Kinematic Batch Processing Accuracies of One Data Set at Varying Baseline Distances using CORS Stations in GrafNav Version 7.50

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Introduction

A major new functionality added to GrafNav, Waypoint's GPS post-processing package, is the ability to perform true multi-base processing. Users are now able to process multiple base station data and a remote file simultaneously in one Kalman filter. This is generally considered an improvement over the old-style method of applying a statistical weighting strategy to individually processed baselines.

The purpose of this report is twofold. Firstly, it investigates the difference in the new and old-style batch processing results as a function of average baseline length for one airborne data set. At the same time, it shows (also as a function of baseline length) how accurately a solution can be obtained using CORS stations instead of your own established base stations. The original trajectory and the location of the original base stations are shown below.

The airborne survey presented in this report followed very good field procedures in that multiple base stations were used, airplane turns were not so sharp as to cause GPS dropouts and high quality receivers were used. The results presented below are thus only representative of data of similar quality. All data was processed using the "Airborne" processing profile within GrafNav, which was developed specifically for airborne surveys. The survey in this report was just over two hours in length.

Both the new and old style batch processing results are presented from four processing runs. In each run, three base stations are used. Firstly, the airborne data is processed with the locally established base stations which provide a truth solution for other processing runs. These base stations provide an average baseline length of 14 km, allowing Kinematic Ambiguity Resolution (KAR) techniques to be successfully used.

Processing runs are then performed at average baseline lengths of 130 km, 545 km and 1270 km. While it is hardly a practical exercise to process airborne data at 1270 km, it serves to show the effect on the two batch processing methodologies when significant noise is present in the data. Very long baselines had to be used to introduce large atmospheric errors, as this survey was performed at the mid-latitude range and in the year 2005, a period of relative calm for the ionosphere.

Batch Processing Results Using Locally Established Base Stations – Average Baseline Length 14 km

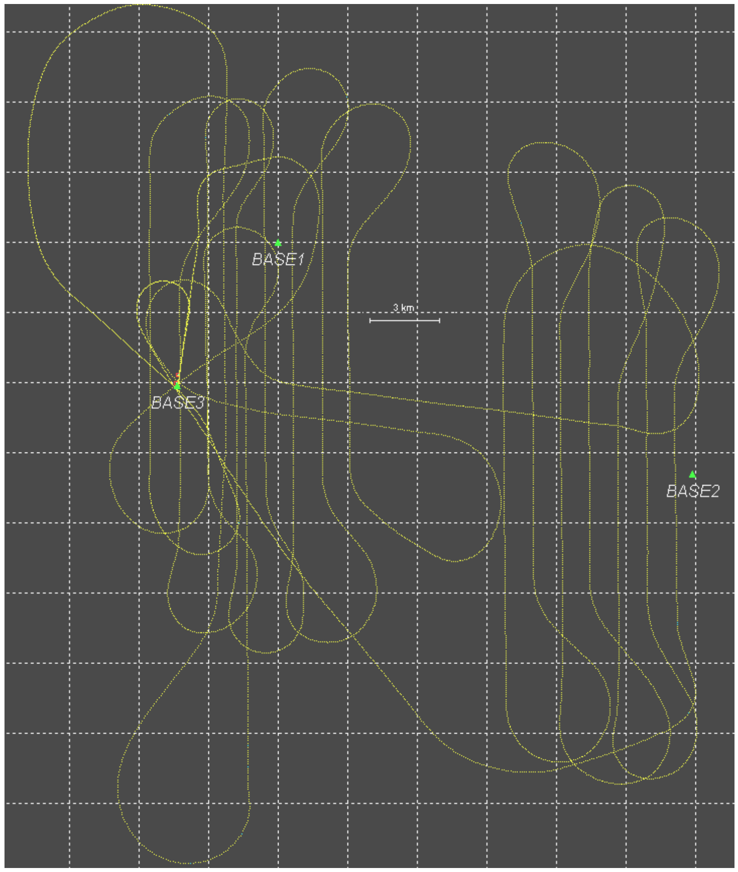

Figure 1: Original Flight Trajectory and Location of Base Stations

GrafNav post-processes GPS data both forwards and backward in time. This is useful in determining the reliability of a solution. Forward and backwards processing independently estimate satellite ambiguities provided the satellite constellation is appreciably different at the beginning and end of the survey. This is true for the length of any typical airborne survey.

Should the forward and reverse solutions agree well, it is an indication the ambiguities were chosen correctly by the software as it is very unlikely the same wrong ambiguity was chosen by both independent processes. Shown below is the difference in the forward and reverse solutions for the new batch processing methodology.

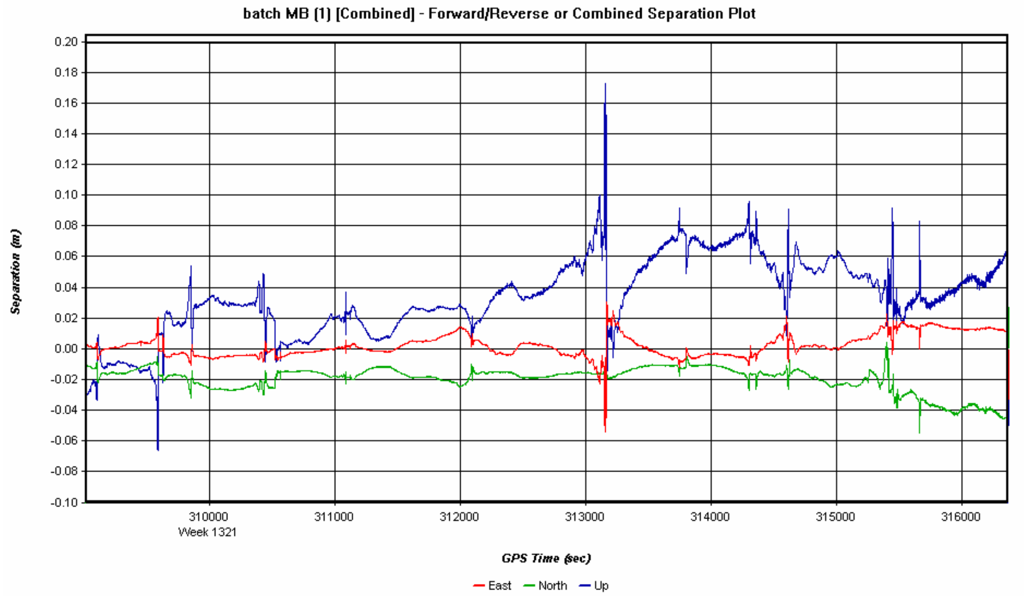

Figure 2: Forward/Reverse Separation using True Multi-Base Processing

The forward/reverse separation plot of the old sequential method of batch processing cannot be interpreted in exactly the same fashion as for the new method. The difference is that the old method uses a statistical weighting scheme to combine individually processed baselines, and thus by definition is simply the largest absolute difference in the solution for the baselines that are included in the final trajectory.

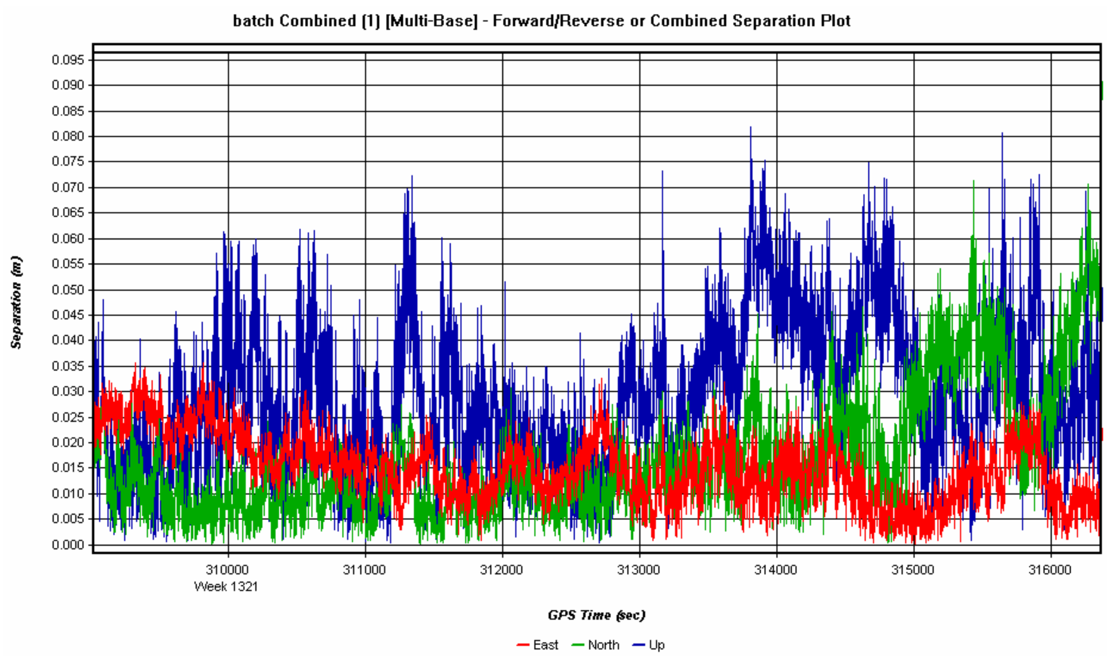

Figure 3: Forward/Reverse Separation using Old Style Method

Table 1: FWD/REV RMS Differences (cm) using Established Base Stations		
	Horizontal	Height
New Method	2.3	4.3
Old Method	2.6	3.3

The difference in the horizontal separation is negligible, while the old method produced an RMS difference that is 1 cm lower than the new method. It is important to note that this does not indicate a 1 cm improvement in the solution as the final solution is weighted. To view the actual differences in the final trajectories, we must directly compare them as shown below.

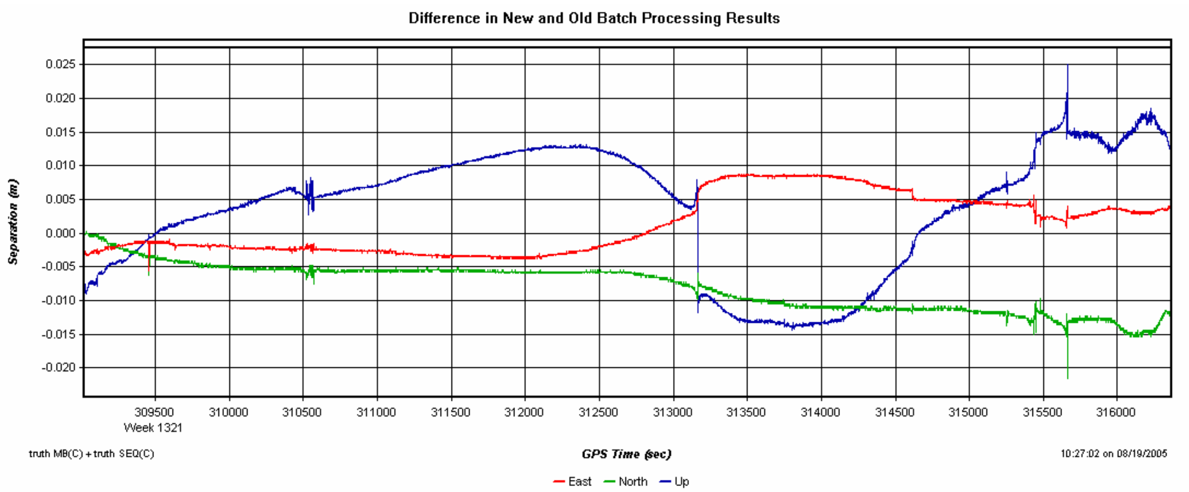

Figure 4: Difference between New and Old Batch Processing Techniques – Average Baseline Length 14 km

Table 2: RMS Difference in Final Solutions using Established Base Stations	
	RMS (cm)
Horizontal	1.0
Vertical	1.0

The RMS difference between the two solutions is one centimeter in both the horizontal and vertical components. This shows that there is very little difference between the two batch processing methodologies given a very good data set. The difference in the solutions is extremely small considering that instantaneous kinematic GPS accuracies under high dynamics such as this survey are not even widely considered to be accurate to the one cm level. In this event, either solution can be used as the truth trajectory in comparing results on the longer baselines using CORS data which is to follow.

Batch Processing Results Using CORS data – Average Baseline Length 130 km

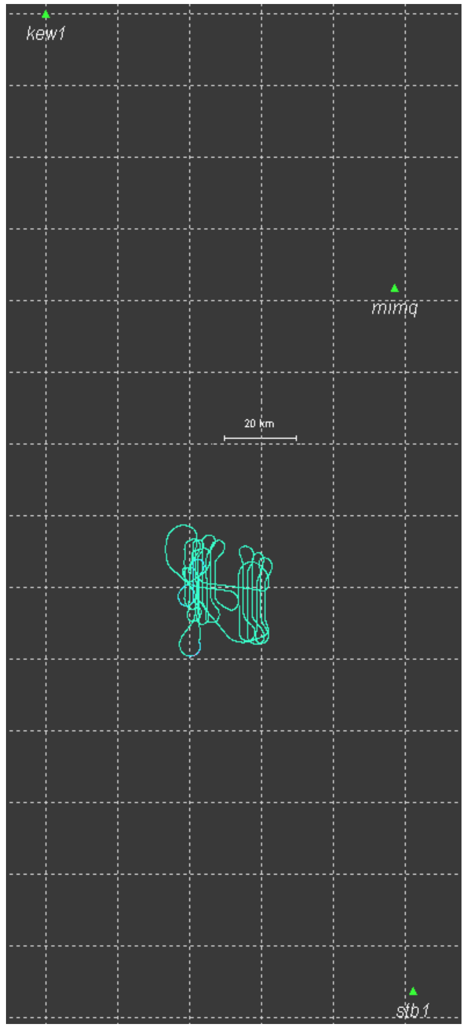

Figure 5: Flight Trajectory and Location of Three CORS Stations with an Average Baseline Length of 130 km

Downloading CORS station data is easily done within the "Download Service Data" utility within GrafNav. This program searches for the nearest stations given a latitude and longitude value and will download the data if it is available.

Three base stations were downloaded, KEW1, MIMQ and STB1 and batch processed using both the new and old methodologies. The final weighted solutions were then compared to the truth solution as shown below.

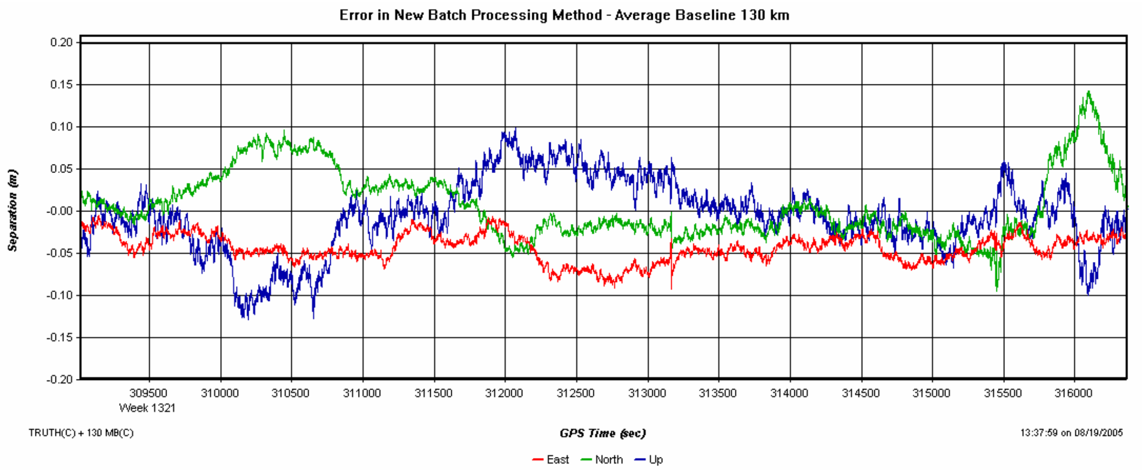

Figure 6: Errors in New Batch Processing Method – Average Baseline Length 130 km

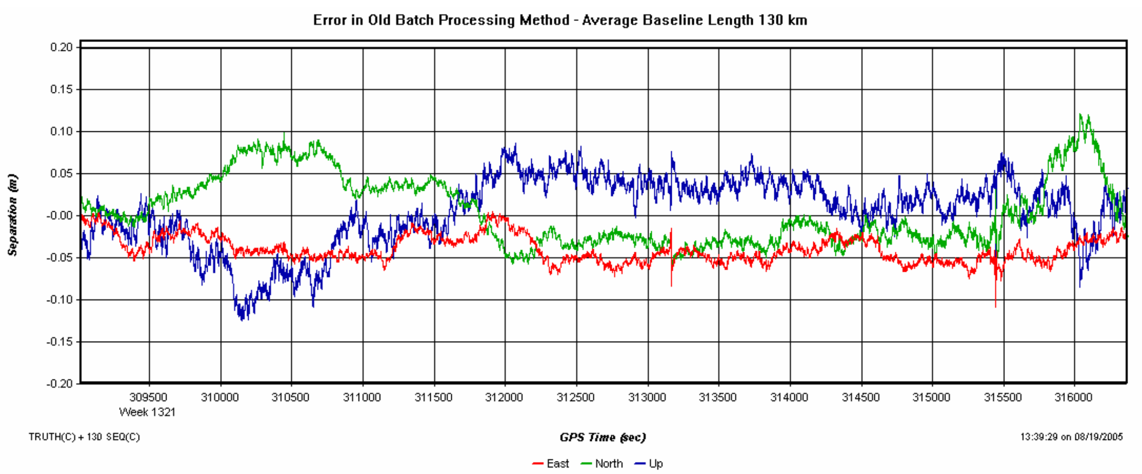

Figure 7: Errors in Old Batch Processing Method – Average Baseline 130 km

Table 3: RMS Batch Processing Errors (cm) for Average Baseline Length 130 km		
	Horizontal	Vertical
New Method	6.2	4.3
Old Method	5.9	4.2

The difference between the old and new methodologies is again essentially negligible.

Batch Processing Results using CORS data – Average Baseline Distance 545 km

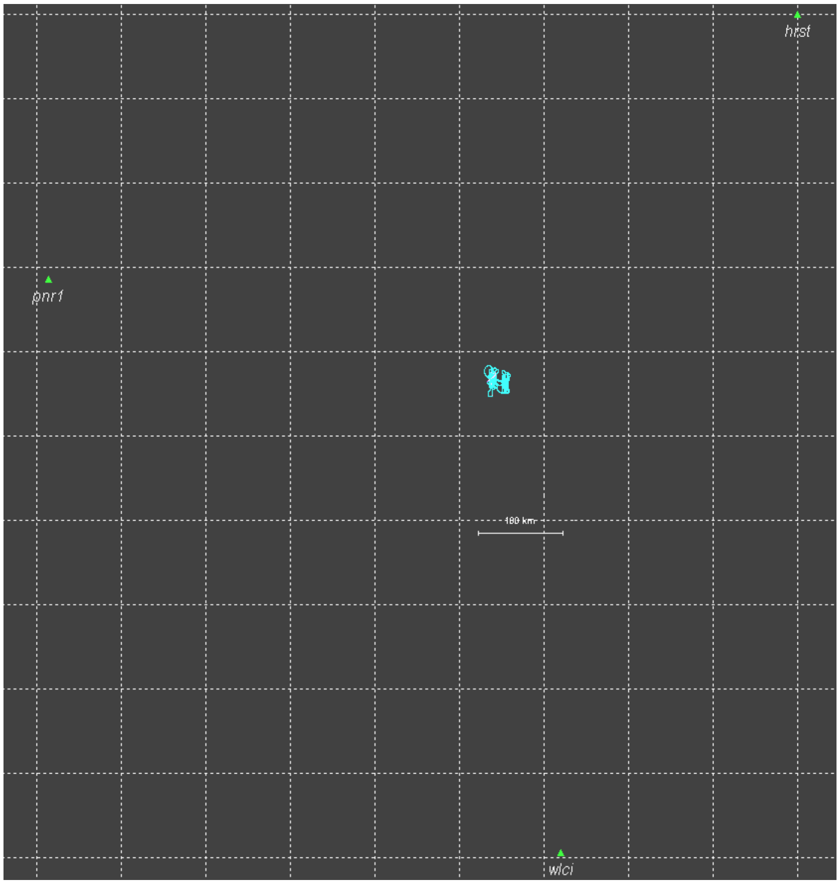

Figure 11: Flight Trajectory and Location of Three CORS Stations at an Average Baseline Length 545 km

The CORS stations used in this test are PNR1, WLCI and HRST. The errors in the old and new solutions are shown below.

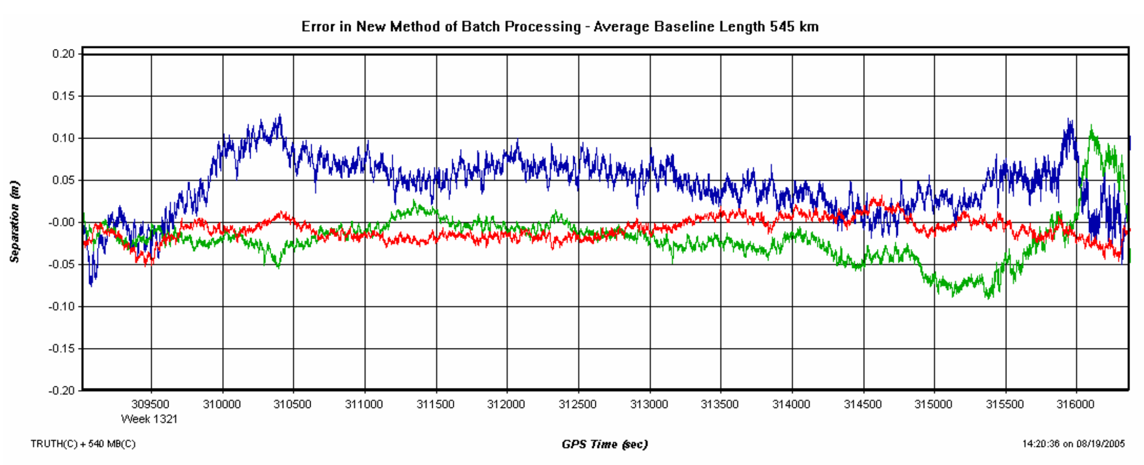

Figure 12: Errors in New Batch Processing Method – Average Baseline Length 545 km

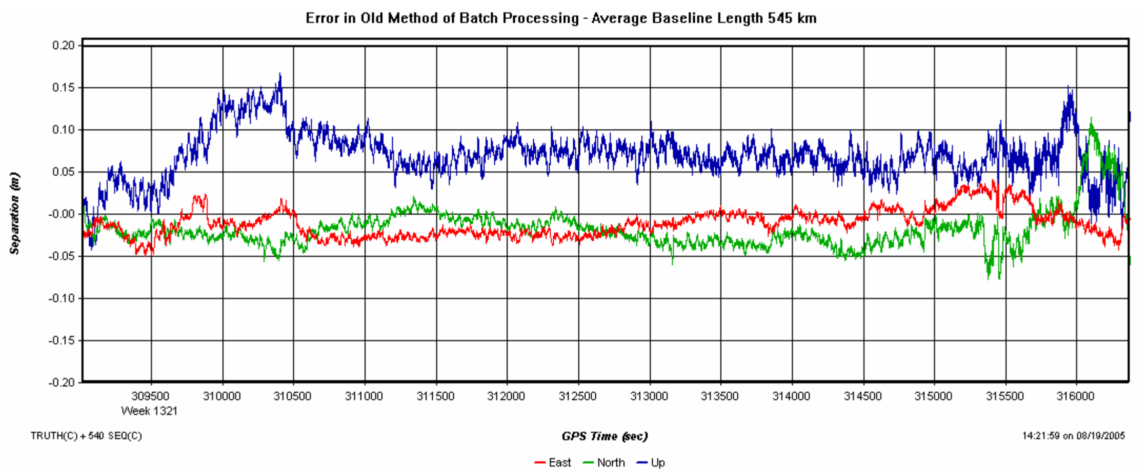

Figure 12: Errors in Old Batch Processing Method – Average Baseline Length 545 km

Table 5: RMS Batch Processing Errors (cm) for Average Baseline Length 545 km		
	Horizontal	Vertical
New Method	3.8	5.4
Old Method	3.5	7.5

Horizontally, the solutions agreed very well. Vertically, the new method showed a 2 cm RMS improvement over the old method.

Batch Processing Results Using CORS Data – Average Baseline Length 1270 km

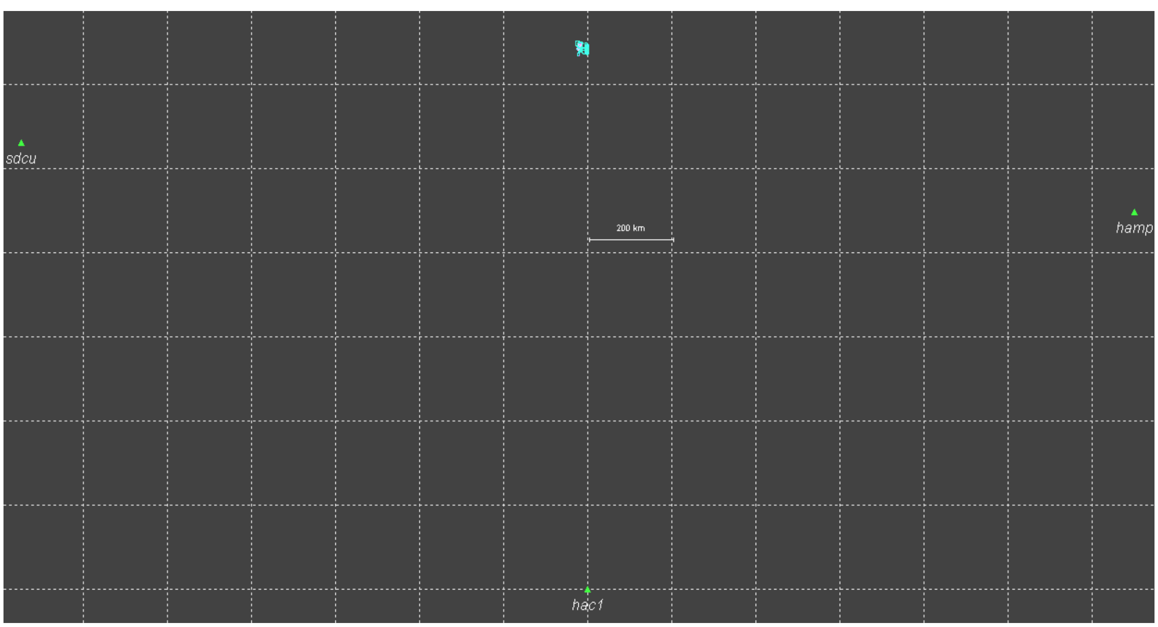

Figure 13: Trajectory of Flight and Location of three CORS Stations at an Average Baseline Length of 1270 km

The CORS Stations SDCU, HAC1 and HAMP were used in this test. The errors in both the new and old solutions are shown below.

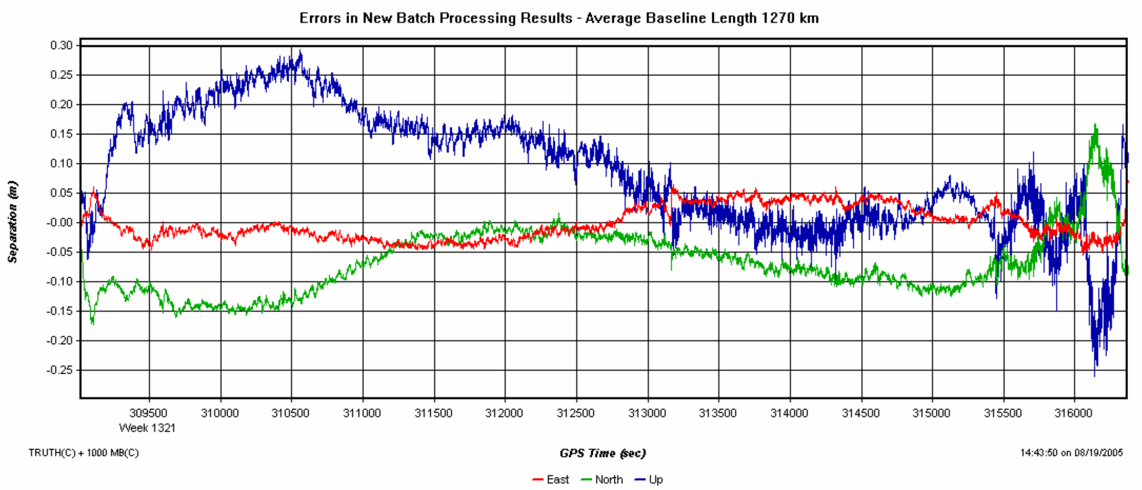

Figure 14: Errors in New Method of Batch Processing – Average Baseline Length 1270 km

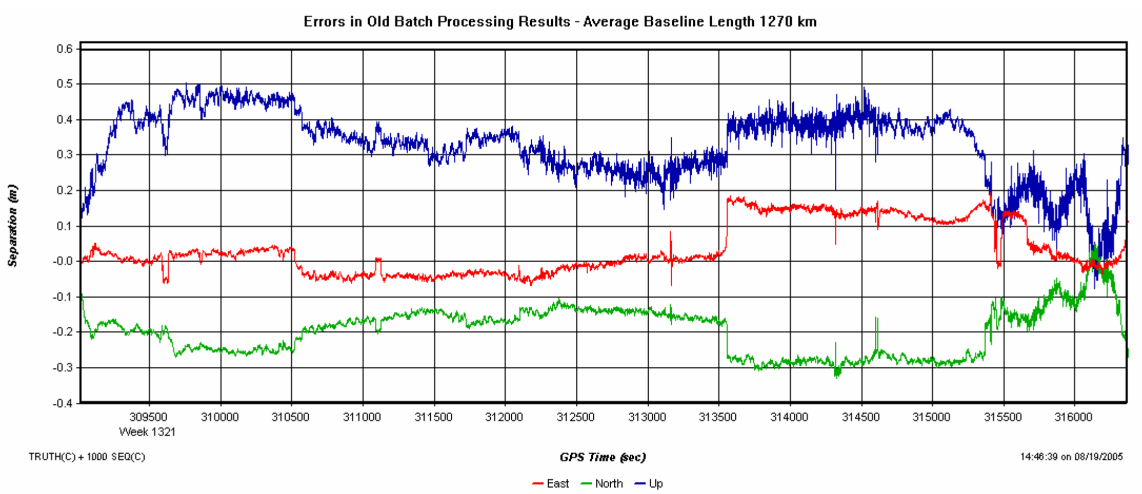

Figure 15: Errors in New Method of Batch Processing – Average Baseline Length 1270 km

Table 6: RMS Batch Processing Errors (cm) for Average Baseline Length 1270 km		
	Horizontal	Vertical
New Method	9.1	13.2
Old Method	22.0	34.1

Conclusions

A significant addition to Waypoint's GPS post-processing software is the ability to perform true batch processing. This allows users to simultaneously process data from multiple base stations in one Kalman filter. Previously, GrafNav users had to process each baseline individually and then combine the baselines using a statistical weighting scheme. The purpose of this report was to take one data set and process at a range of baseline lengths to determine firstly the effectiveness of the new batch processing technique as more atmospheric noise is introduced into the data. Secondly, the accuracies of the solutions using CORS base station data could be directly compared to a truth solution obtained by using the locally established base stations.

Provided accuracy requirements are not the most stringent (such as for applications like airborne mapping at scales of 1:20 000 or greater, GIS and asset location, agriculture and farming applications, and seismic and oil-field applications) using freely downloadable CORS base station data offers an attractive alternative to establishing your own base stations.

Virtually no difference is seen between the two batch processing methods when the locally established base stations are used, or with the closest three CORS stations. This shows that given relatively little noise in the data either method can be used with equal success. The first indications that the new method handles noisy data more effectively than the old method are in the 545 km test, in which a 2 cm improvement is seen with the new method.

An appreciable difference between the old and new solutions is only seen on the last baseline processed, which had an average baseline length of 1270 km. A 240% improvement was seen in the RMS error in the horizontal solutions and nearly a 260% improvement was seen in the vertical component. Although this is not representative of an application many users would be conducting, it serves to introduce noise into a data set which was otherwise very clean.

In evaluating the obtainable accuracies that were observed using CORS data, it is vitally important to look at the maximum error during the survey and not simply an RMS value over the entire period. The errors from the CORS solutions in this data set did not exceed 20 cm in either the horizontal or vertical component for baselines of averages length of 545 km or lower. Maximum errors approached 30 cm in both the horizontal and vertical components for the longest average baseline processed (1270 km). It should be stressed once again that these results are representative only of data collected using very good field procedures and high quality GPS receivers. Additionally, this survey was conducted at a time (2005) and place (mid latitude regions) which minimized the effect of the ionosphere on the GPS signal.