

Height Reference Surface North Macedonia HREF2022A

10 March 2023

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Kartverket

1 Update

This report describes the HREF2022A, which is an update of the "Height Reference Surface North Macedonia" from 5 July 2020 (HREF2020A). The underlying quasigeoid is the same as for the previous HREF (HREF2020A).

2 Introduction

A Height Reference Surface (HREF) was created which fit the selected height system. Adding the ellipsoidal height obtained from GNSS-equipment in combination with a HREF surface gives the selected height system (either NVT1 or NORMAL).

3 Quasigeoid

Starting point is our estimated gravimetric geoid. We have selected a geoid that uses gravity data covering North Macedonia combined with extra gravity data from the global model EGM08 out to 150 km outside our local gravity data. We use global model XGM2190 in the geoid calculation and a Stokes kernel truncation at level 140 with a linear tapering to 160. This geoid is fitted to the connection points by removing the mean difference. The quasigeoid is named: `qgeoid_2020A_nvt1` and `qgeoid_2020A_normal` for the two height systems below, respectively. For a detailed description of the quasigeoid computation see the report Quasigeoid for North Macedonia by Omang.

4 Height system

The official height system is H_{nvt1} and the new unofficial height system is H_{normal} . Both system uses normal heights.

The height system H_{nvt1} :

- also referred to as the NVT High Precision Leveling Network 1
- normal orthometric heights based on the high-precision leveling conducted in the period 1946 - 1957.
- The vertical reference level of the NVT1 heights coincides with the mean level of the mareographic measurements carried out on the mareograph in Trieste in 1875.

The height system H_{normal}

- also referred to as NVT2

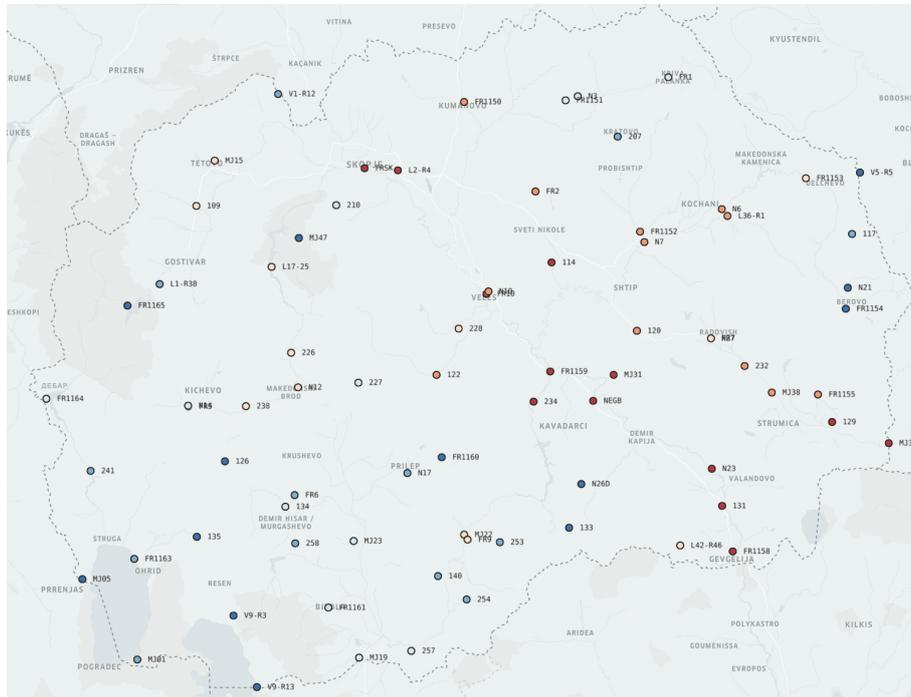


Figure 1: The selected 77 GNSS/leveling data (H_{nvt1}) as circles

- normal orthometric heights based on the high-precision leveling conducted in the period 1968 - 1973
- The vertical reference level to the heights is the mean level of mareographic measurements conducted on mareographs in Kopar, Rovinj, Bakar, Split, Dubrovnik and Bar, along the Adriatic Sea, from 1962 to 1980 (epoch 1971.5).

For more information about the height systems is given in Law for Real Estate Cadastre (Official Gazette of the Republic of Macedonia” No. 55/2013, 41/2014, 115/2014, 116/2015, 153/2105, 192/2015, 61/2016, 172/2016, 64/2018 and ”Official Gazette of Republic of Northern Macedonia ”No. 124/2019) and the Sub-law for basic geodetic works (Official Gazette of the Republic of Macedonia, no. 151 dated 04.11.2013).

5 GNSS/Leveling points

There are 77 combined GNSS and leveling points, called connection points, they are given as circles in Figure 1. The GNSS points are given in the ETRS89 reference frame, with epoch 1989.0, while the leveling points are described in section 4.

6 Height Reference Surface (HREF)

A Height REFERENCE Surface (HREF) is created by modifying a gravimetric geoid to fit the connection points (height system H_{nvt1} or H_{normal}). The HREF model is estimated in three steps

1. The difference between the quasigeoid and the connection points is estimated. A long wavelength surface is estimated using collocation/second degree Gauss-Markov using a correlation length of 100 km and noise 5 cm. This surface is added to the original quasigeoid.
2. Step 1 is repeated with correlation length of 20 km, noise 2 cm and quasigeoid from step 1.
3. Step 1 is repeated with correlation length of 3 km, noise 0.5 cm and quasigeoid from step 2.

Starting geoids are:

- qgeoid_2020A_nvt1
- qgeoid_2020A_normal

The HREF are named after their height system:

- HREF; height system NVT1: HREF2022A_HNVT1
- HREF; height system NORMAL: HREF2022A_HNORMAL

The difference (up to 10 cm) between the original geoid and the estimated HREF is illustrated in Figure 2 and `refdiff-geoid-href-hnormal`. This HREF will give the transfer from ellipsoidal (GNSS) height to the official height system NVT1.

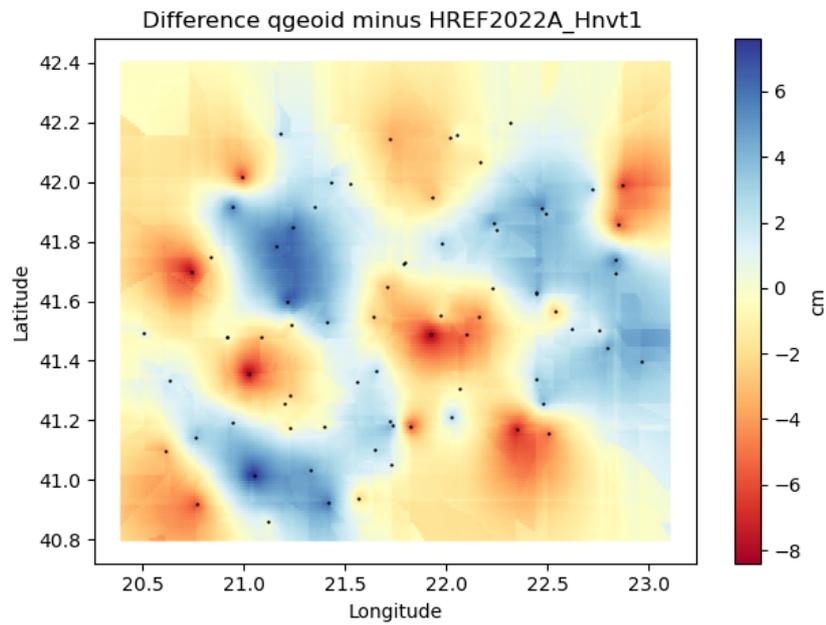


Figure 2: Difference between quasigeoid and the estimated HREF. Connection points are indicated as black dots. Height system is H_{nvt1}

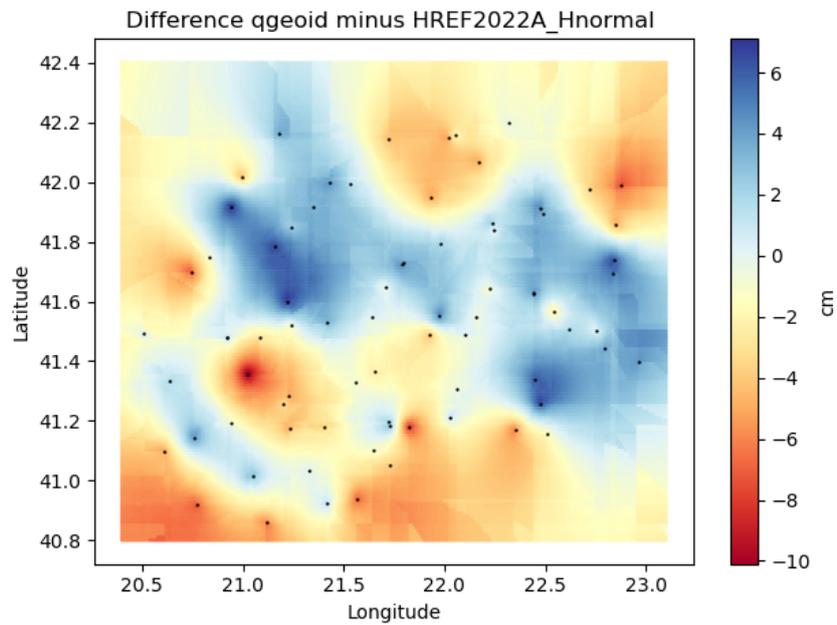


Figure 3: Difference between quasigeoid and the estimated HREF. Connection points are indicated as black dots. Height system is H_{normal}

Station	Latitude	Longitude	H_{ell}	H_{nvt1}	H_{normal}
L1-R38	41.7460454	20.8361509	871.002	826.554	826.889
L2-R4	41.9954367	21.5293055	276.418	231.874	232.216
N3	42.1563552	22.0534995	634.308	589.044	589.353
N7	41.8384057	22.2481586	348.389	303.915	304.221
N10	41.7303287	21.7936428	308.128	263.674	264.041
N12	41.5195662	21.2383941	579.114	534.571	534.900
L17-25	41.7839405	21.1614360	583.895	538.863	539.195
FR1164	41.4945556	20.5052247	628.418	586.289	586.609
134	41.2567067	21.2017704	675.459	631.857	632.163
N17	41.3308821	21.5570861	718.972	674.545	674.851
FR1159	41.5543736	21.9739381	181.571	137.545	137.934
N27	41.6271813	22.4421166	437.324	392.824	393.155
N21	41.7380932	22.8389748	888.208	843.207	843.546
N23	41.3399792	22.4456708	120.457	76.521	76.882
N26D	41.3069652	22.0633462	900.717	856.403	856.734
253	41.1786757	21.8264245	850.523	806.237	806.545
MJ15	42.0163121	20.9955163	495.299	450.564	450.911
V1-R12	42.1607069	21.1807607	824.353	778.915	779.260
V5-R5	41.9891626	22.8729480	1192.183	1147.056	1147.375
MJ37	41.3965434	22.9615222	235.182	191.546	191.875
MJ19	40.9226903	21.4164627	631.061	588.434	588.714
MJ01	40.9188550	20.7708854	823.773	782.681	782.996
MJ05	41.0972370	20.6118369	1034.189	993.100	993.416
N14	41.4792552	20.9185061	681.455	637.714	638.050
FR1158	41.1571707	22.5068207	100.302	56.908	57.270
109	41.9172720	20.9421605	525.973	481.414	481.758
207	42.0680548	22.1694100	792.795	747.498	747.793
228	41.6486482	21.7065648	444.246	399.683	400.040
122	41.5469929	21.6419269	347.036	302.294	302.649
227	41.5298663	21.4144799	694.029	649.037	649.359
210	41.9187168	21.3498665	657.678	612.706	613.046
MJ47	41.8465082	21.2417892	1192.085	1146.809	1147.100
226	41.5957102	21.2182920	556.588	511.772	512.102
238	41.4780930	21.0868105	625.274	581.150	581.481
241	41.3358300	20.6346780	735.727	693.271	693.601
126	41.3569997	21.0262878	941.444	897.781	898.090
234	41.4880677	21.9252955	195.875	151.865	152.240
MJ31	41.5470592	22.1588301	268.415	224.264	224.634
120	41.6437975	22.2264411	359.501	315.087	315.412

Table 1: Connection points for HREF2022A, part 1. Points 1 - 39 of 77.

Station	Latitude	Longitude	H_{ell}	H_{nvt1}	H_{normal}
MJ38	41.5081601	22.6200882	328.354	284.484	284.815
232	41.5665194	22.5406138	364.000	319.806	320.137
NEGB	41.4898405	22.0991645	209.911	165.975	166.360
131	41.2579187	22.4756711	119.881	76.151	76.512
MJ22	41.1948620	21.7225515	533.577	489.469	489.789
MJ23	41.1810436	21.4005280	653.842	610.332	610.628
258	41.1760947	21.2306480	799.952	756.547	756.838
135	41.1908152	20.9449201	1091.662	1048.619	1048.915
257	40.9376797	21.5684626	641.087	598.059	598.341
254	41.0519603	21.7296305	811.742	767.764	768.044
140	41.1035261	21.6463616	716.063	672.170	672.465
129	41.4431952	22.7959522	267.883	224.266	224.587
FRSK	41.9999705	21.4322148	296.495	251.896	252.241
FR1150	42.1444009	21.7223554	391.353	346.426	346.747
FR1	42.1976729	22.3171693	660.727	615.102	615.424
FR2	41.9490604	21.9304461	405.030	360.379	360.690
FR10	41.7248805	21.7875920	245.576	201.107	201.475
FR1165	41.6987368	20.7437457	1271.609	1227.183	1227.522
FR5	41.4775940	20.9188433	678.976	635.218	635.553
FR6	41.2823258	21.2287829	720.427	676.675	676.981
FR1160	41.3659672	21.6570516	1034.770	990.033	990.317
FR7	41.6275731	22.4419329	437.247	392.737	393.068
FR1154	41.6920025	22.8331551	882.013	837.070	837.413
FR1155	41.5038021	22.7542047	388.285	344.388	344.707
FR9	41.1839987	21.7324665	624.063	579.957	580.274
FR1163	41.1416397	20.7618415	746.590	704.807	705.144
FR1161	41.0337429	21.3270083	675.285	632.227	632.509
FR1153	41.9776091	22.7181571	627.481	582.507	582.775
117	41.8557236	22.8519428	761.486	716.500	716.839
L42-R46	41.1708269	22.3523886	493.704	449.744	450.088
V9-R3	41.0165493	21.0511619	925.725	883.034	883.311
V9-R13	40.8579865	21.1192478	900.009	857.680	857.946
N6	41.9104602	22.4738599	420.206	375.344	375.667
L36-R1	41.8955808	22.4902844	409.186	364.359	364.684
114	41.7938368	21.9776690	282.817	238.466	238.788
133	41.2106934	22.0276410	1011.500	967.095	967.404
FR1152	41.8612277	22.2356036	357.706	313.178	313.482
FR1151	42.1472621	22.0179764	699.373	654.167	654.470

Table 2: Connection points for HREF2022A, part 2. Points 40 - 77 of 77.