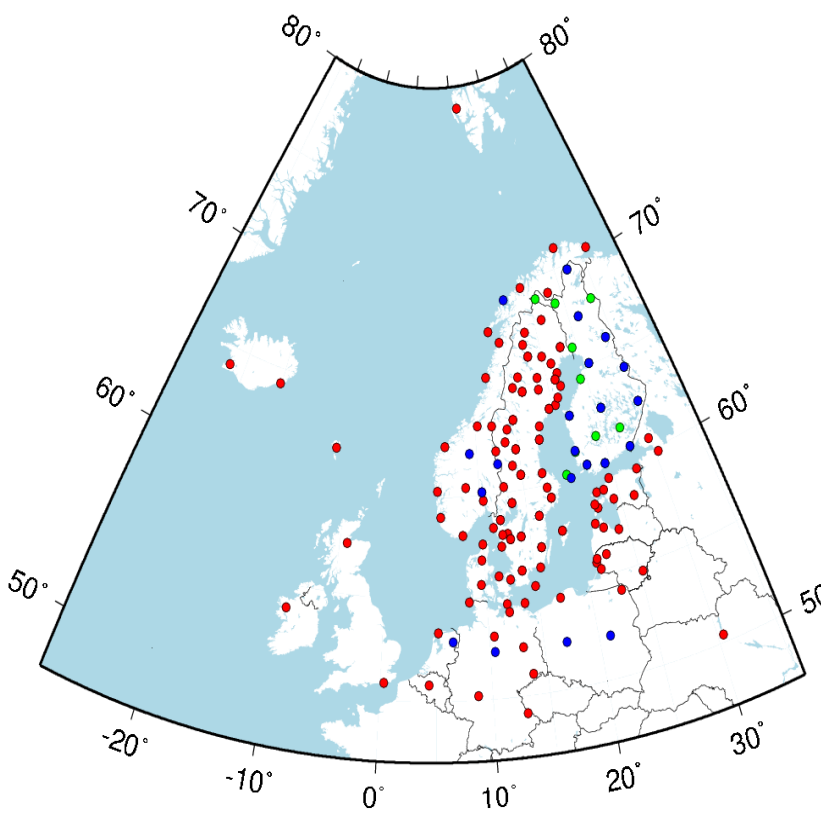
WORK DONE

THREE CAMPAIGNS

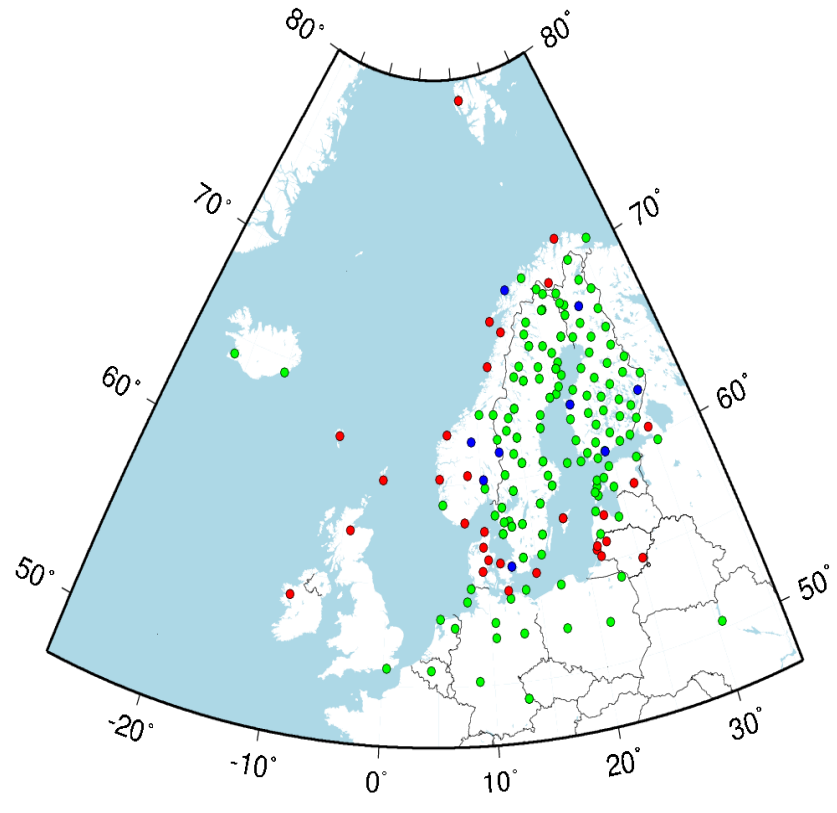
1999



2015



2019



● = GPS ● = GPS+GLO ● = GPS+GLO+GAL

COMPUTED SOLUTIONS

Solution type	1999		2015		2019	
	I08	I14	I08	I14	I08	I14
Campaign GPS	S08_99_G	S14_99_G	S08_15_G	S14_15_G	S08_19_G	S14_19_G
Campaign GPS/GLO			S08_15_GR	S14_15_GR	S08_19_GR	S14_19_GR
Campaign GPS/GLO/GAL				S14_15_GRE		S14_19_GRE
NKG GPS	N08_99		N08_15R			
NKG GPS/GLO			N08_15O			
NKG GPS/GLO/GAL						N14_19_3v/9v

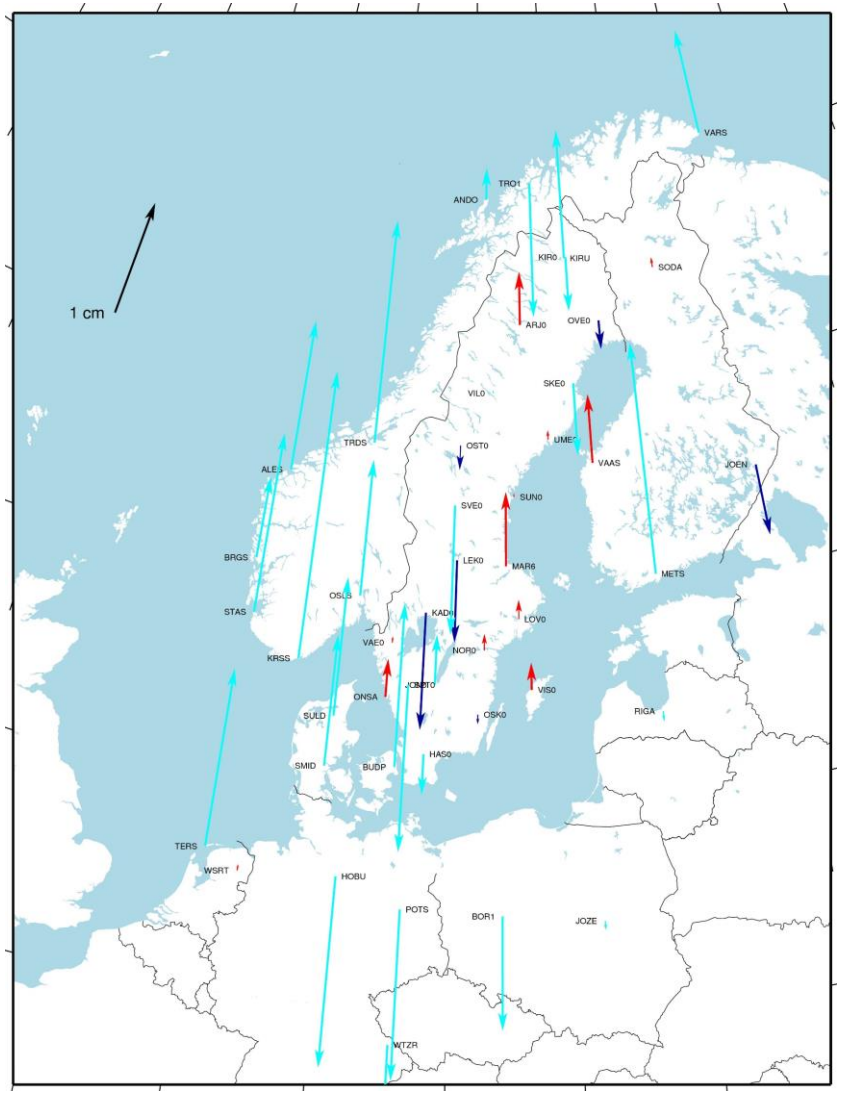
16x2 = 32 solutions
3° and 10° grader

+ time series analysis based on NKG
(repro1 and operational)

UNCERTAINTIES (STANDARD UNCERTAINTIES NE/U)

contributor \ cut-off angle	3°	10°
Net/cluster/baselines	0.2 / 0.8 mm	0.2 / 0.8 mm
GPS – GPS+GLO	0.7 / 1.5 mm	0.8 / 2.1 mm
GPS+GLO – GPS+GLO+GRE	0.3 / 1.1 mm	0.3 / 1.2 mm
I08-I14	max 4 / 21 mm	max 4 / 24 mm
I08-I14 jmf IGN-korr	0.5 / 1.8 mm	0.5 / 1.6 mm
1999 – 2019 17 stn (N/E/U) 1999 – 2015 28 stn (N/E/U)	1.3 / 1.0 / 4.4 mm 1.2 / 0.7 / 4.0 mm	1.3 / 1.1 / 4.5 mm 1.2 / 0.7 / 4.2 mm

2019 CAMPAIGN FITTED TO 1999 CAMPAIGN



Turquoise arrows for stations with antenna changes (not included in the fit)

2019 campaign reduced with **NKG_RF17vel**

S14_99_G minus S14_19_G (114, GPS, 3°)

18 stations w/o antenna change

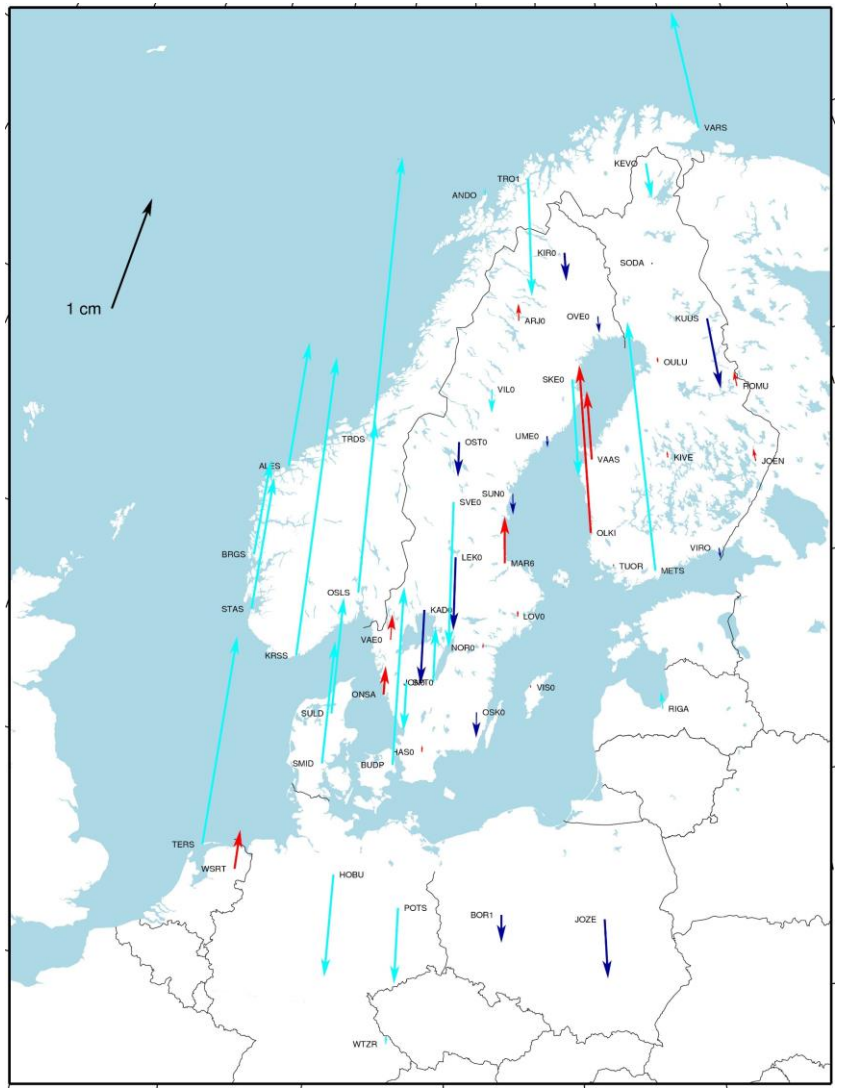
Rms i N E U:
2.7 1.4 4.3 mm

Rms w/o WSRT:
1.3 1.0 4.4 mm

Residuals depend on:

- Uncertainties in NKG_RF17vel
- Differences in the GPS and at stations

2015 CAMPAIGN FITTED TO 1999 CAMPAIGN



2015 campaign reduced with **NKG_RF17vel**

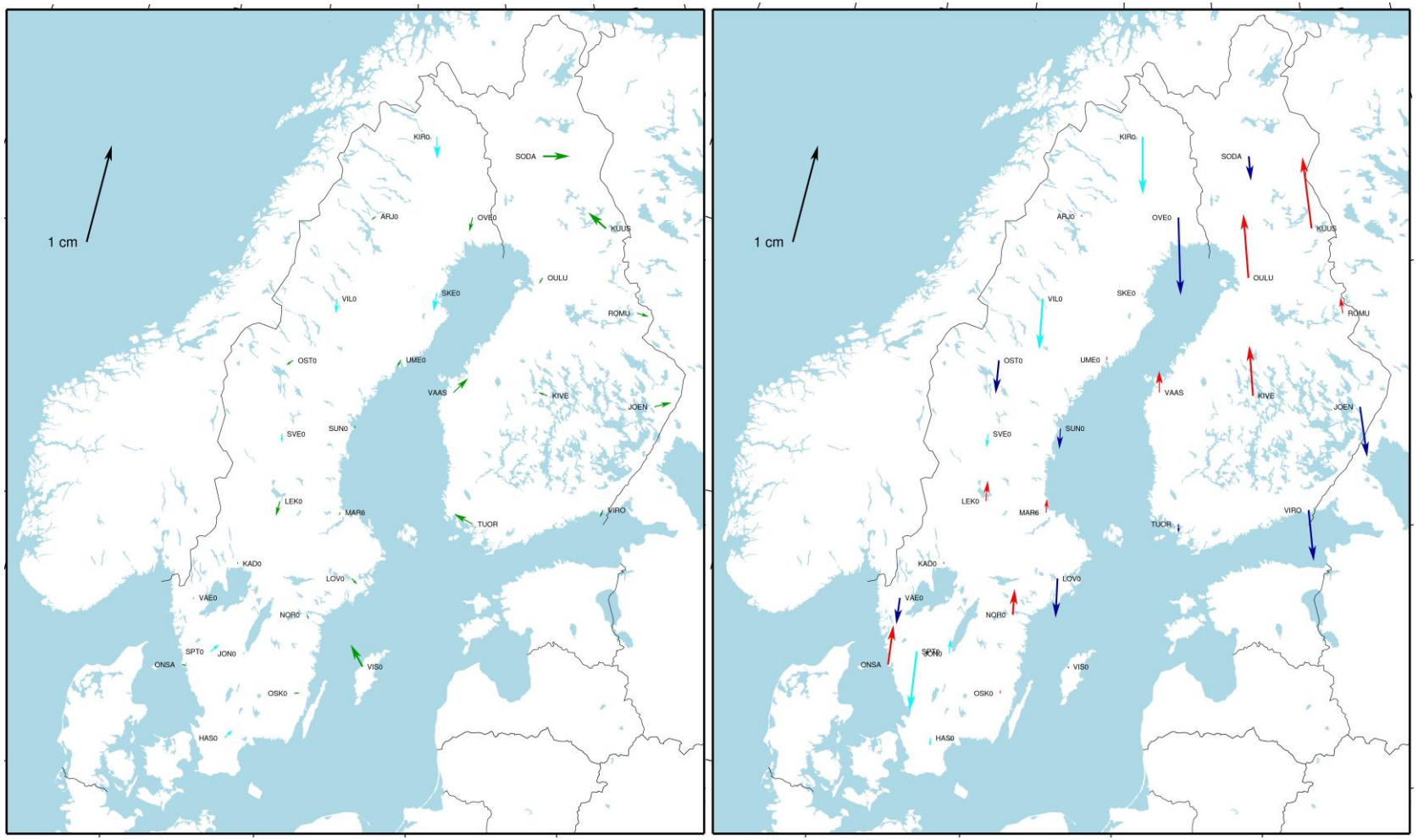
29 stations w/o antenna change

Rms N E U:
2.0 0.9 4.0 mm

Rms w/o WSRT:
1.2 0.7 4.0 mm

Turquoise arrows for stations with antenna changes (not included in the fit)

1999 CAMPAIGN FITTED TO OFFICIAL SWEREF 99 (114, EP1999.5)



Turquoise arrows for stations with antenna changes

SWEREF 99 (114) from coord. DB (epoch 1999.5) minus S14_99_G (1999,114, GPS, 3°)

Totally 30 stations:
RMS 0.9 1.0 3.7 mm in N E U

23 unchanged:
RMS 0.9 1.0 3.8 mm in N E U

Residuals depend on:

- Uncertainties of corrections rel → 108 → 114
- Model differences (trop, elev.cut off)
- Uncertainties of antenna changes

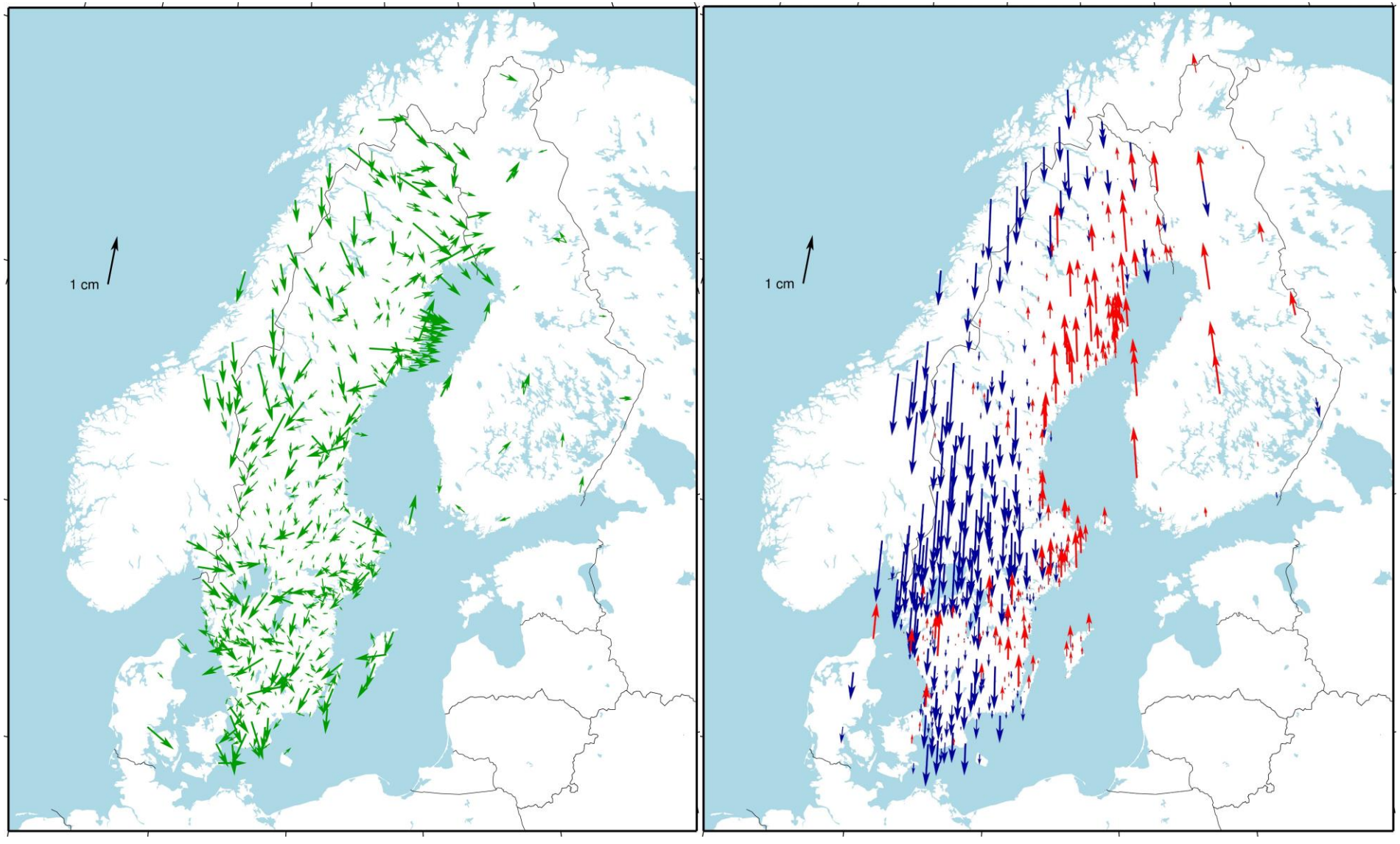
NEW COORDINATE SET: SWEREF 99 UPDATE 2021

- Consistent with present observations and processsing models
- Agree with present coordinates within the uncertainty limits of the SWEPOS services

NEW COORDINATE SET

- Based on 2019 campaign, 114, GPS+GLO+GAL (S19_14_GRE)
- 3°, more consistent solutions than 10°, standard in EPN/EUREF
- Fit to ”present” official SWEREF 99
  - NKG_RF17vel used for reduction to epoch 1999.5
  - Add old Finnish stations from 2015 campaign to get more fitting points
  - Re-determine SWEREF 99 for Finnish stations with SNOW-radome (problems from rel → I08 conversion)
  - Different alternatives for fitting points (all available, just without antenna changes, or simply use the preliminary NKG-transformation) - best alternative selected based on two criterias:
    - Best fit with priority to areas with the lowest uncertainties in SWEPOS services (procjet adapted areas)
    - Best agreement of orientation with EPN’s realisation of ETRS89

SWEREF 99 MINUS SWEREF 99, UPDATE 2021



RMS:
2.7 2.4 4.9 mm

577 points

At the epoch 2019-09-18

RMS project adapted areas (14):
2.1 2.1 3.1 mm

UPDATE OF THE NKG-TRANSFORMATION

- The new coordinate solution was finalized just before the NKG transformations were prepared for publication in PROJ → opportunity to update
- This NKG-transfomation based on NKG_RF17vel will be extra important to us as it is the same LUP-model as was used to define our updated SWEREF 99
- As the fit is done at epoch/solution number 2015.0, we used only stations which had no antenna changes between 2015.0 and 2019-09-18.
  (Only class A in Sweden, excluded some far away stations, ended up with 69 fitting points.)
- Further on the SWEREF 99 coordinates for the fit were converted for 114 → 108 and as well GPS/GLO/GAL →GPS to be consistent with NKG Repro1.

IMPLEMENTATION

- Coordinates for time intervals after 2019-09-18 have been computed for all stations in the usual way.
- Coordinates for earlier intervals are computed for fundamenat stations and for projected adapted stations where our partners wished so, to be usable for post-processing. The NKG Repro1 upd2020 is used to check jumps between intervals.
- The new updated coordinates were implemented in SWEPOS 2021-02-07 (SWEREF 99, update 2021).
- Next step will be to decide how much re-processing of static points (300 2x24 h points) are needed, input for next geoid model.

SUMMARY

- The review shows that we had a general uncertainty level on 2/2/5 mm in N/E/U
- The remaining errors after taken NKG_RF17vel into account on the period 1999-2019 is 1-2 mm in NE and 4 mm in U, which corresponds to 2-3% of the total deformation.
- Larger differences for GPS - GPS/GLO than GPS/GLO - GPS/GLO/GAL
- Better agreement for 3° than 10°
- A new set of SWEREF 99 coordinates have been implemented in SWEPOS
  - Consistent with observations and models of today
  - Better geographical coverage and better agreement of the orientation with EPN ETRS89
  - Agree with earlier used coordinates within the uncertainty limits of the SWEPOS services, but for users with high demands on repeatability (e.g. deformation measurements) re-processing or corrections could be done

THANKS FOR YOUR ATTENTION!

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