

## Using CORS/IGS Base Stations for Airborne Surveys

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### Introduction

This report investigates the accuracy of differential GPS airborne trajectory determination using CORS/IGS networks as base stations. Traditionally, in airborne mapping applications the user will set up one or more of their own base stations at points near the survey area. This can be expensive and may not be required for smaller scales (i.e. lower accuracy levels). In principle, the low rate data from the CORS/IGS stations can be interpolated and used as a back up, or replacement of the base receiver data. If a CORS/IGS station is well within range, high accuracy is possible with fixed integer solutions. Generally though, float solutions are only attainable due to longer distances and errors present in the interpolated data. The objective of this report is to obtain an accuracy of 20 cm in the horizontal and 30 cm in the vertical.

For all of the airborne data chosen for this report, the actual user installed base stations are less than 20 km away from the survey area, and they will provide the “truth” trajectory. These solutions are assumed to be error free, even though it is likely that 1 – 10 cm error are present in the “truth” coordinates. The airborne data in this report are generally clean with minimal losses of lock. However a couple of less than ideal data sets are also included. The CORS/IGS data were downloaded using the Download Service Data program embedded in the GrafNav environment. This also interpolates to 1 or 2 Hz from the 5 or 30 second data stored at the CORS or IGS ftp site. Download also supports networks in Japan, France, and Australia.

### Methods

1. To test the accuracy of using CORS/IGS networks, 5 sets of airborne data were used to obtain a good cross-section of receivers, areas and baseline lengths.
2. In order to minimize localized datum and survey errors, the user supplied base coordinates were not used in favor of a network solution obtained from CORS/IGS. This used the nearest 2 to 3 CORS/IGS station along with Waypoint’s GrafNet static network processing software.
3. With the coordinate of the base station determined from the previous step, Waypoint’s GrafNav, a kinematic/static baseline processing software, was used to process each airborne data set to form the truth trajectory.
4. 2 to 3 CORS/IGS stations are chosen based on proximity and availability.
5. Data from these CORS/IGS stations were downloaded with the Download Utility and interpolated from 30-second interval to 1-second interval. Note that some errors are introduced from the interpolation, analysis of this error are also presented in this report. The CORS/IGS stations are can be up to 200 km away from the remote; with such long distances

some atmospheric errors are inevitable as well. GrafNav Batch, a kinematic/static multi-baseline processing software, was used to process the data set with the multiple CORS/IGS stations. It uses a distance based weighting methodology to combine the trajectories from the multiple base stations.

6. The combined multiple CORS/IGS based trajectory is then compared with the “truth” trajectory.
7. To test the interpolation error, an airborne data set was used. The base of this particular data set was originally 1-second interval. It was then reduced to 30-second interval and interpolated back to 1-second interval. This scenario resembles the CORS/IGS stations, which was interpolated from 30-second to 1-second. The original 1-second base station and 1-second interpolated base station was processed and compared.

## Results

### Airborne Data 1

The original baseline is less than 20 km with a height profile of 2000 m. The three CORS/IGS stations chosen for the network adjustment of the original base station are:

- CSST
- RCA2
- UCSB

The same three stations were also used in the Batch Processing. There are quite close, approximately 20 to 45 km away.

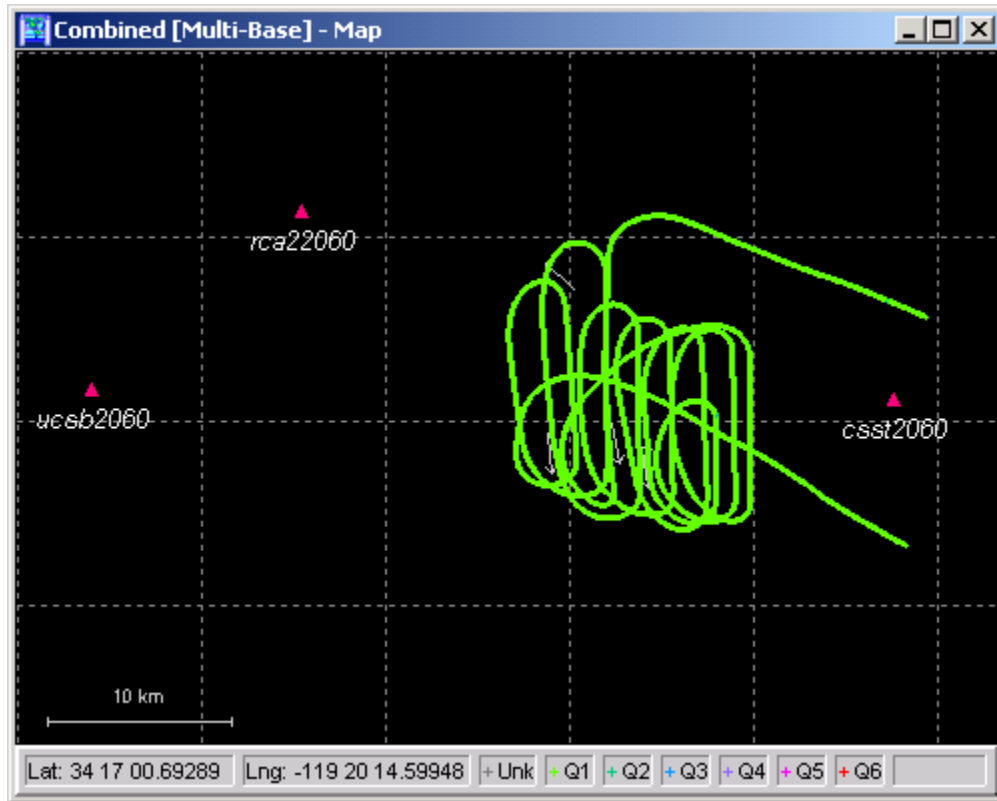


Figure 1. Map of airborne trajectory and CORS/IGS stations

Figure 2 shows the differences between the Original solution and CORS/IGS processed solution. The plot shows an accuracy of 5 cm in the horizontal and 20 cm in the vertical. Table 1 shows the size of the errors.

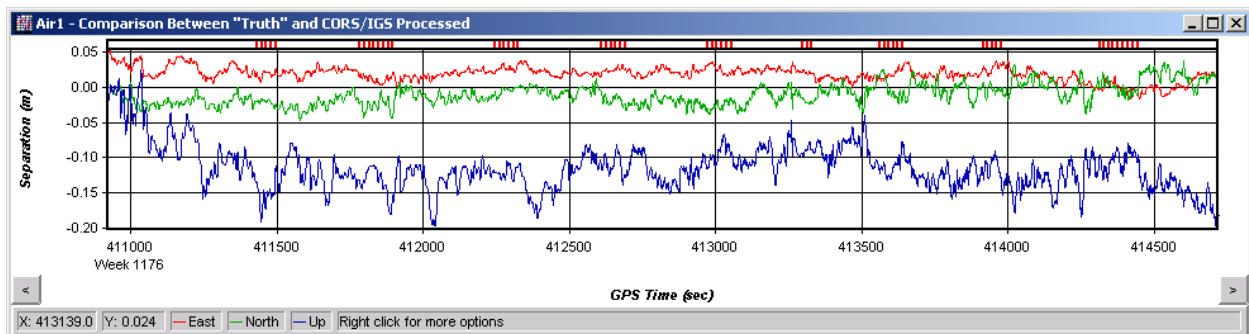


Figure 2. Comparison between the Original and CORS/IGS processed  
 Original baseline: < 20 km  
 CORS/IGS baselines: 20 – 45 km

**Table 1. Comparison RMS Values**

	Horizontal (m)	Vertical (m)
<b>RMS</b>	0.0282	0.1189

## Airborne Data 2

The original baseline is approximately 5 km with a height profile of 1450 m. There were only two CORS/IGS stations chosen for the network adjustment, they are:

- COSA
- SRP1

In addition to the two CORS/IGS stations, COT1 was also used in the Batch Processing. The baseline distances are approximately 35 to 140 km away.

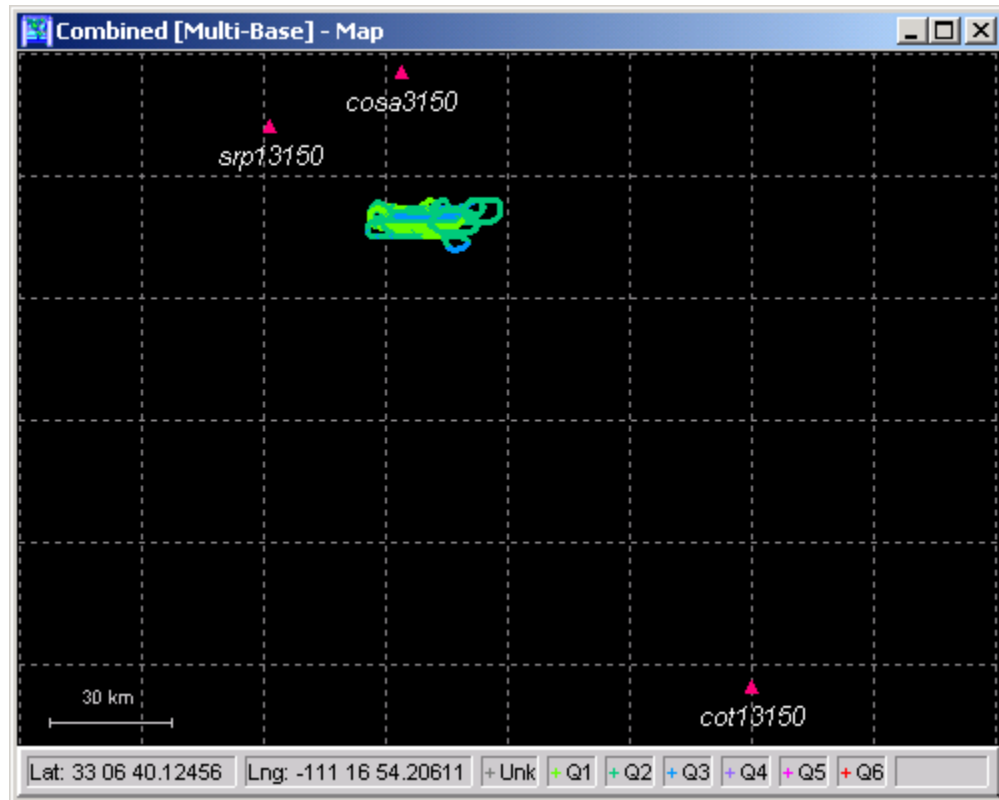


Figure 3. Map of airborne trajectory and CORS/IGS stations

Figure 4 shows the differences between the Original solution and CORS/IGS processed solution. The plot shows an accuracy of 20 cm in the horizontal and 30 cm in the vertical. L2 cycle slips are the reason for the spikes and gaps in the plot. Figure 5 shows the L2 Satellite Lock plot of the remote (airborne). The red marks represent cycle slips or unusable data. The areas with red marks correspond to the spikes and gaps in Figure 4. Despite a number of L2 cycle slips, the accuracy is still acceptable. Table 2 shows the size of the errors.

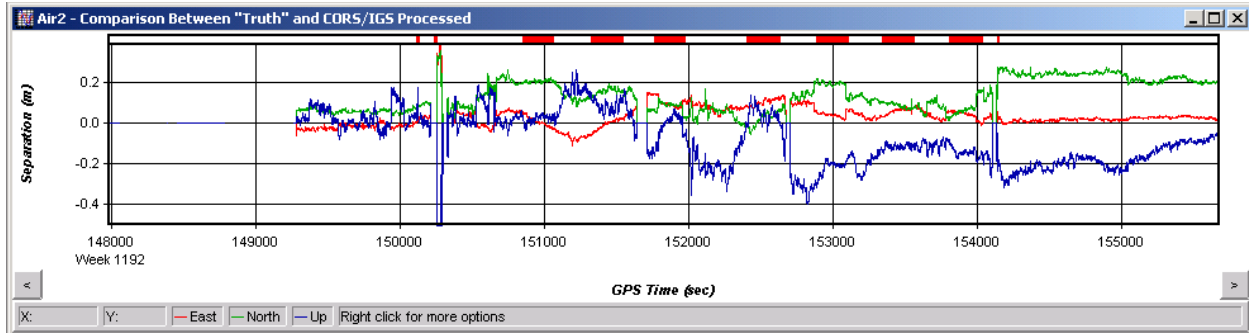


Figure 4. Comparison between the Original and CORS/IGS processed  
 Original baseline: 5 km  
 CORS/IGS baselines: 35 – 140 km

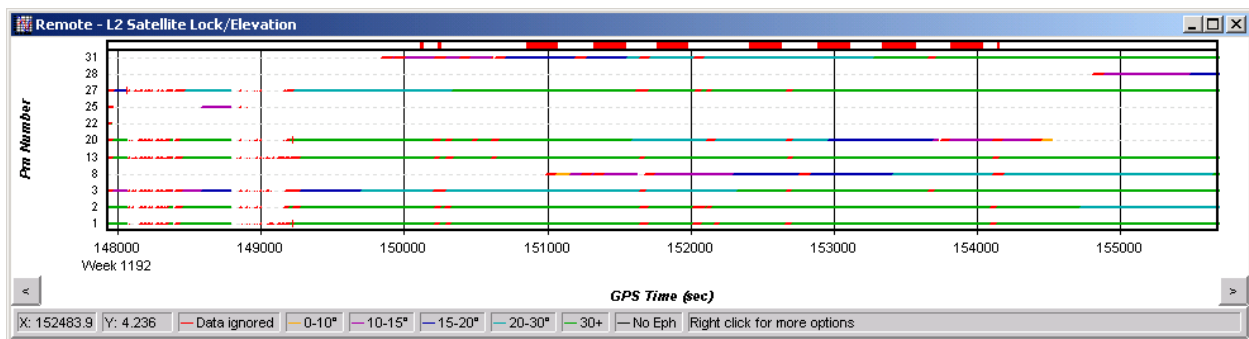


Figure 5. L2 Satellite Lock Plot

**Table 2. Comparison RMS Values**

	Horizontal (m)	Vertical (m)
<b>RMS</b>	0.1643	0.1896

### Airborne Data 3

The original baseline is approximately 7.5 km with a height profile of 1450 m. Again there were only two CORS/IGS stations chosen for the network adjustment:

- COSA
- SRP1

In addition to the two CORS/IGS stations, COT1 was also used in the Batch Processing. The baseline distances are approximately 35 to 140 km away.

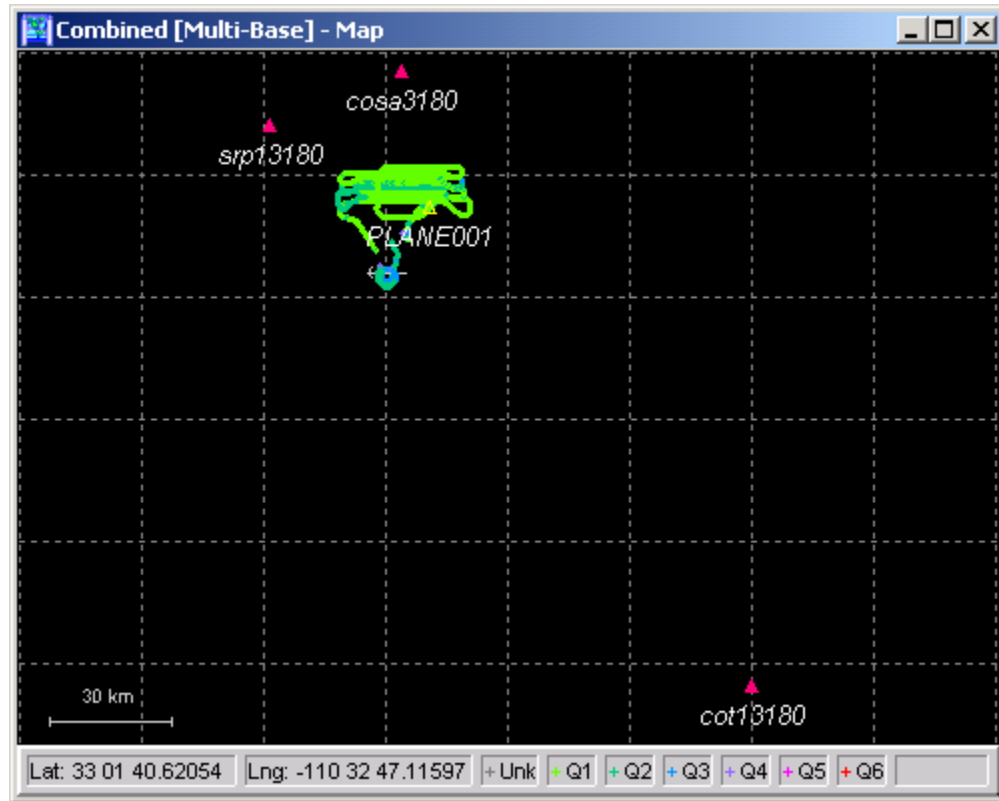


Figure 6. Map of airborne trajectory and CORS/IGS stations

Figure 7 shows the differences between the Original solution and CORS/IGS processed solution. The Plot shows an accuracy of 20 cm in the horizontal and 30 cm in the vertical. Just like the previous data set, there are also a number of L2 cycle slips, and this can be seen in Figure 8. Again, despite the number of L2 cycle slips, the accuracy is still acceptable. Table 3 shows the size of the errors.

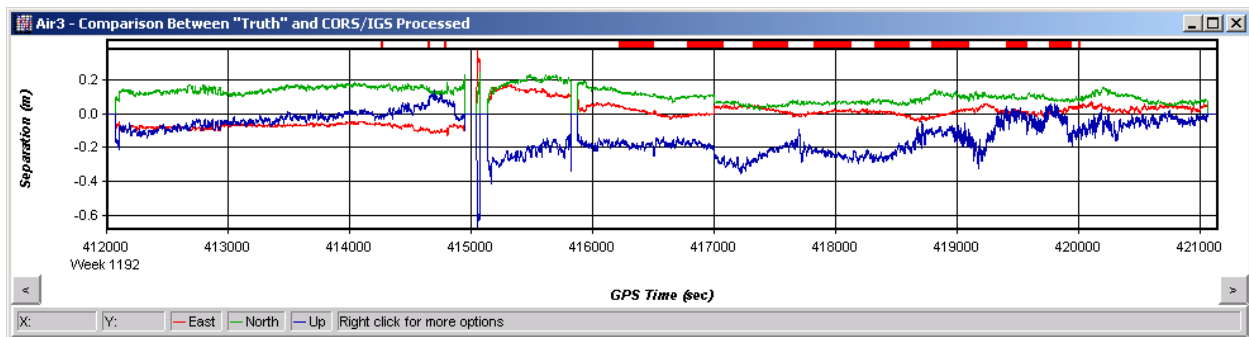


Figure 7. Comparison between the Original and CORS/IGS processed  
 Original baseline: 7.5 km  
 CORS/IGS baselines: 35 – 140 km

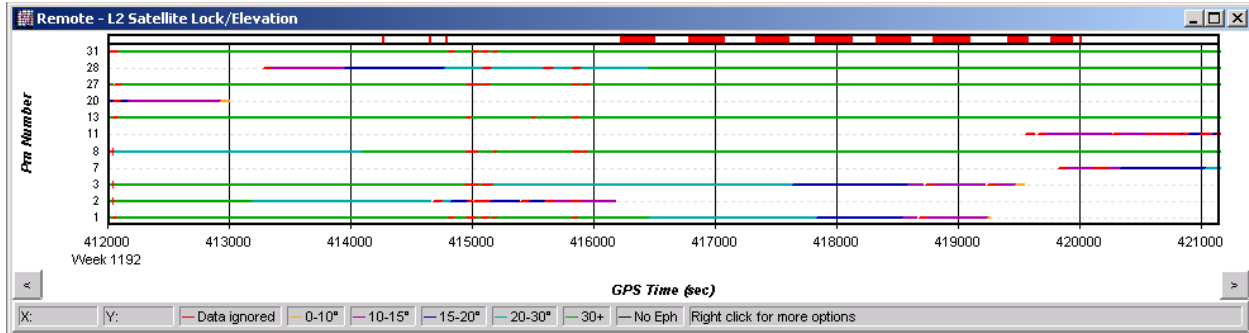


Figure 8. L2 Satellite Lock Plot

**Table 3. Comparison RMS Values**

	<b>Horizontal (m)</b>	<b>Vertical (m)</b>
<b>RMS</b>	0.0901	0.1610

#### **Airborne Data 4**

The original baseline is approximately 10 km with a height profile of 1600 m. The two CORS/IGS stations chosen for the network adjustment are:

- MLF1
- MOB1

In addition to the two CORS/IGS stations, NDBC was also used in the Batch Processing. The baseline distances are approximately 30 to 185 km away.

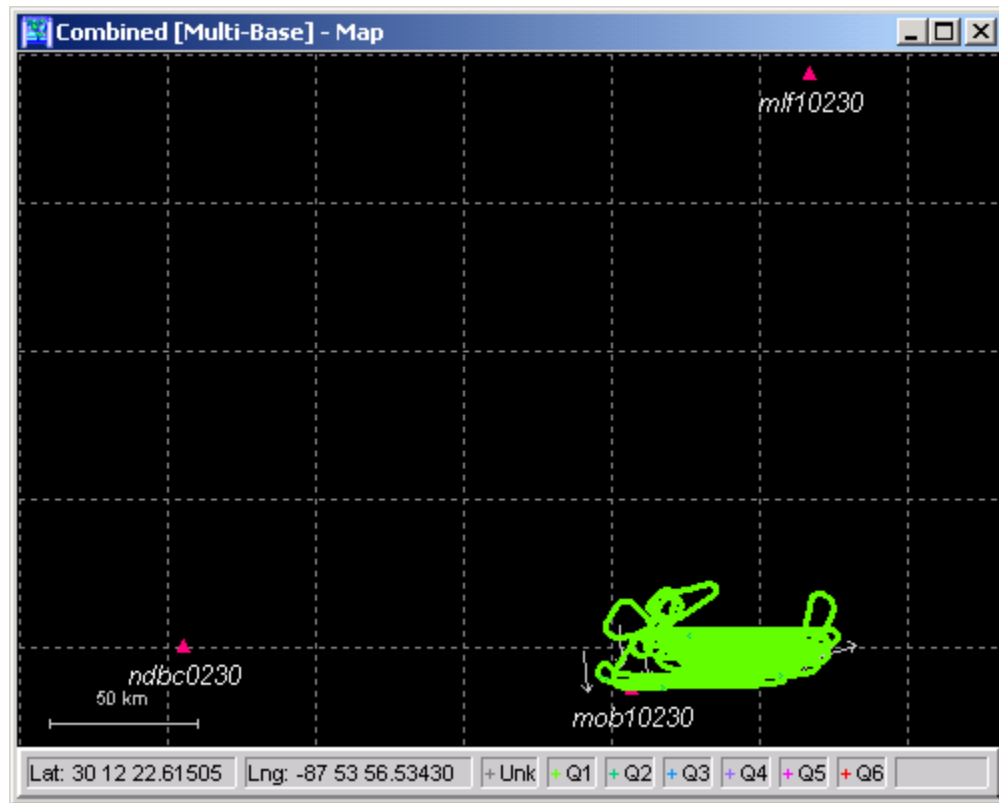


Figure 9. Map of airborne trajectory and CORS/IGS stations

Figure 10 shows the differences between the Original solution and CORS/IGS processed solution. The plot shows an accuracy of 5 cm in the horizontal and 10 cm in the vertical. Table 4 shows the size of the errors.

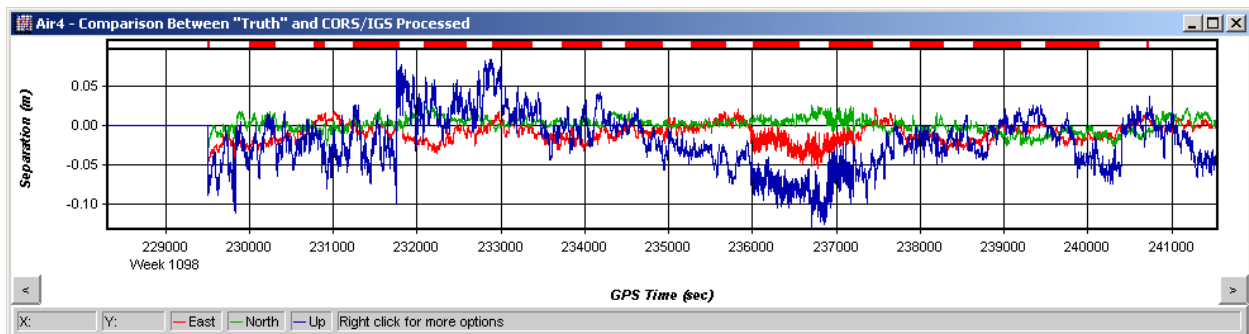


Figure 10. Comparison between the Original and CORS/IGS processed  
 Original baseline: 10 km  
 CORS/IGS baselines: 30 – 185 km

**Table 4. Comparison RMS Values**

	Horizontal (m)	Vertical (m)
<b>RMS</b>	0.0172	0.0283



### Airborne Data 5

The location of the original base station is located at the starting point of the survey, with a height profile of 2500 m. The three CORS/IGS stations chosen for the network adjustment are:

- COSA
- COT1
- FERN

The same stations were used in the Batch Processing except for COT1, which was replaced by BLYT since it was closer. The baseline distances are approximately 20 to 240 km away.

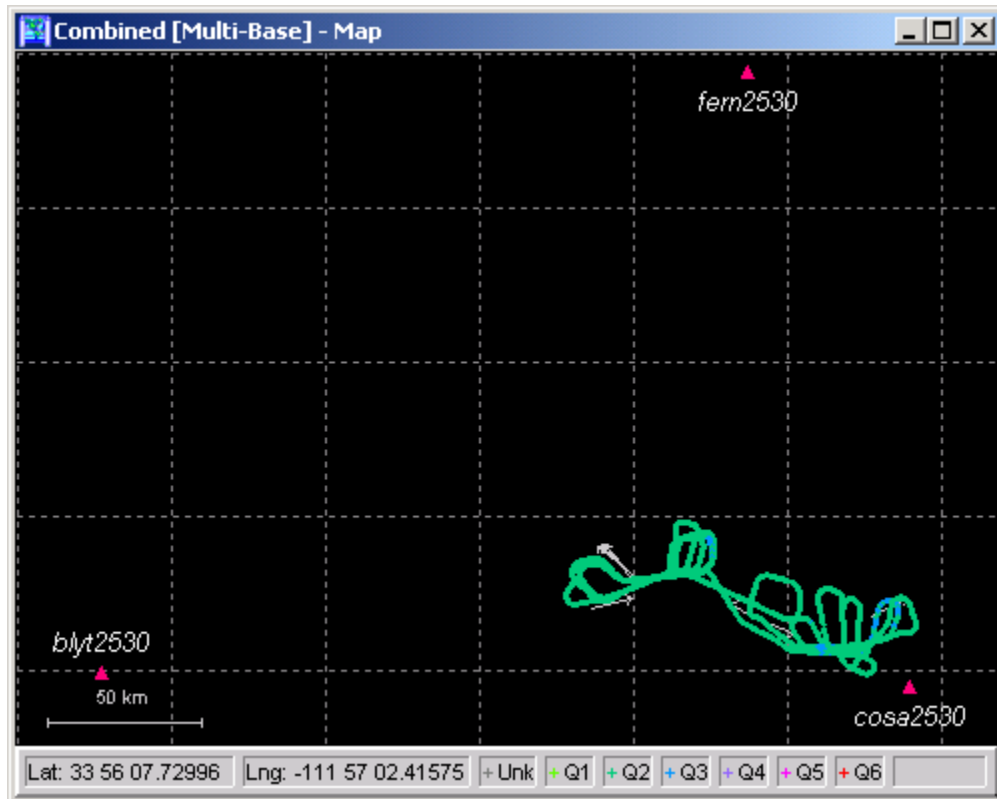


Figure 11. Map of airborne trajectory and CORS/IGS stations

Figure 12 shows the differences between the Original solution and CORS/IGS processed solution. The Plot shows an accuracy of 10 cm in the horizontal and 20 cm in the vertical. Table 5 shows the size of the errors.

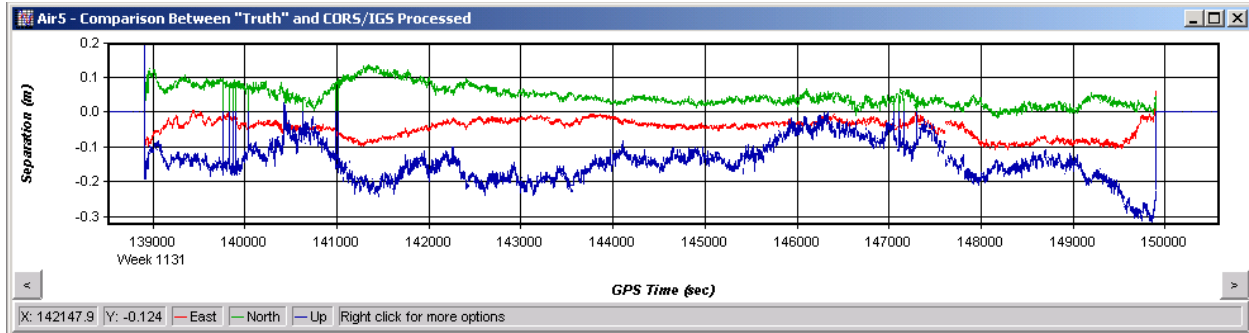


Figure 12. Comparison between the Original and CORS/IGS processed  
 Original baseline: 0 km  
 CORS/IGS baselines: 20 – 240 km

**Table 5. Comparison RMS Values**

	Horizontal (m)	Vertical (m)
<b>RMS</b>	0.0642	0.1443

### Interpolation Error

Figure 13 shows the differences in solution between the original and interpolated data. The error is approximately 2 cm. Although this error is not significantly large compared to the effect of the ionosphere, which can be much larger on longer baselines, it does affect integer ambiguity determination and in many cases, only float solutions are attainable. To circumvent this, the Waypoint software can utilize only the 30-second data (which has no interpolation error) for integer determination. This can be effective but also much less data is used which also reduced the likelihood of obtaining a fix. Hence, interpolated data is best used in conjunction with float solutions.

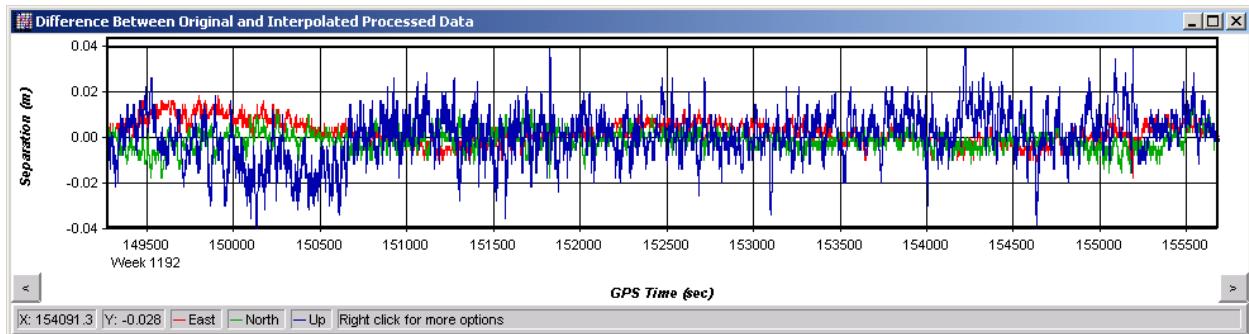


Figure 13. Interpolation error at 30 second CORS/IGS station

## Conclusion

Table 6 summarizes the accuracy of CORS/IGS processed results. Data set 2 and 3 are examples of data with less than ideal conditions. Despite the number of L2 cycle slips, the two data sets maintained acceptable accuracy. Data set 1 and 4 shows the best results. The shorter baselines are the greatest contribution to such good results. The longer baseline in data set 4 was rejected or ignore by the Batch processor. Data set 5 is an example of a long baseline and ability to achieve acceptable results. Overall, CORS/IGS networks can be used to obtain accuracy of 30 cm or better in a conservative sense.

**Table 6. Accuracy of CORS/IGS**

Data	Baseline (km)	Accuracy (cm)		RMS (m)	
		Horizontal	Vertical	Horizontal	Vertical
1	20 – 45	5	20	0.0282	0.1189
2	35 – 140	20	30	0.1643	0.1896
3	35 – 140	20	30	0.0901	0.1610
4	30 – 185	5	10	0.0172	0.0283
5	20 – 240	10	20	0.0642	0.1443

The question arises whether CORS/IGS can be used to replace user base stations. For photo scales 1:15000 and larger (accuracies < 20 cm), integer solutions are desired, and the 30 second COR/IGS data is not suitable for this. However, even for smaller scales (lower accuracy requirement) some CORS/IGS stations may have gaps or no data at all. For this reason, installing a user base station reduces risk. Regardless, CORS/IGS trajectories provided good accuracy and can be a good supplement to or check on satellite based correction services. With the addition of reverse processing and inevitable closer base stations, a CORS/IGS trajectory will most likely be more accurate than the real-time solution.