

BALTIC+

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

Electronic Corner Reflector Station Description

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Document Approval

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Geodetic SAR for Baltic Height System Unification and Baltic Sea Level Research ECR Station DescriptionDoc. Nr:SAR-HSU-TN-0015Issue:1.1Date:07.07.2021Page:3 of 43

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



Geodetic SAR for Baltic Height System Unification and Baltic Sea Level Research Doc. Nr: Issue: Date: Page:

ECR Station Description SAR-HSU-TN-0015 1.1 07.07.2021 4 of 43

Table of Content

1	Introduction	. 5
1.1	Purpose	5
1.2	Project Overview	5
1.3	Applicable Documents	6
2	ECR Station Descriptions	• 7
2.1	Estonia	7
2.2	Finland	. 12
2.3	Poland	. 19
2.4	Sweden	.25
2.5	Germany	.33
0		00



Geodetic SAR for Baltic Height System Unification and Baltic Sea Level Research ECR Station DescriptionDoc. Nr:SAR-HSU-TN-0015Issue:1.1Date:07.07.2021Page:5 of 43

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.

Date:

Page:

Applicable Documents 1.3

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



Geodetic SAR for Baltic Height System Unification and Baltic Sea Level Research ECR Station DescriptionDoc. Nr:SAR-HSU-TN-0015Issue:1.1Date:07.07.2021Page:7 of 43

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	
109,000	Reference systems and t	transformations
Height system	EH2000 (a national	
	realization of EVRS) epoch	
	2000.0	
National reference	FUPEE-ESTOZ apoch 1007 56	
frame	EOREI-ES19/, cpoch 199/.50	
Reference frame	ETRS80	
Transformation	none	
	Tide gauge connection t	to height system
Description	The initial survey:	Benchmark 00101 (GPA ID 205878) taken as
Description	Precise levelling from the tide	initial
	gauge staff to the benchmark	http://www.magamet.ee/rr/geo/
	of the National first order	$2mitu=108rofnr_id=205878$
	L ovelling Network	:Intu=10&1em1_1u=2050/0
	Levening Network.	
	The man and a FOD and	nta States State
	simply connected to the tide	
	simply connected to the tide	
	gauge stan.	
		Initial benchmark
		A A A
		Loksatrannikulaam SB 275
		a star and a star
		nda
		A Start Start
		TG
		110 A.
		ECR ECR
		Monamet 2019
ECR connection to height system		



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

ECR Station Description SAR-HSU-TN-0015 1.1 07.07.2021 8 of 43 Doc. Nr:

Levelling	High-precise levelling from the	
description	the gauge stall to the NW	
	corner of the ECR (staff was	
	placed on the cover, not on top	
	of the corner bolt). Bottom	A state of the second se
	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)	
	ionowcuj.	
	Equipment: 2x Trimble LD12	
	(invar) barcode staffs: Trimble	
	DiNi o 2 digital level	
Lovelling	Standard losst squares	
computations	adjustment: no rod calibration	
descention	aujustinent, no rou campiation	
description	included due to your short	
	distances	
L avalling aloging	0 17 mm (for the initial survey	
Levening closing	on 14 on 2020)	
L avallad naint	011 14.02.2020)	The NIM company of the cover (not the ten of the
Levened point	2.0508 III (valid between	and the lot the cover (not the top of the
neight on ECK	14.02.2020 and 28.09.2020)	corner boit).
	2 6526 m (valid from	
	2.0550 in (valid from	
I evelled point	0.0182 m (valid from	Measured with a caliner from the top of the
hoight difference to	14 02 2020 to 28 00 2020)	cover to the bottom of the ECP valid for ECP
amigin of ECP	14.02.2020 to 20.09.2020)	18 0009
origin of ECK	0 0100 m (valid from	18_0098.
		The server of the ECD was replaced during the
	29.12.2020)	ropairs
FCR reference	2 6285 m (valid between	The NW corner of the bottom plate
point height	14.02.0000 and 28.00.2020	The NW corner of the bottom plate.
point neight	14.02.2020 and 20.09.2020)	
	2 6407 m (valid from	
	20 12 2020)	
FCR ellipsoidal	10 521 m (valid between	Transformed by utilizing EST-GEOID2017
reference point	14.022020 and 28.002020	model: intuitively 1 cm accuracy is expected
height	14.02.2020 una 20.09.2020)	see.
neight	10 522 m (valid from	500.
	20 12 2020)	Fllmann A Märdla S and Oia T 2010 The 5
	29.12.2020)	mm Gooid Model for Estonia Computed by the
		Least Squares Modified Stokes's Formula
		Survey Paview doi:
		10 1080/00206265 2010 1582848
	ECR connection to Re	ference frame
Description	Network RTK measurements	Static GNSS measurements (accompanied with
	rection rene incustrements.	post-processing with Bernese) to be performed
	Equipment: Leica GS15	after receiving unified guidelines
GNSS data	An average of 5 min 1 Hz	and receiving unified guidelines.
Siloo uutu	GNSS measurements.	



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

ECR Station Description SAR-HSU-TN-0015 1.1 07.07.2021 9 of 43 Doc. Nr: Issue: Date:

Page:

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	25.70586265	No reliable height can be determined from such
coordinates / ECK	59.58255145	KIN measurements.
Measured point	2916917.78680	
coordinates / ECR	1404186.02230	
origin transformed	5477094.05180	
ITRF2014	(valid between 14.02.2020 and	
coordinates	28.09.2020)	
	0016015 59550	
	2910917.78750	
	5477094 05370	
	(valid from 29.12.2020)	
ITRF2014 epoch	2020.0000	
	ECR orientation paral	lel 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.	



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

Site ECR ID Operator Logbook Height system National reference frame	Vergi 18_0086 TUT Logbook_ECR_18_0086.txt Reference systems and the system of EVRS), epoch 2000.0 EUREF-EST97, epoch 1997.56	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. TUT owned transformations
Reference frame	ETRS89	
Transformation	none	
T 11'	ECR connection to h	eight system
Leveling 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) ECR connection to Re	The NW corner of the bottom plate.



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

ECR Station Description SAR-HSU-TN-0015 1.1 07.07.2021 11 of 43 Doc. Nr:

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.	Bases for trigonometric levelling N-S directional baseline for orientation
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	
- f •F • • • •	ECR orientation paral	lel 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.



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

ECR Station Description SAR-HSU-TN-0015 1.1 07.07.2021 12 of 43 Doc. Nr: Issue: Date:

Page:

Finland 2.2

Site	Emäsalo	
ECR ID	19_0110	DLR owned
Operator	FGI	
Logbook	Logbook_19_0110.txt	
Monument and	1 m tall aluminium mast	
foundation	fastened to bedrock with	
	four threaded rods	
	Reference systems an	d tranformations
Height system	Finnish N2000	Saaranen, V., P. Lehmuskoski, P. Rouhiainen, M.
		Takalo, J. Makinen, M. Poutanen (2009): The
		New Finnish Height Reference N2000. In H.
		Drewes (Ed.), Geodetic Reference Frames. IAG
		2006 Springer IAC Symposia 124, 207–202
		2000. Springer, IAG Symposia 134, 29/-302.
		JHS 162 Finlands Height System N2000.
		http://www.ihs-suositukset.fi/suomi/ihs162
National reference	EUREF-FIN	Ollikainen, M., Koivula, H. ja Poutanen, M.
frame		2000. The densification of the EUREF network in
		Finland. Publications of the Finnish Geodetic
		Institute N:0 129. 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:
D 6	INDE	http://www.jhs-suositukset.fi/suomi/jhs197
Reference frame	TIRF2014	
Transformation	EUREF-FIN to 11 RF2014	Software Proj Kel. 6.0.0, March 1 st , 2019
		transformation activers library. Open Source
		Geospatial Foundation URL https://proj.org/
		Geospatial Foundation. OKE 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
	Tido gougo compositor	2010
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	2 starting bolts (732894,	
computations	13406), 3 ending points	
description	(EMSAR1-3), levelled 2 two	· p
	times forward and back,	
	levelling procedure: back-	
	IOFWARD-IOFWARD-DACK,	
	equipment: Zeiss Dini 12,	
	320243, Neuo 13920, Neuo	EMSAR 3: The most northwestern bolt top
	14094	1



Geodetic SAR for Baltic Height System Unification and Baltic Sea Level Research Doc. Nr: Issue: Date: Page:

ECR Station Description SAR-HSU-TN-0015 1.1 07.07.2021 13 of 43

		EMSAR2: top of threaded rod
		EMSAR1: new levelling bolt 20m west from transponder.
Levelling	Least squares adjustment,	•
desricption	temperature,	
Levelling closing error	-0,03 mm	
Levelled point	17.8400 m	The most northwestern bolt top (EMSAR3),
Levelled point	0.0245 m	Measured with mauser, top of bolt to bottom of
height difference to origin of ECR		ECR, valid for ECR 19_0110
ECR reference	17.8155 m	N2000,
point neight		ECR Installation and Local Tie Survey, C.
	ECR connection to F	Reference frame
Description	Metho	d 1
Description	transformation from EUREF-FIN to ITRF2014	
GNSS data	Mean of 5 NRTK fixed	
	initialized between fixes,	
	Geotrim Trimnet NRTK	
	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	2864912.8423	
EUREF-FIN	13/4213.9/55 551101/.0904	
Measured point	2864912.2539	
ITRF2014	13/4214.30/0 5511010.0200	
coordinates Measured point	-0.1800 0.2850 0.0206	East and north: FCP manual drawings
offset to origin of ECR	East, North, Up [meters]	Up: 360 rotating supportive frame thicknesses measured with mauser
Measured to Origin	ENU	Local tangent plane aligned to north and on
method		ref: Thomas H Meyer, University of Connecticut.
		Grid, ground, and globe: Distances in the GPS era, 2002
ECR origin		
EUREF-FIN	-	

BALTIC+ Theme 5 Geodetic SAR for Baltic Height System Unification and Baltic Sea Level Research	E Doc. Nr: Issue: Date:	CCR Station Description SAR-HSU-TN-0015 1.1 07.07.2021
	Page:	14 of 43

ECR origin	2864912.1180	
transformed	1374214.1030	
ITRF2014	5511818.1803	
coordinates		
Ellipsoidal ECR	34.465 m	The NW corner of the bottom plate.
reference (origin)		
point height		
ITRF2014 epoch	2020.0	
	ECR orientation para	allel 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	



Geodetic SAR for Baltic Height System Unification and Baltic Sea Level Research ECR Station DescriptionDoc. Nr:SAR-HSU-TN-0015Issue:1.1Date:07.07.2021Page:15 of 43

Site	Loviisa, LOV3	
ECR ID	18 0091	FGI owned
Operator	FGI	
Logbook	Logbook 18 0091.txt	
Monument and	1 m tall aluminium mast	
foundation	fastened to bedrock with	
	four threaded rods	
	Reference systems a	nd 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	EUREF-FIN	Ollikainen, M., Koivula, H. ja Poutanen, M. 2000.
frame		The densification of the EUREF network in Finland.
		Publications of the Finnish Geodetic Institute N:o
		129. KIrkkonummi.
		IUS 106 FUPEE FIN goordinates in Finland.
		http://www.ibe-suositukset fi/suomi/ibe106
		.IHS 107 EUREE-FIN coordinate systems related
		conversions and map sheet distribution:
		http://www.ihs-suositukset.fi/suomi/ihs197
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.
		Parseliunas (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/j0gs-2010-
	Tide gauge connecti	on to height system
Description	No tide gauge near Loviisa	
2 courption	SAR-site	
	ECR connection	to height system
Levelling	Precise levelling from the	
description	the benchmarks of the	LOSAR1: The most northwestern bolt top of the
	National First Order	ECR
	levelling network.	
Levelling	Least squares adjustment,	
computations	corrections: rods	
description	calibration, temperature,	
Levelled point	30.7153 m	The most northwestern bolt top (LOSAR1), N2000
Levelled point	0.0250 m	Measured with mauser top of bolt to bottom of
height difference	0.0200 III	FCR valid for FCR 18, 0001
to origin of ECR		
ECR reference	30 6003 m	N2000
point height	J3.0303 III	ERC reference point, see project document.
Point noight		ECR Installation and Local Tie Survey. C. Gisinger
Ellipsoidal ECR	46.3036 m	The NW corner of the bottom plate. From LOV3
reference origin		GNSS antenna ARP to four benchmark boults with
point height		tacheometer and from bolts to ECR with levelling (+
1		plate thickness 0.0250).



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

ECR Station Description Doc. Nr: SAR-HSU-TN-0015 1.1 07.07.2021 16 of 43

Issue:

Date:

Page:

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 2828357.4722 coordinates in 1396893.6952 **EUREF-FIN** 5524908.0875 **Measured** point 2828356.8805 transformed 1396894.0839 **ITRF2014** 5524908.4065 coordinates East and north: ECR manual drawings **Measured** point -0.1800, 0.2850, 0.0250 offset to origin of East, North, Up [meters] Up: 360 rotating supportive frame thicknesses measured with mauser ECR Measured to ENU Local tangent plane aligned to north and on **Origin method** 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** 2828356.74899 transformed 1396893.81819 **ITRF2014** 5524908.56884 coordinates Ellipsoidal ECR The NW corner of the bottom plate. VRS measured. 46.315 m reference origin See also value from levellings+tachymeter+ GNSS point height LOV3 ITRF2014 epoch 2020.0 ECR orientation parallel to meridian Method RTK measured ECR mast description center hole and RTK pole moved as far as visible in same meridian then sighting with naked eve using ECR box sides and top to turn box towards RTK-pole Azimuth accuracy RTK: < 0.5 degree

Sighting: about 1 degree



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

ECR Station Description SAR-HSU-TN-0015 1.1 07.07.2021 17 of 43 Doc. Nr: Issue: Date:

Page:

Site	Rauma	
ECR ID	19_0111	DLR owned
Operator	FGI	
Logbook	Logbook_19_0111.txt	
Monument and	1 m tall aluminium mast	
foundation	fastened to big block	
	(>5000kg) of exploded (some	
	years ago) bedrock with four	
	threaded rods	
	Reference systems and t	ransformations
Height system	Finnish N2000	Saaranen, V., P. Lehmuskoski, P. Rouhiainen,
		M. Takalo, J. Makinen, M. Poutanen (2009):
		The New Finnish Height Reference N2000. In
		H. Drewes (Ed.), Geodetic Reference Frames.
		AG Symposium Munich, Germany, 9–14 October 2006, Springer, IAC Symposis 104
		207-202
		29/-302.
		JHS 163 Finlands Height System N2000.
		http://www.ihs-suositukset.fi/suomi/ihs163
National reference	EUREF-FIN	Ollikainen, M., Koivula, H. ja Poutanen, M.
frame		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,
		distribution: http://www.ibc
		suositukset fi/suomi/ihs107
Reference frame	ITRF2014	subsiturset.ii/subiii/jiisig/
Transformation	EUREF-FIN to ITRF2014	Software Proi Rel 600 March 1st 2010
11 unsion mution		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
		(Opling) appl appl DOL:
		https://doi.org/10.1515/jogs-2016-0001
		March 2016
	Tide gauge connection t	o 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.	
Levellin -	ECR connection to he	BASAD to The ment of a state of the sector o
Levening	2 starting poits 2 ending	the ECP
acscription	2 two times forward and back	
	levelling procedure back-	RASAR2: top of threaded rod
	forward-forward-back	Takina, top of threaded fou
	levelling distance about 15 m	
	from both bolts	
Levelling	Least squares adjustment.	
computations	corrections: rods calibration.	
description	temperature,	
Levelled point height	5,032 m	The most northwestern bolt top (RASAR1),
in FCR		N2000



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

Page:

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.
	ECR connection to Ref	ference frame
	Method 1	
Description	Network RTK +	
	transformation from EUREF-	
	FIN to ITRF2014	
GNSS data	Mean of 5 NRTK fixed	
	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.	
	hole. Antenna on top of	
	mast's top surface. Receiver's	
	ARP bottom of receiver center	
	screw hole.	
Measured point	2873769.751	
coordinates in	1127720.938	
Measured point	2873760 215	
transformed	1127721.352	
ITRF2014	5562562.611	
coordinates		
Measured point	-0.1800, 0.2850, 0.029	East and north: ECR manual drawings
ECR	East, North, Op [meters]	measured with mauser
Measured to Origin	ENU	Local tangent plane aligned to north and on
method		ellipsoid in one point
		ref: Thomas H Meyer, University of
		Connecticut, Grid, ground, and globe:
ECR origin		
coordinates in	-	
EUREF-FIN		
ECR origin	2873769.062	
TREPOIA	1127721.098	
coordinates	5502502.774	
Ellipsoidal ECR	24.297 m	The NW corner of the bottom plate.
reference origin		
point height		
11KF2014 epoch	2020.0 ECR orientation parall	el 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	
Azimuth accuracy	RTK: < 0.5 degree	
	Sighting: about 1 degree	



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

ECR Station Description SAR-HSU-TN-0015 1.1 07.07.2021 19 of 43 Doc. Nr: Issue: Date:

Page:

2.3 Poland

Site	Władysławowo	
ECR ID	19_0114	CBK PAN owned
Operator	CBK PAN	
Logbook	Logbook ECR 19 0114.txt	
0	Reference systems	s and transformations
Height system	PL-EVRF2007-NH (a	
	national realization of	
	EVRS), epoch 2000.0	
National	PL-ETRF2000-XYZ, PL-	
reference frame	ETRF2000-GRS80h (a	
	national realization of	
	ETRS), epoch 2011.0	
Reference frame	ITRF2014	
Transformation	none	
Transformation	Tide gauge conne	rtion to height system
Description	Procise levelling	As the initial and reference henchmark BM 20520058
Description	massurements connecting	As the mittal and reference benchmark $BM_30530058$
	vertical reference points of	00-10/11 in a closed traverse
	all trace of instruments	bmp
	installed on the station	Del.
	including the tide gauge staff	ECR_RP -
	(TC CP) CNSS WIAD	
	station bonchmark	cel. 300360
	(WI AD BM) and the	
	hanchmarks of the Polish	305358
	National First Order	iept. 305362
	Levelling Network with	WLAD_BM
	benchmark 20520062	port ryb.
	(TG_BM) and 7 other	AT 11 300309 82 A
	Levelled two times forward	
	and back levelling	
	procedure: back-forward-	JUJJ64
	forward-back	
	Fauinment: Sokkia SDI 20	
	Topcon inver barcode staffs	
	(/5105, /5551).	
	ECR connectio	n to height system
Levelling	Precise levelling from the	
description	tide gauge primary	· 12 F1
description	benchmark 20520062	11 Have Martin
	(TG_BM) to the reference	
	benchmark of the WLAD	
	GNSS station (WLAD_BM)	
	and from the WIAD ARP to	
	the NW corner of the ECR	
	(staff was placed directly on	
	the reference point	
	(FCR_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	
	WIAD BM and	
	WIAD ARP was massured	3053063588
	by calibrated steel tane and	2 2 2 1 2 3 C 2 . 2 3 Z 2
	still rod (used for periodic	
	height control of the WI AD	
	CNSS station)	
	GINOO STATIOITJ.	



Geodetic SAR for Baltic Height System Unification and Baltic Sea Level Research Doc. Nr: Issue: Date: Page:

ECR Station Description SAR-HSU-TN-0015 1.1 07.07.2021 20 of 43

Levelling	Standard least squares	
computations	adjustment; rods calibrated,	
description	temperature corrections.	
Levelling closing	1.35 mm on 3.89 km	From the whole closed levelling traverse.
Levelled point	5.6382 m	The transponder's reference point (ECR_RP) was
height on ECR	00.	levelled directly from WLAD_ARP).
Levelled point	Not measured	
height difference		
to origin of ECR		
ECR reference	5.6382 m	The NW corner of the bottom plate (ECR_RP).
FCP allingaidal	04 6000 m	Computed from static CNSS sossions, performed on
reference point	34.0233 11	2020-00-10/11 using Trimble 5700/ TRM41240.00
height		Vector WLAD ARP > ECR RP (~1.5 m length).
- 0 -		
	ECR connection	to Reference frame
Description	Static GPS/GNSS	Two static GNSS measurements made on 2020-09-
	measurements with	10/11 on vector WALD_ARP – ECR_RP, ~1.5 m
	antennas installed directly	distance between the antennas. Equipment: Trimble
	both instruments	GR20/I FIAR20 I FIM on WI AD ARP
GNSS data	Static sessions, sampling	4 static GNSS meas, sessions: 2020 DOY080 (2h/5m)
STIGS untu	data 5 sec, (GPS,	2020:DOY254 (3h45m), 2020:DOY254 (9h06m).
	GPS+GLONASS)	2020:DOY255 (8h40m).
Measured point	The top surface of the	
	adapter screw with a 5/8"	0
	threaded rod screwed into it,	
	intended for the installation	
	Before the measurement the	
	adapter was screwed into the	
	threaded hole made in the	ECR. RP METASENSING
	transponder installation	Radar Solutions
	construction, which	A ANC AND
	coincides with the NW	
	corner of the transponder,	
	point (FCR-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 point	Lat = 54 47" 48 49044957"	From WLAD -> WLAS (= ECR_RP) vector solutions
coordinates /	Lat = 54.47 + 40.42044357 Lon = 18.25' 07.52248105"	(from 4 static meas sessions: 2020 DOY080 (2h45m)
ECR reference	h = 34.6233 m	2020:DOY254 (3h45m), 2020:DOY254 (9h06m),
point ECR_RP		2020:DOY255 (8h40m). Coordinates of the reference
coordinates		point of ECR_19_0114 transponder in the ITRF2014,
	.	ep. 2020.42.
Measured point	Lat = 5447 ' 48.42044357 "	Data processed and coordinates determined in
Coordinates /	Lon = 1825 07.52248105''	11KF2014, not transformed.
point ECR RP	n – 34.0233 m	
transformed		
ITRF2014		
coordinates		
ITRF2014 epoch	Not conducted.	To be done after receiving unified guidelines.

ECR orientation parallel to meridian			
Method	1.) Orientation of the marked		
description	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	About 1 degree or better.		
accuracy	-		



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

Doc. Nr: Issue: Date: Page:

ECR Station Description SAR-HSU-TN-0015 1.1 07.07.2021 22 of 43

Cita				
Sile ECD ID		TUM owned		
ECKID	18_0104	I UM owned		
Operator	CBK PAN			
Logbook	Logbook_ECR_18_0104.txt			
	Reference systems	s and transformations		
Height system	PL-EVRF2007-NH (a			
	national realization of			
	EVRS), epoch 2000.0			
National	PL-ETRF2000-XYZ, PL-			
reference frame	ETRF2000-GRS80h (a			
	national realization of			
	ETRS), epoch 2011.0			
Reference frame	ITRF2014			
Transformation	none			
	Tide gauge conne	ction to height system		
Description	Precise levelling	As the initial and reference benchmark BM 30430019		
1	measurements connecting	was chosen. The measurements were made on 2020-09-		
	vertical reference points of	11/12 in a closed traverse.		
	all types of instruments			
	installed on the station,			
	including the tide gauge staff			
	(TG CP), TG BM (5382),	A Real Contraction of Provide And		
	ECR D, ECR RP and the	and and the second		
	benchmarks of the Polish	and a second sec		
	basic levelling network with			
	benchmarks: 30430019 (AB			
	2733) and 30430028.	ECR_RP GNSS		
	Levelled two times forward			
	and back, levelling			
	procedure: back-forward-	/ Net Version		
	forward-back.	Winside Marsel Souge Q Second State		
	Equipment: Sokkia SDL30.			
	Topcon invar barcode staffs	Company of Water O		
	(75105, 75551).	Loss Bally There is a constraint of the second seco		
	(700),7000-9	Provide Lines V Lines V		
		Microsoft 0 10 30430019		
		Handy Read L. T Tayyoptana Annual Ang		
		Dan senter 0		
		Sould introducer V Lond B Printers		
		ECR-C Unit Taret Longiture O Darge Magain		
		GNSS POLONAND		
		The stand of the s		
ECR connection to height system				

ECR connection to height system



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

ECR Station Description SAR-HSU-TN-0015 1.1 07.07.2021 23 of 43 Doc. Nr:

Levelling	Precise levelling from the		
description	LEB_W benchmark in		
	meteorological garden,		
	through the point ECR_D,		
	ECK_KP to IG_BM and TC_CP_Op the way back	202	
	from TG_CP through the		
	reference benchmark of the		
	national vertical network Nr.	ECR RP	
	30430019 to the starting	TG_BM.	
	benchmark (see maps on the		
	forward and back Levelling		
	procedure: back-forward-		
	forward-back.		
Levelling	Standard least squares		
computations	adjustment; rods calibrated,		
Levelling closing	1 80 mm on 7 13 km distance	From the whole closed levelling traverse	
error	(0.25 mm/km)		
Levelled point	3.0491 m	The transponder's reference point (ECR_RP) was	
height on ECR		levelled from national basic vertical network benchmark	
I evelled point	Not measured	Nr. 30430019.	
height difference	Not measured		
to origin of ECR			
ECR reference	3.0491 m	The NW corner of the bottom plate (ECR_RP).	
FCR allinsoidal	00.0501 m	Computed from a static CNSS sassions, performed on	
reference point	33.9531 III	2020-09-11/12 using Trimble 5700/ TRM41249.00.	
height		Vector LEBI_ARP -> ECR_RP (~15 m length).	
	ECD commonstion	to Defense as from a	
Description	Static GPS/GNSS	Two static GNSS measurements made on 2020-00-	
Description	measurements with	11/12 on vector LEBI_ARP -> ECR_RP, ~20 m	
	antennas installed directly	distance between the antennas. Equipment: Trimble	
	above the reference points of	5700/ TRM41249.00 on ECR_RP and Leica	
CNSS data	Static measured 5 sec (CPS	GR30/LEIARIO NONE ON LEBI_ARP.	
Onoo uutu	GPS+GLONASS)	2020:DOY256 (5h055m).	
Measured point	The top surface of the		
	adapter screw with a 5/8"		
	intended for the installation		
	of the GNSS antenna.		
	Before the measurement, the		
	adapter was screwed into the		
	threaded hole made in the	GNSS antenna installed on the adapter vertically above	
	construction which	the ECR_RP points.	
	coincides with the NW	GNSS measurements were made before ECR	
	corner of the transponder,	Installation. GNSS_AKP height above ECK_KP was	
	defined as the ECR reference	incasureu by camprateu steer tape.	
Management maint	point (ECR-RP).	From LEDI & LEDG (- ECD DD) yester solutions (from	
coordinates /	Lon = 17.32' 05.54830034''	2 static meas, sessions: 2020 DOV255 (10h15m)	
ECR reference	h = 33.9531 m	2020:DOY256 (5h055m). Coordinates of the reference	

the second secon	BALTIC+ Theme 5 Geodetic SAR for Baltic Height System	ECR Station Description Doc. Nr: SAR-HSU-TN-0015 Issue: 1.1	
	Unification and Baltic Sea Level Research	Date: Page:	07.07.2021 24 of 43

point ECR_RP		point of ECR_18_0104 transponder in the ITRF2014,
coordinates		ep. 2020.42.
Measured point	Lat = 54 45" 13.17744414"	Data processed and coordinates determined in
coordinates /	Lon = 17 32' 05.54830034"	ITRF2014, not transformed.
ECR reference	h = 33.9531 m	
point ECR_RP		
transformed		
ITRF2014		
coordinates		
ITRF2014 epoch	Not conducted.	To be done after receiving unified guidelines.
	ECR orientation	parallel to meridian
Method	1.) Orientation of the marked	
description	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	About 1 degree or better.	
accuracy	-	



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

ECR Station Description SAR-HSU-TN-0015 1.1 07.07.2021 25 of 43 Doc. Nr:

Issue: Date: Page:

2.4 Sweden

Site	Mårtsbo	
ECR ID	19 0107	Lantmäteriet
Operator	LM	
Logbook	Logbook ECR 19 0107 -	
8	updated.txt	
	Reference systems and tr	ansformations
Height system	RH2000	
National reference	SWEREF 99	
frame		
Reference frame	ITRF2014	
Transformation		
	Tide gauge connection to	height system
Description	There is no tide gauge nearby.	
	MARo Pillar in Mårtsbo is only	
	1 meter away from permanent	
	GNSS station MAR6.	
	ECR connection to he	ight system
Levelling	Levelling was done between	
description	MAR6 (close by GNSS station)	
T 11.	and MARO (ECR pillar).	
Levelling	Direct leveling between Pillar	
computations	MARG (the close by GNSS pillar	
description	station) and MARO (ECK	
	surface is 4.5 mm lower than	
	MAR6	
Levelling closing		
error		
Levelled point	Leveling was done before ECR	
height in ECR	installation.	
Levelled point		
height difference to		
origin of ECR		
ECR reference point		
height		
	ECR connection to Refe	erence frame
	Method 1	
Description	GNSS static measurements,	A A L. Internet and a la
	Using Ashtech Chock ring	
	TRE COT SIGMA Receiver	Ashterh
	Measured location of ECR	
	(MARo station) is just beside	
	MAR6 EPN permanent GNSS	
	station (see photo LR).	
	Measurement DOY: 317(15 hrs)	IMG 20191113 100702 Pg
	and 318(full day), 2019	concoccocco
	Data processed via online	
	services: AUSLIG (network	
	processing) and CSRS-PPP	
	online positioning service and	
	coming Notwork and PPP	
	estimated coordinates in	
	ITRF14 are just about 2-5 mm	IMG 20191115 103446.jpg
	different.	00000000000000000000000000000000000000
GNSS data	Static, measured 1 sec, sampled	
	to 30 sec, (GPS+GLONASS)	
Measured point	Top Center of MARo pillar	before ECR installation
-	station (see photo)	



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

ECR Station Description SAR-HSU-TN-0015 1.1 07.07.2021 26 of 43 Doc. Nr: Issue: Date:

Page:

Measured point	N=6719816.166	Using LM online processing service, Helmet
coordinates in	E=623689.075	transformation, SWEN17_RH2000 geoid
SWEREF 99 IM	H= 50.664	model was used to convert to RH2000.
RH2000		see processing report in this folder:
1412000		GNSS_measurements_results
Measured point	X=2998190.645	See processing report in this folder:
ITRF2014	Y=931452.401	GNSS_measurements_results
coordinates	Z=5533398.043	
	Lat=60 35 42.46940	
	Long= 17 15 0.71058	
Measured point	Offset N= 28.5 cm	
offset to origin of	Offset $E = 18 \text{ cm}$	METAS NSING
ECR	Vertical Offset = 41 mm (ECR	Rad Solutions
	bottom is 4.1 cm higher than	
	top surface of MARo pillar)	
	h (FCP rof	
	point)=7557+0041=75508	A CONTRACTOR OF THE OWNER
	point, /3.33/ 0.041 /3.390	
		.Au
Measured to Origin		
method		
ECR origin	N=6719816.451	Based on instructions: ECR origin point is
coordinates in	E=623688.895	located on NW corner of ECR (bottom
SWEREF99 IM and	h = 50.705 h(ellip)-75 508	surface)
ECR origin	X=2998190.471	
transformed	Y=931452.170	
ITRF2014	Z=5533398.218	
coordinates		
ITRF2014 epoch	14/11/2019 (2019.8712)	a static (NGC)
	memou 2 (ii executed, e.	5. Statte ONSS/
	GNSS station connection t	o height system
Description	Direct leveling between Pillar	
	MAR6 (the close by GNSS pillar	
	location) showed MARO is $4 =$	
	mm lower than MAR6.	
Station		
GNSS ARP height		
	ECR orientation paralle	l to meridian
Method description	Compass	
Azimuth accuracy	± 5 degrees? (not sure how	
	accurate the compage week	

	BALTIC+ Theme 5 Geodetic SAR for Baltic Height Unification and Baltic Sea Level	t System Research	ECR Station Description Doc. Nr: SAR-HSU-TN-0015 Issue: 1.1 Date: 07.07.2021 Page: 27 of 43
Site	Kobben (Forsmark) Note: There is fine mesh metal fence around the Transponder (see the photo to the right).	4G ro	euter GNSS
ECR ID	19_0108	Lantmäter	riet
Operator	LM		
Logbook	Logbook_ECR_19_0108.txt		
Ileight gugton	Reference systems	and trans	formations
National	SWEREF 00		
reference frame	SWEREF 99		
Reference frame	ITRF2014		
Transformation			
D	Tide gauge connec	tion to hei	ight system
Description	in Forsmark		
	ECR connection	n to height	t 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)	Rödören Svalören Per Jansgrut Härneraffreder	Trigonometric leveling "220 m Grisselymonet Refiningswork Refiningswork Refiningswork Refiningswork Refiningswork Refiningswork
Levelling computations description			
Levelling closing	5		

Ł	+

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

ECR Station Description SAR-HSU-TN-0015 1.1 07.07.2021 28 of 43 Doc. Nr:

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)	upper surface
Levelled point	ECR origin point is located	
height	at bottom plate, so we	
difference to	should subtract 21 mm.	
ECR reference	ECR H (origin	
point height	point)=2.9765 m	
	ECR connection	to Reference frame
D	Me	thod 1
Description	GNSS network KIK measurements (using	
	SWEPOS service) was done	
	to find the positions of 4	
	screws at the corners of the	
	accuracy in 2 dimensions	
	This way, we found the	
	center position of the ECR.	
	-We used GNSS Leica	
	RTK rover to measure the	
	positions.	
GNSS data	NRTK measurements on 4	
	screws at the corners of the the ECR	
Measured point		
Measured point	N= 6701423.835	The center plate, upper edge.
coordinates in	E=677898.499	6 mm was subtracted from the estimated height for
And height in	2.982	the neight of screw above the upper plate.
RH2000	,	
Measured point	X=2999000.5138	
ITRF2014	Y=987781.0353	Center plate, Upper edge, see this <u>link</u> :
coordinates	2-5523191.9/90	



Geodetic SAR for Baltic Height System Unification and Baltic Sea Level Research Doc. Nr: Issue: Date: Page:

ECR Station Description SAR-HSU-TN-0015 1.1 07.07.2021 29 of 43

Massured point	Offset $N = 28 \pi$ cm	
Measured point	Offset $E = 40$ and	
onset to origin	Offset $E = 18 \text{ cm}$	
of ECR	Vertical offset $=2.7$ cm	
Measured to		
Origin method		
ECR origin	N= 6701424.120	
coordinates in	E=677898.319	
SWEREF99 TM	H= 2.955	
and RH2000	,	
ECR origin	X=2999000.311	
transformed	Y=987780.795	
ITRF2014	Z=5523192.099	
coordinates		
ITRF2014 epoch	2010-01-01	
Method 2 (if executed, e.g. static GNSS)		
•••		
	GNSS station conne	ection to height system
Description		
Station		
GNSS ARP		
height		
	ECR orientation	parallel to meridian
Method	Compass	
description		
Azimuth	±5 degress? (not sure how	
accuracy	accurate the compass was)	



Geodetic SAR for Baltic Height System Unification and Baltic Sea Level Research ECR Station DescriptionDoc. Nr:SAR-HSU-TN-0015Issue:1.1Date:07.07.2021Page:30 of 43

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



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

ECR Station Description SAR-HSU-TN-0015 1.1 07.07.2021 31 of 43 Doc. Nr:

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	
Measured point	N = 6918190.565	
coordinates in	E = 625580.955	
SWEREF 99 TM And height in RH2000	H= 123.535	
Measured point	X=2829284.3114	
ITRF2014 coordinates	Y=888154.0780 Z=5628089.9707	Center plate, Upper edge, see this <u>link</u> :
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	N= 6918190.850	
coordinates in SWEREF99 TM and RH2000	E= 625580.775 H= 123.508	
ECR origin	X=2829284.103	
transformed ITRF2014	Y=888153.837 Z=5628090.081	
coordinates ITRF2014	2010-01-01	
epoch	Nr 11 1 - //0	
	Method 2 (11 exec	utea, e.g. static GNSS)
	•••	
	GNSS station conn	ection to height system
Description Station		
Julion	1	



Geodetic SAR for Baltic Height System Unification and Baltic Sea Level Research ECR Station DescriptionDoc. Nr:SAR-HSU-TN-0015Issue:1.1Date:07.07.2021Page:32 of 43

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



Geodetic SAR for Baltic Height System Unification and Baltic Sea Level Research ECR Station DescriptionDoc. Nr:SAR-HSU-TN-0015Issue:1.1Date:07.07.2021Page:33 of 43

2.5 Germany

-	-	
Site	DLR Oberpfaffenhofen	ECR113 CR-OBE1 CR-OBE2 50m
ECB ID	10, 0110	DI R ourmed
ECK ID Operator	19_0112	DLK Owned
Loghaph	DLK Loghaph to otto tet	
LOGDOOK	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.	ransformations
II-1-1-1-1	Duulla at (
rieigni system	DHHN2010	 Feidmann-Westendorn, U., Liebsch, G., Sacher, M., Müller, J., Jahn, CH., 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 Geodä- sie, 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	



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

Transformation	GREF to ITRF2014	Not known	
ECR connection to height system			
Levelling	No levelling performed		
description			
	ECK connection to Rel	terence trame	
Description	Static GNSS Measurement		
Description	performed with Javad		
	Triumph V receiver and		
	antenna mounted with	V -	
	tribrach on tripod centered		
	above ECR frame with optical		
	plummet (aligned to central		
	bore noie of earth stud).		
		A CARLEND AND A CARLEND	
GNSS data	3 hours static baseline data		
	with respect to IGS reference		
	station OBE4. Double		
	fixed ambiguities and fixed		
	reference station OBE4		
	computed with Bernese for		
	GPS+GLO		
Measured point	Center of ECR base plate,		
	plate bottom edge. GNSS		
	central point. Vertical offset		
	between GNSS ARP and ECR		
	plate bottom measured with		
	yard stick and inserted as		
	processing		
	processing.		
Measured point	N/A		
coordinates in GREF			
Measured point	4186629.0879		
coordinates in	835142.4129		
11 KF2014	4/23050.1/80		
Measured point	Offset E= 18 cm	East and north: ECR manual drawings	
offset to origin of	Offset N= 28.5 cm		
ECR	Vertical Offset = 0 cm		
Measured to Origin	ENU	Local tangent plane aligned to north and on	
method		ellipsoid in one point	
		ref: Thomas H Meyer, University of	
		Connecticut, Grid, ground, and globe:	
ECR origin	N/A	Distances III IIIC GI S ci a, 2002	
coordinates in GREF			
ECR origin	4186628.8447	The NW corner of the bottom plate.	
transformed	835142.5479	_	
ITRF2014	4723656.3684		
coordinates Filipsoidal FCP	625 046 m	The NW corner of the bottom plate	
reference origin	020.940 III	The ryw corner of the bottom plate.	
point height			



Geodetic SAR for Baltic Height System Unification and Baltic Sea Level Research ECR Station DescriptionDoc. Nr:SAR-HSU-TN-0015Issue:1.1Date:07.07.2021Page:35 of 43

ITRF2014 epoch	2020 08 06	
	ECR orientation parall	el 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	



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

ECR Station Description SAR-HSU-TN-0015 1.1 07.07.2021 36 of 43 Doc. Nr: Issue: Date:

Page:

Site	DLR Oberpfaffenhofen	
ECP ID	10 0110	DI P owned
	19_0113	DLK Owneu
Operator	DLK	
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.	ransformations
Unight gystore	DUUN0014	Eoldmann Wostendorff II Lichach C
ineight system	D1111112010	Sacher, M., Müller, J., Jahn, CH., 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 Geodä- sie, Geoinformation und Landmanagement, Heft 5/2016, 141. Jg. S. 354–367. DOI: 10.12902/zfv-0140-2016.
National reference	GREF	Not known
frame		



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

Transformation	GREF to ITRF2014	Not known	
	ECR connection to h	eight system	
Levelling	No levelling performed		
description			
	ECR connection to Reference frame		
	Method 1	1	
Description	Static GNSS Measurement	and the second	
	performed with Javad	A Star Service and Andrews	
	Triumph V receiver and		
	antenna mounted with	A DECEMBER OF THE REAL PROPERTY OF THE REAL PROPERT	
	tribrach on tripod centered		
	above ECK frame with optical		
	bore hele of conthestud)		
	bore noie of earth stud).	the second s	
		and the second se	
		And a second	
GNSS data	3 hours static baseline data		
	with respect to IGS reference		
	station OBE4. Double		
	difference static solution with		
	nixed ambiguines and fixed		
	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	N/A		
coordinates in GREF	14/21		
Measured point	4186415.9489		
coordinates in	834943.0585		
ITRF2014	4723875.7253		
Measured point	Offset E= 18 cm	East and north: ECR manual drawings	
offset to origin of	Offset N= 28.5 cm		
ECR	Vertical Offset = 0 cm		
Maggunged to Origin	ENILI	Least tangant plane aligned to north and an	
measured to Origin	ENU	allipsoid in one point	
method		ref: Thomas H Mover, University of	
		Connecticut Grid ground and globe	
		Distances in the GPS era. 2002	
ECR origin	N/A	, , , , , , , , , , , , , , , , , , ,	
coordinates in GREF			
ECR origin	4186415.7057	The NW corner of the bottom plate.	
transformed	834943.1935	_	
ITRF2014	4723875.9157		
coordinates			
Ellipsoidal ECR	623.645 m	The NW corner of the bottom plate.	
reference origin			
point neight	1		



Geodetic SAR for Baltic Height System Unification and Baltic Sea Level Research ECR Station Description Doc. Nr: SAR-HSU-TN-0015 Issue: 1.1 Date: 07.07.2021 Page: 38 of 43

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	



Geodetic SAR for Baltic Height System Unification and Baltic Sea Level Research ECR Station DescriptionDoc. Nr:SAR-HSU-TN-0015Issue:1.1Date:07.07.2021Page:39 of 43

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 t	ransformations
Height system	DHHN2016	Feldmann-Westendorff, U., Liebsch, G.,
		Sacher, M., Müller, J., Jahn, CH., 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 Geodä- sie, 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 h	eight system
Levelling	No levelling performed	
description		



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

ECR Station Description SAR-HSU-TN-0015 1.1 07.07.2021 40 of 43 Doc. Nr: Issue: Date:

Page:

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	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 orientat	ion	
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.		
	degree Elevation: < 1 degree		



Geodetic SAR for Baltic Height System Unification and Baltic Sea Level Research ECR Station Description Doc. Nr: SAR-HSU-TN-0015 Issue: 1.1 Date: 07.07.2021 Page: 41 of 43

Site	DLR Oberpfaffenhofen	ECR113 CR-OBE1 CR-OBE2
		terretaria 500m
CRID	CP OPEn	DI P ourod
CK ID Operator	DLP	DLK Owned
Logbook	Logbook CR OBE2 txt	
Monument and	Triangular base frame	
foundation	anchored in soil with 30 cm	
	bolts. Orientable elevation	
	azimuth mount with screws	
	for horizontal levelling and	
	bolts to secure the aligned	
	Reference systems and t	ransformations
Height system	DHHN2016	Feldmann-Westendorff, U., Liebsch, G.,
		Sacher, M., Müller, J., Jahn, CH., 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 Geodä- sie, Geoinformation und Landmanagement, Heft 5/2016, 141. Jg. S. 354–367. DOI: 10.12902/zfv-0140-2016.
National reference	GREF	Not known
frame		
Reference frame	ITRF2014	
Transformation	GREF to ITRF2014	Not known
Levelling	ECK connection to h	ergnit System
description	no levening performed	
	CR connection to Ref	erence frame
Method 1		



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

ECR Station Description SAR-HSU-TN-0015 1.1 07.07.2021 42 of 43 Doc. Nr: Issue: Date:

Page:

Description	Static GNSS Measurement	and the second
-	performed with Leica GX1230	
	receiver and antenna	
		and the second state of the second
	mounted with survey rod	alle man a constant
	placed in corner point. Rod	the second se
	clamped to corner.	
	P	and the second of the second o
		and a second party party and the second
		A SALAN AND A S
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.	
F	GNSS antenna mounted	
	above corner point Vertical	
	above corner point. Vertical	
	offset between GNSS ARP and	
	corner as indicated on survey	
	rod. Reading inserted as	
	antenna height during GNSS	
	processing.	
	1 0	
Measured point	N/A	
coordinates in GREE		
Monsured point	4196907 9005	CP geometrical phase conter
Measured point	4100037.0925	en geometrical phase center
coordinates in	834974.7565	on geometrical phase center
coordinates in ITRF2014	4100037.8925 834974.7565 4723504.0803	
coordinates in ITRF2014 Ellipsoidal ECR	418083/.8925 834974.7565 4723504.0803 627.655 m	CR geometrical phase center
coordinates in ITRF2014 Ellipsoidal ECR reference origin	4180837.8925 834974.7565 4723504.0803 627.655 m	CR geometrical phase center
coordinates in ITRF2014 Ellipsoidal ECR reference origin point height	4180837.8925 834974.7565 4723504.0803 627.655 m	CR geometrical phase center
coordinates in ITRF2014 Ellipsoidal ECR reference origin point height ITRF2014 epoch	4180837.8925 834974.7565 4723504.0803 627.655 m	CR geometrical phase center
coordinates in ITRF2014 Ellipsoidal ECR reference origin point height ITRF2014 epoch	4100037.0925 834974.7565 4723504.0803 627.655 m 2020 03 13 CR orientat	CR geometrical phase center
Measured point coordinates in ITRF2014 Ellipsoidal ECR reference origin point height ITRF2014 epoch Method description	4100037.0925 834974.7565 4723504.0803 627.655 m 2020 03 13 CR orientat Azimuth aligned to ascending	CR geometrical phase center CR geometrical phase center ion
Measured point coordinates in ITRF2014 Ellipsoidal ECR reference origin point height ITRF2014 epoch Method description	4180837.8925 834974.7565 4723504.0803 627.655 m 2020 03 13 CR orientat Azimuth aligned to ascending zero. Doppler direction (110	CR geometrical phase center
Measured point coordinates in ITRF2014 Ellipsoidal ECR reference origin point height ITRF2014 epoch Method description	418083/.8925 834974.7565 4723504.0803 627.655 m 2020 03 13 CR orientat Azimuth aligned to ascending zero-Doppler direction (110 degrees) with dirich even	CR geometrical phase center
Measured point coordinates in ITRF2014 Ellipsoidal ECR reference origin point height ITRF2014 epoch Method description	A180837.8925 834974.7565 4723504.0803 627.655 m 2020 03 13 CR orientat Azimuth aligned to ascending zero-Doppler direction (110 degrees) with digital compass	CR geometrical phase center CR geometrical phase center ion
Measured point coordinates in ITRF2014 Ellipsoidal ECR reference origin point height ITRF2014 epoch Method description	418083/.8925 834974.7565 4723504.0803 627.655 m 2020 03 13 CR orientat Azimuth aligned to ascending zero-Doppler direction (110 degrees) with digital compass with correction for magnetic	CR geometrical phase center CR geometrical phase center ion
Measured point coordinates in ITRF2014 Ellipsoidal ECR reference origin point height ITRF2014 epoch Method description	Arious 37.8925 834974.7565 4723504.0803 627.655 m 2020 03 13 CR orientat Azimuth aligned to ascending zero-Doppler direction (110 degrees) with digital compass with correction for magnetic inclination. Alignment	CR geometrical phase center CR geometrical phase center ion
Measured point coordinates in ITRF2014 Ellipsoidal ECR reference origin point height ITRF2014 epoch Method description	4180837.8925 834974.7565 4723504.0803 627.655 m CR orientat Azimuth aligned to ascending zero-Doppler direction (110 degrees) with digital compass with correction for magnetic inclination. Alignment verified with Leica sighting	CR geometrical phase center CR geometrical phase center ion
Measured point coordinates in ITRF2014 Ellipsoidal ECR reference origin point height ITRF2014 epoch Method description	4180837.8925 834974.7565 4723504.0803 627.655 m CR orientat 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	CR geometrical phase center CR geometrical phase center ion
Measured point coordinates in ITRF2014 Ellipsoidal ECR reference origin point height ITRF2014 epoch Method description	4180837.8925 834974.7565 4723504.0803 627.655 m 2020 03 13 CR orientat 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	CR geometrical phase center CR geometrical phase center ion



Geodetic SAR for Baltic Height System Unification and Baltic Sea Level Research ECR Station DescriptionDoc. Nr:SAR-HSU-TN-0015Issue:1.1Date:07.07.2021Page:43 of 43

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