HET MEEST VEELZIJDIGE NETWERK

OG-GPS

GPS Survey NAM Waddenzee

Date:	October 26, 2006
Author:	ir. Jean-Paul Henry, 06-GPS
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06-GPS B.V.
Kubus 11
NL 3364 DG Sliedrecht
Tel.: 0184 – 44 89 00
Fax: 0184 – 44 89 09

e-mail: info@06-gps.nl
internet: www.06-gps.nl

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1 Introduction

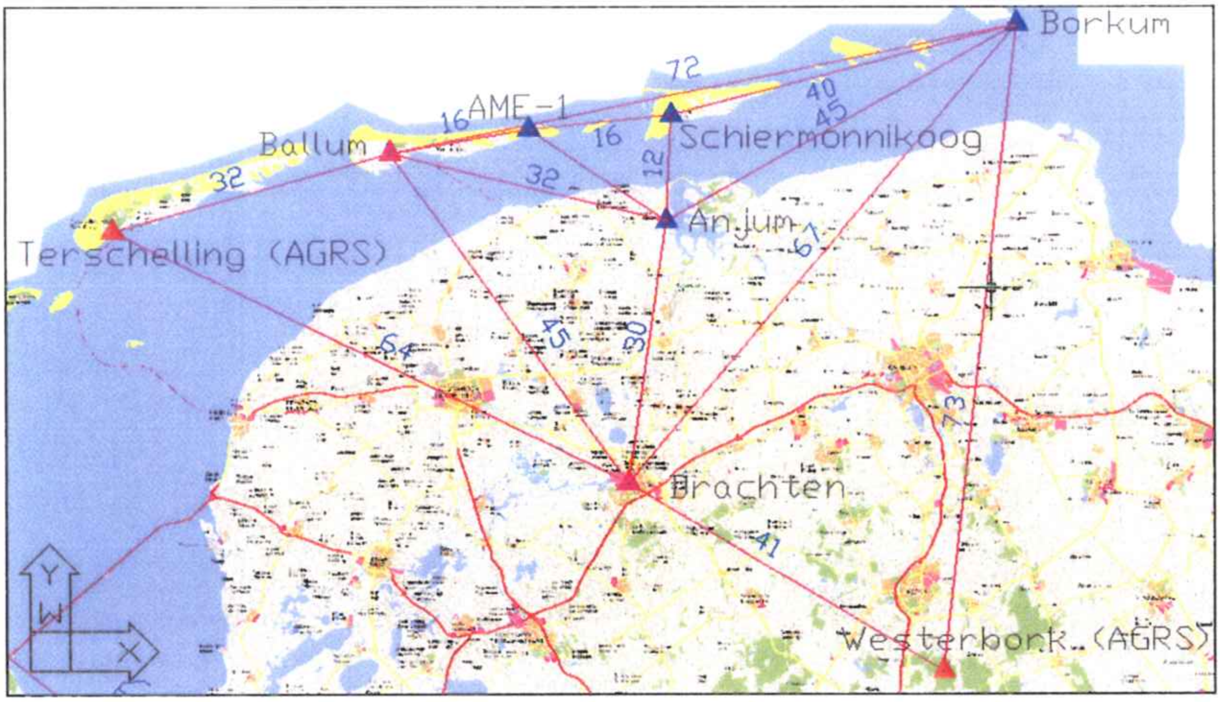
06-GPS has been assigned by SHELL / NAM to assist with a GPS survey and its processing for determining exact elevations of underground benchmarks in and around the Waddenzee. These surveys are expected to deliver elevations / heights with mm-accuracies. This report describes in short the activities as perfomed by 06-GPS concerning the preparations and actual GPS surveys. The main part however will describe the methods of how to process the GPS data to get the highest accuracy possible.

2 Preparation

For the positioning of the underground benchmarks in and around the Waddenzee it was necessary to use the technique of GPS post processing. This is a method of processing gathered GPS observations from both GPS reference stations (exactly known in position) as well as GPS observations from unknown points together to obtain relative but highly accurate positions for the unknown points. The use of fixed GPS receivers and antennas on well known points does not only make the results fit in the local coordinate system, but also creates conditions for determining and eliminating all the error sources that influence the quality of GPS positioning.

As a base three reference stations of the 06-GPS network for the Netherlands were used: Ballum (Ameland), Drachten en Borkum (Germany). For better coverage and redundancy some extra stations in the direct neighbourhood of the Waddenzee area were build.
These stations are Schiermonnikoog, East Ameland (NAM plant AME-1) and Anjum (also a NAM location). The last two stations also have a permanent monitor function since they are located inside the area where subduction due to gas extraction takes place. At the end of the year 2006 one more extra permanent monitor station will be build very near to the Moddergat NAM plant south of the Waddenzee. For an optimal fit within the Dutch geometrical infrastructure also two first order so called AGRS stations (Terschelling and Westerbork) are used in the computations.

This picture gives an impression of the situation and size (km-distances)of the GPS-infrastructure:



For all permanent stations as for the mobile GPS masts the same equipment is chosen. On all locations except for the AGRS-stations and Borkum a combination of a Topcon GB-1000 and a Topcon CR-3 choke ring antenna is used. All antennas are also individually calibrated so that their receiving characteristics are exactly known. Especially for an accurate determination of elevations/height it is necessary to have exact knowledge of the phase centre variations of the antennas. A simple comparison between individual antenna models shows that differences of 1 to 2 mm's exist between individual antennas.

Photos of the reference antennas placed in May, 2006 on respectively Schiermonnikoog and AME-1:

All GPS reference antennas are also surveyed relatively to several nearby height benchmarks by means of levelling, to be able to detect (unsuspected) local subduction of the antennas.

3 Post-processing techniques

For the GPS-processing "raw" observations per stations are collected with an interval of 15 seconds. The permanent stations have gathered data since May, 2006, while all mobile stations only collect observations for a typical 5 days per unknown point.
Storing observations of the permanent stations is done in two different ways to minimise the risk of loosing data. Except for the governmental AGRS-stations all reference stations are connected to the 06-GPS control centre in Sliedrecht 24 hours per day either using KPN Managed VPN or a Shell VPN-connection to the stations of Anjum and East Ameland. Data is stored in the general used RINEX format (Receiver INdependent EXchange format). Next to the central RINEX storage all data is also stored on the internal Flash Memory card of the Topcon GPS receivers in a so called TPS-format (Topcon Positioning Systems). This TPS data serves as a back up in case of communication interruptions between SLiedrecht and one of the reference stations. Before the final processing all data has to be converted to the RINEX format. In these RINEX files phase- code- and dopppler observations are stored for both GPS frequencies L1 and L2 as well as Signal to Noise Ratios.

For the final post-processing the NAM has chosen to use the GNSMART software of the Geo++ GmbH company from Hannover, Germany. GNSMART stands for "GNSS State Monitoring and Representation Technique". In the year 2005 positive tests were held with this software package at the Anjum site where deliberate lowering of the GPS-antenna could be detected on the mm-level within a few days of observation time.

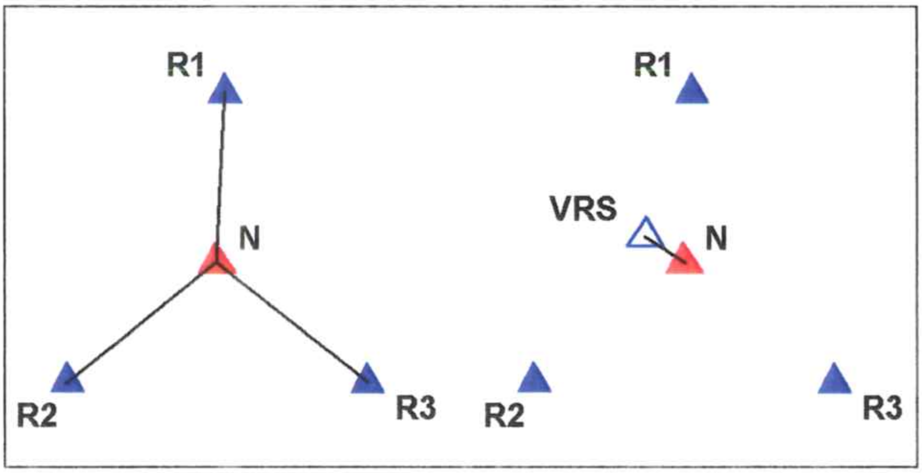
The Geo++ software is able to deliver a highly accurate result for the combination of fixed, dynamic (Anjum and AME-1) and unknown Waddenzee stations in one single processing with optimal use of antenna calibration models and modelling of all error sources involved with GPS surveying. Next to that it is able to deliver cross correlations between all individual stations making it a surveying tool comparable to optic levelling.

For an early impression of the quality of the data and to obtain an approximate coordinate needed for the Geo++ processing, another software package has been used. This package is called Wasoft and uses the technique of presenting Virtual Reference Stations (VRS) right next to the unknown points using the original data of four existing reference stations.

Both ways of processing are now explained:

VRS technique
Traditionally the processing of static GPS-observations is performed per single base line. A base line represents the coordinate difference between a fixed and a mobile station. This baseline can be accurately determined when the phase ambiguities are solved for the mobile station. This must be done by combining (differencing) of the raw data of these two stations. The longer the baseline the longer the needed observation time becomes and the more inaccurate the solution will be. This is due to the main error sources involved with GPS positioning: atmospheric disturbances and irregularities, also called distance dependant errors.
When normally baselines are to be determined to more fixed stations every time the modelling of these distance dependant sources is performed with data of only two stations.
Afterwards all baselines from fixed stations to the same unknown point have to be processed by adjustment software for a proven quality, weighted solution and detection of outliers.

When however three reference stations can be processed at once, one is able to "interpolate" between these stations and perform a modelling of distance dependant error sources. After the modelling "the knowledge" of these error sources can be presented/individualized in the shape of a Virtual Reference Station only a few meters away from the unknown point. Now only one very short baseline has to be solved. This can deliver high accurate results in already a short time. See picture. On the left the traditional way of solving multiple long baselines from 3 reference stations, on the right the VRS solution:



Another advantage of the software is that also individual antenna models can be introduced. These are not the Geo++ type, where also azimuth dependency is build in, but the IGS/NGS type of calibration, where only elevation dependencies are given.

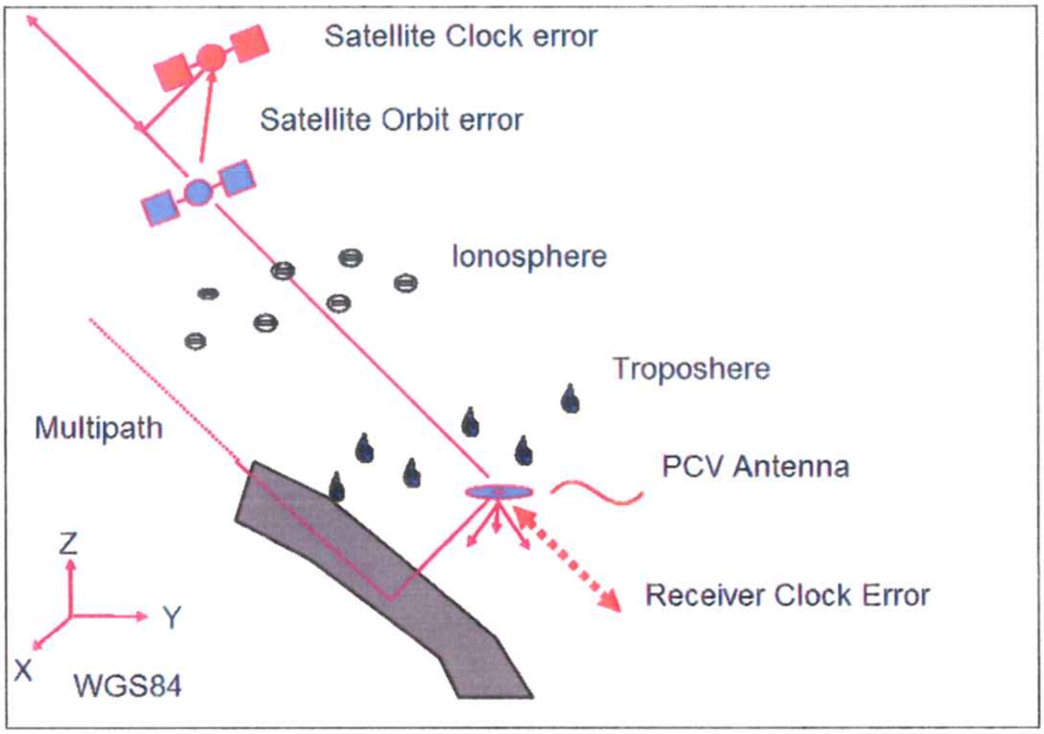
The quality of the solution can be proven by making day solutions and process these statistically. In this case there are often 5 to 7 day solutions. Day solutions that are more than two times the standard deviation different from the average height have been deleted.

GNSMART
(This text has been copied from Geo++ documents).
Geo++® has developed the system GNPOM (Geodetic Navstar - Permanent Object Monitoring) to overcome the general restrictions using real time GNSS techniques. GNPOM is based on the multi-station real-time software GNNET, which is able to process the carrier phase observations of multiple receivers simultaneously. The result is not a set of single baselines, but a homogeneous set of coordinates with a realistic variance-covariance estimation for all stations.
For the processing the Software Package Geo++ GNSMART is used. GNSS-SMART stands for **S**tate **M**onitoring **A**nd **R**epresentation **T**echnique describing the essential concept, while GNSMART is the actual Geo++ software implementation of this technique. The GNSS errors must be precisely modelled and monitored to resolve phase ambiguities as a **primary task**. For any time and location within the covered network area sophisticated services must provide information on the GNSS errors based on the state monitoring. The methods for this **secondary task** are generally termed "representation technique". This secondary task meets the requirements for the Waddenzee stations in and around the Waddenzee. In GNPOM the primary and secondary task can be done in one process, because all stations (reference and object station) are available at the central computer where GNSMART is running. As part of Geo++ GNSMART the program module GNNET enables a high precision GNSS multi-station processing. Normally GNNET processes the carrier phase measurements from single or dual frequency GPS and (optionally) GLONASS receivers in real time. Generally, the observations are provided by other program modules, for example reference station modules GNRT or GNREF. Thus, measurements from directly or indirectly accessible GNSS receivers or derived observations, e.g. RTCM correction, data can be processed. Depending on the individual application, GNNET can determine coordinates and/or system parameters such as atmospheric errors or orbit errors. The data set is based on RINEX observation. Therefore GNNET is run in post processing mode.

Consideration of GNSS errors
The modelling approach of GNSS is an important aspect. A complete state space model (SSM) with millimeter-accuracy is implemented for the rigorous and simultaneous adjustment of GNSS observables, which is essential for the **primary task**. The state space modeling follows the idea to model the actual error sources instead of handling the effects of the errors. The error effects belong to the observation space, while the error sources are associated with the state space. All error sources build up the state space model (SSM).To determine the (error) state of a GNSS system, GNSMART estimates the following state parameters:

- satellite clock synchronization error
- satellite signal delays (group delays)
- satellite orbit error (kinematic orbits)
- ionospheric signal propagation changes
- tropospheric signal delays
- receiver multipath (optional)
- carrier phase ambiguities
- receiver coordinates (optional)
- receiver clock synchronization error
- receiver signal delays (group delays)

The next picture is a simplified illustration of the main error sources and their influence on the distance measurements from receiver to satellite:



The state space modelling of GNSMART applies beforehand corrections to the GNSS observations. The SSM model is prepared for the following corrections:

- satellite-receiver phase wind-up effect (satellite attitude)
- (absolute) satellite antenna PCV correction
- site displacement effect (solid earth tide, pole tide, ocean loading, atmospheric loading, local displacement)
- relativistic corrections
- higher order ionospheric correction
- (absolute) receiver antenna PCV correction

The extension of the network defines the significance of the corrections and consequently the quality of the state space modeling. In smaller networks, like the present six station network, some corrections can be neglected. Therefore GNSMART currently does not correct for loading effects and higher order ionosphere. The adjustment model is a Kalman filter for real time applications. The Kalman filter is proofed to be well suited for state estimation and monitoring tasks. The actual adjustment is a simultaneous adjustment of all L1 and L2 observations. Advantages of simultaneous L1/L2 adjustment are:

- rigorous modelling of correlations between linear combinations
- rigorous modelling of common parameters like L1-L2 delays for satellite and receiver
- improvement of noise level for derived state parameters

The separation and modelling of individual GNSS error components is straight forward using un-differenced or also termed non-differenced observations. The use of non-differenced observations is a key issue in ambiguity resolution, optimized modelling and processing in GNSMART. The advantages of non-differenced modelling and ambiguities are:

- network operates in absolute mode
- no mathematical correlation between observations
- robustness against failures of single reference stations
- optimal reliability

The use of differenced observations (i.e. double difference observable) and accordingly the use of baselines/triangles between reference stations is a limitation and a loss of information compared to the non-differenced approach. Information on the GNSS errors can be best obtained from the rigorous adjustment of multiple reference stations with sufficient redundancy and network size.

Consideration of station dependent errors

Multipath (MP) is the most limiting factor for very precise positioning applications with GNSS. Several MP mitigation techniques are known and implemented in many receiver types. However, these techniques normally only attack the code MP effects. MP errors in carrier phase measurements are much more complicated to be mitigated through signal tracking techniques. All GPS receivers from Topcon use the AMR (Advanced Multipath Mitigation) technique for both code and phase observations. Also all antennas have been chosen to be choke ring antennas which are much less receptive for multipath than normal, light rover antennas.
Geodetic and precise GPS measurements make the exact knowledge of the reception characteristics of the used antennas and therefore a calibration necessary. Intensive use of such characteristic have been made in the development of the absolute antenna calibration method. All used antennas in this project are individually calibrated.

Differences between VRS and GNSMART

Although GNSMART was supposed to be the ultimate software package, the VRS computations have also proven to be of high quality.

Aspects of VRS processing:

- all stations and all day solutions are uncorrelated
- does not use Precise Orbit information (but is possible)
- only uses simplified antenna models
- works directly with RINEX observation files
- results directly computable after survey every unknown point

Aspects of GNSMART processing:

- one rigorous solution of all stations, fixed, dynamic or unknown
- all correlations known in 1 run
- uses Ultra rapid Precise orbits
- all RINEXdata needs to be converted to internal Geo++ format (*.zdb files) using the reference station module GNREF
- Very heavy computations
- Processing has to wait for end of survey campaign

Due to the fact that the results were needed fast and the GNSMART contained some bugs concerning the input of Precise Orbits, it was decided to use the VRS results in the final NAM / SURE processing.

Preliminary tests however show that in the most important observable, the height differences, almost no differences larger than 1 mm can be found between the solutions coming from VRS or GNSMART processing. It is therefore recommended that in a next campaign the solution of GNSMART is used because of it's correlations, solutions in time (4D) and the use of Precise Orbits.

<u>Processing steps</u>
The following steps have been taken for the processing:

General

- checking completeness of Ballum, Drachten and Borkum data
- repairing gaps Ballum and Drachten with locally stored data
- downloading tps-data from Schiermonnikoog, East Ameland and Anjum
- converting tps data to RINEX
- downloading AGRS data
- conversion AGRS data to RINEX with inverse Hatanaka compression
- conversion of tps data from Waddenzee points to RINEX format

VRS

- programming of batch files for producing VRS data using antenna information and approximate coordinates from the RINEX files
- making 1 VRS RINEX file per day per station with an interval of 15 s.
- programming and processing of short baselines between unknown points and VRS's.
- sorting and statistical analysis of all VRS results

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- gathering of Precise Ephemerides from internet (IGS sites)
- converting of broadcast navigation files into one overall file per day
- conversion of all RINEX file into .zdb files using the accurate position from VRS processing, antenna information and antenna heights
- running of GNNET with options of station dynamics, numbers of stations to process, etc. (see Appendix IV for some screen dumps of GNNET)
- conversion of ETRS89 XYZ results into Latitude, Longitude and Height.
- Sorting of LLH data per station.
- Graphical analysis

Of course the GPS results give a height of each ARP (Antenna Reference Point); in our case always the bottom of the antenna. Additional measurements have taken place for the antenna heights: the vertical distance between unknown point and ARP. Every mast used has a different length and throughout the project these distances have been monitored, carefully.
Only after relating the ARP heights to the actual survey points the data can be imported in the deformation analysing software and databases of the NAM.

4 Results

In order to obtain the best results it was first necessary to have good reference station coordinates that are not only good in absolute position, but also very homogenous: discrepancies should be as small as possible. At first coordinates from the certification of the Dutch Cadastre were used for the stations Drachten (drac), Ballum (ball) and Borkum (0674). With these stations uncorrelated coordinates were calculated with the VRS method for the until then unknown stations East Ameland (AME1), Anjum (anjm) and Schiermonnikoog (schi) using one week of data.

Four stations (maximum for VRS) were used as a reference for the Waddenzee point computations using the VRS-method. For the Waddenzee they were (with a few exceptions) : schi, anjm, ame1 and ball. For the computation of the Lauwersmeer points and the Grijpskerk trial the reference stations schi, anjm, ame1 and 0674 were used, since they lay outside of the area formed by the first four stations.

After having gathered a complete month (july 2006) of data all reference stations were evaluated once more with the GNSMART solution. Now also the data of the AGRS stations Terschelling and Westerbork was entered and only these two stations and station Borkum were kept fixed. This resulted in slightly different coordinates for the reference stations (on average 4.5mm higher). This last dataset is used for all GNSMART processing because it is more homogeneous, while the first VRS results remained to be used for all VRS processing. On the level of height differences this absolute shift in height will however not be noticeable. An overview of the two coordinate sets can be found in Appendix I.

<u>VRS results</u>
In Appendix II all the Waddenzee points as well as underground benchmarks on land and at the Lauwersmeer and Grijpskerk points are shown including their standard deviations and observation periods.

<u>GNSMART results</u>
In Appendix III plots are shown for the GNSMART results for the 2 dynamic stations AME1 and Anjum which are expected to sink about 5 – 10 mm's per year. From GPS days 145 to 273 the elevations are shown and one can see there's less subduction than suspected.
The position filter used is a mm/hour filter. Although the results show some movement a subduction is clearly vivsible. The trend (straight line) is determined by using a linear least squares approximation. The standard deviation of this least squares approximation is 0.9mm.

APPENDIX I: reference station parameters

Reference Coordinate overview for VRS and GNSMART solutions for all permanent stations together with information about the antenna type and number:

VRS

Station	owner	N [ø,',"]		ETRS89 (m)	E [ø,',"]		ETRS89 (m)	ell. h [m]	X-RD (m)	Y-RD (m)	Z-NAP (m)	ant. h. (m)	ser. no. ant.	ant. Type	
0674	SAPOS	53	33	49.10129	6	44	50.79499	54.2120	245130.274	620586.321	14.028	0.053	220180416	TRM29659.00	SNOW
ame1	NAM	53	27	51.94256	5	55	16.80653	48.0185	190474.980	608822.470	7.424	0.148	2170510	TPSCR3_GGD	CONE
anjm	NAM	53	22	15.04176	6	9	8.59176	45.2888	205931.147	598546.040	4.663	0.000	2170642	TPSCR3_GGD	CONE
ball	06-GPS	53	26	29.58836	5	41	15.67022	54.5489	174967.387	606186.359	13.720	0.101	2170556	TPSCR3_GGD	CONE
drac	06-GPS	53	6	31.75445	6	4	58.04685	56.3659	201580.592	569339.058	15.052	0.147	2170593	TPSCR3_GGD	CONE
schi	NAM	53	28	38.43921	6	9	44.16453	50.8150	206461.097	610405.715	10.359	0.148	2170643	TPSCR3_GGD	CONE

GNSMART

Station	owner	N [ø,',"]		ETRS89 (m)	E [ø,',"]		ETRS89 (m)	ell. h [m]	X-RD (m)	Y-RD (m)	Z-NAP (m)	ant. h. (m)	ser. no. ant.	ant. Type	
0674	SAPOS	53	33	49.10129	6	44	50.79499	54.2100	245130.275	620586.321	14.026	0.053	220180416	TRM29659.00	SNOW
ame1	NAM	53	27	51.94252	5	55	16.80639	48.0146	190474.980	608822.470	7.421	0.148	2170510	TPSCR3_GGD	CONE
anjm	NAM	53	22	15.04173	6	9	8.59165	45.2834	205931.146	598546.038	4.657	0.000	2170642	TPSCR3_GGD	CONE
ball	06-GPS	53	26	29.58829	5	41	15.67011	54.5499	174967.385	606186.357	13.716	0.101	2170556	TPSCR3_GGD	CONE
drac	06-GPS	53	6	31.75441	6	4	58.04678	56.3542	201580.591	569339.056	15.040	0.147	2170593	TPSCR3_GGD	CONE
schi	NAM	53	28	38.43917	6	9	44.16452	50.8109	206461.096	610405.715	10.355	0.148	2170643	TPSCR3_GGD	CONE

Station	owner	N [ø,',"]		ETRS89 (m)	E [ø,',"]		ETRS89 (m)	ell. h [m]	X-RD (m)	Y-RD (m)	Z-NAP (m)	ant. h. (m)	ser. no. ant.	ant. Type
ters	AGRS	53	21	45.84903	5	13	9.78826	56.1008	143827.237	597385.497	14.689	0.000	220193243	TRM29659.00
wsra	AGRS	52	54	52.58929	6	36	16.20650	82.2751	236880.508	548192.307	40.725	0.389	273	AOAD/M_T

APPENDIX II: VRS processing results

Height differences in NAP for the VRS processing including their standard deviations, all in meters:

stat	x (RD)	y (RD)	z (NAP)	St. dev.	ref. 1	dz stat-ref1	ref. 2	dz stat-ref2	ref. 3	dz stat-ref3	ref. 4	dz stat-ref4	start GPS	start date	end GPS	end date
c028	188625.316	602813.660	2.909	0.0009	ball	-10.811	ame1	-4.515	schi	-7.450	anjm	-1.754	156	5-6-2006	162	11-6-2006
c031	188454.182	604597.237	2.960	0.0011	ball	-10.760	ame1	-4.464	schi	-7.399	drac	-12.092	149	29-5-2006	155	4-6-2006
c035	188355.779	606458.857	3.106	0.0009	ball	-10.614	ame1	-4.318	schi	-7.253	anjm	-1.557	151	31-5-2006	157	6-6-2006
c065	184854.985	603073.136	3.471	0.0007	ball	-10.249	ame1	-3.953	schi	-6.888	drac	-11.581	146	26-5-2006	153	2-6-2006
d050	190433.021	607537.863	3.566	0.0015	ball	-10.154	ame1	-3.858	schi	-6.793	anjm	-1.097	160	9-6-2006	164	13-6-2006
d056	190473.429	602117.838	2.988	0.0035	ball	-10.732	ame1	-4.436	schi	-7.371	anjm	-1.675	169	18-6-2006	174	23-6-2006
d061	199816.983	608005.085	4.925	0.0006	ball	-8.795	ame1	-2.499	schi	-5.434	anjm	0.262	172	21-6-2006	178	27-6-2006
d065	194666.506	603761.323	2.953	0.0017	ball	-10.767	ame1	-4.471	schi	-7.406	anjm	-1.710	163	12-6-2006	168	17-6-2006
d068	192543.419	603400.443	3.216	0.0007	ball	-10.504	ame1	-4.208	schi	-7.143	anjm	-1.447	161	10-6-2006	166	15-6-2006
d107	191533.474	605358.076	2.825	0.0029	ball	-10.895	ame1	-4.599	schi	-7.534	anjm	-1.838	155	4-6-2006	159	8-6-2006
d110	195800.048	605089.658	3.573	0.0010	ball	-10.147	ame1	-3.851	schi	-6.786	anjm	-1.090	165	14-6-2006	170	19-6-2006
g043	202537.499	604100.078	3.537	0.0008	ball	-10.183	ame1	-3.887	schi	-6.822	anjm	-1.126	177	26-6-2006	181	30-6-2006
g049	200137.766	605640.122	3.134	0.0002	ball	-10.586	ame1	-4.290	schi	-7.225	anjm	-1.529	181	30-6-2006	186	5-7-2006
h033	214815.483	602720.678	3.107	0.0020	ball	-10.613	ame1	-4.317	schi	-7.252	anjm	-1.556	213	1-8-2006	219	7-8-2006
h036	217079.937	603895.609	3.408	0.0010	ball	-10.312	ame1	-4.016	schi	-6.951	anjm	-1.255	220	8-8-2006	228	16-8-2006
h039	211562.765	606165.962	4.037	0.0017	ball	-9.683	ame1	-3.387	schi	-6.322	anjm	-0.626	185	4-7-2006	190	9-7-2006
h043	212349.350	608265.476	3.299	0.0015	ball	-10.421	ame1	-4.125	schi	-7.060	anjm	-1.364	179	28-6-2006	184	3-7-2006
h048	214191.924	609202.327	3.295	0.0010	ball	-10.425	ame1	-4.129	schi	-7.064	anjm	-1.368	223	11-8-2006	231	19-8-2006

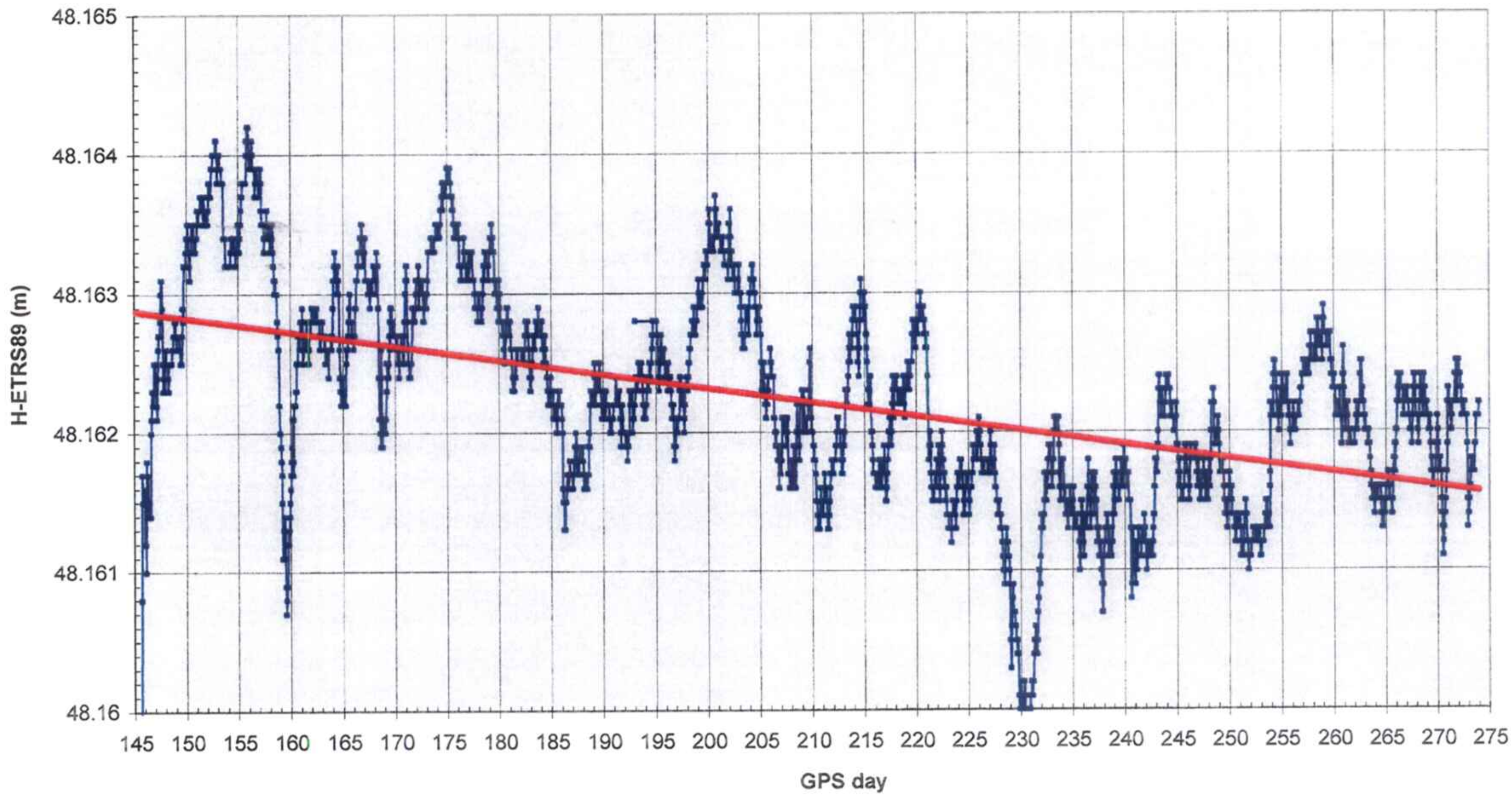
h058	216166.512	606324.875	3.652	0.0028	ball	-10.068	ame1	-3.772	schi	-6.707	anjm	-1.011	183	2-7-2006	188	7-7-2006
m001	189816.225	605603.871	2.940	0.0009	ball	-10.780	ame1	-4.484	schi	-7.419	anjm	-1.723	217	5-8-2006	222	10-8-2006
m002	191025.657	606473.636	2.971	0.0008	ball	-10.749	ame1	-4.453	schi	-7.388	anjm	-1.692	216	4-8-2006	221	9-8-2006
m003	197020.072	604166.539	3.716	0.0012	ball	-10.004	ame1	-3.708	schi	-6.643	anjm	-0.947	207	26-7-2006	215	3-8-2006
m004	198927.942	609190.496	4.290	0.0007	ball	-9.430	ame1	-3.134	schi	-6.069	anjm	-0.373	171	20-6-2006	178	27-6-2006
m005	196485.093	606399.793	3.999	0.0012	ball	-9.721	ame1	-3.425	schi	-6.360	anjm	-0.664	203	22-7-2006	208	27-7-2006
m006	198322.821	604840.425	3.235	0.0012	ball	-10.485	ame1	-4.189	schi	-7.124	anjm	-1.428	209	28-7-2006	214	2-8-2006
m007	198457.342	603006.318	3.411	0.0007	ball	-10.309	ame1	-4.013	schi	-6.948	anjm	-1.252	201	20-7-2006	206	25-7-2006
m008	200841.375	603918.417	3.502	0.0009	ball	-10.218	ame1	-3.922	schi	-6.857	anjm	-1.161	197	16-7-2006	202	21-7-2006
m009	207494.960	606354.267	3.761	0.0008	ball	-9.959	ame1	-3.663	schi	-6.598	anjm	-0.902	193	12-7-2006	198	17-7-2006
m010	210171.927	605191.423	3.431	0.0007	ball	-10.289	ame1	-3.993	schi	-6.928	anjm	-1.232	187	6-7-2006	192	11-7-2006
m011	211529.870	606949.830	4.076	0.0008	ball	-9.644	ame1	-3.348	schi	-6.283	anjm	-0.587	205	24-7-2006	210	29-7-2006
m012	214108.540	605081.554	3.730	0.0024	ball	-9.990	ame1	-3.694	schi	-6.629	anjm	-0.933	195	14-7-2006	200	19-7-2006
m013	208614.186	605155.756	2.815	0.0013	ball	-10.905	ame1	-4.609	schi	-7.544	anjm	-1.848	189	8-7-2006	194	13-7-2006
m014	205175.281	607365.822	4.131	0.0007	ball	-9.589	ame1	-3.293	schi	-6.228	anjm	-0.532	191	10-7-2006	196	15-7-2006
m015	188715.393	605140.574	3.002	0.0011	ball	-10.718	ame1	-4.422	schi	-7.357	anjm	-1.661	199	18-7-2006	204	23-7-2006
m016	204339.872	603934.554	3.662	0.0008	ball	-10.058	ame1	-3.762	schi	-6.697	anjm	-1.001	224	12-8-2006	229	17-8-2006
2686	201519.196	601592.606	5.205	0.0014	ball	-8.515	ame1	-2.219	schi	-5.154	anjm	0.542	199	18-7-2006	205	24-7-2006
2689	211507.365	600203.910	3.407	0.0008	ball	-10.313	ame1	-4.017	schi	-6.952	anjm	-1.256	177	26-6-2006	186	5-7-2006
2691	205074.133	602130.892	5.690	0.0009	ball	-8.030	ame1	-1.734	schi	-4.669	anjm	1.027	192	11-7-2006	198	17-7-2006
4025	208914.241	602779.562	8.224	0.0011	ball	-5.496	ame1	0.800	schi	-2.135	anjm	3.561	206	25-7-2006	210	29-7-2006
pal1	180085.924	606746.017	8.924	0.0009	ball	-4.796	ame1	1.500	schi	-1.435	anjm	4.261	153	2-6-2006	159	8-6-2006
pal2	180085.904	606746.076	8.921	0.0008	ball	-4.799	ame1	1.497	schi	-1.438	anjm	4.258	168	17-6-2006	173	22-6-2006
pal3	180085.925	606746.001	8.921	0.0006	ball	-4.799	ame1	1.497	schi	-1.438	anjm	4.258	187	6-7-2006	192	11-7-2006

pal4	180085.933	606746.039	8.920	0.0002	ball	-4.800	ame1	1.496	schi	-1.439	drac	-6.132	147	27-5-2006	151	31-5-2006
gr01	216356.276	588654.147	5.517	0.0011	0674	-8.511	drac	-9.535	schi	-4.842	anjm	0.854	265	22-9-2006	271	28-9-2006
gr02	216356.174	588662.261	5.310	0.0015	0674	-8.718	drac	-9.742	schi	-5.049	anjm	0.647	265	22-9-2006	271	28-9-2006
gr03	216356.041	588670.256	5.504	0.0013	0674	-8.524	drac	-9.548	schi	-4.855	anjm	0.841	265	22-9-2006	270	27-9-2006
gr04	216356.011	588678.181	5.281	0.0021	0674	-8.747	drac	-9.771	schi	-5.078	anjm	0.618	265	22-9-2006	271	28-9-2006
l100	208079.797	602147.706	3.880	0.0005	0674	-10.148	drac	-11.172	schi	-6.479	anjm	-0.783	248	5-9-2006	254	11-9-2006
l101	208197.616	599877.861	3.909	0.0003	0674	-10.119	drac	-11.143	schi	-6.450	anjm	-0.754	248	5-9-2006	254	11-9-2006
l102	207909.016	598551.549	3.869	0.0008	0674	-10.159	drac	-11.183	schi	-6.490	anjm	-0.794	256	13-9-2006	263	20-9-2006
l103	210678.274	596407.729	3.814	0.0012	0674	-10.214	drac	-11.238	schi	-6.545	anjm	-0.849	241	29-8-2006	247	4-9-2006
l104	211295.132	594605.092	4.807	0.0020	0674	-9.221	drac	-10.245	schi	-5.552	anjm	0.144	257	14-9-2006	263	20-9-2006
l105	210075.859	593900.813	4.932	0.0017	0674	-9.096	drac	-10.120	schi	-5.427	anjm	0.269	250	7-9-2006	257	14-9-2006
l106	208413.615	594932.147	3.608	0.0013	0674	-10.420	drac	-11.444	schi	-6.751	anjm	-1.055	247	4-9-2006	254	11-9-2006
l107	208345.375	596833.921	3.759	0.0013	0674	-10.269	drac	-11.293	schi	-6.600	anjm	-0.904	241	29-8-2006	247	4-9-2006

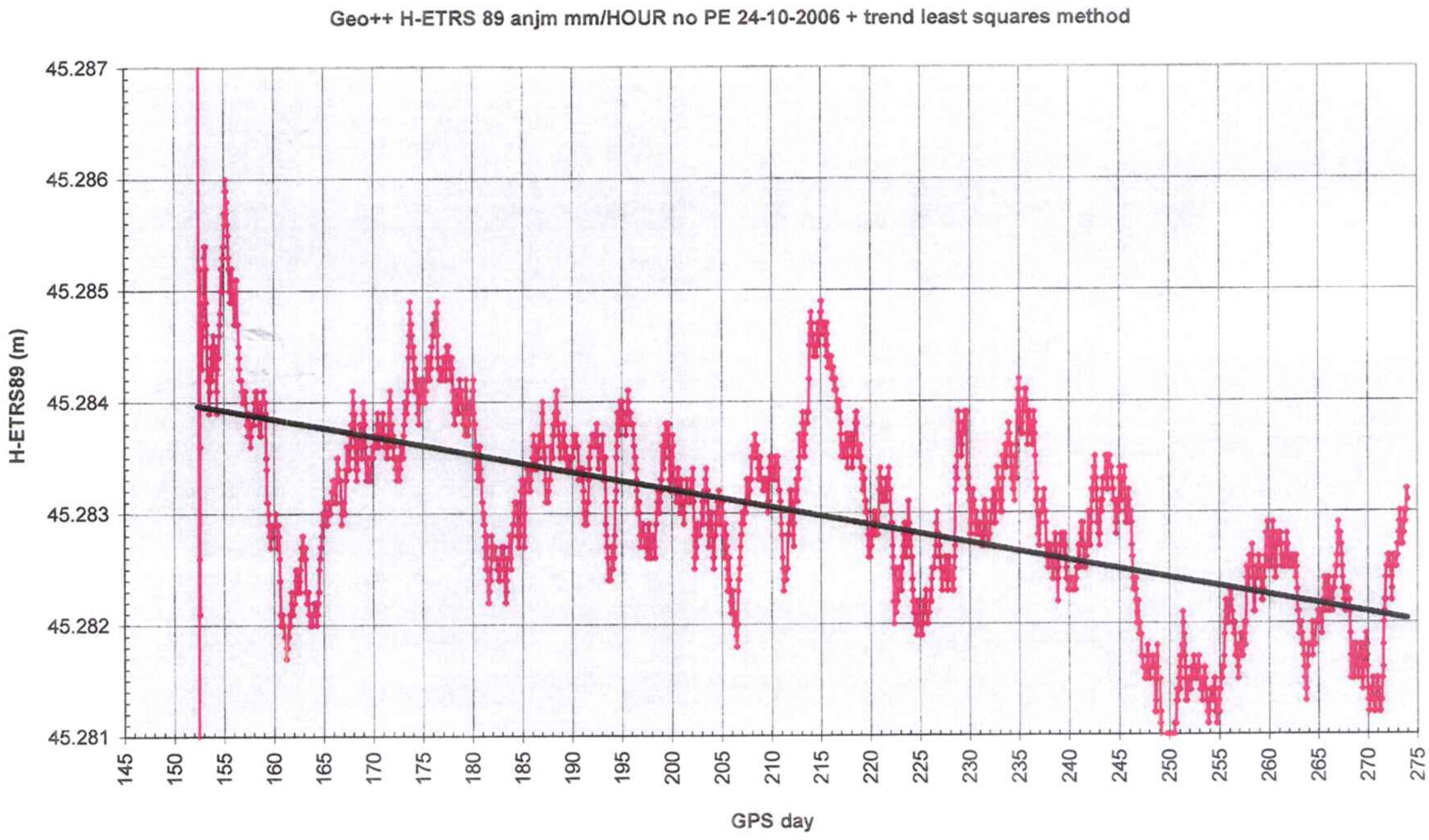
APPENDIX III: dynamic plots for AME-1 and Anjum

Height plot for station AME-1 with mm/hour position filter, period May, 25 – September, 30 2006 .

GEO++ H-ETRS89 ame1 mm/HOUR no PE 24-10-2006 + trend least squares method

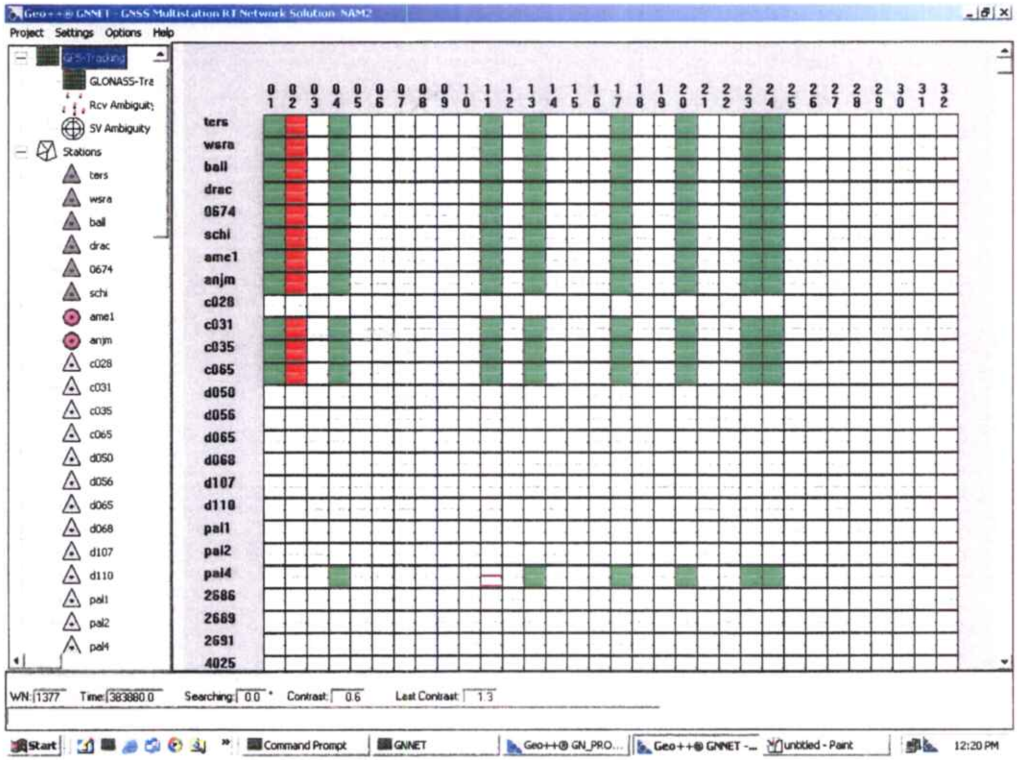


Height plot for station ANJUM with mm/hour position filter, period May, 25 – September, 30 2006.



APPENDIX IV: screen dumps of GNSMART processing

GPS Tracking status for 8 reference stations and 4 unknown stations



Station parameters for point c035