BALTIC+

Geodetic SAR for Baltic Height System Unification and Baltic Sea Level Research

Electronic Corner Reflector Station Description

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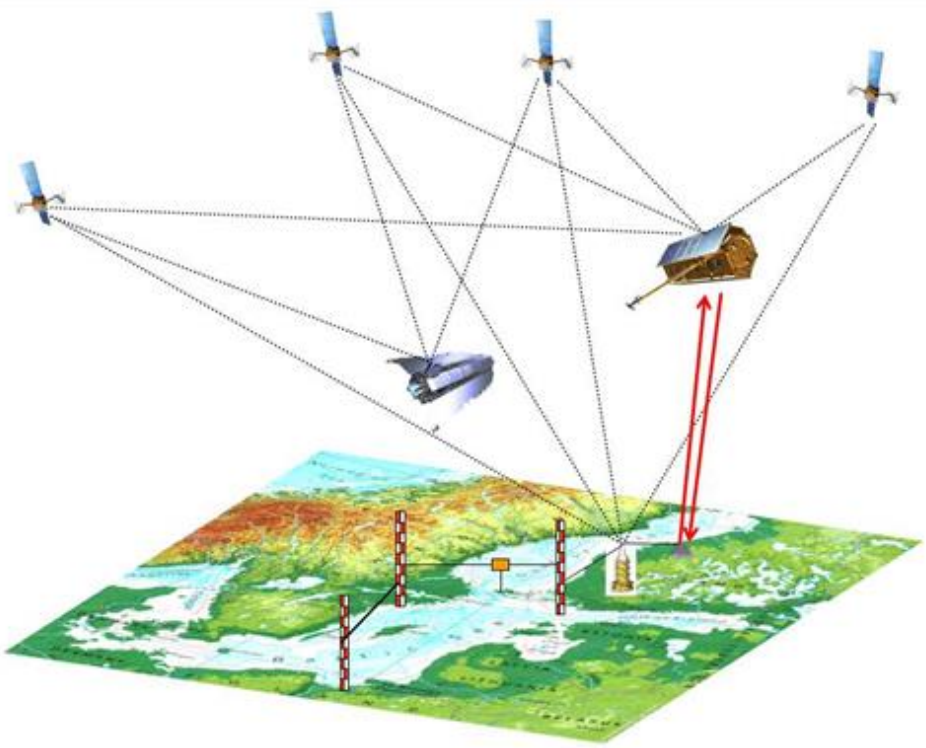

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Abbreviations and Acronyms

CBK-PAN	Centrum Badań Kosmicznych Polskiej Akademii Nauk
CR	Corner Reflector
DLR	Deutsches Zentrum für Luft- und Raumfahrt
ECR	Electronic Corner Reflector
EUREF	Regional Reference Frame Sub-Commission for Europe
FGI	Finnish Geospatial Research Institute
GNSS	Global Navigation Satellite System
IERS	International Earth Rotation and Reference Systems Service
IGS	International GNSS Service
ITRF	International Terrestrial Reference Frame
LM	Lantmäteriet, Swedish Mapping, Cadastral and Land Registration Authority
SAR	Synthetic Aperture Radar
SAR-HSU	Geodetic SAR for Baltic Height System Unification and Baltic Sea Level Research
TUM	Technical University of Munich
TUT	Tallinn University of Technology

Table of Content

1 INTRODUCTION

1.1 Purpose

The purpose of this technical note is a harmonized description of the electronic corner reflectors installed for the project and related measurements done in order to connect them to existing geodetic networks. This is basic information needed to analyse the results obtained with the ECR's in the frame of the defined experiments. It shall be noted that coordinates and contents only apply for the duration of the project (i.e. 2020) and that operation or support beyond 2020 are not given.

1.2 Project Overview

Traditionally, sea level is observed at tide gauge stations, which usually also serve as height reference stations for national levelling networks and therefore define a height system of a country. Thus, sea level research across countries is closely linked to height system unification and needs to be regarded jointly. The project aims to make use of a new observation technique, namely SAR positioning, which can help to connect the GNSS basic network of a country to tide gauge stations and as such to link the sea level records of tide gauge stations to the geometric network. By knowing the geoid heights at the tide gauge stations in a global height reference frame with high precision, one can finally obtain absolute sea level heights of the tide gauge stations in a common reference system and can link them together. By this method, on the one hand national height systems can be connected and on the other hand the absolute sea level at the tide gauge stations can be determined. By analysing time series of absolute sea level heights their changes can be determined in an absolute sense in a global reference frame and the impact of climate change on sea level can be quantified (e.g. by ice sheet and glacier melting, water inflow, global warming).

The major scientific challenges to be addressed by this project then can be summarized as follows:

(1) Connection of the tide gauge markers with the GNSS network geometrically in order to determine the relative vertical motion and to correct the tide gauge readings. For this the new technique of SAR positioning is applied.
(2) Determination of a GOCE based high resolution geoid at tide gauge stations in order to deliver absolute heights of tide gauges with respect to a global equipotential surface as reference.
(3) Joint analysis of geometrical and physical reference frames to make them compatible, and to determine corrections to be applied for combined analysis of geometric and physical heights.

In order to provide answers to these challenges the project has been structured accordingly (Figure 1-1).

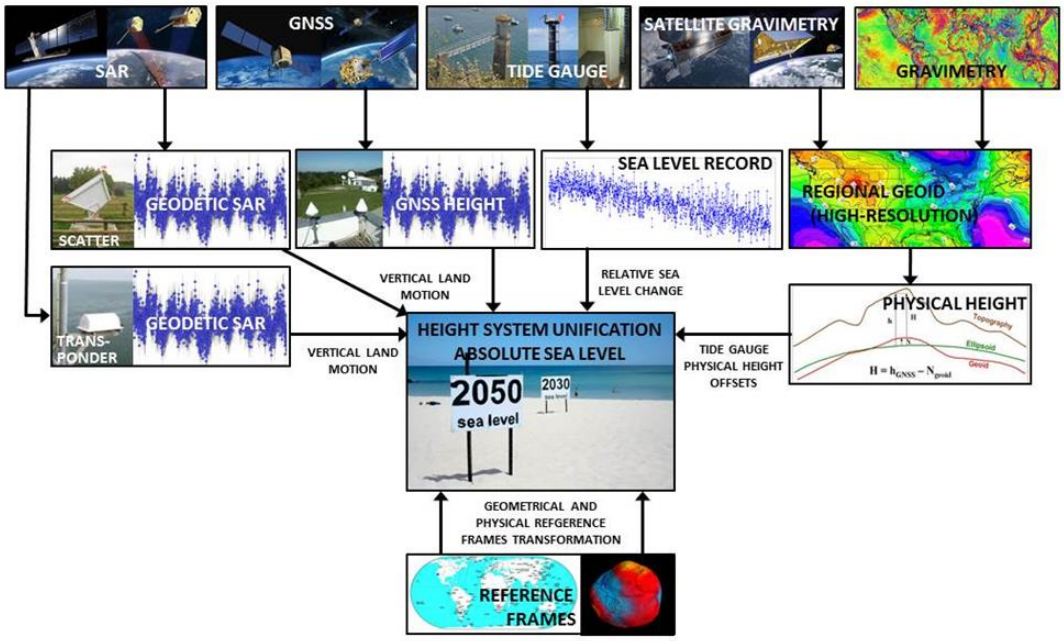


Figure 1-1: Overview of observations and their combination needed to reach the project goals. The boxes at the top line represent the observations needed to estimate the absolute sea level and its changes at tide gauge locations. All observations need to be processed consistently by applying common standards and reference frames in order to compute the absolute sea level at tide stations and

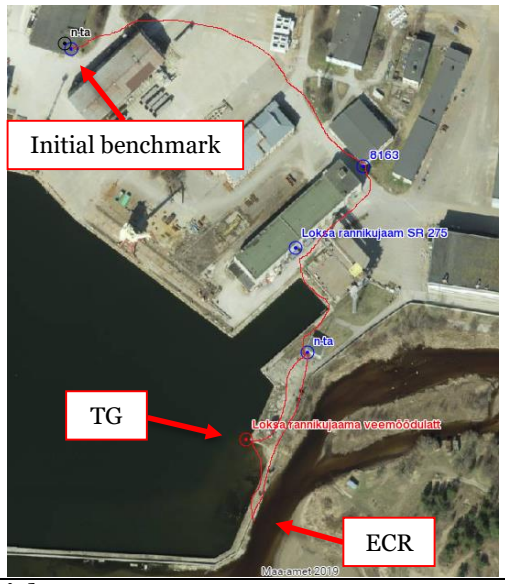
its changes. Further-on this information then can be used for height system unification between different countries.

1.3 Applicable Documents

[AD-1] Final Report, SAR-HSU-FR-0022, Issue 1.1, dated 07.07.2021

2 ECR STATION DESCRIPTIONS

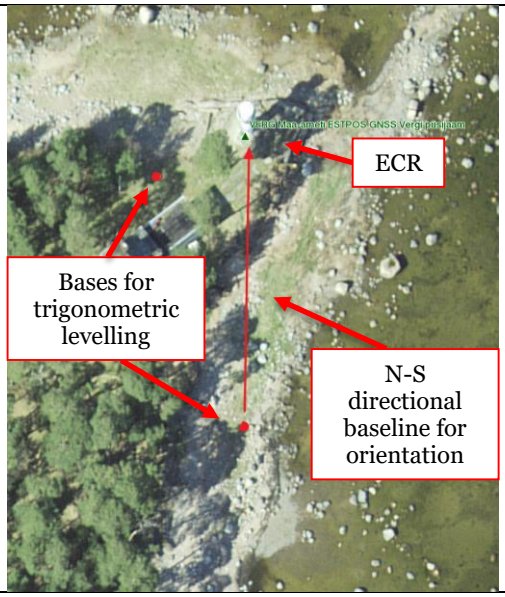
2.1 Estonia

Site	**Loksa**	Initially, the ECR was mounted to the site between 14.02.2020 and 28.09.2020. Due to malfunction, the ECR had to be dismounted and sent for repairs, after which the ECR was remounted to the site. This caused height-wise change in the coordinates.
ECR ID	18_0098	TUM owned
Operator	TUT	
Logbook	Logbook_ECR_18_0098.txt	
Reference systems and transformations		
Height system	EH2000 (a national realization of EVRS), epoch 2000.0	
National reference frame	EUREF-EST97, epoch 1997.56	
Reference frame	ETRS89	
Transformation	none	
Tide gauge connection to height system		
Description	The initial survey: Precise levelling from the tide gauge staff to the benchmark of the National first order Levelling Network. The remounted ECR was simply connected to the tide gauge staff.	Benchmark 90101 (GPA ID 205878) taken as initial: http://www.maaamet.ee/rr/geo/?mitu=10&refnr_id=205878 
ECR connection to height system		

Levelling description	High-precise levelling from the tide gauge staff to the NW corner of the ECR (staff was placed on the cover, not on top of the corner bolt). Bottom plate and cover thickness measured with a caliper. Levelled two times forward and back. Levelling procedure: back-forward-forward-back (equality of shoulders strictly followed). Equipment: 2x Trimble LD12 (invar) barcode staffs; Trimble DiNi 0.3 digital level.	
Levelling computations description	Standard least squares adjustment; no rod calibration or temperature corrections included due to very short distances.	
Levelling closing error	0.17 mm (for the initial survey on 14.02.2020)	
Levelled point height on ECR	2.6568 m (valid between 14.02.2020 and 28.09.2020) 2.6536 m (valid from 29.12.2020)	The NW corner of the cover (not the top of the corner bolt).
Levelled point height difference to origin of ECR	0.0183 m (valid from 14.02.2020 to 28.09.2020) 0.0129 m (valid from 29.12.2020)	Measured with a caliper from the top of the cover to the bottom of the ECR, valid for ECR 18_0098. The cover of the ECR was replaced during the repairs.
ECR reference point height	2.6385 m (valid between 14.02.2020 and 28.09.2020) 2.6407 m (valid from 29.12.2020)	The NW corner of the bottom plate.
ECR ellipsoidal reference point height	19.521 m (valid between 14.02.2020 and 28.09.2020) 19.523 m (valid from 29.12.2020)	Transformed by utilizing EST-GEOID2017 model; intuitively 1 cm accuracy is expected, see: Ellmann, A., Märdla, S., and Oja, T. 2019. The 5 mm Geoid Model for Estonia Computed by the Least Squares Modified Stokes's Formula. Survey Review. doi: 10.1080/00396265.2019.1583848
ECR connection to Reference frame		
Description	Network RTK measurements. Equipment: Leica GS15	Static GNSS measurements (accompanied with post-processing with Bernese) to be performed after receiving unified guidelines.
GNSS data	An average of 5 min 1 Hz GNSS measurements.	

Measured point	Bolt through the mast's center hole (also the center of the ECR), tightened with a nut and receiver put on top of the bolt.	
Measured point coordinates / ECR origin coordinates	25.70586265 59.58255145	No reliable height can be determined from such RTN measurements.
Measured point coordinates / ECR origin transformed ITRF2014 coordinates	2916917.78680 1404186.02230 5477094.05180 (valid between 14.02.2020 and 28.09.2020) 2916917.78750 1404186.02240 5477094.05370 (valid from 29.12.2020)	
ITRF2014 epoch	2020.0000	
ECR orientation parallel to meridian		
Method description	RTK measured ECR mast center hole; RTK pole then moved as far as possible on the same meridian. ECR was then oriented with the naked eye.	
Azimuth accuracy	At least 1 degree or better.	

Site	**Vergi**	Initially, the ECR was mounted to the site between 03.03.2020 and 10.09.2020. Due to malfunction, the ECR had to be dismounted and sent for repairs, after which the ECR was remounted to the site. This caused height-wise change in the coordinates.
ECR ID	18_0086	TUT owned
Operator	TUT	
Logbook	Logbook_ECR_18_0086.txt	
Reference systems and transformations		
Height system	EH2000 (a national realization of EVRS), epoch 2000.0	
National reference frame	EUREF-EST97, epoch 1997.56	
Reference frame	ETRS89	
Transformation	none	
ECR connection to height system		
Levelling description	The height difference between Vergi GNSS antenna ARP and ECR NW corner of the cover (not the corner bolt) determined with total station measurements from two stations. Bottom plate and cover thickness measured with a caliper. Equipment: Trimble S6 DR Plus robotic total station; Leica GA-MP11L prism.	The trigonometric height determination to be repeated, to ensure the stability of the transponder. Vergi GNSS station (GPA ID 228151): http://www.maaamet.ee/rr/geo/?refnr_id=228151 Vergi GNSS station coordinates (EUREF-EST97, epoch 1997.56): 59.60148539 26.10078758 
Ellipsoidal point height on ECR	29.0147 m (valid between 03.03.2020 and 10.09.2020) 28.9740 m (valid from 29.12.2020)	The NW corner of the cover (not the top of the corner bolt).
Levelled point height difference to origin of ECR	0.0186 m (valid between 03.03.2020 and 10.09.2020) 0.0180 m (valid from 29.12.2020)	Measured with a caliper from top of the cover to the bottom of the ECR, valid for ECR 18_0086.
Ellipsoidal ECR reference point height	28.9961 m (valid between 03.03.2020 and 10.09.2020) 28.9920 m (valid from 29.12.2020)	The NW corner of the bottom plate.
ECR connection to Reference frame		

Description	A point established via 3 min network RTK measurement (using Trimble R8 GNSS system) on the same meridian as is the Vergi GNSS station. Total station then centered on the established point and oriented to the GNSS antenna. Measurements conducted from the established base station (to the south of the lighthouse). Control of electronic level after the measurements indicated no movement of the total station.	
Measured point	Coordinates of 4 corners of the ECR.	
ECR origin coordinates	26.10078763 59.60148885	Center of the ECR determined geometrically from the measured coordinates of 4 corners. Absolute height was not determined with these measurements.
ECR origin transformed ITRF2014 coordinates	2905540.21350 1423459.67500 5478170.07090 (valid between 03.03.2020 and 10.09.2020) 2905540.21140 1423459.67420 5478170.06750 (valid from 29.12.2020)	Vergi GNSS station coordinates in ITRF2014: X=2905540.961 Y=1423460.042 Z=5478170.742 Transformation parameters: http://etrs89.ensg.ign.fr/pub/EUREF-TN-1.pdf
ITRF2014 epoch	2020.0000	
ECR orientation parallel to meridian		
Method description	Oriented with total station measurements from the same base station that was used for location measurements.	
Azimuth accuracy	At least 1 degree or better.	Total station measurements indicate 2-3 mm east-west differences between the northern and southern corners.

2.2 Finland

Site	**Emäsalo**	
ECR ID	19_0110	DLR owned
Operator	FGI	
Logbook	Logbook_19_0110.txt	
Monument and foundation	1 m tall aluminium mast fastened to bedrock with four threaded rods	
Reference systems and tranformations		
Height system	Finnish N2000	Saaranen, V., P. Lehmuskoski, P. Rouhiainen, M. Takalo, J. Mäkinen, M. Poutanen (2009): The New Finnish Height Reference N2000. In H. Drewes (Ed.), Geodetic Reference Frames. IAG Symposium Munich, Germany, 9–14 October 2006. Springer, IAG Symposia 134, 297–302. JHS 163 Finlands Height System N2000: http://www.jhs-suositukset.fi/suomi/jhs163
National reference frame	EUREF-FIN	Ollikainen, M., Koivula, H. ja Poutanen, M. 2000. The densification of the EUREF network in Finland. Publications of the Finnish Geodetic Institute N:o 129. Kirkkonummi. JHS 196 EUREF-FIN coordinates in Finland: http://www.jhs-suositukset.fi/suomi/jhs196 JHS 197 EUREF-FIN coordinate systems, related conversions and map sheet distribution: http://www.jhs-suositukset.fi/suomi/jhs197
Reference frame	ITRF2014	
Transformation	EUREF-FIN to ITRF2014	Software Proj Rel. 6.0.0, March 1st, 2019 PROJ contributors (2020). PROJ coordinate transformation software library. Open Source Geospatial Foundation. URL https://proj.org/. Häkli, P., M. Lidberg, L. Jivall, T. Nørbech, O. Tangen, M. Weber, P. Pihlak, I. Aleksejenko and E. Paršeliunas (2016): The NKG2008 GPS campaign – final transformation results and a new common Nordic reference frame. Journal of Geodetic Science. Volume 6, Issue 1, ISSN (Online) 2081-9943, DOI: https://doi.org/10.1515/jogs-2016-0001, March 2016
Tide gauge connection to height system		
Description	Precise levelling from the tide gauge basic marker to the benchmark of the National First Order levelling network. Repeated every three years.	
ECR connection to height system		
Levelling computations description	2 starting bolts (732894, 13406), 3 ending points (EMSAR1-3), levelled 2 two times forward and back, levelling procedure: back-forward-forward-back, equipment: Zeiss DiNi 12, 320243, Nedo 13926, Nedo 14092	 EMSAR 3: The most northwestern bolt top

		 EMSAR2: top of threaded rod EMSAR1: new levelling bolt 20m west from transponder.
Levelling computations desricption	Least squares adjustment, corrections: rods calibration, temperature,	
Levelling closing error	-0,03 mm	
Levelled point height in ECR	17.8400 m	The most northwestern bolt top (EMSAR3), N2000
Levelled point height difference to origin of ECR	0.0245 m	Measured with mauser, top of bolt to bottom of ECR, valid for ECR 19_0110
ECR reference point height	17.8155 m	N2000, ERC reference point, see project document: ECR Installation and Local Tie Survey, C. Gisinger
ECR connection to Reference frame		
Method 1		
Description	Network RTK + transformation from EUREF-FIN to ITRF2014	
GNSS data	Mean of 5 NRTK fixed solution, ambiguities initialized between fixes, Geotrim Trimnet NRTK correction, GPS+GLO+GAL+BDS	
Measured point	Hole center in the top of mast and level of that surface. Screw through mast's center hole, tightened with nut, receiver on top of nut (nut thickness 0.0096 m), receiver's ARP bottom of receiver center screw hole	
Measured point coordinates in EUREF-FIN	2864912.8423 1374213.9753 5511817.6984	
Measured point transformed ITRF2014 coordinates	2864912.2539 1374214.3678 5511818.0208	
Measured point offset to origin of ECR	-0.1800, 0.2850, 0.0206 East, North, Up [meters]	East and north: ECR manual drawings Up: 360 rotating supportive frame thicknesses measured with mauser
Measured to Origin method	ENU	Local tangent plane aligned to north and on ellipsoid in one point ref: Thomas H Meyer, University of Connecticut, Grid, ground, and globe: Distances in the GPS era, 2002
ECR origin coordinates in EUREF-FIN	-	

ECR origin transformed ITRF2014 coordinates	2864912.1180 1374214.1030 5511818.1803	
Ellipsoidal ECR reference (origin) point height	34.465 m	The NW corner of the bottom plate.
ITRF2014 epoch	2020.0	
ECR orientation parallel to meridian		
Method description	RTK measured ECR mast center hole and RTK pole moved as far as visible in same meridian then sighting with naked eye using ECR box sides and top to turn box towards RTK-pole	
Azimuth accuracy	RTK: < 0.5 degree Sighting: about 1 degree	

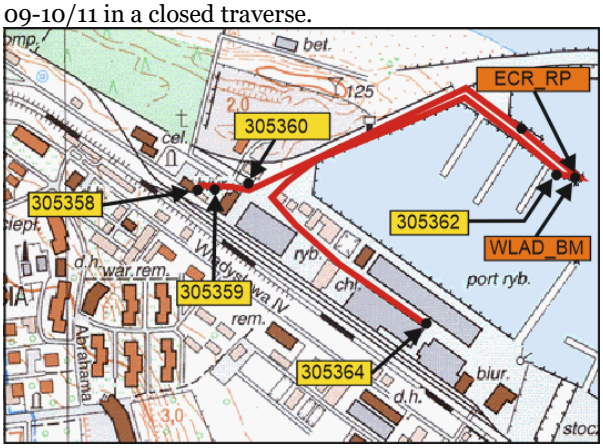
Site	**Loviisa**, LOV3	
ECR ID	18_0091	FGI owned
Operator	FGI	
Logbook	Logbook_18_0091.txt	
Monument and foundation	1 m tall aluminium mast fastened to bedrock with four threaded rods	
Reference systems and transformations		
Height system	Finnish N2000	Saaranen, V., P. Lehmuskoski, P. Rouhiainen, M. Takalo, J. Mäkinen, M. Poutanen (2009): The New Finnish Height Reference N2000. In H. Drewes (Ed.), Geodetic Reference Frames. IAG Symposium Munich, Germany, 9–14 October 2006. Springer, IAG Symposia 134, 297–302. JHS 163 Finlands Height System N2000: http://www.jhs-suositukset.fi/suomi/jhs163
National reference frame	EUREF-FIN	Ollikainen, M., Koivula, H. ja Poutanen, M. 2000. The densification of the EUREF network in Finland. Publications of the Finnish Geodetic Institute N:o 129. Kirkkonummi. JHS 196 EUREF-FIN coordinates in Finland: http://www.jhs-suositukset.fi/suomi/jhs196 JHS 197 EUREF-FIN coordinate systems, related conversions and map sheet distribution: http://www.jhs-suositukset.fi/suomi/jhs197
Reference frame	ITRF2014	
Transformation	EUREF-FIN to ITRF2014	Software Proj Rel. 6.0.0, March 1st, 2019 PROJ contributors (2020). PROJ coordinate transformation software library. Open Source Geospatial Foundation. URL https://proj.org/. Häkli, P., M. Lidberg, L. Jivall, T. Nørbech, O. Tangen, M. Weber, P. Pihlak, I. Aleksejenko and E. Paršeliunas (2016): The NKG2008 GPS campaign – final transformation results and a new common Nordic reference frame. Journal of Geodetic Science. Volume 6, Issue 1, ISSN (Online) 2081-9943, DOI: https://doi.org/10.1515/jogs-2016-0001, March 2016
Tide gauge connection to height system		
Description	No tide gauge near Loviisa SAR-site	
ECR connection to height system		
Levelling description	Precise levelling from the the benchmarks of the National First Order levelling network.	LOSAR1: The most northwestern bolt top of the ECR
Levelling computations description	Least squares adjustment, corrections: rods calibration, temperature,	
Levelled point height in ECR	30.7153 m	The most northwestern bolt top (LOSAR1), N2000
Levelled point height difference to origin of ECR	0.0250 m	Measured with mauser, top of bolt to bottom of ECR, valid for ECR 18_0091
ECR reference point height	30.6903 m	N2000, ERC reference point, see project document: ECR Installation and Local Tie Survey, C. Gisinger
Ellipsoidal ECR reference origin point height	46.3036 m	The NW corner of the bottom plate. From LOV3 GNSS antenna ARP to four benchmark boults with tacheometer and from bolts to ECR with levelling (+ plate thickness 0.0250).

ECR connection to Reference frame		
Method 1		
Description	Network RTK + transformation from EUREF-FIN to ITRF2014	
GNSS data	Mean of 5 NRTK fixed solution, ambiguities initialized between fixes, Geotrim Trimnet NRTK correction, GPS+GLO+GAL+BDS	
Measured point	Hole center in the top of mast and level of that surface. Screw through mast's center hole. Antenna on top of mast's top surface. Receiver's ARP bottom of receiver center screw hole.	
Measured point coordinates in EUREF-FIN	2828357.4722 1396893.6952 5524908.0875	
Measured point transformed ITRF2014 coordinates	2828356.8805 1396894.0839 5524908.4065	
Measured point offset to origin of ECR	-0.1800, 0.2850, 0.0250 East, North, Up [meters]	East and north: ECR manual drawings Up: 360 rotating supportive frame thicknesses measured with mauser
Measured to Origin method	ENU	Local tangent plane aligned to north and on ellipsoid in one point ref: Thomas H Meyer, University of Connecticut, Grid, ground, and globe: Distances in the GPS era, 2002
ECR origin coordinates in EUREF-FIN	-	
ECR origin transformed ITRF2014 coordinates	2828356.74899 1396893.81819 5524908.56884	
Ellipsoidal ECR reference origin point height	46.315 m	The NW corner of the bottom plate. VRS measured. See also value from levellings+tachymeter+ GNSS LOV3
ITRF2014 epoch	2020.0	
ECR orientation parallel to meridian		
Method description	RTK measured ECR mast center hole and RTK pole moved as far as visible in same meridian then sighting with naked eye using ECR box sides and top to turn box towards RTK-pole	
Azimuth accuracy	RTK: < 0.5 degree Sighting: about 1 degree	

Site	**Rauma**	
ECR ID	19_0111	DLR owned
Operator	FGI	
Logbook	Logbook_19_0111.txt	
Monument and foundation	1 m tall aluminium mast fastened to big block (>5000kg) of exploded (some years ago) bedrock with four threaded rods	
Reference systems and transformations		
Height system	Finnish N2000	Saaranen, V., P. Lehmuskoski, P. Rouhiainen, M. Takalo, J. Mäkinen, M. Poutanen (2009): The New Finnish Height Reference N2000. In H. Drewes (Ed.), Geodetic Reference Frames. IAG Symposium Munich, Germany, 9–14 October 2006. Springer, IAG Symposia 134, 297–302. JHS 163 Finlands Height System N2000: http://www.jhs-suositukset.fi/suomi/jhs163
National reference frame	EUREF-FIN	Ollikainen, M., Koivula, H. ja Poutanen, M. 2000. The densification of the EUREF network in Finland. Publications of the Finnish Geodetic Institute N:o 129. Kirkkonummi. JHS 196 EUREF-FIN coordinates in Finland: http://www.jhs-suositukset.fi/suomi/jhs196 JHS 197 EUREF-FIN coordinate systems, related conversions and map sheet distribution: http://www.jhs-suositukset.fi/suomi/jhs197
Reference frame	ITRF2014	
Transformation	EUREF-FIN to ITRF2014	Software Proj Rel. 6.0.0, March 1st, 2019 PROJ contributors (2020). PROJ coordinate transformation software library. Open Source Geospatial Foundation. URL https://proj.org/. Häkli, P., M. Lidberg, L. Jivall, T. Nørbech, O. Tangen, M. Weber, P. Pihlak, I. Aleksejenko and E. Paršeliunas (2016): The NKG2008 GPS campaign – final transformation results and a new common Nordic reference frame. Journal of Geodetic Science. Volume 6, Issue 1, ISSN (Online) 2081-9943, DOI: https://doi.org/10.1515/jogs-2016-0001, March 2016
Tide gauge connection to height system		
Description	Precise levelling from the tide gauge basic marker to the benchmark of the National First Order levelling network. Repeated every three years.	
ECR connection to height system		
Levelling description	2 starting bolts 2 ending points (RASAR1 & 2), levelled 2 two times forward and back, levelling procedure: back-forward-forward-back. levelling distance about 15 m from both bolts	RASAR 1: The most northwestern bolt top of the ECR RASAR2: top of threaded rod
Levelling computations description	Least squares adjustment, corrections: rods calibration, temperature,	
Levelled point height in ECR	5,032 m	The most northwestern bolt top (RASAR1), N2000

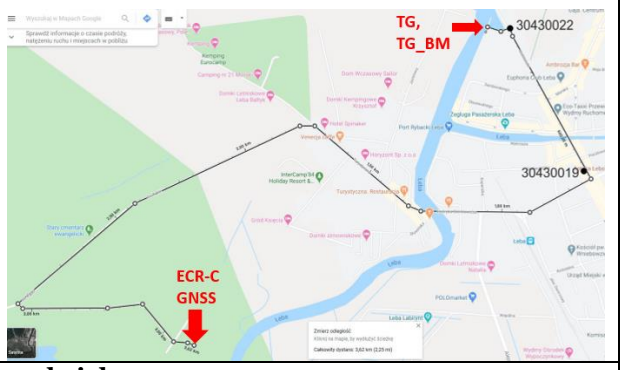
Levelled point height difference to origin of ECR	0.026 m	Measured with mauser, top of bolt to bottom of ECR, valid for ECR 19_0111
ECR reference point height	5.006 m	N2000, ERC reference point, see project document: ECR Installation and Local Tie Survey, C. Gisinger
ECR connection to Reference frame		
Method 1		
Description	Network RTK + transformation from EUREF-FIN to ITRF2014	
GNSS data	Mean of 5 NRTK fixed solution, ambiguities initialized between fixes, Geotrim Trimnet NRTK correction, GPS+GLO+GAL+BDS	
Measured point	Hole center in the top of mast and level of that surface. Screw through mast's center hole. Antenna on top of mast's top surface. Receiver's ARP bottom of receiver center screw hole.	
Measured point coordinates in EUREF-FIN	2873769.751 1127720.938 5562562.214	
Measured point transformed ITRF2014 coordinates	2873769.215 1127721.352 5562562.611	
Measured point offset to origin of ECR	-0.1800, 0.2850, 0.029 East, North, Up [meters]	East and north: ECR manual drawings Up: 360 rotating supportive frame thicknesses measured with mauser
Measured to Origin method	ENU	Local tangent plane aligned to north and on ellipsoid in one point ref: Thomas H Meyer, University of Connecticut, Grid, ground, and globe: Distances in the GPS era, 2002
ECR origin coordinates in EUREF-FIN	-	
ECR origin transformed ITRF2014 coordinates	2873769.062 1127721.098 5562562.774	
Ellipsoidal ECR reference origin point height	24.297 m	The NW corner of the bottom plate.
ITRF2014 epoch	2020.0	
ECR orientation parallel to meridian		
Method description	RTK measured ECR mast center hole and RTK pole moved further away in same meridian then sighting with naked eye using ECR box sides and top to turn box towards RTK-pole	
Azimuth accuracy	RTK: < 0.5 degree Sighting: about 1 degree	

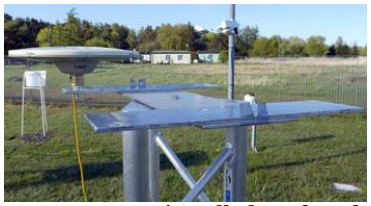
2.3 Poland

Site	**Władysławowo**	
ECR ID	19_0114	CBK PAN owned
Operator	CBK PAN	
Logbook	Logbook_ECR_19_0114.txt	
Reference systems and transformations		
Height system	PL-EVRF2007-NH (a national realization of EVRS), epoch 2000.0	
National reference frame	PL-ETRF2000-XYZ, PL-ETRF2000-GRS80h (a national realization of ETRS), epoch 2011.0	
Reference frame	ITRF2014	
Transformation	none	
Tide gauge connection to height system		
Description	Precise levelling measurements connecting vertical reference points of all types of instruments installed on the station, including the tide gauge staff (TG_CP), GNSS WLAD station benchmark (WLAD_BM) and the benchmarks of the Polish National First Order Levelling Network with benchmark 30530062 (TG_BM) and 7 other. Levelled two times forward and back, levelling procedure: back-forward-forward-back. Equipment: Sokkia SDL30, Topcon invar barcode staffs (75105, 75551).	As the initial and reference benchmark BM_30530058 was chosen. The measurements were made on 2020-09-10/11 in a closed traverse. 
ECR connection to height system		
Levelling description	Precise levelling from the tide gauge primary benchmark 30530062 (TG_BM) to the reference benchmark of the WLAD GNSS station (WLAD_BM) and from the WLAD_ARP to the NW corner of the ECR (staff was placed directly on the reference point (ECR_RP) and on the granite plate with installed GNSS antenna. Levelled two times forward and back. Levelling procedure: back-forward-forward-back. Vertical distance between WLAD_BM and WLAD_ARP was measured by calibrated steel tape and still rod (used for periodic height control of the WLAD GNSS station).	 

Levelling computations description	Standard least squares adjustment; rods calibrated, temperature corrections.	
Levelling closing error	1.35 mm on 3.89 km distance (0.35 mm/km)	From the whole closed levelling traverse.
Levelled point height on ECR	5.6382 m	The transponder's reference point (ECR_RP) was levelled directly from WLAD_ARP).
Levelled point height difference to origin of ECR	Not measured	
ECR reference point height	5.6382 m	The NW corner of the bottom plate (ECR_RP). Determined from geometric precise levelling.
ECR ellipsoidal reference point height	34.6233 m	Computed from static GNSS sessions, performed on 2020-09-10/11 using Trimble 5700/ TRM41249.00. Vector WLAD_ARP > ECR_RP (~1.5 m length).
ECR connection to Reference frame		
Description	Static GPS/GNSS measurements with antennas installed directly above the reference points of both instruments.	Two static GNSS measurements made on 2020-09-10/11 on vector WALD_ARP – ECR_RP, ~1.5 m distance between the antennas. Equipment: Trimble 5700/ TRM41249.00 on ECR_RP and Leica GR30/LEIAR20 LEIM on WLAD_ARP.
GNSS data	Static sessions, sampling data 5 sec, (GPS, GPS+GLONASS)	4 static GNSS meas. sessions: 2020:DOY080 (2h45m), 2020:DOY254 (3h45m), 2020:DOY254 (9h06m), 2020:DOY255 (8h40m).
Measured point	The top surface of the adapter screw with a 5/8" threaded rod screwed into it, intended for the installation of the GNSS antenna. Before the measurement, the adapter was screwed into the threaded hole made in the transponder installation construction, which coincides with the NW corner of the transponder, defined as the ECR reference point (ECR-RP). The GPS antenna was mounted in addition on tribrach (see Fig. on the right) only during obs. session performed on 2020:DOY080. On 2020:254 and 2020:255 GPS antenna was mounted directly on the adapter.	  GNSS measurements were made before ECR installation. GNSS_ARP height above ECR_RP was measured by calibrated steel tape.
Measured point coordinates / ECR reference point ECR_RP coordinates	Lat = 54 47" 48.42044357" Lon = 18 25' 07.52248105" h = 34.6233 m	From WLAD -> WLAS (= ECR_RP) vector solutions (from 4 static meas. sessions: 2020:DOY080 (2h45m), 2020:DOY254 (3h45m), 2020:DOY254 (9h06m), 2020:DOY255 (8h40m). Coordinates of the reference point of ECR_19_0114 transponder in the ITRF2014, ep. 2020.42.
Measured point coordinates / ECR reference point ECR_RP transformed ITRF2014 coordinates	Lat = 54 47" 48.42044357" Lon = 18 25' 07.52248105" h = 34.6233 m	Data processed and coordinates determined in ITRF2014, not transformed.
ITRF2014 epoch	Not conducted.	To be done after receiving unified guidelines.

ECR orientation parallel to meridian		
Method description	1.) Orientation of the marked transponder axis to a distant (approx. 150m), well-defined object on the map and in the field. 2.) orientation using a precision compass with correcting the magnetic declination angle, calculated for this area.	
Azimuth accuracy	About 1 degree or better.	

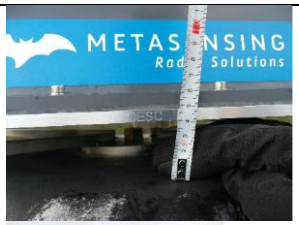
Site	**Łeba**	
ECR ID	18_0104	TUM owned
Operator	CBK PAN	
Logbook	Logbook_ECR_18_0104.txt	
Reference systems and transformations		
Height system	PL-EVRF2007-NH (a national realization of EVRS), epoch 2000.0	
National reference frame	PL-ETRF2000-XYZ, PL-ETRF2000-GRS80h (a national realization of ETRS), epoch 2011.0	
Reference frame	ITRF2014	
Transformation	none	
Tide gauge connection to height system		
Description	Precise levelling measurements connecting vertical reference points of all types of instruments installed on the station, including the tide gauge staff (TG_CP), TG_BM (5382), ECR_D, ECR_RP and the benchmarks of the Polish basic levelling network with benchmarks: 30430019 (AB 2733) and 30430028. Levelled two times forward and back, levelling procedure: back-forward-forward-back. Equipment: Sokkia SDL30, Topcon invar barcode staffs (75105, 75551).	As the initial and reference benchmark BM_30430019 was chosen. The measurements were made on 2020-09-11/12 in a closed traverse.  
ECR connection to height system		

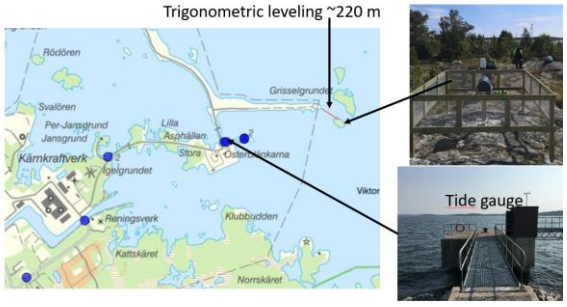
Levelling description	Precise levelling from the LEB_W benchmark in meteorological garden, through the point ECR_D, ECR_RP to TG_BM and TG_CP. On the way back from TG_CP through the reference benchmark of the national vertical network Nr. 30430019 to the starting benchmark (see maps on the right). Levelled two times forward and back. Levelling procedure: back-forward-forward-back.	 
Levelling computations description	Standard least squares adjustment; rods calibrated, temperature corrections.	
Levelling closing error	1.80 mm on 7.13 km distance (0.25 mm/km)	From the whole closed levelling traverse.
Levelled point height on ECR	3.0491 m	The transponder's reference point (ECR_RP) was levelled from national basic vertical network benchmark Nr. 30430019.
Levelled point height difference to origin of ECR	Not measured	
ECR reference point height	3.0491 m	The NW corner of the bottom plate (ECR_RP).
ECR ellipsoidal reference point height	33.9531 m	Computed from 2 static GNSS sessions, performed on 2020-09-11/12 using Trimble 5700/ TRM41249.00. Vector LEBI_ARP -> ECR_RP (~15 m length).
ECR connection to Reference frame		
Description	Static GPS/GNSS measurements with antennas installed directly above the reference points of both instruments.	Two static GNSS measurements made on 2020-09-11/12 on vector LEBI_ARP –> ECR_RP, ~20 m distance between the antennas. Equipment: Trimble 5700/ TRM41249.00 on ECR_RP and Leica GR30/LEIAR10 NONE on LEBI_ARP.
GNSS data	Static, measured 5 sec, (GPS, GPS+GLONASS)	2 static GNSS meas. sessions: 2020:DOY255 (10h15m), 2020:DOY256 (5h055m).
Measured point	The top surface of the adapter screw with a 5/8" threaded rod screwed into it, intended for the installation of the GNSS antenna. Before the measurement, the adapter was screwed into the threaded hole made in the transponder installation construction, which coincides with the NW corner of the transponder, defined as the ECR reference point (ECR-RP).	  GNSS antenna installed on the adapter vertically above the ECR_RP points. GNSS measurements were made before ECR installation. GNSS_ARP height above ECR_RP was measured by calibrated steel tape.
Measured point coordinates / ECR reference	Lat = 54 45" 13.17744414" Lon = 17 32' 05.54830034" h = 33.9531 m	From LEBI -> LEBS (= ECR_RP) vector solutions (from 2 static meas. sessions: 2020:DOY255 (10h15m), 2020:DOY256 (5h055m). Coordinates of the reference

point ECR_RP coordinates		point of ECR_18_0104 transponder in the ITRF2014, ep. 2020.42.
Measured point coordinates / ECR reference point ECR_RP transformed ITRF2014 coordinates	Lat = 54 45” 13.17744414” Lon = 17 32’ 05.54830034” h = 33.9531 m	Data processed and coordinates determined in ITRF2014, not transformed.
ITRF2014 epoch	Not conducted.	To be done after receiving unified guidelines.
ECR orientation parallel to meridian		
Method description	1.) Orientation of the marked transponder axis to a distant (approx. 150m), well-defined object on the map and in the field. 2.) orientation using a precision compass with correcting the magnetic declination angle, calculated for this area.	
Azimuth accuracy	About 1 degree or better.	

2.4 Sweden

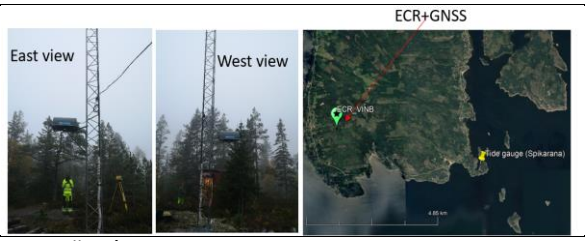
Site	**Mårtsbo**	
ECR ID	19_0107	Lantmäteriet
Operator	LM	
Logbook	Logbook_ECR_19_0107 - updated.txt	
Reference systems and transformations		
Height system	RH2000	
National reference frame	SWEREF 99	
Reference frame	ITRF2014	
Transformation		
Tide gauge connection to height system		
Description	There is no tide gauge nearby. MAR0 Pillar in Mårtsbo is only 1 meter away from permanent GNSS station MAR6.	
ECR connection to height system		
Levelling description	Levelling was done between MAR6 (close by GNSS station) and MAR0 (ECR pillar).	
Levelling computations description	Direct leveling between Pillar MAR6 (the close by GNSS pillar station) and MAR0 (ECR pillar) showed MAR0 pillar surface is 4.5 mm lower than MAR6.	
Levelling closing error		
Levelled point height in ECR	Leveling was done before ECR installation.	
Levelled point height difference to origin of ECR		
ECR reference point height		
ECR connection to Reference frame		
Method 1		
Description	GNSS static measurements, Using Ashtech Chock ring antenna (see photo)+ Javad TRE_G3T SIGMA Receiver. Measured location of ECR (MAR0 station) is just beside MAR6 EPN permanent GNSS station (see photo LR). Measurement DOY: 317(15 hrs) and 318(full day), 2019 Data processed via online services: AUSLIG (network processing) and CSRS-PPP online positioning service and Lantmäteriet Online processing service. Network and PPP estimated coordinates in ITRF14 are just about 2-5 mm different.	   
GNSS data	Static, measured 1 sec, sampled to 30 sec, (GPS+GLONASS)	
Measured point	Top Center of MAR0 pillar station (see photo)	before ECR installation

Measured point coordinates in SWEREF 99 TM And height in RH2000	N=6719816.166 E=623689.075 H= 50.664	Using LM online processing service, Helmet transformation, SWEN17_RH2000 geoid model was used to convert to RH2000. see processing report in this folder: GNSS_measurements_results
Measured point ITRF2014 coordinates	X=2998190.645 Y=931452.401 Z=5533398.043 Lat=60 35 42.46940 Long= 17 15 0.71058 Ellip. height=75.557	See processing report in this folder: GNSS_measurements_results
Measured point offset to origin of ECR	Offset N= 28.5 cm Offset E= 18 cm Vertical Offset = 41 mm (ECR bottom is 4.1 cm higher than top surface of MAR0 pillar) h (ECR ref. point)=75.557+0.041=75.598	 
Measured to Origin method		
ECR origin coordinates in SWEREF99 TM and RH2000	N=6719816.451 E=623688.895 H= 50.705 h(ellip)=75.598	Based on instructions: ECR origin point is located on NW corner of ECR (bottom surface)
ECR origin transformed ITRF2014 coordinates	X=2998190.471 Y=931452.170 Z=5533398.218	
ITRF2014 epoch	14/11/2019 (2019.8712)	
Method 2 (if executed, e.g. static GNSS)		
…	…	…
GNSS station connection to height system		
Description	Direct leveling between Pillar MAR6 (the close by GNSS pillar station) and MAR0 (ECR location) showed MAR0 is 4.5 mm lower than MAR6.	
Station		
GNSS ARP height		
ECR orientation parallel to meridian		
Method description	Compass	
Azimuth accuracy	±5 degrees? (not sure how accurate the compass was)	

Site	**Kobben (Forsmark)** Note: There is fine mesh metal fence around the Transponder (see the photo to the right).	
ECR ID	19_0108	Lantmäteriet
Operator	LM	
Logbook	Logbook_ECR_19_0108.txt	
Reference systems and transformations		
Height system	RH2000	
National reference frame	SWEREF 99	
Reference frame	ITRF2014	
Transformation		
Tide gauge connection to height system		
Description	There is a tide gauge nearby, in Forsmark.	
ECR connection to height system		
Levelling description	A combination of direct and trigonometric Levelling was done to link the ECR in Kobben in the island and tide gauge. -2 new benchmarks were established near the transponder. The rod placed on the top of the screw on upper plate of ECR for leveling. the screws are 6 mm high from the upper plate. Note: The upper edge of ECR is ~21 mm higher than the lower edge)	
Levelling computations description		
Levelling closing error		

Levelled point height in ECR	For measurements, the rod was on the ECR screw (6 mm high, see photo). The estimated leveled height for Kobben is 2.9846 m (NE screw) and 2.9786 m (upper plate)	
Levelled point height difference to origin of ECR	ECR origin point is located at bottom plate, so we should subtract 21 mm.	
ECR reference point height	ECR_H (origin point)=2.9765 m	
ECR connection to Reference frame		
Method 1		
Description	GNSS network RTK measurements (using SWEPOS service) was done to find the positions of 4 screws at the corners of the transponder with 1-5 cm accuracy in 3 dimensions. This way, we found the center position of the ECR. -We used GNSS Leica GS18T: tilt compensated RTK rover to measure the positions.	
GNSS data	NRTK measurements on 4 screws at the corners of the the ECR	
Measured point		
Measured point coordinates in SWEREF 99 TM And height in RH2000	N= 6701423.835 E=677898.499 H(mean of the 4 corners)= 2.982	The center plate, upper edge. 6 mm was subtracted from the estimated height for the height of screw above the upper plate.
Measured point ITRF2014 coordinates	X=2999000.5138 Y=987781.0353 Z=5523191.9790	Center plate, Upper edge, see this link:

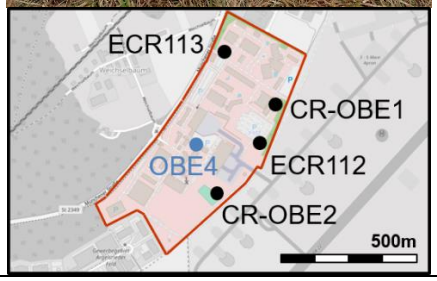
Measured point offset to origin of ECR	Offset N= 28.5 cm Offset E= 18 cm Vertical offset =2.7 cm	
Measured to Origin method		
ECR origin coordinates in SWEREF99 TM and RH2000	N= 6701424.120 E=677898.319 H= 2.955	
ECR origin transformed ITRF2014 coordinates	X=2999000.311 Y=987780.795 Z=5523192.099	
ITRF2014 epoch	2010-01-01	
Method 2 (if executed, e.g. static GNSS)		
…	…	…
GNSS station connection to height system		
Description		
Station		
GNSS ARP height		
ECR orientation parallel to meridian		
Method description	Compass	
Azimuth accuracy	±5 degress? (not sure how accurate the compass was)	

Site	**Vinberget**	
ECR ID	19_0106	Lantmäteriet
Operator	LM	
Logbook	Logbook_ECR_19_0106.txt	
Reference systems and transformations		
Height system	RH2000	
National reference frame	SWEREF 99	
Reference frame	ITRF2014	
Transformation		
Tide gauge connection to height system		
Description	There is a tide gauge nearby (Spikarna)	
ECR connection to height system		
Levelling description	Direct-levelling was done between tide gauge (Spikarna) and two newly established benchmarks near the ECR, these are called: 177*7*3622 and 177*73623 -leveling was done between these benchmarks, tide gague and the ECR upper plate.	
Levelling computations description	The height of ECR (upper plate) was obtained using leveling and also from the mean of 4 measurements from the NRTK GNSS measurements on the screws and the difference was ~12 mm.	
Levelling closing error	see above	
Levelled point height in ECR	upper plate of ECR, 123.529 m (GNSS NRTK) and 123.541 m (leveling)	
Levelled point height difference to origin of ECR	Vertical Offset =2.1 cm	
ECR reference point height	123.520 m	
ECR connection to Reference frame		
Method 1		

Description	GNSS network RTK measurements (using SWEPOS corrections) was carried out to find the positions of 4 screws at the corners of the ECR with 1-5 cm accuracy in 3 dimensions. This way, we found the center position of the ECR. We used GNSS Leica GS18T: tilt compensated RTK rover to measure the positions. As shown in the photo, high up on the mast it was difficult to hold the pole vertically, so the tilted pole measurement was useful.	
GNSS data	NRTK measurements on 4 screws at the corners of the the ECR (Similar to Kobben ECR)	
Measured point	Center point (mean of 4 corners coordinates)	
Measured point coordinates in SWEREF 99 TM And height in RH2000	N= 6918190.565 E= 625580.955 H= 123.535	
Measured point ITRF2014 coordinates	X=2829284.3114 Y=888154.0780 Z=5628089.9707	Center plate, Upper edge, see this link:
Measured point offset to origin of ECR	Offset N= 28.5 cm Offset E= 18 cm Vertical offset =2.7 cm	
Measured to Origin method		
ECR origin coordinates in SWEREF99 TM and RH2000	N= 6918190.850 E= 625580.775 H= 123.508	
ECR origin transformed ITRF2014 coordinates	X=2829284.103 Y=888153.837 Z=5628090.081	
ITRF2014 epoch	2010-01-01	
Method 2 (if executed, e.g. static GNSS)		
…	…	…
GNSS station connection to height system		
Description		
Station		

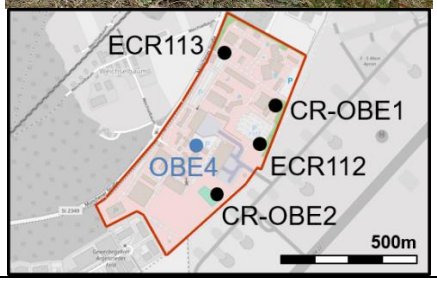
GNSS ARP height		
ECR orientation parallel to meridian		
Method description	Compass	
Azimuth accuracy	±5 degrees? (not sure how accurate the compass was)	Not sure how accurate our compass was, but we think it was good enough.

2.5 Germany

Site	**DLR Oberpfaffenhofen**	 
ECR ID	19_0112	DLR owned
Operator	DLR	
Logbook	Logbook_19_0112.txt	
Monument and foundation	1.3 m earth stud drilled to a depth of about 0.9m. Leveled frame attached to the stud and oriented to geographic North to mount the ECR.	
Reference systems and transformations		
Height system	DHHN2016	Feldmann-Westendorff, U., Liebsch, G., Sacher, M., Müller, J., Jahn, C.-H., Klein, W., Liebig, A., Westphal, K. (2016): Das Projekt zur Erneuerung des DHHN: Ein Meilenstein zur Realisierung des integrierten Raumbezugs in Deutschland. In: zfv – Zeitschrift für Geodäsie, Geoinformation und Landmanagement, Heft 5/2016, 141. Jg. S. 354–367. DOI: 10.12902/zfv-0140-2016.
National reference frame	GREF	Not known
Reference frame	ITRF2014	

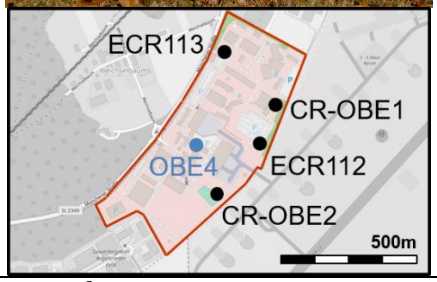
Transformation	GREF to ITRF2014	Not known
ECR connection to height system		
Levelling description	No levelling performed	
ECR connection to Reference frame		
Method 1		
Description	Static GNSS Measurement performed with Javad Triumph V receiver and antenna mounted with tribrach on tripod centered above ECR frame with optical plummet (aligned to central bore hole of earth stud).	
GNSS data	3 hours static baseline data with respect to IGS reference station OBE4. Double difference static solution with fixed ambiguities and fixed reference station OBE4 computed with Bernese for GPS+GLO	
Measured point	Center of ECR base plate, plate bottom edge. GNSS antenna mounted above ECR central point. Vertical offset between GNSS ARP and ECR plate bottom measured with yard stick and inserted as antenna height during GNSS processing.	
Measured point coordinates in GREF	N/A	
Measured point coordinates in ITRF2014	4186629.0879 835142.4129 4723656.1780	
Measured point offset to origin of ECR	Offset E= 18 cm Offset N= 28.5 cm Vertical Offset = 0 cm	East and north: ECR manual drawings
Measured to Origin method	ENU	Local tangent plane aligned to north and on ellipsoid in one point ref: Thomas H Meyer, University of Connecticut, Grid, ground, and globe: Distances in the GPS era, 2002
ECR origin coordinates in GREF	N/A	
ECR origin transformed ITRF2014 coordinates	4186628.8447 835142.5479 4723656.3684	The NW corner of the bottom plate.
Ellipsoidal ECR reference origin point height	625.946 m	The NW corner of the bottom plate.

ITRF2014 epoch	2020 08 06	
ECR orientation parallel to meridian		
Method description	Aligned to geographic North with digital compass with correction for magnetic inclination. Alignment verified with Leica sighting binoculars with built in compass.	
Azimuth accuracy	Sighting: about 1-2 degree	

Site	**DLR Oberpfaffenhofen**	 
ECR ID	19_0113	DLR owned
Operator	DLR	
Logbook	Logbook_19_0113.txt	
Monument and foundation	1.3 m earth stud drilled to a depth of about 0.9m. Leveled frame attached to the stud and oriented to geographic North to mount the ECR.	
Reference systems and transformations		
Height system	DHHN2016	Feldmann-Westendorff, U., Liebsch, G., Sacher, M., Müller, J., Jahn, C.-H., Klein, W., Liebig, A., Westphal, K. (2016): Das Projekt zur Erneuerung des DHHN: Ein Meilenstein zur Realisierung des integrierten Raumbezugs in Deutschland. In: zfv – Zeitschrift für Geodäsie, Geoinformation und Landmanagement, Heft 5/2016, 141. Jg. S. 354–367. DOI: 10.12902/zfv-0140-2016.
National reference frame	GREF	Not known
Reference frame	ITRF2014	

Transformation	GREF to ITRF2014	Not known
ECR connection to height system		
Levelling description	No levelling performed	
ECR connection to Reference frame		
Method 1		
Description	Static GNSS Measurement performed with Javad Triumph V receiver and antenna mounted with tribrach on tripod centered above ECR frame with optical plummet (aligned to central bore hole of earth stud).	
GNSS data	3 hours static baseline data with respect to IGS reference station OBE4. Double difference static solution with fixed ambiguities and fixed reference station OBE4 computed with Bernese for GPS+GLO	
Measured point	Center of ECR base plate, plate bottom edge. GNSS antenna mounted above ECR central point. Vertical offset between GNSS ARP and ECR plate bottom measured with yard stick and inserted as antenna height during GNSS processing.	
Measured point coordinates in GREF	N/A	
Measured point coordinates in ITRF2014	4186415.9489 834943.0585 4723875.7253	
Measured point offset to origin of ECR	Offset E= 18 cm Offset N= 28.5 cm Vertical Offset = 0 cm	East and north: ECR manual drawings
Measured to Origin method	ENU	Local tangent plane aligned to north and on ellipsoid in one point ref: Thomas H Meyer, University of Connecticut, Grid, ground, and globe: Distances in the GPS era, 2002
ECR origin coordinates in GREF	N/A	
ECR origin transformed ITRF2014 coordinates	4186415.7057 834943.1935 4723875.9157	The NW corner of the bottom plate.
Ellipsoidal ECR reference origin point height	623.645 m	The NW corner of the bottom plate.

ITRF2014 epoch	2020 08 06	
ECR orientation parallel to meridian		
Method description	Aligned to geographic North with digital compass with correction for magnetic inclination. Alignment verified with Leica sighting binoculars with built in compass.	
Azimuth accuracy	Sighting: about 1-2 degree	

Site	**DLR Oberpfaffenhofen**	 
CR ID	CR-OBE1	DLR owned
Operator	DLR	
Logbook	Logbook_CR_OBE1.txt	
Monument and foundation	Triangular base frame anchored in soil with 30 cm bolts. Orientable elevation azimuth mount with screws for horizontal levelling and bolts to secure the aligned orientation.	
Reference systems and transformations		
Height system	DHHN2016	Feldmann-Westendorff, U., Liebsch, G., Sacher, M., Müller, J., Jahn, C.-H., Klein, W., Liebig, A., Westphal, K. (2016): Das Projekt zur Erneuerung des DHHN: Ein Meilenstein zur Realisierung des integrierten Raumbezugs in Deutschland. In: zfv – Zeitschrift für Geodäsie, Geoinformation und Landmanagement, Heft 5/2016, 141. Jg. S. 354–367. DOI: 10.12902/zfv-0140-2016.
National reference frame	GREF	Not known
Reference frame	ITRF2014	
Transformation	GREF to ITRF2014	Not known
ECR connection to height system		
Levelling description	No levelling performed	

CR connection to Reference frame		
Method 1		
Description	Static GNSS Measurement performed with Javad Triumph V receiver and antenna mounted with survey rod placed in corner point. Rod secured with spider tripod strapped to corner.	
GNSS data	3 hours static baseline data with respect to IGS reference station OBE4. Double difference static solution with fixed ambiguities and fixed reference station OBE4 computed with Bernese for GPS+GLO	
Measured point	CR geometrical phase center. GNSS antenna mounted above corner point. Vertical offset between GNSS ARP and corner as indicated on survey rod and verified with yard stick. Reading inserted as antenna height during GNSS processing.	
Measured point coordinates in GREF	N/A	
Measured point coordinates in ITRF2014	4186546.9324 835170.7594 4723722.0818	CR geometrical phase center
Ellipsoidal ECR reference origin point height	624.871 m	CR geometrical phase center
ITRF2014 epoch	2020 08 06	
CR orientation		
Method description	Azimuth aligned to ascending zero-Doppler direction (110 degrees) with digital compass with correction for magnetic inclination. Alignment verified with Leica sighting binoculars with built in compass. Elevation set to 55 degrees with digital inclinometer for average Sentinel -1 incidence angle.	
Orientation accuracy	Sighting: azimuth about 1-2 degree Elevation: < 1 degree	

Site	**DLR Oberpfaffenhofen**	
CR ID	CR-OBE2	DLR owned
Operator	DLR	
Logbook	Logbook_CR_OBE2.txt	
Monument and foundation	Triangular base frame anchored in soil with 30 cm bolts. Orientable elevation azimuth mount with screws for horizontal levelling and bolts to secure the aligned orientation.	
Reference systems and transformations		
Height system	DHHN2016	Feldmann-Westendorff, U., Liebsch, G., Sacher, M., Müller, J., Jahn, C.-H., Klein, W., Liebig, A., Westphal, K. (2016): Das Projekt zur Erneuerung des DHHN: Ein Meilenstein zur Realisierung des integrierten Raumbezugs in Deutschland. In: zfv – Zeitschrift für Geodäsie, Geoinformation und Landmanagement, Heft 5/2016, 141. Jg. S. 354–367. DOI: 10.12902/zfv-0140-2016.
National reference frame	GREF	Not known
Reference frame	ITRF2014	
Transformation	GREF to ITRF2014	Not known
ECR connection to height system		
Levelling description	No levelling performed	
CR connection to Reference frame		
Method 1		

Description	Static GNSS Measurement performed with Leica GX1230 receiver and antenna mounted with survey rod placed in corner point. Rod clamped to corner.	 
GNSS data	1 hour static baseline data with respect to IGS reference station OBE4. Double difference static solution with fixed ambiguities and fixed reference station OBE4 computed with Leica Infinity for GPS	
Measured point	CR geometrical phase center. GNSS antenna mounted above corner point. Vertical offset between GNSS ARP and corner as indicated on survey rod. Reading inserted as antenna height during GNSS processing.	
Measured point coordinates in GREF	N/A	
Measured point coordinates in ITRF2014	4186837.8925 834974.7565 4723504.0803	CR geometrical phase center
Ellipsoidal ECR reference origin point height	627.655 m	CR geometrical phase center
ITRF2014 epoch	2020 03 13	
CR orientation		
Method description	Azimuth aligned to ascending zero-Doppler direction (110 degrees) with digital compass with correction for magnetic inclination. Alignment verified with Leica sighting binoculars with built in compass. Elevation set to 55 degrees with digital	

	inclinometer for average Sentinel -1 incidence angle.	
Orientation accuracy	Sighting: azimuth about 1-2 degree Elevation: < 1 degree	