How To
Adjust Deformation networks

Version 4.4

SWECO

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1. Introduction

This document describes how the networks of 2 (or more) measurement epochs can be adjusted together to test for deformations.

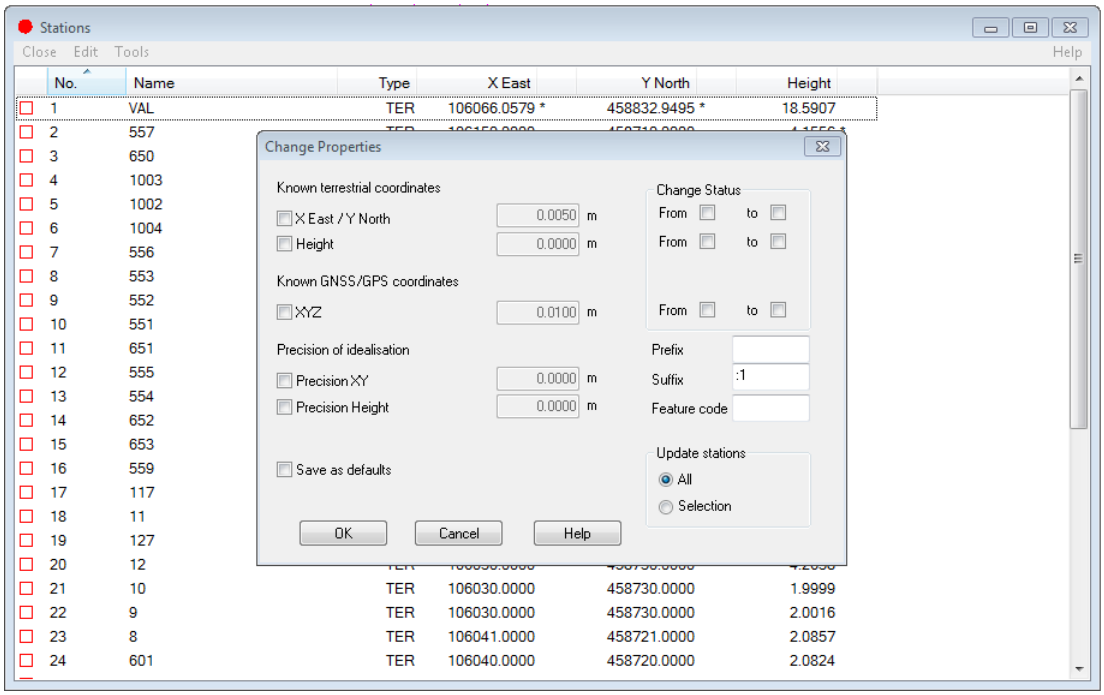
The first step is always an adjustment of the measurements for each individual epoch to remove the measurement errors. To achieve this a free network adjustment would be sufficient, but of course one could also compute a constrained adjustment to check if the measurements will fit on the control points.

For more information on the adjustment of networks please refer to the How To: Combined TPS and GPS adjustment and How To: Levelling.

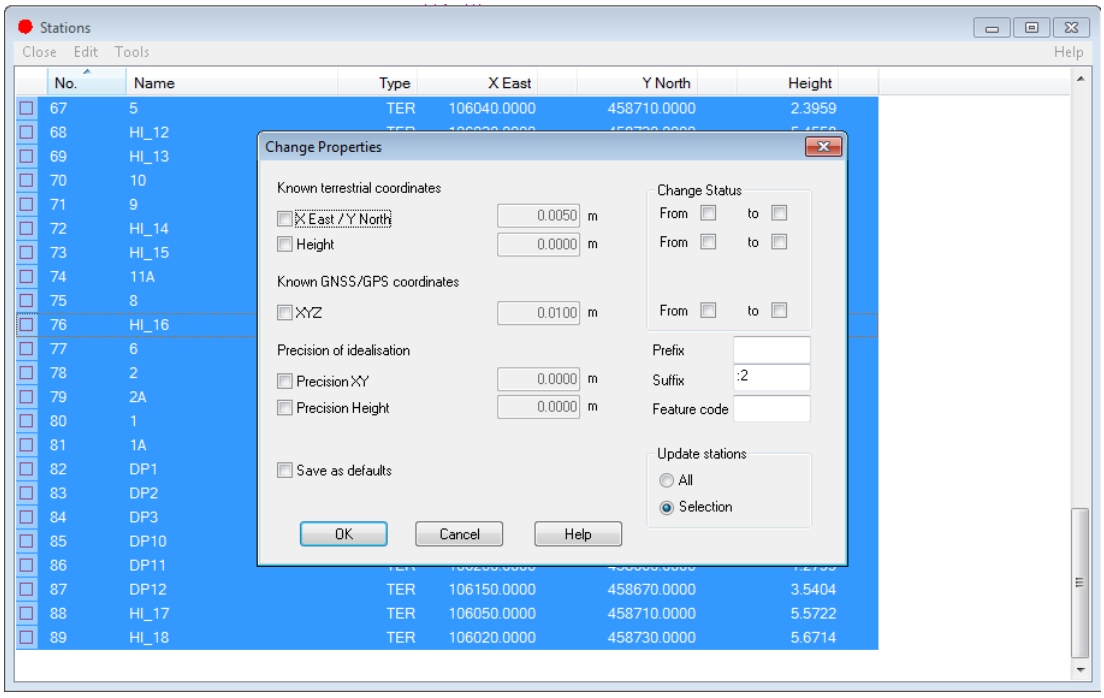
Please note that this is a sample. The actual settings may differ depending on your requirements.

2. Combined MOVE3 Project

Open the project with the first epoch. Save this project under a new name. Then label the stations by adding a suffix, for example :1, to the all station names.



Then import the second epoch into this project using Import|MOVE3 project. The second epoch stations can be labelled by adding a suffix, for example :2.



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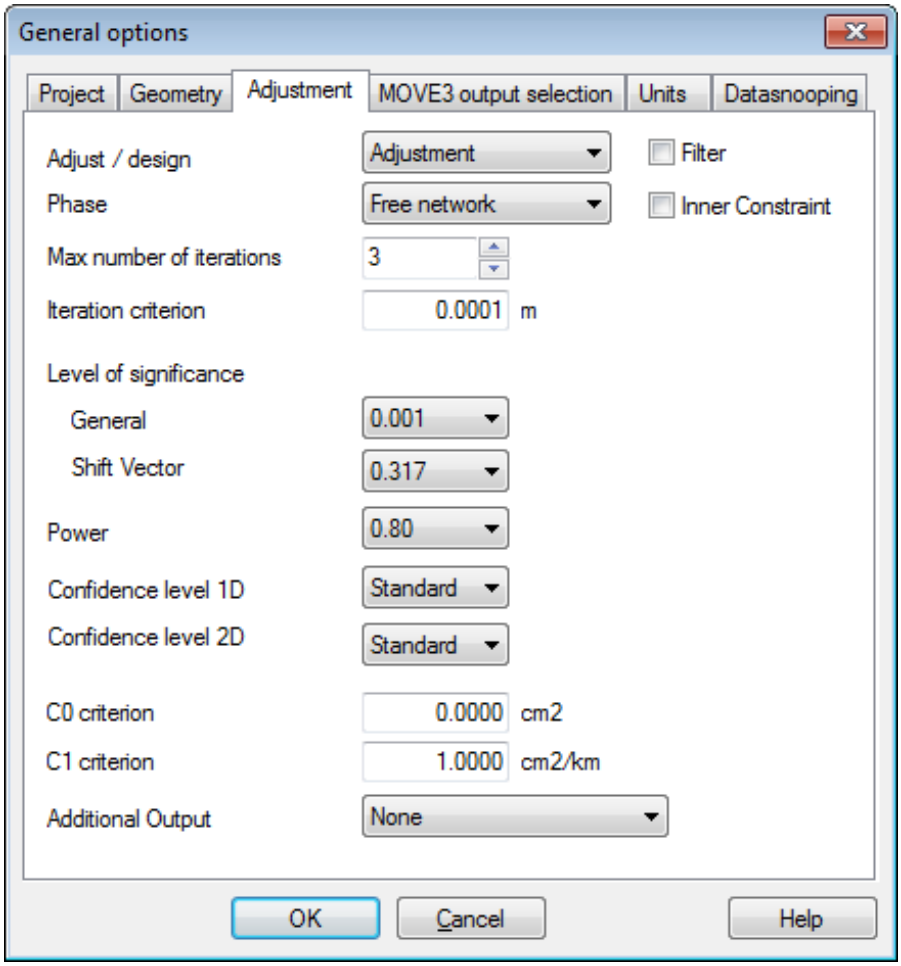
3. Options Adjustment

In the General Options Adjustment tab the Level of Significance for the Shift Vector can be set separately from the Level of Significance of the other observations.

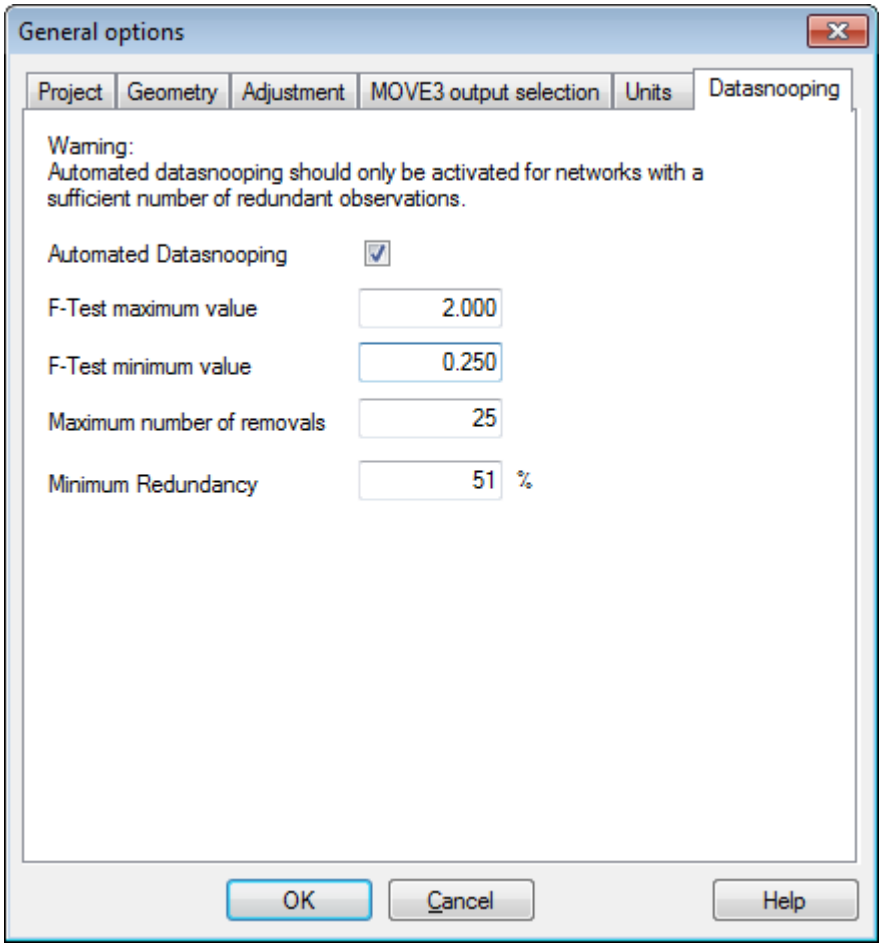


Adjustment tab sheet.

For an early warning the Level of significance can be set to for example 0.317, this will test the Shift Vectors at a 1 sigma level.

4. Options Datasnooping

In the General Options Datasnooping tab Automated Datasnooping can be activated.

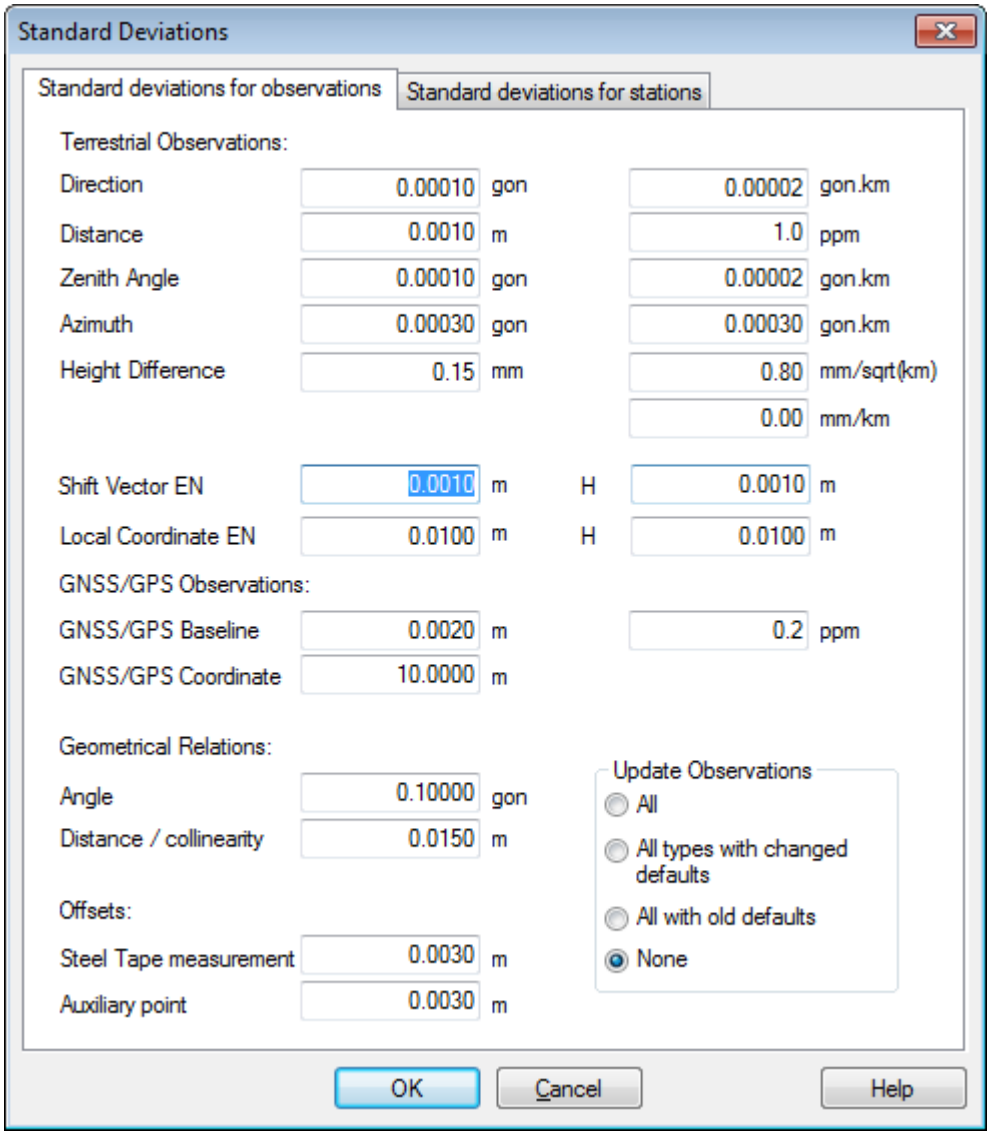


Datasnooping tab sheet.

With the automated datasnooping on the rejected Shift Vectors will automatically be removed from the adjustment in a one by one process, largest rejected Shift Vector first. Especially in deformation analysis it is important to release Shift Vectors that are rejected, since keeping them constrained would influence the final result.

5. Default standard deviations

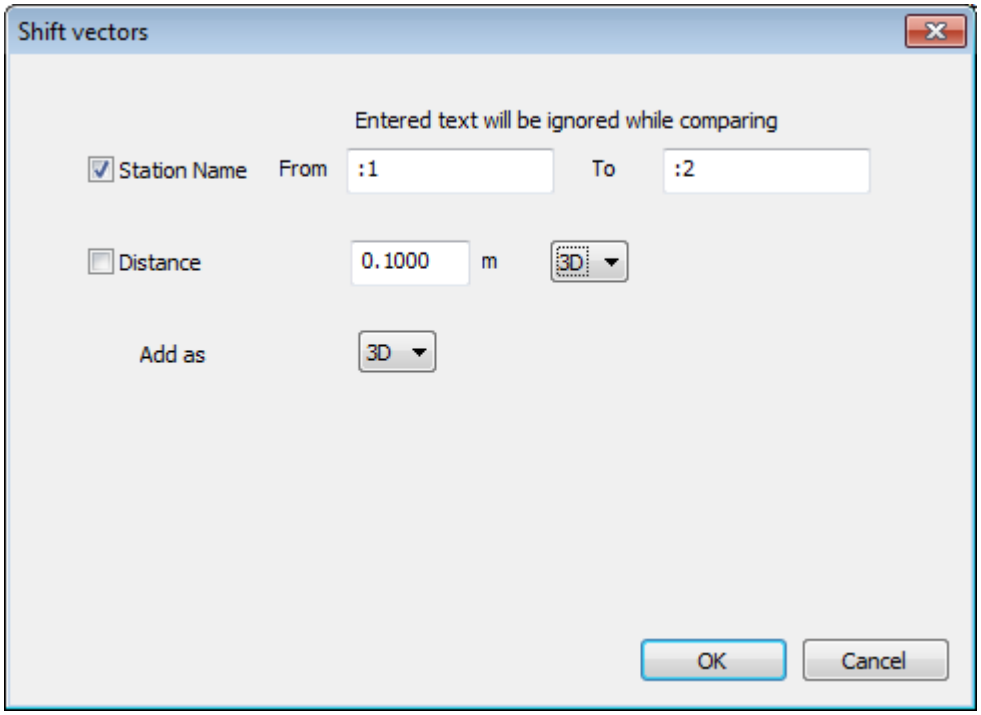
Before Adding the Shift Vectors it is important to properly set the defaults for the standard deviations of the shift vectors. The default values are added to each added shift vector.



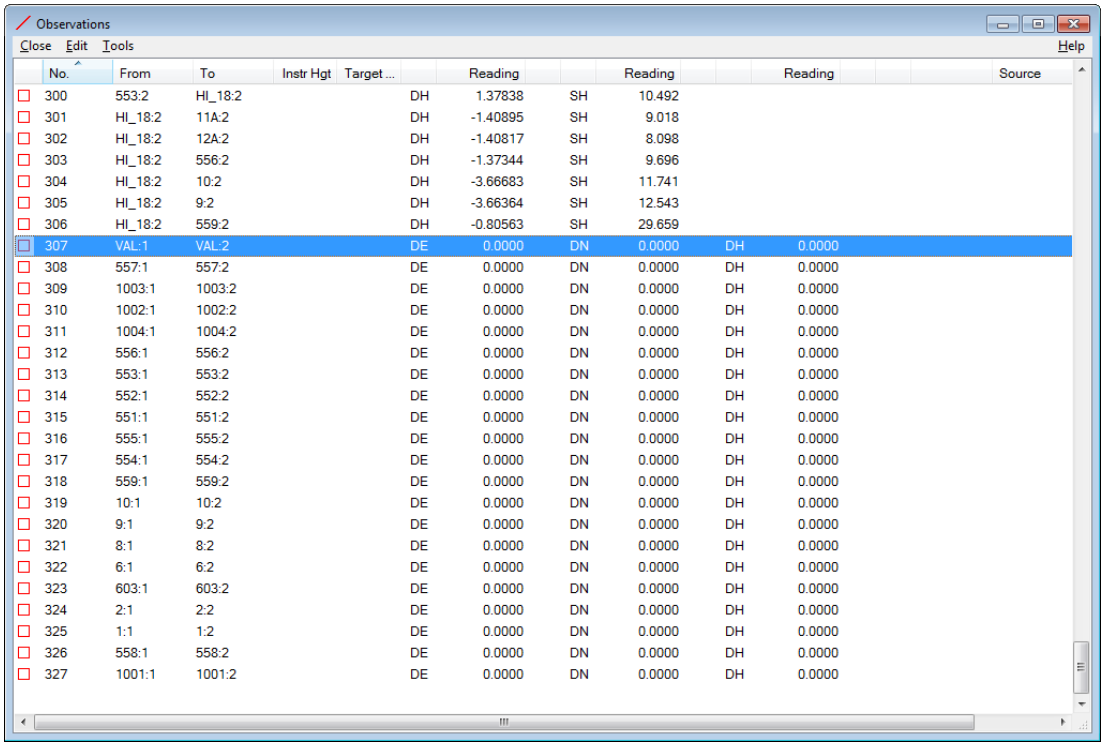
Standard Deviations.

6. Adding Shift vectors

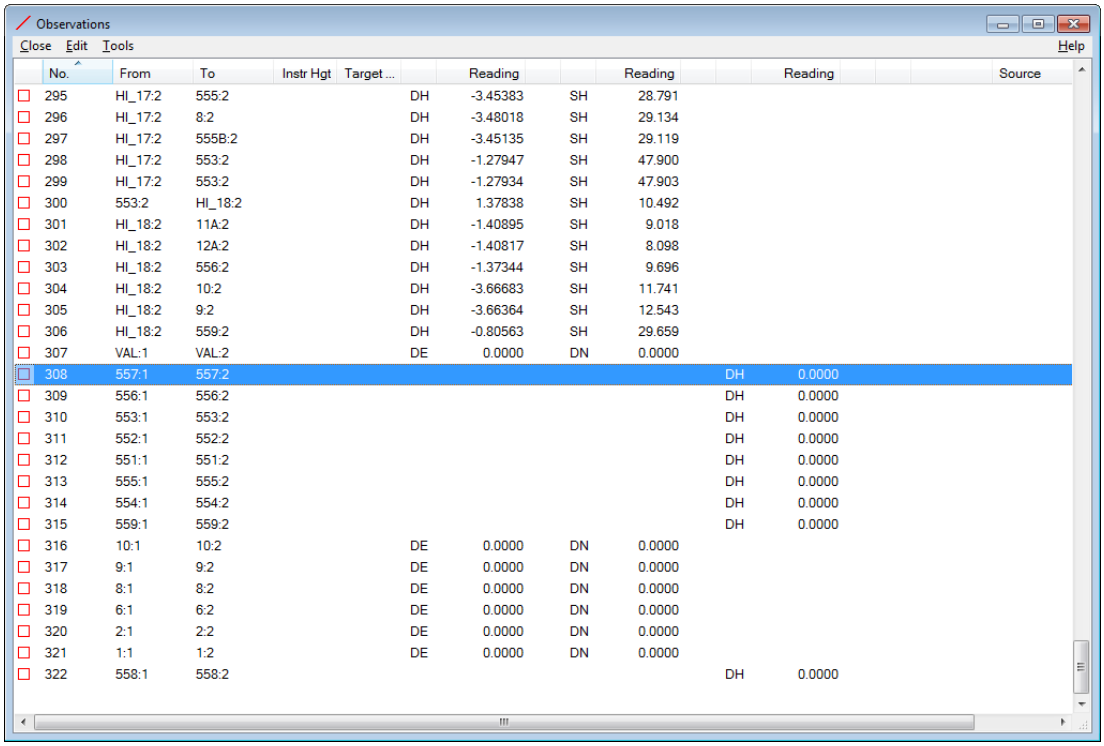
The shift vectors can be added via the View|Observations menu item Edit|Shift vectors. Use the station name to add the shift vectors.



In the example above :1 and :2 will be ignored when comparing station names. If the station names match then a 3D Shift Vector will be added. The value for the shift will be 0.



No.	From	To	Instr Hgt	Target ...		Reading		Reading		Reading	Source
300	553:2	HI_18:2			DH	1.37838	SH	10.492			
301	HI_18:2	11A:2			DH	-1.40895	SH	9.018			
302	HI_18:2	12A:2			DH	-1.40817	SH	8.098			
303	HI_18:2	556:2			DH	-1.37344	SH	9.696			
304	HI_18:2	10:2			DH	-3.66683	SH	11.741			
305	HI_18:2	9:2			DH	-3.66364	SH	12.543			
306	HI_18:2	559:2			DH	-0.80563	SH	29.659			
307	VAL:1	VAL:2			DE	0.0000	DN	0.0000	DH	0.0000	
308	557:1	557:2			DE	0.0000	DN	0.0000	DH	0.0000	
309	1003:1	1003:2			DE	0.0000	DN	0.0000	DH	0.0000	
310	1002:1	1002:2			DE	0.0000	DN	0.0000	DH	0.0000	
311	1004:1	1004:2			DE	0.0000	DN	0.0000	DH	0.0000	
312	556:1	556:2			DE	0.0000	DN	0.0000	DH	0.0000	
313	553:1	553:2			DE	0.0000	DN	0.0000	DH	0.0000	
314	552:1	552:2			DE	0.0000	DN	0.0000	DH	0.0000	
315	551:1	551:2			DE	0.0000	DN	0.0000	DH	0.0000	
316	555:1	555:2			DE	0.0000	DN	0.0000	DH	0.0000	
317	554:1	554:2			DE	0.0000	DN	0.0000	DH	0.0000	
318	559:1	559:2			DE	0.0000	DN	0.0000	DH	0.0000	
319	10:1	10:2			DE	0.0000	DN	0.0000	DH	0.0000	
320	9:1	9:2			DE	0.0000	DN	0.0000	DH	0.0000	
321	8:1	8:2			DE	0.0000	DN	0.0000	DH	0.0000	
322	6:1	6:2			DE	0.0000	DN	0.0000	DH	0.0000	
323	603:1	603:2			DE	0.0000	DN	0.0000	DH	0.0000	
324	2:1	2:2			DE	0.0000	DN	0.0000	DH	0.0000	
325	1:1	1:2			DE	0.0000	DN	0.0000	DH	0.0000	
326	558:1	558:2			DE	0.0000	DN	0.0000	DH	0.0000	
327	1001:1	1001:2			DE	0.0000	DN	0.0000	DH	0.0000	

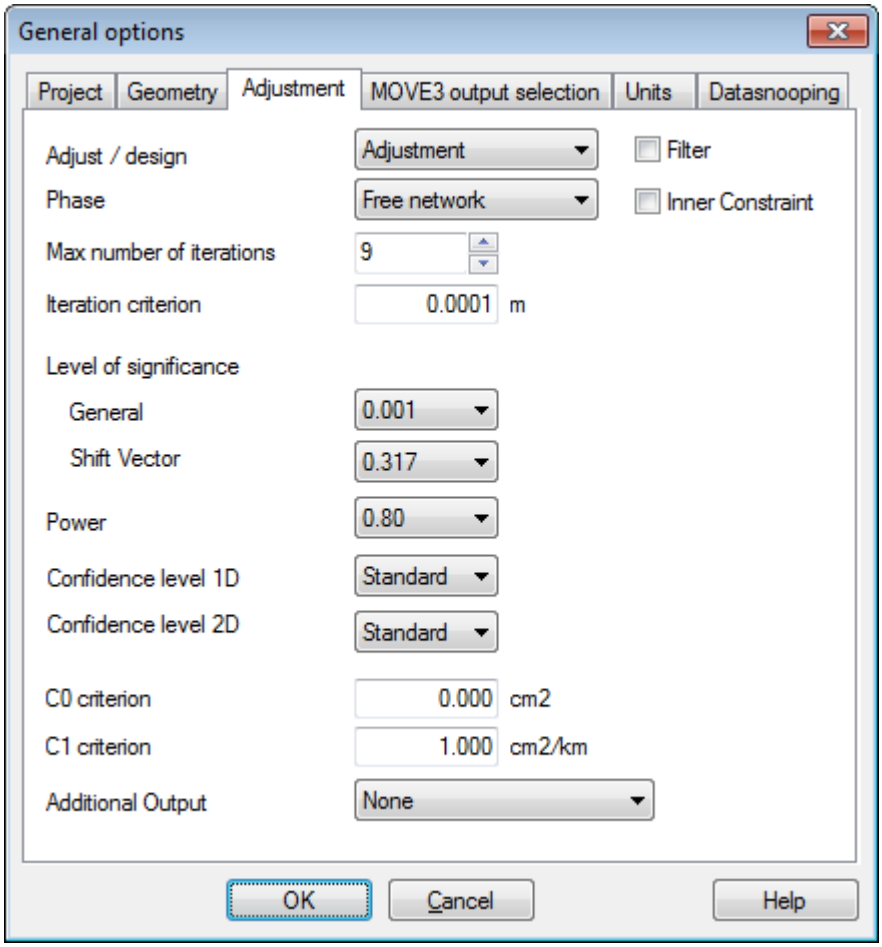


	No.	From	To	Instr Hgt	Target ...		Reading		Reading		Reading	Source
☐	295	HI_17:2	555:2			DH	-3.45383	SH	28.791			
☐	296	HI_17:2	8:2			DH	-3.48018	SH	29.134			
☐	297	HI_17:2	555B:2			DH	-3.45135	SH	29.119			
☐	298	HI_17:2	553:2			DH	-1.27947	SH	47.900			
☐	299	HI_17:2	553:2			DH	-1.27934	SH	47.903			
☐	300	553:2	HI_18:2			DH	1.37838	SH	10.492			
☐	301	HI_18:2	11A:2			DH	-1.40895	SH	9.018			
☐	302	HI_18:2	12A:2			DH	-1.40817	SH	8.098			
☐	303	HI_18:2	556:2			DH	-1.37344	SH	9.696			
☐	304	HI_18:2	10:2			DH	-3.66683	SH	11.741			
☐	305	HI_18:2	9:2			DH	-3.66364	SH	12.543			
☐	306	HI_18:2	559:2			DH	-0.80563	SH	29.659			
☐	307	VAL:1	VAL:2			DE	0.0000	DN	0.0000			
☐	308	557:1	557:2							DH	0.0000	
☐	309	556:1	556:2							DH	0.0000	
☐	310	553:1	553:2							DH	0.0000	
☐	311	552:1	552:2							DH	0.0000	
☐	312	551:1	551:2							DH	0.0000	
☐	313	555:1	555:2							DH	0.0000	
☐	314	554:1	554:2							DH	0.0000	
☐	315	559:1	559:2							DH	0.0000	
☐	316	10:1	10:2			DE	0.0000	DN	0.0000			
☐	317	9:1	9:2			DE	0.0000	DN	0.0000			
☐	318	8:1	8:2			DE	0.0000	DN	0.0000			
☐	319	6:1	6:2			DE	0.0000	DN	0.0000			
☐	320	2:1	2:2			DE	0.0000	DN	0.0000			
☐	321	1:1	1:2			DE	0.0000	DN	0.0000			
☐	322	558:1	558:2							DH	0.0000	

Here some of the points need to checked for deformation in height, while others are to be checked for deformation in position. This requires manual changes to the individual records.

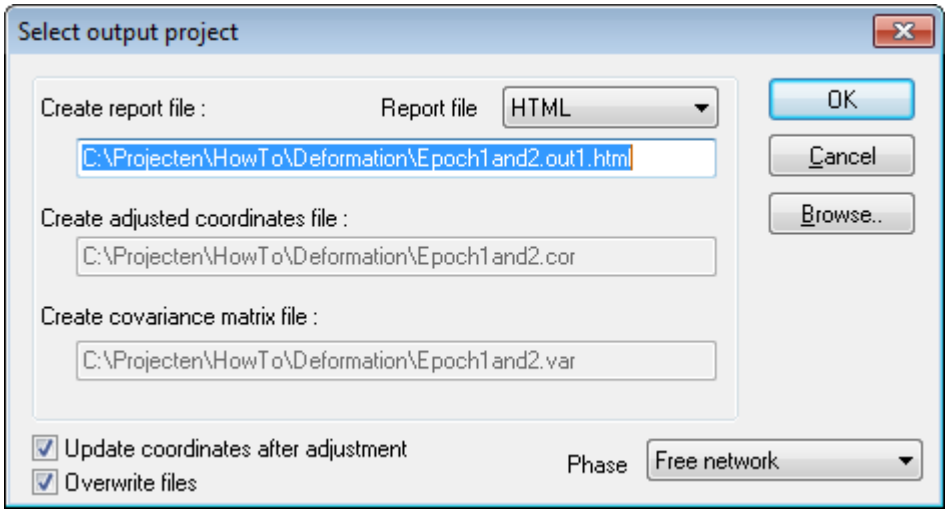
7. Free network adjustment

This network can be adjusted as a free network or as an inner constraint network if you select to use the inner constraint adjustment in the Adjustment tab



General options Geometry tab

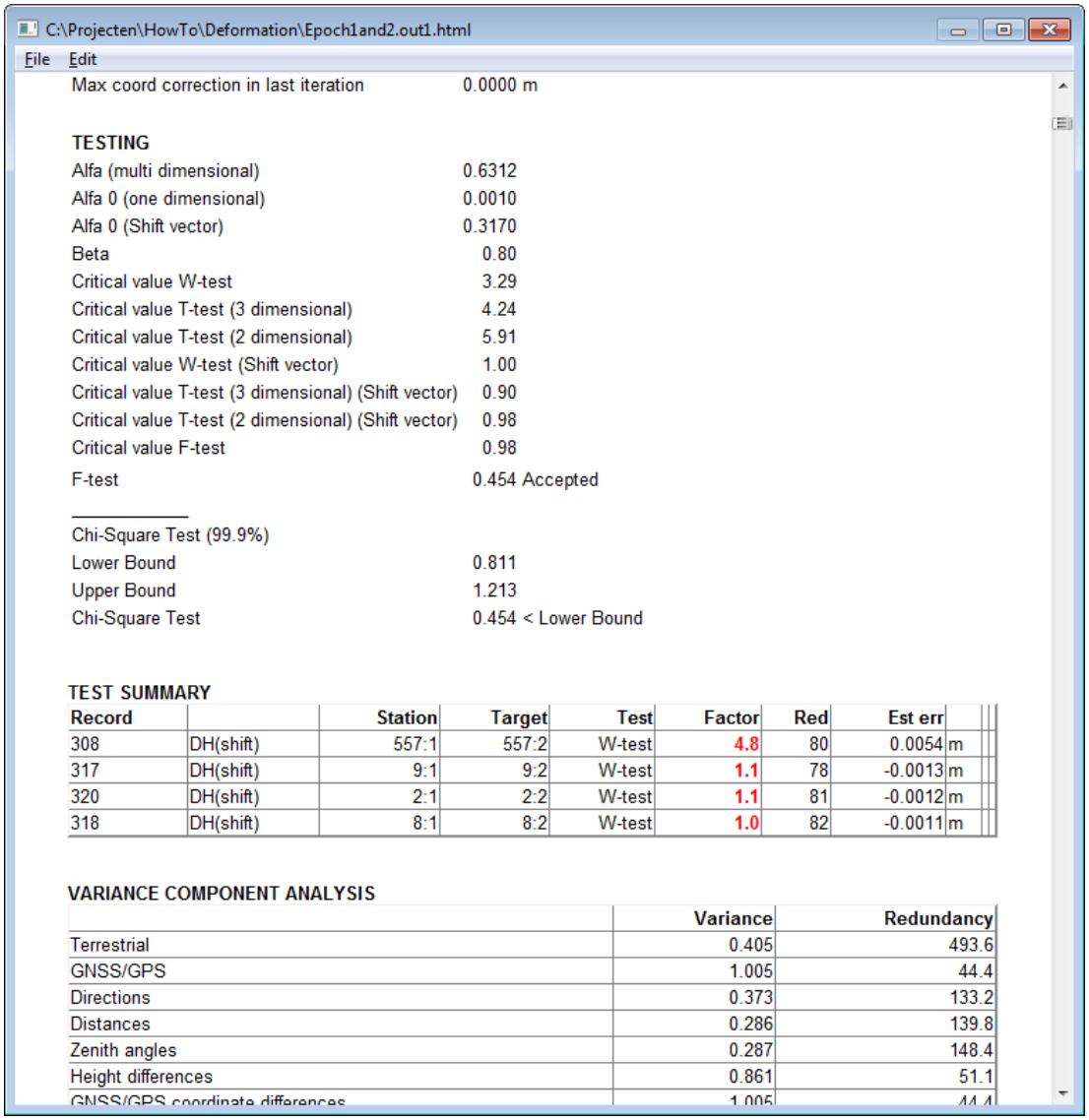
Then go to Compute| MOVE3 and adjust the free network to find errors in the observations.



Compute Free network

The MOVE3 report will give the testing results of the adjustment, allowing to identify the points that have been affected by deformation. If the correction is bigger than what is expected based on the standard deviation this case the shift vectors will be rejected.

First we will show the results with automated datasnooping off.


C:\Projecten\HowTo\Deformation\Epoch1and2.out1.html

File Edit

Max coord correction in last iteration 0.0000 m

TESTING

Alfa (multi dimensional)	0.6312
Alfa 0 (one dimensional)	0.0010
Alfa 0 (Shift vector)	0.3170
Beta	0.80
Critical value W-test	3.29
Critical value T-test (3 dimensional)	4.24
Critical value T-test (2 dimensional)	5.91
Critical value W-test (Shift vector)	1.00
Critical value T-test (3 dimensional) (Shift vector)	0.90
Critical value T-test (2 dimensional) (Shift vector)	0.98
Critical value F-test	0.98
F-test	0.454 Accepted

Chi-Square Test (99.9%)

Lower Bound	0.811
Upper Bound	1.213
Chi-Square Test	0.454 < Lower Bound

TEST SUMMARY

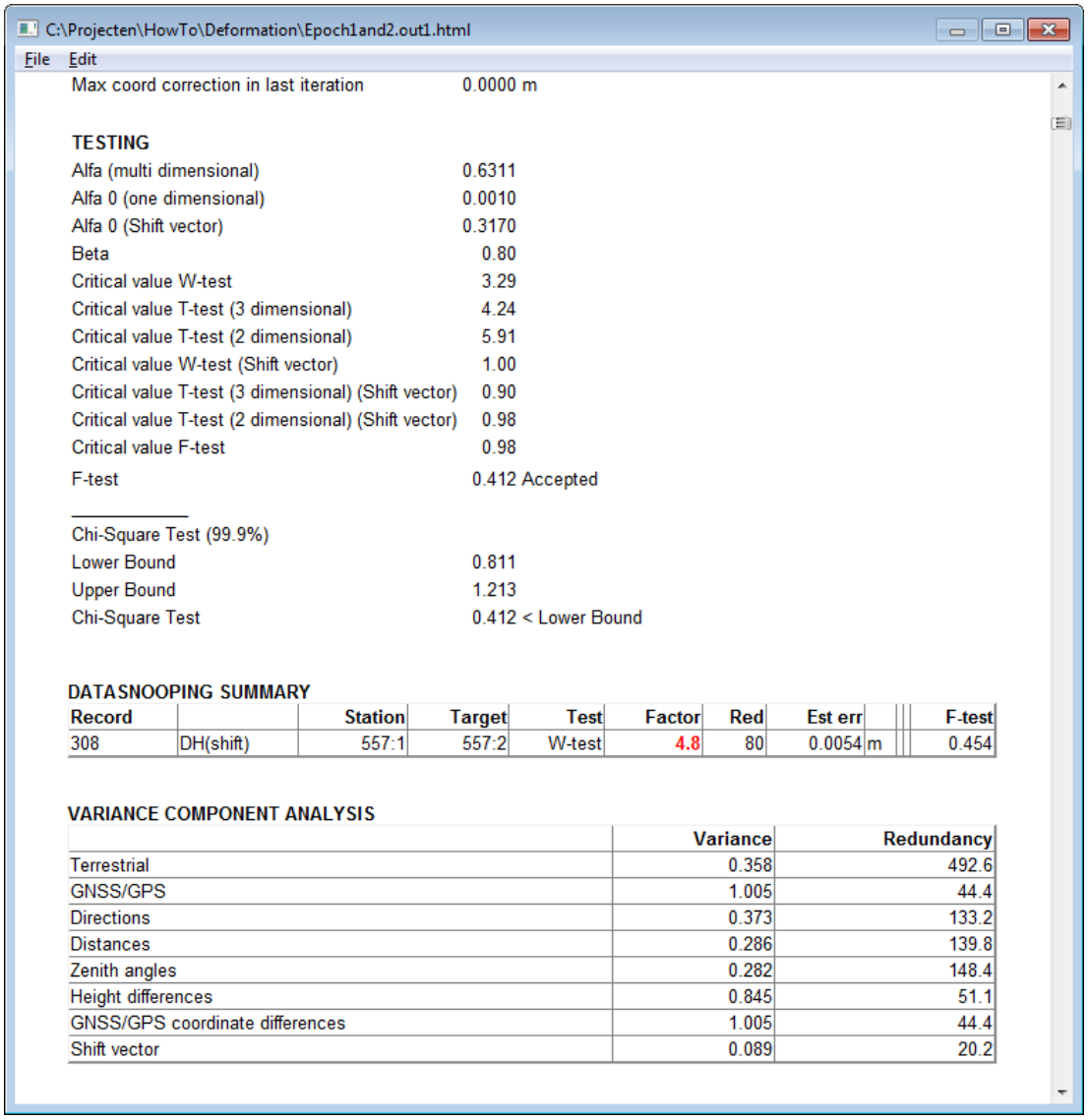
Record		Station	Target	Test	Factor	Red	Est err	
308	DH(shift)	557:1	557:2	W-test	4.8	80	0.0054	m
317	DH(shift)	9:1	9:2	W-test	1.1	78	-0.0013	m
320	DH(shift)	2:1	2:2	W-test	1.1	81	-0.0012	m
318	DH(shift)	8:1	8:2	W-test	1.0	82	-0.0011	m

VARIANCE COMPONENT ANALYSIS

	Variance	Redundancy
Terrestrial	0.405	493.6
GNSS/GPS	1.005	44.4
Directions	0.373	133.2
Distances	0.286	139.8
Zenith angles	0.287	148.4
Height differences	0.861	51.1
GNSS/GPS coordinate differences	1.005	44.4

The Test Summary shows 4 rejected height shifts, the biggest is related to point 557. This is the most suspect one.

After activating the automated datasnooping we get following results.



C:\Projecten\HowTo\Deformation\Epoch1and2.out1.html

File Edit

Max coord correction in last iteration 0.0000 m

TESTING

Alfa (multi dimensional)	0.6311
Alfa 0 (one dimensional)	0.0010
Alfa 0 (Shift vector)	0.3170
Beta	0.80
Critical value W-test	3.29
Critical value T-test (3 dimensional)	4.24
Critical value T-test (2 dimensional)	5.91
Critical value W-test (Shift vector)	1.00
Critical value T-test (3 dimensional) (Shift vector)	0.90
Critical value T-test (2 dimensional) (Shift vector)	0.98
Critical value F-test	0.98
F-test	0.412 Accepted

Chi-Square Test (99.9%)

Lower Bound	0.811
Upper Bound	1.213
Chi-Square Test	0.412 < Lower Bound

DATASNOOPING SUMMARY

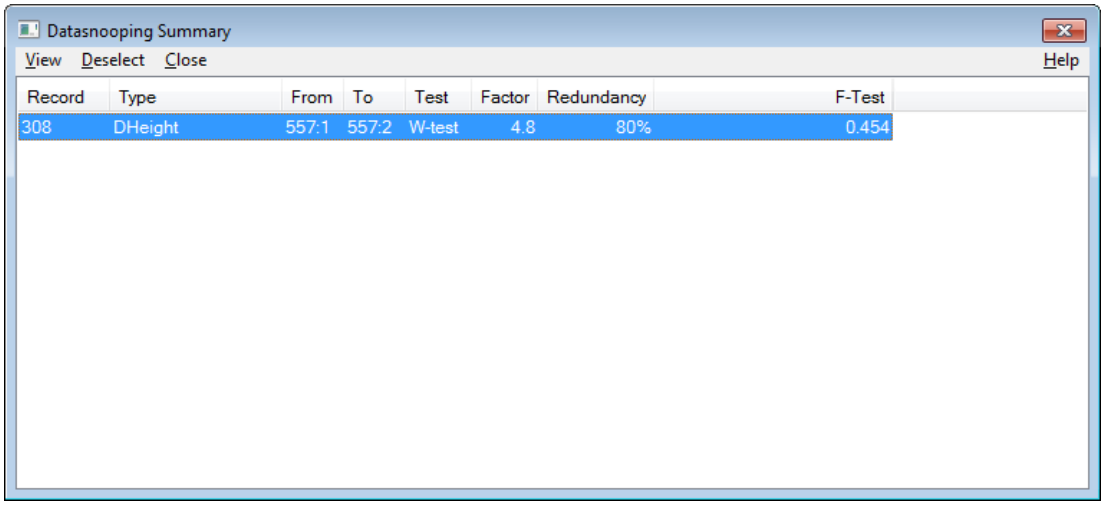
Record		Station	Target	Test	Factor	Red	Est err		F-test
308	DH(shift)	557:1	557:2	W-test	4.8	80	0.0054	m	0.454

VARIANCE COMPONENT ANALYSIS

	Variance	Redundancy
Terrestrial	0.358	492.6
GNSS/GPS	1.005	44.4
Directions	0.373	133.2
Distances	0.286	139.8
Zenith angles	0.282	148.4
Height differences	0.845	51.1
GNSS/GPS coordinate differences	1.005	44.4
Shift vector	0.089	20.2

MOVE3 adjustment report

In the report the Datasnooping Summary shows all rejected and removed observations (in this case just one). To access the observation tab open the Datasnooping items view from the Results menu. This view shows the observations listed in the Datasnooping Summary.



Datasnooping Summary

View Deselect Close Help

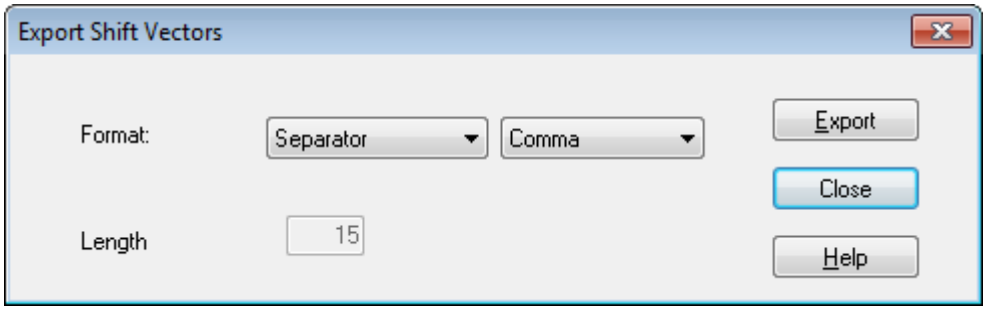
Record	Type	From	To	Test	Factor	Redundancy	F-Test
308	DHeight	557:1	557:2	W-test	4.8	80%	0.454

Datasnooping Summary

Click the first item in the list to open the observation tab of the removed observation. This observation can be deselected permanently (use CTRL-A and click Deselect to deselect all the observations that were removed during automated datasnooping).

8. Exporting results

After the adjustment the adjusted coordinates and computed shift vectors can be exported in a csv file



Export Adjusted Coordinates tab sheet

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	VAL:1	106066.1	458832.9		VAL:2	106066.1	458832.9		0.0024		-0.0043			
2	557:01:00			4.1556	557:02:00			4.1501					-0.0055	** #
3	556:01:00	106021	458730.3		556:02:00	106021	458730.3		0.0014		0.0045			
4	553:01:00	106018.1	458723		553:02:00	106018.1	458723		-0.0026		0.0029			
5	552:01:00	106035.4	458717.4		552:02:00	106035.4	458717.4		0.0009		0.0003			
6	551:01:00	106057.3	458707.8		551:02:00	106057.3	458707.8		-0.0012		0.0015			
7	555:01:00	106038.5	458724.3		555:02:00	106038.5	458724.3		0.0002		0.0011			
8	554:01:00	106060.2	458715		554:02:00	106060.2	458715		-0.0006		0.0006			
9	559:01:00	105982.2	458736.2		559:02:00	105982.2	458736.2		0.0032		-0.0019			
10	10:01			1.9999	10:02			1.9994					-0.0005	
11	9:01			2.0017	9:02			2.002					0.0004	
12	8:01			2.0858	8:02			2.086					0.0002	
13	6:01			2.0765	6:02			2.0765					0	
14	2:01			4.1477	2:02			4.1479					0.0002	
15	1:01			4.1412	1:02			4.1409					-0.0003	
16	558:01:00	106092.3	458693.1		558:02:00	106092.3	458693.1		-0.0036		-0.0047			

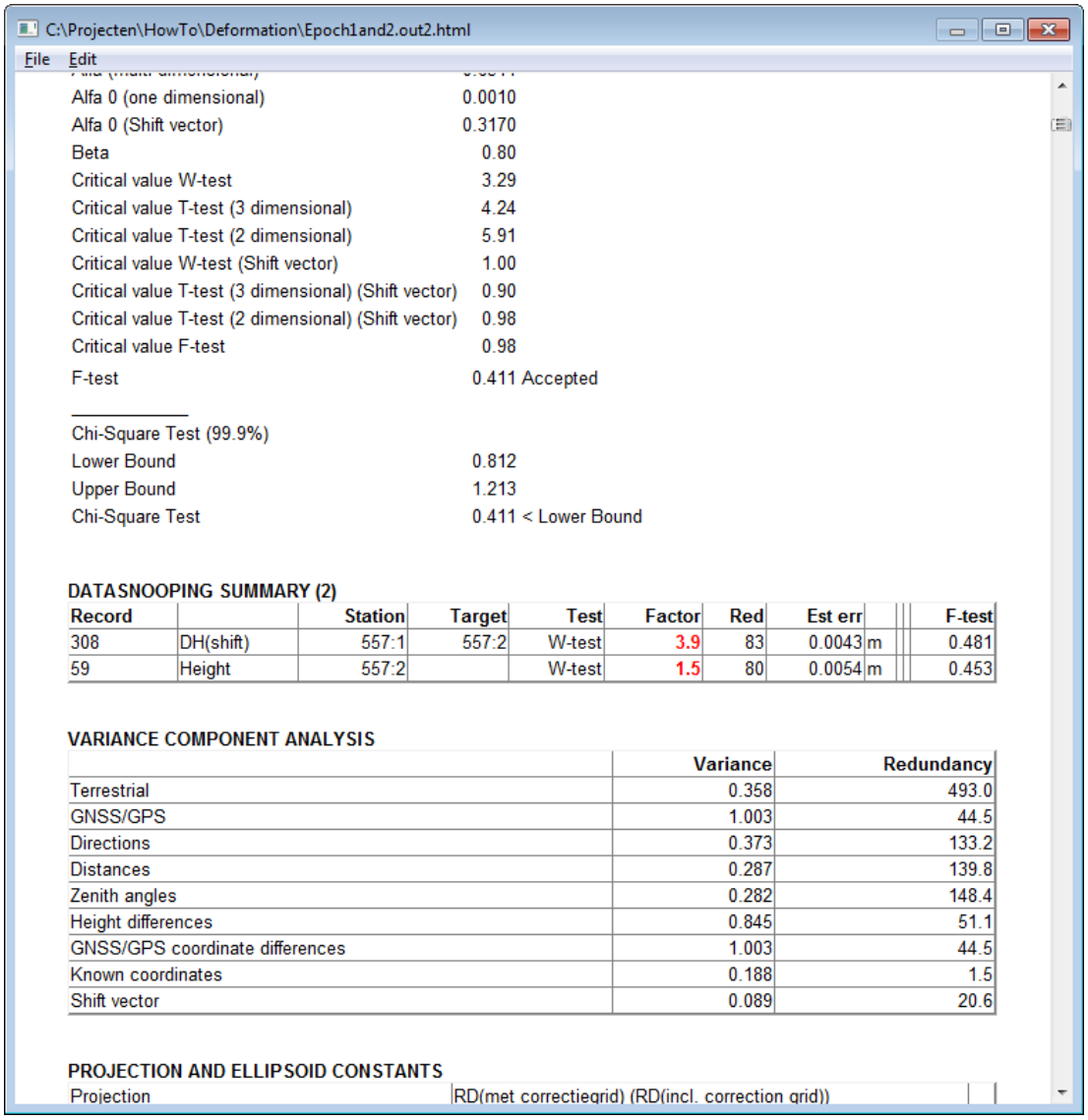
Exported Shift Vectors in Excel

The ** identifies the rejected shift vectors, the # indicates that the shift vectors have been deselected, either manually or via automated datasnooping (**#).

Note that using suffix :1 etc combined with numeric point names may confuse Excel, assuming that these are hours and minutes.

9. Constrained adjustment

If you have stable control points you can also use a constrained adjustment to check for deformations. In this example there is just one control point in height, 557. Here a problem is detected in this control point.



C:\Projecten\HowTo\Deformation\Epoch1and2.out2.html

File Edit

Alfa 0 (one dimensional)	0.0010
Alfa 0 (Shift vector)	0.3170
Beta	0.80
Critical value W-test	3.29
Critical value T-test (3 dimensional)	4.24
Critical value T-test (2 dimensional)	5.91
Critical value W-test (Shift vector)	1.00
Critical value T-test (3 dimensional) (Shift vector)	0.90
Critical value T-test (2 dimensional) (Shift vector)	0.98
Critical value F-test	0.98
F-test	0.411 Accepted

Chi-Square Test (99.9%)	
Lower Bound	0.812
Upper Bound	1.213
Chi-Square Test	0.411 < Lower Bound

DATASNOOPING SUMMARY (2)

Record		Station	Target	Test	Factor	Red	Est err		F-test
308	DH(shift)	557:1	557:2	W-test	3.9	83	0.0043	m	0.481
59	Height	557:2		W-test	1.5	80	0.0054	m	0.453

VARIANCE COMPONENT ANALYSIS

	Variance	Redundancy
Terrestrial	0.358	493.0
GNSS/GPS	1.003	44.5
Directions	0.373	133.2
Distances	0.287	139.8
Zenith angles	0.282	148.4
Height differences	0.845	51.1
GNSS/GPS coordinate differences	1.003	44.5
Known coordinates	0.188	1.5
Shift vector	0.089	20.6

PROJECTION AND ELLIPSOID CONSTANTS

Projection	RD(met correctiegrid) (RD(incl. correction grid))

It is most likely that in in the second epoch the adaptor (6 mm) was not used at point 557. When just comparing the results of the adjusted heights based on the control point 557 may conclude that all points levelled may have been shifted up for 6 mm, where the problem is in the control height.