



Check reference station coordinates NAM

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1 Procedure

Since 2006, OG-GPS processes GPS data of three subsidence monitoring stations near the Waddenzee in a network with six reference stations on a monthly bases, see Fig. 1. During processing with GPS software package GNSMART, the coordinates of these reference stations are kept fixed (standard deviation 0.0 mm), whereas the coordinates of the permanent monitoring stations get some freedom to move. However, in reality there is always the possibility that the positions of the reference stations change as well.

To deal with this problem, the coordinates of all reference station will be recalculated and eventually updated on a yearly basis (middle of the year). OG-GPS follows the advice of Geo++, the software company who developed GNSMART. The advise was formulated as follow:

“To detect the small moving of the gas field stations you should keep the reference station fixed. We suggest to check periodically the used reference station. In case of detected reference station movements, the coordinates of the reference station must be updated.”

The following procedure is performed ones per year:

1. Recalculate all reference station coordinates; i.e. giving them an a priori standard deviation of 1.0 mm for the horizontal position and 2.0 mm for the height.
2. Change the reference station coordinates for stations with a height deviation of more than 2 mm compared to the existing coordinates.
3. Process the network again with all reference stations fixed to be able to calculate the influence of the new reference station coordinates on the permanent monitoring stations.
4. Evaluation of the results.



Fig. 1. Reference stations (yellow) and permanent monitoring stations (green)



2 Reference checks

2.1 Check 2009

Time series: 17-05-2009 until 27-06-2009
 Duration: 6 weeks
 Reference: coordinates 2006 (see appendix A.1)

The differences between the reference station coordinates of 2006 and the recalculated coordinates is shown in Table 1. Notice that the stations 0687 (Borkum) and drac (Drachten) show a height deviation of more than 2 mm. Drachten has subsided even 6 mm in 3 years.

Station	dX (m)	dY (m)	dZ (m)
0687	0.0072	0.0076	0.0031
ball	-0.0001	-0.0006	-0.0003
drac	-0.0030	0.0027	-0.0061
schi	-0.0018	-0.0016	0.0006
ters	0.0005	-0.0061	0.0002
wsra	-0.0036	0.0021	-0.0011

Table 1. Differences between coordinates 2006 and recalculated coordinates

New reference station coordinates are calculated for Borkum and Drachten, these can be found in appendix A.2 (Reference station coordinates 2009). All data since May 3th 2009 is processed with the new reference station coordinates for Borkum and Drachten.

Table 2 shows the influence of the new reference station coordinates for Borkum and Drachten on the permanent monitoring stations. Notice the extra subsidence of almost 1 mm at Moddergat and Anjum, while for ame1 the result did not change. An explanation for this effect is that Moddergat and Anjum are located somewhat closer to reference station Drachten (see Fig. 1), that subsided 6 mm relative to most other reference stations. Also the stable station of Westerbork may have contributed in the minor influences on Moddergat and Anjum.

Station	dx (m)	dy (m)	dH (m)
ame1	0.0002	0.0004	-0.0001
anjm	-0.0002	0.0019	-0.0009
modd	-0.0002	0.0013	-0.0006

Table 2. Influence of the new reference station coordinates on the permanent monitoring stations



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2.2 Check 2010

Time series: 23-05-2010 until 03-07-2010
Duration: 6 weeks
Reference: coordinates 2009 (see appendix A.2)

The differences between the reference station coordinates of 2009 and the recalculated coordinates is shown in Table 1. Notice that all height differences are within the maximum tolerance of 2 mm. This makes it unnecessary to change the reference station coordinates. All stations will maintain the coordinates of 2009, see appendix A.2.

Station	dx (m)	dy (m)	dH (m)
0687	0.0004	0.0012	-0.0018
ball	0.0006	0.0019	-0.0011
drac	0.0006	0.0031	0.0012
schl	-0.0007	-0.0007	-0.0002
ters	0.0028	-0.0061	-0.0015
wsra	-0.0037	0.0052	0.0004

Table 1. Differences between coordinates 2009 and recalculated coordinates



2.3 Check 2011

Time series: 17-04-2011 until 28-05-2011
 Duration: 6 weeks
 Reference: coordinates 2009 (see appendix A.2)

The differences between the reference station coordinates of 2009 and the recalculated coordinates are shown in Table 1. Notice that the stations 0687 (Borkum) and ters (Terschelling) show a height deviation of more than 2 mm. The deviation of station Borkum is most likely related to an antenna replacement on October 20th 2010, in spite of the fact that a new individual antenna calibration file has been used for processing since that time.

Station	dx (m)	dy (m)	dH (m)
0687	0.0006	0.0006	-0.0037
ball	0.0013	0.0019	0.0012
drac	0.0000	0.0050	-0.0004
schi	-0.0009	-0.0013	0.0010
ters	0.0033	-0.0071	0.0024
wsra	-0.0039	0.0058	-0.0011

Table 1. Differences between coordinates 2009 and recalculated coordinates

The recalculated coordinates are applied for reference stations Borkum and Terschelling, these coordinates can be found in appendix A.3 (Reference station coordinates 2011).

The time series is processed again to calculate the influence of the new reference station coordinates for Borkum and Terschelling on the permanent monitoring stations. Table 2 shows the results. Notice that station Anjum (anjm), which is located closest to Borkum, gets the largest correction.

Station	dx (m)	dy (m)	dH (m)
ame1	0.0002	-0.0003	-0.0003
anjm	0.0000	0.0000	-0.0006
modd	0.0002	0.0000	-0.0004

Table 2. Influence of the new reference station coordinates on the permanent monitoring stations

All data since May 1st 2011 has been processed with the new reference station coordinates for Borkum and Terschelling.



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A.1 Reference station coordinates 2006

Reference: coordinates 2006
Date: 27-6-2009

Station	owner	status	Date	N ETRS89 (° ' ")			E ETRS89 (° ' ")			ell.h. (m)	ant.h. (m)	ARP (m)	X-RD (m)	Y-RD (m)	Z-NAP (m)	ant.h. (m)	ARP (m)	ser.no.ant.	ant. Type
0687	SAPOS	fixed	2006	53	33	49.15550	6	44	50.78800	54.4070	0.054	54.4610	245130.114	620587.995	14.2226	0.054	14.2766	200110	LEIAT504GG
ball	06-GPS	fixed	2006	53	26	29.58829	5	41	15.67011	54.5499	0.101	54.6509	174967.385	606186.357	13.7208	0.101	13.8218	2170556	TPSCR3_GGD CONE
drac	06-GPS	fixed	2006	53	6	31.75441	6	4	58.04678	56.3542	0.147	56.5012	201580.590	569339.057	15.0405	0.147	15.1875	2170593	TPSCR3_GGD CONE
schi	NAM	fixed	2006	53	28	38.43917	6	9	44.16452	50.8109	0.148	50.9589	206461.096	610405.714	10.3550	0.148	10.5030	2170643	TPSCR3_GGD CONE

Station	owner	status	Date	N ETRS89 (° ' ")			E ETRS89 (° ' ")			ell.h. (m)	ant.h. (m)	ARP (m)	X-RD (m)	Y-RD (m)	Z-NAP (m)	ant.h. (m)	ARP (m)	ser.no.ant.	ant. Type
ters	AGRS	fixed	2006	53	21	45.84903	5	13	9.78826	56.1008	0.000	56.1008	143827.236	597385.498	14.6893	0.000	14.6893	220193243	trm29659.00
wsra	AGRS	fixed	2006	52	54	52.58929	6	36	16.20650	82.2751	0.389	82.6641	236880.508	548192.307	40.7251	0.389	41.1141	273	AOAD/M_T

Station	owner	status	Date	N ETRS89 (° ' ")			E ETRS89 (° ' ")			ell.h. (m)	ant.h. (m)	ARP (m)	X-RD (m)	Y-RD (m)	Z-NAP (m)	ant.h. (m)	ARP (m)	ser.no.ant.	ant. Type
ame1	NAM	mobile	27-6-2009	53	27	51.94272	5	55	16.80630	47.9925	0.148	48.1405	190474.976	608822.476	7.3985	0.148	7.5465	2170510	TPSCR3_GGD CONE
anjm	NAM	mobile	27-6-2009	53	22	15.04173	6	9	8.59146	45.2720	0.000	45.2720	205931.142	598546.039	4.6457	0.000	4.6457	2170642	TPSCR3_GGD CONE
modd	NAM	mobile	27-6-2009	53	24	19.27159	6	4	2.98542	47.4165	0.147	47.5635	200244.559	602329.794	6.8040	0.147	6.9510	2170639	TPSCR3_GGD CONE



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A.2 Reference station coordinates 2009

Reference: coordinates 2009
Date: 27-6-2009

Station	owner	status	Date	N ETRS89 (° ' ")			E ETRS89 (° ' ")			ell.h. (m)	ant.h. (m)	ARP (m)	X-RD (m)	Y-RD (m)	Z-NAP (m)	ant.h. (m)	ARP (m)	ser.no.ant.	ant. Type
0687	SAPOS	fixed	27-6-2009	53	33	49.15574	6	44	50.78840	54.4101	0.0540	54.4641	245130.121	620588.003	14.2257	0.0540	14.2797	200110	LEIAT504GG
ball	06-GPS	fixed	2006	53	26	29.58829	5	41	15.67011	54.5499	0.1010	54.6509	174967.385	606186.357	13.7208	0.1010	13.8218	2170556	TPSCR3_GGD CONE
drac	06-GPS	fixed	27-6-2009	53	6	31.75455	6	4	58.04662	56.3480	0.1470	56.4950	201580.587	569339.061	15.0343	0.1470	15.1813	2170593	TPSCR3_GGD CONE
schi	NAM	fixed	2006	53	28	38.43917	6	9	44.16452	50.8109	0.1480	50.9589	206461.096	610405.714	10.3550	0.1480	10.5030	2170643	TPSCR3_GGD CONE

Station	owner	status	Date	N ETRS89 (° ' ")			E ETRS89 (° ' ")			ell.h. (m)	ant.h. (m)	ARP (m)	X-RD (m)	Y-RD (m)	Z-NAP (m)	ant.h. (m)	ARP (m)	ser.no.ant.	ant. Type
ters	AGRS	fixed	2006	53	21	45.84903	5	13	9.78826	56.1008	0.0000	56.1008	143827.236	597385.498	14.6893	0.0000	14.6893	220193243	trm29659.00
wsra	AGRS	fixed	2006	52	54	52.58929	6	36	16.20650	82.2751	0.3890	82.6641	236880.508	548192.307	40.7251	0.3890	41.1141	273	AOAD/M_T

Station	owner	status	Date	N ETRS89 (° ' ")			E ETRS89 (° ' ")			ell.h. (m)	ant.h. (m)	ARP (m)	X-RD (m)	Y-RD (m)	Z-NAP (m)	ant.h. (m)	ARP (m)	ser.no.ant.	ant. Type
ame1	NAM	mobile	27-6-2009	53	27	51.94273	5	55	16.80631	47.9924	0.148	48.1404	190474.976	608822.476	7.3984	0.148	7.5464	2170510	TPSCR3_GGD CONE
anjm	NAM	mobile	27-6-2009	53	22	15.04179	6	9	8.59145	45.2711	0.000	45.2711	205931.141	598546.041	4.6448	0.000	4.6448	2170642	TPSCR3_GGD CONE
modd	NAM	mobile	27-6-2009	53	24	19.27163	6	4	2.98541	47.4159	0.147	47.5629	200244.559	602329.796	6.8034	0.147	6.9504	2170639	TPSCR3_GGD CONE



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A.3 Reference station coordinates 2011

Reference: coordinates 2011
Date: 28-05-2011

Station	owner	status	Date	N ETRS89 (° ' ")			E ETRS89 (° ' ")			ell.h. (m)	ant.h. (m)	ARP (m)	X-RD (m)	Y-RD (m)	Z-NAP (m)	ant.h. (m)	ARP (m)	ser.no.ant.	ant. Type	
0687	SAPOS	fixed	28-5-2011	53	33	49.15576	6	44	50.78843	54.4054	0.0550	54.4604	245130.1219	620588.0031	14.2220	0.0540	14.2760	10211024	LEIAR25.R4	LEIT
ball	06-GPS	fixed	2006	53	26	29.58829	5	41	15.67011	54.5499	0.1010	54.6509	174967.3850	606186.3570	13.7208	0.1010	13.8218	2170556	TPSCR3_GGD	CONE
drac	06-GPS	fixed	27-6-2009	53	6	31.75455	6	4	58.04662	56.3480	0.1470	56.4950	201580.5870	569339.0610	15.0343	0.1470	15.1813	2170593	TPSCR3_GGD	CONE
schi	NAM	fixed	2006	53	28	38.43917	6	9	44.16452	50.8109	0.1480	50.9589	206461.0960	610405.7140	10.3550	0.1480	10.5030	2170643	TPSCR3_GGD	CONE

Station	owner	status	Date	N ETRS89 (° ' ")			E ETRS89 (° ' ")			ell.h. (m)	ant.h. (m)	ARP (m)	X-RD (m)	Y-RD (m)	Z-NAP (m)	ant.h. (m)	ARP (m)	ser.no.ant.	ant. Type	
ters	AGRS	fixed	28-5-2011	53	21	45.84880	5	13	9.78844	56.1032	0.0000	56.1032	143827.2394	597385.4907	14.6917	0.0000	14.6917	220193243	trm29659.00	
wsra	AGRS	fixed	2006	52	54	52.58929	6	36	16.20650	82.2751	0.3890	82.6641	236880.5080	548192.3070	40.7251	0.3890	41.1141	273	AOAD/M_T	

Station	owner	status	Date	N ETRS89 (° ' ")			E ETRS89 (° ' ")			ell.h. (m)	ant.h. (m)	ARP (m)	X-RD (m)	Y-RD (m)	Z-NAP (m)	ant.h. (m)	ARP (m)	ser.no.ant.	ant. Type	
ame1	NAM	mobile	28-5-2011	53	27	51.94285	5	55	16.80630	47.9812	0.1480	48.1292	190474.9760	608822.4800	7.3872	0.1480	7.5352	2170510	TPSCR3_GGD	CONE
anjm	NAM	mobile	28-5-2011	53	22	15.04182	6	9	8.59135	45.2637	0.0000	45.2637	205931.1395	598546.0420	4.6374	0.0000	4.6374	2170642	TPSCR3_GGD	CONE
modd	NAM	mobile	28-5-2011	53	24	19.27163	6	4	2.98540	47.4103	0.1470	47.5573	200244.5584	602329.7957	6.7978	0.1470	6.9448	2170639	TPSCR3_GGD	CONE