Evaluation of newly installed SWEPOS mast stations, individual vs. type PCV antenna models and comparison with pillar stations

Faramarz Nilfouroushan[1*], Lotti Jivall[1], Christina Lilje[1], Holger Steffen[1], Martin Lidberg[1], Jan Johansson[2], Per Jarlemark[3]

1) Lantmäteriet, Gävle, Sweden, 2) Chalmers University of Technology, 3) SP Technical Research Institute of Sweden, (*) University of Gävle

Faramarz.nilfouroushan@lm.se

Introduction

For about two decades, SWEPOS (the Swedish Permanent GNSS network) pillar stations have been used in different geodetic and geodynamic studies. To keep continuous measurements of these long lived pillar stations and at the same time modernizing the SWEPOS network, it has been decided to install new truss mast stations, equipped with modern and individually calibrated antennas and radomes, capable of tracking all new GNSS satellites. Installation of mast stations started in 2011. Today, each pillar station in the SWEPOS permanent GNSS network has a close-by truss mast station (Fig. 1), mostly in 10 meters distance with individual calibrated Leica choke ring antenna and its attachment (LEIAR25.R3, LEIT). Due to their closeness to pillars, the modern mast stations may provide additional information for the analysis of ground movements in Sweden e.g. to distinguish between tectonic and geodynamic processes (e.g. land uplift in Sweden).

In this study, we have used two datasets from two different seasons for 21 pillars and 21 mast stations and formed different networks. The mast network has been processed using both IGS standard (type) and individually calibrated PCV (Phase Center Variation) models and therefore the effect of these two different PCV models on height components has been investigated. In a combined network, we processed all 42 stations (21 pillars+21 mast) to see how this multi-baseline network (861 baselines) combination differs from independent mast or pillar networks with much less baselines (210 baselines). For our analysis, we used the GAMIT-GLOBK software and compared different networks. Ambiguity resolutions, daily coordinate repeatability and differences between height components in different solutions are presented. Moreover, the GAMIT and BERNESE solutions for combined mast and pillar networks are compared.

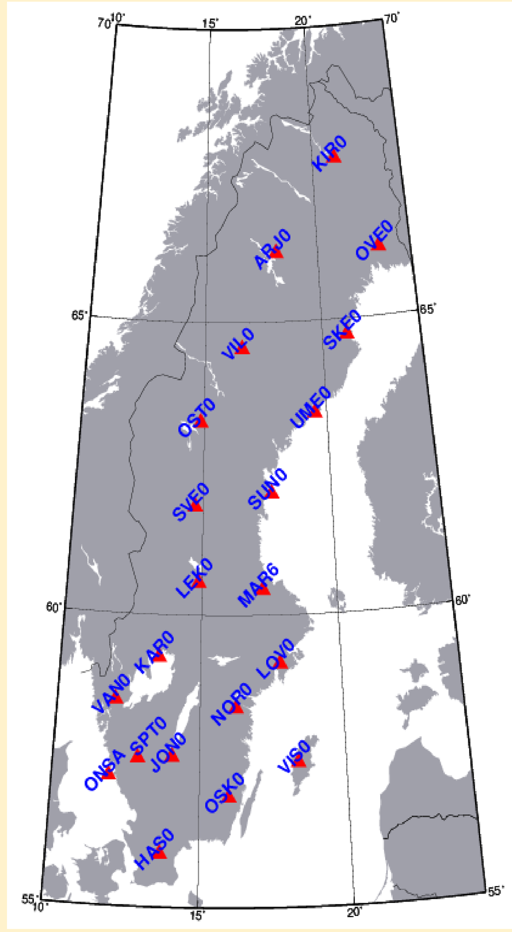

Figure 1. Right: Distribution of SWEPOS pair stations used in this study. Left: Example of the pillar (ARJ0) and truss mast (ARj6) stations.

Data Processing and Results

- 2 sets of 4-weeks data, 24-hours RINEX files (2014:DOY 132-159 & 251-278) of SWEPOS mast and pillar stations
- Type (standard) absolute calibration values were applied for antenna-radome pair (LEIAR25.R3, LEI): http://www.ngs.noaa.gov/ANTCAL/Antennas.jsp?manu=Leica
- Individually calibrated PCV models by GEO++ (EPNC_08.atx file, Table 1)
- GAMIT-GLOBK software (V. 10.5)
- 4 independent or combined mast or/and pillar networks processed (**Fig. 2**)
- Baseline option
- 10º elevation cut off angle (Elevation- and azimuth-dependent model, AZEL option in GAMIT)
- Tropospheric zenith delay every 2 hours and daily gradients
- IGS products, orbits fixed, ITRF2008 ref. frame
- Ref. frame realization through IGS stations VIL6, LOV6 and ONS1 for combined and mast stations, and VIL0, LOV0, ONSA for pillar network.
- The combined network (42 stations) was compared with BERNESE (5.2) results. For this comparison, 28 daily solutions from GAMIT were combined using GLOBK and constrained with 3 stations ONSA, MAR6 and SPT0. The final coordinates of GLOBK combined solution were compared with Bernese combined solution using the same reference stations.

Table 1: List of 21 mast stations, their receivers, antenna types and individual calibrated antenna model parameters.

LEIAR25.R3

LEICA Radome

Stations and receivers			Individual antenna calibration values (m)						
No.	Name	Receiver	Offset U (L1)	Offset N (L1)	Offset E (L1)	Offset U (L2)	Offset N (L2)	Offset E (L2)	Ant. model
1	ARJ6	JAVAD TRE_G3TH DELTA	0.1608	0.0012	0.0015	0.1579	-0.0001	-0.0001	EPNC_ARJ6
2	HAS6	JAVAD TRE_G3TH DELTA	0.1621	0.0009	0.0005	0.1584	0.0013	-0.0009	EPNC_HAS6
3	JON6	JAVAD TRE_G3TH DELTA	0.1596	0.0000	0.0004	0.1583	-0.0003	0.0006	EPNC_JON6
4	KAR6	JAVAD TRE_G3TH DELTA	0.1604	0.0006	0.0010	0.1588	-0.0001	-0.0007	EPNC_KAR6
5	KIR8	TRIMBLE NETR9	0.1640	0.0016	0.0006	0.1594	0.0001	0.0002	EPNC_KIR8
6	LEK6	JAVAD TRE_G3TH DELTA	0.1592	0.0010	-0.0000	0.1578	0.0006	-0.0004	EPNC_LEK6
7	LOV6	JAVAD TRE_G3TH DELTA	0.1607	0.0009	0.0002	0.1592	-0.0002	-0.0006	EPNC_LOV6
8	MAR7	TRIMBLE NETR9	0.1599	0.0008	0.0005	0.1593	-0.0001	-0.0013	EPNC_MAR7
9	NOR7	JAVAD TRE_G3TH DELTA	0.1612	-0.0002	0.0005	0.1586	-0.0002	-0.0004	EPNC_NOR7
10	ONS1	TRIMBLE NETR9	0.1639	0.0016	-0.0000	0.1576	0.0009	-0.0004	EPNC_ONS1
11	OSK6	JAVAD TRE_G3TH DELTA	0.1610	0.0015	0.0005	0.1581	0.0012	-0.0000	EPNC_OSK6
12	OST6	JAVAD TRE_G3TH DELTA	0.1630	0.0016	-0.0004	0.1573	0.0008	-0.0010	EPNC_OST6
13	OVE6	JAVAD TRE_G3TH DELTA	0.1604	0.0009	-0.0005	0.1585	0.0004	-0.0004	EPNC_OVE6
14	SKE8	JAVAD TRE_G3TH DELTA	0.1604	0.0005	0.0001	0.1567	-0.0010	-0.0002	EPNC_SKE8
15	SPT7	JAVAD TRE_G3TH DELTA	0.1614	0.0008	0.0003	0.1585	0.0001	-0.0002	EPNC_SPT7
16	SUN6	JAVAD TRE_G3TH DELTA	0.1593	0.0008	0.0002	0.1582	0.0006	-0.0009	EPNC_SUN6
17	SVE6	JAVAD TRE_G3TH DELTA	0.1630	0.0016	-0.0004	0.1573	0.0008	-0.0010	EPNC_SVE6
18	UME6	JAVAD TRE_G3TH DELTA	0.1616	0.0004	0.0004	0.1580	0.0001	-0.0003	EPNC_UME6
19	VAN6	JAVAD TRE_G3TH DELTA	0.1638	0.0016	0.0009	0.1568	0.0002	0.0004	EPNC_VAN6
20	VIL6	JAVAD TRE_G3TH DELTA	0.1610	-0.0003	0.0007	0.1582	0.0005	0.0011	EPNC_VIL6
21	VIS6	JAVAD TRE_G3TH DELTA	0.1616	-0.0000	0.0010	0.1589	0.0004	-0.0002	EPNC_VIS6

Standard IGS PCV values (m)

offset U (L1)	offset N (L1)	offset E (L1)	offset U (L2)	offset N (L2)	offset E (L2)	antenna PCV model
0.1617	0.0002	0.0001	0.1588	0.0002	-0.0006	IGS08_1842

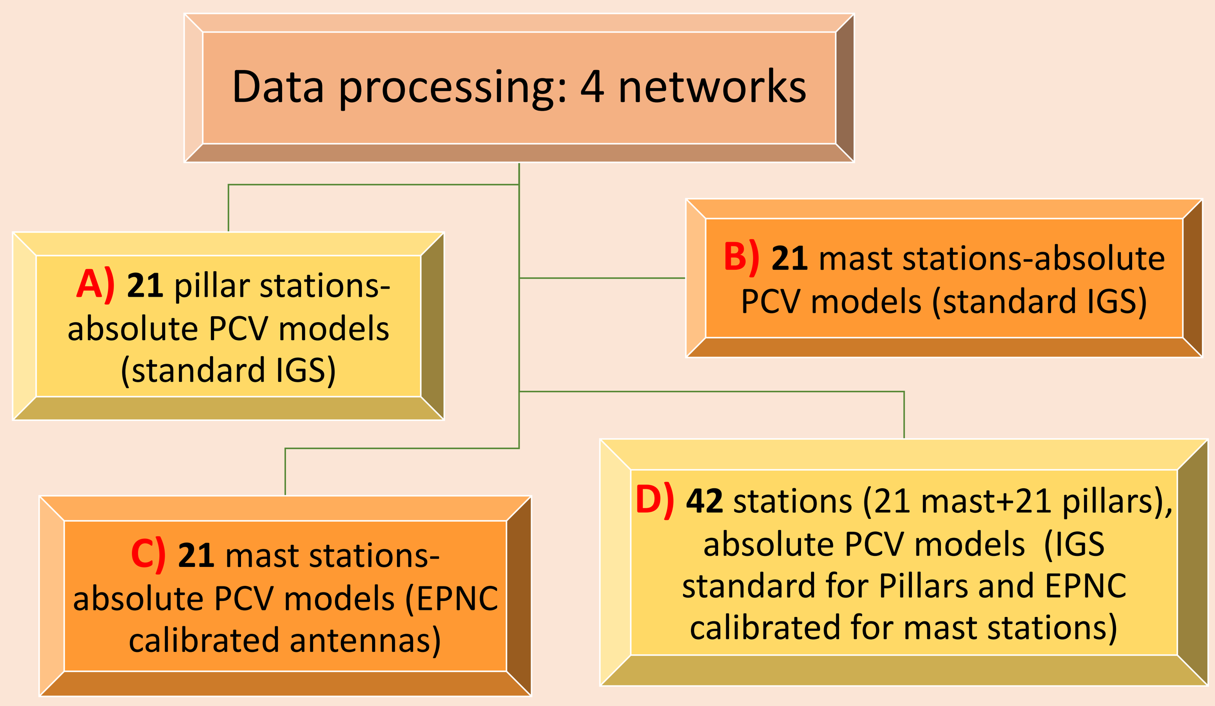

Figure 2. Overview of analyzed networks. Networks A, B and C with 21 stations had a total of 210 baselines. The combined network (D) with 42 stations had 861 baselines.

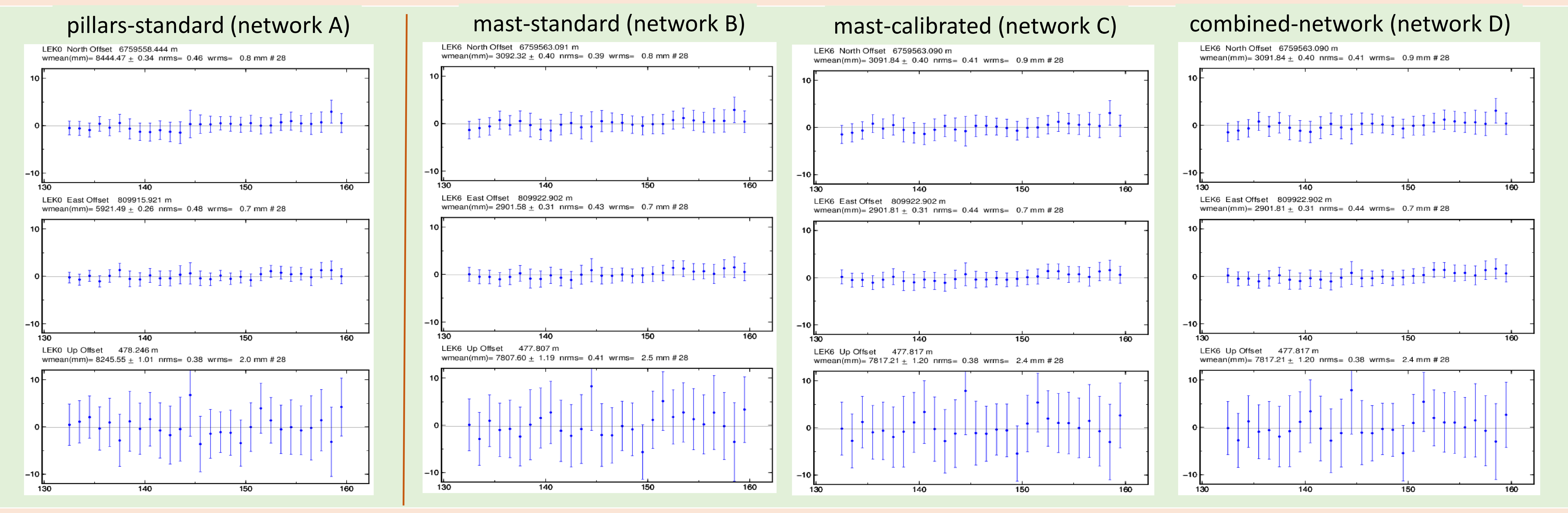

Figure 3. Daily coordinate repeatabilities for sample mast station LEK6 and its close-by (8.4 m) pillar station LEK0. The same processing strategy and same constraints were used for all 4 networks. The time series look similar for both pillar and mast stations in all networks. Vertical axis is in mm and horizontal axis is DOY (132-159).

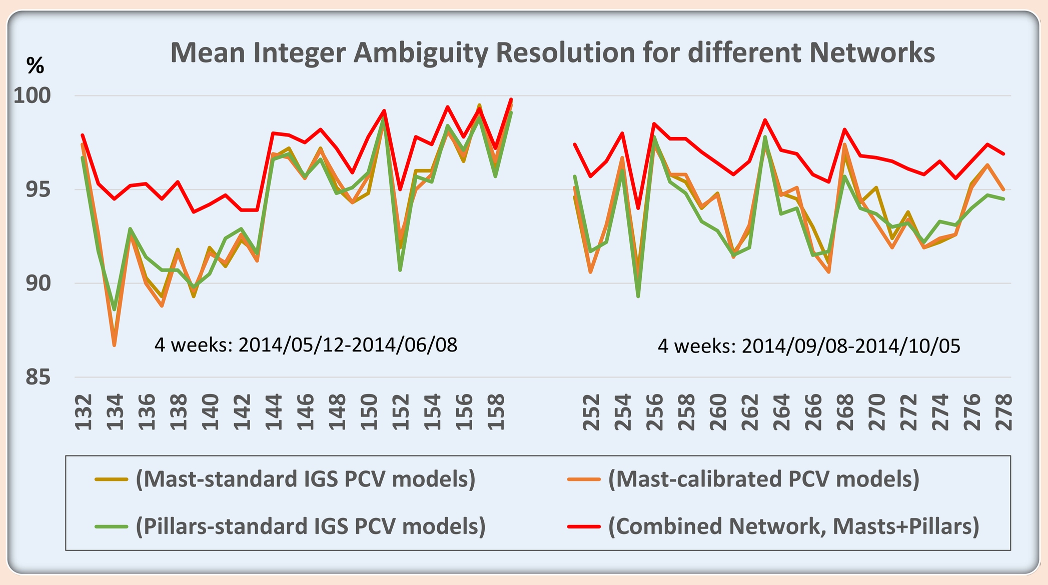

Figure 4: Mean wide-lane integer ambiguity resolution for the different networks.

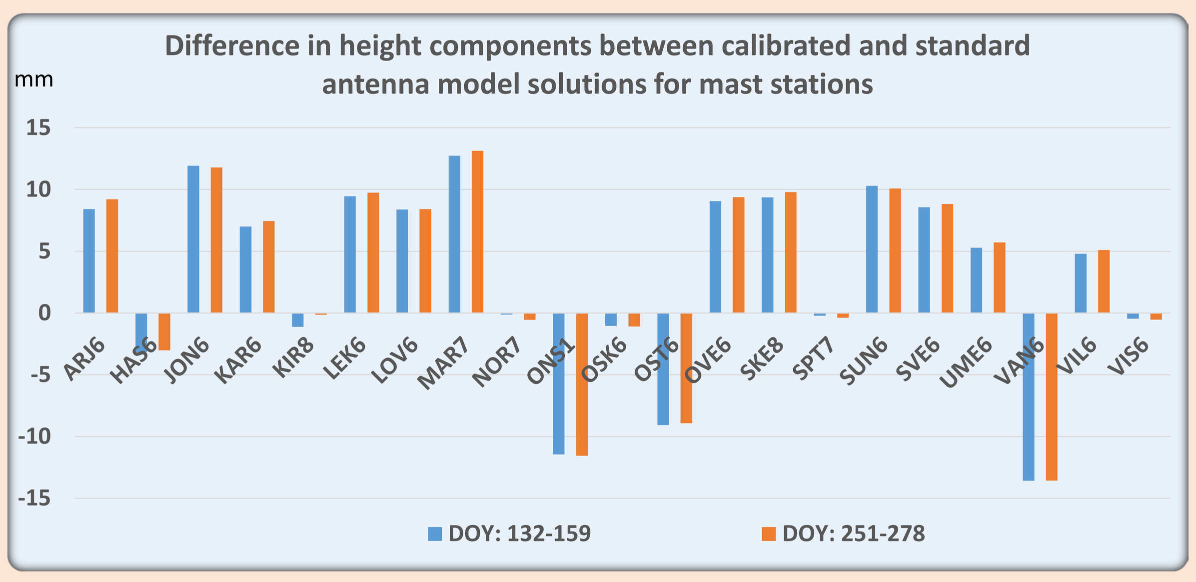

Figure 5: Difference in height components between individually calibrated and standard antenna model solutions for 21 mast stations. The blue and brown colors represent two independent combined solutions for two different seasons and look similar.

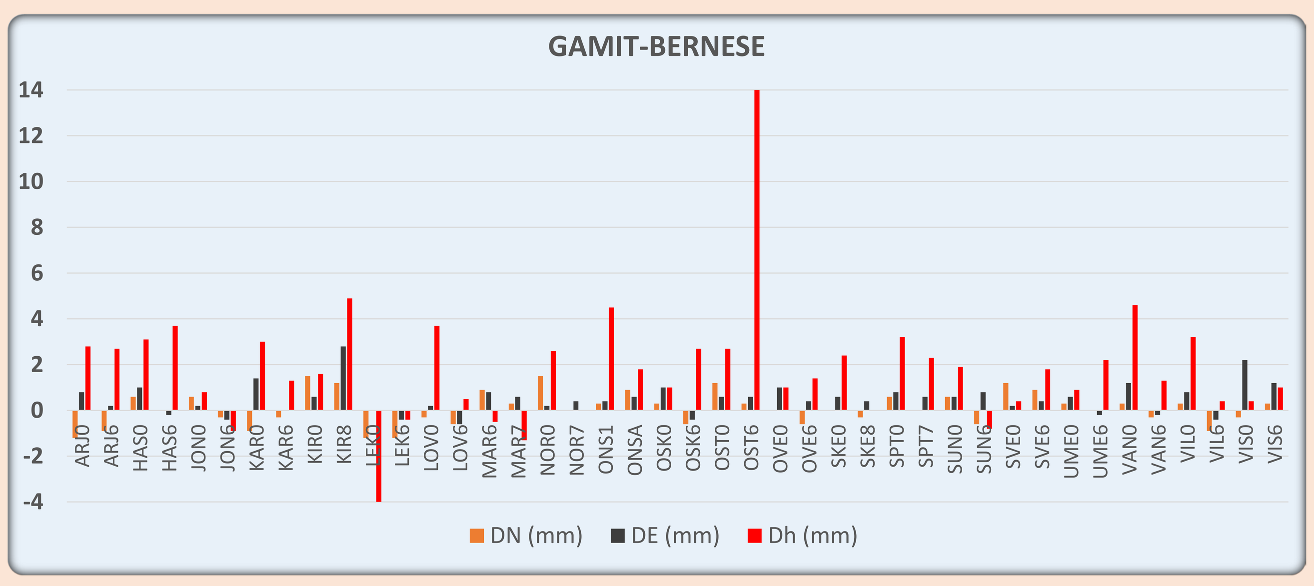

Figure 6: The difference between GAMIT and BERNESE (5.2) solutions in geodetic coordinates for 4 weeks data (140908-141005). Average differences in north, east and height coordinates are 0.1 mm, 0.5 mm and 1.8 mm respectively. Stations with relatively large height differences, such as OST6 and KIR8 should be further investigated.

Conclusions

- Comparison of standard and calibrated PCV models for mast stations show notable differences in height components and reach up to ±14 mm (**Fig. 2**, networks B and C). These differences are antenna-dependent and are not systematic offsets (**Fig. 5**). Therefore, whenever available, individual calibrated antenna models have to be used instead of standard (type) calibrated models.
- Our results suggest that SWEPOS truss mast stations can reliably be used for crustal deformation studies. The comparison between pillar and mast stations **(Fig. 3)** shows similar time series for different horizontal and vertical components and their normalized rms (nrms) and weighted rms (wmrs) are almost equal.
- The wide-lane (WL) ambiguity resolutions for mast and pillar networks are high and mostly between 90-95%. The combined network resolves more ambiguities and rise up to 95-99% (**Fig. 4**).
- The final adjusted coordinates of 42 stations resulting from combined daily solutions of 4 weeks data were compared with the results of BERNESE (5.2) software (**Fig. 6**). All stations coordinates are compatible at 1-5mm level but OST6 has large difference which needs further investigation.