Should I Use Precise Ephemeris?

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What is SA?

SA, or Selective Availability, was the intentional degradation of the GPS signal by the US DoD (Department of Defense). This degradation had the effect of limiting commercial single receiver users to accuracies of about 10 times what are achievable today without SA. In part, SA was effective by inducing errors in the broadcast ephemeris, which is the predicted satellite orbits used to compute satellite position.

One common method in reducing the effects of SA was to use a precise ephemeris (post-mission satellite orbits) in place of the broadcast ephemeris (real-time). Precise orbits are in effect a more accurate computation of the actual satellite orbits, obtained using data collected at tracking stations around the world. There are several types of precise orbits, which vary in their precision and speed of availability. Precise ephemeredes can be found on the following website: http://www.ngs.noaa.gov/GPS/GPS.html.

Do I Still Need to use Precise Ephemerides?

SA was removed on May 1st 2000. Since it's removal, many post-processing software users are unsure of the necessity of using precise ephemerides, and how much it improves accuracy. Generally speaking, accuracy requirements and baseline length are the major considerations. This report attempts to quantify these factors.

As the GrafNav/GrafNet package caters to both static and kinematic applications, flight data as well as static baselines of varying lengths are examined.

Airborne Data

In these data sets, two receivers are typically used. A stationary master station is located on the ground, and t he remote is on an aircraft. It is difficult to gauge the absolute accuracy of this type of data, as the receiver is never held stationary over a known point. Therefore in this experiment the data was fist processed using the broadcast ephemeris, and then reprocessed with the precise ephemeris. The differences in the solutions were then plotted.

It is assumed (but cannot be directly verified) that the use of the precise ephemeris will improve accuracy. Thus, the observed difference between the solutions is treated as the degree to which the precise ephemeris *improves* the solution.

Two graphs are presented for each flight. The first shows the difference in the coordinates when using the precise ephemeris and the second shows the distance separation of the master and remote.

Flight 1

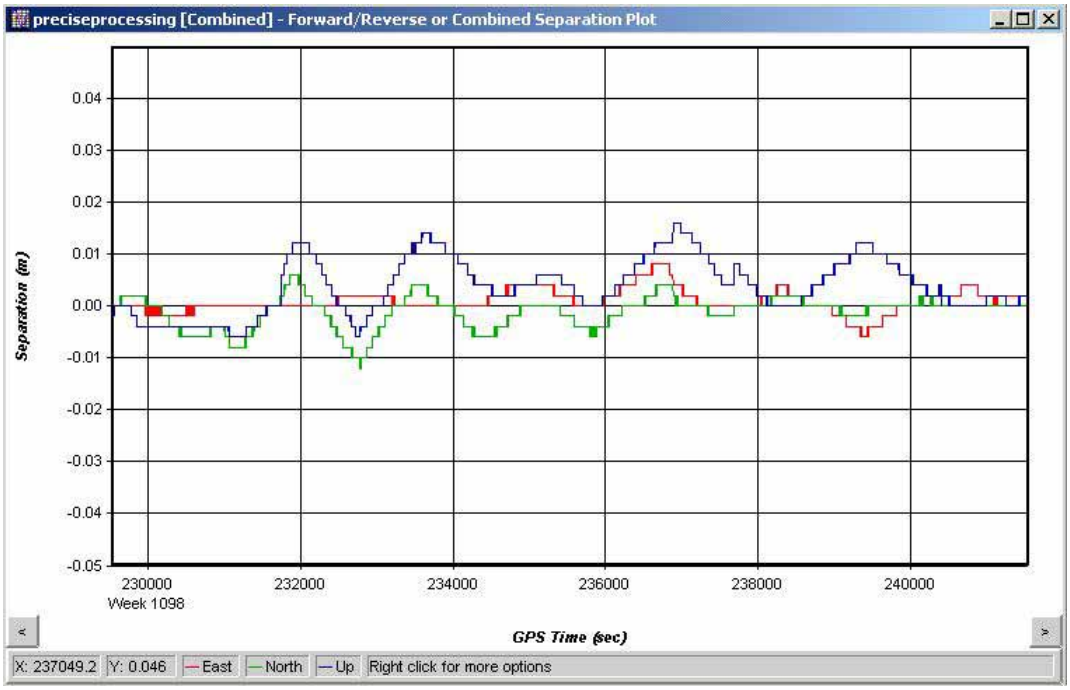

Figure 1: Coordinate difference when using precise ephemeris

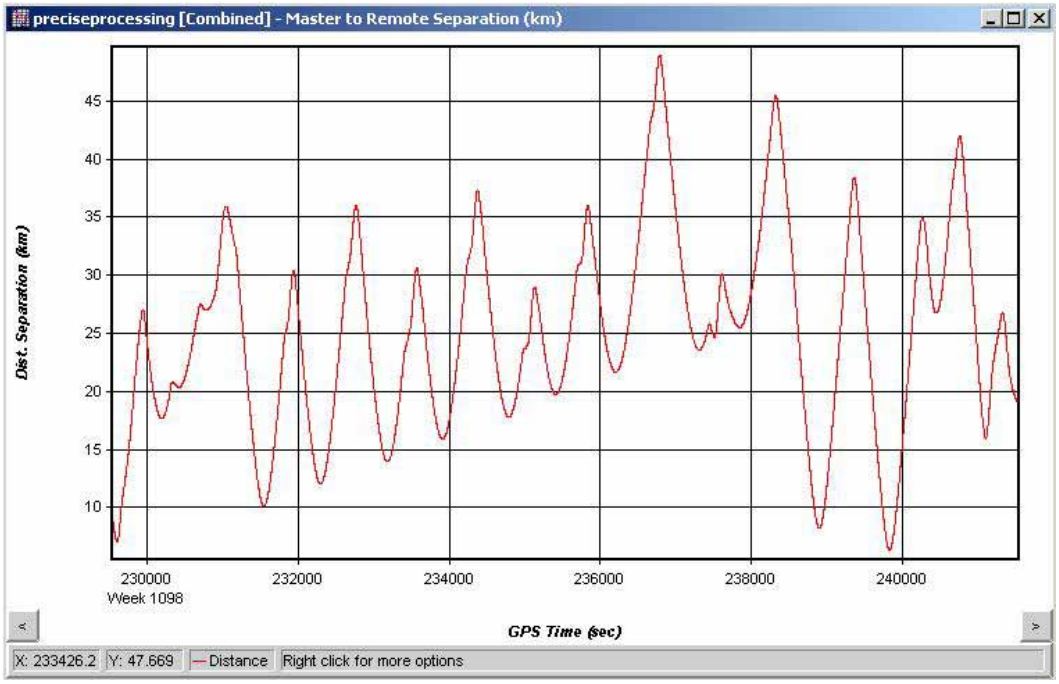

Figure 2: Master-Remote distance separation

Flight 2

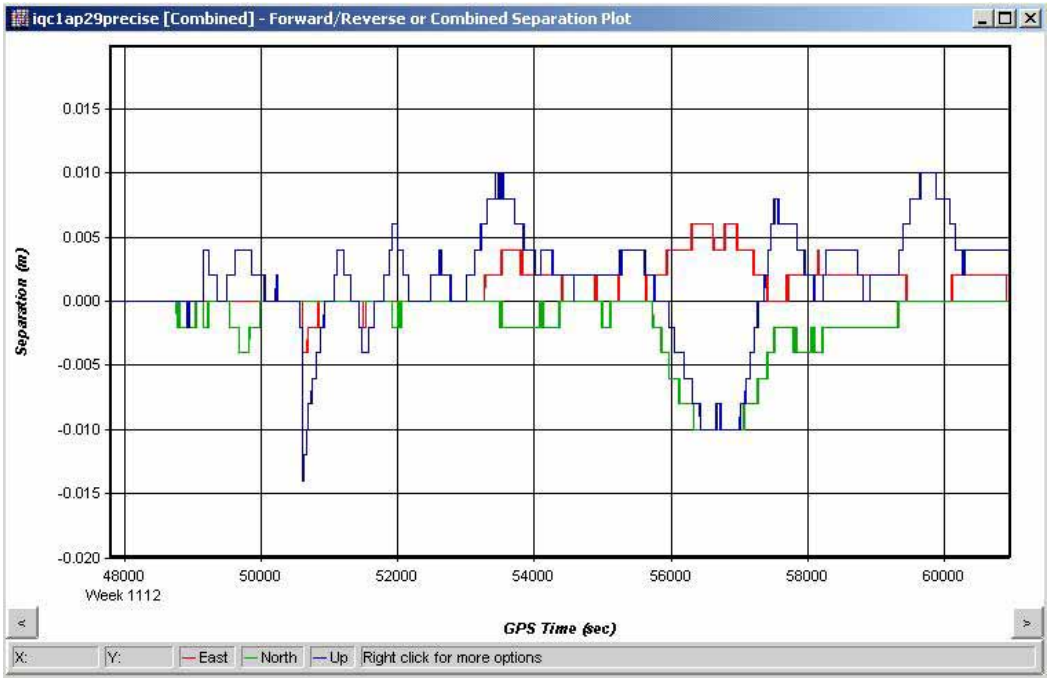

Figure 3: Coordinate difference when using precise ephemeris

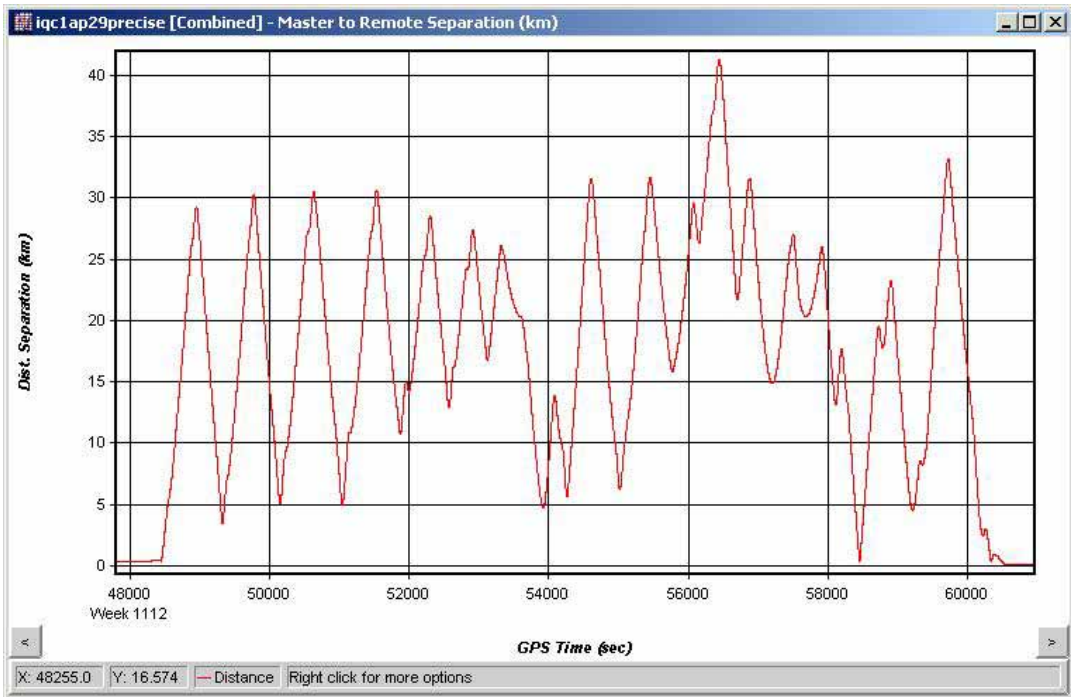

Figure 4: Master-Remote distance separation

Flight 3

Figure 5: Coordinate difference when using precise ephemeris

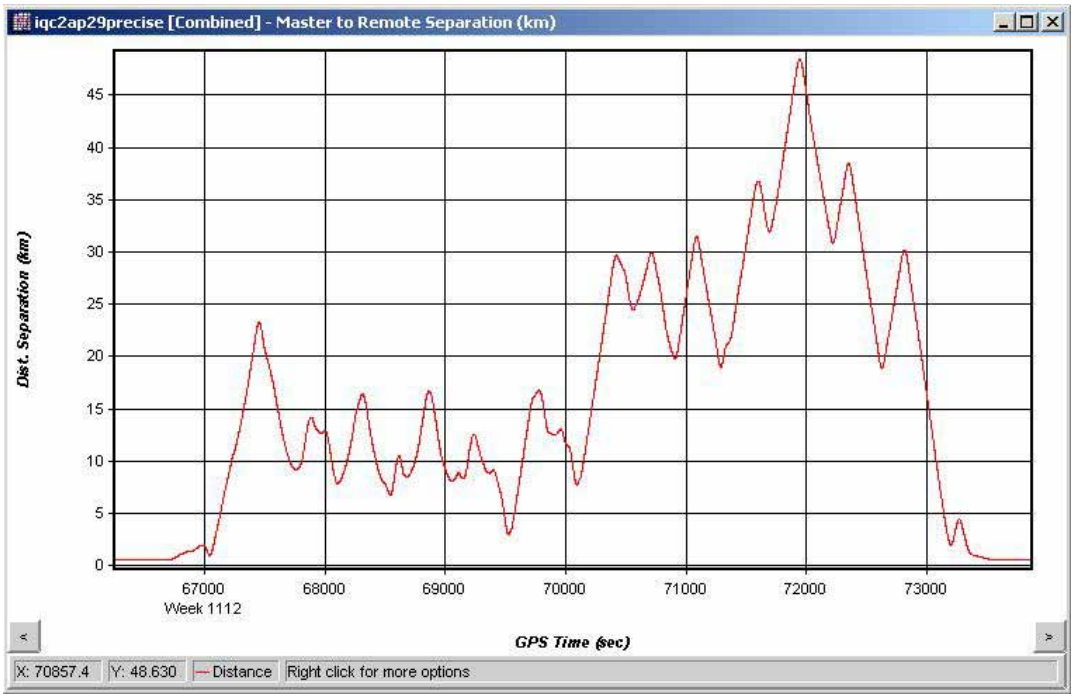

Figure 6: Master-Remote distance separation

Flight 4

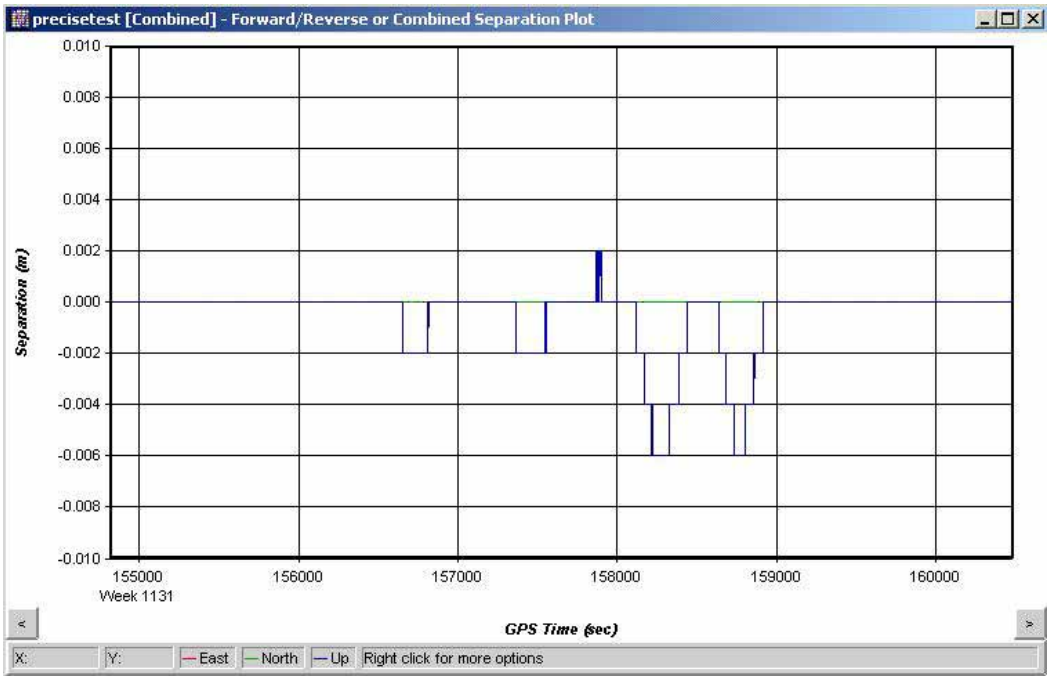

Figure 7: Coordinate difference when using precise ephemeris

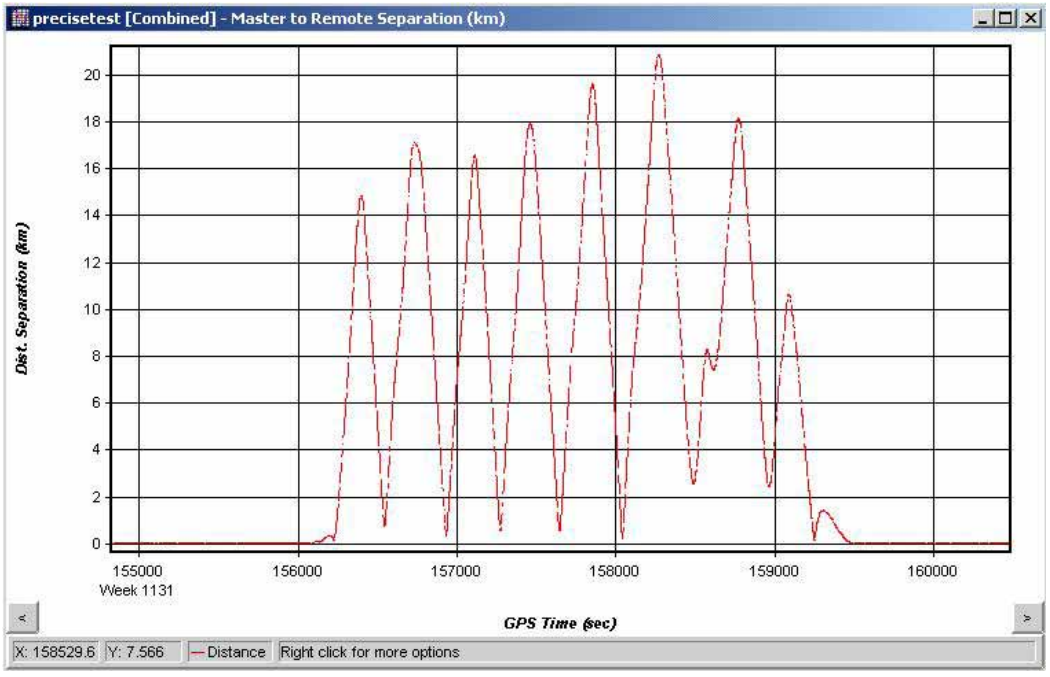

Figure 8: Master-Remote distance separation

Flight 5

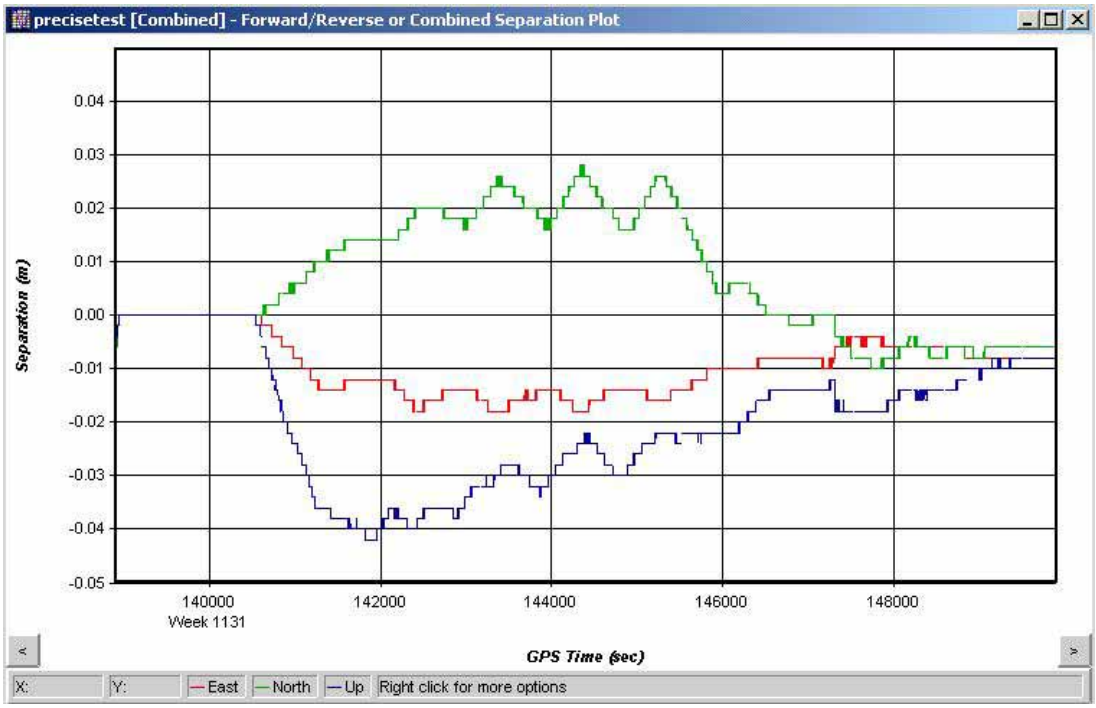

Figure 9: Coordinate difference when using precise ephemeris

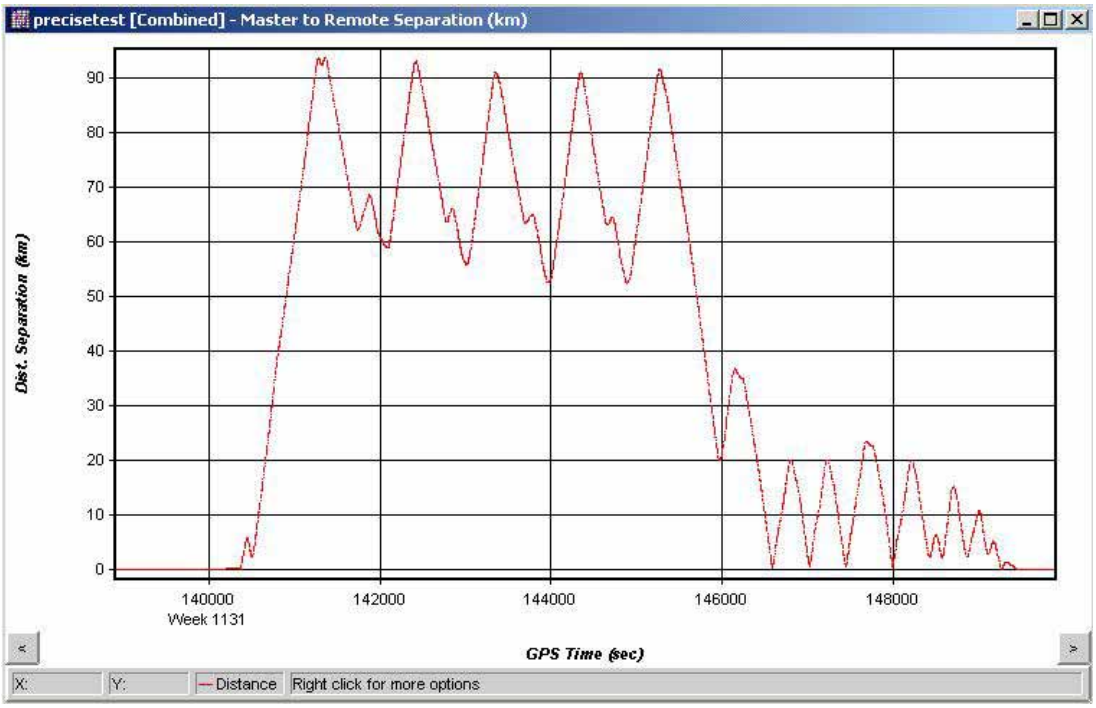

Figure 10: Master-Remote distance separation

Analysis

It is clear from these five flights that the amount of improvement obtainable by using the precise ephemeris is limited to at most a few centimeters. As expected, a correlation is shown between the baseline length and the magnitude of the difference in the solutions.

Flight # 5 shows the largest difference in coordinates, and the largest variability in master-remote separation. The remote receiver was initialized close to the base in this survey, and as expected for this length of time there is no benefit to using the precise ephemeris. However, as the master-remote separation increases to a maximum of about 90 kilometers, there is a noticeable coordinate difference. A relatively constant difference of almost three centimeters in latitude, two centimeters in longitude, and 3 centimeters in height are observed. However, as the master-remote separation once again decreases towards the end of the survey, the significance of using the precise ephemeris reduces as well.

Flight # 4 shows negligible differences in horizontal coordinates and only sporadic sub-centimeter differences in height. This is attributable to the very small master-remote separation, which barely exceeded 20 km.

Flight #3 shows a comparable negligible difference in coordinates to those of flight #4. Much of this flight was flown with a master-remote separation under 30 km. Flight #2 was also mostly flown within 30 km of the master station, and at most shows 1 cm differences in any given coordinate (north, east, or up).

Flight #1 was flown at a slightly higher average master-remote separation than Flights 2 to 4. Not surprisingly, it also displays a more significant difference in the coordinates obtained using the precise ephemeris. These coordinates varied mostly in latitude and height, however were consistently within 2 cm of the broadcast-ephemeris derived results.

Static Baselines

In this test, one full day of data was downloaded from 6 CORS stations. The CORS stations used were:

- LUBB
- JTNT
- SUM1
- TCUN
- PRCO
- ODS5

LUBB, located roughly in the middle of the network (as shown below) was used as the base station. All other points were used as check points, which means their computed coordinates were compared with the known values.

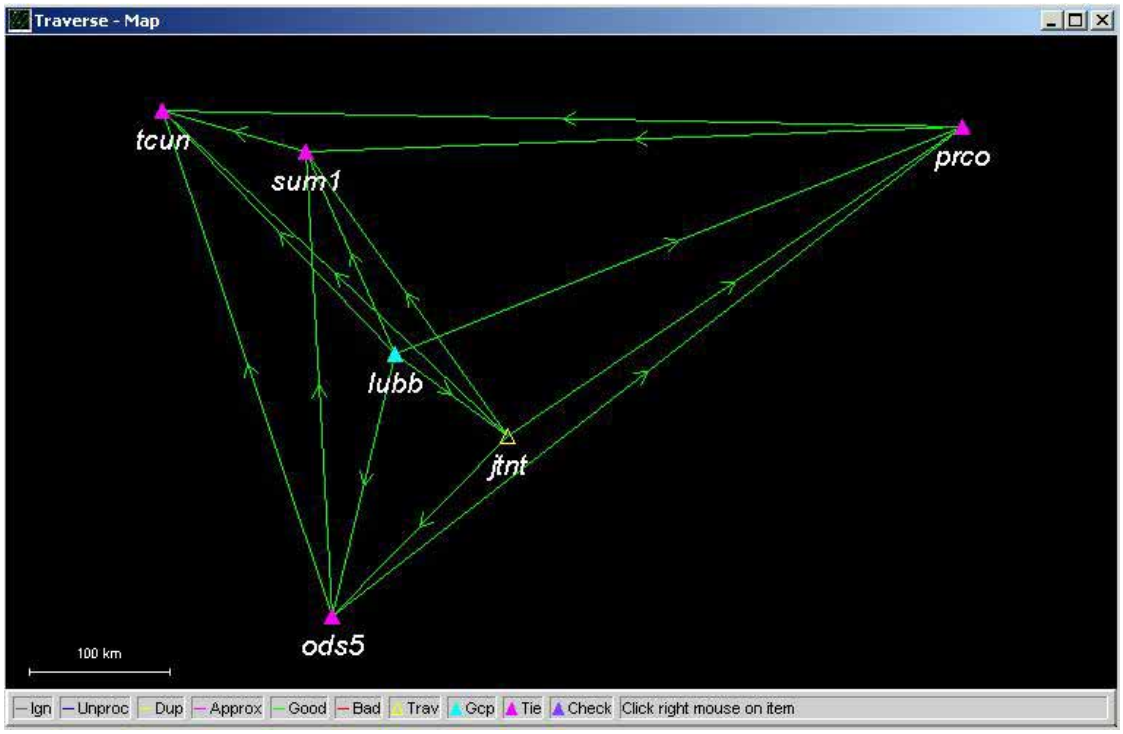

Figure 11: CORS Network

The entire project was processed once with a broadcast ephemeris, and then again with a precise ephemeris.

Results

Broadcast Ephemeris	NAME	Dist (km)	DN (m)	DE (m)	DH (m)
POINT	jtnt	99	0.0152	-0.0105	-0.0041
POINT	ods5	190	0.0251	0.0261	-0.0389
POINT	prco	429	-0.0101	-0.0838	0.1427
POINT	sum1	156	-0.0235	-0.0301	0.0535
POINT	tcun	237	-0.0144	-0.0029	-0.0195

Precise Ephemeris	NAME	Dist (km)	DN (m)	DE (m)	DH (m)
POINT	jtnt	99	0.0062	-0.0086	0.0079
POINT	ods5	190	0.0204	0.0028	-0.0466
POINT	prco	429	-0.0165	-0.0402	0.1693
POINT	sum1	156	-0.0147	-0.019	0.0479
POINT	tcun	237	0.0028	-0.0129	-0.0472

Analysis

It was found that the horizontal accuracy improved on each baseline when using the precise ephemeris:

Station	Horizontal Accuracy Improvement (cm)	Distance (km)
jtnt	0.79	99
ods5	1.56	190
prco	4.10	429
sum1	1.42	156
tcun	0.15	237

Curiously, in these five baselines the precise ephemeris did not improve vertical accuracy, and actually decreased it four out of the five trials. However, it is known that height coordinates are generally 2-3 times less accurate than the horizontal coordinates, which was still true in three out of the five results obtained using the precise ephemeris.

Conclusion

Is the precise ephemeris required? As shown, this depends largely on baseline length and accuracy requirements. The flight tests showed sub-centimeter differences over a 20 km master-remote separation, centimeter differences over a 40 km separation, and roughly a 3-4 cm differences over a 90 km separation. If centimeter level accuracies are required for airborne data, the precise ephemeris seems to be worthwhile only for baseline lengths of approximately 40 km or greater.

It was also consistently shown that horizontal accuracy is improved with the use of the precise ephemeris in static baselines. As expected, the size of the improvement was largely correlated with baseline length, with the largest improvement of 4 cm being observed on a 429km baseline.

If accuracy is of critical importance, however, the inclusion of the precise ephemeris is always recommended.